Volume 83, No. 1 *THE QUARTERLY REVIEW OF BIOLOGY* March 2008

THE BORDERLANDS BETWEEN SCIENCE AND PHILOSOPHY: AN INTRODUCTION

Massimo Pigliucci
Departments of Ecology & Evolution and Philosophy, Stony Brook University
Stony Brook, New York 11794 USA
e-mail: pigliucci@genotypebyenvironment.org

keywords
science, philosophy, intelligent design, paranormal phenomena, pseudoscience

abstract

Science and philosophy have a very long history, dating back at least to the 16th and 17th centuries, when the first scientist-philosophers, such as Bacon, Galilei, and Newton, were beginning the process of turning natural philosophy into science. Contemporary relationships between the two fields are still to some extent marked by the distrust that maintains the divide between the so-called "two cultures." An increasing number of philosophers, however, are making conceptual contributions to sciences ranging from quantum mechanics to evolutionary biology, and a few scientists are conducting research relevant to classically philosophical fields of inquiry, such as consciousness and moral decision-making. This article will introduce readers to the borderlands between science and philosophy, beginning with a brief description of what philosophy of science is about, and including a discussion of how the two disciplines can fruitfully interact not only at the level of scholarship, but also when it comes to controversies surrounding public understanding of science.

THE RELATIONSHIP BETWEEN SCIENCE AND PHILOSOPHY has always been tormented, ever since science itself slowly evolved from "natural philosophy" during the 16th and 17th centuries, thanks to the work of people who thought of themselves as philosophers, and most of whom we consider scientists: Francis Bacon, Galileo Galilei, and Isaac Newton, to mention a few. As in any parent-offspring relationship, things can get acrimonious, with the offspring staking out its territory while denying the parent's relevance or contribution, and the latter having a difficult time letting go of the now adult and independent progeny.

In this paper, I wish to provide some considerations for a constructive discussion of the science-philosophy borderlands, which I unofficially call "sci-phi," in the hope that both scientists and philosophers will be prompted to give more thought to the matter and see where there are meaningful bridges to build, and where the two disciplines can operate largely independently of each other. This

The Quarterly Review of Biology, March 2008, Vol. 83, No. 1

0033-5770/2008/8301-0002$15.00

is neither an apology on behalf of philosophers nor an invitation to scientists to become philosophers. The first is not needed because philosophy is an autonomous area of scholarship, which certainly does not need any more justification than, say, literary criticism or quantum electrodynamics. The second would be missing the point since, although I think that scientists may benefit from a better acquaintance with philosophy, the latter is not something that a scientist could easily do on his own if only he had a couple of spare weekends a month.

Therefore, I will begin by outlining what philosophy of science actually consists of, discussing where it can directly contribute to science and where it is best thought of as an independent field of study. I will then provide examples of how philosophers can be useful to scientists, not just within the narrow confines of scientific research, but in the broader quest for a better understanding of science on the part of the general public. I will then conclude by advocating "sci-phi" as a good model for much needed interdisciplinarity in the pursuit of new models of scholarship and teaching.

What Philosophy (of Science) Is and Is Not About

Nobel physicist Steven Weinberg (1992) took the rather unusual step of writing a whole essay entitled "Against Philosophy." In it, he argued that not only is philosophy not useful to science, but that, in some instances, it can be positively harmful. The example he provided was the alleged slow acceptance of quantum mechanics, due to the philosophical school of positivism endorsed by so many scientists in the early 20th century, beginning with Einstein.

