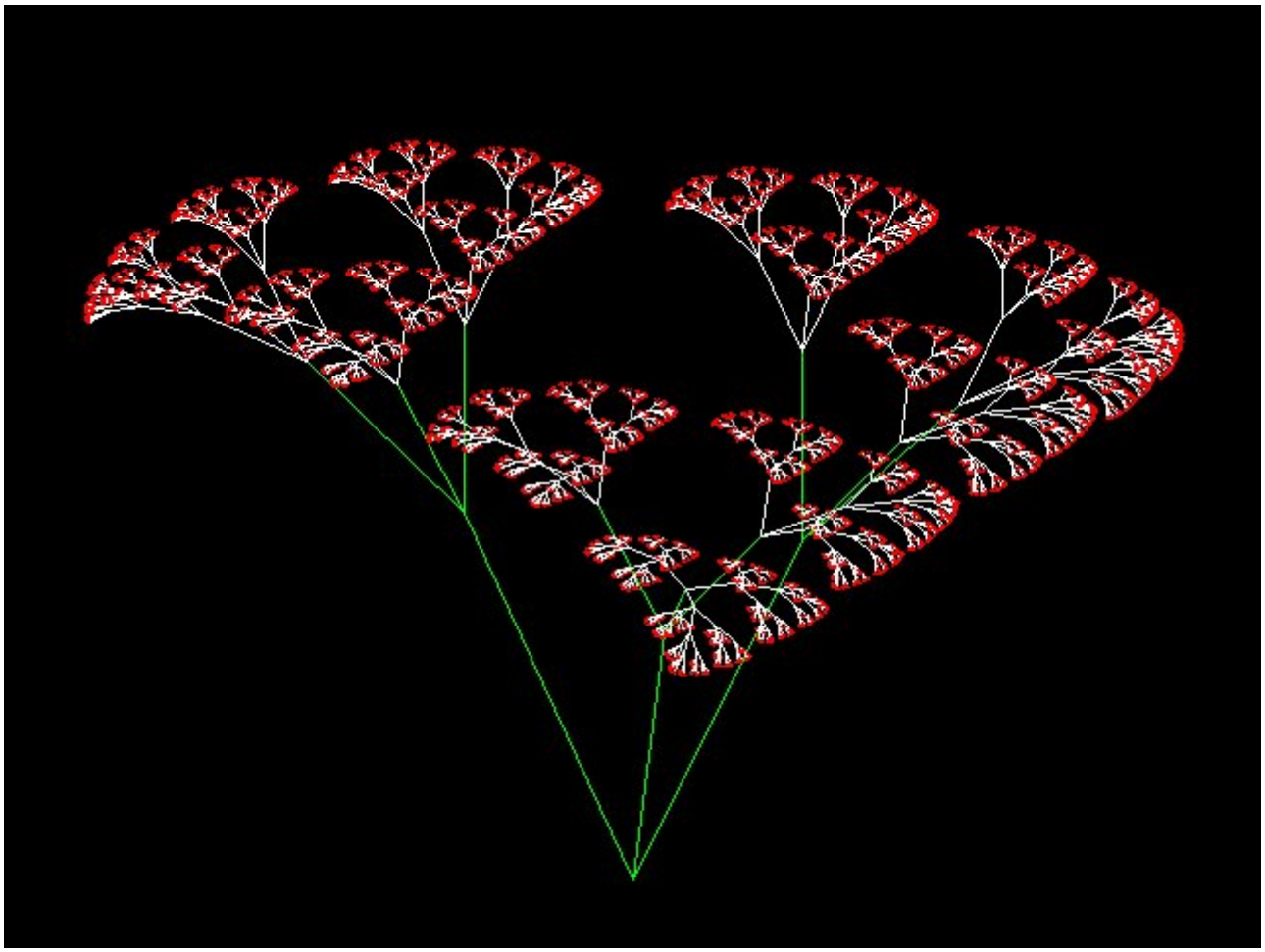
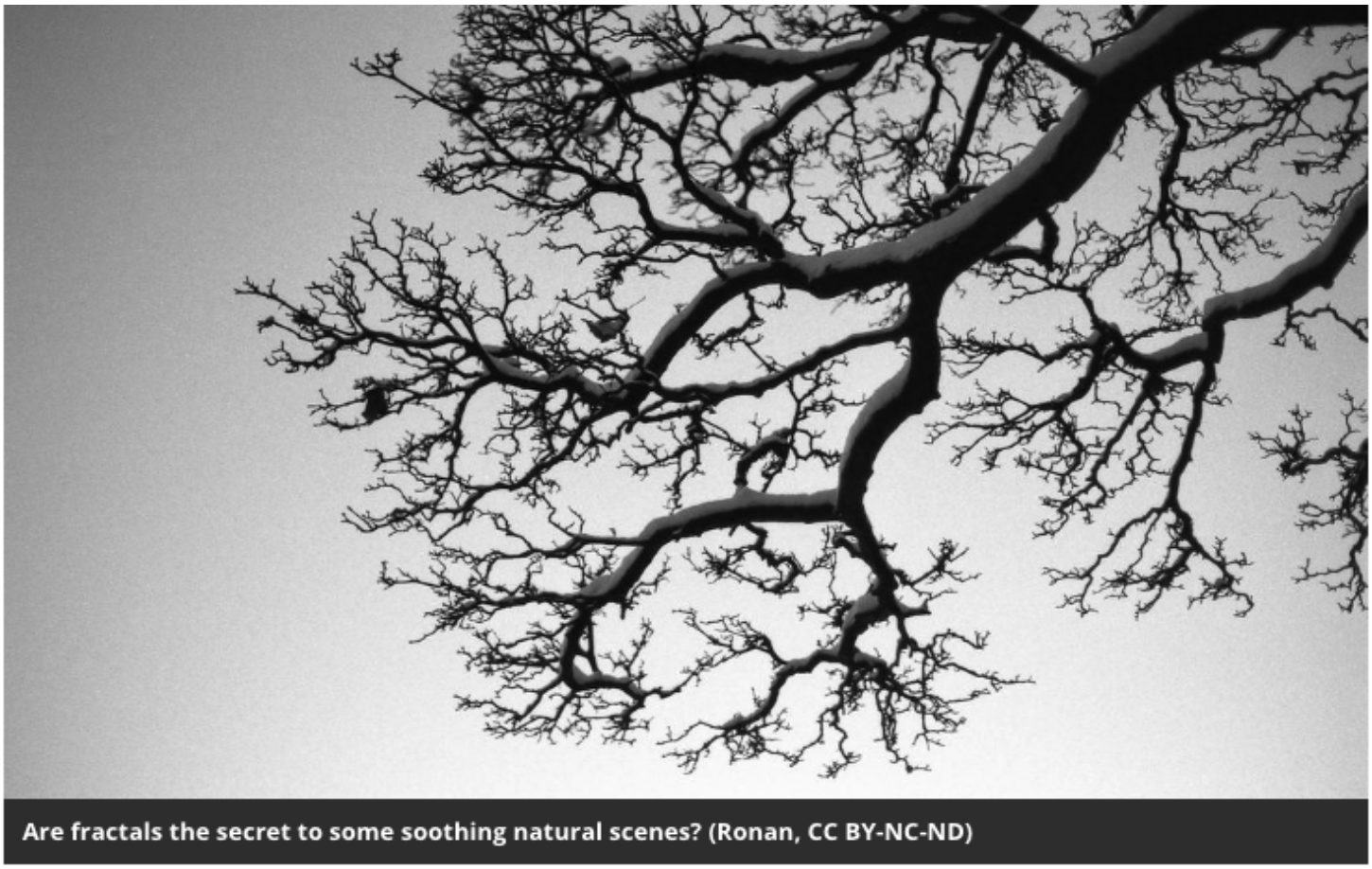
Lecture 19 - Recursion

