COGITATIONES

Information as a Quantitative Criterion of Biospheric Evolution

It has been suggested[1] that 'the total informational content of the biosphere [is] a quantitative measure of functional efficiency in processing information and... an objective criterion of evolutionary progress'. Further, it has been suggested[2] that 'the structure and the function of living organisms can be best described in terms of the physical quantity of information'. The purpose of this note is to point out that the quantity of information may be a misleading parameter to consider in genetic evolution, since it takes no account of different kinds of information, nor does it possess any kind of predictive value, which is perhaps what is missing from the theory of evolution by natural selection, which measures everything a posteriori.

THEODORIDIS and STARK[1] present the following scheme: let us consider that solar flux is the main source of information (in the form of energy) for the evolving earth. Then a quasi steady-state situation exists and the solar information input i_s can be divided into a biospheric part i_b and a non-biospheric part i_{nb}. Now if τ_b and τ_{nb} are the biospheric and non-biospheric information lifetimes, the biospheric information I_b is given by $\tau_b \simeq I_b/i_b$, and similarly $\tau_{nb} \simeq I_{nb}/i_{nb}$. Then $I_b \simeq \tau_b(i_s - i_{nb})$. It is clear immediately that as we do not have estimates of τ_b and i_{nb}, we cannot estimate I_b; furthermore, as THEODORIDIS and STARK[1] note, cataclysmic events such as earthquakes, etc., affect I_b without materially affecting i_s, so that temporal comparisons may well be meaningless.

To see how informational arguments may be misleading in genetical evolution consider the simple case of two competing species, whose information contents are I_1 and I_2. If species 1 replaces species 2 (and species 2 becomes extinct), this does not imply that $I_1 > I_2$, except in a trivial sense; we do not in any case know how to measure I for a given species. (The amount of DNA could be used as a criterion[3], but there is evidence that closely related species can differ substantially in this measure[4], and in any case not all DNA is equivalent[5].) When in about 1681 the last dodos died without issue, their eggs eaten by pigs or dogs[6], some information was lost; unless a temporary part of the increase in abundance of these inadvertent predators is counted, it is difficult to argue objectively that there was a biospheric information gain in this disappearance, even though this highly specialized and not numerous species was probably unlikely to survive long. While less than 1% of all species even arizing are still extant[7], the loss of many species (not just the dodo) represented a loss in information not necessarily regained as suggested[1]. For example, during the last ice-age, many species of trees and several of the great mammals were extinguished[8], and there is no real evidence to suggest that they or their descendents would all, inevitably, have proved inadequate competitors, as (most probably) were the South American marsupial carnivores when, in the upper Pliocene, North and South America became joined[7].

Evolution by natural selection acting on genetically determined variation acts to increase information within a species[9], but does not necessarily do the same between species, since it has as characteristics both adaptive radiation (increasing variance) and frequent extinction (decreasing variance). The process of acquisition of information in genetic (as opposed to pregenetic[2]) evolution is far removed from the steady state information gain by solar flux. Rates of evolution in particular groups of animals have by no means been constant; for example, the lungfishes changed as much in 30 million years of the middle and late Devonian as they have in the 250 million years since[7]. With any particular species, the rate of acquisition of information may well decline as the amount of information increases[10], though this need not always be the case[11].

It is suggested[1] that 'the viability of a new biological species... can be assessed by determining whether [its] survival results in a biosphere of a higher information content', but apart from problems of measurement this is to reverse the problem or reduce it to a tautology, since survival of a species is the measure of viability. Furthermore, as already indicated, survival of one species if at the expense of another need not result in increased biospheric information content.

