It's the System !

On defining and coming to understand what we mean by the term "system,"

And, applying that to understanding the Earth as a System.

The term "system" has become a buzz word. But, what does it mean for something to be a system?

It's . . . the system,

You can't beat . . . the system,

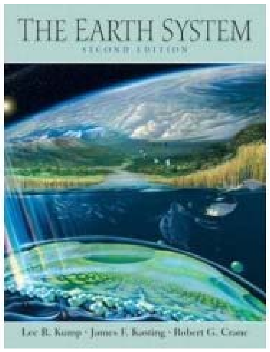
You haf'ta play . . . the system,

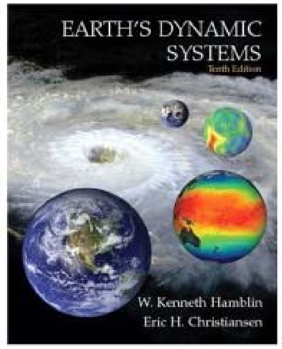
Or, more specifically (for us). . .

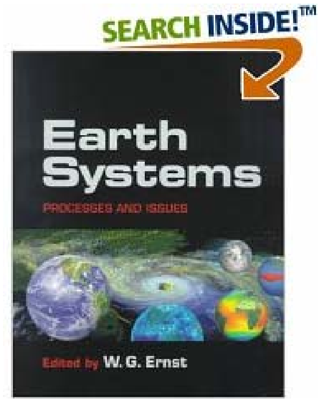
The Earth is a System . . .

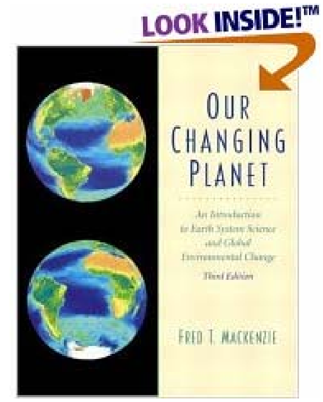
Or, more specifically (for us). . .

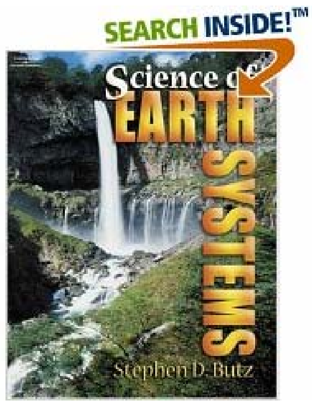
The Earth is a System . . .

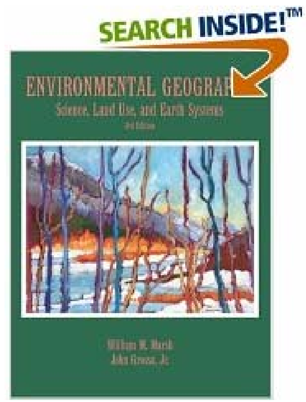


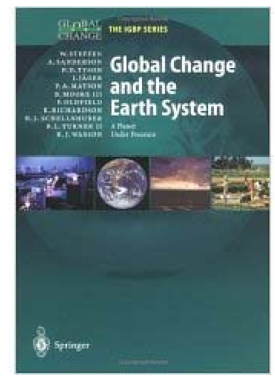












But, what does it mean to say the Earth is a System? Is it similar to or different from a school* system*,

the Federal Reserve* System*, ***an operating* system*,***

the Global Positioning* System*, ***or the solar* system*.***

What is a System?

Clarification One

Preliminary Dictionary Definitions

P 15

6. A set of objects or phenomena grouped together for classification or analysis.

(Does not specify whether the objects are or are not related. They could be unrelated.)

What is a System?

Clarification One

Preliminary Dictionary Definitions

6. A set of objects or phenomena grouped together for classification or analysis.

9. The prevailing social order; the establishment. Used with: "You can't beat the system."

Implies something or someone is in control.

What is a System?

Clarification One

Preliminary Dictionary Definitions

6. A set of objects or phenomena grouped together for classification or analysis.

9. The prevailing social order; the establishment. Used with the: “You can't beat the system.”

5. A naturally occurring group of objects or phenomena: the solar system.

Ah, now we are on to something, but does “naturally occurring” mean anything?

Naturally occurring sounds like magic. “It occurs naturally.” What does it mean to occur naturally?

What is a System?

Clarification Two

Final Dictionary Definition

1A. A naturally occurring group of interacting, interrelated, or interdependent elements, forming a complex whole.

Yet, we might ask, "Interacting how?" "Interrelated how?" "Interdependent how?"

- *Is it Accidental? Random? Purposeful (teleological)?*

And "complex whole?" Is it complex just because it has a bunch of parts, or is behavior important?

- *And, what about a bunch of parts that have simple behavior?*
- *Or, simple parts that have complex behavior?*

And, does "whole" mean discrete boundaries? Can something with indistinct or diffuse boundaries be a whole.

And, how did this whole - this system - come into existence in the first place ?

- *It is one thing to talk about the behavior of a system that already exists.*
- *It is something else to ask where and how these systems came into existence.*

This leads us to . . . The problem of problems . . . . .

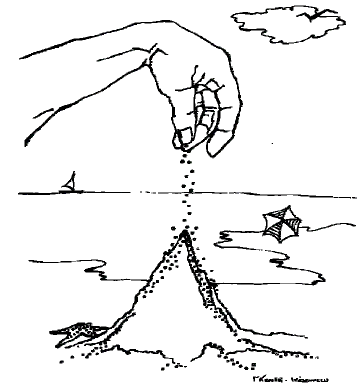
How can something become more complex with time in light of the 2nd law of thermodynamics ?

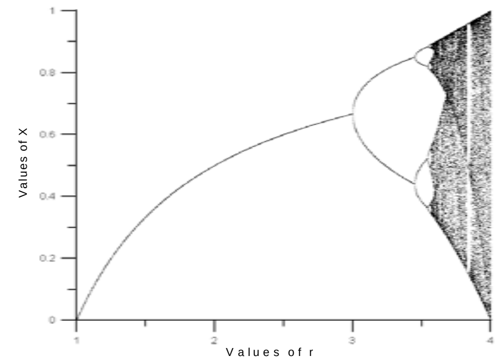
Well, we have already dealt with that, systems we are dealing with are open systems that dissipate energy and as a result evolve by elaboration, fractionation, and self organization.

What is a System?

A "system" is a group of naturally occurring interacting, interrelated, or interdependent elements, forming a complex whole . . .

- . . . existing far from equilibrium, . . .
- . . . forming a dynamic network where everything is connected to everything else by positive and negative feedback, . . .
- . . . self organized by bottom-up processes . . .
- . . . that have evolved together through time, . . .
- . . . such that a change in one component affects the states of the other components, . .
- exhibiting:
  - sensitive dependence,
  - fractal organization,
  - and avalanche behavior that follows a power-law distribution.





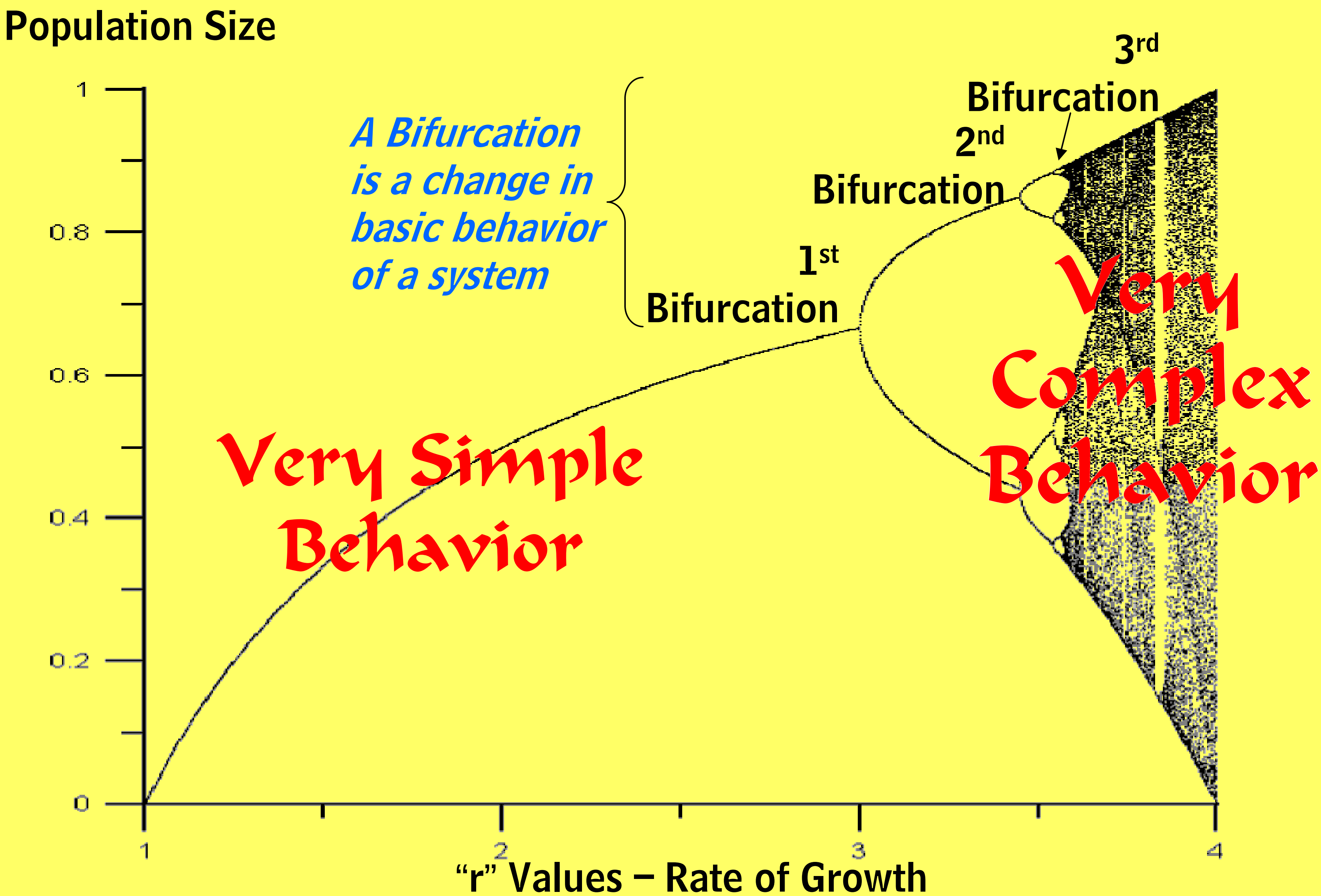
Xnext = rX (1-X)

