

# Bioscene

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# Bioscene

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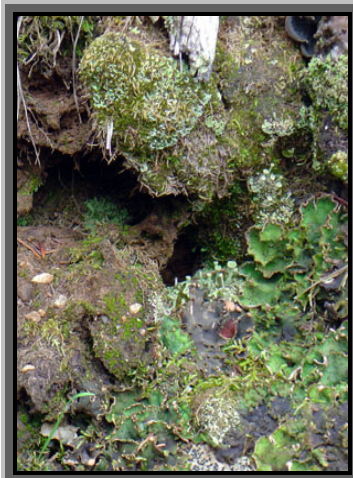
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Bioscene is published in March,  
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Please submit manuscripts by  
Feb. 1, 2004 for consideration in  
the next issue.



**Cover image:** Photograph of  
various liverwort species and  
moss. Courtesy of Ethel  
Stanley.

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# Bioscene: Journal of College Biology Teaching

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Suggestions for manuscripts include: announcements, web site and book reviews, labs/field studies that work, course development, technological advice, software reviews, curricular innovation, history of biology, letters to the editor, undergraduate research opportunities, professional school, funding sources, current issues, etc.

### Deadlines for Submissions

February 1, 2004 for the March 2004 Issue

April 1, 2004 for the May 2004 Issue

# Professionalizing College Science Teaching: Training a New Type of Science Academician

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**Abstract:** Traditional graduate programs in science are not always appropriate for training future faculty desiring jobs in non-research institutions where teaching undergraduates is the primary mission. What the author proposes is a specific biology Ph.D. program to train professional academics who will have a strong science background and systematic training to teach at the undergraduate level. The newly graduated would be intent on improving undergraduate curricula and programs through evaluation, assessment, and classroom level research

**Key words:** graduate students, college science teaching, innovative graduate program, restructuring graduate education,

## DEFINING THE PROBLEM

The traditional research training model has been retained over the years as adequate preparation for a college science teaching/research career. Two of the reasons for this are the lack of research on undergraduate learning outcomes in higher education and lack of Ph.D. program outcomes assessment. A different concept in training doctoral students to be professional educators and pedagogical researchers in college science teaching is one that needs to be considered (Richlin, 1995; Tice, 1997; Golde, 1999; Nyquist, *et al.*, 1999; Preparing Future Faculty listserv; Re-Envisioning the PhD Website, 1999; Nerad and Cherny, 2000; Murray, 2000; The Responsive PhD, 1001). The idea is not new, but in view of recent recommendations for improving graduate education, we should begin to rethink how we are preparing future academicians. Borrowing from the words of Dr. Jerry Gaff, vice president for education and institutional renewal at the Association of American Colleges and Universities (AAC&U) and director of the Preparing Future Faculty program, "It is timely to develop doctoral programs that address the mismatch with hiring institutions and that address changing responsibilities of faculty members" (Gaff, *et al.*, 2000). This call is a stark admission that the time is right for a change in graduate training. We need academicians who have been trained for discipline-based, college science teaching and who are qualified to produce new scholarship on learning in the science discipline.

Accepting new ideas for preparing doctoral students will require a paradigm shift from the German university training model, which has been the standard for many years. It can be argued that the traditional Ph.D. training program creates a mismatch between

training and actual work experience of the academic. Ph.D. graduates in science earn their degrees in Research I universities and then assume faculty positions in liberal arts colleges and comprehensive universities. Only about 10% of newly graduated Ph.D.'s will actually find themselves in an academic setting similar to the one in which they were trained (Finkelstein, 1999). These newly graduated Ph.D.s do not have substantive experiences in teaching practices, knowledge of research on learning, nor familiarity with institutions with missions different than Research I universities. Will these new faculty members have the skills to cope with the plethora of demands in academia today? Some of the preferred experiences listed in the job announcements include recognizing and honoring different learning styles, dealing with the handicapped and disabled students, understanding diversity issues of gender, race, and religion, coping with educational technology, and participating in strong academic advising. Many agree that the traditional doctorate programs do not give sufficient or any training in these areas (Whitt, 1991; Boice, 1992; Sorcinelli, 1992; Olsen, 1993; Rice, 1996; Tierney and Bensimon, 1996; Tierney, 1997; Olsen and Crawford, 1998; Golde, 1999).

The important question that needs to be asked is why do we not professionalize teaching in doctoral programs as we have research training? After all, as faculty, we do both. Most science departments are limited to offering degrees within highly specialized disciplines whose purpose is to train research scientists. Since these specialized research degrees may not always be most suitable for a graduate who desires to work in non-research institutions (AAAS, 1990; Sigma Xi, 1990; NSF, 1997), would it not be far-sighted to prepare at least some science faculty for these

institutions in which their professional expertise would be required for undergraduate science teaching and service to the institution?

This paper discusses a new type of doctoral program that addresses the above concerns. By offering broad content training in biological subdisciplines, plus training in educational research, the Ph.D. Biology--Science Education program attracts students who desire terminal degrees but will seek employment in non-research undergraduate institutions. This paper serves as a potential model for any science discipline that wishes to broaden its existing doctoral programs to include more than one type of graduate training.

### WHAT NATIONAL REPORTS TELLS US

Major constituencies of doctoral education have called for programs of study that support a more inclusive definition of academic work (Finkelstein, 1999). The National Academy of Science, National Academy of Engineering, and National Institute of Medicine jointly reported that a new Ph.D. degree program is needed--one that develops a full-range of

career skills for the program participant. The American Association of Universities, which produces over one-half of all doctoral degrees, reported in 1998 that graduate curriculum needs to be redesigned to address all student career interests (Gaff, *et al.*, 2000).

The report entitled, *Building the Faculty We Need*, (Gaff, *et al.*, 2000) summarized findings from several important national research studies on doctoral education. The surveys concluded that nearly one-third (30%) of graduate students were dissatisfied with the way their doctoral programs were organized. Doctoral students reported that they only felt prepared to do research whereas many of them were interested in a wide range of faculty roles. 25% of the doctoral students reported that they would like to have had courses in other departments (Nerad and Cherny, 2000). All findings of the national graduate student surveys can be grouped into global recommendations that provide information to justify the worthiness and to define the objectives of the new Ph.D. Biology--Science Education program discussed herein. These recommendations are enumerated in Table 1.

*Table 1. Summary of Recommendations Based on Graduate Student Studies*

Greater breadth of knowledge through interdisciplinary work should be emphasized during graduate training,
Greater emphasis should be placed on teaching and teacher training during graduate school,
Opportunities to work for potential employers should be a part of the training program,
Socialization of doctoral students to life in the academy needs to be addressed, and
Emphasis needs to be placed on developing various skills necessary for success in the academic profession in its entirety not exclusively on research.

### WHAT THE JOB MARKET TELLS US

Since the present academic job market is slow, the time could actually be favorable for the creation of new doctoral training programs. The reason is that faculty searches are attracting large numbers of applicants, and institutions are being more selective for applicants who can offer some evidence of teaching efficacy. Many job announcements require that the applicant teach in two or more subdisciplines of biology and have skills with distance or on-line education.

According to reports (Finkelstein, *et al.*, 1998; Finkelstein, 1999), the academic work force (n=1,033,966) is in a state of great change. The number of part-time faculty is increasing, while a number of faculty members are non-teaching professionals such as librarians and counselors. The data demonstrate that only one-half of the total academic work force is full-time teaching faculty (n=514,976). This fact does not discourage but rather encourages the timeliness of a new type of doctoral preparation program. The reason is because as many as 40% of the full-time teaching faculty will be replaced in the next decade. This means

that the number of new doctoral graduates entering academe could be as high as 250,000 during the next 10 years. Therefore, the hiring potential for the new graduate will only be increased. New training standards in doctoral education could supply the demands for excellent teachers, *i.e.*, faculty who can perform assessment of their own teaching and curricula, conduct classroom research, produce research on pedagogy, and participate sooner in service to the institution.

### ABOUT A NEW PH.D. PROGRAM IN BIOLOGY Program Description and Objectives

The Ph.D. in Biology--Science Education is a doctoral degree that is not less rigorous than a traditional Ph.D., but is an alternative training program that emphasizes teaching effectiveness in science through educational research and breadth of disciplinary content. The graduate students will become content experts in biology as well as experts in educational theory, pedagogy, and research. The new program was designed in collaboration with the Department of Curriculum and Instruction in order to

provide greater depth and focus on research techniques unique to education. Since education research is based on social science methodologies, the biology graduate student must learn a new set of research skills that are often different than those used in biological science.

In addition, students of this program will have "practiced" and assessed their academic performance through internship components detailed below. The teaching internship potentially familiarizes the students with different types of higher education institutions. Many institutions require that new faculty participate in community outreach, faculty governance, search committees, and/or student advising even in the first year of employment. Not having had practice with service requirements adds an extra burden to new faculty who are just beginning to put their first courses together and starting research/scholarship programs. The service internship gives graduates experience with the nonacademic portions of their job.

The intent of the new doctoral program is not new. The Ph.D. Biology-Science Education is similar

to the Doctorate of Arts (D.A.) degree implemented in 1967 with the support of the Carnegie Foundation. The D.A. training program was adopted at ten major universities for preparing faculty as postsecondary educators in several fields, mathematics and sciences included. However, the D.A. programs in biology have dwindled to two, one at Idaho State University and the other at Northern Colorado State University.

The program designed for the biology department at the University of Arkansas has substantive differences than the D.A., mostly in the approach to the program evaluation through assessment. (See the section on assessment of the program below.) The following summarizes the objectives outlined for the new graduate program. These objectives were based on a literature review of teaching future undergraduate science faculty (Smith, 1974; Stockdale and Wolchok, 1974; Allen, 1976; Krockover, 1980; Monaghan, 1989; Cruikshank, 1990; Lawrenz, *et al.*, 1992; Lumsden, 1993; Druger, 1997).

**Table 2.** *Expectations of graduates of the new program.*

be able to synthesize a broad range of concepts in biology and communicate these concepts effectively both orally and in writing,
have produced significant, original contributions to the field of science teaching/learning through rigorous evaluation/assessment,
possess skills and attitudes to teach undergraduate biology in a variety of higher education institutions with missions different than research universities, and
obtain knowledge and skills involved in the academic culture by participating in academic service components at the institutional, national, and community levels.

### **How Degree Program Objectives Are Achieved**

The major difference between the traditional Ph.D. training model and the new program is the deliberate teacher preparation with objectives more explicitly set forth. Through formalized internships, education-focused dissertation, required courses in education and breadth of content expertise, instead of "less," the student gets "more" training without the addition of extra years to the terminal degree program. Since the learning objectives are stated, the program must and should be assessed for efficacy of preparation.

The trainees are derived from applicants who have already completed a Ph.D. or M.S. research thesis in the sciences. This assures that the graduates of the program will understand scientific process. The course work will be determined in part by a diagnostic examination that assesses content knowledge in a core of biology content in addition to selected topics from educational theory. Diagnostic examinations may serve as pre-tests in assessing outcomes of the program. The candidacy exam and final written examination will serve as post-tests. Upon completion

of the dissertation, the student will give a public seminar.

The teaching internship is a supervised pedagogical activity that provides for the development of skills in traditional and/or innovative teaching methods. Under the supervision of an experienced faculty member, the intern will develop instructions for an undergraduate course at the home institution or other college. The service internship is a supervised activity that provides for socialization of graduate students into the role as faculty. This experience will allow students to explore roles in committee work, administration, and/or service to the community at large (for example, outreach to K-12 teachers). A learning agreement or contract will be drawn up between the intern and supervisor that specify the tasks to be performed. Students will be expected to document the outcomes of the two internships. These documents will be used for program assessment.

The research component will be oriented toward undergraduate science education. All students must complete an original research-based dissertation in science teaching/learning, or design an undergraduate biology curriculum or manufacture some artifact to be

used in undergraduate instruction that represents a significant and original contribution to the field of science teaching/learning.

**Assessment of the Program**

The new program will be formally evaluated with the help of the Office of Research in Measurement in Education in the College of Education and Health Professions. One major goal of the evaluative component intends to assess the effectiveness of the program in producing graduates who are successful in the areas of educational research and biological science instruction at the college level. Specifically, assessment of the program effectiveness will be based on quantitative objective measures of student technical skills, participation in faculty service and administrative committees, and production of research, in addition to perception assessments of student abilities by faculty and employers. Additional information will be obtained for addressing student perceptions of strengths and weaknesses of the program, including evaluations of course work and

training components, for the improvement of the delivery of education within the new program. Longitudinal databases will be created for the purposes of assessing change across time for cohort groups within programs, in addition to allowing for comparisons of traditional and non-traditional program participants.

The evaluation plan is divided into four phases. The first two phases provide for the creation of a longitudinal student database for evaluating program participants and non-participants on the selection of cognitive, academic, and interpersonal characteristics that are hypothesized to be related to the unique training provided by the new program. The third phase provides for the creation of a cross-sectional database that will provide a program assessment component as assessed by potential employers. The fourth phase is the creation of a longitudinal database for assessing program participants and non-participants' early career performance and long-term success as perceived by their employers and the graduates themselves. A summary of the evaluation plan is given in Table 3.

