Oxford Bibliography in Philosophy of Evolutionary Biology

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Introduction

Philosophy of evolutionary biology is a major subfield of philosophy of biology concerned with the methods, conceptual foundations, and implications of evolutionary biology, as well as the relationships between evolutionary biology and neighboring fields, such as biochemistry, genetics, cell and molecular biology, developmental biology, and ecology. One can roughly distinguish three major approaches to the philosophy of evolutionary biology. The first starts with questions of interest to philosophy of science, more generally, and then considers evolutionary biology as a special case. For instance, one long-standing debate in philosophy of science concerns the distinction between science and pseudoscience. Various criteria have been proposed to demarcate science’s aims and methods, and whether evolutionary biology meets these criteria is a matter both of interest to philosophers, science educators, and indeed, the larger public. Another longstanding debate in philosophy of science concerns whether there is any legitimate role for values in science, and whether the influence of values is always pernicious. The study of the evolution of human behavior and cognition has been scrutinized as an instance of both potentially pernicious and positive influence of values in science. A second approach draws upon evolutionary biology to address broader questions of philosophy. For instance, some have turned to evolutionary biology in service of exploring questions about whether and in what sense events or states of affairs in the natural world are “contingent,” what it means to speak of an organism having consciousness, intentions, or intelligence, or whether human beings are disposed to be rational or altruistic. A third approach engages with debates internal to evolutionary biology, using the tools of philosophical analysis. Of course, these tools are not unique to philosophy; scientists as well as philosophers engage in conceptual and methodological debates about the scope and limits of various models or theories, or how best to define theoretical concepts. In this third category, then, the line between science and philosophy blurs; the participants in many of these debates are both philosophers and biologists. Debates over the appropriate conditions for testing hypotheses about adaptation, the role(s) of optimality modeling, the units, targets, or levels of selection, mechanisms and measures of inheritance, classification and systematics, are all examples of debates internal to evolutionary biology, to which philosophers and scientists have contributed.

**General Overviews**

Brandon, Robert. 1990. *Adaptation and Environment*, Princeton, N.J.: Princeton University Press.

Brandon gives an exposition of his Principle of Natural Selection (PNS), which he uses to undermine the tautology objection (the argument that appeals to fitness are not explanatory, but circular), to engage with debates about levels of selection, and the nature of explanations in evolutionary biology.

Godfrey-Smith, P. (2009). *Darwinian Populations and Natural Selection*. Oxford University Press.

Godfrey-Smith provides an account of the minimal conditions for a Darwinian population, and offers a multi-dimensional measure of more or less paradigmatic cases. Paradigmatic Darwinian populations have high fidelity of heredity, abundance of variation, strong dependence of fitness on intrinsic characters, and a variety of other properties. Godfrey-Smith uses this model to consider marginal cases (such as evolution of cultural artifacts) and to examine the nature of reproduction and biological individuality.

Kitcher, P. (1993). *The Advancement of Science:**Science without Legend, Objectivity without Illusions*. Oxford University Press.

Kitcher’s classic book is a defense of scientific realism – i.e., science progresses via the identification of natural kinds and objective relations. He argues that the individual motivations and cognitive values of scientists and the social structure of science promote progress. His case study is Darwin’s “explanatory schemata,” which made possible a progressive research program.

Lloyd, E. A. (1988). *The Structure and Confirmation of Evolutionary Theory*. Greenwood Press.

Lloyd defends the semantic view of the structure of scientific theories, according to which theories are families of models (versus the “syntactic” view, according to which scientific theories consist in sets of laws). Lloyd gives a detailed discussion of how classical population genetics can be thus described, and describes how confirmation works on such a picture.

Pigliucci, M. and Kaplan, J. M. (2006). *Making Sense of Evolution: The Conceptual Foundations of Evolutionary Theory*. University of Chicago Press.

The authors explain how certain conceptual mistakes or habits of thinking have led to deployment of methods that are unsuitable to test various hypotheses, e.g., about the effects of selection, the unit or target of selection, the role(s) of constraint, and the mechanisms of speciation. They engage with both methodological questions, e.g., about use and abuse of genetic variance-covariance matrixes, and conceptual debates about, e.g., the nature of species.

Sober, E. (1984, 2004). *The Nature of Selection: Evolutionary Theory in Philosophical Focus*. MIT Press. (see also: (2008). *Evidence and evolution: the logic behind the science*. Cambridge University Press.)

Sober (1984) discusses the nature of natural selection, the role of chance in evolution, and the ways evolution is a probabilistic theory. He also explains why the tautology objection to evolutionary theory is misguided, criticizes Dawkins’s “gene’s eye view,” and explains the conditions under which altruism is likely to evolve. Sober’s recent (2008) illustrates how Bayesian and Likelihood approaches can be used to confirm in hypotheses in evolution.

Wimsatt, W. C., & Wimsatt, W. K. (2007). *Re-engineering philosophy for limited beings: Piecewise approximations to reality*. Harvard University Press.

This book contains classic essays by Wimsatt about the roles of modeling and idealization in science, scientific realism and reductionism, reductive heuristics and biases in science, and science as an evolutionary process. Wimsatt’s view is that humans are products of contingent evolutionary and developmental histories, such that our cognitive abilities, behaviors, and the history of science, are shaped by various trade-offs, and forms of entrenchment.

**Textbooks**

**Monographs:**

Okasha, S. (2020). *Philosophy of Biology: A Very Short Introduction*. Oxford University Press.

Godfrey-Smith, P. (2016). *Philosophy of Biology*. (Princeton Foundations of Contemporary Philosophy). Princeton University Press.

Sober, E. (1999). *Philosophy of Biology*. Westview Press.

Sterelny, K. & Griffiths, P.E. (1999). *Sex and Death: An Introduction to Philosophy of Biology*. University of Chicago Press.

Rosenberg, A. and McShea, D. W. (2008). *Philosophy of Biology: A contemporary introduction*. Routledge.

**Edited collections:**

Downes, S.M. and Machery, E. (2013). *Arguing About Human Nature*, New York: Routledge.

The text is organized into major topics and subtopics – Section 1 is “Human Nature and Evolution”; Section 2 is “Human nature and Human Diversity”; and Section 3 is “Human Nature and Normality.” Each section covers a range of topics: e.g., innateness, genetic determinism, human universals, social construction, race, sex, and transhumanism. The book contains both classic and contemporary articles by philosophers and scientists.

Fox Keller, E. & Lloyd, E.A. (1992). *Keywords in Evolutionary Biology*. Harvard University Press.

This is a classic, comprehensive introduction to key ideas in evolutionary biology, with chapters by Beatty, Crow, Darden, Feldman, Kevles, Kimura, Kitcher, Lewontin, Sober, Wade, and Sloan Wilson. Chapters are both historical, and address current controversies over adaptation, altruism, characters, competition, Darwinism, environment, epigenetics, epistasis, eugenics, fitness, gene, neutralism, parsimony, random genetic drift, sexual selection, species, and more.

Hull, D. L. and Ruse, M. (eds.) (1998). *The Philosophy of Biology*. Oxford University Press. (see also: 2007. *The Cambridge Companion to the Philosophy of Biology*. Cambridge University Press.)

A very useful general introduction to philosophy of biology, with chapters on major topics ranging from human sexuality, to genes, to species, to phylogenetics. The more recent volume contains excellent essays on an array of topics from human nature to ecology.

Livingstone Smith, D. (ed.), (2017). *How Biology Shapes Philosophy: New Foundations for Naturalism*. Cambridge University Press.

Classic and contemporary papers illustrate how biology has influenced philosophical thinking on topics ranging from the emergence of conscious experience, to the origins of morality. Further topics include the nature of rationality, the scope and import of evolutionary biology for theories of human nature, sex and race. Essays are by Dennett, Neander, Okasha, Machery, Godfrey-Smith, Dupré, and others.

Matthen, M. & Stephens, C. (eds.). (2007). *Philosophy of biology*. Elsevier.

One of a series of handbooks, the book includes both biographical chapters on major figures in the history of biology, as well as specific topics: natural selection, evolvability, levels of selection, species, homology, phylogenetics, reduction, functions, innateness, evolutionary ethics., etc.

Mayr, E. & Provine, W. B. (eds.). (1980). *The Evolutionary Synthesis: Perspectives on the Unification of Biology*, Harvard University Press.

This collection of essays is a landmark text in the history of the modern synthesis. The essays offer a window into particular view of the history of the modern evolutionary synthesis as understood by some of the major players in the U.S. and Europe: Mayr, Stebbins, Dobzhansky, Rensch, and Ford. There are also excellent essays by historians and philosophers of evolutionary biology, including Allan, Provine, and Shapere.

Sarkar, S. & Plutynski, A. (2008). *A Companion to the Philosophy of Biology*. Blackwell.

This contains chapters on a wide range of topics in biology – from ecology to human behavior – a third of which focus on conceptual and methodological issues in evolutionary biology specifically. Lewontin contributed an essay on heredity and heritability; Lennox on Darwin and Darwinism; Ereshefsky on systematics; Stephens on population genetics; Okasha on units and levels of selection; Dietrich on molecular evolution; Godfrey-Smith and Wilkins on adaptation; and Bickerton on the evolution of language capacities.

Singh, R. C., Krimbas, B., Paul, D. B., & Beatty, J. (eds.) (2001).*Thinking About Evolution.*(Historical, Philosophical, and Political Perspectives, vol. 2). Cambridge University Press.

This collection of essays is the second of two volumes honoring the work of Richard Lewontin. Contributors worked in Lewontin’s laboratory at Harvard from the 1970s through the early 90s. Topics covered include genetic determinism, concepts of fitness, methodological and conceptual issues in behavioral genetics, the history of eugenics, and the units and levels of selection.

Sober, E. (2006). *Conceptual Issues in Evolutionary Biology*. (3rd Edition) MIT Press.

There are several editions of this text, which contains classic papers that set the terms of debate for over a decade on fitness, species, methods of phylogenetic inference, units and levels of selection, and the evolution of morality.

**Journals:**

*Biological Theory*

*Biology and Philosophy*

*Studies in the History and Philosophy of Science Part C: Biological and Biomedical Sciences*

*History and Philosophy of the Life Sciences*

*Acta Biotheoretica*

*Philosophy of Science*

*Philosophy, Theory, and Practice in Biology*

*British Journal for Philosophy of Science*

**Special Topics**

**Evolution and Intelligent Design**

The question of whether and in what sense evolutionary biology is a legitimate scientific enterprise has been a central concern of philosophers, religious scholars, educators, politicians, and the general public, for nearly a century. In the U.S., in particular, there has been a history of legal battles over teaching evolution in public schools. Defenders of either creationism, or more recently, “intelligent design” (ID), have argued that evolutionary biology is either not science, or, that ID is a legitimate scientific theory, warranting equal time in the science classroom. Philosophers of biology have sought to combat such arguments.

Kitcher, P. (1982). *Abusing science: The case against creationism*. MIT press.

Kitcher’s 1982 book provides an overview of problems with naïve falsificationist views of science, and an argument for the legitimacy of evolutionary theory, in light of its independent testability, unifying power, and fecundity. It also provides a critical summary of the variety of objections to evolution mounted by creationists, and a critique of appeals to tolerance as grounds for the ‘equal time’ argument.

Kitcher, P. (2007). *Living with Darwin: Evolution, Design and the Future of Faith*. Oxford University Press.

Kitcher’s 2007 book engages with many of the moral and religious concerns motivating the objection to teaching evolution in public schools, such as how evolution seems to pose a challenge to Christian providentialism (the view that all events are determined by God, and that God has a special concern for humanity and its salvation).

Pennock, R. (1998). *Tower of Babel: Scientific Evidence and the New Creationism*. M.I.T. Press.

Pennock’s book gives a history of a variety of different forms of creationism, and gives an argument for evolution as legitimate science. Pennock’s book is notable for its discussion of parallels between the evolution of life on earth and the evolution of languages, its explanation and discussion of “naturalism,” and engagement with values and motivations underlying objections to the teaching of evolution in public schools.

Sarkar, S. (2007). *Doubting Darwin?: Creationist designs on evolution*. John Wiley & Sons.

Sarkar’s book is an accessible and philosophically sophisticated overview of arguments creationists have mounted against evolutionary biology, exposing their various flaws. The book also provides a thoughtful analysis of key concepts deployed by intelligent design advocates: the “no free lunch” theorems, “irreducible” complexity, and “biological information.” Sarkar also engages with the cosmological and “fine tuning” arguments, and debates over various species of naturalism.

Sober, E. (2018). *The Design Argument*. Cambridge University Press. (See also: Chapter 2 of (2008). *Evidence and evolution: the logic behind the science*. Cambridge University Press.; (2007). What is wrong with intelligent design? *The Quarterly Review of Biology*, 82(1), 3-8.; (2004). The design argument. *The Blackwell guide to philosophy of religion*, 117-147.; (1999). Testability. *Proceedings and Addresses of the American Philosophical Association*, 73(2): 47-76.)

Sober gives critical analyses of various forms of the design argument (Sober, 2018, 2007, 2004, 1999b). He explains how appeals to design often involve various fallacious forms of reasoning, for instance, by deploying false contrasts between mere “chance” and design. In his 2008, he also explains how one can model hypothesis testing in evolutionary biology using both likelihoodist and Bayesian frameworks.

**Laws in Evolutionary Biology**

Whether there are laws in biology generally, and in evolutionary biology specifically, is a contested matter. In part, the debate has to do with what a “laws of nature” is, and in part, it has to do with the character of generalizations found in evolutionary biology. Some insist that laws must be “necessary” truths, i.e., that they could not be otherwise. On this view, it may seem that there can be no biological laws, since living things, their properties and behaviors, are (generally agreed to be) contingent products of historical events. If the earth were somewhat further from the sun, or the biochemistry of the early earth were slightly different, there may never have been life on earth at all, let alone the particular kinds of living things or typical patterns and processes we see. The contingency of both the particular and general patterns and processes typical of life on earth, would, on this very stringent view of laws, render evolutionary biology not suitably law-like. On a more permissive view of laws of nature, however, all that is required is that laws perform the *function* typical of laws in science – namely, featuring centrally in explanation and prediction. It is surely true that evolutionary biologists appeal to generalizations that predict and explain, or, in philosophers’ jargon, “support (probabilistic) counterfactual generalizations.” On this more permissive view, then, evolutionary biology has laws aplenty. Resolving the debate about which account one ought to endorse has been complicated by the fact that evolutionary biologists typically do not speak of “laws.” Rather, they talk about “models.” The mathematical models of evolutionary genetics are intended to represent dynamic features of populations; provided certain conditions are met, they can be used to make predictions and give explanations of patterns in the natural world. Thus, some take the models of classical population genetics to generate law-like generalizations about evolutionary change in any population.

Beatty, J. (1995). The evolutionary contingency thesis. *Concepts, theories, and rationality in the biological sciences*. G. Wolters and J. Lennox (eds.) University of Pittsburgh Press, 45, 81.

Beatty argues that most candidates for biological laws describe contingent products of evolution; i.e., they could have been otherwise. Other candidate biological laws can be reduced to or explained in terms of chemical or physical laws. He also argues that biology’s lack of laws explains its theoretical pluralism: i.e., that debates in biology are often “relative significance” debates.

Brandon, R. (1997). Does biology have laws? The experimental evidence. *Philosophy of Science,* 64, S444-S457. (see also: (2006). The principle of drift: Biology's first law. *Journal of Philosophy,* 103(7), 319–335)

Brandon argues (1997) that there are empirical laws in biology, but that they have limited range. In contrast, analytic generalizations in biology, though non-empirical, are nonetheless explanatory. For example, the “Principle of Natural Selection” (PNS) to be such a law. He argues (2006) that drift is to evolution as inertia is to Newtonian mechanics, and that the Hardy-Weinberg Law is not a zero-force law.

Elgin, M. (2006). There may be strict empirical laws in biology, after all. *Biology and Philosophy*, 21(1), 119-134. (see also: (2003). Biology and a priori laws. *Philosophy of Science*, 70(5), 1380-1389.)

Elgin disputes the in principle reasons various philosophers have offered to think that biology cannot have strict empirical laws, and argues that recent research in biology suggests that there are such strict laws in biology. In his earlier paper (2003), Elgin argues that the function of a priori laws in biology are the same as those of empirical laws in physics. He thus disputes the requirement that laws be empirical.

