5.1 Array/vector concept (general)

A typical variable stores one data item, like the number 59 or the character 'a'. Instead, sometimes a *list* of data items should be stored. Ex: A program recording points scored in each quarter of a basketball game needs a list of 4 numbers. Requiring a programmer to declare 4 variables is annoying; 200 variables would be ridiculous. An ***array*** is a special variable having one name, but storing a list of data items, with each item being directly accessible. Some languages use a construct similar to an array called a ***vector***. Each item in an array is known as an ***element***.

PARTICIPATION ACTIVITY 5.1.1: Sometimes a variable should store a list, or array, of data items.

Animation captions:

1. A variable usually stores just one data item.
2. Some variables should store a list of data items, like variable pointsPerQuarter that stores 4 items.
3. Each element is accessible, like the element numbered 3.

You might think of a normal variable as a truck, and an array variable as a train. A truck has just one car for carrying "data", but a train has many cars, each of which can carry data.

Figure 5.1.1: A normal variable is like a truck, whereas an array variable is like a train.

Source: Truck (Ian Britton / freefoto.com), train (Ian Britton / freefoto.com)

In an array, each element's location number is called the ***index***, myArray[2] has index 2. An array's key feature is that the index enables direct access to any element, as in myArray[2]; different languages may use different syntax, like myArray(3) or myVector.at(3). In many languages, indices start with 0 rather than 1, so an array with 4 elements has indices 0, 1, 2, and 3.

PARTICIPATION ACTIVITY 5.1.2: Update the array's data values.

This activity failed to load. Please try refreshing the page. If that fails, please try clearing your browser's cache (and email support@zybooks.com indicating the browser and OS versions).

PARTICIPATION ACTIVITY 5.1.3: Array basics.

Array peoplePerDay has 365 elements, one for each day of the year. Valid accesses are peoplePerDay[0], [1], ..., [364].

1) Which assigns element 0 with the value 250?

- peoplePerDay[250] = 0
- peoplePerDay[0] = 250
- peoplePerDay = 250

2) Which assigns element 1 with the value 99?

- peoplePerDay[1] = 99
- peoplePerDay[99] = 1

3) What is the value of peoplePerDay[8]?

```
peoplePerDay[9] = 5;
peoplePerDay[8] = peoplePerDay[9] - 3;
```

- 8
- 5
- 2

4) Assume N is initially 1. What is the value of peoplePerDay[2]?

```
peoplePerDay[N] = 15;
N = N + 1;
peoplePerDay[N] = peoplePerDay[N - 1] *
3;
```

- 15
- 2
- 45

PARTICIPATION ACTIVITY 5.1.4: Arrays with element numbering starting with 0.

Array scoresList has 10 elements with indices 0 to 9, accessed as scoresList[0] to scoresList[9].

1) Assign the first element in scoresList with 77.

Check **Show answer**

2) Assign the second element in scoresList with 77.

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Check **Show answer**

3) Assign the last element with 77.

Check **Show answer**

4) If that array instead has 100 elements, what is the last element's index?

Check Show answer

5) If the array's last index was 499, how many elements does the array have?

Check Show answer

5.2 Arrays

Array declarations and accessing elements

A programmer commonly needs to maintain a list of items, just as people often maintain lists of items like a grocery list or a course roster. An ***array*** is an ordered list of items of a given data type. Each item in an array is called an ***element***.

Construct 5.2.1: Array declaration.

```
dataType arrayName[numElements];
```

This statement declares an array having the specified number of elements in memory, each element of the specified data type. The desired number of elements are specified in [ ] symbols.

Terminology note: [ ] are ***brackets***. { } are ***braces***. In an array access, the number in brackets is called the ***index*** of the corresponding element. The first array element is at index 0.

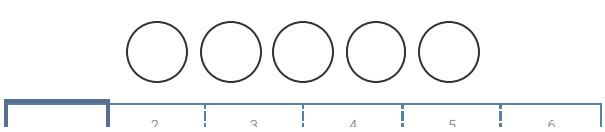
PARTICIPATION ACTIVITY 5.2.1: An array declaration creates multiple variables in memory, each accessible using [ ].

Animation captions:

1. An array named itemCounts is declared. The array consists of 3 elements, each of data type int.
2. An element is accessed with brackets. The number in brackets is called the index of the corresponding element.

PARTICIPATION ACTIVITY 5.2.2: Select the index shown.

Start



1

Check Next

PARTICIPATION ACTIVITY 5.2.3: Array basics.

Given:


```
int yearsArr[4];

yearsArr[0] = 1999;
yearsArr[1] = 2012;
yearsArr[2] = 2025;
```

1) How many elements in memory does the array declaration create?

- 0
- 1
- 3
- 4

2) What value is stored in yearsArr[1]?

- 1
- 1999
- 2012

3) With what value does `currYear = yearsArr[2]` assign currYear?

- 2
- 2025
- Invalid index

4) With what value does `currYear = yearsArr[3]` assign currYear?

- 3
- 2025
- Invalid index
- Unknown

5) Recall that the array declaration was `int yearsArr[4]`. Is `currYear = yearsArr[4]` a valid assignment?

- Yes, it accesses the fourth element.
- No, yearsArr[4] does not exist.

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6) What is the proper way to access the *first* element in array yearsArr?

- yearsArr[1]
- yearsArr[0]

7)

What are the contents of the array if the above code is followed by the statement: yearsArr[0] = yearsArr[2]?

- 1999, 2012, 1999, ?
- 2012, 2012, 2025, ?
- 2025, 2012, 2025, ?

8) What is the index of the *last* element for the following array: `int pricesArr [100];`

- 99
- 100
- 101

Using an expression for an array index

A powerful aspect of arrays is that the index is an expression. Ex: userNums[i] uses the value held in the int variable `i` as the index. As such, an array is useful to easily lookup the Nth item in a list.

An array's index must be an integer type. The array index cannot be a floating-point type, even if the value is 0.0, 1.0, etc.

The program below allows a user to print the age of the Nth oldest known person to have ever lived. The program quickly accesses the Nth oldest person's age using `oldestPeople[nthPerson - 1]`. Note that the index is `nthPerson - 1` rather than just `nthPerson` because an array's indices start at 0, so the 1st age is at index 0, the 2nd at index 1, etc.

Figure 5.2.1: Array's ith element can be directly accessed using [i]: Oldest people program.

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

int main() {
   int oldestPeople[5];
   int nthPerson;       // User input, Nth oldest person

   oldestPeople[0] = 122; // Died 1997 in France
   oldestPeople[1] = 119; // Died 1999 in U.S.
   oldestPeople[2] = 117; // Died 1993 in U.S.
   oldestPeople[3] = 117; // Died 1998 in Canada
   oldestPeople[4] = 116; // Died 2006 in Ecuador

   cout << "Enter N (1..5): ";
   cin  >> nthPerson;

   if ((nthPerson >= 1) && (nthPerson <= 5)) {
      cout << "The " << nthPerson << "th oldest person lived ";
      cout << oldestPeople[nthPerson - 1] << " years." << endl;
   }

   return 0;
}
```

```
Enter N (1..5): 1
The 1th oldest person lived 122 years.

...

Enter N (1..5): 4
The 4th oldest person lived 117 years.

...

Enter N (1..5): 9

...

Enter N (1..5): 0

...

Enter N (1..5): 5
The 5th oldest person lived 116 years.
```


PARTICIPATION ACTIVITY 5.2.4: Nth oldest person program.

1) In the program above, what is the purpose of this if statement:

```
if ((nthPerson >= 1) && (nthPerson <=
5)) {
   ...
}
```

- To avoid overflow because nthPerson's data type can only store values from 1 to 5.
- To ensure only valid array elements are accessed because the array oldestPeople only has 5 elements.

PARTICIPATION ACTIVITY 5.2.5: Array declaration and accesses.

1) Declare an array named myVals that stores 10 items of type int.

Check Show answer

2) Assign variable x with the value stored at index 8 of array myVals.

Check Show answer

3) Assign the second element of array myVals with the value 555.

Check Show answer

4) Assign myVals array element at the index held in currIndex with the value 777.

Check Show answer

5) Assign tempVal with the myVals array element at the index one after the value held in variable i.

Check Show answer

Loops and arrays

A key advantage of arrays becomes evident when used in conjunction with loops. The program below uses a loop to allow a user to enter 8 integer values, storing those values in an array, and then printing those 8 values.

Figure 5.2.2: Arrays combined with loops are powerful together: User-entered numbers.

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

int main() {
   const int NUM_ELEMENTS = 8;  // Number of elements in
array
   int userVals[NUM_ELEMENTS];  // User numbers
   int i;                       // Loop index

   cout << "Enter " << NUM_ELEMENTS << " integer values..."
<< endl;
   for (i = 0; i < NUM_ELEMENTS; ++i) {
      cout << "Value: ";
      cin >> userVals[i];
   }

   cout << "You entered: ";
   for (i = 0; i < NUM_ELEMENTS; ++i) {
      cout << userVals[i] << " ";
   }
   cout << endl;

   return 0;
}
```

```
Enter 8 integer values...
Value: 5
Value: 99
Value: -1
Value: -44
Value: 8
Value: 555555
Value: 0
Value: 2
You entered: 5 99 -1 -44 8 555555
0 2
```


PARTICIPATION ACTIVITY 5.2.6: Array with loops.

Refer to the program above.

1) How many times does each for loop iterate?

- 1
- 8
- Unknown

2) Which one line of code can be changed to allow the user to enter 100 elements?

- `const int NUM_ELEMENTS = 8;`
- `for (i = 0; i < NUM_ELEMENTS; ++i) {`

Array initialization

An array's elements are not automatically initialized during the variable declaration and should be initialized before being read. A programmer may initialize an array's elements in an array variable declaration by specifying the initial values in braces {} separated by commas. Ex: `int myArray[3] = {5, 7, 11};` initializes element at index 0 with 5, element at index 1 with 7, and element at index 2 with 11. For larger arrays, a loop may be used for initialization.

Like other variables, the keyword ***const*** may be prepended to an array variable declaration to prevent changes to the array. Thus, `const int YEARS[3] = {1865, 1920, 1964};` followed by `YEARS[0] = 2000;` yields a compiler error.

PARTICIPATION ACTIVITY 5.2.7: Array initialization.

1) Declare an array of ints named myVals with 4 elements each initialized to 10. The array declaration and initialization should be done in a single statement.

Check Show answer

2) Given: int maxScores[4] = {20, 20, 100, 50};. What is maxScores[3]?

Check Show answer

CHALLENGE ACTIVITY 5.2.1: Enter the output for the array.

Start

Type the program's output.

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

int main() {
   const int NUM_ELEMENTS = 3;
   int userVals[NUM_ELEMENTS];
   int i;

   userVals[0] = 1;
   userVals[1] = 4;
   userVals[2] = 8;

   for (i = 0; i < NUM_ELEMENTS; ++i) {
      cout << userVals[i] << endl;
   }

   return 0;
}
```

```
1
4
8
```

1 2 3 4

Check Next

CHALLENGE ACTIVITY 5.2.2: Printing array elements.

Write three statements to print the first three elements of array runTimes. Follow each statement with a newline. Ex: If runTime = {800, 775, 790, 805, 808}, print:

```
800
775
790
```

Note: These activities may test code with different test values. This activity will perform two tests, the first with a 5-element array (int runTimes[5]), the second with a 4-element array (int runTimes[4]). See "How to Use zyBooks". .

Also note: If the submitted code tries to access an invalid array element, such as runTime[9] for a 5-element array, the test may generate strange results. Or the test may crash and report "Program end never reached", in which case the system doesn't print the test case that caused the reported message.

Run

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CHALLENGE ACTIVITY 5.2.3: Printing array elements with a for loop.

Write a for loop to print all elements in courseGrades, following each element with a space (including the last). Print forwards, then backwards. End each loop with a newline. Ex: If courseGrades = {7, 9, 11, 10}, print:

```
7 9 11 10
10 11 9 7
```

Hint: Use two for loops. Second loop starts with i = NUM_VALS - 1. (Notes)

Note: These activities may test code with different test values. This activity will perform two tests, the first with a 4-element array (int courseGrades[4]), the second with a 2-element array (int courseGrades[2]). See "How to Use zyBooks". .

Also note: If the submitted code tries to access an invalid array element, such as courseGrades[9] for a 4-element array, the test may generate strange results. Or the test may crash and report "Program end never reached", in which case the system doesn't print the test case that caused the reported message.

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

int main() {
   const int NUM_VALS = 4;
   int courseGrades[NUM_VALS];
   int i;

   courseGrades[0] = 7;
   courseGrades[1] = 9;
   courseGrades[2] = 11;
   courseGrades[3] = 10;

   /* Your solution goes here  */

   return 0;
}
```


Run

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5.3 Iterating through arrays

Iterating through an array using loops

Iterating through arrays using loops is commonplace and is an important programming skill to master.

Because array indices are numbered 0 to N - 1 rather than 1 to N, programmers commonly use this for loop structure:

Figure 5.3.1: Common for loop structure for iterating through an array.

```
// Iterating through myArray
for (i = 0; i < numElements; ++i) {
   // Loop body accessing myArray[i]
}
```

Note that index variable i is initialized to 0, and the loop expression is i < N rather than i <= N. If N were 5, the loop's iterations would set i to 0, 1, 2, 3, and 4, for a total of 5 iterations. The benefit of the loop structure is that each array element is accessed as myArray[i] rather than the more complex myArray[i - 1].

PARTICIPATION ACTIVITY 5.3.1: Iterating through an array.

1) Complete the code to print all items for the given array, using the above common loop structure.

```
int daysList[365];
...

for (i = 0;
                    ; ++i) {
   cout << daysList[i] << endl;
}
```

Check Show answer

2) Given that this loop iterates over all items of the array, how many items are in the array?

```
for (i = 0; i < 99; ++i) {
   cout << someArray[i] << endl;
}
```

Check Show answer

Determining a quantity about an array's items

Iterating through an array for various purposes is an important programming skill to master. The program below computes the sum of an array's element values. For computing the sum, the program initializes a variable sum to 0, then simply adds the current iteration's array element value to that sum.

Figure 5.3.2: Iterating through an array example: Program that computes the sum of an array's elements.

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

int main() {
   const int NUM_ELEMENTS = 8; // Number of elements
   int userVals[NUM_ELEMENTS]; // User numbers
   int i;                      // Loop index
   int sumVal;                 // For computing sum

   // Prompt user to populate array
   cout << "Enter " << NUM_ELEMENTS << " integer values..." << endl;

   for (i = 0; i < NUM_ELEMENTS; ++i) {
      cout << "Value: ";
      cin >> userVals[i];
   }

   // Determine sum
   sumVal = 0;
   for (i = 0; i < NUM_ELEMENTS; ++i) {
      sumVal = sumVal + userVals[i];
   }

   cout << "Sum: " << sumVal << endl;

   return 0;
}
```

```
Enter 8 integer values...
Value: 3
Value: 5
Value: 234
Value: 346
Value: 234
Value: 73
Value: 26
Value: -1
Sum: 920

...

