Biology-inspired algorithms

What looks complicated in biology can often be explained by simple rules

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What looks complicated in biology can often be explained by simple rules

Biology creates ***self-similar*** forms

Fractals

Biology Rules…

What looks complicated in biology can often be explained by simple rules

Tree Rules

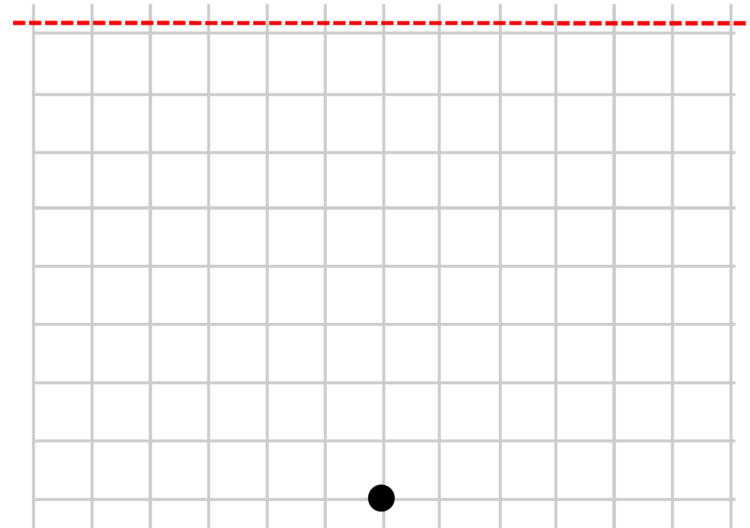
height = 4 cm

(1) At each new dot:

(2) Draw a **T** with dots on its ends

(3) Divide *height* by 2

Go back to step (1) and continue



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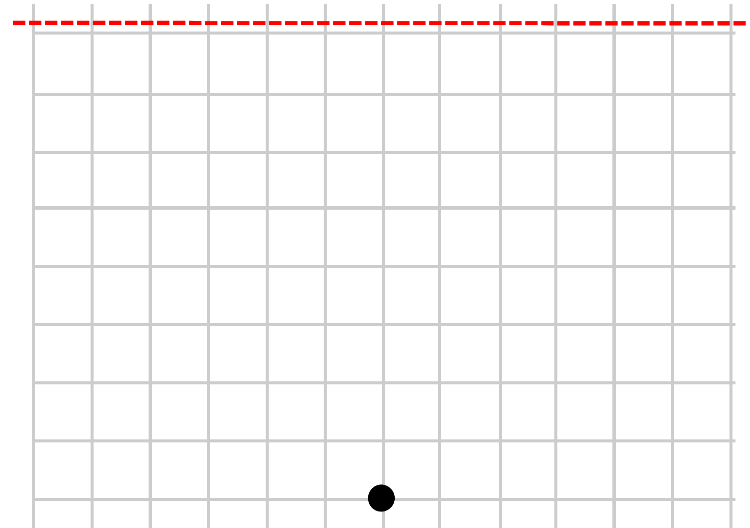

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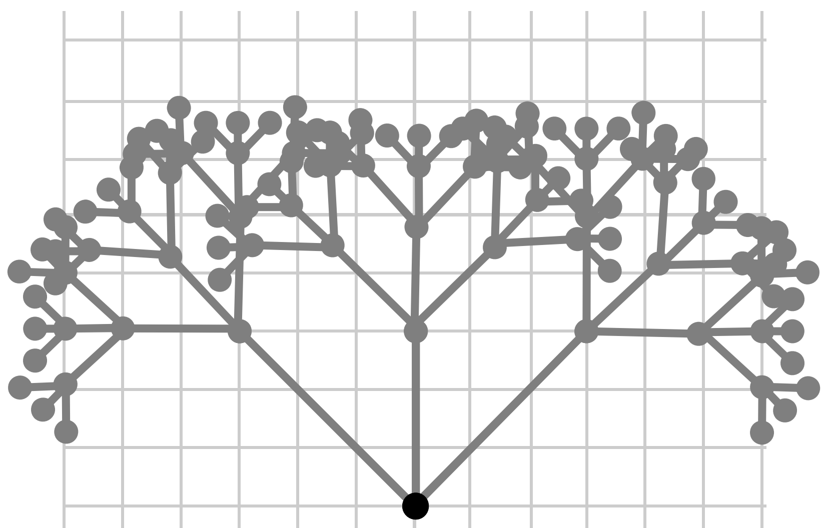

Change the underlined parts...

...to create this "tree"

Are these rules for real? Yes... and no.

