" ... in the long run the only human activities really worthwhile are the search for knowledge and the creation of beauty. This is beyond argument; the only point of debate is which comes first." (Arthur C. Clarke, *Profiles of the Future*, CBS Popular Library, New York, 1973, p. 105)

A Sermon on Science

John A. Ball[1]

"What is science?" asked the creationist and would not stay for an answer. Science is what can be tested by experiments or observations. Scientific hypotheses, at least in principle, can be tested and proved *wrong*—they are *falsifiable*. In addition to *falsifiable*, science also encompasses two other categories of statements: *verifiable* and *problematic*. A verifiable statement usually contains concepts such as *some* or *sometimes*. An example: [Some] Extraterrestrial life exists. Find one case, and this statement is verified. A problematic statement is one that is falsifiable or verifiable in principle but not in practice because falsification or verification would require infinite time or some other essentially impossible situation. An archetypical example is: All men are mortal. A falsifiable statement cannot be verified but only made plausible; a verifiable statement cannot be falsified but only made implausible.

> **Do Science**
> Observe, experiment, measure, and calculate. Then try to understand; try to infer the truth. Predict. Repeat.

Scientific questions have scientific hypotheses for answers. Questions and hypotheses outside the realm of science might be, instead, in the realm of philosophy or religion. As mankind progresses, the boundaries of science grow at the expense of philosophy and religion, which thus form the cutting edge of the endless effort to dispel ignorance.

Here are examples from the pen of Charles Darwin discussing his theory of natural selection as an explanation of biological evolution:

> "If it could be demonstrated that any complex organ existed [that] could not possibly have been formed by numerous, successive, slight modifications [of some simpler organ that was

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itself useful to the organism], my theory would absolutely break down." (C. R. Darwin, *Origin of Species*, 1859, p. 189)

"Natural selection cannot possibly produce any modification in a species exclusively for the good of another species ... . If it could be proved that any part of the structure [or behavior] of any one species had been formed for the exclusive good of another species, it would annihilate my theory, for such could not have been produced through natural selection." (*Ibid.*, p. 201)

Ask your favorite creationist to describe an experiment or observation an outcome of which would change his mind about the origin of the world. Or the existence of God. How about experiments or observations that would enable us to choose among the various creation stories: Genesis in the Bible, the Vedas, the Enuma Elish, the Egyptian Book of the Dead, the Kalevala, and many others. If there are no such experiments or observations, even in principle, then these theories are religious or philosophical rather than scientific.

Creationists urge that the story of creation from Genesis be included in public-school biology courses. I recommend, instead, that public-school curricula be augmented with courses on comparative religion to include the creation story from Genesis and creation stories from other religions and cultures. The constitutional guarantee of freedom of religion implies a *duty* to teach comparative religion. Freedom of choice without information is hollow.

Various scientific alternatives to, or variations on natural selection, such as saltational evolution and random evolution, should be discussed in public schools in biology courses. Rather than confusing students, this would emphasize that science in general and biology in particular are dynamic human activities, alive with contention, competition, even progress.

An aristocratic matron, a contemporary of Darwin, is reported to have said, "Let us hope that what Mr. Darwin says is not true; but, if it is true, let us hope that it will not become generally known." You may snicker at this, but this woman realized, what many of Darwin's critics do not, that natural selection is a scientific theory to be tested against observations, measurements, and experiments. Whether you want it to be true just doesn't matter.

The products of science are information and knowledge about the real world, but the essence of science is the method by which these products are obtained. Too often science is taught as only a collection of facts to be memorized, which drives many students away and stifles enthusiasm, creativity, and a sense of wonder. The comparable method in athletics would be to teach “stats” about teams and players rather than how to play the game. Don’t!

> “[Teach students] to distinguish evidence from propaganda, probability from certainty, rational beliefs from superstitions, data from assertions, science from folklore, theory from dogma.” (Paul DeHart Hurd quoted in *Scientific American*, 281–4, October 1999, p. 92)

I claim to be a scientist. I know little about philosophy and religion, but I claim to know where to locate that craggy cliff edge that defines the boundary between the solid ground of science and the mists and vapors of philosophy and religion. But this boundary moves, often advancing. As technology progresses and scientists learn how to do more and better experiments and observations, the boundary of science encroaches into regions formerly claimed by religion and philosophy. Those theologians and philosophers who would stand firm on ancient revelations and eternal truths find this progress annoying or worse.

