BOOKS: ECOLOGY

Living at Extremes

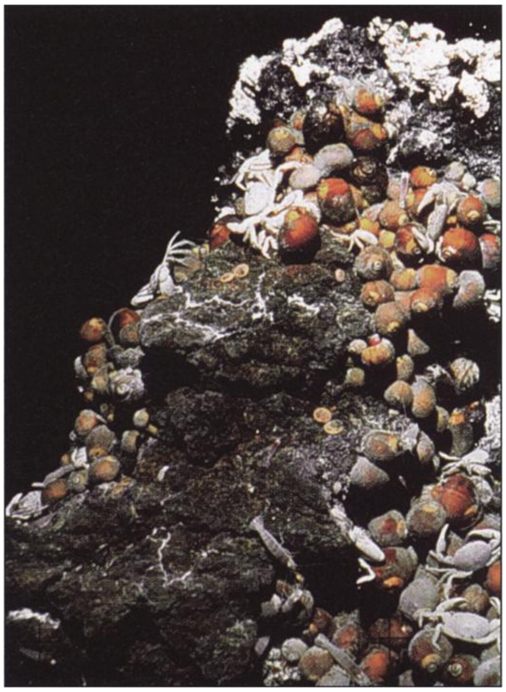
Kathleen A. Campbell

Unexpectedly teeming with life, deep-sea hydrothermal vents were first detected near the Galápagos Islands in 1977. They have since been found wherever oceanic plates are torn asunder and the heat of rising magma drives seawater circulation. Scientists have marveled at the bizarre extremes to which vent life has adapted and have launched international research efforts to monitor these remote habitats. Indeed, deep-sea biologist and former pilot of the submersible *Alvin* Cindy Lee Van Dover compares the study of hydrothermal vent environments to discovering life on another planet. In *The Ecology of Deep-Sea Hydrothermal Vents*, the first textbook on the topic, she explores biological, chemical, and geological aspects of a luxuriant ecosystem based on geochemical energy rather than sunlight.

The Ecology of Deep-Sea Hydrothermal Vents
by Cindy Lee Van Dover
Princeton University Press, Princeton, NJ, 2000. 444 pp. $85, £53.50. ISBN 0-691-05780-X. Paper, $39.50, £24.95. ISBN 0-691-04929-7.

The book offers scientists and nonspecialists a foray into a growing yet still young field of scientific inquiry. It provides a rather prosaic but valuable compilation of recent advances in understanding vent ecology, with a review of the major processes and products of a system situated at a dynamic planetary interface. Van Dover's up-to-date account covers a spectrum of topics from volcanic eruptions to hot springs, symbioses, whale skeletons as stepping-stones for vent faunas, and ideas about the origin of life. Her thoughtful synthesis of the primary literature is enhanced by an extensive selection of graphs, figures, and photographs. In flashes scattered throughout the text, Van Dover also presents vignettes about the startling and fascinating ways organisms work, especially in all the deep, dark cracks and crevices we have searched.

Van Dover's account of how organisms make a living at hydrothermal vents reads like science fiction on alien life or a *Guinness Book of World Records*. For example, the vent tubeworm *Riftia pachyptila* flourishes in acidic settings toxic to most normal marine organisms. The tubeworm lacks a gut and relies on chemosynthesis for sustenance. The bacterial symbionts require sources of inorganic carbon (in the form of CO_2), sulfide, oxygen, and nitrogen to release geochemical energy and drive production of organic carbon via the Calvin-Benson cycle (the same biochemical pathway plants use to photosynthesize with the energy from sunlight). The worms must juggle both reduced and oxidized fluids. Poisonous materials must be transported through up to 2 m of animal tissue to reach symbionts deeply embedded within the host. And demands for raw materials are high: symbionts use oxygen for sulfide oxidation at twice the rate of the host's tissues. Sulfide is bound to animal hemoglobin to keep it from spontaneously oxidizing or blocking aerobic respiration during transport. Half the CO_2 demanded by the symbionts comes from the host's respiration, with the remainder sequestered from ambient vent fluids. To facilitate CO_2 flux from outside to inside, tubeworm blood is alkaline and tubeworms can maintain partial pressures of dissolved CO_2 greater than 60 mM, values approaching the CO_2 levels in carbonated beverages. The steep gradient of inorganic carbon influx is twice that required for *Riftia*'s maintenance, and it can produce growth of more than 85 cm in the worm's first year. These whopping growth rates exceed those known from any other aquatic species. Hence, *Riftia pachyptila* is supremely successful in colonizing nascent, and ultimately ephemeral, vent fields.



