



From the President

Mark D. Little
NABT President – 2013

Quantitative Skills & Biology

The challenges of the 21st century require students to think critically and use quantitative skills. As the field of biology evolves, these skills will become fundamental to the study of biology. John von Neumann, the Hungarian-born mathematician, once said, “If people do not believe that mathematics is simple, it is only because they do not realize how complicated life is.” From a science–math point of view, people do not realize how complicated life is. If one is going to study science and/or engineering, they are going to need to develop skills in mathematics because it is at the core of all science and engineering. As we study biology, and start digging deeper and peel back layer after layer, math will be at the core.

The major focus in biology has always been the study of life. However, there have been many changes in biology over recent years. New fields of biological research have been emerging. Synthetic biology, bioinformatics, and systems biology are just a few. The development and the rapid changes in technologies available have expanded the research opportunities in these fields and many others. All these developments, plus the massive amounts of data that have been collected, stored, and available for analysis, make skills in mathematics, statistical analysis, and computational skills necessary competencies in studying modern biology.

The need for more “quantitative skills” in biology education and biology research for undergraduates was highlighted in the *BIO2010* report (National Research Council [NRC] 2003), which states:

How biologists design, perform, and analyze experiments is changing swiftly. Biological concepts and models are becoming quantitative and biological research quantitative, and biological research has become critically dependent on concepts and methods drawn from other scientific disciplines. The connections between the biological sciences and the physical sciences, mathematics and computer science are rapidly becoming deeper and more expansive.

America’s Lab Report: Investigation in High School Science (NRC, 2005) stated in summary that “laboratory experiences provide opportunities for students to interact directly with the material world (or with data from the material world), using the tools, data collection techniques, models, and theories of science.” Why are mathematical, computational, and statistical skills necessary? Mathematics is difficult to define, but the characteristics usually included are quantity, change, structure, and shape. Mathematicians look for patterns and create an unproven inference. Skills students need to use mathematics include quantities and skills involving measuring

and collecting data (http://apcentral.collegeboard.com/apc/public/repository/AP_Bio_Quantitative_Skills_Guide-2012.pdf).

Computational thinking uses computers to do calculations for us and are another approach to look at science today. For example, using computers allows students to develop simulations that combine the mathematical representations to explore models of complex systems. In the classroom, students can use a free modeling program found online and study a population model using Hardy–Weinberg to observe changes in allele frequencies. Students can use probes like a carbon dioxide sensor to collect large amounts of data and to learn to analyze it and evaluate the data (http://apcentral.collegeboard.com/apc/members/courses/teachers_corner/218954.html).

I have talked to many high school colleagues, and like me, they are surprised how few of their students have used a simple spreadsheet program before reaching their classroom. It is so important that students learn how to use spreadsheets, run statistical analyses, and display data in appropriate formats such as tables and graphs. Using statistics with the mathematical and computational tools today will help students design experiments and move on to the next step in their research.

The goal in biology and science classes at all levels is to teach students how to learn and process information as a scientist would. If more inquiry, reasoning, and “quantitative skills” are incorporated into your curriculum, students can and will model the behavior of a scientist. One of the goals of the Next Generation Science Standards (<http://www.nextgenscience.org/>) is to help students perform observations, explore, design scientific investigations, and discover some knowledge him or herself in working through the process of problem solving (NRC, 2011).

All levels of biology education need to embrace these changes and become part of the solution to improve biology education. We can do that by embracing mathematics and quantitative lessons now and in the future. Even if our students do not become scientists, many, many careers today require that students be able to use these tools, and we need to prepare them to do so.

Mark D. Little
NABT President – 2013

References

- AP Biology Lab Manual. http://apcentral.collegeboard.com/apc/members/courses/teachers_corner/218954.html.
- AP Biology Quantitative Skills: A Guide for Teachers. http://apcentral.collegeboard.com/apc/public/repository/AP_Bio_Quantitative_Skills_Guide-2012.pdf.
- National Research Council. (2003). *BIO2010: Transforming Undergraduate Education for Future Research Biologists*. Washington, D.C.: National Academies Press.

- National Research Council. (2005). *America's Lab Report: Investigations in High School Science*. Washington, D.C.: National Academies Press.
- National Research Council. (2011). *A Framework For K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, D.C.: National Academies Press.

