Portions of this slideshow: Philippe Pasquier

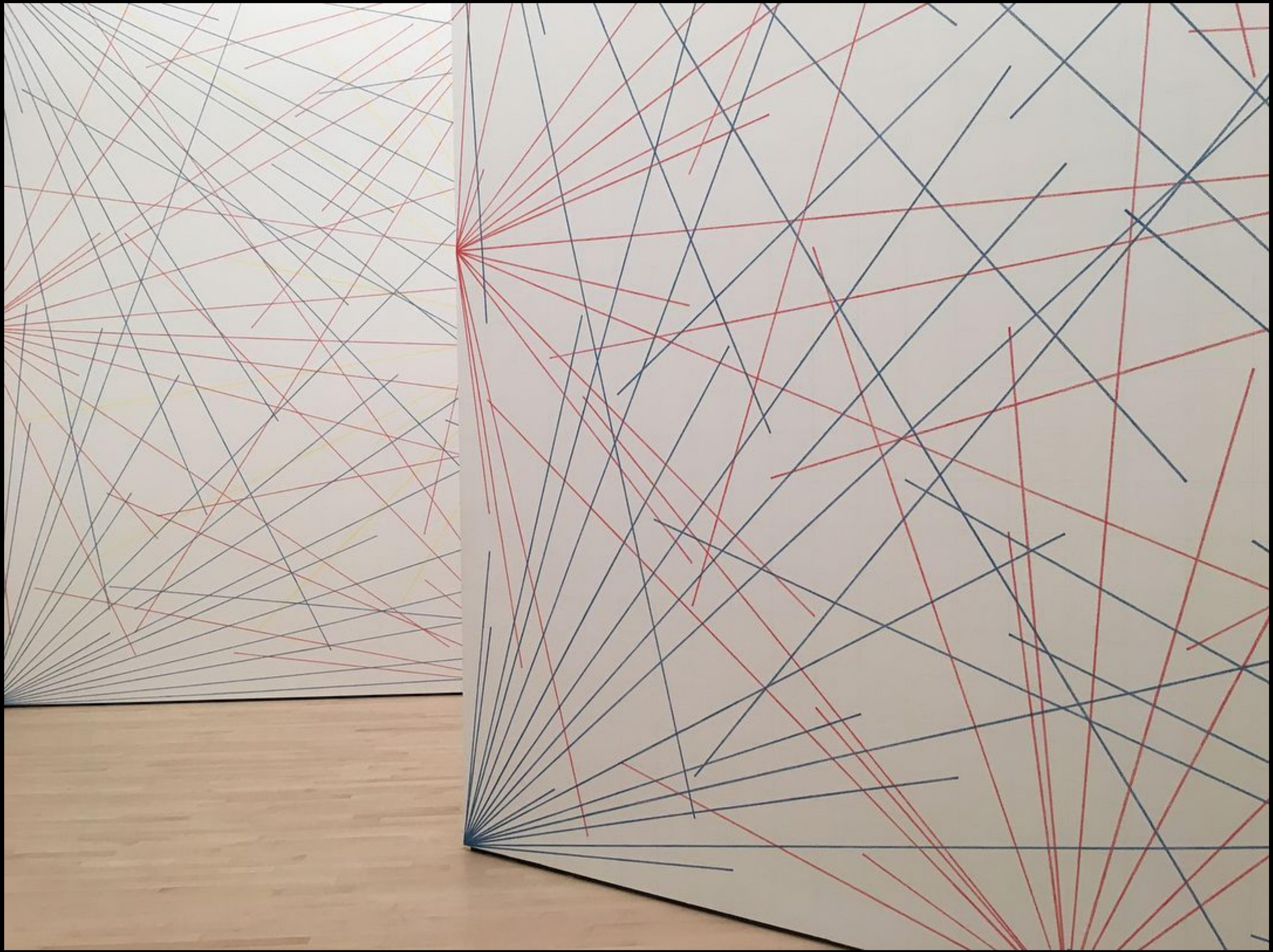
Image credit: Marcel Duchamp, *3 Standard Stoppages* (1913-14)

Carlos Castellanos | School of Interactive Games & Media | Rochester Institute of Technology

# Aesthetics & Computation - IGME 531

# Outline of Today's Lecture

- John Cage, Randomness and Chance Operations
- Fractals, Chaos and Rule-based systems



*Wall Drawings* (1969-), Sol Lewitt

# Art and Rules

## Artists have been developing their own rule systems for many years

- Lewitt did not draw the lines himself. He just sent instructions to the gallery/museum. This is important (complicates notions of authorship)
- Lewitt helped establish Conceptualism and Minimalism as dominant movements of the postwar era.
- tested a viewer's psychological and visual flexibility - contemplate something as simple as a line
- use of logic and non-rationality at the same time
- "Ideas can be works of art; they are in a chain of development that may eventually find some form. All ideas need not be made physical."

# Selected Fluxus Event Scores

**GEORGE BRECHT**

**Direction**
(1961)
Arrange to observe a sign indicating direction of travel.
Travel in the indicated direction.
Travel in another direction.

**No Smoking Event**
(1961)
Arrange to observe a NO SMOKING sign.
smoking
no smoking

**ALBERT M. FINE**

**Ice Cream Piece**
(1966)
Performer buys an ice cream cone and then [a] eats it, or [b] gives it to a stranger, or [c] waits until it melts completely, then eats the cone, or [d] on finishing the piece, buys another ice cream cone.

**KEN FRIEDMAN**

**Cheers**
(1965)
Conduct a large crowd of people to the house of a stranger. Knock on the door. When someone opens the door, the crowd applauds and cheers vigorously.
All depart silently.

**HI RED CENTER**

**Street Cleaning Event**
(date unknown)
Performers are dressed in white coats like laboratory technicians. They go to a selected location in the city. An area of a sidewalk is designated for the event. This area of sidewalk is cleaned very thoroughly with various devices not usually used in street cleaning, such as: dental tools, toothbrushes, steel wool, cotton balls with alcohol, cotton swabs, surgeon's sponges, tooth picks, linen napkins, etc.

Event Scores

# Systems Art

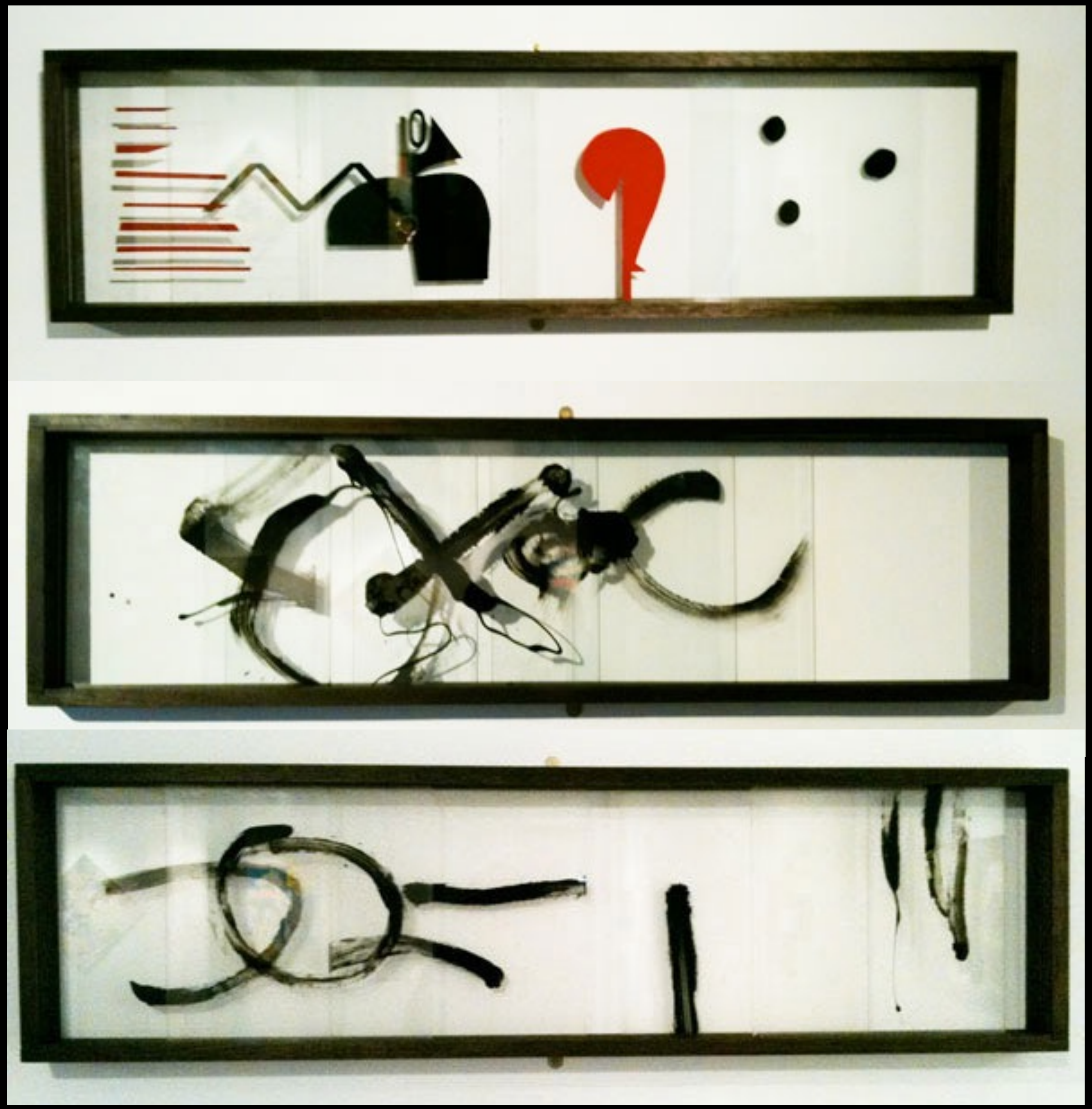
## Before “interactive art”, there was “systems art”

- Systems Art
    - Systems approach to art-making
    - Influenced by cybernetics & systems theory
    - “Systems Aesthetics” (Burnham 1968)
        - “The specific function of modern didactic art has been to show that art does not reside in material entities, but in relations between people and between people and the components of their environment. This accounts for the radicality of Duchamp and his enduring influence. It throws light on Picasso’s lesser position as a seminal force. As with all succeeding formalist art, Cubism followed the tradition of circumscribing art value wholly within finite objects.”
        - “In an advanced technological culture the most important artist best succeeds by liquidating his position as artist vis-à-vis society.“
        - Burnham also offers a crucial insight on the impact of intelligent systems on the arts when he notes that the emerging expansion of the art experience brought upon by the then nascent field of “cybernetic” art “encourages the recognition of man [sic] as an integral part of his environment” (Burnham, 1970, p. 100)
    - Early AI works come out of this context

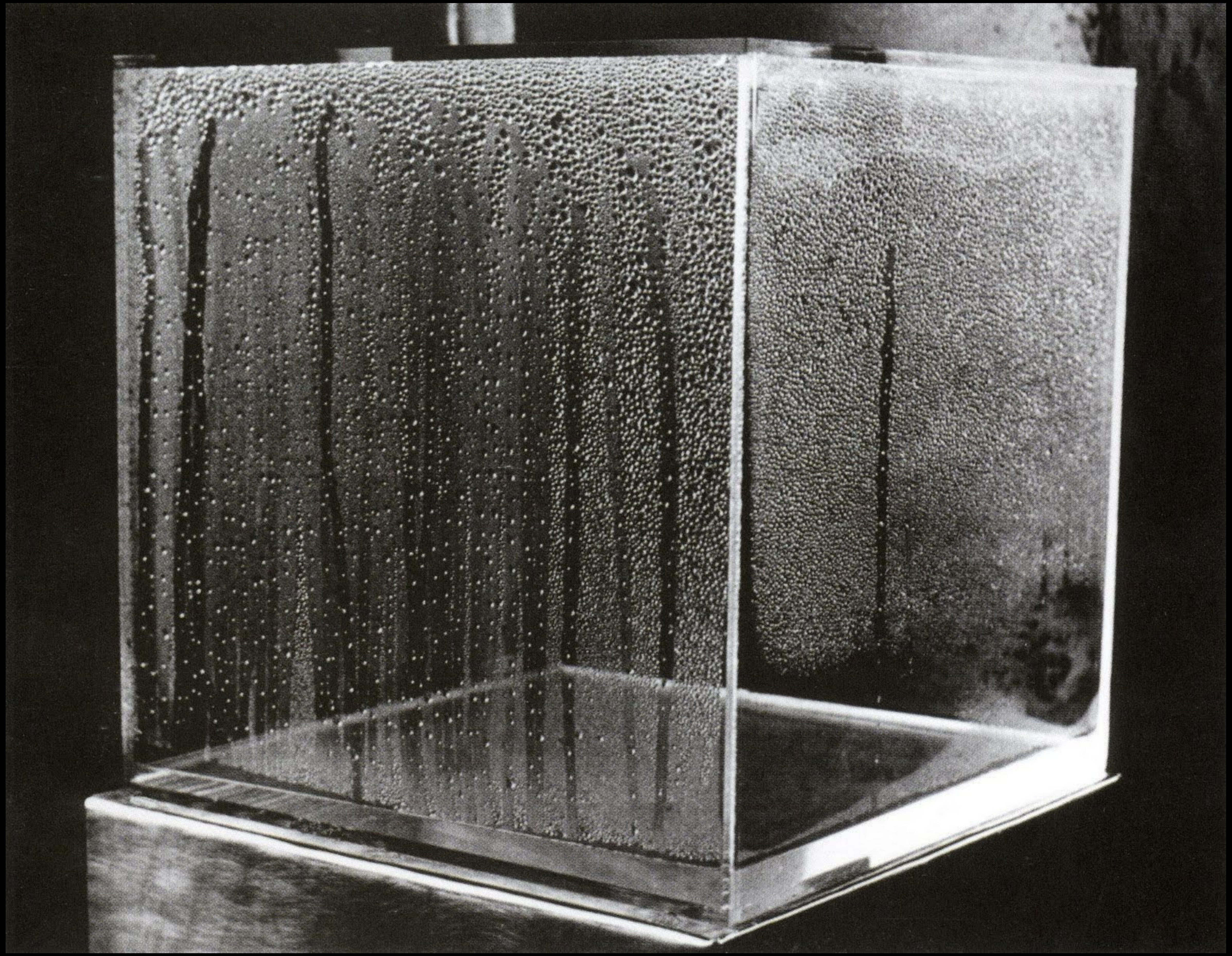
- Roy Ascott

- *Change Paintings* (1959) (plexiglass, wood and oil)

"Interchangeable elements, each with an individual identity, may, by the physical participation of the spectator be brought into a series of relationships, each one adding up to a whole which is more directly related to the manipulator of the parts than if it were static and at a distance. The act of changing becomes a vital part of the total aesthetic experience of the participant" - Roy Ascott



