SECOND EDITION

Biochemistry and Physiology of Protozoa

Volume 4

Edited by

M. LEVANDOWSKY

S. H. HUTNER

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New York, New York

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Preface to the Second Edition

This inaugurates, some 15 years after its predecessor, a multivolume second edition of "Biochemistry and Physiology of Protozoa." In this sense, in retrospect the preceding volumes (three in all) constitute a first edition, but as the intervals between the new volumes will be measured in months and a year or two rather than decades, and the new volumes have been planned as a whole, "second edition" seems fitting, and emphasizes that protozoology has vastly expanded in recent years and, by most evidence, will continue expanding.

The causes of this expansion are easily detected. That the gulf separating prokaryotes and eukaryotes seems evolutionarily the widest among extant organisms is unchallenged. Kluyverian unity of biochemistry remains firmly established, but is perceived in a perspective at once deeper and more practical. How easy it was to find drugs against prokaryotes, how cursedly hard and expensive to find them against the eukaryotic parasites—protozoa, fungi, and helminths!

The World Health Organization designates malaria, leishmaniasis, and trypanosomiasis as three of the six infectious diseases posing the most important global challenges. In the developed countries recognition of the grudging pace of progress with chronic diseases and aging is widening the demand for eukaryotic "models" which will be easier to handle than conventional laboratory animals. The more conspicuously animal protozoa are increasingly meeting this hunger for expeditious approaches to eukaryotic fundamentals; they will not be neglected in this new series nor will the pathogens (taking into account that several other volumes on parasitic protozoa have recently been published or are listed in press).

Advances in identifying molecular kinships have attracted biochemists (and other gentry not formally protozoologists) into the enterprise of building abutments for bridges between eukaryotes and prokaryotes. Fittingly, therefore, this edition leads off with an overview of phytoflagellate phylogeny.

The increase in knowledge of metabolic pathways and descriptive biochemistry permits more penetrating analyses of the protozoan equiva-

lents of endocrinology, neurology, especially as manifest in behavior. I therefore am delighted to welcome as senior editor for this edition my colleague Dr. Michael Levandowsky. In doing so I follow the precedent set up by the founder of this enterprise, Andre Lwoff, when he invited me to serve as senior editor with him for Volume II of what was, in retrospect, a three-volume first edition, with long intervals between Volumes II and III. The pace has quickened; the old verities need new kinds of substantiations.

S. H. Hutner

Contents of Other Volumes

Volume 1

Volume 2

Volume 3

Preface to Volume 4

With this fourth volume we bring to a close the second edition of this treatise. Several important topics in the original plan, such as ameboid motion, electrophysiology, ciliary physiology, the biochemistry of *Entamoeba* and of the trichomonads, and some new genetic engineering approaches, were not written. After all, the best authors are the busiest scientists, and manuscripts sometimes lose in competition with other pressures.

Science is not easily compassed in wide-ranging, thoughtful syntheses. We live in an age of "information retrieval," and a critical review writer is a rather undersung hero, to say the least. During a period of intense specialization, the generalist is not a competitor. The people best qualified to think about the meaning and direction of science are those active researchers, in the thick of the fray, who have the least time and energy for generalization and synthesis. The dilemma was always present, no doubt, but its magnitude is now greatly increased.

In this treatise we attempted to help a little, by putting together a set of essays by active workers, and trying to indicate to the harried researcher the practical worth of episodic doses of generality, as a source of new ideas and fruitful provocation.

M. Levandowsky
S. H. Hutner

Contents

Introduction 1

M. LEVANDOWSKY AND S. H. HUTNER

The wise reader, having diligently mastered the contents of the preceding three volumes of this new treatise, will pause for perspective before tackling the fourth.

