Digital growth

Nature-inspired procedural generation

Complex patterns emerge from simple rules

Modern understanding of nature (for this presentation) rely on four works:

The Chemical Basis of Morphogenesis, Alan Turing (1952)

Mathematical models for cellular interaction in development, Astrid Lindenmayer (1968)

The Fractal Geometry of Nature, Benoît B. Mandelbrot (1982)

The Algorithmic Beauty of Plants, Przemyslaw Prusinkiewicz and Aristid Lindenmayer (2004)

Goals of this presentation

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Presented algorithms fits in two categories:

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- Physics models (Reaction-Diffusion and Diffusion-Limited Aggregation)
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What I'll show:

- Brief outlines of each method

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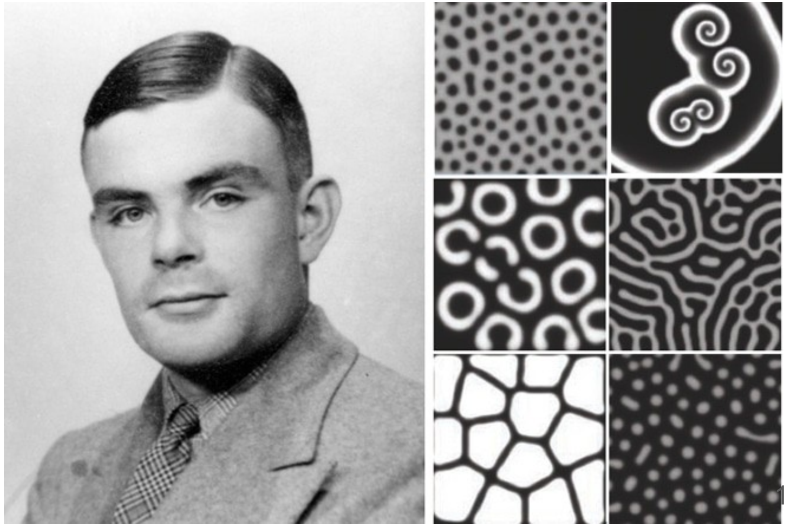
- Physics models (Reaction-Diffusion and Diffusion-Limited Aggregation)
- Biological growth models (L-System and Space Colonization)

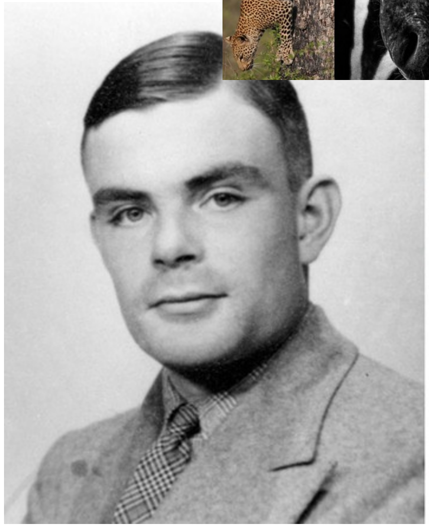
What I’ll show:

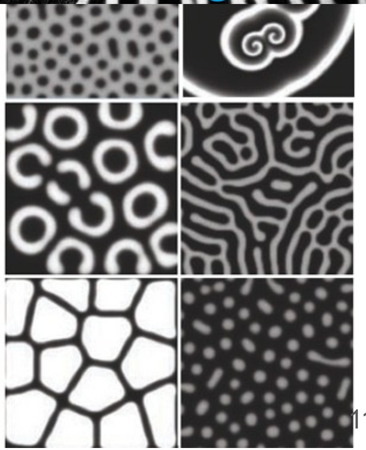
- Brief outlines of each method
- Implementation ease

Reaction-Diffusion for Turing Patterns



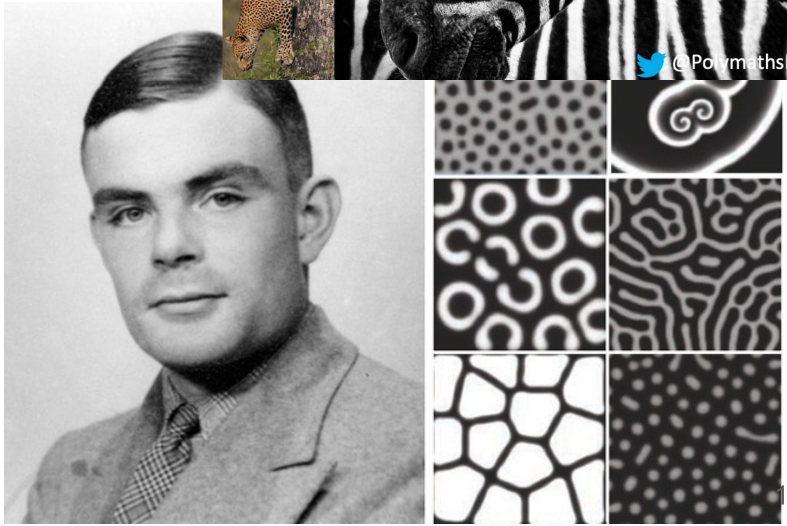
Reaction-Diffusion for Turing Patterns





Reaction-Diffusion for Turing Patterns

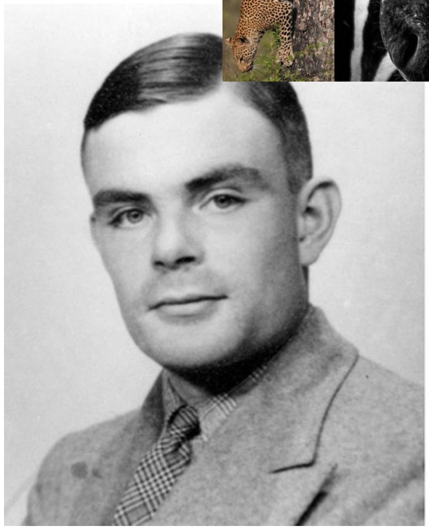
2 components (u and v) are evolving in an environment

