

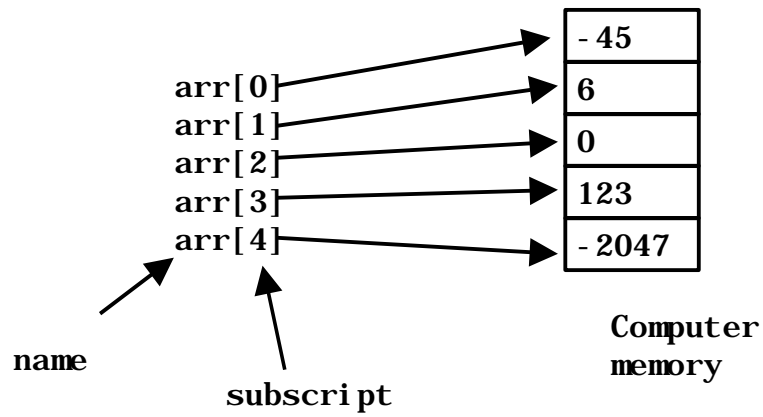
W 4.1

Use Arrays, learn subscripting of arrays, assignment, and examination of contents.

What Are Arrays ?

- A compound type composed of many items (variables), all of the same type and organised in a consecutive (contiguous) set of memory locations.
- Like a row of boxes, each box may contain a different value, all boxes of the same type.

A 5 Element Array



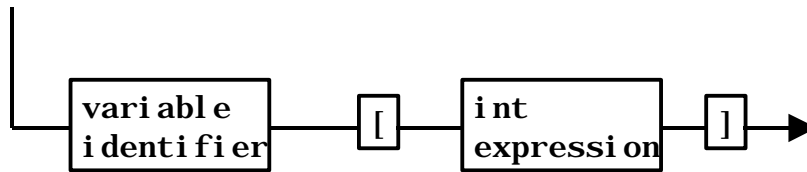
Name of array (Note that all elements of this array have the same name, `c`)

<code>c[0]</code>	-45
<code>c[1]</code>	6
<code>c[2]</code>	0
<code>c[3]</code>	72
<code>c[4]</code>	1543
<code>c[5]</code>	-89
<code>c[6]</code>	0
<code>c[7]</code>	62
<code>c[8]</code>	-3
<code>c[9]</code>	1
<code>c[10]</code>	6453
<code>c[11]</code>	78

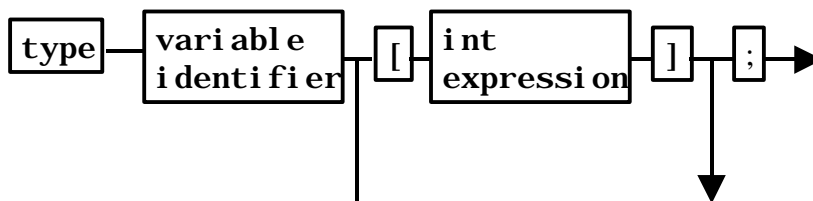
Position number of the element within array `c`

Array Syntax

array element



Declaration Syntax



Sample Code - Array Initialisation I

```
#include <iostream.h>
#include <iomanip.h>
int main()
{
    int i, n[10];
    for ( i = 0; i < 10; i++)    // initialize array
        n[ i ] = 0;
    cout << "Element" << setw( 13 ) << "Value" << endl;
    for ( i = 0; i < 10; i++)    // print array
        cout << setw( 7 ) << i << setw( 13 ) << n[ i ] << endl;
    return 0;
}
```

Sample Code - Array Initialisation II

```
#include <iostream.h>
#include <iomanip.h>

int main()
{
    int n[ 10 ] = { 32, 27, 64, 18, 95, 14, 90, 70, 60, 37 };

    cout << "Element" << setw( 13 ) << "Value" << endl;
    for ( int i = 0; i < 10; i++ )
        cout << setw( 7 ) << i << setw( 13 ) << n[ i ] << endl;
    return 0;
}
```

**Same thing achieved within
the declaration of the array**

Programming Tips

- Remember that the first element is subscripted at zero i.e. arr[0] is first and arr[1] is second !
- Initialise your arrays before using them
- `int arr[5] = {32, 27, 64, 18, 95, 14}` will produce a compile time error
- if you declare
 - `int arr[] = {32, 27, 64, 18, 95, 14}`
 - then the size of the array will be 6 i.e. arr[5] (yes!)

