INTRODUCING HIGH SCHOOL STUDENTS TO NEUROPHYSIOLOGY

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University-based scientists are increasingly meeting the challenge to communicate with the public to improve general science literacy, explain their research to a lay audience, and recruit science students. At the University of Western Ontario, graduate student volunteers of Let's Talk Science have launched a project that introduces senior high school students to research presentations given by undergraduate physiology students. The project has given the undergraduate students an opportunity to present their work to an interested audience other than their peers or faculty, while it provides the high school students with positive role models and a greater awareness of postsecondary science. This project was judged a success by all participants, because many of the high school students became interested in physiology and claimed to be more confident in their ability to participate in science, and it also appeared to improve the presentation and communication skills of the undergraduates. This innovative and cost-efficient project is an effective way to demonstrate the excitement of physiology to potential future scientists while showing undergraduate students that public communication of science is not only important but can also be fun.

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Although enrollment in postsecondary science programs appears to be declining across North America, science and technology have become increasingly important for our economic well-being. In addition to a decline in people formally studying science, a trend leading to concerns about a shortage of workers for emerging knowledge-based industries, several surveys have also suggested that the general population is not only scientifically illiterate but also unclear about the role of science and scientists in society and modern economic life (2, 3).

In response to these challenges, an entire ''Public Awareness of Science'' enterprise has been established over the last decade to promote the value of science and engineering. The goal of establishing a scientifically literate society has been clearly encouraged by leading scientific agencies, including Canada's Medical Research Council and the Natural Sciences and Engineering Research Council, the American Association for the Advancement of Science (1), the National Science Foundation, and the National Research Council (4). Possibly driven by decreased research funding and increased demands for accountability, many university-based scientists have entered the public spotlight and are now key players in this industry. The scientists involved in outreach activities appear to have three broad goals: to explain scientific activities to an often skeptical community, to improve the general understanding of the importance of sci-

ence in everyday life, and to recruit promising students for postsecondary science study.

As part of this effort, Let's Talk Science is an outreach organization, based in Canada, that aims to increase the awareness and interest in science, technology, engineering, and mathematics in preschool, elementary, and high school teachers and students. The Let's Talk Science ''Partnership Program'' was launched by graduate students in the Department of Physiology at the University of Western Ontario (UWO) in 1991. Now, volunteers from more than 20 UWO science-related departments are involved annually, and the program has received national recognition with a 1995 Michael Smith Award for Science Promotion and Honorable Mention for the 1995 Peter Drucker Award for Nonprofit Innovation. Let's Talk Science Partnership Programs, based on the UWO model, are currently offered at 11 Canadian universities.

The Partnership Program matches graduate student volunteers (both MSc and PhD candidates) with individual elementary and high school teachers. These partners work together regularly throughout the volunteer's graduate studies (2–5 years). Although the partners design individualized outreach programs, they are often similar and usually include classroom visits by the graduate student volunteer to discuss research interests and life as a science student, helping teachers update classroom material and design novel activities, acting as advisers for school projects, judging science fairs, providing career information to students, and organizing campus visits for the class or individuals.

Of these activities, bringing high school students to campus to do hands-on science is one of the most popular. Graduate student volunteers usually design these experiences specially for their teacher partner and class; however, in 1993, Let's Talk Science volunteers from the Department of Physiology also invited senior high school students into a third-year neurophysiology laboratory as part of their campus trip. No alterations were made to the undergraduate laboratory activities because of the high school students, and the success of that project has led to its continuation by Let's Talk Science and the Department of Physiology. Now up to four classes are invited annually to participate in the undergraduate neurophysiology presentation event.

NEUROPHYSIOLOGY PRESENTATION EVENT

The presentation event occurs at the end of the neurophysiology component of a third-year undergraduate course in mammalian physiology. As part of the neurophysiology labs, undergraduate students choose one of twelve experiments (see Table 1) to study in greater detail over a 3-wk period. During this time the undergraduate students research, design, and conduct experiments to test an hypothesis they have developed. Although the majority of these experiments are conducted on humans, some involve the use of frogs. At the end of the experiment phase, students present their findings to their peers, graduate student demonstrators, and faculty members. The unique aspect of the presentation is that students are required to demonstrate some aspect of the experiment.

