

Bioscene



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CRITICAL THINKING IN A NEUROBIOLOGY COURSE

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Critical thinking skills are fostered in an upper level undergraduate neurobiology course in several ways. First, students formulate questions about neurobiology that personally interest them to motivate their thinking critically. Second, critical thinking is defined, and the instructor's goals for the course are clearly stated, at the outset of the course. Third, the instructor models critical thinking, demonstrating how to read the technical literature, and encouraging active discussion of data. Fourth, students are given opportunities to develop this skill through practice. Fifth, assessment of performance in the course reflects a student's success in acquiring the ability to think critically. Though this approach may have limitations, it does improve students' ability to respond effectively to novel problems.

Introduction

There is a growing interest in enhancing critical thinking skills among students in the biological sciences (Allen and Stroup, 1993). Critical thinking may be defined operationally as the ability to assess the truth or falsehood of an assertion by carefully weighing evidence, by recognizing assumptions that may underly one's reasoning, and by taking responsibility for arguing a particular position (Perry, 1970; Mellon and Sass, 1981; Arons, 1976; Allen and Stroup, 1993; Allen, 1995).

Over the last seven years, I have taught an upper level undergraduate/ beginning graduate student course called Introduction to Neurobiology. It is an elective course, ranges in size from 12 to 30 students, and is about equally divided between undergraduates (generally Juniors and Seniors), and graduate students. I have gradually introduced a wide variety of changes into the course that foster critical thinking. These changes came from a careful consideration of the educational goals for the course, and the difficulties that students were experiencing in learning the material.

There are several educational goals for the course. I wanted students to get excited about the great advances and new understanding in the neurosciences, and to grasp key concepts in the field. Most importantly, they should be able to teach themselves what they needed to know once

they had defined their own area of interest, and to critically assess the information they obtained from the technical literature. The ability to do this would serve them for many years, even after the specific facts of the course were superseded by advances in the field. It would also help them in many other subject areas.

In the first years of the course, students had several difficulties in mastering the material. Many students showed almost no retention of material that had been taught to them, even as recently as the previous semester. Many would attempt to master new material by memorizing it, repeating it back on exams, and then forgetting it in order to repeat this process with later exams, and with other courses. Moreover, many students had difficulty dealing with problems that required them to use material that they had learned previously if it was presented in an unfamiliar context. Exhortations to think critically about material that had not been assimilated led to feelings of anxiety and bafflement on the part of students. These problems were serious obstacles to the educational goals of the course.

The following steps have helped to overcome the difficulties and achieve the goals:

- (1) Students are motivated to engage in critical thinking;
- (2) The educational goals of the course, and the process of critical thinking, are explained explicitly at the outset;

- (3) Critical thinking is modeled, so students can learn by example how to do it themselves ;
- (4) Students practice critical thinking to improve their skill in it;
- (5) Assessments of performance reflect success in critical thinking.

After describing the methods used to achieve these five steps, I will discuss some of the limitations of the approach, and of the course. Despite these caveats, I will argue that this approach has improved the educational experience of my students, and may be of general utility for many other courses in the sciences.

Motivation

Critical thinking, like spinach, may be good for students, but it may not be something they choose on their own. It requires sustained intellectual effort. It can make students anxious. It requires repeated practice to master. Thus, it is crucial to provide students with a positive motivation for engaging in it. The desire to get a good grade in a course, or to please a professor, are unlikely to be adequate motivations for the hard work that is necessary. Moreover, the whole rationale for engaging in critical thinking is that students should be enthusiastically responsible for what they learn, and want to master the skill of critical thinking in order to improve their ability to learn, assess, and assimilate new material.

In order to help students discover their motivation for learning the material in the course, the entire first session of the class is devoted to the

following two questions: (1) What question in the field of neurobiology would you like to answer by the end of the semester? (2) What information would you need to know in order to answer that question?

I call on different students, and ask them if they wish to tell us their question. If they do, I ask them to tell me their name and their major in addition to the question they would like to answer. I write the question up on the board, and initiate a discussion about it. Table 1 shows a few of the questions that students asked last year and this year.

If the question refers to a medical condition (e.g., understanding how to cure Alzheimer's disease, stroke, or brain trauma after an accident), I ask them what else they would need to know in order to answer that question. As they discuss the question, they realize that, in order to cure a disease, one must understand its underlying causes, and that it is therefore essential to understand the cellular and molecular mechanisms that go awry and lead to pathology. In order to understand abnormal states, it is generally useful to understand the normal function of the system. Furthermore, the more we understand about a system's normal function, the more likely we are to cure novel diseases. If one can answer "How does it work?", one can answer "How can we fix it?"; but if one only knows the answer to the second question, one may still not be able to answer the first question. This provides a motivation for understanding basic neuroscience even if one's major interest is in medical applications.

If the question refers to an engineering problem (e.g., building a machine that could think, or a robot that could see and move about in a natural environment), I again ask them what they would need to know in order to answer that question. As the students discuss the question, they realize that even simpler animals can solve some of these problems, and that it may be much easier to

Table 1. Student Questions.

1. How does the brain build circuits?
2. What are the mechanisms of long term potentiation, and how do they relate to learning?
3. Can we surgically repair nerve damage, e. g., spinal cord injuries?
4. Could we simulate in an artificial system thinking and consciousness?
5. What are the mechanisms of cerebral damage before and after a stroke?
6. What neural parameters can be observed in the fossil record, especially in early hominids?
7. Is there a neural basis for intelligence?

engineer a solution after looking at the details of a previously solved problem. I emphasize that biological organisms have evolved, so that one cannot assume that their design is either (a) optimal or (b) readily comprehensible to us, but that we may gain valuable insight by studying how they work. If one can answer "How does it work?", one can answer "How can we build something that does the same thing?". The first question is the fundamental one to answer. This helps motivate the study of basic neuroscience even if one's major interest is in engineering applications.

If the questions reflect an interest in basic neuroscience, we discuss the need to understand the cellular and molecular properties of nerve cells, their synaptic interactions, how they are put together during development, their function within small circuits, and their function within large brain systems, all within the context of an animal's body, behavior, and environment. This provides the students with my rationale for the syllabus for the course. More importantly, this first session helps students develop a specific personal motivation for learning the material in the course.

Goals and definitions

If students have succeeded in other courses by memorizing facts, or by memorizing problem solving templates, they are not likely to abandon these techniques in favor of a completely different approach. Nor should they. There are many circumstances in which these techniques can be effective for recalling material, or more efficient for solving familiar problems. My goal is to add another tool to their intellectual toolbox, that is, the skill of critical thinking.

To motivate the idea of critical thinking as an intellectual tool, I ask students to imagine a trade school that teaches how to use a hammer, screwdriver, or a drill, by showing slides of these different tools, and describing what they do in lectures. These students are then given multiple choice tests with questions like, "A hammer is used for (a) screwing screws, (b) banging in nails, (c) bending wires, (d) drilling holes, (e) none of the above." Assume a student gets As in this course, and all the other courses in the school, which are taught in the same way. I ask them, "Would you hire a graduate of this school to build you a chair?" They all laugh. Then I say, "But how is it any different if all you know how to do is to answer multiple choice questions? Unless you use the intellectual

tools your professors give you, you won't do any better!" This makes them think. It emphasizes that memorization of facts or templates alone will not allow them to deal with real problems. They must use the information, and learn to think critically about it, if they wish to cope effectively with novel, real world situations.

We then discuss the stages that lead to critical thinking, based on ideas developed by William G. Perry Jr. (Perry, 1970; Mellon and Sass, 1981). In this schema, one begins with Dualism, the notion that all statements are either right or wrong, and that truth and falsehood can be determined by reference to an authority. The recognition that there is fundamental uncertainty leads to the next stage, Multiplicity, the notion that truth is personal. Students at this stage will cite the views of different authorities, but will not defend any particular statement. The recognition that evidence is relevant to the value of different statements leads to Relativism, in which a student can cite a viewpoint and the evidence that supports it, but does not have his or her own viewpoint. Finally, the recognition that one must weigh evidence oneself leads to Commitment, in which one actively seeks evidence for evaluating a particular hypothesis, can effectively weigh evidence and reach a decision about its truth or falsehood, and can argue for one's views using logic and evidence. This is the essence of critical thinking. This skill is not just valuable for studying science, but for analyzing more general questions, such as those of public policy.

Having provided the students with an introduction to critical thinking, I explicitly define the goals of the course (described above), and emphasize the centrality of critical thinking to achieving those goals. I stress that a significant part of the first half of the course will be a quantitative introduction to neurophysiology, and this will require students to use mathematical formulae to solve problems. In order to give the students a feeling for the level of mathematical sophistication of the course, I hand out a math quiz. I give the students 15 minutes to complete the quiz, then collect it and hand out an answer sheet, which I briefly discuss with them. I grade the quiz, but do not count it for the final grade. If the quiz indicates that a student has serious deficiencies, I strongly suggest that the student practices problem solving, and seeks tutoring if necessary. Thus, I clearly state my expectations for student performance during the first half of the semester.

In the same class session, I hand out copies of a recently published article in the neurosciences from the journal *Science*, and spend the rest of the session discussing and demonstrating how one reads the technical literature. First, I talk about the structure of a scientific article, which is generally as stereotyped in form as a sonnet. A scientific article begins with a brief Abstract, and then an Introduction, Materials and Methods, Results, and Discussion. Second, I point out that most scientific writing is, in a sense, a form of fiction. The historical sequence of discovery is eliminated, the blind alleys and false leads are suppressed, and history may be effectively re-written so that the article presents a logical sequence of steps, each one following inevitably from the previous one. Some investigators may actually obtain their results in a completely logical sequence, but most don't, not because they are sloppy, but because they discover that their pet theory was wrong, and that the truth is stranger and more interesting. Third, I point out that scientists can never prove they are correct; they can only ingeniously rule out different explanations by careful experimentation, that is, they can fail to prove that they are wrong. If they do manage to refute their own theories, they have to dismiss them, even though this may be emotionally wrenching. The consolation is that well designed experiments not only rule out theories; they may suggest better ones.

"Is an article correct because it has been published in *Science*?", I ask the class. "If not, how could it be wrong?" This leads to an interesting discussion on possible sources of error: (a) the authors could have been untruthful; (b) the data could have been misinterpreted; (c) the method used to obtain the data could be flawed; (d) the results might not be repeatable, or (e) the underlying assumptions could be wrong.

