# ECE 220

## Lecture x000A - 02/20

**Slides based on material originally by: Yuting Chen & Thomas Moon**

# Recap + reminders

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  - Introduction to pointers & arrays, `sizeof` function, etc.

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  - Wrap up pointer/array duality
  - Strings & multidimensional arrays

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  - Strings & multidimensional arrays
  - Problem solving examples

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  - Introduction to pointers & arrays, `sizeof` function, etc.
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  - Strings & multidimensional arrays
  - Problem solving examples
  - Quiz #2

# Thoughts on the midterm

# Recap

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```c
#include <stdio.h>

int my_first_sum(int arr[]){
  int sum=0, i=0;
  for (i=0; i<5; i++)
    sum += arr[i];
  return sum;
}

int main(void){
  int i, arr[5];
  for (i=0; i<5; i++){
    printf("Enter an integer:\t");
    scanf("%d", &arr[i]);
  }
  printf("\nThe sum is %d", my_first_sum(arr));
}
```

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How did we let the compiler know `my_first_sum` takes an array of integers as a parameter?

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Fact: The name of the array is *pointer* to the array!

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- The parameter declaration `int array[]` in the function definition is *syntactic sugar* for `int *array`.
- However, `int p[]` makes it clear we are passing an array of integers while `int *p` … not so much.

*This is called pointer/array duality in C.*

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```
int my_third_sum(int *arr){
  int i, sum=0;
  for (i=0; i<5; i++)
    sum += *(arr + i);
  return sum;
}
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would also work just fine!

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```
char arr[10];
 char *cptr;
cptr = arr;
```

| Pointer arithmetic |
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char arr[10];
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 cptr = arr;
```

| Pointer arithmetic | Pointer arithmetic | Array notation |
|---|---|---|
| cptr | arr | &arr[0] |
| (cptr + n) | (arr + n) | &arr[n] |
| *cptr | *arr | arr[0] |
| *(cptr + n) | *(arr + n) | arr[n] |

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char arr[10];
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`cptr` is defined as a variable. The compiler allows it to be redefined.

- Try doing:

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cptr = cptr + 1;
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```

`arr` without the `[]` *decays* to a pointer but once declared is not assignable *sans* subscript.

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```c
#include <stdio.h>

int main(){
    int *arrp;
    int (*arrpw)[5];
    int arr[5]={5,2,3,1,4};

    arrp = arr;
    arrpw = &arr;

    printf("arrp= %p, arrpw= %p\n", arrp, arrpw);
    arrp++;
    arrpw++;
    printf("arrp= %p, arrpw= %p\n", arrp, arrpw);
}
```

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- What is the difference between `arrp`, `arrpw` in the code snippet on the right?
- **Hint**: Consider the output.

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int main(){
    int *arrp;
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- What is the difference between `arrpw, parr` in the code snippet on the right?

```c
#include <stdio.h>

int main(void){
  int arr[5] = {1, 2, 3, 4, 5};
  int (*arrpw)[5] ;
  int *parr[5];

  arrpw = &arr;

  for (int i=0; i<5; i++){
    printf("*(*arrpw + %d): %d\n", i, *(*arrpw + i));
    printf("*parr[%d]: %d\n", i, *parr[i]);
  }
}
```

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Same as before.

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  int (*arrpw)[5] ;
  int *parr[5];

  arrpw = &arr;

  for (int i=0; i<5; i++){
    printf("*(*arrpw + %d): %d\n", i, *(*arrpw + i));
    printf("*parr[%d]: %d\n", i, *parr[i]);
  }
}
```

Same as before.

`parr` is now an *array* of five pointers.

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```c
#include <stdio.h>

int *printx(void){
    static int x = 0;
    printf("value of x is %d \n",x++);
    return (&x);
}

int main(){
    int *x_ptr;
    x_ptr = printx();
    x_ptr = printx();
    *x_ptr = (*x_ptr) + 1;
    printx();
}
```

# More bewares …

- Pointers can be used to modify *static* variables defined inside functions.
- Actually, pointers can also modify `const` variables.

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int *printx(void){
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- Actually, pointers can also modify `const` variables.

```
int main(void){
    const int var = 10;
    int *ptr = &var;

    *ptr = 12;
    printf("var = %d\n", var);
}
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- Pointers can be used to modify *static* variables defined inside functions.

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#include <stdio.h>

int *printx(void){
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- Actually, pointers can also modify `const` variables.

```
int main(void){
    const int var = 10;
    int *ptr = &var;

    *ptr = 12;
    printf("var = %d\n", var);
}
```

Yes there are things called `const` pointers - but we will only go there when we have to.

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- Pointer
  - Stores the address of a variable in memory
  - Allows us to indirectly access/change variables
- Arrays
  - A list of values arranged sequentially in memory
  - Array name without index is the same as pointer to the array
  - Therefore in C, all arrays are ***passed by reference,*** i.e., if you change array passed to a function, change will be reflected outside!

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- **Question:** Write a C *function* that sums an array of integers of given length $n$.

- Any loops in the function will need to know the size of the array to correctly terminate. Two common strategies:

  - Define the length as a global variable.

  - Write the *function* so that it accepts the array length as a *parameter*.

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- When using arrays we need to know the size or *dimensions* of the arrays.
- **Question:** Write a C *function* that sums an array of integers of given length $n$.

```c
# include<stdio.h>

int any_sum(int arr[], int arr_len){
int i, sum = 0;
  for (i=0; i < arr_len; i++)
    sum += arr[i];
return sum;
}

int main(void){
  int arr1[] = {1, 2, 3, 4, 5};
  int arr2[] = {1, 2, 3, 4, 5, 6, 7, 8, 9};

