

Chapter 2: C++ Basics

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Variables and Assignments

- Variables are named memory locations to store data in
- Think of them like a box that you can store data in
 - We put a number (data) in the box
 - We can change the number (data) in the box
 - We can remove (erase) the number (data) in the box
- You refer to a particular box through a name (called an *identifier*)
- Variables must be declared
 - Variable declarations tell the computer “I want a box named `my_variable_name` to store data of a particular type”

Basic datatypes

Datatype	Description
<code>int, short, long</code>	whole (integer) numbers
<code>double, float</code>	decimal numbers
<code>string</code>	characters
<code>bool</code>	<code>true</code> or <code>false</code>
<code>char</code>	a single character

Identifiers

- Identifiers are the names of variables
- Identifiers must:
 - Begin with `a-z`, `A-Z`, or `_`
 - Followed by `a-z`, `A-Z`, `0-9` or `_`
- Identifiers are case-sensitive
- It is best practice to initialize variable values when they are declared

Declaring variables

- Before you can use a variable, you must declare it. Declaring a variable tells the compiler the type of data to store and allocates memory (a box to store data in) in computer memory.
- Examples:
 - `int counter;` //declares one integer named counter
 - `double weight, height;` //declares two doubles, one named weight, another named height

Assignment statements

- Assignment statements change the value of a variable.
 - Example: `counter = 5;` //sets the variable counter to be the value 5
- We can also assign variables to the value of other variables:
 - Example: `counter = b;`
- The variable that will be changed is always on the left of the assignment operator =
- The righthand side of an assignment can be:
 - A constant (`age = 21;`)
 - A variable (`valueA = valueB;`)
 - Expressions (`valueA = valueB * 10 + valueC;`)
- Note that the assignment operator is not the same as an algebra statement - we are not saying “the left-hand side is equal to the right-hand side.” We are saying “the variable on the left-hand side now contains the value of the right-hand side.”
- We *initialize* a variable, we assign it to a value as we declare it
 - Declaring a variable does not give it a value - we must either initialize the variable as we declare it, or assign the variable later

```
1 int a = 5; // this initializes a to be 5
2 int b;    // this declares the variable b
3 b = 7;    // this assigns b the value 7
```

Keywords

- Keywords have special meaning to C++; they are reserved for the language itself

<code>break</code>	<code>case</code>	<code>char</code>
<code>const</code>	<code>default</code>	<code>do</code>

<code>double</code>	<code>else</code>	<code>extern</code>
<code>float</code>	<code>for</code>	<code>if</code>
<code>int</code>	<code>long</code>	<code>return</code>

- We will learn more about these keywords as we go, but you cannot use a keyword for anything other than its purpose as a keyword (i.e. you cannot use a keyword as an identifier)

Input and Output in C++

- Input and output allows you to get information from the user (input) and display information to the user (output)
 - We have already seen output with our `cout` statements in `hello_world.cpp`
- C++ input statement:
 - `cin >> number;`
 - Value is extracted from the keyboard and stored in the variable called `number`
- C++ output statement:
 - `cout << "Hello, world!";`
 - Sends information from program to the terminal screen
 - Double quotes `"..."` delimit a *string*
 - `\n` sends a *newline character* to the terminal (carriage return)
 - * The `\` character indicates we are entering an *escape sequence*. Other notable escapes sequences include `\t` (tab), `\\` (backslash), `\"` (quote character)
 - * We must escape these characters because they have a special meaning in C++

Formatting numbers

- When we `cout` floating point numbers (`double` or `float`), we may wish to specify the precision of the output
- Suppose we wanted to output a dollar amount, like \$35.40

```
1 double price = 35.4;
2 cout << "The price is $" << price << endl;
```

- The output could be: `The price is $34.4`, `The price is $34.400000`, `The price is $3.4400000e1`.
- If we want to output \$34.40, we need to tell the compiler what level of precision to use

```
1 cout.setf(ios::fixed); // specify fixed point notation
2 cout.setf(ios::showpoint); // specify the decimal will always be shown
3 cout.precision(2); // specify that two decimal places will always be
  shown
4 // cout is now ready to print to two decimal places
5 cout << "The price is " << price << endl;
```

Prompts

- It's very common to prompt for a value with `cout` and then receive it with `cin`
 - Many homework assignments will expect you to do something similar!

```
1 cout << "Enter your age: ";
2 cin >> w;
3 age;
```

Literals

- A literal, fixed, static value used in a program
- Literals are invariant values. They can never be changed. They can never store data.
- Literals are literally some value.
- 2 is the literal integer value 2. 2.0 is the literal floating point value 2.0
 - Note that these are actually different types of literals

Literals vs. Variables

- A literal is a fixed values that never changes
- A variable is a container for data
 - A variable can change its data over time
 - A variable can only hold one value at a time
- A literal has no “box” (memory) to store data in; a literal is a fixed value embedded in your program.
- This means that a literal can **never** be on the left-hand side of an assignment statement
 - `5 = 6;` is not possible because 5 is a literal. It is not a box (variable) that we can store data in
 - Always think about the left-hand side of the assignment statement in terms of boxes that you can store data in

- Literals are literal values and not boxes to store data in, and therefore cannot be on the left-hand side of an assignment statement.