*Table 3. Summary of Objectives and Assessment Methods for the Program*

<b>GOALS</b>	<b>OUTCOME EVALUATION</b>
Synthesis of broad range of content concepts which can be effectively communicated	1. Comparison of written and oral examinations, project proposals, and dissertations by biology faculty member for both traditional and new program cohorts
Educational research/original and significant contribution to the field	2. Faculty survey
Pedagogical skills in undergraduate teaching	3. Course work comparisons (performance and breadth of content)
Knowledge of academic culture	Number and types of publications, presentations, grants, and scholarly activities from both cohorts
	1. Teaching evaluations
	2. Teaching effectiveness/observational measures
	3. Student surveys of perceived proficiency of educational delivery
	4. Reported use of research in the classroom for guidance in pedagogical practices
	5. Internship reports
	1. Level and types of participation in institutional, national, and community service activities
	2. Service internship reports

**SUMMARY**

There have been few alternatives to the traditional research training model for preparing future faculty. Two reasons for this are the lack of research on undergraduate student learning outcomes in higher education and lack of Ph.D. program outcomes assessment. Because well-established institutional habits are difficult to change, it will not be easy to convince colleagues that examining traditional practices is worthwhile. After all, the system seems to work. Hopefully, we can begin to break away from more narrow models of graduate training, which are

reported to be inadequate in the complex academic milieu today. With more explicitly designed doctoral programs which include a number of different experiences, we can begin to prepare future faculty with skills and experience necessary for meeting challenges of the entire academic profession. The key to a successful program is the “design,” however, with program objectives stated as well as methods of assessment planned before the inception of the program. Perhaps the data will suggest that there is a better way of preparing college science teachers.

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## Call For Resolutions

The Steering Committee of ACUBE requests that the membership submit resolutions for consideration at the 2004 Annual meeting to the Chair of the Resolutions Committee. Submit proposed resolutions to:

Brenda Moore, Truman State University, Division of Science, MG3062, Kirksville, MO 63501,  
bmoore@truman.edu Phone (660)785-7340

## Call for Nominations

### ***Bioscene* Editorial Board**

We are soliciting nominations for four (4) *Bioscene* Editorial Board positions (term through-2007). Board members provide input concerning the publication of *Bioscene* to the Editors. Board members provide rapid review of manuscripts as requested. Board members are expected to assist in the solicitation of manuscripts and cover art for *Bioscene*. Board members are expected to provide assistance in proofing the final copy of *Bioscene* prior to publication. If you are interested in serving a three-year term on the Editorial Board, please e-mail the editors

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# A Simplified Bacterial Growth Curve Using Bioluminescence

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**Abstract:** We describe the design, classroom testing and teaching assessment of a simplified bacterial growth curve laboratory exercise. This exercise uses a bioluminescent derivative of the common environmental bacterium *Serratia marcescens* and the luminescence substrate *n*-decanal. Bacteria were grown at room temperature to 30°C and at low cell density. Culture aliquots were removed at regular intervals and assayed with the aldehyde *n*-decanal in an inexpensive analog luminometer. Because luminescence under balanced growth conditions is directly proportional to cell number, increases in cell number were followed luminometrically. Doubling time, the time required for one complete multiplication cycle, was calculated from plots of log luminescence vs. time. This approach to the growth curve exercise is more rapid and less expensive than traditional methods and has produced excellent results with an undergraduate microbiology laboratory class. Because the lab setup was minimal, the students were able to introduce and evaluate their own experimental variables in the same laboratory period, an option, which is much more cumbersome with other methods. The bioluminescence method can also accommodate separate cultures for each student; modern spectrophotometric methods are often limited by shaker availability for adequate aeration of higher-density cultures.

**Keywords:** bacterial growth curve, bioluminescence, *Serratia marcescens*, laboratory exercise

## INTRODUCTION

Bacterial growth differs in several important respects from growth of multicellular organisms. As single-celled organisms, "growth" defined as size increase is actually limited in bacteria. Size increase is almost exclusively associated with a population transition from a non-multiplying to multiplying state under favorable environmental conditions. Therefore, "growth" in the prokaryotic realm is best understood as an increase in population number.

The bacterial growth curve is a classic laboratory illustration of exponential population increase. Bacterial growth under ideal conditions of constant temperature, adequate oxygen, and nutrient excess may be modeled simply as:

$$\text{initial cell number} \cdot 2^n = \text{final cell number}$$

where  $n$  = number of elapsed cell doubling times. The number of cell doubling times during balanced growth

depends only on elapsed time  $t$ , since the time needed for one multiplication event  $d$  is constant. We can write:

$$n = t/d$$

With  $I$  equaling the initial cell number and  $F$  equaling the final cell number, we have:

$$I \cdot 2^{t/d} = F \quad (\text{Equation 1})$$

Equation 1 may be solved for  $t$  by taking the logarithm of both sides to produce:

$$\log F - \log I = ((\log 2)/d) \cdot t \quad (\text{Equation 2})$$

Equation 2 suggests that plots of log (cell number) vs. time will produce straight lines because the slope,  $(0.301/d)$ , is constant when nutrients and oxygen are not limiting. The time required for one doubling under exponential growth conditions may therefore be

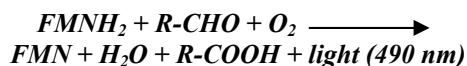
calculated by dividing the slope of a plot of log (cell number) vs. time into 0.301. Slope may be approximated by hand or calculated by linear regression using statistical software packages.

Traditional classroom approaches to the bacterial growth curve are of either the plating or turbidity measurement type (6, 8). The plating approach involves sampling an exponentially growing culture at regular intervals, diluting the sample, and spread or pour plating for the enumeration of colony forming units. This requires the preparation of large amounts of bacterial medium and is generally performed once as a demonstration for an entire class. Data are not available until 18-24 hours after plating, and coefficients of variation for plate count data are in the range of 20-23% (P. L. Haddix, unpublished). The turbidity measurement approach is more rapid and accurate but requires more sophisticated instrumentation, including a spectrophotometer and a mechanical shaker for aeration of high density cultures. In our experience this approach has been limited by the small number of separate culture flasks, which can fit into a shaker, requiring students to work in pairs or groups.

This paper describes a simple bacterial growth curve exercise, which measures cell yield indirectly as light emitted from a strain of *S. marcescens*. Bacteria were diluted to low cell density and incubated at room temperature to 30°C. Under these conditions bacteria were found to emit exponentially increasing luminescence in proportion to exponentially increasing cell number. Luminescence measurements, using inexpensive instrumentation and an artificial luminescence aldehyde substrate, were found to accurately predict doubling time. The technical simplicity of this method facilitates student comprehension and encourages student-designed research.

## MATERIALS AND METHODS

*S. marcescens* MTN5-7 was constructed as described elsewhere (4). This organism is resistant to kanamycin at 25 µg/mL and expresses the *luxCDABE* operon under transcriptional control of an unidentified cellular operon. Light is emitted at very low levels during normal growth according to the following reaction (5, 7):



Light emission is greatly increased by the addition of luciferase substrate directly to cell

suspensions. *S. marcescens* MTN5-7 luminescence is not visually detectable, even in the presence of added substrate. This strain will be supplied by Dr. Pryce L. "Pete" Haddix to legitimate teaching laboratories upon request.

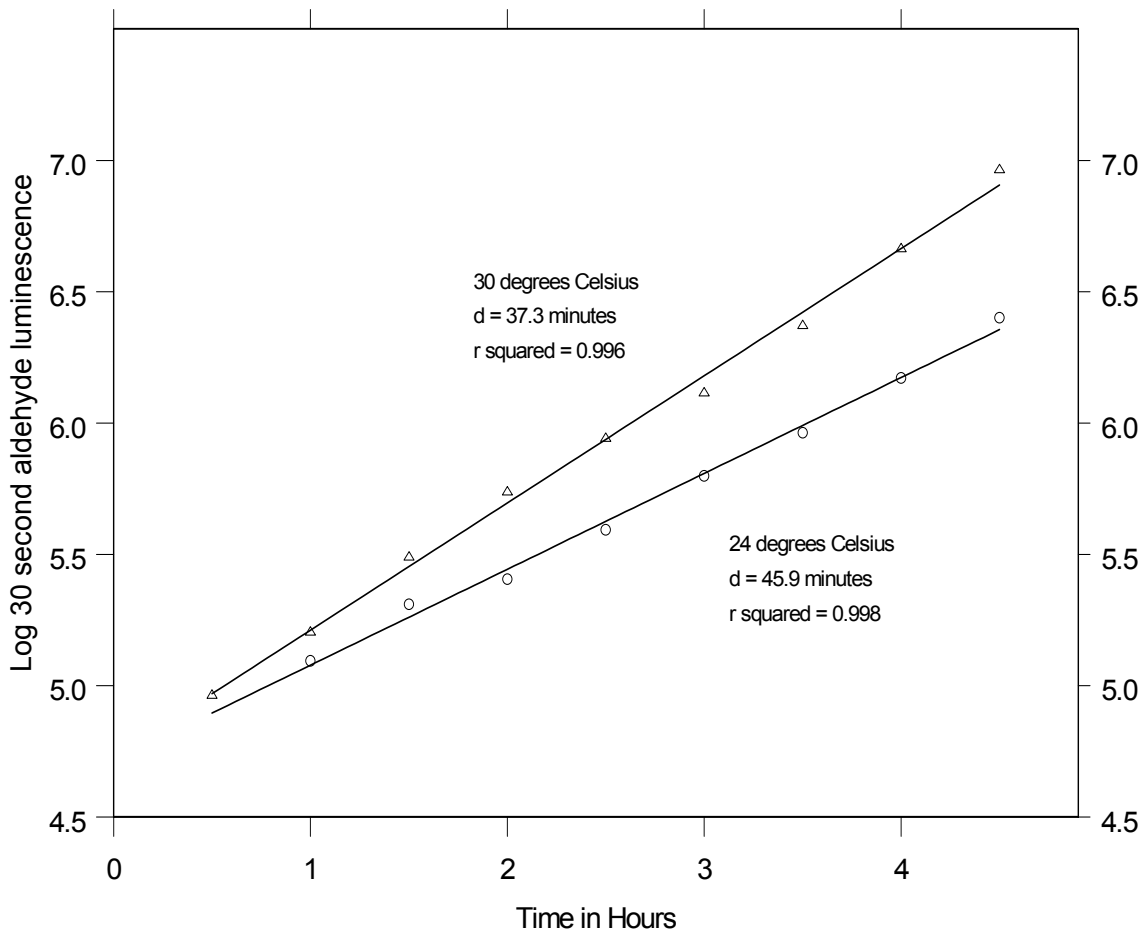
Bacterial strains were stored at -20°C in 40% glycerol and routinely propagated in tryptic soy broth (TSB) or on TSB + 1.5% agar (TSA; Difco, Detroit, MI). Cultures of *S. marcescens* MTN5-7 for growth curve exercises consisted of 10-20 mL TSB at about 10<sup>6</sup> cells/mL initial density. These cultures were made two ways: either by 1:1000 dilution of an overnight aerated culture at approximately 6 x 10<sup>9</sup> cells/mL or by suspension of agar growth in TSB to visible turbidity and dilution to slight or just undetectable turbidity.

The luminescence substrate *n*-decanal was purchased from Sigma (St. Louis, MO; cat. # D-7384). Aldehyde substrate was made to 2% (v/v) in denatured ethanol. 10 µL of this stock was mixed with a 1 mL culture aliquot in a 12 x 75 mm transparent polystyrene culture tube (VWR Scientific; cat. # 60818-292) for luminescence assay. All solutions of *n*-decanal should be handled in a fume hood or in a well-ventilated room with a fan. Luminescence was detected and quantified with an UltraSource TL® analog luminometer (Peachtree City, GA). Analog luminometers, as distinguished from digital (photon-counting) luminometers, convert light to an electric current (5). Data are displayed as relative light units or RLU. Measurement sensitivity may be increased by extending the sample read time, but the read time must be consistent for all assays of a given curve. Analog luminometers are available for about two thousand dollars. All luminescence measurements are reported here as cumulative values over 30 second read times. Media-only luminescence blanks for each measurement showed less than 1000 RLU; nonspecific background was considered negligible.

Doubling times were calculated as described in the introduction with the substitution of aldehyde luminescence values for the quantities *I* and *F* in Equation 2. Linear regression analysis was performed with Axum 6.0® (MathSoft, Inc.) or Excel® (Microsoft, Inc.) software.

## RESULTS

Bacterial luminescence growth curves generated by the authors are presented in Figure 1. Both room temperature (24°C) and 30°C curves show excellent linearity. The doubling time calculated for the 30°C luminescence curve agrees well with the same parameter determined by the spectrophotometric method (39.0 minutes; reference 4).



**Figure 1.** Luminescence growth curves of *S. marcescens* MTN5-7 in TSB at two temperatures. Data were compiled by the authors.

The applicability of this laboratory exercise to the classroom was tested with a microbiology class at Harris-Stowe State College in St. Louis, Missouri during the Fall 2002 semester. These students had completed at least one semester of introductory biology and various other advanced biology classes. Student data, presented in Table 1, show usable but relatively poor results for the first attempt on November 20. Subsequent growth curves performed on November 27 show much better data, with  $r^2$  values greater than 0.97. November 27 data were determined from cultures which had been serially diluted from an overnight stationary phase pregrowth. Table 1 data also show some effect of cell density on doubling time, particularly at lower temperatures.

