

Bioscene

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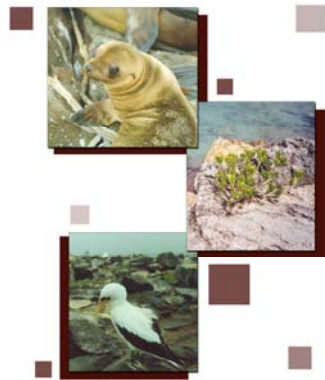
Association of College
and University Biology Educators

Editor:

Stephen S. Daggett
Avila University

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Bioscene is normally published in March, May, August and December. Please submit manuscripts by March 1, 2008 for consideration in the next issue.



Cover images: Photographs taken in Bermuda by Conrad Toepfer. Clockwise from the top is a seal pup, the beach lobelia or ink berry (*Scaevola plumieri*), and a masked booby.

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Bioscene: Journal of College Biology Teaching is a refereed quarterly publication of the Association of College and University Biology Educators (ACUBE). Submissions should reflect the interests of the membership of ACUBE. Appropriate submissions include:

- Articles: Laboratory and field studies that work, course and curriculum development, innovative and workable teaching strategies that include some type of evaluation of the approaches, and approaches to teaching some of the ethical, cultural, and historical impacts of biology.
- Reviews: Web site, software, and book reviews
- Information: Technological advice, professional school advice, and funding sources
- Letters to the Editor: Letters should deal with pedagogical issues facing college and university biology educators

II. Preparation of Articles

Submissions can vary in length, but articles should be between 1500 and 4000 words in length. This includes references, but excludes figures. Authors must number all pages and lines of the document in sequence. This includes the abstract, but not figure or table legends. Concision, clarity, and originality are desirable. A complete submission will consist of the following:

A. Cover letter: All submissions should come with a cover letter indicating that the manuscript is being submitted exclusively to *Bioscene* and why it is appropriate for this journal. Authors may also offer graphics from the article as possible cover art.

B. Cover Sheet: Submissions should include a cover sheet that includes the title of the article, the number of words in the manuscript, the corresponding author's name, and all co-authors. Each author's name should be accompanied by complete postal and email addresses, as well as telephone and FAX numbers. Even with hardcopy submissions, email will be the primary method of communication with the editor of *Bioscene*.

C. Abstract: The first page of the manuscript should contain the title of the manuscript, the names of the authors and institutional addresses, a brief abstract (200 words or less) or important points in the manuscript, and keywords in that order.

D. Manuscript Text: The introduction to the manuscript begins on the second page. No subheading is needed for this section. This supply sufficient background for readers to appreciate the work without referring to previously published references dealing with the subject. Citations should be reports of credible scientific or pedagogical research.

The body follows the introduction. It is recommended that it be broken into sections with appropriate subheadings including Materials and Methods, Results, and Discussion. Some flexibility is permitted here depending upon the type of article being submitted.

Acknowledgment of any financial support or personal contributions should be made at the end of the body in an Acknowledgement section, with financial acknowledgements preceding personal acknowledgements. Disclaimers and endorsements (government, corporate, etc.) will be deleted by the editor.

A variety of writing styles can be used depending upon the type of article. Active voice is encouraged whenever possible. Past tense is recommended for descriptions of events that occurred in the past such as methods, observations, and data collection. Present tense can be used for your conclusions and accepted facts. Because *Bioscene* has readers from a variety of biological specialties, authors should avoid extremely technical language and define all specialized terms. Also, gimmicks such as capitalization, underlining, italics, or boldface are discouraged. All weights and measures should be recorded in the SI (metric) system.

In- text citations should be done in the following manner:

"...rates varied when fruit flies were reared on media of sugar, tomatoes, and grapes" (Jaenike, 1986).

or

"Ulack (1978) presents alternative conceptual schemes for observations made..."

E. References: References cited within the text should be included alphabetically by the author's last name at the end of the manuscript text with an appropriate subheading. All listed references must be cited in the text and come

from published materials in the literature or the Internet. The following examples indicate *Bioscene's* style format for articles, books, book chapters, and web sites:

Articles-

Single author:

DEBURH, L.E. 1991. Using *Lemna* to study geometric population growth. *American Biology Teacher* 53(4): 229-32.

Multi-authored:

GREEN, H., GOLDBERG, B., SHWARTZ, M., AND D. BROWN. 1968. The synthesis of collagen during the development of *Xenopus laevis*. *Dev. Biol.* 18: 391-400.

Books-

BOSSEL, H. 1994. *Modeling and Simulation*. A.K. Peters, London. 504p.

Book chapters-

GLASE, J.C. AND M. ZIMMERMAN. 1991. Population ecology: experiments with Protistans. In Beiwenger, J.M. 1993. *Experiments to Teach Ecology*. Ecological Society of America, Washington, D.C. 170p.

Web sites-

MCKELVEY, S. 1995. Malthusian Growth Model. Accessed from <http://www.stolaf.edu/people/mckelvey/envision.dir/malthus.html> on 25 Nov 2005.

Note that for references with more than five authors, note the first five authors followed by *et al.*

F. Tables

Tables should be submitted as individual electronic files. Placement of tables should be indicated within the body of the manuscript. All tables should be accompanied by a descriptive legend using the following format:

TABLE 1. A comparison of student pre-test and post-test scores in a non-majors' biology class.

G. Figures

Figures should be submitted as individual electronic files, either TIFF or BMP. Placement of figures should be indicated within the body of the manuscript. Figures include both graphs and images. All figures should be accompanied by a descriptive legend using the following format:

FIG. 1. Polytene chromosomes of *Drosophila melanogaster*.

III. Letters to the Editor

Letters should be brief (400 words or less) and direct. Letters may be edited for length, clarity, and style. Authors must include institution address, contact phone number, and a signature.

IV. Other Submissions

Reviews and informational submissions may be edited for clarity, length, general interest, and timeliness. Guidelines for citations and references are the same for articles described above.

V. Manuscript Submissions

Article manuscripts may be sent to the current editor either electronically or by hard copy, accompanied by a disc copy. Electronic submissions are preferable. All authors will receive confirmation of the submission within three weeks. Manuscripts should be submitted either as a Microsoft Word or RTF (Rich Text File) to facilitate distribution of the manuscript to reviewers and for revisions. A single-email is required to submit electronically, as the review process is not blind unless requested by an author. If the article has a number of high resolution graphics, separate emails or separate discs mailed to the editor may be required.

If hard copy is sent it must be accompanied by a disc containing the complete submission. Three copies of the manuscript, as well as the original, should be submitted. Standard paper should be used with lines of sections of the manuscripts numbered and enough margin to permit reviewer comments. Two self-addressed stamped envelopes must be included if the authors wish to receive reviews and responses by methods other than email.

VI. Editorial Review and Acceptance

All manuscripts will be sent to two anonymous reviewers as coordinated through the Editorial Board.

Reviewers will examine the submission for:

- **Suitability:** The manuscript relates to teaching biology at the college and university level.
- **Coherence:** The manuscript is well-written with a minimum of typographical errors, spelling and grammatical errors, with the information presented in an organized and thoughtful manner.
- **Novelty:** The manuscript presents new information of interest for college and university biology educators or examines well-known aspects of biology and biology education, such as model organisms or experimental protocols, in a new way.

Once the article has been reviewed, the corresponding author will receive a notification of whether the article has been accepted for publication in *Bioscene*. All notices will be accompanied by suggestions and comments from the reviewers. Acknowledgement of the reviewers' comments and suggestions must be made for resubmission and acceptance. Upon acceptance, the article will appear in *Bioscene* and will be posted on the ACUBE website. The review process can take 4-5 months. Upon final acceptance, the article will appear in *Bioscene* and will be posted on the ACUBE website within six months of publication. Depending upon volume, time from acceptance to publication may take up to a year.

VII. Editorial Policy and Copyright

It is the policy of *Bioscene* that authors retain copyright of their published material.

Call for Nominations for *Bioscene* Editorial Board, Call for Cover Art, and Letters to the Editor for *Bioscene*

We are (constantly) soliciting nominations for three (3) *Bioscene* Editorial Board positions (terms through 2011). Board members provide input in the form of reviews and suggestions concerning the publication of *Bioscene* to the Editor. Board members are also expected to assist in the solicitation of manuscripts and cover art for *Bioscene*. Board members may be called upon to proofread the final copy of *Bioscene* prior to publication and one member will be called upon to act as Book Review editor. **Preference will be given to individuals who regularly attend the annual meeting.** Also, the Editorial Board of *Bioscene* **welcomes cover images and letters to the editor** for future issues of *Bioscene*. Send images and letters according to the image guidelines given in the guidelines for submissions section of this journal to the editor. If you are interested in serving a 3-year term on the Editorial Board or have cover art for consideration, please email the editor, Stephen S. Daggett, at stephen.daggett@avila.edu.

Making Competitive Binding Assay Theory Interesting in an Undergraduate Endocrinology Lab

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Abstract: The theories associated with competitive binding assays are important aspects to be covered in an endocrinology course. Yet, it is unlikely that assay theory alone will fully capture students' interests. Additionally, other difficulties are often encountered at undergraduate institutions including lack of sampling expertise, unavailable counters, or facilities for radioactive material. In this report, a procedure is described which engages students in the measurement of salivary cortisol responses to physical exercise in fellow classmates. Necessary equipment includes only a cycle ergometer, centrifuge, plate reader and pipettors. The primary learning objectives for this activity are: 1) To gain an understanding of how competitive binding assays are utilized to estimate hormone concentrations; 2) To develop an appreciation for the importance, *a priori*, of experimental design, and 3) To begin to explore the physiology of the steroid hormone cortisol. As expected, exercise elicits increased salivary cortisol levels. More importantly, because most students have a natural attraction for exercise, this hormone stimulus also becomes a means for capturing and retaining interest in the lab. Students complete all aspects of the assay, construct a standard curve and determine sample concentrations. Through this hands-on approach to assay theory and techniques, students are able to gain an appreciation for an important research and clinical tool designed to measure human hormone levels.

Keywords: undergraduates, competitive binding assay, ELISA, exercise, cortisol

Introduction

The development of meaningful laboratory activities is always challenging. In constructing labs for advanced undergraduate courses at small colleges there can be difficulties associated with limited equipment and expertise. Additionally, it can be challenging to develop activities that provide exposure to critical techniques used in a field while at the same time maintaining an interest on the part of the students. In this communication a laboratory activity is described that incorporates one form of a competitive binding assay (an enzyme-linked immunosorbent assay; ELISA) together with an activity meant to capture and maintain students' interest in determination of hormone concentration changes due to an applied stimulus. In addition, the laboratory described, although incorporating human subjects, does not involve significant invasive procedures, and allows students hands-on participation throughout.

This lab is used for Biology 367, Endocrinology, taught at Luther College each fall semester. The laboratory portion of the course is taught during a single 3 hr block each week. Since its inception, the class has been comprised almost entirely of senior biology majors, with a class enrollment of 15-16 students. The laboratory activity described in this report is used early in the semester

during a section covering methodologies critical to the study of endocrinology.

Competitive Binding Assays and ELISA Theory

Historically, the determination of cortisol levels has been accomplished utilizing radioimmunoassay (RIA) techniques applied to plasma samples. An ELISA, however, may be favorable in many instances to RIA tests due to the lack of radioactive materials and relatively simple equipment required for measurement. Commercially available ELISAs can be used; indeed, the procedures outlined in this communication make use of a kit purchased from Salimetrics, LLC (State College, PA). This particular kit has the added advantage of utilizing salivary samples instead of the more commonly required plasma. In this way, the invasive nature of the study is limited, and little training or expertise is required for sample collection.

The commercial ELISA utilized in this lab makes use of a microtitre (96-well) plate pre-coated with monoclonal antibody to cortisol. Standards (known concentrations) and samples "compete" for the antibody binding sites against hormone conjugated to horseradish peroxidase. The plate is washed to remove unbound hormone. Then, the enzyme substrate tetramethylbenzidine (TMB) is added, and the reaction produces a blue color, the

concentration of which is proportional to the amount of enzyme-conjugated hormone found in each well (The amount of conjugated hormone remaining in the well is inversely proportional to the sample concentration). The substrate-enzyme reaction is stopped with an acidic solution, and the optical density is determined on a plate reader at a wavelength of 450 nm. Optical density values for standards are plotted against their known concentrations. Sample concentrations are determined from the generated standard curve. Thus, the sample analysis portion of this activity requires only very basic laboratory equipment: Freezer/refrigerator, centrifuge, pipettors, plate reader, and basic glassware.

Cortisol and the Hypothalamus-Pituitary-Adrenal(HPA) Axis

A fair amount of attention is given to the hormone cortisol in undergraduate endocrinology courses (Hadley, 2000; Raven, 2005), and most biology students are at least aware that cortisol is a “stress” hormone. Cortisol is a steroid hormone produced and released from the adrenal cortex. Cortisol release is directly stimulated by the pituitary hormone adrenocorticotropin (ACTH). Cortisol is the primary glucocorticoid produced in humans. That is, a major action of this hormone is elevation of plasma glucose levels via binding to the liver and stimulation of gluconeogenesis. In addition, cortisol has catabolic actions in skeletal muscle and adipose tissue, ultimately causing the release of amino acids and free fatty acids, respectively. Cortisol also appears to be necessary for proper catecholamine synthesis and re-uptake. Finally, excessively high levels of cortisol can limit the development of inflammation, and sustained pathophysiological levels may suppress activity of lymphoid tissues (Hadley, 2000).

Pituitary ACTH release is regulated by the hypothalamic corticotropin-releasing hormone (CRH). Release rates of CRH and ACTH are often elevated during human adaptive responses to “stress” (departure from homeostasis). It is believed that a role for the elevation of hormones during such a period could be generation of adequate circulating glucose for key organs- brain, kidney, heart, etc. Plasma catecholamines are also often elevated during stress, and cortisol is known to augment the epinephrine-induced generation of free fatty acids and glycerol by adipocytes (i.e., lipolysis). Moderate to heavy exercise can be used as a model of acute stress in humans. Indeed numerous reports have indicated that several hormones, including cortisol, are elevated following various periods and intensities of aerobic exercise (Kuoppasalmi, 1980; Mastorakos, 2005; Viru, 2004).

Steroid hormones are present in human saliva and, although salivary levels are much lower than plasma concentrations, there appears to be a strong correlation between values in the two fluids under basal or stimulated states (Calixto, 2002; Kumar, 2005). The ability to measure changes in hormone levels from salivary rather than plasma samples has obvious advantages for the development of undergraduate labs. First, little training is required to allow students to collect samples. Second, recruitment of subjects is not hindered by the prospect of multiple blood samples. Finally, the relative non-invasive procedure of obtaining multiple salivary samples should not present a major concern to human subjects review boards. Certainly, students who assist with sample collection must be instructed in safe handling procedures of bodily fluids, and all samples must be handled as if containing blood (which is possible).

Students tend to have a natural interest in exercise, and thus this laboratory activity incorporates controlled physical activity as a stimulus to hormone release together with theory and practical application of a competitive-binding assay. As opposed to peptide hormones, cortisol is quite stable in samples, and appears to survive freeze-thaw episodes that may be necessitated by the time constraints of an academic schedule.

Methods

Exercise Protocol and Sample Collection. All procedures have been reviewed and approved by the Luther College Human Subjects’ Review Board. Additionally, informed consent is obtained from all subjects. Volunteers are sought from a class of 16 students. Subjects are divided between exercise (EX) and control (CON) groups. To be more certain that we are able to measure a cortisol response to exercise, we limit the number of CON subjects. Despite the inclusion of only one or two CON subjects, students are able to appreciate the purpose of incorporating a time control in the study as verification of a stimulus-induced change in hormone levels. The exercise protocol is a modified step protocol that mandates increasing power output by the subjects. In recognition of the fact that many of our subjects will likely not be highly trained, the protocol also utilizes achievable workloads, yet also requires concerted effort on the part of the subjects. The protocol is not intended to be a predictor of subjects’ maximal power output.

