shortly after the peak intensity of outstanding solar flares. The interval between the peak brightness and the arrival of the particles—high energy (10^9 to 10^{11} eV.) cosmic-ray protons—at the Earth varied between 3 min. and 1 hr. These high-energy particles constitute the third group and indicate that in solar flares there exists a mechanism by which particles can be accelerated to relativistic energies.

The enormous energy—about 10^{33} ergs—which is released during a few minutes by an intense solar flare is greater than the entire heat-energy stored up within the solar corona and chromosphere. It cannot, therefore, have been drawn in from the surrounding regions, but must have been stored up slowly *in situ*, almost certainly in the complex magnetic fields permeating the flare region above a large sunspot. It is now recognized that the magnetic lines of force in the flare region are anchored in a plasma of ionized particles, which is in a state of flux, but the mechanism by which the energy is slowly stored in the plasma and then explosively released is not fully understood. About 1 per cent of the energy released is used to accelerate the high-energy particles.

The positions of Class 3 and 3+ flares, in general, are distributed uniformly with respect to the Sun's central meridian, but the positions of the intense cosmic-ray flares which have occurred during the past twenty years are such that seven are located on, or near, the west limb of the solar disk and none nearer than 75° to the east limb. This longitudinal asymmetry and strong preponderance in the western hemisphere means that there is a greater probability that the cosmic rays accelerated into space by a flare west of the meridian will reach the Earth and produce ground-level effects. Since high-energy particles are guided to their destinations by magnetic fields, there must exist at these times a radial magnetic field in the Sun-Earth space and the lines of force along which the particles spiral in towards the Earth must be bent by the solar rotation convex to the west.

When the particles enter the Earth's magnetic field, their trajectories are bent into complicated Störmer orbits, depending on their energies and their directions of travel relative to the Earth's magnetic axis. The positions of the impact zones where the intensities are much greater than elsewhere have been observed and the directions of the original trajectories before entering the Earth's field have been computed for many of the showers. The showers

have all been found to approach the Earth from a limited region of the sky containing the Sun.

The particles are accelerated during the flare flash, which is probably all over within a few minutes; but the cosmic rays in some cases continue to arrive at the Earth for as long as 24 hr. after the flare has died away. This is strong evidence for the trapping and storage of the particles in the interplanetary magnetic fields. These interplanetary fields also modify the 'constant' incoming flux of galactic cosmic rays. For example, at the commencement of a magnetic storm there is a sudden decrease of cosmic-ray intensity—the Forbush decrease—when the primary particle radiation reaching the Earth may be reduced by as much as 30 per cent and may not return to normal for ten days or more. The Earth is apparently trapped inside a 'magnetic bottle', formed by lines of magnetic force which are drawn out into space from a sunspot region by the issuing clouds of storm particles, and within this bottle the Earth is shielded from the normal cosmic-ray flux entering from the galaxy. Particles of lowest energy suffer the greatest reduction of intensity. Furthermore, if when a solar flare occurs within the neck of the bottle, it is assumed that the bottle is bent by the solar rotation convex towards the west and that, at its point of anchorage in the Sun, the neck subtends a solid angle of about one radian, we have a model with which to explain in general terms the longitude asymmetry characteristic of the cosmic-ray producing flares.

The discovery that the Sun accelerates into space particles with energies as high as 10^{11} eV. suggests that the origin of cosmic rays is to be sought in specific astronomical bodies, such as the atmospheres of flare-active stars, in supernovæ explosions and in objects like the Crab nebula where powerful magnetic fields anchored in turbulent, unstable plasmas are known to exist. However, treating the Sun as an 'average star' in regard to its cosmic-ray output leads to too small a value by a factor of 10^6 for the total injection of cosmic rays into galactic space from stellar sources. Nor can solar showers account for the acceleration of the very high-energy particles up to 10^{19} eV. These problems, together with the questions as to how the high-energy particles are contained within the galactic magnetic fields and whether the particles we receive are generated within our own galaxy or have crossed inter-galactic spaces, still require elucidation.

FUNCTIONS OF PROTEIN MOLECULES

THE British Biophysical Society held a discussion on the "Functions of Protein Molecules" on December 13, 1961, as part of their Christmas meeting at the Royal Institution in London. Instead of presenting a diffuse discussion of all possible aspects of biological activities of proteins the symposium was concerned with a fairly detailed treatment of some selected subjects.

The session was introduced by Prof. A. Neuberger, who issued a timely warning about too circumscribed discussions of active sites of protein molecules. He quoted recent work from Prof. Rossi-Fanelli's laboratory which showed that though haemoglobin still reacted rapidly and reversibly with oxygen when some amino-acid residues had been removed, important changes in the kinetics of the reaction occurred

after such chemical modification. The first main speaker was Prof. Q. H. Gibson (Sheffield), who gave a most interesting survey of "Haem-protein and Haemoprotein-ligand Reactions". An impressive range of techniques has been applied to the study of the mechanisms of the reactions of globin with haem and of haemoglobin with oxygen, carbon monoxide and other ligands. Globin from human haemoglobin is a heat-labile protein of molecular weight 33,000 which combines with haem in a rapid and complex reaction via an intermediate complex:

to form the relatively stable haemoglobin of molecular weight 68,000.

