Review of Minnesota Academic Standards First Draft in Science by Chris Macosko

Thank you for the work that you are doing to revise the Minnesota Science Standards. This is an excellent opportunity for all of us to evaluate what is being taught to our K-12 students in science. I would like to offer the attached analysis of the Draft Science Standards.

Let me highlight just one of my points here: the controversy surrounding the origin of life (1.e). Most biology texts present the theory for chemical origin of life as fact. This is simply not true and the severe weaknesses, which I outline below, have been known for many years. When I ask students in my freshmen course to read papers which point out these problems many feel that they were severely mislead in their high school biology course. It is excellent practice in critical thinking and good for science for students to learn about the controversy in such an important topic.

Please forward to the science standards committee. I would be glad to elaborate on these points further or speak to the committee in person. I am forwarding this letter and my comments on to other colleagues. I am asking them to drop you a note if they agree with the attached analysis.

Thanks for your attention,

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ANALYSIS OF DRAFT MINNESOTA SCIENCE STANDARDS

Public hearings are now being held around the state of Minnesota for public comment on the first draft of the proposed 9-12 science standards. Minnesotans have an important opportunity to improve and enhance those standards through their comments and testimony. While there are a number of positive features of the draft standards (especially in the area of the "History and Nature of Science"), the proposed benchmarks dealing with the theory of evolution are incomplete, failing to introduce students to the full range of scientific views and evidence on this important topic. Below is an analysis of some positive benchmarks in the initial draft as well as proposals for additional benchmarks that would strengthen how the standards cover evolution.

POSITIVE BENCHMARKS IN THE EXISTING DRAFT

The "History and Nature of Science" section of the initial draft contains many benchmark standards concerning the nature of science that promote good science education. The "Scientific World View" subsection contains a particularly important benchmark:

> Students will be able to explain how scientific innovations and new evidence can challenge accepted theories and models, including cell theory, atomic theory, theory of evolution, plate tectonic theory, germ theory of disease, Big Bang theory.

Another positive benchmark immediately follows the above cited provision:

> Students will know that scientific explanations must meet certain criteria to be considered valid, including that they must be consistent with experimental and observational evidence about nature, logical, respect the rules of evidence, be open to criticism, and report methods and procedures.

Inclusion of these two provisions is important so that students will learn that science is based on critical inquiry rather than dogmatism and that existing scientific theories should always be open to challenges from new evidence.

SUGGESTED BENCHMARK IMPROVEMENTS

Because the theory of evolution is such a central concept in the life sciences, students should be fully informed about it. They should learn not only the best evidence for the modern theory of evolution (known as "neo-Darwinism"), but also about current scientific criticisms of key tenets of the theory. Unfortunately, the draft benchmarks on evolution in the "Life Science" section do not address any scientific weaknesses of modern evolutionary theory, nor do they acquaint students with the full range of scientific views about evolutionary theory. Following are three suggestions for improving the coverage of evolution:

1. Add the following five additional benchmarks to the “Life Science” section to improve the coverage of evolution:

a. Students will be able to distinguish the different meanings of the term evolution, as well as explain the different levels of evidentiary support for each meaning.

b. Students will be able to distinguish between microevolution and macroevolution and explore the controversy over whether microevolution can be extrapolated to explain macroevolution.

c. Students will be able to explain the limits of natural selection and random mutation to explain complexity.

d. Students will be able to critically analyze the evidence for universal common ancestry.

e. Students will be able to explain the controversy surrounding the origin of life.

2. To encourage full discussion and critical thinking relating to evolution, substitute the the phrase "analyze the theory that " for, respectively, "understand," "explain how," "be able to identify," and "describe how," in the following: (a) Sub Strand E in the Life Sciences for Grades 7 through 12; (b) Grade 8, IV Life Science, Strand E, Fifth Benchmark, (c) Grade 9-12, History and Nature of Science, Strand A, Fourth Benchmark; and (d) Grade 9-12, IV Life Science, Strand B, Fourth Benchmark

3. Add the following benchmark to History and Nature of Science, Stand B beginning at an appropriate grade level:

"Students will understand the methods used to test historical hypotheses that can not be confirmed by experiment."

Brief explanations concerning these suggestions:

1.a. Students will be able to distinguish the different meanings of the term evolution, as well as explain the different levels of evidentiary support for each meaning.

“Evolution” is a term that is employed at different times to mean everything from “change over time” to “microevolution” to “universal common ancestry” to the claim that natural selection acting on random mutations has been the primary cause of the major changes that have happened in the history of life. It is important that students learn about these different meanings of the term evolution and understand the difference between empirical support for change over time and microevolution—which can be directly observed—and empirical support for universal common ancestry and the mechanisms responsible for long-term evolutionary change—which cannot be directly observed.

1.b. Students will be able to distinguish between microevolution and macroevolution and explore the controversy over whether microevolution can be extrapolated to explain macroevolution.

Microevolution refers to small intergenerational changes within existing species or gene pools, such as the acquisition of antibiotic resistance in bacteria or a change in average beak size in birds. Macroevolution refers to the process that creates innovations occurring above the species level, such as new complex organs, new body parts, or new body plans.

Natural selection often oscillates with changing conditions from year to year, and it has never actually been observed to produce new species. Furthermore, the genetic mutations that supposedly provide raw materials for selection are almost always harmful, and the rare ones that are beneficial have only been observed to produce minor biochemical changes rather than the major anatomical changes required by evolution. For these and other reasons, the simple extrapolation of microevolution to explain macroevolution is controversial, even among evolutionary biologists. Students should know why the controversy exists.

