touches on the small amount of available information concerning the physiology of *Tetrahymena*. This is a minor criticism, however, made only because the title includes "physiology". This attractive and important book will be indispensable not only to protozoologists but to biochemists and biologists in general, providing ample food for comparative thought and stimulating much further experimentation.

MIKLÓS MÜLLER

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Life as a *Schein-Problem*

The Nature of Living Things: An Essay in Theoretical Biology. By Stephen Black. Pp. 156. (Martin Secker and Warburg; William Heinemann Medical Books: London, 1972.) £1.95.

The theme of *The Nature of Living Things,* as Stephen Black states it, is this: the second law of thermodynamics says that the disorder of the universe is increasing, yet it is obvious to commonsense that in the biosphere it is order, not disorder, that is increasing. Thus, he argues, there must be a conflict between evolution and thermodynamics. Where does the information come from?

The well-known answer (upon which Dr Black's essay is completely dependent) that Erwin Schrödinger gave to this perplexing problem was that an organism feeds on "negative entropy"; it gets its order from the environment. What is less well known, however, is that, in response to criticism by F. Simon, Schrödinger withdrew this formulation of the problem—pleading that he had been trying to explain highly technical ideas in simple terms and, for physicists, he would have used "free energy" instead. In later editions of *What is Life?* he also appended the following argument; geometrical orderliness is, in itself, unimportant because the entropy of diamond (which is as ordered as one could wish), together with that of the oxygen it burns in, is roughly the same as the entropy of the carbon dioxide produced, once the heat evolved has dissipated. Thus if there were an organism which fed on diamonds it would use the enthalpy change for its energy and it could solve the problem of entropy, not by doing anything as drastic as breaking the second law, but merely by being a little hotter than the surroundings, and dissipating the entropy, as before, as heat. This is not my argument, it is Schrödinger's. Unfortunately, while this clarification detracts little from Schrödinger's book, it takes away the whole point from *The Nature of Living Things.*

The trouble with a word like "order" is that we have an intuitive idea of what it means (regularity perhaps, or tidiness), and it is surprising to discover that any evaluation of order is always relative to some external standard. In P. W. Bridgemann's words, from his *The Nature of Thermodynamics,* "All disorder is order from a different point of view". Thus, to illustrate this point, one might say that ABCD has a more "conventional" order than ABDC; *Botulinus* toxin has less "functional" order in men than it has in *Botulinus*; *"schein-problem"*, to someone who cannot speak German, has less "linguistic" order than "apparent problem" and so on. But simply to equate all these totally different kinds of order with entropy is a (widespread) semantic confusion. When the second law states that order is decreasing it means that energy contained in one degree of freedom is continually getting spread over more degrees of freedom. In this sense what we could call "energetic" order is always decreasing, but functional order, linguistic order and any other sort of order can simultaneously do what they like.

Having stated this *schein-problem,* however, Dr Black attempts to solve it by declaring that DNA is Maxwell's demon. And he is quite right to highlight the problem of Maxwell's demon in biology. But not for the reason Dr Black supposes. If we accept the exorcism of this demon by Szilard then the real lesson, as Popper has shown (*Brit. J. Philos. Sci.,* **8**, 151 ; 1057), is not that entropy and information are identical, but rather, as Pippard unequivocally states in his *Classical Thermodynamics,* that there is now no justification for the view that the second law is only statistically true. The correct conclusion to draw then, to use Popper's argument, is that we need a new statement of the second law which is consistent with Brownian motion and thus applicable at the molecular level. Thus the issues raised by (but not in) Dr Black's essay are by no means simple.

The answer to these problems, Dr Black suggests, is that "Life is a quality of matter which arises from mechanical realization of the informational potential inherent in the improbability of form". Now it is perfectly true that some problems are made much more simple if looked at in a new light, but, for me at least, this formulation is not helpful, because, using Sir Karl Popper's invaluable criterion, it is impossible to disagree with it. Life, apparently, is something to do with shape. Yes indeed, but what, exactly? After many pages of intrinsically interesting material and one very enjoyable poetic simile (a mutation is like a successful cadenza written into the score), Dr Black claims that he has actually answered the problem. Unfortunately he has only restated it.

C. W. F. McCLARE

Lampreys

The Biology of Lampreys. Edited by M. W. Hardisty and I. C. Potter. Vol. 2. Pp. xiv+466. (Academic: London and New York, July 1972.) £6; $18.50.

THE study of lamprey physiology and endocrinology has probably contributed more to our appreciation of the evolution of the sophisticated control mechanisms found in higher vertebrates than has the study of any other single group of animals. Consequently, Volume 2 of *The Biology of Lampreys,* with its emphasis upon physiology, will interest biologists of many different disciplines.

The first six chapters deal specifically with the endocrine system, yet the reader is left with many basic questions still unanswered. This reflects the state of our knowledge and not the competence of the authors. Perhaps the most valuable contribution is that of Larsen and Rothwell on the adenohypophysis. Many hitherto unpublished data on the ultrastructure and physiology of this gland are presented together with a good review of the previous work. But in the chapters by Sterba (Neuro and Gliasecretion), Eddy (The Pineal Complex), Barrington and Sage (The Endostyle and Thyroid Gland) and Hardisty (The Interrenal) it becomes clear that a high proportion of the available data is concerned with the structure of the endocrine system and as yet we only know a little about its functions. Barrington also discusses the phylogenetic implications of the unique structure of the pancreas, the absence of glucagon and the occurrence of secretin-like and pancreozymin-like activity in the intestine. This article, above all others, illustrates the important role of lamprey physiology in elucidating the evolutionary pathways leading to the situations found in higher vertebrates.

Lamprey haemoglobins and immunoglobulins are functionally similar to those of the gnathostomes, yet Riggs and Good, Finstad and Litman respectively demonstrate unique and peculiar properties of these blood proteins. Large differences in the circulatory system and respiratory capacities of larval and adult lampreys are considered in chapters by Fänge and Randall. These differences underline the caution needed in the analysis of presumed primitive conditions in a specialized animal. In a well-written chapter Morris depicts the possible evolutionary relationships between lampreys, hagfishes and teleosts when considered in terms of their