The work of Roughton, Gibson and others on the kinetics of individual constants of the reactions of various ligands with the four haems of haemoglobin have presented us with data for the correlation of structure and function. The rapid developments in the crystallographic and chemical elucidation of the structure of haemoglobin, which were discussed by Dr. M. F. Perutz and his colleagues, together with the work described by Gibson, promise an exciting period of fitting together information obtained from widely different approaches.

The paper by Dr. B. R. Rabin and Dr. A. P. Mathias (University College, London) discussed "The Active Site of Ribonuclease". The complete amino-acid sequence and cross-linking of this enzyme is now established, thanks to the work of Moore, Stein, Anfinsen and their colleagues. As a result of work in several laboratories it has been suggested that histidine has an important role in the catalytic activity of ribonuclease. Rabin, Mathias and their colleagues made a very thorough study of the dependence on pH of the velocity and Michaelis constants of the reactions of ribonuclease in a variety of buffer and solvent systems. From these investigations they came to the conclusion that two histidine imidazole groups are involved, one as acid imidazolium ion the other as a base. The two groups reverse their role in the two steps involved in nucleotide hydrolysis. Similar conclusions have also been reached by M. Panar and F. H. Westheimer in a privately circulated description of model building.

Dr. D. E. Koshland (Brookhaven National Laboratory) presented a paper on "Methods for the Study of Active Sites" which was illustrated with examples from work on chymotrypsin and phosphoglucomutase. Dr. Koshland showed that careful quantitative application of the various established methods of chemical modification of histidine and methionine side-chains can give information about the behaviour of enzyme molecules in which only one of several, for example, methionine residues, has been modified. He also described his 'all or none' assay methods, which show, for example, that chymotrypsin with one methionine group oxidized has fractional activity in every molecule and is not a mixture of fully active and inactive molecules. While histidine is essential for the activity of chymotrypsin, methionine modification reduces the activity to about one-third without change in binding, when acetyl-L-tyrosine ethyl ester is used as a substrate.

Dr. B. S. Hartley showed a slide of the sequence of amino-acid residues near the active serine of chymotrypsin and verified the prediction that from the point of view of kinetics methionine must be close to this serine residue. There was some light-hearted

discussion between Prof. Neuberger, Dr. Gutfreund, Dr. Hartley and others about the value of kinetic analyses. It was agreed during the symposium that methods involving kinetics had been sensibly used as a powerful analytical tool. Clearly, kinetic analyses of reaction sequences of enzymes form a solid framework into which any proposed mechanism has to fit. The finer resolution of the electronic detail of reaction mechanisms has to be established from the direct observation and identification of transient intermediates by chemical or physical methods.

After the three main papers a round-table discussion of different aspects of sub-unit structure of enzymes was organized. Dr. H. Gutfreund introduced the subject with a statement of the terms of reference. It was proposed that the study of the physico-chemical aspects of dissociation and aggregation of protein molecules will get a new impetus now that protein structures are being solved and biological functional applications of these phenomena are being discovered. Dr. G. A. Gilbert (Birmingham) discussed some new aspects of the energetics of protein aggregation. Dr. J. R. S. Fincham (John Innes Institute) gave an account of sub-unit structure and genetic complementation, with special reference to his work on glutamic dehydrogenase. A discussion followed between Drs. F. H. C. Crick, Fincham and Hartley with questions from the audience. Attempts were made to define the structural conditions which make complementation possible and those which are suitable for experimental investigation. More space and diagrams would be needed to give a fair presentation of this part of the discussion. The time-limit was reached before the possible role of sub-unit dissociation in metabolic control could be discussed. Dr. Gutfreund had stated in his introduction that various physical mechanisms have been described which cause either dissociation into inactive units or in other systems dissociation into active units. More sophisticated mechanisms causing control by dissociation or activation by reduction or oxidation of —S—S—linkages could also be imagined. In connexion with this and the discussion on genetics he also suggested a classification of control phenomena according to the time-scale involved. First, instantaneous control, over milliseconds to seconds, which involves enzyme activation or inhibition and corresponds to the usual term 'primitive control'. Secondly, adaptive control, over minutes to days, which involves *de novo* enzyme synthesis on addition of an inducer or removal of a repressor. Thirdly, evolved control; this is on an evolutionary time-scale and involves the adaptation of tissue to a new and specialized purpose.

H. GUTFREUND

NON-DESTRUCTIVE TESTING IN ELECTRICAL ENGINEERING

TWO groups of tests used industrially constitute 'non-destructive testing'. One group verifies that apparatus in continual use is not deteriorating, and the other is used for initial testing of every article of a batch rather than of samples only. The methods which may be needed range widely and call on experience from many different fields; and it is probably for this reason that organizations exist for bringing together the people interested in these otherwise unrelated topics. The British National Committee for Non-Destructive Testing is a joint body

representing physicists and mechanical and electrical engineers. At the request of this Committee, the Institution of Electrical Engineers held, in November, a conference on the applications of non-destructive testing in the electrical industry. Its theme was: "How best may the electrical engineer test the quality and endurance of his materials and structures?"

Dr. R. W. Sillars, in an introductory lecture, stated emphatically that there was no well-defined group of physical principles underlying non-destructive testing,