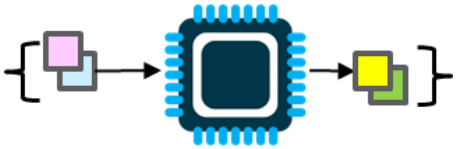
Unit 4c

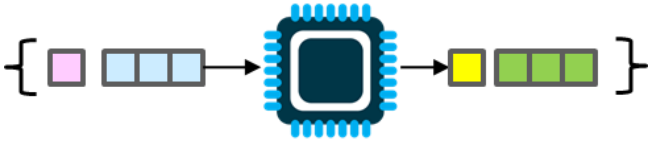
Argument Passing

Unit 4

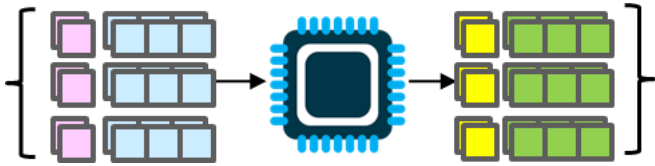
- **Unit 1**: Scalar processing
  - aka IPO=Input-Process-Output Programs



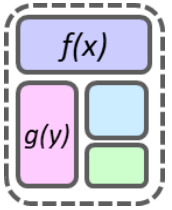
- **Unit 2**: Linear (1D) Processing



- **Unit 3**: Multidimensional Processing



- **Unit 4**: Divide & Conquer (Functional Decomposition)

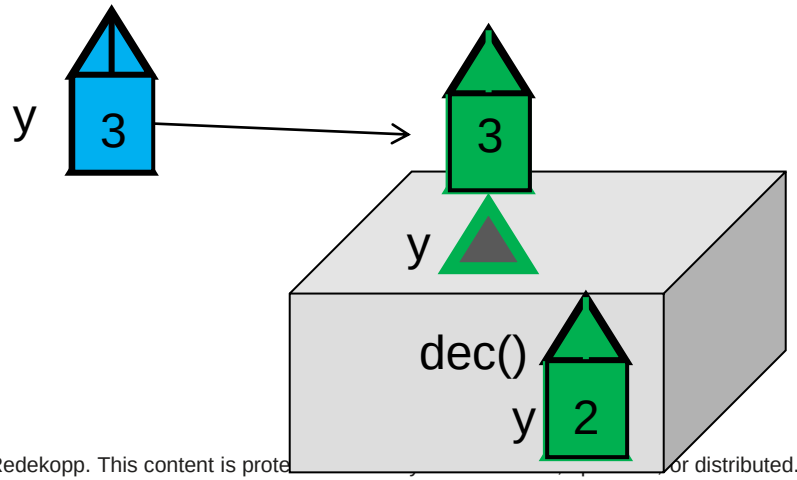


Argument Passing (Pass-by-Value)

- Passing an argument to a function **makes a copy of the argument**
- It is like e-mailing an **attached document**
  - You still have the original on your computer
  - The recipient has a copy which she can modify but it will not be reflected in your version
- Communication is essentially one-way
  - Caller communicates arguments to callee, but callee cannot communicate back because she is working on copies…
  - The only communication back to the caller is via a return value.

Pass by Value (1)

- **Fact**: Function **arguments/parameters act like local variables to that function**
  - They only as long as the function is executing and then get deallocated.
- When arguments are passed a **copy** of the actual argument value (e.g. 3) is given to the function's input argument
  - So the function is operating on a copy and that copy only lives as long as the function




```
void dec(int);
int main()
{
  int y = 3;
  dec(y);
  cout << y << endl;
  return 0;
}
void dec(int y)
{
   y--;
}
```

```
void dec(int);
int main()
{
  int y = 3;
  dec(y);
  cout << y << endl;
  return 0;
}
void dec(int y)
{
   y--;
}
```

Pass by Value (2)

- Wait! But they have the same name, 'y'
  - What's in a name…Each function is a separate entity and so two 'y' variables exist (one in main and one in decrement it)
  - The only way to communicate back to main is via return
  - Try to change the code appropriately
- **Main Point:** Each function is a completely separate "sandbox" (i.e. is isolated from other functions and their data) and copies of data are passed and returned between them

```
void dec(int);
int main()
{
  int y = 3;
  dec(y);
  cout << y << endl;
  return 0;
}
void dec(int y)
{
   y--;
}
```

```
____ dec(int);
int main()
{
  int y = 3;
  ____________ dec(y);
  cout << y << endl;
  return 0;
}
___ dec(int y)
{
   y--;
   ____________________
}
```

