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Stephen S. Daggett
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Bioscene is normally published in March, May, August and December. Please submit manuscripts by November 1, 2006 for consideration in the next issue.

Cover image: Image of a black bear (*Ursus americana*) at Yellowstone National Park provided by Melissa A.F. Daggett.

Articles:

News & Views:

Bioscene: Journal of College Biology Teaching

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The manuscript itself should contain the following:

- Manuscript in RTF (Rich Text File) to facilitate distribution of the manuscript to reviewers and to make revisions.
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- Author(s)
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- A brief abstract (200 words or less), followed by keywords
- Number all pages

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Once the article has been reviewed, the corresponding author will receive suggestions and comments from the reviewers. Acknowledgement of reviewers' comments and suggestions must

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Deadlines for Submissions

November 1, 2006 for December, 2006 Issue **February 1, 2007 for March, 2007 Issue**

The Pesticide Malathion Disrupts *Xenopus* and Zebrafish Embryogenesis: An Investigative Laboratory Exercise in Developmental Toxicology

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Abstract: Malathion is an organophosphorus insecticide, which is often sprayed to control mosquitoes. When applied to aquatic habitats, malathion can also influence the embryogenesis of non-target organisms such as frogs and fish. We modified the frog embryo teratogen assay in *Xenopus* (FETAX), a standard toxicological assay, into an investigative undergraduate laboratory exercise. This exercise provided students with experience in developmental toxicology, experimental design, quantitative morphology, digital imaging, and presentation of research results. Their results demonstrated that *Xenopus* embryos exposed to malathion on the first or second day of development were indistinguishable from controls, while embryos exposed to malathion on the third day of development exhibited significantly bent tails and shorter body lengths. Similarly, sublethal malathion exposures also compromised early zebrafish development. To determine if this investigative laboratory exercise met its goal of fostering conceptual understanding of developmental toxicology, we compared student performance on a questionnaire before and after the laboratory exercise, which demonstrated significant improvement in conceptual understanding. Moreover, all (45/45) students successfully completed a modified FETAX and prepared posters of their results, indicating that students learned quantitative morphology and imaging skills while also gaining valuable experience in designing, executing, and communicating an experiment.

Keywords: undergraduate, *Xenopus*, zebrafish, malathion, developmental biology, environmental biology, laboratory exercises, toxicology

Introduction

Development is a critically sensitive period where changes in environmental conditions can alter the normal program of embryogenesis (Gilbert, 2001). The limb malformations of children exposed to thalidomide (Newman, 1986; Stephens and Brynner, 2001), cognitive difficulties in children with fetal alcohol syndrome (Dorris, 1989; Mattson *et al.*, 2001), and concerns when retinoids are used as acne treatments for women of child-bearing ages (Lammer et al., 1985; Ross et al., 2000) provide dramatic evidence for the existence of sensitivity to external factors and critical periods in human embryogenesis. Such striking examples of windows of sensitivity to teratogens often capture considerable attention and interest from undergraduate students.

Amphibian and fish embryogenesis are sensitive to environmental factors including temperature, pH, nutrient levels, or chemicals such as pesticides. Malathion, an organophosphorus (OP) insecticide, is frequently sprayed on aquatic habitats and crops to control soft-bodied insects such as mosquitoes and boll weevils. Approved for residential, agricultural, and public health uses, OPs account for half of the total insecticide use in the U.S. (Environmental Protection Agency, 1998). OP insecticides are particularly favored in agriculture because they are inexpensive, kill a wide variety of insects, rarely lead to resistance, and degrade relatively quickly (Kumar and Ansari, 1984; Environmental Protection Agency, 1998). Malathion, like all OPs, acts by inhibiting the enzyme acetylcholinesterase (AChE), which is present in cholinergic synapses and prevents excessive stimulation of postsynaptic neurons and muscles by breaking down the neurotransmitter acetylcholine (ACh) (Alam and Maughan, 1992). While malathion's toxicity is targeted to invertebrates, non-target organisms are often exposed during pest control events (Hall and Kolbe, 1980). Despite malathion's rapid degradation, even brief exposure can alter the development of non-target

animals, particularly aquatic vertebrate embryos (Cook et al., 2005). Thus, the influence of the pesticide malathion on the development of non-target, aquatic embryos is of considerable environmental relevance. Recently, vigorous debate on pesticide testing in humans has highlighted the importance of understanding how chemicals influence human health (Skokstad, 2005; Resnick and Portier, 2005).

FETAX (frog embryo teratogen assay: *Xenopus*) is a common toxicological method used to evaluate a substance's ability to disrupt normal development (Davies and Freeman, 1995). FETAX is a simple test that rears recently fertilized *Xenopus laevis* embryos in a solution containing the potential teratogen. External tadpole morphology is assessed after 96 hours of exposure and any substance is considered a teratogen if it causes significant alterations in external tadpole morphology. Because numerous mechanisms of development are conserved between vertebrate species, substances that impair *Xenopus* development may potentially impair the development of other vertebrates, including humans (National Toxicology Program Interagency Center for the Evaluation of Alternative Toxicological Methods & National Institute of Environmental Health Sciences, 2000).

Recent widespread declines in amphibian populations (Blaustien and Wake, 1990; Stuart et al., 2004) make collecting native embryos potentially threatening to local populations and ecology. As an alternative, the South African clawed frog, *Xenopus laevis*, is ideal for developmental toxicology research because *Xenopus* are commercially available, reproduce year round, produce large numbers of eggs that can be fertilized *in vitro*, and embryonic development is exceptionally well documented (Nieuwkoop and Faber, 1956; Xenbase, 2005). Similarly, the zebrafish (*Danio rerio*), a more recent model vertebrate, provides comparable advantages of rapid development, year-round fertilization, large clutch size, transparent embryos, and well-documented embryology, with the additional advantages that the genome is well characterized and many mutant and transgenic fish are readily available and amenable to developmental toxicology studies (Westerfield, 200; Grunwald and Eisen, 2002; Spitsbergen and Kent, 2003; Bradbury, 2004; Hill et al., 2005; Zebrafish Information Network, 2005).

FETAX analysis has shown that malathion exposure causes pigmentation abnormalities, severe edema, and abnormal gut and notochordal bending in tadpoles (Snawder and Chambers, 1989). Moreover, *Xenopus* embryos were specifically sensitive to malathion's teratogenic effects in discrete developmental windows (Snawder and Chambers, 1990). In order to provide undergraduates in a developmental biology course with opportunities to examine the sensitivity of *Xenopus* embryos to malathion's teratogenic effects, we modified the FETAX into an investigative laboratory exercise. Our goals for this exercise were for students to 1) work with developing *Xenopus* embryos, 2) design a FETAX experiment, 3) execute the experiment they designed, 4) use imaging software to quantify embryo morphology, and 5) understand important concepts in developmental toxicology such as teratogens and critical windows of sensitivity. Moreover, this example of an investigative laboratory experience is consistent with current science pedagogy that encourages undergraduate courses to provide opportunities to learn science in the way science is done, specifically by encouraging students to propose and test hypotheses in quantitative ways (McNeal and D'Avanzo, 1997; National Research Council, 1997, 1999, 2000a, 2000b, 2003). This participatory, inquiry-based approach to laboratory exercises is favored over traditional "cookbook" labs, because in the design, execution, and communication of an experiment students experience the process and excitement of research methods and they have opportunities to think independently and creatively.

Methods

Xenopus laevis embryos

Xenopus laevis embryos were obtained by *in* vitro fertilization and staged visually according to pictorial staging tables (Nieuwkoop and Faber, 1956; Cebra-Thomas, 2003; Graham et al., 2005; Xenbase, 2005). Adult females (Xenopus One) were induced to superovulate by subcutaneously injecting 600 units human chorionic gonadotropin (Sigma). The next morning eggs were manually extirpated from the superovulating females into sterile plastic dishes containing a modified rearing (MR) solution (also known as 20% modified Steinberg's solution: 60 mM NaCl, 0.67 mM KCl, 0.3 mM $Ca(N0_3)_2$, 0.83 mM $MgSO_4$, 10 mM HEPES, and 40 mg/L gentamycin, pH 7.4) (Keller, 1991). Eggs were immediately mixed with a small piece of crushed testes, harvested from an adult male within the previous week, which had been stored in 5X sterile MR at 4 °C. About 30 minutes after fertilization (at room temperature) cortical rotation was observed, which was indicated by most eggs oriented with the dark (animal) pole facing up. About 90 minutes after fertilization the first cleavage occurred and the eggs were clearly divided into two symmetrical blastomeres. After several more rounds of mitosis, asymmetric blastomers became apparent. To make embryo distribution and handling more convenient, jelly coats were removed from cleaving embryos (stages 2-8) by brief immersion in 2% (w/v) cysteine in MR just long enough until the jelly coats had dissolved (usually less than five minutes). All dejellied embryos were

then thoroughly rinsed with at least three changes of MR and placed in new plastic petri dishes. Fertilizing eggs at approximately 9:00 AM conveniently provided stage 6-8 blastulas for a laboratory session that started at 1:00 or 1:30 PM. *Xenopus* can be obtained from a variety of providers (Xenopus One, Nasco, Carolina). Helpful manuals (Carolina Biological, 1993; Sive et al., 2000) and media (Grainger and Sive, 1999; Pickett-Heaps and Pickett-Heaps, 1999; Tyler and Kozlowski, 2003) are available for more detailed information on *Xenopus* husbandry, techniques, and development. All animal procedures were approved by Davidson's Institutional Animal Care and Use Committee.

Zebrafish embryos

Adult zebrafish from a local pet store were maintained in 5 L aquaria at 27-28°C, pH range 6.8-7.5 with high dissolved oxygen levels (83-87% saturation), and a 14:10 hour light:dark photoperiod. The fish were fed a rotating diet of commercial flake food, frozen brine shrimp, and bloodworms. Eggs were obtained as described by Westerfield (2000) with modifications per Cook et al. (2005). Three to four zebrafish (at least two females and one male) were placed into homemade false-bottom plastic containers before the dark period began. When the light period began, the fish laid and fertilized eggs that fell through the false-bottom grids and collected in a container below that was inaccessible to the adults who would otherwise consume the eggs. Within two hours, adult fish were returned to the aquaria and eggs were transferred to a glass finger bowl using a plastic pipette (with the tip cut off to minimize chorion damage during transfer). Embryos were rinsed once with clean tank water and then observed under a stereomicroscope to discriminate between fertilized and unfertilized eggs. Fertilized eggs were identified by the presence of distinct blastomeres, while unfertilized eggs were often milky and lacked discernable blastomeres. Shortly after fertilization, zebrafish embryos were reared in tank water that included malathion for exposure durations lasting up to 120 hours. Helpful laboratory manuals for research (Westerfield, 2000; Nusslein-Volhard and Dahm, 2002) and teaching (Tyler, 2003) as well as websites (Zebrafish Information Network, 2005) are available for more detailed information on zebrafish care and techniques. Movies of early zebrafish development are also available (Kane and Warga, 1991; Kane and Karlstrom, n.d.; Karlstrom and Kane, 1996) on the internet as are zebrafish staging tables (Kimmel et al., 1995; Cebra-Thomas, 2001) to help students identify embryo stages and anatomical structures.

Malathion solutions

Malathion solutions, widely available to consumers in the pesticide section of most home and garden stores, are frequently sold as 50% solutions with labels indicating that the pesticide is harmful to amphibian embryos. Manufacturer's guidelines for consumer use of malathion suggest application of malathion at approximately 34 g/L. We conducted preliminary FETAX experiments using two different commercial malathion solutions diluted to 0.001% (v/v) in MR. We observed that aqueous solutions of commercial malathion stored at room temperature often formed a white precipitate and its potency changed with storage. 0.001% (v/v) solutions of commercial malathion caused obvious developmental deformities in *Xenopus* embryos, though with inconsistent efficacy (data not shown). Consequently, we recommend that instructors who wish to use commercial malathion should dilute the 50% solution immediately before use and avoid prolonged storage. Further, neither of the two commercial malathion solutions we purchased identified the constituents of the other 50% of the solution, making it impossible for students to design appropriately controlled experiments. Given the disadvantages of using commercial malathion, all results reported here were obtained with pure (99.5%) malathion from a chemical supplier (Supelco). While the cost of purified malathion was approximately $50 more than consumer products, the pure malathion produced more consistent results, permitted longer storage of stock solutions, and allowed students to design appropriately controlled experiments. We diluted malathion in acetone to generate a stock solution of 10 g/L, which was stored at 4°C in glass bottles shielded from light with aluminum foil. Working malathion solutions were diluted in MR immediately before use with *Xenopus* or were diluted in tank water for use with zebrafish embryos.

Modified FETAX procedure

Approximately 20 properly cleaving dejellied stage 6-8 (Nieuwkoop and Faber, 1956) *Xenopus* embryos were placed in a total of 50 mL of MR solution (untreated), MR + acetone (vehicle control), or MR + malathion) in 100 mm plastic Petri dishes at room temperature. To determine a window of sensitivity to malathion, groups of embryos were exposed to malathion concentrations for day 1 (0-24 hours), day 2 (24-48 hours), or day 3 (48-72 hours) of development. Sibling embryos were reared in malathion for the entire three day period (0-72 hours). All solutions were changed at 24 hour intervals to control for any effects of embryo handling. When embryos were removed from malathion they were rinsed three times with MR and

subsequently reared in a fresh dish of MR. After 72 hours tadpoles reached stages 41-42 of development (Nieuwkoop and Faber, 1956). They were anesthetized in MR containing anesthesia (0.05% (w/v) MS-222 at pH 7.4) for approximately five minutes before fixation in 1% (v/v) gluteraldehyde in phosphate buffered saline (PBS). Tadpoles were fixed at 4 °C for 1-30 hours, then rinsed thoroughly with at least four changes of PBS and stored in PBS at 4 °C until morphological analysis.

Morphological analysis

To capture digital images of each tadpole or zebrafish for quantitative morphology we used CoolPix 995 cameras (Nikon) mounted on the eyepieces of stereomicroscopes via MMCOOL adaptors (Martin Microscope, Easley, SC). The free digital imaging program, ImageJ (rsb.info.nih.gov/ij) was used to measure tadpole (or zebrafish) morphology. A best-fit midline of each embryo was manually traced along the spine using a segmented line. The axis angle was defined as the angle formed between the embyro's posterior spine and a straight line extending from the anterior spine. Similarly, the length of each embryo was determined by drawing a line along the axis of the embryo from the cement gland (anterior) to the tip of the tail (posterior).

Statistical analysis

Using Minitab software (Release 13.3 for Windows), analyses of variance (ANOVAs) were performed on the two response variables of axis angle and body length (both $\log_{10}$-transformed to approximate normality). The statistical model was a one-way ANOVA with the ten treatments (eight treatments and two controls) as a fixed effect and nested within trial. If a trial was determined to be non-significant, as it was for log-transformed axis angle, we combined all trials to determine overall treatment effects. This approach allowed us a more robust assessment of treatment effects, regardless of trial effects. Tukey pairwise comparisons were used to compare the average response among the ten groups. For body length, because of significant trial effects, we performed the ANOVA separately for each trial so the Tukey test could be used to determine treatment effects within a trial instead of across treatment-trial combinations, which would have been unwieldy due to forty different combinations. The alpha level was set at 0.05.