Enter 8 integer values...
Value: 3
Value: 5
Value: 234
Value: 346
Value: 234
Value: 73
Value: 26
Value: 1
Sum: 922
```


Finding the maximum value in an array

Programs commonly iterate through arrays to determine some quantity about the array's items. The program below determines the maximum value in a user-entered list. If the user enters numbers 7, -9, 55, 44, 20, -400, 0, 2, then the program will output "max: 55". The program uses the variable maxVal to store the largest value seen "so far" as the program iterates through the array. During each iteration, if the array's current element value is larger than the max seen so far, the program assigns maxVal with the array element.

Before entering the loop, maxVal must be initialized to some value because max will be compared with each array element's value. A logical error would be to initialize maxVal to 0, because 0 is not in fact the largest value seen so far, and would result in incorrect output (of 0) if the user entered all negative numbers. Instead, the program peeks at an array element (using the first element, though any element could have been used) and initializes maxVal to that element's value.

Figure 5.3.3: Iterating through an array example: Program that finds the max item.

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

int main() {
   const int NUM_ELEMENTS = 8;  // Number of elements
   int userVals[NUM_ELEMENTS];  // Array of user numbers
   int i;                       // Loop index
   int maxVal;                  // Computed max

   // Prompt user to populate array
   cout << "Enter " << NUM_ELEMENTS << " integer values..." << endl;

   for (i = 0; i < NUM_ELEMENTS; ++i) {
      cout << "Value: ";
      cin >> userVals[i];
   }

   // Determine largest (max) number
   maxVal = userVals[0];        // Largest so far

   for (i = 0; i < NUM_ELEMENTS; ++i) {
      if (userVals[i] > maxVal) {
         maxVal = userVals[i];
      }
   }
   cout << "Max: " << maxVal << endl;

   return 0;
}
```

```
Enter 8 integer values...
Value: 3
Value: 5
Value: 23
Value: -1
Value: 456
Value: 1
Value: 6
Value: 83
Max: 456

...

Enter 8 integer values...
Value: -5
Value: -10
Value: -44
Value: -2
Value: -27
Value: -9
Value: -27
Value: -9
Max: -2
```


PARTICIPATION ACTIVITY 5.3.2: Array iteration.

Given an integer array myVals of size N_SIZE (i.e. int myVals[N_SIZE]), complete the code to achieve the stated goal.

1) Determine the minimum number in the array, using the same initialization as the maximum number example above.

```
minVal = [          ] ;
for (i = 0; i < N_SIZE; ++i) {
   if (myVals[i] < minVal) {
      minVal = myVals[i];
   }
}
```

Check Show answer

2) Count how many negative numbers exist in the array.

```
cntNeg = 0;
for (i = 0; i < N_SIZE; ++i) {
   if ( [                ] ) {
      ++cntNeg;
   }
}
```

Check Show answer

3) Count how many odd numbers exist in the array.

```
cntOdd = 0;
for (i = 0; i < N_SIZE; ++i) {
   if ( (myVals[i] % 2) == 1 )
{
        [          ] ;
   }
}
```

Check Show answer

zyDE 5.3.1: Print the sum and average of an array's elements.

Modify the program to print the average (mean) as well as the sum. Hint: You don't actually have to change the loop, but rather change what you print.

Load default template...

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

int main() {
   const int NUM_ELEMENTS = 8; // Number of elements
   int userVals[NUM_ELEMENTS]; // User numbers
   int i;                      // Loop index
   int sumVal;                 // For computing sum

   // Prompt user to populate array
   cout << "Enter " << NUM_ELEMENTS << " integer values.

   for (i = 0; i < NUM_ELEMENTS; ++i) {
      cout << "Value: " << endl;
      cin >> userVals[i];
   }

   // Determine sum
   sumVal = 0;
   for (i = 0; i < NUM_ELEMENTS; ++i) {
```

3 5 234 346 234 73 26 -1

Run

zyDE 5.3.2: Print selected elements of an array.

Modify the program to instead just print each number that is greater than 21.

Load default template...

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

int main() {
   const int NUM_ELEMENTS = 8; // Number of elements
   int userVals[NUM_ELEMENTS]; // User numbers
   int i;                      // Loop index
   int sumVal;                 // For computing sum

   // Prompt user to populate array
   cout << "Enter " << NUM_ELEMENTS << " integer values.

   for (i = 0; i < NUM_ELEMENTS; ++i) {
      cout << "Value: " << endl;
      cin >> userVals[i];
   }

   // Determine sum
   sumVal = 0;
   for (i = 0; i < NUM_ELEMENTS; ++i) {
```

3 5 234 346 234 73 26 -1

Run

Common error: Accessing out of range array element

A common error is to try to access an array with an index that is out of the array's index range. Ex: Trying to access highScores[8] when highScores's valid indices are 0-7. Care should be taken whenever a user enters a number that is then used as an array index, and when using a loop index as an array index also, to ensure the index is within the array's valid index range. Checking whether an array index is in range is very important. Trying to access an array with an out-of-range index is not only a very common error, but is also one of the hardest errors to debug. The following animation shows what happens when a program writes to an out-of-range index using an array.

PARTICIPATION ACTIVITY 5.3.3: Writing to an out-of-range index using an array.

Animation captions:

1. Variable userAge is allocated a location in memory immediately after the array userWeights. userAge is assigned with 44.
2. Each element of array userWeights is assigned a value.
3. 3 is out of userWeights's index range, and results in overwriting userAge's value.

A write to an array with an out-of-range index may simply write to a memory location of a different variable X residing next to the array in memory. Later, when the program tries to read X, the program encounters incorrect data. For example, a program may write X with the number 44, but when reading X later in the program X may be 2533, with X never (intentionally) written by any program statement in between.

PARTICIPATION ACTIVITY 5.3.4: Iterating through an array.

Given the following code:

```
const int NUM_ELEMENTS = 5;
int myArray[NUM_ELEMENTS];
int i;
```

1) The normal for loop structure iterates as long as: `i <= NUM_ELEMENTS`

- True
- False

2) To compute the sum of elements, a reasonable statement preceding the for loop is: `sumVal = 0;`

- True
- False

3) To find the maximum element value, a reasonable statement preceding the for loop is: `maxVal = 0;`

- True
- False

CHALLENGE ACTIVITY 5.3.1: Enter the output for the array.

Start

Type the program's output.

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

int main() {
   const int NUM_ELEMENTS = 3;
   int userVals[NUM_ELEMENTS];
   int i;

   userVals[0] = 2;
   userVals[1] = 4;
   userVals[2] = 8;

   for (i = 0; i < NUM_ELEMENTS; ++i) {
      cout << userVals[i] << endl;
   }

   return 0;
}
```

```
2
4
8
```


1 2 3 4 5

Check Next

CHALLENGE ACTIVITY 5.3.2: Finding values in arrays.

Set numMatches to the number of elements in userValues (having NUM_VALS elements) that equal matchValue. Ex: If matchValue = 2 and userValues = {2, 2, 1, 2}, then numMatches = 3. (Notes)

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

int main() {
   const int NUM_VALS = 4;
   int userValues[NUM_VALS];
   int i;
   int matchValue;
   int numMatches = -99; // Assign numMatches with 0 before your for loop

   userValues[0] = 2;
   userValues[1] = 2;
   userValues[2] = 1;
   userValues[3] = 2;

   matchValue = 2;

   /* Your solution goes here  */

   cout << "matchValue: " << matchValue << ", numMatches: " << numMatches << endl;
```

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CHALLENGE ACTIVITY 5.3.3: Populating an array with a for loop.

Write a for loop to populate array userGuesses with NUM_GUESSES integers. Read integers using cin. Ex: If NUM_GUESSES is 3 and user enters 9 5 2, then userGuesses is {9, 5, 2}.

Run

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CHALLENGE ACTIVITY 5.3.4: Array iteration: Sum of excess.

Array testGrades contains NUM_VALS test scores. Write a for loop that sets sumExtra to the total extra credit received. Full credit is 100, so anything over 100 is extra credit. Ex: If testGrades = {101, 83, 107, 90}, then sumExtra = 8, because 1 + 0 + 7 + 0 is 8.

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

int main() {
   const int NUM_VALS = 4;
   int testGrades[NUM_VALS];
   int i;
   int sumExtra = -9999; // Assign sumExtra with 0 before your for loop

   testGrades[0] = 101;
   testGrades[1] = 83;
   testGrades[2] = 107;
   testGrades[3] = 90;

   /* Your solution goes here  */

   cout << "sumExtra: " << sumExtra << endl;
   return 0;
}
```

Run

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CHALLENGE ACTIVITY 5.3.5: Printing array elements separated by commas.

Write a for loop to print all NUM_VALS elements of array hourlyTemp. Separate elements with a comma and space. Ex: If hourlyTemp = {90, 92, 94, 95}, print:

```
90, 92, 94, 95
```


Your code's output should end with the last element, without a subsequent comma, space, or newline.

Run

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5.4 Array/vector iteration drill

The following activities can help one become comfortable with iterating through arrays or vectors, before learning to code such iteration.

PARTICIPATION ACTIVITY 5.4.1: Find the maximum value in the array.

Click "Store value" if a new maximum value is seen.

Start

X	X	X	X	X	X	X

Stored value

-1

Next value

Store value

Time -

Best time -

Clear best

PARTICIPATION ACTIVITY 5.4.2: Negative value counting in array.

Click "Increment" if a negative value is seen.

Start

X	X	X	X	X	X	X

Counter

0

Next value

Increment

Time -

Best time -

Clear best

PARTICIPATION ACTIVITY 5.4.3: Array sorting largest value.

Move the largest value to the right-most position. Click "Swap values" if the larger of the two current values is on the left.

Start

X	X	X	X	X	X	X

Next value Swap values

Time - Best time -

Clear best

5.5 Multiple arrays

Programmers commonly use multiple same-sized arrays to store related lists. The program below maintains a list of letter weights in ounces, and another list indicating the corresponding postage cost for first class mail (usps.com).

The `if (userLetterWeight <= letterWeights[i])` statement compares the user-entered letter weight with the current element in the letterWeights array. If the entered weight is less than or equal to the current element in the letterWeights array, the program prints the element in postageCosts at the same index.

The loop's expression `(i < NUM_ELEMENTS) && (!foundWeight)` depends on the value of the variable foundWeight. This expression prevents the loop from iterating through the entire array once the correct letter weight has been found. Omitting the check for found from the loop expression would result in an incorrect output; the program would incorrectly print the postage cost for all letter weights greater than the user's letter weight.

Figure 5.5.1: Multiple array example: Letter postage cost program.

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

int main () {
   const int NUM_ELEMENTS = 14;
   // Weights in ounces
   double letterWeights[NUM_ELEMENTS] = {1.0, 2.0, 3.0, 3.5, 4.0, 5.0, 6.0,
                                         7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0};
   // Costs in cents (usps.com 2017)
   int postageCosts[NUM_ELEMENTS] = {49, 70, 91, 112, 161, 182, 203,
                                     224, 245, 266, 287, 308, 329, 350};
   double userLetterWeight;
   bool foundWeight;
   int i;

   // Prompt user to enter letter weight
   cout << "Enter letter weight (in ounces): ";
   cin >> userLetterWeight;

   // Postage costs is based on smallest letter weight greater than
   // or equal to mailing letter weight
   foundWeight = false;

   for (i = 0; (i < NUM_ELEMENTS) && (!foundWeight); ++i) {
      if (userLetterWeight <= letterWeights[i]) {
         foundWeight = true;
         cout << "Postage for USPS first class mail is ";
         cout << postageCosts[i] << " cents" << endl;
      }
   }

   if( !foundWeight ) {
      cout << "Letter is too heavy for USPS first class mail." << endl;
   }

   return 0;
}
```

```
Enter letter weight (in ounces): 3
Postage for USPS first class mail is 91 cents

...

Enter letter weight (in ounces): 9.5
Postage for USPS first class mail is 287 cents

...

Enter letter weight (in ounces): 15
Letter is too heavy for USPS first class mail.
```


PARTICIPATION ACTIVITY 5.5.1: Multiple arrays in the above postage cost program.

1) letterWeights[0] is 1, meaning element 0 of letterWeights and postageCosts correspond to a weight of 1 ounce.

- True
- False

2) postageCosts[2] represents the cost for a weight of 2 ounces.

- True
- False

3) The program fails to provide a cost for a weight of 7.5.

- True
- False

zyDE 5.5.1: Postage calculation with negative weight error message

Improve the program by also outputting "The next higher weight is ___ with a cost of ___ cents".

Load default template...

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

int main () {
   const int NUM_ELEMENTS = 14;
   // Weights in ounces
   double letterWeights[NUM_ELEMENTS] = {1.0, 2.0, 3.0,
                                         7.0, 8.0, 9.0,
   // Costs in cents (usps.com 2017)
   int postageCosts[NUM_ELEMENTS] = {49, 70, 91, 112, 16
                                     224, 245, 266, 287,
   double userLetterWeight;
   bool foundWeight;
   int i;

   // Prompt user to enter letter weight
   cout << "Enter letter weight (in ounces): ";
   cin >> userLetterWeight;

   // Postage costs is based on smallest letter weight g
```

3

Run

PARTICIPATION ACTIVITY 5.5.2: Multiple arrays.

1) Using two separate statements, declare two related integer arrays named seatPosition and testScore (in that order) each with 130 elements.

Check Show answer

2) How many total elements are stored within the two arrays int familyAges[50] and double familyHeights[50]?

Check Show answer

CHALLENGE ACTIVITY 5.5.1: Multiple arrays.

Start

Subtract each element in origList with the corresponding value in offsetAmount. Print each difference followed by a space.
Ex: If origList = {4, 5, 10, 12} and offsetAmount = {2, 4, 7, 3}, print:

```
2 1 3 9
```

1 2

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

int main() {
   const int NUM_VALS = 4;
   int origList[NUM_VALS];
   int offsetAmount[NUM_VALS];
   int i;

   origList[0] = 40;
   origList[1] = 50;
   origList[2] = 60;
   origList[3] = 70;

   offsetAmount[0] = 6;
   offsetAmount[1] = 7;
   offsetAmount[2] = 3;
   offsetAmount[3] = 4;

   /* Your solution goes here */
```


5.6 Loop-modifying or copying/comparing arrays

Modifying array elements

A program may need to modify elements while iterating through an array. The program below uses a loop to convert any negative array element value to 0.

Figure 5.6.1: Modifying an array during iteration example: Converting negatives to 0 program.

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

int main() {
   const int NUM_ELEMENTS = 8;  // Number of elements
   int userVals[NUM_ELEMENTS];  // User values
   int i;                       // Loop index

   // Prompt user to input values
   cout << "Enter " << NUM_ELEMENTS << " integer values..." << endl;
   for (i = 0; i < NUM_ELEMENTS; ++i) {
      cout << "Value: ";
      cin >> userVals[i];
   }

   // Convert negatives to 0
   for (i = 0; i < NUM_ELEMENTS; ++i) {
      if (userVals[i] < 0) {
         userVals[i] = 0;
      }
   }

   // Print numbers
   cout << "New numbers: ";
   for (i = 0; i < NUM_ELEMENTS; ++i) {
      cout << userVals[i] << " ";
   }

   return 0;
}
```

```
Enter 8 integer values...
Value: 5
Value: 67
Value: -5
Value: -4
Value: 5
Value: 6
Value: 6
Value: 4
New numbers: 5 67 0 0 5 6 6 4
```


PARTICIPATION ACTIVITY 5.6.1: Modifying an array in a loop.

What is the resulting array contents, assuming each question starts with an array of size 4 having contents -55, -1, 0, 9?

1)
```
for (i = 0; i < 4; ++i) {
   itemsList[i] = i;
}
```

- -54, 0, 1, 10
- 0, 1, 2, 3
- 1, 2, 3, 4

2)
```
for (i = 0; i < 4; ++i) {
   if (itemsList[i] < 0) {
      itemsList[i] = itemsList[i] * -1;
   }
}
```

- -55, -1, 0, -9
- 55, 1, 0, -9
- 55, 1, 0, 9

3)
```
for (i = 0; i < 4; ++i) {
   itemsList[i] = itemsList[i+1];
}
```

- -1, 0, 9, 0
- 0, -55, -1, 0
- Error

4)
```
for (i = 0; i < 3; ++i) {
   itemsList[i] = itemsList[i+1];
}
```

- -1, 0, 9, 9
- Error
- -1, 0, 9, 0

5)
```
for (i = 0; i < 3; ++i) {
   itemsList[i+1] = itemsList[i];
}
```

- -55, -55, -55, -55
- 0, -55, -1, 0
- Error

zyDE 5.6.1: Modifying an array during iteration example: Doubling element values.

Complete the following program to double each number in the array.

Load default template...

