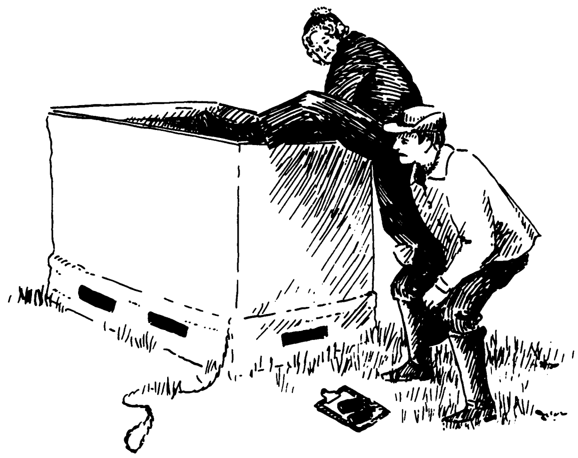

Amateur bird observers preparing to spend the day in a blind that they are not aware has been turned upside down by the wind. [From *My Double Life*]

matter-of-factly notes that she and Frederick "wanted to work together, but most administrators were afraid to hire a female biologist" (p. 190). She laughed at the people who gloomily predicted the curtailment of her career when she became pregnant. She was instrumental in shaping the conservation ethic of the 20th century, and she did it using the Hamerstrom "rule of thirds" she and her husband developed when they took their first "pay job" at the University of Michigan:

> Spend one-third of your time on the mostly worthless red tape required by the administration. Spend one-third of your time doing what is wanted of you, and what you want too. Spend one-third of your time doing exactly what you please.

Frances Hamerstrom, still traveling the world and observing wildlife well into her 80s, lived up to the rule admirably.

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Life from the Beginning

Early Life on Earth. STEFAN BENGTSON, Ed. Columbia University Press, New York, 1994. x, 630 pp., illus. $45 or £34. Nobel Symposium no. 84. Based on a symposium, Björkborn, Karlskoga, Sweden, May 1992.

I hope that in retirement I can look back to my pre-emeritus years as my "early life." This thick volume of 43 chapters does that on behalf of Earth, examining nearly 90 percent of life's history to date—through its birth, childhood, and finally maturation into the immense diversity of organisms that has inhabited Earth for the last half billion years. The book derives from a symposium attended by biochemists, molecular biologists, geologists, paleontologists and paleobotantists, invertebrate and developmental biologists, and geochemists, who completed their manuscripts for the volume in October 1993. The common thread is observations and ideas about what molecules, cells, fossils, and rocks tell us about the events and processes that led up to the late advent of complex animal life. As Bengtson explains in his preface, the purpose of the volume was not to hammer out a consensus but to share the various, and sometimes disparate, understandings and observations of scientists (mostly Western) actively researching questions about how life and ecosystems originated and evolved in their simpler forms.

The chapters are mostly short essays of 8 to 17 pages, organized around three themes: the chemistry and environments of life's origin; the geological and biological records of life's middle period (2.5 to 0.6 billion years ago); and the records of the explosion of complex animal life 600 to 530 million years ago. What is perhaps most interesting in this book is the cacophony of voices heard around these themes, particularly in the first and third sections. This is indicative of only nascent understanding of many problems and therefore fertile grounds for research and discovery. Indeed, as Vidal (p. 311) writes regarding life's middle period, "the situation . . . is that one single fossil find could substantially alter our understanding of the level of complexity attained by biotic evolution at a given point."

The same is even more true with respect to the chemistry of life's origin, which eons of biotic evolution and geological recycling have obscured. The 10 chapters on this topic reflect two fundamental problems. First, the organismal definition of life is simple, but the chemistry that underlies it is not. Life is membrane-enclosed organic factories capable of metabolism, of exchange of matter and energy with the external environment, and of reproduction, all controlled by a molecular blueprint (Lazcano). Below this, however, is an extraordinarily complex chemistry involving high-weight organic compounds whose functions and syntheses are incompletely understood. The origins of some of these compounds are discussed in chapters by Oró, Lazcano, Baltscheffsky and Baltscheffsky, Gedulin and Arrhenius, and Deamer and others. One of the few points of consensus is that RNA was an essential early molecule for governing prebiotic metabolism by memory and by enzymatic activity (although Wächterhäuser provides his interesting dissenting view). Another consensus is that life did not begin as heterotrophs in Darwin's "warm little pond" but as autotrophs in hot, chemically active microenvironments.

This consensus comes from molecular studies of phylogenetic relationships among living primitive organisms, which are autotrophic and thermophilic (Stetter). But herein lies the second fundamental problem. The oldest divisions of extant life—the Eubacteria and Archae-

"Subtidal stromatolites at Carbla Point, Hamelin Pool, Shark Bay, Western Australia, showing fish and attached macroscopic algae. Exposed portion of vertically oriented spirit level is about 50 cm high." [From Walter's chapter in *Early Life on Earth*] bacteria plus Eukaryota (or "Archaea" plus "Eukarya")—are not closely related. The universal phylogenetic tree of Woese (see C. R. Woese *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* **87**, 4576 [1990]), accepted by all discussants, exhibits huge genetic distances between the Eubacteria and Archaebacteria, much greater than within either group or within the Eukaryota. Thus, missing from laboratory study are organisms with primitive metabolisms, perhaps because of extinction or, in a more hopeful view, lack of detection. And, more critically, laboratory organisms are lacking from deepest time, before the branch between the Eubacteria and the Archaebacteria.