How does one read a technical article? A natural tendency in reading these extremely complex articles is to read the Abstract, the Introduction, and the Discussion, in order to understand the claims that the authors are making. Most readers then accept these claims, and ignore the detailed evidence because it is too complicated to understand. This is not the way to read critically. Begin with the Abstract, then look carefully at the Methods, being especially careful to think about their possible limitations. Spend most of the time looking at the Results, and attempt to understand what each figure shows, and whether it actually supports the hypothesis. Are there other explana-

tions for the results? Does the evidence rule out these other explanations, or not? Are there internal contradictions in the data presented? Then it is time to read the Discussion, and see if the authors' claims actually follow from the data. Good scientific articles will attempt to raise and eliminate the most serious objections, and discuss some of the limitations of the conclusions. Good readers may be able to spot unwarranted assumptions, flaws in logic, and experimental limitations in the data. The goal is not to be so critical that all one can see are the flaws, but to have a healthy scepticism about claims, however authoritatively presented, until one has weighed the evidence oneself and come to one's own conclusions.

I then read the Abstract of the article that I handed out, and translate it phrase by phrase into English, providing background information necessary to understand its key points. We look at the figures together, try to understand them, and discuss whether or not they support the hypothesis. We discuss some of the assumptions that the authors have made implicitly or explicitly, as well as other possible interpretations of the data. At the end of the session, I tell the students that I have shown them what I expect them to be able to do by the end of the second half of the semester. Thus, by the end of the second class session the students have a clear sense of the goals and expectations of the course.

Modeling critical thinking

It is not enough for a professor to talk about critical thinking; he or she needs to model the behavior by engaging in it regularly. Handing out and analyzing a technical article is a good start, but if one then relapses into a standard lecture format, the students are likely to relapse into the standard passive learning mode. Modeling critical thinking requires that the professor treat students as potential colleagues who should be respected as sources of information and novel insights. The goal is to develop an ongoing dialogue with students in which they are engaged with the professor in critiquing and assessing data.

In order to engage students in discussions throughout the course, I learn students' names, encourage students to ask questions, and ask the students questions. By asking students to tell me their name during the first few class sessions, by handing back problem sets to students individually, and by keeping the class list with me during

the first sessions, I can usually master most of the students' names within the first four or five class sessions. This indicates to the students that I regard each of them as unique individuals. It also prevents them from lapsing into unobtrusive passivity, since I can call on any one of them by name at any time.

I begin each class by asking if students have any questions. If a student does ask a question, I spend the first few minutes of the session answering it.

During the class period, I encourage students to ask questions. If I see a student with a puzzled look on his face, I will ask him if he can ask a question that clarifies what it is he doesn't understand. I treat all questions respectfully, and never denigrate a student for asking a "stupid" question.

I encourage challenging questions that exemplify critical thinking, such as "What is the evidence for what you just told us?", or "What mechanism could account for this phenomenon?", or "How is this consistent with this other material that I learned in another course?", or "Are you sure you got the signs right in the equation you just wrote on the board?". These questions are an opportunity to introduce more advanced material, or an opportunity to be honest about my own mistakes, or the limitations of my knowledge. I publicly correct myself if I made a mistake in something I presented in class, and will come back with an answer during the next session if I didn't know the answer when the question was asked. I will sometimes defer certain questions to after class if they will take me too far afield, or will force me to repeat material that most of the class appears to have grasped.

I regularly intersperse my lecture with questions to the students. I convince them that these questions are not rhetorical by waiting up to half a minute for them to answer, by calling on particular students by name, and by seriously considering their responses. If a student does not prefer to answer, I go on to another, but I may return to this student later in the session. I avoid the "one right answer" syndrome, which discourages creative

thinking. For example, during this past semester, I asked students what an animal could do with a visual system that could only distinguish light from dark. I expected that they would say that the animal could distinguish day from night, affecting when it was active or inactive. Instead, one student pointed out that an animal that lives underwater or underground could use this kind of visual system to find the surface, which

Table 2. Questions as Lecture Outline.

Questions for lecture on locomotion

- 1. What are the problems that need to be solved by a neural system that controls locomotion?**
 - a. How do the properties of an animal's body affect the way it locomotes?**
 - b. How do the properties of the environment affect the way an animal locomotes?**
 - c. In legged locomotion, how does one maintain stability?**
 - d. In legged locomotion, how does one generate a range of gaits?**
 - e. How does a locomotion system incorporate sensory feedback?**
 - f. How does a locomotion system steer?**
 - g. How does a locomotion system plan movements, especially over rough terrain?**

was a very good answer that I had never thought of before!

During the second half of the course, I hand out lecture outlines in the form of questions [Table 2]. The questions serve as the basis for both lecture and discussion, as well as for the data figures analyzed in class.

Practicing critical thinking

The ability to think critically is a skill that can be learned and can be improved by practice. For this reason, students are given multiple opportunities throughout the semester to engage in activities that encourage them to solve problems and think critically:

- (a) problem sets
- (b) "lab" sessions using computer simulations

- (c) student-led problem sessions after class
- (d) a review exam prior to the midterm, and
- (e) data figures to analyze in class.

During the first half of the semester, which emphasizes a quantitative understanding of electrophysiology, students are given weekly problem sets. Two of the problem sets use computer programs: AXOVACS, written by Professor Stephen Jones, (Department of Physiology and Biophysics), and HH, written by Mark Dimaline, Randall Beer (Department of Computer Engineering and Science), and myself. The problems give students the opportunity to calculate, simulate, and explore many of the properties of nerve cells, e.g., their current/frequency characteristics, threshold, refractory period, response to pharmacological agents, ionic conductances, channel properties, signal conduction, and spatial and temporal summation. Some problems can be solved in many different ways. [Table 3 shows excerpts from one of the problem sets]. As I hand back a graded problem set, I give the student a detailed answer key, so that the student has immediate feedback.

In the last two years, I have introduced additional problem sessions. The sessions are led by an undergraduate who took the course in the previ-

ous year, and occur at two different times (one is usually right after class, the other early in the evening). These times are chosen so that, in principle, all students in the class can attend at least one session. During the first half of the semester, the problem sessions are devoted to solving quantitative neurophysiological problems. Students may ask about problems that were on problem sets, but the sessions are not designed to work these problems for them. Students are encouraged to propose problems and work together in small groups to solve them. During the second half of the semester, problem sessions are devoted to analysis of experimental data from articles. Part of the session reviews material covered in class, and part of the session explores new data. I regularly sit in during one of the two weekly sessions, but defer to the student leader, unless he directly asks me to contribute to the discussion, or is inadvertently misleading the students.

One week prior to the midterm, I run a review session during a regularly scheduled class session. Prior to the class session, I write all the necessary equations on the board, along with other information that might or might not be useful. I then hand out a review exam that consists of questions similar to those that are likely to be on the midterm,

Table 3. Problem Set Questions.

(Excerpt from Problem Set 3, Fall 1995, using the program HH)

4. In this exercise you will examine the effectiveness of a current input to a neuron as a function of its location on the neuron's dendrites.

c. Set the injected current for all compartments to zero. What is the minimum current that must be injected into the eight most distant compartments (4, 5, 7, 8, 11, 12, 14 and 15) in order to induce an action potential in compartment 1? What is the minimum current that must be injected into four of the most distant compartments (e.g., 4, 5, 7, and 8) in order to induce an action potential in compartment 1? What is the minimum current that must be injected into two of the most distant compartments (e.g., 4 and 5) in order to generate an action potential in compartment 1? What is the minimum current that must be injected into a single most distant compartment (e.g., 4) in order to generate an action potential in compartment 1? What is the relationship between these different minimum currents? What does this indicate about the importance of spatial summation in determining the activity of a nerve cell?

***d. Design a neuron that can be activated only by one particular pattern of spatial and/or temporal inputs. Note that you can create your own branching neuron by clicking on the soma or any other segment, and then selecting Add Compartment from the Tools menu. Compartments can also be deleted. After you are done creating the morphology of your neuron, you can also choose Renumber segments from the Tools menu to simplify the numbering of your neuron's compartments.**

though they may be somewhat easier. Students spend half an hour taking this exam. I do not collect the exam, but I do ask the students to assess how well they would have done if this was their actual midterm. The rest of the session is spent discussing these problems, any other questions the students may have, and reviewing other material. I point out to them different strategies for solving problems, and encourage them to reason qualitatively about the problems, based on the data that is presented. This tends to help them focus their studying, and reduce their anxiety about the exam.

During the second half of the semester, I regularly practice critical thinking about experimental data by handing out data figures as part of my lectures, and devoting a significant amount of class time to discussing them with the students. I will sometimes encourage the students to look at the figures in groups with specific questions in mind before beginning to discuss them. I call on a student after she has had a chance to look at the figure, and ask her to help me understand it. What does the data show? Does it support the hypothesis? What other information would you need to answer the question? Students are initially hesitant to answer, but as they gain more experience, they become more willing to do so, and by the end of the semester can respond with facility.

After the midterm, and at the very end of the last class session, I also hand the students the list of questions that they posed at the very beginning of the semester. We discuss two questions: Can you answer these questions now? Would you ask them in the same way? After the midterm, many students see how they might be able to use what they have learned in the first half of the course to address the questions that most interested them. By the end of the semester, the students feel that they could begin to answer the questions, but they also feel strongly that they should be rephrased. They make many suggestions of ways to make the questions more precise, more specific, and more subject to empirical testing. I point out to them the considerable progress they have made, and congratulate them.

Table 4. Problem from Midterm Exam.

An investigator is studying the actions of glycine on a nerve cell. She applies small controlled pulses of glycine to a nerve cell which she has voltage clamped, and observes the following results (holding voltages are indicated to the left of each diagram; the peak magnitude of each current is indicated to the right of each diagram):

- (a) (5 points) Is the postsynaptic potential likely to be inhibitory or excitatory?
- (b) (10 points) Calculate the reversal potential of the postsynaptic potential.
- (c) (10 points) Calculate the conductance of the postsynaptic potential.
- (d) (20 points) If the resting potential of this neuron is close to the reversal potential of the postsynaptic potential, how can it change the likelihood that this neuron will fire?