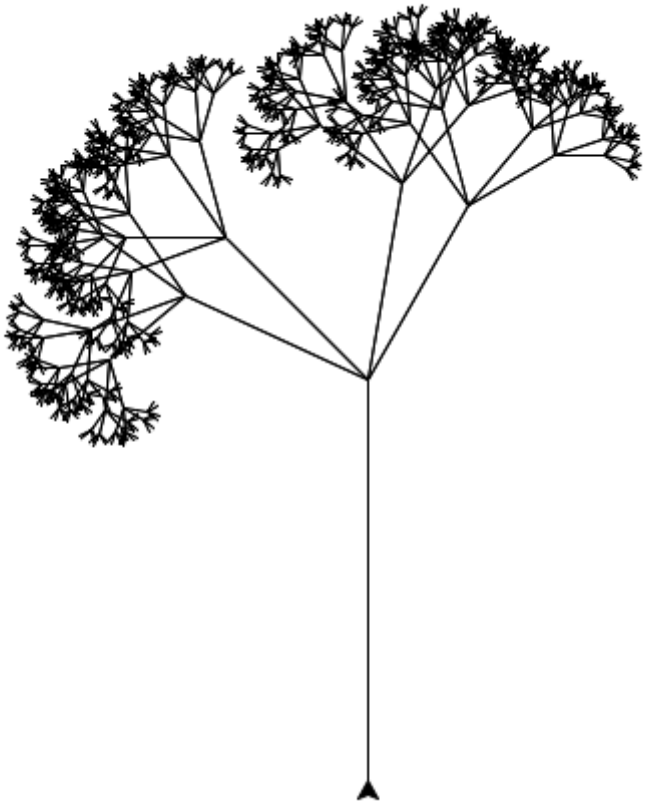
Why Recursion?