Pass by Value Solution

- Wait! But they have the same name, 'y'
  - What's in a name…Each function is a separate entity and so two 'y' variables exist (one in main and one in decrement it)
  - The only way to communicate back to main is via return
  - Try to change the code appropriately
- **Main Point:** Each function is a completely separate "sandbox" (i.e. is isolated from other functions and their data) and copies of data are passed and returned between them

```
void dec(int);
int main()
{
  int y = 3;
  dec(y);
  cout << y << endl;
  return 0;
}
void dec(int y)
{
   y--;
}
```

```
int dec(int);
int main()
{
  int y = 3;
  y = dec(y);
  cout << y << endl;
  return 0;
}
int dec(int y)
{
   y--;
   return y;
}
```

Reminders: Common Mistakes

- Problem 1: Don't list return type when you call a function. It will substitute the return value in place of call
- Problem 2: Need to save return value

```
int dec(int val); // prototype
int main()
{
  int y = 3;
  int dec(y);  //  y = dec(y);
  cout << y << endl;
  return 0;
}
int dec(int val)
{
   val--;
   return val;
}
```

- Problem 1: Don't relist the type of the argument when you make the call
- Problem 2: Need to pass a variable that exists in the calling function

```
int dec(int val); // prototype
int main()
{
  int y = 3;
  y = dec(int val);  //  y = dec(y);
  cout << y << endl;
  return 0;
}
int dec(int val)
{
   val--;
   return val;
}
```

Passing Arrays As Arguments

- Can we pass an array to another function?
  - YES!!
- Syntax:
  - **Step 1**: In the prototype/signature: Put empty square brackets after the parameter name if it is an array (e.g. `int data[]`)
  - **Step 2**: When you call the function, just provide the name of the array

```
// Function that takes an array
int sum(int data[], int size);

int sum(int data[], int size)
{
  int total = 0;
  for(int i=0; i < size; i++){
    total += data[i];
  }
  return total;
}

int main()
{
  int vals[100];
  /* some code to initialize vals */
  int mysum = sum(vals, 100);
  cout << mysum << endl;
     // prints sum of all numbers
  return 0;
}
```

Pass-by-Value & Pass-by-Reference

- What are the pros and cons of emailing a document by:
  - Attaching it to the email
  - Sending a link (URL) to the document on some cloud service (etc. Google Docs)
- **Pass-by-value** is like emailing an attachment
  - A **copy** is made and sent
- **Pass-by-reference** means emailing a link to the original
  - **No copy is made** and **any modifications by the other party are seen by the originator**

Arrays And Pass-by-Reference

- **Single (scalar) variables** are passed-by-value in C/C++
  - Copies are passed
- **Arrays** are passed-by-reference
  - Links are passed
  - This means any change to the array by the function is visible upon return to the caller

```
void dec(int);
int main()
{
  int y = 3;
  dec(y);
  cout << y << endl;
  return 0;
}
void dec(int y)
{  y--;  }
```

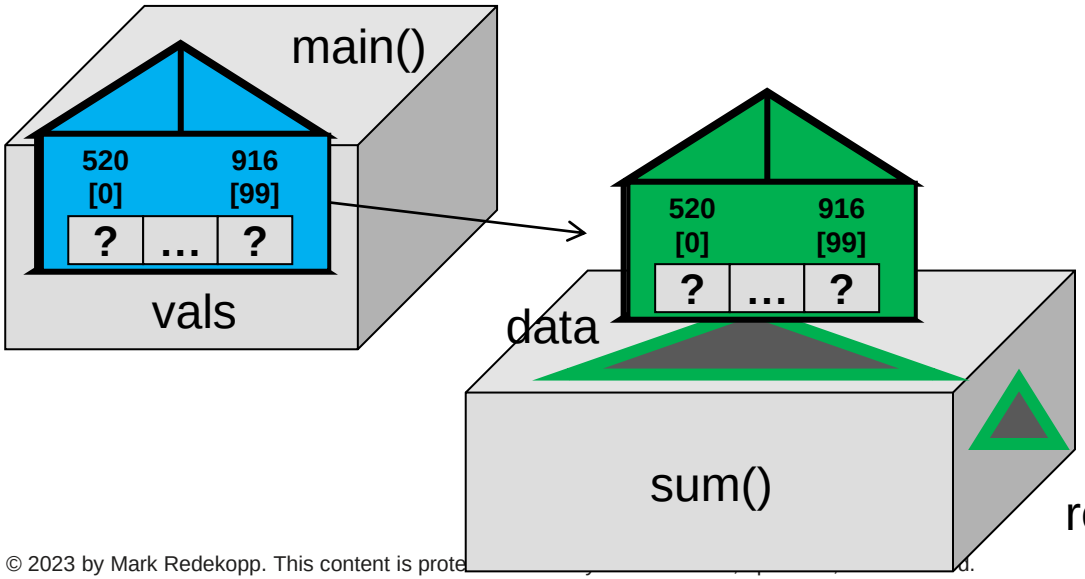
Single variables (aka scalars) are passed-by-value but arrays are passed-by-reference

```
void init(int x[], int size);
int main()
{
  int data[10];
  init(data, 10);
  cout << data[9] << endl;
     // prints 0
  return 0;
}
void init(int x[], int size)
{  // x is really a link to data
   for(int i=0; i < size; i++){
     x[i] = 0; // changing data[i]
   }
}
```