  printf("sum(arr1): %d\n", any_sum(arr1, 5));
  printf("sum(arr2): %d\n", any_sum(arr2, 9));
}
```

# Using arrays

- **Challenge:** Can the function be modified so `any_sum` can determine the size of the array *itself* (without passing in the value)?

Definitely let me know if you find a way. 😉

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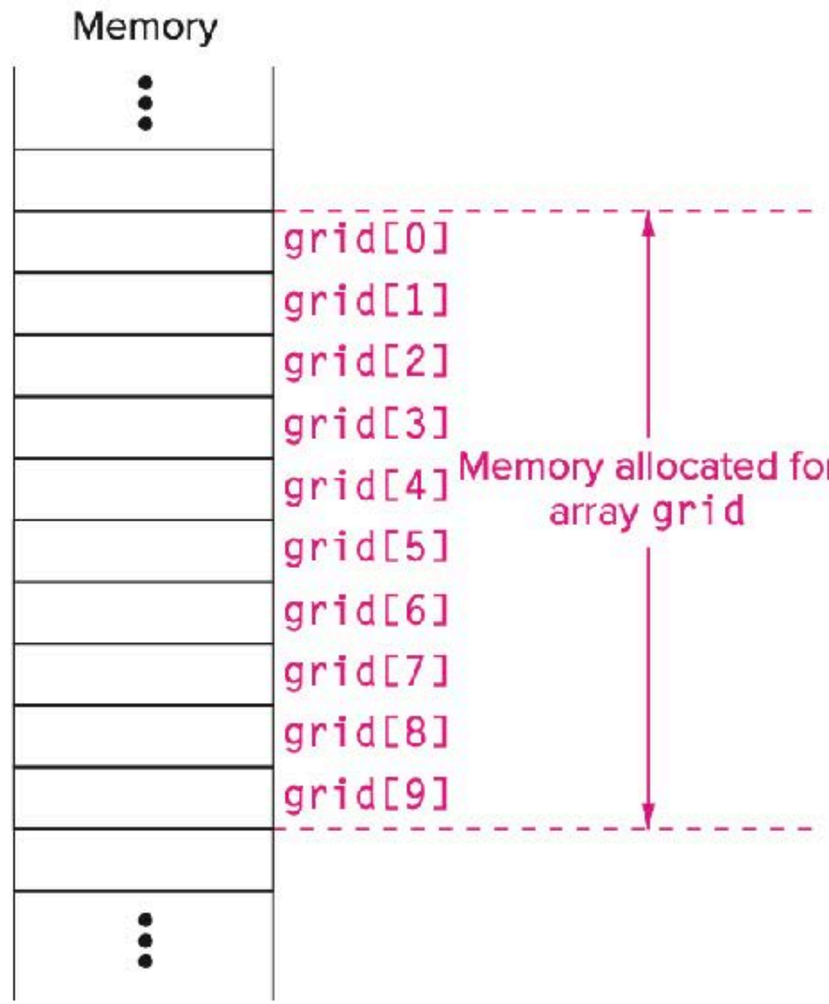

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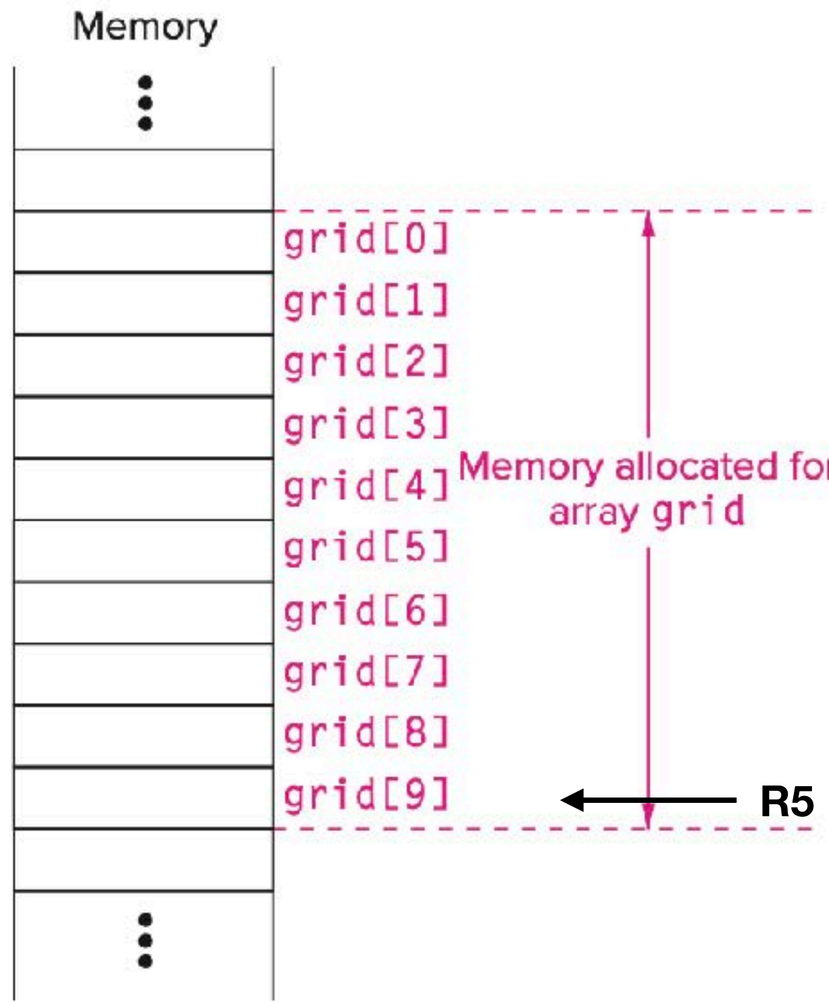

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grid[6] = grid[3] + 1;
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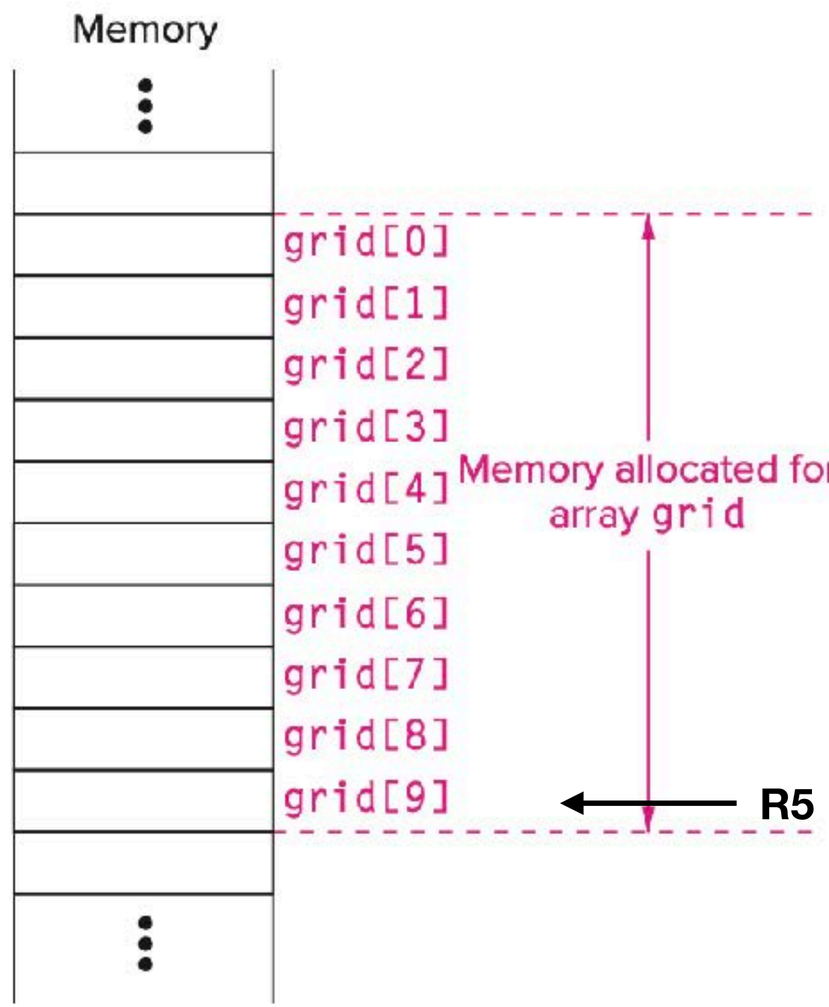

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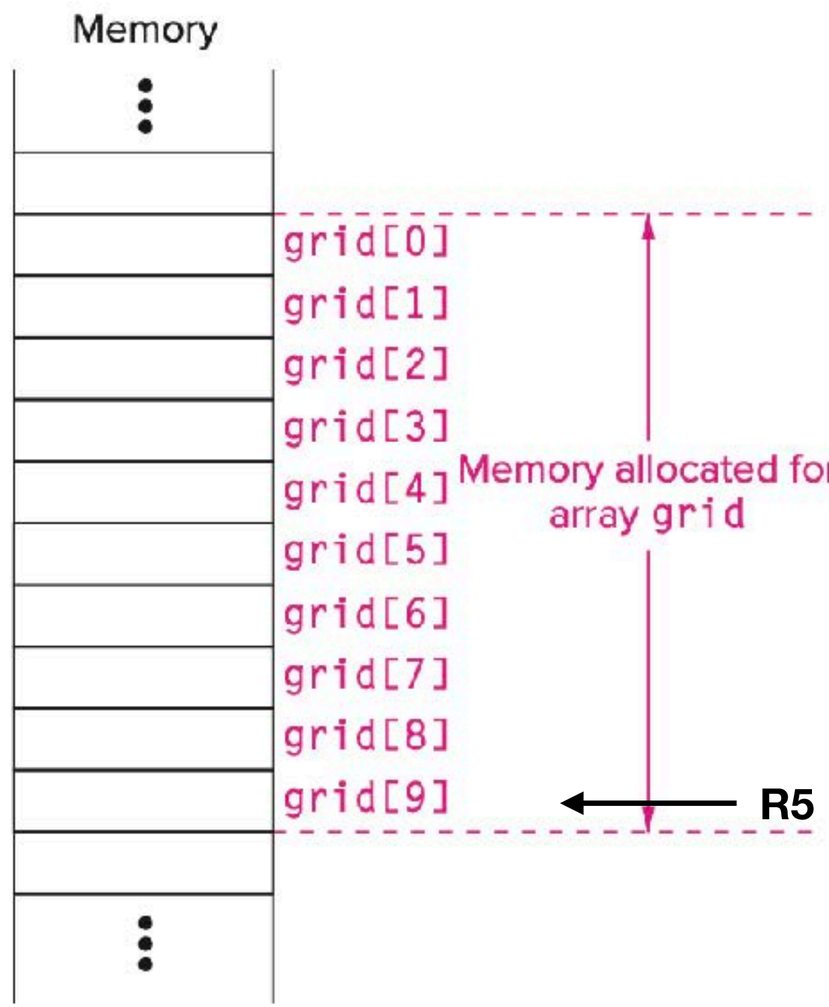

