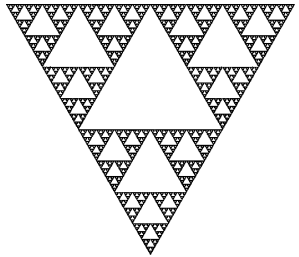
YEAH - Recursion!

Anton Apostolatos

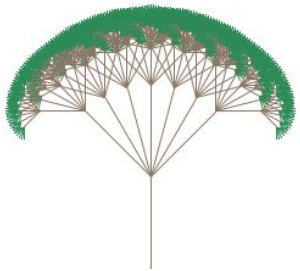
Source: The Office

A3: Recursion!

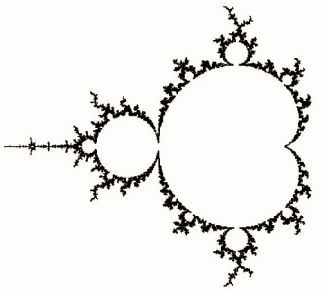
Sierpinksi



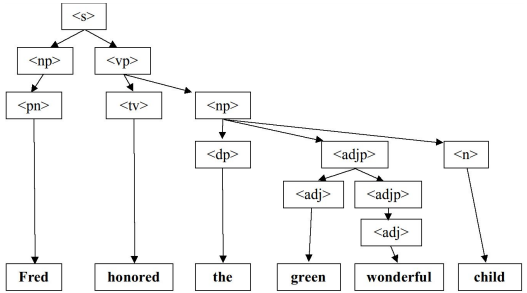
Recursive Tree



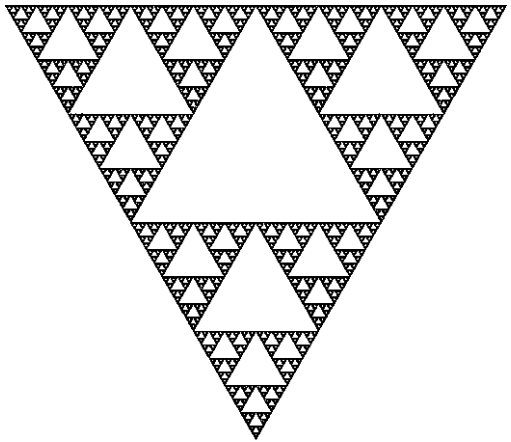
Mandelbrot Set

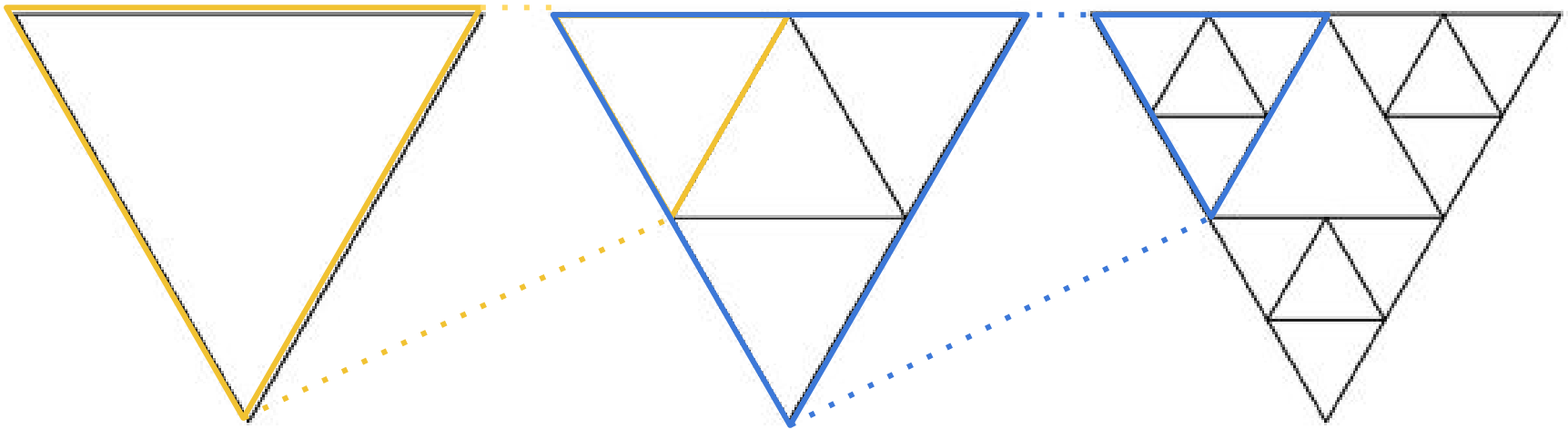


Grammar Solver



Sierpinski

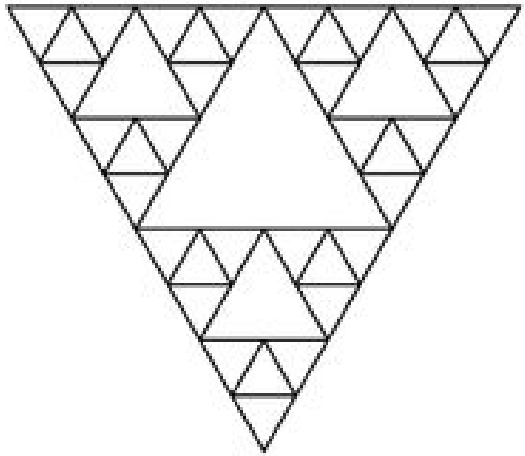




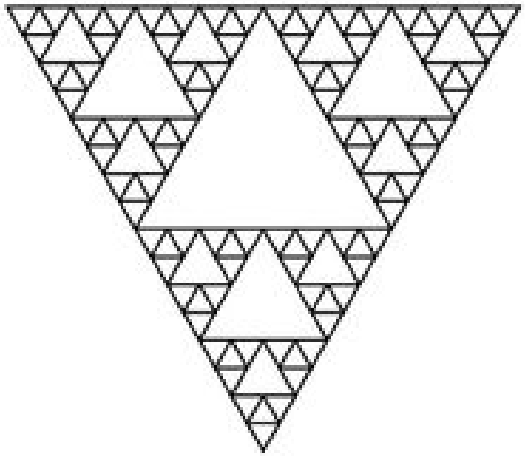
Order 1

Order 2

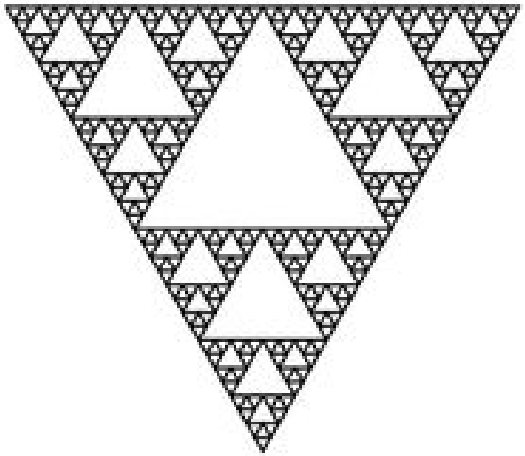
Order 3