Galloping 3 billion years forward (and skipping over insightful summaries of middle ecosystems by Veizer, Hayes, Holland, Grotzinger, Golubic, and others), vexing problems like those surrounding life's origin recur with respect to animals' origins. The earliest putative animal fossils constitute the Ediacaran fauna of approximately 580 to 550 million years ago. Five authors deal with these fossils and contribute a nearly equal number of interpretations. In Runnegar's, Sun's, and Conway Morris's opinions, these unskeletalized fossils at the top of the Precambrian rock record include the precursors of such advanced phyla as arthropods and annelids; in Fedonkin's opinion, they represent animals at the lower, coelenterate grade of animal organization, exploring different styles of symmetry; and in Seilacher's opinion, these are not animals at all, but perhaps a pre-animal branch of the eukaryote tree assembled with large, multinucleate cells and quite distinct from the unpreserved bilaterians that burrowed through contemporaneous sediments. The puzzle here is that there just is not sufficient information in the preserved fossils and among extant animals to constrain interpretation, a problem not unlike those confronted with respect to life's origin. Interestingly, only Conway Morris makes use of current molecular phylogenies in attempting to interpret the Ediacarans (and later extinct Cambrian animals). But he does not speculate on the possibility that Seilacher's "quilted" organisms might represent early, and quickly extinct, experiments at the blastular grade of animal evolution, prior to the evolutionary acquisition of the developmental machinery for gastrulation.

I have focused on just two biological issues debated by the many contributors. There is much more to be gained from this volume, including thumbnail summaries of the exterior, geological parts of early ecosystems by Chang, Lowe, Towe, Knoll, and the mentioned authors of the Proterozoic (middle) chapters; of the early fossil record by Schopf, Walter, and Hofmann; of molecular phylogenies by Sogin and Christen; and of the lessons learned from living organisms by Pierson, Valentine, and Raff. I have not named all.

"The pseudofossil Eophyton in Lower Cambrian sandstones commonly shows pairs or triplets of parallel drag marks. In this slab from the Mickwitzia Sandstone of Lugnås (Riksmuseet, Stockholm) one couplet even made a McDonald's sign as the oscillating storm wave reversed. The common and widespread occurrence of Eophyton suggests that self-stabilized sand skeletons were much more abundant than their exceptional preservation as body fossils would suggest." [From Seilacher's chapter in *Early Life on Earth*]

This 630-page book follows on Schopf and Klein's even more massive *The Proterozoic Biosphere* (Cambridge University Press, 1992) and, before, Schopf's *Earth's Earliest Biosphere* (Princeton University Press, 1983). Those two volumes were group efforts that attempted to arrive at some minimum of consensus. *Early Life on Earth* contains more individual statements; its authorship does overlap with that of the Schopf volumes but includes more contributions by molecular biochemists and microbial and invertebrate biologists. The 82 pages of references collected near the end of the new volume include 40 percent postdating *The Proterozoic Biosphere*. This wealth of knowledge is made accessible, though, by Bengtson's superb 32-page subject index. My only wish is that more non-Western scientists had been included among the contributors or at least had their works cited.

Early Life on Earth shows clearly that the science of deep time is fast-moving and that the events involved are far more disparate, complex, and lost to view than those of any pre-retirement life. The volume is an essential work for all scientists attempting to keep up with any aspect of this field or to teach it to their students. It is also a superb volume for anyone who wishes to analyze what scientists know and do not know—or even don't ask—at the frontiers of scientific knowledge.

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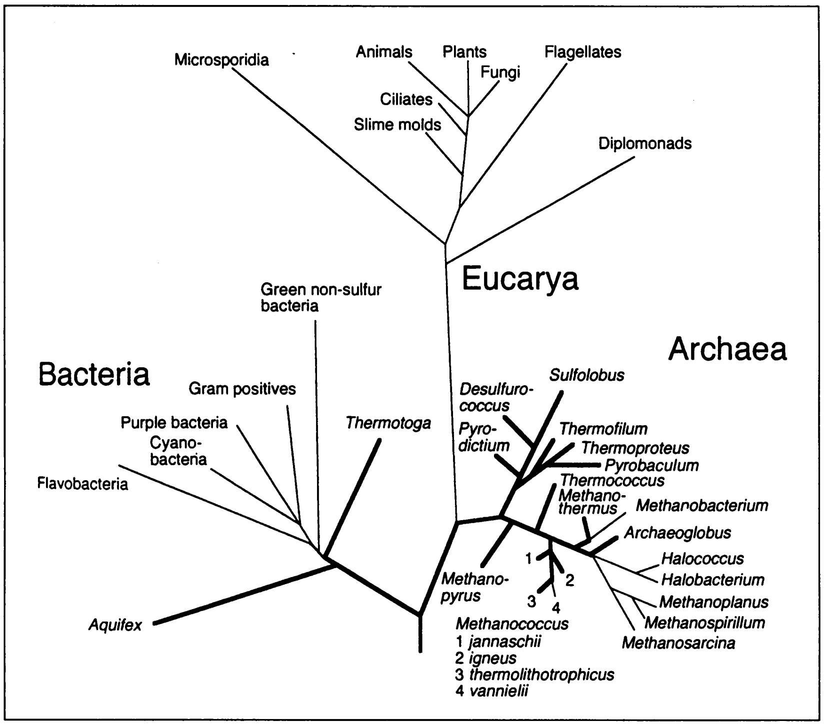

The "universal tree of life," showing evolutionary relationships among eubacteria, archaebacteria, and eukaryotes, based on the similarities of their ribosomal RNA. In this adaptation of the tree the heavy lines represent hyperthermophiles. [From Stetter's chapter in *Early Life on Earth*]