Generative Design | Difference and Repetition as Creative Process

Week 5 – Design Thinking and Material Practices

Lecture 14 | Coexistent Perspectives (ADAA7000)

Lecture Aims

Generative Design

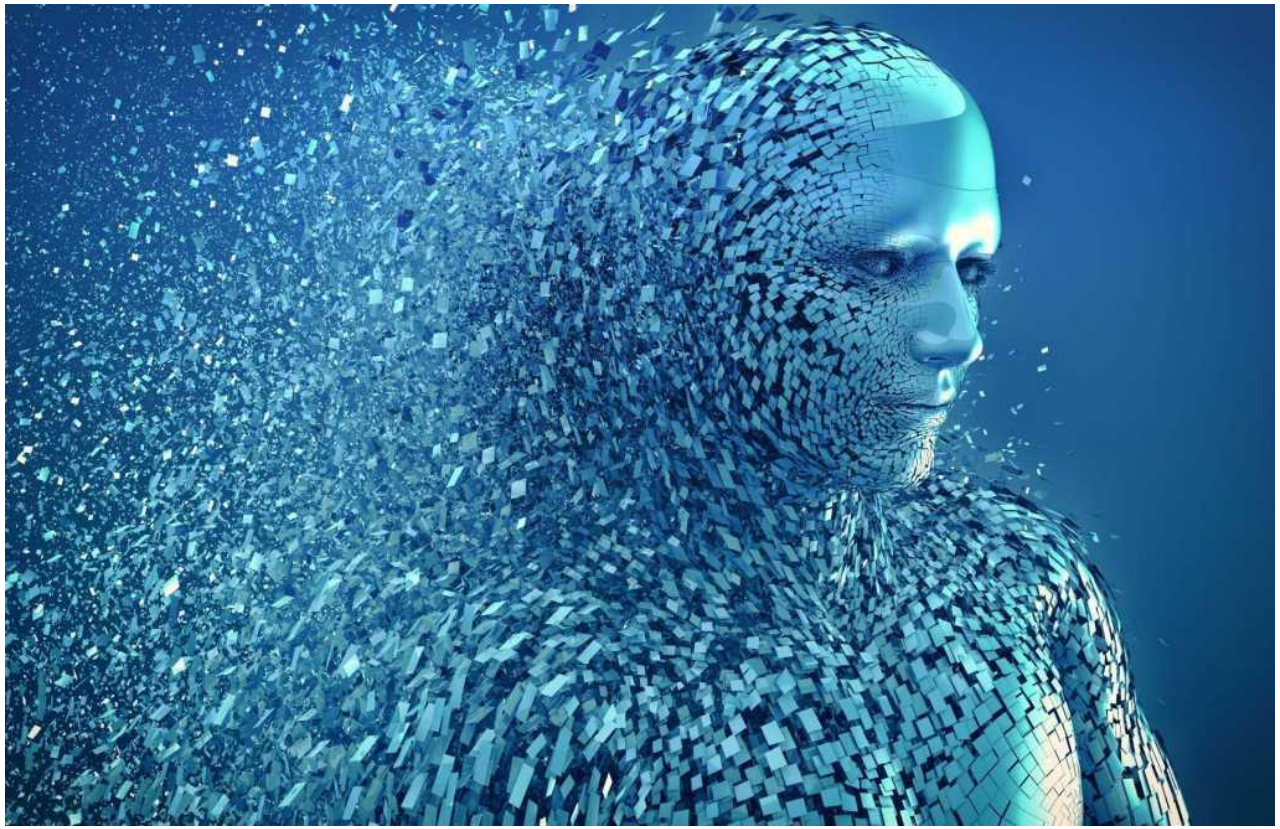
Difference and Repetition as Creative Process

- The lecture explores how generative design and AI use **difference and repetition** to foster creativity and innovation.
- It highlights the shared foundations and practical uses of these fields, inspired by **natural processes, emergence, and complexity.**
- The lecture examines how **algorithmic generation, iteration, constraints, and feedback loops** lead to novel solutions.
- It discusses future **synergies between generative design and AI**, showing their potential to revolutionize architecture, design, art, and entertainment.

The Evolutionary Origins of Generative Design and Generative AI

I think it's quite conceivable that *humanity is just a passing phase in the evolution of intelligence.* **You couldn't directly evolve digital intelligence.** It would require too much energy and too much careful fabrication. **You need biological intelligence to evolve so that it can create digital intelligence…**

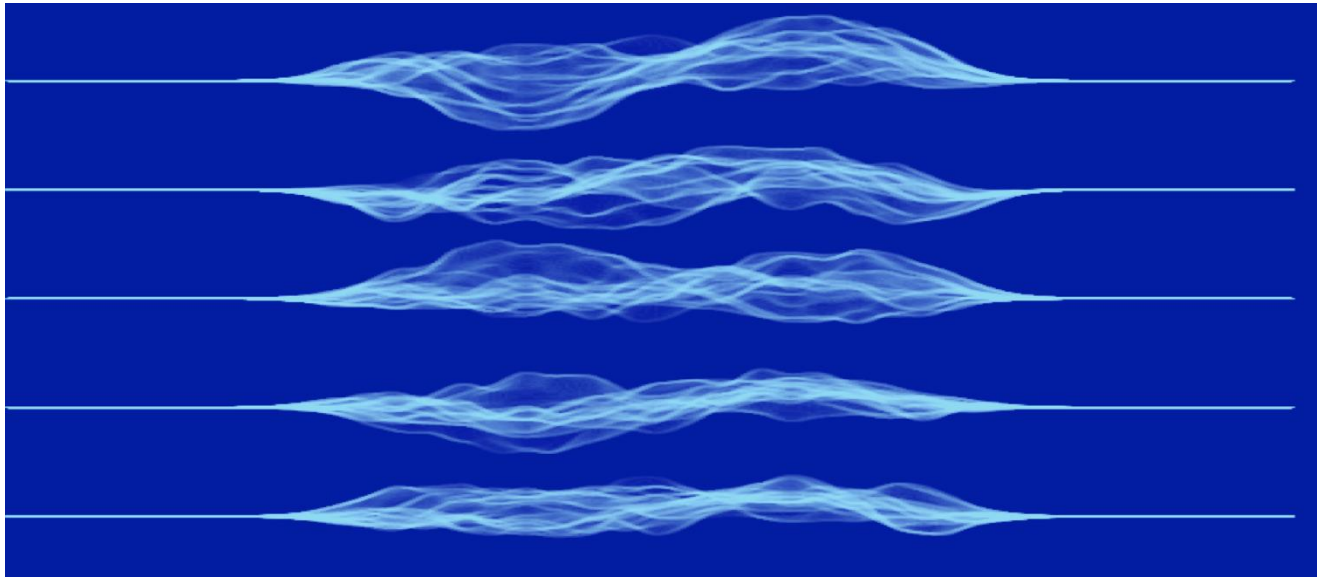
Geoffrey Hinton ('the Godfather of AI'**)**



Biological intelligence evolved to create digital intelligence, which can absorb everything humans have created…

What?

…is generative design



What is Generative Design

a definition

Generative design is an iterative design process that uses software to generate outputs that fulfil a set of constraints iteratively adjusted by a designer.

“generative design is **not** about **designing the building**, it is about designing the **system that builds** a building”

Lars Hesselgren

systems thinking | thinking systems

We are now in transition from an *object-oriented* to a ***systems-oriented*** *culture*. Here change emanates, ***not from things***, but from ***the way things*** *are done*.

Jack Burnham (1968), System Esthetics

Who is a Generative Designer?

a definition

A **generative designer** is a professional who uses computational algorithms and iterative processes to create innovative designs by exploring a vast range of possibilities based on predefined constraints and parameters.

This approach leverages principles from nature, mathematics, and artificial intelligence to optimize and evolve design solutions.

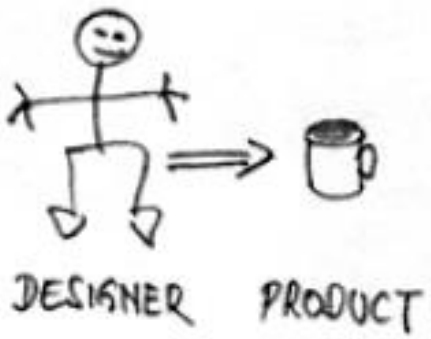


Figure 1: Traditional design approach

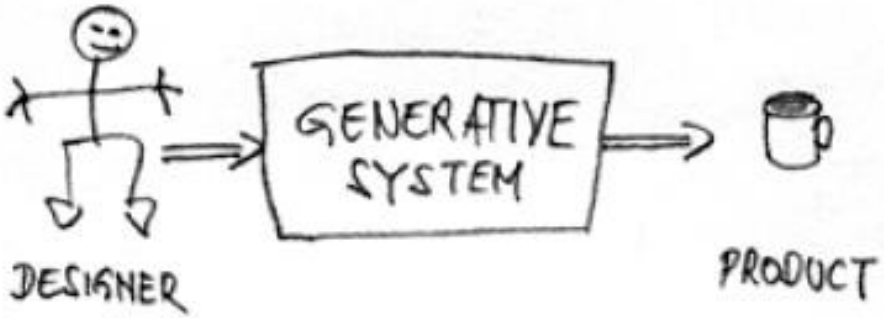
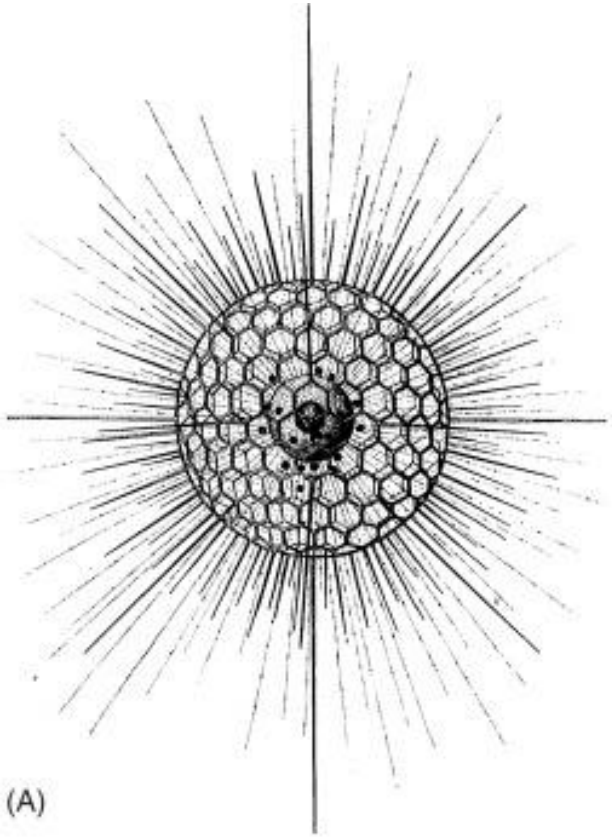
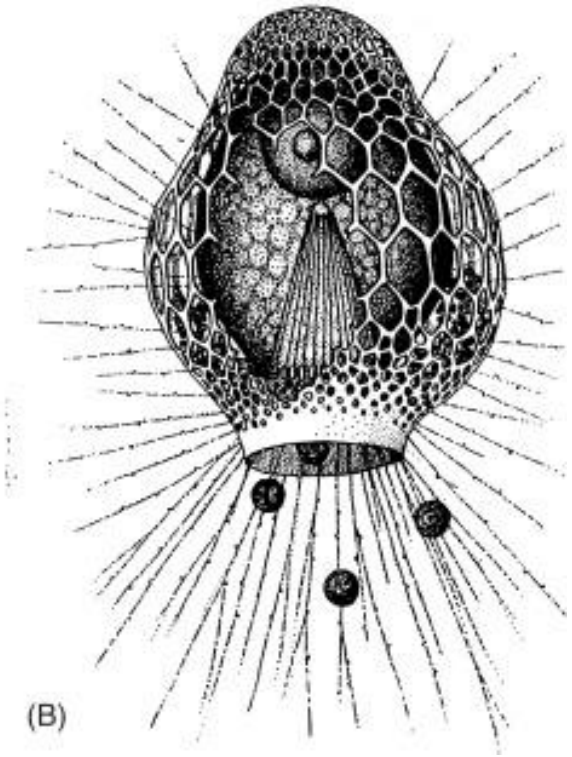


Figure 2: Generative design approach

Generative Design

evolutionary principles and historical context



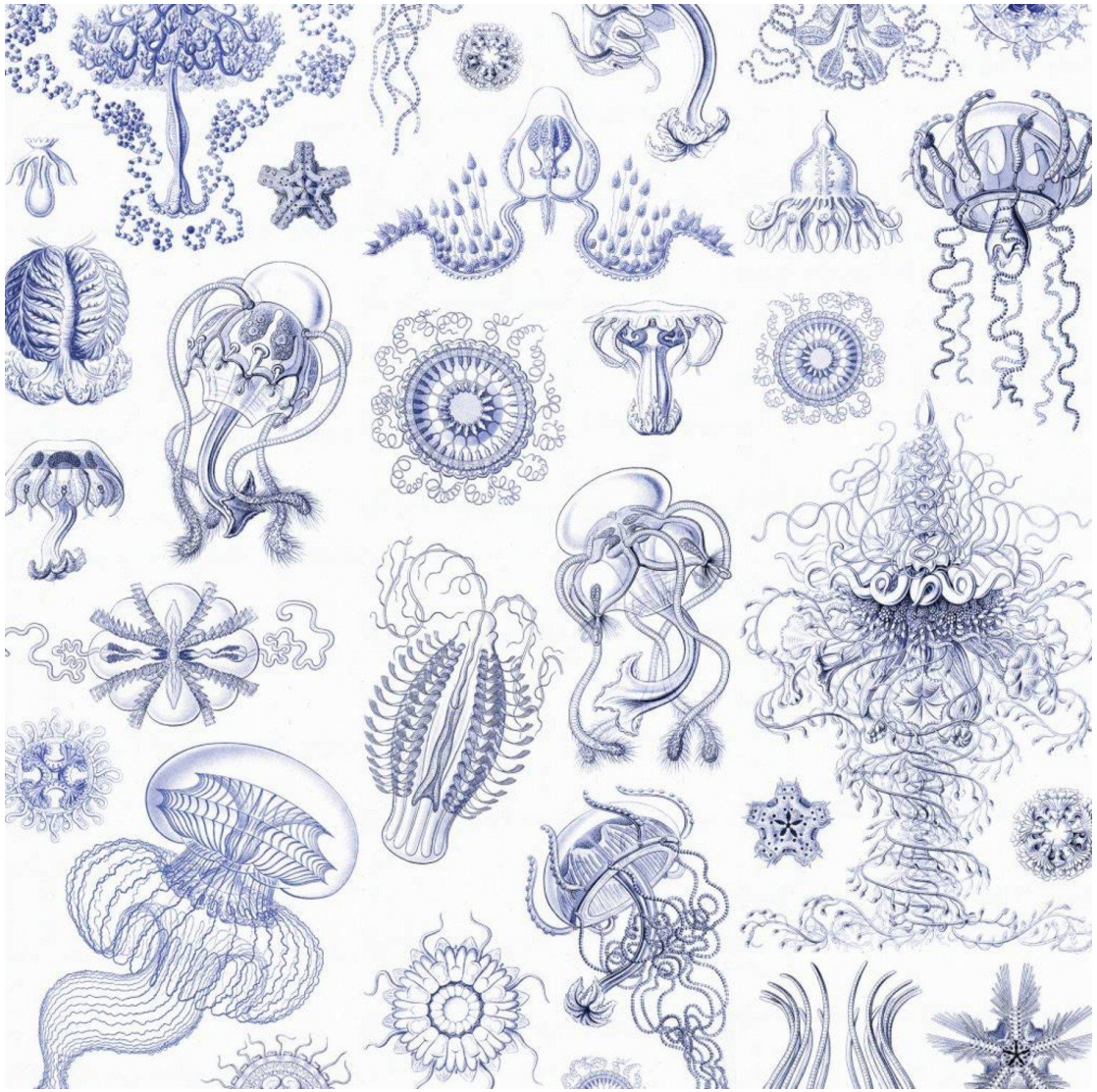


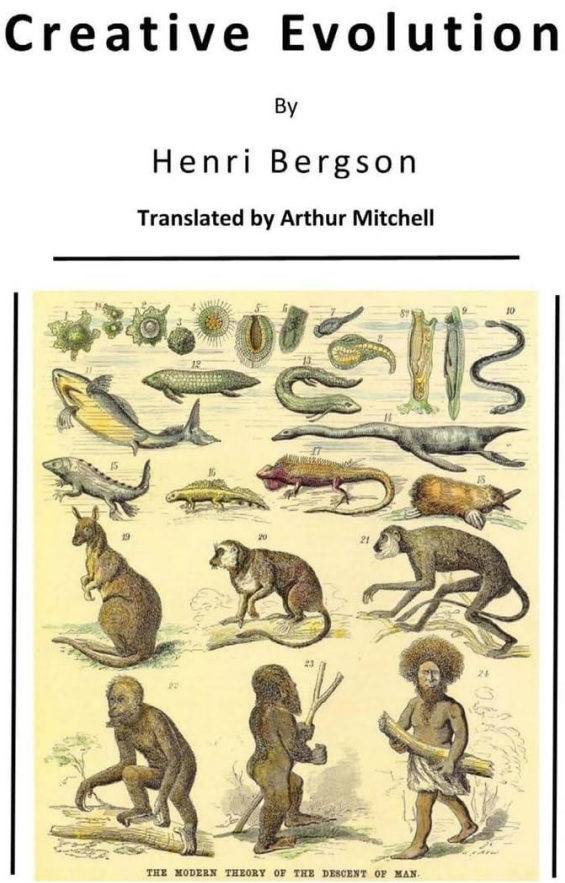
Radiolarians | Ernst Haeckel

Generative Design in Nature

evolutionary principles in design

- Concept of evolution in nature versus design
- Key evolutionary principles: **variation, inheritance, selection and time**
- Case studies of evolutionary design in practice





form and function

creativity and aesthetics

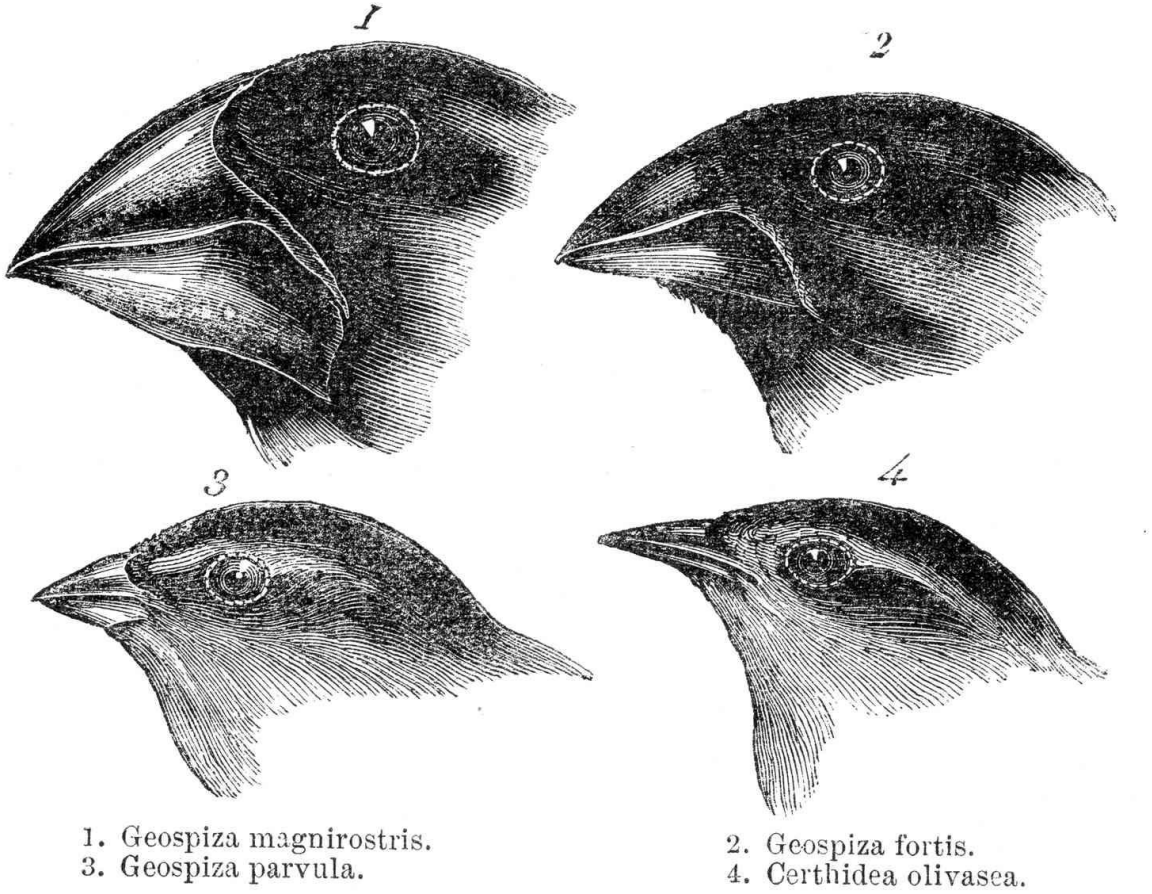
the whole evolutionary process should be seen as the endurance of an **élan vital** (“vital impulse”) that is continually developing and **generating** new forms. **Evolution, in short, is creative, not mechanistic.**

Henri Bergson

Generative Design in Nature

evolutionary principles in design

There are four principles at work in evolution—**variation, inheritance, selection and time.** These are considered the components of the evolutionary mechanism of **natural selection**.



