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The Social Amoebae: The Biology of Cellular Slime Molds

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Source: BioScience, 60(2) : 156-157

Published By: American Institute of Biological Sciences

URL: https://doi.org/10.1525/bio.2010.60.2.11

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amphibian physiology, particularly with regard to water balance. The book is valuable to physiologists and to those amphibian biologists whose research focuses on water exchange, but I suspect that its usefulness to a wider audience is limited by its technical prose and restricted focus.

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GIVING THE AMOEBAE EQUAL TIME

The Social Amoebae: The Biology of Cellular Slime Molds. John Tyler Bonner. Princeton University Press, 2008. 156 pp., illus. $19.95 (ISBN 9780691139395 cloth).

In *The Social Amoebae*, John Tyler Bonner, professor emeritus of ecology and evolutionary biology at Princeton University, writes about his beloved slime molds—organisms he has cherished for more than 60 years. While we often hear that men are from Mars and women are from Venus, slime molds are truly from Earth, and after reading Bonner's book, one feels the need, as I did, to walk outside, pick up a handful of soil, and look for a slime mold—to study, to admire, and to gain down-to-earth knowledge and insight into the fundamental processes that make all life on Earth possible.

Bonner describes the stages and transformations that occur in the life cycles of the cellular slime molds. He explains how these molds have provided researchers with many opportunities to conduct meaningful studies, using simple equipment, that enabled us to understand general biological problems, including the differentiation of cells, functional redundancy, cell motility, cell signaling, self organization, and the development of multicellularity. The life cycle of a cellular slime mold begins when a spore germinates to form a single-celled amoeba that feeds on bacteria. As long as there is plenty of food, the amoebae divide and live as single-celled organisms. As the bacterial food source becomes depleted, however, the amoebae aggregate to form a multicellular slug in response to a chemical signal from a single group of cells or a single founder cell. By sensing light, thermal or gaseous gradients, the multicellular slug then migrates to find an appropriate location for fruiting so that the spores can be dispersed by animals living in the soil. Bonner shares with us that "When one arrives in the laboratory in the morning, the slugs in every culture dish will all be pointing towards the window." Upon finding a suitable location, the cells of the slug transform into stalk cells or spore cells as they form the fruiting body, or sorocarp. Information on cellular slime molds obtained from slowly publishing individual craftspeople using inexpensive equipment is currently being supplemented by information obtained by rapidly publishing, multinational consortia using expensive molecular techniques.

Realizing that the number of publications on cellular slime molds had risen from an average of 3.4 per year to an average of 224 per year over the course of his career, Bonner decided to write *The Social Amoebae* as an exercise to place the "factual bricks" created by the growing literature on the molecular biology of cellular slime molds into a coherent "mansion," so that the curious layperson could gain a complete picture of the biology of slime molds. In so doing, I believe he found that the new molecular facts had such a short half life and rapid turnover rate that he wrote *The Social Amoebae* so practicing cellular slime mold biologists would plan and analyze their work with a "more generalized biological point of view" to guarantee that "the lessons learned would last for some time."

The book is extremely well written. In fact, the rhetorical style reminds me of the funeral oration given by Mark Antony in *Julius Caesar.* In the introduction of *The Social Amoebae,* Bonner writes: "The molecular genetics of the developmental biology of *D. discoidium* (which was now simply called *Dictyostelium*, reflecting its newfound status as a model organism) became central. The most recent high point in this program has been the sequencing of its entire genome: now it is possible to find out how many genes we share with a slime mold. The result is that our insights and understanding of the development of *Dictyostelium* has vastly increased." Although Bonner acknowledges "that it is inconceivable to study the biology today of any organism without genetics and molecular biology," he warns us in the chapter titled "The Future" that "we are looking at finer and finer details at the risk of losing the big picture," and "it is increasingly obvious that knowing all the genes identified in an organism does not really tell us how the organism is constructed or how it develops. Again, it is a pile of bricks and the architect's plans are hidden from us."

Another motivation for writing *The Social Amoebae* came from Bonner's realization that research on the nonmolecular biological aspects of cellular slime molds had been overshadowed by the number of workers and publications in molecular developmental biology. In order to illuminate the aspects of cellular slime mold biology that have been overshadowed, Bonner gives "equal time to their evolution, their ecology, their behavior, both as single amoeba and as cell masses, and their development."

