legislation amended much more to their liking.

For his part, Representative Seiberling, whose subcommittee will begin marking up the Alaska lands legislation any day now, is not of a mind to offer substantive concessions to those who speak of a resources lock-up. But he would have the legislation prescribe expedited congressional consideration of any future request by a President to open up certain protected areas in Alaska to resource exploration and development or to transportation corridors—provided, however, that the justification for such requests be convincingly documented.

More important in terms of the politics of getting a bill through Congress, Seiberling also now shrewdly proposes that the same legislation which settles the d-2 lands issue also convey to the state and to the natives all land patents to which they are entitled.

But, whatever Congress finally does about the Alaska lands issue, the impending debate over just how far Congress should go in raising barriers to development of pristine natural areas is likely to be audible and intense. From this debate the public may get a sharpened appreciation of the dilemmas that are involved.—LUTHER J. CARTER

RECENT DEATHS

Oscar Bodansky, 76; biochemist and former vice president, Sloan-Kettering Institute for Cancer Research; 21 August.

Albert S. Coolidge, 83; former professor of physics, Harvard University; 31 August.

Clarence M. Ferguson, 78; professor emeritus of agriculture, North Carolina State University; 11 August.

A. H. Gayton, 77; professor emeritus of design and anthropology, University of California, Berkeley; 18 September.

Alphaeus M. Guhl, 79; professor emeritus of biology, Kansas State University; 25 August.

W. H. Horr, 85; professor emeritus of biology, University of Kansas; 12 March.

Aleksandr R. Luria, 75; Soviet neuropsychologist and former head, Moscow Institute of Defectology; 14 August.

John H. Moss, 58; professor of geology, Franklin & Marshall College; 28 July.

John R. Pellam, 62; professor of physics, University of California, Irvine; 23 July.

John T. Maynard, 58; chemist and head, Elastomer Chemicals Department Patent Service, E. I. Du Pont de Nemours & Company; 17 September.

Harold C. Zweng, 54; clinical professor of surgery, Stanford University Medical School; 26 August.

APPOINTMENTS

David B. Ludlum, professor of pharmacology and experimental therapeutics, University of Maryland, to chairman of pharmacology and experimental therapeutics, Albany Medical College. . . . **Ruy V. Lourenco**, professor of medicine, University of Illinois at the Medical Center, to chairman of medicine, Abraham Lincoln School of Medicine at the university. . . . **Charles I. Smith**, chairman of geology-mineralogy, University of Michigan, to chairman of geology, University of Texas, Arlington. . . . **Robert N. Rose**, professor of psychiatry, Boston University, to chairman of psychiatry, University of Texas Medical Branch, Galveston. . . . **James F. Arens**, chairman of anesthesiology, University of Mississippi, to chairman of anesthesiology, University of Texas Medical Branch, Galveston.

RESEARCH NEWS

High Energy Physics: A Proliferation of Quarks and Leptons

Determining the fundamental constituents of matter has been one of the age-old problems of physics. Currently the most popular view—although there are holdouts—is that particles known as quarks and leptons are the most fundamental of all. But, if the interpretations given the most recent experiments at accelerators in the United States and Europe hold up, the number of these basic particles is showing a disturbing tendency to grow—disturbing because, whenever the number of elementary particles begins to increase, it usually means that they are not really elementary after all.

Illustrating this pattern well is the class of protonlike elementary particles called hadrons, which also includes the neutron and the pi meson. Experimentalists have found so many hadrons (literally hundreds) in the last quarter-century that the concept of an elementary particle no longer seemed to fit these entities. Although no quark has ever been unambiguously found, all the properties of hadrons can be elegantly explained under the assumption that quarks exist and are the even more fundamental constituents from which hadrons are formed. For this, as well as certain other reasons, physicists' faith in quarks is very strong right now.