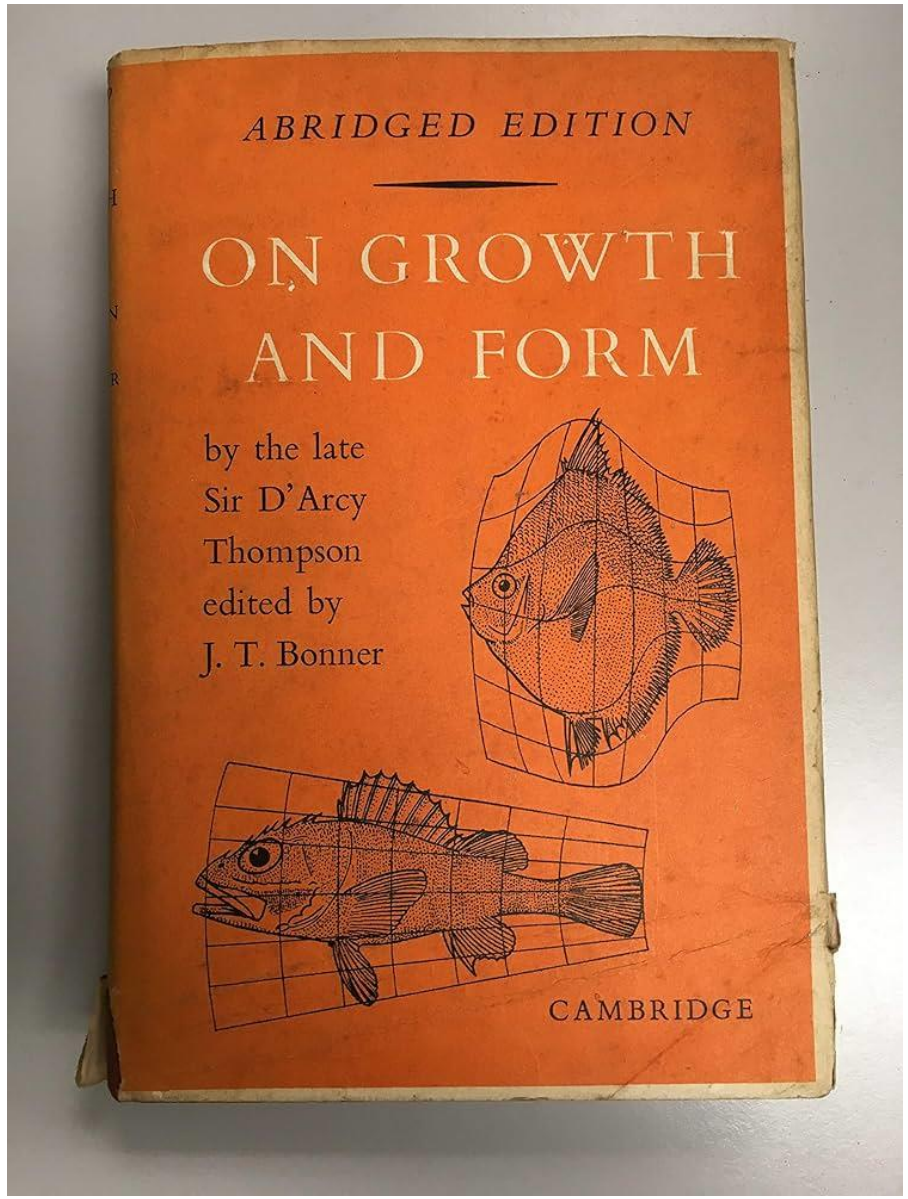
Charles Darwin sketches of four variations in finch beaks from *On the Origin of Species* (1859)

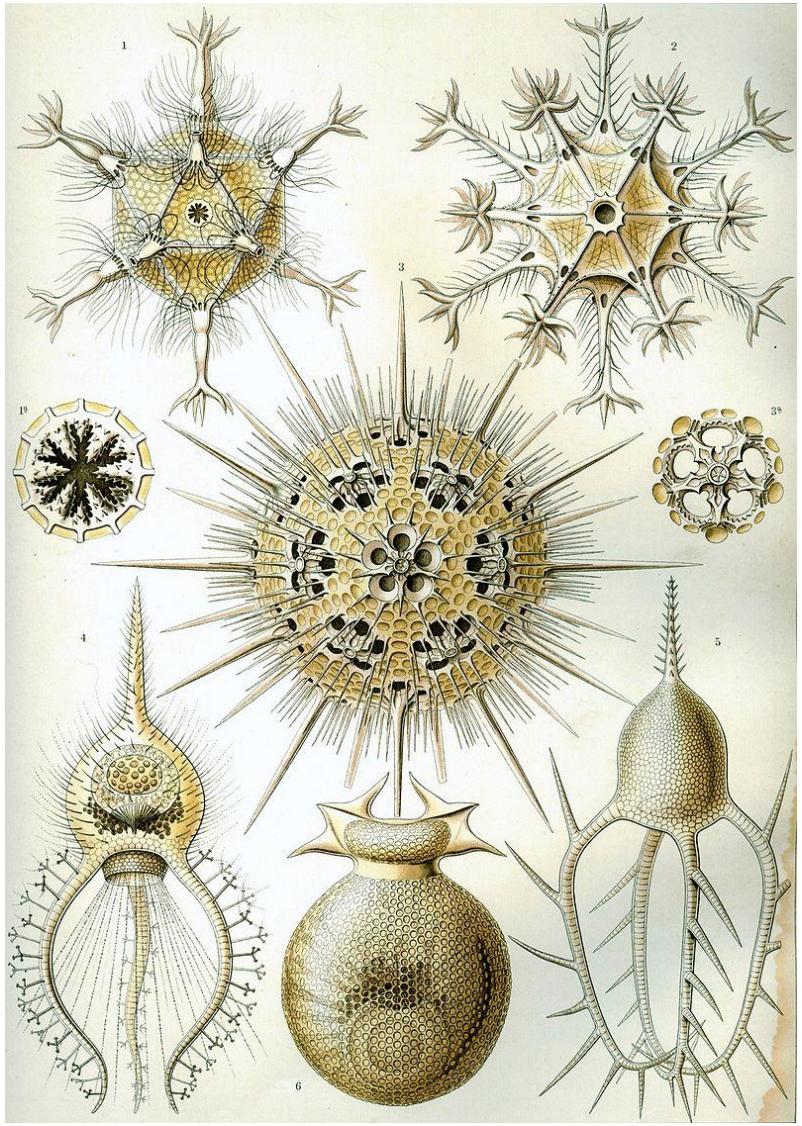
On Growth and Form

D'Arcy Thompson

Mathematical Principles in Nature: Thompson's work demonstrates how mathematical laws underlie the growth and form of natural organisms.

Morphogenesis: The process by which biological forms develop and evolve, driven by physical and mathematical principles.





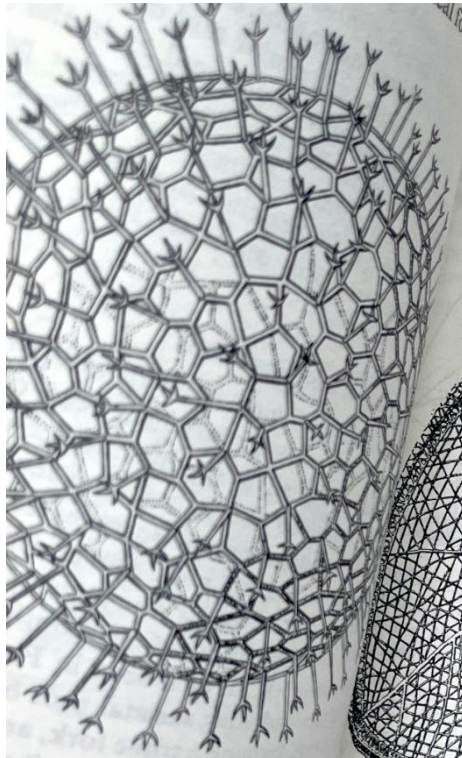


Fig. 60. *Aulastrum triceros* Hkl.

made the wire framework of a
oap-solution, he obtained in an
m of six films, meeting three by
ges running from the corners
y. Here they meet, two by
meet three by three, to form
e called a 'Maraldi pyramid'
he honeycomb. The very
e minute siliceous skeleton

rmed by the boundary-edges of a tetrahedral cluster of four
qual bubbles; and just as Plateau extended his experiment by
ing a small bubble in the centre of his tetrahedral system, so
ave a central bubble also here.

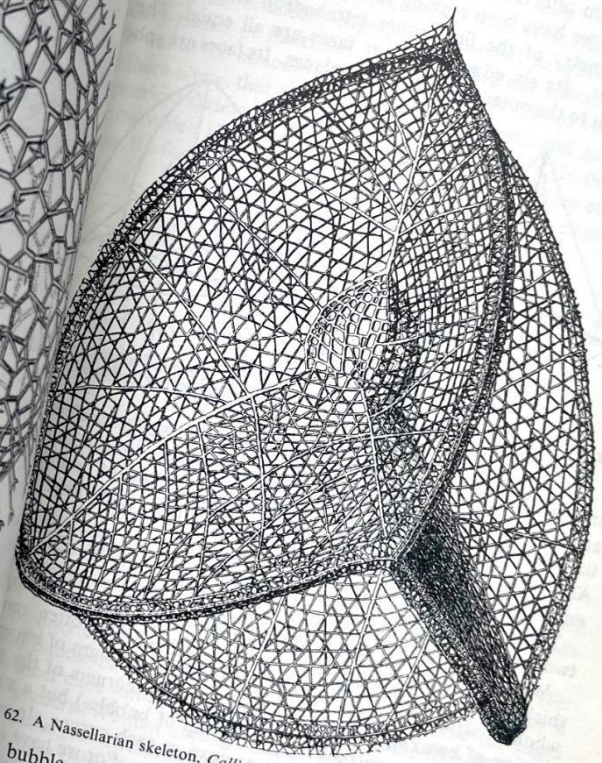
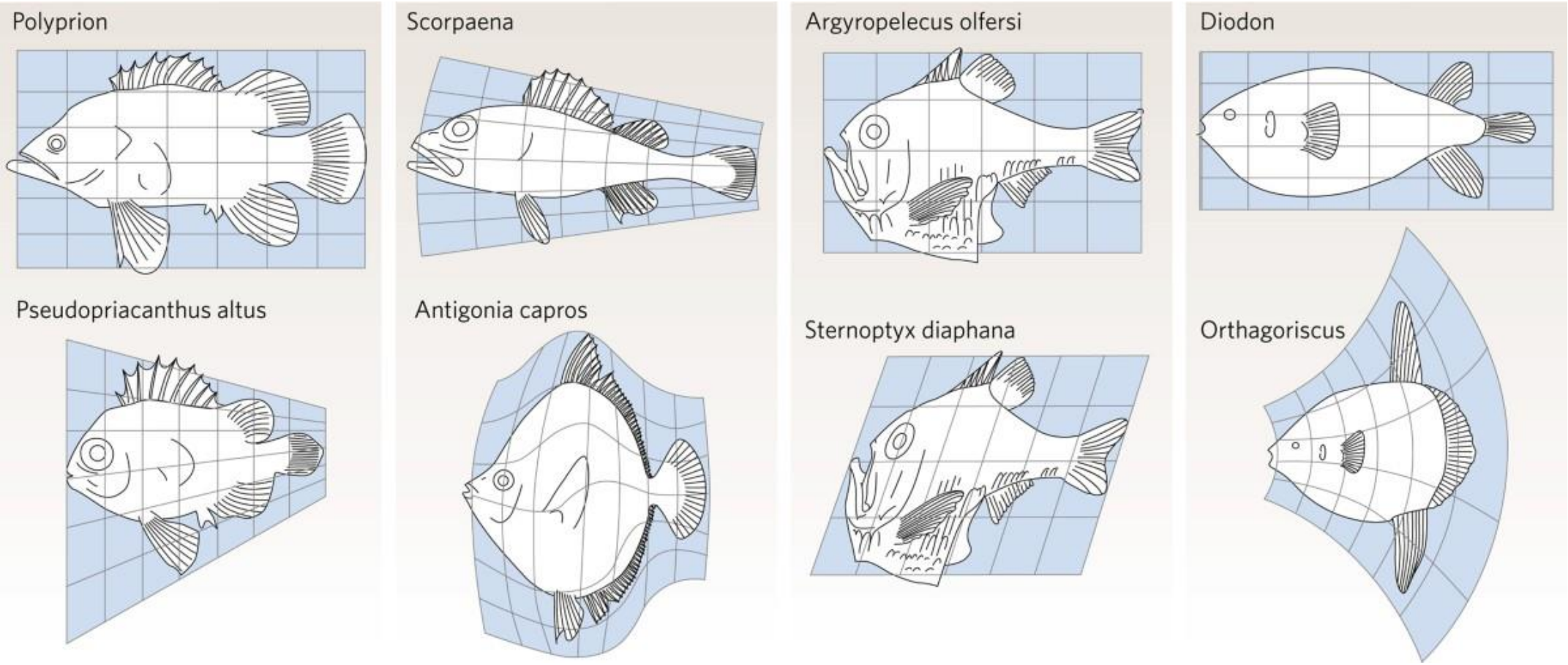


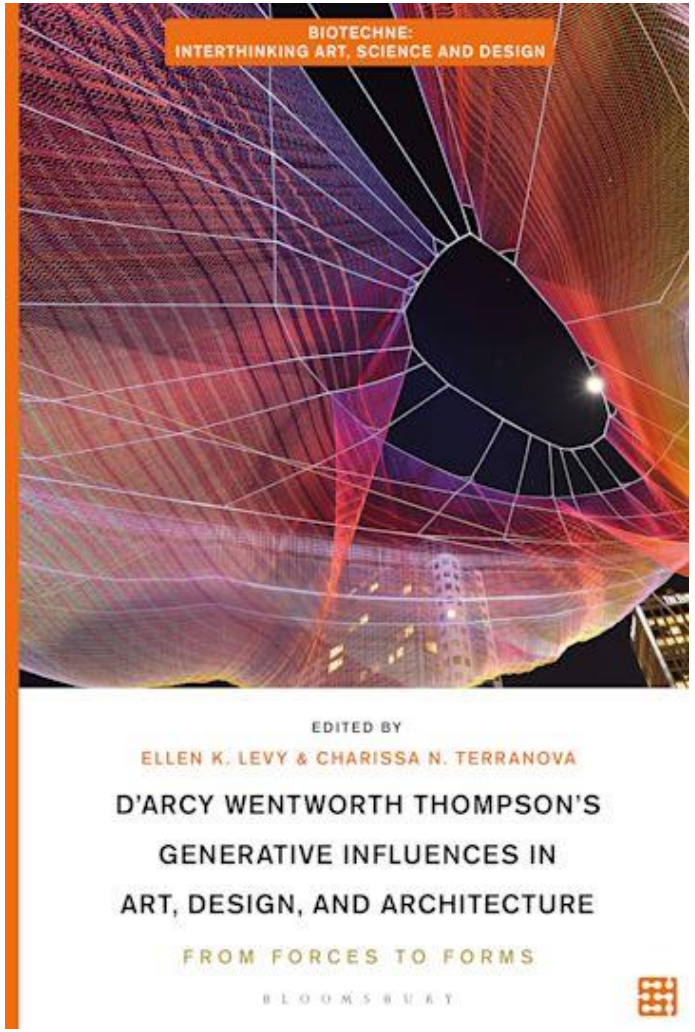
Fig. 62. A Nassellarian skeleton, *Callimitra agnesae* Hkl. (0·15 mm. diameter).

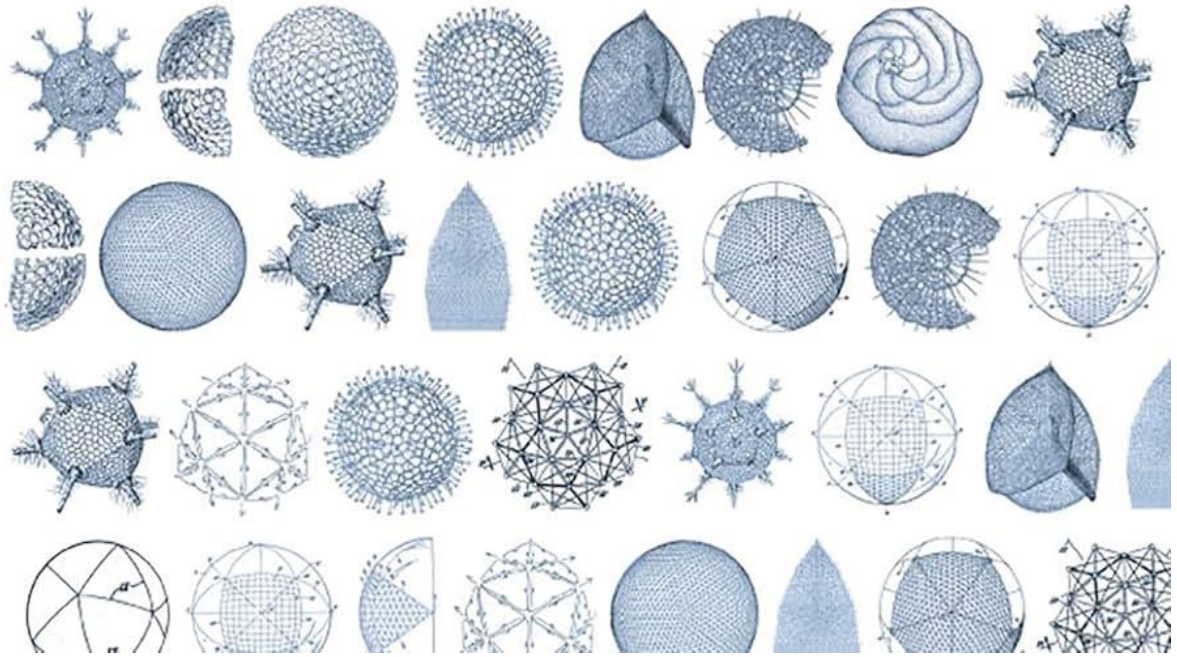
This bubble may be of any size;[1] but its situation (if it be present
ll) is always the same, and its shape is always such as to give the
raldi angles at its own four corners. The tensions of its own walls,
Plateau introduced the central bubble into his cube or tetrahedron by dipping the
a second time, and so adding an extra face-film; under these circumstances the
ble has a definite magnitude.

All fish are the same shape if you stretch them?



