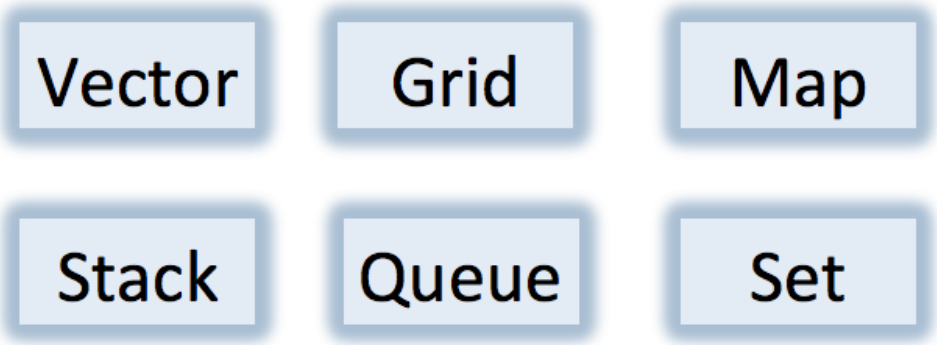
# Collections and Usage

We have learned about a variety of data structures so far in the course. In this handout, we will review the major data structures and how to use each one. Recall that collections have 3 major properties:

1. Defined as Classes -- they have constructors and member functions
2. Templatized -- they have a mechanism for collecting different variable types
3. Deep copy assignment -- they are taxing to pass by value, should pass by reference!

For each of the following collections, we will cover how to declare the data structure and how to manipulate the contents.




Collections get their name because they are data structures that is a grouping of some variable number of data items (possibly zero) that have some shared significance to a problem being solved and need to be operated upon together in some controlled fashion.

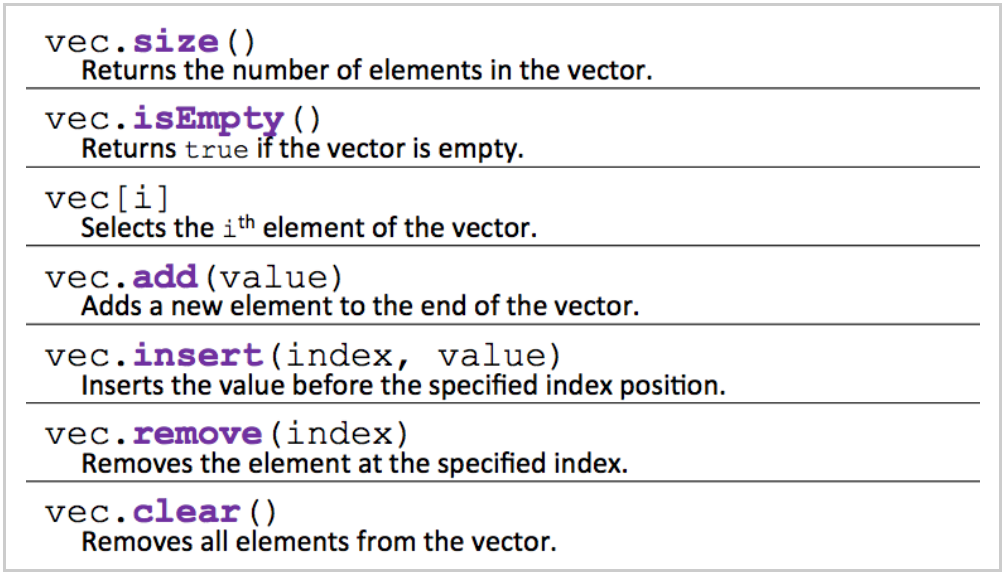
In CS106B (in lecture and in the book) collections are often referred to as Abstract data Types.

## Vectors

The Vector class provides the same abilities as the ArrayList class you encountered in Java. In C++, collection classes specify the type of object they contain by including the type name in angle brackets following the class name. Therefore, a Vector of ints could be declared in the two following ways:

```
Vector<int> vec;
Vector<int> vec();
```

The above constructors create an empty list and the Vector is indexed starting at 0. The following methods can be invoked on a Vector to manipulate and read the data it contains.




### Example code: prints out contents of a vector in a comma-separated list

```
void printContents(Vector<int> vec) {
  cout << "[";
  for (int i = 0; i < vec.size(); i++) {
    if (i > 0) cout << ", ";
    cout << vec[i];
  }
  cout << "]" << endl;
}
```

## Grids

The Grid class allows us to represent two-dimensional structures. They are helpful in representing spreadsheets, gameboards, matrices and other 2D array structures. Note that the Grid class is a Stanford collection but there is no counterpart for the class in the Standard Template Library.

```
Grid<int> grid; // default constructor
Grid<int> grid(2, 2); // initializes a 2x2 Grid
```

The default constructor will create a grid of size zero whereas the second constructor will create an empty 2x2 grid. The following methods can be invoked on a Grid to manipulate and read its data:

| |
|---|
| `grid.numRows()`<br>Returns the number of rows in the grid. |
| `grid.numCols()`<br>Returns the number of columns in the grid. |
| `grid[i][j]`<br>Selects the element in the $i^{th}$ row and $j^{th}$ column. |
| `grid.resize(rows, cols)`<br>Changes the dimensions of the grid and clears any previous contents. |
| `grid.inBounds(row, col)`<br>Returns `true` if the specified row , column position is within the grid. |

