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Book Review

Making Sense of Development?

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A Review of *Making Sense of Life*: *Explaining Biological Development With Models, Metaphors, and Machines* by Evelyn Fox Keller. Cambridge, MA: Harvard University Press, 2002.

Evelyn Fox Keller offers us an extended meditation on the modern history of developmental biology. In her own description of it, this work is driven not so much by the details and internals of developmental biology as by her wish to discover what it is that counts as an explanation in science. The field of biological development is her type-specimen. This disciplinary history is a workmanlike sampling, but it is a sampling only; the scholarship is a contemporary mixture of history of science with philosophy of science. The study, as she further declares, is in significant part an *empirical* one, rather than a deductive philosophical inquiry.

The author has undertaken to account for several of the large movements, the well-accepted investigative styles and emphases, that dominated research on embryogenesis and, more generally, on the mechanisms of biological development, during the hundred or so years past. In effect it is a search for rules, at least for a generalizable description, of what working scientists in the business think they are doing when they seek to understand (that is, to *explain*) development. Fox Keller sets out to discover what it is about some forms of explanation or conclusion, and is not about possible others, that satisfies or pleases scientists. She will then consider the extent to which that pleasure signals the achievement of understanding. Workmanlike scholarship this is; but in light of its intentions, its success must be measured by the extent to which such rules for, or generalizations about, scientific explanation are discovered and displayed. The somewhat dispiriting general conclusion reached is that there are no rules of doing (this) science that transcend the *tempora* and the *mores*.

The plan of study based on certain assumptions, and those are set forth early. The assumptions have strong philosophical implications. "A description of a phenomenon counts as an explanation…[Fox Keller argues]…if and only if it meets the needs of an individual or community." To be sure. But surely it is unlikely that any widely-practiced, long-lived form of inquiry would be decidedly *contrary* to the needs of the investigator of or the investigator's community. The devil is in the detail of "needs." Relevant needs can be defined and interpreted in a broad range of analytical styles, ranging from a lofty philosophical neutrality (of course the conditions of inquiry vary with time and place!)—with strictly non-presentist historiography, to a thoroughgoing presentist, epistemological relativism. When Fox Keller asserts, then, that "…temporal, disciplinary, and cultural specificity of needs is responsible for the specificity of what I call the epistemological culture," the reader has no way of knowing, definitional clarity aside, where on the spectrum of epistemological positions her conclusions will lie. By that definition, the author's conclusions will depend upon *her* needs and those of her professional milieu.

In fact, the good match of explanations to needs is a truism. Or, the statement of it is equivalent to the following claim: that what is accepted as explanation (we speak here of scientists, not of all humanity), that is, what is taken by them to be truth-indicative, depends significantly or primarily on socio-cultural factors rather than on the internal logic of the science at a particular time. Working developmental biologists, faced with that opening to what is clearly an historically erudite account, will be astonished, amused, or annoyed, depending upon their acquaintance with contemporary science studies.

But amusement would be foolishly patronizing. Whether or not the implied epistemological relativism is serious, the author derives from it a strong and therefore interesting corollary claim. It is, in her own words, that "…[D}espite such unquestionable success [during the last 100 years of biology] , biology is scarcely any closer to a unified understanding (or theory) of the nature of life than it was a hundred years ago." A serious claim indeed, and if true, nothing to be patronized, or amusing. Whatever it turns out the "unified" means, there cannot be a significant number of life scientists, including the most historically- and philosophically-aware among them, who would agree that no progress toward conceptual unification was made during twentieth century. If the mystery of mysteries is, as Fox Keller believes, "the nature of life," then biologists generally and most developmentalists in particular are convinced that progress toward unification and understanding has been spectacular. Indeed, the contemporary rise of "evo-devo" (the evolution of developmental mechanisms) is the case in point for all biology.

Fox Keller's narrative proceeds by way of a series of vignettes, all of them not only interesting but gracefully written. They are grouped, for purposes of this

investigation, as three Parts, each comprising several chapters. Part One ("Models: Explaining Development Without the Help of Genes") deals with efforts, especially in the decades surrounding the opening of the twentieth century (nothing much about "genes" then to think about), to explain development with the aid of models that were meant to be simplifying but assumed close enough to the biological reality to be informative. This begins with the inorganic chemical and physical "models" à la Stephane Leduc, of cells, cell division, cellular motility, and plant growth that fascinated students (and some, but by no means most professional biologists) for about a decade. Within Part One, comparative and analytical morphology, and then the early, triumphantly announced, but soon forgotten mathematical models of developmental processes—from Rashevsky to Turing—are discussed. This is a progression of models from the wet laboratory demonstration to the abstract and mathematical.

