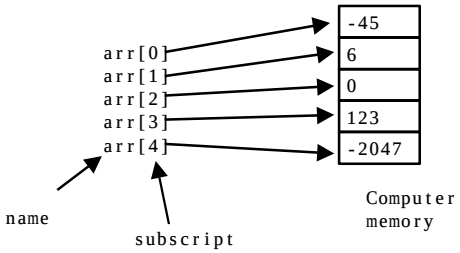
W 4.1

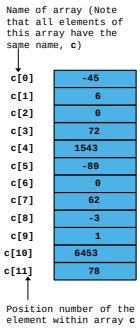
Use Arrays, learn subscripting of arrays, assignment, and examination of contents.

What Are Arrays ?

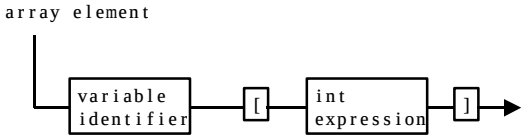
- A compound type composed of many items (variables), all of the same type and organised in a consecutive (contiguous) set of memory locations.
- Like a row of boxes, each box may contain a different value, all boxes of the same type.

A 5 Element Array

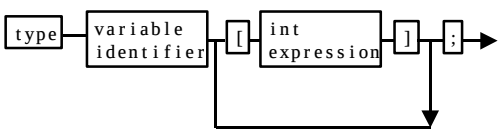




Array Syntax



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 }
```

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

Notice how string elements are referenced like arrays.

```
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
```

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

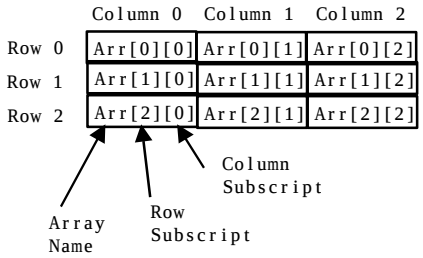
More Programming Tips for Arrays

- 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



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\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 copy of
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 }
```

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
```

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

```
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) varaible
- 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

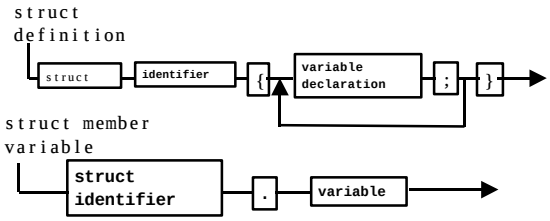
The *struct* User Defined Data Type

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 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 *struct*s 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];
};
```

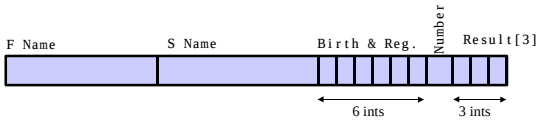
Arrays of *struct*

- 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 *struct*s used to store mealtimes

struct In Memory

```
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];
};
```

- Memory locations are contiguous for a single *struct*



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!