If the biospheric information content were really an objective criterion of evolutionary progress then it should be possible to derive minimum conditions for the existence of life (however defined) and hence to establish the time at which life began, assuming it not to have an extraterrestrial origin. However, we do not yet know how much information there is in the biosphere, nor what solar input is necessary to maintain some life (apart from human use of stored energy); perhaps the current solar flux is the least upper bound of information input for the maintenance of the biosphere in its present state. Even this is not certain; as HALDANE[12] recognized many years ago, in macro-evolutionary terms it is necessary to consider such factors as the possible decline in g, the gravitational constant, by as much as one part in 10^9 per year[13,14]. At the moment, it is not clear whether more or less genetical information is necessary to cope with a reduction in the strength of the gravitation field. In any case, the evolved conservatism of genetic systems[15] can be expected to retain obsolete information for long periods of time.

Overall, it can be stated that the solar flux of information cannot yet provide any criterion for genetic evolution, and possibly for pregenetic evolution as well. Results yielded by the information-theoretical approach[1,2] suggest essentially that we do not have enough data to apply the

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[1] G. C. THEODORIDIS and L. STARK, Nature, Lond. *224*, 860 (1969).

[2] G. C. THEODORIDIS and L. STARK, J. theoret. Biol. *31*, 377 (1971).

[3] M. KIMURA, Genet. Res. *2*, 127 (1961).

[4] D. L. HAYMAN and P. G. MARTIN, in *Mammalian Cytogenetics* (Ed. K. BENIRSCHKE; Springer, Berlin 1969).

[5] E. SOUTHERN, Nature, Lond. *227*, 794 (1970).

[6] H. E. STRICKLAND and A. G. MELVILLE, *The Dodo and its Kindred* (Benham & Reeve, London 1848).

[7] E. MAYR, *Animal Species and Evolution* (Belknap Press, Cambridge, Mass. 1963).

[8] F. E. ZEUNER, *Dating the Past* (Methuen, London 1946).

[9] R. A. FISHER, *The Genetical Theory of Natural Selection* (University Press, Oxford 1930).

[10] R. C. LEWONTIN and C. H. WADDINGTON, in *Towards a Theoretical Biology* (Ed. C. H. WADDINGTON; University Press, Edinburgh 1967), vol. 1.

[11] O. MAYO, *Genetica 42*, 329 (1971).

[12] J. B. S. HALDANE, Nature, Lond. *139*, 1003 (1937).

[13] P. A. M. DIRAC, Nature, Lond. *139*, 323 (1937).

[14] B. KUCHOWICZ, Experientia *27*, 161 (1971).

[15] C.D. DARLINGTON, *The Evolution of Genetic Systems* (University Press, Cambridge 1939).

method properly. More precise definitions of varieties of biological information appear necessary.

Zusammenfassung. THEODORIDIS und STARK[1] haben vorgeschlagen, dass der Informationsinhalt der Biosphäre ein objektives Kriterium des Evolutionsfortschritts schafft. In dieser Aufzeichnung prüfe ich diesen Informationsbegriff nach und schliesse daraus: 1. dass ein zuständiges Mass noch nicht vorhanden ist; 2. dass die Informationsbeweise in der genetischen Evolution irreführend sein mögen; und 3. dass wir vorerst die folgenden Parameter zu bestimmen und zu messen versuchen sollten: die Gesamtinformationen der Biosphäre; die mindeste Obergrenze der Eingangsinformationen, die für jede besondere Lage der Biosphäre unentbehrlich ist; und die überholte Informationenmenge in dem Genom der einzelnen verschiedenen Spezies.

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PRO EXPERIMENTIS

Time Saving Improvements in the *Galleria* Bioassay for Juvenile Hormone

The great wax moth (*Galleria mellonella*) bioassay for juvenile hormone[1] is the most sensitive so far known, but it has the disadvantage that the whole procedure, from collecting the pupae until the application of the hormone sample, lasts rather long. As a consequence only a limited number of samples or extracts can be bioassayed per day.