Subjects are instructed to report to the laboratory in comfortable clothing suitable for exercising. Additionally, subjects are encouraged to abstain from ingesting dairy products within 4 hrs of

the activity (as per assay manufacturer's instructions). A salivary sample is collected immediately prior to exercise by placing a sterile, cotton gauze ("Salivette", Sarstedt) under the subject's tongue for a period of 3 min. The subjects can easily accomplish this procedure themselves, or the subjects can be aided by gloved assistants. The cotton role is then removed and returned to its original container for later analysis. Next, the subject climbs aboard a cycle ergometer ("Corival V2", Lode BV, Netherlands) and begins pedaling at a workload of 60 watts (W) for a 6 min warm up period. Next, the workload is increased to 120W and at the 3 min time point of the workload, a salivary sample is obtained (IE, salivette removed at end of workload). Also at this time, subjects are asked to indicate their relative perceived exertion (RPE), by pointing to the appropriate number on a modified Borg Scale (Astrand, 2003). The Workload is then increased by 60W, and the subject maintains this load for another 6 min period. Again, a salivary sample is obtained at the midpoint. The subject continues at progressively higher workloads if possible. Once 240W is achieved, the subject is encouraged to complete the 6 min time period, and if possible and not yet indicating an RPE of 12-13 (we have found that reported RPE values of 12-13, "somewhat hard", are very likely to be associated with measurable changes in salivary cortisol; unpublished observations), continue at this same workload for an additional ("extra") 3 min. Salivary samples are taken during the 240W workload at the midpoint and 6 min time, and again at 3 min-extra. Thus, if the subject is capable, the maximal total duration of the 240W workload may reach 9 min. Because each salivette remains in the mouth for 3 min, the 3 min-extra salivette is placed immediately upon removal of the 6 min salivette. It is quite possible that subjects may not complete or exceed the 240W level. This is especially likely if the class is comprised of relatively unconditioned individuals. Nonetheless, we have found that exercise through workloads less than 240W will produce apparent changes in cortisol levels (see data in this report). Following completion of exercise (to whatever level), subjects remain stationary for a period of 30 min. Additional salivary samples are taken at 15 min and 30 min post-exercise. If incorporated, CON subjects remain seated for the duration of the experiment. Salivary samples are collected from CON subjects at the same time intervals as described for the exercise protocol.

Sample Handling. Upon return of the cotton salivette from the test subject, it is placed in a plastic centrifuge tube (Sarstedt). Samples are kept on ice until completion of the protocol. At that time,

samples can be centrifuged (1500xg) immediately prior to initiating assay procedures or placed in a freezer (-4C) for later work. If frozen, samples are allowed to thaw on ice, and then are centrifuged to remove insoluble elements of the saliva. Finally, samples are briefly vortexed before utilized in the assay.

Assay Procedure. Because of time limits, the exercise protocol and sample collection are completed during one laboratory session and the determination of cortisol levels through ELISA techniques is accomplished during a separate time period. We have found it helpful to distribute paper schematic 96-well templates for students to verify the placement of appropriate standards and samples in corresponding wells. Sample tubes are arranged appropriately and the assay is completed as per manufacturer's instructions. Briefly, 25 ml of standards (supplied) are pipetted into pre-determined wells (all standards and samples are measured in duplicate). A "zero" standard is included to determine maximal binding of enzyme-conjugated hormone. Additionally, two wells are included that are not coated with antibody. Thus, these wells will be used for the determination of non-specific binding (NSB; IE, non-antibody binding) of enzyme-conjugated hormone. Also, high and low cortisol controls (Salimetrics) are incorporated to verify assay results. After appropriate standards or samples are pipetted, enzyme-conjugated hormone is added to each well. The plate is mixed and allowed to incubate at room temperature for 60 min. Next, all wells in the plate are washed four times with supplied buffer before application of enzyme substrate (TMB). Again, the plate is mixed and incubated at room temperature (in the dark) for a total of 30 min. Finally, an acidic stop solution is added to all wells, and the plate is mixed briefly before being read on a plate reader (Biorad) at 450 nm. Absorbance values are recorded on a laptop computer utilizing commercial software (Biorad Microplate Manager).

Data Analysis and Construction of Standard Curve. Students are given the absorbance values for all wells in the assay and directed in the process of generating a standard curve. Briefly, the average optical density is determined from each pair of wells. Then, the average optical density of the NSB wells is subtracted from all other average optical density values to generate a "bound" value (B). The percent bound (B/B₀) for each standard, control and sample is calculated by dividing the B value for each sample by the average, corrected optical density reading for the zero sample (B₀). The standard concentrations are plotted against their respective B/B₀ values to generate a standard curve. A 4-parameter sigmoid

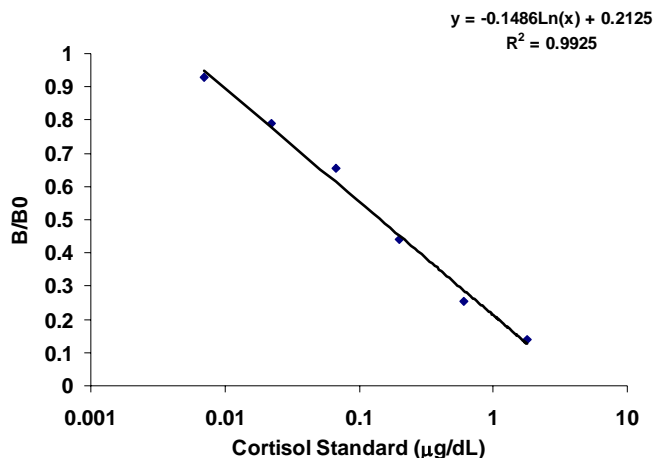
curve fit can be utilized. Alternatively, and perhaps more easy for students, a log/linear plot can be generated by expressing the standard concentrations in log format on the x-axis of the graph. This second procedure has the added benefit of students being very capable of generating an equation to describe the line, and in so doing, providing a simple basis for determination of sample concentrations. Students are provided values for the included high and low controls, and are thus able to check the “accuracy” of the assay. In a follow up session, students are provided the software-generated standard curve and extrapolated sample values for comparison to their results.

Results and Discussion

Cortisol ELISA. We have found the ELISA method for detection of salivary cortisol to be a solid model for demonstrating the concepts of competitive binding assays. Further, the commercially available antibody-coated microtitre plate utilized in this report is reliable, reproducible, and appears to be quite accurate. Lastly, the procedures necessary to collect samples and determine hormone concentration are easily achievable in an undergraduate teaching laboratory setting, allowing for greater focus on key concepts behind the test as well as the associated endocrinology.

FIG 1 depicts a typical, student-generated standard curve, along with a mathematical expression of the line. High and low control samples were supplied by the manufacturer ($1.05 \pm 0.265 \mu\text{g/dL}$ and $0.108 \pm 0.027 \mu\text{g/dL}$, respectively) and were estimated as $0.983 \mu\text{g/dL}$ and $0.070 \mu\text{g/dL}$, respectively, from this standard curve. By requiring students to generate their own standard curves, as opposed to utilizing only software generated relationships, key concepts inherent to competitive binding assays are reinforced. The concepts of utilizing standards, determination of percent bound, and validation of the assay through incorporation of controls are strengthened in this way. Importantly, too, students gain an appreciation that the determination of sample hormone concentrations is a “best estimate” that relies on the careful construction of a standard curve. To that end, students have found it relatively easy to determine sample concentrations from B/B₀ values and a mathematical description of the standard curve. A software program with spreadsheet and graphing capabilities (EG, Excel™) is helpful in this regard.

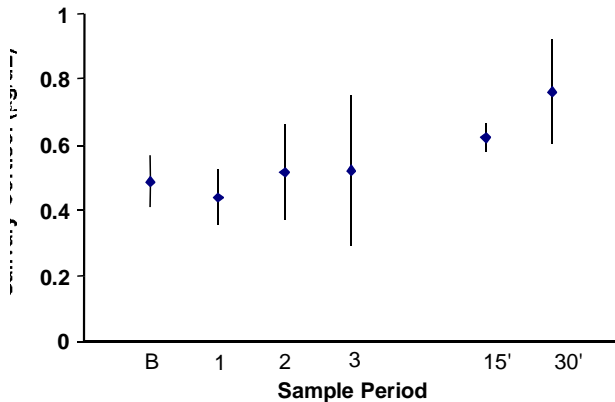
FIG 1. Student-generated standard curve. Cortisol standard concentrations are expressed on a log scale to linearize the curve.



Cortisol responses to exercise. FIG 2 illustrates the typical salivary cortisol concentration prior to, during and following submaximal exercise. The values in this figure are from a single laboratory session, although we have repeatedly seen such results each year that this activity has been utilized. As expected exercise is associated with an increase in salivary cortisol levels, with the peak response occurring at the 30 min post-exercise time period. It is worth noting that the data presented were taken from a year in which none of the EX subjects completed a workload greater than 240W. Values from a single CON subject, although not plotted, ranged from 0.321 to 0.427 $\mu\text{g/dL}$ over the same time frame. A fair amount of variability is present in the cortisol response to exercise between subjects. No attempt has been made in our laboratory activity to distinguish subjects based on sex or experience with endurance training. Nonetheless, it is apparent that on average the exercise protocol employed in this report is a sufficient stressor, being associated with a measurable increase in cortisol levels.

FIG 2. Salivary cortisol response to graded exercise. B= baseline; 1,2,3 = sample period during workload; 15' and 30' = post exercise values at 15 and 30 min.

Note: only two samples were assayed at the 240W period. All other values represent the mean \pm S.E. of five samples.



Evaluation of student learning. The primary learning objectives for this activity are: 1) To gain an understanding of how competitive binding assays are utilized to estimate hormone concentrations; 2) To develop an appreciation for the importance of experimental design, and 3) To begin to explore the physiology of the steroid hormone cortisol. To focus on those learning objectives, students are required to submit a formal report of this laboratory activity, with special emphasis placed on assay theory and generation of a standard curve. In that write up, students are asked to define and give rationale for incorporating measures such as NSB, B0 and controls. From evaluating these formal reports, it has become apparent that a hands-on activity that utilizes a competitive binding assay strengthens the understanding of such key concepts. Further, students are asked to comment on the importance of experimental design, with special emphasis placed on inclusion of control subjects and accurate duplication of sampling procedures. Lastly, students are asked to consider the likely stimuli for the measured increase in cortisol and the likely physiologic roles this hormone plays during and following the exercise bout. As stated at the outset of this report, this laboratory activity is conducted at a relatively early

point in the semester, and thus students may not have yet had full exposure to lecture material on the HPA axis and glucocorticoids. However, this laboratory activity generates sufficient student interest in the topic, and we have found students have little trouble “reading ahead” to incorporate some basic information regarding the control of cortisol release and its physiologic roles.

Shortcomings and likely extensions. Whereas the principle goal of this activity is to provide a hands-on approach toward understanding competitive binding assays, it can be challenging to involve 16 (or more) students in assay procedures. A commercially available assay, such as that utilized in this activity, requires little more than sample centrifugation and pipetting. Although risky, and certainly not an accepted practice in research or clinical labs, we have found it useful to divide the assay protocol steps among groups of students. In this way, all play an active role in the outcome of the test. It is important during the assay procedure to engage nonparticipating students in conversation regarding the theory and importance of the current “step” of the assay. A potential solution to the above-mentioned issue would be the inclusion of additional microtitre plates with small groups each completing an assay. However, owing to both cost and sample volumes this solution may not be feasible.

Because of the relatively small class size, it is not always possible to recruit more than a total (exercise and control) of 6-8 subjects. Despite this, trends in data are normally observed (as above). However, if statistical analysis becomes an important aspect of the lab, data from consecutive years can be pooled. In fact, knowing that others have similarly measured changes in hormone levels can buoy student confidence in the ability to complete the assay protocol. Students enrolled in Biology 367 must complete a research-based project by semester’s end. This laboratory activity and others like it, provide a springboard for student generated project ideas.

Although beyond the scope of the course this lab has been used for, it would be possible to expand the protocol to include measurement of oxygen consumption (if equipment is available), changes in blood glucose, blood lactate, etc. In addition, students could be involved in the process of developing and submitting human use consent forms or other key design aspects. Lastly, because many students at small liberal arts colleges are involved in organized athletics, it might be possible to divide test subjects into categories based on endurance training volume. This might be especially useful if the lab

activity was incorporated into a human performance or exercise science course.

Acknowledgements I would like to thank all the students who have taken Bio 367, Endocrinology. Their curiosity and commitment to learning have provided the impetus for the development of many laboratory activities.

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Gene Discovery for Comparative Biology of Parasitic and Non-Parasitic Plants. A Five-Week Molecular Research Immersion

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Abstract: As part of an NSF-funded initiative, biology students, primarily those in the early stages of their degree program, were recruited to participate in ongoing research alongside principal investigators. In this example, ten students were given five weeks of intensive training in molecular research methods, with the objective of cloning genes involved in core metabolic processes in the parasitic plant *Cuscuta pentagona* (dodder) and its non-parasitic relative *Ipomoea hederacea* (ivy-leaf morning glory). During the session, students used bioinformatic tools to search gene databases, designed PCR primers, isolated genomic DNA for use in amplification and molecular cloning, mapped candidate clones, and prepared templates for sequencing. The students were provided resulting sequence data and asked to determine whether the effort had been successful. Each of these activities provided an opportunity for students to learn biological principles through their application towards a research objective.

Keywords: undergraduate research, molecular biology, bioinformatics, gene discovery, *Cuscuta pentagona*

Introduction

This paper describes a summer research program designed in response to a solicitation for faculty involvement in undergraduate research. The STEM Talent Expansion Program (STEP), a National Science Foundation-funded initiative at the University of Nebraska at Omaha, supports faculty who provide opportunities for undergraduate participation in original research in the STEM disciplines: Science, Technology, Engineering, and Math. STEP was itself undertaken to address several aspects of undergraduate education in the STEM disciplines, including a perennial concern that undergraduates -- in this instance, undergraduates in biology and allied disciplines -- often complete their degree programs without significant research experience. Consequently, these students may lack an appreciation for the process by which facts are acquired, and the intellectual rigor, in the form of careful experimental design, integral to this process. An additional aim of STEP was to increase the rates of undergraduate recruitment into the STEM disciplines, targeting students who might be highly capable, but yet undecided about their educational goals, providing them with an opportunity to experience the daily work of a research scientist. This "second tier," as described by Tobias (1990), represents an attractive target for STEM discipline recruitment.

The undergraduate research experience has been promoted as a means of achieving several desired outcomes, not the least of which, to promote the graduation rate of high-quality research scientists (National Research Council, 2003). Studies of the efficacy of undergraduate research programs (reviewed by Rodrick and Dickmeyer, 2002; Seymore, et al., 2004), suggest the following benefits: an increased capacity for critical thinking; improvement in problem identification; development of technical skills; an appreciation of theory and research; and better informed decisions about graduate school.

The five-week program described in this work was similar to a conventional summer course insofar as it kept a regular daily schedule. However, the program was distinct from typical laboratory courses in that each day's activities were dictated by a single research objective, the development of which included solicited student input. Consequently, the students learned several essential techniques in the context of an integrated research program. Additionally, while some undergraduate programs offer "capstone" research courses for advanced students, this program was developed for students at the earliest stages of their undergraduate education, in the hopes that it would have a positive impact on their subsequent educational progress.

Program objectives

The pedagogical goal of the five-week research immersion was to provide students with the set of technical and intellectual skills outlined here.

