matics of stability theory; likewise it is another important insight drawn from system theory that automata theory, far from being different in kind from dynamical system theory, is actually as close a paraphrase to a discrete setting of the formalism of dynamical system theory as possible. These are very important unifying insights, and come from the technical development of system theory itself.

More important even than these insights is the more general fact that the further development of system theory is likewise, of necessity, going to be technical in character. It is one thing (a most important thing, to be sure) to draw attention to dynamical homologies and analogies between systems at different levels of organization, and quite another to formally exploit these analogies and homologies to obtain information about a particular class of systems. This is already being done in biology; to learn in detail how and when it may be done in general terms is perhaps the most exciting vista in system theory. This technical development of system theory itself is essential if it is to play the integrative role envisaged by Bertalanffy; but (perhaps partly owing to Bertalanffy's dislike of technical specialization) the role of these developments seems to have been deliberately minimized. In the reviewer's opinion, this failure to emphasize or even to recognize the role of the technical side of system theory and its application from today's vantage point almost unbalances the entire book.

Despite this important caveat, Bertalanffy's book is an authoritative and noble volume, and the scientific literature is richer for having his contributions assembled in this definitive form.

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Describing Life Processes

Mathematical Ideas in Biology. J. MAYNARD SMITH. Cambridge University Press, New York, 1968. viii + 152 pp., illus. Cloth, $5; paper, $1.95.

The purpose of this book is to show that mathematical reasoning can sometimes illuminate biological processes. The author points out that many biologists are likely to suppose that the mathematics applied to biology is mainly statistics, and since there are many books covering this area of mathematics it is not included as a topic in this one. Emphasis is on the use of mathematics as a tool in the development of concepts and in the formulation of quantitative models which give insight into biological processes. A brief rationale for the importance of this approach is well stated in the introduction. The book is not meant to be a text or treatise. The intention is to treat a variety of problems in order to illustrate the utility of various branches of mathematics. The author is able to present many of the arguments in an intuitive way that can be of benefit to the biologist without a background in mathematics. Concise mathematical appendices are included to help make this possible.

The chapter "Some consequences of scale" emphasizes the importance of dimensional analysis. It introduces the principle that certain minimum design requirements restrict the sizes of animals and their organs. Thus the tensile strength of bone, the maximum tension that can be developed by muscle, and its rate of development limit the size of animals, restrict their shape, and limit their rate of movement. Very simple arguments give insight into the observation that the height to which an animal can jump is relatively independent of its size. The concept of optimality is touched on. Several additional topics are brought up in this chapter.

While one might feel that too many ideas are presented in so short a chapter, a more serious criticism is that the ideas have not been adequately related to work in the literature. Most of the topics have been treated in detail (for example, by Rashevsky in *Mathematical Biophysics*, ed. 3, 1960), but no reference is made directly to such work, and there are only a few general references listed at the end of the book. Thus the reader is given little assistance in finding out what work has been done on a particular topic. For example, the statement "Therefore *V*, the velocity of flow in the aorta, will not vary with size [of the animal]" is in the nature of a prediction. The addition of a sentence stating that the velocity of blood in the aorta of mammals is about 24 centimeters per second [W. R. Stahl, *Science* **137**, 205 (1962)] would have made it clear that the prediction is borne out. This case should have been presented in greater detail, and the example would have been more complete had a discussion of how the thickness of the ventricle wall should increase with heart size been included.

The next four chapters give a good introduction to population regulation and interaction and to the genetics of families and populations, with adequate references. The opportunity is taken to introduce a number of important and useful concepts and methods. Among these are conditional and inverse probability, recurrence equations, stability and instability of equilibria, and the solution of problems by means of both difference and differential equations. In these and other chapters many interesting questions are raised and hints for finding their answers are often given.

In a chapter on regulation and control, one of the examples treated is the control of protein synthesis. This example was chosen from the literature in part to illustrate a system that can exhibit maintained oscillations. In the model the gene produces messenger RNA, which in turn produces an enzyme capable of converting a precursor into a product. The product then acts as a repressor on the gene activity through competitive inhibition. If the system is linear and irreversible, except for the repression, one obtains three equations for the rates of change of the three substances. Analog computer simulations of the solutions, showing the amounts of the three substances as functions of time, are given. The concept of phase space is discussed and the amount of enzyme is plotted against the amount of product to illustrate a limit cycle. (Note that the notation used in the legend follows the original reference, not that used in the book.) However, since this system does not in fact show oscillations, the oscillations obtained presumably being introduced by the analog simulation procedure, the author suggests modifying the equations by introducing a time delay to allow for travel of mRNA from gene locus to ribosome. Unfortunately the system given cannot give maintained oscillations even with the time delay. However, this difficulty can be overcome by assuming second-degree inhibition or by assuming that there is an enzymatic removal of mRNA at a sufficient rate, the enzyme affinity being high.

