Life Detection Instruments

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The author spent a summer at Wallops Island in a Bio-Technology Training Program sponsored by NASA. This article may serve as a stimulus for other teachers to begin an extended reading program in the area of exobiology.

Introduction

The field of biology has been confronted recently with the paradox of being the only natural science which has yet to demonstrate that any of its terrestrially based conceptual schemes have any universal significance. The various thoughts, ideas, and principles of present day biology apply to only one kind of life—life on Earth. Prior to recent times, biologists were not in a position to attempt any progress in what was to become a new biological discipline of exobiology, or the study of extraterrestrial life. The sciences of physics and chemistry have long enjoyed the utilization of celestial mechanics and stellar spectra as a means of extending terrestrial principles to levels of universal significance. But now, with the growing space program, there are tools with which biologists can undertake the exploration of other planets in an attempt to detect, understand, and perhaps one day, develop an abstract definition of life as it exists throughout the Universe.

The relationship of our planet's geologic history, as well as its past and present astronomical heritage, has provided a somewhat well understood model of how life has arisen, evolved, and is presently existing on Earth. The exploration of other planets in terms of astronomical and geologic experiments can lead to certain conclusions regarding extraterrestrial life. The Russian biochemist, A. I. Oparin, has pointed out that: "Consequently, the origin of life is not a fortunate, extremely improbable event, but quite a regular phenomena subject to a deep and scientific analysis and all-around study. It is obvious that there must be numerous inhabited planets in the Universe and, in particular, in our Galaxy. This quite indisputable assertion, however, is based on consideration of a general nature and must be confirmed in each concrete case by an examination of the actual conditions which prevail on the cosmic bodies accessible to investigation by the methods of modern science." (1)

The most advantageous condition for the study of extraterrestrial life would be to have an actual sample of it for study right here on Earth. The process of returning planetary samples over millions of miles of space is, as yet, beyond the present capabilities of space technology. In fact, by the time such an advanced state of technology is reached, it may not be necessary, as manned spacecraft flights to Mars and Venus may have become equally feasible. (2)

What follows is an attempt to describe the present approaches to designing automatic life detection devices which available launch vehicles can transport to the surfaces of various planets. These instruments range in various stages of development from laboratory-based experiments to operational models currently being tested for space flight. The techniques for carrying out such missions have been well demonstrated by American and Russian interplanetary space probes. Most notable among these missions was the 1964-65 American Mariner IV fly-by of Mars at a distance of 7,000 miles. The prime trajectory and mid-course secondary trajectory maneuvers of the spacecraft Mariner IV illustrated the excellent state of the art with regard to interplanetary spacecraft control. The numerous experiments and vidicon television photographs of the Martian surface substantiated the telemetry reception capabilities of

Earth based antennaes and computers. (3)

A Strategy for Life Detection

Most exobiologists tend to feel that life is conceivable on any of the planets, their satellites, and asteroids. But when considering the most probable sites for life with regard to various parameters such as temperature and atmospheric composition, the general conclusion is that the planets Venus and especially Mars are most favorable. (4) Consequently major astronautic planning calls for designing a strategy for the integration of instruments into spacecraft hardware for delivery to the planets Venus and Mars.

Many specific instruments and measurements have been suggested for the use of known biochemical and biological techniques for detecting extraterrestrial life. Certain engineering decisions must be made concerning which instruments to incorporate in the spacecraft package. This process involves the balancing of the biological importance to be obtained, the weight of the apparatus, its power requirements, its volume, its liklihood of successful operation or failure, its data rate requirements, and many other factors as well. There is the added consideration of what is called the COSPAR (Committee on Space Research) agreement regarding the sterilization of the entire spacecraft and its equipment. (5) The sterilizing procedure (heat soaking, gases, and radiation) imposes a severe strain on the spacecraft modules, subassemblies, and separate components. The COSPAR resolution imposes a standard that requires that less than one viable microorganism be contained in each 10,000 within a spacecraft intended for planetary entry. These quarantine factors seek to minimize the probability of contaminating Mars or any other planet and thereby destroying possible extraterrestrial organisms or modifying the biochemical environment so as to reduce the usefulness of a planet for biological study or utility at a future time. Present attempts at sterilizing spacecraft systems have met with serious problems—especially the lander spacecraft intended for Mars. Serious degradation of system components with a resulting loss in reliability or functional lifetime has occurred consistently. Because of the costly technology that must be developed to overcome these problems there has been consideration of relaxing the 1×10^{-4} microorganism restriction as set by COSPAR. (6)

