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AN INVESTIGATIVE APPROACH TO CELLULAR/MOLECULAR INTRODUCTORY BIOLOGY

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Many of us have had the opportunity to involve undergraduate students in our research and have seen the development that occurs when students become actively engaged in the intellectual and technical challenge of solving a scientific problem. This experience often stands in stark contrast to the students' experience in more traditional courses where they adopt a passive role, taking notes from an authority in the lecture component and following technical instructions in the laboratory. While this system apparently does not deter students who enter college with strong interest in science, it does little to attract undecided students to the field. In fact, traditional science courses seem to select and reward students who tolerate passivity well and who readily accept information delivered by those in authority. A scientific work force selected for these traits would be a sterile lot, lacking creativity, intellectual drive, skills in critical analysis, and the courage to take intellectual risks.

Much has been written and presented about the success of investigative laboratories in engaging students intellectually and infusing life and excitement into undergraduate science courses. Many of us have used investigative formats in our intermediate level courses with great success. With funding from the Howard Hughes Medical Institute, we have planned and, last year, implemented a completely investigative format in the laboratories of Introductory Biology I (Introduction to Cell and Molecular Biology). We administered an evaluation instrument at the end of the course and found that the lab experience was decidedly positive for most students in the course. Seventy-three students completed the instrument. When asked "Was the lab educationally worthwhile?", 60 answered yes, definitely; 12 answered yes, with reservation; and 1 answered no. While it is tempting to detail the structure of the laboratory component of this course, many protocol-level ideas are not widely exportable to other institutions. I think a more useful discussion will center on the highly successful design of the laboratory, which is widely exportable across different institutions and disciplines.

Overview of the Laboratory in Introductory Biology

The labs in Introductory Biology were based on a design used successfully in several intermediate level labs at Macalester in which each experiment is performed through a series of steps taking 3-4 weeks to complete. Students work in groups of three (I thank John Jungck at Beloit for this suggestion). In this way, students are never stuck in pairs with completely incompatible partners, yet groups are still small enough that all students must participate. All lab work is evaluated on a group basis and, when work is handed in, students rate each other on the percentage of work each of them contributed toward the various aspects of the project (I thank the biologists at Hope for this idea). Students are never lectured to in lab. All information is disseminated in hand-outs, in textbook assignments or through library reserve readings. Students learn the needed information by reading and discussing with each other.

After initial skills in group process (see below) and computer use are established, students begin the first experiment. The first week is spent discussing the nature of the experimental system (e.g., photosynthesis), understanding the tools available for investigation (e.g., spectrophotometry, micropipets, balances, centrifuges, etc.), defining an experimental question (e.g., what is the optimal wavelength of light for photosynthesis in this organism?) and developing a working protocol for the experiment. For more naive students (e.g., the first experiment in the first introductory course) this phase may take two weeks.)

At the beginning of the next lab, students have their protocols checked by an instructor and they receive some points for having completed the protocol. (N.B. A flawed and an unflawed protocol receive the same grade. We try to reward effort, creativity and willingness to accept outside suggestions rather than correctness.)

The staff acts as consultants to the students along the way, giving as much information as students request, but trying not to impose our ideas about how the experiment should be designed or performed.

This is especially true if a student group develops an unusual experimental approach. We look for soundness, not adherence to convention. The students then perform their experiment and discuss how the results should be graphed and presented the following week.

The next week, students come to class prepared to give a short oral presentation on their findings. Students usually use overhead transparencies to give their presentations and we try to leave enough time for student discussion about findings. Since the entire class is working on the same experimental system (e.g. photosynthesis) but on different problems (e.g. wavelength, temperature, pH), they have a common basis for understanding one another's presentations, but the presentations are different enough from one another to maintain interest.

The following week we begin a new experiment and each group turns in a written paper on the completed experiment. They also turn in an evaluation of the percent effort of each member of the group (including themselves) on various aspects of the task (design, performance, presentation, written report). The written reports increase in difficulty throughout the semester. The first report includes a protocol, graphs and a paragraph summarizing results while the last report is a full scientific paper with introduction through discussion.

A note about our emphasis on honesty:

We continually tell students throughout the course that it is not important to get "the right" answer (in fact, the labs are designed such that the staff has minimal information about what a "right" answer is.) When they collect and analyze their data, students know that they will have to support their conclusions solely from the quality of their data (supplemented with any reading they have done) and will not be able to rely on the judgement of an authority in the course. This frees them from trying to second guess the staff, places them in the sole position of authority with respect to their own work, and allows the more insecure students to relax a bit about experimental performance. Students are never penalized for mistakes in lab and they are told that they must report their results exactly as they occurred, no matter how dreadful.

Students reported being grateful for this approach. On the last day of class this term, the students viewed the *Nova* presentation "Do Scientists Cheat?" Afterward, we had a discussion about the true definition of scientific cheating and fraud and whether they had cheated in this course. They said there was virtually no pressure to cheat in this course because of the emphasis on honesty. Surprisingly, however, students volunteered that they frequently cheat in other science courses where the emphasis was on obtaining a correct answer. Virtually all the students said they cheated in their science courses in high school for the same reason.

An overemphasis on getting the "right" results may, in fact, not be that different from the actual practice of science where publications at any cost mean success, but it sends the wrong message about what is ideally most important about the scientific enterprise. When good scientists make mistakes, they try again until they get it right because they have the time to do so, unlike most undergraduates in courses. They do not pretend that their experiment worked. Given the pressures on young scientists today to publish, this is a dangerous message for students to receive early in their scientific careers.

When we penalize students for not getting it right on the first try (either by lowering their grade or placing unrealistic demands on their time), we misrepresent the practice of science and may send a message to students that science is about getting the right answer by legitimate or, if necessary, illegitimate means.

What Works in the Investigative Format?

Focus on group work: During the first week of lab, we focus directly on group process. We talk to students and do exercises that demonstrate differences in learning styles and problem-solving styles. At the end of the lab, students generate a list of behaviors for themselves and the instructors that will facilitate good group interactions. They also share their ideas about grievance procedures and a process for staff intervention if group work is going badly. We only had one case of intervention during the semester, although 7 members of the class complained on the evaluation that group work detracted from the educational value of the lab. Although we do not have hard data, I do think that making group process an explicit part of the learning experience, rather than simply letting it happen, helped to make students more accountable for their behavior and facilitated their group interactions.

Student involvement in experimental design, protocol development, and data analysis: Overwhelmingly, this aspect of the course was reported by the students to be the most educationally beneficial. Typical student comments about this aspect of the lab were as follows:

> "Experiments made sense because I was involved in planning the experimental design, in performing the actual experiment, and in analyzing the results. This format helped me understand the experiment as a whole."
>
> "This type of lab approach certainly requires much more thought and analysis than less investigative approaches. Therefore, it taught me a lot about how to analyze, compare and contrast results to reach a conclusion. It helped me think not only in this field, but it will help in many others."
>
> "I had hoped that college biology would be like this. This course is a bridge between high school biology and real science. My group work skills improved immeasurably and I really liked the way the labs made you think out each step to make the lab a success. At the end of the lab, I really felt like I had accomplished and learned something worthwhile."

Forty-one percent of the students reported that experimental design and analysis was the most educationally valuable aspect of the lab component.

Students reported again and again that they understood the experiments well and that they were genuinely interested in the results. This is quite different from reports in previous years when we offered "cookbook" labs. Students frequently reported that they did not understand the point of the lab exercises and complained that lab was a waste of time. Ironically, design and analysis, the most successful part of the investigative format, is the part that is almost entirely missing from traditional formats. The actual performance of the experiment received much lower marks from students. Fifteen percent of the students actually reported that the performance of the experiment was the least educationally valuable part of the lab component.

Oral reports: Speaking in public is, by far, the most common fear of Americans. So we were not surprised when students reported being intimidated by oral reports. However, they also reported that they benefited from the experience. Twenty-nine percent of the students said it was the most educationally valuable part of the lab component. The oral reports in Introductory Biology worked, in part, I think, because they were relatively informal (although visual aids were required) and they were frequent (four per semester). This lowered the anxiety level considerably. What we did wrong in this iteration of the course was to make the topics of the presentations (and the experiments) too similar to one another, and therefore students got bored with some reports. Reports need to be on a common topic, but about different aspects.

Concerns about this Format.

Lack of coverage : The most frequently voiced concern about this format by colleagues in biology (not by students in the course) is that we cannot cover many lab experiments or techniques in one term if it takes at least three weeks for each experiment. This is certainly true. However, rather than focussing on classical experiments which demonstrate various aspects of cell and molecular biology, we have chosen to focus on important and widely-used experimental tools and on the intellectual process of scientific investigation. The tools, most of which are used in several experiments during the term, include the centrifuge, analytical balance, pH meter, micropipets, serological pipets, spectrophotometer, and gel electrophoresis equipment. We feel that repeated use of these tools in different experimental contexts will reinforce student skill with the equipment and will build student confidence in their ability to use scientific instruments. The intellectual elements include *reasoning skills* in experimental design, protocol development and data analysis; *use of information resources* in seeking answers to questions through reading and interviewing the staff; *organizational skill* in design, data collection and experimental performance; *communication skills* in the writing of four papers and presentation of four oral reports; *skills in mathematics and graphical analysis* in analyzing data and presenting it in appropriate graphical form; *interpersonal skills* in working effectively in groups; and *simple manual skills* in the accurate performance of the experiment.

The emphasis on tools and skills, rather than on the coverage of certain illustrative experiments, seem to us to make better educational sense for many types of introductory courses. In the former case, students play an active role in lab, interacting with the instruments and practicing the skills of the professional scientist. In the coverage model, students play a passive role, performing experiments that have been chosen and designed and, in some cases where elaborate data collection sheets are handed out to students, analyzed by the instructor. In my experience with this approach, students frequently "successfully" complete the lab without understanding why they were performing the experiment or what it was designed to illustrate.

In this model, we present science to students stripped of its basic nature; intellectually rich, oriented toward problem-solving, complex, messy, frustratingly dependent on detailed technical success, and dependent on communication skills at every level. As professional scientists, this is what we love (and sometimes hate) about our disciplines. If we had to do science that way we teach science, I suspect many of us would be looking for different jobs.

It is tempting for us to believe that a lab is successful if it "works", i.e. if students are able do the experiment and get positive results. However, I think this approach does great disservice to our students and our disciplines.

Lack of connection to the lecture component: Although students understood very well the purpose of the lab and did not complain about its disconnectedness to the lecture, I do think that the lab and lecture can enhance one another if designed to correspond. In the future, we plan to try to tie the lecture and lab material together into units around central themes (see "Future Directions" below).

Method for placing students into groups: This is a significant problem in a lab where group process is an explicit part of the students experience. We have not found an ideal way to do this. This term, we randomly assigned students to new groups for each new experiment. Students did not complain about changing groups often (some actually enjoyed it), but they did complain when they were placed with people with whom they had difficulty working. Because all lab grades are group grades, incompatibility in groups is a significant problem. Next year we plan to try allowing students to self-assign to groups but giving students the option to change groups at the beginning of each new experiment. Our rationale is that, in a course where students must endure a lecture section of 80-100 people, we would like to give them as much power and autonomy in decisions as possible. Allowing them the simple freedom of choosing their own working groups, we think, would significantly improve student morale and enhance learning.

