Functions

Unit 6

Gaddis: 6.1-5,7-10,13,15-16 and 7.8

CS 1428
Fall 2017

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6.1 Modular Programming

- <u>Modular programming</u>: breaking a program up into smaller, manageable components (modules)

- <u>Function</u>: 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

This program has one long, complex function containing all of the statements necessary to solve a problem.

```
int main()
{
   statement;
   statement;
   statement;
   statement;
   statement;
   statement;
   statement;
   statement;
   statement;
   statement;
   statement;
   statement;
   statement;
   statement;
   statement;
   statement;
   statement;
   statement;
   statement;
   statement;
}
```

In this program the problem has been divided into smaller problems, each of which is handled by a separate function.

```
int main()
{
   statement;
   statement;            main function
   statement;
}
```

```
void function2()
{
   statement;
   statement;            function 2
   statement;
}
```

```
void function3()
{
   statement;
   statement;            function 3
   statement;
}
```

```
void function4()
{
   statement;
   statement;            function 4
   statement;
}
```

6.2 Defining and Calling Functions

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

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

- <u>Function call</u>: statement (or expression) that causes a function to execute

```
function-name (arguments)
```
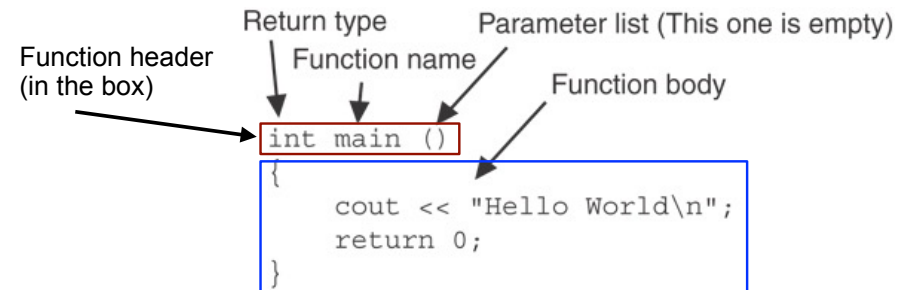
Function Definition

A Function definition includes:

- <u>return type</u>: data type of the value that the function returns to the part of the program that called it.

- <u>function-name</u>: name of the function. Function names follow same rules as variables.

- <u>parameters</u>: optional list of variable definitions. These will be assigned values each time the function is called.

- <u>body</u>: statements that perform the function's task, enclosed in { }.

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Function Definition

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

Return type   Parameter list (This one is empty)
Function header   Function name
(in the box)   Function body

```
int main ()
{
    cout << "Hello World\n";
    return 0;
}
```

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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";
}
```

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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.

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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;
}
```

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Functions in a program

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

- Flow of Control (order of statements):

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

Control always starts at **main**

```cpp
int main()
{
    cout << "Hello from main.\n"
    displayMessage();
    cout << "Back in function main again.\n";
    return 0;
}
```
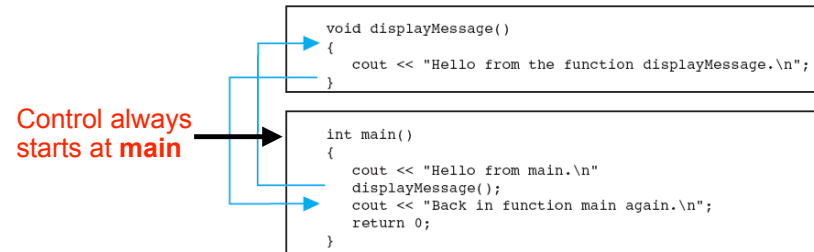
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Calling Functions: rules

- 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"

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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 <u>body</u> 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

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Prototypes in a program

```
#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";
}
```

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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.

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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.

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A Function with a Parameter

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

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

```
displayValue(5);
```

- 5 is the argument.

