interactions of particles, and there are no known conflicts between theory and experiment. This body of theory has come to be called the standard model.

Particle physicists think that the present description is incomplete, because it does not provide "why" explanations for several basic phenomena, such as the equality of magnitudes of electric charge of the electron and proton, the origin of particle masses, and the apparent existence of several families of particles that have identical interactions but differ in mass. The standard model also requires another particle, the "Higgs boson," to exist; its properties, and whether it must be fundamental or can be dynamical, are not well understood.

The contributions to the proceedings can be divided into three sets. In each set there are some that review the field or provide introductory material (suitable for a particle physicist who has not worked on the specific subject), some that present recent developments, and some that provide a current perspective.

One set of contributions refers to further tests of the standard model. Before one can be confident of the validity of the model, many important tests must be done. Even if confidence can be achieved, small deviations from standard model predictions may be a clue to the answers to some of the questions that go beyond the model. A number of detailed tests are reported from neutrino reactions. Some of the first results from the new e^+e^- collider at Stanford (PEP) are prsesented, as are a number of results from the older e^+e^- collider at Hamburg (PETRA). Important results on decays of b-quarks from the e^+e^- collider at Cornell (CESR) are given by Kass and Sadoff and by Franzini and Bohringer. Tests of quantum chromodynamics in photon-photon collisions and large transverse momentum collisions (where quarks will appear as "jets" of conventional particles, mainly pions) are described.

The most important tests of the standard model will come in the near future. The electroweak theory requires the existence of fundamental bosons, like the photon, to mediate the interactions. A proton-antiproton collider at CERN, Geneva, is the first accelerator in the world with enough energy to produce these bosons—although they are like the photon, they should be heavy, about 90 proton masses. Quantum chromodynamics also has a major prediction that requires the CERN collider, that there should be collisions that produce a pair of quarks (which would appear as narrow jets of mainly pions) carrying 20 to 30 percent of the total energy of the collision. Some of the papers in the proceedings review the predictions and some describe the first events from the CERN machine, which had been turned on only shortly before the meeting. (Very recently jet events that may have the expected properties have been observed, but further data and quantitative comparisons are needed. It was planned that a week of the 18th Rencontre de Moriond, in March, would be devoted to results from the CERN collider.)

All of the results mentioned so far arise from predictions of the theory where a perturbation series should be valid. Another set of contributions discusses ways to try to learn about quantum chromodynamics in the nonperturbative realm, which is much more difficult. Coherent phenomena such as elastic scattering or collisions of heavy ions where a plasma of quarks and gluons might be formed are discussed. Work on this subject is very difficult and is consequently in a primitive state.

The third set of contributions is concerned with the effort to go beyond the standard model to answer some of the "why" questions and to further unify the known forces. The main activity of many workers in this direction is on supersymmetry, which introduces a symmetry between the bosons of the theory (like the photon) and the fermions of which matter is composed. Supersymmetric theories have many nice properties and could address some of the open questions, though so far they have not improved the situation. They also have many experimental implications but none have been observed; although many workers consider supersymmetry the most promising approach to questions beyond the standard model, there is not yet one item of experimental evidence in its favor. Several papers, particularly a review by P. Fayet, describe the activity on this subject. Other contributions cover motivation and searches for axions (there is a nice review by G. Girardi), neutrino masses, and proton decay.

There is an increasing overlap of particle physics with astrophysics and cosmology, mainly in the realm beyond the standard model. The Rencontre de Moriond has recognized this by holding a week of simultaneous meetings in these fields, with some overlapping sessions. Some of the contributions by particle physicists are in the present volumes, though there is a separate volume of proceedings for the astrophysics week (called *The Birth of the Universe*).

As is consistently the case, particle physicists will find the Rencontre de Moriond proceedings to be timely and useful. Although they are for active workers, they contain enough of a pedagogical and review nature that others may find them to be helpful in gaining some insight into what is going on in particle physics (and why) at a given time.

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A Small Peptide

Substance P in the Nervous System. Papers from a symposium, London, Dec. 1981. Pitman, London, 1982 (U.S. distributor, CIBA Pharmaceutical Company, West Caldwell, N.J.). x, 350 pp., illus. $35. Ciba Foundation Symposium 91.

The history of substance P, a small peptide of 11 amino acids, is almost as old as the history of acetylcholine in biology. A few years after the discovery that it is acetylcholine that transmits signals from motor neurons to muscles in vertebrates, Von Euler and Gaddum found a substance in intestine that was different from acetylcholine but very potent in causing smooth muscle contraction. Because this substance was present in the powder fraction of the tissue extract, they referred to it as P in their first paper on the subject, in 1931. Subsequently substance P was found to be concentrated in nervous tissue such as the brain and the spinal cord.

