



Texas Science Curriculum Standards

Recommendations for Dealing with Pedagogical and Scientific Problems

Ryan Valentine

Deputy Director
Texas Freedom Network Education Fund

Ben Pierce

Professor of Biology and holder of the Lillian Nelson Pratt Chair
Southwestern University

John Wise

Research Associate Professor of Biological Sciences and
Adjunct Associate Professor of Biological Sciences
Southern Methodist University

Executive Summary

In 2013 the Texas State Board of Education (SBOE) will undertake a once-a-decade adoption of new instructional materials (textbooks) for science classes. Those instructional materials will be based on new science curriculum standards revised by the SBOE in 2009.

The 2009 debate over Texas science standards — or TEKS, Texas Essential Knowledge and Skills — was mired in controversy, as a bloc of anti-science board members attempted to undermine, cast doubt upon or outright censor the treatment of evolution in the standards. While those board members did not wholly succeed in their anti-evolution crusade, they were able to insert language into the new standards that creationists hope will force publishers to weaken discussion of evolution. These compromised standards now include concepts and buzzwords that originate in the intelligent design/creationism community, creating the possibility that scientifically inaccurate and possibly unconstitutional content could find its way into Texas science materials.

Since the review and adoption of these instructional materials will involve a number of complicated legal and scientific issues, the Texas Freedom Network Education Fund asked Dr. Ben Pierce, Professor of Biology and holder of the Lillian Nelson Pratt Chair at Southwestern University in Georgetown, and Dr. John Wise, Research Associate Professor of Biological Sciences and Adjunct Associate Professor of Biological Sciences at Southern Methodist University in Dallas, to analyze four potentially problematic changes to the biology standards:

- Part 1** TEKS (3)(A) — requirement that students analyze “all sides of scientific evidence”
- Part 2** TEKS (7)(B) — requirement that students evaluate “sudden appearance, stasis...” in the fossil record
- Part 3** TEKS (7)(G) — requirement that students evaluate the “complexity of the cell”
- Part 4** TEKS (9)(D) — requirement that students evaluate the “DNA molecule for self-replicating life”

The subsequent analyses consists of several parts: (1) a review of the background and board debate that led to the adoption of the standard; (2) an examination of the scientific and pedagogical problems with the standard (especially connections to the intelligent design/creationism community); and (3) suggestions for how publishers might address these problematic standards and include scientifically rigorous information in their materials. (Dr. Wise authored all analysis of the pedagogical problems, while Dr. Pierce prepared the sections on how publishers can responsibly address each standard.)

The ramifications of Texas’ pending adoption of new science materials extend far beyond the borders of the state. Because of the influence the enormous Texas market has among textbook publishers, decisions made in Texas often influence textbook content in a number of other states around the country.

Part 1: ‘All Sides of Scientific Evidence’

(3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:

(A) in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;

Background

The wording of this standard was at the center of the controversy surrounding the 2008-09 revision to science curriculum standards at the Texas State Board of Education. The existing standard – which had been in place since 1998 – was worded as follows:

(3) Scientific processes. The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to:

*(A) analyze, review, and critique scientific explanations, including the hypotheses and theories, as to their **strengths and weaknesses** using evidence and information; (emphasis added)*

Even before the board began the revision process, the wording of this standard came under heavy criticism from the scientific community, which observed that the phrase “strengths and weaknesses” had been misused by evolution opponents to single out evolution for special and unfair criticism. More troublingly, evolution opponents used “strengths and weaknesses” as a way to introduce creationist/intelligent design arguments into science class. As a result, board-appointed curriculum writing teams — composed primarily of classroom biology teachers and scientists from Texas universities — proposed more rigorous scientific language to replace the old standard:

(3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions based on laboratory and field investigations.

(A) analyze and evaluate scientific explanations by using empirical scientific data, logical reasoning, and experimental and observational testing;

History suggests that promoters of intelligent design/creationism – and their allies on the Texas State Board of Education – will view the currently adopted language of TEKS (3)(A) “to examine all sides of scientific evidence” as an opportunity to introduce non-scientific materials into classrooms.