Basic datatypes (revisited)

Datatype	Description
int, short, long	whole (integer) numbers
double, float	decimal numbers
string	characters
bool	true or false
char	a single character

int

- Stores an integer value.
- Typically stored in 32 bits (the computer uses 32 bits to represent the number)
 - If you have a set of integers centered around 0, what's the maximum and minimum integer you can represent with 32-bits?
 - * 32 bits leads to 4294967296 which is 2^{32} (binary is base 2, and we have 32 bits)
 - * Maximum value: +2147483647
 - * Minimum value: -2147483648
- Example usage:

```
1 int a = 5;
```

char

- Capable of holding any member of the character set.
- Stored in 1 byte (8 bits).
- The underlying structure has the same type of data as an **int** (with a smaller range of data)
 - However, the way we *should* use chars is not through integer references
 - This is all because internally a character is literally an integer to the computer
- Examples of characters:

```
1 'a'
2 'b'
```

```
3 '3'
4 '\0' // null character
5 '\n' // newline character
6 '\t' // tab character
```

string

- A **string literal** is a collection of characters in a single string
 - "Hello, world!" is an example of a string literal
 - String literals are denoted by " instead of ' for their wrapping quotations
- In C++, a string is class, which is different from the other primitive datatypes we've discussed thus far.
- Strings are used to store collections of characters.
- You can use strings by including the string library with `#include <string>`
 - Then you can declare and initialize a string with `string name = "Mark Edmonds";`

float

- Holds a floating point number, such as 32.2
- All representations of floating point numbers are inexact.
- Adding `f` to the end of a number indicates it is to be interpreted as a float
- Examples of floats:

```
1 32.3
2 3223.64563f
3 4.0f
4 6.022e+23f
```

double

- Exact same as a **float**, but uses double the precision (i.e. double the computer memory) to store the data

Type Modifiers

- We may want to modify the amount of storage used by a type.
- This enables data to use more or less memory depending upon the use case.
- Adding a modifier of **long** will make the type use more memory

- Adding a modifier of **short** will make the type use less memory
- Adding a modifier of **unsigned** will make the type non-negative in all cases (changes the range of possible values)
- If you use **short** or **long** by itself, the **int** type is implied

```
1 unsigned short int usi; /* fully qualified -- unsigned short int */
2 short si;               /* short int */
3 unsigned long uli;      /* unsigned long int */
```

- The **const** makes a particular variable constant, or unmodifiable.
 - You *must* initialize the value when you declare it.
 - What's the advantage?
 - * You gain additional protections against a programmer making a mistake and modifying a value they shouldn't
 - * Also protects against magic numbers - don't put the same literal all over your program. Use a constant to define the value once and use the constant everywhere you need that value

Type Compatibility

- Intuitively, it makes sense that we'd be able to convert between certain types.
 - For instance, converting between an integer and a floating point number seems like a reasonable thing to do
 - There are a few rules regarding these implicit type conversions, so we should avoid using them unless it's really justified
- Implicit type conversions:
 - **int** <-> **double** conversion: when converting to an **int**, the decimal place will **not** be rounded; it will be *truncated*
 - * This means writing something like **int** a = 2.4; will result in a holding the integer 2. Similarly, writing something like **int** b = 2.7; will also result in a holding the integer 2.
 - **int** <-> **float** conversion: same as **int** <-> **double**.
 - **char** <-> **int** conversions: characters are really stored as integers, but there's no semantically meaningful way to convert between them.
 - * For instance, we could write **int** value = 'A';, but this integer has no semantic meaning
 - * It's best to avoid this at all costs - there's really no reason to convert between an **int** and a **char**

- `bool` <-> `int` conversion: any non-zero integer is evaluated to `true` and the integer 0 is evaluated to `false`
 - * If we convert `true` to an integer, we get the integer 1
 - * It's also best to avoid this - there's no reason to convert between an `int` and a `bool`