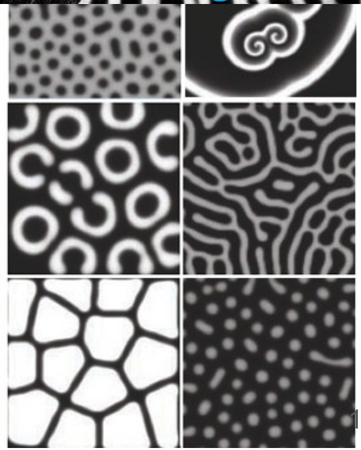


Reaction-Diffusion for Turing Patterns

2 components (u and v) are evolving in an environment

1. They diffuse

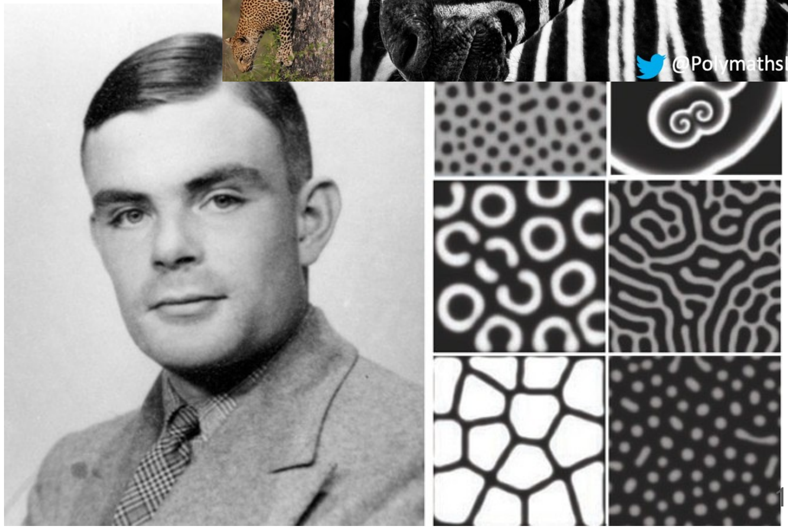




Reaction-Diffusion for Turing Patterns

2 components (u and v) are evolving in an environment

1. They diffuse
2. They react to each other



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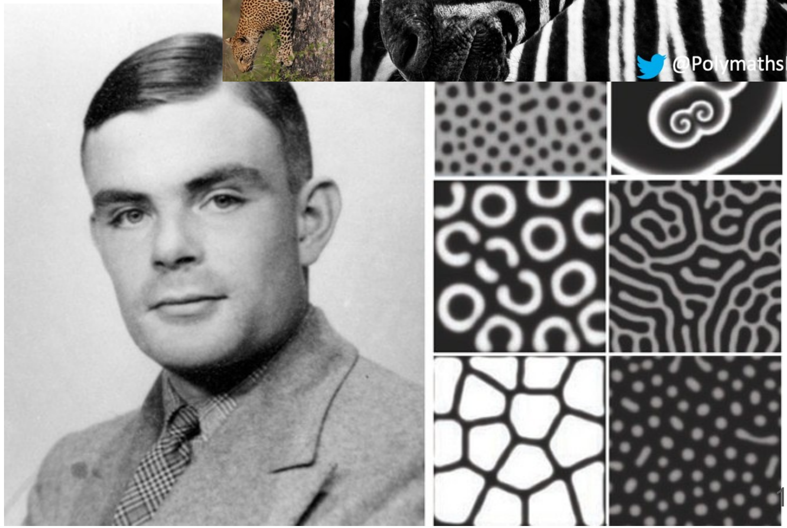

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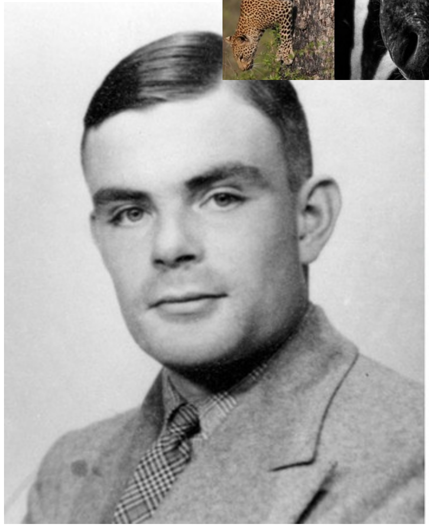

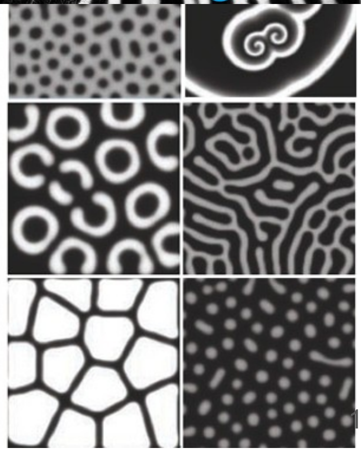

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$$\frac{\partial u}{\partial t} = D_u \nabla^2 u + f(u, v),$$
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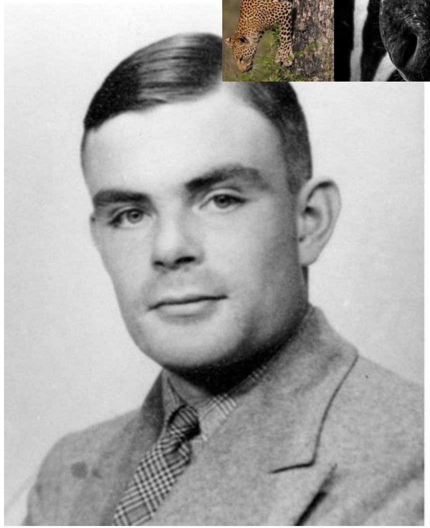

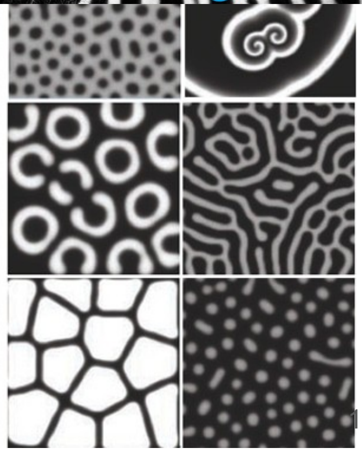

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Diffusion

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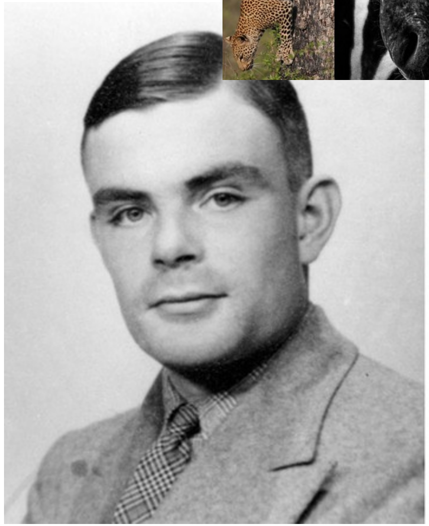

