

Introduction



I took a drop or so of this water and looked at it through the microscope; and I discovered a great many animalcules that were red, and others that were green, whereof the biggest looked no bigger through the microscope than coarse sand doth to the naked eye, and others smaller and smaller, each after its kind. These animalcules were for the most part round, and the green ones were somewhat yellowish in the middle of their bodies. Their bodies seemed to be composed of particles that presented an oval figure; and therewithal they had short thin instruments which stuck out a little way from the round contour, and wherewithal they performed the motions of rolling round and going forward; and when they took a rest and fixed themselves to the glass, they looked like a pear with a short stalk.

So wrote the Dutch draper and self-taught microscopist Antony van Leeuwenhoek on 9 February 1702 in a letter to his countryman Hendrik van Bleswyk. Along with an equally remarkable figure, the English polymath Robert Hooke, it was Leeuwenhoek who founded the science of microbiology three centuries ago by constructing and using elementary microscopes to observe otherwise invisible forms of life (see chapter 43). All of today's microbiologists (who, ironically, spend less

time observing their subjects directly than studying them in other ways) are indebted to these diligent pioneers. Their work is all the more praiseworthy for being conducted nearly two centuries before Louis Pasteur, Robert Koch, Paul Ehrlich, and their fellow "microbe hunters" began to establish bacteriology as an experimental science closely linked with practical applications for human welfare.

Through the biochemical and serological techniques introduced by these luminaries, recently augmented by those of molecular genetics, our knowledge of what Leeuwenhoek called animalcules has deepened considerably. So too has awareness of our paradoxical relationship with the microbial world. We are conscious that microorganisms continually assail our tissues, those of other animals, and those of plants, and that they exhibit unparalleled versatility and adaptability in doing so. Yet we also recognize that animalcules have fashioned the biosphere and indeed much of the physical world, that they are crucial to the health of our planet, and that they provide many of the means by which we promote human health and environmental well-being.

Our grasp of these twin aspects of microbiology, though formidable, is far from complete—a most enticing factor for young people contemplating a career in science today. On one hand, we confront new, newly recognized, and resurgent pathogens, all posing intellectual and practical challenges. On the other hand, and perhaps even more astonishingly, research in recent years has demonstrated many hitherto unrecognized contributions of animalcules to the ever-renewing, ever-changing texture of nature.

The nitrogen cycle (almost the only aspect of nonmedical microbiology many of us encounter at school) is a prime example. Among its previously unsuspected contributors as nitrogen fixers are *Montastraea cavernosa* in Caribbean coral (7), *Bacillus marisflavi* in plant rhizospheres in the Beijing region of the People's Republic of China (4), and a methanogenic archaeon in deep-sea hydrothermal vents in the Pacific Ocean (8). Even more radically, discoveries such as the anammox reaction (in which bacteria oxidize ammonium anaerobically, using nitrite rather than oxygen as the electron acceptor, producing N_2 gas) have raised profound questions about the validity of the conventional model of the nitrogen cycle.

Meanwhile, advances elsewhere have revealed similar lacunae in our picture of other segments of the cat's cradle of processes that sustain the biosphere. Just two recent examples are the revelation of a fifth pathway of carbon fixation (1) and the realization that picoplankton, tiny unicellular plants, play major roles in mobilizing organic matter deep in the oceans (9).

Sometimes overlooked as an important component in the portfolio of microbiology is the degree to which its insights and practical skills assist other sciences and promote our understanding of the world in often surprising ways. Just over 50 years ago, Jan Kluyver and C. B. van Niel published their splendid book *The Microbe's Contribution to Biology* (6). This reviewed the many spin-offs from studies, largely on bacteria, that were enhancing both knowledge of other aspects of biology and the conceptual foundations of science. Topics ranged from work on phototrophic bacteria, which facilitated understanding of green plant photosynthesis, to emerging ideas about the unity, flexibility, and evolution of terrestrial life.

A 21st-century revision of Kluyver and van Niel would have a good deal more to say on all of these issues in the light of modern molecular genetics. It might, for example, cite the remarkable work of Roman Biek and others in using a fast-evolving organism (feline immunodeficiency virus) to discern the population structure and demographic history of its natural wildlife host, the cougar. As they point out (2), these findings could not have been obtained in any other way and were not apparent from host genetic data.

Another item for inclusion would be the extraordinary paper by Tom Dillehay and colleagues which indicates that when the first Americans came from Asia, they took a coastal route rather than traveling inland (3). The evidence was microbiological: the remains of nine species of marine algae recovered from hearths and other features at an archaeological site in Monte Verde in southern Chile.

Furthermore, there are the ways in which investigations on microbial cilia (shorter cousins of Leeuwenhoek's "short thin instruments" or flagellae) are contributing to our comprehension of another unexpected series of discoveries, in very recent years, on the roles of cilia in human development and disease. For example, patients with polycystic kidney

disease, one of the commonest genetic disorders, have cilia whose abnormalities are becoming better understood through research on the flagellae of the alga *Chlamydomonas*.

The present book is based on the "Animalcules" columns which I have been writing regularly since 1996 for *Microbe* (formerly *ASM News*), published by the American Society for Microbiology. I am grateful to Michael Goldberg for asking me to make these contributions and to both him and Patrick Lacey, the production manager of *Microbe*, for their support over the past decade. I also thank the many people who, in recent years, have suggested that the articles could be brought together in book form. Above all, I am grateful to my partner, Kath Adams, for help in manifold ways.

As an edited and orchestrated collection of pieces about animalcules, their activities, and their investigators, this book certainly does not purport to be comprehensive. Moreover, while I have resisted temptations to revise the entire text, or even to modify assertions that seem more questionable with the passage of time, I have added a significant amount of new material here and there in order to accommodate more recent developments. Just two pieces (those on Antony van Leeuwenhoek and Cecil Hoare) did not appear originally as articles in *Microbe*. One piece ("Pioneers of American Microbiology") was published in *ASM News*, though not in the "Animalcules" series.

Contributing to a recent special section of *Science*, James Tiedje and Timothy Donohue (10) pointed out that the incredible diversity of today's microbial world reflects the accumulated evolutionary response to diverse environments over the 3.5 billion years that microorganisms have inhabited Earth. Paul Falkowski and colleagues (5) added that the microbial world drives some of the largest-scale phenomena on the planet, from photosynthesis and nitrogen cycling to pandemics of infectious disease.

Animalcules contains no more than snapshots taken from this vast mosaic of microbial (and macrobial) activity. Experts are unlikely to learn anything on their own subject here, but I hope that they may find items of interest about happenings elsewhere in the jungle.

Bernard Dixon