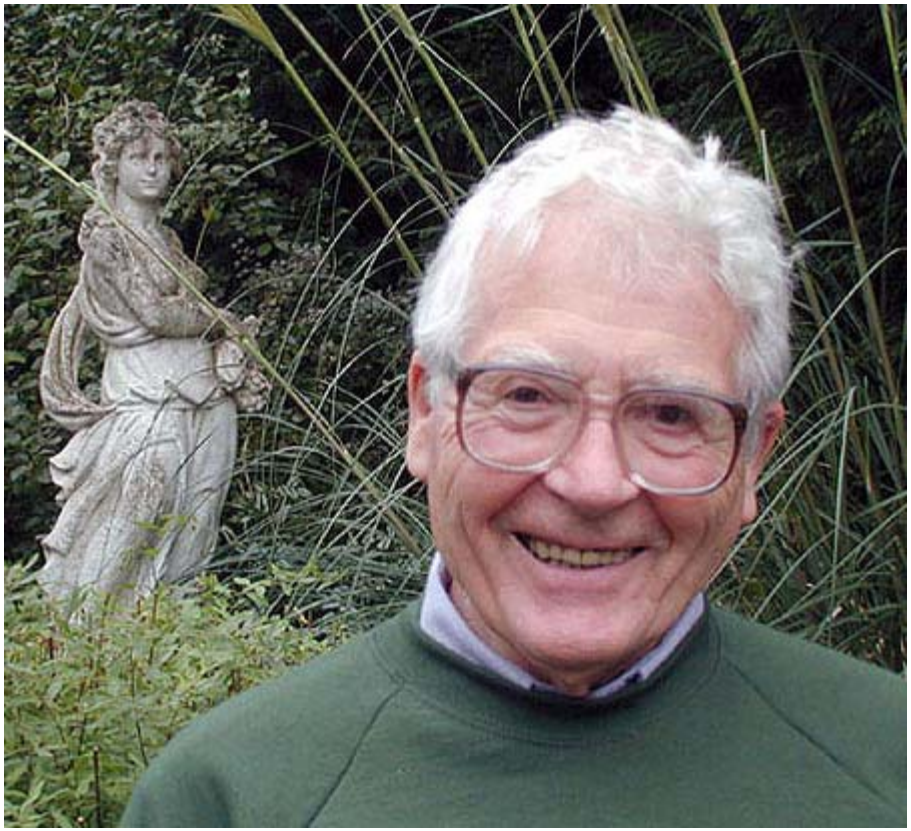
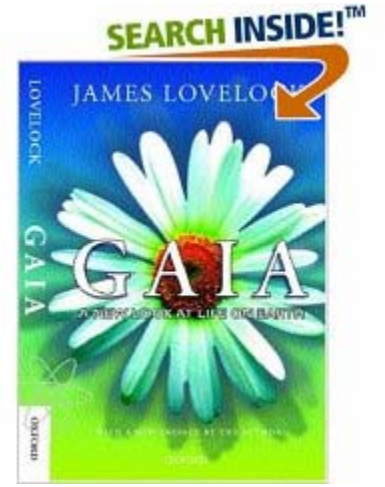
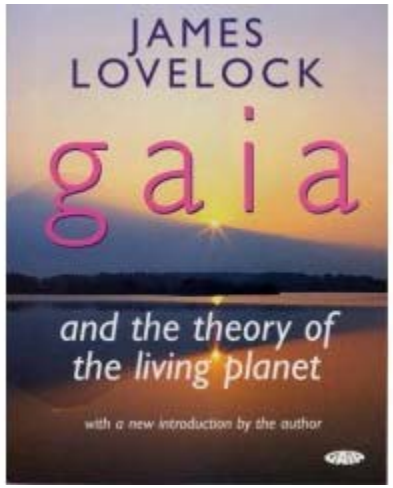
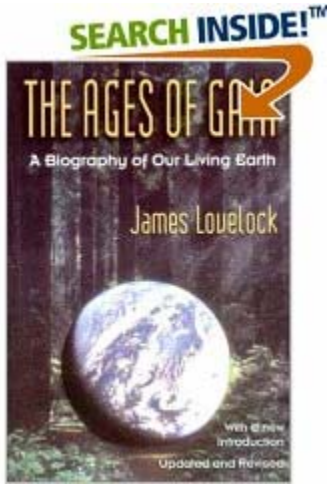


James Lovelock Gaia Theory

The idea that life on Earth regulates the physical and chemical conditions of the environment suitable for life.

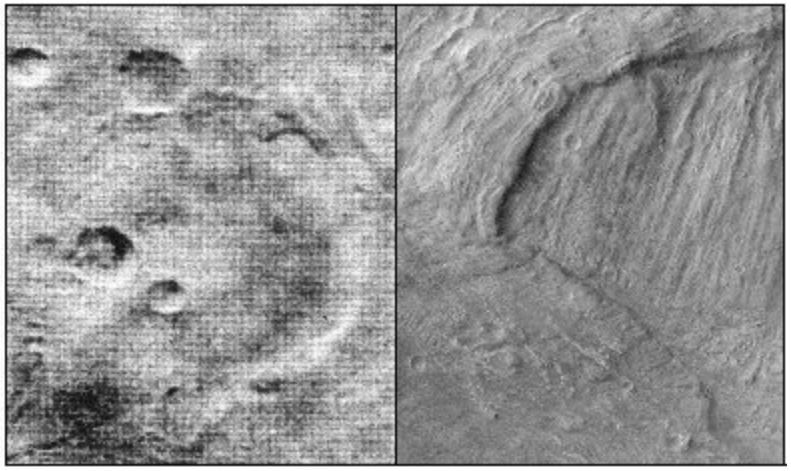






Mariner Missions 4, 6, and 7 to Mars

Scientists work on a Mariner spacecraft. Mariner 4 reached its Mars orbit in July 1965.



Photographs like these taken by the Mariner spacecrafts show that the Martian surface is very different from that of Earth.

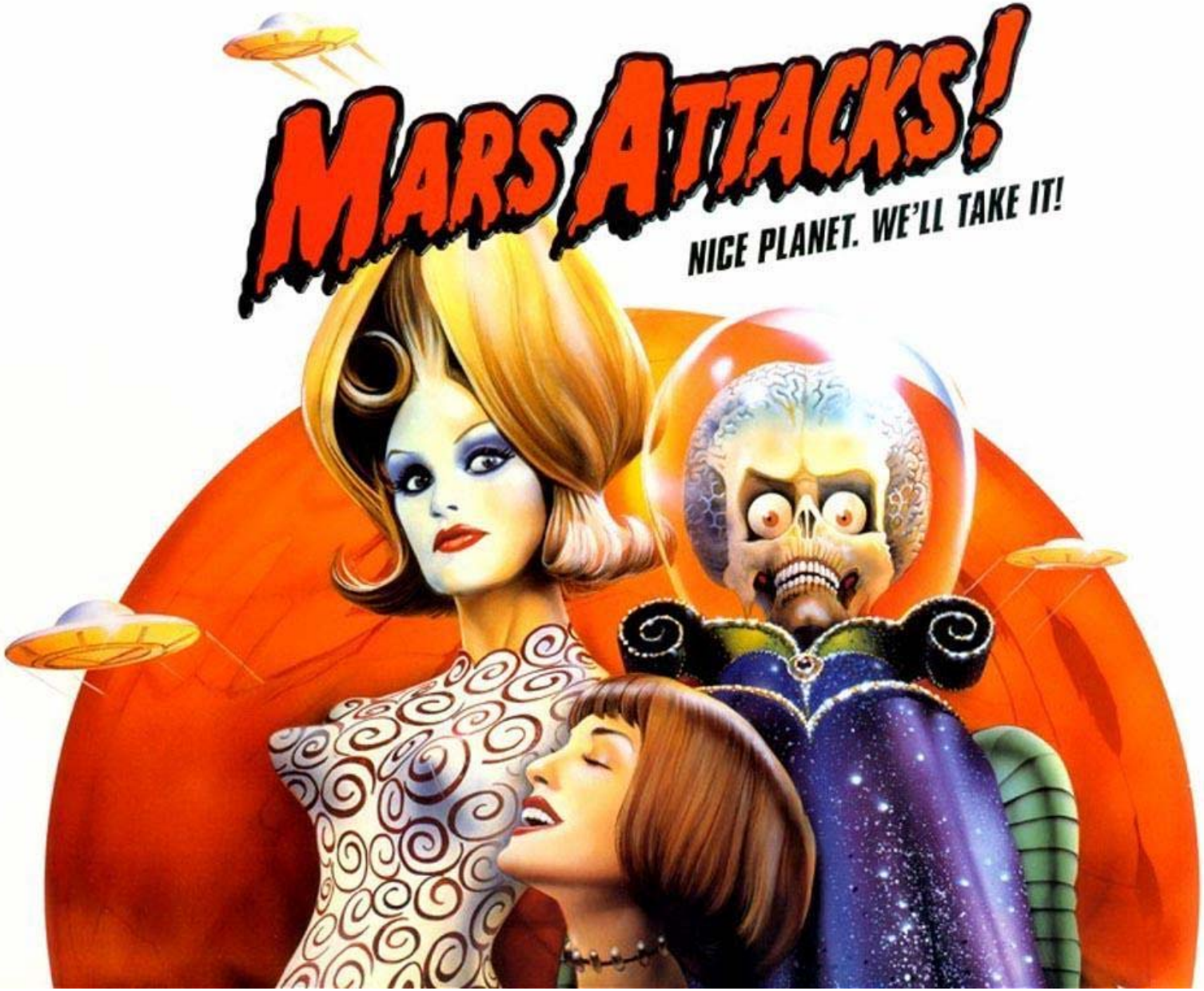
When the fuzzy images of the Martian surface finally began to appear the mood at NASA changed from euphoria to stunned silence. For years, Mars and Earth were thought to be very much alike, so scientists expected to see many similarities. Instead, they stared with disbelief at a planet that was scarred with enormous craters and looked every bit as dead and lifeless as Earth's own moon. Scientific author Robert Godwin describes the reaction at NASA as the photos began to come into focus:

Mariner Missions 4, 6, and 7 to Mars

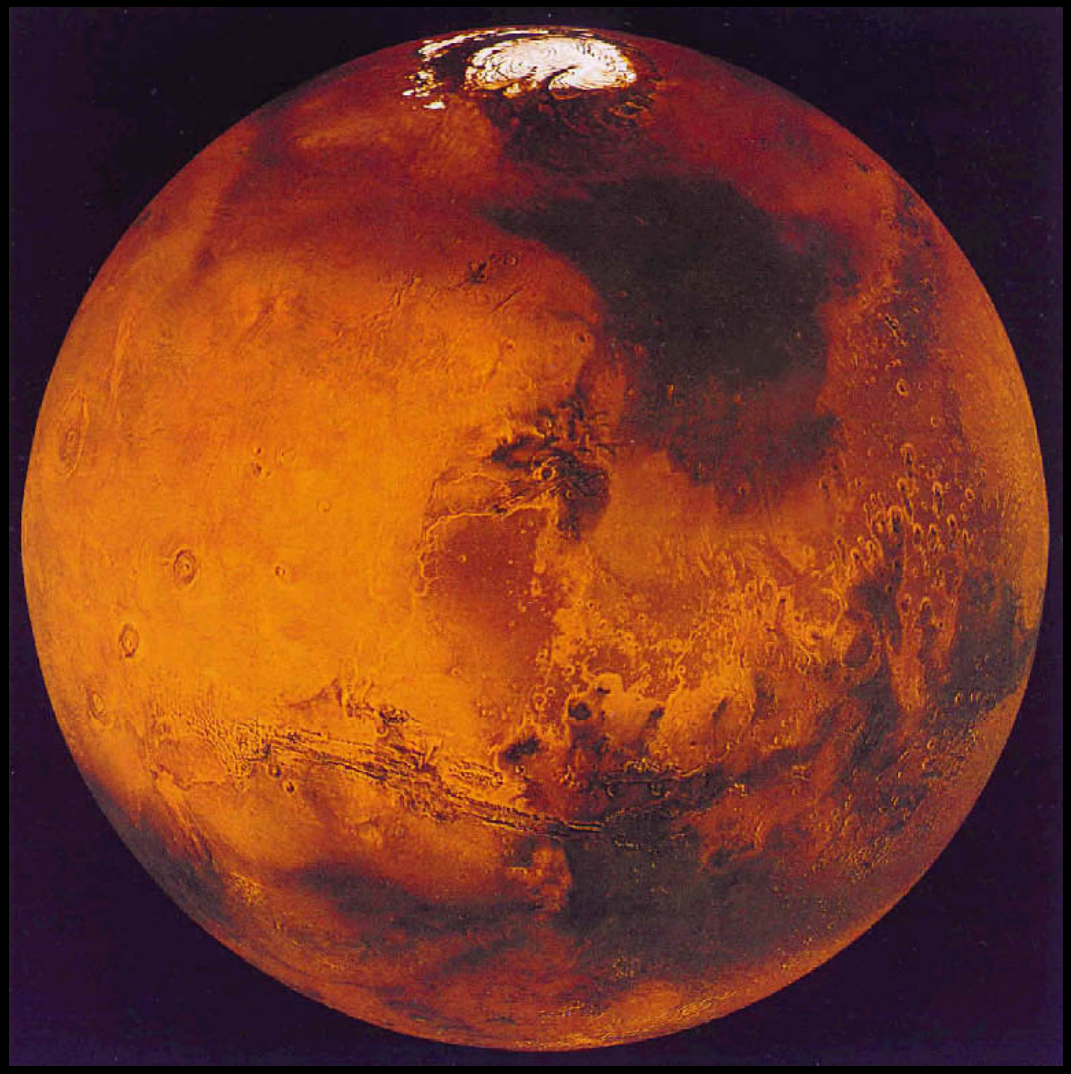
Robert Godwin describes the reaction at NASA as the photos began to come into focus:

"The 22 grainy black and white pictures returned by Mariner 4 changed mankind's notion of Mars forever. No canals, no ancient cities. . . . For many it was a disillusioning blow that almost killed the romance of the red planet forever. The science fiction writers would be forever forced to revise their Martian fables, no more Barsoom and the beautiful Princesses, no elegant crystal cities or lush jungle landscapes. The masterworks of Burroughs and Bradbury would finally have to be appraised in a different way, as great literary works from a different and more romantic era."

http://www.scienceclarified.com/scitech/Exploring-Mars/The-Space-Race.html


MARS ATTACKS!
NICE PLANET. WE'LL TAKE IT!