1.c. Students will be able to explain the limits of natural selection and random mutation to explain complexity.

In neo-Darwinian theory, natural selection improves the function of an existing system gradually, step by step, with no thought for its future utility. According to some biologists, however, "irreducibly complex" systems present a problem for neo-Darwinian theory. An irreducibly complex system is one that functions only when several well-matched parts, all working together, are present; some examples are the human blood clotting cascade, intracellular transport systems, and the bacterial flagellum. Since a partially assembled irreducibly complex system has no function at all, it cannot be improved by natural selection, and thus poses a problem for neo-Darwinian theory.

Students should know the evidence and scientific arguments for and against the sufficiency of neo-Darwinian theory. In particular, they should be encouraged to evaluate critically various claims about the power or limitations of natural selection and genetic mutation.

1.d. Students will be able to analyze critically the evidence for universal common ancestry.

The Darwinian view that living things in all the major kingdoms of life (such as bacteria, fungi, plants and animals) are modified descendants of a common ancestor has been challenged in recent years by a growing number of discrepancies in the molecular evidence previously thought to support that view. Students should know enough about that evidence to understand the controversy over this issue.

Evidence for the common ancestry of all animals has traditionally come from the fossil record, embryology, homology, and molecular studies. Yet the fossil record shows the major groups ("phyla") of animals appearing fully formed in a relatively short time (5-10 million years according to standard geologic dating), a phenomenon known as the "Cambrian explosion." Embryos which Darwin thought were almost identical in their early stages (thus pointing to their common ancestry) are now known to be very different. Neo-Darwinians once thought that homologous features (such as the bones in vertebrate limbs) were produced by similar genes inherited from a common ancestor, but it is now known that there is no simple correlation between genes and homology. Finally, molecular studies have not produced a consistent evolutionary tree for the animal phyla.

Students should understand that common ancestry may be true at some levels (such as the cat family), but may not be true at others (such as the major kingdoms of life). They should know enough about the evidence to be able to evaluate it critically, at least at some representative levels of the biological hierarchy.

1.e. Students will be able to explain the controversy surrounding the origin of life.

While Darwin's theory purported to explain how life could have grown gradually more complex starting from one or a few simple forms, it did not explain, nor did it attempt to explain, how life first originated.

Chemical evolutionary theory has in recent years encountered severe criticisms on many fronts. First, geochemists have failed to find evidence of the "primordial soup" required by the standard model. Second, the remains of single-celled organisms in the very oldest rocks testify that, however life may have emerged, it did so relatively quickly. Third, new geological and geochemical evidence suggests that prebiotic atmospheric conditions did not favor the production of amino acids and other essential building blocks of life. Fourth, molecular biology has revealed such great complexity in living cells that standard origin-of-life scenarios now look quite simplistic.

Even if it could be demonstrated that the building blocks of essential molecules could arise in realistic prebiotic conditions, the problem of assembling those building blocks into functioning proteins or DNA chains would remain. This problem of explaining the specific sequences—and thus the information—in biopolymers lies at the heart of the current controversy over the adequacy of materialistic explanations for the origin of life. Students should at least be aware of the controversy and why it has arisen.

2. To encourage full discussion and critical thinking relating to evolution, substitute the the phrase "analyze the theory that " for, respectively, "understand," "explain how," "be able to identify," and "describe how," in the following: (a) Sub Strand E in the Life Sciences for Grades 7 through 12; (b) Grade 8, IV Life Science, Strand E, Fifth Benchmark, (c) Grade 9-12, History and Nature of Science, Strand A, Fourth Benchmark; and (d) Grade 9-12, IV Life Science, Strand B, Fourth Benchmark

The referenced strands and benchmarks use language that suggests a close minded approach to evolution. The suggested change will encourage critical analysis that will open minds about a controversial subject.

3. Add the following benchmark to History and Nature of Science, Stand B beginning at an appropriate grade level:

"Students will understand the methods used to test historical hypotheses that can not be confirmed by experiment."

According to Ernst Mayr, a highly regarded evolutionary biologist, "Darwin introduced historicity into science. Evolutionary biology, in contrast with physics and chemistry, is a historical science – the evolutionist attempts to explain events and processes that have already taken place. Laws and experiments are inappropriate techniques for the explication of such events and processes. Instead one constructs a historical narrative, consisting of a tentative reconstruction of the particular scenario that led to the events one is trying to explain."[[Ernst Mayr, "*Darwin's Influence on Modern Thought,"* p. 80, (July 2000, Scientific American)]. Other historical sciences include certain aspects of geology, paleontology, anthropology, and archeology.

In the absence of experiment, historical scientists postulate multiple competing hypotheses about the cause of past events and seek to test a given historical hypothesis by collecting evidence that will not only rule in the hypothesis to be tested, but also rule out the reasonable competing hypotheses. [Carol Cleland, *Historical Science, Experimental Science and the Scientific Method,* Vol 29 No. 11, 987-990 (Geology, November 2001)]. According to Kenneth Miller, we "learn about the past by applying good, old-fashioned detective work to the clues that have been left behind." [Kenneth Miller, *Finding Darwin's God,* (Cliff Street Books, 1999), pp. 22-23.] Because the record of past unobserved events is often incomplete with many evidentiary gaps, historical sciences frequently yield only a "best current explanation." This benchmark would complement the second Benchmark in the same sub-strand which requires students to "give examples of how different domains of science use differing bodies of scientific knowledge and employ different methods to investigate questions."