GenSci 102

Environment: Earth

Lynn S. Fichter
Department of Geology/Environmental Science
James Madison University

http://csmres.jmu.edu/geollab/Fichter/Fichter/Fichterls.html

Fichter's GGEOL 102: Environment: Earth Course Home Page - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://csmres.jmu.edu/geollab/Fichter/GS102/index.html

Customize Links Free Hotmail Windows Marketplace Windows Media Windows Five Myths About U.S...

Google Search Bookmarks AutoLink AutoFill Send to Settings

Lynn S. Fichter - Fichtels@jmu.edu
James Madison University; 7100E Memorial Hall - phone 6531

About the Course
Syllabus - pdf
Text Books

During May 2008 this course is undergoing major revisions. It is happening piece by piece; if there is confusion e-mail or come talk with me.

Part One - Geological Earth
Part Two - Evolutionary Earth
Part Three - FINAL EXAM - Earth Does Not Have an Environmental Problem

Catalog Description

GGEOL 102: Environment Earth—Formerly GSCI 102: Environment Earth. GSCI 101 deleted as prerequisite (Formerly UMSC 102A.)

A study of geological processes causing global change and their impact on human thought. The relationship between some geological processes and life on the Earth is also considered. Not available for major or minor credit in geology. Formerly GSCI 102. Students may not receive credit for both GGEOL 102 and GSCI 102.

or

The Earth As A System

Office Hours

Before and after class. By Appointment, but any time I am in my officeand not immediately

Why do I have to take a general education science course,

especially one as boring as geology? What does it matter? And who really cares!? And what possible

Done

What we are about here . . .

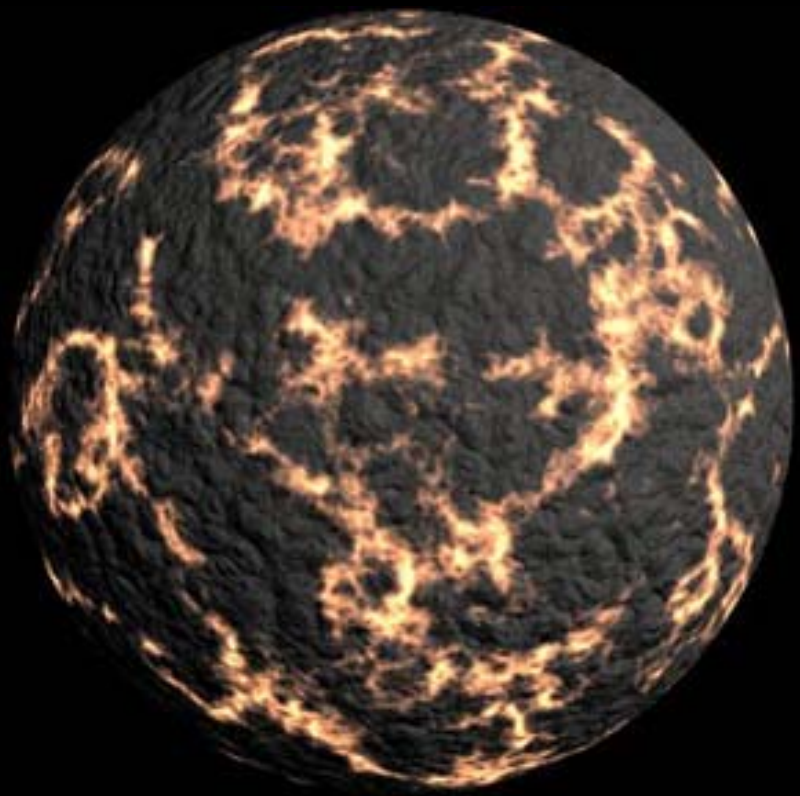
Is coming to understand this planet we live on, and our relationship with it.

This will require coming to understand . .

How it works geologically, hydrologically, climatically, and biologically, not only today, but over 4 billion years of history, and into the future.

It is not about the nitty-gritty of one or a few subjects . . .

But, how many, complex systems interact with each other.



We are born.

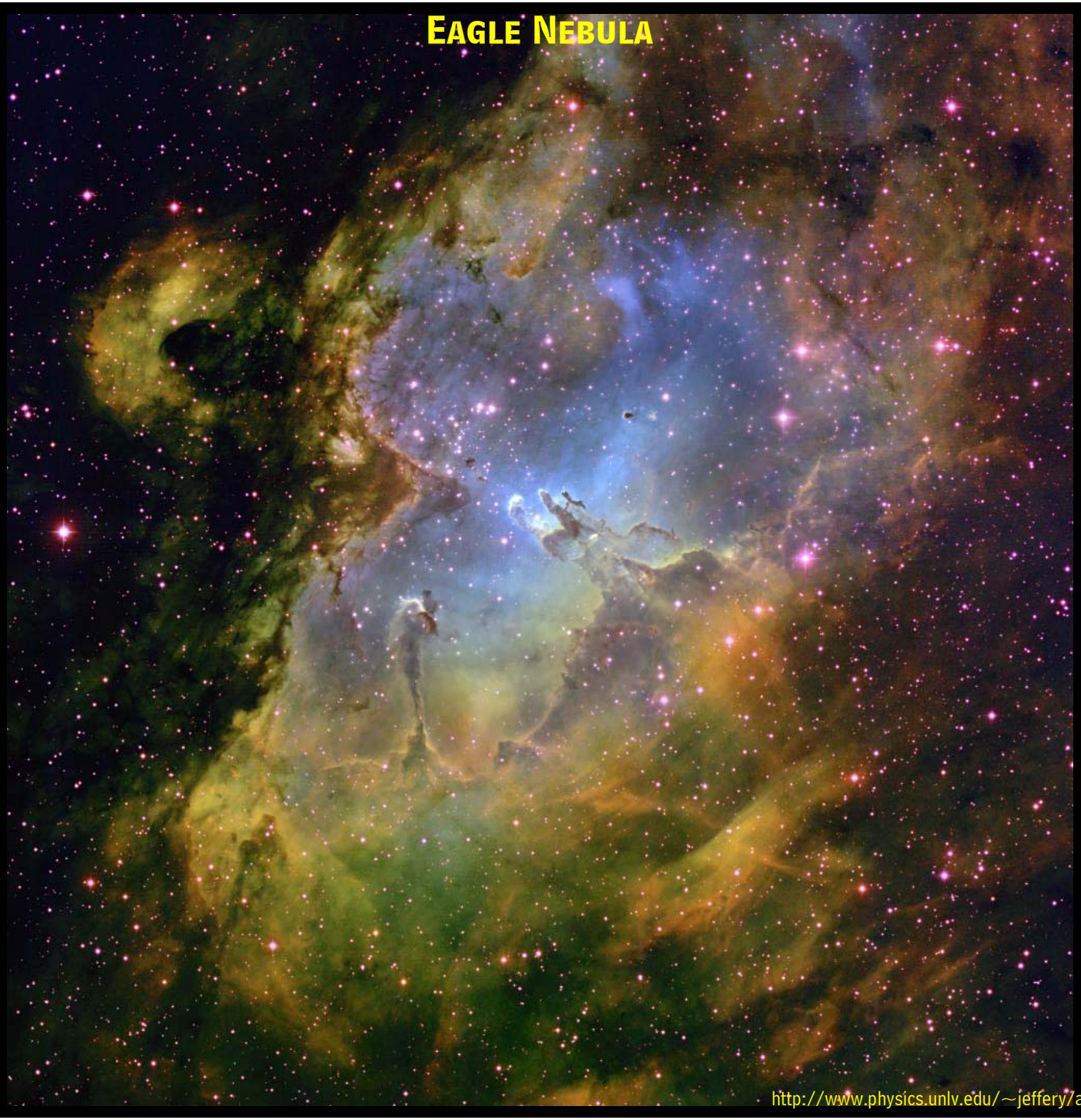
We are born.

Origin of the Solar System and Earth

Solar Nebular Theory

http://members.cox.net/the_courier/

Eagle Nebula



http://www.physics.unlv.edu/~jeffery/astro/astro1/lec009.html

Infant Solar Systems? Tantalizingly akin to Laplace's solar nebular the 1996 HST photo shows protoplanetary disks (proplyds) in the Orion Nebula. Scale is 0.14 light year across.

http://www.howardastro.org/documents/HET607Essay.htm

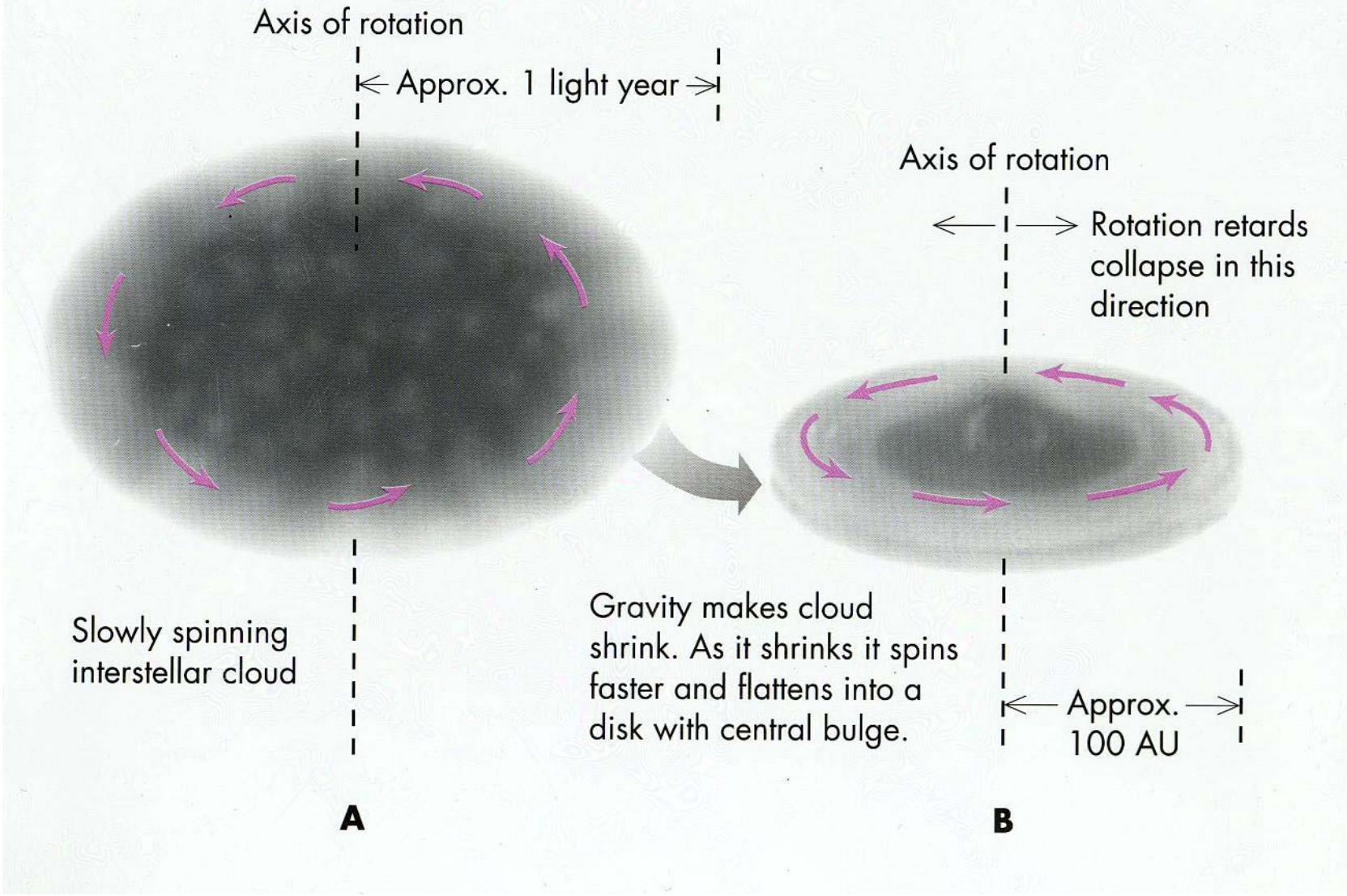
Artist's reconstruction of a developing solar system

The solar system began as a spinning cloud of gas and dust, called the solar nebula, which collapsed under its own weight to form a new star, our Sun. As the solar nebula spun and churned, dust grains stuck together to form dustballs, and huge bolts of lightning melted them into small spheres. These solidified into rocky balls called chondrules. (Painting by Don Dixon, NASA JSC photo S76-25001)

Click for web site for description of solar system formation

http://www-curator.jsc.nasa.gov/outreach1/expmetmys/slide set/Slides16-20.htm

The original gas clouds are roughly spherical, but as they contract under gravity two things happen. First, their speed of rotation increases, and, second, they begin to flatten into a disc.

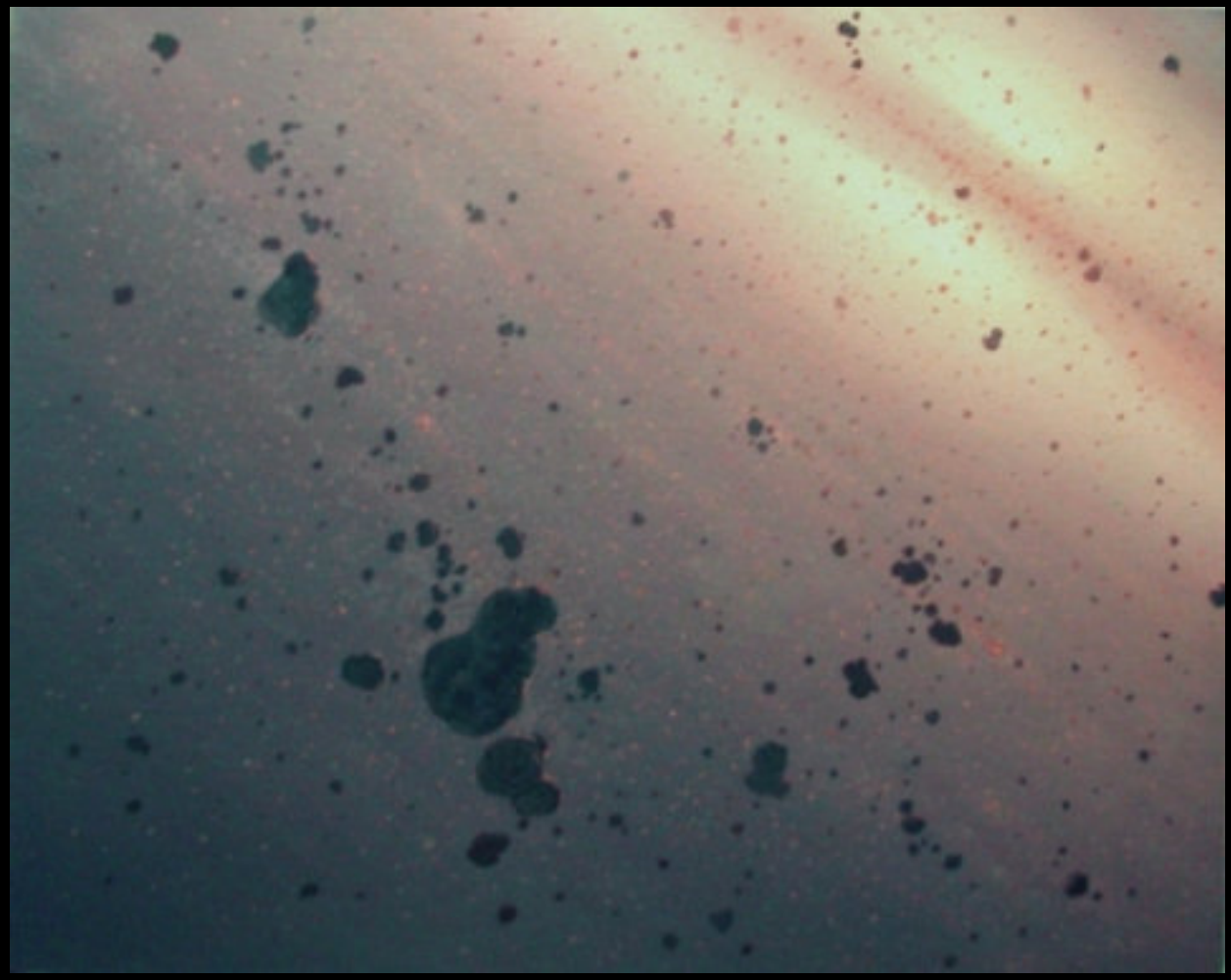


http://pegasus.phast.umass.edu/a100/handouts/ssrecip.html

Inside the solar nebula, less than a million years after the sun formed, as depicted by scientist/artist Bill Hartmann. This shows the view in the region where the Earth will form. Small grains of dust are aggregating into planetismals during stage 1 of planet formation.

http://pegasus.phast.umass.edu/a100/handouts/ssrecip.html

Another artist's reconstruction of the solar nebula roughly a million years after the collapse, the infant Sun, obscured by a dust lane at the top right, backlights material in the disc. Against this scattered light silhouetted metre-sized bodies -- themselves the result of the gentle accumulation of particles smaller than a speck of dust -- will eventually coalesce and grow to form the building blocks of the planets.



http://www.nataraja.demon.co.uk/Solar%20Nebula.htm

Embryonic planets emerge from the chaos of the protoplanetary disk. They endured constant bombardment by a progression of ever-larger objects.

http://www.howardastro.org/documents/HET607Essay.htm

The Earth-Moon System

http://www.cosmographica.com/gallery/portfolio/portfolio151/pages/188-MoonFormingImpact.htm

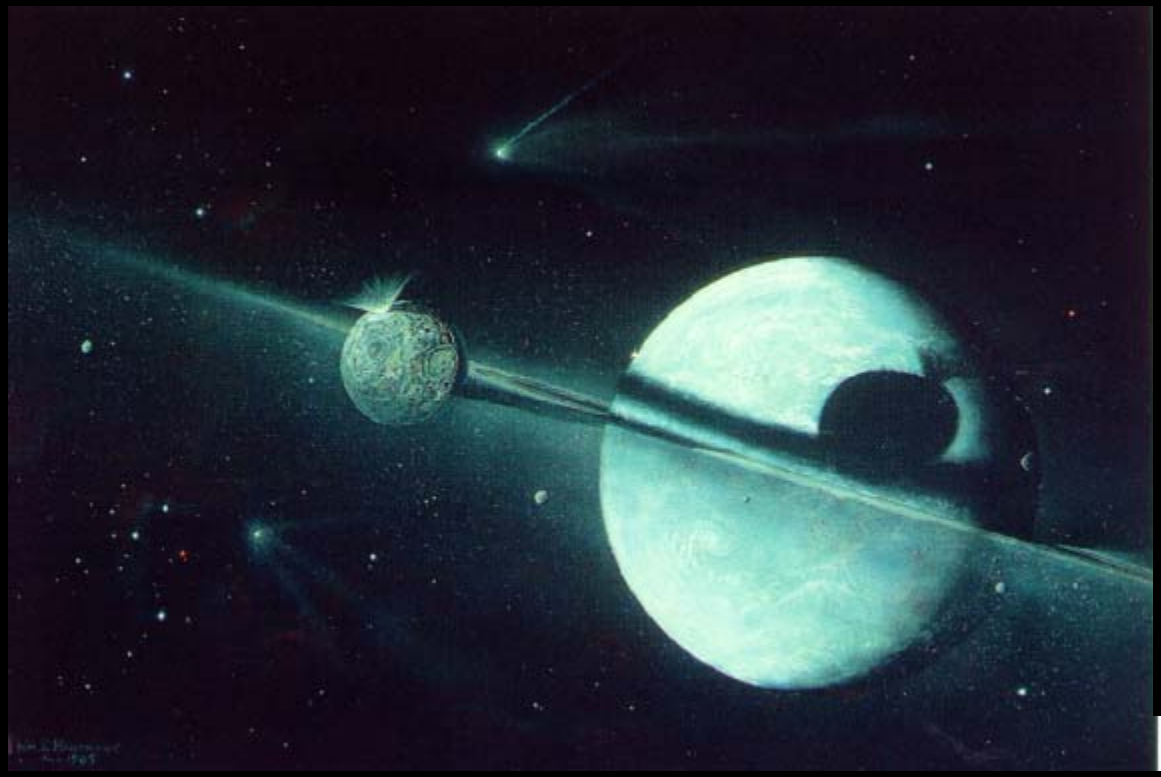
~ 4.5 Ga ~ 4.5 Ga ~ 4.5 Ga

At ~4.5 Ga the Earth-Moon collision provided enough energy to melt them and begin their physical evolution.

The Moon as seen from Earth

~ 4.3 Ga **~ 4.3 Ga** **~ 4.3 Ga**

At ~4.3 GA the Earth-Moon system reach this stage. The Earth is already stratified by density, convection cells are operating, and tectonic processes have begun.



~ 4.2 Ga ~ 4.2 Ga ~ 4.2 Ga

Earth About 4.2 billion years ago

Still molten hot, without water or life, being bombarded continuously by meteorites.

http://www.gps.caltech.edu/~mjwillis/research/bugbuster.html

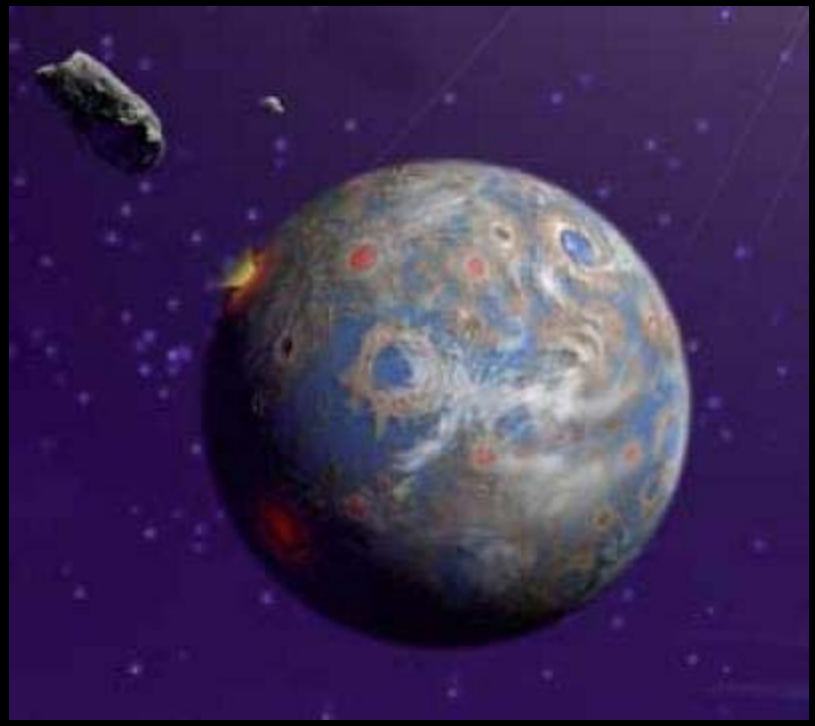
~ 4.2 Ga ~ 4.2 Ga ~ 4.2 Ga

Earth About 4.2 Billion Years Ago

http://www.cosmic-art.co.uk/pics3.html

~ 4.0 Ga ~ 4.0 Ga ~ 4.0 Ga

Earth About 4.0 Billion Years Ago

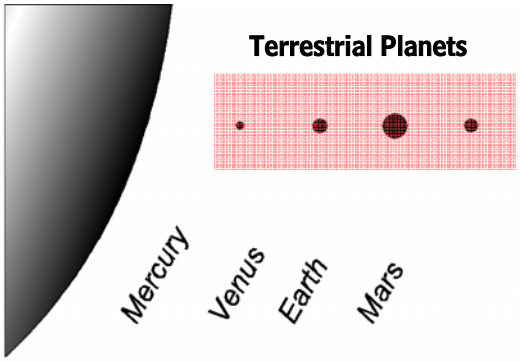


Sara Seager, Massachusetts Institute of Technology, Cambridge, Mass.; Marc Kuchner, NASA Goddard Space Flight Center, Greenbelt, Md.; Catherine Hier-Majumder, Carnegie Institution of Washington, (deceased); and Burkhard Militzer, Carnegie, have created models for 14 different types of solid planets that might exist in our galaxy. The 14 types have various compositions, and the team calculated how large each planet would be for a given mass. Some are pure water ice, carbon, iron, silicate, carbon monoxide, and silicon carbide; others are mixtures of these various compounds.

