Complex dynamic systems

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SELF-ORGANIZATION

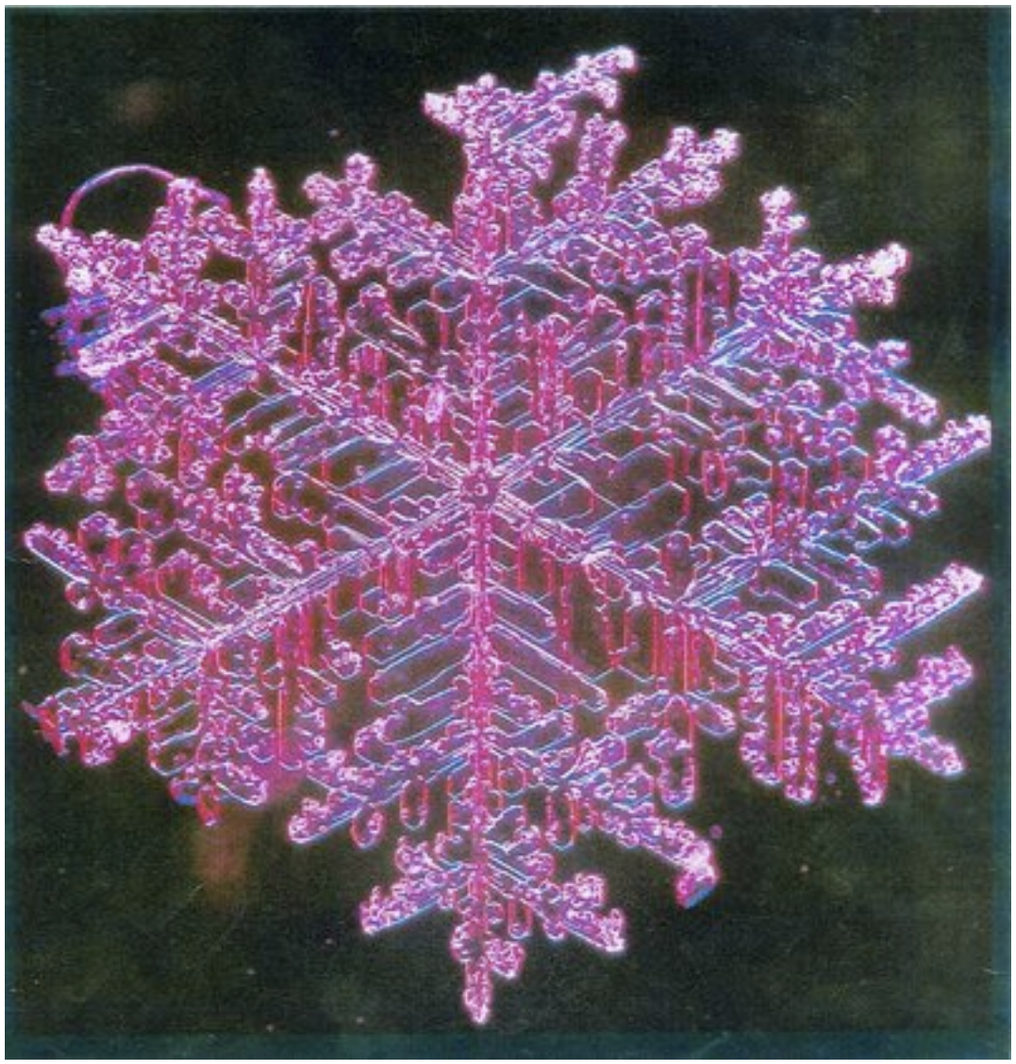
→ Either:

- REPETION ON ALL SCALES

— or —

- PATTER FORMATION

The Snow Crystal

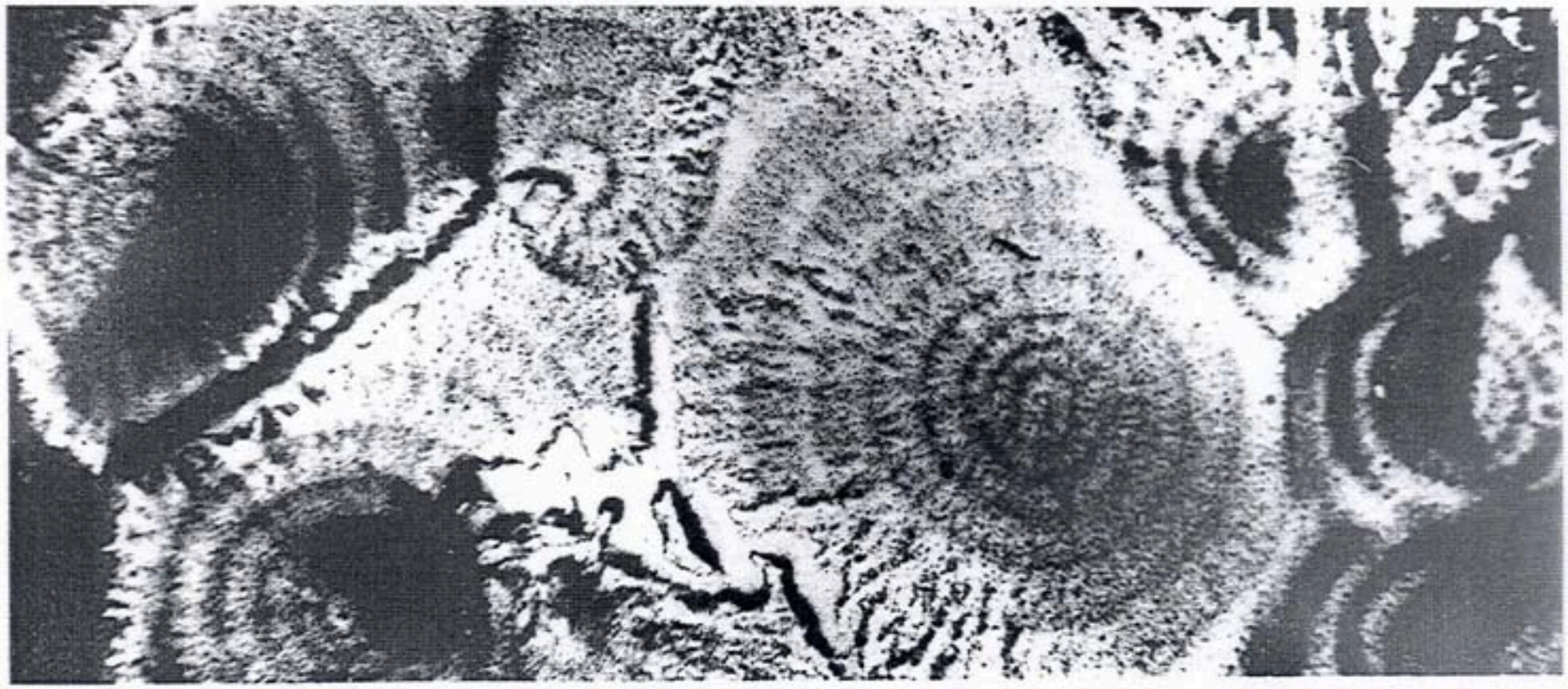


A Satellite image (NASA)

