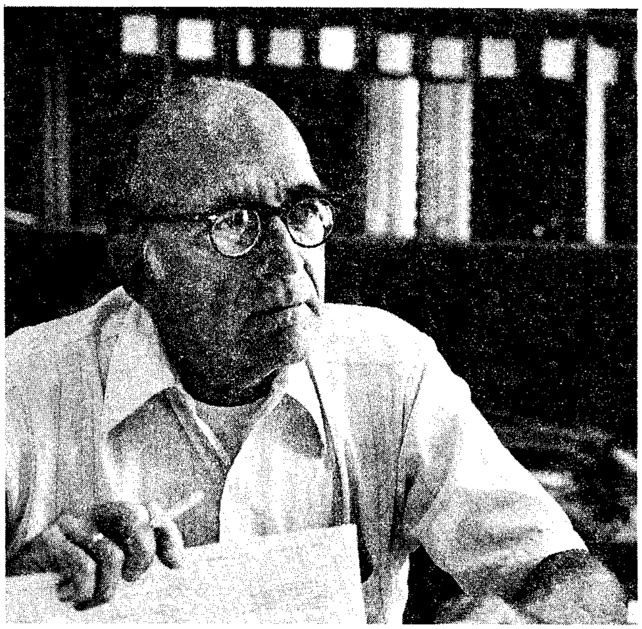
SLAC AND THE ADVENTURE OF SCIENCE

(Deputy Director, Sidney Drell, opened SLAC's Anniversary Celebration in August with this essay on science, particle physics, and SLAC.)

Since the beginning of recorded history mankind has pursued the great adventure of trying to determine what we are made of. And for the past five centuries we have done so realistically with experiments, for there is no other way to uncover Nature's secrets. Poets can rhapsodize about the beauties of nature, and philosophers can define the best of all possible worlds. But to learn the bricks and mortar of nature--that is, nature's elementary particles and the forces acting between them--we must go into the laboratory for the necessary clues.

There has been a rhythmic quality to our understanding of Nature as we oscillate between a simplicity in terms of elegant ideas and a complexity in terms of murky ones. But one of the nice features of science--some would suggest it to be a unique feature of science and science alone--is that this oscillation has always proved to be the mark of progress in our understanding of Nature.

Nowhere has this pattern been displayed more strikingly than in the physics of elementary particles--or what the Greeks originally called "atoms." Throughout the 19th century a pattern of many different chemical elements began to emerge. It was soon realized that many, many complex substances were but simple combinations or compounds of a few elemental things--the things we now call atoms. Incidentally, there were some 50 different kinds of known atoms in the early 19th century and now there are about 100. But the number of identified compounds continues to grow without limit--the last time anyone looked there were some 5,800,000 chemical substances in the Registry of Chemical Abstracts, and they are being discovered at the rate of 6000/week--or 10 or so during these remarks. So be thankful for physics--look at the complexities of chemistry we have saved you from. (In the presence of our distinguished visitors from Washington I would not want anyone to draw a different conclusion--to wit, that we are really rather stupid if it takes us typically several years and more than a hundred million dollars to discover one so-called elementary particle when all those organic compounds roll in so rapidly and cheaply. But then how can one compare one diamond with a benzene ring?)



We enjoyed a moment of great simplicity fifty years ago at the birth of modern particle physics. In 1932 we had only three fundamental or elementary particles--the proton and neutron that make up the nucleus, and the electron, the particle of electricity that circulates around the nucleus like a planet around the sun. It was a beautiful picture, but it failed to explain what held the nucleus together so tightly!

By the time SLAC turned on, just 15 years ago, we had gone through a stage of extreme complexity in our picture of particles akin to that of the periodic table of the chemical elements. Protons and neutrons had been shown to be very complex structures, and in order to achieve a simplicity in our understanding of this structure and of the strong nuclear force, it was necessary to introduce another layer of matter--the quarks--as constituents within the proton and neutron. This gave a very attractive picture according to which well over a hundred different observed forms of nuclear matter could all be accounted for--and some predicted before they were seen--in terms of a simple structure built by putting together 3 quarks, or a quark and an anti-quark. There were just three different kinds of quarks (we whimsically call them differents flavors, like vanilla, chocolate and pistachio) and they could move in different paths. This formed a great picture all right--and SLAC contributed a major advance in confirming it when the Linear Accelerator's electron bullets--the fastest, the mostest of their kind anywhere--actually revealed those quarks inside the proton and neutron. SLAC confirmed that they were there as hard, little seeds.