The laboratory instructor was easily able to use a single luminometer and assign all four students one or more separate cultures during the laboratory period. Regimens of 20-30 minute culture sampling time points were staggered among the students at five minute intervals or less. The instructor found that student ability to grasp the exponential growth concept was obtained within one lab period and verified by the experiments of the second period. The students took great care in the precision of the techniques and were excited to be doing original experiments. Students also suggested and implemented further experimentation to extend their results, including the addition of potentially toxic chemicals such as household disinfectants.

TABLE 1. Summary of Data for Student Growth Curves

Date	Overnight Culture Serial Tenfold Dilution	Incubation Temperature, °C	Number of Data Points, $n$	$r^2$	Doubling Time, $d$ , min.
11-20-02	ND	ca. 21	4	0.858	63.1
11-20-02	ND	30	5	0.938	46.2
11-27-02	-1	25	7	0.997	55.1
11-27-02	-2	25	9	0.994	41.8
11-27-02	-3	25	7	0.973	47.6
11-27-02	-4	25	5	0.971	83.7
11-27-02	-1	30	3	0.999	37.5
11-27-02	-2	30	6	0.991	37.0
11-27-02	-3	30	8	0.989	34.2
11-27-02	-4	30	5	0.991	33.8

ND, not done

## DISCUSSION

The direct relationship between cellular luminescence and cell number during logarithmic growth has allowed the use of luminescence as a reporter of cell physiology for environmental microbiology applications (1, 2, 3, 9, 10). Here we apply the same principles to the measurement of bacterial population doubling time for an introductory microbiology laboratory exercise.

Table 1 shows relatively poor student results for their first attempt on November 20; this was likely due to unfamiliarity with the procedure. We have noticed that extremely low density cultures of *S. marcescens* tend to lag for longer periods of time before entry into exponential phase (unpublished observations). Therefore, we recommend beginning with barely visible turbidity and incubating the culture tubes without shaking at 23-25°C for the bioluminescence growth curve exercise.

The ability to obtain results, analyze them, and discuss their significance in one lab period is usually not possible with bacterial growth experiments. When it does, the scientific and pedagogical

importance is quite easy to see, and student understanding of the significance of the results is very rewarding. Students in our classroom became practicing scientists by extending the growth curve technique to other areas. One area of student investigation was the effect of environmental toxins on biological systems. Because reduced flavin mononucleotide is used to generate light, toxic chemicals can be detected by their detrimental effects on luminescence measurement. Preliminary work in this area led to enthusiastic discussion and student participation in extra experiments outside of regularly-scheduled class time.

This report describes a simple method for demonstrating bacterial exponential growth and the calculation of doubling time from bioluminescence data. This method is rapid, accurate and requires a minimal investment in instrumentation. Further, this exercise has been shown effective in undergraduate laboratory sessions. Student results were clear-cut, well-understood, and useful as a starting point for design and performance of other experiments using the same basic techniques.

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# Effect of Essay-Style Lecture Quizzes on Student Performance on Anatomy and Physiology Exams

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**Abstract:** A challenge facing many instructors of large (greater than 100 students) lecture sections is to encourage students to review course material on a regular basis. This 9-year study examined the impact of essay-style lecture quizzes on student performance in a two-semester anatomy and physiology course sequence. Results suggest quizzes improved student performance on regular hourly exams during the first semester of the course but not during the second semester of the course. In addition, lecture quizzes did significantly improve student performance on the Human Anatomy and Physiology Society (HAPS) comprehensive final exam. The "average" student, in years when quizzes were not given, ranked in the 56th percentile nationally; whereas, the "average" student, in years when quizzes were given, ranked in the 72nd percentile nationally on the HAPS exam. While very time consuming to grade and process, quizzes allowed the instructor to get to know more about the ability of individual students in the class, enabling the instructor to be able to write more valid letters of recommendation. In addition, all students received regular individual feedback from the instructor, making them feel less distanced from the instructor.

**Key words:** anatomy and physiology, quizzes, standardized exam, student performance

## INTRODUCTION

One challenge facing many university professors is encouraging students to study on a regular basis rather than cram for lecture exams. This is especially true in large lecture classes where students may feel disconnected from the professor and where regular attendance and class participation are not included in the students' final grades. Inclusion of a series of lecture quizzes, especially if the quizzes are a significant part of the students' final grade in the class, may be a method of encouraging students to study regularly.

Quizzes have been shown to have a positive affect on attendance, reading, and student confidence, and may reduce student anxiety (Ehrlich, 1995; Ruscio, 2001; Sporer, 2001; Wilder et al., 2001). In addition, the feedback from regular quizzes allows students to identify areas on which to focus for exams (Sporer, 2001). Quizzes do not, however, appear to improve reading for comprehension (Johannessen, 1995) or on student performance on general biology exams (Haberyan, 2003).

The primary class for which the author has been responsible for the past 10 years is a sophomore-level, two-semester anatomy and physiology (A&P) sequence (A&P I and A&P II). This class is not part of our university's general studies curriculum and is specifically designed to meet the needs of students pursuing a wide variety of careers in the health sciences, including chiropractic medicine, dentistry, dental hygiene, medical technology, nursing, occupational therapy, optometry, osteopathy, pharmacy, physical therapy, physician, physician assistant, podiatry, and radiography. Therefore, students enrolled in this class should be self-motivated to do well since they must earn a minimum grade of "C" to be eligible to apply for professional school. The course is taught according to the guidelines and expectations established by the Human Anatomy and Physiology Society (HAPS). To be in accordance with these guidelines, a prerequisite of a least one semester of college-level chemistry was placed on A&P I in the fall of 1999. Since the spring of 1995 a comprehensive final exam written by this society has been

administered. When it is announced at the beginning of the first semester that the final exam at the conclusion of the following semester will be comprehensive over both semesters, many students are immediately overwhelmed. To break the material down into smaller units for study and review, as well as to encourage students in the class to keep up with the material, a series of essay-style lecture quizzes was initiated in the fall of 1997.

The purpose of this study is to examine the effectiveness of essay-style lecture quizzes on student performance in a college-level pre-professional anatomy and physiology class. The hypothesis was that regular quizzes would improve student performance on both regular hourly exams as well as on the HAPS comprehensive final exam.

## METHODS

A&P I was offered fall semester only; whereas, A&P II was offered spring semester only. Successful completion of A&P I was a required prerequisite for enrollment in A&P II. The lecture portion of the course was taught in 50-minute morning sessions on Mondays, Wednesdays, and Fridays. Each semester there were four, 50-minute exams composed of multiple-choice (80%) and fill-in-the-blank (20%) questions. Each exam was worth 10% of the final grade in the course. At the conclusion of the second semester, students took the HAPS comprehensive exam. This exam consisted of 100 multiple-choice questions and was worth 20% of the final grade in the course. The remainder of the final grade came from the laboratory portion of the course.

Starting in the fall of 1998, a series of short-answer, essay-style lecture quizzes was added. Each semester a total of seven 20-point quizzes was given, and the total of the best five grades on the quizzes was included in the student's final grade. Students were not permitted to make-up a missed lecture quiz since the lowest two grades were dropped. Exceptions were made for students with excessive absences due to extenuating personal circumstances or travel with athletic teams. The sum total of the lecture quiz grades was equal to that of a regular lecture exam. The dates of all quizzes were scheduled at the beginning of the semester and the first two quizzes were prior to the first lecture exam. The quizzes were given at the end of the lecture period and students had 20 minutes to complete each quiz.

The text used for this class has always been the most current edition of *Hole's Human Anatomy & Physiology* by Shier, Butler, and Lewis (McGraw-Hill Publishers). The lecture and laboratory sequence has been consistent over the years, as has the material covered on each lecture test. In addition, students had an outline of the lecture notes, which they purchased from the university's bookstore. The only difference over the years of this study was the method of delivery.

In the 2002-2003 academic year the lectures were presented in Powerpoint® format, whereas in all previous years an overhead projector and transparencies had been used.

Statistical analysis was performed on all raw student grades with significance ascribed for  $p < 0.05$ .

## RESULTS

The number of students completing both semesters of A&P ranged from 94 in the 2000-2001 academic year to 158 in the 1995-1996 academic year (Table 1). The mean composite ACT scores ranged from  $22.0 \pm 3.6$  in the 1994-1995 academic year to  $23.6 \pm 3.4$  in the 1999-2000 academic year (Table 1). The mean scores for each exam, plus the mean score for lecture quizzes when implemented, are presented in Table 2. The distribution of data from A&P I was normal and a t-test was performed on the overall exam average. The overall mean exam score for all lecture exams given in A&P I during years when quizzes were not given was  $76.4 \pm 10.6$ , which was significantly less than the overall mean exam score ( $78.0 \pm 11.0$ ) for all lecture exams during years when quizzes were given. The distribution of data from A&P II was not normal. The Mann-Whitney rank sum test demonstrated that the overall median exam score during years when quizzes were not given (75.5) was not significantly different than the overall median exam score during years in which quizzes were given (75.4). The mean scores for the HAPS comprehensive exam are presented in table 3. The distribution of data for the HAPS comprehensive exam was not normal. A Kruskal-Wallis one-way analysis of variance on ranks showed that the median score on the HAPS test during years when quizzes were not given (53.0) was significantly lower than the median score during years when quizzes were given (58.0).

## DISCUSSION

Lecture quizzes had a significant impact on student performance on hourly exams in A&P I but not in A&P II. The addition of quizzes may have helped the students better understand the expectations of the instructor, which is why the quizzes had an impact on scores during the first semester of the course. By the second semester of the course, however, the students were more familiar with the instructor's expectations. Consequently, the lecture quizzes did not significantly affect performance on A&P II exams. The addition of lecture quizzes did significantly improve student performance on the HAPS comprehensive exam. A national percentile ranking, representing the percentage of individuals who scored below a particular raw score, is calculated for the HAPS exam. In years when lecture quizzes were not given, the "average" student in the class ranked in the 56th percentile nationally; whereas, in years when lecture quizzes were given, the "average" student ranked in the 72nd percentile

nationally. Students were not allowed to keep lecture exams for future study or review (exams were available for review in my office), but all students were allowed to keep their quizzes, and blank copies of the quizzes were given to students who missed quizzes. Therefore, reviewing the lecture quizzes from both A&P I and A&P II may have helped students prepare for the

HAPS exam. The quantity of material covered on the HAPS comprehensive exam is certainly daunting, and students may see lecture quizzes as a way to more easily review the material than to attempt to review all their lecture notes.

**Table 1.** Profile of students completing A&P I and A&P II over the 9-year study period. Only students who completed both semesters of the course during the same academic year are included in the profile. ACT scores, which were not available for all students, represent mean composite scores ( $\pm$  standard deviation). The year in which a significant change in class structure was implemented is also presented.

Academic Year	Enrollment	ACT Score (n)	Change in class structure
1994-1995	122	22.0 $\pm$ 3.6 ( 93)	
1995-1996	158	22.3 $\pm$ 3.4 (136)	HAPS standardized test first administered
1996-1997	117	22.8 $\pm$ 3.4 ( 99)	
1997-1998	145	22.7 $\pm$ 3.6 (131)	Lecture quizzes first administered
1998-1999	136	23.8 $\pm$ 4.0 (120)	
1999-2000	110	23.6 $\pm$ 3.4 ( 92)	Chemistry pre-requisite placed on class
2000-2001	94	22.1 $\pm$ 3.3 ( 83)	
2001-2002	98	23.3 $\pm$ 3.9 ( 87)	
2002-2003	108	22.6 $\pm$ 3.4 ( 95)	Powerpoint® lecture format introduced

**Table 2.** Student performance on lecture exams and lecture quizzes (when given) in A&P I and A&P II. All scores are means ( $\pm$  standard deviation) out of 100 possible points.

