Phys. perspect. 8 (2006) 83–89
1422-6944/06/010083–7
DOI 10.1007/s00016-005-0279-6

Physics in Perspective

Perspectives on Current Issues

What Makes a Theory Testable, or Is Intelligent Design Less Scientific Than String Theory?

Robert Ehrlich*

I compare the theory of intelligent design to string theory to see on what basis, if any, only the former can be justifiably excluded as being scientific. We shall see that the classic criterion of testability or falsifiability is sometimes not so straightforward, and that there are other criteria to help us make such a distinction.

Key words: intelligent design; irreducible complexity; evolution; string theory; anthropic principle; theoretical testability; falsifiability; Michael Behe; Leonard Susskind.

Introduction

Our understanding of the physical universe has deepened enormously over the last three centuries, and with that increased understanding has come an ability to influence the future of our planet for good or ill. This ability, and the corresponding inability of science to provide any deeper meaning to our existence, has been the source of anti-science positions on the part of some "new-agers," postmodernists, and religious fundamentalists. While such external challenges are serious, we need to consider whether scientists themselves may also undermine public confidence in their enterprise by using inconsistent criteria as to what properly defines the boundaries of science.

For example, there is much debate today in the United States about having "intelligent design" (or at least criticisms of Darwin's theory of natural selection) taught alongside evolution. This approach, supported by two thirds of the American public,[1] has been rejected by most scientists on the ground that intelligent design is not a scientific theory, since it is untestable and hence cannot be disproved. Most scientists also note that by contrast evolutionary theory is a highly successful explanation of what is found in the natural world, and has been well-tested. Thus, to require intelligent design to be taught alongside evolution makes as little sense as requiring flat-Earth theory to be taught in science courses, so that students "can make up their own minds" whether the Earth is round or flat.

* Robert Ehrlich, the author or editor of twenty books, is Professor of Physics at George Mason University in Fairfax, Virginia, USA.

Intelligent design (ID) hypothesizes that certain microscopic structures, such as the cell or the "outboard motors" (flaggella) of bacteria are irreducibly complex, meaning that if you remove a single part, or even alter it significantly, the structure cannot function.[2] On that basis, ID claims that these structures cannot have evolved in a step-by-step manner, and that an "intelligent designer" must have been responsible, although they coyly decline to identify the designer. ID is compatible with the fact of evolution; it simply says that certain steps in the process had to be guided by a designer – presumably God.* By conceding that natural selection controlled all steps except for those few where a designer had to intervene, the advocates of ID are able to sidestep the objection that no competent designer would have made some unsatisfactory structures that are found in nature.** It is not very well-known, for example, that the other developer of evolution besides Charles Darwin, Alfred Russel Wallace, himself believed in ID when it came to the origin of the human brain.[3] Although physicists (and other scientists) have gone on record as opposing the teaching of ID in science courses on the ground that it lies outside science,[4] I wish to examine here whether or not they have applied the same criterion in evaluating other theories, such as string theory, whose claim to be considered science might be open to question on a similar ground.

Evaluating String Theory

String theory was developed to try to unify all of the fundamental forces of nature, which was also Albert Einstein's primary unfulfilled quest during the last decades of his life. The theory claims that the fundamental entities of physics, like electrons and quarks, are actually not point particles, but incredibly small vibrating strings or "branes" (as in membranes). There obviously has been no clamor to consider string theory outside the realm of science or to ban its teaching in science courses. In fact, quite the opposite course of action has been followed – with well-funded efforts to promote media explorations of the subject, and workshops for high school teachers so that they can introduce this exciting subject to their students.[5] A number of string theorists including Brian Greene also have written excellent popular books on the subject.[6]

Now, it is certainly false that string theory is untestable, and makes no predictions. It actually makes two specific predictions: (1) that we live in a world with 9 spatial dimensions, and (2) that the cosmological constant responsible for accelerating the expansion of the universe – a kind of "antigravity" – is around 10^{120} times larger than has been recently observed. Both of these predictions would seem to be spectacularly refuted, although string theorists are able to explain away the first failure on the ground that six of the nine dimensions of space are "curled up" to such tiny size that they are unobservable to us. (To get the idea of curled-up unobservable dimensions, imagine a thin wire on which an ant is crawling, which appears from a distance to be a one-dimensional line, rather than a three-dimensional cylinder as it appears to the ant, which is capable of crawling around its circumference.)

---

* Two other possibilities for a "designer" include aliens and time travelers!