Positivism is a now abandoned philosophical position—originally associated with the so-called Vienna Circle—that takes a rather narrowly naïve view of what counts as science. Most famously, positivists thought that science had no business dealing with "unobservables," i.e., with postulating the existence of entities that cannot be subjected to experimental tests. Quantum mechanics is rife with such unobservables, including electrons and forces, and positivists were indeed highly skeptical of the whole affair, which smelled too much of metaphysics (a bad word, in their vocabulary). It is also true that some scientists, first and foremost Einstein, were rather uncomfortable with the wildest implications of quantum mechanics (as in Einstein's famous quip that "God doesn't play dice") and resisted them while searching for alternative interpretations of the theory. Nonetheless, I seriously doubt that one can lay an alleged "slowing down" of turn-of-the-century physics at the doorsteps of philosophy. First, philosophy has simply never had, in recent memory, much of a sway with scientists. This is in part because scientists tend to be interested in whichever approaches maximize discovery, not in philosophical issues about metaphysical truths (Franklin 2005). Second, although it is of course impossible to rewind the tape and experiment with historical sequences, quantum mechanics was actually accepted very quickly by the scientific community, especially when one considers its radical departure from any previous physical theory—for example, the introduction of the concept of true, as opposed to instrumental, indeterminability (the Heisenberg principle).

A diametrically opposite view to Weinberg's is the one expressed by Daniel Dennett (perhaps not surprisingly, a philosopher), in his *Darwin's Dangerous Idea*: "There is no such thing as philosophy-free science; there is only science whose philosophical baggage is taken on board without examination" (1995:21). This will strike most scientists as preposterously arrogant, but a moment's reflection shows that Dennett, of course, is right. For example, scientific practice requires the assumption of naturalism, i.e., the idea that natural phenomena are indeed natural, and, therefore, scientists do not need to invoke the supernatural to explain them. I shall say more about this specific point below, but it is interesting to note that scientists themselves invoke naturalism as a postulate of science whenever they need to make the (convincing) argument that Intelligent Design "theory" is not science (Pigliucci 2002). The important thing to realize is that naturalism is not an empirically verifiable position, and, therefore, it is by definition outside of science itself (if science is about anything at all, it is about empirically verifiable statements about the world).

Attitudes such as Weinberg's are largely the result of ignorance of what philosophy of science is about, and I am convinced that such ignorance hurts science. It certainly does not help to bridge what C P Snow (1959) famously referred to as the divide between "the two cultures." Let me then briefly sketch what I think are the proper domains of philosophy of science, and where they do, or do not, intersect with the practice of science. Generally speaking, philosophy of science deals with three broad areas of inquiry, which I refer to as nature of science, conceptual and methodological analysis of science, and science criticism (Chalmers 1999).

Most scientists, if they are familiar with philosophy at all, have some acquaintance with philosophical studies of the nature of science. Names such as Karl Popper and Thomas Kuhn even make it into the occasional biology textbook, and one can argue that falsificationism and paradigm shifts—the most important respective contributions of these two philosophers—are among the few concepts in modern philosophy of science that are ever mentioned in the halls of science departments. Popper and falsificationism are representative of a *prescriptive* streak in philosophy of science; that is, they exemplify a tradition of philosophers seeking to tell scientists how they ought to carry out their work. Popper was motivated by the so-called demarcation problem, the difficulty in distinguishing science from pseudoscience (he included in the latter Freudian psychoanalysis and Marxist theories of history). He was also bothered by Hume's problem of induction, the idea that science is based on inductive reasoning, and yet the only reason we have to trust induction is because it worked in the past (which is itself a form of induction, making the whole thing perilously close to circular). Popper thought he solved both problems with the idea of falsification: science is really based on deductive logic, not induction. This solves Hume's conundrum, but, since deduction cannot truly establish proof of natural phenomena (although it works fine for mathematical proofs), it turns out that science can never prove anything but can only disprove (i.e., falsify) theories.