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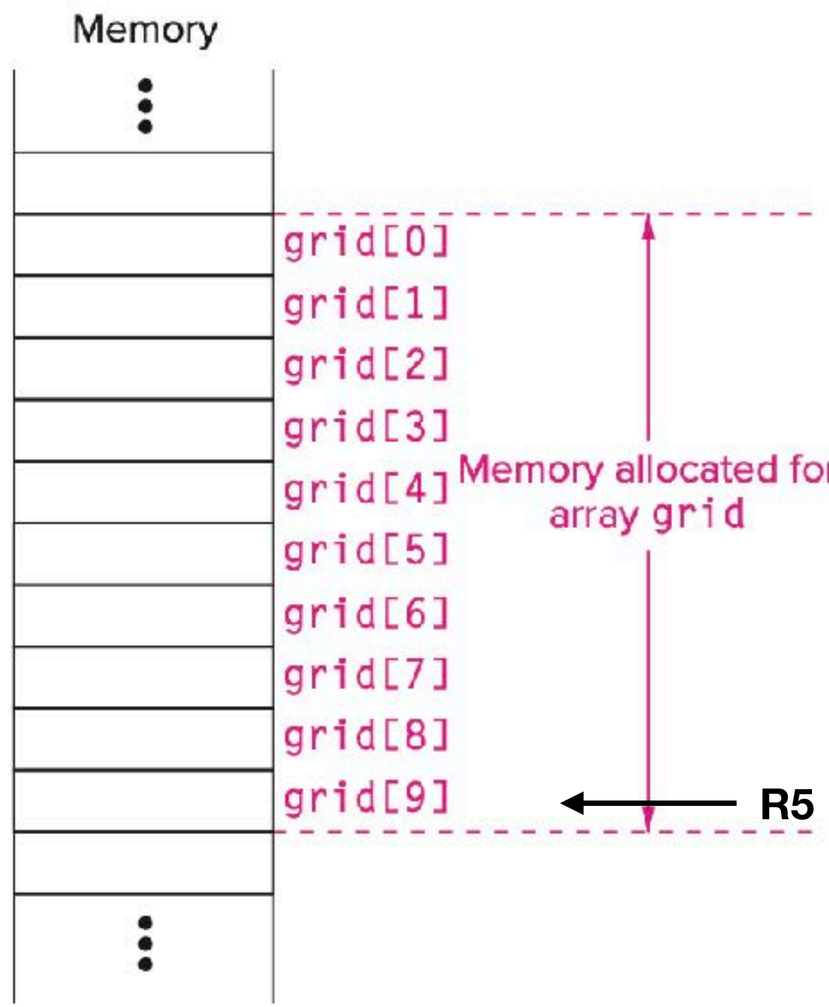

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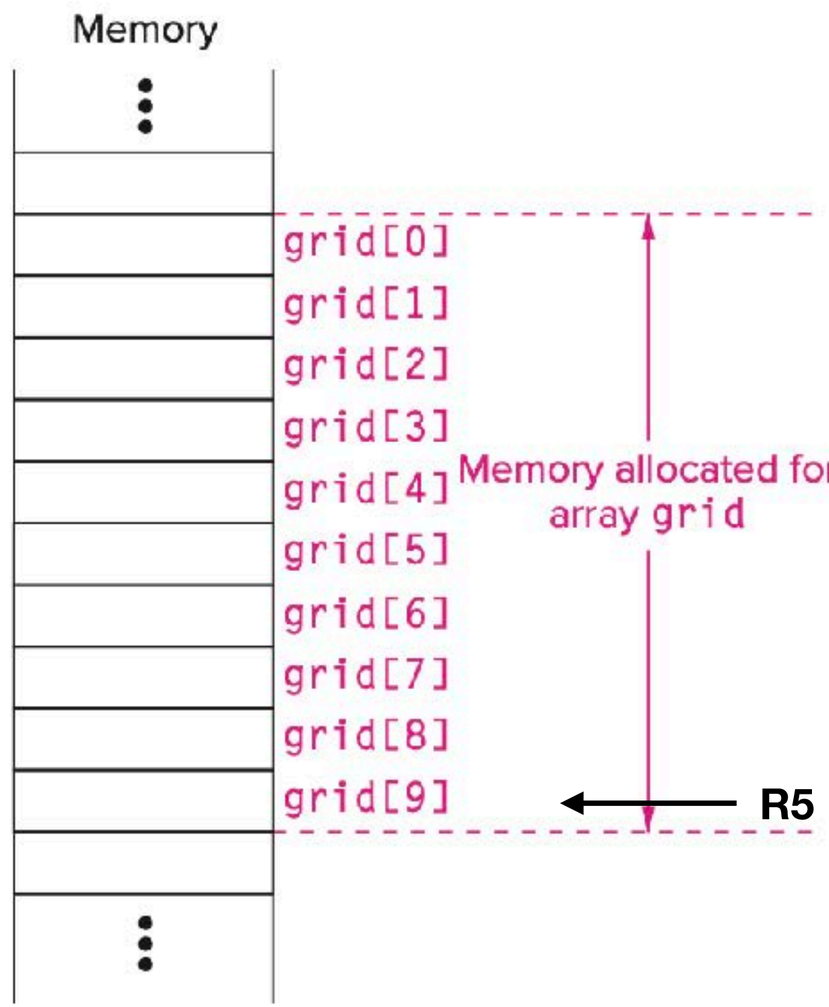

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ADD R1, R1, #1  ; R1 <-- grid[3] + 1
STR R1, R0, #6  ; grid[6] = grid[3] + 1;
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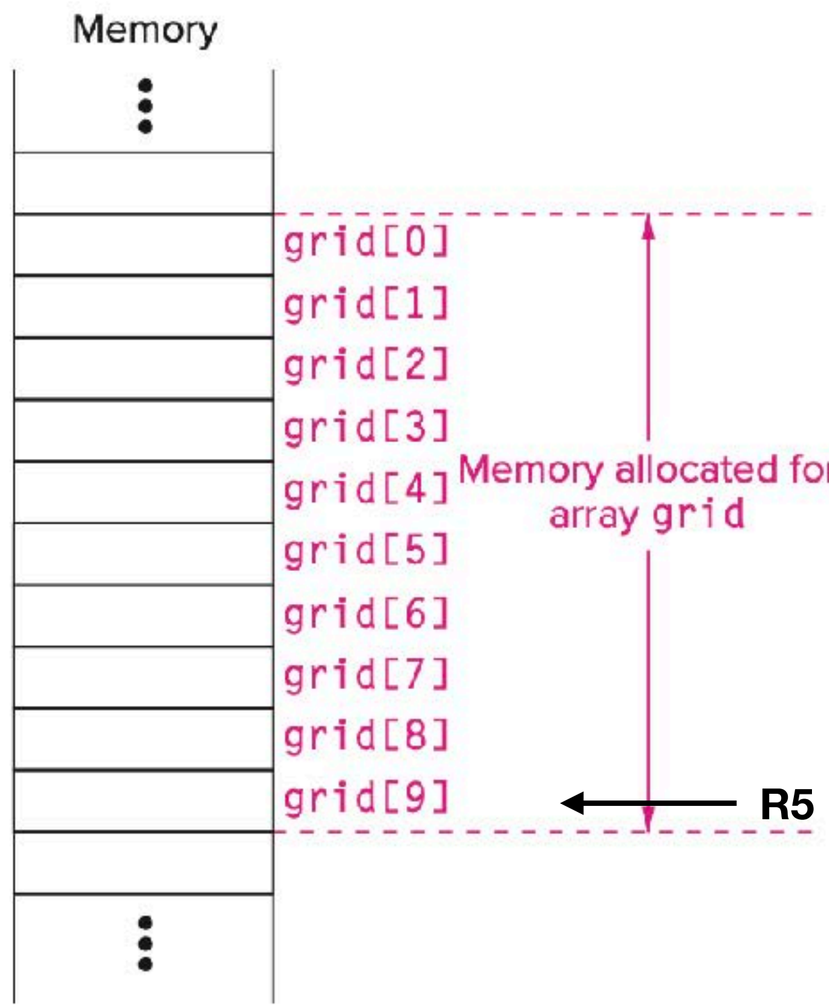

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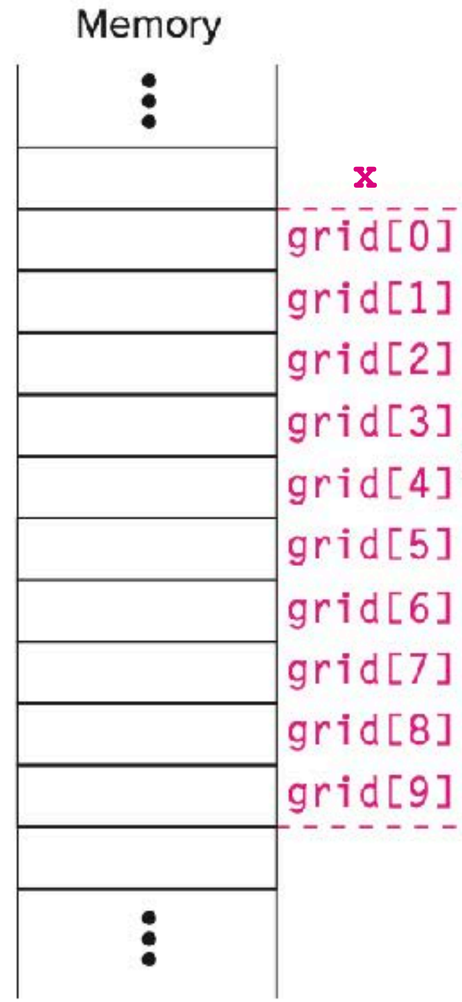

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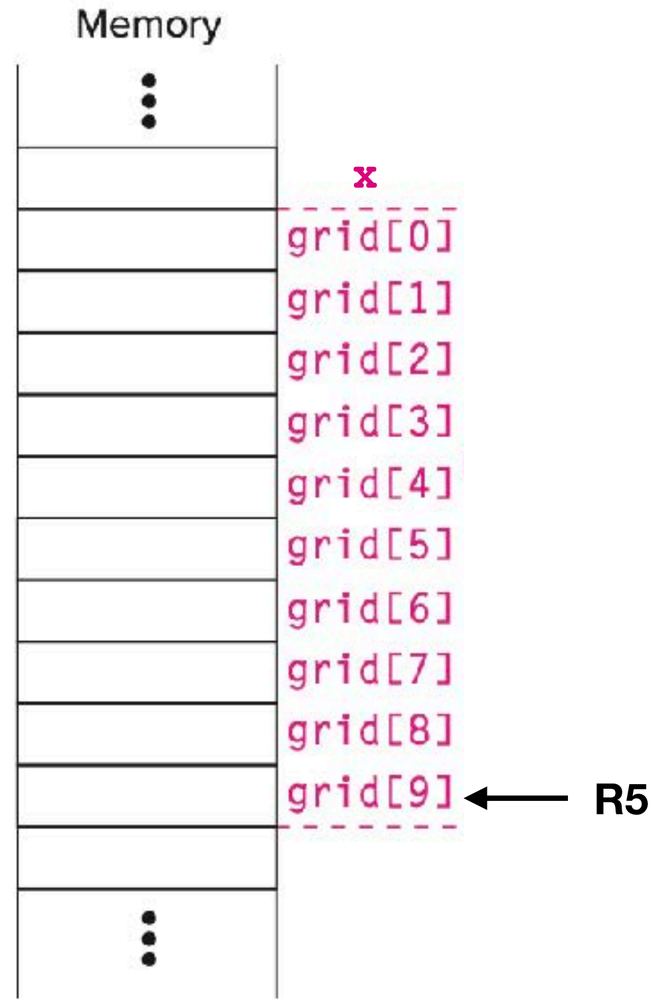

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LDR R0, R5, #-10 ; Load the value of x
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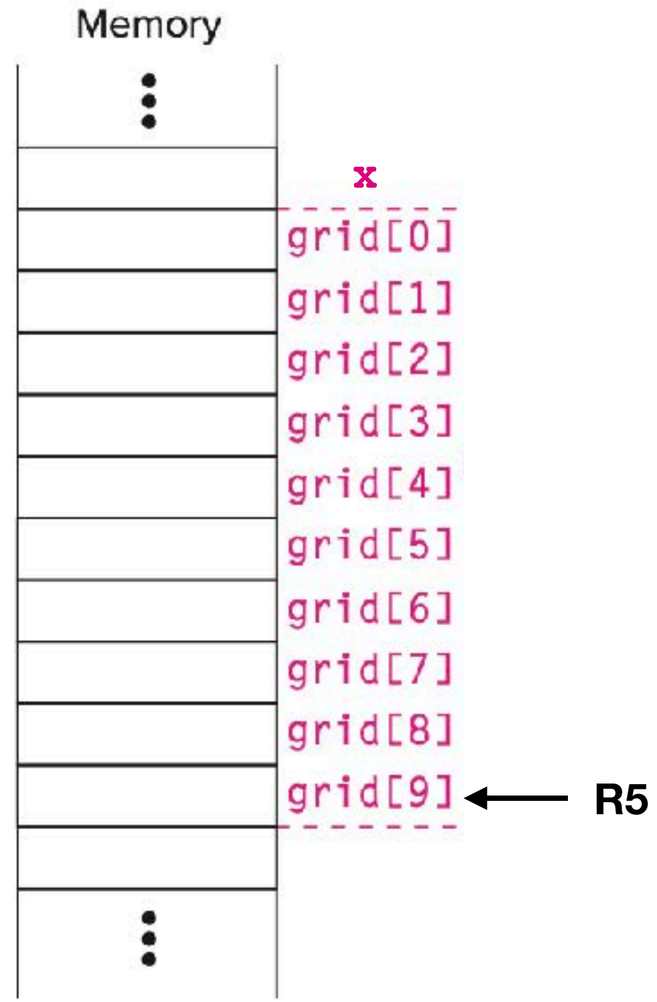

