Chapter 9: Lists

- Arrays: A Mechanism for representing lists

Lists

- Problem solving often requires information be viewed as a list
  - List may be one-dimensional or multidimensional
- C++ provides two list mechanisms
  - Arrays
    - Traditional and important because of legacy libraries
    - Restrictions on its use
  - Container classes
    - First-class list representation
    - Common containers provided by STL
      - Vector, queue, stack, map, …
    - Preferred long-term programming practice

Lists

- Analogies
  - Egg carton
  - Apartments
  - Cassette carrier

Array Terminology

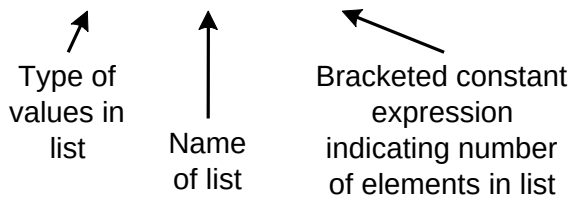
- List is composed of elements
- Elements in a list have a common name
  - The list as a whole is referenced through the common name
- List elements are of the same type — the base type
- Elements of a list are referenced by subscripting or indexing the common name

C++ Restrictions

- Subscripts are denoted as expressions within brackets: [ ]
- Base type can be any fundamental, library-defined, or programmer-defined type
- The index type is integer and the index range must be 0 ... n-1
  - where n is a programmer-defined constant expression.
- Parameter passing style
  - Always call by reference (no indication necessary)

Basic Array Definition

```
BaseType Id [ SizeExp ] ;
```




```
double X [ 100 ] ;

        // Subscripts are 0 through 99
```

Example Definitions

- Suppose

```
const int N = 20;
const int M = 40;
const int MaxStringSize = 80;
const int MaxListSize = 1000;
```

- Then the following are all correct array definitions

```
int A[10];               // array of 10 ints
char B[MaxStringSize];   // array of 80 chars
double C[M*N];           // array of 800 floats
int Values[MaxListSize]; // array of 1000 ints
Rational D[N-15];        // array of 5 Rationals
```

Subscripting

- Suppose

```
int A[10];    // array of 10 ints A[0], … A[9]
```

- To access individual element must apply a subscript to list name A
  - A subscript is a bracketed expression also known as the index
  - First element of list has index 0

    `A[0]`
  - Second element of list has index 1, and so on

    `A[1]`
  - Last element has an index one less than the size of the list

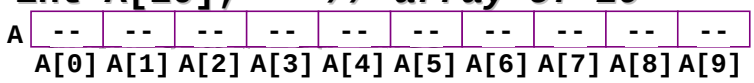
    `A[9]`
  - Incorrect indexing is a common error

    `A[10]` *// does not exist*

Array Elements

- Suppose

```
int A[10];     // array of 10
```

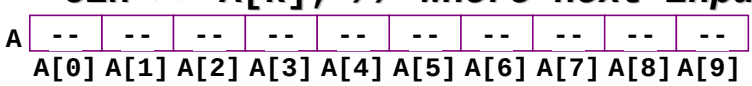


- To access an individual element we must apply a subscript to list name A

Array Element Manipulation

- Consider

```
int i = 7, j = 2, k = 4;
A[0] = 1;
A[i] = 5;
A[j] = A[i] + 3;
A[j+1] = A[i] + A[0];
A[A[j]] = 12;
cin >> A[k]; // where next input
```



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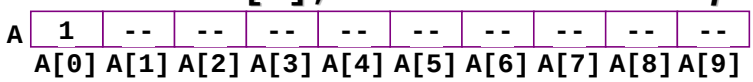

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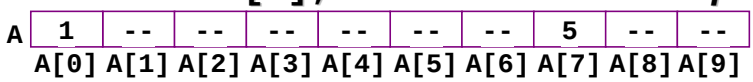

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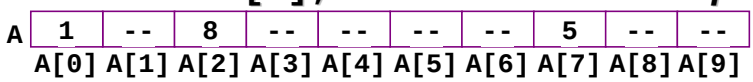

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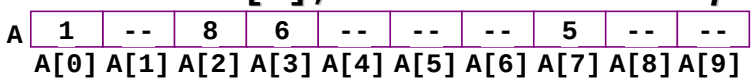

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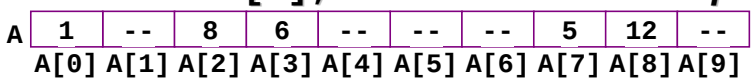

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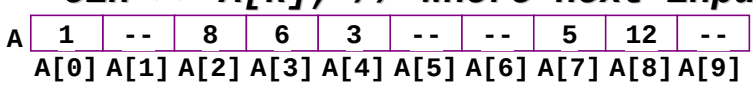

Extracting Values For A List

```
int A[MaxListSize];
int n = 0;
int CurrentInput;
while((n < MaxListSize) && (cin >>
  CurrentInput)){
  A[n] = CurrentInput;
  ++n;
}
```

Displaying A List

```
// List A of n elements has already
  been set
for (int i = 0; i < n; ++i) {
   cout << A[i] << " ";
}
cout << endl;
```

Smallest Value

- Problem
  - Find the smallest value in a list of integers
- Input
  - A list of integers and a value indicating the number of integers
- Output
  - Smallest value in the list
- Note
  - List remains unchanged after finding the smallest value!

