Evolution of Complex Earth Systems

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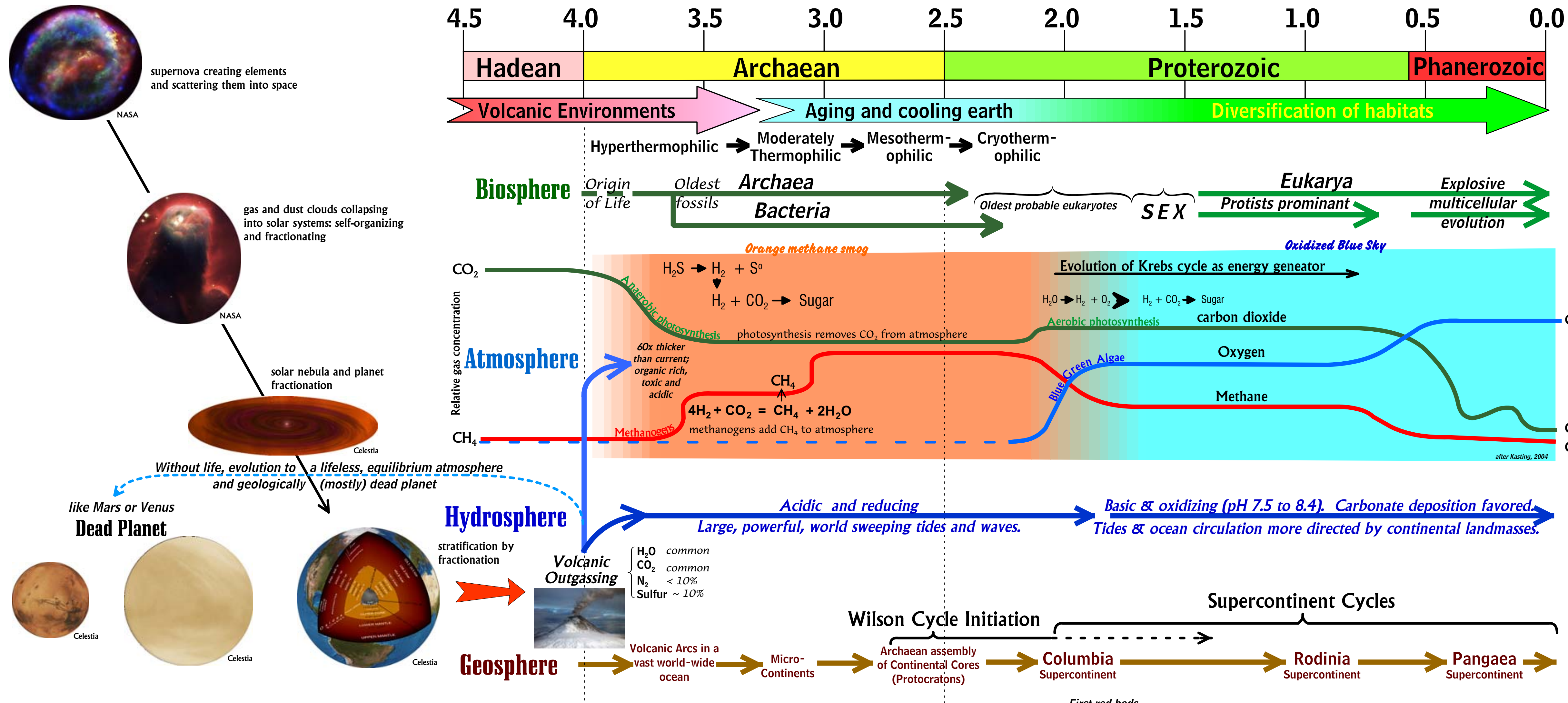


Evolution by increasing . . .

> complexity

> diversity

> interconnectedness

By the complex systems mechanisms of . . .

> elaborating evolution

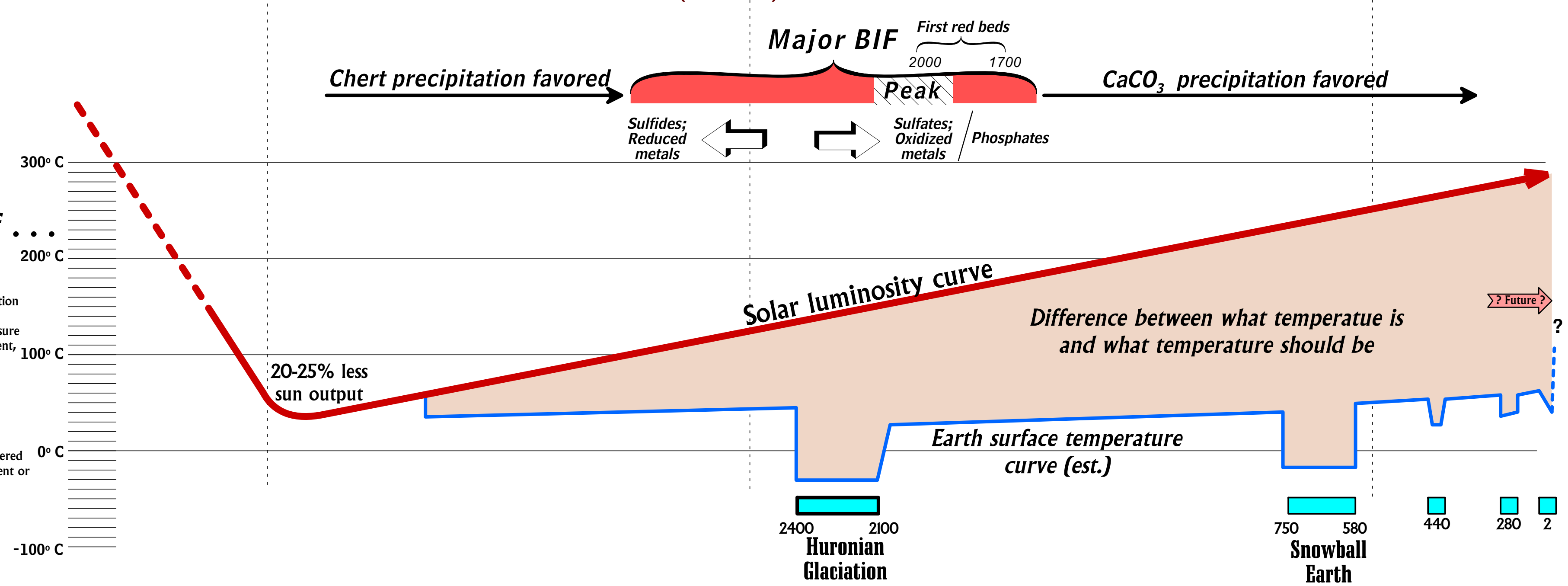
Elaborating evolution begins with a seed, an ancestor, or a randomly generated population of agents, and evolves by generating, and randomly mutating, a large diversity of descendants which are evaluated by an external fitness function; those that do not measure up selected out. The fitness function may be a real environment, an abstract environment, or another "species" of agents.

> self-organizing evolution

Self-organizing evolution begins with an initial state of random agents that through the application of simple rules of interaction among the agents (e.g. an algorithm, or chemical/physical laws)—Local Rules leads to Global Behavior—evolves a system of ordered structures, patterns, and/or connections without control or guidance by an external agent or process; that is, pulls itself up by its own boot straps.

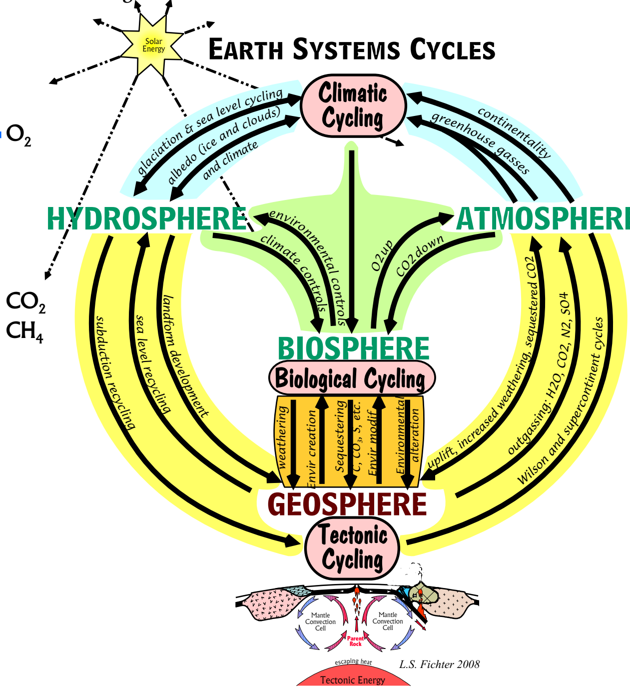
> fractionating evolution

Fractionating evolution begins with a complex parent which is physically, chemically, or biologically divided into fractions—through the addition of the right amount of energy—because of differences in the size, weight, valence, reactivity, etc. of the component particles.



Thinking has its strategies and tactics too, much as other forms of action have. Which avenues of thinking are apt to be useful and to help yield the truth depends not on how we might prefer to think about a subject, but rather on the inherent nature of the subject itself. Merely to think about the Earth and get somewhere, one of the main things to know is what *kind* of problem the Earth is.

Earth systems are not simple systems (e.g. classical mechanics), or systems of disorganized complexity (classical thermo dynamics). They are what Warren Weaver called problems of organized complexity, and Ilya Prigogine called dissipative structures, and we call complex systems, in which a half-dozen and even several dozen quantities are all varying simultaneously and in subtly interconnected ways. The variables are many, but they are not helter-skelter; they are interrelated into an organic whole.



To approach Earth systems from a complex systems viewpoint we are interested in how the evolutionary processes in one sphere influences the evolutionary processes in another sphere. For example:

- The fractionating evolution of atmospheric gasses over geologic time has been largely mediated by biological processes, but not all fractionations are biological (e.g. fractionation of atmospheric oxygen isotopes, and many but not all mineral fractionations).
- Over short geologic time scales (e.g. thousands of years), elaborating evolutionary change has little influence on how fractionation occurs, but at longer geological time scales the evolution of biological elaboration mechanisms has changed the way that chemical fractionation occurs.
- The fractionating evolution of the atmosphere has at times changed opportunities for elaborating evolution and subsequently the long-term evolution of life on Earth.
- Meanwhile, the origin of life, and development and structure of ecosystems are not elaborating mechanisms, but self-organizing systems, and they influence how Earth environments have evolved through time.

By looking at evolution through the universality principles of chaos/complex systems we will see new dimensions and new possibilities that might not have occurred to us before. A whole new vision of teaching based on complex evolutionary systems lies before us. At the same time there is a vast arena of problems and understanding yet to be worked out.