X – Next and Chaos Theory

Sensitive Dependence

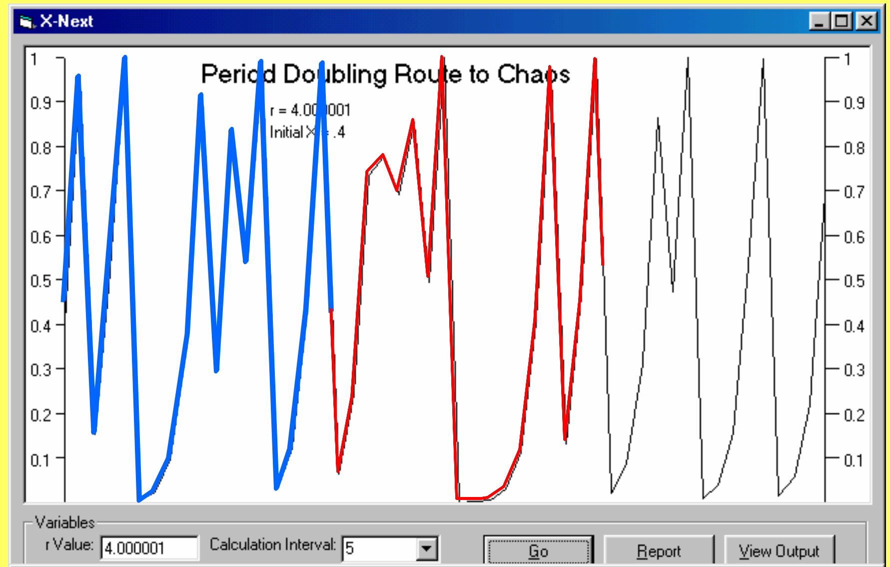
The harder a system is pushed the more unstable it becomes.

X_{next} (Logistic System) Bifurcation Diagram

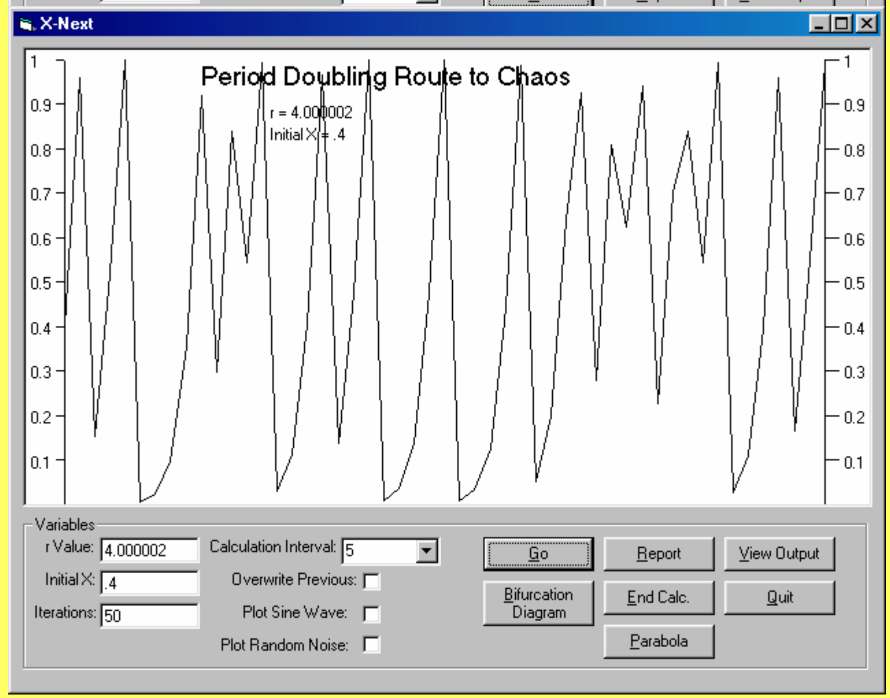


Sensitive Dependence on Initial Conditions: X_{next}

r = 4.000001



r = 4.000002



Universality

Properties of Complex Evolutionary Systems

Sensitive Dependence - the Everyday World

The straw that broke the camel's back.

For want of a nail the shoe was lost.

For want of a shoe the horse was lost.

For want of a horse the rider was lost.

For want of a rider the battle was lost.

For want of a battle the kingdom was lost.

And all for the want of a horseshoe nail.

Universality

Properties of Complex Evolutionary Systems

Sensitive Dependence on Initial Conditions:

a.k.a The
Butterfly Effect

Edward Lorenz

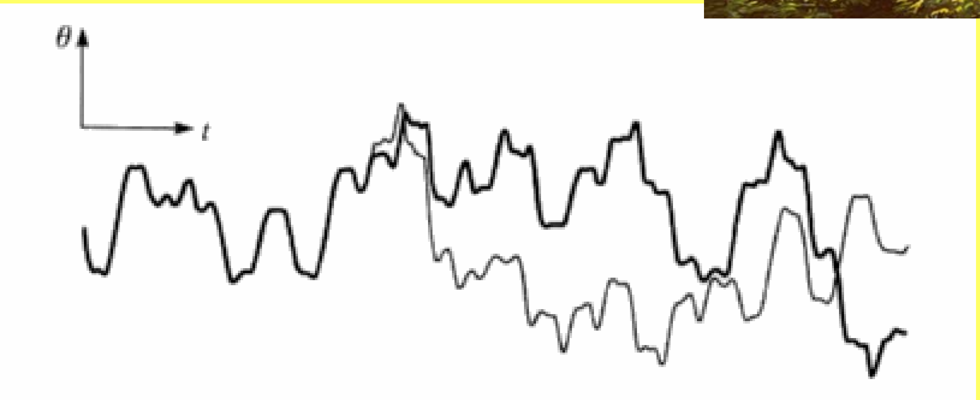
The "Butterfly Effect" originated in 1963 when Edward Lorenz, after giving a paper to the New York Academy of Sciences commented:

One meteorologist remarked that if the theory were correct, one flap of a seagull's wings would be enough to alter the course of the weather forever.

By the time of his talk at the December 1972 meeting of the American Association for the Advancement of Science in Washington, D.C. the sea gull had evolved into the more poetic butterfly - the title of his talk was:

Predictability: Does the Flap of a Butterfly's Wings in Brazil set off a Tornado in Texas?

Sensitive Dependence on Initial Conditions:



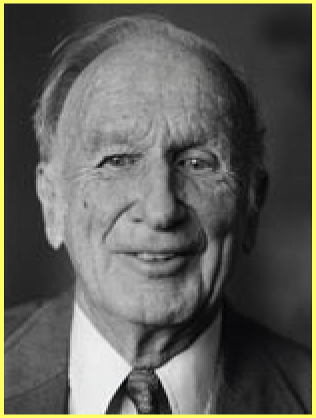
A computer program is by nature deterministic, that is, the same data in yields the same data out each time. One day Lorenz wanted to start his toy weather program later in the run. He flipped into the back pages of one of his hefty printouts and typed in a line of numbers, then went out for coffee.

