Talking Points for Texas Teachers

✔ Teachers are especially concerned that textbooks be high quality in content and pedagogical approach. These books have been reviewed extensively by teachers and found acceptable. The board should not second-guess that process.

✔ The TEKS Knowledge and Skills (3)(A) standard, "analyze, review and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information" is applicable to all scientific fields and any explanation. Textbooks should not be expected to present "strengths and weaknesses" of every hypothesis and theory – the idea is absurd. Let teachers make the decision as to which scientific hypotheses and theories should be used to meet this standard. The board should not second-guess that process by mandating any particular theory as a means of meeting standard (3)(A).

✔ Because the job of the high school teacher is to present state-of-the-art science, it is important that the books reflect the consensus view of the scientific community, which is that evolution occurred, and that natural selection is a critically important mechanism, though not the only mechanism, of evolutionary change. The books in their extant form express these ideas.

✔ The textbook criticisms proposed by the Discovery Institute have been rejected by the scientific community. It is detrimental to students' education to modify the submitted textbooks to reflect criticisms that are not accepted by the scientific community.

✔ When textbook selection time comes, educators are going to be looking for textbooks that express the consensus view of science: an unqualified, honest presentation of the scientific evidence concerning evolution as understood by evolutionary biologists, who are most qualified to evaluate this material. Textbooks that include invalid "evidence against evolution," or unaccepted "alternative scientific theories," will not be selected for purchase by school districts.

Background Information

The State Board of Education is being pressed to modify high school biology textbooks submitted for adoption in ways that would be detrimental to the quality of the books. Several individuals and some organizations have submitted reviews to the Board of Education which both praise and criticize the books. Most of the praise has come from teachers and scientists; criticism has come from creationists. The Discovery Institute, a Seattle-based "Intelligent Design" (ID) think tank, has submitted a highly critical evaluation of the textbooks, rejecting them for their treatments of four topics often included in textbooks as illustrations of mechanisms of evolution, or for historical reasons. The evaluation is based on an especially egregious book, *Icons of Evolution* by Discovery Institute Senior Fellow Jonathan Wells, which castigates textbooks for their treatment of these same four topics (and others).

Textbooks are hardly perfect, but the Board of Education should not make them less accurate by inserting ideas outside the scientific mainstream. We do not want to have the books modified in the ways called for by the DI. For further information about the Discovery Institute's misleading textbook review, see the section "Analysis of Discovery Institute's Textbook Analysis," below.

Another issue in the current Texas textbook controversy is the question of how to implement the Texas Essential Knowledge and Skills (TEKS) standard on "scientific processes." This is a common, almost boilerplate statement found in most states' science education standards. It occurs in the TEKS from third grade forward, and for every scientific subject from physics, chemistry, astronomy, geology, environmental science, *and* biology. The wording of the standard, abbreviated as "(3)(A)," the numbering that occurs through the TEKS, is "[the student is expected to] analyze, review and critique scientific explanations, including hypotheses and theories, as to their strengths and weaknesses using scientific evidence and information."

This wording was placed into the TEKS as a compromise between board members who wanted to have "alternative theories" (i.e., creationism or "intelligent design") inserted into the TEKS and board members who wanted science presented honestly. The statement was wisely applied to all scientific disciplines, rather than merely evolution, as a way of heading off antievolutionists. Teachers can use this broad application to defend themselves. They can argue, as presented in the talking points above, that obviously it is absurd to expect *all* scientific hypotheses and theories to be dissected in terms of strengths and weaknesses if more than two or three scientific topics are to be taught per semester! Therefore, teachers have to select *which* hypotheses and theories to have students "analyze, review, and critique." The board should not mandate any particular scientific theory or concept be used to meet standard (3)(A). Teachers, not board members, have the expertise and experience to make this decision, as they are the ones most familiar with the curriculum and what scientific ideas are most appropriate to the age level, and background strengths and limitations of their students.