```
5 67 -5 -4 5 6 6 4
```

Run

Copying an array

Copying an array is a common task. Given a second array of the same size, a loop can copy each element one-by-one. Modifications to either array do not affect the other.

Figure 5.6.2: Array copying: Converting negatives to 0 program.

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

int main() {
   const int NUM_ELEMENTS = 8;   // Number of elements
   int userVals[NUM_ELEMENTS];   // User numbers
   int copiedVals[NUM_ELEMENTS]; // Copied/modified user numbers
   int i;                        // Loop index

   // Prompt user for input values
   cout << "Enter " << NUM_ELEMENTS << " integer values..." << endl;
   for (i = 0; i < NUM_ELEMENTS; ++i) {
      cout << "Value: ";
      cin >> userVals[i];
   }

   // Copy userNums to copiedNums array
   for (i = 0; i < NUM_ELEMENTS; ++i) {
      copiedVals[i] = userVals[i];
   }

   // Convert negatives to 0
   for (i = 0; i < NUM_ELEMENTS; ++i) {
      if (copiedVals[i] < 0) {
         copiedVals[i] = 0;
      }
   }

   // Print numbers
   cout << endl << "Original and new values: " << endl;
   for (i = 0; i < NUM_ELEMENTS; ++i) {
      cout << userVals[i] << " became " << copiedVals[i] << endl;
   }

   return 0;
}
```

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

int main() {
   const int NUM_ELEMENTS = 8;  // Number of elements
   int userVals[NUM_ELEMENTS];  // User values
   int i;                       // Loop index

   // Prompt user to input values
   cout << "Enter " << NUM_ELEMENTS << " integer values.
   for (i = 0; i < NUM_ELEMENTS; ++i) {
      cout << "Value: " << endl;
      cin >> userVals[i];
   }

   // Double each element - FIXME write this loop

   // Print numbers
   cout << "New numbers: ";
   for (i = 0; i < NUM_ELEMENTS; ++i) {
```

```
Enter 8 integer values...
Value: 12
Value: -5
Value: 34
Value: 75
Value: -14
Value: 33
Value: 12
Value: -104

Original and new values:
12 became 12
-5 became 0
34 became 34
75 became 75
-14 became 0
33 became 33
12 became 12
-104 became 0
```

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PARTICIPATION ACTIVITY 5.6.2: Array copying.

Given array firstList with size 4 and element values, 33, 44, 55, 66, and array secondList with size 4 and elements values 0, 0, 0, 0.

1) firstList = secondList copies 0s into each firstList element.

True

False

2) This loop copies firstList to secondList, so that secondList becomes 33, 44, 55, 66:

```
for (i = 0; i < 4; ++i) {
   secondList[i] = firstList[i];
}
```

True

False

3) After a for loop copies firstList to secondList, the assignment secondList [0] = 99 will modify both arrays.

True

False

4) Given thirdList with size 5 and elements 22, 21, 20, 19, 18, the following causes firstList's values to be 22, 21, 20, 19, 18:

```
for (i = 0; i < 5; ++i) {
   firstList[i] = thirdList[i];
}
```

True

False

CHALLENGE ACTIVITY 5.6.1: Decrement array elements.

Write a loop that subtracts 1 from each element in lowerScores. If the element was already 0 or negative, assign 0 to the element. Ex: lowerScores = {5, 0, 2, -3} becomes {4, 0, 1, 0}.

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

int main() {
   const int SCORES_SIZE = 4;
   int lowerScores[SCORES_SIZE];
   int i;

   lowerScores[0] = 5;
   lowerScores[1] = 0;
   lowerScores[2] = 2;
   lowerScores[3] = -3;

   /* Your solution goes here  */

   for (i = 0; i < SCORES_SIZE; ++i) {
      cout << lowerScores[i] << " ";
   }
   cout << endl;

   return 0;
```


Run

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CHALLENGE ACTIVITY 5.6.2: Copy and modify array elements.

Write a loop that sets newScores to oldScores shifted once left, with element 0 copied to the end. Ex: If oldScores = {10, 20, 30, 40}, then newScores = {20, 30, 40, 10}.

Note: These activities may test code with different test values. This activity will perform two tests, the first with a 4-element array (newScores = {10, 20, 30, 40}), the second with a 1-element array (newScores = {199}). See "How to Use zyBooks". .

Also note: If the submitted code tries to access an invalid array element, such as newScores [9] for a 4-element array, the test may generate strange results. Or the test may crash and report "Program end never reached", in which case the system doesn't print the test case that caused the reported message.


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

int main() {
   const int SCORES_SIZE = 4;
   int oldScores[SCORES_SIZE];
   int newScores[SCORES_SIZE];
   int i;

   oldScores[0] = 10;
   oldScores[1] = 20;
   oldScores[2] = 30;
   oldScores[3] = 40;

   /* Your solution goes here  */

   for (i = 0; i < SCORES_SIZE; ++i) {
      cout << newScores[i] << " ";
   }
   cout << endl;

```

Run

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CHALLENGE ACTIVITY 5.6.3: Modify array elements using other elements.

Write a loop that sets each array element to the sum of itself and the next element, except for the last element which stays the same. Be careful not to index beyond the last element. Ex:

```
Initial scores:        10, 20, 30, 40
Scores after the loop: 30, 50, 70, 40
```

The first element is 30 or 10 + 20, the second element is 50 or 20 + 30, and the third element is 70 or 30 + 40. The last element remains the same.


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

int main() {
   const int SCORES_SIZE = 4;
   int bonusScores[SCORES_SIZE];
   int i;

   bonusScores[0] = 10;
   bonusScores[1] = 20;
   bonusScores[2] = 30;
   bonusScores[3] = 40;

   /* Your solution goes here  */

   for (i = 0; i < SCORES_SIZE; ++i) {
      cout << bonusScores[i] << " ";
   }
   cout << endl;

   return 0;
```

Run

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CHALLENGE ACTIVITY 5.6.4: Modify an array's elements.

Double any element's value that is less than minValue. Ex: If minValue = 10, then dataPoints = {2, 12, 9, 20} becomes {4, 12, 18, 20}.


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

int main() {
   const int NUM_POINTS = 4;
   int dataPoints[NUM_POINTS];
   int minValue;
   int i;

   cin >> minValue;

   for (i = 0; i < NUM_POINTS; ++i) {
      cin >> dataPoints[i];
   }

/* Your solution goes here  */

   for (i = 0; i < NUM_POINTS; ++i) {
      cout << dataPoints[i] << " " ;
   }
   cout << endl;
```

Run

View your last submission

5.7 Char arrays / C strings

A programmer can use an array to store a sequence of characters, known as a ***string***. Char arrays were the only kinds of strings in C++'s predecessor language C, and thus are sometimes called ***C strings*** to distinguish them from C++'s string type. An example is: `char movieTitle[20] = "Star Wars";`. Because a string can be shorter than the character array, a string in a char array must end with a special character known as a ***null character***, written as '\0'. Given a string literal like "Star Wars", the compiler automatically appends a null character.

PARTICIPATION ACTIVITY 5.7.1: A char array declaration and initialization with null-terminated string.

Animation captions:

1. The character array must be large enough to include the null character. The compiler automatically inserts the null character to indicate the end of a string.

A char array of size 20 can store strings of lengths 0 to 19. The longest string is 19, not 20, since the null character must be stored.

If a char array is initialized when declared, then the char array's size may be omitted, as in `char userName[] = "Hellen";` . The compiler determines the size from the string literal, in this case 6 + 1 (for the null character), or 7.

An array of characters ending with a null character is known as a ***null-terminated string***.

Output streams automatically handle null-terminated strings, printing each character until reaching the null character that ends the string.

Figure 5.7.1: Printing stops when reaching the null character at each string's end.


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

int main() {
   char cityName[20] = "Forest Lake"; // Compiler appends null char

   // In each cout, printing stops when reaching null char
   cout << "City:" << endl;           // Compiler appends null char to "City:"
   cout << cityName << endl;

   return 0;
}
```

```
City:
Forest Lake
```

PARTICIPATION ACTIVITY 5.7.2: Char array strings.

Indicate whether the array declaration and initialization are appropriate.

1) `char firstName[10] = "Henry";`

- True
- False

2) `char lastName[10] = "Michelson";`

- True
- False

3) `char favoriteMuseum[10] = "Smithsonian";`

- True
- False

4) Printing catBreed will print 19 characters.

`char catBreed[20] = "Persian";`

- True
- False

After a string is declared, a programmer may not later assign the string as in `movieTitle = "Indiana Jones";`. That statement tries to assign a value to the char array variable itself, rather than copying each character from the string on the right into the array on the left. Functions exist to *copy* strings, such as strcpy(), discussed elsewhere.

A programmer can traverse a string using a loop that stops when reaching the null character.

A common error is to loop for the string's array size rather than stopping at the null character. Such looping visits unused array elements beyond the null character. An even worse common error is to loop beyond the last valid element, which visits memory locations that are not part of the array. These errors are illustrated below. Notice the strange characters that are output as the contents of other memory locations are printed out; the program may also crash.

Figure 5.7.2: Traversing a C string.

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

int main() {
   char userStr[20] = "1234567890123456789"; // Input string
   int i;

   // Prompt user for string input
   cout << "Enter string (<20 chars): ";
   cin >> userStr;

   // Print string
   cout << endl << userStr << endl;

   // Look for '@'
   for (i = 0; userStr[i] != '\0'; ++i) {
      if (userStr[i] == '@') {
         cout << "Found '@'." << endl;
      }
   }
   cout << endl;


   // The following is an ERROR.
   // May print chars it shouldn't.
   // Problem: doesn't stop at null char.
   cout << "\""; // Print opening "
   for (i = 0; i < 20; ++i) { // Print each char
      cout << userStr[i];
   }
   cout << "\"" << endl;      // Print closing "


   // The following is an even WORSE ERROR.
   // Accesses beyond valid index range.
   // Program may crash.
   cout << "\""; // Print opening "
   for (i = 0; i < 30; ++i) {
      cout << userStr[i];
   }
   cout << "\"" << endl; // Print closing "

   return 0;
}
```

```
Enter string (<20 chars): test@gmail.com

test@gmail.com
Found '@'.

"test@gmail.com6789"
"test@gmail.com6789P!"
```


The above output is machine and compiler dependent. Also, some values aren't printable so don't appear in the output.

PARTICIPATION ACTIVITY 5.7.3: C string errors.

Given the following char array declaration, which of the following code snippets are bad?

```
char userText[10] = "Car";
```

1)
```
for (i = 0; userText != '\0'; ++i) {
   // Print userText[i]
}
```

- OK
- Bad

2)
```
for (i = 0; userText[i] != '\0'; ++i) {
   // Print userText[i]
}
```

- OK
- Bad

3)
```
for (i = 0; i < 10; ++i) {
   // Print userText[i]
}
```

- OK
- Bad

4)

```
for (i = 0; i < 4; ++i) {
   // Print userText[i]
}
```

- OK
- Bad

5) `userText = "Bus";`

- OK
- Bad

Yet another common error with C strings is for the program user to enter a string larger than the character array. That may cause the input statement to write to memory locations outside the array's locations, which may corrupt other parts of program or data, and typically causes the program to crash.

zyDE 5.7.1: Reading in a string too large for a C string.

Run the program, which simply reads an input string and prints it one character at a time. Then, lengthen the input string beyond 10 characters, and run again. The program *might* work, if the extra memory locations being assigned don't matter. Try larger and larger strings, and see if the program fails (be sure to scroll to the bottom of the output to look for erroneous output or an error message).

Load default template...

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

int main() {
   char userStr[10]; // Input string
   int i;

   // Prompt user for string input
   cout << "Enter string (<10 chars): ";
   cin >> userStr;

   // Print 1 char at a time
   cout << endl;
   for (i = 0; userStr[i] != '\0'; ++i) {
      cout << userStr[i] << endl;
   }
   cout << endl;

   return 0;
}
```

Hello

Run

C string usage is fraught with common errors. C++ introduced its own string type, as in `string myString;` and accessible after `#include <string>`, to reduce those errors and increase programmer convenience. C strings are still used in some legacy code and are thus good to learn. C++ provides common functions for handling C strings, which can be used by including the following: `#include <cstring>`.

The following program is for illustration, showing how a string is made up of individual character elements followed by a null character. Normally a programmer would not create a string that way.

Figure 5.7.3: A C string is an array of characters, ending with the null character.

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

int main() {
   char nameArr[5];

   nameArr[0] = 'A';
   nameArr[1] = 'l';
   nameArr[2] = 'a';
   nameArr[3] = 'n';
   nameArr[4] = '\0'; // Null character

   cout << nameArr << endl;

   nameArr[4] = '!';         // Oops, overwrote null char
   cout << nameArr << endl; // *Might* still work

   return 0;
}
```

```
Alan
Alan!
```


When printing a string stored within a character array, each character within the array will be printed until the null character is reached. If the null character is omitted, the program would print whatever values are found in memory after the array, until a null character happens to be encountered. Omitting the null character is a serious logical error.

It just so happens that the null character '\0' has an ASCII encoding of 0. Many compilers initialize memory to 0s. As such, omitting the '\0' in the above program would not always cause erroneous execution. Like a nail in the road, that bug in your code is just waiting to wreak havoc.

PARTICIPATION ACTIVITY 5.7.4: C string without null character.

Given:

```
char userText[10];
userText[0] = 'C';
userText[1] = 'a';
userText[2] = 'r';
userText[3] = '\0';
...
userText[3] = 's';
```

1) The first four characters in userText are now: Cars.

- True
- False

2) The compiler generates an error, because element 3 is the null character and can't be overwritten.

- True
- False

3) Printing userText should work fine because the new string is 4 characters, which is still much less than the array size of 10.

- True
- False

5.8 String library functions

C++ provides functions for working with C strings, presented in the ***cstring*** library. To use those functions, the programmer starts with: `#include <cstring>`.

Some C string functions for *modifying* strings are summarized below.

Table 5.8.1: Some C string modification functions.

Given:

```
char orgName[100] = "United Nations";
char userText[20] = "UNICEF";
char targetText[10];
```


strcpy()	`strcpy(destStr, sourceStr)`
	
	Copies sourceStr (up to and including null character) to destStr.
		`strcpy (targetText, userText); // Copies "UNICEF" + null char`
		
		`// to targetText`
		`strcpy (targetText, orgName);  // Error: "United Nations"`
		
		`// has > 10 chars`
		`targetText = orgName;`
		`// Error: Strings can't be`
		
		`// copied this way`

strncpy ()	`strncpy(destStr, sourceStr, numChars)` Copies up to numChars characters.	`strncpy (orgName, userText, 6);` `// orgName is "UNICEF Nations"`
strcat()	`strcat(destStr, sourceStr)` Copies sourceStr (up to and including null character) to *end* of destStr (starting at destStr's null character).	`strcat (orgName, userText); // orgName is "United NationsUNICEF"`

strncat ()	`strncat(destStr, sourceStr, numChars)`
	
	Copies up to numChars characters to destStr's end, then appends null character.
		`strcpy (targetText, "abc");`
		`// targetText is "abc"`
		`strncat (targetText, "123456789", 3); // targetText is "abc123"`

For strcpy(), a common error is to copy a source string that is too large, causing an out-of-range access in the destination string. Another common error is to call strcpy with the source string first rather than the destination string, which copies in the wrong direction.

Note that string assignment, as in targetText = orgName, does not copy the string and should not be used. The exception is during initialization, as in `char userText[20] = "UNICEF";`, for which the compiler copies the string literal's characters into the array.

PARTICIPATION ACTIVITY 5.8.1: String modification functions.

Given: char userStr[5];
Do not type quotes in your answers.
If the function call is incorrect, causes an out-of-range access, or the resulting string does not end with a null character, type Error.

1) What is userStr after: strcpy(userStr, "Bye");

Check Show answer

2) If userStr is initially "Hi", what is userStr after: strcpy(userStr, "Bye");

Check Show answer

3) What is userStr after: strcpy(userStr, "Goodbye");

Check Show answer

4) If userStr is initially "Hi, Sema", what is userStr after: strncpy(userStr, "Bye", 3);

Check Show answer

5) What is userStr after: strncpy(userStr, "Goodbye", 4);

Check Show answer

6) If userStr is initially "Hi", what is userStr after: strcat(userStr, '!');

Check Show answer

7) If userStr is initially "Hi", what is userStr after: strcat(userStr, "!");

Check Show answer

8)

If userStr is initially "Hi", what is userStr after: strncat(userStr, "?!$#@%", 2);

Check Show answer

Several C string functions that get *information* about strings are summarized below.

Table 5.8.2: Some C string information functions.

Given:

```
char orgName[100] = "United Nations";
char userText[20] = "UNICEF";
char targetText[10];
```

strchr()	`strchr(sourceStr, searchChar)`
	
	Returns NULL if searchChar does not exist in sourceStr. (Else, returns address of first occurrence, discussed elsewhere).
	NULL is defined in the cstring library.
		`if (strchr(orgName, 'U') != NULL) { // 'U' exists in orgName?`
		`  ...  // 'U' exists in "United Nations", branch taken`
		`}`
		`if (strchr(orgName, 'u') != NULL) { // 'u' exists in orgName?`
		`  ...  // 'u' doesn't exist (case matters), branch not taken`
		`}`

strlen()	`size_t strlen(sourceStr)`
	
	Returns number of characters in sourceStr up to, but not including, first null character. size_t is integer type.
		`x = strlen(orgName);  // Assigns 14 to x`
		`x = strlen(userText);  // Assigns 6 to x`
		`x = strlen(targetText); // Error: targetText may lack null char`

strcmp()	`int strcmp(str1, str2)`
	
	Returns 0 if str1 and str2 are equal, non-zero if they differ.
		`if (strcmp(orgName, "United Nations") == 0) {`
		`  ... // Equal, branch taken`
		`}`
		`if (strcmp(orgName, userText) == 0) {`
		`  ... // Not equal, branch not taken`
		`}`

strcmp() is usually used to compare for equality, returning 0 if the strings are the same length and have identical characters. A common error is to use == when comparing C strings, which does not work. str1 == str2 compares the strings' addresses, not their contents. Because those addresses will usually be different, str1 == str2 will evaluate to 0. This is not a syntax error, but clearly a logic error. Another common error is to forget to compare the result of strcmp with 0, as in `if (strcmp(str1, str2)) {...}`. The code is not a syntax error, but is a logic error because the if condition will be false (0) when the strings are equal. The correct condition would instead be `if (strcmp(str1, str2) == 0) {...}`. Although strcmp returns 0, a good practice is to avoid using `if (!strcmp(str1,str2)) {...}` because that 0 does not represent "false" but rather is encoding a particular situation.

strcmp(str1, str2) returns a negative number if str1 is less than str2, and a positive number if str1 is greater than str2. Evaluation first compares the character pair at element 0, then at element 1, etc., returning as soon as a pair differs.

PARTICIPATION ACTIVITY 5.8.2: String comparison.

Animation captions:

1. Each comparison uses ASCII values.
2. Values at indexes 0-4 are the same for both student_name and teacher_name.
3. 'J' is greater than 'A', so student_name is greater than teacher_name.

strlen is often used to iterate through each string character in a loop.

Figure 5.8.1: Iterating through a C string using strlen.


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

int main() {
   char userName[15] = "Alan Turing";
   int i;

   cout << "Before: " << userName << endl;

   for (i = 0; i < strlen(userName); ++i) {
      if (userName[i] == ' ') {
         userName[i] = '_';
      }
   }
   cout << "After:  " << userName << endl;

   return 0;
}
```

```
Before: Alan Turing
After:  Alan_Turing
```

PARTICIPATION ACTIVITY 5.8.3: Some C string library functions.

Animation captions:

1. The strlen() function returns the number of characters in str1 up to, but not including, the first null character.
2. The strcpy() function copies str2 to str1, up to and including str2's null character.
3. The strcat() function starts at str1's null character, then copies str2 to str1, up to and including str2's null character.
4. The strchr() function returns the address of the first occurrence of 'w' in str1. If 'w' does not exist in str1, then the strchr() function returns NULL.

PARTICIPATION ACTIVITY 5.8.4: String information functions.

Given:

```
char str1[10] = "Earth";
char str2[20] = "Earthlings";
char str3[15] = "Mars";
```


Answer the following questions. If appropriate, type: Error

1) What does strlen(str3) return?

Check Show answer

2)

Is the branch taken? (Yes/No/Error)

```
if  (strchr(str1, '@') != NULL) {
   // Print "Found @"
}
```

Check Show answer

3) Is the branch taken? (Yes/No/Error)


```
if  (strchr(str1, 'E') != NULL) {
   // Print "Found E"
}
```

Check Show answer

4) Is the branch taken? (Yes/No/Error)

```
if  (strchr(str2, "Earth") != NULL) {
   // Print "Found Earth"
}
```

Check Show answer

5) Is the branch taken? (Yes/No/Error)

```
if (strcmp(str1, str2) == 0) {
   // Print "strings are equal"
}
```

Check Show answer

6) Is the branch taken? (Yes/No/Error)

```
if (str1 == str3) {
   // Print "strings are equal"
}
```

Check Show answer

7) Finish the code to take the branch if str1 and str3 are equal.

```
if (strcmp(str1, str3)
        ) {
   // Strings are equal
}
```


Check Show answer

Exploring further:

- More C string functions from cplusplus.com

5.9 Two-dimensional arrays

An array can be declared with two dimensions. `int myArray[R][C]` represents a table of int variables with R rows and C columns, so R*C elements total. For example, `int myArray[2][3]` creates a table with 2 rows and 3 columns, for 6 int variables total. Example accesses are `myArray[0][0] = 33;` or `num = myArray[1][2]`.

PARTICIPATION ACTIVITY 5.9.1: Two-dimensional array.

Animation captions:

1. Conceptually, a two-dimensional array is a table with rows and columns.
2. A two-dimensional array is implemented in a one-dimensional memory by placing each row following the previous row.

Conceptually, a two-dimensional array is a table with rows and columns. The compiler maps two-dimensional array elements to one-dimensional memory, each row following the previous row, known as ***row-major order***.

Figure 5.9.1: Using a two-dimensional array: A driving distance between cities example.

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

/* Direct driving distances between cities, in miles */
/* 0: Boston  1: Chicago  2: Los Angeles */

int main() {
   int cityA;                  // Starting city
   int cityB;                  // Destination city
   int DrivingDistances[3][3]; // Driving distances

   // Initialize distances array
   DrivingDistances[0][0] = 0;
   DrivingDistances[0][1] = 960;  // Boston-Chicago
   DrivingDistances[0][2] = 2960; // Boston-Los Angeles
   DrivingDistances[1][0] = 960;  // Chicago-Boston
   DrivingDistances[1][1] = 0;
   DrivingDistances[1][2] = 2011; // Chicago-Los Angeles
   DrivingDistances[2][0] = 2960; // Los Angeles-Boston
   DrivingDistances[2][1] = 2011; // Los Angeles-Chicago
   DrivingDistances[2][2] = 0;

   cout << "0: Boston  1: Chicago  2: Los Angeles" << endl;

   cout << "Enter city pair (Ex: 1 2) -- ";
   cin >> cityA;
   cin >> cityB;

   if ((cityA >= 0) && (cityA <= 2) && (cityB >= 0) && (cityB
<= 2)) {
      cout << "Distance: " << DrivingDistances[cityA][cityB];
      cout << " miles." << endl;
   }

   return 0;
}
```

```
0: Boston  1: Chicago  2: Los
Angeles
Enter city pair (Ex: 1 2) -- 1 2
Distance: 2011 miles.

...

0: Boston  1: Chicago  2: Los
Angeles
Enter city pair (Ex: 1 2) -- 2 0
Distance: 2960 miles.

...

0: Boston  1: Chicago  2: Los
Angeles
Enter city pair (Ex: 1 2) -- 1 1
Distance: 0 miles.
```


A programmer can initialize a two-dimensional array's elements during declaration using nested braces, as below. Multiple lines make the rows and columns more visible.

Construct 5.9.1: Initializing a two-dimensional array during declaration.

```
// Initializing a 2D array
int numVals[2][3] = { {22, 44, 66}, {97, 98, 99} };

// Use multiple lines to make rows more visible
int numVals[2][3] = {
   {22, 44, 66}, // Row 0
   {97, 98, 99}  // Row 1
};
```


Arrays of three or more dimensions can also be declared, as in `int myArray[2][3][5]`, which declares a total of 2*3*5 or 30 elements. Note the rapid growth in size -- an array declared as `int myArray[100][100][5][3]` would have 100*100*5*3 or 150,000 elements. A programmer should make sure not to unnecessarily occupy available memory with a large array.

PARTICIPATION ACTIVITY 5.9.2: Two-dimensional arrays.

1) Declare a two dimensional array of integers named dataVals with 4 rows and 7 columns.

Check Show answer

2) How many total elements are in an array with 4 rows and 7 columns?

Check Show answer

3) How many elements are in the array declared as: char streetNames[20][50];

Check Show answer

4) Write a statement that assigns 99 into the fifth row, third column of array dataVals. Note: the first row/column is at index 0, not 1.

Check Show answer

CHALLENGE ACTIVITY 5.9.1: Find 2D array max and min.

Find the maximum value and minimum value in milesTracker. Assign the maximum value to maxMiles, and the minimum value to minMiles. Sample output for the given program:

```
Min miles: -10
Max miles: 40
```

(Notes)

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

int main() {
   const int NUM_ROWS = 2;
   const int NUM_COLS = 2;
   int milesTracker[NUM_ROWS][NUM_COLS];
   int i;
   int j;
   int maxMiles = -99; // Assign with first element in milesTracker before loop
   int minMiles = -99; // Assign with first element in milesTracker before loop

   milesTracker[0][0] = -10;
   milesTracker[0][1] = 20;
   milesTracker[1][0] = 30;
   milesTracker[1][1] = 40;

   /* Your solution goes here  */

   cout << "Min miles: " << minMiles << endl;
   cout << "Max miles: " << maxMiles << endl;
```


Run

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5.10 Vectors

Vector declaration and accessing elements

A programmer commonly needs to maintain a list of items, just as people often maintain lists of items like a grocery list or a course roster. A ***vector*** is an ordered list of items of a given data type. Each item in a vector is called an ***element***. A programmer must include the statement `#include <vector>` at the top of the file when planning to use vectors.

Construct 5.10.1: Vector declaration.

```
vector<dataType> vectorName(numElements);
```

The statement above declares a vector with the specified number of elements, each element of the specified data type. The type of each vector element is specified within the angle brackets (<>). The number of vector elements is specified within parentheses following the vector name. Ex: `vector<int> gameScores(4);` declares a vector gamesScores with 4 integer elements.

Terminology note: { } are ***braces***. < > are ***angle brackets***, or ***chevrons***. In a vector access, the number in .at() parentheses is called the ***index*** of the corresponding element. The first vector element is at index 0.

If you have studied arrays, then know that a vector was added to C++ as a safer and more powerful form of arrays, discussed elsewhere.

PARTICIPATION ACTIVITY 5.10.1: A vector declaration creates multiple variables in memory, each accessible using .at().

Animation captions:

1. A vector named itemCounts is declared. The vector consists of 3 elements, each of data type int.
2. An element is accessed with the at() function. The number in parentheses is the index of the corresponding element.

PARTICIPATION ACTIVITY 5.10.2: Vector basics.

Given:

```
vector<int> yearsList(4);

yearsList.at(0) = 1999;
yearsList.at(1) = 2012;
yearsList.at(2) = 2025;
```

1) How many elements does the vector declaration create?

- 0
- 1
- 3
- 4

2) With what value is yearsList.at(1) assigned?

- 1
- 1999
- 2012

3) With what value does `currYear = yearsList.at(2)` assign currYear?

- 2
- 2025
- Invalid index

4) Is `currYear = yearsList.at(4)` a valid assignment?

- Yes, the fourth element is accessed.
- No, yearsList.at(4) does not exist.

5) What is the proper way to access the *first* element in vector yearsList?

- yearsList.at(1)
- yearsList.at(0)

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6) What are the contents of the vector if the above code is followed by the statement: yearsList.at(0) = yearsList.at(2)?

- 1999, 2012, 1999, 0
- 2012, 2012, 2025, 0
- 2025, 2012, 2025, 0

7) What is the index of the *last* element for the following vector: `vector<int> pricesList(100);`

- 99
- 100
- 101

Using an expression for a vector index

A powerful aspect of vectors is that the index is an expression. Ex: userNums.at(i) uses the value held in the int variable i as the index. As such, a vector is useful to easily lookup the Nth item in a list.

A vector's index must be an integer type. The vector index cannot be a floating-point type, even if the value is 0.0, 1.0, etc.

The program below allows a user to print the age of the Nth oldest known person to have ever lived. The program quickly accesses the Nth oldest person's age using `oldestPeople.at(nthPerson - 1)`. Note that the index is `nthPerson - 1` rather than just `nthPerson` because a vector's indices start at 0, so the 1st age is at index 0, the 2nd at index 1, etc.

Figure 5.10.1: Vector's ith element can be directly accessed using .at(i): Oldest people program.

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

int main() {
   vector<int> oldestPeople(5);
   int nthPerson;               // User input, Nth oldest
person

   oldestPeople.at(0) = 122; // Died 1997 in France
   oldestPeople.at(1) = 119; // Died 1999 in U.S.
   oldestPeople.at(2) = 117; // Died 1993 in U.S.
   oldestPeople.at(3) = 117; // Died 1998 in Canada
   oldestPeople.at(4) = 116; // Died 2006 in Ecuador

   cout << "Enter N (1..5): ";
   cin  >> nthPerson;

   if ((nthPerson >= 1) && (nthPerson <= 5)) {
      cout << "The " << nthPerson << "th oldest person
lived ";
      cout << oldestPeople.at(nthPerson - 1) << " years."
<< endl;
   }

   return 0;
}
```

```
Enter N (1..5): 1
The 1th oldest person lived 122
years.

...

Enter N (1..5): 4
The 4th oldest person lived 117
years.

...

Enter N (1..5): 9

...

Enter N (1..5): 0

...

Enter N (1..5): 5
The 5th oldest person lived 116
years.
```

PARTICIPATION ACTIVITY 5.10.3: Nth oldest person program.

1) In the program above, what is the purpose of this check:

```
if ((nthPerson >= 1) && (nthPerson <=
5)) {
   ...
}
```

- To avoid overflow because nthPerson's data type can only store values from 1 to 5.

To ensure only valid vector elements are accessed because the vector oldestPeople only has 5 elements.

PARTICIPATION ACTIVITY 5.10.4: Vector declaration and accesses.

1) Declare a vector named myVals that stores 10 items of type int.

Check Show answer

2) Assign x with the value stored at index 8 of vector myVals.

Check Show answer

3) Given myVals has 10 elements, assign the last element in myVals with the value 555.

Check Show answer

4) Assign myVals' element at the index held in currIndex with the value 777.

Check Show answer

5) Assign tempVal with the myVals' element at the index one after the value held in variable i.

Check Show answer

Loops and vectors

A key advantage of vectors becomes evident when used in conjunction with loops. The program below uses a loop to allow a user to enter 8 integer values, storing those values in a vector, and then printing those 8 values.

A vector's ***size()*** function returns the number of vector elements. Ex: In the program below, userVals.size() is 8 because the vector was declared with 8 elements.

Figure 5.10.2: Vectors combined with loops are powerful together: User-entered numbers.

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

int main() {
   const int NUM_VALS = 8;          // Number of elements in
vector
   vector<int> userVals(NUM_VALS); // User values
   unsigned int i;                 // Loop index

   cout << "Enter " << NUM_VALS << " integer values..." <<
endl;
   for (i = 0; i < userVals.size(); ++i) {
      cout << "Value: ";
      cin >> userVals.at(i);
   }

   cout << "You entered: ";
   for (i = 0; i < userVals.size(); ++i) {
      cout << userVals.at(i) << " ";
   }
   cout << endl;

   return 0;
}
```

```
Enter 8 integer values...
Value: 5
Value: 99
Value: -1
Value: -44
Value: 8
Value: 555555
Value: 0
Value: 2
You entered: 5 99 -1 -44 8 555555
0 2
```


PARTICIPATION ACTIVITY 5.10.5: Vector with loops.