When he came back he was stunned to find that the new data initially matched the old data. But after a period of time it diverged. Figure 6 shows an example of this divergence with time. When he thought about it, Lorenz realized that the numbers from the printout were rounded off from the numbers in the actual computer calculations. He thought that the small amount of rounding error would be insignificant, but in fact, non-linear systems can show a great deal of sensitivity to initial conditions.

http://mywebpages.comcast.net/laellis/Chaos/

Edward Lorenz, father of chaos theory and butterfly effect, dies at 90 (April 16, 2008)

Sensitive Dependence on Initial Conditions:



"By showing that certain deterministic systems have formal predictability limits, Ed put the last nail in the coffin of the Cartesian universe and fomented what some have called the third scientific revolution of the 20th century, following on the heels of relativity and quantum physics," said Kerry Emanuel professor of atmospheric science at MIT. "He was also a perfect gentleman, and through his intelligence, integrity and humility set a very high standard for his and succeeding generations."

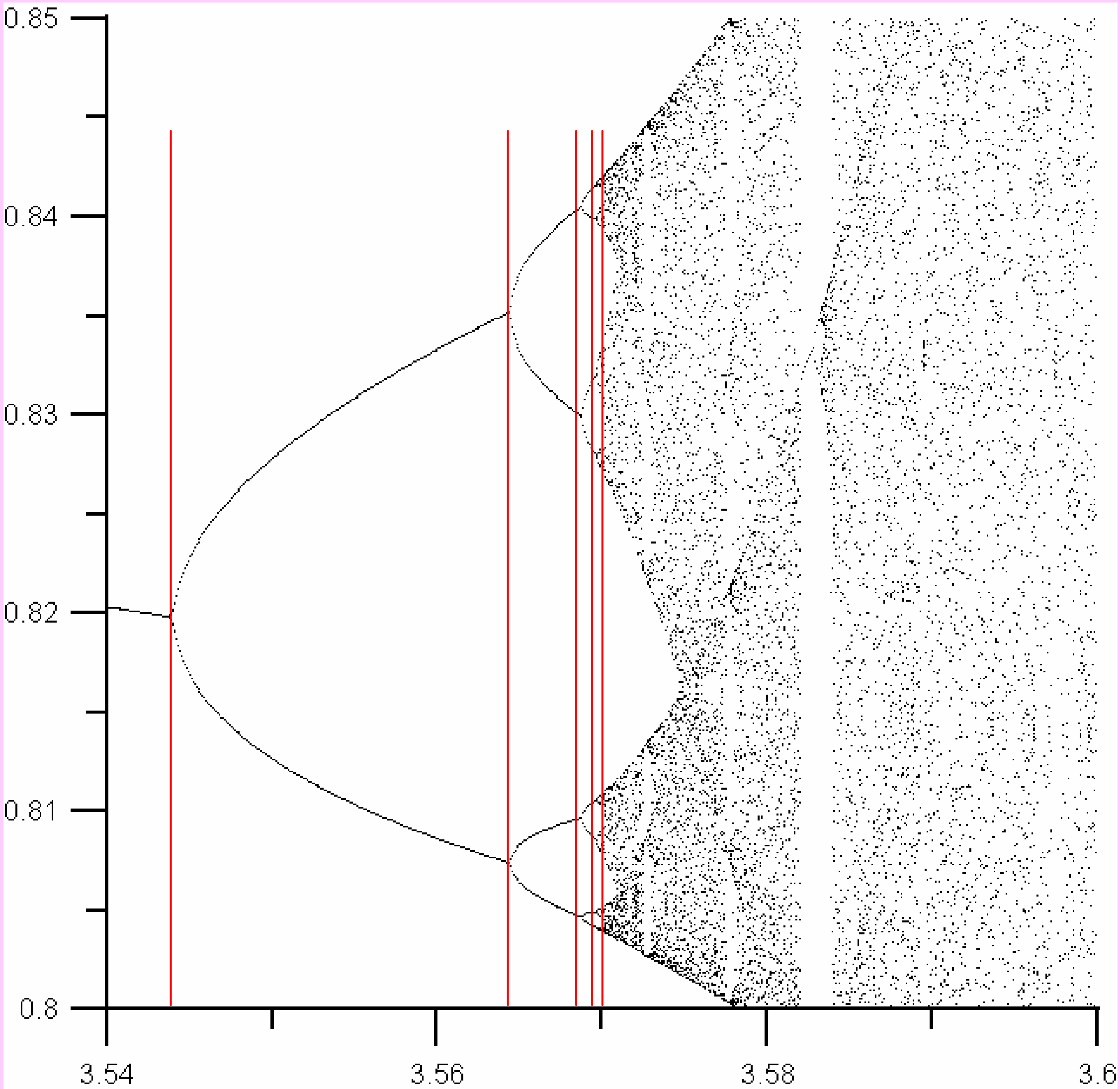
http://web.mit.edu/newsoffice/2008/obit-lorenz-0416.html

X – Next and Chaos Theory

The Harder a System is Pushed the Faster the Change Comes

Properties of Complex Evolutionary Systems

The Harder a System is Pushed the Faster the Change Comes



Feigenbaum Ratio

Named for the mathematician Mitchell J. Feigenbaum the Feigenbaum ratio is a bifurcation fractal produced by a period-doubling cascade, such as in the X_{next} bifurcation diagram. The period doubling comes at a constant rate given by the delta constant: 4.66921166091029 etc. Feigenbaum discovered that this constant arose in any dynamical system that approaches chaotic behavior via period-doubling bifurcations: fluid-flow turbulence, electronic oscillators, chemical reactions, and even the Mandelbrot set.

X – Next and Chaos Theory

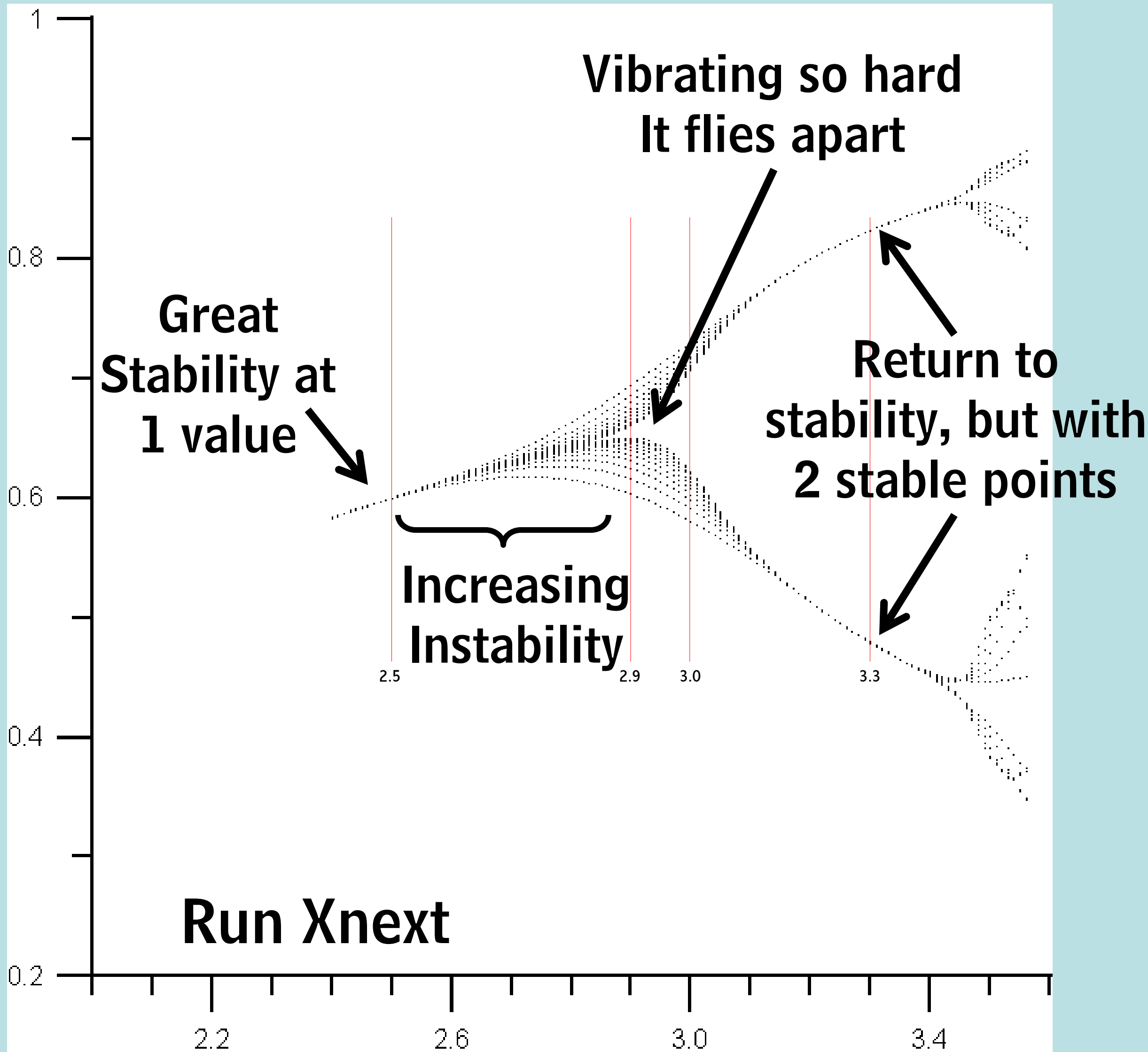
Bifurcations

(changes in behavior)