This draft language was initially approved by a narrow vote of the state board at the January 2009, meeting – over loud objections from the block of evolution-deniers on the board.

However, on March 27, 2009 – the final day of the 18-month long debate – new “compromise” language was cobbled together by a handful of board members in an impromptu meeting during a short break of the board. The resulting 13-2 vote inserted this new compromise language (which had not been vetted or even discussed with scientists, teachers or curriculum experts) into the Texas science standards at the eleventh hour. That compromise language is current standard (3)(A).

Scientific and Pedagogical Problems with Standard

While the removal of the “strengths and weaknesses” language from the previous version of TEKS (3)(A) represented a nominal defeat for evolution opponents in Texas, the revised wording of this standard – the expectation that students will examine “all sides of scientific evidence” – still leaves open the possibility that some school districts or publishers will emphasize nonscientific or pseudoscientific alternatives to sound science in our children’s science classrooms. As noted by the United States National Academies of Science, “the pressure to downplay evolution or emphasize nonscientific alternatives in public schools compromises science education.”¹

The “strengths and weaknesses” phrase found in the previous TEKS was used extensively in the past by organizations opposing evolution to promote the teaching of intelligent design/creationism. See for example “The Theory of Intelligent Design: A Briefing Packet for Educators,” where this phrase is used 11 separate times in language that encourages educators to teach nonscientific alternatives like intelligent design/creationism instead of sound science.² Additionally, the Science Teachers Association of Texas pointed out that “the ‘strengths and weaknesses’ language as stated in the [previous] TEKS was vague and misleading” and that “some groups ... with distinct religious views would have used this language to insert their religious beliefs ... which could have detrimental effects on not only what students learn in school, but on the quality of textbooks.”³

History suggests that promoters of intelligent design/creationism – and their allies on the Texas State Board of Education – will view the currently adopted language of TEKS (3)(A) “to examine all sides of scientific evidence” as an opportunity to introduce non-scientific materials into classrooms.

How Publishers Can Responsibly Address Standard

Publishers should recognize two important aspects of this new standard. First, the requirement to analyze, evaluate, and critique scientific explanations applies to all areas of science, not just evolution. Thus, publishers should not single out evolution for special treatment with regard to this standard. Second, the standard calls for examination of all sides of scientific evidence. There is no requirement to examine or discuss nonscientific ideas. This means that creationist and intelligent design arguments, which have been defined as nonscientific by the courts, need not be introduced.⁴

To meet this standard for evolution, publishers should present scientific evidence and reasoning for evolution, which is abundant and comes from multiple sources. Evidence for evolution comes from direct observation, DNA sequences, the fossil record, comparative anatomy, the geographic distribution of plants and animals, embryology, and many other sources. Succinct presentations of the evidence for evolution can be found in modern textbooks of evolutionary biology.^{5 6} More extensive but still accessible treatments are also available.^{7 8 9}

Part 2: ‘Sudden Appearance’

(7) Science concepts. The student knows evolutionary theory is a scientific explanation for the unity and diversity of life. The student is expected to:

(B) analyze and evaluate scientific explanations concerning any data of sudden appearance, stasis, and sequential nature of groups in the fossil record;

Background

This standard was a new addition to the Texas science TEKS in 2009. It originated at the January 22, 2009, state board meeting in an amendment proposed by Don McLeroy, R-Bryan, a self-identified young earth creationist. The original wording of McLeroy’s amendment – approved by the board in January – was as follows:

(B) analyze and evaluate the sufficiency or insufficiency of common ancestry to explain the sudden appearance, stasis and sequential nature of groups in the fossil record;

At the March 27, 2009, board meeting, Lawrence Allen, D-Houston, moved to strike this standard entirely. In a final appeal to preserve his proposal, McLeroy stated that the purpose of his standard was to argue against: “...the idea that all life is descended from a common ancestor by the unguided natural processes.”

