Expert Statement *(Kenneth R. Miller)*

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Professional Background:

I earned a Bachelor of Science degree in Biology at Brown University (1970), and attended the University of Colorado on a National Defense Education Act Fellowship, earning my Ph. D. in Biology in 1974. I joined the faculty of Harvard University in 1974 as a Lecturer, and was promoted to Assistant Professor in 1976. In 1980, I accepted a position at Brown University, and was subsequently promoted to Associate Professor (1982) and Professor (1986). I am a cell biologist whose research centers on the structure and function of biological membranes and membrane proteins. I have published more than 50 research papers in scientific journals, including Nature, Scientific American, and Cell. I have also written a number of scientific reviews, commentary articles, and book reviews published in similar journals. Together with Joseph S. Levine, I am coauthor of a number of high school and college textbooks in general biology that are widely used throughout the United States. I am a member of the American Association for the Advancement of Science, the American Institute for Biological Sciences, and The American Society for Cell Biology. I serve as a advisor to the Science Unit of The News Hour, a news and public affairs program on PBS, and also served as a scientific advisor to the Evolution television series produced by NOVA for PBS in 2001. In 2005 I was awarded the Presidential Citation of the American Institute for Biological Sciences. In 2006 I received the Public Service Award of the American Society for Cell Biology, and was also named a Fellow of the American Association for the Advancement of Science.

I have taught general biology at the university level for 31 years, lecturing and supervising teaching laboratories in courses at Brown and Harvard with enrollments ranging from 200 to 500

students. A conservative estimate of student numbers suggests that I have directly taught nearly 10,000 general biology students during that time, and more than 1,000 students in my upper-level cell biology courses at both schools. When Brown University established a Presidential award for teaching in the Life Sciences in 1993 (The Leduc Award), I was its first recipient. Since that time I have received 4 other teaching awards, including Brown University's Sheridan Medal for distinguished contributions to teaching and learning. Three decades of teaching experience have provided me with extensive insights into the ways in which students study and learn the science of biology, including the science of evolution.

In 1991, Dr. Joseph S. Levine and I authored a general biology textbook (*BIOLOGY by Miller & Levine*) published by the Prentice Hall publishing company. The text, which was intended for 9th and 10th grade biology courses at the high school level, was an immediate success, and has since that time appeared in 5 different editions, used in every state, including Georgia. In writing this textbook, I gained an extensive understanding of state curriculum requirements and the ways in which complex scientific material can be effectively presented to 14 and 15 year old students. Dr. Levine and I have since written two other textbooks for Prentice Hall, including the so-called "dragonfly textbook" (also known as *BIOLOGY by Miller & Levine*), which was selected in 2002 by Cobb County science teachers and the Cobb County Board of education as the best textbook for their students. Each of these textbooks has been planned and written with careful attention to scientific accuracy, to student learning patterns and styles, and with the advice of master teachers and curriculum specialists. Nearly 4 million copies of our textbooks have been produced since 1991, and I would estimate that they have introduced at least 20 million American students to the wonders of biology. By any standard, this work has provided me with a wealth of experience into the ways in which science textbooks are understood and received by teachers as well as by students and their parents.

In 1981 I accepted an invitation to debate the science of evolution with Dr. Henry Morris, Founder and President of the Institute for Creation Research. Since that first encounter with the "scientific creationism" movement, I have debated advocated of "creationism" and "intelligent design" nearly 20 times, and have carefully studied the techniques and tactics of the American creationist movement. In these debates I have faced the leading advocates of creationism and intelligent design, including Duane Gish, Michael Behe, Jonathan Wells, William Dembski, Steven Meyer, Paul Nelson, and Phillip Johnson. I have written several articles dealing with creationist and "design" challenges to evolution, and served as an expert witness in the Dover intelligent design trial (Kitzmiller v. Dover) in 2005. In 1999, I wrote *Finding Darwin's God – a Scientist's Search for Common Ground*, a trade book published by HarperCollins that deals with both the religious and scientific issues of evolution. This book is now in its 25th printing in paperback, and is widely used as a text for religion and science courses in colleges and universities. I have frequently appeared as a spokesman for mainstream science in the mass media, including commercial and public television and radio, featured in programs such as NOVA and Science Friday. I am intimately familiar with the tactics employed by the anti-evolution movement in the United States, and have closely followed their efforts to weaken and undermine the teaching of evolution throughout the United States.