The present program which calls for a space vehicle capable of delivering life detecting packages to the surface of Mars is the Voyager series of spacecraft. (7) Some $3 billion are involved in the research and development of the Voyager series. The Voyager module will utilize the Saturn V as a launch vehicle which has the capability of injecting a spacecraft weighing up to 60,000 pounds into a transfer trajectory to Mars. The Atlas-Agena launch vehicle in comparison, was able to initiate a fly-by of Mars in 1964-65 with the Mariner IV which weighed only 500 pounds. The Voyager spacecraft will consist of two major modules, an orbiting spacecraft and a surface lander spacecraft. The two will separate as they approach Mars, one to orbit the planet, serving as a communications link to Earth, and the other to explore the surface of the planet. The landing vehicle will carry the life detecting instruments, as well as an array of devices to collect data regarding the physical and chemical parameters of the Martian surface in general. While economic factors may hamper program development, there still exists the 1973 and 1975 target dates for delivery of the Voyager package to the planet Mars.

The decision to search for extraterrestrial life poses the question of just what kind of life to look for. Exobiologists are unanimous in rejecting any attempts that might be characterized as attempting to catch a hopping insect or other such energetic extraterrestrial organism, should it exist. Consequently there must be a strategy for detecting life which has the highest probability of being where the spacecraft lands and of having its presence detected with the most simple and reliable of biochemical techniques. Because of the ubiquitous presence of microorganisms on Earth, it would be hard to imagine life on Mars without the presence of microbes. (8) For purposes of fundamental biology, it would be just as valuable to find microbe life on Mars as higher forms.

In general, the detection of living systems on another planet will depend upon detection of a biochemistry similar to that of terrestrial organisms. The presence of macromolecules like nucleic acids, proteins, and enzymes would certainly increase our confidence in the existence of life, since they are the components of living systems on Earth. The design and development of various life detecting instruments has consequently been based upon the terrestrial macromolecule premise. Yet, while chemical analysis is strong evidence, it is not, strictly speaking, detection of life. The living quality of an organism is apparently a very intricate and delicate state. Living systems are often purely chemical states which may be the more common condition rather than the more sensitive living condition they may bracket.

The task set before a planetary landing vehicle when it touches down on the surface is strictly one of obtaining samples from the environment in the form of dust or other fine materials. The assumption is that these small samples will harbor microorganisms. At the present time there are two primary designs for collecting the above samples: sticky retractable strings and pneumatic collectors that suck up fine particles from the surface or ingest aerosols from the atmosphere. The environmental samples are then brought into analysis compartments, or in the case of a microscope, on the focal plane. (9)

Methods and Techniques for Life Detection
Morphological Evidence

The high-resolution (0.4 mm from a 4 meter height) television system appears to be one of the best ways for obtaining evidence of macroscopic organisms or aggregations of microorganisms. (10) An instrument related to this one has particularly proven itself by photgraphing lunar surface materials from a Surveyor spacecraft. The primary disadvantages of such a system are the power requirements and extensive amounts of time for data transmission.

Various microscopes are being designed for the purpose of detecting microorganisms on planetary surfaces. The Jet Propulsion Laboratory of the California Institute of Technology is developing a vidicon microscope. This design originally suggested by Joshua Lederberg, a noted geneticist and exobiologist, will allow a field area of 100 mu with 0.5 mu resolution. The sample to be observed will be injected in the form of a spray into the focal plane through an opening in the condenser lens. The transmitted photographs will have light levels of gray shading, about 400 lines per frame, and will require more than 500,000 bits per frame for transmission.

Another instrument being developed is the automated scanning, flying-spot, photometric microscope. Dust particles are collected on a sticky tape, stained, and monitored. Organic particles will be differentially stained and will stand out in contrast to other opaque particles. Low bit-data requirements make this particular instrument especially important for life detection consideration.

Chemical Evidence
Optical Shifts in Dye Complexes

The Aeronutronic Division of the Philco Corporation has devised an experimental technique called the "J Band" for detecting chemical evidence indicating the presence of extraterrestrial life. (11) The procedure involves the use of visible spectrometry to determine the shift of the absorption band of a dye (thiocarbocyanine) to one or two new wavelengths upon the interaction of the dye with certain organic macromolecules such as proteins and nucleic acids. The sensitivity is in the range of one gamma of biologically important molecules.

