

ADVANCE SCIENCE—MENTOR AN UNDERGRADUATE!

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INTRODUCTION

The inclusion of undergraduate students in research has become increasingly common over the past two decades. Many institutions now offer students the chance to learn science by being involved in research (1, 2, 3, 4). ASPET is one of several organizations that generously provide funds for this purpose. There are, however, many scientists who still have not added undergraduate researchers to their teams. This article is designed to encourage them to involve undergraduates in their research by providing a rationale and suggestions for getting started.

WHY BRING AN UNDERGRADUATE INTO THE LABORATORY?

Many reasons exist to bring undergraduates into the laboratory—some are altruistic and some are not. Listed below are some of the advantages to the scientist.

Benefits to the Scientist

1. Contributes to good science. Research is laboratory intensive.

Most well functioning laboratory groups can easily incorporate a bright but inexperienced undergraduate into their daily work routine and accomplish even more than they would without this additional worker. Moreover, the observations made and the naïve questions asked by individuals who are not “experts” in a particular area can bring fresh insights to research questions. These observations and questions are sometimes just what are needed to come up with a creative approach to an old problem. Moreover, undergraduates can make a substantial contribution as their skills advance with training and experience.

2. Improves teaching. Investigators who need to explain something to an undergraduate often discover which methods work and which do not when trying to impart specific concepts.

3. Provides practice in communicating with non-scientists. Scientists are better advocates for science when they can explain their work in ways that the general public can understand. Having undergraduates in the laboratory provides a ready audience on whom to practice these skills. Moreover, undergraduates who are excited about doing research often bring their families or friends to their laboratory. This provides additional opportunity for teaching. Scientists need to insure that the public is aware of and understands what research is and why it is important. Communication is the key to maintain the support of the public.

4. Undergraduates can be amusing and fun to have around (seriously!).

Benefits to the student

1. Effective way to learn. When undergraduates become involved in research, they find that material from classes that just seemed no more

than abstract concepts can be applied to unsolved problems. They begin to understand the relevance of what they have learned; they develop critical thinking skills; they learn to think creatively; and they begin to understand the importance of patience and perseverance. The undergraduate years present an opportune time for students to learn that knowledge has an application.

2. Career exploration. Working in a laboratory gives students a taste of what a scientist’s life is like. This experience can help them make informed and realistic career decisions. Deanna Adams, an alumnus of the Undergraduate Biology Research Program at the University of Arizona, articulates this well in her brief comments that follow this article.

3. Contacts. Relationships developed with faculty sponsors and other laboratory personnel help students to make the personal contacts they need to get letters of recommendation and leads on jobs, as well as to find out about other opportunities. These relationships provide students with sources of advice about career, academic, and personal matters.

4. Home base on campus. The laboratory can provide students with a “home base,” critical to their sense of belonging. At a large research institution such as ours, undergraduates can easily get lost. When they join a laboratory group, they develop an identity that combats feelings of alienation common to students at large institutions. Developmentally, many college students are young adults just negotiating their independence from their families. At this critical point in their lives, it can be quite helpful to them to form relationships with other adults—to have friendships with people outside their families who share interests in common with them (5).

WHERE TO LOOK FOR PROMISING UNDERGRADUATE RESEARCHERS

There are numerous ways of identifying undergraduate workers. The approach taken may vary depending upon the work to be performed and the kind of institution at which it is done. Following are some ideas for identifying the students with excellent research potential:

University or College Honors Programs. Most institutions have these programs, and they tend to attract bright, motivated undergraduates. They often have e-mail lists through which scientists can promote their interest in finding an undergraduate assistant. The scientist should describe the background or coursework applicants should have as well as the number of hours per week required and the nature of the project. This screens the responses to the notice. Don't be afraid to hire a bright, but totally inexperienced student. Motivation is often a better predictor of success in the laboratory than the number or difficulty of science or math courses taken. One big advantage to hiring freshmen or sophomores is that they are farther from graduation than juniors or seniors. Once they are trained, they can stay in the laboratory longer, and thus there is greater potential for them to produce significant results.

