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 physicochemical 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.

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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
possibility of imagining it, we have a memory that registers changed energy patterns in space. This indirect perception of time leads to the conclusion that time order is specific for the system under observation: 'every system makes its own time', and further, it means that order in time may be converted into order in space and vice-versa. For instance, annual periodicity in growth of trees of the temperate zone leads to fairly regularly spaced growth rings in woods from this region. Now, many tropical trees also display reasonably regular growth rings and, incidentally, regular branching patterns. They represent periodic efforts of growth if growth is measured in terms of biomass or perhaps number of mitoses. However, the stimuli which trigger these growth periods may be irregularly spaced if plotted on an annual time axis. (Growth dynamics in tropical woods is as yet poorly understood; exceptionally cool days or specific water levels in inundation forests etc. may initiate florescence and growth periods). Distortions between 'system-specific times' are not a privilege of Einstein's theory of relativity, they occur inevitably whenever units of one kind of system serve as measurement for a different kind of system.

II. Complexity and repeatability

1. Complexity. The complexity of a given system is measured by counting the number of categories of sub-units and the number of sub-units in each category, and, if necessary, number and categories of links between sub-units. This information may be converted into 'probability for a specific state of the system'.

2. Order. It is generally agreed that order is somehow connected with repeated elements or patterns. Every measurement, for instance, consists of counting similar unit-intervals. Order in space is given in terms of symmetry (n-fold, radial, translational, bilateral, etc.), and apparent permanent states on the macroscopic level are maintained by oscillation of vectors on the level of infra-structure. Even the ordering effect of laws, conventions, axioms and principles, etc., depends on repeated statement, teaching and tradition.

If, then, we want to understand the order of dynamic systems, we must ask for the basic mechanisms that can generate repeats.

3. Repeatability in inorganic systems. For inorganic systems, classical physics has given its basic answer: elementary physical processes are in principle reversible and therefore repeatable. Swinging pendula and bouncing balls may illustrate the case (assuming that the process is friction-free; fig. 1). Planets might just as well cycle in opposite direction. Movies of such processes, if copied with right-left inversion, or if shown in reverse, display the same pattern as 'normal' demonstration. Time has no arrow and space has no screw (the symmetry conditions of particle physics need not concern us here). Repetitions of macroscopic states of large populations of molecules, such as crystallization and dissolution, or the water cycle between earth and atmosphere by evaporation and condensation, rely on the reversibility of elementary processes between similar sub-units.

Repetitions by reversion have the general, and highly significant, property that they do not accumulate in space. Each reversal destroys the former state. Yet, the very fact of reversibility means that the system as a whole does not get lost.

Next, we consider a somewhat more complex process than a bouncing ball: two ideally elastic balls with independent vectors happen to collide (fig. 2). Then they move away from each other, never to meet again.