ANATOMY AND PHYSIOLOGY I					
Academic Year	Exam 1	Exam 2	Exam 3	Exam 4	Quizzes
1994-1995	80.6 $\pm$ 10.7	74.8 $\pm$ 13.67	7.8 $\pm$ 13.5	74.9 $\pm$ 14.6	none given
1995-1996	83.3 $\pm$ 9.3	75.8 $\pm$ 12.1	81.2 $\pm$ 12.5	73.8 $\pm$ 14.0	none given
1996-1997	74.3 $\pm$ 9.5	75.2 $\pm$ 9.5	67.4 $\pm$ 12.8	74.5 $\pm$ 13.3	none given
1997-1998	77.4 $\pm$ 8.6	71.4 $\pm$ 10.2	68.4 $\pm$ 12.7	70.1 $\pm$ 11.2	76.3 $\pm$ 12.5
1998-1999	85.9 $\pm$ 10.0	79.0 $\pm$ 11.8	73.4 $\pm$ 15.6	77.5 $\pm$ 11.9	79.3 $\pm$ 12.7
1999-2000	87.1 $\pm$ 9.4	81.6 $\pm$ 11.4	79.8 $\pm$ 12.4	77.0 $\pm$ 13.3	79.1 $\pm$ 12.6
2000-2001	84.0 $\pm$ 11.1	77.0 $\pm$ 11.6	75.6 $\pm$ 16.8	78.3 $\pm$ 12.2	78.8 $\pm$ 12.4
2001-2002	85.1 $\pm$ 10.6	80.2 $\pm$ 10.8	77.1 $\pm$ 13.6	81.4 $\pm$ 12.9	82.9 $\pm$ 9.5
2002-2003	83.5 $\pm$ 11.7	78.5 $\pm$ 13.1	73.7 $\pm$ 14.6	77.9 $\pm$ 15.0	76.0 $\pm$ 14.2
ANATOMY AND PHYSIOLOGY II					
Academic Year	Exam 1	Exam 2	Exam 3	Exam 4	Quizzes
1994-1995	78.4 $\pm$ 13.9	78.5 $\pm$ 12.8	77.4 $\pm$ 13.6	71.1 $\pm$ 16.1	none given
1995-1996	80.2 $\pm$ 12.6	77.2 $\pm$ 12.8	78.9 $\pm$ 13.2	71.4 $\pm$ 14.9	none given
1996-1997	65.2 $\pm$ 13.6	68.4 $\pm$ 12.7	69.9 $\pm$ 13.8	74.3 $\pm$ 11.5	none given
1997-1998	78.1 $\pm$ 11.8	77.2 $\pm$ 11.6	79.6 $\pm$ 10.7	70.0 $\pm$ 14.9	69.8 $\pm$ 13.9
1998-1999	75.3 $\pm$ 12.1	75.2 $\pm$ 13.1	82.8 $\pm$ 12.2	70.6 $\pm$ 14.9	71.7 $\pm$ 15.3
1999-2000	81.0 $\pm$ 11.5	71.8 $\pm$ 13.7	82.6 $\pm$ 11.8	77.0 $\pm$ 13.4	71.5 $\pm$ 15.1
2000-2001	76.3 $\pm$ 12.2	70.3 $\pm$ 12.9	76.5 $\pm$ 13.4	69.6 $\pm$ 13.3	73.7 $\pm$ 14.2
2001-2002	74.7 $\pm$ 12.4	78.6 $\pm$ 12.3	75.6 $\pm$ 12.6	73.2 $\pm$ 21.6	80.5 $\pm$ 12.6
2002-2003	71.2 $\pm$ 14.3	78.8 $\pm$ 12.5	75.4 $\pm$ 14.0	71.7 $\pm$ 14.5	72.9 $\pm$ 15.7

**Table 3.** Student performance on the Human Anatomy and Physiology Society (HAPS) comprehensive exam. Exam scores are means ( $\pm$  standard deviation) out of 100 possible points.

Academic Year	Exam Score
1995-1996	51.0 $\pm$ 10.9
1996-1997	55.1 $\pm$ 10.3
1997-1998	56.4 $\pm$ 10.6
1998-1999	57.0 $\pm$ 11.1
1999-2000	62.1 $\pm$ 10.6
2000-2001	59.4 $\pm$ 11.1
2001-2002	60.8 $\pm$ 10.4
2002-2003	59.4 $\pm$ 12.2

While an attempt was made to maintain a similar level of expectation throughout the years of this study, it is certainly possible that more was expected of the students when they had quizzes and this resulted in subtle changes to the lecture exams to reflect these expectations. The quizzes required students to synthesize information into a written answer rather than select the proper answer from a list in a multiple-choice question or supplying a single word in a fill-in-the-blank question (Table 4). This could explain both the lack of impact of quizzes on student performance on hourly exams and the significant positive impact of quizzes on student performance on the HAPS comprehensive exam. In addition, the variation in class composition may have impacted the study. As professional programs changed the required prerequisites for student admission, more students were choosing to enroll in A&P I and A&P II as sophomores and juniors rather than as freshmen and sophomores. In addition, the requirement of a college-level chemistry course in 1999 also had an impact on class composition. This increased level of student maturity may have positively impacted student performance because a comprehensive final exam may not have been as imposing to sophomores and juniors as it may have been to freshmen.

One question that must be asked is whether or not the impact of quizzes was worth the effort on the part of the instructor. Essay-style quizzes are very time-consuming to grade even for a small class. A sincere effort was made to write constructive comments on each student's quiz paper, so it took me approximately 3-4 minutes to grade a single quiz paper. Therefore, depending on the size of the class and the complexity of the quiz, the time required to grade a single quiz for the entire class took anywhere from 6.5 and 15 hours. This does not include the time required to record and post the quiz grades, the time required to sort the papers to be handed back to the students during

laboratory, and the time required to cope with absences and possible make-up quizzes. One significant benefit to the instructor, however, was the ability to learn much more about the capabilities of individual students by grading their written work. It was extremely difficult to get to know all the students in such large lecture sections. There were 8-10 laboratory sections associated with this course, but I typically taught only 3 of these sections. Therefore, grading each student's lecture quiz provided more information about each student in the class. Moreover, each student got individualized feedback. The students in my lab sections said they appreciated the written suggestions and comments on their quiz papers, and the instructors of the other lab sections reported similar comments.

The majority of the students in these classes are pre-professional, so they often will need a letter of reference to include in their application materials for professional school. If I agree to serve as a reference for a student, I must be able to write a valid, accurate, and defensible letter of reference for that student. If I cannot do this, it is my professional obligation to inform the student that I cannot serve as a reference for him or her. By grading written quizzes I learned which students could understand the question being asked and synthesize complex information into a concise answer. This was in sharp contrast to students who consistently did not answer the question asked or simply wrote everything they knew about the topic, hoping the answer I was looking for was in there somewhere. I also learned which students could construct coherent sentences, spell, and use proper grammar, in contrast to students who still did not know the difference between, for example, "it's" and "its" or "there" and "their." This enabled me to comment on the ability of the student to effectively analyze, synthesize, and communicate complex information rather than on the student's ability to simply memorize, recognize, and recite factual information.

In conclusion, it is up to the individual instructor to weigh the costs and benefits of essay-style lecture quizzes. The most significant cost to the instructor is the time required to grade and process the quizzes. The benefits to the student do not appear to be improved performance on hourly exams but instead individual feedback and better long-term retention of the material, as evidenced by the significantly higher scores on the HAPS comprehensive exam. In return, the instructor gets to know the students in his or her class better by reading their written work. As an instructor who regularly teaches large lecture classes, any method by

which I can get to know more about each of the students in my class is well worth the time commitment.

#### ACKNOWLEDGMENTS

The author would like to thank Elaine Gokie, Associate Director of the Office of Student Records and Registration, for supplying composite ACT scores, and Dr. W. Wyatt Hoback, Associate Professor of Biology, for assistance in analysis of the data.

**Table 4.** Examples of quiz questions from A&P I and A&P II which require students to demonstrate critical thinking, analysis, and synthesis of the material. In italics following each question are its classification levels according to Bloom's taxonomy (Bloom, 1956).

1.	Describe the negative feedback mechanism used to lower blood levels of calcium to "normal" if blood levels of calcium increased.	<i>knowledge, comprehension</i>
2.	Abnormal thirst and frequent urination are symptoms of diabetes mellitus, because the glucose in the urine creates an osmotic diuresis. Explain.	<i>knowledge, comprehension, application</i>
3.	Anatomy and physiology are interdependent at all levels of organization. Explain the reason the phospholipid bilayer arrangement (anatomy) is necessary for the cell membrane to properly perform its function (physiology).	<i>knowledge, comprehension, analysis</i>
4.	Olfactory epithelium and taste buds are both composed of epithelial tissue and neural tissue. If they are composed of the same two types of tissue, what is the reason the sense of smell diminishes as one ages; whereas, the sense of taste does not?	<i>knowledge, comprehension, analysis</i>
5.	In amphibians, the heart is divided into only three chambers (two atria, one common ventricle), whereas in mammals and birds, the heart is divided into four chambers. Explain how this anatomical difference is physiologically advantageous for mammals and birds.	<i>knowledge, comprehension, analysis</i>
6.	The following statements are from a newspaper advertisement for an exercise program (cost = \$37) that guarantees rapid weight loss with only 10 minutes of exercise 5 days a week while eating 300 to 400% more food. "A study has proven that anaerobic exercise actually burns more than 5 times more calories than aerobic exercise. Aerobic exercise can typically burn 25% muscle and 75% fat for body energy. Anaerobic exercise burns 100% fat for body energy." The ad goes on to claim that "anaerobic exercise causes the body to create energy without oxygen because the demand for energy is so fast and large that the body must create it from numerous natural body chemicals." Identify two serious errors with the claims of this advertisement and explain the reason(s) these statements are not correct.	<i>knowledge, comprehension, analysis, application, synthesis, evaluation</i>

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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 *upper division undergraduate and graduate students in the field of Biology* to attend the Fall Meeting of ACUBE.

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

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

Dr. William J. Brett, Department of Life Sciences  
Indiana State University, Terre Haute, IN 47809  
Voice—(812) 237-2392; FAX (812) 237-4480  
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# Wabash College

Site of the 48<sup>th</sup> Annual Meeting

## Association of College and University Biology Educators

Wabash College was founded in 1832 as an independent non-sectarian college for men. For more than 170 years Wabash has been educating young men to "think critically, act responsibly, lead effectively, and live humanely" with a classical liberal arts educational experience. Students may pursue one of twenty-one different majors. The curriculum seeks to allow maximum flexibility as well as to provide the broad base of understanding that is at the core of the liberal arts concept. At Wabash about 25% of the students participate in over 140 study abroad programs. The 850 students come from 34 states and 13 foreign countries. Nearly 21% are students of color. Approximately 90% of the students receive some form of financial aid. The U.S. News and World Report rank Wabash in the top 20% of the 212 National Liberal Arts Colleges. Wabash set two national benchmarks in The National Survey of Student Engagement and ranked in the 90<sup>th</sup> percentile in three other categories. Wabash ranked first in the level of academic challenge and students' interaction with the faculty. About 75% of Wabash alums attend graduate school within five years of graduation. Thirteen percent of our alums hold Ph.Ds and 12% hold the title of "President" or "Chairman." Only two Ivies have a higher percentage of alumni in Who's Who.



### Crawfordsville, Indiana

Located on the banks of Sugar Creek in West Central Indiana, Crawfordsville was organized into a city in 1823. As the seat of Montgomery County, Crawfordsville has served as the financial and trading center for surrounding counties. Because of its cultural strengths, by the end of the 19<sup>th</sup> Century, it became known as the "Athens of Indiana." In addition to being the home of General Lew Wallace, author of "Ben Hur," Crawfordsville has been the home of numerous other writers. Today, the City has diverse industry sectors including, steel production and processing, agribusiness, printing, education, distribution, optics, metal and plastic fabrication and lighting. With a growing population of over 15,000 diverse residents, Crawfordsville is one of the "Top 100 Best Small Towns in America."



# The Control of Gene Expression by the cI Protein: A Single Experiment to Teach Concepts in Genetics, Molecular Biology and Transcription Regulation

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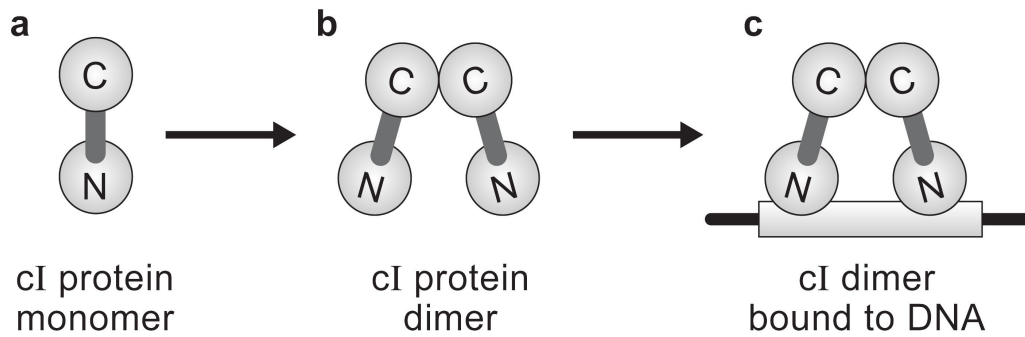
**ABSTRACT:** To integrate theory and practice in our undergraduate Molecular Genetics class, I have designed an experiment that uses an inquiry-based approach to develop students' understanding of molecular biology, genetics and transcription regulation. Students first identify and classify a mutant protein, then perform several fundamental techniques of molecular biology, specifically the transformation of bacterial cells and the isolation and restriction analysis of plasmid DNA. Since the protein in question regulates transcription, students who perform this experiment gain first hand experience with some questions and concepts of gene expression. This is not a traditional genetics experiment to model the predicted 3:1 outcome of a genetic cross. Similarly, this is not a cloning experiment to demonstrate that DNA can be moved from one place to another. Instead, this experiment presents a framework for the students to find a protein with a defect and then provides tools for them to determine the nature of that defect. There are many possible outcomes to this experiment and students who perform the work must use their data to decide what has happened in their case.

**KEY WORDS:** *E. coli*, cI protein, transcription regulation, mutant, plasmid

## INTRODUCTION

Laboratory exercises should put into practice the complex and often abstract ideas presented in the classes they support. In an ideal world, students will not only see the relevance of the experiments they perform to the material and concepts presented in their textbooks, but will also learn up to date and classic techniques used in the field they are studying. The protein central to this experiment is the lambda cI protein, also known as the lambda repressor protein found in the bacteriophage. The role this protein plays in the life cycle of the bacteriophage is not central to the experiment presented here. Rather, the cI protein was chosen as the basis for this experiment because it is one of the best understood and most thoroughly studied examples of a transcription regulatory protein. Mutations in the protein are known to affect distinct and well defined functions. Furthermore, the gene is readily manipulated with molecular techniques, and so is ideal for studies in bacterial genetics.