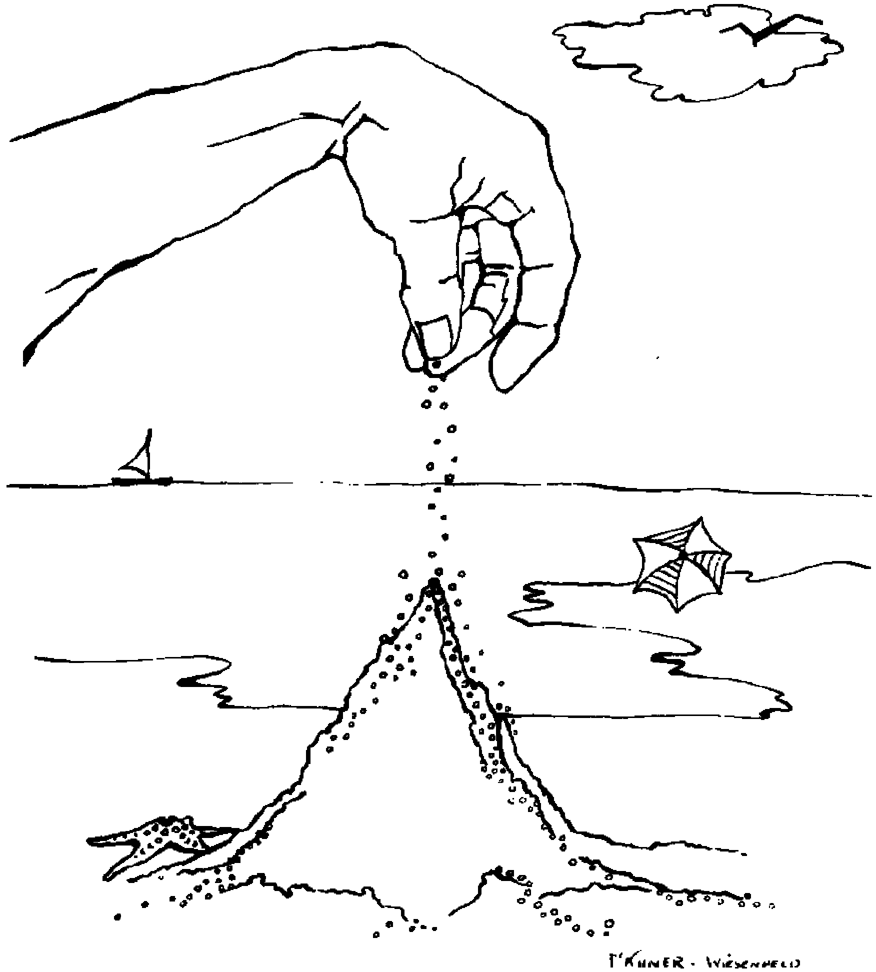
Are Always Preceded by Destabilization

Sensitive Dependence - Bifurcation Instabilities

Xnext; first two bifurcations plotting only X values 20-25. What we observe is that as a bifurcation is approached it takes progressively longer for the system to attenuate. For example, for r = 3.0 the system is still attenuating at the decimal places 4 - 6 at 1 million generations. On the other hand, at r=3.3 the system attenuates to one value after 5 iterations. The bifurcation comes because the system is sensitive dependent enough it flies apart.



Self Organized Criticality



Avalanche behavior follow a power-law distribution

Avalanche Behavior

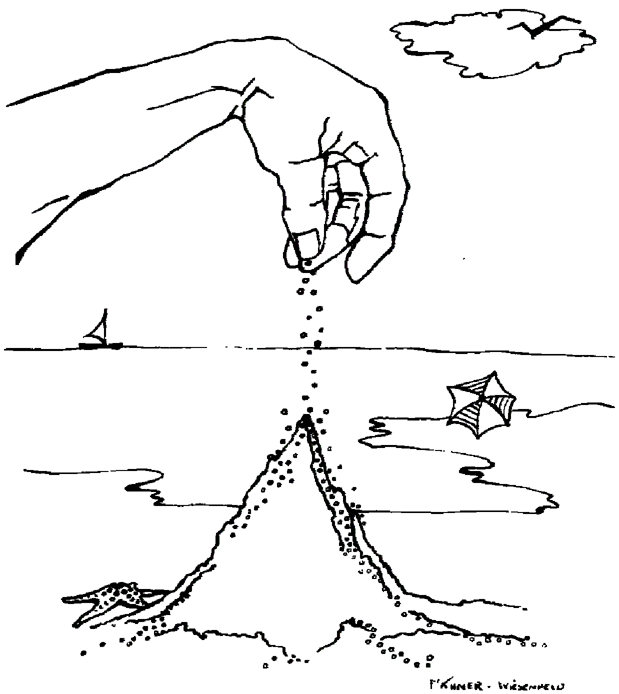
The sand pile builds . . . grain . . . by grain . . .

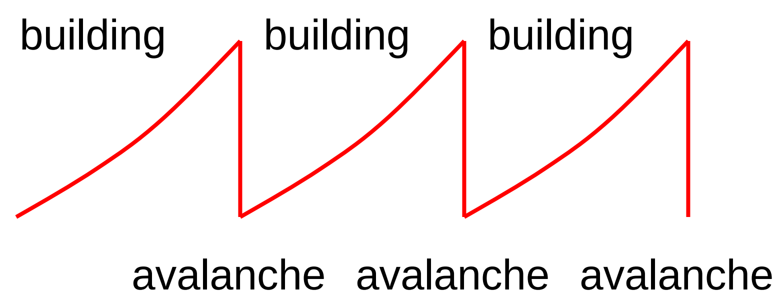
by grain . . . by grain . . . by grain . . .

by grain . . . by grain . . . by grain . . .

Building toward the critical state . . .

Where it avalanches



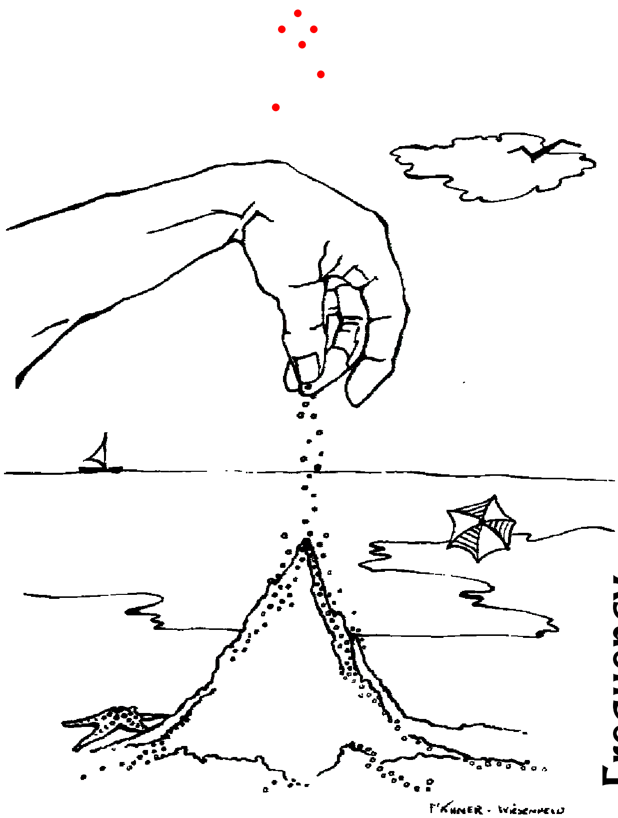


Avalanche- a large mass of snow, ice, etc., detached from a mountain slope and sliding or falling suddenly downward.

Avalanche- anything like an avalanche in suddenness and overwhelming quantity: an avalanche of misfortunes; an avalanche of fan mail.

