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The philosophy of biology is one of the most exciting new areas in the field of philosophy and one that is attracting much attention from working scientists. This *Companion*, edited by two of the founders of the field, includes newly commissioned essays by senior scholars and by up-and-coming younger scholars who collectively examine the main areas of the subject – the nature of evolutionary theory, classification, teleology and function, ecology, and the problematic relationship between biology and religion, among other topics. Up-to-date and comprehensive in its coverage, this unique volume will be of interest not only to professional philosophers but also to students in the humanities and researchers in the life sciences and related areas of inquiry.

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philosophy of biology and in the relationship of epistemic and ethical values in science. His book *Tower of Babel*: *The Evidence against the New Creationism* has been reviewed in more than fifty publications; the *New York Review of Books* called it "the best book on creationism in all its guises." Dr. Pennock also does scientific research on experimental evolution and evolutionary computation, some of which was featured in a cover story in *Discover* magazine. Pennock speaks regularly around the United States on issues of science and values and was named a national Distinguished Lecturer by Sigma Xi, the Scientific Research Society.

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Embryology, Epigenesis, and Evolution: Taking Development Seriously (Cambridge University Press, 2004).

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PREFACE

The philosophy of biology is one of the most vigorous and exciting areas in modern philosophy. There are many active researchers and their students, there is a plethora of new ideas and suggestions, there are good-quality, dedicated outlets for the work – notably the journal *Biology and Philosophy* – and there are organizations – notably the International Society for the History, Philosophy, and Social Studies of Biology – that embrace and encourage the workers in the field. This heady and forward-looking community is of recent vintage. Although in the history of philosophy some of the very greatest thinkers – Aristotle in the ancient world and Immanuel Kant in the modern world – had things of great importance to say about the life sciences, for much of the past two hundred years biology was ill served and little regarded by philosophers. This will seem strange. After all, in the nineteenth century came the great evolutionary theory of Charles Darwin, expounded in his *On the Origin of Species by Means of Natural Selection* in 1859, and in the twentieth century there was the coming of molecular biology, as represented by the double helix discovered in 1953 by the American James Watson and the Englishman Francis Crick. Generally, however, it was physics that caught the attention of philosophers. Biology was often neglected or worse, being put to use by people with deeply antiscientific metaphysical agendas, especially the vitalists at the beginning of the twentieth century.

Conditions started to change about forty years ago, in the 1960s, at first slowly and then with increasing speed as the topic attracted attention. A number of young philosophers of science took note of the exciting developments in the biological sciences, not just

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molecular advances but also the ways in which traditional areas (notably evolutionary biology) were now developing new ideas and attracting first-class minds. These philosophers sensed that there was an important part of science that was neglected, and they moved to understand and work on the conceptual problems that are always raised by empirical studies. At the same time, a number of biologists started to turn seriously to philosophy for help in articulating issues in their science, realizing that good empirical work demands sound philosophical bases to the theories and models that guide research. Spurring and stimulating each other, the philosophers and biologists worked on such issues as the nature of evolutionary explanation and the role played by Darwin's mechanism of natural selection; the extent to which biology is an autonomous science and whether issues like teleology and historicity mark the life sciences as something irreducibly different from the physical sciences, or whether ultimately these are matters that drop away in a mature science; problems of classification, both about the basic units of division (notably species) and about the proper way to conceptualize life's history (the coming of phylogenetic systematics, or cladism, was a major issue here); the relationship between the older Mendelian genetics and the newer molecular genetics, and whether this was a case of theory absorption (reduction) or of theory change (replacement); as well as related topics. Perhaps reflecting the interests of the early researchers, perhaps reflecting the fact that it is simply of great philosophical interest in its own right, evolutionary theory tended to dominate discussions, and indeed you will sense that this tendency persists to this day.

In the past four decades, biology itself has continued to advance in many exciting ways. The already-mentioned revolution in classification, systematics, brought on fiery debates about the nature and intentions of workers in the field, and ever-increasing sophistication as molecular techniques became readily available, backed by the increasing power of computer programs. There was the development of the evolutionary approach to social behavior, sociobiology, with highly controversial attempts to expand the science from other animals to us humans. There were debates about the history of life as revealed through the fossil record, and whether pure Darwinism is adequate as an explanation, or whether new approaches (particularly

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the theory of jerky change, punctuated equilibrium) demand new theoretical approaches. Most recently, there has been the revival of embryology and consideration of the ways in which this can be improved and extended through molecular findings. The field of evolutionary development, or "evo-devo," has attracted some of the best biological minds of the generation.

