Why Can't School Science Be More Like Science?

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August 8, 2010.

Society for Developmental Biology, Albuquerque, New Mexico.

It is a deep honor to receive the Viktor Hamburger Award. I am old enough to have used Hamburger's 1941 book, *A Manual of Experimental Embryology*, as an undergraduate. Hamburger's own favorite experimental organism, the chick embryo, was the star of our course. His 1951 paper with Howard Hamilton, "*A series of normal stages in the development of the chick embryo*," was published in 1951, in the nick of time for that class.

I was actually in that course only with the sufferance of the professor, an embryologist named Robert K Enders, who did NOT think that a chemistry major belonged in a class for biology majors. Professor Enders was an extraordinary teacher, but he would probably think that a society that would give me the Hamburger Prize was a strange society indeed. He did not see that I would evolve to be more biologist than chemist or that embryology itself would evolve to become Developmental Biology and even Developmental Genetics. He would have been amazed with the insights and methods that you have reported at this meeting.

Viktor Hamburger was one of those unplanned gifts that Adolph Hitler gave to American science. He came to study and work here in 1935 and was, along with many others, unable to return home. He connects us to the early history of developmental biology because he was a student of Hans Spemann when the organizer was discovered. Hamburger also connects us to the modern history of developmental biology through Rita Levi-Montalcini. According to her autobiography (http://nobelprize.org/nobel_prizes/medicine/laureates/1986/levi-montalcini.html), it was a paper of his that inspired her, in 1940, to investigate how the excision of peripheral appendages in chick embryos affects the development of the central nervous system (e.g., spinal cord). Her life too was shaped by the tragedies of World War II. Hiding from the Nazi attempts to cleanse Italy of Jews, Levi-Montalcini took her microscope and the makings of an incubator with her to her family's country hideout outside Turin. She scoured the farms nearby on her bicycle to collect fertilized eggs. And once she had dissected the embryos from the eggs, the remainder went to the kitchen, to the disgust of her older brother. Just a year after the end of WWII, Hamburger invited Levi-Montalcini to come to Wash U to continue her experiments. And that lead to the discovery of nerve growth factor and all that followed from that discovery.

These stories are inspiring. But they, and similar tales about biology don't appear in school classrooms. Neither do chick embryos or other invitations to explore. The best summary I know of how school science is now taught is in an essay written by Alison Gopnik and published in the New York Review in 1999. Gopnik, who is Professor of Psychology at Berkeley and a recognized leader in the study of how children learn, asked her readers to imagine "*if we taught baseball the way we teach science. Until they were twelve, children would read about baseball technique and occasionally hear inspirational stories of the great baseball players. They would answer quizzes about baseball rules. Conservative coaches would argue that we ought to make children practice fundamental baseball skills, throwing the ball to second base twenty times in a row, followed by tagging first base seventy times... Undergraduates might be allowed, under strict supervision, to reproduce famous historic baseball plays. But only in graduate school would they, at last, actually get to play a game. If we taught baseball this way, we might expect about the same degree of success in the Little League World Series that we currently see in science performance."* Now, ten years on, Gopnik's comments are still true.

Some years ago I was invited by a middle school biology teacher to visit with her class. I asked the students what they would like to talk about. Several of them asked me if we could talk about meiosis, which puzzled, challenged, and bored them. In fact, they had learned (or memorized) a good bit about the stages of meiosis. But they had no idea that meiosis is a story about themselves. No wonder they thought it was boring. They had no idea that meiosis held the secret of why they are such unpredictable combinations of their ancestors. No one had told them the story of the young student, W.S. Sutton, who, just after the start of the 20th century, realized the connection between meiosis and Mendel's demonstration of the law of segregation (and of course Mendel also confused them). And, because biology teachers and language teachers rarely talk about connections, no one asked them to find out about the origins in Greek of those strange words leptotene and zygotene.

Neither experience, nor history, nor observation, nor making connections are standard tools for teaching biology U.S. classrooms. Nor is extensive use of the web, which is more challenging for many teachers than for their students. That's certainly true of the schools in our nation's capital, where I live and have been involved in science and math education for more than 20 years.