Refer to the program above.

1) How many times does each for loop iterate?

- 1
- 8
- Unknown

2) Which one line of code can be changed to allow the user to enter 100 elements?

- `const int NUM_VALS = 8;`
- `for (i = 0; i < userVals.size(); ++i) {`

Vector initialization

A vector's elements are automatically initialized to 0s during the vector declaration.

All of a vector's elements may be initialized to another single value. Ex: `vector<int> myVector(3, -1);` creates a vector named myVector with three elements, each with value -1.

A programmer may initialize each vector element with different values by specifying the initial values in braces {} separated by commas. Ex: `vector<int> carSales = {5, 7, 11};` creates a vector of three integer elements initialized with values 5, 7, and 11. Such vector declaration and initialization does not require specifying the vector size, because the vector's size is automatically set to the number of elements within the braces. For a larger vector, initialization may be done by first declaring the vector, and then using a loop to assign vector elements.

PARTICIPATION ACTIVITY 5.10.6: Vector initialization.

1) Write a single statement to declare a vector of ints named salesGoals with 4 elements each initialized to 10.

Check Show answer

2) Given the following, what is maxScores.at(3)?

```
vector<int> maxScores = {20, 20, 100,
50};
```

Check Show answer

Common error: Forgetting to include <vector>

A common error is to forget the #include <vector> at the top of the file when using vectors. Trying to then declare a vector variable may yield a strange compiler error message, such as:

```
testfile.cpp:12: error: ISO C++ forbids declaration of vector with no type
testfile.cpp:12: error: expected ; before < token
```

The same error message may be seen if the vector library is included but the namespace std is not used.

CHALLENGE ACTIVITY 5.10.1: Enter the output for the vector.

Start

Type the program's output.

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

int main() {
   const int NUM_ELEMENTS = 3;
   vector<int> userVals(NUM_ELEMENTS);
   unsigned int i;

   userVals.at(0) = 2;
   userVals.at(1) = 4;
   userVals.at(2) = 8;

   for (i = 0; i < userVals.size(); ++i) {
      cout << userVals.at(i) << endl;
   }

   return 0;
}
```

2
4
8

1 2 3 4

Check Next

CHALLENGE ACTIVITY 5.10.2: Printing vector elements.

Write three statements to print the first three elements of vector runTimes. Follow each with a newline. Ex: If runTime = {800, 775, 790, 805, 808}, print:

```
800
775
790
```

Note: These activities may test code with different test values. This activity will perform two tests, the first with a 5-element vector (vector<int> runTimes(5)), the second with a 4-element vector (vector<int> runTimes(4)). See "How to Use zyBooks".

Also note: If the submitted code tries to access an invalid vector element, such as runTime.at(9) for a 5-element vector, the test may generate strange results. Or the test may crash and report "Program end never reached", in which case the system doesn't print the test case that caused the reported message.

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

int main() {
   vector<int> runTimes(5);

   // Populate vector
   runTimes.at(0) = 800;
   runTimes.at(1) = 775;
   runTimes.at(2) = 790;
   runTimes.at(3) = 805;
   runTimes.at(4) = 808;

   /* Your solution goes here  */

   return 0;
}
```

Run

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CHALLENGE ACTIVITY 5.10.3: Printing vector elements with a for loop.

Write a for loop to print all NUM_VALS elements of vector courseGrades, following each with a space (including the last). Print forwards, then backwards. End with newline. Ex: If courseGrades = {7, 9, 11, 10}, print:

```
7 9 11 10
10 11 9 7
```

Hint: Use two for loops. Second loop starts with i = NUM_VALS - 1. (Notes)

Note: These activities may test code with different test values. This activity will perform two tests, the first with a 4-element vector (vector<int> courseGrades(4)), the second with a 2-element vector (vector<int> courseGrades(2)). See "How to Use zyBooks".

Also note: If the submitted code tries to access an invalid vector element, such as courseGrades.at(9) for a 4-element vector, the test may generate strange results. Or the test may crash and report "Program end never reached", in which case the system doesn't print

the test case that caused the reported message.

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

int main() {
   const int NUM_VALS = 4;
   vector<int> courseGrades(NUM_VALS);
   int i;

   courseGrades.at(0) = 7;
   courseGrades.at(1) = 9;
   courseGrades.at(2) = 11;
   courseGrades.at(3) = 10;

   /* Your solution goes here  */

   return 0;
}
```


Run

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5.11 Iterating through vectors

Iterating through vectors using loops

Iterating through vectors using loops is commonplace and is an important programming skill to master. Because vector indices are numbered 0 to N - 1 rather than 1 to N, programmers commonly use this for loop structure:

Figure 5.11.1: Common for loop structure for iterating through a vector.

```
// Iterating through myVector
for (i = 0; i < myVector.size(); ++i) {
   // Loop body accessing myVector.at(i)
}
```

Note that index variable i is initialized to 0, and the loop expression is i < myVector.size() rather than i <= myVector.size (). If myVector.size() were 5, the loop's iterations would set i to 0, 1, 2, 3, and 4, for a total of 5 iterations. The benefit of the loop structure is that each vector element is accessed as myVector.at(i) rather than the more complex myVector.at (i - 1).

PARTICIPATION ACTIVITY 5.11.1: Iterating through a vector.

1) Complete the code to print all items for the given vector, using the above common loop structure.

```
vector<int> daysList(365);
```

```
for (i = 0;
                    ; ++i) {
   cout << daysList.at(i) <<
endl;
}
```

Check Show answer

2) Given that this loop iterates over all items of the vector, how many items are in the vector?


```
for (i = 0; i < 99; ++i) {
   cout << someVector.at(i) << endl;
}
```

Check Show answer

Determining a quantity about a vector's items

Iterating through a vector for various purposes is an important programming skill to master. Programs commonly iterate through vectors to determine some quantity about the vector's items. The example below computes the sum of a vector's element values.

Figure 5.11.2: Iterating through a vector example: Program that finds the sum of a vector's elements.

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

int main() {
   const int NUM_ELEMENTS = 8;          // Number of elements in vector
   vector<int> userVals(NUM_ELEMENTS); // User values
   unsigned int i;                      // Loop index
   int sumVal;                          // For computing sum

   cout << "Enter " << NUM_ELEMENTS << " integer values..." << endl;
   for (i = 0; i < userVals.size(); ++i) {
      cout << "Value: ";
      cin >> userVals.at(i);
      cout << endl;
   }

   // Determine sum
   sumVal = 0;
   for (i = 0; i < userVals.size(); ++i) {
      sumVal = sumVal + userVals.at(i);
   }
   cout << "Sum: " << sumVal << endl;

   return 0;
}
```

```
Enter 8 integer values...
Value: 3
Value: 5
Value: 234
Value: 346
Value: 234
Value: 73
Value: 26
Value: -1
Sum: 920
```


Finding the maximum value in a vector

The program below determines the maximum value in a user-entered list. If the user enters numbers 7, -9, 55, 44, 20, -400, 0, 2, then the program will output "max: 55". The program uses the variable maxVal to store the largest value seen thus far as the program iterates through the vector. During each iteration, if the vector's current element value is larger than the max seen thus far, the program assigns maxVal with the current vector element.

Before entering the loop, maxVal must be initialized to some value because maxVal will be compared with each vector element's value. A logical error would be to initialize maxVal to 0, because 0 is not in fact the largest value seen so far, and would result in incorrect output (of 0) if the user entered all negative numbers. Instead, the program peeks at a vector element (in this case the first element, though any element could be used) and initializes maxVal with that element's value.

Figure 5.11.3: Iterating through a vector example: Program that finds the max item.


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

int main() {
   const int NUM_VALS = 8;          // Number of elements in vector
   vector<int> userVals(NUM_VALS); // User values
   unsigned int i;                 // Loop index
   int maxVal;                     // Computed max

   cout << "Enter " << NUM_VALS << " integer numbers..." << endl;
   for (i = 0; i < userVals.size(); ++i) {
      cout << "Value: ";
      cin >> userVals.at(i);
      cout << endl;
   }

   // Determine largest (max) number
   maxVal = userVals.at(0);        // Largest so far
   for (i = 0; i < userVals.size(); ++i) {
      if (userVals.at(i) > maxVal) {
         maxVal = userVals.at(i);
      }
   }
   cout << "Max: " << maxVal << endl;

   return 0;
}
```

```
Enter 8 integer values...
Value: 3
Value: 5
Value: 23
Value: -1
Value: 456
Value: 1
Value: 6
Value: 83
Max: 456

...

Enter 8 integer values...
Value: -5
Value: -10
Value: -44
Value: -2
Value: -27
Value: -9
Value: -27
Value: -9
Max: -2
```

PARTICIPATION ACTIVITY 5.11.2: Iterating through vectors.

Complete the code provided to achieve the desired goal.

1) Find the minimum element value in vector `valsVctr`.

```
tempVal = valsVctr.at(0);
for (i = 0; i < valsVctr.size
(); ++i) {
   if (valsVctr.at(i) <
                        ) {
      tempVal= valsVctr.at(i);
   }
}
```

Check **Show answer**

2) Find the sum of all elements in vector `valsVctr`.

```
valSum = [                    ]
;
for (i = 0; i < valsVctr.size
(); ++i) {
   valSum += valsVctr.at(i);
}
```

Check Show answer

3) Count the number of negative-valued elements in vector `valsVctr`.

```
numNeg = 0;
for (i = 0; i < valsVctr.size
(); ++i) {
   if (valsVctr.at(i) < 0) {
      numNeg =
[                    ];
   }
}
```

Check Show answer

zyDE 5.11.1: Computing the average of a vector's element values.

Complete the code to compute the average of the vector's element values. The result should be 16.

Load default template... Run

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

int main() {
   const int VALS_SIZE = 6;
   vector<int> valsVctr(VALS_SIZE);
   unsigned int i;
   int sumVal;
   int avgVal;

   valsVctr.at(0) = 30;
   valsVctr.at(1) = 20;
   valsVctr.at(2) = 20;
   valsVctr.at(3) = 15;
   valsVctr.at(4) = 5;
   valsVctr.at(5) = 10;

   sumVal = 0;
   avgVal = 0;
   /* FIXME: Write for loop to iterate through vector */
```

Common error: Accessing out of range vector element

A common error is to try to access a vector with an index that is out of the vector's index range. Ex: Trying to access highScores.at(8) when highScores valid indices are 0-7. Care should be taken whenever a user enters a number that is then used as a vector index, and when using a loop index as a vector index also, to ensure the array index is within a vector's valid index range. Accessing an index that is out of range causes the program to automatically abort execution, typically with an error message being automatically printed. For example, for the declaration `vector highScores(8)`, accessing highScores.at(8), or highScores.at(i) where i is 8, yields the following error message when running the program compiled with g++:

Figure 5.11.4: Sample error message when accessing an out of range vector index

```
terminate called after throwing an instance of 'std::out_of_range'
  what():  vector::_M_range_check
Abort
```

zyDE 5.11.2: Loop expressions.

Run the program, which prints the contents of the vals vector. Modify the program's loop expression to be `i <= VALS_SIZE` rather than `i < VALS_SIZE`, and observe that the program aborts.

Load default template...

Run

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

int main() {
   const int VALS_SIZE = 6;
   vector<int> myVals(VALS_SIZE);
   unsigned int i;

   myVals.at(0) = 30;
   myVals.at(1) = 20;
   myVals.at(2) = 20;
   myVals.at(3) = 15;
   myVals.at(4) = 5;
   myVals.at(5) = 10;

   for( i = 0; i < myVals.size(); ++i){
      cout << "myVals.at(" << i << ") = " << myVals.at(i
   }
```

PARTICIPATION ACTIVITY 5.11.3: Iterating through a vector.

Given the following code:

```
const int NUM_ELEMENTS = 5;
vector<int> myVctr(NUM_ELEMENTS);
unsigned int i;
```

1) The normal for loop structure iterates as long as: `i <= myVctr.size()`

- True
- False

2) To compute the sum of elements, a reasonable statement preceding the for loop is: `sumVal = 0;`

- True
- False

3) To find the maximum element value, a reasonable statement preceding the for loop is: `maxVal = 0;`

- True
- False

CHALLENGE ACTIVITY 5.11.1: Enter the output for the vector.

Start

Type the program's output.

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

int main() {
   const int NUM_ELEMENTS = 3;
   vector<int> userVals(NUM_ELEMENTS);
   unsigned int i;

   userVals.at(0) = 1;
   userVals.at(1) = 9;
   userVals.at(2) = 5;

   for (i = 0; i < userVals.size(); ++i) {
      cout << userVals.at(i) << endl;
   }

   return 0;
}
```

```
1
9
5
```


1 | 2 | 3 | 4 | 5

Check Next

CHALLENGE ACTIVITY 5.11.2: Finding values in vectors.

Set numMatches to the number of elements in userValues (having NUM_VALS elements) that equal matchValue. Ex: If matchValue = 2 and userValues = {2, 2, 1, 2}, then numMatches = 3. (Notes)

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

int main() {
   const int NUM_VALS = 4;
   vector<int> userValues(NUM_VALS);
   unsigned int i;
   int matchValue;
   int numMatches = -99; // Assign numMatches with 0 before your for loop

   userValues.at(0) = 2;
   userValues.at(1) = 2;
   userValues.at(2) = 1;
   userValues.at(3) = 2;

   matchValue = 2;

   /* Your solution goes here  */

   cout << "matchValue: " << matchValue << ", numMatches: " << numMatches << endl;
```

Run

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CHALLENGE ACTIVITY 5.11.3: Populating a vector with a for loop.

Write a for loop to populate vector userGuesses with NUM_GUESSES integers. Read integers using cin. Ex: If NUM_GUESSES is 3 and user enters 9 5 2, then userGuesses is {9, 5, 2}.

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

int main() {
   const int NUM_GUESSES = 3;
   vector<int> userGuesses(NUM_GUESSES);
   unsigned int i;

   /* Your solution goes here  */

   for (i = 0; i < userGuesses.size(); ++i) {
      cout << userGuesses.at(i) << " ";
   }

   return 0;
}
```


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CHALLENGE ACTIVITY 5.11.4: Vector iteration: Sum of excess.

Vector testGrades contains NUM_VALS test scores. Write a for loop that sets sumExtra to the total extra credit received. Full credit is 100, so anything over 100 is extra credit. Ex: If testGrades = {101, 83, 107, 90}, then sumExtra = 8, because 1 + 0 + 7 + 0 is 8.

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

int main() {
   const int NUM_VALS = 4;
   vector<int> testGrades(NUM_VALS);
   unsigned int i;
   int sumExtra = -9999; // Assign sumExtra with 0 before your for loop

   testGrades.at(0) = 101;
   testGrades.at(1) = 83;
   testGrades.at(2) = 107;
   testGrades.at(3) = 90;

   /* Your solution goes here  */

   cout << "sumExtra: " << sumExtra << endl;
   return 0;
}
```

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CHALLENGE ACTIVITY 5.11.5: Printing vector elements separated by commas.

Write a for loop to print all NUM_VALS elements of vector hourlyTemp. Separate elements with a comma and space. Ex: If hourlyTemp = {90, 92, 94, 95}, print:

```
90, 92, 94, 95
```

Your code's output should end with the last element, without a subsequent comma, space, or newline.

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

int main() {
   const int NUM_VALS = 4;
   vector<int> hourlyTemp(NUM_VALS);
   unsigned int i;

   hourlyTemp.at(0) = 90;
   hourlyTemp.at(1) = 92;
   hourlyTemp.at(2) = 94;
   hourlyTemp.at(3) = 95;

   /* Your solution goes here  */

   cout << endl;

   return 0;
}
```


Run

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5.12 Multiple vectors

Programmers commonly use multiple same-sized vectors to store related lists. The program below maintains a list of country names, and another list indicating average minutes of TV watched per day in each corresponding country.

