EXPERIENTIA

Volume 39/No. 8 Pages 805–930 August 15, 1983

## Reviews

# Contemporary aspects of evolution

## Introduction

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The development of science during the last century has been characterized by the fact that the most fundamental ideas in biology – Darwin's theory of evolution by natural selection and Weismann's concept of the independence of germ line and soma – were conceived quite independently of the physical sciences. Natural selection is a theory about the behavior of populations of entities, in which the essential processes of birth, death, and mutation are stochastic. Although today we can see parallels between Darwin's theory and the ideas of Maxwell and Boltzmann, those parallels were far less obvious at the time. Indeed, the most obvious contemporary impact of physics on Darwin's theory was Kelvin's (erroneous) estimate of the age of the earth, which allowed an embarassingly short period for the operation of geological and evolutionary processes.

If Darwin's theory was largely independent of the physical sciences, Weismann's seems at first sight to be directly contradictory to them. Since all the materials and energy needed for the manufacture of the germ cells are provided by the body, in what sense can it possibly be true that the germ line is independent of the soma? Today we recognize that Weismann was asserting that information does not pass from soma to germ line, and, in the 'central dogma' of molecular biology, we have a good understanding of why that is so. The concept of information, however, was unfamiliar to nineteenth century physics, just as population thinking was unfamiliar to Darwin's physicist contemporaries.

The last century has, of course, seen the steady invasion of biology by physics and chemistry. A large part of both physiology and biochemistry consists of the explanation of biological processes – digestion, respiration, the functioning of sense organs, and so on – in terms of previously known physical and chemical principles. Important as this process has been, however, it has not removed the more fundamental dichotomy in science arising from the independence of our theories of evolution and of physics.

The dichotomy still has its effects. To an evolutionary biologist like myself, it is striking how many theoretical physicists apparently never grasp the principles of natural selection. To give a recent and bizarre example, in the trial in Arkansas last December over the question of whether schools should be required to give equal time to the idea that species were specially created as to the theory of evolution, the creationists called as an expert witness on their side a theoretical astronomer who was under the impression that the theory of natural selection could be refuted by showing that the probability of a living organism arising in a single step by chance is so small as to be effectively zero.

However, as the articles which follow demonstrate very clearly, the dichotomy is fast disappearing, although it still has some influence. That the bridge from physics to biology is still difficult to cross is illustrated by Walker's article. Thus I find myself in agreement with much of what she says in the first part of her article, which is mainly concerned with physical principles, and yet I disagree with almost everything she later says about evolution. Two of the other articles illustrate the 2 ways in which the gap is being bridged. One way, some aspects of which are described in Ayala's article, is through the development of molecular genetics. Heredity is the one essential characteristic of living organisms, from which all others follow, but it is one which can now be explained in chemical terms. Ayala's main interest, however, is in variation. Without variation there could be no evolution, because there would be no differences upon which selection could act. During the last

20 years, molecular techniques have completely transformed our knowledge of the ways in which the members of a population differ from one another genetically. Only in the past few years has it become possible to determine the sequence of DNA molecules. At present, information is coming in so fast that many of us are suffering from indigestion. When the facts have been digested, some of the controversial issues of the past 20 years are likely to have been settled.

A second, and ultimately decisive, way in which the gap between physics and biology is being bridged is through a study of the origin of life. To understand the origin of life would be to understand how physico-chemical processes can give rise to biological ones. Some questions which have to be answered are among the following. How can a sufficiently accurate mechanism of hereditary replication arise? How did the genetic code, and the resulting distinction between a replicating genotype and a mortal phenotype, originate? What was the origin of individuation, whereby one organism was separated off from others? The aim is to answer these questions in terms of the kinetics of chemical reactions. The article by Kuhn and Waser shows that encouraging progress is being made; indeed, it may be that in retrospect we shall see that the decisive answers to at least the first 2 of these questions have already been given at the level of theory, even if the processes have not yet been fully realized experimentally.

Of course, not all progress in evolutionary biology is concerned with its reduction to physics and chemistry. The article by Stebbins shows how biologists are constantly seeking higher level generalizations. There is everything to be said for striving to show the logical consistence of physics and biology, but no reason to abandon the search for biological laws.

0014-4754/83/080805-02$1.50+0.20/0


## Complex-irreversibility and evolution

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*Summary.* Both, irreversibility and evolution, imply order in time. It is argued that the only possible concept of time is a 'system-specific time', and that order in time is convertible into order in space and vice-versa. While life-less, complex systems are irreversible because of their complexity and, hence, not repeatable, living systems are reproduced by irreversible copy-reproduction and by coding. This mode of reproduction results of necessity in an arrow of time of growth and increasing complexity with death as its antagonist, and in obligatory spatial asymmetry. This arrow of increasing organic complexity is simultaneous with, and independent of, the arrow of increasing entropy. – A generalized, organic hierarchy is proposed as the model to study higher evolution. This hierarchy reproduces itself by differential rates of reproduction of its subunits within and between the various hierarchical levels of organization. Phylogenetic change is brought about by a change in this hierarchy's specific phase pattern of growth. Continuous and discrete organization is defined, and it is shown that specific relations between continuous and discrete levels within the hierarchy result in accumulation of neutral alleles. This accumulation is due to complex-irreversibility and causes genetic stabilisation, i.e. heritability, of the species-specific morphology of organisms.

### *I. Time is system-specific*

Both 'irreversibility' and 'evolution' are concepts in which time is intrinsic. For a valid model of organic evolution an agreement must be reached upon the meaning of time.

The simple, and purely empiric proposition I am going to make is, that there can be no generally valid concept of time; that, whatever time order there may be, is only pertinent to the type of system actually under observation.

If we walk along a road and see it disappear over the horizon, we know that we still have to go a long distance until we reach that particular point. We may want to measure this distance in terms of kilometers or meters. We perceive extension in space and measure it by units of extension. Similarly, we experience force or energy, qualify it by the respective sense organs and measure it in the appropriate units (temperature, pressure, sound, light, etc.). If, however, we want to know how long we talk on the telephone, we have to watch how many times the second hand of a watch rotates over the dial. We perceive time as changed energy patterns in space and measure it by counting repeated patterns of change. We have no sense organs to perceive 'time per se', and hence no