

Can Science Test Supernatural Worldviews?

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Published online: 21 August 2007
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Abstract Several prominent scientists, philosophers, and scientific institutions have argued that science cannot test supernatural worldviews on the grounds that (1) science presupposes a naturalistic worldview (Naturalism) or that (2) claims involving supernatural phenomena are inherently beyond the scope of scientific investigation. The present paper argues that these assumptions are questionable and that indeed science can test supernatural claims. While scientific evidence may ultimately support a naturalistic worldview, science does not presuppose Naturalism as an a priori commitment, and supernatural claims are amenable to scientific evaluation. This conclusion challenges the rationale behind a recent judicial ruling in the United States concerning the teaching of “Intelligent Design” in public schools as an alternative to evolution and the official statements of two major scientific institutions that exert a substantial influence on science educational policies in the United States. Given that science does have implications concerning the probable truth of supernatural worldviews, claims should not be excluded a priori from science education simply because they might be characterized as supernatural, paranormal, or religious. Rather, claims should be excluded from science education when the evidence does not support them, regardless of whether they are designated as ‘natural’ or ‘supernatural’.

The whole of science is nothing more than a refinement of everyday thinking.—
Albert Einstein

I have steadily endeavored to keep my mind free so as to give up any hypothesis, however much beloved (and I cannot resist forming one on every subject), as soon as the facts are shown to be opposed to it.—Charles Darwin

There is one thing even more vital to science than intelligent methods; and that is, the sincere desire to find out the truth, whatever it may be.—Charles Sanders Pierce

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The universe we observe has precisely the properties we should expect if there is, at bottom, no design, no purpose, no evil and no good, nothing but blind pitiless indifference.—Richard Dawkins

The recent court ruling in the United States against the teaching of “Intelligent Design” (ID) as an alternative to evolution in biology classes (*Kitzmiller v. Dover Area School District*; Jones 2005) has sparked public interest and has been hailed as a victory by the scientific community. One of the reasons given for the verdict is the notion that science is limited strictly to the study of natural phenomena and therefore that ID and other claims involving supernatural phenomena are outside the proper domain of scientific investigation.

While the verdict is widely viewed as correct for other reasons cited in the court’s opinion, that particular rationale upon which it is based is questionable. Indeed, is science limited to the study of ‘natural’ phenomena? Does science presuppose Naturalism and thereby exclude supernatural explanations *by definition*? Are claims involving ‘supernatural’ phenomena inherently untestable and therefore outside the province of science? The present article argues that this is not the case. Science does not presuppose Naturalism and supernatural claims are amenable in principle to scientific evaluation [see Monton (2006) and Stenger (2006a) for a similar critique of Judge Jones’ verdict]. Indeed, science does have implications for the probable truth of supernatural worldviews (Gauch 2006, defends a similar thesis).

To exclude, a priori, the supernatural would validate the complaint voiced by some ID adherents and other creationists that science is dogmatically committed to Naturalism and thus opposed in principle to considering supernatural explanations (Johnson 1999; see Stenger 2006a). On the other hand, if there is no fundamental barrier preventing science from evaluating supernatural claims, then to declare the study of supernatural phenomena out of bounds to scientific investigation imposes artificial constraints on scientific inquiry, which potentially would deny science the noble task of purging false beliefs from the public sphere or the opportunity to discover aspects of reality that may have significant worldview implications.

1 Major Scientific Institutions Claim That Science Cannot Test Supernatural Worldviews

The notion that supernatural phenomena are fundamentally beyond the scope of scientific examination is promoted by two prominent scientific institutions, the American Association for the Advancement of Science (AAAS) and the National Academy of Sciences (NAS). For instance, in a letter to Senator Taylor of Oklahoma concerning the teaching of ID as an alternative to evolution in science classes the AAAS writes:

...because ID relies on the existence of a supernatural designer it is a religious concept, not science, and therefore does not belong in the science classroom. (AAAS 2006).

Similarly, in the NAS publication, *Teaching About Evolution and the Nature of Science*, the following statements appear:

Because science is limited to explaining the natural world by means of natural processes, it cannot use supernatural causation in its explanations... Explanations

employing nonnaturalistic or supernatural events, whether or not explicit reference is made to a supernatural being, are outside the realm of science and not part of a valid science curriculum. Evolutionary theory, indeed all of science, is necessarily silent on religion and neither refutes nor supports the existence of a deity or deities. (NAS 1998).

Echoing this position, in his verdict, presiding Judge John E. Jones III writes:

...we find that while ID arguments may be true, a proposition on which the Court takes no position, ID is not science...ID violates the centuries-old ground rules of science by invoking and permitting supernatural causation...While supernatural explanations may be important and have merit, they are not part of science...This rigorous attachment to ‘natural’ explanations is an essential attribute to science by definition and by convention. (Jones 2005).

Given the prestige of these sources, their impact on the public’s view of science and on educational policy in the United States, and that they are presumed to represent the views of the scientific community at large, their assertions are not trivial and require careful scrutiny. The common position expressed by these statements is that science, by definition, is limited to studying phenomena of the natural world and hence can neither confirm nor deny supernatural claims. Thus, science is necessarily mute on the question of whether or not supernatural phenomena exist. Consequently, to the extent that religion involves supernatural entities or phenomena, there can be no conflict between scientific claims and religious claims. The late evolutionary paleontologist, Stephen Jay Gould, is commonly cited as a champion of the view that science and religion properly occupy two independent realms of inquiry, and hence that there can be no conflict between them. Science and religion, according to Gould, constitute non-overlapping magisteria (NOMA): the magisterium of science covers the empirical realm- what the universe is made of and why it works the way that it does, whereas the magisterium of religion deals with questions of ultimate meaning and value (Gould 1997). As the magisteria of science and religion do not overlap, a comfortable co-existence between them is guaranteed. Gould’s position concerning whether the existence of God is amenable to scientific inquiry follows similar lines: “Science simply cannot (by its legitimate methods) adjudicate the issue of God’s possible superintendence of nature. We neither affirm nor deny it; we simply can’t comment on it as scientists.” (Gould 1992).

Similarly, some philosophers of a naturalistic bent have suggested that supernatural claims are untestable on the grounds that “supernatural entities are inscrutable and inaccessible as a matter of principle” (Mahner and Bunge 1996a, p. 17). On the other hand, in the same paper these authors have also argued that many supernatural claims are incompatible with scientific findings. That such a conflict is possible entails, however, that science can provide evidence against supernatural claims. Thus, if ‘testability’ means that there can be “evidence of whatever kind for or against a claim” (Mahner and Bunge 1996b, p. 11), then supernatural claims are testable after all.

2 Science Can Test Supernatural Claims: A Bayesian Perspective

The aforementioned view that the supernatural is beyond the reach of scientific investigation- or, put more bluntly, that science cannot test, and indeed has nothing at all to say about the validity of supernatural claims- has been challenged by a number of scientists

and philosophers. Before presenting these arguments, it is important first to define what is meant by a claim being ‘testable’. In the context of the present discussion, ‘testability’ is defined according to the definition offered by Mahner and Bunge (1996b). Specifically, a claim is ‘testable’ if there can be “evidence of whatever kind for or against a claim.” [italics added] (Mahner and Bunge 1996b, p. 11).

