

## C++ Strings

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*Original handout written by Neal Kanodia and Steve Jacobson.*

### C++ Strings

One of the most useful data types supplied in the C++ libraries is the string. A string is a variable that stores a sequence of letters or other characters, such as "**Hello**" or "**May 10th is my birthday!**". Just like the other data types, to create a **string** we first declare it, then we can store a value in it.

```
string testString;  
testString = "This is a string.";
```

We can combine these two statements into one line:

```
string testString = "This is a string.";
```

Often, we use strings as output, and **cout** works exactly like one would expect:

```
cout << testString << endl;
```

will print the same result as

```
cout << "This is a string." << endl;
```

In order to use the string data type, the C++ string header **<string>** must be included at the top of the program. Also, you'll need to include **using namespace std;** to make the short name **string** visible instead of requiring the cumbersome **std::string**. (As a side note, **std** is a C++ *namespace* for many pieces of functionality that are provided in standard C++ libraries. For the purposes of this class, you won't need to otherwise know about namespaces.) That means you need the following **#include** in your program in order to use the **string** type.

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

### Basic Operations

Let's go into specifics about the string manipulations you'll be doing the most.

**Counting the number of characters in a string.** The **length** method returns the number of characters in a string, including spaces and punctuation. Like many of the string operations, **length** is a *member function*, and we invoke member functions using *dot notation*. The string that is the receiver is to the left of the dot, the member function we are invoking is to the right, (e.g. **str.length()**). In such an expression, we are requesting the length from the variable **str**.

*example program:*

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

#include "console.h"

int main() {
    string small, large;
    small = "I am short";
    large = "I, friend, am a long and elaborate string indeed";

    cout << "The short string is " << small.length()
          << " characters." << endl;
    cout << "The long string is " << large.length()
          << " characters." << endl;
    return 0;
}
```

*output:*

```
The short string is 10 characters.
The long string is 48 characters.
```

**Accessing individual characters.** Using square brackets, you can access individual characters within a string as if it's a **char** array. Positions within a string **str** are numbered from 0 through **str.length() - 1**. You can read and write to characters within a string using **[ ]**.

*example program:*

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

#include "console.h"

int main() {
    string test;
    test = "I am Q the omnipot3nt";

    char ch = test[5];           // ch is 'Q'
    test[18] = 'e';             // we correct misspelling of omnipotent

    cout << test << endl;
    cout << "ch = " << ch << endl;
    return 0;
}
```

*output:*

```
I am Q the omnipotent
ch = Q
```

Be careful not to access positions outside the bounds of the string. The square bracket operator is not range-checked and thus reading from or writing to an out-of-bounds index tends to produce difficult-to-track-down errors. There is an alternate member function

**at(int index)** that retrieves the character at a position with the benefit of built-in range-checking, but it's used much less often.

**Passing, returning, assigning strings.** C++ strings are designed to behave like ordinary primitive types with regard to assignment. Assigning one string to another makes a deep copy of the character sequence.

```
string str1 = "hello";
string str2 = str1; // makes a new copy
str1[0] = 'y';     // changes str1, but not str2
```

Passing and returning strings from functions clones the string. If you change a string parameter within a function, changes are not seen in the calling function unless you have specifically passed the string by reference (e.g. using that **&** trick we learned about in the Queen Safety example.)

**Comparing two strings.** You can compare two strings for equality using the **==** and **!=** operators. Suppose you ask the user for his or her name. If the user is Julie, the program prints a warm welcome. If the user is not Neal, the program prints the normal message. Finally... if the user is Neal, it prints a less enthusiastic response.

*example program:*

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

#include "console.h"
#include "simpio.h"

int main() {
    string myName = "Neal";
    while (true) {
        cout << "Enter your name (or 'quit' to exit): ";
        string userName = getLine();
        if (userName == "Julie") {
            cout << "Hi, Julie! Welcome back!" << endl;
        } else if (userName == "quit") {
            // user is sick of entering names, so let's quit
            cout << endl;
            break;
        } else if (userName != myName) {
            // user did not enter quit, Julie, or Neal
            cout << "Hello, " << userName << endl;
        } else {
            cout << "Oh, it's you, " << myName << endl;
        }
    }
    return 0;
}
```

**output:**