Assessment

Perhaps the single most important factor in encouraging students to engage in critical thinking is that a good grade in the course must depend on mastering this skill. If an instructor emphasizes critical thinking, but administers examinations that assess memorization and/or the ability to do small variations on problems that have been repeatedly drilled, students will fall back on rote memorization, or on memorized problem templates. Thus, every form of assessment for this course explicitly requires critical thinking skills. Students are assessed by means of problem sets (described above), a midterm, brief critical thinking questions, a term paper, and a final.

On the midterm examination, students are presented with data-based problems in neurophysiology, and must use quantitative and qualitative reasoning in order to solve the problems [See Table 4]. The midterm requires that students know the different formulae used in neurophysiology. Many of the problems introduce novel information that can be understood based on the material that has already been presented, but requires applying it to a new situation. For example, the question shown requires students to think about the role of "shunting inhibition" - even though this synaptic input will clamp the membrane potential close to the resting potential, by

increasing the conductance of the postsynaptic neuron, it will decrease the effectiveness of excitatory inputs. Once the midterm exam is graded, it is handed back with a detailed answer key, so that students have immediate feedback on their performance.

During the second half of the semester, in the middle of lectures, I hand out critical thinking questions. These are based on the approach of Robert D. Allen, who has used these successfully in large lecture courses (Allen and Stroup, 1993; Allen, 1995). The students are posed a question, and then offered several alternatives. They are asked to choose the best answer, as they would for a standard multiple choice question, but they are also asked to write two or three lines explaining their rationale for accepting or rejecting each alternative. I give the students about ten minutes to do this, collect their answers, and then discuss the question with them. I read but do not grade the responses.

For example, in the lecture on cortical function, I described the results of lesion studies, which suggest that occipital cortex plays an important role in processing visual information, that temporal cortex plays an important role in memory and recognition of objects, that parietal cortex plays an important role in focus of attention and locating objects in space, and that prefrontal cortex plays an important role in organizing and planning behavior over time, and flexibly adjusting it to changing contingencies. I describe one test of prefrontal function that involves giving a subject blocks, and asking the subject to build a four-walled square. Most prefrontal patients build a long single wall. They can recall the instructions of the task, but are not disturbed about their failure to plan ahead and use the material appropriately in order to construct four walls. I then describe the Wisconsin Card Sort Task, in which subjects are given cards which have one, two or three circles, triangles, crosses or

squares on them, all of a particular color. The subject is instructed to find a rule for sorting these cards based on whether the experimenter says "Yes" or "No" to a particular card. For example, the rule could be "three objects or triangle", and thus a card with any three objects on it, or a card with any number of triangles would satisfy the rule. Unexpectedly, however, the experimenter changes the rule in the middle of the task. I then hand out a critical thinking question about this information [see Table 5]. Note that the information just presented makes it possible to deduce that the best answer is choice e.

The results of administering these questions regularly are somewhat sobering. Some students can clearly utilize the information that they have just been given in the lecture to deduce the correct answer and eliminate the alternatives. Other students may misinterpret the alternatives, and choose an incorrect alternative. Still other students clearly have not grasped the key concepts, and have no idea how to answer the question. However, as the semester progresses, most students improve.

Students are offered two options for a term paper: they may write a critical review of the literature or a grant proposal. For a critical review, they need to find a well-defined hypothesis that is currently a source of contention in the field (e.g., "Adult neurons are incapable of regeneration", or "Processing of visual information is due to a feed-forward hierarchical analysis of features extracted from visual inputs."). They should locate about 5 papers that support the hypothesis, and about 5 papers that do not, and explain the evidence for or against the hypothesis, and ultimately come to some conclusion themselves about it.

For a grant proposal, they should follow the NIH guidelines (which I hand out to them), and answer the following four questions (the text of these questions is from pp.20 - 21, Application for Public Health Service Grant [PHS 398]):

- (1) What do you intend to do? (Specific Aims),
- (2) Why is the work important? (Background

Table 5. Critical Thinking Question.

Critical thinking on the cortex

A patient with a prefrontal cortical lesion is administered the Wisconsin Card Sorting Task. His most serious deficits on this task are likely to be

- a. inability to recognize particular shapes on the cards;**
- b. inability to learn the rules for sorting;**
- c. inability to stack the cards precisely;**
- d. inability to understand the instructions for the task;**
- e. inability to learn a new rule for sorting after learning a previous rule;**
- f. none of the above.**

and Significance),

- (3) What has already been done? (Progress Report/Preliminary Studies), and
- (4) How are you going to do the work? (Research Design and Methods).

Students are asked to volunteer to present the contents of their term paper to the rest of the class during the last session or two of the term. Each student has 10 to 12 minutes for their presentation, and then the class asks them questions. Though students tend to be nervous as they speak in front of the class, they generally appreciate the opportunity to discuss the research that they did for the term paper with the class. Their presentations also allow me to expose the rest of the class to many different topics that could not be covered during the semester.

The final examination is open book and open notes, eliminating the need to memorize large amounts of material. It also counts equally with the midterm, problem sets, and term paper, thus making it harder for a student to do well (or poorly) in the course simply by doing well (or poorly) on this single exam. Each question on the exam shows a figure from a recently published paper, and asks variants of the following three questions: (a) What does the data show?, (b) Does the data support the hypothesis?, and (c) What experiments would you do next? [Table 6 shows a question from a recent final exam.] Even though the exam is open book and notes, I tell students that they need to carefully review all the material of the course. Otherwise, they will spend most of the exam looking things up and reading, and not spend enough time on their answers. The exam has the complete references for the articles from which the figures are taken. Since students may take their exams home (their essays

Table 6. Problem from Final Examination.

A variety of experiments have established a distinction between short term memory and long term memory. Some investigators have hypothesized that formation of short term memories is a crucial prerequisite for the formation of long term memories. This hypothesis was examined in a study by Emptage and Carew, and some of the results of that study are shown in the Figure below.

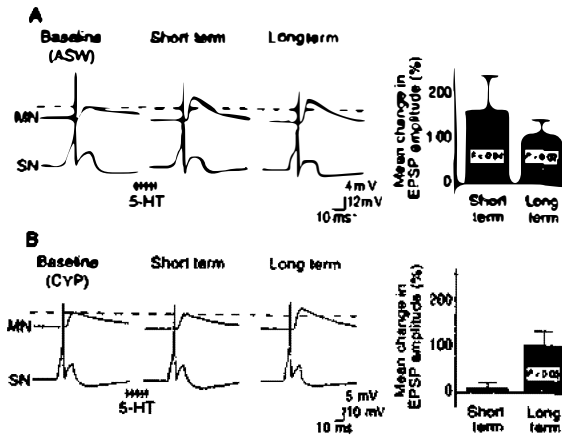


Figure abbreviations: MN: motor neuron, SN: sensory neuron, ASW: artificial seawater (control solution); 5HT: serotonin; CYP: cyproheptadine, a serotonin antagonist; all experiments were performed in the intact nervous system.

- a. (5 points) What is the effect of serotonin on the amplitude of the motor neuron EPSP in part A of the Figure? Is the effect significant? What is the effect of serotonin on the amplitude of the motor neuron EPSP in part B of the Figure? Is the effect significant? How does part A differ from part B?
- b. (10 points) Is the formation of a short term change in synaptic efficacy obligatory for the formation of a long term change in this experimental system? Explain. Propose one additional experiment to test this hypothesis in this experimental system.
- c. (15 points) In another part of this study, the investigators were able to demonstrate that bathing the cell body in serotonin induced a long term change in synaptic efficacy, but no short term change, whereas bathing the synapses in serotonin induced a short term change in synaptic efficacy, but no long term change. Propose a mechanism to explain these results, and an experiment to test your hypothesis.

[Emptage and Carew, Science, 262:253 - 256, 1993]

are written in blue books), I encourage them to look up the articles to determine the correct answers to the questions.

In general, the different assessment measures are highly correlated. Most students who do well in the course do well on all of them. Some students are very anxious during examinations, and

do more poorly on the midterm and final than they do on the problem sets or term paper. Some students work better under pressure, and do better on the midterm and the final than they do on the term paper or the problem sets, which they may fail to turn in on time or to complete. Students who have difficulty with mathematical manipulations may do better on the final than on the midterm. On the whole, however, these different instruments provide a reasonably balanced and accurate view of a student's mastery of the material in the course.

Discussion

Once I began to teach, I found myself repeatedly asking "How do I know whether a student has learned what I have taught?" A parrot can repeat meaningless phrases back to its trainer with high fidelity, but this does not imply understanding. A better indication of understanding is that one can use information that one has learned to solve novel problems. The other question I asked myself was: "What should students still remember about this course in a year, or in ten years?" In thinking back over the courses I had taken, I recalled teachers whose enthusiasm had gotten me excited about the subject matter, teachers who had taken a personal interest in me and had encouraged my creativity, and teachers who had challenged me to think critically about my work in their course. In contrast, many of the specific facts I had learned, especially in Biology courses, had to be unlearned or modified, since so much has changed over the last few years. These considerations impelled me to introduce the changes that I have described above.

There are several aspects of the course that may make it hard to apply to other courses. First, the course is an elective. Thus, if students do not like the emphasis on critical thinking, they can choose to drop the course and take other electives. At CWRU, Drop/Add does not end until the second week of the semester. A few students do drop the course, but several others often add it during the same period. In contrast, if a course is a requirement for a major, and demands critical thinking, then students will not be able to avoid it. This suggests that emphasizing critical thinking in core courses requires a commitment on the level of both the instructor and the Chair of the Department. This also suggests the need for systemic reform if critical thinking is to become part

of the entire curriculum. If students do not have regular practice in using this skill in multiple contexts, they will tend to forget it.

Second, the course is designed for upper level undergraduates and beginning graduate students. It is possible to argue that students are more likely to be able to engage in critical thinking if they have a solid background of material, and are sufficiently mature. I would disagree with this viewpoint, however, because I observe that material is poorly retained, and I believe that the ability to think critically would help students retain the material better, as it would aid their ability to assimilate it and synthesize it with their prior knowledge.

Third, the class is relatively small, ranging in size from 12 to 30 students over the last seven years. The size facilitates discussion, and learning all of the student's names. However, recent studies have shown that one can encourage discussion and small group work even in large lecture courses (McKeachie, 1986; White, in press). The small size of the course also makes it more feasible to administer assessments that involve essays. With large class sizes, multiple choice exams become much more attractive to an instructor because they can be graded more quickly. It may be possible to design multiple choice questions that encourage critical thinking, and grade a subset of these questions during the semester (Allen and Stroup, 1993). At some universities, an instructor may get help from upper level undergraduates and graduate students in grading questions that involve essays.