Given this definition, there are at least three ways in which science can evaluate the probable truth of a claim: (1) by consideration of the prior probability of a claim being true, (2) by “looking and seeing” (i.e., by consideration of the evidence for or against a claim), and (3) by consideration of plausible alternative explanations for the evidence. These considerations (to be discussed further below) are naturally captured within the framework of Bayesian confirmation theory, which is widely considered to be a good description of how scientists (and indeed ordinary people under mundane circumstances, such as in a court of law) update or revise their degree of confidence in a hypothesis, starting with a given prior probability, on the basis of new evidence (see Howson and Urbach 1993 for a book-length discussion of Bayesian inference as a model of scientific reasoning; see also Pigliucci 2002, 2005). Bayes’ theorem, named after its originator, Reverend Thomas Bayes, can be straightforwardly derived from the probability axioms, and is commonly represented in the following form:

$$P(H|E) = P(E|H)P(H)/[P(E|H)P(H) + P(E|-H)P(-H)]$$

In this formula, H stands for a hypothesis that is being considered and E represents a new piece of evidence that seems to confirm or disconfirm the hypothesis. The term on the left-hand side of the equation represents the posterior probability of the hypothesis, given that some evidence, E, is observed. The right-hand side of the formula is a ratio, with the numerator representing the product of the prior probability of the hypothesis being true before considering the new evidence, P(H), and the probability of observing E given that H is in fact true, P(E|H). This latter quantity is referred to as the ‘likelihood’, and represents the degree to which the hypothesis *predicts* the data given the background information. The denominator of the formula represents the probability of observing the evidence under all mutually exclusive hypotheses. This can be expressed as the sum of the product of the likelihood and prior for the hypothesis in question and the product of the likelihood and prior for the negation of the hypothesis, or for any mutually exclusive set of alternative hypotheses.

Thus, Bayes’ theorem indicates that our degree of confidence in a given hypothesis, in light of the evidence, P(H|E), is proportional to the prior probability of the hypothesis, P(H), times the likelihood given the truth of the hypothesis, P(E|H), and is inversely proportional to the prior probability times the likelihood given the truth of an alternative hypothesis or set of hypotheses, -H. All of these probabilities are assumed to be conditional also on any background information that may be available. Bayes’ theorem embodies how our initial degree of confidence in a hypothesis, represented by its prior probability, P(H), is modified on the basis of new evidence, which may either confirm or disconfirm the hypothesis in question by raising or lowering, respectively, its posterior probability, P(H|E). Thus, E confirms H to the extent that P(H|E) > P(H) and disconfirms H to the extent that P(H|E) < P(H).

Support for Bayes’ theorem as a model of scientific inference is bolstered by its ability to formally capture many features of scientific practice, such as confirmation and disconfirmation by logical entailment, i.e. the hypothetico-deductive model of scientific explanation, the confirmatory effect of surprising evidence, and the differential effect of

positive and negative evidence (for further discussion of how a Bayesian framework elucidates common scientific reasoning practices, see Howson and Urbach 1993).

Important for the present discussion is how this Bayesian framework can be applied to the testing of supernatural claims. Recall that according to the definition of ‘testability’ presented earlier, a claim is testable if there can be evidence *of whatever kind* for or against the claim. Thus, the probability of a given supernatural claim, H , being true can be evaluated in the following mutually reinforcing ways: (1) by H ’s prior probability, $P(H)$, given our background evidence and theories, (2) by whether the available evidence, E , is probable or improbable on the assumption that claim H is true, represented by the likelihood, $P(E|H)$, and (3) by whether or not there exist plausible alternative non-supernatural hypotheses, $\neg H$, that can account for the data, particularly hypotheses that enjoy a higher prior probability given their greater consistency with our background knowledge.

Each of these three factors contributing to the evaluation of supernatural hypotheses will be discussed below.

2.1 Hypotheses Evaluated Based on Prior Probabilities

Carl Sagan famously remarked that ‘extraordinary claims require extraordinary evidence’. The Bayesian framework of scientific inference formally captures the relationship between the prior probability of a hypothesis and the notion of the ‘burden of proof’ (see Pigliucci 2005). The more extraordinary the claim (that is, the lower its prior probability, given our background evidence and knowledge of how the world operates), the greater the burden of proof on the claimant to provide evidence of sufficient strength and quality to overcome the initially low probability of that claim being true. Philosopher Richard Carrier provides an intuitive illustration of how the burden of proof shifts with the prior probability of a claim. The claim that ‘I own a car’, is not ‘extraordinary’, given that many people in my situation own cars; hence the burden of proof is low. In contrast, if I claim that ‘I own a nuclear missile’, it is quite reasonable to be skeptical, given the low prior probability of this claim being true in light of our background knowledge, and to demand some fairly convincing evidence for the claim (Carrier 2005, p. 223). Similarly, the claim that one has clothes hanging in one’s closet carries a low burden of proof, given prior experience of closets, most of which contained clothes, whereas the claim that one has an ‘invisibility cloak’ in one’s closet carries a high burden of proof, given the unprecedented nature of such entities (Sinnott-Armstrong 2004). Thus, even in the absence of direct evidence against a claim, the low prior probability of the claim being true can provide rational grounds for skepticism and disbelief. All else being equal, the extreme extraordinariness of supernatural phenomena in light of our background knowledge of how the world works provides good grounds for being initially very skeptical indeed. After all, supernatural entities have capacities that go far beyond powers that we know exist. For this reason, most adults are not agnostic about the existence of Santa Claus, given his possession of powers that transcend well-established generalizations concerning how the world works. Moreover, more mundane alternative hypotheses consistent with our background knowledge (to be discussed in Sect. 3 below) are available that can explain events that are traditionally attributed to Santa Claus, e.g., the seemingly miraculous overnight appearance of presents under the tree and the disappearance of milk and cookies. In the absence of evidence for Santa Claus, one should not remain agnostic, considering the probability of his existence to be around 50%, but should actually lean toward disbelief in his existence (see Scriven 1966).

An important and related point is that just because we cannot definitively disprove a claim (such as the claim that ‘Santa Claus exists’), does not mean that we should believe it or remain agnostic about it. Indeed, in science no hypothesis, regardless of whether it concerns ‘natural’ or ‘supernatural’ phenomena, can be definitively proven or disproven. The ultimate aim of science is to explain the world by means of models that are more or less supported by the available evidence. As new evidence may arise that conflicts with our currently accepted models, no scientific hypothesis or theory can be proven with certainty or be immune from potential falsification. Scientific theories and hypotheses are defeasible. Nonetheless, a rough probability value, perhaps assessed via the Bayesian framework outlined above, can still be placed on a hypothesis, such that the hypothesis can be ‘proven’ or ‘disproven’ beyond a reasonable doubt (a familiar example being the innocence or guilt of a defendant in a court of law). Thus, our degree of confidence in a hypothesis based on the available evidence and our background knowledge may be expressed as a graded spectrum of probabilities ranging from near complete certainty through 50–50 agnosticism to near complete skepticism (see Scriven 1966; Dawkins 2006).

As Richard Dawkins puts it in various ways in his book, *The God Delusion*, “[w]hat matters is not whether God is disprovable (he isn’t) but whether his existence is probable (Dawkins 2006, p. 54)... even if God’s existence is never proved or disproved with certainty one way or the other, available evidence and reasoning may yield an estimate of probability far from 50 percent (Dawkins 2006, p. 50)...[t]he fact that we can neither prove nor disprove the existence of something does not [necessarily] put existence and non-existence on an even footing.” (Dawkins 2006, p. 49). Thus, just because something is possible does not mean that it is probable. Just because the existence of the Flying Spaghetti Monster has not been disproved does not mean that one is justified in believing that it exists. Dawkins’ use of the terms ‘prove’ and ‘disprove’ requires some clarification here. Dawkins intends these terms in this context to mean to prove or disprove *definitively* or *with certainty*, as is characteristic of deductive logic and mathematics. However, as the central thesis of his book is that God almost certainly does not exist (i.e., his existence is extremely improbable), it is clear that Dawkins does consider God’s existence to be disprovable in the weaker, defeasible sense used in law and science—namely, disprovable ‘beyond a reasonable doubt’ (cf. Stenger 2007, for further discussion of this point).