The rules ***can*** create many different fractal forms

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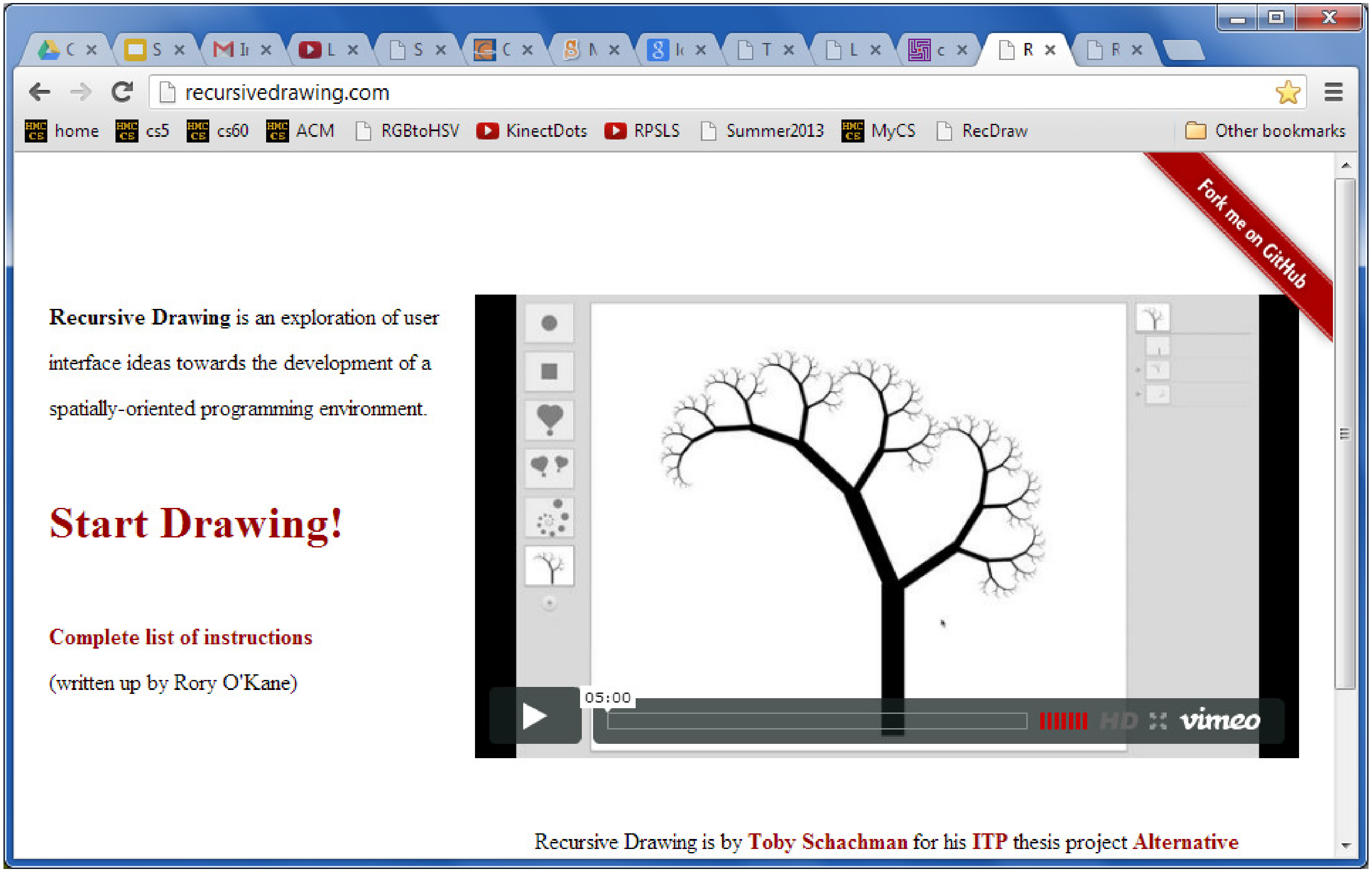
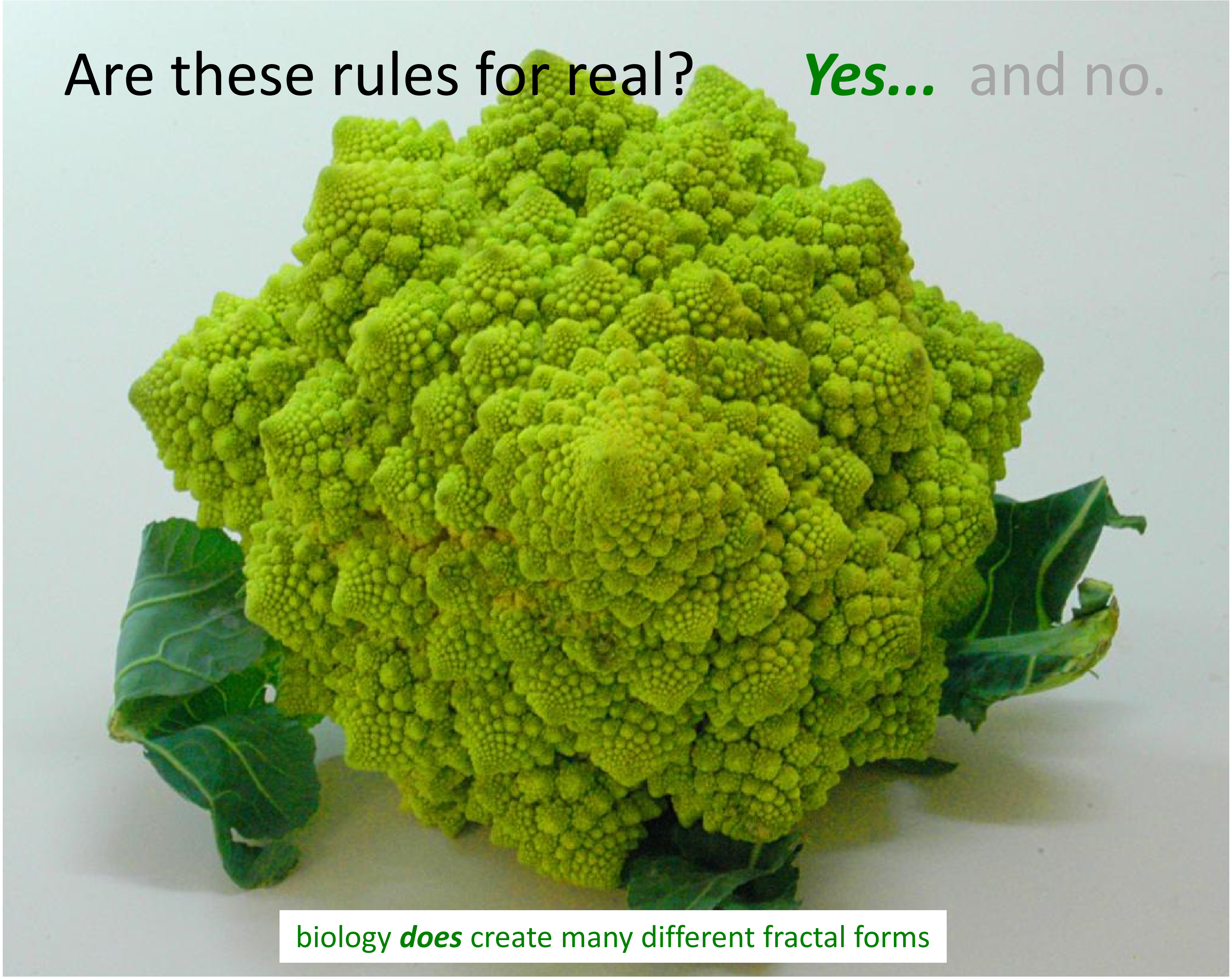
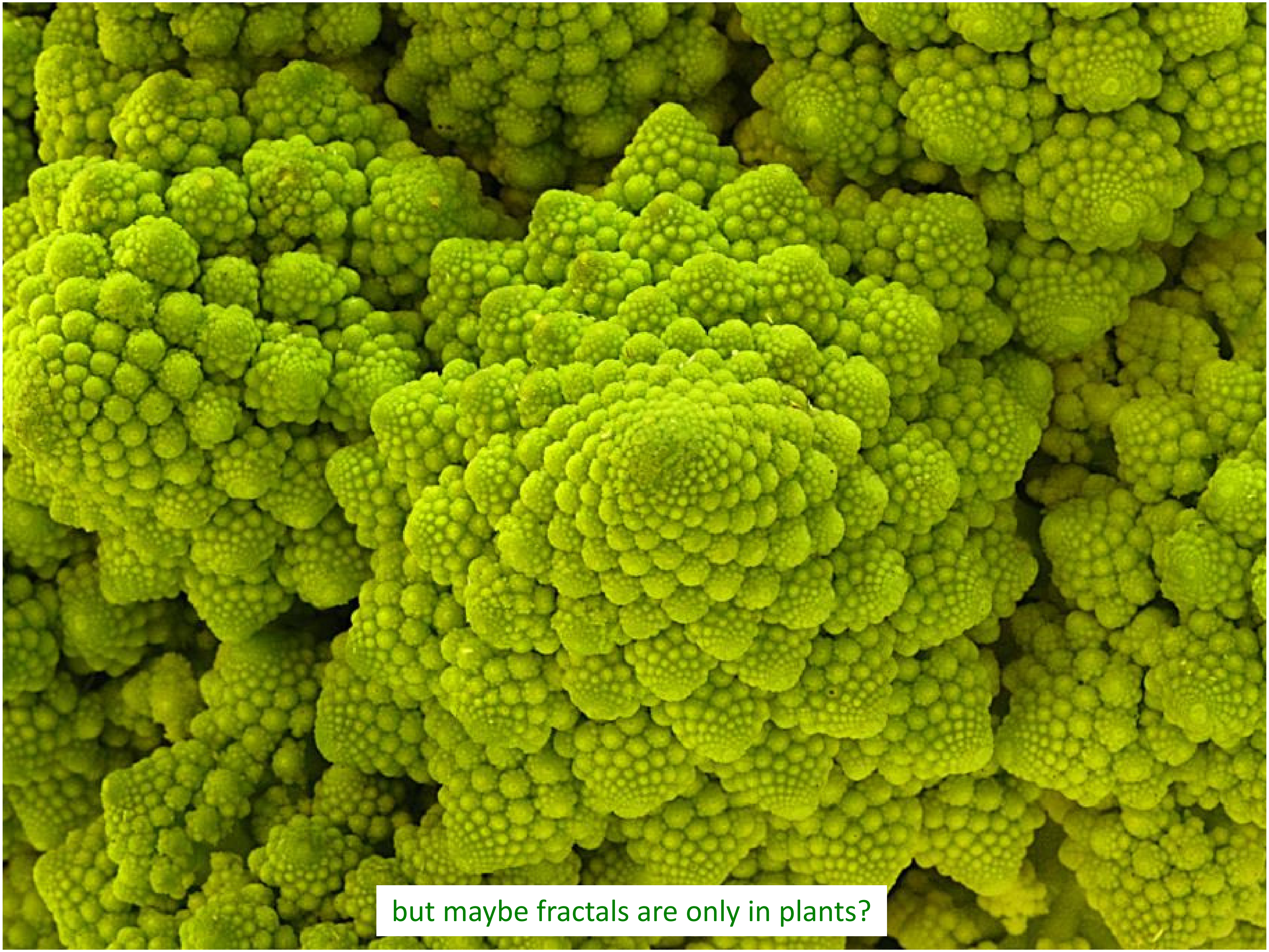


An elegant recursive drawing site...

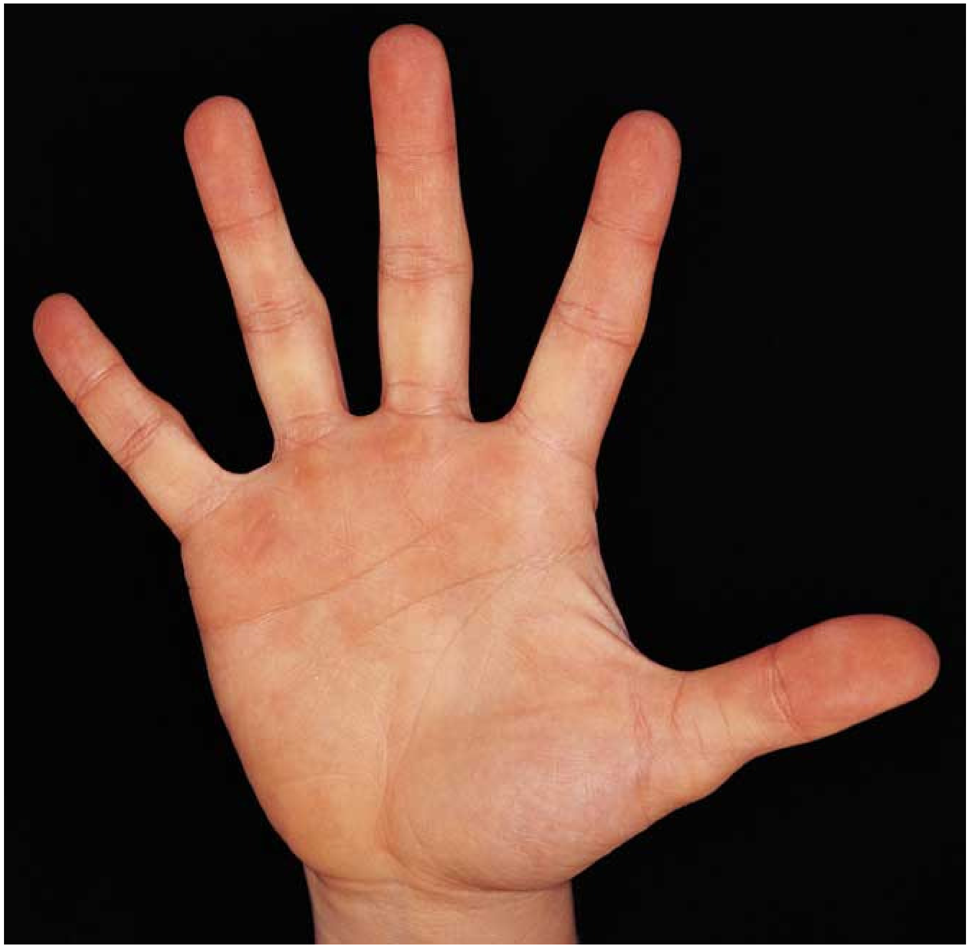
Are these rules for real? ***Yes...*** and no.



