

How Do Things Evolve?

**How do things change,
become more complex,
through time?**

Earth about 4.0 Ga.

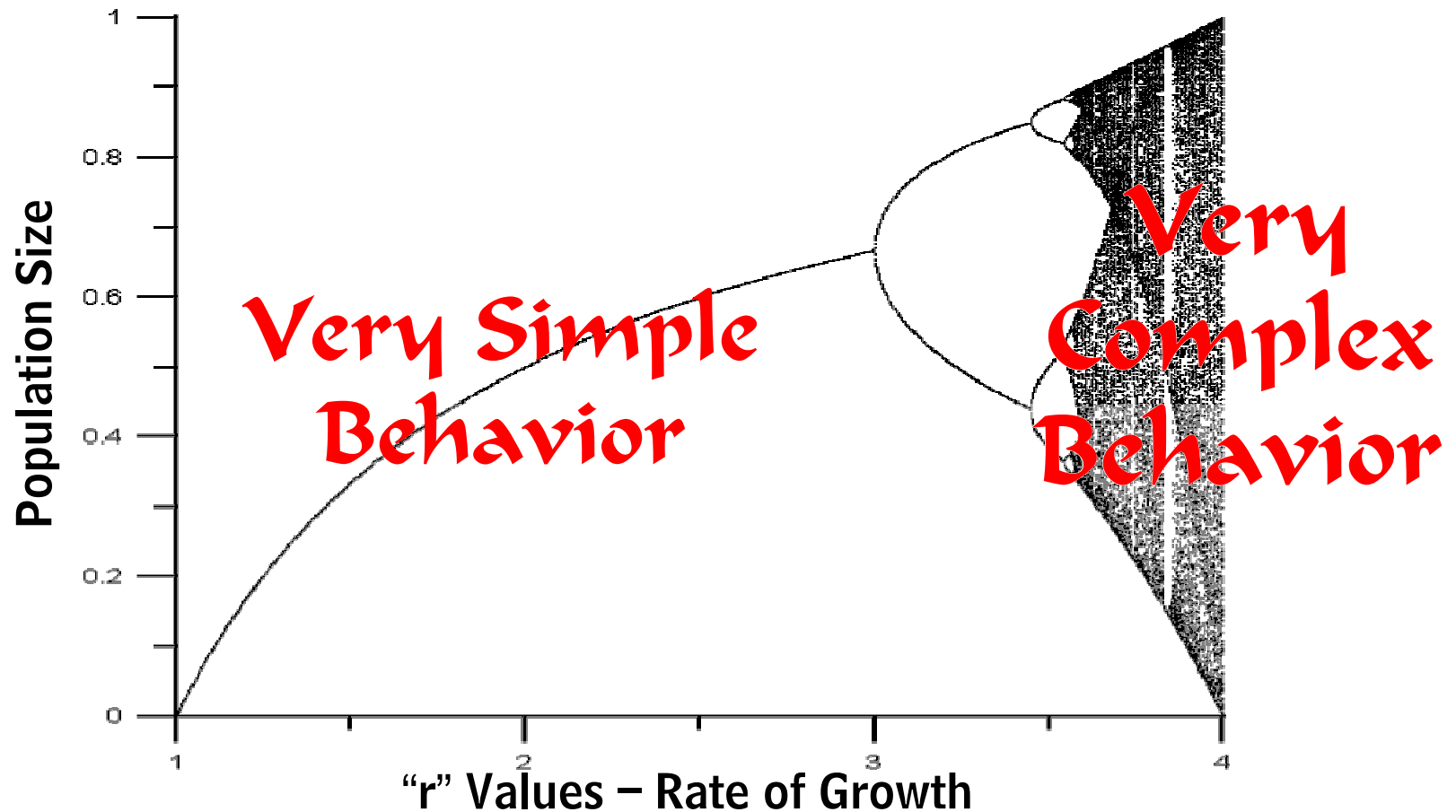
**Ok, we have created the
Earth**

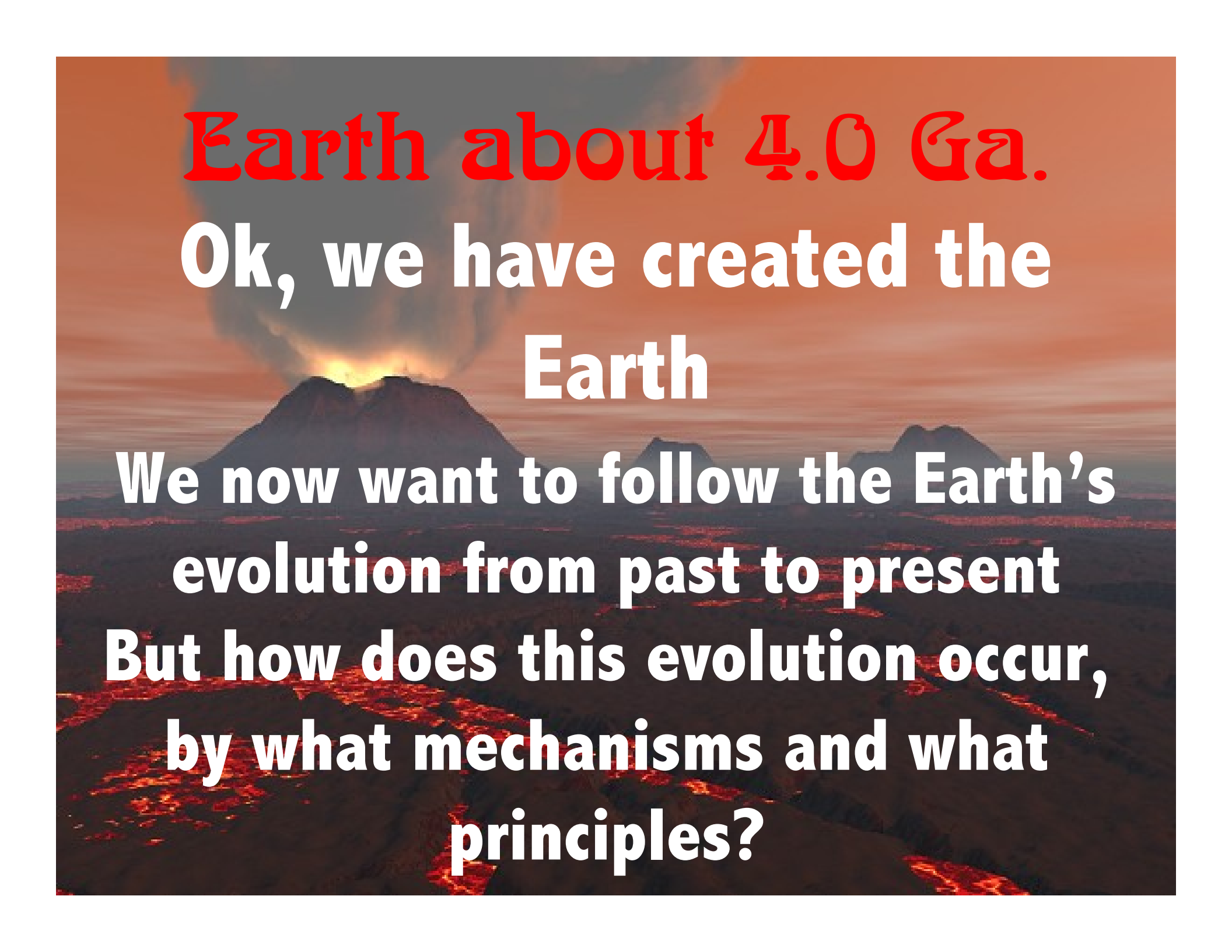


MODELING AN EVOLUTIONARY SYSTEM

Bifurcation Diagram

And we have observed that if we put enough energy through a system its behavior evolves to greater and greater complexity . . .





Earth about 4.0 Ga.

**Ok, we have created the
Earth**

**We now want to follow the Earth's
evolution from past to present
But how does this evolution occur,
by what mechanisms and what
principles?**

How Do Things Evolve?

Ask the average person on the street what the theory of evolution is

. . . and they are likely to answer

- Natural selection ?
 - Darwin's theory of evolution?
 - Survival of the fittest?
- a.k.a.
The Modern
Synthesis

But, biological things are not the only things that evolve.

- Economies evolve.
- Cities evolve.
- Political systems evolve.
- Earthquake systems evolve.
- Earth Environments evolve.
- Neural networks in the brain evolve.
- Elements in stars evolve.

Evolution just means change through time.

So, if we are to assume that biological evolutionary theory is a general theory of evolution . . .