** Most notably, this would include the photoreceptors of the eye being placed on the "wrong" side of the retina.

String theorists offer no reasons why six rather than seven or eight spatial dimensions should be curled-up, nor for the precise way this curling up should occur. Richard Feynman once opined that the theory offers only excuses, rather than predictions.[7] String theory is not even a theory, as the term is usually understood in physics. This point is granted by its "father," Leonard Susskind, who notes in his recent book that, "We know neither what the fundamental equations of the theory are, or even if it has any. Well then, what is the theory if not a collection of defining equations? We really don't know."[8]

Instead, one can only say that string theorists have reason to believe that in the future it may be possible to write down a theory, that is, an equation or set of equations, for a nine-dimensional space (or ten-dimensional space-time), making it at present more properly a hope than a theory, as the term is usually understood. Furthermore, when one considers the near-infinite number of ways that six of the spatial dimensions can be curled up, string theorists also have the hope that one of those ways will cause that future equation to reduce to the highly successful "standard model" of particle physics, a theory that has been well-tested by experiment.[9]

Some string theorists, including Michio Kaku, take the view that it is unnecessary that their (future) theory be proven experimentally, and still be considered being within the realm of science.* There is a sense in which this claim is perfectly valid. For example, were a future string theory able to calculate the masses and other properties of all known subatomic particles and other constants of nature to high accuracy, it would have to be taken very seriously, even if it predicted nothing new. But, obviously, in that case the theory should not have many undefined free parameters that could be adjusted to make it fit what is observed! This type of adjustability currently appears to be an unavoidable feature of string theory, given the near infinite number of ways the six hidden dimensions can be curled up.

String theorist Susskind has noted that as string theory has developed, rather than zeroing in on a unique set of laws, it has yielded an "ever expanding collection of 'Rube-Goldberg' concoctions"[10] – a number possibly as large as 10^{500} possibilities – with no clear fundamental physical principle to choose among them. Susskind, wanting to turn this apparent weakness into a strength, recently suggested that perhaps one can choose among these many different versions of the (future) theory by using the "Anthropic Principle." This principle begins by noting that only extremely narrow ranges of the fundamental constants of nature would allow life to exist – we truly live in a "Goldilocks" universe.[11]

In Susskind's view, we need to think of the universe as really being a "multiverse" consisting of a near infinite set of noninteracting "pocket universes," such as our own, each having its own set of physical laws and fundamental constants. One assumes that the values of those constants would follow directly from the theory, based on different ways of curling up those hidden six dimensions. In this scheme, we can say that only in the exceptionally lucky case – such as our own pocket universe – life can exist, because

---

* Note, for example, the discussion between Michio Kaku and John Horgan accompanying their bet on whether by the year 2020 no one will have won a Nobel Prize for work on superstring theory; see <http://www.longbets.org> (bet number 12).

in almost all of the others the fundamental constants of nature are simply not sufficiently fine-tuned for life to have evolved. Perhaps in most of them atoms might not exist, or galaxies would not form, or stars would not ignite, and the like. Thus, the very large number of possible versions of the theory and the resulting constants of nature to which they give rise helps ensure that by chance there will be some rare pocket universes in which life can exist – even without any "intelligent designer" doing the fine-tuning to make it happen. It is, of course, unclear how one might test such a conjecture, given that by definition we cannot communicate with or observe the pocket universes that lie outside our own – though as history shows, one cannot underestimate the cleverness of theorists to make testable predictions based upon seemingly unobservable entities, and some already have begun thinking along this line.[12]

Comparison with Intelligent Design

Despite all of the above reservations expressed about string theory, most physicists are quite aware of the significant differences between it and the theory of intelligent design Unlike ID theory, string theory is at least (a) highly mathematical, (b) pursued by a cadre of highly intelligent scientists who publish regularly in reputable physics journals, and (c) considered to be legitimate science by much of the mainstream physics community. Still, whether or not a theory can be regarded as scientific needs to hinge on the theory itself, and not on how mathematical it is, or the reputations of the people who work on it, or the status of the journals in which they publish – or on what other people say about the emperor's beautiful clothes.

