Prospects for Physics in The 1990's Surveyed

A National Academy of Sciences report says that American physics has been a highly diversified and productive enterprise, but continued excellence cannot be taken for granted

How much should the United States be spending on basic and applied physics research? The bottom line of the first full-scale survey of the field since 1972, a 2000-page opus from the National Academy of Sciences titled *Physics Through the 1990's*, is that the nation is not devoting enough of its financial resources to maintaining the current level of excellence, although no particular figure is proposed.*

Among the specific recommendations the report does contain are doubling over the next 4 years the present level of federal support for university-based small-group physics from $260 million annually to $520 million and construction of a spectrum of centralized research facilities, including the multibillion-dollar superconducting supercollider for high energy physics research. Measures to ease a projected shortage of physicists in the 1990's, such as simplifying immigration laws for foreign-born researchers who were trained in the United States, are also advocated.

A 16-member committee headed by William Brinkman of Sandia National Laboratories had overall responsibility for the physics survey, which took 3 years to complete. The report comprises a 184-page overview volume highlighting the committee's findings and a set of seven supplements providing in-depth examinations of the subfields of physics and of technological applications. The supplements are the work of separate panels, each chaired by a committee member and made up of additional physicists from the respective subfields.

The Brinkman committee did not set out to make a case for more federal spending on physics, although it is hardly surprising that it ended up doing so. Brinkman told *Science* that the objective was to document the progress in the field over the last decade and the opportunities for the next 10 years in as clear a way as possible.

Exploiting future opportunities implies, of course, the availability of adequate resources—facilities, equipment, and support for research and for training new physicists. The overall message of the survey is that, despite Spartan funding during the interval since the last survey, physics has been a remarkably vital, diverse, and productive enterprise. However, maintaining this high level of excellence will require more than has been available. To take the most conspicuous example, with a price tag of $3 billion or more, the superconducting supercollider, which high energy physicists regard as essential if their field is not to stagnate, cannot be funded by reallocating existing resources without harming other physicists. New money is needed.

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Overall, basic physics research merits a greater fraction of the gross national product than the 0.027% it now commands. In the glory days of the late 1960's, the fraction reached 0.044% before declining to a low of 0.023% in the mid-1970's. In the end, the committee makes the probably true but nonetheless well-worn argument that the health of the U.S. economy depends in part on the ability of American physics to maintain a competitive edge relative to other countries but does not come up with a specific figure to accomplish this.

While money is the bottom line of the physics survey, the Brinkman committee waxes more enthusiastic over the accomplishments in the field, on the forging of ties with neighboring disciplines (including chemistry, biology, materials science, a geology), and on the contributions of ph ics to technology. What the committee ports is that the once rather specialized subject has blossomed to encompass an enormous breadth and that progress has been substantial across the board, with concomitant benefits to our national well-being.

It is unfortunate that this very breadth gives that part of the survey chronicling past advances and future opportunities a catalog-lil quality without a unifying theme other than progress. In any case, highlights of the subfields and applications include the following:

- *Elementary particle physics.* Development of the Standard Model comprising quarks, leptons, and quantum field theories for the forces by which the particles interact. Unification of the weak and electromagnetic forces. Prospect of explaining all forces as manifestations of a single basic force and of understanding why the Standard Model works.
- *Nuclear physics.* Evidence that the properties of nuclei are ultimately and sometimes expli y fixed by quarks and by the gluons that l nd them together in protons and neutrons. Exploration of nuclei under extreme conditions. Creation of new elements. Prospect of creating a nuclear quark-gluon plasma at high temperature and pressure, thereby recreating conditions in the early moments of the universe.
- *Condensed-matter physics.* Development of theoretical and experimental techniques for studying surface and interfaces and systems with varying degrees of disorder, such as amorphous solids. Ma ng of synchrotron radiation as a tool fo dying matter. Understanding the fund ntals of phase transitions and other phenomena characterized by strong fluctuations. Ability to create artificial structures on an atomic scale.
- *Atomic, molecular, and optical physics.* Development of ultrahigh-resolution spectroscopic techniques. Construction of electron and ion traps that can store single particles for several months. Precision measurement of fundamental properties, such as the Lamb shift in hydrogen. Advent of pulsed lasers with pulse lengths as short as a few femtoseconds.
- *Plasma and fluid physics.* Development of free-electron lasers and related relativistic electron beam sources of electromagnetic radiation. Progress of magn confinement fusion to the brink of rgy breakeven. Space probes of solar wind and planetary magnetospheres. Improved understanding of the onset of turbulence in fluids. Prospect that laser-induced space-charge waves in plasmas can accelerate elementary particles to ultrahigh energies.
- *Gravitation, cosmology, and cosmic-ray physics.* Space-based tests of Einstein's general relativity. Evidence for gravitational radiation and prospect of its direct observation. Evidence for the primordial explosion or Big Bang at the origin of universe. Marriage of elementary part hysics and cosmology to explain the e on of the

**Physics Through the 1990's*, overview and seven supplements available in individual volumes or as a set from the National Academy Press, 2101 Constitution Avenue, NW, Washington, DC 20418.

universe. Detection of ultrahigh-energy cosmic rays of extragalactic origin.

■ *Applications*. Fission and photovoltaic energy and the prospect of fusion energy. More efficient combustion. X-ray, ultrasonic, and nuclear magnetic resonance medical imaging. Laser surgery. Weapons systems and strategic defense systems. Microelectronics. Laser optical communications and printing. Laser-assisted manufacturing and robotics.

To maintain the pace of progress, the Brinkman committee endorsed several major construction projects that had been previously approved by other study groups. The criterion for approval of these quite expensive, centralized research centers is, "Is this facility necessary to maintain research at the cutting edge?"