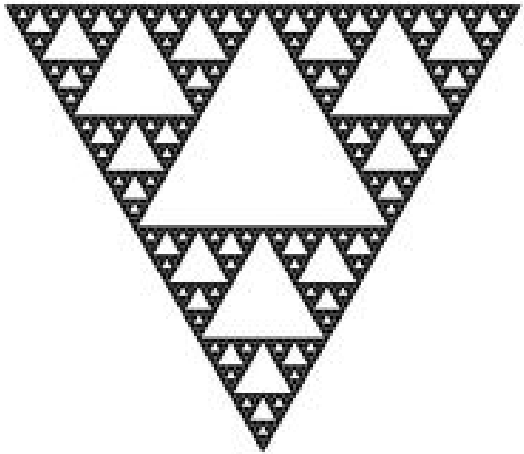
Order 4



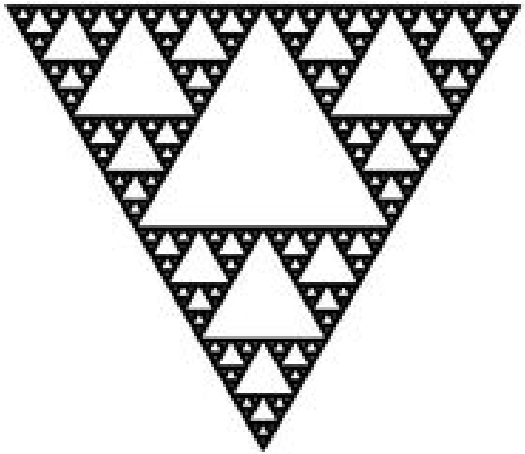
Order 5



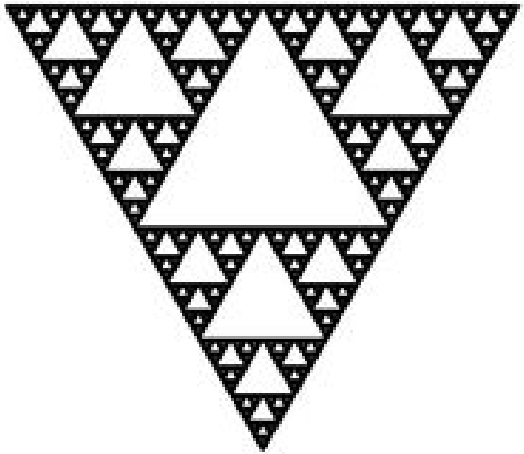
Order 6



Order 7



Order 8

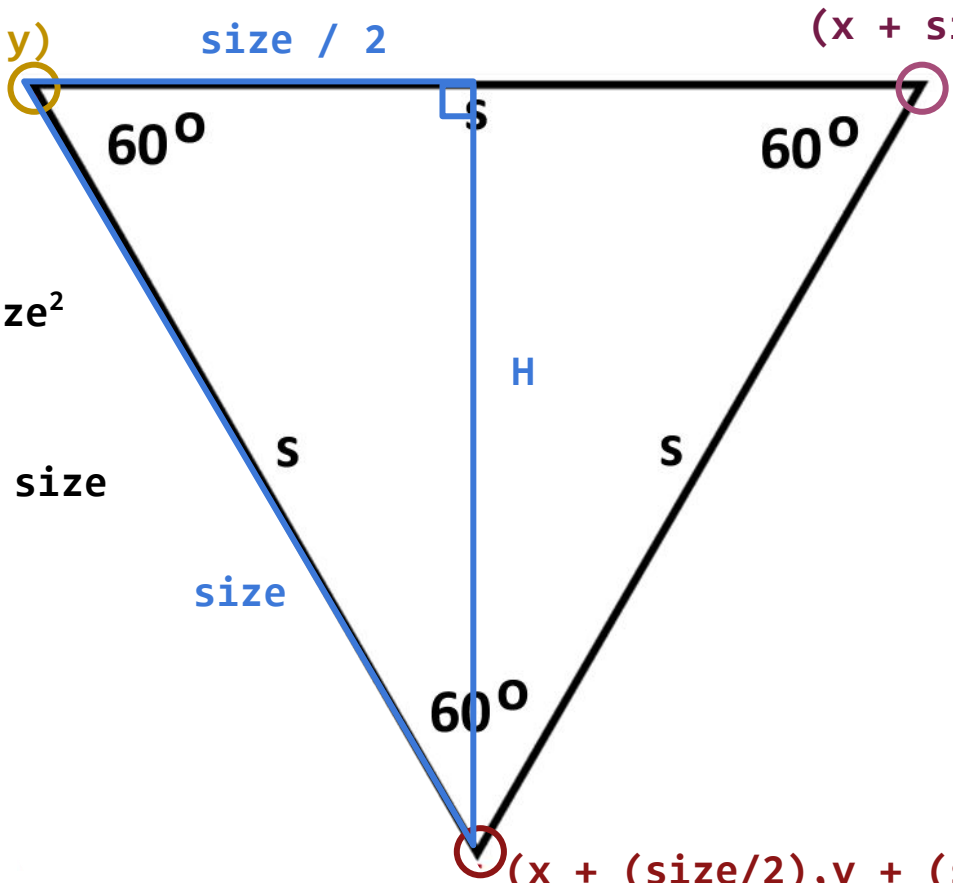


Order 9

Write the recursive function

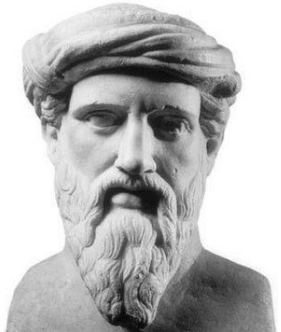
```
void drawSierpinskiTriangle(GWindow& gw,
   double x, double y, double size, int order)
```

gw: where to draw the triangle (see C++ docs!)
(x, y): top-left corner of the triangle
size: length of triangle side
order: the order of the triangle to draw