. . . THEN . . .

. . . What in an economic system is equivalent to . . .

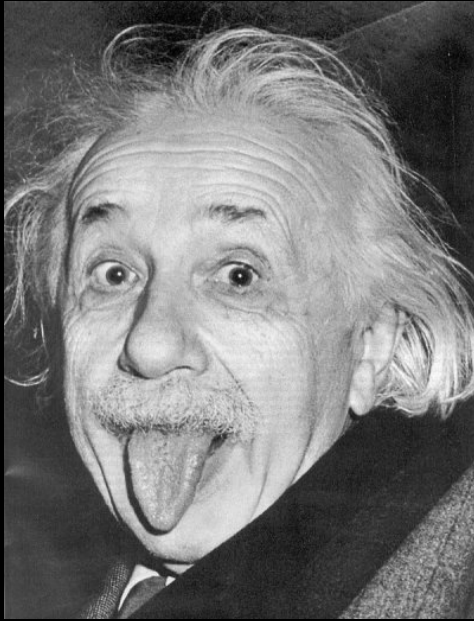
- A Gene?
- An individual?
- A species?
- A mutation and genetic recombination?

Is it accurate to say economic systems evolve like biological systems?

If biological things evolve and economies evolve . . .

And we cannot make a direct one-for-one comparison of the units and processes between them . . .

Then Darwinian evolutionary theory (the Modern Synthesis) is a **special case** of evolution, not a general case.



Einstein's special and general theories of relativity.

The **special theory** applies the principle of relativity only to inertial frames i.e. does not account for gravity, but it can deal with accelerations.

The **general theory** applies the principle of relativity generally, that is, to any frame including gravity.

A General Evolutionary Algorithm

1. Differentiate
 2. Select
 3. Amplify
- Repeat

*So, is this the general
theory of evolution we
are looking for ?*

*The units of selection and the information
carriers are different in each kind of system
but the algorithm is the same . . .*

Well, not really . . .