Preliminary Design

- Realizations
  - When looking for value with distinguishing characteristics, need a way of remembering best candidate found so far
    - Make it a function -- likely to be used often
- Design
  - Search array looking for smallest value
    - Use a loop to consider each element in turn
    - If current element is smallest so far, then update smallest value so far candidate
  - When done examining all of the elements, the smallest value seen so far is the smallest value

Necessary Information

- Information to be maintained
  - Array with values to be inspected for smallest value
  - Number of values in array
  - Index of current element being considered
  - Smallest value so far

A More Detailed Design

- Solution
  - Function that takes array of values and array size as its two in parameters; returns smallest value seen as its value
  - Initialize smallest value so far to first element
  - For each of the other elements in the array in turn
    - If it is smaller than the smallest value so far, update the value of the smallest value so far to be the current element
  - Return smallest value seen as value of function

Passing An Array

Notice brackets are empty

```
int ListMinimum(const int A[], int asize) {
   assert(asize >= 1);
   int SmallestValueSoFar = A[0];
   for (int i = 1; i < asize; ++i) {
      if (A[i] < SmallestValueSoFar ) {
         SmallestValueSoFar = A[i];
     }
   }
   return SmallestValueSoFar ;
}
```

Could we just assign a 0 and have it work?

Using ListMinimum()

- What happens with the following?

```
int Number[6];
Number[0] = 3; Number[1] = 88; Number[2] = -7;
Number[3] = 9; Number[4] = 1;  Number[5] = 24;

cout << ListMinimum(Number, 6) << endl;
```

Notice no brackets

```
int List[3];
List[0] = 9;   List[1] = 12;   List[2] = 45;

cout << ListMinimum(List, 3) << endl;
```

Remember

- Arrays are always passed by reference
  - Artifact of C
- Can use **`const`** if array elements are not to be modified
- Do not need to include the array size when defining an array parameter

Some Useful Functions

```
void DisplayList(const int A[], int n) {
   for (int i = 0; i < n; ++i) {
      cout << A[i] << " ";
   }
   cout << endl;
}
void GetList(int A[], int &n, int MaxN =
  100) {
  for (n = 0; (n < MaxN) && (cin >> A[n]);
  ++n) {
      continue;
   }
}
```

Useful Functions Being Used

```
const int MaxNumberValues = 25;
int Values[MaxNumberValues];
int NumberValues;

GetList(Values, NumberValues,
  MaxNumberValues);
DisplayList(Values, NumberValues);
```

Searching

- Problem
  - Determine whether a value key is one of the element values
- Does it matter if
  - Element values are not necessarily numbers
  - Element values are not necessarily unique
  - Elements may have key values and other fields

Sequential List Searching

```
int Search(const int List[], int m,
  int Key) {
   for (int i = 0; i < m; ++i) {
     if (List[i] == Key) {
       return i;
     }
   }
   return m;
}
```

Run time is proportional to number of elements

Example Invocation

```
cin >> val;
int spot = Search(Values,
  NumberValues, val);
if (spot != NumberValues) {
   // its there, so display it
  cout << Values[spot] << endl;
}
else { // its not there, so add it
   Values[NumberValues] = val;
   ++NumberValues;
}
```

Sorting

- Problem
  - Arranging elements so that they are ordered according to some desired scheme
    - Standard is non-decreasing order
      - Why don't we say increasing order?
- Major tasks
  - Comparisons of elements
  - Updates or element movement

Common Sorting Techniques

- Selection sort
  - On ith iteration place the ith smallest element in the ith list location
- Bubble sort
  - Iteratively pass through the list and examining adjacent pairs of elements and if necessary swap them to put them in order. Repeat the process until no swaps are necessary

Common Sorting Techniques

- Insertion sort
  - On ith iteration place the ith element with respect to the i-1 previous elements
    - In text
- Quick sort
  - Divide the list into sublists such that every element in the left sublist <= to every element in the right sublist. Repeat the Quick sort process on the sublists
    - In text

SelectionSort

```
void SelectionSort(int A[], int n) {
  for (int i = 0; i < n-1; ++i) {
    int k = i;
    for (int j = i + 1; j < n; ++j) {
      if (A[j] < A[k])
        k = j;
    }
    if (i != k)
      swap(A[k], A[i]);
  }
}
```

Complexity

- SelectionSort() Question
  - How long does the function take to run
    - Proportional to n*n time units, where n is the number of elements in the list
- General question
  - How fast can we sort using the perfect comparison-based method
    - The best possible worst case time is proportional to n log n time units