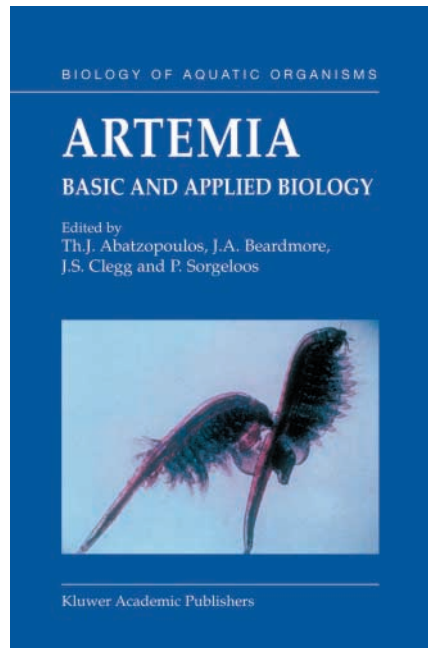


SALTY SURVIVORS

**Artemia: Basic and Applied Biology**

Edited by Th. J. Abatzopoulos,
J. A. Beardmore, J. S. Clegg and
P. Sorgeloos

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The power of brine shrimp (*Artemia* sp.) to survive and even thrive in forbidding environments has long been of interest to biologists. The first scientific reference was in 1756 by L. Schlösser, to a now-extinct population found in the salt pans of Lymington, UK. In the mid-1930s, the value of *Artemia* as a commercial source of fish feed was realized, and by the 1950s research began in earnest on the organism's biochemistry, physiology and development. Over the past 15 years, molecular data and gene expression have begun to receive increasing attention. A welcome addition to collections of research released over the decades is the inaugural volume in the 'Biology of Aquatic Organisms' series from Kluwer Academic, entitled *Artemia: Basic and Applied Biology*.

The book is organized into six chapters, authored by internationally recognized leaders in their field, which summarize recent literature in each area and give historical overviews that provide context for newly described research. Although not

overly weighty compared with some of its predecessors, this volume boasts extensive if selective references to the primary literature and strong production value, particularly for micrographs. Chapter topics are organized as follows: morphology, reproduction, physiology and biochemistry, zoogeography, evolution, and applications. Aimed at graduate students and researchers, a substantial proportion (~170 pages of 280 pages) is devoted to morphology and physiology. The remainder focuses on zoogeographic patterns and speciation, with commercial applications receiving less attention.

Chapters 1 and 2, by G. Criel and T. MacRae, review internal and external morphology, embryonic and larval development, and early events of oogenesis, spermatogenesis and fertilization in *Artemia*. The topics are covered in engaging detail and cover a variety of interesting questions. An example from cellular physiology (the roles of *Artemia* hemocytes in phagocytosis, vitellogenesis and wound healing) demonstrates the plasticity of particular cell types. This plasticity has been associated with acetylation of tubulin, which permits extensive cytoskeletal rearrangement, and indeed *Artemia* is touted as an emerging model system for the study of tubulin dynamics. In addition to detailed discussion of many aspects of development and reproduction, the authors forecast increased study of environmental influences on gene expression in *Artemia*, especially from the standpoint of development. Numerous beautiful micrographs also accompany these chapters and add immensely in many sections (for example, see fig. 49, a gorgeous SEM of a fertilizing sperm cell).

The third chapter, by J. Clegg and C. Trotman, examines ecological influences on biochemistry and physiology. They point to *Artemia* cysts as "arguably the most resistant of all animal life history stages to environmental stress" and a useful model for many biological processes. Discussion of alternate developmental pathways (oviparous vs ovoviviparous or diapause vs direct) is followed by summaries of *Artemia*'s responses to desiccation, oxidative challenge, anoxia, the role of changing pH during stress and development, and the expression of stress proteins. Specifically, recent work on the small α -crystallin protein p26 is reviewed, and the authors point out similarities in the ontogenetic profiles of p26 and artemin. The latter is a protein of enigmatic function

that may provide an interesting counterpart to the role of p26.

Clegg and Trotman also discuss many other aspects of *Artemia* physiology and note, almost in passing, the implication that "...diapause, heat shock, and anoxia utilize very similar regulatory and protective mechanisms at the cellular and molecular levels". This conclusion seems to echo the analysis of many workers in comparative biochemistry, and its rich implications are left to the reader to ponder.

Meanwhile, work in the fields of evolution and biogeography continues to raise fascinating questions about the natural history of these animals. Unusual habitats such as sulfide, chloride and carbonate lakes, and coexistence of bisexual and parthenogenetic forms, including *Parartemia*, are well described and documented in an indispensable table of Chapter 4 by G. van Stappen. Asymmetric reproductive isolation based on ecological factors (as with the Mono Lake and San Francisco Bay populations) and the presence of egg banks as a source of "migration from the past" are among the interesting processes contributing to observed distributions. In addition to a formidable bibliography, there is a detailed discussion of bioconservation issues, which are reviewed in terms of approaches and challenges to maintaining strong breeding stocks.

Chapter 5, by G. Gajardo, Th. Abatzopoulos, I. Kappas and J. Beardmore, allocates much of its space to complexities of speciation. After discussing evidence

from chromosomal squashes, allozymes and other molecular markers, *Artemia persimilis* is established as highly divergent from all other species, although the origin of *Artemia franciscana* (found in North and South America and Australia) is unclear. It is possibly derived from *Artemia salina*, the European counterpart of *A. franciscana*, which nevertheless shows interesting differences, including co-occurring parthenogenetic strains. Parthenogenesis is concluded to be a polyphyletic (multiply evolved) trait.

The importance of parthenogenesis and polyploidy are given special attention in Chapters 4 and 5. Incipient speciation as a consequence of asexuality is approached from an interesting perspective: "[it] should be regarded as the evolution of cohesion mechanisms", say Gajardo et al., rather than reproductively isolating mechanisms, such as in reinforcement. Although the predominance of parthenogenetic reproduction in more stressful conditions (e.g. high salinity, low food) may be due to a twofold advantage of asexuality temporarily overwhelming the ability of sexual genotypes to compete, the debate continues. Stable maintenance of sexual and asexual forms is currently being studied in *Daphnia*, which should provide an interesting comparison. Another intriguing link with daphniids is a recent observation of higher rates (threefold) of molecular evolution in halophilic compared with freshwater lineages of zooplankton (daphniids and anostracans; Hebert et al., 2002). *Artemia* shows considerable promise as a system to study evolutionary dimensions of stress response. Additionally,

basic questions of life history evolution have been examined in *Artemia*, by taking advantage of commercial inoculations of previously uninhabited salterns.

The final chapter, by J. Dhont and P. Sorgeloos, concerns commercial applications and reviews, in brisk style, the history of brine shrimp cultivation, including technological innovations such as cold storage, feeding enrichment and even use of *Artemia* to turn algal blooms into 'productive' biomass. Dhont and Sorgeloos have many years of combined experience at the *Artemia* Reference Center (Ghent, Belgium) and offer an intriguing glimpse into the volatile and competitive world of commercial *Artemia* suppliers.

Overall, the book represents a synthesis of work on *Artemia* over the past decade and a half and is a worthy addition to research on this remarkable animal. Covering a delightful variety of current research, I am confident that it will be referenced by scientists working in the field for years to come.

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Hebert, P. D., Remigio, E. A., Colbourne, J. K., Taylor, D. J. and Wilson, C. C. (2002). Accelerated molecular evolution in halophilic crustaceans. *Evolution* **56**, 909-926.

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