But Why?

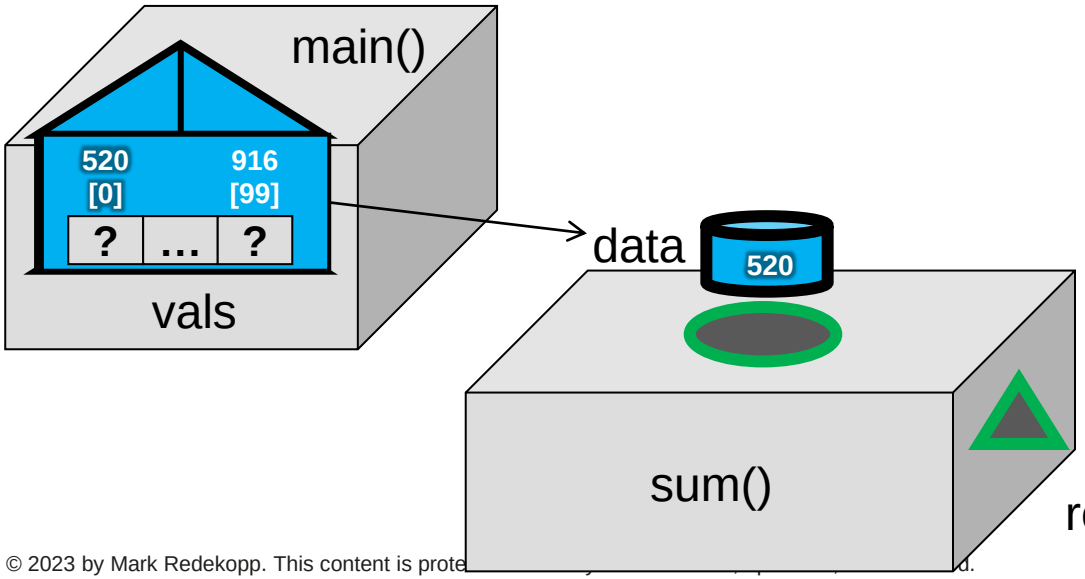
- If we used pass-by-value then we'd have to make a copy of a potentially HUGE amount of data (what if the array had a million elements)
- To avoid copying vast amounts of data, we pass a link

```
// Function that takes an array
int sum(int data[], int size);

int sum(int data[], int size)
{
  int total = 0;
  for(int i=0; i < size; i++){
    total += data[i];
  }
  return total;
}

int main()
{
  int vals[100];
  /* some code to initialize vals */
  int mysum = sum(vals, 100);
  cout << mysum << endl;
     // prints sum of all numbers
  return 0;
}
```



So What Is Actually Passed?

- The "link" that is passed is just the starting address (e.g. 520) of the array in memory
- The called function can now use 520 to access the original array (read it or write new values to it)




```
// Function that takes an array
int sum(int data[], int size);

int sum(int data[], int size)
{
  int total = 0;
  for(int i=0; i < size; i++){
    total += data[i];
  }
  return total;
}

int main()
{
  int vals[100];
  /* some code to initialize vals */
  int mysum = sum(vals, 100);
  cout << mysum << endl;
     // prints sum of all numbers
  return 0;
}
```