During the 3-h presentation event (conducted on 4 separate days because of the large class size), all the undergraduates observe and discuss each other's experiments. To do this, every group of six to eight students working on an experiment is divided into two subsets: ''presenters'' and ''visitors.'' During the first day of presentations, the presenters demonstrate their experiment to visitors from the other groups. All presentations are restricted to 10 min and must include a description of the experiment and hypothesis being tested, results, a hands-on component, and a ''take-home message.'' Presentations must include time for questions from the visitors, and all group members must participate in the presentation. The visitors, on the other hand, proceed to an experiment (except their own) every 10 min to hear, see, and discuss what other groups have been studying (i.e., they usually see 11 or 12 presentations during the 3-h event). On the second presentation day the roles are reversed, so that everyone has the opportunity to learn about all the experiments that are performed. Hands-on participation during the presentations is stressed, and the student-teaching-student model has been very successful. Let's Talk Science graduate student volunteers, several of whom were teaching assistants in this undergraduate laboratory, felt that this environment would also be an effective, exciting,

TABLE 1
Description of experiments offered during the neurophysiology section of a third-year mammalian physiology course

Experiment	Description
Human stretch reflex	Latency between onset of the tendon tap and onset of electromyographic activity in various muscles is examined in student subjects to understand spinal stretch reflexes. Measurements are also made of conduction velocity of alpha motoneurons and of the distance of conduction in peripheral nerves.
Human proprioception	Tendons of different muscle groups are vibrated to activate muscle spindles and the conscious perception of limb position is examined.
Human balance	Ability to stand steadily requires integration of several different sensory modalities including those of proprioceptive, vestibular, and visual systems. Effect of manipulating these sensory systems is examined in subjects as they attempt to maintain their balance on a specially designed platform.
Frog vestibular function	To understand the major functions of the vestibular apparatus, the effects of removing normal labyrinthine activity on swimming, righting and postural reflexes is examined in an intact frog, a decerebrate frog, and a spinal frog (vestibular apparatus intact).
Human vestibular function	Strong labyrinthine stimulation is produced by rotation of human subjects to examine the function of the vestibular apparatus.
Human eye movements	Students record and study the characteristics of all the different types of eye movements in human subjects.
Frog spinal reflexes	To study reflex arcs, students examine the characteristics of flexion reflexes and scratch reflexes in decerebrate frogs using noxious stimuli.
Human electroencephalogram	Electrical activity of the brain during different states of wakefulness, emotional states, and during mathematical problem solving is studied.
Human evoked potentials	Following stimulation of one sensory modality (optic, auditory, or somatosensory), primary evoked potentials over various regions of the human skull are recorded and examined.
Human visual-motor recalibration	Ability of visual motor acts, such as overarm throwing, to be tuned-up or recalibrated by the cerebellum is examined in human subjects. Throwing accuracy of subjects who wear fresnel prisms, which shift the visual world 30 degrees, is examined.
Human cutaneous receptors	Properties of receptive field, adaptation, and adequate stimulus of human cutaneous receptors is investigated in response to a variety of stimuli.

Senior high school students are invited to attend the presentations given by undergraduate students. Abstracts of these projects can be obtained from the authors.

and fun way to interest high school students in the science of physiology.

ADDING HIGH SCHOOL STUDENTS

On each of the four presentation days, one Let's Talk Science graduate student volunteer is encouraged to invite their teacher partner with a senior biology class (final high school year) to participate. During the event, the high school class is divided into small groups and two or three high school students are introduced into every undergraduate visitor group. This way about 25 high school students can actively participate each day (~100 students are involved every year). For them to participate in a meaningful way during the presentation event, the high school students receive a minimum 1-h prelab tutorial that outlines the basic physiological principles which are addressed in the presentations. Because frogs are used in some of the experiments, the regulations governing animal use are also reviewed and discussed during the tutorial. In the first year of the project the high school students were told not to ask any questions because the university students were being graded. However, it quickly became clear that the tutorial had prepared them adequately and that they had excellent questions and comments to make. In fact their questions are now actively encouraged as they are often insightful and challenging.

During the presentations high school students are treated as visitors (i.e., in the same way as undergraduates). After the presentations, high school students are either brought together at the university to discuss the event or the teacher does this during a subsequent science class, usually with their Let's Talk Science partner.

DISCUSSION

The addition of high school students to the neurophysiology presentations has been extremely successful. Initially the project was organized only to introduce high school students to the study of physiology. However, the response by everyone involved surpassed expectations, and the effect on the presentations was unexpected: the quality improved in the presence of high school students. The presentation event has become very popular with all participants: high school and university students, teachers, faculty, and Let's Talk Science graduate student volunteers.

The goals of the event now are to introduce high school students to the study of physiology in a university setting, provide an opportunity for high school teachers to meet informally with university faculty, encourage undergraduate students to communicate clearly and effectively with younger high school students, and to encourage faculty members to meet promising high school science students.

The program is considered successful because many high school students claim to become very excited about physiology and leave the campus with a greater feeling of confidence in their ability to succeed in university science (especially those who ask questions or make comments during the presentations). Their exposure to positive and credible role models has helped many rethink preconceived ideas about scientists. Table 2 lists representative comments made by high school students after their participation in the event.