Despite McLeroy’s protestations, Allen’s amendment to strike the standard prevailed by an 8-7 vote, and it was temporarily removed from the standards. However, another member of the board’s anti-evolution faction, Cynthia Dunbar, R-Richmond, immediately offered new “compromise” language. An amendment by Bob Craig, R-Lubbock, slightly revised Dunbar’s “compromise.” Dunbar’s wording – as amended by Craig – was approved by a vote of 13-2. This compromise language was the final version adopted by the board.

Scientific and Pedagogical Problems with Standard

Language referencing “sudden appearance” appears commonly in – and is closely associated with – the intelligent design movement.¹⁰ The inclusion of the expectation that students “analyze and evaluate scientific explanations concerning any data of sudden appearance ... in the fossil record” parallels the major thesis of a book promoting intelligent design/creationism written by five members affiliated with the Discovery Institute’s Center for Science and Culture.¹¹ Essentially the book, *Exploring Evolution*, promotes the hypothesis that the Cambrian Explosion, a geological period about 530 million years ago that revealed a great radiation of new animal body forms in the fossil record, cannot be explained by current evolutionary science. The book extends this thesis by requiring that an intelligent, supernatural agent was required to create the new animal body forms. None of these hypotheses are supported by scientific evidence (as explained below).

... TEKS (7)(B) should therefore be deemed as an attempt to open the Texas public school educational system to old, refuted, religiously based, nonscientific intelligent design arguments.

The intelligent design/creationism thesis that the Cambrian Explosion occurred too “suddenly” to be explained by modern biological science completely ignores a number of recent advances made in the science of evolutionary development that describe how animal bodies are made in a genetically modular way, thereby enabling rapid evolution.¹² These intelligent design arguments also ignore many pre-Cambrian organisms that show relatedness to Cambrian organisms (see, for example, endnote¹³). In short, misleading claims about the Cambrian Explosion made in the intelligent design community have been specifically refuted on many detailed grounds and in many different places.^{14 15 16}

This part of TEKS (7)(B) should therefore be deemed as an attempt to open the Texas public school educational system to old, refuted, religiously based, nonscientific intelligent design arguments. Likewise, the expectation that students analyze and evaluate scientific explanations of “stasis, and sequential nature of groups in the fossil record” is another use of language that can be traced to biased publications from anti-evolution, intelligent design/creationism proponents. The word “stasis” is used to describe the observation that fossil forms appear fully formed in the fossil record and remain relatively unchanged for long periods of time. In fact, these types of observations are fully compatible with evolutionary science. What other than fully formed organisms could be fossilized, for example? In addition, species that are well-adapted and exist in relatively stable environments would in many cases have the advantage of superior numbers over any organisms that would try to replace them. The predominant species would then be expected to dominate the fossil record over that period of time where its numbers predominated.

That fossils of transitional species (those species that are intermediate in characteristics between more widely separated organisms) are rare is a simple logical consequence of the time it takes the transition to occur versus the time of existence of the ancestor and descendant species. If the ancestor and then later the descendant species are well-adapted and are lucky enough to exist in stable environments, their total time on Earth can be very long. The transitions on the other hand can occur relatively quickly (in geologic time). The chance of finding a fossil of one of the transitional intermediates can therefore be low compared to finding a fossil of the stable ancestor or stable descendant species. Even though transitional fossils are rare and difficult to find, many transitional fossils species have been discovered by paleontologists. The existence of transitional fossils, as well as the general concept which these fossils support — namely, the sequential nature of descent from common ancestors — is so greatly supported by real scientific evidence that the vast majority of biological scientists and paleontologists accept these principles as fact.