Originally there were three quarks, but the discovery 2 years ago of the J/psi particle, a hadron, and the subsequent particles related to it have been widely accepted as evidence for a fourth quark. What one of the new experiments reveals is the possibility of there being five or even six quarks. Confirming evidence in the coming months could also cement the acceptance of a new meaning for high energy physics. Just as the mantle of high energy physics was once worn by nuclear physics but passed years ago to elementary particle (hadron) physics, so now it may be passing from elementary particle physics to quark physics as more powerful accelerators probe more deeply into the heart of matter.

The discovery of the J/psi particle also capped an emerging realization of a particularly efficient way of searching for elementary particles of a certain type. This method has been used by a collaboration of physicists from Columbia University, the Fermi National Accelerator Laboratory (Fermilab), and the State University of New York at Stony Brook in their discovery of the most massive elementary particle yet found. Dubbed the upsilon, it is this particle that may indicate the existence of a fifth and (possibly) sixth quark. The group did their experiment at the Fermilab's 400 billion electron volt (Gev) proton accelerator.

Complicating the search for new elementary particles during the collisions between protons from the accelerator and nuclei in a solid or liquid target is that most collisions do not produce new particles and even those that do can produce a bewildering variety of debris because the new entity decays too rapidly to be observed directly. Even worse, it is not practical to build a single detector that can detect all particles, charged and neutral, light and heavy, leptons and hadrons. Thus, the problem is to figure out what combination of particles in the debris would be a signal of a new entity and design a detector to watch for that signature.

One of the triumphs of the J/psi discovery was provided by Samuel Ting of the Massachusetts Institute of Technology and his collaborators in their experiments at the Brookhaven National Laboratory. The J/psi, found by Ting's group and by a collaboration of groups from the Stanford Linear Accelerator Center (SLAC) and the Lawrence Berkeley Laboratory, headed by Burton Richter of Stanford, is composed of the fourth quark, called a charmed quark, and its antiquark. Ting's group showed that such particles are among those that can be efficiently searched for by precisely measuring those events in which an electron and its antiparticle, the positron, are found.

Fig. 1. Detector used by Lederman's group at Fermilab to record pairs of muons. Collisions between 400-Gev protons and a copper-platinum target takes place out of sight in the foreground. Shown are symmetric arrays of magnets, charged particle detectors, and steel absorbing blocks to select out the highly penetrating muons. [Source: Fermi National Accelerator Laboratory]

The experiment at Fermilab, which was headed by Leon Lederman of Columbia, involved a search for pairs of muons (the negatively charged muon and its antiparticle, the positively charged muon, are similar to the electron and the positron, but are 210 times heavier) and was carried out at higher collision energies (400 Gev as opposed to 30 Gev) (Fig. 1). In other respects, however, it was quite similar to the experiment at Brookhaven in which the J/psi was found. The most conservative interpretation of the new upsilon particle is also quite similar: it is thought to be a hadron consisting of a fifth quark—called in one theory either the bottom or top quark—and its antiquark. Particle systems of this type now generally go by the name of oniums, after positronium, which is an electron and a positron bound together, Thus, the J/psi is also called charmonium, and the upsilon is tentatively "bottomonium" or "toponium."

What Lederman and his collaborators found was that the number of muon pairs detected increased significantly above background when the energy of the pairs was near 10 Gev. A peak in the production of any kind of particle or combination of particles at a particular energy is a signal that the detected entities are the decay products of an unknown particle with the same energy (mass). Since the initial reports last spring, the group has accumulated much more data, having now about 1200 events above a background of about the same magnitude. Moreover, there is clear evidence for at least two peaks, one at 9.4 Gev and the other at 10.0 Gev, and weaker evidence for a possible third peak at 10.4 Gev. Thus, there may be three particles: upsilon, Υ', and Υ''.