Objective 1. Technical competency. Students were to master a basic set of laboratory skills. In the pursuit of the subsequently-described research objective, students would need to employ basic bioinformatic skills, accurate micropipetting, and standard molecular techniques including nucleic acids purification, the polymerase chain reaction, gel electrophoresis, molecular cloning, and DNA sequencing.

Objective 2. Comprehension of principles underlying the methods. To complement the development of technical skills, students were to develop an appreciation of the capacities and limitations of each. The employment of a range of technical methods provided several opportunities to present the underlying chemical and biological theory. Provisioned with this knowledge, students were able to participate in the experimental design process.

Objective 3. Comprehension of the research process and strategy. Students were asked to consider how research projects originate. Given a biological system, the students were to identify features amenable to measurement and experimentation, and that would provide information about the function of the system. Having identified a question, the students would next consider how available methods might be brought to bear in answering the question.

Recruitment of participants

Recruiting efforts were intended to target biology undergraduates at the earliest stages of their program. In the first two years of the program (2004-2005), invitations were extended during introductory-level botany and zoology lectures mid-way through the spring semester. As an incentive, participants could use the research to fulfill biology course electives. In the third and most recent year of the program (2006), non-biology undergraduates were also encouraged to participate, and a similar invitation was extended through the Principles of Biology course, which largely serves this audience. Each summer's research group comprised at least ten students working in pairs. In the most recent year, however, a second summer session was added to accommodate demand, with a total of seventeen students participating in the two groups. A majority

of participants identified themselves as biology, biotechnology, and environmental studies majors, though students from English, math, and computer science programs (three students, from a three-year total of 37 participants) also enrolled, with two of these recruited from the Principles of Biology course. Student surveys conducted at the beginning of the session indicated that, with the rare exception, none of these students had participated in an organized research effort prior to this program.

The parasite dodder, and its non-parasitic relative, ivy-leaf morning glory.

While the research program had the previously-stated pedagogical objective of training the participants to function as capable researchers, the daily laboratory activities were focused on achieving an explicit research objective. The research focus was the comparative physiology of a parasitic organism with a non-parasitic relative, in this instance two flowering plant species. After comparing the growth and developmental habits of the parasite and its relative, the students chose for further investigation genes that likely contribute to physiological functions that might have changed in the process of, or subsequent to, the adoption of the parasitic habit. The students would then attempt to isolate fragments of DNA from the corresponding genes of both species, to serve as tools for subsequent molecular investigations.

Cuscuta pentagona, shown in FIG 1a, is a rootless, leafless, epiphytic parasite representative of the genus commonly called the dodders. Emerging from seed, the dodder seedling uses environmental cues such as phytochemical emissions (Runyon *et al.*, 2006) or light quality (Furuhashi *et al.*, 1995; Haidar *et al.*, 1997) to seek out potential host plants and establish parasitic attachment. Through a combination of nutation and directional growth, the seedling twines around any object it encounters. Upon contacting most plant tissues, and also many non-plant materials, dodder uses a secretion to adhere to the target, subsequently breaching the host surface with penetrating haustoria that grow into an association with the host vascular tissues (Lee and Lee, 1989; Vaughn, 2002; Vaughn, 2003). It is from the host phloem that the parasite appears to draw most of its fixed carbon and nitrogen (Jeschke *et al.*, 1994). Current analyses indicate that the clade Cuscutaceae has emerged from the Convolvulaceae (Neyland, 2001; Stephanovic and Olmstead, 2004), and morning glory species have previously been used as points of comparison in characterizing the biology of the parasite (MacPherson, 1921.)

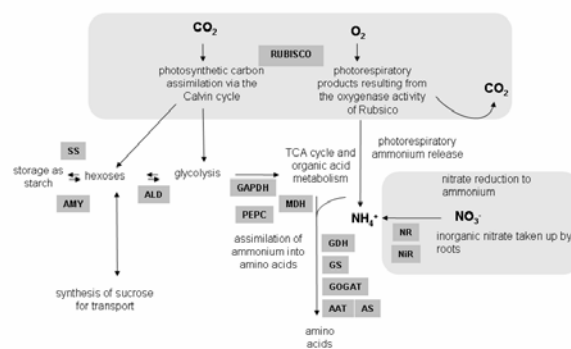
FIG 1. The parasitic angiosperm *Cuscuta pentagona* on its host (left) and its non-parasitic relative *Ipomoea hederacea*. Recent molecular investigations place the genus *Cuscuta* in the family Convolvulaceae with *Ipomoea*.



Since the completion of the Arabidopsis genome project (Arabidopsis Genome Initiative, 2000) most of the genes encoding enzymes of plant core metabolism have been identified. For the purpose of this investigation, “core metabolism” comprises the major reactions the Calvin cycle, starch synthesis and breakdown, glycolysis, sucrose synthesis, and organic acid metabolism as it relates to the primary assimilation of ammonium into glutamine, glutamate, aspartate, and asparagine, as illustrated in FIG 2. Given the developmental and trophic differences between the parasite and non-parasite, students were asked to postulate how expression of the genes underlying these processes might differ. As an example, many non-parasitic plants transport environmentally-acquired mineral nitrogen, in the form of nitrate, from the roots to the leaves via xylem, at which point the nitrate is reduced to ammonia and assimilated into the amino acid pool. Lacking roots and leaves, and drawing a majority of its nitrogen supply from the host phloem, it is unclear under what circumstances *Cuscuta* might employ nitrate reductase, the first step in nitrate reduction. While nitrate reductase activity is not detected stems of parasitizing plants, it may be detected under artificial conditions following nitrate application (Chauhan and Srivastava, 1980; Schoenbeck, unpublished observations). Furthermore, the activity of ammonia-assimilating enzymes, such as glutamate dehydrogenase, may also be detected under some circumstances (Srivastava and Dwivedi, 2003). The genes encoding the enzymes of photosynthesis and carbon metabolism could be considered in a similar light. The identification of these genes, and those encoding other activities indicated in Figure 2, in

both the parasite and the non-parasitic relative, would provide a starting point for the comparison of how these functions are employed.

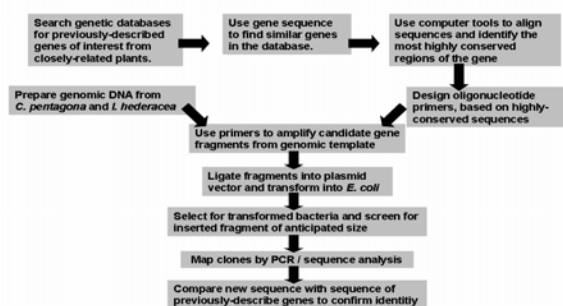
FIG 2. A generalized scheme of carbon and nitrogen core metabolic processes in C3 plants. Shaded boxes indicate physiological processes that are necessarily reduced, or possibly absent, in species of *Cuscuta*. Of physiological interest is the determination of which shaded processes are indeed present and to what degree, or to determine how related processes (unshaded) are affected by the parasite’s altered metabolism. Enzymes contributing to core metabolism are indicated by gray boxes: AAT, aspartate aminotransferase; AS, asparagine synthetase; ALD, aldolase; AMY, amylase; GDH, glutamate dehydrogenase; GOGAT, glutamate synthase; GS, glutamine synthetase; MDH, malate dehydrogenase; NR, nitrate reductase; NiR, nitrite reductase; PEPC, phosphoenolpyruvate carboxylase; RUBISCO, ribulose 1,5-bisphosphate carboxylase/oxygenase.



Overview of activities.

The progress of research activities is outlined in Figure 3. The first two weeks were dedicated to establishing technical competency and to the development of a research plan for the recovery of the target genes. The remaining three weeks were used for implementation of the strategy and evaluation of results.

FIG 3. A flow chart describing the strategy for identifying genes involved in core metabolic processes in dodder and ivy-leaf morning glory. The gene discovery strategy employed a range of skills, comprising the use of bioinformatic tools as well as standard molecular research methods.



Development of technical skills. As nearly all aspects of molecular cloning require the precise handling of small reagent volumes, a significant effort was dedicated to training the students in accurate micropipetting. Students were introduced to the range of micropipettors that they would be using, and instructed in how to read and adjust them. Emphasis was placed on “chemical hygiene” pointing out the ease with which cross-contamination of reagents could occur should they fail to use clean tips, or accidentally draw materials up into the pipetter barrel. Students practiced their skills in liquid handling by pipetting volumes of liquids with different viscosities and with low surface tension (isopropanol and chloroform) to observe the limitations of a negative-displacement pipetter, and practices employed to overcome these difficulties, such as pre-saturating the tip volume with solvent vapor prior to pipetting, in order to prevent the liquid from running out. An especially helpful exercise had the students generate a row of 5 μL and 1 μL droplets on a strip of Parafilm using a dye solution, comparing their volumes to an example placed by the instructor or lab assistant. Using this approach, the students quickly came to recognize the volumes they were to be working with regularly.

Pipetting error was the most frequently identified cause for control experiments to fail. Initially students, working as teams, were issued freezer boxes with volumes of molecular reagent that should have been sufficient for several days’ work. However it was soon recognized that students’ unfamiliarity with typical working volumes could

result in their using several-fold excess of a reagent. Improved performance was achieved in subsequent sessions by issuing measured amounts of reagents, sufficient for the experiment at hand, and explaining to the students that they had a limited margin for error in manipulating the correct volumes. Pipetting skills increased markedly under these strictures, as students monitored their pipetting much more closely and identified their errors sooner. Upon mastering pipetting skills, students practiced casting and loading agarose gels for DNA electrophoresis. These exercises were repeated until the most frequent mistakes and poor technique were identified and eliminated.

A third technical skill developed during the first two weeks of the session and central to the conduct of the research was the polymerase chain reaction (PCR). The principles of PCR were presented from the perspective of DNA replication, noting all of elements needed for synthesis of a new DNA strand: DNA polymerase, nucleotides, template, and a free DNA 3’ end as a starting point. Subsequently, the features that make PCR useful for experimental purposes were introduced -- that the location of the 3’ “priming” site could be determined by designing artificial oligonucleotides to anneal to selected points on the template, and that repeated cycling in a reaction with oppositely-oriented primers resulted in exponential synthesis of the region between them.

As previously noted, students were initially issued a standard kit of PCR reagents, including a stock of dNTPs, MgCl_2 , 10X concentrated PCR buffer, and Taq DNA polymerase. Using a stock template of plasmid and standard primers, the success rate of initial attempts was typically less than half of the class. With second and third attempts, students generally became confident in their ability to assemble a successful reaction. However, the amount of pipetting required was clearly the factor that led to the high variability in results. In subsequent sessions, students were issued a stock of PCR “ready-mix”, comprising buffer, dNTPs, and MgCl_2 at working concentrations, and requiring only the addition of primers, template, and Taq polymerase. After substituting this “ready-mix”, the rate of student success at PCR on the first attempt increased to greater than half of the class, and several students were able to generate consistently successful amplifications.

At stages following the second week, students also practiced assembling DNA ligation reactions, transforming recombinant plasmid vectors into *Escherichia coli*, and recovering plasmid DNA from bacterial cell cultures, skills that would be required in the later stages of the project.

Developing a strategy

At the same time that students were developing their molecular research skills, they were also engaged in developing a research strategy for examining the physiological differences between the parasite dodder and its non-parasitic relative through the identification of genes that may contribute to these processes. The students were guided in this task through a series of discussions.

Introduction to the process of research. To introduce students to the process of research, they were asked to offer their best understanding of where and why research is performed, and by whom. While most students had a general appreciation that research occurs at universities and similar institutions, they were largely unaware of the typical structure of a laboratory regarding the roles of the principal investigator, graduate and undergraduate researchers, post-doctoral scholars, and technicians. The description of the principal investigator's role in providing the focus and direction for research led to the question "what constitutes a good research objective, and how does one begin to pursue it?"

The students were given for consideration the contrasting habits of dodder and morning glory, and asked to propose what biological insight might be gained by studying the differences between these organisms. Through many observations and suggestions, a theme emerged, addressing the question of how core physiological processes might change in the course of, or as a consequence of, the adoption of the parasitic habit. The students were subsequently introduced to the central dogma of molecular biology, relating cellular functions, mediated by enzymes and other proteins, to distinct genes. Consequently, the students were able to propose that the identification and characterization of genes for core metabolic processes could serve as a promising starting point for understanding how these two very different plants function. A list of enzyme activities contributing to the major metabolic pathways, as illustrated in FIG 2, thus provided a list of cognate genes for subsequent examination.

Establishing a research plan. A set of research skills that were clearly not well-developed among the student researchers was that needed for the identification, gathering, and employment of current knowledge in developing a research strategy. Simply stated, even given the objective, there was little sense of how to proceed. It was thus impressed upon them that it is important to establish the "state of the science" concerning the research objective, as learning how other researchers have addressed a

problem will provide ideas for how to advance a new project. In this example, the question at hand was whether the target genes had been identified previously, whether in the target plant species, or from other closely- or distantly-related plant species. The pursuit of the answer to this question was the focus for an introduction to commonly-used bioinformatic tools.

The National Center for Biotechnology Information site (<http://www.ncbi.nlm.nih.gov/>) hosts an array of tools that may be employed to help students develop competency in searching for relevant information. Information was gathered using a combination of search strategies. Initially, students used the PubMed search function to identify helpful publications and their authors, submitting combinations of key words such as the enzyme activity and the organism. Once it had been established that a gene for a target enzyme had been identified, the author name could be used to search the nucleotide database and find the cognate sequence. An alternative approach was to use the Taxonomy database to determine how many nucleotide sequences were available from the target species, genus, or family, noting whether any of the known, or putative, genes were among those contributing to core carbon or nitrogen metabolism.

Using a known nucleotide sequence as a starting point, the students used the Basic Local Alignment Search Tool (BLAST, Altschul *et al.*, 1990) to identify similar gene sequences from other sources. When they had retrieved gene sequences from a range of species, including both species closely related to Convolvulaceae, and species more distantly related, the students generated sequence alignments using the Clustal X DNA alignment program (Thompson *et al.*, 1994). Figure 4 illustrates the sequence alignment between starch synthase genes from members of the clade Solanales (to which Convolvulaceae and Solanaceae both belong), comprising sweet potato, tomato, and tobacco, and more distantly-related Arabidopsis. Because many of the students had only limited exposure to advanced concepts of molecular genetics, this gene alignment exercise served as an effective method for demonstrating several characteristics of the genetic code:

Regions of high and low sequence identity – Students noted that not all regions of aligned gene sequences share the same degree of sequence identity. Speculating that this reflected a difference in selection pressure among different locations within the gene, students could thus choose the most highly-conserved regions of the gene as potential sequences for DNA oligonucleotides for use in PCR.