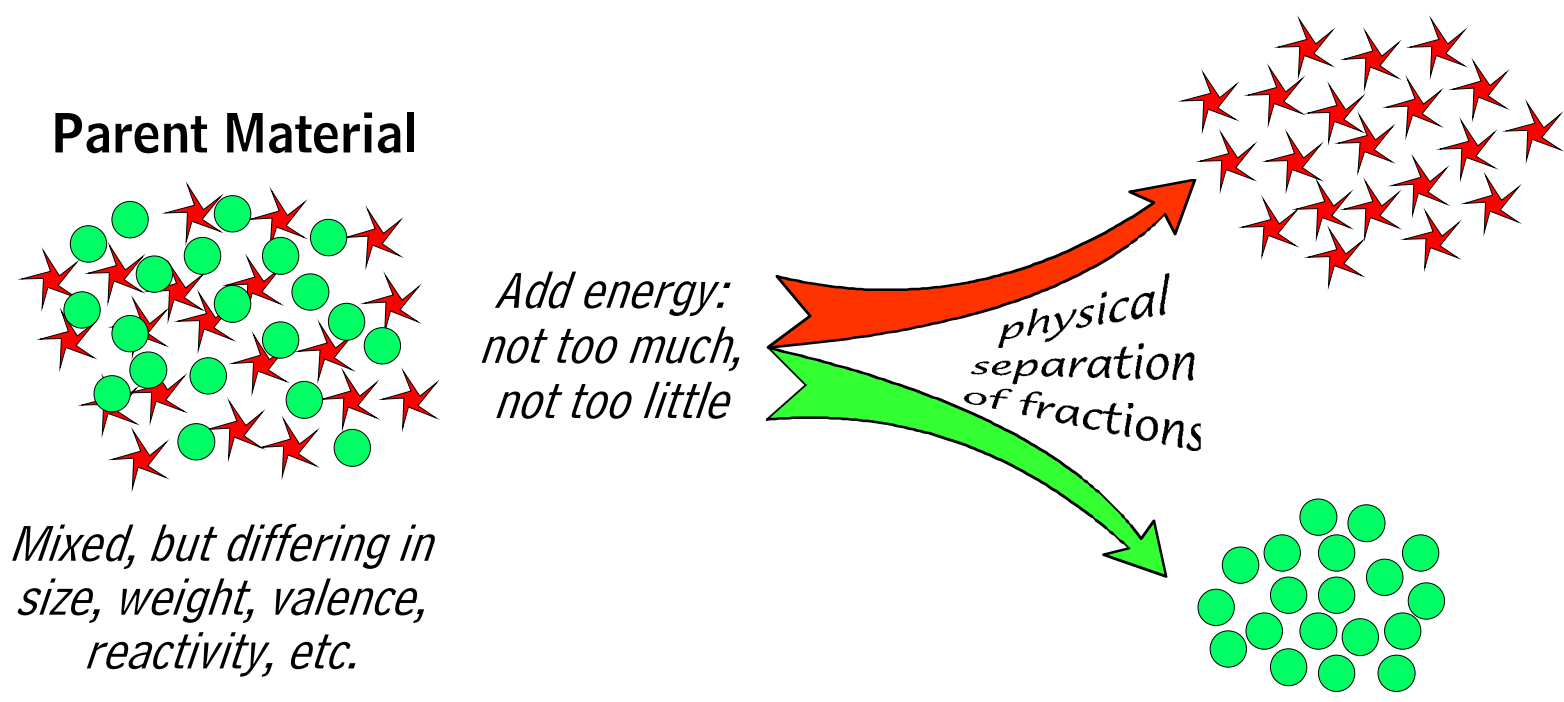
Differentiate, select, and amplify do not really explain how . . .

- Rocks evolve
- The atmosphere has evolved
- The Earth has evolved

They evolve by completely different mechanism from the evolution of life and it is meaningless to talk about life evolution without the evolution of Earth environments

EVOLUTION BY FRACTIONATION

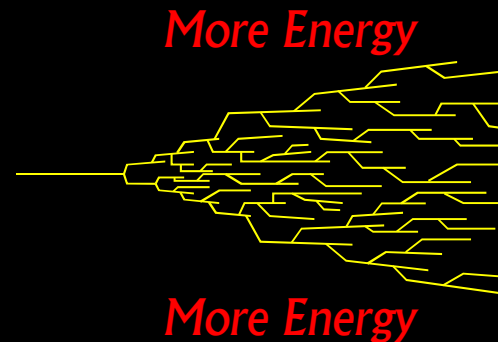
Fractionation - also called differentiation - is the separation of components of a whole into fractions each of which has a different composition from the whole.



This means there are at least two General Evolutionary Algorithms . . .

1. Elaborating evolution

Begin with something simple and increase its abundance, diversity, and complexity with time.



Systems increase in

- Abundance
- Complexity
- Diversity

2. Fractionating evolution

Begin with something complex and subdivide it into fractions.

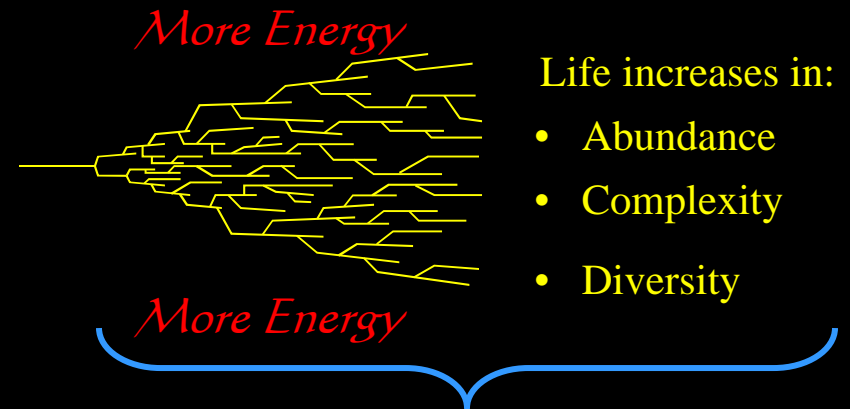
Is this it then – two theories of evolution?

Elaborating Evolutionary theory

Fractionating Evolution theory

Hummm . . .