A fern repeats its pattern at various scales. (Michael , CC BY-NC)



Are fractals the secret to some soothing natural scenes? (Ronan, CC BY-NC-ND)



An example of a recursive addition

Let's define the sum of values from 0 to n as

```
sum(n) = { 0 if n <= 0
         { n + sum(n-1) if n > 0
```

Then we can build a function that matches this.

```
 1:
 2: def recursive_sum ( n ):
 3:     if n <= 0:
 4:         return 0
 5:     return n + recursive_sum(n-1)
 6:
 7:
 8:
 9: # Automated Test
10: if __name__ == "__main__":
11:     n_err = 0
12:     x = recursive_sum ( 5 )
13:     if x !=  15:
14:         n_err = n_err + 1
15:         print ( "Error: Test 1: sum not working, expected {} got {}".format (  15,
16:     x = recursive_sum ( 0 )
17:     if x != 0:
18:         n_err = n_err + 1
19:         print ( "Error: Test 2: sum conversion not working, expected {} got {}".fo
20:
21:     if n_err == 0 :
22:         print ( "PASS" )
23:     else:
24:         print ( "FAILED" )
25:
```

What is a recursive function definition:

$$f(n) = \begin{cases} f(n-1) & n \geq 1 \\ 1 & n < 1 \end{cases}$$

For a positive initeger:

```
n! = n * (n-1) * ... * 2 * 1
```

or

```
f(n) = n * (n-1) * ... * 2 * 1
```

or

```
f(n) = n * f(n-1)
```

or

```
f(n) = { n <= 1 : 1
       { n > 1  : n * f(n-1)
```

Now to Code:

```
 1: #!/Users/pschlump/anaconda3/bin/python
 2:
 3: def calc_factorial(x):
 4:     # A recursive function to find the factorial of a number
 5:     if x <= 1:
 6:         return 1
 7:     else:
 8:         return (x * calc_factorial(x-1))
 9:
10: if __name__ == "__main__":
11:     num = 5
12:     print("The factorial of", num, "is", calc_factorial(num))
13:
14:     err = False
15:     v = calc_factorial(num)
16:     if v != 120:
17:         err = True
18:         print ( "Incorrect result: {n}! Expected {good} got {bad}".format(n=num, g
19:
20:     if not err :
21:         print ( "PASS" )
22:     else :
23:         print ( "FAIL" )
24:
```