So, why are these integral parts of science largely missing from biology teaching in U.S. schools? There are endless numbers of ideas out there to explain the shortcomings of and to improve science education in the U.S. Some of them are terrible. Some of them are interesting. With only rare exceptions there are precious few data available to tell us how well they work…which doesn't stop many people from passionate defense of one or another idea.

I think there are at least 3 interrelated reasons for our current failure to teach science effectively although students, even inner-city students, are truly curious and really do want to and can learn. One is that Standards, nation-wide, require teaching too many things. Another is that textbooks follow the lead of the Standards and have too much material. Pick up a high school biology book, if you can. The one I weighed came in at just about 6 pounds. It's full of facts and names of mixed importance. It's devoid of the most interesting things…like how we know what we do, and what we don't know. Also, a lot of students in high-risk schools like those in my city don't have the reading skills necessary to read those books. No wonder that they aren't enthusiastic about learning biology. And very few people seem to realize that different books could not only help them learn biology but even motivate them to improve their reading skills.

The third reason why school biology classes are the way they are, and the one I believe to be most important, is the teaching. There are of course some really excellent teachers out there, but too many science teachers have no background in biology at all. Of those who did study biology in college, many did so 20 or more years ago and have not had the opportunity to refresh their knowledge with up-to-date concepts and information. Sabbaticals are virtually unknown for school teachers. Even relatively young teachers are likely to have learned biology in weak courses taught in departments of education rather than by biology faculty.

There are two common approaches to trying to improve science teaching. One, called 'Professional Development" addresses a need to improve the efforts of current biology teachers.

Professional development consists of sessions lasting from a couple of hours to a few weeks that try to enrich teachers' knowledge of biology and appropriate pedagogy. Some of these 'professional development' programs are terrible and some are interesting. At Carnegie we have held such programs for DC teachers from preK through 12th grade for years. We think we are pretty good at it. Our staff members are all scientists with deep teaching experience. We emphasize observation, experience, and experimentation. But we, along with many others who have tried such programs, know that most have disappointing outcomes…assessed either by changes in classroom teaching or student achievement. The anecdotal evidence that we and others have collected about the general failure of professional development was recently confirmed by two controlled studies, albeit in math and reading. Intensive, high quality professional development failed to have a significant effect on student learning (article in Education Week, April 16, on line).

Why is it that professional development doesn't work? First, there is rarely any meaningful follow-up or support from principals for essential materials or space or running water. More important though is that the teachers' own educations, in traditional high school and college classes using traditional textbooks, have not provided the flexibility of thought processes or hands on experience that permit ease for the teacher or the ability to make connections. Their education too presented biology as a series of disconnected issues and facts. It failed to make the connections to history, or current events, or language study that make sense of the living world or to connect biology to anything else that matters to the students.

The second approach to improving the teaching of biology is to do a different kind of job in training teachers to begin with, when they are in college themselves. And this is where the members of this Society come in. You and your university colleagues are in a unique position to address this need. Right now, university teaching itself often suffers from the same challenges as school biology teaching. Arguably, the long list of required topics is designed to fulfill the needs of those who want to be professional scientists or go to medical school. Too often it is also dictated by the particular interests of the professor. Why shouldn't the education of teachers be as important as the education of professional scientists or those aspiring to medical school?

You all know undergraduates and graduate students who are deeply interested in biology but not inclined to a career in research. They might, if encouraged, consider teaching. This has not been a high priority for our community in the past; it needs to be. We should take as much pride in a student who becomes a great teacher as in those who obtain a tenure-track research position. Doing something about this presents a lot of challenges that many of you would prefer to avoid…for example working with education schools in your universities which is, admittedly, often a difficult task. College and university teacher training programs are too frequently deficient both in modern content and enlightened pedagogy. And ed schools are often disinclined to cooperate with other departments. In some universities, science departments have set up their own teacher training programs.