At the present time, this technique has only been carried out under laboratory conditions. Problems involving sample acquisition, sample treatment, and apparatus sterilization have yet to be solved. There are consequently no working breadboard models being constructed as yet.

Ultraviolet Spectroscopy

Experiments with various compounds such as amino acids, dipeptides, tripeptides, polypeptides, and proteins indicate that all substances containing peptide bonds exhibit an absorption maximum in the 185-190 millimicron region. (12) This property of biologically important molecules suggests another approach to detecting extraterrestrial organisms.

Analysis of various non-peptide materials in soils shows that they too absorb in the 1800Å (4) range giving false positive measurements. Such a situation coupled with stray light errors has made this particular technique in need of further research and development at the laboratory level.

Optical Activity

Terrestrial organisms exhibit a property of life which seems to be intrinsic within the life-associated molecules. This unique property of life is almost a sure indication of life and as such may prove an important technique for determining the chemical evidence of extraterrestrial life. That property is optical activity, the ability of molecules of a dissolved substance to rotate the plane of polarized light. Most molecules of a biological origin show this property. Amino acids, for example, usually rotate light to the left (levorotatory). Materials which are ordinarily synthesized by non-biogenic means show no optical activity because their molecular makeup is made of equal numbers of left handed and right handed (dextrorotatory) molecules. Such a combination results in both forms canceling each other out with no resulting activity of an optical nature.

An instrument utilizing such a property of life is being developed by Ira Blei and John Liskowitz of Melpar, Inc. (13) Present designs call for the measurement of the optical rotation of plane polarized monochromatic light at 240-260 millimicrons when it is passed through a solution prepared from a soil sample. Sensitivity of such a device is approximately 1-10 micrograms and would thus require between 10^4 to 10^5 microorganisms for a positive measurement.

Such an instrument is now at the engineering breadboard stage and will soon enter the operation-testing stage. This device appears extremely durable in standing up to the sterilization stresses and the rigors of a harsh extraterrestrial environment. A flight-sized model will weigh approximately six pounds, occupy an area of 130 cubic inches, and require 2 watts with data transmission at the 20 bit level.

Gas Chromatography in Combination with Mass Spectrometry

Gas chromatography and mass spectrometry in combination are among the primary analysis procedures in life detecting equipment. (14) They are capable of rapid separation, detection, and precise identification of organic materials on planetary surfaces. A sample component (derived from a gaseous, liquid, or solid material) vapor is removed from a gas chromatographic column by means of a carrier gas and is concentrated many times via one or several molecular separators and fed directly into the ion source of a mass spectrometer. At this point, the compound is ionized, the ions accelerated and deflected, and the ion masses of the parent molecule and its characteristic molecular fragments are measured and recorded. Such a combination can detect dozens of complex chemicals ranging from acetaldehyde and propionaldehyde to amino acid fragments of any weight.

Multivator

The multivator concept in detecting extraterrestrial life interjects a quality of versatility that other instruments have lacked in various degrees. Multivators are often referred to as miniaturized, biological laboratories. Such an instrument was originally devised by Joshua Lederberg of Stanford University and is currently being developed, built, and tested at the Jet Propulsion Laboratory. (15)

A procedural series of steps begins with a fine, filtered sample of the planetary dust being blown into different chambers by a sample collecting mechanism. The collected sample is then combined with an appropriate reagent or biological material. These different chemicals and nutrients are added to only certain chambers while others are kept as controls. The resulting reactions are then detected with a photomultiplier which serves as an output transducer. This technique also can be adapted for use in the detection of biologically important molecules by fluorimetry, turbidimetry, nephelometry, absorption spectroscopy, or absorption spectral shifting in a test substrate.

The multivator has gone through a series of different designs, the early designs having 30 module-chambers, later ones had only 10, but the most recent multivator model has 15 module-chambers arranged in a circle. One of the chambers is primarily aimed at detecting the enzyme phosphatase. This catalyst is involved in the role which phosphorus carries out in metabolism and energy transfer. Such processes are considered almost ubiquitous among terrestrial organisms and may also be taking place in extra terrestrial organisms if they are of a carbon-based aqueous nature.

