polysomes from *Astasia longa* by means of the zonal ultracentrifuge. They also analyzed the TCA soluble nucleotides during the repetitive synchronized cycle of *Astasia longa*. The mono-, di-, and triphosphates are much reduced in concentration at the end of the cold period. They appear, however, to increase in amount during the warm period. Their involvement in the initiation of the division process was suggested.

The regulation of cell division and chromosome replication in *Bacillus subtilis* was discussed by N. Sueoka (Princeton University). Synchronization of chromosome replication was obtained either by releasing the growth from stationary phase or by germinating spores. Sequential replication of the *Bacillus subtilis* chromosome from one end (origin) to the other end (terminus) was demonstrated by comparing relative frequencies of various transforming markers in DNA preparations obtained from exponentially grown cells and stationary cells. In contrast to strain W26 of *B. subtilis*, strain W168 does not show polarity of chromosome replication. The apparent nonpolar behavior of strain W168 arises from poor regulation of chromosome replication rather than from a basic difference in the mode of replication with regard to origin and sequence. Evidence was presented for multifork replication of chromosomes during rapid growth of the cells.

G. L. Whitson, G. M. Padilla, and W. D. Fisher (Oak Ridge National Laboratory) presented a paper on the inhibition by actinomycin D in *Tetrahymena pyriformis* synchronized by the method of Padilla and Cameron. It was found that the cells are sensitive to actinomycin D (10 μg/ml) added 1 hour before the temperature shift from the cold to the warm period. More than 90 percent of the cells failed to divide. Partial inhibition of cell division occurs if actinomycin D is added later in the temperature cycle. Stomatogenesis, which is confined to the warm period, does not occur in the cells treated with actinomycin D. Zonal centrifugation of cells treated with actinomycin D showed a decrease in the 110*S* ribosome fraction and an increase in the 70*S* fraction. In addition, pulse-labeling experiments with RNA precursors show a marked inhibition of uptake after treatment with actinomycin D. Studies of long-term incorporation indicate that the fraction of RNA synthesized during actinomycin D treatment is not a short-lived messenger. Relations between development and maintenance of differentiated structures and RNA inhibition were discussed.

In a complementary presentation D. S. Nachtwey and W. J. Dickinson (U.S. Naval Radiological Laboratory, San Francisco) discussed the effects of actinomycin D treatment on *Tetrahymena* synchronized by the method of Scherbaum and Zeuthen. They showed that *Tetrahymena* synchronized by the heat-shock method are much more resistant to actinomycin than *Tetrahymena* synchronized by the repetitive cold temperature cycle. The variables studied in this presentation were the concentration of the drug, duration of exposure after the end of the synchronization treatment, and the type of medium on which exposure occurs. It was found that the critical time at which the drug must be added to block division in 50 percent of the cells yields a saturation-type curve. In nonnutrient medium the cells are much less sensitive whether they are exposed to actinomycin D continuously or for shorter periods of time. It was suggested that the relative sensitivity of the cells in the two media is correlated with the relative rate and extent of food vacuole formation. This interpretation does not exclude the dependence of inhibition on the extent of saturation at the target site.

Cytological studies on the cortical organelle development of *Tetrahymena pyriformis*, as related to the cell cycle, were noted by J. Frankel (State University of Iowa). He used exponentially growing *Tetrahymena* or *Tetrahymena* synchronized by the Scherbaum-Zeuthen method. Frankel was able to demonstrate a stabilization point about two-thirds of the way through the cell cycle, beyond which addition of numerous RNA and protein inhibitors had no effect on the ensuing cortical development, that is, on the development of oral cilia. He concluded that new RNA and protein synthesis are necessary during each cell cycle to support cortical organelle development.

Some of the participants in this conference suggested that a synchrony conference of this nature be held in two years. Plans for such a conference are being formulated by the organizing committee which consists of G. M. Padilla, chairman; I. L. Cameron; and G. L. Whitson (Oak Ridge National Laboratory).