Philosophy has responded to these developments in the biological sciences. They offer new challenges to those who are interested in deep conceptual issues of science, and at the same time they offer new insights into some of the perennial questions of philosophy itself, about knowledge and truth and about action and morality. It is this response that we as editors have tried to capture in this *Companion*. We have tried to give the reader a sense of the exciting work that today characterizes the discipline or subdiscipline of the philosophy of biology. We have not tried simply to give a survey or a textbook introduction. There are already good works of this ilk, some written by contributors to this *Companion*. Rather we have tried to give a sense of the issues that engage today's philosophers of biology and an understanding of how these issues are tackled. We have asked our contributors to write in a way and at a level that a nonexpert would find interesting and understandable, but at the same time we have emphasized that this should not be at the expense of trying to tackle complex problems and showing by example of work in action rather than simply through overall surveys.

We did not set out to impose formal divisions on the subject and we would like to think that all of the contributions to the *Companion* are freestanding, in that one could read any one in isolation from the others. However, the reader will sense that there is a kind of informal flow to the issues, with one topic leading naturally to another, and we have tried to reflect this in the order in which the contributions are presented. We start with Darwin's theory of evolution through natural selection, or rather with its modern-day successor. For Darwin, as for today's evolutionists, the important point about selection is that it explains not just change but change of a particular kind, namely, in the direction of adaptive advantage – it explains the eye and the hand and all of the other organic features that were at the heart of the traditional argument from design for the existence of God. It is this topic of adaptation that is the focus of Tim Lewens's contribution, as he teases apart the meaning of the term in

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modern science and tries to assess its significance as something in need of explanation.

From adaptation, with the contribution by Roberta L. Millstein and Robert A. Skipper Jr., we move to the structure and nature of modern evolutionary thinking. After Darwin, the most important advance in such thinking accompanied the discovery and development of genetics, the theory of heredity. This transformed our ideas about the past, especially after the so-called population geneticists embedded natural selection in a theoretical framework based on Mendelian genes interacting in groups. Millstein and Skipper discuss how this happened and then go on to look at some consequences, especially whether the importance of selection is now diminished by other factors, notably Sewall Wright's notion of genetic drift, essentially a matter of random change caused by contingent factors overwhelming the systematic effects of differential reproduction. From here we move naturally and smoothly to Elisabeth A. Lloyd's essay, which takes up a topic that plagued Darwin himself and which has raised much discussion in recent years, about the level or levels at which natural selection may be said to act, in particular whether it is always something between individuals, perhaps even between "selfish genes," or whether it can and does act significantly at higher levels between groups. Then, completing this part of the *Companion*, we have an analysis by Robert N. Brandon and Grant Ramsey of some of the most interesting issues that emerge from modern evolutionary thinking, namely, those that concern the statistical nature of the theory and how it works with and tries to explain the actions and effects not of individuals working alone but of individuals in groups and of the cumulative results.

Next comes a batch of articles dealing with some of the issues in the philosophy of biology that relate to traditional questions in the philosophy of science. Much time has been spent on questions about whether new theories are absorbed into old theories (reduction) or whether they simply push them aside and replace them. The essay by Paul E. Griffiths and Karola Stotz opens the way for discussion of this topic in biology with respect to the nature of genetics and how concepts of the gene have changed through the years, especially in the light of the coming of molecular techniques and theories. Complementing this piece is the contribution by Peter Godfrey-Smith, taking up the topic of biological information and of how and

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in what sense something like the gene (or in its modern guise, the DNA molecule) can be said to carry such information. After this, Alexander Rosenberg gives us a more general discussion of reduction in biology and the ways in which one can and should expect continuous change between theories of different times and levels. From here we move to Lindley Darden, who looks at explanations in biology and at how models are an important factor in trying to explicate mechanisms. André Ariew then brings this kind of discussion to a conclusion by surveying and discussing a perennial question for the philosopher of biology: whether in some sense evolutionary understanding is teleological or forward-looking in a way alien to the physical sciences, and whether in some sense this represents a nonreducible factor that enters into all explanations in the life sciences.

