be more directly related to dynamic function?

The answer to the first question, given implicitly by several contributors to the present volume (notably by Monod in the introductory chapter), and elsewhere discussed explicitly and in depth by Bernal (*J. Mol. Biol.* **24**, 379 [1967]), is unequivocally no. We must distinguish among three ways in which symmetrical structures arise: (i) self-assembly on the basis of intrinsic atomic properties, as in crystals; (ii) self-assembly on the basis of biologically evolved recognition and binding sites (Bernal refers to this as "prescription and self-assembly"), as in enzyme aggregates, virus shells, and the like; and (iii) growth. Ambiguous, borderline cases doubtless occur, as in other biological classifications, but in general these mechanisms are clearly distinct. As Bernal points out, the symmetry of a sea star does not arise from self-assembly of the arms.

Many readers will recognize the second question as one that has received much attention in connection with the study of oligomeric regulatory enzymes. The cooperative kinetic behavior that is characteristic of this type of enzyme evidently depends on interaction between aggregated subunits. Are such symmetry elements as the molecules possess merely a necessary consequence of self-assembly of identical units, or may the symmetry itself be functionally important, as is postulated in the well-known model of Monod, Wyman, and Changeux? Several participants in this symposium deal, implicitly or explicitly, with this problem, but the answer remains in doubt.

As might be expected, those speakers who deal with structure emphasize symmetry, whereas those whose topics are more functional or dynamic deal with asymmetry. The distinction is emphasized by Malmström, who comments, in effect, that the search for order in nature may all too easily become self-directing—symmetry sometimes lies in the eye of the beholder. Because scientists search for ordering principles, "we tend to invent models involving a high degree of symmetry. This predilection may be a distinct disadvantage when we are investigating a system whose function involves an asymmetric structure." Malmström's investigation of copper-containing oxidases has shown that these molecules, previously thought to contain identical units in a highly symmetric structure, are in fact both functionally and structurally asymmetric, with at least three distinct environments for copper atoms.

Because of the general title and the wide range of topics covered in this symposium, a listing of authors and topics seems desirable. Most of the authors are sufficiently well known that their names will indicate the general approach.

An initial short section, Basic Views on Symmetry, includes a general essay on biological symmetry by Monod, an elementary mathematical treatment of helices and spirals by Coxeter, and a discussion of symmetry in nuclear, atomic, and complex structures by Weisskopf. The next section, Prediction of the Conformation of Macromolecules, includes survey articles by Scheraga, Ramachandran, and Liquori. A section on Interaction between Subunits in Polymeric Proteins contains a discussion by Rossman and colleagues of their exciting findings on the alterations in symmetry and structure of M_4 lactate dehydrogenase that follow from ligand binding, a discussion by Theorell of isozymes and subunits of liver alcohol dehydrogenase, the article by Malmström previously mentioned, an article on electron microscopy of oligomeric proteins by Valentine, an article on oxygen-hemoglobin interactions by Schuster and Ilgenfritz, and one on poly-L-glutamic acid aggregation by Schuster, Jennings, and Spach. A section on Symmetry and Cooperativity in Biological Membranes contains theoretical discussions by Kilkson and by Wyman and a theoretical-experimental treatment by Changeux of cooperativity and transitions in membranes, an article on enzymes immobilized in artificial membranes by E. Katchalski, and one on membrane crystallites in insect photoreceptors by Gemne. The section on Assembly and Structures of Viruses quite naturally bears the closest resemblance to the overall title of the symposium, since the symmetrical assemblages of the virus proteins presumably serve mainly structural, rather than dynamic, functions. Klug discusses tubular variants of the spherical papilloma viruses, Lonberg-Holm and colleagues discuss proteins of adenovirus, Höglund and colleagues write on the nucleocapsid of influenza A2 virus, Kellenberger presents a very interesting discussion of polymorphic assemblies of virus proteins, and Lundin and colleagues report on satellite tobacco necrosis virus. A section on Aspects of Macromolecular Arrangements in Muscles begins with an interesting general article by Engelhardt on biological movement, expressing doubts concerning the popular sliding-filament model for muscle movement. This is followed by a very informative discussion by Caspar and Cohen on polymorphism and protein function, with special emphasis on tropomyosin, and a brief discussion by Afzelius of filament symmetries in arrow worm muscle. The appendix consists of an admirably lucid short article by Klug on point groups and the design of aggregates, which will be helpful to readers with little background in these matters.

As is usual in such symposium proceedings, nearly everything in this book has been previously published in the original literature. Juxtaposed in one volume and, in some cases, more generally oriented than the research papers, these articles may, however, deepen the reader's insight into the dualism between symmetry and structure on the one hand and asymmetry and function on the other. Recognition of this dualism is far from new, either in biology or more generally; Caspar and Cohen cite Coleridge, and Changeux follows Nietzsche in invoking Apollo and Dionysius. As perhaps the most fundamental of the contradictory/complementary relationships of life, this dualism takes on new aspects at each stage in the advance of knowledge; it will be with us, always new but always the same, for as long as men seek to understand living systems. It is the chief merit of this volume that it brings together the contemporary views of scientists who have approached the problem in different ways, guided by quite different conceptual backgrounds.

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A Memorial in Embryology

Organization and Development of the Embryo. ROSS GRANVILLE HARRISON. Sally Wilens, Ed. Yale University Press, New Haven, Conn., 1969. xxvi + 294 pp., illus. $15. Silliman Lectures, Yale University.

