Advanced Object Oriented Programming

Strings

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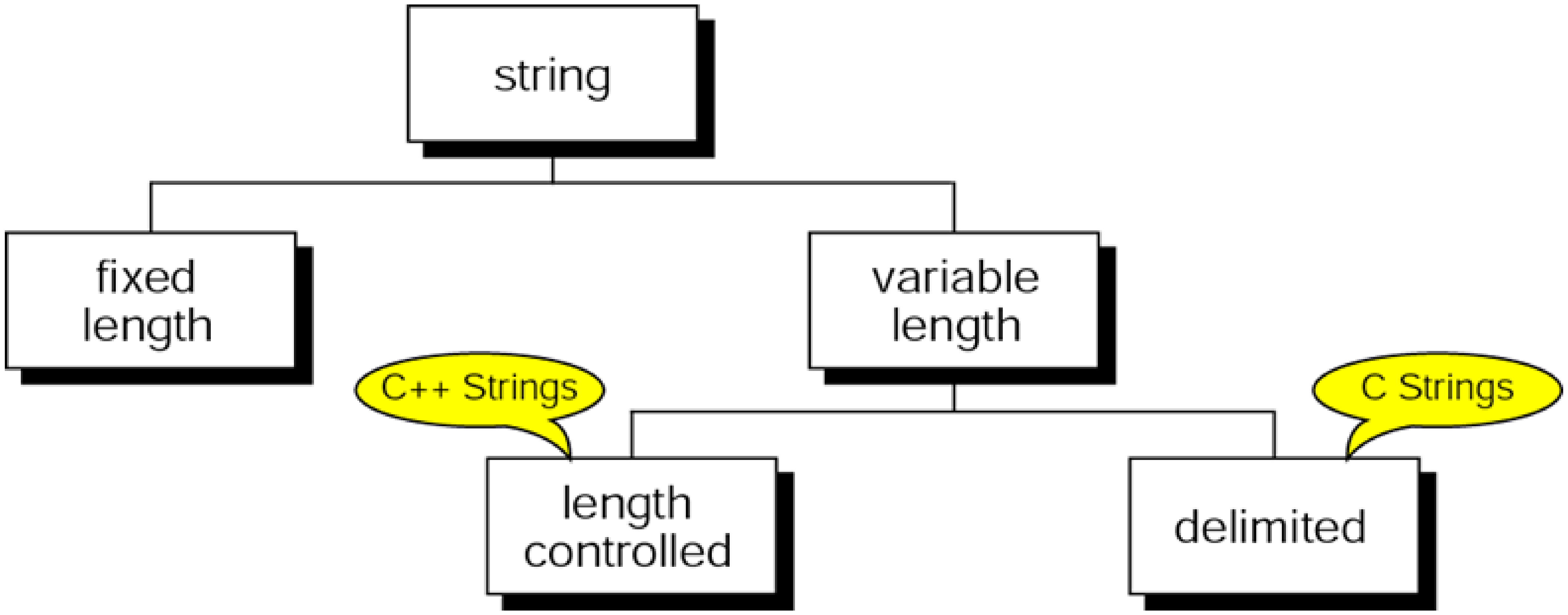
String

- A String is a series of characters treated as a unit
- Examples:
  - “Dog”, “Steve Jobs”, “세종대왕”

String taxonomy



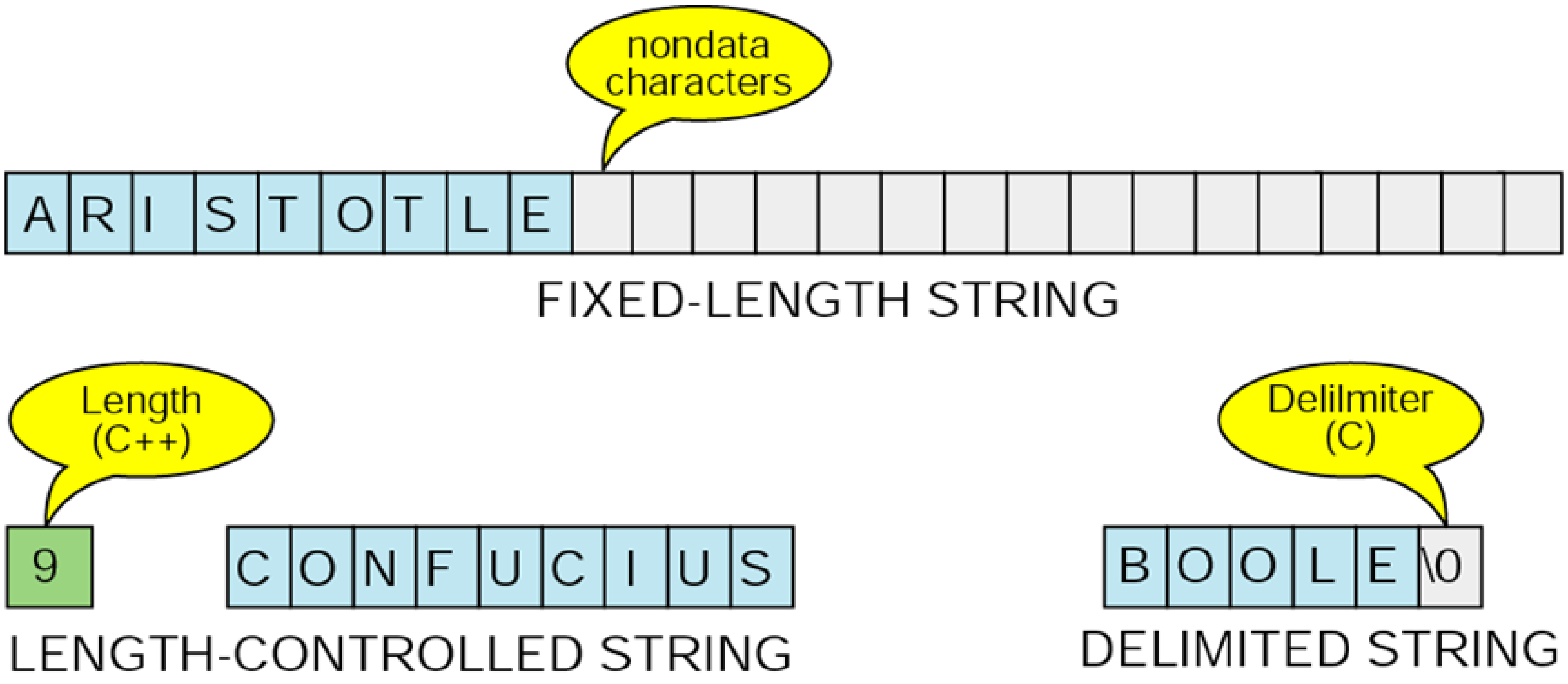
Fixed-length strings

- A fixed-length string is implemented as an array of characters
- We must first decide what size to make the variable
- Problem: how to tell the data from the nondata

Variable-length strings

- Create a structure that can expand and contract to accommodate the data
- Length-Controlled Strings
  - Add a count that specifies the number of characters in the string
  - The amount of bytes used for the count determines the max length of possible strings
- Delimited Strings
  - Add a delimiter to identify the end of the string
  - It eliminates one character from being used for data

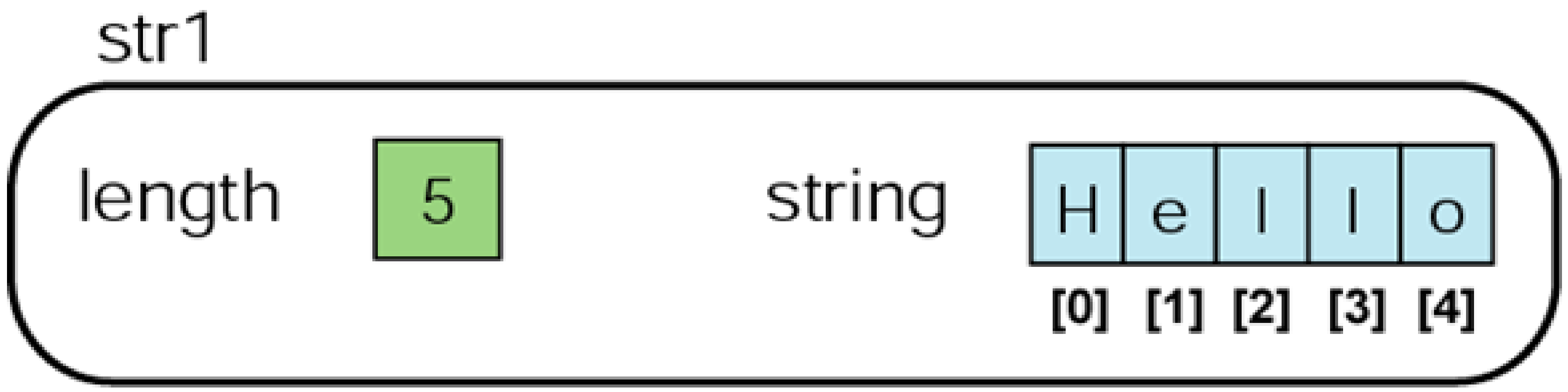
String formats



C++ String (It’s a Class)

- A C++ string is a sequence of characters implemented as a length-controlled string object (an instantiation of the string class)
- The C++ name for the string class is basic_string
- Within the basic string class is a type definition for the type string, which equates the two