Fourth, I give two-thirds of the lectures in the course. This provides me with a great deal of flexibility that is much harder to obtain in a team-taught course. For example, if I do not cover all the material I wished to in one lecture, I can continue and finish it in the next lecture. Since a third of the course is taught by guest lecturers from several different Departments, I do need to deal with integrating very different teaching styles with my own. I explain to the guest lecturers how I encourage critical thinking, and sit in on their lectures, so that I can integrate the material they present into my own subsequent lectures in the course.

Teaching a course that encourages critical thinking is in some ways harder than teaching a more traditional lecture course. Questions from students may reveal the limitations of the instructor's knowledge. Asking questions of the students that do not require a single right answer, but also

do not lead the discussion astray, requires skill and practice. Selecting key pieces of data to share with the students may require reading that goes beyond the textbook. Assigning readings becomes more difficult as well, since much of the material is in the technical literature, and may not yet have found its way into the textbook. The instructor must also deal with the tension between "covering the material" and insuring that students have actually incorporated the material into their own thinking. Finally, I can recall undergraduate lecture courses that were exciting, entertaining, and inspiring, and were associated with recitation sections in which discussions led by graduate students allowed students to explore the material in greater depth. Thus, traditional lecture courses may be of great value, if they are taught by truly gifted lecturers.

Being a student in a course that encourages critical thinking is also harder. One's lack of understanding is more likely to be publicly exposed, and the material may be presented in a less linear and logical way than it is in a good lecture. If one is used to memorizing material, or problem templates, it creates a great deal of anxiety to have to master another set of skills in order to do well in a course. Students also tend to be less interested in what other students have to say during discussion, because they believe that the only source of useful information is the professor. Sometimes they are correct; but a course that encourages group interactions can also encourage students to study together and work problems together. This is, in general, a more effective strategy for learning material, as long as each student contributes his or her share to the effort.

Students' ability to master the skill of critical thinking varies greatly. Some students are already able to do it when they take the course, and find it a pleasure to be in a course that rewards this skill. Still others find it anxiety-provoking to be asked to do it, but begin to feel a sense of mastery by the end of the semester. Some students cannot master the skill at all by the end of the semester, either from lack of appropriate prior experience, their stage of cognitive development, or their learning styles. Adjusting to these differences will require additional work. I hope to foster more inquiry-based approaches to allow students to construct their own understanding of the material, especial-

ly in the problem sessions (Hammer, 1995), and this may help to deal with these individual differences.

It is difficult to objectively assess the value of a particular educational approach. In general, it is not feasible to randomly divide students into two equivalent class sections, matched by gender, background, grade point average, and so on, and teach one class using a traditional lecture format, while teaching the other class using the approaches described above. Thus, in thinking critically about critical thinking, it is hard to assert definitively that it is superior to traditional approaches. Though the course that I teach has consistently had very positive evaluations from students over the years, it could be due to my enthusiasm for the

[Critical thinking] is, in general, a more effective strategy for learning material, as long as each student contributes his or her share to the effort.

subject, or the time I spend with students, and not to the critical thinking aspects of the course. Over the years, a variety of students have commented that the course had a major impact on their way of

thinking, and some have claimed that it influenced their choice of careers, and encouraged them to go into the neurosciences. Again, this may reflect aspects of my personality as a teacher, and not my insistence on critical thinking skills.

Despite these caveats, I believe that critical thinking is an important and useful skill that should be introduced into a variety of science courses. My enthusiasm for these skills comes from my experience as a scientist. I have to think critically all the time. Moreover, I find that people who have these skills in many other fields, even nonacademic fields, often do better than those that do not. Reform efforts in the field of mathematics have focussed on critical thinking as essential (Curriculum 1989), as have more recent attempts to establish standards for science education (Benchmarks 1993). It is interesting that a co-founder of the Princeton Review, Adam Robinson, who has advised a very large number of students about studying for standardized tests, has recently published a book that, in essence, encourages students to think critically, asking questions about what they are learning, relating it to other things they know, "boiling it down" to key ideas, and forging connections with other subjects (Robinson 1993). My experience also suggests that students who do master these skills feel a real sense of accomplishment, and have much greater enthusiasm for research, and for science in general.

Acknowledgments

I am grateful to the help I have had from the students who have taken Introduction to Neurobiology; their responses to my efforts and helpful comments continue to affect the design of the course. I thank the Howard Hughes Medical Institute for support of innovations in curriculum, which made it possible to develop the program HH, and provided support for students to lead problem sessions. I am also grateful to the members of the Curriculum Enhancement Committee in the Department of Biology at CWRU, as well as to other colleagues in the Department, who by their example and suggestions have influenced the way I teach. I thank Drs. Morris Burke and Elizabeth Dreben for their helpful comments on an earlier draft of this paper. Finally, I thank John Jungck for encouraging me to write up a description of my course for a wider audience.

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*** Notice ***

At the 1996 AMCBT Annual Meeting we will elect two individuals for seats on the Steering Committee and one person as President-elect. Individuals wishing to run for one of these positions or those wishing to nominate others for a position should send nominations to Marc Roy by May 1, 1996. Nominations should include a brief CV that includes information about the candidate's past activities in AMCBT. The CVs will be published in the June issue of *Bioscene* and will be posted at the Annual Meeting.

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Community Building as Teaching: Reforming an Introductory Biology Course

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Until 1992, Principles of Biology I at Hope College was a typical introductory course for majors, described by some as "boot camp biology." Students referred to the course as a "weed-out class" and acted accordingly: 10% or more of the 200 students dropped out before the end of the semester, and only about 50% of the students continued on to the second semester. We taught the course like that for many years and had found ways to justify it, but in 1990 and 1991 I was learning about movements to reform introductory biology, and I had to face the unpleasant fact that my own sons, about to enter college, would not thrive in my course, nor would I want them in there! I could see that it didn't have to be that way, so I applied what I was learning to transform our boot camp into an inclusive and cooperative learning community.

Tobias' (1990) study of a "second tier" of students who are very capable of learning science but not inclined to tolerate the standard way of teaching introductory courses was one important starting point for changing Principles of Biology, as was Project Kaleidoscope's (1991) call for the construction of "natural science learning communities." But the central experience behind the change was the opportunity to be academic director of the first Woodrow Wilson National Fellowship Foundation Leadership Institute for high school biology teachers. (See Howard Hughes Medical Institute 1994 for a description.) Those institutes are among the most intense experiences of learning communities that I have ever encountered. Just as the Woodrow Wilson teachers modeled for me what a learning community could be, I decided to set up a model community of faculty and students engaged in Principles of Biology.

The common life of the learning community

The construction of an atmosphere for community is our single most important act as teachers. A successful community strikes a balance between the vision and goals of the group and the differences among its individuals, so the job of teachers

who build communities is to make possible the development of a common vision and to identify and respect the individual differences among our students. We work hard on the common life of our community.

Our first step simply involved changing the order in which we presented material. Instead of starting with molecular and cell biology, we put plant and animal diversity and physiology in the first semester. We wanted to begin with the students' own experience since that was a common possession that we could build on. Molecules, cells, genes and ecosystems are abstractions for most of our students, but they experience a diversity of middle-sized plants and animals, and they experience their own physiological control mechanisms every day. We now teach molecular and cell biology and genetics as well as population and ecosystem ecology in the second semester course and consider the five kingdoms and their physiology in Principles of Biology I. We call it "Homeostasis In All Its Living Diversity." That change alone raised the percentage going on to the second semester from 50% to 70%.

Most communities have common symbols like flags or company trademarks, so we developed a logo for the course which appears on the syllabus and on much of the other material we hand out during the semester. We used a bison for our logo the first year and an egret the last three because those animals were on the cover of our text book. The syllabus contains short essays about the philosophy of the course which call for personal responsibility but also give numerous indications that we are all in this together and are ready and willing to help each other out. There is a discussion of how to form study groups and an indication of the resources of the college Academic Support Center. We also appeal to an ethic of hard work and high standards, which we think is appropriate for any learning community.

Throughout the semester we create events which become the property of the group, things the class can talk about and incorporate as part of

a community identity. For example, we hold our second class period at a movie theater rather than in the class room in order to show *Anima Mundi*, a 35 minute movie of fantastically beautiful wildlife photography set to the music of Philip Glass. It revels in the great diversity of living things and does so in a way that excites and inspires the students. Its images hover over the rest of the course. About three times during the semester we play a game that resembles Bingo which is designed as a review of some of the material we have been covering. We play the games in teams of two and give the winners prizes of sufficient nuttiness to make them memorable, such as yeast rolls when reviewing fungal life cycles.

Functioning communities have media for communication that build an identity. Radio stations certainly do that for groups of teens, and newspapers function

for cities or regions. For our community, we established an advice column called Ask the Bison or "Ask the Egret," which was built upon questions students sent in about how the course was conducted, about the subject matter of the course, about broader questions on biology or about college life in general. Students deposit their questions in an "Egret Box" brought to class each day or send them via Hope College e-mail to the address EGRET.

The advice column has become an exciting aspect of the course. At first it seemed a bit frivolous, but it has knit the community together in wonderfully gratifying ways. Students can ask questions about things that bother them — the difficulty of a recent test, a sudden upsurge in the number of terms they have to learn, how to cope with ideas that seem to contradict long held values. We answer every question, so they know they will get a hearing, but we do not identify the writers, which reduces anxiety about asking. There are many other kinds of questions being asked. Last year a continuing series on squirrel behavior was launched by a question from a student about squirrel vocalizations. Others wrote in to challenge the conclusions of the first student and of the Egret by making their own observations and reporting on those. Other questions are decidedly

frivolous and just for fun, and the Egret (and the Bison before it) tries to maintain a humorous and light-hearted tone in replying. Thus the serious questions lose some of their sting. Students feel more comfortable about speaking up. The weekly appearance of Ask the Egret is eagerly anticipated by the students, but we equally eagerly anticipate the questions to keep us posted on potential problem areas and to give us the chance to continue encouraging and building the community.

