

# Ch09-Strings

October 13, 2020

## 1 Strings

### 1.1 Topics

- string library
- string objects and methods
- string operators
- slicing string
- string traversal
- comparing and updating strings

### 1.2 string and variables

- we've used string library to declare string variables in earlier chapters
- we've seen few examples of string applications over the chapters
- this chapter goes in depth on string data
- string variable is a container for a sequence of 0 or more characters
  - characters are anything from symbols (% , & , \$ , etc.)
  - alphabets (a, B, x, etc.)
  - digits (1, 9, 0, etc.)
- in C++ string is represented using a pair of double quotes ("")
- string is made up of sequence of character elements as depicted in the following figure
- each character has an internal indexing or placing we can refer to it by its index

string fruit = " 

b	a	n	a	n	a
---	---	---	---	---	---

 " ;

indices: 0    1    2    3    4    5

**Fig. C++ string representation**

### 1.2.1 c-string variables examples

```
[2]: #include <iostream>
```

```
using namespace std;
```

```
[3]: // C way to declare string - painful to work with!  
// array of characters; we don't know array yet!!  
char text[] = "this is a c-string";
```

```
[3]: cout << "text = " << text << endl;
```

text = this is a c-string

- cin and other operations on c-strings are not easier without knowing array and pointers

### 1.2.2 C++ string objects

- std::string is a std::basic\_string<char> template type defined in **string** header
- more: [https://en.cppreference.com/w/cpp/string/basic\\_string](https://en.cppreference.com/w/cpp/string/basic_string)
- string is an advanced type of container with many members variable and member functions
  - variables of advanced type are called objects
  - member functions are called method
  - one can define any type using **struct** or **class** that we'll learn later

```
[4]: // C++  
#include <string>  
  
using namespace std;  
  
// declare a string variable  
string first;
```

```
[5]: // assign string value to string variable  
first = "Hello, ";
```

```
[6]: // declare and initialize string variable  
string second = "World";
```

```
[7]: // out put string literals and variables  
#include <iostream>  
  
cout << first << second << "!" << endl;
```

Hello, World!

## 1.3 Member functions

- there are many member functions and methods available in string objects

- a complete list is provided in this reference: [https://en.cppreference.com/w/cpp/string/basic\\_string](https://en.cppreference.com/w/cpp/string/basic_string)
- we'll go over some commonly used ones with examples
- syntax to access members from objects:

`object.data_member`

`object.member_function()`

- we use `.` (dot) member access operator

## 1.4 Element access

- extracting and updating characters
- the following member functions/methods let's you access element:
  - **at(index)** - access the specified character at index with bounds checking
  - **operator[index]** - access the specified character at index without bounds checking
  - **front( )** - access the first character
  - **back( )** - access the last character
- index must be a valid index between **0 to length-1**

```
[35]: string fruit = "banana";
```

```
[36]: char first_letter;
```

```
[37]: // access the first character at index 0
first_letter = fruit.at(0);
```

```
[38]: cout << "first letter of " << fruit << " is " << first_letter << " = " <<
    ↪fruit[0];
```

first letter of banana is b = b

```
[39]: //second character
cout << "second character = " << fruit[1] << " = " << fruit.at(1);
```

second character = a = a

```
[ ]: // there are 6 characters in banana
cout << "last character = " << fruit[6];
// [] - doesn't check the bound; output is undetermined
```

```
[41]: // at() - checks the bounds; throws runtime-error
cout << "last character = " << fruit.at(6);
```

last character =

Standard Exception: `basic_string`

```
[42]: cout << "front = " << fruit.front() << " and back = " << fruit.back();
```

front = b and back = a

### 1.4.1 updating string in place

- string is mutable type; that can be changed in place!
- using [ ] operator, we can assign new character at some index
  - index must be a valid one [0 ... length-1]

```
[43]: // capitalized the first character by replacing b with B
fruit[0] = 'B';
```

```
[44]: cout << "I love, " << fruit << "!";
```

I love, Banana!

