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Co-Editors:

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colorful lilies. Photo courtesy of
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Bioscene: Journal of College Biology Teaching

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Deadlines for Submissions

July 1, 2003 for the August 2003 Issue

November 1, 2003 for the December 2003 Issue

A Directed Research Project Investigating Aggressive Behavior in Paradise Fish

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ABSTRACT: This laboratory experiment examines the aggressive behavior of male paradise fish. In this laboratory exercise students examine whether the presence of a female paradise fish influences the aggressive behavior of male paradise fish. This exercise is appropriate for introductory biology, ecology, and animal behavior classes and is designed to allow students to be involved in the entire scientific process. Students design the experiment, collect the data, and analyze and interpret the results.

KEY WORDS: *aggression, aggressive behavior, territoriality, paradise fish*

INTRODUCTION

In recent years, a number of authors have advocated the importance of inquiry-based learning approaches in which students are expected to pose their own research questions and devise their own experiments to answer those questions (Ahern-Rindell, 1998; Grant and Vatnick, 1998; Harker, 1999; McGraw, 1999; McLean, 1999). Providing students with hands-on experience in designing experiments, conducting research, analyzing results, and presenting their findings should be an important component of any upper division course in the sciences. Providing these opportunities for students presents some challenges for faculty members. Often it is difficult to find appropriate research questions that can be addressed by students given the limited time and funding available for laboratory exercises. Another challenge in performing inquiry-based investigations is that students often lack the experience and confidence necessary for designing their own open-ended inquiry-based investigations. Many students have had little or no experience conducting independent research because frequently undergraduate laboratories have structured exercises where the instructor provides the research question and experimental procedure, and tells the students the data to be collected, and the method of analysis.

I teach an Animal Behavior class that provides students an opportunity to gain experience designing and conducting their own independent research projects. A large portion of the course is devoted to independent research projects designed and conducted by the students. Before students begin their independent research projects, they conduct a series of

several two or three week "directed" research exercises. These exercises provide the students with the skills needed for designing and conducting their independent research projects.

For each of these directed research projects, the study system is selected and students are given the information about the behavior of the species they will be using. Then, the class discusses possible hypotheses that can be tested. Next, the design and procedure for the experiment are discussed. The students design, set-up, and conduct the experiment. Then they are introduced to statistical analysis and they statistically analyze the data and write scientific reports presenting their results. Performing several short directed research exercises in this manner gives students the experience and confidence that they need to pursue their own independent research projects.

This paper describes a "directed" research project designed to examine the aggressive behavior of male paradise fish. This is a relatively inexpensive project that can be conducted easily in the lab over a period of several weeks. In this exercise, students design and conduct an experiment to analyze differences between the aggressive behavior of male paradise fish in the presence and absence of a female.

INTRODUCTION TO THE RESEARCH PROJECT

First, students were provided with background information about paradise fish (*Macropodus opercularis*) and their display behavior (Mayland, 1975; Verhoef-Verhallen, 1997). Male paradise fish show an interesting pattern of aggressive displays that can be easily observed in the classroom. This display

behavior may be observed during nest building, mating, parental care, or when one fish intrudes into the territory of another fish (Southwick and Ward, 1968). This display sequence is observable in the laboratory by placing two fish together that have been isolated for 24 hours or more (Southwick and Ward, 1968).

A complete aggressive encounter involves a series of displays: 1) frontal display, 2) lateral display, 3) flank attack, 4) frontal attack, and 5) jaw lock (Southwick and Ward, 1968). During the frontal display, the fish approach each other and erect their gill covers. The lateral display involves the fish aligning side to side, and expanding their dorsal and caudal fins. During the lateral display the fish often assume an s-

shaped body posture and it may quiver or vibrate its body (Fig. 1). As the display progresses, the fish may attack each other. The flank attack involves biting directed toward the lateral surface of the opponent. The frontal attack involves biting directed toward the mouth or head region of the opponent (Southwick and Ward, 1968). If the displays and attacks do not result in resolving the conflict between the two fish, the fish may become jaw locked. During jaw lock, the frontal attacks strike the mouth and result in a firm mouth-to-mouth lock. Generally, the display sequence results in one fish signaling subordination. The subordinate fish generally becomes pale and assumes a 45° angle in the water with its head up and its fins collapsed (Southwick and Ward, 1968).



Figure 1. Two paradise fish displaying. Fish will display to each other when their bowls are placed adjacent to each other; however, their displays are more intense if the two fish are placed on opposite sides of a dividable tank and then the partition is removed. Photo credit: David Harris-Fried, Westfield State College.

After introducing the students to the display pattern, the students observe the display behavior of the fish. It is then explained to the students that they will work together to examine the aggressive behavior of male paradise fish, and discuss possible factors that may influence the duration and intensity of the aggressive interaction between fish. The students are asked if they can think of any factors that may

influence the display behavior of male fish. Students will often offer various suggestions. For example, in past years students have suggested that the size of the fish may affect the duration and outcome of the display. Relative size significantly influences social dominance in a variety of fishes (Francis, 1980; Schwank, 1980; Frey and Miller, 1972) with larger fish usually being more dominant. Students may also

hypothesize that similarly sized fish will escalate encounters to a greater extent and will display longer than fish that differ in size.

If students do not mention that the presence of a female may affect the aggressive interaction between males, they are presented some hints. Then, some of the reasons and ways the presence of a female may influence the aggressive interaction between males are discussed. A number of possible hypotheses regarding the effect of the presence of a female on the aggressive interaction between males are discussed. The null hypothesis is that there will be no difference in the aggressive behavior between the males when a female is present and when she is absent. An alternative hypothesis is that males will be more aggressive toward each other when a female is present because of competition for the female. Another alternative hypothesis is that the males will be less aggressive toward each other when the female is present because they will be distracted by the presence of the female. Generally, students expect that males will be more aggressive toward each other in the presence of a female because they expect that males will compete for the female.

METHODOLOGY

After the students have established the hypotheses to be tested, they are engaged in a discussion about experimental design, and then they determine the experimental design that will be used. Below are provided some guidelines and suggestions. This information can be used to direct student discussion about experimental design.

Fish

Paradise fish are easily kept in the lab. They are long lived, hardy fish that do well at room temperature. However, it does take the fish several weeks to become acclimated to the lab. When they are first brought into the lab they may be jittery and may not eat for several days. Therefore, to acclimate the fish to their laboratory surroundings, it is preferable for the instructor to purchase the fish approximately four weeks before experiments will begin.

Paradise fish can be purchased from pet shops. For this experiment, purchase a sufficient quantity of paradise fish to provide a pair of male fish and a female fish for each group of students. The number of fish needed will depend upon your class size and the number of replicates desired. Purchase a few extra fish to compensate for any mortality. Students can work in groups of four; therefore, for a class of twenty students you will need approximately twelve male fish which can be housed in six dividable 10-gallon tanks (see below), and six females which can be housed in individual one gallon bowls. Paradise fish live for several years; therefore, once purchased, these fish can be used repeatedly.

Housing and Feeding Fish

Male fish can be housed in dividable 10-gallon aquaria. Line the back, sides and bottom of each tank with white paper to prevent fish from viewing each other and to provide a uniform background. Fill each tank with water and condition the water to remove chlorine (appropriate chemicals for removing chlorine can be purchased from pet stores). It is not necessary to have filters in each tank as long as any debris is siphoned out regularly and periodic partial water changes are performed (once a week siphon out approximately 20% of the water from the tank and replace it with conditioned water). Paradise fish do well at room temperature; therefore, heaters are not required (Verhoef-Verhallen, 1997). Divide each tank in half using an opaque partition (these can be purchased from biological supply companies). Place a male fish in each side of the tank. The female fish can be kept in individual fish bowls (Fig. 2). Paradise fish tend to jump and to prevent fish from jumping out of the tanks, either keep the water level in the tanks several inches below the top of the tank, or cover tanks with plastic wrap and poke holes in the wrap to allow for air exchange. All fish can be fed commercial fish food daily.



Figure 2. Housing of paradise fish. Fish are housed individually while acclimating to the laboratory. Photo credit: David Harris-Fried, Westfield State College

Experimental Design and Procedures

Because male body size can influence the outcome of aggressive encounters (with larger individuals being more likely to win in aggressive encounters), males should be measured and paired by size. The length of each fish can be measured by placing a ruler adjacent to the tank, and gently moving each fish toward the ruler.

Once fish are acclimated to the lab, trials can begin. Students should examine the aggressive interactions between male fish in the presence of a female (male-male-female treatment) and in the absence of a female (male-male treatment). For example, half of the class can conduct the male-male-female trials first and the male-male trials second, while the other half of the class conducts the trials in the reverse order. During each trial, students should lift the partition separating the fish and allow the two fish to interact. After one trial is conducted, the fish should be returned to their separate compartments by gently placing a hand in the tank and moving each fish to one side of the tank and then inserting the partition. Before the second trial is conducted, the fish should be given some time to rest (a period of twenty minutes). For the male-male-female treatment, the tank holding the female should be placed adjacent to the center of the tank that holds the males so that both males can see her.

Students should be prepared to separate the fish if the encounter between the fish becomes so intense that one fish may injure the other. If necessary, a student can separate the fish by gently placing his/her hand in the tank and moving one fish to one side and then inserting the partition.

To increase the number of replicate pairings and enable sufficient replicates for statistical analysis, students can repeat their trials using a different pair of fish. Students can remove one male from their tank and replace it with a new male (by switching a male fish from their tank with one from another group's tank). The new pair should be given at least 24 hours to acclimate before conducting experiments.

Data Collection

Rather than telling the students what data to collect, students are lead through a discussion of what data should be collected. Some suggestions are included below.

During each pairing between males, students should observe the behavior of both males and record all observations. Students should record: each display behavior (frontal display, lateral display, flack attack, frontal attack, and jaw lock) made by each male, the amount of time fish spend performing each type of display behavior, and the duration of the aggressive encounter between the males, and the "winner" of each encounter (Fig. 1). The class should discuss how they will determine when one male has established dominance. Often, after a confrontation progresses,

one male will establish dominance and the other will behave submissively. However, sometimes aggressive confrontations can proceed for a very long time before a clear cut "winner" is observed. Therefore, prior to running the experiments, students may want to choose a time limit for each aggressive encounter. For example, your class may decide to observe each pair of males for sixty minutes to see if one male establishes dominance. If neither fish establishes dominance within that time period, then the observations for that pair will be terminated and it will be noted that neither male appeared dominant.

RESULTS AND DISCUSSION

Rather than telling students which comparisons to make, it is preferable to engage them in a discussion about appropriate ways to analyze the data. Students can analyze the data to examine if:

- 1) There is a difference in the number of attacks made by males in the presence and absence of a female. Students can calculate the mean (mean \pm SD) number of attacks made by males in the presence and absence of females. The two treatments can be compared by performing a t-test.
- 2) There is a difference in the number of displays made by males in the presence and absence of a female. Students can calculate the mean (mean \pm SD) number of displays made by males in the presence and absence of females. The two treatments can be compared by performing a t-test.
- 3) There is a difference in the length of the entire aggressive display sequence in the presence and absence of a female. Students can calculate the mean (mean \pm SD) duration of the display sequences made by males in the presence and absence of females. The two treatments can be compared by performing a t-test.

Students can graph histograms of the raw data to check for skewness. Students can also graph the means and standard deviations to visually compare differences between the treatments.

Questions students can address include: Did males show more or less aggressiveness toward each other when a female was present?; What factors may explain any observed differences in the aggressive behavior between males in the presence and absence of a female?; and, Were males distracted from their aggressive interaction by the presence of the female?. Students are required to write laboratory reports (in a scientific format) outlining their experiments.

Conduction of this experiment several times indicates that males show more aggressiveness toward each other when a female is not present. Often, the students find this result surprising because they expect males will attack each other more aggressively when

they are competing for a female. However, we have found that when a female is present, the males spend less time displaying to each other, and devote more time to interacting with the female.

CONCLUSIONS

This is an interesting and inexpensive project that can be conducted easily in the lab. The students enjoy observing the display behavior of the fish, and this research project provides students with an opportunity to be involved with every step of the experimental process. Leading students through several short directed laboratory exercises, such as the one outlined in this paper, provides an effective means of acquainting students with the scientific research process. Furthermore, the combined approach of conducting several short directed research projects

followed by group independent research projects provides students with an opportunity to learn firsthand the procedures involved in scientific investigation. Anonymous evaluations at the end of the course show 100 percent of the students in the class believe that it had improved their ability to design and conduct their own research experiments. Moreover, 100 percent of the students reported that the course had increased their understanding of the processes involved with scientific investigation.

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ACUBE
47th Annual Meeting
Truman State University
Kirksville, MO
October 9-11, 2003
Biology for Contemporary Living





ACUBE 47th Annual Meeting

Truman State University

Kirksville, MO

October 9-11, 2003

Biology for Contemporary Living

Call for Abstracts

Living in the contemporary world requires an ever-increasing need for biological information and understanding. Students are facing issues such as understanding emerging diseases, spread of invasive species, stem cell research, loss of habitats and species, and implications of the human genome project. How are we meeting the need to educate students in a biocomplex world?

Presentations and workshops addressing other topics are welcome; here are some examples of potential presentations:

Bioinformatics

Research with students

Using case-based learning and current issues

Labs that work/Field courses that work

Characteristics of our students as learners

Curricula: content/method/delivery/assessment

Preparing K-12 teachers/biologists/citizens etc.

Interdisciplinary courses and problem solving

Influencing public policy as informed by science

Approaches to teaching evolution

Many of you have addressed these issues in creative ways. Please consider sharing your ideas and techniques at the ACUBE 47th Annual Meeting at Truman State University in Kirksville, MO in 2003.