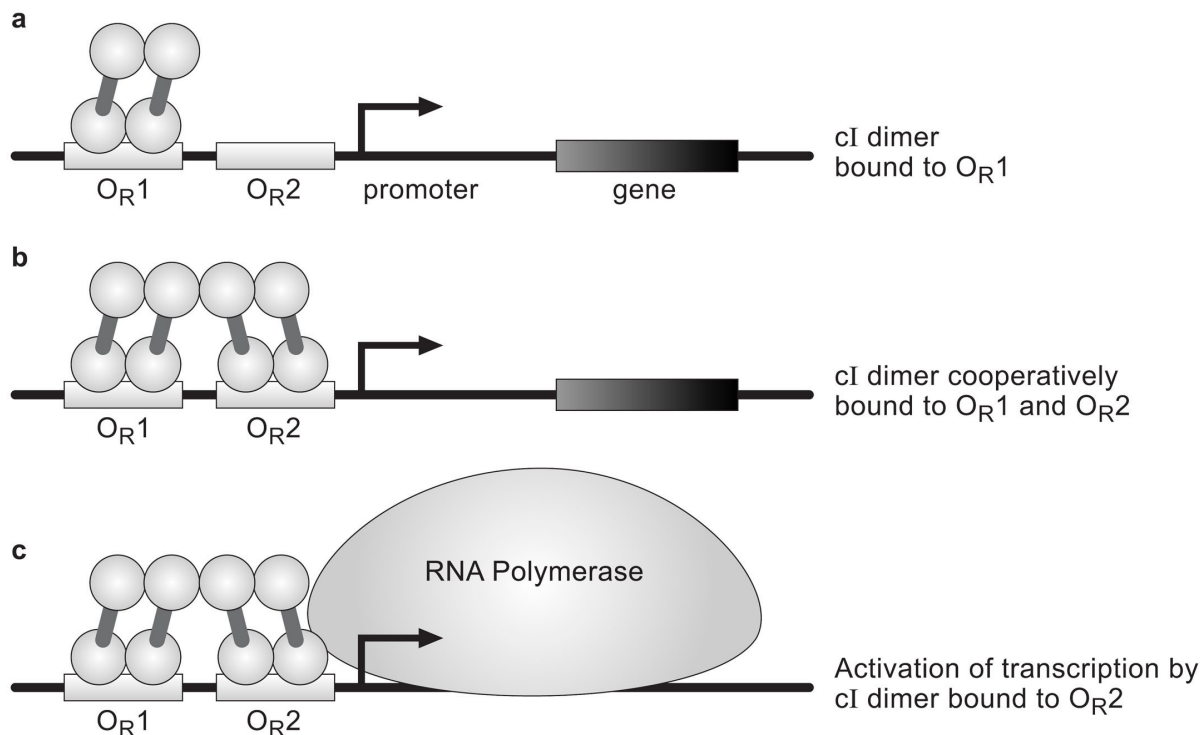
The cI protein folds into a dumbbell-shaped molecule (Figure 1a), with two globular sections that are referred to as the N-terminal and the C-terminal domains (reviewed in Ptashne 1992). A flexible linker region separates the two domains. Many of the functions of the cI protein can be ascribed to either the N- or the C-terminal domain. For example, when the cI protein forms a dimer (Figure 1b), it is the C-terminal domains of each monomer that "stick" to one another. Once they have dimerized, the N-terminal domains of the proteins can recognize and bind particular sequences of DNA (Figure 1c). Such sequences are given the name "operators." Several operators that differ in their affinity for cI dimers are known. The operator called O<sub>R1</sub> has a high affinity for cI dimers, whereas O<sub>R2</sub>, an operator with a slightly different DNA sequence, has a lower affinity. Consequently, if a single cI dimer existed in a cell it would bind to O<sub>R1</sub> rather than O<sub>R2</sub>, and a higher concentration of protein dimers would be needed for occupancy of O<sub>R2</sub>.



**Figure 1.** Interactions of the *cI* protein with itself and with DNA. The *cI* protein folds into two globular domains connected by a flexible linker (panel a). The *cI* protein will dimerize, principally through protein-protein contacts in the C-terminal domains of the two monomers (panel b). Dimers of the *cI* protein are able to bind specific DNA sequences called operators (panel c). This DNA binding is mediated by the N-terminal domains of the protein.

To begin their experiment, students look for defective versions of the *cI* protein. Mutations in the gene encoding *cI* protein can affect protein structure altering dimer formation and DNA binding, or they can disrupt other functions of the *cI* protein illustrated in Figure 2. Cooperative DNA binding (Figure 2b) is the ability of a *cI* dimer bound to a high affinity site like  $O_{R1}$  to help another dimer bind an operator of lower affinity such as  $O_{R2}$ . These cooperative interactions

occur through the C-terminal domains of the dimers (Bell et al., 2000). Several examples of changes in the *cI* protein that specifically inhibit cooperative binding of the mutant dimers have been described in the scientific literature (Beckett et al., 1993; Benson et al., 1994; Burz & Ackers., 1996; Whipple et al., 1994, 1998). As one would expect, the amino acid substitutions in such mutants are all found in the protein's C-terminal domain.



**Figure 2.** Interactions of *cI* dimers at  $O_{R1}$  and  $O_{R2}$ . The operator  $O_{R1}$  has the greatest affinity for a *cI* dimer and so it will be occupied before  $O_{R2}$  (panel a). The dimer bound to  $O_{R1}$  facilitates the binding of a second dimer to  $O_{R2}$  (panel b). This dimer:dimer interaction is called cooperative DNA binding and is mediated by the C-terminal domains of the dimers. The N-terminal domain of the dimer at  $O_{R2}$  can interact with RNA polymerase to enhance transcription of the downstream gene (panel c).

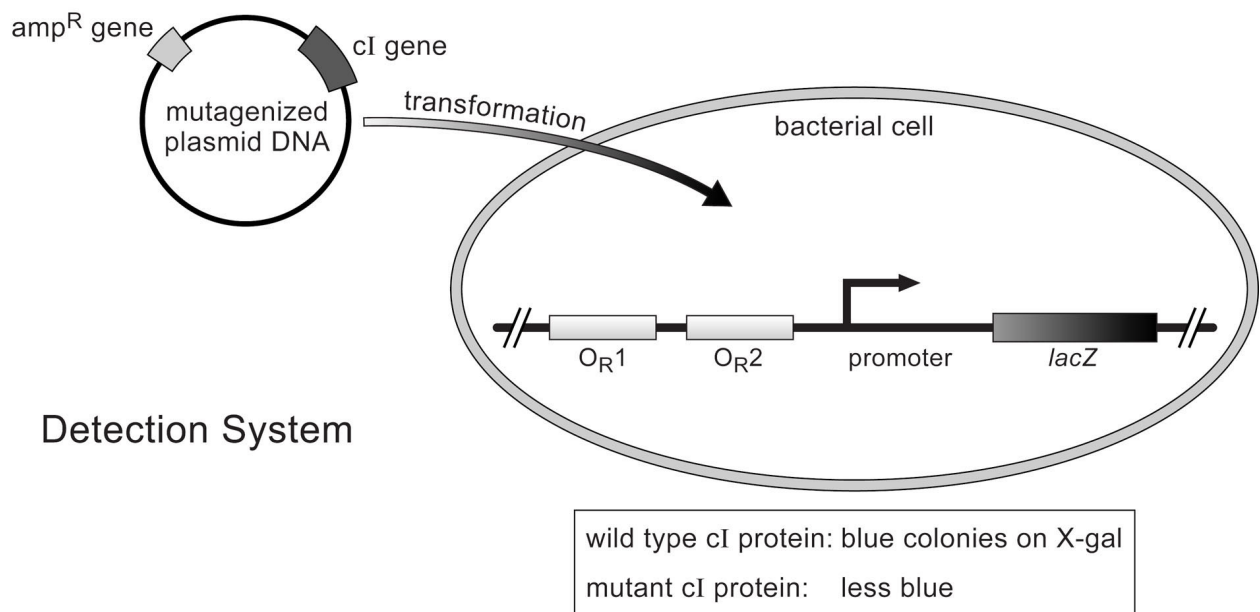
The final function of the cI protein that can be affected by gene mutation is the activation of transcription. Transcription is the copying of a DNA strand into its complementary RNA sequence. The enzyme that carries out this process is called RNA polymerase. Genes are preceded by particular sequences of DNA, called promoter sequences. For transcription of a gene to occur, RNA polymerase must recognize and bind to the gene's promoter. Other proteins in a cell can affect the interaction of RNA polymerase with the promoter of a gene and consequently the amount of RNA transcribed. When the binding of a protein near a gene increases the RNA production of that gene, the protein is called an "activator." The cI protein is an activator when it is properly positioned just upstream of a promoter (Figure 2c). In such an arrangement, the N-terminal domain of a DNA-bound cI dimer "touches" RNA polymerase causing more RNA copies of the gene to be made. Again, there are several examples of changes in the N-terminus of the cI protein that diminish or abolish transcription activation but do not affect the protein's other functions such as dimerization, DNA binding or cooperative DNA binding (Guarente et al., 1982; Hochschild et al., 1983; Bushman et al., 1989). The

goal of the experiment described here is for students to isolate a cI mutant from bacteria transformed with a plasmid pool of both normal and defective genes encoding cI protein. They must classify their selected mutant as defective for binding the DNA, for cooperative interactions, or for activation. Finally, students examine the overall structure of the gene that encodes the cI mutant protein to determine if there are any gross changes in the structure of the gene that could explain the mutant phenotype.

## METHODS AND RESULTS

### 1<sup>st</sup> LAB MEETING

To perform their screen for cI mutants, students begin by transforming a specialized bacterial strain with a pool of plasmid DNA that has previously been exposed to a mutagen (Figure 3). The gene for the cI protein is encoded on the plasmid DNA, and at some low frequency the sequence of the gene is expected to be changed by exposure to the mutagen. When expressed in a cell, the mutated cI gene can produce a cI protein with one or more amino acid substitutions, some of which could affect the protein's function.



**Figure 3.** Detection System for cI mutants. Bacterial cells are modified with an artificial promoter construct so they can be used to identify defects in cI function. The artificial promoter construct fuses two operator sequences, *O<sub>R1</sub>* and *O<sub>R2</sub>*, just upstream of the promoter for the *lacZ* gene. Wild type cI protein dimers can cooperatively bind the adjacent operators to activate transcription of the *lacZ* gene. On X-gal indicator plates, such cells appear blue. Cells appear less blue when they express a cI mutant unable to dimerize, unable to bind DNA, unable to cooperatively interact with another dimer, or unable to activate transcription. The cI protein is expressed from a plasmid transformed into the modified bacterial cells.

To identify mutants with altered functions, students transform the plasmids into bacteria with a “detection system” integrated in the genome. This detection system consists of two operator sequences ( $O_{R1}$  and  $O_{R2}$ ) just upstream of a promoter sequence and the *lacZ* gene. Transcription of this artificial construct can be detected and quantified. When transcription of the *lacZ* gene is high, significant amounts of  $\beta$ -galactosidase, are made. The  $\beta$ -galactosidase can react with the chromogenic compound, 5-bromo-4-chloro-3-indolyl- $\beta$ -D-galactopyranoside (“X-gal”), which is colorless until it is cleaved by  $\beta$ -galactosidase to produce a blue colored product. Thus, cells with normal cI function bind dimers of cI protein to the operator sequences and activate transcription of the *lacZ* gene, thus making significant amounts of  $\beta$ -galactosidase in our detection system. Bacteria with the normal cI protein can be identified by their dark blue color when grown on a medium that contains X-gal. Cells expressing mutant cI proteins appear pale blue or white.

Importantly, the arrangement of operators in the detection strain is such that any defect in cI protein function will lead to less transcription of the *lacZ* gene. A cI protein defective for dimerization, DNA binding, cooperative DNA binding or transcriptional activation, all appear less blue than cells expressing wild type cI protein. The students survey their transformation plates to find the occasional pale blue colony among the darker blue ones. One such colony becomes their candidate mutant to be analyzed further.

Pedagogically, this portion of the experiment illustrates an important technique of molecular biology in addition to reinforcing lessons in genetics and concepts in gene regulation. Transformation of bacterial cells with plasmid DNA is a common procedure performed in many research laboratories. In our labs, students make the cells competent for transformation. This is a simple procedure, done by incubating the cells with  $CaCl_2$  and washing them gently so as not to lyse the cells in their fragile condition. The competent cells are then incubated with the mutagenized plasmid DNA. Since the plasmid used in the transformation encodes the gene for ampicillin resistance in addition to the gene for cI protein, transformants are selected on petri dishes with an ampicillin-containing medium. The transformed cells become colonies after they are grown at 37° overnight. The medium in the petri dishes also contains X-gal, and so the colonies appear dark blue except for occasional pale blue colonies that express a mutant cI protein.