Forms shaped through evolutionary **Forces**





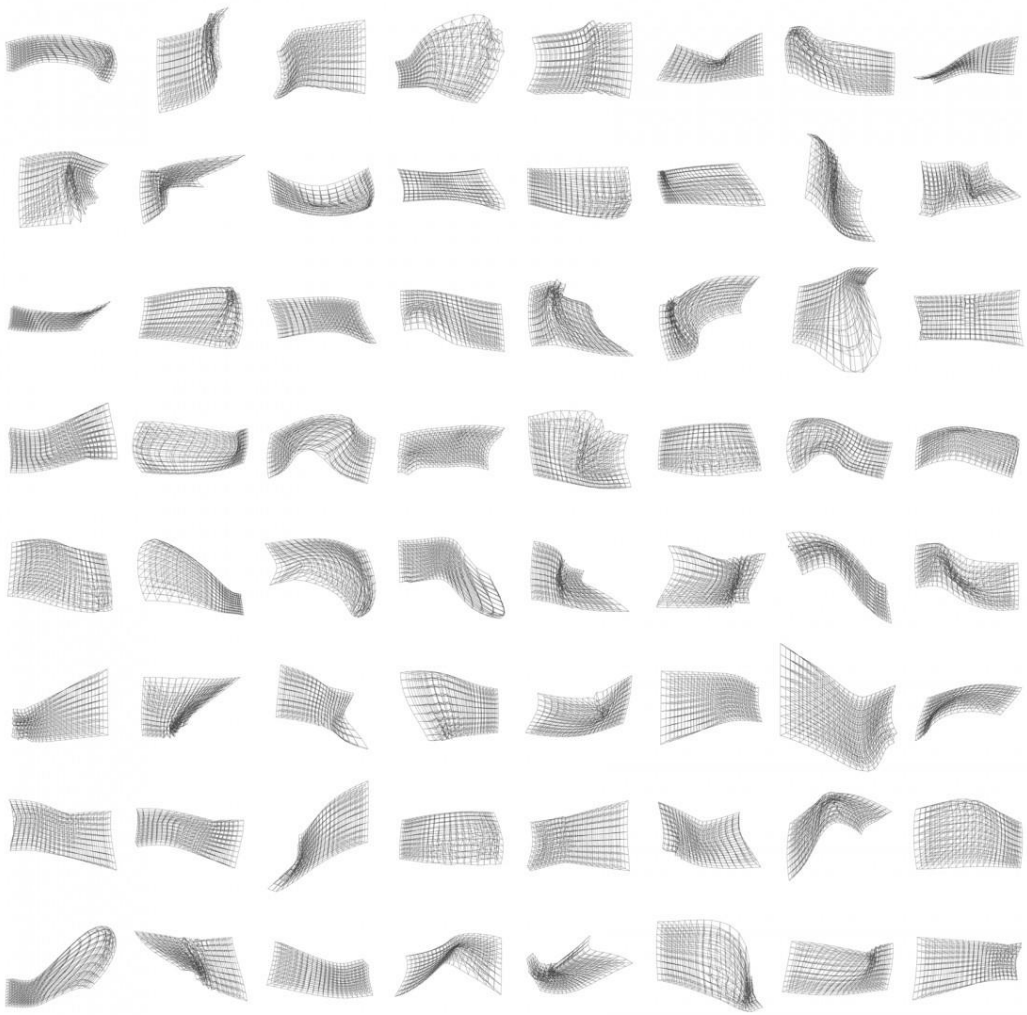
Generative Processes and Thompson's Insights

Generative Processes and Thompson’s Insights

Generative Design: Applies mathematical and physical principles to generate optimised designs, reflecting Thompson’s view of natural forms as products of mathematical laws.

Generative Processes and Thompson’s Insights

Generative AI: Utilises algorithms to learn patterns and generate new content, paralleling the way natural processes follow mathematical rules to create complex structures.



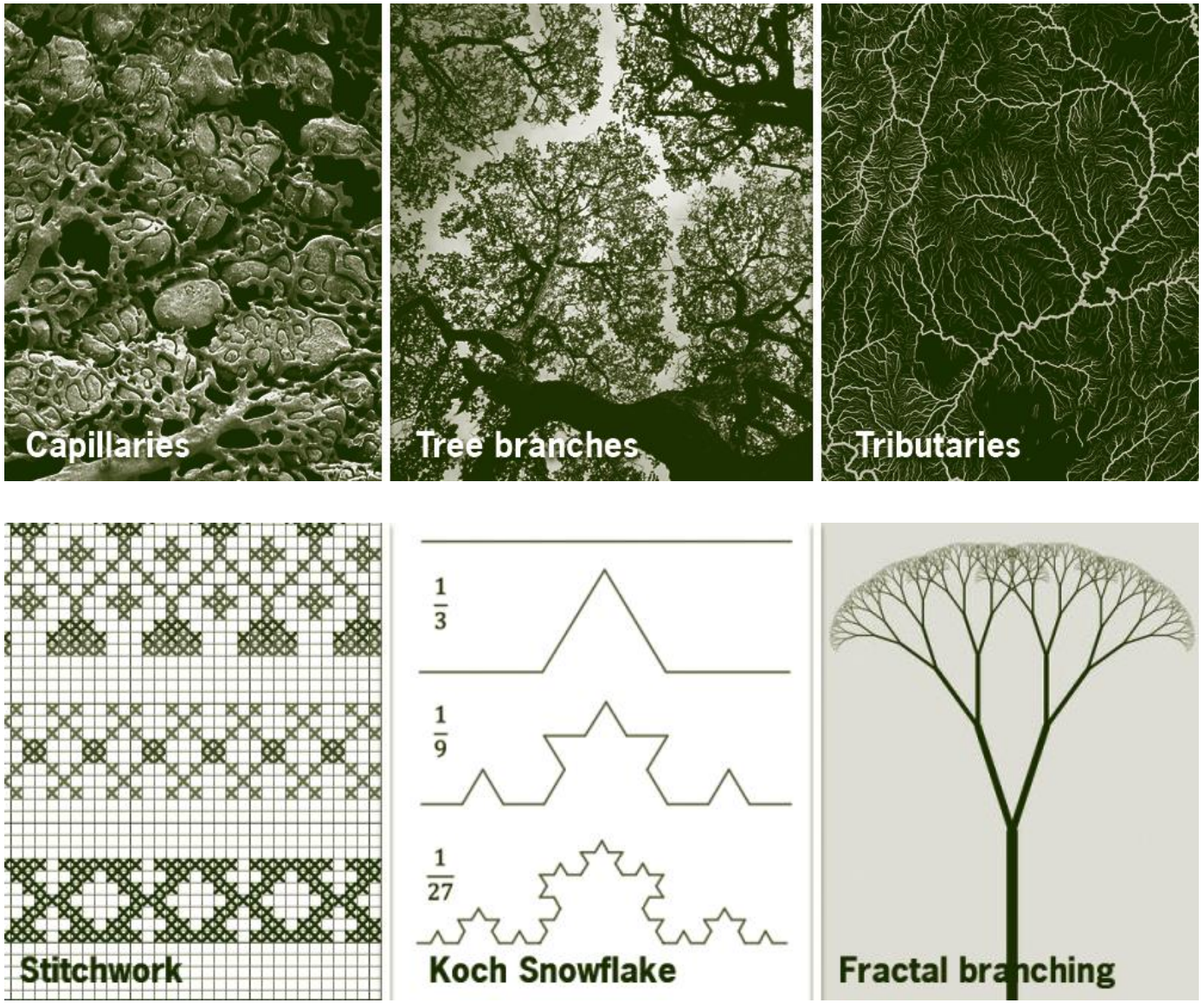
Order within Chaos

Complexity and Emergence

Order within Chaos

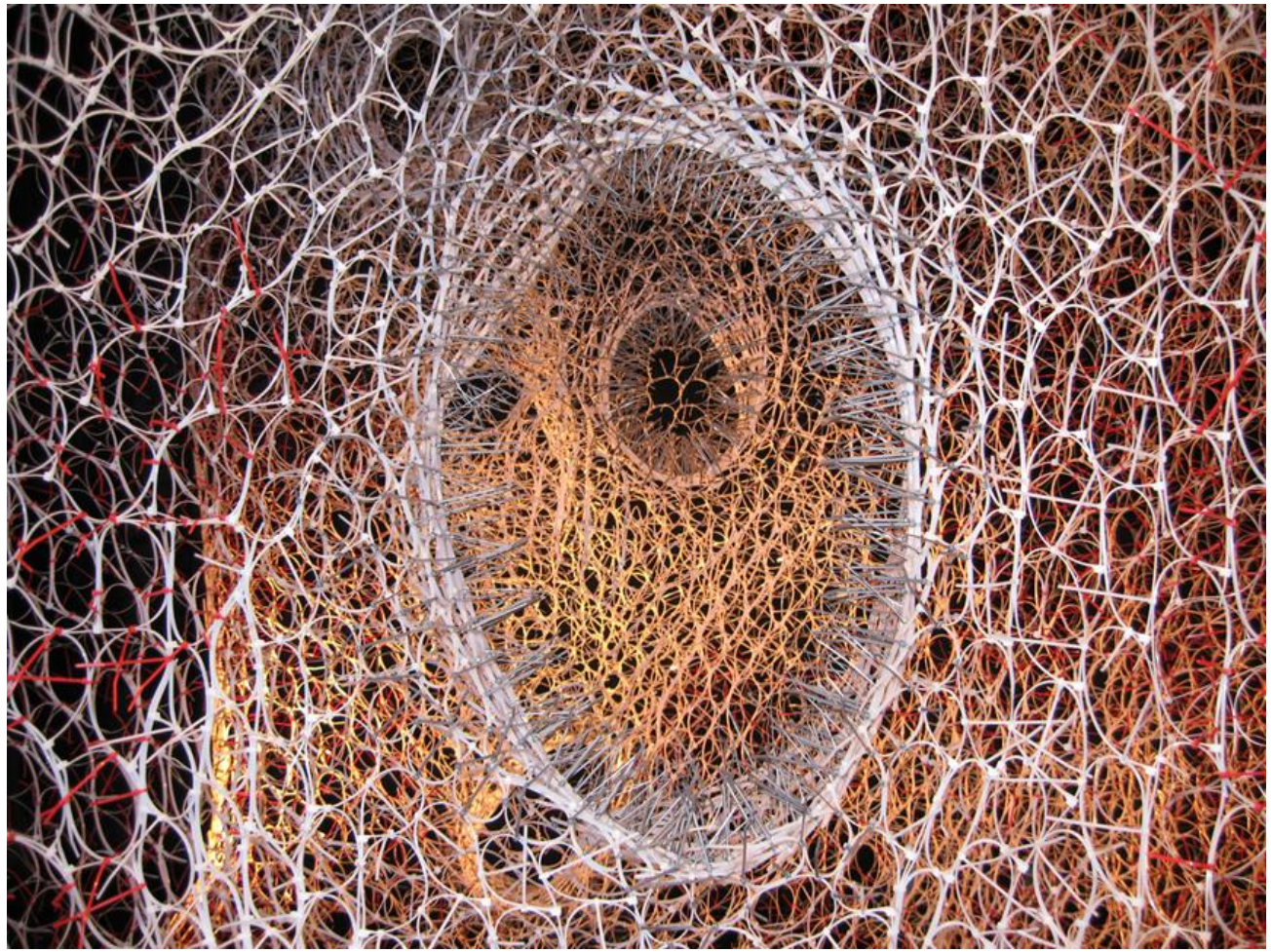
complexity

(systems, patterns, structure)



Morphogenesis

the generation of form Morphogenesis (from the Greek morphê shape and genesis creation, literally "the generation of form") is the biological process that causes a cell, tissue or organism to develop its shape.



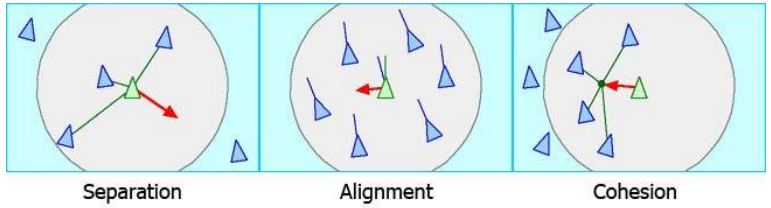
Order within Chaos

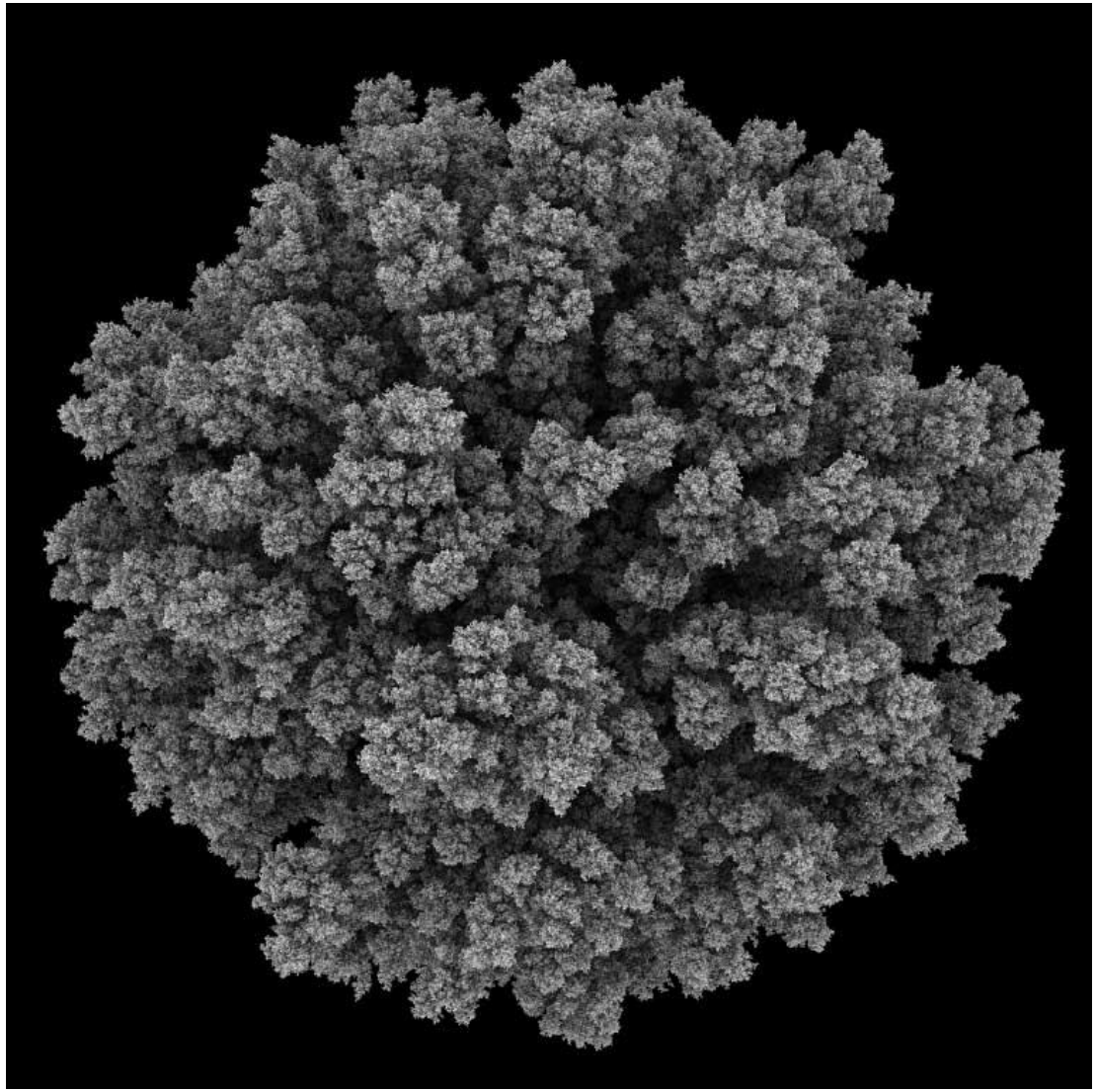
Emergence

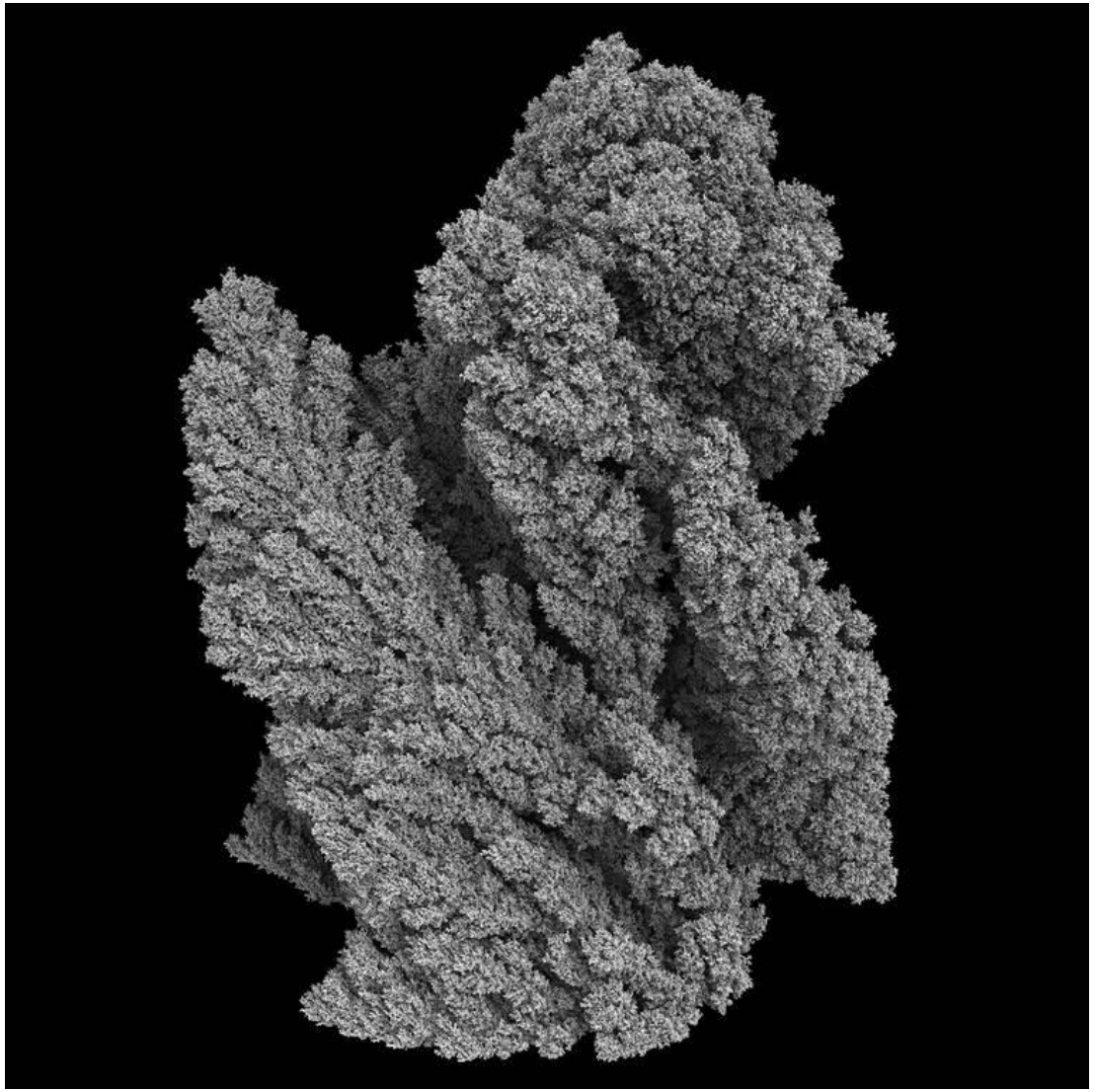
Emergence describes the distinct patterns and behaviors that can arise out of complex systems.

