himself among Judaism if he doesn't believe in its basic concepts? What does he consider the purpose of life? Could you have morals without religion? And I asked him why he advocated the atomic bomb production if he didn't believe in the ultimate good in man.

"I can't tell you any more about his ideas in this letter because I couldn't do them justice without stretching the letter to 19 or 20 pages, but was I thrilled when we left the meeting. A few of the fellows and I went to Nassau Tavern afterwards and filled ourselves full of beer. I felt so good when I went to bed that my roommates were sure that I was drunk."

BERTRAM WOLFE
Monte Sereno, California

Give Grad Students a Good Talking, Too

As just about all American scientists are now aware, we live in times in which "strategic national needs" (whatever those are) are being held up as desirable funding criteria. (Consider, for example, Senator Barbara Mikulski's view of the NSF mission.) For better or worse, curiosity about the universe as a justification for scientific activity is under some attack.

At the same time, the employment outlook for new PhD physicists has been bleak for years, and some graduate physics departments seem to be responding by reevaluating their programs and by considering changing some of the emphases (for example, away from narrow specialization and toward flexibility). APS meetings now sometimes have special sessions concerning so-called alternative careers for physicists.

I herewith propose an activity that can potentially address many of the above concerns, plus others: *As a standard part of graduate training in physics, have graduate students present, annually, a talk about their work to students at public schools.* I have in mind elementary, middle and high schools. Whenever possible, such presentations should be videotaped. To ensure that the graduate student receives experience in addressing a wide variety of audiences, the audience should vary from year to year, so that, for example, he or she addresses kindergartners one year, middle school students the next year and so on.

There would be many benefits to such an activity:

▷ The aiding of public education by the scientific community would go some way toward responding to the Mikulskiesque attitude that scientists should contribute directly to the national well-being. (I might add that I share that attitude.) The direct interaction of grad students with teachers and principals would be highly instructive for all parties, and some professional directions and contacts would likely develop. (For example, some grad students might decide that they want eventually to teach in public schools.) With such enormous visibility, the physics community would come to be viewed as directly participating in and contributing to the education of the nation's children.

▷ The exposure of many tens of thousands of students to thousands of highly trained scientists, on a regular basis, would be a healthy antidote to a culture in which athletes are worshipped (and paid) like gods. The students would get to meet real scientists and hear about real science in the making. The nature of science would be made more clear to the students as they came to understand that knowledge evolves incrementally as a result of hard work and that real science isn't something that pops magically out of a textbook.

▷ My proposed idea, if implemented, would force physics graduate students to *regularly* confront a problem every bit as real, and probably more important to their long-term professional success, as an eigenvalue problem, a coding problem, an optics problem or an electronics problem; namely, the problem of conveying one's ideas, and hence worth, interestingly, persuasively and accurately to an audience whose background is very different from that of the speaker. A scientist's career frequently hinges on her or his ability to persuade people such as corporate managers (some of whom have little technical background and view research expenditures as a necessary evil for generating cash later on), grant application evaluation committee members (some of whom may not be very familiar with the scientist's general field of work) or even a thesis committee. Why not include in graduate education regular training in real-world communication of ideas, especially when such communication can benefit the graduate student, the perception of the scientific community and the nation?

▷ The videotapes could be used by the public schools for further discussions after the scientist left the school; by the graduate student for detailed examination, evaluation and criticism of the quality of the presentation (preferably in the company of supportive fellow students and faculty *and* an abundant supply of coffee and donuts); and by the graduate department for evaluating the student's communication skills. Perhaps such departmental evaluations should become as regular, and maybe even as important to the student's advancement through grad school, as the more traditional evaluations of prowess in theory and mathematical agility.

It is obvious that if the above proposal is good for physics, it is also good for chemistry, biology, engineering and perhaps other fields. There is nothing unique to physics in the proposal, and the proposal is hence immediately transferable to other graduate departments.

I confess that there is an ulterior motive at work in my proposal: As a scientist who dislikes coding and detests having to work with electronics but enjoys writing and giving talks, the proposal obviously suits my inclinations. A nationwide enactment of this proposal would then constitute a revenge of the articulate nerds.

JEFFREY MARQUE
Beckman Instruments
Palo Alto, California

On Science Schooling, Seminar Style

George Greenstein's advocacy of a seminar format for teaching science (May 1994, page 69) has much to recommend it. Many of us who have been lucky enough to spend at least some part of our lives teaching physics at various levels appreciate the importance of continued classroom dialogue and know that we can readily maintain it even in the lecture format. If nothing else, it keeps the students and the professors awake! It provides instant feedback to the lecturer and permits him or her to continue with confidence. Indeed, the great entertainer Al Jolson, once finding himself spotlighted on stage, demanded that the auditorium lights also be turned up: He could not sing, dance or tell stories unless he saw the smiles on the audience's faces! A class (whether of 30 or 300 students) would be dull for me and even duller for the listeners if I did not stop to toss out questions, wait for some students to discuss their thoughts, and let everyone share in the process of responding (often by polling for yes or no answers and noting that nature's laws are not necessarily determined by majority rule). In my opinion a lecture format that does not permit, even demand, questions from the students is no class at all!