When a dust sample is blown into the above chamber, it is allowed to settle upon a substrate containing fluorescein, a normally fluorescent chemical bound to one or more phosphate ions. This bonding renders the compound non-fluorescent. Any phosphatase present in the dust sample will catalyze dissociation of the bound molecule, and the fluorescein will fluoresce. This activity is then detected by the photomultiplier. This information is then reduced to digital form and transmitted. Sensitivity for this particular experiment is in the microgram range (about 10^5 microorganisms per milliliter). It is important to note that live organisms are not required in this experiment.

Pre-flight models are some 3 pounds in weight, about 90 cubic inches in volume, require a maximum of 5 watts for power, and have a transmission level of 5,000 bits. This particular model is not affected by radiation, pressure, impact, or vibration. Sterilization of all components by various means has been accomplished without any loss in reliability.

Gulliver

The Gulliver was first realized by Gilbert Levin of Hazelton Laboratories and Norman Horowitz of the California Institute of Technology. (16) This instrument makes use of several small projectiles to which is attached a line with chenille at the end. The projectiles are fired away from the instrument with the thread unwinding. A small electric motor reels in the lines along with any particles that stick to the line and chenile. The line is introduced into a chamber which contains a growing medium of basal salts fortified with soil extract and radioactive organic C^{14} substrates in the form of formate, glucose, lactate, and glycine. The presence of extraterrestrial organisms would be indicated by their use of the added sources of carbon and nitrogen.

The organisms introduced into such a medium would, by virtue of their metabolism involving the isotopic carbon compounds, begin to release radioactive carbon dioxide. The binary fission process of growth results in an exponential production of carbon dioxide. This activity is measured by a special Geiger counter and digitized for transmission.

If the above carbon dioxide production is not exponential in nature, then it becomes difficult to abscribe the activity to either non-growth metabolic activity or merely to the chemical degradation of the substrate. Another major problem involves the selection of adequate culture mediums. The use of controls is also proving a hindrance in that identical samples are not provided to both the test and control chambers. Present designs use an antimetabolite introduced into one of two growth chambers.

The Gulliver at present weighs 7 to 12 pounds, has a volume of 300-600 cubic inches, requires 3-5 watts, and transmits about 700 bits. Specific components in the Gulliver are a sample processing mechanism, a main chamber containing a sample processing mechanism, a radiation counter, an electronic signal and data processing system, an electronic programer, and a heating unit. The entire package appears adaptable to the strains of space flight, stresses of sterilization, and the rigors of harsh environments.

The Gulliver is the most advanced life detecting apparatus and has undergone very intensive field testing. (17) Several extreme natural environments were selected, ranging from cold, rocky, 12,000 foot White Mountain in California to the sand dunes of Death Valley, and the hot, dry, highly saline Salton

Salt Flats. All of these sites had some environmental characteristics similar to the planet Mars. Some tests were even conducted in Virginia, where hard clay soils heavy with limonite would simulate the probable Martian surface. Significant positive responses were obtained from the Gulliver tests at all sites within sixty minutes. Variations in testing indicated that when the radioactive medium was added directly to the soil that responses were even more pronounced.

Wolf Trap

The Wolf Trap represents one of the most rugged life detecting instruments yet devised and tested. The Wolf Trap was originally conceived by Wolf Vishniac and C. R. Weston of the University of Rochester and is currently being developed by Ball Brothers Corporation. (18)

The Wolf Trap measures two common characteristics of fluid cultures which contain multiplying microorganisms—the increase in cloudiness or turbidity, and the increase in acidity brought about by the accumulation of metabolic waste products. Measurement of these activities is accomplished by a photocell that detects the intensity of light passing through the culture, as well as the degree of light scattering (nephelometry). Acidity is monitored by glass pH electrodes. Actual detection rests upon the increase of turbidity and acidity and not merely the presence of the two. The instrument appears to have a sensitivity of 10^3 bacteria per milliliter.

Concern has been expressed regarding the length of time the apparatus may have to function before any signs of life are evident. Organisms on Mars may have a very slow rate of development and, consequently, turbidity and acidity measurements would be difficult. Other problems regarding the transmission of false positives are the forming of colloidal particles in the nutrient and the occurrence of hydrophilic substances swelling in the medium material. Several controls are being planned: a nutrient sample to which no extraterrestrial material is added, a non-nutrient flask (to account for any false positives due to power surges or other external conditions), and a nutrient flask to which formaldehyde has been added. (19)

The present model of the Wolf Trap contains thirteen chambers, including controls. Samples of planetary dust are to be collected from a flexible tube ejected upon the planet's surface. The final specifications of the Wolf Trap call for a weight of approximately fifteen pounds, about 600 cubic inches in volume, and having a power consumption of about 3-5 watts for transmission of 300-900 bits of information. The apparatus is expected to withstand space environment stresses and sterilization procedures.