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Correlations of Particles Emitted in Nuclear Reactions

The three-body problem is the most celebrated of all dynamical problems and has troubled physicists from the earliest days. In a few well-known systems, such as the sun, earth, and moon and the helium atom, accurate numerical solutions have been obtained by successive approximations. The approximations which make these examples *relatively* simple cannot be made in the three-body problem of nuclear physics, because here the interacting particles have comparable masses and the forces acting between them are extremely complex, since the particles are often so close together that their intrinsic structure becomes important. The hope, however, is the same: that the nuclear three-body system is capable of description in terms of two-body forces.

The bound three-body systems in nuclear physics, namely the H^3 and He^3 nuclei, have only static properties, such as binding energy, that can be used to test a theory. The dynamical structure of the system cannot be discovered from its static properties. Three-body systems in excited states, if they have sufficient energy, can decay into three free particles; the kinematics of the decay reflects the internal dynamics of the system so that experiments can be performed which give information about specific dynamical configurations of the system.

Problems connected with such systems were studied at a conference on "Correlations of particles emitted in nuclear reactions" held at Gatlinburg, Tennessee, 15–17 October.

C. Zupancic of the J. Stefan Institute in Ljubljana, Yugoslavia, opened the conference with a talk in which he pointed out that most of the phenomena under study here have analogues in atomic physics, where better approximations can be used. As an example he chose the scattering of photons by atoms. For very low energy photons, the scattering occurs from the atom as a whole, and no structure is revealed (Tyndall effect). For photons of intermediate energy, the Raman effect occurs: in the initial process the photon is scattered with reduced energy, while the atom is left in a long-lived excited state which decays by emission of a second photon. At very high energies, the incident photon is scattered from an individual electron in the atom, and in a single-stage process both a reduced-energy photon and a recoil electron are emitted (Compton effect).

In nuclear physics, the kinematic relationships between the three particles in the final state are more complicated than in the atomic analogues because the particles have comparable masses. It is necessary to find for each scattering event the energies and directions of all the particles emitted. Because energy and momentum conservation have to hold for the interaction as a whole, it is only necessary to measure two of the particles; the energy and direction of the third can then be inferred. These energies are measured in the laboratory frame of reference, which is rarely the one of interest, so it is necessary to choose frames of reference of likely importance and transform all the relevant momenta and energies to these frames. Which frames of reference are useful depends on the reaction mechanism. If the reaction proceeds by a sequential process, emitting one particle first and leaving behind a long-lived state of two particles which later decays, it will be found that the total energy of the latter two particles measured in the rest frame of the center-of-mass of the pair is almost constant, the energy spread reflecting the lifetime of the two-body state according to the uncertainty principle. If the reaction proceeds in this fashion, the properties of the two-body state can be found by well-established procedures using the laws of conservation of angular momentum and parity. This type of reaction is dominated by the interaction between the two particles which form an almost bound state. In the nuclear analogue of the Compton effect (knockout reactions) the center-of-mass frame of the incident and struck particles is of prime importance. Furthermore the laboratory frame of reference is now significant because whatever remains after the particle is knocked out remains almost at rest in the laboratory. Zupancic stressed that, as for the atomic interactions, it is possible to choose experimental conditions (bombarding energy or counter angles) such that particular reaction mechanisms predominate; we usually choose situations in which the mechanism is dominated by the two-body forces. However, in general, several reaction mechanisms can contribute, and interference effects will appear to complicate or in some cases to assist the interpretation.

P. Swan, of Rice University, described a theory of sequential decay processes which had been derived by Phillips, Griffy, and Biedenharn by modifying Watson's well-known final-state-interaction theory. The theory of Phillips *et al.* makes it possible, in sequential processes, to derive the decay behavior of the system from the cross sections for elastic scattering of the two interacting particles, which can be measured in a separate experiment. This approach typifies the purpose of these studies and is essential, since even in a sequential process the secondary two-body system may not be in a state of well-defined spin and parity. If such a theory can be proved, it will be possible to use it in reverse and deduce from the three-body decay what the two-body interactions are. Thus it would be possible to deduce the interaction between two neutrons or two pions where scattering experiments are impossible.