The statement `if (ctryNames.at(i) == userCountry)` compares the current ctryNames element with the user-entered country name. If the names match, the program prints the ctryMins element at the same index.

The loop's expression `(i < ctryNames.size()) && (!foundCountry)` depends on the value of the variable foundCountry. This expression prevents the loop from iterating through the entire vector once the correct country is found.

The program's numbers aren't made up, by the way: Americans watch nearly 5 hours of TV per day on average.

Figure 5.12.1: Multiple vector example: TV watching time program.

```
Enter country name: USA
People in USA watch 274 mins of TV
daily.

...

Enter country name: Sweden
People in Sweden watch 154 mins of
TV daily.

...

Enter country name: Brazil
Country not found; try again.
```

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

int main() {
   // Source: www.statista.com, 2015
   const int NUM_COUNTRIES = 5;              // Num countries
supported
   vector<string> ctryNames(NUM_COUNTRIES); // Country names
   vector<int>    ctryMins(NUM_COUNTRIES);  // Mins TV
watched daily
   string userCountry;                       // User defined
country
   bool foundCountry = false;                // Match to
country supported
   unsigned int i;                           // Loop index

   // Fill vector contents
   ctryNames.at(0) = "China";
   ctryMins.at(0) = 155;

   ctryNames.at(1) = "Sweden";
   ctryMins.at(1) = 154;

   ctryNames.at(2) = "Russia";
   ctryMins.at(2) = 246;

   ctryNames.at(3) = "UK";
   ctryMins.at(3) = 216;

   ctryNames.at(4) = "USA";
   ctryMins.at(4) = 274;

   // Prompt user for country name
   cout << "Enter country name: ";
   cin >> userCountry;

   // Find country's index and average TV time
   foundCountry = false;
   for (i = 0; (i < ctryNames.size()) && (!foundCountry);
++i) {
      if (ctryNames.at(i) == userCountry) {
         foundCountry = true;
         cout << "People in " << userCountry << " watch ";
         cout << ctryMins.at(i) << " mins of TV daily." <<
endl;
      }
   }
   if (!foundCountry) {
      cout << "Country not found; try again." << endl;
   }

   return 0;
}
```


PARTICIPATION ACTIVITY 5.12.1: Multiple vectors.

Consider the above TV watching program involving multiple vectors.

1) Multiple vectors saved memory over using one larger vector.

- True
- False

2) Each vector should be the same data type.

- True
- False

3) Each vector should have the same number of elements.

- True

○ False

zyDE 5.12.1: Improve the TV watching time program.

Modify the program such that if a user types a country name that isn't found, print a list of known countries.

Load default template...

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

int main() {
   // Source: www.statista.com, 2015
   const int NUM_COUNTRIES = 5;              // Num count
   vector<string> ctryNames(NUM_COUNTRIES); // Country r
   vector<int>    ctryMins(NUM_COUNTRIES);  // Mins TV w
   string userCountry;                       // User defi
   bool foundCountry = false;                // Match to
   unsigned int i;                           // Loop inde

   // Fill vector contents
   ctryNames.at(0) = "China";
   ctryMins.at(0) = 155;

   ctryNames.at(1) = "Sweden";
   ctryMins.at(1) = 154;
```

USA

Run

CHALLENGE ACTIVITY 5.12.1: Printing the sum of two vector elements.

Add each element in origList with the corresponding value in offsetAmount. Print each sum followed by a space. Ex: If origList = {40, 50, 60, 70} and offsetAmount = {5, 7, 3, 0}, print:

```
45 57 63 70
```

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

int main() {
   const int NUM_VALS = 4;
   vector<int> origList(NUM_VALS);
   vector<int> offsetAmount(NUM_VALS);
   unsigned int i;

   origList.at(0) = 40;
   origList.at(1) = 50;
   origList.at(2) = 60;
   origList.at(3) = 70;

   offsetAmount.at(0) = 5;
   offsetAmount.at(1) = 7;
   offsetAmount.at(2) = 3;
   offsetAmount.at(3) = 0;

   /* Your solution goes here  */
```


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CHALLENGE ACTIVITY 5.12.2: Multiple vectors: Key and value.

For any element in keysList with a value greater than 100, print the corresponding value in itemsList, followed by a space. Ex: If keysList = {42, 105, 101, 100} and itemsList = {10, 20, 30, 40}, print:

```
20 30
```

Since keysList[1] and keysList[2] have values greater than 100, the value of itemsList[1] and itemsList[2] are printed.


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

int main() {
   const int SIZE_LIST = 4;
   vector<int> keysList(SIZE_LIST);
   vector<int> itemsList(SIZE_LIST);
   unsigned int i;

   keysList.at(0) = 42;
   keysList.at(1) = 105;
   keysList.at(2) = 101;
   keysList.at(3) = 100;

   itemsList.at(0) = 10;
   itemsList.at(1) = 20;
   itemsList.at(2) = 30;
   itemsList.at(3) = 40;

   /* Your solution goes here  */
```

Run

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5.13 Vector resize

Commonly, the size of a list of items is not known during a program's compile time. Thus, a vector's size need not be specified in the vector's declaration. Instead, a vector's size can be set or changed while a program executes using ***resize(N)***. Ex: `highScore.resize(10)` resizes the highScores vector to have 10 elements.

resize() can be called multiple times. If the new size is larger, resize() adds elements at the end. If smaller, resize() deletes elements from the end. If userScores has size 3 (elements 0, 1, 2), `userScores.resize(2);` would delete element 2, leaving elements 0 and 1. A subsequent access to userScores.at(2) would result in an error.

PARTICIPATION ACTIVITY 5.13.1: Vector resize.

Animation captions:

1. When initially declared, the vector carSales has a size of 0.
2. Accessing any element, such as carSales.at(0), would result in a runtime error.
3. carSales.resize(3) allocates 3 elements with indices 0, 1, and 2. Elements can now be accessed using the .at() function.

The program below asks a user to indicate the number of values the user will enter, allocates that number of elements for a vector, assigns the vector's elements with user-entered values, and then displays the vector's elements.

Figure 5.13.1: Resizing a vector based on user input.

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

int main() {
   vector<int> userVals; // No elements yet
   int numVals;
   unsigned int i;

   cout << "Enter number of integer values: ";
   cin >> numVals;

   userVals.resize(numVals); // Allocate elements

   cout << "Enter " << numVals << " integer values..." << endl;
   for (i = 0; i < userVals.size(); ++i) {
      cout << "Value: ";
      cin >> userVals.at(i);
   }

   cout << "You entered: ";
   for (i = 0; i < userVals.size(); ++i) {
      cout << userVals.at(i) << " ";
   }
   cout << endl;

   return 0;
}
```

```
Enter number of integer values: 7
Enter 7 integer values...
Value: -5
Value: -99
Value: 0
Value: 13
Value: 7
Value: -22
Value: 1
You entered: -5 -99 0 13 7 -22 1
```


PARTICIPATION ACTIVITY 5.13.2: Vector resize and size functions.

Given the vector declaration:

```
vector<int> agesVctr;
```

1) Immediately after the declaration, agesVctr has only 1 element.

- True
- False

2) agesVctr.size(4) allocates 4 elements for agesVctr.

- True
- False

3) Given agesVctr has 3 elements, agesVctr.resize(4) adds 4 more elements, totalling 7 elements.

- True
- False

4) Given agesVctr has 3 elements with values 22, 18, and 19, agesVctr.resize(2) changes agesVctr to have 2 elements with values 22 and 18.

- True
- False

5) After agesVctr.resize(5) and agesVctr.at(0) = 99, agesVctr.size() evaluates to 1.

- True
- False

CHALLENGE ACTIVITY 5.13.1: Determining the size of a vector.

Assign currentSize with the size of the sensorReadings vector.

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

int main() {
   vector<int> sensorReadings(4);
   int currentSize;

   sensorReadings.resize(10);

   /* Your solution goes here  */

   cout << "Number of elements: " << currentSize << endl;

   return 0;
}
```


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CHALLENGE ACTIVITY 5.13.2: Resizing a vector.

Resize vector countDown to have newSize elements. Populate the vector with integers {newSize, newSize - 1, ..., 1}. Ex: If newSize = 3, then countDown = {3, 2, 1}, and the sample program outputs:

```
3 2 1 Go!
```

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

int main() {
   vector<int> countDown(0);
   int newSize;
   unsigned int i;

   newSize = 3;

   /* Your solution goes here  */

   for (i = 0; i < countDown.size(); ++i) {
      cout << countDown.at(i) << " ";
   }
   cout << "Go!" << endl;

   return 0;
}
```


Run

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5.14 Vector push_back

Appending items to a vector

A programmer can append a new element to the end of an existing vector using a vector's ***push_back***. Ex: `dailySales.push_back(521)` creates a new element at the end of the vector dailySales and assigns that element with the value 521.

PARTICIPATION ACTIVITY 5.14.1: The vector push_back() function.

Animation captions:

1. When initially declared, the vector dailySales has a size of 0.
2. The push_back() function appends a new element to the vector.

PARTICIPATION ACTIVITY 5.14.2: Vector push_back().

1) If vector `itemPrices` has two elements with values 45, 48, what does itemPrices.size() return?

Check Show answer

2) If itemPrices has element values 45, 48, then after itemPrices.push_back(38), what are itemPrices' element values? Type answer as: 50, 60, 70

Check Show answer

Vector pop_back() and back()

The following table summarizes a few common functions dealing with the back (or last element) of a vector.

Table 5.14.1: Functions on the back of a vector.

push_back()	`void push_back(const int newVal);`
	
	Append new element having value newVal.
		`// playersList initially 55, 99, 44 (size is 3)`
		`playersList.push_back(77); // Appends new element 77`
		`// playersList is now 55, 99, 44, 77 (size is 4)`

back()	`int back();`
	
	Returns value of vector's last element. Vector is unchanged.
		`// playersList initially 55, 99, 44`
		`cout << playersList.back(); // Prints 44`
		`// playersList is still 55, 99, 44`

pop_back()	`void pop_back();`
	
	Removes the last element.
		`// playersList is 55, 99, 44 (size 3)`
		`playersList.pop_back(); // Removes last element`
		`// playersList now 55, 99 (size 2)`
		
		`cout << playersList.back(); // Common combination of back()`
		`playersList.pop_back();  // followed by pop_back()`
		`// Prints 99. playersList becomes just 55`
		
		`cout << playersList.pop_back(); // Common error:`
		
		`pop_back() returns void`

Shown for vector<int>, but applies to other types.

The program below declares a vector groceryList, which is initially empty. As the user enters grocery items one at a time, the program uses push_back() to append the items to the list. When done, the user can go shopping, and is presented one list item at a time (which the user presumably finds and places in a shopping cart). The program uses back() to get each item from the list and pop_back() to remove the item from the list. When the list is empty, shopping is finished.

Note that because the program removes items from the end of the list, the items are presented in reverse order.

Figure 5.14.1: Using push_back(), back(), and pop_back(): A grocery list example.

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

int main() {
   vector<string> groceryList; // Vector storing shopping list
   string groceryItem;         // Individual grocery items
   string userCmd;             // User input

   // Prompt user to populate shopping list
   cout << "Enter grocery items or type done." << endl;
   cin >> groceryItem;
   while (groceryItem != "done") {
      groceryList.push_back(groceryItem);
      cin >> groceryItem;
   }

   // Display shopping list
   cout << endl << "Enter any key for next item." << endl;
   while (groceryList.size() > 0) {
      groceryItem = groceryList.back();
      groceryList.pop_back();
      cout << groceryItem << "   ";
      cin >> userCmd;
   }
   cout << endl << "Done shopping." << endl;

   return 0;
}
```

```
Enter grocery items or type done.
Oranges
Apples
Bread
Juice
done

Enter any key for next item.
Juice   a
Bread   a
Apples   a
Oranges   a

Done shopping.
```


PARTICIPATION ACTIVITY 5.14.3: Vector back() and pop_back() functions.

1) If itemPrices has elements 45, 22, 38, what does price = itemPrices.pop_back() assign to price? Type Error if appropriate.

Check Show answer

2) If itemPrices has elements 45, 22, 38, what does price = itemPrices.back() assign to price? Type Error if appropriate.

Check Show answer

3) If itemPrices has elements 45, 22, 38, what is the vector after itemPrices.back() is called? Type answer as: 50, 60, 70

Check Show answer

4) If itemPrices has elements 45, 22, 38, then after itemPrices.pop_back(), what does itemPrices.at(2) return? Type Error if appropriate.

Check Show answer

CHALLENGE ACTIVITY 5.14.1: Appending a new element to a vector.

Append newValue to the end of vector tempReadings. Ex: If newValue = 67, then tempReadings = {53, 57, 60} becomes {53, 57, 60, 67}.

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

int main() {
   vector<int> tempReadings(3);
   int newValue;
   unsigned int i;

   tempReadings.at(0) = 53;
   tempReadings.at(1) = 57;
   tempReadings.at(2) = 60;

   newValue = 67;

   /* Your solution goes here  */

   for (i = 0; i < tempReadings.size(); ++i) {
      cout << tempReadings.at(i) << " ";
   }
   cout << endl;
```


Run

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CHALLENGE ACTIVITY 5.14.2: Removing an element from the end of a vector.

Remove the last element from vector ticketList.

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

int main() {
   vector<int> ticketList(3);
   unsigned int i;

   ticketList.at(0) = 5;
   ticketList.at(1) = 100;
   ticketList.at(2) = 12;

   /* Your solution goes here  */

   for (i = 0; i < ticketList.size(); ++i) {
      cout << ticketList.at(i) << " ";
   }
   cout << endl;

   return 0;
}
```

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CHALLENGE ACTIVITY 5.14.3: Reading the vector's last element.

Write a statement to print "Last mpg reading: " followed by the value of mpgTracker's last element. End with newline. Ex: If mpgTracker = {17, 19, 20}, print:

```
Last mpg reading: 20
```

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

int main() {
   vector<int> mpgTracker(3);

   mpgTracker.at(0) = 17;
   mpgTracker.at(1) = 19;
   mpgTracker.at(2) = 20;

   /* Your solution goes here  */

   return 0;
}
```

Run

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5.15 Loop-modifying or copying/comparing vectors

Modifying vector elements

A program may need to modify elements while iterating through a vector. The program below uses a loop to convert any negative vector element value to 0.

Figure 5.15.1: Modifying a vector during iteration example: Converting negatives to 0.


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

int main() {
   const int NUM_ELEMENTS = 5;          // Number of elements
   vector<int> userVals(NUM_ELEMENTS); // User values
   unsigned int i;                     // Loop index

   // Prompt user to populate vector
   cout << "Enter " << NUM_ELEMENTS << " integer values..." << endl;
   for (i = 0; i < userVals.size(); ++i) {
      cout << "Value: ";
      cin >> userVals.at(i);
   }

   // Convert negatives to 0
   for (i = 0; i < userVals.size(); ++i) {
      if (userVals.at(i) < 0) {
         userVals.at(i) = 0;
      }
   }

   // Print numbers
   cout << "New values:";
   for (i = 0; i < userVals.size(); ++i) {
      cout << " " << userVals.at(i);
   }
   cout << endl;

   return 0;
}
```

```
Enter 5 integer values...
Value: 67
Value: -5
Value: -99
Value: 4
Value: 22
New values: 67 0 0 4 22
```

PARTICIPATION ACTIVITY 5.15.1: Modifying a vector in a loop.