Please email your 200 word abstract AND mail a hard copy of the abstract with the completed form BEFORE May 31, 2003 to

Lynn Gillie, Division of Math and Natural Science, One Park Place, Elmira College, Elmira, NY 14901

Ph: 607-735-1859 Fax: 607-735-1947 email: lgillie@elmira.edu

Proposed Title: _____

(Please print clearly)

Presentation type: _____ 90 minute workshop _____ 45 minute paper _____ Poster

(Rank your choice)

Equipment/facility needs: _____ 35 mm slide projector _____ Overhead projector
_____ Macintosh projection system _____ Macintosh computer lab
_____ PC projection system _____ PC computer lab
_____ Other: (explain)

Name of presenter: _____

Work address of presenter: _____

Phone No. presenter: _____ email _____

Please include names and contact information for additional presenters on back.

Structuring Research Opportunities for All Biology Majors

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ABSTRACT: Several years ago the Biology Department at Carroll College instituted a required research experience for all Biology majors. The research program consists of a three-semester series of courses that help students plan and carry out a research project of their own design. The research program gives students an opportunity to apply what they have learned in their course work to a project in which they have strong interest, and builds skills in organization, time management, and personal responsibility. During the first semester of the program students are guided through the process of identifying and planning their project as they write a research proposal. During the second semester, students gather the necessary equipment, learn the appropriate techniques, and complete a pilot study. During the final semester, they complete the research, write a final report and present a poster at the annual science symposium held on campus. This program has recently expanded to include students majoring in Chemistry. Here, is discussed the successes and challenges of coordinating a program that involves 20 to 40 research projects each year.

KEY WORDS: *Undergraduate Research, Mentoring, Curriculum Design*

INTRODUCTION

Science education reform, at its roots, is a process designed to improve student learning. At the 1998 American Association of Higher Education Conference on Institutional Change, participants defined learning as a process that culminates in the ability: to ask the right questions and frame good problems, to acquire information and evaluate sources of information, to critically investigate and solve problems, to make choices among many alternatives, to explain concepts to others (both verbally and in writing), and to generalize to new situations (Ganter and Kinder, 2000).

Clearly, that level of learning requires more than a simple lecture approach to teaching. A key foundation of science education reform holds that learning is enhanced and students more fully understand the process of scientific research when they have opportunities for hands-on investigation. Students majoring in science, in particular, benefit from authentic research experiences. Various authors indicate that students more fully engage in learning when they participate in inquiry-driven investigations as compared to traditional “cookbook” labs (Project Kaleidoscope, 1991; Jarmul, 1996; National Research Council, 1996). In particular, the personal ownership

of learning in student-designed investigations can increase retention of content significantly (Clark *et al.*, 2000). Further, the investigations build skills in measurement, observation, writing, oral communication, and critical thinking that are transferable to all disciplines (National Research Council, 1996).

For the most talented of our students, authentic research experiences can come from participation in summer research programs, such as those funded by the National Science Foundation’s Research Experience for Undergraduates (REU) program. Competition for such programs is intense, however, and many students are constrained, for various reasons, from participating in them. Faculty members will also recruit their most talented students as research assistants in the faculty member’s own laboratory. However, providing opportunities for *every* student to participate in research is much more challenging.

The Biology Department at Carroll College has encouraged students to design and carry out independent research for over two decades. Because it was felt the skills developed in this experience were essential for all biologists, a research project was made mandatory for all majors in 1997. In 2000, the

Department of Chemistry and Biochemistry joined the research program and now an interdisciplinary Scientific Problem Solving program is offered that provides opportunities for Biology, Biochemistry, and Chemistry majors to design and carry out their own research. In this paper, the structure of that program is described, preliminary assessment data on the effectiveness of the program is presented, and methods to overcome various obstacles to successful implementation of the program are discussed.

INSTITUTIONAL BACKGROUND

Carroll College is a primarily undergraduate, comprehensive college with 2000 full-time students. Most Carroll students are female (67%), and many (40%) are the first in their family to attend college. The College has two 14-week semesters per year, with most students taking four 4-credit courses each semester. The Science Division offers degrees in Biology, Chemistry, Biochemistry, Forensic Science, Psychology, Computer Science, Environmental Science, and Geography. Carroll also has a strong Health Science Department, with programs in Exercise Science, Nursing, Athletic Training, and an entry-level Master's degree program in Physical Therapy. Currently, students from two departments participate in the research capstone sequence: Biology with 20 – 35 majors per year (6 full-time faculty) and Chemistry/Biochemistry with 5 – 10 majors per year (4 full-time faculty). A relatively small percentage (5 to 10%) of these students will go on to graduate-level research after Carroll. Faculty members in both

departments participate in mentoring research students and share in teaching the three seminar courses.

Carroll College is one of the many colleges and universities that doesn't have a grand endowment or cutting-edge facilities. Carroll is a tuition-driven institution with an endowment of approximately \$32 million. The science facilities are dated and space is very tight. Equipment holdings vary from excellent to ancient, depending on how recently a grant was received to support the acquisition of new equipment. On the other hand, students have access to everything that is here. In short, the research program is supported by whatever resources are available. It is hoped that this model will thus be useful to other institutions working under similar constraints.

DESCRIPTION OF THE PROGRAM

The core of the research program is a series of 2-credit seminars, typically taken by students in the spring of their junior year and both semesters of their senior year. The student learning objectives for the research sequence are outlined in Box 1. During each of the three semesters, the seminars meet for two hours per week. One hour is devoted to instruction or discussion pertaining to the design and implementation of research or the transition from college to post-graduate careers/education. In the second hour, students either meet with their faculty mentors to discuss their research or they attend a science seminar in which local graduate students or professionals present results or applications of scientific research. The focus of the three semesters is described in more detail below.

Box 1: Student learning outcomes for the capstone research sequence.

At the completion of this course sequence, students should be able to:

1. Demonstrate competency in the fundamentals of scientific inquiry, including:
 - a. formulating a testable hypothesis
 - b. designing experiments that test this hypothesis and yield meaningful data
 - c. collecting and analyzing data
 - d. interpreting data within the context of current knowledge in the field
 - e. being able to define ethical practice in research and demonstrate ethical behaviors
2. Demonstrate the ability to independently:
 - a. identify a problem
 - b. suggest possible solutions
 - c. apply most appropriate solution and evaluate outcome
 - d. ask for help when needed
3. Demonstrate competency in searching for, reading, and critically evaluating scientific literature
4. Demonstrate effective time management
5. Provide evidence of growth in skills related to communicating scientific information both orally and in writing.

Semester 1 – Introduction to Problem Solving:

The first semester of the research sequence is focused on designing the research project the student will complete the following year. The objectives of the course are the development of the student's ability to:

- formulate a scientific question and develop an appropriate research protocol,
- conduct library research for pertinent literature,
- develop an awareness of ethical issues involved with scientific research,
- formally present scientific information in both oral and written formats, and
- critique oral and written presentations of scientific information.

During the semester, students review principles and practices of scientific investigations, reinforce their library search strategies, design a research project, write a formal research proposal, and practice oral presentation skills. They also have an opportunity to discuss ethics in research through simulated ethical case studies. Students use two textbooks to support their work in this and subsequent courses: *Handbook of Biological Investigation* (Ambrose, H.W. III and K.P. Ambrose. Hunter Textbooks Inc., Knoxville TN, 1995) and *How to Write and Publish a Scientific Paper* (Day, R.A. Oryx-Press, Phoenix, AZ, 1994).

Students choose their own projects in consultation with a faculty mentor. Although the mentor helps the student design the research, students are not required to

work on a project directly related to the mentor's area of research expertise. This is based on the belief that students will be more committed to a project of their own design, even though the scientific rigor of such a project may be lower than one prescribed by the mentor. Students have an opportunity to indicate with which faculty member they would like to work, but typically no mentor works with more than four students. For this reason, faculty mentors sometimes work with students whose research area differs substantially from their own area of expertise. Student projects cover a diverse array of topics and levels of complexity, as evidenced by the sample project titles in Box 2.

The faculty mentor and the course instructors work with students throughout the project development process to ensure that the project will be workable with the resources available at the college. Students are encouraged to seek external collaborations if their interests cannot be accommodated on campus. Typically, four to six students complete their work in summer REU programs, and a few others work at the Medical College of Wisconsin, the Veterans' Affairs hospital, or at other sites where they have both an on-site and a campus mentor. On-campus collaborations are also encouraged as necessary – particularly with members of the Mathematics Department who provide statistical consultations throughout the research process.

Box 2: Sample Project Titles

The Effects of Estrogen on the Skeletal Muscle Tensile Strength of Gastrocnemius in Male and Female Rats
Homerange Size in Juvenile Piping Plovers (<i>Charadrius melodus</i>) from Hatching Until Natal Site Dispersal
<i>Cmu1</i> , a Mutant <i>Chlamydomonas reinhardtii</i> : Characterization of Microtubules
Diversity of Aquatic Insects in Deep Marshes in Southeastern Wisconsin
The Effect of a GHRH Infusion on the Ovaries of Female Rats
Distribution and Quantification of Mononuclear Lymphoid Cells in the Northern Leopard Frog, <i>Rana pipiens</i>
Correlations Between Aggressive and Courtship Behavior in Two Species of African Cichlids
Social Interactions of an Orphaned Juvenile Bonobo at the Milwaukee County Zoo
Primary Observation of the Characteristics and Morphology of Hemocytes Isolated from <i>Tenebrio molitor</i> .
The Effects of Steam Autoclave Sterilization and Gas Sterilization on Four Types of Suture Materials: Silk, Cat Gut, Vetafil, and Vicryl
Effect of Long- and Short-day Photoperiod on Respiratory Rate and Escape Reflex Velocity on Brook Sticklebacks
A Taxonomic Survey of the Water Molds at the Greene Field Station of Carroll College
Developmental Color Preference Changes in <i>Rana pipiens</i>

Semester 2 – Problem Solving I: The second semester of the research sequence focuses on pulling together the skills, equipment, and supplies necessary to carry out the research. Students are expected to carry out a pilot study of their project (if appropriate), and some begin data collection during this semester. Students also refine oral presentation skills as they present a progress update to their peers. Because the research sequence is designed to aid students in the transition from college to future educational or career opportunities, time is devoted in this course to helping students compose a resume and practice effective job interviewing skills. The campus career center collaborates on this aspect of the course.

As the course title suggests, students are expected to work on problem solving skills, and to demonstrate effective time management as they learn to set priorities and work independently. In both the second and third semesters, students are required to develop a grade contract and time line for their research at the beginning of the semester. In the contract, they specify research objectives for the term, weight those objectives, and develop grading criteria against which they will be evaluated. This places the responsibility for effective time management on the students and they are held accountable with both a mid-semester and an end-of-semester progress report. Time management is often one of the most difficult obstacles for the students in the second semester, because the final “goal” is less well defined than that of the first semester (the proposal) or the third semester (the poster and final paper). The grade contract and progress reports have helped students significantly in this regard, as do the biweekly lab meetings with the mentors.

Semester 3 – Problem Solving II: In this course, students complete their research project. As part of the third semester course, students are expected to demonstrate proficiency in data collection and interpretation and select appropriate figures and tables for summarizing their results. In addition to a formal written report of their work, students present the results of their research in a science poster symposium held late in the semester. Posters are displayed in the science building throughout the day, with a reception in late afternoon. Students, faculty members, and administrators from around the campus are encouraged to attend. Members of the department’s Advisory Council are invited to evaluate posters as part of the department’s program assessment efforts. During this semester, many of the weekly meetings are structured like a typical graduate-level journal club, in which students participate in critical discussion of scientific literature. The journal articles they discuss are recommended by the guest speaker who will speak during the second hour of class.

In cases where students have participated in an NSF REU program (or equivalent), the students still participate in (and receive credit for) the Problem

Solving seminars the following year. Because REU opportunities tend to be very rushed, students use the seminars to revise and improve upon their literature review, data analysis and written report, as well as to develop the ancillary skills stressed in the seminars (e.g., resume writing, etc.).

ASSESSMENT DATA

The formal assessment program for the research capstone sequence currently consists of a questionnaire survey asking students to evaluate their progress relevant to the student learning outcomes for the research series, and a focus group interview conducted by a member of the College’s Assessment Committee at the conclusion of the third semester. Data from the course surveys indicate that students feel they have grown substantially in the areas related to the outcomes and that they are satisfied with their research experience. Sample data obtained from the April 2000 survey of students in the final course (n=16) are provided in table 1.

In the focus groups, some students complain about the “unpredictable nature” of research and report dissatisfaction with difficulties encountered. However, most students state that they have learned and grown from such experiences. Most comments support the results obtained from the questionnaire above; namely, that students have learned a great deal in the research series and they feel that they will be better prepared for jobs in the sciences. Students have also made suggestions on how to improve the series, many of which have been incorporated over the years.

In addition to the formal assessment data, anecdotal evidence supports the view that the research program strengthens the educational experience of those students involved. In unsolicited letters, our graduates have stated that their experience in the research series has been invaluable. Alumni have donated money to the College specifically to support future students in the research sequence. Also, students in Biology have been extremely successful at receiving external grants for research and very active in presenting their research at professional meetings. In 2000-01, Carroll students received almost ten percent (5 of 57) of all research grants awarded by Beta Beta Beta, the National Biological Honor Society, to support undergraduate research. In the past five years, 11 of 37 students presenting research at scientific meetings received awards.

The experience of the Science Division faculty also indicates clear value to the research capstone sequence. Seven years ago, student research projects conducted in the sciences at Carroll College were often poorly defined, ineffectively executed, or not completed. Since the restructuring of the program six years ago, a definite improvement in the student research experience has been noted. The quality of the projects has increased and nearly all current students

complete their research on time. There has been clear growth in student independence and time management. Perhaps most importantly, there has been significant improvement in student problem-solving skills and in their self-confidence as researchers.

Continued assessment and evaluation of the research program, focused on ways to improve student

learning, has identified deficiencies in our respective core courses. Thus, review of student performance in this research capstone is fast becoming a valuable means of assessing the success of our programs as a whole.

Table 1: Sample assessment data for the research capstone experience. The assessment statement and the % of students responding “more true than false” or “definitely true” are shown.