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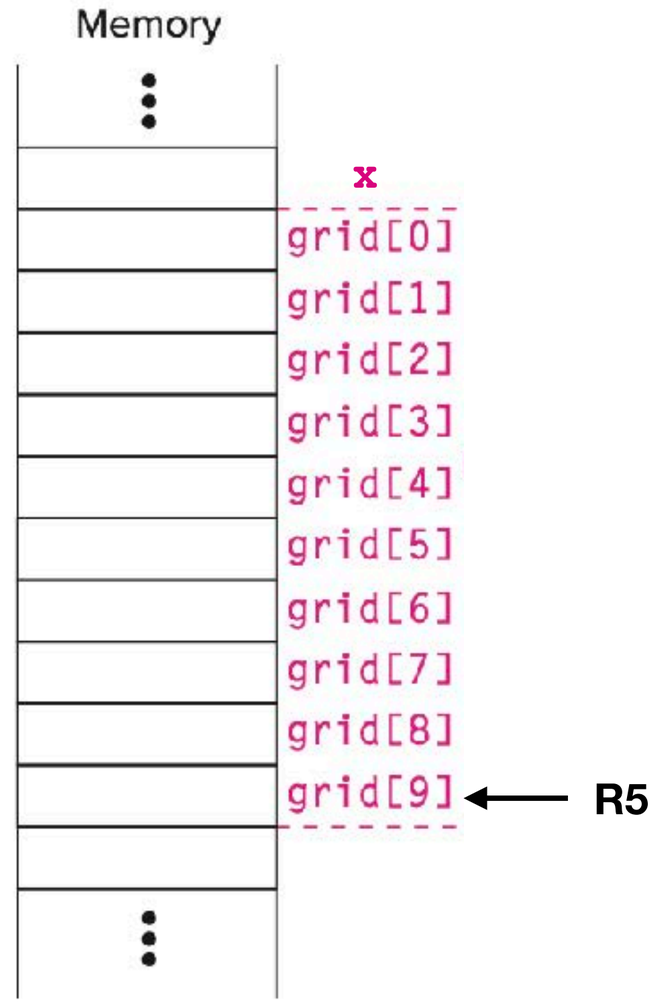

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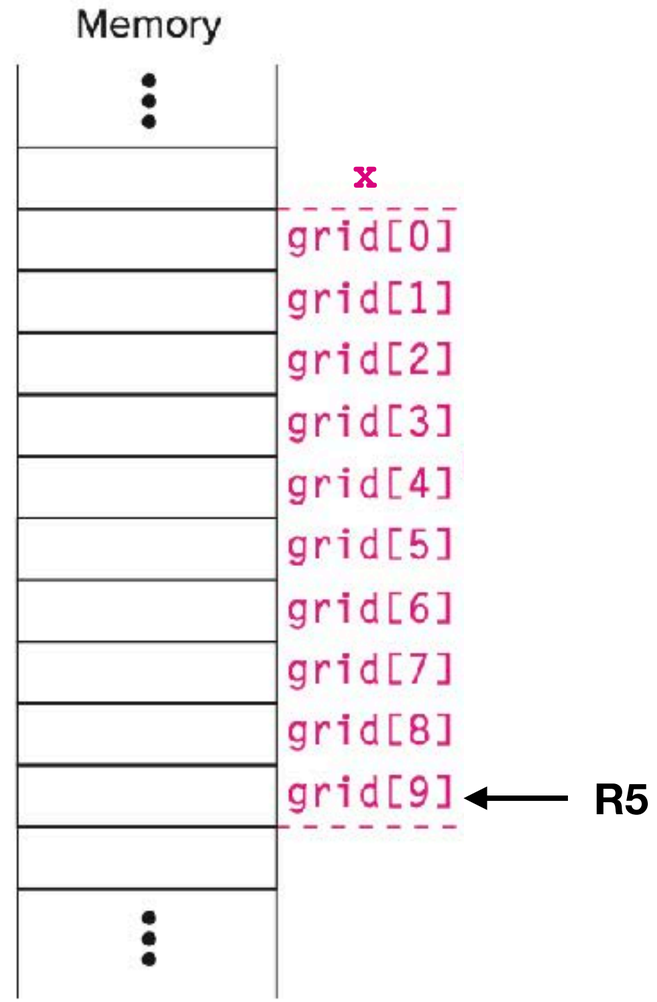

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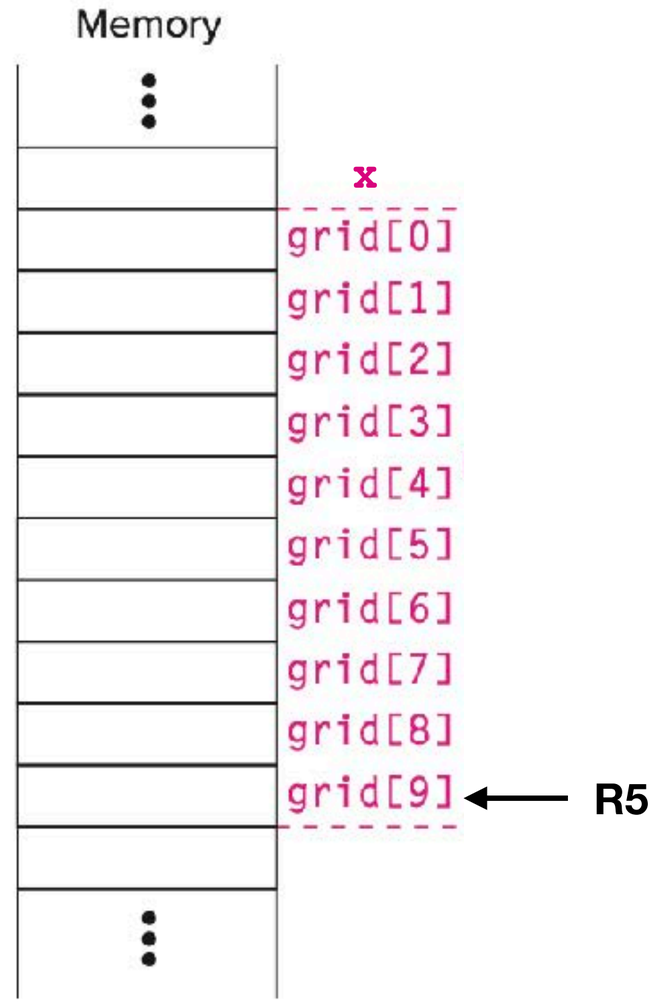

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Note “ vs. ‘

Did not use all 10 characters - some are unused

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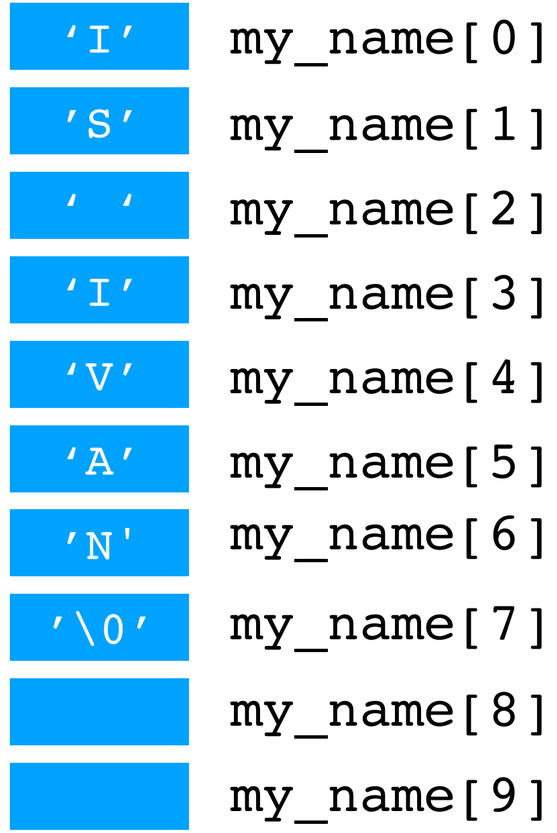

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- To use strings with `printf` use the format specifier `%s`:

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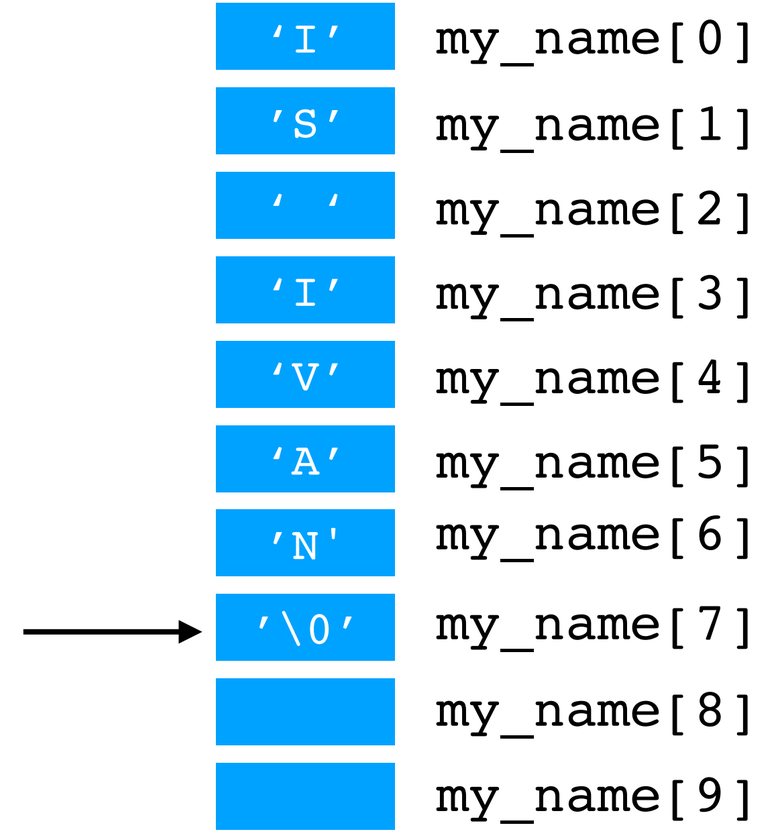
  - *Null-termination* for strings.



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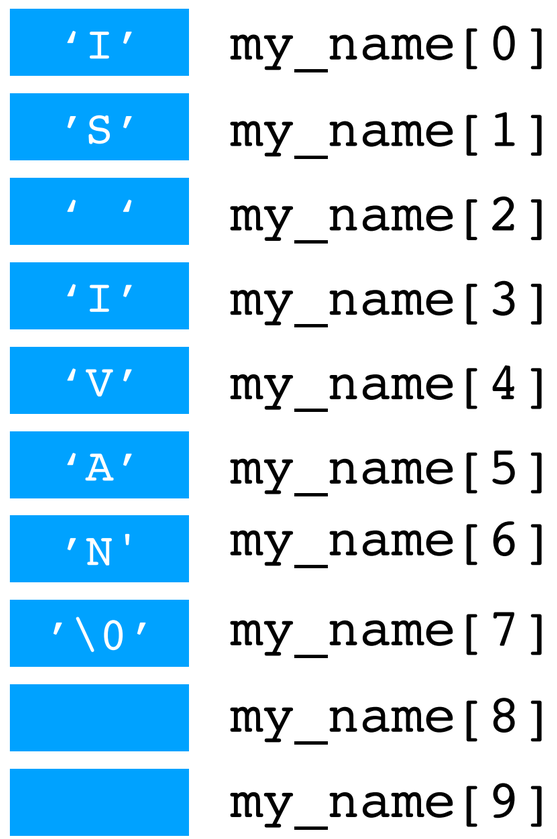