biology ***does*** create many different fractal forms

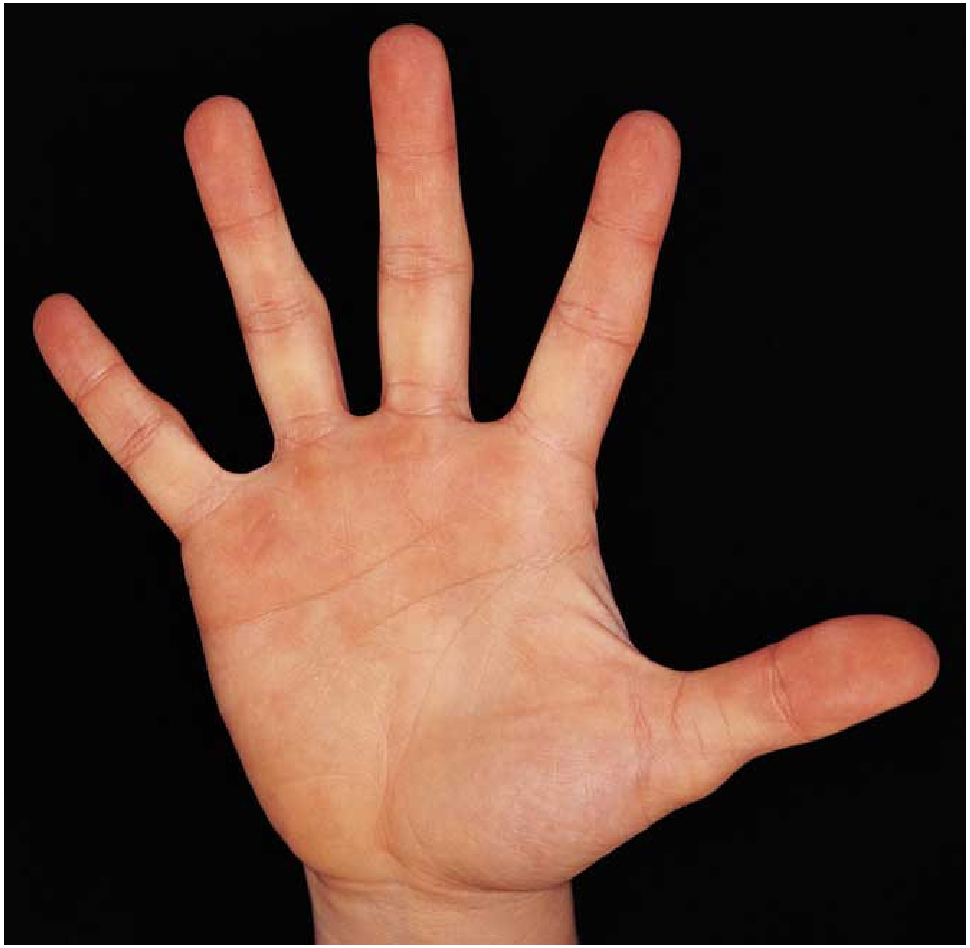

but maybe fractals are only in plants?

Are these rules for real? ***Yes...*** and no.



self-similarity?

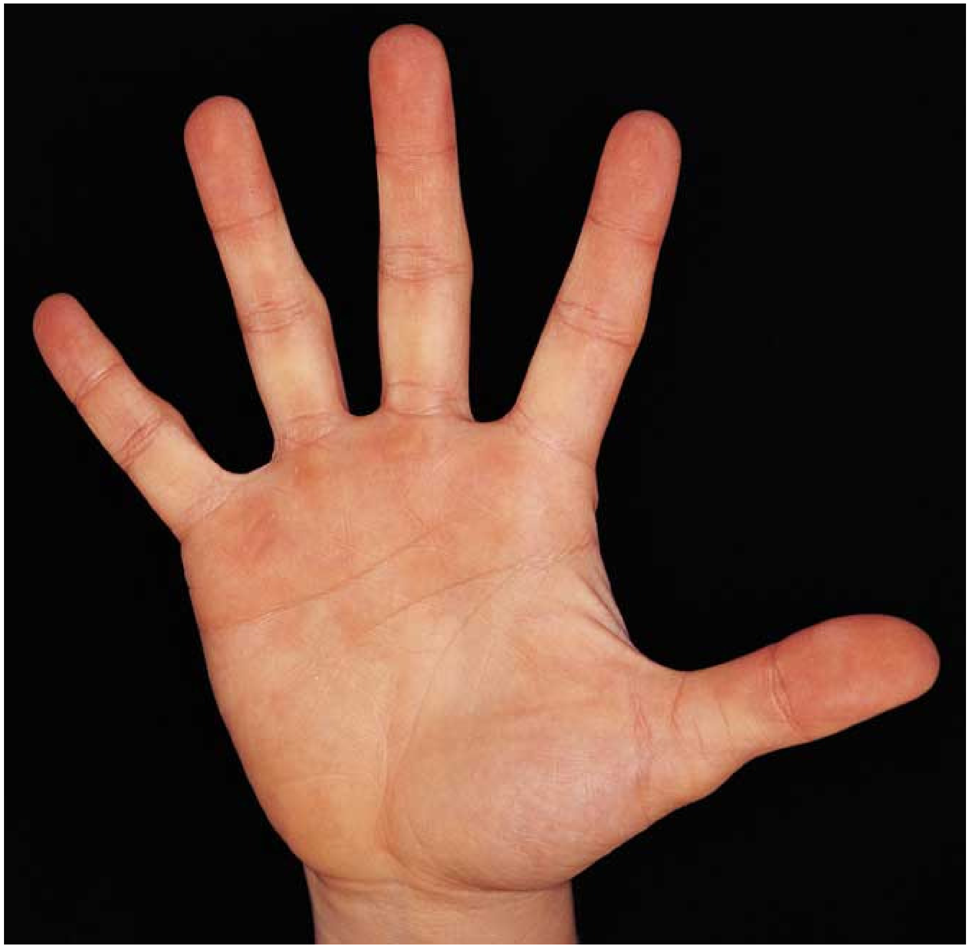
Are these rules for real? Yes... ***and no.***



All this self-similarity must stop somewhere...

What if our hand were more like the Dragon's-blood tree?

Are these rules for real? Yes... ***and no.***



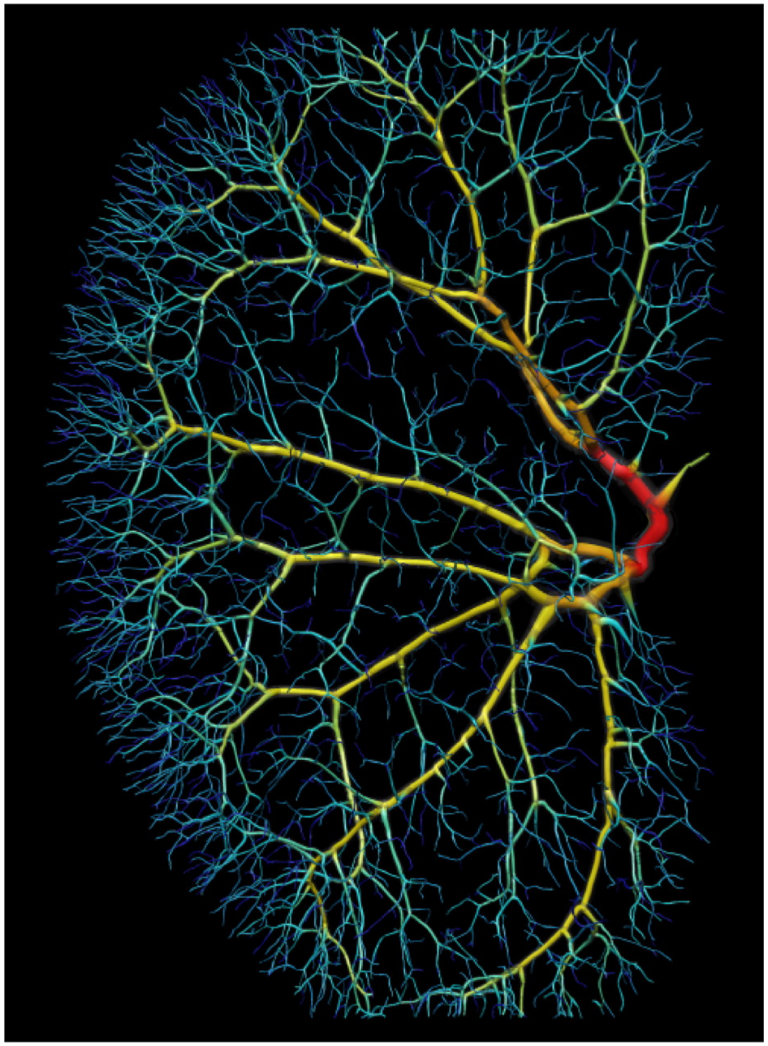
All this self-similarity must stop somewhere...

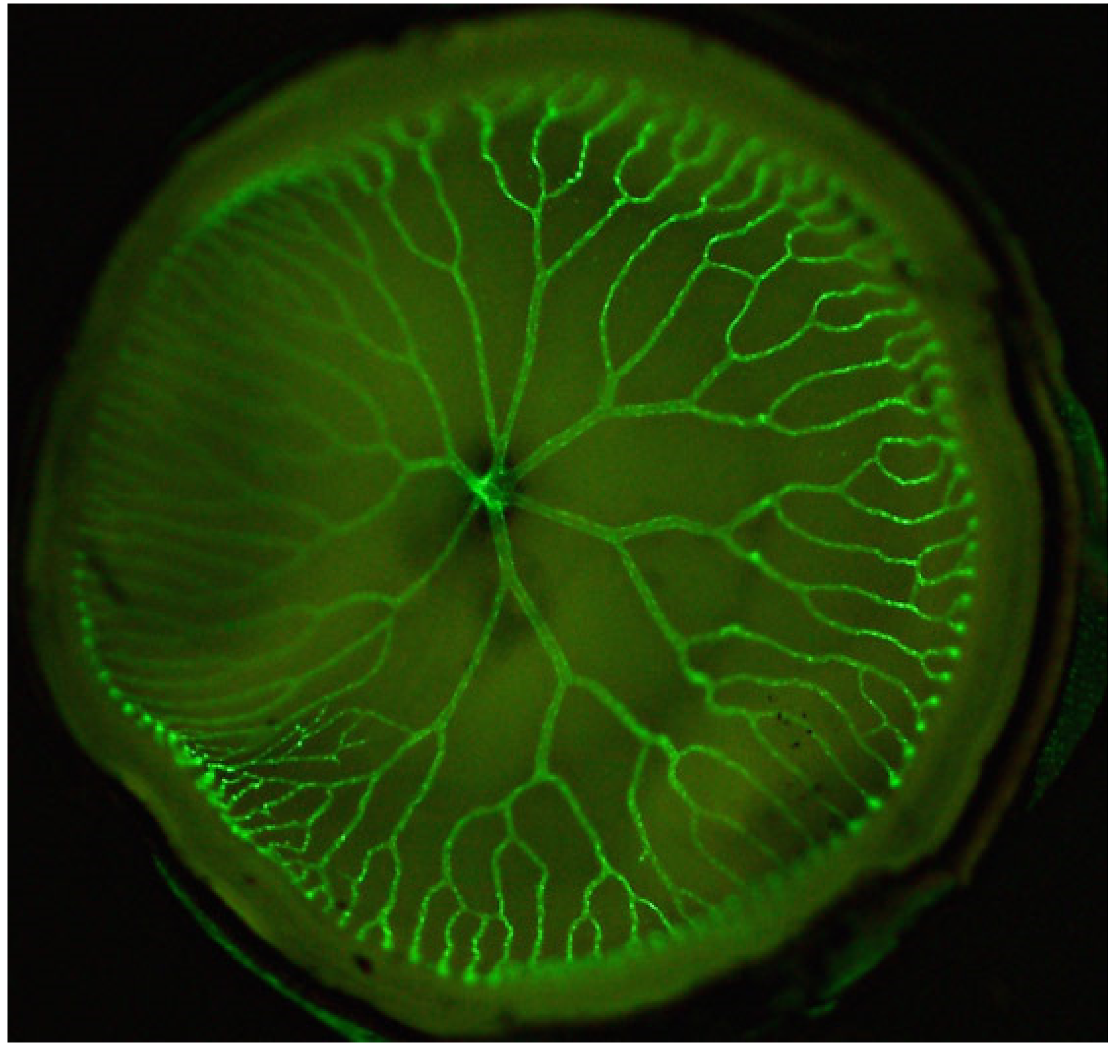
... or who knows what could happen!?