This was 14 years ago, or soon after the linac turned on. And just 8 years ago, in the era of SPEAR, (that well known equipment project that was assembled, but never constructed) there was the spectacular discovery of a new quark with a fourth flavor in the famous November revolution of 1974. The fact that it was also found simultaneously by independent and different experiments at Brookhaven National Laboratory shows how interwoven is the path of progress in our field. The extraordinary outpouring of work and progress based on this discovery over the next five years--including the discovery of a fifth quark at Fermilab, both solidified and enriched our understanding of these elusive quarks. We studied in beautiful detail in the laboratory many new structures built out of the new and the old quarks, as well, and devised working theoretical models in terms of them. Looking back, it is clear that our understanding of the subnuclear world advanced by major strides during the past decade. We unpeeled another layer of subnuclear matter in our search for the basic building blocks of Nature, finding five different kinds of quarks. And there may be more. Most theorists, like myself, bet there is at least one more--because for all sorts of mathematical reasons we prefer the number 6 to 5! Whether these point-like quarks are, indeed the fundamental constituents of subnuclear matter, or whether within the quarks we will find yet another layer as we search with even more powerful probes in the future, such as the planned SLAC linear collider, is an open question. Only experiments can tell us.

Of course, we all know that SLAC's favorite particle is the electron which, along with the proton and neutron, was the third elementary particle known back in 1932. In contrast with the proton and neutron, the electron still remains one of Nature's basic building blocks, or elementary particles, at our present level of understanding. No substructure to it has been discovered, despite the most detailed probing here at SLAC and elsewhere. However, the extraordinary discovery of the tau particle here at SLAC in 1975 challenges the electron's reign as the elementary unit of electricity. There now exist three different particles with identical properties as point-like units of electricity, but with very different masses: the mu particle is 200 times as heavy and the tau is 3600 times as heavy as the electron. A troubling shadow of complexity has entered our simple picture here. This growing family of heavy electrons reminds us that simplicity was recovered out of complexity in nuclear matter by first postulating and then experimentally confirming the quark constituents. Will the advancing high energy frontiers reveal more family members and even a substructure to the electron family as well? Without further data we can only speculate.

In our quest for a deeper understanding of nature, we ask not only "what are the building blocks?", but also "what are the forces that bind or glue the building blocks together?" Our understanding of these forces in the '70's made a giant leap forward which history may well prove to rival in importance that great stride taken by Sir Isaac Newton in the 17th century when he first deduced the universal character of Nature's laws. Think of the profound influence on our understanding of the universe when Newton first showed that the very same laws that govern how objects move on earth such as a pencil falling from a table top, also govern the planets around the sun! Newton first understood the universality of Nature's laws. Einstein extended Newton's majestic edifice with his general theory of relativity early in this century, and he went on to attempt to unify the theory of gravitational phenomena and of electromagnetic phenomena into one theoretical framework. Einstein strove for forty years, until his death in 1955, to accomplish the unification of these two apparently very different phenomena. It is a measure of the difficulty of the challenge of unification that Einstein failed. During the past decade, however, we have accomplished a step of comparable importance: the theory of the weak forces responsible for radioactivity has been successfully unified with the theory of electromagnetism. And one of the pivotal experiments confirming this was done right here at SLAC in 1978 by measuring a minute asymmetry in the scattering of polarized electrons.

To conclude, SLAC has compiled a proud record of achievements in 15 years of operation. SLAC has made major contributions to the understanding of the structure and spectroscopy of subnuclear matter, to the confirmation of the quark hypothesis, to the discovery of new quarks and to the systems of particles that are built from them, to the discovery and study of the tau or heavy electron, to the discovery of jet structure in high energy electron-positron collisions, and to the discovery of interference between the weak and electromagnetic forces in support of the theoretical understanding of their unification. SLAC has made pioneering advances in accelerator and storage ring design and construction, in experimental devices, including spectrometers of various design and rapid-cycling bubble chambers, and in microwave technology. I salute all of you out there whose technical and scientific and management skills are at the heart of SLAC's success.

It is truly awesome to realize that in this century with instruments of the power and beauty of those here at SLAC, we have shrunk the scale of distances on which we are now probing Nature by 100 million times--about the same factor as in all the previous 25 centuries of mankind's recorded history!

-Sidney Drell