Mars



As planetary scientist Bruce Murray explains: "Lowell's Earthlike Mars was forever gone, but so was the moonlike Mars portrayed by our first three flyby missions. . . . The Mars revealed by Mariner 9 was not one-dimensional; it was an intriguingly varied planet with a mysterious history. The possibility of early life once more emerged."

Gaia Theory

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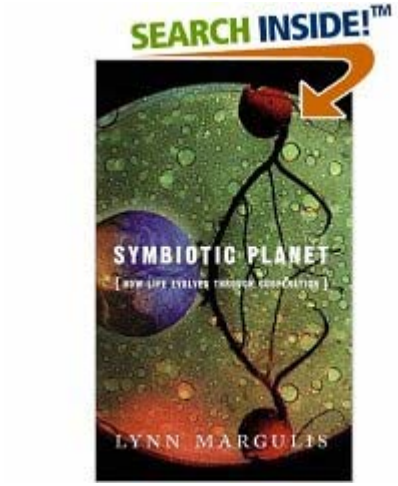
"The Gaia hypothesis, when we introduced it in the 1970's supposed that the atmosphere, the oceans, the climate, and the crust of the Earth are regulated at a state comfortable for life because of the behavior of living organisms. Specifically, the Gaia hypothesis said that the temperature, oxidation state, acidity, and certain aspects of the rocks and waters are at any time kept constant, and that this homeostasis is maintained by activity feedback processes operated automatically and unconsciously by the biota. Solar energy sustains comfortable conditions for life. The conditions are only constant in the short term and evolve in synchrony with the changing needs of the biota as it evolves. Life and its environment are so closely coupled that evolution concerns Gaia, not the organisms or the environment taken separately." [The Ages of Gaia, p 19]

Gaia Theory

"By looking at life through Gaia's telescope, we see it as a planetary-scale phenomenon with a cosmological life span. Gaia as the largest manifestation of life differs from other living organisms of Earth in the way that you or I differ from our population of living cells. At some time early in the Earth's history before life existed, the solid Earth, the atmosphere, and oceans were still evolving by the laws of physics and chemistry alone. It was careening, downhill, to the lifeless steady state of a planet almost at equilibrium. At that instant the living things, the rocks, the air, and the oceans merged to form the new entity, Gaia. Just as when the sperm merges with the egg, new life was conceived. [The Ages of Gaia, p 19]

Gaia Theory



The Gaia hypothesis is not, as many claim, that "the Earth is a single organism." Yet the Earth, in the biological sense, has a body sustained by complex physiological processes. Life is a planetary-level phenomenon and the Earth has been alive for at least 3,000 million years.

To me, the human move to take responsibility for the living Earth is laughable the rhetoric of the powerless.

The planet takes care of us, not we of it. Our self-inflated moral imperative to guide a wayward Earth or heal our sick planet is evidence of our immense capacity for self-delusion. Rather, we need to protect us from ourselves.

Gaia Theory

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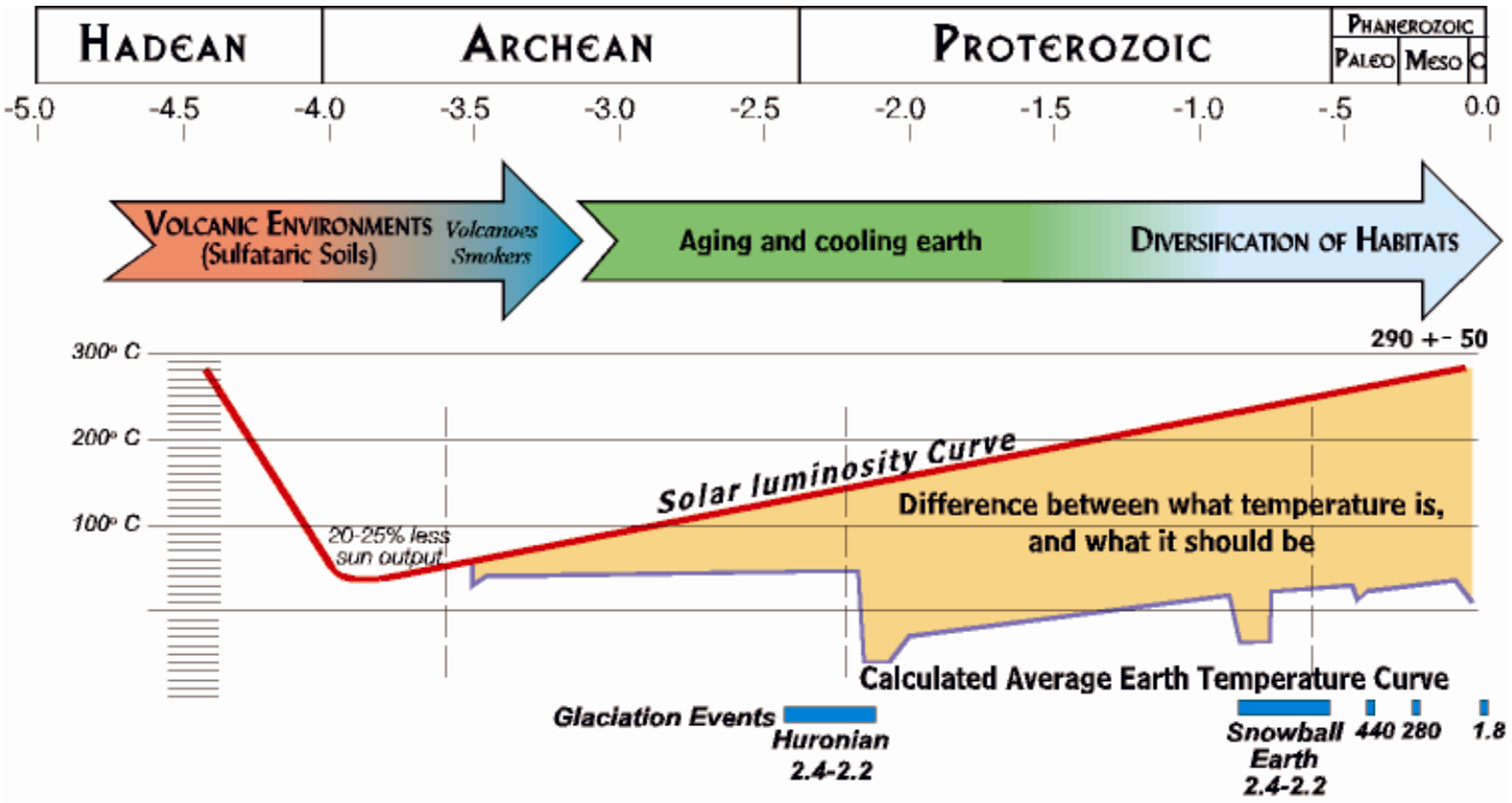
The oceans, the atmosphere, and all biological material on Earth are thus portrayed as integral components of a vast, self-regulating system. Not only that but life, in the original concept of Gaia, is seen as regulating the environment so as to maintain suitable planetary conditions for the good of life itself. In the opinion of Lovelock and Margulis:

. . . the Earth's atmosphere is more than merely anomalous; it appears to be a contrivance specifically constituted for a set of purposes . . . it is unlikely that chance alone accounts for the fact that temperature, pH and the presence of compounds of nutrient elements have been, for immense periods, just those optimal for surface life. Rather . . . energy is expended by the biota to actively maintain these optima.

Gaia Theory

Some Proposed Gaian Effects

1. Earth Temperature Regulation
   - Problems of increasing insolation through time.
   - Problems of Runaway Greenhouse effects with CO_2

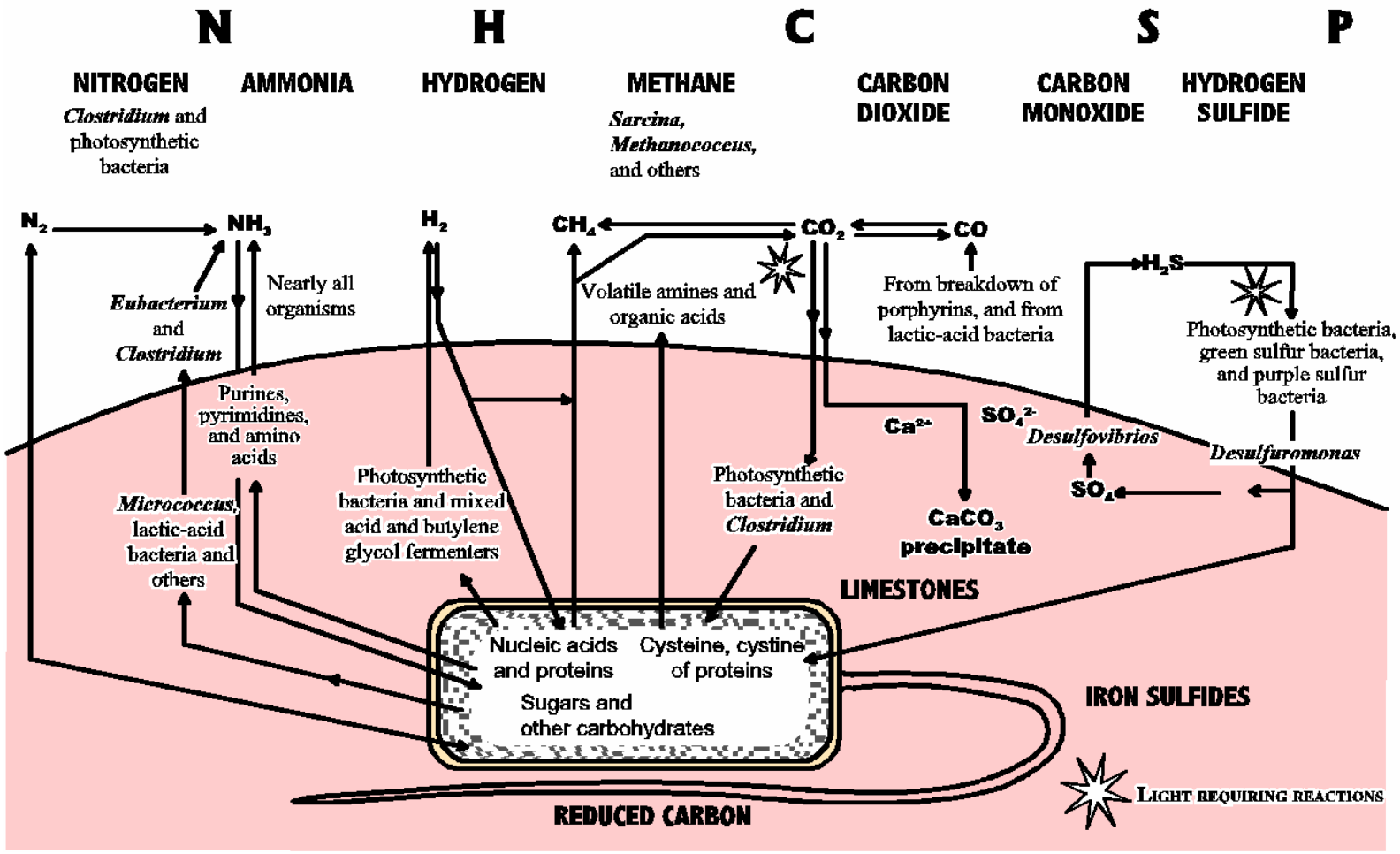


Gaia Theory

Some Proposed Gaian Effects

2. Ocean water geochemistry
   - Transition from acidic to reducing ocean conditions.
   - Sea water pH today is 7.5 to 8.4 (< 7 is acidic)
   - Regulation of salt and other dissolved solids.
3. Atmospheric balancing
   - Reduction of early acidic atmosphere from volcanic outgassing.
   - Methane, carbon dioxide, and oxygen balances.
4. Carbon and other element cycling
   - Carbon is the 4th most abundant element and flows through a complex of geological, biological, atmospheric, and oceanographic systems.

Archaean Bio-Geo-Chemistry



Gaia Theory

Some Proposed Gaian Effects

5. Plate Tectonics

   It has been argued that without the effects of life plate tectonic processes would have not begun, or would have halted early in the Earth's history, leading to a state like Venus.