Time commitment by staff: This lab approach appears to be more labor intensive than it actually turned out to be. Some time benefit is gained by having to "prep" lab only once every third week. Given that, there are three areas that require a major time commitment. First, when labs are prepped, a bit more time is required in planning, since each student group is doing a different experiment. The amount of latitude given students in experimental choice is certainly a function of how ably the staff can handle the chaos this induces. Secondly, staff must work closely with students in groups to help design experiments, develop protocols and analyze data. In our experience, most of this work (≈75-80%) can be done during the lab period. Finally, student written work must be carefully graded. However, this task can be dramatically reduced by having all reports produced by groups. Using this model, in a class of 85 students, we graded only 28 papers every three weeks. This was not excessive.

The teaching staff for the 80-100 student course at Macalester (one lecture section, four lab sections) is comprised of one professor, one full-time laboratory instructor (master's level) and 12 upper class biology major teaching assistants. The professor and laboratory instructor do all the evaluation and grading for the course. Student aids help prep lab and assist the students in all aspects of their work in lab.

Future Directions

We will continue to make modifications in the lab design in the future. We are always looking for good experiments that are fairly straight-forward, can be easily done in one lab period and are robust enough to allow multiple student projects on a single theme. We are especially interested in experiments that can

One of the benefits of working closely with students in research is that, once they get to know you, they can candidly tell you things about what doesn't work in your courses.

be integrated with themes being developed in the lecture component.

My major interest in the next years, however, is to focus on the lecture component of the course. My junior and senior research students have repeatedly told me that the coverage-oriented, linear model, used in Introductory Biology lectures, does not work. Students tell me they need more context, they need to know why they are learning something, they need to know what it relates to, and they need to be able to insert their own questions into the direction of the course.

Ultimately, I would like to see us move completely away from the lecture format. Priscilla Law's much acclaimed "Workshop Physics" model should be an inspiration to us to design alternative methods to the lecture format in science courses. When we impart information in a lecture format, we force students into a passive role, a kind of receptacle for information. The information we give is chosen by us (and frequently textbook authors) and therefore is disconnected from the personal experience, intellectual context and curiosity of the student. This is in stark contrast to the actual practice of science in which information is acquired because it is needed to solve a problem or because the investigator has an interest in knowing. I think wanting to know is an essential prerequisite for true learning, and when we deliver standard lectures to passive audiences, we disconnect our students from this essential prerequisite.

However, ideals aside, in the falll of 1991, I will face 80-100 primarily first-year students in a lecture hall. So what am I going to do? For several years, I have been threatening to drop the linear, coverage model (Biochemistry, then Cell Biology, then Genetics) and organize the course around topics, drawing in information on a need-to-know basis. I intend to use this model next term and have developed a tentative outline for the teaching of Cellular/Molecular Introductory Biology in context. For example, I plan to cover four topics in the semester term: Photosynthesis, The Life Cycle of the Cell, Intracellular Communication, and Biotechnology. Each unit will draw on the traditional disciplines previously taught in linear array as well as other disciplines. For instance, to study photosynthesis, students need to understand the cell membrane, protein structure, oxidation-reduction reactions, the physics of light, the chemistry of pigments, enzyme function, the carbon cycle, plant structure, etc. In addition, biotechnology, bioethics and standard experimental approaches will be incorporated into each unit. By focussing on topics and spending time talking about why each topic is of significance in science and society, I hope to help students make the learning process more personal and, therefore, deeper and longer-lasting.

Both the investigative laboratory format and the contextualized lecture approach are based on the notion that we ought to teach science the way we do science.

Summary

Our own lab work is powered by our own interests and creativity, we learn on a need-to-know or interest-in-knowing basis, and we constantly communicate our ideas to our students and colleagues both orally and in writing. We discuss, we argue, we make mistakes, we reason, we perform technical tasks, we work on things together, and we care about the importance of our work. If our jobs entailed passively acquiring knowledge chosen by others as important and simply following technical directions in the lab, we would soon become bored and disillusioned with our disciplines and would seek other forms of employment.

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ACCESSING "THE SCIENTIFIC LITERATURE"

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To many undergraduate students, the term "The Scientific Literature" represents a vague, immutable collection of complicated writing. It is important for these students to recognize that "The Scientific Literature" is a dynamic collection of information that is constantly changing and subject to considerable interpretation. A series of four exercises have been developed that allow students to gain an understanding of what is meant by "The Scientific Literature". These exercises can be added as enrichment to any number of undergraduate science courses, although here they are cast with a biological perspective.

Assignment One:

A major, short, original source article.
A good starting point in demythologizing the scientific literature is with James Watson and Francis Crick's first DNA paper. The reference is Nature *171*: 737-738 (1953). Begin by asking the students: "Who are the most important figures in modern biology?" Mendel, Darwin, and Watson & Crick usually head the list. Charles Darwin expressed his notable thoughts in the *Origin of Species* in 1859; Gregor Mendel in his publication "Versuche über pflanzenhybriden" in *Verhandlungen des Naturforschenden Vereins Brünn 4:* 3 in 1865; and, Watson & Crick in their Nature article. Of the three major biology works cited above, the Nature article is the most accessible as a pedagogical tool.

Although most students have read the Declaration of Independence as a school assignment in an American History class, few Biology students have ever been instructed to read the original work of the four major figures listed above.

Ask the students to characterize what they think they will find in the original Watson & Crick paper. Questions that could be posed would include the following: 1) How long is the paper; 2) How many figures and tables; 3) How extensive are the literature citations; and 4) What are the major thoughts expressed in the paper? Generally, students expect the research paper to be more than ten pages long with perhaps a dozen or so figures, accompanied by 40 or 50 references, and possibly laced with information about introns and exons. These impressions, although regrettable, are understandable. Most Biology students have only encountered textbook representations of their subject. They have not had the opportunity to experience original source material.

Send the students to the library stacks to seek the nearly 40 year old article. Nestled among rows of the neatly bound Nature series is the sought after Volume 171. Resist the temptation of handing out a photocopy of the article. Fresh stark photocopies just don't have the texture, the color, or the smell of 40 year old, acid containing paper. This trip may well be a student's first act of reading original source material in science. Request the students do something else on this library trip: Go and look at *Life* magazine of the same date as the Watson & Crick paper. This act helps place the paper into a historical context. It is important that the students experience the world of these scientists at the time they were recording their thoughts.

At the next class session, students need to compare their findings with their previous impressions. By analogy to the scientific method, will a student modify his/her hypothesis of what the seminal DNA paper was like? Most students are surprised that the paper was only one page long. These students also agree that the subject material was very simple and that their textbook accounting is far more complex. What reallly amazes students is the realization that Watson & Crick did little laboratory research in support of the paper. At this point, I introduce students to the work of Thomas S. Kuhn, author of *The Structure of Scientific Revolutions,* University of Chicago Press, 1972. The concept of paradigmatic shift is nicely represented by the Watson & Crick paper. For students who seek term paper subjects in modern history, reading concepts of the molecular basis of heredity three years before Watson & Crick's paper and three years after is quite illustrative of a paradigmatic shift. You might want to direct students to Watson's & Crick's second *Nature* paper, published five weeks after the first (*Nature 171*: 964-67 (1953)) The rush to be first into press is quite evident in these two papers. A fact that Watson recounts in his book *The Double Helix,* Athenum Press,1968.

Assignment Two:

Types of papers and accuracy

This first assignment has taken students into original source material and attempts to put that material into context. The second step is to show students how to measure the importance of a paper. *Science Citation Index* (Institute for Scientific Information, Philadelphia) offers a path to this objective. The structure and function of *Science Citation Index* as a reference guide should be explained to the students. The following question is posed: "Does the number of times a paper is cited in other scientific works bear a relationship to the importance of the paper?" Most students intuitively accept that important papers are cited often. Students are given the assignment to see how often the Watson & Crick paper is cited each year during 1985-1989 as recorded in *Science Citation Index*. They are also asked to review the citation rate for the same period of the paper by O. H. Lowry, N. J. Rosebrough, A. L. Faw, and A. J. Randall, in the *Journal of Biological Chemistry 193*: 265 (1951).

Of course, most students have never heard of the Lowry *et al*. paper nor do they know that this work is easily the most cited science paper of all time. The paper is typically cited more than 5,000 times per year. Watson & Crick's two papers are referred to about a 100 times or so per year in the *Science Citation Index*. Watson & Crick have a Nobel prize but who has heard of Lowry; certainly many scientists. At this point, the different styles and types of scientific papers can be introduced. Categories could include the following:

a) technique and methodology,
b) concept and theoretical,
c) review,
d) abstracts, and
e) the "standard" research paper.

Lowry *et al*. would serve as an example of the first category and Watson & Crick would fit into the second category best. Students should recognize that scientific findings are generally reported in small segments called the "the scientific paper." Darwin's *Origin of Species* is atypical as a means of introducing bold new ideas.

The contrast between Lowry *et al*.'s and Watson & Crick's citation rate indicates that a 100 to 1 difference does not necessarily translate into quality or differences in importance. A question to be considered is: What was the influence of a methodology that allowed a quick, reliable, and inexpensive determination of protein concentration to Watson's & Crick's thinking two years later? The relatedness of scientific literature can be established by this type of contrast.

Another feature of the scientific literature can be illustrated by the Lowry *et al.* paper. Students may have noted how many incorrect citations of that paper appeared each year in the *Science Citation Index*. One percent or more of this paper's citations are incorrect. What does this observation have to say about other possible errors in research papers? How does an incorrect citation of such a well known paper get through the review process? At this point students are presented with their third assignment.

Assignment Three:

The citation rate of the "standard" paper
Attention is now directed to the "standard" research paper. As I keep up with the literature, I look for papers that are about six pages in length, with about twenty references, and in the "standard" form; i.e., introduction, methods, results, and discussion. Reprints are acquired and filed by year. Each student is given a paper that is ten years from the date of publication. Each paper assigned has been cited at least once during the ten year interval since its publication.

The third assignment involves four students and strict deadlines. Each student receives at random a reprint and is designated as the "author" of the reprint. This reprint now serves as an original article submission. The "author" must now submit the article to another student who serves as the "editor" of a journal. The student "editor" agrees to take the paper. Then the editor sends copies of the paper to two other classmates who agree to serve as "reviewers". A great deal of cooperation between the students is necessary, an action that mirrors the real scientific community.

The responsibilities of the reviewer include the following: 1) expression of the sense of the paper, 2) determination of the correctness and suitability of the citations and references, 3) placement of the contribution of the paper to the body of knowledge, and 4) recommendation of the suitability of the paper for publication. The student reviewer has a distinct advantage over "real" reviewers. There are ten years of literature since publication of the assigned paper upon which to base judgements. The editor has the following tasks to perform: 1) assignment of the paper to reviewers, 2) keeping the reviewers on schedule, 3) evaluating the reviewers comments, 4) rejecting or accepting the paper, and 5) preparing a one page letter to the author expressing the publication decision. The "author's" actions include the following: 1) selection of the editor, 2) collection of the ten year citation rate data for the paper, and 3) the submission of all documentation for instructor evaluation.

This involved exercise has each student serving as an author, editor, and a reviewer of two papers. The interconnected nature of scientific publication is revealed, as well as its process.

Teamwork, deadlines, and decisions are all intermingled. This assignment typically requires one month to perform. To conclude this section I inform the students that half of all scientific papers published are never cited. The question is often asked if that means half the papers published are irrelevant. The discussion can be surprising. In one class a student remarked that Van Gogh only sold two paintings while he was alive. Her question was: "Should he not have painted?" I finish the discussion by asking the class: "If the year was 1875 and Mendel's 1865 paper was part of our class exercise, what would we conclude?"

Assignment Four:

Finding a current worthwhile paper.
The fourth assignment is based on the current literature. Each student is asked to find a research paper published within the last twelve months that represents a significant contribution to science. The identified paper is accompanied by a one

page justification of the selection. I have the class discuss among themselves the attributes of a good paper. Concluding the assignment, I challenge each member of the class to write me in ten years and indicate how good his or her choice was.

