

Analysis of Ohio's "Critical-Analysis" Standard & Lesson Plan

The Standards

- The standards single out evolution for special and scientifically unwarranted criticism.
- Such terms as *critical analysis*, *critical evaluation*, and *critical thinking* have become publicly associated with attempts to introduce pseudoscience into high school curricula.
- The benchmark & indicator were given the benefit of the doubt initially, but now that the lesson plan has explicated the meaning of the standards language, there is no doubt that the standards endorse creationism.

The Lesson Plan

- The lesson undermines students' comprehension of the scientific method.
- The debate format of the lesson plan is pedagogically unsound.
- The lesson plan does not promote critical thinking skills.
- The lesson plan misleads students into thinking that evolution is a scientifically controversial theory.
- The lesson plan does not accurately represent the process by which scientific controversies are resolved.
- The lesson plan is based on creationist materials and includes claims that have no scientific basis.
- The lesson plan includes an inaccurate and misleading definition of *Theory* and many other terms.
- The lesson plan misrepresents the scientific meaning of *microevolution* and *macroevolution*.

The Aspects of Evolution

- The five aspects are drawn directly from creationist sources.
- None of the aspects provides a challenge to the theory of evolution.
- The criticisms of evolution presented simply do not exist in the peer-reviewed scientific literature.
- **Homology** is an invalid argument for special creation of humans.
- **Fossil Record** is an invalid argument that the fossil record does not support evolution.
- **Antibiotic Resistance** is an invalid argument against evolution of new species.
- **Peppered Moths** misrepresents an example of natural selection
- **Endosymbiosis** is an invalid argument against the evolution of eukaryotic cells.

The Standards

- **The standards single out evolution for special and scientifically unwarranted criticism.**

Ohio's standards single out the theory of evolution as the only scientific topic to be subject to critical analysis. In *Kitzmiller v. Dover*, p. 49, Judge Jones writes:

In summary, the disclaimer singles out the theory of evolution for special treatment, misrepresents its status in the scientific community, causes students to doubt its validity without scientific justification, presents students with a religious alternative masquerading as a scientific theory, directs them to consult a creationist text as though it were a science resource, and instructs students to forego scientific inquiry in the public school classroom and instead to seek out religious instruction elsewhere.

Ohio's standards also single out the theory of evolution for special treatment. The intent of the standards is made clear in the *Critical Analysis of Evolution* lesson plan. As in *Kitzmiller v. Dover*, the status of evolution in the scientific community is misrepresented and students are not only directed to creationist texts - the content of those texts is included in the lesson plan.

On p. 57, Judge Jones also writes:

Second, the Dover School Board singles out the scientific theory of evolution, specifically and repeatedly targeting it as a “theory” with “[g]aps,” “problems,” and inadequate empirical support. In singling out the one scientific theory that has historically been opposed by certain religious sects, the Board sent the message that it “believes there is some problem peculiar to evolution,” and “[i]n light of the historical opposition to evolution by Christian fundamentalists and creationists[,] . . . the informed, reasonable observer would infer the School Board’s problem with evolution to be that evolution does not acknowledge a creator.”

Ohio's standards send the same message, particularly since they have been interpreted in the *Critical Analysis of Evolution* lesson plan in exactly the way that Judge Jones describes.

- **Such terms as *critical analysis*, *critical evaluation*, and *critical thinking* have become publicly associated with attempts to introduce pseudoscience into high school curricula.**

Courts in Louisiana, Georgia, and Pennsylvania have ruled on the use of the phrases *critical thinking* and *critically considered* that were used in disclaimers by various school boards. In each case, the courts have rejected the professed secular purpose. Most recently, in *Kitzmiller v. Dover*, p. 130, Judge Jones wrote (emphasis added):

Although Defendants attempt to persuade this Court that each Board member who voted for the biology curriculum change did so for the secular purpose of improving science education and to exercise **critical thinking** skills, their contentions are simply irreconcilable with the record evidence. Their asserted purposes are a sham, and they are accordingly unavailing, for the reasons that follow.

Bills before legislatures in Michigan, Missouri and Utah single out evolution with the phrases *critically evaluate*, *critical analysis*, and *critically analyze*. The Michigan legislature uses this wording:

Use the scientific method to **critically evaluate** scientific theories including, but not limited to, the theories of **global warming and evolution**.

These bills have the obvious intent of introducing unscientific criticisms of evolution into the science curriculum. Michigan's attempt to include global warming with evolution is a sham designed to deflect the criticism of singling out evolution. The same sham has been suggested to the Ohio Board of Education by board member Deborah Owens Fink.

