

ers, parents, administrators, and the 134 other constituencies that make up our educational system. A next step, following the compelling arguments of Gary Kinsland, would mandate four years of science and add geology or Earth and space science. And of course my colleagues and I strongly favor elective science courses like advanced placement and more. We must then examine and restructure the K–8 science and mathematics sequence along the lines argued by Lev Berger and Donald Rehfuss. Here I only insist that the design be for *all* children and within a flexible set of consensus standards; there should be a variety of local options for branch topics and for implementing teaching methods. We want to stress connections between the science disciplines and between the sciences and the humanities and social sciences, as Paul Rutherford articulated so well.

Martin Stewart has reminded us that teaching physics to 9th graders may well exacerbate the problem of teaching to students with a wide variety of preparations. But the few hundred schools now experienced in the P-C-B sequence seem to manage, and as we begin to create a seamless K–8 math and science curriculum, the problems will diminish.

The only difficulty I have is with Vinson Bronson, who, in my view, misses the point. I do not advocate teaching conceptual physics in 9th grade, because of speed-versus-time graphs and drawing free-body diagrams. These are important examples of how science works—and they illustrate some of the advantages of 9th-grade physics over conventional 9th-grade biology. However, in 9th grade, students should learn about atoms, their structure, and their behavior in company. Atoms make molecules—that is the basic theme for all of chemistry and, increasingly, for modern biology. It is this hierarchy that recommends 9th-grade physics before chemistry and biology. My comment on Bronson's last quotation: Biology is not at the center of the sciences, but at the pinnacle. Physicists, chemists, and mathematicians rejoice in the growing comprehension of life, and we are proud to support the pyramid, on top of which sits triumphant biology.

It is difficult for me to understand, however, how the “phenomena of life” are relevant to cosmology, astrophysics, particle physics, the solar system, the quantum principles that support condensed matter

physics, or even the earlier phases of geological history. But George Gaylord Simpson was a great biologist. Why do I have an uneasy feeling that I am the one who is missing the point?

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Love, Not Paycheck, Motivates Best Physics Students

Rarely do I read an issue of *PHYSICS TODAY* or other science journal and not find some hand-wringing about the decline in the number of physics majors (*PHYSICS TODAY*, January 2002, page 42; November 2001, page 32; October 2001, page 11). I started hearing this kind of lament when I was in high school in the late 1970s: “I cannot urge students strongly enough to seek a degree in the physical sciences. In the 1990s, there will be a shortage of physical scientists that will be disastrous to the nation. People with PhDs in physics will be able to get any job they want.”

I defended a PhD in physics at Caltech in 1992 and searched for a postdoc position during 1991–93. Jobs were scarce, and many of my peers ended up modeling fast neutrons or fast money—not what they expected. Incoming students caught on, and many stayed away from physics. No sermons about the disastrous consequences of a lack of physics majors can compete with Adam Smith's “invisible hand” (in *The Wealth of Nations: An Inquiry into the Nature and Causes*, 1776). That is, if no one is buying widgets, then maybe you should not be in the widget business.

I managed to find a position teaching physics and chemistry at a private high school. Now I love teaching, and I love doing research. The bittersweet reality is that I get to enjoy the one while I miss the other.

A new popular argument to boost physics enrollment has appeared (*PHYSICS TODAY*, April 2001, page 42): A physics degree prepares a student for many jobs outside academia. But few study physics in order to practice medicine or law; most physics students spend 4 to 10 years in school because they love physics.

Nonphysics jobs do not provide a strong attraction to a physics major. Professors praise nonacademic careers for physics majors, but I have seen few forego tenured positions to seek those careers. If they did, university positions would open for young aspirants. Any takers? Don't crowd the door.

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Phenomenologists Are Underrated in Theory–Experiment Debate

Although Norman Ramsey's letter in the September 2001 issue of *PHYSICS TODAY* (page 78) claims not to be taking sides in the debate between theory and experiment, his message is clear. We are now back in particle physics with the same need for critical experiments that Ramsey noted for quantum electrodynamics in 1947. Today's theorists must face present reality with the humility appropriate to the situation.

We have a standard model that everyone admits is incomplete. Experimenters are looking for clues to the new physics beyond the standard model, but no theorist can provide reliable advice on where or how to look. It is all up for grabs.

We have a theory called quantum chromodynamics (QCD) for strong interactions—a theory that everyone believes is correct. But nobody knows how to calculate parameters crucially important for our search for new physics, like the strong interaction phases in weak decay final states. Theorists on the lattice think that they are making great progress when they can get a good approximation to the mass of ρ , which we know already from experiment. But they are useless in getting values of parameters that we don't know, need to know, and should be given by QCD.