Placing Values in Arrays

```
// Initialize array s to the even integers from 2 to 20. Fig. 4.5
#include <iostream.h>
#include <iomanip.h>
int main()
{
    const int arraySize = 10; // note here, const, cannot modify this later !
    int j, s[ arraySize ];
    for ( j = 0; j < arraySize; j++ ) // set the values
        s[ j ] = 2 + 2 * j;
    cout << "Element" << setw( 13 ) << "Value" << endl;
    for ( j = 0; j < arraySize; j++ ) // print the values
        cout << setw( 7 ) << j << setw( 13 ) << s[ j ] << endl;
    return 0;
}
```

Getting at Values in Arrays

```
// Compute the sum of the elements of the array // Fig. 4.8
#include <iostream.h>
int main()
{
    const int arraySize = 12;
    int a[ arraySize ] = { 1, 3, 5, 4, 7, 2, 99, 16, 45, 67, 89, 45 };
    int total = 0;
    for ( int i = 0; i < arraySize ; i++ )
        total += a[ i ];
    cout << "Total of array element values is " << total << endl;
    return 0;
}
```

Figure this out !... Use Debugger

```
#include <iostream.h> //fig 4.9
#include <iomanip.h>
int main()
{
    const int responseSize = 40, frequencySize = 11;
    int responses[ responseSize ] = { 1, 2, 6, 4, 8, 5, 9, 7, 8, 10, 1, 6, 3, 8,
    6, 10, 3, 8, 2, 7, 6, 5, 7, 6, 8, 6, 7, 5, 6, 6, 5, 6, 7, 5, 6, 4, 8, 6, 8, 10 };
    int frequency[ frequencySize ] = { 0 };
    for ( int answer = 0; answer < responseSize; answer++ )
        ++frequency[ responses[answer] ];
    cout << "Rating" << setw( 17 ) << "Frequency" << endl;
    for ( int rating = 1; rating < frequencySize; rating++ )
        cout << setw( 6 ) << rating
            << setw( 17 ) << frequency[ rating ] << endl;
    return 0;
}
```

See pp249, 250

```

1 // Fig. 4_12: fig04_12.cpp
2 // Treating character arrays as strings
3 #include <iostream>
4
5 using std::cout;
6 using std::cin;
7 using std::endl;
8
9 int main()
10 {
11     char string1[ 20 ], string2[] = "string literal";
12
13     cout << "Enter a string: ";
14     cin >> string1;
15     cout << "string1 is: " << string1
16         << "\nstring2 is: " << string2
17         << "\nstring1 with spaces between characters is:\n";
18
19     for ( int i = 0; string1[ i ] != '\0'; i++ )
20         cout << string1[ i ] << ' ';
21
22     cin >> string1; // reads "there"
23     cout << "\nstring1 is: " << string1 << endl;
24
25     cout << endl;
26     return 0;
27 }

```

Enter a string: Hello there
string1 is: Hello
string2 is: string literal
string1 with spaces between characters is:
H e l l o
string1 is: there

Inputted strings are separated by whitespace characters. "there" stayed in the buffer.

Notice how string elements are referenced like arrays.

- 1. Initialize strings
- 2. Print strings
- 2.1 Define loop
- 2.2 Print characters individually
- Program Output

More Programming Tips for Arrays

- Validate correctness of input values, computed values for array subscripts, ensure not out of bounds
- Referencing elements outside array bounds gives rise to serious effects (crash !)
- Never reference below 0 and never reference greater than one less than max. subscript.
- Ensure loop terminating conditions obey rules

Multi-dimensional Arrays

- So far we have used an array as a linear collection of things of the same type, like rows or columns
- May now use arrays which have **both** rows **and** columns.
- These may be 2D, 3D or nD arrays
- Month is a 2D array, while week is a 1D array

Example Multi-dimensional Array

	Column 0	Column 1	Column 2
Row 0	Arr[0][0]	Arr[0][1]	Arr[0][2]
Row 1	Arr[1][0]	Arr[1][1]	Arr[1][2]
Row 2	Arr[2][0]	Arr[2][1]	Arr[2][2]

Diagram illustrating the structure of a 2D array. The array is represented as a grid with 3 rows and 3 columns. The rows are labeled Row 0, Row 1, and Row 2. The columns are labeled Column 0, Column 1, and Column 2. The elements are accessed using the syntax Arr[Row][Column].