Unlocking Natures **'hidden'** rules of behaviour

e.g. flocking systems

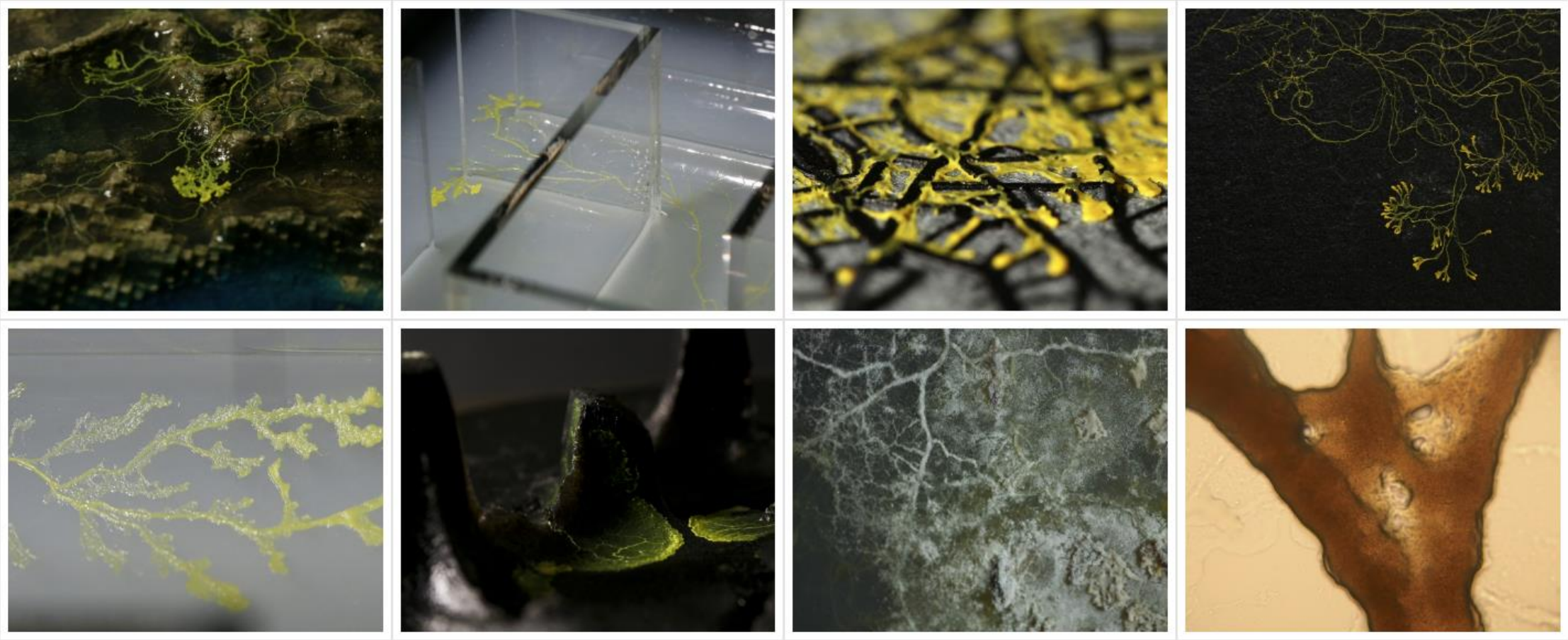






Aggregation (2007) | Andy Lomas

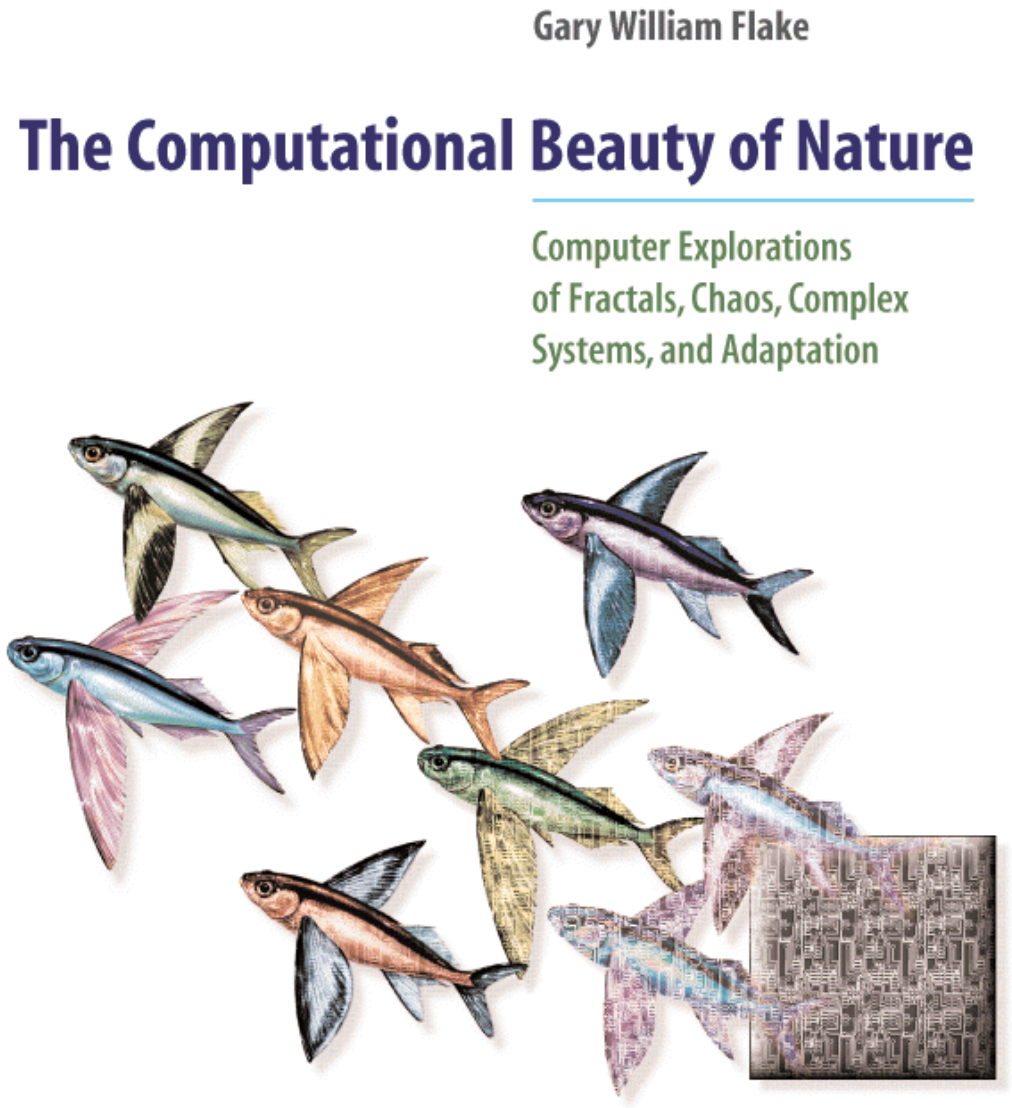
The Physarum Experiments| Heather Barnett

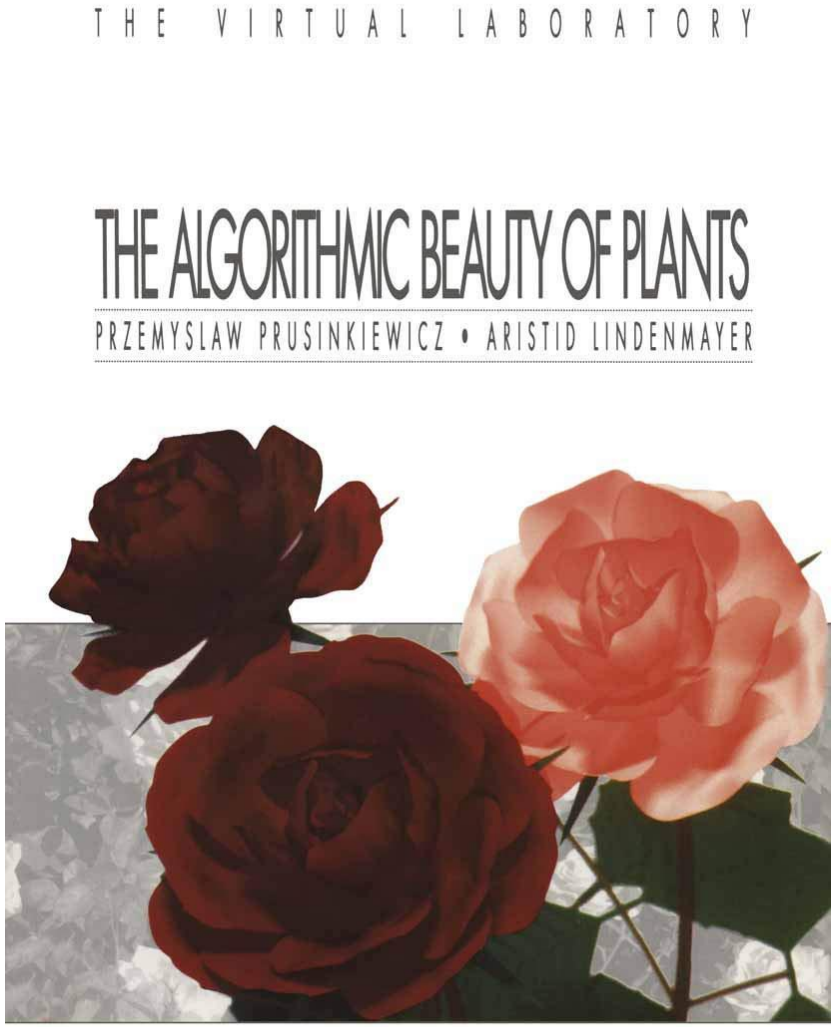


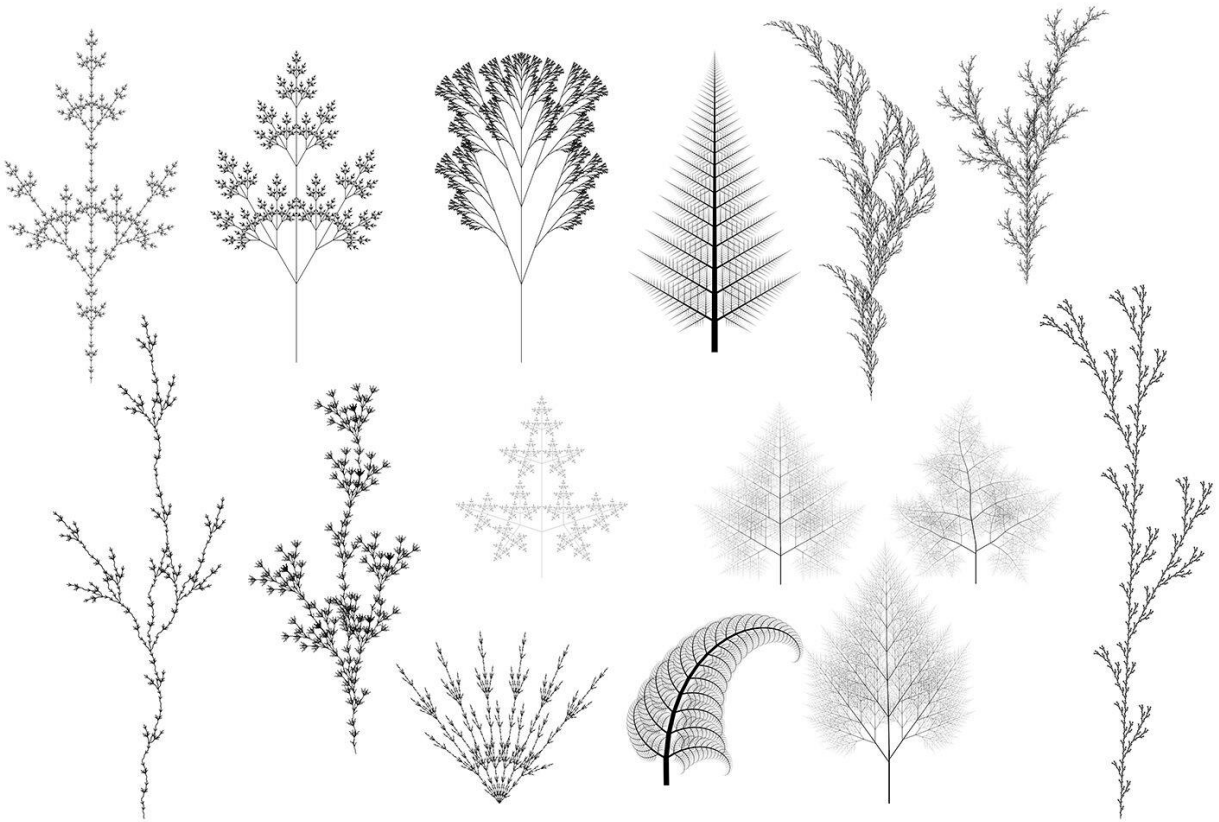
Creeping Garden

Algorithms & Aesthetics

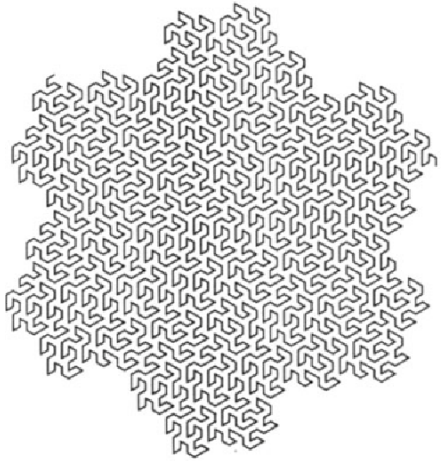
Algorithmic Generation and Natural Form







L-Systems | Algorithmic Beauty of Plants



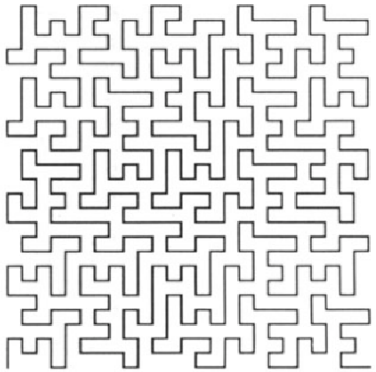
a

n=4, δ=60°

F_l

$F_l \rightarrow F_l+F_r++F_r-F_l--F_lF_l-F_r+$

$F_r \rightarrow -F_l+F_rF_r++F_r+F_l--F_l-F_r$



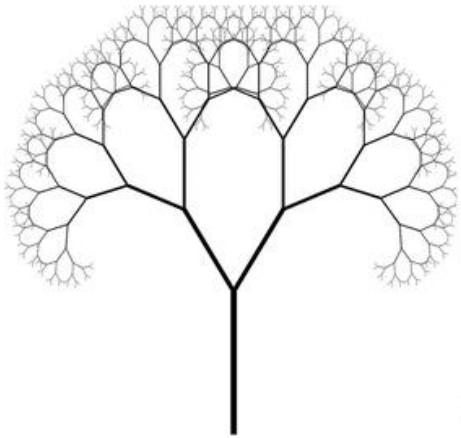
b

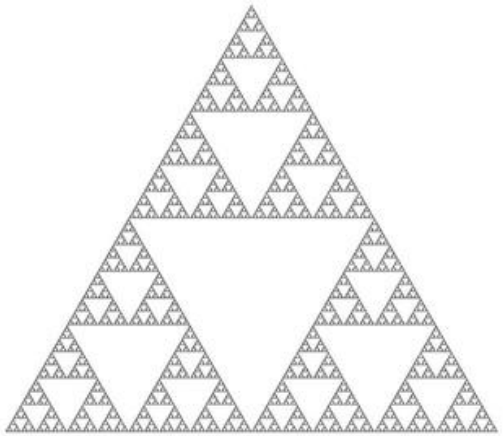
n=2, δ=90°

$-F_r$

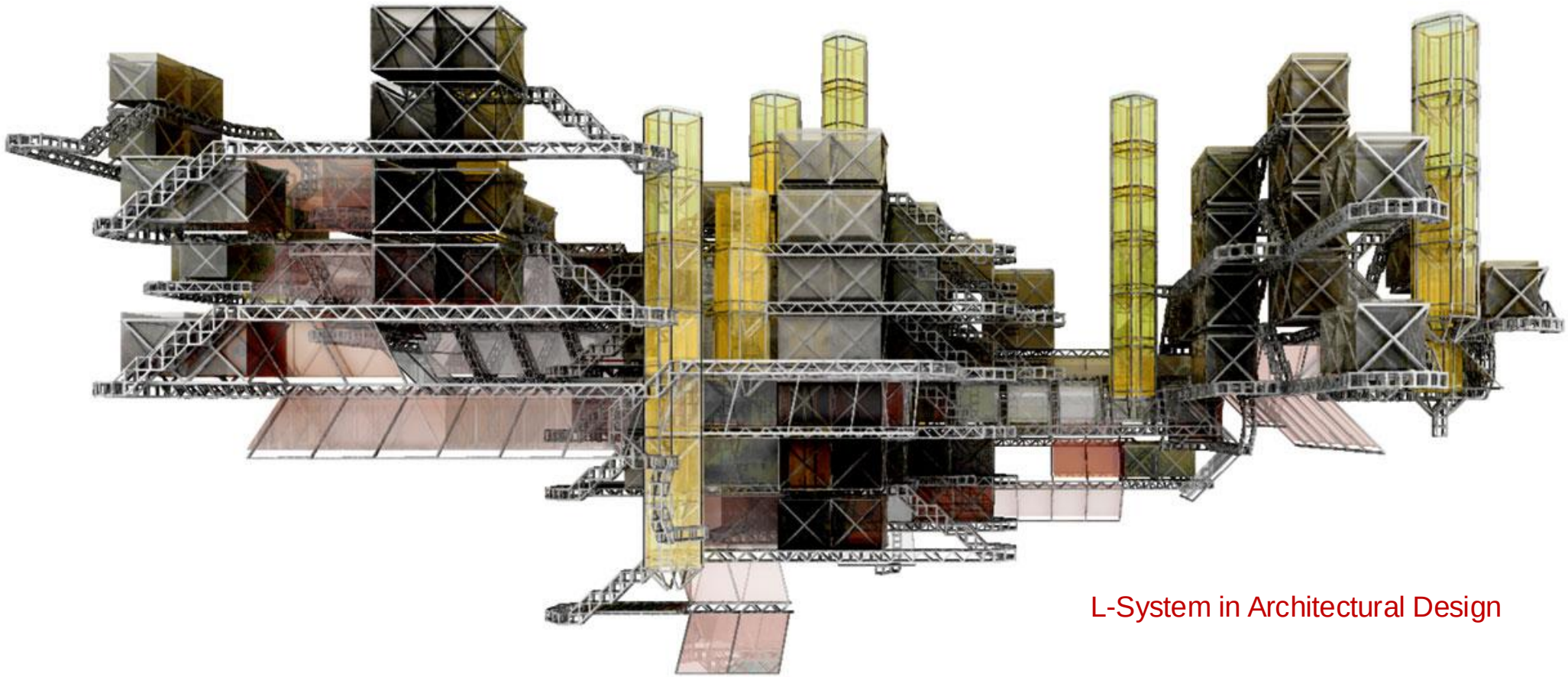
$F_l \rightarrow F_lF_l-F_r-F_r+F_l+F_l-F_r-F_rF_l+$
$F_r+F_lF_lF_r-F_l+F_r+F_lF_l+$
$F_r-F_lF_r-F_r-F_l+F_l+F_rF_r-$

$F_r \rightarrow +F_lF_l-F_r-F_r+F_l+F_lF_r+F_l-$
$F_rF_r-F_l-F_r+F_lF_rF_r-F_l-$
$F_rF_l+F_l+F_r-F_r-F_l+F_l+F_rF_r$





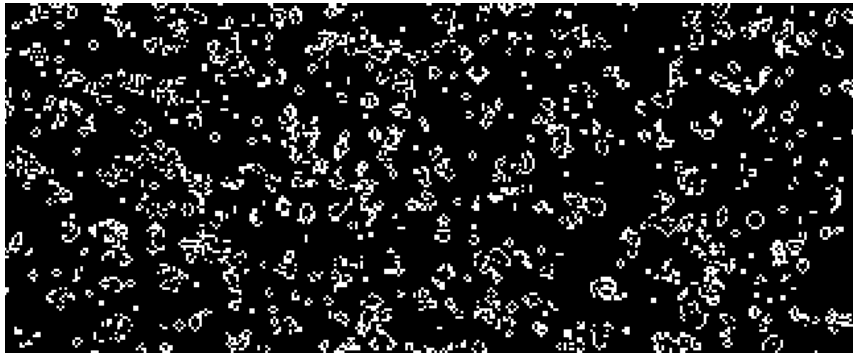
$$f(x,y) = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix}$$



