6.1 Modular Programming

- Modular programming: breaking a program up into smaller, manageable components (modules)
- Function: a collection of statements that perform a task, grouped into a single named unit.

Why is modular programming important?
- Improves maintainability/readability of programs by giving structure and organization to the code
- Simplifies the process of writing programs: programmer can write one small function at a time

6.2 Defining and Calling Functions

- Function definition: statements that make up a function, along with its name, parameters and return type.

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int main() {
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Function Definition

A Function definition includes:

• **return type**: data type of the value that the function returns to the part of the program that called it.

• **function-name**: name of the function. Function names follow same rules as variables.

• **parameters**: optional list of variable definitions. These will be assigned values each time the function is called.

• **body**: statements that perform the function’s task, enclosed in { }.

Function Return Type

• If a function computes and returns a value, the type of the value it returns must be indicated as the return type: `int getRate() { return 8; }

• If a function does not return a value, its return type is void:

  `void printHeading() { cout << "Monthly Sales\n"; }`

Calling a Function

• To execute the statements in a function, you must “call” it from within another function (like main).

• To call a function, use the function name followed by a list of expressions (arguments) in parens:

  `printHeading();`

• Whenever called, the program executes the body of the called function (it runs the statements).

• After the function terminates, execution resumes in the calling function after the function call.
Functions in a program

Example:
#include <iostream>
using namespace std;

void displayMessage()
{
    cout << "Hello from the function displayMessage.\n";
}

int main()
{
    cout << "Hello from Main.\n";
    displayMessage();
    cout << "Back in function Main again.\n";
    return 0;
}

Output:
Hello from main.
Hello from the function displayMessage.
Back in function main again.

Flow of Control (order of statements):

Control always starts at main

Calling Functions: rules

- A program is a collection of functions, one of which must be called “main”.
- Function definitions can contain calls to other functions.
- A function must be defined before it can be called
  - In the program text, the function definition must occur before all calls to the function
  - Unless you use a “prototype"

6.3 Function Prototypes

- Compiler must know the following about a function before it can process a function call:
  - name, return type and data type (and order) of each parameter
- Not necessary to have the body of the function before the call.
- Sufficient to put just the function header before all functions containing calls to that function
  - The complete function definition must occur later in the program.
  - The header alone is called a function prototype
#include <iostream>
using namespace std;

// function prototypes
void first();
void second();

int main() {
    cout << "I am starting in function main.
    first(); // function call
    second(); // function call
    cout << "Back in function main again.\n";
    return 0;
}

// function definitions
void first() {
    cout << "I am now inside the function first.\n";
}
void second() {
    cout << "I am now inside the function second.\n";
}

6.4 Sending Data into a Function

• You can pass (or send) values to a function in the function call statement.
• This allows the function to work over different values each time it is called.
• **Arguments**: Expressions (or values) passed to a function in the function call.
• **Parameters**: Variables defined in the function definition header that are assigned the values passed as arguments.

Prototype Style Notes

• Place prototypes near the top of the program (before any other function definitions)--good style.

• Using prototypes, you can place function definitions in **any** order in the source file

• Common style: all function prototypes at beginning, followed by definition of main, followed by other function definitions.

A Function with a Parameter

```cpp
void displayValue(int num) {
    cout << "The value is " << num << endl;
}
```

• num is the **parameter**.
• Calls to this function must provide an argument (expression) that has an integer value:

```cpp
displayValue(5);
```
• 5 is the **argument**.
Function with parameter in program

```cpp
#include <iostream>
using namespace std;

// Function Prototype
void displayValue(int); // prototype

int main() {
    int num = 5; // this stmt is executed implicitly
    cout << "I am passing 5 to displayValue.\n";
    displayValue(5);
    cout << "Back in function main again.\n";
    displayValue(8); // call again with diff. argument
    return 0;
}

// Function definition
void displayValue(int num) {
    cout << "The value is " << num << endl;
}
```

Output:
```
I am passing 5 to displayValue.
The value is 5
Back in function main again.
The value is 8
```

Parameter Passing Semantics

- Given this function call, with the argument of 5:
  ```cpp
displayValue(5);
  ```
- Before the function body executes, the parameter (`num`) is initialized to the argument (5), like this:
  ```cpp
  int num = 5; // this stmt is executed implicitly
  ```
- Then the body of the function is executed, using num as a regular variable:
  ```cpp
cout << "The value is " << num << endl;
  ```