C++ string (It’s a Class)



String constructors

Constructor format	Operation
string s1;	Default constructor (empty string)
string s2(“Hello World”);	Initialization constructor using C string
string s3(num,’c’);	Initialization constructor using *num* identical characters
string s4(s2);	Copy constructor
string s5(s2, num);	Copy constructor that copies *num* characters from beginning of string
string s6(s2, start, num);	Copy constructor that copies *num* characters from index location *start* in s2
string s7(“Hello”, num);	Initialization constructor using the first *num* characters of the C string
string s8(“Hello”, start, num);	Same as s6, but with C string

C++ String Input/Output

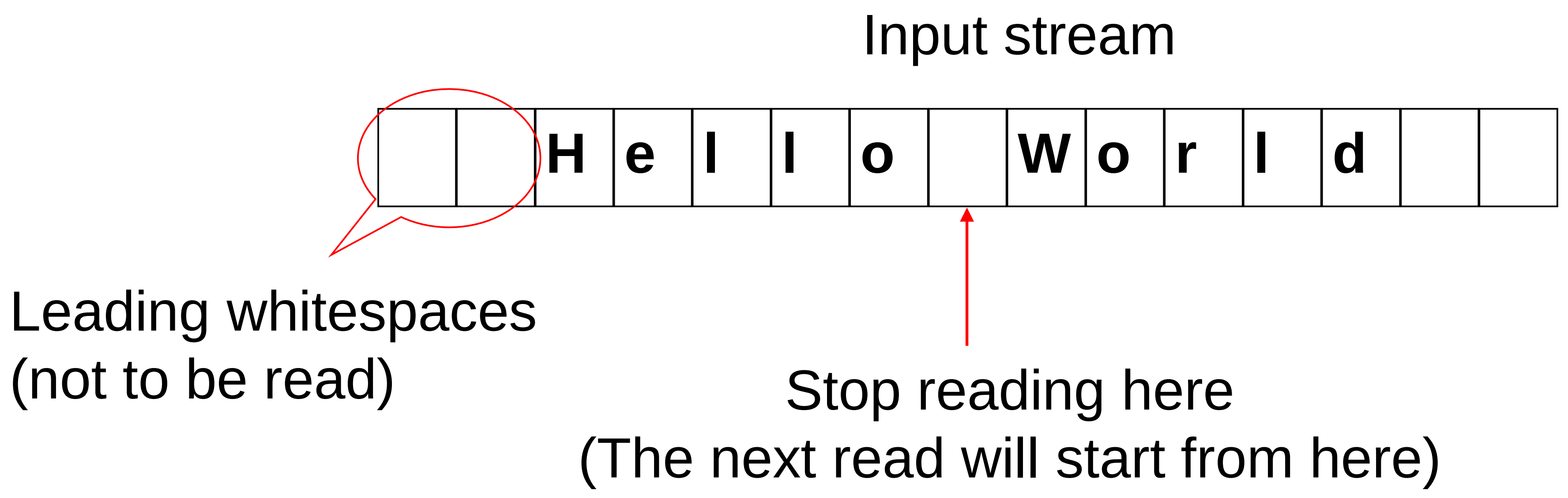
- The string class is overloaded for the insertion and extraction operators
  - We can read a string just like any other variables

- String output (<<)
  - E.g., `cout << month;` or `fsOut << month;`

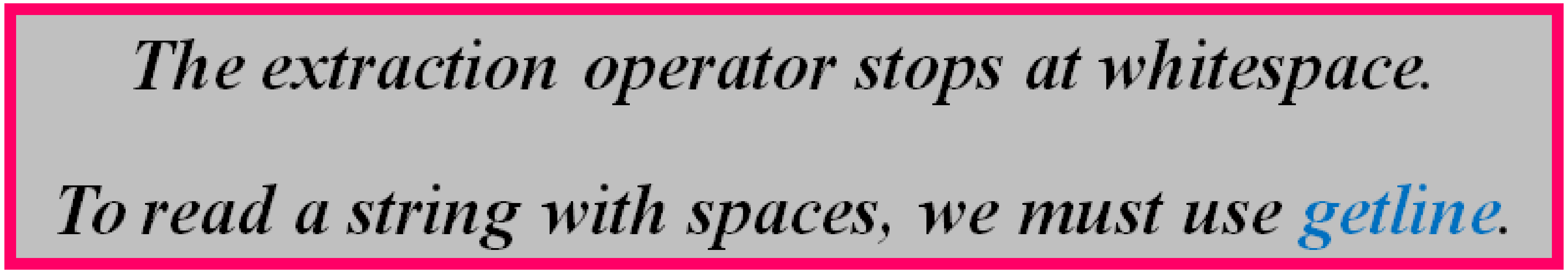
- String input (>>)
  - E.g., `cout >> month;` or `fsIn >> month;`

String extraction operator as a ‘cin >>’

- Skips any leading whitespace
- Extracts all contiguous non-whitespace characters
- Stops at any whitespace character
- The terminating whitespace character is left in the input stream
- Example:



String extraction operator as a ‘cin >>’



The extraction operator stops at whitespace.

To read a string with spaces, we must use getline.

‘getline’ function

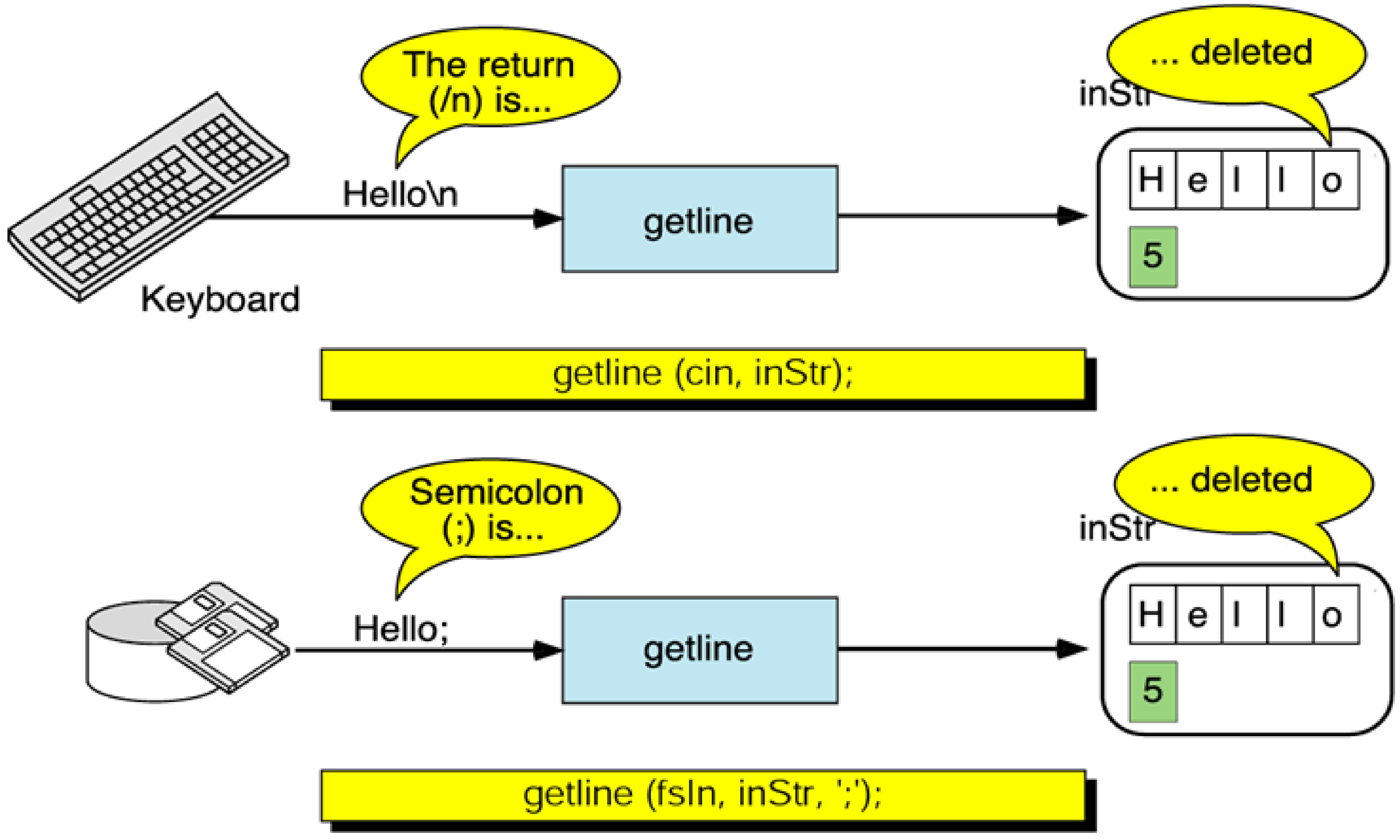
- All characters, including whitespace, are read into the string until the terminating character is found
- The terminating character, usually a new line, is deleted (extracted and discarded)
- The getline function is a stand-alone function (not a class member)

Overloaded functions

getline(stream, StringName); // Delimiter : ‘\n’

getline(stream, StringName, Delimiter);

‘getline’ function



Program 14-2 Demonstrate *getline* operation

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

int main ()
{
   cout << "Enter a name in the form <last,first>: \n";
   string  lastName;
   getline (cin, lastName, ',');
   string  firstName;
   getline (cin, firstName);

   cout << "Here is your name:\n\t|"
        << firstName << ' '
         << lastName << "|\n";
   return 0;
}  // main
```

The string input /output operators and functions are defined in the string header file, not the I/O stream header file.