The erroneous assumption that science cannot even make probability judgments concerning the validity of supernatural claims Dawkins refers to as the ‘poverty of agnosticism’. Accordingly, Dawkins considers himself agnostic about God only to the extent that he is agnostic about fairies at the bottom of the garden (Dawkins 2006). Illustrating his position, he cites a well-known parable of Bertrand Russell concerning a claim that there is a china teapot in orbit about the sun (Russell 1952). Even though there is no direct evidence for or against the celestial teapot, background information can still provide a rational basis for evaluating the prior probability that the claim is true. Thus, most of us are not “teapot agnostics” but consider ourselves “a-teapotists”. Even though the orbiting teapot has not been disproved, no one believes in it because there is no evidence for it and there is a lot of background evidence against it: teapots come from Earth, it would be expensive to send one into orbit around the sun, etc. So, *a fortiori*, no one should believe in God or spirits simply because their existence has not been definitively disproved. After all, they do violate known physical laws, and that constitutes an enormous amount of background evidence against them. In general, whether the so-called “argument from ignorance” (namely, that a claim is false because there is no evidence for it, or that a claim is true because there is no evidence against it) is fallacious depends on the context of prior probabilities (see Oaksford and Hahn 2004; Sinnott-Armstrong 2004).

Absence of evidence can indeed be evidence of absence when either the prior probability of a given claim is low, or when the absence of evidence is unexpected on the assumption that the claim is true (to be discussed further in Sect. 2).

In addressing the existence of what is widely considered to be the paragon of supernatural beings, Dawkins' book, *The God Delusion*, goes right to the heart of the question of the testability of supernatural claims. Indeed, in his chapter, 'The God Hypothesis', Dawkins argues that "the existence of God is a scientific hypothesis like any other" (Dawkins 2006, p. 50) and that "a universe with a supernaturally intelligent creator is a very different kind of universe from one without." (Dawkins 2006, p. 58). Dawkins' arguments against the existence of God can be understood from a Bayesian perspective, as outlined earlier, whereby the probable truth of claims can not only be evaluated by whether or not their observational consequences are confirmed, but also by their prior probabilities given our background evidence and accepted theories.

Dawkins argues that even though God's existence cannot be definitively disproved, his existence is still highly improbable. Following other philosophers and scientists, Dawkins first dismisses several traditional arguments for the existence of God (e.g., the cosmological and teleological arguments) on the grounds that they either amount to special pleading or lead to an infinite regress of intelligent designers. If the universe's existence requires an explanation in terms of an intelligent designer, then why doesn't God, with all of his supreme and complex attributes, beg for an explanation in terms of yet another intelligent designer, *ad infinitum*? Indeed, who designed the designer? Alternatively, if God can simply exist without requiring an explanation, then why can't the universe simply exist unexplained as well, thereby removing the need to posit a designer in the first place? As the character Philo remarks to his interlocutor Cleanthes in David Hume's *Dialogues Concerning Natural Religion*:

How, therefore, shall we satisfy ourselves concerning the cause of that Being, whom you suppose the Author of Nature, or, according to your system of Anthropomorphism, the ideal world, into which you trace the material? Have we not the same reason to trace that ideal world into another ideal world, or new intelligent principle? But if we stop, and go no further; why go so far? Why not stop at the material world? How can we satisfy ourselves without going on in infinitum? And, after all, what satisfaction is there in that infinite progression? Let us remember the story of the Indian philosopher and his elephant. It was never more applicable than to the present subject. If the material world rests upon a similar ideal world, this ideal world must rest upon some other; and so on, without end. It were better, therefore, never to look beyond the present material world...To say, that the different ideas which compose the reason of the Supreme Being, fall into order of themselves, and by their own nature, is really to talk without any precise meaning. If it has a meaning, I would fain know why it is not as good sense to say that the parts of the material world fall into order, of themselves, and by their own nature. Can the one opinion be intelligible, while the other is not so? (Hume 1779, pp. 63–64).

Similarly, philosopher Thomas Nagel writes:

...it is surely incongruous to postulate a first cause as a way of escaping from the coils of an infinite series. For if everything must have a cause, why does not God require one for His own existence? The standard answer is that He does not need any, because He is self-caused. But if God can be self-caused, why cannot the world itself be self-caused? (Nagel 1959, p. 7).

To the extent that these critiques demonstrate the failure of philosophical arguments to prove the existence of God, they neutralize whatever boost these arguments might have given to the prior probability of God's existence. However, Dawkins goes further. Expanding upon this line of reasoning and reversing a common creationist argument, Dawkins maintains that God (a supremely intelligent being) is the "ultimate Boeing 747". If the probability of a 747 aircraft assembling by chance in a junkyard is infinitesimal, then so much lower must be the probability that a superior intelligence, such as God, just "happens to exist" without explanation. If a biological structure or phenomenon is so complex as to be vastly improbable in the absence of an evolutionary explanation for its existence, then all the more improbable and begging for an explanation must be the mind of a supremely intelligent being. As Dawkins comments:

...any God capable of designing a universe, carefully and foresightfully tuned to lead to our evolution, must be a supremely complex and improbable entity who needs an even bigger explanation than the one he is supposed to provide (Dawkins 2006, p. 147)... [t]o suggest that the original prime mover was complicated enough to indulge in intelligent design, to say nothing of mindreading millions of humans simultaneously, is tantamount to dealing yourself a perfect hand at bridge. (Dawkins 2006, p. 155).

This 'argument from improbability', as Dawkins calls it, serves to dramatically lower the prior probability of God's existence. The argument is intended to undermine the plausibility not just of particular gods, but of gods in a generic sense, including the non-interventionist God of Enlightenment Deism, provided that they are all conceptualized, at minimum, as highly intelligent beings. [A similar argument against Deism can be found in Shelley (1814).] However, the plausibility of the existence of particular conceptions of God, e.g., possessing the attributes of omnipotence and benevolence, or the existence of other supernatural entities may be further evaluated if their existence implies certain observational consequences that may be confirmed or disconfirmed by evidence. This describes the second way in which supernatural hypotheses can be evaluated, as will be discussed in the next section.

2.2 Hypotheses Evaluated Based on Confirming or Disconfirming Evidence

The most commonly cited way to test a hypothesis in science- and indeed in everyday life- is, to use the words of philosopher Keith Parsons, by simply "carefully looking and seeing" (Parsons 1989). This approach is embodied in the so-called hypothetico-deductive method thought to characterize the core of scientific practice.

The basic idea is that if an entity, phenomenon, or effect exists, it is detectable in some way. Either its existence is directly observable or its existence is not directly observable but it causes effects or implies consequences which are directly observable (such as the track made by a subatomic particle in a bubble chamber). To test the hypothesis that there is an elephant sitting in the closet, all one has to do is to open up the closet and take a look. The absence of evidence for an elephant inside is good evidence that there is none. To take a more familiar example from medicine, a doctor has good reason to believe that a patient does not have a virus if he looks closely and finds no evidence for that virus, given that the patient would have easily detectable symptoms if the virus were truly present (Sinnott-Armstrong 2004).

It is important to note that in disconfirming the existence of an entity or phenomenon, the absence of evidence is evidence of absence only when there is a good reason to believe

that the evidence would be present if the hypothesis is true, or conversely that the evidence would be absent if the hypothesis is false (see Oaksford and Hahn 2004). Thus, contrary evidence is constituted either by the lack of evidence that is expected to be observed if the hypothesis is true or by the presence of evidence that is not expected to be observed if the hypothesis is true.

These considerations are readily captured within the framework of Bayesian confirmation theory (Howson and Urbach 1993; Oaksford and Hahn 2004). Specifically, the likelihood, $P(E|H)$, is high or low depending on whether the evidence, E , that is observed is probable or improbable, given that the hypothesis, H , is true. If hypothesis H entails or predicts with high probability certain observations, E , then H is confirmed to the extent that E is observed, and H is disconfirmed to the extent that E is not observed (provided that $P(E|H)$ is greater than $P(E|\neg H)$ and assuming in this case equal prior probabilities for H and $\neg H$).