The situation is entirely reminiscent of the J/psi, where there was also a family of particles, including a ψ' and a ψ'', ranging from 3.1 Gev to 4.4 Gev. Although it is possible that some additional information about the upsilon can be garnered from experiments using protons, pi mesons, or neutrinos to bombard targets at Fermilab or at the European Organization for Nuclear Research (CERN) near Geneva, most observers expect the parallel with the J/psi particle to continue. If so, then the definitive experiments deciding for sure what the upsilon is will come from an altogether different type of particle accelerator, the electron-positron colliding beam storage ring. A machine of this type, which is part of the SLAC facility, was used by Richter's collaboration to find the J/psi at the same time Ting's group was using the Brookhaven proton accelerator. However, all subsequent members of the J/psi family were found in the Stanford storage ring, which has a maximum energy of 4 Gev in both the electron and positron beams, or in a similar machine located at the DESY Laboratory near Hamburg.

For studying the upsilon, electron-positron storage rings have two advantages. Since all of the energy in each beam is available for making new particles, the machines do not need to have the high energies required by fixed target accelerators, such as proton synchrotrons, in which only a fraction of bombarding particle's energy is transferred to the target. More importantly, the energy of the circulating positrons and electrons can be quite accurately controlled, leading to precise, clean experiments.

For the present, however, no existing storage ring is energetic enough to study the upsilon, although, according to Hinrich Meyer of DESY, researchers there are trying to upgrade their machine by just enough to take a peek at the new particle this spring. If this attempt fails, researchers will have to wait until one of three larger rings now under construction will be completed at DESY (September 1978), Cornell University (October 1979), and SLAC (January 1980). An interesting sidelight of this situation is that SLAC and DESY, who have been racing to be the first to skim the cream off the new physics expected to come from experiments at the larger storage rings, may find that their rings (18 and 19 Gev maximum per beam, respectively) are too energetic to permit easy study of the upsilon, whereas the smaller Cornell ring with 8 Gev maximum per beam will be much better suited. Lederman and his collaborators have already asked for time at Cornell to pursue the upsilon.

The upsilon offers an additional opportunity to physicists who are studying the interactions between quarks, the possibility of extracting the force law operating between these entities. With the J/psi particle and its relatives, explains Kurt Gottfried of Cornell, a respectable job of calculating the energies (masses) of the particles was possible with the use of an assumed force between the quarks. The same can be done for the upsilon family; in fact, the job is even easier because the heavy quarks move more slowly and are less affected by relativistic effects. The real hope, however, is that with two (and, in the future, more) families of similar particles it will be possible to extract the true form of the force. Theorists have been unsuccessful at calculating forces between quarks so far. Gottfried points out that the problem is similar to that which would have been faced by atomic spectroscopists if Coulomb's Law had never been discovered.

Some of the most recent experiments also indicate that leptons, which are the second major category of elementary particles, including electrons and muons, may be evolving in parallel with quarks. A second recently discovered new particle, called the tau, is believed by many to be a new lepton or, in the jargon, a heavy lepton. The discovery was made in experiments with storage rings.

In storage rings, the counterrotating beams of positrons and electrons can intersect several times during each revolution, but actual collisions are rare. Thus, it is inefficient to use specialized detectors for each experiment as with proton synchrotrons like that at the Fermilab. Instead, researchers must design as best they can an all-purpose detector to collect a maximum amount of data of all kinds. Later, individual groups can analyze the data as they like in order to ex-

New Accelerators: Cornell Gets an Electron Storage Ring

These are exhilarating times for high energy physicists with new elementary particles and tantalizing hints of even more that seemingly arrive with each physics conference. Rivaling accounts of the new particles are speculations about what the next generation of accelerators, now under construction or soon to be so, will bring. In the midst of the excitement over these huge machines, Cornell University has bagged what might be called a smaller, intermediate energy electron-positron colliding beam storage ring. Ironically, this modest-sized accelerator will apparently be better suited than the larger machines to study some of the newest particles of interest (see accompanying story).

Almost all of the large accelerators in the United States are located at the national laboratories of the Department of Energy or are under sponsorship of the department. Cornell has run against this grain in the past, and the new storage ring there will continue this tradition. The facility, which will take 2 years to complete and cost $20.7 million, is being supported by the National Science Foundation (NSF).