Parameters in Prototypes and Function Definitions

- The **prototype** must include the **data type** of each parameter inside its parentheses:
  ```cpp
  void evenOrOdd(int); // prototype
  ```
- The **definition** must include a **definition** for each parameter in its parens
  ```cpp
  void evenOrOdd(int num) // header
  { if (num%2==0) cout << "even";
    else cout << "odd";
  }
  ```
- The **call** must include an **argument** (expression) for each parameter, inside its parentheses
  ```cpp
  evenOrOdd(x+10); // call
  ```

Passing Multiple Arguments

When calling a function that has multiple parameters:

```cpp
void power(int, int); // prototype
```

- the following must all match:
  - the number and order of data types in the prototype
  - the number and order of parameters in the function definition
  - the number and order of arguments in the function call
- the first argument will be used to initialize the first parameter, the second argument to initialize the second parameter, etc.
  - they are assigned in order.
Example: function calls function

```cpp
void deeper() {
    cout << "I am now in function deeper.\n";
}

void deep() {
    cout << "Hello from the function deep.\n";
    deeper();
    cout << "Back in function deep.\n";
}

int main() {
    cout << "Hello from Main.\n";
    deep();
    cout << "Back in function Main again.\n";
    return 0;
}
```

Output: Hello from Main.
Hello from the function deep.
I am now in function deeper.
Back in function deep.
Back in function Main again.

Example: call function more than once

```cpp
#include <iostream>
#include <cmath>
using namespace std;

void pluses(int count) {
    for (int i = 0; i < count; i++)
        cout << "+";
    cout << endl;
}

int main() {
    int x = 2;
    pluses(4);
    pluses(x);
    pluses(x+5);
    pluses(pow(x,3.0));
    return 0;
}
```

Output:
```
++++
++
++++++
```

Example: multiple parameters

```cpp
#include <iostream>
#include <cmath>
using namespace std;

void pluses(char ch, int count) {
    for (int i=0; i < count; i++)
        cout << ch;
    cout << endl;
}

int main() {
    int x = 2;
    char cc = '!';
    pluses('#',4);
    pluses('!',x);
    pluses(cc,x+5);
    pluses('x',pow(x,3.0));
    return 0;
}
```

Output:
```
####
**
!!!!!!!
```

6.7 The return statement

```cpp
return;
```

• Used to stop the execution of a void function
• Can be placed anywhere in the function body
  ‣ the function immediately transfers control back to the statement that called it.
• Statements that follow the return statement will not be executed
• In a void function with no return statement, the compiler adds a return statement before the last

```cpp
return;
```
6.8 Returning a value from a function

- You can use the return statement in a non-void function to send a value back to the function call:
  ```c++
  return expr;
  ```
- The value of the `expr` will be sent back.
- The data type of `expr` must be placed in the function header:
  ```c++
  int doubleIt(int x) {
      return x*2;
  }
  ```

Calling a function that returns a value

- If the function returns void, the function call is a statement:
  ```c++
  pluses(4);
  ```
- If the function returns a value, the function call is an expression:
  ```c++
  int y = doubleIt(4);
  ```
- The value of the function call (underlined) is the value of the `expr` returned from the function, and you should do something with it.

```c++
#include <iostream>
using namespace std;

int sum(int x, int y) {
    return x + y;
}

int main() {
    int value1;
    int value2;
    int total;
    cout << "Enter 2 numbers: " << endl;
    cin >> value1 >> value2;
    total = sum(value1, value2);
    cout << "The sum is " << total << endl;
    return 0;
}
```

Output:

Enter 2 numbers: 20 40
The sum is 60
The function call from main: \texttt{sum(value1, value2)} passes the values stored in \texttt{value1} and \texttt{value2} (20 and 40) to the function, assigning them to \texttt{x} and \texttt{y}.

The result, \texttt{x+y} (60), is returned to the call and stored in \texttt{total}.

### 6.9 Returning a boolean value

```c
bool isValid(int number) {
    bool status;
    if (number >=1 && number <= 100)
        status = true;
    else
        status = false;
    return status;
}
```

The above function is equivalent to this one:

```c
bool isValid (int number) {
    return (number >=1 && number <= 100);
}
```

### Function call expression

- When a function call calls a function that returns a value, it is an \textit{expression}.
- The function call can occur in any context where an expression is allowed:
  - assign to variable (or array element) \texttt{total = sum(x,y);}
  - output via \texttt{cout} \texttt{cout << sum(x,y);}
  - use in a more complicated expression \texttt{cout << sum(x,y)*.1;}
  - pass as an argument to another function \texttt{z = pow(sum(x,y),2);}
- The value of the function call is determined by the value of the expression returned from the function.