```

Enter your name (or 'quit' to exit): Neal
Oh, it's you, Neal
Enter your name (or 'quit' to exit): Julie
Hi, Julie! Welcome back!
Enter your name (or 'quit' to exit): Leland
Hello, Leland
Enter your name (or 'quit' to exit): quit

```

You can use `<`, `<=`, `>`, and `>=` to compare strings as well. These operators compare strings lexicographically, character by character and are case-sensitive. The following comparisons all evaluate to true: `"A" < "B"`, `"App" < "Apple"`, `"help" > "hello"`, `"Apple" < "apple"`. The last one might be a bit confusing, but the ASCII value for `'A'` is 65, and comes before `'a'`, whose ASCII value is 97. So `"Apple"` comes before `"apple"` (or, for that matter, any other word that starts with a lower-case letter).

**Appending to a string:** C++ strings are wondrous things. Suppose you have two strings, `s1` and `s2` and you want to create a new string of their concatenation. Conveniently, you can just write `s1 + s2`, and you'll get the result you'd expect. Similarly, if you want to append to the end of string, you can use the `+=` operator. You can append either another string or a single character to the end of a string.

**example program:**

```

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

#include "console.h"

int main() {
    string firstname = "Leland";
    string lastname = "Stanford";

    string fullname = firstname + lastname; // concat the two strings
    fullname += ", Jr"; // append another string
    fullname += '.'; // append a single char

    cout << firstname << lastname << endl;
    cout << fullname << endl;

    return 0;
}

```

**output:**

```

Leland Stanford
Leland Stanford, Jr.

```

## More (Less Used) Operations

The string class has many more operations; we'll show just a few of the more useful ones below.

**Searching within a string.** The string member function **find** is used to search within a string for a particular string or character. A sample usage such as **str.find(key)** searches the receiver string **str** for the **key**. The parameter **key** can either be a string or a character. (We say the **find** member function is *overloaded* to allow more than one usage). The return value is either the starting *position* where the key was found or the constant **string::npos** which indicates the key was not found.

Occasionally, you'll want to control what part of the string is searched, such as to find a second occurrence past the first. There is an optional second integer argument to **find** which allows you to specify the starting position; when this argument is not given, 0 is assumed. Thus, **str.find(key, n)** starts at position **n** within **str** and will attempt to find **key** from that point on. The following code should make this slightly clearer:

### *example program:*

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

#include "console.h"

int main() {
    string sentence = "Yes, we went to Gates after we left the dorm.";

    int firstWe = sentence.find("we");           // finds the first "we"
    int secondWe = sentence.find("we", firstWe + 1); // finds "we" in "went"
    int thirdWe = sentence.find("we", secondWe + 1); // finds the last "we"
    int gPos = sentence.find('G');
    int zPos = sentence.find('Z');              // returns string::npos

    cout << "First we: " << firstWe << endl;
    cout << "Second we: " << secondWe << endl;
    cout << "Third we: " << thirdWe << endl;

    cout << "Is G there? ";
    cout << (gPos != string::npos ? "Yes!" : "No!") << endl;
    cout << "Is Z there? ";
    cout << (zPos != string::npos ? "Yes!" : "No!") << endl;
    return 0;
}
```

### *output:*

```
First we: 5
Second we: 8
Third we: 28
Is G there? Yes!
Is Z there? No!
```

**Extracting substrings.** Sometimes you would like to create new strings by extracting portions of a larger one. The **substr** member function creates substrings from pieces of

the receiver string. You specify the starting position and the number of characters. For example, `str.substr(start, length)` returns a new string consisting of the characters from `str` starting at the position `start` and continuing for `length` characters. Invoking this member function does not change the receiver string, as it makes a *new* string with a copy of the characters specified.

*example program:*

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

#include "console.h"

int main() {
    string oldSentence;
    oldSentence = "The quick brown fox jumped WAY over the lazy dog";
    int len = oldSentence.length();
    cout << "Original sentence: " << oldSentence << endl;
    int found = oldSentence.find("WAY ");
    string newSentence = oldSentence.substr(0, found);
    cout << "Modified sentence: " << newSentence << endl;
    newSentence += oldSentence.substr(found + 4);
    cout << "Completed sentence: " << newSentence << endl;
    return 0;
}
```

*output:*

