Assignment 3: Short Recursion Problems

Assignment 3 is going out in two parts: this one, which has you implement a few short recursion problems and submit them for feedback, and a larger one, which has you implement the game of Boggle. Both parts are required, but you're to complete and submit solutions for the problems described in this handout first, and then move on to the larger assignment—one that has you implement the game of Boggle—afterwards, which is discussed in Handout 17. (There's an Assignment 3 overview session on Wednesday, October 17th at 4:15 in our normal lecture hall.)

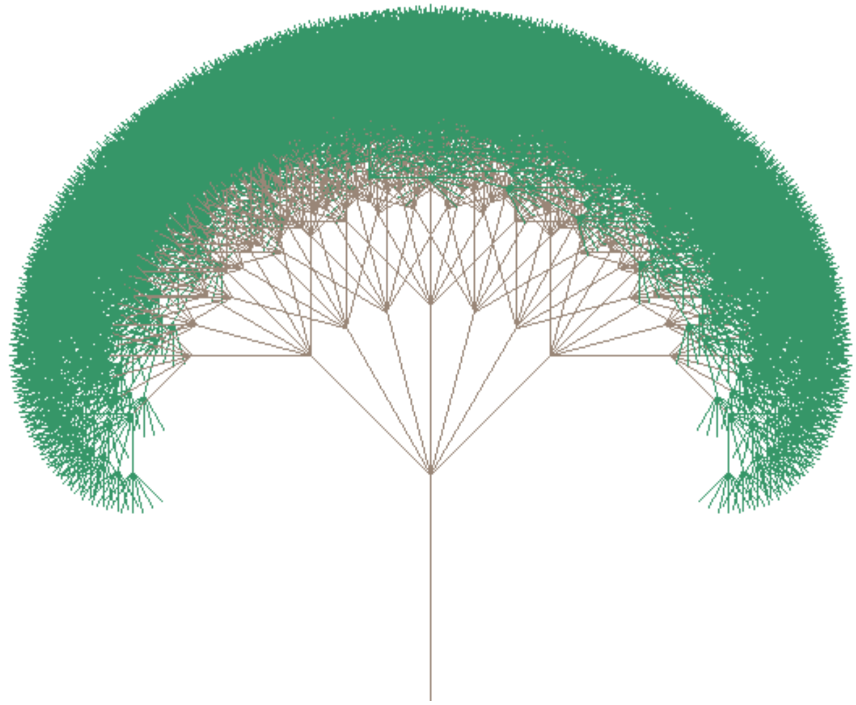
Solutions to Warm-up Problems Due: Monday, October 22nd at 3:00 p.m.
Solution to Boggle Due: Friday, October 26th at 3:00 p.m.

For the three warm-up exercises, we specify the function prototype. **Your function must exactly match that prototype** (same name, same arguments, same return type, although you're welcome to implement it to wrap around another function with a different prototype). Your function must use recursion; even if you can come up with an iterative alternative, we insist on a recursive formulation! Also, note that the Boggle assignment is much more involved than these warm-up problems, so don't be left with the impression that you somehow need a week to complete the warm-ups and just four more days for Boggle. In practice, you'll want to press through these problems fairly quickly and move on to Boggle pronto. I'm giving you seven days for this part, not because it takes that long to complete them, but because it's obnoxious to give you less than a week for anything.

Think of these three problems and the Boggle portion of the assignment as one big assignment, and consider the completion of these three problems to be a milestone that needs to be completed by next Monday. As opposed to Assignment 1's checkpoint, these problems are required and solutions to them need to be submitted.

Late day computation is the sum of the late days used between the two, so ideally you'd turn in the solutions to the warm-up exercises on time and take at most one late day for Boggle, so you have Monday to collect your thoughts and mentally prepare for the midterm on Tuesday evening.