An Example of the Problem



General Evolutionary
Algorithm

→ *How can something be naturally
selected for before it exists?*

Self Organization

Self-organization is a process of evolution where the effect of the environment is minimal, i.e. where the development of new, complex structures takes place primarily in and through the system itself.

● *But, such a process violates the 2nd law of thermodynamics*

> *Entropy always increases*

> *Disorder always increases*

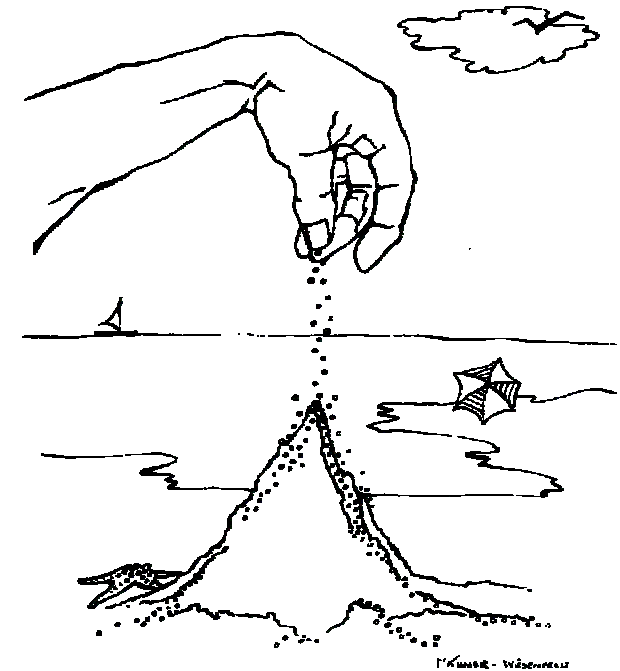
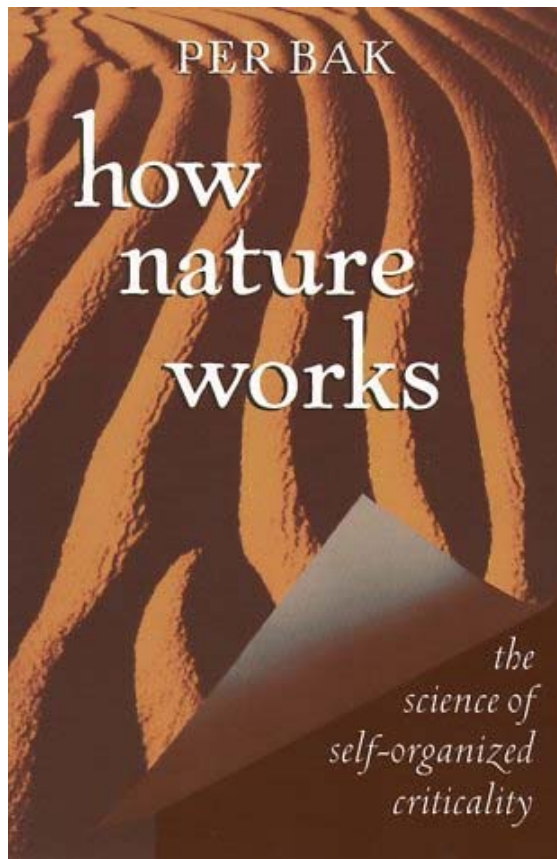
→ **Can a random process violate the second law, that is, result in an increase in order with time; i.e. self organize itself, pull itself up by its own bootstraps so to speak?**