Statement Provided	% in agreement
I feel that I am able to clearly formulate and state a research question supported by appropriate literature.	100
I feel confident that if asked to construct the research design and provide an outline of the appropriate methodology (supported by the literature) for a project in the future that I would be successful.	94
As a result of my research experience, I am better quipped to execute an experiment and to effectively collect data.	94
As a result of my research experience, I am better able to analyze data and interpret results.	88
As a result of my research experience, I am better able to set priorities and to manage my time.	82
By the end of the course sequence, I feel that I demonstrated the ability to work independently.	100
Overall, I feel that this course sequence provided a worthwhile experience.	94
I feel that the knowledge and experiences obtained from the research program will be useful in my chosen career path.	75

PROGRAM LOGISTICS

What are the implications with respect to faculty load? A full time course load for faculty in the laboratory sciences is four courses per year (non-laboratory science faculty teach six courses per year). Three or four of these courses have labs. Participation in the capstone (as a mentor or seminar instructor) occurs in addition to this course load. A faculty member will mentor from one to four (occasionally more) students each year. Responsibility for teaching the three-semester seminar sequence rotates among departmental faculty. One pair of faculty members will “progress” through the 3- semester sequence with the same group of students. In the year following this teaching responsibility, that pair is responsible for coordinating the speakers in the bi-weekly seminars, and for organizing the spring science symposium. Their responsibilities then return to only mentoring students until their turn in the rotation comes up again.

The number of students working with any given faculty mentor varies, but an attempt is made to keep it less than four. Because many of the students are interested in the health sciences, faculty members with research interests in those areas tend to be requested more often as mentors. Similarly, because whole-organism projects such as behavioral studies at the local zoo may seem more accessible to students than projects with, for example, a molecular focus, faculty members interested in mentoring behavioral or ecological projects are frequently requested. Students are allowed to work with a mentor from either department, and such cross-disciplinary collaborations are relatively frequent.

How are student research projects funded? Students are strongly encouraged to apply for external funding for their research. They have been particularly successful in receiving grants from Beta Beta Beta, the National Biological Honor Society. Limited funding

comes from departmental budgets and gifts from alumni. Occasionally, and of their own volition, students cover some of the costs. Because funding is limited, students receive significant mentoring in the initial stages of project planning to ensure that their research plans are cost-effective and appropriate with the resources available.

What are the implications regarding research space? Space is one of the major constraints. The science facilities do not have dedicated space for undergraduate research. If appropriate, students work in the small-animal room or in the greenhouse. More often, students set up their research in a corner of a teaching laboratory. Occasionally, even more creativity is required, and projects may be conducted in storerooms, basement mechanical rooms, or in student apartments if such space is appropriate and safe for the planned research. As mentioned above, several students complete their research over the summer, often in conjunction with an NSF REU program, which decreases the need for laboratory space on campus.

Conclusions

The undergraduate research program in the sciences at Carroll College has evolved from one with little structure and student accountability to one that is showing significant signs of success in enhancing the learning experience of the students. The three-semester format gives students the time and support they need to develop a well-reasoned and viable project. Students conclude the process with a strong understanding and appreciation of the nature of scientific research that will be of value regardless of

whether or not they pursue careers in scientific research. Moreover, the skills students develop in problem solving, critical thinking, time management, and oral and written communication will be transferable to any career. Finally, many students develop a much greater confidence in their own abilities as researchers, problem-solvers, writers, and speakers as a result of successfully completing their research project.

The program is also important in that it has pushed us to identify the specific attributes desirable in the development of our graduates. That effort has led to the evaluation and modification of the research seminar. In addition, it has led to the reform of earlier courses in the departmental core curriculum as specific weaknesses in the preparation of the students entering the research sequence are identified and addressed. For example, in Biology, it was found that students entering the research seminar sequence were not comfortable with the process of forming concrete research questions and testable hypotheses. This led to evaluation of how such skills are established in our freshmen and sophomore courses and refinement of the methods to accomplish this.

The interdisciplinary nature of the program is unique. Although still in its early stages, it is anticipated that both students and faculty will benefit from the shared sense of community and purpose that the research program reinforces. For the students, the interdisciplinary model reinforces the integration of science and encourages them to broaden their perspectives on research.

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Using Bioinformatic Software to Understand the Central Dogma of Biology

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ABSTRACT: We describe a computer-based exercise that provides students with a method of viewing the relationship between a gene and its amino acid sequence. Students search and retrieve the nucleotide and amino acid sequences of the *Caenorhabditis elegans unc-22* gene and nucleotide sequence of the transposon Tc5 from the GenBank database. The Lasergene[®] software package from DNASTAR[®] is then used to manipulate and analyze the nucleotide and amino acid sequences. Intron sequences are removed from the wild-type and Tc5 mutated *unc-22* alleles to generate cDNAs. The open reading frame, once located in each cDNA, is translated and the sequence homology of each protein product is compared to the wild-type sequence obtained from GenBank. Having the student physically manipulate the wild-type and mutated gene sequences to mimic the post-transcriptional processing events permits not only a greater understanding of the processes involved in the expression of a gene but also the effect that a mutation has on the gene's protein product.

KEY WORDS: Central Dogma, bioinformatics, DNASTAR, Lasergene, EditSeq, MegAlign, *C. elegans*, *unc-22*, Twitchin

INTRODUCTION

Having been involved in several Biology and Biochemistry courses at the levels of professor and teaching assistant, we have found that numerous students become mired in the many intricate details of the central unifying principle of all living organisms, the Central Dogma: DNA nucleotide sequence determines RNA nucleotide sequence, which in turn determines amino acid sequence. Unfortunately, being overwhelmed by the details, many students do not see the logical connections between gene sequence, protein sequence, protein structure, and protein function, and fail to establish a strong lasting working knowledge of the processes. Our experience, with the challenges so many students face in not seeing the forest for the trees, is not a unique one. Ultimately, we believe that students could benefit greatly from a practical, state-of-the-art, hands-on experience that effectively demonstrates how information is passed from DNA to protein. Herein is described a computer-based activity, carried out by first-semester Biology and Biochemistry majors taking a sophomore level Cell Biology course, that illuminates many of the details of the processes that comprise the Central Dogma by requiring the

students to perform those processes using a bioinformatics software package available to educators for no charge when its use is for pedagogical purposes only.

The conversion of genomic DNA to functional protein products entails two fundamental steps: transcription of DNA into mRNA and translation of mRNA into protein. The initiation of transcription involves a tightly regulated cast of transcription factors that collectively initiate the conversion of DNA into pre-mRNA. The pre-mRNA is processed such that introns (intervening sequences) are spliced out and exons (expressed sequences) are spliced together to create a mature mRNA. The mature mRNA now possesses an uninterrupted tandem array of codons (*i.e.*, a grouping of three nucleotides), each specifying a particular amino acid. The consecutive array of codons within the mature mRNA, that dictates the sequence of amino acids within a protein, is referred to as the open reading frame (ORF).

Disruption of an ORF, whether in genomic DNA or precursor RNA, has the potential to impact the sequence of amino acids within a protein. Christian Anfinsen (1973) illustrated through a series of elegant

experiments on ribonuclease the extent to which a protein's amino acid sequence determines its ability to fold and achieve a particular three dimensional structure. An extension of the important relationship between a protein's sequence of amino acids and its conformation is the association between a protein's conformation and its function (Nelson and Cox, 2000; Berg *et al.*, 2002). Therefore, nucleotide and amino acid sequence changes have the potential to alter protein conformations and functions and consequently cellular activities.

However, it should not be assumed that all alterations to a gene are equivalent, because they are not. Point mutations, deletions, frameshifts, and insertions, may or may not compromise the integrity of an amino acid sequence. The result of these mutations rests entirely upon their effect on an ORF. For instance, point mutations maintain the correct ORF; however, they may or may not alter a single amino acid. A point mutation which alters the codon CAU, which encodes for histidine, to CAC, will not be reflected in the protein product since it also codes for histidine. This is the result of the genetic code being redundant or degenerate. That is, all but two amino acids, methionine and tryptophan, are encoded for by two, three, four, or six different codons. The redundancy, known as the Wobble Hypothesis (Crick, 1966), is due to a reduced stringency in the bonding between the anticodon of the tRNA carrying an amino acid and the third position of the mRNA codon such that non-Watson-Crick basepairing is allowed. Alternatively, changing the codon CAU to GAU results in a histidine to aspartic acid change. Not only does this point mutation alter the amino acid in the polypeptide, but it also replaces a basic amino acid with an acidic one. Such a replacement may result in a functional change in the protein either because a catalytic residue is lost or the introduction of a negative charge where there should be a positive charge affects the ability of the protein to fold properly. Deletions and insertions, if in multiples of three nucleotides, may also affect a protein's structure and function since they will result in the removal or addition, respectively, of one or more amino acids. In contrast, if the deletions or insertions are not in multiples of three, the reading of the ORF will be shifted, altering the amino acid sequence from that point forward. This type of mutation has one of the greatest potentials for altering a protein's function due to its ability to alter the amino acid sequence on such a grand scale. The amino acid sequence of the mutated protein shares homology with that of the wild type only up to the location of the mutation. Since the remainder of the amino acid sequence varies from that of the wild-type protein product, it is reasonable to conclude that its structure, and therefore function, will also be dramatically affected. It is our experience that, when the Central Dogma is discussed at this level, students tend to

become caught up in the details and lose sight of the "big picture".

In this learn-by-doing computer exercise, students use the Lasergene[®] bioinformatic software package to manipulate and analyze gene and amino acid sequences which they obtain from the GenBank database. Students experience first hand the flow of information through the Central Dogma and observe for themselves the drastic effect that a mutation in a gene has on the encoded protein product. The students manipulate the *unc-22* and *Tc5* genes from the free-living soil nematode *Caenorhabditis elegans*, a favorite model organism for molecular genetic analysis of a wide range of problems in biology. An advantage to having the students work with the *unc-22* gene is its size; the unprocessed genomic version contains 47,081 nucleotides. Students, especially those who have not yet seen or manipulated an intact gene sequence, are generally impressed, even amazed, when they first view and scroll through the *unc-22* nucleotide sequence. Students also work with a sizable gene product; *unc-22* encodes for a single protein consisting of 6,048 amino acids. It is a component of the worm's body-wall muscle and plays a role in achieving a smooth relaxation following contraction. The *unc-22* gene product is termed "Twitchin" since when mutated, relaxation of the body wall muscle is improperly regulated and results in an overall body twitch. The distinctive twitcher phenotype can be easily seen by the *C. elegans* novice when a Petri dish of the *unc-22* mutants are observed under a dissecting microscope. Students also become acquainted with transposons, mobile pieces of DNA, which "jump" throughout the genome and cause various mutations as a result of their insertion and/or excision. Frequently, a gene's ORF is disrupted when a transposon finds its way into exonic DNA. This mutation often has deleterious downstream effects on gene expression and protein function. This exercise introduces the *C. elegans* transposon *Tc5* into the third exon of *unc-22* resulting in a shift in the reading frame and introduction of a premature stop codon. The mutant Twitchin, consisting of only 542 amino acids, is less than 9% of the size of the wildtype protein.

The lab exercise requires students to (1) search and retrieve the complete nucleotide sequences of *unc-22* and *Tc5* from the on-line GenBank database, (2) insert the transposon sequence in the correct location of *unc-22*, (3) process both the wild-type and *Tc5*-containing *unc-22* gene sequences by removing the introns and splicing together the exons to produce two cDNAs (complementary DNA: a DNA copy of a mature mRNA), (4) determine the open reading frame within the cDNA, (5) translate each of the ORFs into amino acid sequences, and (6) align the two translation products and compare their degree of homology.

In today's research environment, computers are being utilized more than ever. Improvements in

technology have given birth to fields of proteomics, RNomics, and the like (Alberts *et al.*, 2002). Microarrays allow us to obtain gene expression data at a speed and scale of which we once only dreamed possible (MacBeath and Schreiber, 2000). Therefore, a concomitant goal of this exercise is to familiarize students with sequence databases and common bioinformatic software used to manipulate nucleotide and amino acid sequences. Introducing students to common computer programs and services will acquaint them with what is available for their use as scientists.

MATERIALS AND METHODS

Macintosh or PC

Macintosh system requirements: Any Power Macintosh or compatible computer running System 8.6 or later, CD-ROM drive, 16 MB RAM (32 MB recommended), 40 MB of free hard disk space (60 MB for a demo downloaded from the DNASTAR[®] website: <http://www.dnastar.com>),

PC system requirements: Intel compatible Pentium/100 computer running Windows 95, Windows 98 or Windows NT 4.0 or later, CD-ROM drive, 32 MB RAM (64 MB recommended), 40 MB of free hard disk space (60 MB for a demo downloaded from the DNASTAR[®] website: <http://www.dnastar.com>)

Database

The *unc-22* and *Tc5* sequences can be obtained from the GenBank database which is maintained by the National Center for Biotechnology Information (NCBI; <http://www.ncbi.nlm.nih.gov/>) at the National Library of Medicine (NLM), a part of the National Institutes of Health (NIH). GenBank contains all publicly available DNA sequences submitted by individual laboratories and obtained through sequence exchanges with international nucleotide sequence databases as a member of the International Nucleotide Sequence Database Collaboration. Entrez (<http://www.ncbi.nlm.nih.gov/Entrez/>) is a search engine that allows for the retrieval of molecular biology data and bibliographic citations from the NCBI's integrated databases.

Software

A web browser is necessary to access the NCBI website to search GenBank. A word processing program is used to store nucleotide and amino acid sequences following their retrieval from GenBank and prior to their import into the bioinformatics software. The Lasergene[®] biocomputing software is provided free of charge by DNASTAR, [®] Inc. [Madison, WI; www.dnastar.com/] to educators using it for pedagogical purposes only, operates on both Macintosh and PC platforms, and should be installed prior to lab. A Lasergene[®] Navigator alias should be placed on the desktop. The software, installed from a CD-ROM, is accompanied by a detailed user's guide that is comprehensible to the beginner. Two programs within the Lasergene[®] package are used in this exercise. The

first, EditSeq[®], allows for manipulation and analysis of imported sequences. MegAlign[®], the second program, generates alignments between two or more nucleotide or amino acid sequences thus demonstrating consensus.