Conclusion and Summary

These exercises can serve as a very viable alternative to a term paper. The students learn to find original source material, how to use a major reference tool, follow the course of scientific paper review, and try to pick out a significant recent paper. Students bibliographic skills are enhanced as they learn to access "The Scientific Literature."

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Editor's Note: For a very different reading of Watson and Crick(namely, as a fairy tale) that is likely to excite or enrage your students, consult Alan G. Gross's "The Tale of DNA" in his (1990) book entitled *The Rhetoric of Science.* Cambridge, Massachussetts: Harvard University Press.

Teaching Students about Science -- A Modest Proposal

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Many, if not most students in high school take biology as their one, and possibly only, course in natural science. Yet the understanding of this complex science in the way in which it is usually taught presents the most difficulty for beginning students for both theoretical and practical reasons. The unifying theory which explains observations about plants and animals is evolution. This theory is one in which at least a third of the teachers do not themselves believe and do not teach. In addtion, many school districts frown on teachers who attempt to teach this theory. These are practical difficulties. The theoretical difficulty lies in evolution itself, which can best be understood as a . . ."chancy result of a long string of unpredictable antecedents, rather than as a necessary outcome of nature's laws" (Gould, 1991).* Thus, evolutionary theory is not predictive. Prediction of the results of future experiments is the strongest support for an hypothesis. In traditional biology, students are presented with masses of empirical information, but the only theory available to organize the data cannot predict future events. It becomes clear that teaching students to understand that science is a problem solving procedure that depends upon a theoretical understanding of the subject is not readily done in the framework of classical biology.

Molecular biology suffers neither the practical or theoretical problems listed above. It has a strong theoreticall foundation in basic atomic theory, and the important subject of evolution may be taught as a natural consequence of molecular events. There is yet no organized religious movement to obstruct the teaching of molecular biology. My modest proposal is that in the future, high school teachers of biology should be educated most thoroughly in molecular biology, rather than the more traditional botany and zoology. By concentrating on the teaching of molecular biology, future teachers of biology can demonstrate easily the basic principles of scientific thought, as well as the unbroken thread that unites all of the naturall sciences, including biology.

*S. J. Gould, *Bully for Brontosaurus* New York: W. W. Norton Co., 1991, p. 69.

Evolution and Creationism Revisited: Philosophy, Religion, Ethics and Education

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Introduction

For almost a decade, I have taught a course entitled Evolution and Creationism: Understanding the Controversy. The course, a university colloquium, is interdisciplinary in nature and is open to students from all disciplines, both graduate and undergraduate. During this time, the course has undergone an evolution of its own. Readings have changed, and lectures and discussions have been altered both because of my own thinking and that of a number of the students as well. This paper is an effort to formalize some of my thinking about the false religious and philosophical dilemma forced on people by "creationists," or "scientific creationists," as many of these fundamentalist Christians prefer to identify themselves. In this paper I will present a history of the development of this dilemma, that is, what historical antecedents to Darwin and events during the time of Darwin led to the particular world view still espoused by creationists. In this context I will also explore the work of several scholars that clearly show there are historical precedents for a very different world view and that a general understanding of the rich religious, philosophical, and scientific ideas of western civilization leads one to alternative world views that produce harmony between science and religion. Finally, I will explore some ideas regarding the appropriate educational responses to this continuing debate and the false dilemma posed by such statements as 'one must choose evolution or creation.'[1] Specifically, my suggestions will focus on liberal education and what we might do in teaching both science and non-science majors.

Background

"Creation scientists," part of a larger group of evangelical, fundamentalist Christians, reduce their descriptions of the modern world and its historical antecedents to black and white statements about the nature of truth. From their perspective, there is but one way to understand the world and the universe. Simply put, there is only one cosmogony: "In the beginning God created the heavens and the earth" (Revised English Bible, 1989). This simple statement and the truth of John 3:16, "God so loved the world that he gave his only Son, that everyone who has faith in him may not perish but have eternal life" (Revised English Bible, 1989), provide a Weltanschauung that spells truth with a capital "T." Biblical exegesis for the "creation scientist" is based upon claims of divine revelation and scriptural inerrancy of the Bible.

In my classes when clergy, from the Catholic Church, the liberal Protestant denominations, or mainstream Judaism, discuss their denominations' understanding of the Bible, especially the first eleven chapters of Genesis, they are typically asked such questions as: "If the first eleven chapters of Genesis are to be viewed as myth, then how do we know what is true when the Bible speaks of such things as the sins of homosexuality?" Or after class, a student may come up and tell me that, "the Catholic Church has sold out, they are not Christians." The same is said of other Christian denominations whenever they fail to understand the biblical text as a plain, simple truth with a capital "T." Parenthetically, I assume that I and the rabbi who presents one of the Judaic exegetic explanations personally escape such comments regarding Judaism and its beliefs because Judaism rejects the messianic nature of Jesus at the outset. While these students may be simply parroting what their clergy tell them,

an understanding of the historical development of Protestantism and its relation to science seems to be a necessary educational ingredient to illuminate the false dilemma.

Further, responses to a survey questionnaire that I give my students at the beginning of the course show that 20 - 50% of the students are not sure whether they have to choose between the Bible and the findings of science. The statement "I accept the theory of evolution" elicits similar responses. Specifically, in the class that I am currently teaching (mean age = 36.4 with a S.D. = 6.18), 48.7% are "not sure" how one interprets the following statement: The theory of evolution can not be correct, since it disagrees with the biblical account of creation. In the same group of 23 students, 56.5% chose "undecided" on a Likert scale in response to the statement, "I accept the theory of evolution." (Even students whose religious commitment when growing up consisted of being taken to church only on Christmas and Easter have said that their parents taught them that they must choose between God and evolution.) I infer from these survey questions that a large number of students know little of their religious heritage and they are also confused about the nature of science and its boundaries in their particular world view.

Since approximately 20% of the students indicate that evolutionary theory should be rejected and that one must choose between God and evolution, I decided that is might be useful for me to explore the historical context that leads to this false dilemma of conservative evangelicals, especially "Creation Scientists." Thus, this exercise is in part for my own intellectual curiosity, in part for this audience, and in part for what I might do with my courses, Evolution and Creationism and Evolution, as they continue to evolve.

Historical Development of the Dilemma

It is hard to know where to begin to examine this modern dilemma. As with the development of any paradigm, there are variant themes that compete in the effort to provide some sort of truth about the nature of our world. If my sense of history is correct, the clerics, who were more often than not the philosopher/scientists of ancient and more recent times formed a continuum of ideas that led among some of these philosopher/scientists to the dichotomy in science and religion and to the false dilemma in the late 19th and early 20th century. According to McMullin (1985), the problem grew out of the way that 17th and 18th century philosopher/scientists approached their science and their theology. The result was the evolution of two central epistemes as Gillespie (1979, p. 2) prefers to describe them.[2] They are creationism and positivism (Gillespie, p. 3). Creationism and positivism differ with respect to interpretations of natural history. As the knowledge of the natural world grew, the epistemic framework labeled as creationism evolved among philosopher/scientists. In the 19th century, these changes led naturalists to invoke different standards of scientific knowledge and these various standards influenced the practices of naturalists as well as their theories about nature. Positivists limited scientific knowledge to the laws of nature and to processes which involved only secondary or natural causes. For the time period noted, this was their only valid form of scientific knowledge. In contrast, creationists " . . . saw the world and everything in it as being the result of direct or indirect divine activity" (Gillespie, 1979, p. 3). Science, to creationists, was inseparable from their theology and a First Cause was essential to their thinking. I examine, in part, the historical evolution below.

The Protestant reformation occurred in the 16th century beginning with Luther; in England the church underwent a similar transformation, especially during and following the reign of Henry VIII.

The explosion of learning, reading, and writing, because of the availability of the printed word produced new ideas in religion, philosophy, and science, let education become accessible to more than the aristocracy.

However, scholars are not in agreement regarding the role of the Reformation on the flowering of modern science (Hooykaas, 1972, pp. 98ff.). What is clear is that there were a disproportionate number of Protestants in the sciences, and that religion and science (and capitalism) were intertwined. Hooykaas (1972, p. 105), a scholar of the history of modern science and religion notes that early Protestant scientists expressed " . . . their love for nature, in which they recognize the work of God's hands, and their pleasure in investigating natural phenomena." The subsequent evolution of Protestant-based theologies and numerous Protestant denominations, especially in higher education, set the stage for the conflict among competing theological interpretations and between science and philosophy on one hand and some of these theological interpretations on the other. It was inevitable, given the place of prominent Protestant philosopher/scientists that they would influence the trend toward positivism in biology.

While Protestantism encouraged individual opinion and free thinking with regard to theology and science and "the rejection of Tradition as a source of revelation"[3] (Hooykaas,1972, p. 115), in general, in the universities many scholars seemed more determined to cling to scriptural inerrancy and the authority of the text as a historically accurate document. The conflicting views reached their zenith following the publication of Darwin's *Origin of Species*. Clearly Darwin's theories "separated God from his creation" and "required a new concept of God and a new basis of religion" (Mayr, 1972, p. 988). I will not review the details of the changes in scientific thinking that led Darwin to transcend the barrier from the individualistic and idealistic concept of species to populational thinking in this paper, but simply let Dewey's description of the impact on science and society as he saw it, in 1909, suffice.

The conceptions that had reigned in the philosophy of nature and knowledge for two thousand years, the conceptions that had become the familiar furniture of the mind, rested on the assumption of the superiority of the fixed and final; they rested upon treating change and origin as signs of defect and unreality. In laying hands upon the sacred ark of absolute permanency, in treating the forms that had been recorded as types of fixity and perfection as originating and passing away, the "Origin of Species" introduced a mode of thinking that in the end was bound to transform the logic of knowledge, and hence the treatments of morals, politics, and religion (Dewey, 1909, 52).

However, we need to return to the pre - *Origin* . . . period of the 17th, 18th and early 19th century to understand how Darwin's conceptualization of the theory of evolution set the stage for this modern false dilemma. The gradual adoption, or evolution, of a physicotheology by the "virtuosi" of the Royal Society, who were opponents of Descartes ideas on the physics of nature, led to a "God of the gaps" approach to understanding the natural world (McMullin, 1985, pp. 27ff.). The physicotheologists used the knowledge of science, *i.e.*, secondary causes and explanations, to explain the natural world where they were able; they invoked a first cause where science had no adequate explanation. The result would lead to a retreat of religion as the body of knowledge about the universe grew. To put it another way, the "God of the gaps" would ultimately shrink. Thus, when Darwin set forth his ideas in 1859, the false dilemma for the philosopher/scientist and for theological thinking became sharply focused.

Since Darwin's philosopher/scientist contemporaries could not conceive of species without special creation, the origin of species required divine intervention and one was simply ignorant of God's methods (Gillespie, 1979, chapter 2). But the logic of many of his contemporaries was flawed. Some physicotheologists had accepted the uniformitarian geology of Lyell. Whewell, a philosopher of science and a defender of catastrophism (McMullin, 1985, p. 34ff.), recognized the problem that these physicotheologists had created in accepting uniformitarianism in geology. This theoretical construct as understood by Lyell and his contemporaries provided for a " uniformitarian God," if you will permit me the liberty of such a phrase. Whewell wrote that geological history now consists of

. . . *the transition from an earth peopled by one set of animals to the same earth swarming with entirely new forms of organic life, a distinct manifestation of creative power, transcending the known laws of nature: and, it appears to us, that geology has thus lighted a new lamp along the path of natural theology* (Whewell as quoted in McMullin, 1985, p. 35).