Program Directors for grant funded undergraduate research programs. Most undergraduate summer research programs receive more applications from students than their funds can support. Program directors can be a good source of referrals of talented students who otherwise might miss an opportunity to do research. Organizations that fund undergraduate research often maintain lists of programs with contact persons as a service to

students looking for opportunities. These lists identify the individuals at institutions around the country who would be aware of students looking for research experience. What follows is a partial list of website addresses for undergraduate research programs:

ASPET Institutional Summer Undergraduate Research Fellowship Site: <http://www.faseb.org/aspetsurf.htm>

The National Science Foundation Research Experiences for Undergraduates Site: <http://www.nsf.gov/home/crssprgm/reu/reulist.htm>

Undergraduate Advisors in Biology Departments. These individuals often know who are their best students and which students are looking for a research experience.

Instructors of introductory science and math courses. Faculty usually are willing to announce the availability of research opportunities to their classes. Provide them with a transparency to show at the beginning of a lecture or laboratory, about the research opportunity, so they can more effectively recruit students. Include contact information on the transparency.

Career Planning and Placement Centers. Most campuses post announcements for paying jobs, volunteer jobs, and jobs for credit. It is important to describe in general terms the nature of the work involved and to provide any desired qualifications as well as how best to reach the contact person. It is important to have the notice removed once the position has been filled.

HOW TO INSURE A GOOD EXPERIENCE

Undergraduate research experience can be a transforming experience for the student and a benefit to the scientist. Here are a few points to keep in mind when working with undergraduates that can insure a successful experience for everyone.

Select an appropriate project. The project to which the student is assigned will depend upon that student's knowledge, experience, and interests. Think about what an inexperienced person can accomplish in the time available. Experiential limitations suggest that the student learn one or two techniques and that the project be a circumscribed part of a larger project. The project, however, should not simply be "busy work."

It is important that the student feel that his/her contribution is important to the overall work of the laboratory. Over time the student can work into a position of increasing independence and may eventually work on a project of his/her own design.

Expectations. For many students, a laboratory position is their first job. Be sure the expectations are clear before the student begins work. Is this a paid or a volunteer experience? How many hours a week is the student expected to work? Will s/he ever be expected to come in at night or on weekends? Is the student expected to attend and present at laboratory meetings?

Such an expectation is highly recommended. If the student is earning credit for work, what "product" is expected and how much credit will the student receive? Will the credit be pass/fail or will a letter grade be assigned? Who will provide most of the student's direct supervision? Be sure the student is aware of how data are recorded in

the laboratory and the laboratory's norms for maintaining a laboratory notebook. Be sure that s/he understands principles regarding the ownership of data. Encourage the student not only to collect and analyze data, but also to present it. Presenting one's experimental results is a part of the scientific process. Students should present first in the laboratory group and then in a larger forum. Encouraging them to apply for travel funds to present at an ASPET meeting or similar scientific conference will provide further introduction to the culture of science.

Safety training and regulations. A student must have the required safety training for the work s/he will do in the laboratory. Keep in mind that regulations place a minimum age requirement for using radiation.

Communication. It is often a good idea, particularly initially, to have a regularly scheduled time each week to meet with the student to answer questions and to assess his/her overall progress. This meeting does not substitute for day-to-day supervision, but it will provide a time for the scientist and the student to reflect on the work at hand and other issues that invariably arise. While this generation of students is accustomed to obtaining information from the computer, be sure to include some face-to-face meetings and do not rely entirely on e-mail communication.

Employment eligibility. If the student is to be paid from a federally funded research grant, insure that s/he is a US citizen or permanent resident. International students can generally work 20 hours a week on campus, but they typically need to be paid by a non-federal source. If the position is off campus, and the applicant is an international student, check that the student has authorization from immigration to work off

campus before making a commitment.