'I'
my_name[0]
'S'
my_name[1]
' '
my_name[2]
'I'
my_name[3]
'V'
my_name[4]
'A'
my_name[5]
'N'
my_name[6]
'\0'
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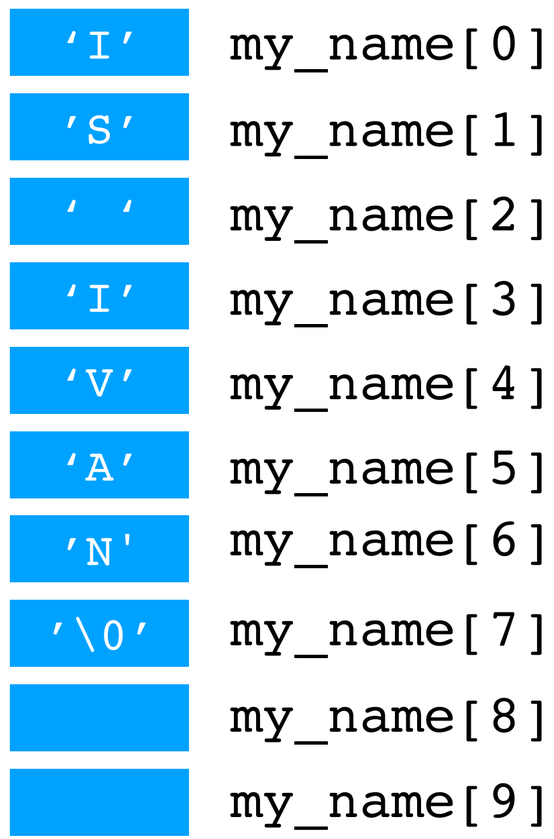

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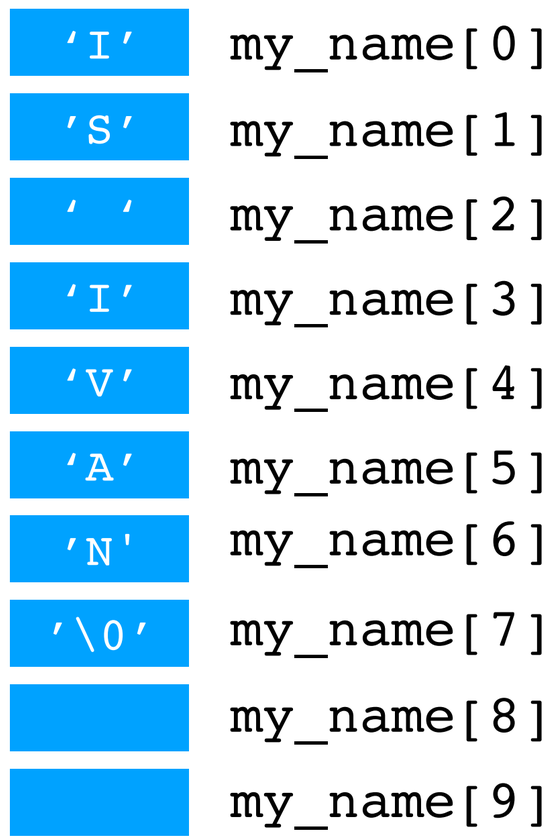

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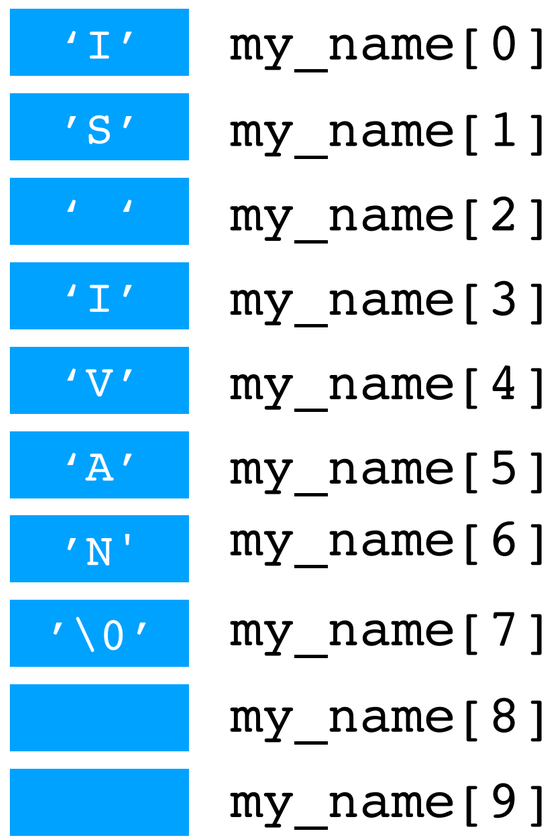

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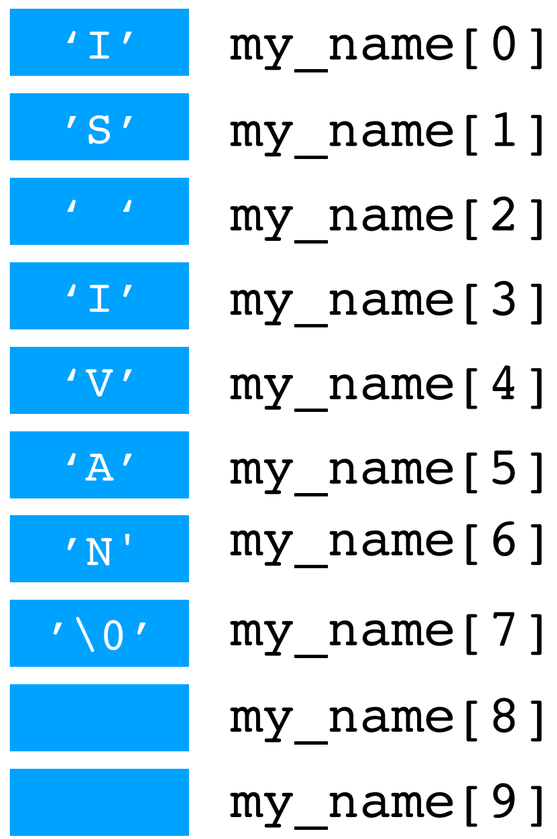

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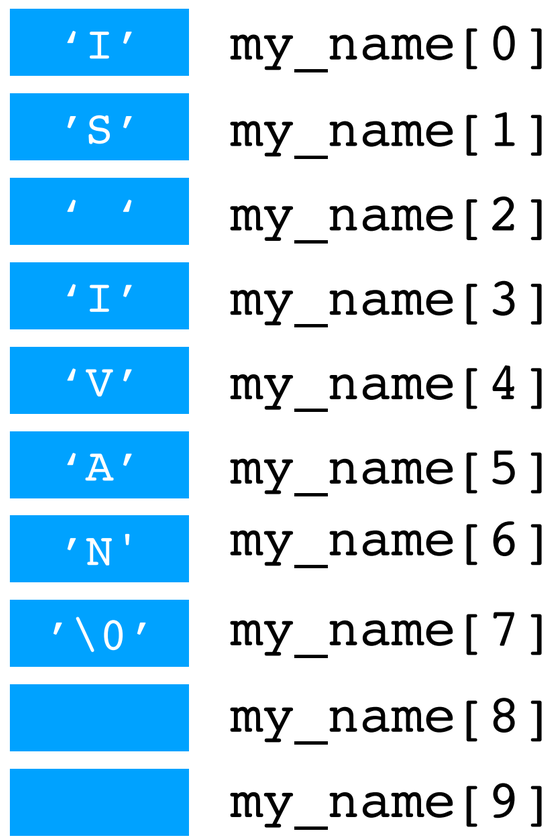


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**Single quote**

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- Run code on right with input “ECE 220” typed in from the console.