## 1.5 Capacity

- knowing the length of a string (numbers of characters) helps with many operations
- the following methods give some form of capacity of string objects:
  - **length()** or **size()** - returns the number of characters
  - **empty()** - checks whether the string is empty

```
[45]: cout << "length of " << fruit << " = " << fruit.size() << " = " << fruit.
      ↪length();
```

length of Banana = 6 = 6

```
[48]: cout << "is fruit empty? " << boolalpha << fruit.empty();
```

is fruit empty? false

## 1.6 Traversal

- traversing a string is a common task where you access every character from first to the last
- there are several ways to traverse a string

```
[96]: // using capacity to traverse/iterate over a string
for(int i=0; i<fruit.length(); i++) {
    cout << "fruit[" << i << "] = " << fruit[i] << endl;
}
```

```
fruit[0] = B
fruit[1] = a
fruit[2] = n
fruit[3] = a
fruit[4] = n
fruit[5] = a
```

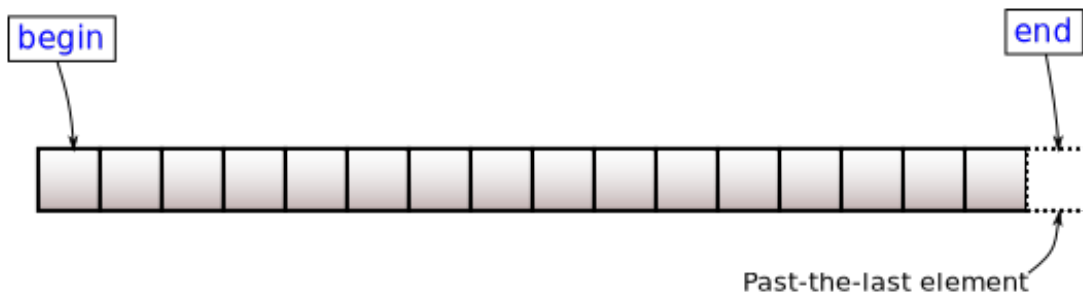
```
[95]: #include <cctype>

for(auto ch: fruit)
    cout << ch << " -> " << char(toupper(ch)) << endl;
```

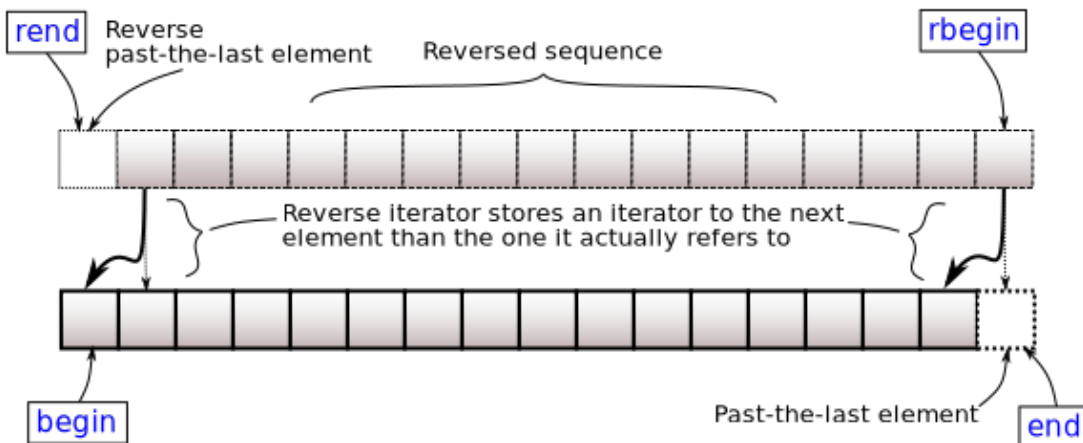
```
B -> B
a -> A
n -> N
a -> A
n -> N
a -> A
```

## 1.7 Iterators

- iterators are special pointers that let you iterate or traverse a string
- the following methods return an iterator:
  - **begin()** - returns a forward iterator to the beginning
  - **end()** - returns a forward iterator to the end
  - **rbegin()** - returns a reverse iterator to the beginning
  - **rend()** - returns a reverse iterator to the end
- the following figure demonstrates **begin()** and **end()** iterators