It is rather ironic that many science textbooks have essentially adopted Popper's view of science as an enterprise dealing in falsificationism, with many scientists actually *defining* science in Popperian terms. Popperian falsificationism has long been superseded in philosophy of science, partly through the work of one of Popper's own students, Imre Lakatos (1977), who argued that falsificationism does not work because it is often possible to "rescue" a given theory from demise by modifying some of the ancillary assumptions that went into building it. This is a good thing too, and indeed a reflection of how science really works. Just think of the fact that the original Copernican theory did not actually fit the data very well, and yet it was not rejected as "falsified." Rather, scientists gave it some time to develop because it seemed a promising approach. Subsequently, Kepler modified an important, though not central, assumption of the theory, thus producing results that correlated very well with the data: the sun is indeed (almost) at the center of the solar system, but the planets rotate along elliptical, not circular, orbits, of which the sun occupies not exactly the center, but one of the foci.

Kuhn's (1970) ideas as developed in *The Structure of Scientific Revolutions*, are an example of the *descriptivist* approach to the study of the nature of science. Kuhn did not pretend to tell scientists how to do their work but was interested in figuring out how science, as a process of discovery, actually proceeds. His idea of paradigm shifts was based on historical studies of astronomy and physics (arguably, biology has never undergone a paradigm shift after Darwin), and represents a type of "punctuated equilibria" theory of science, where long periods of quasi-stasis are punctuated by sudden bursts of change. Kuhn thinks of most scientific activity as “puzzle solving” within an established conceptual framework, the “paradigm.” Only rarely does the accepted paradigm begin to show increasing signs of inadequacy, which eventually generates a crisis, which, in turn, is resolved when the community shifts to a new paradigm. The change from the Ptolemaic to the Copernican views of the solar system is the classic example of a paradigm shift.

Another irony lies in the fact that many scientists bought into the Kuhnian view, although it also has been shown to be highly problematic. In particular, his talk of “incommensurability” (the inability to translate concepts from one paradigm to another) comes perilously close to denying that science makes progress—as opposed to simply shifting from one arbitrary view of the universe to another. Indeed, despite Kuhn’s own later protestations, the original metaphor for a paradigm shift was what in psychology is known as a Gestaltian switch. We have all seen those pictures that can be interpreted *equally well* as, say, being an old witch or a beautiful young woman. The point is that our brain suddenly switches perspective from one interpretation to the other, but also that the switch is, in fact, arbitrary, because the lines on the paper do not actually favor *either* representation (indeed, they are meant to be ambiguous).

Although scientists are aware of both the prescriptive and descriptive streaks in the philosophical study of the nature of science, they seem to have accepted some abandoned or at least highly problematic views from philosophy, without much evidence that more recent formulations (such as Hull’s idea of “conceptual selection” [1990] or Kitcher’s [1995] work on the advancement of science) have even made it to the scientist’s radar screen.

The second major area of inquiry in philosophy of science is what I term conceptual and methodological analysis, and it deals largely with tracing the historical use and clarifying the meaning of fundamental ideas and practices in the sciences. Hume (1748) was among the first ones to take this approach, inquiring about what we mean when we talk about causality. (His analysis, still surprisingly challenging today, was not very encouraging.) More recently, critical work on the conceptual foundations of evolutionary theory and the practices of quantitative genetics (Pigliucci and Kaplan 2006) falls into this group.

The third major type of philosophy of science is what I term science criticism, and it directly addresses the interface between science and society. For example, philosophical issues surrounding the nature-nurture debate are relevant to the uses and, more importantly, the misuses, of genetic medicine (Kaplan 2000). Here the philosopher becomes a critic not just of how the science is being conducted and its findings interpreted, but, primarily, of how such findings are understood by the public and used to guide social policies (Kitcher 2001).

What is a scientist to do with all this? Scientists may largely and safely ignore what philosophers say about how science does or should work in broad terms—after all, scientists want to *do* science, not to think about how it is done (except occasionally, when they are close to retirement). They do, however, have a responsibility to update their understanding of philosophy when it comes to writing science textbooks or teaching the nature of science in the classrooms. Also, philosophers clearly have the intellectual right to pursue such inquiry into the nature of science without having to justify themselves to scientists by defending the “utility” (implicitly, to science) of what they do.