Labels and arrows pointing to the first row of the array:

- Array Name: Arr
- Row Subscript: 0
- Column Subscript: 0, 1, 2

Handling Multi-dimensional Arrays

```
#include <iostream.h>
int main()
{
    int myarr1[2][3]={{1,2,3},{4,5,6}};
    int myarr2[2][3]={{1,2,3}};
    int myarr3[2][3]={{1}, {2,3}};
    int i,j;
    cout << "Values in array1 by row are:" << endl;
    for (i = 0; i < 2; i++)
    {
        for (j = 0; j < 3; j++)
            cout << myarr1[i][j] << ' ';
        cout << endl;
    }

    cout << "Values in array2 by row are:" << endl;
    for (i = 0; i < 2; i++)
    {
        for (j = 0; j < 3; j++)
            cout << myarr2[i][j] << ' ';
        cout << endl;
    }

    cout << "Values in array3 by row are:" << endl;
    for (i = 0; i < 2; i++)
    {
        for (j = 0; j < 3; j++)
            cout << myarr3[i][j] << ' ';
        cout << endl;
    }

    return 0;
}
```

See 2Darr. cpp

Array: Exercises

- Build an array (1D), dimension 15, of integers in the range of 0..20
 - print a bar chart with a series of '+' to represent the contents of the array
 - +++ is 3, ++++++++ is 7
- Build an array of *char* and reverse it
 - do it using 2 arrays, then do it using 1 array
- Check arrays of *char* for palindromes
- NB **char** arrays may be null '\0' terminated

Array: Graded Exercise

- Write a program to play knots & crosses, the program should be written in stages
 - print out the contents of a 2D array (3 x 3)
 - select a point (tell a user to select column, row)
 - place a 1 or a 0 in that position
 - print the contents again to view the board
 - check for a win (row, column, diagonal)
 - stop playing if board full or a win occurs
 - go to step 2

Functions with Array Parameters

Pass by Value
Pass by Reference

Notes

- Section 4.5 in Deitel & Deitel
- Prototype declaration appears as follows
 - `void modifyArray(int [], int);`
- The declaration has an array of *int* and one *int*
- Function call as follows
 - `modifyArray(a, arraySize);`
- Only **name** of array (no “[]”) and then an **int** passed

```
1 // Fig. 4.14: fig04_14.cpp
2 // Passing arrays and individual array elements to functions
3 #include <iostream>
4
5 using std::cout;
6 using std::endl;
7
8 #include <iomanip>
9
10 using std::setw;
11
12 void modifyArray( int [], int ); // appears strange
13 void modifyElement( int );
14
15 int main()
16 {
17     const int arraySize = 5;
18     int i, a[ arraySize ] = { 0, 1, 2, 3, 4 };
19
20     cout << "Effects of passing entire array call-by-reference:"
21         << "\n\nThe values of the original array are:\n";
22
23     for ( i = 0; i < arraySize; i++ )
24         cout << setw( 3 ) << a[ i ];
25
26     cout << endl;
27
28     // array a passed call-by-reference
29     modifyArray( a, arraySize );
30
31     cout << "The values of the modified array are:\n";
```

Functions can modify entire arrays. Individual array elements are not modified by default.

No parameter names in function prototype.

The values of the original array are:
0 1 2 3 4
The values of the modified array are:
0 2 4 6 8

- 1. Define function to take in arrays
- 1.1 Initialize arrays
- 2. Modify the array (call by reference)

```

32
33   for ( i = 0; i < arraySize; i++ )
34       cout << setw( 3 ) << a[ i ];
35
36   cout << "\n\n"
37       << "Effects of passing array element call-by-value:"
38       << "\n\nThe value of a[3] is " << a[ 3 ] << '\n';
39
40   modifyElement( a[ 3 ] );
41
42   cout << "The value of a[3] is " << a[ 3 ] << endl;
43
44   return 0;
45 }
46
47 // In function modifyArray, "b" points to the original
48 // array "a" in memory.
49 void modifyArray( int b[], int sizeofArray )
50 {
51     for ( int j = 0; j < sizeofArray; j++ )
52         b[ j ] *= 2;
53 }
54
55 // In function modifyElement, "e" is a local
56 // array element a[ 3 ] passed from main.
57 void modifyElement( int e )
58 {
59     cout << "Value in modifyElement is "
60         << ( e *= 2 ) << endl;
61 }

```

- 2.1 Modify an element (call by value)
- 3. Print changes.