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**      ****      *  *****  **  *  **      *  *  *****  **  **  **
sweetpotato  GATGG-----
tomato       GATGG-----
tobacco     GATGG-----
athalc      GACGG-----
athalg      GACGGTACTGGTTTCTCTGAAGAACAGATCATTACACCATTTTGTCTCATGTTTCAATC
** **

sweetpotato  -----GTATGACAAGCCAGTGAAGGGGAGAAA
tomato       -----ATATGAGAAAACCTGTTAAGGGTAGGAA
tobacco     -----ATATGAAAAGCCTGTTAAGGGTAGGAA
athalc      -----GTATGAAAAGCCAGTAAAAGGACGGAA
athalg      TTAATTTACTGTAACCTCTTGTTCATTTCAGGTATGAAAAGCCAGTAAAAGGACGGAA
***** ** ** ** ** ** ** ** ** ** ** ** ** ** ** **

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|<- primer SSRev
  GTACGATACGCTATACCTT
sweetpotato  TCATTTCAGTTGCATGCTATGCGATATGGAACACCGTGCATCTGTGCCTCAA
tomato       TCATTTCAGTTACATGCTATGCGATATGGAACAGTGCCAATCTGTGCCTCAA
tobacco     TCATTTCAGTTACATGCTATGCGCTATGGAACAGTGCCAATCTGTGCCTCAA
athalc      TCATTTCAGCTGCACGCAATGAGATATGGAACCGTCCCTATTGTGGCATCTA
athalg      TCATTTCAGCTGCACGCAATGAGATATGGAACCGTCCCTATTGTGGCATCTA
***** * ** ** ** ** ** ** ** ** ** ** ** ** ** ** **
                ↑                ↑
                B                C

```

By end of the second week of the session, the students had submitted their suggestions for oligonucleotide primer combinations. The suggested primers were considered in a group discussion, noting the degree of sequence identity at each site and the predicted size of the amplified product. The most promising combinations were submitted for synthesis. Typically, for both the forward and reverse directions, multiple primers were designed and synthesized; from these the students could choose the primer combinations for their attempts at gene amplification.

Preparation of research materials (week three)

During the third week, student researchers prepared the necessary genomic DNA for use as the template for experimental PCR using one of several suitable phenol:chloroform-based DNA extraction methods (Nishiguchi *et al.*, 2002). Before proceeding, the students were led through the protocol in detail, explaining the chemistry of nucleic acid purification and the purpose of each stage, from cell disruption to the final spooling of precipitated DNA. Students first practiced DNA isolation from leaf tissue of *I. hederacea*. The quality and quantity of the prepared DNA were judged by inspection of a sample following gel electrophoresis. Each student prepared a minimum of two DNA samples, and each team was required to have at least one good DNA preparation from each *C. pentagona* and *I. hederacea*.

Experimental amplification, cloning, and screening (week four)

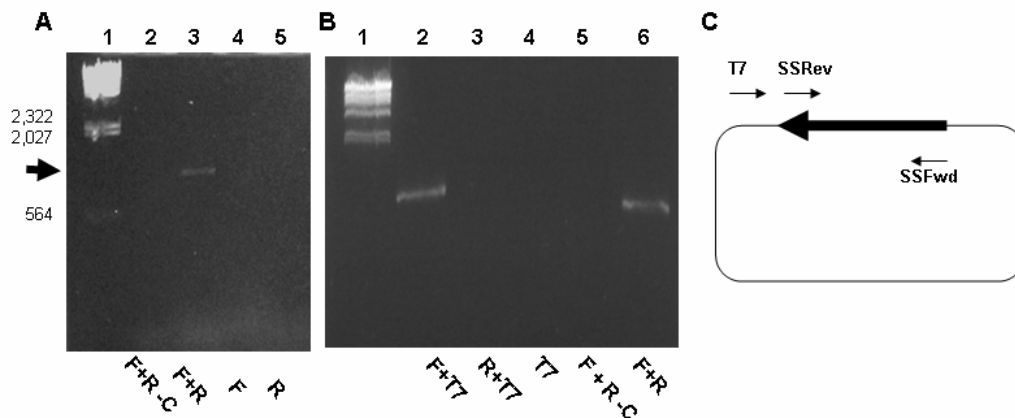
With suitable templates in hand by the end of the third week, students were ready to attempt the amplification of target gene fragments from each of the two species. As previously noted, when sequence identity between aligned gene sequences permitted, multiple forward and reverse primers were designed for each target gene, so that multiple combinations of primers were available. For any given experimental PCR, the student teams were allowed to choose the primer combination and the template that they would pursue. Students were required to prepare all needed controls (forward primer alone with template, reverse primer alone with template, forward and reverse primers together but without template) to qualify any resulting amplification products. Results of a typical student gel are presented in FIG 5a. Success rates varied between groups, but in every instance, there were enough successful amplifications – yielding amplification products in the experimental, as opposed to the control reactions – to provide material for all groups to participate in subsequent steps.

Amplified products were ligated into the pGEM-T Easy PCR cloning vector (Promega) and transformed into *E. coli* strain DH5 α , plated onto solid LB medium containing ampicillin (100 $\mu\text{g mL}^{-1}$) for selection. Successful ligation of an amplified product into the vector cloning site prevents the otherwise constitutive bacterial expression of *lacZ*, encoding β -galactosidase, the activity of which hydrolyzes the artificial substrate X-gal to generate a blue precipitate. As a fraction of the ligation reaction regularly generated closed plasmids lacking inserts, this exercise provided an opportunity to distinguish between *experimental selection* for bacteria carrying

the ampicillin resistance gene on the vector, and *experimental screening*, employing blue versus white colony color developed in the presence of X-gal, distinguishing plasmids without inserts from plasmids with inserts, respectively. White bacterial colonies were screened for insert size; students

picked bacteria directly from the plate into PCR mix with primers flanking the plasmid cloning site. In this way the students could rapidly determine which colonies were carrying fragments of a size comparable to candidate amplification products from the original experimental amplification.

FIG 5. Student amplification of putative starch synthase gene fragment from *Cuscuta pentagona*, PCR mapping of a cloned fragment to determine orientation, and schematic map of the cloned fragment. A. PCR amplification experiment using *C. pentagona* genomic DNA as a template and primers described in Figure 4. Primer combinations are indicated at the bottom of the gel: F=SSFwd, R=SSRev, -C=negative control from which template DNA has been omitted. A single amplification product appears within the predicted size range in lane 3. B. Single primers and primer combinations were used to demonstrate the orientation of a cloned fragment (not the same fragment as in panel A). Primer combinations are the same as in panel A, with the addition of the T7 primer. *Hind*III-digested phage λ DNA appears as a size marker in lane 1 of both A and B. C. The amplification pattern from B demonstrates that the T7 and SSFwd primers are in opposition to each other, indicating that the cloned fragment is in the “reverse” orientation.



Molecular characterization of cloned fragments (weeks four and five)

From among the bacterial colonies with plasmids containing an insert, student researchers were to choose the best candidates, based primarily on size predictions for the corresponding fragment in known sequences, for subsequent analysis.

Clone mapping- This first step in the characterization of individual clones was the mapping of the inserted fragment’s orientation with respect to the vector. Students used the forward primer from the experimental amplification in combination with either of the two primers flanking the cloning site, using these as reference points. Representative results of a student’s mapping exercise are shown in FIG 5b and 5c.

Sequencing and analysis- From the results of the screening and mapping exercises, students could choose cloned fragments that represented the most promising candidates, those that matched predictions for the size of the targeted gene region. Each group generated template DNA by amplification of the clone from T7 and Sp6 priming sites flanking the cloning site. PCR-amplified template was cleaned using a glass-powder protocol, and, upon confirming sufficient template recovery, students assembled sequencing reactions (Sequi-Therm sequencing reagent, Epicentre) using fluorescent tag-labeled T7 primer. To the extent that time permitted, students assisted in sequencing gel preparation and sample loading on a Li-Cor 4300 DNA analyzer. Alternatively, prepared samples were submitted to an external sequencing facility. DNA sequence data resulting from the sequencing reactions was returned to the students directly, and it became their

responsibility to determine, by comparing their sequence data with database sequences, whether they had been successful in their pursuit.

A majority of the student-generated clones were determined to have sequences that did not match the target gene. However, over the course of three summers' effort, students were successful in recovering cloned fragments with sequence similarity to plant aspartate aminotransferase, glyceraldehyde 3-phosphate dehydrogenase, and starch synthase genes, from one or both of the target organisms. These cloned gene fragments represent genuine student contributions to this ongoing research, as each clone will be used to generate gene-specific molecular probes for the experimental determination of mRNA levels in subsequent experiments. Other genes that were pursued without success included malate dehydrogenase, phosphoenolpyruvate carboxylase, and nitrate reductase.

The wrap-up

At the conclusion of the research session, the group completed surveys addressing the quality of the instructor and the research activities. Uniformly, the students indicated that they perceived the research experience to have been positive, that it increased their comprehension of some of the more complicated concepts of genetics and molecular

biology, and for those majoring in biology, that they expected to benefit from the research in their subsequent coursework. Communications with students one or more years after their participation has indicated that these students have especially benefited in their increased capacity to operate with confidence in a laboratory setting.

Notes on the pace of daily work. With the exception of those exercises requiring a computer lab, all of the activities reported here were performed in a standard science teaching lab, during a three hour block, four days per week, with one additional day reserved for necessary preparation. As the daily work often entailed a waiting period, as in the cases of gel electrophoresis or PCR, discussions of research strategy were interjected at opportune times. The amount of work here described, including the time spent training students, consumed the entire five-week schedule.

Acknowledgements

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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

Optimal Foraging Theory: Enhancing Student Understanding Through Role Play and Strategy Gaming

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Abstract: The use of interactive role playing games is shown to benefit both student experience as well as their depth of understanding and ability to apply specific principles. With this in mind, a game was developed to improve student awareness of optimal foraging theory within the behavioral ecology module of a bachelor's degree. The basic structure of the game addressed the major principles existing within scientific research to date and allowed students to generate their own "foraging entities." The game itself was followed by an informal feedback session, during which the students were asked to critique their adopted strategies relative to their success, or lack thereof, within the game. Student responses were found to fit well within experimental models of optimal foraging theory.

Keywords: optimal foraging theory (OFT), behavioral ecology

Introduction

Role-playing can be defined as a game or activity which allows participants to actively immerse themselves within a learning environment through the assumption of a character (Feinstein et al., 2002). Although, in this case, a rudimentary understanding of Optimal Foraging Theory (OFT) is an important basis for successful role-play learning, loose application of rules allows players to respond to cues given by others within the game. Role-playing also identifies misconceptions or increases meaningful dialogue between participants (McDonald and Hannafin, 2003). Such learning tools are systematically applied to action learning (Zuber-Skerritt, 2001) and business theory (Zgodavová et al., 2001), but are rarely, if ever, applied to disciplines within the biological sciences. Previous exploration of role-play and strategy learning has been relative to the creation of computer and mathematical simulations, rather than situations into which the player is physically co-opted. In reference to the former, research suggests both an increase in student motivation and desire to learn through increased engagement (Vogel et al., 2006). These findings may still be pertinent if applied to the latter.

Often, within science, student engagement with pure theory may be greeted with disinterest by those who find the topic difficult or, likewise, by those for whom theoretical concepts are unchallenging. However, role-playing serves to give the student an experiential perspective, supported by the direct application of previously imparted research and theory, rather than a passive knowledge based on traditional teaching methods. Such immersion tactics may not only address what is learned but how,

allowing students to build upon what they already understand through creative role-play as part of an interactive learning environment (Hackbarth, 1996).

OFT is commonly used to explain nutritive choices made by animals, both spatially (Marion et al., 2005), and temporally (Hills and Adler, 2002). Many of these choices can be predicted and are based on simple models of cost benefit analysis, where the energetic value of a particular foraging event must outweigh the concurrent risk of predation (Arcis and Desor, 2003; Winterrowd and Devenport, 2004). However, other costs must also be considered, including the quality of the foraging area, or "patch," in terms of food abundance, or cues which may be indicative thereof (Butler et al., 2005), and the travel time and distance between suitable feeding sites (Genaro and Schmidek, 2000). OFT may also be facilitated (by reducing predation risk) or hindered (by increasing rate of patch depletion) by the presence of conspecifics. In such cases, further tradeoffs emerge between group versus solitary foraging strategies (Giraldeau and Beauchamp, 1999). Finally, as with any finite resource there will be a cost of defense which must be considered, and this will also impact directly on the cost benefit analysis of a particular nutritional choice. In addition, any and all of these considerations must account for future benefits to the group or individual versus immediate costs relative to time and energy (Heinsohn, 1997).

OFT can therefore be identified as consisting of several interlocked components, each of which has an effect on whether or not an individual functions optimally. Although the interaction may appear complex, simple rules, combined

synergistically with the flexibility of role-play gaming, may allow greater understanding of the underlying principles.

Methods

Before the beginning of the game students are asked to pick roles based on their own knowledge of OFT and predictions as to which strategy may best serve their goals as “foraging entities.” The role falls into one of six categories, although players are allowed to develop their strategy and alter roles as the game progresses. The categories are:

- **Sharing:** Individuals show a greater propensity for group foraging and sharing of patch resources.
- **Lone forager:** Individuals are unlikely to share a patch and are more likely to desert or defend than share resources.
- **Risk taker:** Individuals are more likely to risk predation if returns are great.
- **Selective forager:** Individuals will reject low quality forage and are more likely to forage alone or in small groups. In this case individuals may collect one more forage item than others and all items with a value less than five must be returned.
- **Patch faithful:** Individuals are less likely to move between patches.
- **Defender:** Individuals are liable to forage alone and will aggressively defend their patch against intruders even if outnumbered.

Although these roles appear prescriptive the degree to which students are able to alter or negotiate their role is dependent on the evolution of the game. Roles may also be added or deleted relative to the desired outcome for the tutor.

In accordance with OFT, patches of variable quality must be provided, allowing students the opportunity to forage. The easiest method is through the use of ballot boxes which allow physical access but not visual assessment. Approximately one per three students is ideal. The forage items are represented by printed numbers ranging from one to ten, where ten is the highest value item. The total number of items and the range of values should differ between ballot boxes, but for a 30 minute tutorial a minimum of 50 forage items per patch is recommended.

All students begin the game at a central patch from which they are able to disperse at will. A foraging event occurs that lasts a set, or standard amount of

time, with 30 seconds often being appropriate. During a single foraging event, students may take one or more items from the ballot box. The number of items taken will depend on the number of individuals engaged at any one site: Lone foragers receive three items; groups of two receive two items each and groups of three or more only one item per student.

Each ballot box will also carry a number that is either one, two or three times the duration of the event (e.g., for a 30s interval it will read 30s, 1min, 1min30s). This represents the time cost associated with traveling between patches and should therefore affect the readiness of a student to desert their current patch. On arrival, for whatever reason, the time on the box represents how long the player must wait before being able to recommence foraging.

In addition some boxes carry a “danger” sign. These represent patches where the risk of predation is relatively great. Predation events are dictated by the tutor and occur once after every two foraging events. At this point the tutor randomly selects from the students a single individual who receives a penalty as outlined below. It is important that two of every three predation events should target either single foragers, or those at the danger areas. This represents greater risks associated with certain patches or with lone foraging and is not communicated to the students prior to the beginning of the game. As removal from the game following predation is counterproductive for student learning, a penalty is imposed for each student “predated.” This may be either a time penalty of one minute during which the student cannot forage, or the removal of a pre-established value of foraged items, a value of 20-30 is suitable.

Finally, as patches are encroached upon by others within the game, the resident (the first student at the patch) may choose to desert the patch, to accept the intruder or repel the intruder. This will depend on his/her chosen strategy, but also on the perceived resource value. Defense itself carries a time penalty of one foraging event for both or all participants and the loser must immediately vacate the patch. The dispute is decided through the traditional “rock, paper, scissors” game and is the best of three. In the case of a group attack on the territory the defender will automatically be displaced if he/she does not wish to join the group.

At the end of the game all players must reach a composite score for the tutorial. This is done by adding the value of all foraged items, which should carry a number from one to ten. Students should then tally the number of times they were predated, if predation carried a pre-established penalty (e.g. minus 20) they should then remove this from their overall score. If the predation penalty was associated with a loss of foraging time it should be noted and

brought into the discussion relative to the strategy adopted. The game is then followed by a discussion based on each individual's strategy and whether or not it was successful, the discussion should start with each student announcing their composite score, number of predation events, the strategy they selected and if or how their strategy developed during the tutorial. The tutor should allow free discussion to a point, but also be prepared to direct the students towards conclusions they may not have fully explored. The tutorial will allow each student to assess the role he/she played and how it did or did not fit within the boundaries of OFT. One of the more interesting points within the discussion is that success may often depend on both the individual strategy and those employed by the other players. As such, if played in a "free choice" format, results will differ for each cohort of students and will allow greater immersion into the variability that is prevalent within natural systems of behavioral ecology.

Discussion

Active participation by students through the development of games not only helps increase understanding, but allows the students themselves to generate an active body of knowledge around the subject, as opposed to the traditional passive transfer of pre-established theory. Informal feedback from 50 participants suggests that, for the majority, the experience was well received and improved understanding of the underlying principles involved in OFT. Brief written statements from the students