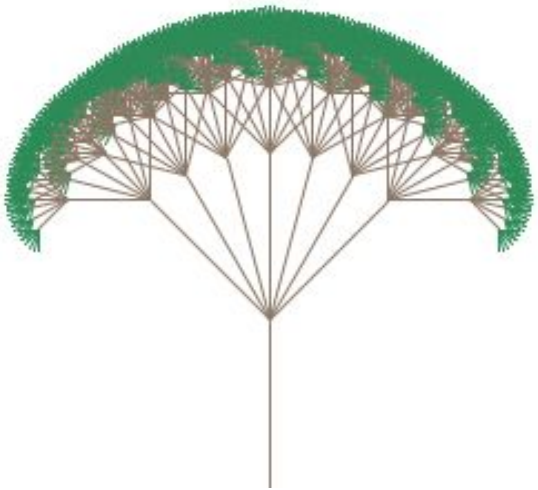
$(size / 2)^2 + H^2 = size^2$

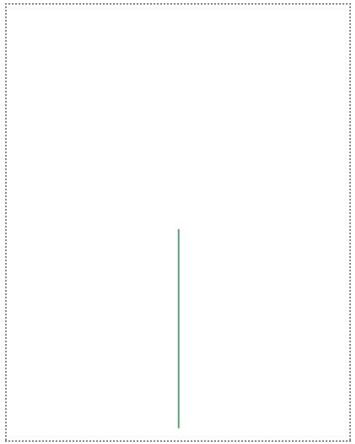
$H = (sqrt(3) / 2) * size$



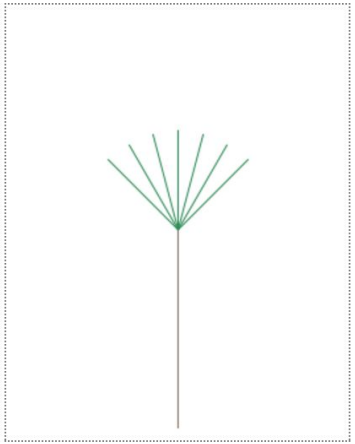
Questions?