Analysis of the Discovery Institute's Textbook Critique

The following discussion refers specifically to the Discovery Institute's "A Preliminary Analysis of the Treatment of Evolution in Biology Textbooks currently being considered for adoption by the Texas State Board of Education." This document evaluates textbooks on a set of four criteria selected from Jonathan Wells's book, *Icons of Evolution*. (Jonathan Wells, *Icons of Evolution: Why much of what we teach about evolution is wrong* (Washington, DC: Regnery Publishing, 2000)

These criteria are based on four topics often included in textbooks as illustrations of mechanisms of evolution, or for historical reasons. In *Icons,* Wells presents them as being inaccurate, out of date, or downright fraudulent. Reviews of this book have shown how wrong he is, but nonetheless, these claims are being circulated. The "Analysis" document given to the Texas Board of Education is just one example.

***The four topics considered*:**

Miller-Urey experiment

Cambrian explosion

Vertebrate embryos and Haeckel's drawings

Peppered moths

What follows does not support, advocate, or defend any particular textbook. It comments on the Discovery Institute critique, which is based on *Icons of Evolution*.

Summary of the Discovery Institute's Criteria

In the Discovery Institute (DI) analysis, each submitted book is evaluated according to the above four topics. Ironically, to get a high grade, a textbook must present the icon and criticize it! Of course, if the icons truly represented such bad science, a textbook should just omit them, not waste space presenting and criticizing them!

The presentation of each icon, predictably, is found wanting, largely because each book presents the standard scientific view of these topics, rather than the revisionism expected by the authors of the "Analysis." Because the DI's analysis is probably written by Jonathan Wells, or taken so substantially from his work as to be authored by him, we will refer from here on to the DI analysis as Wells's work.

Your testimony will be far more valuable if you have examined at least one of the textbooks being considered. In your testimony, you might want to point out that the evaluation of the textbooks is done on invalid criteria that are not acceptable to scientists, and refer them to the sources below for additional information. Here is a quick summary of their view of the four icons. If you choose one to comment on, look below for more details on its scientific flaws.

1. The Miller-Urey experiment. They claim that the early earth atmosphere was greatly different from that used in the original experiment, thus the Miller-Urey experiment is irrelevant and misleading to students. They claim that the origin of life "remains an impenetrable mystery." *See below for flaws in this view.*

2. Tree of life and Cambrian explosion. The theory of evolution says that all organisms have descended from a common ancestor in the distant past. In Darwin's *Origin,* this is made clear in the "tree of life" diagram. They claim that if evolution by natural selection were true, the pattern of emergence of different types of organisms would be slow and gradual, but because "most major phyla appear fully formed at the beginning of the geological period known as the Cambrian, with no fossil evidence that they branched off from a common ancestor" they claim that the fossils – and the Cambrian explosion – are a huge problem for evolution. *See below for flaws in this view.*

3. Vertebrate embryos and Haechel's drawings. Nineteenth-century biologist Ernst Haeckel's drawings "misrepresent the evidence in three respects" and have been repeatedly pointed to as "frauds"; even textbooks which don't recycle Haeckel's drawings still mislead students by selective use of data which supports Darwin and by omitting evidence the theory has trouble explaining. *See below for flaws in this view.*

4. Peppered moths. Peppered moths "don't normally rest on tree trunks"; textbook photos are staged; photos are "false and misleading." *See below for flaws in this view.*

Each textbook is evaluated on these criteria, and given a D or F in virtually every case. We believe that this hatchet job on the textbooks is intended to 1) encourage teachers to avoid these useful teaching examples, and 2) intimidate textbook publishers to reduce the coverage of evolution in their future books. For many reasons, these criticisms are scientifically flawed. As NCSE's Executive Director, Dr. Eugenie C. Scott has said about Wells's book in her review in *Science*, "Textbooks are, alas, far from perfect, but authors and publishers would do little to improve their wares by altering their texts to suit Wells. This is because Wells presents a systematically misleading view of evolution. Individual sentences in Icons are usually technically correct, but they are artfully strung together to take the reader off the path of real evolutionary biology and into a thicket of misunderstanding" (*Science* 292 [2001]: 2557–2558).