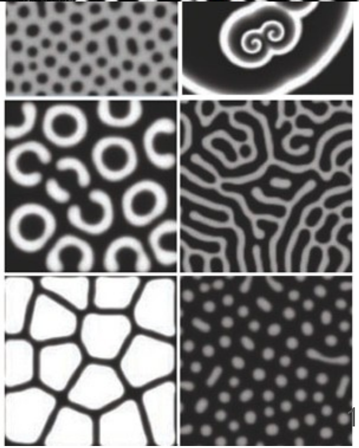

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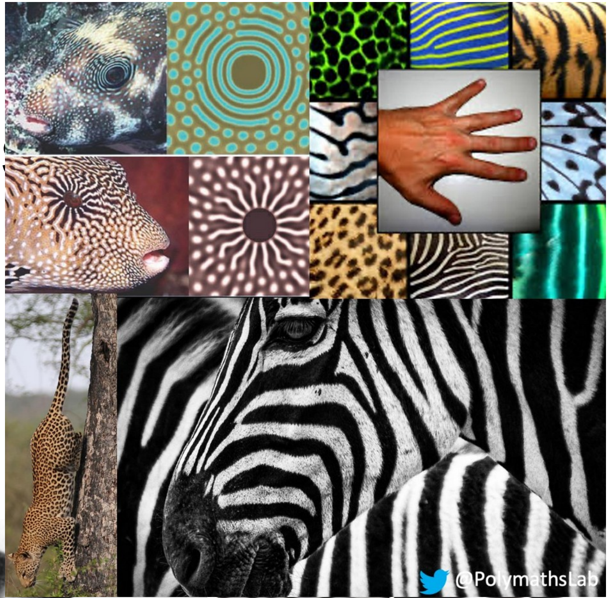
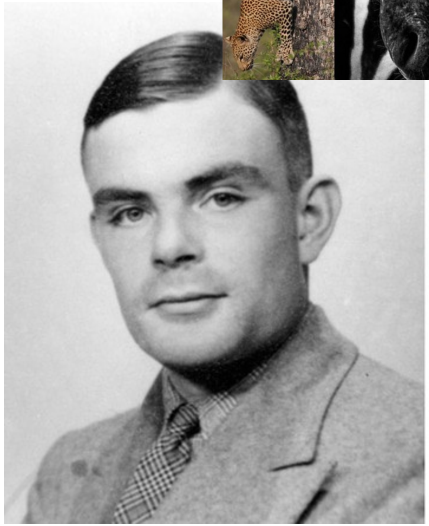
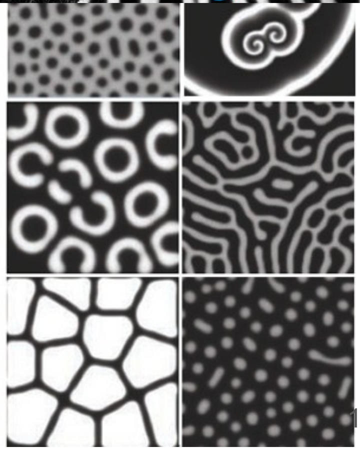
Diffusion Reaction

$$
\begin{aligned}
\frac{\partial u}{\partial t} &= \boxed{D_u \nabla^2 u} + \boxed{f(u, v)}, \\
\frac{\partial v}{\partial t} &= \boxed{D_v \nabla^2 v} + \boxed{g(u, v)}
\end{aligned}
$$







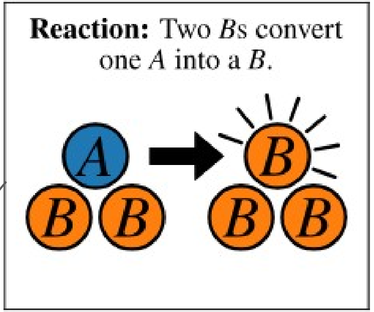
Reaction-Diffusion for Turing Patterns

Gray-Scott model:

$$\frac{\partial u}{\partial t} = D_u \nabla^2 u - uv^2 + F \cdot (1 - u),$$
$$\frac{\partial v}{\partial t} = D_v \nabla^2 v + uv^2 - (K + F)v$$

Reaction-Diffusion for Turing Patterns

Gray-Scott model:



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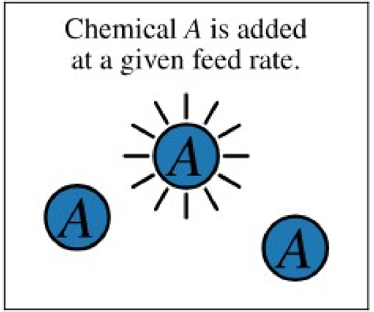

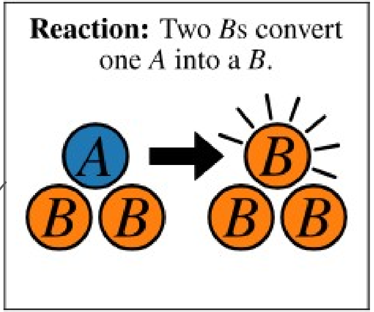

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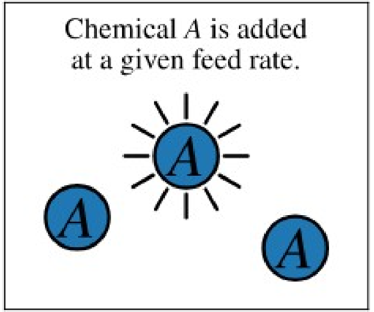

