ADDENDUM. Since this review was written, Paul Ehrlich's book *The Population Bomb* (Sierra Club-Ballantine, New York, 1968, 223 pp., paper $.95) has become available. In one chapter Ehrlich quotes *Famine — 1975!* extensively and devotedly, saying (p. 161) that it "may be remembered as one of the most important books of our age." Ehrlich's book does not seem to be just a reiteration of *Famine,* however, since he sounds some of the same warnings as do Rachel Carson *(Silent Spring)* and the conservationist Sierra Club concerning "the progressive deterioration of our environment [which] may cause more death and misery than any food-population gap" (p. 46). A cursory examination leaves me with the impression that, compared with the Paddocks' *Famine,* Ehrlich's *Bomb* is less statistical, more philosophical, and equally fervent.

REFERENCES AND NOTES

1 RICHARD T. GILL, *Evolution of Modern Economics* (Englewood Cliffs, New Jersey: Prentice-Hall, 1967).

2 DUDLEY KIRK, World Population: Hope Ahead, *Stanford Today* 8 (winter 1968).

3 PAUL R. EHRLICH, World Population: A Battle Lost? *Stanford Today* 2 (winter 1968).

4 It does not seem likely that all cattle production will become economically unfeasible, since certain land has always been (or has become, through overgrazing and resulting erosion) suitable only for cattle grazing.

Problems in Darwinism

ARIEL A. ROTH

MATHEMATICAL CHALLENGES TO THE NEO-DARWINIAN INTERPRETATION OF EVOLUTION
Edited by Paul S. Moorhead and Martin M. Kaplan
Wistar Institute Press, Philadelphia, 1967 xii plus 140 pp illustrations paper $5.00

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This report of a symposium held at the Wistar Institute of Anatomy and Biology, April 25 and 26, 1966, outlines some of the problems and questions that can be raised about the currently accepted mechanism for evolution (neo-Darwinian evolution). These problems are presented by the use of mathematical models based on the concepts of modern genetics. The formal presentations of the symposium are enriched by what appears to be a verbatim record of the often spirited discussions during and following each presentation.

The symposium was organized as a result of a "heated debate" that had developed between four mathematicians, Drs. Murray Eden, Marcel Schützenberger, Stanislaw

Ulam, and V. F. Weisskoph, and two biologists, Drs. Martin Kaplan and Hilary Koprowski, about problems of contemporary explanations for neo-Darwinian evolution. Fifty-two participants were present, including a few mathematicians and a number of biologists specializing in evolution or in fields related to evolution. Many of the leading authorities in these fields were among the participants.

The contents of the report suggest that none of the speakers, including the mathematicians posing the challenges, entertain any idea but the general theory of evolution as an explanation for the origin of living forms. Doctor Eden states that "what looks to us as teleology need not be," and Doctor Schützenberger denies an accusation that his "argument is simply that life must have come about by special creation." The challenges are directed at the inadequacies of the present mechanism proposed for evolution, not at the general conclusions of the theory. The fact that the symposium was held indicates willingness to recognize and study problems with the theory.

Doctor Eden, of the Massachusetts Institute of Technology, suggests that, on the basis of random variation, there has not been enough time, on a geological scale, to permit a significant degree of probability for evolution. One of the first problems he outlines has to do with obtaining the proper sequence of amino acids for a specific protein needed for a particular function in a living organism. It should be explained that the term "space" as used by Doctor Eden in the quotation below refers to the total number of different kinds of proteins possible within the defined limits. The problem is posed in the following terms:

> Let us consider first the space of polypeptide chains of length 250 or less. We may think of words which are 250 letters long, constructed from an alphabet of 20 different letters. There are about 20^{250} such words or about 10^{325}. Let us compare this with certain other quantities, for example the number of protein molecules that could ever have existed on earth in organisms. Assume a biosphere of cells 1 cm. thick over the surface of the earth, a protein concentration in these cells of 30%, a density of 1, an age for life on earth of 10 billion years and an average lifetime of a protein molecule of 1 second. Of course all these quantities except density err very heavily toward the high side. The number of protein molecules that ever existed is by this computation about 10^{52}. Clearly the number of species of protein molecules is much smaller than this, say 10^{40}, but it would be immaterial to our purposes to try to make such a reduction. It is obvious that 10^{52} is such an infinitesimal number when compared with 10^{325} that we would be understating the case badly to say the space of protein molecules has barely been scratched. Yet this relatively small set of 10^{52} proteins contains within it all the useful proteins which have existed to date.