But I am deeply offended by Green-

stein's argument that "humanities and social sciences deal with matters to which everyone has a direct, personal connection," while physics appears too technical and esoteric for active classroom participation. Students relate comfortably enough to the physics of baseball or radar speed detection or "whiter than white" detergents. James Randi's beautifully articulated call[1] for scientists to take a more active part in the debunking of popular superstitions offers another outstanding opportunity for classroom interaction. Those of us fortunate enough to live by the ocean are continually challenged by students knowledgeable about deep-diving creatures as well as their own scuba activity. Tides are an everyday occurrence, and today's newspapers boldly discuss them in relation to black holes. Hopefully Greenstein's remark "But science students are incapable of telling their instructors anything worth listening to" is tongue in cheek. It's amazing how anxious students recently back from "bungee jumping" are to compare *their* experiences to Galileo's!

Perhaps my remarks do refer more to introductory than advanced courses. But surely the name of the game today is not so much to get more students into science as it is to get more science into students. Somehow I feel that the students in Greenstein's junior–senior course in astrophysics, where students are "fresh from a lecture on Bessel functions," are already pretty well committed to a career in which science will play an important, if not dominant, role. With educational budgets what they are today, it is unlikely that large lecture classes can be broken into five smaller ones with equally competent instructors. But working to keep the lecture hall a discussion hall is a realistic, challenging and potentially rewarding goal for students and faculty alike.

Reference

1. APS News, June 1994.

ELLIOT H. WEINBERG
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I could not agree more strongly with George Greenstein's recommendation to physics professors in "Teaching Science by Seminar." I would add that what Greenstein refers to as the "enforced passivity" of the standard lecture course and the "traditional emphasis on problem sets" as the sole method of evaluation not only discourage bright and creative students but artificially narrow the field of physics, to its detriment.

By the time they reach second year most physics undergraduates have figured out that what they are doing bears little resemblance to the world of their professors. They realize that physics is done by conceiving experiments and struggling with equipment, by reading the work of others and searching for the next foothold, by presenting findings at conferences and colloquia, and by discussing problems with peers—in short, by living in a dynamic realm of evolving ideas. These same students observe that in other university departments their cohorts are busy applying the tools and techniques they acquire to develop their own ideas. Why should physics be different?

The traditional reply, which Greenstein acknowledges, is that "it follows from the highly technical nature of the field." But this explanation doesn't wash with students when it comes to the evaluation process. While they may need to "shut up, buckle down and seek to understand" physical theory, what about the rest of it? Where in the weekly problem set do we find the innovative experiment designer, the dogged observer, the organized presenter, the intuitive synthesist or the exhaustive researcher? How, based on a single final exam, can we judge the computer wizard, the resourceful technician, the charismatic team-builder, the gifted teacher?

These are important skills, and physics needs them. Physics students have few avenues to display their strengths in these areas and less chance to convert them into academic recognition. Instead all are viewed alike through the one-dimensional slit of the problem set. Those who endure enter graduate school with little research experience and often a serious inability to communicate effectively as teaching assistants. Small wonder, in a discipline where it is conceivable to graduate with honors and never once utter a word.

The problem now is not just too few students, but too little variation among them—the familiar characteristics of an endangered species.

IVAN SEMENIUK
Ontario Science Centre
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George Greenstein correctly points out some of the pitfalls of teaching science through lecture courses and then goes on to describe an upper-level undergraduate seminar in astrophysics that overcomes some of the problems of lectures. By posing questions in the seminar and then forcing the students to find the answers, the seminar instructor enables the students to take an active role in their own learning and introduces them to a more realistic picture of how science is practiced. Since the pace of such a seminar cannot be pre-

dicted, Greenstein comments that this mode of teaching is more suited to special-topic courses.

A type of physics seminar that has been taught at Swarthmore College for over 70 years combines the active learning done by students in Greenstein's seminar with the more predictable pace characteristic of lecture courses. In a sense this mode of instruction bridges the gap between the traditional lecture course and the special-topic seminar. Such seminars may be of interest to faculty desiring to break out of the mold of lecture courses.

