Helpful extensions

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The extended organism.

by J. Scott Turner

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An organism is clearly defined and easily identifiable by its boundaries. Or is it? In his beautiful book, J. Scott Turner, a physiological ecologist at SUNY College of Environmental Science and Forestry in Syracuse, demonstrates that the answer to this question must be 'no'. Turner's book picks up theories from Richard Dawkins, a zoologist at Oxford University. In 1982, Dawkins published his book *The Extended Phenotype* in which he worked out the basis for a theory according to which selection not only acts on organisms directly, but also through the structures they build. Now, almost 20 years later, Turner finally puts 'empirical meat on the theoretical bones' of Dawkins's theory, as one comment on his book states.

The author looks at the physiology, ecology and evolution of organisms and the interconnections between these fields from a stimulating point of view. He makes clear that the concept of an extended phenotype is incomplete without an understanding of the physiological principles and laws involved. Genes can only act outside an organism if they manipulate the flows of energy and matter between organism and environment to an extent that leads to reproductive success. Next he explains that adaptation and natural selection are inevitably linked to physiology and, hence, energetics. Calculations, thoughts and arguments around the energetics of organisms are the continuing thread running through the book.

To provide or refresh the physical background, the first three chapters are devoted to thermodynamics and describe how animal-built structures manipulate flows of physical energy. Here, the author uses analogies with electricity to explain how organisms manage to resist, rectify, switch or store the flow of energy.

From chapter four onward, the book deals with 'real biology'. Carefully selected examples are used as stepping-stones that guide the reader through a fascinating system of ideas. Incidentally, while reading through Turner's book, the reader improves her or his general education and learns a wealth of interesting and entertaining information such as—presented with a wink—'occult forces' means 'unseen forces' and thus occult forces are used by scientists all the time. More seriously, fractal geometry, the concept of inclusive fitness and a lot more are explained so clearly that the reader wonders why he has not had these ideas himself.

'Whenever energy flows through a living thing, order is created.' Turner demonstrates this by describing water flows as seen in suspensions of the single-cell algae *Chlamydomonas nivalis*. The algae generate this bioconvection to create an external circulatory respiration system. This example forces an uncomfortable question: what is adapted to what? The organism to the environment or the environment to the organism? In order for bioconvection to build up as a phenotype, the physical properties of the fluid and its solubles are as essential as the algae themselves.

Even very primitive animals—sponges and corals—build external structures using physiological work. By creating flows of water, they achieve a calcium gradient that results in an increased deposition of calcium around the organism. We also learn that earthworms build tunnels to use the soil as accessory kidneys, and that spiders make use of oxygen-filled air-bubbles to breathe under water.

Whether it is plant gall formation triggered by mites, sound communication among insects or temperature stabilisation in termite mounds or the nests of honeybees, each chapter starts with an entertaining paragraph describing the specific 'extended organism' problem treated therein. Separate text boxes explain terms, concepts and implications of the main idea of each chapter. And so as not to lose track of the book's major theme—the flow of matter and energy channelled by organisms—relevant empirical details are linked into convincing chains of arguments.

A key concept in the book is that of a super-organism: single-cell algae acting

together to create a circulatory respiration system outside of the organism form a super-organism, as do social insects co-operating to create their own micro-climate.

In the final chapter, the book's view is further expanded with the suggestion that the whole Earth is a super-organism with global physiology, if not global homeostasis. This is not a philosophical question, and an answer may be useful in understanding our own environment or deciding if a distant planet supports life. As described by the author, a large-scale symbiosis between organisms could throw a planet's chemistry out of its thermodynamic equilibrium. If competition is then added to the general concept, a physiological definition of evolutionary fitness becomes possible. Conventionally, fitness is the likelihood to pass on a gene. But genes are just useless templates without energy. If fitness is also considered to be a matter of energetics, it becomes clear that the rate at which energy can be mobilised determines the rate of reproduction. Here, the cycle to animal-built structures that manipulate the flow of energy is completed.

Looking at evolution from this perspective makes one wonder why the whole Earth does not appear as Gaia. However, the author honestly points out the unsolved problems of this hypothesis. Group selection would be an easy way to look at the evolution of a global system, but group selection is incompatible with the current thinking about evolution.

The book is written in a refreshing style and its arguments are crystal clear. At the end, the reader starts to think whether, as the author states in his introduction, more effort of biological research should indeed be invested to solve the problems outlined here. This would also mean that scientists should expand extreme reductionistic approaches by asking more integrative questions about nature.

For this missionary message, the book can also be highly recommended.

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