# The New Biology: A Battle between Mechanism and Organicism

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The Scientific Revolution, lasting from Copernicus to Newton, was above all a change in what linguists call ‘root metaphors’: from seeing the world as an organism – organicism – to seeing the world as a machine – mechanism. To use other language, science pre-Revolution demanded that one think of entities as functioning wholes, ‘holism.’ Science post-Revolution worked by looking at entities as composed of individual parts, ‘reductionism.’ The flies in the mechanistic ointment were living organisms. They seemed too intricately constructed for us to think that they could be the product of the blind laws we associate with machines. People worried about this problem from the time of Robert Boyle, in the seventeenth century, to Charles Darwin, in the nineteenth century, who claimed that through his mechanism of natural selection we can explain the nature of organisms using only blind laws. Not all were convinced and until the end of the nineteenth century there were many professional biologists as well as laypeople, who thought that a return to the old metaphor of the organism was necessary. In the first half of the twentieth century, thanks to advances in the study of heredity, culminating in the discovery of the structure of the genetic material, DNA, in 1953, to many, mechanism was all triumphant.

It turned out, however, that it was too soon to write obituaries for organicism. It is true that understanding the way in which DNA functions demanded one think in terms of its parts, reductionism; but, many phenomena, most particularly the growth and development of organisms, seemed still to demand a more integrated understanding, holism. Today there is a lively, often bitter, divide among biologists over this division.

*The move from reductionism*

A variety of developments have contributed to recent moves in biology away from the reductionism that sometimes accompanies molecular biology, cell biology and genetics. One such development has been contemporary understandings of inheritance which, rather than simply explaining the appearance of organisms, their phenotypes, in terms of their genes, recognize that genes themselves interact and are sensitive to triggers from the environment that can switch them on or off. The interface between evolutionary and developmental biology ('Evo-Devo') has perhaps been at the epicenter of the New Biology (sticking with this term for the moment), but there are other important developments too. Ecology recognizes the significance for each species of its interactions with other species.

More generally, systems biology – meaning that the level of analysis is the system as a whole (e.g., an entire cell or an ecosystem) rather than focusing only on its separated components – recognizes that there are many biological phenomena that cannot be adequately understood in terms of reductionist explanations, and is developing mathematical modeling in attempts to capture the complex processes involved.

These are no longer points of deep controversy within the academic biology community. Although, of course, there are localized areas of dispute, as with any science in the process of developing new knowledge, by and large, these points are widely accepted, and are guiding current research. A new more systemic, organismal biology *is* gaining ground (Watts & Reiss 2017). However, controversy remains within academic biology and outside of academia, the debate between mechanism/reductionism and organicism/holism is as raucous as it ever was.

*Organicism reconsidered*

In his *Metaphysics*, Aristotle said "the totality is not, as it were, a mere heap, but the whole is something besides the parts" (Book VIII, 1045a.8–10; in Barnes 1984). It is this insight that lies behind the so-called philosophy of 'holism' or 'organicism', namely that one cannot rest content with a purely reductionistic approach to understanding – particularly the understanding of organisms – but must in some sense look at the whole or the entire body, be this an individual organism or a collection like a population, species, or even a whole ecosystem. Another popular term is 'emergence', meaning that from the parts considered together new overall properties appear.

An eloquent passage that brings together aspects of both organicism and emergence is found in the writings of John Stuart Mill:

> All organised bodies are composed of parts, similar to those composing inorganic nature, and which have even themselves existed in an inorganic state; but the phenomena of life, which result from the juxtaposition of those parts in a certain manner, bear no analogy to any of the effects which would be produced by the action of the component substances considered as mere physical agents. To whatever degree we might imagine our knowledge of the properties of the several ingredients of a living body to be extended and perfected, it is certain that no mere summing up of the separate actions of those elements will ever amount to the action of the living body itself. (Mill 1843/1974, Book III, Ch. 6, §1)

In the Anglophone world, with the coming of genetics and then of molecular biology, it looked as if reductionism-mechanism had triumphed. Richard Dawkins' *The Selfish Gene* (1976) seemed to be the apotheosis of that philosophy, with the behavior of individual organisms 'explained' by the (metaphorical) unconscious urge of their constituent genes to spread at all costs. But the rival organicist philosophy has proved a sturdy plant. In the world of evolution, the eminent population geneticist Sewall Wright (who for many years worshipped with the Unitarians) was always sympathetic to holism.