There is a clear danger that the “stasis, and sequential nature” part of TEKS (7)(B) will be used to introduce discredited, scientifically falsified accounts from intelligent design/creationist publications that species appear in the fossil record without any transitional fossil evidence. Examples of these types of discredited arguments in intelligent design publications include the textbook supplement *Of Pandas and People*, which was the book at the center of the Dover trial¹⁷, and *Icons of Evolution*¹⁸, which pursues the discredited idea that major phylogenetic groups in biology arose without any connection through descent from a common ancestor. In the age of modern biology, the hypotheses that fossil transitions are not evident in the fossil record as presented in *Pandas* and *Icons* has been fully refuted by many legitimate fossil transition discoveries. These real discoveries fully support modern evolutionary theory.

Unfounded doubts about the cornerstone of evolutionary theory, namely descent from common ancestors, introduced into students’ learning expectations via the use of intelligent design/creationism

language like “sudden appearance” and “stasis, and sequential nature” have absolutely no place in biology classrooms or biology textbooks in Texas or anywhere else.

How Publishers Can Responsibly Address Standard

To meet this new standard, publishers need not and should not introduce creationist arguments, as they do not meet the requirement that students analyze and evaluate “scientific explanations.”

One way for publishers to satisfy this new standard is to include a discussion of evidence for and against the theory of punctuated equilibrium. This idea, first proposed by evolutionary biologists Niles Eldredge and Stephen Jay Gould in 1972, is a scientific explanation for long periods of no evolution (stasis) followed by the sudden appearance of new organisms in the fossil record.¹⁹

Punctuated equilibrium proposes that major evolutionary change occurs when new species arise and that, between these speciation events, many organisms undergo little change. Evolutionary biologists have long debated whether evidence supports or refutes the theory of punctuated equilibrium. The fossil record of some organisms does indeed suggest a pattern of stasis followed by bursts of rapid evolution,²⁰ but this pattern is not seen in other organisms.²¹ A review of 58 different studies that examined the theory of punctuated equilibrium across a range of organisms and geological periods concluded that sometimes evolution is gradual and sometimes punctuated — neither pattern is characteristic all of evolution.²² There is considerable disagreement over what processes are responsible for stasis in evolution.²³

Part 3: ‘Complexity of the Cell’

(7) Science concepts. The student knows evolutionary theory is a scientific explanation for the unity and diversity of life. The student is expected to:

(G) analyze and evaluate scientific explanations concerning the complexity of the cell.

Background

This standard was a new addition to the Texas science TEKS in 2009. It originated at the March 26, 2009, board meeting in an amendment proposed by Don McLeroy, R-Bryan, a self-identified young earth creationist. The original wording of McLeroy’s original amendment was as follows:

(G) analyze and evaluate the sufficiency or insufficiency of natural selection to explain the complexity of the cell.

During the board debate, McLeroy explained that this standard:

“...questions the two key parts of the great claim of evolution, which is [sic] common ancestry by unguided natural processes.”

The board approved McLeroy’s amendment by a vote of 8-6. The following day (March 27, 2009) Lawrence Allen, D-Houston, moved to strike this standard entirely, and by a vote of 8-7, the board approved his motion. However, Bob Craig, R-Lubbock, immediately proposed “compromise” language for this standard that was approved by a vote of 13-2. This compromise language was the final version adopted by the board.

Scientific and Pedagogical Problems with Standard

The language of this standard comes directly out of the intelligent design/creationism movement and represents discredited and scientifically falsified hypotheses. The expectation that students are required to “analyze and evaluate scientific explanations concerning the complexity of the cell” potentially opens the classroom and textbooks to discussions of thoroughly refuted creationist claims of the “irreducible complexity” of the cell’s components, an idea most recently popularized by Discovery Institute Fellow Michael Behe.

Behe was the primary witness for the defense in the 2005 Dover intelligent design trial, which ruled that intelligent design is simply creationism relabeled.²⁴ The cross examination of Behe by the plaintiffs’ attorney during this trial provides an important context for the appearance of the phrase “complexity of the cell” in the Texas science standards.²⁵ During the trial Behe testified that there were no explanations in the scientifically peer-reviewed literature that could explain how random mutation and natural selection, the cornerstones of evolutionary theory, could build a complex system. Unfortunately for the intelligent design creationist movement, however, this claim was patently proven false during cross

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examination. For a short and non-exhaustive listing of the scientifically falsified claims of Behe’s “irreducible complexity” hypothesis, including examples for the eukaryotic cilium, bacterial flagellum, blood clotting cascade, and the mammalian immune system, see endnotes ²⁶ and ²⁷. Mechanisms for the evolution of biological complexity by fully naturalistic, evolutionary mechanism have been postulated and are supported by experimental, observational and inferential evidence. (See endnote ²⁸ for a survey article.) These mechanisms include the incremental additions model, the scaffolding model, the co-option model and the emerging complexity model.