```
/*        Results:
Enter a name in the form <last,first>:
Washington,George
Here is your name:
   |George Washington|

User Error: spaces after comma
Enter a name in the form <last,first>:
Washington,   George
Here is your name:
   |   George Washington|
*/
```

Assignment operator

- Overloaded for three source types:
  - The value of a C++ string
  - The value of a C string
  - A single character

Program 14-3 Demonstrate string assignment

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

int main ()
{
    string str1 ("String 1");
    string str2;
    string str3;
    string str4;
    string str5 = "String 5";

    cout << "String 1: " << str1 << endl;
    str2 = str1;
    cout << "String 2: " << str2 << endl;
    str3 = "Hello";
    cout << "String 3: " << str3 << endl;
    str4 = 'A';
    cout << "String 4: " << str4 << endl;
    cout << "String 5: " << str5 << endl;
    return 0;
}   // main
```

```
/*      Results:
String 1: String 1
String 2: String 1
String 3: Hello
String 4: A
String 5: String 5
*/
```

Assignment vs. Copy Constructor

- String s1 = ”Hello”; // correct
- String s2 = ’a’; // error
  - Compare with String s2 = ’a’, which is correct

Example: Array of Strings

- Of course, strings can be used in an array

```
int main ()
{
        string daysAry[7];  // declaration of an array of strings

        daysAry[0] = "Sunday";
        daysAry[1] = "Monday";
        daysAry[2] = "Tuesday";
        daysAry[3] = "Wednesday";
        daysAry[4] = "Thursday";
        daysAry[5] = "Friday";
        daysAry[6] = "Saturday";

        cout << "\nThe days of the week\n";
        for (int daysIndex = 0; daysIndex < 7; daysIndex++)
          cout << daysAry[daysIndex] << endl;
        return 0;
} // main
```

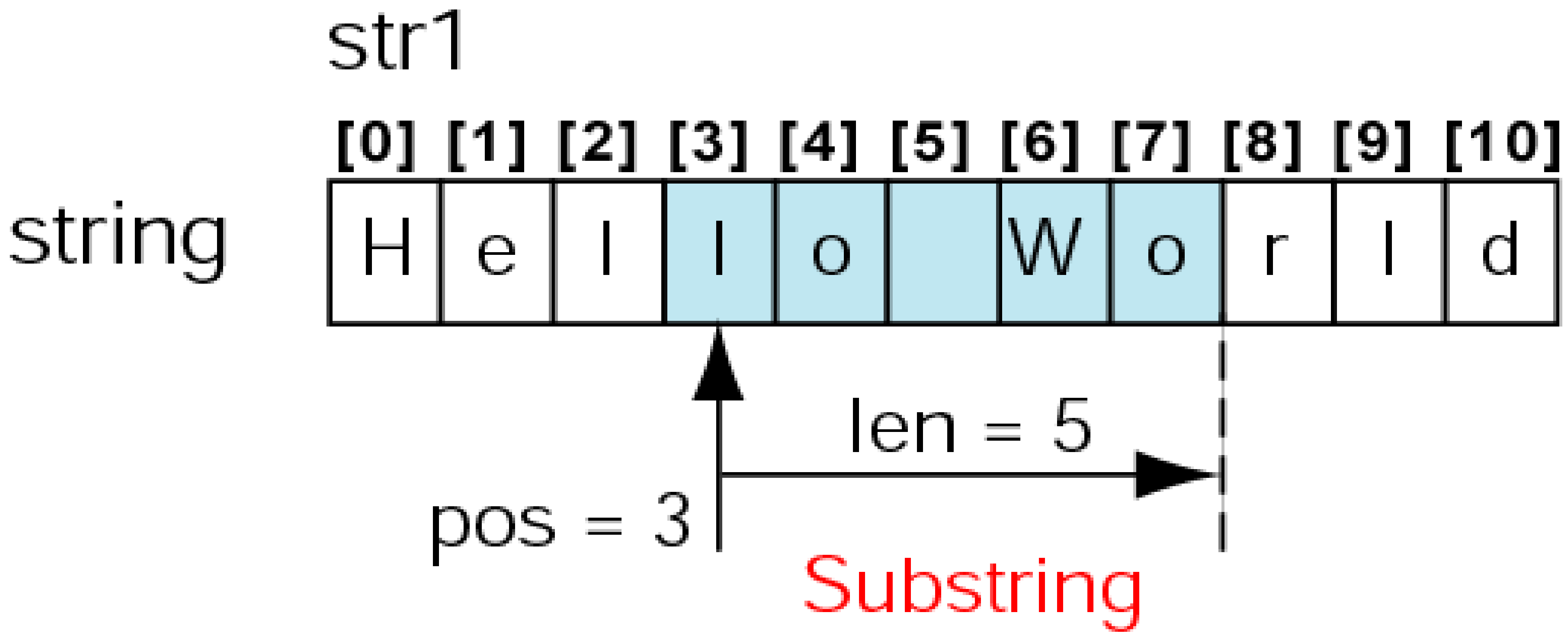
```
/*      Results

The days of the week
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
*/
```

String Manipulation Function

- A rich set of methods that can be used to manipulate strings
- Make it easier for us to write programs

Substring

- A contiguous set of characters within a string
- Identfied by ***a start position and a length***



Extracting a Substring

- Creates a new string by extracting part of a string

  str1.substr(starting_pos, len)

  - str1.substr(starting_pos): length defaults to *string::npos*, a constant defining the maximum length

String Length (*length* and *size*)

- Returns the length of a string, which is defined as the number of characters in the string

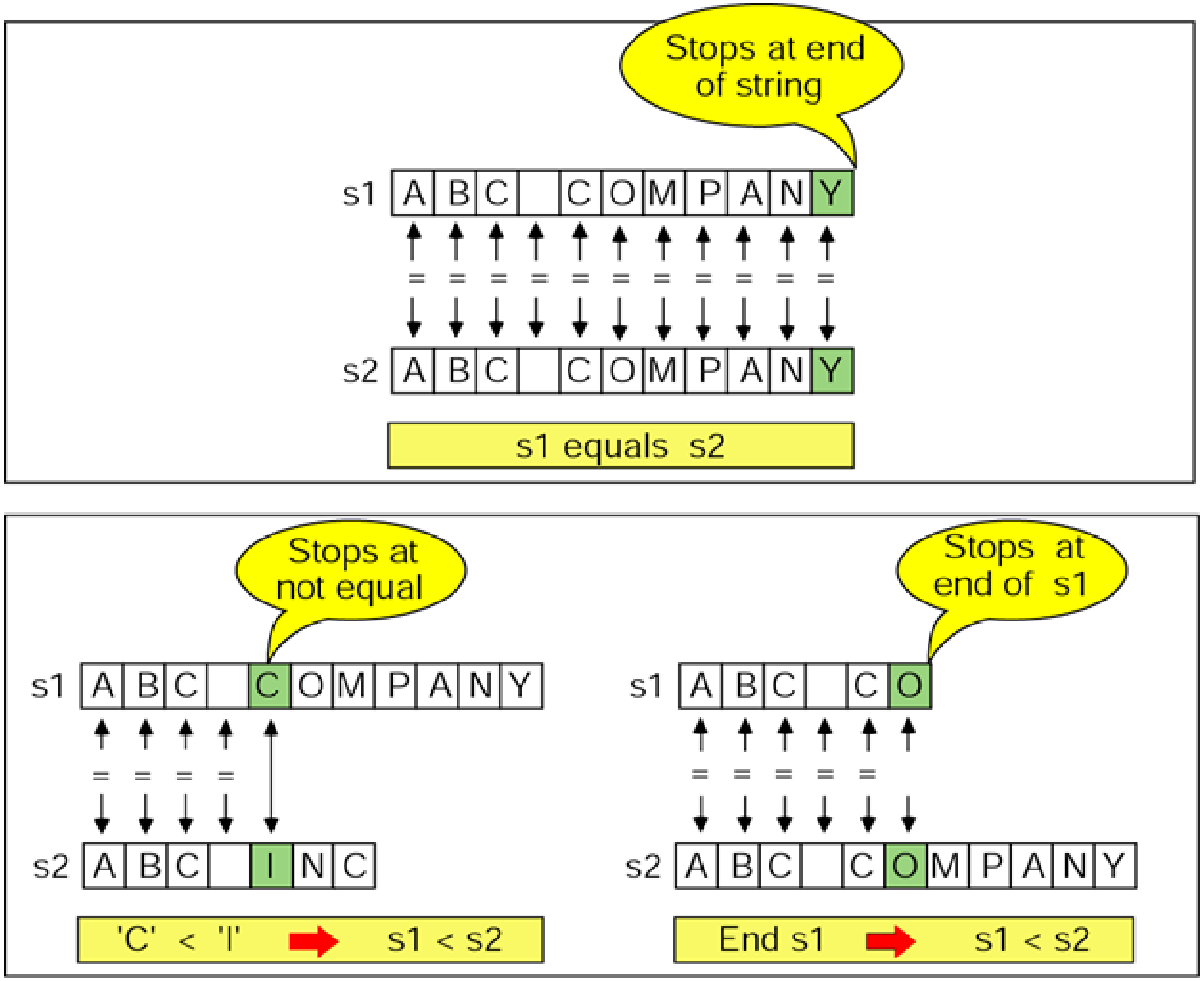
```
len = str1.length();
len = str1.size();
```

