Extraterrestrial Microbiology

WOLF VISHNIAC, PH.D.

IN THE EFFORT of devising ways and means of studying the existence of living organisms on other planets, attention must be focussed on microorganisms. This is not entirely due to professional prejudice of microbiology, but is the consequence of accepted realization that microorganisms are responsible for the major amount of turnover of matter on earth and that life of the higher plants and animals is inconceivable in the absence of microorganisms. To cite only a few major examples, it must be remembered that 80 per cent of all photosynthesis, that is, 80 per cent of the total amount of oxygen released into the atmosphere is carried out by oceanic microorganisms, and 90 per cent of the total carbon dioxide released into the atmosphere is brought forth by the actions of microorganisms. Without microorganisms the nitrogen content of the soil would not be replenished, nor would sulfur be available in a biologically useful form. It is apparent then that, even in the absence of higher plants and animals, the basic ecology of the earth would not be changed. Since it is therefore possible to maintain a planetary ecology by microorganisms alone, but not by animals and higher plants in the absence of microorganisms, it is reasonable to look for microorganisms first when other planets are explored for living organisms. Furthermore, it is technically simpler to look for microorganisms than for higher plants or animals.

The known activities of microorganisms and the relationship to their environment has enabled microbiologists to make use of the "enrichment culture" in the isolation of microorganisms from natural sources. The enrichment culture is nothing more than an artificial environment designed to favor a particular kind of microorganism over its competitors. Conversely, a consideration of a known environment allows one to predict with reasonable accuracy the type of microorganism that will flourish in it. Since, of the other planets of our solar system, only Mars holds the promise of existing life, Mars shall be considered as a gigantic enrichment culture and a few predictions are offered concerning the microflora which may exist there. Such predictions have nothing to do with the morphology of the microorganism, either in its microscopic appearance or its molecular structure. It only deals with its physiology: the activities which such an organism would have to carry on to flourish in such an environment.

From the Department of Biology, Brookhaven National Laboratory, Upton, N. Y., and Department of Microbiology, Yale University, New Haven, Conn.

Presented at the Aerospace Medical Association meeting on May 10, 1960 at Miami, Florida.

Since Mars in its essential chemical features is an environment probably devoid of oxygen, rich in carbon dioxide, and subject to illumination, data are already available necessary to outline a probable microbial ecology for it.

Photosynthesis must be the basic economy of Mars as it is on earth. therefore cannot be oxygen-dependent. It must be assumed that anaerobic types of respiration exist, such as sulfate reduction. Organisms are known which will oxidize hydrogen or organic matter with sulfate as the terminal respiratory substrate, and such activity could balance bacterial photosynthesis.

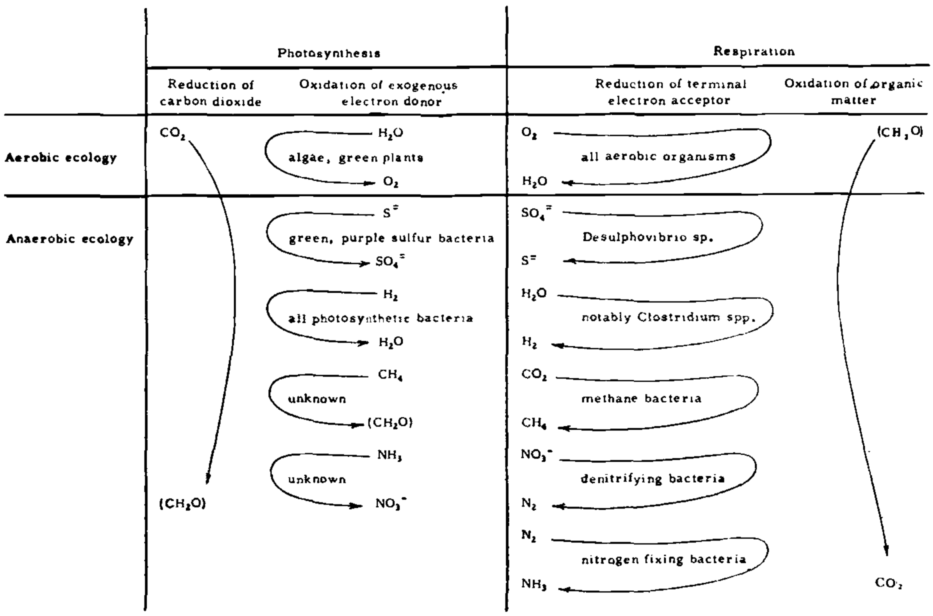

Fig. 1. Summary of a few oxidation reduction reactions which affect the balance of nature.