Thanks to people like the late Stephen Jay Gould, there has been much written recently by biologists about the relationships between microprocesses of change and the overall macronature of life's history. Can the latter be explained in terms of the former? This is the topic of Kim Sterelny's contribution, which focuses on a notion that he calls ''minimalism,'' namely, the thesis that small-scale changes can explain all. The ways in which this topic ties in with some of the earlier contributions about reduction hardly need stressing. The systematist Maureen Kearney then discusses the perennial problem of biological classification and the extent to which it can and should reflect life's history. Her contribution reflects some of the (earlier-mentioned) major debates that have occurred in this area, particularly about the nature of biological species and whether they are to be considered as individuals or as groups, and then about the techniques and significance of the apparently all-conquering taxonomic approach of the cladists with their interesting (and controversial) assumptions about such notions as simplicity or (as they call it) parsimony.

Biologically speaking, humans may or may not be the most important of all organisms. They are certainly the organisms of most interest to us humans! The geneticist Francisco J. Ayala gives important background to the problems facing researchers into the evolution of humans. In the light of the completed mapping of the human genome, he stresses that we still face issues about how we sense and feel, how the mind emerges and its connection to the

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material body, and how and why humans emerged from the ape line. David J. Buller then rows into controversial waters surrounding the new science of human sociobiology or (as it is now often called) evolutionary psychology. Is human nature to be explained as a function of the genes as sifted by natural selection, or is this approach altogether too simplistic? In her discussion of neurobiology, Valerie Gray Hardcastle takes up in more detail some of the issues raised by Ayala. She stresses how in attempts to understand the functioning of the brain and its relationship to mind, methodological and metaphysical questions arise, and often it is not easy to tease out the questions that should be asked and the relevance of empirical findings that result from research.

Next, going from the general to the more particular, Christopher Horvath turns to the much-discussed topic of human sexual orientation. He stresses the way in which when we get to controversial aspects of human nature it is not easy to disentangle strongly held social and moral beliefs from more objective scientific findings and theories. Horvath's contribution illustrates the way in which modern philosophy of science, philosophy of biology in particular, has moved from participating in purely theoretical discussions to addressing issues of immediate societal interest and concern – and so to moral theory and behavior. For almost all of the twentieth century, thanks particularly to the devastating critique in G. E. Moore's *Principia Ethica* (1903), attempts to relate biology to ethics were regarded as the philosophical equivalent of a bad smell – not just wrong, but in some sense unclean. Matters have changed dramatically in recent years, thanks to the development of such areas as sociobiology but also thanks to formal work by economists and philosophers and others. Very significant has been work on the topic of game theory and how it applies to human evolution. In his contribution, Zachary Ernst introduces us to this topic.

For much of the nineteenth century and well into the twentieth century, embryology was an important part of the biological scene. Then with the coming of genetics and the move to molecular topics, it rather dropped from sight, being regarded as somewhat of a descriptive topic of little theoretical interest. In the past two or three decades, as mentioned, conditions have changed dramatically as molecular biologists and evolutionists have joined forces to look at development. Today evolutionary development, or evo-devo, is one

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of the hottest areas of biological research. The historian and philosopher of science Jane Maienschein opens our cluster of articles on this topic, looking at the changing meaning of the notion of an embryo, how it evolved from rather crude notions in the eighteenth century to a variety of sophisticated concepts today. She stresses in a fashion akin to that of Horvath that, in discussions of this nature, it is often difficult to distinguish claims of fact from deeply held moral, social, and religious beliefs. Manfred D. Laubichler follows with a more detailed discussion of evo-devo and stresses how it opens up questions of great philosophical interest. He himself focuses on the problem of innovation and of how new features get produced and introduced into populations. Is this a challenge to traditional Darwinian explanations that emphasize the all-sufficiency of natural selection? Jason Scott Robert concludes this part of the *Companion* by looking at how molecular biology has brought new insights. He talks of "systems biology," the area of study that looks at how the genes get translated and used to build the functioning organism, referring explicitly to ethical issues that are raised and showing that at this point philosophy of biology touches on and in respects blends with the sorts of concerns that occupy bioethicists.

