

Feature Educator Highlight

Robert Full

Interviewed by Laura L. Mays Hoopes

Halstead-Bent Professor of Biology and Molecular Biology, Pomona College, Claremont, CA 91711

Note from the Editor

Educator Highlights for CBE–LSE show how professors at different kinds of institutions educate students in life sciences with inspiration and panache.

Laura Hoopes: How would you describe your teaching?

Bob Full: Investigative, interdisciplinary in approach. It's inquiry-based learning and covers the whole spectrum of science and engineering.

LH: You teach undergraduate and graduate courses and do research with undergraduates and graduate students, correct?

BF: Yes, that's right.

LH: Could you tell me more about your classes?

BF: The most introductory one, with no prerequisites and students from all over the campus, is called Biomotion. I give some lectures on background material; we get into art, design, robotics, comparative biomechanics, physiology, sports—all sorts of different topics.

LH: How do you organize the work the students do in Biomotion?

BF: They hear lectures and discuss topics for about half of the course, and then they do projects. I ask them to work in teams to design something that moves, inspired by biology. For example, they might design the next Mars Rover, using principles of biological movement. They buy toys—construction kits, and they build their designs.

LH: What do they do with these designs?

BF: We have a Bio-Inspired Inventors Night, where we have them present their work and rate each other. We give out awards. One of the best things I've observed is that the teams with the most diversity (ethnic and gender diversity, as well as other dimensions—like origami vs. farming vs. insect interests)

DOI: 10.1187/cbe.10-09-0115

Address correspondence to: Laura L. Mays Hoopes (lhoopes@pomona.edu).

© 2010 L. L. Mays Hoopes. CBE—Life Sciences Education © 2010 The American Society for Cell Biology. This article is distributed by The American Society for Cell Biology under license from the author(s). It is available to the public under an Attribution–Noncommercial–Share Alike 3.0 Unported Creative Commons License (<http://creativecommons.org/licenses/by-nc-sa/3.0>).



Robert J. Full, Chancellors Professor, University of California, Berkeley

come up with the most creative ideas. It is a great way to demonstrate to students the strength that comes from diversity. We don't even have to point it out. They really get it.

LH: How have the students surprised you with their designs?

BF: They've developed some clever designs that are far better than motors, making next-generation artificial muscles. We would like to get the capacities of muscles out of our mechanical designs, but it's very hard to do. Muscles aren't just rubber bands, and they go beyond being motors—shorten and lengthen, generate power, act as springs, act as struts, become shock absorbers. It's hard to approach the excellent way muscles operate using purely mechanical designs. Students see the advantages of organisms over robots. They add springs and dampers or use clever gearing of motors to get some of these special abilities of muscles into their devices. They come up with some truly novel ideas.

LH: Can you give us one specific example?

BF: Years ago, we had an undergraduate woman, Naomi Davidson, who came up with a fish-like robot. It was amazing, really state of the art in how it moved and acted. She

went on for a degree in engineering and built an advanced version of this robot, and then went on for another degree at Massachusetts Institute of Technology. Her original design was as good as any fish-like robot anywhere in the world, built by anyone. It was outstanding!

LH: Could you describe another course for us?

BF: I teach Comparative Physiology to more advanced students. We talk about organ systems in very different animals: humans, vertebrates, and lots of invertebrates. That material takes up about two-thirds of the course. In the other third we have the students take on the personas of researchers. Each student gets a paper to read and “becomes” that scientist. They post the papers online 2 wk ahead of the final symposium, and their presentation goes up online 1 wk ahead. They present a talk at the symposium as if they were the researcher they represent, putting forth all the data from the paper and discussing it, proposing future experiments based on the paper’s results. They’ll say, “I’m so-and-so from X University. I have this question . . .” It’s incredibly interesting and interactive. They ask each other questions and answer as if they were professors.

LH: Then are they graded just on the presentations?