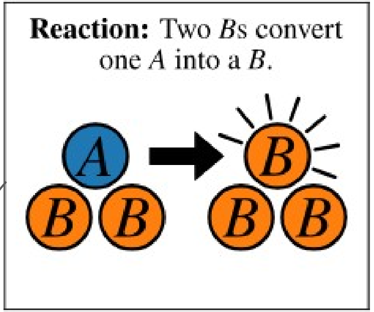

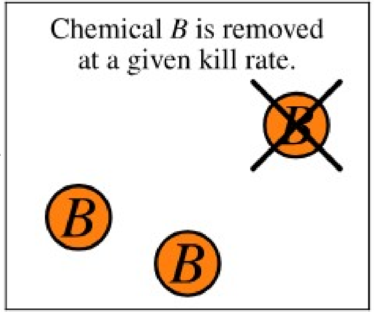

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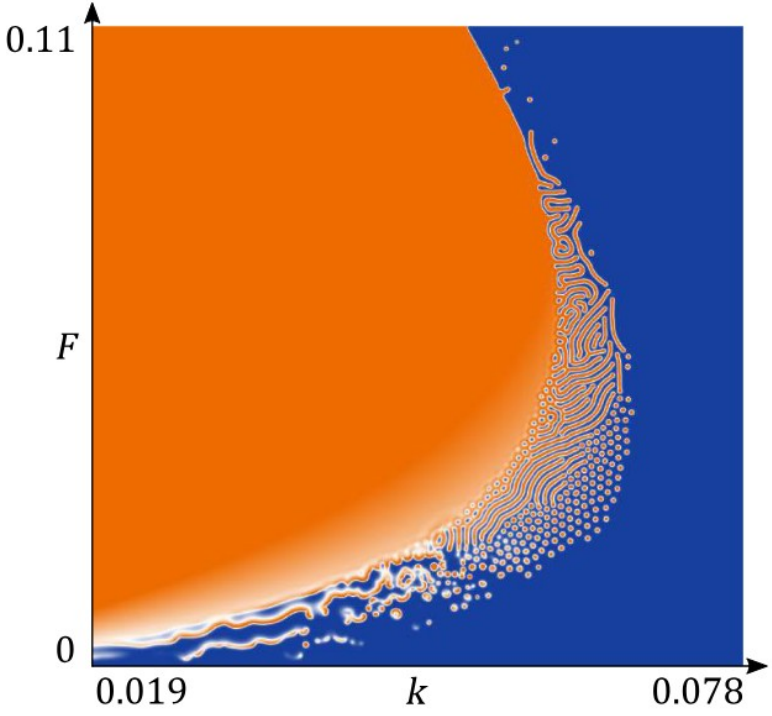
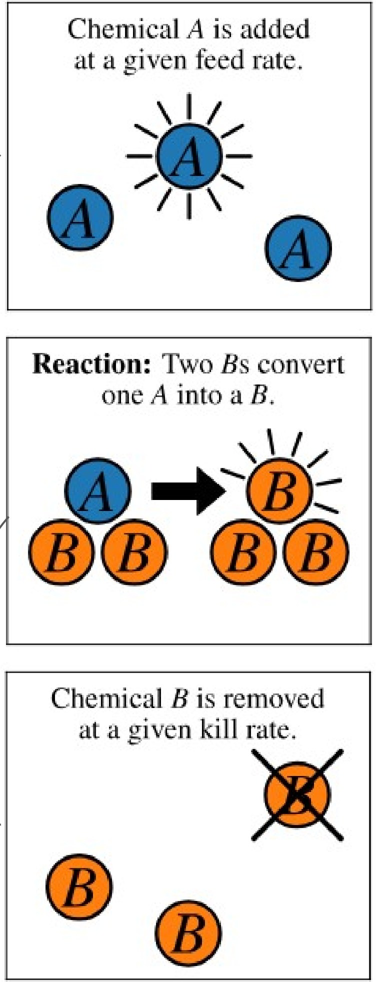


$$+\boxed{F\cdot(1-u)},$$

$$-\boxed{(K+F)v}$$



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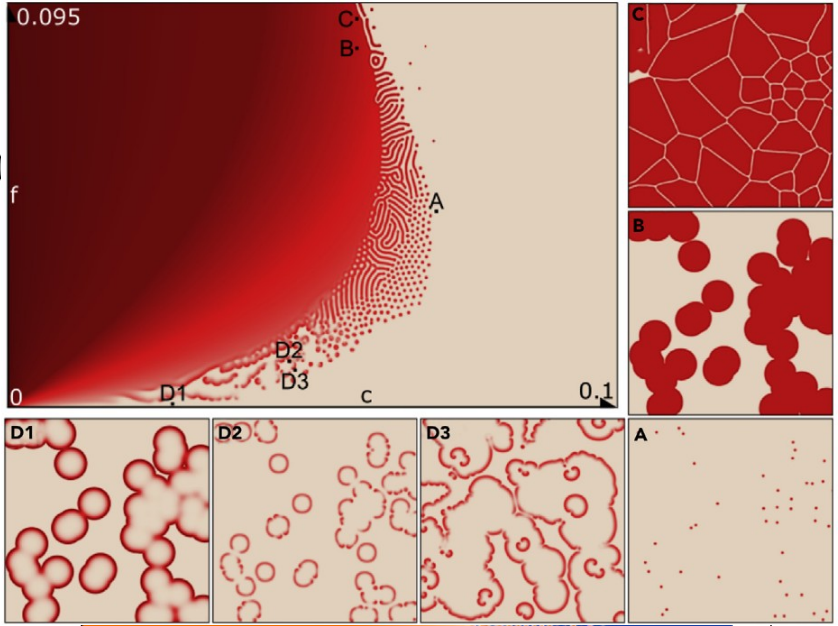
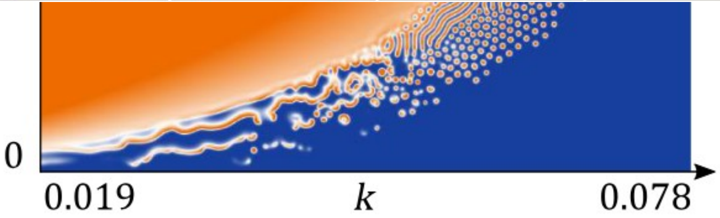
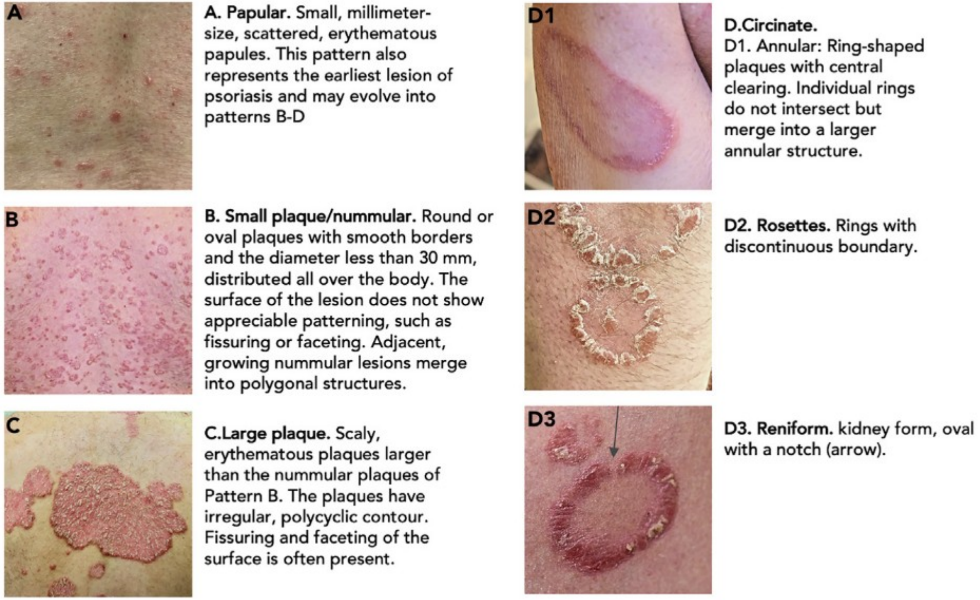
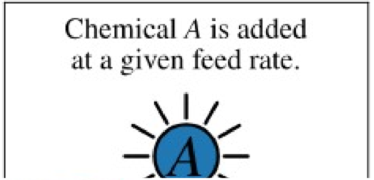
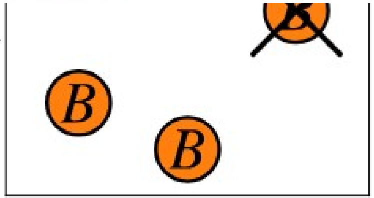