Are these rules for real? ***Yes…*** and no.

Where **does** fractal growth happen in *animals*?

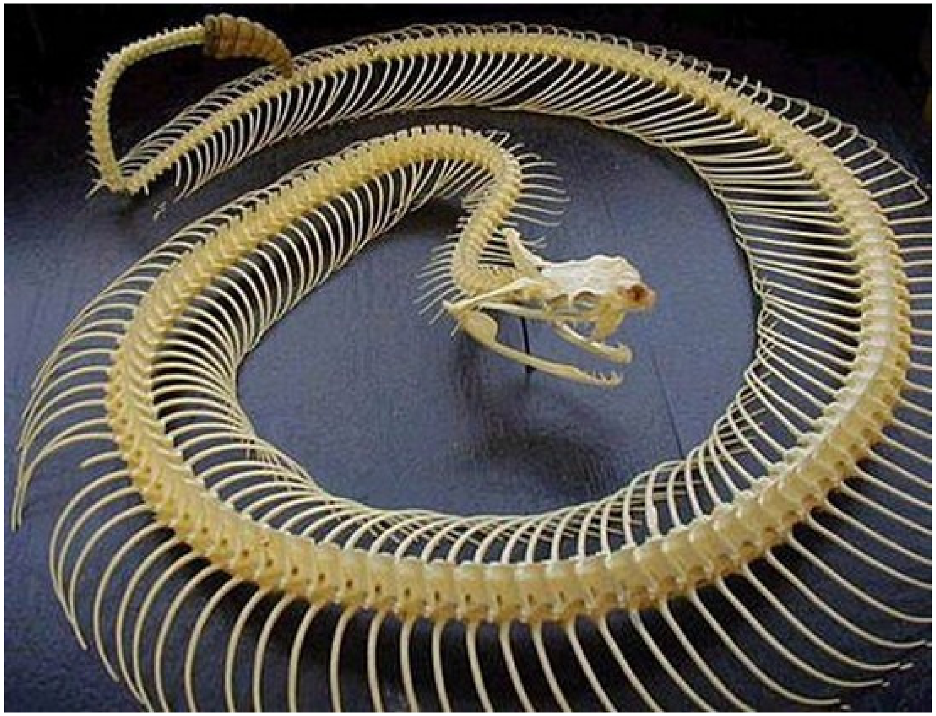
Are these rules for real? ***Yes...*** and no.

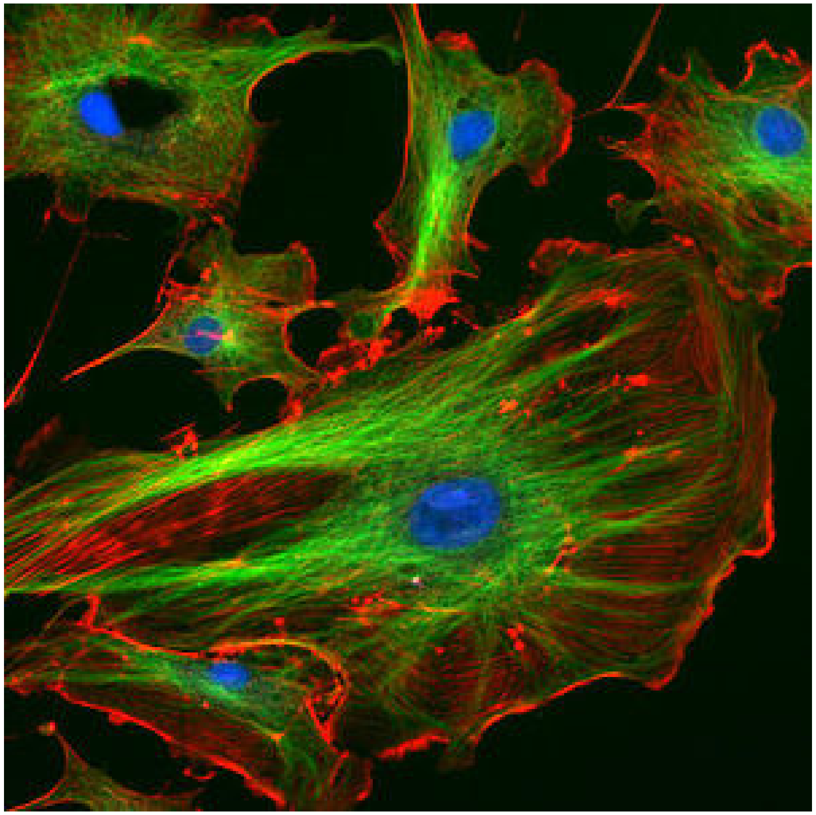




What are these?

Are these rules for real? ***Yes...*** and no.

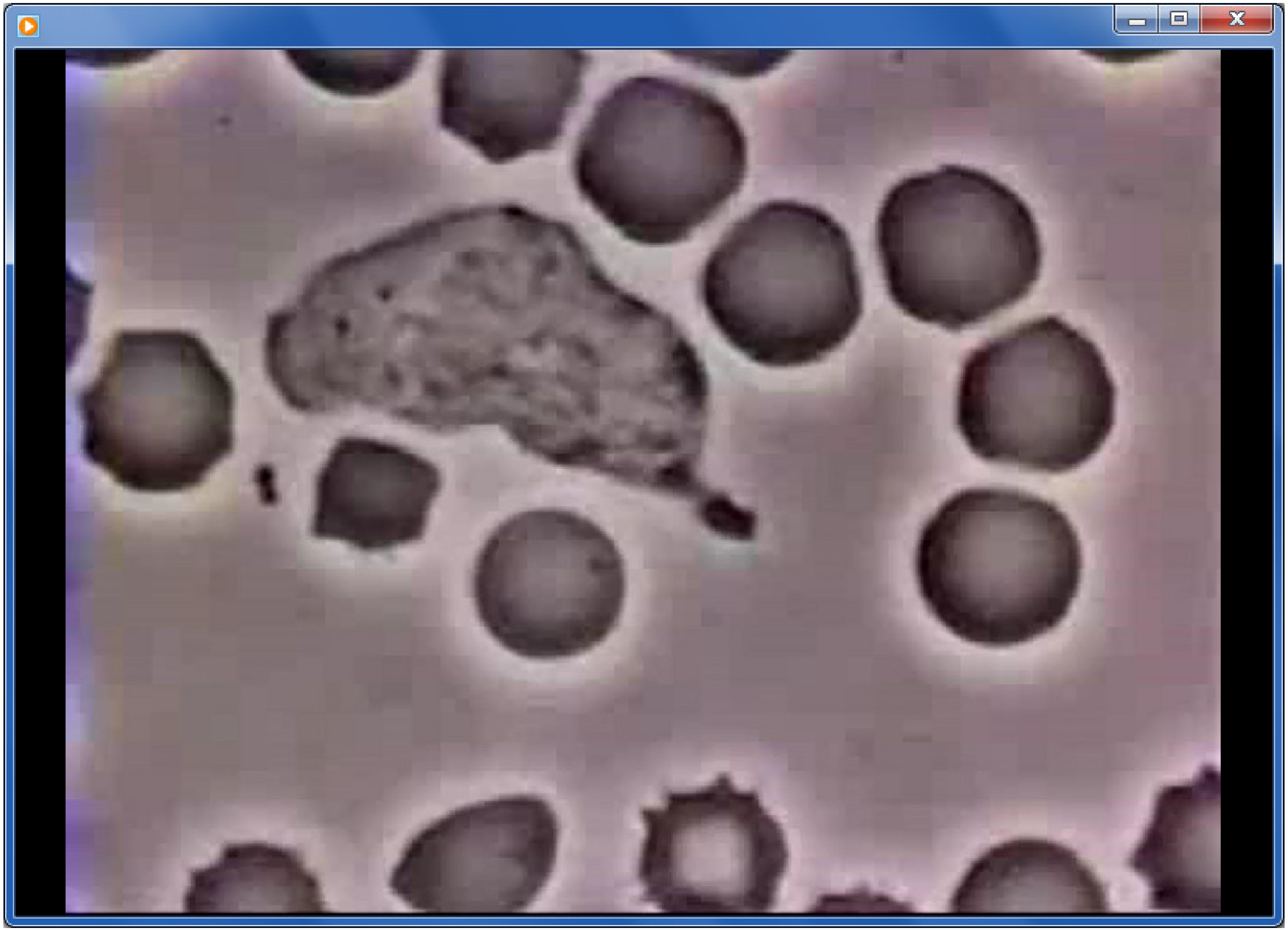




green: cell's skeleton (microtubules)
blue?