- Hans Haacke
- *Condensation Cube* (1963-65)



- What most of these works have in common:
    - Un-art or Anti-art
    - Reaction against modernism/mainstream art world
    - DIY aesthetic
    - Non-traditional media and processes (e.g. mail, science, etc)
    - Emphasis on viewer participation
    - Works of art are completed by the observer/listener
    - social critique and critical reflection

# Chance & Randomness

## Giving Up Control

- Chance Operations & Randomness
  - Randomness is when order or patterns cannot be observed
  - Dada: poems from randomness and rule systems (like Fluxus event scores)
  - Paintings and sculptures from chance and randomness
  - John Cage: musician and pioneer in chance operation in music
  - The basic idea was to move away from your own aesthetics judgment and taste; let another system make decisions for you - autonomous processes, systems, etc
    - chance & randomness easiest/most common way
    - Artist defines a space with various parameters that can take values within certain ranges; those values are then randomly selected (or via some set of rules) and applied to generate the artwork

- Marcel Duchamp
- 3 Standard Stoppages (1913-14)
- 3 threads dropped over 3 stretched canvasses. Canvasses cute along the curves they created upon landing

- John Cage

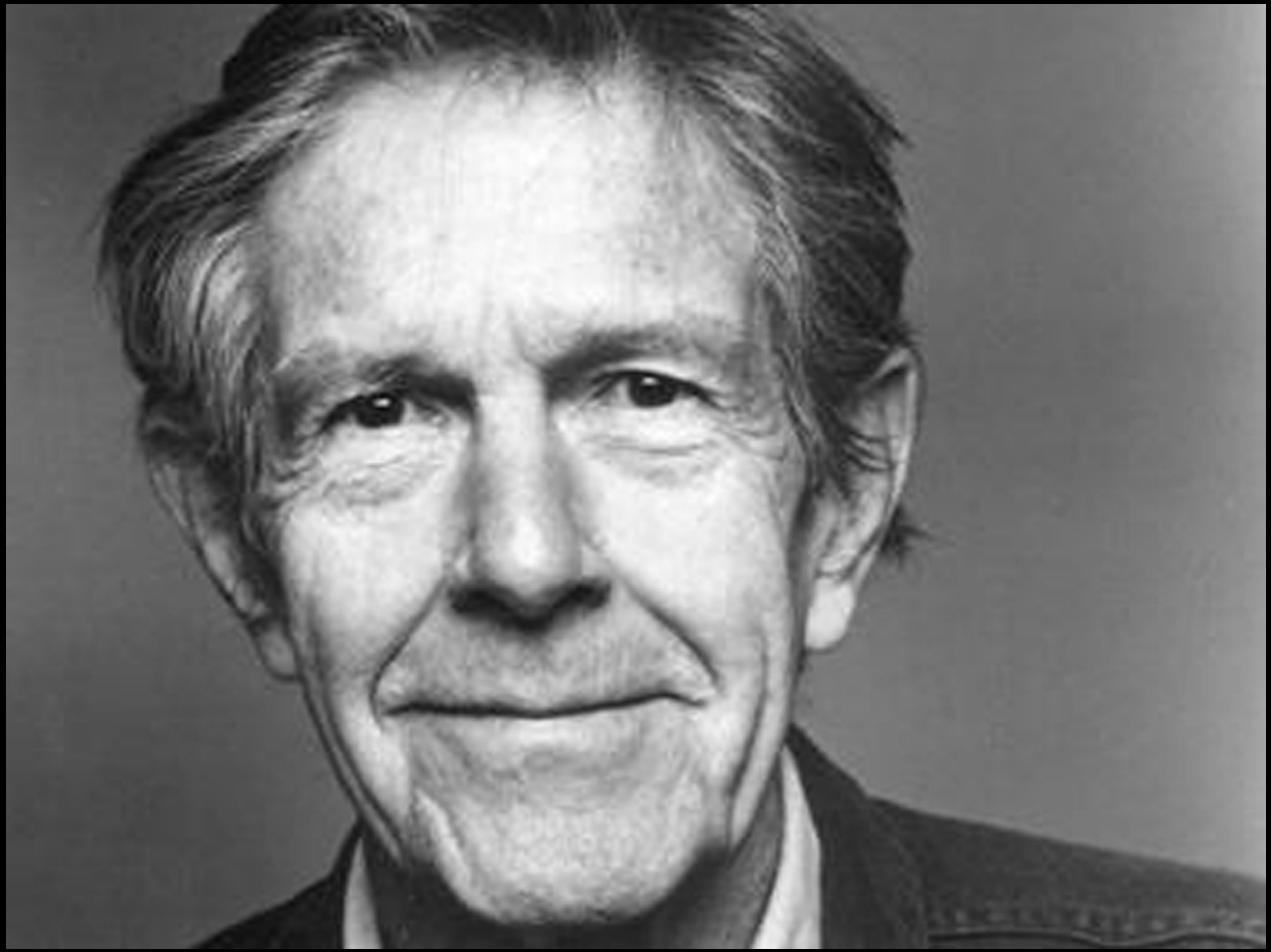
- Used the *I Ching* is an ancient Chinese text; a kind of divination that was sometimes used to provide guidance for moral decision making; uses apparently random numbers turned into a hexagram, which can then be looked up in the text (and interpreted)

- move away from one's own aesthetic choices

- Music of Changes: https://youtu.be/B_8-B2rNw7s

- custom scores

- prepared piano



# Chance & Randomness

## Giving Up Control

- Indeterminacy in music is represented by three main tendencies:
  - Chance music - indeterminacy at the level of composition. During the writing of the piece, the composer employs a chance procedure. Once the work is finished, the score is followed exactly in the same way all traditional music scores are. Representative composer: John Cage.
  - Aleatory music - indeterminacy at the level of performance. The performer is asked to make decisions which will affect either details or even the form of the piece. Representative composers: Pierre Boulez, Karlheinz Stockhausen, Luciano Berio, etc.
    In many instances elements of chance music and aleatory music coexist in the same work. (John Cage).
  - Stochastic music - indeterminacy at the level of composition but involving strict mathematical tools (stochastic distributions). Representative composer: Iannis Xenakis.
- More info: http://cmp.music.illinois.edu/courses/tipei/M202/Notes/cage1.html

# Randomness on a Computer

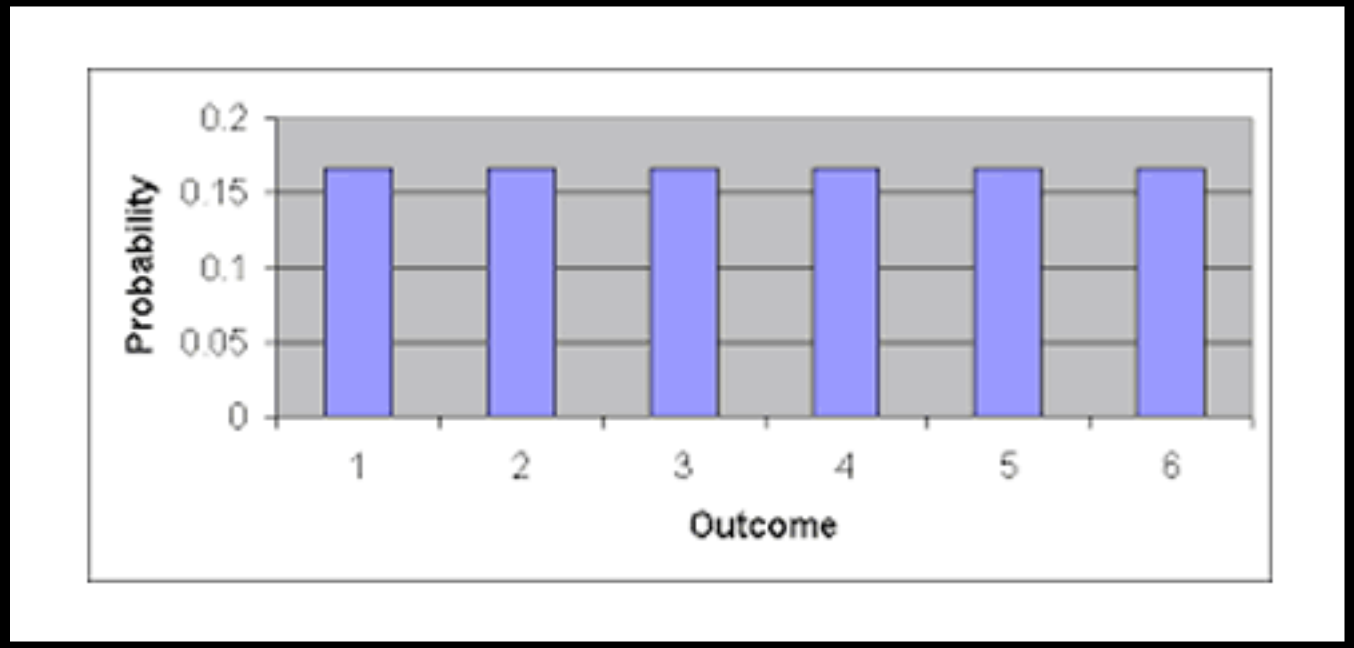
## NOT the Same as Chance & Indeterminacy

- Randomness is when order or patterns cannot be observed
- To get randomness from a computer you can:
    - measure some kind of physical phenomenon (e.g. atmospheric noise, cosmic background radiation, etc)
    - table of stored random numbers
    - computers can only generate *pseudo-random* numbers (using a using a mathematical formula)
        - take seed number (e.g. number of seconds since the computer was booted) and feed it to your equation/algorithm
            - this is the type of randomness we have access to when programming (e.g. Random class in Java)

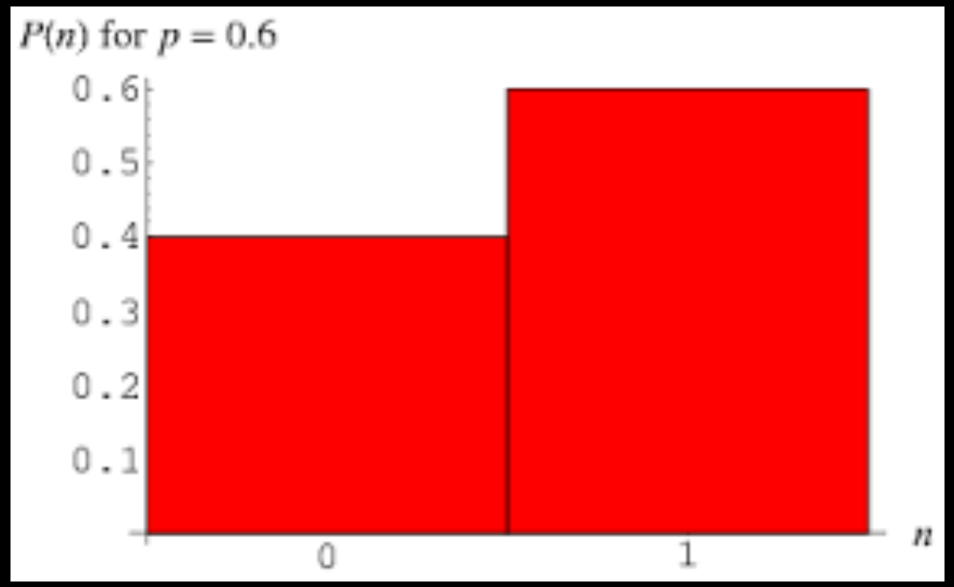
# Randomness on a Computer

## NOT the Same as Chance & Indeterminacy

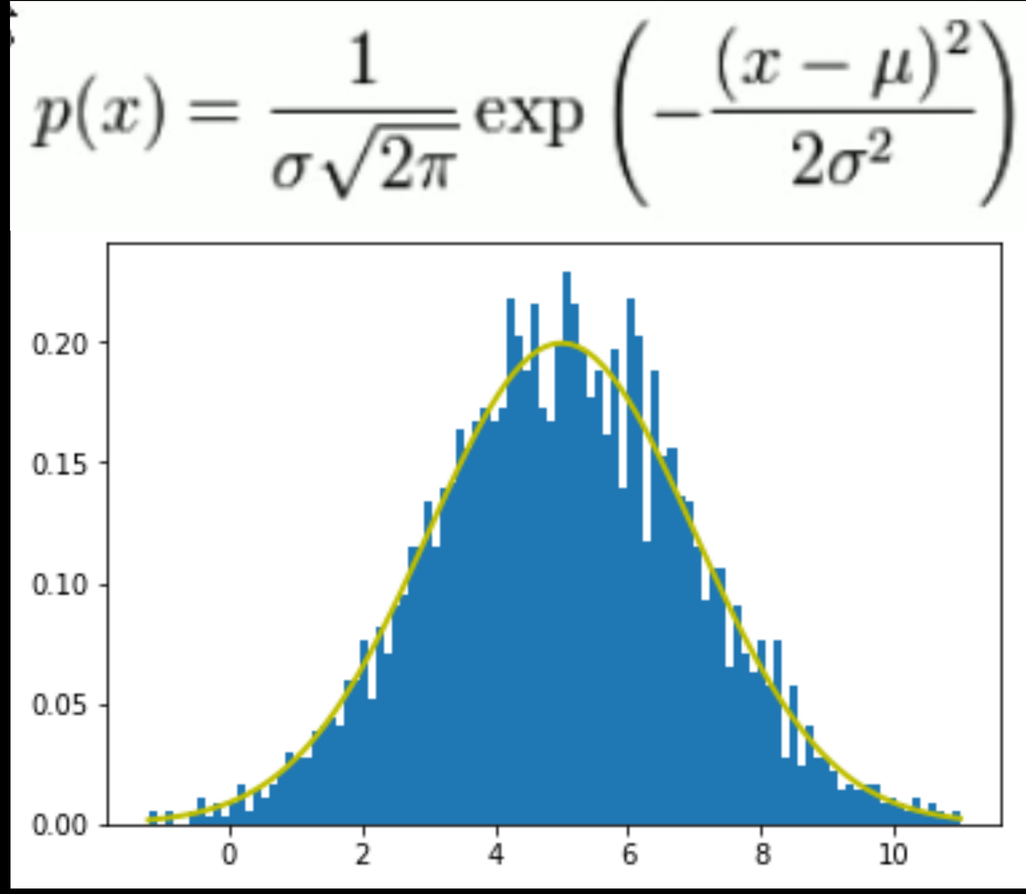
- Probability theory is the main framework for randomness
  - Probability Distributions (likelihood of a given number appearing in set of numbers)




Uniform (e.g. dice)




Bernoulli (e.g. single coin flip)




Gaussian (or normal)
(continuous distribution
of random variables)

# Randomness on a Computer

## NOT the Same as Chance & Indeterminacy

- many other distributions
  - Binomial
  - Poisson
  - Hypergeometric
  - etc...