$$-(K+F)v$$







Reaction-Diffusion for Turing Patterns

Short demo: https://editor.p5js.org/marchartley/sketches/q-kafkilA

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Diffusion-Limited Aggregation

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1. Particles move in a brownian motion

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3. Any other particle touching it also freeze

Diffusion-Limited Aggregation

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3. Any other particle touching it also freeze
4. And so on

Diffusion-Limited Aggregation

Short demo: https://editor.p5js.org/marchartley/sketches/ZwPy8xGOp

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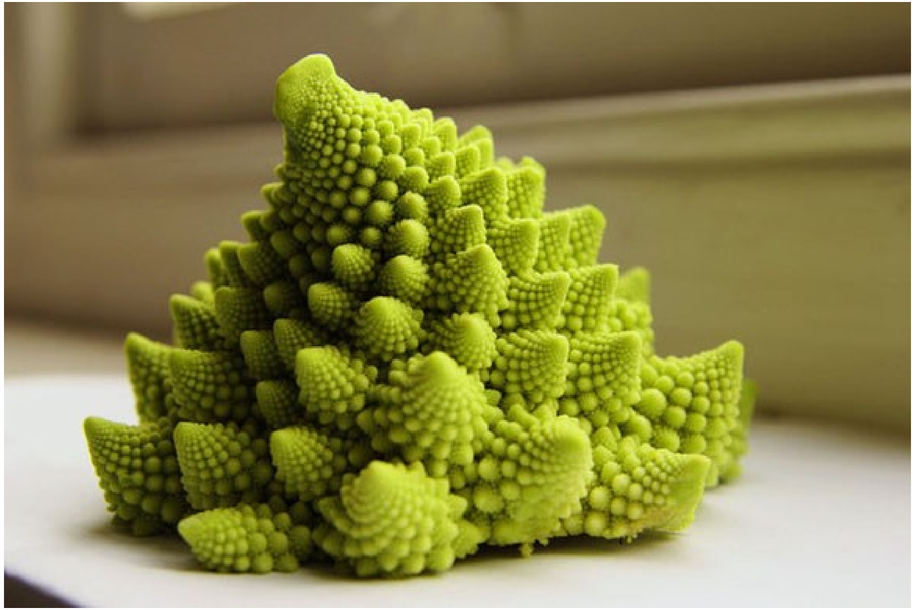
Nature is fractal



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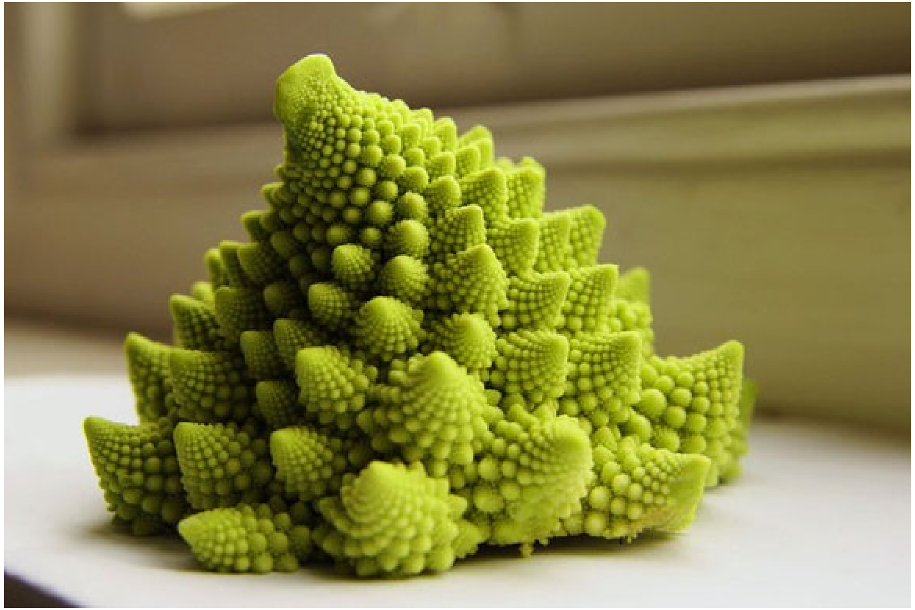

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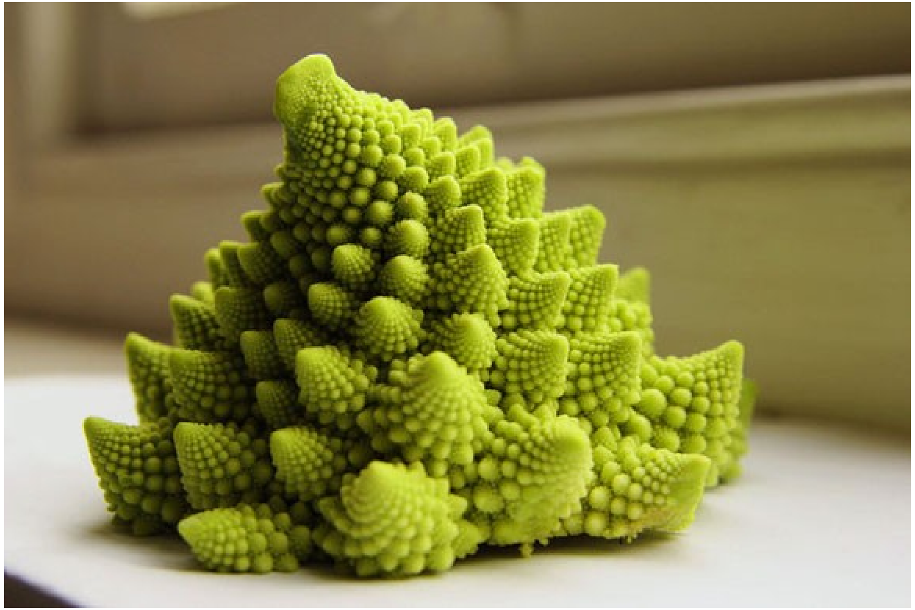

