

## **The Tangled Bank Gets More Tangled: How to Approach the Teaching of Evolution**

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### **INTRODUCTION**

In 1859, Charles Darwin ended his “Origin of Species” with what is surely one of the most evocative paragraphs in natural science. “It is interesting to contemplate a tangled bank”, he begins. Near the end of that paragraph, Darwin fairly shouts of the magnificence of both nature and God...”There is grandeur in this view of life...having been originally breathed by the Creator into a few forms or into one...” It is possible that his construction of this paragraph left Darwin convinced that he had settled any religious disagreements concerning his ideas. Nothing could be further from truth. The tangled bank is more tangled than ever. In my opinion, the largest burden for the tangled state of evolution teaching lies squarely with the leaders of local and state school districts which for decades abdicated responsibility for teaching solid science, resulting in little or no teaching of evolution and its supporting concepts. My own school system can be used as a typical case study.

In 1983, the Cobb County, Georgia, school district weathered the “Equal time for Creationism and Evolution” nightmare with official equal time policies which wreaked havoc on science teaching. These policies did not withstand much challenge, but did result in several months during which teachers were subjected to observers timing evolution lessons with stopwatches. Our school board even tried, for a time, to make Biology an optional course for graduation, so that our students would not be unfairly tainted with the “one-sided” views of modern biology. Fortunately, our state curriculum forbade abandoning biology. But that was at the beginning of my teaching career, and that was long ago. I imagined that the most difficult hurdles had been crossed and the most difficult problems had been solved.

But, twenty years later, a different Cobb school board did much worse. First, in March, 2002, they bowed to political expedience when some parents presented a petition opposed to the adoption of our Biology textbooks (*Biology* by Miller and Levine, and *Concepts and Connections* by Campbell) due to their “secular emphasis on evolution.” Fortunately, our Board voted to adopt the texts, but only if a “statement” was affixed to the inside front cover. School board members stated that they intended to encourage academic freedom, but actually they diminished the theory of evolution (and theories in general) and opened the door for the teaching of “disputed views of origins.” A lawsuit was filed to have these stickers removed, and a new policy was adopted in August, stating that teachers are allowed to teach “disputed views” in science. I was able to testify in Federal court against my school board’s decision. I found that some school district staff turned away from me and would not speak to me after that day. I also found school district staff that came up to me in quiet hallways, looked both

ways and then whispered their support to me ... what were they afraid of? What were they angry about?

At the last minute (literally one minute before a board meeting packed with citizens), an addendum was added to the policy, requiring the teaching of evolution and specifically prohibiting the teaching of creationism. The new policy allowed the teaching of “alternative scientific theories”, by which the school board meant “intelligent design theory.” After this meeting, creationist citizens, of which there were many, cheered and believed they had “won” the day. However, people who discussed the policy more carefully were not so sure. The board was banning the teaching of creationism. Why did they think they won? What did the board want? What will occur when the new regulation is formulated?

What we can say for sure is that their idea of “compromise” was to do what creationists endorse, which is to “teach the controversy.” In a nation grounded in fair play and equal rights, it is easy to claim that teaching “alternatives to evolution” is the fair thing to do. But the “controversy” is not scientific in nature. Our school board had needlessly singled out evolution for a warning to our students and their parents. Further, they had clouded the definition of the word theory to mean a simple guess, rather than an explanation well-supported by evidence. Adding non-scientific ideas to our science curriculum is the worst possible solution. The result in our teaching community is that teachers disagree on the implementation of the policy. Some think the policy means for us to teach evolution only. Other teachers think we are meant to teach “intelligent design” as legitimate science. Still others wish to teach “intelligent design” as pseudoscience, in the same way that astronomy teachers might teach the basics of astrology.