Color Printer

The amino acid sequence alignment to compare homology between the wild-type and *Tc5*-containing *unc-22* alleles will yield a colored histogram of consensus strength. Therefore, if you want to provide high quality hardcopies of the alignment you will need access to a color printer.

Computer Disk

Each student or student group will be able to save its work on disk. Prior to beginning the exercise each team should title its disk and create the following three folders on it: "word – sequences", "editseq – sequences", and "megalalign – protein alignments". The folders provide a means of organizing data that will be filed periodically and allow for its easy and fast retrieval.

PROCEDURE

The students may work individually, in pairs, or in larger groups. To maximize active-learning it is recommended that students work in teams of at least two or three so as to be able to capitalize on one another's strengths and compensate for individual weaknesses. However, group size may simply be determined by the class size and the number of computers available. The exercise can be completed within 1-1.5 hours.

During a pre-lab introduction, students are made aware that they will carry out a dynamic exercise that will depict aspects of the Central Dogma that could not be conveyed in the classroom. They are told that they will use bioinformatics to simulate the processing of wild-type and mutant alleles of the *unc-22* gene of *C. elegans*. It is explained that their manipulations of the gene sequences will illustrate and clarify the intricate and sensitive nature of the events of gene expression that comprise the Central Dogma. In addition, the exercise will require that they analyze not only the Central Dogma but also the downstream effects, *i.e.*, the relationships between nucleotide and amino acid sequences, and amino acid sequence and protein function, and ultimately the consequences of alterations in nucleotide and amino acid sequences on protein function.

The following are descriptions of the major steps of the procedure used by the students. A detailed step-by-step procedure is available upon request from the senior author.

Retrieval and Storage of DNA Sequences

Entrez, NCBI's search engine, is used to search the GenBank database for complete nucleotide and amino acid sequences for the wild-type *unc-22* gene and protein product Twitchin. Also obtained are the

unc-22 exon/intron boundaries and Tc5 nucleotide sequence. The sequences are saved in separate word processing and EditSeq® files for subsequent retrieval and manipulation.

Construction of Wildtype *unc-22* cDNA and Determination of its ORF. The *unc-22* gene sequence is manipulated to mimic the post-transcriptional processing that occurs to the *unc-22* mRNA. The exon/intron boundary information is used to remove the introns and ligate the exons. The product of the manipulation is a DNA sequence that is complementary to the processed mRNA of the *unc-22* gene. EditSeq® is used to locate the ORF within this complementary DNA sequence, known as cDNA, which is comprised solely of exon sequences.

Construction of Tc5-mutated *unc-22* cDNA and Determination of its ORF. The transposon Tc5 will be inserted into the third exon of the *unc-22* gene between nucleotides 16,114 and 16,115. This means that the ORF will be altered by the Tc5 element within the mRNA. This point is illustrated by introducing the Tc5 sequence into the *unc-22* cDNA sequence and using EditSeq® to locate the ORF.

Translation of *unc-22* mRNA. Now that the wild-type and Tc5-mutated alleles have been constructed, EditSeq® is used to translate each of the ORFs identified previously. One comment should be made. The sequence that was manipulated represents cDNA sequence because it contains thymine and is complementary to the fully processed mRNA encoded by the *unc-22* gene. EditSeq® translates the sequence by making the assumption that uracil replaces thymine.

Align and Compare Twitchin Sequences

An extension of the Central Dogma of Biology is that the primary amino acid sequence of a protein influences how it will fold into a conformation that determines its function within the cell. Therefore, if two proteins have similar amino acid sequences it is probable, although not guaranteed by any means, that their conformations and thereby their functions may be similar. The Twitchin sequence retrieved from the GenBank database along with the wild-type and Tc5-mutated Twitchin sequences just constructed are aligned using MegAlign® to allow for a comparison of their homology.

QUESTIONS FOR REVIEW

The following questions are provided to assist students in their processing and analysis of the exercise:

1. How did you determine the appropriate reference among the many that came up after each of your searches using Entrez?

2. What are the uses of the EditSeq® and MegAlign® programs?
3. How many amino acids are coded for by the ORF of the wildtype *unc-22* gene?
4. Tc5 is inserted into which codon of the *unc-22* ORF? What effect does the insertion of Tc5 have on the codon?
5. How many amino acids are coded for by the ORF of the Tc5-mutated *unc-22* gene?
6. How does the Twitchin protein product from the Tc5-mutated *unc-22* gene differ from that obtained from wild-type *C. elegans*?
7. Can you extrapolate from the data the explanation as to the reason the insertion of Tc5 into the *unc-22* gene results in a mutant twitcher phenotype?
8. Did the wild-type *unc-22* that you processed match the amino acid sequence that you retrieved from GenBank? If not, can you hypothesize when and where you might have gone wrong? Can you verify the accuracy of your hypothesis?
9. Prepare a detailed diagram that illustrates each of the processes below and where in a eukaryotic cell each would occur?
 - (a) insertion of a transposon within a gene
 - (b) transcription of the transposon-mutated gene
 - (c) post-transcriptional processing of the mRNA
 - (d) translation of the mRNA

RESULTS

A portion of the alignment of the three Twitchin sequences analyzed in this exercise is presented in Figure 1. The Twitchin protein constructed from the wild-type *unc-22* gene is 100% homologous to the amino acid sequence retrieved from GenBank. This is not observed in a comparison of the amino acid sequence of wild-type Twitchin and that derived from the Tc5-mutated *unc-22* gene of *C. elegans* (Figure 2). The transposon is inserted between the second and third nucleotides of the 538th codon. The codon, although altered from ACT to ACC encodes for the same amino acid, threonine, since the code is degenerate. Even though the transposon is inserted into the 538th codon an alteration is not observed until the 541st amino acid because the sequence of the 2nd through 7th nucleotides of Tc5, which now comprise the 539th and 540th codons, is identical to the wild-type codons. Only two different amino acids are introduced since the 543rd codon is a termination signal. Therefore, the Tc5-mutant Twitchin possesses 542 amino acids, of which all except the last two share 100% homology to the first 540 of the 6,048 amino acids of the wild-type version.



Figure 1. Alignment of Twitchin sequences. The three Twitchin sequences are, from top to bottom, the wild-type Twitchin obtained from GenBank, and the wild-type and Tc5-mutated Twitchins, both constructed during the exercise. The numbers across the top of each segment represent the amino acid positions. The letters above the numbers represent the consensus amino acid sequence while the black and grey colored bar indicates the complete and incomplete degree of homology shared among the three proteins, respectively. Note the presence of different amino acids and a termination signal, represented by a period, in positions 541, 542, and 543, respectively, of the Tc5-mutated Twitchin in comparison to the other Twitchin sequences.

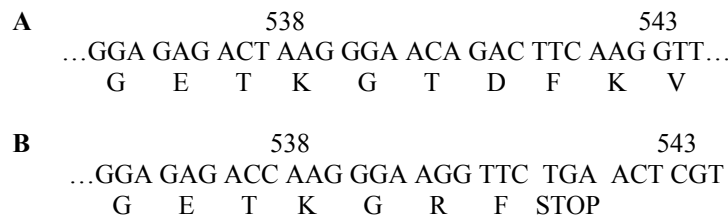


Figure 2. Comparison of Nucleotide and Amino Acid Sequences at the Tc5 Insertion Site in unc-22. (A) Wild-type unc-22 and Twitchin sequences. (B) Tc5-containing unc-22 and Twitchin sequences. Tc5 sequence is underlined. The introduction of Tc5 sequence alters the 538th codon but codes for the same amino acid, threonine, as the wild-type sequence due to the genetic code being degenerate. The subsequent two amino acids are identical to those found in wild-type Twitchin. Three novel codons are then introduced resulting in two different amino acids and a termination signal.

DISCUSSION

We believe this is a valuable exercise to teach the relationship between a gene's nucleotide sequence and the protein product that it encodes by allowing the students to conduct certain steps within the processes that comprise the Central Dogma. It introduces students to the use of on-line databases, and encourages them to use their decision-making skills while sorting through the many entries that are yielded from a search for the one that contains the desired information. The use of bioinformatic software to process a nucleic acid sequence and generate a cDNA, determine the location of and translate its ORF, and align amino acid sequences, allows the students to walk their way

through the Central Dogma and perform a comparative analysis of wild-type and mutated gene products. Rather than having to simply conceptualize the effects of a transposon insertion within the exon of a gene, students generate the Tc5 mutation and carry out the excision and ligation of the introns and exons, respectively, to produce a mature transcript which is translated. The alignment of the amino acid sequences clearly demonstrates how successful the students were at generating their protein products. Since the wild-type Twitchin product is compared to the amino acid sequence retrieved from GenBank there should be 100% homology. The introduction of the Tc5 sequence

results in a frameshift which introduces a premature stop codon and therefore a truncated protein product.

This exercise has been used with first-semester sophomore Biology and Biochemistry majors taking Cell Biology. Student reactions subsequent to their completion of this exercise have been overwhelmingly positive. For the majority of the students, the exercise was credited for being their first exposure to and use of a database such as GenBank to retrieve nucleotide and amino acid sequences, and use of bioinformatics software to manipulate gene and protein sequences. What impressed the students was the “massive number of nucleotides that make up a gene” and “how easy it must be to make an error in copying the sequence into RNA” or “during the removal of introns.” Students stated that the physical, and often times tedious, manipulation of the sequences allowed for “a better appreciation of the intricate nature of the processes of the Central Dogma” and a surprise that “mutations or mistakes are not a common occurrence.” Some students expressed that since the computer performed the conversion of nucleotide sequence to amino acid sequence that “the process of translation wasn’t really explained or clarified.” The comparison of a group’s alignment of the three amino acid sequences with those of other groups allowed students to determine unequivocally whether any mistakes were made. Inevitably there have been one or two student groups which did not get the proper results, and this has provided a perfect problem-solving opportunity. The students used their critical thinking skills and analytical abilities, as they reviewed what was done during the exercise, to hypothesize when and how the error was made. Since all of the major steps were saved as individual files it was possible to return to any given step and test their hypothesis and verify its accuracy by obtaining the three correct amino acid alignments. The chance to troubleshoot was a valuable opportunity for students to enhance their self-confidence as they reinforced their working knowledge of the events of the Central Dogma and the relationship between gene sequence and amino acid sequence. While the exercise does not generate three dimensional models from the amino acid sequences, the dramatic effect that the

insertion of Tc5 has on the Twitchin protein enabled students to conceptualize the detrimental effect on its function.

There are a variety of ways in which this lab can be modified to illustrate the relationship between a gene’s nucleotide sequence and the amino acid sequence for which it encodes. Nucleotides can be altered within the cDNA sequence illustrating that not all mutations are equivalent. Point mutations can be incorporated into the cDNA sequence to illustrate that certain changes are silent, that is they result in a codon change but not an amino acid change, while others are not since they code for a different amino acid. The color coding of amino acids in the alignment indicates the degree of homology, thereby illustrating the degree to which the chemical identities of amino acids within a given position are similar or different. Insertions or deletions in multiples of three will illustrate the subsequent effect on the open reading frame. As an open-ended follow-up exercise, students could pick a disease of interest, do a database search for wild-type and mutant amino acid sequences, and from an alignment of those sequences determine how the mutant protein’s structure differs from the wild type’s. The students could then predict how the mutant protein’s structure alters its normal function, and verify their prediction by an analysis of the relevant primary literature.

This exercise has the built-in flexibility to be manipulated in a variety of ways to satisfy a wide range of purposes of the instructor. This sometimes straightforward, yet challenging and demonstrative exercise has been helpful to alleviate the confusion our students have had with the Central Dogma. We hope you find it beneficial to your students.

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Step-by-Step procedure for the lab exercise described. The following is the procedure that the students use to guide them through the exercise on a Macintosh computer. *Minor alterations to the directions will be necessary if a PC is used.*

Prior to Beginning

Each student team should create the following three folders on the desktop: "word - sequences", "editseq - sequences", and "malign - protein alignments". The folders provide a means of organizing data that will be filed periodically and allow for its easy and fast retrieval.