Doctor Eden emphasizes his conclusion by pointing out that existing proteins appear to have great similarities in amino acid residues and do not appear to have been drawn from a random assemblage of polypeptides.

One of the interesting findings of modern bacterial genetics is that, in a number of instances, several genes, which for our purposes we may interpret as ordered sequences of nucleotides producing ordered sequences of amino acids, are under the direction of an operon. The striking feature of some of these arrangements is that the genes are arranged in the order in which they will be utilized in a particular metabolic pathway. Thus, not only are the amino acids for a particular gene in order, but the genes are arranged in the order in which they will be utilized. This poses a further restriction on the random organization of genetic material. Doctor Eden considers the probability of obtaining by transfer in the bacterium *Escherichia coli* two genes in the order in which they will be utilized. After outlining the assumptions and mechanisms necessary, Doctor Eden states:

> Then to achieve a single ordered pair of genes on these assumptions would require something like 10^{36} genetic transfers. Sexual genetic transfer in *E. coli* takes about two hours and there are only about 10^{12} such periods dating from the beginning of life to now. Finally, genetic transfer between bacteria is a rare event. I have been unable to find estimates in the literature but I will assume that at any instant in time 10^{-6} of the bacterial population are "mating." Thus, one would need an average population of *E. coli* of 10^{30} (about 10^{13} tons or a layer on the surface of the earth two centimeters thick) if one expected to find a single ordered pair in 5 billion years.

It should be noted that sometimes more than two ordered pairs of genes are present. Doctor Eden does not discuss the probability of obtaining this more complex picture by random rearrangements. A further problem implying that the geological time scale is too short for neo-Darwinian evolution involves the changes necessary for the development of higher forms of life. As an example, the complement of man comprises about 10^9 nucleotides, or bits of information, which together comprise the hereditary dictum of an individual. If one assumes no nucleotides to start out with, an average rate of accrual of one meaningful nucleotide per year is necessary to develop a full complement of genetic information. Assuming randomness for the substitutions and additions, the development of a meaningful system seems highly improbable. In his preliminary working paper, also published in this book, Doctor Eden states:

> If randomness is taken to mean that a uniform probability is assigned to each possible independent substitution or addition, the chance of emergence of man is like the probability of typing at random a meaningful library of one thousand volumes using the following procedure: Begin with a meaningful phrase, retype it with a few mistakes, make it longer by adding letters, and rearrange subsequences in the string of letters; then examine the result to see if the new phrase is meaningful. Repeat this process until the library is complete.

It does not help the problem very much if one starts with a simple form of life instead of nothing. For instance, a bacterium having 10^7 nucleotides represents only one percent of the 10^9 nucleotides needed for man.

Doctor Schützenberger, of the University of Paris, has directed a challenge at the gap between the genetic material of an organism, which is viewed as a blueprint, and the physicochemical makeup, which reacts with the environment. Both systems represent highly organized structures. When one follows a neo-Darwinian model, the question arises as to how selection pressure on the organism can effect organized changes in the genetic system. Using a sequence of letters to represent genetic material, Doctor Schützenberger concludes:

> We believe that it is not conceivable. In fact if we try to simulate such a situation by making changes randomly at the typographic level (by letters or by blocks, the size of the unit does not really matter), on computer programs we find that we have no chance (i.e., less than $1/10^{1000}$) even to see what the modified program would compute: it just jams.

Doctor Schützenberger concludes that there is a considerable gap in the neo-Darwinian theory of evolution, and he does not believe that this gap can be bridged "in the current conception of biology."

The arguments presented by the mathematicians do not go unchallenged by the biologists. A number of mechanisms are not considered in the models presented by the mathematicians. Examples are: restriction of space to permit altered probability, block substitutions, epigenetic mechanisms (causal study of the way the genotype space is translated into the phenotype), multiple changes, meaningless changes, etc. These concepts are either not applicable to the challenges posed or cannot be defined in terminology sufficiently precise to permit their incorporation into mathematical models. The problems faced by some of the participants can be noted in comments, such as, "We are comforted in knowing that evolution has occurred" and "We are not interested in your computers!"