The last chapter, on diffusion and similar processes, gives the author an opportunity to introduce the notion of partial differentiation. Some brief examples illustrate the utility of dimensional arguments. This discussion could have been used to make reference to the approximation methods of Rashevsky and others, which have been used extensively. Also discussed in this chapter is the model system of Turing, in which diffusion, coupled with chemical reactions, leads to inhomogeneities of concentration which are stable. These inhomogeneities could be the basis for the development of patterns in morphogenesis. The arguments for this example are necessarily qualitative, but the graphical presentation makes the process understandable.

Although there are additions and changes that could have substantially facilitated the reading and understanding of some of the topics discussed, many biologists with diverse interests could profit from reading this book, becoming acquainted with unfamiliar areas of mathematics or gaining insight into the ways in which mathematical ideas can prove to be useful aids in understanding biological processes.

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Organization

The Art of Organic Forms. PHILIP C. RITTERBUSH. Smithsonian Institution Press, Washington, D.C., 1968 (distributed by Random House, New York). x + 152 pp., illus. $10.

Most scientists have esthetic reactions to their subject matter. On a plane of deep abstraction, a theoretical physicist may see beauty in a mathematical relationship. More objectively, to a mammalogist the teeth of beasts are beautiful, and a pathologist may apply that adjective to a suppurating abscess. An artist, professionally esthetic, is not likely to appreciate those examples, but there is a wide range of forms—a diatom, an orchid, an impala—appealing in an esthetic way equally to scientist and to artist. One might add a snowflake and a bird's song as further examples, but it is noteworthy that most of the examples that rise to mind are organic and are visual.

That community of reactions among scientists and artists does not in itself constitute a functional connection between science and art. Some connection may be claimed in terms of search for truth along different paths, but the two concepts of truth involved are so equivocal that little concrete sense emerges. It is more significant that the sciences and the arts have in common a search for organization and relationships that in scientific terms are rationally meaningful and in esthetic terms are emotionally satisfying. That, too, may be especially evident in the organic and the visual.

It is that sort of connection that is traced historically by Ritterbush in a broad sweep from the botanist Nehemiah Grew, born 1628, to the painter Michael Clark, born 1946. The thesis is that organic forms, that is, the forms of living things, are in fact organized to unique degrees and in unique ways, that this kind of organization often has been taken as an exemplar by artists, and that artistic or esthetic perception conversely sometimes has been a guide for scientific comprehension of organisms. This history is a fascinating one, and it is here well and succinctly told—the text in the volume totals only about 75 pages.

It is emphasized that reference is not to the literal copying or illustration of organic forms on the part of artists. "Rather than imitate the external forms of nature, which [Kandinsky] compared to trying to recreate the sound of the chicken farm in music, the aim of art should be to represent the innermost quality of nature, its atmosphere." And indeed the 24 reproductions of paintings in this volume are almost completely nonrepresentational. Those that do most nearly resemble actual organic forms, for example Kawashima's "New Symbolism," are not the most esthetic, and they suggest parody more than organic creativity. Others, for example "Geography of Phantasy" by Tobey, have no evident relationship to the concept of organic form, or indeed of organization. Nevertheless, the collection as a whole does illustrate artistic concepts that do embody organic analogies without homologies. However, some of the works given special emphasis in the text, for example those of Ernst Kupferman, are not illustrated.

The other side of the thesis is the influence of esthetics on science. It is demonstrated that such an influence exists, but the impression left is that when esthetic considerations became really dominant over scientific enquiry the result was, at best, a blind alley. Goethe's idealistic morphology, treated at length in introducing this side of the matter, is a good example of the flat failure of the primarily artistic approach to scientific problems. Unfortunately Ritterbush's devotion to the idea of fruitful reciprocity of science and art has led him to some extremes that are false or inane. It simply is not true that "the progress of biology beyond the cell theory has consisted in large measure of demonstrating the existence of significant symmetry properties in the organisms themselves (or in forms abstracted to represent them)." It is absurd to impute connection between Harrison's invention of tissue culture and an observer's expectation that figures painted by Kandinsky will similarly flow or extend.

This book was prepared with reference to an exhibit of paintings, also entitled "The Art of Organic Forms," and a catalogue of the exhibit is included. The exhibit has been dispersed, and many of the paintings are now neither visible to the public nor here illustrated.

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Biophysics of Ecology

Energy Flow in Biology. Biological Organization as a Problem in Thermal Physics. HAROLD J. MOROWITZ. Academic Press, New York, 1968. xii + 179 pp., illus. $9.50.

This book is a biophysicist's view of the complex levels of organization of biology, ecology, and the biosphere. It is an effort to resolve the deep contradiction felt by many physicists in the biological tendency toward order in systems whose molecular components have tendencies toward disorder. The book starts with two chapters on physical theorems concerning the behavior of energized populations of molecules, including aspects of steady-state thermodynamics, and a chapter that recapitulates biology into 13 generalizations as seen from the molecular stance. Chapters 4 and 5 are lucid statements of the thermochemistry of protoplasm, including calculations of the entropy contents of formation that will allow more biologists to change their calorimetry data on heats of reaction to potential energies instead of incorrectly using one to approximate the other. Included is the quantitative