Good science education in general – and the writing of good science textbooks in particular – requires that the educator and author select hypotheses that are well supported by experimental and observational evidence. Any examples utilized as a part of this instruction should focus on successful scientific analyses of natural phenomena to explain particular details about the natural world and how it works. To allow the incorporation of falsified hypotheses such as those of Michael Behe’s “irreducible complexity” hypothesis into the Texas public school curricula and textbooks, for any reason other than as examples of bad scientific thought that has been conclusively rejected, does an injustice to our children. The time allotted for our students to learn real science is preciously short and should not be diluted with falsified information from nonscientific, intelligent design/creationist sources.

How Publishers Can Responsibly Address Standard

This standard requires that students analyze scientific explanations concerning the complexity of the cell—it does not require that publishers introduce nonscientific explanations, such as intelligent design arguments that complex cells can only be explained by invoking an intelligent designer. Although “complexity” is not defined in this standard, it is often interpreted in terms of the number of parts, number of genes, number of interactions between parts, or number of hierarchical levels. Publishers can discuss the scientific evidence for the evolution of cellular complexity, which is extensive and comes from a number of sources, including physical, biochemical, cellular, DNA, and fossil evidence.^{29 30} Scientific understanding of key steps in the evolution of cellular complexity has been greatly facilitated in recent years by progress in reconstructing the tree of life, which consists of the evolutionary branching patterns among all living organisms.³¹ Fossil evidence has also played an important role, providing calibration for events inferred by evolutionary trees, as well as independent verification of conclusions based on the evolutionary trees.

One of the most important steps in evolution of cellular complexity is the evolution of eukaryotic cells, which possess nuclear membranes and membrane-bound organelles lacking in simpler prokaryotic cells. One way that publishers can meet standard (7)(G) is by discussing scientific evidence for this key evolutionary transition. Much evidence supports the idea that eukaryotic organelles originated from free-living bacteria that were ingested by early cells and lived inside the cell as endosymbionts. This idea, called the endosymbiotic theory, proposes that the endosymbionts eventually evolved into chloroplasts, mitochondria, and perhaps even nuclear membranes.³² The endosymbiotic theory is supported by considerable biochemical, cellular, and genetic data.³³ Other studies provide scientific explanations for how the first cells evolved.^{34 35}

Although creationists often argue that evolution cannot explain complex cellular structures, the ability of natural selection and other evolutionary forces to generate complex adaptive features has been demonstrated theoretically^{36 37}, by computer simulation³⁸, and in the laboratory.³⁹ For example, a recent study demonstrated through ancestral gene reconstruction how the functional integration between a hormone and hormone receptor evolved through the process of Darwinian evolution⁴⁰.

Part 4: 'Self-Replicating Life'

(9) Science concepts. The student knows the significance of various molecules involved in metabolic processes and energy conversions that occur in living organisms. The student is expected to:

(D) analyze and evaluate the evidence regarding formation of simple organic molecules and their organization into long complex molecules having information such as the DNA molecule for self-replicating life.

Background

This standard was added to the Texas science TEKS in 2009. The amendment first appeared at the March 26, 2009, board meeting – the next-to-last day of the 18-month-long board curriculum revision process – in a proposal by Terri Leo, R-Spring.

During board debate, Don McLeroy, R-Bryan, explained that the new standard was “basically an origin of life amendment,” referencing public testimony provided previously by Ide Trotter, a well-known promoter of intelligent design.” The amendment passed on an 8-6 vote.