Parameter names required in function definition

Definitions

Effects of passing array element call-by-value:
The value of a[3] is 6
Value in modifyElement is 12
The value of a[3] is 6

```

Effects of passing entire array call-by-reference:

The values of the original array are:
0 1 2 3 4
The values of the modified array are:
0 2 4 6 8

Effects of passing array element call-by-value:

The value of a[3] is 6
Value in modifyElement is 12
The value of a[3] is 6

```

- Program Output

Notes on Example I

- Available on
 - g:\public\bstone\
- Size of array should be passed, as function only told where array starts, not where it ends.
- Default is pass by Reference as we are passing a pointer (memory location) variable
- Function has access to original array, so can change values.
- Parameter names are optional on prototype.

Notes on Example II

- Program demonstrates passing an array Vs passing an individual element
- Passing the individual element and then operating on it does not modify the contents of the original array (pass by value)
- If you do not want to modify the contents of an **array**, then you must explicitly say so, see next program

```

// Demonstrating the const type qualifier
#include <iostream.h>
void tryToModifyArray( const int [] );
int main()
{
    int a[] = { 10, 20, 30 };
    tryToModifyArray( a );
    cout << a[ 0 ] << ' ' << a[ 1 ] << ' ' << a[ 2 ] << '\n';
    return 0;
}
void tryToModifyArray( const int b[] )
{
    b[ 0 ] /= 2; // error
    b[ 1 ] /= 2; // error
    b[ 2 ] /= 2; // error
}

```

Notes on **const** Qualifier

- The const qualifier prevents programmer from changing the contents of the argument / variable
- With other parameter types, pass by value is the default, with arrays the opposite holds, default is pass by reference, programmer must stipulate pass by value explicitly.

Self Study Exercise

- Check out bubble sort in Ex. 4.16
- Check out statistics example in Ex. 4.17
- Check out search algorithms in Ex.4.19 and Ex. 4.20
- Make sure that you understand all constructs and code. Ask your tutor any questions that you have, bring them to tutorial.

W4.2

The *struct* User Defined Data Type

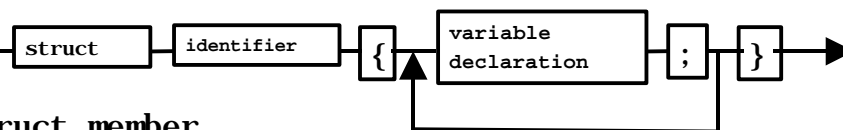
struct Definitions

- Aggregate data types built using elements of other types.
- Deitel & Deitel jump straight into OO, we will linger...

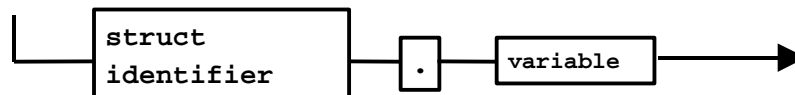
```
struct Time { // structure definition
    int hour; // 0-23
    int minute; // 0-59
    int second; // 0-59
};
```

struct Syntax

**struct
definition**



**struct member
variable**



struct Example

- Keyword *struct* introduces definition
- **Time** tag establishes **Time** as a new type within the language
- Members declared within braces
- Three *int* declared within *struct*

```
struct Time { // structure definition
    int hour; // 0-23
    int minute; // 0-59
    int second; // 0-59
};
```

Notes on Declaration

- Definition of **Time** contains three variables, may be of any type, must be uniquely named within this **struct**
- Other *structs* may have same names within *struct* but must have unique *identifiers*.
- No space is reserved in memory until an *instance* of type **Time** is created.

Accessing Members of Structures

- Member access operators:

- Dot operator (.) for structures
- Arrow operator (->) for pointers
- Print member **hour** of **timeStruct**:

```
cout << timeStruct.hour;
```

OR

```
timePtr = &timeStruct;  
cout << timePtr->hour;
```

- **timePtr->hour** is the same as (***timePtr**).hour
- Parentheses required: ***** has lower precedence than **.**