```c
#include <stdio.h>

int main(void){
  char mystr[10];
  char mychar;
  printf("Enter a string:\t");
  scanf("%s", mystr);
  printf("\nYou entered: %s", mystr);
  printf("\nEnter a character:\t");
  scanf("%c", &mychar);
  printf("\nYou entered: %c\n", mychar);
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- Run code on right with input “ECE 220” typed in from the console.

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  - **Answer**: No. Could use regexes:

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scanf("%10[0-9a-zA-Z ]", mystr);
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- For example if the user enters: `217-333-2300` we may want to store it as three integer variables: `area_code, prefix, pnum`.
- We use the `sscanf` function.

```
sscanf(char_buffer, format_string, variables…)
```

# Example

- Write a C program that will parse user input of a sequence of digits in the format `xxx-xxx-xxxx` as 10 digit phone number. In other words into an area code, prefix and a local identifying number. Print each out to the console separately.

# Example

# Example

```c
#include <stdio.h>

int main(void){
  int area_code, prefix, pnum;
  char mystr[13];

  printf("Enter a 10-digit phone number.\n");
  printf("Format: xxx-xxx-xxxx\n");

  fgets(mystr, 13, stdin);
  sscanf(mystr, "%d-%d-%d", &area_code, &prefix, &pnum);

  printf("\nArea code: %d", area_code);
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# Example

Why 13?

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```

`sscanf` will return number of values correctly parsed

# Entering multiple strings?

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```
#include <stdio.h>

int main(void){
char arr[][6] = {"cat",
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                 "golf"};

int i;
printf("Elements are:\n");
for (i = 0; i < 3; i++)
   printf("%s\n", arr[i]);
}

arr[1] = "cat";
}
```

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Memory allocation

| | | | | | | |
|---|---|---|---|---|---|---|
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To modify character arrays after declaration use `strcpy` from `<string.h>` (which also houses a `strlen` function just FYI).

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arr[1] = "dog";
}
```

# Strings - pain points

- Common point of confusion responsible for much frustration is conflating *character arrays* with *string literals*.

- You will often see the code from the previous slide written this way.

- But they are **NOT** equivalent.

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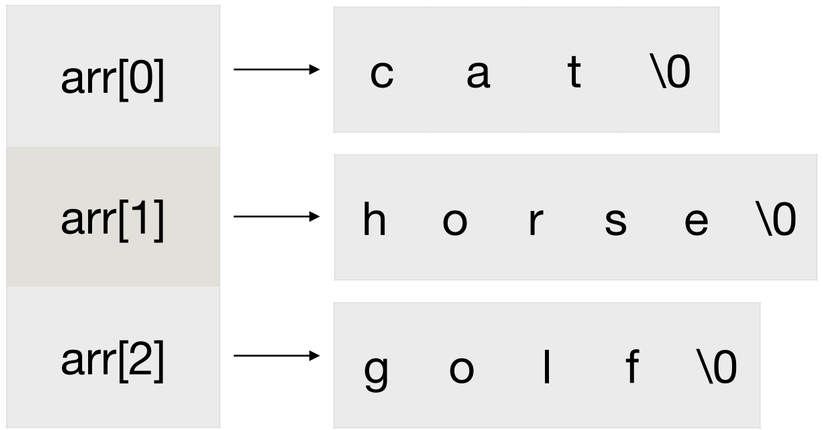


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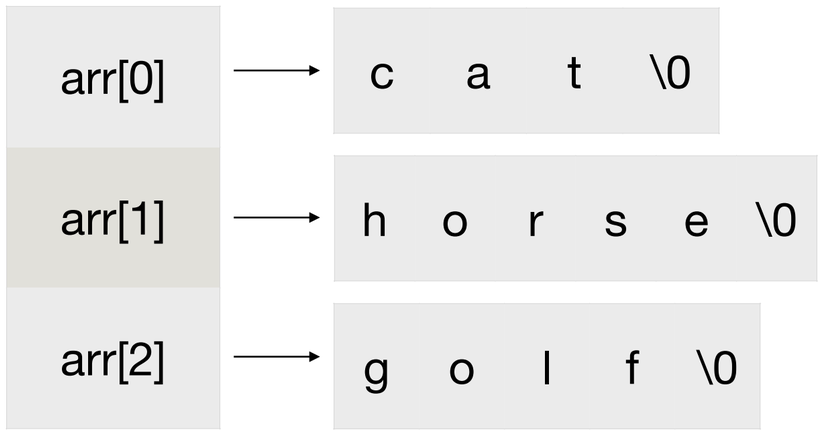
# Strings - pain points

Memory allocation




```c
#include <stdio.h>

int main(void){
char *arr[3] = {"cat",
               "horse",
               "golf"};

printf("Elements are:\n");
for (int i = 0; i < 3; i++)
   printf("%s\n", arr[i]);

arr[1] = "dog";
}
```

Now okay!

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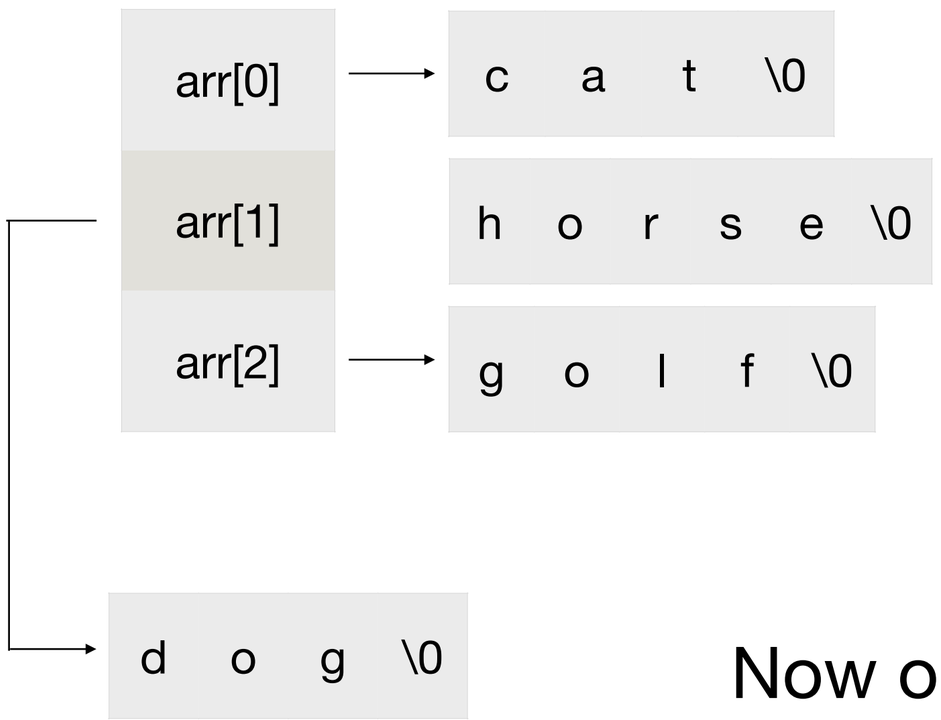


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```c
#include <stdio.h>

int main(void){
char arr[3][6] = {"cat",
                  "horse",
                  "golf"};

printf("Elements are:\n");
for (int i = 0; i < 3; i++)
   printf("%s\n", arr[i]);
}

arr[0][1] = 'o';
}
```

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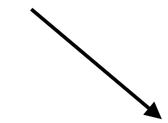

Undefined behavior!

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These are stored as *string literals*, often in read-only memory. `arr` just points to them.

Undefined behavior!

