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Life on Mars?

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Within this decade the National Aeronautics and Space Administration plans to explore Mars for the existence of life. If a positive result is obtained, it would mark one of the momentous milestones in science and the history of mankind. While several lines of approach are under development for this important experiment, one tentatively designated to be included in the first capsule sent to Mars is a radiobiochemical probe, hopefully named Gulliver.

The basic premise for Gulliver is one subscribed to by many biologists—that the most probable form of extraterrestrial life would consist of aqueous and carbonaceous microorganisms. A common characteristic of known forms of life is the ability to assimilate nutrients and to evolve gases in the respiration process that contain some of the atoms from the compounds absorbed. If appropriate atoms in the nutrient compounds are radioactive, the gases produced by the organisms will contain the radioactive atoms and thus be readily detected. One of the most important gases, perhaps universally evolved by living organisms, is carbon dioxide. Others are hydrogen sulfide, methane, hydrogen and ammonia.

The Gulliver experiment (Fig. 1) consists in sending a carefully developed radioactive medium to Mars, inoculating it with a sample of Martian soil, collecting any gas that may be evolved from the culture and measuring the radioactivity of the gas. The data are telemetered back to Earth. Radioactive gas produced in a test culture, but not in a control culture containing an antimetabolite, constitutes evidence of life. If a plot of radioactivity evolved as a function of time results in the typical sigmoid curve* (Fig. 2) associated with biological populations, this, even in the absence of a control, would strongly suggest the presence of life.

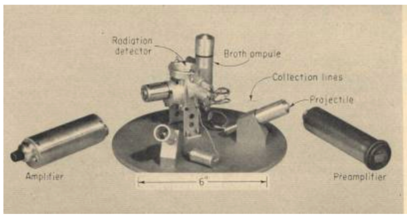
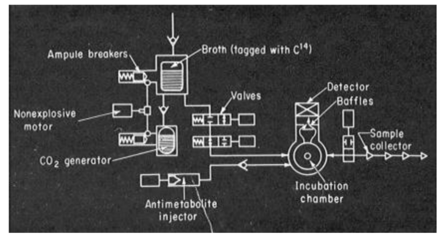


FIG. 1. EXPERIMENT GULLIVER will detect presence of microorganisms on surface of Mars with radioactive tracer techniques. Samples of Martian soil collected on strings extended by two tiny projectiles are injected into radioactive nutrient broth. Detection of radioactive gas evolved from broth constitutes evidence of life



The medium we developed induces growth in a wide variety of test microorganisms. These include aerobes, anaerobes, heterotrophs, phototrophs, autotrophs and spore formers. Results are obtained far more rapidly than is possible with classical bacteriological testing methods—a matter of minutes or several hours compared to one or two days. Moreover organisms can be detected in growth or resting states. This sensitivity is important because only a few hours may be available to complete the experiment on Mars, owing to the limited power available.

Instrumentation for the experiment is now in its third generation. Field tests have been made, and the results of one test, performed to detect the presence of life in a park in Washington, are shown in Fig. 2. The curve shows that two distinct types of organisms were present. One had a shorter lag period than the other, as evidenced by the first exponential portion of the curve. The other organism was still in lag during the maximum growth period of the first. After the growth of the first was attenuated, the second organism went into exponential growth, as indicated by the second, steep portion of the curve. This tells us something about the microorganisms in that it directly reflects their ability to adjust to the medium used. Furthermore the slope of each exponential portion of the curve gives the generation period of the organisms. This is the time required by the organisms to double in the exponential phase. The generation period is characteristic of various groups of organisms. For example some types of bacteria reproduce faster than others, and bacteria reproduce faster than algae, and so on. While it is desirable to obtain the entire curve, the initial portion is sufficient to establish the presence of life.