In the context of philosophical debates concerning the existence of God, such evidential arguments are often referred to in the philosophical literature as “God versus world” arguments (see Drange 1998). One well-known example is the so-called Argument from Evil. For instance, if God is conceived as all-good, all-powerful, and all-knowing, then it would seem unlikely that there should be as much evil and suffering in the world as there is, particularly if this evil and suffering has all the appearance of being gratuitous and failing to provide any greater good or moral benefit to the creatures involved. The atheistic Argument from Evil is one of the most widely discussed arguments in the philosophy of religion, and given the volumes written on the subject, an in-depth examination of the topic is beyond the scope of this paper (for further discussion, the author recommends the following: McCloskey 1960; Rowe 1979; Parsons 1989; Martin 1990; Rowe 1996; Drange 1998; Rowe 1998; Weisberger 1999; Everitt 2003; Metcalf 2004). Other evidential arguments against the existence of God include the argument from non-belief (Drange 1998) and the argument from divine hiddenness (Schellenberg 1993, 2004), to name a few. For instance, according to the argument from non-belief, the hypothesis that the God of the Abrahamic religions exists would imply that there should be no atheists, which is flatly contradicted by observations (cf. Drange 1998). These evidential arguments are generally intended not to definitively prove that God does not exist, but that, given the available evidence and God’s presumed attributes, the existence of God is highly improbable. Important for the present discussion, the fact that such evidential arguments are considered in the philosophical literature (from both atheistic and theistic perspectives), demonstrates that evidence is indeed relevant to the question of whether or not a deity with particular attributes exists. Some of these evidential arguments have been evaluated from a Bayesian perspective (cf. Rowe 1996; Ikeda and Jefferys 1997).

Expanding upon philosophical “God versus world” arguments, a number of scientists and philosophers have advocated an empirical approach to the evaluation of supernatural claims. For instance, Dawkins argues that the existence of God is a legitimate scientific hypothesis that has observational consequences which may be confirmed or disconfirmed by the available evidence:

The presence or absence of a creative super-intelligence is unequivocally a scientific question, even if it is not in practice- or not yet- a decided one. So also is the truth or falsehood of every one of the miracle stories that religions rely upon to impress multitudes of the faithful. (Dawkins 2006, p. 58–59).

As an example of an empirical test of the God hypothesis, Dawkins cites a recent double-blind, controlled study investigating the efficacy of intercessory prayer on the health and

recovery outcomes of 1,802 patients undergoing coronary bypass surgery. The study, published in the *American Heart Journal* and funded by the John Templeton Foundation, which supports research on spirituality, showed no significant difference in recovery outcome between patients who were prayed for and those who were not (Benson et al. 2006; Dawkins 2006). In fact, subjects who knew that they were being prayed for actually fared worse than subjects who were blind with regard to their experimental group assignment, possibly due to anxiety caused by learning that they were being prayed for (Dawkins 2006). The essential point is that methodologically sound studies published in reputable scientific journals have been conducted to directly test the consequences of a supernatural hypothesis.

In general, as reflected by the likelihoods in Bayes' theorem, whenever a supernatural claim predicts with a specified degree of probability some state of the world, that claim can be tested simply by inspecting the world to see whether or not the world displays that state. For instance, the findings of modern neuroscience strongly support the dependence of perception, cognition, emotion, memory, decision making, and personality on the function of the physical brain. These mental functions can all be selectively altered, impaired, or obliterated by anatomically and physiologically specific modifications of brain function, as induced by drugs, hypoxia, stimulation with electric currents and magnetic fields, and brain damage. As Richard Carrier puts it, "...nothing mental happens without something physical happening...If destroying parts of a brain destroys parts of a mind, then destroying all the parts of a brain will destroy the whole mind, destroying *you*." (Carrier 2005, pp.151–152). Since these neuroscientific findings are unexpected on the hypothesis of a transcendent, disembodied soul that survives death of the brain and retains personal identity, they constitute strong evidence against supernaturalism (see also Augustine 1997). Conversely, these neuroscientific findings are likely to be observed if Naturalism is true.

In addition to controlled scientific experiments, some supernatural claims are testable by simple observation and a little statistics. At one time it was supposed that lightning was an instrument of the wrath of God. Benjamin Franklin's lightning rod was even condemned as an attempt to thwart God's will. But a little statistical research, of the kind that keeps insurance companies profitable, showed that lightning struck the wicked and virtuous without moral discrimination.¹ More generally, the claim that there is a moral dimension to the cosmos concerned with human affairs is difficult to reconcile with the simple observation that natural calamities are randomly distributed with respect to religious affiliation, religiosity, and moral status. A classic example (which motivated Voltaire's *Candide*) is the Lisbon earthquake of 1755 that killed tens of thousands on a Catholic holiday and destroyed numerous important churches.

The cruelty and wastefulness of evolution by natural selection as well as the imperfections and suboptimal design of biological organisms constitute additional observations that are difficult to reconcile with the existence of a benevolent and intelligent supernatural designer (Darwin 1876; Smith 2001; Olshansky et al. 2003; Martin and Martin 2003). Scientists estimate that greater than 99% of all the species that have ever existed on earth have gone extinct. Moreover, the entire food chain, characterized by predation and parasitism, is a clear expression of the uncaring brutality of nature. As Dawkins comments, "[p]redators seem beautifully 'designed' to catch prey animals, while the prey animals seem equally beautifully 'designed' to escape them. Whose side is God on?" (Dawkins 2006, p. 134). While the existence of a benevolent and intelligent God is not logically inconsistent with the imperfection of organisms, mere logical possibility is not sufficient.

¹ Thanks to Brent Meeker for suggesting this example.

As Kelly Smith notes, “If we accept the mere possibility of an alternative explanation [i.e., supernatural creationism] as sufficient grounds to abandon an hypothesis [i.e., naturalistic evolution], we will never commit to any hypothesis whatsoever, because the alternatives to be ruled out are limited only by our imaginations.” (Smith 2001, p. 719). If God is a reasonable and intelligent being then He could reasonably be expected to produce designs *at least as good* as those that a human engineer could produce (Smith 2001). Yet there are numerous instances of flawed, deficient, or inefficient biological structures and mechanisms that no competent human engineer would countenance and which are indicative of the jury-rigged, mindless tinkering of evolution by natural selection rather than intelligent design (to name a few: the inverted wiring of the human retina, yielding a blind-spot, the close proximity of human reproductive and excretory organs, which increases susceptibility to infection, the shared function of the pharynx in eating, breathing, and speaking, which increases susceptibility to choking, the circuitous path of the recurrent laryngeal nerve, which extends down the neck to the chest, loops around the subclavian artery and then ascends back up to the larynx, instead of running directly from the brainstem to the larynx, as any competent engineer would have designed it; see also (Olshansky et al. 2003; Sawyer 2005; Martin and Martin 2003). As Smith comments, “...if a design in nature is clearly *inferior* to what a human engineer could produce, then we are entitled to request an explanation of this deviation from the RG-creationist [reasonable God-creationist] prediction.” (Smith 2001, p. 724). Whereas such observations are not necessarily unexpected on the hypothesis of a malevolent or incompetent deity, they are unexpected (and hence are improbable in terms of Bayesian likelihoods) on the hypothesis of a benevolent and intelligent designer who created the world with the interest of humans in mind. On the other hand, such observations can be expected on the hypothesis of naturalistic evolution.