This posthumous volume is based upon the outline and notes prepared by the author for the Silliman Lectures he delivered under this title at Yale Uni-

versity in 1949. Prolonged illness thereafter prevented him from completing the manuscript for publication prior to his death in 1959. The present volume owes its existence to Sally Wilens, whose long association with the author has permitted her to select the text and illustrations with judicious perception and in keeping with the author's plan for presentation.

The volume is a summary of Harrison's major research contributions presented in the context of more general problems of embryonic development. Five of the seven chapters are reprintings of major published addresses delivered at various congresses, symposia, and conferences held between 1927 and 1939. The great body of the book, therefore, is the author at his most studied, incisive, and analytical best, which few have excelled. His own scientific work, as well as that of his predecessors and contemporaries, is objectively reviewed as part of discussions of cell differentiation, the significance of tissue culture, differentiation within the nervous system, the origins of symmetry in embryonic primordia, and the application of transplantation techniques to the analysis of embryonic systems. These chapters, although autonomous, collectively afford a rich source of historical perspectives, as well as provide insights into the status of experimental embryology in the third decade of this century as seen through the eyes of the preeminent American vertebrate experimental embryologist of his day. This selection of essays should take its place in the enduring literature of developmental biology.

It is desirable that the volume be read with an awareness of the time of its writing. One is impressed anew with the penetrating analyses and deductions that were possible prior to the application of more recent techniques of biochemistry, radiography, and electron microscopy. The tools of chemistry are almost totally absent from the experimental methods enumerated in this volume. The biological techniques of tissue culture, microsurgery, and transplantation which Harrison used in a masterly way and thereby helped to elevate as sovereign instruments for embryonic analysis are exploited in his classic studies on nerve outgrowth, as well as in his analyses of polar symmetries in the amphibian ear and limb. The sequential determination of anteroposterior, dorsoventral, and mediolateral axes within these primordia was revealed through elegantly simple transplantation and rotation experiments, and is described with eloquence. The interpretation of data clearly revealed a progressive acquisition of regional specificities in differentiation at a level of subtlety that probably cannot, even today, be duplicated by any chemical means. It is to be hoped that by bringing to the fore again the concepts of differentiation fields the accounts of these experiments will refresh memories of old problems and will reactivate interest in their solution.

The second chapter is a hitherto unpublished but long known work of the author on normal development in the spotted salamander, *Amblystoma punctatum*. All students of amphibian embryology will welcome the publication, at long last, of the elegant halftone illustrations of the "Harrison developmental stages" prepared under his direction by Lisbeth Krouse. The illustrations are accompanied by morphological definitions of each stage, and with developmental growth curves for this species at 15° and 20°C. This chapter will be an essential reference for embryologists as long as ontogenic studies are carried out on eggs of the spotted salamander. Omitted from this volume is any reference to the unremitting attempt by Harrison to reverse the law of priority in nomenclature and reestablish the intended name for the spotted salamander, which had been misspelled through a printer's error in the original listing. To all but the experimental embryologists following the Harrison tradition, the spotted salamander is known as *Ambystoma maculatum*.

The primary purpose of the volume can be read between the lines of the editor's preface. It is a biography of the author written with warmth and sensitivity. In addition, there are appendices giving complete bibliographic references of the author's publications and memorial tributes to him. Thus, although the volume is largely a compendium of writings by Harrison, it is also a memorial to him. The community of science owes a lasting debt of gratitude to the editor for bringing this major work in embryology to completion.

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Zoology for Zoos

International Zoo Yearbook. Vol. 10. JOSEPH LUCAS, Ed., assisted by Ruth Biegler. Zoological Society of London, London, 1970. x + 372 pp. + plates. $21.

Man and Animal in the Zoo. Zoo Biology. HEINI HEDIGER. Translated from the German edition (Zurich, 1963) by Gwynne Vevers and Winwood Reade. Delacorte, New York, 1969. vi + 306 pp. + plates. $11.95. A Seymour Lawrence Book.

The World's a Zoo. JOHN PERRY. Dodd, Mead, New York, 1969. x + 308 pp. $6.95.

However its critics may carp about its power structure and its pet peerage, the Zoological Society of London continues to deliver the goods. Under the shelter of the British Establishment energetic underlings manage to accomplish more for the science of zoology than all the other zoo societies put together. The *International Zoo Yearbook*, now in its tenth triumphant year, gets better and better, growing in quality rather than size. As it receives more support from academic zoologists, it begins to provide the practical zoo man with the intellectual ballast which his profession sorely needs, especially in the United States. This annual production provides the needed literary links between the zoo keeper, the veterinarian, the administrator, and even that archvillain of the zoo world, the architect. The latest volume has birds of prey as its main theme, but contains, as usual, a wide spectrum of zoological notes. It is very well illustrated, and benigly edited by Joseph Lucas.

Perhaps the voluminous reference sections on breeding records and zoo stocks are a necessary nod in the direction of conservation, but they must add greatly to the cost, without contributing much reliable or relevant information.

As zoology tends to be organized along ecclesiastical lines, one is tempted to regard Hediger's book as a doctrinal work by a bishop and Perry's as that of a lay preacher. Hediger's misfortune has been to be in advance of his time. When he cried out long ago for zoo reform and for a zoo philosophy, the animal worshipers couldn't have cared less. It is sad to reflect that one article in *Life* written by a disciple could produce so much more impact than the work of the master, merely by being read so much later. Now that Hediger's ideas are available in English anew, he