common evolutionary origin:[4] the human brain's conception of time, its unique capability of creating images of the future and making long-term predictions, the innate urge to do so, and a feeling of satisfaction when it is done.

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As a chemical physicist I have followed both chemistry and physics for more than 40 years. In recent years, I have noticed a gradual change in the language of physics. Physicists now are more willing to accept that our knowledge may be limited and to admit that we will probably never be able to answer the major questions of existence that also fall in the realm of religion. In fact, some modern physics theories are beginning to require a certain belief system of their own and could be criticized as to whether they remain science (Burton Richter discusses this in his Reference Frame in PHYSICS TODAY, October 2006, page 8). This change has been noteworthy and has provided for a healthier self-analysis by many physicists. However, I was a little shocked by the Opinion piece by Murray Peshkin, a theoretical physicist. It indicated, unfortunately, that the old arrogance of physics is still very much alive. It appears that a theoretical physicist is needed to present both Darwin's theory of evolution and religion to the general public to help resolve any conflict and emphasize that the theory is supported by extensive experimentation. Peshkin apparently has never read Fred Hoyle's book *Mathematics of Evolution* (Acorn Enterprises, 1999), which severely criticized the theory and outlined its limitations. Many chemists and physicists have great trouble with Darwin's theory, especially if one tries to extrapolate it to higher life forms or modify it from an evolutionary concept to one of creation. If scientists cannot agree no wonder the general public is confused. I am still amused that even NASA justifies some of its programs in the belief that creation of life forms is some simple mechanism and with luck will be easily found somewhere else.

To extrapolate from nothing to the incredibly complex DNA-replicating molecule takes an even greater leap of faith than any religion. If I give a talk to a general audience, I emphasize the severe limitations of science and our lack of true understanding. We have good models and theories and have made great advances, but we still confuse data and the accumulation of knowledge with true understanding. Moreover, because of our apparently superior knowledge, some people now accept science as their religion.

The older I get, the more I recognize the great commonality between the sciences and the arts. In reality, science is no more than the technical branch of the arts. For example, who was more talented: Albert Einstein, Ludwig van Beethoven, Leonardo da Vinci, or William Shakespeare? Each discipline requires ingenuity, creativity, and insight. One would hope also some wisdom but that is an area that still needs more emphasis and is not taught or easily acquired.

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Being a PhD geneticist and a creationist, I was disappointed that Murray Peshkin did not give references for the statement "Hundreds of Darwin's predicted missing links have been found." I find quite the opposite. The scientific turmoil behind whether birds are descendants of dinosaurs is but one example of how the popular press does not accurately reflect the disagreements in the scientific community. As Storrs Olson, curator of birds for the Smithsonian Institution, stated in a 1999 letter to *National Geographic*,

> The idea of feathered dinosaurs and the theropod origin of birds is being actively promulgated by a cadre of zealous scientists acting in concert with certain editors at *Nature* and *National Geographic* who themselves have become outspoken and highly biased proselytizers of the faith. Truth and careful scientific weighing of evidence have been among the first casualties in their program, which is now fast becoming one of the grander scientific hoaxes of our age—the paleontological equivalent of cold fusion.

If Peshkin could provide some solid references, it would add credibility to his opinion.

Also, equating Charles Darwin's and Gregor Mendel's theories does not work for me. Mendel observed inheritance patterns and developed a theory of Mendelian genetics, which is verifiable in simple reproducible experiments. His theory of genetic inheritance provides the mechanism for natural selection, which is observable. Darwin, on the other hand, postulated that natural selection would extend to species changes and therefore provide the mechanism for macroevolution. I have never found that to be observable. As traits are favored through selection, genetic information is reduced, not increased. Man's very behavior exhibited through gene conservation activities is evidence that genetic information is not gained, as required for macroevolution to occur, but is actually lost.

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Peshkin replies: We scientists need to teach the nonscientist public what science is about: what an established theory is and how we know when it's right; how the requirement of falsifiability serves as a fence between science and nonscience, defining the limitations of science and insulating it from attacks based on pseudoscience; and especially why science, correctly understood, does not threaten most people's religious beliefs.