In his book, *God: The Failed Hypothesis- How Science Shows that God Does Not Exist*, physicist Victor Stenger (2007) rigorously applies a “looking and seeing” approach to evaluating the God hypothesis and various religious claims. Although his book does not explicitly adopt a Bayesian perspective, many of his arguments are expressible in the hypothetico-deductive form typically used in the sciences and are hence easily accommodated within the Bayesian framework outlined here. Many of the attributes commonly associated with the traditional God of Judaism, Christianity, and Islam have specific consequences that can be tested empirically using the same standards that are applied in the investigation of any extraordinary claim in science. Like Dawkins, Stenger takes the existence of God to be a legitimate scientific hypothesis and, employing the standard scientific method of hypothesis testing, examines the observational implications of that hypothesis. Stenger argues that there are features of the world, revealed both by casual observation and by scientific examination, which would not be expected given the existence of an all-powerful, all-knowing, and benevolent intelligence that created the universe with humans in mind. These observations therefore count as evidence against the God hypothesis. After evaluating all the evidence, Stenger concludes beyond a reasonable doubt that the universe and life look exactly as they can be expected to look if there is no God. While discussion of the contents of Stenger’s book is beyond the scope of the present article, the important point to be made is that the existence of a deity, at least as conceptualized by the world’s great monotheistic religions, is inherently testable via approaches commonly employed in scientific practice (see also Pigliucci 1998).

In general, most believers hold that gods, spirits, and paranormal phenomena have real effects on the world and on their lives. These effects should be testable by the methods of science. Indeed, many supernatural and paranormal claims have already been investigated by scientists, often at the behest of those intending to validate the supernatural. To name a

few: the beneficial effects of intercessory prayer on patient outcomes (Aviles et al. 2001; Benson et al. 2006), paranormal or “psi” phenomena (see Alcock 2003), astrology (Carlson 1985; McGrew and McFall 1990; Kelly 1998), and the so-called “Bible Code” prophecies (McKay et al. 1999). If these hypotheses can legitimately be examined by science, then there is no principled reason why other supernatural claims cannot be so examined as well.

2.3 Hypotheses Evaluated Based on the Availability of Plausible Alternative Explanations

Historically, the boundary between what has been defined as ‘natural’ or ‘supernatural’ has shifted with scientific progress. Disease, lightning, meteorites, and comets were all considered ‘supernatural’ phenomena until they were given law-like ‘natural’ explanations consistent with other empirically supported ‘natural’ theories. Thus, it is not just the lack of convincing evidence for the supernatural, but also the availability of alternative natural explanations that can provide grounds for skepticism about supernatural claims. Conversely, indirect support for the supernatural may be constituted by the absence of any plausible alternative natural explanation for a given phenomenon. For instance, if intercessory prayer were found to benefit prayed-for patients, this would constitute at least *prima facie* evidence for the existence of the supernatural. While a natural explanation for an effect of distant prayer is not logically impossible, it is reasonable to assess the probability of there being such an explanation to be low relative to a supernatural explanation.

In general, the relevance of alternative explanations to the evaluation of hypotheses is formally captured within the Bayesian framework described earlier. Specifically, the posterior probability of a hypothesis, $P(H|E)$, is inversely proportional to the likelihood for an alternative hypothesis (or set of alternative hypotheses), $P(E|¬H)$, times the prior probability of the alternative hypothesis, $P(¬H)$. These values are found in the denominator of Bayes’ theorem. Thus, the better the evidence is predicted by the alternative hypothesis, i.e., the higher $P(E|¬H)$, the less the evidence, E , supports the original hypothesis, H . Indeed, as Howson and Urbach (1993) note, the rationale behind the use of controls in scientific and medical research, e.g., a control group receiving a placebo instead of an experimental drug, is to make the denominator in Bayes’ theorem as small as possible. Thus, any differences that are observed between experimental groups can reasonably be judged to be due to the independent variable of interest (e.g., the experimental drug), rather than to some other extraneous factor (e.g., the swallowing of pills).

Accordingly, the history of science has been characterized by the progressive ‘naturalization of the world’, providing non-supernatural alternative explanations for phenomena that were once thought to be explicable only by appeal to supernatural agents. When Napoleon asked Laplace about why there was no mention of a Creator in his work on celestial mechanics, the mathematician replied that he had no need for that hypothesis. Prior to the discovery of evolution by natural selection, even Darwin considered the argument for intelligent design as propounded by William Paley (1802) to be “conclusive” (Darwin 1876). However, the theory of evolution by natural selection effectively shattered Paley’s argument. As Darwin commented:

The old argument from design in Nature, as given by Paley, which formerly seemed to me so conclusive, fails, now that the law of natural selection has been discovered.

We can no longer argue that, for instance, the beautiful hinge of a bivalve shell must have been made by an intelligent being, like the hinge of a door by man. There seems to be no more design in the variability of organic beings, and in the action of natural selection, than in the course which the wind blows. (Darwin 1876).

Modern science has already provided or is actively investigating naturalistic explanations for the origins of the cosmos (cf. Stenger 2006b; Vilenkin 2006), the formation of complex patterns in nature from simple rules (cf. Ball 1999), the emergence of complex biological traits and adaptations (cf. Carroll 2005; Davidson 2006), morality (cf. Ridley 1996; Katz 2000; Hinde 2002; Hauser 2006), the so-called “anthropic coincidences”, i.e., the fine-tuning of constants of physics for the emergence of complex life (cf. Stenger 1999; Stenger 2006b; Vilenkin 2006), religious and mystical experiences (Persinger 1983; Persinger and Healey 2002; Arzy et al. 2005), “near-death” experiences (Britton and Bootzin 2004; French 2005), “out-of-body” experiences (Blanke and Arzy 2005; Bunning and Blanke 2005; Arzy et al. 2006), and other phenomena that have been traditionally thought to be explicable only by invoking supernatural causes. While some of these explanations are still speculative, though still rooted in evidentially well-supported theories, the availability of alternative natural explanations for purportedly supernatural phenomena effectively serves to undercut evidential support for supernatural worldviews.

To summarize, given the definition of ‘testability’ offered by Mahner and Bunge (1996b), there are at least three means by which supernatural hypotheses can be tested by science: by their prior probabilities, by their likelihoods, and by the availability of plausible alternative non-supernatural explanations. These considerations are readily captured within a Bayesian framework which models the reasoning by which hypotheses are commonly evaluated in scientific practice (Howson and Urbach 1993; Pigliucci 2002, 2005). A quantitative illustration of a Bayesian approach to the evaluation of a supernatural hypothesis is included in the Appendix.

3 Believing “On Faith”

In light of the absence of evidence or in the face of negative evidence for their claims many believers in the supernatural insist that their belief in the supernatural is based “on faith”, where “faith” is understood to be a legitimate justification for a claim irrespective of what the evidence might be.

However, if evidence is entirely irrelevant to the justification of beliefs about reality, then (barring emotional motivations) the foundation of those beliefs becomes completely arbitrary. If a belief is thought to be immune to the standards of science because it refers to an entity or phenomenon for which no evidence is possible, then one is not only permitted to believe in a countless number of absurdities, but one is logically compelled to do so. If it is legitimate to believe without evidence in the existence of ancestral spirits, then it is not only legitimate, but obligatory to believe also in goblins, fairies, the Flying Spaghetti Monster, numerous ‘discredited’ gods, and countless other extraordinary entities for which there is no evidence. Moreover, as Richard Carrier notes, “[b]lind faith is inherently self-defeating. The number of false beliefs always vastly outnumbers the true. It follows that any arbitrary method of selection will be maximally successful at selecting *false* beliefs. So the probability is always very high that a belief based on mere faith will be false.” (Carrier 2005, p. 60).

