ever, the crass funding imbalance that characterizes the present research support strategy cannot help but aggravate the already precarious technological stature of the US. Applied research, particularly when it targets nontechnocrat end users, has been flagrantly neglected. In time, perhaps such research may share in a crumb of the national research pie.

E. R. MENZEL
Texas Tech University
Lubbock, Texas

5/86

Superstrings: Another view

In responding to Paul Ginsparg and Sheldon Glashow's column "Desperately seeking superstrings?" (May, page 7) let us start with the things one must agree with: Standard physics is not incorporated in superstring theory. The theory does not offer a solution to any known puzzle in particle physics, such as the generation puzzle, the CP problem or the axion problem, nor does it give any clue to the various parameters of the standard model. It is hoped in superstring theory that if we know the correct six-dimensional compact manifold with all its warts and holes, the theory will determine all the masses of the quarks and leptons, and all the coupling constants. This is a tall order. The discovery of the correct manifold may require more sophisticated mathematics than most physicists know. The goal of superstring theory almost amounts to saying that if you put in all of mathematics, all of physics will come out.

So let us grant that superstrings have not done anything for particle physics (at least not so far). Hence the real motivation for superstrings at present must lie elsewhere. In fact it lies in quantum gravity.

Gravity must be incorporated into the rest of physics. It is intolerable to have one world where gravity is ignored and quantum mechanics reigns supreme and another world where gravity cannot be ignored and use of quantum mechanics to describe it leads to meaningless divergent results. To search for a consistent physical theory describing all known physical phenomena is surely a scientific requirement and not mere theology!

Even superstrings may not lead to a unique, ultimate theory. All this semitheological talk about the "unique and ultimate theory" is nonsense. There may be many superstring theories, out of which only experiment and empirical knowledge may allow us to choose one as the most promising. Already at least five consistent string theories are claimed to be available in the market, and there may well be more, even an infinite number of consistent theories.

Further, search for consistent theories of even more complicated objects than strings, for instance, membranes and lumps, must continue. Any reported "no go" theorem in this context need not be regarded as a permanent barrier. Remember, without supersymmetry and higher dimensions, even string theories would not work. So other things will be discovered that will make the theories of membranes, lumps and even objects extending to higher dimensions "go."

It is illogical to claim that extrapolation of known physics up to 10^{15} GeV (Grand Unified Theories) is science, but further extrapolation up to 10^{19} GeV is theology. Actually, coming up from 100 GeV, 10^{15} GeV is already so near the Planck mass of 10^{19} GeV that the only logical possibility is to work on physics, including gravity, up to 10^{19} GeV.

It should be admitted that such a preoccupation with superhigh energies in the range 10^{15}–10^{19} GeV is bound to strain experimental physics very much. The preeminence of experiments in physics must be reestablished. So it is imperative that physicists and technologists put their minds together to solve this crucial problem of the energy barrier. After all, no law of nature forbids the attainment of such energies in the laboratory. Human ingenuity knows no bounds and a method will be found to reach the superhigh energies so that controlled laboratory experiments can be done to test superstring theories, or even theories beyond them.

At present, nobody has the wisdom to claim that superstrings are the only correct theory. With equal emphasis one may say that nobody can brand a theory as theology just because it does not offer any immediate experimental test. Nobody yet knows the golden path to truth and hence all avenues of scientific inquiry must be kept open.

Echoing Paul A. M. Dirac, one might declare that theorists must be free to invent consistent theories without bothering too much about their immediate experimental confrontation. (If Dirac had bothered too much about the possible experimental discovery or nondiscovery of the positively charged particle predicted by his relativistic equation, we would not have got the Dirac equation.) Sooner or later, consistent theories do find their experimental application.

Superstring theory is welcome even

continued on page 108

letters

continued from page 15

as a free invention of the human mind, since it broadens our horizons and allow us to go beyond the shackles of point particles and local quantum field theories based on them.

Finally, a note of caution. Since the path is so long, ranging from 100 to 10^{19} GeV, many new and unexpected things may happen on the way. Even fundamental changes in our ideas comparable to the quantum revolution and the relativity revolution might occur. In this respect, superstrings turn out to be conservative: In superstring theory, nothing really so new and revolutionary seems to be happening and yet the theory is claimed to be valid even at Planck energies. In some sense, this is the most disappointing aspect of superstring theories. Real physics may turn out to be even stranger!

G. RAJASEKARAN
Institute of Mathematical Sciences
Madras, India
SAN FU TUAN
University of Hawaii at Manoa

5/86

India: Another 'pioneer'

The article "Pioneer scientists in pre-independence India," by William A. Blanpied (May, page 36), revived a flood of memories of my own association with one such "tribal leader." I am referring to Vikram A. Sarabhai (1919–71), who was a scion of a famous Gujrati industrial family. The Sarabhais of Ahmedabad, in Gujarat State, had strong links to the Indian independence movement and its important leaders like Mahatma Gandhi, Jawaharlal Nehru and Sardar Patel. The Sarabhais were leaders in the textile industry.