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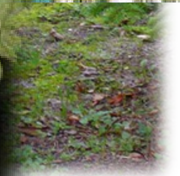

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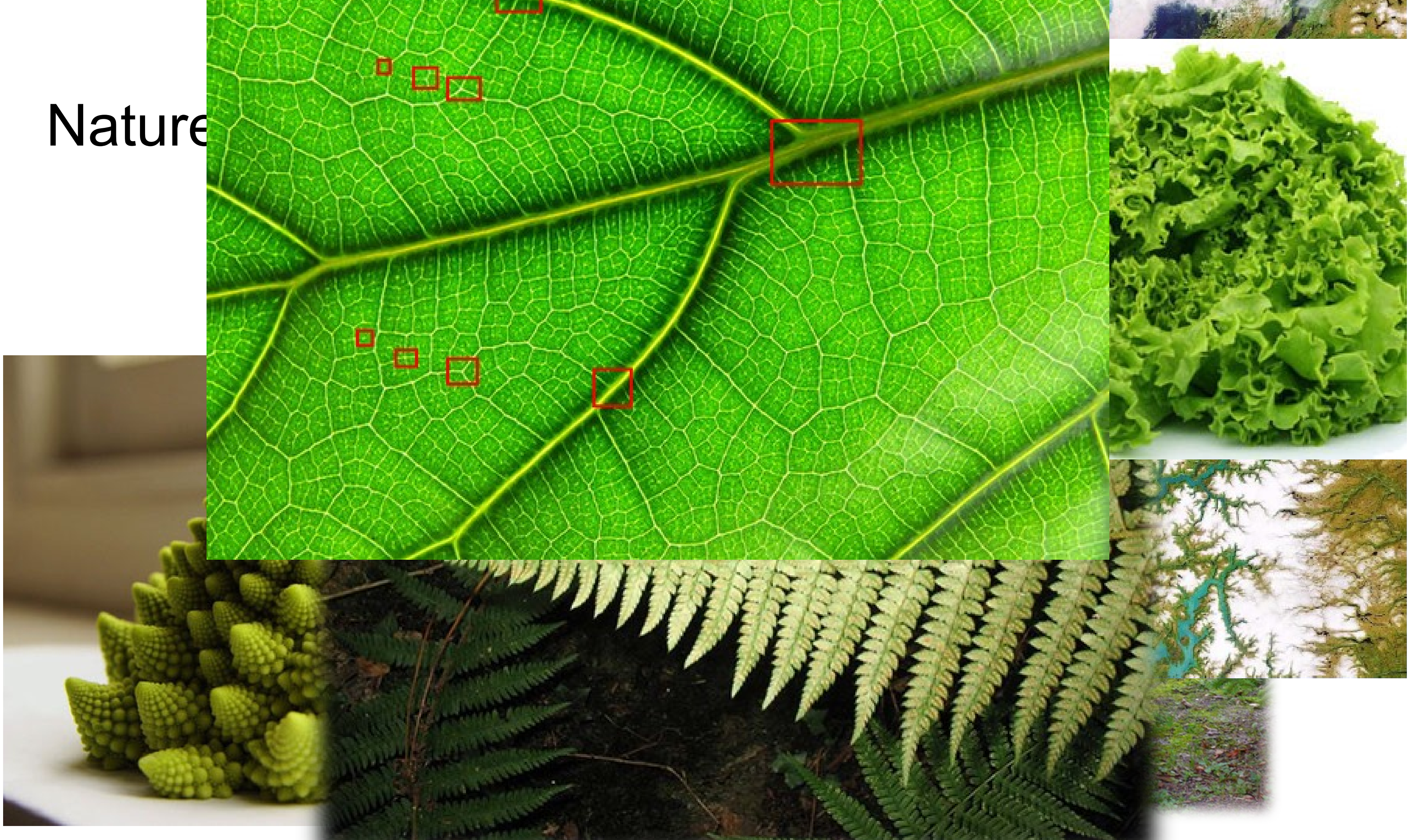

L-System, the language of nature

Rewriting system for modeling plant growth with recursivity

Composed of:

- Alphabet (letters to use),
- Axiom (starting point),
- Production rules (how to rewrite each letter)

Usually, the final string is used to command a Turtle generat

L-System, the language of na

Rewriting system for modeling plant growth w

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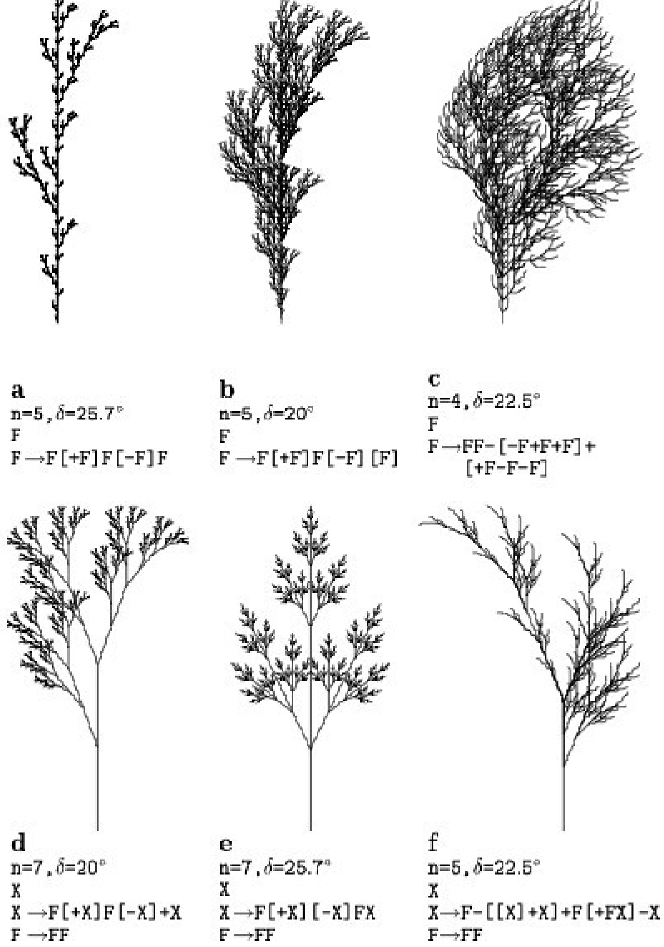

Figure 1.24: Examples of plant-like structures generated by bracketed OL-systems. L-systems (a), (b) and (c) are edge-rewriting, while (d), (e) and (f) are node-rewriting.