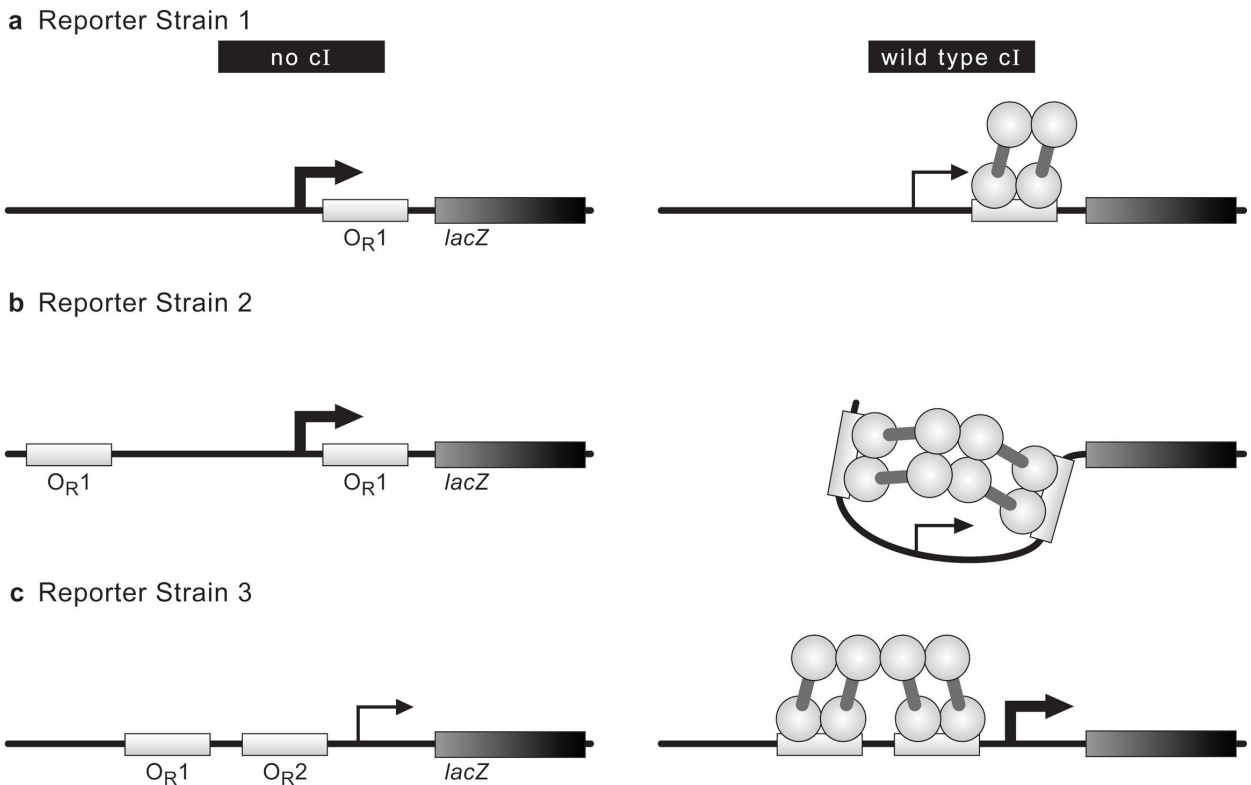
## 2<sup>nd</sup> LAB MEETING

Once the mutant has been identified, the goal is the isolation of the plasmid with the mutated gene and classification of the protein defect it encodes. Students inoculate a few milliliters of ampicillin-containing liquid medium with the colony they believe expresses a

mutant cI protein and they grow the cells at 37° overnight. The cells multiply and since each cell carries the same version of the mutated plasmid, students are able to isolate a usable quantity of purified plasmid DNA using a “miniprep.” Like the bacterial transformations performed on the first day of the experiment, minipreps are another fundamental technique of molecular biology and are widely used in modern research labs. The technique involves lysing the cells in the presence of detergent and base, separating plasmid DNA from chromosomal DNA and cell debris, and finally concentrating the plasmid DNA by precipitating it with ethanol. This procedure is done in 1.5 milliliter microfuge tubes, involves no harsh chemicals, and is completed in approximately 30 minutes. Students finish with a tube containing relatively pure plasmid DNA for further study.

To identify the cI protein defect in their mutants, students transform the plasmid DNA they have isolated into three bacterial strains that contain different detection system constructs called “reporters.” These reporter strains are designed so that transcription of the *lacZ* gene differs in the presence and the absence of functional cI protein. In Reporter Strain 1 (Figure 4a), the promoter upstream of the *lacZ* gene is immediately followed by  $O_{R1}$ , a strong binding site for cI dimer. Expression of the *lacZ* gene is lower in cells expressing cI protein that can dimerize and bind  $O_{R1}$  than in cells expressing no cI protein at all. Presumably this occurs because the cI dimer blocks the RNA polymerase from binding the promoter thereby inhibiting transcription of the *lacZ* gene. In Reporter Strain 2 (Figure 4b), the promoter for the *lacZ* gene is flanked by  $O_{R1}$  sequences. In this case, the operators are a significant distance from the promoter and do not sterically occlude interaction of the RNA polymerase with its binding site. However, when operators are bound by cI dimers that can cooperatively interact, the intervening DNA forms a DNA loop. This reduces transcription of the *lacZ* gene, presumably by making the promoter inaccessible to RNA polymerase. In Reporter Strain 3 (Figure 4c), adjacent binding sites,  $O_{R1}$  and  $O_{R2}$ , precede a weak promoter for the *lacZ* gene. Transcription of *lacZ* is detectable in cells that express no cI protein, but more *lacZ* transcription occurs in cells expressing wild type cI protein. Expression requires a cI protein that can bind the DNA, cooperatively interact with a second dimer, and interact with RNA polymerase to activate transcription.

Students transform their mutant plasmids into each of the three reporter strains. They select transformants on ampicillin-containing medium just as they did the preceding week. In this case however, the medium contains no chromogenic compound. Instead, transcription of the *lacZ* gene in each reporter strains will be measured using a quantitative enzymatic assay performed during the 3<sup>rd</sup> lab meeting.



**Figure 4.** Reporter Strains 1, 2 and 3. Reporter Strain 1 (panel a) is used to assess the ability of a *cI* protein to dimerize and bind the DNA. In the absence of *cI* protein, the operator downstream of the strong promoter is unoccupied and transcription of the *lacZ* gene is high. Transcription is reduced when a *cI* dimer occupies the operator. Reporter Strain 2 (panel b) is used to assess the ability of *cI* dimers to cooperatively interact. Operators flank a strong promoter of the *lacZ* gene. Dimers of the *cI* protein decrease transcription only when they can cooperatively interact and form the repressive DNA loop. Reporter Strain 3 (panel c) is used to assess the ability of a *cI* dimer to interact with RNA polymerase to activate transcription. When *cI* dimers can bind the DNA and cooperatively interact, then the N-terminal domain of the downstream *cI* dimer is positioned to interact with RNA polymerase and activate transcription.

### 3<sup>rd</sup> LAB MEETING

In order to classify their *cI* mutants, students assess *lacZ* transcription by measuring  $\beta$ -galactosidase activity in the three reporter strains, comparing the activity in the strains expressing their mutant to the activity of the same strains with and without *cI* protein. This measurement is done using a colorimetric assay. The compound o-Nitrophenyl  $\beta$ -D-galactopyranoside (“ONPG”) is colorless and can be cleaved by the  $\beta$ -galactosidase enzyme to yield galactose, also colorless, and o-nitrophenol, which is yellow colored. To perform these assays, students first lyse their transformed cells and then react the lysate with ONPG for a precisely measured time. The amount of yellow color formed in the reaction tubes can be measured spectrophotometrically and reflects the amount of  $\beta$ -galactosidase present in the sample. The students also assay reporter strains that express either no *cI* protein or wild type *cI* protein. For greater confidence, they

perform assays in duplicate and average the activity they measure.

Table 1 presents an example of data that were generated by a student who performed this part of the experiment in the Fall of 2002. The data include spectrophotometric measurements for cell density (OD600), for o-nitrophenol (OD420) and for cell debris in the sample (OD550). These values are converted to units of enzyme activity using the formula: Units =  $1000 \times [\text{OD420} - (1.75 \times \text{OD550})] / [\text{time of reaction} \times \text{volume of lysate in reaction} \times \text{OD600}]$ .

Students are able to classify their mutants as defective for either DNA binding, cooperative binding or transcription activation, after performing these calculations. The classification requires that they compare the  $\beta$  galactosidase activity of their mutant with the activity for the “no *cI*” and the “wild type *cI*” controls in all three of their strains. A mutant with a defect in dimerization or DNA binding should behave

like the no cI control in all three reporter strains. A mutant with a defect in cooperative DNA binding will behave like wild type cI in Reporter Strain 1 but like the no cI control in Reporter Strains 2 and 3. Finally, a mutant with a defect in transcription activation will behave like wild type cI in Reporter Strains 1 and 2 but like the no cI control in Reporter Strain 3. For effective analysis of their mutants, students must perform the assays competently and must compare results for the controls and their mutant in all three

reporter strains. It is emphasized to students that technical competence in the lab and critical thinking skills are challenged by this part of the experiment. Inevitably a few students each semester generate data that seem unreliable, and so everyone is asked to enter their data into a class spreadsheet. Thus all students are able to analyze the no cI and the wild type cI measurements from samples that behaved as predicted at the outset of the analysis.

**Table 1.** Example of data that were generated by a student who performed this part of the experiment in the Fall of 2002. The data include spectrophotometric measurements for cell density (OD600), for o-nitrophenol (OD420) and for cell debris in the sample (OD550). These values are converted to units of enzyme activity using the formula:  $Units = 1000 \times [OD420 - (1.75 \times OD550)] / [time\ of\ reaction \times volume\ of\ lysate\ in\ reaction \times OD600]$ .

REPORTER STRAIN for DNA binding	CELL DENSITY (OD600)	o-NITROPHENOL (OD420)		CELL DEBRIS (OD550)		β-GALACTOSIDASE ACTIVITY (AVERAGE UNITS)
no cI	0.365	0.413	0.428	0.008	0.010	1478
wild type cI	0.277	0.168	0.244	0.025	0.003	874
mutant cI	0.350	0.312	0.206	0.005	0.012	930
<b>for cooperative interactions</b>						
no cI	0.281	0.381	0.262	0.011	0.009	1442
wild type cI	0.280	0.108	0.175	0.009	0.010	595
mutant cI	0.293	0.404	0.439	0.018	0.045	1668
<b>for transcription activation</b>						
no cI	0.292	0.338	0.153	0.068	0.050	65
wild type cI	0.276	0.283	0.267	0.051	0.044	93
mutant cI	0.298	0.307	0.301	0.075	0.060	83

Students generally gather sensible measurements for the controls, but find the classification of their mutant is not as clear-cut as they predicted. For example, from the data presented in Table 1, students might conclude that they isolated a cooperative DNA binding mutant. The ability of the mutant to form the repressive DNA loop in Reporter Strain 2 appears to be impaired since β-galactosidase activity is repressed 2.4 fold by wild type cI protein and not at all by the mutant. A defect in DNA binding cannot explain this result since the repression in Reporter Strain 1 is significant (wild type cI protein represses activity 1.7 fold and the mutant cI protein represses it 1.6 fold). Logically, one might predict no transcription activation for the mutant since the cooperative interaction of the dimers is required to position the cI protein to touch RNA polymerase and