### Example code: computes the sum of the contents of a Grid of ints

```
int computeSum(Grid<int>& grid) {
  int sum = 0;
  for (int i = 0; i < grid.numRows(); i++) {
    for (int j = 0; j < grid.numCols(); j++) {
      sum += grid[i][j];
    }
  }
  return sum;
}
```

## Stacks

Conceptually, a stack provides storage for a collection of data values with the restriction that values must be removed from a stack in the opposite order from with they were added. This implies that the last item added to a stack is *always* the first item that gets removed. The common visual representation of a stack is a literal stack of plates. To **push** a plate onto the stack you place it on top. To **pop** a plate from the stack you take the plate that was on top.

```
Stack<int> plates;
```

The above constructor would create an empty stack of integers. The following methods can be invoked on a Stack object:

| |
|---|
| `stack.size()`<br>Returns the number of values pushed onto the stack. |
| `stack.isEmpty()`<br>Returns `true` if the stack is empty. |
| `stack.push(value)`<br>Pushes a new value onto the stack. |
| `stack.pop()`<br>Removes and returns the top value from the stack. |
| `stack.peek()`<br>Returns the top value from the stack without removing it. |
| `stack.clear()`<br>Removes all values from the stack. |

### Example code: print lines of a file in reverse

```
void printLinesInReverse(ifstream& infile) {
  Stack<string> lines;
  while (true) {
    string line; getline(infile, line);
    if (infile.fail()) break;
    lines.push(line);
  }

  while (!lines.isEmpty()) {
    cout << lines.pop() << endl;
  }
}
```

## Queue

The Queue Class uses the “first in, first out” strategy, also known as FIFO. The operations on a queue - which are analogous to the push and pop operations for stacks - are called enqueue and dequeue. The enqueue operation adds a new element to the end of the queue. The dequeue operation removes the element at the beginning of the queue.

```
Queue<string> line;
```

The above constructor would create an empty Queue of strings. The following methods can be invoked on a Queue object:

| |
|---|
| `queue.size()`<br>Returns the number of values in the queue. |
| `queue.isEmpty()`<br>Returns `true` if the queue is empty. |
| `queue.enqueue(value)`<br>Adds a new value to the end of the queue (which is often called its *tail*). |
| `queue.dequeue()`<br>Removes and returns the value at the front of the queue (its *head*). |
| `queue.peek()`<br>Returns the value at the head of the queue without removing it. |
| `queue.clear()`<br>Removes all values from the queue. |

### Example code: print names of people in a line in order

```
void printLine(Queue<string> line) {
  while (!line.isEmpty()) {
    cout << line.dequeue() << endl;
  }
}
```

## Maps

The Map collection is a data structure conceptually similar to a dictionary. A map holds an association between an identifying tag called a ***key*** and an associated ***value***. We also learned about the HashMap. The key difference between a HashMap and a Map is the ordering. When iterating over a Map, the for loop will return the elements in the natural order of the type. For a HashMap, the for loop will return the elements in random order.

```
Map<string, string> dictionary;
Map<string, double> symbolTable;
Map<string, Set<string> > pals;
```

The above constructors create empty maps that contain noy keys and values. Note that the constructor requires two parameters, one for the key and one for the value. You would subsequently need to add key/value pairs to the map. The following methods can be invoked on a Map object:

| | |
|---|---|
| `m.clear();` | removes all key/value pairs from the map |
| `m.containsKey(key)` | returns `true` if the map contains a mapping for the given key |
| `m[key]` or<br>`m.get(key)` | returns the value mapped to the given key;<br>if key not found, **adds** it with a default value (e.g. 0, "") |
| `m.isEmpty()` | returns `true` if the map contains no k/v pairs (size 0) |
| `m.keys()` | returns a `Vector` copy of all keys in the map |
| `m[key] = value;` or<br>`m.put(key, value);` | adds a mapping from the given key to the given value;<br>if the key already exists, **replaces** its value with the given one |
| `m.remove(key);` | removes any existing mapping for the given key |
| `m.size()` | returns the number of key/value pairs in the map |
| `m.toString()` | returns a string such as `"{a:90, d:60, c:70}"` |
| `m.values()` | returns a `Vector` copy of all values in the map |

### Example code: print all the key/value pairs in a map

```
Map<string, double> gpa = load();
for (string name : gpa) {
  cout << name << "'s GPA is ";
  cout << gpa[name] << endl;
}
```

## Sets

The Set class is one of the most useful collection classes. This class models the mathematical abstraction of a set, which is a collection in which the elements are unordered and in which each value appears only once. We do not think of sets as having indices so you cannot use a normal for loop to iterate over the values. We also learned about the HashSet. Just like Maps, the only major difference between a HashSet and a Set is the ordering. When iterating over a Set, the for loop will return the elements in the natural order of the value type. For a HashSet, the for loop will return the elements in random order.

```
Set<string> friends;
```

The above constructor will create an empty Set of strings. The following methods can be invoked on a Set object:

| |
|---|
| `set.size()`<br>Returns the number of elements in the set. |
| `set.add(value)`<br>Adds a new value to the set (ignores it if the value already was in the set). |
| `Set.contains(value)`<br>Return true if the value is in the set. |

Example code: print all the strings in a Set of strings:

```
Set<string> friends = loadFriends();
for (string name : friends) {
    cout << name << endl;
}
```