



1-d Arrays

Array

- Many applications require multiple data items that have common characteristics
 - In mathematics, we often express such groups of data items in indexed form:
 - $x_1, x_2, x_3, \dots, x_n$
- Array is a data structure which can represent a collection of data items which have the same data type (float/int/char/...)

Example: Printing Numbers in Reverse

3 numbers

```
int a, b, c;
scanf("%d", &a);
scanf("%d", &b);
scanf("%d", &c);
printf("%d ", c);
printf("%d ", b);
printf("%d \n", a);
```

4 numbers

```
int a, b, c, d;
scanf("%d", &a);
scanf("%d", &b);
scanf("%d", &c);
scanf("%d", &d);
printf("%d ", d);
printf("%d ", c);
printf("%d ", b);
printf("%d \n", a);
```

The Problem

- Suppose we have 10 numbers to handle
- Or 20
- Or 100
- Where do we store the numbers ? Use 100 variables ??
- How to tackle this problem?
- Solution:
 - Use arrays

Printing in Reverse Using Arrays

```
void main()
{
    int n, A[100], i;
    printf("How many numbers to read? ");
    scanf("%d", &n);
    for (i = 0; i < n; ++i)
        scanf("%d", &A[i]);
    for (i = n - 1; i >= 0; --i)
        printf("%d ", A[i]);
    printf("\n");
}
```

Using Arrays

- All the data items constituting the group share the same name

```
int x[10];
```

- Individual elements are accessed by specifying the index



x[0] **x[1]** **x[2]**

x[9]

X is a 10-element one dimensional array

A first example

```
void main()
{
  int i;
  int data[10];
  for (i=0; i<10; i++) data[i]= i;
  i=0;
  while (i<10)
  {
    printf("Data[%d] = %d\n", i, data[i]);
    i++;
  }
}
```

“data refers to a block of 10 integer variables, data[0], data[1], ..., data[9]



The result

Array size should be a constant

```
void main()
{
    int i;
    int data[10];
    for (i=0; i<10; i++) data[i]= i;
    i=0;
    while (i<10)
    {
        printf("Data[%d] = %d\n", i, data[i]);
        i++;
    }
}
```

Output

```
Data[0] = 0
Data[1] = 1
Data[2] = 2
Data[3] = 3
Data[4] = 4
Data[5] = 5
Data[6] = 6
Data[7] = 7
Data[8] = 8
Data[9] = 9
```

Declaring Arrays

- Like variables, the arrays used in a program must be declared before they are used
- General syntax:

`type array-name [size];`

- `type` specifies the type of element that will be contained in the array (int, float, char, etc.)
- `size` is an integer constant which indicates the maximum number of elements that can be stored inside the array

`int marks[5];`

- `marks` is an array that can store a maximum of 5 integers



- Examples:

```
int x[10];
```

```
char line[80];
```

```
float points[150];
```

```
char name[35];
```

- If we are not sure of the exact size of the array, we can define an array of a large size

```
int marks[50];
```

though in a particular run we may only be using, say, 10 elements

Accessing Array Elements

- A particular element of the array can be accessed by specifying two things:
 - Name of the array
 - Index (relative position) of the element in the array
- In C, the index of an array starts from **zero**
- Example:
 - An array is defined as `int x[10];`
 - The first element of the array x can be accessed as `x[0]`, fourth element as `x[3]`, tenth element as `x[9]`, etc.

Contd.

- The array index must evaluate to an integer between 0 and $n-1$ where n is the maximum number of elements possible in the array

$$a[x+2] = 25;$$

$$b[3*x-y] = a[10-x] + 5;$$

- Remember that each array element is a variable in itself, and can be used anywhere a variable can be used (in expressions, assignments, conditions,...)

How is an array stored in memory?

- Starting from a given memory location, the successive array elements are allocated space in consecutive memory locations

Array a



- x: starting address of the array in memory
- k: number of bytes allocated per array element
- $a[i] \rightarrow$ is allocated memory location at address $x + i * k$

Storage

```
void main()
{
    int i;
    int data[10];
    for(i=0; i<10; i++)
        printf("&Data[%d] = %u\n", i, &data[i]);
}
```

Output

&Data[0] = 3221224480

&Data[1] = 3221224484

&Data[2] = 3221224488

&Data[3] = 3221224492

&Data[4] = 3221224496

&Data[5] = 3221224500

&Data[6] = 3221224504

&Data[7] = 3221224508

&Data[8] = 3221224512

&Data[9] = 3221224516

Initialization of Arrays

- General form:

```
type array_name[size] = { list of values };
```

- Examples:

```
int marks[5] = {72, 83, 65, 80, 76};
```

```
char name[4] = {'A', 'm', 'i', 't'};
```

- The size may be omitted. In such cases the compiler automatically allocates enough space for all initialized elements

```
int flag[ ] = {1, 1, 1, 0};
```

```
char name[ ] = {'A', 'm', 'i', 't'};
```

How to read the elements of an array?