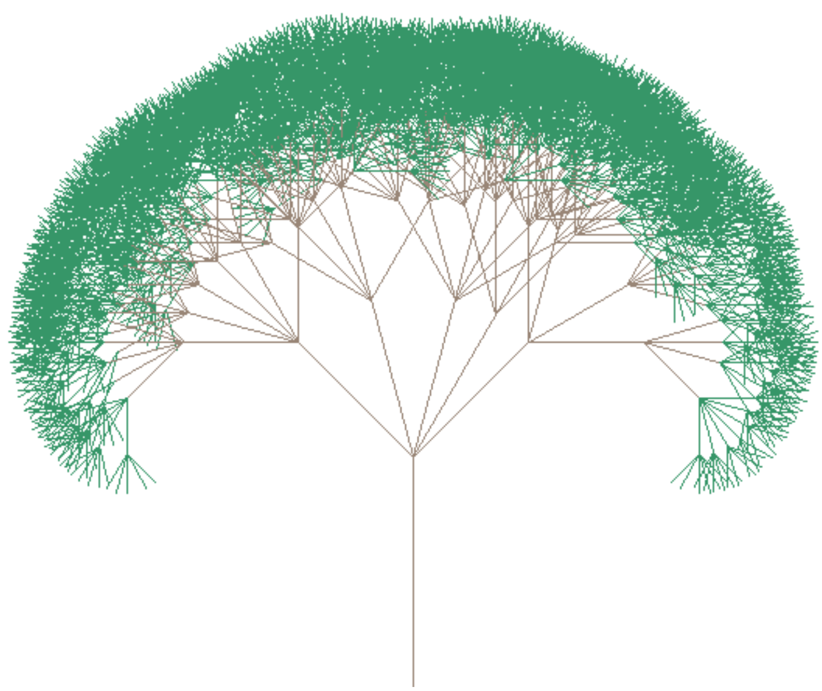
Problem 1: Recursive Trees



The drawing on the right is a tree of order 5, where the trunk of the tree is drawn from the bottom center of the graphics window straight up through a distance of **`kTrunkLength`** pixels. Sitting on top of that trunk are **seven** trees of order 4, each with a base trunk length that's 70% of the original. Each of the order-4 trees is topped off with seven order-3 trees, which are themselves comprised of order-2 trees, and so on.

The seven trees extend from the top of the tree trunk at relative angles of ±45, ±30, ±15, and 0 degrees. And even though you can't see it in the printout, if you run the sample application, you'll notice that the inner branches—or more specifically, all contributions at order 2 and higher—are drawn in **`kTrunkColor`**, and the leafy fringe of the tree is drawn in **`kLeafColor`**.

I've set up a **`trees.cpp`** file that draws an order-0 tree, and then layers an order-1 on top of it, and then an order-2 tree on top of that, and so forth. You're to complete the implementation so that the full sweep of the tree gets drawn. You should rely on the library method **`GWindow::drawPolarLine`** to draw lines at various angles, just as the **`draw-coastline`** example in Handout 14 does.



Once you get this working, adapt your implementation so that it potentially draws something like the tree drawn on the right. The same code used to generate the first drawing above was used to generate this one, except that in the first, each recursive call was made with probability 1.0, whereas in the second, each recursive call was made with probability 0.8.

Problem 2: Generating Mnemonics [adapted from Chapter 8, Exercise 10]

On a telephone keypad, the digits are mapped onto the alphabet as shown here:

Service providers like to find numbers that spell out some word (called a **mnemonic**) appropriate to their business that makes that phone number easier to remember.

Write a function **`generateMnemonics`** that generates all possible letter combinations for a given number, represented as a string of digits. The call **`generateMnemonics("723")`**, for example, should generate:

```
PAD PBD PCD QAD QBD QCD RAD RBD RCD SAD SBD SCD
PAE PBE PCE QAE QBE QCE RAE RBE RCE SAE SBE SCE
PAF PBF PCF QAF QBF QCF RAF RBF RCF SAF SBF SCF
```

and plant them, in alphabetical order, into a **`Vector<string>`**.

I've set up a **`mnemonics.cpp`** file that is complete, save for the implementation of the **`generateMnemonics`** function, which you should flesh out. Your implementation should generate all possible letter combinations and plant them into the referenced **`Vector<string>`**.

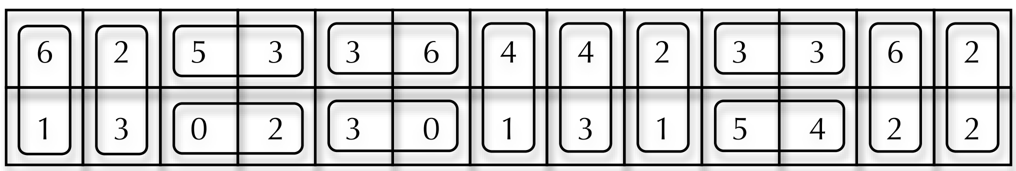
Problem 3: Finding Dominosa Solutions

The game of Dominosa presents a grid of small nonnegative integers, perhaps as follows:

6	2	5	3	3	6	4	4	2	3	3	6	2
1	3	0	2	3	0	1	3	1	5	4	2	2

There are always two rows of numbers, but the number of columns can, in principle, be any positive integer.

The goal is to pair horizontally and vertically adjacent numbers so that every number takes part in some pair, and no two pairs include the same two numbers. As such, one solution to the above problem would pair everything as follows:



Sadly, not all boards can be solved. One small, obvious example is:

3	1
1	3

Run the **`dominosa-sample`** sample application we've included in the collection of starter files. You'll see that the program generates random 2 x n boards (where you choose the value of n to be between 9 and 25 inclusive). For each randomly generated board, the application will animate the recursive backtracking search that determines whether some such pairing exists. The starter code provides the core of the interactive program, and it also provides a fully operational **`DominosaDisplay`** class that can be used to manage all aspects of the visualization. Your job is to implement the **`canSolveBoard`** function, which has the following prototype:

```
bool canSolveBoard(DominosaDisplay& display, Grid<int>& board);
```

You'll need to read over the **`dominosa-graphics.h`** file to see how the **`DominosaDisplay`** can be used to script the animation, which if properly implemented will do a superb job of visually confirming that your recursive backtracking algorithm is working properly.