Comparing ***skeletons***

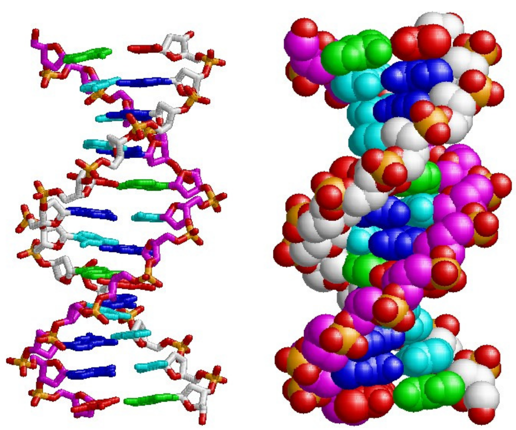
Cells: they *live their own lives*!



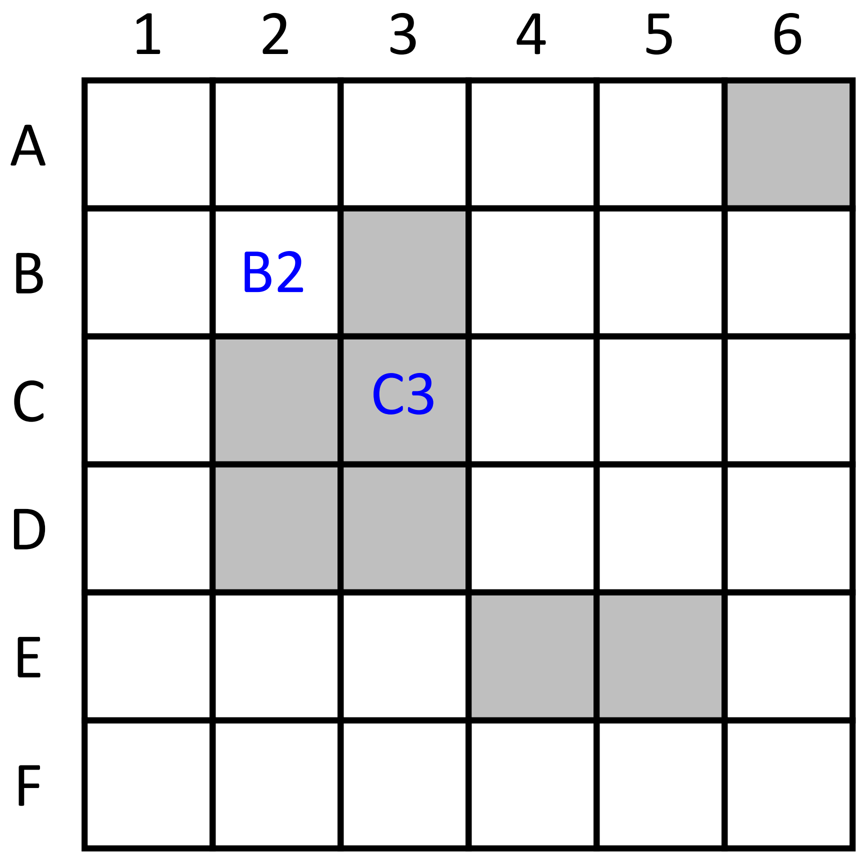
But what *controls* each cell?

What ***controls*** each cell?

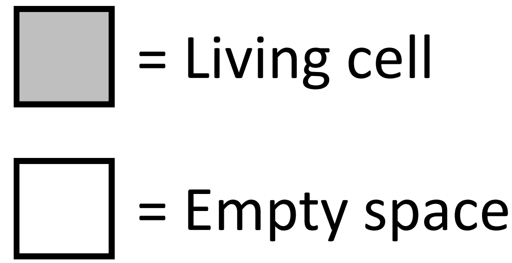
each cell has its own program (life)!



Simple cell rules



How many live cells are in this grid?

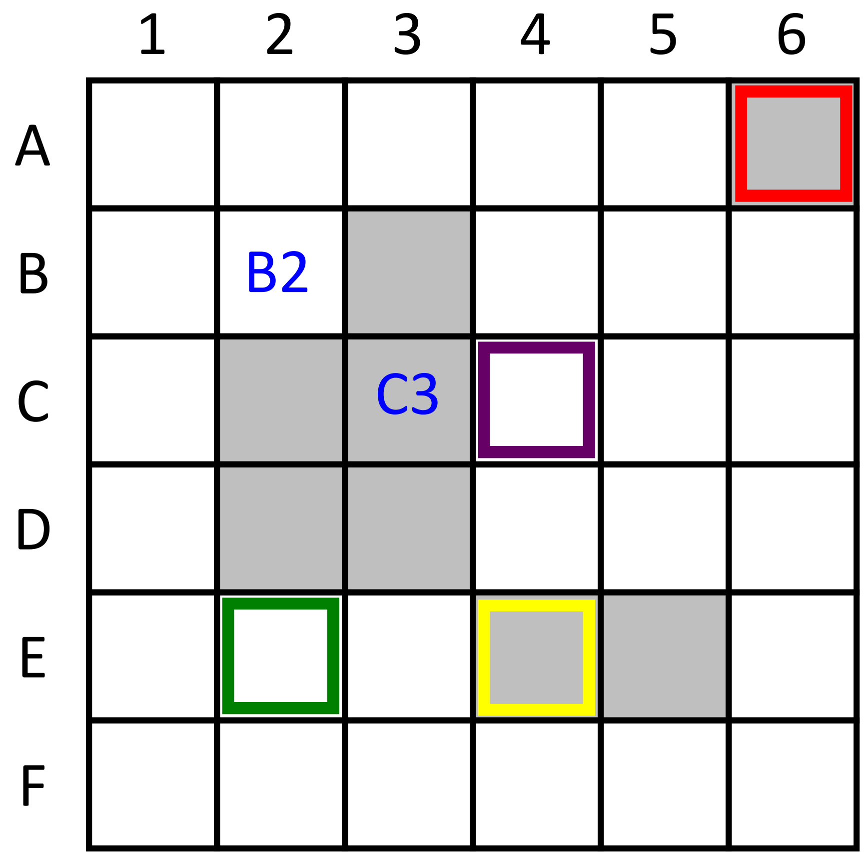


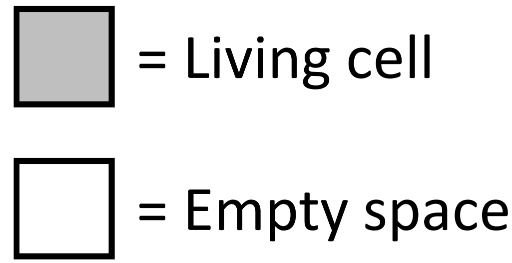
A grid of cells depending on

(1) their rules (DNA)

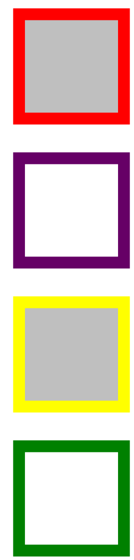
(2) environment (neighbors)

Simple cells

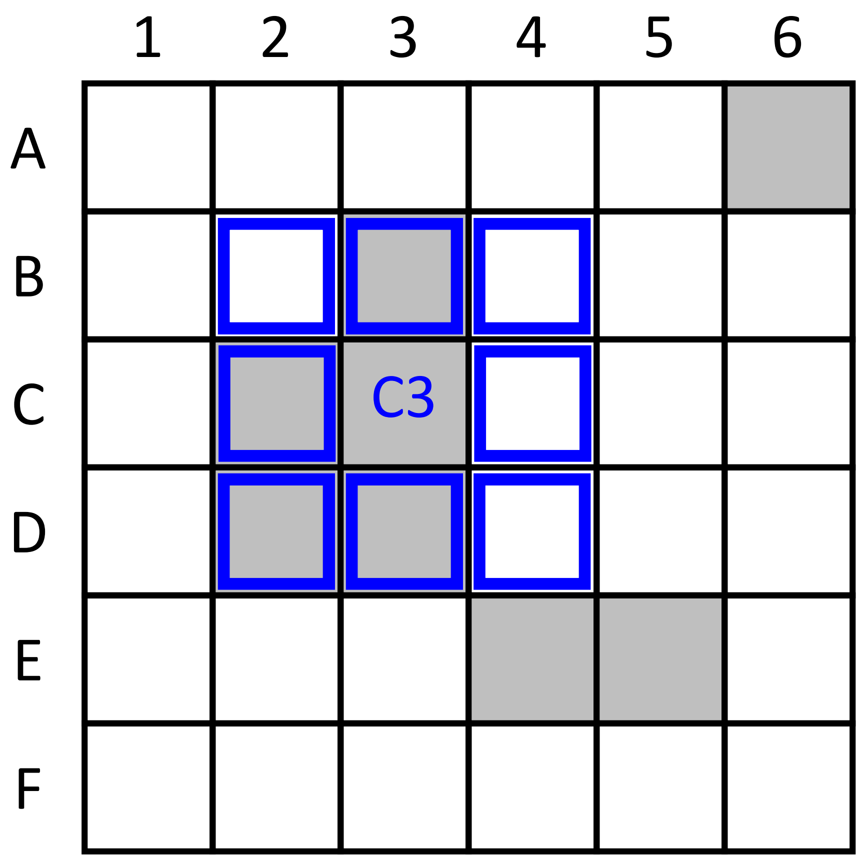




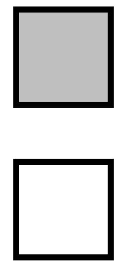
Name | Live or empty?



