

Reviews

book & software

The Extended Organism

Where do we position the boundary between an organism and its environment? At first sight, this might seem a simple question with a simple answer: the boundary is the outer membrane in unicellular organisms, the outer layer of cells or cuticle in multicellular organisms and so on. However, as Turner convincingly argues in *The Extended Organism* this is not necessarily so, and an organism—in particular its *physiology*—may extend beyond these traditional boundaries. In short, Turner's book is admirable attempt to exemplify Richard Dawkins's [1] concept of the "extended phenotype."

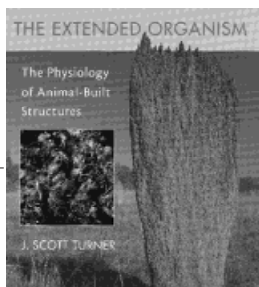
Dawkins argues that a gene's influence may extend well beyond its physi-

cal boundary (the cell in which it is located) and that the organism is an adaptive external vehicle used to favor the gene's propagation. Similarly, Turner argues that an organism's sphere of influence may extend beyond its physical embodiment and that it may actively adapt and modify the environment around itself to favor its survival, and that of its genes.

This central idea is perhaps best illustrated by an example; my personal favorite is that of the air-breathing aquatic beetle, *Notonecta*. The beetle spends most of its time underwater, but every five to six hours it swims to the surface, traps a layer of air around itself, and re-submerges. This bubble had previously been thought to be simply a buoyancy aid, or an oxygen store (i.e., when it had used all the oxygen in the bubble, it returned to the surface for more). However, an elegant set of experiments by biologist Richard Ege [2] demonstrated that neither of these explanations sufficed. Beetles that surfaced to an atmosphere rich in nitrogen suffocated after only five minutes when confined underwater—it was therefore not simply a buoyancy aid. But beetles that surfaced to an atmosphere of pure oxygen (which we would expect should prolong underwater survival) survived for only 35 minutes, just one tenth of the survival time for air. The answer to this puzzle lies in external physiology: the bubble acts as an external lung. Surface ten-

sion and the air bubble's nitrogen keep it at a reasonably constant size. As the beetle consumes the oxygen, the bubble's partial pressure of oxygen falls to below that of the water. When this occurs there is a flow of oxygen from the water to the bubble. (The reverse flow occurs with a bubble of pure oxygen.) That is, consumption of the oxygen encourages its replenishment. This is so effective that the beetle can glean more than eight times the initial amount of oxygen from the bubble lung before having to resurface. In this way, it is clear that physiologically, the beetle's boundary does not stop at its cuticle but farther away, the surface of the bubble.

The book is full of similar fascinating and convincing tales and examples. However, the reader is not treated to these delights until a significant number of pages into the book. The first five or so of the book's twelve chapters are devoted primarily to terminology, the concept of physiology, thermodynamics, different energy flows, and so on. I personally found the first half of the book a slow and laborious slog, perhaps because I had accepted Turner's basic premise early on and was keen to get to the details and examples. However, other readers may appreciate the review and the slow and deliberate construction of the argument from first (physical and energetic) principles. The book is clear and well written and certainly aimed at



**THE EXTENDED ORGANISM: THE
PHYSIOLOGY OF
ANIMAL-BUILT STRUCTURES**

by J. Scott Turner,

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Massachusetts, 2000 235 pp., \$47.50
(Hardcover)



a broad audience, for the most part I suspect understandable to the majority of freshmen undergraduates. The price, however, for this inclusiveness of readership is numerous distracting boxes and asides explaining basic terminology and concepts, e.g., meaning of “10⁻².”

If I have one true gripe, then it is that Turner focuses very strongly on invertebrates. There may be some readers, such as mammalogists and botanists, who could feel a little short-changed. For instance, plants appear in a chapter on galls and in a chapter on Lovelock’s [3] “Gaia hypothesis,” but hardly anywhere else (and mammals even less). As a biological sciences undergraduate I was taught numerous examples of “allelopathy,” in which plants somehow chemically alter their environment to favor themselves; for instance, pine tree needles produce a leachate that favorably acidifies the soil beneath the canopy, and rhododendrons produce chemicals that essentially poison the soil around them to all plants, except of

course the rhododendron. In future editions, and I hope there will be, I would like to see the set of examples broadened to produce a more balanced review of external physiology. This is admittedly a lot to ask from any one researcher; however, I strongly suspect that Turner’s important book will spur such research.

A problem I see with new and radical notions such as these is that it leaves critics free to take the ideas to ridiculous extremes. For instance, adopting Turner’s logic I could argue that a spaceship is part of an astronaut’s physiology: the spaceship is an adaptive external feature in that it retains heat and captures exhaled breath preventing it from escaping into deep space and enabling it to be re-inhaled by the occupant. However, I suspect that few of us, including Turner, would be comfortable saying that a spaceship is a part of *Homo sapiens*’ physiology. This is simply a comment, not a criticism, that these ideas are new and in many respects fuzzy and open to some subjectivity. (Turner himself admit-

tedly stretches some of his ideas to their logical limits.) In summary, Turner challenges our neatly defined and packaged view of organisms—they *do* have fuzzy boundaries. Additionally, he persuasively refutes an assertion by the evolutionary biologist G. C. Williams that “adaptation is asymmetric; organisms adapt to their environments, never *vice versa*” [4, p. 484], by which he meant that organisms do not adapt their environments to suit themselves. Apparently, sometimes they do.

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REFERENCES

1. Dawkins, R. *The Extended Phenotype*. Wiley and Sons: San Francisco, 1982.
2. Ege, R. *Z Allg Physiol* 1915, 17, 81.
3. Lovelock, J. E. *Gaia: A New Look at Life on Earth*; Oxford University Press: Oxford, 1988.
4. Williams, G. C. *Quart Rev Biol* 1992, 67, 479.



Cultural Creation of Intelligence

Within the pages of a thin book, Ken Richardson tackles the task of defining intelligence and explaining how it is created. In so doing, he washes away a river of theories with the strong suggestion of an alternative. In this *Maps of the Mind* volume, Richardson advances the idea that the concept of intelligence is gaining in importance because of psychological and neuroscientific efforts to identify where intelligence lies in the genetic structure and how it is produced by the brain. The concept of intelligence, he stresses, plays a critical role in identifying individual differences upon which educational, governmental, and business decisions are

based; therefore, defining it in terms of how it is created is vastly important. Thus, Richardson begins his treatise by detailing a chronological perspective of various theories that he systematically dismisses before boldly advancing his own.

For example, he argues that intelligence tests generate IQ scores, but “As in the construction of tests themselves, you don’t get what you see: you get what you want to see. . . . The items are, after all,” he states, “devised by test designers from a very narrow social class and culture, based on intuitions about intelligence and variation in it, and on a technology of item selection which builds in the required



THE MAKING OF INTELLIGENCE
by Ken Richardson
Columbia University Press, New York,
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210 pp., \$24.95 (cloth)