Malathion FETAX as a laboratory exercise

The malathion FETAX laboratory exercise was adapted into an investigative laboratory exercise in Biology 306 (Developmental Biology), an upper level laboratory course at Davidson College that enrolled 15 students in 2003 and 30 students in 2004, most of whom were biology majors. Laboratory sections consisted of 6-16 students and were taught by the course instructor (BL). Students had been introduced to staging embryos with pictorial staging tables, using digital cameras on double-headed stereomicroscopes, generating scale bars and calibrating software, analyzing morphology with ImageJ, and preparing figures with Adobe PhotoShop software in previous laboratory sessions (Figure 1). In preparation for this developmental toxicology laboratory, students were required to read a brief laboratory handout that outlined the exercise and suggested avenues for experimentation (Appendix I) and a short section in their textbook on teratogens (Gilbert, 2003). At the start of the laboratory session, the instructor briefly introduced malathion's use as an insecticide, the concept of teratogens, and FETAX procedures. Students then designed experiments employing FETAX to assess malathion's influence on *Xenopus* development by developing a plan and discussing that plan with classmates and the instructor. Students were then invited to design an experiment that tested a single variable of their own choosing such as duration of treatment, embryonic stage at treatment, or pesticide concentration, *etc*. Healthy embryos at various stages of development, the 10 g/L stock solution of malathion, acetone, and MR were provided at the beginning of the laboratory period for students to use in their experiments. Students wore protective gloves and worked in a chemical fume hood while handling the acetone and malathion. Allowing students to dilute the stock malathion (and control acetone) into working concentrations provided valuable reinforcement of the practical lab skills required to prepare solutions. Because a specific goal of this exercise was to allow students to quantify morphological features of malathion-treated embryos (using techniques they had been introduced to in previous laboratory sessions), we discouraged students from using lethal concentrations of malathion in their experiments so that they would have viable embryos to measure. Sublethal malathion concentrations of 1.0-2.5 mg/L were recommended as reasonable concentrations for experimentation, though students were free to select other concentrations for their experiments. A traditional three-hour laboratory period provided ample time for the instructor to consult with each of the 6-16 students regarding experimental design and for students to set up a FETAX experiment of their own. A typical FETAX rears embryos for 96 hours, however we modified the assay to 72 hours so that weekend laboratory work was not required. Students worked alone (2003) or with a laboratory partner (2004) and were responsible for returning to the laboratory on their own time to change solutions and fix embryos as their individual experimental designs dictated (Figure 1). The subsequent scheduled laboratory period provided open working time for

students to acquire images, analyze their results, and discuss their findings. For communication and evaluation purposes, students were required to submit two color copies of a small scientific poster (8.5 x 11 inch) illustrating their experiment and results. One copy was posted in the laboratory as a way for students to share their results with their classmates and the other copy was graded by the instructor (BL).

Pre	**Scientific skills introduced in previous laboratory periods:** • Introduction to pictorial tables to stage *Xenopus* embryos • Introduction to ImageJ to measure distances on magnified images • Introduction to using Photoshop to assemble figures & scale bars
Week 1	**Formal 3-hr laboratory period** • Experimental design (written plan & consultation) • Experiment execution (placing embryos in appropriate solutions) **Students return to lab on their own time** • Experiment execution (change solutions, fix embryos, *etc*.)
Week 2	**Formal 3-hr lab period** • Data collection (capturing digital images of embryos) • Data analysis (measuring embryo morphology) • Data interpretation (identifying conclusions)
Post	**Scientific posters** • Data communication (posters displayed in the laboratory) • Evaluation (posters graded by instructor)

Figure 1. General plan of the malathion developmental toxicology exercise. This investigative laboratory exercise in developmental toxicology was completed in two, traditional afternoon laboratory sessions. Basic embryo staging and digital imaging skills were introduced in an earlier laboratory session and access to the lab after hours was provided so that students could fully execute their experiments.

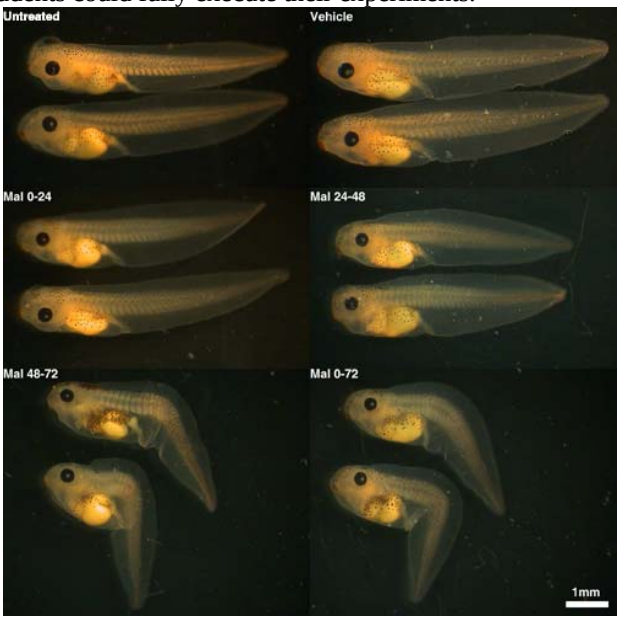


Figure 2. The pesticide malathion disrupts *Xenopus* axis development. Images show typical examples of 72 hour tadpoles representing untreated controls, control tadpoles exposed to vehicle (0.05% acetone), and tadpoles exposed to 2.5 mg/L malathion for one of the three days (0-24 hr, 24-48 hr, or 48-72 hr) or the entire three day period (0-72 hr). Note the dramatic axis deformation in the tadpoles exposed to malathion on the third day of development (Mal 48-72) or throughout the first three days of development (Mal 0-72).

Assessing the Modified FETAX Laboratory Exercise

To determine if students learned the concepts of teratogens, target vs. non-target organisms, and critical periods of development, we administered a brief questionnaire. Students completed this voluntary and ungraded questionnaire twice: first prior to any classroom discussion of teratogens, developmental toxicology, or critical periods (pre-lab) and then again approximately one week after submitting posters reporting their results (post-lab). Specifically the questionnaire asked: 1. What is a teratogen? 2. What is a target organism? 3. What is a non-target organism? 4. Compare how pesticides affect target and non-target organisms. 5. What is a sensitive period? Each questionnaire was independently scored several weeks later by two individuals (2003 – DCC and BL; 2004 – IRW and BL) who were each blind to the students' names and whether a questionnaire was completed pre- or post-lab. Each response was scored on a scale from zero to three with zero demonstrating no understanding of the question material and three demonstrating a secure understanding of the question material. The scores from the two graders were then averaged together. Paired t-tests were performed on the pre-lab versus post-lab scores using Prizm (GraphPad). Assessment methods were approved by Davidson College's Human Subjects Internal Review Board.

Results

Control and malathion treated embryos reliably developed to stage 41-42 in 72 hours (Figure 2). Vehicle-treated tadpoles developed indistinguishably from control tadpoles, indicating that the small volume of acetone used to dissolve the malathion had no demonstrable effects on *Xenopus* embryogenesis. In contrast, tadpoles treated with malathion exhibited dramatically bent morphologies that were clearly visible to eyes unfamiliar with *Xenopus* embryo development (Figure 2). To evaluate the extent of axis deformation the angle of deviation between the anterior and posterior axes was measured for each tadpole. *Xenopus* tadpoles exposed to 1.0 or 2.5 mg/L malathion either on the third day of development (48-72 hours) or throughout the three-day experiment (0-72 hours) exhibited significantly bent axes ($F = 70.57$; $df = 9, 910$; $P < 0.0001$; Figure 3) and were shorter in length than control embryos ($F = 52.00$; $df = 36, 879$; $P < 0.0001$; Figure 4). Thus, the effects of malathion on external *Xenopus* embryo morphology were reliable and dramatic.

In addition to axis and length abnormalities, malathion treatment also resulted in tadpoles that did not swim as frequently or as rapidly as the controls (Chemotti and Lom, *personal observation*). When these tadpoles with bent axes did move, they swam in circles, unlike control tadpoles that could swim in straight trajectories.

In addition to the dramatic and easily measurable effects of malathion on *Xenopus* embryos, a subset of undergraduates pursuing independent study projects demonstrated that zebrafish embryogenesis is also sensitive to similar malathion concentrations when treated for 96 hours (Figure 5). Zebrafish embryo lengths, eye diameters, abdominal areas, hatching schedule, heart rate, and AChE activity are altered by malathion exposure (Cook *et al.*, 2005; Davis, Rose, Garren, Hodge, and Lom, unpublished). Thus this laboratory exercise can be easily adapted to other aquatic vertebrate species such as zebrafish to provide novel research experiences in developmental toxicology.

To assess student learning via this malathion FETAX laboratory exercise, performance on pre-lab and post-lab questionnaires was compared (Figure 6). All students who completed both surveys scored higher on the post-lab survey than they did on the pre-lab survey, indicating that understanding of concepts such as teratogens and sensitive windows of development was enhanced after completing this investigative exercise. Paired t-tests for each question revealed that student performance was significantly improved ($P < 0.05$) after completing the laboratory exercise.

Discussion

Malathion exposure on the third day of development (via 48-72 hr or 0-72 hr exposures) induced significant and dramatic axis deformation and shortened lengths of *Xenopus* embryos. These results indicate that the third day of development in *Xenopus* is a critical window of sensitivity to malathion's teratogenic effects. While this 72 hr, modified FETAX revealed a critical window in which *Xenopus* sensitivity to malathion's teratogenic effects begins, longer experiments to determine if and when *Xenopus* tadpoles cease to be sensitive to malathion's teratogenic effects could be designed and conducted by undergraduates. Similarly students could design longer-term experiments to determine if brief, early exposure to a pesticide exerts long-term effects on tadpole morphology, physiology, or behavior.

Whereas malathion is an acetylcholinesterase (AChE) inhibitor, the mechanisms by which the pesticide causes axis deformation are not well understood, but may be related to the integrity of the extracellular matrix. The 48-72 hour sensitivity window to malathion coincides with a period of increased collagen synthesis in *Xenopus* development (Green *et al.*, 1968). Collagen makes up the notochord sheath and

malathion induces abnormalities consistent with collagen defects, including bent notochords, circulatory defects, and shortened body lengths

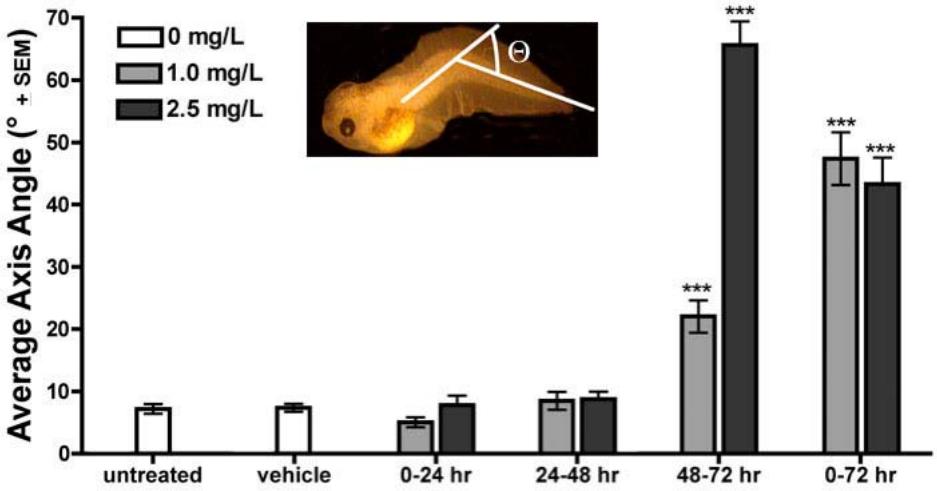


Figure 3. Malathion significantly bends the axes of developing *Xenopus*. When exposed to 1.0 or 2.5 mg/L malathion on the third day of development (48-72 hr) or for the first three days of development (0-72 hr) tadpoles axes were significantly more bent than untreated or vehicle-treated control tadpoles. Inset image demonstrates how axis angles ( ) were measured. *** = $p < 0.001$ when compared to controls. N=920 tadpoles total from four separate experiments.

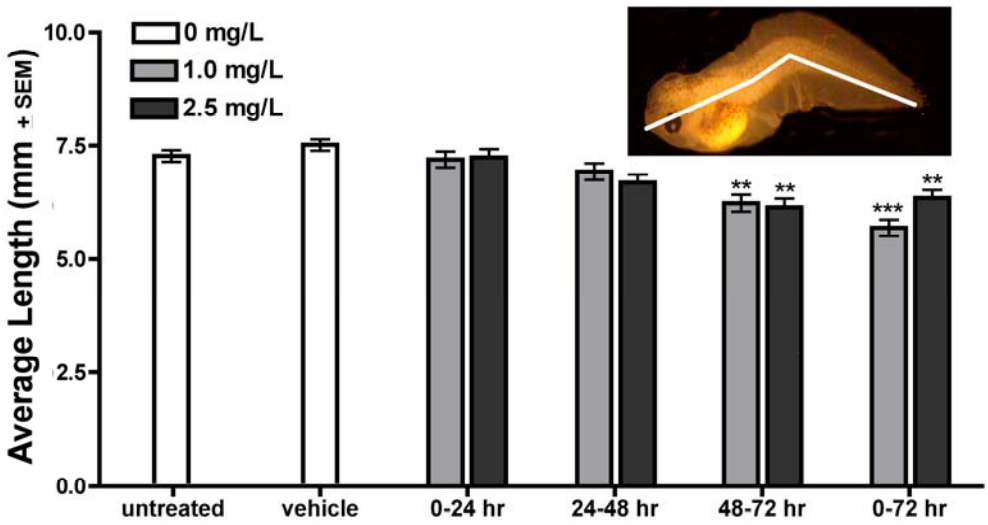


Figure 4. Malathion significantly shortens developing *Xenopus*. When exposed to 1.0 or 2.5 mg/L malathion on the third day of development (48-72 hr) or for the first three days of development (0-72 hr) tadpoles were significantly shorter than untreated or vehicle-treated controls. Inset image demonstrates how lengths were measured. ** = $p < 0.01$, *** = $p < 0.001$ when compared to controls. N=920 tadpoles total from four separate experiments.

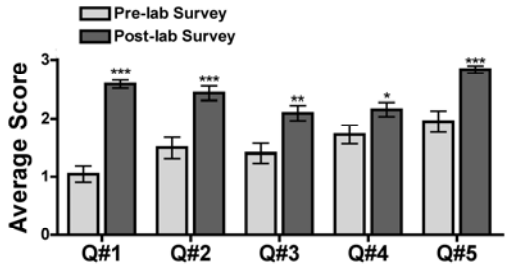
(Snawder and Chambers, 1990, 1993). Thus, disruptions of the notochord sheath may contribute to abnormal bending and/or shortening of the embryo. Additionally, malathion affects ascorbic acid, hydroxyproline, lysyl oxidase, and NAD^+ (Snawder and Chambers, 1989, 1993). Proper hydroxyproline levels are necessary for the formation of collagen's triple helix, which allows fibroblasts to release collagen (Deyl and Adam, 1989). In

Figure 5. Malathion also alters zebrafish axis development. Undergraduates can also apply FETAX methodologies to zebrafish embryos. Images show typical examples of 96 hour zebrafish representing control embryos continuously exposed to vehicle (0.05% acetone), or 2.5 mg/L malathion for 96 hours. Similar to results with *Xenopus*, pesticide-treated zebrafish embryos exhibited axis deformations, shorter lengths, and smaller eyes (see Cook *et al.*, 2005).

Xenopus, malathion reduces ascorbic acid and hydroxyproline levels and inhibits collagen proline hydroxylase, resulting in a reduced number of extracellular collagen fibers. Even though total collagen amounts are unaffected, this may suggest that malathion may target collagen extracellular transport and crosslinking (Snawder and Chambers, 1993). Since lysyl oxidase aids in proper extracellular collagen cross-linking and is more sensitive to malathion than proline hydroxylase, malathion's axis deformation may be a result of reduced lysyl oxidase activity (Snawder and Chambers, 1993).

The concentrations of malathion employed in this modified FETAX (1.0 and 2.5 mg/L) are lower than recommended malathion application concentrations (estimated at 34 g/L per manufacturer's guidelines), and higher than aquatic malathion concentrations detected after application. Reported malathion concentrations in a shallow wetland ranged from <0.002 - 0.015 mg/L after malathion spraying for mosquito control (Fordham *et al.*, 2001). Lower concentrations (<0.00016 mg/L) were detected in running water of an urban stream (Kimbrough and Little, 1996). While environmental malathion concentrations are lower than the malathion concentrations tested in this exercise, several studies have shown that higher concentrations of organophosphates can occur in small, shallow ponds, which are prime breeding habitats for amphibians (Berrill *et al.*, 1994, 1995; Fordham *et al.*, 2001). Moreover, pulses of higher pesticide concentrations are likely to occur immediately after application; higher concentrations of malathion can persist in the water for a few weeks following a single mosquito control event (Eichelberger and Lichtenberg, 1971) or for several months when malathion is sprayed more regularly (Fordham *et al.*, 2001). Because malathion is often used in agricultural settings, the resident non-target organisms of neighboring wetlands could be subject to pesticide exposure that is sufficient to compromise embryogenesis.