Michael Matthews says that the approach I advocate is condescending to the religious. It has not been so perceived by the several dozen people who have approached me after my public lectures or in response to my writings for the public. A majority of the many who identified themselves as people of religious faith, from high-school students to the former president of a theological seminary, started the conversation by saying that they appreciated my respect for religion. Nevertheless, Matthews's warning should be heeded. People can be hypersensitive to unintended slights about their religion, especially slights from scientists. If you do not have respect for people's religion, you should not be conducting such discussions; if you do have that respect, you should make it obvious from the outset. You don't have to pretend to share your audience's religious beliefs; you only have to respect them. Otherwise, people will tune you out.

Matthews misrepresents the fence I described. It surrounds—and is defined by the demands of—science, not religion. Nobody can reasonably deny religion its own perspectives regarding natural phenomena as well as religious beliefs. Science's fence is violated only if a pretense is made that such a discussion is science when it is not. That point of violation is the reason for the conflict, and that is where we have to guard against attempts to substitute pseudoscience for science in our schools. Explaining the conflict to the public has not been made easier by recent contemptuous attacks on religion by atheists who are scientists but who abuse science when they claim falsely that it disproves religion. I explicitly disown such attacks and advise others to do the same.

Matthews, joined by David Morrison and Moorad Alexanian, also objects to my use of experiment as the sole criterion for defining science; they say observation is also part of science. They are right. Henceforth I will say "experiment and observation," but that alone does not address the substance of their complaint. The subtleties of the difference between experiment and observation and their interaction with predictive power and falsifiability may be suitable for advanced students, but they cannot usefully be addressed in a typical one-hour general-interest lecture, at least not by me. Each person who gives such talks has to use an approach with which he or she is comfortable. I am comfortable with describing the discovery of the cosmic microwave background as a make-or-break experiment that could have falsified the Big Bang theory. Big Bang cosmology was on a back burner until the CMB was predicted and subsequently discovered. Was that an experiment or an observation? I don't think it matters. An example from geology is the speculation that the K-T extinction was caused by a meteor impact. That idea became generally accepted when its prediction of a global iridium-rich layer at the right depth was confirmed experimentally—or was it observationally? Absent that widespread iridium, the theory would have been falsified. That's what made it science.

Testing the theory is more difficult in biology. Biologists can tout simple individual experiments and observations that test evolution, but biologists are also dependent on the overall success of the big picture, the observation of which must agree with their theories. I defer to the biologists for an authoritative description of all that. My point is that what is science and what is not remains the same.

Morrison also suggests that we drop the word "theory" because it has diverse meanings. Particle physicists and astrophysicists often do just that, speaking instead of "the standard model." I see no useful answer to the argument that evolution is "just a theory" other than to explain what an established scientific theory is and why it must be respected despite our near certainty that future research will find its applicability limited.

Alexanian says that experiments to test evolution's description of the origin of the earliest life forms are not possible. We can never prove that any theory is true; we can only challenge it with tests. The famous Miller–Urey experiment and its successors, in which amino acids were created from hydrogen, methane, carbon dioxide, and water in a process that credibly mimics nature, constitute such a test.

Joe Heafner serves his students well by discussing the nature of evidence and related questions. I hear anecdotally that others are beginning to do the same. I hope they will all emphasize the limitations of science and why science and religion, reasonably understood, do not threaten each other.

Juan Roederer addresses issues that go beyond the conflict we currently face in our schools and our courts. He seeks a generalization of science and religion into a philosophy that not only includes both but creates a unified system in which the two are non-trivially entangled and which satisfies the core needs of both. The clarity with which Roederer describes that ambitious quest in a short letter is remarkable. However, its success is uncertain, as is the time scale on which we will learn whether it succeeds. Protecting the teaching of good science in our public schools cannot wait. We must defend the science we have, which is distinct from religion, and we must do it now.

I note that Roederer enjoins science to "turn away from the easy way out offered by the anthropic principle." But observations of atomic spectra in distant quasars hint at a slight shift in the fine structure constant. If that result is confirmed, the improbability of finding conditions right for life somewhere at some time becomes at least a semiquantitative question that needs to be investigated by the methods of science.

Keith Schofield makes three substantive points: that his experience as a chemical physicist leads him to believe that DNA cannot have arisen in a natural process, that physicists should butt

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out and leave the discussion to biologists, and that scientists have a faith of their own. The first is asserted without explanation and the second seems curious in light of the first. Schofield's third point is interesting. I think most scientists take on faith that there is some understandable pattern to the things we can observe, that we are on the right track in investigating that pattern by the methods of science, and that we are closing in on something that corresponds to our intuitive idea of reality. That belief is a matter of our metascience, or perhaps of our psychology, not part of the science itself, which deals only with the observable world. The important thing for the present discussion is that this belief neither confirms nor contradicts religion.