Like prophets of old, the business of science is prediction. Most scientific statements are in the form: Given certain specified conditions, certain specific results are likely, and certain other specific results are unlikely or even impossible. Some of these impossibility rules or impotence principles are cornerstones in the edifice of science. Examples: Entropy in a closed system cannot decrease (and usually increases). Neither matter, energy, nor information can travel faster than the speed of light. These are extremely well established principles of science, but, like every other statement in science, they might turn out to be wrong or perhaps only some approximation to the truth. Science is progressive. Scientists reserve the right to change their minds and their theories when prompted by results from new experiments or observations. You’re not likely to get any scientist to say that he or she is absolutely certain about anything. If you must have certainty, ask a theologian, not a scientist.

Some of the predictions of science are, nevertheless, dazzlingly precise. If you want to know where and when a solar eclipse will occur, to the mile and to the minute, even centuries in advance, ask an astronomer, not an astrologer. If you need to know the trajectory of electrons in a magnetic field and which colored dot they will light up on your television screen, ask a physicist, not a psychic. If you want to know how to eliminate smallpox germs from Earth, ask a biologist, not a creationist. Our entire technological civilization, including what we eat, wear, and live in, is built on such predictions of science. If you don't trust science, better stay in bed with covers over your head.

But science has very significant limitations. Some very important questions are—probably forever—outside the realm of science. Given that we humans have some free will—some of what we do is not determined by genes and memes—then an example of such a question is just the most important question that we humans know how to ask: What should we do? The opening quote from Arthur C. Clarke, for example, is clearly religious or philosophical, not scientific. Science and technology can often answer questions of the form: What could we do in order to achieve a prescribed goal and avoid prescribed undesirable side effects? Or: What would happen if we do such? And science has made some progress in predicting what folks will *want* to do and want not to do. But setting that *first* goal, what we should and should not do—what we should try to accomplish—is beyond science. The goal or function of religion is to answer such questions. And the corollary: Judge a religion by what its adherents do.

"Science promotes atheism," says the critic. While this is actually incorrect, as I'll discuss in a moment, it represents a widespread perception among both scientists and non-scientists. A larger percentage of scientists compared with the general public express doubts about God and especially immortality. Only about 12% of American physicists and astronomers, for example, say that they believe in God. Statistical association, however, does not establish causality: Maybe agnostics tend to become scientists rather than scientists tend to become agnostics.

Most such comments and surveys fail to distinguish among at least three categories of unbelief. Asked about God or immortality, one might answer:

Soft-core agnostic:	"I do not know."
Hard-core agnostic:	"No one can know."
Atheist:	"There is no God or immortality."

Can experiments or observations be designed or even imagined to settle questions about God or immortality? In the absence of such experiments or observations, theological questions such as these are just outside the realm of science. Disproving either theistic or atheistic theories is equally impossible. Absence of proof is *not* proof of absence. Thus, I argue, we scientists should be agnostics, soft or hard, not atheists. There is some possibility that future technological advances will change this outlook by providing opportunities for new experiments and observations not now imagined; but I doubt it. Some scientists disagree.

> "I know that God exists; [but this proposition] cannot be substantiated by the methods of scientific investigation; therefore there must be something wrong with [these] methods at least [as] applied to the supernatural (or paranormal)." (James Lett, *Skeptical Inquirer*, 16–4, Summer 1992, pp. 386–387)

Science is flawed and imprecise in part because scientists are human; they make mistakes. The truth or falsity of a scientific theory is disconnected from questions of its desirable or undesirable political or social implications and its psychological appeal or pleasantness. But scientists are people, and they are influenced by all sorts of human emotions—good and bad. Some scientists, like some other folks, lie, cheat, and steal. But this is rare among scientists because they realize that they'll usually get caught. What one scientist can observe, measure, or calculate, another can. Sometimes scientists are just foolish. You can fool all scientists some of the time; you can even fool some scientists all the time; but you can't fool all scientists all the time. Mistakes get fixed, wrong hypotheses eventually get trash-canned. Progress is often difficult, halting, stumbling, even backsliding, but it is progress, and it's fun. To learn a new thing, even one *little* new thing, that nobody ever knew before, for that high, scientists strive.

The effort of science is to show that all the phenomena can be understood within science. Only if this effort were to fail would we be forced to hypothesize something such as manipulation by God or by extraterrestrial aliens. For a scientist, this amounts to giving up. Don't give up!