Tadpoles that develop a bent body axis can suffer severe consequences. A bent axis impedes normal locomotion, which in turn can limit ability to reach food sources and increase the risks of predation and desiccation. While effects beyond 72 hrs of exposure (including metamorphosis) were not examined in this report, it is likely that tadpoles with bent axes could experience impaired locomotion, feeding, and/or difficulty during metamorphosis. Additional examination of other morphological parameters (Altig et al., n.d.), survival, metamorphosis, and/or locomotion in malathion-treated tadpoles provide additional open questions that could readily be addressed by undergraduates as a part of an expanded version of this laboratory



Q#1 What is a teratogen?
Q#2 What is a target organism?
Q#3 What is a non-target organism?
Q#4 Compare how pesticides affect target & non-target organisms.
Q#5 What is a sensitive period?

Figure 6. Students mastered concepts in developmental toxicology. Comparing average scores of pre- and post-lab questionnaires demonstrate that students scored significantly higher in the post-lab survey for each question. Thus by conducting a modified FETAX with malathion, students increased their understanding of important concepts such as teratogens, target organisms, and sensitive periods. Error bars = SEM. * = $p<0.05$, ** = $p < 0.01$, and *** = $p < 0.001$. N = 45 students.

exercise or through independent study situations. We found that many undergraduates were inspired by this 72 hour FETAX experiment to pursue, related studies later in the semester via more open-ended and longer (seven week) experiments of their own design (that did not require students to execute FETAX or study pesticides). Examples of such student projects included: investigating the influence of malathion on heart rate in older *Xenopus* embryos, comparing the effects of malathion on *Xenopus* development with other pesticides such as parathion and chlorpyrifos, examining the influence of malathion on zebrafish development, the influence of malathion on zebrafish heart morphology and rate, and examining the influence of malathion on *Planaria* regeneration. Moreover, many students used their FETAX experience to design more in-depth experiments that investigated the effects of a wide variety of potential teratogens such ethanol, caffeine, retinoids, *etc*. on the development of tadpoles, fish, and chick. Such investigations of teratogens on organisms at various stages of development and regeneration provide both compelling and practical undergraduate research experiences (Cruz, 1993; Keller et al., 1999; Johnson, 2001; Gibbs, 2003; Tyler, 2003; Mari-Beffa and Knight, 2005).

This modified FETAX assay successfully attained its objectives of providing students with an investigative laboratory experience in which they: 1) worked with developing *Xenopus* embryos, 2) had significant control over experimental design, 3) had full control over experimental execution, 4) used imaging software to quantify embryo morphology, and 5) had first-hand opportunities to understand the concepts of teratogens and critical windows of sensitivity. 100% (45/45) of the undergraduates successfully designed and executed their own, appropriately controlled variation of a FETAX. Their scientific posters (Appendix II) demonstrated that they had acquired skills to: work successfully with *Xenopus* embryos (aim 1), design experiments (aim 2), execute the experiments (aim 3), quantify embryo morphology (aim 4), and communicate their results (aim 4). Comparing responses on pre-lab and post-lab questionnaires provided a means of evaluating the effectiveness of the modified FETAX to teach concepts in developmental toxicology (aim 5; Figure 6). Student responses after the laboratory demonstrated significantly improved knowledge of teratogens, target organisms, non-target organisms, and sensitive periods. Students scored only slightly better in response to the question asking them to compare the effects of pesticides on target versus non-target organisms. The less dramatic improvement on this particular topic may result from the fact that students did not directly examine the effects of malathion on invertebrates or the question may have been obvious given the preceding two questions. The higher pre-test score on this question favors the latter possibility. Finally, this investigative FETAX laboratory exercise served as a practical and useful introduction to scientific design and execution in a developmental biology course. Later in the semester all undergraduates (45/45) successfully proposed more substantial experiments of their own design (experimental questions, controls, and organisms unspecified by the instructor) that they then conducted, analyzed, and reported to their classmates. Qualitative, end-of-semester evaluations consistently remarked that such investigative opportunities provided useful educational experiences that allowed students to develop creativity, confidence, and a practical appreciation for the process of performing and communicating scientific experiments. In summary, the modified malathion FETAX laboratory exercise described here allows students to design, execute, and analyze an experiment and evaluate quantifiable measures of vertebrate development in the larger context of ecotoxicology and teratology

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Appendix I

FETAX LABORATORY GUIDELINES

http://www.bio.davidson.edu/biology/balom/306/teratogenLab.html

Background:
Normal embryogenesis can be disrupted by environmental factors that result in physically deformed embryos. In many cases embryos are more or less susceptible to teratogens at specific stages. Periods of increased susceptibility are known as critical (or sensitive) periods. Any agent that causes embryonic malformations is classified as a teratogen. The Frog Embryo Teratogenesis Assay: *Xenopus* (FETAX) is often used as a means to assess the potential teratogenicity (and toxicity) of water-soluble agents. FETAX is also used to test water quality. This week in lab you will design a modified FETAX assay to test the teratogenicity of malathion.

Laboratory Objectives:
- to become familiar with concepts in developmental toxicology
- to determine the influence of malathion on *Xenopus* development by designing, conducting, analyzing, and communicating an experiment
- to design a meaningful experiment that includes appropriate controls
- to conduct a FETAX assay with careful attention to detail and develop an awareness of tadpole morphology
- to learn how to stage Xenopus embryos using staging tables
- to learn how to use digital cameras to image embryos
- to learn how to quantify morphological abnormalities using ImageJ software
- to learn how to document and communicate results in both images and graphs
- to communicate your experiment via a scientific poster

Assigned reading (to be completed before you come to lab)**:**
Gilbert (2003) pp. 740-745

Safety:
- Wear gloves when working with potential teratogens, particularly the malathion.
- The modified rearing (MR) solution contains a tiny amount of the antibiotic gentamycin. If you have allergies to this antibiotic, please wear gloves.
- Always wear gloves when working with fixatives such as gluteraldehyde. Bottles of fixative should only be opened in the chemical fume hood.
- Always mark your bottles, petri dishes, etc. with the concentration of the chemical contained therein and fill out an "experiment in progress" sheet.

Experimental Procedures:
- You may choose to vary the concentration of the teratogen, the duration of exposure, the age at which the exposure begins, or any other parameter that is reasonable to test. You may or may not have a range of tadpole ages available at the start of lab.
- Prepare solutions in plastic vials (with caps) so you can mix solutions thoroughly by shaking. Mix solutions immediately before use.
- Use a minimum of 12 embryos per petri dish. Take time to select similarly aged embryos without malformations at the onset of your experiment.
- Check on your embryos regularly (daily recommended). If an embryo dies remove the dead embryo and record the approximate stage of death in your notes.
- Fix embryos 72 hours after starting your experiment. Transfer anesthetized tadpoles to a glass fix vial, in 2 ml of 1% gluteraldehyde for at least one hour (gluteraldehyde is a powerful fixative - always WEAR GLOVES and WORK IN THE FUME HOOD when working with gluteraldehyde). Fixed embryos must then be rinsed thoroughly (>4x) with PBS. All liquid waste must be discarded in the gluteraldehyde waste containers in the fume hood, and only fix tools (marked with black electrical tape) should be used to manipulate fixed embryos. Fixed embryos should be stored in the fix frig (marked with a large X in black tape).

Malathion
• Concentrations of either 1 mg/L or 2.5 mg/L are recommended, but you are welcome to use other concentrations. The following are directions for preparing approximately 50 ml of solution. You will use 10 ml for each 60 mm petri dish or 50 ml for each 100 mm petri dish.
- 1 mg/L = 5 ul of 1% malathion stock in 50 ml MR
- 2.5 mg/L = 12.5 ul of 1% malathion stock in 50 ml MR
- Control = 5 ul or 12.5 ul of acetone in 50 ml MR

Quantifying abnormalities:
Think about how you will quantify abnormalities in your embryos. Make sure you analyze abnormalities in your embryos by at least two distinct measures. Percentage of abnormal embryos per group is one obvious and easy measure, but it is subjective. You may want to categorize abnormalities generally *(i.e.* head deformities, ventral deformities, axis deformities, *etc.*) or more specifically (reduced eye, missing tail, secondary axis, *etc.*), depending on what you observe. You must include at least one method of comparing embryos that employs ImageJ to measure some aspect of embryo morphology (*i.e.* embryo length, eye diameter, gut area, *etc.*). You can expect to have SOME time during lab next week to get assistance measuring embryo morphologies, but

you should also expect to spend some time outside of our formal lab time measuring your embryos.

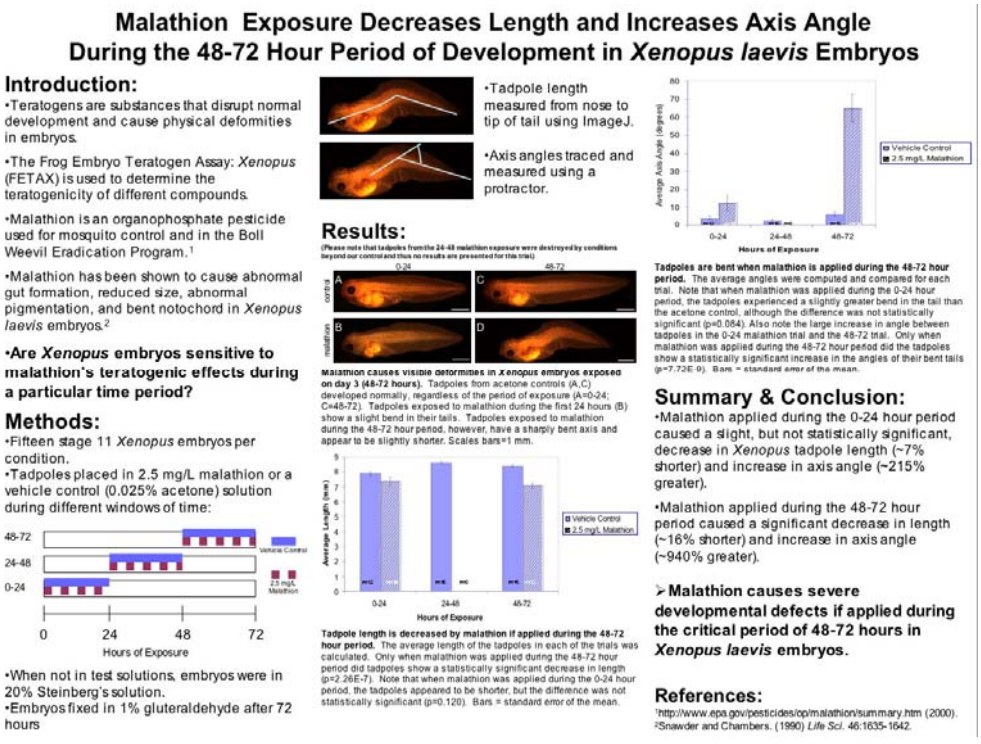
Poster Assignment:

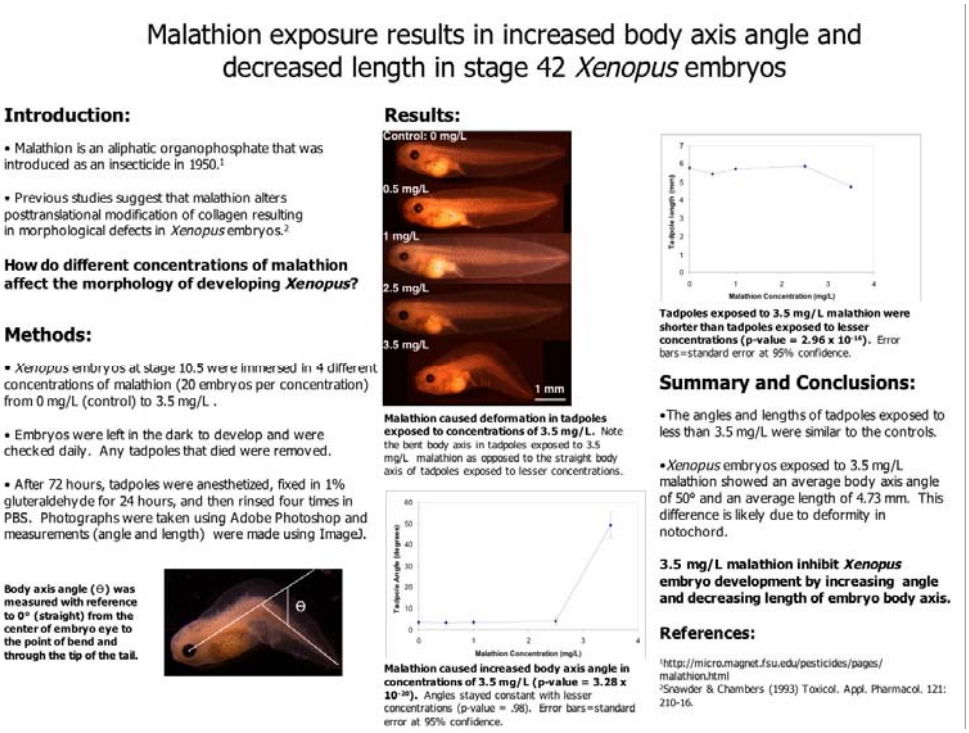
- Generate a mini poster presentation of your experiment & results.
- The poster must include a descriptive title that indicates the outcome of the experiments.
- The poster must include sections titled Introduction, Methods, Results, Summary & Conclusion, & References (with at least two references).
- Posters should be 8.5 x 11 (landscape orientation).
- Use one sans serif font consistently throughout your poster (*i.e.* Helvetica, Gil Sans, or Arial not Times or New York).
- Use bullet points to keep your statements concise (complete sentences are not necessary).
- Digital images of at least one representative embryo from each condition must be included in the poster. An accurate scale bar must be included and labeled appropriately.
- At least two graphical representations of your data must be included in the poster and one of these graphs must come from a method of analysis that employed ImageJ.
- No "raw" data allowed in the poster & always avoid tables if possible.
- Think carefully about the best graphic and visual representations of your data - try to convey your results as simply and as directly as possible - use pictures to tell your story.
- Strive to make your poster as reader-friendly as possible with simple, well-labeled figures.
- Make sure each figure includes a legend (figures do not need to be numbered in a poster).
- Each figure legend should have a title in bold that indicates the main point of your figure. The legend should be at least two sentences that briefly explains the basics of the experiment as well as defines any symbols, abbreviations, *etc*. used in the figure.
- Make sure your poster is well labeled - sample size (n), axes, scale bars, *etc*. should all be indicated.
- Submit two color printouts and email your PowerPoint file to the instructor by the deadline indicated on the syllabus.

Hints & Helpful Resources:

- The Nieuwkoop & Faber staging table diagrams of *Xenopus* development can be found at www.xenbase.org/atlas/NF/NF-all.html
- Will Graham, '02 created a photographic atlas of *Xenopus* stages that can be found at: www.bio.davidson.edu/xenopus
- A sample poster template (in PowerPoint) is available on the course's Blackboard site (look in the course material section)
- A black binder in the lab contains copies of several research articles describing the influence of malathion on embryos (do not feel limited to these articles, but feel free to use other peer-reviewed journal sources as well)

Appendix II
TWO EXAMPLES OF STUDENT POSTERS





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Call for Resolutions

The Steering Committee of ACUBE requests that the membership submit resolutions for consideration at the 2006 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,
Email: bmoore@truman.edu
Phone: 660-785-7340

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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: Stephen S. Daggett, *Bioscene* editor, at stephen.daggett@avila.edu.

Call for Applications -- John Carlock Award

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

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

Application: Applications, in the form of a letter, can be submitted anytime during the year. The application letter should include a statement indicating how attendance at the ACUBE meeting will further her/his professional growth and be accompanied by a letter of recommendation from a member of ACUBE. Send application information to: Dr. William J. Brett, Department of Life Sciences, Indiana State University, Terre Haute, IN 47809; Phone: 812-237- 2392; FAX: 812-237-4480; Email: lsbrett@scifac.indstate.edu.