Here is more accurate information about each of the four criteria and why their application to the textbooks submitted in Texas are inappropriate. The following analyses are rewritten from an extensive analysis by Dr. Alan Gishlick, of the National Center for Science Education. His detailed essay is "ICONS OF EVOLUTION? Why much of what Jonathan Wells writes about evolution is wrong." We strongly urge you to familiarize yourself with the fuller version, which you will find online at http://www.ncseweb.org/icons/.

For additional reviews of *Icons of Evolution*, see http://www.ncseweb.org/resources/articles/9144_reviews_of_icons_of_evolution_ 10_31_2002.asp.

The Miller-Urey Experiment

The Discovery Institute document says that the Miller-Urey experiment should be deleted from textbooks (or severely altered in its presentation) because the experiment used an atmospheric composition that is now known to be incorrect. Wells's ultimate concern of course, is to present origin-of-life research as failing to "solve the problem of the origin of life" and to cast doubt that such a problem will in fact, ever be solved – it is, they say, an "impenetrable mystery."

In support of this goal, the document falsely claims that the results of the famous and historical Miller-Urey experiment are invalidated by new information. Wells also implies that textbooks present the experiment as proving the origin of life through natural processes, which of course the experiment did not claim to do and which is not how scientists view the experiment. Wells's major complaint is that textbooks don't discuss how current estimates of the composition of the early atmosphere show a different composition from the atmosphere hypothesized in the original experiment. Wells then claims that the actual atmosphere of the early earth makes the Miller-Urey type of chemical synthesis impossible, and asserts that the experiment does not work when an updated atmosphere is used. Therefore, textbooks should either discuss the experiment as an historically interesting yet flawed exercise or not discuss it at all. Wells concludes by saying that textbooks should replace their discussions of the Miller-Urey experiment with an "extensive discussion" of all the problems facing research into the origin of life.

In fact, Wells's knowledge of prebiotic chemistry is seriously flawed. First, scientists working on the origin and early evolution of life are well aware of the current theories of the earth's early atmosphere and have found that the revisions have little effect on the results of various experiments in biochemical synthesis. Despite Wells's claims to the contrary, new experiments since the Miller-Urey ones have achieved similar results using various corrected atmospheric compositions (Rode 1999; Hanic et al. 2000). Further, although some authors have argued that electrical energy might not have efficiently produced organic molecules in the earth's early atmosphere, other energy sources such as cosmic radiation (e.g., Kobayashi et al. 1998), high temperature impact events (e.g., Miyakawa et al. 2000), and even the action of waves on a beach (Commeyras et al. 2002) would have been quite effective.

Teachers can also criticize Wells's evaluation criteria (Wells 2000:251–252), which are pedagogically ridiculous. Any textbook containing a picture of the Miller-Urey apparatus could receive no better than a C, unless the caption of the picture

explicitly says that the experiment is irrelevant, in which case the book would receive a B. Therefore, the use of a picture is the major deciding factor on which Wells evaluated the books, for it decides the grade *irrespective of the information contained in the text!* A grade of D is given even if the text explicitly points out that the experiment used an incorrect atmosphere, as long as it shows a picture. This is absurd: almost all textbooks contain pictures of experimental apparatus for any experiment they discuss. It is the text that is important pedagogically, not the pictures.

In order to receive an A, a textbook must first omit the picture of the Miller-Urey apparatus (or state explicitly in the caption that it was a failure), discuss the experiment, but then state that it is irrelevant to the origin of life. This type of textbook would be not only scientifically inaccurate but pedagogically deficient.

The Miller-Urey experiment represents a first step – not the final step – in the puzzling process leading to the first replicating structure. The first stage in the origin of life was chemical evolution. This involves the formation of organic compounds from inorganic molecules already present in the atmosphere and in the water of the early earth. This spontaneous organization of chemicals was spawned by some external energy source. Lightning (as Oparin and Haldane thought), proton radiation, ultraviolet radiation, and geothermal or impact-generated heat are all possibilities. Obviously there are many additional problems to solve (and that are being considered by researchers) before we have a complete understanding of how life originated – but the synthesis of organic compounds from inorganic ones is the beginning – and that is all the Miller-Urey experiment shows. Textbooks do not present it as solving all the problems of the origin of life!