Why should anyone object to this idea? After all, don't most Americans believe in God anyway? Sure they do. And a lot of scientists believe in God, too. But the real objections to intelligent design ideas stem from the fact that ID enthusiasts claim to have scientific proof of the action of God. This notion causes negative reactions among theologians as well as scientists. Scientific inferences cannot extend to the transcendence people experience when they confront the sacred, the spiritual, the holy. Those terms have no meaning in science. Love, honor, courage, faith, hope and prayer are all concepts with deep religious meaning but with little scientific meaning, for they are quantities that are not measurable with instrumentation. Controversy, perhaps, but not scientific. It is a cultural, religious controversy. It has no place in a science course.

### **WAYS OF KNOWING**

Where is the source of this conflict and how can it be handled best in a science classroom? The conflict, of course, comes from fear and anger. The fear comes from a religious notion that evolution is incompatible with the doctrine of God as a creator. The anger comes from the idea that evolution may be a ploy to convince our children to doubt or deny religious faith. The best explanation for the problem can be found in the writings of William Cobern, a leading researcher in the field of world view in science education. World view, states Cobern, is formed from the underlying presuppositions with which people understand the

world. World view includes rational as well as non-rational, emotional, components. Learning science is not strictly based on logical concept development. Studying the rationality of a high school student cannot give us a complete picture of the student's learning processes. Some students view some scientific concepts as antithetical to those parts of their life that are most important to them. They may believe that science contradicts their family and their religion. It would be very difficult for a student to accept a science concept from school if it caused them difficulty in their family, or limited their social or job opportunities. Accepting evolution could be a tacit sentence of banishment in some communities. Most high school students demonstrate the ability to partition their beliefs into "school views", which allow them to learn and pass science tests, and "real views", the way they really believe the world works. Some students find it easy to answer questions about evolution, giving the teacher the impression that they understand and accept the premises of natural selection. But many students who answer evolution questions "correctly" according to a science teacher still have serious reservations about whether or not evolution is "true". Even more students answer questions about evolution poorly, indicating a lack of familiarity with the basic premises of evolution theory. Even those students who say they accept that evolution is really true often explain it in Lamarckian terms, or describe changes over time in individual organisms rather than in populations.

### **BEST PRACTICES: Standards MATTER**

What can be done about this?

First, strong, well-written state and local standards must be adopted. They are the scaffold upon which all other decisions within the state will be based. A set of strong state standards (as in Indiana or North Carolina) make it nearly impossible for a teacher to omit evolution or include pseudoscience. The state standards should probably SPELL OUT what is meant by evolution. A five or six sentence description of the main ideas of evolution could be sufficient.

Second, it is critical that science teachers (grades K-16) have excellent training in the concepts in biological evolution and the pedagogical content knowledge necessary to discuss the science behind evolution without insulting the personal beliefs of a student. It is especially important that teachers reflect carefully on their own understanding of evolution in relation to their own religious outlook. In my own state of Georgia, it is estimated that at least one third of all certified teachers feel both ill-prepared for and ill at ease when asked to teach evolution and related concepts. Any objections to the teaching of evolution will be felt first by the classroom teacher. It is in those early moments of questioning when a well-prepared teacher can explain the necessary attributes of a high quality science education. In many cases, these educational encounters can be some of the most meaningful, productive and lasting lessons taught.

Third, teachers must be mindful that teaching science, no matter how it is accomplished, does impact upon a student's preconceived notions of the world, including their religious world view. Therefore, science must be taught as a way

of knowing the world with identifiable limitations. It must be stated very clearly that science cannot investigate certain phenomena, which may be called transcendent or religious in nature. But, at the same time, it must be noted that science does intersect with religion frequently, in matters of ethics as well as in matters of origin and fate of the universe. It is certainly advisable that teachers deliberately teach the provisional nature of science by purposely asking students to identify those questions which are and are not based on scientific principles. Building a strong relationship of trust with students can help the students understand that science education is not about overturning religious ideas, but rather should be focused on increasing understanding of science. It is the sincere hope of all science educators that this process of increasing understanding will be a lifelong journey for every student.