Part Two ("Metaphors: Genes and Developmental Narratives"), the second set, represents the real paradigm shift of twentieth-century biology. Embryologists began to think seriously about heredity, about genes, and about their expression as controlling development. Some of them, of course, ended by thinking about nothing else, that is, of ontogeny as explained by a catalogue of genes. Fox Keller, like most of her peers in science studies, is basically of such gene-centeredness. Part Three (Machines: "Understanding Development with Computers, Recombinant DNA, and Molecular Imaging") is intended as a survey of the contemporary preoccupations of developmental biologists, driven as they obviously are by the marvelous technologies and machines enumerated in the Part title. It should be noted that these technologies are macromolecule-centered, and therefore still gene-centered, since the former are encoded in the latter.

One sample from among the book's samples: "Morphology as a Science of Mechanical Forces," an early chapter, in Part One the book, deals with the work of D'Arcy Thompson and his masterpiece, *On Growth and Form*, first published in 1917 and issued in final revision in 1942. Masterpiece indeed it was and is, as measured for example by the plaudits of best-known biologist-essayists such as Joseph Needham, Peter Medawar, and Stephen Jay Gould, and by its inevitable presence in elevated monographs and textbooks on morphology and development. Fox Keller's is a useful account of the origin and the purposes of Thompson's work as he and his admirers saw it. And yet, of course, despite the universal appreciation, *On Growth and Form* has had negligible effect on the growth and form of biological explanations, including those characteristic of developmental biology. Appropriate to her purposes in this book, therefore, the author examines Thompson's explanatory intentions and analyzes their failure, in the end, to have *counted* as explanation, or understanding, of morphology or development.

Thompson was engaged on the same great task as were most of his

colleagues in the early twentieth century—the demonstration that ordinary physical forces and processes are sufficient for an understanding of "the nature of life." And of course he had the missionary fervor that we see often enough in those who come to biology with strong preparation in physics and mathematics: to show that life can be explained using the appropriate simplifying assumptions and sound physico-mathematical reasoning. It is clear, in fact, that for D'Arcy Thomson and many of his contemporary admirers, a dynamical theory of biological form could explain it—and the process, development, by which its characteristic finished condition, the phenotype as we would now call it, is achieved.

Accordingly, he was dismissive of that key element of Darwinism—and also the most misunderstood, and most misrepresented element of it: "gradualism." Thompson could show, by formal geometrical analysis alone, how a vast array quite different, but related, forms might be generated from a particular basic body plan; but there was no "gradual" transformative pathway from a squid to a beetle to be found in geometric modeling. So for Thompson and his followers, "gradualism" had to be wrong. Thompson knew no genetics, at the start, because there wasn't any. His formalistic tastes and biases, later when there was a developmentally-relevant genetics, allowed him to ignore genetics; and of course, Darwin's ideas on hereditary mechanism had been wrong. Fox Keller's view of all this is, however that far from a matter of specific knowledge lacking: it is a conflict of epistemological cultures. And indeed, by the late 1930s, genetics had begun its invasion both of morphology and of development, and the experimental/ observational culture of (which had already begun in the prior century as "entwicklungsmechanik") had triumphed over abstract modeling.

Nevertheless Fox Keller's conclusion, as generally engaging as is the rest of the book, is unsatisfying. It invokes a vague cultural phenomenon as explanation (!) for what seems, to many of us at least, the normal, straightforward, internal process of scientific change: the dependence for success of new theory on the extent to which it suggests hard tests, makes meaningful predictions (for observation as well as for experimental outcomes), and encompasses regular but heretofore peripheral phenomena that were not neatly explicable under preceding theory. Dynamical morphology was superlative, elegant description, and it suggested interesting physical analogies and mathematical descriptors for biological form and development. But it remained description, which is not explanation.

What superceded it—the modern synthesis of evolution and, especially, the reductionist discoveries of experimental embryology and later of molecular developmental biology—gave life scientists work to do beyond elegant contemplation, and provided an inexhaustible supply of potentially falsifying tests, strong experiments, and observations at all levels from the molecular and subcellular to the organism to the population of organisms to the ecosystem. Of

course this was a change of culture! But it is not at all clear what is meant by the claim that it has been a change of *epistemological* culture. There do not seem to have been significant changes, over its course, in formal and informal logic, in the applications thereof, or in the slow process whereby vast numbers of replicable results and observations fill up the conceptual matrix of the way the world is. It is within that ever-expanding matrix that warrant and justification for new theory (and explanation!) emerge as—trajectories.

Making Sense of Life is eminently worth reading, especially for younger developmental biologists who tend, these days, to be uninformed on a number of significant historical trends in their subject. It is a learned and stylish short history of what is rapidly becoming the frontier sub-discipline of evolutionary as well as cellular and organismal biology. There is no need to accept the author's conclusion that "the question of what qualifies as a scientific explanation may not be answerable in absolute terms, but perhaps…that is only as it should be." In what relative terms, then, the question *is* answerable, one is hard-put to know from the argument. Nonetheless, Fox Keller's selection of narratives, and their organization in this work, make it a useful contribution to the modern history of this important scientific field.

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