1) The Scientific Status of Evolutionary Theory

Evolution is the process of biological change over time that has characterized life on Earth since its beginning billions of years ago. An appreciation of the sweeping nature of evolutionary change developed during the early years of the industrial revolution, when widespread excavations first began to reveal the Earth's successive geologic ages. By the end of the 18th century, pioneering scientists such as Georges Cuvier (1769-1832) had demonstrated that living things had changed dramatically over time. These discoveries led many naturalists to seek the forces that might have caused these changes. Best known may be Jean-Baptiste Lamarck (1744-1829), whose explanations for change focused on the creative power of the environment to shape the adaptations of organisms over time.

The modern theory of evolution originates in the ideas of Charles Darwin (1809-1882), who articulated his views in a series of books, the best-known of which is *On the Origin of Species* (1859). Darwin's observations convinced him that forces at work in the world today can account for the origin of new species, and documented his hypothesis with the results of years of careful observation and analysis. Darwin's ideas included a series of testable predictions regarding the character of the fossil record, the age of the earth, and the nature of inheritance (genetics). In the years following the first publication of his ideas, each of these predictions was confirmed, and Darwin's theory of evolution by natural selection earned general acceptance by the scientific community. The National Academy of Sciences, the most prestigious scientific body in the United States, summarized the scientific importance of evolution in this way:

> *The concept of biological evolution is one of the most important ideas ever generated by the application of scientific methods to the natural world. The evolution of all the organisms that live on Earth today from ancestors that lived in the past is at the core of genetics, biochemistry, neurobiology, physiology, ecology, and other biological disciplines. It helps to explain the emergence of new infectious diseases, the development of antibiotic resistance in bacteria, the agricultural relationships among wild and domestic plants and animals, the composition of Earth's atmosphere, the molecular machinery of the cell, the similarities between human beings and other primates, and countless other features of the biological and physical world. As the great geneticist and evolutionist Theodosius Dobzhansky wrote in 1973, "Nothing in biology makes sense except in the light of evolution." [from Science and Creationism, 1999, preface]*

The enduring power of evolution as a scientific idea stems in part from the simplicity of its core propositions, all of which are strongly supported by accumulating scientific evidence. The first of these is the observation that life has changed over time. As noted earlier, the historical realization of the magnitude of such changes was one of the formative elements in Charles Darwin's original formulation of evolution. In the 20th century, a dramatic expansion of the fossil record and its attendant evidence for biological change over time has made the pattern of biological change abundantly clear.

The second core proposition of evolution is that living things share common ancestries. This is a direct inference drawn from the clear and convincing patterns of change seen in the fossil record. In cases where fossil records of living organisms are complete enough to trace the pattern of life over millions of years, the conclusion of common ancestry, also known as descent with modification, is the only reasonable inference supported by the evidence. One recent example can be seen in Bruce J. MacFadden's 2005 review of the fossil record of the horse, which described the common ancestry shared by this group of organisms as documented in its rich and detailed fossil history.

Continuing discoveries on several fronts have only served to reinforce this critical element of evolution. Earlier this year, Daeschler *et al* (2006) described an extraordinary series of fossil specimens recovered in the Canadian arctic that serve as unquestioned intermediates between lobe-finned fish and the first true land vertebrates, or tetrapods. This fossil specimen, given the scientific name of *Tiktaalik roseae*, fits neatly into a series of transitional fossils that document the water-to-land transition that took place in the Devonian period, more than 300 million years ago. Only a few months later, Long *et al* (2006) discovered yet another fossil species that fit into this same transitional series (*Gogonasus andrewsae*).