struct

Example Code

```
// Fig. 6.1: fig06_01.cpp  
// Create a structure, set its members, and print it.  
#include <iostream.h> // Fig. 6.1: fig06_01.cpp
```

```
struct Time { // structure definition  
    int hour; // 0-23  
    int minute; // 0-59  
    int second; // 0-59  
};
```

```
void printMilitary( const Time & ); // prototype  
void printStandard( const Time & ); // prototype
```

```
int main()  
{  
    Time dinnerTime; // variable type Time  
    dinnerTime.hour = 18;  
    dinnerTime.minute = 30;  
    dinnerTime.second = 0;  
    cout << "Dinner will be held at ";  
    printMilitary( dinnerTime );  
    cout << " military time,\nwhich is ";  
    printStandard( dinnerTime );  
    cout << " standard time.\n";  
    dinnerTime.hour = 29; // invalid values  
    dinnerTime.minute = 73;  
    cout << "\nTime with invalid values: ";  
    printMilitary( dinnerTime );  
    cout << endl;  
    return 0;  
}
```

```

// Print the time in military format
void printMilitary( const Time &t )
{
    cout << ( t.hour < 10 ? "0" : "" ) << t.hour << ":" <<
        << ( t.minute < 10 ? "0" : "" ) << t.minute;
}
// Print the time in standard format
void printStandard( const Time &t )
{
    cout << ( ( t.hour == 0 || t.hour == 12 ) ?
        12 : t.hour % 12 )
        << ":" << ( t.minute < 10 ? "0" : "" ) << t.minute
        << ":" << ( t.second < 10 ? "0" : "" ) << t.second
        << ( t.hour < 12 ? " AM" : " PM" );
}

```

Notes on Example I

- Time has three members
 - `int hour`
 - `int minute`
 - `int second`
- Dot operator (.) used, initialise values to 18:30:00
- Pass by reference (&) used, so overhead of copying individual elements avoided (runs faster).
- `const` also used so that functions will not alter parameters.

Notes on Example II

- Initialisation can be accomplished as with an array as follows.....
 - `Time dinnerTime = {12, 20, 10};`
- Programmer must explicitly assign, read and handle in every way elements of a struct.

struct Within *struct*

- Because a struct is an extension to the C++ types, it is allowed to embed a *struct* inside another *struct* as though it were an *int* or a *float*
- See example code on public directory

```
struct Date {  
    int Year;  
    int Month;  
    int Day;  
};
```

```
struct Employee{  
    char Fname[20];  
    char Sname[20];  
    Date Birth;  
    Date Start;  
};
```

Another Example

- Students sit examinations and record a series of results
- Struct contains many data types, as well as other structs
- See Public directory for *student.cpp*

```
struct Name{
    char Fname[20];
    char Sname[20];
};
struct Date {
    int Year;
    int Month;
    int Day;
};
struct Student{
    Name FullName;
    Date Birth;
    Date Registration;
    int Number;
    int Result[3];
};
```

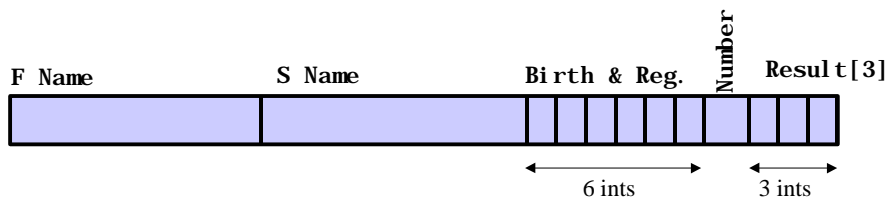
Arrays of *struct*

- Because we have established a new type, we can use this type as a building block for arrays
 - `Time DailySchedule[3];`
 - `DailySchedule[0].hour = 9;`
 - `DailySchedule[0].minute = 0;`
 - `DailySchedule[0].second = 0;`
- Modify the code provided to handle all times within an array or three *structs* used to store mealtimes

struct In Memory

- Memory locations are contiguous for a single *struct*

```
struct Name{
    char Fname[20];
    char Sname[20];
};
struct Date {
    int Year;
    int Month;
    int Day;
};
struct Student{
    Name FullName;
    Date Birth;
    Date Registration;
    int Number;
    int Result[3];
};
```



struct As Function Parameters

- In the example, a struct was passed as a single parameter (by reference)
 - `void printStandard(const Time &); // prototype`
- It is as though **Time** were just a normal *type* of the language, indeed it is now !

```
void printStandard( const Time &t )
{
    cout << ( ( t.hour == 0 || t.hour == 12 ) ?
        12 : t.hour % 12 )
        << ":" << ( t.minute < 10 ? "0" : "" ) << t.minute
        << ":" << ( t.second < 10 ? "0" : "" ) << t.second
        << ( t.hour < 12 ? " AM" : " PM" );
}
```

Graded Exercises

- Not graded
 - See examples on my public directory
 - structex.cpp, struct2.cpp, struct3.cpp
- Graded
 - Rewrite the code in *student.cpp* and use an array of 3 students. Break the code up into *sensible functions* using “*pass by value*” or “*pass by reference*” as appropriate. Show off a little, but justify your design!