Recursive Tree

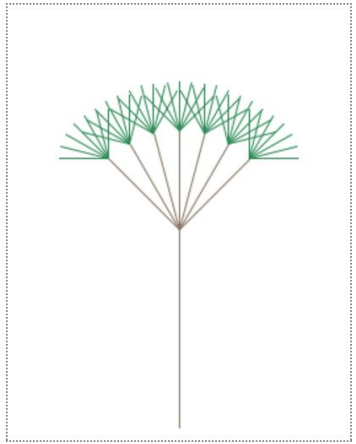




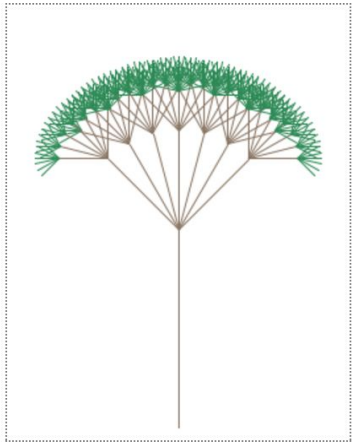
Order-1



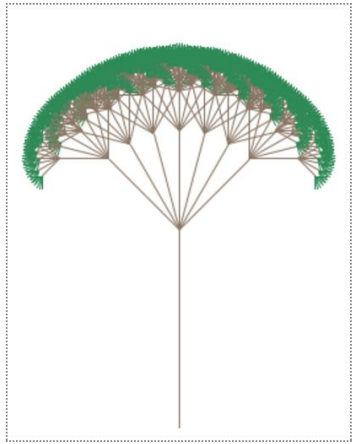
Order-2



Order-3



Order-4

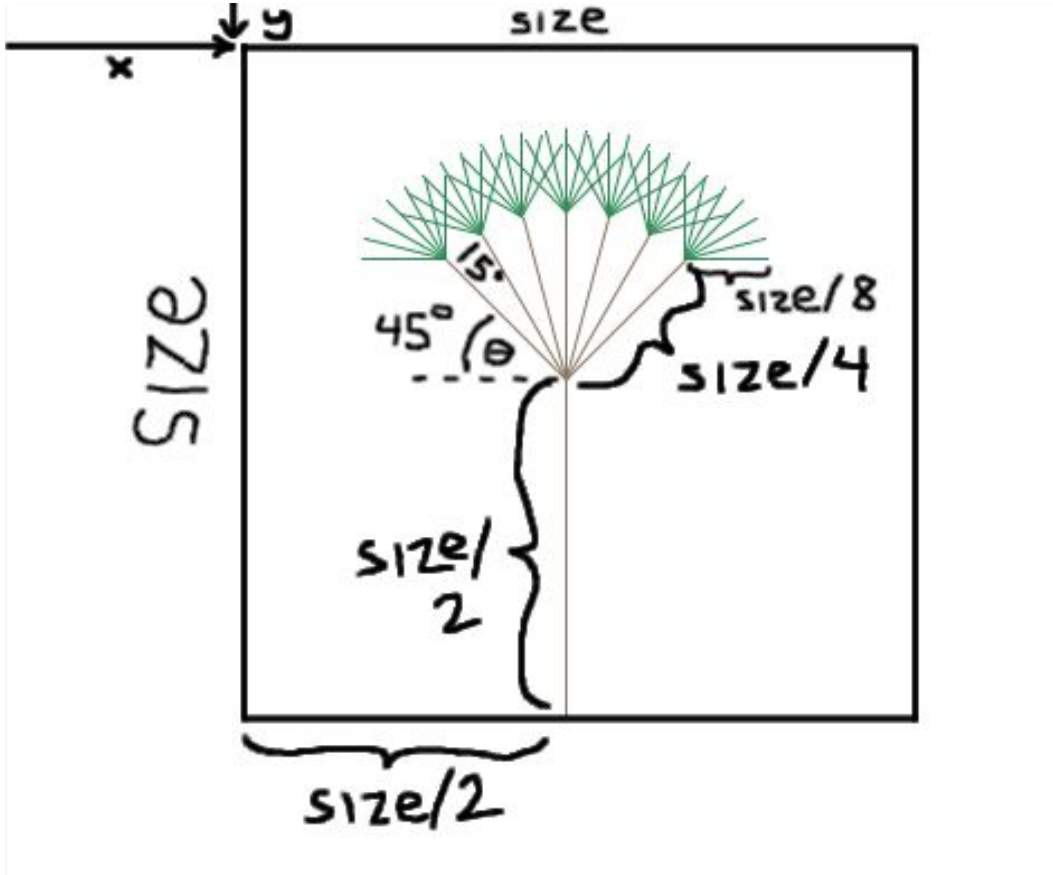


Order-5

Write the recursive function

```
void drawTree(GWindow& gw,
   double x, double y, double size, int order)
```

gw: where to draw the triangle
(x, y): top-left corner of the bounding box
size: length of bounding box
order: the order of the tree to draw

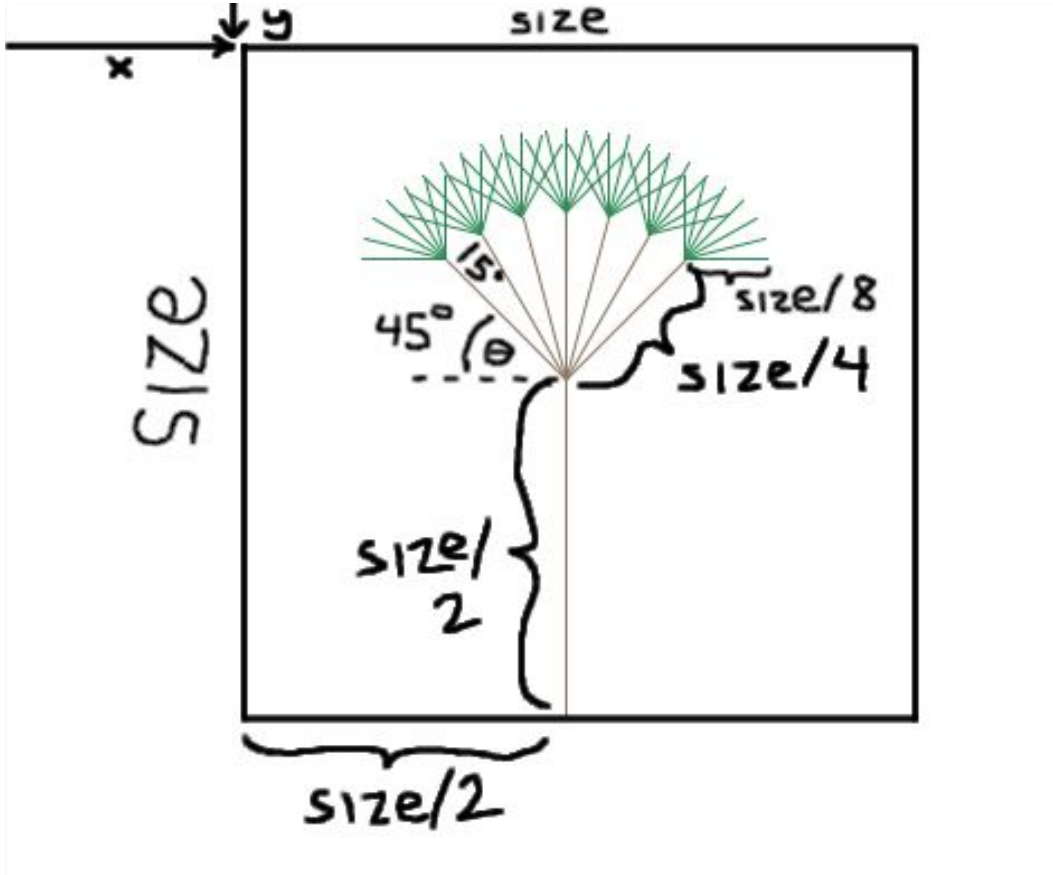

y
x
size
size
15°
45°
θ
size/8
size/4
size/
2
size/2

Every order **n** tree has seven trunks of order **n-1**

Lengths: each trunk has half their parent's length

Angles: Each subtree extends from the tip of the previous trunk at angles ±45, ±30, ±15, and 0 degrees

Colors: Branches order >=2 are drawn in a color of **BRANCH_COLOR** and the leafy fringe branches of the tree (branches drawn at level 1) are drawn in a color of **LEAF_COLOR**


y
x
size
size
15°
45°
θ
size/8
size/4
size/
2
size/2

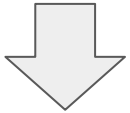
Useful functions

Member	Description
`gw.drawPolarLine(x0, y0, r, theta);` `gw.drawPolarLine(p0, r, theta);`	draws a line the given starting point, of the given length ***r***, at the given angle in degrees ***theta*** relative to the origin
`gw.setColor(color);`	sets color used for future shapes to be drawn, either as a hex string such as `"#aa00ff"` or an RGB integer such as `0xaa00ff`