These discoveries are not confined to a single portion of the fossil record, nor are they confined to paleontology. In September of this year a spectacular new juvenile specimen of *Australopithecus afarensis* was reported by Alemseged *et al* (2006). This is the species to which the famous "lucy" fossil (discovered in 1973 by Donald Johanson and Timothy White) belongs, and the details of this new specimen have substantially increased our knowledge of this important period of pre-human evolution. As remarkable as the new fossil discoveries are, molecular and genetic studies have provided an even more detailed look at the common ancestry of our own species with our primate relatives. In 2005, a study in the journal Nature (Hillier *et al*, 2005) provided unequivocal evidence that human chromosome 2 was produced by a fusion of two chromosomes from a primate ancestor, and the same journal published the detailed DNA sequence of the chimpanzee. As the authors of the lead article reporting the chimpanzee genome noted:

> *More than a century ago Darwin and Huxley posited that humans share recent common ancestors with the African great apes.* ***Modern molecular studies have spectacularly confirmed this prediction*** *and have refined the relationships, showing that the common chimpanzee (Pan troglodytes) and bonobo (Pan paniscus) are our closest living evolutionary relatives. [Mikkelsen et al, 2005]*

The third element of the theory of evolution is the proposition that biological change over time is driven by forces observable in the world today. Darwin noted that living species contain great reservoirs of diversity, and that additional diversity appears spontaneously (by mechanisms that include mutation). He argued that the interactions of organisms with their environment selected for those organisms best-suited to thrive, and that a process known as natural selection resulted. Natural selection was thought by Darwin to be the primary force driving descent with modification, or evolution. Evolutionary biologists have confirmed the process of natural selection through direct observation, but have discovered that other processes also are important

in evolutionary change. These include genetic drift, the so-called founder effect, genetic recombination, transposition, and horizontal gene transfer between species.

In modern science, evolution is far more than the study of events that took place in the past. Evolution is a hard-working and productive scientific theory put into practice every day by scientists in a wide variety of fields. Evolutionary theory is used to design new drugs based on the process of natural selection, to check the spread of insects able to prey upon genetically-modified plants, and to align and identify genes and DNA sequence data in studies of organismic genomes. Evolutionary theory provides the basic rationale for the three drug HIV regimen that has prolonged hundreds of thousands of lives of AIDS patients, and is at the heart of efforts to control the spread of infectious diseases and microbial drug resistance. This makes evolution a key weapon in medicine's battles against infectious killers such as tuberculosis and malaria.

Evolution, like all scientific theories, is necessarily incomplete. Because the evidence of the Earth's past is fragmentary, natural history does not document each and every major evolutionary event in the history of life. Nonetheless, the evidence that we do have abundantly confirms Darwin's general ideas regarding evolutionary change, a point also made by the National Academy in its 1999 report:

> *So many intermediate forms have been discovered between fish and amphibians, between amphibians and reptiles, between reptiles and mammals, and along the primate lines of descent that it often is difficult to identify categorically when the transition occurs from one to another particular species. (Science and Creationism, 1999)*

All scientific ideas are subject to change, revision, and rejection if they are contradicted by new evidence, and evolution is not an exception. Nonetheless, in nearly a century and a half of investigation, not a single piece of scientific evidence has emerged to contradict the idea that a process of evolutionary change gave rise to the species that exist today. In fact, quite the opposite is true. Evidence from a wide variety of fields, many not even imagined during the lifetime of Charles Darwin, has shed light on the mechanism of evolutionary change and further supported the general outline of his ideas. The concept of evolution, therefore, is not at all controversial within science, and is generally accepted as the central idea upon which all of modern biology is based. Underscoring exactly this point, on February 16, 2006, the Directors of the American Association for the Advancement of Science (AAAS) noted that "Evolution is one of the most robust and widely accepted principles of modern science. It is the foundation for research in a wide array of scientific fields and, accordingly, a core element in science education" (AAAS, 2006).