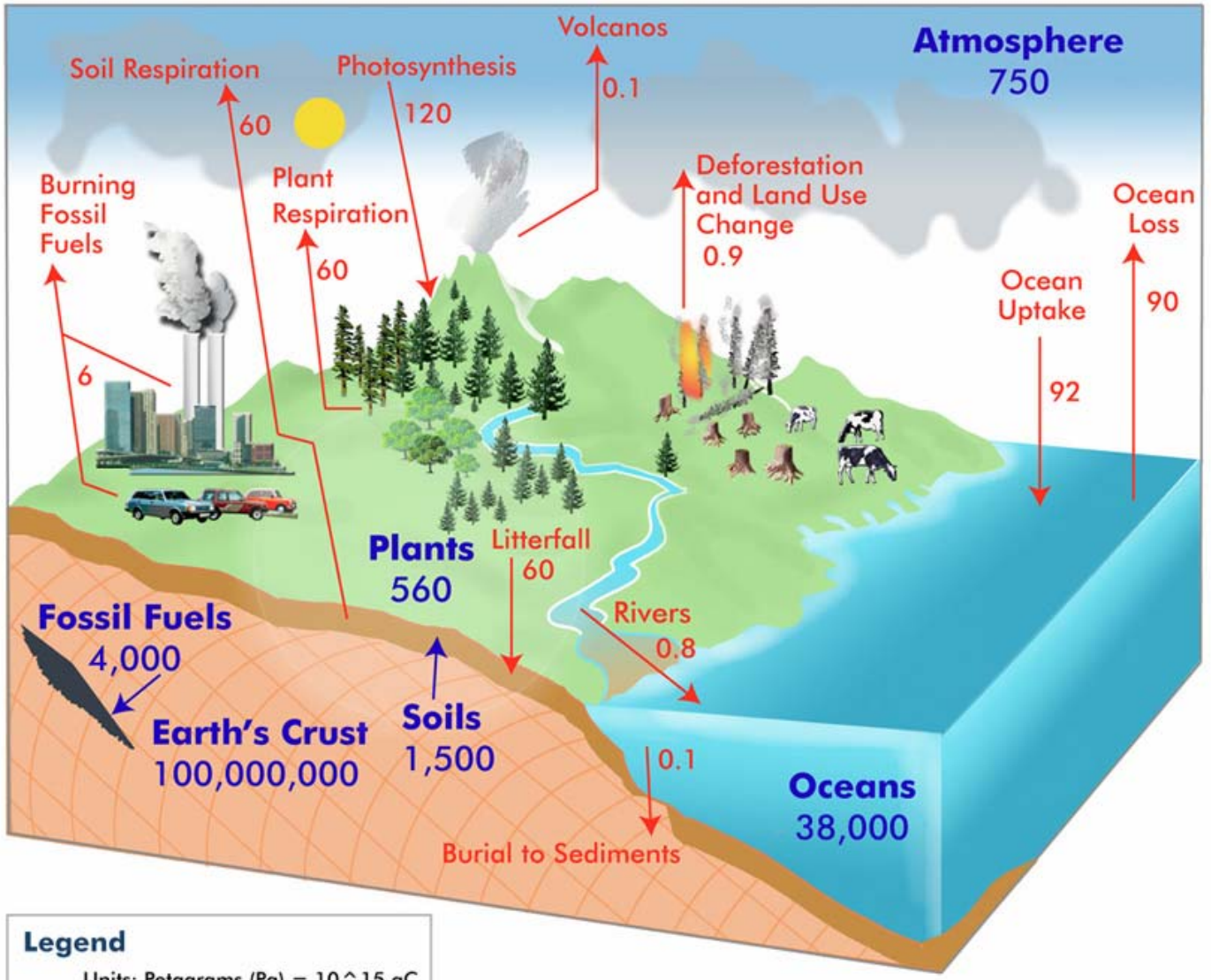
6. Rock Generation

   Carbonate deposition

   Banded Iron Formation

   Chert Deposition

Global Carbon Cycle



Legend

Units: Petagrams (Pg) = 10^15 gC

- Pools: Pg
- Fluxes: Pg/year

Gaia Theory
Some Early Objections

1. **Teleological Objections.**

"To many scientists Gaia was a teleological concept, one that required foresight and planning by the biota."

"Some people joked about there being some kind of annual meeting of representatives from the various ecosystems where they reviewed the past years progress and set goals for the coming year."

Richard Dawkins and Ford Doolittle argued organisms could not act in concert as this would require foresight and planning from them. They rejected the possibility that feedback loops could stabilize the system. In 1982, Dawkins claimed "there was no way for evolution by natural selection to lead to altruism on a Global scale". They find it impossible to see how the feedback loops which Lovelock says stabilize the Gaian system could have evolved.

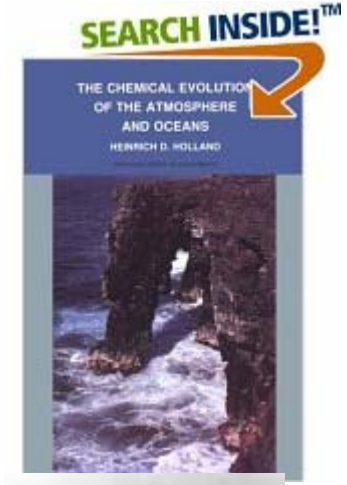
Gaia Theory
Some Early Objections

1. **Teleological Objections.**

   "To many scientists Gaia was a teleological concept, one that required foresight and planning by the biota."

2. **Coevolution Criticism.**

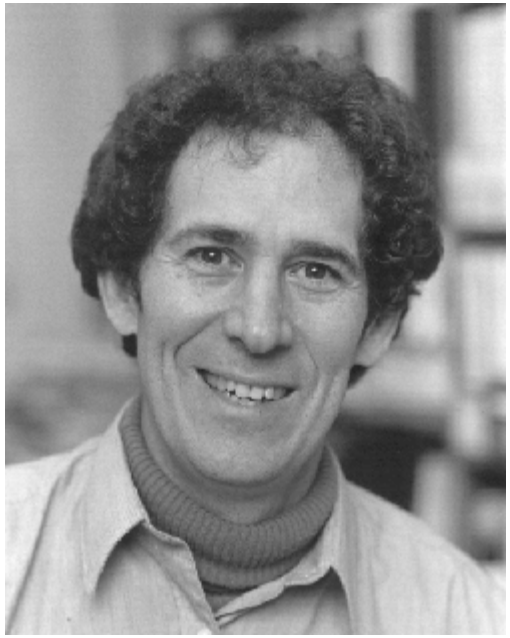
   Biological regulation is only partial, and that the real world is a "coevolution" of life and the inorganic."



Heinrich D. Holland

"I find the hypothesis intriguing and charming, but ultimately unsatisfactory. The geologic record seems much more in accord with the view that the organisms that are better able to compete have come to dominate, and that the Earth's near surface environment and processes have accommodated themselves to changes wrought by biological evolution. Many of these changes must have been fatal or near fatal to parts of the contemporary biota. We live on an Earth that is the best of all worlds but only for those who have adapted to it."

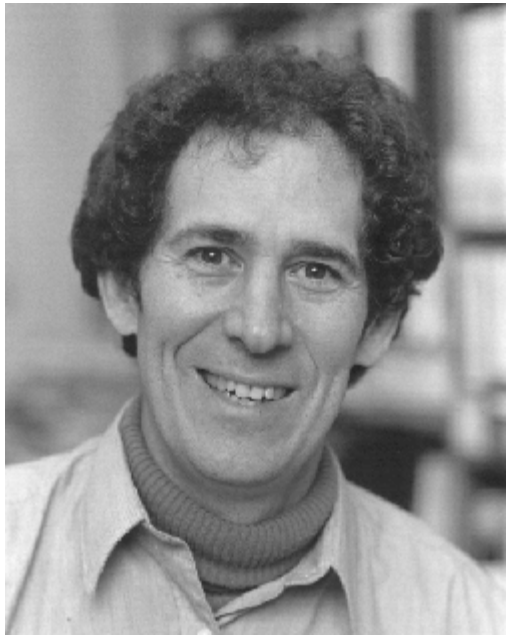
Gaia Theory
Some Early Objections



In 1988, the climatologist Stephen Schneider organized a conference of the American Geophysical Union solely to discuss Gaia. The accusations of teleologism were dropped after that meeting.

Lovelock presented a new version of the Gaia Hypothesis, which abandoned any attempt to argue that Gaia intentionally or consciously maintained the complex balance in her environment that life needed to survive. This new hypothesis was more acceptable by the scientific community.

Gaia Theory
Some Early Objections



In 1988, the climatologist Stephen Schneider organized a conference of the American Geophysical Union solely to discuss Gaia. The accusations of teleologism were dropped after that meeting.

Lovelock supported his new hypothesis with the metaphor of Daisyworld. Using computer simulations of the Daisyworld parameters (no atmosphere, taking into account different albedos for each daisy type) and a mathematical approach, Lovelock proved that the controlled stability of the climate by life was not being teleological.

Gaia Theory
Some Early Objections

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During the Gaia conference, James Kirchner, now a professor of Earth and Planetary Science at University of California, Berkeley, took the opportunity of the meeting to explain that there are not one Gaia hypothesis, but several ones ranging from "weak Gaia" to "strong Gaia". He then described five of these: Influential Gaia, Coevolutionary Gaia, Homeostatic Gaia, Teleological Gaia, Optimizing Gaia.

Weak Gaia – Weak Gaian models assert simply that the biota have a substantial influence over certain aspects of the abiotic world, such as temperature and composition of the atmosphere. Or, they may go further and argue that just as the biota influence their abiotic environment, so the environment influences the evolution of the biota by exerting Darwinian selection pressures. But, there are not strongly coupled interrelations.

Gaia Theory
Some Early Objections

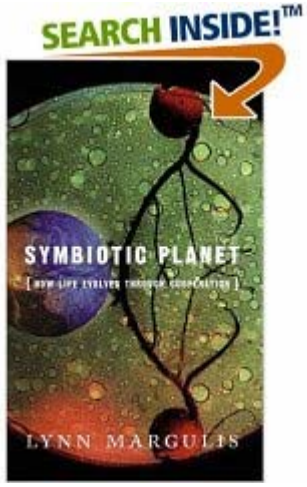
P 250

During the Gaia conference, James Kirchner, now a professor of Earth and Planetary Science at University of California, Berkeley, took the opportunity of the meeting to explain that there are not one Gaia hypothesis, but several ones ranging from "weak Gaia" to "strong Gaia". He then described five of these: Influential Gaia, Coevolutionary Gaia, Homeostatic Gaia, Teleological Gaia, Optimizing Gaia.

Strong Gaia The version put forward by Lovelock and Margulis is strong in that it depicts terrestrial life as influencing the abiotic world by a series of negative feedback loops in a way that is fundamentally stabilizing.

The biota manipulates its physical environment for the purpose of creating biologically favourable or even optimal conditions for life.

Gaia Theory



A version of Gaia theory was developed by Lynn Margulis, a model that is in some ways more limited in scope than the one that Lovelock proposed. In particular, that only homeorhetic and not homeostatic balances are involved, and that there is no special tendency of biospheres to preserve their current inhabitants, and certainly not to make them comfortable. Accordingly, the Earth is not a living organism which can live or die all at once, but rather a kind of community of trust which can exist at many discrete levels of integration.

That is, the composition of Earth's atmosphere, hydrosphere and lithosphere are regulated around 'set points' as in homeostasis, but those set points change with time... Gaia is just symbiosis as seen from space."

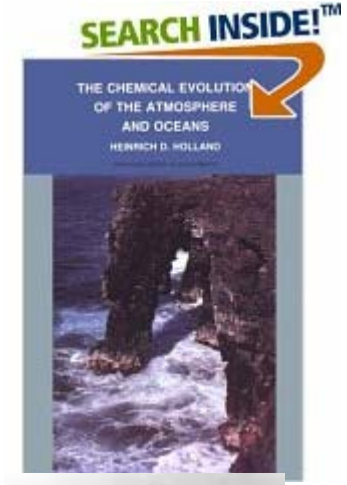
Gaia Theory
Some Early Objections

1. **Teleological Objections.**

   "To many scientists Gaia was a teleological concept, one that required foresight and planning by the biota."

2. **Coevolution Criticism.**

   Biological regulation is only partial, and that the real world is a "coevolution" of life and the inorganic."

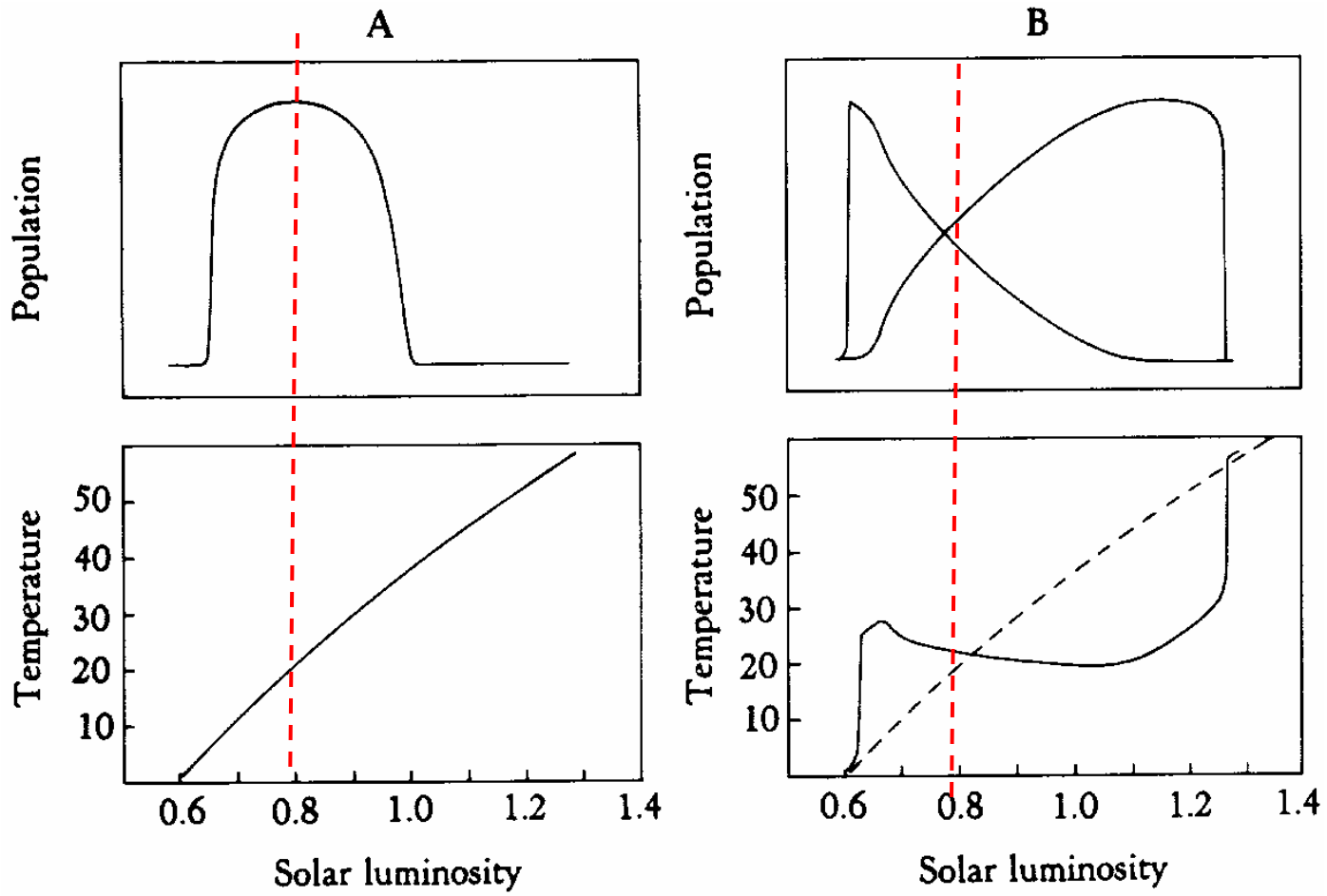


"I find the hypothesis intriguing and charming, but ultimately unsatisfactory. The geologic record seems much more in accord with the view that the organisms that are better able to compete have come to dominate, and that the Earth's near surface environment and processes have accommodated themselves to changes wrought by biological evolution. Many of these changes must have been fatal or near fatal to parts of the contemporary biota. We live on an Earth that is the best of all worlds but only for those who have adapted to it."