A few years later, a number of scholars, notably Richard Lewontin at Harvard, argued for a more holistic philosophy, first in their more scientific works like Lewontin's *The Genetic Basis of Evolutionary Change* (1974), and then in more general writings like Lewontin's *Biology as Ideology: The Doctrine of DNA* (1991), where those espousing a reductionistic account of biology are excoriated at naïve and ill-informed. In paleontology, Stephen Jay Gould argued at length for a more Germanic, organicist view of organisms if we are to understand the diversity of life, first in a massive historical overview, *Ontogeny and Phylogeny* (1977), and then in numerous more scientifically directed publications, like 'Darwinism and the expansion of evolutionary theory' (1982).

*Development and Emergence*

Inheritance segues into the topic of development. From the time of Aristotle, the remarkable phenomenon of development has lent itself to emergent interpretations, as a whole organism apparently miraculously (or 'bewitchingly') emerges from seemingly undifferentiated matter. The *Naturphilosophen* (the German Romantics) were particularly interested in this, and embryology became a science of great significance. As Richards notes in his book on Haeckel (2008), development was embedded in Haeckel's thinking, not the least because of his championing of the so-called biogenetic law – ontogeny (development of an individual from single cell to adult) recapitulates phylogeny (the history of the evolution of species).

In the twentieth century, with the coming of genetics, development rather fell by the wayside as organisms were treated something like sausage machines – genes and raw materials in at one end, organisms emerging at the other end. Even embryologists, like Gavin de Beer (1940), wrote this way to some extent. However, some pushed the significance of embryology in a major way, linking it to a more organicist view of life. Noteworthy were the already mentioned Stephen Jay Gould (1977) and, most particularly, the physician-turned-biologist, very deeply committed to computer programing, Stuart Kauffman (1993, 1995, 2008). Both of these scientists felt that an emergentist philosophy was necessary for a full understanding of the workings of life.

Then came the full-flowering of molecular biology with its major insights into the functioning of genes – from DNA to RNA to amino acids to proteins, and so on up the chain. Advances in techniques used in molecular and cell biology, such as proteomics (in which increasingly automated approaches are used to study the entire set of proteins produced by a cell or other system), and bioinformatics and computational biology (where software is used to try to make sense of the vast amount of biological information that is increasingly available about organisms), gave added impetus to the hope that by studying the constituents of organisms in more detail we would be able to understand them.

However, it soon became obvious – and if it was not obvious then major projects like the Human Genome Project made it so – that growth is a matter of organization as much as materials, and an emergentist approach was nigh mandatory. This was made clear by the scientists themselves, for instance Sean Carroll in *Endless Forms Most Beautiful: The New Science of Evo Devo* (2005) and plant biologist Ottoline Leyser (Leyser & Wiseman 2020), and in those reflecting on the science, for instance Scott Gilbert (2006). More generally, perspectives tied this thinking to emergentist areas elsewhere in science, for instance in physics in *Complexity and the Arrow of Time* (Lineweaver et al. 2013).

*Ecology*

Ecology and environmental issues generally have always attracted those with emergentist leanings. This is hardly surprising because, as historian Gregory Mitman (1992) documented, ecology does push one towards thinking at the macro, even the mega, level. In addition, historical factors are significant for understanding the present-day distribution of organisms. On the one hand, much ecological thinking has been rooted in the 'balance of nature' doctrine. Although this had pagan origins, it was taken over by Christian thinkers and pushed people to think holistically.

Later ecological thinkers, much influenced by G. Evelyn Hutchinson (1948), were more inclined to mechanistic thinking – work on feedback systems in the Second World War was significant here – but some of Hutchinson's most important followers, notably the Odum brothers, were very inclined to holistic thinking. In many cases, this subsequently connected to a sympathy for the brainchild of the English scientist James Lovelock, the Gaia hypothesis, the idea of the Earth as an organism. It is noteworthy that Lovelock's great supporter, Lynn Margulis, was always deeply committed to symbiosis. It is also noteworthy that the Gaia hypothesis is disliked both by scientists such as Richard Dawkins (1982), who think it insufficiently reductionistic, and by Evangelical Christians, who think it deifies the Creation (Van Dyke et al. 1996; Ruse 2013).

The philosophical issues surrounding holistic biology are more subtle than is sometimes appreciated. At the very least, the new more organismal biology seems to move away from a mode of explanation that assumes that higher level phenomena can be explained entirely in terms of lower level ones. Instead, it moves towards a recognition (i) of the reality and importance of 'emergence' (that phenomena that are genuinely new can be seen at higher levels, follow their own laws and cannot be explained entirely in terms of lower level phenomena), and (ii) that biological explanations often need to be systemic, and to take into account the possibility that lower-level phenomena can be influenced by higher-level organismal factors and by functional context.