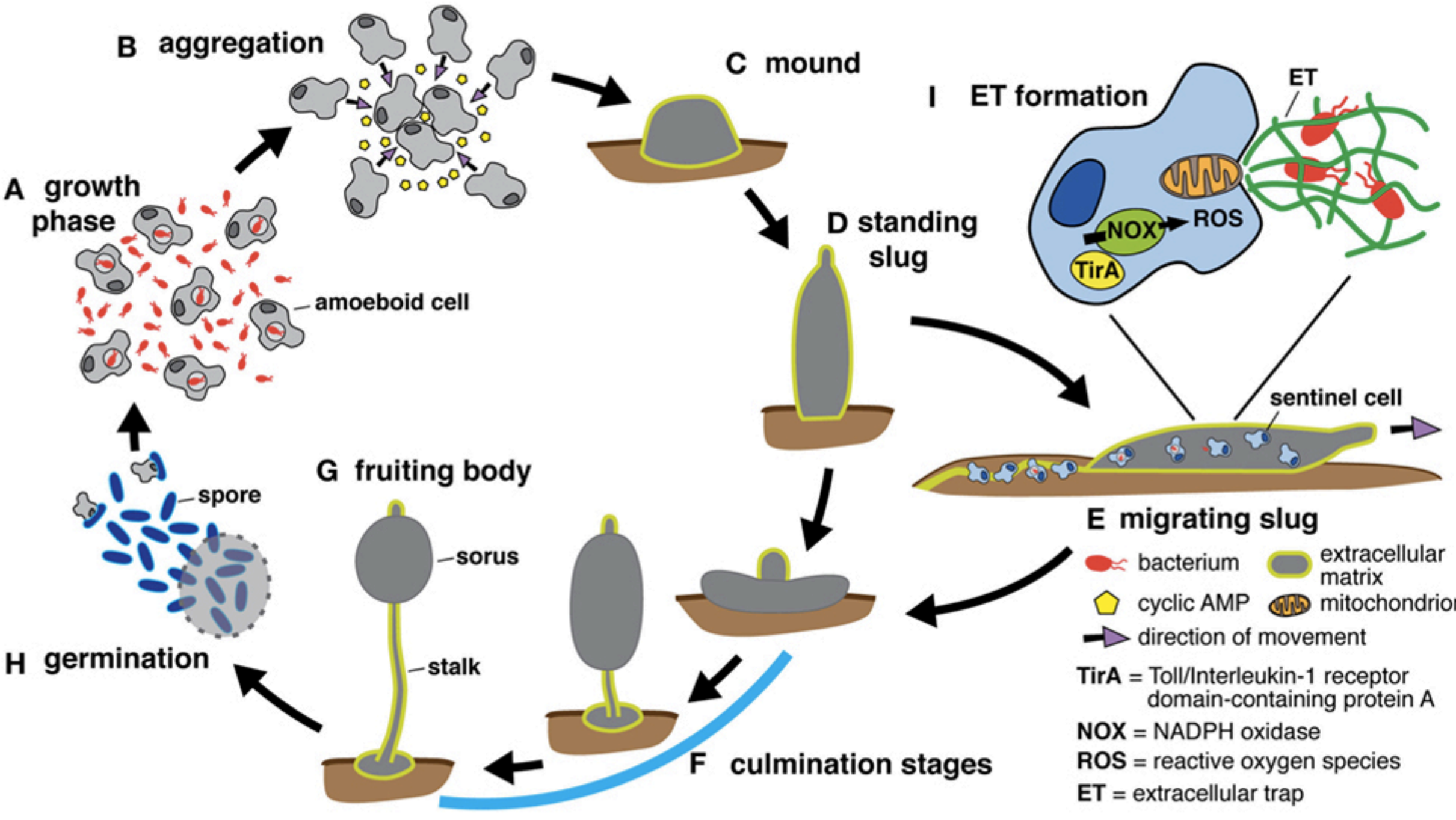
Fig. 2

Chemical Reactions (The Belousov-Zhabotinsky reaction)

The Slime Mold



The Dictyostelium discoideum



Synchronization

https://sciencedemonstrations.fas.harvard.edu/presentations/synchronization-metronomes

Brain processes (as a complex system.)

- Perceptual processing is not a passive process of reaction
- Perception does not begin with causal impact on receptors; it begins within the organism with internally generated (self–organized) neural activity that lays the ground for processing of future receptor input. In the absence of such activity, receptor stimulation does not lead to any observable changes in the cortex
- Perception is a self–organized dynamic process of interchange inaugurated by the brain in which the brain fails to respond to irrelevant input, opens itself to the input it accepts, reorganizes itself, and then reaches out to change its input
- We suggest that the self–organized process that replaces environmental input with an internally generated, chaotic activity pattern is one that gives "biological meaning" to the stimulus

- Def [SYNCRONIZATION]:
  A group of OSCILLATION that have the same FREQUENCY

- Def [OSCILLATION]: an element that has a FREQUENCY (a PERIOD) if some oscillation have the same frequency they are SYNCRONISED

COLLECTIVE BEHAVIOR

Fireflies synchronization

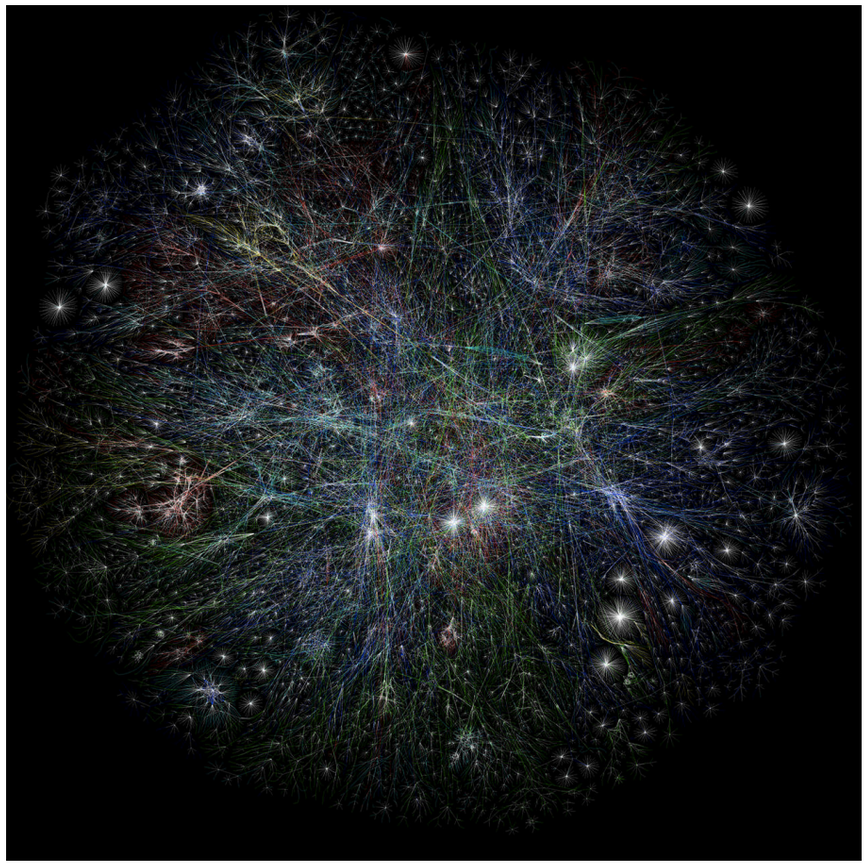
http://it.youtube.com/watch?v=sROKYelaWbo