Evolutionary theory explains the process by which evolutionary change takes place. Darwin's general idea of evolutionary change focused on variation within species, acted upon by natural selection, as the driving force in adaptation and speciation (the formation of new species). Because his ideas were formed at a time before modern genetics, they did not include the detailed mechanisms by which variation appears and is acted upon over time. In the early part of the 20th century, a synthesis of biochemistry, genetics, and evolutionary theory emerged to produce what became known as neo-Darwinian theory. The neo-Darwinian theory successfully

incorporated evolution into the rapidly advancing field of molecular genetics, and enabled scientists, for the first time, to study and to test evolution at the molecular level.

These advances have led to many refinements of evolutionary theory, and to efforts to understand and define the relative contributions of scores of processes, including genetic recombination, transposition, horizontal gene transfer, gene duplication, sexual selection, and developmental mutations to the process of evolutionary change. There is considerable discussion and debate within the scientific community as to the relative importance of these and other mechanisms, and these conflicts continue to motivate vigorous research and investigation. The emergence of new scientific knowledge ensures that evolutionary theory will remain an active and productive branch of science for many years to come.

Significantly, none of these debates undermines the scientific standing of evolution itself, despite the free and open inquiry that characterizes the scientific process. In fact, each of these has added to our understanding of the ways in which evolution works, and strengthened each of the core elements of the theory.

2) *Biology* by Miller and Levine

The coverage of evolution in *Biology by Miller and Levine* (© 2002) reflects the broad consensus on evolutionary biology held by the scientific community. To biologists, evolution is the central organizing idea around which our modern concept of the life sciences is framed. As noted by the National Academy of Sciences (1998), "The scientific consensus around evolution is overwhelming. "

Science education standards in Georgia support this view. Georgia Biology Content Standard SB2 states that "Students will evaluate the role of natural selection in the development of the theory of evolution," and the "Evolution of Life" is one of the Georgia Performance Standards for Biology. The Performance Standard describes a number of key elements that should be part of the understanding of every student in Georgia as a result of their studies in Biology. These include:

- *The basic idea of biological evolution is that the earth's present-day species developed from earlier, distinctly different species.*
- *Molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descent branched off from one another.*
- *Natural selection provides the following mechanism for evolution: Some variation in heritable characteristics exists within every species, some of these characteristics give individuals an advantage over others in surviving and reproducing, and the advantaged offspring, in turn, are more likely than others to survive and reproduce.*
- *The proportion of individuals that have advantageous characteristics will increase.*

Our textbook, *Biology*, has been written with these requirements very much in mind. Evolution occupies a prominent position in the textbook, and is explicitly dealt with in Chapters 15-18. In addition, many other parts of the text, including Chapter 29 ("Comparing Invertebrates") and Chapter 33 ("Comparing Chordates"), use the notion of common evolutionary ancestry to explain similarities of structure and function among closely related organisms. This textbook presents the student with the view of biology shared by the vast majority of working scientists in the United States and throughout the world. Evolution is presented as an explanation for the diversity of living organisms and for the rich library of fossil specimens that illustrate the natural history of life on this planet. *Biology* therefore meets the requirements of Georgia's state science education standards in every respect.

Our approach in *Biology* has been to emphasize the scientific method and the process of science. An example of this emphasis can be found in our text:

> *A useful theory may become the dominant view among the majority of scientists, but no theory is considered absolute truth. Scientists analyze, review, and critique the strengths and weaknesses of theories. As new evidence is uncovered, a theory may be revised or replaced by a more useful explanation. Sometimes, scientists resist a way of looking at nature, but over time new evidence determines which ideas survive and which are replaced. Thus, science is characterized by both continuity and change. (Miller and Levine, 2002. p. 15)*

In line with our emphasis on critical thinking and helping students to understand the history of science, evolutionary theory is not presented to students as a completed body of work, but rather as a theoretical solution to the puzzle of life's history and diversity. Section 15-1 of our text ("The Puzzle of Life's Diversity") points out many of the facts and observations that puzzled the young naturalist Charles Darwin during and after his voyage on H. M. S. Beagle. The attempts of other naturalists of the 18th and 19th century to deal with these facts are described in section 15-2, including the first comprehensive theory of evolution, developed by Jean-Baptiste Lamarck.

