# Labs

## Questions

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When I began this column, I had hopes of starting a dialog about laboratory teaching problems. After writing a few columns, I spoke with Paul Hummer who edits the biology section of the Idea Bank column in *The Science Teacher*. He told me he gets only about a dozen letters a year and that I should not expect to get much participation.

A tremendous amount of camaraderie occurs at conventions and dialog via phone and letter often occurs after these meetings. Perhaps dialog via magazine column is too slow? There are many biology and teaching organizations, but I haven't seen any well-established question and answer columns. Does anyone know of any?

Why do I raise the question in the first place? When one becomes familiar with the tremendous amount of material available for teaching, it is easy to conclude that there shouldn't be any problems, because devices and methods exist for every conceivable circumstance. Yet, when one talks to teachers, visits classrooms and looks at the success of biology education, it's equally relavent to ask why the methods most commonly used are so primitive compared to what is possible.

I think one of the reasons for this situation is that there is so much information that no one can keep track of it all, let alone have experience with everything. Just trying to keep up with the Carolina Biological Supply Company catalog is a tremendous task. Consequently, the biology community needs to talk to itself, share experience and raise questions. Certainly publications like *ABT* contribute to such a dialog, but such written conversations have limitations. Most manuscripts submitted for publication are several hundred words in length, too long for simple questions and answers, unless they are hidden in a larger context. The biology teaching community does not evaluate its methods and materials except on an individual or local basis. School of education people do research which deals more with learning strategies than with practical problems. Dialog using smaller-sized and less formal pieces of information could be very beneficial to teachers of biology. If you have any suggestions about how to encourage participation in such a dialog, please write to me.

### Exam Questions

Over the last year, I have received four questions which I will answer or raise to you. The first letter I received came before I even saw the first column in print, thanks to the postal system. It was from Virginia Malone of San Antonio, Texas, who raised the problem of writing lab questions that deal with lab content. Her teaching experience showed that the use of living organisms in lab provided tremendous motivation to her students. She found it very difficult, however, to write questions about these experiences. The BSCS Green Version helped her develop the balance between lab and lecture she desired, but lab questions were still difficult, even using the BSCS tests. What was even more painful was that her students did not do as well on standardized tests as students whose teachers emphasized lecture. She felt torn between helping her students do better on standardized tests and giving them the lab experience they found so meaningful.

In my column on that general question I did not get into the details of how to prepare questions on specific content. Good questions are hard to find. Virginia was interested in writing a few sample questions about each subject area as it was discussed in the column. I suggested there was a need for better communication about exams and, since she had some expertise in the area, thought she might consider writing a column. She was unable to take on such a large responsibility, but was still interested in contributing a few questions.

I think there is a real need for sharing ideas about exams. College English teachers have a publication called "The Exercise Exchange" in which they share materials they have developed for students. *ABT* could use more of the kind of sharing that occurs in the Projector Center. We can use this kind of sharing in every area of biology teaching. In the area of exams, if an editor could be found, subject areas could be announced in advance, people could submit their best questions and the editor could publish a selection of great questions. I cannot overemphasize the importance of this idea. We each have our own perspective on how to ask about a concept, but looking through other teachers' eyes we can broaden our view of ourselves and our students.

When this column begins to deal with specific content areas, I'll be calling on Virginia Malone to help.

### Double Period Science Labs

I received my second question in the fall, just before going to the Baltimore NABT Convention. I had hoped to raise the question with people there but, like at most meetings, time ran out before I could deal with all the problems I had hoped to discuss with others. That's another reason why I'm convinced published dialog is needed.

The question was from Joseph R. DeWitt, chairman of the Science Department of Miami Country Day School, 601 Northeast 107th Street, P.O. Box 380608, Miami, FL 33138. He was concerned about the loss of double-period science labs at his school and wanted advice on where to find pertinent information on the subject.

Even though it is obvious that many laboratory exercises cannot be done in a 40-minute period, this question is probably best answered by someone with a track record on this topic, such as BSCS and advanced placement people. I think one needs a trump card like "AP credit is only given to courses with double lab periods" to deal with this problem quickly. If anyone can advise Mr. DeWitt, please write him at the above address.

### Photosynthesis

I received my third letter after the October NABT meeting from Yvonne

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Coffey of Stuarts Draft, Virginia. Studying to be a middle school science teacher, she was interested in "workable" lab experiments. She was developing a photosynthesis lab and wanted to know what plants work best.