Furthermore, as philosopher Michael Scriven writes:

...one cannot break the connection between everyday experience and religious claims, for purposes of defending the latter, without eliminating the consequences of religion for everyday life. There is no way out of this inexorable contract: if you want to support your beliefs, you must produce some experience which can be shown to be a reliable indicator of truth, and that can be done only by showing a connection between the experience and what we know to be true in a previously established way. So, if the criteria of religious truth are not connected with the criteria of everyday truth, then they are not criteria of truth at all... (Scriven 1966, pp. 104–105)

Certainly, it is possible to devise ad hoc explanations for the absence of evidence or disconfirming evidence of the supernatural that would render supernatural claims immune to falsification. However, if such a strategy is permissible, then mundane claims involving natural phenomena are not falsifiable either, as one can always invent an ad hoc hypothesis to explain away any observation or the outcome of any experimental test. Clearly, science would never have developed to its present stage by following such an approach to the evaluation of evidence. This is not to say, however, that ad hoc explanations are never introduced in scientific practice to ‘save a hypothesis’. This can occur when the hypothesis in question has already received considerable empirical support via other experimental tests or convergent and independent observations. A single negative result is not sufficient to overthrow a well-worn theory, such as General Relativity. There may be plausible alternative explanations for the negative findings that would first need to be ruled out. However, the postulation of ad hoc explanations is rightly viewed with skepticism if the proposed explanations are themselves highly implausible; continued ad hoc rationalization of repeated bouts of contrary evidence betrays a commitment to preserve a desired hypothesis at all cost. As philosopher Walter Sinnott-Armstrong notes, “If we weaken our epistemic standards to accommodate irrefutable beliefs, then we might end up believing in the Great Pumpkin or, at least, holding that many absurd beliefs like this are justified.” (Sinnott-Armstrong 2004, p. 381).

It might be argued that there are some supernatural hypotheses that are forever beyond the capacity of science to evaluate. An historical example is the existence of the non-interventionist God of Enlightenment Deism, as mentioned in Sect. 1. These might also include, for instance, the claim that ‘God has a beard’ or that ‘Heaven has gilded streets’, with information relevant to the evaluation of these specific claims being inherently inaccessible to mere mortals.² However, these claims presuppose the existence of God and the persistence of some form of consciousness after death. Thus, if the existence of God and an afterlife are judged to be improbable in light of the available evidence and arguments, such as Dawkins’ ‘argument from improbability’ (discussed in Sect. 1), then such claims are rendered moot. On the other hand, even if *some* claims involving supernatural phenomena are inherently beyond scientific evaluation, this does not mean that *all* supernatural claims are, contrary to the official views of the AAAS and the NAS. Finally, there is no intrinsic difference between ‘natural’ claims and ‘supernatural’ claims concerning inaccessible entities (entities that will forever lack observable consequences). A contemporary example is the hypothesis that there exists not a single universe, but rather an infinite number of “bubble” universes comprising a gigantic “multiverse”. In principle, information from each of these bubble universes is inaccessible from all the other bubble universes, so the existence of such additional universes cannot be empirically confirmed.

² Thanks to an anonymous reviewer for suggesting these examples.

[Nonetheless, the multiverse scenario is a consequence of inflationary cosmological theories for which there is some empirical support (e.g., see Stenger 2006b; Vilenkin 2006).] Thus, whatever difficulties inaccessibility of information might present for the evaluation of a hypothesis, they are neither inherent to nor exclusive to hypotheses involving supernatural entities or phenomena, but may apply also to natural hypotheses.

4 NOMA Again

In the face of negative evidence, believers in the supernatural may retreat to a NOMA position, claiming that the phenomenon is in principle beyond the reach of science to investigate. For instance, responding to the ambiguous or negative results of earlier studies on the therapeutic effects of distant intercessory prayer, Chibnall et al. (2001) urge that research should avoid attempting to validate God through scientific methods. Specifically, they state that “the epistemology that governs prayer (and all matters of faith) is separate from that which governs nature” (Chibnall et al. 2001, p. 2530) and, in implicit endorsement of the NOMA position, that “prayer resists scientific explication and, unfortunately, nature has nothing to say about the ways of God.” (Chibnall et al. 2001, p. 2532). Chibnall et al. (2001) conclude that “[w]e do not need science to validate our spiritual beliefs, as we would never use faith to validate our scientific data.” (Chibnall et al. 2001, p. 2535). However, many see NOMA as a ploy designed to insulate supernatural claims from potential scientific refutation. As Dawkins comments:

NOMA is popular only because there is no evidence to favour the God hypothesis. The moment there was the smallest suggestion of any evidence in favour of religious belief, religious apologists would lose no time in throwing NOMA out of the window (Dawkins 2006, p. 59).

A common criticism of scientific research into the efficacy of intercessory prayer, which has been voiced by Chibnall et al. (2001) and other commentators, is that the Bible forbids ‘testing God’, and that prayer studies are in fundamental violation of this admonition. However, in response to the article by Chibnall et al. (2001), Harris and Isley (2002) note that there are passages in the Bible where ‘testing God’ is quite acceptable:

Have the authors considered I Kings 18:19–40? In this record, the prophet Elijah conducted a controlled experiment designed to show the Israelites the power of the true God. Elijah challenged 450 prophets of Baal to offer a sacrifice to their god, and he would do the same to his God. The prespecified end point in this trial was “and the God which answers by fire, let Him be God.” After hours of observing spirited but fruitless pleas to Baal, Elijah called on his God, and the rest is history (as were the 450 prophets also soon to be!). This was clearly “testing God”. Why did He not only allow the test, but convincingly participate as well? (Harris and Isley 2002)

Another commentator on the article by Chibnall et al. (2001) writes as follows:

If prayer and faith, however intangible these concepts may be, are touted to have physiological effects, then they should be subject to scientific measurement. You cannot have it both ways: claiming physical effects for prayer but demanding that these claims be exempt from scientific study because they are in the realm of beliefs. It is hard to imagine that God, the infinite creator of the universe, would feel threatened by having the physical effects of prayer subjected to scientific study!

However, some of those who claim to speak for Him are clearly threatened by this prospect. (Smith 2002).

Along similar lines, Dawkins writes:

...the alleged power of intercessory prayer is at least in principle within the reach of science. A double-blind experiment can be done and was done. It could have yielded a positive result. And if it had, can you imagine that a single religious apologist would have dismissed it on the grounds that scientific research has no bearing on religious matters? Of course not. (Dawkins 2006, p. 65).

There is empirical support for the suggestion that earnest believers in the supernatural will often count any empirical evidence favorable to their hypothesis as highly significant and ignore negative evidence as ‘irrelevant’ or ‘inappropriate’ or try to explain it away by introducing ad hoc rationalizations (cf. Kelly 1998). When the evidence overwhelmingly goes against their hypothesis they may suggest that their theory is scientifically untestable after all, thereby retreating to a NOMA position. However, this line of reasoning does not indicate that supernatural hypotheses are inherently untestable, but rather the dedication of true believers to a favored hypothesis. The cognitive foundations and psychological motivations underlying belief in the supernatural are considered in the next section.

5 Natural Psychological Explanations for the Origin and Persistence of Supernatural Worldviews

If there is no independently verifiable evidence for the supernatural, and indeed there is evidence against the supernatural, then why do so many continue to hold a supernatural worldview? Why do gods persist?

There is a growing literature dealing with the psychology of religion and the cognitive foundations of belief in supernatural agents, such as gods, spirits, and ghosts. For instance, in his book, *Faces in the Clouds: A New Theory of Religion*, Stewart Guthrie (1993) provides ethnographic and psychological evidence for a widespread tendency of humans to anthropomorphize their experience of the world, to see faces in the clouds, to hear voices in the wind, to see purpose in events, even when none is present. Along similar lines, a number of cognitive scientists (Hinde 1999; Barrett 2000; Castelli et al. 2000; Blakemore and Decety 2001; Boyer 2001; Atran 2002; Blakemore et al. 2003; Atran and Norenzayan 2004; Tremplin 2006) have proposed the existence of ‘agency detection’ and ‘theory of mind’ modules in the brain that predispose us to infer an agent behind events and to expect that agent to have a mind with intentions. There would be powerful selective pressures for the evolution of such modules, as detection of agents would confer clear survival advantages. Given that false positives (e.g., mistaking a rock for a bear) are tolerable, but that false negatives (e.g., mistaking a bear for a rock) can be deadly, the best policy is to err on the side of assuming agents as causes of events. Hence, people are particularly sensitive to the presence of intentional agency and seem biased to over-attribute intentional action as the cause of a given state of affairs, particularly when the evidence is ambiguous or vague (Guthrie 1993; Barrett 2000). Inferring the existence of gods, spirits, and ghosts as agents responsible for unexplained events is therefore a natural byproduct of psychological and cognitive processes that evolved to deal with more mundane issues of survival (Hinde 1999; Barrett 2000; Boyer 2001; Atran 2002; Boyer 2003; Atran and Norenzayan 2004; Tremplin 2006). Dennett (2006) and Dawkins (2006) have also advocated an evolutionary

byproduct explanation for the near universal tendency of humans to believe in supernatural agents, or at least to be prone to acquiring the concepts from their cultural milieu.