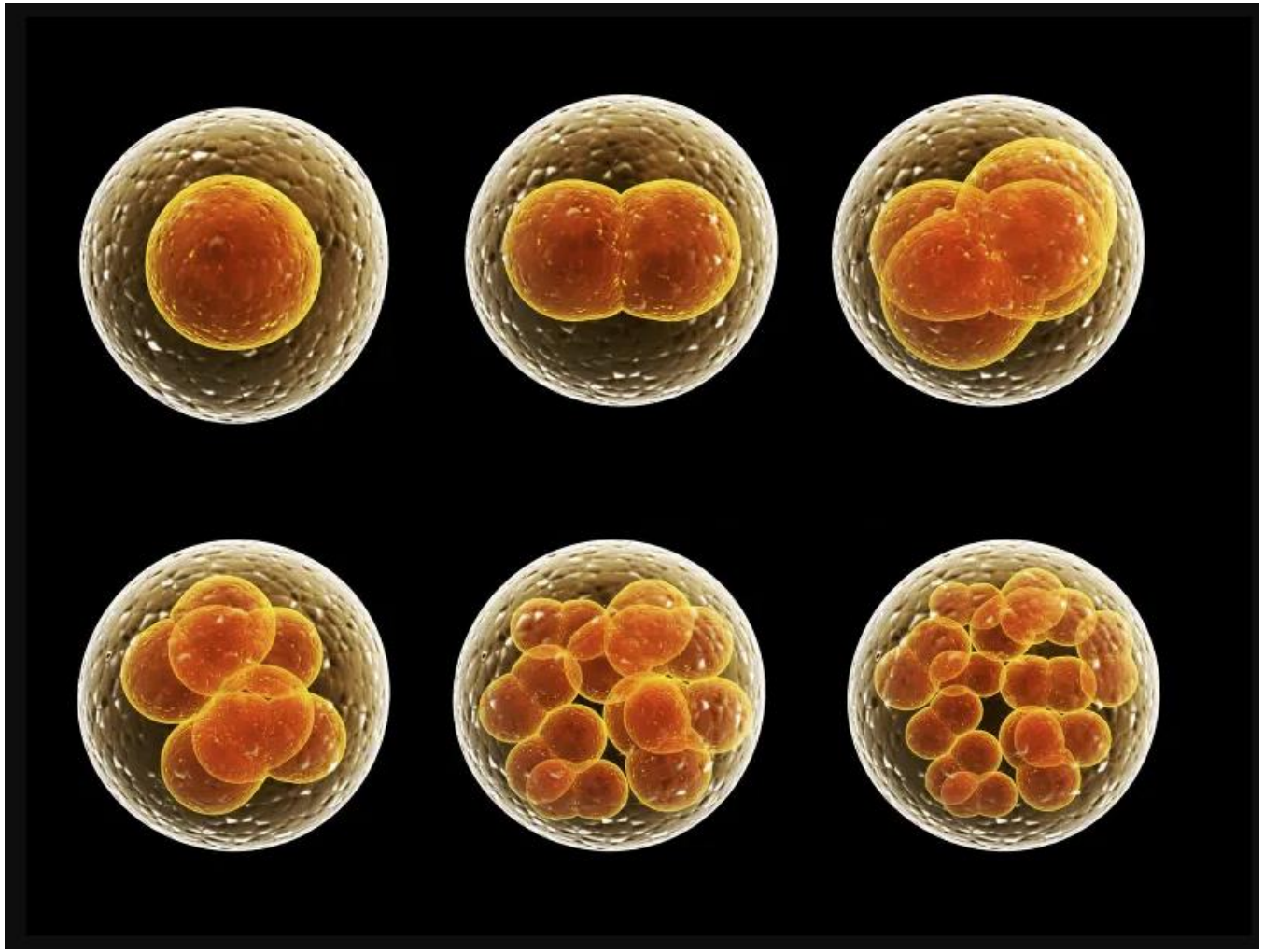
L-System in Architectural Design

Biological Cells and Cellular Automata

difference and repetition in the evolutionary process of creation

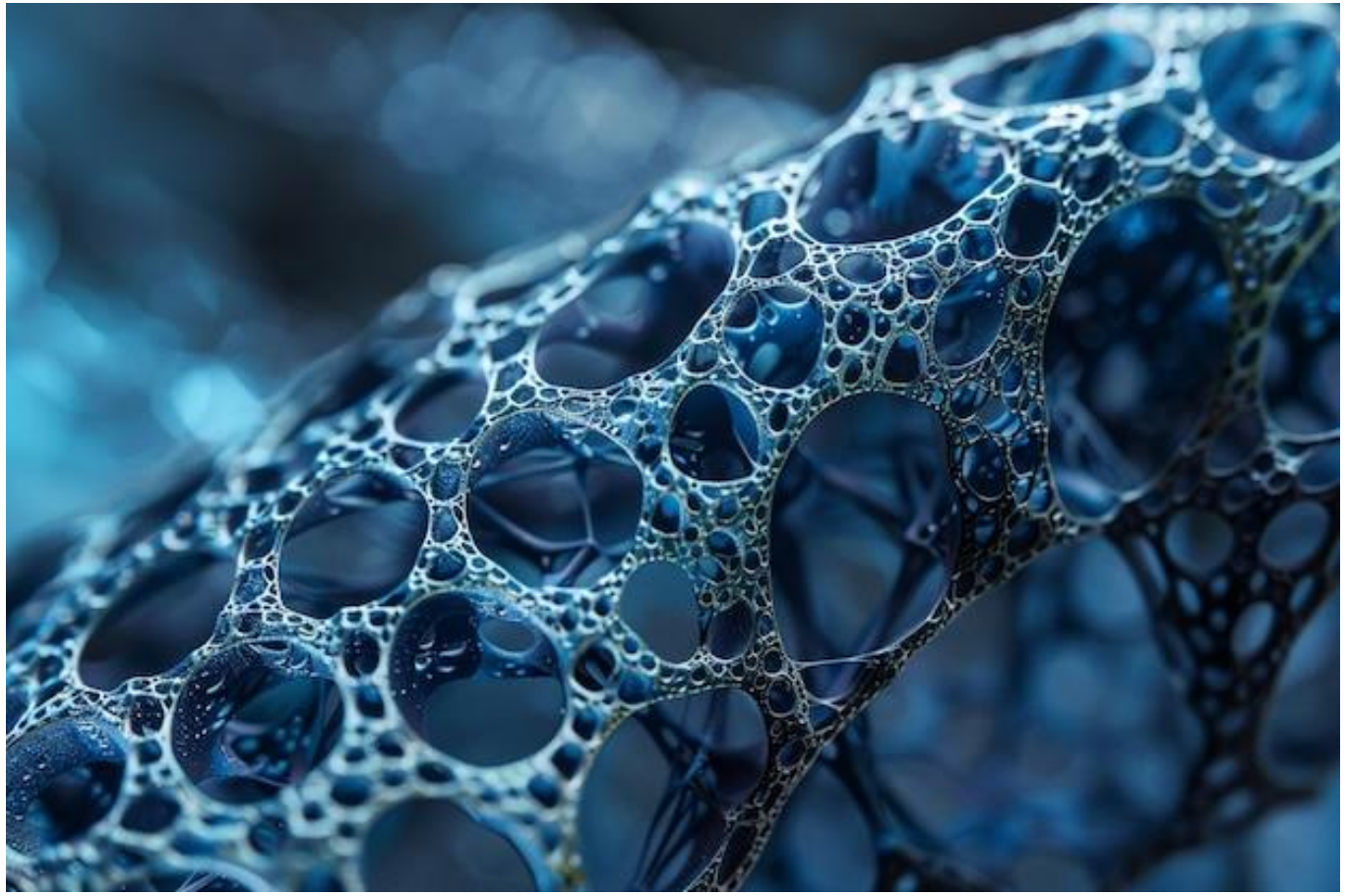


Cellular automata are grid-based models where each cell changes state based on simple rules, similar to how biological cells interact and evolve.



Harnessing Nature's Genius

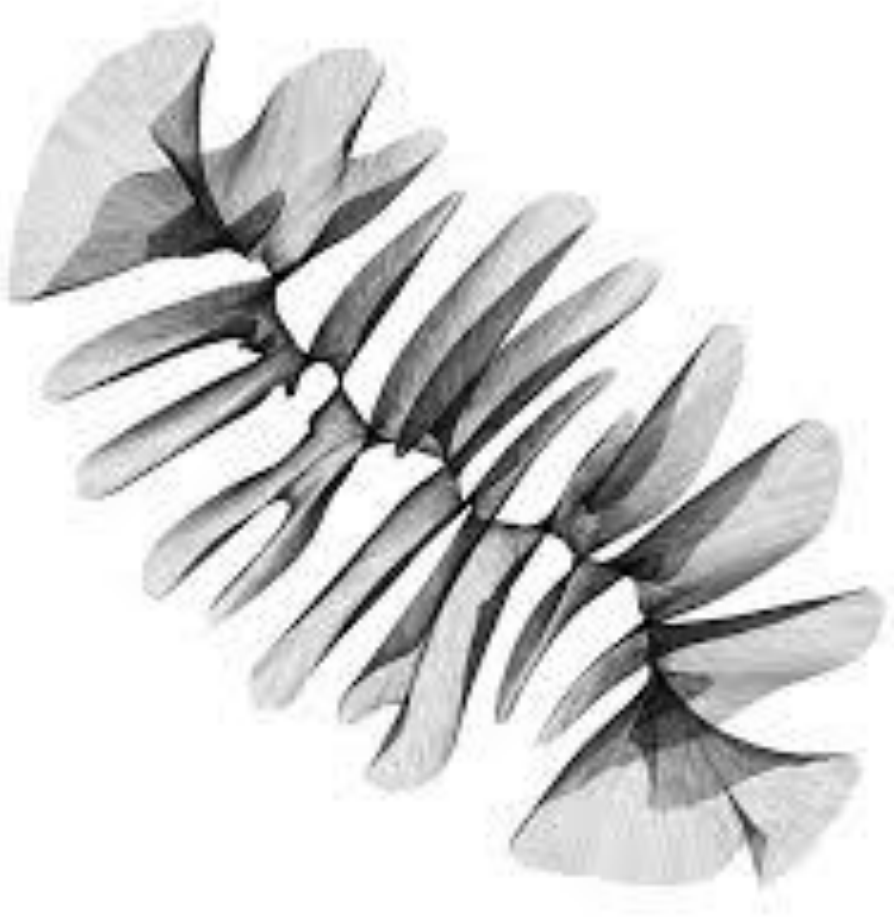
The Convergence of **Evolutionary Algorithms** and **Cellular Automata** in Generative Design using **AI**



Algorithms & Aesthetics

Natural Algorithms: Thompson's ideas on how natural forms arise from simple rules and constraints align with the principles of algorithmic generation in design and AI.

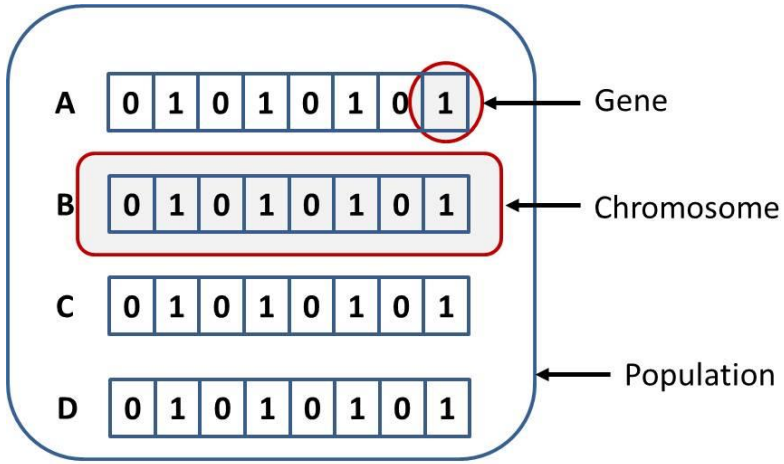
Generative Algorithms: Mimic the natural processes Thompson described, using mathematical models to create diverse and innovative designs.



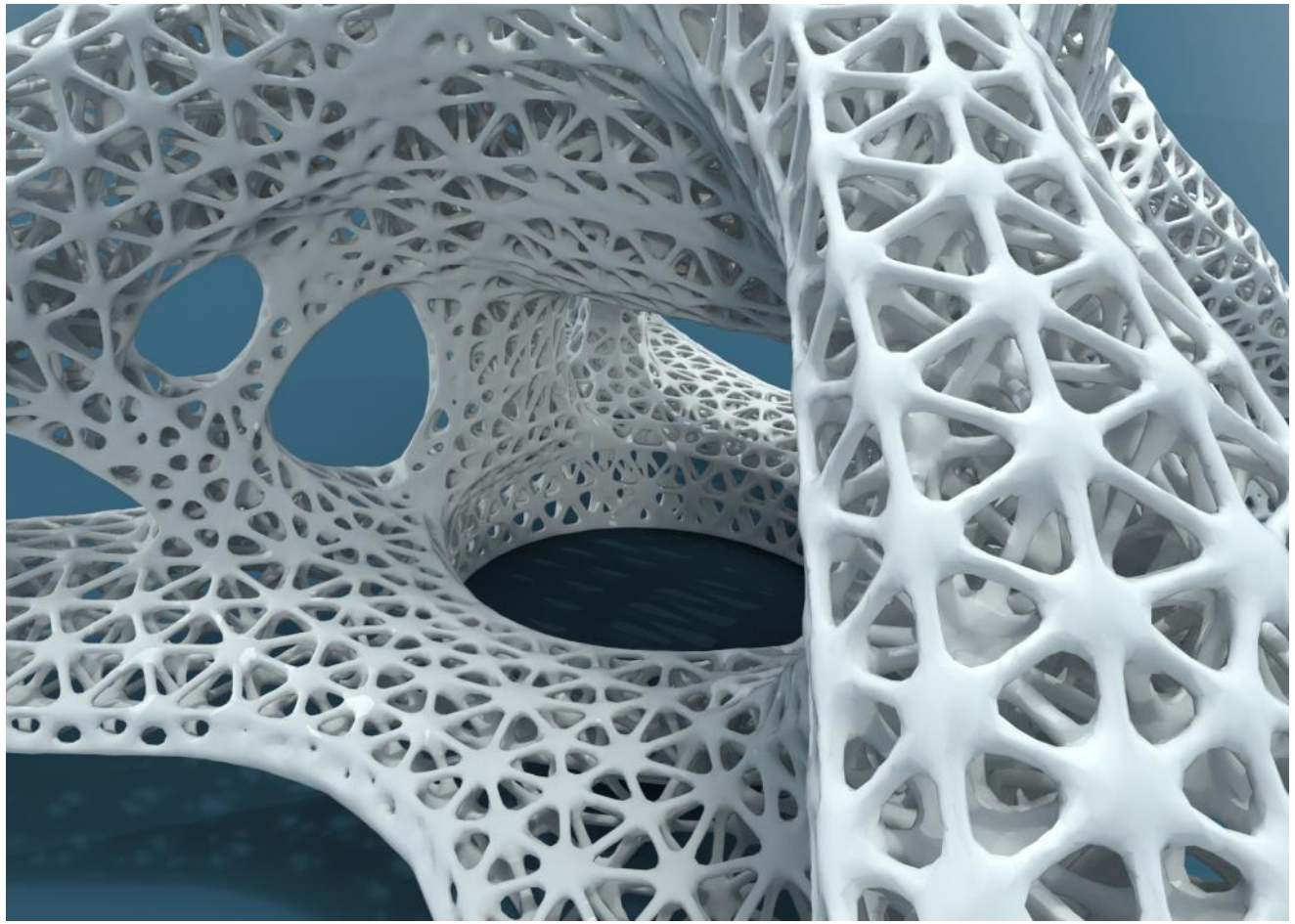
genetic algorithms

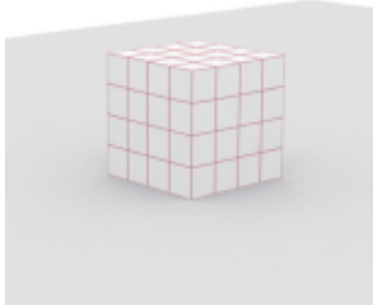
Use in Creative Design Processes

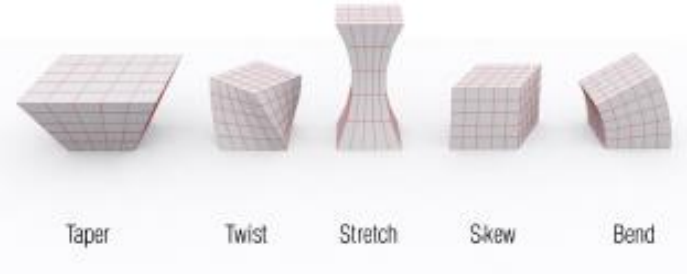
a genetic algorithm is a metaheuristic inspired by the process of **natural selection** that belongs to the larger class of **evolutionary algorithms.**

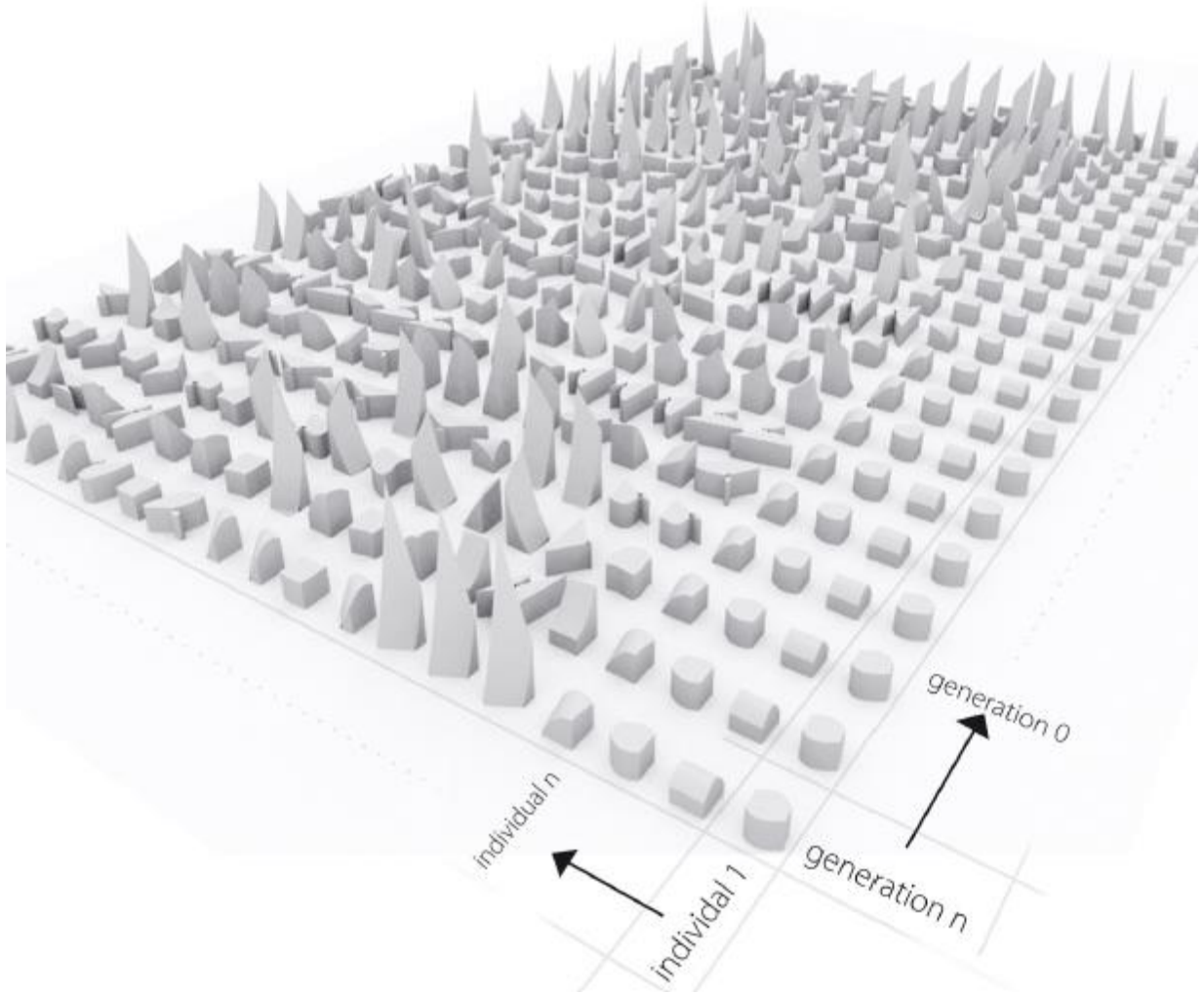


Gene, Chromosomes and Population






Taper
Twist
Stretch
Skew
Bend


generation 0
individual n
individal 1
generation n

neural networks

A neural network is a method in artificial intelligence that teaches computers to process data in a way that is inspired by the human brain. It is a type of machine learning process, called deep learning, that uses interconnected nodes or neurons in a layered structure that resembles the human brain.

