discussed here may be largely academic. Most long-range space in the foreseeable future flights will certainly be unmanned, and, when it sometimes becomes desirable to bring back a vehicle, this can often be done by propelling the vehicle at right angles to the solar direction so as to decrease its orbital angular momentum. When this is done, gravitation will quickly bring the vehicle back. Certainly far more important is the ability of a propulsion system to offer a reasonable acceleration in combination with an acceptable fuel consumption. Although it is too early to state the merits of solar wind sailing, it seems to offer sufficient possibilities to encourage further studies.

Note added in proof: We have just learned that some of the ideas proposed in (*1*) and (*2*) have already been discussed by Moore (*6*). Our results are in general agreement with those of Moore, and we regret very much our ignorance of his work.

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26 September 1972

Time Reversal and Irreversibility

Sachs (*1*) has presented a thought-provoking article on time reversal. However, I find that his introductory arguments regarding the "flow of time" and the origin of irreversibility are somewhat captivated by traditional thinking in statistical mechanics. Among other things, the author states that irreversibility is introduced in the averaging process over the detailed molecular motions.

In a previous article (*2*) I demonstrated that the introduction of statistics does not by itself produce irreversibility. The origin of irreversibility, time asymmetry, or the law of increasing entropy, as given by any of the statistical mechanical "theorems," is not to be found in the mathematical formulations, but rather in an a priori choice made by the statistical physicist of a probability that is actually asymmetrical in time. This can be related to the empirical fact that blind statistical prediction is "physical," whereas blind statistical retrodiction is not. Thus, one can calculate the probability that something physical will happen, but not the probability that something physical did happen. This should be recognized as an imposed direction of time or an imposed initial condition on symmetric probability theory. It is a selection which is usually undeclared but which is essentially equivalent to an a priori introduction of the essence of irreversibility (and the so-called second law) into what is widely (and wrongly) believed to be a deduced statistical time asymmetry, statistical law of the increase of entropy or mixing, and so forth. Consequently, I stress that statistical (classical or quantum) mechanics fails to deduce the origin of irreversibility and time anisotropies in nature.

Without any other convincing arguments as to the origin of irreversibility, an increasing number of scientists are now convinced that the only explanation presently acceptable is that of the new astrophysical school of thermodynamics (*2–4*). Also, weak violations of the invariance of the laws of motion under time reversal (T-invariance) or space reversal and charge conjugation (CP-invariance) can now be explained by the astrophysical school (*2, 4, 5*).

My last remark is related in part only to semantics. The use of the conception flow of time has in the past produced logical havoc for physics. This conception also vitiated Bridgman's objections to Eddington's thermodynamic account of the anisotropy of time (*6*). The term flow of time should be replaced by a term such as anisotropy of time.

I stress that these remarks do not affect the contribution of Sachs' article. I hope that it will provoke all of us to reexamine the "fundamental" concepts in some of our theories.

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Gal-Or's reference to the statement that "irreversibility is introduced in the averaging process over the detailed molecular motions" takes it out of context. I introduced the concept of averaging to give a loose definition of the macroscopic (thermodynamic) variables of a complex system in terms of the microscopic motions, which are reversible. My complete statement places the emphasis on the incredibly small probability for attaining the initial conditions required for exact reversal of the motion if one can fix only the macroscopic conditions.

This emphasis on the role of initial conditions, which is to be found throughout my discussion, does not seem to be in disagreement with Gal-Or's remarks. However, I do disagree with his suggestion that there is a time asymmetry to be explained. If a complex system is initially in an ordered state, the probability is overwhelming that it will behave symmetrically in time; that is, if the detailed microscopic motions are followed either forward or backward in time from that initial moment, the corresponding thermodynamic variables determined by averaging over the particle motions will change irreversibly.

My article is not intended to be a discussion of the laws of irreversible thermodynamics. My only purpose in bringing up the subject at all is to show, in as naive a way as possible, that there is no contradiction between the time reversal invariance of the laws of motion and irreversibility of the variations of the thermodynamic variables.

Although my arguments may be "captivated by traditional thinking," they are given in connection with a traditional problem in physics which yields to traditional answers. The problem arises not in trying to determine the answers but in trying to phrase them in terms suitable for a wider audience.

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