http://thedragonstales.blogspot.com/2007_09_01_archive.html

Early Planetary Evolution

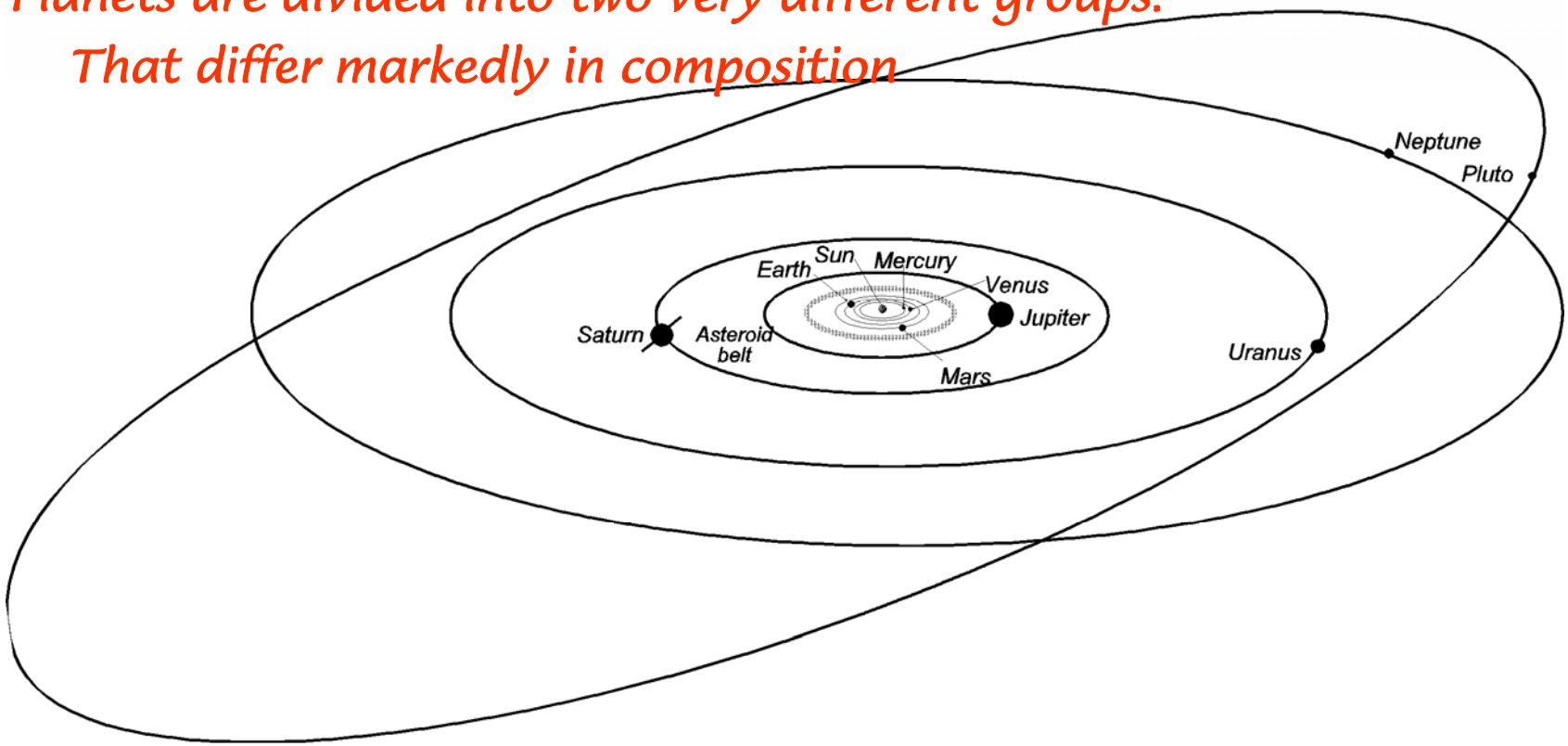
P 8



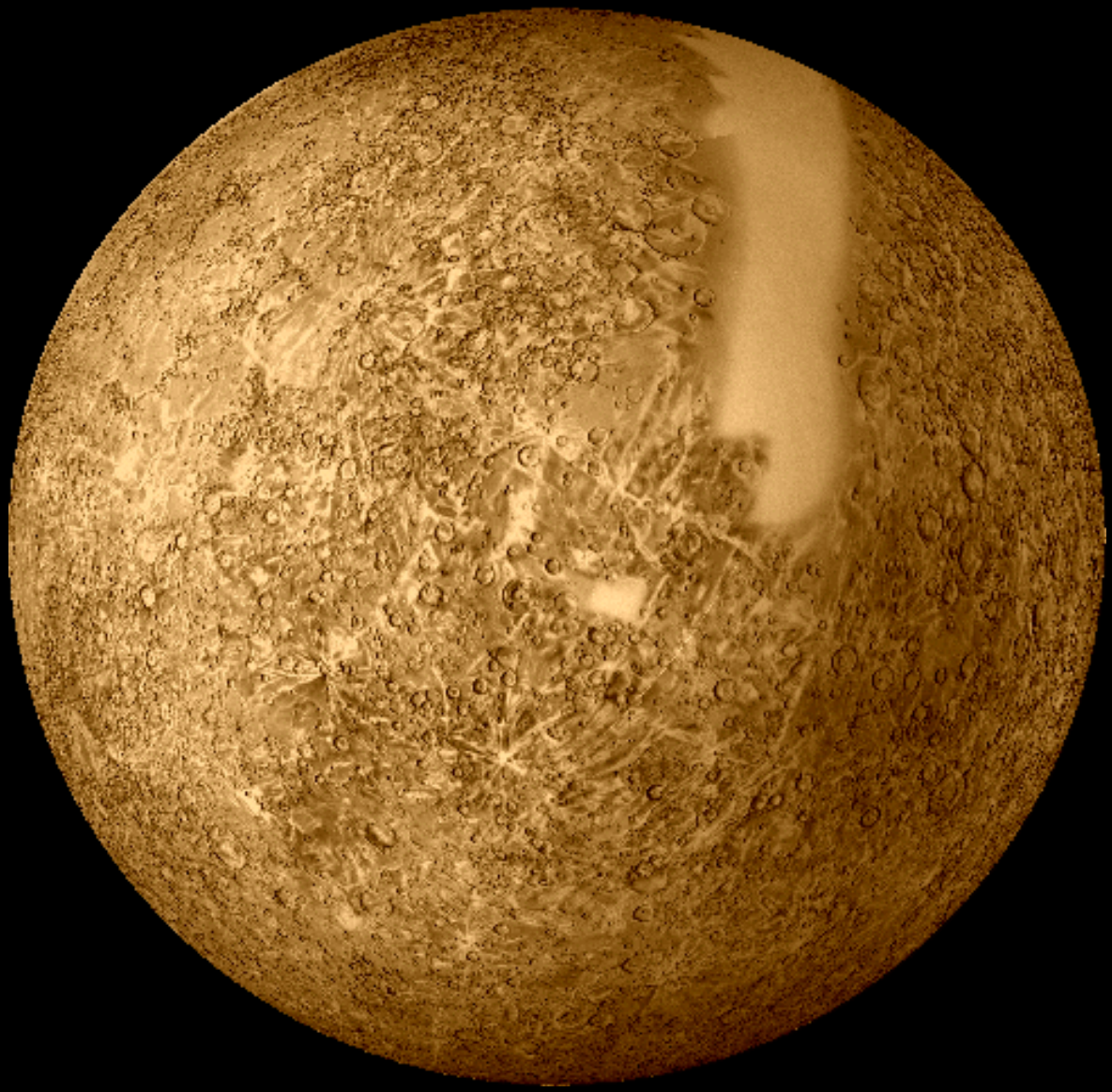
We are interested only in the inner four

Planets are divided into two very different groups.

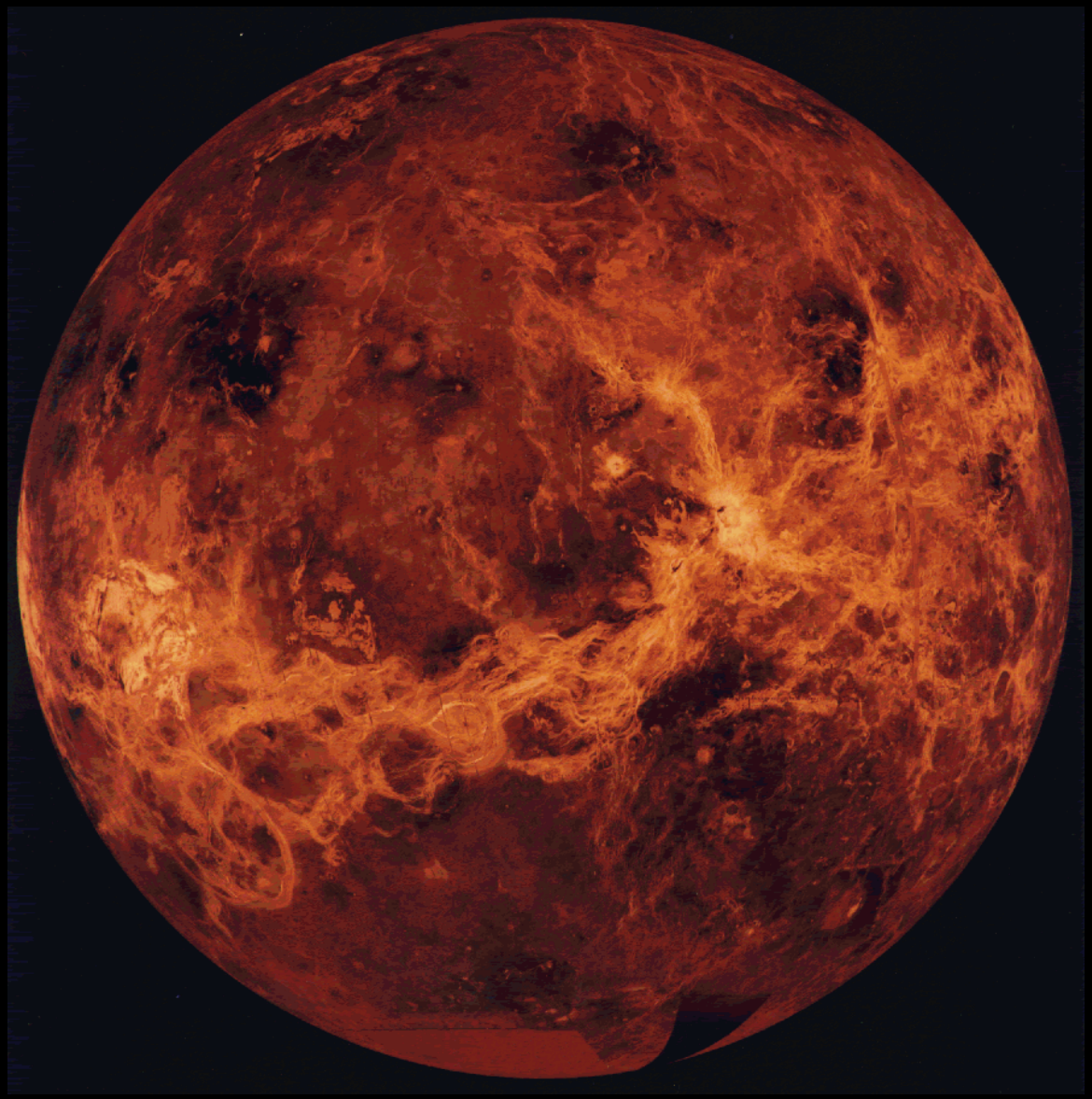
That differ markedly in composition



Mercury

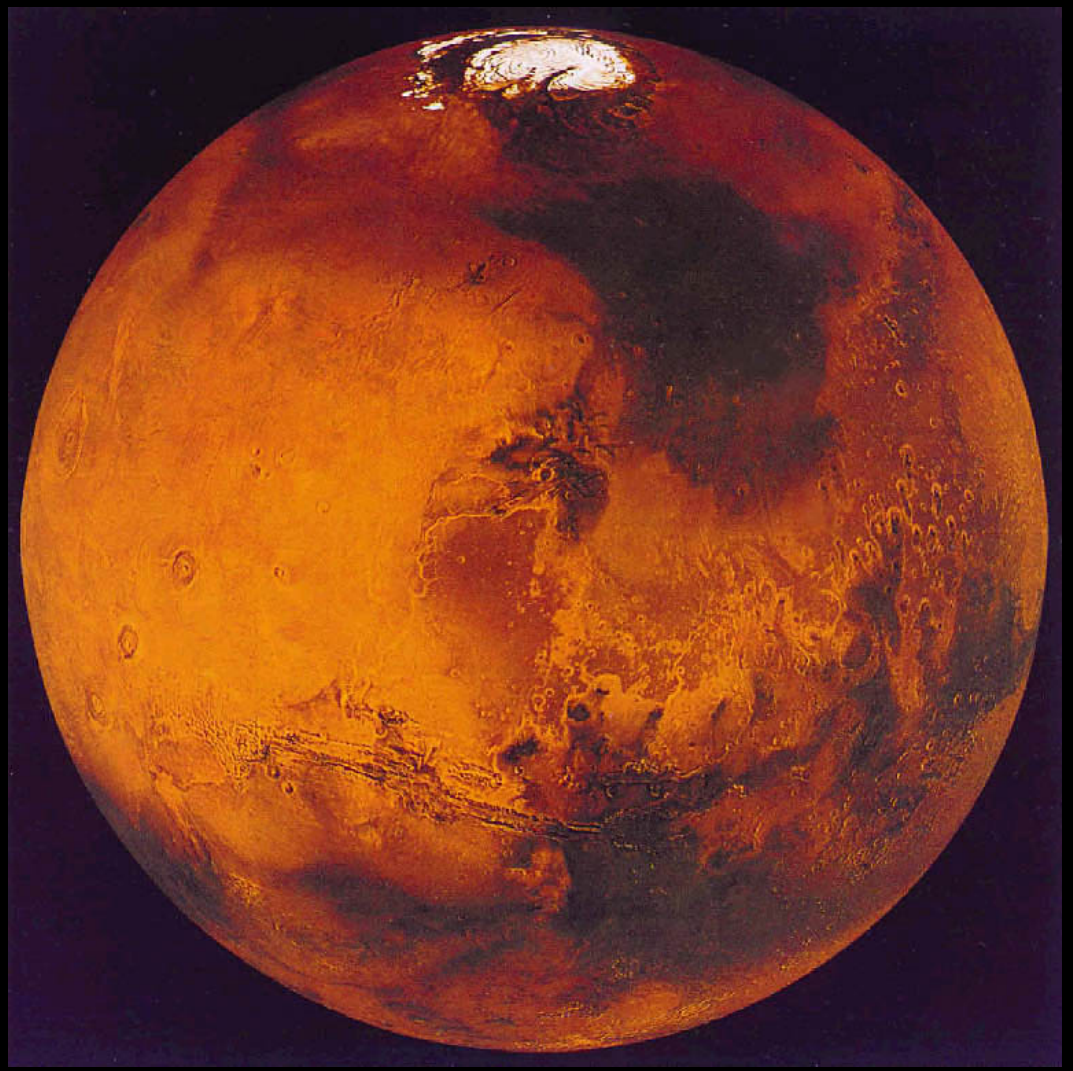


Venus



Earth

Mars



Mercury

Venus

All of these formed from the same processes at the same time. Why are they so different?

Earth

Mars

The Earth could have evolved in the direction of Mars

Bitter cold (-53° C), dry, with an atmosphere weighing only .06 times the Earth's.

A cold, dead, equilibrium planet

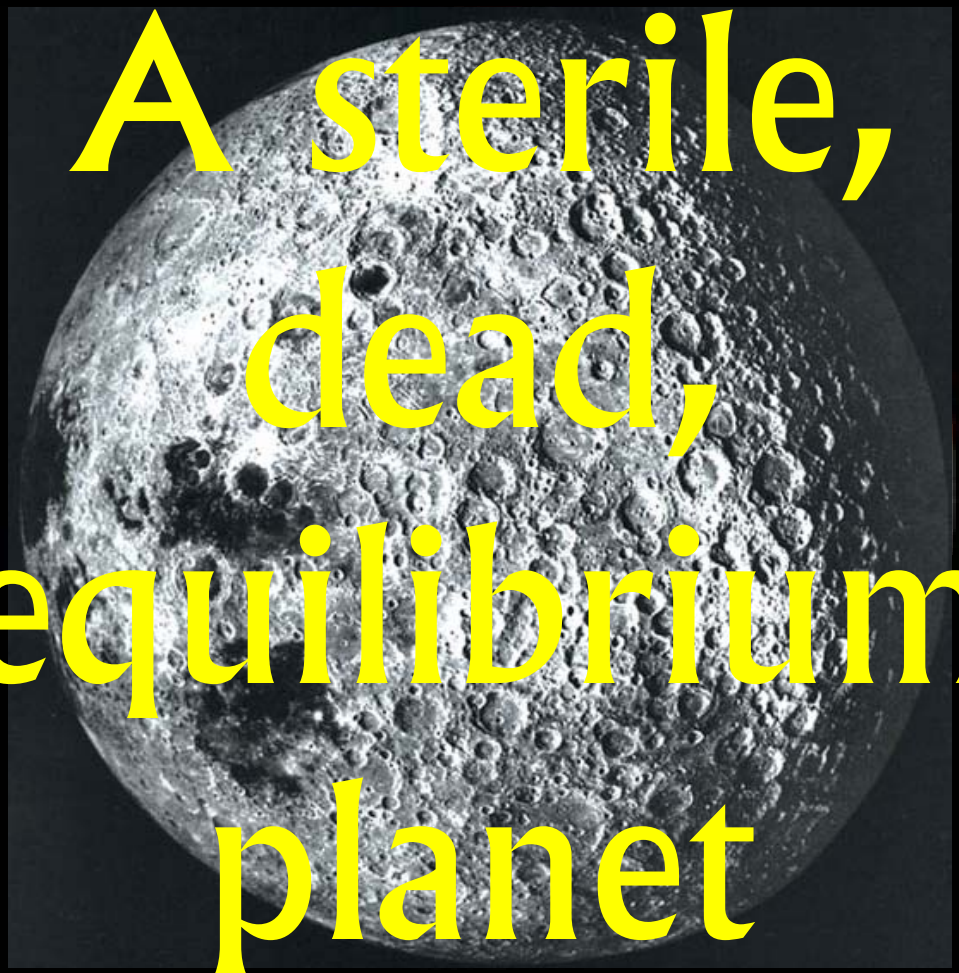
Or, the Earth could have evolved in the direction of Venus

A hot, dead, equilibrium planet

Fiery hot (477° C), a dense, choking acidic atmosphere, weighing about 90 times more than the Earth's atmosphere.

Radar image of Venus seen through the thick cloud cover that blocks the surface

Or, the Earth could have evolved in the direction of the moon

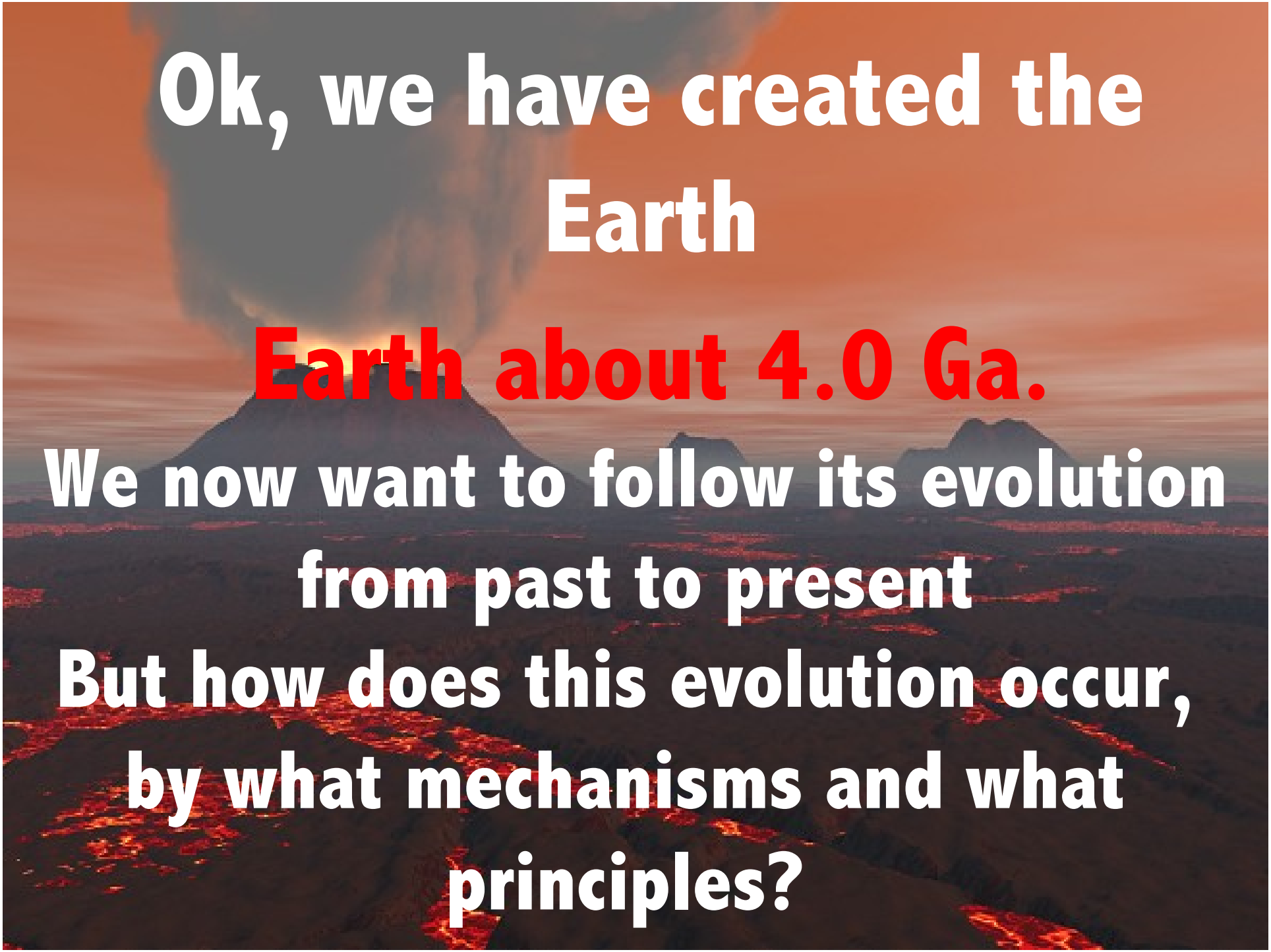


A sterile, dead, equilibrium planet

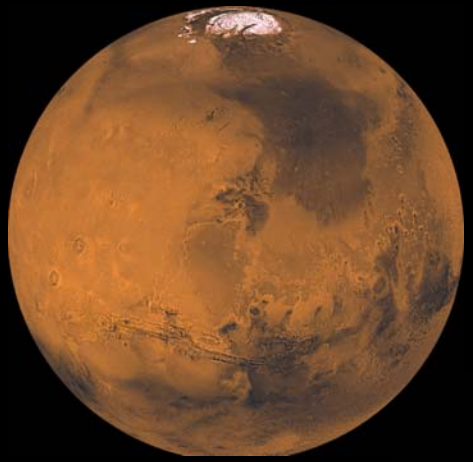
But, the Earth did none of these things

It remained an open, dynamic, living thing.

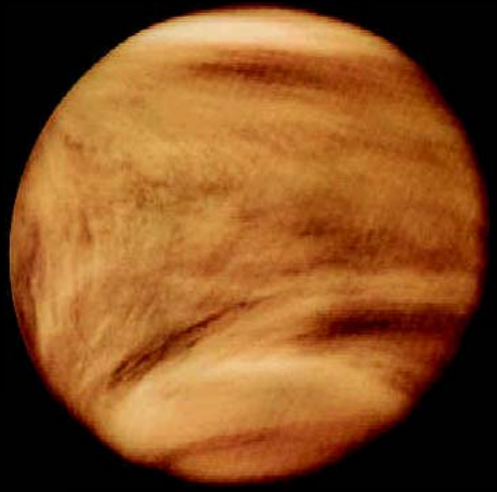
WHY ?


Ok, we have created the Earth
Earth about 4.0 Ga.
We now want to follow its evolution from past to present
But how does this evolution occur, by what mechanisms and what principles?

Mars is an equilibrium planet, and it is dead



Venus is an equilibrium planet, and it is dead

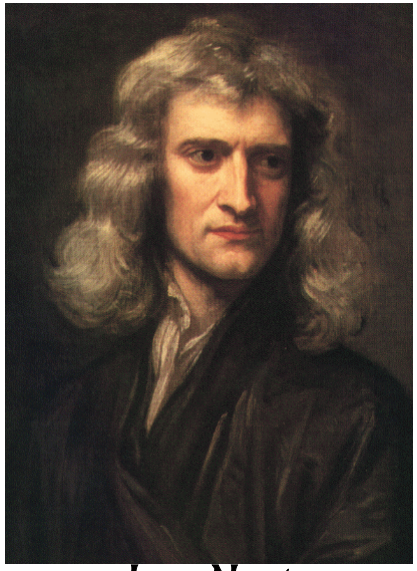


The Earth is a non-equilibrium planet, and it is alive.