Gaia Theory – Daisyworld Models

Models of the evolution of Daisyworld according to conventional wisdom (A) and to geophysiology (B)

P 251



Gaia Theory – Daisyworld Models

The following account of the Daisyworld is an extract from Guide to the Blue Planet by M. Bjornerud, J. Hughes and A. Baldwin, 1995.

"James Lovelock's Daisyworld is a hypothetical Earth-like planet, the same size as Earth and orbiting the same distance from a star similar to Earth's Sun. Like our Sun, this star has grown progressively brighter through time, radiating more and more heat. Yet the surface temperature on Daisyworld has remained nearly constant for most of the planet's history. This is because the biosphere on Daisyworld, which consists only of dark-, light-, and gray-colored daisies, has acted to moderate the temperature. The daisies influence the surface temperature simply through their albedo or reflectivity. Dark daisies absorb most of the Sun's heat; light-colored daisies reflect much of it back to space. Gray daisies absorb about as much heat as they reflect. But how could the reflectivities of individual daisies affect the global temperature?"

Gaia Theory – Daisyworld Models

The following account of the Daisyworld is an extract from Guide to the Blue Planet by M. Bjornerud, J. Hughes and A. Baldwin, 1995.

[A] Early in the history of the planet, when the young Sun was still relatively cool (see figure below), dark daisies would be the fittest species, because clusters of them create local warm spots that favor the growth of more daisies. Soon the planet would be covered by dark daisies, and their collective effect would be to increase the global temperature above what it would have been in the absence of life

[B] When the dark daisies had established a comfortable temperature, gray and white daisies would begin to take advantage of the pleasant conditions. At first, gray daisies would do better than light ones because clusters of reflective light daisies wouldn't be able to keep local temperatures warm enough for survival.

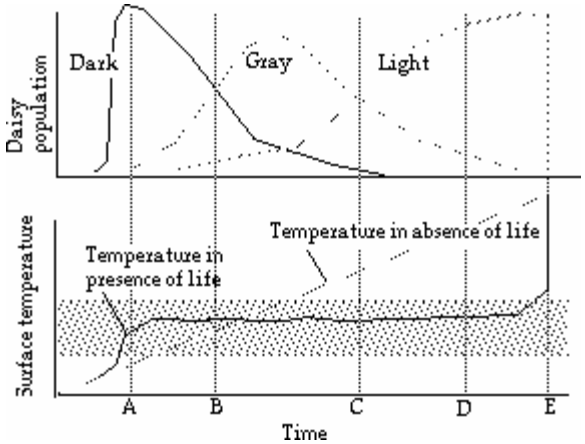
[C] Eventually, the Sun's output would reach the point where unmoderated surface temperatures would exceed the maximum tolerable to daisies.

Gaia Theory – Daisyworld Models

The following account of the Daisyworld is an extract from Guide to the Blue Planet by M. Bjornerud, J. Hughes and A. Baldwin, 1995.

[D] At this point, light-colored daisies would begin to become the fittest species because clusters of them would create cool spots that would favor the growth of more daisies. As light-colored daisies spread, their collective effect would be to decrease the global temperature well below what it would have been in the absence of any life forms. In this way, individual daisies, without knowledge of or concern for the planet as a whole, would have acted to control the global environment.

[E] Finally, the heat produced by the Sun would be so great that neither type of daisy would be able to moderate the temperature, and all species would die out.



Gaia Theory – Daisyworld Models

Models of the evolution of Daisyworld according to conventional wisdom (A) and to geophysiology (B)

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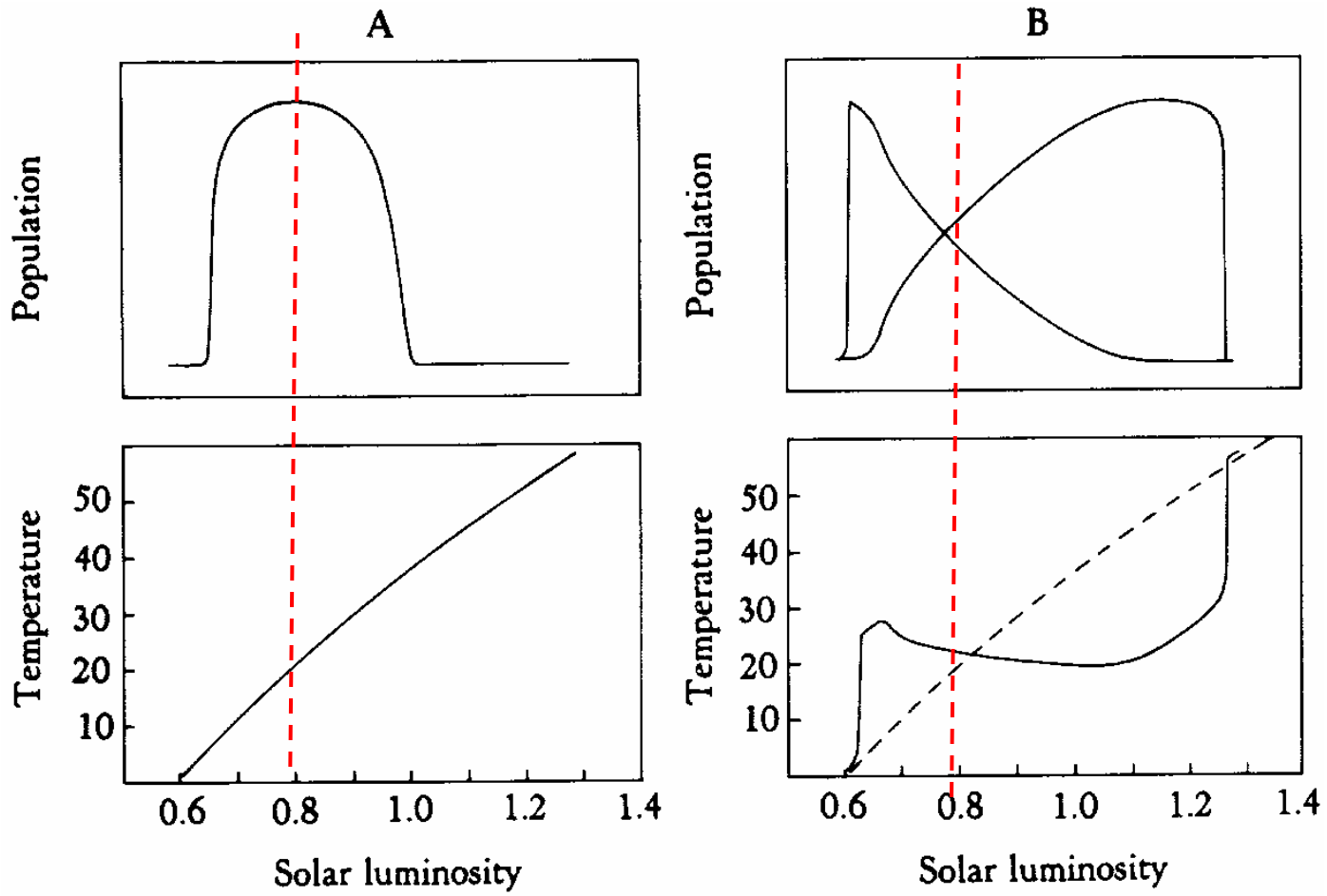


Gaia Theory – Daisyworld Models

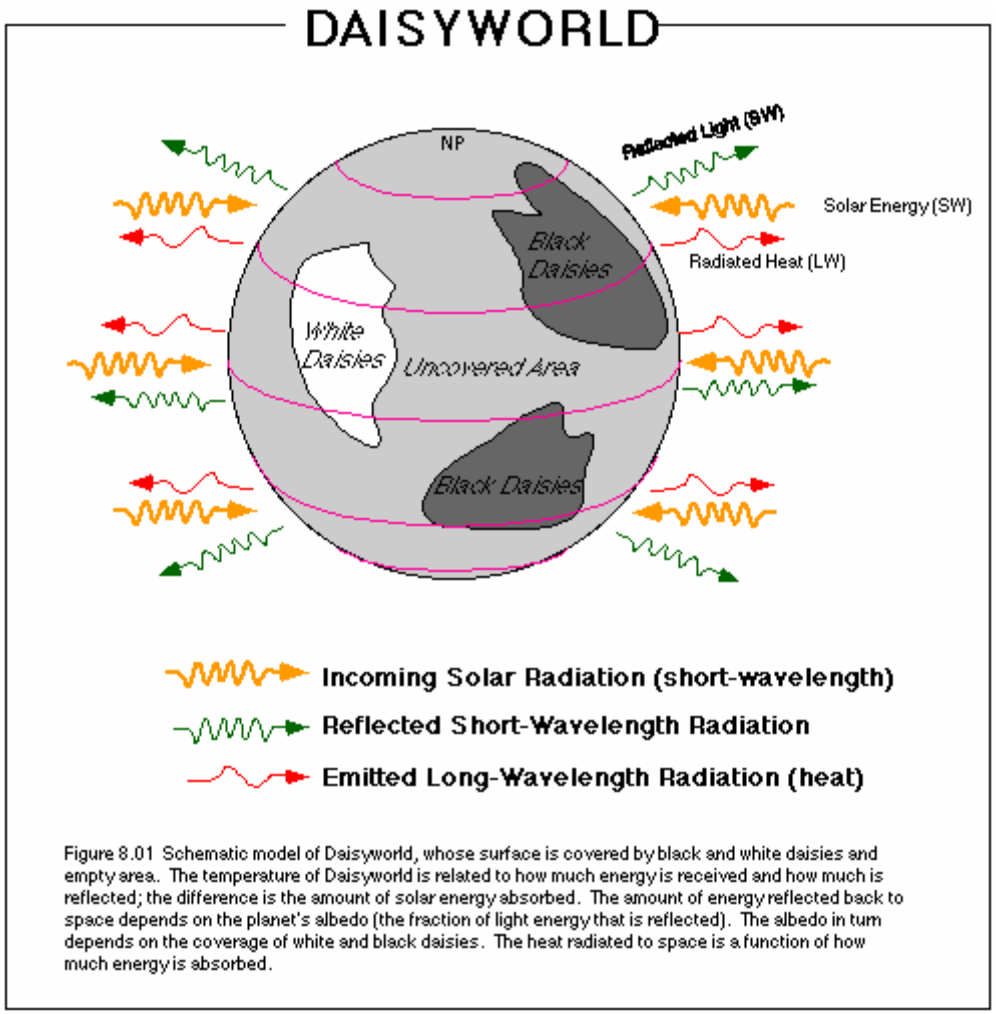
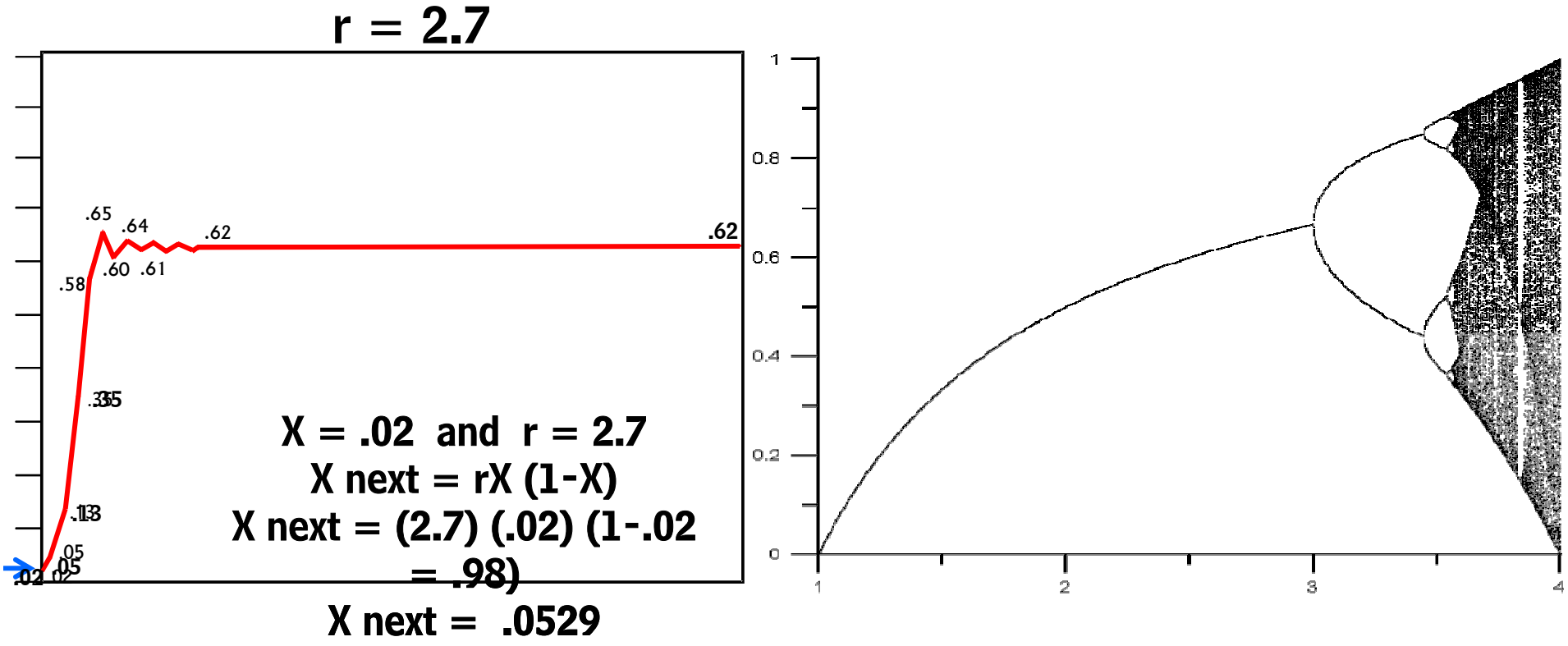


