THE Horace H. Rackham Fund of the University of Michigan has made an annual gift of $10,000 to a new clinic for the study of rheumatism. Dean A. C. Furstenberg, of the Medical School, has appointed a committee to take charge of the work and has placed Dr. Richard H. Freyberg at its head. Other members are: Dr. Cyrus C. Sturgis, director of the department of internal medicine; Dr. Harley A. Haynes, director of the University Hospital, and Dr. Carl E. Badgley, of the department of surgery.

DISCUSSION

LIFE; A PHOTOCHEMICAL STEADY STATE

THE assumption that living systems obey the second law of thermodynamics is made, at least tacitly, by most biologists, but is occasionally questioned by physicists and chemists. There is a great amount of experimental evidence to support the assumption, and none that definitely opposes it. Thus all opposition is based on theoretical argument, and a brief reconsideration from such a standpoint seems justified.

Actually, the system to be studied is somewhat different from those ordinarily postulated for thermodynamic treatment. From an energetic point of view it is not correct to consider living organisms inclusively, as an isolated system limited to the surface of the earth; they should be treated as a coupled system including both the sun and the earth. The free energy used for virtually all life processes is derived from sunlight through the photosynthetic activity of plants, the free energy so obtained being spent by both plants and animals. The accumulation and expenditure of free energy appear to be virtually equal, so that the total process may be considered roughly as a photochemical steady state. The chemosynthetic organisms may be excluded from the picture as comprising only a very small part of the total energy exchange; they do not disobey the second law of thermodynamics.[1]

The difference in temperature between sun and earth makes it possible to convert the energy of sunlight into chemical energy. The sun may be assumed to be a black-body at 6000° K, the maximum radiation from which is emitted at the wave-length 4800 Å, according to Wien's displacement law: $T \times \lambda_{max} = 0.2884$ cm. deg., where T is the absolute temperature and λ_{max} the wave-length of maximum emission. The earth may be assumed to be a black-body at 288° K, whose maximum emission is at 100,000 Å. The quantum of energy is inversely proportional to the wave-length ($e \times hc/\lambda$, where e is the quantum, h is Planck's constant, c is the velocity of light and λ the wave-length), so that the energy of the quantum for 4800 Å is twenty times that for 100,000 Å, the values being, respectively, 3.9×10^{-12} and 2.0×10^{-13} ergs. Since the temperature of the earth is virtually constant, it must radiate the same quantity of energy which it receives from the sun, but the quanta radiated must be smaller and more numerous than those received. For the latter reason the energy radiated by the earth must be considered to be more random in character than that received from the sun, which allows for the capture of free energy by the plant in the course of degradation of energy from larger to smaller quanta. Considered more specifically, a great part of the quanta in sunlight are of magnitude sufficient to produce changes in the electron orbits of those molecules which absorb them, and thus to produce photochemical reactions, whereas the reradiated quanta are not of sufficient magnitude to bring about such changes. Since the quantum is directly absorbed by the molecule, photochemical reactions, unlike thermal reactions, may go with an increase of free energy. Opportunity for the efficient capture of the energy of sunlight is thus provided, and plants have developed appropriate mechanisms which accomplish this.

It seems, then, that the complexity of the living world, which has been the basis of most arguments against the application of the second law of thermodynamics to living organisms, is only made possible by processes for which the degradation of energy is obligatory; and that the energy exchange of the total system is not contrary to the second law of thermodynamics.

If life is considered as a photochemical steady state, it seems to offer no exception to the second law of thermodynamics, unless many photochemical reactions *in vitro* also constitute such exceptions. The problem of the maintenance of such a steady state offers less difficulties to a thermodynamic approach than the problem of the development of complex living systems through evolution from less complex systems. However, as the writer has pointed out elsewhere,[2,3] the latter problem may also be approached from such a standpoint.

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[1] Baas-Becking and Parks, *Physiol. Rev.*, 7: 66, 1927.

[2] Blum, *American Naturalist*, 69: 354, 1935.

[3] Blum, *American Naturalist*. In press.

COAL IN GLACIO-FLUVIAL DEPOSITS IN OHIO

DURING an investigation of molding sands in the vicinity of New Philadelphia, Ohio, for the Mus-