String Compare

- Two alternatives
  - compare operators: used for a boolean result
  - compare method: used for a ternary answer (less than, equal, or greater-than)

- The comparison can be between two string objects or between a string object and a C string

String compare concept



String Relational Operators

- All of the relational operators are overloaded for the string class
- Return a boolean value–*true* or *false*

```
str1 == str2     str1 <  str2        str1 >   str2
str1  != str2     str1 <= str2  str1 >= str2
```

(Either str1 or str2, but not both, can be a C string)

- Usually used in a *while* or *if* statement

String Compare Method

- Results are a negative number (less than), 0 (equal), or a positive number (greater than)
- Basic formats

```
str1.compare(str2);
str1.compare(pos1, len1, str2);
str1.compare(pos1, len1, str2, pos2, len2)
```

(str1 must be a C++ string while str2 can be a C string)

- Usually used for searching or sorting

Concatenating and Appending

- Places the contents of one string at the end of another
- Concatenation
  - uses the plus(+) operator
  - The result must be placed in another string object

```
str3 = str1 + str2;
```

  - str1 & str2 remains unchanged
- Append
  - when using the overloaded plus-assign operator

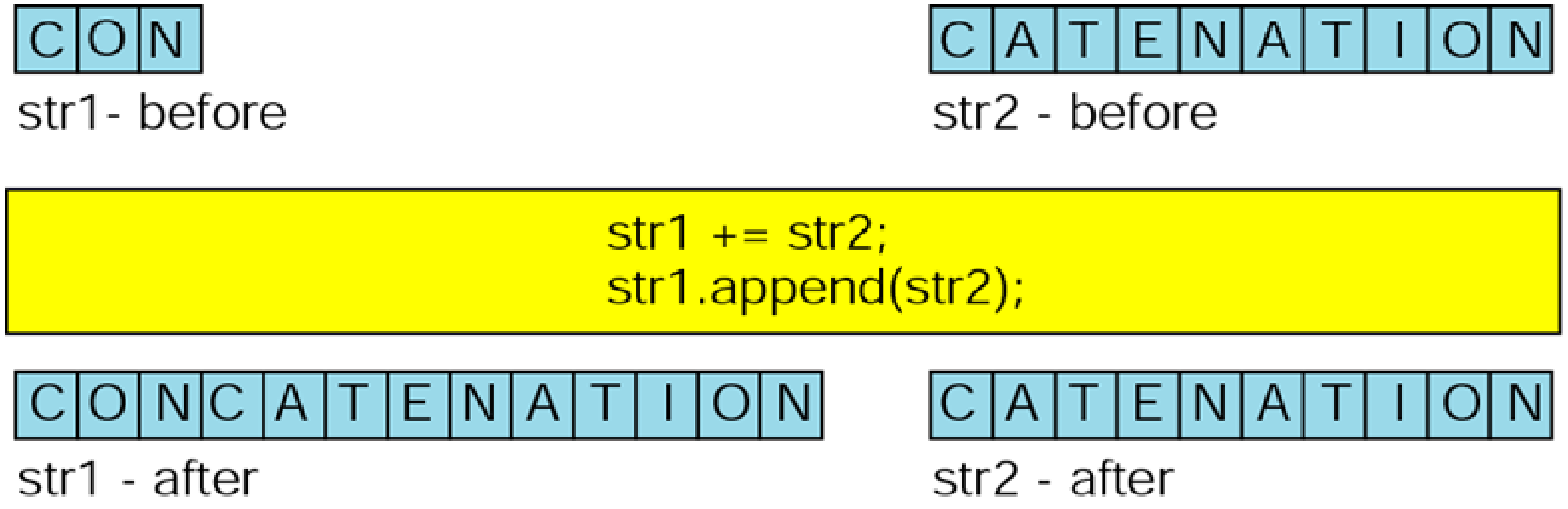
```
str1 += str2;
```

  - when using the *append* method in the string class

```
str1.append(str2);
str1.append(str2, pos2, len2);
```

  - str1 contains the result while str2 remains unchanged

String append concept



```
str1 += str2;
str1.append(str2);
```

Substring Searching Forward: *find*

- Searches for a substring anywhere in a string

  ```
  where = str1.find (str2);          // from the beginning
  where = str1.find (str2, pos1);    // starting at pos1
  ```

- Returns the *index location* within the string for the substring it located; *string::npos* if not found
- Examples
  - to locate the first occurrence where = str.find(“ten”);
  - to determine if the find was successful

    ```
    if (where != string::npos) // test for success
        // Found processing
    else
        // Not found processing
    ```

  - To find the next occurrence where = str.find(“ten”, where+1);

Substring Searching Backward: *rfind*

- Search for a substring starting at the end of a string and searching toward the beginning of the string

```
where = str1.rfind (str2, pos1);
```

Character Search Forward

- Find first matching character

  whereFwd = str1.find_first_of (str2, pos1);

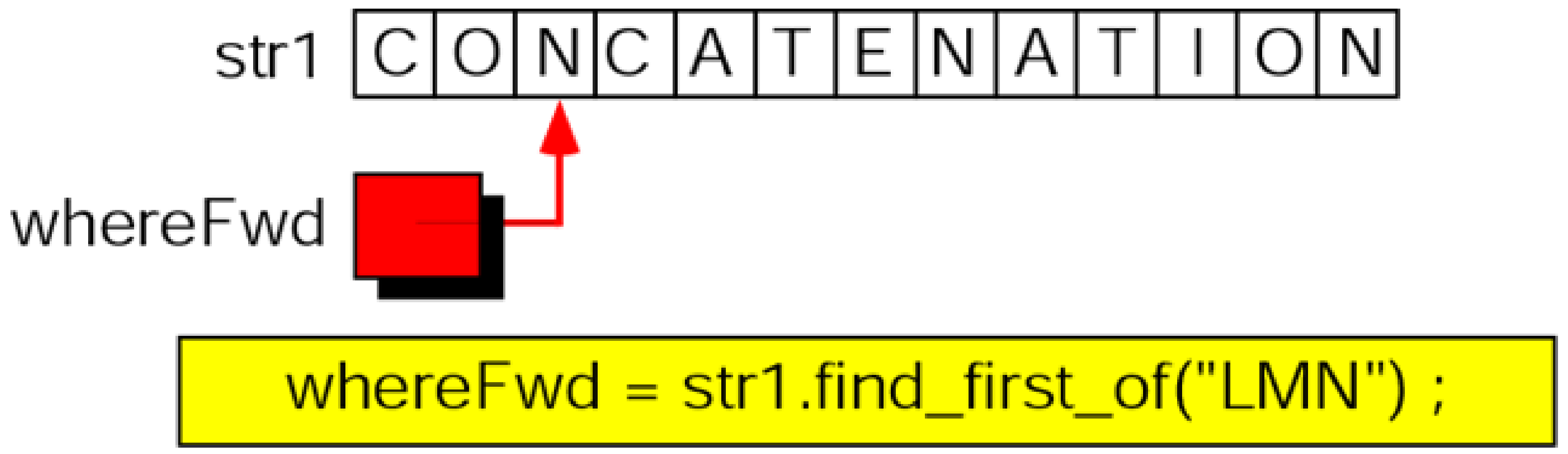
  - Search for the first character in the string that matches any of the characters in the input set (str2)
  - Returns the *position of the matching character*; if no matching characters are found, it returns *string::npos*

- Find first nonmatching character

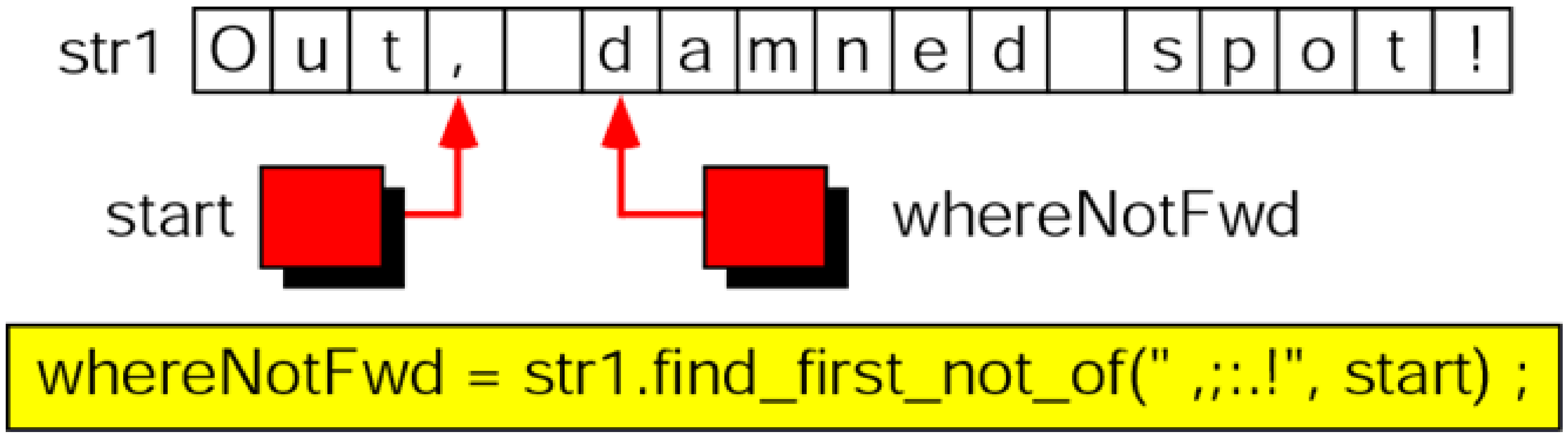
  whereNotFwd = str1.find_first_not_of (str2, pos1);

