Array Lesson 1 Outline

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Mean of a List of Numbers

Consider a list of real numbers of length $n$ elements:

$x_1, x_2, x_3, \ldots, x_n$

The mean (average) of this list is:

$\frac{x_1 + x_2 + x_3 + \ldots + x_n}{n}$
Mean: Declarations

```c
#include <stdio.h>

int main ()
{
    const float initial_sum = 0.0;
    const int number_of_elements = 5;
    const int first_element = 0;
    const int program_success_code = 0;
    float input_value[number_of_elements];
    float sum;
    float mean;
    int element;
```
Mean: Greeting, Input

`printf("I'm going to calculate the\n");`
`printf("  mean of a list ");`
`printf("of length %d values.\n", number_of_elements);`
`printf("What are the %d values of the list?\n", number_of_elements);`
`for (element = first_element; element < number_of_elements; element++) {`
  `scanf("%f", &input_value[element]);`
`} /* for element */`
Mean: Calculation

sum = initial_sum;
for (element = first_element;
    element < number_of_elements; element++) {
    sum += input_value[element];
} /* for element */
mean = sum / number_of_elements;
Mean: Output

printf("The %d input values of the list are:\n", number_of_elements);
for (element = first_element;
    element < number_of_elements; element++) {
    printf("%f ", input_value[element]);
} /* for element */
printf("\n");
printf("The mean of the %d values", number_of_elements);
printf(" in the list is %f.\n", mean);
return program_success_code;
} /* main */
Mean: Compile, Run

% gcc -o mean5 mean5.c
% mean5
I'm going to calculate the mean of a list of length 5 values.
What are the 5 values of the list?
123.25   234.50   345.75   456.00   567.25
The 5 input values of the list are:
123.250000 234.500000 345.750000 456.000000 567.250000
The mean of the 5 values in the list is 345.350006.
#include <stdio.h>

int main ()
{
    const float initial_sum = 0.0;
    const int number_of_elements = 5;
    const int first_element = 0;
    const int program_success_code = 0;
    float input_value[number_of_elements];
    float sum;
    float mean;
    int element;
#include <stdio.h>

int main ()
{
    const float initial_sum = 0.0;
    const int number_of_elements = 7;
    const int first_element = 0;
    const int program_success_code = 0;
    float input_value[number_of_elements];
    float sum;
    float mean;
    int element;

    The rest of the program is EXACTLY THE SAME!
Mean: One Line Different

```
% diff mean5.c mean7.c
6c6
< const int number_of_elements = 5;
---
> const int number_of_elements = 7;
```

The `diff` Unix command compares two files of text and shows which lines are different.
The only statement that differs between `mean5.c` and `mean7.c` is the declaration of `number_of_elements`. 
Mean: Compile, Run for 5

```bash
% gcc -o mean5 mean5.c
% mean5
I'm going to calculate the
mean of a list of length 5 values.
What are the 5 values of the list?
123.25  234.50  345.75  456.00  567.25
The 5 input values of the list are:
123.250000  234.500000  345.750000  456.000000  567.250000
The mean of the 5 values in the list is 345.350006.
```
Mean: Compile, Run for 7

```bash
% gcc -o mean7 mean7.c
% mean7
```

I'm going to calculate the mean of a list of length 7 values. What are the 7 values of the list?

```
12.75 23.75 34.75 45.75 56.75 67.75 78.75
```

The 7 input values of the list are:

```
12.750000 23.750000 34.750000 45.750000 56.750000 67.750000 78.750000
```

The mean of the 7 values in the list is 45.750000.
Scalors #1

```c
#include <stdio.h>

int main ()
{
    int b, c, d, e, f;
    b = 0;
    c = 2;
    d = 4;
    e = 6;
    f = 8;
    printf("b = %d\n", b);
    printf("c = %d\n", c);
    printf("d = %d\n", d);
    printf("e = %d\n", e);
    printf("f = %d\n", f);
    return 0;
}
```

Note that, in Unix, a \textbf{backslash} at the end of a Unix command line means: “continue this Unix command on the next line.”
All of the variables in the program are simple int variables. Each of the individual int variables has a **single** name, a **single** address, a **single** data type and a **single** value. Such variables, whether their type is int, float, char or whatever, are referred to as **scalar** variables.
Another Scalar Example

```c
#include <stdio.h>

int main ()
{ /* main */
    int a0, a1, a2, a3, a4;
    a0 = 0;
    a1 = 2;
    a2 = 4;
    a3 = 6;
    a4 = 8;
    printf("a0 = %d\n", a0);
    printf("a1 = %d\n", a1);
    printf("a2 = %d\n", a2);
    printf("a3 = %d\n", a3);
    printf("a4 = %d\n", a4);
    return 0;
} /* main */
```

The only difference between this program and the previous program is the names of the scalar variables (and therefore some of the output).
A Similar Program, with Multiplication