William C. Elmore described the Swarthmore physics seminars in a PHYSICS TODAY article about 25 years ago (March 1968, page 32). Each seminar typically consists of no more than nine students, who meet once a week for at least three hours. At the end of each seminar meeting the instructor hands out assignments for the next meeting. Usually these consist of some reading in the textbook and some problems, which all students are required to do; a few presentations that individual students are to prepare; and several problems that individual students are to present. When the seminar next meets, the students take charge and determine how they want to use the assignments to make sure the material is properly discussed and understood by all. The options include general discussion of some of the more difficult concepts, presentations followed by questions and discussion, and presentations of the problems with significant discussion, as well as conversation concerning how the material is related to other concepts they have learned. Each student understands that he or she shares the responsibility not only for his or her own learning but for the learning of others in the seminar. Most students are not afraid to speak up when they don't understand something or think ideas have not been made sufficiently clear.

As Greenstein mentions concerning his seminar, the students sometimes lose track of the important ideas and it is up to the instructor to lead them back on track without resorting to lecturing. Once in a while the students are not able to understand some portion of the material or resolve an argument. Here again the instructor must attempt to give them direction without telling them the answer. The meeting ends when all of the material has been covered to the satisfaction of both the students and the instructor. While this seldom occurs before three hours have elapsed, this grueling session is made more pleasant by a 15-minute break during which a snack of some type, provided by either a student or the instructor, is available.

Seminars are offered in all of the standard upper-level subjects of the undergraduate physics and astronomy curriculum. The textbooks and the amount of material covered are typical of lecture courses at other institutions. While it is certainly true that some students find the seminar format more conducive to their style of learning than do others, history has demonstrated that all Swarthmore students can succeed with the approach if they are willing to devote the necessary time and energy. Some can go off on their own between seminar meetings and learn effectively. Others must work extensively with other seminar students and the instructor to be prepared for the next seminar meeting. Even more so than in lecture courses, the instructor must identify those students who are not keeping up and take steps to correct the situation. In all cases, we hope, the students gain an appreciation of what it takes to understand scientific concepts, what their own strengths and weaknesses are and how they can use various techniques and resources to aid their learning.

PETER J. COLLINGS
Swarthmore College
Swarthmore, Pennsylvania

GREENSTEIN REPLIES: Each of the above letters describes an additional nonstandard strategy, above and beyond those I described in my Opinion column, for effectively teaching science. Peter J. Collings discusses how the seminar has been used at Swarthmore College as an alternative format in a traditional "bread and butter" course, such that students work their way through the material in a textbook on their own rather than in a lecture environment. Ivan Semeniuk, in turn, emphasizes repeatedly the role of the innovative design of experiments in the conduct of science: What more exciting way to teach a subject than to present students with a scientific issue and then ask them to design for themselves an experiment by which it may be probed, rather than presenting them with one already assembled and merely asking them to passively take the data? And Elliot H. Weinberg emphasizes that all students, nonscience and science majors alike, invariably bring to the classroom various personal experiences—bungee jumping, scuba diving—that can be used to motivate the study of important physical principles.

I would argue that the distinction between the lecture and the seminar format is too narrow to do justice to the full range of strategies we are discussing here. I'd vote to term this kind of learning *active learning*, to distinguish it from the more passive learning of the traditional lecture course. These letters testify that active learning is a multifaceted affair and that it has a role throughout all science education.

GEORGE GREENSTEIN
Amherst College
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'Critical' Thinking *re* the Nervous System

John J. Hopfield writes in "Neurons, Dynamics and Computation" (February 1994, page 40): "The phenomena displayed by coupled integrate-and-fire neurons will be richer when the synaptic connection patterns are more complex. Even the replacement of equal all-to-all coupling by a fixed near-neighbor synaptic coupling in two dimensions . . . greatly changes the kinds of behavior that are found. This problem, which does not seem to have been studied in neurobiology, has in a limiting case a very close parallel with the Burridge–Knopoff model of earthquake generation at a junction between tectonic plates. (This point was jointly understood in discussions last spring between Andreas Herz, John Rundle and me.) . . . . The slipping [in that model] is 'self-organized' and produces a power-law distribution of earthquake magnitudes." With respect to the term "self-organized," Hopfield cites 1989 work by Per Bak and Chao Tang.

In a 1979 paper[1] I compared the nervous system with a physical system near a critical point. What I then called "the principle of critical development in a nervous system" is related to what is now called "self-organized criticality." I discuss this principle in neurobiology further in my 1992 article "Target of Brain Activity: Its Own Critical Point."[2] The 2nd Appalachian Conference on Behavioral Neurodynamics (see reference 3), attended by Ilya Prigogine and by Bak, devoted several sessions to self-organization on 3–6 October 1993.

References

1. C. J. A. Game, Proc. Aust. Soc. Biophys. **3**, 15 (1979).
2. C. J. A. Game, Clin. Neurol. Neurosurg. **94** (Suppl.), S78 (1992).
3. C. J. A. Game, in *Origins: Brain and Self-Organization*, K.H. Pribram, ed., Lawrence Erlbaum, Hillsdale, N. J. (1994), p. 196.

CHRISTOPHER J. A. GAME
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HOPFIELD REPLIES: What distinguishes physics from more philosophical forms of discourse, or from