Adaptation: a flock of birds

https://www.youtube.com/watch?v=V4f_1_r80RY

NETWORKS

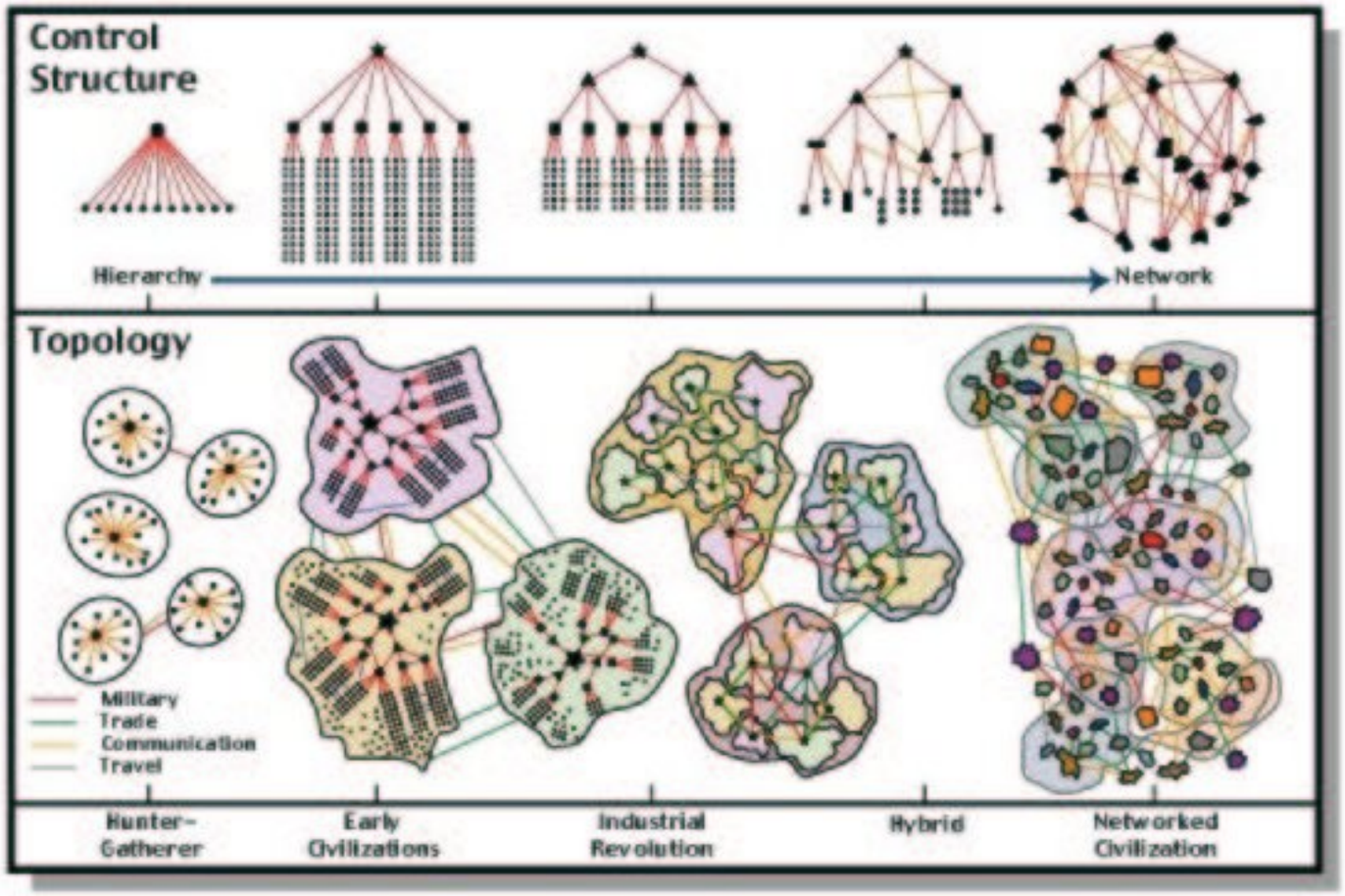
Networked systems



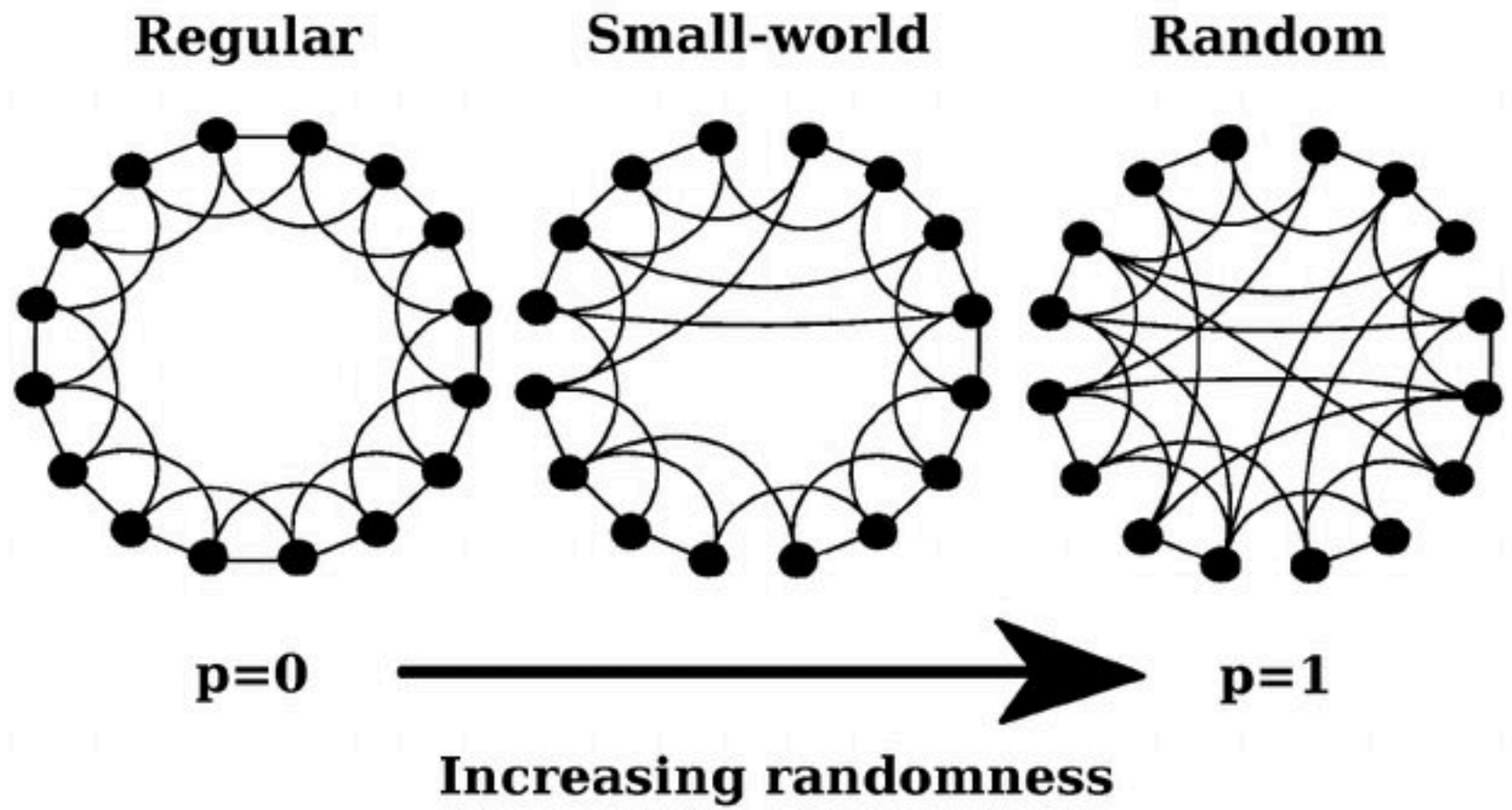
Internet

Social networks

Human civilization as a complex systems



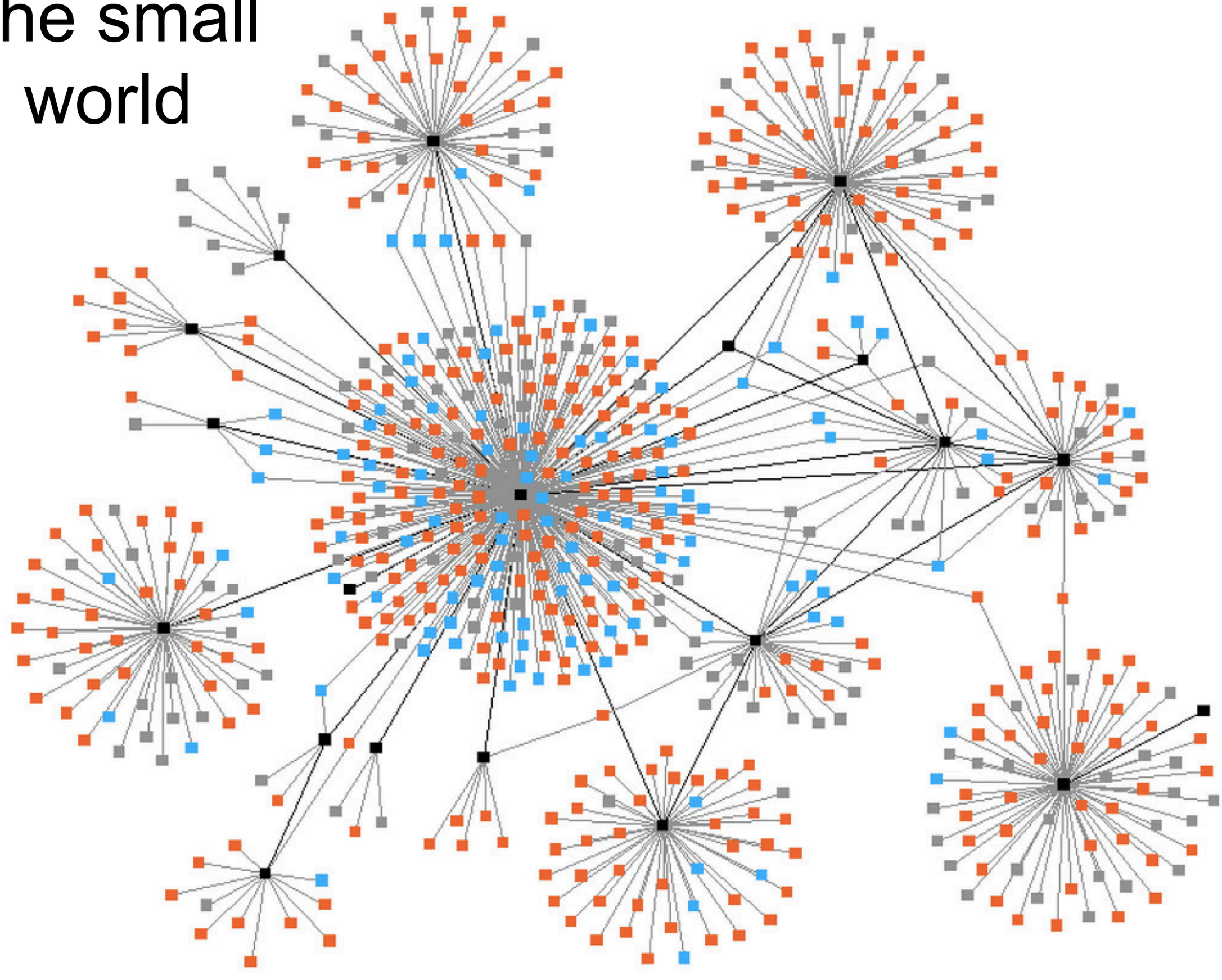
The complex networks



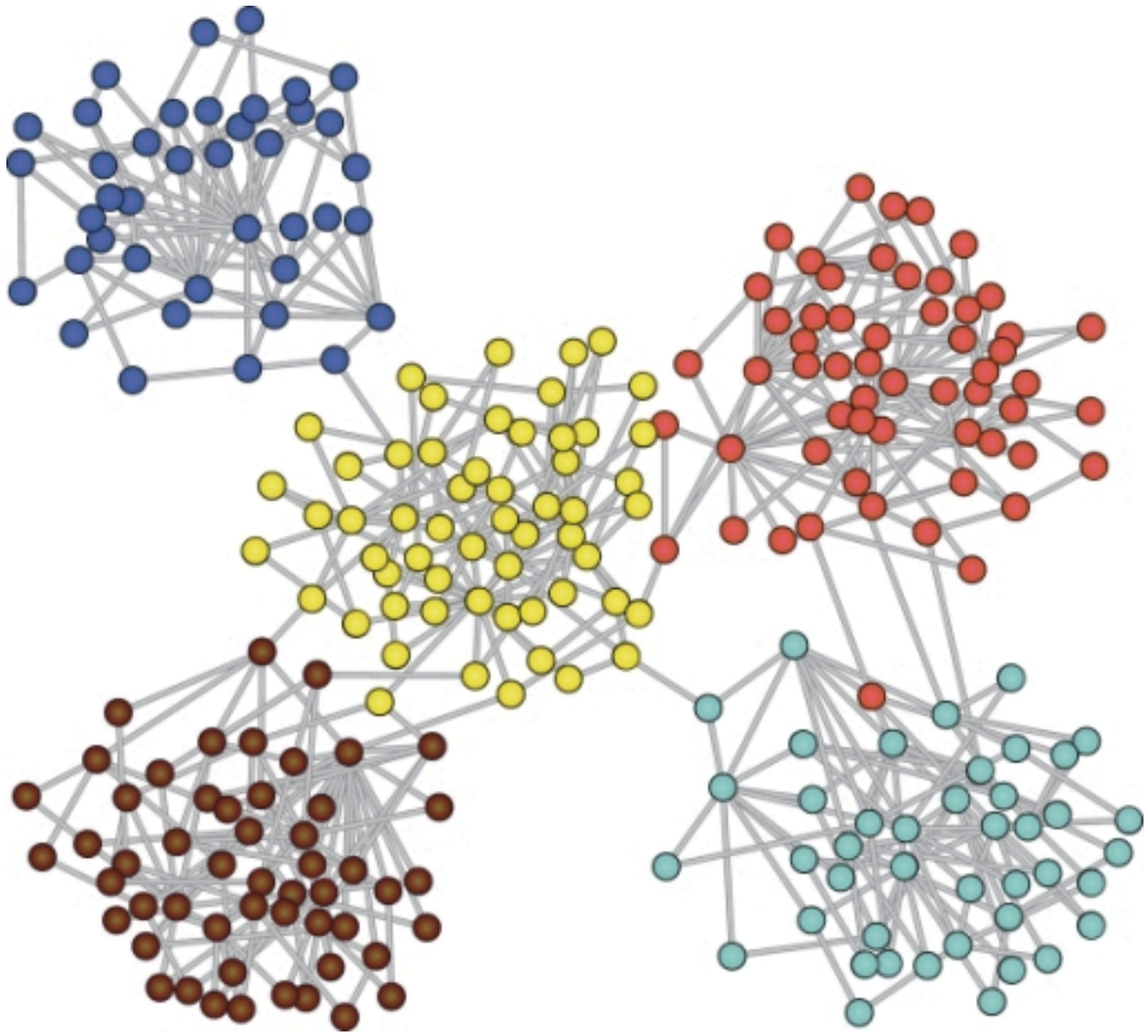
- Complex systems stands usually at the middle (the small-world example)

not completely random

The small world



Communities



Innovation Systems

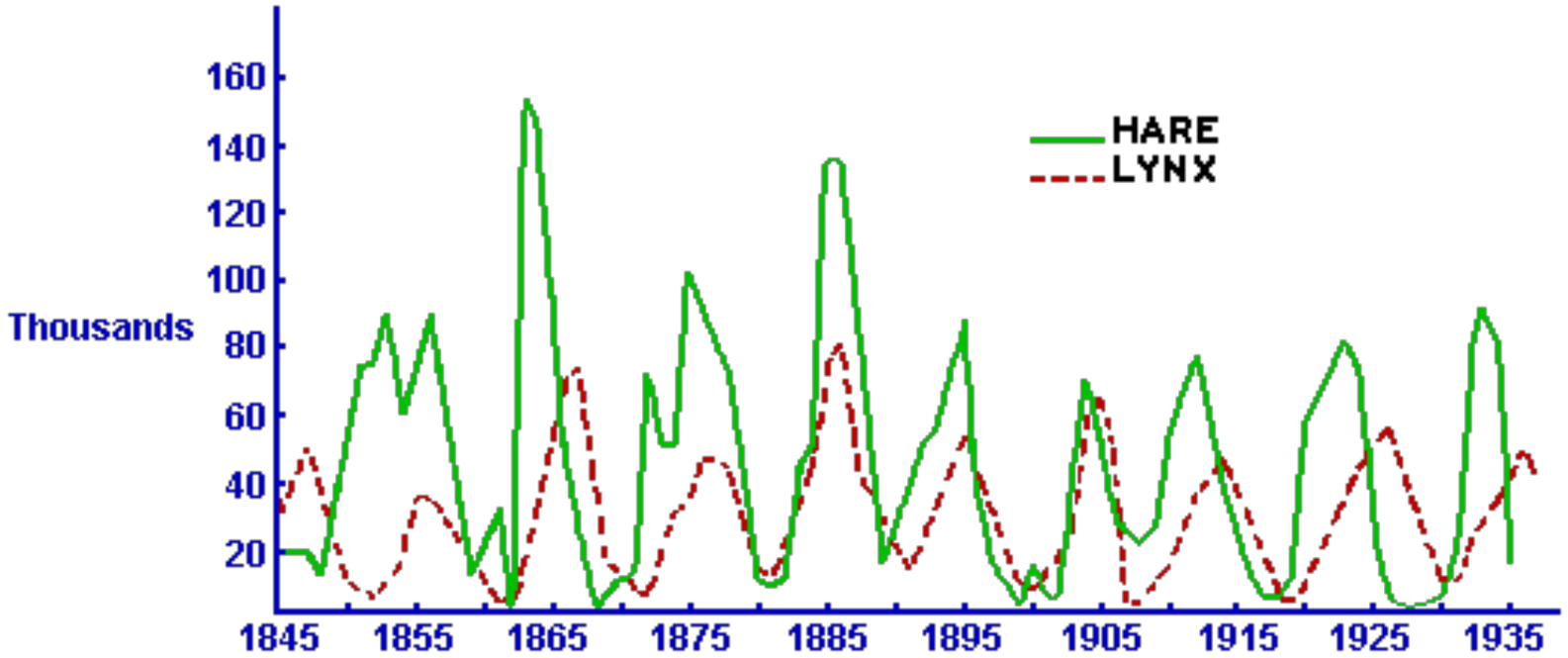
- An innovation system is a network of organisations within an economic system involved in the creation, diffusion and use of scientific and technological knowledge as well as the organisations responsible for the coordination and support of these processes.
- Innovation is strictly related to unknowability and unpredictability