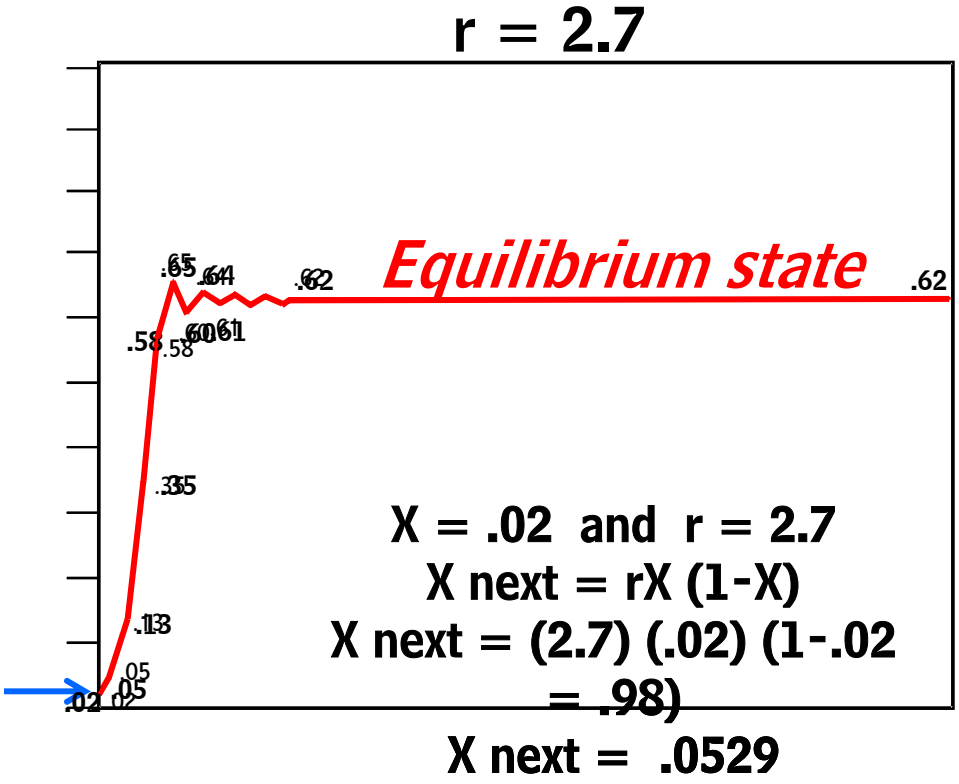
Figure 8.01 Schematic model of Daisyworld, whose surface is covered by black and white daisies and empty area. The temperature of Daisyworld is related to how much energy is received and how much is reflected; the difference is the amount of solar energy absorbed. The amount of energy reflected back to space depends on the planet's albedo (the fraction of light energy that is reflected). The albedo in turn depends on the coverage of white and black daisies. The heat radiated to space is a function of how much energy is absorbed.

Daisyworld models are positive/negative feedback models analogous to the logistic system Xnext.

The system has coupled components such that when the positive component gets too large it causes the negative component to kick in and reverse the direction the system is going.

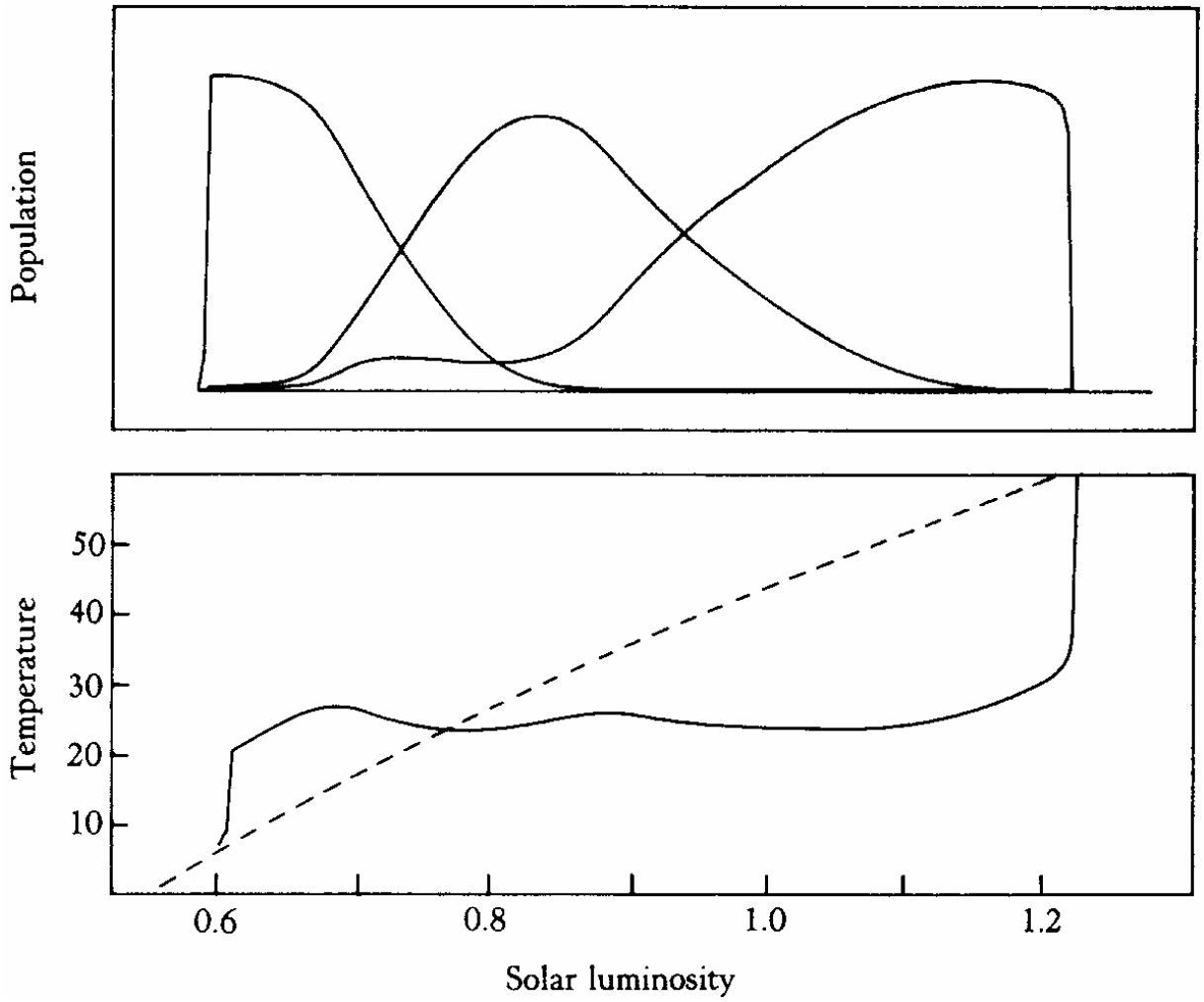
The system is homeostatically regulated, at least as long as the r value is not too high.




r = 2.7
Equilibrium state
.62
X = .02 and r = 2.7
X next = rX (1-X)
X next = (2.7) (.02) (1-.02
= .98)
X next = .0529

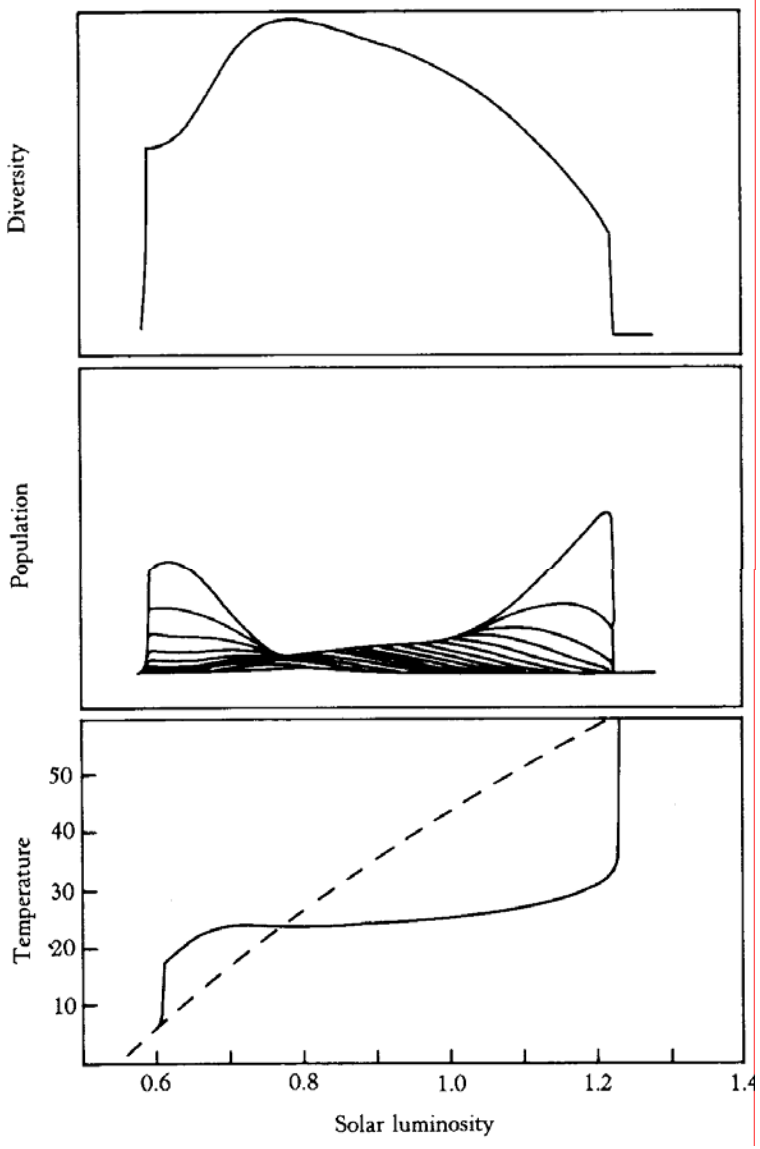
Gaia Theory – Daisyworld Models

The evolution of climate on a three species Daisyworld with dark, gray, and light daisies present.