What does it mean to be in equilibrium or evolve to equilibrium ?

Newtonian Science
Classical Science

Newton combined two long running historical threads of Truth-searching, empirical truth and analytical truth to create the foundations of modern science.



Isaac Newton
(1642-1727)

1. He began empirically – by making observations. The apple fell from the tree.
2. And then described the process analytically (mathematically).

By combining empirical and analytical methods Newton laid the foundations of modern science – still with us today.

Classical Science works from a number of assumptions.

Assumption # 1

"The world is simple and is governed by time-reversible fundamental (mathematical) laws."

For Example . . .

$$Force = M \times A$$

$$F_g = \frac{M_1 \times M_2}{d^2}$$

$$X_{next} = rX \cdot (1-X)$$

Growth
Positive feedback

Death
Negative feedback

Assumption # 2

Change is: deterministic – there is a direct relationship between cause and effect – and the outcome is predictable

Determinism and Predictability

Determinism is the philosophical doctrine that every state of affairs, including every human event, act, and decision is the inevitable consequence of antecedent states of affairs. It holds that no random, spontaneous, mysterious, or miraculous events occur.

Since you can write down equations and solve them in order to predict the second event based on the occurrence of the first event, the predictability becomes the key issue.

Another word for such predictability is determinism; the first event determines the occurrence of the second.

In classical science

To be deterministic is to be predictable

Assumption # 3

Science tells us that change is linear: slow, gradual, and stately

Linear – Gradual - Change

As attributed to Aristotle, Newton, Leibniz, Linnaeus, Darwin, . . . and others.

natura non facit saltum

"Nature does not make leaps."

Assumption # 4

The natural outcome of these laws is an equilibrium state; a body at rest, or a completed reaction, entropy at the maximum.

How can something become more complex and diverse with time, when the trend is for everything to decay, wear down, wear out?

Laws of Thermodynamics

1st Law: You can't win. In any process, the total energy of the universe remains the same.

2nd Law: You can't break even. The entropy of an isolated system not in equilibrium will tend to increase over time, approaching a maximum value at equilibrium.

3rd Law: You can't get out of the game. Absolute zero cannot be attained by any procedure in a finite number of steps. Absolute zero can be approached arbitrarily closely, but it can never be reached.

The Problem of Problems

Is about the 2nd Law: You can't break even.

Which is about . . .

Entropy

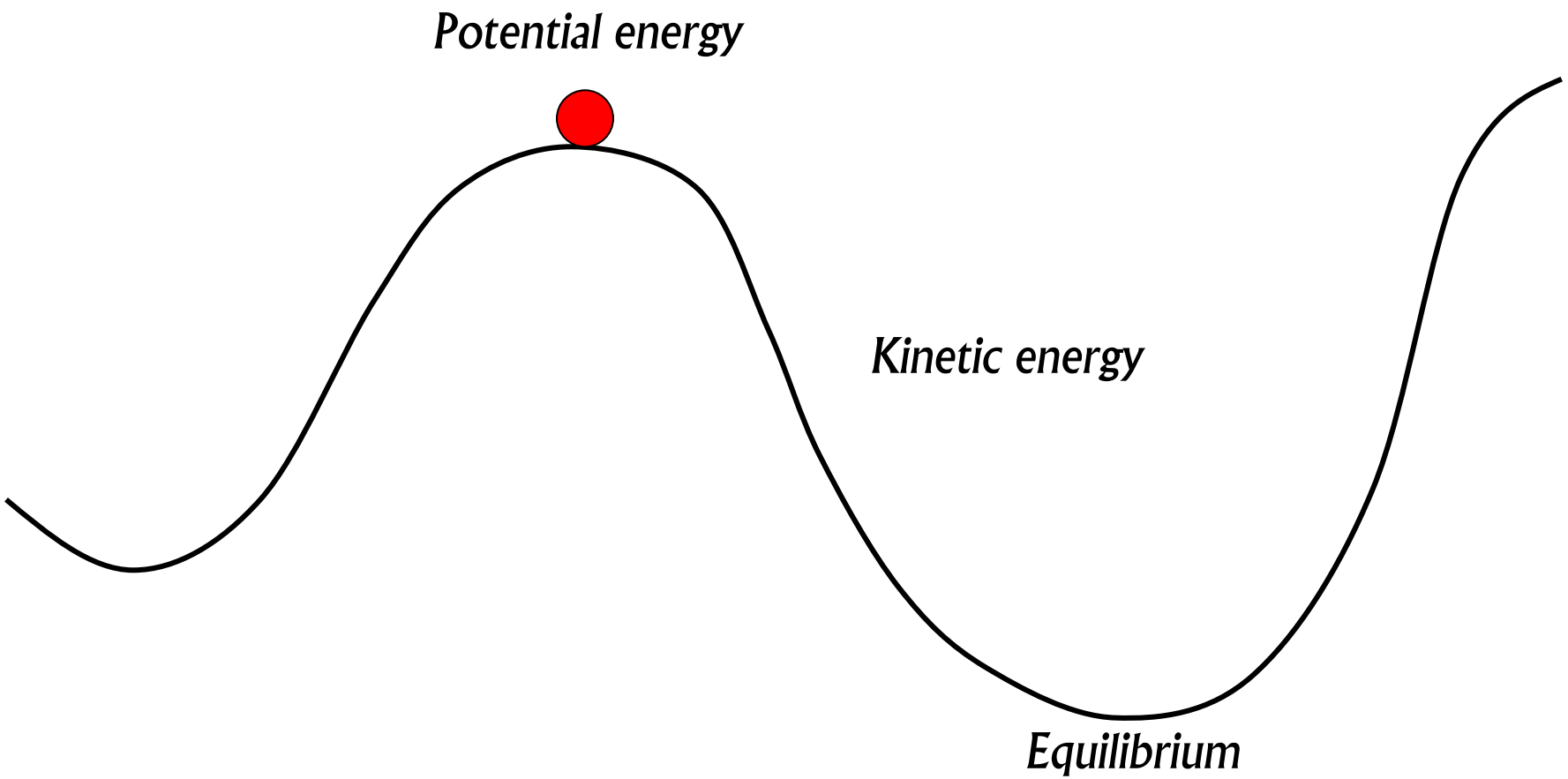
Thermodynamic Entropy - *"For a closed system, the quantitative measure of the amount of thermal energy* ***not*** *available to do work."*

- The higher the entropy the more uniform heat is distributed.
- Entropy in a closed system can never decrease.
- It's a negative kind of quantity, the opposite of available energy.

Logical Entropy - *"A measure of the disorder in a closed system."*

- The higher the disorder the higher the entropy.
- Entropy in a closed system can never decrease.
- Without someone to fix it a broken glass never mends.

Kinetic Equilibrium

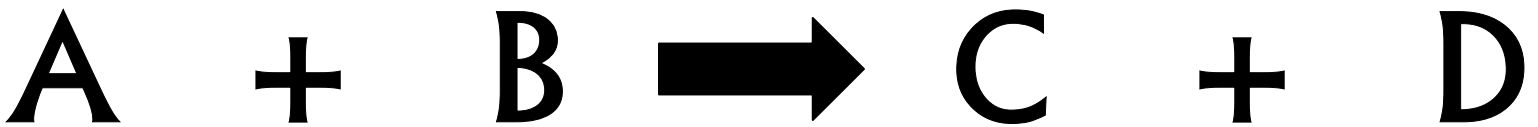


End of Story

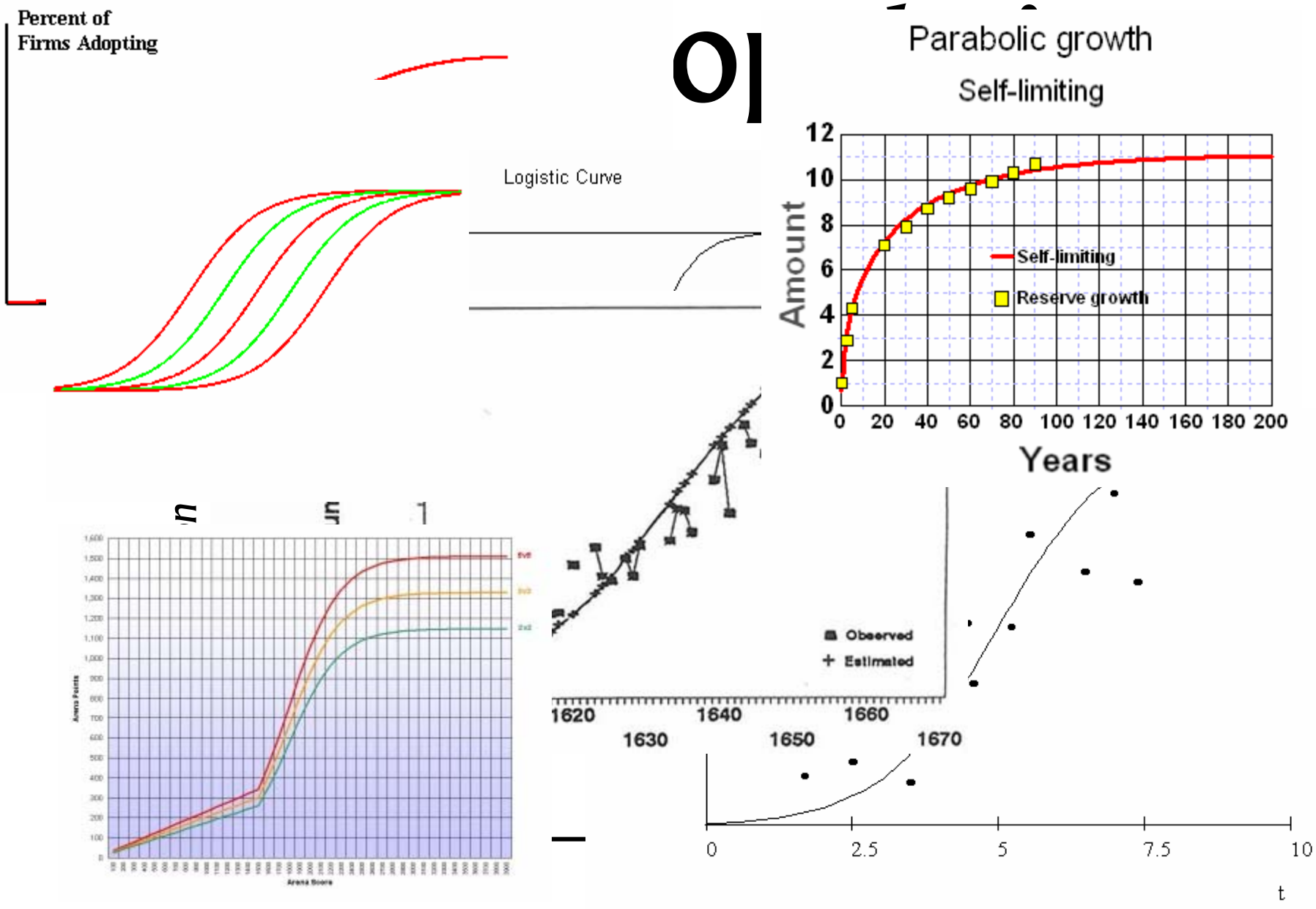
Chemical Equilibrium

Chemical Reactants

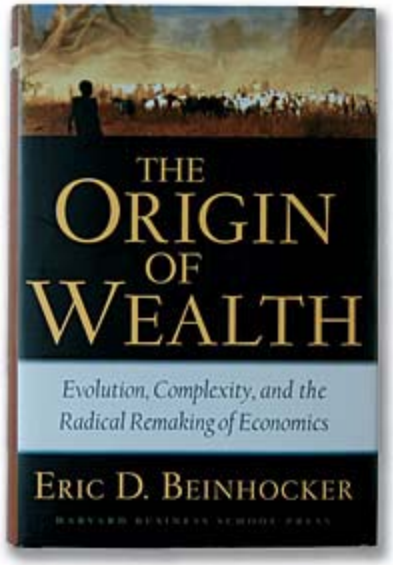
Chemical Products



End of Story


Percent of
Firms Adopting
Logistic Curve
Parabolic growth
Self-limiting
Amount
Years
Self-limiting
Reserve growth
0
2
4
6
8
10
12
0
20
40
60
80
100
120
140
160
180
200
Observed
Estimated
1620
1630
1640
1650
1660
1670
0
2.5
5
7.5
10
t

Economic Equilibrium



Eric Beinhocker

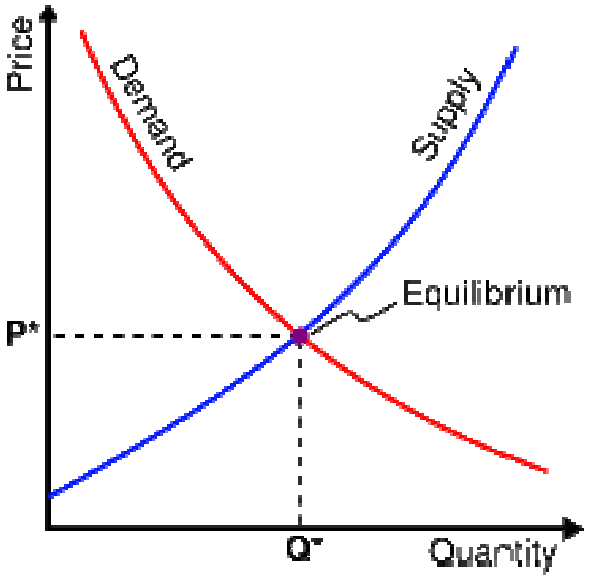
Since the late nineteenth century, the organizing paradigm of economics has been the idea that the economy is an equilibrium system, essentially a system at rest. (p 17)

Economic Equilibrium

Leon Walras

(1834 - 1910)

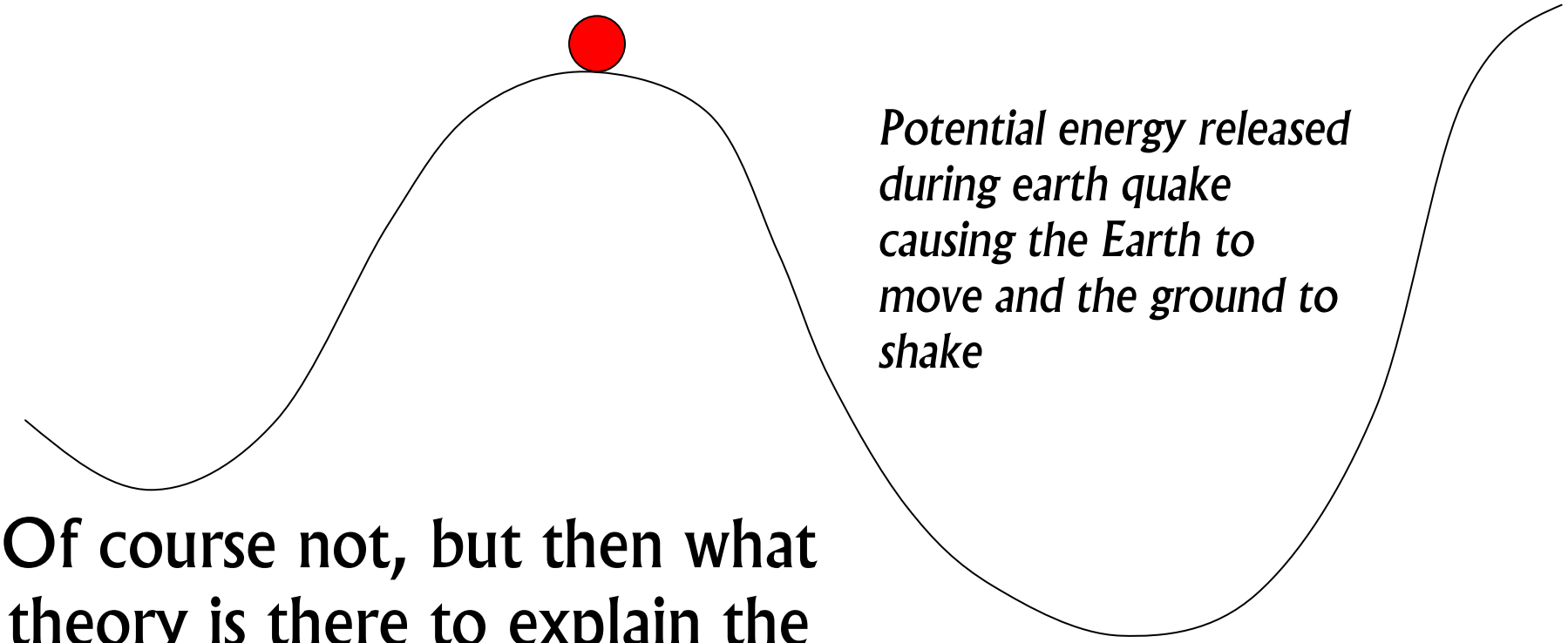
When Walras imported the concept of equilibrium from physics into economics, he gained mathematical precision and scientific predictability. (p 17)



The mathematical equations of equilibrium imported from physics were ideal for answering the allocation question . . .

Take Earthquakes

Lots of potential energy stored in the rocks



Potential energy released during earth quake causing the Earth to move and the ground to shake

Earthquake finished

Does this mean that the system is now closed, dead, unable to change more?

Of course not, but then what theory is there to explain the behavior of systems through which energy passes continuously?

IF the assumption is true that all systems evolve naturally and directly to equilibrium (like you have been taught) . . .

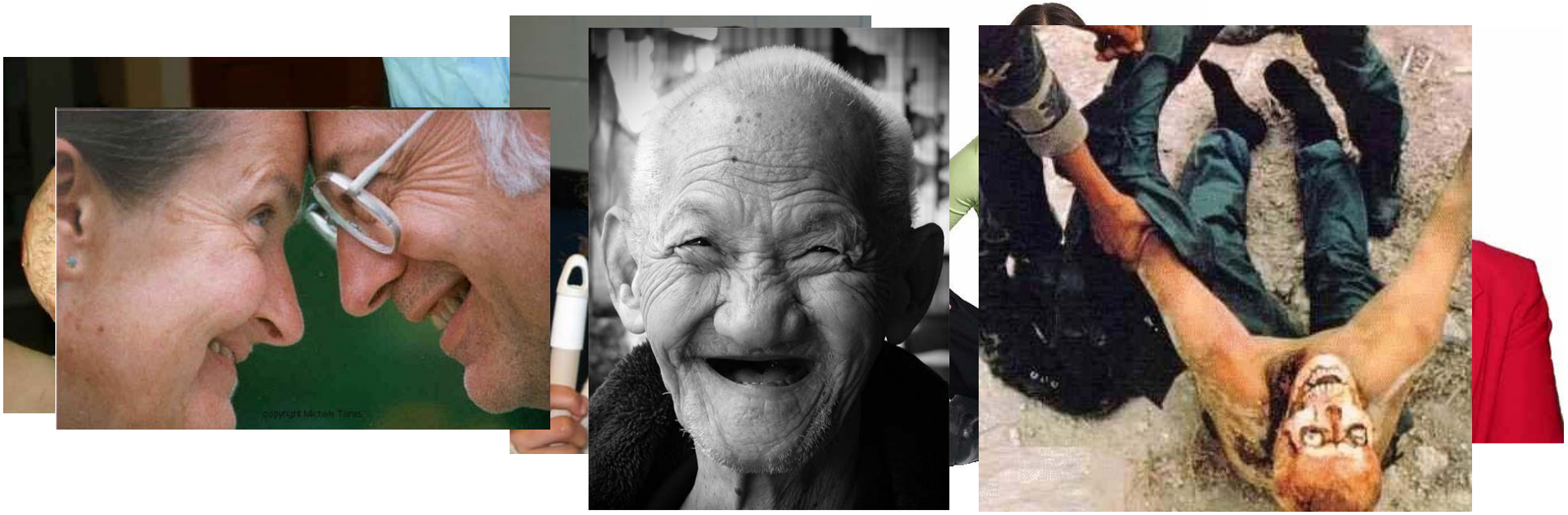
Then you would be ...

dead.

You are not an equilibrium system (at least not yet).

In fact, if we think about your (ourselves) as being open systems, what do we observe, how do we behave?

We evolve, change with time.



IF the assumption is true that all systems evolve naturally and directly to equilibrium (as we have been taught) . . .

Then how do things - like the Earth and the human body - evolve?

What natural process gives a system that always heads to the lowest energy state and the greatest disorder to get more complex?

THERE IS A CONTRADICTION HERE THAT WE NEED TO RESOLVE

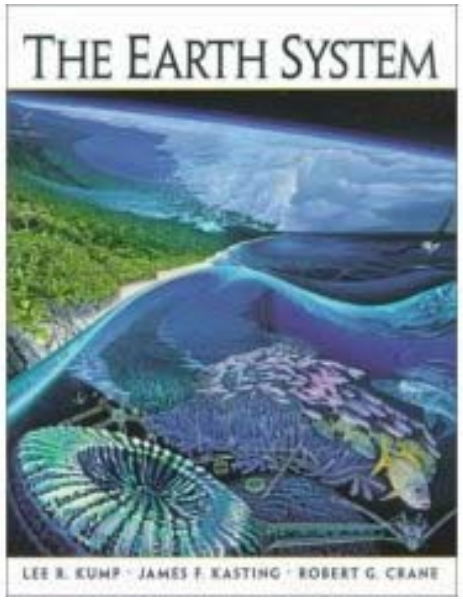
The Elephant in the Room

An English idiom for an obvious truth that is being ignored.

How Long Has That Been There ?

The expression "elephant in the room" refers to a situation where something major is going on, it's on everyone's mind and impossible to ignore –– like an elephant in the room. But nobody talks about the "elephant" because nobody knows what to do about it.

The Elephant in the Room



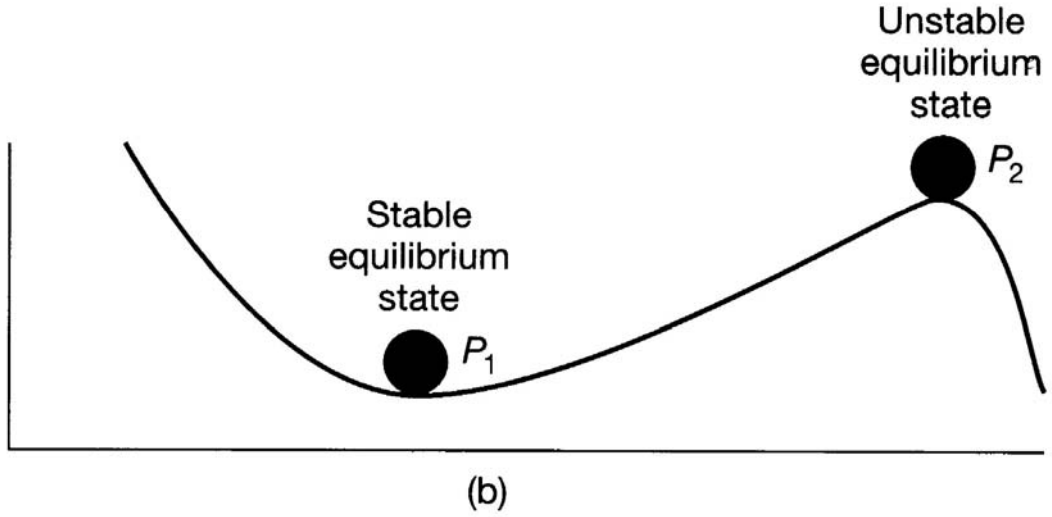


FIGURE 2-11

The response of Daisyworld to perturbation. (a) Daisyworld experiences a small (step a_1) and a large (b_1) reduction in daisy coverage. Responses (steps a_2 through a_9 and b_2) are shown as individual steps (for example, first a temperature response and then a daisy-coverage response); in reality, temperature and daisy coverage would respond simultaneously. (b) The stability of P_1 and instability of P_2.

The Elephant in the Room

An English idiom for an obvious truth that is being ignored.

Everything we are going to discuss is the way it is, or the way it was, because of the dissipation of energy.

Yet we teach in all of our classrooms that everything is evolving to equilibrium.

It in like the game Monopoly: go to equilibrium, go directly to equilibrium, do not pass Go, do not collect $200

That is Elephant in the Room

We know how equilibrium systems evolve . . .

It is what we have all been taught.