Cornell has been the site of electron accelerators for more than two decades, and its current 12-Gev electron synchrotron has been running for about 10 years. The new storage ring will be built around the existing synchrotron, a feature that accounts for its modest price tag, which is about one-quarter that of a much larger storage ring now under construction at Stanford University. As compared to the Stanford storage ring, which will be about 2 kilometers in circumference and will have a maximum energy of 18 Gev in each of the electron and positron beams, the Cornell facility will be about 760 meters in circumference and have an energy of 8 Gev in each beam. In addition, no new tunnel will need to be dug because Cornell's new ring, to be called CESR, will lie just outside the synchrotron ring in the same tunnel. The synchrotron will act as a source of the electrons and positrons that are injected into and stored in CESR. The only new construction required will be the excavation of a pit in the existing experimental hall to house the detector that analyzes the particles produced by the energy released when the electrons and positrons are annihilated during collisions.

The CESR project has had a checkered history. First submitted about 2½ years ago for evaluation to the High Energy Physics Advisory Panel, CESR ran into formidable competition from the Stanford storage ring, then unfunded, and plans for other types of accelerators at Brookhaven National Laboratory and the Fermi National Accelerator Laboratory. Two years later, with more money available and the other projects no longer in competition, Cornell officials resubmitted a scaled-down proposal for CESR. The project originally involved a 10-Gev ring and a second experimental hall. With an energy of 8 Gev and a single experimental hall, the project has now been approved by the advisory committee, the NSF, and the Office of Management and Budget. Maury Tigner, director of operations at Cornell's Wilson Laboratory, points out that it would not be a major problem to jack the energy back up to 10 Gev, however, if that should be desirable in the future.

Although the electron synchrotron preceding CESR at Cornell has operated with about one-eighth the budget of the better-known Stanford Linear Accelerator Center, it has also been a true national facility. In its most recent year of operation, experiments were divided about equally between Cornell researchers and outsiders. Tigner foresees that the same division of labor will apply to CESR and emphasizes that the NSF definitely conceives of the facility as a national one. For starters, a collaboration involving physicists from Harvard University, the University of Rochester, Syracuse University, Rutgers University, and Vanderbilt University are now at work designing a detector for CESR.

Tigner says that among the first experiments on the new storage ring will probably be studies of the upsilon and tau particles, which are now of so much interest. In a happy turn of events, CESR will have a luminosity (the number of collision events) in the energy range (5 Gev per beam) needed to make the 10-Gev upsilon particles which is four times higher than that of the larger storage rings being built at Stanford and at the DESY laboratory in Hamburg. All in all, it seems that a modest investment in a modest facility need not result in only modest research.—A.L.R.

tract the information needed for their particular experiment. The tau was first noticed in this way by Martin Perl of Stanford and his collaborators from SLAC and the Lawrence Berkeley Laboratory in experiments with the Stanford storage ring.

It is an interesting coincidence that the signature for the tau, as for the upsilon, is two leptons, although in this case it is the combination of an electron and a muon rather than two muons. Perl's collaboration first reported the so-called e-μ events more than 2 years ago, but the heavy lepton hypothesis was only one of many possible explanations. A particle related to the J/psi could have been responsible, for example. Since then data gathered by Perl's and other groups at Stanford and by two groups using the DESY storage ring seem to have eliminated the possibility that particles containing charmed quarks are involved. The most widely accepted explanation is that two particles, the heavy lepton and its antiparticle, are produced in the collision between electrons and positrons and that these decay into the electron-muon pairs that are detected.

But the job of substantiating this hypothesis is likely to be a tougher task than that of tying down the upsilon. Part of the difficulty is that, as the heavy leptons decay into electrons and muons, neutrinos are also released. Since the neutrinos are not detected, not all the information investigators need to reconstruct the event is available. Elucidating the tau, then, is a matter of accumulating various, somewhat circumstantial data which, taken together, build up a strong case for the heavy lepton.