- the following figure demonstrates **rbegin()** and **rend()** iterators



```
[20]: // automatically determine the type of iter which is a forward iterator
      auto iter = fruit.begin();
```

```
[21]: // what is iter pointing to?
      cout << *iter;
```

B

```
[22]: // increment iterator by one element
      iter += 1;
```

```
[23]: cout << *iter;
```

a

```
[24]: // forward iterator
      for(auto it=fruit.begin(); it != fruit.end(); it += 1) {
          cout << *it << " ";
      }
```

B a n a n a

```
[25]: // reverse iterator
      for(auto it=fruit.rbegin(); it!=fruit.rend(); it++) {
          cout << *it << " ";
      }
```

a n a n a B

## 1.8 Operations

- string objects have a bunch of methods to perform various common operators on strings data
- the following are some commonly used operations:

### 1.8.1 clear

- clears the contents; making string object empty!

```
[3]: string strData = "Pirates of the Carribean!";
```

```
[4]: // clear the content
      strData.clear();
      cout << " strData = " << strData;
```

strData =

### 1.8.2 insert

- insert a character or string at some given index

- **insert(index, count, char)** insert count characters at some index
- **insert(index, string)** - insert some string at index

```
[5]: strData = "Pirates of the Carribean!";
```

```
[7]: // insert 1 $ at index 0
strData.insert(0, 1, '$');
```

```
[8]: cout << "strData = " << strData;
```

```
strData = $Pirates of the Carribean!
```

```
[10]: strData.insert(5, 5, '*');
```

```
[11]: cout << "strData = " << strData;
```

```
strData = $Pira*****tes of the Carribean!
```

```
[12]: strData.insert(0, "The ");
```

```
[13]: cout << "strData = " << strData;
```

```
strData = The $Pira*****tes of the Carribean!
```

### 1.8.3 erase

**erase(index, count)** - erases count characters starting from index

```
[14]: // erase all 5 asterics
strData.erase(9, 5);
```

```
[15]: strData
```

```
[15]: "The $Pirates of the Carribean!"
```

### 1.8.4 append

- the following methods append characters to the end
  - **push\_back(ch)** - appends a character to the end
  - **append(str)** - appends string to the end
  - **operator+=** - appends string to the end

```
[ ]: string some_str;
```

```
[55]: some_str = "";
```

```
[56]: some_str.push_back('1');
some_str.append("2");
some_str += "3456";
```

```
[57]: some_str
```

```
[57]: "123456"
```

### 1.8.5 replace

- replaces the part of string indicated by index with a new string
- `replace(index, count, newStr)`
  - replace some string from index to index+count by newStr

```
[58]: some_str.replace(0, 1, "A");
```

```
[59]: some_str
```

```
[59]: "A23456"
```

```
[60]: some_str.replace(1, 5, "B");
```

```
[61]: some_str
```

```
[61]: "AB"
```

```
[62]: // insert with replacing 0 character  
some_str.replace(1, 0, "WXYZ");
```

```
[63]: some_str
```

```
[63]: "AWXYZB"
```

### 1.9 sub string

- **substr(pos, count)** returns a substring from pos index to pos+count index
  - if count is not provides, returns to the end or **npos**
  - **npos** is a constant value that's the largest possible index for string objects
    - \* largest possible value for **size\_t**

```
[73]: // what is npos?  
cout << string::npos;
```

```
18446744073709551615
```

```
[64]: // return from index 1 to the end or npos  
cout << some_str.substr(1);
```

```
WXYZB
```

```
[74]: // return 4 characters starting from 1  
cout << some_str.substr(1, 4);
```



WXYZ

## 1.10 Search

- searching for a substring is often a common task performed with strings data
- also referred to as finding needle in haystack
- following methods help in finding substrings in strings:

### 1.10.1 find(str, pos)

- finds the first substring in the string starting from pos
  - if no pos is provided, first index is used
- returns position of the first character of the found substring or **npos** if no such substring is found

```
[75]: string haystack, search_str;
      size_t found;

[79]: haystack = "There are many needles or just a few needle in the haystack!";

[87]: search_str = "needle"; // change this to "Needle" and find

[88]: found = haystack.find(search_str);

[89]: cout << found;
```