Student groups. If you are working with a group of students and they are placed in different laboratories, it is desirable to provide opportunities for them to become acquainted with one another. This leads to the development of a community of scholars. Once students meet one another, they can be encouraged to give laboratory tours to their colleagues, which augment the educational experience for both the tour giver and the tour takers. It is often helpful to organize a weekly meeting at which the students present their experimental results to one another. Explaining their work to one another is a quick way of helping the students discover what they do not yet understand. It also provides students practice in making presentations. It is useful, too, to organize a session at the end of the summer or academic year at which students present their work in poster form. This helps students summarize what they have accomplished and what they have learned. It is good to invite parents, administrators, students' friends, scientists, and the local media to the poster presentations.

EVALUATION

Evaluation is important to sustaining a program, whether the scientist is working with a single student or a group of students. Evaluation can be accomplished informally, if only one student is involved and the scientist has frequent contacts with him/her, or it can be a more formal process, which tends to be necessary when working with several students or students from a larger undergraduate research program. Having students reflect upon their experiences will lead to modifications that make the experience maximally beneficial to everyone. It will also provide valuable information in reporting to

funding agencies, which are increasingly interested in how the next generation of scientists is being educated.

In addition to subjective questions that are appropriate in an evaluation, such as "how effective was this experience in teaching you about biologically related research," it is also critical to keep track of objective data such as the presentations made at scientific meetings and publications that include work done by the undergraduates. Tracking of students following their experience in the laboratory is also important. Do they choose to continue to graduate school? Do they pursue research careers?

Tracking is most easily done when the scientist has developed a relationship with the student that the student values. Over time, however, it can be increasingly difficult to keep in contact with past students, and thus it is important to get the student's permanent (i.e. parents') address at the time s/he starts work. Parents typically move less frequently than their children and they generally know where their children can be reached.

Starting a database to help with tracking and evaluative data is important even if you are dealing with a small number of students.

CONCLUSION

Many articles have been written about the benefits of an undergraduate research experience for students. Working with undergraduates also can be rewarding for scientists. Further amplification of the ideas in this paper can be found in related publications. The National Academy of Sciences has a particularly good guide to mentoring called "Adviser, Teacher, Role Model, Friend: On Being a Mentor to Students in Science and Engineering" (6). Another excellent book about

working with undergraduates is "At the Bench: A Laboratory Navigator" from Cold Spring Harbor Laboratory Press (7). We all gain when scientists open their laboratories to undergraduates who become our colleagues!

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Note from a student who participated in the Arizona Program

I worked in academic research laboratories as an undergraduate beginning fall 1992 through December 1994 by participating in the Undergraduate Biology Research Program (UBRP) at the University of Arizona. Originally I began undergraduate research as a means to pay for part of the costs of my undergraduate education and because I had always had an interest in science. I thought that I wanted to pursue a career in medicine because my brother was autistic. I believed the research experience would be a good addition to my pre-medicine studies. This experience was a great complement to my coursework and beneficial towards developing problem solving skills.

Surprisingly, I found that I preferred laboratory research to any of my experiences in the hospital. I was fortunate to interact with a wide range of researchers, expand my communication skills through participation in weekly laboratory meetings, and ultimately be given the opportunity to instruct other laboratory personnel in techniques with which I was most familiar. Additionally, the yearly undergraduate research symposium provided an opportunity to interact with other members of the scientific community and present findings. As I progressed through the undergraduate research program, I decided to remain in research and obtain my Ph.D. Prior to graduate school, I completed studies as an undergraduate researcher in the Department of Respiratory Sciences at the Arizona Health Sciences Center, studying the molecular pharmacology of the PAF (Platelet-Activating Factor) receptor. This position influenced my decision to study pharmacology in graduate school. Thanks to the benefit of my undergraduate research experience, I was able to begin graduate school with a clear idea of the expectations of graduate study, an understanding of how studies are conducted in a research laboratory, and a certainty that I wanted to pursue a research career. My present studies are supported by a pre-doctoral fellowship from the Pharmaceutical Researchers and Manufacturers of America Foundation. I am currently a Ph.D. candidate in the Department of Pharmacology & Toxicology utilizing molecular pharmacology to characterize protein kinase signal transduction pathways. My future objective is to work in the area of molecular pharmacology and/or proteomics to gain a better understanding of human disease states.