Analogy

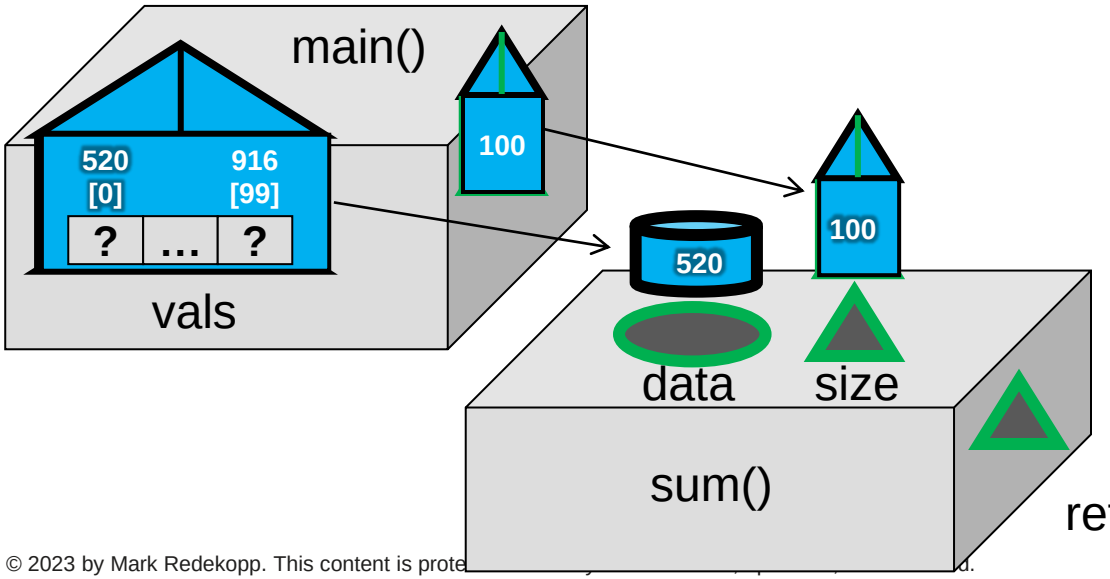
- The first house on a certain block of Catalina Ave. has the address 3600.
- How many houses are on that block?
- There is no way to know!! We would have to count that separately.

- Suppose a large family reunion reserves a block of hotel rooms. The first room is number 428.
- How many rooms are in the reserved block?
- There is no way to know!! We would have to count that separately.

Arrays in C/C++ vs. Other Languages

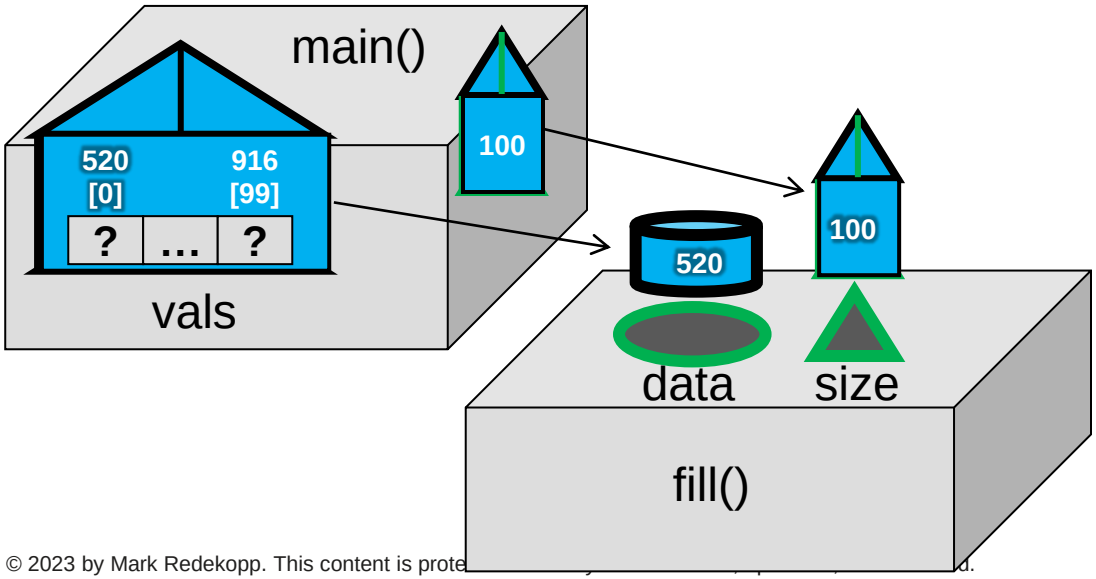
- Notice that if sum() only has the start address it **would not know** how big the array is
- **Unlike Java, Python** or other languages where you can call some function to find the size of an array, **C/C++ requires you to track the size yourself in a separate variable and pass it as a secondary argument**

```
// Function that takes an array
int sum(int data[], int size);

int sum(int data[], int size)
{
  int total = 0;
  for(int i=0; i < size; i++){
    total += data[i];
  }
  return total;
}

int main()
{
  int vals[100];
  /* some code to initialize vals */
  int mysum = sum(vals, 100);
  cout << mysum << endl;
     // prints sum of all numbers
  return 0;
}
```