15

```
[90]: // check if substring is found or not
      if (found == string::npos)
          cout << search_str << " NOT found!\n";
      else
          cout << search_str << " found at: " << found << endl;
```

needle found at: 15

### 1.10.2 rfind(str, pos)

- search the first substring in backward direction starting from pos
  - if no pos is provided, last index is used

```
[91]: found = haystack.rfind(search_str);
      // check if substring is found or not
      if (found == string::npos)
          cout << search_str << " NOT found!\n";
      else
          cout << search_str << " found at: " << found << endl;
```

needle found at: 37

## 1.11 string comparisons

- two string values can be compared using comparison operators
- operators (`==`, `!=`, `<`, `<=`, `>`, `>=`) are all overloaded to work with string types
- strings are compared character by character using ASCII value

```
[97]: string a = "apple";
```

```
[98]: string b = "ball";
```

```
[104]: string c = "Apple";
```

```
[100]: // both size and values must be equal!  
if (a == b) // every character in a must equal to corresponding character in b  
    cout << a << " equals to " << b << endl;  
else  
    cout << a << " is NOT equal to " << b << endl;
```

apple is NOT equal to ball

```
[102]: if (a <= b)  
    cout << a << " comes before " << b << endl;  
else  
    cout << a << " doesn't come before " << b << endl;
```

apple comes before ball

```
[106]: if (a <= c)  
    cout << a << " comes before " << c << endl;  
else  
    cout << a << " doesn't come before " << c << endl;
```

apple doesn't come before Apple

## 1.12 Numeric conversions

- strings can be converted into numeric values (integers or floating points) as appropriate

### 1.12.1 string to signed integers

- `stoi( )`, `stol( )`, `stoll( )` - converts a string to a signed integers

```
[107]: cout << stoi("123");
```

123

```
[117]: cout << stoi("-454532") << " " << stol("-45352343441 asdf") << " " <<   
↪stoll("552353253 adsfasf");
```

-454532 -45352343441 552353253

### 1.12.2 string to unsigned integers

`stoul( )`, `stoull( )` - converts a string to unsigned integer

```
[118]: cout << stoul("454532") << " " << stoull("-45352343441 text");
```

454532 18446744028357208175

### 1.12.3 string to floating point value

- `stof( )`, `stod( )`, `stold( )` - converts a string to floating point value

```
[119]: cout << stof("-454532") << " " << stof("-453.123 text") << " " << stof("552.34_↪adsfasf");
```

-454532 -453.123 552.34

```
[120]: // throws run-time error
cout << stof("a5235");
```

Standard Exception: `stof: no conversion`

```
[6]: cout << stod("-454532") << " " << stod("-453.123 text") << " " << stod("552.34_↪adsfasf");
```

-454532 -453.123 552.34

### 1.12.4 integral or floating point value to string

- `to_string( )` converts integral or floats to string

```
[123]: string new_str = to_string(123).append("456");
```

```
[124]: new_str
```

```
[124]: "123456"
```

```
[5]: cout << (to_string(345.44545)).append(" some text");
```

345.445450 some text

## 1.13 Dynamic string variables

- pointers can point to string types
- string pointers can be used to allocate dynamic memory in heap

```
[1]: #include <iostream>
#include <string>
```

```
using namespace std;
```

```
[2]: string full_name = "John Doe";  
string * ptr_full_name = &full_name;
```

```
[3]: // dereference ptr_full_name  
cout << full_name << " = " << *ptr_full_name;
```

John Doe = John Doe

```
[4]: // allocate dynamic memory in heap and initialize it with data  
string * ptr_var = new string("Jake Smith");
```

```
[5]: cout << *ptr_var;
```

Jake Smith

```
[6]: // assign new value to *ptr_var  
*ptr_var = "Jane Fisher";
```

