Admin

- Assign 1 due next Wed
  - Web announcements for late-breaking news
- MLK, Jr Day on Monday, no lecture
- Today's topics
  - CS106 class library: Vector, Grid, Stack, Queue
- Reading
  - Handout 14 (today & next)
- A note about arrays/pointers
  - Covered in Ch. 2, but we wait to introduce until we have a good use for them, so don't worry for now
- Terman cafe today after lecture

Lecture #5

Client use of templates

- Client includes interface file as usual
  - `#include "vector.h"`
- Client must specialize to fill in the placeholder
  - Cannot use Vector without qualification, must be `Vector<char>`, `Vector<locationT>` , ...
  - Applies to declarations (variables, parameters, return types) and calling constructor
- Vector is specialized for its element type
  - Attempt to add `locationT` into `Vector<char>` will not compile!

Vector class

- Indexed, linear homogenous collection
  - Knows its size
  - Access is bounds-checked
  - Storage automatically handled (grow & shrink)
  - Convenient insert/remove
  - Deep-copy on assignment, pass/return-by-value
- Usage
  - Constructor creates empty vector
  - Add/insert adds new element
  - Access elements using setAt, getAt or operator []
- Useful for:
  - every kind of list you can imagine!

Vector interface

```
template <typename ElemType>
 class Vector {

  public:
   Vector();
    ~Vector();

   int size();
   bool isEmpty();

   ElemType getAt(int index);
   void setAt(int index, ElemType value);

   void add(ElemType value);
   void insertAt(int pos, ElemType value);
   void removeAt(int pos);
};
```

Template specialization

```
 class Vector <double> {

  public:
   Vector<double>();
    ~Vector <double>();

   int size();
   bool isEmpty();

    double  getAt(int index);
   void setAt(int index,  double  value);

   void add( double  value);
   void insertAt(int pos,  double  value);
   void removeAt(int pos);
};
```

Client use of Vector

```
#include "vector.h"

Vector<int> MakeRandomVector(int sz)
{
   Vector<int> numbers;
   for (int i = 0; i < sz; i++)
      numbers.add(RandomInteger(1, 100));
   return numbers;
}

void PrintVector(Vector<int> &v)
{
   for (int i = 0; i < v.size(); i++)
      cout << v[i] << " ";
}

int main()
{
   Vector<int> nums = MakeRandomVector(10);
   PrintVector(nums);
   ...
```

Templates are type-safe!

```
#include "vector.h"

void TestVector()
{
    Vector<int> nums;
   nums.add(7);

   Vector<string> words;
   words.add("apple");

   nums.add("banana");         // COMPILE ERROR!
   char c = words.getAt(0);    // COMPILE ERROR!
   Vector<double> s = nums;    // COMPILE ERROR!
}
```

Grid class

- 2-D homogenous collection indexed by row & col
  - Access to elements is bounds-checked
  - Deep-copy on assignment, pass/return by value
- Usage
  - Set dimensions in constructor (can later resize)
  - Elements have default value for type before explicitly assigned
  - Access elements using getAt/setAt or operator ()
- Useful for:
  - Game board
  - Images
  - Matrices
  - Tables

Grid interface

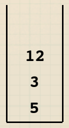
```
template <typename ElemType>
 class Grid {

   public:
     Grid();
      Grid(int numRows, int numCols); // overloaded constructor
      ~Grid();

     int numRows();
     int numCols();

     ElemType getAt(int row, int col);
     void setAt(int row, int col, ElemType value);

     void resize(int numRows, int numCols);
};
```

Client use of Grid

```
#include "grid.h"

// Returns a new 3x3 grid of chars, where each
// elem is initialized to space character
Grid<char> CreateEmptyBoard()
{
   Grid<char> board(3, 3); // create 3x3 board of chars

   for (int row = 0; row < board.numRows(); row++)
      for (int col = 0; col < board.numCols(); col++)
         board(row, col) = ' '; // board.setAt(row, col, ' ')

   return board; // btw, it's ok to return object
}
```

Stack class

- Linear collection, last-in-first-out
  - Limited-access vector
  - Can only add/remove from top of stack
  - Deep-copy on assignment, pass/return by value
- Usage
  - Constructor creates empty stack
  - push to add objects, pop to remove
- Useful for:
  - Reversing a sequence
  - Managing a series of undoable actions
  - Tracking history when web browsing



Stack interface

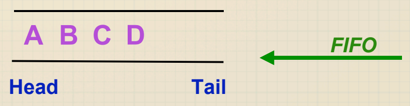
```
template <typename ElemType>
  class Stack {

   public:
     Stack();
     ~Stack();

     int size();
     bool isEmpty();

     void push(ElemType element);
     ElemType pop();
     ElemType peek();
};
```

Client use of Stack

```
void ReverseResponse()
{
    cout << "What say you? ";
    string response = GetLine();

    Stack<char> stack;
    for (int i = 0; i < response.length(); i++)
        stack.push(response[i]);

    cout << "That backwards is :";
    while (!stack.isEmpty())
        cout << stack.pop();
 }
```

Queue class

- Linear collection, first-in-first-out
  - Limited-access vector
  - Can only add to back, remove from front
  - Deep-copy on assignment, pass/return by value
- Usage
  - Constructor creates empty queue
  - enqueue to add objects, dequeue to remove
- Useful for:
  - Modeling a waiting line
  - Storing user keystrokes
  - Ordering jobs for a printer
  - Implementing breadth-first search



Queue interface

```
template <typename ElemType>
  class Queue {

    public:
      Queue();
      ~Queue();

      int size();
      bool isEmpty();

      void enqueue(ElemType element);
      ElemType dequeue();
      ElemType peek();
  };
```

Client use of Queue

```
void ManageQueue()
{
   Queue<string> queue;

   while (true) {
      cout << "? ";
      string response = GetLine();
      if (response == "") break;
      if (response == "next") {
         if (queue.isEmpty())
            cout << "No one waiting!" << endl;
         else
            cout << "Handle" << queue.dequeue() << endl;
      } else {
         queue.enqueue(response);
         cout << "Add" << response << endl;
      }
   }
}
```

Nested templates

- Queue can hold stacks or vector of vector, etc

```
Vector<Queue<string> > checkoutLines;
Grid<Stack<string> > game;
```

- Need space between >> closers
  - Otherwise compiler see stream extraction
- Can use typedef to make shorthand name
  - `typedef Vector<Vector<int> > calendarT;`