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following the game supported its use in future years and in one case even suggested "I would feel far more confident in answering a question on OFT in the final exam, can we have one please". In addition, the exercise was found to improve participation and interaction between members of the class as well as generating free discussion. Although the event was not formally assessed, future comparisons between cohorts who have played the game, relative to those who have not, may reveal interesting differences in learning and examination success.

Responses during feedback often supported the findings of research, including principles such as: movement associated with food density (Butler et al., 2005), remaining patch faithful when success is high (Bradshaw et al., 2004) and modifying behavior relative to perceived predation risk (Powell and Banks, 2003). Sharing of resources was found to be of overall benefit to the group whilst providing advantages (e.g. reduced predation, moderate intake) to each individual within the group (Mitani and Watts, 2001). In addition, those individuals that selected to defend resources found it to be a costly strategy in line with research findings (Chapman and Kramer, 1996).

As with any role-playing game the opportunity for refinement is ever present. Compared with the ever changing face of behavioral research this may be considered one of the strengths of any such teaching strategy. It is possible that such a framework could similarly be applied to the principles of hierarchical structures and breeding strategies.

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*Learning by Doing: Integrating Teaching and Research
in the Biology Classroom*



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**Bill Brett looks cool during a cruise down
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David Horn of Millikin University presents his poster.



One of several informative sessions.

Trolley taking members to the Mississippi cruise.



Abstracts of Presentations

Concurrent Workshop Session I

Development of a new outcome –based curriculum in the University of Wisconsin-Platteville program

Beth Frieders, Jeff Huebschman, and Wayne Weber, *U. Wisc-Platteville*

The Biology Department at the University of Wisconsin-Platteville has undergone a comprehensive curriculum overhaul, in which we identified learning outcomes for students completing our program. To achieve these outcomes, we created new courses and new emphases, and revised the major and minor programs. Numerous factors drove this change, including: to offer a more competitive and attractive program, to allow new faculty to teach courses within their expertise areas, to minimize content overlap in courses, and to include biology as a discovery process. The details of the department's new program will be covered in this presentation, specifically highlighting its plan to encourage undergraduate research by incorporating the process of science in multiple courses as well as devoting courses specifically to research. We also will present the process the department followed on this five-year journey, involving a combination of department-as-a-whole and sub-discipline discussions interspersed with much individual thought and effort. We will conclude with what we perceive as challenges and benefits of both the new program and the curriculum revision process itself.

Integrating Research in Introductory Biology Courses in a New Curriculum

Jeff Huebschman, Beth Frieders and Kris Wright, *U. Wisc-Platteville*

The Biology Department of the University of Wisconsin-Platteville is implementing a new curriculum in Fall 2007. Among the courses required of all biology majors are Unity of Life and Diversity of Life, both freshmen-level courses, and Fundamentals of Biological Investigations, a sophomore-level course. All three courses were newly developed as part of the curriculum revision to provide students with foundational knowledge, skills, and attitudes, both in preparation for upper-level biology courses and, more generally, to address specific learning outcomes of the overall biology

curriculum. To ensure that foundational elements were provided in Unity and Diversity of Life all faculty and teaching academic staff were asked to provide input on specific learning outcomes they expected these courses to provide. Complementing the foundation in knowledge provided by the aforementioned courses, Fundamentals of Biological Investigations was designed to meet primarily skills-based learning outcomes, specifically in regards to the practice of science. We will discuss the creation of these courses, focusing on their educational intent, the collaborative nature of their development, and the reflection undertaken by all department members that occurred as a result of being engaged in the process of their creation.

The case study method: Using case studies to bring research into the biology classroom

Debra Meuler; *Cardinal Stritch University*

The case study method of teaching is an effective alternative approach to the more traditional lecture method of delivering science content. Case studies encourage students to think critically and become active learners. Case studies can also be used to illustrate the process of science and to provide students with an opportunity to design experiments as well as analyze and interpret data using authentic research. During the last few years, I have begun to include case studies in many of my biology courses to illustrate how science is done. In this presentation, I will share some of my most popular and effective case studies that allow students to design experiments, develop hypotheses, make predictions, and analyze real data while at the same time teaching content. To model how to 'run' a case study, the audience will do a case study that improves student understanding of science as process as well as data analysis and critical thinking skills.

Pandemic Flu Then and Now: A Problem Space for Student Investigation

Margaret Waterman, *Southeastern Missouri State University*

In this session participants will explore a problem space on influenza which includes: a case based on oral history research of the 1918 flu pandemic; an interactive, excel-based model

on disease spread; a set of maps as visual data sets; data from the CDC and WHO; primary research articles on flu structure as well as on disease mitigation strategies; and curricular resources for teaching with this problem space. Participants will analyze the case and conduct a brief investigation using the model to see impacts of different mitigation strategies. All participants will receive a book of cases and investigations as well as a copy of the new curricular resources on avian influenza.

Concurrent Workshop Session II

Bridging the Gap: Connecting the Scientific Literature with Learning and Research

Katherine O'Clair; *Arizona State University*

One of the challenges of integrating research activities into the biology curriculum is conveying to students the importance of using the scientific literature to situate their question into the larger framework of scientific knowledge. Consulting the literature and synthesizing information from it is a critical component of the research process, yet it remains difficult to get students to do this using appropriate sources. The sources they do use and cite often fall short of our expectations. How do we bridge this gap and connect students with the best source - the scientific literature? In this workshop we will explore ways to integrate the scientific literature into the biology curriculum whether it is part of a short laboratory exercise or semester-long research project. Participants will reflect on their past experiences, create learning outcomes for their students, and identify activities that can be used in a variety of settings to expose students to the scientific literature and convey its purpose in research. Attendees are encouraged to bring their course syllabi to use during this workshop.

Integrating Chemistry and Microbiology in a Single Course for Nursing and Health Science Students

Linda O. Michel, Farahnaz Movahed Zadeh², Farrokh Asadi³, Abour H. Cherif¹, Bob Aron, Dianne M. Jedlicka¹, Frank S. Burrows⁴; ¹*DeVry University*, ²*University of Illinois at Chicago*, ³*Harold Washington College*, ⁴*Pearson Custom Publishing*.

Foundations of Microbiology and Chemistry is a unique course designed to offer a comprehensive

introduction to the fields of chemistry and microbiology for nursing and allied health students. This course provides understanding of the basic foundations of chemistry and microbiology using an integrated approach for conceptual and teamwork strategies. The course is four credit hours and includes a laboratory component. This course is offered in three formats: online, a hybrid online/onsite iOptimize format and a traditional on-site format. The online and iOptimize formats utilize Model ChemLab and VirtualUnknown™ Microbiology software in the laboratory portion. These programs simulate chemistry and microbiology laboratories and allow students to perform a wide variety of laboratory simulations utilizing the Scientific Method as well as higher cognitive thinking in the lab write-ups. A custom text, *Microbiology and Chemistry: An Integrated Approach*, has been created for this novel course by Pearson Custom Publishing. Topics covered include microscopy, the structure of matter and basic chemistry, cellular structure and function, microbial genetics and recombinant DNA technology, characterization of microorganisms, chemical reactions, microbial metabolism, nutrition, and growth, the immune system, infectious diseases, epidemiology, and applied and environmental microbiology. The integration of chemistry and microbiology subject matter throughout this course makes it unique; the virtual labs complimenting the lecture topics and allowing students to interpret their results, make this course and text outstanding.

Microbiology in the News

Nighat P Kokan; *Cardinal Stritch University*

This project allows the students to incorporate both writing and speaking assignments into the curriculum and enables the student to see relevance of microbiology in their life and career. Students are required to write a two-page synopsis of current topic of interest of their choice as long as it relates to microbiology. They must describe the topic in some depth, using primary sources to show that they have understood the process or the techniques related to the area of interest. After completion of the report they make a five-minute oral presentation to class. This assignment allows me to cover and incorporate a wide variety of microorganisms into my teaching, which have a current effect on society. These assignments result in interesting class discussions of microbes and their impact on

health, disease, economics and the environment. Students find these topics rewarding since they pick their own topics to investigate in some depth. Furthermore, they see the relevance of basic science and the application of specific techniques to current discoveries. I will share the rubrics that I have developed for this process and some of the modifications and adaptations made for other classes such as Biology and Genetics courses as well as student responses.

A Freshman Laboratory Curriculum – Buh-bye cookbook and hello research!

Tara Maginnis, *St. Edward's University*

Traditionally, many freshman biology laboratories have been run in a 'cookbook' format; students follow a set of instructions and write/describe the results. While some of this is appropriate at the freshman level, newer approaches to inquiry and research based thinking have been shown to drastically improve the quality of the undergraduate mind.

In this session I will present a curriculum implemented at St. Edward's University, a small private institution in Austin, Texas. During the first semester, students are introduced to scientific inquiry and hypothesis testing, and these foundations are re-enforced in almost every laboratory activity. In addition, they acquire and/or are exposed to several scientific 'tools' such as basic statistics, presentation and writing practice, library databases, biological equipment, and experience evaluating scientific experimental designs and manuscripts. In the second semester, students apply these tools when they design, implement, write and present a small yet high quality group research project. The curriculum and each individual laboratory (18 total, student and instructor copies) will be provided.

Concurrent Paper Session I

Student Contribution to the Conservation of Timber Rattlesnakes in Eastern Kansas

Mindy Walker, Rockhurst University

The timber rattlesnake (*Crotalus horridus*) is considered a species of special concern in the state of Kansas. Such a label ostensibly indicates a statewide attempt to protect this species, though little is being done at the governmental level. In our study, my undergraduate students and I are piloting a

project aimed at actively salvaging a local population of these animals. Individuals are first collected from a den site currently being decimated by human development, and snakes are subsequently measured, weighed, marked using internal microchips, and released at a separate locality. A subset of this population has been, and other collected individuals will be, surgically implanted with radio transmitters so as to allow tracking of individuals once they have been released at the secure site. The above students, and others who will follow them, are able to observe safe handling and collecting procedures for venomous animals as well as an *applied* understanding of these organisms' role in the environment, the threat of human land development to natural populations, the organismal biology of these animals, and the biological consequences of relocating threatened populations. Such an endeavor fosters an enhanced interest in field biology and a desire to continue their involvement in conservation efforts.

Teaching Evolution in Secular and Christian Educational Settings - Obstacles and Opportunities for Student Learning

Richard G. Colling; *Olivet Nazarene University*

Responding to continued assaults on evolution, the National Academy of Sciences, the American Association for the Advancement of Science, the National Science Teachers Association, and others, have issued clear statements that science and the scientific community are not anti-religion. Yet despite these attempts to appropriately define the boundaries of science and faith, a sharp disconnect persists between what science reveals and what many people actually believe. The potential stakes are enormous: Erosion of science definitions to fit political and religious agendas weakens foundations of science and a democratic society. It even diminishes the long-term viability and credibility of faith.

National polls reveal a key role for education in overcoming this disconnect. Yet effective teaching of evolution presents unique and striking challenges for faculty teaching at secular vs. religious universities, teaching majors vs. non-majors, and for those teaching in secondary or middle schools.

This proposed paper will address four areas:

1. Recent genetic data confirming evolutionary creation.

2. The crucial need for science educators to stay abreast of recent developments in evolutionary biology.
3. Finding language and communication techniques that successfully engage diverse student populations in the classroom.
4. The importance of responding to escalating religious and political pressures on biology educators.

Concurrent Paper Session II

A Biology Course for the Less-Than-Prepared Prospective Biology Major

Janice Bonner; *College of Notre Dame of Maryland*

Many undergraduate institutions are dealing with less-than-prepared students entering the biology major. When the biology department at College of Notre Dame of Maryland analyzed data from five past cohorts of prospective biology majors, it found a significant correlation between students' success in the introductory course and their math SAT score (Spearman's $\rho = 0.058$). Based on these results, the biology department developed a preparatory course for students whose MSAT score was below a prescribed cutoff value and stipulated that a student must pass this preparatory course with a grade of at least C+ to take the introductory course. Of the 73 students enrolled in the first three cohorts, 81% passed the preparatory course, 15% withdrew, and 4% failed. Ninety-five percent of the 40 students who subsequently enrolled in the introductory course passed. There was no correlation between their grade and their MSAT score. This workshop will explain the design of the course curriculum and the process by which students are assigned to enroll in the preparatory course; it will provide specific examples of assignments, laboratory experiments and assessment within the course. Finally, it will present student feedback and an analysis of the first three cohorts of students to progress through the course.

An Example of Integrating a Community Action - Service Learning [CASL] Project into an Introductory Microbiology Class

Christine Bezotte, Elmira College

The project addresses the "disconnect" students perceive between classroom learning

and its application to "real-life." By incorporating the practical aspects of investigating a community wide condition with hands-on research and analysis, the project provides contextual relevance to understanding the biology behind the observed effect. An active learning opportunity enhances problem solving and encourages critical thinking skills through evaluation of correlations between Methicillin Resistant *Staphylococcus aureus* [MRSA] presence in general and hospital worker populations to disease spread. The goal of the project is to engage students in a relevant contextual learning experience.

Acquisition and spread of MRSA is an increasing problem, not only hospital acquired but also in the general public. Nursing majors need to be especially aware of this and be prepared to understand and prevent its spread. This investigation combines a community and hospital survey for carriers with microbiological techniques to evaluate the health and economic impact of the problem. In addition, students are asked to develop a community action plan educating the general public and devise ways to prevent further disease spread. The exercise encourages student integration of concepts in microbiology with disease processes and epidemiology in ways that have personal significance. Results will be presented and discussed

Partnering with Biotechnology Companies to Promote Student Research Experiences

Richard G. Colling; *Olivet Nazarene University*

Biological research provides an essential foundation for ongoing discovery and progress in the fields of biomedicine, biotechnology, and other related fields. Providing opportunities for students to experience and appreciate the rigor and detail of biological research is a valuable part of an overall biological science education. Yet, exponentially expanding biological complexity, coupled with university infrastructure obstacles, make it increasingly difficult to successfully integrate relevant student research experiences into the regular teaching curriculum. Common obstacles that work against this noble goal include upfront material costs, additional time needed for research over traditional class periods, laboratory facilities and equipment, scheduling, faculty expertise and teaching loads.

The current paper describes a way to address these obstacles by partnering with

biotechnology/biopharmaceutical companies. Win/win for everyone, these partnerships have provided opportunities for students to participate in meaningful and relevant research experiences. It has also elevated the visibility and value of research in the department and on campus as well as spawning individual laboratory exercises for use in other biology courses. In addition, it has produced positive public relations material for the university, and also helped the biotechnology company meet their productivity goals.

Proactive communication and coordination with all involved parties is essential to this approach, but we have found it to be extremely valuable, and a cost-effective way to achieve student research goals.

Integration of zebrafish research projects in an upper level molecular biology course

Lisa Felzien; *Rockhurst University*

