BOOKS: PHYSIOLOGY

Fuzzing the Boundary of Animal Life

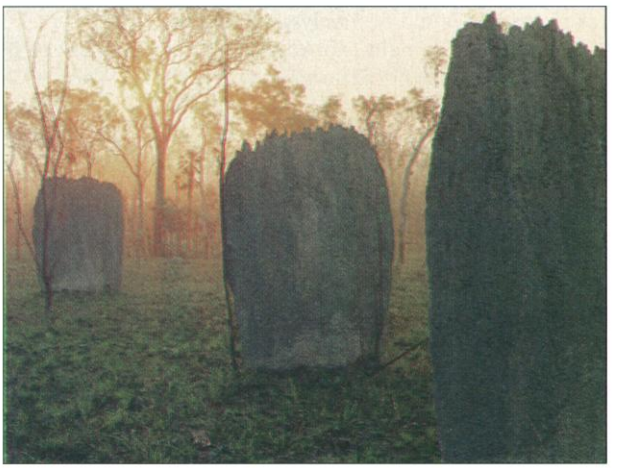
Michael LaBarbera

Where does the boundary of an organism lie? For a cell biologist looking at a squirrel or a laboratory mouse, the answer would probably be the skin. For a physiologist, the answer would probably be the fur—even though nonliving, mammalian fur does play a practical role in thermoregulation. If the animal were an orb-weaving spider, however, the answer is less straightforward. Spiders build webs to catch their prey, and without a web, many spiders can neither catch prey nor feed. The web is protein produced and arranged by, but clearly distinct from, the spider. Without it, many spiders are not viable entities. For that matter, the squirrel and laboratory mouse both build nests using materials wholly external to their bodies. Such nests play a vital role in these animals' thermoregulation and energy balance. In the ecological and physiological senses, where is the boundary of these organisms?

The Extended Organism
The Physiology of Animal-Built Structures
by J. Scott Turner
Harvard University Press, Cambridge, MA, 2000. 247 pp. $47.50. ISBN 0-674-00151-6.

The classical work on this topic is Karl von Frisch's charming and insightful *Animal Architecture* (*1*). Richard Dawkins argues that animal constructs and, indeed, all aspects of behavior must be considered part of an organism's phenotype and thus part of the organism (*2*). In *The Extended Organism*, J. Scott Turner poses a more limited but more radical thesis: that these external constructs in many cases represent the physical manifestations of an "external physiology" whereby organisms adapt their environment to themselves. Interestingly, in another recent book from the same publisher (*3*), Richard Lewontin also argues that organisms modify their environment as much as the environment modifies them, but his perspective is strictly evolutionary, not physiological.

Pinning down this "external physiology" is not, however, straightforward. Turner, a physiologist at the State University of New York College of Environmental Science and Forestry, Syracuse, claims that "if animals use energy to do work on the 'external' environment, their activity is as much physiology as when they use energy to do work on the 'internal' environment." This statement potentially encompasses a lot of biology, from the strictly physiological to locomotor mechanics. Some of the most interesting examples of external physiology involve animals indirectly exploiting environmental energy gradients to support processes that would otherwise demand the investment of metabolic energy. Prairie dogs ventilate their burrows and albatrosses fly tens of kilometers without flapping their wings; both exploit velocity gradients in the wind. Neither example makes it into this volume, although the flow-induced stability of the bubble-gill of stream-dwelling beetles does. Some of the examples offered seem of dubious relevance. Turner devotes an entire chapter to bioconvection in cultures of *Chlamydomonas*. This intriguing phenomenon is elegantly explained, but unlikely to occur in any natural context. The two most compelling examples the author offers of an external physiology involve social insects—bees and termites. For these species, the interaction of physical processes and negative feedback loops involving the animals clearly regulates the microclimate in their nests.



Microclimate controllers. The north-south aligned mounds of the magnetic termite, *Amitermes meridonalis*, dominate the landscape on open forested plains of Litchfield National Park, Australia.

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Turner presents physiological concepts with noteworthy clarity. Boxes on selected topics permit those who are rusty on their physiology (or who managed to avoid the topic altogether) to understand the background to the main text. When, however, the volume strays from physiology, the reader should be extremely cautious; small but irritating errors abound. The implied equivalence of photosynthesis and oxygen production ignores the wide diversity of prokaryotes that are photosynthetic but use compounds other than water as electron donors. The tracheal system of spiders is not derived from the book lungs. Human hearing extends well beyond frequencies of five kilohertz. Not all Archaea are obligate anaerobes. The common ancestor of protostomes and deuterostomes was certainly not a bryozoan or rotifer, nor likely to be morphologically similar to either. One should be particularly suspicious of the timing claimed for paleontological events: the origin of oxygenic photosynthesis is off by almost a billion years, the appearance of metazoans is a half-billion years too late, and the invasion of terrestrial environments by animals would have preceded the invasion of land by plants.

In the end, you may find yourself unconvinced that an organism's physiology typically extends much beyond its physical boundaries. But before rejecting the concept of the extended organism outright, consider that this volume focuses almost exclusively on animals, organisms in which motility and microhabitat choice are the norm. Had Turner given greater prominence to prokaryotes (the planet's biochemical specialists) and higher plants (whose symbiosis with mycorrhizal fungi profoundly affects the structure and chemistry of soils), his case would have been considerably more convincing. Still, *The Extended Organism* is a worthy companion to books by Stephen Vogel (*4*) and Mark Denny (*5*). Turner provides an interestingly different perspective on the interface between organisms and their external environments—however those concepts should be defined.

The author is in the Department of Organismal Biology and Anatomy, University of Chicago, 1027 East 57th Street, Chicago, IL 60637, USA. E-mail: mlabarbe@midway.uchicago.edu

References
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4. S. Vogel, *Life in Moving Fluids* (Princeton Univ. Press, Princeton, NJ, 2nd ed.,1994).
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