Why Don't We Return Arrays from Functions

- In C++, we generally do **NOT** return arrays from a function…because we do **NOT** need to!
- **WHY?**
  - **Because we modified the original array in the function**




```
// Function that takes an array
int[] fill(int data[], int size);
void  fill(int data[], int size);

int[] fill(int data[], int size)
void  fill(int data[], int size)
{
  for(int i=0; i < size; i++){
    data[i] = i;
  }
}

int main()
{
  int vals[100];
  /* some code to initialize vals */
  fill(vals, 100);
  cout << vals[0] << endl;
     // prints sum of all numbers
  return 0;
}
```

Array Passing Summary

- Syntax:
  - In the prototype/signature: Put empty square brackets after the parameter name if it is an array
    (e.g. `void f1(int data[])`)
  - When you call the function, just provide the name of the array (e.g. `f1(data);`)
- Functions only know what you pass them
  - You must pass the size of the array as an additional parameter in addition to the link to the array
  - Arrays are passed-by-reference meaning no copy is made and changes by a function are actually being made to the original
- The C++ std:: library provides some alternatives to "plain-old arrays" (like vectors), but you will learn about these in CS 103/104 and should not use them in CS 102

Functions as modular units

TIPS FOR CODING FUNCTIONS

Tips

- Look for common, repeated code and factor it out as a function
  - Find differences in data values or constants that are used and turn those into parameters
  - Any variables the code uses must be passed in as arguments
  - A value used after the code must be returned as the return value
- If you can carve out several lines of code that perform one logical task, consider pulling those lines out as a function

Finding Functions

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


int main()
{
  // Print flag of 3 rows
  for(int i=0; i < 3; i++){
     for(int k=0; k < 3-i; k++){
       cout << '/';
     }
     cout << endl;
  }

  // Print flag of 5 rows
  for(int i=0; i < 5; i++){
     for(int k=0; k < 5-i; k++){
       cout << '/';
     }
     cout << endl;
  }

  return 0;
}
```

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

void printFlag(int rows);

int main()
{
  printFlag(3);
  printFlag(5);
  return 0;
}

void printFlag(int rows)
{
  for(int i=0; i < rows; i++){
    for(int k=0; k < rows-i; k++){
      cout << '/';
    }
    cout << endl;
  }
}
```

Functions As Independent Units (1)

- Functions should be self contained units
  - Cannot access variables from other functions
  - Should implement a general "recipe" for how to do a task given generic inputs (parameter names)
  - Consider the arguments/parameters as generic names that represent specific inputs when the function is invoked

Remember:
- Functions can only access:
  - The input arguments
  - The local variables they declare
- Functions can only return one value
  - All other values (local variables & input arguments) "die" at the end of the function

```
// Doesn't work
#include <iostream>
using namespace std;
void getInput(); // prototype
void getInput()
{
  cout << "Enter an int: ";
  cin >> x; // Can't access
            // x from main
}

int main()
{
  int x; // get from user
  getInput();
  cout << x << endl;
  return 0;
}
```

```
// Does work
#include <iostream>
using namespace std;
int getInput(); // prototype
int getInput()
{
  int num;
  cout << "Enter an int: ";
  cin >> num;
  return num;
}

int main()
{
  int x; // get from user
  x = getInput();
  cout << x << endl;
  return 0;
}
```

Functions As Independent Units (2)

- Generally, don't do input/output in a function (unless the function specifically indicates it should)…just process values and return something
  - Example: Take the maximum of 2 numbers and print them out
  - Easy to extend to other tasks: take max of 3 numbers

```
// Good function decomposition; generic, easy to reuse
#include <iostream>
using namespace std;

int max(int a, int b);

int main()
{
  int x, y, mx;
  cin >> x >> y;
  cout << max(x,y) << endl;
  return 0;
}

int max(int a, int b)
{
  if(a > b)
     return a;
  else
     return b;
}
```

```
// Extend to take max of 3 numbers
#include <iostream>
using namespace std;

int max(int a, int b);

int main()
{
  int x, y, z, mx;
  cin >> x >> y >> z;
  cout << max( max(x,y), z) << endl;
  return 0;
}

int max(int a, int b)
{
  if(a > b)
     return a;
  else
     return b;
}
```

Could you extend to take the max of 4?