A number of presentations are made on subjects related to the main theme of the symposium. One deals with principles to be followed in the mathematical formulation of rates of evolution and another with mathematical optimization in natural selection.

Several of the biologists also present topics pertinent to the symposium. Dr. Ernst Mayr, of Harvard University, discusses "Evolutionary Challenges to the Mathematical Interpretation of Evolution." He gives some examples of what he considers rapid evolutionary changes, including the well known case of industrial melanism. Also he emphasizes the importance of small isolated populations as a means of rapid evolution and the unpredictable nature of a combination of factors. Other presentations by biologists include discussions of the problems of vicarious selection by interaction within a society of organisms, and the effect of the order of environmental changes on the genetics of a population of organisms. None of these topics provides answers to the precise challenges posed above by the mathematicians.

A number of times during the discussion, reference is made to the statement by Professor Karl Popper that the real inadequacy of evolution is that it is unfalsifiable. In other words, the postulated changes of evolution are so broad in their scope that they can be used to explain anything if the variables are changed; and since evolution can explain anything, one cannot suggest a way of disproving the theory. Not all of the participants at the symposium agree with this criticism of evolution.

An interesting incident that illustrates the ease with which one can adjust his thinking to various desired patterns of thought is reported by one of the participants, Dr. John C. Fentress, of the University of Rochester. At one time he was testing the effect of an overhead moving object on the activities of two species of field mice. He found that one species that lived in the woods would freeze in the presence of an object moving overhead, whereas a species living in the field would run away. Not being a zoologist, he went to see some of his zoologist friends for an explanation — except, for fun, he reversed the data, asking them why a mouse in the field should freeze and one in the woods should run. Doctor Fentress states, "I wish I had recorded their explanations, because they were very impressive indeed."

Reading this book is a rewarding experience because it gives insight and understanding to the struggles involved in the search for truth. To follow the arguments demands some basic background in genetics as well as in mathematics. Unfortunately the mathematicians did not elaborate on most of their calculations in the presentations made. Although this omission makes the book readable for a person without background in mathematics, one with such training can be somewhat unsatisfied.

As one considers the highly significant improbabilities of the neo-Darwinian concept of evolution, one is constrained to consider other possible solutions, including solutions beyond the generally accepted but limited confines of formal science. Once one permits possibilities beyond these confines, the challenges posed in this volume can become strong support for an alternate concept, that of creation, and, in the words of Doctor Eden, "what looks like teleology" might very well be interpreted, under a broader system of possibilities, as teleology.

A New Role for Eschatology

HEROLD WEISS

THEOLOGY OF HOPE
By Jürgen Moltmann; translated by James W. Leitch
Harper and Row, New York, 1967 342 pp $8.50

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When the history of twentieth-century theology is written from the vantage point that only time can give, it will probably characterize this period as the time when eschatology came into its own.

Rationalism and romanticism had all but given the death blow to eschatology, especially in its apocalyptic form. This situation, however, was altered by the radical studies of Johannes Weiss, who gave to the concept of the kingdom of God its proper eschatological meaning. Then Albert Schweitzer conducted a postmortem examination of the vast theological effort (called "the quest of the historical Jesus") that had overlooked the basic eschatological thrust of Jesus' life and message because it failed to take His apocalyptic background seriously. Since Weiss and Schweitzer, eschatology has taken a predominant position in Biblical studies.

Opinion has polarized between those who understand the eschatological message of the New Testament to refer to a future consummation of history and those who deny the legitimacy of any transcendental expectations for the future. Among the latter there are those who view eschatology as a *summum bonum* actualized in the Incarnation (e.g., C. H. Dodd) and those who consider that eschatology has no chronological reference at all but transcends time and partakes of eternity (e.g., Rudolf Bultmann). The existentialists assign only relative theological value to history, whereas those who see eschatology as having to do fundamentally with the future (e.g., Oscar Cullmann, W. Kümmel) tie theology closely to history.

Jürgen Moltmann's *Theology of Hope* represents an attempt to take seriously the basic polarities of futuristic and existentialistic eschatology and yet find a third position beyond them. He defines the polar alternatives as, on the one hand, "the reflective philosophy of transcendental subjectivity for which history is reduced to the 'mechanism' of a closed system of causes and effects," and, on the other hand, "a theology of