In the early years of contemporary philosophy of biology, ecology was curiously and unfortunately overlooked. Although environmentalists were raising important issues, most of which called out for detailed analytic scrutiny, philosophers of biology were unresponsive. Things have now changed, and there is increasing interest in the issues raised by the interactions of organisms on a daily (rather than historical and evolutionary) basis. Gregory M. Mikkelson gives us a background to ecology and the philosophical issues that it raises. He shows how there are questions about the notion of hierarchy, from individuals up to groups and then to whole systems; about the relationship of ecology to evolutionary questions; about the very notion of law-governed explanations in ecology (is it more of a subject dealing with the unique and the contingent?); and about the extent to which ecologists should be naturalists, observing what is happening in the wild, and the extent to which they should be experimenters, manipulating situations and trying to predict outcomes. Sahotra Sarkar follows by looking at concepts of ecological diversity, and how in their new guise of "biodiversity" many fascinating philosophical questions about understanding and measurement get raised.

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Coming to the end of the *Companion*, we have next Robert T. Pennock, who takes up the question of biology and religion. Pennock has been much involved in the fight against creationists, particularly in their new incarnation as so-called intelligent design theorists. His contribution reflects this activity, but he aims to put his discussion in the broader context of biology and religion generally, and thus he is led into issues such as the meaning of morality in a post-Darwinian world, as well as the autonomy of religion itself. Is it just an adaptation like any other and does this have implications for its truth value? Pennock raises the issue of biology, religion, and sexual orientation, and it is interesting to compare his thinking with the earlier contribution of Christopher Horvath on the same topic. Finally, through an examination of the thinking and use of language of the nineteenth-century biologist Ernst Haeckel, the historian and philosopher of science Robert J. Richards takes on questions about understanding science by the study of the history of the subject. We think this a particularly appropriate contribution with which to end the *Companion*. The relationship between the history of science and the philosophy of science has not always been as intimate and fruitful as one might desire, but the philosophy of biology has been exceptional in the ways in which it has (as many of our contributions show) drawn on the history of biology for insights about the conceptual nature of present-day biology. Richards's contribution shows the value of this practice and why it should be cherished and encouraged as a mode of inquiry by the next generation of philosophers of biology.

We hope that you enjoy the collection. Good philosophy, like good science, is never finished. If you are lucky, you have more questions at the end of the day than at the beginning. We invite you to engage with our contributors and to add to the exciting advances in the philosophy of biology. We invite you also to take a moment and think about the man to whose memory this volume is dedicated. Ernst Mayr, who died in 2005 in his hundred-and-first year, was a German-born taxonomist who emigrated to America and became one of the most important and influential evolutionists of the twentieth century. He was always interested in philosophy and was the leader among those mentioned earlier who worked from the side of science to develop the newly invigorated field of the philosophy of biology. This volume in your hands started in 2001 as the first conference at Florida State University sponsored by the legacy of William H. and Lucyle T. Werkmeister.

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Mayr, very old, still spent his winters in Florida and was invited to the conference. He accepted, but the organizers were warned that he would stay only a short while, that much attention must be paid to the needs of old age, and that he would be too fatigued to attend any social events. He arrived and within minutes was on his feet making points, leveling objections, and stressing the correct (that is, Mayrian) way of seeing things. On the Saturday, he started at nine o'clock in the morning and insisted on joining the participants in an afternoon trip to Wakulla Springs, a local beauty spot of unspoiled river with alligators, fish, and many birds (the site of the original Tarzan movies as well as the classic science fiction movie *The Creature from the Black Lagoon*). Mayr stood in the prow of the boat, identifying birds and explaining the differences since his last trip to the spot in 1931. At ten o'clock that night, the exhausted organizers finally had to shuffle Mayr out of the door and insist that he go home to bed! Ernst Mayr was a great scientist, but more than this, he was a mensch. For the editors especially, who frequently were the focus of Mayr's scolding, it is a real privilege to acknowledge our debt and our love.

More immediately, the editors thank Jason Zinser, who was our assistant on this project, and Alan Casselman, who worked on the bibliography. Sadly, because of his too-early death, we cannot thank Terry Moore at the Press, who responded with such enthusiasm to the idea of this volume, but we do remember him with gratitude. Beatrice Rehl, who took over the project, has supported and helped us in an exemplary way. We are grateful to our production editor, Janis Bolster, and our indexer, Lin Maria Riotto. Finally, the editors want to thank each other. We have been fellow philosophers now for forty years and good friends from the beginning. Never a cross word has been exchanged between us. Deliberately, we did not ourselves contribute to the volume, wanting rather to commission and promote the work of others. It is the field or discipline of the philosophy of biology that is our main creation, and inasmuch as this volume shows that we have succeeded, it is because each of us knows how much we owe to the other.

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