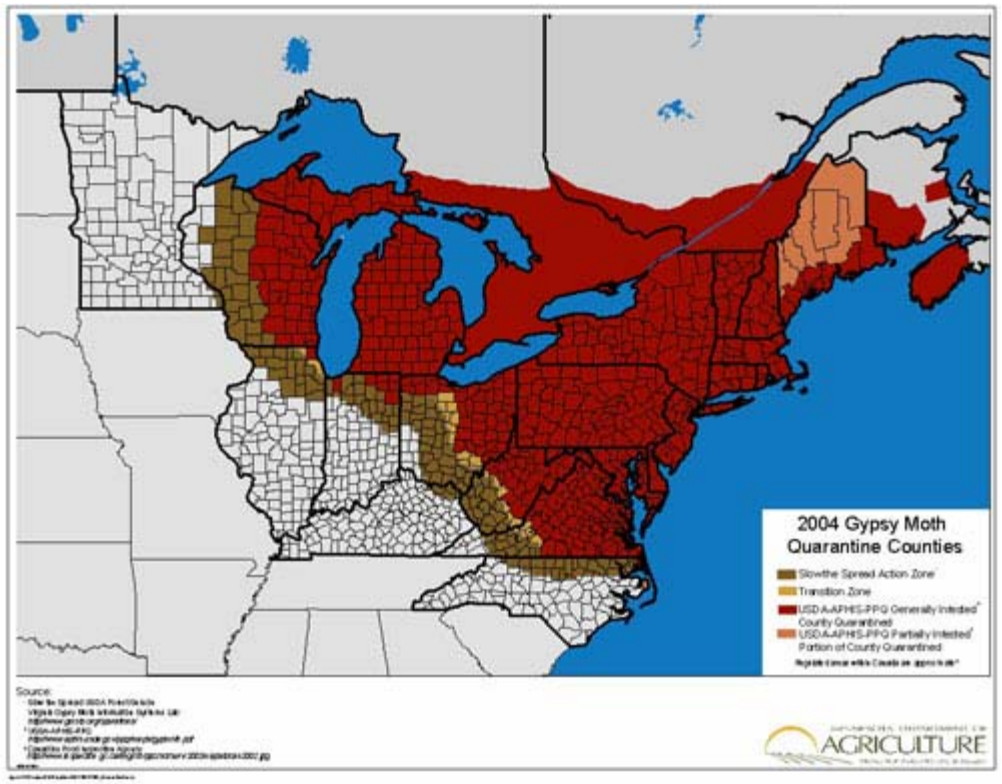
They evolve to lowest energy.

But, how do non-equilibrium systems behave ?

Chaos and Complex Systems Theory

Why the Earth does not behave as an equilibrium system

Population Growth and the Gypsy Moth



Population Growth and the Gypsy Moth

rate of growth

$$X_{next} = r \; X$$

Next years population

this years population

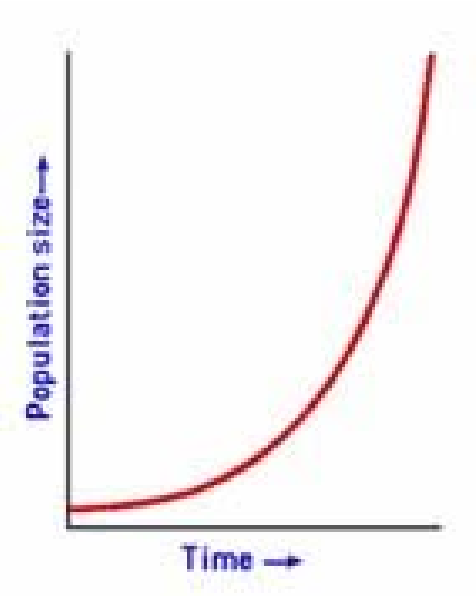
Population Growth and the Gypsy Moth

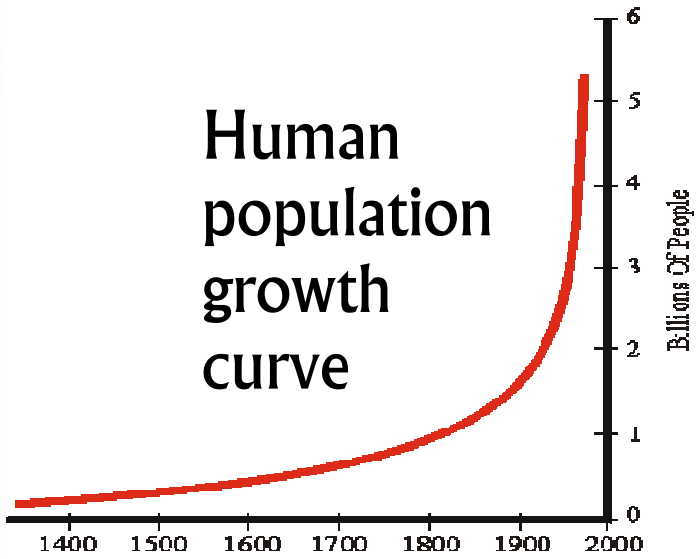
rate of growth

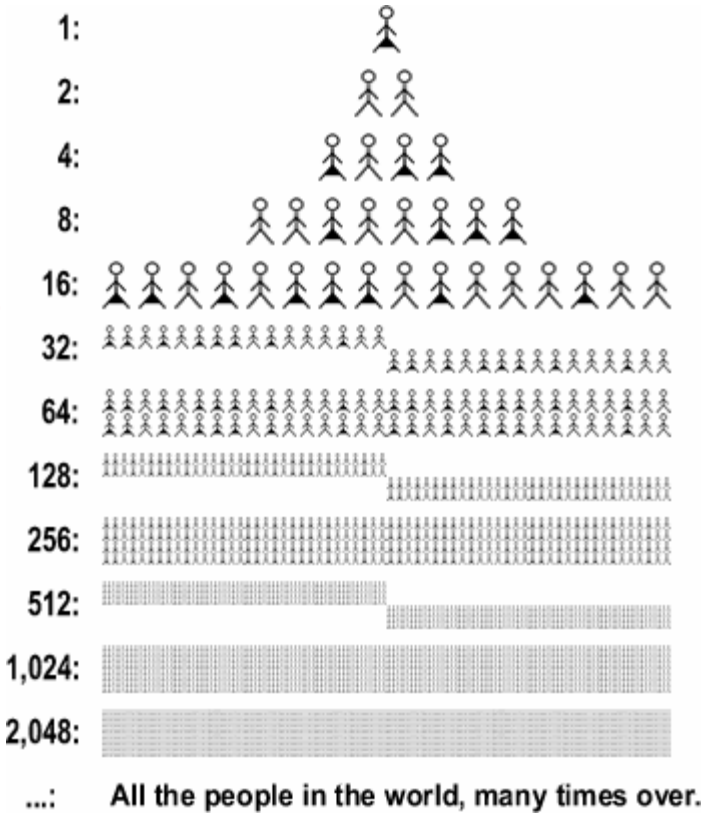
$$X_{next} = r \times$$

Next years population

this years population







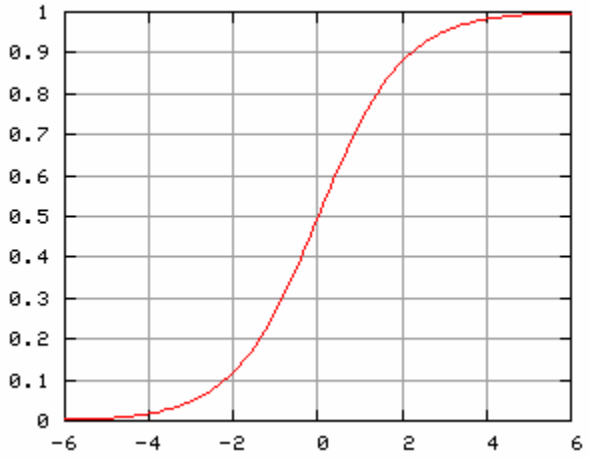
Population Growth and the Gypsy Moth

Positive feedback *Negative feedback*

$$X_{next} = r \; X \; (1-X)$$

Equilibrium state

The logistic function or logistic curve models the S-curve of growth of some set P. The initial stage of growth is approximately exponential; then, as competition arises, the growth slows, and at maturity, growth stops.



Modeling an Evolutionary System

X_{next} :A Model of Deterministic Chaos

(A.k.a. the Logistic or Verhulst Equation)

$$X_{next} = rX\ (1-X)$$

Logistic – population ranges between 0 (extinction) and 1 (highest conceivable population)

Iterated – algorithm is calculated over and over

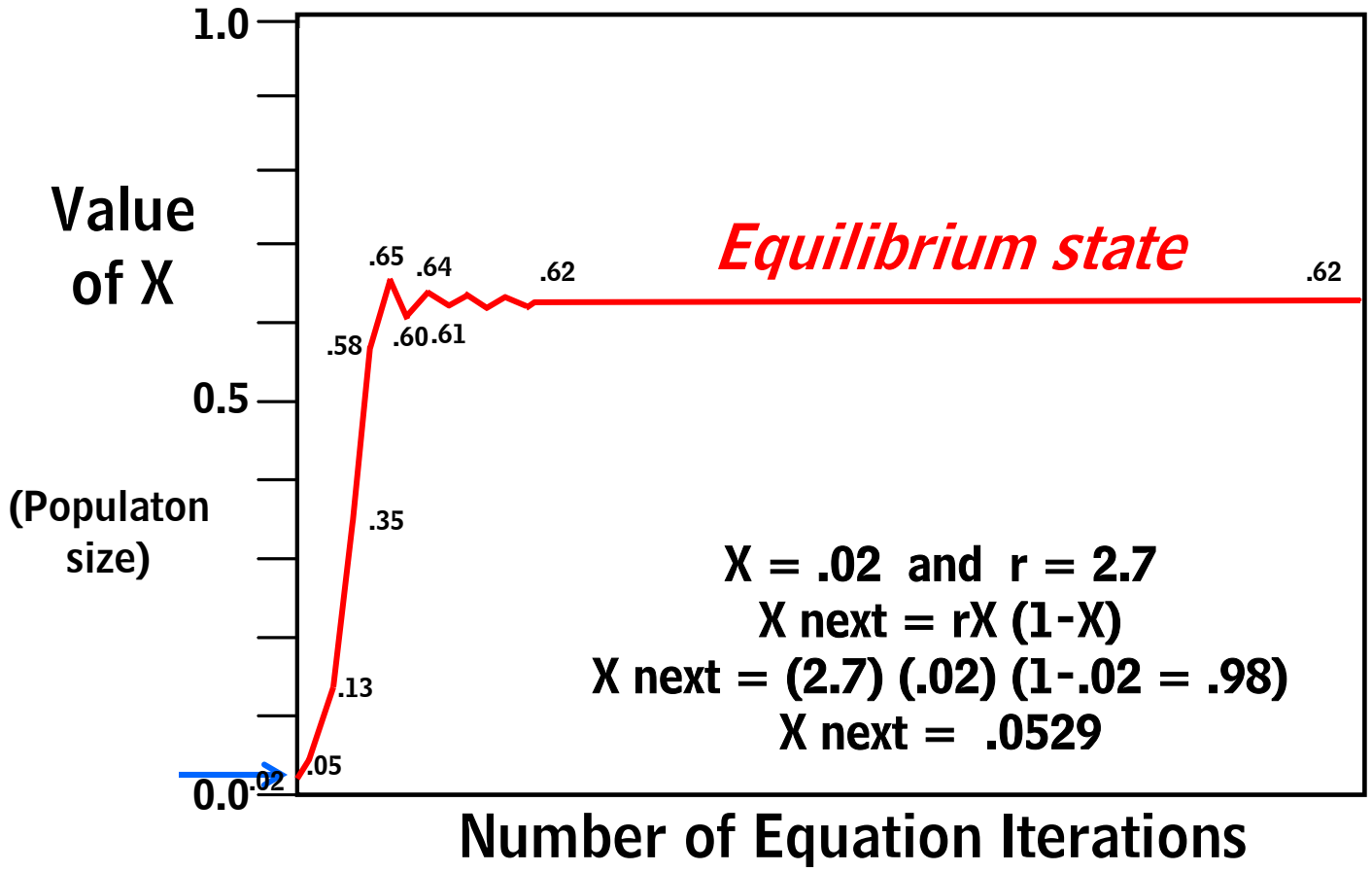
Recursive – the output of the last calculation is used as the basis of the next calculation.

Modeling an Evolutionary System

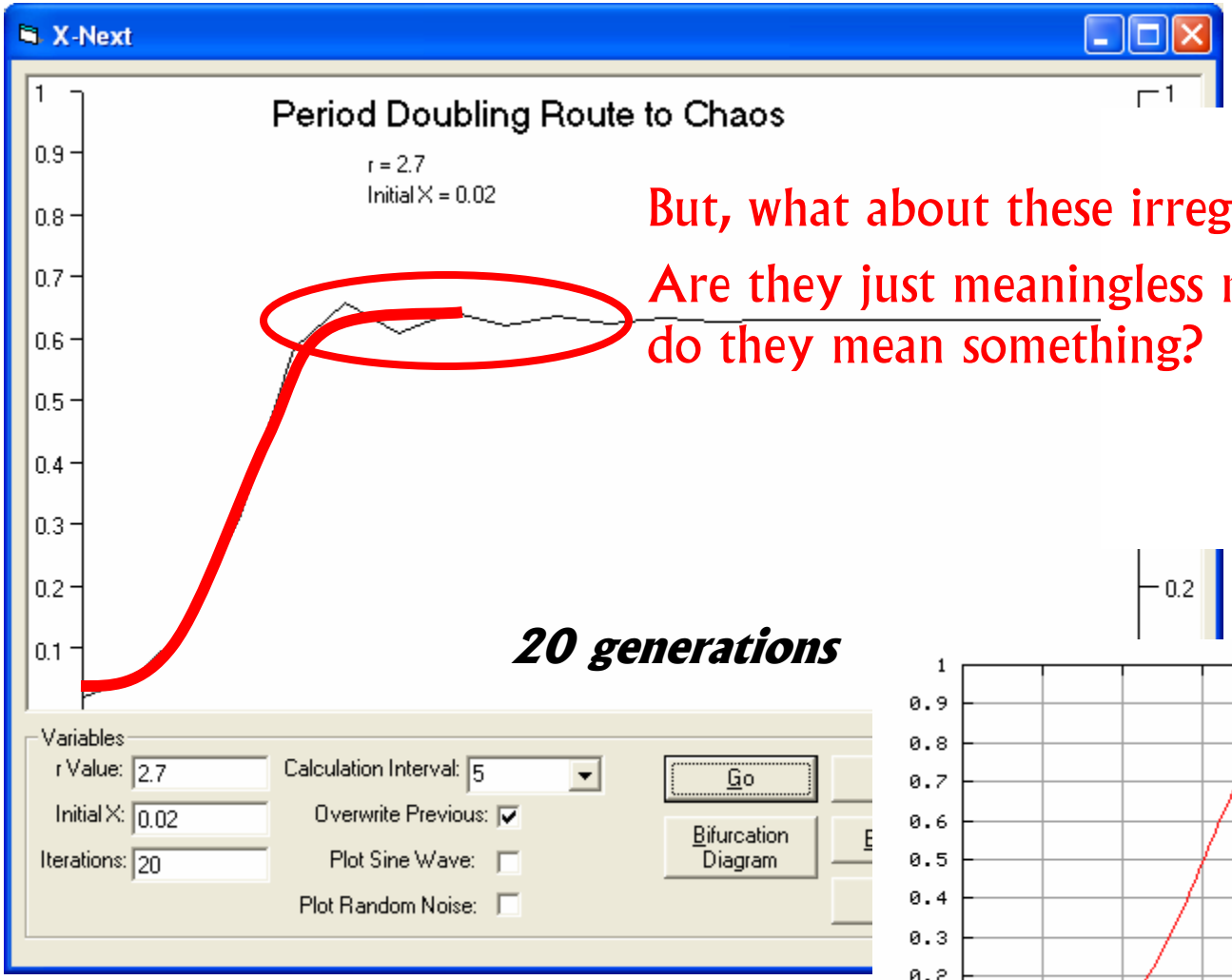
X_{next} and Deterministic Chaos

$$X_{next} = rX(1-X)$$

r = 2.7



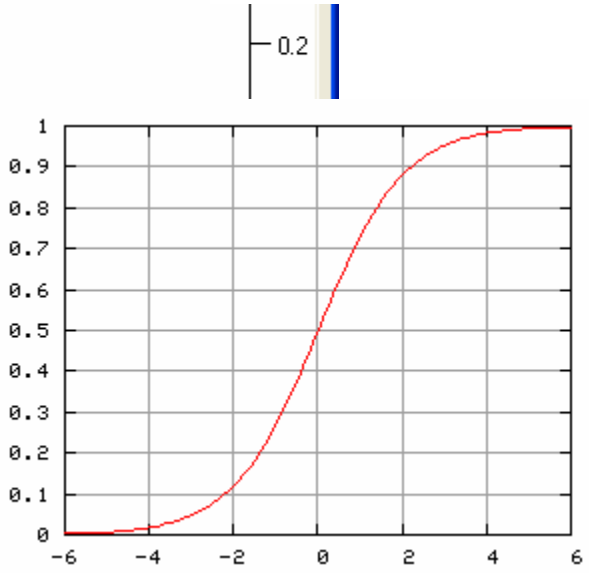
Iteration	X Value
0	0.0200000
1	0.0529200
2	0.1353226
3	0.3159280
4	0.5835173
5	0.6561671
6	0.6091519
7	0.6428318
8	0.6199175
9	0.6361734
10	0.6249333
11	0.6328575
12	0.6273420
13	0.6312168
14	0.6285118
15	0.6304087
16	0.6290826
17	0.6300117
18	0.6293618
44	0.6296296
45	0.6296296
46	0.6296296
47	0.6296296
48	0.6296296
49	0.6296296
50	0.6296296



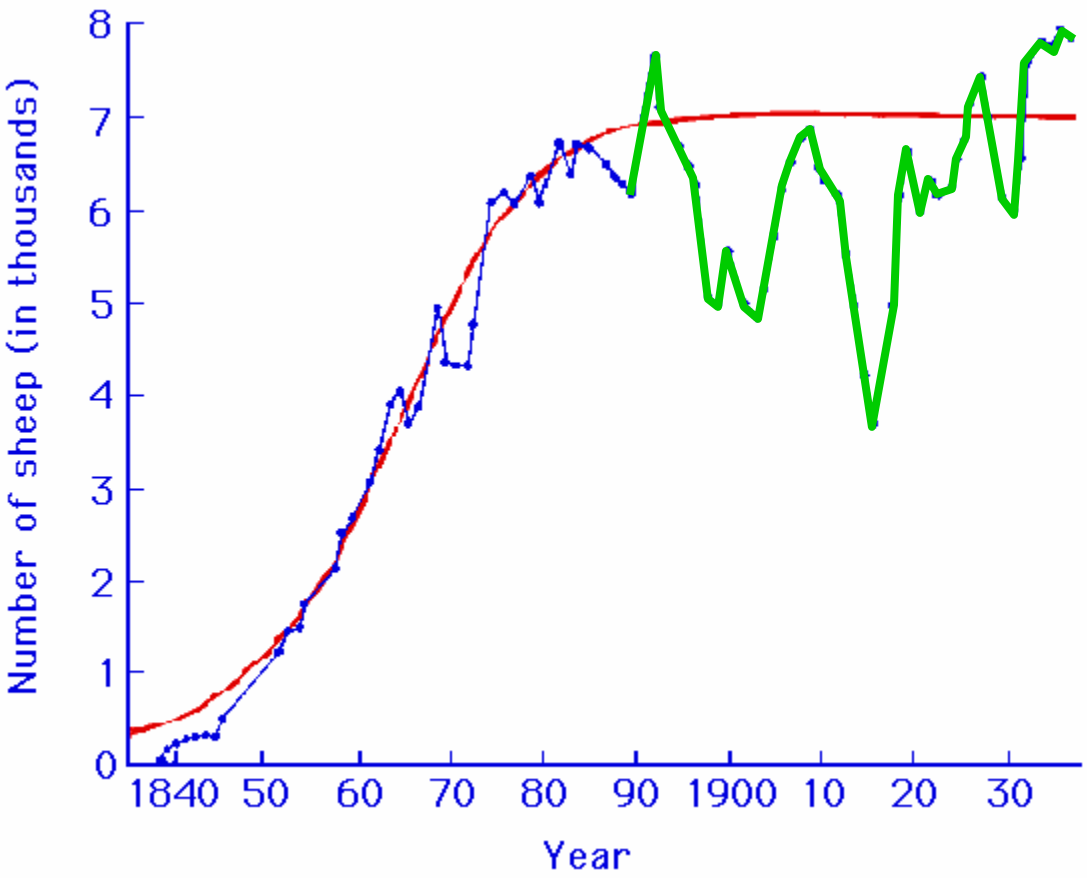
But, what about these irregularities?

Are they just meaningless noise, or do they mean something?

20 generations



Here is a brave attempt to make a real population curve follow a logistic "S" shape.



"The exponential growth phase exists because that is when the population has already begun to grow, but not a lot yet, and it rises quickly because there are no limiting factors yet and the resources are in unlimited amounts. The plateau phase begins when the organism hits it's carrying capacity, which is the maximum number of organisms in a population that can be supported by the environment at a certain time, in a certain ecosystem. The transitional phase in between these two phases occurs because this is when the limiting factors in the environment start to limit the increase, slowing the population increase."

Plateau - a land area having a relatively level surface

Plateau - to reach a state or level of little or no growth or decline

http://www.cic-caracas.org/departments/science/Topic4.php

Population Growth and the Gypsy Moth

Positive feedback *Negative feedback*

$$X_{next} = r \; X \; (1-X)$$

The question we have in front of us is what happens it I just keep increasing the r value; just keep pushing the system harder, and harder, and harder.

Population Growth and the Gypsy Moth

Positive feedback *Negative feedback*

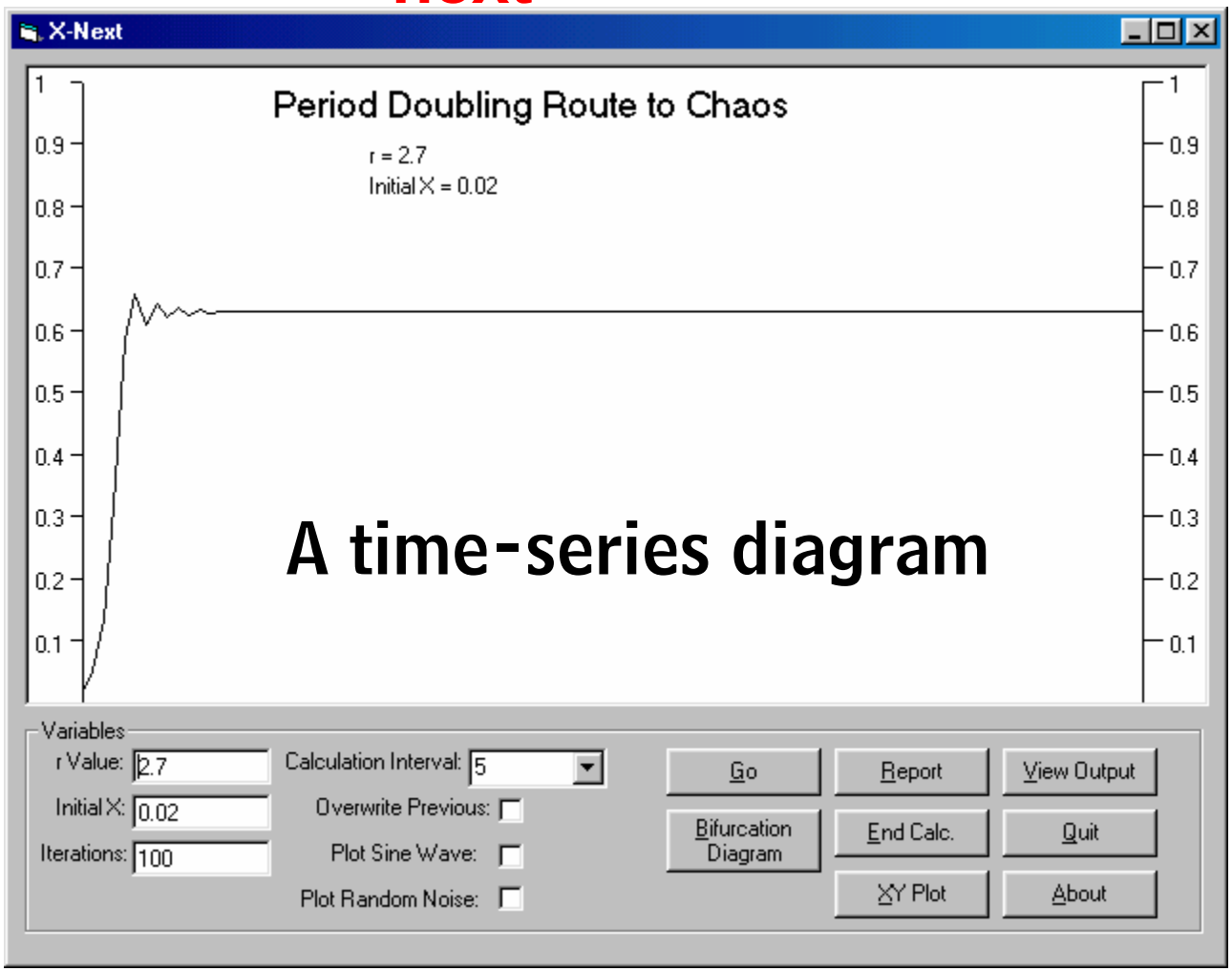
$$X_{next} = r \; X \; (1-X)$$

So, far we have talked about r as just rate of population growth.