# Strings - pain points

These are allocated on the stack and so `arr` remains modifiable.

```c
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```

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# Multi-dimensional arrays

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One dimensional array

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One dimensional array

| 0 | 1 | 2 | 3 |
|---|---|---|---|

- The *dimension* of an array is determined by the minimum number of indices required to access its individual elements.

Two dimensional array

| 0,0 | 0,1 | 0,2 | 0,3 |
|---|---|---|---|
| 1,0 | 1,1 | 1,2 | 1,3 |
| 2,0 | 2,1 | 2,2 | 2,3 |

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One dimensional array

| a[0] | a[1] | a[2] | a[3] |
|---|---|---|---|

Two dimensional array

| a[0][0] | a[0][1] | a[0][2] | a[0][3] |
|---|---|---|---|
| a[1][0] | a[1][1] | a[1][2] | a[1][3] |
| a[2][0] | a[2][1] | a[2][2] | a[2][3] |

# Allocating memory

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One dimensional array

| a[0] | a[1] | a[2] | a[3] |
|---|---|---|---|

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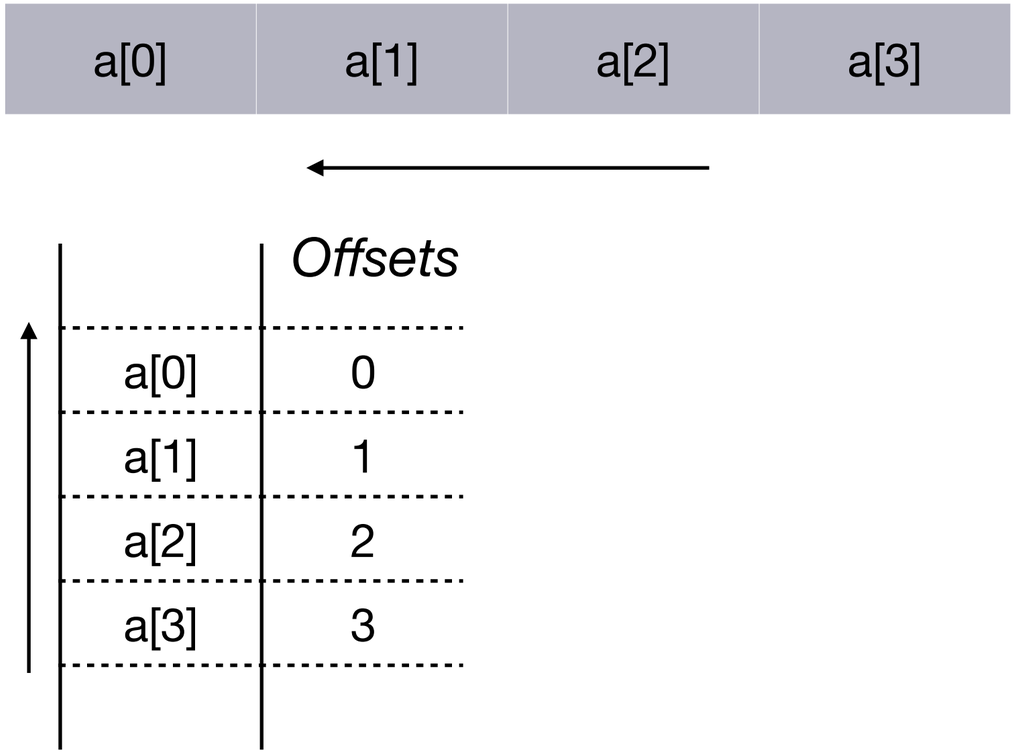
One dimensional array

| a[0] | a[1] | a[2] | a[3] |
|---|---|---|---|

| | *Offsets* |
|---|---|
| a[0] | 0 |
| a[1] | 1 |
| a[2] | 2 |
| a[3] | 3 |

# Allocating memory

One dimensional array



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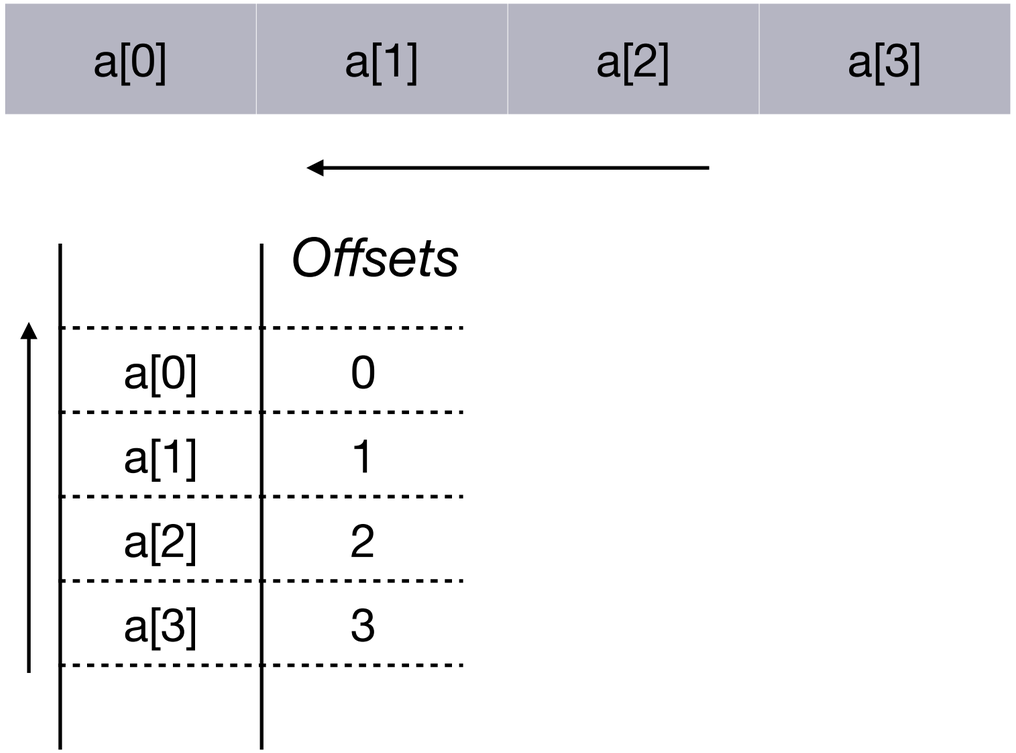


Two dimensional array

| a[0][0] | a[0][1] | a[0][2] | a[0][3] |
|---|---|---|---|
| a[1][0] | a[1][1] | a[1][2] | a[1][3] |
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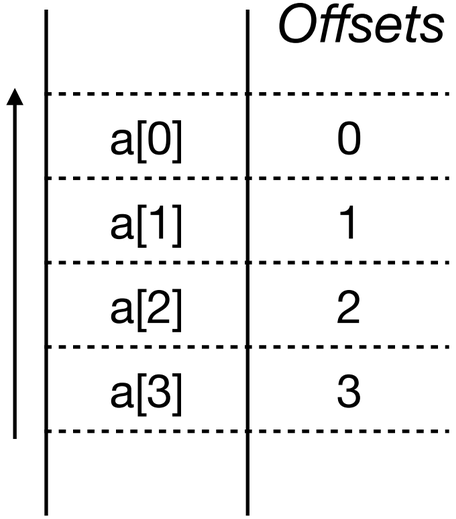

| | *Offsets* |
|---|---|
| a[0] | 0 |
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| a[2] | 2 |
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| … | *Offsets* |
|---|---|
| a[1][2] | 6 |