Mitchell, S. D. (2000). Dimensions of scientific laws. *Philosophy of Science*, 67, 242–265. (see also: (1997). Pragmatic laws. *Philosophy of Science*, 64, S468-S479.)

Mitchell takes a pragmatic approach to the question of whether biology contains laws. She starts with the function that laws serve, and asks whether any biological generalizations that serve those aims. She argues that there are a variety of generalizations in biology that function as laws, and “dimensions” along which they exhibit greater or lesser “stability” “strength,” or “abstraction.”

Smart, J.C. (1959) Can Biology be an Exact Science? *Synthese*, 11(4), 359-368.

Smart draws an analogy between biology and electronics. Biology does not have universal laws. Biological generalizations are explained by biochemistry and biophysics (“plus natural history”), just as electronics is explained by physics (plus “wiring diagrams”). Smart grants that there are “intra-theoretical” uses of statistics in evolution and ecology akin to their use in statistical mechanics, but contends that these uses yield historical generalizations or “reduce to tautologies.”

Sober, E. (1997). Two outbreaks of lawlessness in recent philosophy of biology. *Philosophy of Science*, 64, S458-S467.

Sober critiques two arguments for the claim that there are no laws in biology, Beatty’s (1995) and Rosenberg’s (1994). He argues that biologists derive “if-then” generalizations that have similar properties to laws (they are used in prediction and explanation). “Source laws” describe general ecological relations between organisms and environments. “Consequence laws” describe the consequences of these relations for evolution.

**Chance and Evolutionary Contingency**

One long-standing debate in philosophy of biology – related in part to the debate over laws of nature – concerns how we ought to interpret claims about “chance,” or “contingency” in evolutionary biology. There are two questions at issue: First, Is evolutionary theory committed to determinism or indeterminism? (Determinism is the view that given the complete state of the world at one point in time, the state of the world at every future point in time is uniquely determined. In contrast, indeterminism is the view that, given the complete state of the world at one point in time, the state of the world at every future point in time is not uniquely determined (more than one future state is possible).) Second, are evolutionary processes as a matter of fact indeterministic? Consider drift – the process by which variation is sampled from one generation from the next. Granting that drift plays an important role in evolution seems to suggest that at least some evolutionary processes are indeterministic. On the other hand, drift may simply be a shorthand for complex causes of which we are ignorant – causes that are fundamentally deterministic in character. If drift is simply a shorthand, then we might grant appeals to drift as playing an important explanatory role in biology, while at the same time being committed to determinism at some more “fundamental” level. This debate is closely related to the debate over laws of nature, as well as debates over the autonomy of biology, or reducibility of biology to physics. Authors on both sides make appeal, for instance, to the indeterminism of quantum mechanics (QM), though they have very different views of its implications. Some suggest that if we take this theory seriously, we must be committed to fundamental indeterminism in nature, and this may well “percolate up” to the biological. Others argue that quantum indeterminism has little to no import for biology, and that we may treat biological processes as “asymptotically deterministic.”

Beatty, J. (2006). Replaying Life’s Tape. *Journal of Philosophy,* 103 (7), 336-362.

Beatty critically examines Gould’s claim that were one to play the history of life back again, the outcome would be entirely different. He considers Losos’s work on adaptive radiations of island lizards and Travisano’s experimental tests as case studies. The paper usefully distinguishes two senses of “contingency” at work in Gould’s claim: unpredictability, and “causal-dependence.”

Brandon, R. N., & Carson, S. (1996). The indeterministic character of evolutionary theory: no ‘no hidden variable proof’ but no room for determinism either. *Philosophy of Science,* 63, 315–337.

Brandon and Carson defend the view that evolutionary processes are indeterministic in character. More precisely, they argue that this view follows from realism about evolutionary theory – the view that the theory is true. They make appeal to the propensity interpretation of fitness and drift, as well as a "percolation argument,” to support the claim that the probabilities used in the theory are not merely epistemic.

Fisher, R. A. (1934). Indeterminism and natural selection. *Philosophy of science,* 1(1), 99-117.

Fisher argues that an indeterministic view of the natural world is a more “unified” and comprehensive basis for modern science than the alternative. Further, Fisher takes the purposive behavior of animals to be evident and a genuine cause of evolutionary change, (organisms act and interact with one another and their environments, thus shaping their genetic future), and takes this as further grounds for indeterminism.

Glymour, B. (2001). Selection, Indeterminism, and Evolutionary Theory. *Philosophy of Science,* 68, 518-535.

Glymour’s focus in this paper is on random foraging behavior. He demonstrates that when foraging, several species use a random search strategy, a random walk. He takes this to be evidence for the indeterminism of the foraging process. Moreover, since foraging affects energy expended and the number of prey captured, and thus natural selection, he concludes that evolution is at least sometimes indeterministic, at the “macro-level.”

Graves, L., Horan, B. L., & Rosenberg, A. (1999). Is indeterminism the source of the statistical character of evolutionary theory? *Philosophy of Science*, 66(1), 140-157.

The authors engage with three arguments (the propensity argument, the percolation argument, and the argument from drift), and contend that none of these provides reason to reject the view that the probabilities of evolutionary theory merely represent our epistemic limitations. They argue that biological processes “asymptotically approach determinism,” and that positing of deterministic hidden variables in evolutionary theory has been essential to theoretical and experimental advances in the biological sciences.

Hodge, M. J. S. (1992). Biology and philosophy (including ideology): A study of Fisher and Wright. *The founders of evolutionary genetics*, Springer, 231-293.

Hodge describes the views on determinism of two influential evolutionary biologists, Fisher and Wright. Fisher endorsed an “indeterministic” worldview – one that admitted of probabilistic, or statistical, laws and explanations. Wright took laws of nature to be “condensed statistical descriptions.” Determinism was simply a fruitful presupposition, not a metaphysical commitment. Wright’s “dual aspect pan-psychism” was an attempt to reconcile mechanistic determinism with evidently purposive behavior in animals.

Merlin, F. (2010). Evolutionary Chance Mutation: A Defense of the Modern Synthesis' Consensus View. *Philosophy & Theory in Biology*, 2, 22.

Merlin defends the view that all genetic mutations occur at random with respect to fitness. She contends that the increased chance of a reverse mutation, by activation of the *leu* operon, was not a “directed” (adaptive) response to environmental conditions.

Millstein, R. L. (2000). Is the evolutionary process deterministic or indeterministic? An argument for agnosticism. (See also: (2003). Interpretations of probability in evolutionary theory. *Philosophy of Science*, 70(5), 1317-1328; (2011). Chances and causes in evolutionary biology: How many chances become one chance. *Causality in the Sciences*, *2*, 425.)

In her 2000 paper, Millstein argues that neither evolutionary determinists nor evolutionary indeterminists convincingly make a decisive case; one should be agnostic. In her 2003 paper, she argues that one can be ecumenical about the appropriate interpretation of probability for evolutionary theory. In her 2011 paper, she discusses the variety of causes and consequences of drift.

Ramsey, G. & Pence, C. H. (Eds.). (2016). *Chance in evolution*, University of Chicago Press.

This edited volume contains several chapters by biologists, historians and philosophers of biology about the history of thinking about the role of chance in evolution, and engages with current debates about the nature, and causes and effects, of contingency in evolution.

Wagner, A. (2012). The role of randomness in Darwinian evolution. *Philosophy of Science*, 79(1), 95-119.

The paper argues that even though mutation is random with respect to fitness, genotypic change is non-random, and phenotypic variation is “nonrandom and highly structured… in ways that facilitate evolutionary adaptation and innovation.” In particular, metabolic networks, regulatory gene circuits, and protein or RNA macromolecules are highly constrained in how they vary, and thus constrain the direction and rate of evolutionary change.

**Autonomy, Reduction, and Integration**

What exactly is the logical or conceptual relationship between the laws, theories, and subject matter of the various sciences (physics, chemistry, biology)? One rather intuitive view is that the more “fundamental” sciences (physics, chemistry, etc.) constrain or inform the “special” sciences (biology, sociology), in some fashion, since the “lower level” sciences set the range of conditions on what is possible at “higher levels” of organization. While the idea of mutual constraint seems plausible, making this idea of constraint more rigorous has proven contentious. When one attempts to characterize the logical relationships between concepts and theories in the sciences, it is difficult to link the terms and theories of biology, chemistry and physics in a seamless fashion. Generalizations about “fitness” and “drift,” for instance, are not easily reduced to, or explainable in by appeal to concepts or empirical generalizations of biochemistry, for instance. In part due to these challenges, many philosophers of biology have resisted “reductionism,” a view of the relationship between theories according to which the more “fundamental” sciences (i.e., physics) replace or “reduce” higher-level sciences by way of deductive subsumption. Philosophers of biology have argued that such logical reductions are impossible, not only in practice, but in principle. This argument does not (necessarily) require a denial of “physicalism,” the view that all biological things just are physical things. Rather, it concerns in what sense biology is “autonomous” from other sciences. Some claim that concepts such as “fitness,” cannot be reduced to, or explained in terms of, concepts or relations of biochemistry and physics.

Ayala, F. J. (1968). Biology as an autonomous science. *American Scientist,* 56, 207-221. (See also: (2000). Evolution and the autonomy of biology. *Aquinas-Rome*43(2), 283-312; (1970). Teleological Explanations in Evolutionary Biology. *Philosophy of Science*, 37(1): 1–15; and, (1977). Teleological Explanations. in *Evolution*, San Francisco: W. H. Freeman, 497–504.)

Ayala grants that progress in science often involves the discovery of new relationships among scientific disciplines, such as derivations of one scientific theory from another, but argues that the conditions required for the reduction of biology to physics are not (as yet) met. There are patterns of explanation indispensable to biology, “teleological” (or purposive) explanations, which cannot be reformulated in nonteleological form without loss of explanatory content.

Brigandt, I. & Love, A. (2017). Reductionism in biology. *The Stanford Encyclopedia of Philosophy.* Edward N. Zalta (ed.), [https://plato.stanford.edu/archives/spr2017/entries/reduction-biology/].

This is a comprehensive overview of the literature on the relationships between biology, and chemistry or physics. The authors consider several important arguments against reductionism, review key distinctions in the reductionism debate, and then discuss a variety of alternatives to the relation of reduction – interfield theories, problem agendas, mechanistic approaches, multilevel and multifield explanations, and integration.

Eronen, M. I. & Brooks, D. S. (2018) Levels of Organization in Biology, *The Stanford Encyclopedia of Philosophy*, Edward N. Zalta (ed.), URL = <https://plato.stanford.edu/archives/spr2018/entries/levels-org-biology/>.

The notion of “levels” of organization in biology – e.g., molecular, cellular, tissue, organ, organismal, group, population, community, ecosystem, landscape, and biosphere – raises a variety of questions about both hierarchical depictions of nature, and the nature of the relationship between levels. This encyclopedia article reviews the history of debates about levels and relationships between levels (e.g., reduction, emergence, downward causation).

Nicholson, D. J., & Dupré, J. (Eds.). (2018). *Everything flows: towards a processual philosophy of biology*. Oxford University Press.

While this volume is not exclusively concerned with evolutionary biology or reduction, it engages with a variety of overlapping metaphysical and methodological questions that arise from adopting a “processual” perspective on the living world. On this view, processes, rather than discrete substances, are the fundamental stuff of life; authors argue that this view challenges deterministic, preformationist, and mechanistic explanations of biological phenomena.

Kaiser, M. (2015) *Reductive Explanation in the Biological Sciences*, Springer.

While this book is not concerned exclusively with evolutionary biology, Kaiser’s discussion of the role philosophers of science should play viz. the sciences provides a useful background for debates about reduction. She argues that some explanations in biology are reductive, while many are not, and offers three features of a reductive explanation that provide useful contrast with part-whole explanations and mechanistic explanations.

Kitcher, P. (1984). 1953 and all that: a tale of two sciences. *Philosophical Review*, 93, 335–373.

Kitcher considers whether the relationship between classical and molecular genetics is one of reduction (where this is understood in terms of whether laws of the higher level science can be deduced from laws of the lower level). He argues that the conditions necessary for such deductions are not met; the relationship between classical and molecular genetics is not reduction but “conceptual refinement.”

Lange, M. (2004). The autonomy of functional biology: a reply to Rosenberg. *Biology and Philosophy*, 19, 93–109.

Lange argues that Rosenberg’s arguments against the explanatory autonomy of functional biology beg the question. He offers a novel account of laws and counterfactual generalizations, which preserves the autonomy of biology.

Mitchell, S. D. (2003). *Biological complexity and integrative pluralism*. Cambridge University Press.

Mitchell’s aim in this book is to carve out a middle ground between “anything goes” pluralism and reductionism. Her thesis is that the biological world is complex, and, this complexity, plus the limitations of our representations, requires explanation via a plurality of models and theories deployed at multiple levels. Mitchell appeals to case studies (including social insect colonies) where order emerges from feedback process operating at the individual level.

Rosenberg, A. (2008). *Darwinian reductionism: Or, how to stop worrying and love molecular biology*. University of Chicago Press. (See also: (2001a). Reductionism in a historical science. *Philosophy of Science,* 68, 135–163.; (2001b). How is biological explanation possible? *British Journal for the Philosophy of Science,* 52, 735–760; (1994). *Instrumental biology, or the disunity of science*. University of Chicago Press; (1985). *The structure of biological science*. Cambridge University Press.)

Rosenberg (2008) argues for “Darwinian” reductionism, the view evolutionary explanations are a necessary part of biology, but that functional explanations at the macro-level need to be completed, corrected, or superceded by molecular biology. He thus “reconciles” physicalism and antireductionism. Earlier (1984, 1998, 2001a, b) Rosenberg has argued that Nagel’s concept of reduction as a matter of deductive subsumption fails in biology, and that biology is a fundamentally instrumental science.

Sterelny, K. (1996). Explanatory pluralism in evolutionary biology. *Biology and Philosophy*, 11, 193–214.

Sterelny argues that it is consistent for one domain to depend for its existence on another, and yet for it to be explanatorily autonomous. He distinguishes several ways in which higher levels are explanatorily independent that are important for evolutionary biology – either understanding the origins of adaptation or the nature of macroevolutionary change.

Waters, K. (1990). Why the Antireductionist Consensus Won't Survive the Case of Classical Mendelian Genetics. *Proceedings of the Biennial Meeting of the Philosophy of Science Association*, 1, 125–139. (See also: (1994). Genes made molecular. *Philosophy of Science*, 61, 163–185.)

Waters criticizes three arguments against the reduction of classical Mendelian genetics (CMG) to molecular biology: the “unconnectability” argument, “explanatory incompleteness” argument, and “splintering argument.” He concedes to the antireductionist that we ought to expect disjunctive characterizations of Mendelian gene at the molecular level. With respect to explanatory autonomy, however, he argues that molecular accounts are “deeper.” He goes on to give a detailed example: the molecular basis of linkage.

**Function and Teleology**

Philosophers have long been concerned about how to interpret references to “design,” and “function” in the biological sciences. On the one had, teleological language seems to attribute purposes or goals to natural phenomena, and this seems inimical to science. Thus, some take talk of “function” as metaphorical at best. On the other hand, functional explanations seem to be ubiquitous in the biological sciences, and in ethology and evolutionary biology in particular. So, while some philosophers (e.g., Searle, 1993) have suggested that functions are not natural features of the world, others argue to the contrary that functions and functional explanations can be given a naturalistic foundation. Philosophers have offered up various conditions of adequacy on appropriate uses of the term, “function.” For instance, some philosophers argue that biological functions are best understood in terms of causal contribution of a trait to a system’s larger capacity or persistence (sometimes called “causal role” theories of function). Others take a history of natural selection on some trait to be essential for attribution of functions to traits (sometimes called “selected effects” theories). Others still argue that rather than be “monists” about functions (according to whom there is one set of conditions on proper attributions of “function” in biology), we ought to be “pluralists” (different analyses are appropriate in different contexts).

Allen, C. and Bekoff, M. (1995). Function, Natural Design, and Animal Behavior: Philosophical and Ethological Considerations. *Perspectives in Ethology* 11: *Behavioral Design*. New York: Plenum Press.