### **A WAY TO INCORPORATE IMPORTANT CONCEPTS OF EVOLUTIONARY BIOLOGY INTO A SEMESTER**

Classroom Activity: "Agree or Disagree: The Nature of Science"

This activity should be completed within the first few days of the semester, so that students may then refer back to their learning throughout the school term. Students are presented with a dozen or so statements and asked to indicate whether they agree or do not agree with them. I present the statements in a PowerPoint presentation and ask students to indicate their agreement covertly by a "thumbs up or down" sign. Sometimes students give me a "thumb sideways" sign, indicating that they can't decide. This can also be accomplished with student response devices. I quickly count agreements and make a note of the number of students disagreeing with each statement.

#### **SAMPLE STATEMENTS FOR ACTIVITY:**

Agree or Disagree?

1. Birds eating rice thrown at weddings swell up and die (even burst).
2. Giving chocolate to dogs causes toxic (poison) reactions.
3. When cows fall asleep standing up, it is easy (and fun!) to sneak up next to them and tip them over.
4. Bugs can crawl into your ear and live there, laying eggs.
5. Earthworms come up onto the sidewalks after a heavy rain to avoid being drowned in their underground tunnels.
6. People licking toads have hallucinations.
7. Daddy long legs (harvestmen) have the most toxic venom of any arthropod. They don't kill people because their fangs are so weak.
8. Goats will faint if shocked by a loud noise.
9. Animals exposed to radioactive waste mutate and turn into other types of animals.
10. The President of the United States has the authority to stop construction of new roads in a National Forest.
11. Stopping construction of roads in a National Forest slows down the extinction of species.

12. John Lennon wrote better music than Peter Tchaikovsky.

When we have quickly gone through all 12 statements, I then explain that “this is not how science is done. We do not simply ask people whether they do or do not agree with statements. We must gather measurements as evidence for the statements.”

Then I ask the students to go back with me through the statements to determine whether there are any measurements or observations which might provide evidence for or against a proposition.

For example, the first statement is “Bird eating rice thrown at weddings swell up and die (even burst).” Many students believe this to be true, and they tell me their church members tell them this is true. I have students explain how observations in the world might support or not support this statement. This, I tell them, is a real question that can be answered by doing real science. We can examine areas near rice paddies and see if birds eat the seeds, and, if so, if they burst afterwards. We could count dead birds in areas near weddings. We could even experiment on captive birds. The result is that we would see that birds do not burst, anymore than people do when eating pecans or other raw seeds.

Some statements are included which are known to be true (people licking toads can have hallucinations) and some statements are included which are questions for law, art, or music. I purposely omitted questions about religion since they could be problematic for students to answer in class, even covertly.

When the activity has ended, I find very few instances of unanimity among my students. I explain that there are some questions which science can answer very well, like how species change over time. Science can determine whether dogs are harmed by chocolate, whether harvestmen have toxic bites, and whether building roads in forests can harm endangered species. Science can't really be used to determine whether the President has certain legal powers, or who is the better composer. Those are legal and artistic questions. In the same way, there are religious questions which science does not answer very well. What is the purpose of our lives? Do we have a soul? Where did our soul come from and what is our eventual fate? What is the relationship of God to the world? These questions are certainly worthwhile and very serious questions. Science does not provide us with a means of answering them. We must rely on our heart, our faith, prayer, inspiration, love and intuition. None of those factors can be measured with scientific instruments.

## HOW SHOULD I RESPOND TO STUDENT QUESTIONS ABOUT EVOLUTION AND FAITH?

Several biology teachers have spoken to me about how to properly present their reasons for teaching evolution, and how to react in their classroom to questions about religious views. Usually, these teachers are a bit confused about their own religious beliefs and where evolution may fit into their particular faith's doctrines. Teachers are usually the only adult in a room with many children, and there is nobody to rely on other than themselves. Before any

questions from students arise, it is best that teachers understand the concepts of evolution thoroughly, so that the concepts are presented in the same manner as photosynthesis and cell respiration (concepts which rarely produce questions about religion). Additionally, I suggest two things. First, I urge teachers to contact their own religious leaders and the headquarters of their denomination and ask if there is an official view from their church body about acceptance or rejection of evolution. Second, I ask them if they would be willing to teach about evolution in their churches. It could be that full disclosure of what biological evolution means would generate healthy religious discussions within congregations. Certainly, it is worth trying.