What is the resulting vector contents, assuming each question starts with a vector of size 4 having contents -55, -1, 0, 9?

1)
```
for (i = 0; i < 4; ++i) {
   itemsList.at(i) = i;
}
```

- -54, 0, 1, 10
- 0, 1, 2, 3
- 1, 2, 3, 4

2)
```
for (i = 0; i < 4; ++i) {
   if (itemsList.at(i) < 0) {
      itemsList.at(i) = itemsList.at(i)
* -1;
   }
}
```


- -55, -1, 0, -9
- 55, 1, 0, -9
- 55, 1, 0, 9

3)

```
for (i = 0; i < 4; ++i) {
   itemsList.at(i) = itemsList.at
(i+1);
}
```

- -1, 0, 9, 0
- 0, -55, -1, 0
- Error (program aborts)

4)
```
for (i = 0; i < 3; ++i) {
   itemsList.at(i) = itemsList.at(i+1);
}
```


- -1, 0, 9, 9
- Error (program aborts)
- -1, 0, 9, 0

5)
```
for (i = 0; i < 3; ++i) {
   itemsList.at(i+1) = itemsList.at(i);
}
```

- -55, -55, -55, -55
- 0, -55, -1, 0
- Error (program aborts)

zyDE 5.15.1: Modifying a vector during iteration example: Doubling element values.

Complete the following program to double each number in the vector.

Load default template...

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

int main() {
   const int NUM_ELEMENTS = 5;          // Number of elem
   vector<int> userVals(NUM_ELEMENTS); // User values
   unsigned int i;                     // Loop index

   // Prompt user to populate vector
   cout << "Enter " << NUM_ELEMENTS << " integer values.
   for (i = 0; i < userVals.size(); ++i) {
      cout << "Value: " << endl;
      cin >> userVals.at(i);
   }

   // Convert negatives to 0
   for (i = 0; i < userVals.size(); ++i) {
      if (userVals.at(i) < 0) {
         userVals.at(i) = 0;
```

67 -5 -99 4 22

Run

Element by element vector copy

In C++, the = operator conveniently performs an element-by-element copy of a vector, called a ***vector copy operation***. The operation vectorB = vectorA resizes vectorB to vectorA's size, appending or deleting elements as needed. vectorB commonly has a size of 0 before the operation.

Figure 5.15.2: Using = to copy a vector: Original and sale prices.

```
Original prices:  10 20 30 40
Sale prices:      10 20 27 35
```

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

int main() {
   const int   NUM_ELEMENTS = 4;         // Number of elements
   vector<int> origPrices(NUM_ELEMENTS); // Original prices
   vector<int> salePrices(NUM_ELEMENTS); // Sale prices
   unsigned int i;                       // Loop index

   // Assign original prices
   origPrices.at(0) = 10;
   origPrices.at(1) = 20;
   origPrices.at(2) = 30;
   origPrices.at(3) = 40;

   // Copy original prices to sales prices
   salePrices = origPrices;

   // Update salePrices. Note: does not affect origPrices
   salePrices.at(2) = 27;
   salePrices.at(3) = 35;

   // Output original and sale prices
   cout << "Original prices: ";
   for (i = 0; i < origPrices.size(); ++i) {
      cout << " " << origPrices.at(i);
   }
   cout << endl;

   cout << "Sale prices:     ";
   for (i = 0; i < salePrices.size(); ++i) {
      cout << " " << salePrices.at(i);
   }
   cout << endl;

   return 0;
}
```


PARTICIPATION ACTIVITY 5.15.2: Vector copy operation.

Assume vectors have been declared as follows and have been initialized as indicated in the comments:

```
vector<int> userVals(4); // {44, 55, 66, 77}
vector<int> newVals;     // No elements yet
```

1) What is newVals after: `newVals = userVals;`
   Type answer as: 10, 20, 30, 40
   If appropriate type: Error

   Check Show answer

2) What is newVals after:
   `newVals = userVals;`
   `userVals.at(0) = 33;`
   Type answer as: 10, 20, 30, 40
   If appropriate type: Error

   Check Show answer

3) Given: vector<int> otherVals(9).
   What *size* is newVals after:
   `newVals = userVals;`
   `...`

```
newVals = otherVals;
```

If appropriate type: Error

Check Show answer

Element by element vector comparison

In C++, the == operator conveniently compares vectors element-by-element, called a ***vector equality operation***, with vectorA == vectorB evaluating to true if the vectors are the same size AND each element pair is equal.

PARTICIPATION ACTIVITY 5.15.3: Vector copying.

Assume vectors have been declared as follows and have been initialized as indicated in the comments:

```
vector<int> vectorX(2); // {3,4}
vector<int> vectorY(5); // {3,4,0,7,8}
vector<int> vectorZ(5); // {3,4,0,6,8}
```

1) (vectorX == vectorY) will evaluate to:

- True
- False

2) Given: vectorX = vectorY; (vectorX == vectorY) will evaluate to:

- True
- False

3) (vectorZ == vectorY) will evaluate to:

- True
- False

4) (vectorZ.size() == vectorY.size()) will evaluate to:

- True
- False

CHALLENGE ACTIVITY 5.15.1: Decrement vector elements.

Write a loop that subtracts 1 from each element in lowerScores if the original element was greater than 0, and otherwise just assigns the element with 0. Ex: lowerScores = {5, 0, 2, -3} becomes {4, 0, 1, 0}.

Run

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CHALLENGE ACTIVITY 5.15.2: Copy and modify vector elements.

Write a loop that sets newScores to oldScores shifted once left, with element 0 copied to the end. Ex: If oldScores = {10, 20, 30, 40}, then newScores = {20, 30, 40, 10}.

Note: These activities may test code with different test values. This activity will perform two tests, both with a 4-element array. See "How to Use zyBooks".

Also note: If the submitted code tries to access an invalid array element, such as newScores[9] for a 4-element array, the test may generate strange results. Or the test may crash and report "Program end never reached", in which case the system doesn't print the test case that caused the reported message.

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

int main() {
   const int SCORES_SIZE = 4;
   vector<int> oldScores(SCORES_SIZE);
   vector<int> newScores(SCORES_SIZE);
   unsigned int i;

   for (i = 0; i < oldScores.size(); ++i) {
      cin >> oldScores.at(i);
   }

   /* Your solution goes here  */

   for (i = 0; i < newScores.size(); ++i) {
      cout << newScores.at(i) << " ";
   }
   cout << endl;

```

Run

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CHALLENGE ACTIVITY 5.15.3: Modify vector elements using other elements.

Write a loop that sets each vector element to the sum of itself and the next element, except for the last element which stays the same. Be careful not to index beyond the last element. Ex:

```
Initial scores:        10, 20, 30, 40
Scores after the loop: 30, 50, 70, 40
```

The first element is 30 or 10 + 20, the second element is 50 or 20 + 30, and the third element is 70 or 30 + 40. The last element remains the same.

Run

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CHALLENGE ACTIVITY 5.15.4: Modify a vector's elements.

Subtract 4 to any element's value that is greater than maxVal. Ex: If maxVal = 10, then dataPoints = {2, 12, 9, 20} becomes {2, 8, 9, 16}.

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

int main() {
   int maxVal;
   const int NUM_POINTS = 4;
   vector<int> dataPoints(NUM_POINTS);
   unsigned int i;

   cin >> maxVal;

   for (i = 0; i < dataPoints.size(); ++i) {
      cin >> dataPoints.at(i);
   }

/* Your solution goes here  */

   for (i = 0; i < dataPoints.size(); ++i) {
      cout << dataPoints.at(i) << " " ;
   }
```

Run

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CHALLENGE ACTIVITY 5.15.5: Comparing and copying vectors.

If the vector oldData is the same as the vector newData, print "Data matches!" ended with a newline. Otherwise, assign oldData with newData. Ex: If oldData = {10, 12, 18} and newData = {25, 27, 29, 23}, then oldData becomes {25, 27, 29, 23}.

Run

View your last submission

5.16 Arrays vs. vectors

C++ supports two kinds of ordered list types.

- *Arrays:* declared as `int myList[10]`, accessed as `myList[i]`.
- *Vectors:* declared as `vector<int> myList(10)`, accessed as `myList.at(i)`.

Arrays have a simpler syntax than vectors, but vectors are safer to use. Thus, using vectors rather than arrays is good practice.

Vectors are safer because the access v.at(i) is checked during execution to ensure the index is within the vector's valid range. An array access a[i] involves no such check. Such checking is important; trying to access an array with an out-of-range index is a very common error, and one of the hardest errors to debug.

PARTICIPATION ACTIVITY 5.16.1: Writing to an out-of-range index using an array.

Animation captions:

1. Variable userAge is allocated a location in memory immediately after the array userWeights. userAge is assigned with 44.
2. Each element of array userWeights is assigned a value.
3. 3 is out of userWeights's index range, and results in overwriting userAge's value.

As shown above, assigning with an out-of-range index can mysteriously change some other variable's value. Debugging such an error can be a nightmare.

Vectors have more advantages, like resizing during runtime, easy insertion of items at the front or rear, determining vector size, etc., discussed later. Arrays have minor benefits that don't really outweigh drawbacks. Like choosing to not wear seatbelts, choosing to not use vectors may be quite risky.

C++ allows vectors to be accessed using brackets [], but brackets involve no range checking, so a good practice is to use .at() to access vector elements.

PARTICIPATION ACTIVITY 5.16.2: Arrays and vectors.

Given:

```
int arrayList[5];
vector<int> vectorList(5);
```

1)

arrayList[6] = 777 will yield a compiler error.

- True
- False

2) vectorList[6] = 777 will yield a compiler error.

- True
- False

3) arrayList[6] = 777 will execute without an error message.

- True
- False

4) vectorList.at(6) = 777 will execute without an error message.

- True
- False

5) vectorList[6] = 777 will execute without an error message.

- True
- False

6) `while ( i < arrayList.size() )` loops while i is less than the array's size.

- True
- False

5.17 Debugging example: Reversing a vector

A common vector modification is to reverse a vector's elements. One way to accomplish this goal is to perform a series of swaps. For example, starting with a vector of numbers 10 20 30 40 50 60 70 80, we could first swap the first item with the last item, yielding 80 20 30 40 50 60 70 10. We could next swap the second item with the second-to-last item, yielding 80 70 30 40 50 60 20 10. The next swap would yield 80 70 60 40 50 30 20 10, and the last would yield 80 70 60 50 40 30 20 10.

With this basic idea of how to reverse a vector, we can attempt to write a program to carry out such reversal. Below we develop such a program but we make common mistakes along the way, to aid learning from examples of what not to do.

A first attempt to write a program that reverses a vector appears below.

Figure 5.17.1: First program attempt to reverse vector: Aborts due to invalid access of vector element.

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

int main() {
   const int NUM_ELEMENTS = 8;         // Number of
elements
   vector<int> revVctr(NUM_ELEMENTS); // User values
   unsigned int i;                    // Loop index

   cout << "Enter " << NUM_ELEMENTS << " integer
values..." << endl;
   for (i = 0; i < revVctr.size(); ++i) {
      cout << "Value: ";
      cin >> revVctr.at(i);
   }

   // Reverse
   for (i = 0; i < revVctr.size(); ++i) {
      revVctr.at(i) = revVctr.at(revVctr.size() -
i); // Swap
   }

   // Print values
   cout << endl << "New values: ";
   for (i = 0; i < revVctr.size(); ++i) {
      cout << " " << revVctr.at(i);
   }
   cout << endl;

   return 0;
}
```

```
Enter 8 integer values...
Value: 10
Value: 20
Value: 30
Value: 40
Value: 50
Value: 60
Value: 70
Value: 80
libc++abi.dylib: terminating with uncaught
exception
of type std::out_of_range: vector
```


Something went wrong: The program aborted (exited abnormally). The reported message indicates an "out of range" problem related to a vector, meaning the program tried to access a vector element that doesn't exist. Let's try to find the code that caused the problem.

The first and third for loops are fairly standard, so let's initially focus attention on the middle for loop that does the reversing. The swap statement inside that loop is `revVctr.at(i) = revVctr.at(revVctr.size() - i)`. When i is 0, the statement will execute `revVctr.at(0) = revVctr.at(8)`. However, revVctr has size 8 and thus valid indices are 0..7. revVctr.at(8) does not exist. The program should actually swap elements 0 and 7, then 1 and 6, etc. Thus, let's change the right-side index to `revVctr.size() - 1 - i`. The revised program is shown below.

Figure 5.17.2: Revised vector reversing program: Doesn't abort, but still a problem.

```
Enter 8 integer values...
Value: 10
Value: 20
Value: 30
Value: 40
Value: 50
Value: 60
Value: 70
Value: 80

New values:  80 70 60 50 50 60 70
80
```

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

int main() {
   const int NUM_ELEMENTS = 8;        // Number of elements
   vector<int> revVctr(NUM_ELEMENTS); // User values
   unsigned int i;                    // Loop index

   cout << "Enter " << NUM_ELEMENTS << " integer values..."
<< endl;
   for (i = 0; i < revVctr.size(); ++i) {
      cout << "Value: ";
      cin >> revVctr.at(i);
   }

   // Reverse
   for (i = 0; i < revVctr.size(); ++i) {
      revVctr.at(i) = revVctr.at(revVctr.size() - 1 - i); //
Swap
   }

   // Print values
   cout << endl << "New values: ";
   for (i = 0; i < revVctr.size(); ++i) {
      cout << " " << revVctr.at(i);
   }
   cout << endl;

   return 0;
}
```


The program didn't abort this time, but the last four elements are wrong. To determine what went wrong, we can manually (i.e., on paper) trace the loop's execution.

- i is 0: revVctr.at(0) = revVctr.at(7). Vector now: 80 20 30 40 50 60 70 80.
- i is 1: revVctr.at(1) = revVctr.at(6). Vector now: 80 70 30 40 50 60 70 80.
- i is 2: revVctr.at(2) = revVctr.at(5). Vector now: 80 70 60 40 50 60 70 80.
- i is 3: revVctr.at(3) = revVctr.at(4). Vector now: 80 70 60 50 50 60 70 80.
- i is 4: revVctr.at(4) = revVctr.at(3). Vector now: 80 70 60 50 50 60 70 80. *Uh-oh, where did 40 go?*

We failed to actually swap the vector elements, instead the code just copies values in one direction. We need to add code to properly swap. We add a variable tmpValue to temporarily hold `revVctr.at(revVctr.size() - 1 - i)` so we don't lose that element's value.

Figure 5.17.3: Revised vector reversing program with proper swap: Output isn't reversed.

```
Enter 8 integer values...
Value: 10
Value: 20
Value: 30
Value: 40
Value: 50
Value: 60
Value: 70
Value: 80

New values:  10 20 30 40 50 60 70
80
```

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

int main() {
   const int NUM_ELEMENTS = 8;        // Number of elements
   vector<int> revVctr(NUM_ELEMENTS); // User values
   unsigned int i;                    // Loop index
   int tmpValue;                      // Placeholder

   cout << "Enter " << NUM_ELEMENTS << " integer values..."
<< endl;
   for (i = 0; i < revVctr.size(); ++i) {
      cout << "Value: ";
      cin >> revVctr.at(i);
   }

   // Reverse
   for (i = 0; i < revVctr.size(); ++i) {
      tmpValue = revVctr.at(i);  // These 3 statements swap
      revVctr.at(i) = revVctr.at(revVctr.size() - 1 - i);
      revVctr.at(revVctr.size() - 1 - i) = tmpValue;
   }

   // Print values
   cout << endl << "New values: ";
   for (i = 0; i < revVctr.size(); ++i) {
      cout << " " << revVctr.at(i);
   }
   cout << endl;

   return 0;
}
```


The new values are not reversed. Again, let's manually trace the loop iterations.

- i is 0: revVctr.at(0) = revVctr.at(7). Vector now: 80 20 30 40 50 60 70 10.
- i is 1: revVctr.at(1) = revVctr.at(6). Vector now: 80 70 30 40 50 60 20 10.
- i is 2: revVctr.at(2) = revVctr.at(5). Vector now: 80 70 60 40 50 30 20 10.
- i is 3: revVctr.at(3) = revVctr.at(4). Vector now: 80 70 60 50 40 30 20 10. *Looks reversed.*
- i is 4: revVctr.at(4) = revVctr.at(3). Vector now: 80 70 60 40 50 30 20 10. *Why are we still swapping?*

Tracing makes clear that the for loop should not iterate over the entire vector. The reversal is completed halfway through the iterations. The solution is to set the loop expression to `i < (revVctr.size() / 2)`.

Figure 5.17.4: Vector reversal program with correct output.