G. C. Phillips, of Rice University, presented a very detailed experimental study of the decay of excited states of C^{12} by emission of three alpha particles. A preliminary interpretation of these results was presented by I. Duck, also of Rice University, who used the theory described by Swan. He startled the audience by emphatically stating his belief that the problem of three alpha particles is the most important problem in nuclear physics today. This is true in the sense that the alpha particles have no spin; thus, insofar as their internal structure is unimportant, the problem is far simpler both experimentally and theoretically than the more obviously fundamental three-nucleon problem. It is worth noting that it is identical in symmetry to the three-pion problem but much easier to study, since the alpha particle is stable and alpha-alpha scattering parameters may be fed into the calculations.

In the session on knockout reactions, experiments analogous to Compton scattering were described. M. Riou of the Joliot-Curie Laboratory at Orsay, France, described a type of experiment of great elegance. A nucleus is bombarded with 150- to 400-Mev protons, and events are studied in which two high-energy protons are emitted at angles and energies near to those at which they would appear if the incoming beam had been scattered by free protons. The results are analyzed as a two-body collision between the incoming and struck protons. Experimentally it is found that the struck protons have well-defined binding energies in the nucleus and that these energies vary from nucleus to nucleus in a way which gives strong support to the shell model of nuclei; furthermore, it is possible to find from the kinematics what momentum the struck proton originally had in the nucleus. The momentum distributions thus found once more correspond closely to shell-model ideas of nuclear structure. These knockout reactions have been very fruitful, but for further progress significant improvements in accelerator design are needed.

I. E. McCarthy of the University of California at Davis showed how these $(p, 2p)$ reactions can be analyzed in detail with high-speed computers. He said that it is possible not only to find the wave function of the struck protons but also to show that the interaction between the incident and struck protons is in fact slightly different from the interaction between two free protons: the proton-proton interaction has to be of shorter range inside the nucleus. This is a suggestion of considerable significance for our understanding of nuclear reactions, and it is to be hoped that it will be followed up by other studies. In the same session J. R. Mines of the University of Liverpool attempted to show how to describe (d,p) stripping reactions when the final state of the nucleus is unstable. In studying this problem he found it necessary to reexamine the fundamental assumptions of the distorted-wave Born approximation.

An entire session of the conference was devoted to invited papers, mainly of a pedagogical nature, on high-energy physics. The speakers were W. Selove of the University of Pennsylvania, R. K. Adair of Yale University, and J. D. Jackson of the University of Illinois. The chairman of this session was R. H. Dalitz of the Clarendon Laboratory, Oxford. The speakers outlined the way many-particle final states are studied in high-energy physics, where the proper description is of great importance, since the particles involved are usually unstable and it is only from the many-particle reactions that information on two-particle interactions can be obtained.

It is interesting to compare the methods of approach used in high-energy and nuclear physics. The aims are the same, but the types of data that can be obtained are quite different, being determined by the very different techniques that have to be used. At high energies the bubble chamber is universally used. This gives an overall picture of the reaction, however many particles are emitted. The experimenter has no choice, however, but to scan all the photographs taken to pick out the few that are of interest. With present methods the scanning and measurement of photographs is very slow, and after months of effort several tens of thousands of events may have been measured, out of which only a hundred or so may be in the kinematic configuration of major interest. An imminent breakthrough in automatic photograph analysis is, fortunately, expected. The nuclear physicist, by contrast, has no direction-sensitive detectors with good energy resolution. He has to make his counters small enough to define the direction precisely. With these small counters he can only study a minute proportion of the possible kinematic configurations needed to study a three-body reaction as a whole. Four- or more-body reactions cannot be studied because the counting-rates become too low, but they cannot be excluded and produce an unwelcome background in the energy spectra. Here, too, there is hope: one method applicable for three-body processes was described by E. Norbeck of the University of Iowa, who showed results obtained with the use of a new type of solid-state detector which is sensitive to the location at which a particle enters it.