One of the things that always amazes me is that the science curriculum seems to use the same experiments over and over again at different levels. The instructional approaches and contexts vary greatly, but when the actual experiment shows up, it is almost always a classic where someone has modified the apparatus so it can be used at that level. I have done a number of plant physiology labs including some on photosynthesis. It was interesting to look at middle school books to see what was being done.

In one book I found the same experiment I had done with college freshmen, but with simplified equipment. A sprig of *Elodea* was inverted and placed in a test tube containing water and some baking soda. Lamplight was filtered through a bottle of cold water. A two hole stopper was placed in the top of the test tube with two rubber tubes attached to the glass tubing in the holes. The shorter piece of rubber tubing was open, and the longer piece was connected to a foot-long glass tube on a ruler. A drop of ink was introduced into the end of the long glass tube with an eyedropper. The student was told to move the drop of ink to the middle of the long glass tube by sucking on the shorter piece of rubber tubing. The tube was then clamped and the movement of the drop measured for one to three minutes.

Teachers who have done this classic experiment are familiar with the problems. Some *Elodea* sprigs work better than others. Students may have to try several sprigs to get a good one. Even so I doubt that good results could be obtained in one to three minutes. Since simple closed systems are notorious for leakage, unless the inside of the test tube is dry and the rubber stopper dried before insertion, one often ends up measuring the pressure change as the wet rubber stopper gradually moves out of the tube. If the glass tubing used to measure the change is large enough that a student can draw a drop of ink to the middle of the tube by sucking, it is probably too large to measure any change that would occur in one to three minutes. Even with systems using tuberculin syringes (e.g., the Zollinhoffer manometer sold by Carolina Biological Supply Company) students have trouble keeping the manometer fluid in the measuring tube.

I use this example to make two points: (1) Many laboratory activities are developed by designing new ways of using classic experiments that are thought to be so reliable they can be modified in many ways without actually trying them in the lab. (2) Many people seem to think that students will not be bored with the same experiments in new contexts.

Photosynthesis is an area where there are all kinds of opportunities for new ideas or simpler, but more reliable, approaches. A wide variety of plant materials are available everywhere so no one should have to buy or ship in materials for these activities. The problem is that classical exercises depend on *Elodea*, spinach, geraniums and other materials which may or may not be available. Often there is a local organism that is equally satisfactory. For example some people claim pine branches work very well for potometer, transpiration experiments. By developing dialog about specific kinds of experiments, we can communicate practical experience and help teachers improve their labs.

Below are a few examples of activities with comments related to photosynthesis. Some of these ideas will be well known to some, but more communication about them can only help give biology teachers more freedom to choose the best activities for their students.

There are a variety of simple ways to measure photosynthesis without using a manometer. One of the easiest ways is to count the bubbles released from a plant like *Elodea*. The advantage here is that if the plant does not respond in a few minutes, another plant can be tried without taking apart and setting up a manometer. Although counting bubbles is less precise than using a manometer, the effect of changes in light intensity, color, temperature and other factors are easy to study. Another aquarium plant that has been used with some success is wisteria. A list of plants that work well would be very useful.

Photosynthesis can also be studied using discs cut from leaves with a cork borer or paper punch. The discs are placed in an illuminated bicarbonate solution and oxygen production causes them to rise. A similar system has been used to study enzyme activity by putting discs of filter paper soaked in hydrogen peroxide into catalase extract solutions. This apparently works well with paper discs, but I have heard that some people have had trouble with the leaf discs in the photosynthesis experiment. The leaf discs must be placed in solution under reduced air pressure to remove residual air from the leaf so it will sink. Does anyone have comments on this problem? Steucek and Hill have two excellent articles about this method in the February 1985 issue of *ABT* (pp. 96-102). They discuss the problem indicating that rapidly growing plants should be used. Hairy leaves such as on geranium plants do not work well. They used English ivy (*Hedera helix*) for basic experiments and a wide variety of weeds to study herbicide resistance. Feedback from teachers trying this method would be very helpful. With the best materials, it could be an elegant and reliable tool for teaching about photosynthesis.

Oxygen evolution can also be studied by using color indicators or by measuring it with an oxygen electrode, but I cannot comment on how well these methods work. Does anyone have experience with these methods?