Absence of oxygen from the atmosphere means that photosynthesis cannot be of the oxygen-evolving type, and it may be assumed that it resembles photosynthesis as carried out by terrestrial photosynthetic bacteria. Concomitant with a light-dependent reduction of carbon dioxide, there must therefore be the oxidation of some external substrate. As an example one may cite reduced sulfur compounds such as hydrogen sulfide which will then be oxidized to sulfuric acid. The Martian counterpart of respiration which will balance photosynthesis Other anaerobic respirations which may take place on Mars and which are also known among terrestrial organisms would be the use of carbon dioxide as a terminal respiratory substrate with the resultant formation of methane or nitrate which would give rise to free nitrogen. One cycle which may be difficult to complete on Mars would be the nitrogen cycle. On earth, ammonia is oxidized in the presence of free oxygen to nitrate, and no similar reaction under anaerobic conditions is known. However, photosynthetic organisms in the light can frequently

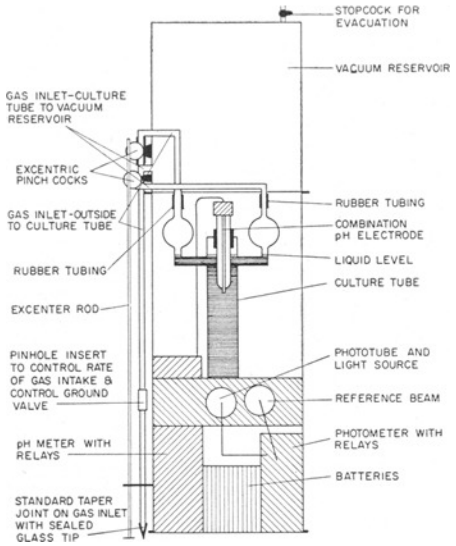

Fig. 2. The "Wolf Trap." Prior to use, the gas inlet tube is sealed off with a glass cap (lower left), the culture tube is isolated from the vacuum reservoir by closing the excentric pinch cocks (upper left), the vacuum reservoir evacuated, and the entire device sterilized. On impact the excenter rod (left) will open the pinch cocks, the glass tip of the gas inlet will shatter, and the atmosphere carrying surface dust will enter the inlet tube, pass through the liquid in the culture tube, and finally fill the vacuum reservoir. The rate of gas flow will be checked by a constriction, and a conical ground valve, lifted by the inrush of gas, will drop into place once pressure has been equalized. Changes in pH or turbidity of a predetermined magnitude will close relays which in turn can activate transmitters.

carry out oxidations of the type usually associated with strictly aerobic processes. It is therefore possible that in such an anaerobic environment one may find photosynthetic bacteria oxidizing ammonia. The reduction of nitrate is a process which is well known to occur under anaerobic conditions, as is also nitrogen fixation. Similarly, methane might be oxidized by certain photosynthetic bacteria. Figure 1 shows possible schemes to accomplish such exchange.

The exploration of life on Mars may be carried out by a device which in principle is a culture tube, provided with a suitable medium, which can be monitored for changes in acidity and turbidity. Figure 2 shows an apparatus with a single culture tube, which on impact will be inoculated by dust and atmospheric particles drawn into the vacuum reservoir at the top of the apparatus. Changes in acidity or turbidity will set off relays which in turn will activate transmitters so that one can follow from earth changes in the culture medium. The media would be devised to support life of probable anaerobic microorganisms.

The Design Limitations of Human Performance

During the past several years, it has become apparent that in terms of cause factors, human error is of critical importance. Almost half (47 per cent) of all accidents are consistently charged to "pilot error." Another 10 per cent are charged to other human errors, and a large proportion of the undetermined accidents imply some type of human error. Taken collectively, the human contribution to accidents exceeds all other primary causes by a ratio of almost 2 to 1. Further critical examination of these accidents indicates, however, that this human error is not necessarily the result of negligence or willful violations on the part of the human involved, but could be the direct result of a situation which forces the human to perform in a situation which demands more than his design limitations are capable of responding to.—Joseph D. Caldara: Flight Safety. *SAE Journal*, June 1957.