Letters

Crisis in Physics Spurs Spirited Dialogue

Although Sidney Nagel's Opinion piece (PHYSICS TODAY, September 2002, page 55) was interesting and thought-provoking, I disagree with some of the points he made. US physics may be in crisis because of the rather poor funding support that it has received in recent years, but not for the reasons Nagel suggests.

Let me list some points of disagreement:

▶ "Great discoveries [in particle physics] are less frequent," Nagel says. Actually, the past few years have seen remarkable advances: the detection of oscillations of atmospheric neutrinos, the solution of the solar neutrino problem, the establishment of charge conjugation–parity violation in the B system, and affirmation of the standard model at CERN's Large Electron–Positron Collider and at Fermilab.

▶ The notion that "we do not really appreciate what is done in other areas" may be true of some physicists, but many faithfully attend weekly physics colloquia that cover every subfield. Because physics knowledge has expanded so much in recent years, it is more difficult to remain well informed even within one's own field, but that knowledge explosion is, in my opinion, a good thing, not a crisis.

▶ Nagel says that "small physics . . . has gotten even smaller." I think some areas that used to be small physics have actually gotten bigger rather than smaller. For example, many condensed matter physicists now use synchrotron light or neutron sources and sophisticated beam lines, devices that require substantial teams to build and operate. In my opinion, most of experimental physics has gotten bigger.

▶ "To study . . . condensed matter physics, . . . does one need to know the standard model?" Nagel rightly answers, "Of course not." On the other hand, some older reductionist results, like the fact that atoms are made of nuclei and electrons, do seem useful. Note that the tools of particle physics (like particle accelerators) may be useful to areas such as condensed matter physics. I cannot believe that a condensed matter or plasma physicist would not marvel at the beauty of the standard model and the intellectual accomplishment it represents, even if it had no impact on his or her own work.

▶ Nagel also mentions "the growing split between theory and experiment in all areas of physics." It is my impression that theory and experiment have been working very well together in many areas. I just read a piece about recent theoretical work done to explain experimental observations on the new superconductor MgB_2. The combination of theory and experiment that led us to our present understanding of solar neutrino astrophysics is extraordinary.

Despite these disagreements, I fully agree that closer interaction between the practitioners of various areas of physics is desirable. James Langer, former president of the American Physical Society, had urged that the March meeting be an example to other APS divisions to meet together to allow improved cross-fertilization and give young people the opportunity to see many different subfields. My division, particles and fields, has decided to hold every second divisional meeting within the APS April meeting, starting with the 2003 gathering in Philadelphia.

The real crisis arises from the inadequate funding of the physical sciences. In arguing for improved funding, we physicists should push for all of science and, within that, for all active areas of physics. I strongly agree that, in our talks, we ought to always explain why others in different fields should care about what we are doing.

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As a particle physicist, I was a bit surprised to hear Sidney Nagel speak of particle physics as holding "pride of place" in the discipline. I am not sure that my condensed matter physics colleagues would have characterized the field that way, even when the Superconducting Super Collider seemed alive and well. Perhaps what Nagel has hit upon is that very large projects take on a symbolic significance, and their cancellation can't but have implications for the morale of the whole discipline of physics.

In the nearly ten years since the SSC was cancelled, the field of particle physics has remained vibrant and exciting. The Large Electron–Positron program at CERN and the Linear Collider at SLAC, after elevating the standard model to a precision branch of science, have recently shut down. The current experimental programs on B physics at both SLAC and KEK, Japan's High Energy Accelerator Research Organization, have been enormously successful. Recent data from Kamiokande and the Sudbury Neutrino Observatory in Canada have provided compelling evidence for neutrino masses and mixing.

The upgraded Tevatron is running at Fermilab and has the potential to make major discoveries. On the theoretical front, particle physicists have worked hard in the past few years to understand the flood of new data, have made predictions for new facilities, and have addressed difficult questions about black holes, electric–magnetic duality, and other issues.

The international community, with vigorous US participation, is working on CERN's Large Hadron Collider, which is currently scheduled to begin running in 2007. And in the last few years, an international consensus has crystallized as to the future after the LHC. The picture certainly has some clouds, particularly involving funding—but overall, there is cause for optimism.

Nagel raises a number of other important issues. Our parochialism is not new. When I was a graduate student, it was the nuclear physicists who ridiculed both condensed-matter and applied physics; my particle-theorist teachers admonished me that condensed matter had much to teach us, and even suggested that we might occasionally

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be able to contribute something to that field as well. The split between small and big science is inevitably a source of tension. It is important that researchers in big collaborations working on very large projects and those on smaller-scale efforts support each other. In my department, it is not uncommon to find, for example, our high-energy lab lending some of its resources to research in condensed matter (including soft condensed matter), and to find condensed matter physicists providing advice on detectors and detection strategies. But the exchange could be better.

As for hiring, when we serve on search committees in others' subfields, we must often defer to colleagues, but I find that we usually have enough in common to exchange useful advice. A candidate search can be an opportunity to learn about what is interesting to our colleagues.

Nagel does not mention another field that has altered the physics landscape during the past decade. When I was a student, astrophysics was peripheral and cosmology disreputable. Today, many physicists, both theorists and experimentalists, from other subfields are spending much of their time on these subjects.

Cosmology and astrophysics highlight the issue of reductionism. The two fields are not exactly reductionist, but neither are they simply emergent. They are phenomenological in the most exciting sense. We are finding that the data fit into a fantastic picture. Cosmologists have used an impressive array of techniques from various fields to attack and apparently solve the classic problem of galaxy formation. Yet we don't yet know the physical laws that account for dark matter, dark energy, inflation, and the very origin and nature of the universe. The reductionists, both theorists and experimentalists, are attacking these questions vigorously.

In the end, Nagel's article gives me some hope for optimism. I, too, could list what I find to be the burning questions, and there would be a surprising amount of overlap. The question Nagel mentions of systems far from equilibrium arises frequently in particle physics and cosmology. Most recently it has been raised by the discovery—by astronomers, cosmologists, and astrophysicists—of a nonzero cosmological constant. Particle physicists and astrophysicists are proposing that these questions be studied further, using technologies developed in part by condensed matter physicists. So, while we face many challenges, ours remains a rich and exciting field.

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Sidney Nagel claims that the goal of physics to find the basic underlying laws of nature has slowly been eroded—particularly in the US—since the demise of the Superconducting Super Collider.

The crash of a few commercial giants indeed depresses the stock market, but physics is not a stock market! Cancellation of the SSC cannot be used to define the vitality of the field. The edifices of particle physics still stand and are used by our cosmology colleagues with great benefit to our worldview. Inflationary theory of the Big Bang has its origins in the theories put forward by Peter Higgs about the sought-after Higgs particle. It is most likely that particle physicists will find dark matter, if indeed it exists in particle form. The symbiotic relationship between particle physicists and cosmologists is yielding a most active

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