Another experiment that is often used to study photosynthesis is one where part of a leaf from a plant kept in the dark for a day or two is masked, exposed to light, and tested for starch with iodine solution. Only the part of the leaf exposed to light turns black after the leaf is boiled in water and the chlorophyll removed with hot alcohol. I mention this experiment because I saw a variation of it, which students and teachers would enjoy, in an Encyclopaedia Britannica film entitled "Photosynthesis." If the leaf is masked with photographic negative, a good print is produced on the leaf when it is tested for starch. These kinds of modifications can make a routine experiment into a memorable experience for students. Undoubtedly, many of you know of similar improvements that we could communicate via this column.

The EB film, produced in 1982, also showed some of Melvin Calvin's work on photosynthesis but does not explain it as well as it is explained in the film *The Riddle of Photosynthesis* produced by Handel Film Corporation in 1965. The Handel film is now dated because of the dress of the scientists and the attitude it takes in presenting the Nobel Prize winning scientist, but it is the only biology film I have seen that explains how a metabolic pathway is determined using radioactive tracers, radioautography and two-dimensional chromatography. Since these methods are still so basic, a revised edition or similar kind of film would be very useful. Despite its dated nature I highly recommend this

film where it is appropriate.

The extraction and chromatography of plant pigments are also common procedures at many levels. Usually there is also some discussion of the nature of light and color accompanying these activities. Color is a fascinating subject but students often do not get much opportunity to experiment with it, other than with paints. Since video and photography depend on the addition and subtraction of primary colors, students can gain valuable understanding if they experiment with light. When I first taught about photosynthesis a friend told me about a set of color filters sold by Creative Playthings. It was a durable set which was fun to play with, but it was not until I saw a presentation by a photographer that I appreciated what one could learn by superimposing projected images of the primary negative and positive colors. My students and I have had fun doing this demonstration using three slide projectors and filters of the primary additive colors (red, blue and green) and the primary subtractive colors (magenta, yellow and cyan). Unfortunately, often there is so little time in a biology course to deal with principles of physics that one cannot include this kind of activity. I mention it here because I feel strongly that students need this kind of experience at some level, and middle school might well be one of the best places for it.

Color is discussed in the context of photosynthesis more to emphasize what wavelengths of light are being absorbed by the chlorophyll. An inexpensive spectroscope can be used to view a chlorophyll solution. These solutions will also fluoresce if placed in front of a bright light (e.g., a slide projector) demonstrating what colors of light have been absorbed and emitted. If one takes a flash picture of a chlorophyll solution, half of the solution can be shown to be fluorescing.

Chromatography is done in many courses. Usually an extract is provided to students who spot a piece of filter paper or other medium with a capillary tube or similar device. This is usually the most time-consuming part of the exercise. A number of years ago an Illinois biology teacher published a note in the *ABT* indicating that if a coin was rolled across a leaf on a piece of filter paper, enough pigment was deposited to make a good chromatogram. This past summer I finally got a chance to try this procedure at an ABLE conference. Kathy Nolan from Yeshiva University was demonstrating chromatography using the bluegreen alga, *Spirulina*, and thin layer chromatography. I suggested, since all the materials were readily available, that we try the coin procedure as well. Paul Monson from the University of Minnesota at Duluth indicated he had done the exercise using the bottom edge of a jar rather than a coin with good results. We tried the procedure on a variety of leaves from the Cornell campus and found it very useful for rapid analysis. A variety of samples could be studied (colored leaves, leaves in the fall, etc.) without the problems of extraction commonly encountered. I am surprised the procedure has not been adopted more widely since it has been known for a number of years.

For more refined analysis, a procedure like Kathy Nolan's is excellent. She used *Spirulina*, which is available as a powder from General Nutrition Center and may be found in local health food stores. She places 10 grams in 30 ml of acetone for one-half hour, shakes it vigorously for five minutes and then vacuum filters it through Whatman #1 filter paper. The chromatogram is made using ITLC Gelman silica gel paper and a 9:1 solution of petroleum ether and acetone. She also has her students extract the separated pigments from the paper by cutting it and placing each pigment in a small amount of acetone, which is then examined with a spectrophotometer.

The composition of the solvent is critical for obtaining the best separation. Some manuals suggest pure petroleum ether can be used but 92 percent pet ether and 8 percent acetone works much better, as does the 9:1 solution mentioned above.

## Learning About Labs

My last letter for 1986 came in December from Naomi Weizenbaum, who is teaching biology for the second year at Chatham Hall in Virginia. She was interested in where she could learn more about laboratory instruction in the summer, how I learned about it and what advice I would give beginning teachers.