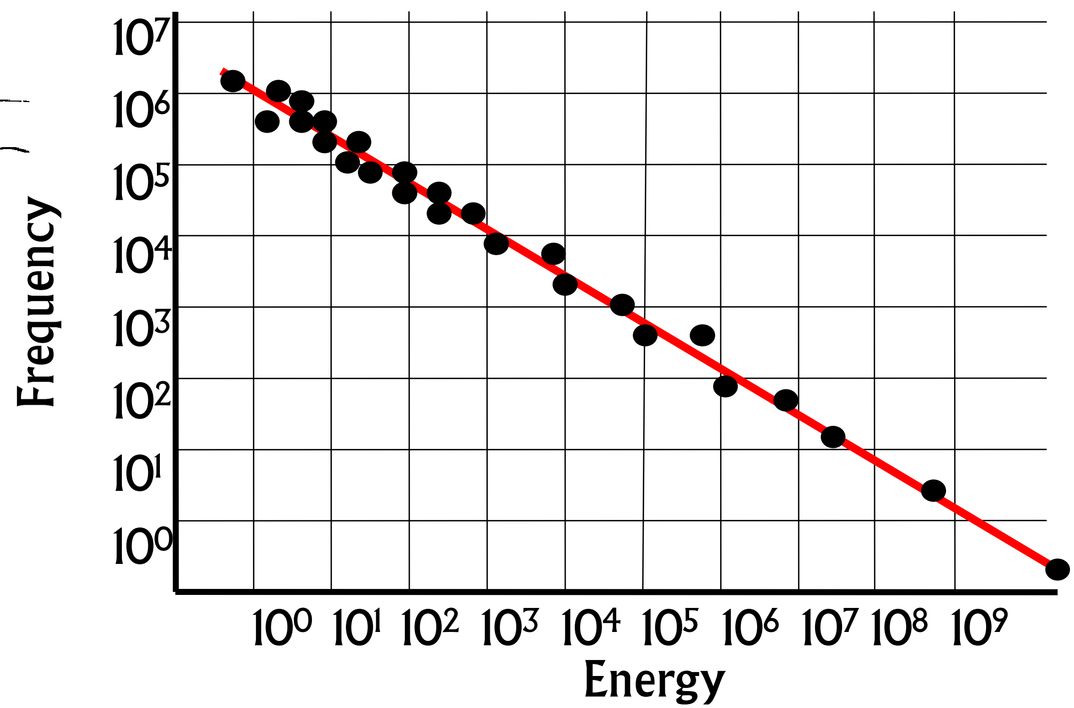
Hysteresis as the Lag Between Cause and Effect

Fractal sand supply



Now, imagine the sand supply follows a power law (or is fractal), with different numbers of grains falling at different times.

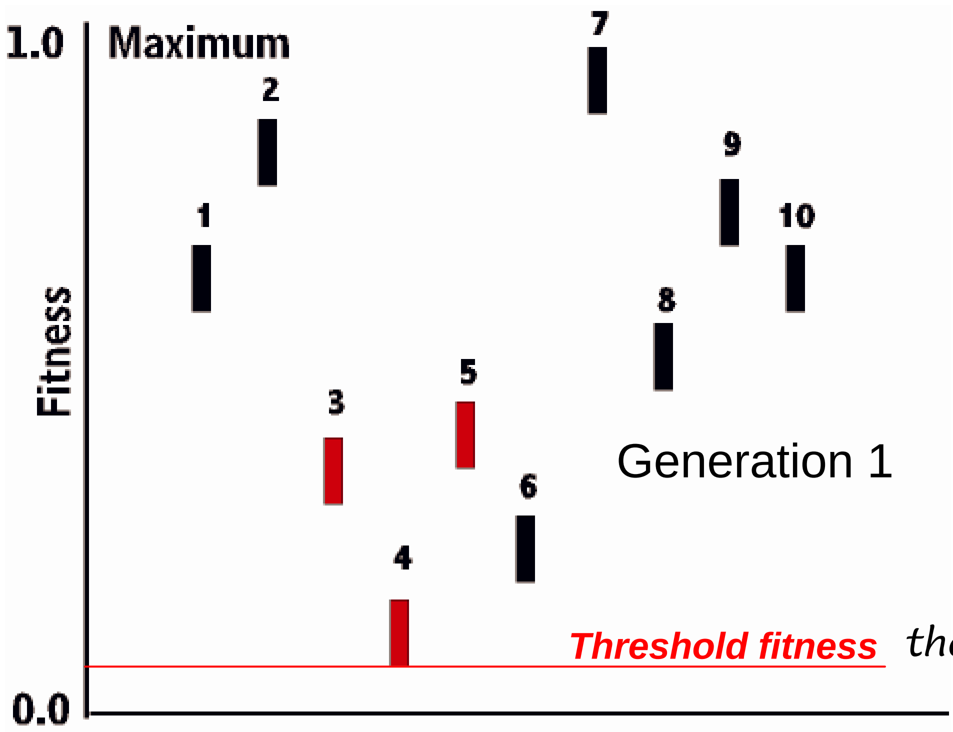
Avalanches will also be fractal, and follow a power law distribution.



A Model of Self-Organized Criticality

Bak~Sneppen Ecosystem

MODELING AN EVOLUTIONARY SYSTEM



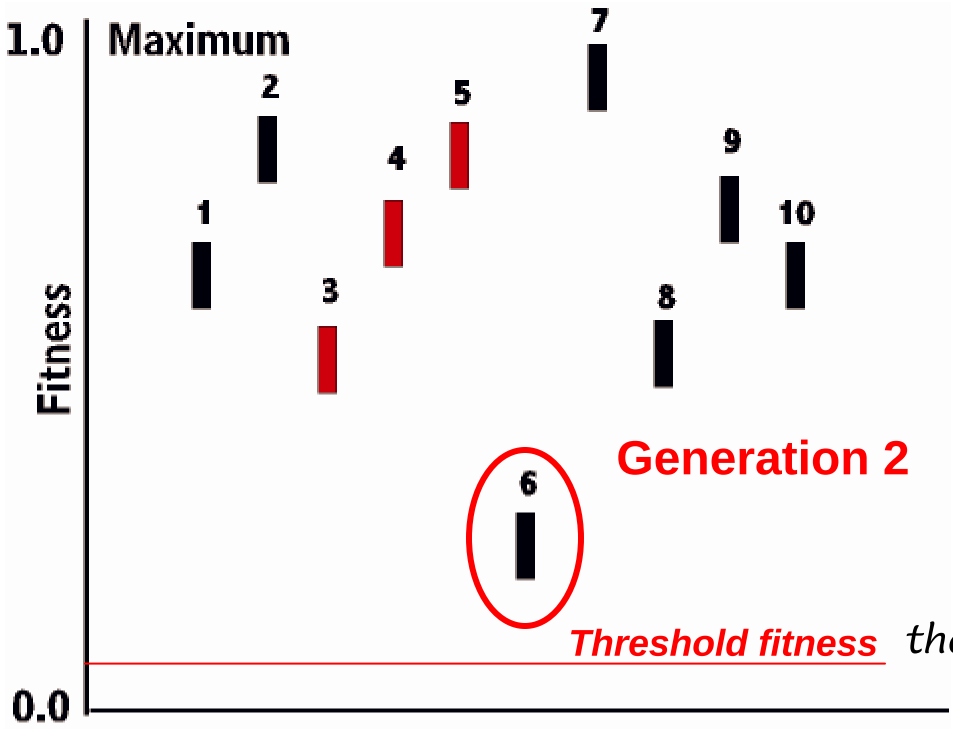
the highest level the lowest fitness species has reached

The Bak-Sneppen evolutionary model is an "ecosystem" in which the fitness of each "species" changes because of its relationships with other "species", following two simple rules

Rule One **- find the species with the lowest fitness and randomly change its fitness.**

Rule Two **- at the same time the lowest fit species is changed, also randomly change the fitness of the species to the immediate left and right.**

Modeling an Evolutionary System



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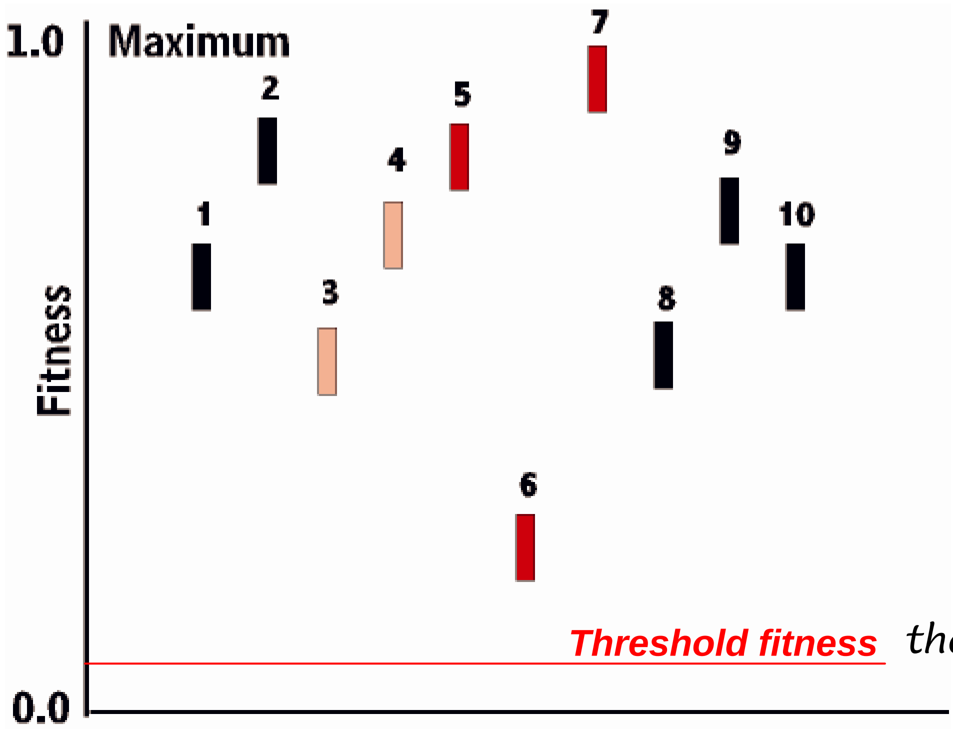