Neighbor cells



Cell C3 has **8** neighbors

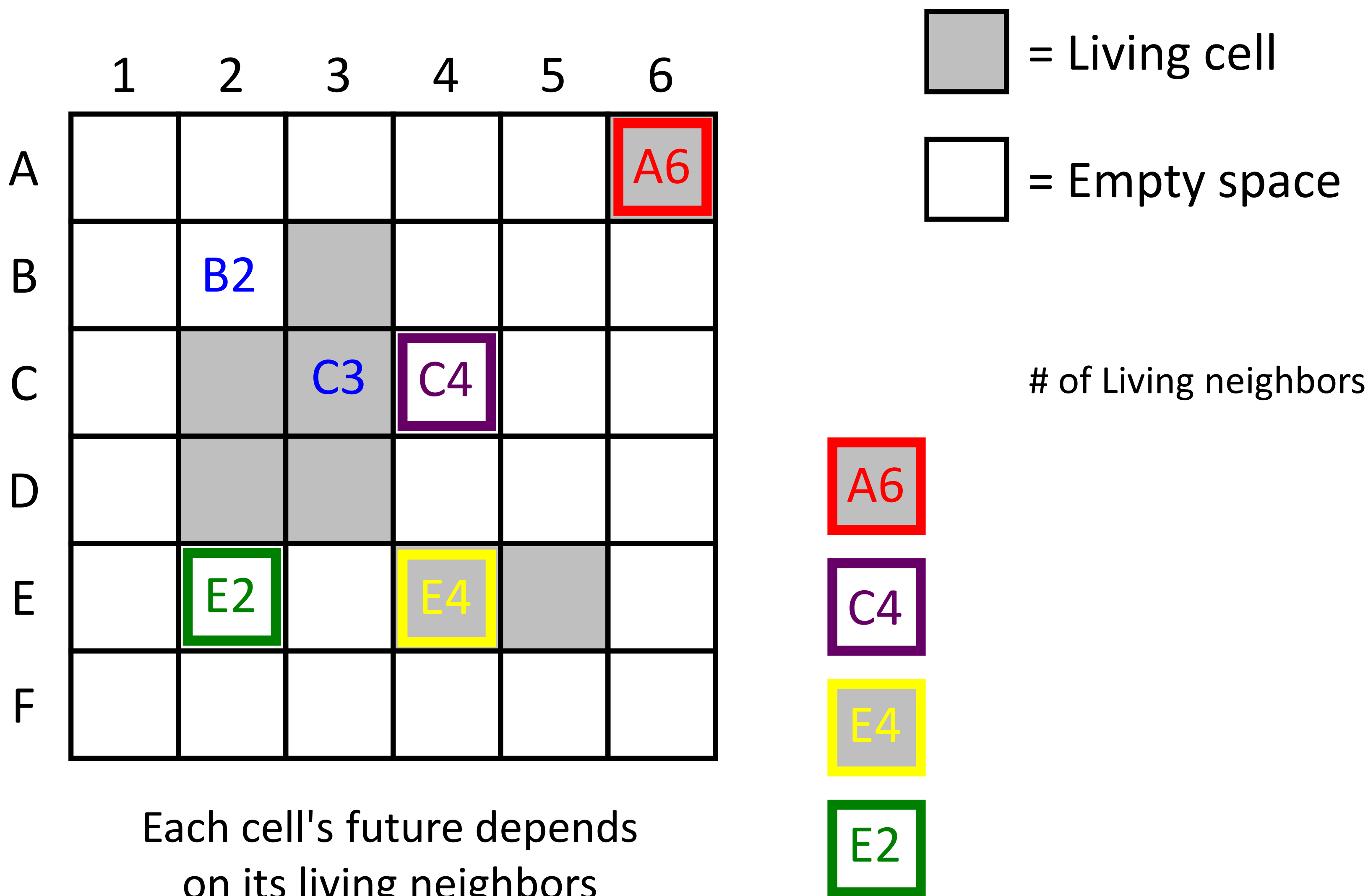


	Living neighbors	**Empty** neighbors
C3		

How many are living?

How many are empty?

Neighbor cells



Each cell's future depends
on its living neighbors

The rules…

all depend on how many ***living*** neighbors each cell has

	1	2	3	4	5	6
A	0	1	1	1	0	0
B						
C	2	4	4	3	0	0
D	2	3	4	4	2	1
E	1	2	3	2	1	1
F	0	0	1	2	2	1

BEFORE

The rules…

A living cell with ***2 or 3*** living neighbors ***survives***. Others die.

An empty cell with exactly 3 living neighbors ***comes to life***.

	1	2	3	4	5	6
A	0	1	1	1	0	0
B	1	3	2	2	1	1
C	2	4	4	3	0	0
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F	0	0	1	2	2	1

BEFORE

	1	2	3	4	5	6
A						
B						
C						
D						
E						
F						

Which ones will be living AFTER these rules run?

Rules of *Life*

A living cell with ***2 or 3*** living neighbors ***survives***. Others die.

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BEFORE

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A						
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E						
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AFTER

Rules of *Life*

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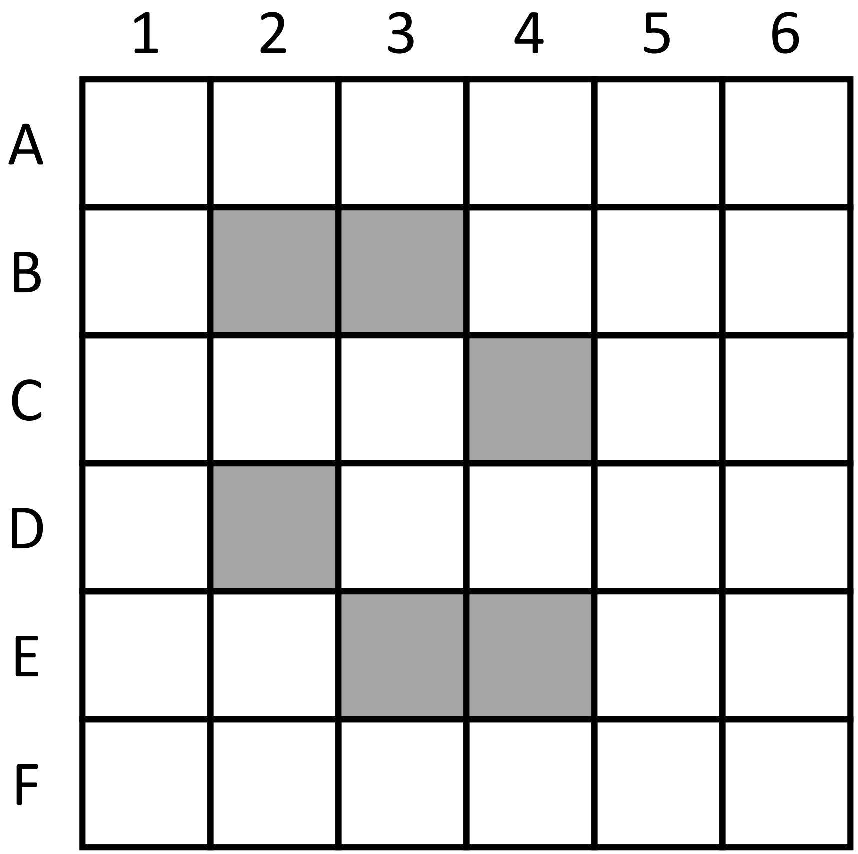
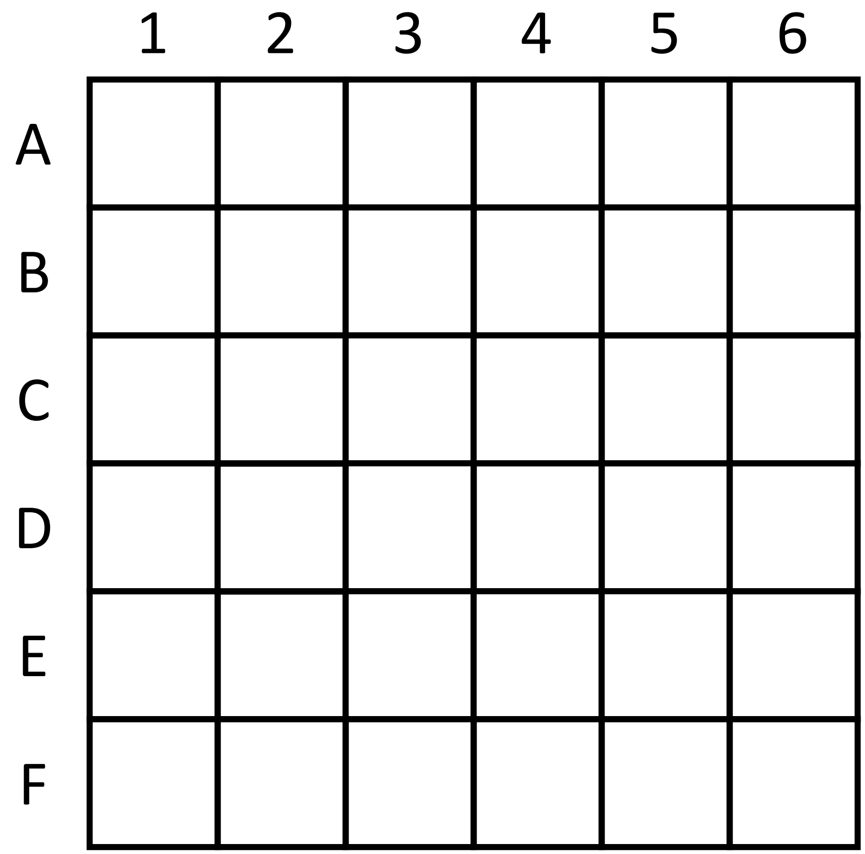


Fill in the number of living neighbors on top of this grid.



then, fill in the next generation here.

Rules of *Life*

A living cell with ***2 or 3*** living neighbors ***survives***. Others die.