The Lesson Plan

- **The debate format of the lesson plan is pedagogically unsound.**

Students are asked to take sides in a debate, with one side presumably representing the scientific theory of evolution and the other side (although students are not told this) representing refuted creationist claims.

According to one outside reviewer:

The lesson relies solely on the vacuous pedagogical tool of staged debate. There is no room or value placed on intellectual growth or learning; rather, indoctrination is the apparent point of this lesson.

An ODE staff scientist wrote:

ODE does not support this kind of teaching strategy.

- **The lesson plan does not promote critical thinking skills.**

Outside field test reviewers wrote:

From the perspective of how to debate, resort to rhetoric in the absence of data or just plain creation of red-herrings – if those things represent "critical thinking skills" – it's brilliant. As a tool to develop objective scientific critical thinking skills it is an insult.

and

Not scientific critical thinking

- **The lesson plan misleads students into thinking that evolution is a scientifically controversial theory.**

There is absolutely no scientific controversy about the material that is customarily taught in a tenth grade biology class. This material represents the fundamentals of the subject, about which there is virtual unanimity among biologists. To present it otherwise, as this lesson plan does, is a serious abrogation of the OBE's responsibility to students.

The lesson plan implies that the theory of evolution has flaws that are not addressed in the students' textbooks. It further implies a conspiracy of silence to suppress these controversial ideas. In reality, flaws in a scientific theory always provoke a flurry of research that can be traced in the scientific literature. There is no scientific literature supporting *any* of the so-called challenges to evolution in the lesson plan. In fact, all of these challenges are demonstrably false.

- **The lesson plan does not accurately represent the process by which scientific controversies are resolved.**

Scientific controversies are not resolved by debate. They are resolved by looking at evidence, and by proposing experiments that have the potential of falsifying at least one of the competing ideas.

Students would be better served by looking at the historical development of the theory - at the evidence and the key experiments that helped form the scientific consensus.

- **The lesson plan is based on creationist materials and includes claims that have no scientific basis.**

An earlier draft of the lesson plan had explicit references to creationist materials. The content of the lesson plan can be easily traced to these, and other, creationist sources.

The religious motivation behind the lesson plan was recognized by outside field test reviewers, in response to the prompt "The lesson connects the content and skills with the real world":

Not the real scientific world. The real religious world, yes! The real world based on faith, yes! The real world of fringe thinking, yes.

and

The arguments presented as exemplary statements for students in a debate connect with the real world of religious beliefs and the current rise of evangelical/pentacostal cognitive disequilibria.

The so-called challenges to evolution appear nowhere in the scientific literature, but are found only in creationist materials. When asked for scientific references to support the challenges, Dr. Bobby Bowers responded:

... we've found that all of them are legitimate disagreements in the scientific community

and

... our researcher at the office went to the public library ... and did some online work and was able to find them with relative ease within three or four days.

These references have been requested by board member Martha Wise and by some members of the public. They have never been produced. It's not surprising; they don't exist.

- **The lesson plan includes an inaccurate and misleading definition of *Theory*.**

According to the lesson plan, a scientific theory is:

A supposition or a system of ideas intended to explain something, especially one based on general principles independent of the thing to be explained.

A scientific theory is *not* a supposition. A scientific theory is not *intended* to explain *something* – a scientific theory *successfully* explains a *broad range* of phenomena, bringing a coherent explanation to otherwise disparate facts. The phrase *based on general principles independent of the thing to be explained* is nonsensical.

A theory is predictive – it predicts new phenomena that would be otherwise unsuspected, and it must be tested against those predictions.

The definition of *theory* given in the lesson plan explicitly confuses a scientific theory with the colloquial understanding of a theory being a supposition. Courts have recognized this strategy as an attempt to undermine students' understanding of the significance of the theory of evolution. For example, in *Kitzmiller v. Dover*, p. 40, Judge Jones writes (quoting from *Selman v. Cobb County*):

This paragraph singles out evolution from the rest of the science curriculum and informs students that evolution, unlike anything else that they are learning, is “just a theory,” which plays on the “colloquial or popular understanding of the term [‘theory’] and suggest[ing] to the informed, reasonable observer that evolution is only a highly questionable ‘opinion’ or

a ‘hunch.’” ... Immediately after students are told that “Darwin’s Theory” is a theory and that it continues to be tested, they are told that “gaps” exist within evolutionary theory without any indication that other scientific theories might suffer the same supposed weakness. As Dr. Alters explained this paragraph is both misleading and creates misconceptions in students about evolutionary theory by misrepresenting the scientific status of evolution and by telling students that they should regard it as singularly unreliable, or on shaky ground.