*4900 Colours* (2007), Gerhard Richter

*4900 Colours comprised bright monochrome squares randomly arranged in a grid formation to sheets of kaleidoscopic color. Richter created many version of these paintings*

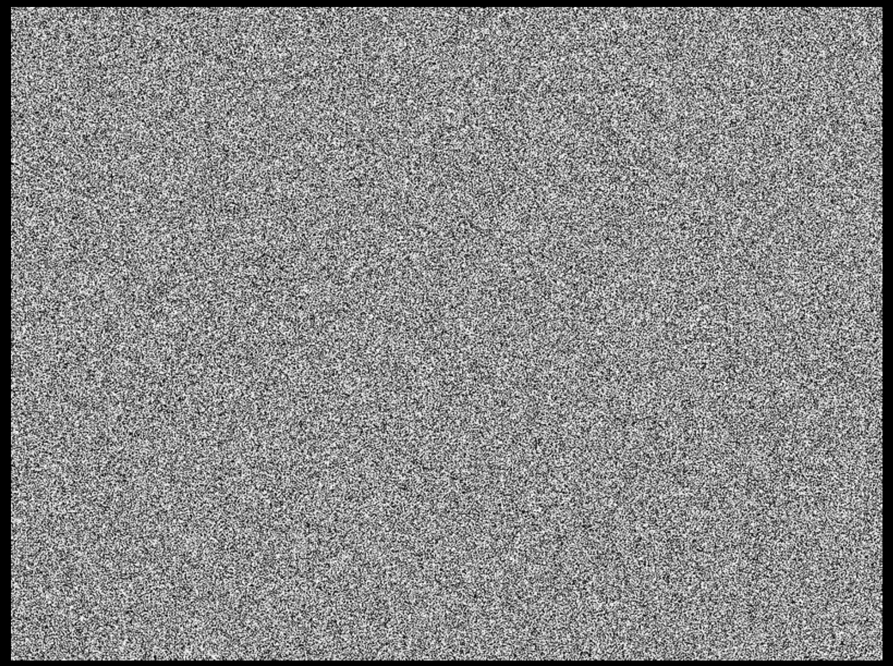
# Noise

## Randomness in a Sequence

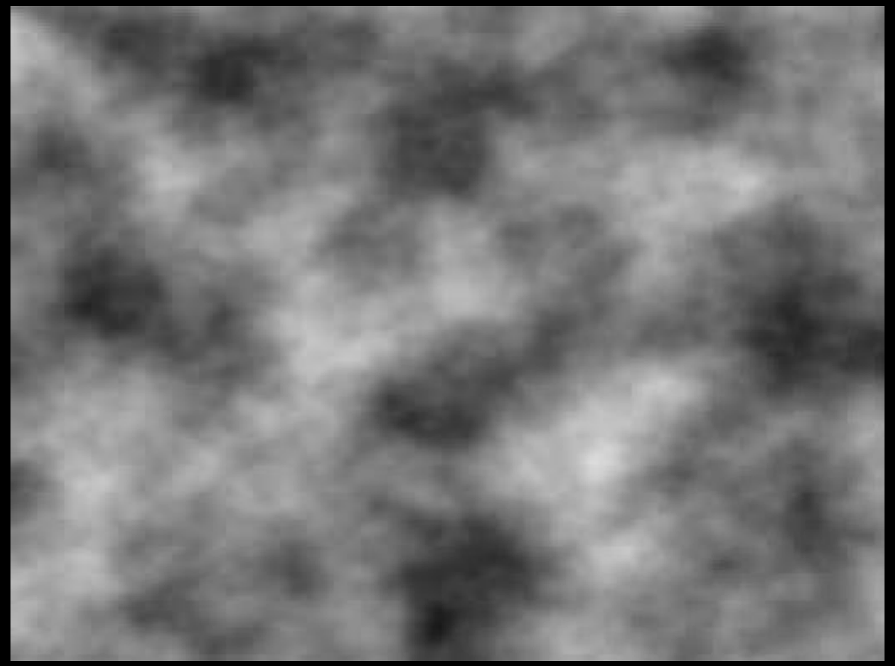
- When all the elements of a sequence that serves as a signal are decided at random, we usually refer to this as *noise*.
- White noise (no correlation between the values) (uniform distribution and flat spectrum) (“pure randomness”)
- Many other types of noise:
    - Sound: Pink, Blue, Violet, etc
    - Images: Perlin, Brownian, Worley, etc

# Noise

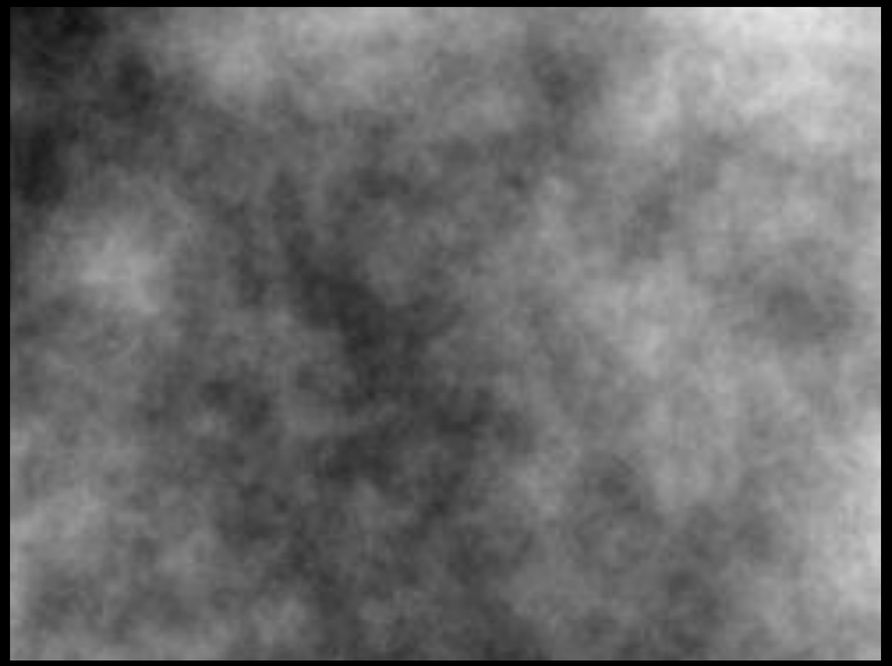
## Randomness in a Sequence



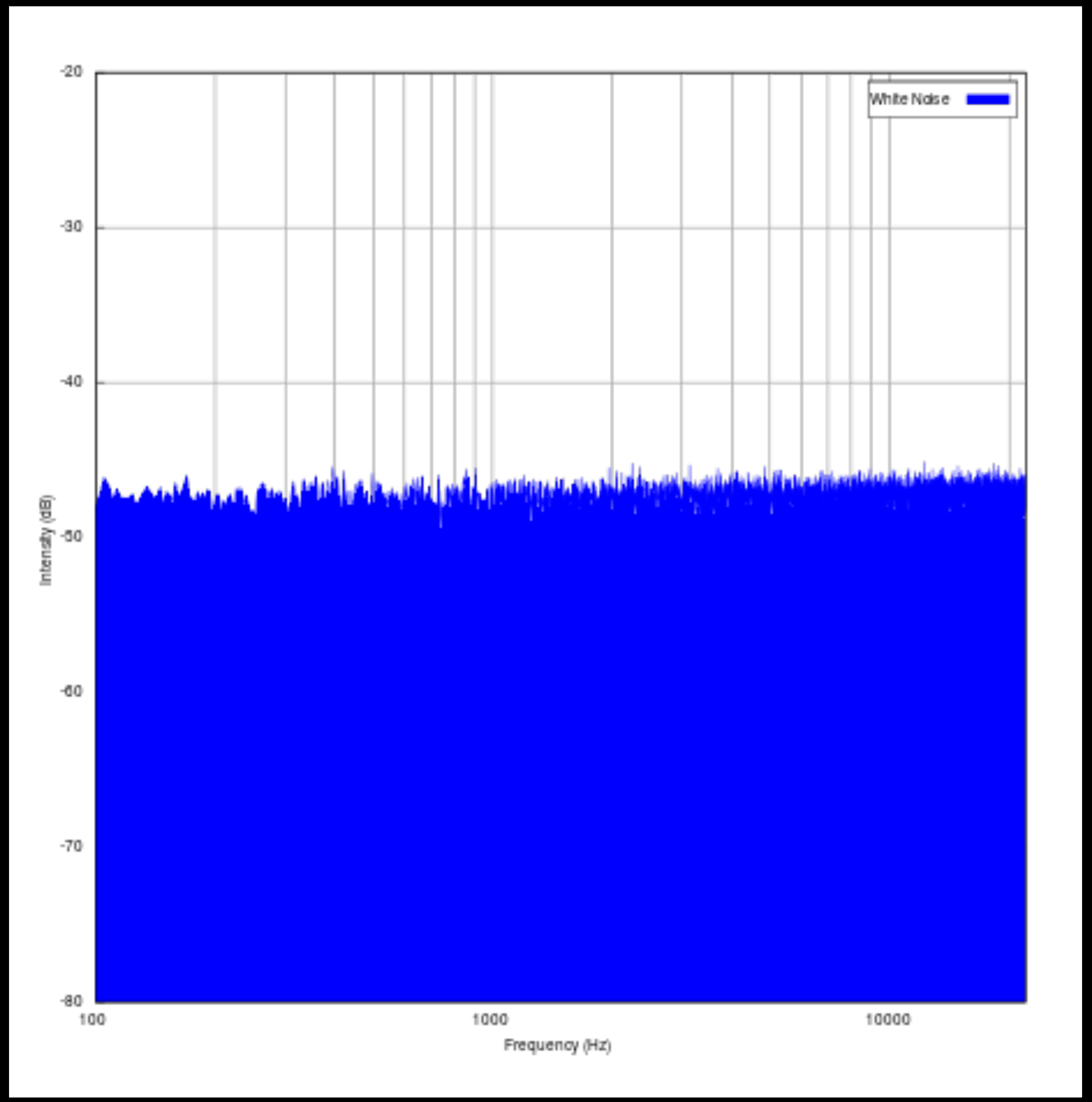
White noise



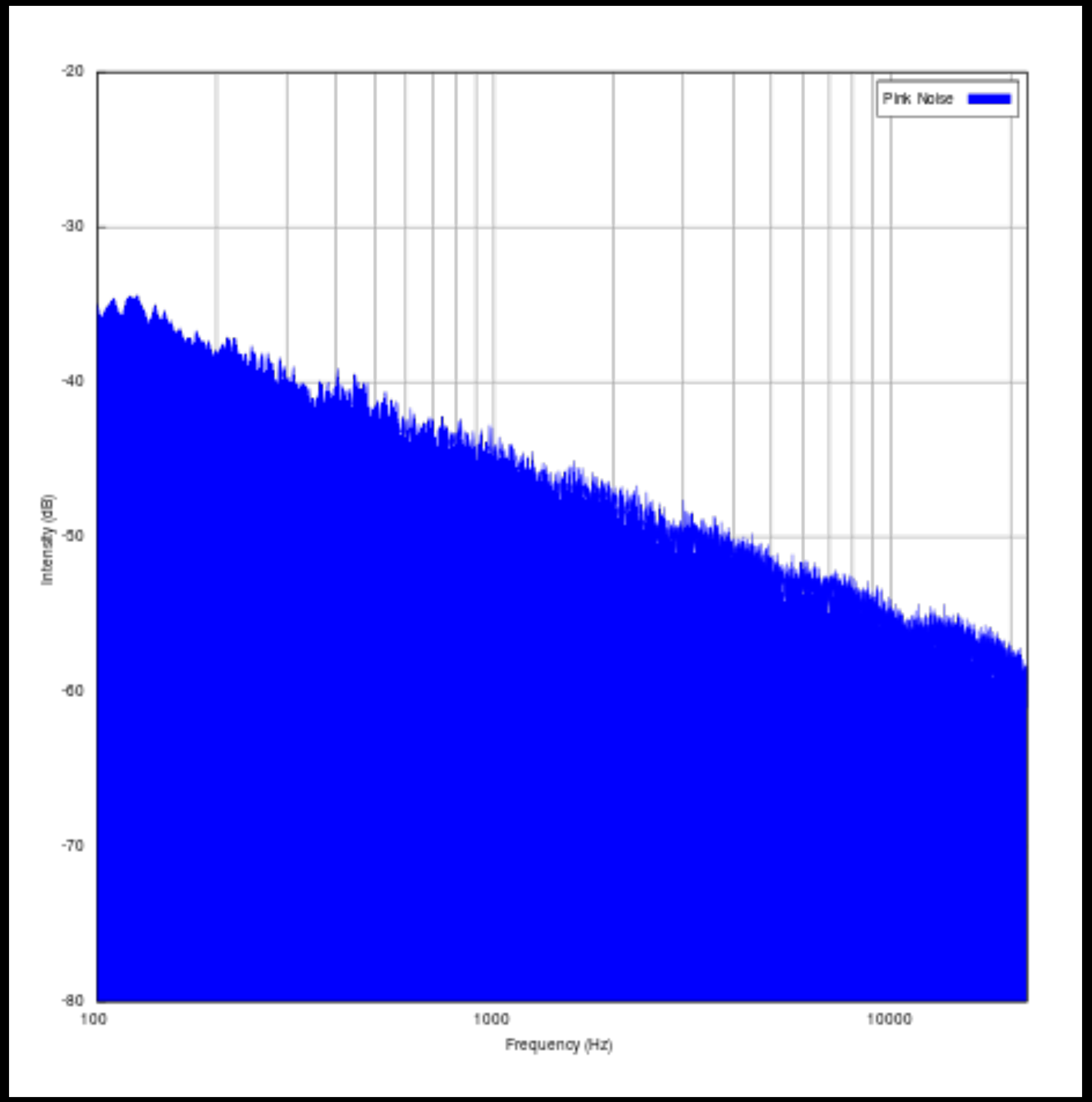
Perlin noise



Brownian noise




White noise



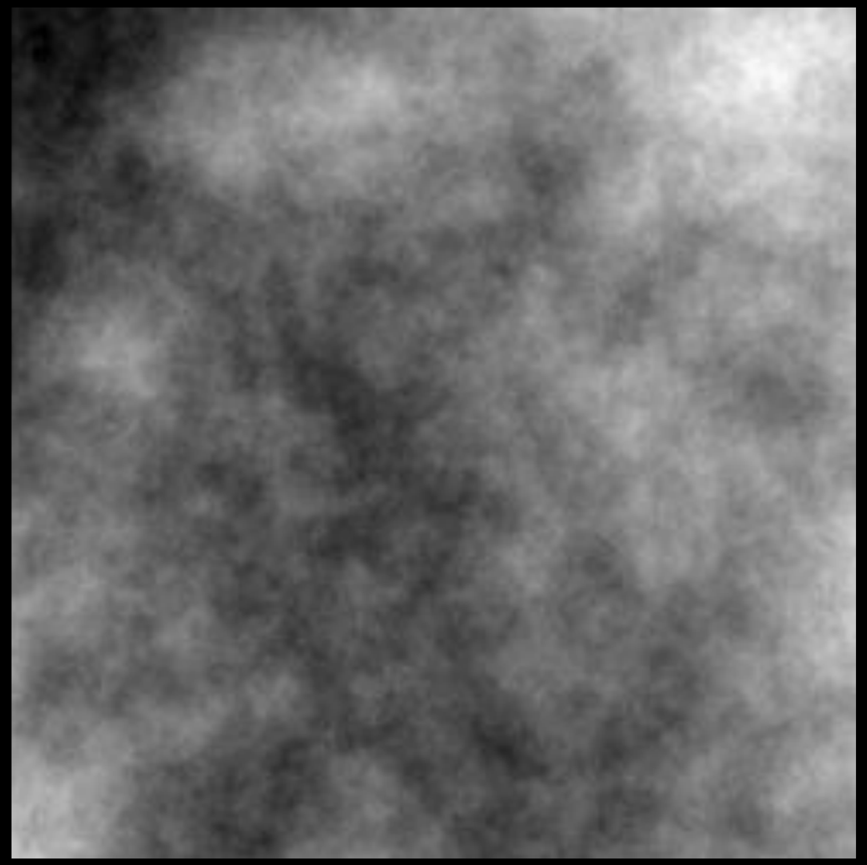

Pink noise

# Noise

## Randomness in a Sequence

- Brownian motion (simple model of how a gas molecule moves)