Lamarck's theory, as described and illustrated on page 376, had many strengths. Among these was its success in explaining why organisms seem to be so well-adapted to their environments. Lamarckian theory also helped to explain how organisms had changed over time, as documented in the fossil record. Despite these strengths, a critical examination of his hypothesis showed many glaring weaknesses, most notably the lack of any evidence that acquired traits can be passed on to an organism's offspring. It is against the failure of Lamarck's theory of evolution that students are first introduced to Darwin's alternative theory.

The elements of Darwin's theory of evolution are laid out on pages 378-382. Once students have had a chance to see how evolution explains the puzzle of life's diversity, the text then asks students to examine the evidence in favor of this theory. Very clearly, evolutionary theory has exceptional strengths, which is why virtually all biologists regard it as the central organizing principle of the life sciences.

The Tentative Nature of Scientific Theory

The need for students to review and critique scientific explanations requires that textbooks clearly depict the tentative nature of scientific conclusions. We have done this time and time again, especially in sections of the text that deal with evolution. For example, we describe the uncertainty inherent in Darwin's explanation of the remarkable diversity of finches on the Galapagos Islands like this:

> *Could the island birds have changed over time, as populations in different places adapted to different local environments? Darwin struggled with this question for a long time. He finally decided that all these birds could have descended with modifications from a common mainland ancestor. . (Miller and Levine, 2002. p. 383)*

The tentative nature of Darwin's conclusion, reflected in the language that these birds "could have descended" from a common ancestor, is reinforced by more detailed discussions of speciation later in the book (Chapter 16). Although modern evidence from molecular biology has dramatically reinforced Darwin's conclusions, and even identified the mainland species from which the island birds arose, we nonetheless describe a "hypothetical scenario" for the evolution of the Galapagos finches [p. 408], clearly indicating the fact that our reconstruction of these historical speciation events remains incomplete, as science often is.

The self-correcting nature of science is made clear in our description of vestigial organs (only a "possibility" for their origin is claimed), and in our discussion of similarities in embryology (the fraudulent drawings of Ernst Haeckel are pointed out on p. 385), is essential in giving students a chance to review and critique the scientific adequacy of these explanations.

Scientific theories exist to make sense of the natural world, by tying together the relationships between myriad facts and observations. In this respect, our prominent mention of continuing debate on crucial issues such as speciation and the origin of life clearly indicates that evolutionary theory remains incomplete and unfinished, highlighting some of the uncertainties of this theory, which exist side-by-side with its remarkable strengths:

> *A stew of organic molecules is a long way from a living cell, and the leap from nonlife to life is the greatest gap in scientific theories of Earth's early history. …. Another unanswered question in the evolution of cells is the origin of DNA and RNA. Remember that all cells are controlled by information stored in DNA, which is transcribed into RNA and then translated into proteins. How could this complex biochemical machinery have evolved? Science cannot yet solve this puzzle, although molecular biologists have made surprising discoveries in this area. (Miller and Levine, 2002. p. 425)*

One of the shortcomings of Darwin's formulation of the theory of evolution was its author's ignorance of the nature of biological inheritance. Darwin was not alone in this respect, of course. Like other naturalists working in the middle of the 19th century, his ideas on biological

inheritance were highly speculative, and ultimately turned out to be incorrect. In our introduction to Chapter 16 we point out that:

> *Without an understanding of heredity, Darwin was unable to explain two important factors. First, he did not know the source of the variation that was so central to his theory. Second, he could not explain how inheritable traits were passed from one generation to the next. (Miller and Levine, 2002. p. 393)*

The emergence of modern genetics and molecular biology has helped to fill both of these gaps, as we explain in Chapter 16. As we note, natural selection can now be studied in more precise genetic terms, with the result that scientists are now able to model and study the effects of natural selection on single-gene traits, on polygenic traits, and on entire populations. The results of such studies, significantly, have not been to weaken the theory of evolution. Quite the contrary — the application of genetic and molecular techniques to the study of evolution has enhanced our appreciation of the nature of evolutionary change and strengthened the status of evolution as the central organizing principle of the science of biology.