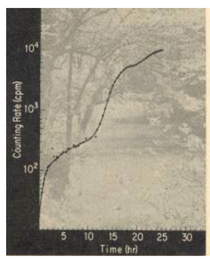


FIG. 2. PRESENCE of life is confirmed by double sigmoid-shaped curve obtained by Gulliver in test in Rock Creek Park, Washington, D. C. (photo shown in background)

To detect the presence of microorganisms on Mars, Gulliver was designed to obtain soil samples, to process and transfer tagged nutrient broth, to collect the evolved tagged gases and to detect activity in the collected gases. Design also was influenced by the requirement for minimum power, size and weight and by the need for rugged construction to withstand sterilization, shock and vibration and long exposure to high vacuum in transit and to provide good stability for operation at reduced pressure, humidity and temperature. The weight of the current instrument, shown in Fig. 1 with detector, preamplifier and amplifier, is about 1.5 lb. Power requirements, excluding temperature control, are about 250 milliwatts for the detection system and 2 watts for 3 min for collecting the sample.

Sampling is carried out as follows: The soil sample from the Mars surface is collected on two 25-ft strings coated with a sticky silicone grease selected for its constant viscosity over a very wide temperature range. The strings are laid out on the ground from inside hollow projectiles fired from two small guns (see Fig. 1). The lines are brought into an incubation chamber through a port and wound onto a spool driven through a gearbox by a d-e motor.

The tagged nutrient broth is transported in a glass ampoule. So far our plans include the use of C^{14} only, although we are investigating the use of S^{35} and H^3. These tags will be explored in many different compounds.

Nonmetabolic tagged gases evolved from the broth in trace quantities during the approximately eight-month voyage to Mars are removed to improve the sensitivity in detecting metabolically evolved gases. This is done by flushing with "cold" carbon dioxide before the broth is put into the incubation chamber. The flushing gas bubbles through the broth and vents to the atmosphere through a check valve. After flushing, the broth is transferred into the incubation chamber by opening a normally closed valve in a line between the bottom of the broth chamber and the incubation chamber. The transfer takes place by gravity and by the carbon-dioxide pressure head that is retained by the tension of the check valve used in venting the flushing gas. After the transfer is accomplished, a normally open valve in the transfer line is closed.

The incubation chamber is completely sealed from the atmosphere after the broth and collection lines are inside, and any metabolically evolved gases diffuse into the free space above the liquid. The gas deposits on a thin getter [for carbon dioxide $Ba(OH)_2$ is used] on the radiation detector. This deposition establishes a gradient that drives gas to the getter. An open baffle between the detector and the broth prevents the detector from "seeing" the broth directly but presents little resistance to gas diffusing from the broth.

The control will consist of a duplicate Gulliver contained in the space capsule. The entire procedure will be identical with the test Gulliver with the exception that an antimetabolite will be injected into the control Gulliver. The data from each will be telemetered back to Earth, where the comparison of curves will be made.

Detection of the beta particles from the collected gases is currently done with a 2-cm^2 surface-barrier semiconductor detector using transistor circuitry. Other types of detectors have been, and are currently being, investigated, but the semiconductor is best for size, weight, power and voltage considerations. Efficient detection of the low energy betas with such a system requires a low noise detector and preamplifier. The voltage-sensitive preamplifier that has been developed has a noise resolution of 37-kev full width at half maximum with a 100-μμf input capacitance.

A charge-sensitive preamplifier is also being developed. A low- and -high level discriminator in the amplifier provides an energy window that aids in reducing the background counting rate to allow for the uncertainty in the ambient radiation intensity and spectrum at the surface of Mars.

The signals for actuating the motors (small pyrotechnic devices) that perform the mechanical functions are to be provided by the programmer in the vehicle or capsule.

Because recent information indicates that the capsule may have no attitude control, Gulliver is currently being redesigned to obviate the need for such control. Although the geometry and materials may change, the basic concept will remain essentially as described above.

Should the presence of life on Mars be established, more sophisticated Gullivers would be planned. Various specific-questions would be put to the organisms to find out whether or not they are related genetically to life on Earth and, thereby, to seek to determine whether life on the two planets evolved independently or was transported from one to the other or from a common source.

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* The sigmoid curve is generated by all biological populations plotted as a function of time. When a population is transferred to a new medium and incubated, at first there is a period of adjustment; then reproduction begins and increases rapidly into a logarithmic progression. This exponential growth continues until essentials in the nutrient are exhausted or until the bacteria produce by-products that are self-inhibiting. At this point the population would cease to increase, remain steady for a period of time and finally begin to die off at an exponential rate until the last remaining organisms, selected by the process, would die at a much slower rate.