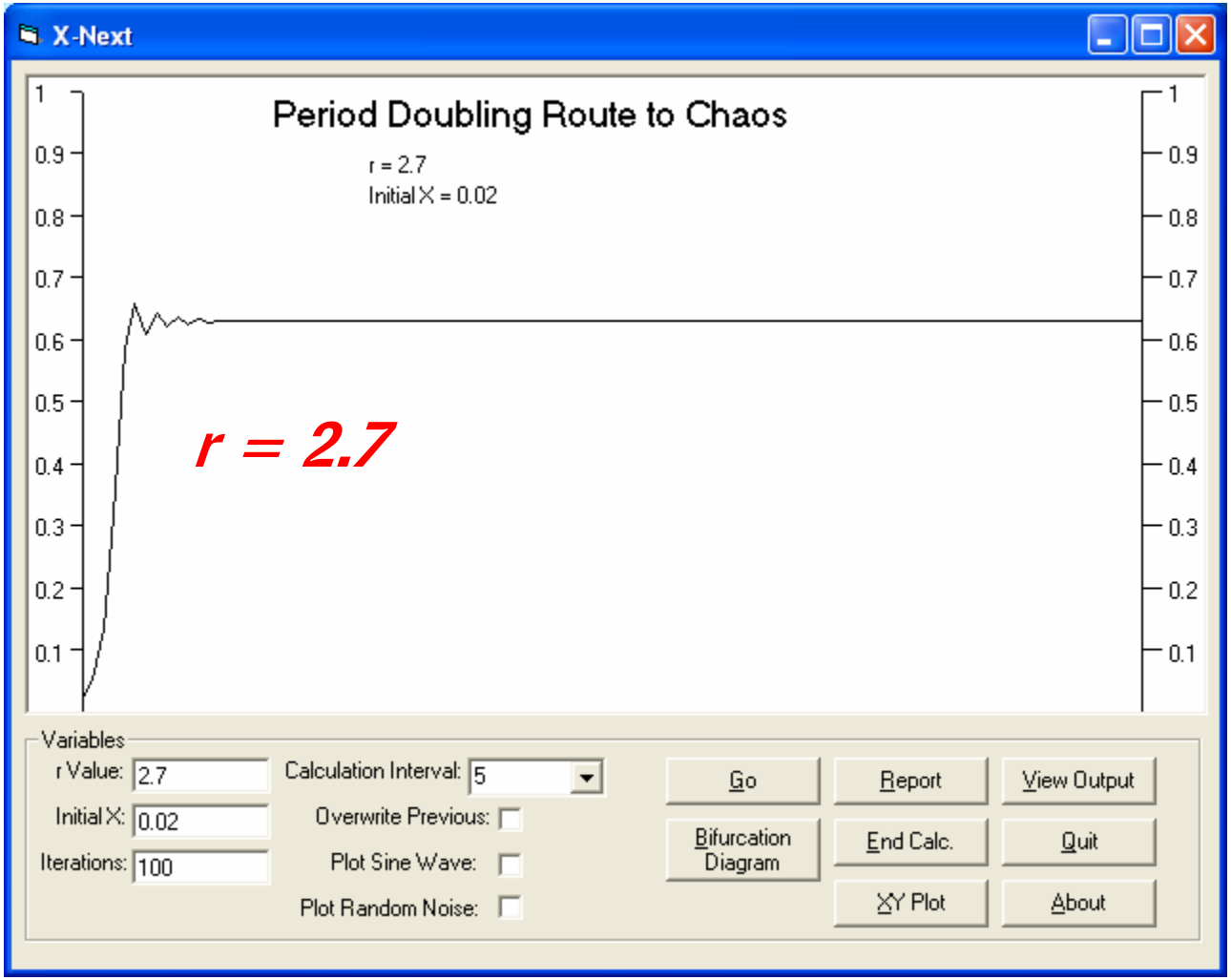
But, we will generalize r. It is an increase in anything, usually boiling down to increasing flow of energy and/or flow of information.

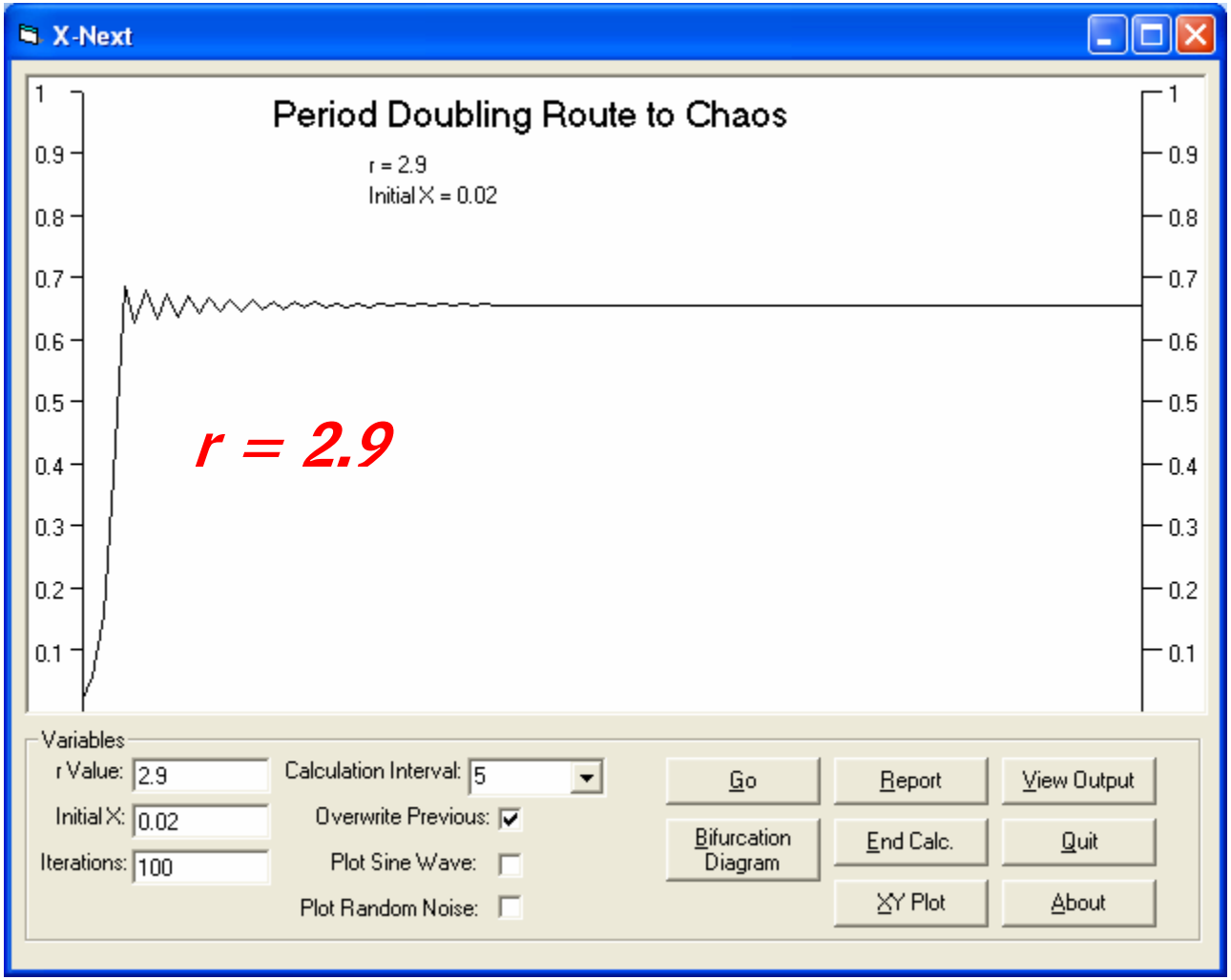
X_{next} and Deterministic Chaos

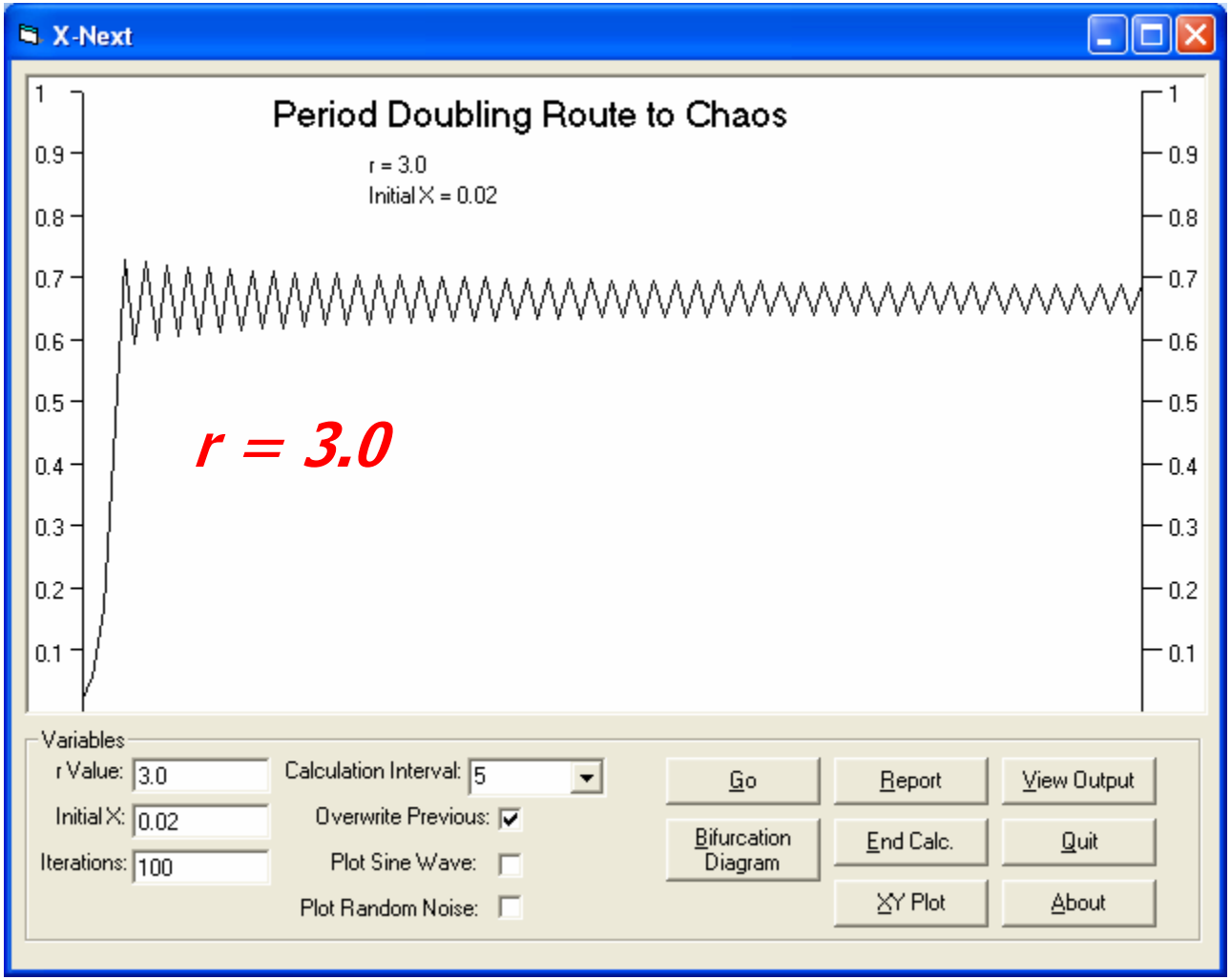
$X_{next} = rX(1-X)$

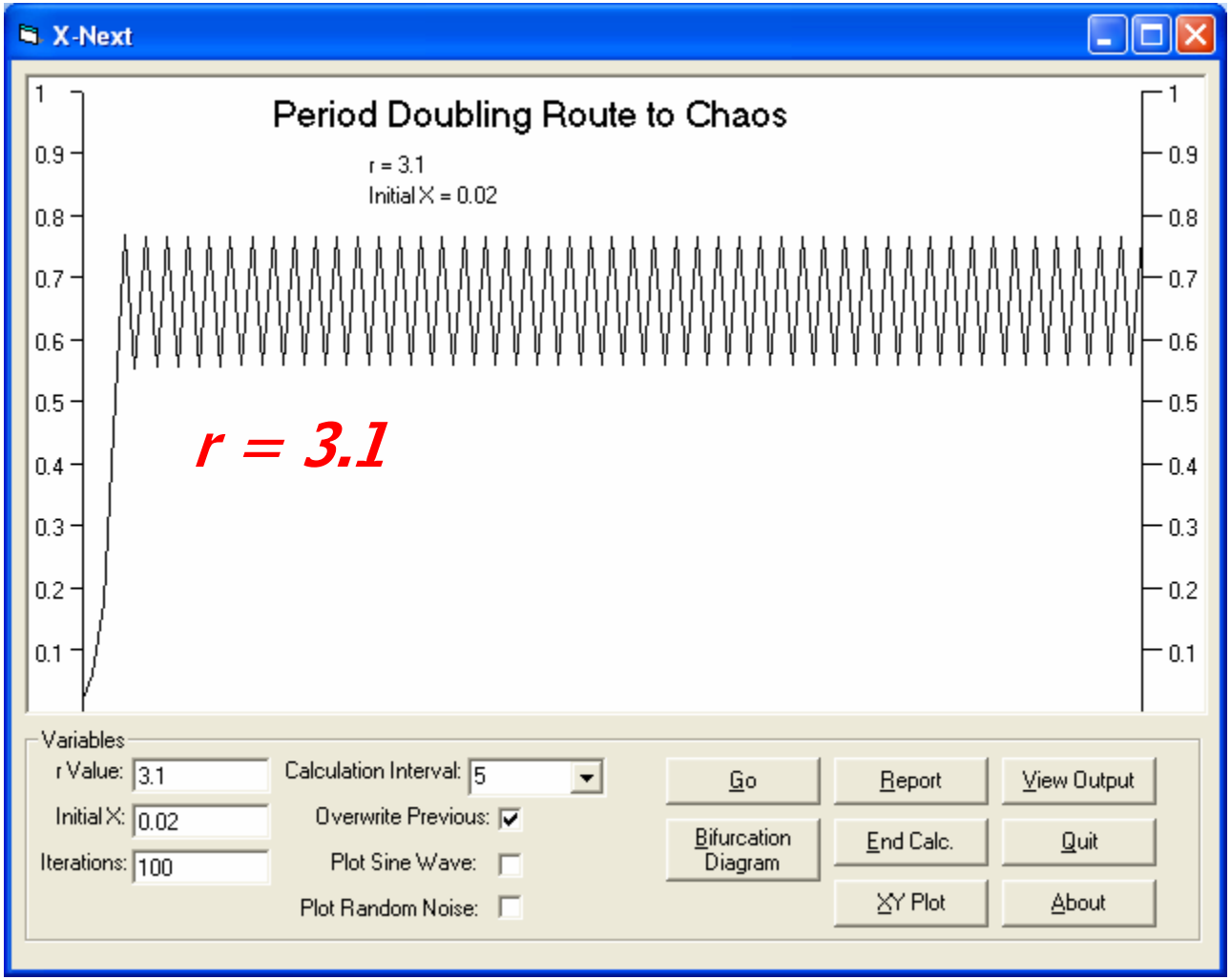


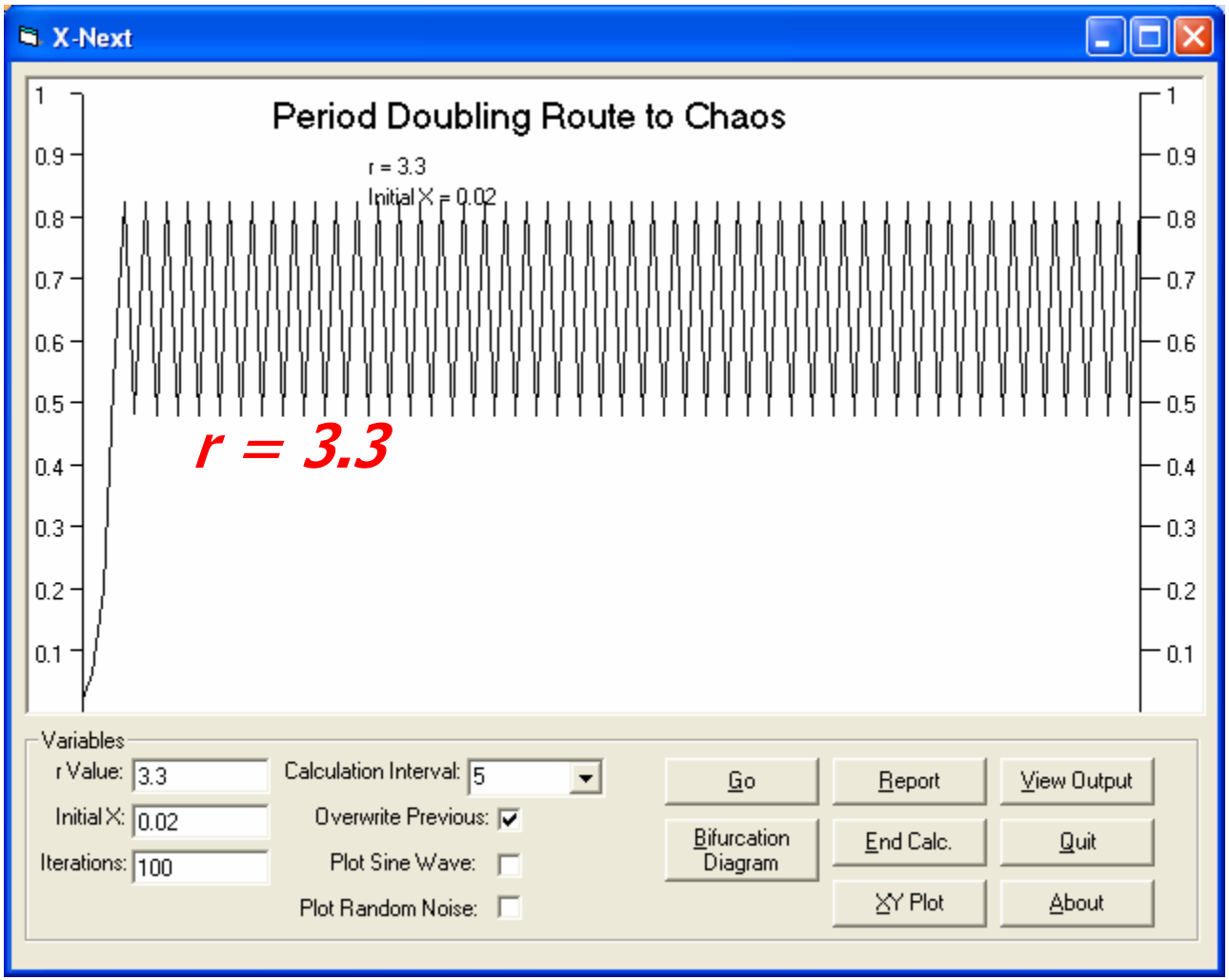
Run Xnext

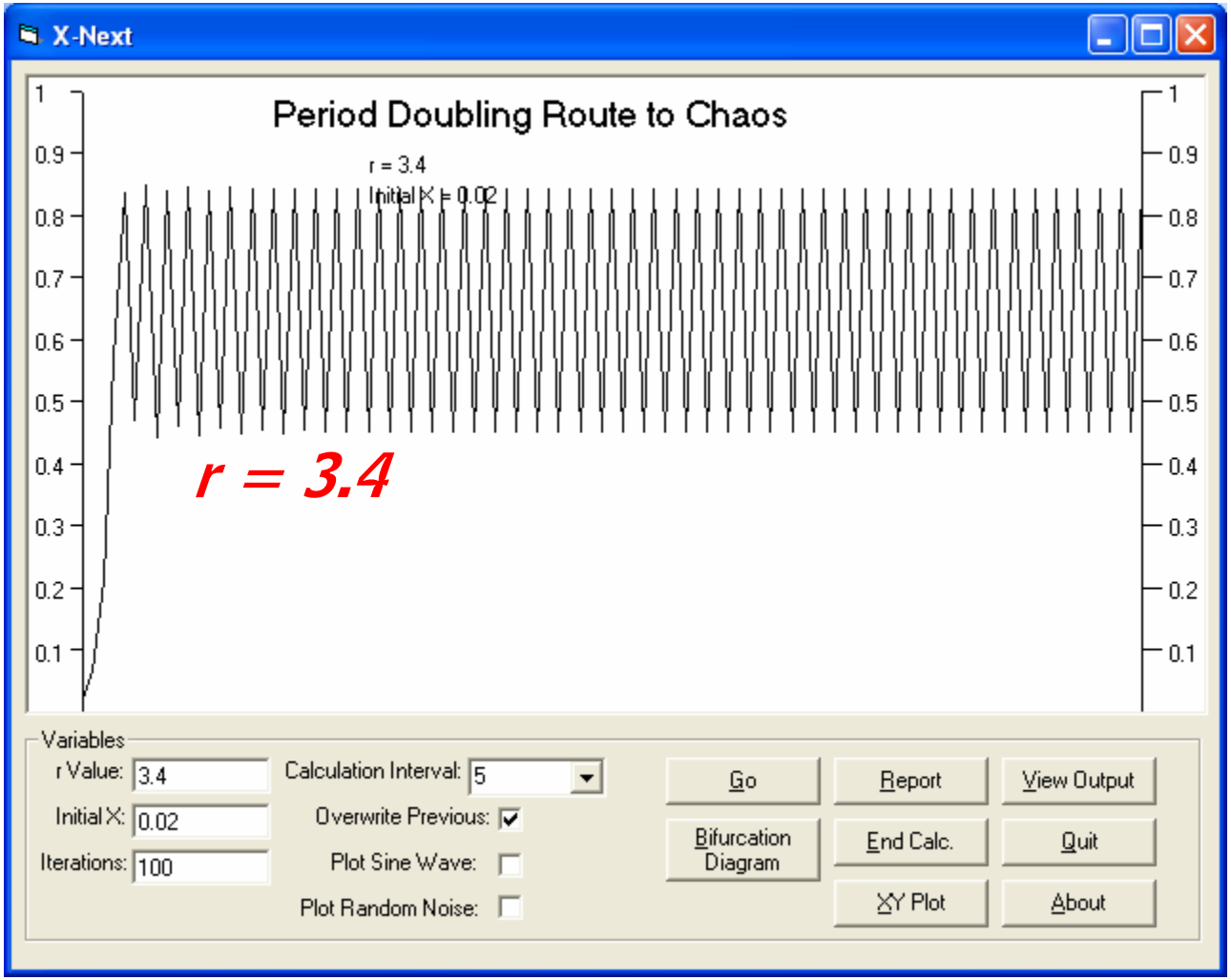

X-Next
Period Doubling Route to Chaos
r = 2.7
Initial X = 0.02
r = 2.7
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Variables
r Value: 2.7
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About