When we move to the second and third areas of philosophical inquiry, we come closer to the sci-phi borderlands, to the point where, in some cases, philosophy may be thought of as “the continuation of science by other means” (Chang 2004). Indeed, in areas from evolutionary biology to quantum mechanics, it is sometimes difficult to tell whether a theoretical paper is written by a scientist or by a philosopher without directly checking the author’s institutional affiliation. Here the word “theory” takes on its original and broader meaning of formulation of concepts, not just mathematical treatment (although there are examples of philosophers engaging in the latter as well). What makes this blurred line between philosophy and science interesting is that the two disciplines bring different backgrounds and approaches to the study of the same issues—i.e., this is not just a matter of science-envy by philosophers (or the even more rare phenomenon of philosophy-envy by scientists).

Sci-Phi and the Fight Against Pseudoscience

There are many published examples of interaction between science, particularly biology, and philosophy when it comes to squarely scientific questions: niche-construction theory (Okasha 2005), the role of evo-devo within the Modern Synthesis (Love 2003), the various conceptions of biological species (Pigliucci 2003), the existence of laws in ecology (Mikkelson 2003), and the concept of fitness (Ariew and Lewontin 2004), to mention just a few of those that have been vigorously debated in recent years. In what follows, I will briefly explore the potential for fruitful interactions between science and philosophy when it comes to forming a joint defense against the assault from pseudoscientific quarters. I will provide two examples, one illustrating how the methods of science and philosophical inquiry can be complementary in debunking pseudoscientific claims, and the other of how philosophy can play a decisive role in court rulings concerned with the teaching of science in public schools.

As an example of sci-phi debunking pseudoscience, consider the oft-made claim that people have "out-of-body" experiences, when, under certain conditions (for example, during a surgical operation), a subject recalls having found himself somehow outside of his own body, observing the scene from a different point of view, and even recalling some of the things that were said or done despite the fact that he was under sedation at the time (see Novella 2002 and 2003). Now the classical, scientific approach to analyzing this sort of claim may begin, for instance, by analyzing the physical circumstances of the alleged event, such as the details of the operating room and the condition of the patient. A scientifically-minded investigator may then proceed to look for corroborating details supporting the subject's version of the story: Was he really able to hear what the doctors where saying? Did he actually, somehow, observe specific events that occurred in the room? A scientist would then propose possible alternative explanations for the facts so gathered (e.g., that the experience was caused by a side effect of the anesthetics used in preparation for the operation).

This *modus operandi* is typical of science in general, not just when applied to claims of the paranormal. The idea is that one works within certain assumptions, e.g., that there is no conscious attempt to deceive the investigator, just as in the case of normal scientific research, where fraud is a hypothesis of last resort. The investigator then focuses on the details of the alleged experience, attempting to see if they do or do not correlate with the available evidence, essentially playing the role of an investigative detective—an analogy often brought up to explain the nature of everyday scientific research (what Kuhn aptly called "normal" or "puzzle solving" science).

A philosopher would approach the same problem differently. In particular, she would focus on the broad picture, on the validity of background assumptions, and on the internal coherence of the claims under investigation. For example, she may question what it means to "see" one's body from outside. To the best of our knowledge, seeing is something we do with a complex bodily apparatus that includes not just eyes but a brain connected to them and capable of interpreting light signals. But if one is disembodied, how would "vision" work? Moreover, subjects who claim to have undergone out-of-body experiences usually talk as if their vision were of the same kind as ordinary vision, i.e., with a limited horizon. But if vision were somehow possible outside of the constraints imposed by biological structures, why would people not be able see at 360°? These sorts of questions would complement and, perhaps, even aid the scientific approach, resulting in our understanding that the experience must have been more psychological than physical, since it not only fails to square with verifiable details (science), but is internally incoherent (philosophy)—like a dream. The point of this exercise is hardly to convince the true believer, but this kind of dual approach could be used to teach students and the general public about the nature of both science and philosophy, while, at the same time, heightening people's critical awareness when they read about alleged paranormal phenomena.