***Note**: recursive helper functions are sometimes required!*

Recursive helper functions are friends, not food

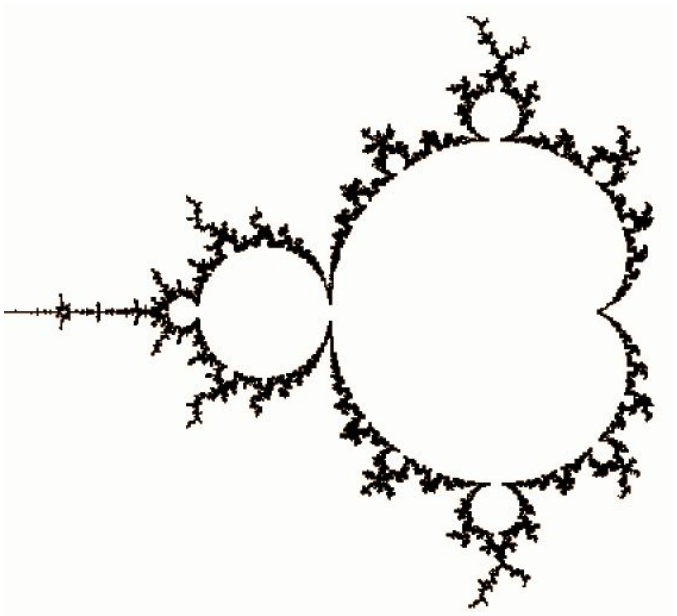
```
void drawPrettyTrees(Gwindow& gw)
```



```
void drawTree(GWindow& gw, double x,
  double y, double size, int order)
```

Questions?

Mandelbrot Set



Definition of a complex number

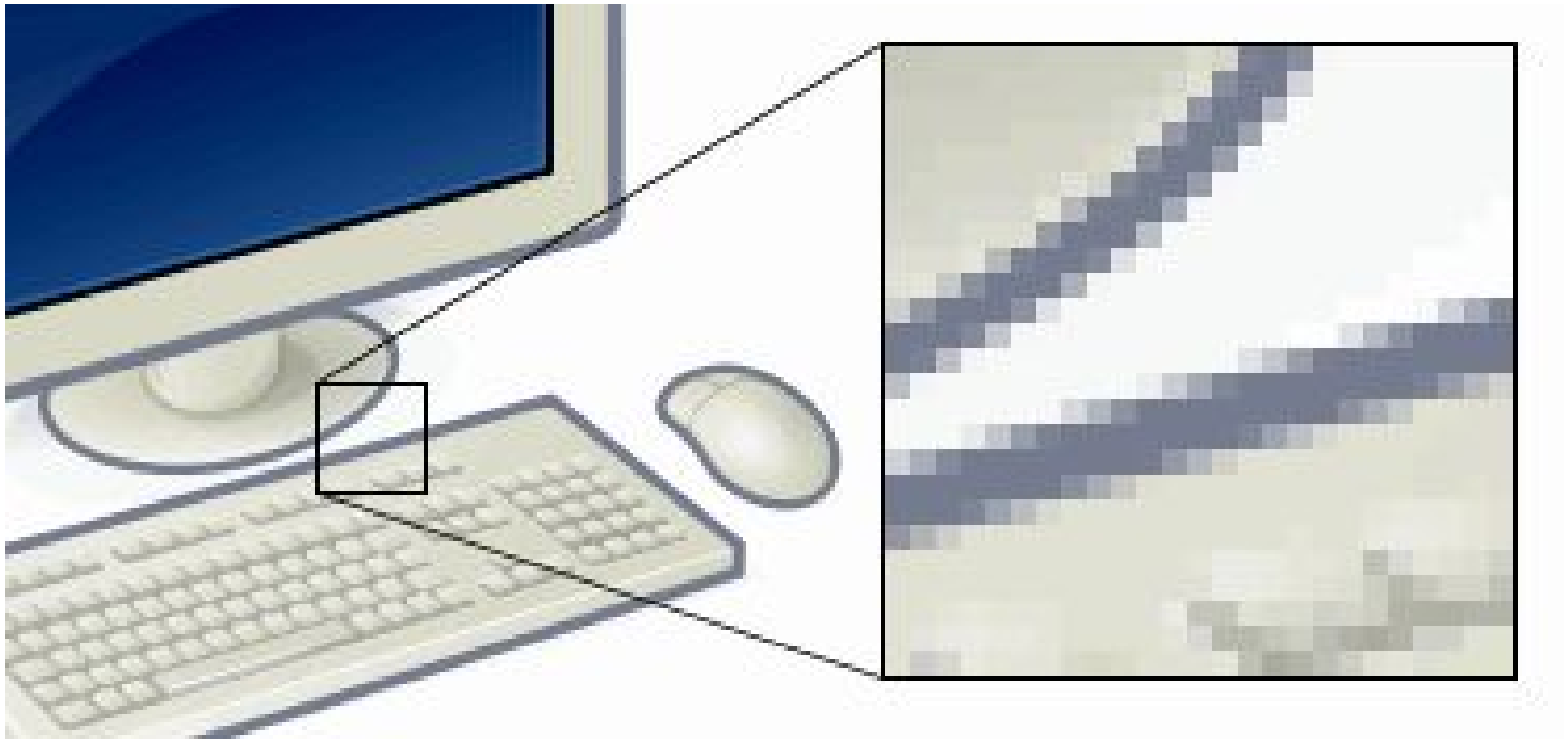
$$Z = a + bi$$

Mandelbrot Set Definition: A complex number **C** is in the Mandelbrot set if, as n approaches infinity, $\mathbf{Z_n}$ does not converge where $\mathbf{Z_0 = 0}$ and:

$$z_{n+1} = z_n^2 + c$$

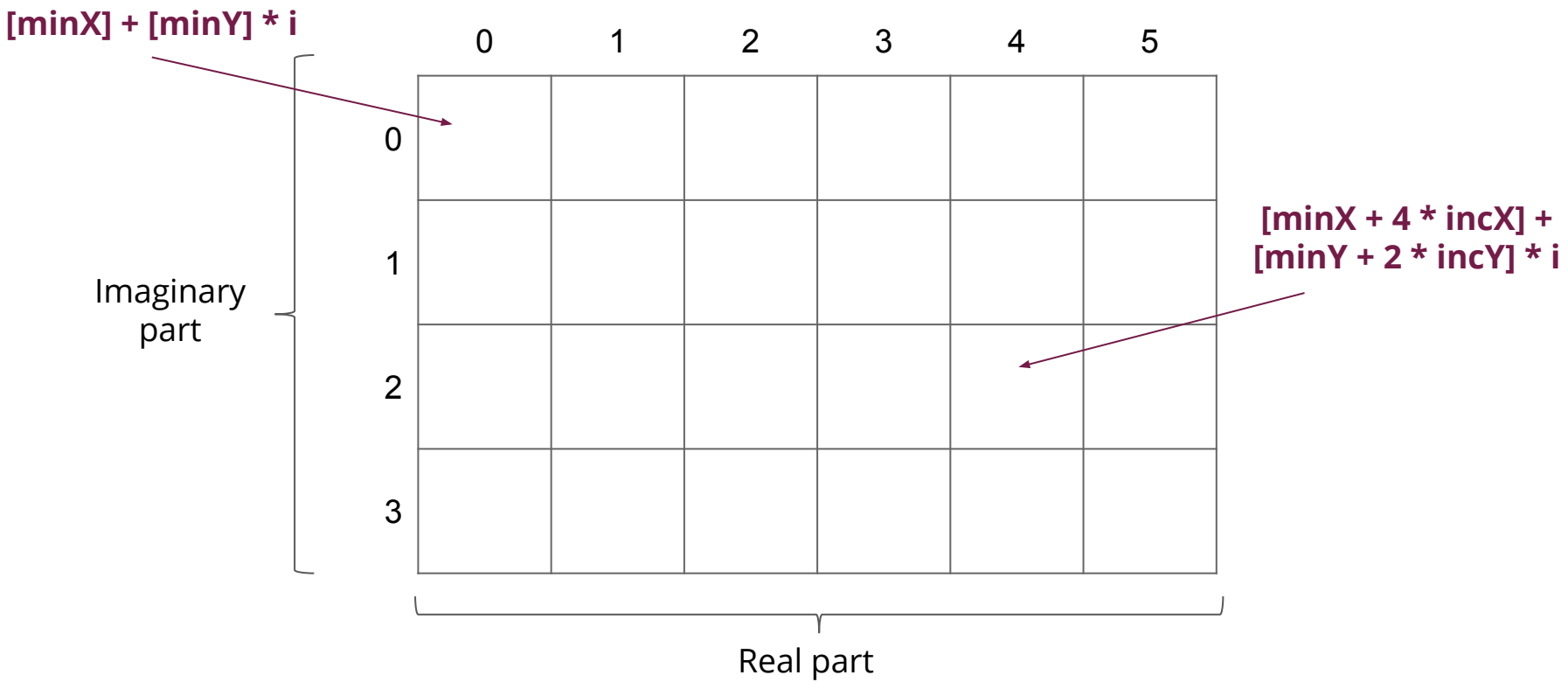
CS106B's Mandelbrot Set Definition: A complex number **C** is in the Mandelbrot set if, after **maxIterations**, $\mathbf{Z_{maxIterations}}$ is not greater than **4** (diverging) where $\mathbf{Z_0 = 0}$ and:

$$z_{n+1} = z_n^2 + c$$

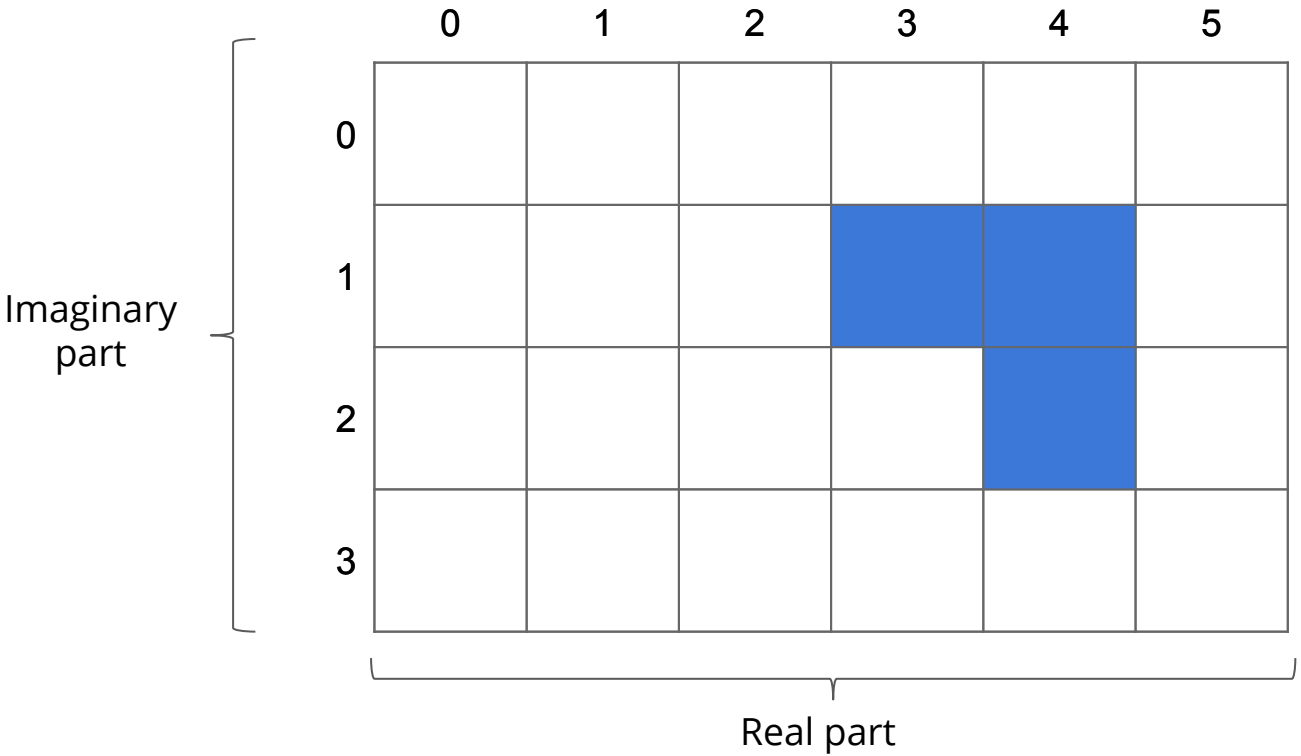


Complex Plane

Conversion: **(row, col) → [minX + col * incX] + [minY + row * incY] * i**



Let’s say only (1, 3), (1,4) and (2,4) are in the Mandelbrot Set

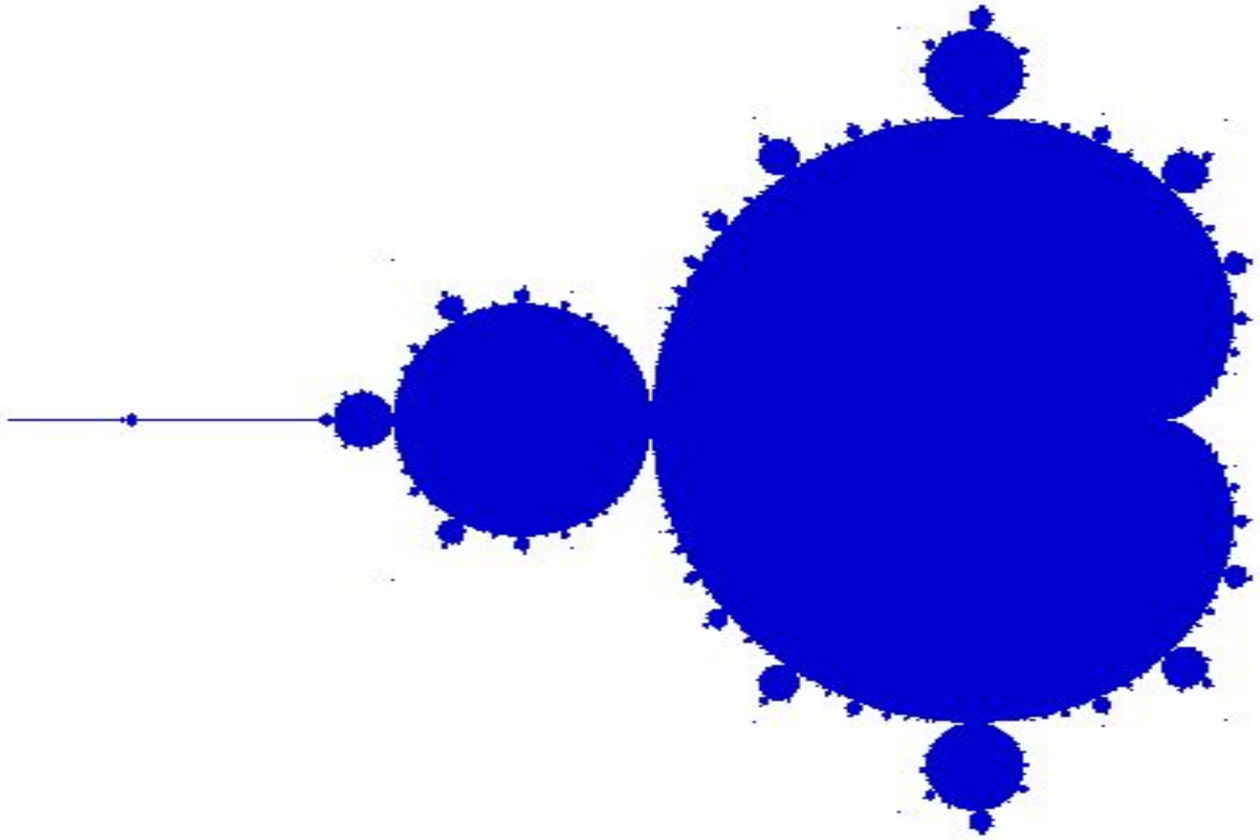


Function	Description
`Complex(double a, double b)`	Constructor that creates a complex number in the form a + b*i*
`cpx.abs()`	returns the absolute value of the number (a double)
`cpx.realPart()`	returns the real part of the complex number
`cpx.imagPart()`	returns the coefficient of the imaginary part of the complex number
`cpx1 + cpx2`	returns a complex number that is the addition of two complex numbers
`cpx1 * cpx2`	returns a complex number that is the product of two complex numbers

Write the recursive function

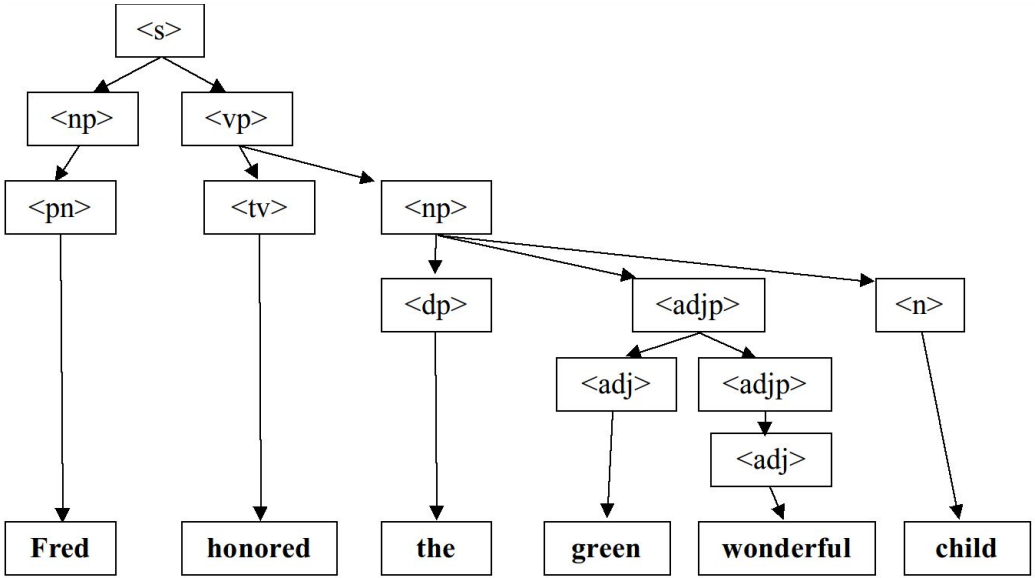
```
int mandelbrotSet(GWindow& gw, double minX,
   double incX, double minY, double incY,
   int maxIterations, int color)
```

gw: where to draw the Mandelbrot Set
(minX, minY): values of top-left corner of the grid
(incX, incY): how much to increment per row/col
maxIterations: the maximum number of iterations
color: the color of the Mandelbrot set



Questions?