  - find the first character that does not match the input set

Find matched character in the string (forward direction)


str1
C O N C A T E N A T I O N
whereFwd
whereFwd = str1.find_first_of("LMN") ;

Find non-matched character in the string (forward direction)



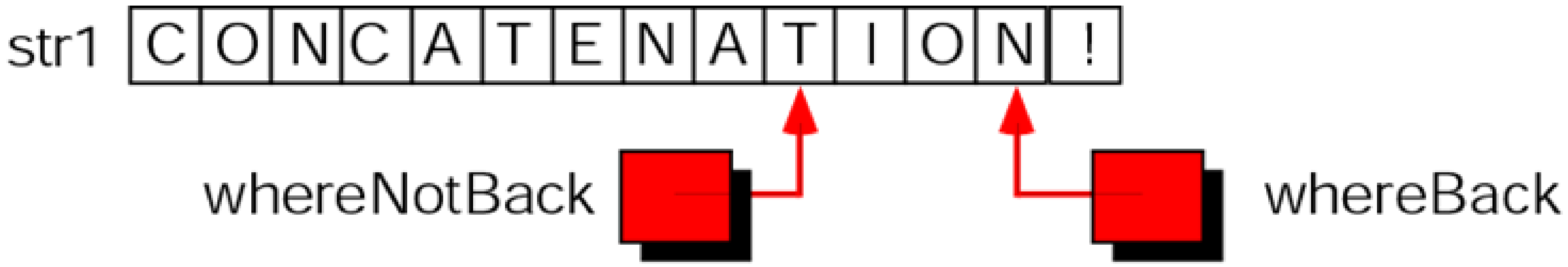
```
whereNotFwd = str1.find_first_not_of(" ,;:.!", start) ;
```

Character Search Backwards

- Search for a character in a string starting at the end of the target string
- Search toward the beginning of the string stopping at
  - the first matching character for a *find last* or
  - the first nonmatching character for a *not-find last*

```
whereBack = str1.find_last_of (str2, pos1);

whereNotBack = str1.find_last_not_of (str2, pos1);
```

Find matched and non-matched character in the string (reverse direction)



```
whereBack      =  str1.find_last_of("CION") ;
whereNotBack =  str1.find_last_not_of("CION") ;
```

Access and Modify Characters

- The ***at*** method can be used to access a character in a string
  - The *at* function tests for an invalid index and may abort the program if it is out of range

```
oneChar = str.at (where);
```

- The ***index*** location (***brackets***) can be used to access and modify a character in a string
  - Bracket access does not check for a out-of-range error

```
oneChar = str[where];
```

String Insertion

- Insert a character, a character a specified number of times, a string, or a substring at a specified position in a string object

```
str1.insert (pos1, str2);
str1.insert (pos1, str2, pos2, len2);
str1.insert (pos1, char);
str1.insert (pos1, numchar, char);
```

- str2 can be a string object or a C string

Replace String

- Replace all or part of a string with another string

```
str1.replace (pos1, len1, str2);
str1.replace (pos1, len1, str2, pos2, len2);
```

- The replacement string value can be a string object or a C string

- While the replace method can be used to replace the entire string, the assignment is faster

Erase String

- The *erase* method can be used to erase the entire string or to erase from a specific index position

```
        str.erase (pos, num);
```

- The *clear* method erases the entire contents of the string

```
        str.clear ();
```

Swap String

- Swap two string objects

  ```
  swap (str1, str2);
  ```

- Notice it is a standalone function (not a class member)

Convert to C String

- Converts a C++ string object to a C string
- Returns a character pointer constant

```
string str(“Hello”);
char* cString = str.c_str();
```

C String

- A variable-length array of characters that is delimited by the null character ('\0')
- Described in C string header file <cstring>

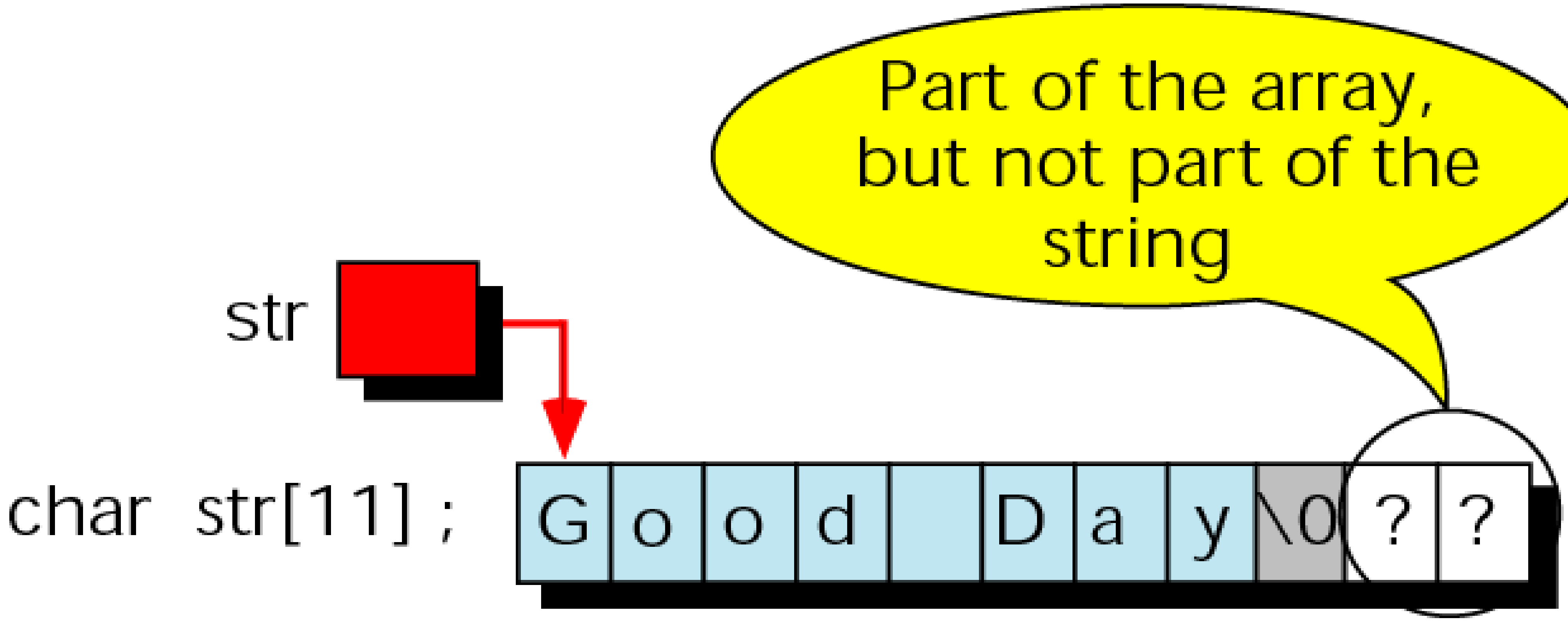
C string

H	**e**	**l**	**l**	**o**		**W**	**o**	**r**	**l**	**d**	**\0**

Storing C Strings

- Must provide enough room for the maximum-length string that will be stored *plus one for the delimiter*
- An array may have the null character in the middle when the stored string is less than the array size
  - The part of the array from the beginning to the null character is considered as the string

Strings in Arrays



Initializing Strings: Two Alternatives

Using an array of characters

- Define the string as an array of characters and assigns a value to it

```
char str[11] = “Good Day”;
```

  - Creates an 11-byte array and fills the first 9 positions with the string value and a delimiter

Using a character pointer

- Define the string as a character pointer and assigns a value to it

```
char* str = “Good Day”;
```

  - A constant string is created that consumes the minimum memory space needed to hold the string

Review: Lvalue and Rvalue

- Every C++ expression has a value, but the value in an expression (after evaluation) can be used in two different ways: lvalue and rvalue
- An **lvalue** expression can be used to access, modify, examine, or copy its data

```
a = …            a[5] = …
(a) = …          *p = …
```

- An **rvalue** expression can be used only to supply a value for an expression

```
5                a+2            a*6
a[2]+3           a++
```

- Some operators need an lvalue as their operand
  - E.g., the left operand of the assignment operator

Strings and the Assignment Operator

- The name of the string is a pointer constant
- As a pointer constant, it is an rvalue and therefore cannot be used as the left operand of the assignment operator

```
char str1[11] = “Hello”;
char str2[11];
str2 = str1;            // Compile error
str1 = “Hello”;         // Compile error
```

Copy C strings

We cannot use the assignment operator to copy C strings.
We must use the strcpy function.