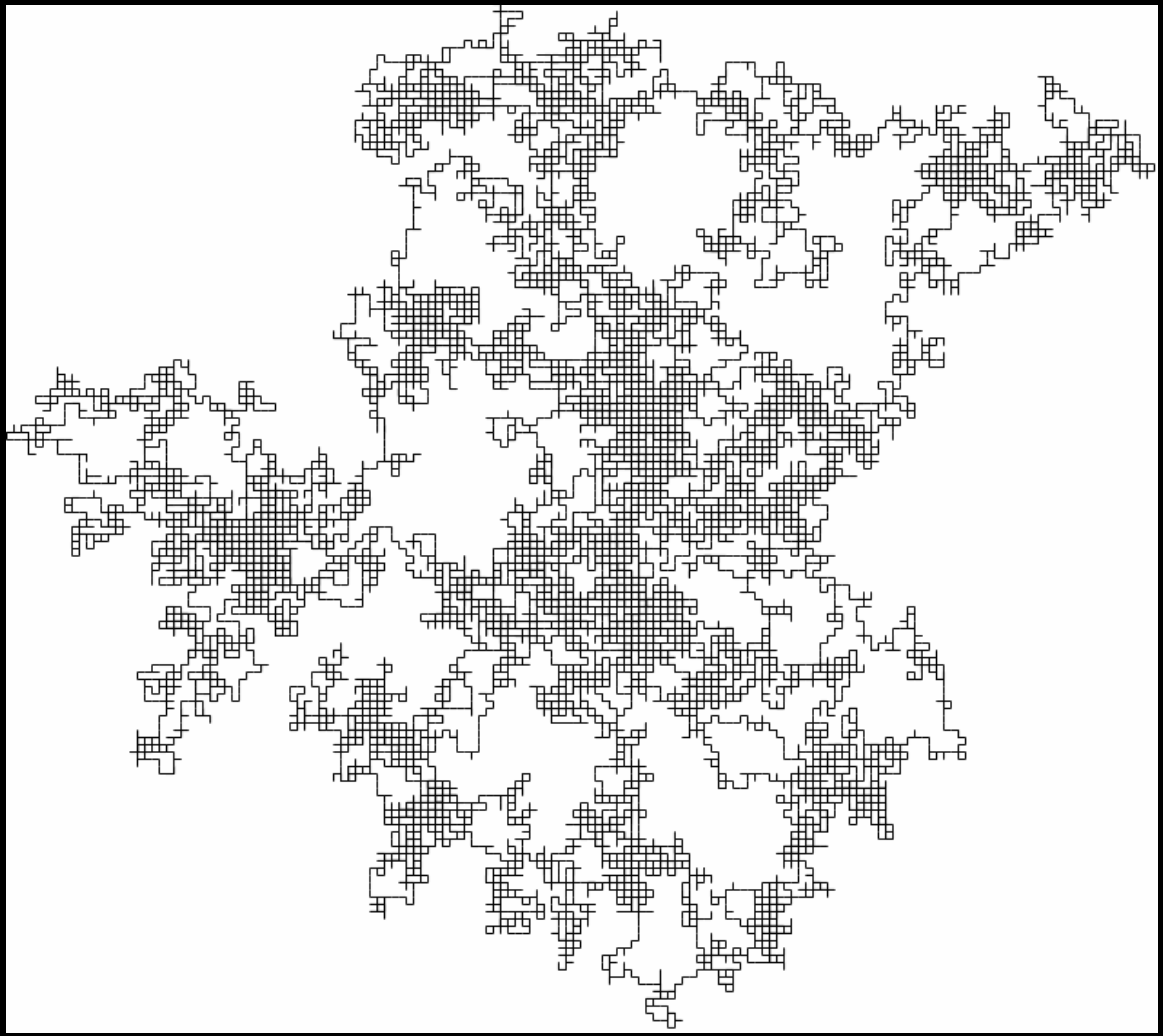

- Brownian noise



# Art and AI

## Noise

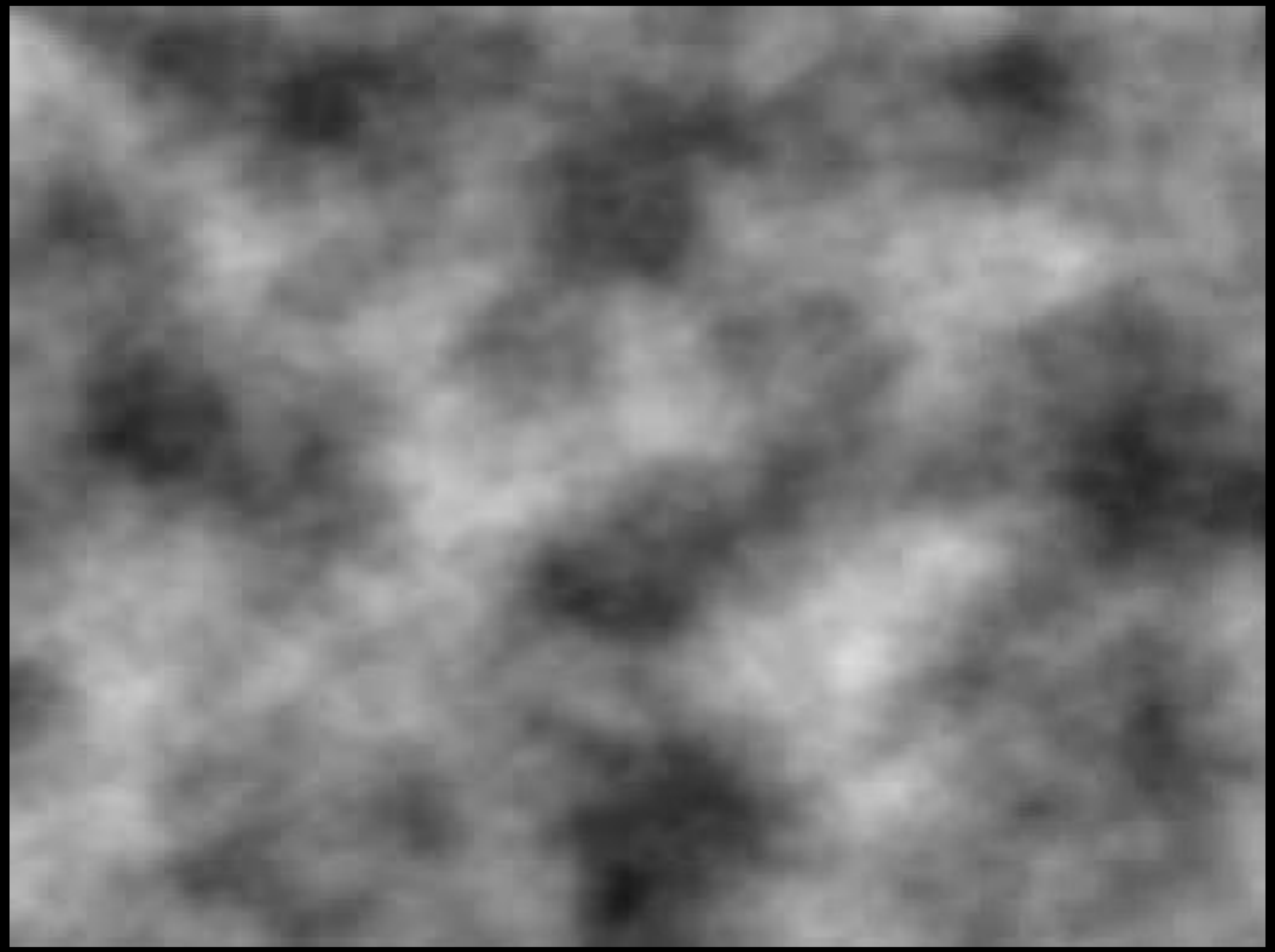
- Random walk
- similar to brownian motion



# Art and AI

## Noise

- Perlin Noise, developed by Ken Perlin is useful for creating natural/realistic randomness in CG environments. It used to create smoke, fire, terrain and so on. Perlin developed it for the early '80s for a film he was working on called Tron. In 1997, he won an Academy Award for his discovery. He also never patented the technique which is why we can all use it freely today.
- The noise() function in Processing uses Perlin Noise



# ?

*“Why do people think artists are special? It's just another job.”*

Andy Warhol

# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena

- Fractals & Chaos are dynamical systems
  - change through time; sensitive to initial conditions; small changes in input lead to large changes in output; output is not directly proportional to the input (thus hard to predict in the long-term)
  - Dynamical systems theory attempts to understand, or at least describe, the changes over time that occur in physical and artificial systems
    - swinging pendulums, growth of crystals, the stock market are examples of dynamical or chaotic systems
  - All part of the “sciences of complexity”
    - Complexity: behavior that is not clearly random nor ordered. Complexity arises when several (often many) components interact with each other in multiple ways.

# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena

- Fractals are geometric shapes that have the following characteristics:
  - Self-similarity (at multiple scales): small pieces of a fractal look similar to the entire object
  - Fractal dimension: as opposed to an integer dimension, this is a measure of how "complicated" a fractal is. Sometimes used as an aesthetic measure
  - The term "fractal" was coined by 20th century mathematician, Benoit Mandelbrot. His fractal theory was developed in order to try to more precisely quantify the immense complexity of nature in relatively simple equations.
  - More info: http://www.cs.cornell.edu/courses/cs212/1998sp/handouts/Fractals/similar.html

# Fractals, Chaos, Rule-Based Systems

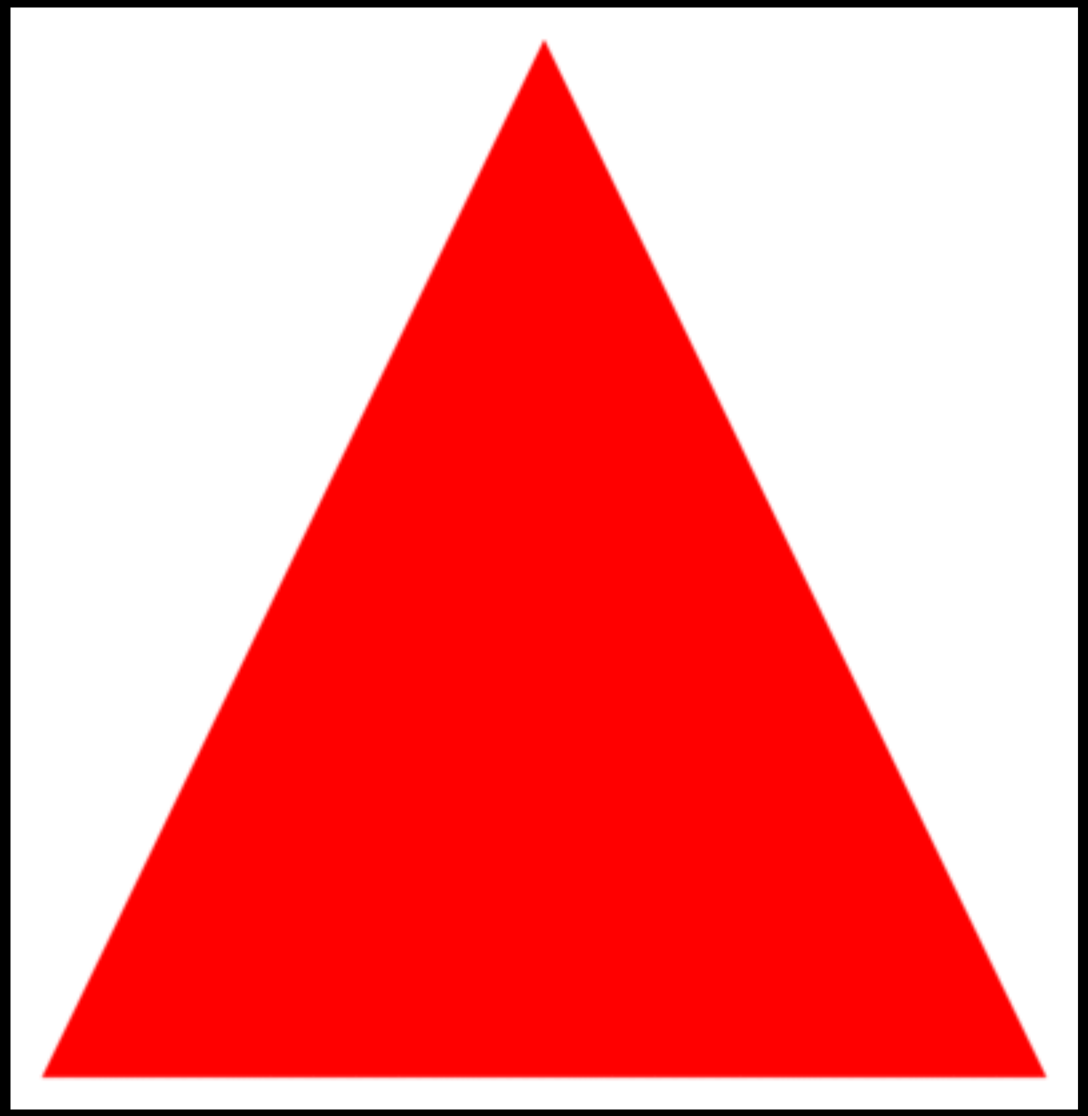
## Simulating Natural and Emergent Phenomena