Basic Arithmetic Operators

- C++ supports basic arithmetic operators to help you do math.
- Basic operators include:
 - + addition
 - - subtraction
 - * multiplication
 - / division (floating point and integer division depending upon type)
 - % modulo (remainder division)

Increment and decrement

- Adding 1 to a variable is so common, we have a custom operator for it
- We have three methods of incrementing (the same is true for decrement) variables in C
- Using addition (not technically an increment operator):

```
1 a = a + 1;
```

- Using the prefix increment operator

```
1 ++a;
```

- Using the postfix increment operator

```
1 a++;
```

- What's the difference between these two statements?
 - A lot of the time, there is no difference in practice
 - **HOWEVER**
 - The semantics are technically different
 - How are they different?
 - * `++a` increments `a` and then returns the value of `a` (meaning the value returned has already been incremented)
 - * `a++` returns the value of `a` and then increments `a` (meaning the value returned has *not* yet been incremented)

– When does this matter?

* Two cases:

```
1 int a = 5;
2 int b = 5;
3 int c = ++a; // c has the value of 6 after this executes, a has the
               value of 6
4 int d = a++; // d has the value of 5 after this executes, a has the
               value of 6
```

- All of the above also applies for the decrement operator `--`, which subtracts 1 from a variable instead of adding 1

Floating point vs. Integer division

- We have a few different types of division in C++
- Noticing when we are using floating point vs. integer division is a common mistake
- Floating point division occurs when at least one of the operands is a floating point variable or floating point literal
- Integer division occurs when both operands are integers

```
1 int a = 5;
2 int b = 7;
3 double c = 5.0;
4 int int_div1 = a / b; // result is 0, because we are doing integer
                       division and 5/7 is 0r5
5 int int_div2 = b / a; // result is 1, because we are doing integer
                       division and 7/5 is 1r2
6 double float_div1 = c / b; // result is 0.71, because we are doing
                             floating point division and 5.0/7 is 0.71
7 double float_div2 = a / b; // result is 0.0, because we are doing
                             integer division and 5/7 is 0r5
```

- The last line above may be surprising, but the right-hand side of the assignment performs integer division, resulting in 0, and then the 0 is assigned to a double, resulting in 0.0

Modulo (remainder division)

- Remember integer division from elementary school?
- e.g. 7/5 was 1r2 (1 with a remainder of 2) because 5 goes into 7 one time with a remainder of 2.

- When you divide two ints, you only get the quotient (number of times the denominator goes into the numerator).
- Modulo % gives us a way to get the remainder from the quotient division.
- Modulo is *extremely* useful.
 - It lets you add a bound to possible values.
 - For instance, suppose you want to pick a random number between 0 and 9.
 - Let's say you have a `rand()` function that returns a random number between 0 and a really, really big number (say 10000000000).
 - You can do `rand() % 10` and you are guaranteed to get a number between 0 and 9.
 - It doesn't matter how big the number is, the remainder *must* be between 0 and 9.
 - Otherwise, the quotient increments

calculations.cpp

```
1  /* Let's try writing some calculations... */
2  #include <iostream>
3
4  using namespace std;
5
6  int main() {
7      float value1 = 0.0, value2 = 0.0;
8      int i1 = 0, i2 = 0;
9
10     /* Prompt for values */
11     cout << "\t\tCalculation Program\n\n";
12     cout << "Please enter two values: ";
13     cin >> value1;
14     cin >> value2;
15
16     /* perform calculations */
17     cout << "Their sum: " << value1 + value2 << endl;
18     cout << "Their product: " << value1 * value2 << endl;
19     cout << "The first minus the second: " << value1 - value2 << endl;
20     cout << "The second minus the first: " << value2 - value1 << endl;
21     cout << "The first divided by the second: " << value1 / value2 <<
22         endl;
23     cout << "The second divided by the first: " << value2 / value1 <<
24         endl;
25
26     /* what if they are integers? */
27     cout << "Let's try again, as if the values were int\n";
```

```
26     i1 = (int) value1;
27     i2 = (int) value2;
28     cout << "Their sum: " << i1 + i2 << endl;
29     cout << "Their product: " << i1 * i2 << endl;
30     cout << "The first minus the second: " << i1 - i2 << endl;
31     cout << "The second minus the first: " << i2 - i1 << endl;
32     cout << "The first divided by the second: " << i1 / i2 << endl;
33
34     /* FYI: The modulo operator is only defined on int operands... */
35     cout << "The modulus of the first by the second: " << i1 % i2 <<
        endl;
36     cout << "The second divided by the first: " << i2 / i1 << endl;
37     cout << "The modulus of the second by the first: " << i2 % i1 <<
        endl;
38     return( 0 );
39 }
40 }
```

