treatment different from the one employed by us (ether extraction) would reveal specific peaks in cells infected by viruses other than EMC. So far we have no information as to the identity, or chemical character of the metabolite represented by the peaks discussed above, apart from their ether solubility.

Résumé. Des extraits, par l'éther, de cellules BHK 21,L929 et de fibroblastes d'embryon de poulet, infectés par le virus EMC contiennent des métabolites spécifiques qui peuvent être décelés par chromatographie en vapeur sous forme de pics ayant des temps de retention de 6,8 et 7,9 min.

A. LEVANON, Y. KLIBANSKY and A. KOHN

Israel Institute for Biological Research and Tel-Aviv University Medical School, P.O. Box 19, Ness Ziona (Israel), 27 February 1973.

COGITATIONES

Information and Evolution

In an article on the use of information in the description of biological systems and of their evolution, MAYO[1] raises several points concerning our treatment of this subject[2,3]. We described a terrestrial system whose input consists of a flow of solar information i_s; a fraction i_b enters the biosphere, while the remainder i_{nb} does not. If the biospheric and nonbiospheric information lifetimes are τ_b and τ_{nb}, the corresponding information contents will be, under 'quasi steady-state', $I_b \approx i_b \tau_b$ and $I_{nb} \approx i_{nb} \tau_{nb}$. The essence of this approach is the conclusion that the biosphere will evolve toward a higher I_b, both through changes that increase τ_b, and through the increase of the fraction i_b of the information flow. Since $\tau_{nb} \ll \tau_b$, the total information content and the average information lifetime of the overall system will also be increasing.

The conclusion that a system of information content I which receives an input i flowing with a dwell time $\tau \approx I/i$ will evolve toward longer τ's and larger I's is based on the following argument. Irreversibilities are the only way in which information is dissipated; if irreversibilities are reduced, information lifetime is extended. Changes in biospheric components that are 'good' and lead to better efficiency and improved survival, always reduce irreversibilities; spread of such 'improvements' leads toward longer τ's and larger I's. The statement that 'improved' forms will survive and spread is indeed a tautology, as pointed out by MAYO; the essence of the argument, however, lies in the fact that such 'improvements' always reduce irreversibilities. This is true whether the 'improvement' is the reduction of friction in an engine, a change in the foot skeleton of an animal that allows movement at less effort, or the development of a smoother societal organization that reduces tensions, conflict, or loss of life and property.

In the case, for instance, of a sketelon alteration that reduces the effort necessary for a particular movement, this activity will require the transformation of a smaller amount of energy from a high-grade chemical form (contained, e.g., in energy-rich ATP molecules) into a low-grade form (ultimately heat, after taking such forms as the instantaneous potential or kinetic energy of the limb of the animal). Thus, the skeleton alteration reduces the rate at which the irreversible transformation of high-grade energy into heat occurs.

The manner in which the replacement of a species I_1 by an improved species I_2 leads to a net increase in τ and I has been discussed elsewhere[4]. Assume that the 2 species compete for a fixed information input i_{12}, and that the improvement is the capability of species 2 to maintain its body temperature at a lower cost in high-grade (i.e., information-rich) energy; this may result from better fur coverage or, perhaps, from the use of clothing. Since the transformation of chemical energy into heat is an irreversibility, its reduction results in a lifetime τ_2 for the information that enters species 2 that is longer than τ_1. Before the appearance of species 2, the information content of this niche was $I_1 \approx i_{12} \tau_1$. After species 2 will replace species 1, the new information content will be $I_2 \approx i_{12} \tau_2 > I_1$. The inequality $I_2 > I_1$ implies that for the same input i_{12} the new species will be able to maintain a higher population than the old one.

MAYO states that one can hardly argue that the biospheric information increases when the last eggs of a species are eaten by predators. The information increase that we are discussing occurs in essence while the species declines from its peak population (e.g., several million) to near extinction (e.g., several thousand), and not when the last member dies; and it is represented by the information content of the new species (one or several) that replaced the old species in its niche. We are not considering, therefore, the type of informational transaction that occured in 1861 when the eggs of the last dodos were inadvertently eaten by pigs or dogs; the corresponding change in biospheric information content would have been practically identical if chicken eggs had been eaten instead. The biospheric information change due to the disappearance of the dodos is rather the difference between the information content of their population when they were stably entrenched in their ecological niche (i.e., when they were equal or better than any existing competition), and the information content of the species that replaced them in that particular niche, feeding on and being preyed upon by about the same species. If, as usually happens, the disappearance of the dodos was part of a rearrangement of niches within a wider ecological domain, the entire domain that was affected must be considered in assessing the change in biospheric content.