- By reading them one element at a time

```
for (j=0; j<25; j++)
```

```
    scanf ("%f", &a[j]);
```

- The ampersand (&) is necessary
- The elements can be entered all in one line or in different lines

A Warning

- In C, while accessing array elements, array bounds are not checked

- Example:

```
int marks[5];  
:  
:  
marks[8] = 75;
```

- The above assignment would not necessarily cause an error
- Rather, it may result in unpredictable program results

Reading into an array

```
void main()
{
    const int MAX_SIZE = 100;
    int i, size;
    float marks[MAX_SIZE];
    float total;
    scanf("%d",&size);
    for (i=0, total=0; i<size; i++)
    {
        scanf("%f",&marks[i]);
        total = total + marks[i];
    }
    printf("Total = %f \n Avg = %f\n", total,
total/size);
}
```

Output

4

2.5

3.5

4.5

5

Total = 15.500000

Avg = 3.875000

How to print the elements of an array?

- By printing them one element at a time

```
for (j=0; j<25; j++)  
    printf (“\n %f”, a[j]);
```

- The elements are printed one per line

```
printf (“\n”);  
for (j=0; j<25; j++)  
    printf (“ %f”, a[j]);
```

- The elements are printed all in one line
(starting with a new line)

How to copy the elements of one array to another?

- By copying individual elements

```
for (j=0; j<25; j++)
```

```
    a[j] = b[j];
```

- The element assignments will follow the rules of assignment expressions
- Destination array must have sufficient size

Example 1: Find the minimum of a set of 10 numbers

```
void main()
{
    int a[10], i, min;

    for (i=0; i<10; i++)
        scanf ("%d", &a[i]);

    min = a[0];
    for (i=1; i<10; i++)
    {
        if (a[i] < min)
            min = a[i];
    }
    printf ("\n Minimum is %d", min);
}
```

Alternate Version 1

Change only one
line to change the
problem size

```
const int size = 10;

void main()
{
    int a[size], i, min;

    for (i=0; i<size; i++)
        scanf ("%d", &a[i]);

    min = a[0];
    for (i=1; i<size; i++)
    {
        if (a[i] < min)
            min = a[i];
    }
    printf ("\n Minimum is %d", min);
}
```

Alternate Version 2

Change only one line to change the problem size

Used #define macro

```
#define size 10

void main()
{
    int a[size], i, min;

    for (i=0; i<size; i++)
        scanf ("%d", &a[i]);

    min = a[0];
    for (i=1; i<size; i++)
    {
        if (a[i] < min)
            min = a[i];
    }
    printf ("\n Minimum is %d", min);
}
```

#define macro

- `#define X Y`
- Preprocessor directive
- Compiler will first replace all occurrences of string X with string Y in the program, then compile the program
- Similar effect as read-only variables (`const`), but no storage allocated
- We prefer you use `const` instead of `#define`

Alternate Version 3

Define an array of large size and use only the required number of elements

```
void main()
{
    int a[100], i, min, n;

    scanf ("%d", &n); /* Number of elements */
    for (i=0; i<n; i++)
        scanf ("%d", &a[i]);

    min = a[0];
    for (i=1; i<n; i++)
    {
        if (a[i] < min)
            min = a[i];
    }
    printf ("\n Minimum is %d", min);
}
```

Example 2: Computing cgpa

Handling two arrays
at the same time

```
const int nsub = 6;

void main()
{
    int grade_pt[nsub], cred[nsub], i,
        gp_sum=0, cred_sum=0;
    double gpa;

    for (i=0; i<nsub; i++)
        scanf ("%d %d", &grade_pt[i], &cred[i]);

    for (i=0; i<nsub; i++)
    {
        gp_sum += grade_pt[i] * cred[i];
        cred_sum += cred[i];
    }
    gpa = ((float) gp_sum) / cred_sum;
    printf ("\n Grade point average: is %.2lf", gpa);
}
```

Example: Binary Search

- Searching for an element k in a sorted array A with n elements
- Idea:
 - Choose the middle element $A[n/2]$
 - If $k == A[n/2]$, we are done
 - If $k < A[n/2]$, search for k between $A[0]$ and $A[n/2 - 1]$
 - If $k > A[n/2]$, search for k between $A[n/2 + 1]$ and $A[n-1]$
 - Repeat until either k is found, or no more elements to search
- Requires less number of comparisons than linear search in the worst case ($\log_2 n$ instead of n)

```

void main() {
    int A[100], n, k, i, mid, low, high;
    scanf("%d %d", &n, &k);
    for (i=0; i<n; ++i) scanf("%d", &A[i]);
    low = 0; high = n - 1; mid = low + (high - low)/2;
    while (high >= low) {
        printf("low = %d, high = %d, mid = %d, A[%d] = %d\n",
            low, high, mid, mid, A[mid]);
        if (A[mid] == k) {
            printf("%d is found\n", k);
            break;
        }
        if (k < A[mid]) high = mid - 1;
        else low = mid + 1;
        mid = low + (high - low)/2;
    }
    If (high < low) printf("%d is not found\n", k);
}