Thus far my experience has been in academics; however, I would like to pursue a research position in industry after completion of the Ph.D. requirements. Although my undergraduate coursework provided a good background in scientific techniques and methods, I believe I would have been ill prepared as a future researcher without hands-on experience with the program. Overall I am pleased to have had the opportunity to pursue undergraduate research, as it certainly changed my career objectives.

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Note from a student who participated in the Arizona Program

As an undergraduate student at the University of Arizona, I was fortunate to be involved in the Undergraduate Biology Research Program (UBRP). I participated in UBRP for three years (May 1994 to May 1997) as a Pre-Pharmacy and Pharm.D. student. My positive experiences as a student researcher in UBRP were pivotal as I made pertinent career choices to stay involved in research.

While involved in UBRP, I gained numerous skills I never would have learned in a traditional classroom. In addition to learning specific techniques used in a toxicology laboratory, I was able to learn valuable communication skills. I interacted with graduate students, post-doctoral students, and faculty alike, in addition to participating in weekly laboratory meetings.

After my initial familiarization with my research project in the area of reproductive toxicology, I also gained independence and confidence in my ability to be a competent researcher. I presented my results at several UBRP symposiums, as well as annual Society of Toxicology conferences and the International Symposium for the Evaluation of Butadiene and Isoprene Health Risks. Additionally, UBRP helped make my travel feasible with their gracious financial support.

Because of my influential experiences in UBRP, I knew that I wanted to be actively involved in research as a career. As a Pharm.D. student in the established pharmacy program at the University of Arizona, I decided to partake in the joint Pharm.D./Ph.D. program. In this program, I concentrated on the pharmacy school curriculum and took additional "elective" graduate school courses that were required in the Pharmacology and Toxicology Graduate Program. In addition to a heavy class load, I continued to be involved in research. In 1999, I graduated from pharmacy school with a Pharm.D. degree. Now, I am concentrating on completing my Ph.D. degree. For my dissertation work, I am continuing to work on the project I initially started as a UBRP student. I am studying the possible ovarian metabolism of an environmental chemical, 4-vinylcyclohexene, that is known to cause ovarian toxicity and cancer in rodents.

My UBRP experiences were an important element of my undergraduate training. Thus, I would encourage any student interested in science to pursue the challenge of laboratory research.

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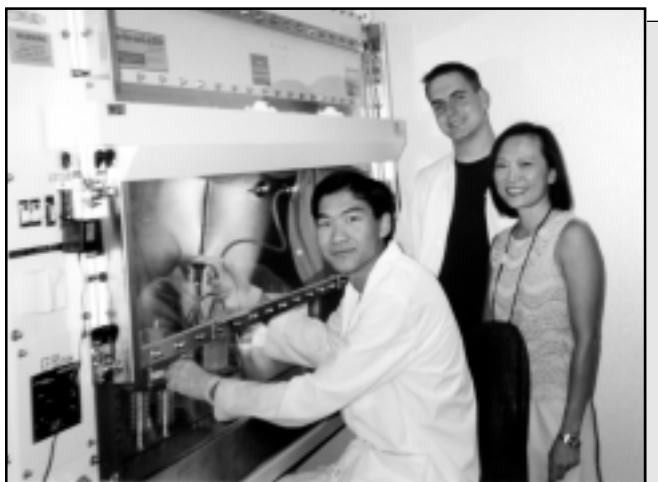


Photo from the Summer 2000 Arizona Program

SURF fellow, **Brian On Ock Lew** (seated left), performs secondary cell culture for pharmacological characterization of cholecystokinin A receptors transfected in HEK293 while SURF fellow, **Robert Oakes**, and faculty sponsor and ASPET member, **Dr. Josephine Lai** observe.