The following day, at the March 27 meeting, an attempt to strike this standard failed by a 5-10 vote.

Scientific and Pedagogical Problems with Standard

This is a clear example of the incorporation of intelligent design/creationist language into student expectations and parallels the “complexity of the cell” language found in the new TEKS (7)(G). The problematic assertion here stems mainly from the writings of Discovery Institute Fellow William Dembski. Dembski asserts that an intelligent designer must be involved in the creation of meaningful information whenever “specific complexity” is found because his own “Law of Conservation of Complex Specified Information” prevents natural selection from increasing the amount of information in a genome (see reference ⁴¹ and citations within). Dembski’s argument requires that information be complex (have a very low probability of being produced by random processes) and that it be “meaningful.” Meaningful information in the case of genetic sequences such as in DNA can be inferred to be those that increase the fitness of an organism (make it well adapted or better adapted to its environment).

Dembski’s proof of his “Law of Conservation of Complex Specified Information” has met with deep skepticism in the scientific community. Critics like Joe Felsenstein have gone so far as to term the proof “completely irrelevant” to biological-genetic informational complexity because it is “inapplicable to real biology.”⁴¹ Felsenstein points out that Dembski’s proof would require that a scrambled genome (the DNA sequences) of a well-adapted organism to be of equal fitness to an organism with an unscrambled,

... this is an example of the intelligent design/creationist tactic of pushing unsubstantiated, refuted and/or falsified hypotheses forward as a scientifically legitimate alternative to known, real and substantiated evolutionary mechanisms.

naturally selected genome. As Felsenstein points out, the scrambled genome would not have the same functionality, and hence the fitness of the organism with the scrambled genome would drop drastically. A large number of other criticisms of Dembski's unsupported views on information theory have also been published (endnote ⁴¹ points out 15 such articles).

As is the case with the "complexity of the cell" argument in TEKS (7)(G), this is an example of the intelligent design/creationist tactic of pushing unsubstantiated, refuted and/or falsified hypotheses forward as a scientifically legitimate alternative to known, real and substantiated evolutionary mechanisms. Good science education in general – and the writing of good science textbooks in particular – requires that the educator and author select hypotheses that are well supported by experimental and observational evidence. And any examples utilized as a part of this instruction should focus on successful scientific analyses of natural phenomena to explain particular details about the natural world and how it works.

To allow the unsubstantiated assertion that the mechanisms of evolution cannot lead to increasing complexity in biological systems does an injustice to our children. We must use the time available in our children's science education for presenting real evolutionary mechanisms – supported by scientific evidence – and not dilute curriculum materials with unsubstantiated musings of intelligent design creationists.

How Publishers Can Responsibly Address Standard

Publishers can meet this standard by discussing the extensive research undertaken by scientists over the past 60 years that focuses on how simple organic molecules such as sugars, amino acids, and nucleotides can develop spontaneously from chemical reactions taking place in conditions present during Earth's early history. Additional study has shown how simple organic molecules might have polymerized into long complex molecules such as DNA and RNA. For a summary of this research see Fry, 2006⁴² and Scott and Herron, 2007.⁴³

Much evidence suggests that early life was an RNA world.⁴⁴ RNA has the ability to store genetic information and to catalyze chemical reactions, both functions that are critical to life processes. Evidence for the important role of RNA in early evolution comes from observations that RNA can serve as catalytic molecules, the role of RNA in basic cellular processes such as replication and metabolism, RNA's integral part in the ribosome (the protein factory of the cell) and the important role of ribonucleoside triphosphates such as ATP and GTP in basic energy conversions in the cell.