Retrieval and Storage of DNA and Protein Sequences

1. Access the Entrez search engine at: <http://www.ncbi.nlm.nih.gov/>
2. Select "Nucleotide" within the "Search" drop box.
3. Click on the dialog box to get the cursor, enter "*unc-22*", and then hit the "return" key or click on "Go".
4. Review the entries and determine which one would most likely contain the following information: (a) *unc-22*

- gene sequence, (b) locations of introns and exons within *unc-22*, and (c) the single letter amino acid sequence of the Twitchin protein encoded by *unc-22*.
5. Click on the hotlink for your entry choice.
 6. Scroll down and review the information provided. Verify that it contains all of the necessary information mentioned above.
 7. Confirm your choice with the instructor. **Instructor's Note: The correct entry is X15423: *Caenorhabditis elegans unc-22 gene for twitchin*.**
 8. Highlight and copy the amino acid sequence of the *unc-22*-encoded protein Twitchin.
 9. Paste the amino acid sequence into a Word document, and save it in the "word – sequences" folder as "word - Twitchin genbank".
 10. Close the Word window.
 11. Double Click on the "LASERGENE Navigator" icon on the desktop.
 12. Click on the "Sequence Editing & Analysis" box.
 13. Click on "File", highlight "New" and then once the drop down box appears highlight "New Protein" to open an EditSeq window.
- Note: Following the next step a window will appear saying that the data "doesn't seem to be protein data" because the sequence you copied had line returns. By clicking the "OK" box it will filter out the line returns and only enter the protein sequence. Ignore this warning each time it appears during this exercise.**
14. Click on "Edit" and highlight "Paste". (You are pasting in the last thing you copied which was the Twitchin sequence.)
 15. Title this document "editseq - Twitchin genbank" and save it to the "editseq - sequences" folder.
 16. Close the EditSeq window.
 17. Return to Netscape and highlight and copy the exon and intron basepair information including the poly A-site for the *unc-22* gene.
 18. Paste the exon and intron boundaries into a new Word document, and save it in the "word – sequences" folder as "word - *unc-22* exon/intron".
 19. Close the Word window.
 20. Return to Netscape and highlight and copy the nucleotide sequence of the *unc-22* gene.
 21. Paste it into a new Word document, and save it in the "word – sequences" folder as "word - *unc-22* genomic".
 22. Close the Word window.
 23. Return to EditSeq.
 24. Click on "File", highlight "New" and when the drop down box appears highlight "New DNA".
 25. Paste in the *unc-22* sequence.
 26. Save this in the "editseq - sequences" folder as "editseq - *unc-22* genomic".
 27. Close the EditSeq window.
 28. Return to Netscape, click on the "Back" button in the upper left corner of the Netscape window.
 29. Highlight the phrase "*unc-22*" in the dialog box at the top of the page and enter "Tc5", then click on "Go" or press the "return" key.
 30. Review the entries and determine which one would most likely contain the complete Tc5 gene sequence.
 31. Click on the hotlink for your entry choice.
 32. Scroll down and review the information provided. Verify that it contains the complete Tc5 gene and amino acid sequences and intron/exon boundaries.
 33. Confirm your choice with the instructor. **Instructor's Note: The correct entry is U12433: *Caenorhabditis elegans mut-2 mutator strain transposon Tc5 putative transposase gene, complete cds*.**
 34. Highlight and copy the nucleotide sequence.
 35. Paste it into a new Word document, then save it in the "word - sequences" folder as "word - Tc5 seq".
 36. Close the Word window.
 37. Return to EditSeq.
 38. Click on "File", highlight "New" and when the drop down box appears highlight "New DNA".
 39. Paste in the Tc5 sequence.
 40. Save the Tc5 sequence in the "editseq - sequences" folder as "editseq - Tc5 seq".
 41. Close the EditSeq window.

Construction of Wildtype *unc-22* cDNA and Determination of its ORF: The *unc-22* gene encodes for a protein that functions in the regulation of muscle contraction. The protein is called Twitchin because, when mutated, the muscle contraction is not properly regulated and the worm has a distinctive body twitch. The following steps will mimic the post-transcriptional processing that occurs to the *unc-22* mRNA to remove the introns and ligate together the exons. The product of the manipulation is a DNA sequence that is complementary to the processed mRNA of the *unc-22* gene. This complementary DNA sequence is known as cDNA.

1. Open the "word - *unc-22* exon/intron" file and print it out.
2. Close the Word window.
3. Examine the print out and note that the numbers across from the word "intron" represent the first and last nucleotides of that intron. To process the *unc-22* sequence, each of the intron sequences must be removed by

highlighting the respective nucleotides and then deleting them.

Note: The introns must be removed in reverse order (i.e., the 13th intron is spliced out first and the 1st intron is spliced out last).

4. Return to EditSeq.
5. Open the "editseq - unc-22 genomic" file.
Note: The range of nucleotides you highlight is shown at the top of the window. It is critical to the successful construction of the proper cDNA, that you verify prior to the deletion of the highlighted sequence, that it contains only the desired nucleotides.
6. Remove intron 13 by highlighting the corresponding nucleotides and then pressing the "delete" key.
7. Repeat step 4 for each of the remaining 12 introns.
8. Save the final sequence in the "editseq - sequences" folder as "editseq - unc-22 cDNA".
9. An open reading frame (ORF) is the sequence between start and stop codons. To determine the ORF within the cDNA, position the cursor to the left of nucleotide 14,070 (i.e., the first nucleotide in the start codon) in the sequence, click on "Search", highlight "Find ORF...", and when the new window appears click on "Find Next".
10. Copy the highlighted sequence and paste it into a "New DNA" window.
11. Save this sequence in the "editseq - sequences" folder as "editseq - unc-22 ORF".
12. Close the EditSeq window.

Construction of Tc5-mutated unc-22 cDNA and Determination of its ORF: The transposon Tc5 will be inserted into the third exon of the unc-22 gene between nucleotides 16,114 and 16,115. This means that the ORF will be altered by the Tc5 element within the mRNA. This point can be illustrated by copying the Tc5 sequence and introducing it into the unc-22 cDNA sequence.

1. Open the file "editseq - Tc5 seq".
2. Select all of the sequence and then copy it.
3. Close the EditSeq window.
4. Open the file "editseq - unc-22 ORF".
5. To find the insertion site of Tc5 within the *unc-22* open reading frame, click on "Search", highlight "Find...", click "Literal", type in the following sequence, which precedes the Tc5 sequence in the *unc-22* gene: "TAAAGTTGGAGAGAC", and click "Find Next".
6. Position the cursor to right of the final highlighted "c" and Paste the Tc5 sequence, which you previously copied, into this location.
7. Position the cursor to the left of the first nucleotide in the sequence, click on "Search", highlight "Find ORF...", and when the new window appears click on "Find Next".
8. Copy the highlighted sequence and paste it into a "New DNA" window.
9. Save this sequence in the "editseq - sequences" folder as "editseq - unc-22/Tc5 ORF".
10. Close each of the EditSeq windows.

Translation of unc-22 mRNA: Now that all of the intron sequences have been removed, the remaining nucleotide sequence can be translated. One comment should be made. The sequence that was manipulated represents cDNA sequence because it contains thymine and is complementary to the fully processed mRNA encoded by the *unc-22* gene. The EditSeq program will be used to translate the mature mRNA sequence that was previously constructed by making the assumption that uracil replaces thymine.

1. Open the file "editseq - unc-22 ORF".
2. Click on "Edit" and highlight "Select All".
3. Click on "Goodies" and highlight "Translate DNA".
4. The new window contains the single letter amino acid sequence for the Twitchin protein. A period at the end of the sequence indicates the presence of a STOP codon.
5. Save this sequence in the "editseq - sequences" folder as "editseq - Twitchin ORF".
6. Open the file "editseq - unc22/Tc5 ORF".
7. Highlight all of the sequence, click on "Goodies", and highlight "Translate DNA".
8. The new window contains the single letter amino acid sequence specified by the *unc-22* mRNA possessing the Tc5 sequence.
9. Save this sequence in the "editseq - sequences" folder as "editseq - Twitchin/Tc5 ORF".
10. Close each of the EditSeq windows.

Align and Compare Twitchin Sequences: An extension of the Central Dogma of Biology is that the primary amino acid sequence of a protein influences how it will fold into a conformation that determines its function within the cell. Therefore, if two proteins have similar amino acid sequences it is probable, although not guaranteed by any means, that their conformations and thereby their functions will be similar. One of the first things that was done in this exercise was the retrieval of the Twitchin sequence from the GenBank database. The following steps will allow for that sequence along with the wild-type and Tc5-mutated Twitchin sequences, you just constructed, to be compared for homology.

1. Click on the "LASERGENE Navigator" and then click on the "Multiple Sequence Alignment" box.
2. Click on "File" and highlight "Enter Sequences..."

3. In the top window find and double click on the file "editseq - Twitchin genbank".
4. Double click on the file "editseq - Twitchin ORF".
5. Double click on the file "editseq - Twitchin/Tc5 ORF" and click on "Done".
6. Note the information contained in the three sections of the new window.
 - a. The left section contains a color code to indicate the degree of homology among the compared sequences, the consensus sequence (*i.e.*, the most common amino acid for each position), and the file names of the protein sequences being compared.
 - b. The center section contains the N-terminal portion of the protein sequences and above the consensus sequence is a color bar that indicates the degree of homology among the proteins.
 - c. The right section contains the C-terminal portion of the protein sequences and also contains a color bar to indicate homology among the proteins.
7. Save this comparison in the folder "megalign - protein alignments" as "megalign - Twitchin seqs".
8. Print out this comparison on the color printer.

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Using a Contextual Approach in Teaching Evolutionary Theory and its Attendant Controversy to Undergraduates

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ABSTRACT: Pedagogical research indicates that student engagement and comprehension are enhanced by methodologies that promote active participation, critical thinking, and an interdisciplinary, "contextualist" approach. In light of these findings, we developed several activities to teach evolutionary theory to students (many of whom are non-biology majors) in an upper-division "capstone" course. We begin by introducing evolutionary theory from a historical context, through which early geologic and paleontologic evidence is considered. To augment this portion of the unit, student volunteers make a class presentation using transparencies from the book *Darwin for Beginners* (Miller and Van Loon, 1982), which provides additional historical information pertaining to social and religious contexts. Subsequent activities involve (1) in-class viewing and discussion of a 1997 *Firing Line* debate between evolutionists and creationists, which enables students to draw parallels between past and current resistance to evolutionary theory; and (2) discussion of the range of contemporary views regarding evolution, which Scott (1999) refers to as the "creation/evolution continuum." After consideration of evolutionary theory in both past and current times, students individually write a mock letter to a newspaper editor in which they articulate their opinion regarding the teaching of evolution in public schools. This paper provides examples of critical thinking questions for the *Firing Line* debate, informative web sites and a rubric for the mock letter to the editor, and a review of resources that instructors can use to place evolutionary theory in various other contexts (e.g., human illness and sexuality, biomedical research and ethics, Social Darwinism and eugenics).

KEY WORDS: *evolution, creationism, context, historical, rubric, critical thinking*

INTRODUCTION

The undergraduate curricula of many colleges and universities include General Education Requirements (GERs), which are intended to expose students to a broad range of academic disciplines. At our institution, courses that satisfy the GERs are structured as a Tier system. Tier III "capstone" courses serve as the upper-division final component, designed to enable students to integrate and synthesize knowledge across curricula. In the capstone course entitled "Invertebrates in Biological Thought," students are engaged in class discussions and presentations that promote active

learning and critical thinking. The course presents a chronological narrative on the human perspective of the natural world, surveying the development of scientific ideas and knowledge from antiquity, through Darwinism, and into the 20th century. The course also emphasizes the sweeping relevance of evolutionary theory by highlighting the insight, applicability, and advances gained from past and current research involving invertebrates as "model systems."

The stated objectives of this capstone course are to (1) foster a historical, interdisciplinary perspective on the origin and growth of biological concepts and

knowledge; (2) provide students with a deeper appreciation for the paradigm of organic evolution and its significance for everyday life; and (3) promote the development of scholarship, critical thinking, and effective communication skills. Toward this end, approaches are employed that enable students to view evolutionary theory in historical and other contexts. For example, to gain a historical perspective, students first examine natural theology, which proffers an explanation for life on earth that prevailed before Darwin published the *Origin of Species* (1859). Students also consider geologic findings that emerged during the 18th and 19th centuries. They are then presented with an overview of Darwin's life, including his 5-year voyage around the world onboard the *H.M.S. Beagle*, which provided him with ample evidence for evolution and reasons to question the tenets of natural theology. Following this, students are given a detailed view of Darwinian theory, which they then compare and contrast with natural theology. At this point, they are poised to explore the reasons that evolutionary theory met with strong opposition in Darwin's time. Having thus constructed a broad, historical framework for Darwinian theory, students can then be led logically through an exploration of reasons underlying current anti-evolution sentiments. This enables discussion of evolutionary theory within other contexts, including societal ramifications (e.g., social Darwinism and the eugenics movement) and contemporary religious objections.

Matthews (1992) lists several reasons that a contextualist approach in science teaching translates into more effective student learning: "It motivates and engages students; humanizes the subject matter; promotes the better comprehension of scientific concepts by tracing their development and refinement; ...demonstrates that science is mutable and changeable, and that consequently current scientific understanding is liable to be transformed, which thus combats scientific ideology; and... history allows a richer understanding of scientific method and displays the patterns of change in accepted methodology." In an article that examined biology teaching methods through history and how students learn, Bicak and Bicak (1999) state, "Effective learning is typically linked to the importance or relevance of the concept to the student. For most of us, the content or processes of the sciences are best internalized in the context of models we have constructed for some phenomenon." The approaches we developed to present evolutionary theory to undergraduates, many of whom are non-biology majors, embody the views espoused by Matthews (1992), Bicak and Bicak (1999), and others (Spiece and Colosi, 2000; Alles, 2001; Turco and Byrd, 2001). The activities we devised promote active student engagement, critical thinking, and a practical understanding of the biological sciences; the benefits of these activities have been recounted by others (Chiel,

1996; Steglich, 2000; Lawson, 2001; Rutledge, 2001; Wells and Neff, 2001).

This paper begins with an overview of historical ideas that helped set the stage for evolutionary thought, then describes the pedagogy employed to enable students to develop a contextual perspective of Darwin and Wallace's theory of species origin, including the controversy that ensued and persists to the present day. It concludes with a brief review of additional resources that help contextualize evolutionary theory in the classroom.

HISTORICAL BACKGROUND

Inferences from Paleontology and Geology

During the 17th century, naturalists began to question long-held perceptions regarding the age of the earth and the constancy of its species (Mayr, 1982; Moore, 1993). The discovery of fossils that resembled living organisms perplexed naturalists. Had fossils once been living creatures? If so, how had they changed to stone? How could one explain the appearance of fossils that resembled no known living organisms? If fossils had once been living organisms, how had those that resembled marine organisms come to lie embedded at the tops of mountains, far from the sea? Mounting paleontologic and geologic evidence gathered by luminaries Robert Hooke, James Hutton, William Smith, Georges Cuvier, and Charles Lyell also cast doubt on the perceived constancy of the earth's crust. Thus it became increasingly apparent that the earth's surface had changed, species had gone extinct, and the earth itself had a very long history, much greater than suggested by a literal interpretation of the Bible.