Breeding wax moths in large quantities is easy and not time consuming[2]. DE WILDE et al.[3] described a method for obtaining pupae with thin cocoons, using pieces of plastic tube, 3 cm long and with an inner diameter of 4 mm. This procedure has been simplified by Dr. Schooneveld, Wageningen. The Netherlands (personal communication), using siliconized glass tubes of the same diameter which allow a quick removing of the cocoons from the tubes. The bottle neck of the bioassay is setting free the pupae from their cocoon. Although the cocoon is thin when the larvae are forced to spin in the 4 mm glass tubes, it takes a long time to open the cocoons by forceps and always a rather high percentage of the pupae are damaged and useless in the bioassay. A second difficult step in the procedure is the application of the hormone sample on the pupae. Hitherto, this was done by scraping a small amount of the hormone-paraffin-olive oil mixture with a blunt mounted needle and melting it over a flame and applying it to the wound just before the mixture hardens again by cooling. Only very well trained assistants can carry out this step without causing burns to the pupae.

We have developed simple techniques to overcome these two difficulties. First, a trick is described to remove the pupae from their cocoons very quickly without damaging them. Secondly a device was designed for the application of the hormone-paraffin-olive oil sample which completely avoids burns.

Materials and method. Setting free the pupae from their cocoon. Prepare a solution of 40 gm NaOH in water (1*N*). A sieve in plastic (small sieve for milk, available in ordinary shops, is very well suited). Beaker for the NaOH solution and 2 petri dishes or any other shallow containers, filled with water. Filter paper.

Procedure (Figure 1). Put groups of 5 to 10 pupae with cocoons in the sieve. Bring the sieve in the NaOH solution and immerse the cocoons. They begin to dissolve within a few seconds. After about 15–30 sec, the thinnest parts of the cocoons are dissolved. The sieve with the pupae is removed from the NaOH solution and it is turned over so that the pupae fall into the first petri dish with water. With a glass rod the pupae are turned around in the water to remove most of the NaOH and subsequently the undissolved parts of the cocoons are removed by hand. After this step the pupae are picked up again with the sieve and thrown in the second petri dish filled with water and they stay there for 2–3 min to remove the rest of the NaOH. Then they are put on filter paper to dry. Although this procedure may seem very drastic, it is not at all harmful to the pupae. Even pupae which remain for 5 min in the NaOH solution are not damaged. About 5% of the pupae are mechanically damaged during this procedure, but this is less than when the cocoons are removed by forceps. This

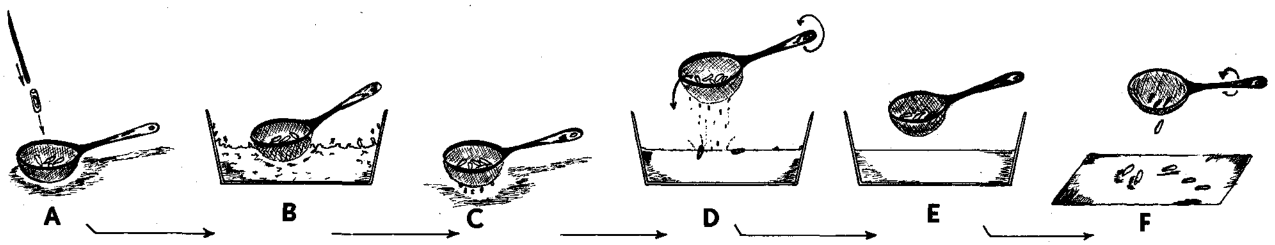

Fig. 1. A) Remove the cocoons from the siliconised glass tubes and put them in a plastic sieve. B) immerse the cocoons in the NaOH solution. C) Shake the sieve to remove most of the NaOH. D) Throw the pupae in H_2O and remove the undissolved parts of cocoons by hand. E) Pick the pupae up with the sieve, wash them in H_2O for 2–3 min. F) Dry the pupae on filter paper.

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[1] L. I. GILBERT and H. A. SCHNEIDERMAN, Trans. Am. microsc. Soc. *79*, 38 (1966).

[2] S. D. BECK, Trans. Wis. Acad. Sci. Arts Lett. *49*, 137 (1958).

[3] J. DE WILDE, G. B. STAAL, C.A.D. DE KORT, A. DE LOOF and G. BAARD, Proc. K. ned. Akad. Wet. *71*, 321 (1968).