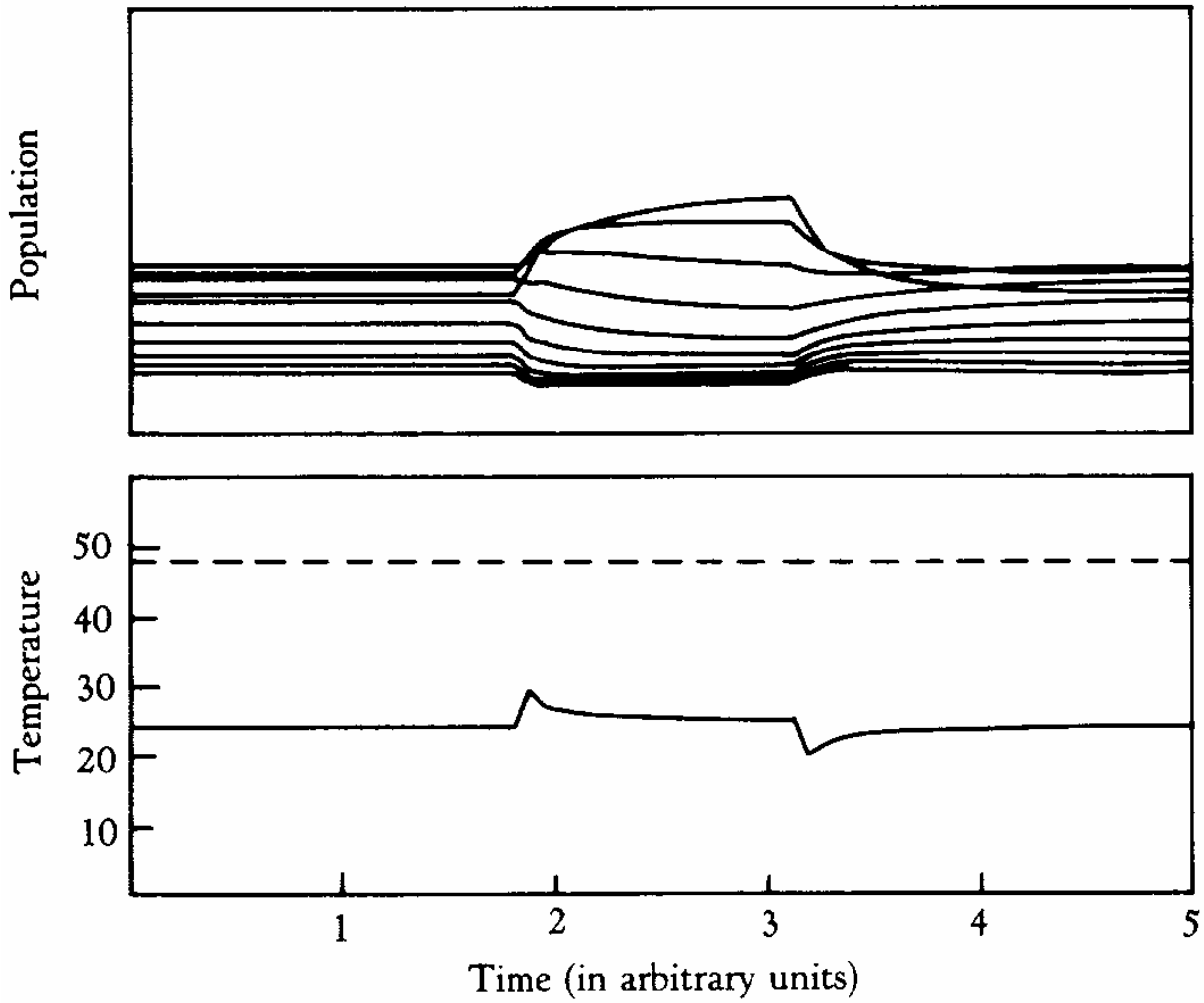
Gaia Theory – Daisyworld Models

The evolution of climate on a 20 species Daisyworld



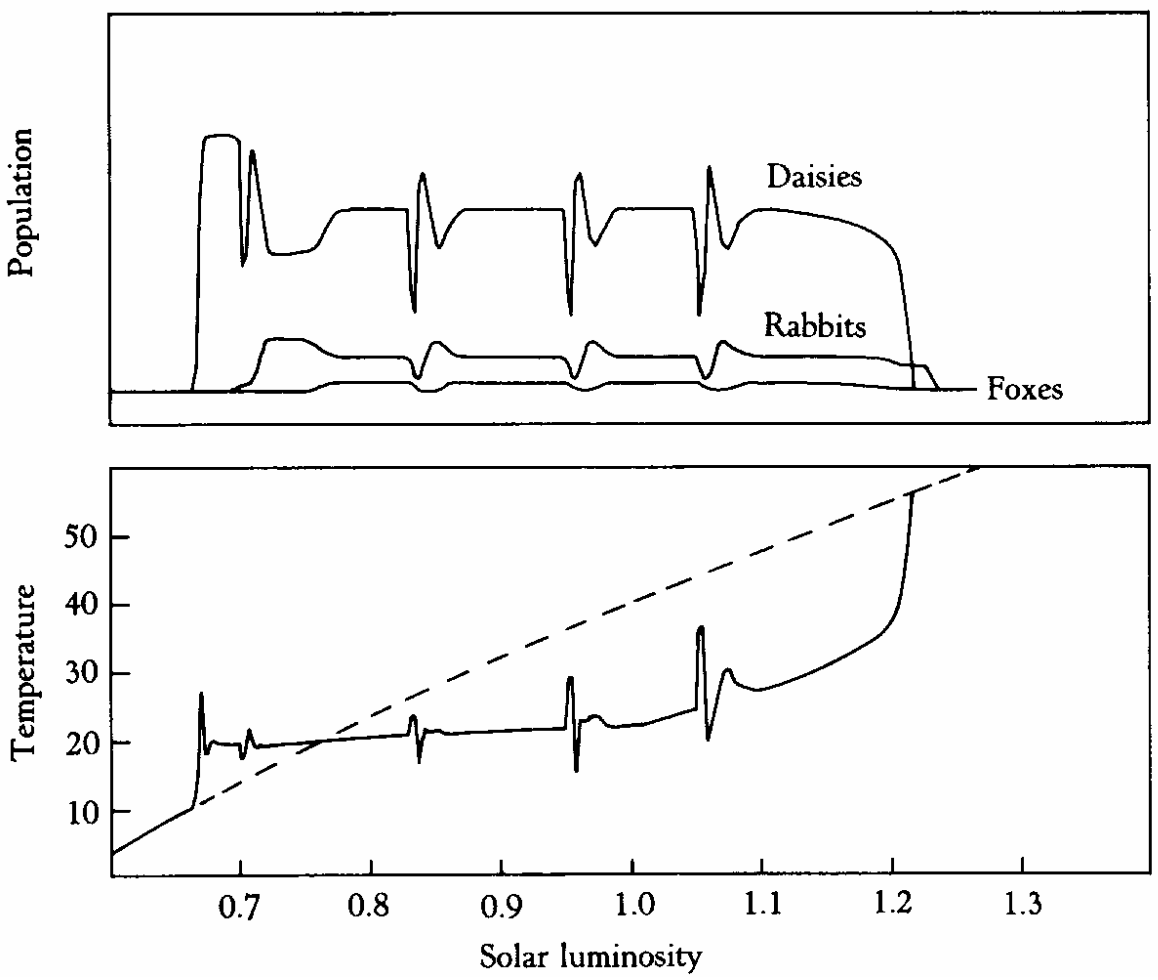
Gaia Theory – Daisyworld Models

The effect on climate of a plague that kills off 60% of the daisies on a Daisyworld when the solar luminosity is at a constant



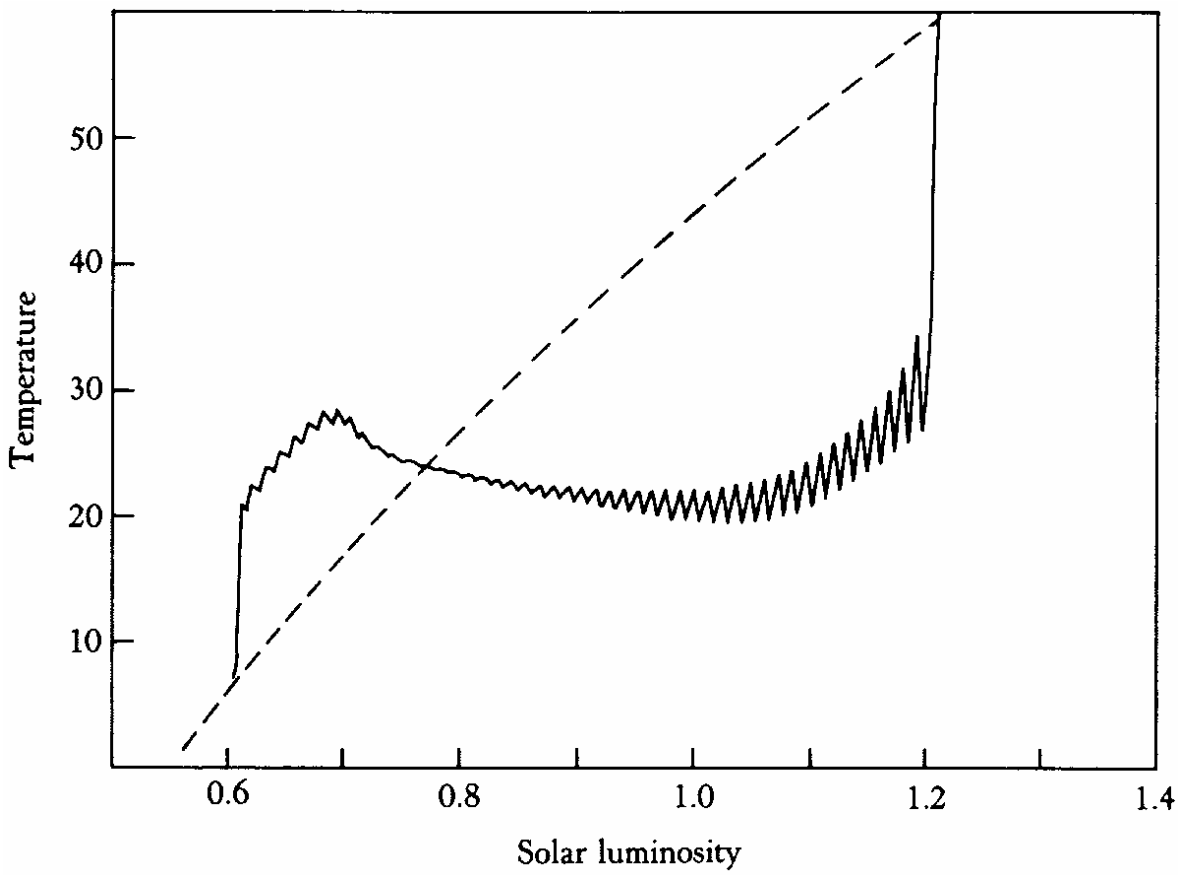
Gaia Theory – Daisyworld Models

Daisyworld with rabbits and foxes, perturbed by four plagues that killed 30 percent of the daisies



Gaia Theory – Daisyworld Models

The effect of a plague of constant intensity on the ability of the daisies to control the climate.



Gaia Theory – Daisyworld Models

Model of the Archean Before and After Life Following Daisyworld Models

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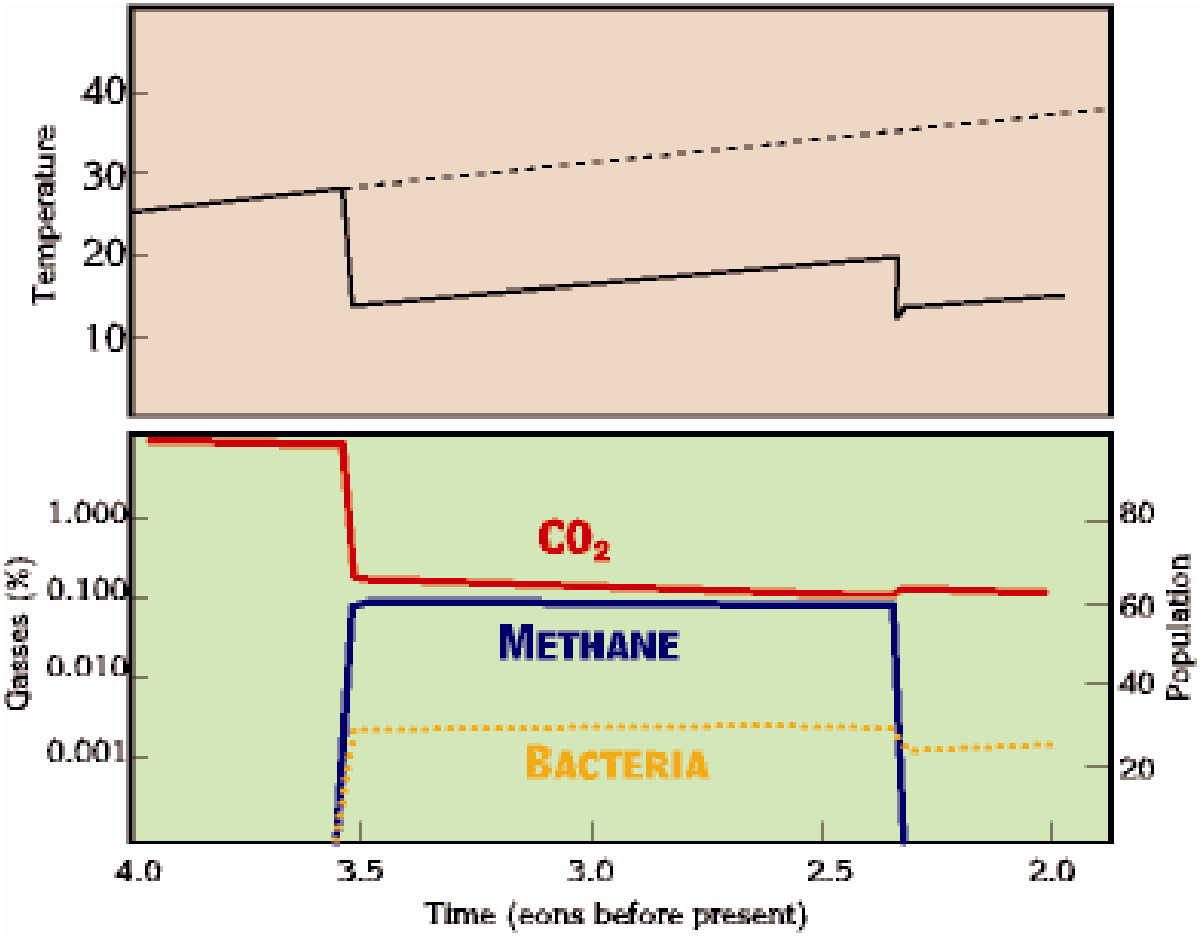


Gaia Theory – Daisyworld Models

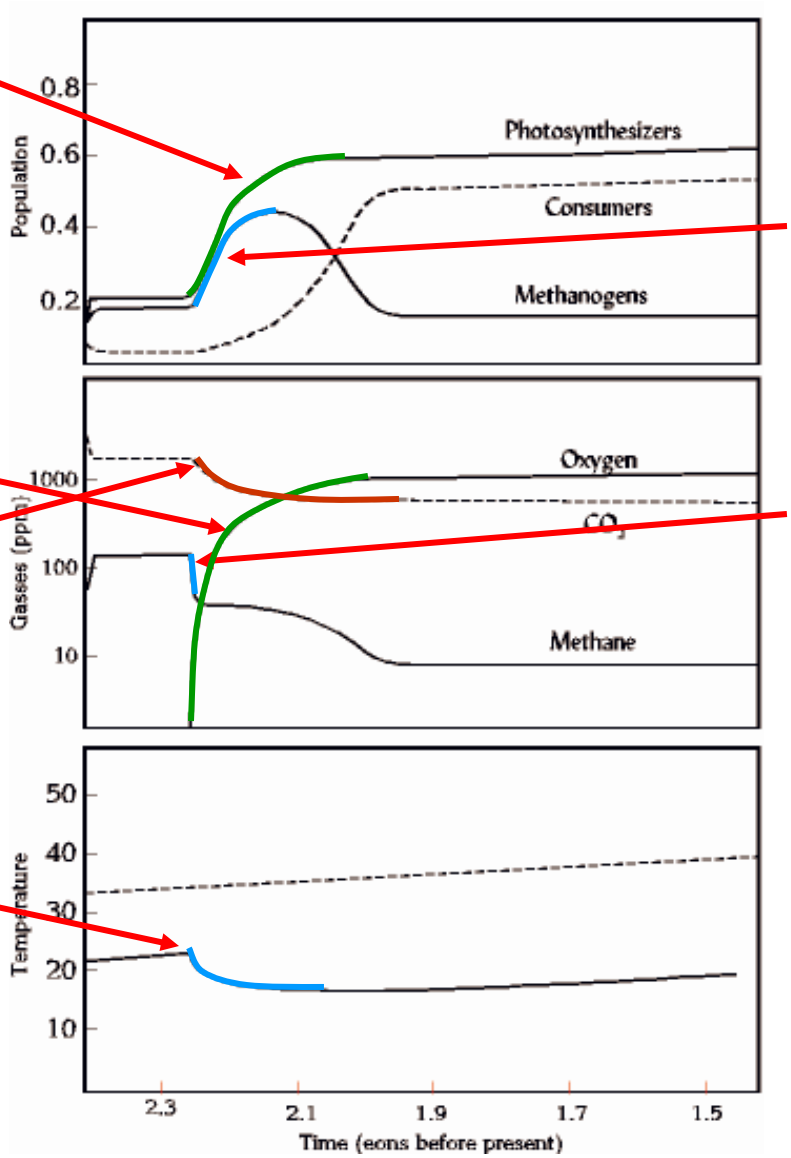
Model of the Archean-Proterozoic Transition

1 – BGA Evolve: stromatolite population expands exponentially on new continental shelves

2 – O_2 begins to accumulate from aerobic photosynthesis

3 – CO_2 begins to drop due to exponentially expanding photosynthesis

5 – Drop in CO_2 and CH_4 drops temperature due to loss of greenhouse effects



4 – Methanogen population expands

> Negative feedback on temp from CO_2 drop balanced by positive feedback of methanogenic CH_4 on temperature.