 This paper defends a pluralistic view about teleological concepts in biology and ethology, arguing that both “natural design” and “biological function” concepts can be provided with a naturalistic foundation. This paper argues that both notions have a role to play in biology.

Bigelow, J. & Pargetter, R. (1987). Functions. *The Journal of Philosophy*, 84(4), 181–196.

Bigelow and Pargetter model their account of functions on the propensity view of fitness (Mills and Beatty 1979); functions are dispositions or propensities to succeed via selection in terms of survivorship. The advantage of this view is that it can accommodate forward-looking functional ascriptions; the disadvantage, however, is that it leaves a number of questions open about how far into the future these dispositions must be expressed to count as functions.

Cummins, R. (1975). Functional Analysis. *The Journal of Philosophy*, 72(20), 741–765.

Cummins offers criticisms of “selected-effects” accounts of functions, and offers an alternative, “function analytic” account, where one ascribes functions to parts of a system in light of the causal role they play in the larger capacity of the system of which it is a part. Functional explanation thus requires an analysis of the parts and their capacities relative to the system’s capacities, and the complexity of the system.

Garson, J. (2016). *A Critical Overview of Biological Functions*. Springer International Publishing. (see also: (2017). How to be a function pluralist. *The British Journal for the Philosophy of Science*, 69(4), 1101-1122.)

This is a thorough review of the entire body of literature on functions in philosophy going back over twenty-five years. Garson discusses the merits and limitations of competing philosophical accounts of functions, as well as various “pluralist” versus “monist” approaches to the analysis of function. Garson (2017) distinguishes two forms of pluralism about biological functions, between-discipline pluralism and within-discipline pluralism, and recommends the latter.

Godfrey-Smith, P. (1994). A Modern History Theory of Functions. *Noûs*, 28(3), 344–362.

Godfrey-Smith defines functions as dispositions or effects of a trait that contribute to maintenance of the trait by natural selection, and addresses several common objections to the historical account of functions. He also distinguishes between two different kinds of evolutionary explanations in biology: explanations of the historical origins of a trait, versus explanations describing selection in the recent past.

Griffiths, P. E. (1993). Functional Analysis and Proper Functions. *The British Journal for the Philosophy of Science*, 44(3), 409–422.

Griffiths gives an analysis of the notion of “proper function” according to which they are the “functions it is assigned in a Cummins-style functional explanation of the fitness of ancestral bearers of the trait”. He also specifies further conditions on etiological functions that permit one to distinguish proper functions from vestigial traits, and extend proper functions to artifacts.

Laubichler, M., Stadler, P.F., Prohaska, S.J., & Nowick, K. (2015). The relativity of biological function. *Theory in Biosciences,*134(3-4), 143-147.

Laubichler, et. al., are writing in response to the recent controversy over ENCODE, concerning what proportion of the human genome consists of functional DNA; they diagnose this debate as turning on competing theories of function. They argue that functional ascriptions are context dependent: different implicit contextual assumptions and using different measurement procedures are at work, and defend a “constrained pluralism” with respect to functional ascription.

Lewens, T., (2004). *Organisms and Artifacts: Design in Nature and Elsewhere*, Cambridge, MA: MIT Press.

Lewens considers the limitations of the “artifact” analogy, taking organisms and artifacts to be similarly products of design, and defends a “deflationary” view of functions, i.e., a non-teleological account. His alternative account of function, the “naïve fitness’’ (NF) account, is that functions serve biological needs.

Millikan, R. G. (1989a). In Defense of Proper Functions. *Philosophy of Science*, 56(2), 288–302. (See also (1989b) An Ambiguity in the Notion "Function." *Biology and Philosophy,*

4, 172-176.)

Millikan offers an account of proper function similar to Wright’s, but attempts to address several common objections. Functions can only be ascribed to properties shared by a “reproductively connected family,” where reproduction is due in part to possession of the properties reproduced. In (1989b), Millikan grants there are two senses in which the term function plays important explanatory roles in biology.

Mitchell, S. (1993). Dispositions or Etiologies? A Comment on Bigelow and Pargetter. *Journal of Philosophy*, 90, 249-59. (see also: (1995). Function, Fitness and Disposition. *Biology and Philosophy*, 10, 39-54.)

Mitchell challenges Bigelow and Pargetter’s objections to the “selected effects” account of functions, arguing that selected effects are vacuous only if we read "persisted" as meaning "evolved by natural selection.” Selection is not the only mechanism that explains a trait’s persistence. She also (1995) defends the dispositional account of fitness and the etiological account of function against Bigelow and Pargetter's objections.

Neander, K. (1988). What Does Natural Selection Explain? Correction to Sober. *Philosophy of Science*, 55(3), 422–426. (see also: (1991a). Functions as Selected Effects: The Conceptual Analyst’s Defense. *Philosophy of Science*, 58(2), 168–184.; (1991b). The Teleological Notion of ‘Function’. *Australasian Journal of Philosophy*, 69(4), 454–468.; (2017) *A mark of the mental: In defense of informational teleosemantics*. MIT Press.)

Neander defends the selected effects account of functions, according to which a history of selection legitimates talk of function. She disagrees with Sober (1984) that selection only acts as a filter on variations; it has a creative role to play in evolution. Neander (1991, 2017) defends conceptual analysis, and also has defended the view that our sensory-perceptual systems have proper functions: appropriate functional role in typical environments.

Walsh, D. M. & Ariew, A. (1996). A Taxonomy of Functions. *Canadian Journal of Philosophy*, 26(4), 493–514.

This article explicates a relation between “C” functions and “E” functions, and defends a “relational” theory of function, where a trait token has a function when it makes a positive average fitness contribution for individuals of that type in a specified environment. They argue that once one specifies an appropriate account of evolutionary function, one can better understand how C-function analysis enables discovery of historical functions.

Weber, M. (2017). How objective are biological functions? *Synthese*, 194(12), 4741-4755 (See also: (2005), *Philosophy of Experimental Biology*. Cambridge University Press.)

Weber replies to a critique of functional ascriptions by Searle (1995). Searle argued that attributions of function merely reflect our interests. Weber argues that the objectivity of functions hinges on whether various objective conditions obtain, that these conditions do obtain, and that different dependency relations may be in play in different contexts of functional ascription: causal, constitutive, mereological, or grounding relations. Functional ascriptions cannot reduce to these more fundamental relations.

Wright, L. (1973). Functions. *The Philosophical Review*, 82(2), 139–168. (See also: (1976). *Teleological Explanations*. University of California Press.).

For Wright, a function is a particular consequence of some component of a system “being where it is, which explains why it is there" (1976 p.78). His account is intended to accommodate artifacts and biological functions. Critics argue that this account is too permissive, as it would seem to warrant ascribing functions to accidental (and unfortunate) states of affairs – e.g., a leak in a gas hose rendering a mechanic unconscious.

**Evolutionary Genetics, Evolutionary Theory, & The “Extended Synthesis”**

If one’s view is that the aim of science is to arrive at true theories, it seems a central concern of philosophers of biology should be with the development and confirmation of evolutionary theory. But, what is the theory of evolution? Answering this question is complicated by the fact that there are competing views about the nature of scientific theories. On one view of theories, theories are sets of laws – true, universal generalizations. On a more permissive view, theories are families of models, which are taken to stand in some more or less exact relationship to the world. The former is called the “syntactic,” and the latter is often called the “semantic” view of theories. Several philosophers of biology have argued that the semantic is a more natural fit for evolutionary theory, and take evolutionary genetics to be something like the “theoretical core” of evolutionary biology. Classical evolutionary genetics consists of families of mathematical models, which may be used to predict (or retrodict) change in populations over time. However, some of the work of classical population genetics seems less concerned with prediction or explanation than with deriving something akin to “necessary” truths about the conditions on evolutionary change. For instance, Fisher’s fundamental theorem is, strictly speaking, not an empirical hypothesis; and, Kimura’s demonstration of the neutral theory is more akin to a formal mathematical proof than an empirical discovery. Given examples like these, some philosophers of biology have suggested that the role of evolutionary genetics is somewhat different from the role of scientific theories typically understood. They disagree, however, about that role. Others still disagree about the centrality of evolutionary genetics to evolutionary biology. Recent advances in molecular biology and developmental biology, according to some, indicate that we ought to reject classical models of evolutionary genetics, and adopt a new, “extended,” evolutionary synthesis.

Burian, R. M. (1988). Challenges to the evolutionary synthesis. *Evolutionary biology*, 23, 247-269.

Ostensibly a review of four books by biologists, Burian’s essay is a reflection on the nature of the synthetic theory of evolution, the value of synthesis, and a consideration of the import of then novel insights from genetics, epigenetics, and development. Burian argues that the synthesis was a less a body of theory than “a modus vivendi that allowed theorists, experimentalists, and field naturalists… to work together on various problems from within a common framework.”

Lu, Q, & Bourrat, P. (2018) The Evolutionary Gene and the Extended Evolutionary Synthesis. *The British Journal for the Philosophy of Science*, 69(3), 775–800.

The paper considers the role of the “gene” in evolutionary theory, and argues that epigenetic inheritance can be incorporated into formal evolutionary models. Genes in this context are defined by their effects, not their physical make up. The authors consider two challenges to the modern synthesis, stemming from epigenetic inheritance, and argue that neither threatens modern synthetic evolutionary theory.

Millstein, Roberta L., Skipper, Robert A., and Dietrich, Michael R. (2009). (Mis)interpreting Mathematical Models: Drift as a Physical Process. *Philosophy and Theory in Biology,* 1:e002.

The authors argue that Matthen and Ariew (2002), Walsh, Lewens, and Ariew (2002), Pigliucci and Kaplan (2006), and Walsh (2007) mistakenly take the meaning of concepts such as drift to be derived straightforwardly from the mathematical models in which drift appears. They argue that mathematical models must be in interpreted in light of the phenomena that they were designed to represent.

Morrison, M. (2004). Population Genetics and Population Thinking: Mathematics and the Role of the Individual. *Philosophy of Science*, 71, 1189–1200. (see also: (2001) *Unifying scientific theories: Physical concepts and mathematical structures.* Cambridge University Press.)

Morrison argues that while there is a kernel of accuracy in Mayr’s critique of classical population genetics, she argues that the primary concern of population genetics is an explanation of variation. So, classical population genetics is squarely within the Darwinian research program. Her book (2001) argues that classical population geneticists offered unified mathematical models, but divergent explanations of evolution.

Pigliucci, M., & Muller, G. (2010). *Evolution–the extended synthesis*. MIT Press.

This edited volume contains excellent essays, some questioning whether recent work in molecular genetics, development, etc., requires that we revise the commitments of the modern synthesis, others leaning toward major revisions, and some taking a middle ground. Contributors include Beatty, Callebaut, Draghi, Gavrilets, Gerhart, Jablonka, Jablonski, Kirschner, Lamb, Love, Müller, Newman, Odling-Smee, Pigliucci, and others.

Pigliucci, M. (2008) The Proper Role of Population Genetics in Modern Evolutionary Theory. *Biological Theory,* 3(4), 316–324.

Pigliucci critiques Lynch’s (2007) argument for the claim that “nothing in biology makes sense except in light of population genetics.” While he agrees with Lynch (2007) that nonadaptive processes play an important role at the genomic level, he disagrees that anything substantive follows viz. an “account of phenotypic complexity.” He refutes Lynch’s “myths” about organismal complexity (which he takes to be a straw man), and defends a more nuanced view.

Plutynski, A. (2006) Strategies of Model Building in Population Genetics. *Philosophy of Science*, 73, 755–764. (see also: (2004). Explanation in classical population genetics. *Philosophy of Science*, 71(5), 1201-1214; (2005). Explanatory unification and the early synthesis. *The British journal for the philosophy of science*, 56(3), 595-609.)

Plutynski defends Levins (1966) against Orzack and Sober’s (1993) argument that generality, precision and realism can be maximized simultaneously. She also argues (2004, 2005), that while the explanatory aims of mathematical modeling are diverse, mathematical demonstrations can serve in arguments for, e.g., the compatibility of two research programs.

Okasha, S. (2008). Fisher's “Fundamental Theorem” of Natural Selection: A Philosophical Analysis. *British Journal for the Philosophy of Science*, 59, 319–351.

Okasha gives a very clear account of the difference between competing interpretations of R.A. Fisher’s ‘fundamental theorem’ of natural selection, and defends proponents of the modern interpretation in their claim that the theorem is mathematically correct, pace the traditional consensus. He then turns to consideration of the biological significance and implications of the theorem.

Sarkar, S. (Ed.), 1992. *The founders of evolutionary genetics: a centenary reappraisal* (Vol. 142). Springer. (see also: (2004). Evolutionary theory in the 1920s: the nature of the “synthesis”. *Philosophy of Science*, *71*(5), 1215-1226.)

An excellent set of essays providing a thorough grounding in both the personal biographical details of its founders, as well as larger historical context and import of classical population genetics, as well as larger implications of debates among its proponents for both evolutionary biology and philosophy of science. Contributors include Sarkar, Maynard Smith, Seidenfeld, Crow, Wimsatt, Provine and Hodge.

**Fitness, Explanation and Causation**

One of the most well known arguments that some use to suggest that evolution is not a genuinely scientific theory is that evolutionary explanations that appeal to “fitness” are “circular.” This is known as the “tautology” argument: if fitness is just whatever promotes survival and reproductive success, then it is hardly explanatory to point out that fitter organisms survive. It’s simply tautologically true. Despite the fact that this argument mischaracterizes the explanations biologists actually give, more ink has been spilled on the topic of “fitness” and its role in evolutionary explanation in philosophy of biology than the causal observer might think it deserves. The bulk of this literature is not concerned with answering the tautology argument, however. There are at least three key strands in the literature on fitness: First, what is fitness? Second, if one takes fitness to be a “propensity” or disposition, what kind of disposition is it, and what is it a disposition of – individuals, populations, or pairings of each with specific environments? Third, how do appeals to fitness explain? A related debate concerns whether and in what sense natural selection is a cause. Overlapping with these questions are debates concerning the nature of causation and explanation in evolutionary biology, the proper interpretation and application of the equations of classical population genetics and the Price equation, the links between various ways of representing fitness, and the relationships between various models of fitness and optimality.

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Special Issue: The Formal Darwinism Project

This special issue concerns the merits and limitations of Grafen’s formal Darwinism project. The papers are by and large critical, though the reasons why vary: it is “based upon a misconception of the relationship between theory and empirical analysis” (Okasha); it equates “appearing designed” with “solving an optimization programme” (Birch); it ignores intragenomic conflict (Haig); and, it underestimates the significance of frequency-dependent selection (Sarkar).

Birch, J. (2016) “Natural selection and the maximization of fitness.” *Biological Reviews*, 91 (3), 712-727.

Birch argues that neither the “new” interpretation of Fisher’s fundamental theorem of natural selection nor the Formal Darwinism project establish a biologically significant fitness maximization principle. He uses this argument to show that evolutionary ecologists’ presuppositions about fitness maximization are flawed.

Drouet, I. & Merlin, F. (2015) The Propensity interpretation of fitness and the propensity interpretation of Probability. *Erkenntnis*, 80(S3), 457-468.

Drouet and Merlin consider whether the propensity interpretation of fitness requires an appeal to the propensity interpretation of probability and conclude that it does not. They show that fitness is not a propensity in Popper’s sense of the propensity interpretation of probability, because fitness is reducible to probabilities on the various possible environments and/or disturbances, and the propensity interpretation’s account of evolutionary explanations does not require that probabilities be propensities either.

Kaplan, J. M. (2013) ‘‘Relevant similarity’’ and the causes of biological evolution: selection, fitness, and statistically abstractive explanations. *Biology and Philosophy*, 28, 405–421.

Kaplan defends the view that selective explanations are “robust process” explanations, following Sterelny (1996). He then appeals to Matthen’s (2009) suggestion that selective explanations are “statistically abstractive” to point the way toward an answer to the question of how to specify “relevantly similar” events and processes, traits, populations, and environments in service of explaining the evolution of the populations in selective terms.