You don't need to reinvent the wheel to move forward on encouraging better school teaching; good ideas and curricula from institutions that have taken this challenge seriously abound on the Internet. For example, the U-Teach program at the University of Texas at Austin has more than a decade of experience and knowledge and is a terrific model for what can be done. The University of Washington has a web-based program called Neuroscience for Kids. The University of Utah has a terrific site for teaching genetics. If you google *high school biology on the web* you can find others.

And there is money available to accomplish this. For example, federal grants increasingly require that you show the "broader impacts" of your proposals. Training teachers is one way to satisfy that requirement.

Federal and private grant funds are available to support such efforts. The NSF Robert Noyce program provides funds, including tuition grants and departmental support for both undergraduate and graduate programs. The NSF Graduate Stem Fellows program for K-12 supports graduate students to bring modern research practice and findings to schools.

The Noyce Teaching Fellows program is especially interesting. This is a graduate program for people with undergraduate degrees in science, engineering, or math, who decide they would like to teach. Universities partner with independent organizations and school systems. Fellows must be selected in rigorous, competitive procedures and NSF provides funds for recruitment and for tuition and stipends for a full year of academic study in their fields and in teaching, and salary supplements for the first 4 years of teaching in hi-needs schools. It also gives funds for mentoring the Fellows for the whole 5 years. I like this program because it recruits for classrooms people who are already well educated in science or math and then trains them to be teachers. It also provides incentive to remain in the classroom. And, it competes with regular graduate work by providing the money to support graduate studies in education; usually aspiring teachers have to pay for their own educations. At Carnegie we have such a grant for training math teachers. We are part of the growing nation-wide Math for America programs that all have the same kind of programs as required by the NSF for Noyce Teaching Fellows. How about starting a nation-wide movement for Biology for America?

Improving the teaching of biology and other sciences matters. The current recession and the slow improvement in unemployment reflects not only the general economy but a concurrent change in the kinds of jobs that are available. A story in the July 2 New York Times (by Motoko Rich) described the kinds of jobs that ‘go begging’ even as unemployment continues…and these are not jobs only for Ph. Ds. The story describes a contract drug maker outside of Cleveland that only found 47 people qualified for 100 available jobs out of 3600 applications. And last year, in a survey of 779 industrial companies, 63 percent of life science companies reported moderate to serious skills shortages (among applicants?). The current unemployment situation is meeting, head-on, a shift to more skilled workers that exacerbates the economic troubles.

A recent article in the newsletter of the American Society for Biochemistry and Molecular Biology, like others I have read, addresses the disparity between the number of biologists being trained in graduate programs and the available academic jobs (June, 2010, by Clifford S. Mintz). The article says that “Newly minted doctorates and postdocs are finding it nearly impossible to find jobs.” And goes on to discuss a whole list of interesting alternative careers for such folks. BUT guess what, teaching is NOT on that list!

Imagine a whole high school biology course that begins with the story of Viktor Hamburger and Rita Levi-Monalcini? Or one that makes meiosis the jumping off point for teaching biology? Only people with a solid understanding of biology can pull off such challenges. And you are the people who can identify and encourage such people to be teachers.

Following article documents failure of intensive math PD for middle school teachers.
http://www.edweek.org/ew/articles/2010/04/16/29pd_ep.h29.html?tkn=TOYFao2JLLlZmfQ4wk1eYeBW5R%2B9g24sUb%2Fs&intc=es

See Science March 26 page 1589-90 for online bio lessons.
Rita Levi-Montalcini. In Praise of Imperfection: My Life and Work. Basic Books, New York 1988.

"A series of normal stages in the development of the chick embryo," by Viktor Hamburger and Howard L. Hamilton. Journal of Morphology v.88, pp. 49-92, 1951.

Alison Gopnik. 1999. Small Wonders. The New York Review. May 6. pp. 33-35.

Maxine Singer received Viktor Hamburger Outstanding Educator Prize from SDB President Richard Harland and SDB Professional Development and Education Committee Chair Karen Bennett.

SDB 69th Annual Meeting, Albuquerque, NM

Photos by M.Halpern