Sarabhai studied with Chandrasekhara V. Raman and Homi J. Bhabha of the Indian Institute of Science at Bangalore and developed a lifelong interest in the study of the time variation of cosmic rays. In 1941 he reported on the muon intensity measurements that he made near the geomagnetic equator at Bangalore and in 1943 he led an expedition to Kashmir that measured muon intensity at altitudes up to 13 900 feet. After the end of World War II he went to England to study with Patrick M. S. Blackett. His association with Blackett appears to have gotten him excited about the idea of setting up continuous-monitoring instruments for measuring vertical muon intensity at several sites in India. Upon his return, he obtained support from his family trust fund to put his ideas to work. He set up continuous-monitoring Geiger–Müller counter telescopes at a site on Mount Kodiakanal in South India and another one in his hometown of Ahmedabad. The results on daily variation of muon intensity encouraged him to set up a research group to understand the nature of this phenomenon. This led to the establishment of the Physical Research Laboratory in 1952. It was to be the first of many premier institutions that Sarabhai set up during his life. I joined him there as a graduate student in August 1954. He persuaded me to set up and supervise a continuous-monitoring muon telescope at a Himalayan mountain site at Gulmarg (8900 ft.) in Kashmir. I had to design and build my own equipment, which we transported to Gulmarg in May 1955. This is how my own involvement with the study of the time variation of cosmic-ray intensity began. I spent the next three years, almost continuously, collecting data on time variation of muon intensity at Gulmarg. The herculean effort paid off when we were able to establish the extraterrestrial nature of most of the observed variations after correcting the data for meteorological and environmental effects. One of the early excitements came about when we discovered a spectacular enhancement in muon intensity on 23 February 1956, immediately after the occurrence of a giant solar flare, at all four observing sites in India. This led us to conclude that the Sun must have produced cosmic rays with energies as large as 67.5 GeV! Several large solar flares and associated ground level enhancements have been observed in the intervening 30 years, but none have produced solar cosmic rays of such high energy. So the event is unique.

Sarabhai was a great believer in the future of science enterprise in India. He believed that "the development of a nation is intimately linked with the understanding and application of science and technology by its people." He used to talk enthusiastically about projects such as large nuclear power stations serving giant agro-industrial complexes and synchronous satellites for direct broadcast television for use in educating the masses of India in remote villages. Fortunately for him he was able to lay a foundation for his dream during his short life span of 52 years. When Bhabha was killed in a plane crash in 1966, Sarabhai was chosen to succeed him. What a worthy successor he turned out to be! He set up an Electronic Commission to encourage the development of high-technology electronic industry in India, and founded the Indian Space Research Organization to launch India into the space age, among other achievements. He was a believer in international collaborations. He himself served on several important international organizations. He invited well-known scientists from other lands to visit India and teach graduate students for varying periods of time. Henry V. Neher, George Clark, Philip Morrison, Herbert S. Bridge, Alexander J. Dessler, Eugene N. Parker, Donald A. Glaser, Hugh Carmichael, Linus Pauling, Maurice M. Shapiro, Y. Sekido, Blackett, Paul A. M. Dirac, Pierre V. Auger, A. Ehmert, Hannes Alfvén and a host of others visited the Physical Research Laboratory while I was still a graduate student there. Such visits turned out to be very inspiring for the students and resulted in collaborations and lifelong friendships. For example, in 1961 Dessler and I collaborated on a model that related the diurnal anisotropy of cosmic rays to the dynamics of the solar wind and the interplanetary magnetic field, which later led to the development of an extremely successful diffusion–convection model for understanding a variety of modulation effects observed in cosmic rays. So I agree completely with one of Blanpied's conclusions: "Basic research conducted in less developed countries, under far from optimal conditions, can contribute significantly to international scientific progress."

HARJIT S. AHLUWALIA
University of New Mexico
Albuquerque, New Mexico

5/86

Refuseniks' thanks

For the past 14½ years, we have been refusenik physicists in the USSR. Now we are very pleased to announce that we are finally out and living in freedom in Israel.

We believe that the long-term support from hundreds of physicists is what kept our cases alive. Senator Edward Kennedy played a role in our release, for which we are most thankful. The moral support from our fellow scientists kept our spirits up. Our memberships in The American Physical Society and in the New York Academy of Sciences helped us also. The scientific journals we received enabled us to keep up with important scientific developments in the West. Unfortunately, the KGB often confiscated these journals during raids on our apartment. We would like especially to thank Joel Leibowitz and Paul Plotz for their efforts on our behalf. We apologize that we cannot thank every individual who helped us but we would like to say thank you to all members of The American Physical Society.