In *Kitzmiller* and *Selman*, the denigration of the term *theory* was implicit. In this lesson plan, the denigration is explicit. And of course, this lesson plan follows the same trajectory, pointing out supposed "gaps" in the theory of evolution.

- **The lesson plan misrepresents the scientific meaning of *microevolution* and *macroevolution*.**

Nothing betrays the lesson plan's creationist roots more than its insistence on a misleading distinction between microevolution and macroevolution. This is an attempt to deny the possibility of speciation while acknowledging the reality of "small but limited changes in populations and species." (From Aspect 3: Antibiotic Resistance.) No such distinction is made in the scientific literature. According to one ODE staff scientist:

There is no difference between micro and macroevolution except that genes between species usually diverge, while genes within species usually combine. The same processes that cause within-species evolution are responsible for above species evolution.

The Aspects of Evolution

Some (but by no means all) errors in the aspects are noted. Text from the lesson plan is given in italics. Some of the interspersed comments are taken from an analysis prepared by scientists affiliated with Ohio Citizens for Science. These are designated by OCS below.

Aspect 1: Homology

This aspect suggests to students that evidence for common ancestry can be ignored. It is a direct appeal to special creation of species. The claims made in the challenging sample answer are false. They have no basis in any scientific literature, but appear only in creationist publications.

From the OCS analysis:

The challenging sample answer does not consider the significant genetic data that has revealed deep similarities between highly divergent animal groups. These are the HOX genes, and these genes show a consistent pattern of gene duplication and modification moving from the most primitive multicellular animals to the most derived. This genetic data provides an independent source of data in support of common descent. The role of gene regulation is ignored by this critique.

Brief Challenging Sample Answer:

Some scientists think similarities in anatomical and genetic structure reflect similar functional needs in different animals, not common ancestry.

The lesson plan does not name these scientists, does not specify if they have any relevant expertise, and does not give any references for their published work. There is, in fact, nothing in the scientific literature to support this claim.

The nucleotide sequence of hemoglobin DNA is very similar between chimps and humans, but this may be because they provide the same function for both animals.

This speculation is unsupported by anything in the scientific literature. It is clearly false, since hemoglobin serves the same function in many different animals without there being such strong genetic similarities.

Also, if similar anatomical structures really are the result of a shared evolutionary ancestry, then similar anatomical structures should be produced by related genes and patterns of embryological development. However, sometimes, similar anatomical structures in different animals are built from different genes and by different pathways of embryological development.

An early version of this included "... many times, similar anatomical structures in different animals are built from different genes ..." An ODE staff scientist responded:

... inaccurate ... Similar structures in closely related organisms are always controlled by the same genes, no exceptions.

The change in the text from "many times" to "sometimes" leaves the inaccuracy in place.

Scientists can use these different anatomical structures and genes to build versions of Darwin family trees that will not match each other. This shows that diverse forms of life may have different ancestry.

The last sentence is arguing against common ancestry and for special creation of species. This conclusion does not follow from the preceding sentence. Even when questions are raised in the scientific literature about the precise relationships among some species, the principle of common ancestry is never called into doubt.

Aspect 2: Fossil Record

This aspect misrepresents the significance of the fossil record to the theory of evolution. Students are falsely led to believe that the fossil record implies the "sudden appearance of new biological forms." It is again an argument, not from science, but from creationist literature.

Brief Supporting Sample Answer:

The fossil record shows an increase in the complexity of living forms from simple one-celled organisms, to the first simple plants and animals, to the diverse and complex organisms that live on Earth today. This pattern suggests that later forms evolved from earlier simple forms over long periods of geological time.

This misrepresents the fossil evidence for common descent. From the OCS analysis:

The increase in observed complexity is not the basis for common descent, which is what "later forms evolved from early simple forms" means. Among the main bases for the theory of common descent are (1) the distribution of homologous organs and structures (2) the observed biogeographical distribution of species, (3) the many transitional forms observed in the fossil record, and (4) the concordance of phylogenetic trees constructed from morphological and molecular data. The observed change in complexity over geological time has no particular bearing on the theory of common descent.

Macroevolution is the large-scale evolution occurring over geologic time that results in the formation of new taxonomic groups. The slow transformations are reflected in transitional fossils such as Archaeopteryx (a reptile-like bird) and mammal-like reptiles. These transitional fossils bridge the gap from one species to another species and from one branch on the tree of life to another.

Transformations occur at different rates — it is inappropriate to refer to them as uniformly "slow."

The sample answer misrepresents transitional fossils. They do not "bridge the gap from one species to another species." From the OCS analysis:

... transitional forms are recognized as we move down the tree of life into the past, not by trying to jump from limb to limb.