Natural Theology Usurps Scholasticism

The 17th century also marked the beginnings of natural theology with the writings of clergyman John Ray (1627-1705), whom historians regard as the greatest English naturalist of his day. In 1691, Ray published "*The Wisdom of God Manifested in the Works of the Creation*," in which he discussed and provided descriptions of God's animate earthly creations in an attempt to ascertain the Deity's attributes (Ray, 1691). Natural theology held that anyone could honor God and strive to comprehend Him by studying His handiwork--i.e., the countless seemingly perfect adaptations of organisms in the natural world. As such, natural theology stood in contrast to traditional theology (termed scholasticism), which dictated that only theologians could interpret scripture, which became church dogma and thus, the embodiment of "truth."

Ray's approach became popularized by Reverend William Paley (1743-1808) with his 1802 publication, "*Natural Theology: or, Evidences of the Existence and Attributes of the Deity Collected from the Appearances of Nature*" (Paley, 1802). Paley's book was required

reading for matriculation in Cambridge University and was widely admired and studied by naturalists, including T. H. Huxley (also known as “Darwin’s Bulldog” due to his steadfast and vociferous support of the famous naturalist) and Charles Darwin. Indeed, nine days prior to the publication of the *Origin of Species* Darwin averred, “I do not think I hardly ever admired a book more than Paley’s ‘Natural Theology.’ I could almost formerly have said it by heart.” (Darwin, 1959). Paley’s *Natural Theology* put forth what became known as the “argument from design”-- *i.e.*, the view that the remarkably adaptive structures found in living organisms must have been purposefully designed and thus, bespoke the existence of an intelligent Creator. Paley employed the now famous “watch metaphor” to illustrate the argument from design. He pointed out that for a watch to serve its function as a time piece, its various gears and parts must be constructed and assembled very precisely, an accomplishment unachievable by chance association of components. Thus, the watch must have had an intelligent maker. By analogy, he reasoned, the much more complex human eye must also have had an intelligent Creator.

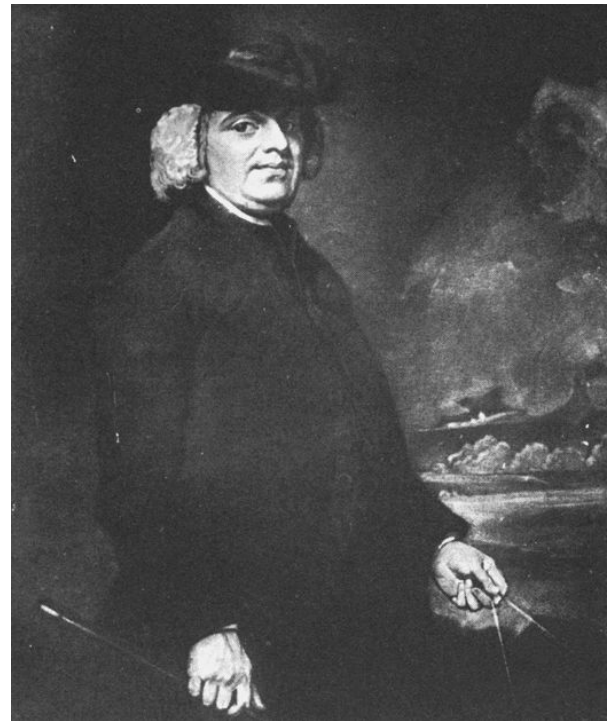


Fig. 2. William Paley



Figure 1. John Ray

ACTIVITIES THAT CONTEXTUALIZE EVOLUTIONARY THEORY

The textbook used for this course, *Science as a Way of Knowing* (Moore, 1993), presents a cultural history of biology and the scientific advances that led to our modern understanding of evolutionary theory, including information summarized above as historical background. The basic conceptual framework provided by Moore's text was augmented with information from other sources, *e.g.*, *One Long Argument* (Mayr, 1991) and *The Growth of Biological Thought* (Mayr, 1982). To prepare students for the unit on evolutionary theory, the impact of geologic and paleontologic evidence in various contexts (scientific, societal, religious) was introduced. Next, students were engaged in various activities designed to foster oral communication skills, cooperative learning, and meaningful group discussion, while enabling them to better contextualize the reasons that Darwinian theory has met marked resistance since its inception. In the first activity, student volunteers were asked to make a class presentation using transparencies that were provided from *Darwin for Beginners* (Miller and Van Loon, 1982). The illustrations that comprise this book's whimsical (yet accurately representational) text provide a thumbnail sketch of Darwin's formative years, the influences on his scientific thinking, the various factors (social, scientific, religious, *etc.*) that led him to delay publication of his theory for more than 20 years, and the far-reaching impact of his revolutionary theory.

Following completion of this activity, students participate in three additional activities designed to enhance their understanding of the various factors that underlie current resistance to evolutionary theory. The first activity involves an in-class viewing of a *Firing Line* (1997) debate entitled, "Resolved: The evolutionists should acknowledge creation." The debate features William F. Buckley, Jr., Phillip Johnson, Michael Behe, and David Berlinski representing the creationist side, and Barry Lynn, Eugenie Scott, Michael Ruse, and Kenneth Miller arguing for the evolutionist side. Before watching the video, students were instructed to view the debate in light of what they have learned about 19th century arguments against Darwinian theory. [Note: Useful

background information for this exercise is provided in Mayr (1982), Miller and Van Loon (1982), and Moore (1993)]. At the conclusion of the video, questions were posed that challenge the class to identify parallels between 19th and 20th century opposition to evolutionary theory. [See Box 1.] The following topics should emerge in the post-video discussion: intelligent design (*i.e.*, as being comparable to argument from design), inadequacy of the fossil record, insignificance of intraspecific variation, inability of natural selection to serve as an evolutionary mechanism for macroevolutionary change, methodological objections, and religious objections.

Box 1. Examples of Critical Thinking Questions for *Firing Line* debate

1. What complex human structure does Buckley invoke that recalls Paley's argument from design? (Answer: the human eye)
2. What example does Behe use that is reminiscent of Paley's argument? (Answer: complexity of a bacterial flagellum evidences an Intelligent Designer)
3. What does Berlinski claim about the fossil record that echoes concerns raised in Darwin's time? (Answer: absence of intermediate forms) Is this correct today?
4. What is Johnson's major complaint regarding Darwinian theory that also was raised by Darwin's contemporaries? (Answer: mechanism of natural selection-- unable to account for macroevolution)
5. How does Berlinski's carping (re: number of changes required to produce a macroevolutionary change) remind you of historical objections to Darwin's methodology? (Answer: historical opposition to Darwin's use of hypothetico-deductive method, which was viewed as speculative rather than experimental/ predictive)
6. Do the exchanges between Buckley vs. Miller and Ruse recall arguments that Darwin's contemporaries raised against his theory? Explain. (Answer: yes; these portions of the debate focus on religious objections; claim is that evolution removes God from creation)

For the next in-class activity, students are provided copies of the article entitled "The Creation/Evolution Continuum" for discussion (Scott, 1999; available on-line with permission to reproduce). This article argues that the dichotomy used to pit creationism against evolutionism is based on a misconception, since in reality a broad continuum exists between two extremes (the article defines eleven categories that range from Flat-Earthers to Materialistic Evolutionists) (Fig. 3). For this activity, students are arranged into groups and each is assigned a portion of the creation/evolution continuum to discuss, summarize, and present to the class.

The final activity allows students to reflect on their own views and opinions regarding evolution and theology without negative peer pressure or instructor bias. Each student writes (out-of-class) a mock letter to a newspaper editor regarding the teaching of evolution in primary and/or secondary public schools. This exercise engages students in both a reflective and a contemporary context, as it requires them to account for their convictions in an informed, substantive manner. Students are encouraged to present their beliefs freely in their letters and are permitted to take either side of the argument or even assume a "middle-of-the-road" stand. The primary objectives of this

activity are for students to: (1) argue their point of view persuasively and cogently using evidence to support their arguments, and (2) summarize, analyze, critique, and respond to the opposing viewpoint in a mature, appropriate fashion. These objectives and specific criteria for the letters are fully articulated (both orally and in written form) to the students. In brief, students must: clearly state their beliefs, define any terms/jargon both scientifically and in lay language, argue fairly and interpret information accurately,

identify the assumptions that underlie their argument(s) and that of their opponents, identify specific points of agreement (if any) and disagreement with the opposition, critique the opposing viewpoint, cite at least three references, and write clearly and effectively. Each student receives a rubric listing the required elements of the letter and associated point values. [See Box 2.]

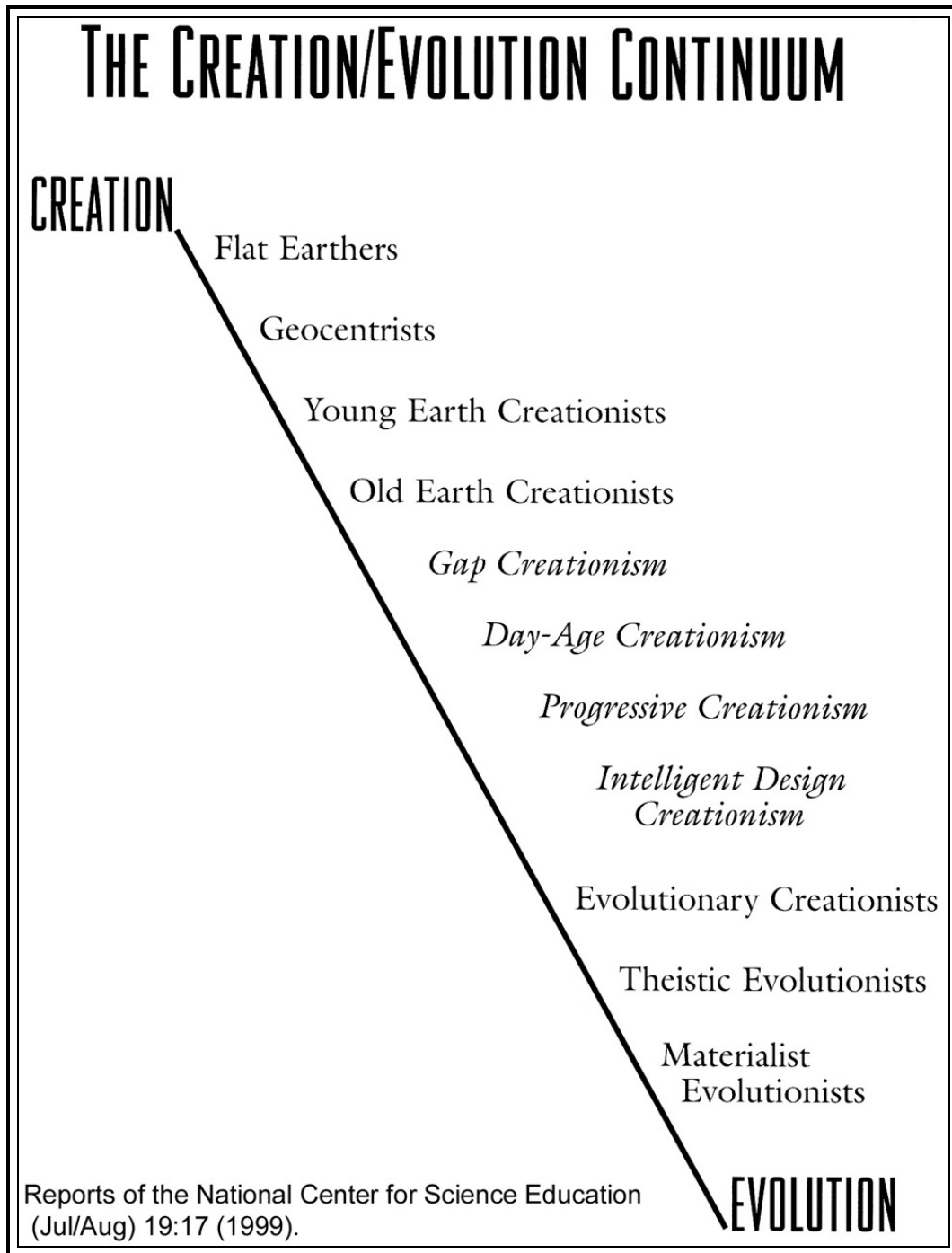


Figure 3. Creation/Evolution Continuum (Scott, 1999)

Box 2. Rubric for Letter to the Editor regarding teaching evolution in public schools. Except for #6, bullets for each numbered entry represent an incremental improvement in performance. Total possible points for a given bullet appear at the end of each bulleted statement.

1) Identifies & explains the issue/topic at hand (10%)

- Does not identify nor explain main issue/topic at hand (0)
- Identifies main issue but does not explain clearly; is confusing (5)
- Identifies main issue/topic clearly, explains in limited fashion (8)
- Identifies main issue/topic clearly, explains fully, and discusses implications of the issue (10)

2) Identifies & uses at least 3 sources (references) (15%)

- Does not identify 3 sources (0)
- Cites and correctly interprets one appropriate source (5)
- Cites and correctly interprets two appropriate sources (10)
- Cites and correctly interprets three appropriate sources (15)

3) Identifies & presents the student's own perspective of the issue at hand (25%)

- Fails to identify and state his/her own perspective/analysis of the issue at hand (0)
- Confusedly states own perspective/analysis (12)
- Identifies and states own perspective/analysis, but does so in a limited fashion (18)
- Identifies and states fully his/her own perspective/analysis (25)

4) Identifies and fairly represents and critiques the opposing viewpoint (15%)

- Does not identify, fairly represent, nor critique opposing viewpoint (0)
- Identifies opposing viewpoint, but misrepresents it or critiques it improperly (8)
- Identifies opposing viewpoint and represents and critiques it in a limited fashion (12)
- Identifies opposing viewpoint and represents and critiques it satisfactorily (15)

5) Writes clearly and effectively (20%)

- Fails to present a logical flow of ideas (0)
- Presents logical flow of ideas, but does so with many errors (guidelines, grammatical, *etc.*) (10)
- Presents logical flow of ideas, but does so with some errors (guidelines, grammatical, *etc.*) (16)
- Presents logical flow of ideas, follows guidelines and rules of English usage and grammar (20)

6) Meets technical requirements for letter to editor (15%)

- Fails to meet length requirement (*ca.* 450 words of TEXT; *record word count on your letter*)
- Fails to double-space letter
- Fails to meet deadline for letter submission
- Meets requirements for length, spacing, and deadline (15)

A good starting place for students to obtain information needed to write their letter to the editor is the home page for the National Center for Science Education (<http://www.natcensci.ed.org>), which provides particularly useful links, including one for the Science and Creationism page of the National Academy of Sciences, and web sites for various Creation Science related sites [*e.g.*, Center for Renewal of Science and Culture (an Intelligent Design "think tank" associated with the Seattle-based Discovery

Institute), Reasons to Believe (a Christian ministry that favors an Old Earth view), Institute for Creation Research (a major center for Young-Earth Creationism), Christian Answers (a Christian site with links to many other sites), and Access Research Network (advocates of Intelligent Design)]. In addition to these web sites, several works scrutinize American attitudes toward evolutionary theory and the controversy surrounding teaching evolution, including Ruse (1982), Webb (1994), Larson (1997), Numbers

(1998), and Moore (2000). Books that present specific evidence in support of evolutionary theory while refuting creationist claims include those by Ruse (1982), Futuyma (1983), and Pennock (2000). Miller (1999) addresses creationist opposition while advancing a strong, personal argument in favor of the reconciliation of science and religion.