GANs

Generative Adversarial Networks

Generative Adversarial Networks use a unique approach to generating new data by pitting two **neural networks** against each other in a competitive setting. One network attempts to create new data. The other network attempts to discern whether or not it’s fake. Through repeated training, both networks become better at their jobs.

GANs

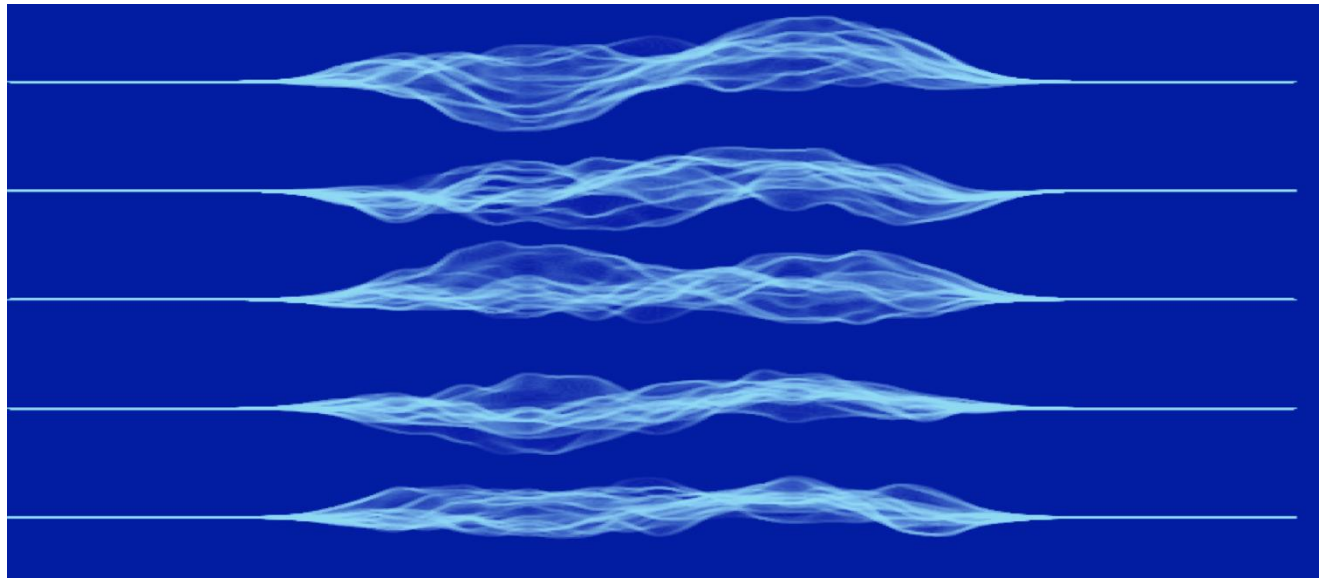
Generative Adversarial Networks

Generative Networks makes the mapping between source image and target image easier and it calculates the loss function also to improve the quality of generated target image.

Text-to-Image Generation is a task in computer vision and natural language processing where the goal is to generate an image that corresponds to a given textual description

Why?

…generative design



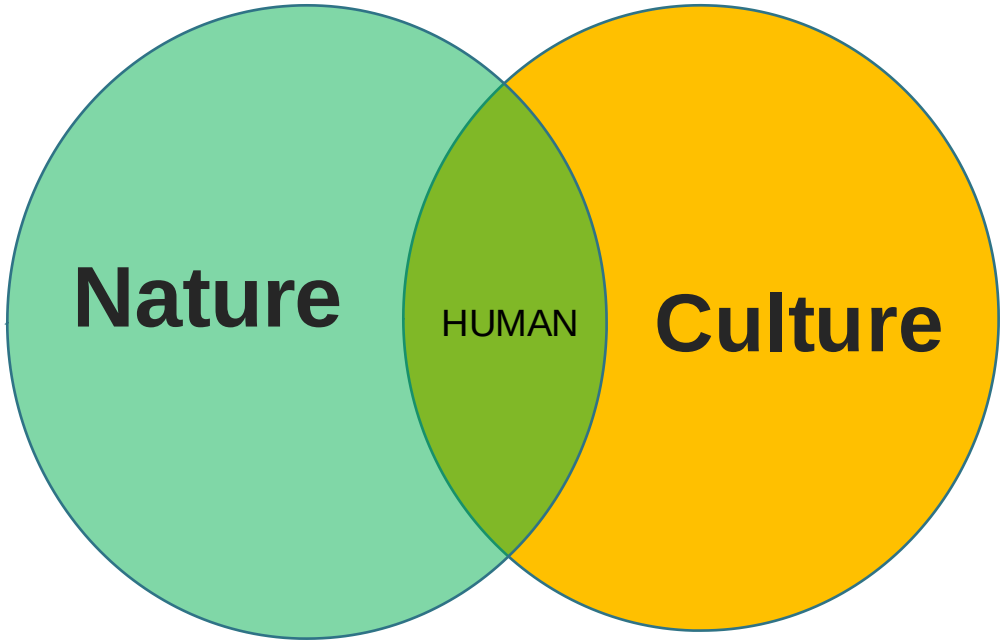
Generative Design is changes Traditional Processes

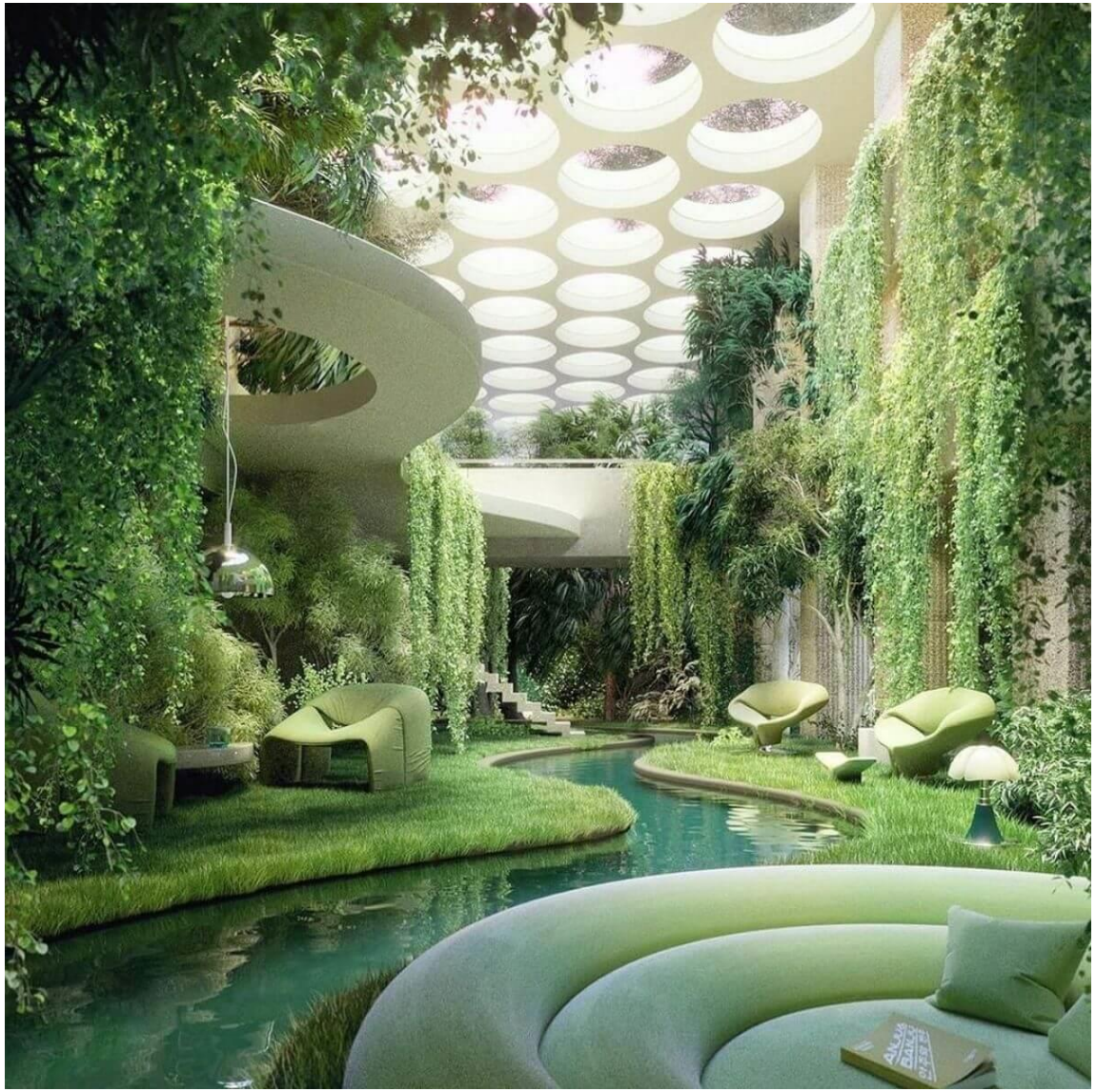
Generative design is a process of design exploration. It uses computer software to find the best possible solution for a given project

Generative design is an advanced, algorithm-driven process, sometimes enabled by AI, used to explore a wide array of design possibilities that meet predefined criteria set by engineers or designers.

Biophilic Design

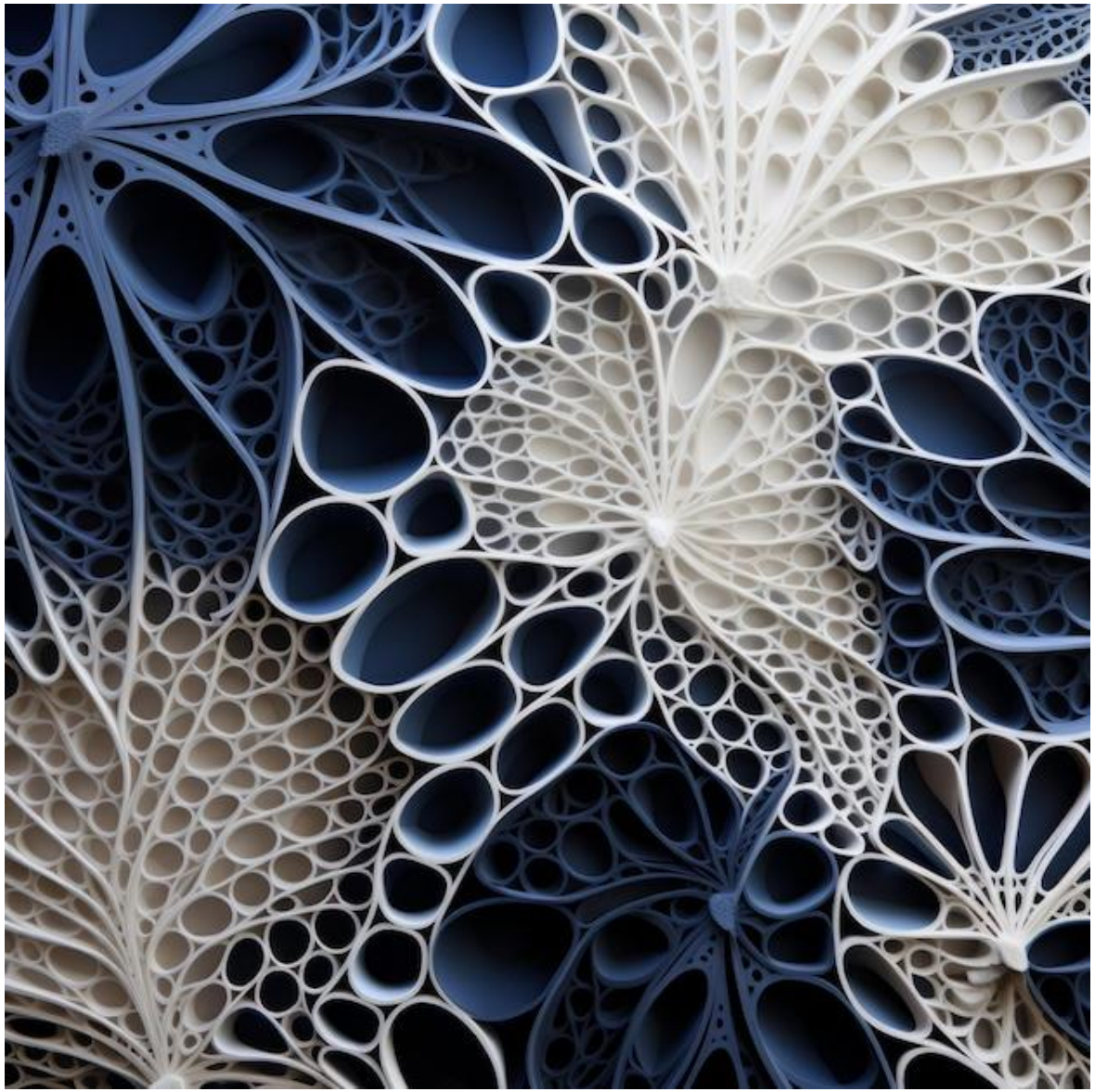
Biophilic refers to the inherent human inclination to affiliate with nature and other forms of life.



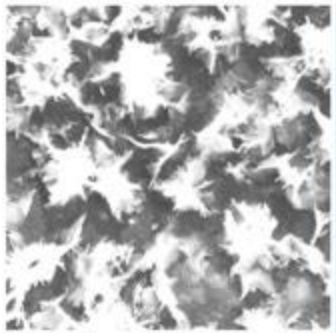


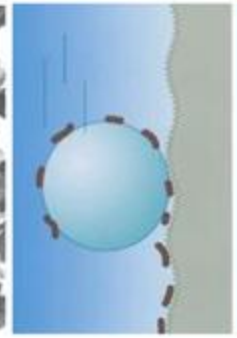
Biomorphism

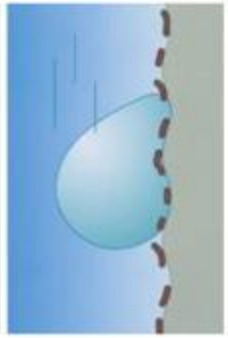
Biomorphism refers to designs that visually resemble elements from life (they “look like” nature), whereas biomimetic designs focus on function (they “work like” nature).

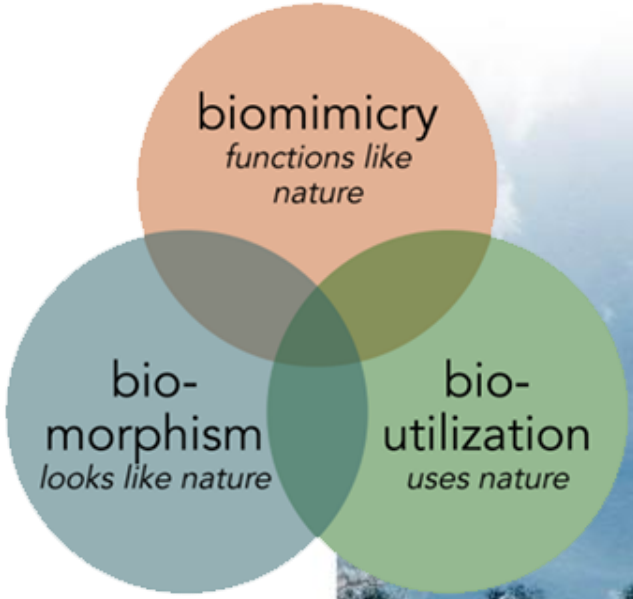


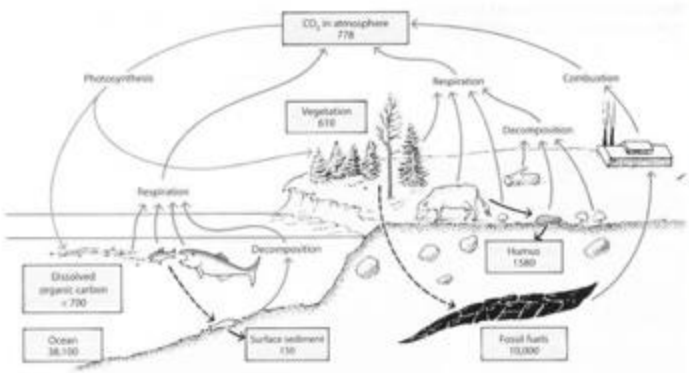
RATIO
PROPORTION:







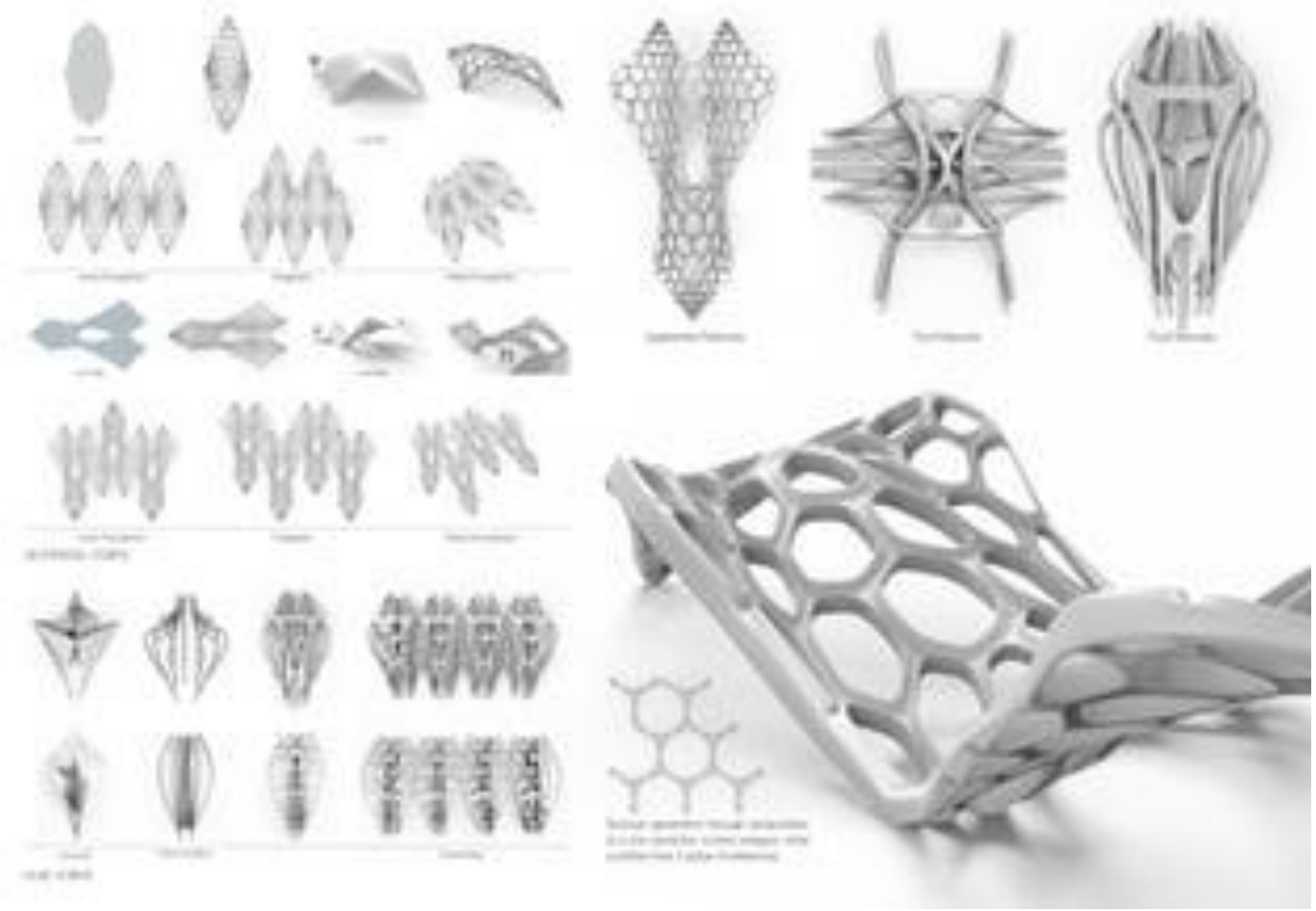

biomimicry
functions like nature
bio-morphism
looks like nature
bio-utilization
uses nature