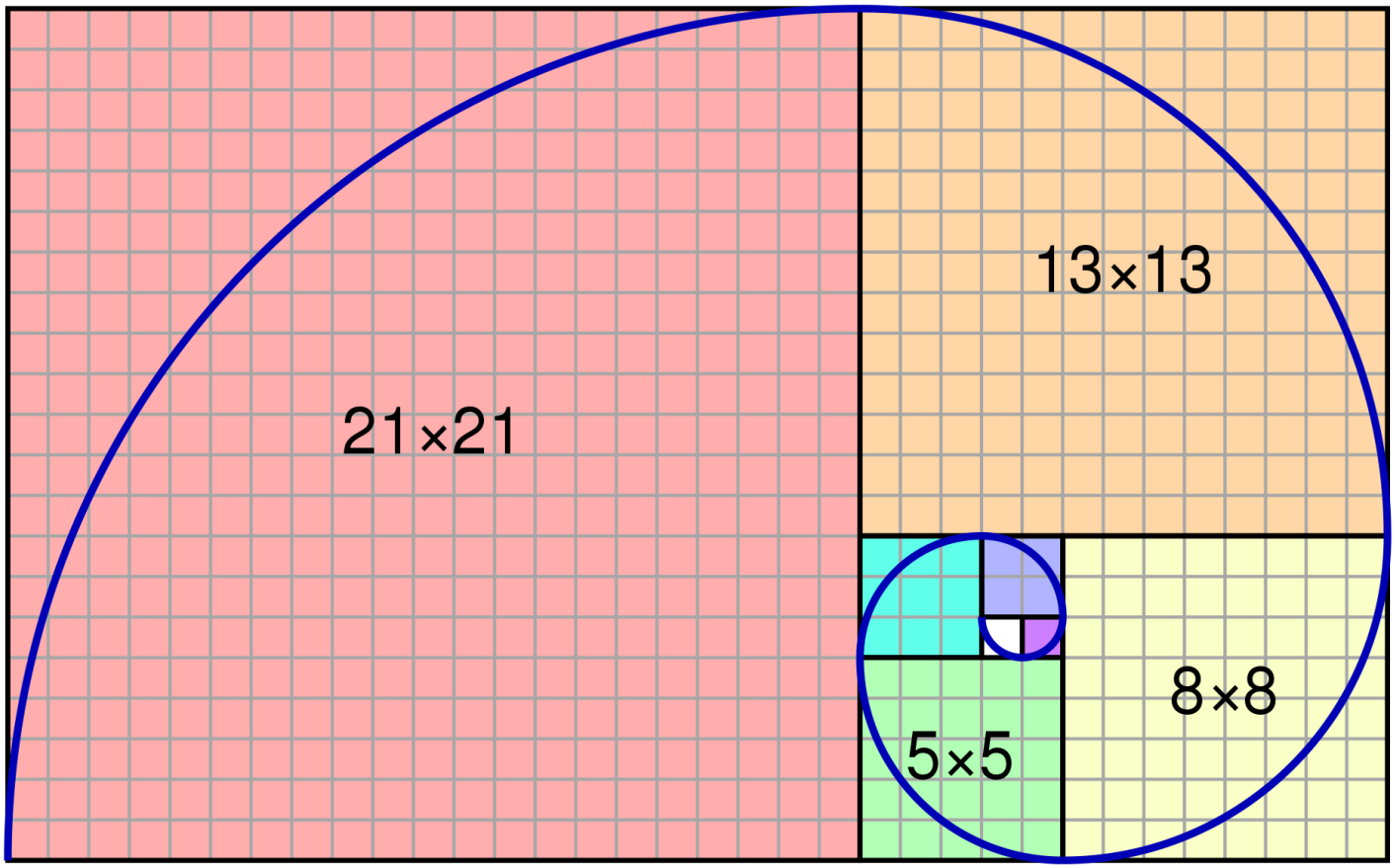
Compare to an iterative version:

```
 1: #!/Users/pschlump/anaconda3/bin/python
 2:
 3: def factorial_iterative(x):
 4:     if x <= 1:
 5:         return 1
 6:     nn = 2
 7:     rv = 1
 8:     while ( nn <= x ):
 9:         rv = rv * nn
10:     return rv
11:
12: if __name__ == "__main__":
13:     num = 5
14:     print("The factorial of", num, "is", factorial_iterative(num))
15:
16:     err = False
17:     v = factorial_iterative(num)
18:     if v != 120:
19:         err = True
20:         print ( "Incorrect result: {n}! Expected {good} got {bad}".format(n=num, g
21:
22:     if not err :
23:         print ( "PASS" )
24:     else :
25:         print ( "FAIL" )
26:
```

A better example is a fractal tree:

Fibonacci Numbers


3dham.com
Split ammonite




```
fib(n) = { 0 : n = 0
         { 1 : n = 1
         { fib(n-1) + fib(n-2)
```

Weed

```
 1: #!/usr/bin/python
 2:
 3: import turtle
 4:
 5: def tree(length,n):
 6:     if length < (length/n):
 7:            return
 8:     turtle.forward(length)
 9:     turtle.left(45)
10:     tree(length * 0.5,length/n)
11:     turtle.left(20)
12:     tree(length * 0.5,length/n)
13:     turtle.right(75)
14:     tree(length * 0.5,length/n)
15:     turtle.right(20)
16:     tree(length * 0.5,length/n)
17:     turtle.left(30)
18:     turtle.backward(length)
19:     return
20:
21: turtle.left(90)
22: turtle.backward(30)
23: tree(200,4)
24:
25: input("Press Enter to continue...")
```

The Koch curve.

So a program to run the Koch curve:

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