Matthen, M. and Ariew, A. (2009) Selection and Causation. *Philosophy of Science*, 76, 201–224. (see also: (2002) Two Ways of Thinking About Fitness and Natural Selection. *The Journal of Philosophy*, 99, 55–83; Walsh, D. M., Lewens, T. and Ariew, A. (2002) The Trials of Life: Natural Selection and Random Drift. *Philosophy of Science*, 69, 452–73.)

Walsh, Matthen and Ariew (2002) argue that natural selection is not a cause of evolution, but a population level statistical effect consequence of lower-level events. They also deny fitness to be a cause of evolution. Matthen and Ariew (2002, 2009) defend their ‘hierarchical realization model’ for combining evolutionary influences, and argue that variation in a trait causes evolutionary change in populations, but natural selection is not a causal force.

Mills, S.K. & Beatty, J. (1979) The Propensity Interpretation of Fitness. *Philosophy of Science*, 46(2), 263-286.

Mills and Beatty argue that though actualsurvival and reproductive success can be used as *evidence* for fitness, it is *not a definition of fitness*. They define fitness1 as a propensity of an organism in environment to leave an expected number of descendants, define fitness2 as the expected contribution of a gene or trait, and argue that most explanations in biology refer to fitness2.

Millstein, R., (2006), “Natural Selection as a Population-Level Causal Process,” *The British Journal for the Philosophy of Science* 57(4): 627-653. (see also (2002) Are Random Drift and Natural Selection Conceptually Distinct? *Biology and Philosophy*, 17, 33–53.)

Millstein argues (contra Walsh, et. al., 2002 and Bouchard and Rosenberg, 2004) that natural selection is a causal process, but it operates at the population level. She also argues (2002, 2006) that selection is a discriminate, whereas drift is an indiscriminate sampling process, and that population-level causality is consistent with three commonly accepted philosophical of causality.

Otsuka, Jun. (2016). A Critical Review of the Statisticalist Debate. *Biology and Philosophy*. 31, 459–482. (see also: Otsuka, J., Turner, T., Allen, C. and Lloyd, E.A. (2011) Why the Causal View of Fitness Survives. *Philosophy of Science*, 78, (2):209-224.)

Otsuka reviews key assumptions, applications, and explanations of evolutionary theory at work in the debate over whether natural selection is a causal process, and argues that overconfidence in conceptual analysis as a tool to understand the scientific theory has led to the debate’s failure to be resolved. In 2016, Otsuka, et. al., argue that Walsh’s argument for the claim that the causalist view of fitness is a reductio fails.

Pence, C. H. and Ramsey, G. (2013) A New Foundation for the Propensity Interpretation of Fitness. *British Journal for the Philosophy of Science,*64(4), 851-881.

Pence and Ramsey offer a definition of individual fitness that they take to answer many of the common objections to the propensity account of fitness, by incorporating and combining all possible daughter populations over indefinitely many reproductive generations.

Rosenberg A, Bouchard F (2015) "Fitness", The Stanford Encyclopedia of Philosophy (Fall 2015 Edition), Edward N. Zalta (ed.), URL = <https://plato.stanford.edu/archives/fall2015/entries/fitness/> (see also (2005) Matthen and Ariew’s obituary for fitness: reports of its death have been greatly exaggerated. *Biology and Philosophy*, 20 (2–3), 343–353; (2004) [Fitness, Probability and the Principles of Natural Selection.](https://philpapers.org/rec/BOUFPA%22%20%5Ct%20%22_blank) *British Journal for the Philosophy of Science*, 55 (4), 693-712.)

Rosenberg and Bouchard (2015) provide an overview of work on the concept of “fitness” in philosophy of biology – reviewing “vernacular” or “ecological” fitness concepts, individual versus trait fitness, the propensity interpretation, and the relationship between fitness and the principle of natural selection (PNS). In 2005, they argue that the mathematical equations of population genetics are in fact based on a causal principle, the principle of natural selection.

Sober, E. (2001). The Two Faces of Fitness. *Thinking about Evolution: Historical, Philosophical, and Political Perspectives*. Cambridge: Cambridge University Press. (see also: (2013) Trait Fitness is Not a Propensity, but Fitness Variation Is. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences*, 44 (3), 336-341.)

Sober explains that fitness is both an “ecological descriptor and a mathematical predictor.” He engages with a debate over the merits of the propensity interpretation of fitness, and shows how frequency- and density-dependent selection challenge us to think about fitness as not a propensity of an organism, per se, but a property of the organism’s relation to its environment, including properties of the containing population such as census size.

**Evolutionary Developmental Biology**

Developmental biologists study the patterns and processes of organismal development. Evolutionary developmental biologists are interested in both the origins of evolutionary novelty, and the causes of stasis, and how attention to developmental patterns and processes can yield insight into both. Evolutionary developmental biologists insist that these questions cannot be addressed except by attention to intersecting processes of development and evolution. Thus, many see themselves as presenting a challenge to the mid-century “modern synthesis” or “neo-Darwinian” synthesis articulated by major figures such as Dobzhansky and Mayr, with their dual emphasis on genes as the units of inheritance, and the power of natural selection. The push back against the neo-Darwinian view arguably began with Gould and Lewontin’s (1979) infamous “Spandrels” paper, for instance, which argued that evolutionary biologists at that time were overemphasizing selective explanations, and insufficiently attentive to developmental constraints. More recently, advances in developmental biology have suggested to both biologists and philosophers of biology that closer attention to the organismal structure and ontogeny will be essential to understanding the emergence of “evolutionary novelties,” and the conditions on “evolvability” of a lineage. Proposed conditions include modularity, plasticity, or some combination of these. Some have argued that attention to development requires an “expanded” evolutionary synthesis. Several historians and philosophers of biology have contributed to this literature – either by tracing its historical origins, or, by clarifying the terms of the debate over an ‘expanded’ synthesis, as well as how best to define and measure “homology,” “constraint,” “evolvability,” “plasticity” or “modularity.”

Amundson, R. (2005). *The Changing Rule of the Embryo in Evolutionary Biology Structure and Synthesis*. Cambridge: Cambridge University Press.

Amundson’s classic book is a history of how and why the attention to the embryo and development waned in 20th century evolutionary biology, and the consequences of modern synthesis thinkers failing to attend to the processes of development and their role in evolution.

Brown, R. L. (2013). What evolvability really is. *The British Journal for the Philosophy of Science*. 65(3), 549-572.

Brown offers a unified account of evolvability, namely, the “objective probability of a particular feature or set of features (F) arising at some future time (T) given the state of a population (X) and relevant features of its environment (B) at some particular starting point.” Brown grants that there are distinct physical bases of this disposition, but argues that the property picks out a distinctive object of explanation, and a kind of explanation.

Callebaut, W., Rasskin-Gutman, D., & Simon, H. A. (Eds.). (2005). *Modularity: understanding the development and evolution of natural complex systems*. MIT press.

This collected volume contains papers on the ubiquity, dimensions, and varieties of modularity, and its role in evolution, the emergence of mind and cognition, and culture. Contributors include Altenbuerg, Eble, Brandon, McShea, Simon, Schlosser, Wagner, Winther, and others.

Love, A. C. (2003). Evolutionary morphology, innovation, and the synthesis of evolutionary and developmental biology. *Biology and Philosophy*, 18(2), 309-345. (see also: (2008). Explaining evolutionary innovations and novelties: Criteria of explanatory adequacy and epistemological prerequisites. *Philosophy of Science*. 75(5), 874-886.)

Love offers an account of how the new interdisciplinary research program of evolutionary developmental biology or `evo-devo’ has emerged, requiring the “meshing” of disciplines, concepts, and explanations. In particular, Love draws attention to the significant roles of functional and devolutionary morphology and comparative anatomy, as well as the idea of *evolutionary innovation,* in this synthesis.

Müller, G. B., & Newman, S. A. (2003). *Origination of organismal form: Beyond the gene in developmental and evolutionary biology*. MIT Press.

This collected volume contains papers on concepts and nature of homology and homoplasy, the causes and consequences of the Cambrian explosion, the importance of viewing the genome as “reactive”, the significance of tissue specificity in the process of development, and the role of physical and organizational factors in the generation of morphology. Authors include Mina Bissell, Scott Gilbert, Fred Nijhout, Stuart Newman, Gunter Wagner, and the authors themselves.

Pigliucci, M. (2001). *Phenotypic Plasticity: Beyond Nature and Nurture*. Johns Hopkins University Press. (see also: (2010) Genotype–phenotype mapping and the end of the ‘genes as blueprint’ metaphor. *Phil. Trans. Royal Soc. B*. 365, 557–566.)

The author provides a thorough explanation of phenotypic plasticity, how to study it, and considers common principles governing plasticity in evolution, using examples in genetics, plant and animal development, ecology, and behavior. Along the way, the author explains and describes phenotype-genotype mapping, reaction norms, analysis of variance, and other key concepts and tools for the study of plasticity in nature.

Oyama, S. (1985, 2000a). *The Ontogeny of Information*. Duke University Press. (see also: (2000b). *Evolution's Eye: A Systems View of the Biology-Culture Divide*, Duke University Press.; Oyama, S., Griffiths, P.E. & Gray, R.D. (2001). *Cycles of Contingency: Developmental Systems and Evolution*. MIT Press.)

Oyama offers an explication and defense of developmental systems theory, an approach that takes serious the role of many developmental resources in both ontogeny and evolution. The books offer both historical background to, and empirical examples of applications of this view, which was a provocative challenge to the view that genes are the origins of organization and order in life.

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

Robert considers the theoretical commitments, scope and limitations of developmental systems theory. The first five chapters critique reductionist heuristics in developmental biology, showing how the theoretical presuppositions about the “developmental program” inform methods and outcomes, and substitutes a “constitutive epigenetic” approach.

Wagner, A. (2004). *Robustness and Evolvability in Living Systems*. Princeton University Press.

Though authored by a biologist, this book is arguably a philosophical landmark in evolutionary theory. The author offers a working definition of robustness, and gives detailed examples of robust systems both above and below the level of the gene. The book also considers whether there are common principles governing the evolvability of molecules, gene networks, genes, organisms, and lineages.

Wagner, G. P. (2017) *Homology, Genes, and Evolutionary Innovation.* Princeton: Princeton University Press. (See also: Wagner, G. P., 2007, “How wide and how deep is the divide between population genetics and developmental evolution?” *Biology and Philosophy*, 22(1), 145-153.;Wagner, G. P., C. Chiu, and M. Laubichler, 2000. “Developmental evolution as a mechanistic science: the inference from developmental mechanisms to evolutionary processes,” *American Zoologist*, 40: 819–831.; Wagner, G. P. and L. Altenberg, 1996. “Complex adaptations and the evolution of evolvability,” *Evolution*, 50: 967–976.)

Wagner argues that the key to understanding the evolution of novelty is a close look to homology, and in particular, developmental mechanisms and gene networks. A key thesis of the book is that character identity, and so the identification of homology, has a distinctive genetic basis – the gene network, or “ChIN” (Character Identity Networks). Attention to development can yield important insights into patterns and processes of evolutionary change.

West-Eberhard, M. J. (2003) *Developmental plasticity and evolution*, New York: Oxford University Press.

West-Eberhard offers criticisms of neo-Darwinian evolutionary theory, and sets out a programmatic alternative. She argues that taking into account the roles of plasticity, modularity, and other features of development largely under-appreciated in mainstream evolutionary thought will radically transform biologists’ investigations of the history of life.

**Adaptation & Adaptationism**

Starting with Gould and Lewontin’s critique of adaptationism in the 1970s, there’s been a long debate both among evolutionary biologists and philosophers about what it means to be an “adaptationist,” whether and when adaptationist thinking is fruitful, and how to test hypotheses about adaptation. There’s also been a long-standing concern among philosophers of evolutionary biology about the design and testing of optimality models in evolutionary biology. More recently, there has been some contention around whether and how to integrate game theoretical models and evolutionary population genetics.

Amundson, R. (1994) Two concepts of constraint: adaptationism and the challenge from developmental biology. *Philosophy of Science*, 61(4), 556–578.

A central concern in the debate over adaptationism concerns how one ought to define “developmental constraint.” Amundson distinguishes “constraint on adaptation” and “constraint on form,” where the former concerns how natural selection limits the potential for adaptive change, and the latter concerns how developmental organization limits the role of selection in shaping some trait.

Dupré, J., (ed.) (1987). *The Latest on the Best: Essays on Optimality and Evolution*. MIT Press.

A collection of essays by philosophers and evolutionary biologists (Dupré, Beatty, Cosmides and Tooby, Kitcher, Lewontin, Maynard Smith, Kitcher, Sober, and others) concerning methodological questions about how to test hypotheses about adaptation, conceptual questions about how to define “adaptationism,” practical and theoretical questions about the role and interpretation of optimality models in evolutionary biology, and applications of these models in the context of ecology and behavioral evolution.

Forber, P. (2009) Spandrels and a pervasive problem of evidence. *Biology and Philosophy*, 24, 247–266. (See also: (2010) Confirmation and explaining how possible. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences,* 41, 32–40.)

Forber identifies the methodological critique in Gould and Lewontin’s (1979) as an instance of a general problem: “specific observations may fail to discriminate between rival evolutionary hypotheses.” He distinguishes this from underdetermination, and demonstrates how the former arises in scientific practice, considering a debate over the evolution of *M. scurra*. In (2010), Forber extends his discussion to consider the role and limitations of how possible explanations in evolutionary biology.

Godfrey-Smith, P. (2001) Three kinds of adaptationism. *Adaptationism and Optimality*, Cambridge University Press, pp. 335–357.

Godfrey-Smith distinguishes three different senses of “adaptationism.”: “empirical,” “explanatory,” and “methodological.” The first is that natural selection is unconstrained and ubiquitous; the second is that explaining adaptation is the “core intellectual mission” of evolutionary biology; and, the third is that looking for features of adaptation is a sound methodological strategy. Godfrey-Smith argues that these views are logically independent; and that debates over adaptationism can arise out of conflating these theses.

Gould, S. J. & Lewontin, R.C. (1979) The Spandrels of San Marco and the Panglossian Paradigm: A Critique of the Adaptationist Programme. *Proceedings of the Royal Society of London* B, 205(1161), 581–598.

Gould and Lewontin argue that many purported adaptations may in fact be byproducts of developmental constraints, or products of an organism’s “Bauplan.” They argue that evolutionary biologists have overemphasized adaptive explanations to the exclusion of other plausible, non-selective explanations, such as appeals to drift. They question whether evolutionary biologists have adhered to sufficiently rigorous standards of evidence for claims about adaptation.

Lewontin, R. C. (1978) Adaptation. Scientific *American* 239 (9): 156–169.

In which Lewontin sets out the conditions of adequacy on adaptive hypotheses, and the range of ways in which a lineage may be more or less “evolvable.”

Orzack, S. H., & Sober, E. (1994) Optimality models and the test of adaptationism. *The American Naturalist*, 143, 361–380. (See also, 2001 *Adaptationism and Optimality*, Cambridge University Press.)

Sober and Orzack distinguish three different kinds of hypotheses that optimality modeling could test: (1) Natural selection played some role, (2) was an important cause; or (3) the only important cause of the evolution of T in the lineage leading to X. The edited volume contains essays biologists and philosophers, representing a wide range of opinions and approaches to testing adaptationist hypotheses.

Potochnik, A. (2009) Optimality modeling in a suboptimal world. *Biology and Philosophy*, 24, 183–197. (See also: (2012) Modeling Social and Evolutionary Games. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences,* 43(1), 202-208; and, .)

Potochnik argues that optimality models are explanatory. An explanation should represent the causes that figure into the relationship of interest in the particular context of inquiry at hand, and, be maximally general within these constraints. Optimality models meet these criteria, in the context of research programs concerned with the particular distribution of phenotypic traits in a population, rather than some other possible distribution.

Rose, M.R. & Lauder, G.V. (Eds.) (2006) *Adaptation*. Academic Press.

This collection of essays reviews the history of the concept of adaptation, empirical methods for studying adaptation, and a variety of examples of adaptive processes. Seger and Stubblefield’s “Optimization and adaptation,” provides an overview of how optimality models are developed and tested; Hudson’s “Molecular Population Genetics of Adaptation” explains how hypotheses about adaptive processes at the molecular level are tested; other essays describe how to test hypotheses about adaptation in laboratory, contexts, as well as in the wild, and in the evolutionary past.