If you wish to contribute to the John Carlock award fund, please send check to: Dr. Tom Davis, ACUBE Excecutive Secretary, Department of Biology, Loras College, 1450 Alta Vista, Dubuque, IA 52004-0178

A Classroom Activity to Illustrate the Demographic Transition

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Abstract: A discussion of the Demographic Transition is included in many Environmental Biology or Environmental Science classes. The Demographic Transition occurs as a nation becomes more urban and wealthy, and was widely observed in the twentieth century. The phenomenon includes decreasing family size (fewer children) across generations. In this classroom exercise, students provide numbers of children in past and future generations in their own families, and then the class analyzes the pooled data and hypothesizes why and how this change in human population biology occurs.

Keywords: human population, demographic transition, classroom investigation, inquiry, student data collection

Introduction

The human population is a topic of interest in most Environmental Biology, Environmental Science, and similar courses. Instructors have various classroom or laboratory activities available to explore population models (Moore and Holt 1973), including using computer simulation with packages like STELLA (Bice 2001, Bossel 1994, McKelvey 1995) or EXTEND (Odum and Odum 2000). Protocols using small organisms such as Duckweed (*Lemna*) (DeBuhr 1991, Jeffries 1991) or protistans (Glase and Zimmerman 1991) also exist. Many ecology classes examine survivorship curves or other aspects of human demography by collecting data in cemeteries (Flood and Horn 1991).

To appreciate human population dynamics, one must consider factors beyond population growth models. Although subject to biological constraints, human population biology is complicated by religious, cultural, economic, and other factors unknown in other organisms. For example, the population biology of a human society changes as it becomes more urban and industrial. The phenomenon of cultural changes resulting in decreased family size is known as the demographic transition. It is characterized by increased wealth, literacy, access to health care, and average lifespan. The phenomenon usually is phased, with initial improvements in infant mortality being followed by lowered birth rates and population sizes reaching an asymptote, and possibly even falling later. Sixteen popular environmental science textbooks published in the last five years all include a discussion of the demographic transition, sometimes comparing age distribution pyramids or fecundity among different countries.

Despite the recognized significance of the phenomenon, few teaching resources exist to help students explore the demographic transition. Bannister (1990) uses Egypt as a case study, comparing its population dynamic to that of Europe. Ulack (1978) presents alternative conceptual schemes for observations made in different world regions. Mulvihill (1981) describes an activity using population data from Latin America, including statistical analyses and an exploration of socioeconomic dynamics.

In this article I describe a classroom exercise in which students provide data about numbers of children (generation size) in their own families, and the data are immediately pooled and analyzed. The trend evident in the data stimulates a discussion of why women are bearing fewer children in recent generations in the United States and many other countries.

Methods

This activity takes place in the regular 50 minute class period. I enter data into a spreadsheet file and project them onto a screen, although simply making a table on the blackboard and filling in the data works as well. The spreadsheet can perform simple arithmetic to determine a normalized value (percent) across all generational data, and can also automatically generate a graph as data are entered. These functions make the data trend more apparent and can aid student comprehension. The spreadsheet file is available by request from the author.

When conducting the exercise, I begin by drawing or projecting the blank data table (Table 1) I explain that the activity is strictly voluntary and I assure students that participation has no effect on the course grade. I ask students to provide only reliable data; if a student is unsure about anything, s/he shouldn't respond.

I begin with the "Self" generation (i.e., the students in the room). I ask, "How many of you are an only child, without brothers or sisters?" I count the raised hands of students and the result goes in Column "1," row "self" in the table. I then ask for the number of students who have a single sibling and the count is placed in the same row under the column "2." Likewise I ask for the generation size of three, four, etc. Obviously the generation size must be at least one. I limit the maximum generation size to seven (grouping all answers greater than seven into this "7+" category). I have found from experience that very few students will have more than six siblings.

Likewise, the generation size will be at least one for the parents generation (i.e., the parents of the students), and the grandparents. I collect data for the parents, instructing students to raise both hands simultaneously if both parents have the same number of siblings. I do the same for grandparents, telling students to raise both hands even if they have three or four grandparents all having the same number of siblings; I simply point to a student and ask "How many?" and add to the running total. The case of step parents or half-siblings complicates the process; I tell students to answer for their own two biological parents and all their children (sib or half-sib). Each student could give two generation size responses for the Parents category, and four for Grandparents. When examining the data later, calculating the percent of responses in each size category normalizes the responses, and makes comparisons between generations much easier.

The "next" generation (bottom row of the table) is the last to be tallied, and is hypothetical: "How many children would you like to have, assuming your partner agreed?" My students are almost all 17-22 years old, and very few of them are parents. However most seemed to have considered the prospect of parenthood, and cheerfully respond. Here, the zero column is needed, as some students will indicate a desire to remain childless.

We examine the data immediately, and conduct a discussion during the class period. A 50-minute lecture period sometimes proves insufficient, so additional time may be needed in a subsequent class. The discussion is greatly improved if the data can be summed and converted to percentages in each generation, and a graph of those percentage data drawn immediately. Obviously the raw data have unequal sample sizes; each student might report a single number for Self and Next generations, two numbers for Parents, and four for Grandparents. Comparing percentages in each sibling size class, and average (mean) numbers of siblings across generations, is a more valid and illustrative approach.

Here, I present data from the Spring 2005 class of Introduction to Environmental Science (NASC 120) at Central College in Iowa. I tallied the data in class, and entered them into a Microsoft Excel spreadsheet to calculate percentages of families with each generation size. I also prepared weighted averages by multiplying the numbers of responses by the magnitude in each (i.e., generation size) and dividing these products by the total number of responses in each generation. Note that this weighted mean calculation actually underestimates the larger families, because families with seven or more children are all treated as if they had only seven.

To determine if differences in these generation sizes are significant, I performed a Chi-square contingency test using Microsoft Excel, comparing observed tallies with those expected if no generational difference exists. I consider $P \leq 0.05$ level to be statistically significant.

Results

Data from the Spring 2005 class of Introduction to Environmental Science (NASC 120) at Central College (n = 48 students) are shown in Table 2 and Figure 1. These data are typical, and clearly illustrate the demographic transition: family size (generation size) decreases over time. The Grandparents have the largest generation, averaging 4.6 children in each family. Parents have a mean of 4.1 children in the generation, and the students have a mean of 3.1 children per family. The students in the class will continue the trend, for if they act as they suggest, an average of 2.7 children will be born per family in the next generation. As noted in the Methods, these data actually underestimate the trend, since the frequencies of 7+ families decrease across time, and this category underestimates the true averages: families with eight, nine, or more children are weighted as if they had seven. Nevertheless, the results of the Chi-square contingency are highly significant ($P<<0.0001$).

In the eight semesters in which I have employed this exercise at Central College, we have always collected data illustrating the demographic transition. Students comment afterward that they enjoyed and appreciated the activity. Despite the potentially personal nature of the data, I have been sensitive about assuring students that they are free to decline participation, and I have never heard or read comments about the exercise causing discomfort.

In my class, I use an inquiry approach for this activity. We perform this exercise before I lecture or

explain about the demographic transition. Seeing the data trend, students are curious and ask questions (and I ask questions to prompt them as well). Why are families smaller today than in the past? Did women not have access to contraception in the past? Are children more of a financial responsibility today? Have the social norms and expectations regarding families changed?

Table 1. Blank table used to record data on generation (family) sizes. "Next" refers to number of children desired by the students themselves.

Generation	0	1	2	3	4	5	6	7+	total
Grandparents	--								
Parents	--								
Self	--								
Next?									

Table 2. Generation sizes reported by students in the NASC 120 class at Central College, Spring 2005.

Generation	0	1	2	3	4	5	6	7+	total
Grandparents	--	1	11	17	12	8	9	21	79
Parents	--	1	12	17	23	9	7	9	78
Self	--	0	14	15	7	1	2	1	40
Next?	1	0	19	14	4	2	0	0	40

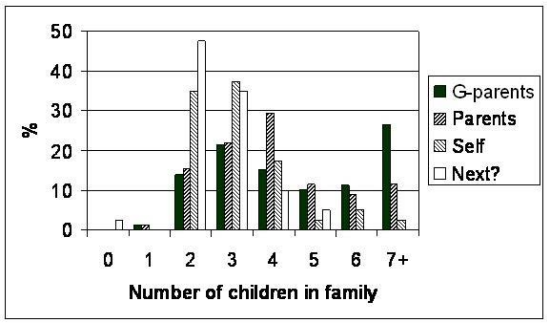

Figure 1. Graphic representation of the data in Table 2, normalized as percentages.

Discussion

Here, students indicate that their grandparents came from big families, averaging 4.6 children. Meanwhile, the students will approach zero population growth in their generation. I ask the students to speculate about reasons for this pattern. Class discussion generally centers on availability of effective contraception, and factors associated with the changing role of women, including postponing marriage and childbearing. In Iowa especially, the discussion can compare children as an economic resource (workers on the farm) versus children as a financial liability causing increased family expenditures.

Are Iowa students typical? Their recent ancestors may be more likely to live in a rural area than are the families of students elsewhere. However, even many city families are only two generations removed from an agrarian lifestyle, and the complex pattern of increased education for girls, more opportunities for women for employment outside the home, cultural norms, and other factors are probably present throughout any industrialized nation such as the United States.

I find this activity useful in teaching a critical environmental topic. By collecting data from the students in class, the topic is immediate and personal to them, and they are interested and invested in the outcome. By doing this activity first, before explaining the concepts, students are primed and curious to understand the phenomenon they've observed. I take advantage of this innate curiosity to practice scientific methodology in the classroom. We make observations, create a hypothesis, and test it against real data. For example, if the demographic transition occurs in nations as they industrialize, then it should be observed in European, but not African, nations. Data available in an environmental science textbook will support this assertion (see e.g., Cunningham et al. 2003).

I have always confined this activity to a single class period, but presumably this could be expanded. The data could be further analyzed and become the basis for a lab report. Students could interview people outside of class; reference population data from published sources such as the U.S. Census Bureau, or the United Nations; or design novel approaches to studying this phenomenon.

The demographic transition has been observed in numerous societies in the twentieth century. Some experts suggest that global human population growth is stabilizing, and will soon level off. If indeed this is the case, it will likely be the result of factors associated with the demographic transition.

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Rearing Media as a Variable in Fruit Fly Fecundity: An Activity to Introduce Scientific Methods of Inquiry to Biology Students

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Abstract: A major challenge in teaching the process of science to students is designing and implementing laboratory activities that emulate what is actually done in a research laboratory. To facilitate this effort, science educators have been encouraged to design exercises that span multiple laboratory periods, encourage independent thinking, promote hypothesis-driven experimentation, and data collection and analysis. We have designed an inquiry-based, semester-long laboratory activity amenable to majors or nonmajors and to introductory or advanced biology students. This activity utilizes *Drosophila melanogaster*, the fruit fly, as a model organism that allows students to investigate how different rearing media additives affect female fecundity measured as numbers of eggs laid. To explore the feasibility of our activity aimed in helping students learn the processes of science, we assigned the activity independently to three different student populations. These included 1) students in an undergraduate biology laboratory; 2) an independent undergraduate research project; 3) a Distance Education Biology Master's graduate student summer research project. The goal of this laboratory activity is to allow students the opportunity to design a controlled experiment, formulate testable hypotheses, identify variables, make quantitative and qualitative observations, and analyze data using a simple computer spreadsheet program.
Keywords: Inquiry-based, fruit fly, fecundity, rearing media

Introduction

Drosophila melanogaster, the fruit fly, was an early model for genetics research, which prompted scientists to develop media that produced consistently high numbers of offspring. Early studies proposed that the different varieties of yeast within the various media were influencing factors in fruit fly nutrition and subsequent development (Baumberger, 1917; Tatum, 1939; Robertson and Sang, 1944). Media containing a variety of additives including pears, raisins, rice, molasses, and oat hulls have been reported (Bridges and Darby, 1933). More recent work showed that developmental and fecundity (egg-laying) rates varied when fruit flies were reared on media of sugar, tomatoes, and grapes (Jaenike, 1986). Currently, commercially available dry mixtures aim to standardize the media used for rearing fruit flies (Flagg, 2005). These media are intentionally produced unsupplemented and uncolored, allowing researchers to personalize it with their own additives. The effects of different food media ± yeast on fly fecundity can be easily observed and quantified, which lends itself to use as an activity for biology students.

Fruit flies represent an exemplary investigatory tool for studying genetics both in the research and classroom laboratories. They are inexpensive, easy to rear, have a short life span (15-20 days), are easy to sex, and require very little space or special equipment (Ashburner and Roote, 2000). In addition, fruit flies are commonly used at all levels of biology education, from middle and high schools, to college level biology courses as a tool for teaching introductory Mendelian genetics. For these reasons, fruit flies make an ideal model organism for use in this laboratory activity.

Evidence, models, and explanation are part of the unifying concept and process themes in the National Science Education Standards (NSES). Teaching biology students how scientists use

controlled experiments to answer questions and test hypotheses is essential to their understanding of the scientific process. The NSES (1996) states, "Science as inquiry is basic to science education and a controlling principle in the ultimate organization and selection of students' activities." In this paper, the use of fruit flies as a classroom model for scientific inquiry is discussed.

The investigation of fecundity rates in *D. melanogaster* was performed at three levels of biology education. These included 1) an undergraduate biology laboratory exercise, 2) a two-semester long independent undergraduate senior research project, and 3) a Distance Education Biology Master's graduate student summer research project. In testing this activity, students were allowed to design and perform hypothesis-driven controlled experiments in order to measure the fecundity rates of female fruit flies reared on plain media ± yeast and media supplemented with a variety of additives including, artificial colors, fruits, cooking additives, grapes used exclusively in wine making, and a commercial energy drink. This simple, but engaging activity was amenable to all levels of science students. This laboratory activity uses inquiry-based learning to help students develop scientific process skills by comparing short-term fecundity rates of female flies reared on different media in a controlled environment over the entire semester. Guidelines are given for setting up culture vials and data collection, but the students choose the independent variable they wish to test in their experiment. At the beginning of the investigation, students are asked to formulate null and alternative hypotheses about the results they expect to obtain and to identify the experimental variables. A discussion with students concerning hypothesis acceptance or rejection using statistical analyses is undertaken. It takes only a few minutes to analyze a set of data for significant differences using appropriate software. By graphing their data, either through the use of a spreadsheet program or by hand, students are better able to visualize the potential differences in their data, aiding them in formulating and writing their conclusions. Lastly, the students were required to present their findings in the form of a written manuscript following the guidelines of a peer-reviewed journal, which included an extensive review of the literature, and a formal discussion of their results. In their discussion, students were encouraged to include observations and perceptions of the process of science after completing the activity. This paper allowed assessment of student understanding of the activity and the process of science in general.

Materials

Fruit flies were reared in seventy-five mL plastic culture vials or 250 mL plastic culture bottles with foam plugs. Boiled baby food jars with cheesecloth rubber-banded around the mouth could be used as an inexpensive alternative. An insect culture chamber maintained the fruit flies at a constant temperature ranging between 24-26°C during all experiments. If you do not have access to an incubator, a room in which the temperature can be maintained at ~25°C during the entire experiment can be used. It is important to note that the warmer the temperature, the faster the fruit flies will complete their life cycle. The plain medium for control vials or plain medium used in mixtures with different food additives was purchased from Carolina Biological (Catalog # 17-3200). The yeast used was Fleishman's brand baker's yeast and can be obtained from almost any medium-sized grocery store. For immobilizing the fruit flies, a homemade etherizer consisting of a 250 mL glass bottle with cotton balls in the bottom, a 50 mL plastic conical tube with holes punched in the side, and a powder funnel was used with ether as the anesthetic. In order to dispose of fruit flies, they were "morgued" or dumped into a fly morgue that consisted of a flask containing water with a pinch of salt, a drop of liquid detergent, and a powder funnel inserted into the mouth of the flask. Other supplies that were needed included a soft-bristled paintbrush to manipulate the fruit flies, a white note card for contrast when viewing fruit flies, a dissecting microscope for analyzing fruit flies, and the food additive of choice to be tested (Ashburner and Roote, 2000; Flagg, 2005).