The asymmetrical reactions of most scientists to these two theories, string theory and intelligent design, raises the question of whether they may be applying a double standard in evaluating what constitutes science. John S. Rigden is one of a number of physicists who has sounded the alarm about needing to be much more careful in speaking about highly speculative topics in physics, such as the "multiverse" – and to make clear that they are indeed speculations rather than actual theories, as the term is usually understood.[13] Concerning string theory in particular, mathematician Peter Woit, a long-time observer of developments in string theory, comments in much more detail on the issues discussed here in his new book, *Not Even Wrong*.[14] Woit is not a string theorist, nor am I, but decisions as to what constitutes a legitimate scientific theory are simply too important to be left to the practitioners of that field, who obviously have vested interests in it, such as a desire to keep the funding coming. Also, its highly mathematical nature, requiring many years to master it, has allowed string theorists, in string theorist Susskind's words, to keep "their Achilles heel under wraps until fairly recently."[15] It is to Susskind's great credit that he has publicized these problems in talks and popular writings.

Conclusions

Are there then any grounds for considering string theory scientific that would exclude intelligent design? String theorists sometimes cite specific possible observations that would support it, including for example finding evidence for those unseen six spatial

dimensions, through their "leakage" into our three-dimensional space. This, in principle, might be observed by finding that the gravitational attraction between two tiny masses departs from the usual inverse-square law at very small separation distances.* Some string theorists also have provided highly speculative reasons why such a departure might occur at distance scales only slightly less than what has so far been explored.[16] This means that the failure to find a departure from the inverse-square law in no way would refute the theory, since the departure might occur at still smaller distances – hardly a falsifiable prediction. By contrast, intelligent design theorist Michael Behe has at least suggested a falsifiable test for ID, namely, that ID could be disproved if evolutionary biologists are able to evolve one of the so-called irreducibly complex structures starting with some simpler functioning structure. Needless to say, Behe dismisses all published papers that have ever proposed a detailed model for such an evolution.[17] Moreover, Behe's proposed test is not taken seriously by most scientists for an actual experiment, because there is no way of knowing exactly what the starting point for this evolution should be, what environment the proto-structure should be placed in, and whether the time for the evolution to occur is going to be feasible to study in one's lifetime.[18]

But there is one important sense in which string theory is more within the scientific realm than ID. While string theory has not yet suggested a falsifiable test, it has provided experimentalists with a reason to extend their observations of the gravitational inverse-square law into a new domain. It also has provided similar motivations to extend observations of subatomic-particle reactions to still higher energies (which might be sufficient to create so-called "supersymmetric" partners of known particles) – another prediction of string theory, albeit a "weak" one, since no particle masses have been predicted. Thus, unlike intelligent design, string theory – while not yet able to make falsifiable predictions – does give guidance to experimenters on where they might find something significant in support of the theory. An analogous situation for ID would be if intelligent-design theorists were to provide some plausible scientific (nonbiblical!) reason to believe that there is a message from the designer hidden within the cell,** or perhaps a message hidden in some seemingly random physical process, such as radioactive decay. Finding such a "designer label" or hidden message would certainly give strong support to their theory – assuming that the observation could be replicated – but I am unaware of any ID supporters ever making any such specific suggestions, or having the slightest interest in carrying out the necessary experiments. On the contrary, despite the scientific-sounding exposition by Behe and others, their theory appears to be a politically clever effort to undermine the teaching of evolution under the guise of "fairness." Still, to question the motives of the majority of believers in intel-

---

* In three spatial dimensions the gravitational lines of force from a point mass spread out over the two-dimensional surface of a surrounding sphere, hence giving the $1/r^2$ behavior. By extension, in the case of N spatial dimensions, the analogous force law would be $1/r^{N-1}$. Hence, if we investigate distance scales smaller than that, where the hidden dimensions begin to be curled up, we should notice departures from $1/r^2$ behavior.

** Of course, a believer in ID would likely claim that the "irreducible complexity" of the cell is precisely that sort of message.

ligent design in this way is just as unjustified and unfair as when some creationists portray evolution and evolutionists as being against God.*

In sum, there certainly is a role for "speculative science" within physics – I have had fun doing it myself with faster-than-light tachyons. Speculative science includes ideas such as string theory and its multiverse, which one hopes will lead to falsifiable predictions in the future, but which currently generate only "weak" ones, that is, predictions that offer encouragement to experimenters to improve the sensitivity of specific sorts of observations. Yes, string theory really is for this reason marginally within the realm of science, and that cannot be said about intelligent design. Still, one cannot help but wonder how much longer, beyond the twenty years since string theory was first proposed in its present form, it can remain a productive area of study without it generating a falsifiable test – or without some experimenter "hitting the jackpot" and validating one of its more speculative predictions. Further, if one keeps at a theory for over twenty years, and evidence keeps accumulating that it does not work, at some point it becomes unclear if it still deserves to be called science.