Each segment of the spinal cord is connected to the peripheral tissues such as skin and muscles by two nerves, the dorsal root containing sensory nerve fibers and the ventral root containing motor nerve fibers. The finding that substance P was much more abundant in dorsal roots than in ventral roots led Lembeck to suggest in 1953 that substance P might be a transmitter that is released by certain sensory neurons. Since then much attention has been directed toward understanding the function of substance P in the nervous system. Research on the subject has gained tremendous momentum since Chang and Leeman purified and sequenced substance P in 1970, using its ability to stimulate salivation in the rat as a bioassay during purification. With the chemical structure of substance P known, large quantities of synthetic peptides became available, allowing study of the biological activity of pure peptides. Also, antibodies against substance P were generat-

ed, providing very sensitive assays of substance P and related molecules and allowing precise localization of these peptides in nervous tissues. This Ciba Foundation symposium volume summarizes recent findings about substance P in the nervous system after a decade of intensive research effort and examines whether substance P is a sensory transmitter. Most of the papers are informative and interesting. Transcripts of informal discussions following each paper serve to clarify important issues and identify unresolved questions.

Is substance P a sensory transmitter? The answer is still unclear. Substance P is present in dorsal root ganglia. Through the use of immunohistochemistry it is found in a fraction of the small sensory neurons. It is released both centrally in the spinal cord and peripherally in the target tissues of sensory fibers, and it excites many neurons in the spinal cord. Since noxious stimuli are known to excite small sensory neurons, it was hypothesized that substance P is the transmitter that mediates the sensation of pain. This hypothesis was encouraged by an early finding that capsaisin, an active ingredient of red pepper, depletes substance P and decreases the sensation of pain. As this book reveals, there is a serious problem with this line of reasoning, for all of these characteristics are not unique to substance P but seem to be exhibited by certain other peptides (for example, somatostatin and vasoactive intestinal polypeptide). Moreover, quite likely there are different small sensory neurons that distinguish different sensations of pain (mechanical, thermal, chemical, and so on). Could it be that these different sensory neurons use different transmitters? Is substance P one of the transmitters used? Here we encounter difficulties intrinsic to studies of the central nervous system; with the complex anatomy and relative inaccessibility of the spinal cord, there is yet no detailed comparison of the direct action of a particular type of sensory neuron on the membrane properties of its target neurons in the spinal cord and the direct action of substance P on the same neurons. More definitive results have been obtained from studying the action of sensory neurons on their peripheral targets. It has been known for over a century that stimulating sensory nerve fibers causes dilation of blood vessels in the skin, which is probably the basis for the slowly spreading inflammatory response around an injured area of skin (the axon reflex). This response was mimicked by substance P and could be blocked by an antagonist of substance P, suggesting a peripheral function of substance P in sensory neurons (Lembeck and Gamse in this book; similar findings on inflammatory responses in the eye have been reported by Homdahl *et al.*). Rosell and Folkers and their co-workers have recently been successful in synthesizing substance P analogs that function as antagonists. These antagonists are used in several preliminary studies reported in the book; these and future studies using antagonists should clarify the picture significantly.

Two observations discussed in the book are highly relevant to the functional roles of substance P and neuropeptides in general. Hökfelt and others have reported in the last few years numerous cases in which more than one putative transmitter substance was found in the same neuron, suggesting that a neuron may use more than one type of transmitter molecule, perhaps with each serving a somewhat different function, to communicate with its target cells. Further, substance P causes slow membrane potential changes in a neuron lasting for seconds to minutes rather than milliseconds. This is true both for cultured neurons from the spinal cord and for neurons in autonomic ganglia, which are located outside the central nervous system and are much more accessible to experimentation. In fact, neurons in the inferior mesenteric ganglion of the guinea pig appear to receive input from sensory nerve fibers that release substance P. This nerve-evoked response is also slow and long-lasting (Otsuka *et al.*, Cuello *et al.*). Could it be, as Henry suggests in the book, that some sensory neurons use substance P to generate long-lasting influences over other neurons and use some other, yet unidentified, transmitter molecule to mediate the fast responses induced by painful stimuli?

That the release of substance P and certain putative transmitters from sensory neurons is inhibited by enkephalins, which are small neuropeptides with pharmacological actions similar to morphine, led Jessell and Iversen to suggest in 1977 that enkephalin-containing neurons in the spinal cord may act on nerve terminals of those sensory neurons that detect painful stimuli and inhibit their transmitter release—an attractive hypothesis to account for the phenomenon of analgesia induced by the nervous system itself. Having learned much about excitation and presynaptic inhibition from classical studies of the neuromuscular junction, neurobiologists set forth to test this hypothesis by searching for close synaptic contacts between enkephalin-containing neurons and substance-P-containing sensory nerve terminals in the spinal cord and found none. Does this disprove the hypothesis? If the action of enkephalins on neurons is also slow and long-lasting, as is shown in autonomic ganglia (Otsuka *et al.*), couldn't enkephalins be released from nerve terminals that form close synaptic contacts with other neurons and then diffuse for some micrometers and act upon sensory nerve terminals? Diffusion of a neurally released peptide over relatively long distances (tens of micrometers) to its ultimate target cell has been demonstrated in frog autonomic ganglia by Jan and Jan. However, one must be cautious in extrapolating from phenomena found in autonomic ganglia to those in the central nervous system. Thus an understanding of the functional relationship between enkephalin-containing neurons and sensory nerve terminals in the spinal cord awaits future studies that address directly whether peptides diffuse in the central nervous system.

The book provides ample examples of the wide distribution of substance P in the nervous system as well as of the many functions the peptide may have in addition to being a sensory transmitter. Perhaps the most important contribution of the book, however, is the formulation of important questions that warrant future study.

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