I also offer sample statements similar to things I have said in my own classroom.

**Sample student question: “How can scientists say that animals evolved when the Bible says that they were created by God?”**

My sample answer: “That is a very interesting and important question. Thank you for asking it. People have been trying to answer that question and many others like it for centuries. For many people, our religious faith is the most important part of our lives. We strive to learn more and more about religious faith as we grow. In some ways, science can help to inform our religious studies. For most religious questions, though, science really does not have any way to investigate the answers.

Remember that science is powerful but very limited. We can use the methods of science to investigate anything that can be measured. Hypotheses about God and His action in the world really cannot be measured or detected with scientific instruments. Science is not atheistic. Science simply does not have any way to detect God. Earlier this semester, we studied cells, protein molecules, and tiny atoms. At no time was God mentioned. This does not mean that scientists who study cells, proteins and atoms are atheists. In fact many scientists do believe in God. That is a religious choice, not a scientific one.

What can scientists say about evolution? Their first job is to define very carefully exactly what they mean by the word. That is what I have tried to teach you here...what do scientists mean when they talk about the theory of evolution? They are also supposed to show us evidence for the theory, because a theory is an explanation of observations based on a large amount of evidence. Right now, the theory of evolution as I have taught it in this class is the most widely used theory to explain observations of changes in species seen now and in the past through fossil evidence. We expect changes to happen in the future. Scientists use the theory of evolution every day. Peer-reviewed science journals are filled with research reports in which scientists report evidence which uses the theory of evolution as its framework. When scientists go to professional conferences to report the results of their studies, you will not hear scientists arguing about whether or not the theory of evolution is correct. What they argue about is the exact mechanism....exactly how has evolution taken place in the past and how is it occurring right now? Do we see mutations, allele frequency changes, mate selection, natural selection by disease, predators and famine?

To some people, the theory of evolution is distasteful or frightening or even challenging to their ideas about faith. Remember that no one in this class is ever asked to discard a religious idea or their personal faith. Our goal is to understand science. I would recommend that you read about the idea of evolution and read documents written by people of your own faith to see what your church has established as an official position about the theory of evolution. Talk about this with your family and with people at your church. You will probably find that not everyone agrees on their religious views of origin. Some churches deny that evolution can be accepted by a person of faith. Many churches have written documents which affirm that they believe there is no conflict between the theory of evolution and a Creator. Those are decisions to be made by you and your family and your religious leaders. A science class can help you learn what evolution is. Your relationship with God, however you choose that to be, is your own personal decision.

## TEACHING EVOLUTION THROUGHOUT THE SEMESTER

Teaching about evolution as a separate mechanism from all other themes in biology is not the best approach. Evolution is the basis upon which all else in biology is built. Therefore, I teach evolution concepts throughout an 18-week semester and then about week 12 I bring all the concepts together to learn exactly how evolution impacts all of biology.

I try to make sure my students understand these concepts of evolutionary biology:

1. Variation exists in species (populations).
2. Some members of a population survive and reproduce more than other members.
3. Some variations are visible (structural) while other variations are biochemical.
4. Some variations are inherited (genetic) while others are not.
5. Some science is done with controlled experiments, while other science is done by inferences drawn from evidence of past events.
6. Some changes in populations are random (genetic drift) while others are non-random (natural selection).
7. Some changes in populations are genetic changes (mutations, meiosis or crossing over) which may or may not improve survival.
8. Some changes in populations are caused by migration (gene flow).
9. Some changes in populations are caused by nonrandom mating
10. Relationships between species can be inferred by structural, geographic and molecular evidence.
11. Speciation (the formation of a new species) requires some sort of isolating event, whether geographic or reproductive.