Like many teachers, I learned most of what I know from practicing teaching rather than studying about it. Even though I attended a school with a first-rate reputation in science education in the early 1960s, the University of Kansas, and was a preservice participant in an Academic Year Institute of Washington University where I received a masters degree, very few living things were used in my courses. I read as much as I could about the BSCS courses being developed at the time and wanted to teach them. There was, however, no opportunity for me to gain laboratory experience with BSCS when I was a student. I took a course in methods for teaching science where I became familiar with inquiry-based instruction, but when I entered the classroom and had to prepare and use materials, I had to learn everything on my own.

After teaching a year in junior high, I took a teaching position at a small, four-year college that emphasized labs. The first couple of years I spent doing traditional labs that others had developed, which required little practical preparation but considerable mental preparation. Using mostly preserved materials and prepared slides, I helped students learn the same kinds of things I learned as a student: the life cycles and major structures of representative organisms. I do not regret this experience because it gave me a good understanding of this approach to teaching biology.

After teaching this way, the department decided to teach a one-year principles of biology course rather than offering a semester of botany and zoology. We decided to use Keeton as the textbook and discovered that a good lab manual with an excellent instructor's manual was available. When I was given responsibility to develop the labs, a whole new world opened to me.

I spent the next seven years getting those labs to work, trying variations I had seen in other manuals including the BSCS materials. Eventually I discovered that most of the methods were well known to the research community but were not readily available in the literature. In a few cases I visited research labs and will always remember the first time I heard a technician say, "I know he says do it that way, but it works better if you do it this way." I developed a much better understanding of the research community when I took a laboratory teaching position at a major research institution.

During that period of time, I also attended NABT, NSTA and AIBS meetings hoping to learn how to solve these problems. I was surprised that these meetings offered little opportunity to gain practical experience. For many years I felt we needed an organization that was concerned about laboratory teaching problems, and when I took a new position at the University of Calgary, I decided to try and form one. With the help of colleagues from other universities, The Association for Biology Laboratory Education (ABLE) was formed in 1979. We have met

every year since at a major university, each time offering a considerable amount of practical experience to laboratory biology teachers. Unfortunately, because the meeting is limited to about 100 participants for practical reasons, we have not been able to include many precollege teachers, although a number of prep school and advanced placement teachers have attended the workshops.

The organization publishes proceedings, which are the most detailed laboratory teaching methods manuals available. Most of the exercises are too sophisticated for high school teaching but could be modified for use at that level. The proceedings are an excellent resource for science fair projects because they use reliable materials and have extensive references.

NABT offers summer workshops called Updates for high school teachers at several small colleges. In addition, NSF and local universities sponsor a large number of inservice workshops for precollege teachers. Some of these include practical experience with laboratory materials and should be good opportunities to learn laboratory methods.

I learned most of what I know by trying new experiments and by talking to other teachers and visiting their labs. On the local level, the more sharing you can do the quicker you will learn what works. Everyone has had to solve basic problems to get materials to work, but unfortunately, much of this experience is not in the literature.

There are a wide variety of lab manuals and books available. In general, I would say the ones with the most detailed lab instructions are the most reliable, for example BSCS. *A Sourcebook for the Biological Sciences* by Morholt, Brandwein and Joseph, which is a classic and has recently been slightly revised, is a good starting place. The problem with most books like this is they offer general information about many different areas. Often these books omit what seems like a minor point, but really is critical for success, and one must try several methods to find one that works.

Many of the procedures are successful. However, one usually looks in these books to solve a problem. It takes time to try a dozen possible solutions to find one that works for a given situation. For example, a book may contain a whole series of classic, nonliving osmosis and dialysis experiments, but most teachers will have little trouble with these experiments, other than that they take too much time. On the other hand, almost every teacher will have trouble finding a potometer that works well. It is probably much easier to find someone who has one that works than to try a dozen experiments that may or may not succeed or to invent or modify your own.

Unfortunately, our time is limited and we can try only a few new things. By talking to other teachers we can benefit from their experience. If we can develop a large network of interested teachers, we can ask questions and determine what is most reliable.

I'll end by asking a few basic questions in the form of a questionnaire. If you could copy it and send it to me, I'll try to develop next year's columns around the results. Next time I'll talk about reviews.

## Lab Column Questionnaire: "The Best"

Please indicate your choices, briefly telling why, for each of the following categories. If your answer is something that is not well known, please include a copy or reference so I can find additional information if I need it.

Name _____

Address _____

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_____

Best Lab Experiment or Activity

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Worst Lab Experiment or Activity

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Best or Most Useful Organism

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Best Film or Supplementary Material

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_____

Most Useful Item I Purchased for Teaching

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_____

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