Moreover, the potential to alleviate existential anxieties, such as fear of death, calamity, loneliness, and loss, offers powerful emotional motivation to believe in supernatural agents (Atran 2002; Atran and Norenzayan 2004; Norenzayan and Hansen 2006). Indeed, religious ritual and prayer are intended fundamentally to provide an apparent degree of control over events by negotiating with and placating the gods and spirits to ensure protection and enhanced survival (Atran 2002; Boyer 2003; Atran and Norenzayan 2004). In the tradition of Freud, M.D. Faber has written on the psychobiological underpinnings of religious belief, providing evidence that prayer (“supplication”) and accompanying belief in gods and angels can be traced to a subconscious emotional longing for the protection and care that we received from our seemingly omniscient and omnipotent parental figures during our early years as infants. As Faber writes:

Are we to regard it as merely coincidental that the Parent-God, whom we approach as helpless, dependent children, possesses as one of His cardinal attributes the telepathic ability to read our requirements before we have pronounced them, exactly as the caregiver was able to do early on? ...In the beginning was a caregiver who could intuitively fathom, and meet, our needs. Our wishful, religious inclinations will not allow such a one to slip away. (Faber 2004, p. 150–151).

Thus, according to Faber, the foundation of the religious experience as a whole derives from a subconscious effort to “locate for us sources of attachment and security as we undertake our separate, dangerous journeys through the world... [This effort] is inextricably bound up with our animistic tendency to people the environment with projective versions of the parental care-giving figure.” (Faber 2004, p. 215). Thus, “[t]he very basis of religious feeling, the very root itself, is both infantile and naturalistic.” (Faber 2004, p. 216).

However ultimately convincing these accounts may be, they at least provide plausible explanations for the psychology of belief which do not require invoking extraordinary processes or appeal to anything supernatural. In light of the earlier discussion concerning the relevance of alternative hypotheses to the evaluation of supernatural claims, to the extent that this literature provides plausible alternative naturalistic explanations for the prevalence and persistence of belief in supernatural agents and phenomena, it constitutes indirect evidence against supernatural worldviews.

6 Going Wherever the Evidence Leads

In *Science and Creationism: A View from the National Academy of Sciences*, the NAS states:

Creationism, intelligent design, and other claims of supernatural intervention in the origin of life or of species are not science because they are not testable by the methods of science. (NAS 1999).

This statement assumes that there is a well-defined demarcation between ‘natural’ and ‘supernatural’ phenomena, and between ‘science’ and ‘non-science’ or ‘pseudoscience’. However, despite various attempts to do so (see Martin 1994; Mahner and Bunge 1996a, b), defining what properly constitutes ‘science’ and distinguishes it from ‘non-science’ has been notoriously difficult, and runs the risk of arbitrarily excluding from scientific consideration phenomena that might actually exist. What is generally uncontroversial is that

the practice of science, at least ideally, involves adherence to certain epistemological norms that have demonstrated past success as strategies aimed at getting at the truth. These norms include: telling the truth, proportioning one's level of confidence in a hypothesis to the total available evidence (both positive and negative), controlling for extraneous factors and experimenter bias, and attempting to rule out more mundane alternative explanations consistent with background knowledge before considering extraordinary hypotheses.

In agreement with other authors (e.g., Laudan 1983; Monton 2006; Stenger 2006a), the present author maintains that demarcating 'science' from 'pseudoscience' or 'natural' from 'supernatural' is not only problematic but unnecessary. The crucial question is not, *Is it science?* or *Is it supernatural?*, but rather, *Is there any good reason to believe that claim X is true?* Whether the entities or phenomena posited by claim X are defined as 'natural' or 'supernatural' is irrelevant to the scientific status of the claim. If the fundamental aim of science is the pursuit of truth—to uncover, to the extent that humans are capable, the nature of reality—then science should go wherever the evidence leads. If the evidence were to strongly suggest the existence of supernatural phenomena, then so be it.

While the position that science cannot evaluate supernatural or religious claims - and hence that there can be no conflict between science and religion—may satisfy political aims (for instance, ensuring continued support for science by religious taxpayers), it is disingenuous, having the appearance of a ploy designed to protect religion from critical examination. Moreover, such a view is antithetical to the spirit of open and unbiased scientific inquiry, whereby any phenomenon, regardless of whether it is designated 'natural' or 'supernatural', should be a legitimate subject for study and critical examination.

7 Science Does Not Presuppose Naturalism. Whether or Not the Supernatural Exists Is an Empirical Question

Some philosophers have argued that science presupposes a naturalist metaphysics on the grounds that the practice of science would be impossible if supernatural explanations are allowed (Mahner and Bunge 1996a, b). However, Naturalism is not a premise or presupposition of science—it is a conclusion of science, albeit a tentative one, based upon the available evidence to date (for a similar position, see Martin 1994; Isaak 2002; Stenger 2003; Carrier 2005; Monton 2006; Stenger 2006a; Stenger 2007; Gauch 2006). As Richard Carrier notes, "...rejection of the supernatural is not a priori, it is not declared 'before examining the facts.' It comes only from a scientific investigation of the evidence." (Carrier 2005, p. 211). Hugh Gauch expresses a similar view:

Science is worldview independent as regards its presuppositions and methods, but scientific evidence, or empirical evidence in general, can have worldview import...human presuppositions have no power to dictate or control reality... Precisely because science does not presuppose worldview-distinctive beliefs, such beliefs retain eligibility to become conclusions of science if admissible and relevant evidence is available. (Gauch 2006).

After all, science might have discovered evidence for the supernatural, for instance: finding the earth to be less than 10,000 years old (thereby confirming the biblical account and precluding Darwinian evolution by natural selection), that extra-sensory perception and other paranormal phenomena exist (e.g. that psychics routinely win the lottery), that intercessory prayer improves patient outcomes or can lead to re-growth of amputated

limbs, that astrology makes detailed and successful predictions, that mental faculties persist despite destruction of the physical brain, and that specific prophecies claimed to be acquired by communication with the spirits of dead relatives are later confirmed. Indeed, the very aim of so-called ‘Natural Theology’ has been to uncover evidence of divine design in the natural world, as exemplified by the famous opus of William Paley, entitled, *Natural Theology, or Evidences of the Existence and Attributes of the Deity Collected from the Appearances of Nature* (Paley 1802). As noted earlier, even Darwin initially considered Paley’s evidential arguments for intelligent design to be persuasive. The aforementioned observations would not prove conclusively that the supernatural exists, as it is always possible that a naturalistic explanation will ultimately be found to account for them (e.g., evolution by natural selection). However, in the absence of such naturalistic explanations, these observations would still constitute powerful, albeit defeasible, support for supernatural worldviews.

The best explanation for why there has been so far no convincing, independently verifiable evidence for supernatural phenomena, despite honest and methodologically sound attempts to verify them, is that these phenomena probably do not exist. Indeed, as discussed earlier, absence of evidence, where such evidence is expected to be found after extensive searching, is evidence of absence. That empirical science does have implications for the existence of the supernatural may explain why the vast majority of scientists who are members of the NAS are atheists (Larson and Witham 1998). Nonetheless, it is important to emphasize that while the current state of knowledge would argue against the existence of supernatural entities and phenomena, it is conceivable that future evidence might provide support for a supernatural worldview over a naturalistic one. The essential point is that supernatural worldviews are inherently testable via approaches employed in standard scientific practice.