- “Mandelbrot ended up doing a great piece of science and identifying a much stronger and more fundamental idea—put simply, that there are some geometric shapes, which he called “fractals”, that are equally “rough” at all scales. No matter how close you look, they never get simpler, much as the section of a rocky coastline you can see at your feet looks just as jagged as the stretch you can see from space.” - Stephen Wolfram
  - https://www.stephenwolfram.com/publications/the-father-of-fractals/

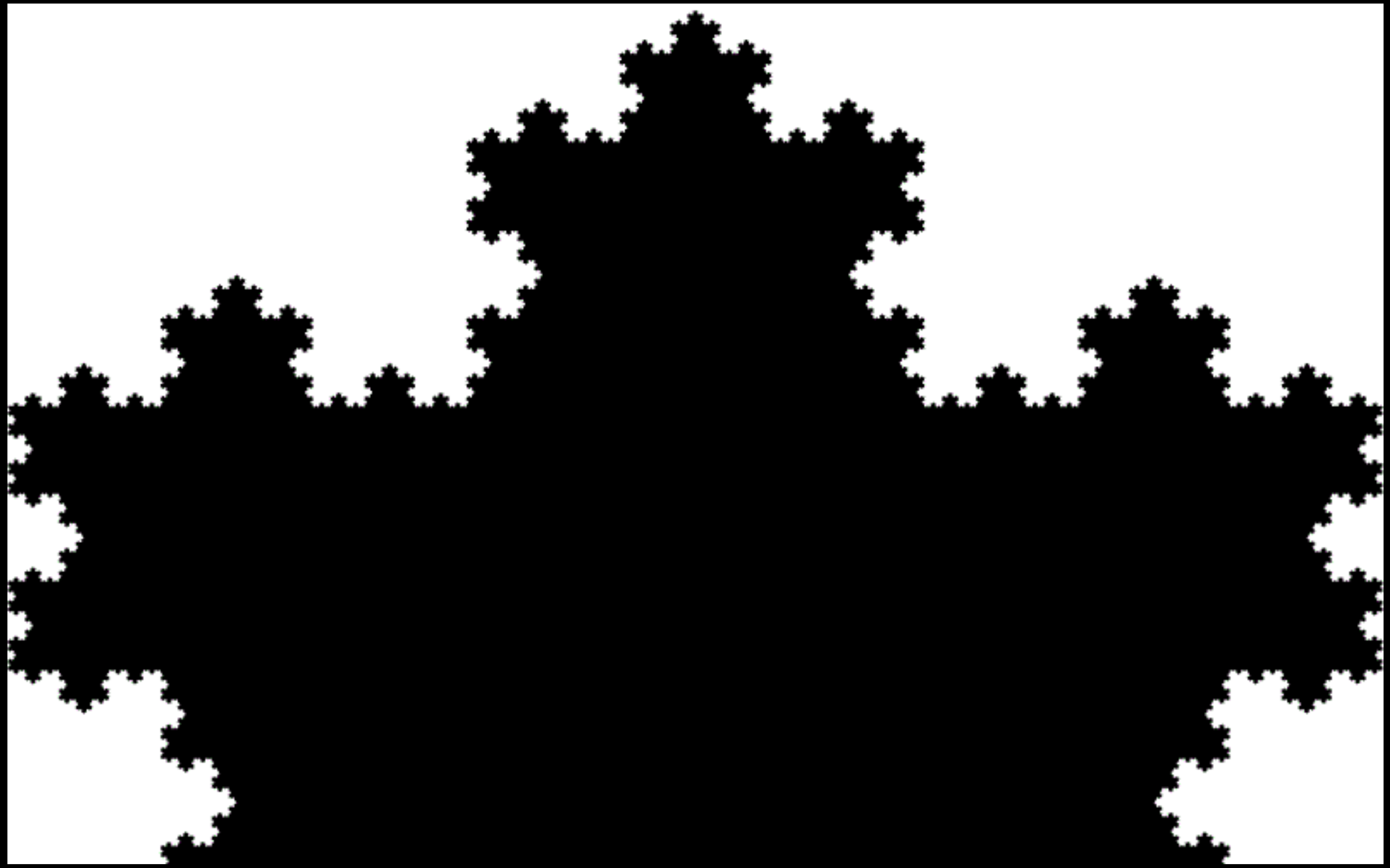
- More info: http://www.cs.cornell.edu/courses/cs212/1998sp/handouts/Fractals/similar.html

# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena



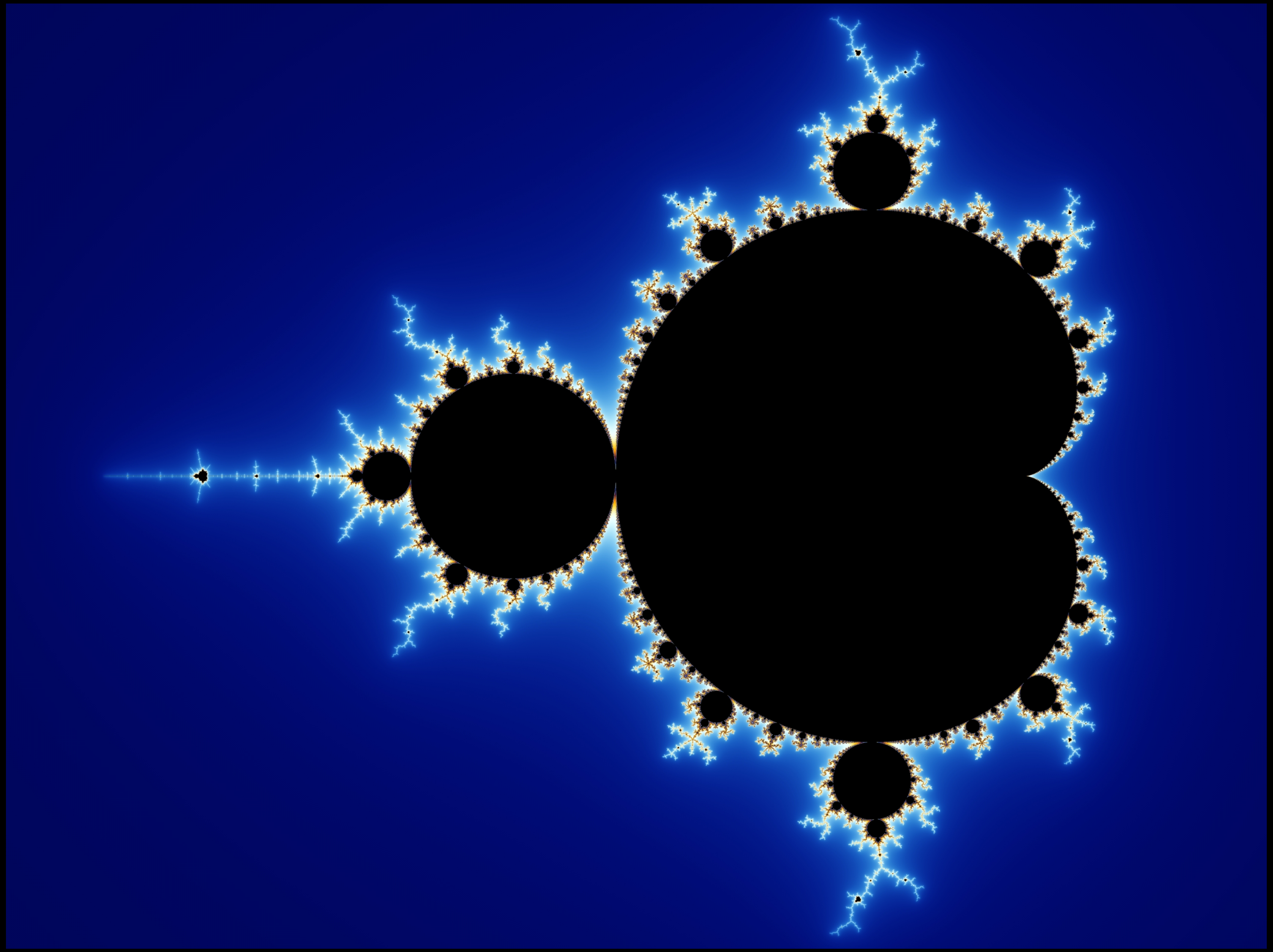
Sierpiński triangle



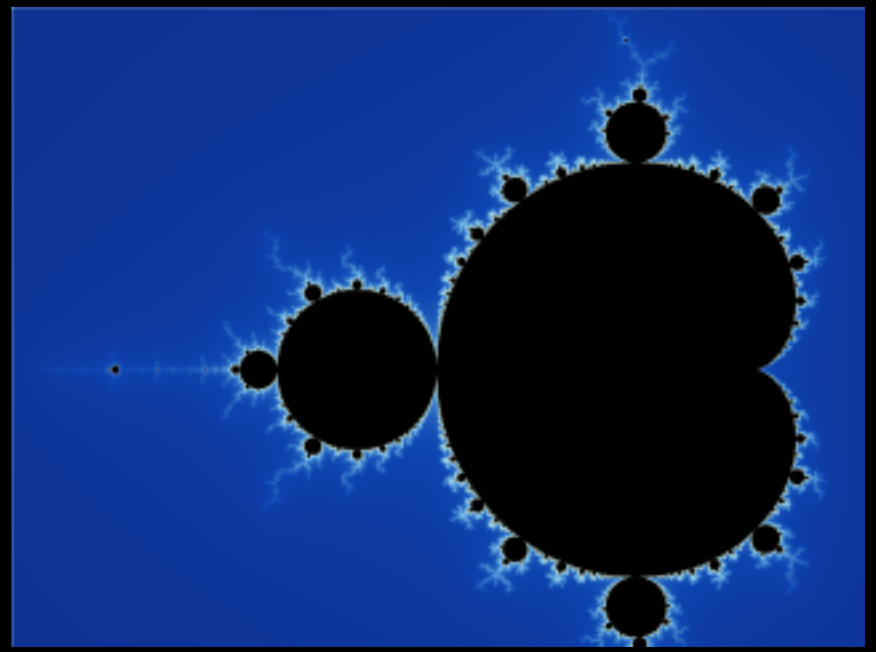
Koch Snowflake

# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena



Mandelbrot set



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

# Fractals, Chaos, Rule-Based Systems

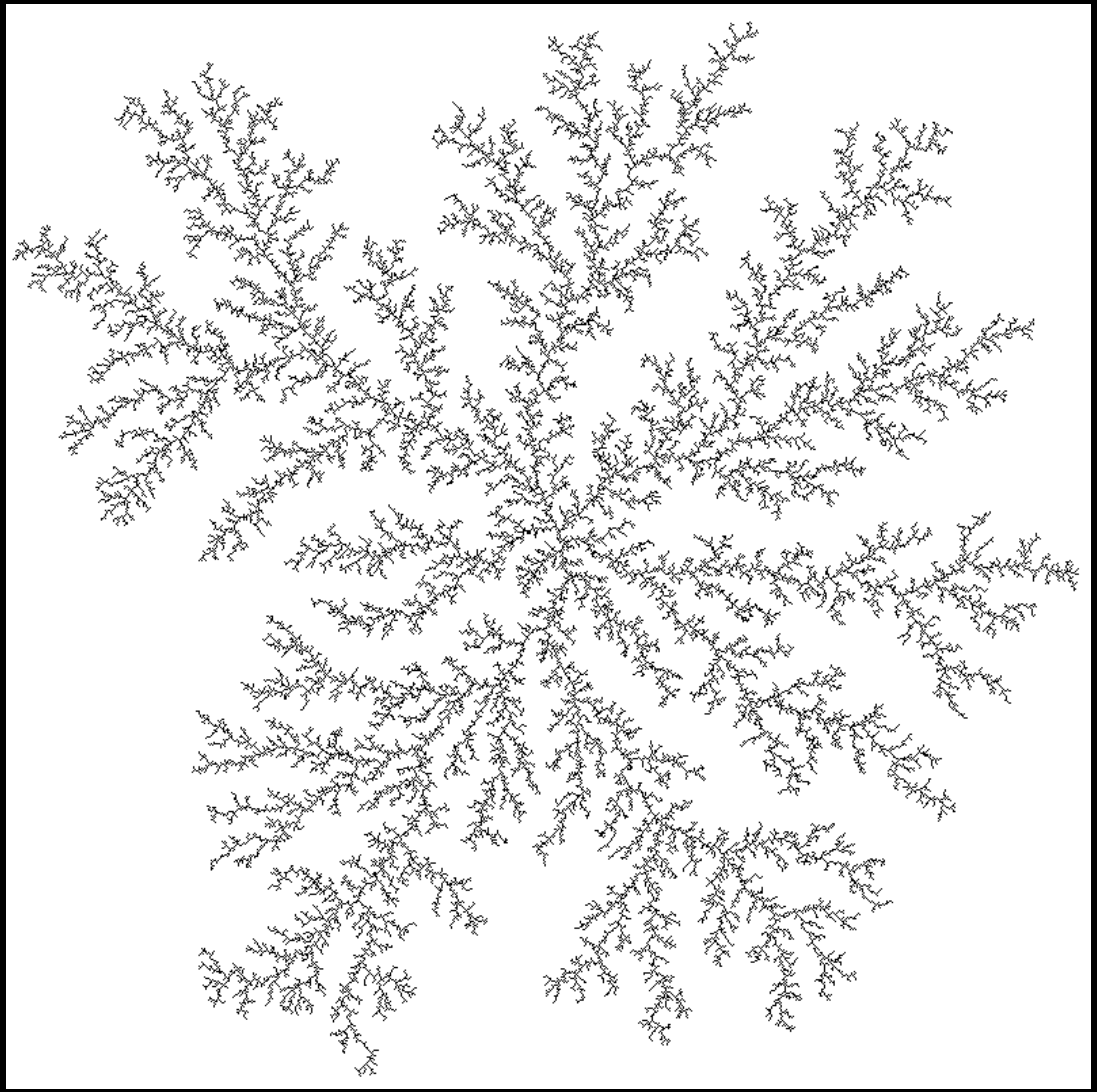
## Simulating Natural and Emergent Phenomena

- Diffusion Limited Aggregation (DLA)
  - Basically a random walk of particles that then cluster together (“stick” to each other) when they when they come in contact with previously fixed particles
  - Used to model electrolytic growth, coral growth, crystal formations, etc.
  - More info: https://paulbourke.net/fractals/dla/

# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena

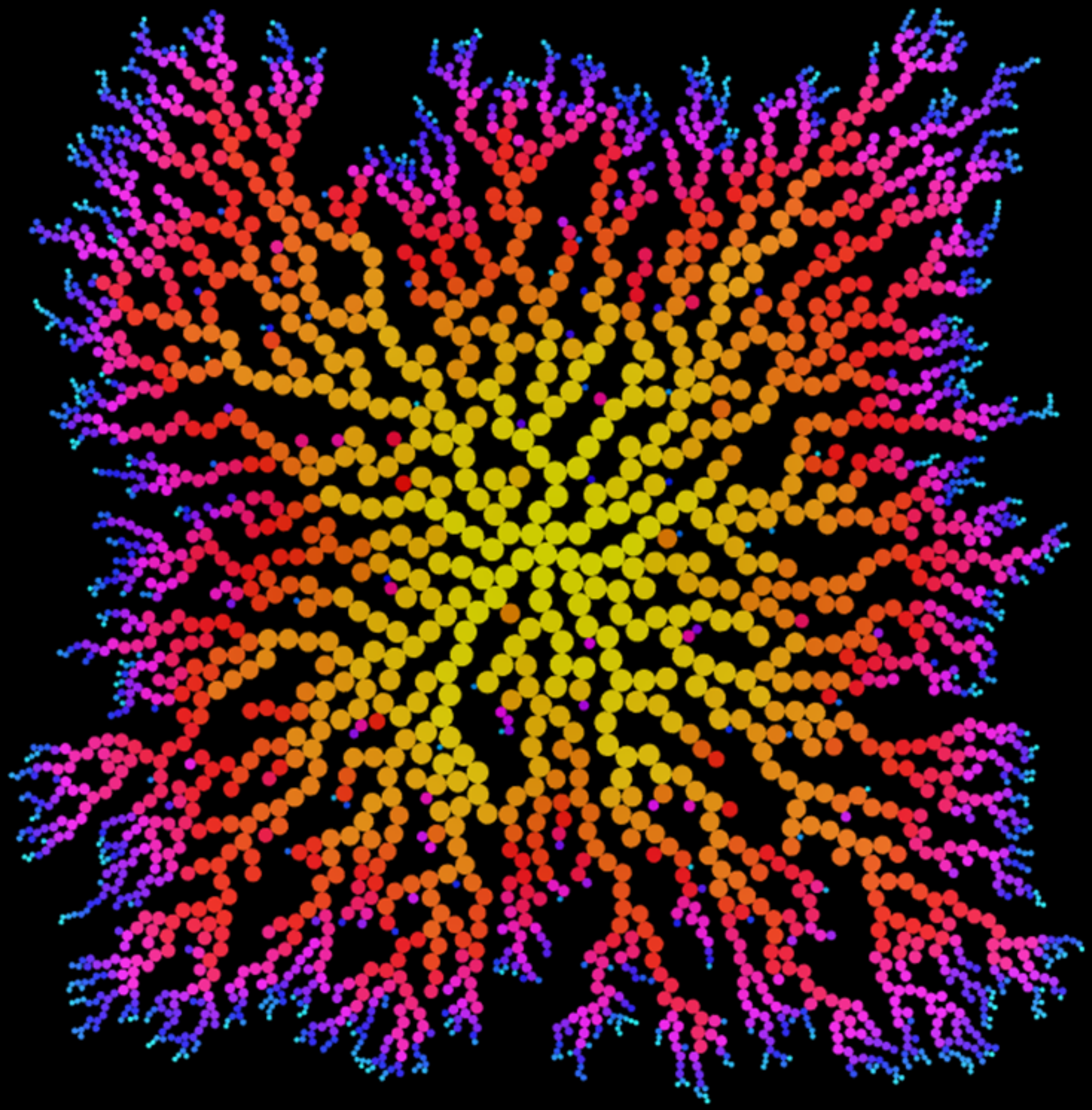
- Diffusion Limited Aggregation (DLA)



# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena

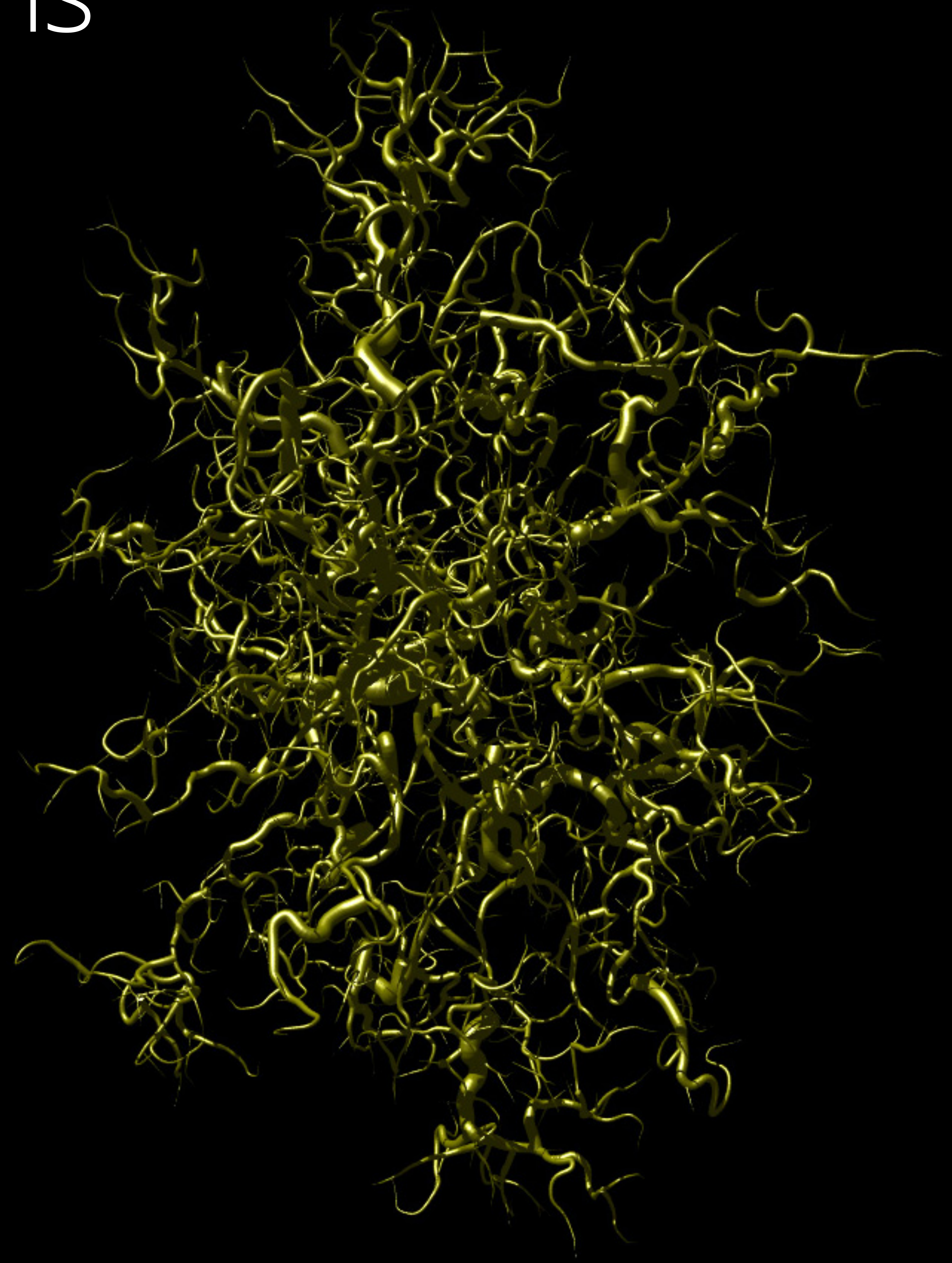
- Diffusion Limited Aggregation (DLA)



# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena

- Diffusion Limited Aggregation (DLA)



# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena

- Chaos
  - many chaotic systems have been used or explored in the arts
    - example: “Drip Music” (1959) by Fluxus artist George Brecht uses fluid dynamics

# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena

- Rule-based systems
  - propositional logic
    - *Modus ponens* (mode that affirms)
      - "*P* implies *Q*. If *P* is true. Therefore *Q* must also be true.”
    - *Modus tollens* (mode that denies)
      - "If *P* implies *Q* and *Q* is false. Therefore *P* must also be false."
    - Note that an argument can be valid, even if one of the premises is false.
  - formal, rule-based systems are ubiquitous in CS (if-then-else, etc), especially in GOFAI

# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena

- Diverse family of rule-based systems
  - Formal logic systems (reasoning rules, theorem solvers, case-based reasoning, etc)
  - Generative grammars and the Chomsky hierarchy
  - Expert systems
  - L-Systems
  - Markov Models/Hidden Markov Models
  - and more…

# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena

- L-systems (or Lindenmayer-systems)
  - L-systems were introduced and developed in 1968 by biologist and botanist Aristid Lindenmayer to formalize the growth process of plants
  - They are parallel rewriting systems (methods of replacing subterms of a formula with other terms) and a type of generative grammar (a set of production rules for strings in a formal language)
  - Basically a string of characters (symbols) is rewritten on each iteration according to some replacement rules (also called production rules).
  - All symbols in an L-system correspond to an action (like turn L or R in turtle graphics, mapped to musical notes or to move a robot, etc)

# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena

- A simple L-system:
  - Consider an initial string (called an axiom):
    - F+F+F+F
    - and a rewriting rule: F --> F+F-F-FF+F+F-F
  - After one iteration the following string would result:
    - F+F-F-FF+F+F-F + F+F-F-FF+F+F-F + F+F-F-FF+F+F-F + F+F-F-FF+F+F-F
  - For the next iteration the same rule is applied but now to the string resulting from the previous iteration:

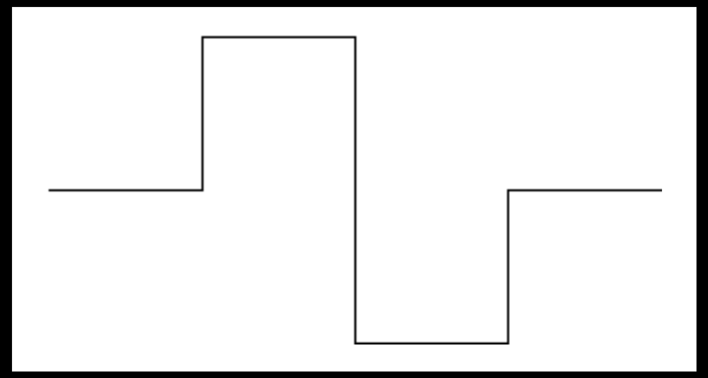
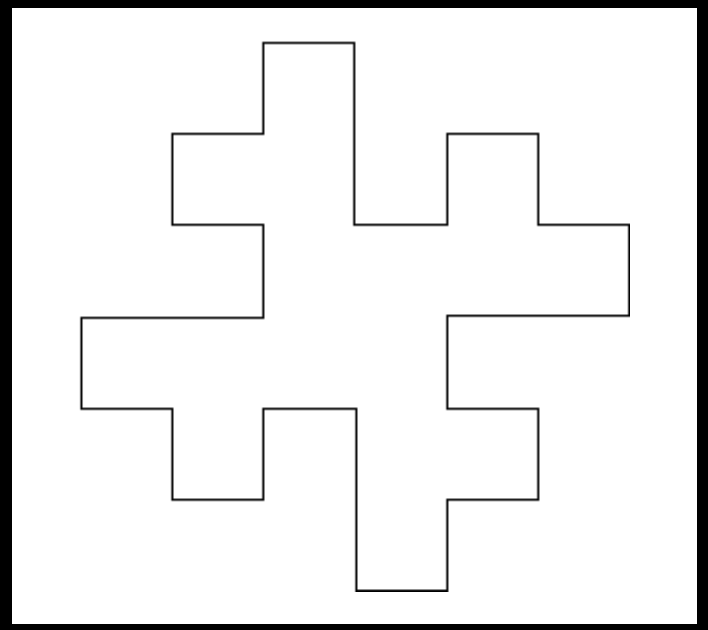
# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena

- F+ F-F-FF+ F+ F-F+ F+ F-F-FF+ F+ F-F-F+ F-F-FF+ F+ F-F-F+ F-F-FF+ F+ F-FF+ F-F-FF+ F+ F-F+ F+ F-F-FF+ F+ F-F+ F+ F-F-FF+ F+ F-F-F+ F-F-FF+ F+ F-F+ F+ F-F-FF+ F+ F-F+ F+ F-F-FF+ F+ F-F-F+ F-F-FF+ F+ F-F-F+ F-F-FF+ F+ F-FF+ F-F-FF+ F+ F-F+ F+ F-F-FF+ F+ F-F+ F+ F-F-FF+ F+ F-F-F+ F-F-FF+ F+ F-F+ F+ F-F-FF+ F+ F-F+ F+ F-F-FF+ F+ F-F-F+ F-F-FF+ F+ F-F-F+ F-F-FF+ F+ F-FF+ F-F-FF+ F+ F-F+ F+ F-F-FF+ F+ F-F+ F+ F-F-FF+ F+ F-F-F+ F-F-FF+ F+ F-F+ F+ F-F-FF+ F+ F-F+ F+ F-F-FF+ F+ F-F-F+ F-F-FF+ F+ F-F-F+ F-F-FF+ F+ F-FF+ F-F-FF+ F+ F-F+ F+ F-F-FF+ F+ F-F+ F+ F-F-FF+ F+ F-F-F+ F-F-FF+ F+ F-F

# Fractals, Chaos, Rule-Based Systems

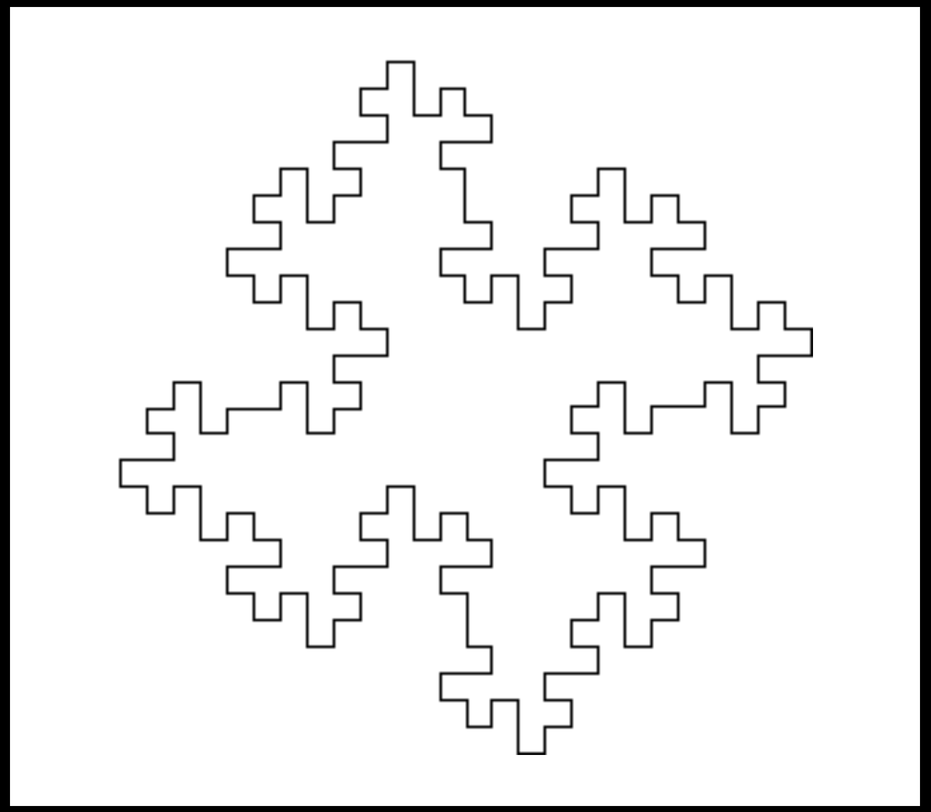
## Simulating Natural and Emergent Phenomena