However, the committee reserved its strongest words for what it called small-group physics; namely, that physics research done by one or a few investigators. "We hit a resonance on the small science issue," Brinkman said. One reason for the concern is that about 70% of physics Ph.D.'s receive their training in such groups. The universities where the research is done face several problems resulting from inadequate support over the years.

Simply put, there is a significant disparity between the cost of doing research (equipping a modern laboratory can cost $1 million) and the size of grants. As a result, many laboratories have outdated instrumentation, and support services, such as machine and electrical shops, have deteriorated. Because of the difficulty of doing research under these circumstances, the most talented prospective faculty members are fleeing to industry, a situation that has long-range consequences for the vitality of research universities and for the training of future physicists.

The committee concluded, "to allow a reasonable number of groups to pursue the new scientific opportunities, and to allow some young investigators to enter the field, the level of operating funds must be doubled over a 4-year period. . . . The endeavor surely represents one of the most important ways for the nation to invest in research."

A related problem is a possible shortage of physicists in the 1990's. The committee recommended several measures aimed at making graduate studies and research in the universities more attractive, such as increasing the number of physics predoctoral fellowships, supporting award programs for young faculty, encouraging women and minorities to take up physics careers, and facilitating the entry of U.S.-trained, foreign-born physicists who wish to work in this country. ■ ARTHUR L. ROBINSON

Briefing:

New Relatives of AIDS Virus Found

The family of retroviruses that includes the virus that causes AIDS (acquired immune deficiency syndrome) has just gained at least one and possibly two new members. In this issue of *Science* (p. 238), Phyllis Kanki and Max Essex of the Harvard School of Public Health and their colleagues describe the isolation of a virus, which is distantly related to the AIDS virus, from apparently healthy individuals who live in the West African country of Senegal.

In addition, Luc Montagnier of the Pasteur Institute in Paris has just announced the finding of a new virus, also distantly related to the AIDS virus, in two individuals who have the disease. Whether there is any relation between this isolate and that of the Essex group is still unclear.

The current results of Kanki, Essex, and their colleagues are an outgrowth of their previous discovery, with researchers from the New England Primate Center, of simian T-lymphotropic virus type III (STLV-III). This virus, which is similar but definitely not identical to the human AIDS virus, was originally found in captive rhesus macaques that have an AIDS-like disease, but the same virus, or one very much like it, also occurs in about 50% of healthy African Green monkeys living in the wild. Essex postulated that there might be a spectrum of related viruses that could infect different primate hosts and have a range of pathogenic effects ranging from none to full-blown AIDS. The work implied that the human AIDS virus might be derived from one of the monkey viruses.

Subsequent work by the Essex group indicated that human beings also harbor an AIDS virus relative that does not cause any obvious pathology. Healthy prostitutes from Dakar, Senegal, where AIDS occurs rarely if at all, carry antibodies indicating that they had been infected with a virus that is closely related to STLV-III, a finding that is consistent with the idea that a virus might have passed from monkeys to humans. Essex first presented these results at the International Symposium on African AIDS, which was held in Brussels in November 1985.

The investigators have now followed up on this observation by isolating the virus from three individuals. As expected, the viral proteins share some similarities with the proteins of the AIDS virus, but more closely resemble those of STLV-III. In addition, the new virus is T-lymphotropic, which means that it infects T cells, and in particular, T cells of the helper class. The AIDS virus and STLV-III also share this predilection for infecting helper T cells. That is one reason why Robert Gallo, whose group discovered the AIDS virus in 1984, called it "human T-lymphotropic virus-III (HTLV-III)" as the third member of a class of human viruses with this property. The Essex group calls their new virus HTLV-IV. However, HTLV-IV does not kill the cells it infects, whereas HTLV-III and STLV-III do.

So far HTLV-IV does not appear to be associated with any illness. "It may be important precisely because it fails to cause disease," Essex suggests. Comparative studies of HTLV-III and -IV may help to pin down the lethal effects of the AIDS virus on helper cells and also aid in determining how the immune system responds to these viruses, information that may be of use in designing strategies to prevent or treat AIDS.

Montagnier, whose group achieved the first isolation of the AIDS virus in 1983 and called it "lymphadenopathy-associated virus" or LAV, has given the name "LAV-II" to his group's new virus. This one resembles HTLV-IV in that it, too, is more closely related to STLV-III than to the AIDS virus. However, LAV-II was isolated from AIDS patients and, unlike HTLV-IV, kills the helper cells it infects. "This may be a different virus. We will have to compare them to find out," Montagnier says.

The announcements of the isolation of the new virus or viruses highlighted the competition that has become a characteristic feature of AIDS virus research (and is also illustrated by the different names borne by the virus). Montagnier first presented his group's results at a Lisbon meeting sponsored by the Gulbenkian Foundation on Wednesday, 26 March—just, as it happens, 1 day before Essex was scheduled to report his group's data at the annual meeting of the American Society for Microbiology in Washington, DC. According to Montagnier, he decided to release the information in Lisbon because researchers from the Hospital Egas Moniz in that city collaborated in the work. The group is publishing a preliminary note of the results in a publication of the French Academy of Sciences and also has a paper under consideration at *Science*.

Meanwhile, according to Essex, as word of the French announcement spread, he and his colleagues were deluged with reporters' requests for information about the virus they were studying. This led Essex to release that information on Wednesday, thereby allowing the work of both investigators to appear in news reports on Thursday morning, several hours before the scheduled presentation at the ASM meeting, and of course, 1 week before this issue of *Science* rolled off the presses. ■ JEAN L. MARX