> But, CH_4 drops anyway due to reaction with rising O_2

Gaia Theory – Daisyworld Models

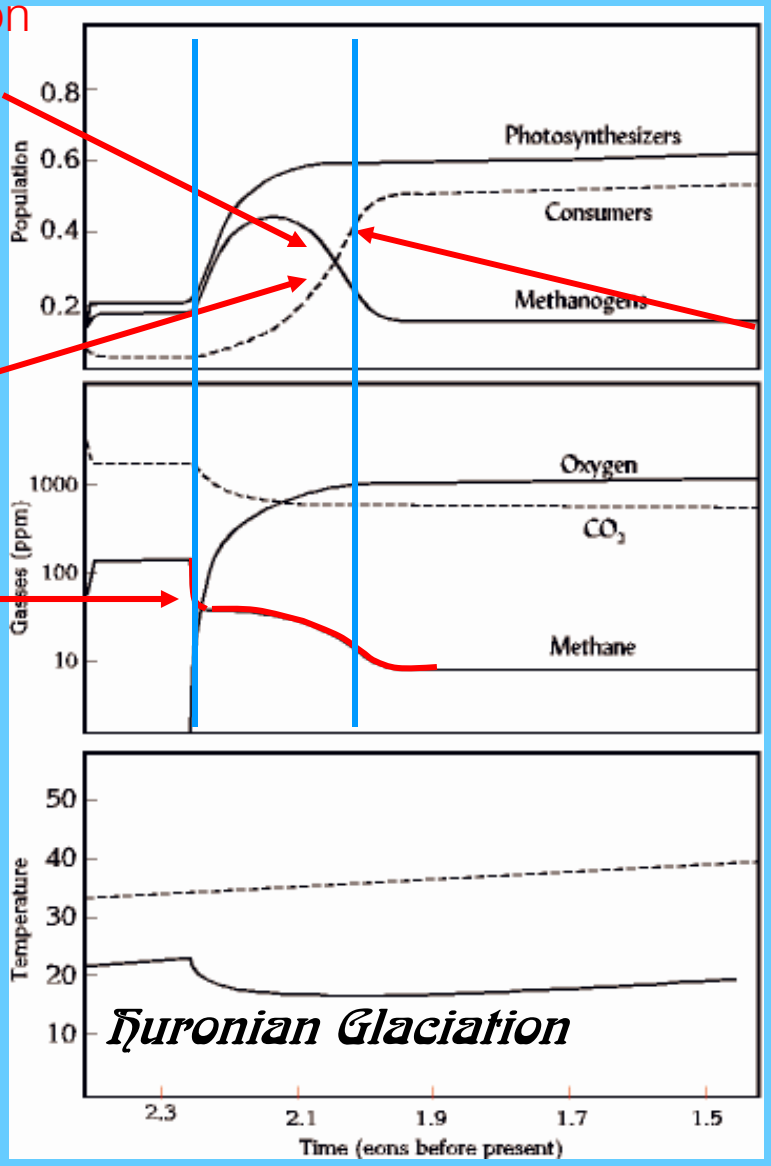
Model of the Archean-Proterozoic Transition

6 – Methanogen population declines as O_2 rich environments expand; a negative feedback.

> Plus, evolving consumers have negative feedback on organic matter getting to methanogens, further declining their population.

7 – Therefore, CH_4 declines, plateaus, then declines again

9 – Temperature drop leads to glaciation



8 – Consumers rise lags behind O_2 rise, perhaps because O_2 rise was intermittent or local in distribution.

10 – Oxygen causes sky to turn blue

Archaean-Proterozoic Transition

1. BGA evolve

   ⇨ Stromatolite population expands.

2. O_2 begins to accumulate.
3. CO_2 begins to drop (as BGA population explodes)
4. Methanogen population expands

   ⇨ Trying to compensate for CO_2 drop, and subsequent temperature drop.

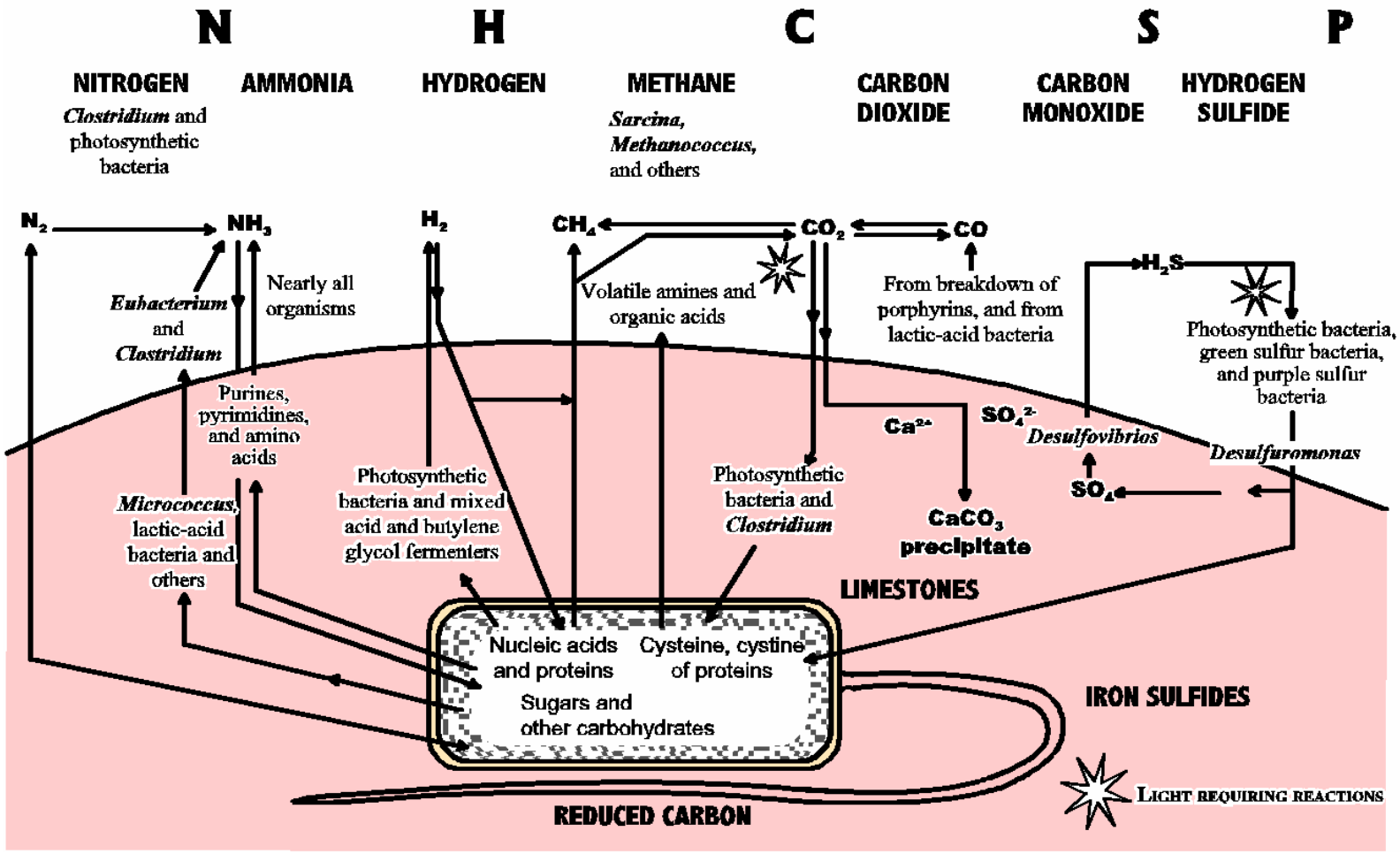
   ⇨ But CH_4 drops anyway due to reaction with increasing O_2.

5. Drop in CO_2 and CH_4 drops temperature due to loss of greenhouse effect.
6. Methanogen population decreases as O_2 rich atmosphere establishes.

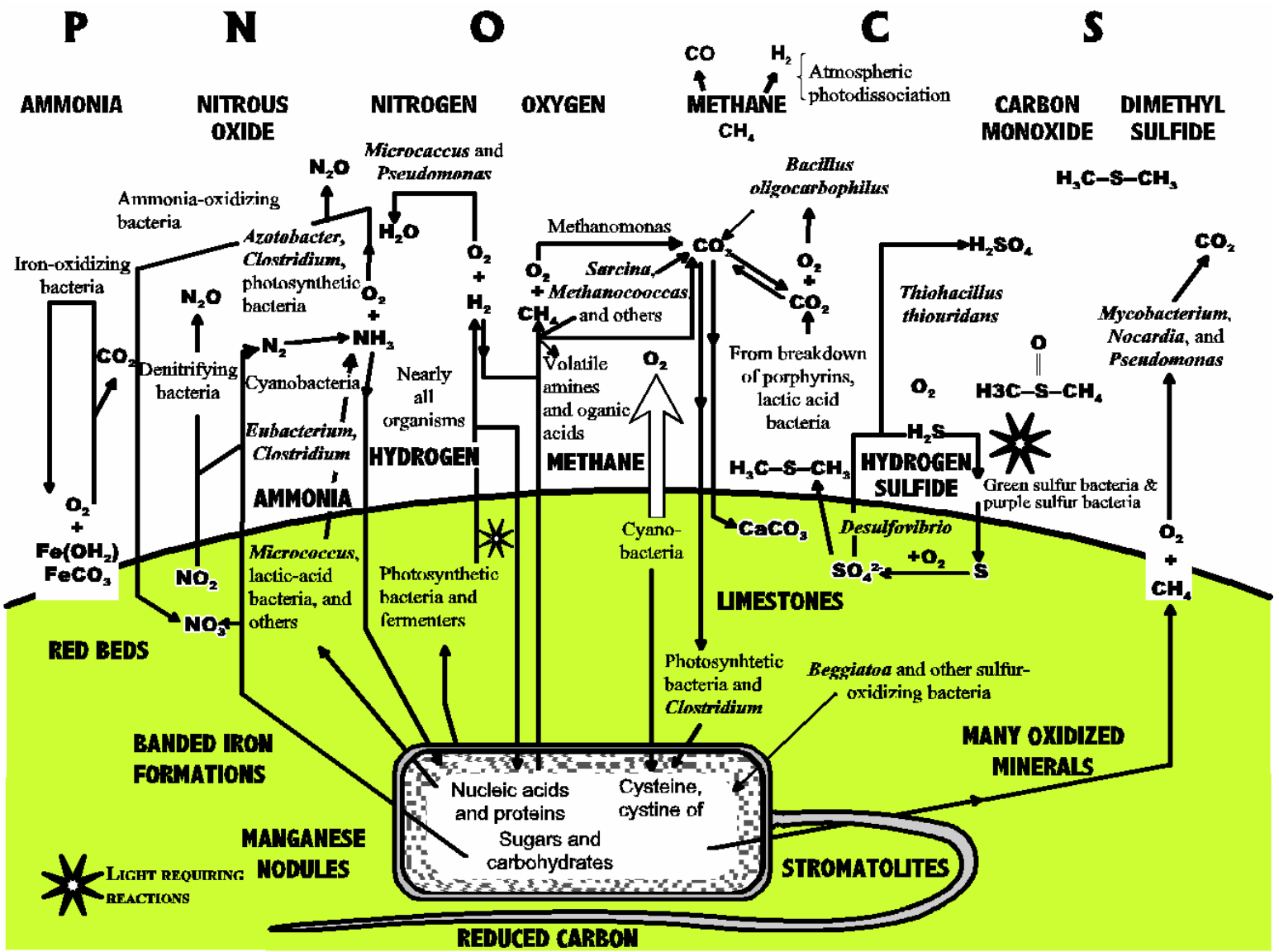
Archaean-Proterozoic Transition

7. BUT CH_4 production limited to short but steady decline.
   - ⇨ Plateau follows
   - ⇨ O_2 attacks CH_4
   - ⇨ Evolving consumers eat organic matter before it become sequestered in the anoxic sediments where methanogens can get it.
8. Consumers expand as O_2 accumulates.
   - ⇨ Lag slightly behind O_2 rise.
9. Glaciation results from loss of greenhouse gasses.
10. Sky goes blue from bleaching effects of O_2.