Procedures and Results From An Undergraduate Biology Laboratory

For the student investigation performed in the undergraduate biology laboratory, the guidelines were explained and the students separated into groups of four. The groups brainstormed to choose their experimental food additive. They were restricted to an additive that was legal to have on campus and that a fruit fly may encounter in the "wild". The students outlined in their laboratory notebooks the procedure they were going to follow in making their experimental food and the process they would follow for the duration of their experiment (approximately 3 months). During this initial class period, the students were trained in fly handling and sorting, especially on how to properly etherize the fruit flies. Briefly, approximately 1 mL of ether was added to the cotton balls in the etherizer. The fruit flies were placed into the conical tube, and watched until the fruit flies stopped moving. The fruit flies were dumped on a white note card, placed on the stage of a dissecting microscope, and sexed. For sexing of fruit flies, the students are instructed on the differences in the size of the females and male fruit flies, as well as other

distinguishing characteristics. Males are slightly smaller than females and have a dark-colored anal ring at the posterior end of their abdomen. The sex combs on the male, which are black hairy tufts on their forelegs, are especially helpful in sexing newly emerged fruit flies. In contrast, females have somewhat pointed posterior ends and no sex combs (Flagg, 2005).

During the second laboratory period, students prepared their experimental media. One group prepared the control media (plain ± yeast) and the other groups prepared media ± yeast with additives including apples, a commercial energy drink, and red or purple food coloring. For the initial set-up, students were provided with two stock bottles of the media ± yeast for a total of 4 bottles per group. Each bottle had approximately 5 grams of plain, uncolored, commercial medium. Apples were pureed in a blender with nanopure distilled water prior to adding to the commercial food mix. Liquid was added to the commercial medium until it reached the consistency of mashed potatoes. For the yeast containing bottles, approximately 1 milligram of yeast was sprinkled on the top. To each of the bottles, 50 female and 50 male wild-type fruit flies were added and allowed to mate for 96 hours, after which time the fruit flies were morgued. For the remainder of the experiment, the students were instructed that they would have to come into the lab outside of their regularly scheduled class period to set-up the experiment and to sex and count fruit flies. This step helps the students to realize that science experiments are not done in a scheduled block of time, one day a week. For the next part of the experiment, the students prepared 3 bottles each of their media ± yeast for a total of 6 bottles per group. They collected virgin females from their stock bottles and mated them to males. To collect virgins, the bottles were "cleared" (i.e., all the fruit flies morgued) early in the morning and females collected within the next 8 hours. For each bottle, 10 virgin females and 10 males were added from the stock bottle, allowed to breed for 72 hours, then morgued. The larvae were left to feed on the media, develop, and eclose (emerge). Once the fruit flies started to eclose, the students had to come in every day to sex and count fruit flies. This had to be done at 8 hour intervals so that the newly eclosed fruit flies would not mate in the bottles. The fruit flies were counted until the bottles did not produce any more fruit flies, which indicated the first generation was finished. The students were instructed to make qualitative and quantitative observations during the experiment, including changes in the media, describing the developing larvae, numbers of larvae, and phenotype of adults. Their data was compiled using a Microsoft® Excel spreadsheet, and their experimental data was compared to the control bottles and included differences observed between males and females. They performed statistical analyses of their data in the spreadsheet using the student's *t*-test function as provided in the software's statistical analysis package (Microsoft® Corporation, Redmond, WA). Lastly, they were instructed to write a complete discussion including published literature to support their ideas.

For all treatments, statistically significant differences in the numbers of offspring from fruit flies reared on all experimental treatments compared to those reared on plain media ± yeast was found (**Figure 1**), suggesting that the additives had a detrimental effect on fly numbers. There were no significant differences in any treatments between the numbers of males and females. In this experiment, the energy drink caused the internal organs of the fruit flies to turn black, which the students found a bit disturbing and concluded that the drink was "rotting" the fruit flies. Other interesting observations were that adding yeast had no effect on the fruit flies reared on purple or apple containing food. The apple containing food was explained by the high amount of fructose in the fruit. The students found that the red food coloring killed the fruit flies. The more likely cause was not found until after some deep probing revealed that the students had used the cooper laden tap water from the building to make their media.

Procedures and Results From a Two-Semester Long Undergraduate Senior Research Project

For the two-semester long independent undergraduate senior research project, the protocol outlined above was followed except that the addition or removal of additives was based upon the preference of the student and yeast was only included for the control. The additives not repeated in this experiment were the red and purple food coloring and the apples. The new additives tested were 10% honey, 25% vinegar, and Traminette and DeChaunac

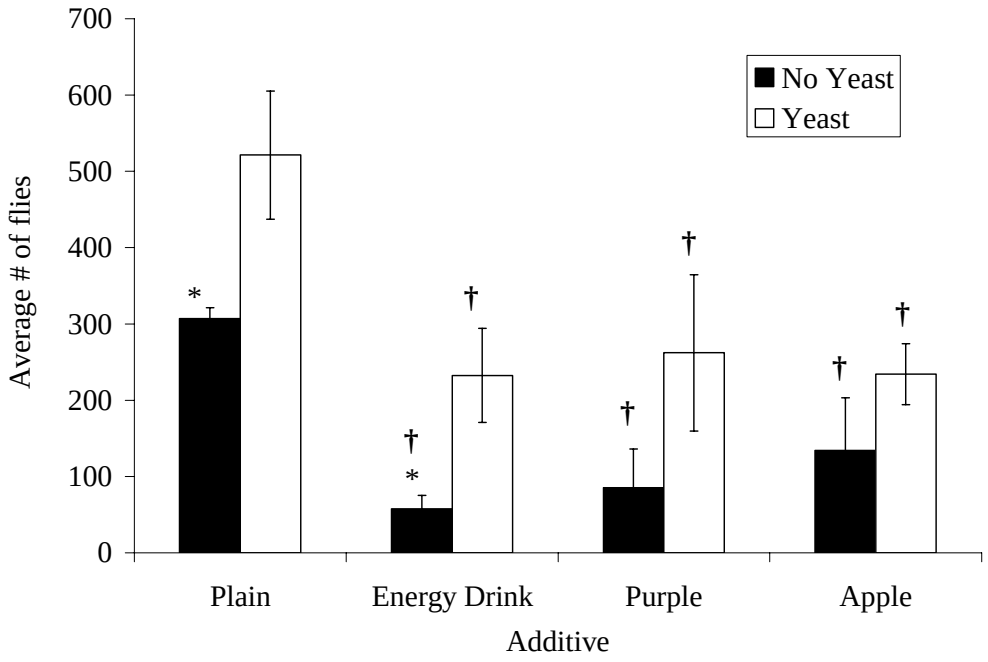

Figure 1. Experiment #1: Comparison of average number of total fruit flies collected for each media ± yeast. * $p < 0.05$ when no yeast medium was compared yeast containing counterpart (i.e., energy drink – yeast compared to energy drink + yeast); † $p < 0.05$ media ± yeast was compared to plain media ± yeast (i.e., energy drink + yeast compared to plain + yeast or energy drink – yeast compared to plain – yeast); error bars are standard error of the mean (SEM).

grape juices obtained from Mac's Creek Vineyards and Winery in Lexington, NE, which is where the student was employed. These were selected because the student noticed a large number of fruit flies associated with these juices compared to the other juices used in the wine making process. The honey and the vinegar treatments arose from the old adage, "You catch more fruit flies with honey than vinegar".

In this study, an interesting observation was that the first emergence of flies from the media containing the energy drink was a full week ahead of all the other treatments, even though the bottles were all started at the same time. The student concluded that this may be due to the high concentration of caffeine found in the energy drink. For all treatments, statistically significant differences in the numbers of offspring from fruit flies reared on all experimental treatments compared to those reared on plain medium with yeast was found (**Figure 2**). The student concluded that there are a couple factors important in considering the effect yeast has on increasing fecundity. One is that the yeast produces an abundance of riboflavin, or vitamin B_2. This vitamin is important in the development of the flies in their larval stages (Bruins, Scharloo, and Thorig, 1997). The other factor is that increased yeast metabolism causes a large amount of yolk protein to be produced. Yolk protein is one of the main constituents of proteins that a female *D. melanogaster* uses in reproduction (Carlson and Harshman, 1999a). There were no significant differences in the numbers of males versus females between any of the treatments.

Procedures and Results From A Distance Education Biology Master's Graduate Student Summer Research Project

The graduate student summer research project was performed to modify the protocol possibly for high school use. In this study, fruit flies were reared in 75 mL culture vials to determine whether the experiment could be scaled down and still be successful. Also, different additives from the previous examples were tested based upon the preference of the graduate student, including plain ± yeast, bananas, and kiwis. Each vial contained 15 mL of total food media, with control vials containing 100% plain medium and each experimental vial containing 25% of the additive. Once again, whole fruits were pureed in a blender prior to adding to plain medium. The yeast treatment had 0.1 mg of yeast sprinkled on top. Stock vials were maintained on plain medium without yeast or any other additives. For the experiment, six virgin females and six males from the stock bottles were added to six vials of each treatment and each treatment was repeated three times over a period of two months. All males were

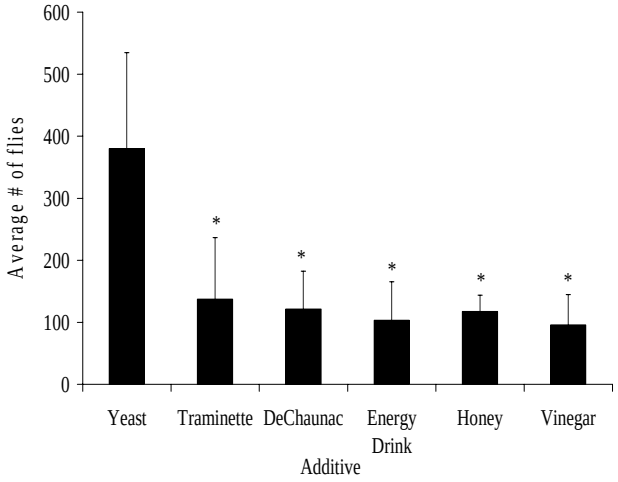

Figure 2. Experiment #2: Comparison of average number of total fruit flies collected for each treatment . * $p < 0.05$ when compared to yeast; error bars are SEM.

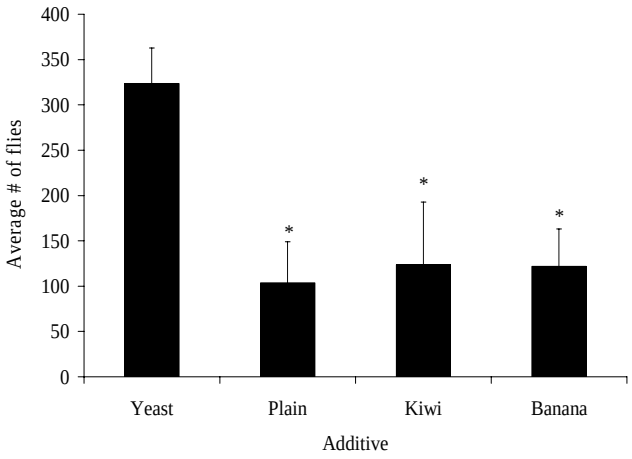

Figure 3. Experiment #3: Comparison of average number of total fruit flies collected for each treatment. * $p < 0.05$ when compared to yeast; error bars are SEM.

removed after forty-eight hours and after another forty-eight hours, the females discarded. The offspring were collected every 12 hours until offspring no longer emerged. The data was compiled using a Microsoft® Excel spreadsheet. Data collected from the control group was compared to the experimental fruit flies reared with or without yeast. Statistical analyses of the data were again done in the spreadsheet using the student's *t*-test function.

This investigation found that the majority of offspring emerged within the first five days of the first emergence. Emergence time was 9-11 days for fruit flies reared on plain medium with yeast, and 13-14 days when reared on banana or kiwi containing media. Statistically significant differences in the numbers of offspring from fruit flies reared on kiwi, banana, or plain media compared to those reared on plain medium with yeast was found (**Figure 3**). No significant differences between kiwi, banana, and plain media or between the numbers of males and females were found. In this experiment, all kiwis were found to not be equal. The first few batches of food killed all of the fruit flies. This was rationalized to be due to the use of pesticides or chemicals during the growing season. Therefore, the fruit was scrubbed before use. This proved to be of no help and the source of death was never identified. Also, mold inhibitor was not used and there were several incidents of mold overtaking vials. In the future, this will be rectified by adding mold inhibitor to the vials. This investigation also found that the experiment could be scaled down and still produce similar results to the larger experiments. The graduate student rationalized that there are many factors affecting fecundity in fruit flies. Female fruit fly body size has been identified as an attributing factor. Large female flies have been shown to lay an average of 80 eggs per day, while medium sized flies lay approximately 30 eggs, and the smallest females lay an average of 15 eggs per day (Chiang and Hodson, 1950). Nutrition can also impact the body size of a female fruit fly by increasing the percentage of ovarioles containing vitellogenic or yolk containing egg stages (Carlson and Harshman, 1999b). Other factors such as age of the female (Shorrocks, 1970) and population density (Sameoto and Miller, 1966) have been identified as factors influencing fecundity.

Discussion

This laboratory activity has now been successfully repeated a number of times at different levels of biology education. Most conventional college laboratory class periods are designed to fit in the allotted time, and are "cookbook" exercises completely laid out for the students to follow with little chance of error. Based upon student comments found in the discussion section of their formal laboratory manuscript, it was found that they learned that science is not performed in the confines of a 1-3 hour lab period and that critical thinking and data analysis are paramount to the scientific process. They appreciated not having the laboratory worked out for them and having some input in what they were studying. This carries over with the fact that many of them stated that they did not mind coming in on their own time to carry out the experiment. The undergraduate student is pursuing a career in teaching

high school biology and the graduate student is a middle school science teacher. Both of these students have stated that they can amend this project for their classrooms and will do so in the future. This process is important because many high school students do not get exposed to this type of hypothesis-driven laboratory activity that more closely resembles an actual research project, unless they do an independent science fair project. Therefore, this activity can be successfully used to expose all students, majors or nonmajors, introductory or advanced biology students, and high school or undergraduate students, to the process and excitement of doing a "real" research project. This investigation gives students an engaging activity to help them learn about the process of scientific inquiry and the components of a controlled experiment.

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Call for Nominations

Bioscene Editorial Board

We are soliciting nominations for four (4) *Bioscene* Editorial Board positions (terms through 2009). Board members provide input in the form of reviews and suggestions concerning the publication ot *Bioscene* to the Editor. Board members are also expected to assist in the solicitation of manuscripts and cover art for *Bioscene*. Board members may be called upon to proofread the final copy of *Bioscene* prior to publication. If you are interested in serving a 3-year term on the Editorial Board, please email the editor, Stephen S. Daggett, at stephen.daggett@avila.edu.

ACUBE

Web Site

http://acube.org

The Association of College and University Biology Educators (ACUBE) placed the organization's rich archive of materials online for the benefit of members and interested biology educators. Nearly 50 years of the society's publications and resources are currently accessible.