The problem as Whewell saw it was how could these scientists preclude the idea that some yet undiscovered natural law might not make a first cause unnecessary (McMullin, 1985, p. 35). Thus, if one is unwilling to accept a retreat of the domain of religion in natural theology, or if one is not prepared to accept a more distant God, as the Deists did, then the evolution of the creationist episteme leads one toward the dilemma, God or evolution .

The historical and scientific truth of Scriptures had been confirmed by both the Catholic Church and the numerous Protestant denominations in debates in the 17th century. The Carmelite Foscarini "who held (like Galileo) that the theory of the motion of the earth, as it did not affect an article of faith or concern salvation, might be true, even though it was contradictory to the letter of Scripture" was soundly rebutted by Cardinal Bellarmine, S.J (1615), a theological leader of the Counter-reformation. Bellarmine responded that the Council of Trent required that Scripture be explained according to the "teaching of the Holy Fathers, and they, as well as the modern commentators on Genesis, Psalms, Ecclesiastes and Joshua, took the movement of the sun around the earth to be in the literal sense" (Hooykaas, 1972, p. 115). He argued that the issue was a matter of faith and that one could no more deny the truth of a geocentric universe than one could deny the fact that Abraham had two sons (Hooykaas, 1972, p. 115).

But, as noted above, it appears that the rise of Physicotheology, in the late 17th century, among the physical scientists, the physicists and chemists, produced the basis for the modern "creation scientist" dilemma. These scientists had deep religious convictions and roots in the Calvinist theology of the Puritans. According to McMullin (1985, p. 27), the heart of the new physicotheology was the argument from design expressed by Boyle in 1688, in his work *A Disquisition about the Final Causes of Living Things.*

Boyle, Newton and others adhered to Gillespie's creationist episteme which, as noted, presupposes a First Cause and then a naturalistic interpretation. Again, it was a world view that combined both theology and positivism. By 1859, one could separate creationism among the philosopher/scientists into two epistemes, both of which included a first cause (Mayr, 1982, p. 502ff.). One model, supported by Lyell and Agassiz, required a continual creation with the perpetual intervention of the creator who replaced species and faunas that had become extinct (Mayr, 1982, p. 103). The other was a teleological

> *. . .and deistic theory of evolution: a belief in the existence of teleological, evolutionary laws ordained at the time of creation, that would lead to ever greater perfection and adaptation and would guarantee an orderly replacement of faunas in the geological sequence* (Mayr, 1982, p. 103).

In contrast, Darwin's thinking was consistent with a positivistic episteme; he made it clear that evolution by means of natural selection was an adequate explanation and that this explanation was free of a First Cause. This break with the creationist epistemes opened new scientific vistas, but philosopher/scientists such as Sedgewick and Lyell continued to maintain a creationist episteme. For example, we would have to wait until 1872, for Lyell to admit that Darwin's theories were acceptable explanations. Ultimately, however, it seems that in England and in the rest of western Europe, the philosopher/scientists and the theologians were able to reconcile their differences. Science and society became more secular and theological expressions of the nature of religion were less insistent on one truth for science and religion. As Barr (1978, p. iv) notes, fundamentalism in England has not been a cause for major denominational splits. Thus, I think it is safe to say that a compromise developed and science became free to explore the nature of the universe from a purely positivistic paradigm.

In the United States, however, no such compromise appeared on the horizon. No gracious retreat for religion seemed possible here. I have found no grand explanation for the differences that have permitted modern "Scientific Creationism" to seemingly have such an impact on many Christians in America today; however I wish to suggest a plausible scenario.

The United States, both before and after the revolution for independence from England, was and has been a haven for the religiously persecuted. The colonists, at least in New England, sought relief from the church and the crown. These people brought their religious values and have largely maintained them since colonial times. Because of the diverse origins of the colonists and subsequent immigrants, the nation is culturally and religiously diverse. Moreover, in spite of coming to the new world to be free of religious persecution, the religious diversity established here was often intolerant of other religious truths. These factors combined with the prohibitions of the First Amendment established the framework for the development of many religious truths, one of them "scientific creationism" developed in this social and cultural context.

Furthermore, as higher education grew and expanded in the United States, we were less constrained by the European traditions in both science and religion. In the pioneer atmosphere which has survived into the 20th century in the United States, the compromise that took place, in the intellectual community of Europe with respect to science and religion, never occurred in our society. Theological seminaries that reformed their faith simply parted religious paths with traditional, fundamentalist realities. Those theologians and clergy who maintained the traditional views established new denominations and new seminaries.

The creationist episteme continued to be promoted by many philosopher/scientists and theologians alike; among the prominent theologians was the Princeton professor Charles Hodge. His extensive critique of Darwinian theory has been recently analyzed by Wells (1988) in his book, *Charles Hodge's Critique of Darwinism*. The writings of Hodge greatly influenced the continuing debate and hence, the current existence of the false dilemma, 'God or evolution.'

I am struck by the similarity of both the logic and the language of Hodge when compared to some of Henry Morris' "scientific" writings. Wells writes, *According to his Systematic Theology, the "Fundamental principle of all sciences" is that "theory has to be determined by facts, and not facts by theory." Facts "do not admit of denial. They are determined by the wisdom and will of God. To deny facts, is to deny what God affirms to be true." Theories, on the other hand, "are human speculations, and can have no higher authority than their own inherent probability." Facts, being divine, cannot conflict with each other; but theories being human, often do. Apparent discrepancies between scientific and religious truth arise only because scientists "are disposed to demand for their theories the authority due only to established facts;" while "theologians, because at liberty to reject theories, are sometimes led to assert their independence of facts"* (Wells, pp. 50 and 51).

Like Charles Hodge, Henry Morris and other "scientific creationists" seem to believe that the sciences are merely collections of facts and that these facts are what give meaning and cohesiveness to science. Similarly, both pick and choose among the "relevant facts" to develop their exegetic framework. Hodge revised his understanding of the relationship between scientific facts and their bearing on religious truths during his tenure at Princeton. To his credit, he did so in the light of new scientific facts which he believed corrected the mistaken theories of scientists. Barr (1978, p. 93) observes that both Hodge and his Princeton colleague Warfield took their doctrinal method of fundamentalism as expressly analogous to the methods of natural science especially in the Newtonian mold. However, while Hodge professed a "profound confidence in the harmony of natural science and religion," and believed that no contradiction between nature and scripture was possible, it is clear that Darwin's truths went too far.

Hodge and Morris differ, however, because Morris and other members of the Institute for Creation Research (ICR) appear to exhibit no constraints when they use the facts of science to support and interpret scriptures. Morris, in *Scientific Creationism* (1974) for example, exhibits no logical or consistent pattern in his quest to reinterpret all of the social and natural sciences based upon the authority of scripture. In contrast, Hodge's writings document that he was not wedded to a literal, fundamentalist interpretation and therefore not committed to a six day creation (Wells, 1988, p. 56); hence, I suspect that Hodge believed new scientific facts would eventually corroborate scriptures. That this has not happened leads to a new problem for Morris and ICR with respect to their cosmogony. Because Morris and other "creation scientists" have retained a principle tenet of early Calvinist doctrine:

Whatever human investigations may discover about natural processes must be interpreted in light of the fundamental truth that such processes are guided by God for divine purposes (Wells, 1988, p. 27),

and because they interpret the principle narrowly, insisting upon literal and inerrant scriptures, they have to reject much of modern science by arguing that it is incorrect. The result is that Morris, "scientific creationists," and fundamentalists in general let doctrine based on scriptural authority drive them to accept an obsolete, if not incorrect, episteme. Thus, one could logically infer that Morris would conclude Hodge had parted with truth.

Modern "scientific creationists" go back in time and in most respects stop the clock with arguments from design proposed in Paley's *Natural Theology* (1802). Their logic is virtually identical to those of the philosopher/scientists of the 18th century. That "scientific creationists" selectively use the data of modern science, especially 20th century science, to argue the correctness of the 18th and 19th century creationist ideas is abundantly clear when one examines the assembled list of scientific disciplines established by "creationist scientists" of the 16th through 20th centuries that have been prepared by

Morris (1982). The list purports to show their readers that the important scientists were creationists. Indeed they were. What Morris neglects to tell his readers is that creationism was a dominant view at that time and that among the names on this list few even lived to enter the 20th century. Most made their contributions to science in a period when various forms of positivism had not yet become fully developed or accepted as the normative ways of science.

In conclusion, the theological schism at Princeton Theological Seminary in the early 1900's and the publication of a series of pamphlets, *The Fundamentals: A Testimony to the Truth* (Dixon, et al, 1910-15), beginning in 1910, completed the development of the false dilemma.

The central problem is that "creation scientists" lack a long historical framework or fail to acknowledge its existence;

hence, they begin with a doctrinal base which has its origin in 1910. Contemporary "creation scientists" then take these truths, Paley's argument from design, and "bits and pieces" of contemporary scientific findings to develop their case for the incompatibility of evolution and creation. For Christians adhering to the Fundamentalis, which are defined and justified by the pamphlets, the choice was clear, God and Darwinian evolution were mutually exclusive. These Christians were simply waiting for the "creation scientists" at ICR to tell them what they already knew - Homo sapiens' next of kin was not an ape and that contemporary science supports Creationism.

An Alternative Interpretation

At the beginning of this paper, I indicated that most scholars, including a majority of contemporary theologians, find this dilemma unnecessary. Numerous scholars, Sarna (1989) and McMullin for example, consider the historic religious views of both Judaism and Christianity, respectively, to support a rational and philosophical compatibility between creation and evolution. McMullin (1988, pp. 8-16) examines both Jewish and Christian teachings. He finds no evidence for a Jewish doctrine of creation and his examination of Augustine's *The Literal Meaning of Genesis* written in the 5th century clearly retrieves Christians from the false dilemma imposed by fundamentalists such as those at ICR. Similarly, the Jewish scholar Moses Maimonides, a 12th century Spanish rabbi and philosopher, in his book *The Guide of the Perplexed* (Pines, 1963) tells his readers "belief in the truth of the Bible does not require a denial of science ('reason,' 'logic') when the two seem to conflict" (Tigay, 1987/88, p. 23). Maimonides argued that the creation story was written metaphorically and in another instance quotes a Talmudic passage rejecting an astronomical theory held by Jewish scholars in favor of one proposed by Christian scholars. Tigay (1987/88, p. 23) notes that Maimonides approved of the Talmudic writers actions stating that "speculative matters everyone treats according to the results of his own study, and everyone accepts that which appears to him established by proof [Guide, II, 8]."

Educational Implications

In consideration of the lengthy and foregoing discussion and the objectives of this paper stated at the outset, I wish to consider briefly the nature of education in the liberal arts and sciences today.

We come to our disciplines from various cultural and religious backgrounds. Most of us would describe our undergraduate education, for me 2.5 decades ago, as a liberal education. Yet, has it prepared us to deal with the complex evolution of ideas about the world we live in that I have presented in a superficial manner? And do we now prepare our students to understand these historic ideas and their bearing on the modern neo-Darwinian synthesis of evolutionary theory? Do our students understand the significance of evolutionary theory in this historical context? Do they understand its application and its implications to modern problems such as ecology, the environment, agriculture, genetics, medicine and public policy (Jungck & Dyke, 1985)? I suggest to you that they do not. Biology students earn baccalaureate degrees without even understanding the role of evolution in biological thinking. And liberal arts students at large pass through the doors of our educational institutions without acquiring any understanding of the value and correctness of evolution as a scientific theory.