References

1 CBS News Poll, December 2004, asking: "In general do you favor or oppose teaching creation science in addition to evolution in public schools?"

2 Michael Behe, *Darwin's Black Box: The Biochemical Challenge to Evolution* (New York: Simon and Schuster, 1996).

3 See, for example, the biography of Alfred Russel Wallace prepared by the British Natural History Museum at <http://www.nhm.ac.uk>.

4 See, for example, the policy statements endorsed by the American Association of Physics Teachers, posted at <http://www.aapt.org/Policy/evolutandcosmo.cfm>, and the American Physical Society, posted at <http://www.aps.org/statements>.

5 In 2001 the University of California at Santa Barbara put on such a workshop; see <http://online.itp.ucsb.edu/online/mt01teach/>. PBS television also made a NOVA program dealing with the subject; see <http://www.pbs.org/wgbh/nova/elegant/>.

6 Brian Greene, *The Fabric of the Cosmos: Space, Time, and the Texture of Reality* (New York: Knopf, 2004); *idem*, *The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory* (New York: W.W. Norton, 1993).

7 Reported on the basis of an interview in 1987 in Peter Woit, *Not Even Wrong: The Failure of String Theory and the Continuing Challenge to Unify the Laws of Physics* (London: Jonathan Cape (Random House), 2005).

8 Leonard Susskind, *The Cosmic Landscape: String Theory and the Illusion of Intelligent Design* (New York and Boston: Little Brown, 2005), p. 124. He is identified on the dust jacket as the "father" of string theory.

9 For a nice popular introduction to the standard model, see Robert Oerter, *The Theory of Almost Everything: The Standard Model, the Unsung Triumph of Modern Physics* (New York: Pi Press, 2005).

10 Susskind, *Cosmic Landscape* (ref. 8), p. 125.

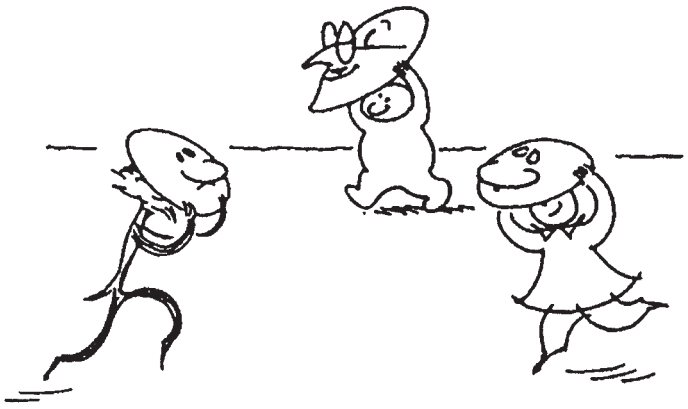
11 See, for example, John D. Barrow and Frank J. Tipler, *The Anthropic Cosmological Principle* (New York: Oxford University Press, 1986).

---

* Evolutionary biologists do include many, who like Kenneth Miller, author of *Finding Darwin's God: A Scientist's Search for Common Ground Between God and Evolution* (New York: HarperCollins, 1999), are devout believers in a personal God.

12 Anthony Aguirre, "On making predictions in a multiverse: conundrums, dangers, and coincidences," astro-ph/0506519 v1, June 22, 2005.
13 John S. Rigden, "The Mystique of Physics: Relumine the Enlightenment" [Millikan Award Lecture 2005], *American Journal of Physics* **73** (2005), 1094–1098.
14 Woit, *Not Even Wrong* (ref. 7).
15 Susskind, *Cosmic Landscape* (ref. 8), p. 127.
16 See, for example, Eric Adelberger, "Testing the Gravitational Inverse-Square Law," *Physics World* **26** (April 2005), 41; see also http://physicsweb.org/articles/world/18/4/6/1
17 Behe, *Darwin's Black Box* (ref. 2), p. 176; see also Michael J. Behe, "Reply to my critics: A response to reviews of Darwin's Black Box: The Biochemical Challenge to Evolution," *Biology and Philosophy* **16** (2001), 685–709.
18 For a more complete discussion of why most scientists do not consider ID to be a scientific theory, see Robert Ehrlich, *Eight Preposterous Propositions, From the Genetics of Homosexuality to the Benefits of Global Warming* (Princeton: Princeton University Press, 2005), pp. 41–77.

Department of Physics and Astronomy
George Mason University
Fairfax, VA 22030 USA
e-mail: rehrlich@gmu.edu



MASQUERADE

It's always wise
to wear disguise;
but hardly ever
to look too clever.

Piet Hein