Functions As Independent Units (3)

- Generally don't do input/output in a function (unless the function specifically indicates it will)…just process values and return something
  - Example: Take the maximum of 2 numbers and print them out
  - Easy to extend to other tasks: take max of 3 numbers

```
// Bad function decomposition
//  -- performs I/O
#include <iostream>
using namespace std;

int max();

int main()
{
  int mx;
  mx = max();
  cout << mx << endl;
  return 0;
}

int max()
{
  int x, y;
  cin >> x >> y;
  if(x > y)
     return x;
  else
     return y;
}
```

This code works for the stated task (output max of 2 inputs) but cannot easily be reused for 3 or more numbers!
[Can't do: `max(max());`]

- **Would cin 4 numbers**
- **Doesn't take in an input**

```
// Bad function decomposition
//  -- performs I/O.
#include <iostream>
using namespace std;

void max(int a, int b);

int main()
{
  cin >> x >> y;
  max(x, y);
  return 0;
}

void max(int a, int b)
{
  if(a > b)
     cout << a << endl;
  else
     cout << b << endl;
}
```

This code works for the stated task (output max of 2 inputs) but cannot easily be reused for 3 or more numbers!
[Can't do: `max(max(x,y),z);`]

- **Would cout 2 values**

EXERCISES

Tracing Exercise 1

- **Order It**: The numbers below represent lines of code in the program to the right. Order the lines of code from 1-8 [1=first to get executed / 8=last to be executed]. Note: Order them when they START execution not when they finish execution.
  - ____ 5
  - ____ 6
  - ____ 7
  - ____ 8
  - ____ 13
  - ____ 20
  - ____ 26
  - ____ 27
- **Scope It**: Notice that there are many 'char c' declarations and parameters. List the **value** of the character 'c' (or **N/A** if no possible value for 'c' exists) just BEFORE the following lines of code get executed:
  - ____ 6
  - ____ 8
  - ____ 13
  - ____ 14
  - ____ 20
  - ____ 21
  - ____ 27

```
    // Assume necessary prototypes have
    // been declared for Q2 and Q3
1   int main()
2   {
3     double f=1.0, g=2.0, h=3.0;
4     int x=5, y=6,z =7;
5     char c='U';
6     x = myfunc();
7     f=doit(x,y,c);
8   }
9
10  double doit(int cat, int dog, char c)
11  {
12    double x = (double) cat;
13    c = 'S';
14    x = x / (double) dog;
15    return x;
16  }
17
18  void yourfunc(char c)
19  {
20    c = 'C';
21    return;
22  }
23
24  int myfunc()
25  {
26    yourfunc('!');
27    return 2;
28  }
```

Exercises

- Exercises
  - extract-method1
  - draw-square
  - is-lower-vowel
  - is-vowel

More Exercises

BREAKING CODE INTO FUNCTIONS AND CALLING THEM

Factoring Code / Extracting Functions

- At this point, we should be able to go back to any program or exercise and "refactor" our code into functions (aka "extracting" functions).
- Approach
  - If a block of code performs one main task, you can try to extract that code as a function whose name matches that task description
  - Argument names in the function DON'T have to match the name used in the calling function (but they can)

Extracting Functions Example

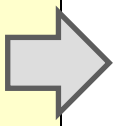
```
int main() {
  // setup array with data
  int n, val, data[100];
  cin >> n;
  for(int i=0; i < n; i++)
    { cin >> data[i]; }
  // now perform the given task
  cin >> val;
  bool found = false;
  for(int i=0; i < n; i++) {
    if(val == data[i]){
       cout << i << endl;
       found = true;
       break;
    }
  }
  if(!found) { cout << -1 << endl; }
  return 0;
}
```

```
#include <iostream>
using namespace std;
int find(int nums[], int len, int target);

int main() {
  // setup array with data
  int n, val, data[100];
  cin >> n;
  for(int i=0; i < n; i++)
    { cin >> data[i]; }
  // now perform the given task
  cin >> val;
  int loc = find(data, n, val);
  cout << loc << endl;
  return 0;
}
int find(int nums[], int len, int target)
{
  for(int i=0; i < len; i++) {
    if(target == nums[i]){
       return i;
    }
  }
  return -1;
}
```

- Here, we extract the code to find an element.
- Can you see another function that might be worth extracting?