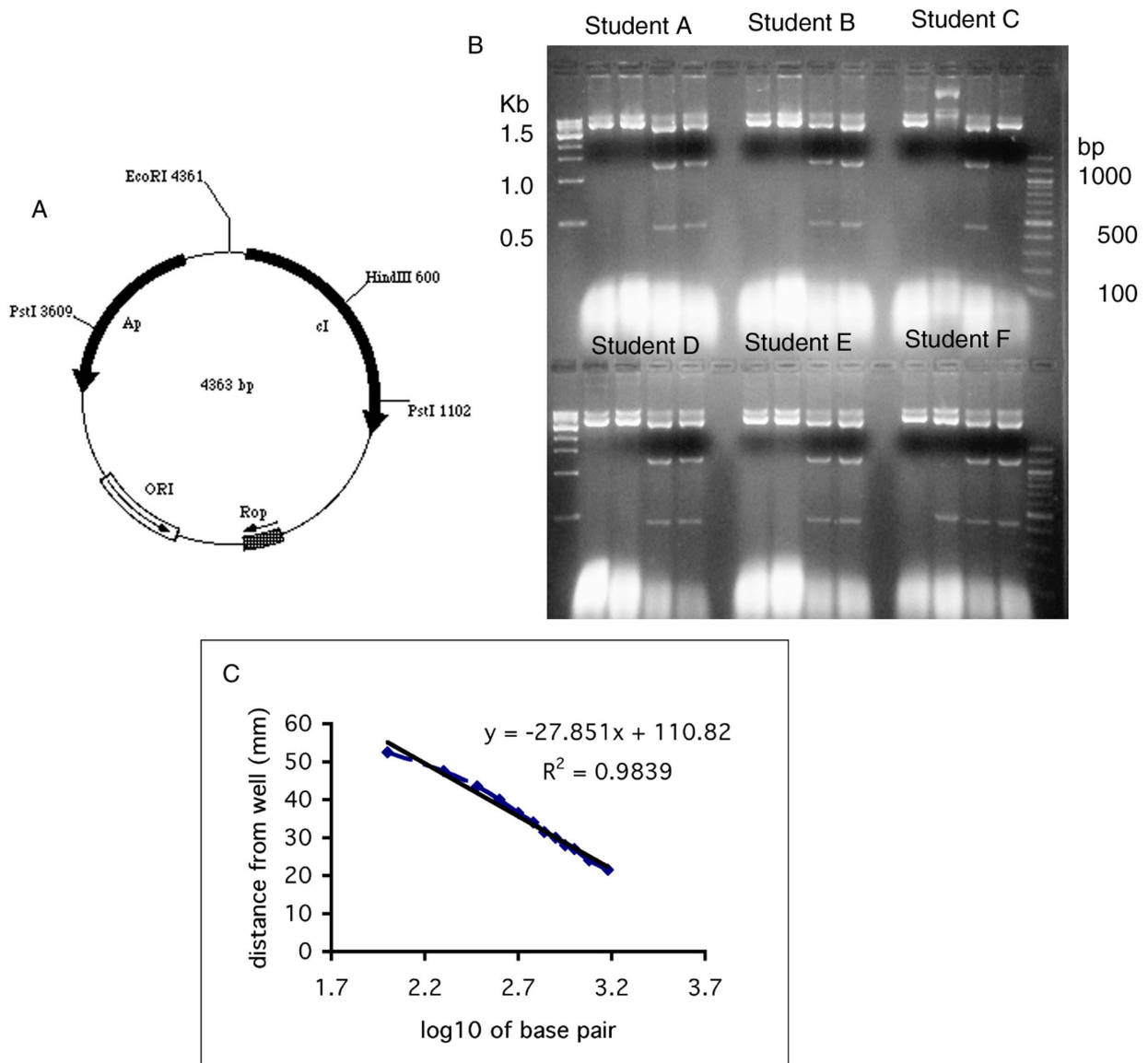
activate transcription. However the activity of the mutant in Reporter Strain 3 is neither as great as is seen for wild type cI protein (93 units), nor as low as for no cI protein (65 units). Thus the mutation in the cI protein affects cooperative DNA binding but does not completely inhibit the interaction between dimers when the binding sites are adjacent to one another.

Since β-galactosidase activity is recorded by the entire class and entered into a single spreadsheet, students are asked to compare their results with those collected by others. How often was their type of mutant isolated? Was their mutant more or less severe than other examples the class identified? In this way, our students see the range of possible outcomes from a common starting point and they discover that the most effective genetic experiments are those that allow nature to lead the way.

#### 4<sup>th</sup> LAB MEETING

To examine the structure of the plasmid that encodes their mutant, students use two restriction enzymes to “digest” it and then separate the resulting fragments by size using agarose gel electrophoresis. The restriction pattern is not expected to differ for the wild type and mutant plasmids since most mutant cI phenotypes arise from point mutations (single base pair changes). However the pattern will change if there has

been a large deletion in the cI gene or if the point mutation happens to alter the sequence recognized by either of the restriction enzymes. Before they come to lab, students can predict the restriction pattern for the wild type plasmid using the map for the cI encoding plasmid (Figure 5a). During the lab session, students react five microliters of the miniprep DNA they prepared in the second lab session with the restriction enzyme HindIII or with HindIII and PstI.



**Figure 5.** Plasmid Structure and Analysis. The plasmid encoding the wild type cI protein (panel A) is digested with the restriction enzyme HindIII or with the combination of HindIII and PstI, and the resulting fragments are separated on an agarose gel (panel B). Students also digest plasmids encoding their mutant cI protein and compare the electrophoretic pattern of the wild type plasmid (panel B, lanes 1 and 3 for each student) to the mobility pattern for their mutant (panel B, lanes 2 and 4 for each student). A standard curve is generated by plotting the migration distance for each molecular weight standard (panel C), and this curve is used to calculate the precise size of each digested fragment.

These restriction enzymes are some of the “work horses” of molecular biology and seem to be able to digest even the dirtiest preparations of DNA. Students also digest unmutagenized plasmid for comparison. After a short incubation at 37°, these reactions are mixed with a colored tracking dye and then loaded onto an agarose gel. The gel contains Ethidium Bromide to visualize the fragments under ultraviolet light. Since Ethidium Bromide is a powerful mutagen, the gel is not prepared or photographed by the students. There are less toxic ways to visualize DNA on agarose gels if the use of Ethidium Bromide is problematic, for example using Methylene Blue or Carolina Blu™ Buffer Stain.

Class data collected in the Fall of 2002 are shown in Figure 5b. Restriction digests of the wild type plasmid are loaded in the first and third lanes of each group. The predicted fragments of 4361 basepairs for the HindIII digest and 2507, 1352 and 502 basepairs for the double digest with HindIII and PstI are seen. The restriction fragments for the mutant plasmids (lanes two and four for each group) are, for the most part, identical to those for the wild type plasmids. One exception can be seen in the reactions performed by Student C. For this student, the plasmid appears to digest only with the PstI restriction enzyme, a result that suggests a mutation or deletion of the HindIII recognition site. A significant change in gene structure such as the deletion of the restriction site is unlikely to encode a functional cI protein and indeed, the  $\beta$ -galactosidase data collected by this student are consistent with the isolation of a mutant unable to dimerize or bind the DNA (data not shown). A second example in which the restriction pattern for the mutant plasmid differs from that of the wild type is seen for Student F. A HindIII digest of the mutant plasmid yields a fragment of approximately 500 base pairs that is not seen when the wild type plasmid is digested. This can be interpreted as a mutation in the plasmid that coincidentally creates a HindIII recognition sequence.

To determine the exact size of the DNA fragments generated by the restriction analysis, students are asked to generate a standard curve using distance traveled by the molecular weight standards (Figure 5c). A regression analysis in Excel gives them a mathematical expression on the distance migrated through the gel to the size of the DNA fragment. They use the equation to calculate the size of the fragments seen for the wild type and mutant plasmids based on the distance they migrated. These values can then be compared with the molecular weights predicted for the fragments based on the plasmid map. The fragments are never precisely the size predicted based on the plasmid map and this also teaches the students an important lesson about the accuracy and precision of their data.

The experiment could be successfully taught without including the restriction analysis of the plasmid

DNA. These data are not essential for the classification of the cI mutant isolated by the students, but this part of the experiment does provide first hand experience with perhaps the most widely used technique in molecular biology. The ability to cut DNA into manageable sizes pieces has allowed scientists to move genes from one context to another. Genes can be expressed under particular experimental condition and cloned into artificial constructs useful for the study of gene function. By performing a restriction analysis, the students begin to see DNA as a defined pattern of bases that can be analyzed both qualitatively by answering the questions: Are the digest patterns for the wild type and mutant different? Is the pattern what I expected?; and also quantitatively by answering the next logical question: How well do the fragment sizes agree with those predicted?

## DISCUSSION

Genetic experiments are often thought of as counting peas or crossing flies, but most modern research labs combine molecular techniques with genetic tools to study the precise mechanism of a protein's function. Taught in part or in its entirety, this experiment is a useful way to integrate many complex concepts in this area of biology.

There are many ways to simplify this experiment depending on the goal of the instructor, the availability of equipment, and the number or background of the students in the course. If the goal is to teach genetics but the students cannot perform the screen themselves, then the instructor could transform the detection strain with some of the wild type plasmid along with the mutant plasmids isolated and then ask the students to find a mutant on the transformation plates provided. The discussion could then center on the frequency of mutagenesis, and the ease with which each type of mutant is isolated. Predictions about the dominant or recessive nature of each type of mutant could be included as well. If including tools and techniques of molecular biology is also a goal, then the initial screen could be eliminated and students could be provided with a mutated plasmid. These students could then perform the transformation into the three reporter strains, the  $\beta$ -galactosidase assays, and the restriction analysis. In this case the discussion could emphasize the transformation efficiency of each reporter strain (which is predicted to be identical but rarely is), and the differences between their data and the predicted patterns for  $\beta$ -galactosidase activities and restriction fragments. Finally, if resources are limited and the cost of X-gal is prohibitive, or if no spectrophotometer or microfuge is available, then students could be provided with data from any part of this experiment to interpret or to discover an inconsistency.

Our students write a comprehensive report in the form of a scientific paper to describe the mutant they isolated, its characterization, and how their mutant relates to mutants isolated by others in the class.

Before the report is due, lab time is taken to discuss an article from the primary scientific literature about the cI protein (Bushman et al., 1989). This discussion is ungraded, but it is an important part of the student's experience since it provides an example of a cI mutagenesis experiment and of a well-written report (Kuldell, 2003).

In many cases, this is the first opportunity students have had to perform data-driven analysis of their own work, and while they often struggle with the analysis, they also learn a great deal. We find students are excited to draw conclusions from their data in the context of a "real" experiment. This is an experiment where there is no single expected outcome and students are encouraged to interpret their data as comprehensively as possible. Their goal is to compare their findings and observations to all predictable outcomes, rather than to evaluate how well their data reproduce an anticipated result. This empowers students to "think like scientists" and to make a sensible argument around the outcome of their own experience in lab.

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### Call for Reviewers

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

# Housing Preview

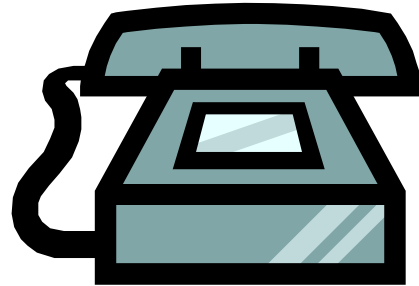
## 48<sup>th</sup> Annual ACUBE Fall Meeting

### *Technology in Biology Education*

**Wabash College**

**Crawfordsville, IN**

**October 14-16, 2004**



**Lodging:** Blocks of rooms have been reserved until September 14, 2004 at the Comfort Inn and Holiday Inn.

**IMPORTANT:** Please note this is the same weekend as the **Parke County Covered Bridge Festival** which draws thousands of visitors on weekends. As you will note, weekend rates can be higher than weekday rates. Rooms are at a premium during this time. **PLEASE BOOK YOUR ROOMS EARLY.**

<p><b>Comfort Inn</b>            Phone: (765) 361-0665            (800) 329-5150  <b>Book by: 9/14/04</b>            10/14 \$ 89.95+tax            10/15 \$ 89.95+tax</p>	<p><b>Holiday Inn</b>            Phone: 765-362-8700  <b>Book by: 8/17/04</b>            10/14 \$ 69.00+tax            10/15 \$122.95+tax</p>
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# ACUBE 47<sup>th</sup> Annual Meeting

## Truman State University 1<sup>st</sup> Steering Committee Meeting October 9, 2003

**Place:** Violette Hall Room 2451, Truman State University, Kirksville, MO

**Present:** Margaret Waterman, Terry Derting, Nancy Sanders, Ethel Stanley, Tim Mulkey, Bill Brett, Janet Cooper, Lynn Gillie, Kathy Marr, Brenda Moore

**Absent:** About Cherif, Pres Martin, Neil Grant, Bob Wallace, Malcolm Levin

**Time:** 3:00 - 5:00 pm

**I. Call to order: Margaret Waterman**

**II. Approval of agenda M/S/A**

**III. Current and continuing business**

**A. Local arrangements: Nancy Sanders**

All is in order, final programs available  
Small number of participants likely  
Field trips well attended  
Few exhibitors

**B. Program: Lynn Gillie**

Extending the time until late summer/early in semester for proposals brought in many more proposals  
Nicely diverse program

**C. Executive Secretary report: from Pres Martin, reported by M. Waterman**

At present, ACUBE has 215 paying members  
Current total assets = \$10,122  
Carlock = 5,640  
*Bioscene* (Dec) = 1,300

Outstanding payments due ACUBE = \$1,500 loaned to Columbia College as down payment on the dinner. Repayment was expected in 2002, but is still outstanding.

Total assets available are \$3,172

This total represents a significant increase since last year and returning financial health.

**D. Standing Committees**

**i. Membership: Aus Brooks, Bob Wallace**

One plan is to use the recruiting model, in which an old member recruits at least one new member each year.

Need to develop other outreach methods, including advertising in AIBS journals, presentations at other national meetings, etc.

**ii. Constitution: Margaret Waterman, Terry Derting**

Issues relating to updating and improving the steering committee handbook, constitution and bylaws were raised and tabled to be discussed further with new members of the SC. Issues include: removal of nonparticipating elected members of the board, increasing the President's term to two years, internet committee responsibilities, duties of members at large, policies for design and content of ACUBE web page.

Discussed procedures for approval of changes to these documents.

**iii. Nomination and elections: Janet Cooper**

No nominees for President. Lynn Gillie was nominated in committee and was approved.

Several nominees for steering committee

Two nominees for secretary.

Discussion of the procedure for distributing and collecting ballots at Friday evening's social events.

**iv. Internet committee: No chairman present**

Issues discussed include: Identification and reallocation of duties for those involved in posting ACUBE information on the web. Proposed is: *Bioscene* and other ACUBE publications AND the technical manager of the website

Managing editor: prepares information, announcements, links, etc. Posted by technical editor.

