Symposium on Mathematical Models of Biophysical Mechanisms

CHAIRMAN: WALTER A. ROSENBLITH

DEPARTMENT OF ELECTRICAL ENGINEERING AND
CENTER FOR COMMUNICATION SCIENCES
(RESEARCH LABORATORY OF ELECTRONICS)

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

CAMBRIDGE, MASSACHUSETTS

INTRODUCTION

This is neither the place to define mathematics and biophysics nor the place to philosophize on the relations between these two fields which differ so drastically in age. Let us, however, examine briefly how certain mathematical approaches and techniques have started to influence the work habits of many who call themselves biophysicists.

Biophysics derives much of its strength from its working partnerships with physics, chemistry and biology. Hence, biophysics found itself naturally endowed with the mathematical tools that chemists and physicists use. In order to deal with the spectrum of behaviors that complexly organized living structures exhibit biologists make use of numerous mensuration and quantification procedures. But there exists as yet no coherent theoretical fabric or mathematical framework that allows us to consider, in a commensurable fashion, the phenomena that characterize the different levels of biological organization. Experiments have done much to weaken the traditional (and almost metaphysical) concern with the well-known dichotomies: living and non-living, structure and function, quantity and quality, discreteness and continuity. The preoccupation with part-whole relations persists, though it, too, has been much attenuated. But we still lack a clear understanding of the range and variety of biophysical mechanisms by means of which nature transcends these dichotomies. It is here that the lack of appropriate mathematical tools has perhaps made itself most critically felt.

About 30 years ago N. Rashevsky started to assemble a group dedicated to the task of building a mathematical biology. The new discipline was to have the same relation to experimental biology that mathematical physics has to experimental physics. Much interesting work has come from this group whose members were rather anxious not to be mere handmaidens of their experimenting colleagues. However the absence of direct contact with experimentation made itself felt over the years, particularly so since Rashevsky and his associates tried to deal, courageously, with the broad realm of the life sciences and even with the social sciences.

Problems of communication and control brought, during and after the second world war, a group of distinguished mathematicians in contact with engineering systems having many components. The necessity of matching these devices to man's sensory and motor capacities led them quite naturally to consider the human nervous system as another rather complex system. Information and communications theory, servo-theory and the study of automata seemed to suggest a multitude of promising models for researchers interested in brain function.

Some of the bright young mathematicians and engineers who followed in Wiener's, Shannon's and von Neumann's footsteps were able to invent biological dream worlds in less time than experimentalists needed to assess the reality-orientation of their postulates. Many traditionally trained biologists reacted by adopting a somewhat defensive posture against the invaders. But today, a few years later, we find that many of the concepts and concerns of the cybernetic era are—often in a considerably altered form—on their way toward becoming the common currency of exchange at the interface of the life sciences with the other sciences.

Life Scientists are about to arrive at a modus vivendi with mathematicians provided the latter acknowledge that biological problems (which involve specificity, irreversibility, non-stationarity, non-linear interactions, to list just a few of the difficulties) deserve to be considered as being more than merely peculiar boundary conditions or constraints. What makes us hopeful that we shall not only be able to coexist peacefully but even to cooperate is the emergence of a mathematical technology that centers about the digital computer. This general-purpose device enables mathematicians and biologists to conduct "mathematical experiments" at a scale and with a speed that were never before possible.

Though there exist as yet no mathematical principles that seem valid for the whole of biology we can now test much more effectively the generality and usefulness of certain concepts that have posed their candidacy at various levels of biophysical complexity. Computers help us in the analysis of our data and in the formulation of our models. We can now combine experimentation on specimens by means of laboratory techniques with experimentation on models which we often carry out by rewriting our programs. We have acquired a mathematical instrument that acts like a microscope of considerable power: it can be focussed upon problems of almost any grain provided we are able to formulate our hypotheses sharply enough. Simulation constitutes thus a powerful tool which helps us in the dissection of complex biological systems. The biophysicist is however aware that he must go further and seek to discover the mechanisms that underlie the behavior he observes. He knows that intelligent model building is a useful art at practically any level of abstraction if for no other reason than that good models lead one to ask questions which mere description tends to ignore.

In recent years mathematical models have enjoyed significant success in predicting certain aspects of human behavior. Their very success has emphasized the need of understanding the relevant biological mechanisms about which the model builders felt disinclined to worry until they had made sense out of the behavior of the organism.

In the future young biophysicists who possess the necessary skills in handling mathematics and computers will produce comprehensive catalogs in which the various entries will, for instance, relate the properties of systems to the properties of components. It is far too early to tell whether such catalogs will have enough in common to deserve the unitary label of "mathematical biophysics."

The papers that follow represent a non-random sample drawn from areas in which experimental work and mathematical models seem at present to be interacting in a particularly vigorous and fruitful manner.

WALTER A. ROSENBLITH

This work was supported in part by the U. S. Army Signal Corps, the Air Force Office of Scientific Research, and the Office of Naval Research; and in part by the National Science Foundation and the National Institutes of Health.