Volume 1 revealed our definition of Protozoa as single-celled eukaryotes trying to be animals, and confronted us immediately with an array of problems in cellular and biochemical evolution. The first of these was, How do we reconcile the various conflicting lines of biochemical and ultrastructural evidence regarding phylogenetic affinities among phytoflagellates? The answer, by Dodge (Chapter 2), was the invocation of symbiotic anastomoses at strategic points of the phylogenetic tree—an exercise requiring ruthless use of Occam's razor. There followed sundry excursions into topics problematic for biochemical evolution: cytochromes, isoprenoid lipids, the puzzling presence of phycobiliproteins in cryptomonads, the dramatic phenomenon of halotolerance of *Dunaliella*, and dinoflagellate luminescence and toxicity—the latter leading to an ecological reconnaissance of the problem of recurrent, massive blooms—"red tides."

From origins to tendencies: we pondered the evolutionary significance of cellular ontogeny in coccolithophores and ameboflagellates, and the multicellularity of the volvocids. Finally, Applewhite's chapter (Chapter 11), full of bleak, dusty answers, poses a question regarding the origins of behavioral adaptability, and possible limits to the animality of a single cell.

Volume 2, after the evolutionary, ecological, even botanical (!) preoccupations of Volume 1, veers closer to the mainstream of biochemical protozoology. Indeed, in the Introduction we took pains to trace the continuity with some classical themes, such as acetate flagellate nutrition. One sees, however, the modern preoccupation with control systems and the integration of intracellular processes (Levandowsky, 1979). The parasitological side of protozoology, with roots going back to Ehrlich and Koch, suddenly fashionable because of awakened interest in symbiosis,

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appears in chapters on rumen ciliates (Chapter 9), trichomoniasis (Chapter 10), and trypanosomiasis (Chapter 11).

Then, in Volume 3, we looked at the horizons—new microbeasts from benthos and plankton, the odd genetics of dinoflagellates, and also some very practical concerns, such as the genetic hazards attending some of the most useful antiprotozoal drugs.

Now, in this volume, we return to the question of identity raised by the definition in Volume 1. We attack this from various angles: First, head-on with the laws of physics: Roberts (Chapter 2) places the Protozoa between bacteria and metazoa in their hydrodynamic niche. This latter proves to be calm but viscous—sheltered from both the buffeting shot noise of Brownian motion and the unpredictable swirling of turbulence, a Stokesian world, lacking inertia and quite foreign to our mechanical intuition. Our usual notions of hydrodynamic streamlining are not valid here—a protozoan-sized anemometer of the usual configuration (hollow cups pointing in opposite directions) simply wouldn't turn, for instance. Given these queer constraints, there follow chapters on photic and chemical senses and behavioral responses; Miyake (Chapter 4) exposes the chemical side of ciliate sexuality: fields of great promise, with an odd mix of biochemistry and behavior. In Chapter 5, the latter appears *in abstracto*, stripped of all vulgar contact with the concrete—a ghostly mathematical protozoan, constructed entirely of probability distributions and differential equations. Whatever the other shortcomings of these creatures, they are surely easiest to culture; a few IBM cards form a perfectly adequate medium.

Recoiling violently from this apparition, we seek solace in more orthodox biochemistry: Holz (Chapter 8) reviews lipidic peculiarities in a phylogenetically diverse array of organisms, linked mainly by their seawater requirement. We are on solid ground here, and the ecological importance of this field, just beginning to be grasped, can be seen from the estimate that one-fourth of the carbon fixed in the world's primary productivity becomes wax at some stage! From lipids to DNA, retreating to molecular bedrock, we come to that profound question: the degree of autonomy of organelles—here, chloroplasts and kinetoplasts—within the cell. *Euglena*, with no known genetics in its life cycle (a puzzling thing in itself), nevertheless yields a great deal of information about the cell's control of plastid number and function. Specific questions can be posed now, e.g., the chemical nature of signal molecules from the plastid at the time of chloroplast induction. Particularly intriguing are cases where synthesis of certain components can be either organellar or cytoplasmic.

The kinetoplast is DNA packaged in fantastic, accessible form. Its very exoticism accounts partly for the large amount of research on it—a multi-