How to Get Students to Stop Asking, "Is This Lab Going to Take the Whole Three Hours?: A Description of a Cell Biology Lab Curriculum Which Emphasizes Scientific Inquiry.

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In this presentation I described the transformation of our cell biology laboratory curriculum to make it more focused on experimentation and inquiry. The three most relevant features of this (ongoing) project are:

1. I have configured the course into modules so that some new labs can be introduced each year (and others retired) without necessarily altering course objectives substantially.
2. The lab program is in the process of shifting to the almost exclusive use of microbial eukaryotes. This approach has a lot of advantages.
3. The project was funded, in part, by a National Science Foundation Instrumentation and Laboratory Improvement (NSF-ILI) grant. The process of writing the grant helped me to make the course better than it otherwise would have been. I had not anticipated this outcome.

Course Design: The Cell Biology lab program is structured so that there are two class projects, several skills building experiments that all students perform, and each student group designs and implements an independent research project. Table 1 shows the outline of the schedule.

Table 1. Lab program.

I. Introduction (1 week)

II. Techniques and Experimentation (8 weeks)

- Microscopy
- Cell Culture
- Cell Fractionation and Organelle Isolation
- Quantitation of Enzyme Activity
- Gel Electrophoresis

III. Independent Projects (3-4 weeks)

IV. Reports on Projects (1-2 weeks)

The "Techniques and Experimentation" component of the course consists of lab exercises and experiments that all students perform in order to build skills. Examples of some of these experiments include analysis of amoeboid movement, cytochemistry of red blood cells and various microbial eukaryotes, isolation study of mitochondria, and gel electrophoresis to study serum proteins. Another aspect of this "Techniques" section, is the implementation of two class projects. One is an examination of crown gall tumor formation and the other is study of cell growth in a variety of microbial eukaryotes.

Perhaps the most important part of the course is the Independent Projects. A team of three or four students asks or identifies a testable question, designs an experiment, does the experiment, and reports on their work both orally and in writing. Table 2 shows some examples of topics students have studied in their independent projects.

Table 2 Examples of independent projects.

- Isolation of Chloroplasts and Study of the Effect of Light Quality on the Rate of Photosynthesis
- Analysis of Red Blood Cell Membrane Permeability
- Effects of Lectins on Cell Recognition
- Gel Electrophoresis and Western Blot Analysis of Lactate Dehydrogenase in Different Types of Tissues
- Study of Growth and Feeding in *Tetrahymena*
- Study of Flagellar Regeneration in *Chlamydomonas*

Outcomes: There were several significant outcomes to doing the course as I have described it here. First, students gained many important laboratory skills the most critical one of which is the ability to design a good experiment. They got a lot of practice in experimental design and analysis. Second, the common goals of the class projects united the entire lab. While this outcome surprised me at first, I realized that it was inevitable since the students depended on everyone else in the class for these projects to work. Finally, students really enjoyed the independent projects. At first, they seemed nervous about the assignments, but very quickly, they became very excited about their experiments. The obvious and justifiable pride that the students displayed when they present their work was also very rewarding.

Use of Microbial Eukaryotes: There are several good reasons for the extensive use of microbial eukaryotes to teach cell biology laboratory. First, they are quite inexpensive, and easy to grow. No special facilities are needed. If an experiment fails or if a student wants to pursue further inquiry (!), more cells can be grown quickly. Second, you can avoid animal welfare issues without compromising rigor. For example, nuclei can be easily isolated from *Tetrahymena*, you don't need a mouse. Finally, it is important for students to observe that not all cells are the same. Microbial eukaryotes are some of the most specialized (and interesting) eukaryotic cells that exist.

Writing an NSF Grant for Instrumentation: Here are four lessons that I learned in the proces of preparing my grant:

1. You must demonstrate that funding will propel you to the "next step." It is not adequate to improve what you are already doing.
2. While substance is important, presentation style is critical. I found it helpful to make tables containing specific information and examples of laboratories and to embed these tables in the text of the grant.
3. Plan on resubmission. While I am sure it happens, I don't know anyone who received funding on the first try. I know a lot of people who got it on the second, or third try.
4. Talk to your NSF program officer. He or she will be very helpful.