Reading C Strings: Extraction Operator

- Simple and natural way for reading strings

```
char month[10];
cin >> month;    or    fsIn >> month;
```

- The extraction operator does not read whitespace (similar to reading C++ string)
  - It skips any leading whitespace
  - Once it finds a character, it reads until it finds whitespace, putting each character in the array in order
  - When it finds a white space character, it stores the string with a null delimiter character
  - The whitespace character is left in the input stream

Protect against entering too much data

Always use set width when reading C strings.

- If the array is not large enough to store all the input data, then whatever follows the array in memory will be destroyed
- Set the width with the set-width manipulator

```
char month[10];
cin >> setw(10) >> month;
```

Reading C Strings: getline()

- Extracts text (including whitespaces) from an input stream and makes a null-terminated string out of it
- Three parameters
  - 1st: the string area into which the string is to be read
  - 2nd: the maximum number of characters that are to be transferred, including the generated string delimiter character (use the sizeof operator)
  - 3rd: an optional terminating character
- Examples

```
cin.getline (inArea, sizeof(inArea));     // stop at \n
fsIn.getline (inArea, sizeof(inArea), ';'); // stop at ;
```

Writing C Strings: Insertion Operator

- String output is provided by the insertion operator (<<)

  cout << month;   or   fsOut << month;

- The width option sets the *minimum* print area for the string in the output
- The justification option specifies the orientation of data in a field
  - left-justified vs. right-justified

```
cout << "*" << "Hi there!" << "*" << endl;
cout << "*" << setw(20) << "Hi there!" << "*" << endl;
cout << right;
cout << "*" << setw(20) << "Hi there!" << "*" << endl;
```

```
/*   Results:
*Hi there!*
*Hi there!           *
*           Hi there!*
*/
```

String Function Library

- A rich set of string functions are in the C string library (<cstring>)

  - String length (strlen)
  - String copy (strcpy, strncpy)
  - String compare (strcmp, strncmp)
  - String concatenate (strcat, strncat)
  - Search for a character (strchr, strrchr)
  - Search for a substring (strstr)
  - Search for characters in a string (strspn, strcspn)

String Length (*strlen*)

- Returns the length of a string, specified as the number of characters in the string excluding the null character

```
length = strlen (str1);
length = strlen (“Hello World”);
```

String Copy

- ***strcpy*** copies the contents of one string to another string

  strcpy (toStr, fromStr);

  - toStr: a pointer to the array that is to receive the string
  - fromStr: the string being copied

- ***strncpy*** (string number copy) contains a size parameter that specifies the *maximum* number of characters than can be moved at a time

  strncpy (toStr, fromStr, size);

  - If the sending string is longer than size, the destination variable will not have a delimiter

- Both functions return the new string’s address, which may be stored or discarded

Example: String Copy

- Make the destination valid after strncpy

```
strncpy (s1, s2, sizeof(s1) – 1);
*(s1 + (sizeof(s1) – 1)) = ‘□0’;
```

String Compare

- ***strcmp*** compares two strings until unequal characters are found or until the end of the string is reached

  result = strcmp (str1, str2);

- ***strncmp*** compares until unequal characters are found, a specified number of characters have been tested, or until the end of a string is reached

  result = strncmp (str1, str2, size);

- Result
  - 0 if two strings are equal
  - a negative number if str1 is less than str2
  - a positive number if str2 is greater than str2

Examples: String Compare

- Example 1

```
if (strcmp(str1, str2) == 0)
    // strings are equal
else
    // strings are not equal
```

- Example 2

```
if (strcmp(string1, string2) < 0)
    // string1 is less than string2
```

- Example 3

```
if (strcmp(string1, string2) > 0)
    // string1 is greater than string2
```

- Example 4

```
if (strcmp(string1, string2) >= 0)
    // string1 is greater than or equal to string2
```

String Concatenation

- Append one string to the end of a second string
- Return the address pointer to the destination string
- The size of the destination string array is assumed to be large enough to hold the resulting string

$$\overset{\text{destination}}{\uparrow}$$

```
strcat (str1, str2);
```

str2 is copied to the end of str1

```
strncat (str1, str2, size);
```

$$\downarrow$$

maximum number of characters to be copied

Examples: String Concatenation

- Example 1

  char str1[20] = “Hello”;
  strcat (str1, “World”); ➔ str1: “HelloWorld”
- Example 2

  char str1[20] = “Hello”;
  char str2[20] = “World”;
  strcat (str1, str2); ➔ str1: “HelloWorld”, str2 remains unchanged
- Example 3

  char str1[8] = “Hello”;
  strcat (str1, “World”); ➔ str1 is destroyed because of lack of space
- Example 4

  char str1[8] = “Hello”;
  strncat (str1, “World”, 2); ➔ str1 becomes “HelloWo”

Searching for Characters

- String character (*strchr*)

  `newStrPtr = strchr (str, ch);`

  - Searches for the first occurrence of a character from the beginning of a string

- String rear character (*strrchr*)

  `newStrPtr = strrchr  (str, ch);`

  - Searches for the first occurrence beginning at the end and working toward the beginning

- They return a pointer to it. (a null pointer if not found)

Searching for a Substring

- Locates a substring in a string
- Returns a pointer to the beginning of the substring in the string

```
newStrPtr = strstr (str, subStr);
```

- There is no function to locate a substring starting at the rear

Searching for Characters in a String

- Locate one of a set of characters in a string
- String span *strspn*

```
numChars = strspn (str1, charSet);
```

  - Searches the string, spanning characters that are in the set
  - Stop at the first character that is not in the set
  - Returns the number of characters that matched those in the set

- String complement span *strcspn*
  - Stop at the first character that matches one of the characters in the set

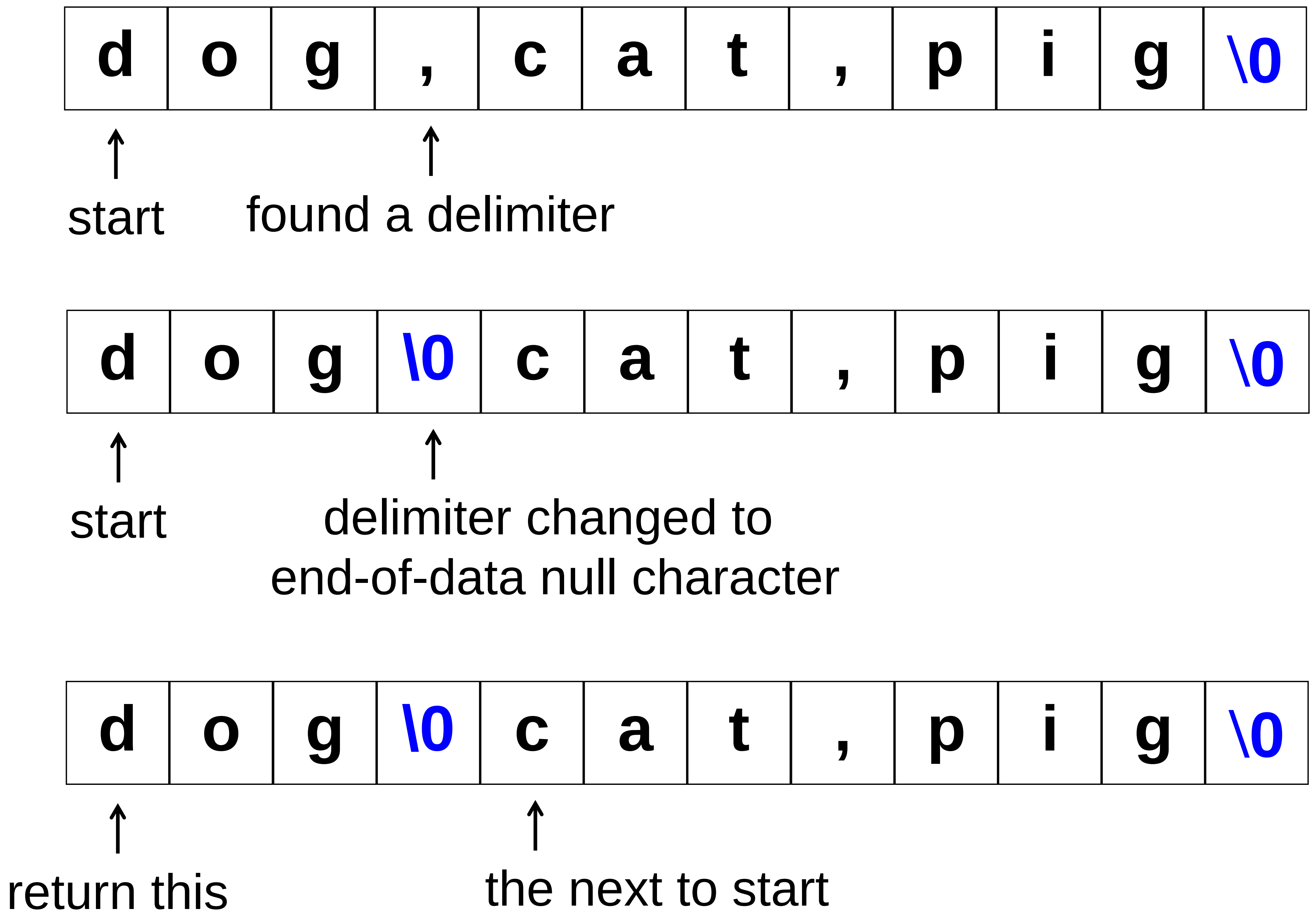
Searching for Tokens (*strtok*)

- Locate substrings, called *tokens*, in a string
  - token: a sequence of characters separated by *delimiters*

charPtr = strtok (str1, delimiters);

- Returns the pointer to the first token overwriting the delimiter followed by a null character
  - NULL is returned when there are no more tokens to be found.
- Use successive calls to *strtok()*, to extract all the tokens
  - When called with NULL as the first parameter, it will follow by where the last call to strtok found a delimiter.
  - *delimiters* may vary from a call to another.