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The Bak-Sneppen evolutionary model is an "ecosystem" in which the fitness of each "species" changes because of its relationships with other "species", following two simple rules

An avalanche is a cascade of fitness changes below the threshold (i.e. all the blinking dots below the line)

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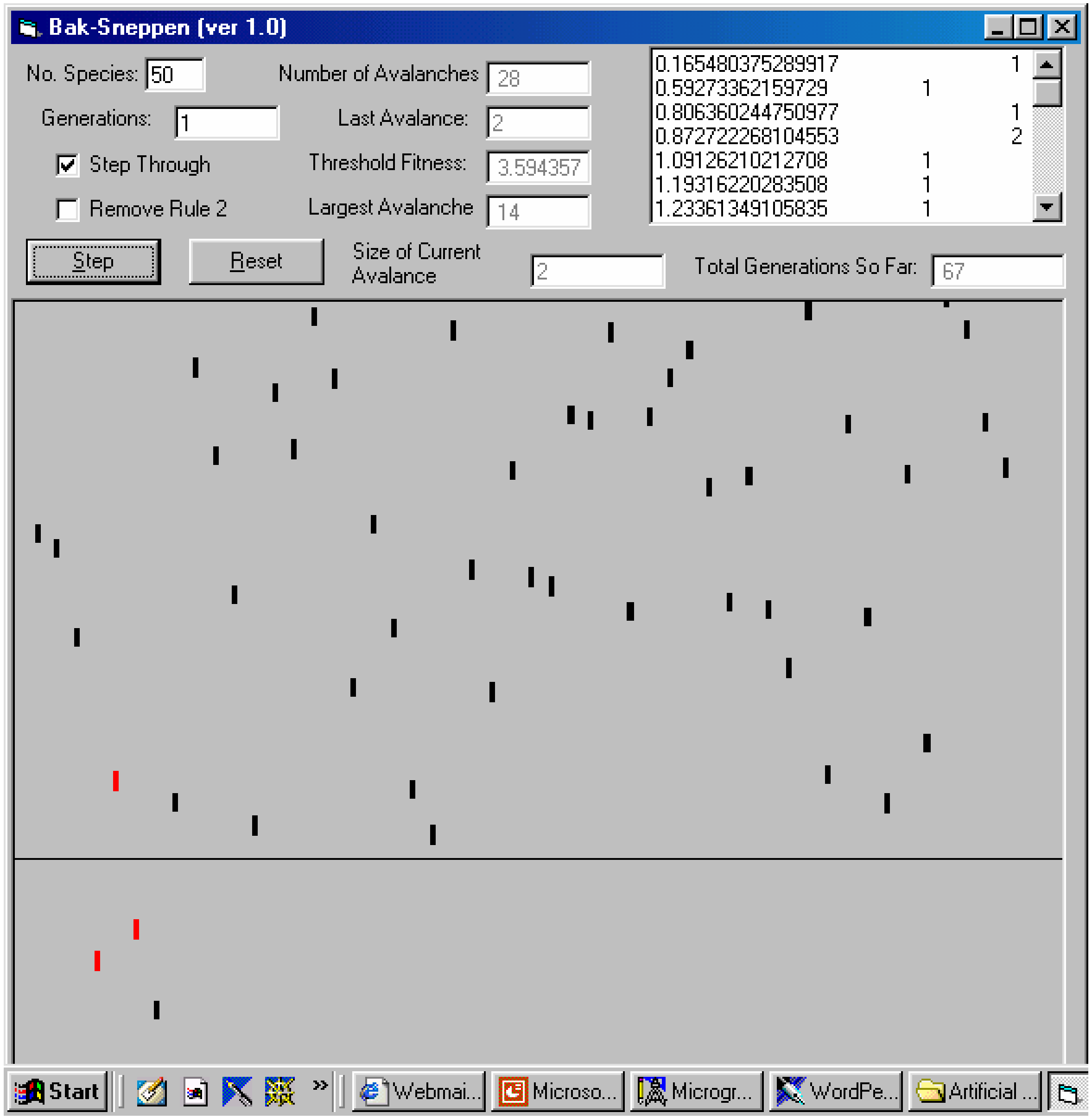
Modeling an Evolutionary System

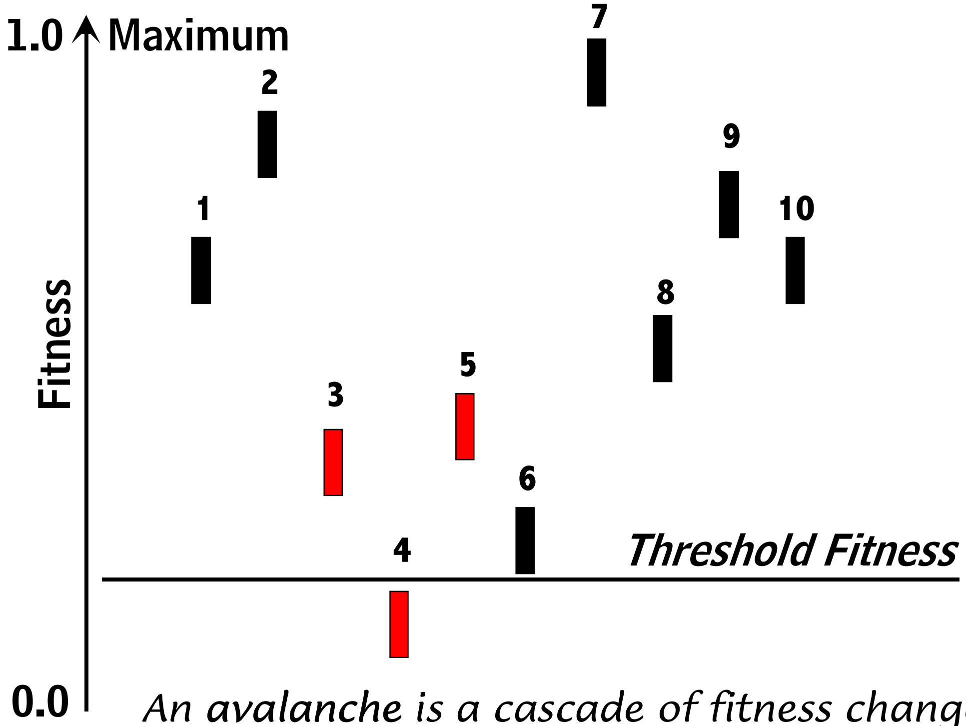


We do not expect random processes to result in an organized outcome. Does any interesting behavior emerge from this simple system?