BF: I do grade the presentations, the questions they ask each other, but I also give examinations. The attendees at the symposium have to turn in a question at the end of each presentation, and if it’s a really good question, I put it on the final examination. The data everyone has presented are also used in creating the final, as illustrations of general principles. They all read all of the papers and attend all the presentations. It’s up-to-the-minute work. One student gave a talk about a drug that was being tested on guinea pigs to allow signals to muscles in the back after spinal cord injury. The student said this drug was ready for testing in a mobile vertebrate. The next day, scientists from Purdue published a test of this drug using dogs and found that the treated ones could walk after spinal injuries. The students were so excited! They see that they can do this type of analysis, that they really understand it as well as the people in the field. They can read and evaluate papers, test scientific claims for drugs, understand pieces of equipment, evaluate the logic behind things. These skills are useful whether or not the students continue in science.

LH: You have one more level at which you teach?

BF: Yes, my advanced class, Comparative Biomechanics Lab, is also research-based, interdisciplinary, and project oriented, but this time it’s all laboratory work. I think the course is very good at helping students develop critical-thinking skills. The students rotate through four stations set up with state-of-the-art research equipment. Teams of four to five students, about half biology students and half engineering students, study problems in two laboratory periods per station. In the first period, they learn about the equipment and try to use it to demonstrate a known solution to a problem, but it does not show what they expect. They keep trying, and get frustrated. Uncertainty is a real tangible result, one that they’ll often meet in the real world. During the second laboratory period, they come back to lab having read some of the literature and they’re ready to try some different ways to further explain their findings. Their reading helps them think of ways to design a new experiment. Then, that team rotates to the second station with different equipment available. After 2 wk there, they move on to the

third one. After another 2 wk, they go on to the fourth one, where they are expected to do some potentially publishable experiments. Out of seven groups last time, one has already published and six more have publications in the works.

LH: What if they aren’t finished when the class is over?

BF: They can continue the project during the summer. It’s intense, and it’s real original research they are doing here.

LH: Do the biologists and the engineers have any trouble communicating?

BF: They can at first, but there’s nothing more valuable they can do than learn this skill. Research in the real world almost always involves interdisciplinary work where you must collaborate with people outside your own field. These students learn how to do it effectively and they really bond with each other. I call it “mutualistic teaming.” Students are most likely to collaborate if each one advances the other’s subject and novel discoveries can be made in both fields. It’s great synergy, and I’m pretty excited about it.

LH: What is your assessment like?

BF: We are working on that. We just got a grant through the National Science Foundation Integrative Graduate Education and Research Traineeship program to develop some new methods of assessment. What we want to know is whether the students understand concepts such as “falsifiability,” whether they understand why you need a comprehensive literature review, why it’s important to show replicability, what is meant by sufficient evidence. But I am not worried that assessment will show a lack of progress. I think by the time they’re through, these students understand in their guts that extraordinary claims require extraordinary evidence. And they are so motivated! By making novel discoveries, they are seeing something no human has ever seen—what better feeling could you have?

LH: Could you give me an example of some of the undergraduate research in your laboratory?

BF: Well, in an earlier version of this undergraduate laboratory, we studied geckos running on a treadmill. The energy they needed was very low for the size of the animals. We found that some of the secret was in the temperature of the animals. Then a Ph.D. student, Kellar Autumn, picked up the question of how their toes might help them to walk on vertical surfaces. An undergraduate student working with him, Tonia Hsieh, looked carefully at the structure of the toes and found hairy toes with many (100–1000) split ends on each hair. She has gone on to receive a Ph.D. at Harvard and become a professor at Temple University.

LH: Split ends? What good does that do?

BF: Surprise: the toes stick, not by suction cups, but by van der Waals forces. All of those hairs make contact and the sum of these weak molecular forces holds the toes onto the surface. Well, we’ve been collaborating with an engineer here to develop a hairy adhesive. It actually works, and it may have a lot of useful applications. That’s a really novel finding, and it came from an undergraduate lab and undergraduate research. I’ve asked a lot of engineers whether they would have ever predicted that a hairy structure would act like a glue, and they’ve all said there’s no way they would have predicted a hairy adhesive.

LH: Thanks for telling *CBE–LSE* about your teaching experiences!