- Innovation is a complex system, indeed it results from nonlinear relationships, self-organisation, emergence, and co-evolution

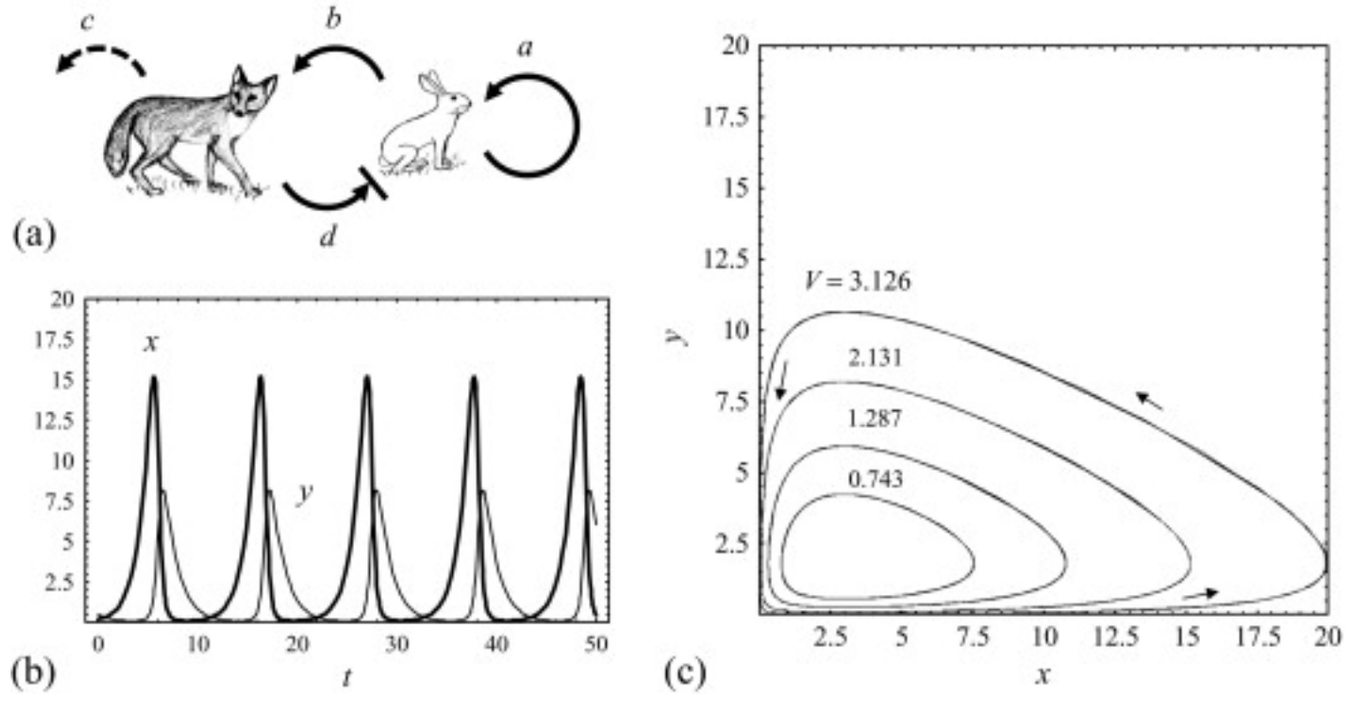
Managing the innovation

- While a company might be obsessed by having control over its own activities, it might not perceive that nascent threats are generated outside of its control, and are therefore unpredictable
- Proper use of the complexity thinking mindset would allow organisations to operate comfortably in both market as well as non market conditions, diversifying their scope as well as their research and development effort
- Complexity management recently emerged at top of the agenda due to new technology enablement, leading to detailed analytics and simulation of complexity optimization measures and their related domino effects within the entire value chain (scale invariance)