```
Enter 8 integer values...
Value: 10
Value: 20
Value: 30
Value: 40
Value: 50
Value: 60
Value: 70
Value: 80

New values:  80 70 60 50 40 30 20
10
```

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

int main() {
   const int NUM_ELEMENTS = 8;        // Number of elements
   vector<int> revVctr(NUM_ELEMENTS); // User values
   unsigned int i;                    // Loop index
   int tmpValue;                      // Placeholder

   cout << "Enter " << NUM_ELEMENTS << " integer values..."
<< endl;
   for (i = 0; i < revVctr.size(); ++i) {
      cout << "Value: ";
      cin >> revVctr.at(i);
   }

   // Reverse
   for (i = 0; i < (revVctr.size() / 2); ++i) {
      tmpValue = revVctr.at(i);  // These 3 statements swap
      revVctr.at(i) = revVctr.at(revVctr.size() - 1 - i);
      revVctr.at(revVctr.size() - 1 - i) = tmpValue;
   }

   // Print values
   cout << endl << "New values: ";
   for (i = 0; i < revVctr.size(); ++i) {
      cout << " " << revVctr.at(i);
   }
   cout << endl;

   return 0;
}
```


We should ensure the program works if the number of elements is odd rather than even. Suppose the vector has 5 elements (0-4) with values 10 20 30 40 50. revVctr.size() / 2 would be 5 / 2 = 2, meaning the loop expression would be i < 2. The iteration when i is 0 would swap elements 0 and 4 (5-1-0), yielding 50 20 30 40 10. The iteration for i=1 would swap elements 1 and 3, yielding 50 40 30 20 10. The loop would then not execute again because i is 2. So the results are correct for an odd number of elements, because the middle element will just not move.

The mistakes made above are each very common when dealing with loops and vectors, especially for beginning programmers. An incorrect (in this case out-of-range) index, an incorrect swap, and an incorrect loop expression. The lesson is that loops and vectors require attention to detail, greatly aided by manually executing the loop to determine what is happening on each iteration. Ideally, a programmer will take more care when writing the original program, but the above mistakes are quite common.

PARTICIPATION ACTIVITY 5.17.1: Find the error in the vector reversal code.

1) for (i = 0; i < prices.size(); ++i) {
   tmp = prices.at(i);
   prices.at(i) = prices.at(prices.size() - 1 - i);
   prices.at(prices.size() - 1 - i) = tmp;
   }

2) for (i = 0; i < (prices.size() / 2); ++i) {
   tmp = prices.at(i);
   prices.at(i) = prices.at(prices.size() - i);
   prices.at(prices.size() - i - 1) = tmp;
   }

3) for (i = 0; i < (prices.size() / 2); ++i) {
   tmp = prices.at(i);
   prices.at(prices.size() - i - 1) = tmp;

   prices.at(i) = prices.at(prices.size() - 1 - i);
   }

5.18 C++ example: Salary calculation with vectors

This section has been set as optional by your instructor.

zyDE 5.18.1: Various tax rates.

Vectors are useful to process tabular information. Income taxes are based on annual salary, usually with a tiered approach. Below is an example of a simple tax table:

Annual Salary	Tax Rate
0 to 20000	10%
Above 20000 to 50000	20%
Above 50000 to 100000	30%
Above 100000	40%

The below program uses a vector salaryBase to hold the cutoffs for each salary level and a parallel vector taxBase that has the corresponding tax rate.

1. Run the program and enter annual salaries of 40000 and 60000, then enter 0.
2. Modify the program to use two parallel vectors named annualSalaries and taxesToPay, each with 10 elements. Vectors annualSalaries holds up to 10 annual salaries entered; vector taxesToPay holds up to 10 corresponding amounts of taxes to pay for those annual salaries. Print the total annual salaries and taxes to pay after all input has been processed.
3. Run the program again with the same annual salary numbers as above.

The following program calculates the tax rate and tax to pay based on annual income.

Load default template...

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

int main() {
   const int MAX_ELEMENTS = 10;
   int annualSalary;
   double taxRate;
   int taxToPay;
   int numSalaries;
   bool keepLooking;
   unsigned int i;
   vector<int> salaryBase(5);
   vector<double> taxBase(5);
   // FIXME: Declare annualSalaries and taxesToPay vectors to hold 10 elements each.
   // FIXME: Use the constant MAX_ELEMENTS to declare the vectors

   salaryBase.at(0) = 0;
   salaryBase.at(1) = 20000;
   salaryBase.at(2) = 50000;
   salaryBase.at(3) = 100000;
```

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Max-Mary Zorbiewu
UDCAPCT231LiangSpring2019

```
40000 60000 0
```

Run

zyDE 5.18.2: Various tax rates (solution).

A solution to the problem follows.

Load default template...


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

int main() {
   const int MAX_ELEMENTS = 10;
   int annualSalary;
   double taxRate;
   int taxToPay;
   int totalSalaries;
   int totalTaxes;
   int numSalaries;
   bool keepLooking;
   unsigned int i;
   int j;

   vector<int> salaryBase(5);
   vector<double> taxBase(5);
   vector<int> annualSalaries(MAX_ELEMENTS);
   vector<int> taxesToPay(MAX_ELEMENTS);
```

```
40000 60000 0
```

Run

5.19 C++ example: Domain name validation with vectors

This section has been set as optional by your instructor.

zyDE 5.19.1: Validate domain names with vectors.

Vectors are useful to process lists.

A ***top-level domain*** (TLD) name is the last part of an Internet domain name like .com in example.com. A ***core generic top-level domain*** (core gTLD) is a TLD that is either .com, .net, .org, or .info. A ***restricted top-level domain*** is a TLD that is either .biz, .name, or .pro. A ***second-level domain*** is a single name that precedes a TLD as in apple in apple.com.

The following program repeatedly prompts for a domain name, and indicates whether that domain name consists of a second-level domain followed by a core gTLD. Valid core gTLD's are stored in a vector. For this program, a valid domain name must contain only one period, such as apple.com, but not support.apple.com. The program ends when the user enters -1.

1. Run the program and enter domain names to validate.

2. Extend the program to also recognize restricted TLDs using a vector, and statements to validate against that vector. The program should also report whether the TLD is a core gTLD or a restricted gTLD. Run the program again.

Load default template...

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

int main() {
   // Define the list of valid core gTLDs
   const int NUM_ELEMENTS = 4;
   vector<string> validCoreGtld(NUM_ELEMENTS);
   // FIXME: Declare a vector named validRestrictedGtld that has the names
   //        of the restricted domains, .biz, .name, and .pro
   string  inputName;
   string  searchName;
   string  theGtld;
   bool isValidDomainName;
   bool isCoreGtld;
   bool isRestrictedGtld;
   int periodCounter;
   int periodPosition;
   unsigned int i;

   validCoreGtld.at(0) = ".com";
```



```
apple.com
APPLE.com
apple.comm
```

Run

zyDE 5.19.2: Validate domain names with vectors (solution).

A solution to the problem follows.

Load default template...

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

int main() {
   // Define the list of valid core gTLDs
   const int NUM_ELEMENTS_CORE = 4;
   vector<string> validCoreGtld(NUM_ELEMENTS_CORE);
   const int NUM_ELEMENTS_RSTR = 3;
   vector<string> validRestrictedGtld(NUM_ELEMENTS_RSTR);
   string  inputName;
   string  searchName;
   string  theGtld;
   bool isValidDomainName;
   bool isCoreGtld;
   bool isRestrictedGtld;
   int periodCounter;
   int periodPosition;
   unsigned int i;

   validCoreGtld.at(0) = ".com";
```



```
apple.com
APPLE.com
apple.comm
```

Run

5.20 Largest/Smallest Array Values

Write a program that lets the user enter 10 values into an array. The program should then display the largest and the smallest values stored in the array.

The program should display the following message to the user at the beginning "This program will ask you to enter ten values. Then it will determine the largest and smallest of the values you entered.Please enter 10 integers separated by spaces: " And then after user entered the numbers, it should display the following: "The largest value entered is " followed by the largest number found, and "The smallest value entered is " followed by the smallest number found.

Please note that your can submit the assignment up to 5 times.

LAB ACTIVITY 5.20.1: Largest/Smallest Array Values 5 / 5

Submission Instructions

Compile command

```
g++ main.cpp -Wall -o a.out
```

We will use this command to compile your code

Upload your files below by dragging and dropping into the area or choosing a file on your hard drive.

main.cpp Drag file here or **Choose on hard drive.**

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1: Compare output 4 / 4

Input
```
10 20 30 40 50 60 70 80 90 100
```

Your output
```
This program will ask you to enter ten values
The largest value entered is  100
The smallest value entered is 10
```

2: Compare output 1 / 1

Input
```
-1 5 6 12 15 24 28 30 34 51
```

Your output
```
This program will ask you to enter ten values
The largest value entered is  51
The smallest value entered is -1
```

5.21 Ch 5 Warm up: People's weights (Vectors) (C++)

(1) Prompt the user to enter five numbers, being five people's weights. Store the numbers in a vector of doubles. Output the vector's numbers on one line, each number followed by one space. (2 pts)

Ex:

```
Enter weight 1:
236.0
Enter weight 2:
89.5
Enter weight 3:
142.0
Enter weight 4:
166.3
Enter weight 5:
93.0
You entered: 236 89.5 142 166.3 93
```

(2) Also output the total weight, by summing the vector's elements. (1 pt)

(3) Also output the average of the vector's elements. (1 pt)

(4) Also output the max vector element. (2 pts)

Ex:

```
Enter weight 1:
236.0
Enter weight 2:
89.5
Enter weight 3:
142.0
Enter weight 4:
166.3
Enter weight 5:
93.0
You entered: 236 89.5 142 166.3 93

Total weight: 726.8
Average weight: 145.36
Max weight: 236
```

LAB ACTIVITY 5.21.1: Ch 5 warm up: People's weights (Vectors) (C++) 6 / 6

Submission Instructions

Compile command

`g++ main.cpp -Wall -o a.out` *We will use this command to compile your code*

Upload your files below by dragging and dropping into the area or choosing a file on your hard drive.

main.cpp Drag file here or **Choose on hard drive.**

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Compiler warnings

```
main.cpp: In function 'int main()':
main.cpp:15:18: warning: comparison between signed and unsigned i
     for(i = 0; i < userWeights.size(); ++i) {
                ~~^~~~~~~~~~~~~~~~~~~
main.cpp:23:18: warning: comparison between signed and unsigned i
     for(i = 0; i < userWeights.size(); ++i) {
                ~~^~~~~~~~~~~~~~~~~~~
main.cpp:30:18: warning: comparison between signed and unsigned i
     for(i = 0; i < userWeights.size(); ++i) {
                ~~^~~~~~~~~~~~~~~~~~~
main.cpp:39:19: warning: comparison between signed and unsigned i
     for( i = 0; i < userWeights.size(); ++i) {
                 ~~^~~~~~~~~~~~~~~~~~~
```

1: Compare output 1 / 1

Input

```
236.0
89.5
142.0
166.3
93.0
```

Your output correctly starts with

```
Enter weight 1:
Enter weight 2:
Enter weight 3:
Enter weight 4:
Enter weight 5:
You entered: 236 89.5 142 166.3 93
```

2: Compare output 1 / 1

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Input

```
123.4
56.0
98.0
174.0
215.8
```

Your output correctly starts with

```
Enter weight 1:
Enter weight 2:
Enter weight 3:
Enter weight 4:
```

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Previous submissions

11:24 PM on 3/19/19	0 / 6	View
11:10 PM on 3/19/19	0 / 6	View

5.22 Ch 5 Program: Soccer team roster (Vectors) (C++)

This program will store roster and rating information for a soccer team. Coaches rate players during tryouts to ensure a balanced team.

(1) Prompt the user to input five pairs of numbers: A player's jersey number (0 - 99) and the player's rating (1 - 9). Store the jersey numbers in one int vector and the ratings in another int vector. Output these vectors (i.e., output the roster). (3 pts)

Ex:

```
Enter player 1's jersey number:
84
Enter player 1's rating:
7

Enter player 2's jersey number:
23
Enter player 2's rating:
4

Enter player 3's jersey number:
4
Enter player 3's rating:
5

Enter player 4's jersey number:
30
Enter player 4's rating:
2

Enter player 5's jersey number:
66
Enter player 5's rating:
9

ROSTER
Player 1 -- Jersey number: 84, Rating: 7
Player 2 -- Jersey number: 23, Rating: 4
...
```


(2) Implement a menu of options for a user to modify the roster. Each option is represented by a single character. The program initially outputs the menu, and outputs the menu after a user chooses an option. The program ends when the user chooses the option to Quit. For this step, the other options do nothing. (2 pts)

Ex:

```
MENU
a - Add player
d - Remove player
u - Update player rating
r - Output players above a rating
o - Output roster
q - Quit

Choose an option:
```


(3) Implement the "Output roster" menu option. (1 pt)

Ex:

```
ROSTER
Player 1 -- Jersey number: 84, Rating: 7
Player 2 -- Jersey number: 23, Rating: 4
...
```

(4) Implement the "Add player" menu option. Prompt the user for a new player's jersey number and rating. Append the values to the two vectors. (1 pt)

Ex:

```
Enter a new player's jersey number:
49
Enter the player's rating:
8
```

(5) Implement the "Delete player" menu option. Prompt the user for a player's jersey number. Remove the player from the roster (delete the jersey number and rating). (2 pts)

Ex:

```
Enter a jersey number:
4
```

(6) Implement the "Update player rating" menu option. Prompt the user for a player's jersey number. Prompt again for a new rating for the player, and then change that player's rating. (1 pt)

Ex:

```
Enter a jersey number:
23
Enter a new rating for player:
6
```

(7) Implement the "Output players above a rating" menu option. Prompt the user for a rating. Print the jersey number and rating for all players with ratings above the entered value. (2 pts)

Ex:

```
Enter a rating:
5

ABOVE 5
Player 1 -- Jersey number: 84, Rating: 7
...
```

LAB ACTIVITY 5.22.1: Ch 5 Program: Soccer team roster (Vectors) (C++) 12 / 12

Submission Instructions

Compile command

```
g++ main.cpp -Wall -o a.out
```

We will use this command to compile your code

Upload your files below by dragging and dropping into the area or choosing a file on your hard drive.

main.cpp Drag file here or **Choose on hard drive.**

Submit for grading

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1: Compare output 2 / 2

Input

```
84 7
23 4
4 5
30 2
66 9
q
```

Your output correctly starts with

```
Enter player 1's jersey number:
Enter player 1's rating:

Enter player 2's jersey number:
Enter player 2's rating:

Enter player 3's jersey number:
Enter player 3's rating:

Enter player 4's jersey number:
Enter player 4's rating:

Enter player 5's jersey number:
Enter player 5's rating:

ROSTER
Player 1 -- Jersey number: 84, Rating: 7
Player 2 -- Jersey number: 23, Rating: 4
Player 3 -- Jersey number: 4, Rating: 5
Player 4 -- Jersey number: 30, Rating: 2
Player 5 -- Jersey number: 66, Rating: 9
```

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2: Compare output 1 / 1

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6:23 PM on 3/26/19	7 / 12	View
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