Finally, we have a single faculty member in any one section. This was a change from a common practice in introductory biology of having a series of faculty each teach part of a semester —

a practice which many students dislike intensely. Having a consistent leader helps develop a sense of common identity, and it is less confusing to the students. The faculty of Principles of Biology form their own cooperative learning group. We coordinate the sections closely so that all of us do the

same things each day, and that allows us to share the efforts of developing learning materials, lectures and tests. Cooperative learning groups work for the faculty too! Respecting individuals in the learning community

Healthy communities respect and value the differences among their members. In a learning community, that means both recognizing the differences in learning styles among the students (3), and including different ways of learning during class periods and corresponding evaluation. We are learning how to teach in new ways. In the first year we agreed that at least one out of every three class periods would be conducted in some manner other than lecture, and we agreed that there should be lots of different approaches. We wanted as many students as possible to find activities that allowed them to thrive as well as the "first tier students" seemed to thrive on lectures and multiple choice tests.

There is no one teaching method in Principles of Biology I. Sometimes we form cooperative learning groups during class, and early in the semester we include an exercise on how to manage learning groups. We sometimes give out data from experiments and work them through together. Occasionally we have formed groups to work on a set of data outside of class and produce a

"Healthy communities respect and value the differences among their members."

written assignment to hand in. I write "dialogues" (1) which the whole class performs simultaneously (aloud!) in pairs. The goal of the dialogues is to provide a safe way for the silent people in the class to talk about the material and to introduce ideas that can be packaged in an engaging manner in a dialogue but are tedious to present as a lecture. We present dramatic demonstrations of concepts such as "Blend-A-Plant" in which we illustrate levels of organization by considering the properties of a flowering plant before and after putting it in a blender and "Fizz Facts" in which we study the solubility properties of gasses using soft drinks. There are debates based upon the information on nutrition labels, and an exercise to consider what part of the human life cycle is affected by various methods of birth control.

We had to find more ways than multiple choice tests for evaluation too. Put simply, if it isn't evaluated, students won't consider it important. Many features of learning can be evaluated with good multiple choice questions, so we still use those. But we have expanded the range of ways students can show what they have learned. Student performance on all of these class and group activities is monitored and evaluated through a system of "cards" which we collect from time to time and which are a significant contribution to the students' overall grade. The Egret Card is a 5X7 card with the Egret logo and a space on one side for a name and other identification. The other side is for information to be evaluated — the conclusions of a cooperative learning group, what a student learned by attending a research seminar, reactions (sometimes even feelings) regarding a movie or other event. The cards are each worth a relatively small number of possible points but collectively all the cards carry significant weight in the final evaluation. Students do not know ahead of time when a card will be collected in class, and there are no make-up cards, so even class attendance has a positive value. We also have occasional written assignments, and our exams have always included essay questions which ask about the experimental basis of ideas presented in the class.

A significant number of students do not do as well as they or we would like on the first exam. On the day when the exam is returned we announce that performance below a certain level is intolerable to us as those responsible for the community, and we provide weekly review sessions which are mandatory for those who got

below a certain score. These sessions result in considerable improvement in the overall performance of the class on subsequent tests, and they are one way we have of making good on our commitment to community success.

How is it working?

Since 1992, in some sections we have had no students withdraw from the class, and we seldom have more than three withdraw out of sixty or seventy even though the grade distribution is only slightly higher than before the changes. This is a decided decrease compared to 10% or more prior to 1992 and is an encouraging sign that students feel included at whatever level of achievement.

The increasing reputation of Principles of Biology I has encouraged other faculty to teach some sections using the same approach. Some have reported that when using the new approach they have received the highest student evaluations they have ever had for this course. In my own case, I have received very high evaluations, but also some wonderfully backhanded complements. For example, one student wrote, Dr. Cronkite didn't teach me a thing in this course. I had to learn it all myself. For a professor who had just launched himself from the safe, controlled world of authoritative lectures into group learning and multiple teaching strategies, this couldn't have been a better evaluation.

At least one of the faculty has begun introducing the methods we use in the introductory course into his upper level physiology course, so the course is functioning as an agent of change for the entire departmental learning community.

The movement for change in science education includes a number of programs for reform from the top down through the creation of national standards or curricula. These efforts have their place, but I am convinced of the need for change from the bottom up, one teacher and even one lab exercise at a time. I was drawn to the Institutes of the Woodrow Wilson National Fellowship Foundation because of their central conviction that given the tools and the inspiration, teachers can be trusted to create the reform we all seek. I see that work with the Woodrow Wilson teachers, and my hope is for Principles of Biology to continue to function in a similar way as an agent of change. Gradually, but in ways that make a difference for our students, my colleagues and I are using the strength of community to change ourselves into better teachers.

Acknowledgments

Special thanks to Christine Oswald, who joined in this effort at the beginning, and Christopher Barney and Paul Van Faasen, who have since become members of the Principles of Biology I community. Two others, David Netzly and Lois Tverberg joined this fall and have already contributed to the continuing project of constructing this learning community. Extra-special thanks to the 200 Woodrow Wilson teachers who were and are the inspiration for making me a better teacher.

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AMCBT Seeks Logo

Interested individuals are invited to design a logo for AMCBT, the Association of Midwest College Biology Teachers, founded in 1957. The designer of the logo selected will be awarded \$100 following the meeting and a short article featuring the logo will be published in the Bioscene. AMCBT logo designs should be submitted to the program chair by September 6, 1996 in order to be posted for members to view at the 40th annual meeting at Loras College on September 19-21, 1996. Logos will remain on display from Friday morning following breakfast through the Saturday morning break in the foyer of St. Joseph Science Hall. Color versions of the logo are encouraged for incorporation into electronic media, but the logo should be easily reproducible in black and white for printed materials.

The objectives of this organization described in its constitution are:

- to further the teaching of the biological sciences at the college and other levels of the educational experience
- to bring to light common problems involving biological curricula at the college level and by the free exchange of ideas; endeavor to resolve these problems
- to encourage active participation in biological research by teachers and students in the belief that such participation is an invaluable adjunct to effective teaching
- to create a voice which will be effective in bringing the collective views of the teachers of the biological sciences to the attention of college and civil government administrations

The organization maintains a web site that includes extensive archives of its journal, the Bioscene, newsletters, and past meeting proceedings as well as current information. This excellent source of information about the organization is found at the URL : <http://papa.indstate.edu/amcbt>

For more information, please contact the current program chair: Ethel Stanley, Beloit College (608) 363-2284 or (217) 428-2373 or be email: stanleye@beloit.edu

News and Views

TIME, SPACE, TURF, AND TRADITION: PUSHING THE BOUNDARIES IN BIOLOGY EDUCATION

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*T*ime. Space. Turf. Tradition. These are but some of the boundaries that appear to exist in the teaching of our biology classes. We teach certain courses because they have always been a part of our curriculum. How can a biology department not offer such essential courses? We teach them in a series of three or four lectures and an accompanying three hour laboratory period because that is the time that we are given by the registrar. We teach them in certain classrooms because that is what we are allotted. We teach them repeatedly, perhaps modifying them slightly from year to year, but with little outside input because they are "our" courses. We hear cries for reform in science education, but they are ignored because these are the limits that we face and we can't change. There isn't sufficient time, money, or space.

At the same time as we face these seemingly rigid boundaries, we see statements in our college literature that encourage students to challenge ideas, to look for different interpretations, and to seek new directions. How can we expect our students to do this if we are not willing to do so ourselves?

In the last year I have attended several conferences that have addressed the teaching of introductory biology. The thrust of those conferences was that we can and must do more to help students to learn biology in the beginning. However, many of the presentations have been about slight changes to the large lecture sections. I have heard and seen many examples of how we can introduce brief periods of discussion time. While this is a step in the right directions, I believe that it is not sufficient.

The National Academy of Sciences Science Education Standards (National Academy Press, 1996, p. 2.) says, "The Standards call for more than "science as process," in which students learn such skills as observing, inferring, and experimenting.

Inquiry is central to science learning. When engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills." If we only look for new tricks to bring to our lectures we are not meeting these goals. Moreover, we are not modeling what we teach, namely science, and we are not truly pushing the boundaries.

Why does a course need to consist of three lectures and a laboratory? It is often argued by my colleagues that carefully crafted lectures convey a wealth of important information. When these lectures are coupled with exciting laboratory investigations the students are exposed to the beauty and complexity of biology. This is the way that we have always taught, and it is good. Or is it? In this model, the professor disseminates information that the students dutifully write down, memorize, and in some way return to us in examinations, quizzes, and papers. The students who work particularly hard will retain much of the information, perhaps even long enough to use it on standardized exams in their junior and senior years. However, in this model they are only learning about science, they are not practicing science. Just as we should not trust a furnace repairer who has only read about furnace repair to fix our broken furnace, we should not allow our future scientists to only read about science. Even those students who will never become scientists need to be scientifically literate. They need to know and understand how to think scientifically and how to do science.

To help our future scientists become scientists, we need to push the boundaries that have limited our teaching of biology. We need to consider how we can help those students to learn important information as well as to practice science. We need to think about the shape and content of our classrooms.

Two Alternative Models

There are many models that we can consider in changing our teaching. One idea is to take one or two of the traditional lecture slots and use it for another purpose. This time slot could be used for discussion of critical issues. Alternatively, it could be used for sessions utilizing computer simulations, for brainstorming sessions in planning laboratory investigations, or for shorter laboratory or field investigations. In alternate weeks the time could be used for student presentations where the students present posters or oral descriptions of their work. Yes, in this model we give up lecture time, but we are giving the students the opportunity to inquire, to observe, to discuss, to learn from each other and to practice science. While this model pushes the boundaries of tradition, and perhaps space, it does not push other boundaries. Another model pushes the boundaries of space, tradition, time and turf. This model is the workshop model. Originally developed as Workshop Physics by Priscilla Laws at Dickinson College, the model has also been used in chemistry and biology classes. At Beloit College, our Chemistry Department adopted the workshop approach in 1992. George Lisensky, Laura Parmentier, and Brock Spencer designed a course in which the students were in the laboratory every day doing what chemists do. Laboratory investigations were coupled with in-class small-group problem-solving exercises on challenging problems, discussions

and occasional mini-lectures of 15 minutes or less. Students learned chemistry by doing chemistry.

In 1995, Marion Fass, Ken Yasukawa and I brought this model to our introductory human biology class. Students meet for two hours, three times a week. Each class period is a mixture of investigative activities, usually done in groups, and discussion. Throughout the semester the students present their work in a variety of formats including poster sessions, oral presentations, models of biological phenomena, and written assignments. The professors are not disseminators of information. Rather, they are guides who help the students to understand biology. In addition, the course belongs to all the teachers. We worked collaboratively to design the course and we meet throughout the semester to discuss upcoming class periods. We frequently visited each other's classes. There is no turf.