These technical differences lead to different methods of data analysis. The high-energy physicist is forced in most cases to average his data over variables assumed not to be significant in order to obtain statistical accuracy. With the poor statistics it is impossible to test many of the assumptions. The nuclear physicist, on the other hand, has to pick out only the events he can interpret. There was discussion about whether the averaging procedure does not in some instances produce misleading results due to interference phenomena. This may be a question that can be answered more easily by a specific nuclear physics experiment designed to test it than by the laborious accumulation of sufficient data at high energies to reveal an effect which might in the end be negligible.

The unity of nuclear and high-energy physics was emphasized by the speakers. The different jargons used do, however, seem to hinder communication. For example, "overlap integral" and "coupling constant" were revealed to be essentially the same, and in a "surface interaction" one gets "peripheral production." The high point in the linguistics struggle was reached in an earlier session when a speaker unwarily spoke of a particle's being "precipitated" out of a system, and G. M. Temmer, the chairman, cautioned him to take care, "otherwise the high-energy people will call us all chemists." The nuclear physicists present were, however, delighted to hear that their favorite tools, the optical model and the distorted-wave Born approximation, are now being used in high-energy physics, while the high-energy physicists were intrigued at the enthusiasm of nuclear physicists for polology.

The final session of the conference was on few-nucleon problems. P. F. Donovan of the Bell Telephone Laboratories described some beautiful work done by a group working with the Brookhaven 60-inch (152-centimeter) cyclotron. The experimental techniques of this group are a model for all. The events recorded are displayed on a two-dimensional pulse-height analyser with oscilloscope display. The analyzer is coupled to a computer which can use any reaction theory to simulate experimental data for direct comparison with experiment on the oscilloscope. Donovan presented results on a number of reactions. Two of these stand out. In the bombardment of deuterium with deuterons there is a large peak in counting-rate for events in which the target deuteron is broken up and its neutron is left stationary in the laboratory. The shape of this peak fitted very satisfactorily with a Chew-Low dispersion theoretical analysis, probably the first really convincing fit to be obtained by this method. In the bombardments of deuterium by He^3, events were picked out in which the final state contained tritons and protons with low relative energies. The yield showed two peaks which were later shown by W. E. Meyerhof of Stanford University to be consistent with the observed cross sections for free proton-triton scattering.

The final session was further notable for the presentation by Y. Y. Yam of results obtained by a group headed by R. D. Amado at the University of Pennsylvania. This group used a high-speed computer to attack the three-nucleon problem numerically, making significant gains by writing the nucleon-nucleon potential in a convenient form. The calculations, which could not even have been considered a few years ago, gave good fits to the binding energies of H^3 and He^3 and to the neutron-deuteron and proton-deuteron low-energy scattering. This report caused a great deal of excitement, and the conference ended on a note of optimism.

The conference was sponsored by the American Physical Society in conjunction with the Oak Ridge National Laboratory and the Nuclear Structure Subcommittee of the National Science Foundation and the National Research Council. It was fascinating because almost every facet of nuclear-reaction theory was touched upon, with excursions into atomic and high-energy physics, and unusual because, while most of the participants were experimental physicists, the long discussions were mainly about theoretical nuclear physics and fundamental quantum mechanical problems. Proceedings of the conference will be published in *Reviews of Modern Physics.*

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The Water Molecule in Biological Systems

The complex problem of the various forms of the water molecule as affected by the environment is approached independently by the biologist, working with complex biologic systems, and by the physicist, who uses a system of models. A synthesis of the experimental data and approaches of scientists from many disciplines, including biology and medicine, physics, chemistry, mathematics, and engineering, was the goal of the Conference on Forms of Water in