### 1.13.1 String Application - Convert Decimal into Binary

- Define a function that takes an integer and returns the binary representation of the integer.
  - e.g.  $10_{10} = 1010_2$
- let's use algorithm defined in Chapter 02 and the partial code in Chapter 03:
  1. repeatedly divide the decimal number by base 2 until the quotient becomes 0
  2. collect the remainders in reverse order
    - the first remainder becomes the last bit (least significant) in binary

```
[4]: string binary(int decimal) {  
    // decimal to binary conversion requires to calculate both quotient and  
    ↪ remainder  
    const int divisor = 2; // divisor is constant name whose value can't be  
    ↪ changed once initialized with  
    int dividend;  
    int quotient, remain;  
    string answer = ""; // collect remainders by prepending as a string  
    quotient = decimal;  
  
    while(quotient != 0) {  
        dividend = quotient;  
        remain = dividend%divisor;  
        quotient = dividend/divisor;  
        // print intermediate results; help us see and plan further computation  
        //cout << dividend << '/' << divisor << " => quotient: " << quotient <<  
        ↪ " remainder: " << remain << endl;
```

```

        answer = to_string(remain) + answer; // prepend remainder to answer
    }
    if (answer == "")
        return "0";
    return answer;
}

```

```
[5]: cout << "10 in binary = " << binary(10) << endl;
```

10 in binary = 1010

### 1.13.2 Convert Binary into Decimal

- algorithm steps as provided in Chapter 02:
  1. multiply each binary digit by its place value in binary
  2. sum all the products
- Define a function that takes a binary number provided in string and converts into decimal representation
  - E.g.  $1010_2 = 10_{10}$

```
[12]: #include <cmath>
#include <iostream>
#include <string>

using namespace std;
```

```
[15]: unsigned int decimal(string binary) {
    int answer = 0;
    int digitCount = binary.size();
    for(int i=0; i<digitCount; i++) {
        if (binary[i] == '0') continue;
        int placeValue = digitCount-i-1;
        answer += pow(2.0, placeValue);
    }
    return answer;
}
```

```
[16]: cout << "1010 binary in decimal = " << decimal("1010") << endl;
```

1010 binary in decimal = 10

### 1.14 Exercises

1. Write a function that checks if the string has at least one digit (0-9) in it.
  - Write 3 automated test cases

```
[8]: // Exercise 1 Sample Solution
#include <iostream>
```

```
#include <string>
#include <cstring>
#include <cassert>

using namespace std;
```

```
[9]: bool hasDigit(string text) {
    for(char ch: text) {
        if (isdigit(ch)) return true;
    }
    return false;
}
```

```
[10]: // test hasDigit
void test_hasDigit() {
    assert(hasDigit("some text with digit!") == true);
    assert(hasDigit("this text has no digit") == false);
    assert(hasDigit("24242") == true);
    cerr << "all test cases passed for hasDigit()\n";
}
```

```
[11]: test_hasDigit();
```

all test cases passed for hasDigit()

2. Convert Exercise 1 into a complete program
  - prompt user to enter string
  - make program continue to run until the user wants to quit
3. Write a function that checks if a given string is a palindrome. Palindromes are words and phrases that read the same backward as forward such as **madam**, **race car**, etc.
  - more on Palindromes: <https://en.wikipedia.org/wiki/Palindrome>
  - it's okay if the function works for word only; but not phrases
  - ignore cases (i.e., A equals a)
  - write at least 3 automated test cases

```
[1]: // Sample solution for exercise #3
#include <iostream>
#include <string>
#include <cstring>
#include <cassert>

using namespace std;
```

```
[2]: /*
    palindromic texts: A, AA, ABA, ABBA

    Algorithm steps:
    1. for each character up to the middle one in a given phrase
```

```

    ii. compare the corresponding characters from left and right of the phrase
        a. do a case insensitive comparison
    iii. if a single pair is not equal, the phrase is NOT reversible
    iv. if all the pairs match, the word is reversible
*/

bool isPalindrome(string word) {
    int left_index = 0; // index from the beginning of the word
    int right_index = word.length()-1; // index from the end of the word
    int mid = word.length()/2; // mid index to stop the comparison
    bool mismatched = false;
    while(left_index < mid && !mismatched) { // stop before the mid index or
    ↪ any pair mismatched
        // convert to lowercase to make case insensitive comparison
        char left_char = tolower(word[left_index]);
        char right_char = tolower(word[right_index]);
        // if no match, set the mismatched flag to true;
        if (left_char != right_char) mismatched = true;
        // if they match, move the indices to point the next pair
        left_index++;
        right_index--;
    }
    // if mismatched return false; else all pairs must have matched, return true
    return mismatched? false : true;
}