Lots of life. Hairy gastropods, alvinocarid shrimp, and bythograeid crabs at vents of the Mariana back-arc spreading center.

Sustained by free-living and symbiotic chemoautotrophic bacteria, the high rates of biological production at deep-sea hydrothermal vents are akin to those of estuaries and salt marshes. In fluids from warm vents, microbial biomass is four orders of magnitude greater than typical deep-sea microbial populations and four times that of surface waters. After seafloor volcanic eruptions, scientists have witnessed sustained blooms of suspended microbes. Indeed, a 5-cm-thick blanket of white bacterial floc covered one large area like freshly fallen snow, and "snow-blowers" of floc were seen pouring out of subterranean cracks. Yet despite the great abundance of microbes at the base of the vent chemosynthetic food chain, at vent fields like Snake Pit on the Mid-Atlantic Ridge, there is basically only one type of free-living bacterium present. In comparison, a single gram of forest soil can contain 4000 bacterial phylotypes. The difference highlights the pattern of low diversity but high abundance that typifies extreme environments with steep gradients in their physical and chemical parameters.

How tube worms and other unusual vent organisms locate and colonize undersea hot springs remains a mystery, but enticing hints are already evident. Chemical cues may signal larvae to settle in active vent fields, and their transport along ridge axes may be accomplished by riding vortices of hydrothermal plumes up to 150 km across. Van Dover has studied vent taxa, like the highly motile shrimp *Rimicaris exoculata* (which swarm over black-smoker chimneys in pitch darkness on the Mid-Atlantic Ridge), that can "see" the infrared glow of 350°C vents with their specially adapted photoreceptors.

The origin and evolution of organisms from hydrothermal vents and other extreme environments (such as cold hydrocarbon seeps and whale skeletons, which slowly weep lipids) are actively being studied through biogeographic analysis of cognate taxa and from the fossil record of equivalent ancient settings. Fossils preserved in vent paleoenvironments span a history of at least 3.2 billion years. Early vent settings may have

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served as crucibles for the origin of life itself. Perhaps the deepest root in the evolutionary tree of life was an ancestral, thermophilic, prokaryotic member of the Archaea that derived from precursor, monomolecular organic layers bound to positively charged mineral surfaces of pyrite (FeS_2) in contact with hot vent waters. This pyrite theory, postulated by Wächterhäuser and reviewed by Van Dover, provides an energy-yielding, cationic surface system that can combine with organic compounds to get life off and running. It also accounts for the importance of sulfide in the biochemical pathways of diverse bacteria.

Van Dover has nearly two decades of experience probing deep-sea vents and has made more than 100 dives to depths below 2000 m. Her comprehensive account of these extraordinary ecosystems will prepare readers for the future surprises that await those who delve into the recesses of Earth and space seeking signatures of life in the most unexpected places.

BOOKS: VIROLOGY

From Infectious Filtrate

Hans-Jörg Rheinberger

Few objects have had such a long-lasting and multifaceted impact on the history of 20th-century life sciences as tobacco mosaic virus (TMV). In 1898, Martinus Beijerinck from the Polytechnical Institute of Delft, Holland, published a remarkable paper entitled "Concerning a *contagium vivum fluidum* as cause of the spot disease of tobacco leaves." On the basis of his innovative experiments, Beijerinck judged the causative agent to be nonparticulate, thus a contagious live fluid. This remarkable work opened a new field of research and began the scientific career of an infective entity distinctly different from bacteria. Early viral phenomenology became based on three characteristics that contrasted with bacteria. Viral agents proved to be filterable, to be invisible under the light microscope, and to require a host for multiplication.

Prepared to commemorate the centennial of virology, *Tobacco Mosaic Virus* provides a collection of classic research papers on TMV accompanied by brief commentaries on their significance. The editors, Karen-Beth Scholthof, John Shaw, and Milton Zaitlin, have assembled a distinctive contribution to the history of virology. They have not presented the history of a discipline, but their concentration on one particular object of changing epistemic interest reveals surprising insights into the trajectories and vagaries of scientific research.

On examination of the chronology of the papers collected in this volume, separate periods of TMV research can be distinguished, each with fairly different scope and orientation. Until the beginning of the 1930s, TMV remained the agent of a particular plant disease; it was mainly of interest, for its phytopathological effects, at agricultural research stations. The year 1935, when Wendell Stanley (at the Rockefeller Institute in Princeton) published "Isolation of a crystalline protein possessing the properties of tobacco-mosaic virus," marked a turning point. TMV was redefined as a huge macromolecule that was crystallizable and susceptible to physico-chemical characterization through the use of the techniques of a rising molecular biology (including ultracentrifugation, electrophoresis, x-ray crystallography, and electron microscopy).

Tobacco Mosaic Virus
One Hundred Years of Contributions to Virology
Karen-Beth G. Scholthof, John G. Shaw, and Milton Zaitlin, Eds.

American Phytopathological Society Press, St. Paul, MN, 1999. 264 pp. $49. ISBN 0-89054-236-8.

In the few years between 1935 and 1940, the composition, size, and structure of what had turned from a "fluid" into a macromolecular particle was assessed. Frederick Bawden (at the Rothamsted Experimental Station) and William Pirie (at Cambridge) showed that Stanley's "protein" contained a small but significant amount of ribonucleic acid. J. D. Bernal and I. Fankuchen (also at Cambridge) took a series of x-ray pictures revealing the contours of an internal structure to the particle. Gustav Kausche, Edgar Pfankuch, and Helmut Ruska (at Berlin) presented the first electron micrographs of a TMV preparation. Within a short time, TMV advanced from a fairly restricted instance of plant disease to the general model of a macromolecule located at the boundary between life and inert matter. In addition, it became a privileged test object for sophisticated new instrumentation. There were also indications that the particles were able to undergo lasting changes comparable to mutations. Thus, they might be taken as a model of the units of heredity found in higher organisms, that is, the genes. Around 1940, however, TMV research got stuck. Although the virus had come to be seen as a nucleoprotein, its nucleic acid part remained marginal in the hands and minds of those who worked with it.

It was not until 1955 that TMV resurfaced as a hot spot in the golden decade of molecular biology. In the mid-1950s, Rosalind Franklin at Birkbeck College in London developed the x-ray crystallography of TMV to the extent that she could determine the location of the RNA within the particle. Researchers at the Max Planck Institutes of Biology and Virus Research in Tübingen, among them Gerhard Schramm, Alfred Gierer, and Karl-Wolfgang Mundry, showed that TMV's ribonucleic acid is the infective part responsible for replication. Heinz Fraenkel-Conrat and Robley Williams (from Stanley's lab in Berkeley) made TMV into a model of molecular self-assembly by demonstrating that it could be taken apart and reconstituted to a functional whole in the test tube. For a while, Heinz-Günter Wittmann in Tübingen and Fraenkel-Conrat in Berkeley had high hopes of making TMV into a tool with which to decipher the genetic code. Separately, they set out to systematically characterize mutations in the nucleic acid of the particle with the corresponding amino acid replacements in its coat protein, whose amino acid sequence had become available in 1960. Their hopes ended in 1961 when Marshall Nirenberg and Heinrich Matthaei identified the first code word through an elegant assay based on a completely different, in vitro prokaryotic protein synthesis system. Again TMV research receded into a lag phase.

Phages, not TMV, became the tool of choice for dissecting the machinery of replication and gene expression in bacteria. It was not until the period between 1975 and 1985 that the genes of TMV, the molecular dynamics of the particle's assembly, its RNA-protein interaction, the details of its RNA as a messenger, and its nucleotide sequence were characterized. This renewed burst of activity had to await the era of reverse transcription and the availability of complementary DNA, the most important of the technical developments that allowed recombinant DNA work with RNA viruses.

TMV has experienced highs and lows as a model organism through the history of molecular biology. In the current era of genetic engineering, the field appears to be returning to where it came from: agriculture and phytopathology. (It is perhaps not by chance that the book was issued by the American Phytopathological Society.) The most recent papers in *Tobacco Mosaic Virus* show that transgenic plants, which carry parts of the viral genome and so are rendered resistant to infection, have become the targets of an intensified collaboration between academic researchers and agribusiness. The anthology thus conveys a vivid impression of the changing status of and interest in TMV as a research object, from the late 19th century to the present.

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