There are also issues about determinism to be explored. Epigenetics and other features of contemporary genetics mark a move away from a simplistic genetic determinism in which it is presumed that the phenotype simply follows from the genotype. Of course, that kind of genetic determinism never received much scientific support, existing more in the media rhetoric of a 'gene for' this or that, but it nonetheless has had and continues to have a powerful role in the popular (public and school) understanding of biology (Reiss et al. 2020).

*Theology and Religious Belief*

These developments in biology have implications for theology and religious belief. The strong reductionism of molecular biology has, in some people's minds, fostered the idea that modern scientific biology is incompatible with religious faith. While that was never a view that stood up to critical examination, work by sociologists (e.g., Ecklund & Johnson 2021) shows it is quite widely accepted, particularly among atheists. The move away from strong reductionism in biology promises to remove what has been, for some people, an obstacle to religious faith, or at best something that sits uneasily with it. There has been fruitful engagement between theology and emergentism (e.g., Gregersen 2017).

We see similar scope for theology to engage with the current trend towards holistic biology. There are also constructive theological implications of the new biology. The systemic complexity of the new biology points to the inter-connectedness of creation in a way that finds a parallel in the religious vision of the unity of all things in God.

Issues about reductionism have been at the heart of work on the interface between science and theology. Philosophical reconciliations have been proposed, including the non-reductive physicalism of Warren Brown, Nancey Murphy and colleagues in *Whatever Happened to the Soul*? (1998), the emergentism of Philip Clayton in *Mind and Emergence* (2006), and elsewhere.

There is a degree of convergence to be explored between the sense of the inter-dependence within nature that emerges from the new biology, the mystical vision of the unity of all things, and the Christian conviction that all things cohere in Christ. This is an approach with a long history, one reflected in fiction and the visual arts (William Blake, Samuel Palmer, Samuel Taylor Coleridge, David Jones and others) as well as in theology. The new biology also adds weight to the point often made by Arthur Peacocke, for example in *Paths from Science towards God: The End of all our Exploring* (2001), that there is 'top-down' causation as well as 'bottom-up' causation, and that wholes influence parts as well as parts giving rise to wholes.

In medicine, a more holistic biology lends strong support to the whole-person approach. To emphasize, we are not against the use of such techniques as molecular biology in medicine. Far from it, we welcome them. Our point is a different one, namely that the (often implicit) presumption made by many that such techniques render redundant consideration of other levels is erroneous, indeed positively harmful.

More recently, the advent of COVID-19 has clearly indicated that a successful response requires action at every level from the molecular biology used to identify new variants through to the regulatory and other measures taken at government level with regards to such diverse considerations as mandating masks and social distancing, and providing temporary economic support to individuals and businesses adversely affected by the pandemic. At the time of writing, one of the notable features of international comparisons is that many countries have done well at one or more of these levels but none has done well at all of them.

Both human health and the workings of the natural world are more complex than biologists' models sometimes presume. We should therefore always be mindful that an approach that takes seriously a number of levels (from molecules, through individual organisms to organisms in ecosystems and beyond) is likely, though more complicated, ultimately to be more fruitful than one that focuses only on one or two of these levels. We also need to remember that there are limits to deterministic predictions. These points do not mean that there is nothing that biology can predict, and, throughout, we try to steer a path between overly reductionist and overly holistic approaches.

*Education*

Finally, we note that the issues we are considering have implications for biology education, which takes place in a number of places and at various times throughout our lives. It happens in our families, in our schools and through such media as popular science books, internet posts, natural history museums, TV and radio. One of the most fundamental issues in biology education is whether one starts with basic scientific principles (e.g., food webs, nutrient cycling and energy flow in ecology; genetics and natural selection in evolution; cell biology in physiology) or with real-life instances (such as the effects of the extinction and re-introduction of wolves in Yellowstone Park; the evolution of the horse; the regulation of the beating of the heart). There are advantages and disadvantages with either approach and there is much to be said for learners of biology coming to appreciate that both bottom-up (reductionist) and top-down (more holistic) approaches can provide us with important ways of understanding what is going on.

Equally, the various metaphors we explore for understanding biological systems each have their place. There is, for example, value in seeing organisms as the product of a natural selection that is blind, selfish and allows for no meaning. Indeed, such an understanding of what it is to be human can help strip away layers of flabby self-congratulation. At the same time, there is value in seeing organisms as entities with purpose, a purpose that started, evolutionarily, simply with leaving copies in succeeding generations, and over time has led to organisms with varying degrees of self-awareness, including to humans capable of appreciating beauty, seeking truth and striving to be good.