My second example has already yielded important results, and it concerns the perennial issue of what does and does not constitute science education, in particular within the creation-evolution controversy (Pigliucci 2002). At the end of 2005, Judge John E Jones handed down a historical verdict against the teaching of Intelligent Design creationism in a case brought against the Dover, Pennsylvania school district. The Dover area school board had decided in October 2004 to include Intelligent Design in the science curriculum, and the case was important because it was the first time that ID, as opposed to classic creationism, was being challenged in a court of law.

One of the interesting features of the Dover trial is that it saw two philosophers, Barbara Forrest of Southeastern Louisiana University and Robert Pennock of Michigan State University, take the stand as witnesses for the plaintiffs, together with several scientists. Although this was not the first time that philosophers have played a prominent role in a trial about creationism, it is the broad and sophisticated use of philosophical arguments by Judge Jones that sets Dover apart. In his deliberation, Jones said that "ID violates the centuries-old rules of science by invoking and permitting supernatural causation" (Kitzmiller v. Dover Area School District, 400 F. Supp. 2d 707 [M.D. Pa. 2005]). Here the Judge drew upon the concept of methodological naturalism, the pragmatic assumption that every scientist has to make that only natural causes are necessary to explain natural phenomena: any activity that violates methodological naturalism (as any form of creationism does) is by philosophical definition not science, and therefore should not be taught in science classes.

Jones went on to state that "the argument of irreducible complexity, central to ID, employs the same flawed and illogical contrived dualism that doomed creation science" (Kitzmiller v. Dover Area School District, 400 F. Supp. 2d 707 [M.D. Pa. 2005]). This is another philosophical argument, as contrived dualism is a logical fallacy when someone is forced to make a choice between two possibilities ("either Darwinism as currently understood or Intelligent Design") when, in fact, there may be a variety of options available (e.g., it is possible that the current version of evolutionary theory will be expanded to include additional causal explanations that are currently unforeseen, without having to resort to supernatural causation to do so). Indeed, Judge Jones clearly reached the conclusion that the so-called "irreducible complexity" of biological structures like the bacterial flagellum has not only been debunked on empirical scientific grounds, but is a vague concept that cannot be made operational at all, and, therefore, cannot constitute a valid challenge to any scientific theory.

These two examples of cooperation outside of the usual academic box between scientists and philosophers are certainly not meant to minimize the challenges that we face in teaching science and improving the public's understanding of its nature. However, there is no reason to limit the proper employment of the sci-phi approach only to technical matters of interest to scientists and philosophers. The debunking of paranormal claims or the defense of public education are certainly worthy areas of endeavor as well.

SCI-PHI AS A MODEL OF INTERDISCIPLINARITY

There is much talk (and usually little action) on university campuses about interdisciplinary teaching and scholarship. A more serious exploration of the borderlands between science and philosophy—what I have referred to here informally as "sci-phi"—offers a fertile ground for the kind of interdisciplinarity that can move both fields forward and also have a positive effect on students and the general public. The idea is not that philosophy will answer scientific questions, as Weinberg demanded in his essay against philosophy. For that sort of task we have science, and it works very well. Nor am I suggesting a model under which science will somehow "reduce" philosophy to biology or chemistry, similar to the "consilience" project of E O Wilson (1998), which is an egregious example of that very same scientistic attitude that so often causes problems in the relationship between science and other disciplines (Haack 1998).

Rather, the model is one of partially overlapping, but largely distinct, spheres of influence. For one thing, the aims and methods of the two disciplines are different: philosophers tend to be interested in posing questions and in analyzing concepts, whereas scientists are inclined toward heuristics that maximize discovery and concentrate on details of data gathering and analysis. More broadly, philosophy is concerned with a range of topics that are often outside the scope of empirically-based approaches, such as metaphysics. Nonetheless, philosophers in recent years have been increasingly sensitive to the information that science can provide them that is relevant to their areas of interest. For example, cognitive science and evolutionary biology have been contributing significantly to understanding questions typically debated in philosophy of mind and ethics.