The Miller-Urey experiment marks the beginning of *experimental* research into the origin of life. Before Miller-Urey, the study of the origin of life was merely theoretical. With the advent of "spark experiments" such as Miller conducted, our understanding of the origin of life gained its first experimental program. Therefore, the Miller-Urey experiment is important from an historical perspective alone. Presenting history is good pedagogy because students understand scientific theories better through narratives. The importance of the experiment is more than just historical, however. The apparatus Miller and Urey designed became the basis for many subsequent "spark experiments" and laid a groundwork that is still in use today. Thus it is also a good teaching example because it shows how experimental science works. It teaches students how scientists use experiments to test ideas about prehistoric, unobserved events such as the origin of life. It is also an interesting experiment that is simple enough for most students to grasp. It tested a hypothesis, was reproduced by other researchers, and provided new information that led to the advancement of scientific understanding of the origin of life. This is the kind of "good science" that we want to teach students.

Finally, the Miller-Urey experiment should still be taught because the basic results are still valid. The experiments show that organic molecules can form under abiotic conditions. Later experiments have used more accurate atmospheric compositions and achieved similar results. Even though origin-of-life research has moved beyond Miller and Urey, their experiments should be taught. We still teach Newton even though we have moved beyond his work in our knowledge of planetary mechanics. Regardless of whether any of our current theories about the origin of life turn out to be completely accurate, we currently have models for the processes and a research program that works at testing the models.

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Tree of life, Cambrian Explosion

Wells claims that the Cambrian Explosion is ignored in textbooks and that its inclusion would "enable students to 'analyze, review, and critique scientific explanations...'" – good old (3)(A). Creationists are enthusiastic about the inclusion of the Cambrian Explosion because they consider it "presents a serious challenge to Darwinian evolution" (Wells 2000:41) and the validity of phylogenetic trees.

Some of the books do discuss the Cambrian, but most books devote so few pages to evolution that even an interesting topic like the Cambrian Explosion gets short shrift. Many other fascinating topics in evolution are also not covered. There is no reason to think that the textbooks deliberately omit the Cambrian Explosion because they believe it shows any "weaknesses in evolution." On the contrary, paleontologists who study the Cambrian are surprised at the idea that it somehow questions or weakens the evidence for evolution.

The DI analysis argues that the Cambrian Explosion happened too fast to allow large-scale morphological evolution to occur by natural selection ("Darwinism"), and that the Cambrian Explosion shows "top-down" origination of taxa. By this Wells means that phylum-level differences appear early in the fossil record rather than develop gradually, which Darwin expected but which modern scientists do not consider the only way evolution can occur. He also hammers away at the lack of *fossil* evidence tying Cambrian fossils to Pre-Cambrian ancestors. These arguments are spurious and show a lack of understanding of basic aspects of both paleontology and evolution.

First, Wells mistakenly presents the Cambrian Explosion as if it were a *single* event. The Cambrian Explosion is, rather, the preservation of a series of faunas that occur over a 15–20 million year period starting around 535 million years ago (MA). Millions of years may be geologically rapid, but it isn't genetically rapid! Substantial changes can occur over tens of millions of years.

And, if major body-plans occur early in the fossil record, this is not incompatible with the predictions of evolution. The issue to be considered is the practical one: "large-scale" body-plan change would of course evolve before minor ones. (How can you vary the lengths of the beaks before you have a head?) An important thing to realize is that many of the "major changes" in the Cambrian were initially minor ones. Through time they became highly significant and the basis for "body-plans." For example,

the most primitive living chordate *Amphioxus* is very similar to the Cambrian fossil chordate *Pikia*. Both are basically worms with a stiff rod (the notochord) in them. The amount of change between a worm and a worm with a stiff rod is relatively small, but the presence of a notochord is a major "body-plan" distinction of a chordate.