Detection of Photoautotrophy

Various hypothetical ecologies of the planet Mars have indicated that the Martian environment would be capable of maintaining some form of photosynthetic bacterial organisms. (20) Terrestrial plants on Earth utilize radiant energy just as those photosynthetic organisms on Mars. The major difference between the two would be the source of an electron donor. Terrestrial green plants utilize water as an electron donor, whereas on Mars, the compound limonite may serve the same purpose. This water substitute condition is familiar to some organisms on Earth, for instance, the sulfur bacteria.

The Hazelton Laboratories have updated one of the Gulliver life detection units (now called Gulliver III) for detecting the presence of photosynthetic organisms. (21) Favorable results have already been gained by utilizing *Chlorella pyrenoidosa*. An experimental medium using a urea salts base with DL-sodium lactate-1-C^{14} was found to be suitable. The light source is within the testing chamber itself, and results indicate that photosynthetic responses to light change are more extreme when the sample is initially introduced into a dark chamber.

Detection of ATP

The Hazelton Laboratories are now in the process of conducting a series of laboratory experiments and field tests to develop an apparatus capable of detecting organisms by the presence of adenosine triphosphate (ATP). (22) These "Diogenes" experiments as they are called, have the unusual advantage of being able to detect organisms in the atmosphere as well as on the surface of a planet. The response time for detection of organisms is on the order of fractions of a second. There is no need of nutrient chambers or growth time. In fact, the organisms need not be alive or even structurally intact.

The present breadboard models call for separating the cellular ATP from the organism by means of ultrasonic vibration, or by chemical extraction with methanol or some other solvent. The cellular ATP is introduced into a chamber containing luciferin, luciferase, magnesium ions, and oxygen as testing reagents. A positive response will result in the emission of visible light. A photomultiplier tube would detect the light and would transmit the data.

The sensitivity of such a technique is on the order of 10^{-4} micrograms of ATP. Positive responses have been gained from as few as 1,000 yeast cells and even as little as 6,000 *Serratia marcescens*. Controls are being developed which will utilize uninoculated reagents and non-reagent (water) chambers.

Sampling can be carried out by devices which scoop in large quantities of the atmosphere as an orbiting probe dips into the planets' atmosphere. Such a technique would equally work by utilizing the sticky string sampling method of the Gulliver apparatus. The first technique is presently being used in sounding rockets to obtain microbial ATP profiles of the Earth's atmosphere.

As yet, no data regarding the operational size, weight, or power requirements is available. Problems regarding the interpretation of a positive ATP reading are the primary concern at the present time. Experiments by Ponnamperumo, Sagan, and Mariner have shown that ATP can, under certain conditions, be derived from non-biogenic sources. If an experiment to detect ATP can be allowed to continue for several hours, then it is possible to determine a distinction between abiogenic ATP and ATP operating in a living system. This resolution to the initial problem results in the inherent advantage of this particular apparatus being put in serious doubt.

Automated Biological Laboratory

The most elaborate and complex life detecting system under consideration at the present time is the ABL. (23) The ABL will be a 6,000 pound surface exploratory vehicle capable of conducting a multitude of biological experiments under extremely flexible conditions. At the core of the ABL will be a master computer exercising control over various sensor and effector subcomponents.

The ABL will be capable of a mobility by virtue of legs or tractor thread assemblies. The velocity of the ABL may range from one meter per second, allowing for example, two circum-navigations of the planet Mars in two years, to one centimeter per second, allowing about 600 kilometer of travel in two years. The slower time is considered most advantageous as the mobile ABL would have traveled only 10 meters, during which time various instructions could be transmitted from Earth regarding any item of interest seen during the movement.

The ABL will be equipped with numerous mechanical manipulators ranging from digging claws to micro-tools. The feasibility of such spacecraft extensions operating adequately at a distance has been demonstrated by several Surveyor lunar spacecraft. Such mechanical manipulators would be guided by different sensor devices such as television cameras, tactile sensors, and even acoustic sensors. Depending upon present development of the state of the art in computerized life detectors, it may even be possible for the above combinations to effect repair to any possible damage the ABL may have suffered during exploration, or at any rate, the replacement of parts.