To me, "equal time" to general biology is a euphemism used by Bonner to remind biologists that there are many valid approaches to study the cellular slime molds besides the reductionist approach of doing molecular biology (or "omics") for its own sake, without extensive integration with the

doi:10.1525/bio.2010.60.2.11

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broad foundation of general knowledge of slime mold biology—and, moreover, that exclusively using such a reductionist approach may result in obtaining data that are devoid of biological information, or even worse, data that are misleading. For example, Bonner discusses the cellular slime mold family tree generated by Schaap and colleagues (2006) based on the sequence of two genes, SSU rDNA and α-tubulin. Schaap and colleagues separated 75 species of cellular slime molds into four major clades, none of which corresponds to the three traditional genera. According to this tree, the two whorled *Polysphondylium* species, *Polysphondylium violaceum* and *Polysphondylium palladium*, both of which initiate aggregation with a single "founder cell" instead of a group of cells, and both of which use the dipeptide glorin as opposed to cyclic AMP as an intercellular signaling agent, are not closely related to each other.

Bonner is skeptical of the conclusion that this suite of characters arose independently in the two species, and cautions us that the phylogenetic tree deduced from modern molecular research "is based on only two genes, and it will be important to examine their differences involving more genes." While the complete revision of dictyostelid taxonomy called for by Schaap and colleagues may be premature, molecular phylogenies on the basis of many and thoughtfully chosen genes may provide profound insights not only for cellular slime mold evolution but also for all of biology. For example, the evolution of the cAMP (cyclic adenosine monophosphate) signaling system can be elucidated by applying the molecular tools used by Alvarez-Curto and colleagues (2005) to study the cAMP receptors to the study of adenylate cyclases and phosphodiesterases. Bonner suggests that by using the genes that are involved in processes that characterize the unique biology of cellular slime molds in future phylogenies, one will not only obtain a more biologically meaningful phylogeny of cellular slime molds but also insight into the cAMP signaling system.

The book is neither fashionable nor trendy, but *The Social Amoebae* is an enlightening and enjoyable read for the layperson and professional who would like to share in the biological insight and knowledge gained by John Tyler Bonner as a result of his lifelong relationship with cellular slime molds. To summarize, I will conclude with a quote from Mark Antony's oration: "Here is the will…. He has left you all his walks, his private arbors and newplanted orchards—he has left them all to you." And to paraphrase Mark Antony, "Here was a biologist! When comes another?"

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AN ODD FISH

The Mermaid's Tale: Four Billion Years of Cooperation in the Making of Living Things. Kenneth M. Weiss and Anne V. Buchanan. Harvard University Press, 2009. 336 pp., illus. $35.00 (ISBN 9780674031937 cloth).

One of the great virtues of Darwin's *On the Origin of Species* is that it presents the case for evolution in a simple, clear, and logical way. Darwin tells us in the introduction what he intends to do, and he does it. He carefully builds up the case for the existence of inherited variations, explains why there is competition between individuals, and describes how the struggle for existence can lead to a slow accumulation of small, favorable modifications that we eventually see as adaptations. As he writes in his final chapter, "this whole volume is one long argument."

doi:10.1525/bio.2010.60.2.12

In the 150 years since *The Origin* was first published, Darwin's argument has been challenged, supplemented, and updated many times. The first major update was the outcome of the early 20th-century advent of Mendelian genetics, which provided a mechanism of heredity that was quite unknown to Darwin. Initially genetics muddied ideas about evolution, but in the 1920s and 1930s, mathematical reasoning was used to show how mutation and selection of genes in populations could explain the Darwinian evolution of phenotypic traits. Population genetics became the basis of the "Modern Synthesis"—the gene-centered view of evolution that solidified in the 1940s and dominated evolutionary thinking for the following half-century. Now, in the light of the discoveries of molecular biology, this version of Darwinism is being reexamined and reassessed. Knowing something about what goes on between genes and the phenotypic traits they influence means that developmental processes can take their rightful place in evolutionary thinking. But how should they be incorporated? What difference, if any, do they make to our basic ideas about evolution?

The Mermaid's Tale: Four Billion Years of Cooperation in the Making of Living Things is one of many recent books to offer a new take on evolution. Its authors, Kenneth Weiss and Anne Buchanan, are researchers in anthropology and biomedical genetics in the Department of Anthropology of Penn State University. According to its first sentence, "this book is a biography of life," but anyone expecting an historical account of life on Earth over the past four billion years will be disappointed. In their preface the authors explain that this biography is about a set of general principles that they

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