Integration of research into coursework provides opportunities for larger numbers of students to experience scientific discovery and for faculty members to maintain an emphasis in discipline based research when time and funds for research are limited. Incorporation of novel research projects also creates unparalleled active learning experiences. In the project described here, students were required to perform literature searches, identify a gene not well-characterized in zebrafish development, design and test a hypothesis, and present results. Research approaches included the use of genbank and BLAST searches to identify zebrafish genes of interest, staging of zebrafish embryos, extraction of RNA from embryos, and RT-PCR. Most student groups obtained results, and frequently results forced students to complete further literature searches to understand why their hypothesis was not completely supported. Early approaches to assessment of the effects of the project on student learning are underway.

Concurrent Paper Session III

Trials and Tribulations of Web-Based Biology Courses

Timothy Mulkey, *Indiana State University*

Web-based distance education biology courses have been taught at Indiana State University for 12 years. These courses include non-major General Education, major electives,

and laboratory courses. A sort presentation of what “works” and “does not work”, student’s expectations and misconceptions, lessons learned from the ISU course offerings will be presented. This will be followed by a discussion by attendees of their experiences, questions, and ideas concerning the future directions of web-based distance education biology courses.

Analysis of Logodiversity in Animal Behavior Textbooks

Rebecca Burton, *Alverno College*

One important consideration in selecting a textbook is the level of specialized technical vocabulary used. Technical vocabulary can be a bridge for entry into advanced study in the discipline; however, it can also be a barrier to students even reading the book or students being willing to engage in the discipline on the most basic level. “Logodiversity” is a measure of how many technical words are used and how often each word is used. The optimal level of logodiversity in a textbook depends on the needs of the specific students in a particular class. For example, a high logodiversity may be most appropriate for well-prepared students intending to enter graduate school in that discipline. A low logodiversity may be most appropriate for students who are bound for other fields or for whom language or reading is problematic. I used a modification of the Shannon–Wiener diversity index to quantify logodiversity in 6 commonly used animal behavior textbooks and found that these textbooks varied greatly in their levels of logodiversity. This diversity index can be approximated by a simple ratio of glossary to text length. We will discuss strategies for accommodating student needs regardless of the logodiversity of the selected textbook.

Stressed by Oxygen—A Laboratory Exercise for Introductory Cell Biology Classes

H. Neval Erturk and Mary Carolyn Frith, *Converse College*

This laboratory exercise is designed to expose students to a full scale scientific investigation while acquiring science processing skills. The project continues over a 6 week period and exposes students to fundamental techniques in cell biology and bioinformatics. Students measure the responses of pea antioxidant enzymes super oxide dismutase, catalase, ascorbate peroxidase, guaiacol peroxidase and glutathione reductase

to abiotic stress. Students can choose from a variety of agents that cause abiotic stress like high light, paraquat, chilling, heat, salinity, drought, or even a combination of few. For Bioinformatics exercises students compare DNA and amino acid sequences of selected antioxidant enzyme from different species for constructing an evolutionary tree. Students also use Deep View Swiss PDV Viewer to study the three dimensional structures of the antioxidant enzymes. This program allows students to analyze several proteins at a time, including superimposing structural alignments, comparing active sites, observing amino acid mutations, etc. Students present their findings during a classroom mini symposium. This learning process is also supported by lecture content. The process aims to create and strengthen a student learning community. The project can be expanded by running native gels for enzyme activity, by having students write their findings as a peer reviewed journal article, and by publishing a classroom journal.

Experimental designs that provide instructors with informative comparisons of alternative teaching strategies while providing students with equivalent experiences

Ralph Preszler, *New Mexico State University*

Instructors who hope to inform their teaching strategies with measures of student performance need experimental designs that have sufficient statistical power to identify true differences in student performance and that are fair to participating students. I will provide general descriptions and specific examples of educational experiments conducted within biology courses that satisfy both of these criteria: they are informative and they provide students in the classroom(s) with similar opportunities to learn. I have conducted experiments in biology classrooms which compare the effects of the following teaching methods on student performance: cooperative concept-mapping sessions vs. individual homework assignments; instructor vs. student-centered workshop teaching; and asking low, medium, or high numbers of clicker questions within biology lectures. Lastly, I will describe challenges associated with answering research questions tied to large scale changes in course structure. This workshop will include discussions of approaches to conducting research within the classroom to address questions that participants

have about their teaching and their students' learning.

Concurrent Paper Session IV

Using Biotechnology Research to Teach Biology to Undergraduates

Kristy L. Halverson, Marcelle A. Seigel & Sharyn K. Freyermuth; *University of Missouri-Columbia*

Finding teaching strategies that connect with undergraduate students' interests can be a challenging task. In addition, current science research is often left out of college science curriculum. We have strived to use current scientific research advancements that society has brought to the forefront of the press as well as our own scientific research interests to help engage our students to learn biology concepts. We have tested our issues within multiple course settings as well as employed these major research advances to teach both basic and advanced biology concepts. Among the issues we included into our curriculum are: stem cell research, global warming, DNA fingerprinting, Human papillomavirus vaccinations, and plant polyploidy. These issues are easily approachable by both science majors and non-science majors and provide a solid foundation to teach a wide variety of biology concepts including, but not limited to: cell characteristics, biochemistry, ecology, conservation of matter, thermodynamic laws of energy, inheritance, characteristics of life, genetics, and more practical tasks such as lab research techniques. Our students responded positively toward the inclusion of current research issues within the courses. By using publicized current research within our courses, we have found a way to help instructors bridge the research-instruction gap even when personal research projects are not available to help contribute science instruction.

Tools from Archaea to Fireflies: a Research Based Laboratory Project for a Molecular Biology Course

Kate Marley; *Doane College*

While there are many techniques that molecular biology students should know, a lab organized around sampling as many of them as possible does not support proficiency in any. Rather a lab centered on addressing a specific research question allows students to learn a few techniques in-depth. The objective of this

project was to examine the role of potential transcription factor binding sites in transcription regulation. In this case, a minimal promoter for the human N-cadherin gene was previously identified and the literature suggested roles for specific transcription factors. Students were responsible for the entire project including database analysis, primer selection, PCR, cloning, sequencing, mammalian transfection and luciferase assays. Students were highly engaged and interested. Ultimately they understood why they used selected techniques, the necessary controls, troubleshooting and data analysis, all quantitatively better than students just completing the pre-requisite genetics course, despite some lab overlap. This project could be adapted in a number of ways to accommodate instructor strengths including techniques such as bandshift, siRNA, RT-PCR, Southern, microarray, while providing for in-depth understanding and engagement. This publication was made possible by the NIH Grant Number P20 RR16469 from the INBRE Program of the National Center for Research Resources

Engaging Student in Introductory Biology Courses through the use of Clickers

Glena Temple and Michael Alfieri;
Viterbo University

Introductory biology courses at Viterbo University have incorporated the TurningPoint™ audience response systems, or "clickers" as part of a Department of Education Title III grant: "Becoming Learner Centered" in an effort to increase the use of active learning techniques on campus. Several faculty within the biology department have used clickers throughout the semester for quizzes, assessment of student mastery of information, to provoke discussion through opinion questions and to take attendance. Overall, students gave positive feedback on the use of clickers in their introductory biology classes. Over 75% of students surveyed indicated that they wished more classes would use clickers on campus. In addition, over 90% of students surveyed indicated that they enjoyed using the clickers and that they preferred taking quizzes through clickers instead of traditional paper quizzes. In this presentation, we will address how clickers are used in our classes, present complete survey data from our students who have used clickers for a semester, and discuss the pros and cons of building clickers into courses from a faculty perspective.

The Undergraduate Research Experience: Enriching Undergraduate Science Programs Through Student Research

Agnes M. Vanderpool and John Copeland;
Lincoln Memorial University

Since 1995, Lincoln Memorial University's Department of Math and Natural Sciences has incorporated undergraduate research into the required curriculum for natural science majors. Structured as one-credit hour seminar course taught during both the junior and senior years, the Junior-Senior Science seminar series, pairs undergraduate science majors with a faculty mentor to develop and implement an independent science research project. This presentation will address the structure and assessments used within the two seminar courses, the impact of delivery of the courses on faculty time, workload, faculty research efforts and the departmental budget. The presentation will also address use of the two course assessments for departmental outcomes reporting, student perspectives on the seminar courses, administrative and financial challenges for conducting the courses, and the impact of the seminar courses on developing departmental budgets and promoting the science major programs. The final portion of the presentation will discuss strategies for structuring the course to accommodate changes in student enrollment.

Posters

Analysis of common topics in introductory biology courses: reinventing the wheel?

James Clack, *Indiana University-Purdue University*

Biology is unique as an academic discipline because of its many different fields. This is one reason for the large number of courses offered by most biology departments. In many colleges and universities another subset of courses are offered to non-majors, further increasing the number and diversity of courses offered. This effectively produces two lines of the introductory courses. Because of the different focus of each introductory course, topics covered in each of the introductory courses tend to vary. However, many of these introductory courses contain a number of topics with very similar content. Indeed, this content similarity is preserved across majors / non-majors courses. Several topics have been identified to be common across several courses

and their corresponding textbooks for three different state universities in Indiana. Identifying a concordance of topics between different courses may allow instructors and/or curriculum developers the ability to condense or align topics shared by different courses and, thus, streamline course offerings. Knowledge of topic concordance in introductory courses may also be advantageous when offering instruction outside of class or when considering topics to be covered in biology assistance centers.

Identification of Unknowns Facilitated by A Computer-Assisted Program (YaIP)

Janet Cooper and Josh Hilliard, *Rockhurst University*
Kevin Burger, *Arizona State University*

The identification of unknown microorganisms in a Microbiology course has been a useful exercise for the understanding of cultural and physiological characteristics of microorganisms as well as introducing students to the process of doing research and interpreting data. For many nursing students this has been a daunting task and they have difficulty knowing where to begin. To aid in this process, students are given three sources to use in their interpretation of results: 1) taxonomic key, 2) computer-assisted program (YaIP) and 3) Bergey's Manual.

The use of adult and embryonic zebrafish in extending bioassays in undergraduate research projects

Melissa Daggett, *Missouri Western State University*

Zebrafish have been incorporated into independent undergraduate research projects at Missouri Western State University. This presentation outlines and presents protocols and practical information for using zebrafish as a model organism at a predominately undergraduate institution. Currently zebrafish are being used for independent research projects in BIO 215 Molecular Cell Biology and BIO 311 Animal Physiology at MWSU. Zebrafish have become an accepted model organism for the study of embryonic development and genetic based diseases. Zebrafish are also becoming an established organism for use in undergraduate teaching laboratories. The advantages of using zebrafish include ease of culturing and maintaining the fish in the lab and the availability of information on the Internet for

performing various scientific investigations using zebrafish. Independent research projects offer an opportunity for students to design, perform and report on their own research question. This presentation will present examples of past student projects in which simple bioassays have been extended to include experimental techniques required to detect and quantify the expression of specific genes during exposure to pharmaceuticals, personal care products and environmental toxins.

Nutritional Assignment for General Physiology Course

Elizabeth I. Evans, *Rockhurst University*

In an effort to help students immediately apply General Physiology information to their personal lives, I include an individual assignment related to diet. Students are given an Excel[®] spreadsheet to enter nutritional data (restaurant, serving size, calories, calories from fat, condiments, cholesterol, etc.) for their specific fast-food choices to meet a list of basic food categories. They choose from their spreadsheet at least two meals (lunch and supper) that provide no more than 1500 calories (assuming 500 calories at breakfast) and include a drink with each meal or snack. Then they reevaluate their chosen menus and find at least three food-related changes that can be made to each meal or snack to reduce daily caloric intake and to ensure their chosen changes are possible at the restaurant of their choice. In addition, they identify at least three non-food-related choices that can decrease their net daily caloric intake. This part of the assignment often causes students considerable difficulty as they keep returning to changes in the food items, missing the fact that activity affects their net caloric intake. After these assignments are turned in, the class watches the movie, *Super Size Me*, and closes with a group discussion. Even if students have previously seen this movie, this assignment is very eye-opening for students and hopefully will continue to impact their food (and activity) choices in the future.

Learning by Doing: Using PowerLab Data Acquisition Units to Help Students Learn Research Skill

Kim Fredricks, *Viterbo University*

Students in an upper level human physiology course will use PowerLab

(ADInstruments' PowerLab™ data acquisition systems are a complete hardware/software computer-based solution for data collection in the student laboratory. Students can record, visualize and analyze data from their experiments using a Windows or Macintosh-based computer and monitor) to learn research skills. The first 3 weeks of the laboratory component of the course will allow students to learn the capabilities of PowerLab™. Students will then design a small research project with consent of the instructor. They will formulate a hypothesis, create the experimental design (including proper statistical tests), conduct the project, analyze their data, and write a formal laboratory report. Undergraduate research is important because it helps students think like scientists and ask questions like scientists. Students can also see a direct application of their “book” knowledge from core curriculum to answer a unique question. Student perceptions of research, the value of research in the curriculum, and their satisfaction with the use of PowerLab in the course will be collected by survey to determine if we our meeting our course outcomes.

Learning by Doing: Service Learning – A Model For Student and Community Engagement

Kim Fredricks, *Viterbo University*

In the 2005-2006 academic year, the Biology Department of Viterbo University initiated a collaborative learning environment with Hixon Forest Nature Center (HFNC), an 800 acre park in La Crosse WI consisting of marsh, bluffs, and prairie lands. A major emphasis of this project was to utilize a community resource as a foundation for developing meaningful assignments that would benefit all involved. Here, we report on two goals specific to this project: (1) to provide much needed educational resource materials for HFNC, and (2) to cooperatively collect data through scientific research on the needs of the forest. The evaluation process used a key informant survey approach: interviewing students, instructors, and the HFNC naturalist. Responses were recorded, transcribed, and coded to discover the key concepts related to this project. The initial findings supported the value of the science learning through service projects. First, students expressed satisfaction with their projects and articulated future plans to build upon this experience. Second, instructors engaged in the project identified

several benefits and plans for expansion of this type of projects in the future. Third, the identified value for HFNC was that they gained much needed materials to support their on-going education of elementary students. Recommendations for future collaboration include: continuing to design real life projects for students (especially non-science majors) to integrate knowledge and skills from their discipline in the development of a science-based project, allowing underclass science majors to begin using their skills and knowledge in collecting data meaningful to HFNC.

Malleability of *Xenopus laevis* Tadpoles in Research-based Physiology Laboratories Involving Heavy Metals

Gregory M. Grabowski, MS, PhD., Michelle Andrzejak, PhD., Emzy Collins*, Nicolas Deboer*, Lindsey Greschak*, Azail Hail*, Yasmin Mikail*, and Josha Thomson*, *University of Detroit Mercy* (*Undergraduate research assistants)

Practical resource limitations can be prohibitive to the integration of research into laboratories with high enrollment, which are historically demonstrative in their presentation. Computer simulations attempt to alleviate time restrictions, but remain demonstrative and provide little hands on experience. The fecundity of the African clawed frog (*Xenopus laevis*) provides enough tadpoles for relatively simple toxicological investigations that integrate scientific methodology, statistics, and cell physiology. Exposure to developing tadpoles to concentration gradients from 0-100 mm of vanadium, calcium, magnesium, and sodium chloride (osmotic control) results in growth deviations via eye-eye and body length comparisons. Student research results demonstrated up to 20% reduction in size ratios under vanadium exposure, and up 64% reductions in calcium and magnesium exposures. A significant decrease in viability was noted at 75 and 100 mm concentrations, which matched results from osmotic controls. Vanadium exposures implicate phosphatase inhibition, calcium exposures implicate membrane-bound phospholipase activity, and magnesium exposures implicate SOD/oxygen radical activity. Undergraduate research does not allow use of radioassay technology typically used in phosphatase studies, however phosphotyrosine phosphatase activity can be assayed colorimetrically within a three hour laboratory