3) Language of the Cobb County Disclaimer

It is my understanding that in 2002 the Cobb County Board of Education decided to affix a sticker to student editions of several science textbooks with this wording:

> *This textbook contains material on evolution. Evolution is a theory, not a fact, regarding the origin of living things. This material should be approached with an open mind, studied carefully, and critically considered.*

This statement singles out evolution in a way that misrepresents its scientific standing, misleads students as to the nature of science theories, conveys a false sense of certainty with regard to other scientific theories, and serves, as far as I am able to tell, no scientific or educational purpose.

Calling Special Attention to Evolution

While the first sentence of the statement is obviously true, since each of the textbooks to which it was affixed did indeed contain material on evolution, students reading it will immediately wonder why it is necessary to point this out. Most of the textbooks to which it was affixed clearly list evolution in their tables of content, and a few present it even more prominently. For example, *BIOLOGY by Miller & Levine*, the text of which I am coauthor, lists evolution as a major topic on its back cover. The presence of evolution in these biology textbooks would therefore come as no surprise to their student readers. Those readers will, however, immediately wonder why the Board felt the need to point out this particular element of textbook content in such a direct way. Clearly, in the opinion of the Cobb Board, there is something genuinely special about evolution that needs to be drawn to the students' attention.

The effect of citing evolution, and only evolution, in this way has the obvious effect of suggesting to students that the scientific support for evolution is weak, and that students should hold this particular theory up for special scrutiny. In reality, evolutionary theory enjoys the same status as other well-tested explanations in science, and there is no rational basis for suggesting that it, and it alone, should be mentioned in the context of doubt and skepticism that pervades this statement from the Cobb County Board of Education.

Misrepresenting the Meaning of a Theory

The Board statement tells students that "Evolution is a theory, not a fact," regarding the origin of living things. This statement is clearly designed to mislead students about the nature of scientific theories in general and evolution in particular.

The Board's emphasis that the theory of evolution is "not a fact" might be appropriate if they had pointed out instead that *no scientific theory* is a fact, and that *all scientific theories* continue to be tested in light of new scientific discoveries. Instead, their claim that evolution is "not a fact" is clearly designed to undermine the scientific standing of evolution. The statement clearly implies that if science were certain of the validity of evolutionary theory, it might some day be regarded as a fact. The important point to be made is that scientific theories don't ever *become* facts; rather, scientific theories *explain* facts. We do not expect, by reason of analogy, that atomic theory will ever become known as "atomic fact," regardless of the weight of evidence supporting it. The Board's language clearly has the effect of promoting student misunderstanding as to the nature and validity of scientific theories.

Three decades of teaching have taught me that the scientific meaning of "theory" is easily misunderstood by students. This is a problem with the university students in my classes, and it is certainly a difficulty for the high school students for whom my textbook is written. A majority of students, in my experience, regard a "theory" as a hunch or casual guess. My professional judgment as an educator is that the language of the Cobb County disclaimer plays directly to this misunderstanding. Rather than clarifying the true meaning of a scientific theory, it amplifies and validates a common student misunderstanding. As such, it is counter-productive to good science education.

Directly stated, my objection to this sentence is not that it describes evolution as a "theory." Indeed, Chapter 15 of my own textbook is entitled "Darwin's Theory of Evolution." Rather, the difficulty arises from the sticker's assertion that evolution is a "theory, not a fact," implying that facts represent a higher level of understanding than theories. Since theories persist in science only when they are broadly supported by factual evidence, they actually represent a higher level of understanding than facts. The language of the Cobb County disclaimer, in other words, gets it exactly backwards. One is left to wonder why this is so.