Moreover, there is a broader question. How do we begin to remedy the lack of understanding of our historical, let alone our intellectual, roots in western civilization and the Judeo-Christian heritage.

Thoughtful observers of the educational system recognize that institutions of higher learning have so carved up the educational turf that most college students can and do omit the components of education that help to explain the origin and nature of the diverse religious, political and socioeconomic values which create the current legislative and judicial dilemmas existing in our society today. Thus, I believe that the real social and educational problem is how to achieve a balance between the educational needs of students in the disciplinary and technical areas, as we have defined them, and still provide students with the ability to function as good citizens in our complex society. To achieve such a goal requires a reevaluation of the undergraduate curriculum across colleges and universities.

I pale at the magnitude of the problem. Designing a course or a few courses that might be required of all students boggles the mind. After giving the problem considerable thought, I am not even certain that I know at what level to pitch these courses, whether they should be for first year students or seniors, who should teach these courses, or what are a realistic set of educational goals. I leave this dilemma to your and my urgent attention. As educators, the problem that I have outlined requires the application of all of our abilities. I believe that the success or failures of our educational system can be measured by our nations' political decisions and by the ethical and political conduct of our citizens. How the nation changes ultimately depends upon what we decide are necessary components of a college education.

We live in a time when more than 50% of our high school graduates attend college. Further, many adults who never attended college are seeking knowledge and skills through higher education. Finally, many have returned to explore areas of knowledge that time did not permit during their early college days.

With wise decisions, we have an opportunity to educate students by teaching them about some of the most influential ideas in the history of human cultures.

Endnotes

[1] In his book *The Remarkable Birth of the Planet Earth*, Morris (1972, pp. 75 - 76) comments on "the semantic curiosity called progressive creation" and on theistic evolution. In his discussion, Morris tells us that Christians who hold such views are dishonoring God, especially those who promote progressive creation.

In *Scientific Creationism*, Morris (1985, 12th Printing, pp. 137 -38) in his discussion of radiometric dating states, "Whether or not the apparent age is really the *true age* depends completely on the validity of the assumptions. Since there is no way in which the assumptions can be tested, there is no *sure* way (*except by divine revelation*) [emphasis added here] of knowing the true age of any geologic formation." While this statement does not demand a choice, it clearly implies that insight into the nature of the universe is limited to what Scriptures tells us.

[2]Gillespie, after analyzing Kuhn and Foucault, elects to take Foucault's terminology for his use in his analysis of the problem of creation as it changed and as it affected the sciences in the 18th and 19th centuries. Foucault in his book, *The Order of Things: An Archeology of the Human Sciences* (London: Tavistock, 1970), describes an episteme as the "*historical a priori*" that

in a given period, delimits in the totality of experience a field of knowledge, defines the mode of being of objects that appear in the field, provides man's [sic] *everyday perception with theoretical powers, and defines the conditions in which he* [sic] *can sustain a discourse about things that is recognized to be true* (Gillespie, 1979).

In light of Foucault's analysis, Gillespie states "Paradigms guide research and epistemes provide them with logic, metaphysics, and epistemology that make scientific work possible" (p. 3).

[3]The word "Tradition" as it is used here refers to the influence of Greek philosophy on the interpretation of the Bible (see Hooykaas, 1972, p. 116).

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The Cloud of Creationism: Is There a Silver Lining?

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Introduction

Judge Overton's ruling in the famous Arkansas trial (January 5, 1982) has no doubt brought a sigh of relief to most biology teachers and science educators. Yet, it is conceivable that such a reaction may signal a lost opportunity for secondary biology education, for the discussion that surrounds "scientific creationism" has all of the attributes of a controversy that could be pedagogically valuable. The Biological Sciences Curriculum Study has argued that controversies can be important for the intellectual development of high school students:

> *...(students) have the right to study those controversial issues that are appropriate to their level of maturity. In general those issues that learners of a particular age are beginning to form opinions about are appropriate to that maturity level* (BSCS Position Statement, 1978, p. 34).

The proposition that creationism might have educational value, however, has been rejected (Gerlovich, 1981; Lewin, 1981; Moramarco, 1981; National Academy of Sciences, 1973; Siegel, 1981). This is because of a failure to realize that while "creation science" has no claim to recognition as legitimate science (and therefore what we are witnessing is not an example of a current controversy in science) it could nevertheless serve to catalyze positive debate in biology education. It has been suggested that creationism be used in the classroom to demonstrate its shallowness (Cloud, 1977), or to demonstrate the merits of evolutionary biology (Alexander, 1978, Moore, 1979). Perhaps only Bergman (1979) has viewed the issue from a more broadly conceived viewpoint of educational utility. The position to be presented in this paper is that the creationism/evolution controversy can be viewed as having a silver lining if the issue of "balanced treatment" — that both views be taught as currently accepted science—doesn't capture all of the attention of biology teachers. The positive influences to be discussed range from complete reorganization of the evolutionary content of biology courses to more specific influences on teachers and students.

One important influence could be increased attention to the historical development of evolutionary theory. Such a focus could be used to demonstrate that creationist ideas have influenced the history of evolutionary thought. In addition, it could be shown that creationists have had their "day in court" and that current creationist objections to aspects of evolutionary theory can and are being addressed—but within the context of science. Important questions could be raised, in an historical approach, about the nature of science, particularly concerning the tentativeness of scientific theory. As a consequence of the change in emphasis outlined above there would be:

1. Increased knowledge of evolutionary theory on the part of biology teachers and students.

2. Increased appreciation, on the parts of teachers and students, of the important and necessary role that controversy has played in the development of any science discipline.

3. Increased debate about the content of introductory high school biology courses, possibly leading to increased "evolutionization" of the curriculum.

The Importance of History

The view that history and "tactics" of science should be a part of pre-college biology instruction dates back to the 19th century, and has been supported by various individuals and commissions since then. For instance, the AAAS committee report of 1948 included the following: "Because biology is the only contact with science for so many students more attention should be given in the course to "the tactics and strategy of science." Hurd (1961) in summing up the report of the Harvard University Commission on General Education (1944) writes that "The committee believes the facts of science should be given a broader perspective and placed in a cultural, historical and philosophical context" (89).

One way to accomplish this might be to treat the historical development of biology in detail in one or two areas. Evolution is a good candidate for such treatment because it is of such fundamental importance in biology; because its history has been extensively written about; because it is generally misrepresented in texts; and because the demise of creationism as science is well documented in the history of evolutionary thought.

While not all of the important issues in the philosophy of science could be taught to high school students by means of evolutionary history, there are a number which could, such as: the importance of theories as heuristics; the tentative nature of scientific theories; the distinction, although blurred, between empirical knowledge and theoretical knowledge; what science is and is not; and the importance of problem solving in science.

Despite the frequent recommendations of numerous commissions to include historical and philosophical issues, examination of high school biology texts indicates that these aspects of science aren't given much attention. Problem solving in particular, if it is mentioned at all, is given superficial treatment in the "methods of biology" section. A view of science as a problem-solving activity could be the means to discuss the other philosophical issues. Laudan (1977) has described the value of viewing science as a problem-solving endeavor:

> *Science is essentially a problem-solving activity. This anodine bromide, more cliche than a philosophy of science, has been espoused by generations of science textbook writers and self-professed specialists on "the scientific method." But for all the lip service which has been paid to the view that science is fundamentally the solving of problems, scant attention has been paid, either by philosophers of science or historians of science, to the ramifications of such an approach for understanding science. Philosophers of science, by and large, have imagined that they can lay bare the rationality of science by ignoring, in their analyses, the fact that scientific theories are usually attempts to solve specific empirical problems about the natural world. Similarly, historians of science, for their part, have usually imagined that the chronology of scientific theories possesses an intrinsic intelligibility which requires little or no cognizance of the particular problems which prominent theories in the past were designed to solve.* (p. 11).

An historical presentation of evolutionary theory could be an ideal way to treat the problem solving aspects of science. Presently the history of evolutionary thought is given short shrift in high school texts. This might have been expected, since evolution itself is receiving less attention in many of the most popular texts (Skoog, 1980). This trend parallels what happened following the Scopes trial of 1925—teaching of evolution was exonerated in the courts but astute publishing firms removed or watered it down in texts in order to maintain sales (Gould, 1982).

The historical treatment in today's texts is, for the most part, limited to Lamarck and Darwin, although many contain no mention of Lamarck, and at least one (Bauer, Magnoli, Alvarez, Chang-Van Horn, and Gomez, 1981) contains no reference to Darwin. In addition, the most extensive treatment of Lamarck simply indicates that he had a theory of evolution based upon the needs of organisms, use and disuse, and the inheritance of acquired characteristics. Not only does the treatment of Lamarck fail to point out what problems he was attempting to solve, in most cases it maligns him. The texts imply that Lamarck was not a very sound thinker, for what respectable biologist could ever accept the theory of the inheritance of acquired characteristics? These texts state that Lamarck's theory was not supported by experimental evidence and that there was at least one very convincing demonstration that acquired traits are not inherited —Weiseman's cutting the tails of mice for 20 generations. However, Weisman's research took place three-quarters of a century after Lamarck. Therefore, a sense that science takes place in the conceptual framework of a given time is overlooked; inheritance of acquired characters was almost universally accepted at the time Lamarck was writing. Lamarck's work then is judged on the basis of standards that are completely inappropriate if the aims of science instruction are to be more than a presentation of the current structure of a discipline. It would be much more challenging for students if evolution and Lamarck were addressed with a series of questions. What problems was Lamarck trying to solve? How did his solution differ from pre-Lamarckian solutions? What was the empirical basis of his solution? In what ways was he unable to throw off the chains of earlier special creationists' solutions? How did creationism influence Lamarck? What was Lamarck's influence on Darwin? These are important questions that are likely to be both accessible and meaningful to most introductory high school aand college biology students. Treating the history of evolutionary thought in such a way could help students to understand important aspects of the "nature of science". It could demonstrate how science progresses by an interaction between the empirical and theoretical. And it could demonstrate how theoretical commitments guide the activities of scientists.

Although Darwin is given more attention in biology texts, and rightly so, the historical context that he was working in is glossed over. The implication is that, working in complete isolation, Darwin stepped off the Beagle and sat down and wrote, although slowly, *The Origin of Species*. This furthers the "great man" view of science in which, again, those questions asked about Lamarck are ignored. What was the problem Darwin was attempting to solve? What positions was he reacting to? What was the Darwinian revolution?

The sole historical insight that is developed in high school texts is that Darwin was reacting to Lamarck. This position is convenient, but historically inaccurate: Darwin knew of Lamarck's work but dismissed it as having no lasting influence on his own evolutionary theory. It is important to recognize that, in spite of Darwin's downplaying of Lamarck's work, both men were advancing evolutionary solutions to the origins question. Textbooks rarely acknowledge this point. If Darwin was not reacting to Lamarck—and it is important to recognize that any theory can be considered as a response to earlier theories—then what was he reacting to? Darwin, in the *Origin of Species, (1859)* provides the basis of the answer:

Let us now see whether the several facts and laws relating to the geological succession of organic beings accord best with the common view of the immutability of species, or with that of the slow and *gradual modification through variation and natural selection.* (p. 256).