Conclusions

These two models are just two ideas of how we can push the boundaries in our thinking about how we educate students in biology classes. They will not necessarily work in all institutions and probably can't be transplanted directly to any other institution. However, they illustrate ways in which we can change our teaching. In each of these models that I have offered, we make trade-offs. We give up time on our soapboxes, and we give up some control on the direction of the learning. These models are often more labor and time intensive. However, we are giving students some control. We are encouraging them to think, observe, question, hypothesize, experiment, think again, and convince others. We are meeting the goals stated by the National Academy Standards. In pushing the boundaries, we are helping students to understand science to become scientists. Isn't this what science education is really about?

MAKE YOUR RESERVATIONS EARLY!

Midway Hotel Best Western
3200 Dodge (Hwy 20 west)

Reservation: 1-800-33MIDWAY

\$50 + tax/night for 1-4 people,
shuttle bus service available.

20 rooms blocked for AMCBT-Loras College
Thursday 9/19 & Friday 9/20 nights

September 5, 1996 Reservation Deadline

MAKE YOUR RESERVATIONS EARLY!

MAKE YOUR RESERVATIONS EARLY!

Heartland Inn WEST

Note: There are 2 Heartland Inns in
Dubuque!

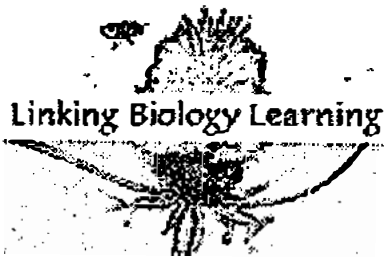
4025 Dodge St (Hy. 20 west)

Reservation: 1-800-334-3277 code 12

\$50 + tax /night for 1,2 or 4 people
20 rooms blocked for AMCBT-Loras College
Thursday 9/19 & Friday 9/20 nights

September 5, 1996 Reservation Deadline

MAKE YOUR RESERVATIONS EARLY!



LINKING BIOLOGY LEARNING

Loras College, Dubuque, Iowa

September 19-21, 1996

PRELIMINARY PROGRAM

THURSDAY, September 19th

- 6:00 PM - **Registration &** Concourse of
 8:00 PM **Reception** Alumni Campus Center (ACC)
- 8:00 PM **Opening Session** ACC Ballroom
 Welcome for AMCBT
Ethel Stanley, Beloit College, Program Chair
Tom Davis, Loras College, Local Arrangements Chair,
Tim Mulkey, Indiana State University, President
- Welcome to Loras College
Joachim Froehlich, President, Loras College

- 8:15 PM **OPENING ADDRESS** Public Welcome to Attend
 Novae - The Spectacular End to a Double Star's Life
Mary Jane Taylor, Loras College

- Orientation to Fall Constellations Heitkamp Planetarium
- 9:30PM **Executive Committee Meeting** Room 544 Arizona Room, ACC

FRIDAY, September 20th

- 7:00 AM **Early Registration** ACC Concourse
- 7:00 AM - **Buffet Breakfast** ACC Ballroom
 8:15 AM **Interest Groups**
- 8:15 AM - **Continuing Registration** Foyer of Science Hall
 11:00 AM
- 8:15 AM - **FIELD TRIPS & WORKSHOPS I**
 11:00 AM
1. **Plankton/Diatom Collecting Trip** Limit: 10, Van \$3
 on the Mississippi River
Dave Czarnecki, Loras College

2. Antibodies as Tools in Biology WorkshopRoom 54, Science Hall
Karen Klyczek, University of Wisconsin- River Falls
3. Dubuque Arboretum and Botanical Gardens TourLimit: 25
Joe Kapler, Loras College (Van \$3)
4. Goat Prairie/ Four Mounds Bluffland Habitat Preserve TourLimit: 15
Ed Cawley, Loras College (Van \$3)
5. Mississippi River Backwater Habitat/Limit: 12
Wildlife/Ecology Boating Trip (Van \$3)
6. Swiss Valley Park Birding/ Hanging Bog HikeLimit: 15
Bob Walton, Dubuque County Conservation Board (Car pool)

11:05 AM - **KEYNOTE ADDRESS** ACC Ballroom
 12:00 PM Connecting Biology: Learning with Cases
Margaret Waterman, Southeast Missouri State University

12:00 PM - **Lunch (Open)**
 1:30 PM Exhibitors (Room 109) Posters (Hall)Science Hall
 and InfoShare (Room 122)

12:00 PM - **FIELD TRIP II**
 2:15 PM 1. Dubuque Sights and Sounds Car pool
Barb Davis

1:30 PM - **CONCURRENT SESSIONS I** Science Hall
 2:15 PM

1. Using BioPacRoom 110
David Ferris, Alverno College (Hennessee Hall)
2. Field Investigations on a Shoe String: Do-It-YourselfRoom 54
Judy Parrish, Millikin University
3. Workshop for Prospective AuthorsRoom 142
William C. Brown and Company
4. A Reform of Science Education: A Case for Local Action
and Global ThinkingRoom 125
Jo Handelsman, University of Wisconsin

2:20 PM - **Afternoon Break Refreshments (Room 109)** Science Hall
 3:05 PM Exhibitors (Room 109) Posters and
 InfoShare (Room 122 and Hall)

2:30 PM - **FIELD TRIP III**
 5:30 PM 1. Dubuque Sights and Sounds Car pool
Barb Davis

3:00 PM - **FIELD TRIP IV**
 4:30 PM 1. William C. Brown and Company Tour Car pool
John Bamrick, Loras College

3:10 PM -

5:00 PM

WORKSHOPS II

Science Hall

1. CASE IT! Student Generated Case Studies *Limit: 12*Room 39
Mark Bergland & Karen Klyczek,, Univ. of Wisconsin-River Falls
2. AMCBT/Web Page Construction WorkshopRoom 110
Tim Mulkey, Indiana State University (Hennessee Hall)
3. Generating Gastropod Graphics: Using Fossils, Shells and
Computers to Investigate Evolutionary MorphospaceRoom 118
John R. Jungck, Beloit College
4. Plankton/Diatom Identification and Biology (Limit: 20)
Using samples collected in morning field tripRoom 19
Dave Czarnecki, Loras College

5:05 PM -

5:45 PM

Bioscene Editorial Board Meeting.....Arizona Room ACC

6:00 PM -

7:00 PM

Social HourACC Ballroom/Hall

7:00 PM

BANQUETACC Ballroom

8:15 PM

BANQUET ADDRESS

Aldo Leopold, Cranes and Conservation Biology: Lessons from History
Curt Meine, International Crane Foundation

9:30 PM -

10:45 PM

Late Night WORKSHOP III

Environmental Biology and the World Wide Web (Limit: 12)Room 110
Buzz Hoagland, Westfield State College (Hennessee Hall)

9:30 PM

Late Night Mississippi River Excursion

Trolleyleaves ACC Concourse at 9:30 PM
Tom and Barb Davis, Loras College

SATURDAY, September 21st

Science Hall

7:30 AM-

Continental BreakfastRoom 109

8:30 AM

Balloting from 8:30 AM through 9:45 AMFoyer

8:30 AM -

9:15 AM

CONCURRENT SESSIONS II

Science Hall

1. Growth: Phenomena for Botany ProjectsRoom 49
Ann Larson, University of Illinois at Springfield
2. Emerging Diseases:A Workshop ApproachRoom 54
Marion Fass, Beloit College
3. Fears, Problems, and Successes of Students Conducting
Field InvestigationsRoom 125
J. H. Kruper and T. L. Derting, Murray State University

9:20 AM - Morning Break Refreshments (Room 109) Science Hall
 9:45 AM Posters (Hall) InfoShare (Room 122)

Balloting Closes at 9:45 AM

9:50 AM -
10:35 AM **CONCURRENT SESSIONS III** Science Hall

1. Developing a Personal Land Ethic: Aldo LeopoldRoom 125
Tom Davis, Loras College
2. Arachnophilia: A Service Learning Approach to BiologyRoom 54
Marianne Robertson, Millikin University
3. AMCBT Revisited
Ed Kos, Rockhurst College,Room 142
David Fagle and Norm Jensen, Millikin University

10:40 AM -
11:05 AM **CONCURRENT SESSIONS IV** Science Hall

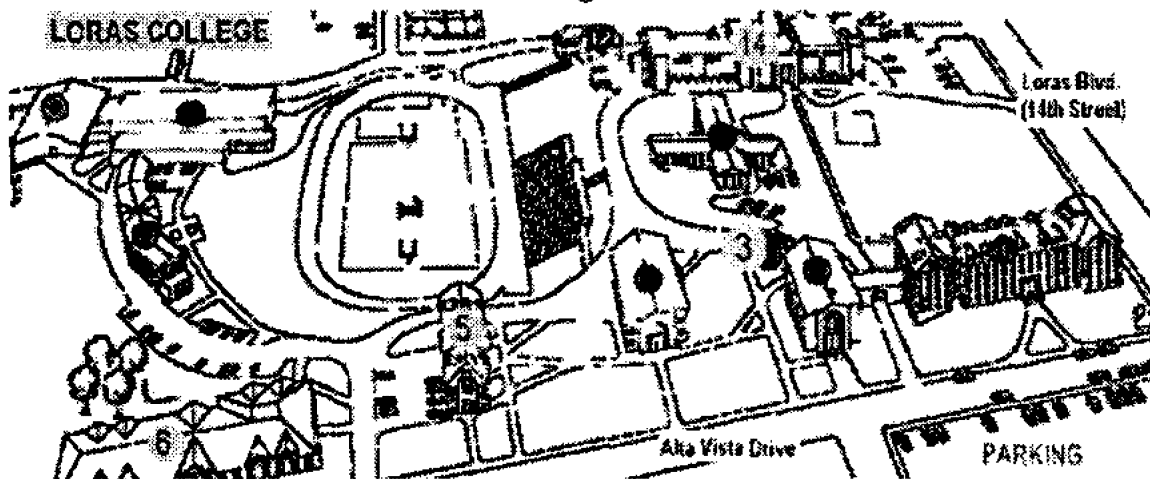
1. Students Tell Us.....Room 125
Bill Brett, Indiana State University
2. Labless LabsRoom 54
Debbie Lively, Comm. College of West Kentucky Univ.
3. Creative Thinking for TeachersRoom 142
Alan Nowicki, Highland Community College
4. A Microbiology Lab for Nursing Students:
 Culture and Sensitivity Techniques.....Room 49
Gopal Krishna, Moberly Area Community College

11:15 AM - **Brunch**.....ACC Ballroom

12:45 PM **BUSINESS MEETING**

Presidential Address: *Tim Mulkey, Indiana State University*
 Election Results: *Marc Roy, Beloit College*
 Bioscene: *John R.. Jungck, Beloit College*
 Executive Secretary Report: *Ed Kos, Rockhurst College*

12:50 PM -
 1:30 PM **Executive Committee Meeting**.....Arizona Room - ACC



Association of Midwest College Biology Teachers 40th Annual Meeting

September 19-21, 1996
Loras College

InfoShare

Biology faculty and their students are invited to share:

- posters featuring research in biology or science education
- software currently used in their courses or under their development
- field or laboratory exercises developed for their courses

Posters:

The title, author(s), and a short abstract of the poster content must be submitted to the program director by **September 6, 1996**. This information will appear in the final program and be published in the Bioscene after the meeting. Posters will remain on display from Friday morning following breakfast through the Saturday morning break. Poster stands will be provided in the second floor hall area off the foyer of St. Joseph Science Hall.