Example: Searching for Tokens


d o g , c a t , p i g \0
start
found a delimiter
d o g \0 c a t , p i g \0
start
delimiter changed to end-of-data null character
d o g \0 c a t , p i g \0
return this
the next to start

Example: Searching for Tokens (*strtok*)

```
#include <iostream>
#include <cstring>
int main ()
{
  char str[] ="This is a sample string,just testing.";
  char * pch;
  cout << “String: \” “<< str <<“\”” << endl;
  cout << "Splitting string in tokens:“ << endl;
  pch = strtok (str," ");
  while (pch != NULL) {
    cout << pch << endl;
    pch = strtok (NULL, " ,.");
  }
  return 0;
}
```

```
/* Output:
String: "This is a sample string,just
testing."
Splitting the string in tokens:
This
is
a
sample
string
just
testing
*/
```

Converting C String to C++ String

- Method 1: Assigns the C string to the C++ string
- Method 2: Use the C string as the copy constructor value

```
char* cStr = “Hello”;
string str1;
str1 = cStr;              // Assignment
string str2 (cStr);       // In copy constructor
```

Comparison between C and C++ Strings 1/3

Action	C++ string	C string
Input	<<, getline	<<, getline
Output	>>	>>
Copy	=	strcpy, strncpy
Compare	Relational operators, compare	strcmp, strncmp
Concatenation	+, +=, append	strcat, strncat

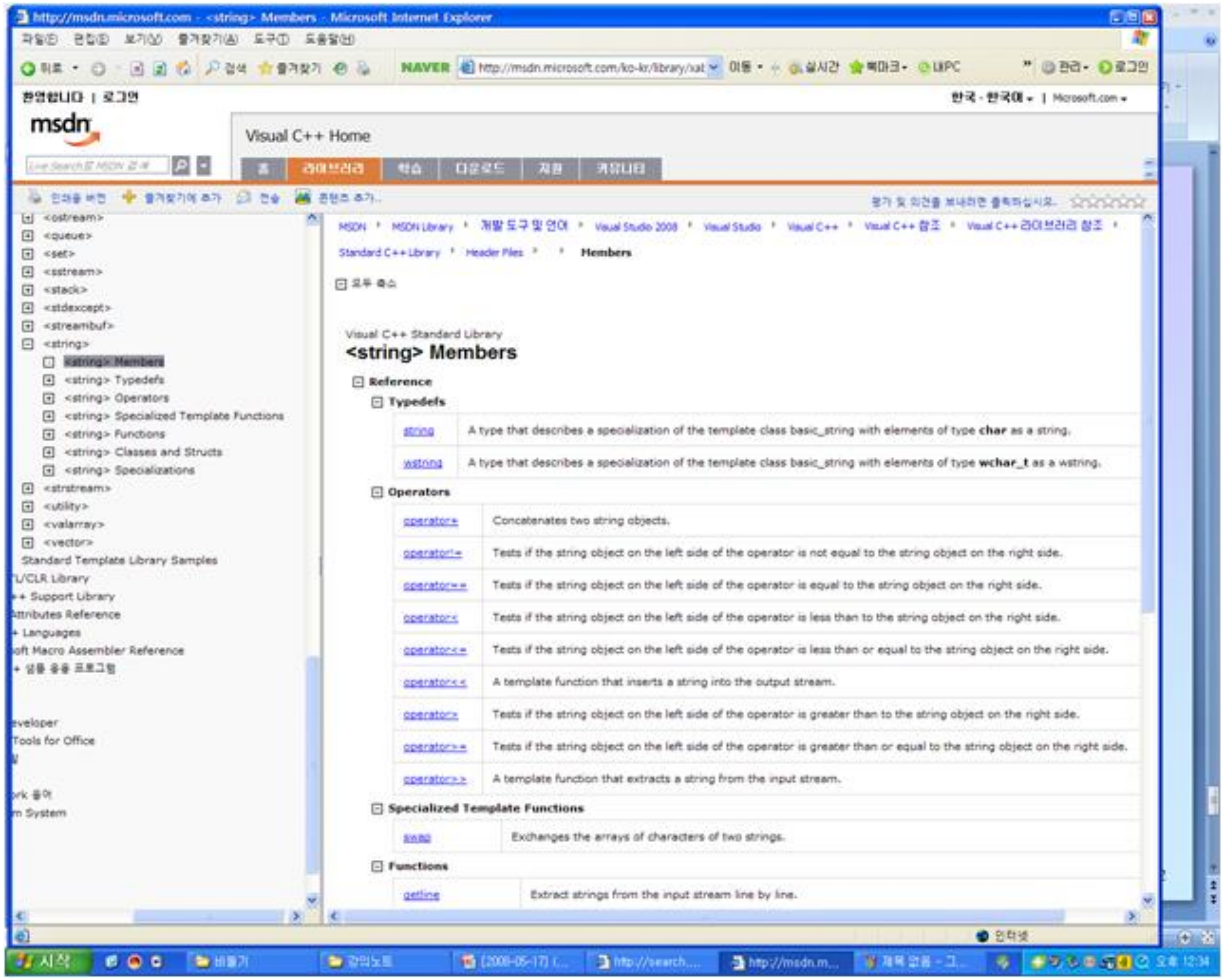
Comparison between C and C++ Strings 2/3

Action	C++ string	C string
Extraction	substr	strstr
Search for substring	find, rfind	strstr
Search for character	find, rfind	strchr, strrchr
Search for character in set	find_first_of, find_last_of	strspn
Search for character not in set	find_first_not_of, find_last_not_of	strcspn

Comparison between C and C++ Strings 3/3

Action	C++ string	C string
Access character	at, []	strchr, []
Insert	insert	N/A
Erase	erase, clear	N/A
Swap	swap	N/A
Convert to other format	c_str	assign or copy constructor

Search ‘String Class’ and its member functions from MSDN (1/2)


http://msdn.microsoft.com - <string> Members - Microsoft Internet Explorer
msdn
Visual C++ Home
<ostream>
<queue>
<set>
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<stdexcept>
<streambuf>
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Standard Template Library Samples
MSDN › MSDN Library › Visual Studio 2008 › Visual Studio › Visual C++
Standard C++ Library › Header Files › Members

Visual C++ Standard Library

<string> Members

Reference

Typedefs

string	A type that describes a specialization of the template class basic_string with elements of type **char** as a string.
wstring	A type that describes a specialization of the template class basic_string with elements of type **wchar_t** as a wstring.

Operators

operator+	Concatenates two string objects.
operator!=	Tests if the string object on the left side of the operator is not equal to the string object on the right side.
operator==	Tests if the string object on the left side of the operator is equal to the string object on the right side.
operator<	Tests if the string object on the left side of the operator is less than to the string object on the right side.
operator<=	Tests if the string object on the left side of the operator is less than or equal to the string object on the right side.
operator<<	A template function that inserts a string into the output stream.
operator>	Tests if the string object on the left side of the operator is greater than to the string object on the right side.
operator>=	Tests if the string object on the left side of the operator is greater than or equal to the string object on the right side.
operator>>	A template function that extracts a string from the input stream.