Further, it is just another small step from a worm with a stiff rod to a worm with a stiff rod and a head (e.g., *Haikouella*; Chen et al. 1999) or a worm with a *segmented* stiff rod (vertebrae), a head, and fin folds (e.g., *Haikouichthyes*; Shu et al. 1999). Finally add a fusiform body, fin differentiation, and scales: the result is something resembling a "fish". But, as soon as the stiff rod evolved, the animal was suddenly no longer just a worm but a chordate – representative of a whole new phylum! Thus these "major" changes are really minor in the beginning, which is the Precambrian–Cambrian period with which we are concerned.

Paleontologists always like more fossils, and in fact, there has been an explosion of Cambrian and pre-Cambrian fossils. Yet the inferences of the relationships among the various Cambrian and modern phyla do not depend just on fossils, but on many other lines of evidence, including morphology, biochemistry, and developmental biology.

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Haeckel's Embryos

The Discovery Institute's analysis of textbooks use of Haeckel's embryos is again overstated, to say the least. Textbooks don't reproduce Haeckel's embryonic drawings, except in historical context, though they *do* properly present comparative embryology as one of the areas of science that reflects evolution, or common descent. Textbooks present drawings or photos of embryos from different groups (such as vertebrate classes) to show how species that more recently shared a common ancestor are similar in embryology as well as morphology. Modern developmental biologists know that in vertebrates, the more recently two forms shared a common ancestor, the more similar their embryology will be; this is what is shown in the drawings/photos of embryos in textbooks, and it is entirely proper that they do so. Wells's analysis is full of red herrings.

For example, the charge that Ernst Haeckel intentionally "faked" his drawings is irrelevant, especially if Haeckel's drawings aren't reproduced anyway! The important question is whether textbooks, and more importantly developmental biologists, still rely on Haeckel's work. The answer is no. Textbooks rely on the work of modern day scientists, in which developmental biology is considered a key player in understanding evolution – and vice versa.

Peppered moths

The DI analysis is particularly misleading in its treatment of the peppered moth example of natural selection. Red herrings abound. Great attention is spent on the shocking notion that textbooks show "faked" photos wherein scientists glued moths to tree trunks – when supposedly moths "don't normally rest on tree trunks." The purpose of gluing a white and a black moth on a tree, of course, is to show protective coloration! It shows that it's harder to see a dark moth against a dark background, and vice versa! What is fraudulent about this? These aren't "faked" photos at all, because the purpose of the photo is not what is claimed.

Of course, whether moths sit on tree trunks is another red herring. The peppered moth story, you recall, argues that the proportions of light and dark moths change with pollution levels, and that the most likely reason for the frequency shifts is bird predation of contrasting moths against a dark or light background. The data presented in the DI analysis is incorrect: a higher proportion of moths actually rest on tree trunks, but this is irrelevant. No researcher doubts that the peppered moth rests in trees (Clarke et al. 1994; Majerus 1998), which means that the resting substrate is bark. *Entire* trees are stained by pollution – the leaves, twigs, branches, trunks, and the surrounding ground (Kettlewell 1973) – and so the colors of the moths are relevant no matter where on the tree they rest – trunks, trunk-branch junctions, branches, twigs, and even the leaves. Wells's argument implies that predatory birds can only see moths that are on exposed *trunks*. By making this argument, however, Wells shows an apparent ignorance of the ecology of birds and woodland ecosystems. If you walk into any forest, you can see that the birds fly from tree to tree, branch to branch, and hunt at all levels of the forest. Woodland species of birds that prey on moths and other insects live and hunt in the canopy (the leafy part of the trees). These birds are not hunting from outside, soaring above the trees like hawks, as Wells's argument would require.

The basic peppered moth story, as presented in textbooks, is accurate. Wells claims that the "classical story" is under question because "their comeback in many locations, however, preceded significant changes in the color of tree trunks," which is highly misleading. The basic story of color changes and pollution has been repeated on three continents in dozens of studies – with a few cases that are exceptions. These few cases do not make scientists throw out all the others; rather, they investigate what local conditions exist in the oddball sites. Should textbooks go into such excruciating detail? Well, we don't expect textbooks to present every nuance of a scientific example, or entire books at the high school level would be devoted only to cell division! Textbooks necessarily simplify. There is no need to change the textbooks, nor to eliminate this example.

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