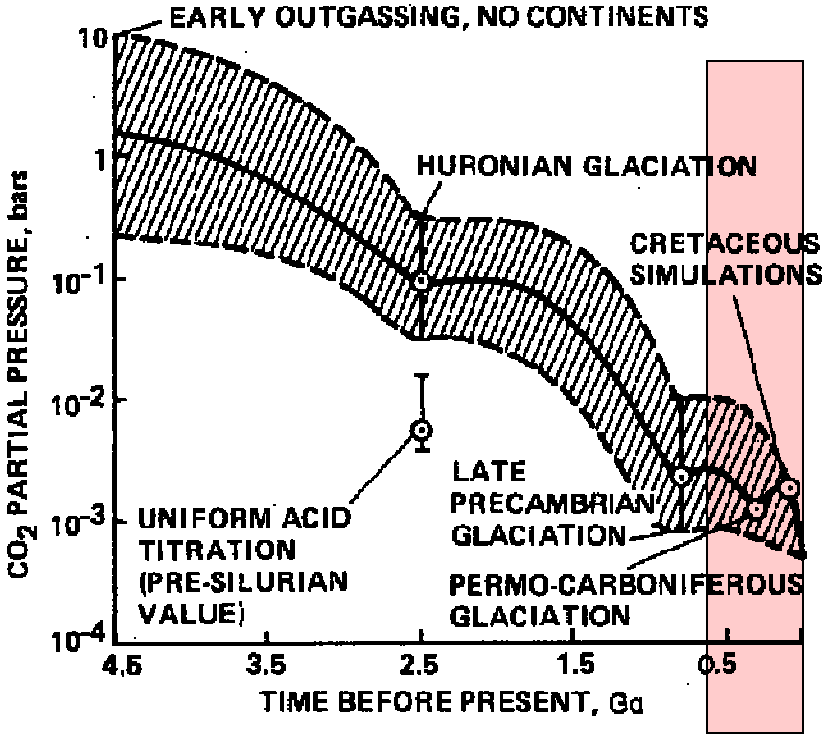
Archaean Bio-Geo-Chemistry



Proterozoic Bio-Geo-Chemistry

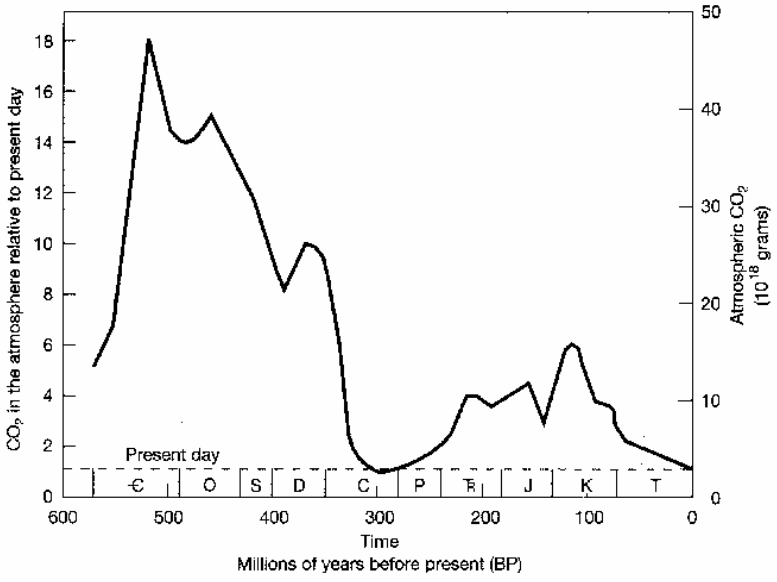


Between a Rock and a Hard Place

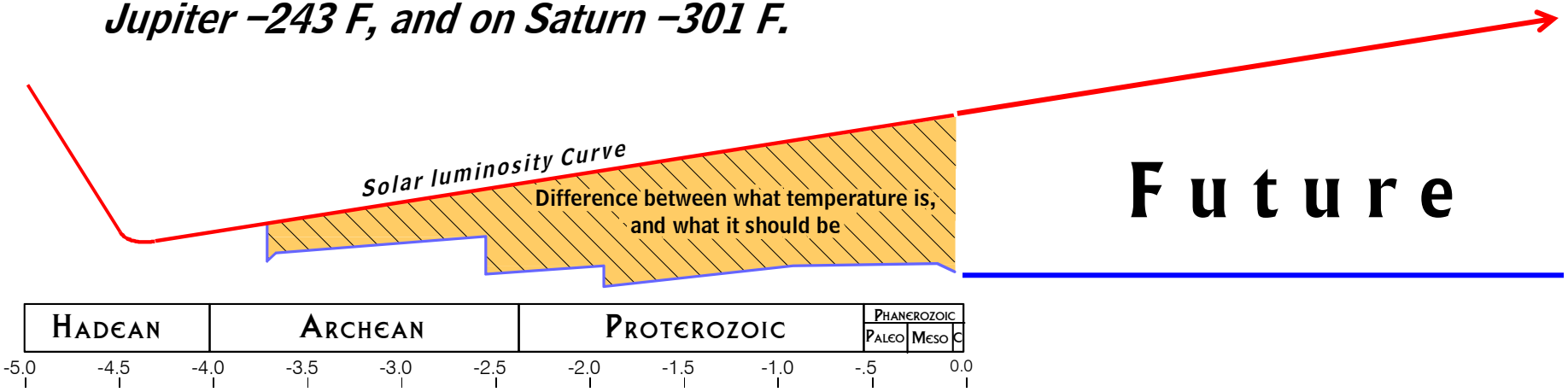


Estimated changes in pCO_3 over geologic time. The shaded area represents the climatically reasonable range of pCO_3.

CO_2 concentration changes during the last 600 million years detailed below



In contrast, temperatures on Venus are about 900 F, on Mars about −193 F, on Jupiter −243 F, and on Saturn −301 F.



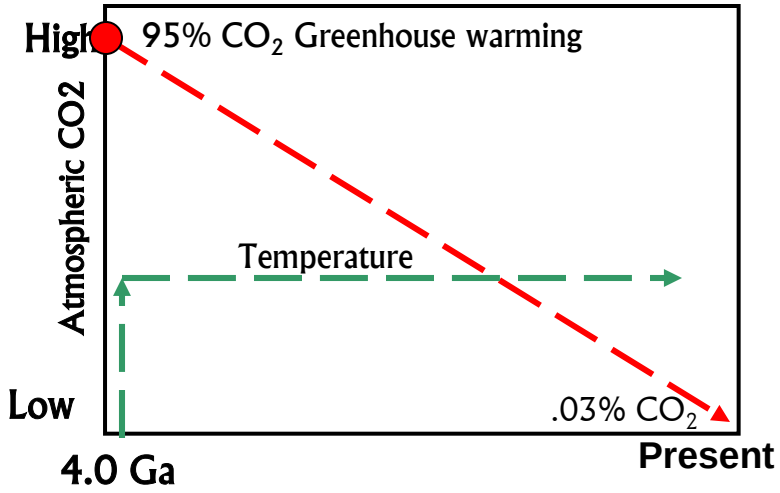
Comparison of Earth With Itself at 4 Billion Years Ago

We on Earth are between a rock . . . and a hard place.

When the sun was small/cool CO_2 was high and the greenhouse effect warmed the Earth.

As the sun has gotten larger/warmer life has sucked down CO_2 to reduce greenhouse effect.

Therefore, temperature has remained regulated at a condition comfortable for life.



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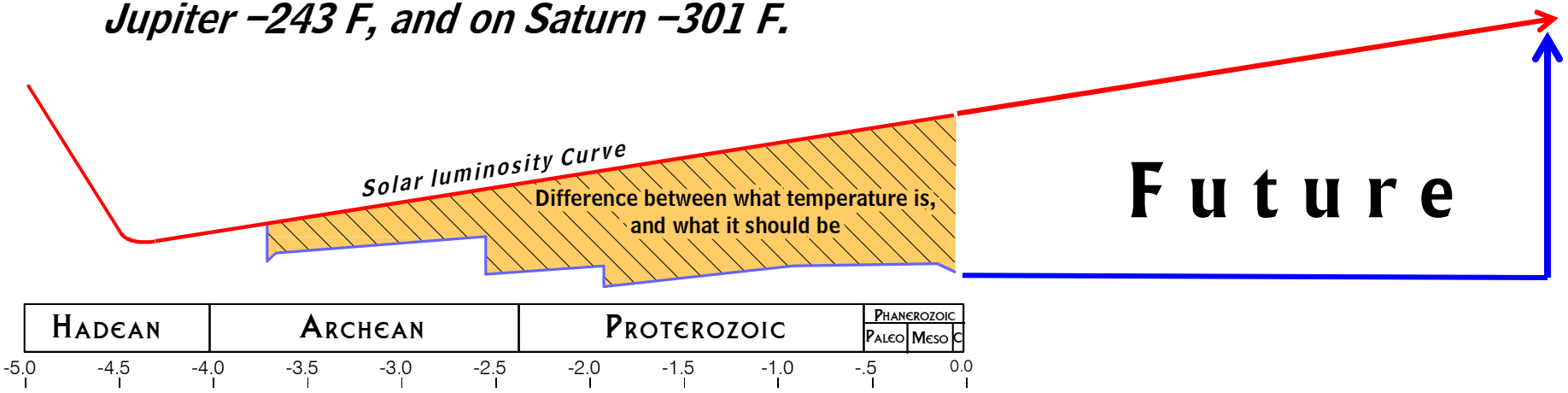
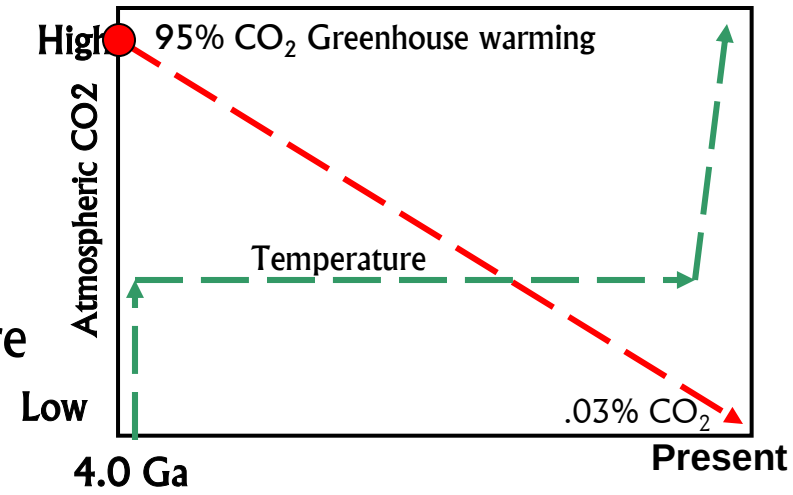


Comparison of Earth With Itself at 4 Billion Years Ago

This is a positive/negative feedback system.

- Expanding sun warms the Earth: + feedback
- Life sucks CO_2 down cooling it: - feedback

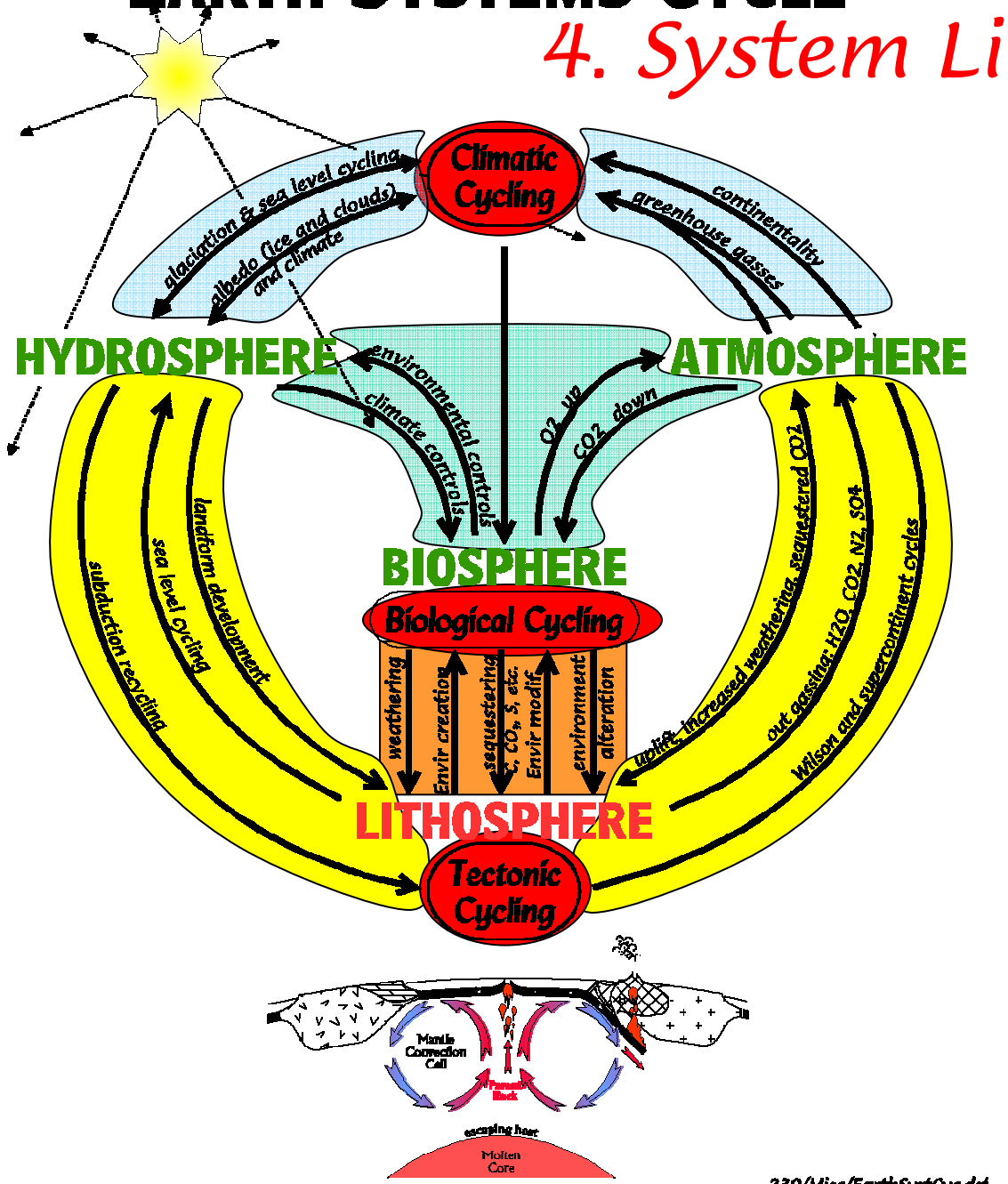
When the CO_2 is gone the Earth's temperature will shoot up to its equilibrium condition.



The history of the Earth is about these positive/negative feedback mechanisms.

EARTH SYSTEMS CYCLE

4. System Linkages



230/Misc/EarthSystCyc.dsf

Thus endith

Our study of Evolutionary Earth

It is time for the second test

What day would work best for the test?

When we do the test we can do it one of two ways.

Decision is by majority vote.

Option One:

- Test begins at 9:00.
- You have 50 minutes to take the test.
- Class begins at 10:00.

Option Two:

- Class begins at 9:00 and ends at 11:00.
- You may begin the test anytime between 11:00 and 1:30.
- You may have a much time as you wish to take the test.