Sterelny, K. (2003) *Dawkins vs. Gould: Survival of the Fittest*. Icon.

The book provides an overview of the major points of agreement and disagreement of Gould and Dawkins. The first half focuses Dawkins’s views on replicators versus interactors, genic selection, selfish genes and the evolution of altruism, and the “extended phenotype.” The latter half of the book discusses Gould’s criticisms of adaptationism, genetic reductionism, and extrapolationism.

**Units and Levels of Selection**

The question of what counts as primary the “unit” or “target” of selection has been a topic of controversy among evolutionary biologists going back to the mid-20th Century. G.C. Williams (1963) argued in *Adaptation and Natural Selection* that it is more “parsimonious” to assume that by and large organisms are the “beneficiaries” of selection, rather than groups. Dawkins (1976) argues that the ‘ultimate’ beneficiaries and agents of selection are genes. Philosophers of biology have been concerned to clarify the terms of this debate, introducing a variety of key conceptual innovations: e.g., the distinction between “interactor” and “replicator,” “dynamic” versus “causal” sufficiency, and have usefully distinguished conceptual and methodological issues about from empirical questions. Much of the debate has turned on the representational adequacy of genic models of selection. However, it is also a debate about the nature or process of “replication,” the variety of entities replicated, the “beneficiaries” of selection, the bearers of “adaptation,” and the causal dynamics of selection. Philosophers of biology have debated whether, and in what senses, empirical adequacy is the same as adequacy in capturing causal dynamics, distinguished more or less permissive conditions on group selection, and assessed the merits of competing theoretical frameworks for parsing the causal factors at work in multilevel selection. Recently, the discussion has been expanded to consider both “synchronic” and “diachronic” questions, about multilevel selection, and its role in major transitions, such as the emergence of multicelluarity.

Brandon, R. N. (1982) The Levels of Selection. *Proceedings of the Philosophy of Science Association*, 1, 315–323. (see also: (1988) Levels of Selection: A Hierarchy of Interactors. *The Role of Behavior in Evolution*, MIT Press, pp. 51–71.; Brandon, R.N. & Nijhout, H.F. (2006) The Empirical Nonequivalence of Genic and Genotypic Models of Selection: A (Decisive) Refutation of Genic Selectionism and Pluralistic Genic Selectionism. *Philosophy of Science*, 73(8): 277–297.)

Brandon notably proposed that screening off be used to identify which levels of entities are causally effective in the selection process, or to isolate interactors. He also (1988) distinguishes the “units” and the “levels” of selection questions. With Nijhout, he argues that the genic account cannot accommodate all cases of selection; it fails when drift is factored in (Brandon & Nijhout 2006).

Brandon, R. N. & Burian, R.M. (eds.) (1984) *Genes, Organisms, Populations: Controversies Over the Units of Selection*. MIT Press/Bradford.

A classic reference with landmark papers on the units of selection debate by Ruse, Wright, Wynne-Edwards, Williams, Mayr, Wimsatt, Sober and Lewontin, Brandon, Hull, Dawkins, Hamilton, Michod, Maynard-Smith, Wade, Wilson, and Arnold and Fristrup. The papers clarify the variety of both conceptual and methodological issues at stake, and provide excellent overviews of the relevant mathematical theory.

Damuth, J. & Heisler, I.L. (1988) Alternative Formulations of Multilevel Selection. *Biology and Philosophy*, 3(4), 407–430.

Damuth and Haisler introduce the distinction between MLS1 and MLS2 to describe two different situations where selection may occur simultaneously at more than one level of analysis. In multilevel selection 1 (MLS1), fitnesses are properties of individuals; in multilevel selection 2 (MLS2), fitnesses are properties of groups, in the sense that some groups propagate more groups, due to characters that can be attributed to the group as a whole.

Dawkins, S. (1976) *The Selfish Gene*. Oxford University Press.

Though written for a popular audience, this book initiated a series of debates concerning the “unit,” “level,” or “target” of selection. Dawkins argued that the "unit of selection" is the gene. Genes (or, “replicators”), on Dawkins view, differ with respect to properties, in ways that affect their abilities to leave copies of themselves in the next generation. Coalitions of replicators construct “vehicles,” (organisms) through which they spread copies of themselves.

Godfrey-Smith, P. (1992) Additivity and the Units of Selection. *Proceedings of the Philosophy of Science Association*, 1, 315–328. (see also: Godfrey-Smith, P. & Lewontin, R. C. (1993) The Dimensions of Selection. *Philosophy of Science*, 60(3), 373–395; Godfrey-Smith, P. (2008) Varieties of population structure and the levels of selection*. The British Journal for Philosophy of Science*, 59(1), 25–50.; (2009) *Darwinian Populations and Natural Selection*, Oxford: Oxford University Press. (2011) Agents and Acacias: Replies to Dennett, Sterelny, and Queller. *Biology and Philosophy*, 26(4), 501–515.)

Godfrey-Smith is a major player in philosophical debates about multilevel selection. He analyzes when and how additivity can be used as criterion for assessing levels of selection (1992), considers the representational and explanatory roles of genic models of selection (1993), analyzes the role of population structure in selection (2008), and considers the limits of the “gene’s eye view” (2009, 2011).

Griffiths, P. E. & Gray, R. (1994) Developmental Systems and Evolutionary Explanation, Journal of Philosophy, 91(6), 277–304. (see also: (1997) Replicator II—Judgment Day, *Biology and Philosophy*, 12(4): 471–492.)

Griffiths and Gray resist the “gene’s eye” view on selection, arguing that replication of genes is simply one aspect of the replication of a life cycle. Griffiths (1997) analyzes Sterelny, Smith and Dickenson’s (1996) “extended replicator” concept, and argues that while it is more or less intertranslatable with the DST perspective, it is a mistake to compare the “heuristic” advantages of the former to the latter.

Hull, D.L. (1980) Individuality and Selection. *Annual Review of Ecology and Systematics*, 11, 311–332.

In this paper, Hull introduces the term “interactor” as a complement to Dawkins’s “replicator.” The latter has two roles: copying themselves and influencing their survival and the survival of their copies. Hull designated an “interactor” as that entity which interacts, as a cohesive whole, directly with its environment in such a way that replication is differential—in other words, an entity on which selection acts directly (Hull 1980: 318).

Kerr, B. and Godfrey-Smith, P. (2002). “Individualist and Multi-level Perspectives on Selection in Structured Populations” and “On Price’s Equation and Average Fitness”, *Biology and Philosophy*, 17(4), 477-517; 551-565.

These papers defend “gestalt-switching pluralism” regarding two different frameworks one may use to model evolution in groups, either “multi-level” and “individualist.” The paper is a response in part to Sober and Wilson (1998), who argue that only a “multi-level” perspective (where selection may act at more than one level simultaneously) makes clear how altruism may evolve, because only her are the actual causal processes at work made explicit. Kerr and Godfrey-Smith demonstrate how the same process can be modeled two different ways, and argue that each type of model has heuristic advantages, and limitations

Kitcher, P., Sterelny, K., & Waters, C.K. (1990) The Illusory Riches of Sober’s Monism. *The Journal of Philosophy*, 87(3), 158–161.

Kitcher, et. al., defend “genic pluralism” – the view that all episodes of selection “can be interpreted in terms of genic selection” (Kitcher, Sterelny, & Waters 1990: 160). In other words, different types of models can equally well represent various patterns of selection, even patterns typically identified as “individual” or “group” selection.

Lloyd, E, A. (2017) Units and Levels of Selection *The Stanford Encyclopedia of Philosophy*(Summer 2017 Edition), Edward N. Zalta (ed.), URL = <https://plato.stanford.edu/archives/sum2017/entries/selection-units/>. (see also: (1986) Evaluation of Evidence in Group Selection Debates. *Proceedings of the Philosophy of Science Association*, 1, 483–493.; (1989) A Structural Approach to Defining Units of Selection. *Philosophy of Science*, 56(3), 395–418.; (2005) Why the Gene Will Not Return. *Philosophy of Science*, 72(2), 287–310.; (2015) Adaptationism and the Logic of Research Questions: How to Think Clearly about Evolutionary Causes. *Biological Theory*, 10: 343–362.; Lloyd, E. A., Dunn, M., Cianciollo, J. & Mannouris, C. (2005) Pluralism without Genic Causes? *Philosophy of Science*, 72(2), 334–341;

Lloyd, E. A. & Gould, S.J. (1993) Species Selection on Variability. *Proceedings of the National Academy of Sciences*, 90(2), 595–599.; Lloyd, E. A., Lewontin, R.C. & Feldman, M. (2008) The Generational Cycle of State Spaces and Adequate Genetical Representation. *Philosophy of Science*, 75(2), 140–156.)

Lloyd’s (2017) encyclopedia article provides an overview of four distinct, though often confused questions: what counts as a “replicator” what an “interactor,” what a “beneficiary” of selection, and what “manifests” adaptation. She then turns to why there has been so much controversy concerning group, species, and genic selection. In her other work, Lloyd has also critiqued defenders of genic selection, as genetic models fail to capture relevant causal information.

Okasha, S. (2007) *Evolution and the Levels of Selection*, New York: Oxford University Press. (See also: (2001) Why Won’t the Group Selection Controversy Go Away?, *British Journal for the Philosophy of Science*, 52(1), 25–50.; (2003) The Concept of Group Heritability, Biology and Philosophy, 18(3), 445–461.; (2004a) Multi-level Selection, Covariance and Contextual Analysis, *British Journal for the Philosophy of Science*, 55(3), 481–504.; (2004b) Multi-level Selection and the Partitioning of Covariance: a Comparison of Three Approaches, *Evolution*, 58(3), 486–494.; (2004c) The ‘Averaging Fallacy’ and the Levels of Selection, Biology and Philosophy, 19(2): 167–184.; (2015) The Relation Between Kin and Multilevel Selection: An Approach Using Causal Graphs, British Journal for the Philosophy of Science, 67(2), 435–470.

Okasha, S. & Paternotte, C. (2012) Group Adaptation, Formal Darwinism and Contextual Analysis, *Journal of Evolutionary Biology*, 25(6),1127–1139.)

Okasha has been one of the most prolific contributors to the levels of selection debate. He makes several key moves: first, he distinguishes two different senses of “group selection.” Second, he uses the Price equation and multilevel selection theory to clarify and operationalize this distinction. Third, he illustrates how this multi-level picture can shed light on major transitions in evolution.

Sober, Elliott, 1984. *The Nature of Selection*. (See also (2011) Realism, Conventionalism, and Causal Decomposition in Units of Selection: Reflections on Samir Okasha's Evolution and the Levels of Selection, *Philosophy and Phenomenological Research*, 82: 221–231.; Sober, E. & Wilson (1994) A Critical Review of Philosophical Work on the Units of Selection Problem, *Philosophy of Science*, 61: 534–555.)

Sober makes explicit the questions at stake in debates about units of selection, parsing off the question of what manifests “adaptation” from the question of which process, at what level, yielded that outcome, gives a critical analysis of Williams’s argument from parsimony, and critically assesses competing (“conventionalist” versus “realist”) views on levels of selection, offering up a variety of criteria for picking out when a process is genuinely higher level.

Sterelny, Kim, 1996b, “The Return of the Group”, Philosophy of Science, 63(4): 562–584. (see also: Sterelny, K. & Kitcher, P. (1988) The Return of the Gene, Journal of Philosophy, 85(7), 339–61.

Sterelny reviews the history of the kin and group selection debates, considering the importance of population structure in evolution, and with Kitcher, critiques the “genic” view of selection.

**Theories of Inheritance and Niche Construction**

Evolution by natural selection requires “heritable” variation in fitness. The measure of heritability – at least in classical quantitative genetics – is correlation between parents and offspring. By itself, a measure of heritability tells us very little about mechanisms of inheritance, or the character of hereditary information. Yet, these matters are rather important for predicting and explaining evolutionary dynamics. If selection is to act over the long term, variation needs to be inherited in a relatively “stable” fashion. Until relatively recently, it was widely believed that the only hereditary material that meets this condition is DNA. For only DNA is a genuine “reproducer,” or (what is often understood as the same thing) “replicator.” On this view, phenotypes are merely the expression of information borne by DNA. However, over the past several decades, a variety of extragenomic mechanisms and processes of heredity have been identified. Moreover, phenotypes are complex products of genes and environments in dynamic interaction; how and when DNA is expressed is contingent on many factors outside the genome. In other words, genes are not the only bearers of “hereditary information.” Some argue that the very notion of “information” treats development as merely passive unfolding of genes; but this is to ignore the complex ways in which reproduction and development are intertwined, and this in turn changes how we ought to understand evolutionary change. However, exactly how and how much extragenomic mechanisms or inheritance and development shape the process of evolution is a matter of some controversy. While “niche construction” (the notion that organisms shape their selective environments) is by now relatively uncontroversial, how and how much organisms actively shape their selective environment in ways that direct the course of evolution is a matter of controversy. In sum, there are at least three issues at stake in the literature on inheritance systems and niche construction and their bearing on evolution: (a) how we define and measure “inheritance,” (b) how important non-genetic inheritance systems are to evolution, and (c) the larger implications of a wider concept of inheritance for the dynamics of evolution, the integration of development and evolution, and the explanatory scope of evolutionary theory.

Caporael, L. R., Griesemer, J. R., & Wimsatt, W. C. (eds.) (2013). *Developing Scaffolds in Evolution, Culture, and Cognition*, Cambridge, Massachusetts: The MIT Press.

This book provides an introduction to the concept of “scaffolding” – the idea that reproduction involves many, heterogeneous relations and parts, more or less temporary, that facilitate growth and development, and may become more or less “entrenched.” The book’s authors argue that this provides an important complement to the model of inheritance in the neo-Darwinian tradition, and transforms how we ought to think about evolutionary change, particularly in the context of human cognition and culture. Contributors include C. Allen, L. Caporael, J. Evans, E. Gerson, S. Ginsburg, J. Griesemer, C. Heintz, E. Jablonka, and others.

Griesemer, J. (2000a). *Development, Culture, and the Units of Inheritance. Philosophy of Science*, 67: 348.(see also: (2000b). The Units of Evolutionary Transition. Selection, 1, 67–80.; (2000c). Reproduction and the reduction of genetics. In P. Beurton, R. Falk, and H.-J. Rheinberger (eds.), *The concept of the gene in development and evolution: historical and epistemological perspectives*, Cambridge: Cambridge University Press, 240–285; (2016) Reproduction in Complex Life Cycles: Toward a Developmental Reason Norms Perspective, *Philosophy of Science*, 83(5): 803–815.; (2018). Landscapes of Developmental Collectivity. In Gissis, S., Lamm, E. and Shavit, A. (eds.), *Landscapes of Collectivity in the Life Sciences*, Cambridge, MA: MIT Press, pp. 25–47. Wimsatt, W. C., & Griesemer, J. (2007). Reproducing Entrenchments to Scaffold Culture: The Central Role of Development in Cultural Evolution. In R. Sansom & R. Brandon (eds.), *Integrating evolution and development: From theory to practice*, Cambridge, MA: MIT Press, pp. 227–323.)

One of the most prolific authors on the concept of “reproduction,” Griesemer has argued that thinking of reproduction myopically as merely genetic has led biologists to ignore the complex, intertwined, and recursive processes of development, the diversity of life cycles, and the role of scaffolding in development and evolution.

Stotz K, Griffiths PE. (2017) Biological Information, causality and specificity—an intimate relationship. In *From matter to life: information and causality*(eds. SI Walker, P Davies, G Ellis), pp. 366–390 Cambridge, UK: Cambridge University Press. (see also: Griffiths, P. E. (2001). Genetic Information: A Metaphor in Search of a Theory. *Philosophy of Science*, 68: 394–412; (2017). Genetic, Epigenetic and Exogenetic Information in Development and Evolution. *Interface Focus*, 7 (5); Griffiths PE, Pocheville A, Calcott B, Stotz K, Kim H, Knight RD. (2015) Measuring causal specificity. *Philos. Sci.*82, 529–555.; Pocheville A, Griffiths PE, Stotz K. (2017) Comparing causes—an information-theoretic approach to specificity, proportionality and stability. In Proc. of the 15th Congress of Logic, Methodology and Philosophy of Science (eds. Leitgeb H, Niiniluoto I, Sober E, Seppälä P.), pp. 250–275. London, UK: College Publications. Griffiths PE, Stotz K. (2013) *Genetics and philosophy: an introduction*. New York, NY: Cambridge University Press.)