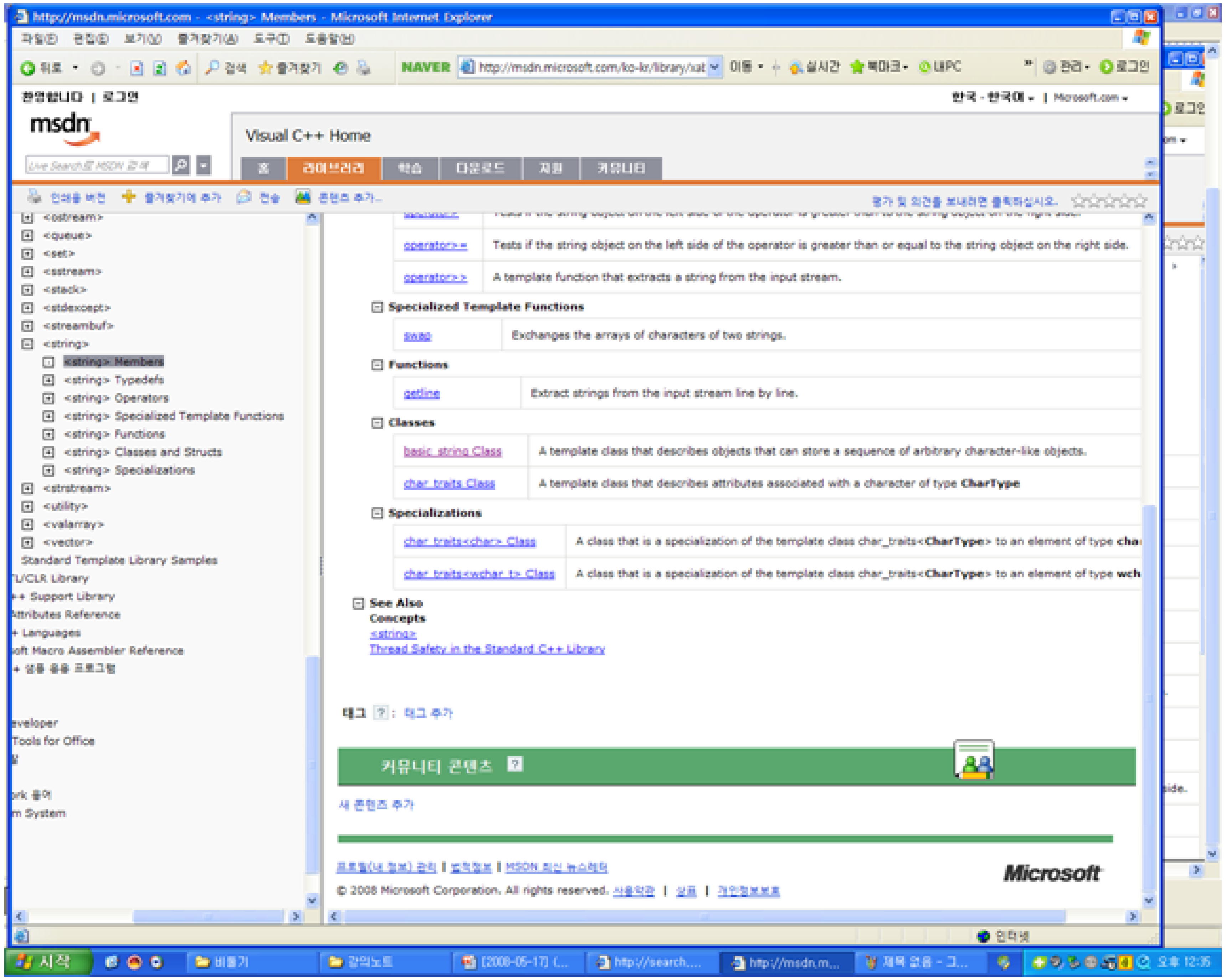
Specialized Template Functions

swap	Exchanges the arrays of characters of two strings.

Functions

getline	Extract strings from the input stream line by line.

Search ‘String Class’ and its member functions from MSDN (2/2)



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- <ostream>
- <queue>
- <set>
- <sstream>
- <stack>
- <stdexcept>
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  - <string> Specialized Template Functions
  - <string> Functions
  - <string> Classes and Structs
  - <string> Specializations
- <strstream>
- <utility>
- <valarray>
- <vector>

Standard Template Library Samples

operator>=	Tests if the string object on the left side of the operator is greater than or equal to the string object on the right side.
operator>>	A template function that extracts a string from the input stream.

Specialized Template Functions

swap	Exchanges the arrays of characters of two strings.

Functions

getline	Extract strings from the input stream line by line.

Classes

basic_string Class	A template class that describes objects that can store a sequence of arbitrary character-like objects.
char_traits Class	A template class that describes attributes associated with a character of type **CharType**

Specializations

char_traits<char> Class	A class that is a specialization of the template class char_traits<**CharType**> to an element of type **cha**
char_traits<wchar_t> Class	A class that is a specialization of the template class char_traits<**CharType**> to an element of type **wch**

See Also

Concepts

<string>

Thread Safety in the Standard C++ Library

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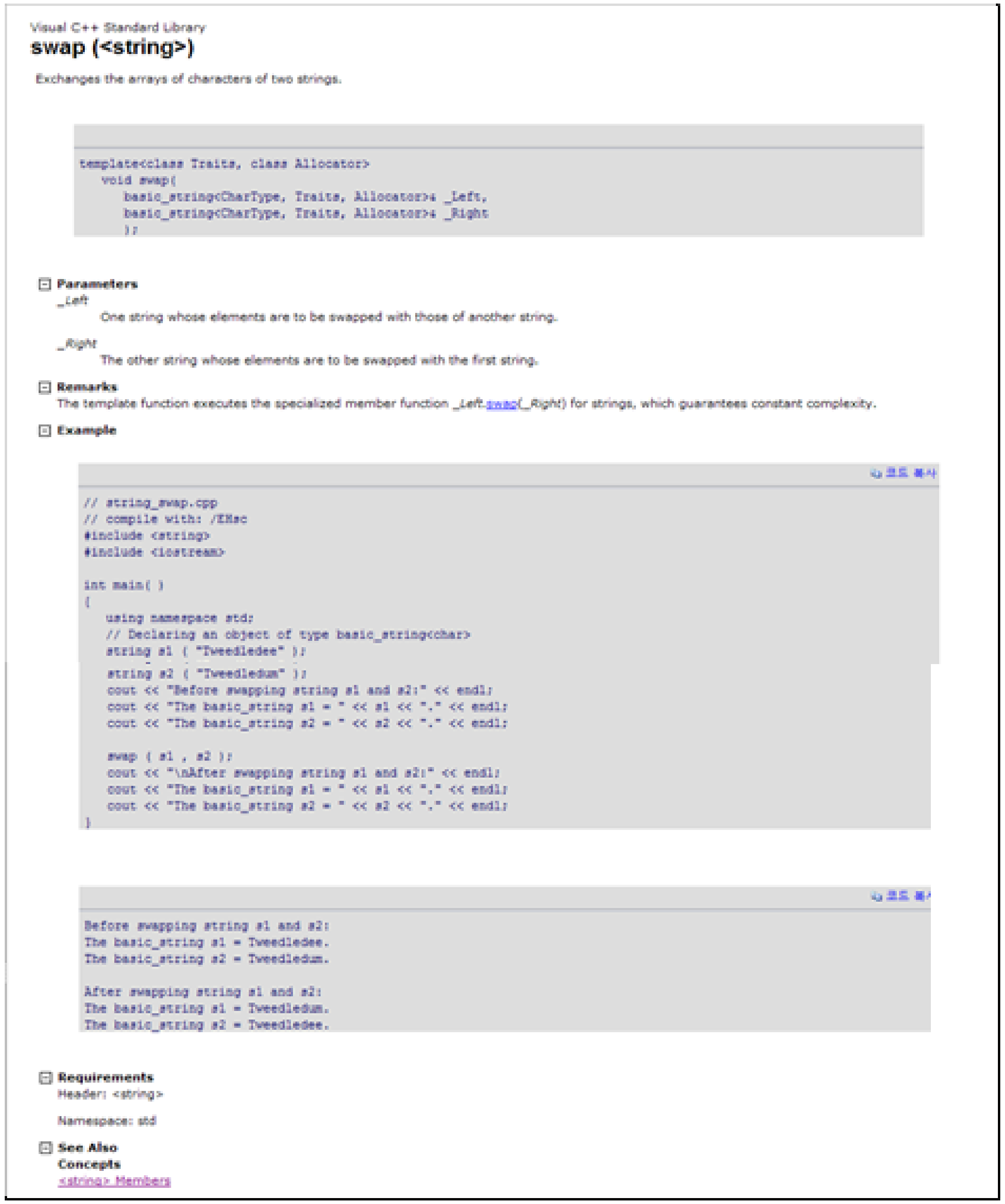
Search ‘swap’ functions from MSDN



Visual C++ Standard Library

swap (<string>)

Exchanges the arrays of characters of two strings.

```
template<class Traits, class Allocator>
   void swap(
      basic_string<CharType, Traits, Allocator>& _Left,
      basic_string<CharType, Traits, Allocator>& _Right
      );
```

⊟ **Parameters**

_Left

One string whose elements are to be swapped with those of another string.

_Right

The other string whose elements are to be swapped with the first string.

⊟ **Remarks**

The template function executes the specialized member function *_Left*.swap(*_Right*) for strings, which guarantees constant complexity.

⊟ **Example**

```
// string_swap.cpp
// compile with: /EHsc
#include <string>
#include <iostream>

int main( )
{
   using namespace std;
   // Declaring an object of type basic_string<char>
   string s1 ( "Tweedledee" );
   string s2 ( "Tweedledum" );
   cout << "Before swapping string s1 and s2:" << endl;
   cout << "The basic_string s1 = " << s1 << "." << endl;
   cout << "The basic_string s2 = " << s2 << "." << endl;

   swap ( s1 , s2 );
   cout << "\nAfter swapping string s1 and s2:" << endl;
   cout << "The basic_string s1 = " << s1 << "." << endl;
   cout << "The basic_string s2 = " << s2 << "." << endl;
}
```

```
Before swapping string s1 and s2:
The basic_string s1 = Tweedledee.
The basic_string s2 = Tweedledum.

After swapping string s1 and s2:
The basic_string s1 = Tweedledum.
The basic_string s2 = Tweedledee.
```

⊟ **Requirements**

Header: <string>

Namespace: std

⊟ **See Also**

Concepts

<string> Members

Questions?