



## **Work Meets Life: Exploring the Integrative Study of Work in Living Systems**

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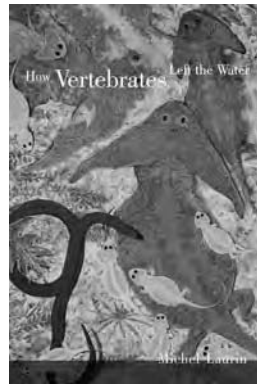
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weaknesses in our methods of learning and the gaps of knowledge pertaining to this evolutionary process. We learn that the challenge of modern paleontologists has been to test various previously formulated theories of explanation using more or less indirect methods. *How Vertebrates Left the Water* is intended for students learning the basics of paleontology, systematics, and evolutionary biology, not just specifically for those interested in the details of the water-to-land transition.

Historical and conceptual elements are woven throughout the book, beginning with a discussion of how evolutionary history can be reconstructed. The volume provides a foundation of classification methods, vertebrate taxonomy, and phylogenetic nomenclature, including some discussion of the PhyloCode ([www.ohio.edu/phylocode](http://www.ohio.edu/phylocode)). We learn about evolutionary trees and the methods to construct them. Paleontological and molecular dating is covered, and a chronology of key events along the geological time scale is presented. Our focus is then directed to the Paleozoic era, in which plants and various animal groups—including vertebrates—became terrestrially dominant. Numerous descriptive elements are also found in the book, and modes of reproduction; skeletal parts; bone histology; structural descriptions of eggs, lungs, and skin; explanations of sensory organs; and descriptions of the taxa of fossils (e.g., sarcopterygians, stegocephalians, temnospondyls, seymouriamorphs, embolomeres, lepospondyls, diadectomorphs) are incorporated.

Phylogenetic controversies embody an important part of this book's discussions; Laurin attempts to explain the delay of scientific progress related to various interpretations of evolutionary pathways and contexts. Some controversies are not yet resolved, but the dialogue adds a welcome element of scholarly rigor and value to the book. In a single chapter that treats the evolution of the vertebrate limb, no fewer than 12 controversies are identified and discussed. Generally speaking, each controversial topic

includes some mention of historical thought, the generation and testing of a hypothesis, and the results from selected studies leading to specific conclusions. Readers also encounter opinions regarding favored hypotheses, alternative hypotheses, and the weight of tradition regarding widely established theories.



The fossil record provides an important, albeit incomplete, account of the phylogeny associated with water-to-air transitions during Earth's early history, and it is the core of *How Vertebrates Left the Water*. Laurin discusses the process of transition in contexts of terrestrial adaptation and the related concept of *exaptation*, and we read about the evolution of locomotor systems related to girdle and limb changes, the loss of gills, terrestrial lung and skin features, changes in jaw suspension, and so on. Although an overview is given on these subjects, much research and detail has been excluded that could have given the book more balance and heft in light of its title. There is no reference, for example, to the earlier book by Gordon and Olson (1995), or to the edited volume by Mittal and colleagues (1999). The evolutionary ideas of Robert Inger, Karel Liem, Gordon Ultsch, Lauren Chapman, George Hughes, among others, could have added depth to the discussion of evolutionary process, but none are mentioned.

Other shortcomings of the book include a lack of clarity in the overall phylogeny of the various fossil clades that are discussed and the occasional ambiguity for some antecedents and in some of the conclusions. The final

chapter of the book, on "Synthesis and Conclusions," ends with a two-page discussion of modern paleontology and the "Indiana Jones" stereotype. This prose defends the usefulness of paleontology, but, to me, it seems unnecessarily defensive and somewhat anticlimactic.

Nonetheless, Laurin's treatment of *How Vertebrates Left the Water* provides a generally well-written and -illustrated synthesis of an interesting evolutionary topic, crafted from the perspective of a talented and qualified paleontologist. I do not hesitate to suggest that readers with an interest in evolution, paleontology, vertebrate morphology, or the fossil record will want to add this book to their bookshelf.

#### References cited

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#### WORKING TOWARD AN INTEGRATIVE UNDERSTANDING OF WORK IN LIVING SYSTEMS

**Work Meets Life: Exploring the Integrative Study of Work in Living Systems.** Robert Levin, Simon Laughlin, Christina De La Rocha, and Alan Blackwell, eds. MIT Press, 2011. 272 pp., illus. \$30.00 (ISBN 9780262014120 cloth).