Some of this information is already available. Perl's collaboration at Stanford, for example, has acquired about 200 events over a 4-Gev-wide energy range; analysis of these events revealed the momentum distribution of the electron and muon, the angle between the two particles, and the probability of producing the electron-muon pair, all as a function of collision energy. This information points to a mass for the tau of about 1.9 Gev, making it 18 times as heavy as a muon. Similar data have been collected by a group at DESY using a detector called PLUTO, which is akin to the detector at Stanford. Although PLUTO does a better job of discriminating between events with three and with two particles and thus the data is "cleaner," only two dozen e-μ events have been found so far.

Besides searching for electron-muon pairs, Perl's collaboration and the PLUTO group have studied events, which are somewhat more numerous, consisting of a muon and any other charged particle; and other groups at Stanford and at DESY, which use detectors that are especially efficient at detecting electrons, found events consisting of an electron and any other charged particle. All results so far are consistent with the heavy lepton interpretation, but none are definitive.

Whatever the outcome of the investigations into the natures of the upsilon and the tau, physicists will likely remain as excited as they are now, for, if the new quarks and leptons fail to materialize, the particles will represent something even more novel and unexpected. New quarks and leptons will be interesting enough, however, because of the seeming proliferation of these most elementary particles. Moreover, the proliferation is further accelerated because physicists expect, for reasons having to do with the symmetries imbedded in the theories describing elementary particles, quarks and leptons to come in certain patterns. For example, in one version of the theory the particles come in pairs. Thus, in addition to the fifth quark and fifth lepton suggested by the experiments, there may be a sixth quark and a sixth lepton lurking in the vicinity and waiting to be found out.

The simplest symmetries are readily seen in the patterns of the four quarks and leptons known previously. Among the four quarks, the so-called up and down quarks and the strange and charm quarks seem to be connected in special ways that are manifested in the manner in which hadrons interact and decay. If this pattern were to be continued, notes theorist Fred Gilman of SLAC, then one would expect a sixth quark to be associated with the fifth, one being the top and the other the bottom quark. Gilman adds that two kinds of experiments would help sort out this pattern: ascertaining the electrical charge of the new quark and determining how particles related to the upsilon particle that contain this quark decay into other particles.

A parallel situation holds among the leptons, where the electron and the muon are each associated with neutrinos (the electron neutrino and the muon neutrino). The natural expectation is that there is a tau neutrino as well, although patterns other than the pairs are also conceivable and certainly not yet ruled out. Again, according to Gilman, the way to unravel this question is to make detailed observations of how the tau particle decays.

In their more expansive moments, physicists muse about the significance of an increasing number of elementary particles. At the moment there is no theory that predicts what and how many elementary particles there are. In the past, numerous physicists point out, the same sequence of events has been followed as the atom, the nucleus, and the hadron—each once thought to be elementary particles—have successively been shown to be composites of more elementary entities. A proliferation of particles accompanied by an underlying structure always seems to signal a new and more fundamental type of particle. If more and more quarks and leptons continue to be found, the question may well become: What are quarks and leptons made of?

—ARTHUR L. ROBINSON

Neutron Scattering: New Look at Biological Molecules

Although biochemists have achieved a great deal of success in determining biological structures, there are still gaps in the accumulating body of knowledge that have been difficult to fill by conventional techniques. Now, however, advances in the biological applications of neutron scattering are providing structural information not previously obtainable. The techniques have proved especially valuable for elucidating the three-dimensional structure of ribosomes (small cellular particles where protein synthesis occurs) and chromatin (the complex of genetic material and protein in the nuclei of higher cells). Equally promising is the application of the techniques to the analysis of cell membrane structure. In a third area of investigation, neutron beams have been used to probe the arrangement of atoms in crystalline materials, including proteins.

In this country research into the biological application of neutron scattering is still a relatively small effort, partly because of the cost of running the experiments which require a nuclear reactor to