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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
```

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Parameter Passing Semantics

- Given this function call, with the argument of 5:

  ```cpp
  displayValue(5);
  ```

- Before the function body executes, the parameter (`num`) is <u>initialized</u> 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;
  ```

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Parameters in Prototypes and Function Definitions

- The <u>prototype</u> must include the *data type* of each parameter inside its parentheses:

  ```cpp
  void evenOrOdd(int);    //prototype
  ```

- The <u>definition</u> 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 <u>call</u> must include an *argument* (expression) for each parameter, inside its parentheses

  ```cpp
  evenOrOdd(x+10);           //call
  ```

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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.

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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.
```

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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:
```
++++
++
+++++++
++++++++
```

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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:
```
####
**
!!!!!!!
xxxxxxxx
```

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6.7 The `return` statement

```
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 }

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The `return` statement: example

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

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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:

  ```
  return expr;
  ```

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

Return type:
```
         int doubleIt(int x) {
             return x*2;
         }            Value being returned
```

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Calling a function that returns a value

- If the function returns void, the function call is a statement:

  pluses(4);

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

  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.

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Returning the sum of two ints

```
#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;
}
```
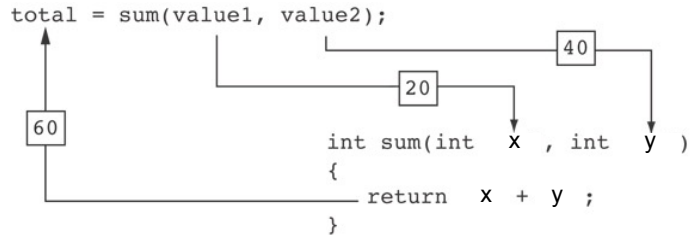
Output:

Enter 2 numbers:
20 40
The sum is 60

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Data transfer

```
total = sum(value1, value2);
                                    40
                        20
  60
                int sum(int  x  , int  y  )
                {
                    return  x + y ;
                }
```

- The function call from main: `sum(value1, value2)` passes the values stored in `value1` and `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 `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)   `total = sum(x,y);`
  - ‣ output via cout   `cout << sum(x,y);`
  - ‣ use in a more complicated expression   `cout << sum(x,y)*.1;`
  - ‣ pass as an argument to another function   `z = 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

```
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:

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

Returning a boolean value

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

```
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)

- <u>Pass by value</u>: 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;
  ```

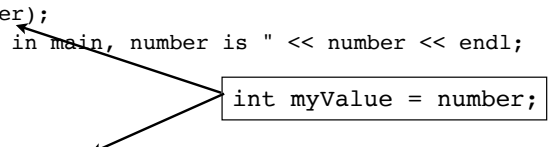- Changes to the parameter in the function definition cannot affect the value of the argument in the call

Example: Pass by Value

```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
```

```
int myValue = number;
```

changeMe failed!

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

- <u>Pass by reference</u>: 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 Reference

```
#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
```

myValue is an *alias* for number, only one shared variable

this statement changes number

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Using Pass by Reference for input

```
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.

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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 <u>variable</u> – 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!

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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.

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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

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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.

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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

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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
```

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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.

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Global Constants: example

```cpp
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;
}
```

Output:

```
Enter the radius of the circle: 2.2
The area is 15.21
The perimeter is 13.82
```

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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;
    return 0;
}

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

Output:

```
4.84 10.89 26.1121 49 10.24
```

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Functions and Array Elements

- An **array element** can be passed by **reference**. What is output by this program?

```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;
}
```

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7.8 Arrays as Function Arguments

- An entire **array** can be passed to a function that has an array parameter

```
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
```

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Passing arrays to functions

- In the <u>function definition</u>, the parameter type is a variable name with an empty set of brackets: [ ]
  - ‣ Do NOT give a size for the parameter

  ```
  void showArray(int values[], int size)  {…}
  ```

- In the <u>prototype</u>, empty brackets go after the element datatype.

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

- In the <u>function call</u>, use the variable name for the array (no brackets!).

  ```
  showArray(numbers, 5);
  ```

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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.

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Passing arrays to functions

- Changing an array inside a function:

```
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;
}
```

Output:

```
3 4 6 8 4
```

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Passing arrays to functions

- Usually functions that have an array parameter also have an int parameter for the count of the number of valid 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.

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