Software:

The title, author, platform(Mac/PC), and a short summary of the use of the program must be submitted by **September 6, 1996** to the program director. Mac and PC (Windows 3.1/ DOS) computers will be provided in Room 122 of Science Hall for display/investigative use of the program. Freeware, shareware and individual software developed by the presenter who wishes to distribute copies must be clearly labelled "For Distribution" otherwise no copying of software is permitted.

Field or Laboratory Exercises:

The title, author, and a brief description of the lab must be submitted by **September 6, 1996** to the program director. Each presenter should bring 50 printed copies of the exercise to distribute. A table will be set up in Room 122 of Science Hall for these copies. A disk copy of the exercise in a standard word processing format or text file would be appreciated as well. These exercises will be entered into an AMCBT file that can be accessed electronically. The steering committee wishes to rebuild the field/laboratory exercises archive the organization used to maintain for distribution.

ALL submissions are greatly appreciated!

Ethel Stanley, Program Director
Beloit College
700 College Street
Beloit, WI 53511
stanleye@beloit.edu

AMCBT STEERING COMMITTEE MINUTES
3 February 1996

Place: Loras College, Alumni Campus Center, Rm 451 (Fahrerheit 451?)

Time: 2 pm

Present: Bill Brett, Tom Davis, Buzz Hoagland, John Jungck, Karen Klyczek, Ed Kos, Tim Mulkey, Ethel Stanley

AGENDA:

I. Called to order by Tim Mulkey

II. Minutes of previous meeting

III. Announcements:

Tom Davis: Dinner reservations at Pasta O'Sheas at 7:00 pm;

Sunday meeting in Rm 554 of the Alumni Campus Center will begin at 8:30 am.

IV. Reports of Officers.

A. Executive Secretary - Ed Kos. See 3-Appendix A.

1. Financial. Income was slightly ahead of expenditures for 1995, however expenses for the final 1995 issue of Bioscene have not all been paid. January renewals are up. Discussion followed concerning dues. No action was taken. There should be a desk at the Loras Meeting for dues collection and possible sale of AMCBT memorabilia. The computerized membership database will be made available to Tim Mulkey by Ed Kos to facilitate dues collection at the Loras Meeting.

2. Membership. Committee members unanimously agreed that a list of Loras Meeting attendees should be made available to all attendees at the Loras Meeting. The list should include names, addresses, phone numbers, and e-mail addresses. Ethel Stanley will begin compiling the list from the program submission forms, and Tom Davis will contribute data obtained from registration forms. Discussion followed regarding members in arrears. The Committee reconfirmed the 28 September 1995 motion "to carry the subscription to Bioscene for only one year if dues are in arrears. A 'warning' sticker should be placed on the last paid issue of the journal." Three personal checks for past dues appeared on the table. Any ex-member may rejoin at any time without penalty. Postcards should be sent to colleagues by Committee members to increase membership.

B. Bioscene Editor - John Jungck. Articles are needed for the upcoming issues of Bioscene. Editorial Board members should serve three-year terms that are staggered.

Motion: In 1996, terms shall expire for the following: Bob Wallace, Ray Reed, Phyllis Kingsbury, and George Garoian. In 1997, terms shall expire for the following: Buzz Hoagland, Joyce Cadwallader, Bill Brett, and Malcom Levin. In 1998, terms shall expire for the following: Robert Wikel, Ethel Stanley, Tim Mulkey, and David Finley. Reappointments are possible. Seconded, passed.

Possible new Editorial Board members for 1996 include: Terry Derting (KY), Tom Davis (IA), Ann Burgess (WI), and Nancy Saunders (MO).

The following description of the duties for Editorial Board members was accepted by the Steering Committee: Each Board member should (1) solicit or write one article for Bioscene annually; (2) review articles in an area of her/his expertise; (3) attend Editorial Board Meetings at the Annual Meeting; (4) assist in the electronic archiving of AMCBT publications (Proceedings, Newsletters, Labs the Work, Bioscene, etc.); and (5) maintain regular contact with the Chairperson and the Editor. All existing and prospective new Board members will be made aware of this policy at the Annual Meeting.

The next issue of Bioscene will include a note in the Instructions to Authors section indicating that Bioscene articles will be made available electronically on the World Wide Web.

C. Resolutions - Buzz Hoagland is responsible for all resolutions.

D. Nominations - Ethel Stanley presented the report for Marc Roy.

1. Steering Committee: Terry Derting, Tom Davis, Ann Larson, and Wally Weber. Marc Roy will

contact these individuals. Claire Rhinehart will serve out the remainder of Norman Waldow's term. Tim Mulkey will notify Claire Rhinehart and Norman Waldow of the change.
2. President: Barb Newman, Charlie Bick

E. Honorary Life
Motion: Accept for Honorary Life Membership. Seconded, passed.

Jean Yackey will be contacted by Marc Roy to provide the formal presentation at the 1996 Annual Meeting at Loras College.

F. Meeting Sites - the following list was presented:
1996 - Loras College, Dubuque, IA
1997 - University of Nebraska at Kearney, Kearney, NE
1998 - Beloit College, Beloit, WI
1999 - University of Wisconsin at River Falls, River Falls, WI
2000 - Indiana State University, Terre Haute, ID
Tim Mulkey will contact Marvin Williams and/or Charlie Bick at Kearney to get dates for the 1997 meeting.

VI. Campus tour - Jim O'Brien, Computer Center, Loras College
Jim O'Brien indicated that the following computer facilities would be available for the Meeting.
St. Joseph Hall of Science: (1) Davis Lab - 3 Macintosh Performa 636 with CD drives; (2) Rm 39 - 9 Power Mac 6100 (one with a CD drive), 1 Power Mac 7100 with a CD drive; (3) Rm 118 (Engineering Lab) - 6 IBM Pentium 75; (4) Rm 122 (Physics Lab) - 6 Macintosh IICx. Two portable LCD projection units are also available. The Power Mac lab is not currently connected to the Internet, however it is likely to be connected in time for the Meeting. Hennessey Hall: Rm 110 - 4 IBM Pentium and 10 IBM 486, all connected to the Internet. One portable LCD projection system. Hoffman Hall (not visited): Lab - 10 Macintosh Performs; Lab - 21 IBM 486 and 1 IBM Pentium, all connected to the Internet. One portable LCD projection system. Alumni Campus Center. Computer Lab - 10 Macintosh LCIII, 10 IBM 386. IBM computers are connected to the Internet. One portable LCD projection system.
The computer facilities and the labs are in very good condition, and wellmaintained. All members believed that Loras College will be an outstanding host for the 40th Annual AMCBT Meeting.

VII. Adjournment: 6:15 pm.

AMCBT ---3- Appendix A
STEERING COMMITTEE MEETING AGENDA
February 3-4, 1996

- I. Call to order
- II. Approval of minutes
- III. Announcements
- IV. Reports of Officers
 - A. Executive Secretary
 - 1. Financial
 - 2. Membership
 - B. Bioscene
 - C. Resolutions
- D. Nominations
- E. Honorary Life
- F. Meeting Sites
- V. Campus tour
- VI. Program
- VII. New Business
 - A. Constitution
 - B. Membership Drive
 - C. John Carlock Memorial Fund

AMCBT STEERING COMMITTEE MINUTES
4 February 1996

Place: Loras College, Alumni Campus Center, Rm 554
Time: 8:35 am.
Present: Bill Brett, Tom Davis, Buzz Hoagland, Karen Klyczek, Ed Kos, Tim Mulkey, Ethel Stanley

I. Called to order by Tim Mulkey

II. Program

- A. Meals were decided upon. Aramark Catering will provide wine and snacks on Thursday evening, breakfast on Friday, a buffet-style banquet dinner on Friday, and a Saturday brunch. The Local Committee will provide refreshments on Friday afternoon and Saturday morning. Tom Davis will finalize details with Aramark. Ethel Stanley and Tom Davis have the list of foods decided upon.
- B. Speakers. AMCBT pays expenses plus an honorarium that varies, but averages \$200. AMCBT is willing to pay more or less. John Jungck (Saturday's meeting) suggested that speakers should emphasize education. One speaker is the responsibility of the Local Committee, one speaker is the responsibility of the Program Chair, and one speaker is the responsibility of the Steering Committee. All agreed to offer Mary Jane Taylor \$100 for her Thursday evening presentation on the stars.
- C. Logo for AMCBT. Ethel Stanley proposed that AMCBT hold a contest for an organizational logo design. All agreed. That contest will be announced in the March issue of Bioscene, and will offer a \$100 prize to the winning entry. The colors tentatively agreed upon for the AMCBT logo are purple and gold. The logo would be put on paraphernalia, such as mugs, mouse pads, and tote bags, as well as on Bioscene and the AMCBT homepage. All agreed that AMCBT should make available, at a nominal fee, items that sport the new AMCBT logo at the Loras Meeting, and at future meetings. Such items will include a tote bag
(Tom Davis will contact John Deere and Loras College for funding to offset the cost of the bags), mugs (future meetings), and mouse pads (Ethel Stanley will check with a Wisconsin company about prices).
- D. Deadlines for submissions. Ed Kos will be out of town 12 July to 28 August. The cut-off date for title/abstract submission is 15 May. All registration materials will go out to members with the second issue of Bioscene in June. Tom Davis will submit 300 maps, registration forms, program announcements, and motel information sheets to Ed Kos before 1 June for inclusion with the second issue of Bioscene. The return date for registration materials is 5 September.
- E. Exhibitors. Tom Davis is responsible for inviting exhibitors. There is a \$50 charge for each exhibitor.