Brief Challenging Sample Answer:

Transitional fossils are rare in the fossil record.

This is false. Transitional fossils are far from rare: most fossils are transitional.

A growing number of scientists now question that Archaeopteryx and other transitional fossils really are transitional forms.

According to an ODE staff scientist:

This sentence is a lie.

There are no scientific publications that support the claim. There has been much debate over the classification of the many different fossils showing bird-like features, and their relationship to modern birds, but the debate does not call into question the transitional nature of the fossils.

The fossil record as a whole shows that major evolutionary changes took place suddenly over brief periods of time followed by longer periods of "stasis" during which no significant change in form or transitional organisms appeared (Punctuated Equilibria). The "Cambrian explosion" of animal phyla is the best known, but not the only example, of the sudden appearance of new biological forms in the fossil record.

The Cambrian explosion is not sudden but took place over tens of millions of years. The claim of sudden appearance of new biological forms is a creationist argument for separate creation of species. The fossil evidence from that time does not support that conclusion. The evidence in early Cambrian and Precambrian fossils is consistent with predictions of evolutionary theory and in no way constitutes a "challenge" to the theory.

Aspect 3: Antibiotic Resistance

Brief Challenging Sample Answer:

The increase in the number of antibiotic resistant bacterial strains demonstrates the power of natural selection to produce small but limited changes in populations and species. It does not demonstrate the ability of natural selection to produce new forms of life.

This is a strawman argument. One does not expect to see bacteria to evolve into anything other than bacteria in response to pressure from antibiotics.

The phrase "forms of life" is not a scientific term. The meaning is, presumably intentionally, vague.

Although new strains of Staphylococcus aureus have evolved, the speciation of bacteria (prokaryotes) has not been observed, ...

Speciation of bacteria has been observed. A well-known example is the evolution of a species of nylon-ingesting bacteria.

... and neither has the evolution of bacteria into more complex eukaryotes.

Scientists do not expect to observe the evolution of bacteria into more complex eukaryotes, any more than one expects to observe a cat evolve into a dog. This is a creationist strawman argument.

Aspect 4: Peppered Moths (Biston betularia)

The peppered moth example is presented as a challenge to evolution, as if the theory of evolution somehow depended on this one example. Even if the example were pure myth, this would not constitute any evidence against evolution. Its inclusion in the lesson plan as a challenge to evolution is a misrepresentation of its status.

Brief Challenging Sample Answer:

English peppered moths show that environmental changes can produce microevolutionary changes within a population. They do not show that natural selection can produce major new features or forms of life, or a new species for that matter—i.e., macroevolutionary changes. From the beginning of the industrial revolution, English peppered moths came in both light and dark varieties. After the pollution decreased, dark and light varieties still existed. All that changed during this time was the relative proportion of the two traits within the population. No new features and no new species emerged.

The peppered moth example is given in introductory biology courses as an easily understood illustration of natural selection. It is not intended to illustrate speciation, and the evolution of a new moth species was not expected under the circumstances illustrated here. The above passage is a strawman argument.

This has been pointed out by an ODE staff scientist:

The study was not designed to look at species formation.

In addition, recent scientific articles have questioned the factual basis of the study performed during the 1950s. Scientists have learned that peppered moths do not actually rest on tree trunks.

This is false. Peppered moths do spend a significant amount of time resting on tree trunks. (See Majerus' 1998 book *Melanism*)

This has raised questions about whether color changes in the moth population were actually caused by differences in exposure to predatory birds.

That predatory birds had an influence on the color changes is not disputed. There are questions about whether there were other factors as well.

Aspect 5: Endosymbiosis (formation of cellular organelles)

Brief Challenging Sample Answer:

Laboratory tests have not yet demonstrated that small bacteria (prokaryotic cells) can change into separate organelles, such as mitochondria and chloroplasts within larger bacterial cells. When smaller bacterial cells (prokaryotes) are absorbed by larger bacterial cells, they are usually destroyed by digestion. Although some bacterial cells (prokaryotes) can occasionally live in eukaryotes, scientists have not observed these cells changing into organelles such as mitochondria or chloroplasts.

From the OCS analysis:

This is a common argument used by creationists of all stripes. They demand that evolutionary processes be demonstrated in their entirety in a controlled laboratory setting. That is not the manner in which evolutionary processes are reconstructed. Rather they rely on multiple observations from a wide range of disciplines that together provide a powerful and compelling theory. Such challenges are akin to demanding that scientists synthesize a granite rock in the lab before the molten origin of igneous rocks can be accepted.

Brian McEnnis
Department of Mathematics
The Ohio State University