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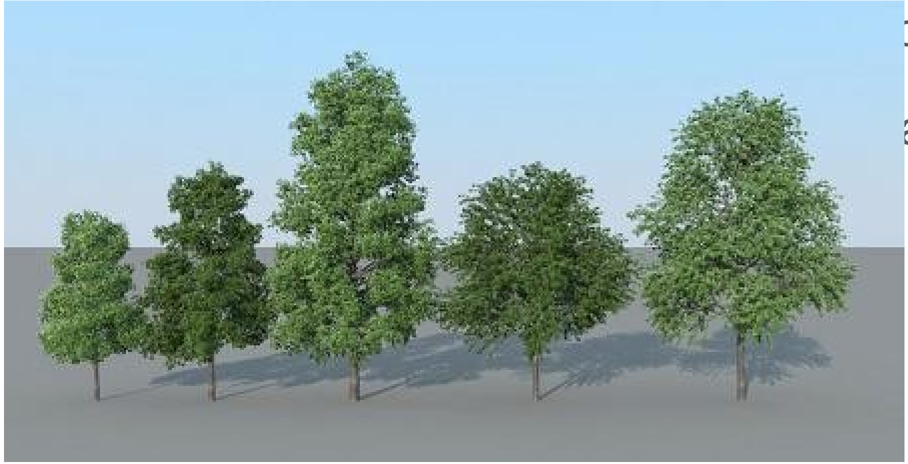

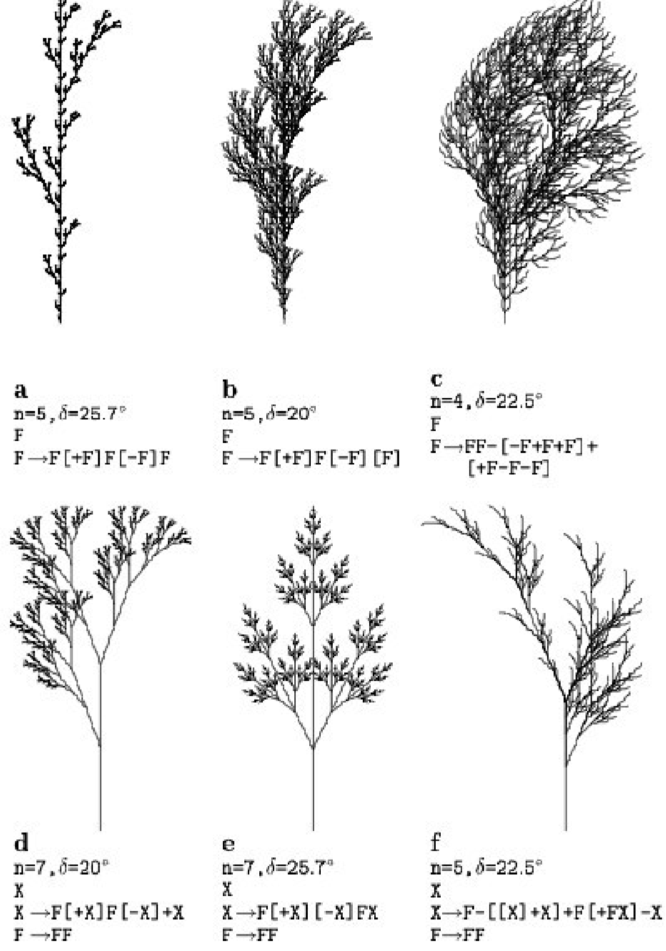

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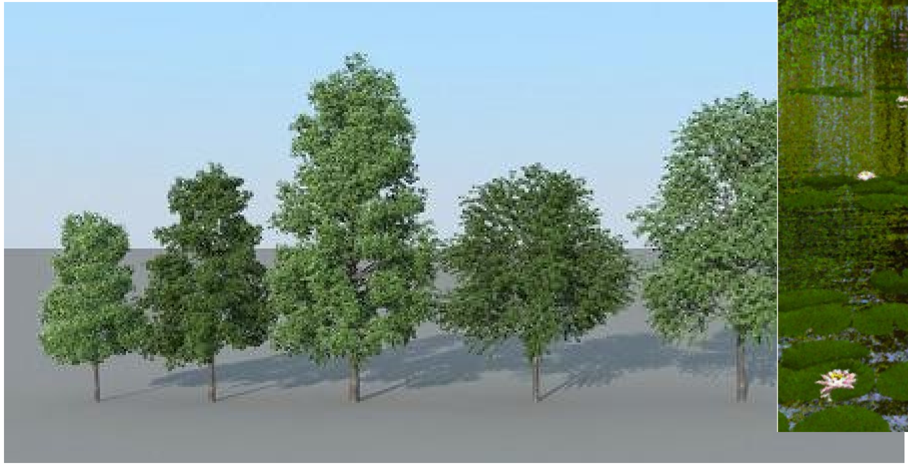
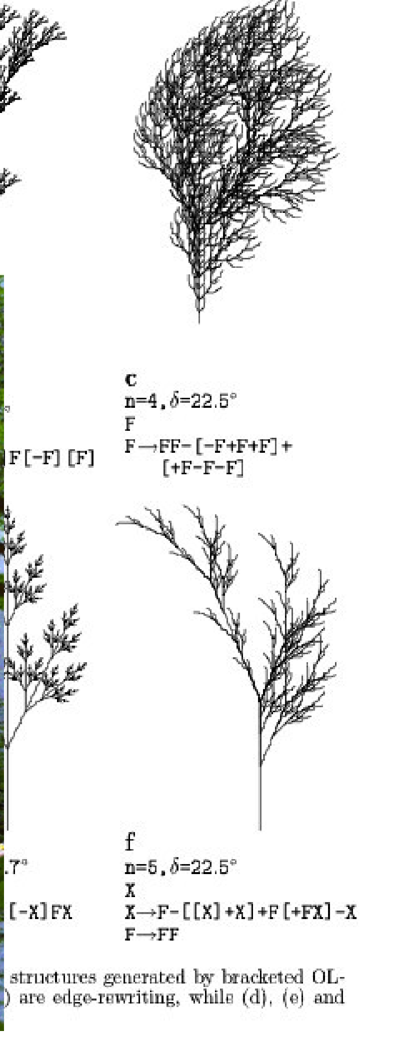