EVOLUTION AND ADAPTATION

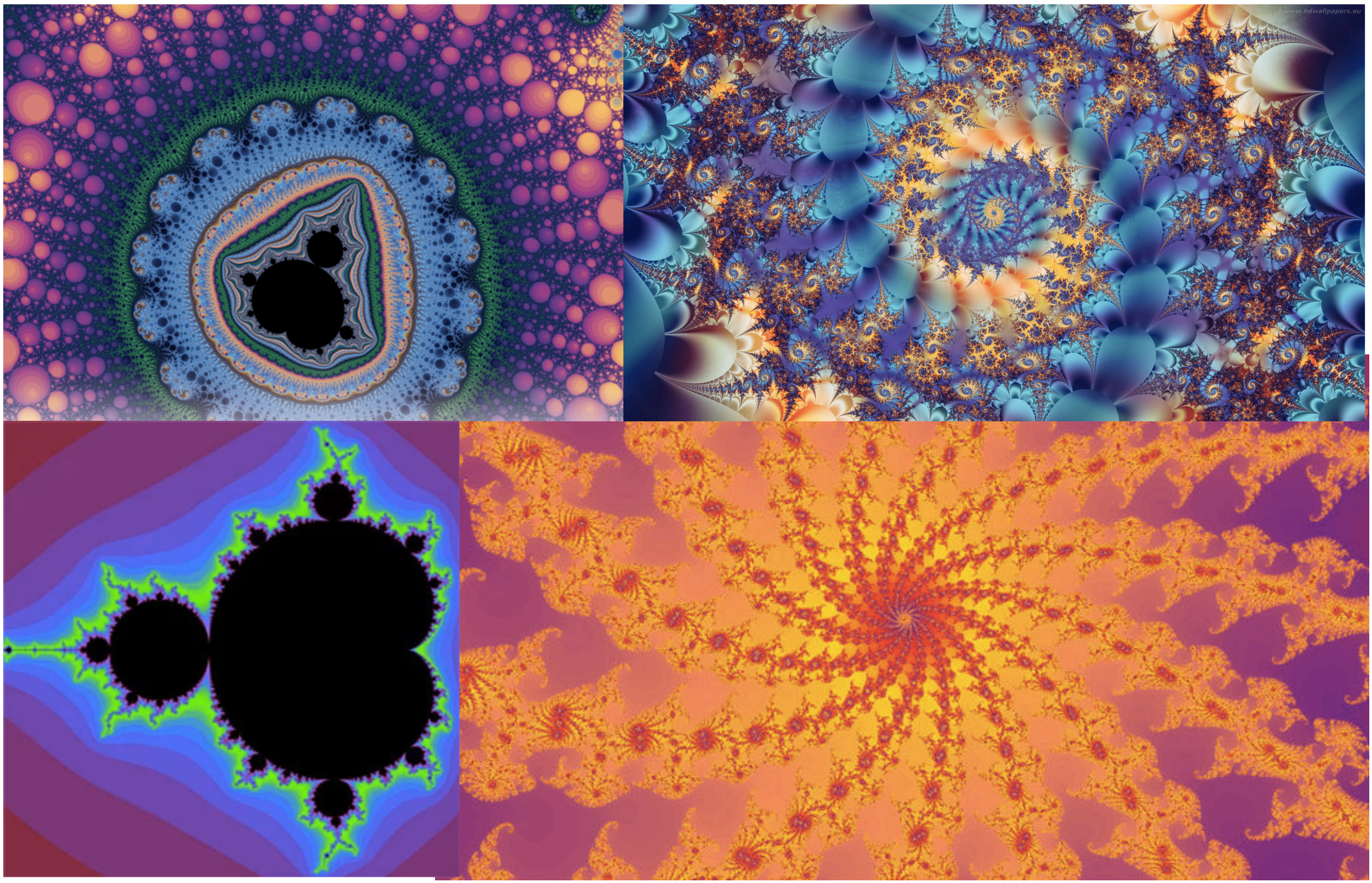
The Lotka-Volterra Model of competition





PATTERN FORMATION

Fractals



https://www.youtube.com/watch?v=PD2XgQOyCCk

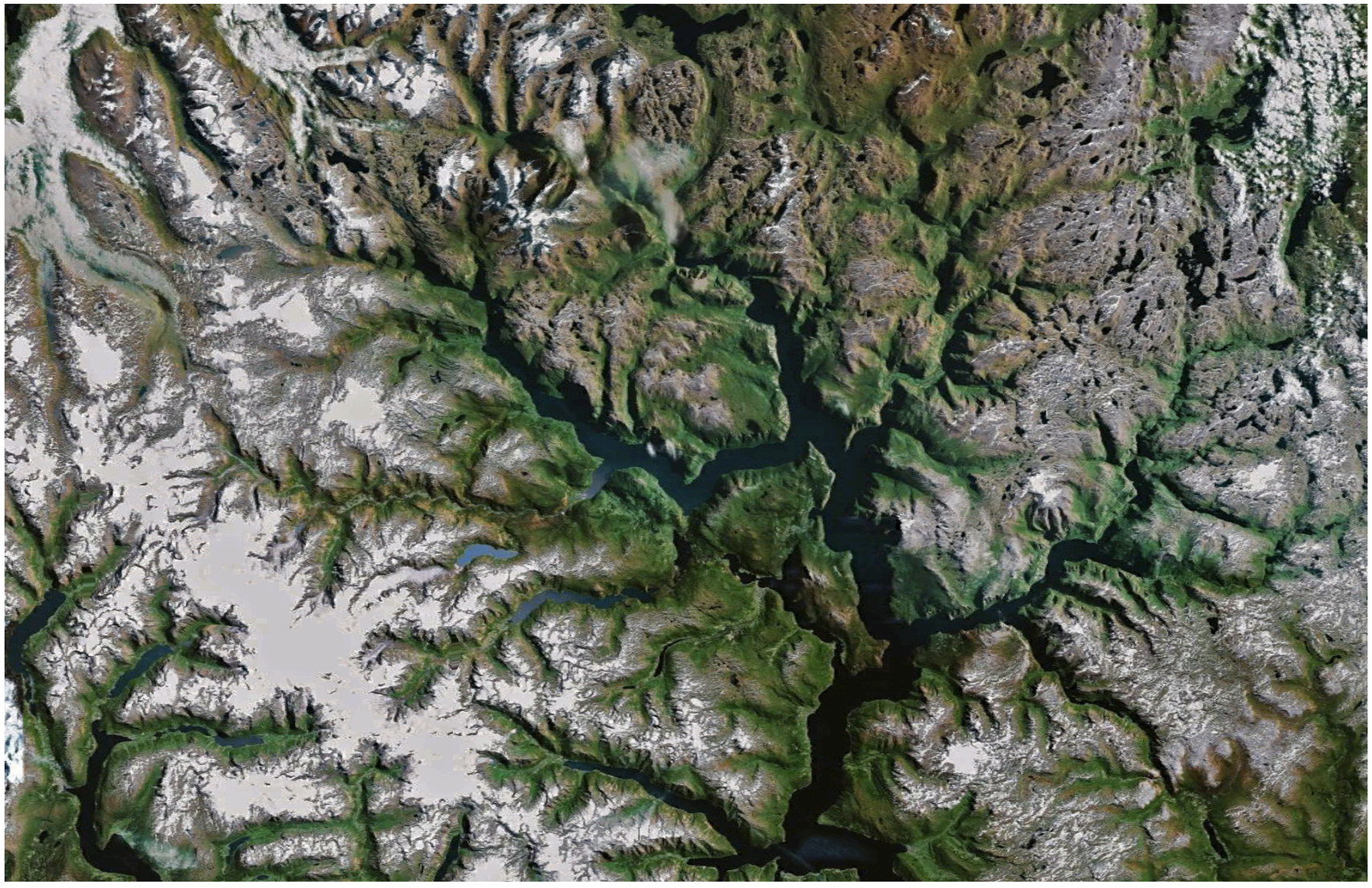
Fractals in nature: the fern leaf

http://www.youtube.com/watch?v=XwWyTts06tU

Trees

- Surface of fractals is immensely greater in respect to a simple sfear of the same volume, usefull for plants to capture sun-light

