photoreductant was discussed by Vennesland, Nakomoto, and Stern, by D. W. Krogmann, and by Jagendorf and Forti. In addition, Vennesland and his colleagues described an apparent confirmation of Warburg's recent discovery that carbon dioxide is required (but not consumed) in the Hill reactions.

The existence of adenosine triphosphatase reaction in chloroplasts under rather specialized conditions was described by Barbara Petrack and F. Lipmann. A lower level of adenosine triphosphatase activity was described by Strehler and Hendley.

K. V. Thimann reviewed the phototropic phenomena in plants and suggested a correlation between the orientation of plastids with respect to light and the phenomenon of lateral transport of growth substances under the influence of light. Further data on phototropism were presented by A. W. Galston and R. Kaur. C. Pittendrigh discussed photoperiodic phenomena, including both plant and animal mechanisms, and W. S. Hillman described experimental modifications of photoperiodic reactions in *Lemna minor*.

In the final session, on vision, discussion ranged from the biochemical basis, described by George Wald, to the electrophysiological responses, discussed by W. A. H. Rushton, T. Goldsmith, and E. F. MacNichol, Jr. The latter, in a very interesting paper, was able to show that the electrical discharges in the optic nerve fibers of the goldfish are differentially affected by changes in wavelength in such a manner as to provide a mechanism for color vision. Color vision in insects was reviewed by T. Goldsmith, with special emphasis on evidence for its occurrence and the spectral sensitivities found.

W. A. H. Rushton considered especially the problem of how nerve signals are generated after bleaching of the visual pigments. This question represents one of the major gaps in our understanding of the mechanism of vision at the present time and was not answered at this symposium. However, various characteristics of the system were defined by Rushton from the relationships between light threshold and the amount of pigment bleached, and between the light intensity and the kind of nerve signal generated.

The symposium volume, to be published shortly by the Johns Hopkins Press, should serve as a useful and up-to-date guide in the range of topics covered.

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Physicomathematical Aspects of Biology

A 3-week postgraduate course on physicomathematical aspects of biology was given in Varenna, Italy, from 11 to 30 July, under the sponsorship of the Italian Physical Society. It was the 16th of the series of postgraduate summer courses that were sponsored by the society.

N. Rashevsky, chairman of the committee on mathematical biology at the University of Chicago, was invited to organize and direct the course. The objective of the course was to present to the students a balanced program of theoretical and experimental research in selected subjects. This objective determined to a large extent the selection of the eight lecturers. Three of the lecturers—A. Bartholomay (Harvard), H. D. Landahl (Chicago), and N. Rashevsky—represented the theoreticians. The other five lecturers—E. Boeri (Ferrara, Italy), M. A. Bouman (Soesterberg, Holand), J. Defares (Leiden, Holland), M. Polissar (San Francisco), and M. Wise (Belmont-

Sutton, England)—represented both experimental and theoretical research.

Altogether, 53 1-hour lectures were given. There were two lectures in the morning and one or sometimes two in the afternoon, with ample time left for discussions. Except for the four lectures by Rashevsky, which were given at the end of the course, the lectures of all speakers were spread over the whole period. All lectures were given in English.

Of the 26 students, two were Americans, one was German, one was a Swede, one was a Dane, and the others were Italians. The physical and the biological sciences were about equally represented among the students. In academic attainment the students ranged from full professor to young Ph.D.'s.

The same topics were sometimes discussed by two different lecturers, one discussing from a theoretical, the other from an experimental, point of view.

Bartholomay lectured on the general subject of reaction rates. The specific topics covered were the classical deterministic model of reaction rates, the collision theory, the modern transition state theory, and the Michaelis-Menton model of enzymatic reactions.

Boeri discussed the general subject of enzyme reactions. He spoke on reactions between proteins and ligands, reaction of hemoglobin with gases, electrotitration of proteins, antigen-antibody reactions, extension of the Michaelis-Menton theory, specificity of reactions, multienzyme states, and the appearance of enzyme activity. His lectures represented a blend of experimental and theoretical considerations. They were closely correlated with the lectures of Bartholomay, and numerous references to the presentation of the other were given by both lecturers.

Bouman spoke on sensory phenomena, discussing the quantum theory of vision (particularly such topics as the dependence of visual threshold on the time and on the stimulated area), color vision, adaptation, discrimination of intensities, visual acuity, color discrimination, and directional color effects in the retina. His lectures, which also represented a blend of the mathematical and the experimental approach, were illustrated by numerous slides.

The general topic of Defares's lectures was the physics of respiration. He discussed, both from a theoretical and experimental point of view, the respiratory system as a feedback mechanism, giving a cybernetic analysis of the respiratory "chemostat." Defares also discussed the problems of the rise of carbon dioxide tension in the lung during rebreathing and his joint work with Wise (presented by the latter) on a mathematical method of estimating the statistical distribution of inspired gases from experimental mixing curves.

Landahl lectured on four different subjects. The first was the mathematical theory of the central nervous system and its applications to numerous phenomena, such as reaction times, flicker phenomena, apparent movement, discrimination and learning, conditioning, and color vision. Several of these topics were closely related to topics discussed by Bouman, and a useful exchange of ideas took place.

The second subject of Landahl's lectures was the mathematical theory of some pharmacological phenomena. He discussed such problems as interaction of drugs, a mathematical model of response to Pitressin, and a mathematical model of the effect of aldosterone on salt excretion.

His third topic was the theory of diffusion phenomena. He discussed steady states and transient phenomena in biological systems and presented a mathematical theory of the diffusion of population with simultaneous growth. He then discussed the application of diffusion theory to spreads of rumors.

Landahl's final subject was the theory of removal of airborne particulate matter from the respiratory tract and the practical application of the theory.

Polissar spoke on mathematical models of the human heart, discussing, in terms of the proposed models, a number of experimental results, such as the analysis of indicator curves. Several alternative models and their experimental implications were discussed.

Wise gave three lectures on human radiation hazards, discussing such problems as the assessment of a small risk in a very large population and the estimation of elimination rates for radioactive particles within the body. He also gave a discussion of radiation-induced leukemia.

Rashevsky gave four lectures on general mathematical principles in biology. In the first two lectures he discussed his own work and the work of his associates on the problem of organic form from the point of view of the "principle of optimal design." In the last two lectures he spoke of the "principle of biological epimorphism," which emphasizes the relational aspects of biology and leads to a number of conclusions, some of which may be of clinical importance.

The course will be published as a book.

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