Research has shown that populations of simple RNA molecules can evolve within a test tube. Scientists have examined the possibility of the evolution of self-replicating RNA molecules in laboratory experiments. The evolution of a completely self-replicating RNA molecule has not yet been achieved, but a number of advances have been made. For example, scientists have observed the evolution within a test tube of an RNA molecule that can add up to 14 nucleotides to a growing RNA chain.⁴⁵

ENDNOTES

- ¹ National Academy of Sciences. 2008. *Science, Evolution, and Creationism*. National Academies Press, Washington, D.C. p.43
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- ³ From the STATellite 52 (4) 16-17 2008 (online at <http://www.statweb.org/statellite/dec-08>) accessed Feb. 18, 2011.
- ⁴ http://www.pamd.uscourts.gov/kitzmiller/kitzmiller_342.pdf
- ⁵ Futuyma, D. J. 2009. *Evolution*, 2nd Edition. Sinauer Associates, Sunderland, MA
- ⁶ Freeman, S. and J. C. Herron. 2007. *Evolutionary Analysis*, 4th Edition. Pearson Benjamin Cummings, San Francisco.
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- ⁸ Coyne, J. A. 2008. *Why Evolution Is True*. Viking, New York.
- ⁹ National Academy of Sciences. 2008. *Science, Evolution, and Creationism*. National Academies Press, Washington, D.C.
- ¹⁰ <http://www.intelligentdesign.org/education.php> accessed on February 18, 2011 at the Discovery Institute's Center for Science and Culture webpage, "The Theory of Intelligent Design: A Briefing Packet for Educators" – see, for example, page 15.
- ¹¹ See Discovery Institute website, http://www.exploreevolution.com/who_is_this_for.php (accessed Feb. 18, 2011).
- ¹² Carroll, S.B. 2005 *Endless Forms Most Beautiful: The New Science of Evo-Devo*, Norton and Co. New York.
- ¹³ Derek E. G. Briggs and Richard A. Fortey, 2005 "Wonderful strife: systematics, stem groups, and the phylogenetic signal of the Cambrian radiation" *Paleobiology* 31:94-112
- ¹⁴ A detailed analysis of fallacious "sudden appearance" arguments from the National Center for Science Education, <http://ncse.com/creationism/analysis/sudden-appearance> (accessed Feb. 18, 2011).
- ¹⁵ A paleontologist's response to fallacious intelligent design arguments about the Cambrian Explosion, <http://whyevolutionistrue.wordpress.com/2010/02/13/a-paleobiologists-response-to-darwins-dilemma/> (accessed Feb. 18, 2011).
- ¹⁶ A listing of problems with intelligent design/creationism's claims about the Cambrian Explosion and other assertions, http://faculty.smu.edu/jwise/big_problems_with_intelligent_design.htm (accessed Feb. 18, 2011).
- ¹⁷ For a critique of the anti-evolutionary theory, pro-intelligent design *Of Pandas and People's* treatment of the fossil record, see the National Center for Science Education <http://ncse.com/creationism/analysis/excursion-chapter-4-fossil-record> (accessed Feb. 18, 2011).
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- ²¹ Chaline, J. and B. Laurin. 1986. "Phyletic gradualism in a European Plio-Pleistocene *Mimomys* lineage (Arvicolidae, Rodentia)." *Paleobiology* 12:203-216.
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- ²⁴ See Judge John Jones, III decision: http://www.pamd.uscourts.gov/kitzmiller/kitzmiller_342.pdf. (accessed February 18, 2011).
- ²⁵ See <http://www.talkorigins.org/faqs/dover/day11pm.html#day11pm132>, and especially <http://www.talkorigins.org/faqs/dover/day11pm2.html> for transcripts of the cross-examination of Behe. The latter concentrates on Behe's irreducible complexity claim. (accessed February 18, 2011).

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- ²⁶ See Niall Shanks and Karl Joplin. 2000. *Reports of the National Center for Science Education* 20 (1-2) 25-30. <http://ncse.com/rncse/20/1-2/mousetraps-men-behe-biochemistry>. (accessed Feb. 18, 2011).
- ²⁷ See “Big Problems with Intelligent Design” website at http://faculty.smu.edu/jwise/big_problems_with_intelligent_design.htm#Irreducible_complexity_fails_scientific_testing. (accessed Feb. 19, 2011).
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