% cat scalar_mult.c
#include <stdio.h>

int main ()
{ /* main */
    int a0, a1, a2, a3, a4;
    a0 = 0 * 2;
    a1 = 1 * 2;
    a2 = 2 * 2;
    a3 = 3 * 2;
    a4 = 4 * 2;
    printf("a0 = %d\n", a0);
    printf("a1 = %d\n", a1);
    printf("a2 = %d\n", a2);
    printf("a3 = %d\n", a3);
    printf("a4 = %d\n", a4);
    return 0;
} /* main */

% gcc -o scalar_mult \ scalar_mult.c
% scalar_mult

a0 = 0
a1 = 2
a2 = 4
a3 = 6
a4 = 8

Notice that, in this program, the values of the scalar variables are obtained by multiplying a constant by the number associated with the scalar variable.
A Similar Program, with a Twist

```c
#include <stdio.h>

int main ()
{
    int a[5];
    a[0] = 0 * 2;
    a[1] = 1 * 2;
    a[2] = 2 * 2;
    a[3] = 3 * 2;
    a[4] = 4 * 2;
    printf("a[0] = %d\n", a[0]);
    printf("a[1] = %d\n", a[1]);
    printf("a[2] = %d\n", a[2]);
    printf("a[3] = %d\n", a[3]);
    printf("a[4] = %d\n", a[4]);
    return 0;
}

% gcc -o array_mult array_mult.c
% array_mult

a[0] = 0
a[1] = 2
a[2] = 4
a[3] = 6
a[4] = 8

Huh?
Arrays

```java
int a[5];
```

An **array** is a special kind of variable. Like a scalar variable, an array has:

- a name;
- an address;
- a data type.

But instead of an array having exactly one single value, it can have **multiple values**.

Each of these values is referred to as an **element** of the array.

If you’re familiar with **vectors** in mathematics, you can think of an array as the equivalent idea, but in computing instead of in mathematics.
Array Element Properties

Each of the elements of an array is just about exactly like a scalar variable of the same data type.

An element of an array has:

1. a name, which it shares with all of the other elements of the array that it belongs to;
2. an address, which we’ll learn about shortly;
3. a data type, which it shares with all of the other elements of the array that it belongs to;
4. a single value.

But, an element of an array also has:

5. an index, which we’ll learn about shortly.
Array Properties #1

int a[5];

An array as a whole has the following properties:

1. It has a data type, which is the data type of each of its elements; for example, int.
int a[5];

An array as a whole has the following properties:

2. It as a dimension attribute, sometimes called its length, which describes the number of elements in the array; for example, [5].
Array Properties #3

int a[5];

An array **as a whole** has the following properties:

3. It has exactly as many **values** as it has elements, and in fact each of its elements contains exactly one of its values.
Array Properties #4

```c
int a[5];
```

An array **as a whole** has the following properties:

4. Its elements are accessed via **indexing** with respect to the variable name; for example,

```c
a[2] = 7;
```
An array **as a whole** has the following properties:

5. Its elements are _contiguous_ in memory; for example,

```
int a[5];
```

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

```
a[0]      Address 12340
?????????

a[1]      Address 12344
?????????

a[2]      Address 12348
?????????

a[3]      Address 12352
?????????

a[4]      Address 12356
?????????
Array Indices #1

```c
int a[5];
```

We access a particular element of an array using

*index* notation:

```c
a[2]
```

This notation is pronounced “*a* of 2” or “*a* sub 2.”

The number in square brackets – for example, the 2 in `a[2]` – is called the

*index* or *subscript* of the array element.

Array indices are exactly analogous to subscript numbers in mathematics:

```c
a_0, a_1, a_2, a_3, a_4
```
Array Indices #2

int a[5];

An individual element of an array – for example, $a[2]$ – has exactly the same properties as a scalar variable of the same data type – except for being accessed via indexing.

Notice that the elements of an array are numbered from 0 through ($length - 1$);
in the above example, the elements of $a$ are

$a[0], a[1], a[2], a[3], a[4]$
Multidimensional Arrays & 1D Arrays

An array can have **multiple dimensions**:

```java
int array2d[8][5];
```

For now, we’re going to concentrate on arrays with only one dimension.

A one-dimensional array is sometimes called a **vector**, because of the close relationship between arrays in computing and vectors in mathematics.

A two-dimensional array is sometimes called a **matrix**.

A three-dimensional array is sometimes called a **field**.
Array Declarations #1

The general form of an array declaration is:

```plaintext
type arrayname1[dim1], arrayname2[dim2], ...;
```

For example:

```plaintext
int a[8], b[4], c[9];
```

does the compiler to set up three `int` arrays in memory.
Array Declarations #2

```c
int a[5], b[4], c[9];
```
causes the compiler to set up three `int` arrays in memory, like so:

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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>?</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

|------|------|------|------|------|------|------|------|------|
int a[8], b[4], c[9];

In principle, these arrays could be remote from each other in memory (for example, a could start at address 12340, b could start at address 67890 and c could start at address 981439294).