**v. Honorary Life and Carlock Awards: Bill Brett**

Plaque for honorary life is ready. Charlie Bicak will present.

No Carlock awardees this year. Discussion of revision of the guidelines to include undergraduates interested in eventually entering college biology teaching.

**vi. Resolutions: Brenda Moore**

Agreed to prepare resolutions for host and others as needed.

**vii. *Bioscene* report: Tim Mulkey and Ethel Stanley**

Brief report of numbers of issues, circulation. Additional information at the second meeting on Saturday.

**E. Logo for ACUBE**

The new logo was approved for use by ACUBE

**ACUBE 47<sup>th</sup> Annual Meeting  
Truman State University  
First Business Meeting  
October 10, 2003**

**Place:** Georgian Room

**Present:** ACUBE membership

**Time:** 12:45 p.m.

**I. Call to Order: Margaret Waterman**

The meeting was called to order by President Waterman

**I. Announcements**

**A.** A call for submissions for "Out of this World Teaching Ideas" was made.

**B.** Nancy Sanders mentioned that copies of past Kansas State Naturalist Journals were available on a table near the Exhibits. Information was also available on the Human Genome Project and Educational Computer Tools. She added that extra copies of the meeting poster were also available.

**C.** A reminder was given that vegetarian meals would be available for the dinner meeting. A social hour was scheduled at the National Osteopathic Museum from 6-6:45. Special reminder was made that the museum houses a completely dissected human nervous system.

The Museum Bookstore would also be open for ACUBE. The Director of Admissions from the School of Osteopathy would also be available.

- D. A reminder that balloting for officers would take place at the evening meal.
- E. Austin Brooks and Joyce Cadwallader made a call for abstracts for next year's meeting to be held at Wabash College.
- F. Austin Brooks also made a call to increase membership relating how he was approached in 1966. He emphasized that ACUBE members have always been friendly, enthusiastic, and diverse and that meetings were filled with vitality and robusticity.
- G. President Waterman pointed out the new logo as accepted by the Executive Committee earlier that weekend.

## II. New Business

- A. A call for nominations was made and the following slate was put forth.
  - President: Marya Czech
  - Member's at large: Chester Wilson, Cynthia Horst, Conrad Toepfer
  - Secretary: Kathy Marr, Jill Kruper

Ann Larsen moved to close the nominations, Nancy Sanders seconded the motion. The motion carried. Final balloting as mentioned above would occur at the evening meeting.

The meeting adjourned; Nancy Sanders introduced the keynote speaker; Dr. Judith Dilts. Her presentation was titled, "The challenges ahead in educating 21<sup>st</sup> century biologists".

# ACUBE 47<sup>th</sup> Annual Meeting

## Truman State University Second Business Meeting October 10, 2003

**Place:** Still National Osteopathic Museum

**Present:** ACUBE membership

**Time:** 6:45 p.m.

### I. Call to Order: Margaret Waterman

The meeting was called to order by President Waterman.

### II. Announcements

- A. Next year's meeting is at Wabash College. Brochures were distributed.
- B. Ann Larson suggested we accumulate ideas for *Bioscene* articles.
- C. President Waterman presented the award for "Out of this World Teaching Ideas". The award went to Wyatt Hoback for his 'survivor idea' awarding extra credit for cricket and worm eating.
- D. Charles Bicek presented the Honorary Lifetime Membership to Dr. Marvin Williams, member since 1967 and nominee for president in 1993.
- E. Nancy Sanders reminded of Breakfast meeting at 7:30 Saturday October 11, 2003
- F. The Editorial meeting for *Bioscene* was to be at 7:45.
- G. Terry Derting asked for resolutions for the final business meeting.

### III. New Business

The meeting moved to the lecture hall and Dr. Philip Wilson presented the Keynote lecture titled "Kirkville's Harry Laughlin (1880-1943): Applying Classroom Genetics for the 'Betterment' of Humanity".

The ballots were counted and the new slate of officers was announced.

They were as follows: Lynn Gillie, President Elect

Jill Kruper, Secretary

Brenda Moore, Conrad Toepfer, Members at Large.

The meeting adjourned at 9:00 pm.

## **ACUBE 47<sup>th</sup> Annual Meeting Truman State University 2<sup>nd</sup> Steering Committee Meeting October 11, 2003**

**Place:** Science Building, Rm. 2034

**Present:** Austin Brooks, Joyce Cadwallader, Terry Derting, Lynn Gillie, Brenda Moore, Tim Mulkey,  
Nancy Sanders, Ethel Stanley, Conrad Toepfer, Margaret Waterman

**Time:** 12:30 pm

#### **I. Call to Order: Terry Derting**

Terry Derting welcomed new members Lynn Gillie (President –Elect), Jill Kruper (Secretary), and Conrad Toepfer, Brenda Moore (Members-at-Large)

#### **II. Motion to approve agenda M/S/A**

#### **III. Current and Continuing Business**

##### **A. Current local Arrangements – Nancy Sanders**

Sixty-four participants attended the meeting not counting spouse/guests.

Nancy recommended that it would be helpful to receive an early email of participants who are thinking of coming to the meeting and participants who think that they will be registering on-site.

Nancy passed out a registration form, evaluation form, and a reimbursement form for speakers that could be used for upcoming meetings.

She also recommended having participants pay an additional fee if registering late for the annual meeting. In addition, she proposed fees for K-12 teachers and graduate and undergraduate students.

Aus Brooks will receive all copies of files that Nancy has compiled.

##### **B. Financial Reporting of Annual Meeting – Nancy Sanders**

Nancy gave out a summary of finances for the meeting. All expenses were paid for through meeting fees. She will send an updated expense report to Terry Derting.

She will write thank-you letters to people at Truman for their efforts and give student helpers gift certificates.

Winston Vanderhoof has the template for the new ACUBE logo.

### **C. Program Chair Report- Lynn Gillie**

All presenters arrived or had substitutes for their presentations. Saturday's attendance of talks was low but OK. Lynn suggests 1) it would be helpful to receive list of presentations as early as possible, 2) if presenters are late in their submission to the meeting, they may not be accommodated due to logistics problems in rescheduling.

Lynn has Excel files of names, addresses, etc. along with a template for the program.

Margaret Waterman asked if the three fieldtrips worked out OK. Lynn does not think any of the field trips detracted from participation in sessions.

### **D. Standing Committees**

#### **i. Membership – Aus Brooks**

Aus proposed recruiting people from each state. He would like several potential members in each state to be contacted via email, regular mail, and a follow-up with a phone call. He would like to see a 10% increase in membership. Conrad Toepfer will serve on this committee.

Terry Derting will forward information on advertising space in *BioScience* to Aus once she receives new issues. Aus will develop an advertisement to be published in *BioScience* and *Bioscene*.

#### **ii. Constitution – Margaret Waterman**

Constitutional by-laws and Hand Book revisions will be given out in the winter meeting. There is no description of the duties for a Member-at-Large. There is also nothing written if people do not do their duty. Items tabled until winter meeting. M/S/A

#### **iii. Nomination – Aus Brooks**

Lynn Gillie suggested spreading out the time-line for nominations. People need to be approached as early as possible so CVs could be printed in *Bioscene*. It was suggested that nominations be made for the following year during the current meeting.

Current Recommendations-

Steering Committee - Marya Czech, Wyatt Hoback, Peter White Greg Grabowski and Bobby Lee

President – Bob Wallace, Cynthia Horst

#### **iv. Internet**

Buzz Hoagland will step down as chairperson of the committee. Margaret Waterman volunteered to chair the committee. A committee is needed that will report to the board to help move towards more policy. Terry will inform Buzz Hoagland of changes in the committee composition.

#### **v. *Bioscene* Report – Tim Mulkey and Ethel Stanley**

*Bioscene* editorial board added two new members, Karyn Turla and Jill Kruper. An updated list will be sent to Terry Derting. It was recommended that non-members should have to pay page-charges to help cover costs. Items were tabled until the winter meeting.

#### **vi. Honorary Life and Carlock Award – Tim Mulkey (for Bill Brett)**

Carlock Award changes – Tim read the proposed changes in the Carlock Award. The award would change to include graduate students *and* upper-class undergraduates. Margaret Waterman moved to accept. M/S/A

The text of the changes will be given in the winter meeting and will be published in the December issue of *Bioscene*.

**vii. Resolutions**

Brenda Moore agreed to Chair this committee.

**E. Arrangement for Approval of Minutes**

Margaret Waterman asked that the minutes be approved as quickly as possible. Terry Derting suggested that drafts of the minutes for the 2003 annual meeting be submitted to her by November 15. The board proposed approving the minutes by the end of the year and being published in the March issue of *Bioscene*.

**F. Future Meeting Site**

- i. **2004 Wabash College, Crawfordsville, IN**
- ii. **2005 Southeast Missouri State U., Cape Girardeau, MO**
- iii. **2006 Carroll College, Waukesha, WI**
- iv. **2007** - Possibilities include Murray State University, Milliken, ISU in Normal and U. of Illinois in Springfield. Items tabled until the winter meeting.

**G. 2005 Meeting**

**i. Program Chair**

Proposed Program Chair – Greg Gabowski, Conrad Toepfer  
Tabled until the winter meeting.

**ii. Meeting Dates**

Most likely October 13-15

**iii. Theme**

An interdisciplinary theme was proposed. Tabled until winter meeting.

**IV. Planning for the 2004 meeting – Aus Brooks, Joyce Cadwallader**

**A. Speakers**

Aus stated that there are several options including a person from the Indianapolis zoo that can talk about the first African elephant born by artificial insemination and an individual from Purdue that developed a biotech company and has an interesting story to tell. John Jungck could talk about the BEDROCK project. There may also be possibilities through NASA.

Joyce Cadwallader will ask John Jungck to speak. Aus Brooks will work on other speakers.

**B. Field Trips**

The options include a trip to fossil beds, bird-watching, and a trip to a State park that has relic hemlocks.

**V. New Business –**

**A. Arrangements for the upcoming winter meeting**

A date was set for January 30-31, 2004. An ice/snow date was set for February 20-21.

Meeting adjourned 2:40 pm.

Respectfully submitted October 12, 2003

Jill Kruper, Secretary ACUBE

## ACUBE Governance for 2004

**President** – Terry Derting, *Murray State University*

**President-Elect** – Lynn Gillie, *Elmira College*

**Immediate Past President** – Margaret Waterman, *Southeast Missouri State University*

**Executive Secretary** – Presley Martin, *Hamline University*

**Secretary** – Jill Kruper, *Murray State University*

**First Vice President** (Program Chair) – Joyce Cadwallader, *St. Mary-of-the-Woods College*

**Second Vice President** (Local Arrangements) – Aus Brooks, *Wabash College*

### Board Members

Abour Cherif, *DeVry University*

Janet Cooper, *Rockhurst University*

Neil Grant, *William Patterson University*

Brenda Moore, *Truman State University*

Conrad Toepfer, *Millikin University*

Robert Wallace, *Rippon College*

### Standing Committees

**Membership** – Aus Brooks, *Wabash College*

**Constitution**– Margaret Waterman, *Southeast Missouri State University*

**Nominations** – Janet Cooper, *Rockhurst University*

**Internet**– Margaret Waterman, *Southeast Missouri State University*

**Bioscience** – Tim Mulkey, *Indiana State University*; Ethel Stanley, *Beloit College*

**Awards**: Honorary Life Award and Carlock Award – William Brett, *Indiana State University*

**Resolutions**– Brenda Moore, *Truman State University*

**Historian** – Edward Kos, *Rockhurst University*

## Call for Nominations Honorary Life Award

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

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

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

# ACUBE

## Association of College and University Biology Educators

NAME: \_\_\_\_\_ DATE: \_\_\_\_\_

TITLE: \_\_\_\_\_

DEPARTMENT: \_\_\_\_\_

INSTITUTION: \_\_\_\_\_

STREET ADDRESS: \_\_\_\_\_

CITY: \_\_\_\_\_ STATE: \_\_\_\_\_ ZIP CODE: \_\_\_\_\_

ADDRESS PREFERRED FOR MAILING: \_\_\_\_\_

CITY: \_\_\_\_\_ STATE: \_\_\_\_\_ ZIP CODE: \_\_\_\_\_

WORK PHONE: \_\_\_\_\_ FAX NUMBER: \_\_\_\_\_

HOME PHONE: \_\_\_\_\_ EMAIL ADDRESS: \_\_\_\_\_

### MAJOR INTERESTS

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

### SUB DISCIPLINES: (Mark as many as apply)

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

RESOURCE AREAS (Areas of teaching and training): \_\_\_\_\_

RESEARCH AREAS: \_\_\_\_\_

How did you find out about ACUBE? \_\_\_\_\_

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

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

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



# BioQUEST

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

We invite you to become involved in BioQUEST - attend a workshop, collaborate on a project, or explore a computer simulation!

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**SYSTEMS  
BIOLOGY  
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Saturday, June 12  
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BELOIT  
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## Modeling in Bioinformatics

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October 21 - 24, 2004

 **Lane**  
Community College

## Mammalian Bioinformatics

Bar Harbor, Maine

November 3 - 6, 2004

**BioQUEST Curriculum Consortium**  
Beloit College  
700 College Street  
Beloit, WI 53511



For more information on these and other BioQUEST Projects:

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