Conveying a False Sense of Scientific Certainty

In its eagerness to undermine student confidence in the descriptions of evolutionary biology presented in their textbooks, the disclaimer's concluding sentence warns that "This material

should be approached with an open mind, studied carefully, and critically considered." At first glance this would seem to be a straightforward admonition that students should apply critical thinking skills to their life science studies. If this were the case, however, the sentence might have suggested that such skills should be applied to all topics within the textbook. Instead, the wording carefully tells students that open mindedness and critical thinking should be applied to only "this material," which is, of course, evolution. The student is left to wonder why one does not need an open mind to study cell biology or why the germ theory of disease should not be subjected to critical consideration. The obvious implication is that the other topics in the textbook rise to a level of certainty that makes such careful analysis unnecessary. That is not the case, according to the Cobb County Board of Education, for evolution.

I object to this final sentence not as an evolutionist — but as an experimental cell biologist. By implication, the Board's wording tells students that they can be certain of the validity of every subject presented in their textbooks — except for evolution. What this means, of course, is that the fundamental questions in every field of biology, except for evolution, have been definitively answered. Were students to take this language to heart, they would see no reason to pursue careers in research, since, according to the Cobb County Board of Education, there is little left to discover. How can there be, when students are told that careful study, open-mindedness, and critical consideration are not necessary for any field of study other than evolution?

Here again, the language of the disclaimer sets evolution apart from the rest of the biological sciences, doing serious damage to student understanding. By attempting to establish evolution's uncertain status as worthy of careful, critical analysis, they foolishly present the rest of biology as so firmly established that it is beyond such treatment. The false sense of certainty about the rest of biology conveyed by this wording does further damage to student understanding.

A Revised Disclaimer

If the goal of the Cobb County Board of Education was to promote critical thinking in biology classes, there are many ways in which this might have been accomplished. They could have requested that their curricular staff organize workshops in critical thinking for their teachers, they might have prepared lesson plans that emphasize the critical thinking exercises already present in textbooks and other materials, or they might have composed a quite different disclaimer to be inserted in their textbooks. The wording of such an alternate disclaimer, following the three-sentence format of the Board's 2002 resolution, might read like this:

> *This textbook contains material on science. Science is built around theories, which are strongly supported by factual evidence. Everything in science should be approached with an open mind, studied carefully, and critically considered.*

Clearly, evolution, as one of many subtopics in biology, would be included in a call for critical consideration by the wording of such a disclaimer. It would not, however, be singled out for special treatment. Nor would students be confused by an incorrect distinction between "facts" and "theories," or by an incorrect implication of certainty in other fields of biology.

Despite the ease with which such a disclaimer might have been composed, the Board obviously chose different wording, leading to the current case.

The Creationist Movement and its use of the term "Theory"

While one cannot know the thoughts of individual Board members who approved the disclaimer's wording, the context in which this disclaimer appeared leaves no doubt as to its intent and ultimate effect. In the Spring of 1981, during my first full year of teaching at my current institution, I was approached by a group of undergraduate students and asked to debate Dr. Henry Morris, a self-described "scientific creationist." Dr. Morris was, in fact, the Founder and President of the Institute for Creation Research, and was the acknowledged leader of the "scientific creationism" movement in the United States. Although I was unfamiliar with scientific creationism as I prepared for our debate, I quickly became aware of the strategies and tactics employed against the teaching of evolution by this movement.

One of these strategies was a deliberate attempt to mislead the public as to the nature of a scientific theory. Knowing that biologists routinely make reference to the "theory of evolution," Dr. Morris and other creationists routinely emphasized that evolution was just a theory and had not been proved, implying that it should be greeted with a greater degree of skepticism than other scientific ideas.