### Returning a boolean value

- You can call the function in an if or while:

```c
bool isValid (int);  
int main() {
    int val;
    cout << “Enter a value between 1 and 100: ” cin >> val;
    while (!isValid(val)) {
        cout << “That value was not in range.\n”;  
        cout << “Enter a value between 1 and 100: ” cin >> val;
    }
    // . . .
```
6.5 Passing Data by Value
(review)

- **Pass by value**: when an argument is passed to a function, its value is copied into the parameter.
- Parameter passing is implemented using variable initialization (behind the scenes):
  ```cpp
  int param = argument;
  ```
- Changes to the parameter in the function definition cannot affect the value of the argument in the call

Pass by Value notes

When the argument is a variable (as in f(x)):

- The parameter is initialized to a _copy_ of the argument’s value.
- Even if the body of the function changes the parameter, the argument in the function call is unchanged.
- The parameter and the argument are stored in separate variables, separate locations in memory.

6.13 Passing Data by Reference

- **Pass by reference**: when an argument is passed to a function, the function has direct access to the original argument.
- Pass by reference in C++ is implemented using a reference parameter, which has an ampersand (&) in front of it:
  ```cpp
  void changeMe (int &myValue);
  ```
- A reference parameter acts as an _alias_ to its argument.
- Changes to the parameter in the function _DO_ affect the value of the argument

Example: Pass by Value

```cpp
#include <iostream>
using namespace std;

void changeMe(int);

int main() {
  int number = 12;
  cout << "number is " << number << endl;
  changeMe(number);
  cout << "Back in main, number is " << number << endl;
  return 0;
}

void changeMe(int myValue) {
  myValue = 200;
  cout << "myValue is " << myValue << endl;
}
```

Output:

```
number is 12
myValue is 200
Back in main, number is 12
```
Example: Pass by Reference

```cpp
#include <iostream>
using namespace std;

void changeMe(int &);

int main() {
    int number = 12;
    cout << "number is " << number << endl;
    changeMe(number);
    cout << "Back in main, number is " << number << endl;
    return 0;
}

void changeMe(int &myValue) {
    myValue = 200;
    cout << "myValue is " << myValue << endl;
}
```

Output:
```
number is 12
myValue is 200
Back in main, number is 200
```

Using Pass by Reference for input

```cpp
double square(double number) {
    return number * number;
}

void getRadius(double &rad) {
    cout << "Enter the radius of the circle: ";
    cin >> rad;
}

int main() {
    const double PI = 3.14159;
    double radius;
    double area;
    cout << fixed << setprecision(2);
    getRadius(radius);
    area = PI * square(radius);
    cout << "The area is " << area << endl;
    return 0;
}
```

During the function execution, `rad` is an alias to `radius` in the main program.

Pass by Reference notes

- Changes made to a reference parameter are actually made to its argument
- The & must be in the function header AND the function prototype.
- The argument passed to a reference parameter must be a variable – it cannot be a constant or contain an operator (like +)
- Use when appropriate – don’t use when:
  - the argument should not be changed by function (!)
  - the function returns only 1 value: use return stmt!

6.10 Local and Global Variables

- Variables defined inside a function are local to that function.
  - They are hidden from the statements in other functions, which cannot access them.
- Because the variables defined in a function are hidden, other functions may have separate, distinct variables with the same name.
  - This is not bad style. These are easy to keep straight
- Parameters are also local to the function in which they are defined.
Local variables are hidden from other functions

```cpp
#include <iostream>
using namespace std;

void anotherFunction();

int main() {
    int num = 1;
    cout << "In main, num is " << num << endl;
    anotherFunction();
    cout << "Back in main, num is " << num << endl;
    return 0;
}

void anotherFunction() {
    int num = 20;
    cout << "In anotherFunction, num is " << num << endl;
}
```

Output:

```
In main, num is 1
In anotherFunction, num is 20
Back in main, num is 1
```

Global Variables

- A global variable is any variable defined outside all the functions in a program.
- The scope of a global variable is the portion of the program starting from the variable definition to the end of the file.
- This means that a global variable can be accessed by all functions that are defined after the global variable is defined.
- A local variable may have the same name as a global variable. The global variable is hidden in that variable's block.

Local Variable Lifetime

- A function's local variables and parameters exist only while the function is executing.
- When the function begins, its parameters and local variables (as their definitions are encountered) are created in memory, and when the function ends, the parameters and local variables are destroyed.
- This means that any value stored in a local variable is lost between calls to the function in which the variable is declared.