Empirical research on moral decision-making (for instance Greene et al. 2001, Koenigs et al. 2007) has shown why human beings react in a puzzling fashion to different versions of classic moral philosophy thought experiments such as the so-called "trolley dilemmas." In these thought experiments, philosophers ask people to consider whether they would pull a switch that would redirect a trolley that is about to kill five people. The catch is that in doing so, another person will be killed instead. Most people say that they would pull the switch, given the circumstances. But when the dilemma is rephrased so that one cannot simply pull a switch, but actually has to throw a bystander in front of the trolley to save the other five, most people say they would not do it. Rationally, there is no difference between the two cases, since in both scenarios five people are saved and one is killed. But neurobiologists have discovered that the second version of the dilemma engages the emotional circuitry of the brain that apparently overrides the logical decision making process, except in people with neural damage that blocks the emotional circuitry!

The study of consciousness is currently the area most clearly poised at the boundary between science and philosophy, with about equal (albeit very different in nature) contributions from the two fields. Just consider the indirect exchange between cognitive scientist Steven Pinker, author of *How the Mind Works* (1997), and philosopher Jerry Fodor, who responded with the provocatively titled *The Mind Doesn't Work That Way* (2000). It is very common at symposia on the philosophy of mind to see cognitive scientists both in the audience and among the presenters.

As I stressed during my earlier discussion of the various types of philosophy of science, the cross-pollination goes both ways, except that scientists have so far been rather recalcitrant to consider the value of philosophical analysis to their discipline. The reasons are, of course, various and complex, and certainly include a certain degree of diffidence toward an unfamiliar field, perhaps augmented by a dose of intellectual arrogance, as in the oft-heard remark that philosophy is "just armchair speculation" (so, technically, is computer modeling, or mathematical biology, though they are never referred to by using that dismissive appellative). The postmodern wave in late 20th century philosophy has not helped either, beginning with Paul Feyerabend's contention that astrology and magic are as legitimate as science, and continuing with Michael Foucault's overly simplistic statement that there are no universal truths, ever. Although it was a scientist (Sokal

1996) who dealt an embarrassing blow to postmodern nonsense, we also need to understand that most philosophers, especially those interested in science, are not postmodern, and that, moreover, some modern critique of the nature and process of science does have a legitimate place in the intercultural dialogue (Longino 1990; Hacking 1999).

In the end, it is up to individual philosophers and scientists to seriously consider when they can martial on largely unconcerned with what the other side has to say, or when and to what extent their respective fields can benefit from each other's influence. This paper is meant as a stimulation for further discussion.

ACKNOWLEDGMENTS

I wish to thank Robert Northcott for comments on a previous draft of this paper, and Robert Crease, Chair of the Philosophy Department at Stony Brook University, for endorsing the 2007 sci-phi symposium in New York City, from which this paper emerged. The Provost's Office of Stony Brook University provided financial support, and the people at Stony Brook Manhattan, particularly Scott Sullivan, made it possible for everything to run incredibly smoothly. Of course, the wine flowing at a local Italian restaurant on the evening of the symposium was also instrumental in bridging the gap between C P Snow's "two cultures."

REFERENCES

Ariew A, Lewontin R C. 2004. The confusions of fitness. *British Journal of the Philosophy of Science* 55(2): 347–363.

Chalmers A F. 1999. *What Is This Thing Called Science? An Assessment of the Nature and Status of Science and Its Methods.* Berkshire (UK): Open University.

Chang H. 2004. Complementary science—history and philosophy of science as a continuation of science by other means. Pages 235–250 in *Inventing Temperature: Measurement and Scientific Progress.* New York: Oxford University Press.