Because the power drain for continuous visual feedback to Earth would be too high, it will be necessary that the ABL computer be capable of deciding what items in the environment should be investigated and reported back to Earth. Considerable effort is being made in the computer sciences to develop such a computer recognition system.

The ABL will contain a sort of chemical laboratory. Operations ranging from sample preparation, filtration, centrifuging, conducting physical measurements, storage and even laboratory cleaning will be possible in the ABL chemical analysis system. The speed of the mechanical analysis aspects will approximate five operations per second. About 3 x 10^8 elementary chemical operations may be performed during the lifetime of the ABL. Limiting conditions are necessitated by virtue of chemical supply capability, about 300 kilograms, being used up at one milligram per second.

Perhaps the primary advantage of the ABL is that the computer can be reprogramed depending upon what it finds on the surface of Mars. The computer memory banks will have a primary storage of 50,000 instructions with a substantial secondary storage on tape. Because the computer is about 100,000 times faster than the many pieces of apparatus it controls, there will be the condition of conducting many separate experiments at the same time. Various Earth-based systems will allow a large number of different scientists to conduct personal investigations with the ABL at the same time without interfering with one another.

Conclusion

The search for extraterrestrial life will become the most intense engineering and scientific enterprise in the exploration of space. The results of such an endeavor will have implications not only for science, and especially biology, but for mankind in general. The opportunities to search for extraterrestrial life will ultimately allow scientists to determine whether life, as Cornell's Phillip Morrison puts it, "is a miracle or a statistic." (24)

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ULCERS AND SWINE

Modern man can't claim a monopoly on stomach ulcers. In some instances, pigs, too, develop stomach ulcers. But the main difference is that while we have a pretty good idea of how to treat human ulcers, we do not know much about the causes of stomach ulcers in hogs.

For some time animal researchers at the University of Wisconsin have been taking a serious look at the problem of stomach ulcers in swine. W. G. Hoekstra, R. H. Grummer, and Tadeusz Kowalczyk ran a series of experiments to determine the factors associated with ulcer development in pigs.

The Wisconsin researchers found that various feed grains had a significant effect on the formation of stomach ulcers in swine. A ration containing 85% oats seemed to prevent ulcers, while one containing corn caused a high incidence of stomach abnormalities.

In another series of trials, the animal researchers studied the effect of various nutritional and management factors on the formation of gastric ulcers in swine.

The effects of different vitamins, nutrients, and antibiotics were examined. Chlortetracycline, arsanilic acid, bacitracin, streptomycin, dried skim milk, ground soybeans, soybean oil, thiamine, riboflavin, vitamins A, D, E, and K and several other additives were mixed with rations in various combinations. None seemed to produce or prevent stomach ulcers in pigs.

Varying the method and schedule of feeding also didn't show much effect on ulcer development. Likewise, crowding the pigs to varying degrees did not appear to cause ulcers, but probably made them more severe.

The researchers feel that more studies are needed to explore the problem of stomach ulcer formation in swine and to determine why oats prevents the problem while corn does not.

MOSQUITO-KILLING FUNGI

The "lowly" mold has come a long way since Fleming's discovery of penicillin. And if applied research keeps at its present pace, the fungi family might well prove to be man's wonder plant.

University of Wisconsin researchers V. K. Shah and his colleagues isolated some soil fungi that produce substances toxic to mosquito larvae. In some instances, up to 93% of the larvae were killed in two hours with as little as one precent of the liquid medium in which the fungus was grown.

So far, four species of fungi (still unidentified) showed potent mosquito-killing properties. In one test, three milliliters of the culture liquid were sufficient to kill all but four of the 54 larvae in two hours. Extracts from the fungi culture medium have been turned over to University entomologists for further study.

In the course of his experiments, Shah also got some intriguing side results. In one test, for instance, the secretion from a certain species of mold did not kill any of the larvae. Instead, the larvae grew to a large size. Whether this effect was due to some kind of growth hormone produced by the mold, Shah has not yet determined.

Another angle being looked into is whether some mold-derived substances cause sterility in male mosquitoes. If this is so, then this would suggest a practical method of controlling malaria by mass sterilization of male mosquitoes.

OSTEOPOROSIS AND FLUORIDE

The prevalence of osteoporosis, a disease in which there is a reduction in bone mass and a fragility of the bones, is lowered significantly in individuals who drink water containing generous concentrations of fluoride.