- If we give these symbols graphical meaning, such as “F” means move forward drawing a line, “+” means turn right by some predefined angle (90 degrees in this case), “-“ means turn left.
  - We get this: 
  - After 1 iteration: 

# Fractals, Chaos, Rule-Based Systems

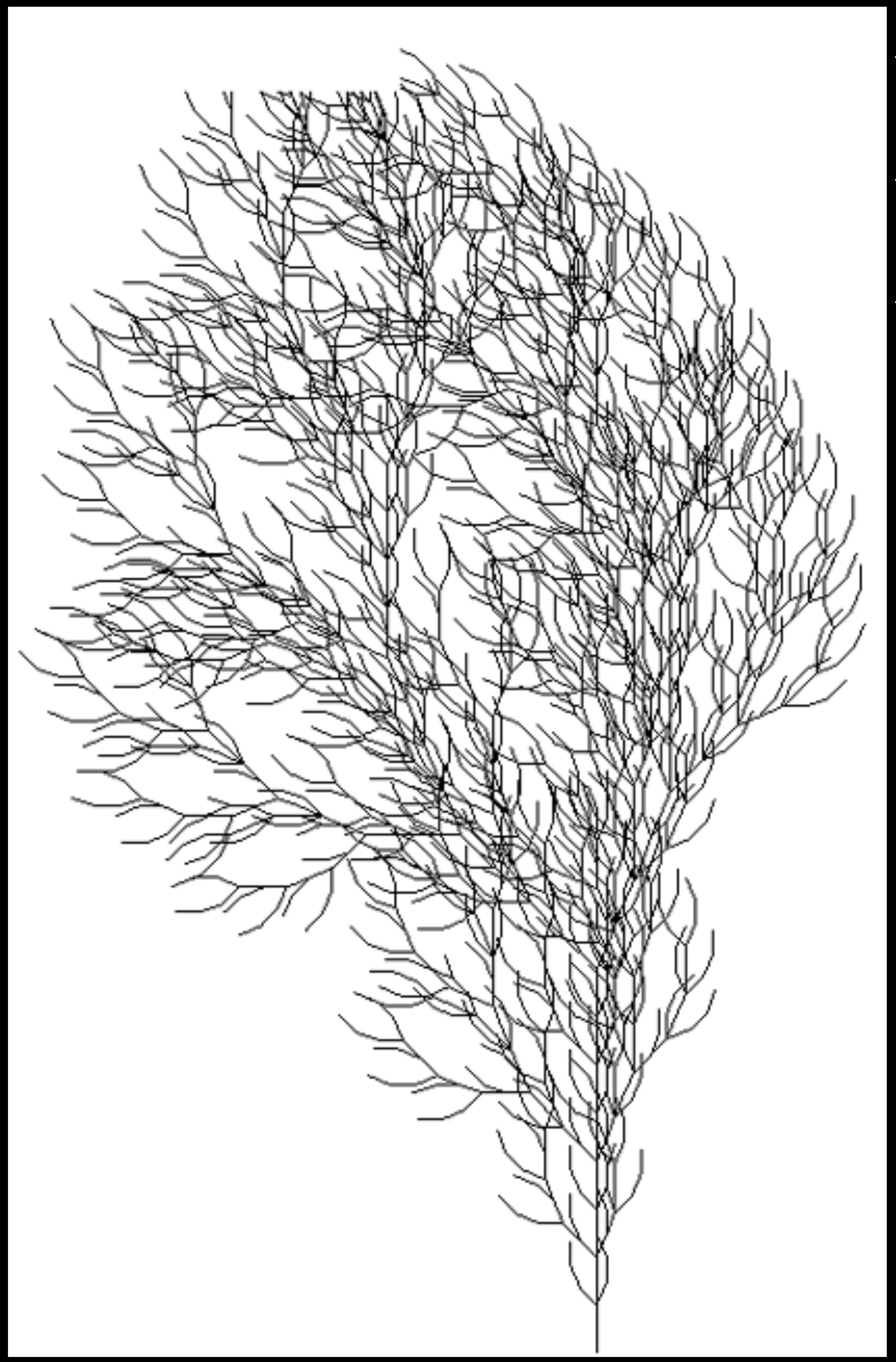
## Simulating Natural and Emergent Phenomena

- And the next iteration:
-

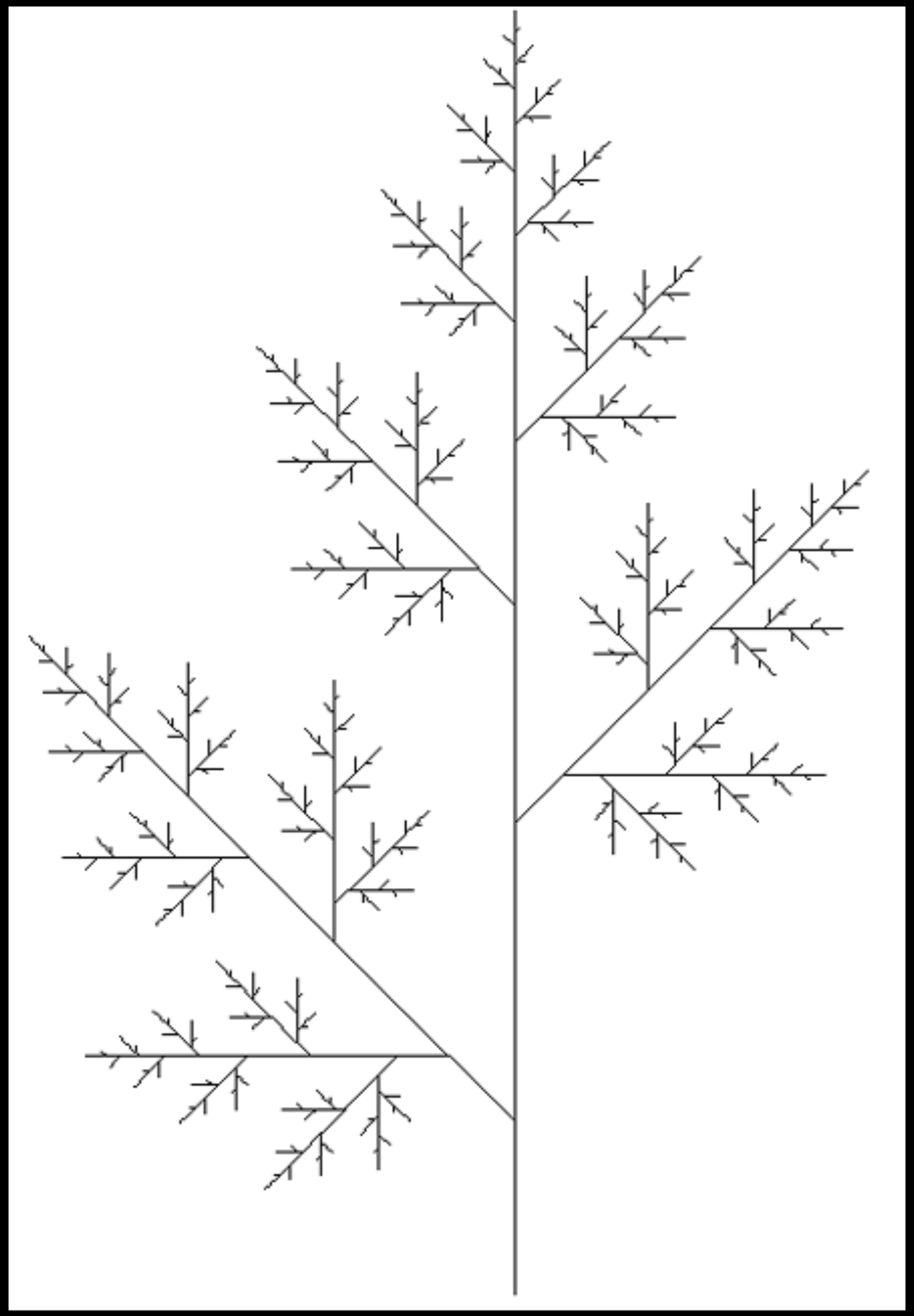


# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena



- axiom = F
- F -> FF+[+F-F-F]-[-F+F+F]
- angle = 22.5



- axiom = a
- F -> >F<
- a -> F[+x]Fb
- b -> F[-y]Fa
- x -> a
- y -> b
- angle = 45
- length factor = 1.36

For more see:

http://paulbourke.net/fractals/lsys/

# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena

*Interactive Plant Growing* (1992), Christa Sommerer & Laurent Mignonneau

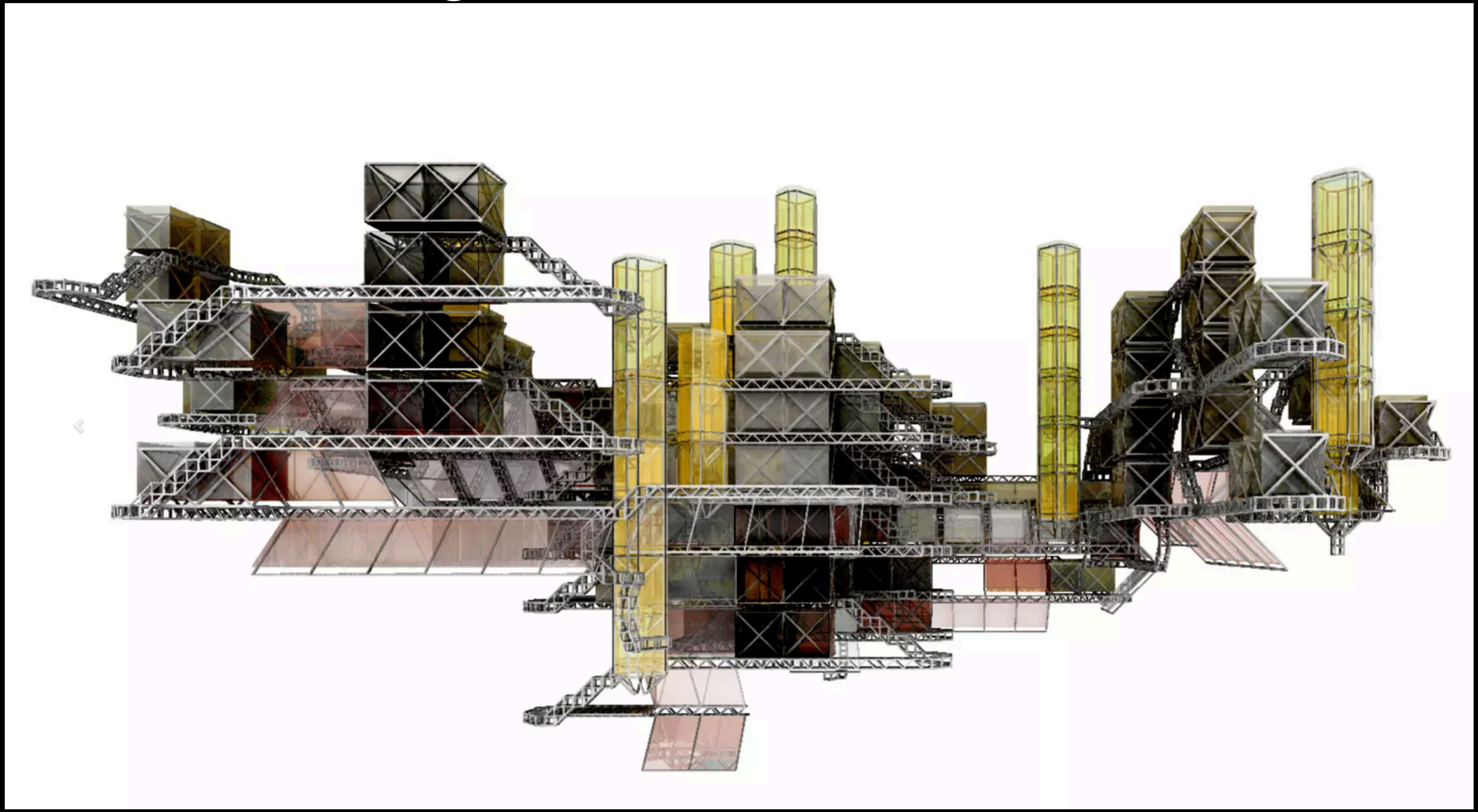
# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena


*Bloom* (2006), Jon McCormack

# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena

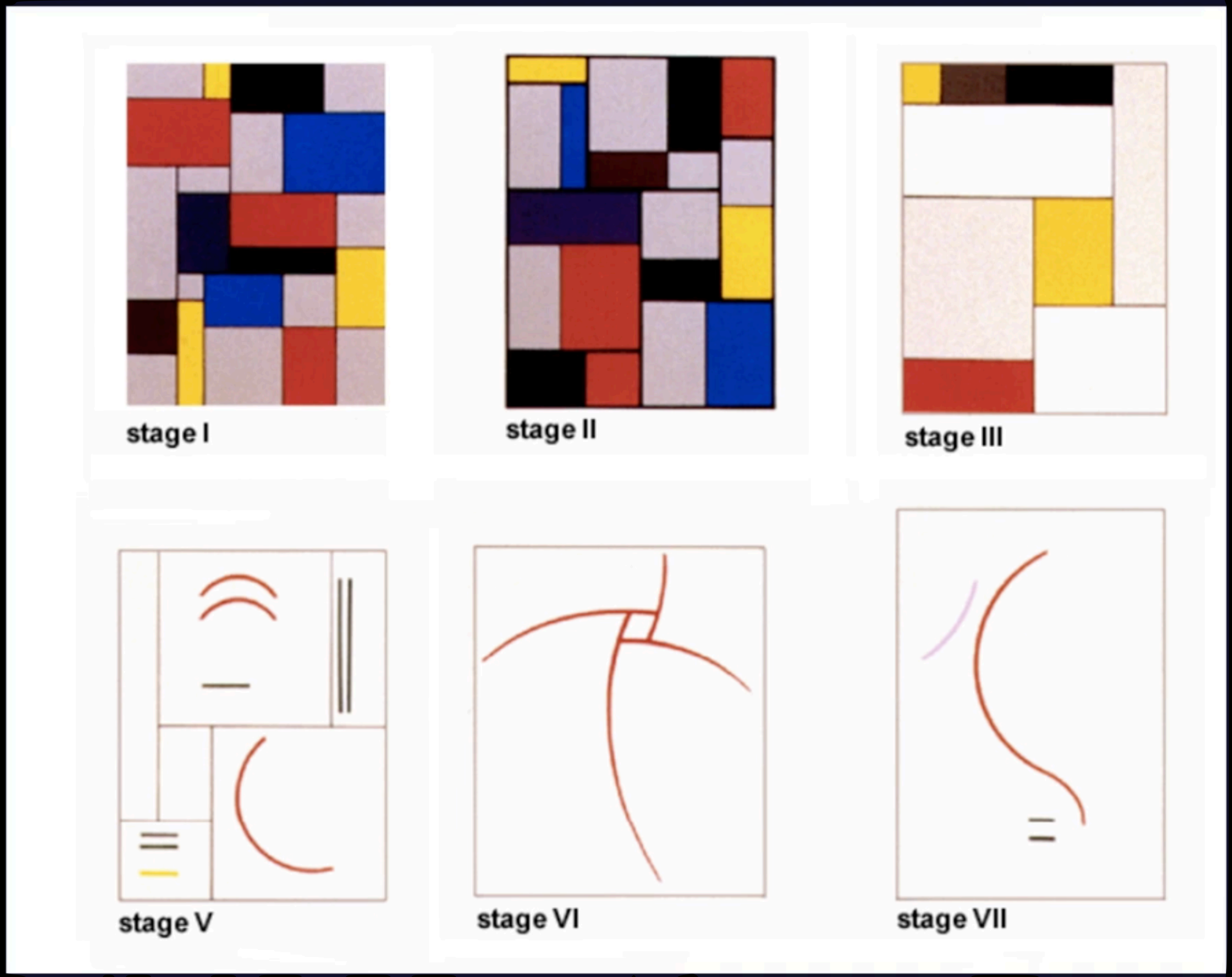


Michael Hansmeyer

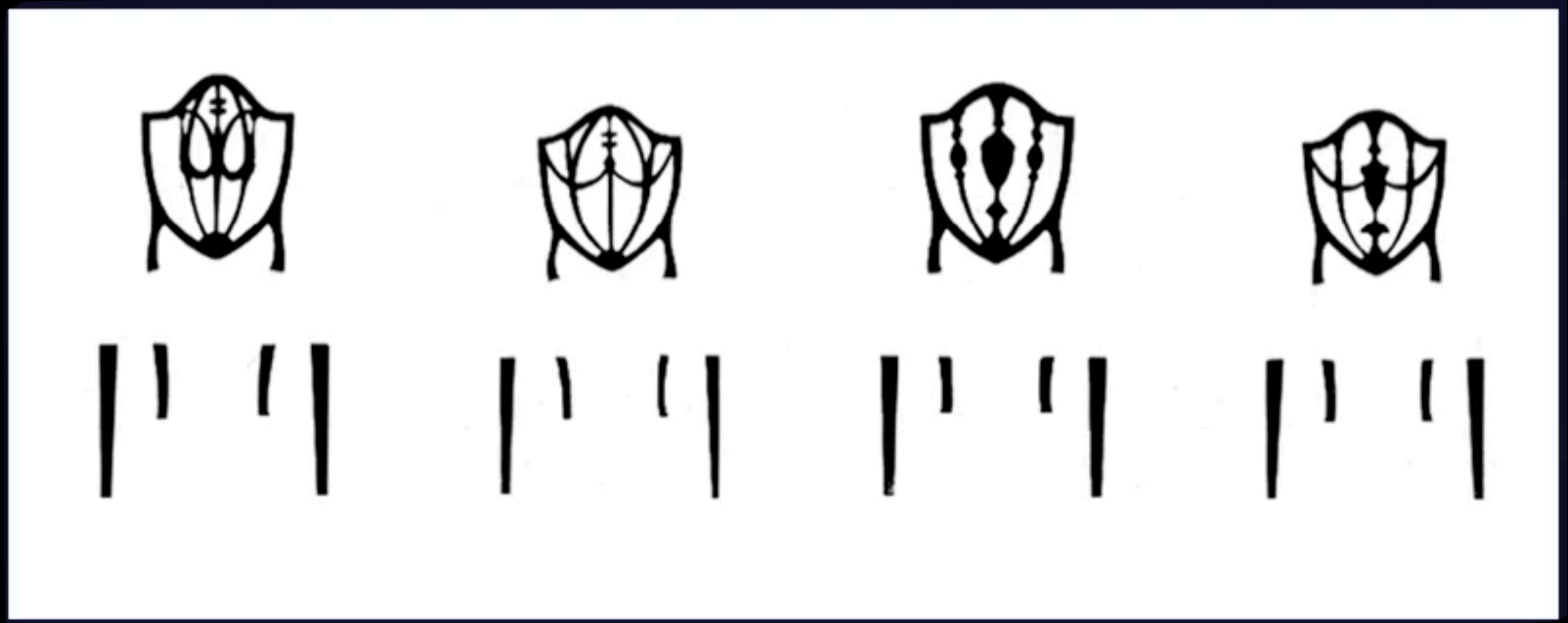
# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena

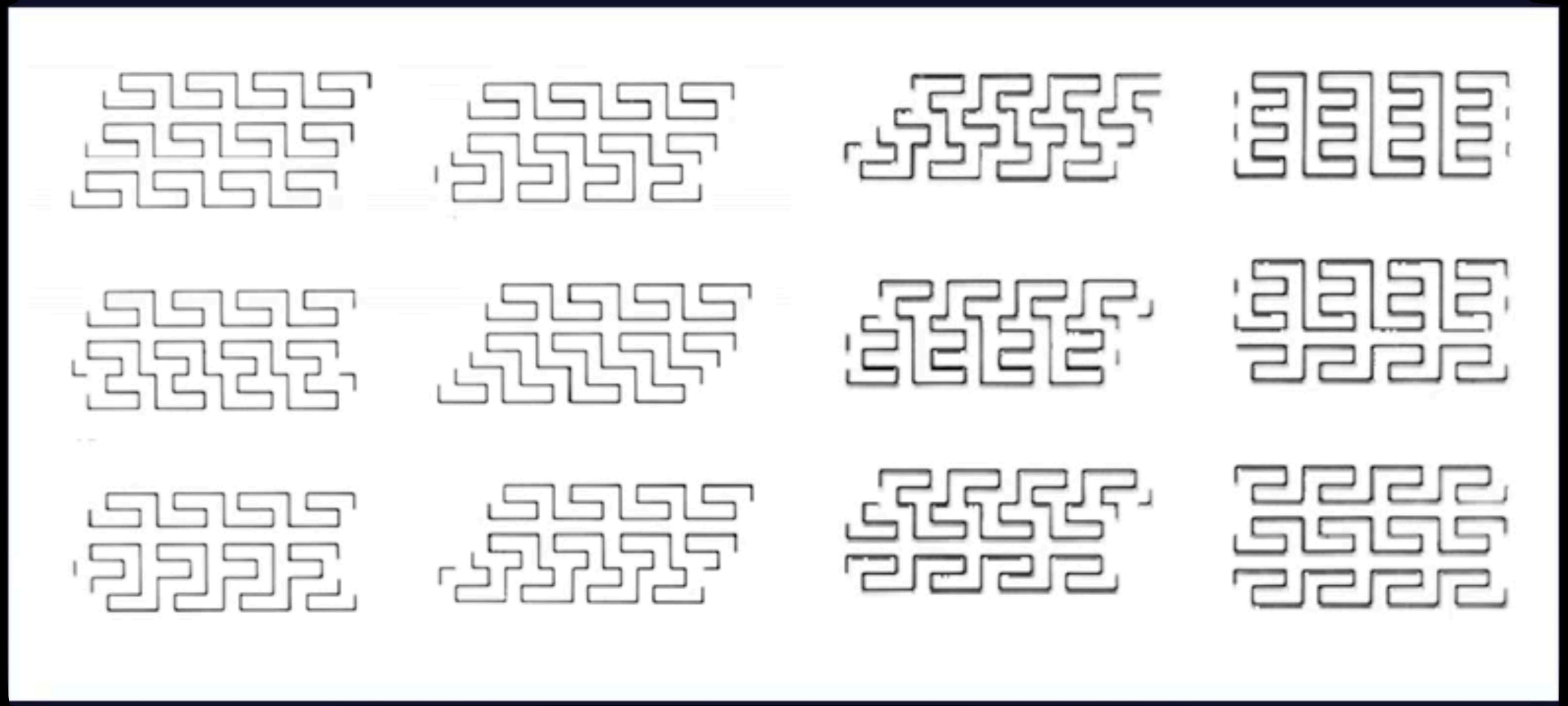
### Shape Grammars




De Stijl painting grammar



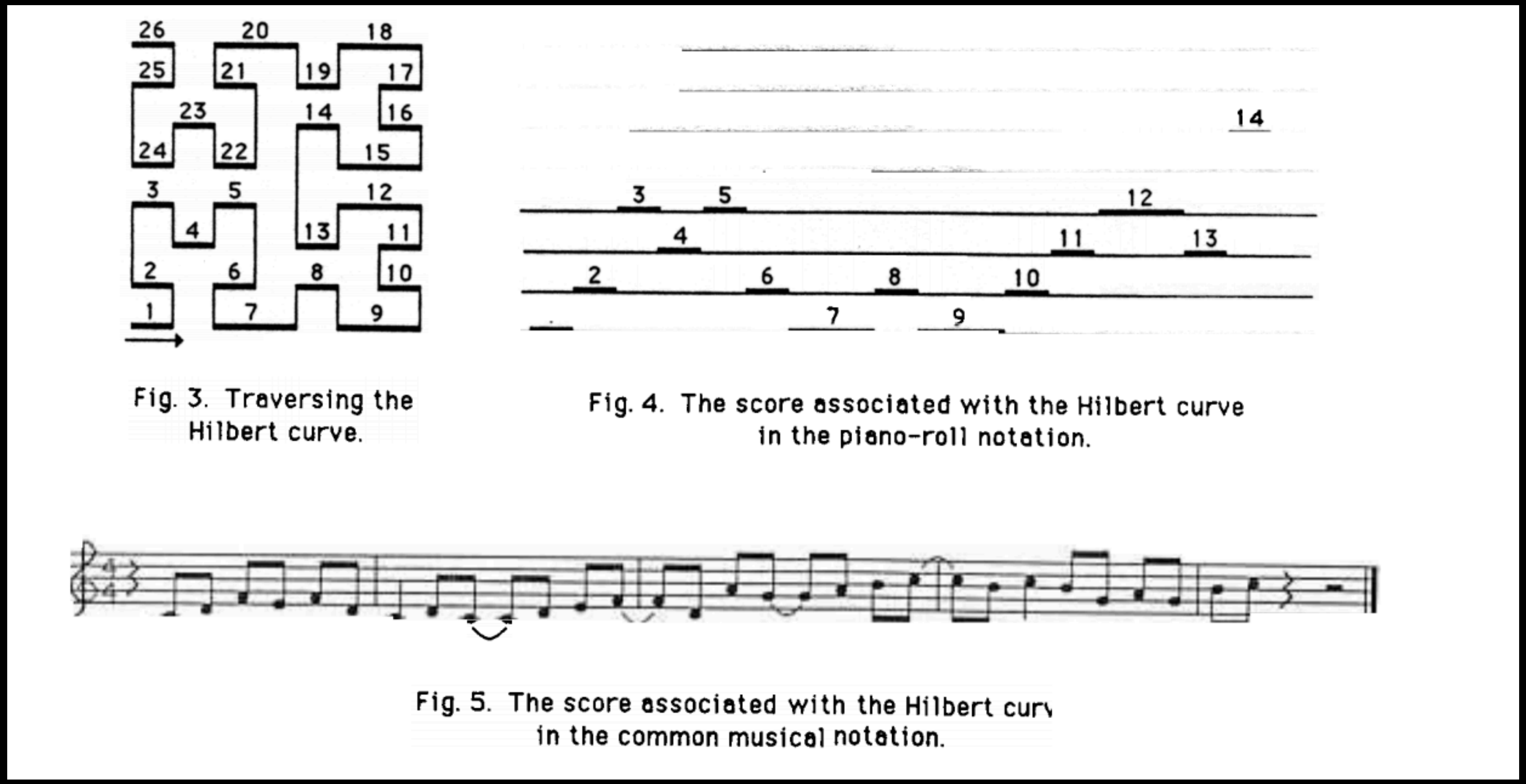
Hepplewhite chair grammar



Ancient Greek meander grammar

# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena




Przemysław Prusinkiewicz, Score Generation with L-Systems, International Computer Music Conference, 1986

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## Simulating Natural and Emergent Phenomena

*Growing Pains*, Luke Dubois, 2003

# Fractals, Chaos, Rule-Based Systems

## Simulating Natural and Emergent Phenomena

- L-systems are good for modeling many self-similar structures
    - so they can model fractals like the Koch snowflake Sierpiński triangle
- Variants of L-systems include:
    - Parametric (allow attachment of parameters to symbols such as sensor data, number of times steps, etc)
    - Context-sensitive (different rules apply in different contexts, e.g. if some variable is more or less than another variable)
    - Stochastic (multiple production rules for a symbol, giving each a probability of occurring)

- For more info on L-systems check the Resources section of the course web site

# ?

*“The task of art today is to bring chaos into order.”*

Theodor W. Adorno - Adorno, T. W. 2015. *Minima Moralia: Reflections on a Damaged Life.* New York: Verso, 222.

# For Next Week

## Proposal (2nd) & Readings

- Submit refined proposal for theoretical research (PDF)
- Readings on machine learning & neural networks (note: this will be our first student-led discussion):
    - Machine Learning for Artists (in-progress online book). Read the first three chapters.
    - Legrady, George. "Pockets Full of Memories." In *Database Aesthetics: Art in the Age of Information Overflow*, edited by Vesna, Victoria, 243-48. University of Minnesota Press, 2007.
    - Snyder, Jeff and Ryan, Danny. 2014. "The Birl: An Electronic Wind Instrument Based on an Artificial Neural Network Parameter Mapping Structure". In *Proceedings of the International Conference on New Interfaces for Musical Expression*, 585-88.
    - OPTIONAL: Aggarwal, Charu C. 2018. “An Introduction to Neural Networks.” In *Neural Networks and Deep Learning: A Textbook*, edited by Charu C. Aggarwal, 1–52. Cham: Springer International Publishing. (Available online via RIT library)
    - OPTIONAL: Andrey Kurenkov, “A Brief History of Neural Nets and Deep Learning”, Skynet Today, 2020.
- Also, start thinking about your project

# In-class discussion

## Readings

- Example:
    - Legrady, George. "Pockets Full of Memories." In *Database Aesthetics: Art in the Age of Information Overflow*, edited by Vesna, Victoria, 243-48. University of Minnesota Press, 2007. (Available online via RIT Library)
        - Analysis of the work
            - What type of ML algorithm/technique is being used?
            - What does this work say about database, archives and machine classification as a cultural form?
            - How are the technical elements used to create meaning and/or support the work conceptually?