Photosynthesis
Respiration
Combustion
Vegetation
Decomposition
Respiration
Decomposition
Humus
Dissolved organic carbon
Ocean
Surface sediment
Fossil fuels

TATE + CO

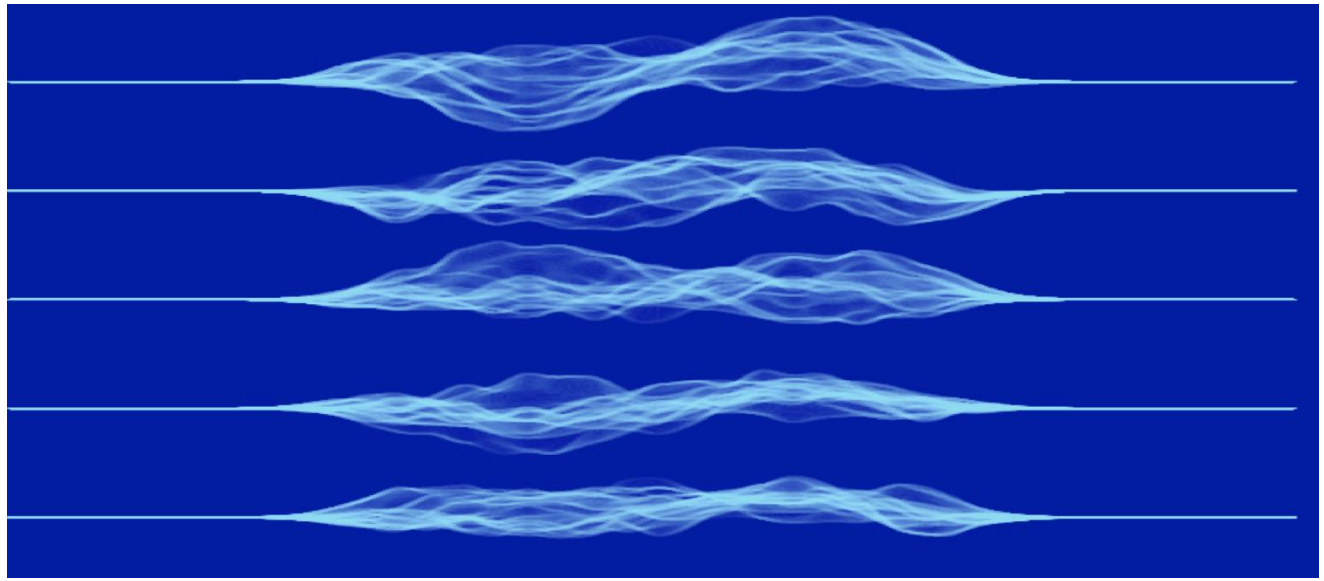
‘Digital’ Morphogenesis

Morphogenesis: The iterative process of form development in nature, guided by genetic and environmental factors, is mirrored in generative design and AI.



How?

…does generative design work?



Repetition
as a Creative Tool

the role of repetition in design aesthetics

techniques for leveraging repetition in generative design

repetition in nature and their application in design

techniques for leveraging **repetition**
in generative design

rhythms and patterns

repetition in nature and their application in design

Natural Patterns and Human Well-being
A Deep Connection

Difference
as a Driver of Innovation

The importance of introducing **variation**

Methods to incorporate **difference and contrast** in generative design

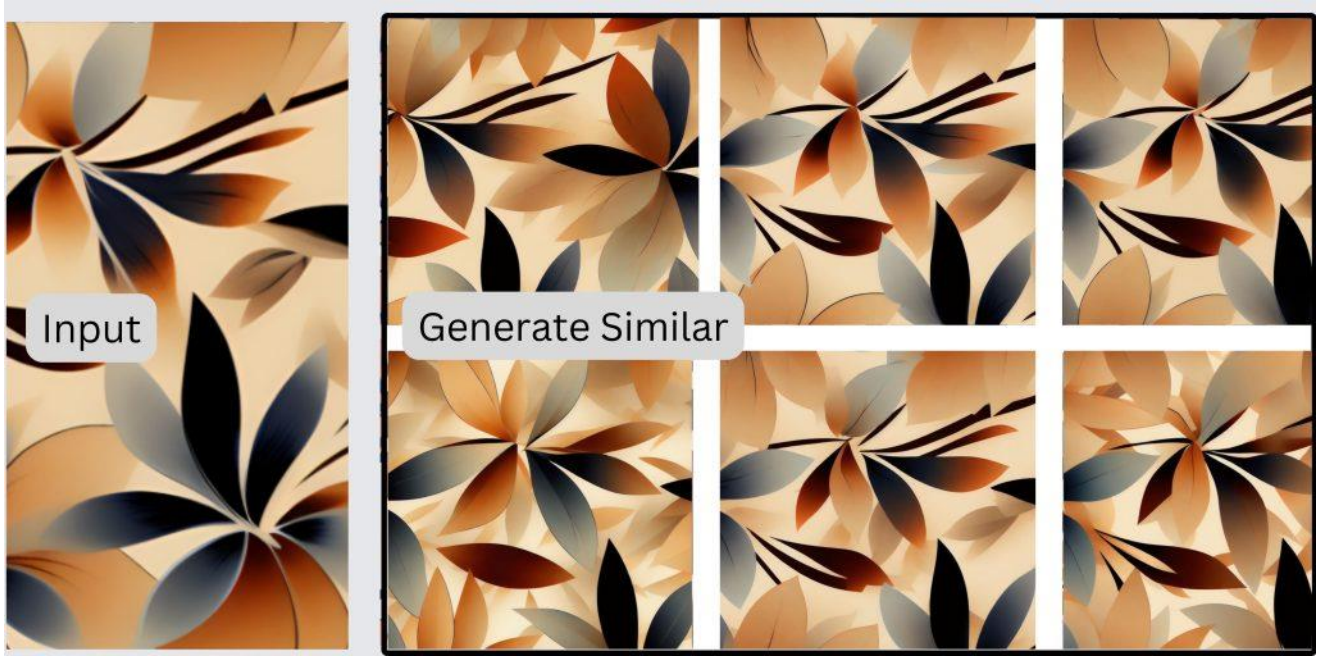
Balancing **repetition and difference** to achieve innovative outcomes

For the new – in other words, **difference** – calls forth forces in thought which are **not the forces of recognition**, today or tomorrow, but **the powers of a completely other model**, from an unrecognised and unrecognisable terra incognita.

Deleuze, Difference and Repetition, 1994, p.136

Difference
as a Driver of Innovation

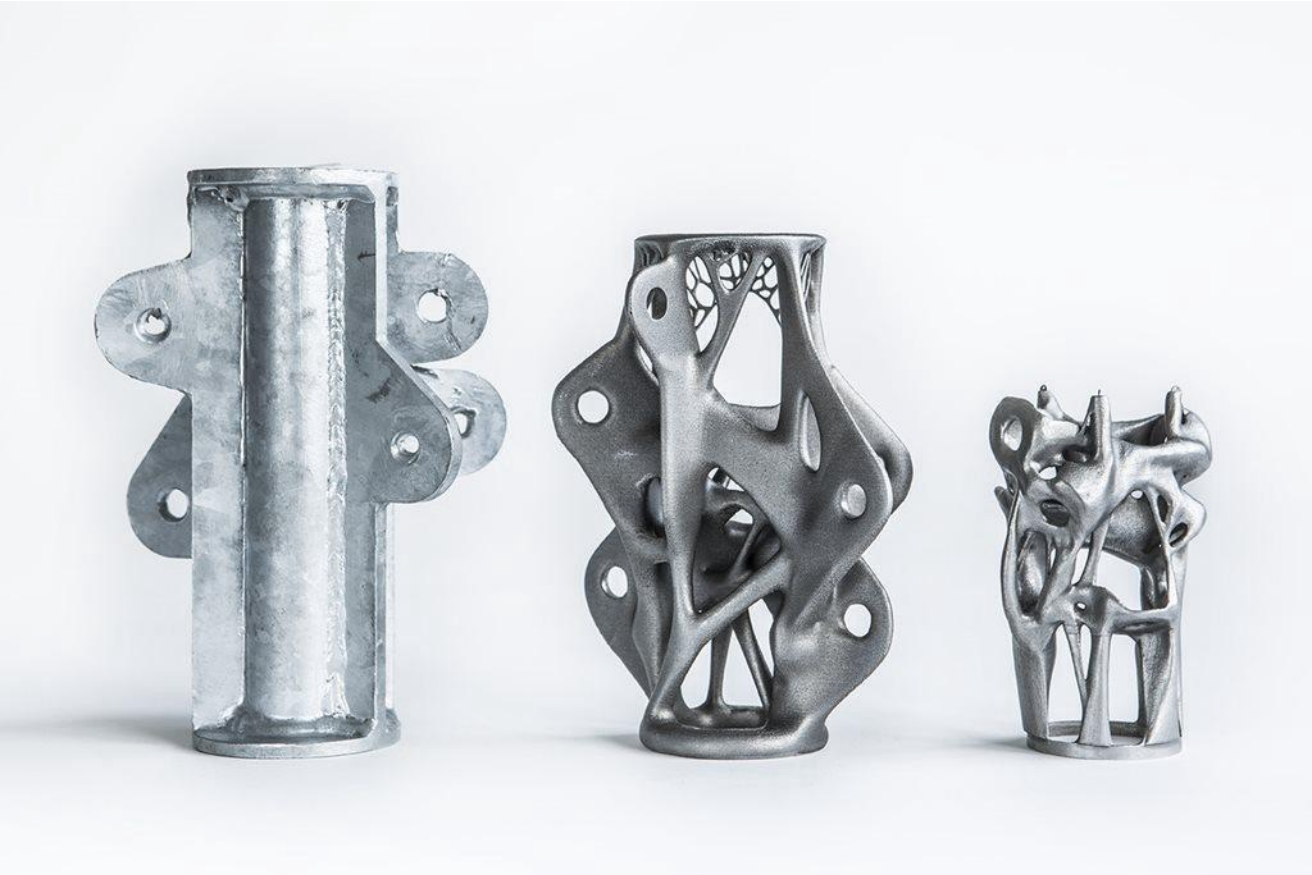
the importance of introducing **variation**



form and function

methods to incorporate difference in generative design

balancing repetition and difference to achieve innovative outcomes

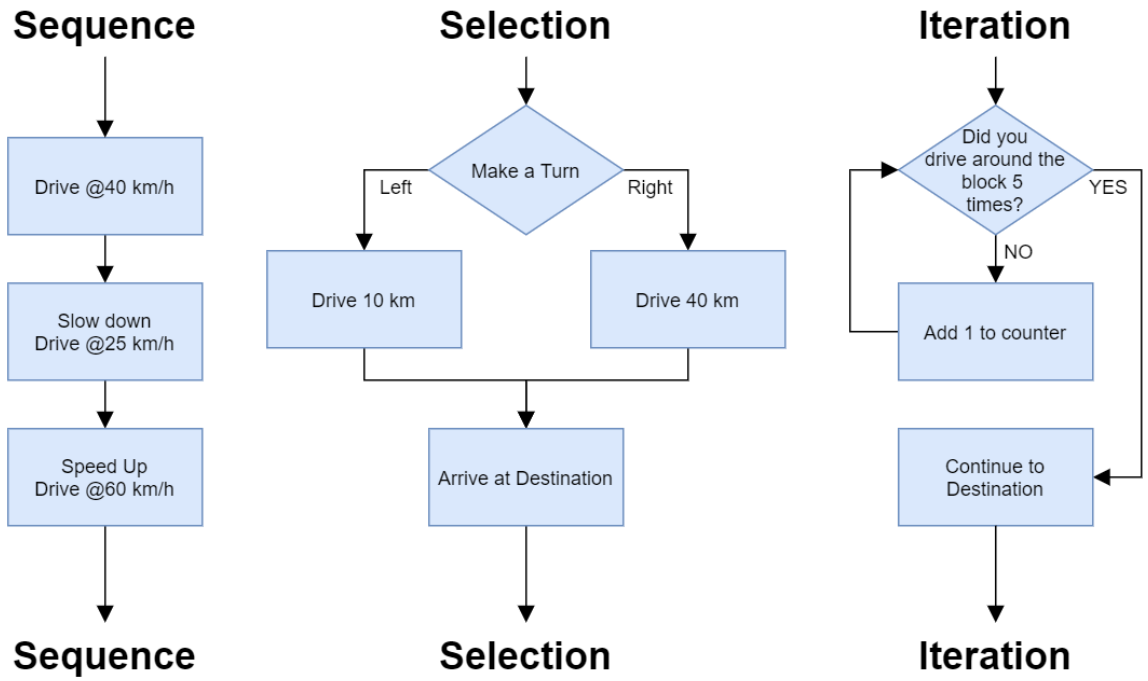


three basic programming constructs

Iterative Processes

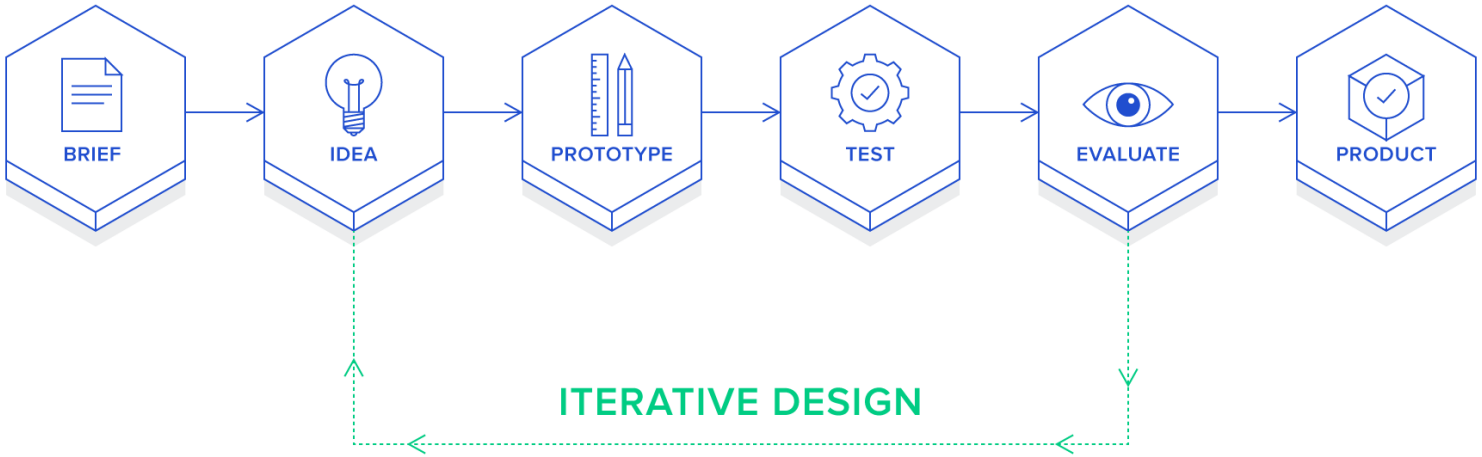
Iterative Design: Generative processes evolve designs through continuous iteration and refinement, similar to the gradual development of natural forms.

The speed of computation – computers very good at repetition and difference…



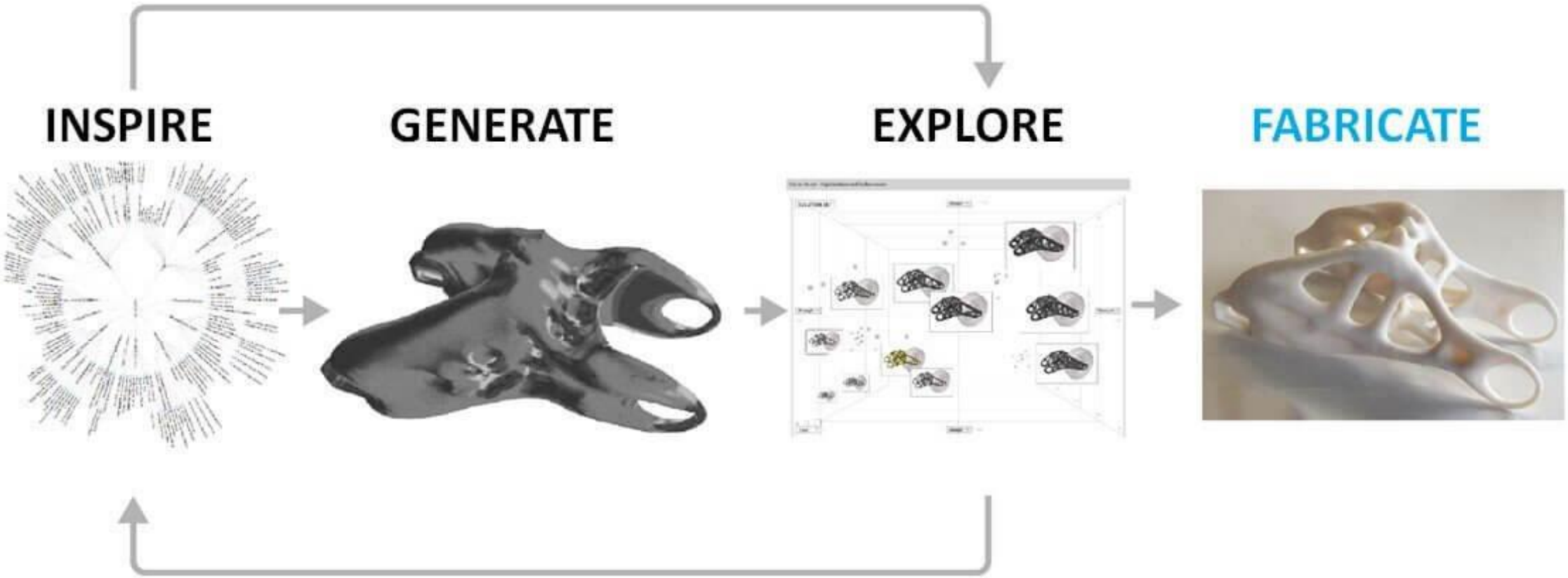
Iterative Processes

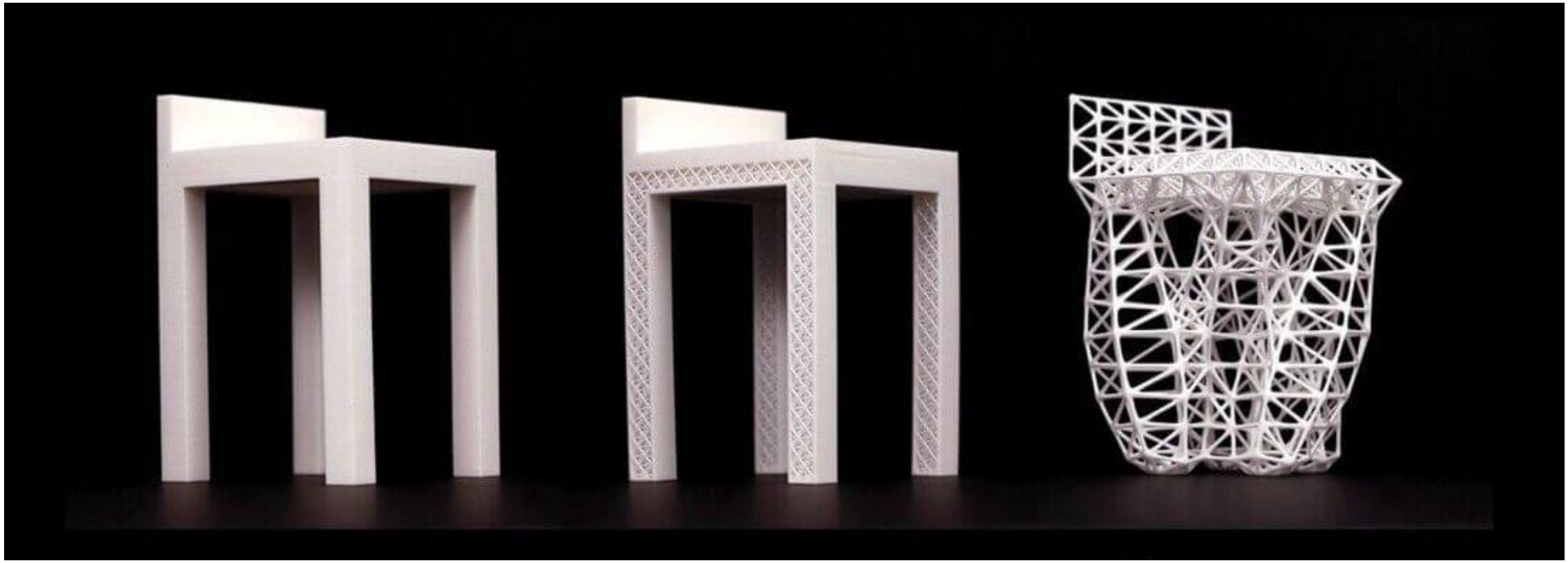
Constraints, Feedback Loops, and Optimization



Natural Constraints: Physical and environmental constraints shape the growth of natural forms, a concept central to D'Arcy Thompson's work.