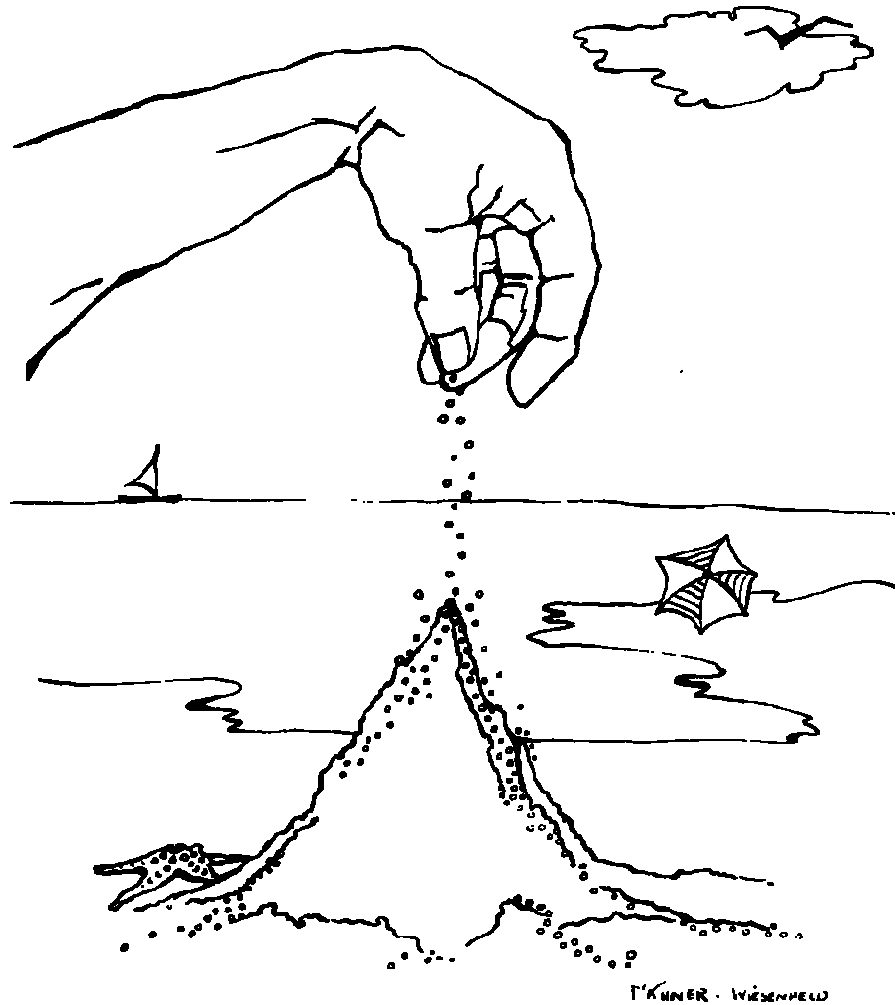
Self Organizing Theories

Other General Theories of Evolution
Through Time

Evolution Via Self Organization

Self Organized Criticality P 16

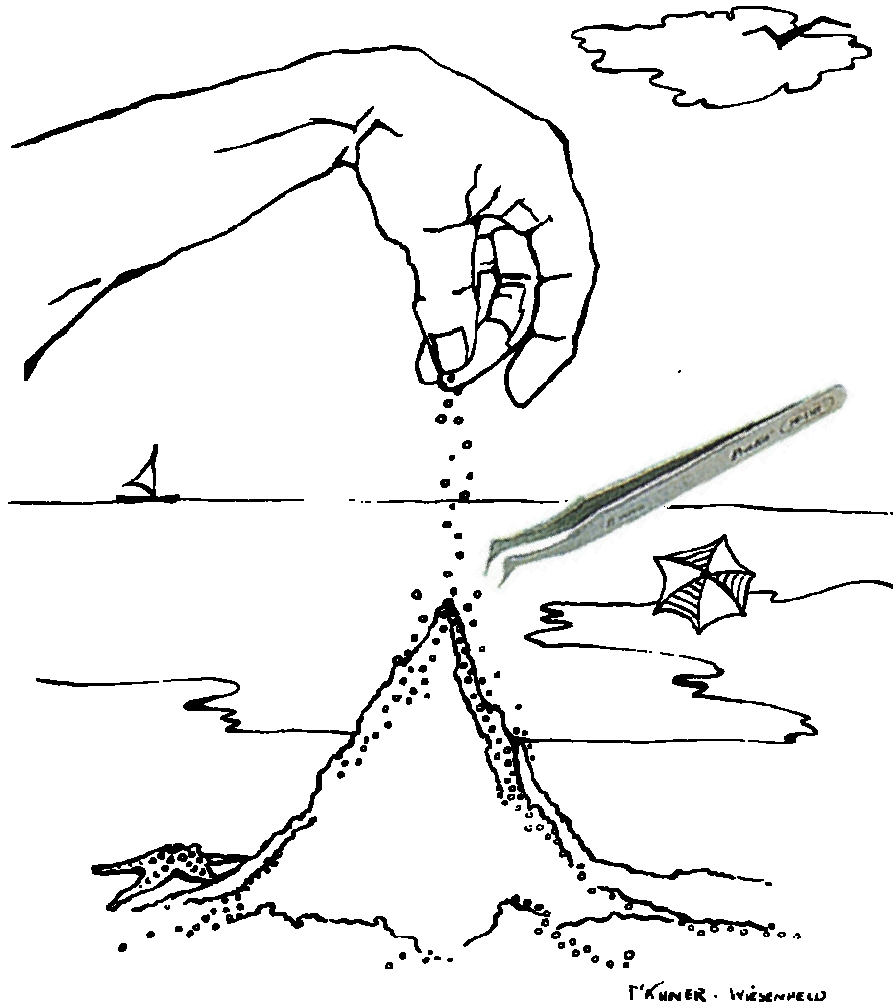




Elongated grains of rice sliding and bouncing down the slope of a pile confined between two vertical glass plates. Grains dropped on the top trigger avalanches that come in all sizes.



Once the sand pile is critical,
... It cannot back down
gracefully



Evolution Via Self Organization

Oscillating Chemical Reactions

Boris P. Belousov

(1893-1970)



Temporal Oscillations

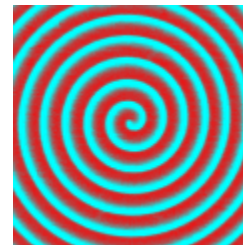
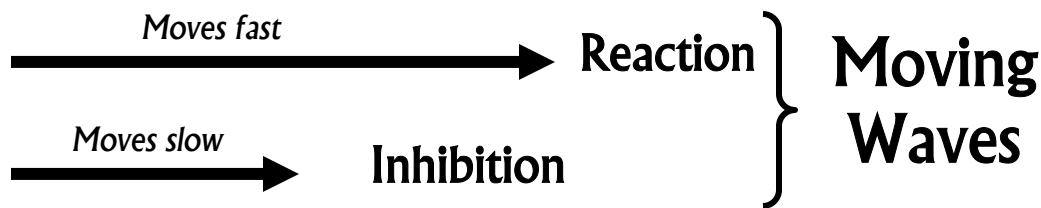


Spatial Oscillations.