Featuring the Online ACUBE Archives:

Bioscene: Journal of College Biology Teaching (1975-present)
AMCBT Newsletter (1964-1974)
AMCBT Proceeding (1957-1972)

ACUBE Organizational Information:

ACUBE Executive Committee
Editorial Board of Bioscene
ACUBE Annual Meeting Information
Meeting Abstract Form
Searchable Member Database
Online Membership Application
Scientific Meetings of Interest
ACUBE in the News
Sustaining Members

ACUBE 50TH Annual Meeting

October 26-28, 2006
Millikin University
Decatur, IL

The Revolution and Evolution of Biology Education: Where 50 Years Can Take Us

Preliminary Program

Thursday, October 26th

12:30-2:30 PM **Pre-Conference Field Trip: Mari-Mann Herb Farm**
Led by **Maribeth King**, Mari-Mann founder
Meet at Registration Area 1st Floor Leighty-Tabor Science Building (LTSC)

3:00-5:00 PM **Pre-Conference Field Trip: Rock Springs Conservation Area**
Led by **Dr. Judy Parrish**, *Millikin University*
Continue from Mari-Mann or meet at registration area

3:00 - 5:00 PM **Steering Committee Meeting** **LTSC 301**

6:00 - 8:00 PM **Registration and Reception**
H'ors d'oerves
Registration: **1st floor LTSC**
Reception: **LTSC 115**

8:00 - 9:00 PM **Opening Session**

Welcome to ACUBE:
ACUBE President: **Ethel Stanley**, *Beloit College*
Welcome to Millikin University: Jamie, Comstock
VP Academic Affairs, *Millikin University*

Greetings from the Conference Chairpersons
Program Chair: **Conrad Toepfer**, *Brescia University*
Local Arrangements Chairs: **Harold Wilkinson, Neil Baird,** *Millikin University*

OPENING PRESENTATION (Public Welcome to Attend) **LTSC 001**
Marc Abrahams, Editor
Annals of Improbable Research
"Annals of Improbable Research and the Ig Nobel Awards"

9:15 - 10:15 PM **Steering Committee Meeting** **LTSC 301**

Friday, October 27th

7:00 AM - 5:00 PM **Registration table**
(Register, pay dues, buy T shirts, etc.) **1st Floor LTSC**

7:15 - 8:20 AM **Hot Breakfast**
(Mentors and Mentees meeting or by Interest Group) **Richards Treat University Center (RTUC): Fireplace and Parquet Rooms**

7:30 - 10:30 AM **Field Trip: Birding, Macon County Conservation District**
Led by **Dr. David Horn**, *Millikin University*
Meet at Registration Area 1st Floor LTSC

9:00 AM - Noon and 2:00 - 5:00 PM **SUSTAINING MEMBER EXHIBITS** **LTSC 224**

8:30- 10:00 AM **CONCURRENT WORKSHOP SESSION I**

The *Bioscene* of Yesterday, Today, and Tomorrow; Stephen Daggett, *Avila University* **LTSC 208**

Video and Digital Cameras in the Modern Biology Classroom, Or How I Got Rid of My Stereoscope and Enabled My Students to Document Everything!; Dick Wilson, *Rockhurst University* (emeritus) **LTSC 115**

A Martian Invasion of Teachable Moments for Environmental Science; Abour H. Cherif[1], David Morabito[1], Robert Aron[1], Jerry Adams[2], and Jeremy Dunning[3], [1]*DeVry University*, [2]*Columbia College*, [3]*Indiana University* **ADM 006**

Teaching the Process of Scientific Inquiry; Teresa Gonya[1], Paul Whitaker[2], and Richard Hein[3], [1]*University of Wisconsin-Fox Valley*, [2]*University of Wisconsin-Marathon County*, [3]*University of Wisconsin-Mantowoc* **LTSC 209**

10:00 - 10:30 AM **POSTER SESSION 1**
Refreshments provided **LTSC 221**
Refreshments: Located between LTSC 224 and 221

A Semester-Long Learning Experience with Aquatic Ecosytems in General Biology; Chad Scholes, *Rockhurst University***

Developing a Genetic Interaction Map of Cytoplasmic Dynein in *Neurospora crassa*; Laura Salem[1], Sarah Lamb[1], Robert Schnittker[2], and Mike Plamann[2], [1]*Rockhurst*

University, [2]*University of Missouri-Kansas City*

Biosafety Education: Drawing Language and Speeches; Marco Antonio Ferreira da Costa, *Oswaldo Cruz Foundation*

1 Librarian + Teaching Faculty = Successful Collaborations!; Andrea Dinkelman, *Iowa State University*

Snake Oil or Cure: An Investigation of How & Why It Works; Melanie Anastasio and Christine Bezotte, *Elmira College*

Teaching Without a Net: A Student-Driven Environmental Biology Course; Conrad Toepfer, *Brescia University*

Histodetective: Using Forensic Pathology to Teach Histology; Lynn Gillie and Mary Anne Perks, *Elmira College*

The Development and Use of Two-week Long Learning Cycle Blocks (LCBs) in a Freshman General Biology Course for Non-majors; John Rushkin, Dick Boutwell, Cary Chevalier, Melissa Daggett, Todd Eckdahl, and Sandie Seeger, *Missouri Western University*

10:30 - 11:15 AM **CONCURRENT PAPER SESSION 1**

From Tourist to Ecotourist to Conservation Biologist: Planning Travel Courses to Teach Biology and Responsible Global Citizenship; Judy Damery Parrish, *Millikin University* — **LTSC 208**

The Essential Physics of the Human Body: An Interactive Learning Module for Nursing and Health Science Students; Mahmoud Khalili[1], Jeremy Dunning[2], Dianne M. Jedlicka[3], Abour H. Cherif[3], Robert Aron[3], Frank Burrows[4], [1]*Northeastern Illinois University*, [2]*Indiana University*, [3]*DeVry University*, [4]*Pearson Custom Publishing* — **ADM 006**

Random Design: A New Paradigm for Creation; Richard Colling, *Olivet Nazarene University* — **LTSC 115**

11:30 - 12:30 PM **Luncheon and First Business Meeting**
First and Final Call for Nominations!!

Out of this World Teaching Idea contributions **RTUC Fireplace and Parquet Rooms**

12:30 - 1:30 PM **Luncheon Program** **RTUC Fireplace and Parquet Rooms**

Celeste Carter, *Foothills Community College*
"Building a Biotechnology Program at Foothill Community College: Lessons Learned and Future Trends"

1:45 - 2:30 PM **CONCURRENT PAPER SESSIONS 2**

The Dover Decision; Neil Baird, *Millikin University* **LTSC 209**

Report from the International Problem Based Learning Conference Lima, Peru; Margaret Waterman, *Southeast Missouri State University* **LTSC 115**

The First-Year Seminar—Setting Students Up for Success; Katherine O'Clair and Robert E. Page, *Arizona State University* **LTSC 208**

2:45 - 3:15 PM **POSTER SESSION 2**
Refreshments provided
Posters from morning available for review **LTSC 221**
Refreshments: Between LTSC 224 and 221

3:00 - 5:00 PM **Field Trip 1: Wabash Railroad Depot Antique Mall and Merchant Street shops**
Led by **Karen Baird**, *Richland Community College*

Field Trip 2: Behind the scenes tour of Scovill Zoo
Led by *David Webster*, Assistant Director **Scovill Zoo** **Meet at Registration Area**

3:30 - 4:15 PM **CONCURRENT PAPER SESSION 3**

The History of NSF-funded Teacher Education; Mary Czech, *Lourdes College* **LTSC 115**

Skill-Specific Assessments in Introductory Cell Biology and Biochemistry Courses. **LTSC 208**
Melissa A. F. Daggett and Benjamin D. Caldwell, *Missouri Western State University*

Easy-to-Use Physiology Lab Kits from iWorx/CB Sciences **TBA**
Steve Andre, *iWorx*/CB Sciences
Note: This presentation will extend to 4:45.

5:00 PM **ACUBE Committee Meetings**
Web Committee Meeting **LTSC 202**

6:00 - 7:00 PM **Social Hour**
Cash bar **RTUC Fireplace and Parquet Rooms**

7:00 - 9:00 PM **Dinner and Second Business Meeting**
(two-minute speeches prior to dinner; balloting after dinner, new officers announced at end of presentation)
The 2006 Out of this World Teaching Idea Award **RTUC Fireplace and Parquet Rooms**

8:00 – 9:00 PM **Dinner Program**
Malcolm Campbell, *Davidson College*
Director, **Genome Consortium for Active Teaching**
"Biology education 2056: balancing innovation with improvement." **RTUC Fireplace and Parquet Rooms**

Saturday, October 28th

7:30 - 8:45 AM **Continental Breakfast** (by Interest Group) **RTUC Fireplace and Parquet Rooms**

7:45 - 8:45 AM **Bioscene Editorial Board Meeting** **RTUC Fireplace and Parquet Rooms**

9:00 – 11:15 PM and 12:15 – 1:30 PM **SUSTAINING MEMBER EXHIBITS** **LTSC 224**

8:45 - 9:30 AM **CONCURRENT PAPER SESSION 4**

Engaging Non-Science Undergraduate Students in a Practical Human Biology Course; Christine Bezotte, *Elmira College* **LTSC 115**

Integrating the Scholarship of Teaching and Research: A Study of Window-Bird Collisions at Millikin University in Decatur, Illinois; David J. Horn, *Millikin University* **LTSC 208**

A Scientific "Holistic" Approach to Nutrition and Health; Dianne M. Jedlicka[1], Abour H. Cherif[1], Sujata Verma[2], Robert Aron[1], and Frank Burrows[3], [1]*DeVry University*, [2]*Ivy Tech State College*, [3]*Pearson Custom Publishing* **ADM 006**

9:45 – 11:15 AM **CONCURRENT WORKSHOP SESSION 2**

Collaborative Case-Based Study of

Genetic and Infectious Disease Via Free Molecular Biology Computer Simulations and Internet Conferencing; Mark Bergland and Karen Klyczek, *University of Wisconsin-River Falls*	**ADM 006**
Wouldn't Less Be Better? A Round-table Discussion of Content in Secondary and Undergraduate General Biology Texts; Marya Czech, *Lourdes College*	**LTSC 208**
Investigation Spaces: An Emerging Model for Online Research and Collaboration; Ethel Stanley[1], Margaret Waterman[2], and Stephen J. Everse[3], [1]*BioQUEST, Beloit College*, [2]*Southeast Missouri State University*, [3]*University of Vermont*	**ADM 005**
Art as Experience: Arts Integration into the Science Classroom; JoElla Eaglin Siuda, *Illinois Institute of Art @ Chicago*	**LTSC 115**

11:15 AM - 12:15 PM **Luncheon and Third Business Meeting**

Resolutions:
Brenda Moore, *Truman State University*

Executive Secretary Report:
Tom Davis, *Loras College*

Bioscene:
Steve Daggett, *Avila University*
Presidential Address: **Ethel Stanley**, *Beloit College*
2007 Meeting (51st) at Loras College:
Program Chair: **Pres Martin**, *Hamline University*
Adjournment: **Ethel Stanley**, *President* — **RTUC Fireplace and Parquet Rooms**

12:30 – 1:30 PM **Steering Committee Meeting** — **LTSC 301**
Includes newly elected members!
1:30 – 1:45 PM **BIOQUEST Workshop Introduction** — **LTSC 001**
1:15 – 4:00 PM BIOQUEST Workshop Sessions

Abstracts of Presentations

INVITED SPEAKERS

Improbable Research and the Ig Nobel Awards

Marc Abrahams, *Editor, Annals of Improbable Research*

Biology Education 2056: Balancing Innovation with Improvement

Malcolm Campbell, *Director, Genome Consortium for Active Teaching*

With the rapid pace of biological research, it is hard to know when to adapt to the new times, and when to hold tight to proven methods. Biology education needs to address many of the concerns enumerated in *Bio2010* (e.g., increase quantitative aspects of biology curricula, improve interdisciplinary training, welcome students from diverse backgrounds, and provide hands-on opportunities that reflect real-world research). We

need to measure and publish when a method helps, hurts, or makes no difference at all. Yet, we cannot forget the personal touch, the extra time answering sincere questions, the pat on the back for trying but failing to understand. College students have not changed as much as the technology around us. What can we do now to prepare our students for a future in science? Every time I see a newborn child, I am reminded how wonderful the natural word is and how fun it is to share biological insights with my students. I will highlight some of my efforts to share the excitement of discovery.

Building a Biotechnology Program at Foothill Community College: Lessons Learned and Future Trends

Celeste Carter, Program Director, Division of Biological and Health Sciences, Foothill College

This presentation will describe the current Biotechnology Program at Foothill College, discussing the growth of both the biotechnology and bioinformatics programs. The integral role of industry partners as both instructors and advisors, and the impact of the regional industry on the program will be presented.

WORKSHOPS

Session I

The Bioscene of Yesterday, Today, and Tomorrow

Stephen S. Daggett, *Avila University*

Bioscene: Journal of College Biology Teaching has been in existence since 1974, replacing the *Proceedings of the AMCBT* newsletter. The journal has evolved in that time and undergone several editorial changes. Four issues of *Bioscene* are currently published annually and distributed two to three times a year. With a new editor at the helm, it is an excellent time for members to reflect on their organization's publication. This workshop presentation will examine *Bioscene* in its past and current forms. Members will be solicited for ideas for future issues, the editor's duties, and the role of the editorial board.

Video and Digital Cameras in the Modern Biology Classroom, Or How I Got Rid of My Stereoscope and Enabled My Students to Document Everything!

Dick Wilson, *Rockhurst University* (emeritus)

Most lecture halls have document or presentation cameras, and we have all begun to use them extensively. The video or digital camera can be an even more powerful tool in the laboratory. Small, complex demonstrations from showing proper dissection technique, to photographs in books, to text highlighting, to final electrophoretic plates, to comparisons between two species of flies, are much more easily done with a laboratory document camera. They can also magnify, almost eliminating the need for a stereo scope. Additionally students can record images of organisms, or dissections, or traits for insertion into papers and posters, or make time lapse movies of seed germination, or effects of acid rain on amphibian embryos. Good document cameras are also portable into the field, even some go underwater for studying aquatic life, *in situ*. All images are exportable to *Word, Word Perfect, and or PowerPoint,* and are PC or Mac compatible. This will be a hands-on workshop and opportunity will be available to try some or all of these things yourself. Bring all your labs alive with the newest generation of laboratory technology --- easy to use, small foot-print, and relatively inexpensive.

A Martian Invasion of Teachable Moments for Environmental Science

Abour H. Cherif[1], David Morabito[1], Robert Aron[1], Jerry Adams[2], and Jeremy Dunning[3], [1]*DeVry University*, [2]*Columbia College*, [3]*Indiana University*

The recent missions to Mars have produced a mass of data and information in all forms and have forced the minds of many people world-wide to rethink their own perspectives on life itself. This drama unfolding about 35 million miles from earth, and digitally on our TV screens, is offering a growing reservoir for teachable moments. The curiosity and wonder of every image received prompts innumerable opportunities for inquiry. In this presentation we will share some of our ideas on how to bring into the classroom these exciting resources emanating from the Red Planet. Myth, reflection, research and behavior are likely targets of this Martian Invasion, stimulating students to examine further the environment around them. In the second part of the presentation, we would like to engage the audience in a discussion about their ideas on how to take advantage of these Mars missions for their classrooms, and other contemporary teachable moments that may capture the imagination of our students as they discover science. After this presentation and whether you are teaching topics related to desertification or deforestation, design and technology, space travel or and colonization, to name a few, the planet Mars and the recent missions to its environment will become part of your Never Ending Resources In Teaching Science.

Teaching the Process of Scientific Inquiry

Teresa Gonya[1], Paul Whitaker[2], and Richard Hein[3], [1]*University of Wisconsin-Fox Valley,*

[2]*University of Wisconsin-Marathon County,* [3]*University of Wisconsin-Mantowoc*

Many students enter college with a dualistic approach to education in general and science in particular: something is 'fact' or 'theory'. This dualistic attitude prevents students from understanding the true nature of scientific inquiry as a continuous process of gathering information about the natural world. Even students of the sciences do not always learn to interpret new information and think critically about the process of science. This general lack of understanding about how science works already threatens to allow pseudoscience ideas to be incorporated into science curricula throughout the nation. Several colleagues in the Biological Sciences Department have completed an education project designed to increase student understanding of the process of scientific inquiry which is so critical to produce educated citizens. We devised two assessment tools to allow us to measure student understanding of good scientific investigations. Students completed one assessment before and a different assessment after completing a biology course. One group of students had experience with teaching tools and case studies designed to encourage practice and interpretation of the scientific process, and the other group did not use the teaching tools. Results from this comparison study will be discussed.

Session II

Collaborative Case-Based Study of Genetic and Infectious Disease Via Free Molecular Biology Computer Simulations and Internet Conferencing

Mark Bergland and Karen Klyczek, *University of Wisconsin-River Falls*

Case It! is a National Science Foundation-sponsored project to promote collaborative case-based learning in biology education, via free molecular biology computer simulations and Internet conferencing. In this session, we will demonstrate how Case It! Software can be used to enhance understanding of molecular biology techniques for analyzing cases based on genetic and infectious diseases, as well as awareness of ethical issues associated with these diseases.

Students first use the Case It! simulation to analyze DNA and protein sequences for cases involving genetic diseases or infectious diseases such as SARS, HIV, West Nile, ebola, and influenza, among others. Simulated tools for case analysis include DNA and protein electrophoresis, Southern blotting, Western blotting, dot blot, PCR, and ELISA.