session. Phosphate freed from phosphotyrosine is precipitated with molybdate to form a color complex. Absorbencies are contrasted with known phosphate standards, which are standardized to the protein concentration of each sample. Students learn to standardize data and utilize controls for determining second messenger activity under various toxicological conditions, and the professor avoids using expensive materials and equipment, as well as avoiding safety problems associated with using phosphate isotopes.

Behavior of woodchucks: ethograms in lab and field

Lynn Gillie, *Elmira College*

The woodchuck or groundhog (*Marmota monax*) is an abundant mammal in grassy areas near woodland edges in the eastern half of North America. In studying four different populations of woodchucks during our summer research program, my students identified many variables that are interesting to examine during courses in Animal Behavior or Ecology. As easily observable, diurnal, burrowing animals, they make good model organisms for studying vigilance rates and durations, flight distance, foraging, and population density and distribution. Students practice making ethograms, records of species-typical behavior, in the laboratory and then apply that experience to animals, such as woodchucks, in the field. The challenges of moving from a lab setting to the field will be discussed.

An Introduction to Research Skills Using Blackworm (*Lumbriculus variegatus*) Regeneration

Elaine Hardwick, *University of Wisconsin, River Falls*

Charles Drewes' blackworm (*Lumbriculus variegatus*) regeneration website, (<http://www.eeob.iastate.edu/faculty/DrewesC/htdocs/>; Accessed August 10, 2007), was used as a resource guide for a project intended to introduce research skills to freshmen and sophomores. Students worked collaboratively to generate a testable hypothesis concerning blackworm regeneration and then applied concept knowledge, lab, and computer skills to complete and present the project. Although course instructors had a minor role in the set-up or completion of the three-week "hands-on" portion

of the project, they were more involved with data analyses and presentation aspects (approximately 2 weeks). Students presented their project as a poster, using a journal-style format, during an informal session that included peer-review and self-reflection. Project assessment included the following areas: collaboration (90% of groups reported positive interactions), library research and writing skills (75%), and data analyses and presentation (80%). Since a majority (> 88%) of students had little to no previous experience with this type presentation format and, surprisingly, use of computer programs (primarily Microsoft Office), completion of this project provided them with experience they could apply in other courses. Student outcomes, instructor comments, and project handouts are included in this presentation.

Integrating the scholarship of teaching and research: a case study examining wild bird food preferences at Millikin University in Decatur, Illinois

David Horn and Stacey Shonkwiler;
Millikin University

The scholarship of teaching and research can be synergistic, and provide students with a learning experience that integrates theory and practice. I describe how a large-scale study on wild bird feeding has been integrated into a semester-long research project for upper-level biology classes. In 2006, over 55 million people fed birds around their home. Despite the large interest in bird feeding, few scientific studies have been conducted on this hobby. PROJECT WILDBIRD is a study of seed and feeder preferences of wild birds being conducted by hundreds of citizen scientists throughout the United States and Canada. The study is headquartered at Millikin University in Decatur, Illinois. Millikin University students are participating in PROJECT WILDBIRD as part of an assigned research project in upper-level courses. Upperclassmen are asked to collect and analyze data, give oral presentations, and write papers on the research. Millikin University students are also involved in the coordination of PROJECT WILDBIRD including the recruitment of citizen scientists and answering questions participants have about the research. At the end of the study, the general public will be provided with recommendations on food and feeder preferences of wild birds, while Millikin students are engaged in a classroom curriculum that provides a meaningful research experience.

Incorporating bioinformatics research into courses

Karen Klyczek, *University Wisconsin, River Falls*

The vast amount of sequences and other data available through online databases provides a good resource for students to address original, open-ended research questions without necessarily requiring equipment and lab supplies. In addition to gaining experience with bioinformatics tools, students go through an authentic research process. One approach is to start with a published research article and ask students to extend the research by posing questions and hypotheses that can be tested by analyzing nucleotide or amino acid sequences. Sequences may be provided with the publication, or students can search for relevant sequences for comparison. As part of the investigation, students may perform sequence alignments that identify differences that can be used to determine evolutionary or other relationships, or conserved regions that may be associated with particular functions. Depending on the course, these studies may include investigation of pathways, protein structure, and other analyses using online analysis tools. Examples will be shared from microbiology and general biology courses. Bioinformatics can also be used to add open-ended investigation to case studies. The presentation will also include a demonstration of new features being developed for the Case It software (caseit.uwrf.edu) that will connect directly from the molecular biology lab simulations to online bioinformatics databases and tools, facilitating the extension of case studies to include original research investigations.

Introducing Cross Discipline Research Projects in Upper Division Courses

Carol M. Maillet, *Brescia University*

Research biochemists frequently contribute to exploration of biological questions by working collaboratively with research groups from other disciplines. In an effort to mimic this research reality, I developed the opportunity for my biochemistry students to work cooperatively with students in other areas. For the laboratory section of the Biochemistry course, students developed joint projects with students in either the Advanced Anatomy and Physiology or in the Marine Biology courses. All of the courses were upper division classes that required a research project spanning several weeks. The

Biochemistry lab experience was divided into four sections: 1) familiarization with the biological system, 2) identification and optimization of the appropriate biochemical assays, 3) application of these assays to the experimental samples, and 4) synthesis and communication of the results. Students grappled with problems such as development and optimization of a protocol based on a description in a primary paper, the availability of material from their collaborators, and the quality of their collaborator's data. In general, Biochemistry students found the research approach to be challenging but interesting. As an instructor, I found that, although I retained course goals, I had to be fluid about deadlines and the means by which goals were achieved.

Using *Neurospora crassa* as a tool for cell biology and genetics

Laura Salem, *Rockhurst University*

This poster will address some advantages of using *Neurospora crassa* as a tool for cell biology and genetics. The research presented was conducted primarily by an undergraduate student. Lissencephaly is a developmental brain disorder characterized by a smooth cerebral surface and abnormal neuronal migration. Classical lissencephaly results from defects in LIS1, which encodes a WD-repeat protein involved in cytoplasmic dynein regulation, mitosis and nuclear migration. Cytoplasmic dynein is a large, microtubule-associated motor complex that facilitates minus-end directed transport of various cargos. In a screen for mutants defective in hyphal growth, mutations in both LIS1 and cytoplasmic dynein were identified. Genetic evidence from several model organisms supports a model in which LIS1 interacts with the dynein heavy chain (DHC), possibly regulating its activity. In this study, we further examined the relationship between LIS1 and DHC by asking whether mutations in DHC could suppress various *lis1* alleles.

Analysis of small-group research projects in an introductory Ecology class

Paul Weihe, *Central College*

Ecology (BIO 229) at Central College is required of all Biology and Environmental Studies majors. For nine years, the class has included original, student-designed research projects conducted in small groups (typically 3-5

students). Projects are completed over about eight weeks, following several traditional, whole-class “canned” lab exercises designed to introduce students to important methods in aquatic and terrestrial ecology. A random sample of 55 projects included 41 (75 %) field-based and the remainder lab-based; popular topics included aquatic, landscape, and applied ecology (comprising 71 % of total). Students analyze results, write a research report, and present findings in a poster such as used at professional meetings. On a form seen only by the instructor, students peer-evaluate all the posters and describe

President's Letter

I will freely admit that I am humbled and slightly—or rather greatly—confused as to how I ended up as ACUBE President. As I reflect back on ACUBE role models I have had since joining a mere eight or nine years ago, I somehow feel like a greenhorn. How exactly did I end up with a title last held by the incumbent Honorary Life member, a title that indicates some role in leadership of teachers both famous and, I suspect in some cases, infamous? I began thinking of names...Stanley, Wilkinson, Davis, Martin, Klyczek, Jungck, Baird, Waterman, Mulkey, Hoagland, Brett, Gillie, etc., etc. who have had lasting impacts on my teaching and participation in ACUBE. What could Toepfer say that would extend the legacy of the deep history of ACUBE membership?

Then it occurred to me...I could use modern research techniques employed by my students and copy stuff straight from the Web. I spent an hour or two digging up columns from roughly the period of my own membership in ACUBE. I would encourage each of you to go back and read some of the previous Presidents` columns to see how the identity of ACUBE has changed at times and at times has remained the same. I have had some of the same thoughts over the past few years but I think it might be instructive to visit what those before me have said.

- “Increasing and expanding our membership will enrich the variety of ideas and perspectives shared, and I am confident that expansion can occur without a loss of the personal connections and other characteristics we have come to value throughout the history of this organization.”—Karen Klyczek, 1997
- “I think it is important that we maintain the communication and sense of connectedness among members that has

group dynamics. Peer review grades are higher than the instructor’s but the relative grades (ranking) are quite similar. Groups are self-selected and work harmoniously; only 2/ 90 groups were dissolved due to poor group dynamics. Outcomes have included several students presenting at professional meetings, or later completing advanced thesis projects. Student evaluations suggest strongly that such work is seen as challenging and valuable. Comments indicate promotion of skills in information literacy, hypothesis formulation, quantitative reasoning, problem-solving, and communication.

characterized ACUBE throughout its history.”—Charles J. Bicak, 2000

- “For the good of biology education, for the good of the Academy, and for the good of educators, we must get involved with this movement to establish national curricula, national standards, and, likely national testing programs.”—Buzz Hoagland, 2000
- “We are the ONLY group in the country that specializes exclusively in helping people teach biology in college more effectively. The need IS out there and in my opinion, we need to respond by increasing the accessibility and visibility of our organization to all biology educators.”—Tom Davis, 2001
- “I would like to suggest that we all need to think about ways to engage our students in the learning process, to impact on them more positively and make biology more relevant.” Malcolm P. Levin, 2003
- “The best way to get our colleagues interested in ACUBE is to have them directly experience what our organization has to offer. I always return home from the annual meeting rejuvenated, with at least one useful idea that I try to use in the classroom or laboratory right away.”—Lynn Gillie, 2003
- “In our 50th year as an organization, we should celebrate the successes of our organization and recognize that it is our members who move us forward. ... However, our organization has not been

active in other areas.”—Ethel Stanley, 2006

Clearly ACUBE provides a wonderful outlet for our members to share information and be inspired and challenged by what our colleagues are doing across the country. We have graduate students, postdocs, faculties in their first few years of their career, and faculties with decades-long careers behind them all working together to better ourselves, our students, our institutions, and our discipline. As Tom has pointed out, we are the only group that does what we do. Then why is it that the other issues crop up time and time again? Why is maintaining a stable membership often difficult? Why are most of us sharing our ideas only with fellow members? Why isn't the association more active in bringing about fundamental changes in how biology is taught at a local, regional, and yes even national level?

I obviously am not the first to ask those more difficult questions and I would not pretend to know the answers to those questions. Most of us undeniably find ACUBE to be personally valuable, but I sense that a few of you may have some unfulfilled desires regarding what ACUBE can provide to you and to teaching in biology. As we continue into our second 50 years, I think perhaps it is time for us to evaluate who we are and what we do. The Steering Committee is working on clarifying many lingering questions regarding the governance of the association. I expect that many of the things we do will continue in exactly the same fashion, but I am hopeful that we might discover some new ways of running things that will benefit all of us. I am also hopeful that we will create additional, less time

consuming means for members to contribute to governance in the future.

What neither I nor the Steering Committee can completely address are those other issues. The future direction and activities of ACUBE need to be identified and driven by the membership. We began the process of identifying those issues through the roundtable discussions at Loras and through the online survey that you should have received before this article reaches your hands. If you have not gotten around to that survey, please do. One of my goals is to develop some version of a strategic plan for ACUBE; we need ideas from each of you to develop a truly representative plan.

I know that there are all kinds of wonderful ideas out there; I've read about them and I've heard them from many of you. I am confident that ACUBE can grow and be a bigger force in the educational landscape. Our future really does depend on each of you, however, so let me close by throwing down the gauntlet. I challenge each one of you to identify a role that you can take in ACUBE, either in service or in taking the lead on an issue. Become passionate about that role, become vocal about that role, inspire others to join you. Change education in such a way that no one at the centennial meeting will remember when ACUBE was not the leader in college biology education. I can't do that but I know you can.

Conrad Toepfer
2008 ACUBE President
Brescia College
Owensboro, KY 42301

Letter to the Editor

A New Resource in Support of the Teaching and Learning of Evolution

The Association of College and University Biology Educators (ACUBE) took a commendably firm stand on the necessity of teaching evolution at its 44th Annual Meeting, writing: “Evolution is good science. Understanding evolution and the nature of science is essential to a well-educated society. Thus, ACUBE supports the teaching of evolution.”

As members of ACUBE well know, the teaching of evolution can be a difficult task given the fact that many evolutionary concepts may seem, at

least initially, counterintuitive to students, and the pedagogical obstacles have been exacerbated by social controversy rooted in religion. Despite the overwhelming acceptance of evolution among scientists and despite evolution's centrality to modern biology, virtually all national polls indicate approximately one-half of North Americans reject evolution, a testament to a great failure of science education.

In an effort to encourage dialogue around the teaching and learning of evolution, the Evolution Education Research Centre (EERC), which opened in 2001 as a collaboration between professors at McGill and Harvard Universities, has produced a special issue of the McGill Journal of Education (MJE) emphasizing three important themes: the need for improved teacher training in pedagogical techniques and content knowledge with regard to evolution, the need for effective classroom tools for teaching evolution, and the need to confront specific issues related to social controversies surrounding evolution education.

In this issue, Randy Moore discusses what college freshmen say they were taught about evolution in high school; Anila Asghar, Jason Wiles, and Brian Alters report on pre-service elementary school teachers' conceptions of evolution and evolution education; Robert Pennock introduces new technology for teaching evolution via experiments with "virtual organisms"; Judy Scotchmoor and Anastasia Thanukos discuss the development and evaluation of the "Understanding Evolution" website; Jeff Dodick describes a tool for teaching evolution

within the framework of geologic time; Eugenie Scott debunks the "teach the controversy" slogan. Also, Craig Nelson and Massimo Pigliucci offer their opinions on strategies to improve evolution education; and Glenn Branch and Andrew Petto each review a relevant book, Branch assessing Brian Alters' *Teaching Biological Evolution in Higher Education: Methodological, Religious, and Nonreligious Issues*, and Petto examining *The Plausibility of Life: Resolving Darwin's Dilemma* by Marc Kirschner & John Gerhardt.

MJE is a long-standing, internationally respected, and fully peer-reviewed publication. This special issue, only the second since the journal adopted an open-access format, is freely available at <http://mje.mcgill.ca/issue/view/54>. The EERC applauds ACUBE for their support of teaching evolution, and we hope that its members will find this issue of MJE to be a valuable resource.

Jason R. Wiles
Evolution Education Research Center
McGill University
Montreal, Canada

2006 Carlock Award Recipient

Editor's Note: Due to technical difficulties, one of last year's two Carlock recipients' letter did not get printed in the December 2006 *Bioscene*. Here it is in full, with our apologies.

The 50th annual meeting of ACUBE was an incredible event. I left Decatur, Illinois energized by the experience and grateful for being given the opportunity. The John Carlock Award was critical to my ability to attend.

The ways I personally benefited from attending this conference are numerous. Three main discoveries that will influence my teaching strategies are:

1. Prompting students' curiosity is key to learning.
2. Enabling and expecting students to hypothesize should begin early in their academic careers.
3. Exposing students to the integration and cooperation between the sciences is essential to solving realistic problems.

Each of these items is not achievable quickly and I plan to tackle them initially in the lab. For example, I