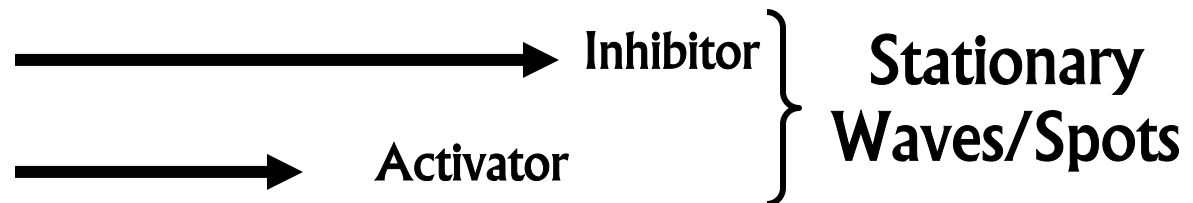


Self Organizing Chemical Systems

Reaction-Diffusion and Activator-Inhibitor Systems



<http://delfin.klte.hu/~gasparv/menuh.html>



Activator-Inhibitor Systems in Biology

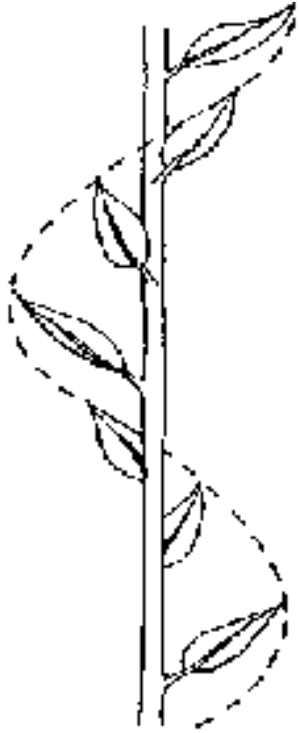


From patterns in animal hides, butterfly wings, and shells, to the distribution of organisms in a ecosystems, activator-inhibitor systems provide explanatory mechanisms.

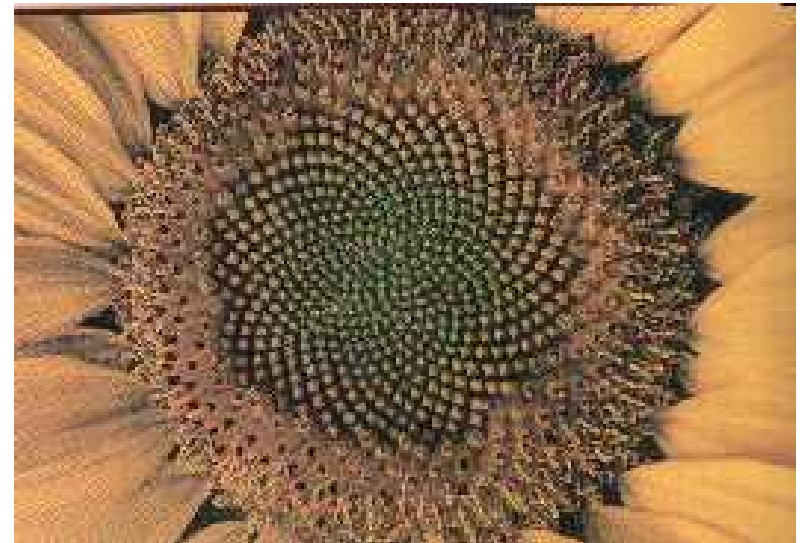


Reaction Diffusion Systems

Fibonacci Spiral Phyllotaxis in plants



<http://www.drjax.co.uk/144%20html%20pages/139.html>



Evolution Via Self Organization

Network Theory – Graph Theory

How Everything Is Connected to
Everything Else and What It Means for
Business, Science, and Everyday Life

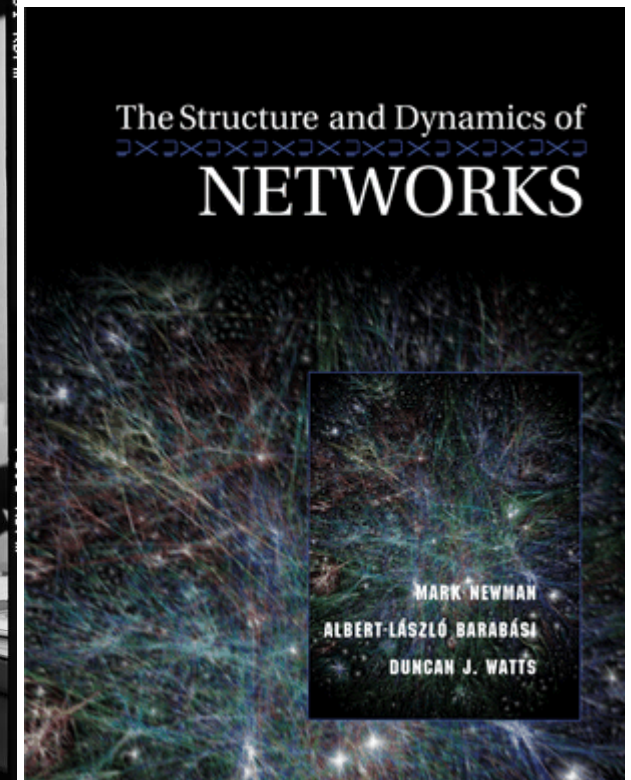
Linked



"*Linked* could alter the way we think about all of the networks that affect our lives." —*The New York Times*