Global Variables: example

```cpp
#include <iostream>
using namespace std;

void anotherFunction();

int main() {
    cout << "In main, num is " << num << endl;
    anotherFunction();
    cout << "Back in main, num is " << num << endl;
    return 0;
}

void anotherFunction() {
    cout << "In anotherFunction, num is " << num << endl;
}
```

Output:

```
In main, num is 2
In anotherFunction, num is 2
But now it is changed to 50
Back in main, num is 50
```
Global Variables/Constants

Do not use global variables!!! Because:

• They make programs difficult to debug.
  ‣ If the wrong value is stored in a global var, you must scan
    the entire program to see where the variable is changed
• Functions that access globals are not self-contained
  ‣ cannot easily reuse the function in another program.
  ‣ cannot understand the function without understanding how
    the global is used everywhere

It is ok (and good) to use global constants because their values do not change.

Global Constants: example

```cpp
class GlobalConstants {
public:
    const double PI = 3.14159;
    double getArea(double number) {
        return PI * number * number;
    }
    double getPerimeter(double number) {
        return PI * 2 * number;
    }
    int main() {
        double radius;
        cout << fixed << setprecision(2);
        cout << "Enter the radius of the circle: ";
        cin >> radius;
        cout << "The area is " << getArea(radius) << endl;
        cout << "The perimeter is " << getPerimeter(radius) << endl;
    }
};
```

Functions and Array Elements

• An array element can be passed to any parameter of the same (or compatible) type:

```cpp
double square (double); 
int main() {
    double numbers[5] = {2.2, 3.3, 5.11, 7.0, 3.2};
    for (int i=0; i<5; i++)
        cout << square(numbers[i]) << " ";
    cout << endl;
}
double square (double x) {
    return x * x;
}
```

Functions and Array Elements

• An array element can be passed by reference.

```cpp
void changeMe(int &myValue) {
    myValue = 200;
}
int main() {
    int numbers[5] = {2, 3, 5, 7, 3};
    for (int i=0; i<5; i++)
        changeMe(numbers[i]);
    for (int i=0; i<5; i++)
        cout << numbers[i] << " ";
    cout << endl;
}
```
7.8 Arrays as Function Arguments

An entire array can(!) be passed to a function that has an array parameter.

```cpp
void showArray(int[], int);

int main() {
    int numbers[5] = {2, 3, 5, 7, 3};
    showArray(numbers, 5);
    return 0;
}

void showArray(int values[], int size) {
    for (int i=0; i<size; i++)
        cout << values[i] << " ";
    cout << endl;
}
```

Passing arrays to functions

- An array is **always** passed by reference.
- The parameter name is an alias to the array being passed in, even though it has no &.
- Changes made to the array (elements) inside the function DO affect the array in the function call.

```cpp
void incrArray(int[], int);
void showArray(int[], int);

int main() {
    int numbers[5] = {2, 3, 5, 7, 3};
    incrArray(numbers, 5);
    showArray(numbers, 5);
    return 0;
}

void incrArray(int values[], int size) {
    for (int i=0; i<size; i++)
        (values[i])++; //values[i]=values[i]+1;
}
```

Passing arrays to functions

- In the **function definition**, the parameter type is a variable name with an empty set of brackets: [ ]
  - Do NOT give a size for the parameter
    ```cpp
    void showArray(int values[], int size) {...}
    ```
- In the **prototype**, empty brackets go after the element datatype.
  ```cpp
  void showArray(int[], int);
  ```
- In the **function call**, use the variable name for the array (no brackets!).
  ```cpp
  showArray(numbers, 5);
  ```

Passing arrays to functions

- Changing an array inside a function:

  ```cpp
  void incrArray(int[], int);
  void showArray(int[], int);
  
  int main() {
      int numbers[5] = {2, 3, 5, 7, 3};
      incrArray(numbers, 5);
      showArray(numbers, 5);
      return 0;
  }
  
  void incrArray(int values[], int size) {
      for (int i=0; i<size; i++)
          (values[i])++;
  }
  ```

  ```cpp
  Output:
  3 4 6 8 4
  ```
Passing arrays to functions

• Usually functions that have an array parameter also have an int parameter for the count of the number of elements in the array.
  ‣ so the function knows how many elements to process.

• The count parameter is just a regular int parameter and must be included in the parameter list and a corresponding argument value must appear in the function call.