| a[1][3] | 7 |
| a[2][0] | 8 |
| a[2][1] | 9 |
| a[2][2] | 10 |
| a[2][3] | 11 |
| | |

Two dimensional array

| | | | |
|---|---|---|---|
| a[0][0] | a[0][1] | a[0][2] | a[0][3] |
| a[1][0] | a[1][1] | a[1][2] | a[1][3] |
| a[2][0] | a[2][1] | a[2][2] | a[2][3] |

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One dimensional array

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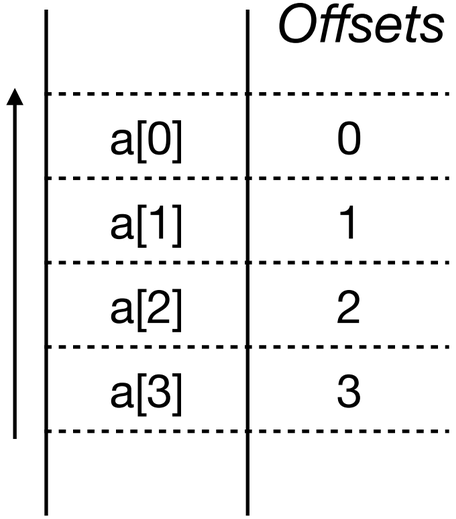

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C follows what is called *row-major order*, i.e rows first.

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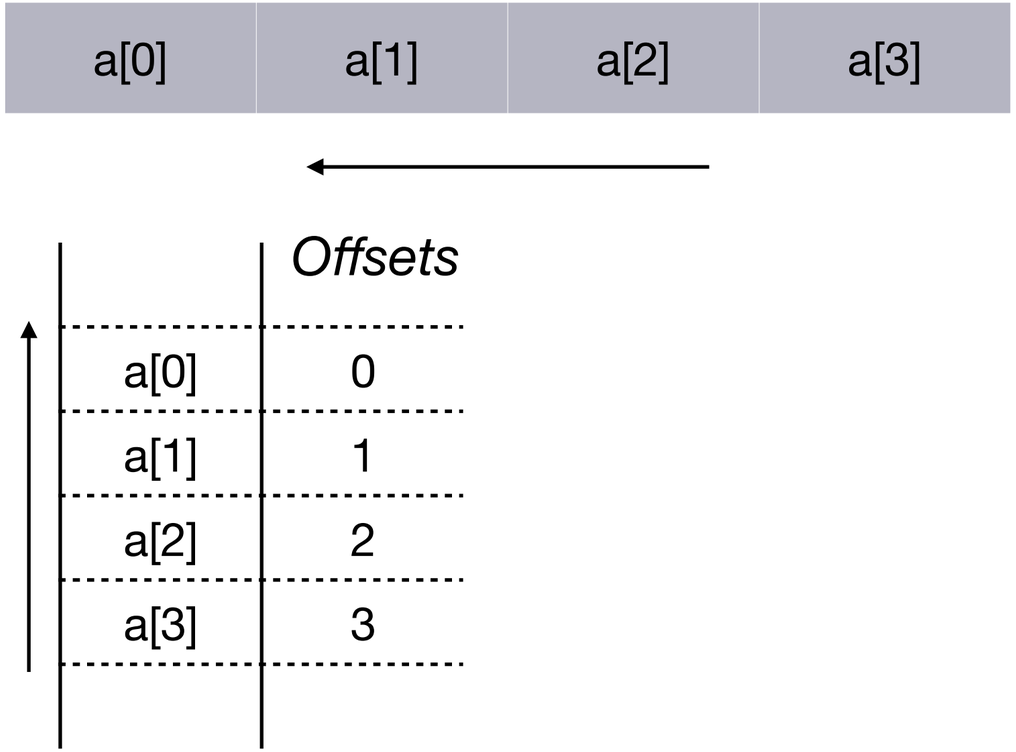
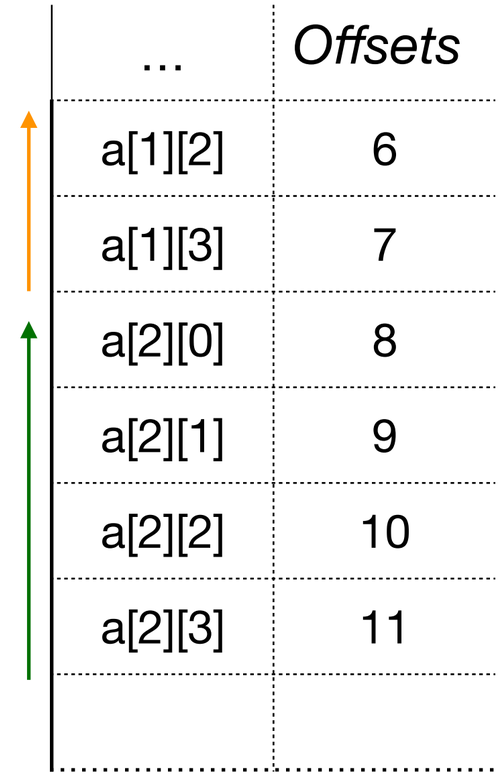
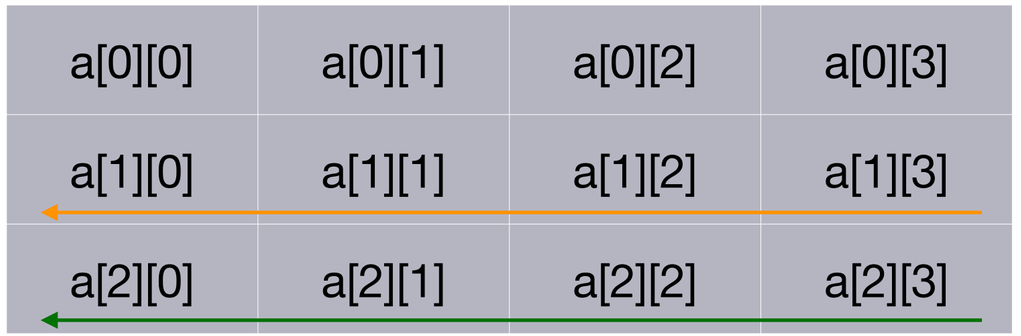



How to calculate offset?




Two dimensional array

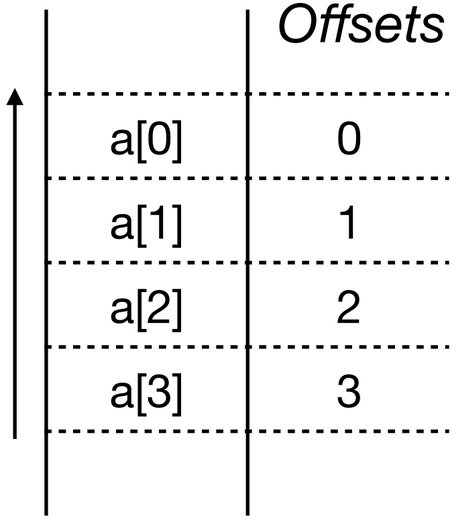



C follows what is called *row-major order*, i.e rows first.

# Allocating memory

One dimensional array

| a[0] | a[1] | a[2] | a[3] |
|---|---|---|---|

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offset = ri * nc + ci
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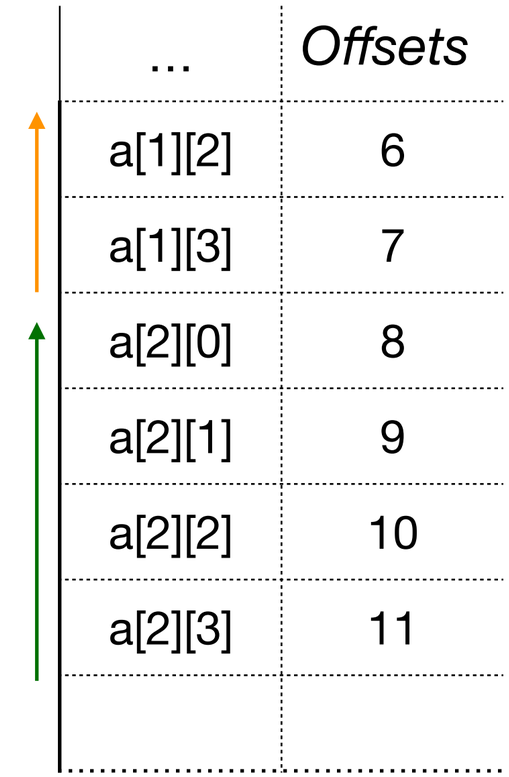


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|---|---|---|---|
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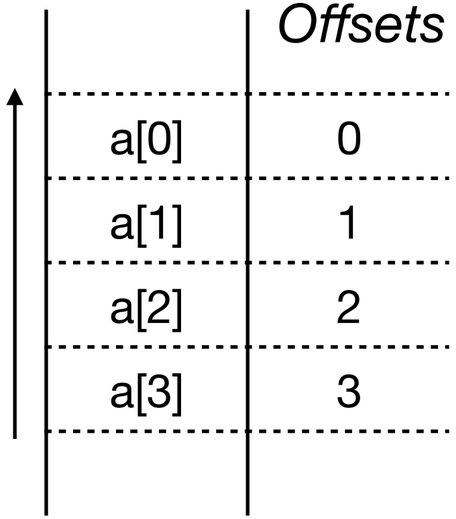

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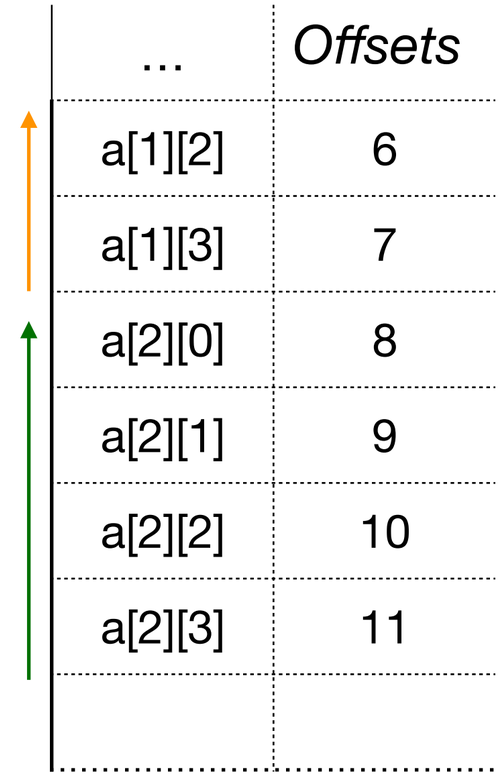
**Row index** **Column index**



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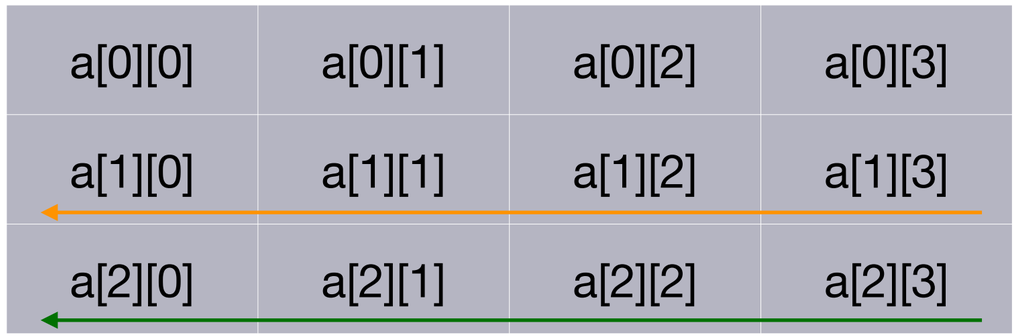

| | | | |
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```

- **Question**: How will `arr3d[4][3][2]` be stored in memory?
  - Hint 1: *Last index varies fastest.*
  - Hint 2: Element `arr3d[x-1][y-1][z-1]` will be bottom most.

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  - `int a[][3] = {1,2,3,4,5,6};`
- Why not: `int a[2][] = {{1,2,3},{4,5,6}};` ?