looking concepts that stress the contribution of structural features to the capacities of biochemical systems. The tendency of philosophers to focus on the etiological view of function may in part reflect their concentration on evolutionary issues to the exclusion of molecular biosciences.

As a collection, the book suggests answers to some meta-questions about the role of teleology in biology. The consensus around the etiological understanding of functional ascriptions is a recognition of an important biological concept that is distinctively teleological. The life sciences also depend on forward-looking concepts of function. But the teleological character of this type of functional ascription is not so clear, as suggested by the alternate forms of forward-looking accounts. The papers on design, and Martin Rudwick's discussion of inferences of function from fossil structure, also outline some conceptual and methodological limitations on teleological explanation. Because teleological concepts are so central to biology, vagueness in these ideas represents an important philosophical gap. *Nature's Purposes* will bring readers up to date with attempts to fill that gap. The book might also interest those curious about what philosophers of biology actually do. The philosophical contributions exemplify the application of contemporary philosophical methods and the resulting incremental advances in conceptual clarity—not unlike how progress is made in science.

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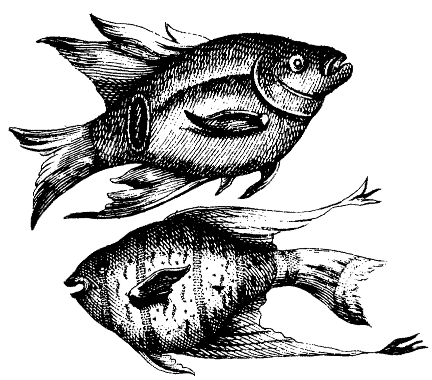


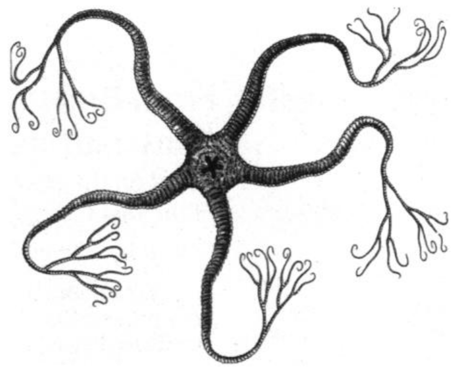
EXTREMES OF BIODIVERSITY

Extremophiles: Microbial Life in Extreme Environments. Koki Horikoshi and William D. Grant, eds. Wiley-Liss, New York, 1998. 322 pp., illus. $119.95 (ISBN 0-471-02618-2 cloth).

My mentor, C. E. ZoBell, and I first started working on microorganisms living in extreme environments in 1950, when the only accepted extremophiles were thermophiles and halophiles. Microbiologists did not readily accept the existence of barophiles, which we isolated during the Danish Galathea Deep Sea Expedition, until approximately 20 years later, when Schwarz et al. (1976) demonstrated that barophiles exist in the Aleutian Trench, confirming our results. When I first discovered true psychrophiles, it took 2 years to get the material into press because journal reviewers would not believe the findings. Now, things have changed so dramatically that the isolation of extremophiles is readily accepted; interest in these organisms has developed since the discovery of hydrothermal rifts by Jack Corliss, of Oregon State University. Interest in extremophiles has also been stimulated by new findings that point to the possibility of life on Mars and by the possible use of extremophiles in biotechnology. But although research on these organisms has increased dramatically, it still lags behind most areas of microbiology. With this concern in mind, *Extremophiles: Microbial Life in Extreme Environments* assembles what information has been obtained, bringing the reader up to date on the most advanced data.

The term "extreme environment" describes habitats that are not extreme to the organisms that grow and multiply in these niches but are extreme in the minds of the humans and for the general run of microorganisms (e.g., *Escherichia coli*) that are used in microbiological research. "Normal" habitats, according to Lee D. Mermelstein and J. Gregory Zeikus (chapter 10) are at 35 °C, neutral pH, aerobic atmosphere, and 1.5% salinity. However, during the evolution of Earth, many different extreme environments evolved with the accompanying microorganisms. Before the present-day environmental conditions that we consider the norm, the earth underwent tremendous changes, starting from an extremely hot, gaseous environment; hence, environmental extremes were probably the norm for much of Earth's existence. Many different extreme environments were created that still exist today, along with the microflora that are adapted to these environments. As Mermelstein and Zeikus suggest, such microflora may have only recently gained the ability to live under extreme conditions. These organisms are termed "extremophiles"—a term that, the editors note, is a useful catchword. MacElroy (1974) suggests that extremophiles "are the result of an accumulation of an immense number of mutations, or that primitive organisms were freely adaptable to a variety of environments." Hence, many extremophiles (e.g., halo–alkaliphiles, barophiles–psychrophiles, and thermophilic acidophiles) are faced with more than one environmental extreme.

Because "extremophiles" is a useful accepted catchword, certain terms



employed in the microbiology literature should be retained because they have also been accepted and used in the past literature. (On the other hand, the least useful terms in the field of aquatic science are "picoplankton" and "nanoplankton" [or "nannoplankton"], mainly because we do not study 10^{-9} or 10^{-12} of a plankton.) Microbiologists have used the term "psychrophile" instead of "cryophile." "Psychrotroph" (psychrotolerant, see chapter 2) is also not a correct term for an organism that can live in cold environments, but it has been in use, especially by food and environmental microbiologists, since 1960 (Eddy 1960) and has even been added into book titles. Likewise, in chapter 3, A. Aristides Yayanos uses the term "piezophile" instead of "barophile" for an organism that lives in high-pressure environments, even though the latter term has been used for 50 years (ZoBell and Johnson 1949). As far as I can determine, Yayanos is the only one who employs the term, and both "psychrotroph" and "barophile" should be retained because they are useful and accepted terms that are common in the literature.

Four books have already been published on organisms living in extreme environments, but this one is a welcome addition, mainly because it includes the latest data gathered on these microorganisms, especially on their biochemistry, physiology, and biotechnology applications. In addition, the various chapters in *Extremophiles* are well referenced and written by well-known researchers.

Chapter 1, by Karl O. Stetter, deals with hyperthermophiles, not thermophiles. Hyperthermophiles grow fastest between 80 and 110 °C and are found in water-containing volcanic areas. Stetter gives an excellent presentation of strategies for their isolation and their biochemistry, physiology, and phylogeny. As Stetter shows, hyperthermophiles can be extremely acidophilic, moderately acidophilic, or neutrophilic. Likewise, they can be chemolithoautotrophic or heterotrophic. What is known about the biochemical basis of heat stability as well as biotechnological applications of hyperthermophiles is well presented.

The main thrust of chapter 2 is the physiology and molecular biology of psychrophiles, although psychrotolerant (psychrotrophs) are also discussed to a limited degree. N. J. Russell and Tetsuo Hamamoto offer an excellent, up-to-date review on the adaptation of lipid composition (fatty acid changes, biosynthetic mechanisms, and membrane permeability), protein stability and enzyme activity (including protein structure, ribosomal stability, and protein turnover), and the isolation of the desaturation gene. The biotechnological significance of psychrophiles is well presented. With time, more research will result in a more complete picture of the ecology, physiology, molecular biology, and biotechnology of psychrophiles. Also, with the increased interest in extraterrestrial life, psychrophiles will attract more attention. As for the microbiology of polar environments, the Russian literature needs to be consulted.

In chapter 3, Yayanos presents all aspects of life under hydrostatic pressure (i.e., in the deep sea). The latest developments in methodology (including instrumentation), growth characteristics of barophiles (which are also psychrophilic), mechanisms of adaptation to hydrostatic pressure (membrane structure and function, chromosome replication and cell division, transcription, translation, and DNA structure) will permit the reader to grasp the entire subject matter readily. In addition, Yayanos includes a useful theoretical discussion of the physical and chemical aspects of hydrostatic pressure.

W. D. Grant, R. T. Gemmell, and T. J. McGenity (chapter 4) provide an excellent review of the formation of hypersaline (both thalassohaline and athalassohaline) environments, along with a table of species of halophiles, their habitat, their optimum salt environment, and their range of salt tolerance. Osmoregulation is covered, as is the biotechnological potential of halophiles.

In chapter 5, Paul R. Norris and D. Barrie Johnson divide the acidophilic organisms into groups based on their temperature ranges for growth (i.e., mesophilic, moderately thermophilic, and thermophilic). The mesophilic acidophilic groups are further divided into eukaryotic acidophiles; chemolithotrophic, mesophilic acidophiles; mixotrophic and heterotrophic mesophilic acidophiles; and moderately thermophilic acidophiles. Again, the diversity of the extremophiles is readily apparent.

Koki Horikoshi (chapter 6) defines alkaliphiles as bacteria that grow optimally or well above pH 9 but cannot grow or grow only slowly at pH 6.5. The author addresses the isolation, physiology (internal pH, Na^+ ion and membrane transport), cell wall composition, and genetic analysis of alkaliphiles, but he gives most attention to the production and industrial use of alkaline enzymes produced by alkaliphiles. Chapter 7 also addresses the alkaliphiles, in this case their bioenergetics. The authors (D. Mack Ivey et al.) present an excellent, up-to-date review of the pH homeostasis problem, of Na^+-coupled bioenergetics as it relates to transport mechanisms and motility, and of oxidative phosphorylation of alkaliphiles.

In chapter 8, Shuisong Ni and David R. Boone cover the adaptions of methanogenic archaea, organisms that can grow in an environment in which the redox potential is less than –300 mV. These organisms can grow at temperatures of 5–110 °C and salinities from freshwater to saturated brines. Again, their biodiversity is well illustrated, as is the need for more than one environmental extreme for their growth. Thus, the methanogenic archaea include hyperthermophiles, halophiles, psychrophiles, and alkaliphiles. Concise but adequate presentations of their habitats and physiologies are given, with the greatest emphasis on methane formation.

Chapter 9, by C. White and G. M. Gadd, addresses anaerobic and metal-resistant microorganisms. The chapter includes short discussions of dissimilatory metal reduction, nondissimilatory metal reduction, metalloids, and sulfate-reducing bacteria in the bioremediation of toxic metal pollution. These metal-contaminated environments are, thus, man-made extreme environments in which certain microorganisms survive and reproduce by genetic or physiological adaptation. Detoxification occurs mainly by reduction of metals and metalloid elements.

Mermelstein and Zeikus (chapter 10) concentrate on the metabolic and physiological characteristics of anaerobic nonmethanogenic microorganisms (primarily chemoorganotrophs) that thrive at high temperature; the species diversity of such organisms is higher than that of their aerobic counterparts—possibly, according to the authors, because of the low solubility of oxygen in aqueous solution at high temperatures. Also included in this chapter is further discussion of syntrophs (syntrophy is a species interaction in which metabolic capabilities are shared to permit both to survive), acidophiles, and alkaliphiles.

Finally, in chapter 11, Rikizo Aono and Akira Inoue discuss microorganisms' tolerance of organic solvents. This man-made extreme environment is created by pollution with petroleum or synthetic solvents (e.g., toluene). (Petroleum is a natural product, and microorganisms have been in contact with it ever since petroleum deposits were laid down.) Mutations of *E. coli* can make the organism more tolerant to organic solvents. Structural membrane changes of *E. coli* due to the presence of organic solvents are also presented, as are applications of these solvent-tolerant microorganisms to bioremediation.

All of the chapters in this volume are written in a concise manner and include sufficient references to allow interested readers to delve more deeply into any of the extremophiles. Extremophiles represent a diverse range of microorganisms and physiological types, and a comparison between their physiological and ecological properties is readily possible. Because these organisms have unique physiologies, ecologies, and biotechnological ramifications, I strongly recommend this book for those working in the ecology, biotechnology, biochemistry, and physiology of microorganisms. With this volume, the editors have certainly accomplished their aim—that is, to provide a detailed and comprehensive overview of current knowledge of the different groups of extremophiles and of their possible use in biotechnology applications.

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