Satellite images: mountains and rivers



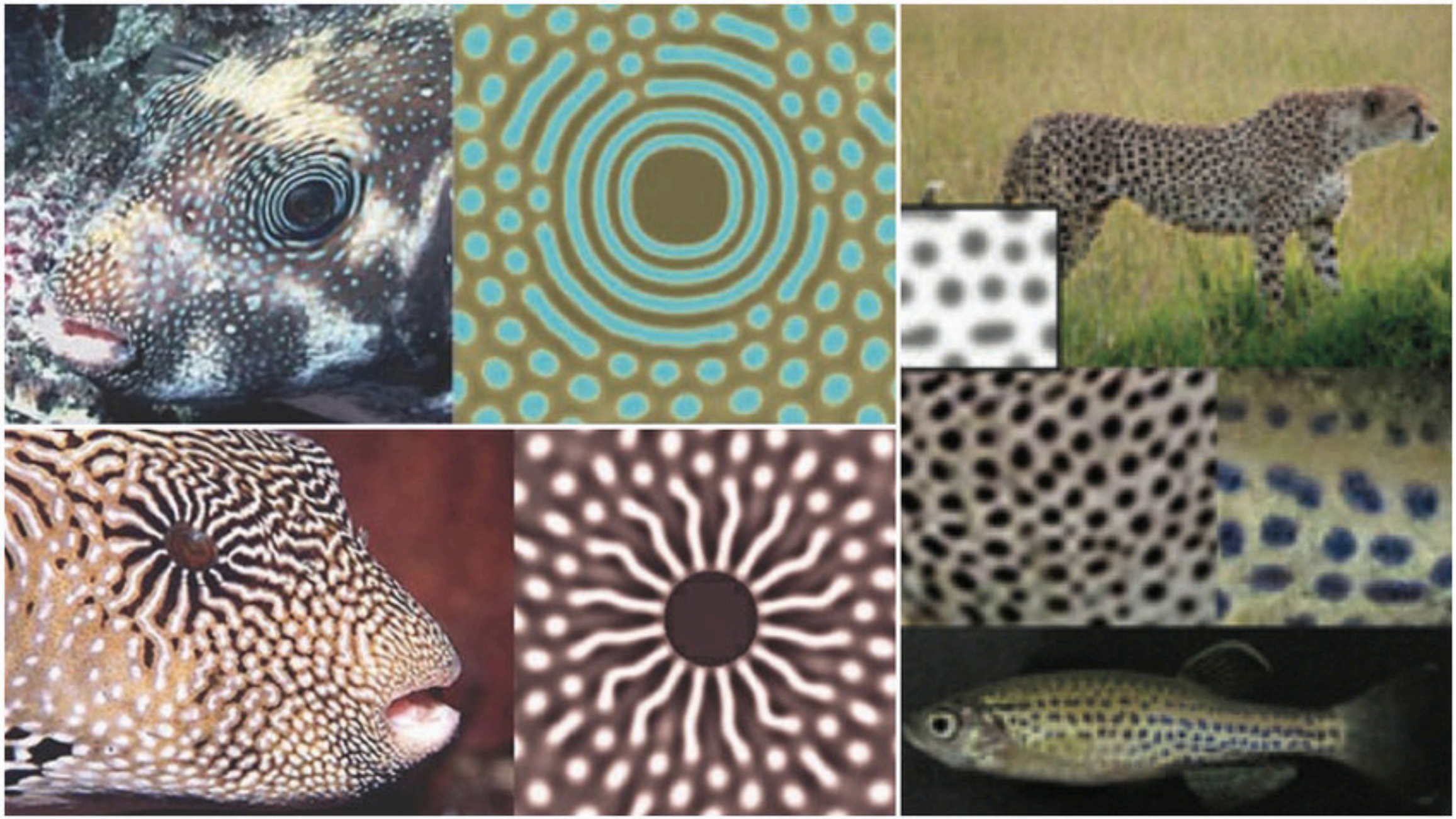
The Romanesco Broccoli

Patterns and structures: Alan Turing

The Chemical Basis of Morphogenesis (1952) by the English mathematician Alan Turing describes the way in which non-uniformity (stripes, spots, spirals, etc.) may arise naturally out of a homogeneous, uniform state.
The theory of morphogenesis has served as a basic model in theoretical biology and is seen by some as the very beginning of chaos theory

Morphogenesis : starting from a stemmed (general-purpose) element, those cells differentiate creating structure

Morphogenesis

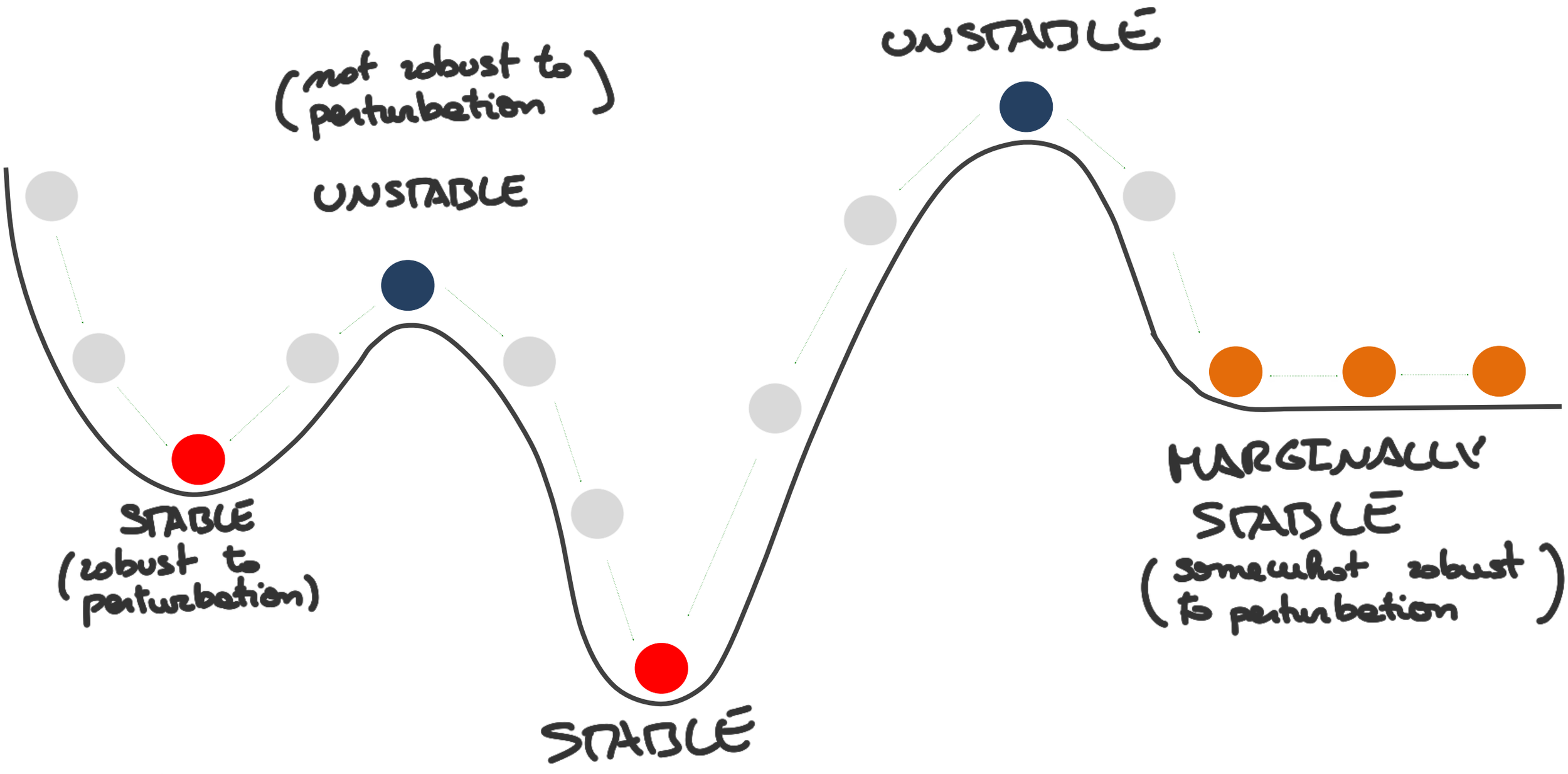


SYSTEMS THEORY

Some concepts

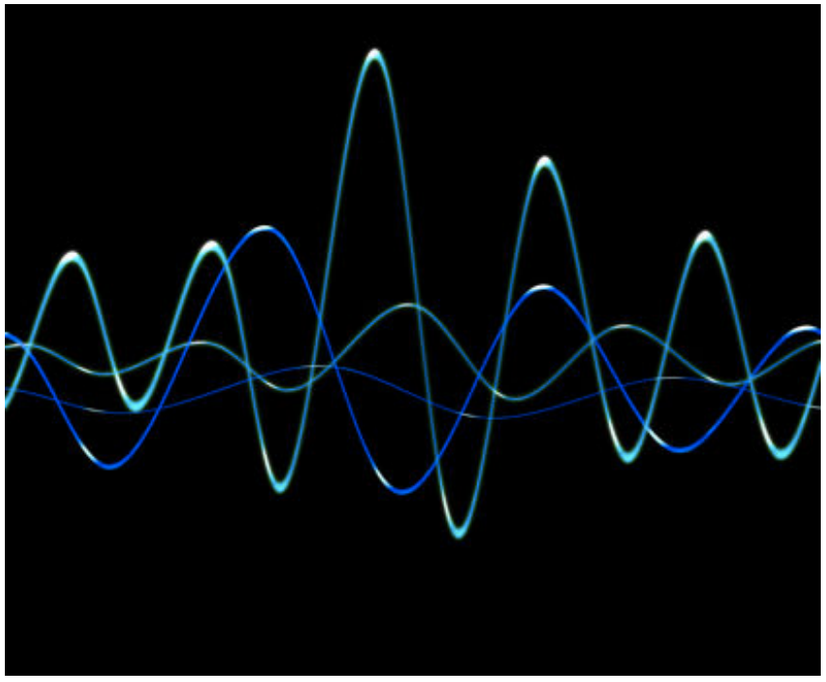
- Static systems and dynamic systems
- Continuous and discrete time
- Finite time and asympthotic time
- Linear and nonlinear
- Satbility and Instability

