the sensing of rotation rate with respect to an inertial frame of reference has been demonstrated using a traveling-wave gas laser in which the light propagates around in a closed loop. Under stationary conditions, a degenerate pair of independent modes exists which consists of waves propagating in opposite directions around identical paths. Rotation of the laser about an axis with a component normal to the plane of the laser path results in an effective lengthening of one path and a shortening of the other. To sustain oscillations, each path must be an integral number of wavelengths long, so the wavelengths of the oscillations must adjust themselves to meet this requirement. This results in a frequency splitting which is proportional to rotation rate. By sampling the output from each of the modes and heterodyning them together on a photocathode, a beat frequency is obtained which is proportional to rotation rate. Beat frequencies as low as 500 cycles per second have been observed corresponding to a rotation rate of two degrees per minute.

The symposium was cosponsored by the Air Force Office of Scientific Research, the Office of Naval Research, and the U.S. Army Research Office and was organized by the Polytechnic Institute of Brooklyn in cooperation with the Institute of Electrical and Electronics Engineers and the Optical Society of America.

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Protein Structure and Crystallography

Protein structure and crystallography have acquired great importance in recent years (as evidenced by the award of the Nobel Prizes last year) and were the subjects of a symposium held at Madras, India (14–18 January). This meeting, organized by the department of physics of the University of Madras, marked the first time that a conference of its type had been held by a university in that country. Outstanding scientists from all over the world attended; of the 100 delegates, nearly 40 foreign participants came from a dozen different countries.

The first half of the symposium was concerned with protein structure; the main themes were x-ray studies, optical studies, electron microscopic studies, chemical studies, and the genetic code.

In his presidential address, W. L. Bragg mentioned that the solutions to the complexity of structures solved by x-ray methods have been increasing steadily and the recent successful studies of myoglobin and hemoglobin by Perutz and Kendrew can be cited as important landmarks in the history of x-ray crystallography. It is also conceivable that the molecular structure of a virus might be forthcoming in the not too distant future. Results of recent x-ray diffraction studies have included a Fourier map at 4-Å resolution of the globular protein, ribonuclease (D. Harker, Roswell Park Memorial Institute) and the discovery that amino acid-transfer RNA has a double helix structure of three and a half turns which is similar to the structure of DNA (M. H. F. Wilkins, London).

In 1954 the first triple helical structure of collagen was discovered by the research of G. N. Ramachandran (University of Madras). Since then the structure has gone through a series of refinements and culminated in the latest version in 1960–61. Ramachandran pointed out how the triple helix and the alpha helix appear to be the two main helical chain configurations which occur in polypeptides and proteins. Additional protein structure work has been carried out on hemoglobin, myoglobin, lysozyme, beta-lactoglobin and alpha-chymotrypsin (D. C. Phillips, Royal Institution, London) and on natural and artificial polypeptides.

An optical method employed in the study of the configuration of proteins has been the use of the ultraviolet absorption spectra. J. T. Edsall (Harvard) has utilized the absorption band near 190 $m\mu$ to estimate the extent of helix formation in peptides and proteins. The frequencies and polarizations of infrared absorption bands can also give useful information about the orientation and configuration of the chains in protein structures. According to T. Miyazawa (Institute for Protein Research, Osaka), the alpha form, the beta form, and the random coil can be identified in this manner. Other optical and hydrodynamic studies have shown poly-L-proline-type polypeptides can exist in two forms, both in solution and in the solid state (E. Katchalski). Measurements of polypeptides and proteins by the optical rotatory dispersion technique have been used to determine helix content and the sense of the helix (E. R. Blout, Harvard).

Information obtained by using the

electron microscope in protein research has supplemented data from other sources. Recent electron microscopic and sedimentation studies on different types of human hemoglobin appear to support the picture of the molecule obtained by x-ray diffraction.

Chemical methods have proven useful for finding the sequence of amino acids in the protein ribonuclease (S. Moore, Rockefeller Institute) and finding the active (zinc binding) site of the enzyme carboxy-peptidase A and determining the amino acid sequence around the thiol there. Other investigations have been made on the physical and chemical properties of resilin, a rubber-like protein found on the wings of insects (T. Weis-Fogh, Copenhagen) and on the amino acid composition of ichthylepidin of fish scales (R. V. Seshaiya, Annamalai University).

The determination of the genetic code, a topic of intense current interest, is dependent upon discoveries in protein structure research. Previously it was thought that the base uracil was essential for all the codes. However, recently S. Ochoa (New York University) has shown that polynucleotides containing only adenine and cystosine lead to the synthesis of polylysine and polyproline, respectively, and several of the coding units do not contain uracil.

The second part of the symposium was devoted to crystallography. The main topics dealt with methods of structure analysis and crystal imperfections.

Several approaches have been attempted in the study of the phase problem. The Patterson function has been described as a special kind of image function which can be studied by using an image algebra developed for this purpose. However, it appears that nonperiodic functions with the same self-convolution do not exist unless the function is centrosymmetrical (M. J. Buerger, Massachusetts Institute of Technology). According to Dan McLachlan (Denver), optical arrangements can be devised to substitute for computation in the phase determining techniques. Another technique, devised by Ramachandran, has been utilized for the determination of a structure when only a part of it is known. When isomorphous crystals or anomalous dispersion data are available it is possible to determine the unknown part by feeding the data into a Fourier synthesis without actually calculating the phase angle. The relative superiority of the beta synthesis, as compared with the

usual heavy atom synthesis, has been demonstrated by practical tests.

Various direct methods of structure determination used at the present time include the statistical method of sign determination (S. Naya *et al.*, Japan); the "shift product" method, and another which employs the Sayre relation to find the signs of additional structure factors (W. Hoppe, Munich); and the use of electronic computers (W. Cochran *et al.*, Cambridge).

The anomalous dispersion technique is another method used in protein structure research. As a result of work on the absolute configuration of $NaClO_3$ and $NaBrO_3$, Bijvoet (Utrecht) found that the crystals of the two compounds, which are alike and have the same sense of optical rotation, have opposite configurations. Additional structure analyses have been performed on the compound factor Vla, a derivative of vitamin B_{12}; barium glucose-6-phosphate; and other crystals.

One useful technique employed in the determination of crystal perfection is x-ray reflection. Defects, such as those of the point type, can be revealed by accurate measurements of x-ray intensities. According to R. Parthasarathy (Madras), the intensity of x-ray reflections from perfect and mosaic crystals reveals that under certain conditions the integrated intensity for a perfect crystal can be greater than that of a mosaic crystal of the same thickness.

Investigations on disorder in crystals have encountered many problems. According to H. Jagodzinski (Würzburg, West Germany) a mathematical treatment for the two- and three-dimensional cases is difficult to handle. He outlined general rules that could be applied for the occurrence of sharp and diffuse maxima in the reciprocal lattice for a disordered crystal.

Advancements in crystallography have occurred not only in research, but also in instrumentation. Two new instruments for use in x-ray crystallographic work are the automatic, four-circle, counter diffractometer and the integrating Weissenberg camera for low and high temperature studies.

The symposium was followed by a winter school (22–27 January) in which ten of the participants delivered seminar lectures. This school was organized with the assistance of the Council of Scientific and Industrial Research and the University Grants Commission, Government of India.

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