Griffiths, along with Stotz, Pocheville, Calcott, Kim, and Knight, have argued that if we take the information metaphor seriously, we can generate an information-theoretic measure of causal specificity in inheritance. Moreover, they find is that epigenetic and exogenetic information all play (measurably) important roles in development and evolution. They provide a formal model that quantifies the relative causal specificity of each (2015, 2017).

Helanterä, H., & Uller, T. (2010). The Price equation and extended inheritance. *Philosophy & Theory in Biology*, 2: 101.

Helanterä and Uller use the Price Equation to evaluate the roles of four different inheritance systems; genetic, epigenetic, behavioral and symbolic. They conclude that while the four systems do not differentially effect on the rate and direction of phenotypic change, but their implications for adaptive evolution nevertheless differ substantially.

Jablonka, E. (2001). The systems of inheritance. In S. Oyama, P. E. Griffiths, & R. D. Gray (eds.), *Cycles of Contingency: Developmental Systems and evolution*, Cambridge, MA: MIT Press, pp. 99–116. (see also: (2002). Information: Its Interpretation, Its Inheritance, and Its Sharing. *Philosophy of Science*, 69: 578–605.; (2004). From Replicators to Heritably Varying Phenotypic Traits: The Extended Phenotype Revisited. *Biology and Philosophy*, 19: 353–375.; (2006). Genes as Followers in Evolution—A Post-synthesis Synthesis? Biology and Philosophy, 21: 143–154.; Jablonka, E., & Lamb, M. J. (1995). *Epigenetic inheritance and evolution: the Lamarckian dimension*, New York: Oxford University Press.; (2005/2014). *Evolution in Four Dimensions: Genetic, Epigenetic, Behavioral, and Symbolic Variation in the History of Life*, Cambridge, MA: MIT Press; (2006). The evolution of information in the major transitions. *Journal of Theoretical Biology*, 239: 236–246; Jablonka, E., & Raz, G. (2009). Transgenerational epigenetic inheritance: prevalence, mechanisms, and implications for the study of heredity and evolution. *The Quarterly Review of Biology*, 84: 131–176.)

Jablonka has launched decades of work by both philosophers and biologists on epigenetic inheritance, and in particular, bringing epigenetic inheritance to bear on evolution.

Kaplan, J. (2008) Evolutionary innovations and developmental resources: from stability to variation and back again. *Philosophy of Science*75 (5):861-873.

Kapan provides a comprehensive overview of the “Evo-Devo/Devo-Evo” debate, demarcating exactly what is at issue in integrating developmental biology and evolution, and in particular, how stability of developmental resources matters to evolution.

Lamm, Ehud, "Inheritance Systems", The Stanford Encyclopedia of Philosophy (Winter 2018 Edition), Edward N. Zalta (ed.), URL = <<https://plato.stanford.edu/entries/inheritance-systems/>>

(See also: Lamm, E. & Jablonka, E. (2008). The Nurture of Nature: Hereditary Plasticity in Evolution. *Philosophical Psychology*, 21 (3): 305–19.)

Lamm provides an excellent overview of a variety of ways in which thinking about inheritance has evolved in both biology and philosophy of biology.

Odling-Smee, F. J., Laland, K. N., & Feldman, M. W. (2003). *Niche construction: the neglected process in evolution*, Princeton: Princeton University Press.

This book argues that a treating the external environment as a given, or, as relatively independent of organisms’ activities, in the interest of theoretical simplicity, is deeply problematic. The aim of the book is to show how and why niche-construction – the ways in which organisms actively shape their selective environments – makes evolutionary theory more complicated, altering the dynamics and rate of evolution.

Stotz, K. (2017). Why Developmental Niche Construction Is Not Selective Niche Construction: And Why It Matters. *Interface Focus*, 7 (5). (see also: Stotz & Griffiths, P. (2016) Epigenetics: Ambiguities and Implications. *History and Philosophy of the Life Sciences*38 (4).; Stotz, K (2006)

Molecular Epigenesis: Distributed Specificity as a Break in the Central Dogma. *History and Philosophy of the Life Sciences*28 (4):533 - 548.)

Stotz has been one of the most passionate advocates for thinking about the role of extra-genomic factors in evolution. She does a beautiful job clarifying various distinctions among different views of “niche construction” (2017), and in clarifying different senses of epigenetics (Stotz and Griffiths, 2016), as well as unpacking Burian’s important idea of molecular epigenesis (2006), and explaining how and why certain phenomena in gene regulation break with the Central Dogma.

Tabery J (2014) *Beyond versus: the struggle to understand the interaction of nature and nurture*. MIT Press, Cambridge.

Tabery does a beautiful job both providing historical perspective, and providing philosophical perspective current research, on the interaction of nature and nurture (particularly in human behavior). Tabery argues that many of the disagreements over, for instance, eugenics, Race and IQ, or the causes of depression, concern how explanation works in science, and offers a way to integrate diverse perspectives.

**Paleontology, Macroevolution & Major Transitions**

There has been a significant expansion in the philosophical literature on macroevolution and paleontology in recent years. Work in these areas concerns whether and how historical sciences like paleontology are different from experimental sciences, and whether this difference in method yields differences in strength of warrant. More recently, the focus has shifted to the ways in which different cases of inference in paleontology are weaker or stronger, how this hinges on the kinds evidence utilized, the variety or independence of evidence gathered, and the appropriate use of models and simulations. In addition, there have been some important insights into both the distinctive features of targets of explanation in macroevolution, styles of explanation, and whether, and if so, how (or how much), macroevolution is “law governed” or contingent in character. In sum, studies of macroevolution present major challenges unique to the historical sciences – distinct from, though of course informed by, the study of microevolution. One central issue in debates over macroevolution is how to classify and demarcate major stages and transitions in the history of life on earth. According to Maynard Smith and Szathmary, the history of life on earth involved several “major transitions.” There remain several open questions, however, about how best to demarcate these transitions, as well as what causes them.

Calcott, B. & Sterelny, K. (eds.) (2011) *Major Transitions in Evolution Revisited*, Cambridge, MA: MIT Press.

An excellent collection of essays intended as a modern update and critical response to Maynard Smith and Szathmary’s classic (1995). The essays, by both biologists and philosophers, range over a variety of theoretical questions (the nature of evolutionary transitions, the variety of modes of explanation of major transitions, demarcating transitions, the nature of evolvability), drawing upon recent theoretical and empirical work.

Cleland, C.E., 2011. Prediction and explanation in historical natural science. The British Journal for the Philosophy of Science, 62(3), pp.551-582. (See also: Cleland, C. E. (2002). Methodological and epistemic differences between historical science and experimental science. Philosophy of Science, 69(3), 447-451.)

Cleland argues that the structure and justification of hypotheses in the historical sciences is distinct from experimental science. Confirmation and disconfirmation in the historical sciences depends primarily upon explanatory (versus predictive) success, and appeal to the principle of the common cause. Such appeals are justified by the pervasive time asymmetry of causation (in particular the “asymmetry of overdetermination”). Events leave widespread, diverse effects, or traces of what even occurred.

Currie, Adrian. 2018. *Rock, bone, and ruin: An optimist's guide to the historical sciences*. MIT Press. (See also: 2017, “Hot-Blooded Gluttons: Dependency, Coherence, and Method in the Historical Sciences,” and 2013 “Convergence as Evidence,” *The British Journal for the Philosophy of Science*, 68 (4): 929–952, and 64(4): 763–786)

Currie defends an “optimist” view with respect to the historical sciences, and paleontology in particular. Currie grants that traces do degrade, and so sometimes we are in a situation of local underdetermination. However, he contends that ever improving background theories (and technologies) can improve our epistemic situation. He also discusses how paleontologists use various models and simulations to narrow the range of alternative hypotheses.

Multiple Authors (Currie, Bonnin, Finkelman, Jones, McConwell, Havstad, Wylie, Turner). 2019. *Topical Collection: Paleobiology and Philosphy. Biology and Philosophy*. 34(2).

This collection of essays covers a range of concerns around the methods and conclusions of paleobiology: whether and in what sense mass extinctions ought to be considered “major transitions”, the nature and variety of types of evidential reasoning in historical sciences, the character of fossil specimens as data, living fossils, the evidential roles of genomics in historical sciences, and whether the history of life is contingent.

Haufe, C. (2015) Gould’s Laws. *Philosophy of Science*. 82 (1), 1-20.

This paper attempts to resolve a tension in Gould’s work: his belief in the “replay thesis” – that the biological facts could have been otherwise – and, the existence of evolutionary laws. Gould’s takes laws to apply to higher-order phenomena to which the Replay Thesis does not apply. His interests in punctuated equilibrium, diversity dynamics, and the extinction of higher taxa were all concerned with a search for higher-order laws.

Grantham, T. (2004). The role of fossils in phylogeny reconstruction: Why is it so difficult to integrate paleobiological and neontological evolutionary biology?. *Biology and Philosophy*. 19(5), 687-720. (Grantham, T. (2007). Is macroevolution more than successive rounds of microevolution?. Paleontology, 50(1), 75-85.)

Grantham discusses how fossils are used as evidence in phylogenetic reconstruction, and considers whether and how macroevolution is distinct from microevolutionary change.

Turner, D. 2011. *Paleontology: A philosophical introduction*. Cambridge University Press. (see also: (2004). The past vs. the tiny: historical science and the abductive arguments for realism. *Studies In History and Philosophy of Science*. 35(1), 1-17.; (2005). Local underdetermination in historical science. *Philosophy of Science*, 72(1), 209-230.; (2007). *Making prehistory: Historical science and the scientific realism debate*. Cambridge University Press.; (2014). Philosophical issues in recent paleontology. *Philosophy Compass*, 9(7), 494-505.; Turner, D. & Havstad, J. "Philosophy of Macroevolution", *The Stanford Encyclopedia of Philosophy*(Summer 2019 Edition), Edward N. Zalta (ed.), URL = <https://plato.stanford.edu/archives/sum2019/entries/macroevolution/>.)

Turner considers philosophical questions about evidence, inference, and explanation in paleontology, using case studies in the history of paleontology, and examples of controversies about macroevolution (e.g., the punctuated equilibrium debate, species selection, evolutionary rates). He also considers how recent transformations in paleontology can yield insight into the nature of scientific change, the role of contingency in the history of life, underdetermination and realism in historical science. His encyclopedia entry with Havstad reviews decades of philosophical work on macroevolution.

Evolutionary Individuals, Species, & Systematics

One central concept of evolutionary biology is that of the “individual.” Evolutionary biologists speak of individual genes, organisms, populations, species, communities, and ecosystems. Individuals are bearers of properties like fitness, functions, and “evolvability.” Individuals may be targets or units of selection, insofar as they may vary, and may also persist, survive, and in some cases, reproduce. However, how best to specify or refine these conditions on evolutionary individuality, and individuality more generally, is contested. Debates over these questions overlap with larger debates over units and levels of selection, systematics (the classification of species and higher taxa), and phylogenetics (the reconstruction of the tree of life). Debates about classification can be broken down into three (interrelated) questions. The first question is whether the taxonomic categories – kingdoms, phyla or divisions, classes, orders, families, genera, species, subspecies – are “real” or “natural,” or merely “conventional” categories. The second question is how to define taxonomic categories (a debate which of course overlaps with debates about phylogenetic reconstruction). For instance, biologists have long debated whether and why one ought to adopt the “biological species concept,” the “ecological species concept,” the “phylogenetic species concept,” etc.. A third question is whether we ought to be monists or pluralists about taxonomic categories (and, if pluralists, whether we can consistently be *realists*). A pluralist might argue, for instance, that biologists with different and equally legitimate research aims may deploy different species concepts and criteria for species demarcation. A puzzle that arises for the pluralist, however, is whether endorsing diverse species concepts leads to inconsistencies in other domains; for instance, would a pluralist about species generate “cross-cutting” classificatory schemes? This counts as an objection, however, only if a hierarchical classification scheme is assumed to be ideal. Is such a scheme ideal? It may depend upon what our classifications are for. Such debates can have larger implications for, e.g., how we measure and define biodiversity, as well as how we develop and test hypotheses in phylogenetics. Debates about phylogenetic methods have turned on questions such as how best to interpret the principle of “parsimony,” how to define and measure character or trait differences, and, more generally, what counts as an adequate test of phylogenetic hypotheses.

Barker, M. and Wilson, R. (2010). Cohesion, Gene Flow, and the Notion of Species. *Journal of Philosophy*, 107: 59–77.

Barker and Wilson challenge the widespread assumption that species are distinctively “cohesive,” and that gene flow is the causal explanation. They argue that integrative cohesion is not a distinctive feature of species, and moreover, that whatever cohesion there is simply reduces to the bare fact of gene flow. This challenge poses further challenges to the concept of a species as an “evolutionary unit,” species individuality, and pluralism about species concepts.

Boyd, R. (1999a). Homeostasis, species, and higher taxa. *Species: New Interdisciplinary Essays*, MIT Press. 141–185. (See also: (1999b) Kinds, complexity and multiple realization: comments on Millikan’s ‘Historical Kinds and the Special Sciences’. *Philosophical Studies*, 95, 67– 98.)

 Boyd characterizes “homeostatic property cluster” kinds as a kind of natural kind, one not identified via “essential properties” or necessary and sufficient conditions, but by "homeostatically" sustained clustering of properties or relations, allowing for indeterminacy in their extensions. He also defends the “accommodation thesis”; namely, conceptual and classificatory practices are accommodated to causal structures, and argues that species are exemplary HPC kinds.

DiFrisco, J. (2019) Kinds of Biological Individuals: Sortals, Projectibility, and Selection. *British Journal for the Philosophy of Science*, 70, 845–875

DeFrisco argues for pluralism about the criteria for individuality, in light of the distinctive explanatory roles of individuals of various kinds – ‘evolutionary,’ ‘physiological’, ‘ecological’, and ‘developmental’ individuals.

Devitt, M. (2008) Resurrecting Biological Essentialism *Philosophy of Science*, 75: 344–382.

The article defends the view that Linnaean taxa, including species, have essences – i.e., intrinsic, and in this case, genetic, properties.

Dupré, J. (1993)*The Disorder of Things: Metaphysical Foundations of the Disunity of Science*, Harvard University Press. (See also: (1981) Natural Kinds and Biological Taxa. *The Philosophical Review*, 90(1), pp. 66-90; and, Dupré, J. & O’Malley, M.A. (2009) Varieties of Living Things: Life at the Intersection of Lineage and Metabolism. *Philosophy and Theory in Biology*, 1, 1–25. )

Dupré critiques microessentialism and “taxonomic realism” (the view that there is one correct taxonomy), and argues for “promiscuous realism”: “there are many sameness relations that serve to distinguish classes … in ways that are relevant to various concerns,” and “none of these relations is privileged.” (1981, 82) Both scientists and ordinary folk generate equally legitimate classifications. Nonetheless, species are real, while higher taxa have at best “nominal” essences.

Ereshefsky, M. (2014) Species, Historicity, and Path Dependency. Philosophy of Science. 81(5), 714-726 (see also: (1992) *The Units of Evolution: Essays on the Nature of Species*. MIT Press.; (1998) Species Pluralism and Anti-Realism *Philosophy of Science*. 65, 103–120; (2001)*The Poverty of the Linnaean Hierarchy: A Philosophical Study of Biological Taxonomy*. Cambridge University Press; (2007) Foundational Issues Concerning Taxa and Taxon Names. *Systematic Biology*. 56: 295–301; (2010a) What’s Wrong with the New Biological Essentialism. *Philosophy of Science*. 77, 674–685; (2010b) Microbiology and the Species Problem. *Biology and Philosophy*, 25, 67–79; (2010c) Darwin’s Solution to the Species Problem. *Synthese*, 175: 405–425; Ereshefsky, M. & Pedroso, M. (2013) Biological individuality: the case of biofilms. *Biology and Philosophy*, 28, 331–349.)