He was reacting to the immutability of species position, which was the Biblically-inspired position of special creation. This is never mentioned in texts, although this point has been well documented. For instance, Gillespie (1979) states:

That natural history, as it was related to the concept of species and the history of life on the earth, had reached a crisis in the 1850s was not an uncommon belief among naturalists at that time. To a great extent, the crisis signified the epistemic breakdown of creationism as a vehicle for scientific work. The legacy of this disintegrating creationism was an attitude of nescience on the species question and of indifference and hostility to theory. Outlooks that were blockages to the development of positive biology as serious as creationism itself and which were related, in ways not always clear to contemporaries, to the assumptions of creationism. Similarly, the "ordinary argument" for special creation with its emphasis on benevolent and rational design in nature, which Darwin constantly attacked in the Origin, was not, in a strict modern sense, a rival scientific theory. It rather represented a persuasion, an atmosphere that permeated natural history so universally that naturalists were often unaware of the extent of its influence. Consequently, it was not a harmless strawman, but a traditional bias found among scientists and laymen alike and one that stood in the path of any novel way of viewing the problem of species. Darwin, then, was not engaged in anachronistic shadowboxing, but had selected his target well and knew exactly what he was doing. His attack on special creation was a response to the crisis and an attempt to resolve it by helping to promote the restructuring of biology along positivist lines. The critique of special creation in the Origin was systematically organized for that end. (P. 19-20).

In order to understand the significance of Darwin it is necessary to place him in an intellectual milieu, something that texts do not do. Perhaps it is unwise to delete this side of Darwin's work. Isn't it possible that by systematically ignoring the role of creationism in Darwin's thought we provide an atmosphere in which modern creationism can appeal to students as science?

It would be unfortunate if high school biology teaching stopped at this point—viewing Darwin's work as marking a revolution in modern biology which laid to rest special creation as science. The many anomalies which were cropping up in the doctrine of special creation could also be examined. Such an approach would have several benefits. First, it might help to dispel the myth that science is practiced in a cultural vacuum, by "great men". Secondly, it would demonstrate that special creation was at one time very influential in biology. Third, it would point out that the scientist-creationists who at the turn of the 18th century began to doubt the literal veridicality of Genesis with nature (on empirical grounds) were not anti-Christian—they were Christians.

In addition to the roles of Lamarck and Darwin, there is much that could be taught in the history of evolutionary thought, particularly pertaining to creationism. Twentieth-century historians of evolutionary science have chronicled the problems that new findings in natural history posed for special creation (Gillispie, 1951; Gillespie, 1979; Ruse, 1979; Lovejoy, 1936; Green, 1959; Eisley, 1961; Glass, Temkin and Strauss, 1968). To include such an historical emphasis in the teaching of evolution might: increase students' understanding of the "nature of science;" demonstrate that science is practiced in a cultural milieu; emphasize that creationism was not abandoned as science for theological reasons but rather because of conceptual and empirical problems which it could not solve. The result could be that students and community groups would no longer perceive biology teachers to be covering up an acceptable alternative to evolutionary theory. If the current interest in creationism sparks such a shift in teaching, or even a debate about such a shift, it will have been useful.

Increased Knowledge of Evolutionary Theory

That evolution is the foundation upon which all of modern biology is built is without question:

The theory of evolution is quite rightly called the greatest unifying theory in biology. The diversity of organisms, similarities and differences between kinds of organisms, patterns of distribution and behavior, adaption and interaction, all this was merely a bewildering chaos of facts until given meaning by the evolutionary theory. There is no area in biology in which that theory does not serve as an ordering principle. (Mayr, 1963, p. 1).

Given the central position of evolutionary theory to biology, it follows that any increase in the understanding of evolutionary theory by high school teachers and their students could easily result in a more coherent view of all of biology. How could the current upsurge of interest in creationism influence teachers' knowledge of evolutionary theory?

One possibility is for teachers to thoroughly acquaint themselves with creationist writings. By taking the time to systematically read, for example, Morris' *Scientific Creationism* (1974) and Gish's *The Fossils Say No!* (1972) and by preparing to respond to the claims and arguments used, there is no doubt that teachers would become more knowledgeable about evolution. It is important to recognize that many of the concerns about evolution that creationists raise, and which are supposed to be viewed as arguments in an evolution/creation controversy, are really aspects of debate <u>within</u> evolutionary theory. Therefore, knowledge of them will add to teachers' knowledge of evolution. The debates would entail reading widely in evolutionary theory and would raise questions of: progress and direction in evolution; the energetics of evolution; modern molecular evolution; current views on mutation and genetic regulation; and the tempo and mode of evolution. In the end they would better understand the heuristic role that evolutionary theory has performed for data collection and analysis in all of biology. They could better appreciate Dobzhansky's (1973) observation: "nothing in biology makes sense except in light of evolution" (p. 125). The following is a brief overview of a single current issue in evolution (one which creationists are helping to publicize) with which teachers could become more familiar.

The dominance of the "modern synthesis" (gradualistic) view of the tempo evolutionary change is being challenged (Eldredge and Gould, 1971; Gould and Eldredge, 1977; Stanley, 1978; and Gould, 1980). These evolutionary theorists do not accept that the "gaps" in the fossil record exist because the record is poor—the gaps are real (stasis is data), are to be expected—and that new forms come into existence in geological instants.

We believe that punctuational change dominates the history of life: evolution is concentrated in very rapid events of speciation (geologically instantaneous, even if tolerably continuous in ecological time). Most species, during their geological history, either do not change in any appreciable way, or else they fluctuate mildly in morphology, with no apparent direction. Phyletic gradualism is very rare and too slow, in any case, to produce the major events of evolution. (Gould & Eldredge, 1977, P. 115).

This model, punctuated equilibrium, posits a very rapid tempo for macro events in evolution, as contrasted to the slow view of the "modern synthesis". In addition to differences with respect tempo, the two positions also differ as to the mode of evolutionary change. The "modem synthesis" evolutionists maintain that slow allopatry is the primary means by which species arise. However, Gould and others have moved away from an allopatric model for macro events:

But it now appears that "slow" allopatry by itself may be less important than a host of alternatives that yield new species even in ecological time. (Gould, 1980, p. 125).

Gould (1977, 1980a, 1980c) discusses these alternatives, many of which are tied to breakthroughs in the genetics of regulatory genes and of developmental control.

It is obvious that evolutionary theory is at a particularly exciting period in its continuing development. High school biology teachers could, by making themselves familiar with these controversies, add to their own knowledge of evolution and in turn increase their students' understanding not only of evolution, but of science in general. Ironically, if such an increase in biology teacher's knowledge were to occur, creationists could be given partial credit. The political controversy surrounding creationism could generate renewed interest in evolution for biology teachers. Specifically, creationist writings on the subject of punctuated equilibrium might cause biology teachers to become more aware, more rapidly, than they would have without the creationists.

A second benefit that could come from creationism might more directly benefit students. Creationist literature could be used by high school biology students as a basis for an increased understanding of evolutionary theory. If students and teachers were to work through creationist books, not in the sense of providing balanced treatment, but rather intending to increase students' understanding of evolutionary theory, pedagogically important outcomes could result.

The Benefit of Controversy

As with any scientific theory, the development of evolution has been rich in controversy. When creationists attempt to establish that current controversies in evolution (such as between gradualism and punctuated equilibrium) undermine the scientific status of evolutionary theory, they seriously misrepresent the creative role that controversy and conflict have played in science. Similarly, typical high school biology instruction usually ignores controversy and its positive consequences. Controversy is not completely omitted from biology texts, however. For example, each has a discussion of the debate over how life began—abiogenesis or biogenesis—but the tone of the presentation implies that such debates slow the pursuit of truth. The participants not on the side promulgating today's views are brushed off. The biology of the past is too often judged in light of our current knowledge!

The study of debate within evolutionary biology, both historical and contemporary, could provide valuable insights into the intellectually important role of controversy and into the lack of a "scientific" outlook on the part of creationists. Two examples from the current literature can illustrate this point. Cracraft (1979), writing about the gradualism/ punctuated equilibrium debate over the tempo and mode of evolutionary change, has this to say about the value of an allopatric model of speciation:

Even if the allopatric model is eventually proven incorrect and replaced, the benefits of its conceptual viewpoint for paleontology compared to the benefits of maintaining the status quo are obvious. This may be the best reason for its adoption. (p. 24).

Cracraft's point was that the allopatric model of macroevolution was bound to spur research, and this is a major function of any scientific model. Whether or not the model is eventually demonstrated to be "true" is not important; what is important is the heuristic value of the theory.

In a similar vein, Gould and Lewontin (1979) have argued for the value of pluralism in science, which will engender debate:

We feel that the potential rewards of abandoning exclusive focus on the adaptationist programme are very great indeed. We do not offer a council of despair, as adaptationists have charged; for non-adaptive does not mean non-intelligible. We welcome the richness that a pluralistic approach, so akin to Darwin's spirit, can provide. Under the adaptationist programme, the great historical themes of developmental morphology and __*Bauplan*__ *were largely abandoned; for if selection can break any correlation and optimize parts separately, than an organism's integration counts for little. Too often, the adaptationist programme gave us an evolutionary biology of parts and genes, but not of organisms. It assumed that all transitions could occur step by step and underrated the importance of integrated developmental blocks and pervasive constraints of history and architecture. A pluralistic view could put organisms, with all their recalcitrant yet intelligible complexity, back into evolutionary theory.* (P. 597).

Testimonies such as these, so common in the writings of scientists, should force university science educators and biology teachers to ask: "isn't it possible that the treatment of controversies in science could be pedagogically valuable?"

That controversy is absent from instruction in science has not gone unnoticed. Welch, Klopfer, Aikenhead, and Robinson (1981) have set the issue in a slightly different context when they note that: "*...most teachers attended to values which would support the careful, productive conforming aspects of schooling and socialization. The values associated with speculative, critical thinking were often ignored and sometimes ridiculed.*" (p. 39). Assuming that what they report is widespread in science instruction, including biology, it is a short step to the understanding of why controversy in science is not common in instruction—teachers don't recognize its importance for either scientific communities or individual students. Welch *et al.* (1981) do not provide a detailed analysis of why this might be the case, although others have. Apple (1979) states:

So far I have been documenting the rather important dimension of conflict in scientific knowledge as it is taught in schools has, in effect, been divorced from the structure of the community from which it evolved and which acts to criticize it. Students are 'forced', because of the very absence of a realistic picture of how communities in science apportion power and economic resources, to internalize a view that has little potency for questioning the legitimacy of the tacit assumptions about interpersonal conflict that govern their lives and their own educational, economic and political situations. Not only are they presented with a view of science that is patently unrealistic, but what is more important for my own position, they are not shown how critical interpersonal intergroup (and, hence, class) argumentation and conflict have been for the progress of science. When this situation is generalized into a basic perspective on one's relation to the economic and political paradigms of activity in a society, it is not difficult to see how it can serve to reinforce the quiescence of students, lead them into 'proper channels' for changing these structures, or help justify this structural argument by providing the constitutive rules of thought that make any other perspective on knowledge seem unnatural (p. 92).

Apple's observations need to be given serious consideration by science educators. It may be that such consideration would be one of the logical outcomes of the discussion of biology curriculum, and creationism might be instrumental in causing such discussion to surface. Biology instruction must certainly focus on knowledge in biology and how that knowledge drives the "processes of science", for these are important components of biology. Yet it is not necessary to slight other components such as the actors, their motives and interactions within a scientific community, and the belief system of the culture in which they practice their science.

Curricular Debate

"Scientific" creationists have contrived a pseudo-scientific controversy—evolution vs. creationism. But a significant curriculum debate could emerge from this dichotomy and benefit biology teaching.

Biology education has had a long history of debate on curricular context (Hurd, 1959; Hurd, Bybee, Kahle, Yager, 1981). Of special importance to biology education were the curricular debates which led to the development of the Biological Sciences Curriculum Study materials (Schwab, 1963; Mayer, 1978). The effort of the individuals involved in these discussions brought high school biology into the modern age, influencing all that has occurred in biology education since.