Thus, contrary to the positions expressed by Judge Jones, the AAAS, and the NAS, the reason why supernatural or religious claims, such as those of ID/Creationism, do not belong in science classes is not because they have supernatural or religious content, but rather because there is either no convincing evidence to support them or science has debunked them. For instance, a major claim of the ID movement is that certain biochemical pathways such as the blood-clotting cascade and cellular structures such as the bacterial flagellum are “irreducibly complex” and hence could not, in principle, have evolved by stepwise Darwinian evolution (Behe 1996). This is a testable claim, which has been tested and empirically falsified, along with many other ID claims (Perakh 2003; Stenger 2003; Shanks 2004; Young and Edis 2004; Monton 2006; Pallen and Matzke 2006; Stenger 2006a). As philosopher Larry Laudan has argued, “Creationists make a wide range of testable assertions about empirical matters of fact... [Creationist] claims are testable, they have been tested, and they have failed those tests.” (Laudan 1982). This position has been echoed by other philosophers and scientists. For instance, physicist Victor Stenger writes:

ID is testable, tentative, and falsifiable. For example, William Dembski [a leading proponent of ID] asserts a ‘law of conservation of information’ which implies that information cannot be generated by natural processes. This is provably wrong. Information is negative entropy and the second law of thermodynamics allows for the entropy of systems interacting with their environments to decrease and thus information to increase naturally. Michael Behe’s examples of “irreducible complexity” have similarly been refuted. (Stenger 2006a).

Thus, there is ample justification for the conclusion of philosopher Bradley Monton that “ID should not be dismissed on the grounds that it is unscientific; ID should be dismissed on the grounds that the empirical evidence for its claims just isn’t there.” (Monton 2006).

8 Implications and Challenges for Science Education

While as a matter of principle, science must pursue truth, regardless of religious or political sensitivities, on a practical level such an endeavor clearly has the potential to offend those who hold supernatural worldviews and thereby impede science education. Thus, science educators face the challenge of maintaining both intellectual integrity and the receptivity of students to potentially controversial scientific material.

As Martin notes with some concern (Martin 1994), beliefs in supernatural and paranormal phenomena are widespread among the general population, students, and even science educators. Martin views this as indicative of a failure of science education. Science educators have not only the duty to communicate scientific findings and currently supported theories to their students, but also to teach a scientific approach to the evaluation of claims, regardless of whether they concern ‘natural’ or ‘supernatural’ phenomena. Martin (1994) maintains that giving students correct information, educating them on how to critically examine evidence for a given hypothesis (including alternative hypotheses), and to utilize fundamental principles of scientific investigation should all be a part of science education. This approach may in turn serve as an antidote to the prevalent acceptance of pseudoscientific and paranormal claims. Indeed, Martin argues that science educators should include a critique of paranormal phenomena, such as ESP, dowsing, and ghosts, as an integral part of science education right from the beginning (Martin 1994). This suggestion may be viewed as a bit extreme, especially given the limited time available in science classes for dealing with more ‘mundane’ science. However, there may be a place in general science classes for considering and evaluating theories that Martin classifies as ‘pseudoscience’ as a pedagogical tool for teaching critical thinking skills. Brent Meeker (personal communication) has recommended that these include pseudoscientific theories that hardly anyone believes and whose refutation can be easily demonstrated, e.g. psychic surgery, dowsing, and astrology, but that the connection to the paranormal, Creationism, and the power of prayer is perhaps best left implicit, as these topics may present a contentious distraction in the classroom.

There is also enormous educational value in presenting a historical perspective on science to provide a framework for understanding how science has arrived at its currently accepted theories about the world. For instance, educators might have students consider questions along the lines of the following: How was it shown that the earth is round and orbits the sun? How was the germ theory of disease proven? Why don’t we believe in phlogiston and the luminiferous aether?

While the question of what material is appropriate in a given educational context will have to be decided by individual educators and their institutions, it is clear that teaching critical thinking skills in addition to factual information will not only foster scientific literacy, but may have far reaching beneficial consequences for how students conduct their daily lives and for a society all too often enticed by the paranormal and deceived by potentially dangerous pseudoscientific claims. By fostering critical thinking and a scientific frame of mind there is an increased likelihood that students will adopt a skeptical attitude toward supernatural claims in light of the scientific evidence against them. Importantly, critical thinking and a scientific approach to claims are not just for scientists and debunkers

of the supernatural. A well-informed population proficient in critical thinking will be better equipped to make intelligent decisions concerning crucial political issues of our day, such as global warming and governmental foreign policy. Indeed, an intellectually honest engagement with reality is a prerequisite for promoting the long-term interest of individuals and society at large.

Acknowledgments This work was motivated in part by discussions on Professor Victor Stenger's 'A-VOID' online list serve and by two articles, Monton (2006) and Stenger (2006a), which defend a similar thesis. The author is grateful to the editor, Dr. Michael Matthews, Jonathan Colvin, Keith Douglas, Anna Grossman, William Jefferys, Brent Meeker, Victor Stenger, RJ Welsh, and two anonymous reviewers for helpful comments and suggestions on a previous version of the paper. Special thanks to Brent Meeker for significant editorial contributions.

Appendix: Testing God: A Bayesian Approach

A believing Christian amputee prays to the Christian God for re-growth of his arm:

Hypotheses:

God exists = +H

God does not exist = -H

Assume equal prior probabilities for H and -H: $P(+H) = 0.5$; $P(-H) = 0.5$

Evidence:

Amputee's arm grows back after prayer = +E

Amputee's arm does not grow back after prayer = -E

$$P(+E|+H) = 0.9$$

If God exists, there is a 9/10 chance that the amputee's prayers will be answered- this is based on the passage in the King James Bible: "And all things, whatsoever ye shall ask in prayer, believing, ye shall receive." Matt 21:22). $P(+E|+H)$ is set equal to 0.9 (a high probability) instead of 1.0 to leave open the possibility that the amputee failed to utter the prayer perfectly or that the amputee's faith, although he is an avowed and devout believer, is not sufficient to merit God's beneficence

$$P(+E|-H) = .00001$$

If God does not exist, there is a 1/100,000 chance that the amputee's arm will grow back naturally. This is empirically a grossly over-optimistic estimate, since there have been many times 100,000 amputees, all of which have failed to have their limb grow back; But we don't set it to zero because there is always a possibility that there is something we don't know about how nature operates. Further, it is possible that, within the lifetime of this particular amputee, medical science will discover a way to cause the arm to re-grow through natural means.

$$P(+H|+E) = P(+E|+H) * P(H) / [P(+E|+H) * P(H) + P(+E|-H) * P(-H)]$$

(Bayes' Theorem)

$$P(+H|+E) = 0.9 * 0.5 / (0.9 * 0.5 + .00001 * .5) = .45 / (.45 + .000005) \sim 1.0$$

$$P(+H|-E) = 0.1 * 0.5 / (0.1 * 0.5 + 0.99999 * .5) = .05 / (.05 + .499995) \sim .09$$

$$P(+H|+E) > P(+H)$$

(i.e., the posterior probability of +H, given +E, is greater than the prior probability of +H.)

$$P(+H|-E) < P(+H)$$

(i.e., the posterior probability of +H, given -E, is less than the prior probability of +H.)

Therefore, the hypothesis that the Christian God exists, H, is confirmed by evidence, E, and is disconfirmed by evidence, -E.

Hence, the fact that no devout Christian amputees have ever had their limbs grow back following prayers to the Christian God requesting limb re-growth is strong evidence that the Christian God does not exist.

(The example presented above is inspired by the website: <http://whywontgodhealamputees.com/>)

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