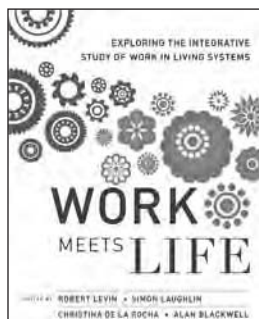
**I**n *Work Meets Life: Exploring the Integrative Study of Work in Living Systems*, Robert Levin and his multidisciplinary colleagues set out on a quest to develop integrative links among varied scientific perspectives on work in living systems—from cellular

metabolism to job performance. Their goal, as it is stated in the introduction, is to create new questions about work through investigations at different levels of analysis and organization and through the identification of connections among those levels. Many groups have attempted interdisciplinary collaboration in the past, pursuing the tantalizing notion that linking across disciplinary perspectives will generate new understanding. Those who have gone down this path know how extremely challenging it can be to understand another's perspective, much less identify and develop interesting connections.

Bob Levin, a biologist and director of the Center for the Integrative Study of Work at the University of Colorado at Boulder, assembled colleagues from an unusually broad set of disciplinary perspectives through working conferences, which led to this edited volume. Within nine chapters, we hear from neuroscientists, environmental scientists, psychologists, evolutionary biologists, management scientists, organizational psychologists, electrical engineers, and even design scientists as they investigate different angles on work in living systems. Each chapter represents an investigation at a certain level of analysis, although connections are drawn with other levels, and connections across all levels are developed in a set of provocative integrative ideas in a final chapter entitled "Reflections: On Exploring Work in Living Systems."

A key observation that runs through the entire book is that although thermodynamic laws limit the amount of work that can be done with a given amount of energy, the actual amount of work done may be less than maximal—potentially much less—depending on how the work is accomplished, which gives rise to the notion of performance envelopes. Chapter 1 grounds all of the examples of work in living systems in the fundamental level of cellular chemiosmosis that produces ATP (adenosine triphosphate), which provides the energy that drives all other work in an organism. From photosynthesis to niche construction or from

information processing to design, all work by living systems depends on the energy created by chemiosmosis and how that energy is partitioned, stored, and used. An interesting observation made by the authors is that the history of work in living systems parallels the radiation of life, because new ways evolved of using energy to perform work—a "tree of work."



Work in living systems is directed by information passed through the nervous system, which requires energy separate and apart from the energy requirements of the physical work produced. The remaining chapters consider the interplay among energy, information, and work, and couch this in terms of trade-offs. This consideration includes investigations of the nervous system itself, photosynthesis, niche construction, designed systems, job performance, and environmental stressors. These chapters are well written and aptly describe complex scientific topics in terms that are understandable to a scientifically literate audience.

At the end of *Work Meets Life*, Levin and his colleagues further develop the cross-cutting themes of energy–information trade-offs and performance envelopes and describe a set of 11 observed cross-cutting patterns. The authors are careful to state that these are not intended to be a robust, thorough examination of all aspects of work in living systems. Rather, these are initial observations and a starting point for further investigation. Among these are rather intuitive observations (e.g., work requires energy, the conversion of energy into work is never 100 percent efficient) and those that

are less intuitive, such as the observation that innovations in work output or work kind are sequential and cumulative over time, which sets boundaries on innovations that can be developed in the future.

This collective work as a whole is breathtaking in its aspiration, and it successfully delivers. Interesting new connections are developed, and novel ways of approaching the subject emerge. In the introduction, Levin states that they hope the book not only reveals new connections but stimulates readers to generate their own new connections. The book did indeed cause me to think about the effort involved in interdisciplinary work—an area on which I have focused my research extensively in recent years. The task of crossing disciplines and organizational levels requires a tremendous amount of time and energy, and the authors use a metaphor of a long journey by explorers that opens up new country. Continuing with this metaphor, I view interdisciplinary collaboration as creating a new intellectual path through a relatively unbounded problem space, with no existing pathways for navigating that space, no landmarks, and with the disorienting effect of finding oneself in deep, unfamiliar intellectual territory.

It is the identification of key concepts that enables collaborators from different perspectives to orient themselves to the larger problem space, which is essential to begin building a mental map of the new area. *Work Meets Life* exemplifies how that process occurs and how desired outcomes can be achieved. The only shortcoming of this book is that it leaves so much unsaid. It is clear that a great deal more work is required to develop a better, integrated understanding of work in living systems.

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