Albert-László Barabási

With a New Afterword

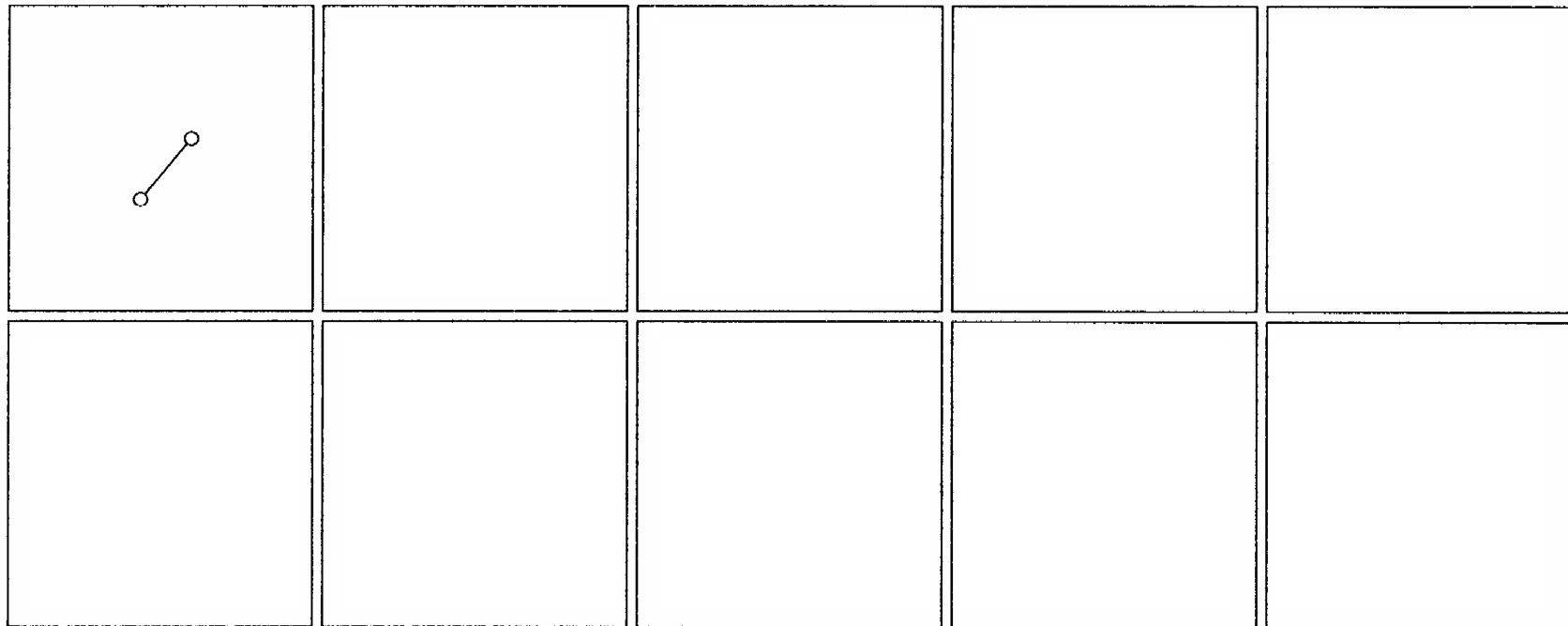


General Rules of Network Growth

The network starts as a nucleus, a node.

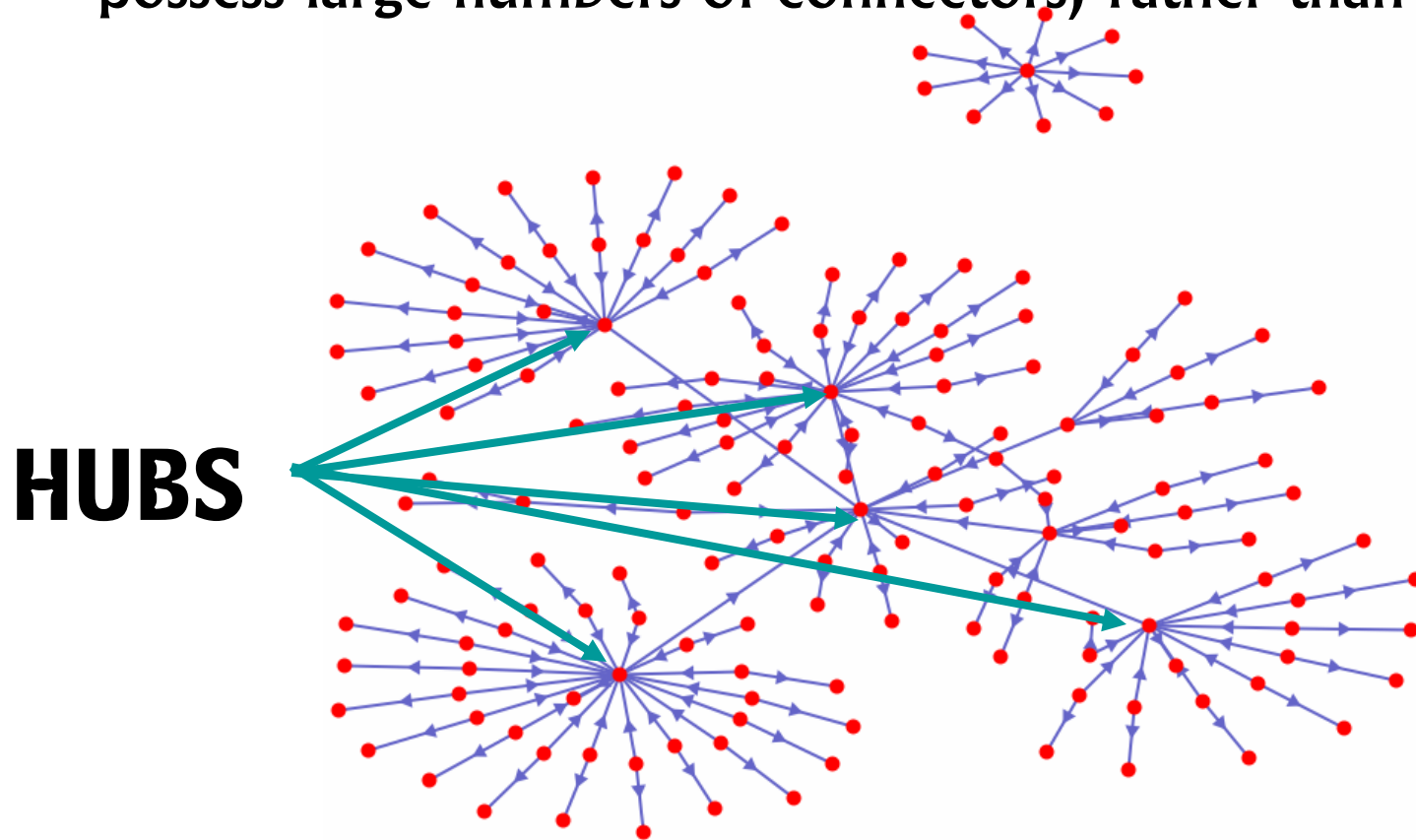
Rule 1 – Growth: *for each given period of time add a new node to the network, one node at a time.*