III. New Business

A. Constitution

1. Bill Brett and Tim Mulkey updated the constitution. All Board Members are encouraged to examine the description of duties for their positions and send changes to Tim Mulkey and /or Bill Brett.
2. Ed Kos will send copies of the original AMCBT Charter to each Board Member.

B. Membership Drive

1. Karen Klyczek and Ethel Stanley will update the traveling display.
2. Tim Mulkey is working on a tri-fold brochure introducing AMCBT to be used as a recruiting tool. All agreed that this brochure would be most effective if mailed to a colleague with a note attached. All Board Members will be expected to send these brochures to colleagues. Tim Mulkey is also working on a membership card.

C. John Carlock Memorial Fund

1. Ed Kos reported that there is currently \$145 in this fund.
2. Members discussed the possibility of combining the Carlock funds with Honorary Life funds and other monies (from a generous donor) to create a fund of approximately \$10,000. Interest from this fund would be awarded to students to help offset the cost of attending the AMCBT Annual Meeting. Considerable discussion followed regarding the mechanism of making these funds available to students. No action was taken.

VI. Adjournment: 11:45 am.

Respectfully submitted,

Buzz Hoagland
26 February 1996

In Memoriam: John Carlock

We are sorry to report that John Carlock, one of the founding members and past Presidents of AMCBT has passed away. We would greatly appreciate it if you would send us stories and memories of John that we could share with others.

Please send to: Teresa Holevas
 Managing Editor, Bioscene
 Beloit College
 700 College St.
 Beloit, WI 53511

or by email: holevast@beloit.edu

Our 1996 Annual Meeting will feature an evening cruise of the Mississippi River as well as field trips with local experts to a rare blufftop goat prairie, the backwaters of the Mississippi River, the blufftop hardwood forest habitat and historic Galena, Illinois. Dubuque is about a three and one half hour drive from Chicago, Des Moines or Milwaukee, or it can be reached by air via American Eagle from Chicago or Northwest Airlink from Minneapolis. Ethnic and traditional restaurants, a hometown brewery, an opera house, art galleries, antique shops, a river museum and several unique natural areas await your visit to Dubuque during the
1996 AMCBT Meeting, September 19-21, at Loras College.

AMCBT Honorary Life Membership

John R. Jungck

At the 1995 Annual meeting held at Alverno College, Professor Jungck was recognized for his involvement in biology education reforms for thirty years. In 1966, he joined the Association of Midwestern College Biology Teachers and served in a variety of capacities, including program chair, local arrangements person, member at large representative to the steering committee, and eventually becoming its President and then serving as Editor of *Bioscene: Journal of College Biology Teaching* since 1988. Also, from 1968 on, he was a participant in the CUEBS (Commission for Undergraduate Education in the Biological Sciences) projects on Pre-Service Preparation of College Biology Teachers (Donald S. Dean, editor) and investigative labs. In the 1970's, he collaborated in reconceptualizing biology curricula at three institutions (Beloit College, Clarkson University, and Merrimack College) and his pedagogical research began to focus on the development of learning long-term strategies of research. In the 1980's his work started to have national implications through his Editorship of the National Association of Biology Teachers' journal, *The American Biology Teacher*. During this period, three awards significantly influenced his career: an NSTA-Ohaus Award for Outstanding Innovations in College Science Teaching; a FIPSE Mina Shaughnessy Scholar Award for developing "new approaches to learning from practice"; and a year-long Fulbright Scholar Award as a visiting professor to Thailand (with extensions to Sri Lanka and Egypt).

In 1986, with Nils Peterson, he started the BioQUEST Curriculum Consortium and became Editor of *The BioQUEST Library*. Significant funding, from the Annenberg Project of the Corporation for Public Broadcasting, NSF, the Howard Hughes Medical Institute, the Foundation for Microbiology, as well as other funders, has enabled the BioQUEST Curriculum Consortium to collaborate with over 6,000 professors in sharing and field testing curricular materials. For the past several years Professor Jungck has served on the executive committee of CELS (the Coalition for Education in the Life Sciences) as the AMCBT representative and several national panels devoted to examining college science education. The BioQUEST Curriculum Consortium has been recognized by awards from EDUCOM, Project Kaleidoscope, and a critical thinking and

problem solving group; has been featured in *Science* and *The Chronicle for Higher Education* as well as many other magazines and journals of professional societies; and regularly offers workshops at AMCBT, NABT, NSTA/SCST, and AIBS as well as other venues.

He continues to maintain an active research program in mathematical molecular evolution and the history, philosophy, and social studies of biology. He has served on the editorial board membership on both the *Bulletin of Mathematical Biology* and *BioSystems*. Since 1976, he has been a regular participant at every Gordon Research Conference on Theoretical Biology and Biomathematics. He has presented talks and workshops on mathematical biology in more than a dozen countries. He was a founding member of the International Society for the History, Philosophy, and Social Studies of Biology and has presented at all but one of its regular meetings since it was founded in 1982.

For many years, he has shared his passion for including more mathematics in biology education by presentations, posters, and workshops at AMCBT annual meetings. Early on he shared aspects of applied combinatorics (enumeration of tree topologies) to phylogenetic systematics, calculus (Lagrange multipliers for overdetermined series of equations) to the multiple allele problem in population genetics, harmonic motion analysis of protozoan ciliary motion, and deterministic chaos (finite difference equation models) in predator-prey games. At more recent AMCBT annual meetings, he has presented aspects of computational geometry (Voronoi polygons) to biological patterns at Southwest Missouri State University, graph theory (interval graphs) to food webs at Rockhurst College, coding and information theory to genetic codes at Indiana State University; knot theory and topology to DNA and topoisomerases at Henderson Community College, and fractal geometry of biological ecospace and morphospace at Alverno College. This year he will continue this tradition with a workshop on mathematical and computational approaches to modelling seashells at Loras College.

Professor Jungck is deeply appreciative of his long term association with AMCBT and the deep friendships that he has maintained for these many years.

Application For Membership

ASSOCIATION OF MIDWESTERN COLLEGE BIOLOGY TEACHERS

NAME: _____ DATE: _____

TITLE: _____

DEPARTMENT: _____

INSTITUTION: _____

STREET ADDRESS: _____

CITY: _____ STATE: _____ ZIP CODE: _____

ADDRESS PREFERRED FOR MAILING: _____

CITY: _____ STATE: _____ ZIP CODE: _____

WORK PHONE: _____ FAXNUMBER: _____

HOME PHONE: _____ E-MAIL 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:

RESEARCH AREAS:

How did you find out about AMCBT? _____

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

.....
PLEASE MAIL **MEMBERSHIP APPLICATION** FORM TO:

Edward S. Kos
Executive Secretary, AMCBT
AMCBT Central Office
Department of Biology
Rockhurst College
1100 Rockhurst Road
Kansas City, MO 64110-2561
Phone: 816-926-4049—FAX: 816-926-4666
Email: kos@vax1.rockhurst.edu

CURRENT DUES ARE **\$25.00**
\$15.00 for Graduate Students

AMCBT 40th Annual Meeting Registration

September 19-21, 1996

Loras College Dubuque, IA

Name: _____

Work Address: _____

City: _____ State: _____ Zip: _____

Office Phone: (____) _____ FAX: (____) _____

Email Address: _____

Are you an AMCBT member? Yes _____ No _____ Wish to join? _____

Name (to Appear on Name Tag): _____

Institution or Company (to Appear on Name Tag): _____

Meeting Registration and Fees (LATE registration at meeting = \$65)	Fees
Regular (\$55.00)	_____
High School Teacher, College Student, Grad Student (\$20.00)	_____
Guest Banquet Fee (\$9.50)	_____

Please check the field trips and activities in which you would like to participate on the list below. Indicate 1st and 2nd choice for Friday morning trips. If more than one person will be participating (i.e. spouses, friends), please note in parentheses.

	First Choice	Second Choice
Plankton Diatom Collecting (\$3)	_____	_____
Dubuque Arboretum/Botanical Gardens	_____	_____
Kaufmann Ave. Hill Prairie (\$3)	_____	_____
Mississippi Backwater Biology (\$3)	_____	_____
Swiss Valley Birdwatching/Hanging Bog	_____	_____
Dubuque Sights and History	_____	_____
Galena Sights and Sounds	_____	_____
Wm. C. Brown Publisher Tour	_____	_____
Moonlight Riverboat Cruise (\$9)	_____	_____

Please make checks payable to AMCBT

Total Payment Enclosed _____

To help us plan for receptions and meals, please estimate your arrival and departure times:

Arriving: _____ Departing: _____

Mail this form and check by **SEPT. 6** to:

Tom Davis
AMCBT Meeting
Department of Biology
Loras College
1450 Alta Vista
Dubuque, IA 52004-0178

← →

Welcome to the AMCBT Home Page



URL: <http://papa.indstate.edu/amcbt>

Featuring the online AMCBT archive for:

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

Other useful AMCBT information includes:

AMCBT Executive Committee
Editorial Board of Bioscene
1995 Annual Meeting of the AMCBT
Searchable Membership Database (coming soon)
On-line Membership Application
Archive of the AMCBT ListServer
Scientific Meetings of Interest to Membership
Position Announcements
AMCBT in the News

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The Association of Midwest College Biology Teachers has developed its own list server to facilitate communication between its members. The purpose of the AMCBT mailing list is to provide announcements, information and discussion of a wide variety of topics.

To subscribe/unsubscribe to the list, send e-mail to:

list-admin@biology.indstate.edu

To subscribe, send this message line:

subscribe amcbt

Information mailed to:

amcbt-l@biology.indstate.edu

To unsubscribe, send this message line:

will be sent to all members of the list.

unsubscribe amcbt

If you have any questions about AMCBT-L,
contact Tim Mulkey at mulkey@biology.indstate.edu

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