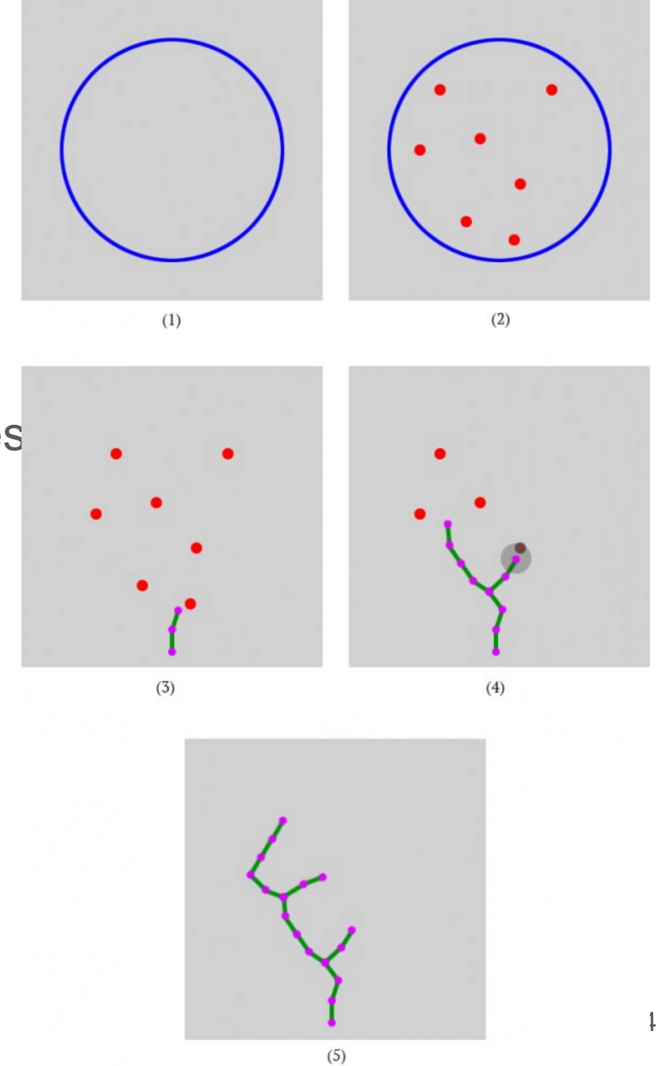


L-System, the language of nature

Short demo: https://editor.p5js.org/marchartley/sketches/UkGvoRwob

Space Colonization

1. Define a space that will contain the tree
2. Randomly add leaves in it
3. Grow branches (or trunk) in direction of the leaves (with a radius of influence)
4. Remove very close leaves
5. Voilà



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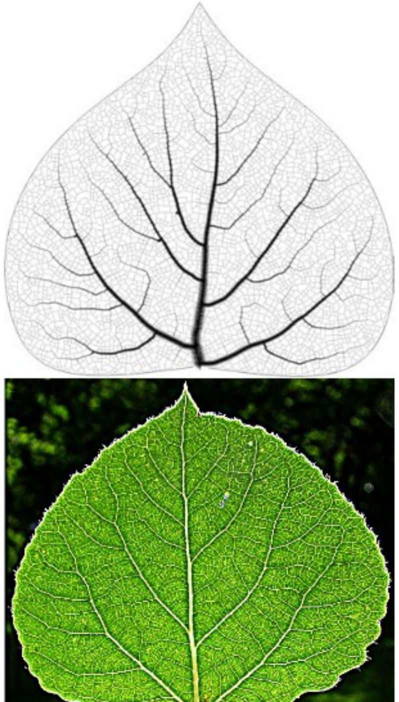

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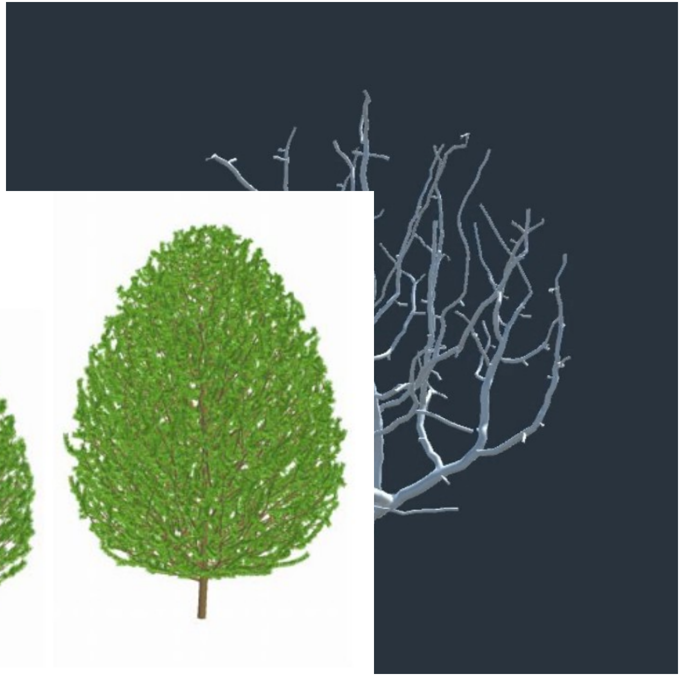

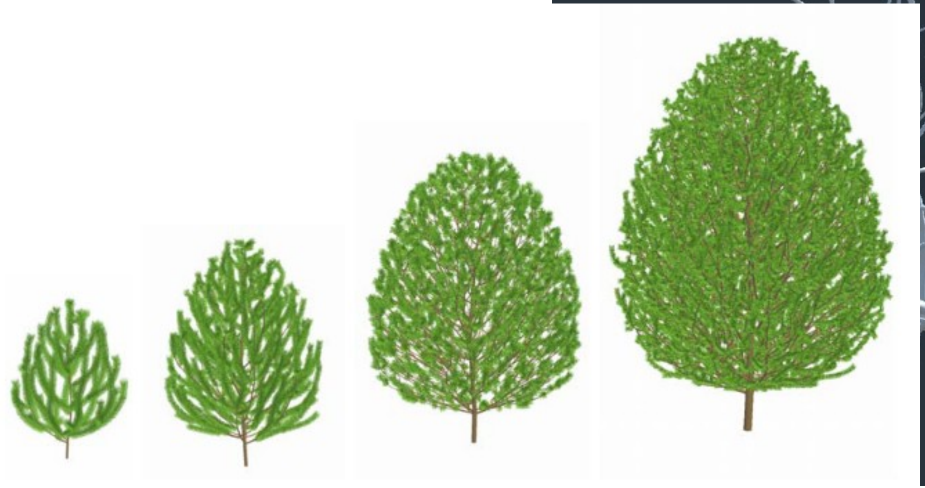

Figure 3.25: Four trees representing pine trees of different ages

Conclusion

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- Procedure comes from a physical process or biological process

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- Procedure comes from a physical process or biological process
- Very easy to implement
- +/- Easy control on the generation process