With respect to the definition of information content, MAYO states that such a quantity cannot be measured, and is in doubt as to how it is defined. Here, information is meant in its thermodynamic sense. In this context, the information in the DNA of an organism is a small fraction of the total content. In thermodynamics, one defines the information of a distribution of particles with respect to their most probable distribution[5]; the information content of a structured organism is defined by considering the distribution of its components versus their

1 O. MAYO, Experientia *28*, 365 (1972).
2 G. C. THEODORIDIS and L. STARK, Nature, Lond. *224*, 860 (1969).
3 G. C. THEODORIDIS and L. STARK, J. theoret. Biol. *31*, 377 (1971).
4 G. C. THEODORIDIS and L. STARK, Math. Biosci. *12*, 375 (1971).
5 A. KATZ, *Principles of Statistical Mechanics; The Information Theory Approch* (W. H. FREEMAN and Company, San Francisco and London 1967).

'most probable' distribution at the prevailing temperature. The definition is rigorous, and this is indeed all one needs to conduct the present argument. In computations, one needs procedures of estimating the information content as defined. This may be easy or difficult, depending on the desired accuracy. Estimates of the information within structures of any complexity are possible, given the definition of this quantity.

In computing I, one lumps all the chemical thermodynamic information, not distinguishing information as meaningful or meaningless, important or trivial. One may ask whether meaningful and important information should not count more. We dealt with this question elsewhere[6], and our views are as follows: The meaning and importance of a piece of information represent our intuitive estimate of its total impact on the biospheric system; this impact can be measured by the total amount of information, anywhere in the biosphere, that would not exist if this piece of information did not exist. Thus, we consider more important a written message describing the cure to a disesae than another message of equal structural information in the form of nonsensical words because the first message can be responsible for a large amount of information in the form of the individuals whose destruction it can prevent; similarly, an individual responsible for the lives and well-being of many people is more important than one who is isolated from, and useless to his environment. Since in computing I we include the entire system, we are not erring in counting the meaningful message or the important individual as equal to their useless counterparts; our computation will include, from elsewhere in the biosphere, the information that is the basis of their meaning and importance.

In our approach we assume a constant input, and an unchanging environment. Changes, such as a cataclysmic event or a gradual change in climate, will have a transient or a permanent impact on the biosphere and on the evolutionary process. It appears reasonable, however, to analyze the evolutionary process assuming, to a first approximation, an unchanging environment. If an adequate theory is obtained for a constant environment, one may then study the impact of environmental changes on the existing evolutionary mechanisms.

Changes in evolutionary mechanisms do occur even without environmental changes. Although increasing biospheric information characterized all evolutionary stages, different mechanisms correspond to pregenetic, genetic, or cultural evolution. Two events mark the transition between these stages. The first was the appearance of the genetic apparatus; the second was the appearance of human culture which introduced biospheric components maintained and reproduced by man. In each case, the appearance and selection of new components became much faster. While during the pregenetic stage the more efficient components might slowly spread due to a lower destruction rate[3], genetic reproduction allowed the carrier of an improvement to spread rapidly by multiplying faster than its competitors. Similarly, during the stage of cultural evolution, an improvement (e.g., better vision) can arise within the time needed to develop the new tools (e.g., the telescope or the microscope), which is much shorter than the time required for this result via genetic evolution (i.e., mutations toward better vision).

An important feature of any formulation is its predictive value. There are several levels at which one might describe and predict evolution. The first is to describe its direction; a higher level is to predict the rate at which evolution will proceed; a still higher level would be to describe the forms that will be generated. This formulation allows us the first level of prediction; in the absence of environmental changes, the biosphere will in the long run, evolve toward a larger I. With some knowledge of the mechanisms involved, one may be able to reach the second level and predict the average rate at which I will be increasing. It is conceivable, however, that the process through which new components arise may so depend on chance, as to never allow us to predict which of several possible forms will be actually generated.

Résumé. Les auteurs discutent la formulation quantitative de l'évolution comme un procès qui augmente le contenu de l'entité thermodynamique d'information dans la biosphère.

G. C. THEODORIDIS and L. STARK

Univesity of Virginia, School of Engineering and Applied Science and School of Medicine, Division of Biomedical Engineering, Charlottesville (Virginia 22901, USA) and University of California, Berkeley (California, USA), 9 April 1973.

[6] G. C. THEODORIDIS and L. STARK, Math. Biosci. *11*, 31 (1971).

PRO LABORATORIO

A Focusing Adapter for the Polaroid ED-10 Photomicrographic Camera

The ED-10 Camera[1] is a moderately-priced instrument designed for instant photomicrography using Polaroid Land film. The main advantage of this camera is that it can be fitted within a few minutes on any standard microscope by means of a universal eyepiece adapter. Several components of the ED-10 system have been markedly simplified for economy's sake. The camera itself has no relay lens, and the magnified image produced by the eyepiece of the microscope is projected directly on the film. Consequently, the quality of the picture depends only on the optics of the microscope; on the other hand, adjustment of focus at the film plane has to be carried out before attaching the camera, by sliding an accessory tube down over the eyepiece adapter and focusing the microscope through a viewing lens mounted in this tube.

The versatility inherent in its design makes the ED-10 camera very useful for obtaining photomicrographs on-the-spot, for instance in the histology classroom, without having to resort to a special or elaborate set-up. Certain features, however, make this instrument less suitable for more exacting purposes. From our experience,

[1] Manufactured by the Polaroid Corporation, Cambridge, Massa chusetts, U.S.A.