Ereshefsky has been one of the most prolific authors on conceptual and methodological problems of classification and taxonomy. He has defended species pluralism and antirealism, and critiqued the Linnaean hierarchy, principally due to its essentialism and emphasis on genera. Ereshefsky’s view is that taxa ought to be classified according to their causal relations rather than their intrinsic features. In particular, historical relations rather than intrinsic similarities determine species identity, and species are spatiotemporally continuous entities, and path-dependent ones.

Franklin, L. (2007) Bacteria, sex, and systematics. *Philosophy of Science*, 74: 69–95.

Franklin argues that neither the biological species concept nor phylogenetic species concepts are apt for bacteria, given variable gene exchange and problems with identification of species typical genes. She then defends the evolutionary species concept.

Ghiselin, M., 1974, “A Radical Solution to the Species Problem”, *Systematic Zoology*, 23: 536–544 (see also: 1987, “Species Concepts, Individuality, and Objectivity”, *Biology and Philosophy*, 2: 127–143; 1997, *Metaphysics and the Origin of Species*, Buffalo, NY: SUNY Press; Griffiths, P., 1999, “Squaring the Circle: Natural Kinds with Historical Essences”, in *Species: New Interdisciplinary Studies*, R. Wilson (ed.), Cambridge, Massachusetts: MIT Press.)

Ghiselin defends “realism” about species – the view that they are real – and argues that they are “individuals,” not “kinds” or “sets.” By “individual,” he means an entity that has a proper name, does not have instances, or necessary or sufficient conditions for membership. This stance, he argues, resolves many confusions about the species category.

Gilbert, S. F., Sapp, J. & Tauber, A.I. (2012) A Symbiotic View of Life: We Have Never Been Individuals. *The Quarterly Review of Biology*, 87(4), 325–341. (see also:

Gilbert, S. F., Rosenberg, E. & Zilber-Rosenberg, I. forthcoming, The Holobiont with Its Hologenome is a Level of Selection in Evolution, in *Landscapes of Collectivity* (Vienna Series in Theoretical Biology), Snait B. Gissis, Ehud Lamm, & Ayelet Shavit (eds.), MIT Press.)

Gilbert, et. al. (2012), argue that “individual” human being is actually a community of organisms co-evolved for mutual benefit; the microbiome is necessary for our survival and development, and our species is also needed in turn for their survival. In the forthcoming paper, Gilbert, et. al., argue that the Holobiont (the collective of humans and their microbiome) is a level of selection.

Hull, D. (1988) *Science as a Process*: *An Evolutionary Account of the Social and Conceptual Development of Science*, University of Chicago Press.

Hull argues for an evolutionary picture of the history of science itself, using the historical conflict between evolutionary cladists and pheneticists as a case in point. Along the way, he gives a comprehensive history of systematics.

Kitcher, P. (1984) Species. *Philosophy of Science*, 51: 308–333.

Kitcher defends pluralistic realism about the species category, i.e., the view that there are several equally legitimate ways to define “species,” argues that species are sets and not individuals, briefly considers some limitations of the biological species concept, argues that other views of the nature of species have shortcomings as well, and finally concludes that biologists’ interests and questions are diverse, yielding different methods of classification.

Okasha, S. (2002) Darwinian Metaphysics: Species and the Question of Essentialism. *Synthese*, 131, 191–213. (see also: (2009) Individuals, Groups, Fitness and Utility: Multi-Level Selection Meets Social Choice theory. *Biology and Philosophy*, 24(5), 561-584.)

In 2002, Okasha argues that the properties that they use to distinguish species are relational rather than intrinsic. Essentialist views of species are “half-right” in the sense that they identify morphological traits that are indirectly relevant to true classification. However, essentialists are mistaken in thinking intrinsic microstructure is always the ultimate determinant of kind membership. That properties that determine species membership are not microstructural, but concern the evolutionary process.

O’Malley, M. (2014) *Philosophy of Microbiology*, Cambridge University Press.

This introduction to an entirely new field of philosophy contains three chapters that deal with evolutionary questions in microbes: concerning high level classification of kingdoms and domains, challenges to the species concept from microbes, and how microbial evolution forces reconsiderations of standard evolutionary theory. Much of the “classical” picture of classification, evolution, and major transitions in the history of life is being fundamentally challenged by work in microbial biology.

Pradeu, T. (2016). Organisms or biological individuals? Combining physiological and evolutionary individuality. *Biology and Philosophy*, 31, 797–817. (see also: (2016). The many faces of biological individuality. *Biology and Philosophy*, 31, 761–773.)

Pradeu compares and contrast the variety of ways in which immunologists and evolutionary biologists demarcate individuals.

Reydon, T.A.C. (2019): ‘Taxa hold little information about organisms: Some inferential problems in biological systematics’, *History and Philosophy of the Life Sciences* 41: 40 (see also

 (2019/2020): On radical solutions in the philosophy of biology: What does “individuals thinking” actually solve?, *Synthese*; Reydon, T.A.C. & Kunz, W. (2019): Species as natural entities, instrumental units and ranked taxa: New perspectives on the grouping and ranking problems, *Biological Journal of the Linnean Society* 126: 623-636.; (2019): ‘Are species good units for biodiversity studies and conservation efforts?’, in: Casetta E., Marquez da Silva, J. & Vecchi, D. (Eds): From Assessing to Conserving Biodiversity: Conceptual and Practical Challenges, Cham: Springer, 167-193. Ereshefsky, M. & Reydon, T.A.C. (2015): ‘Scientific kinds’, Philosophical Studies 172: 969-986.; Reydon, T.A.C. (2009): ‘How to fix kind membership: A problem for HPC-theory and a solution’, Philosophy of Science 76: 724-736; (2008): ‘Species in three and four dimensions’, Synthese 164: 161-184; Reydon, T. (2003). Species Are Individuals Or Are They? *Philosophy of Science*, 70, 49–56.)

One of the most prolific writers on species concepts, Reydon has considered a variety of conceptual and methodological issues about species and higher taxa: competing presuppositions among different schools of thought in systematics and classification, whether species are real, whether species are good units of measure for biodiversity, and whether various competing philosophical views on natural kinds apply in the context of species and higher taxa.

Slater, M. (2013) *Are Species Real? An Essay on the Metaphysics of Species*. Palgrave Mcmillan.

Slater considers various criteria for demarcating natural kinds, and applies them in the context of the debate over we ought to be conventionalists or realists about species.

Sober, E., (1980) Evolution, Population Thinking and Essentialism. *Philosophy of Science*, 47, 350–383. (See also: (1988). *Reconstructing the Past: Parsimony, Evolution and Inference*. MIT Press. Sober, E. (1991) Organisms, Individuals, and Units of Selection. in *Organism and the Origins of Self*, Kluwer Academic Publishers, 275–196.)

In this classic (1980) paper, Sober provides an alternative account of the failures of essentialism and of what is distinctive about “population thinking” from Mayr’s (1959) account: the “natural state” model, and the essentialist's requirement that properties of populations be defined in terms of properties of member organisms are both inconsistent with evolutionary theory. In his (1988) book, Sober explains and defends arguments from parsimony work in phylogenetic reconstruction.

Velasco, J., 2010, “Species, Genes, and the Tree of Life”, *British Journal for the Philosophy of Science*, 61: 599–619.

Velasco argues that both organismal lineages and gene genealogies (and their trees) are objectively real, and play different, important roles in biological practice.

Wilson, Robert A. and Barker, Matthew J., "Biological Individuals", *The Stanford Encyclopedia of Philosophy*(Fall 2019 Edition), Edward N. Zalta (ed.), URL = <https://plato.stanford.edu/archives/fall2019/entries/biology-individual/>. (see also: Wilson, R. A., (ed.) (1999). *Species: New Interdisciplinary Essays*. Cambridge University Press.)

A critical overview of the philosophical literature on the nature of individuals in biology.

Social Evolution, Evolutionary Psychology and Human Nature

Evolutionary theories of human behavior and cognition have been subject to various forms of critique ever since Darwin published the *Expression of Emotions in Man and Animals* 1872. Philosophers have made substantial contributions to this literature. Indeed, the rise of philosophy of biology as a professional discipline coincided with the rise of Sociobiology in the 1960s and 70s. This was no accident. Several evolutionary biologists had concerns about the ambitions of sociobiology, which led them to collaborate with philosophers (as well as historians, anthropologists, and others). An active literature grew out of this collaborative work, and arguably, the pendulum has swung back in the opposite direction. While many philosophers (as well as biologists, psychologists and anthropologists) initially brought attention to methodological and conceptual problems in much of this literature, today, many more are appealing to evolutionary biology, anthropology, etc., favorably, in defense of various accounts of the emergence of our distinctive cognitive architecture. However, philosophers have by and large been very critical of naïve views about genetic determination of behavior, less than ideal evidence in service of claims about adaptation, lack of attention to behavioral plasticity, or variability of ancestral environments. Perhaps in part as a result of early critiques of Evolutionary Psychology, there is now a much more subtle and sophisticated body of work on this topic, and an active and diverse literature in service of developing more robust, empirically informed evolutionary theories of human behavior and cognition. Some philosophers have made substantial contributions to this literature, both defending and clarifying various competing views on the evolution of altruism, sociality, morality, cognition, language, and even musical ability.

Barker, Gillian. 2015, *Beyond Biofatalism: Human Nature for an Evolving World*, New York: Columbia University Press.

This book examines work in philosophy, evolutionary biology, and the social sciences on the scope and limits of evolutionary psychology and its import for addressing social and economic inequalities and responding to the coming challenges associated with climate change. Barker criticizes presuppositions about the immutability of human nature, and draws attention to the importance of phenotypic plasticity, reaction norms, and niche construction.

Birch, J. (2017) *Philosophy of Social Evolution.* Oxford: Oxford University Press.

Birch defends Hamilton’s rule as an organizing framework for social evolution research – i.e., research on the evolution of social behaviors. He also argues that kin and group selection are just varieties of selection on indirect fitness, and expands the scope of the rule to explain the origin of multicellularity, and explores the rule’s application in the context of cultural evolution.

Buller, D. (2005) *Adapting Minds: Evolutionary Psychology and the Persistent Quest for Human Nature*, Cambridge, MA: MIT Press.

Buller’s book is a classic overview and critical assessment of the aims and methods of evolutionary psychology. He argues that evolutionary psychologists endorse a view of human nature and “laws” of human behavior that is antithetical to evolutionary biology.

Downes, S. M., (2018) "Evolutionary Psychology", *The Stanford Encyclopedia of Philosophy*(Fall 2018 Edition), Edward N. Zalta (ed.), URL = <https://plato.stanford.edu/archives/fall2018/entries/evolutionary-psychology/>.

(See also: (2001) Some recent developments in evolutionary approaches to the study of human behavior and cognition. *Biology and Philosophy*, 16, 575–595; (2005) Integrating the Multiple Biological Causes of Human Behavior. *Biology and Philosophy*, 20, 177–190; (2009) The Basic Components of the Human Mind Were Not Solidified During the Pleistocene Epoch. *Contemporary Debates in Philosophy of Biology*. Wiley Blackwell, 243–252.; and, (2016) Confronting Variation in the Social and Behavioral Sciences. *Philosophy of Science*, 83, 909–920.)

Downes has been among the most prolific commentators on evolutionary psychology, both in service of clarifying its major commitments, and in comparing and contrasting approaches typical of evolutionary psychology with behavioral ecology. Downes has given skeptical arguments regarding the distinctive role of the Pleistocene in human evolution, and drawn attention to the importance of variation in cognition and behavior in understanding our evolutionary history.

Dupré, J., (2001) *Human Nature and the Limits of Science*. Clarendon Press. (see also: (1998) Normal People. *Social Research*, 65, 221–248; (2012) Against Maladaptationism: Or, what’s wrong with evolutionary psychology? *Processes of Life: Essays in Philosophy of Biology*, Oxford University Press, 245–260.)

Dupré’s classic paper on “normal people” argues that applying the term “normal” to people presupposes that people form “a kind” (which they do not). His book is an extended treatment of this theme, arguing that Evolutionary Psychologists’ attempt at functional explanations of human mental capacities are largely poor science, and they lend support to pernicious social policy. Dupré grounds his critique in a rejection of metaphysical monism, and endorses a pluralistic view.

Krönfeldner, M. (2018) *What's Left of Human Nature?: A Post-Essentialist, Pluralist, and Interactive Account of a Contested Concept,* (Life and Mind: Philosophical Issues in Biology and Psychology) MIT Press.

Krönfelder’s book is a defense of human nature, though significantly modified in light of decades of critique of essentialist views by philosophers such as Hull, Sober, and Dupré. Part I summarizes three common arguments against the concept of human nature; part II characterizes accounts of human nature that can survive the anti-essentialist and interactionist critiques; and, part III considers Part normative implications of human nature concepts.

Sober, E. and Wilson, D. S. (1998). *Unto Others: The Evolution and Psychology of Unselfish Behavior*. Cambridge, Massachusetts, Harvard University Press.

This is a (now) classic book, arguing that far from inconsistent with evolution, altruistic behavior can and likely did emerge over the course of evolution. The authors critically assess a variety of different models for the evolution of altruism, defending an account that appeals to group level properties, and also discuss a vast array of psychological literature, demonstrating how and why human beings have altruistic tendencies.

Godfrey-Smith, P. (1996) *Complexity and the Function of Mind in Nature*. Cambridge University Press.

Now a classic text in both philosophy of mind and philosophy of biology, Godfrey-Smith offers novel perspectives on the notion of function and teleology, representation, a history of various pragmatists philosophical perspectives, and how they bear on a naturalistic approach to mind.

Griffiths, 1997. What Emotions Really Are. Chicago: University of Chicago Press. (see also: Griffiths, P. E., 2011, “Our Plastic Nature”, in S.B. Gissis and E. Jablonka (eds.), *Transformations of Lamarckism: From subtle fluids to Molecular Biology*, Cambridge, MA: MIT Press, 319–330.; 2008, “Ethology, Sociobiology and Evolutionary Psychology”, in S. Sarkar and A. Plutynski (eds.), *A Companion to Philosophy of Biology*, New York: Blackwell, 393–414; 2006, “Evolutionary Psychology: History and Current Status”, in S. Sarkar and J. Pfeifer (eds.), *Philosophy of Science: An Encyclopedia*, New York: Routledge, Volume 1, pp. 263–268)

Griffiths defends Ekman’s (and Darwin’s) theories regarding the evolution of several core emotional responses, though, he contends that the emotions are not “innate” in the sense typically understood. He draws upon developmental systems theory to illustrate how, contrary to the “folk biological” notion of human “nature” as fixed, typical, and adaptive, that a trait is an adaptation does not imply that it is developmentally canalized, the fact that it is typical does not imply that it is environmentally canalized, and that the fact that it is an adaptation does not imply that it is typical.

Hull, D.L., (1986) On Human Nature. *Proceedings of the Biennial Meeting of the Philosophy of Science Association*, 2, 3–13.

Now a classic in the history of philosophy of biology, Hull’s paper argues that the very idea of “human nature” is empirically and conceptually flawed, drawing in part from evolutionary and population thinking.

Kitcher, Philip, 1985. *Vaulting Ambition: Sociobiology and the Quest for Human Nature*, Cambridge, MA: MIT Press.

A systematic critique and historical analysis of the rise (and fall?) of sociobiology.

Lewens, T. (2015) *Cultural Evolution*, Oxford: Oxford University Press.

An excellent review of conceptual and empirical challenges facing the notion of cultural evolution, and a qualified defense.

Lloyd, E. A., 1999, “Evolutionary Psychology: The Burdens of Proof”, *Biology and Philosophy*, 14: 211–233. (see also: Lloyd, E. A. and M. W. Feldman, 2002, “Evolutionary Psychology: A View from Evolutionary Biology”, Psychological Inquiry, 13: 150–156.)

Lloyd has offers a critical perspective on the methods of evolutionary psychologists in attempting to establish claims about the particular adaptations unique to humans.

Machery, E. (2008) A Plea for Human Nature, *Philosophical Psychology*. 21, 321–329.

Machery argues that philosophers of biology (particularly Hull) have made unjust criticisms of evolutionary psychology, and defends the “nomological” as opposed to the “essentialist” view of human nature, which he takes to be compatible with evolutionary biology. On his view, the properties that are part of human nature are neither necessary nor jointly sufficient for being a human.

