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.
  
  ```
  return-type function-name (parameters) {
  statements
  }
  ```

- Function call: statement (or expression) that causes a function to execute
  
  ```
  function-name (arguments)
  ```
**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:

```cpp
#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):

```
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; 
}
```

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

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”
# Prototypes in a program

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

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

int main() {
    cout << "I am starting in function main.\n";
    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";
}
```

### 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.

## 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.

### 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);

int main() {
    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);
  ```

- 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:

- 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 deep.\n";
    return 0;
}
```

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

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

- 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}
The return statement: example

```cpp
void someFunc (int x) {
    if (x < 0)
        cout << "x must not be negative." << endl;
    else {
        // Continue with lots of statements, indented
        // ...
        // so many it’s hard to keep track of matching {}
    }
}

void someFunc (int x) {
    if (x < 0) {
        cout << "x must not be negative." << endl;
        return;
    }
    // Continue with lots of statements, less indentation,
    // no brackets to try to match ...
}
```

This is equivalent, easier to read

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:

  ```cpp
  return expr;
  ```

- The value of the `expr` will be sent back.
- The data type of `expr` must be placed in the function header:

```cpp
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:

  ```cpp
  pluses(4);
  ```

- If the function returns a value, the function call is an expression:

  ```cpp
  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.

Returning the sum of two ints

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

int sum(int, int);

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;
}

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

Output:

```
Enter 2 numbers: 20 40
The sum is 60
```
Data transfer

- The function call from main: \( \text{sum(value1, value2)} \) passes the values stored in \( \text{value1} \) and \( \text{value2} \) (20 and 40) to the function, assigning them to \( x \) and \( y \).
- The result, \( x+y \) (60), is returned to the call and stored in \( \text{total} \).

Function call expression

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

6.9 Returning a boolean value

```cpp
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:

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

Returning a boolean value

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

```cpp
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):
  ```
  int param = argument;
  ```
- Changes to the parameter in the function definition cannot affect the value of the argument in the call

Example: Pass by Value

```
#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;
}

test

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

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

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:
  ```
  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 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
```

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!

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;
}
```

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

```
#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

This num variable is visible only in main
This num variable is visible only in anotherFunction

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

- 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.

Global Variables: example

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

void anotherFunction();

int num = 2;

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;
    num = 50;
    cout << "But now it is changed to " << 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

This num variable is visible only in main
This num variable is visible only in anotherFunction
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.

Functions and Array Elements

• An array element can be passed to any parameter of the same (or compatible) type:
  ```
  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;
    return 0;
  }

  double square (double x) {
    return x * x;
  }
  ```

Functions and Array Elements

• An array element can be passed by reference. What is output by this program?
  ```
  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;
  }
  ```

Global Constants: example

```
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;
}
```
7.8 Arrays as Function Arguments

- An entire array can(!) be passed to a function that has an array parameter.
  
  ```c
  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;
  }
  ```

  Output:
  
  2 3 5 7 3

- 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.

### 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
    ```c
    void showArray(int values[], int size) {...}
    ```

- In the **prototype**, empty brackets go after the element datatype.
  ```c
  void showArray(int[], int);
  ```

- In the **function call**, use the variable name for the array (no brackets!).
  ```c
  showArray(numbers, 5);
  ```

### Passing arrays to functions

- Changing an array inside a function:
  ```c
  void incrArray(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])++;
    cout <<endl; //values[i]=values[i]+1;
  }
  ```

  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.