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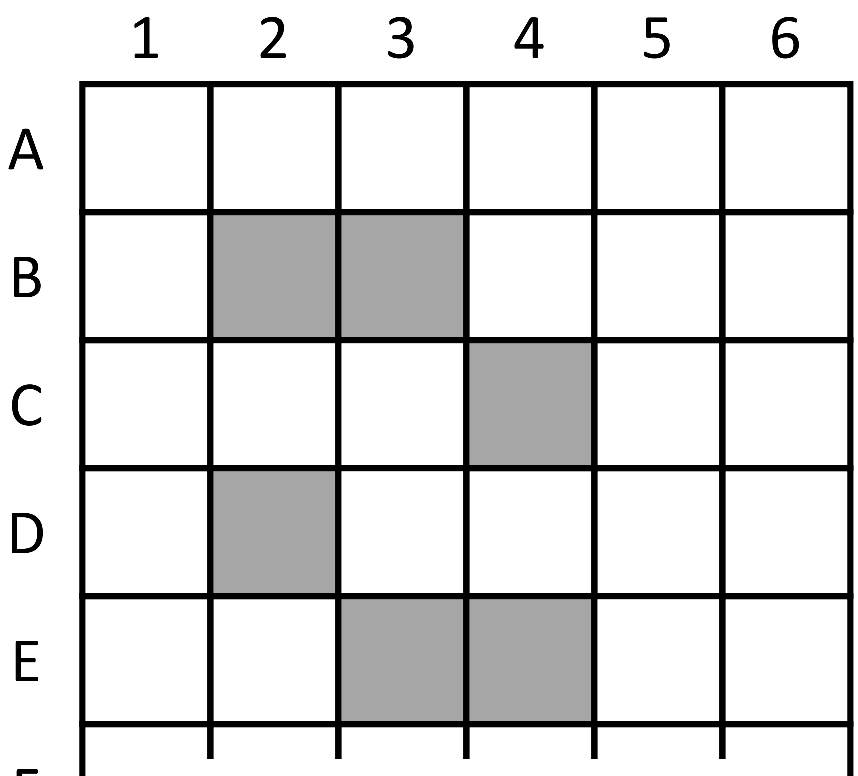
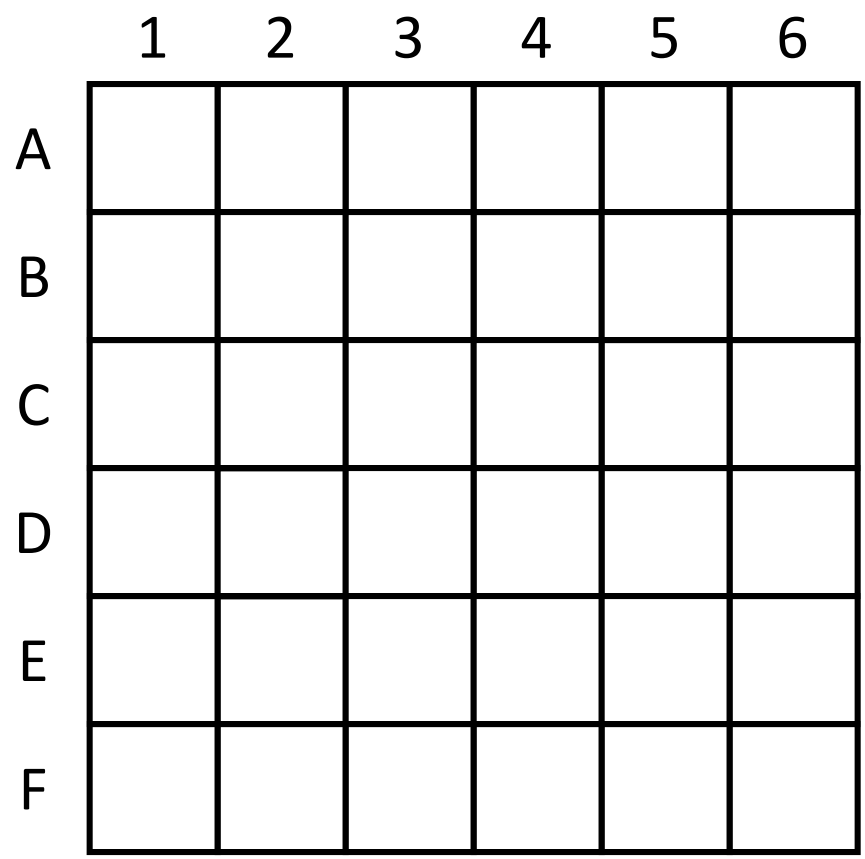


Only TWO survive, and TWO are born.



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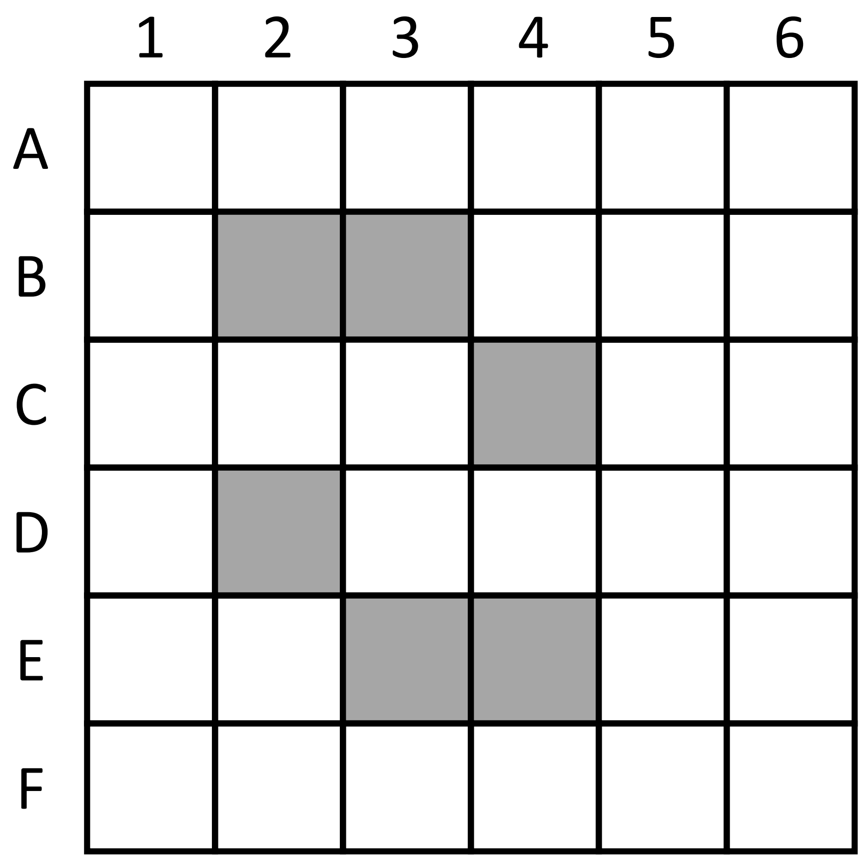
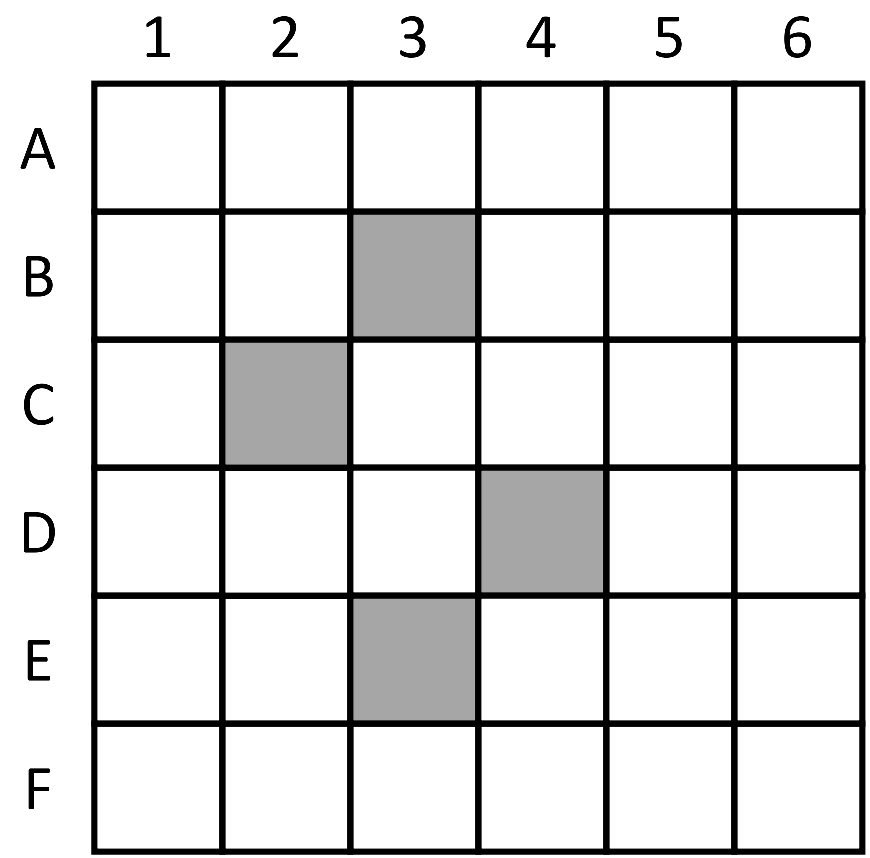
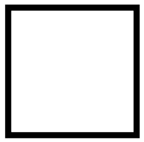


BEFORE



AFTER

next...?



empty space

Simple cells

living cells

\+

Simple rules

A living cell with ***2 or 3*** living neighbors ***survives***. Others die.