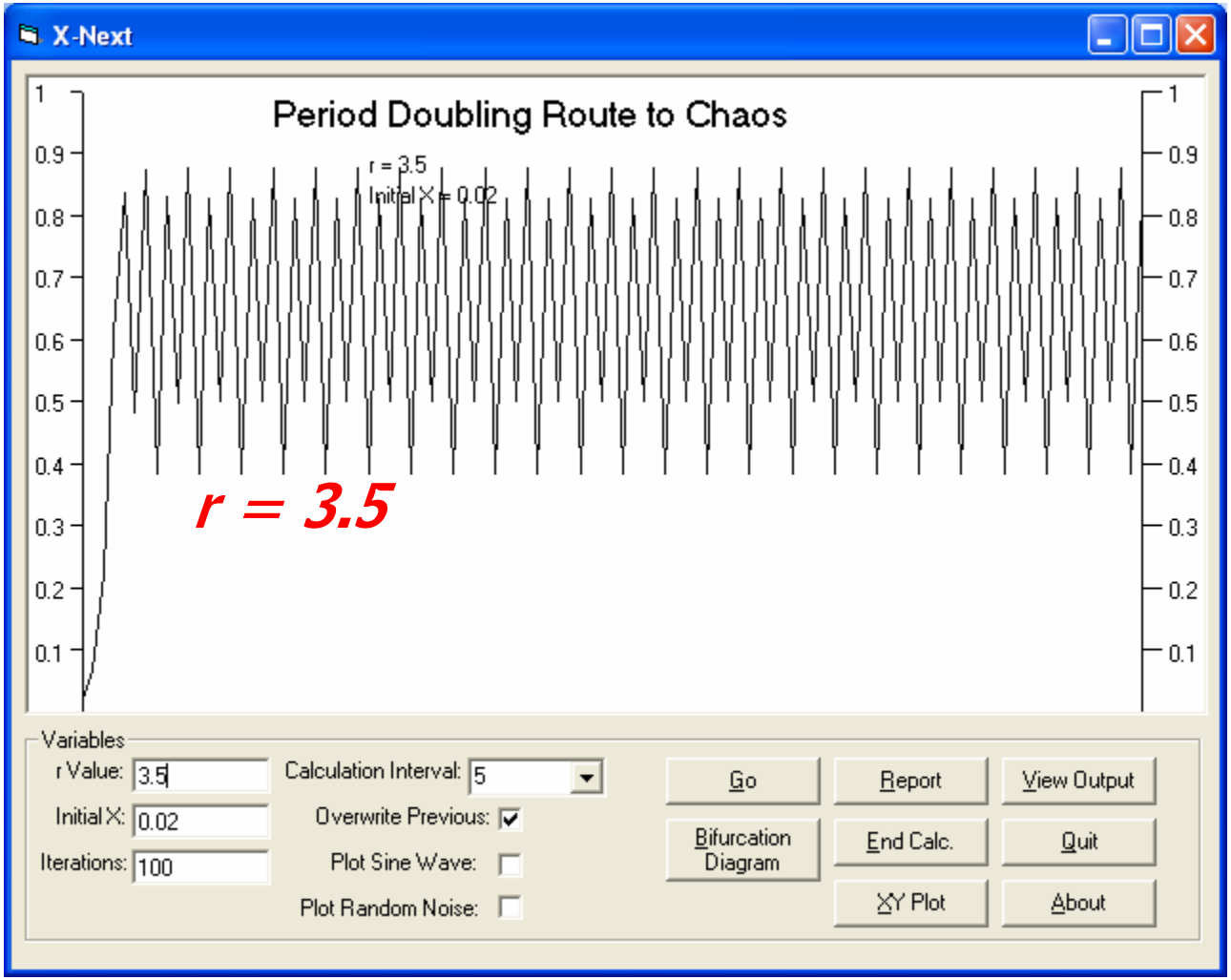

X-Next
Period Doubling Route to Chaos
r = 2.9
Initial X = 0.02
r = 2.9
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Variables
r Value: 2.9
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About

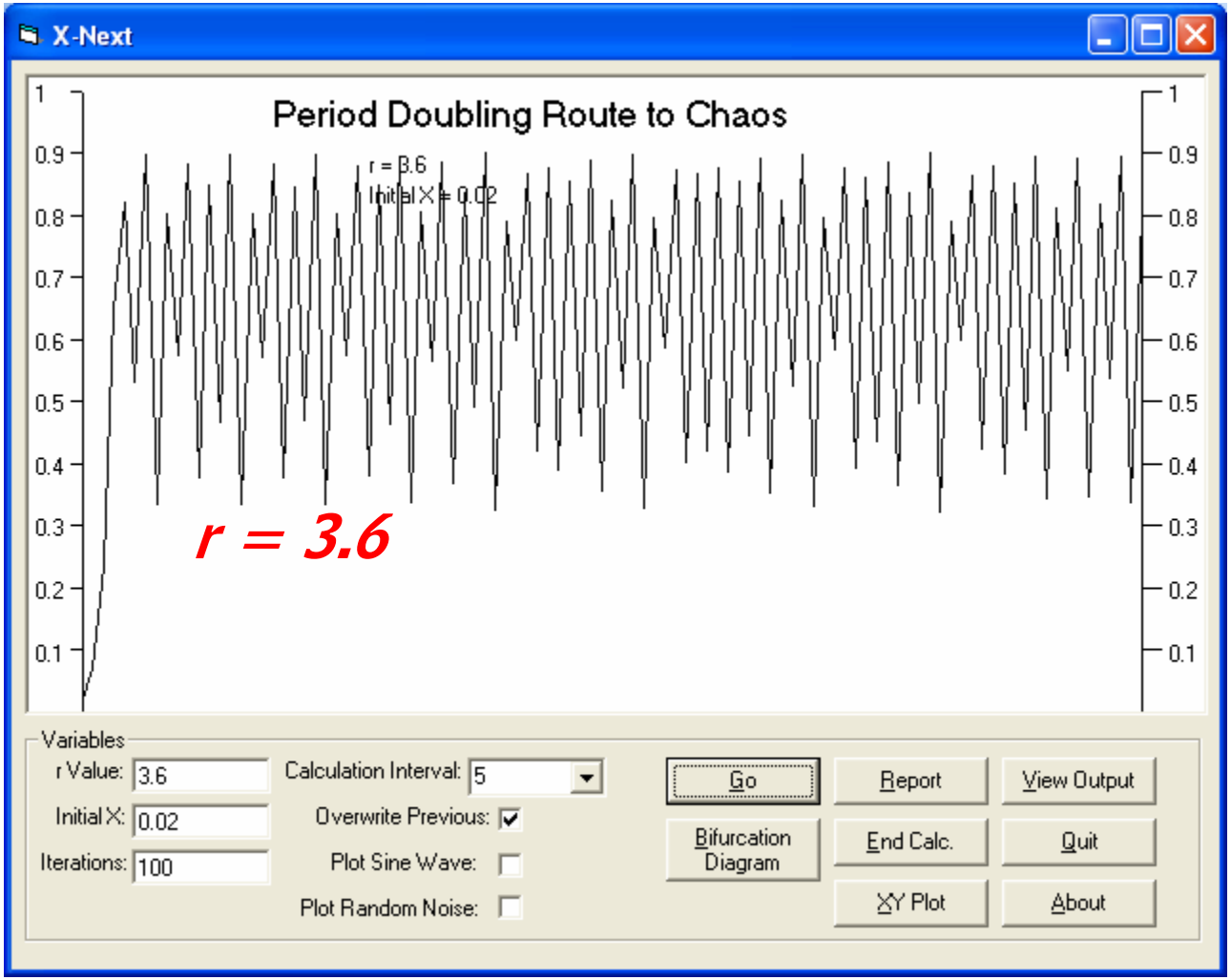

X-Next
Period Doubling Route to Chaos
r = 3.0
Initial X = 0.02
r = 3.0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Variables
r Value: 3.0
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About

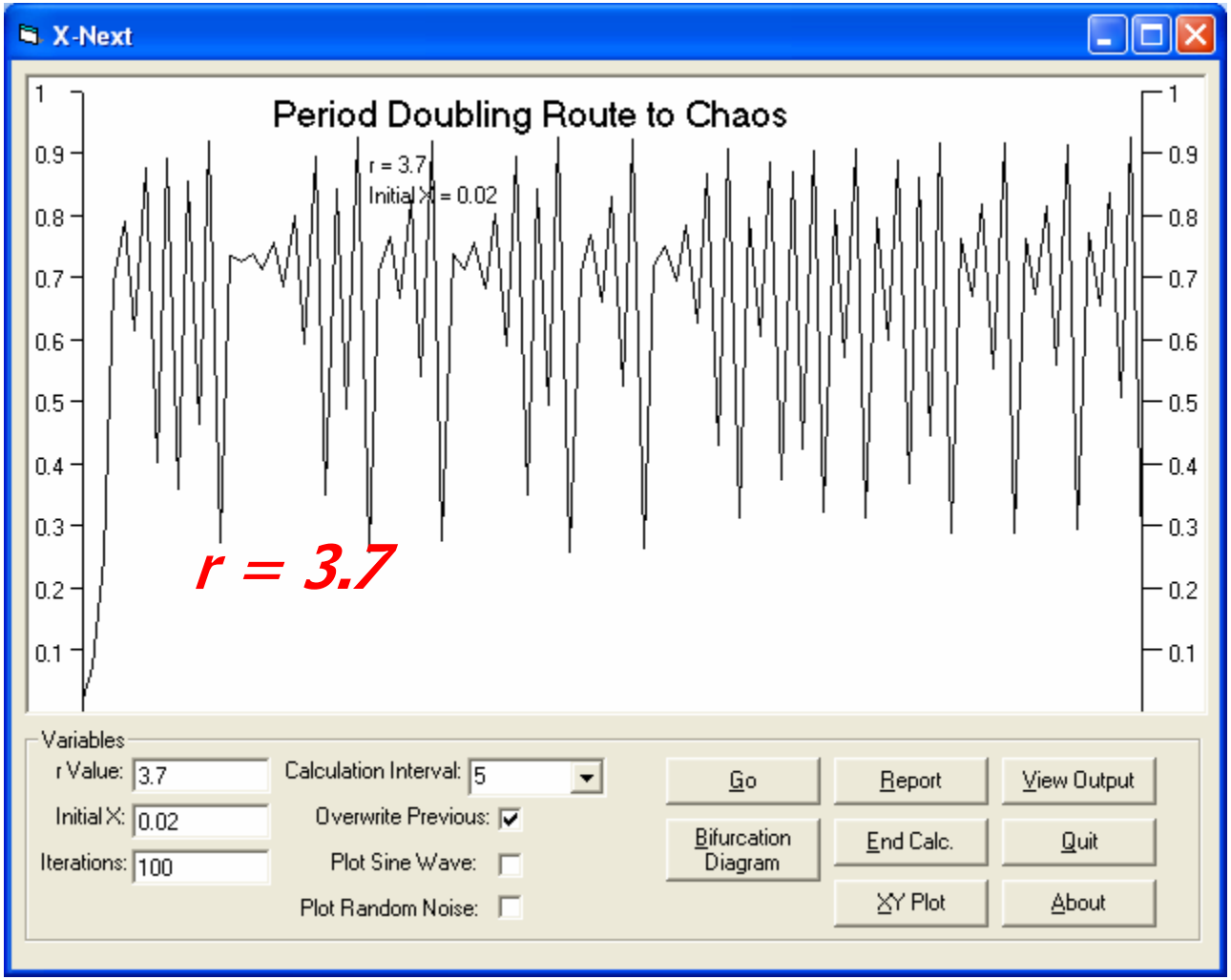

X-Next
Period Doubling Route to Chaos
r = 3.1
Initial X = 0.02
r = 3.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Variables
r Value: 3.1
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About

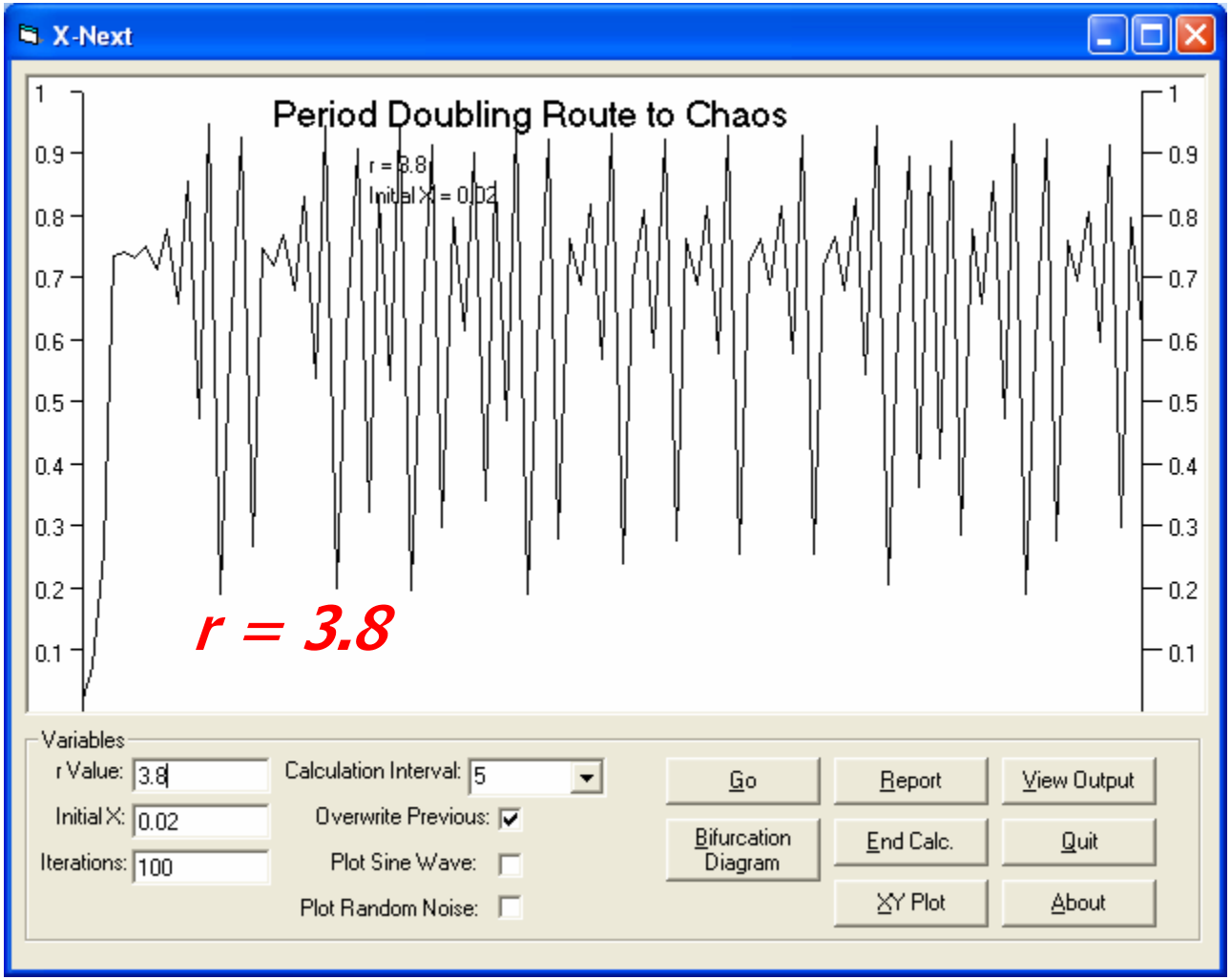

X-Next
Period Doubling Route to Chaos
r = 3.3
Initial X = 0.02
r = 3.3
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Variables
r Value: 3.3
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About

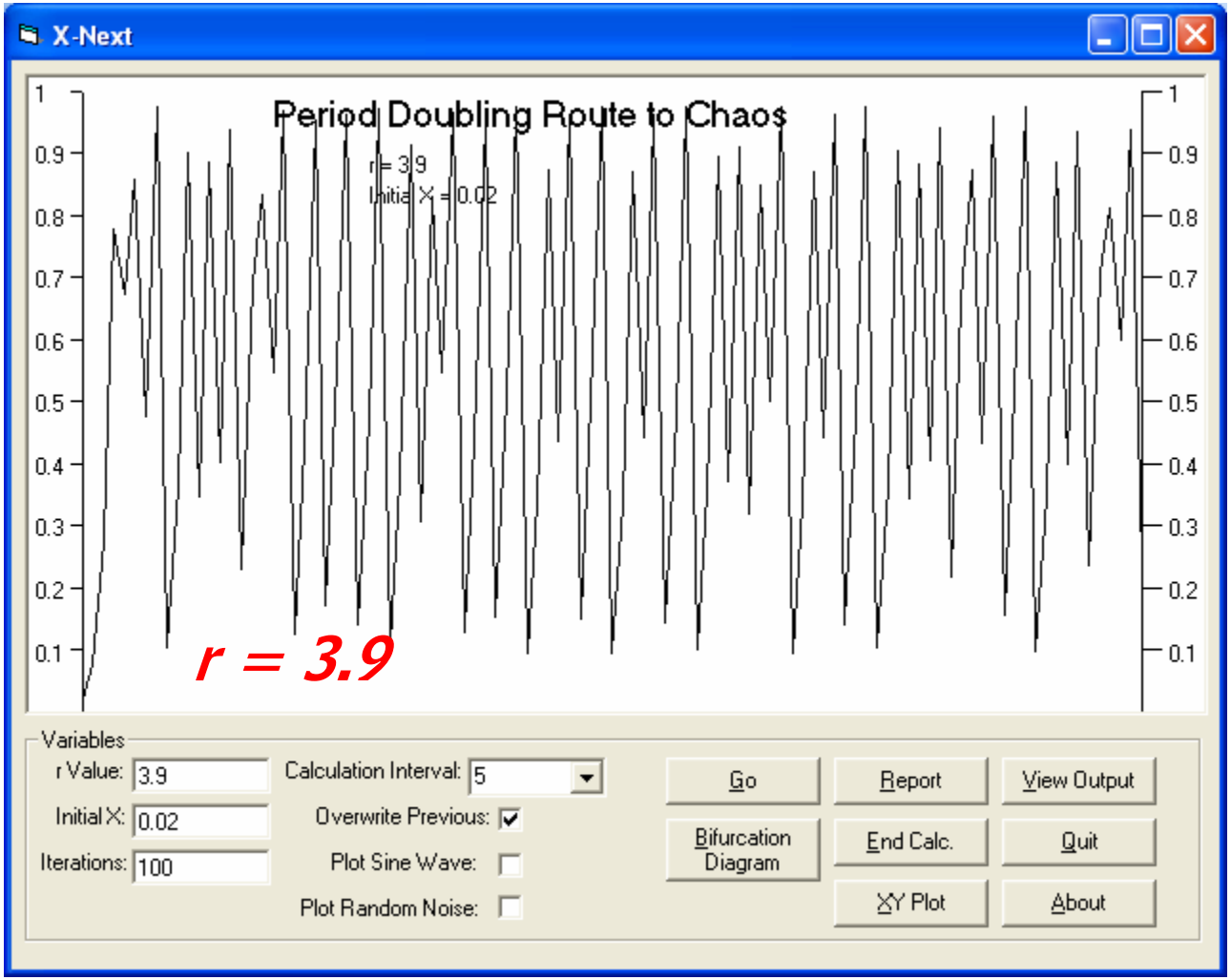

X-Next
Period Doubling Route to Chaos
r = 3.4
Initial X = 0.02
r = 3.4
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Variables
r Value: 3.4
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About

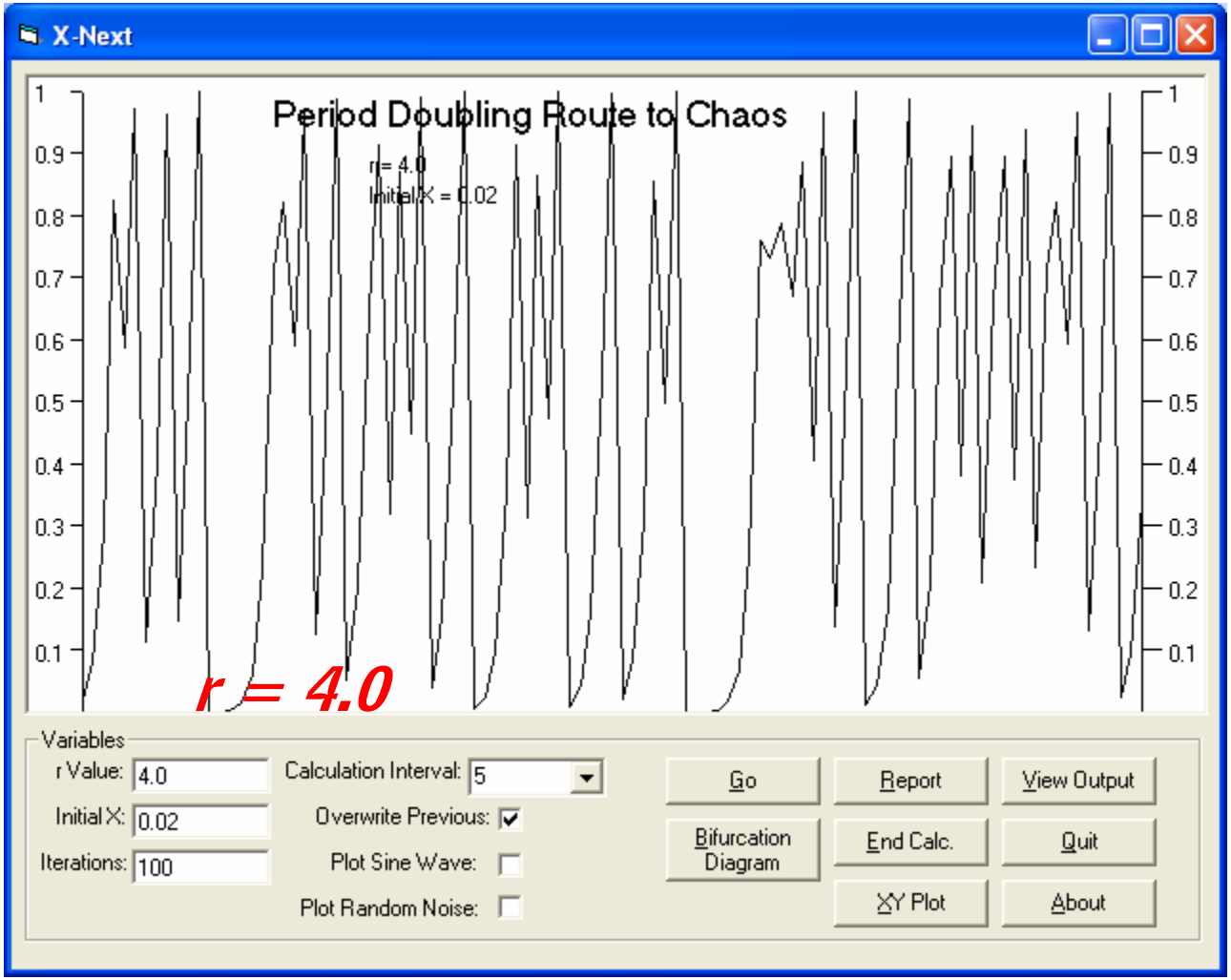

X-Next
Period Doubling Route to Chaos
r = 3.5
Initial X = 0.02
r = 3.5
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Variables
r Value: 3.5
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About

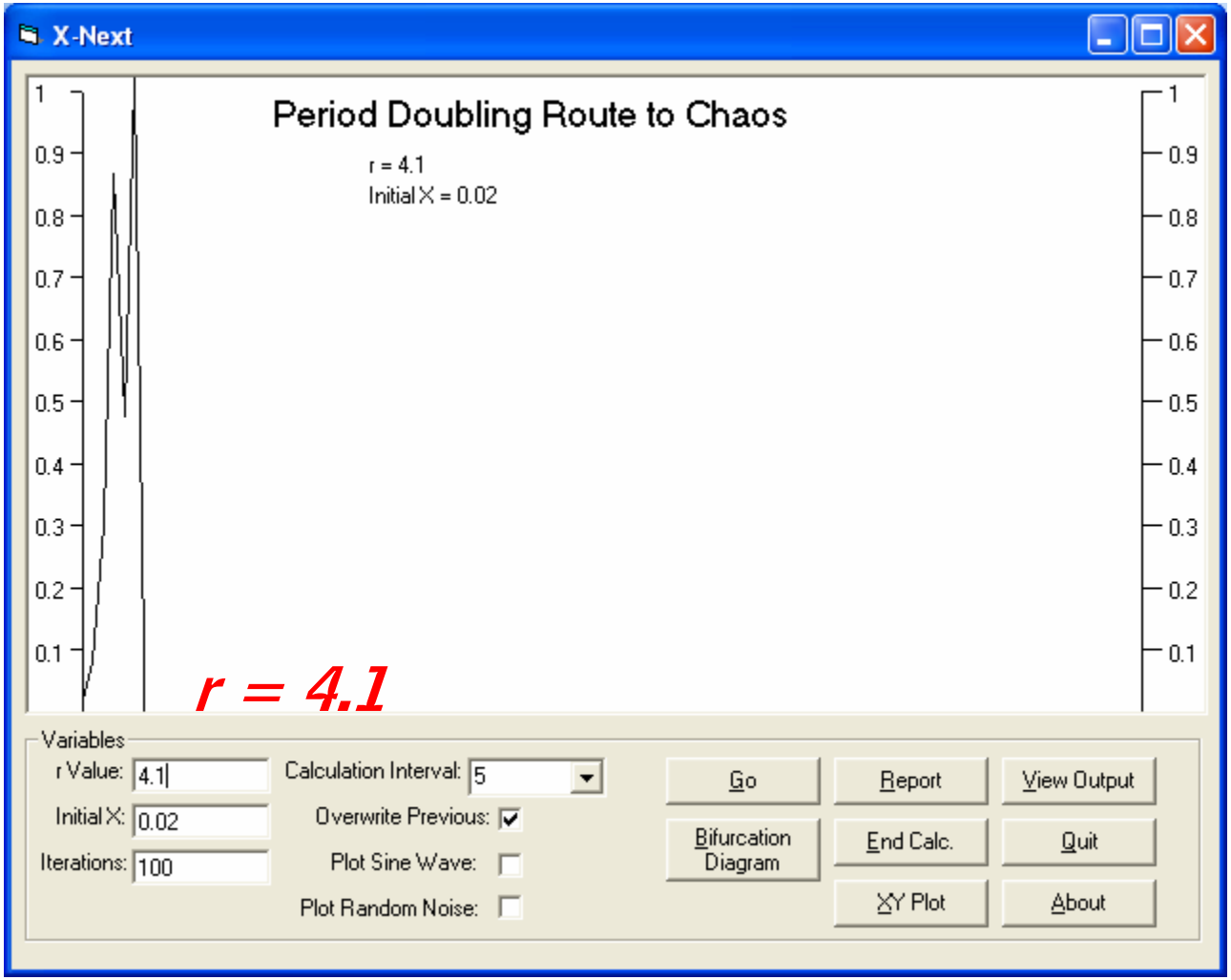

X-Next
Period Doubling Route to Chaos
r = 3.6
Initial X = 0.02
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
r = 3.6
Variables
r Value: 3.6
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About