Instructors who wish to expose students to contemporary viewpoints in opposition to evolutionary theory may find the following books useful: Denton (1985), Johnson (1993), Behe (1996), Behe *et al.* (2000), and Wells (2000).

MODEL SYSTEMS AND EVOLUTIONARY THEORY IN THE CONTEXT OF EVERYDAY LIFE

The course provides numerous examples of the use of invertebrates as model systems in basic and biomedical research, emphasizing that extrapolation from these systems to humans is possible because all life forms share a common ancestry. Invertebrate examples are cited that have profoundly elucidated parallel areas in human biology include: fertilization in sea urchins (Epel, 1976), signal transduction of vision in horseshoe crabs (Sargent, 1987), electrophysiology and biochemistry of neuronal transmission in squid giant axons (Gilbert *et al.*, 1990), neurotransmitter function in memory storage in marine snails (Anonymous, 2002a), electrophysiology and identification of specific ion channels using invertebrate toxins and venoms (*e.g.*, apamin from honey bee venom, conotoxin from cone shells, tetrodotoxin produced by symbiotic bacteria of blue-ringed octopuses, *etc.*) (Anonymous, 2002b), and potential use of scorpion and other venoms to treat certain tumors and types of epilepsy and facilitate improved pharmaceutical design (Anonymous, 2001).

Given the prevalence of applications that derive from evolutionary theory, instructors can demonstrate the significance of the theory in everyday life by couching it within contexts that tend to resonate with students, such as human illness and sexuality, biomedical research and ethics, and the environment. Hillis (1999) explains that phylogenetic analyses of the human influenza type A virus are being used to predict which of the current, constantly evolving strains will likely be most related to the epidemic strain for the following year. This information can then be used to produce a more effective flu vaccine. Evolutionary principles also are being integrated into mathematical models to enable researchers to understand and reduce the rate of bacterial resistance to antibiotics (Levin *et al.*, 1999). Neese and Williams (1994) posit evolutionary explanations for many medical puzzles, including why natural selection has not eliminated cancer and other diseases, why we get sick, and why we crave unhealthy foods. It also has been argued that a search for evolutionary explanations for human

substance abuse may enable us to use psychotherapeutic drugs more safely and effectively (Neese and Berridge, 1997). Diamond (1997) examines human sexuality and various behaviors (*e.g.*, smoking, mate selection, adultery) from an evolutionary perspective. Avise (1998) provides an overview in lay terms of evolutionary genetics and advances made with plant and animal model systems, and discusses ethical issues raised by biotechnologies capable of manipulating the human genome. In the modern classic, *Silent Spring*, Carson (1962) examines the multifarious consequences of pesticide misuse, overuse, and abuse, and in the process, explains in eloquent prose key evolutionary concepts such as selection pressure, fecundity, community level interactions, and predator-prey population dynamics.

ADDITIONAL APPROACHES FOR CONTEXTUALIZING EVOLUTION

Instructors can elaborate, in many ways, on the historical responses to evolutionary theory and its impacts and ramifications. Several scholarly works examine in greater detail various religious, political, and cultural factors underlying 19th century responses to Darwinian theory (Hull, 1973; Glick, 1974; Ruse, 1979; Kohn, 1985). Bowler (1989) provides an analysis of the history of evolutionary ideas and the social implications of Darwinism, including eugenics and racism. Gould (1996) presents a rich contextual analysis of two centuries of racially-biased research on human intelligence (mostly in the U.S. but also in Western Europe), which he traces from its pre- and post-Darwinian origins through the 1994 publication of *The Bell Curve*, by Herrnstein and Murray (1994). Importantly, Gould (1996) emphasizes the devastating social consequences resulting from misinterpretations of Darwinian theory and the inextricably linked field of genetics (*e.g.*, Social Darwinism, U.S. forced sterilization laws and immigration policy during the eugenics movement, the rise of Nazism and the Holocaust).

Several books intertwine historical aspects of evolutionary theory with modern ideas and applications. Ruse (1982) presents an informative look at Darwin's contributions and those who influenced him, and also discusses evolutionary theory in terms of population genetics, sociobiology, punctuated equilibrium, human evolution, and the American "Scientific Creationism" movement. Weiner (1994) provides an engaging sketch of Darwin's life and scientific thinking, interspersed with an account of Peter and Rosemary Grant's lifelong research involving Galápagos finches. Dover (2000) proffers an imagined two-way correspondence between himself at the turn of the new millennium and Darwin in the 19th century, as an ingenious vehicle to bring readers (and Darwin!) up-to-date on advances in evolutionary biology. For instructors who wish to elaborate on the

changing view of the earth's age from the 17th through 19th centuries and its importance to Darwin's theory, Gould (1987) renders a fascinating historical account.

CONCLUDING REMARKS

This paper describes several approaches that can be employed effectively to contextualize evolutionary theory. Use of a historical perspective enables us to present this topic in a less threatening and more comprehensive way than could be achieved solely within the context of biology. The *Firing Line* debate video and mock letter to the editor allow students to examine current issues surrounding the teaching of evolution and offer their own enlightened opinion on the matter. Contributions that invertebrates studies have made to advances in human biology and medicine afford students a better grasp of the very real impact of evolutionary theory on "cutting edge" ideas and technology. Taken together, these pedagogical approaches deepen student understanding of evolutionary theory.

Our general impression, formulated over several years, is that most upper-division undergraduate

students receive scant exposure to the tenets of evolutionary theory and the ongoing controversy that surrounds its being taught in public schools. In an anonymous exit questionnaire, students were asked to respond to several prompts regarding the course using the following scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree. To the prompt, "I learned something about the evolution/creationism controversy from this course," student response (N=19) yielded a mean of 4.63 ± 0.58 . Scott (1999) emphasizes the need for teachers to debunk the commonly held notion that belief in evolution necessitates atheism, a point borne out by a recent survey, which found that approximately 40% of working physicists and biologists hold strong religious beliefs (Easterbrook, 1997). We concur with Scott (1999) and have found that, in general, students have a strong desire to learn more about the evolution controversy and appreciate doing so in an atmosphere of collegiality, open inquiry, and respect. We urge others to explore ways to incorporate a contextual approach when teaching evolutionary theory in their own classrooms.

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ACUBE 47TH Annual Meeting

October 9-11, 2003

Truman State University
Kirksville, MO

Biology for Contemporary Living

Preliminary Program



Thursday, October 9th

2:00 - 5:00 PM	Pre-Conference Field Trip: Crinoid fossil quarry	Location TBA
3:00 - 5:00 PM	Steering Committee Meeting	Conference Room Student Union
6:00 - 8:00 PM	Registration and Reception <i>heavy h'ors d'oerves</i>	Violette Hall
8:00 - 9:00 PM	Opening Session	Violette Hall

Welcome to ACUBE:

ACUBE President: **Margaret Waterman**, *Southeast Missouri
State University*

Welcome to Truman State University:

Program Chair: **Lynn Gillie** *Elmira College*
Local Arrangements Chair: **Nancy Sanders**, *Truman State
University*

OPENING ADDRESS (Public Welcome to Attend)

Michael Kelrick, *Truman State University*
Title: TBA

9:15 - 10:15 PM	Steering Committee Meeting	Conference Room Student Union
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Friday, October 10th

7:00 AM - 5:00 PM	Registration table	(all locations are in the Student Union unless otherwise indicated)
7:00 - 8:00 AM	Buffet Breakfast (by Interest Group)	
7:30 - 10:30 AM	Field Trip: Birding	Location TBA

9:00 AM - Noon and 2:00 - 5:00 PM	SUSTAINING MEMBER EXHIBITS Refreshments provided	Activities Room
8:15-9:45 AM	CONCURRENT WORKSHOP SESSIONS I	3rd Floor
9:50-10:20 AM	POSTER SESSION I Refreshments provided	Activities Room
10:30 - 11:15 AM	CONCURRENT PAPER SESSIONS I	3rd Floor
11:20 - 12:05 AM	CONCURRENT PAPER SESSIONS II	3rd Floor
12:15 - 1:00 PM	Luncheon and First Business Meeting <i>First and Final Call for Nominations!!</i> <i>Out of this World Teaching Idea contributions</i>	Georgian Room
1:00 - 1:45 PM	Luncheon Program Judy Dilts , <i>William Jewell College</i> <i>Title: TBA</i>	Georgian Room
2:00 - 5:00 PM	Field Trip: Restored Prairie	Location TBA
2:00–2:45 PM	CONCURRENT PAPER SESSIONS III	3rd Floor
2:50 - 3:20 PM	POSTER SESSION II Refreshments provided	Activities Room
3:30 - 5:00 PM	CONCURRENT WORKSHOP SESSIONS II	3rd Floor
5:05 - 5:45 PM	Web Committee Meeting	Conference Room
6:00 - 7:00 PM	Social Still National Osteopathic Museum and historic medicinal garden (resumes of candidates available for review)	Tinning Education Center, Kirksville College of Osteopathic Medicine (KCOM)
7:00 - 9:00 PM	NE Missouri Dinner and Second Business Meeting (two-minute speeches prior to dinner; balloting after dinner presentation) Dinner Presentation Phillip Wilson , <i>Penn State</i> <i>Title: TBA</i> <i>Presentation of the 2003 Out of this World Teaching Idea</i>	The Commons, KCOM McCreight Auditorium, KCOM

Saturday, October 11th

7:30 - 8:45 AM	Buffet Breakfast (by Interest Group)	Georgian Room Student Union
7:45 - 8:45 AM	Bioscene Editorial Board	Georgian Room

9:00 - 9:45 AM	CONCURRENT PAPER SESSIONS IV	3rd Floor
10:00 - 10:45 AM	CONCURRENT PAPER SESSIONS V	3rd Floor
11:00 AM - 12:15 PM	Luncheon and Third Business Meeting BUSINESS MEETING Resolutions: <i>Dick Wilson, Rockhurst University</i> Executive Secretary Report: <i>Pres Martin, Hamline University</i> Bioscene: <i>Ethel Stanley, Beloit College & Tim Mulkey, Indiana State University</i> Presidential Address: <i>Margaret Waterman, Southeast Missouri State University</i> 2004 Meeting: <i>Austin Brooks, Wabash College</i>	Georgian Room
12:30 - 3:00 PM	Steering Committee Meeting Includes newly elected Steering Committee members!	Conference Room
12:30 - 4:00 PM	Post conference Field Trip Open-air flea market, game birds and the Mennonite store	Location TBA

ATTENTION GRADUATE STUDENTS

Call for Applications -- John Carlock Award

This Award was established to encourage biologists in the early stages of their professional careers to become involved with and excited by the profession of biology teaching. To this end, the Award provides partial support for graduate students in the field of Biology to attend the Fall Meeting of ACUBE.

Guidelines: The applicant must be actively pursuing graduate work in Biology. He/she must have the support of an active member of ACUBE. The Award will help defray the cost of attending the Fall meeting of ACUBE. The recipient of the Award will receive a certificate or plaque that will be presented at the annual banquet; and the Executive Secretary will provide the recipient with letters that might be useful in furthering her/his career in teaching. The recipient is expected to submit a brief report on how he/she benefited by attendance at the meeting. This report will be published in Bioscene.

Application: Applications, in the form of a letter, can be submitted anytime during the year. The application letter should include a statement indicating how attendance at the ACUBE meeting will further her/his professional growth and be accompanied by a letter of recommendation from a member of ACUBE. Send application information to:

Dr. William J. Brett, Department of Life Sciences, Indiana State University, Terre Haute, IN 47809; Voice -- (812) 237-2392 FAX (812) 237-4480; E-mail -- lsbrett@scifac.indstate.edu

If you wish to contribute to the **John Carlock Award** fund, please send check to: Dr. Pres Martin, Executive Secretary, ACUBE, Department of Biology, Hamline University, 1536 Hewitt Ave., St. Paul, MN 55104.

REGISTRATION FORM

Association of College and University Biology Educators
(ACUBE)

47th Annual Meeting

October 9-11, 2003

Truman State University

Kirksville, MO

Biology for Contemporary Living

Name: (Please print) _____

Address: _____

City, State, Zip: _____

Phone: _____ FAX: _____

Email _____

REGISTRATION FEE: Includes meals Friday-Sat noon., refreshments at breaks, and field trips.

- _____ \$ 75 Regular Member
- _____ \$ 105 New Member (includes dues)
- _____ \$ 105 Non-Member
- _____ \$ 35 Non-Participating guest/spouse (meals only)
- _____ \$ 35 Student (Grad or Undergrad)

_____ TOTAL ENCLOSED (Please make checks payable to ACUBE)
(For those registering on-site a \$10 handling fee will be charged.)

FIELD TRIPS: Indicate the field trip(s) you plan to attend. Space is limited, register early!