Machery, E. (2006) Massive Modularity and Brain Evolution. *Philosophy of Science: Proceedings*, Part 1. 74(5), 825-838.

Machery defends the “massive modularity” (MM) hypothesis: if natural selection has shaped human cognitive architecture, the mind is likely to consist of many systems, each having been designed by natural selection to fulfill a specific function. The allometric relationships between the volume of the whole brain and its parts found across mammals does not undermine the thesis that the neocortex evolved in a mosaic manner, in his view.

Mallon, R. (2016) *The Social Construction of Human Kinds*. Oxford University Press. (see also: Mallon, R. and S. P. Stich, 2000, “The Odd Couple: The compatibility of social construction and evolutionary psychology”, *Philosophy of Science*, 67: 133–154; Mallon, R. (2019) Naturalistic Approaches to Social Construction, *The Stanford Encyclopedia of Philosophy*(Spring 2019 Edition), Edward N. Zalta (ed.), URL = <https://plato.stanford.edu/archives/spr2019/entries/social-construction-naturalistic/>)

Mallon is combines insights from naturalistic approaches to human culture and cognition, and “social constructionist” approaches, arguing that both biological and cultural factors play important reciprocal roles in shaping human “kinds.”

Nichols, S., (2004) *Sentimental Rules: On the natural foundation of moral judgment.* Oxford University Press.

Nichols draws upon psychological research to defend a Humean empirical thesis regarding the psychological mechanisms underlying our capacity for moral judgment – namely, that we come to adopt moral rules because various outcomes generate affective responses, and we can learn these rules through acculturation. The latter view is tied to his critique various meta-ethical theories (moral rationalism, neosentimentalism and moral objectivism) and defense of moral relativism.

Reisman, K. 2007. “Is Culture Inherited through social learning?” *Biological Theory*. 2(3): 300-306.

Reisman challenges what he calls the “Standard Picture” of cultural evolution, distinguishes the matter of whether learning is a distinctively social “process,” and whether learning occurs in distinctively social “contexts,” and argues that once we distinguish these, it becomes clear that learning may be “social” in one sense, and not in another, but that most forms of learning are a hybrid, involving both imitation or instruction, and occur in a social context, in ways that enable culture to be inherited.

Shapiro, L. (2010). James Bond and the Barking Dog: Evolution and Extended Cognition. Philosophy of Science. 77(3), 400-418. (see also: Shapiro, L. A. and W. Epstein (1998) Evolutionary Theory Meets Cognitive Psychology: A More Selective Perspective. *Mind and Language*, 13, 171–194.)

Shapiro argues that – contra defenders of extended cognition – evolutionary theory should not lead us to expect humans to develop cognitive strategies exploit the environment in ways that extend beyond the head of the organism. Defenders of extended cognition defend the “007 principle” (a subset of a “barking dog” principle), that organisms will seek out less costly ways to store and process information, and one such way is in the environment.

Sinnott-Armstrong, W., (ed.) (2008) *Moral Psychology: The Evolution of Morality: Adaptations and Innateness*. (Moral Psychology, Volume 1), Cambridge, Massachusetts: MIT Press.

This edited volume contains (now) classic papers that draw upon cognitive psychology, brain science, and evolutionary biology to better understand morality. There are seven papers, and two responses to each, followed by the author's response. Contributions include Lieberman on incest taboos, Cosmides and Tooby on cheating, Sripada and Prinz on moral development and the moral emotions, and Miller and Tse on sexual selection and its role in the evolution of virtue.

Sterelny, K., (2012), *The Evolved Apprentice: How Evolution Made Human Unique*, Cambridge, MA: MIT Press. (see also: 2003, *Thought in a Hostile World: The Evolution of Human Cognition*, Oxford: Blackwell; and, Sterelny and J. Fitness (eds.), (2003) *From Mating to Mentality: Evaluating Evolutionary Psychology*, New York: Psychology Press.)

One of the most prolific contributors to this field, Sterelny engages with a variety of questions about what makes human cognition unique, and how we evolved the various capacities that make us distinctively human. In particular, Sterelny defends the view that a combination of cultural inheritance and social learning, all have contributed to the emergence of our distinctive cognitive capacities.

**Race, Sex, and Medicine in Light of Evolution**

Whether there is an evolutionary bases of race, as well as whether and in what sense sex and sex-associated traits are selected for, are both matters of some controversy. In part, such debates are continuous with debates about classification and systematics, as well as debates about adaptationism. In part, however, this literature overlaps with a broader literature in feminist philosophy and philosophy of race. Feminists and race theorists have been critical of the role of certain presuppositions in shaping research on race and sex differences. Relatedly, evolutionary medicine raises a variety of questions about warrant for claims about disease and health, and has been subject to critical assessment from philosophers of biology and medicine; such assessments concern matters of classification and definition of disease, as well as standards of evidence for evolutionary hypotheses.

Adriaens, P. R., & De Block, A. (Eds.). (2011). *Maladapting minds: Philosophy, psychiatry, and evolutionary theory*. Oxford University Press.

This edited volume contains critical perspectives on the role of evolutionary thinking in medicine, in particular in the context of psychiatry. Articles by psychiatrists, philosophers, and evolutionary biologists address a range of questions about the nature of mental illness, and the merits (or problems) with evolutionary explanations for particular conditions, such as autism, schizophrenia, and depression.

Andreasen, R. O. (2000). Race: Biological reality or social construct?. *Philosophy of Science*, *67*, S653-S666. (see also: (1998). A new perspective on the race debate. *The British journal for the philosophy of science*, *49*(2), 199-225.; (2004). The cladistic race concept: a defense. *Biology and Philosophy*, *19*(3), 425-442.)

Andreasen challenges the view that races are social constructs, and argues that a cladist perspective provides a new way to define race biologically. She also attempts to reconcile her biological conception with constructivist theories about race by arguing that while human races may historically have been biological clades, they are no longer.

Creager, A., Lunbeck, E., & Schiebinger, L. (eds.), (2001) *Feminism in Twentieth-century Science, Technology and Medicine,* Chicago: University of Chicago Press.

Prominent science and technology studies scholars speak to the changes feminism has wrought in science, and in particular: how feminist theory has shaped the biological and sciences. Wylie comments on feminist influences in archaeology, and Fedigan, Gilbert, Rader, and Fox Keller comment on feminist influences in biology.

Crasnow, S., Wylie, A., Bauchspies, W. K. and Potter, E., (2018) Feminist Perspectives on Science, *The Stanford Encyclopedia of Philosophy*(Spring 2018 Edition), Edward N. Zalta (ed.), URL = <https://plato.stanford.edu/archives/spr2018/entries/feminist-science/>.

A thorough overview of the history of feminist perspectives on the sciences, and current work. They consider a variety of different approaches and methodologies in feminist science scholarship – from consideration of social dynamics and epistemic norms that animate sciences, to the impact of science on society, specifically on women and gender minorities, to critiques of sexist or androcentric bias in various domains, particularly the biological sciences.

Gowaty, P. (ed), (1997) *Feminism and Evolutionary Biology: Boundaries, Intersections and Frontiers*, New York: Chapman and Hall. (see also: (1992) Evolutionary Biology and Feminism, *Human Nature*, 3: 217–249.; (1997a); (2003a). “Power Asymmetries between the Sexes, Mate Preferences, and Components of Fitness, *Evolution Gender and Rape*, Cheryl Travis (ed.), Cambridge, MA: MIT Press, 61–86.; (2003b) Sexual Natures, *Signs*, 28: 902–921.)

Gowaty has been one of the most outspoken critics of evolutionary theories concerning sexual behavior in humans, in particular, concerning mate choice.

Fehr, C., (2012) Feminist Engagement with Evolutionary Psychology, *Hypatia*, 27: 50–72. (see also: (2006) Explanations of the Evolution of Sex: A Plurality of Local Mechanisms. *Scientific Pluralism*, *Minnesota Studies in the Philosophy of Science*, Stephen H. Kellert, Helen E. Longino, C. Kenneth Waters (eds.), 167–189.)

Fehr considers a variety of goals feminists might have in engaging with research in evolutionary psychology, and considers how research practices facilitate or hinder the accomplishment of such goals. She also engages with a variety of evolutionary explanations of sex, offering a feminist critique.

Hubbard, R. (1983) Have Only Men Evolved? *Discovering Reality: Feminist Perspectives on Epistemology, Metaphysics, Methodology, and Philosophy of Science*, Harding, S. & Hintikka, M. (eds.), Dordrecht: D. Reidel, 45–70. (see also: 1990. *The Politics of Women's Biology*, New Brunswick, New Jersey: Rutgers University Press.)

Hubbard is a major representative of critical perspectives on evolutionary theories of human sexuality, and women’s distinctive evolutionary inheritance.

Hausman, D. M. (2012) Health, naturalism, and functional efficiency. *Philosophy of Science*, 79(4): 519–541.

Hausman defends a naturalistic view of health and disease, and gives an account of functional efficiency where departure from function is a matter of degree. His view of “function” is a goal-contribution view. Hausman addresses objections to a version of this view (Boorse, 1979), where goals of functions are relative to systems within organisms, variation is normal, and function is assessed relative to a “benchmark” environment.

Kaplan, J. M., & Winther, R. G. (2014). Realism, antirealism, and conventionalism about race. *Philosophy of Science*, *81*(5), 1039-1052. (see also: Pigliucci, M., & Kaplan, J. (2003). On the concept of biological race and its applicability to humans. *Philosophy of Science*, *70*(5), 1161-1172.)

Kaplan and Winther (2014), and Pigliucci and Kaplan (2003) are critical of race, arguing that population genetics does not provide support for realism about race as a natural biological category.

Keller, E. F. (1985) *Reflections on Gender and Science*, New Haven: Yale University Press.

(see also: (1988) Demarcating Public From Private Values in Evolutionary Discourse, *Journal of the History of Biology*, 21: 195–212.; (1992) *Secrets of Life Secrets of Death: Essays on Language, Gender and Science*, New York: Routledge.)

Keller’s work set a standard going back to the 1980s for critical reflection on thinking about sex and gender in the biological sciences.

Lloyd, E. (1993) Pre-theoretical Assumptions in Evolutionary Explanations of Female Sexuality. *Philosophical Studies*, 69, 139–153. (see also: (1999) Evolutionary Psychology: The Burdens of Proof. *Biology and Philosophy*, 14, 211–233.; (2003) Violence Against Science: Rape and Evolution. *Evolution, Gender, and Rape.*  MIT Press, 235–262.; (2005) *The Case of the Female Orgasm: Bias in the Science of Evolution*. Harvard University Press.)

Lloyd’s 2005 book critiques both the evidential basis and theoretical motivations for various evolutionary accounts of the functional role of female orgasm, and defends what she takes to be the far more plausible (byproduct or, “fabulous bonus”) account. Her work on rape (2003) and evolutionary psychology (1993, 1999) criticizes “just so” stories that lack empirical warrant.

Longino, H. (1987) Can There Be a Feminist Science? *Hypatia*, 3:51–64. (see also (1990) *Science as Social Knowledge: Values and Objectivity in Scientific Inquiry*, Princeton: Princeton University Press.; (2002) *The Fate of Knowledge*, Princeton: Princeton University Press.)

Longino is one of the most influential feminist philosophers of science, defending the view that even though values play a role (both ‘externally’ in motivating research, and ‘internally’ in the context of justification), objectivity is possible in science, even and especially due to the fact that science is a social enterprise. Many of her vivid examples come from the biological sciences, and evolutionary explanations of sex differences in humans.

Mallon, R. (2006). ‘Race': Normative, not metaphysical or semantic. *Ethics*, *116*(3), 525-551.

Mallon argues that “race” is a normative concept, not a metaphysical or semantic one; that is, “race” plays a role in evaluative judgments, and in governing social roles.

Matthewson J, Griffiths PE (2017) Biological criteria of disease: four ways of going wrong. *Journal of Medicine and Philosophy*, 42:447–466. (see also: (2016) Evolution, dysfunction, and disease: A reappraisal. *British Journal for the Philosophy of Science,* 69(2): 301–327.)

Matthewson and Griffiths defend a naturalistic account of pathology, though they grant that there is a normative component to the concept of “disease.” They then describe four ways of going wrong, from a biological perspective (not all of which are necessarily pathology): mechanism failure; abNormal environment; Normal but inhospitable environment; and heuristic failure. Pathology will be a matter of degree.

Murphy D (2005) Can evolution explain insanity? *Biology and Philosophy*, 20:745–766 (see also: (2006) *Psychiatry in the Scientific Image*. The MIT Press, Cambridge; Murphy D, Woolfolk RL (2000) The harmful dysfunction analysis of mental disorder. *Philos Psychiatry Psychol* 7:241–252; Murphy, D. (2015) Concepts of disease and health & Philosphy of psychiatry In *The Stanford Encyclopedia of Philosophy*, edited by E. N. Zalta.)

Murphy (2006) classifies evolutionary explanations of mental illness into “breakdown,” “mismatch,” and “byproduct” explanations, and critically assesses a variety of proposals for evolutionary explanations of mental illness. His 2006 book is a landmark discussion of scientific psychiatry. His encyclopedia entries (2015) provide comprehensive overviews of the state of philosophical discussions of disease and health, and psychiatry.

Richardson, S. S. (2013). *Sex itself: The search for male and female in the human genome*. University of Chicago Press. (see also: (2008) When gender criticism becomes standard scientific practice: The case of sex determination genetics, *Gendered innovations in science and engineering*, Stanford University Press, 22–42; (2010) Feminist Philosophy of Science: History, Contributions, and Challenges, *Synthese* 177(3): 337–362.)

Richardson offers a critical, historical perspective on genetic theories of sex, covering scientific literature through the 20th Century. She highlights how contextual values played a role in shaping research questions, the selection and interpretation of data, and links between data with theory, such as, for instance, in the presupposition that sex is binary.

Spencer, Q. (2015). Philosophy of race meets population genetics. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences*, *52*, 46-55. (see also: (2014). A radical solution to the race problem. *Philosophy of Science*, *81*(5), 1025-1038.; (2016). Do humans have continental populations?. *Philosophy of Science*, *83*(5), 791-802.; (2018). A racial classification for medical genetics. *Philosophical Studies*, *175*(5), 1013-1037.; (2018). Racial realism I: Are biological races real?. *Philosophy Compass*, *13*(1), e12468.)

Spencer has argued (contrary to a pretty majority of philosophers of biology), that there are biological differences between races, which roughly correspond to the continental populations, and the U.S. OMB (Office of Management and Budget) classification. Spencer draws upon genetic results from Rosenberg (2003) and others, in particular, using “structure” to identify 5 major population clusters (with significant overlap).

Wakefeld JC (1992) The concept of mental disorder: on the boundary between biological facts and social values. Am Psychol 47:373–388 (see also: (2000) Spandrels, vestigial organs, and such: reply to Murphy and Woolfolk’s “The Harmful Dysfunction analysis of mental disorder”. Philos Psychiatry Psychol 7:253–270; (2011) Darwin, functional explanation, and the philosophy of psychiatry. In: Adriaens RA, De Block A (eds.) *Maladapting minds: philosophy, psychiatry, and evolutionary theory*. Oxford University Press, Oxford, 143–172.)

Wakefield is the founder and main proponent of the “harmful dysfunction” view of mental illness, according to which, a mental illness must be both harmful to the patient and a disruption of a function. What distinguishes his view is that functions must be selected effects, and thus argues that particular mental illnesses are disruptions of cognitive and/or behavioral adaptive traits.

Valles, S. A. (2012). Evolutionary medicine at twenty: rethinking adaptationism and disease. *Biology & Philosophy*, 27(2), 241-261. (see also (2013) Validity and Utility in Biological Traits, *Biological Theory*, 8:93–102)

Valles is critical of evolutionary medicine’s advocates’ “panselectionist adaptationism” (the assumption that non-adaptive evolutionary processes are causally unimportant relative to natural selection). He gives a critical analysis of arguments for evolutionary hypotheses about neonatal jaundice and asthma. In 2013, he defends Dobzhansky’s 1956 account of ‘‘trait,’’ according to which traits artificially impose order on continuous biological phenomena, and contends that focus on the adaptive values of traits has clouded discussion.