X-Next
Period Doubling Route to Chaos
r = 3.7
Initial X = 0.02
r = 3.7
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Variables
r Value: 3.7
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About


X-Next
Period Doubling Route to Chaos
r = 3.8
Initial X = 0.02
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
r = 3.8
Variables
r Value: 3.8
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About

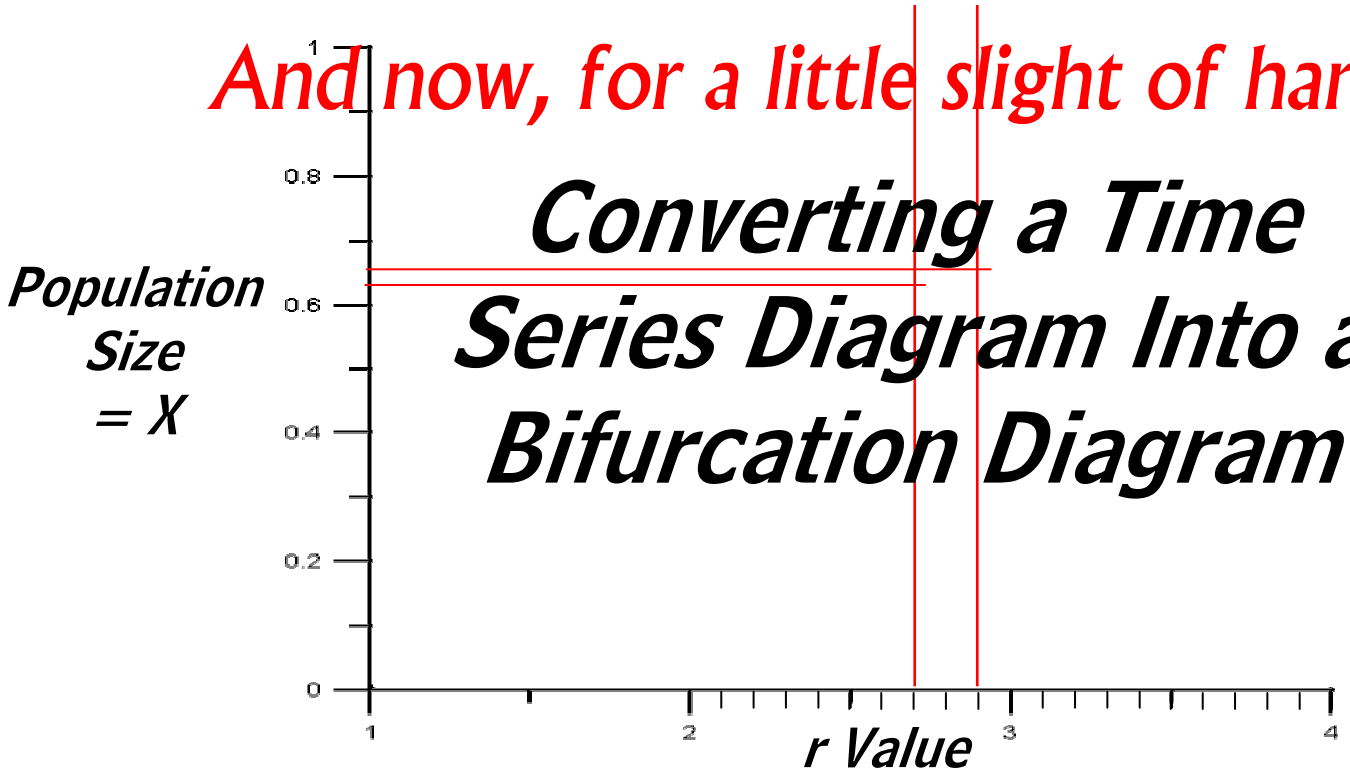

X-Next
Period Doubling Route to Chaos
r = 3.9
Initial X = 0.02
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
r = 3.9
Variables
r Value: 3.9
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About

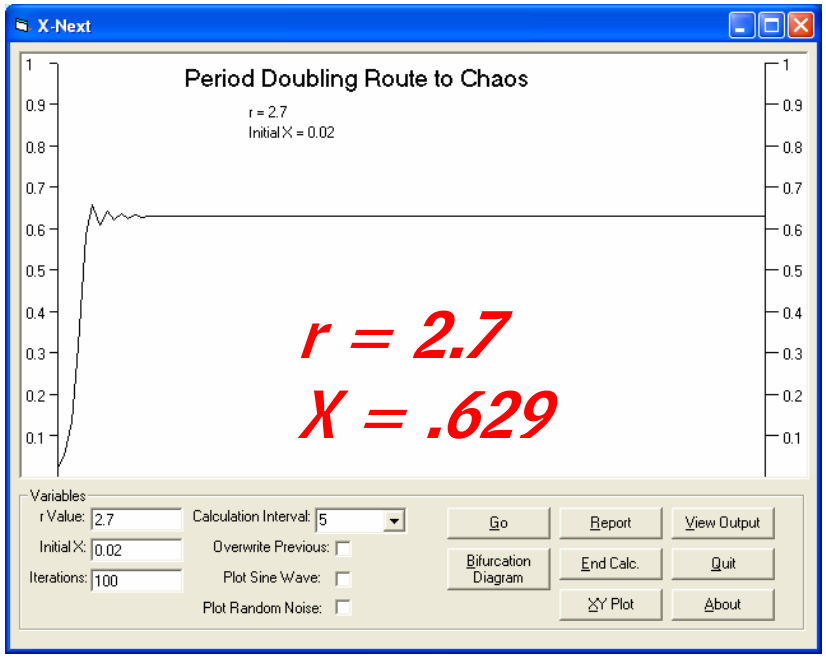

X-Next
Period Doubling Route to Chaos
r = 4.0
Initial X = 0.02
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
r = 4.0
Variables
r Value: 4.0
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About

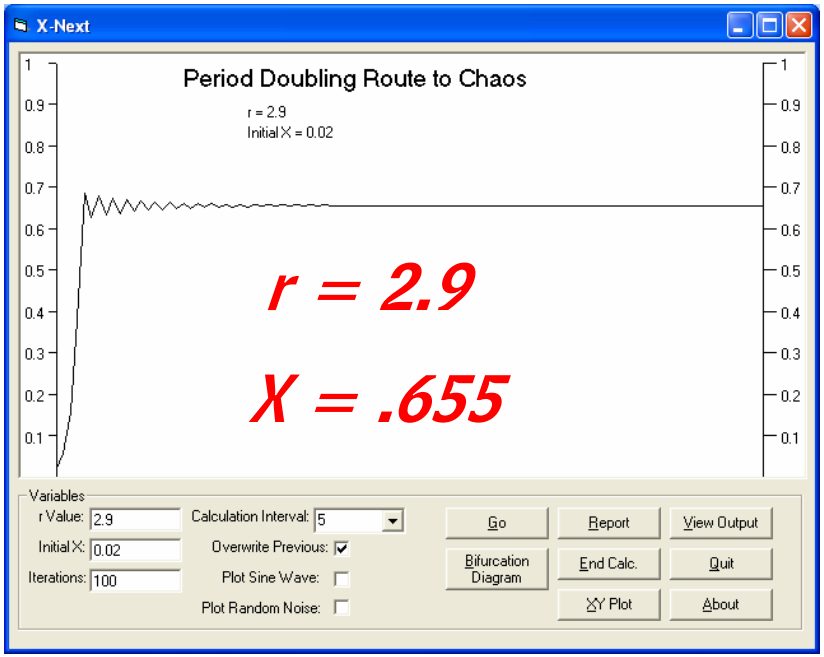

X-Next
Period Doubling Route to Chaos
r = 4.1
Initial X = 0.02
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
r = 4.1
Variables
r Value: 4.1
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About

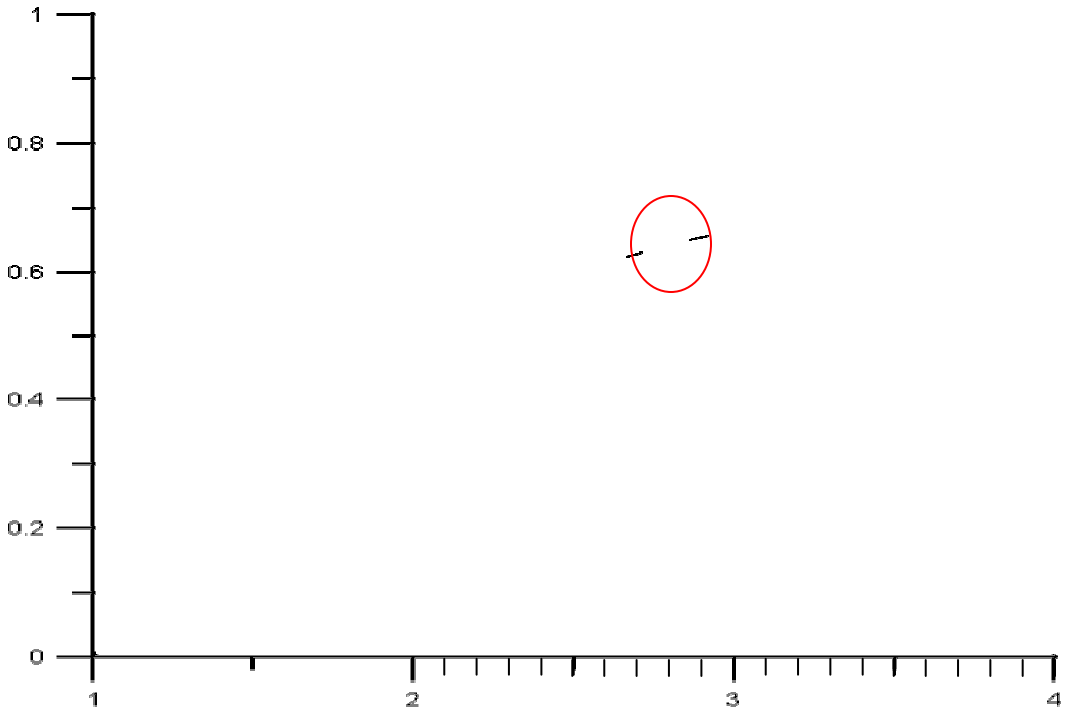
And now, for a little slight of hand

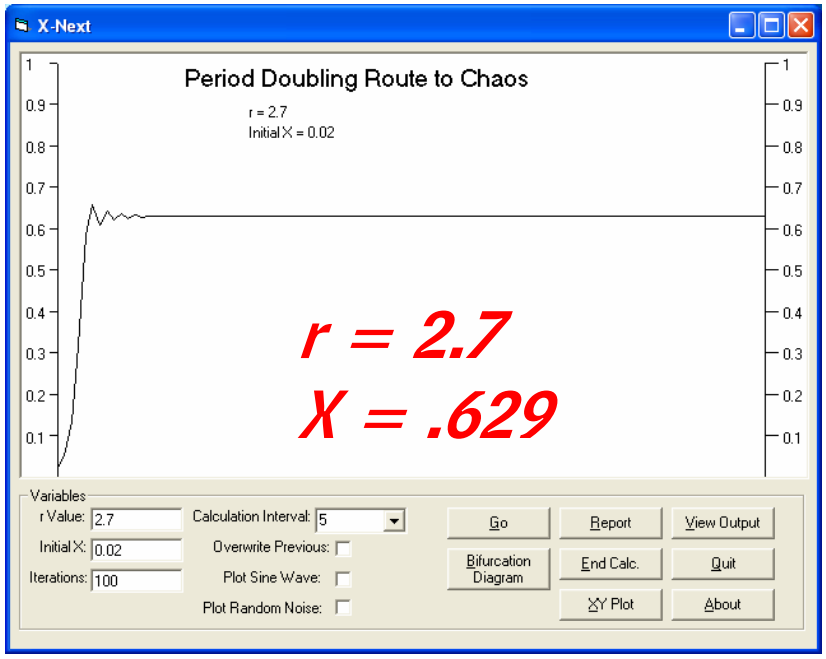
Converting a Time Series Diagram Into a Bifurcation Diagram

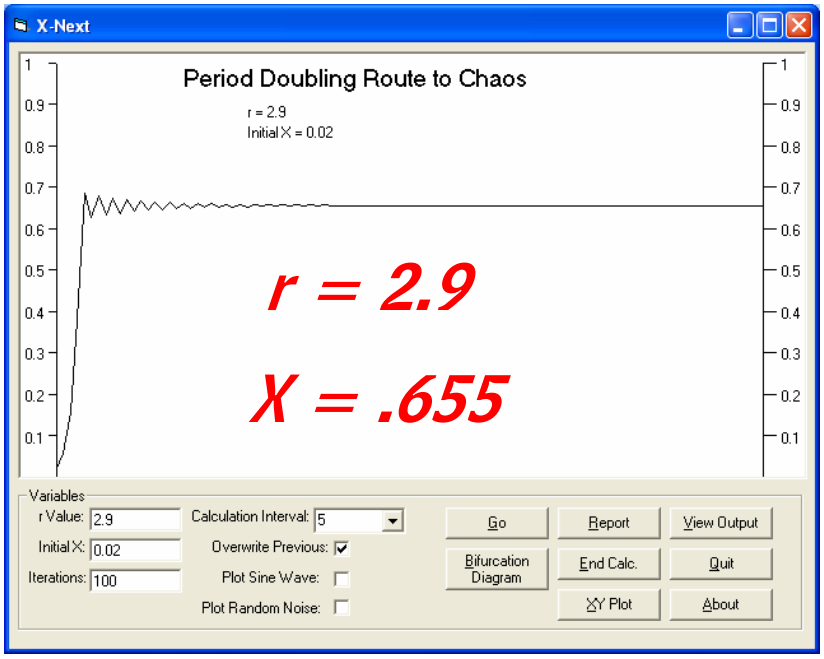


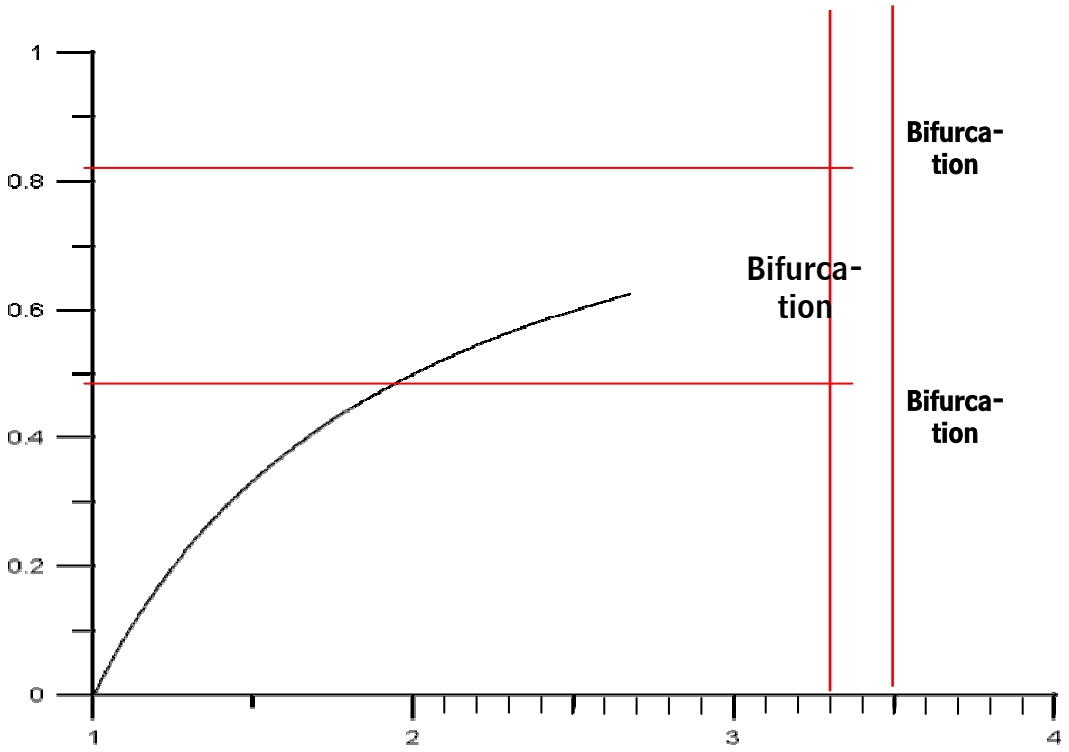


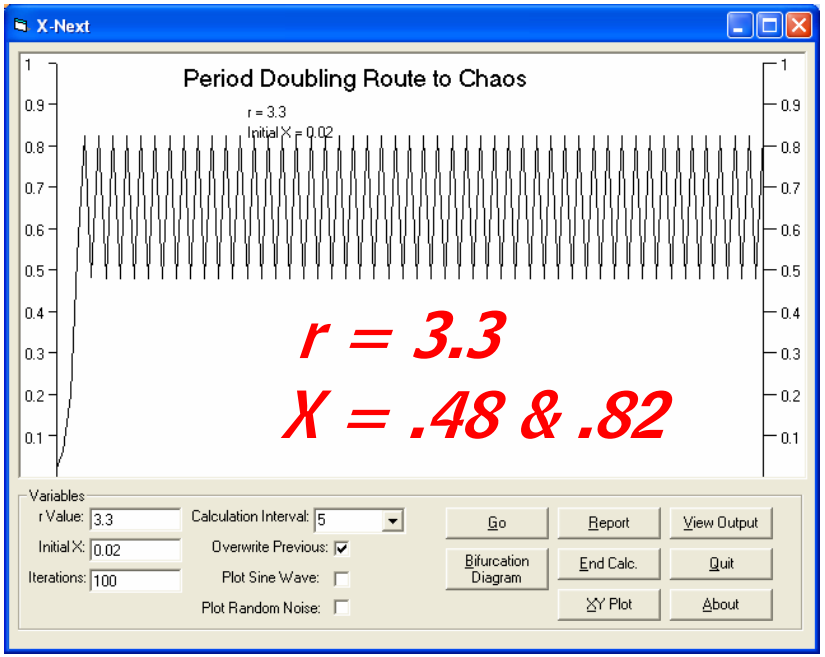


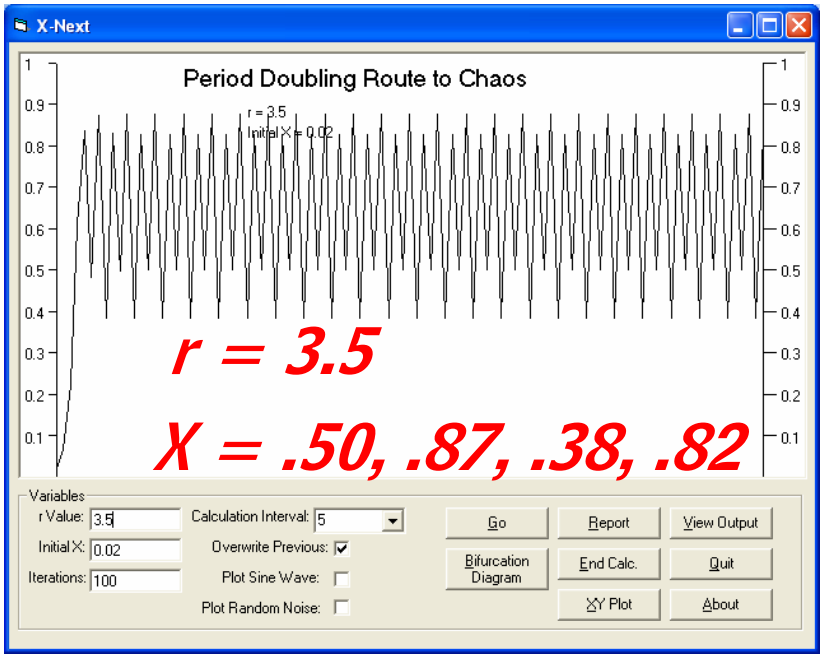

1
0.8
0.6
0.4
0.2
0
1
2
3
4

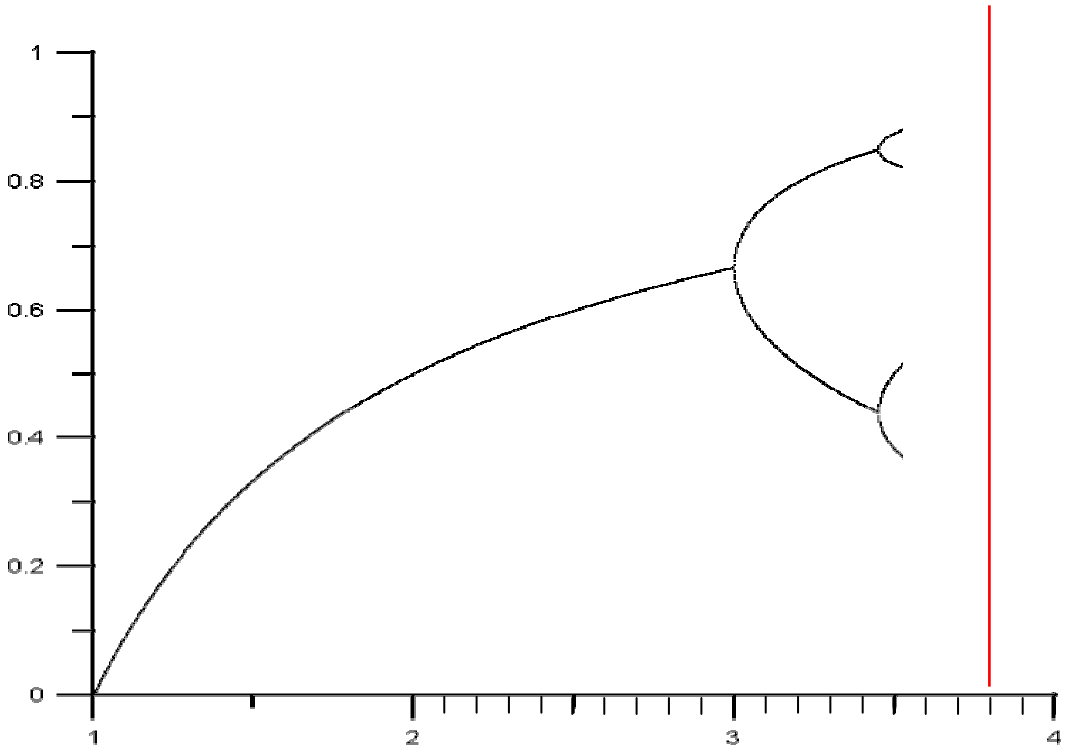

X-Next
Period Doubling Route to Chaos
r = 2.7
Initial X = 0.02
r = 2.7
X = .629
Variables
r Value: 2.7
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About