```

Output

8 21

9 11 14 17 19 20 23 27

low = 0, high = 7, mid = 3, A[3] = 17

low = 4, high = 7, mid = 5, A[5] = 20

low = 6, high = 7, mid = 6, A[6] = 23

21 is not found

8 14

9 11 14 17 19 20 23 27

low = 0, high = 7, mid = 3, A[3] = 17

low = 0, high = 2, mid = 1, A[1] = 11

low = 2, high = 2, mid = 2, A[2] = 14

14 is found

Example: Selection Sort

- Sort the elements of an array A with n elements in ascending order
- Basic Idea:
 - Find the min of the n elements, swap it with $A[0]$ (so min is at $A[0]$ now)
 - Now find the min of the remaining $n-1$ elements, swap it with $A[1]$ (so 2nd min is at $A[1]$ now)
 - Continue until no more elements left

```

void main() {
    int A[100], n, i, j, k, min, pos, temp;
    scanf("%d", &n);
    for (i=0; i<n; ++i) scanf("%d", &A[i]);
    for (i = 0; i < n - 1; ++i) {
        min = A[i]; pos = i;
        for (j = i + 1; j < n; ++j) {
            if (A[j] < min) {
                min = A[j];
                pos = j;
            }
        }
        temp = A[i];
        A[i] = A[pos];
        A[pos] = temp;
        for (k=0; k<n; ++k) printf("%d  ", A[k]);
        printf("\n");
    }
}

```

Output

6

7 12 5 15 17 9

5 12 7 15 17 9

5 7 12 15 17 9

5 7 9 15 17 12

5 7 9 12 17 15

5 7 9 12 15 17

8

9 8 7 6 5 4 3 2

2 8 7 6 5 4 3 9

2 3 7 6 5 4 8 9

2 3 4 6 5 7 8 9

2 3 4 5 6 7 8 9

2 3 4 5 6 7 8 9

2 3 4 5 6 7 8 9

2 3 4 5 6 7 8 9

Things you cannot do

- You cannot

- use = to assign one array variable to another

```
a = b; /* a and b are arrays */
```

- use == to directly compare array variables

```
if (a == b) .....
```

- directly scanf or printf arrays

```
printf (".....", a);
```

Character Arrays and Strings

```
char C[8] = { 'a', 'b', 'h', 'i', 'j', 'i', 't', '\0' };
```

- C[0] gets the value 'a', C[1] the value 'b', and so on. The last (7th) location receives the null character '\0'
- Null-terminated (last character is '\0') character arrays are also called strings
- Strings can be initialized in an alternative way. The last declaration is equivalent to:

```
char C[8] = "abhijit";
```

- The trailing null character is missing here. C automatically puts it at the end if you define it like this
- Note also that for individual characters, C uses single quotes, whereas for strings, it uses double quotes

Reading strings: %s format

```
void main()
{
    char name[25];
    scanf("%s", name);
    printf("Name = %s \n", name);
}
```

**%s reads a string into a character array given the array name or start address.
It ends the string with '\0'**

An example

```
void main()
{
    #define SIZE 25
    int i, count=0;
    char name[SIZE];
    scanf("%s", name);
    printf("Name = %s \n", name);
    for (i=0; name[i]!='\0'; i++)
        if (name[i] == 'a') count++;
    printf("Total a's = %d\n", count);
}
```

Note that character strings read
in %s format end with '\0'

Seen on screen

Typed as input

Satyanarayana

Name = Satyanarayana

Total a's = 6

Printed by program

Palindrome Checking

```
void main()
{
    const int SIZE = 25;
    int i, flag, count=0;
    char name[SIZE];
    scanf("%s", name);    /* Read Name */
    for (i=0; name[i]!='\0'; i++);    /* Find Length of String */
    printf("Total length = %d\n",i);
    count=i; flag = 0;
    /* Loop below checks for palindrome by comparison*/
    for(i=0; i<count; i++) if (name[i]!=name[count-i-1]) flag = 1;
    if (flag ==0) printf ("%s is a Palindrome\n", name);
    else printf("%s is NOT a Palindrome\n", name);
}
```

Some Exercises

- 1. Write a C program that reads an integer n and stores the first n Fibonacci numbers in an array.**
- 2. Write a C program that reads an integer n and uses an array to efficiently find out the first n prime numbers.**
- 3. Read in an integer n , read in n integers and print the integer with the highest frequency.**
- 4. Read in an integer n , read in n numbers and find out the mean, median and mode.**
- 5. Read in two names and compare them and print them in lexicographic (dictionary) order.**
- 6. Read in an integer n , read in n names and print the last name when compared in lexicographic order.**