Run Bak-Sneppen

Modeling an Evolutionary System

Bak-Sneppen Ecosystem



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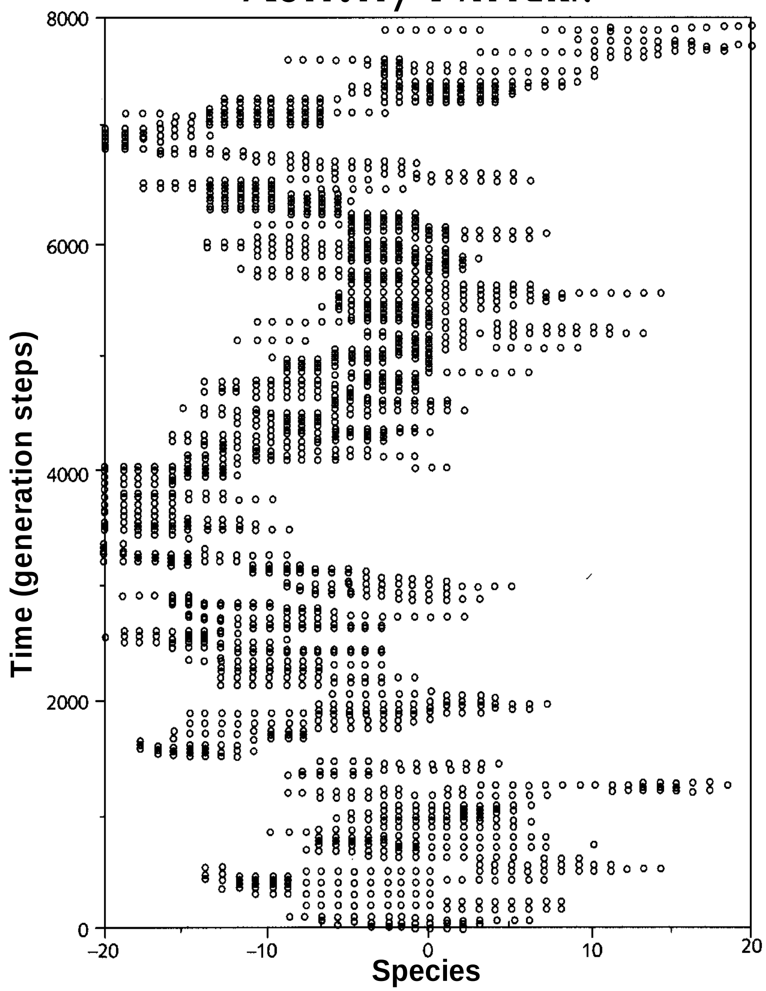
Modeling an Evolutionary System

Dynamics of the Bak-Sneppen Evolutionary Model

Activity Pattern



Activity pattern for the Bak-Sneppen model. Time begins at an arbitrary time after the model has self-organized at the critical state near the 0.66 threshold. Species are arranged along the horizontal axis (from -20 to +20). Each circle indicates a time a given species undergoes a mutation. For example, at about time 2000 species -7 through +7 are undergoing mutations; by time 4000 activity has shifted to -20 to -10. That is, there is an avalanche in that portion of the ecosystem. As the avalanches move to other species the activity circles move to those other species, and species that are not mutating do not have activity circles for that time span.

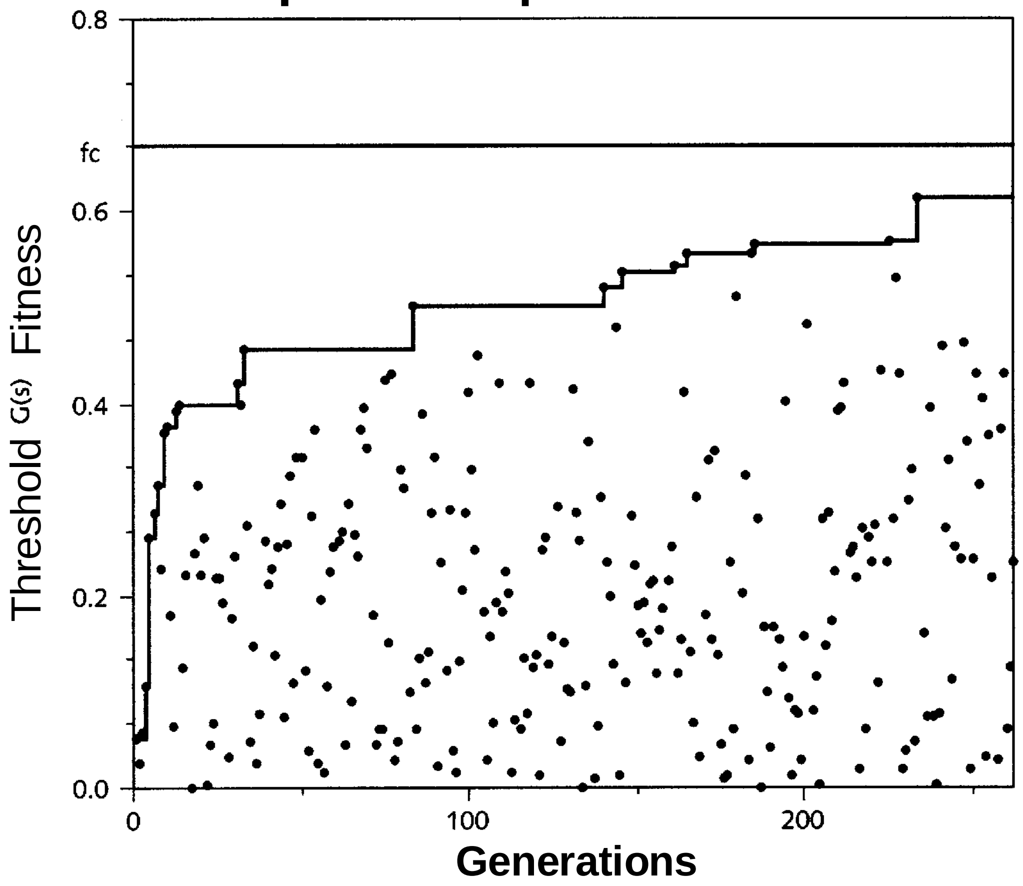
Modeling an Evolutionary System

Dynamics of the Bak-Sneppen Evolutionary Model

P 21

Ecosystem Threshold Fitness

Stepwise rising threshold fitness



Graph showing the climb of the threshold fitness for the whole ecosystem with time. Threshold fitness is the highest fitness the least fit species has attained. A step up to a new threshold occurs only when *all* species climb above the old threshold, thus ending an avalanche. As the graph shows this takes progressively more time as the threshold fitness rises.

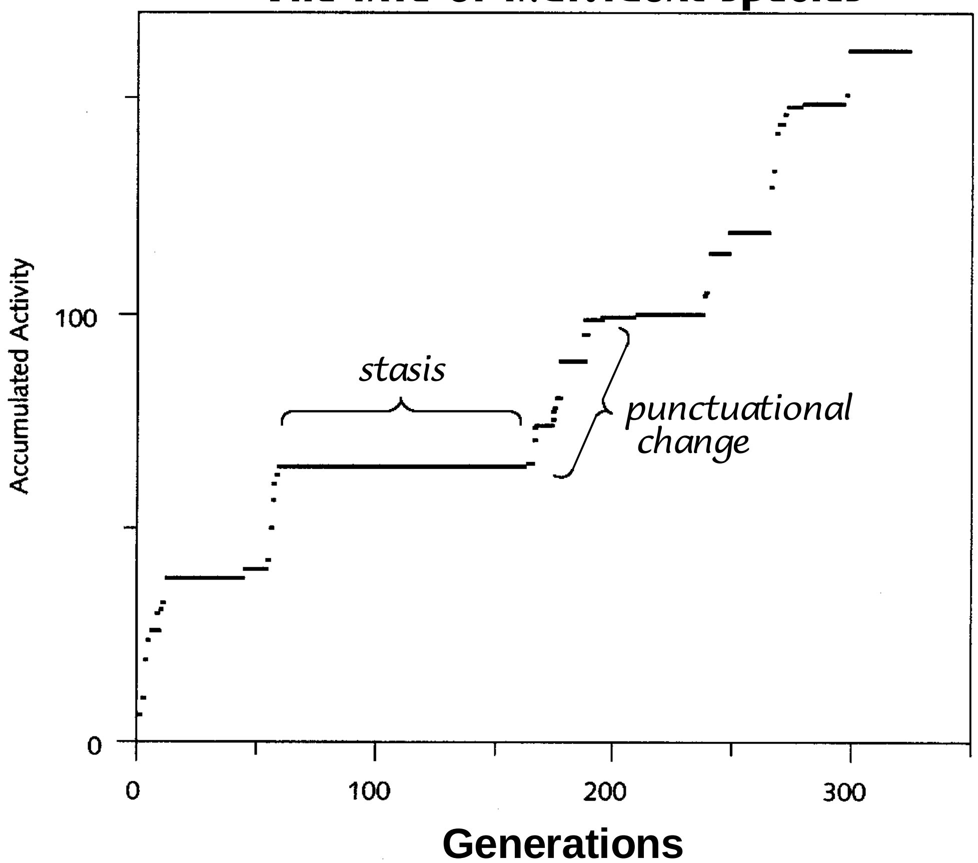
Note that the rise in ecosystem fitness is punctuational, or behaves like a Self Organized Critical sandpile.