Extracting Another Function

```
#include <iostream>
using namespace std;
int find(int nums[], int len, int target);

int main() {
  // setup array with data
  int n, val, data[100];
  cin >> n;
  for(int i=0; i < n; i++)
    { cin >> data[i]; }
  // now perform the given task
  cin >> val;
  int loc = find(data, n, val);
  cout << loc << endl;
  return 0;
}
int find(int nums[], int len, int target)
{
  for(int i=0; i < len; i++) {
    if(target == nums[i]){
       return i;
    }
  }
  return -1;
}
```



```
#include <iostream>
using namespace std;
int fill_n(int nums[]);
int find(int nums[], int len, int target);

int main() {
  // setup array with data
  int n, val, data[100];
  n = fill_n(data);
  // now perform the given task
  cin >> val;
  int loc = find(data, n, val);
  cout << loc << endl;
  return 0;
}
int fill_n(int nums[])
{
  int n;
  cin >> n;
  for(int i=0; i < n; i++)
    { cin >> nums[i]; }
  return n;
}
int find(int nums[], int len, int target)
{ . . . }
```

Exercises To Refactor Using Functions

- Array Tasks
  - Unique
  - Unique-one
  - Insert-sorted
  - Remove-first
  - Remove-all
  - Max-To-Last (use to sort?)
- Nested Loops
  - etox_range
- HW
  - Grid
  - Priority
- Other examples
  - Prime Range
  - Count digits in number

SOLUTIONS

Tracing Exercise 1 (Solution)

- **Order It**: The numbers below represent lines of code in the program to the right. Order the lines of code from 1-8 [1=first to get executed / 8=last to be execute]. Note: Order them when they START execution not when they finish execution.
  - __1__ 5
  - __2__ 6
  - __6__ 7
  - __8__ 8
  - __7__ 13
  - __4__ 20
  - __3__ 26
  - __5__ 27
- **Scope It**: Notice that there are many 'char c' declarations and parameters. List the **value** of the character 'c' (or **N/A** if no possible value for 'c' exists) just BEFORE the following lines of code get executed:
  - __'U'__ 6
  - __'U'__ 8
  - __'U'__ 13
  - __'S'__ 14
  - __'!'__ 20
  - __'C'__ 21
  - __N/A__ 27

```
    // Assume necessary prototypes have
    // been declared for Q2 and Q3
1   int main()
2   {
3     double f=1.0, g=2.0, h=3.0;
4     int x=5, y=6,z =7;
5     char c='U';
6     x = myfunc();
7     f=doit(x,y,c);
8   }
9
10  double doit(int cat, int dog, char c)
11  {
12    double x = (double) cat;
13    c = 'S';
14    x = x / (double) dog;
15    return x;
16  }
17
18  void yourfunc(char c)
19  {
20    c = 'C';
21    return;
22  }
23
24  int myfunc()
25  {
26    yourfunc('!');
27    return 2;
28  }
```

Solutions – Unique

```
#include <iostream>
using namespace std;
// prototypes
int fill_n(int nums[]);
int count(
  int data[], int len, int target);
bool unique_all(int data[], int len);

int fill_n(int nums[])
{
  int n;
  cin >> n;
  for(int i=0; i < n; i++)
    { cin >> nums[i]; }
  return n;
}
int count(int data[], int len, int target)
{
  int cnt = 0;
  for(int k=0; k < len; k++) {
    if(data[k] == target){
      cnt++;
    }
  }
  return cnt;
}
```

```
bool unique_all(int data[], int len)
{
  for(int j=0; j < len; j++) {
    int cnt = count(data, len, data[j]);
    if(cnt > 1) {
      return false;
    }
  }
  return true;
}

int main() {
  // setup array with data
  int n, data[100];
  n = fill_n(data);

  // now perform the given task
  bool allUnique = unique_all(data, n);

  if(allUnique)
    { cout << "All unique" << endl; }
  else
    { cout << "Not all unique" << endl; }
  return 0;
}
```

