EMBO reports

books

Reclaiming biology

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The Triple Helix. Gene, Organism, and Environment.
by Richard Lewontin
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From time to time you come across a book that while you are reading it makes you think: 'If only I were its author!' Honestly, that is how I felt after reading this remarkable book by Richard Lewontin, a population geneticist at Harvard University. *The Triple Helix* is a plea and an attempt to free biology from the reductionist clamps of physics and chemistry. The book's major theme and message to scientists is that our understanding of living systems will never be complete if we continue to view genes, organisms and their environments as separate entities.

The first three chapters of Lewontin's essay are English translations of lectures he originally presented in the Lezioni Italiani in Milan, Italy. They were subsequently published in 1998. The chapters 'Gene and Organism', 'Organism and Environment' and 'Parts and Wholes, Causes and Effects' describe and analyse some of the most important relationships between those tightly interconnected items. The final chapter, 'Directions in the Study of Biology', is a manifesto to give biology its rightful status as a complete science of the same value as physics and mathematics, and it presents practical suggestions and approaches for future research.

First of all, Lewontin draws our attention to the powerful lock of Descartes' philosophy describing organisms as machines. This metaphor has certainly been useful as a starting point for the description and analysis of the living world, but it has hampered the further evolution of biological science for a long time. When dealing with metaphors in science, there is always the inherent danger of confusing the comparison with the real thing. Using the example of two important concepts in biology–development and adaptation–Lewontin exposes the limitations of Descartian philosophy when it comes to explaining the wide variations among organisms in terms of both their life histories and the effects they have on their environment. He harshly criticises biologists who believe that a complete organism and its life can be easily simulated simply by feeding its complete nucleotide sequence into a sufficiently powerful computer. For Lewontin, this is outright 'bad biology' because this approach to explaining the living world is limited and naïve. Indeed, a real organism is not merely a sequence of nucleotides or a collection of genes, but a dynamic living system within the complex context of its surrounding milieu. To strengthen this point, he gives a variety of examples from the plant and animal kingdoms where the apparently fixed genetic programmes of development, growth and differentiation can be easily proven to go beyond any rigid notions of genetic determinism.

When writing about adaptation, Lewontin acknowledges that 'Darwin's alienation of the outside from the inside was an absolutely essential step in the development of modern biology. Without it we would still be wallowing in the mire of an obscurantist holism […].' But going further in his argument, he stresses that the time has come to reconsider the relationship between the outside and the inside, between organism and environment. Instead of agreeing with the prevalent notion of adaptation that sees organisms as merely fitting into an independent environment, Lewontin strongly argues in favour of the view that the environment is a continually re-constructed condition, which works upon an organism and is in return worked upon by the organism. He makes the correct distinction between the purely physical world outside the reach of living things–such as the rotation of the earth, the sequence of interglacial and glacial ages or the impact of volcanoes–and environment which, by definition, is something that surrounds something else. 'Just as there can be no organism without an environment, so there can be no environment without an organism.' However, the author is also cautious in not letting his ideas get mixed up with the Gaia hypothesis, which considers the totality of biosphere, atmosphere and geosphere as a living system that actively reacts to changes within itself. This kind of extreme holism, he says, has only little value as a contribution to the biological sciences as it is not able to define clear boundaries between important and critical influences and trivial and ineffective ones. 'Obscurantist holism is both fruitless and wrong as a description of the world.'

Lewontin wants us to accept the fact as well as its consequences that 'biological systems occupy a different region of the space of physical relations than do simpler physico-chemical systems.' To get any further in biological research, scientists must recognise and explain the internal heterogeneity within biological systems. Biochemistry and molecular biology have had great successes in demonstrating and explaining similarity in life forms. But these reductionist approaches are unable to explain why even genetically identical organisms differ from each other, why different individuals within the same species differ, why different individuals, organs, tissues and cells live, age and die differently. Lewontin also advocates moving biology from the present DNA-focused framework to the realm of gene products functioning within an environment that is being constantly created and altered by biological systems. Only then can biology attain its rightfully independent existence and its own identity as a research field.

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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. 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 act only 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 clearly so 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 outside 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 in order to create a circulatory respiration system outside of the organisms form a super-organism, as do social insects co-operating to create their own microclimate.

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 gets closed.

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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