The search for new physics and for critical tests of the standard model in charge conjugation–parity (*CP*) violation is being carried out at accelerators by large experimental collaborations that have no theory telling them where to look. The one exception is the seminal paper by Ikaros Bigi and Tony Sanda,¹ which pinpointed the “golden” $K_s + J/\psi$

channel.” Experimenters are guided mainly by their own intuition and by the phenomenologists, who are highly undervalued in this debate between theory and experiment. The phenomenologists analyze the experimental information without too much prejudice from unreliable theories. They then attempt to provide guidance regarding profitable directions in the search for new knowledge. Their papers are generally criticized by nitpicking theorist referees and judged by comparison with published theoretical papers that will probably turn out to be wrong. Phenomenologists can thank Paul Ginsparg, who established the online electronic print archives at <http://arXiv.org>, for giving them a way to reach the experimenters who need their advice without having to deal with obnoxious referees.

Here is one small example of the problems faced in looking for clues to new physics. In 1998, I noted that decays like $D^+ \rightarrow K_S + \pi^+$ had contributions from Cabibbo-favored and doubly suppressed decays, and that this might lead to a direct CP violation between charge conjugate D^+ and D^- decays. The standard model says that both the favored and doubly-suppressed amplitudes depend on the same Cabibbo-Kobayashi-Maskawa matrix elements and there should be no CP -violating relative phase. But suppose some new physics contribution has a CP -violating phase. This new physics could give a direct CP violation between charge conjugate D^+ and D^- decays. This can be easily verified when data are available. Even if there is no effect, and no new physics theory that predicts an effect, such data provide information that can be used to constrain future new physics models.

When I suggested this idea to my experimental friends, the response was, “Interesting! Too bad you didn’t tell us sooner. It would have been trivial to check this at the early stages of our experiment, but now it will involve remounting many tapes and a lot of work and expense. We cannot justify that without a good theoretical reason.” I wrote up my suggestion and put it on the Web as <http://arXiv.org/abs/hep-ph/9810375>. I tried to tell all my experimental friends who were planning future experiments so that they could test this and similar ideas in time. Of course I never sent the paper for publication. At my age I don’t need the credit, and I have no patience for

ridiculous arguments with referees.

Today, progress in particle physics depends on the work of postdocs who analyze the tremendous amount of data accumulating at accelerators, and who must establish some record to get future jobs. They need input from good phenomenologists who can point them in profitable directions. Theorists are only marginally useful.

Reference

1. I. Bigi, T. Sanda, *Nucl. Phys. B* **281**, 41 (1987).

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Kepler’s Singular Harmony

In George Gibson and Ian Johnston’s article on the physics of music (PHYSICS TODAY, January 2002, page 42), box 2 on Johannes Kepler’s “The Harmonies of the World” contains two interesting errors. Because a final *s* on a Latin word normally designates a plural, at first glance the title of Kepler’s *Harmonices mundi libri V* suggests the translation “harmonies.” However, Kepler was being erudite, taking *harmonice* as a Greek word and giving it the Greek genitive singular ending. Because he passionately believed in the unity of the cosmos, he used the singular form; for him the title was *Five Books on the Harmony of the World*.

In book 5, chapter 3, Kepler stated his newly discovered harmonic law as the constant proportion between the cube of the planet’s mean distance from the Sun and the square of its period. Concerning his “wonderful speculations,” he wrote in his preface to book 5,

I yield freely to the sacred frenzy; I dare frankly to confess that I have stolen the golden vessels of the Egyptians to build a temple for my God far from the bounds of Egypt. If you pardon me, I shall rejoice; if you reproach me, I shall endure. The die is cast, and I am writing the book—to be read either now or by posterity, it matters not. It can wait a century for a reader, as God himself has waited six thousand years for a witness.

Incidentally, Kepler did not call that harmonic relationship a “law”

or single out three particular relationships. The idea of a “law of nature” was introduced into English when Robert Boyle used the expression decades later. “Kepler’s laws” were apparently first selected and numbered by the French astronomer Joseph-Jérôme de Lalande in his *Abrégé d’astronomie* of 1774.

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New Era for Physics Includes Outreach

I recognize that a great deal of work went into the Physics Survey Overview Committee’s report *Physics in a New Era: An Overview*, which was discussed by Thomas Appelquist and Donald Shapero (PHYSICS TODAY, November 2001, page 34). However, I am disappointed by the generalities and platitudes in the recommendations. There can be little disagreement with any of them, but I wonder if we needed to expend all the time and money to come up with just these. Such reports have little more result than has come from congressional hearings to eradicate drug smuggling or to improve Scholastic Aptitude Test scores in high schools.

A major problem confronting society is the lack of knowledge among the public as to what science is, what constitutes scientific thinking and analysis, and what science’s criteria are for determining the correctness of statements about the phenomenological world. Given this lack of knowledge, it is not surprising that pseudoscience, antiscience attitudes, and calls to return to medieval, anthropocentric, and scriptures-based worldviews abound. There needs to be a carefully considered plan of action to promote science and to inculcate appreciation for, and sensitivity to, science as a cultural enterprise that is beyond laboratories and the intellectual ivory tower of academic seclusion.

As is done occasionally with public service messages about charitable acts, respect for other cultures, and tolerance to all nonhurtful belief systems, the basic results and worldviews of science and scientists could be shown briefly on TV screens during commercial slots of popular shows. One can learn from Madison Avenue in this context. If we can