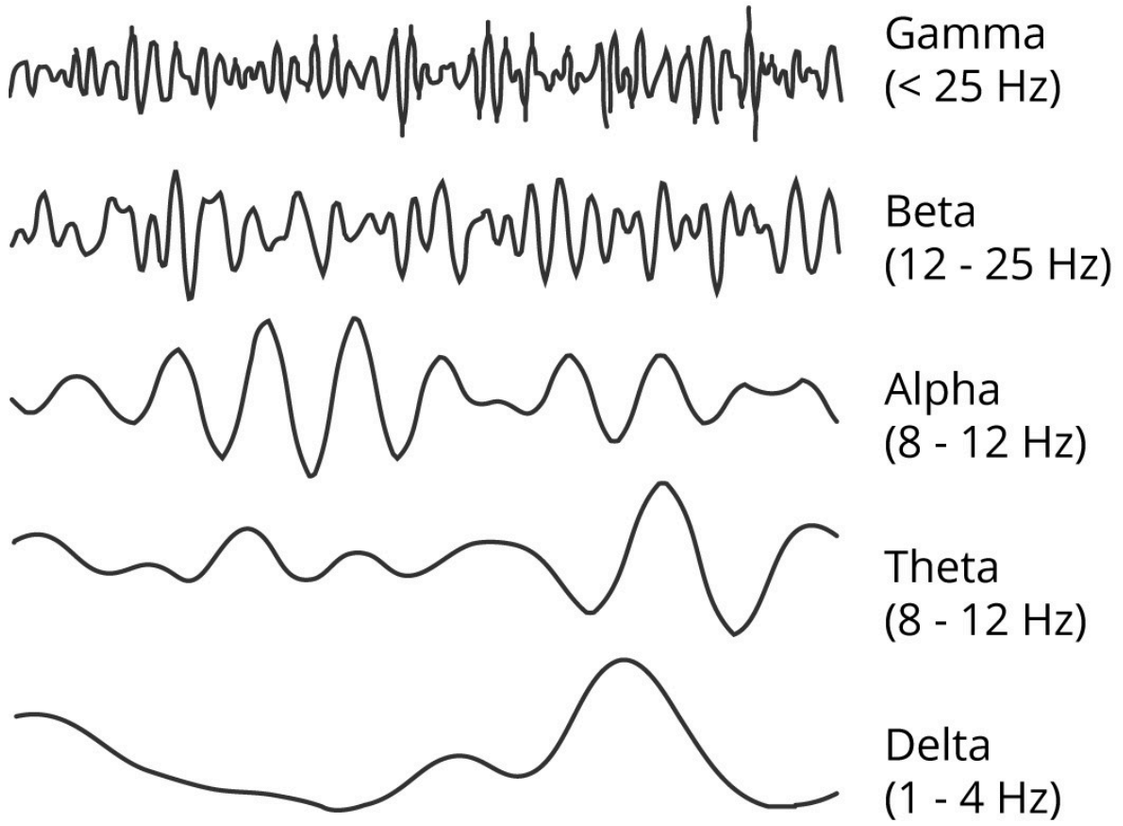
Stability and Instability



(all are STEADY STATES)

Oscillations



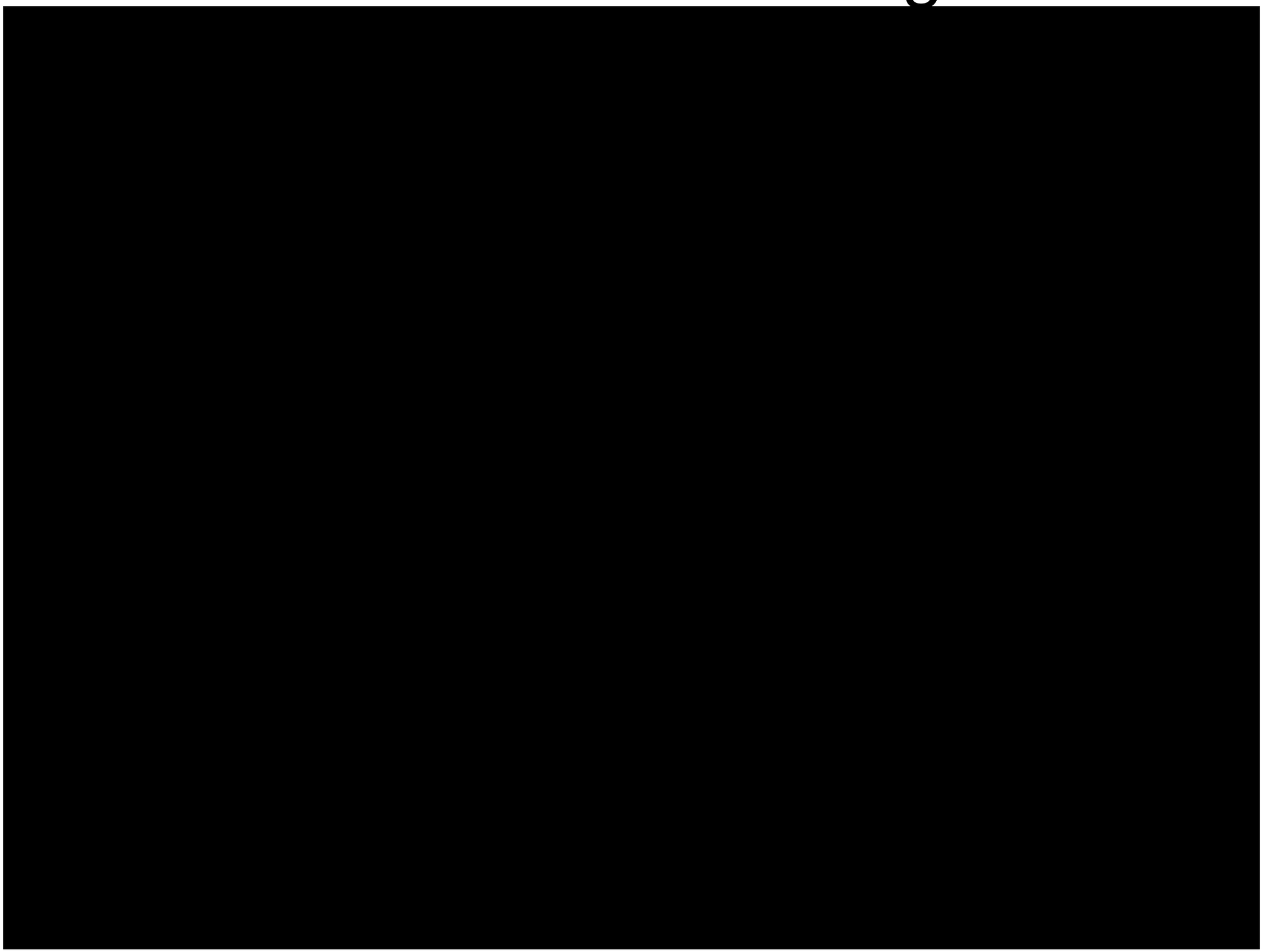


In linear systems oscillations are non robust

In nonlinear systems robust oscillations are possible

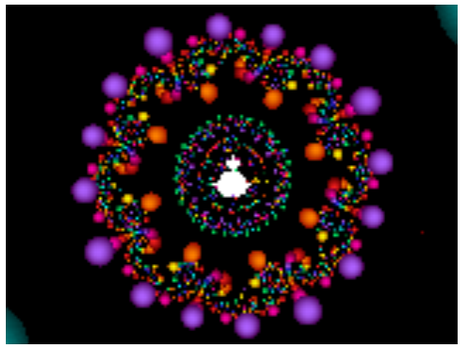
In nonlinear systems robust oscillations can be multifrequency