Modeling an Evolutionary System

Dynamics of the Bak-Sneppen Evolutionary Model

The Devil's Staircase

The fate of individual species



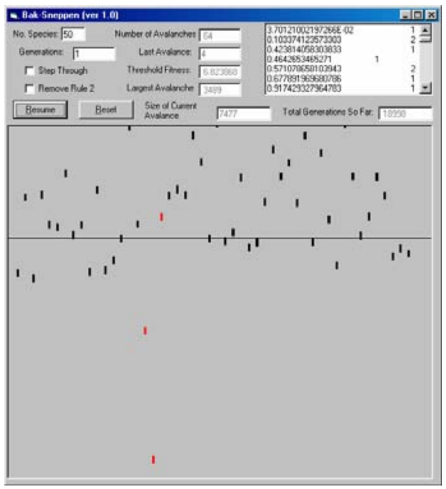
The Devil's staircase shows the accumulated activity of one species. Horizontal lines are times of stasis. Vertical jumps are mutations; note these come in bundles over short time intervals (are punctuational). In reality there are many more mutation steps than shown. One can think of the number of changes as representing the amount of physical change in the animal, such as size. The Self Organized Criticality (aka "punctuated equil-ibrium“) nature of the curve is evident in the long times of stasis followed by jumps in activity.

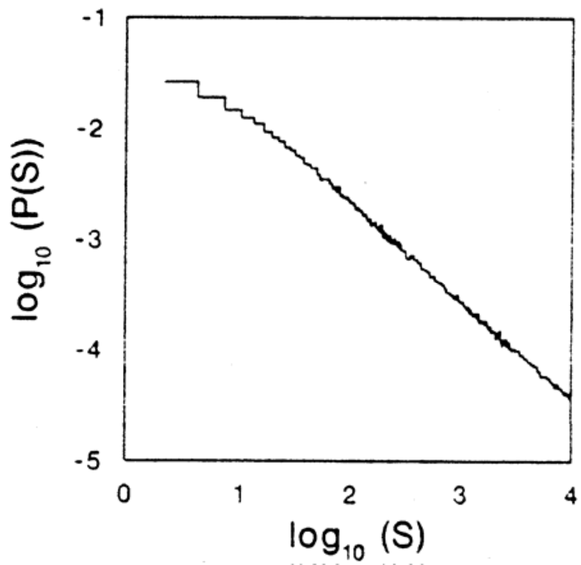
Universality

Properties of Complex Evolutionary Systems

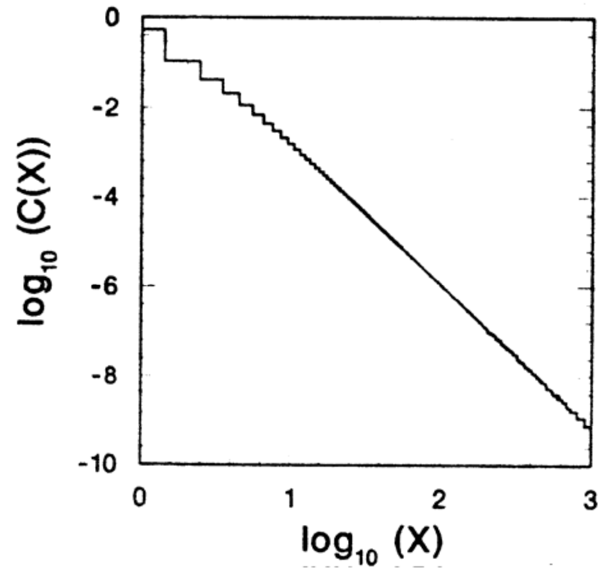
P 21

Power Law Relationships – Bak-Sneppen



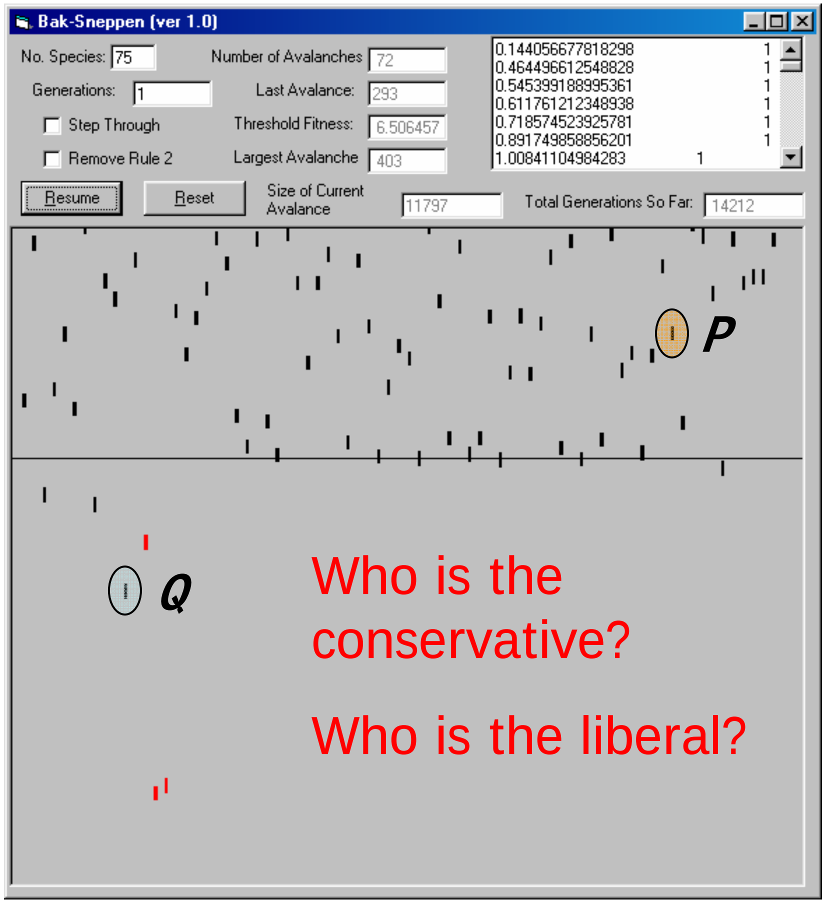


Avalanche sizes in the Bak-Sneppen model



Mutation frequency in the Bak-Sneppen model

? What Are the Implications ?



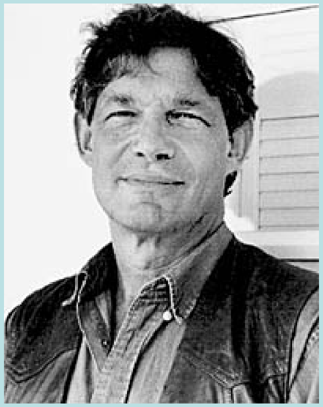
Who is the conservative?

Who is the liberal?

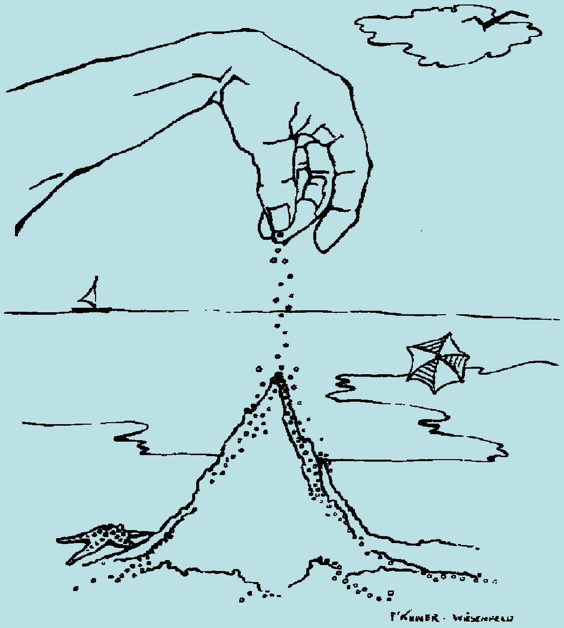
1. Watch the species above the threshold. How stable are they?
   - How much are they able to change on their own?
   - How much do they contribute to raising the threshold line to the next level?
2. Get personal. Pick out one species above the threshold line and identify with it; imagine it is you.
   - How safe are you in this avalanche prone world?
   - How much control do you have over your destiny? Why or why not?
   - Are there any innocent victims?
   - Is there any way to protect yourself in such a world?
3. Is there any part of this ecosystem that is isolated from the rest, sitting in a protected niche, independent and self sufficient?

Run

Stuart Kauffman



"The critical point is not, as Stuart Kauffman once described it, "a nice place to be." So "survival of the fittest" does not imply evolution to a state where everybody is well off. On the contrary, individual species are barely able to hang on - like the grains of sand in the critical sand pile."

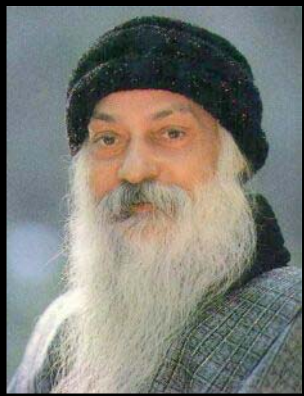


Maybe there is no "cause" to disasters and extinctions

Maybe disasters (avalanches) are just part of the dynamic of evolution.

"The world is one. It is a unity. Nothing is separate, Everything pulsates together. We are joined with each other, interlinked."

OSHO



So, when we say "It's the system" this is what we mean . . .

. . . Everything is linked with, connected with, and dependent on everything else.