The late Stephen Jay Gould described this portion of the creationist strategy this way:

> *In the American vernacular, "theory" often means "imperfect fact"--part of a hierarchy of confidence running downhill from fact to theory to hypothesis to guess. Thus the power of the creationist argument: evolution is "only" a theory and intense debate now rages about many aspects of the theory. If evolution is worse than a fact, and scientists can't even make up their minds about the theory, then what confidence can we have in it? [Gould, 1994]*

Since my 1981 debate with Morris, I have accumulated 25 years' of experience in dealing with the arguments, strategies, and tactics of the creationist movement. Every manifestation of the movement has employed the "theory not fact" tactic, including the more recent groups advocating the variety of creationism known as "intelligent design." Indeed, the intelligent design initiative begun by the Dover, PA, Board of Education in 2004 employed "theory not fact" language nearly identical to that found in the Cobb County Disclaimer:

> *Because Darwin's Theory is a theory, it continues to be tested as new evidence is discovered. The Theory is not a fact. [Dover Board of Education Statement on Evolution and Intelligent Design, cited in Kitzmiller v. Dover, 2005]*

Common to both statements is a false dichotomy between theory and fact that is clearly designed to mislead students as to the scientific standing of evolution, and to promote alternate ideas such as creationism and intelligent design.

4) Educational Impact of the Cobb County Disclaimer

As stated earlier, I am coauthor, with Joseph S. Levine, of a series of high school general biology textbooks published by the Prentice Hall Company. I travel regularly on behalf of my publisher, meeting with teachers, parents, and students throughout the United States, and presenting workshop on biology education. In an average year, I spend roughly 30 days involved in such activities, speaking to an average of 50 educators in the course of each presentation. This means that in a typical year I meet more than 1,000 educators, engaging in detailed discussions with many of them on issues of science education. Considering the fact that our first textbook appeared in 1991, it is fair to say that over the 15 years that have followed I have gathered a great deal of professional information on biology education in American schools.

In meeting with teachers, I have often discussed the issue of special disclaimers or "stickers" of the sort applied by Cobb County to its textbooks. Their responses overwhelmingly indicate that they do not regard such special statements as conducive to good educational practices. A warning label that singles out a single scientific theory for special scrutiny sends an unsubtle message to students that something is seriously wrong with that theory. This, as teachers recognize, is exactly what the Cobb County wording was designed to do, and it will clearly have that effect in any classroom where it is present.

One might argue, of course, that the sticker is required to counteract the dogmatic and inflexible way that evolution is presented in a textbook, but this argument could be made only by deliberately overlooking the way in which our text (*Biology by Miller & Levine)* covers the subject. As noted earlier in this statement, we are careful to point out the tentative nature of scientific theories to students, and do indeed present evolution as such a theory. However, by stating that "evolution is a theory, not a fact," the Cobb County statement turns the relative meanings of "theory" and "fact" on their heads. Evolutionary theory is broadly supported by scientific fact, and to say that it is "not a fact" is to deliberately imply otherwise. This is directly at variance with the mainstream view of evolutionary biology that is found in our text, required by the Georgia science standards, and supported by the American scientific community.

Specifically, the "not a fact" wording of the Cobb statement directly contradicts the explanation of scientific "theory" in the opening pages of our textbook:

> *You may have heard the word theory used in everyday conversations as people discuss ideas. Someone might say, "Oh, that's just a theory," to criticize an idea that is not supported by the evidence.* ***In science, the word theory applies to a well-tested explanation that unifies a broad range of observations****. A theory enables scientists to make accurate predictions about new situations. (Biology by Miller & Levine, 2002. P. 14)*

Ironically, the usage of "theory not a fact" language by the Cobb Board of Education employs exactly the meaning of "theory" that our textbook warns against in its very first chapter. Therefore, in its efforts to undermine the theory of evolution, the Cobb sticker contradicts our

very best efforts, and those of the educators of Cobb County, to educate the students of Cobb County as to the meaning of this important scientific term.

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