The debates that could ensue from a more positive view of how creationism could influence the curriculum might be guided by a series of general questions. Should the history and philosophy of biology be a substantive part of introductory high school biology courses? Should the positive role of scientific controversy be given more attention? Are ninth and tenth grade students intellectually capable of taking part in such instruction? In addition, more specific questions could center on the extent to which modern evolutionary theory, its debates, and allied historical and philosophical issues should underlie biology instruction.

It might be argued that the increasing of evolutionary content in high school biology has already been accomplished by BSCS. As evidence of this one could point to the first of the nine BSCS themes:

Because evolution forms the warp and woof of modern biology, it is no longer possible to give a complete or even coherent account of living things without discussing evolution. The theory of evolution is as basic to biology as the atomic theory is to chemistry and physics and for identical reasons (Mayer, 1978, P. 10).

Without a doubt BSCS has increased the emphasis on evolution, but the two most widely used BSCS texts do not introduce the idea of evolution as early as might be expected given its "atomic theory" status. The yellow version (*Biological Science: An Inquiry into Life,* 1980) doesn't introduce evolution until one-third of the way into the text. The situation is even more dramatic with the Green Version (*Biological Science: An Ecological Approach*, 1982) where evolution isn't introduced until the 18th chapter out of 20. This same pattern exists in other high school biology texts. It would make more sense to start a course with evolution. The rest of the subject matter could be more easily interpreted in light of this important organizing principle.

If evolution, including its history, were to be given increased emphasis, there necessarily would be discussion as to where this increased time would come from. In this respect creationism could precipitate the asking of important curricular question, such as: "Why is it important to 'cover' this content?" and "couldn't this content be dealt with more meaningfully in this fashion?" According to Hurd *et al.* (1981) there are ten content areas commonly taught in high school biology (...genetics, nutrition, behavior, evolution, continuity, structure/function, diversity, integration, life cycles, and energetics...") (p. 394). A review of texts indicates that these ten areas receive approximately equal treatment. It is conceivable that not all of these areas need to be considered essential, especially when we consider that there are other content objectives relating to the nature of science or science as enquiry as well as those relating to the nature of science or science as enquiry as well as those relating to the history of biological concepts. Even if little change came about in biology education, we should be better off for the debate—we should have a better understanding of why we do what we do.

Debate about biology curriculum content should always be welcome, but now is a particularly appropriate time—creationists have provided a focus. The following statements could serve to focus the debate:

1. Much greater emphasis should be placed on the teaching of evolutionary theory.

2. Greater emphasis should be placed on demonstrating how evolutionary theory influences research and understanding of the other areas of biology, e.g. nutrition, behavior, structure/function, integrity, life cycles, and energetics. This should be done at all levels of biological organization.

3. Evolution, as the unifying theme of biology, should be introduced as one of the first units in a high school course.

4. The greatest benefit to biology students with respect to history of biological concepts will not come through superficial treatment of a chronology of "great men", but rather through the treatment of one or two ideas from an historical perspective. Evolution should be one of these ideas, including the influence of creationist thought on biology.

5. The nature of enquiry can be taught not just by having students engage in lab activities but by a detailed study of enquiry in science—enquiry relating to evolutionary theory should be considered.

6. A much greater emphasis should be placed on the heuristic role of evolutionary theory in particular and of any theory in general.

7. Emphasis should be increased on the positive role that controversy plays in biology, and examples from evolutionary theory might be most illustrative.

8. History and philosophy of biology should be given greater emphasis throughout the high school biology curriculum.

Conclusion

In this paper I have pointed to several areas in which the current interest in creationism could catalyze meaningful changes in high school biology curricula. I have argued that the debate which creationists view as scientific is in fact pseudo-scientific. In addition I have argued that there are pedagogical questions which could be prompted by creationism. These include: How much evolution should be taught? What is the role of history and philosophy in biology education?

The worst thing that could happen is that evolution be treated less extensively in high school biology as happened after the Scopes trial. Almost as bad is a situation in which evolutionary theory would be presented with little or no change. The time is appropriate for university biology instructors, and national organizations such as the Association of Midwestern College Biology Teachers, the National Association for Research in Science Teaching, the Association for Education of Teachers in Science and the National Association of Biology Teachers, to begin to examine ways of capitalizing on the interest in evolutionary theory generated by creationists so that biology instruction could be improved.

It would be ironic, although I think quite possible, to look back ten years from now and be able to attribute substantive positive changes in biology teaching to creationism.

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Ten Questions for Creationist Policy Makers

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How will you prepare for vast epidemics in which none of our current antibiotics work because of the evolution of resistance to antibiotics in bacterial populations?

Who will you expect to pay for more and more pesticides, herbicides and fertilizers on our farms? Will intensive monoculture be allowed to completely destroy the diversity in intercropping, permaculture and perrennial polyculture?

How will selective breeding of domestic plants and animals be performed scientifically, if quantitative and population genetics do not inform the research?

When the next energy crisis hits, will petroleum geologists be encouraged to use fossil dating of geological strata and identification of ancient biota?

Are you prepared for a "greenhouse effect" or other global problems associated with destruction of tropical forests and extinction of many, many species within them?

Sanitation, nutrition and vaccination have been the three primary contributers to modern health. Will researchers who investigate AIDS and other infectious diseases be allowed to use the "clonal selection theory" to continue to guide their research in immunology?

Biotechnology promises many new products such as hormones, neurotransmitters, non-addictive analgesics, enzymes, diagnostic probes, monoclonal antibodies, etc. The most difficult part of most cloning research is usually to select for microorganisms that possess particular characters of interest; will this selectionist process be evolutionarily informed?

Personal hygiene involves the use of many personal products which strongly affect the evolutionary ecology of the flora living on your skin, teeth, hair, and mucous membranes. Susceptibility to many diseases is coordinated with the relationships among populations of microorganisms which may be eliminated by too frequent use of strong soaps, mouth washes, etc. What theories will inform sensible hygiene?

If mutation as an evolutionary force is denied, are you prepared to deal with the increased deaths due to cancer and birth defects associated with "Love Canal", "Bhopal", "Three Mile Island", "Chernobyl", "Nagasaki", and "Hiroshima"?

Will this country allow the segregation of haves and have nots in education and power of knowledge to continue? Those students from upper middle class suburban high schools and elite private academies will have the background in evolutionary biology, geology and paleontology, astronomy, history, archaeology, etc. to get jobs in industry, government and academia while those inner city and rural school students whose local school boards enforce a creationist education will not even be considered.

Abstracts Received for 36th Annual AMCBT Meeting 17-19 October 1991 Rockhurst College, Kansas City, MO

CONCURRENT SESSION I
Oct. 18, 8:15 - 9:15 AM

Use of the Winogradsky Column to Demonstrate Biodegredation
Dorothy May, Park College

This closed microecosystem was developed by Sergei Winogradsky in 1877 to study a variety of soil microorganisms. The column, which can be a graduated cylinder or a large test tube, provides a gradient of oxygen, allowing for both aerobic and anaerobic life. Construction of the column involves layers of mud enriched with a sulfur source ($CaSO_4$). The column can be observed weekly for succession of different bacterial populations.

Different columns can have the center of the mud layer packed with biodegradable and non-biodegradable materials as desired. Columns can be incubated for months and years as desired to show effects and non-effects of bacteria on various materials.

Teaching Biology to Nontraditional Students
Larry Padberg, Rockhurst College
Kathy Hunt, Henderson Community College

Increasingly, our biology classes are finding their way to off-campus sites and evening or weekend hours. As this occurs the mean age of the class population increases. Their experiences, both past and future are different from our more traditional student. Are the curriculum demands the same? Do we address different concepts and issues? Should our teaching methods be altered?

We will facilitate a participatory session to explore our ideas for teaching biology for the non-traditional student.

Writing In Biology Courses: Increasing Critical Thinking and Research Skills
Stu Jacobson, MacMurray College

Science is both a body of knowledge and a process; writing is an integral component of the scientific process. Various assignments, including lab reports, research papers, literature reviews, student research proposals and critiques will be described. The multiple draft process and other means of teaching writing also will be discusses. IT IS HOPED THAT THOSE ATTENDING WILL BRING IDEAS AND MATERIALS TO SHARE.

Restricting Animal Use In Science Classes
John Richard Schrock, Emporia State University

A summary of NABT, NSTA, California "opt-out" law and other restrictions that narrow or eliminate the science teacher's professional decision-making responsibilities. Review of major cases where students refused to dissect, current pressures on biological supply companies and efforts to curtail source of dissection materials, and quality of information disseminated about classroom experimentation and dissection.

The George Engelmann Mathematics and Science Institute - "Unifying Concepts In Science"
Charles Granger, Pamela Iverson and Kenneth Mares, University of Missouri - St. Louis

Administered by the University of Missouri - St. Louis, the Institute invites 50 rising high school juniors or seniors, in the upper 5% of their class, to a four-week summer enrichment experience. The unique philosophic framework and set of objectives enhance the students' knowledge of the scientific enterprise, allow them to use technical equipment and advanced laboratory techniques, and give them opportunities to develop technical writing and oral presentation skills, and other critical scientific leadership skills. The Institute uses the UM-St. Louis campus facilities augmented by weekly field trips and guest speakers from St. Louis business, industry, and government. One hundred-fifty greater St. Louis area students have successfully completed the Institute. All alumni are either in college or are planning to attend college. Of those attending college, 85% of their majors are directly related to mathematics, science, or engineering.

CONCURRENT SESSION II
Oct. 18, 9:40 - 10:25 AM

General Education Biology

Bill Brett, Indiana State University

Biology is presented not for biology's sake, but as a means to help the student better understand and hopefully make informed choices about major problems facing the human race. The problems are: (1) Environmental destruction/ maintenance; (2) Population growth; (3) Nutritional inadequacy; (4) "Modern diseases"; and (5) Genetic engineering and supplemental tissues and organs. Social and ethical consequences of these "biological" topics are discussed. Students are required to relate the course material to presentations in various media.

The Communities of the Biological Crossroads (of America)

Charles R. Maier, Wayne State College

The Nature Conservancy's Niobrara Valley Preserve is often called the "Biological Crossroads of the Nation". Six distinct plant communities -- Rocky Mountain pine, eastern deciduous, and northern boreal forests, and tall-grass, sandhills, and mixed prairies -- intermingle or occur within a mile of each other. This diverse habitat provides homes for an amazing variety of flora and fauna, including two federally protected endangered species. The 54,000 acre preserve is also one of the richest paleontological sites in the United States; over 80 species, including 16 previously unknown, have been taken from the preserve. This unique area provides an excellent outdoor classroom experience for a variety of biological courses for colleges in the midlands, including such studies as Geology, Ecology, Plant Communities, Vertebrate Zoology, Ornithology, and Mammalogy.

A Trip to Monte Carlo: Using Random Numbers in Biology

John P. Messick, Missouri So. State College

This presentation introduces the use of random numbers to enhance laboratory exercises and lectures in evolution, genetics, population ecology, and other biological phenomena which depend on underlying random processes. These random or so-called Monte Carlo techniques produce realistic results, stimulate student interest, and can be implemented on a microcomputer, hand calculator, or with the traditional methods of generating random numbers. The presentation minimizes mathematical theory and emphasizes practical applications which work.