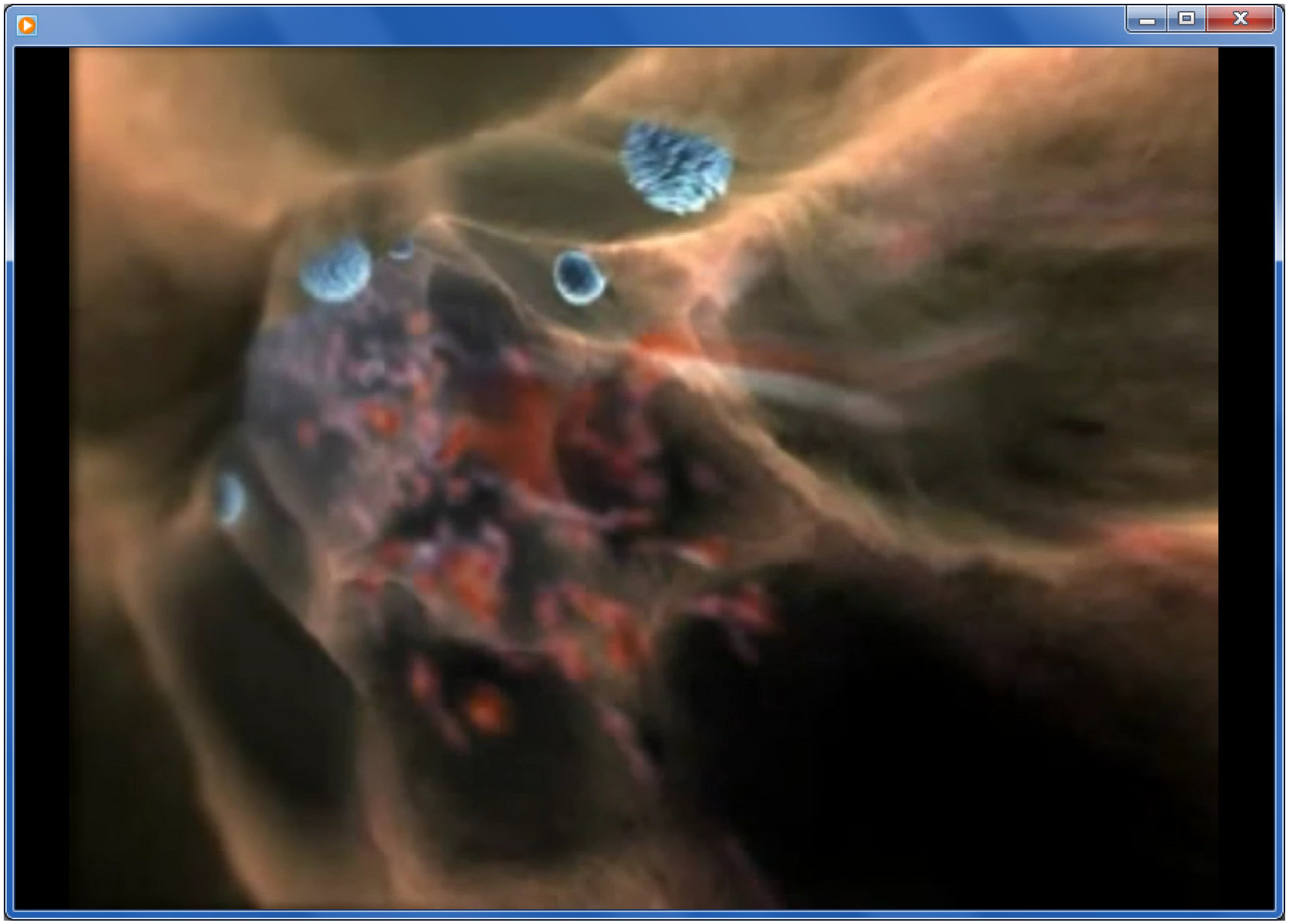
An empty cell with exactly 3 living neighbors ***comes to life***.

=

Complex behavior

"Game of Life"

Let's see it in action…



Lives of a cell, Harvard University

Tree Rules

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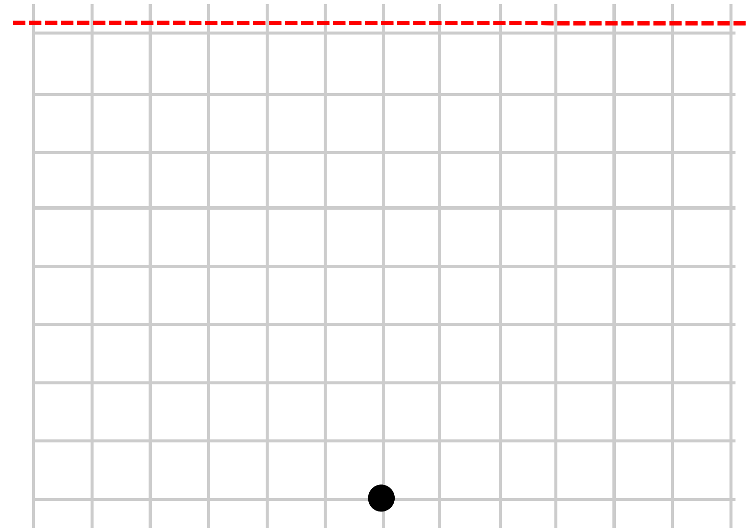
  Go back to step (1) and continue



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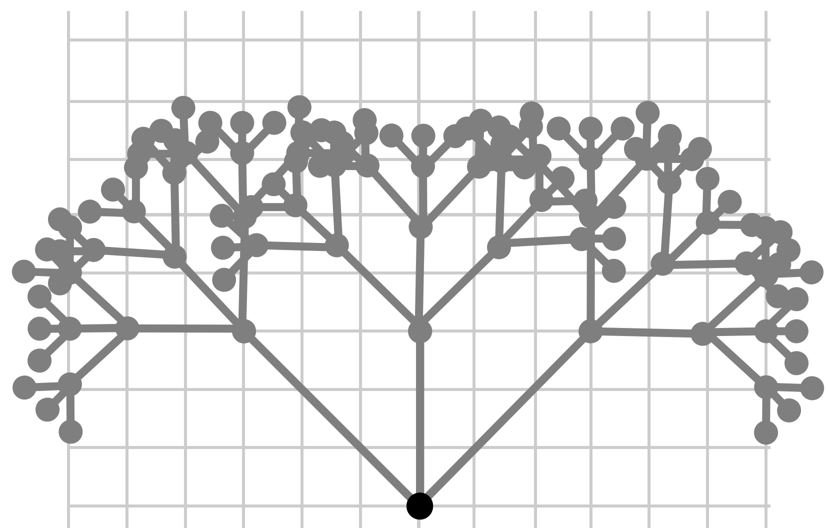

Change the underlined parts... *...to create this "tree"*

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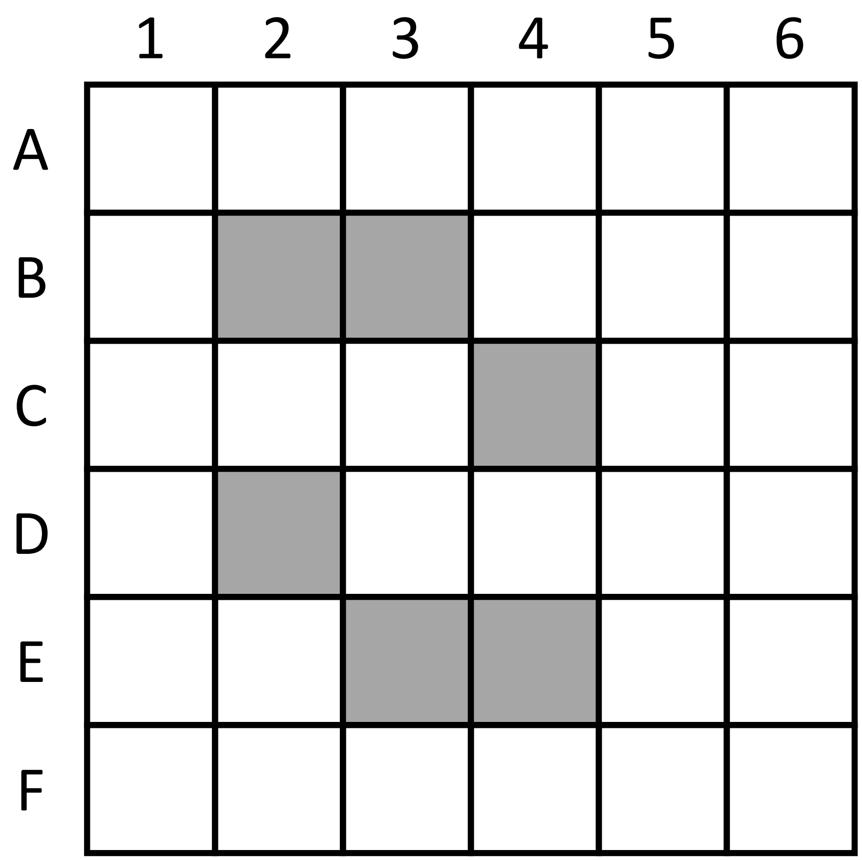
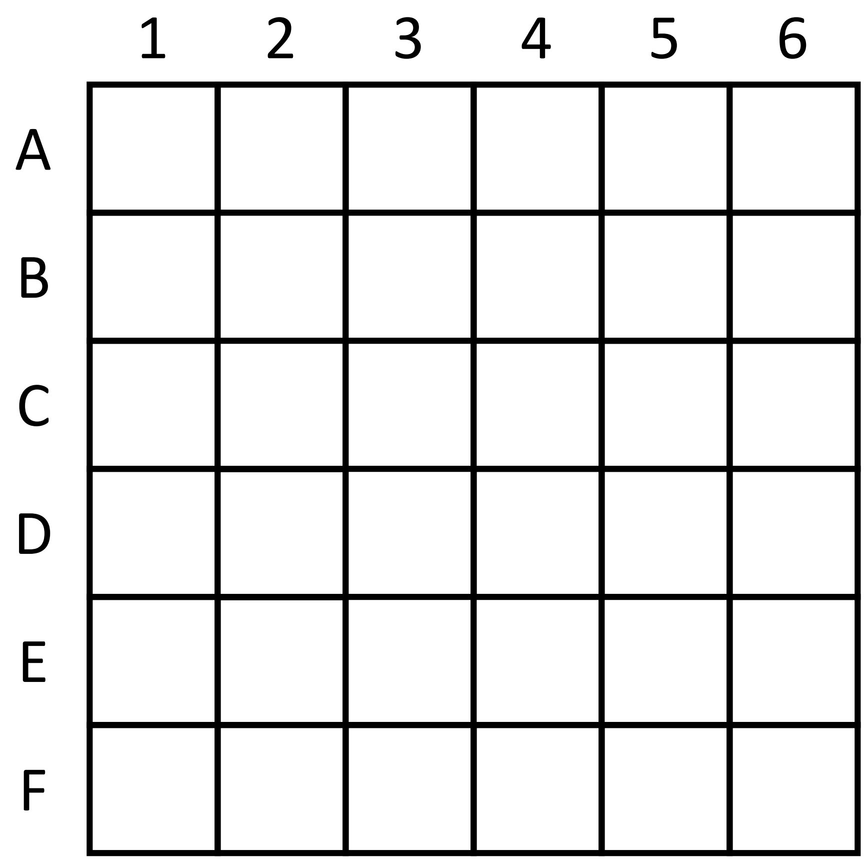


BEFORE



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