```
Original sentence: The quick brown fox jumped WAY over the lazy dog
Modified sentence: The quick brown fox jumped
Completed sentence: The quick brown fox jumped over the lazy dog
```

There are a couple of special cases for `substr(start, length)`. If `start` is negative, it will cause a run-time error. If `start` is past the end of the string, it will return an empty string (e.g., ""). If `length` is longer than the number of characters from the start position to the end of the string, it truncates to the end of the string. If `length` is negative, then the behavior is undefined, so make sure that `length` is always non-negative. If you leave off the second argument, the number of characters from the starting position to the end of the receiver string is assumed.

**Modifying a string by inserting and replacing.** Finally, let's cover two other useful member functions that modify the receiver string. The first, `str1.insert(start, str2)`, inserts `str2` at position `start` within `str1`, shifting the remaining characters of `str1` over. The second, `str1.replace(start, length, str2)`, removes from `str1` a total of `length` characters starting at the position `start`, replacing them with a copy of `str2`. It is important to note that these member functions do modify the receiver string.

*example program:*

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

#include "console.h"

int main() {
    string sentence = "CS106X sucks.";
    cout << sentence << endl;

    // Insert "kind of" at position 8 in sentence
    sentence.insert(7, "kind of ");
    cout << sentence << endl;

    // Replace the 10 characters "kind of su"
    // with the string "ro" in sentence
    sentence.replace(7, 10, "ro");
    cout << sentence << endl;
    return 0;
}
```

*output:*

```
CS106X sucks.
CS106X kind of sucks.
CS106X rocks.
```

### Obtaining a C-style `char *` from a string

Remember, a C++ string is not the same thing as a C-style string (which is merely a `char *` pointer to a sequence of characters terminated by a null character `'\0'`). Although old-style C `char *` strings and C++ strings can co-exist in a program, almost all our use will be of C++ strings, since they have a much richer set of operations and are less error-prone to work with. I say "almost always" because in a few unavoidable situations, we are forced to use old-style C strings, most notably when working with file streams. We can convert a C++ string to the old-style representation using the `.c_str()` member function. One use we will see of this is to get a `char *` to pass to the `iostream::open` function.

*example program:*

```

#include <string>
#include <iostream>
#include <fstream>
using namespace std;

#include "console.h"

int main() {
    ifstream fs;
    string filename = "courseinfo.txt";
    string s;

    // open function requires a C-style string, must convert!
    fs.open(filename.c_str());

    if (fs.fail()) return -1; // could not open the file!

    // process the file

    fs.close();
    return 0;
}

```

**The CS106 Library: `strlib.h`**

In addition to the standard library support for strings, there are a few extensions that the CS106 libraries provide. To use these functions, the **`strlib.h`** library must be **`#included`**.

**`integerToString`, `realToString`, `stringToInteger`, `stringToReal`**: Often your programs will need to convert a string to a number or vice versa. These functions do just that, with the 'integer' functions operating on **`int`** and the 'real' functions on **`double`**.

*example program:*

```

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

#include "genlib.h"
#include "strlib.h"

int main() {
    string str1 = "5.6";
    double num = stringToReal(str1);
    string str2 = integerToString(45);

    cout << "The original string is " << str1 << "." << endl;
    cout << "The number is " << num << "." << endl;
    cout << "The new string is " << str2 << "." << endl;
    return 0;
}

```



**output:**

```
The original string is 5.6.
The number is 5.6
The new string is 45.
```

Any integer or real can be safely converted to a string. However, when converting in the other direction, if you pass an improperly formatted string to convert to an integer or real, an error is raised by the conversion functions.

**topUpperCase**, **toLowerCase**: These functions take a string, and return a new string with all letters in lower or upper case respectively. These can be used to change two strings to a uniform case before comparing to allow a case-insensitive comparison.

**example program:**

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

#include "genlib.h"
#include "strlib.h"

int main() {
    string appleFruit = "apples";
    string orangeFruit = "ORANGES";

    cout << "Do " << appleFruit << " come before " << orangeFruit << "? ";
    cout << (appleFruit < orangeFruit ? "Yes!" : "Nope....") << endl;

    string lowerOrangeFruit = toLowerCase(orangeFruit);

    cout << "Do " << appleFruit << " come before " << lowerOrangeFruit << "? ";
    cout << (appleFruit < lowerOrangeFruit ? "Yes!" : "Nope....") << endl;
    return 0;
}
```

**output:**

```
Do apples come before ORANGES? Nope....
Do apples come before oranges? Yes!
```

There are a few other functions within the **strlib** library (**equalsIgnoreCase**, **startsWith**, **endsWith**, and **trim**) as well.