After analyzing the cases, students construct web-page "posters" using the Case It! Web Editor. They then play the roles of counselors, medical personnel, "family members", and others as they ask and answer questions about the case results using a custom Internet conferencing system hosted on our web site. Workshop participants will discuss how the Case It! system can be adapted to their home institutions. See the Case It home page for additional information - http://caseit.uwrf.edu

Wouldn't Less Be Better? A Round-table Discussion of Content in Secondary and Undergraduate General Biology Texts

Marya Czech, *Lourdes College*

Because the current condition of science education seems to be inversely proportional to increasing science text size, would it behoove us to examine encyclopedic biology texts and make recommendations for their simplification? Many state departments of education are adopting the NSTA content standards for K through 12 science curricula. Could we use the life science/biology standards to recommend a life science/biology curriculum in which the teacher has a resource text, a solid curriculum plan, and a classroom provided with laboratory, print, and online resources in place of encyclopedic texts in every student's desk?

Investigation Spaces: An Emerging Model for Online Research and Collaboration

Ethel Stanley[1], Margaret Waterman[2], and Stephen J. Everse[3], [1]*BioQUEST, Beloit College,* [2]*Southeast Missouri State University,* [3]*University of Vermont*

The use of *Investigation Spaces* is an emerging model for science curriculum, curriculum development and undergraduate research. Investigation Spaces address contemporary issues in science, technology and society and include robust research-based online materials and tools to explore these issues. Available online, each Investigation Space features collaboration tools to support instructors who wish to add to the space as well as student research groups who wish to work together online.

Each *Investigation Space* houses selected data sets, interactive online tools, and curricular materials such as Investigative Case Based Learning modules in order to provide a broad invitational framework for gaining a deeper understanding of the biological sciences. Therefore, Investigation Spaces provide expanded opportunities for learners: (1) to develop skills in the collaborative processes of scientific inquiry, data handling, quantitative analysis, and presenting results; (2) to gain a better understanding of both the requirements and rewards of careers in the

sciences, engineering and mathematics; and (3) to become better prepared for making decisions about complex issues involving science, society and technology.

Participants will explore connections between fetal development and adult cancer within a new Investigation Space on *Stem Cells and the Sonic Hedgehog Pathway.* We will focus on using resources including datasets, tools, and strategies for engaging learners in interdisciplinary, quantitative and collaborative investigations.

Art as Experience: Arts Integration into the Science Classroom

JoElla Eaglin Siuda, *Illinois Institute of Art @ Chicago*

The value of creativity and imagination in a variety of disciplines, has spurred the inclusion of the Arts in non-art classes. The creative process is one of searching for patterns, for orderly connections; using intuition or aesthetic sense, and developing new analogies (Root-Bernstein, 1984). Weisburd (1987) believes that art should play a more central role in education because it stimulates "transmutational thinking between concrete and abstract ideas". John Dewey, Maxine Greene and Elliot Eisner are some that looked at the Arts as a means of forward movement not only in education, but in life. Expanding horizons, contribution to meaning and value of future experiences, and altering ways of perceiving the world were goals of Dewey; Maxine Greene similarly alluded to aesthetic imagination as a vehicle with which to see things "as they could be otherwise" (1981), as did Eisner in his idea on perception through 'different lenses' so as to enrich and liberates cognition so as to develop a 'literacy of the senses'. He believed that "it is with the spark of artistic vision that one is allowed to see the best that science, language and social interaction has to offer" (1982).

It is armed with this background, that I wish to involve my colleagues in a presentation showing just how patterns, symbols, and artifacts in a commercial Arts college science classroom environment foster multimodal literacy, and is in fact are deeply set in the methodology and assessment of the classroom. This involvement will consist of three parts: 1) a brief looping PowerPoint Presentation of the pioneers of Arts integration, 2) a hands-on activity exemplifying Arts integration in the sciences as a means of viewing how experience, patterns, symbols, and artifacts interrelate, followed by guided discussion, 3) and lastly, viewing of some select pieces from the six offered chemistry, biology, and physics that manifest these interrelations.

Our college, The Illinois Institute or Art @ Chicago is a NCA accredited college here in the Midwest, with a population of approximately 3,500 students. Having degrees such as multimedia, web page design, fashion design, culinary, interior design, game art, etcetera, we are driven by industry standards. Nevertheless, this is tempered with a strong underpinning in general education to place individuals in the workforce not only prepared for their respective careers, but also able to envision what society demands will follow. It is this vision that goes back to the idea of Arts integration in the curriculum. At The Illinois Institute of Art, we know that leaders in Arts integration such as Dewey, Greene, and Eisner have sound ideas, and they are definitely in place in our classrooms.

PAPERS

Session I

From Tourist to Ecotourist to Conservation Biologist: Planning Travel Courses to Teach Biology and Responsible Global Citizenship

Judy Damery Parrish, *Millikin University*

Planning and carrying out field ecology courses should not only allow students to experience and integrate principles of ecology, but also prepare them to understand that in order for conservation of resources to be sustainable, needs of people surrounding the ecological sites must be met. Effective classroom work prior to trips prepares students to recognize the "stars" of many of the textbook examples of biotic interactions, and careful planning allows for the proceeds from tourism to benefit the local economy. Trips can also give students the chance to see the side of environmental debates they seldom have contact with, the side of those who are often negatively impacted by environmental preservation. I will present examples of our ecological journeys to Costa Rica, South Africa, and Alaska. A high point of our courses is the exposure to alternative business ventures that allow the rural poor to achieve and maintain an acceptable quality of life while preserving habitat. We try to expose students not only to the fascinating organisms in their habitats, but also to people deeply committed to finding and implementing alternative ways of feeding their families, while conserving biological resources. Instead of coming away with a gloomy outlook because of the diminishing biodiversity, our students are energized with models of economically workable projects and a vision of how they can improve the outcome. In most cases, student journals show gradual transitions in attitude, from ethnocentric superiority to eco-tourist, with understanding of the major conservation issues at the site.

The Essential Physics of the Human Body: An Interactive Learning Module for Nursing and Health Science Students

Mahmoud Khalili[1], Jeremy Dunning[2], Dianne M. Jedlicka[3], Abour H. Cherif[3], Robert Aron[3], Frank Burrows[4], [1]*Northeastern Illinois University*, [2]*Indiana University*, [3]*DeVry University*, [4]*Pearson Custom Publishing*

Utilizing the technical creativity of modern times, Nursing and Health Science students will interact within on-line modules that not only describe and then illustrate the more common Physical laws but they will also play matching "games", fill in boxes, roll wheel chairs up and down ramps…all on their computers, in order to bring home these Physical Laws. Most of the examples and illustrations will focus on the Medical and Health Care fields. Direct applications and illustrations of the Health professions with allow the students a degree of familiarity with the subject and thus make the learning of Physics more appealing. While some math is incorporated into the course, this publication focuses more on applications. DeVry University and Pearson Custom Publishing have teamed up to explore the possibilities on the subject of Physics in the Health Sciences and Nursing. A series of animated and interactive exercises have been created to illustrate Physical Laws in such a way that they will be remembered. Backed up by an illustrated student workbook, once the on-line component is completed, the student fills out the corresponding workbook pages. Students will learn the materials via various formats: by on-line activities, exercises, and animations and also by actual handwritten exercises including "thought questions" of higher order thinking.

Random Design: A New Paradigm for Creation

Richard Colling, *Olivet Nazarene University*

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

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

Language matters. Yet with strong confirmations of evolution arising from molecular genetics, learning the complex scientific language can be daunting for students and teachers alike. Another challenge is to find appropriate words in the context of a science class, that acknowledge the validity of student's religious beliefs, thus creating space for open communication and more effective learning.

The current paper addresses some of these challenges, offering a comprehensive solution to the science-faith controversy * Random Design. Random Design grants to both science and faith everything they claim to want: Science is free; God's place is secure.

Session II

The Dover Decision

Neil Baird, *Millikin University*

For six weeks during the fall of 2005, the small town of Dover, PA was the center of national attention at a landmark trial challenging the presentation of "intelligent design" as a "scientific" alternative to evolution. Dr. Kenneth Miller, professor of biology at Brown University, served as an expert witness during the first two days of the trial. He is co-author of the high school biology text used in the Dover Public Schools (as well as at 35% of the nation's other high schools). Miller's trial testimony serves as an excellent mini-course in helping the public to understand this complex issue. Transcripts of the entire 6-week trial are available on-line. Federal Judge John Jones issued his 139-page decision on December 20, 2005 ruling that ID is a form of creationism and therefore clearly violates the separation of church and state provisions of the First Amendment. Judge Jones' lengthy decision is also available on-line. Elements of the trial testimony and decision will be discussed in this session and compared to the balanced treatment "creation science" trials of the 1980s.

Report from the International Problem Based Learning Conference Lima, Peru

Margaret Waterman, *Southeast Missouri State University*

This session will report highlights of the fourth International Problem Based Learning Conference held at the Universidad Católica del Perú in Lima**,** July 17-24, 2006. Problem Based Learning (PBL) has many forms (including Investigative Case Based Learning), but in every case, learning begins with a meaningful, realistic problem. In the pursuit

of analyzing and solving the problem, students learn appropriate concepts, skills and attitudes, including highly valued skills of information management and collaboration. At the I-PBL conference participants from 50 countries engaged in nearly 300 sessions, workshops and plenary sessions. The sessions featured the use of PBL, creating PBL experiences, and research on learning with PBL in virtually every discipline. The conference website is http://www.pucp.edu.pe/eventos/congresos/pbl2006abp/i01_2.htm

The First-Year Seminar—Setting Students Up for Success

Katherine O'Clair and Robert E. Page, *Arizona State University*

This program will describe a First Year Seminar (FYS) course offered by the School of Life Sciences at Arizona State University at the Tempe Campus. The First Year Seminar is a semester-long, 1-credit course with a small enrollment that is centered around a specific topic related to the faculty member's specialization. It is designed to give students the opportunity to interact with top-level faculty and to introduce students to college-level learning and the resources that will help them to succeed in their academic endeavors. While most seminar courses are designed for upper-division students, this seminar allows entering students to become familiar with the tools, technologies, and strategies they would use in future classes. A strong emphasis is placed on the research process, and how to effectively gather, process, and use information, all within the context of the study of a scientific discipline.

In this program, we will share our approach for teaching this course, including curriculum design, instructional strategies and the integration of information and technology literacy. We will also discuss the goals and outcomes, as well as the evolution of the course. A question and answer period will follow the presentation.

Session III

The History of NSF-funded Teacher Education

Mary Czech, *Lourdes College*

Eleven years of NSF-funded summer institutes provided our secondary schools with a generation of well-educated and competent teachers of science and mathematics. The institutes made available masters level courses which endowed both breadth and depth to high school science and mathematics curricula. These experienced pedagogues translated their knowledge into the solid teaching of science and mathematics in the classrooms of the 1970s and 1980s. The education and training of today's science and mathematics teachers pales by comparison and may be at least partly responsible for both decreasing interest and lagging test scores.

Skill-Specific Assessments in Introductory Cell Biology and Biochemistry Courses.

Melissa A. F. Daggett and Benjamin D. Caldwell, *Missouri Western State University*

Curriculum requirements in the sciences often reflect the importance of a laboratory experience as an opportunity to enhance the learning of science-related skills, content and processes. Most science faculty would agree that laboratories play an important role in enhancing the learning and retention of new information. In today's high tech laboratories and professions, students will be required to work with increasingly sophisticated equipment that many teaching institutions do not have available. However, the lack of experience on sophisticated equipment may not be the most important factor that prevents our students from excelling after graduation, but rather a lack of basic laboratory skills that many laboratory veterans, including faculty, take for granted. In order to ensure that students graduate with the basic skills required for succeeding in the day-to-day operation of a laboratory or as a professional, a series of skill-related assessments are being developed and tested for use in the introductory cell biology and biochemistry courses at Missouri Western State University. These standardized skills can then be assessed later in advanced courses in order to monitor retention. The advantage of developing and using standardized assessment tools will permit changes in future laboratory assignments in order to improve the retention of these skills.

Easy-to-Use Physiology Lab Kits from iWorx/CB Sciences

Steve Andre, Technical Support Manager, iWorx/CB Sciences

Note: This presentation will conclude at 4:45.

Physiology laboratory kits from iWorx/CB Sciences make it easy to perform human and animal physiology experiments, including exercises on the cardiovascular, neuromuscular, and respiration systems. A typical teaching kit includes the data recording unit, probes and electrodes, transducers, LabScribe software for recording and analyzing data, and courseware to perform over 150 experiments with multiple exercises. One click of an electronic button or two, and data can easily be collected or analyzed. Users can also complete experiments of their own design with the same "click and play" ease.

Session IV

Engaging Non-Science Undergraduate Students in a Practical Human Biology Course

Christine Bezotte, *Elmira College*

As scientists we are comfortable with the development and execution of the scientific method in our work. To the non-major the term and its significance is often an abstract concept. To this end, many avoid lab based science classes in their Gen. Ed. requirements. In addition, few Human Biology lab manuals offer students exercises significant to them. These two factors combine to generate little enthusiasm for increasing their knowledge base of experimental concepts and the critical evaluation of a question. We developed a course that is a merging of the sciences [biology and chemistry] to investigate a number of the various modalities available which are related to health and how and why to question a "Snake Oil" claim. Students then applied their "scientific evidence" to what they learned about important anatomical physiological body systems. An emphasis was placed on the critical evaluation of product claims by utilizing the scientific method.

Integrating the Scholarship of Teaching and Research: A Study of Window-Bird Collisions at Millikin University in Decatur, Illinois

David J. Horn, *Millikin University*

Often considered distinct, the scholarship of teaching and research can be complementary, and provide students with a valuable experience that integrates theory with practice. I describe a class project on window-bird collisions being conducted by undergraduates at Millikin University in Decatur, Illinois. Between 100 million and 1 billion birds in North America die annually in window-bird collisions. However, additional research of factors influencing collision frequency and the development of solutions is needed. Millikin University students are studying window-bird collisions through daily searches for carcasses, as well as studies of bird scavengers and search efficiency. The research is coordinated by biology majors in upper-level courses. These students train non-major students to conduct the study. In addition to training non-major students, upperclassman are asked to present oral presentations and written papers of the research, while non-majors chronicle their experiences through a journal, and write a scientific paper on window-bird collisions. Ultimately, results from this teaching and research program may yield practical solutions to reduce collisions that can be implemented at other institutions while providing a curriculum with personal meaning and value.

A Scientific "Holistic" Approach to Nutrition and Health

Dianne M. Jedlicka[1], Abour H. Cherif[1], Sujata Verma[2], Robert Aron[1], and Frank Burrows[3], [1]*DeVry University*, [2]*Ivy Tech State College*, [3]*Pearson Custom Publishing*

Nutrition, Health, and Wellness is a new textbook edited with not only Nursing and Health Science majors in mind but also edited for people who want to learn the basics (including Biology and some Chemistry) about the foods we eat and the fluids we drink. The Digestive System is described in detail including its maintenance and related health issues. The relationship of the Endocrine System with overall health is explained in terms of Biology, Chemistry, and Physics. Also discussed are current ideas about allergies and other disorders, including why some foods might battle or even "prevent" certain conditions. There are sections devoted to biomechanics at the macro level (muscular exercise and fitness) as well as sections focusing on the energetics of metabolic reactions at the molecular level. This is an all encompassing idea and is expressed in a very readable college level text. Not only is the **text** a great resource but so are the accompanying on-line labs, discussions, thought questions, and animations. What a wonderful way to learn using all these multi-media methods and different modes of learning!

POSTERS

A Semester-Long Learning Experience with Aquatic Ecosytems in General Biology

Chad Scholes, *Rockhurst University***

I use aquatic ecosystems in General Biology II as a teaching tool through the entire semester. The first day of class students are assigned a 3-5 page literature review of ecosystem function that specifically addresses biodiversity, energy flow, and nutrient cycling using primary literature. In the first lab of the semester, students are given the assignment of planning a functional 4-5 L freshwater ecosystem. As part of this assignment, students predict what significant interactions will occur using a model or flow chart, which serves as their working hypothesis. Students assemble their ecosystem after assessing the initial abiotic and biotic parameters two weeks later. The ecosystems are observed at least weekly for six weeks and then are deconstructed and assessed for abiotic and biotic changes. Students then write an individual, formal lab report on their ecosystem experiment, focusing particularly on explaining the significant events that occurred during the six week period (e.g. – growth, death, change in pH). A crucial part of the lab report is the formulation of a

revised and significantly more complex model explaining how the ecosystem actually worked. The last component of this process is an essay question on the final exam asking how biodiversity, energy flow, and nutrient cycling interact.