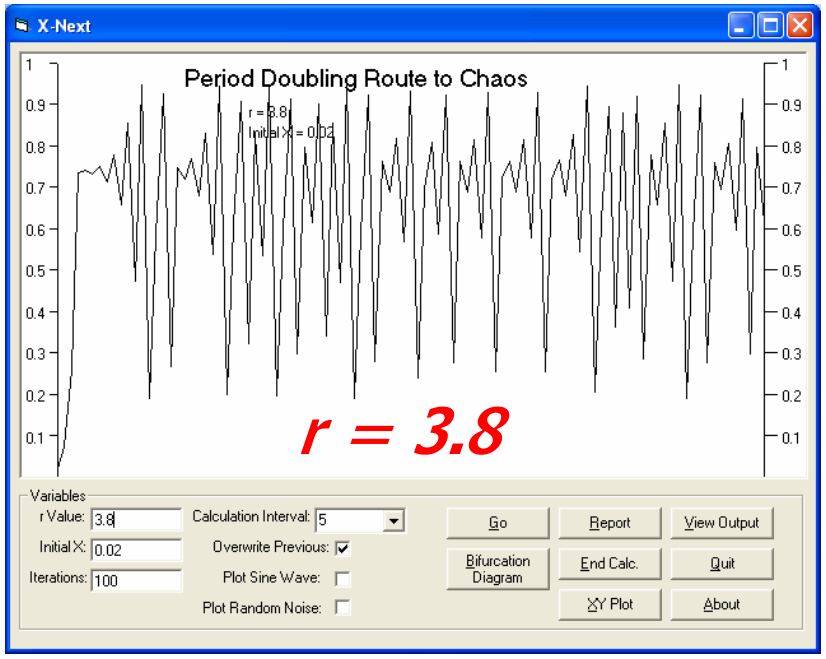

X-Next
Period Doubling Route to Chaos
r = 2.9
Initial X = 0.02
r = 2.9
X = .655
Variables
r Value: 2.9
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About


1
0.8
0.6
0.4
0.2
0
1
2
3
4
Bifurca-
tion
Bifurca-
tion
Bifurca-
tion


X-Next
Period Doubling Route to Chaos
r = 3.3
Initial X = 0.02
r = 3.3
X = .48 & .82
Variables
r Value: 3.3
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About

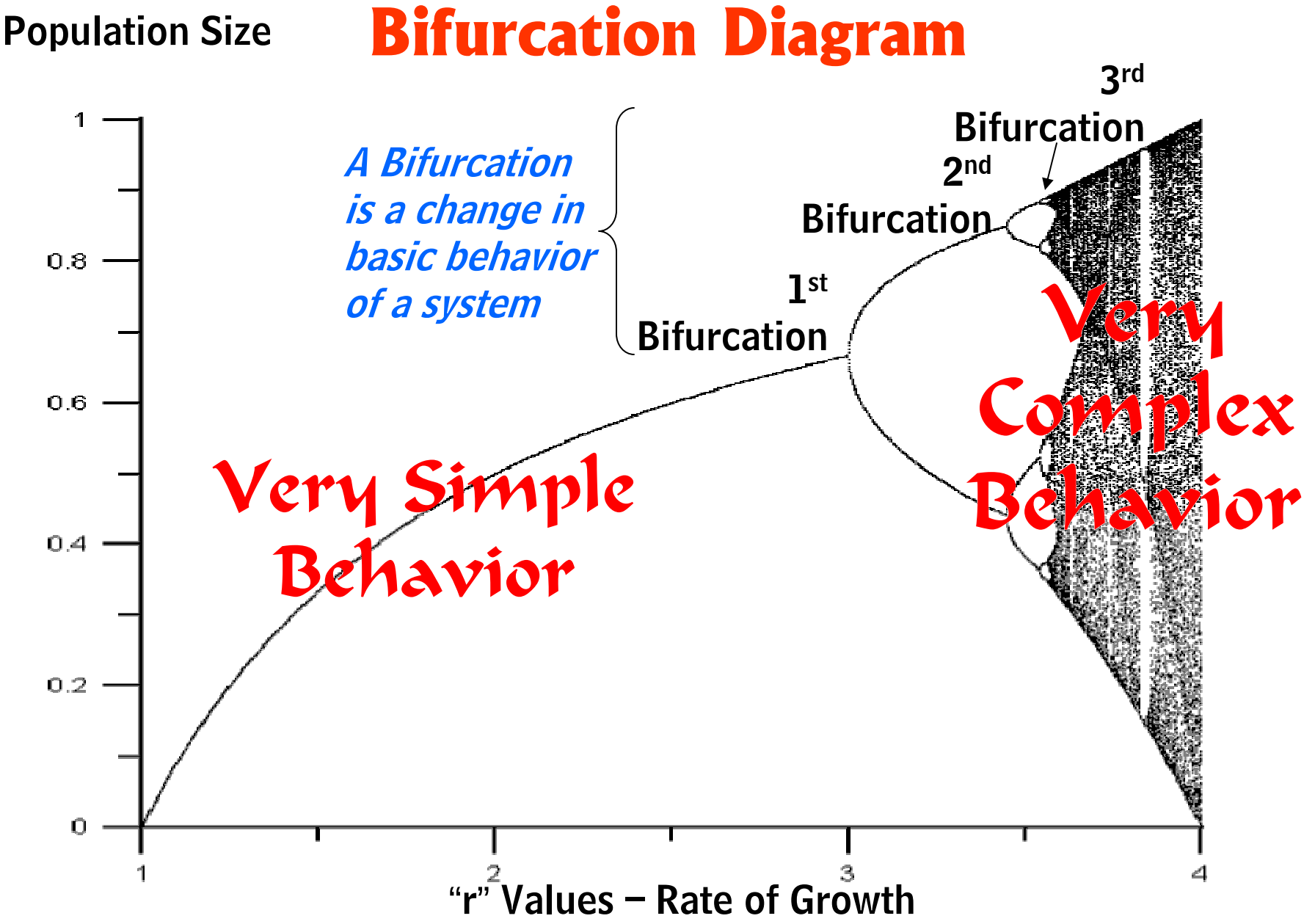

X-Next
Period Doubling Route to Chaos
r = 3.5
Initial X = 0.02
r = 3.5
X = .50, .87, .38, .82
Variables
r Value: 3.5
Initial X: 0.02
Iterations: 100
Calculation Interval: 5
Overwrite Previous:
Plot Sine Wave:
Plot Random Noise:
Go
Report
View Output
Bifurcation Diagram
End Calc.
Quit
XY Plot
About





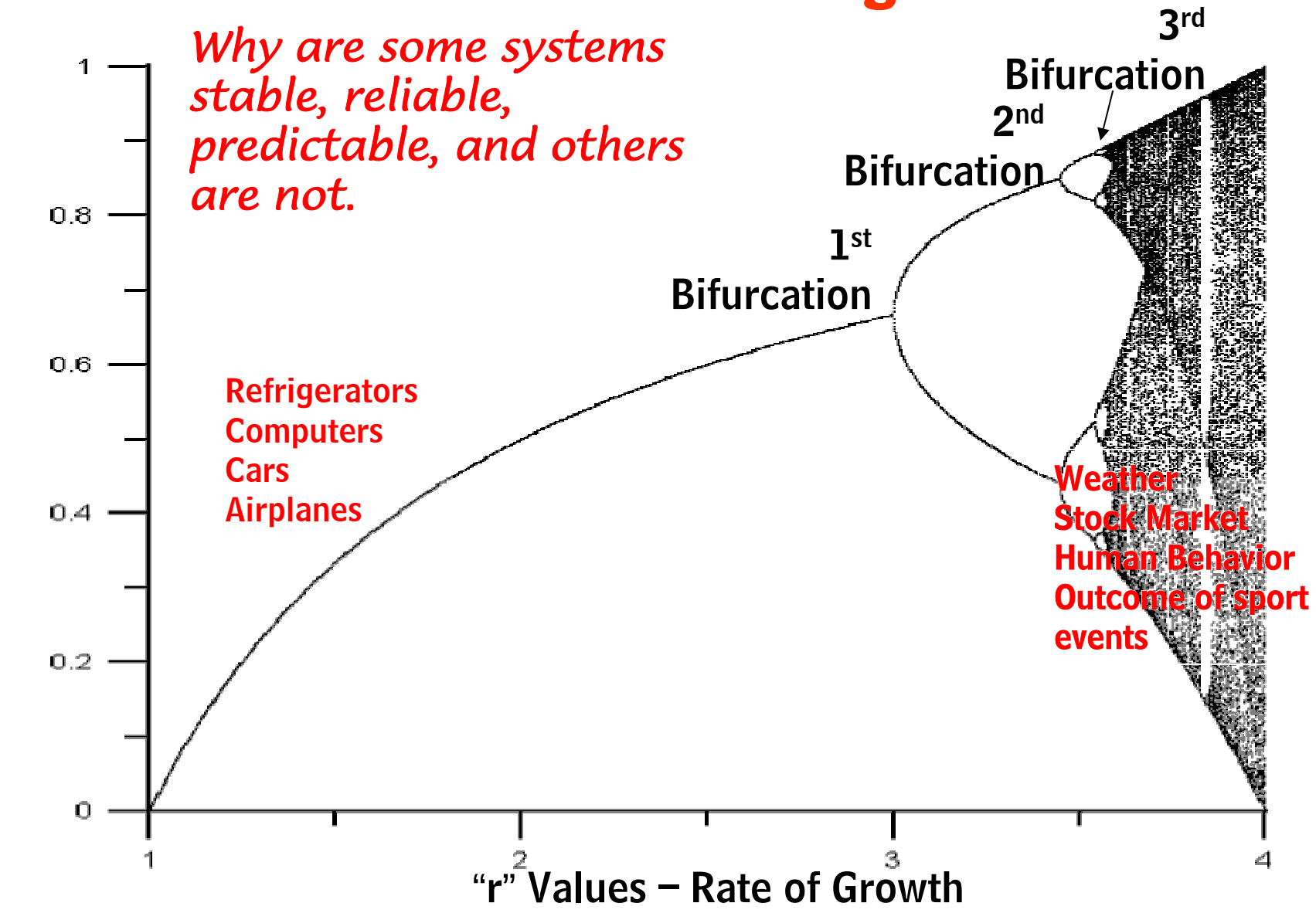
0.877682831619863
0.407951579058487
0.917802935168261
0.286674687986186
0.777070782765993
0.658280769082272
0.854799352927153
0.471646192817398
0.946945034149357
0.190912518507075
0.58696672938057
0.921259794327218
0.27565270559684
0.758739507677205
0.695604695234438
0.80460745216852 1
0.597414340316927
0.913939695942348
0.298884926867995
0.796300363964611
0.616383158394868

Modeling an Evolutionary System



Modeling an Evolutionary System

Bifurcation Diagram



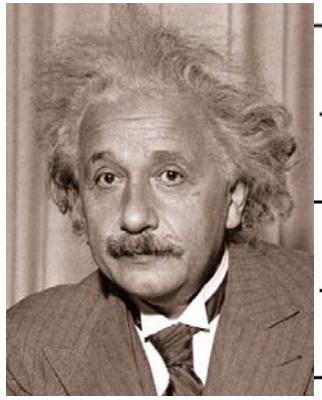
"In my graduate school courses, we were always taught that large nonlinear systems were monsters, practically impossible to solve.

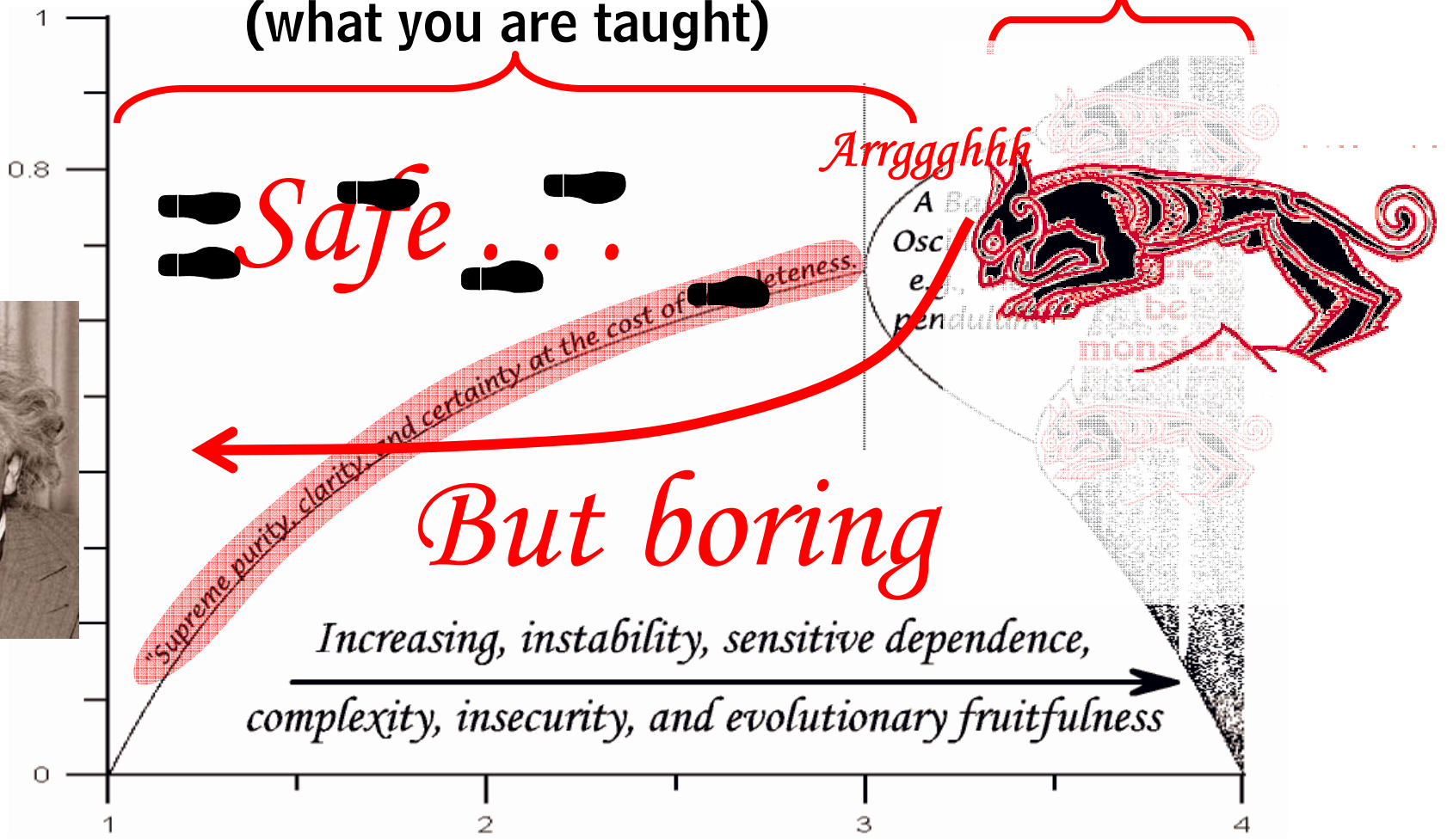
Steve Strogatz, 2003 , Sync: The Emerging Science of Spontaneous Order

Classical Science
Equilibrium Science
(what you are taught)

Exciting but unpredictable

Complex Systems
Non-Equilibrium
(you are not taught)





In the Classical world (assumptions):

"The world is simple . . . "

Change is: deterministic – predictable

Change is linear: slow, gradual, and stately

The natural outcome of these laws is an equilibrium state; a body at rest, or a completed reaction, entropy at the maximum.

In the Non-Equilibrium (Chaos) world things are:

Ambiguous

Unpredictable

Sudden

And Equilibrium means the system is dead

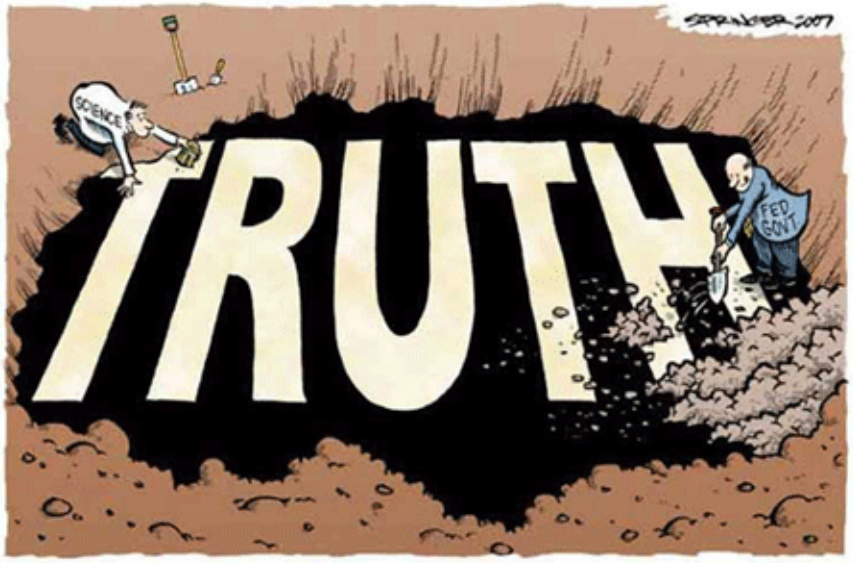
Science and Truth

Non-equilibrium science tells us changes are . .

Ambiguous Unpredictable Sudden

If we are looking for truth . . . science will not give it to us, about the environment, global warming, or anything else.

If we want Truth we must turn to religion.



Scientific knowledge is not about finding (capital T) Truth.

The Paradox Of Scientific Truth

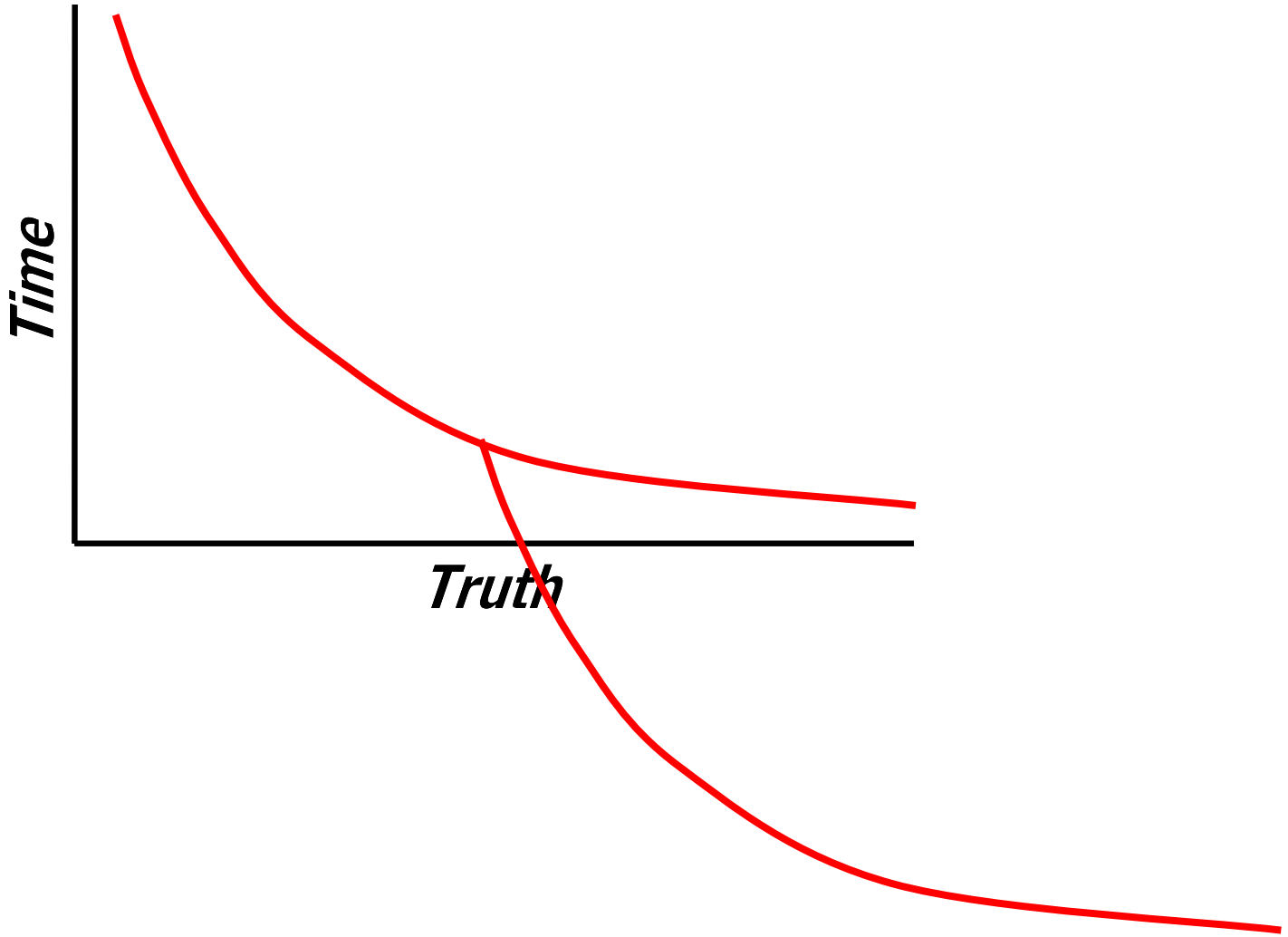
The goal of science is to find the Truth, but the Truth can never be found.

The best we can do is discover what can't be true.

By discovering what can't be true we approach and thus limit what can be true.

Contrasting Views of Science

After Thomas Kuhm



Contrasting Views of Science

Science may give us (small t) truth, but not (capital T) Truth.

Scientific knowledge grows, but not in simple direct ways.

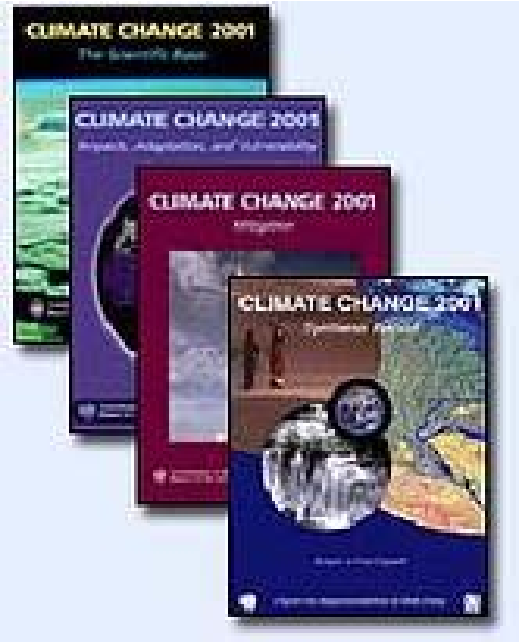
And science today is highly politicized.

We have to work with imperfect knowledge in an imperfect world.

Circumstantial Knowledge

More specifically, science is more about probabilities; like "It is this, but we are only x % confident in it."

For example, the IPCC (Intergovernment Panel on Climate Change) the most authoritative body on climate change not only states a conclusion, they also state their confidence in that conclusion, like below.



i. extremely likely >95%;

ii. very likely >90%;

iii. likely >66%;

iv. more likely than not > 50%;

v. about as likely as not 33% to 66%;

vi. unlikely <33%;

vii. very unlikely <10%;

Circumstantial Knowledge

Phenomenon[a] and direction of trend	Likelihood that trend occurred in late 20th century (typically post 1960)	Likelihood of a human contribution to observed trend[b]	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	*Very likely*[c]	*Likely*[d]	*Virtually certain*[d]
Warmer and more frequent hot days and nights over most land areas	*Very likely*[e]	*Likely (nights)*[d]	*Virtually certain*[d]
Warm spells/heat waves. Frequency increases over most land areas	*Likely*	*More likely than not*[f]	*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not*[f]	*Very likely*
Area affected by droughts increases	*Likely* in many regions since 1970s	*More likely than not*	*Likely*
Intense tropical cyclone activity increases	*Likely* in some regions since 1970	*More likely than not*[f]	*Likely*
Increased incidence of extreme high sea level (excludes tsunamis)[g]	*Likely*	*More likely than not*[f,h]	*Likely*[i]

Bertold Brecht
(1898-1956)

German poet, playwright, and theatrical reformer whose epic theatre departed from the conventions of theatrical illusion and developed the drama as a social and ideological forum for leftist causes.

Truth is the child of time, not authority.

Our ignorance is infinite,

Let's whittle away just one cubic millimeter.

Why should we still want to be so clever when at long last we have a chance of being a little less stupid.

Bertold Brecht
(1898-1956)

German poet, playwright, and theatrical reformer whose epic theatre departed from the conventions of theatrical illusion and developed the drama as a social and ideological forum for leftist causes.

One of the main reasons for the poverty of science is that it is supposed to be rich.

The aim of science is not to open the door to everlasting wisdom, but to set a limit on everlasting error.