The best of our scientists are original and creative. Jacob Bronowski writes:

> "Now I do not think that scientists have yet created anything [that] could be called a system of values. ... But a scientist, in order to be a good creator, has to work out for himself a set of values by which he is going to live. He has to be very independent in thought. He has to take a very questioning attitude to whatever he sees and whatever anybody else sees. He has to make a special fetish of originality and of contradiction, of dissent in general. Without this he is not going to create anything new at all. If you can live in such a world, you have to be extremely tolerant of the dissent of others. You have both to recognize the fallibility of their achievement and yet do them honor because it is their achievement. I hold that you cannot carry out the activity of science if you do not have a society organized in this way: a society rich in dissent and yet rich in tolerance and rich in honor. I think that in this are the beginnings of principles [that] the scientist can teach to the world at large." (J. Bronowski, *A Sense of the Future*, MIT Press, Cambridge, 1977, p. 20)

The best of our scientists are skeptical. They question authority and claims and theories by others. They try new approaches and new ways of studying even the commonplace. They ask new questions and suggest new answers to old questions. But some folks think skepticism dangerous. Skeptics don't make good subjects under authoritarian rule. Carl Sagan wrote:

> "... skepticism is ... dangerous. Skepticism challenges established institutions. If we teach everybody, including, say, high school students, habits of skeptical thought, they will probably not restrict their skepticism to UFOs, aspirin commercials, and 35,000-year-old channelees. Maybe they'll start asking awkward questions about economic, or social, or political, or religious institutions. Perhaps they'll challenge the opinions of those in power. Then where would we be?" (Carl Sagan, *The Demon-Haunted World*, Ballantine, New York, 1997, p. 416)

Scientific activities are often divided into categories such as pure or curiosity-driven science, applied science, engineering, and technology. Calling science "pure" implies that it is somehow better than applied science or engineering, which is supposedly done for monetary or short-term goals. For some purposes, these are useful categorizations, but they should not be taken to imply the quality of either the people involved or the work. Very significant, fundamental, and long-lasting scientific results have come from workers who called themselves engineers. Examples: Sadi Carnot in thermodynamics and Claude Shannon in information theory. And pure or curiosity-driven science is often criticized, especially by funding agencies, for being wasteful. Well, it is wasteful—inevitably wasteful: Those who are truly exploring in the wilderness can't predict in advance what, if anything, they'll find or whether it will be useful.

Humans and most other animals waste some time and effort exploring—searching for information that might be of value in some way that we do not initially recognize. When kids do it, we call it playing; when adults do it, we call it science—pure science. Such quasi-random wanderings in search space sometimes lead to information that is irrelevant or useless and which tends, therefore, to be forgotten. Sometimes it changes the world. Call it venture investment.

Engineering and technology are built on foundations of science, but science also benefits from advances in technology that enable new experiments and observations. The uses to which science and technology are put are usually determined by political, social, or commercial institutions rather than the scientists themselves. Scientists and engineers learn how to make it go bang, but someone else pulls the trigger. Much of our modern technology is based on work done by scientists and engineers, some long dead, who have no say in how their results are used. The products of science are information and knowledge, which, in themselves, are ethically and morally neutral but often can be used for either good or evil.

Konrad Lorenz writes:

> "Science is often accused of having brought terrible dangers upon man by giving him too much power over nature. This accusation would be justified only if scientists were guilty of having neglected man himself as a subject for research. The danger to modern man arises not so much from his power of

> mastering natural phenomena as from his *powerlessness* to control sensibly what is happening today in his own society. I maintain that this powerlessness is entirely the consequence of the *lack of human insight* into the causation of human behavior. … [T]he fact that the functions of our digestive system are well known and that, owing to this knowledge, medicine, particularly intestinal surgery, saves many thousands of human lives annually, is entirely due to the fortunate circumstance that the functions of these organs do not evoke particular awe or reverence. If, on the other hand, we are powerless against the pathological disintegration of our social structure, and if, armed with atomic weapons, we cannot control our aggressive behavior any more sensibly than any [other] animal species, this deplorable situation is largely due to our arrogant refusal to regard our own behavior as subject to the laws of nature and as accessible to causal analysis." (Konrad Lorenz, *On Aggression*, Bantam, New York, 1971, p. 215; emphasis added)

The history of science contains, one after another, a series of blows to mankind's anthropocentric ego. Egypt is not really the center of the universe, nor Earth, nor our Sun, nor our galaxy. We humans seem to be only more-or-less intelligent apes. I predict two further blows to our ego in the near future: (1) We shall discover that our mental processes can be modeled, or even duplicated in detail, by a mechanism such as a computer. Thus vitalism, now living only in a few human minds contemplating themselves, will finally be dead. And (2) we shall become aware of our relationship with advanced extraterrestrial alien intelligence. Could we then still believe that we are the chosen people of God?

References: "Scientists and Religion in America" by Edward J. Larson and Larry Witham, *Scientific American 281-3* (September 1999), pp. 88–93. *Skeptical Inquirer 23-4* (July/August 1999) is a special issue on science and religion with diverse views from Stephen Jay Gould, Richard Dawkins, and a dozen others.

Recommended reading: Any book by Carl Sagan especially on astronomy, any book by Richard Dawkins especially on biology, and any book by Daniel Dennett especially on philosophy of science.