Michael Todhunter asks to debate the evidence for evolution in the fossil record. Books have been written on that subject—I cited two in my Opinion piece. The practical political issue is this: What should our public schools teach when confronted with disagreements they are not themselves able to resolve? The answer is easy. Almost all the most respected biologists are saying that evolution is the theory that works and that it is the central organizing principle of modern biology. If the school boards have any sense, that is what their schools will teach despite a few dissenters, some of whom offer genuine scientific challenges to the theory and most of whom have other agendas. The schools should be teaching their students that all theories have wrinkles that remain to be ironed out. They should be teaching that all theories are tentative and our understanding is always incomplete, but that science progresses by building on what we know best. Well-established theories such as evolution work too well not to have mostly permanent truth in them, even though the theories will evolve in response to new evidence. We should be helping the school boards by educating their constituents.

Contrary to Schofield's advice, all kinds of scientists should be explaining to the public what science is about and emphasizing its strengths and its limitations, because the public and not the courts will decide where this country will go in the 21st century.

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US lacks nuclear-power infrastructure

I read with great interest the hopeful items about the coming nuclear power boom (PHYSICS TODAY, February 2006, pages 11 and 19), but I would like to point out that the US has lost the infrastructure to build these plants. Because of economics, the US no longer has the heavy industry capable of building the reactor heads and steam generators that new plants require. Reactor owners looking to replace aging plant components must contract with Japanese, Korean, or Italian companies for the heavy forging and machine work that was once done in America, and compete against other interests for both valuable plant time and floor space to get their components finished. American nuclear plants are just not a 600-pound gorilla that can command the marketplace anymore.

America is also losing the quality battle for smaller components such as pumps, valves, and circuit breakers. Many of the smaller vendors and foundries that once produced pumps, piping, and valves to the ASME Boiler and Pressure Vessel Code (a nuclear requirement) have been swallowed up by mergers, leaving only a few suppliers. And those few have had little incentive to keep a costly quality program that meets the requirements of a nuclear supplier as defined in the Code of Federal Regulations (10CFR50, appendix B) because the market for nuclear replacement parts is scant. Other suppliers have lost control of their quality programs because of such factors as offshore production and the loss of tribal knowledge due to an aging workforce and downsizing.

This isn't to say that America won't produce new nuclear power generating stations, but a lot of infrastructure investment will be needed to bring the US back to the level where we can make them using American resources and labor.

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Training teachers for college

I have enjoyed the articles about physics education that have appeared in the past several months. They have generated a great deal of knowledge that needs to be integrated into educational programs at all levels. However, I have noticed that much of the discussion about training has focused on K–12 teachers, who are trained in the baccalaureate education programs of colleges and universities. This focus is important, but it avoids a long-standing problem: how to train college and university professors.

Professors are rarely required to have taken education courses, yet they must usually demonstrate a dedication to teaching and state some philosophy of teaching. A prospective professor's approach to teaching must apparently be developed independently. Most physics professors have developed their approaches to teaching through their experiences as graduate students and postdocs.

I believe that current and prospective professors would be well served by a series of courses or training sessions, implemented at many colleges and universities worldwide, that distill current physics education knowledge and provide a venue for practicing it with other students. The courses could be offered as part of undergraduate or graduate curricula or in pre-employment or professional-development training sessions. Alternatively, training sessions could be implemented as an ongoing part of the annual conferences of the various scientific professional societies, and then funding could be secured for conference attendees. (This approach could also work for K–12 teachers.) Implementation of training courses would be helpful not only to current professors but also to those who, like me, are employed in industry but would eventually like a teaching career.

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Diverse thoughts on diversity in physics

I read Shirley Malcom's "Diversity in Physics" article (PHYSICS TODAY, June 2006, page 44) with great interest. As a physics student in college, I often marveled at just how white and male all of my classmates and professors were.

I have been teaching physics for four years in a public high school in Massachusetts, and I think I can address at least one piece of the puzzle. In my first year as a teacher, I made the classic novice error of teaching as I had