Dennett D. 1995. *Darwin's Dangerous Idea: Evolution and the Meanings of Life.* New York: Simon & Schuster.

Fodor J. 2000. *The Mind Doesn't Work That Way: The Scope and Limits of Computational Psychology.* Cambridge (MA): MIT Press.

Franklin L R. 2005. Exploratory experiments. *Philosophy of Science* 72:888–899.

Greene J D, Somerville R B, Nystrom L E, Darley J M, Cohen J D. 2001. An fMRI investigation of emotional engagement in moral judgment. *Science* 293:2105–2108.

Haack S. 1998. Between the Scylla of scientism and the Charybdis of apriorism. Pages 49–63 in *The Philosophy of P F Strawson,* edited by L E Hahn. Chicago (IL): Open Court.

Hacking I. 1999. *The Social Construction of What?* Cambridge (MA): Harvard University Press.

Hume D. 1748. *Enquiry Concerning Human Understanding.* [1956 reprint.] Chicago (IL): Gateway Editions.

Hull D L. 1990. Conceptual selection. *Philosophical Studies* 60:77–87.

Kaplan J. 2000. *The Limits and Lies of Human Genetic Research: Dangers for Social Policy.* New York: Routledge.

Kitcher P. 1995. Précis of *The Advancement of Science. Philosophy and Phenomenological Research* 55(3):611–617.

Kitcher P. 2001. *Science, Truth, and Democracy.* New York: Oxford University Press.

Kitzmiller v. Dover Area School District, 400 F. Supp. 2d 707 (M.D. Pa. 2005).

Koenigs M, Young L, Adolphs R, Tranel D, Cushman F, Hauser M, Damasio A. 2007. Damage to the prefrontal cortex increases utilitarian moral judgments. *Nature* 446:908–911.

Kuhn T. 1970. *The Structure of Scientific Revolutions.* Chicago (IL): University of Chicago Press.

Lakatos I. 1977. *The Methodology of Scientific Research Programmes.* Cambridge (UK): Cambridge University Press.

Longino H E. 1990. *Science as Social Knowledge: Values and Objectivity in Scientific Inquiry.* Princeton (NJ): Princeton University Press.

Love A C. 2003. Evolutionary morphology, innovation, and the synthesis of evolutionary and developmental biology. *Biology and Philosophy* 18(2):309–345.

Mikkelson G M. 2003. Ecological kinds and ecological laws. *Philosophy of Science* 70(5):1390–1400.

Novella R. 2002. Out-of-Body experiences and the astral hypothesis, Part I. *New England Journal of Skepticism* 5(2), www.theness.com.

Novella R. 2003. Out-of-Body experiences and the astral hypothesis, Part II. *New England Journal of Skepticism* 6(1), www.theness.com.

Okasha S. 2005. On niche construction and extended evolutionary theory. *Biology and Philosophy* 20(1):1–10.

Pigliucci M. 2002. *Denying Evolution: Creationism, Scientism, and the Nature of Science.* Sunderland (MA): Sinauer.

Pigliucci M. 2003. Species as family resemblance concepts: the (dis-)solution of the species problem? *BioEssays* 25:596–602.

Pigliucci M, Kaplan J. 2006. *Making Sense of Evolution:*

The Conceptual Foundations of Evolutionary Biology. Chicago (IL): Chicago University Press.

Pinker S. 1997. *How the Mind Works.* New York: W. W. Norton.

Snow C P. 1959. *The Two Cultures and the Scientific Revolution.* [1998 reprint.] New York: Cambridge University Press.

Sokal A D. 1996. Toward a transformative hermeneutics of quantum gravity. *Social Text* 14:217–252.

Weinberg S. 1992. Against philosophy. Pages 166–190 in *Dreams of a Final Theory.* New York: Pantheon.

Wilson E O. 1998. *Consilience: The Unity of Knowledge.* New York: Alfred A. Knopf/Random House.