Developing a Genetic Interaction Map of Cytoplasmic Dynein in *Neurospora crassa*

Laura Salem[1], Sarah Lamb[1], Robert Schnittker[2], and Mike Plamann[2], [1]*Rockhurst University*, [2]*University of Missouri-Kansas City*

Cytoplasmic dynein is a multisubunit complex that functions as a microtubule-associated motor required for organization of Golgi, ER to Golgi trafficking, retrograde transport of organelles in axons, assembly of the spindle, and intracellular transport of viruses such as herpes simplex and rabies. Cytoplasmic dynein function and interaction with various cargoes requires an additional multisubunit complex know as dynactin. A genetic screen has been developed, using the filamentous fungus *Neurospora crassa* that allows the isolation of hundreds of mutants defective for cytoplasmic dynein or dynactin. We took several dynein mutants and used a genetic reversion approach to begin to develop a genetic interaction map of the dynein gene and other interacting proteins.

Biosafety Education: Drawing Language and Speeches

Marco Antonio Ferreira da Costa, *Oswaldo Cruz Foundation*

The new orientations of the researches in education, evidence the importance of investigations that privilege the analysis of the discursive dimensions and using images in the processes of teaching-learning of sciences, in situations of class room. In that context, the present study has as its purpose to analyze the drawing language and the speeches produced by 82 students of a course of technical level of the area of health and 12 teachers of the Oswaldo Cruz Foundation / Rio de Janeiro / Brazil. The results, pointed through this technique, demonstrated that the biosafety-learning occurs through the oral and visual language and with a habitual speech, and that the use of the drawing language isn't properly understood by the teachers.

1 Librarian + Teaching Faculty = Successful Collaborations!

Andrea Dinkelman, *Iowa State University*

This poster presents several examples of my collaborations with teaching faculty at Iowa State University. The following courses are highlighted: English 105/Microbiology & Horticulture Learning Communities; Biology 313: Principles of Genetics Laboratory; and Biology 394A: Biomes of Australia. I have partnered with faculty in a variety of ways including: developing assignments which reinforce information literacy principles such as knowing how to evaluate information quality; providing instruction on library resources and research techniques; and meeting with students individually to track research progress. These partnerships are a result of a growing concern among faculty that students are often unprepared to identify and use appropriate information resources. This poster summarizes my involvement in the courses and includes classroom activities and student assessment data regarding the library instruction component of the courses.

Snake Oil or Cure: An Investigation of How & Why It Works

Melanie Anastasio and Christine Bezotte, *Elmira College*

Non-science majors are quite capable of critically analyzing scientific information when it is presented to them in a context which is familiar to their everyday lives. This poster will detail an interactive laboratory exercise that utilizes the student's natural curiosity for the reasons behind the effectiveness of herbal essential oils. Students studying the body systems through looking at alternative health therapies, scientifically evaluate the therapeutic claims utilizing separation, distillation and chromatographic chemistry and looking at inhibition of microbial growth on medium.

Teaching Without a Net: A Student-Driven Environmental Biology Course

Conrad Toepfer, *Brescia University*

During the Spring 2006 semester, I offered a new course, Applied Environmental Science, as an upper-level elective in the biology major at Brescia University, a small liberal arts school in KY. Most students in the course had completed a four-semester biology core but had no prior exposure to environmental biology. In order to strengthen students' critical thinking skills, I designed the course to be almost entirely free of lectures. One particular system, southern LA, was emphasized through the semester, although comparisons also were made to other locations, locally and globally. The course was loosely based on a case study approach with five themes, loss of land in southern LA, the Gulf Dead Zone, environmental health and justice, the energy industry, and introduced species. Students were evaluated on participation in discussion, their coordination of research for one theme, and in their

production of a journal in which they independently evaluated material for each topic. At the end of the semester, students provided a subjective self evaluation of their before and after understanding of 36 topics that came up during their research and indicated significant (Paired t-tests, $p < 0.001$) improvement on their understanding of all 36 topics. While my evaluation of the approach was less favorable, it was apparent from class discussions and journals that students' awareness of the existence and complexity of environmental issues did improve over the course of the semester. They also developed a greater level of skepticism and were more willing to question the validity of statements from different sides of controversial issues.

Histodetective: Using Forensic Pathology to Teach Histology

Lynn Gillie and Mary Anne Perks, *Elmira College*

Student interest in learning introductory histology can be increased by linking the study of tissues to forensic applications. Students observe and describe standard mammalian tissues using commercially prepared slides. After students are comfortable with identifying the 'normal' set of tissues, they are given a set of 6 unknowns to identify. Each unknown has some type of disease or problem evident through careful observation. The students' challenge is twofold: correctly identify the tissue type, and then describe how it differs from the normal condition. After playing the role of forensic pathologist, students are more likely to see the relevance of learning normal tissue histology.

The Development and Use of Two-week Long Learning Cycle Blocks (LCBs) in a Freshman General Biology Course for Non-majors.

John Rushin, Dick Boutwell, Cary Chevalier, Melissa Daggett, Todd Eckdahl and Sandie Seeger, *Missouri Western State University*

This paper describes the development and use of a series of two-week long learning cycle blocks (LCBs) in the laboratory sections of a traditional large (80 to 130 students) non-major general biology lecture. (Each lab section has a maximum of 24 students.) Week 1 of the LCB involves the students in engagement, exploration and concept explanation using short demonstration-type experiments and discussions. During Week 1, the students work in small groups to set up their own directed scientific mini-investigations in order to elaborate upon the processes and concepts learned earlier in the lab period. These independent mini-investigations are completed over the next week and during the next scheduled laboratory period. The results and conclusions of the mini-investigations are shared with the entire class during the Week 2 lab period. An evaluation of the concepts and processes learned by the students during the LCB is also completed at the end of the Week 2 lab period.

Lodging and Travel Information for
50th Annual ACUBE Fall Meeting

The Revolution and Evolution of Biology
Education: Where 50 Years Can Take Us
Millikin University
Decatur, IL

Group rates have been secured for blocks of rooms at six motels/hotels. All rates are per night plus tax. No other discounts apply to group rates. Be sure to mention ACUBE when making your reservations in order to get the group rate. Rooms not reserved by September 26, 2006 will be released to the general public.

Two of the facilities (numbers 5 and 8 on the list) are located less than 3 miles west of campus near the intersection of I-72 and US 36 (actually where US 36 intersects with Wykles Road).

The four other facilities (numbers 2, 6,7, and 11 on the list) are located 6 miles north and east of campus just north of the intersection of I-72 and US 51. A shopping mall and many restaurants are located nearby.

Other lodging possibilities beyond the six with group rates can be found on the website of the Decatur Area Convention and Visitors Bureau: www.decaturcvb.com.

#2
Baymont Inn
5100 Hickory Pt. Frontage Road
Decatur, IL 62526
217-875-5800
rate: $50.00 single

#5
Days Inn
333 N. Wyckles Rd.
Decatur, IL 62522
217-422-5900
rate: $46.95 Dbl/Dbl

#6
Fairfield Inn
1417 Hickory Point Dr.
Forsyth, IL 62535
217-875-3337
rate: $66.00 flat rate (1-4 persons)

#7
Hampton Inn
1429 Hickory Point Dr.
Forsyth, IL 62535
217-877-5577
rate: $66.00 flat rate (1-4 persons)

#8
Decatur Hotel and Conference Center
(formerly Holiday Inn Select)
Route 36 and Wyckles Rd.
Decatur, IL 62522
217-422-8800
rate: $82.00 flat rate (1-4 persons)

#11
Ramada Limited
355 E. Hickory Point Rd.
Decatur, IL 62526
217-876-8011
rate: $69.00 flat rate (1-4 persons)

ACUBE Governance for 2006

President - Ethel Stanley, *Beloit College*
Immediate Past President - Lynn Gillie, *Elmira College*
Executive Secretary - Tom Davis, *Loras College*
Secretary - Laura Salem, *Rockhurst University*
First Vice President (Program Chair) - Conrad Toepfer, *Brescia College*
Second Vice President (Local Arrangements) - Harold Wilkinson, *Millikin University*

Board Members

Hugh Cole, *Hopkinsville Community College*
Melissa Daggett, *Missouri Western State University*
W. Wyatt Hoback, *University of Nebraska- Kearney*
Bobby Lee, *Western Kentucky Community and Technical College*
Brenda Moore, *Truman State University*
Conrad Toepfer, *Brescia College*

Standing Committees

Membership - Bobby Lee, *Western Kentucky Community and Technical College*
Constitution - Margaret Waterman, *Southeast Missouri State University*
Nominations - Conrad Toepfer, *Brescia College*
Internet - Nancy Sanders and Margaret Waterman
Bioscene - Stephen S. Daggett, *Avila University*
Awards - William Brett, *Indiana State University*
Resolutions - Brenda Moore, *Truman State University*
Historian - Edward Kos, *Rockhurst University*

Call for Nominations

President-Elect & Steering Committee Members

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

If you wish to nominate a member of ACUBE for a position, send a Letter of Nomination to the Chair of the Nominations Committee: Dr. Conrad Toepfer, Brescia University, 717 Frederica St., Owensboro, KY 42301 (270-686-4221, conrad.toepfer@brescia.edu).

ACUBE 50th Annual Meeting

Millikin University
Decatur, IL
October 26-28, 2006

The Revolution and Evolution of Biology Education:
Where 50 Years Can Take Us

Call for Abstracts

From the description of DNA structure in 1953 to the recent discovery of "Hobbits" in Flores, the field of biology has undergone a revolution. At the same time, textbooks for "introductory" biology have rapidly grown from 200 pages to well over 1000 pages. As the amount of information has grown, biology education has evolved to include PBL, case studies, computer simulations, open-ended laboratory projects, and many other innovative methods.

The importance of biology over the last half century is undeniable. For example, 14 of 35 individuals "Who Made a Difference" in a special issue of Smithsonian Magazine are biologists or are influenced by biological topics. As biology continues to blossom, our importance as teachers will make the 2006 Annual Meeting a momentous event for our society. Potential topics for presentations include historical reflections, changes in curriculum, interdisciplinary courses, changes in educational technology, the Web and student learning, seemingly constant threats to teaching evolution, current cutting-edge techniques, and even your newest, untested, and most radical ideas.

Many of you can show us where we came from in the last 50 years, what we should be doing now, and where we should be headed in the next 50 years. Please consider sharing your experiences, your knowledge, and your techniques with us at the 50th ACUBE Annual Meeting in Decatur, IL. Given the importance of this meeting, any type of presentation is welcome. We encourage you to submit a poster, paper or workshop but will gladly try to accommodate additional presentation formats.

Please send a 200-word abstract and the information below as e-mail attachments, by mail, or by fax by May 31, 2006 to

Conrad Toepfer, Brescia University, 717 Frederica St., Owensboro, KY 42301
Ph: 270-686-4221, Fax: 270-686-4222, e-mail: conrad.toepfer@brescia.edu

Proposed Title: _____

Presentation type: _____ 90-min workshop _____ 45-min paper _____ Poster _____ Other (Please explain)
(Rank in order of preference)

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

Name of presenter(s): _____

Work address(es): _____
_____

Presenter phone number: _____ e-mail: _____

ACUBE ELECTIONS NOMINEES 2006

Nominee for President

Conrad Toepfer
Department of Biology
Brescia University
717 Frederica St.
Owensboro, KY 42303

Education:

B.S., Biology, Centre College, 1990
M.S., Zoology, Louisiana State University, 1992
Ph.D., Zoology, Oklahoma State University, 1997

Professional Experience:

2004-Present, Assistant Professor of Biology, Brescia University
1999-2004, Assistant Professor of Biology, Millikin University
1997-1999, Teaching Postdoctoral Associate, Truman State University

ACUBE Experience:

Member since 1998
Bioscene Editorial Board since 2001
Steering Committee member since 2003
First Vice President (Program Chair) for 2006 Annual Meeting
at Millikin University

Publications:

I have fourteen publications mostly in fish ecology with papers on bison and spider foraging tossed in for good measure. Two of the papers have students as co-authors.

Presentations:

I have given or am a co-presenter on nearly fifty presentations at campus symposia and professional meetings. Students have delivered thirty of those presentations, and eight of the students have won a total of ten awards for their presentations.

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Nominees for Steering Committee

Peter A. White
Assistant Professor
Natural Sciences Department
Colby-Sawyer College
541 Main Street
New London, NH 03257

Ph.D. Cell and Molecular Biology, Indiana State University, Terre Haute, IN
1996-2001
Dissertation: Microvillar Disruption and F-Actin Sequestration in Anoxic Proximal Tubular Cells
Advisor: Dr. Jing Chen

B.S. Biology, University of Massachusetts-Dartmouth, N. Dartmouth, MA
1991-1995

Dept. of Natural Sciences, Colby-Sawyer College, New London, NH
Graduate Teaching Assistant (1996-2001)

Dept. of Life Sciences, Indiana State University, Terre Haute, IN

SCHOLARLY INTERESTS
Mechanisms of renal failure, bacterial virulence factors, science pedagogy.

PUBLICATIONS
White, P., L. Gu, and J. Chen. Decreased actin solubility observed during ATP-depletion is mimicked by severing agents but not depolymerizing agents in isolated and cultured proximal tubular cells. *Clinical Physiology and Functional Imaging* 22(5): 312-319, 2002.

White, P., R. B. Doctor, R. Dahl, and J. Chen. Coincident microvillar actin bundle disruption and perinuclear actin sequestration in anoxic proximal tubule. *American Journal of Physiology* 278 (6): F886-F893, 2000.

White, P., and J. Chen. Sequestration of actin by an insoluble perinuclear complex in anoxic renal proximal tubule cells (abstract). *Journal of American Society of Nephrology* 10:624A, Miami Beach, FL, 1999.

White, P. and T.S. Uphoff. Generation and characterization of HpmB mutants of *Proteus mirabilis* calcium-independent hemolysin system (abstract). 98th Annual Meeting of the American Society of Microbiology. Atlanta, GA, 1998.

Chandler, N., T. Lowder, V. Quinn, K. Ruebel, M. Spinks, K. Ward, and **P. White**, editors. *I'm Supposed to Do What?: A Resource Guide for the Graduate Teacher*. Indiana State University, ©1999.

"The customer is always right….right?: Adoption of a new liberal education model and its impact on biology instruction at a small, liberal arts college." Association of College and University Biology Educators (ACUBE), Southeast Missouri State University, Cape Girardeau, MO, October, 2005.

"Can a new dog learn old tricks?: A junior faculty member puts NSF's recommendations for Science, Math, Engineering, and Technology (SME&T) education to task." Association of College and University Biology Educators (ACUBE), Truman State University, Kirksville, MO, October, 2003.

"Mechanisms of dysfunction in ATP-depleted renal proximal tubular cells." Sacred Heart University (CT) invited seminar speaker, March 2002.

"The cellular and molecular alterations associated with acute renal (kidney) failure." Colby-Sawyer College biology department seminar series, September 2001.

"Actin cytoskeleton disruption in anoxic proximal tubule cells." Indiana State University biology department seminar series, April 2001.

"How to run a successful laboratory class." Invited speaker. Graduate Student Orientation, Indiana State University, 1999, 2000.

PROFESSIONAL ACTIVITIES
Participant, The Grant Writing Institute, Dartmouth College, March 2005.
Editor (language), Central European Science Journal, 2003-2006.
Grants Reviewer, NSF- CCLI, 2005.

****

Sr. Marya Czech
Assistant Professor of Biology
Lourdes College
6832 Convent Blvd.
Sylvania, OH 43560

Biography not available at press time.

NAME: _____ DATE: _____

ACUBE

Association of College and University Biology Educators

Formerly the Association of Midwest College Biology Teachers (AMCBT)

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 2005) Regular Membership $25 Student Membership $15 Retired Membership $5

Return to: Association of College and University Biology Educators, Attn: Tom Davis, Executive Secretary, Department of Biology, Loras College, 1450 Alta Vista, Dubuque, IA 52004-0178