During the event teachers also have several opportunities to meet university faculty members. They have indicated that they appreciate the informal setting during which they can talk with these scientists. One teacher, who brings a class every year, wrote after the first visit, ''the (university) students...of the third year physiology labs were wonderful with my students and made a successful effort to make the experience meaningful for them. The best part of the trip was that the (high school) students were able to see real science at a university level. The whole notion of science students taking special courses, in maniacal laughter...was quickly dispelled. My students realized that they too could do science!!''

Additionally, the high school teachers and students appreciate the prelaboratory tutorial, which we have

TABLE 2
Representative comments given by senior high school students after participation in the neurophysiology presentation event

''To be involved in a real university class was the greatest experience . . . I was always intimidated by university, but I now feel much more comfortable.''
''I was able to ask and answer some questions.''
''It was interesting to see university students present their projects to other students from their own class.''
''I was overwhelmed by the fact that the students were down to earth people and not the stereotypical university science student.''
''This trip definitely should be shared with other students because it was very informative and also gave us an understanding of what university is like.''
''The presenters made the presentations fun and involved the people watching in the demonstrations.''
''I was impressed that all the presenters were not nervous, knew what they were doing and knew all the answers.''
''A definite for other classes.''
''The tour was simply amazing. To be involved in a real university classroom was the greatest experience. I have always been intimidated by university but I now feel much more comfortable at campus. I was also surprised at how much I did understand and I look forward to going to university.''
''This was an extremely valuable experience for anyone interested in the sciences. You get a firsthand experience of being in a biology-physiology class . . . this field trip is a MUST!!''
''The university looked very inviting, and it was a clean and friendly atmosphere. The students seemed very comfortable.''
''The presentations were very high quality and very impressive.''
''The hands-on experience gave a better understanding of scientific ideas.''

found to be essential, because they usually have had very little prior exposure to neurophysiology. The tutorial provides everyone with enough information about the nervous system that active participation in discussions is feasible. It also provides an opportunity for them to learn about the many regulations that must be followed to use animal models in research and teaching.

The undergraduate physiology students, on the other hand, also benefit from the event. The presentations are noticeably better in the presence of high school students, in the opinion of the authors and others involved with evaluating the presentations. We believe that the enthusiasm and interest expressed by the visitors inspire the presenters, who begin to feel and act more like teachers themselves. As mentioned by one physiology student, ''the high school students were very interested and asked a lot of questions. It was a very positive experience.'' Rather than simply presenting a message to their peers (who may have learned the material already), they become role models and are keen to share their knowledge with the younger students. They are eager to ensure that the material is understood. Another physiology student noted that ''any difficulties in concepts were easily clarified—they weren't afraid to ask questions when they didn't understand something.'' The physiology students apparently appreciate the opportunity to show, and let others experience, their hard work, particularly because they researched, designed, conducted, and presented their own experiments. High school visitors participate actively and ask challenging questions.

It should also be noted that the neurophysiology presentation is one of the first oral scientific presentations made by the physiology students, and it can be a stressful experience for them. When they understand that high school students may be in the audience, they realize that their presentations should be kept clear and simple. Another physiology student clearly appreciated the younger audience, with the comment that ''the high school students were less intimidating than faculty members.''

The fun experienced by the physiology students during this event may help to reinforce why they chose to pursue science themselves. Their interaction with high school students may also sensitize them to the importance of science communication with the public. This awareness of public accountability is essential for future scientists and is as important as increasing the science interest of our high school visitors.

We have found the integration of senior high school students in a neurophysiology undergraduate student laboratory to be a very effective way to raise the profile of physiology, which is rarely introduced in Canadian high schools. All participants benefit in different ways, as is clearly evident by the increased level of activity and excitement in the lab during the school visit.

For other scientists who might attempt to organize a similar event, several things should be considered. We have found it very important to insist on small numbers of students. Inviting only one high school class to each presentation event ensures minimal disruption to the undergraduate class and provides the best opportunity to involve everyone. To maintain the attention and participation of the high school students during the entire event, adequate preparation with the prelab tutorial and a good hands-on component during the event is critical. We have found that most of our high school student visitors are not familiar with the terminology and concepts used during the presentations, therefore it is very important to explain them before the event. Their level of understanding can be further improved if the high school teacher is aware of the concepts to be covered during the presentations and can discuss them before their arrival at the university. In addition to informing the undergraduate students about the high school visitors well in advance of the event, it is also wise to advise the faculty members who grade the undergraduate presentations.

The role of the university in the new ''Public Awareness of Science'' enterprise is unclear. In every university there are groups of faculty members, staff, and students who are acutely aware of the great importance of outreach activities, and their numbers are growing each year. However, beyond these individuals who judge science fairs, mentor students, and help

teachers (usually while maintaining a full research agenda and/or teaching schedule), there seems to be little coordinated effort by universities to increase pu blic understanding of science and of the role of scientists. This is unfortunate and must change because so much can be gained by opening our doors to the community. This type of activity is one way to do it.

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