```

```

[3]: void test_isPalindrome() {
    assert(isPalindrome("") == true); // empty string is a plindrome!?!?
    assert(isPalindrome("A") == true);
    assert(isPalindrome("AB") == false);
    assert(isPalindrome("ABA") == true);
    assert(isPalindrome("ABBA") == true);
    assert(isPalindrome("racecar") == true);
    assert(isPalindrome("race car") == false);
    cerr << "all test cases passed for isPalindrome()\n";
}

```

```

[4]: test_isPalindrome();

```

all test cases passed for isPalindrome()

4. Convert Exercise 3 into a complete program.
  - program prompts user to enter a string
  - determines and lets the user know if the string is a palindrome or not
  - program continues to run until the user wants to quit
5. Improve Exercise 4 to ignore punctuations including spaces!
  - if you named the improved isPalindrome function as isPalaindromeV1,
    - the following test cases must pass!

```
[ ]: /*
palindromic texts: A, AA, ABA, ABBA, "race car"

Algorithm steps:
1. for each character up to the middle one in a given phrase
    i. ignore all the non-alphabetic characters on both ends of the phrase
    ii. compare the corresponding characters from left and right of the phrase
    iii. if a single pair is not equal, the phrase is NOT reversible
    iv. if all the pairs match, the word is reversible
*/
bool isPalindromeV1() {
    // FIXME using the above algorithm
    return true;
}
```

```
[ ]: void test_isPalindromeV1() {
    assert(isPalindromeV1("") == true); // empty string is a plindrome!?!?
    assert(isPalindromeV1("A") == true);
    assert(isPalindromeV1("AB") == false);
    assert(isPalindromeV1("ABA") == true);
    assert(isPalindromeV1("ABBA") == true);
    assert(isPalindromeV1("racecar") == true);
    assert(isPalindromeV1("race car") == true); // ignore white spaces...
    cerr << "all test cases passed for isPalindromeV1()\n";
}
```

6. Write a program that counts the number of vowels (a, e, i, o, u) and consonants (alphabets except vowels) in a given text.
  - program prompts user to enter the text
  - program should account for both upper and lower case alphabets
  - program should continue to run until the user wants to quit
7. Write a program that checks the strength of the given password.
  - use a scoring system based on the varieties of character type present as described below:
  - 1 point if it contains at least 1 lowercase
  - 1 point if it contains at least 1 uppercase
  - 1 point if it contains at least 1 digit
  - 1 point if it contains at least 1 symbol from the group (~!@#\$%^&\*()\_-=+={})
  - 1 point if the length of the password is 8 characters or long
  - interpretation of total points (max 5):
  - if points is 5 or more - Excellent
  - if points is 3 or more - Good
  - if points is 2 or less - Bad

### 1.15 Kattis problems

- there are a lot of Kattis problems on text/string manipulation
- some simple problems are listed below
- solve each problem using function(s) so that you can write at least 3 test cases for each



function used as part of the solution

1. Hissing Microphone - <https://open.kattis.com/problems/hissingmicrophone>
2. Avion - <https://open.kattis.com/problems/avion>
3. Apaxiaaaaans! - <https://open.kattis.com/problems/apaxiaaans>
4. Alphabet Spam - <https://open.kattis.com/problems/alphabetspam>
5. Simon Says - <https://open.kattis.com/problems/simonsays>
6. Simon Says - <https://open.kattis.com/problems/simon>
7. Fifty Shades of Pint - <https://open.kattis.com/problems/fiftyshades>
8. Quick Brown Fox - <https://open.kattis.com/problems/quickbrownfox>
9. Encoded Message - <https://open.kattis.com/problems/encodedmessage>
10. Trik - <https://open.kattis.com/problems/trik>
11. Digit Product - <https://open.kattis.com/problems/sifferprodukt>

## 1.16 Summary

- this chapter covered C++ string type
- declare and use string type
- various operations and member functions or methods provided to string objects
- exercises and sample solutions

[ ]: