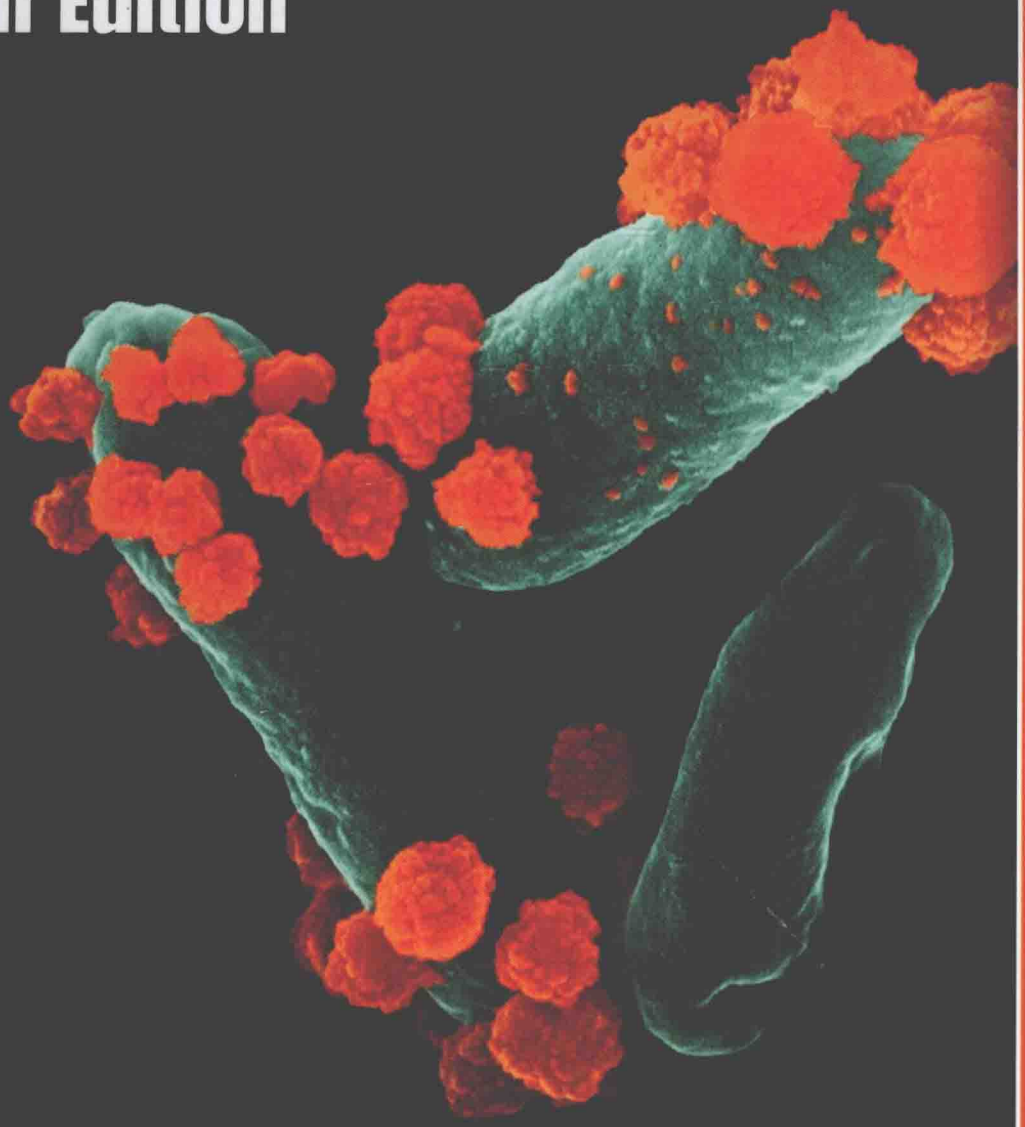
GEOMICROBIOLOGY

Fifth Edition



Henry Lutz Ehrlich
Dianne K. Newman

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Dedication

We dedicate this edition to Terry Beveridge:
dear friend, inspiring mentor, and geomicrobiologist par excellence.

Preface

Several important advances have occurred in the field of geomicrobiology since the last edition of this book, including a number of observations made possible by the introduction of genetic and molecular biological techniques that make revision and updating of the previous edition of *Geomicrobiology* timely.

Henry Lutz Ehrlich, author of the earlier four editions, has been joined by Dianne K. Newman for this fifth edition to lend her expertise in the area of molecular geomicrobiology. This has resulted in a new chapter (Chapter 8) in this edition, which is entitled "Molecular Methods in Geomicrobiology." The techniques described in this chapter illuminate the processes by which bacteria catalyze important geomicrobial reactions. For example, we are beginning to understand the molecular details whereby some gram-negative bacteria export electrons to mineral oxides with which they are in physical contact in their respiratory metabolism. Such electron transfer is enabled by respiratory enzymes in the outer membrane and periplasm of such organisms. Molecular techniques have also demonstrated that at least one gram-negative bacterium can import electrons donated by an electron donor, ferrous iron, in contact with the outer surface of the outer membrane of this organism. In some cases, electron shuttles have been shown to facilitate electron transfer. Further important advances in this area are anticipated. Collectively, these mechanistic observations make clear that microbes play a much more direct role in the transformation of oxidizable and reducible minerals than had been previously believed by many researchers in this field. We anticipate that as mechanistic molecular approaches are increasingly applied to diverse problems in geomicrobiology, exciting discoveries will be made about how life sustains itself even in seemingly inhospitable environments such as the deep subsurface.

Just as in the case of the previous editions of *Geomicrobiology*, the chief aim of the fifth edition is to serve as an introduction to the subject and an up-to-date reference. To continue to provide a broad perspective of the development of the field, discussion of the older literature that appeared in earlier editions of this book has been retained. Changes in understanding and viewpoints are pointed out where necessary. Although we do not claim that the reference citations at the end of each chapter are exhaustive, cross-referencing should reveal other pertinent literature. As before, a glossary of terms that may be unfamiliar to some readers has been added. All chapters have been updated where necessary by introducing the findings of recent research.

We are continuing to retain some of the drawings prepared by Stephen Chiang for the first edition. Other illustrations from the fourth edition have been retained in the current edition, with appropriate acknowledgments to their source when not originating from us, and some new illustrations have been added. We are very grateful to Andreas Kappler for allowing us to use the photomicrograph of *Chlorobium ferrooxidans* for the book cover illustration of this edition.

We owe special thanks to Martin Polz, Victoria Orphan, and Alex Sessions for stimulating discussions that shaped the content of Chapter 8; and we gratefully acknowledge Alexandre Poulain for his help in preparing the figures for this chapter. We also owe sincere thanks to Jon Price for his assistance in obtaining the photograph of the sample of basalt from the rock collection at Rensselaer Polytechnic Institute.

We appreciate the encouragement and editorial assistance of Judith Spiegel, Barbara Norwitz, and Patricia Roberson of Taylor & Francis Group LLC.

Responsibility for the presentation and interpretation of the subject matter in this edition rests entirely with the authors.

Henry Lutz Ehrlich
Dianne K. Newman

Authors

Dr. Henry Lutz Ehrlich earned a BS degree from Harvard College (major: biochemical sciences) in 1948, an MS degree in 1949 (major: agricultural bacteriology), and a PhD degree in 1951 (major: agricultural bacteriology; minor: biochemistry); both of the latter degrees from the University of Wisconsin, Madison. He joined the faculty of the Biology Department of Rensselaer Polytechnic Institute as an assistant professor in the fall of 1951, attaining the rank of full professor in 1964. Dr. Ehrlich became professor emeritus in 1994 but continues to be active in the department in pursuit of some scholarly work. He began teaching a course in geomicrobiology in the spring semester of 1966.

Dr. Ehrlich is a fellow of the American Academy of Microbiology, American Association for the Advancement of Science, the International Union of Pure and Applied Chemistry, and the International Symposia on Environmental Biogeochemistry. He is a member of the Interdisciplinary Committee of the World Cultural Council (Consejo Cultural Mundial) and an honoree of the 11th International Symposium on Water/Rock held in 1994 in Saratoga Springs, New York. Dr. Ehrlich has been a consultant at various times for a number of different companies. He was editor-in-chief of *Geomicrobiology Journal* (1983–1995) and has since continued as co-editor-in-chief. He is a member of the editorial boards of *Applied and Environmental Microbiology* and *Applied Microbiology and Biotechnology*. He is also emeritus member of American Association for the Advancement of Science, American Institute of Biological Sciences, American Society for Microbiology, and the Society of Industrial Microbiology.

Dr. Ehrlich's research interests have resided in bacterial oxidation of Mn(II) and reduction of Mn(IV) associated with marine ferromanganese concretions, marine hydrothermal vent communities, and some freshwater environments; bacterial oxidation of arsenic(III); bacterial reduction of Cr(VI); bacterial interaction with bauxite; and bioleaching of ores including metal sulfides, bauxite, and others. He is author or coauthor of more than 100 articles dealing with various topics in geomicrobiology.

Dr. Dianne K. Newman earned a BA degree from Stanford University (major: German studies) in 1993, and a PhD degree in 1997 (major: environmental engineering with an emphasis on microbiology) from the Massachusetts Institute of Technology (MIT). She spent two years as an exchange scholar at Princeton University in the Geosciences department from 1995 to 1997. Dr. Newman was a postdoctoral fellow in the Department of Microbiology and Molecular Genetics at Harvard Medical School from 1998 to 2000. She joined the faculty of the California Institute of Technology in 2000, where she was jointly appointed in the divisions of Geological and Planetary Sciences and Biology. In 2007, she returned to MIT, where she is currently the John and Dorothy Wilson Professor of Biology and Geobiology, with a joint appointment in the departments of Biology and Earth, Atmospheric and Planetary Sciences. Dr. Newman is also an Investigator of the Howard Hughes Medical Institute.

Dr. Newman's honors include being a Clare Boothe Luce assistant professor, an Office of Naval Research young investigator, a David and Lucille Packard Fellow in science and engineering, an Investigator of the Howard Hughes Medical Institute, and a fellow of the American Academy of Microbiology. She was the 2008 recipient of the Eli Lily and Company Research Award from the American Society for Microbiology. She is an editor of the *Geobiology Journal*, and is on the editorial board of the *Annual Review of Earth and Planetary Science*. She is on the scientific advisory board of Mascoma Corporation, and is a member of the American Society of Microbiology and the American Geophysical Union.

Dr. Newman's laboratory seeks to gain insights into the evolution of metabolism as recorded in ancient rocks by studying how modern bacteria catalyze geochemically significant reactions. Specifically, she focuses on putatively ancient forms of photosynthesis and respiration, with a specific interest in the cellular mechanisms that enable these complex processes to work.

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