plan to transform a biochemical laboratory activity involving herbal oils (described in my poster at the meeting - *Snake Oil or Cure: An Investigation of How and Why It Works*) into a case study.

Furthermore, I am very appreciative for hearing experienced educators tell their tales of what works and what doesn't in the classroom. This meeting reinforced that coordinating curriculums amongst science educators greatly benefits students (as well as instructors). The exposure to the various methods of teaching science was invaluable.

Thanks to all the committee members and to the attendees for making this trip so worthwhile. I hope to see you next year at Loras College for the 51st ACUBE meeting.

Melanie Anastasio
Elmira College
Elmira, NY

2007 Carlock Award Recipient

Dear Members of ACUBE,

Thank you so much for helping support my trip to the 51st annual ACUBE meeting in Dubuque, Iowa by awarding me the John Carlock Award. Being able to attend these annual meetings has helped me find a welcoming teaching community that offers great ideas and support during my journey towards professorship. The annual ACUBE meetings provide a time for me to feel encouraged to share my experiences and build professional relationships with colleagues. This meeting, in particular, helped me learn what it is like to formally develop and present a teaching presentation based upon my colleagues' and my own experiences. I felt that by attending this meeting, I was given a safe environment to share my ideas and while learning from other professors how to improve upon my own teaching practices.

Being a third year doctoral candidate, I am entering the stage of my educational journey where I am trying to find institutions that would be

compatible with my teaching and research goals. ACUBE has allowed me to mingle with instructors at such institutions. I am looking forward to continuing learning about position openings at colleges and universities similar to those represented at this conference. This meeting also provided me with the opportunity to learn different ways I can become involved with ACUBE after I begin my career, opportunities such as recruiting fellow colleagues to become members, serve on the steering committee, and become involved with *Bioscene*. My hopes are that I will be able to soon find an institution I can call home and become a faculty supporter of this organization.

Sincerely,
Kristy Halverson
University of Missouri-Columbia
Columbia, MO

Guest Editorial

The Time is NOW for National Standards for a Biology Major

It's time to propose a set of college courses that every Biology major should take. We, members of ACUBE and our teaching colleagues, have been talking about "the list" for a long time but for some reason it never gets written down and discussed properly. I am talking about a BIOLOGY major here not an Environmental Science major or a track that specializes in Health Science. A true, classic Biology major should have a solid core of courses that should be delivered in the context of the scientific method. The process of learning science should be inquiry-based with practice in computer applications, data sampling, statistical analysis, scientific literature examination and process writing. The process of science is infused into a college Biology curriculum in many ways. But the basic concepts of Biology need to be delivered in a core set of courses so that institutions, businesses, and anyone else who hires or trains a Biology major after they graduate knows what can be expected. Also, with a defined list, textbook publishers can begin to reduce the size of the encyclopedias that our first year students carry around with them. My back aches as I watch students here trudge by with several Biology books in their bookbags that weigh 8 lbs each!

So here is "the list" of one semester courses (each with a lab) that I propose for a classic Biology major:

-Two semesters of Introductory Biology (to include basic concepts in evolution, ecology, genetics, cell biology, physiology, development and biodiversity)
Genetics , Plant Biology, Human or Animal Physiology, Cell/Molecular Biology, Evolutionary Ecology, -Senior Capstone Course (seminar, research, hot topics/current issues in Biology or a combination of these)
-Two semesters of General Chemistry, one semester of Organic Chemistry, one semester of General Physics and one semester of Precalculus Math.

Maybe there is a consensus already! Maybe there are major disagreements with this list. The content of each course is also dependent on the background training of who teaches it: photosynthesis in two lectures or 5 lectures! Ok, so I am biased. I teach at a small liberal arts college where we have a smaller classes and a little more time to mix the process of science with the content. But I think it is important to start the process of establishing a list of college courses that a Biology major needs to take. I think it is also important for the Association of College and University Biology Educators, ACUBE, to discuss this list, tear it down and build it back so that WE can publish these and have good reasons for the presence of each course in the list. So talk about it with your colleagues. Take 15 minutes to discuss "the list" at your next

department meeting. Let me know what you think. That's what editorials are supposed to be for – to get conversation and action started!

Tom Davis
Loras College
Dubuque, IA 52004

Book Review

Biology, eighth edition. E. P. Solomon, L. R. Berg, and D. W. Martin. Thomson Brooks/Cole, Belmont, California, U. S. A., 2008, ISBN 13:9780495107057.

After teaching several years of freshman biology and repeatedly being exasperated by text books that attempt to relate exceptionally detailed information to introductory concepts in general biology, the organization and delivery methods of the eighth edition of *Biology* by Solomon, Berg, and Martin is refreshing. The overall layout of the text bears a continuity that builds initially on basic concepts which are expounded upon in individual chapters, as well as throughout the text. The first chapter exemplifies this as a preview of themes cultivated in subsequent chapters. A progression from basic chemistry to the evolution of macromolecules leading to the organization of cells and metabolic processes, progresses into the continuity of life at molecular, cellular, and organismal levels. From this concepts are expanded to the population level with the continuity of life through evolution and the diversity of life, eventually leading to the interaction of living things with ecology.

Individual chapters begin with several key concepts forming the basis of subsequent sections within the chapter. Each section is preceded by learning objectives that help students relate fundamental elements and concepts to their application and significance. Fortification of the objectives is achieved with specific review questions at the end of each section, as well as at the end of the chapter. The latter is accomplished with learning objectives reiterated and numbered as they appear on corresponding pages in the chapter, with accompanying bullet points allowing students to assess their attainment of the objectives. The chapter's end also contains "Test Your Understanding" and "Critical Thinking" sections that go beyond paraphrasing-type questions that traditionally plagued texts. Rather than recognizing statements a student recently read as an assessment, these sections assess a student's actual knowledge achieved through attainment of the learning objectives, and their ability to interpret and apply it.

Pedagogical aids are highlighted within chapters as 'Key Point' figures, "Key Experiments",

and "Focus On" segments. In addition to figures that visualize specific textual points, "Key Point" figures provide concise summaries of overarching concepts or processes. These figures retain relevant elements and organize them in a coherent manner that is clear and concise, avoiding cluttering detail that frustrates or overwhelms novices to the field of biology. Historical research hallmarks identified in chapters as "Key Experiments" are presented in a scientific format, rather than in historical context. "Key Experiments" contain a Question, Hypothesis, Experiment, and Results and Conclusion, accompanied by figures outlining the research methodology. Hallmark experiments actively demonstrate the scientific method, are presented in a simplified manner, and engage the student in the scientific process. Larger, more encompassing issues are addressed in "Focus On" segments within chapter. These expand the sphere of the subject matter dealing with controversies, societal impacts, health issues, or environmental dilemmas. These additions offer different perspectives that reflect the dynamics of science, rather than treating science as a series of detailed dogmas that need to be memorized.

Overall, chapters are not over wrought with superfluous information, but are sufficiently detailed and organized to make biology less intimidating. This is accomplished through chapter consistency developing function from structure or framing shared phylogenetic characteristics that lead into diversity. Students are reminded of shared phylogenetic relationships with section-leading cladograms highlighting the class being considered in the text. Class sections retain consistency in their organization, especially with consideration to alternation in generations from protists through plants.

Similar techniques are used in handling metabolism and translation. Metabolic pathways are introduced using simplified outlines bearing key branching points, energy yields, and byproducts, and elaborated upon with the addition of molecular structures, enzymes, and reactions. Mitochondria and chloroplasts are clearly compartmentalized first with structure and further developed with associated processes. Complex pathways are not broken down, but built up in a manor that make glycolysis, Krebs' and Calvin cycles, and photosynthesis less daunting. Translation is divided into three segments with

corresponding “Key Point” figures addressing initiation, elongation cycle, and termination. Using several corresponding “Key Point” figures for processes such as translation rather than one, demonstrates to the student that processes typically are a series of reactions linked to a common result or product. Authors make an exceptional effort to make use of figures and tables as learning aids, rather than a synopsis of detailed text. Tables are brief, concise, and descriptive. This is especially true of summary tables, most notably in biologically important organic molecules, post-translational modifications, and of prokaryote groups.

The eighth edition of *Biology* by Solomon, Berg, and Martin contains elements manageable for a freshman science major, being less intimidating and more engaging, yet sufficient as a review text for an upper classman preparing for entry exams to a graduate or professional school. Use of pedagogical learning aids through defined learning objectives and assessment tools, figures and tables, and consistent delivery themes create an introductory active learning experience providing an academic foundation that goes beyond a comprehensive knowledge base.
Greg Grabowski, *University of Detroit-Mercy*
Detroit, MI

Employment

Positions Available

Assistant Professor

The Division of Mathematics and Natural Sciences at Brescia University invites applications for assistant professor in Biology to begin Fall 2008. Applicants must have a commitment to undergraduate education. Demonstrated ability or willingness to teach human anatomy and physiology, microbiology, immunology, and non-majors biology. Serve as pre-professional advisor and maintain relationships with local and regional professional schools. Applicants must have a terminal degree in Biology or related area. Brescia University is a Catholic liberal arts university whose mission emphasizes undergraduate education and service to the community as well as the University. Brescia attracts a diverse student population as well as faculty. For more information on the University, please go to www.brescia.edu. Interested candidates should submit: a letter of application, curriculum vitae, statement of teaching philosophy; a copy of graduate transcripts, and contact information or letters for at least three (3) professional references to Dr. Conrad Toepfer (conrad.toepfer@brescia.edu), Brescia University, 717 Frederica St, Owensboro, KY 42301. Review of applications will begin immediately and continue until the position is filled. EOE

Assistant Professor

Full-time, tenure-track position available in the Division of Molecular and Life Sciences. The successful candidate will teach: 1) Fall semester: Introductory Biology for majors with lab and a new upper level Molecular Biology Techniques course or

Molecular Genetics for majors; 2) Spring semester: Cell/Molecular Biology for majors with lab and a course in the General Education curriculum and/or intensive experiential January term. The Division has two fully equipped recombinant DNA laboratories including a new DNA sequencer. Requires a doctorate in cell or molecular biology; postdoctoral training and prior teaching experience are preferred; the successful candidate will demonstrate commitment to effective teaching of major and non major undergraduates. Ability to involve undergraduates in molecular biology research is highly desirable. Commensurate with qualifications, education and experience. Fringe benefits include: medical/dental/life/disability insurance, flexible spending plan, TIAA-CREF retirement plan, tuition remission program, family membership in Graber Sports Center/San Jose Pool, free admission to many college events and free off-street parking. Founded in 1839, Loras College is a Catholic, four-year, coeducational, liberal arts institution that includes pre-professional and career preparation programs. Loras College is dedicated to high academic, ethical and moral standards. The student body consists of approximately 1,600 students, over 90 percent of whom are full-time undergraduates. Candidates will be expected to support the mission of the College. Loras College's 60 acre campus is located on one of Dubuque's highest bluffs, overlooking the Mississippi River at the junction of the states of Iowa, Illinois, and Wisconsin, about 3 hours west of Chicago. Dubuque's population is approximately 60,000, and

its nineteenth century architecture is woven into limestone bluffs, providing a picturesque backdrop to the river landscape. Many residential and commercial areas have been designated as historical districts to preserve Dubuque's unique heritage. Its strong education base supports numerous cultural activities, and in addition, there are sporting events, shopping facilities, schools, and churches that are convenient to its residents. The climate has marked seasons with a comfortable summer, cool spring and fall, and a winter that encourages a variety of sports that have in recent years attracted a growing tourism industry. For

Assistant Professor

The Department of Biology at Rockhurst University invites applications for a full-time tenure track position at the Assistant Professor level. Candidates should be trained in biology, demonstrate excellence in teaching undergraduate level courses and be able to direct undergraduate student research. Teaching responsibilities include development and teaching of an upper division class in an area of expertise, and participation in General Biology courses including cell and molecular biology and organismal biology. A background in anatomy and physiology is preferred. Duties will also include service activities, and research and publication. Candidates must have a PhD or equivalent degree, teaching experience in the above courses preferred and a verifiable record of research in the biological sciences. Review of applications will begin on Jan.15, 2008. The position will remain open until filled.

Please forward a curriculum vitae, graduate transcript, and at least three letters of reference as well as statements of teaching philosophy and research interests to: Dr. Chad Scholes, Biology Department, Rockhurst University, 1100 Rockhurst Road, Kansas City, Missouri 64110, chad.scholes@rockhurst.edu. Rockhurst University is one of 28 Jesuit colleges and universities in the United States. Reflecting its Catholic and Jesuit roots, Rockhurst seeks to develop the very best in the minds and hearts of men and women who will be leaders in service. The University of 3000 Students is located in the cultural and artistic center of the racially and ethnically diverse Kansas City metropolitan area. For more information about Rockhurst, please visit our website at

more information contact David Speckhard, Chair of Search Committee, at david.speckhard@loras.edu. E-mail letter of application, curriculum vitae, graduate transcripts, evidence of teaching excellence, and three letters of recommendation to: hr@loras.edu. Attention: Chair, Biology Search Committee, c/o Department of HOD, Loras College, 1450 Alta Vista, Dubuque, IA 52004-0178. Do not send reference letters until requested. AA/EOE. Women and minorities encouraged to apply. Visit the Loras College website at <http://www.loras.edu>.

www.rockhurst.edu. Rockhurst is an Equal Opportunity Employer that values diversity.

Visiting Assistant Professor

The Department of Biology at Rockhurst University invites applications for a visiting assistant professor position for the spring of 2008. Candidates should be trained in biology and demonstrate excellence in teaching undergraduate level courses. Teaching responsibilities will comprise participation in majors and non-majors General Biology courses including cell and molecular biology and organismal biology. Candidates must have a PhD or equivalent degree (ABD is acceptable), teaching experience in the above courses (preferred) and a verifiable record of research in the biological sciences. Review of applications will begin on Dec. 1, 2007. The position will remain open until filled. Please forward a curriculum vitae, graduate transcript, and at least three letters of reference as well as statements of teaching philosophy and research interests to: Dr. Laura Salem, Biology Department, Rockhurst University, 1100 Rockhurst Road, Kansas City, Missouri 64110, laura.salem@rockhurst.edu. Rockhurst University is one of 28 Jesuit colleges and universities in the United States. Reflecting its Catholic and Jesuit roots, Rockhurst seeks to develop the very best in the minds and hearts of men and women who will be leaders in service. The University of 3000 Students is located in the cultural and artistic center of the racially and ethnically diverse Kansas City metropolitan area. For more information about Rockhurst, please visit our website at www.rockhurst.edu. Rockhurst is an Equal Opportunity Employer that values diversity.



52nd Annual Meeting

Hopkinsville Community College
Hopkinsville, Kentucky

Assessment in the Biology Classroom: How do we evaluate student learning?

Call for Abstracts

What is assessment? Why is assessment important? What strategies are you using to improve student learning in your courses or programs? How are you measuring student learning? We invite you to submit a paper, poster or workshop on assessment of student learning in the biology classroom and laboratory.

Of course, you are also welcome to present a paper on any topic related to college biology education. We also welcome hands-on laboratory demonstrations, round-table discussions, or other types of presentations. Please plan to share your experiences in the classroom and learn from others at the meeting.

Please send a 200-word abstract and the information below as e-mail attachments, by mail, or by fax by June 15, 2007 to **Laura Salem, Rockhurst University, 1100 Rockhurst Road, Kansas City, MO 64114**
Ph: 815-501-3239 Fax: 816-501-4802 Email: laura.salem@rockhurst.edu

Title: _____

Presentation type: 90-min workshop 45-min paper Poster Other (round table discussion, laboratory demonstration, etc...)

Equipment/facility needs: Overhead projector Wet lab space
 laptop projection system PC computer lab

Name of presenter(s): _____

Work address(es): _____

Presenter phone number: _____ e-mail: _____



Association of College and University Biology Educators

FIRST NAME: _____ INITIAL: _____ LAST NAME: _____ DATE: _____

TITLE: _____ DEPARTMENT: _____

INSTITUTION: _____

STREET ADDRESS: _____

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MAJOR INTERESTS

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

SUB DISCIPLINES: (Mark as many as apply)

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C. Physiology
D. Anatomy
E. History
F. Philosophy
G. Systematics
H. Molecular
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