Grammar Solver

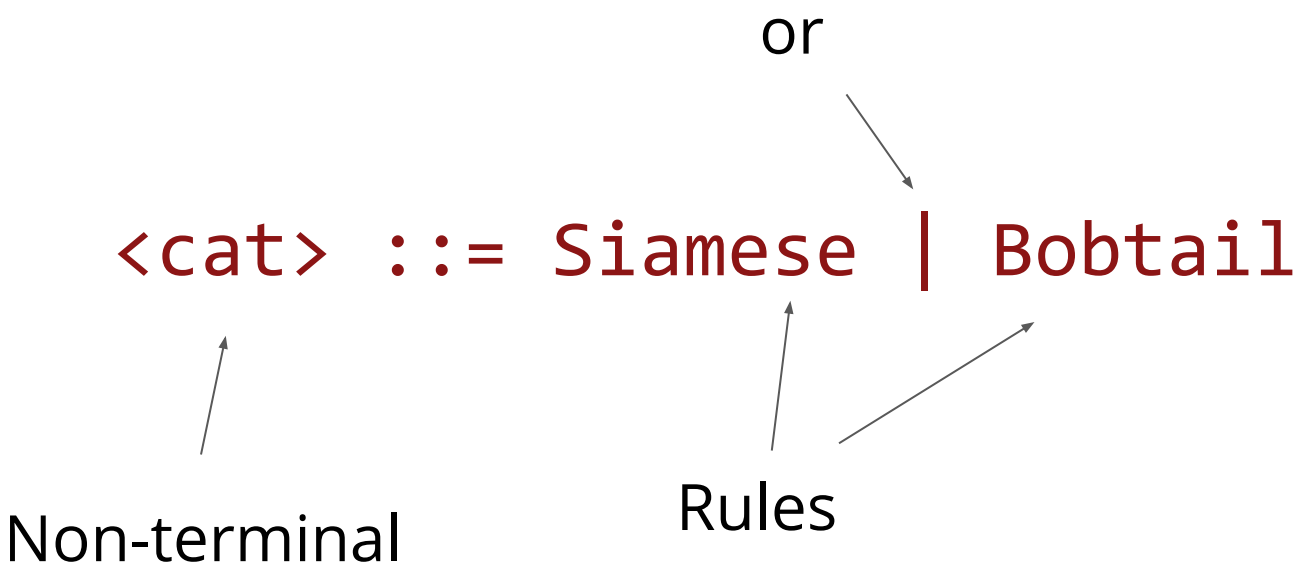


Definitions

Formal language: set of words or symbols along with a set of rules, called syntax of a language

Grammar: way of describing the syntax of a language

Backus-Naur Form (BNF): set of rules where each rule names a **symbol** and the symbol's **legal transformations**

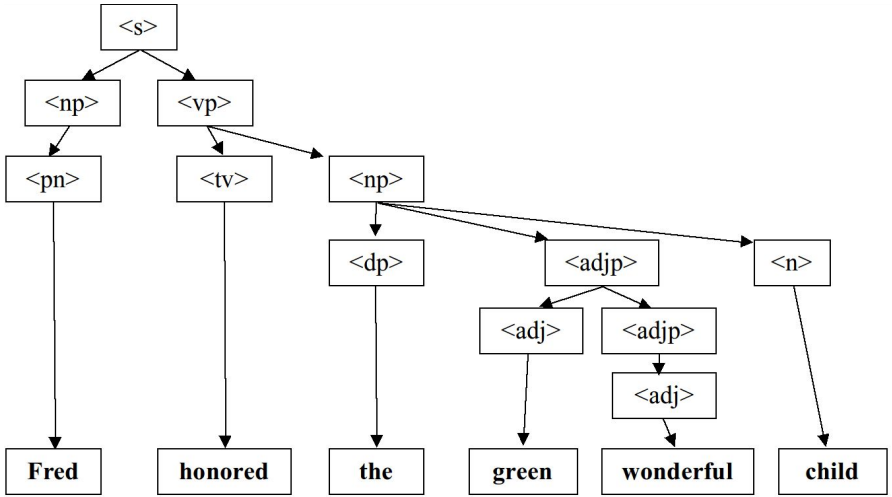

or
<cat> ::= Siamese | Bobtail
Non-terminal
Rules

```
<household-pet> ::= <cat> | <dog>
<cat> ::= Siamese | Bobtail
<dog> ::= Labrador | Xoloitzcuintle
```

```
<s>::=<np> <vp>
<np>::=<dp> <adjp> <n>|<pn>
<dp>::=the|a
<adjp>::=<adj>|<adj> <adjp>
<adj>::=big|fat|green|wonderful|faulty|subliminal|pretentious
<n>::=dog|cat|man|university|father|mother|child|television
<pn>::=John|Jane|Sally|Spot|Fred|Elmo
<vp>::=<tv> <np>|<iv>
<tv>::=hit|honored|kissed|helped
<iv>::=died|collapsed|laughed|wept
```

The fat university laughed

Elmo kissed a green pretentious television



Write the function

```
Vector<string> grammarGenerate(istream& input,
    string symbol, int times)
```

input: input stream with file in BNF form
symbol: symbol to generate
times: number of times to generate symbol

Sample run

```
Symbol to generate (Enter to quit)? <s>
How many to generate? 7

 1: a green green big dog honored Fred
 2: the big child collapsed
 3: a subliminal dog kissed the subliminal television
 4: Fred died
 5: the pretentious fat subliminal mother wept
 6: Elmo honored a faulty television
 7: Elmo honored Elmo
```

Step 1: Reading Input File

- Store contents of the grammar into a **Map**
  - Think about what key/value data types or collections you want to use!
- The **stringSplit** and **trim** functions can be very helpful from **strlib.h** (Read the documentation!)

```
stringSplit(“hello;there”, ";");   // {"hello", "there"}

  trim(“   hello  there ”, ";");   // "hello  there"}
```

Recursively

Step 2: Generating Random Expressions

- **If S is a terminal symbol:** result is symbol
- **If S is a non-terminal symbol:** choose random rule for S and explore it

Questions?