Mathematical Biology

THE aim of mathematical biology is to introduce into the biological sciences not only quantitative, but also deductive, methods of research. The underlying idea has been to apply to biology the method by which mathematics has been successfully utilized in the physical sciences. This method can be briefly described.

First, the actual situation, the biological problem presented by nature, is replaced by an idealized model. This is done because one cannot hope to deal with all aspects of reality at once, and also because some of these aspects may be irrelevant to the question at hand. Next, the idealized model is stated in mathematical terms, and the consequences of the mathematical statement are derived. Finally, these deduced results must be reinterpreted in terms of the original biological problem.

In its early development mathematical biology was largely confined to mathematical genetics and ecology, as represented by the work of R. A. Fisher, J. B. S. Haldane, S. Wright, V. Volterra, V. A. Kostitzin, A. Lotka, and G. F. Gause. With the organization of the Committee on Mathematical Biology (formerly Section of Mathematical Biophysics) at the University of Chicago under N. Rashevsky in 1934, a group of workers, devoting themselves exclusively to this method, have developed mathematical theories of a number of diversified biological phenomena. Among these may be mentioned the following:

Mathematical biophysics of metabolizing systems. The applications of diffusion equations to idealized models of cells characterized by specific metabolic processes and semipermeable membranes lead to equations relating rates of respiration to oxygen concentrations, mathematical expressions describing the deformation of cells during their division, predictions concerning critical size of cells, and rates of growth and division as functions of biochemical parameters, such as the glycolytic coefficient.

The theory of nervous excitation. On the basis of certain assumptions governing the rate of accumulation and dissipation of "excitatory" and "inhibitory" effects impinging on a nerve fiber, equations are derived relating excitation time to the strength of impinging stimulus, the magnitude of an alternating current just sufficient to excite to the frequency, velocity of impulse propagation to the diameter of the fiber, etc. Recently the phenomenon of nerve excitation, particularly its "all-or-none" character, was theoretically related to electrochemical events in the vicinity of the nerve cell.

The theory of transynaptic transmission of excitation. Various models of the central nervous system were constructed to account for conditioning, learning, discrimination, and abstracting phenomena. The derived equations concern such matters as reaction times under various conditions, memory curves, learning curves, discrimination accuracy, and other psychophysical data.

To mention other fields of investigation in mathematical biology, one might list theories on the biological effects of radiation, theories of ontogenetic and phylogenetic development of organic form, and the application of thermodynamic principles to theories of physiological equilibria.

Recent trends indicate a concentration on stochastic methods, in particular their application in attempts to construct a "statistical dynamics" of the nervous system, viewed as a vast collection of units (neurons) interacting in accordance with certain laws. Suggestions implicit in the theory of servomechanisms (cybernetics) are also being investigated for their possible applications to the theory of the nervous system, viewed as a communication mechanism in which closed loop circuits play a prominent part.

It is hoped that in time the suggestions of Schroedinger and Jordan along the lines of applying quantum-mechanical principles to the theory of the life processes will likewise find fruitful application.

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