In practice, they are usually contiguous or almost contiguous in memory; that is, the last byte of array a will typically be right next to the first byte of array b, and the last byte of array b will typically be right next to the first byte of array c.

However, the compiler isn’t required to make the different arrays contiguous in memory.

The only contiguity constraint is that, within each array, all of the elements are contiguous and sequential.
Assigning a Value to an Array Element

Because an individual array element is exactly analogous to a scalar variable, we can assign or input a value into it in exactly the same ways that we assign or input values into scalar variables.

For example, we can use a scalar assignment for each individual element.
Array Element Assignment Example

```c
#include <stdio.h>

int main ()
{
    int a[3];
    a[0] = 5;
    a[1] = 16;
    a[2] = -77;
    printf("a[0] = %d\n", a[0]);
    printf("a[1] = %d\n", a[1]);
    printf("a[2] = %d\n", a[2]);
    return 0;
} /* main */
```

% cat arrayeltassn.c
% gcc -o arrayeltassn arrayeltassn.c
% arrayeltassn
a[0] = 5
a[1] = 16
a[2] = -77
Getting Array Element Value with `scanf`

Just as we can assign a value to an individual array element, we can use `scanf` to obtain the value of each individual array element.
#include <stdio.h>

int main ()
{
  /* main */
  float a[3];

  printf("Input a[0],a[1],a[2]:\n");
  scanf("%f %f %f", &a[0], &a[1], &a[2]);
  printf("a[0] = %f\n", a[0]);
  printf("a[1] = %f\n", a[1]);
  printf("a[2] = %f\n", a[2]);
  return 0;
}
/* main */
Array Element `scanf` Example #2

```bash
% gcc -o arrayeltread arrayeltread.c
% arrayeltread
Input a[0],a[1],a[2]:
5.5 16.16 -770.770
a[0] = 5.500000
a[1] = 16.160000
a[2] = -770.770020
```
#include <stdio.h>

int main ()
{
    /* main */
    const int number_of_elements = 5;
    const int program_success_code = 0;
    int a[number_of_elements];
    int count;

    for (count = 0; count < number_of_elements; count++) {
        a[count] = 2 * count;
    } /* for count */

    for (count = 0; count < number_of_elements; count++) {
        printf("a[\%2d] = \%2d\n", count, a[count]);
    } /* for count */

    return program_success_code;
} /* main */
for  Loops for Tasks on Arrays #2

```bash
% gcc -o array_for_mult array_for_mult.c
% array_for_mult
a[ 0] = 0
a[ 1] = 2
a[ 2] = 4
a[ 3] = 6
a[ 4] = 8
```
Another for/Array Example #1

```c
#include <stdio.h>
#include <stdlib.h>

int main ()
{ /* main */
    const int minimum_number_of_elements = 1;
    const int maximum_number_of_elements = 15;
    const int program_failure_code = -1;
    const int program_success_code = 0;
    int a[maximum_number_of_elements];
    int number_of_elements;
    int count;

    printf("How long will the array be (%d to %d)?\n", minimum_number_of_elements, maximum_number_of_elements);
    scanf("%d", &number_of_elements);
    if ((number_of_elements < minimum_number_of_elements) || (number_of_elements > maximum_number_of_elements)) {
        printf("That’s not a valid array length!\n");
        exit(program_failure_code);
    } /* if ((number_of_elements < ...) || ...) */
```
Another for/Array Example #2

for (count = 0; count < number_of_elements; count++) {
    a[count] = 2 * count;
} /* for count */

for (count = 0; count < number_of_elements; count++) {
    printf("a[%2d] = %2d\n", count, a[count]);
} /* for count */

return program_success_code;
} /* main */
Another for/Array Example #3

```c
% gcc -o array_for_mult_read array_for_mult_read.c
% array_for_mult_read
How long will the array be (1 to 15)?
0
That’s not a valid array length!
% array_for_mult_read
How long will the array be (1 to 15)?
16
That’s not a valid array length!
% array_for_mult_read
How long will the array be (1 to 15)?
5
a[ 0] = 0
a[ 1] = 2
a[ 2] = 4
a[ 3] = 6
a[ 4] = 8
```
Don’t Need to Use Entire Declared Length

#include <stdio.h>

int main ()
{ /* main */
    const int minimum_number_of_elements = 1;
    const int maximum_number_of_elements = 15;
    const int program_failure_code = -1;
    const int program_success_code = 0;
    int a[maximum_number_of_elements];
    ...
} /* main */
...

% array_for_mult_read
How long will the array be (1 to 15)?
5
a[ 0] = 0
a[ 1] = 2
a[ 2] = 4
a[ 3] = 6
a[ 4] = 8

Notice that we can declare an array to be larger than the portion of the array that we actually use, because RAM is cheap.