Solutions – Unique-One

```
#include <iostream>
using namespace std;
// prototype
int fill_n(int nums[]);
int count(int data[], int len, int
target);
int unique_one(int data[], int len);

int fill_n(int nums[])
{
  int n;
  cin >> n;
  for(int i=0; i < n; i++)
    { cin >> nums[i]; }
  return n;
}
int count(int data[], int len, int target)
{
  int cnt = 0;
  for(int k=0; k < len; k++) {
    if(data[k] == target){
      cnt++;
    }
  }
  return cnt;
}
```

```
int unique_one(int data[], int len)
{
  for(int j=0; j < len; j++) {
    int cnt = count(data, len, data[j]);
    if(cnt == 1){
      return data[j];
    }
  }
  return -1;
}

int main() {
  // setup array with data
  int n, data[100];
  n = fill_n(data);
  // now perform the given task
  int unique = unique_one(data, n);
  cout << unique << endl;
  return 0;
}
```

Solutions – Insert-Sorted

```
#include <iostream>
using namespace std;
int findFirstLarger(
  int data[], int len, int val){
  for(int k=0; k < len; k++){
    if(data[k] > val){
      return k;
    }
  }
  return len;
}
void shiftOneRightFrom(
  int data[], int len, int fromIndex)
{
  for(int curr = len-1; curr >= fromIndex;
curr--) {
    data[curr+1] = data[curr];
  }
}
void printResults(int data[], int len){
  for(int i=0; i < len; i++){
    cout << data[i] << " ";
  }
  cout << endl;
}
```

```
int main() {
  // setup array with data
  int n, data[100];
  cin >> n;
  for(int i=0; i < n; i++)
    { cin >> data[i]; }
  // now perform the given task
  int val;
  cin >> val;
  if(n < 100){
    int loc = findFirstLarger(
                        data, n, val);
    shiftOneRightFrom(data, n, loc);
    data[loc] = val;
    n++;
  }
  else {
    cout << "No room" << endl;
  }
  // Output the results
  printResults(data, n);
  return 0;
}
```

Solutions – RemoveFirst

```
#include <iostream>
using namespace std;
// prototypes
int find(int nums[], int len, int target);
void shiftOneLeftFrom(
  int data[], int len, int fromIndex);
void printResults(int data[], int len);

int find(int nums[], int len, int target)
{
  for(int i=0; i < len; i++) {
    if(target == nums[i]){
       return i;
    }
  }
  return -1;
}
void shiftOneLeftFrom(
  int data[], int len, int fromIndex)
{
  // shift items up from loc to n
  //  invariant: data[loc] is always safe
  //             to overwrite
  for(int i = fromIndex ; i < len-1; i++) {
    data[i] = data[i+1];
  }
}
```

```
void printResults(int data[], int len){
  for(int i=0; i < len; i++){
    cout << data[i] << " ";
  }
  cout << endl;
}

int main() {
  // setup array with data
  int n, data[100];
  cin >> n;
  for(int i=0; i < n; i++)
    { cin >> data[i]; }
  // now perform the given task
  int val, loc;
  cin >> val;
  // find first occurrence of val
  loc = find(data, n, val);
  if(loc != -1) {
    // shift items up from loc to n
    //  invariant: data[loc] is always safe
    //             to overwrite
    shiftOneLeftFrom(data, n, loc);
    n--;
  }
  // Output the results
  printResults(data, n);
  return 0;
}
```

Solutions – RemoveAll

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

// prototypes
int find(int nums[], int len, int target);
void shiftOneLeftFrom(
  int data[], int len, int fromIndex);
void printResults(int data[], int len);

int find(int nums[], int len, int target)
{
  for(int i=0; i < len; i++) {
    if(target == nums[i]){
       return i;
    }
  }
  return -1;
}
void shiftOneLeftFrom(
  int data[], int len, int fromIndex)
{
  for(int i = fromIndex ; i < len-1; i++) {
    data[i] = data[i+1];
  }
}
```

```
void printResults(int data[], int len){
  for(int i=0; i < len; i++){
    cout << data[i] << " ";
  }
  cout << endl;
}

int main() {
  // setup array with data
  int n, data[100];
  cin >> n;
  for(int i=0; i < n; i++)
    { cin >> data[i]; }
  // now perform the given task
  int val, lead, trail;
  cin >> val;
  int loc = find(data, n, val);
  while ( loc != -1 ) {
    shiftOneLeftFrom(data, n, loc);
    n--;
    loc = find(data, n, val);
  }
  // Output the results
  printResults(data, n);
  return 0;
}
```