Design Constraints: In generative design and AI, constraints guide the creation of optimized and functional designs, analogous to natural selection processes.


INSPIRE
GENERATE
EXPLORE
FABRICATE



parametic design

Parametric design uses **parameters to define a set of rules or constraints,** allowing for the dynamic alteration of design elements based on these parameters. It's about defining relationships between design elements.

Procedural Generation

Creating infinite algorithmic realities

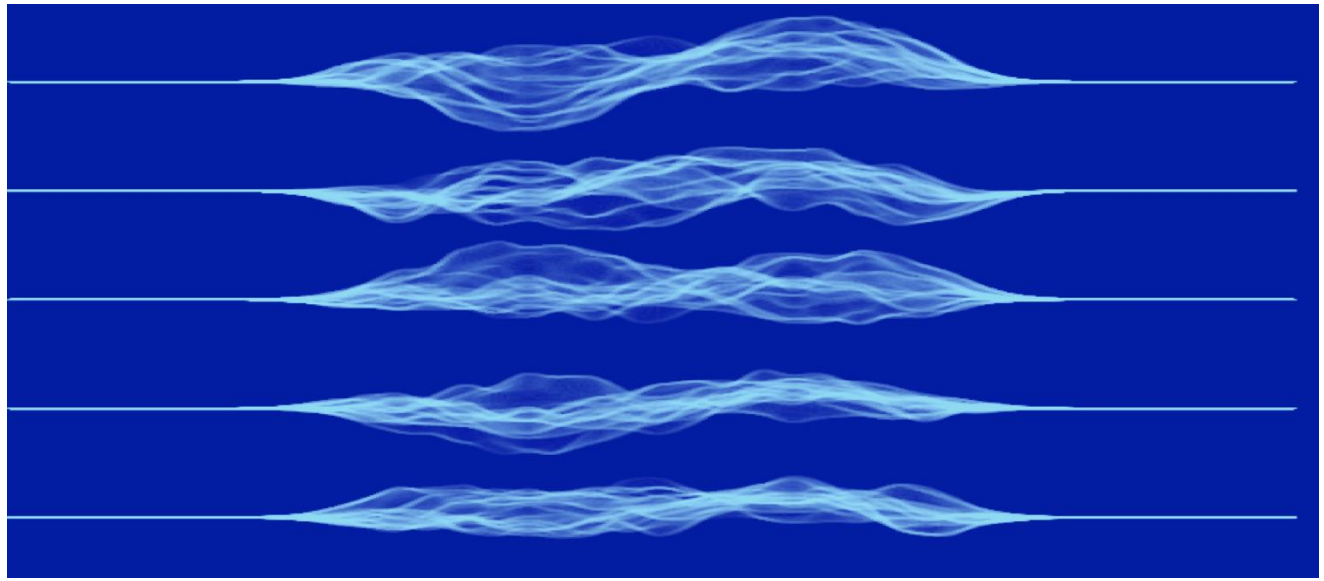
Procedural design involves using algorithms and predefined rules to generate complex structures and patterns. It's heavily reliant on the step-by-step execution of a series of operations or procedures.

procedural generation of game assets

Procedural generation offers game developers a versatile toolkit for dynamically creating a wide range of assets. These assets encompass everything from lifelike terrain, level layouts, textures, and 3D models to characters, items, and quests.

Who?

…artists and designer using generative work?



Michael Hansmeyer
Computational Architecture

Michael Hansmeyer, an artist and computational architect, pushes the boundaries of design by blending art and technology.

Known for his innovative use of algorithms, Hansmeyer creates intricate, detailed forms that challenge traditional architectural norms. His work, often described as a fusion of art and science, explores the potential of **computational processes to generate complex, organic structures.**

Through projects like **"Digital Grotesque,"** he demonstrates the transformative power of digital fabrication, producing breathtakingly elaborate environments.

Hansmeyer's pioneering approach not only redefines architectural aesthetics but also opens new horizons for creative expression in the digital age.

Digital Grotesque III

Michael Hansmeyer

Through his ‘Digital Grotesque’ series, **Michael Hansmeyer** fabricates architectural spaces with the aid of programming, machine learning using **artificial intelligence**, and visual arts, pushing the boundaries of what is possible. Based on purely geometric processes, the team develops what the artists call ‘computational architecture’. The latest installment consists of two parts; a **multimedia installation** and an **ornamental column**. The **360-degree video installation** depicts a digital grotto — a cave that *‘inhabits a space between artificial and natural’,* in endless motion, where spectators can immerse themselves in a constantly changing space generated by detailed, porous, multi-layered structures.

Michael Hansmeyer

Digital Grotesque III

Excerpts from the 360° video installation

Video: Demetris Shammas

Sound: Emiddio Vasquez

Refik Anadol

Machine Hallucinations

abstract Generative Art

Refik Anadol, an artist and computational architect, revolutionises the intersection of art, technology, and spatial design. Utilising **data as his primary medium**, Anadol creates immersive installations that transform physical spaces into dynamic, sensory experiences. His work, characterized by its innovative use of **artificial intelligence and machine learning**, explores **the relationship between digital and physical realities.** Anadol's groundbreaking approach not only redefines the boundaries of digital art but also **offers profound insights into the future of human-machine collaboration in creative expression.**

Refik Anadol Introduces World’s First Open-Source Generative AI-Model Dedicated to Nature

LARGE NATURE MODEL

V1. RAINFOREST

dataland

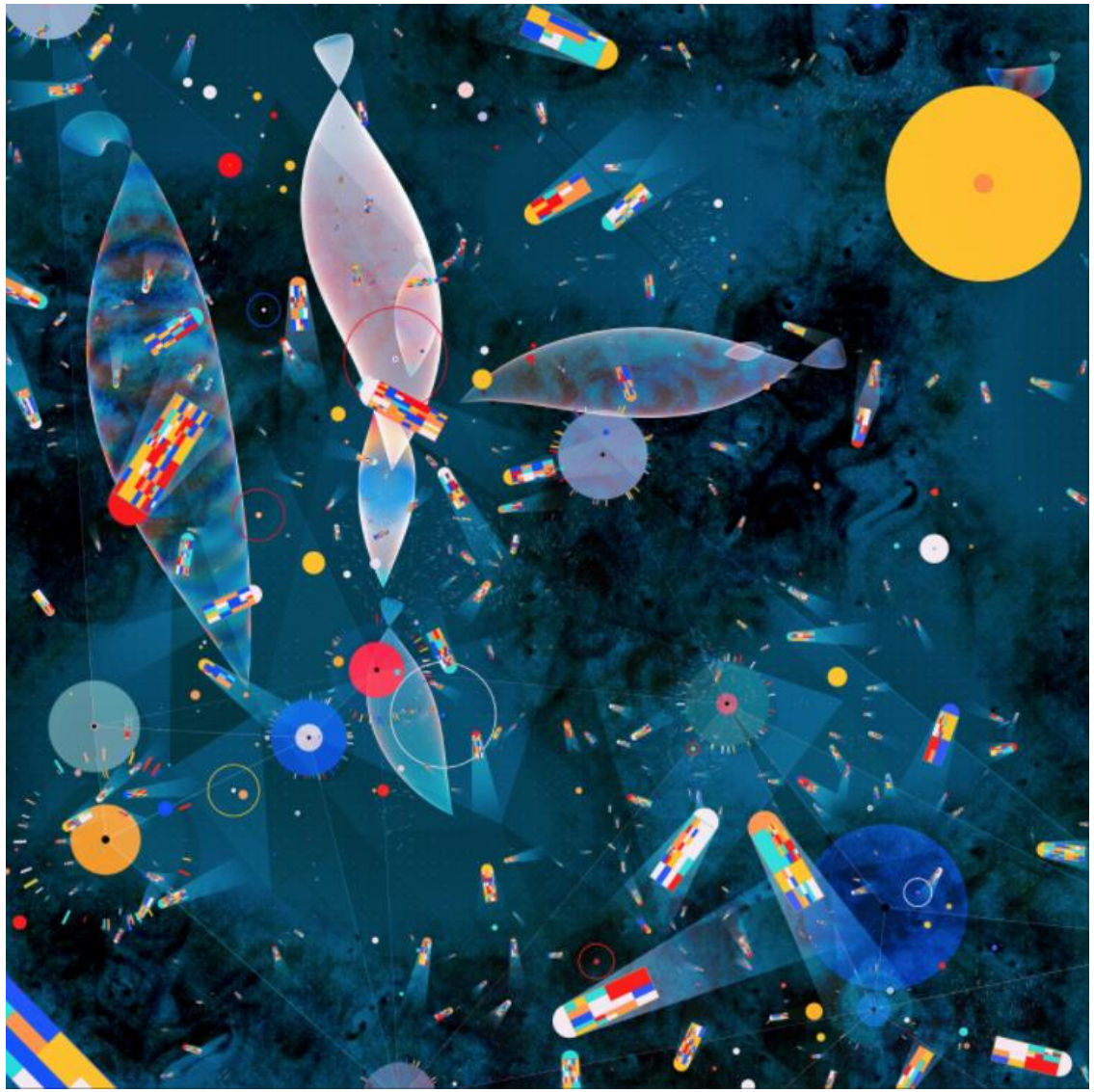
REFIK ANADOL STUDIO (RAS) AND **NVIDIA** JOINED FORCES TO ENHANCE THE **GENERATIVE AI CAPABILITIES** OF THE **NVIDIA PICASSO GETTY IMAGES FOUNDATIONAL MODEL**. BY FINE-TUNING THE EXISTING MODEL WITH A SCIENTIFIC ARCHIVE OF **FLORA**, **FAUNA**, AND **FUNGI** SPECIES, WE ENABLED THE GENERATION OF **HYPER-REALISTIC IMAGES** PORTRAYING AI-GENERATED IMAGES OF DIVERSE SPECIES.

THROUGH THIS COLLABORATION, **RAS**, **NVIDIA**, AND **GETTY IMAGES** PUSHED THE BOUNDARIES OF **ARTIFICIAL INTELLIGENCE** IN DIGITAL ART AND ENVIRONMENTAL REPRESENTATION.

Manolo Gamboa Naon

generative artist whose interest focuses on exploring the **digital surface** as a **plastic space** using **code**

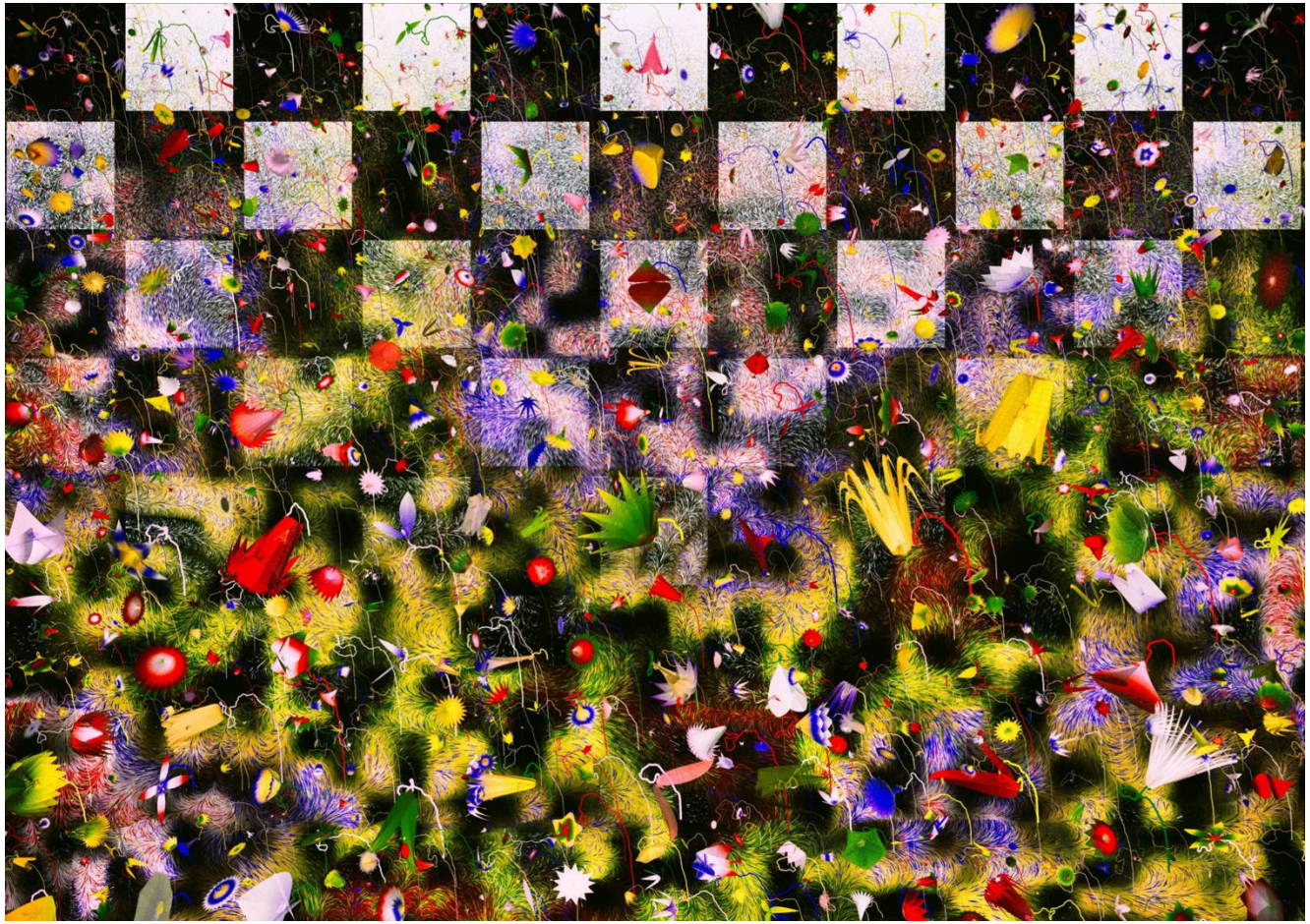
Manolo Gamboa Naon, is a visual artist and creative coder, who captivates audiences with his innovative fusion of art and algorithms. Known for his generative artworks, Naon uses computational processes to create mesmerizing visuals that explore the intersection of geometry, color, and movement. His work, often characterized by its dynamic complexity and organic patterns, pushes the boundaries of digital creativity. By harnessing the power of coding and digital tools, Naon transforms abstract concepts into visually stunning experiences. His pioneering approach not only redefines digital art but also inspires new ways of thinking about the relationship between technology and artistic expression.



88 Allegories

Manoloide (Manolo Gamboa Naon)

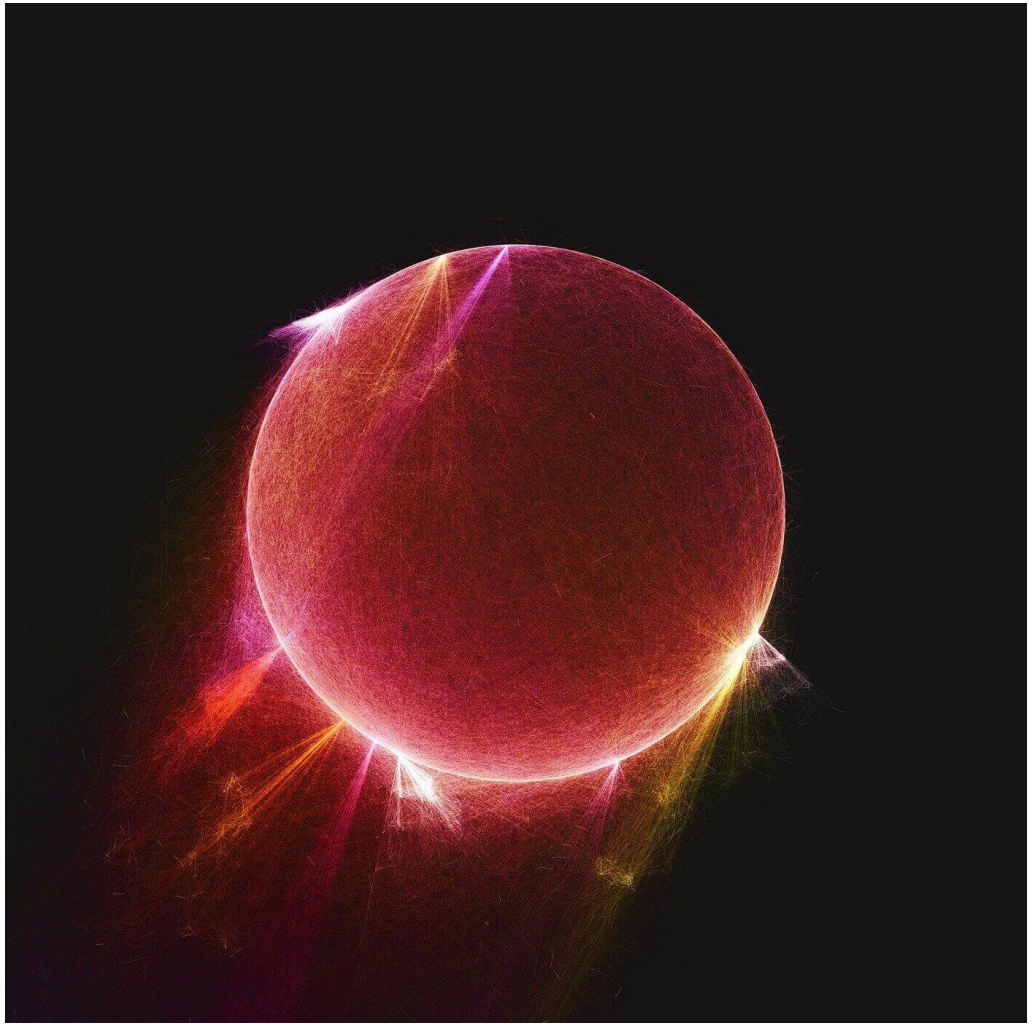
'88 Allegories' **generative masterpiece** by Manoloide, a group of 88 individual artworks, collectively engaged together building up one main canvas. Each image holds its meaningful message with flower, colour, number and shape. Each flower is explicitly positioned to add a vibrant visualization to each arrangement. All 88 are displayed as one body of work as one universal message. Again, this is done intuitively to demonstrate and resonate with the natural system of life. The series of 'Allegories 88' is bound to the concept of a 'symbolism' in history of art that allows the viewer not only to interact with work on the visual basis, but also create an intimate bond to the specific details/signs, which have infinite possibilities of interpretation driven by the erudition and imagination of the viewer.



Generative Design and Generative AI

The Future of Creativity
How Generative AI is Revolutionising Art and Design

synergies and future directions



Generative art by Anders Hoff. This is part of his project “Inconvergent”, which explores the complex behavior that emerges from systems with simple rules.