The Millennium bridge



https://www.youtube.com/watch?v=eAXVa__XWZ8

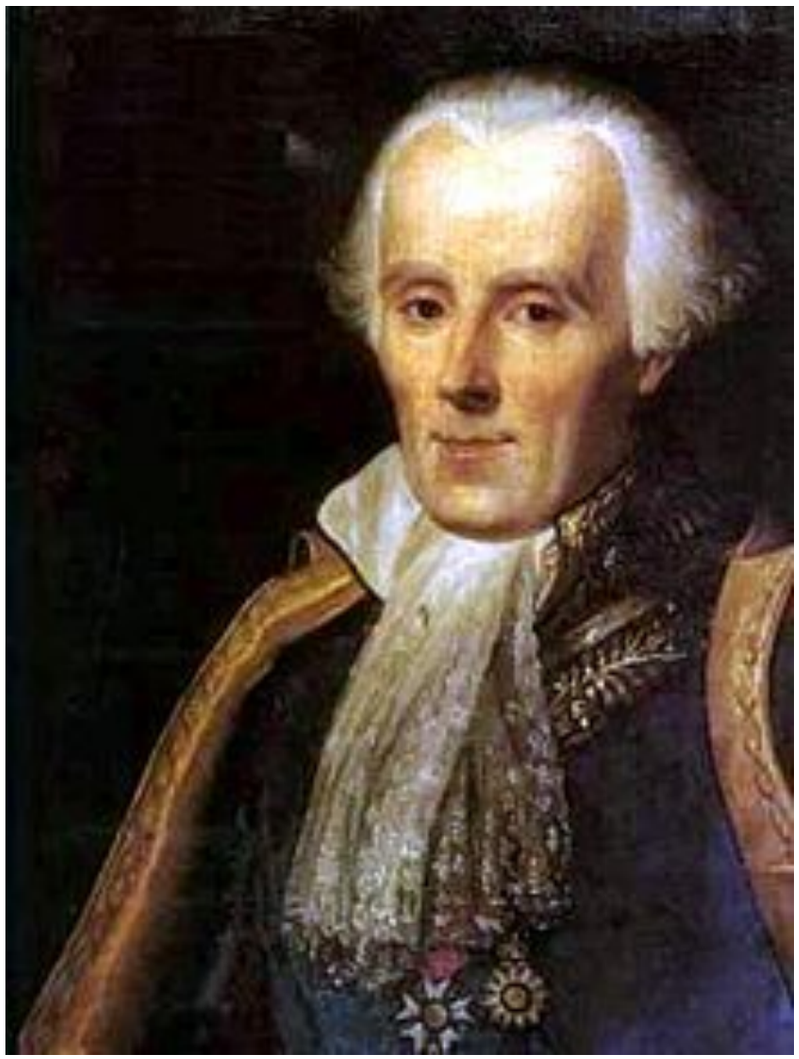
NONLINEAR DYNAMICS



Notes from history and philosophy

- Plato and Pythagoras: everything in nature is a manifestation of the mathematical regularity
- Galileo: “The book of nature is written in the mathematical language, and the symbols are triangles, circles and other geometrical figures” (1623)
- Newton: “Nature has its own laws and we can understand the regularities by means of mathematics” (1687)

Pierre-Simon de Laplace



“An intelligence that, at a given instant, could comprehend all the forces by which nature is animated and the respective situation of the beings that make it up, if moreover it were vast enough to submit these data to analysis, would encompass in the same formula the movements of the greatest bodies of the universe and those of the lightest atoms. For such an intelligence nothing would be uncertain, and the future, like the past, would be open to its eyes.” (1825)

· It was demonstrated that such an intelligence isn't sufficient

Henri Poincaré (1854-1912)

Poincaré introduced a new branch of mathematics: the qualitative theory of differential equations. He showed how it is possible to derive the most important information about the behavior of a family of solutions without having to solve the equation (since this may not always be possible).

- Is a system STABLE or UNSTABLE ?

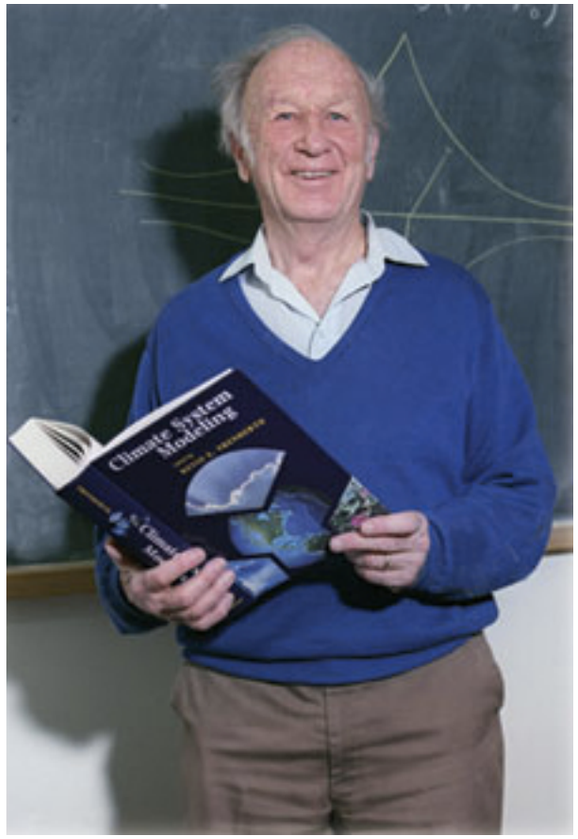
Henri Poincaré

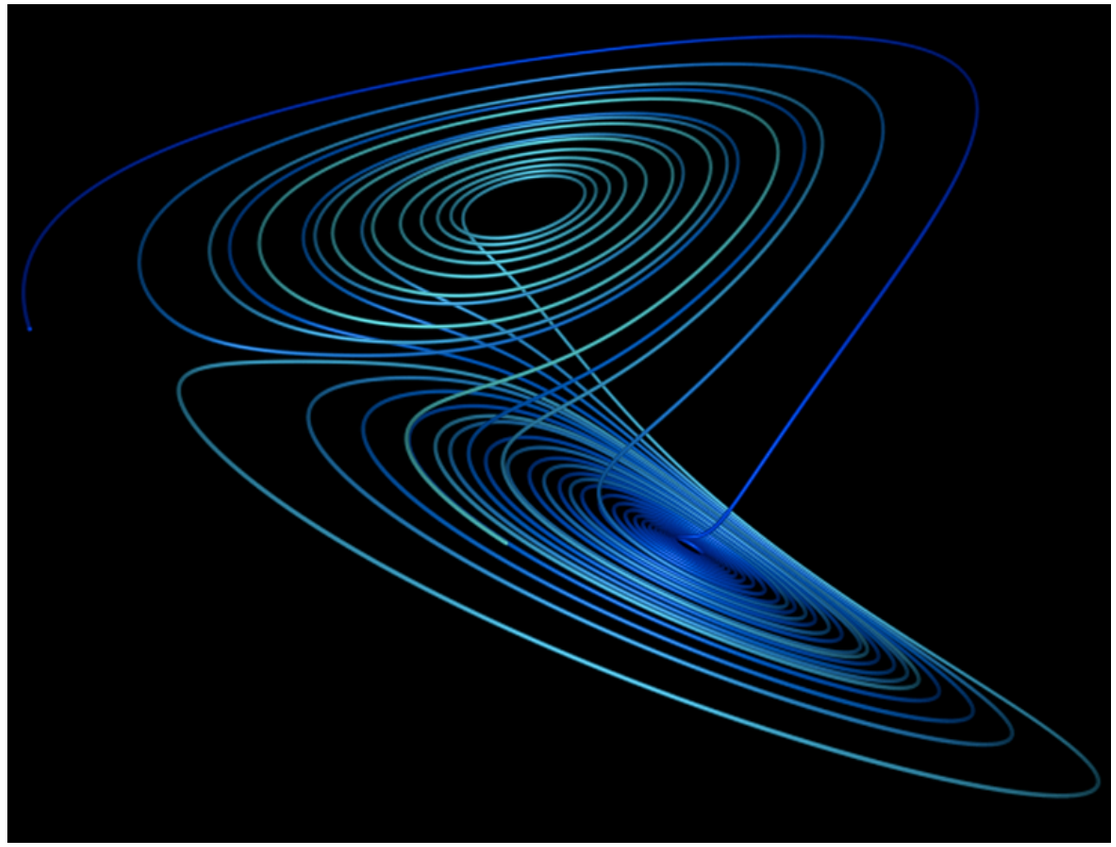
- A very small cause which escapes our notice determines a considerable effect that we cannot fail to see, and then we say that the effect is due to chance
- Even if it were the case that the natural laws had no longer any secret for us, we could still only know the initial situation approximately

Henri Poincaré

- If that enabled us to predict the succeeding situation with the same approximation, that is all we require, and we should say that the phenomenon had been predicted, that it is governed by laws
- But it is not always so - it may happen that small differences in the initial conditions produce very great ones in the final phenomena. A small error in the former will produce an enormous error in the latter... (1903)

The Lorenz attractor





Edward Lorenz discovered deterministic chaos in meterological systems and introduced the concept of *butterfly effect*

Chaos Theory

· What is Chaos Theory ?

- Chaos theory studies the behavior of nonlinear dynamic systems that are highly sensitive to initial conditions (the *butterfly effect)*
- Small differences in initial conditions yield widely diverging outcomes for such dynamical systems, rendering long-term prediction impossible in general
- This happens even though these systems are deterministic, meaning that their future behavior is fully determined by their initial conditions, with no random elements involved
- The deterministic nature of these systems does not make them predictable

Characteristics of Chaotic systems

- Deterministic systems
- Nonlinearity
- Aperiodic behavior
- Sensitivity to initial conditions
- Stretching and folding
- Infinite repulsive cycles
- Emerging patterns
- Adaptation

Something to read

- Strogatz S. Nonlinear Dynamics and Chaos (1994)
- Peitgen H.O., The Beauty of Fractals (1986)
- Stewart I., Does God Play Dice? The New Mathematics of Chaos (1989)
- Gleick J., Chaos. Making a New Science (2008)

To watch

Chaos, interview to James Gleick

http://www.youtube.com/watch?v=3orIIcKD8p4

The movie Jurassic Park

ENG: http://www.youtube.com/watch?v=n-mpifTiPV4

ITA: http://www.youtube.com/watch?v=iTIJR-kyBao