It may, therefore, not be possible to find a single unified framework for biological explanations that commands universal agreement. What we are clear about, though, is that particularly in the policy implications of biology, there is real danger from too great an emphasis on either mechanism/reductionism or organicism/holism. We need, more than ever, policy to draw on the best of biology and to be sensitive to the ways such knowledge is employed.

The above observations are all elaborated in our book *The New Biology: A Battle between Mechanism and Organicism* (Harvard University Press, 2023)

References:


Barnes, J. (Ed.) 1984. *The Complete Works of Aristotle*. Princeton: Princeton University Press.

Brown, W., Murphy, N. & Malony, H. N. 1998. *Whatever Happened to the Soul? Scientific and Theological Portraits of Human Nature.* Minneapolis: Fortress Press.

Carroll, S. B. 2005. *Endless Forms Most Beautiful: The New Science of Evo Devo*. New York: Norton.

Clayton, P. 2006. *Mind and Emergence: From Quantum to Consciousness.* Oxford: Oxford University Press.

Dawkins, R. 1976. *The Selfish Gene*. Oxford: Oxford University Press.

Dawkins, R. 1982. *The Extended Phenotype: The Gene as the Unit of Selection*. Oxford: W.H. Freeman.

de Beer, G. R. 1940. *Embryos and Ancestors.* Oxford: Oxford University Press.

Ecklund, E. H. & Johnson, D. R. 2021. *Varieties of Atheism in Science.* New York: Oxford University Press.

Gilbert, S. 2006. The generation of novelty: The province of developmental biology. *Biological Theory*, 1, 209-212.

Gould, S. J. 1977. *Ontogeny and Phylogeny*. Cambridge MA: Belknap Press.

Gould, S. J. 1982. Darwinism and the expansion of evolutionary theory. *Science*, 216, 380-387.

Gregersen, N. H. 2017. The exploration of ecospace: Extending or supplementing the neo-Darwinian paradigm? *Zygon*, 52, 561-586.

Hutchinson, G. E. 1948. Circular causal systems in ecology. *Annals of the New York Academy of Science*, 50, 221-246.

Kauffman, S. A. 1993. *The Origins of Order: Self-Organization and Selection in Evolution*. Oxford: Oxford University Press.

Kauffman, S. A. 1995. *At Home in the Universe: The Search for the Laws of Self-Organization and Complexity*. New York: Oxford University Press.

Kauffman, S. A. 2008. *Reinventing the Sacred: A New View of Science, Reason, and* Religion. New York: Basic Books.

Lewontin, R. C. 1974. *The Genetic Basis of Evolutionary Change*. New York: Columbia University Press.

Lewontin, R. C. 1991. *Biology as Ideology: The Doctrine of DNA*. Toronto: Anansi.

Leyser, O. & Wiseman, H. 2020. Integrative biology: Parts, wholes, levels and systems. In: *Rethinking Biology: Public Understandings*, Reiss, M. J., Watts, F. & Wiseman, H. (Eds). New Jersey: World Scientific, pp. 17-32.

Lineweaver, C. H., Davies, P. W. & Ruse, M. (Eds) 2013. *Complexity and the Arrow of Time.* Cambridge: Cambridge University Press.

Mill, J. S. 1843/1974. *A System of Logic Ratiocinative and Inductive* (J. M. Robson Ed.). Toronto: University of Toronto Press.
Mitman, G. 1992. *The State of Nature: Ecology, Community, and American Social Thought, 1900-1950.* Chicago: University of Chicago Press.
Peacocke, A. 2001. *Paths from Science towards God: The End of all our Exploring.* Oxford: OneWorld Publications.
Reiss, M. J., Watts, F. & Wiseman, H. (Eds) 2020. *Rethinking Biology: Public Understandings.* New Jersey: World Scientific.
Richards, R. J. 2008. *The Tragic Sense of Life: Ernst Haeckel and the Struggle over Evolutionary Thought*. Chicago: University of Chicago Press.
Ruse, M. 2013. *The Gaia Hypothesis: Science on a Pagan Planet.* Chicago: University of Chicago Press.
Van Dyke, F. H., Mahan, D. C., Sheldon, J. K. & Brand, R. H. 1996. *Redeeming Creation: The Biblical Basis for Environmental Stewardship*. Downers Grove, Ill.: InterVarsity Press.
Watts, F. & Reiss, M. J. 2017. Holistic biology: what it is and why it matters. *Zygon*, 52, 419-441.