Conditionals

- There is no meaningful program that doesn't demonstrate some basic decision-making skills
- For instance, "I will continue driving through the intersection" is not a statement a human would act upon. But "I will stop if the light is red, go if the light is green, go only if I can safely pass if the light is yellow" might be a reasonable driving policy.
- A conditional tells the computer to only execute a block of code if a particular condition has been satisfied (i.e. that condition is true).
- **if...else** is the most common conditional statement
- **switch...case** are used as a shorthand version of **if...else**
- In C, logic is a form of arithmetic
 - 0 represents false
 - **any** other value represents true
 - Logical and arithmetic operators are treated as the same thing in C

Relational Expressions

- Consider the following relational and equivalence operations

```
1  a < b      // 1 if a is less than b, 0 otherwise
2  a > b      // 1 if a is greater than b, 0 otherwise
3  a <= b     // 1 if a is less than or equal to b, 0 otherwise
```

```
4 a >= b    // 1 if a is greater than or equal to b, 0 otherwise
5 a == b    // 1 if a is equal to b, 0 otherwise
6 a != b    // 1 if a is not equal to b, 0 otherwise
```

- Please remember = is for **assignment** and == is for **equality**
- The following conditionals are equivalent due to the definition of **true** and **false** in C++:
 - **false** is equivalent to 0 and **true** is equivalent to anything non-zero.
 - I would recommend avoiding comparing against any integer values and instead compare against **true** or **false** directly.

```
1 if (foo()) {
2     // do something
3 }
4 if (foo() == true) {
5     // do something
6 }
7 if (foo() != false) {
8     // do something
9 }
10 if (foo() != 0) {
11     // do something
12 }
```

selection.cpp

```
1 /* Let's try writing some conditional logic... */
2 #include <iostream>
3
4 using namespace std;
5
6 int main() {
7     float value1 = 0.0, value2 = 0.0;
8     /* Prompt for values */
9     cout << "\t\tConditional Logic Program\n\n";
10    cout << "Please enter two values: ";
11    cin >> value1;
12    cin >> value2;
13
14    if (value1 < value2) {
15        cout << "value1 is less than value2\n";
16    }
```

```
17     if (value1 > value2) {
18         cout << "value1 is greater than value2\n";
19     }
20     if (value1 <= value2) {
21         cout << "value1 is less than or equal value2\n";
22     }
23     if (value1 >= value2) {
24         cout << "value1 is greater than or equal value2\n";
25     }
26     if (value1 == value2) {
27         cout << "value1 equals value2\n";
28     }
29     if (value1 != value2) {
30         cout << "value1 does not equals value2\n";
31     }
32     /* FYI: due to rounding errors, it is unreliable to test for
33        equality on floating point numbers */
33     return( 0 );
34 }
```

If-Else Statements

- Executes a block of code if particular conditions have been met
- Basic syntax:

```
1 if (/* condition goes here */) {
2     /* if the condition is non-zero (true), this code will execute */
3 } else {
4     /* if the condition is 0 (false), this code will execute */
5 }
```

- The first block executes if the condition is true, otherwise the second block executes
- The **else** is completely optional
- An **if** can directly follow an else, creating a chain of conditions to check:

```
1 if (a > b) {
2     c = a;
3 } else if (b > a) {
4     c = b;
5 } else {
6     c = 0;
7 }
```

- This code sets the variable `c` equal to the greater of the two variables `a` or `b`, or 0 if `a` and `b` are equal.
- What's the point of the **else** when you can just do this:

```
1  if (a > b) {  
2    c = a;  
3  }  
4  
5  if (a < b) {  
6    c = b;  
7  }  
8  
9  if (a == b) {  
10   c = 0;  
11 }
```

1. Multiple **if**'s could be true, there is no guaranteed mutual exclusion
 2. Evaluating **if** statements takes time (since the condition must be checked).
- If you only have single statement to statement to execute in your **if** or **else**, you do not need to put a block.
 - **But you should.**
 - Consider the following

```
1  if(5 < 10)  
2    cout << "I am inside the if\n";  
3  else  
4    cout << "I am inside the else\n";  
5    cout << "5 is not less than 10\n";
```

- Only the single statement following the **if** or **else** is associated with the conditional...so when will `5 is not less than 10` be printed?
 - **Every time**
 - Indentation cannot be trusted!
 - Here's a version with indentation reflecting the semantics of the program:

```
1  if(5 < 10)  
2    cout << "I am inside the if\n";  
3  else  
4    cout << "I am inside the else\n";  
5  cout << "5 is not less than 10\n";
```

- How do you fix this?