Why Alternatives to Dissection Don't Work

John Richard Schrock, Emporia State University

Computer simulations, videotapes, cloth frog dolls, anatomy models and external observation of humans and other animals are commonly touted as appropriate and sufficient alternatives to dissection. The inadequacies of these methods are classified: failure to truly interact, failure to test true, failure to provide real consequences, and failure to engage emotions. Real labwork is shown to be critical in providing students with "meaningfulness" of terms for structures and processes, confirmation of science concepts, recognition of where current concepts do not explain phenomena adequately, and insurance against cultural "Lysenkoism."

Galileo Reconsidered

Laddie J Bicak, Univ. of Nebraska at Kearney

In many instances, the reluctance of the scientific and lay communities to accept factual explanations of observable phenomena is based upon prejudice, jealousy, and an unwillingness to accept objective evidence. Because he endorsed the work of Copernicus and because he was arrogant and acerbic, Galileo alienated colleagues and challenged authority. Galileo ignored the admonition of the Catholic Church to cease teaching that the sun was the center of the solar system. And so it was that ultimately Galileo came before the Congregation of the Holy Office, the Inquisitors-General. Over the centuries many attempts were made to have the Church review the case of Galileo. Finally, in 1980, Pope John Paul II appointed a commission to review the condemnation of Galileo. In 1984, the Church admitted its mistake.

WORKSHOP SESSION I
Oct. 18, 1:30 - 5:00 PM

Using Alternative Approaches to Biology Teaching and Assessing

Leona C. Truchan, Alverno College

The current emphasis on creating the active learner and using cooperative learning techniques permeates the literature and professional meetings of K - 12 teachers of sciences. However, only recently is the effectiveness of the lecture and testing approaches at the college and university level being seriously questioned. This workshop will have the participants experience, through a series of activities, multiple alternative strategies to the formal lecture in teaching and assessing biology. Some of these strategies will involve you in how to assist your students to be effective group members; how to use graphic descriptors as a focus aid in group work; how to measure the quality of the cooperative group activity; how to assist students to ask questions of one another; how to create assessments that reflect an alternative teaching strategy beyond the formal lecture. A packet of material will be provided for your further reflection and adaptation to your own classroom.

Computerized Data Acquisition in Physiology Laboratories

Marc M. Roy, Beloit College

In this workshop several common human and animal physiology experiments will be demonstrated, illustrating the ease of use and advantages of computerized data acquisition systems. Although computers are widely used at many colleges and universities, they are often used primarily as word processors. We have replaced chart recorders and oscilliscopes with Macintosh computers, each interfaced with a MacScope A/D converter, to collect, analyze, and graph data in physiology laboratories. This has reduced the amount of in-class time that students spend on learning how to use the equipment, and has increased their hands-on experimentation and problem solving time.

Immunoconjugates: An Emerging Biotechnology For Selective Delivery of Toxic Drugs to Diseased Organs or Tissues

Swapum Ghosh, Indiana State University

A major problem encountered in the treatment of such diseases as cancer or AIDS is the toxic side effects that result from systemic application of the drugs. Chemotherapy is thus a very painful experience, because the drugs used for treatment indiscriminately affect the well-being of all proliferating cells in the body.

In recent years, breakthroughs in biotechnology have brought significant changes in our concepts and capabilities. The concept of linking an active drug with a carrier molecule that has specific affinity for a target organ or cell and then of using such a conjugate as a magic bullet to destroy diseased areas of the body or metastasis, has generated strong enthusiasm in industry and academia. Preliminary success has brought along the need for trained personnel.

The purpose of this presentation is to convince ourselves that the training for such personnel is available in our colleges. The basic knowledge of biology and chemistry can be harnassed to understand the principles involved in the preparation of these "magic bullets."

Antibodies that bind to tissue or organ-specific antigens are the natural choice as the carrier molecules for drug delivery. Various approaches are available for conjugating antibodies to drugs,*i.e.*, to prepare immunoconjugates. We will demonstrate one or two examples.

CONCURRENT SESSION III
Oct. 19, 8:30 - 9:30 AM

Burnout: Causes, Preventions and Interventions

Judy Brett, Hamilton Center (Indiana)

Many helping professions, including teaching, lend themselves to the syndrome labelled burnout. Recent financial exigencies in 37 of the 50 states predict difficult times for institutions of higher education. These conditions are certain to increase the intensity and incidence of burnout among teachers. By learning to recognize early indicators of this debilitating condition, teachers have the opportunity to take preventive and/or corrective measures. The presenters will discuss indicators and corrective measures with the participants. Some members of AMCBT may recall that Judy and Bill made a similar presentation in 1981. Perhaps 1991 is an appropriate year for a refresher.

AIDS

Susan Speece, Anderson University

By the time we convene the AMCBT convention in Kansas City, it is likely that there will be more than 185,000 documented cases of full blown AIDS having been recorded in the U.S. since 1981. While the rate of new cases is slowing somewhat in some populations, there are other populations where the incidence rates are increasing at an alarming rate.

Treatment methodologies now allow many persons with AIDS and those who are HIV+ but have not yet developed AIDS to lead reasonably normal lives.

By understanding where the research is going, we may be better able to help our students deal with this disease and make appropriate choices in their lives.

Teaching the Differences Between Science and Religion: Creationism and Evolutionary Theory
Malcolm Levin, Sangamon State University

Understanding the differences in methods of knowing in science and religion is the single most important criterion in defusing the controversy over the teaching of evolutionary theory in biology. Misconceptions that teachers, parents, and students may have regarding the teaching of evolutionary theory frequently arise from a failure to make such distinctions. Additionally, the accusation that we teach evolution as dogma can readily be defused when the nature of scientific theory is clearly defined and presented to students. Presentation will focus on these and other aspects of the controversy

Roundtable Discussion on Outreach to High Schools
Ann Larson, Sangamon State University
Leona Truchan, Alverno College

1. How to create liaison relationships with the high school teachers of biology?
2. How to impact on the high school student to interest them in careers in the sciences?
3. How to create viable partnerships with high school districts, universities/colleges, and industry to improve science education?

Each panelist will address these questions from her perspective and share her experience in working with the high school teachers and/or students.

Reproductive Biology In General Courses: Are We Missing the Point?
Robert Powell, Avila College
Shirley J. Charde, Avila College

Reproduction is listed by nearly all general biology texts as one of the key characteristics of life. Treatment of the topic, however, is nearly always limited to cellular activities or to the mechanics of the process as it is applicable to higher vertebrates. We suggest a broader approach is not only desirable, but essential in order to provide students (both majors and non-majors) with necessary insights into the relevance of biology to real life.

We suggest a unit to immediately follow cellular functions. This unit encompasses a cost-benefit analysis comparing asexual and sexual modes of reproduction and various alternatives allowed by the latter. Students will see evolutionary and life history applications.

Enzymes Get Things Done: A Demonstration
Richard P. Keeling, Emporia State University

A classroom demonstration (to be performed by the instructor) that compares the efficiency of the thermal activation of the hydrolysis of urea with that of the enzyme-catalyzed reaction (urease) and, also, compares the efficiency of an inorganic catalyst (ferric chloride) with that of an enzyme (catalase) in the degradation of hydrogen peroxide. The latter reaction is performed in a special (but simple) chamber that yields a very visual and dramatic effect.

Worldviews: A Needed Change
Keith Blackmore, Highland Community College

I will open the session with a few remarks which reflect my perspectives and concerns, followed by a 25 minute video on paradigms which I find thought provoking. After the video presentation I invite all attendees to share their views on the topic.

CONCURRENT SESSION IV
OCT. 19, 9:45 - 10:45 AM

Preparing for a Career In Physical Therapy
Neil Baird, Millikin University

Many students who have an interest in science and an interest in helping people to combine the two into a career in physical therapy. Department of Labor projections indicate a need for 50 - 100% more physical therapists in the next 10 years. Work settings for Physical Therapists include hospitals, home health care programs, private practice clinics, rehabilitation centers, schools, nursing homes, and industry. Specialties within PT include pediatrics, geriatrics, orthopedic medicine, neurology, cardiology, and sports medicine.

The American Physical Therapy Association's goal of making the master's degree the entry requirement by 1990 is gradually being realized as more clinical schools expand their programs. Programs vary from school to school. Some programs still offer the bachelor's degree and can be completed in four to five years. The master's degree programs generally take at least six years to complete. Most clinical schools accept transfer students who have taken their pre-PT work at some other school.

Admission requirements to the clinical schools vary but usually require a year of physics, a year of chemistry, at least a year of biology plus anatomy and physiology, college algebra and trigonometry, statistics and several psychology courses. Being able to document hours of exposure to the profession in the form of volunteer work, observing, or internships is also very important.

A fairly strong GPA is required to enter most clinical programs because the competition is keen and because the coursework is rigorous.

Financial aide is available through guaranteed student loans, Easter Seals, AMBUCS, Elks, local hospitals who might provide money in exchange for service later, and other sources. Starting salaries range from $25,000 to $30,000 depending upon the location.

In conclusion, there are many good reasons for choosing PT as a profession. Many therapists claim that the close contact with the patients is very fulfilling.

From Food Webs to Restriction Maps
John Jungck, Beloit College

For several years I have been presenting a series of elementary class presentations in biomathematics. This year I will illustatre how graph theory,especially interval graphs and circular arc graphs, can be used to simplify the analysis of food webs. Besides simplifying food web analysis, several new theoretical questions about the structure and energy utilization in food chains will be raised. In particular, what if the the "n" in n-dimensional niche space has a value of one? Does this strongly modify research in ecology? Then I will illustrate how the same mathematical technique used to explore food webs can be usefully employed in sequencing DNA, RNA, and proteins, doing complementation and deletion mapping, and in restriction mapping. Note: No college level mathematics is required to understand this talk.

A Team-taught Course in Bioethics
Elaine Chapman, Illinois College

A team-taught course in bioethics was developed by a biology professor and a philosophy professor. The three-hour course is cross-listed in both departments and fulfills general education requirements in either philosophy or a non-lab science. Field trips to a hospital and nursing home, a simulated intensive care unit, and guest speakers from health professions have added the dimension of realism to the course. The team of instructors provides information and leadership to the course from their respective areas of expertise

PRESIDENTIAL ADDRESS:
OCT. 19, 11:00 AM

"Teaching Biology, Making Biology"
John Jungck, Beloit College

While many argue that teaching is a form of research because of the challenge of dealing with new students each year in novel problem solving situations and of integrating and evaluating much primary literature, few have taken the position that biology is "made' by teaching practices. I will defend the strong thesis that what we educators of biology decide is biology curriculm, what counts as biological knowledge (I.e., is worth teaching), the labs that we choose, the textbooks we adopt, the syllabi that we develop, and the kinds of people that we hire from graduate schools not only have a strong influence on what is biology, but are actually determinative of "biology." Please appreciate the contribution you make not only to your students, but to your discipline as well.

Application for Membership

ASSOCIATION OF MIDWESTERN COLLEGE BIOLOGY TEACHERS

NAME ________________________________ DATE __________

TITLE ____

DEPARTMENT ____

INSTITUTION ____

CITY__________________________ STATE _______________

ZIP CODE ________________

ADDRESS PREFERRED FOR MAILING ______________________

CITY__________________________ STATE _______________

ZIP CODE ________________

PHONE NUMBER _______________________________________

MAJOR INTERESTS:

( ) 1. Biology
( ) 2. Botany
( ) 3. Zoology
( ) 4. Pre-professional
( ) 5. Teacher Education
( ) 6. Other

RESOURCE AREAS:

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RESEARCH AREAS:

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Have you been a member before?______ If so, when?______

Mail To

Edward S. Kos
Executive Secretary, AMCBT

AMCBT Central Office
Department of Biology
Rockhurst College
Kansas City, MO 64110

CURRENT DUES ARE $15.00