Good morning! Mr. Chairman, members of the committee, ladies and gentlemen, I am Dr. Richard von Sternberg. I hold two doctoral degrees—one in evolutionary biology and the other in systems biology. Before beginning I would like to say three things.

First, I thank you for the invitation to come to South Carolina and speak on the subject of teaching evolution. In some sense South Carolina is my home—though my Ph.D.s were earned in Florida and New York, I received my bachelors' and masters' degrees from the University of South Carolina. Moreover, I met my wife and was married in this state, and many close relatives are from South Carolina, including my mother, who still lives here.

Second, what I say here this morning reflects only my views as an evolutionary biologist. Though I am employed as a staff scientist by the NIH and remain a research associate of the Smithsonian, in no sense do I represent the views of either institution.

Third, and with regard to what follows, in no way am I advocating any religious or philosophical view. Nor will I be mentioning anything even remotely close to Intelligent Design.

Perhaps there is no field of the biological sciences undergoing more rapid change than evolutionary research. Almost every day some new finding is reported that overturns—or seriously calls into question—long-standing assumptions and models. From the genome sequencing projects and studies of how genes operate to the discovery of new fossils, evolutionary biology is in a state of transition. Examples are simply too numerous to cover adequately. But here are a few.

You have leaders in the field like W. Ford Doolittle presenting evidence that there is no "Tree of Life" but, instead, a complex web of gene sharing. Likewise, Carl Woese, one of the fathers of molecular phylogenetics, thinks the data support multiple, independent origins of organisms—that the notion of a Universal Common Ancestor is erroneous. Then again, evolutionary developmental biologists like Stuart Newman have performed experiments that suggest that animal body plans originated <u>before</u> genomes to "encode" them. I know it sounds radical, but he and other leaders in the field of "evo-devo" think that genes support development, but they don't provide the blueprint. Embryos self-organize, and genes provide the building materials. Finally, even the specter of Lamarck has reappeared. Lamarck's idea was, of course, that acquired traits can be passed on to offspring. None other than "Darwin Day" organizer Massimo Pigliucci is giving second thought to Lamarckism—after all, he notes, Darwin was a Lamarckian!

These are revolutionary times in evolutionary biology!

But we are not here this morning to discuss the latest in evolutionary thinking. We are here to discuss standards for teaching evolution in the state of South Carolina. Hence my reason for mentioning intellectual ferment in evolutionary research: we would be imprudent if we taught a particular theory as being the last word on the subject—as if all that remained is to place a few numbers after the Darwinian decimal point. Now the

subtext of the "teach evolution" controversy is usually "Darwinism: Right or Wrong?" I think this is a mistake. Darwinism is "right" in many respects. Mutations do occur and natural selection does operate. However, it is incomplete. Carefully study a textbook on evolutionary theory—not a popularization but an actual book on the mathematics of the theory—and you will notice several things. There are no equations for the development of organisms or even the cell. Nor is there any specification for how all the cellular molecules come together to shape a fly or a whale. Why the origin of new genes alone is a matter of differing views, models, and conjectures. By the way, this is not a trivial matter. It is a core issue of evolutionary biology. And this brings me to my major point: While Darwinian theory should be taught in the science classroom, as rigorously and fully as is appropriate, to present the theory as complete and sufficient for understanding evolution is inaccurate—and thus misleading.

Not only that but I can think no better way to spark a student's interest in evolution than to explore it in a critical way. Either evolution is an exciting, evolving field, or we are reciting passages from 1859; as though we know all there is to know. Such a stance is inimical to both the tentative nature of science and the intellectual process. This is why the suggested revised indicators can do much to improve science education—by stimulating a student's interest in an <u>open</u> area.

On to the suggested revised indicators. Let me summarize by saying that the suggested re-wordings are a marked improvement over the existing ones.

For example, it is incorrect to say that "natural selection results in the continuity of life forms over time" as written in Indicator B-5.2. The transmission of genetic material explains genealogical continuity—selection culls the results of reproduction, namely, offspring. The revised B-5.2 Indicator is technically more correct.

The revised Indicator B-5.4 is also more accurate. Genetic variability and natural selection ("environmental factors") do not *necessarily* lead to macro-evolution, as the current wording seems to imply. Both may also lead to stasis or population variants. The proposed changes to this indicator will challenge the student to think about how speciation may or may not lead to the evolution of new genera and the like.

Many aspects of evolution are constantly being challenged. Prominent self-organizational theorists, for instance, propose that many aspects of the organism are not adaptive—that is, they are shaped more by the laws of physics and chemistry than by natural selection and random mutation. Those who hold this position include Stuart Kauffman and Brian Goodwin. Simon Conway Morris, noted Cambridge paleontologist, has similarly noted that evolution is constrained rather than open ended like the Darwinian process. Informed students should be able to grapple with such challenges to the Darwinian model as well as know *all* the evidence that supports the Darwinian model. Revised Indicator B-5.5 promotes such critical thinking.

Finally, revised Indicator B-5.7 is also an improvement. Constructing phylogenetic trees is a model-dependent exercise with human assumptions built in. When students are

taught to build such trees, they should also be taught to identify the assumptions since they affect the resulting pattern. Some new phylogenetic modeling programs do not even construct trees; they instead result in interlocking, web-like relationships. Because revised Indicator B 5.7 and the other revised indicators would *increase* student knowledge about phylogenetics and evolution in general, South Carolina's students would be better served by adopting these revisions.