– Always use block statements!

```
1 if(5 < 10) {  
2     cout << "I am inside the if\n";  
3 } else {  
4     cout << "I am inside the else\n";  
5     cout << "5 is not less than 10\n";  
6 }
```

Looping

- Loops enable programmers to tell the computer to repeat a particular block of code multiple times.
 - It is generally impractical to use conditionals a large number of times.
- Consider how a dishwasher might describe their time at work.
 - Unlikely the dishwasher would say “I watch a dish, and then another dish, and then another dish, ...”
 - More like they would say “I washed dishes the entire time I was at work”

While Loops

- A while loop is the most basic type of loop.
- **while** loops run until a specific controlling condition is not satisfied (i.e. false).
 - The controlling condition is checked *before* the loop executes and every time the loop loops.
- Syntax:

```
1 while(condition){  
2     //loop body  
3 }
```

- Basic example:

```
1 int a = 1;  
2 while (a < 100) {  
3     cout << "a is " << a << endl;  
4     a = a * 2;  
5 }
```

- How many times will this loop execute?

- 7, last time this executes `a` is set to 128 at the end of the loop
- **A critical note:** something must change in the loop such that the condition is eventually false and the loop exits
 - Otherwise, this is called an infinite loop.
- Consider the following:

```
1 int a = 1;
2 while (42) {
3     a = a * 2;
4 }
```

- The controlling condition in the **while** never changes, and therefore will run forever (since 42 evaluates to true).
- **break** and **continue**
 - Allows you to control the flow of the loop from within the loop
 - **break** will immediately exit the loop
 - **continue** will skip the remainder of the block and start at the controlling conditional statement again.

```
1 int a = 1;
2 while (42) { // loops until the break statement in the loop is executed
3     cout << "a is %d " << a << endl;
4     a = a * 2;
5     if (a > 100) {
6         break;
7     } else if (a == 64) {
8         continue; // Immediately restarts at while, skips next step
9     }
10    cout << "a is not 64\n";
11 }
```

- Similar to **if**, you may omit the braces for the block of code associated with the while loop
 - However, this is not recommended for the same reasons as with an **if** statement
 - Grouping of statements is potentially ambiguous (to the programmer, not the computer) that can lead to bugs

```
1 int a = 1;
2 while (a < 100)
3     a = a * 2;
```

- This will just increase `a` until it is above 100

- When a loop ends, the program goes back to the while statement's controlling condition.
 - If the condition is true, the loop executes again
 - If the condition is false, the loop exits
 - The computer does *not* continuously check the controlling condition after each statement in the loop executes. It only checks at the end of every loop
 - If you need to end the loop during the middle of the loop's block, use a **break** to check for the necessary conditions

Do-While Loops

- The do-while loop is the same as a while loop, except the loop controlling condition is checked at the end of the loop rather than at the beginning
- Means the loop is guaranteed to execute at least one time.
- Syntax:

```
1 do {  
2     /* do stuff */  
3 } while (condition);
```

- Note: the terminating ; is required.
- **break** and **continue** operate the same as with other loops (the controlling condition will still be checked before executing the loop body again when using **continue**)

Program style

- When writing your own programs, it's important to:
 1. Keep indentation clean and readable
 2. Use sensible variable names (don't use **a**, **b**, **c**, etc like I've been using in these small examples. Use names like **change** or **pounds** or **amount**)
 3. Write comments in your code. This will help yourself and future programmers that come across your code

Exercises

1. Write a C++ program to check whether a given number is even or odd

```
1 #include <iostream>  
2  
3 using namespace std;  
4
```

```
5 void main()
6 {
7     int num1, rem1;
8
9     cout << "Input an integer : ";
10    cin >> num1;
11    rem1 = num1 % 2;
12    if (rem1 == 0)
13        cout << num1 << " is an even integer\n";
14    else
15        cout << num1 << " is an odd integer\n";
16 }
```

2. Write a C++ program to determine if a inputted integer is a palindrome

```
1 #include <iostream>
2
3 using namespace std;
4
5 int main()
6 {
7     int n, num, digit, rev = 0;
8
9     cout << "Enter a positive number: ";
10    cin >> num;
11
12    n = num;
13
14    do
15    {
16        digit = num % 10;
17        rev = (rev * 10) + digit;
18        num = num / 10;
19    } while (num != 0);
20
21    cout << "The reverse of the number is: " << rev << endl;
22
23    if (n == rev)
24        cout << "The number is a palindrome\n";
25    else
26        cout << "The number is not a palindrome\n";
27
28    return 0;
```

```
29 }
```