- _____ Pre-conference crinoid fossil collecting trip to local quarry (Thurs. afternoon Oct. 9)
- _____ Birding trip (Friday morning, Oct. 10)
- _____ Restored prairie trip (Friday afternoon, Oct. 10)
- _____ Post-conference trip featuring open-air flea market, fowl and the Mennonite store (Sat., Oct 11)

SPECIAL NEEDS:

If you have any special dietary or other needs that you would like the meeting organizers to know about, please explain in the space below:

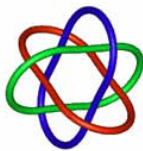
Please mail this form and payment by **September 10** to:

Dr. Nancy Sanders, ACUBE Local Arrangements
Division of Science, Truman State University, 100 E. Normal, Kirksville, MO 63501
Phone: 660-785-4619 Fax: 660-785-4045 Email: nsanders@truman.edu



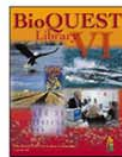
The BioQUEST Curriculum Consortium is an open community of bioscience educators and researchers interested in undergraduate science curricular reform. The projects of the Consortium are designed to help teachers develop tools and resources to provide their students with opportunities to solve complex, research-like problems in the classroom.

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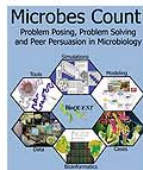
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The BioQUEST Library is a peer-reviewed publication of computer-based curricular materials for biology education. Volume VI includes more than 75 software simulations, tools, datasets, and other support materials for many areas within bioscience.



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in Biology Education**

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Burlington, Vermont



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LifeLines Or

This project emphasizes case-based biology for community colleges. Over forty cases are accessible on the site which includes support for writing and using cases in the classroom.



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Bird Studies: Learning Birds by Sight and Song with an Electronic Guide in the Field.

Peter G. Kevan

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Canada

Bird study (ornithology) is a fast growing hobby with over 55 million participants in North America alone. It grew 155% from 1983 to 1996 (Kinsella 2000). It is commonly part of biology curricula and clearly part of life-long learning. Although computers are commonplace in education, taking electronic information to the outdoors has been difficult. Newer, portable, devices with larger memories are changing that.

Most students learn to identify birds with friends or by taking a course, or both. Ornithology courses usually include field trips, but one of the most difficult exercises is learning the birds by sight and by sound. Excellent illustrated field books are available, as are sets of Compact Discs (CD-ROMs). The books descriptions of birds' calls in "words" are rather cryptic. Audio-tape cassettes and CDs lack images. Videotapes include images and sound; most for particular groups of birds or habitats and cannot be taken into the field. A few CD sets have bird pictures and recordings of sounds, and require personal computer or lap-top computer to use. A new approach (called Dawn Chorus I) that provides the advantages of portability of convenient pocket field guides and the multimedia capability of CD-ROM is now available (Bird Song Bytes 2002).

Dawn Chorus I was developed for teaching Ornithology at Wilfrid Laurier University, Canada where students found the system easy to use and enjoyable on field outings. The system has also been used for the general field course for biology majors at WLU, and instructors found the PDAs in constant use.

Combining CDs, personal computing, and hand-held devices (PDAs), instructors and students can take with them on field trips pictures and sound recordings of the birds they may encounter. The CD set has high quality photographs and sound recordings. The user, student or instructor, downloads the CD to a personal computer to establish a file of all 136 bird images and sounds. For a particular field trip, the user chooses the birds of interest and makes a personalized field guide of images and songs by downloading the selections onto a PDA. The PDA holds about 50 bird images and songs. The birds of interest are chosen from the PC file by mouse-clicking on the catalogue of bird names. The parts of the catalogue needed for the birds' images and sounds are simply downloaded to the PDA and are accessible there by pointing on the PDA screen display with the stylus. For the next field trip, the previously down-loaded files are erased and new ones entered.

To use Dawn Chorus I, standard items are needed. A PC or lap-top with Windows™ 95, 98 (or the most advanced versions) allows use of the CD, but for the most versatility, a hand-held device (PDA) is needed with the Palm™ OS (Operating System). For class use, several PDAs can be distributed to small groups (3-4 works well) of students. PDAs are becoming cheaper and more commonly owned and used by students and teachers.

Sound fidelity on the PDA is not as good as on the PC or lap-top, but is clear and crisp. The volume is low enough that sounds do not carry to interfere with other students, or disturb the birds in the vicinity. The images are clear, but the light intensity of the screen is not enough to allow the image to be seen if full sunlight falls on it. Shading the screen by head, hand, or hat is necessary when using the PDA in bright sunlight.

Technical support is provided by BirdSong Bytes Inc., on the web or by telephone. The web site is birdsongbytes.com is informative.

Kinsella, B. 2000. Autumn: A season for the birds. *Publishers Weekly* 247 (42): 27

Call for Nominations Honorary Life Award

The **ACUBE Honorary Life Award** is presented to ACUBE members who have made significant contributions and/or service to ACUBE and the advancement of the society's mission. The award is presented at the annual fall meeting of the society.

If you wish to nominate a member of ACUBE for this award, send a Letter of Nomination citing the accomplishments/contributions of the nominee and a *Curriculum Vita* of the nominee to the chair of the Honorary Life Award committee:

Dr. William J. Brett, Department of Life Sciences, Indiana State University
Terre Haute, IN 47809, Voice -- (812) 237-2392, FAX (812) 237-4480
E-mail -- lsbrett@scifac.indstate.edu

Call for Reviewers

We are looking for persons who are willing to review manuscripts for *Bioscene*. We need reviewers for a wide variety of subject areas. Reviewers should be willing to provide in depth reviews and detailed suggestions for authors concerning revisions necessary to improve their manuscript for possible publication. Reviewers should be willing to provide a rapid turn-around time for the manuscripts they review. If you are interested in reviewing for *Bioscene*, please send an email that includes your phone number, FAX number, and a list of the areas for which you are willing to review to: William Brett, Chair of the Editorial Board, at lsbrett@scifac.indstate.edu.

Call for Nominations

President-Elect, Secretary & Steering Committee Members

ACUBE members are requested to nominate individuals for the office of President-Elect and two at large positions on the ACUBE Steering Committee. Self-nominations are welcome.

If you wish to nominate a member of ACUBE for a position, send a Letter of Nomination to the Chair of the Nominations Committee: Dr. Janet Cooper, Biology Dept., Rockhurst University, Kansas City, MO 64110, (816 501 4237, janet.cooper@rockhurst.edu).

Manuscript Guidelines for *Bioscene: Journal of College Science Teaching*

A publication of the Association of College and University Biology Educators

Manuscripts submitted to the Bioscene should primarily focus on the teaching of undergraduate biology or the activities of the ACUBE organization. Short articles (500-1000 words) such as introducing educational resources provided by another organization, reviews of new evolution software, suggestions for improving sampling methods in a field activity, and other topics are welcome as well as longer articles (1000-5000 words) providing more in depth description, analyses, and conclusions for topics such as introducing case-based learning in large lectures, integrating history and philosophy of science perspectives into courses or initiating student problem solving in bioinformatics.

Please submit all manuscripts to editor(s):

Ethel Stanley
Department of Biology
Beloit College
700 College St.
Beloit, WI 53511
stanleye@beloit.edu
FAX: (608)363-2052

Timothy Mulkey
Department of Life Sciences
Indiana State University
Terre Haute, IN 47809
mulkey@biology.indstate.edu
FAX: (812) 237-2418

We prefer receiving manuscripts as Rich Text Format or RTF files to facilitate distribution of your manuscript to reviewers and to work on revisions. You can mail us a disk or attach your file to an email message with the subject line as **BIOSCENE**. All submissions should be double-spaced and may follow the style manual for publication you are currently using such as APA. You will also need to include:

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author(s) information:
 full names
 name of your institution with the address
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brief abstract (200 words or less)
keywords
references in an appropriate format



Please refer to issues of the Bioscene from 1998 or later for examples of these items. You can access these issues at: <http://acube.org/bioscene.html>

Graphics are desirable! Lengthy sections of text unaccompanied by tables, graphs or images may be modified during layout of the issue by adding ACUBE announcements or other graphics. While tables and graphs may be included in the manuscript file, images should be submitted as individual electronic files. If you are unable to provide an image in an electronic format such as TIFF for Macintosh or BMP for Windows, please include a clear, sharp paper copy for our use. At this time, graphics will be printed as grayscale images with a minimum resolution of 300 dpi and a maximum resolution of 1200 dpi. Cover art relating to an article is actively solicited from manuscript contributors.

Upon receipt of your manuscript, an email or fax will be sent to the author(s). The editor will forward your manuscript to the chair of the editorial board. Within the next two weeks or so, your manuscript will be sent to two reviewers. You should receive comments when changes are recommended from the reviewers prior to publication of the article. Manuscript format is usually retained as accepted; however, limits of publishing the issue may affect the length of an article. Graphics may be added by the editors when lengthy sections of text are unaccompanied by tables, graphs or images. Previously published work should be identified as such and will be reviewed on a case-by-case basis. Your article will appear in the Bioscene and then on the ACUBE website: <http://www.acube.org> shortly after the issue date.



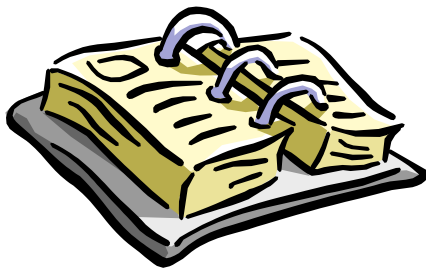
ACUBE 47th Annual Meeting

Truman State University

Kirksville, MO

October 9-11, 2003

Biology for Contemporary Living



Housing Preview

47th Annual ACUBE Fall Meeting

Truman State University

Kirksville, MO

October 9-11, 2003

Lodging: Block of rooms has been reserved at the Days Inn and Shamrock Inn for meeting participants; remember to request the ACUBE block and rate. **IMPORTANT:** Please note there is a Bluegrass Festival in Kirksville on the same weekend, so PLEASE BOOK EARLY

Days Inn

Phone: 660-665-8244

800-329-7466

\$45 (plus tax) single occupancy

\$50 (plus tax) double occupancy

Request ACUBE block and rate.

Shamrock Inn

Phone: 660-665-8352

800-329-7466

All rooms \$50 (plus tax)

Request ACUBE block and rate.

Super 8 Motel

Phone: 660-665-8826

Most rooms about \$55 (plus tax) per night

Holiday Inn Express Hotel and Suites

Phone: 660-627-1100

800-HOLIDAY

Most rooms \$75 and up (plus tax) per night

Thousand Hills State Park Cabins

Phone: 660-665-7119

Cabins run \$55 - \$70 (plus tax) per night

Note - these cabins overlooking the lake and book very early; cabins typically have two double beds, some with kitchens.

Camping

For the adventurous, these are camping sites available at the Thousand Hills State Park

Truman State University

Site of the 47th Annual Meeting Association of College and University Biology Educators October 9-11, 2003



Truman State University, formerly Northeast Missouri State University, is Missouri's premier statewide public liberal arts and sciences university. Founded in 1867, Truman State University has a long history of being nationally recognized for its innovative assessment program and commitment to providing a high-quality education at an affordable price. *U.S. News and World Report* consistently ranks Truman State University as the number one public university in the Midwest region - Master's category - as well as the 8th best university in the Midwest region. Truman is the only public university in Missouri to appear on their top 15 listing. *Money* magazine has also recognized Truman for six consecutive years as one of the nation's top ten best educational values. More than 6200 students attend Truman State University. Truman now offers 43 undergraduate and 9 graduate areas of study in 12 academic divisions. Commitment, uniqueness of purpose, and concentration on student learning has brought Truman to its present mission. Designed to bring a new sense of coherence to each student's educational experience, and to impart the qualities of mind and spirit which distinguish educated persons, the programs and environment of the University are the latest examples in Truman's history of creative, responsive, and innovative planning.



Kirksville, Missouri

Located in northeast Missouri, Kirksville was founded in 1841 as the county seat of Adair County. Kirksville has prospered through the years in large part due to the exceptionally diversified local economy. Agriculture, industry, medicine and education all employ many Kirksville citizens and have helped the community to mature into the economic and cultural center of Northeast Missouri. Kirksville's particular assets include a nationally recognized public liberal arts university, a medical college and long-standing industries. Kirksville has a population of 17,286 and is located 168 miles northeast of Kansas City, 204 miles northwest of St. Louis and 92 miles north of Columbia.

ACUBE

Association of College and University Biology Educators

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INSTITUTION: _____

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MAJOR INTERESTS

- 1. Biology
- 2. Botany
- 3. Zoology
- 4. Microbiology
- 5. Pre-professional
- 6. Teacher Education
- 7. Other _____

SUB DISCIPLINES: (Mark as many as apply)

- A. Ecology
- B. Evolution
- C. Physiology
- D. Anatomy
- E. History
- F. Philosophy
- G. Systematics
- H. Molecular
- I. Developmental
- J. Cellular
- K. Genetics
- L. Ethology
- M. Neuroscience
- N. Other _____

RESOURCE AREAS (Areas of teaching and training): _____

RESEARCH AREAS: _____

How did you find out about ACUBE? _____

Have you been a member before: _____ If so, when? _____

DUES (Jan-Dec 2003) Regular Membership \$30 Student Membership \$15 Retired Membership \$5

Return to: Association of College and University Biology Educators, Attn: Pres Martin, Executive Secretary, Department of Biology, Hamline University, 1536 Hewitt Avenue, Saint Paul, MN 55104

Interactive Software

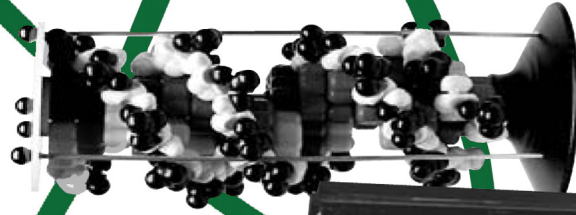


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