Rule 2 – Preferential attachment: *each node attracts new links at a rate proportional to the number of its current links.*



The World of Hubs and Connectors

Unlike random and small world networks the WWW is organized with nodes that become hubs when they come to possess large numbers of connectors, rather than just a few.



A New Testament Social Network



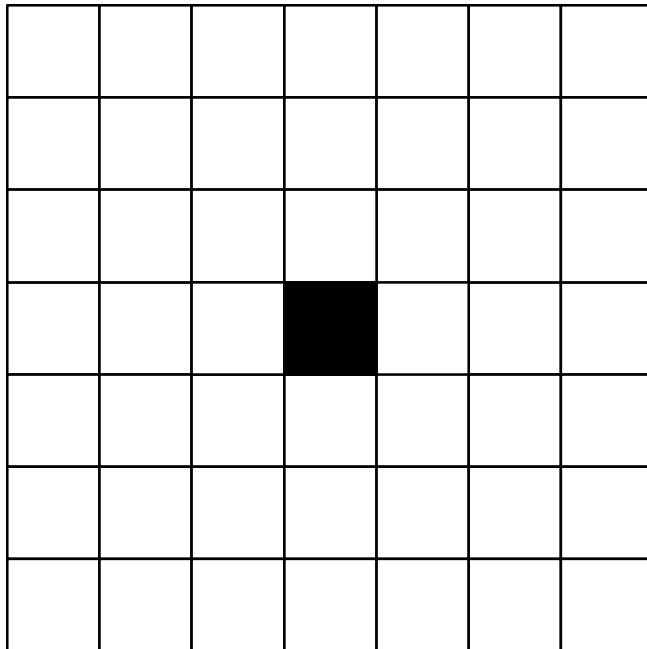
Evolution Via Self Organization

Cellular Automata P 53-60



Cellular Automata and Self Organization

Cellular Automata (CA) are simply grids of cells, where the individual cells change states according to a set of rules. The CA may be one dimensional, or linear, like a string of cells in a row (below), or two dimensional, like a checkerboard



Local Rules/Global Behavior

Sample Local Rules

Survival Rules — number of surrounding cells necessary to make it to the next generation.

Birth Rules — number of surrounding cells necessary for a dead cell to come alive the next generation.

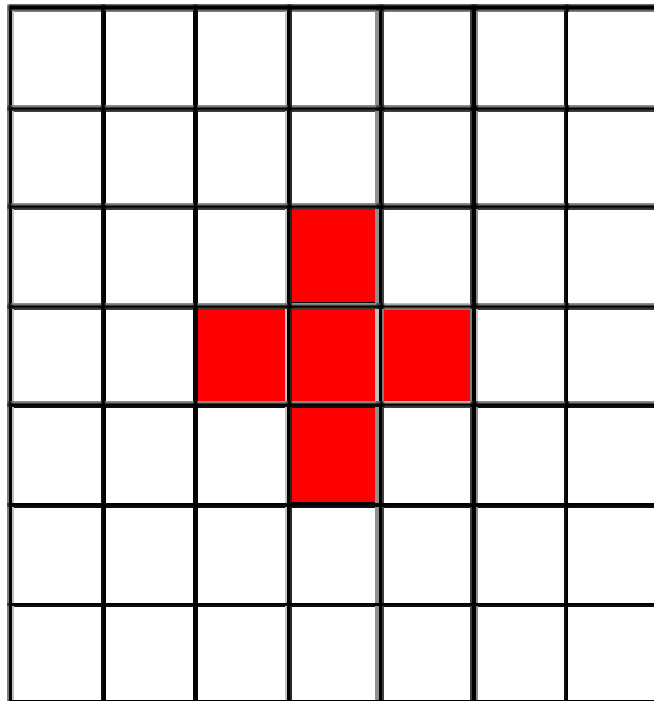
Life3000

LifeWin

Merick's Celebration

Cellular Automata and Self Organization

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Local Rules/Global Behavior

Optimal Local Rule Set

Survival Rules – 2/3 a live cell survives to the next generation if at least 2 but no more than three of the surrounding 8 cells are alive. Less than 2 and it dies of loneliness; more than 3 and it dies of over crowding.-

Birth Rules – 3/3 a dead cells comes alive the next generation if 3, any 3, of the surrounding 8 cells are also alive.

Life3000

LifeWin

Merick'sCelebration

Applet

What are we here to understand this semester?

- 1. What are the systems that make up the Earth?**
 - Lithosphere, atmosphere, hydrosphere, biosphere
- 2. By what evolutionary mechanisms do these change as energy passes through them?**
- 3. What happens when these four systems interact with each other?**
- 4. What happens when humans begin messing with these systems?**