DOI: 10.1525/abt.2013.75.4.1

LETTERS

I recently came across an article called “Why is that dog paralyzed?” in the January 2013 issue of the *ABT* (Milanick et al., 2013). This is a problem-based learning activity that is recommended for AP Biology teachers. As a neuroscientist, a former college professor, and the Biology Staff Scientist at Vernier Software & Technology, I have some serious reservations about recommending this exercise to high school teachers.

The concept behind the activity is excellent, but this exercise uses the compound acetylthiocholine, which is toxic, and the article provides no safety precautions for the teacher or the students. I read through the appendix at the website provided by the authors and did not find any safety precautions there, either. Although most colleges have a chemical safety officer who oversees safety and disposal of toxic compounds, many high schools do not have a person on staff who knows that the compounds used in this assay are toxic. The teacher is going to be handling acetylthiocholine powder, as well as DNTB powder when mixing up stock solutions. The students are going to be handling these solutions. Acetylthiocholine is a substance that high school students should not use without taking proper safety precautions (goggles and gloves).

The enzyme assay used in this exercise (for the enzyme acetylcholinesterase, AChE) is commonly performed in many upper-division neuroscience courses. At Vernier Software & Technology, we have published an activity that uses the reagents presented in the article (this experiment can be found in “Introduction to Neurotransmitters using AChE” in the *Advanced Biology with Vernier* lab book). We provide the safety information for the chemicals in the teacher information pages. The Safety and Hazard Information for the two compounds used for the AChE activity are listed below.

Acetylthiocholine iodide: Hazard code T, Toxic. Respiratory, skin and eye irritant; May be harmful if inhaled, toxic by ingestion, harmful if absorbed through skin. Wear gloves and eye protection and appropriate full face particle respirator (N99 or equivalent).

5,5'-Dithiobis(2-nitrobenzoic acid), (DTNB), (Ellman's Reagent): Hazard code Xi, Irritant. Respiratory, skin and eye irritant; May be toxic by ingestion, inhalation, absorption through skin. Wear gloves and eye protection and appropriate dust mask (N95 or equivalent).

Hazard information reference: Sigma-Aldrich, MSDS, 800-325-5832, <http://www.sigmaaldrich.com>

Standard safety precautions should be taken when performing this activity and when mixing up solutions for this lab. The person (teacher) mixing up the stock solutions should wear eye protection, gloves, and a respirator, in addition to a lab coat, since they will be working with the compounds as solids. The students performing the activity should wear eye protection and gloves, in addition to a lab coat.

Given the safety requirements for using acetylthiocholine, the instructor may want to consider mimicking the AChE reaction when performing the “Why is that dog paralyzed?” activity from the January issue of the *ABT* (Milanick et al., 2013). This is an excellent problem-based learning activity, but it does not appear to be designed to teach students how to perform quantitative enzyme assays or how to perform antibody assays. For example, in the first part of the exercise, fish muscle samples are added to test tubes to make the results of the AChE reaction fit the story line. In the second activity, turmeric is used to mimic the results of a fluorescent antibody reaction. Mimicking the data for both parts of the activity may be a safer and simpler alternative to performing the AChE reaction.

It would be very simple to mimic the AChE reaction. You just need a solution that will turn yellow in color after adding another solution to it. For example, Bio-Rad Laboratories has a very nice BioFuel Enzyme kit that uses p-nitrophenol as a standard. This compound turns yellow when it is mixed with the stop solution found in the kit. The teacher can easily make solutions that “mimic” the AChE reaction by following the steps below.

1. Label two 50-mL bottles Positive and Negative.
2. Put 10 mL of deionized water into each bottle.
3. Add 2 mL of standard + 8 mL of deionized or distilled water to the bottle labeled Positive and mix.
4. Add 10 mL of deionized water or distilled water to the bottle labeled Negative.
5. Mix up the stop solution as directed in the instructions for the BioFuel Enzyme kit.

The teacher can easily make up a series of solutions that can stand in as negative or positive AChE reactions. Simply substitute the solution from the bottle labeled Positive for the fish homogenate in the “Why is that dog paralyzed?” activity. To watch the reaction turn yellow, have the students put 2 mL of the solution from the bottle labeled Positive in a test tube. Then have them add 2 mL of stop solution to the test tube. For negative reactions, have the students put 2 mL of the solution from the bottle labeled Negative in a test tube. Then add 2 mL of stop solution. The instructor can always split the samples into test tubes that are labeled accordingly