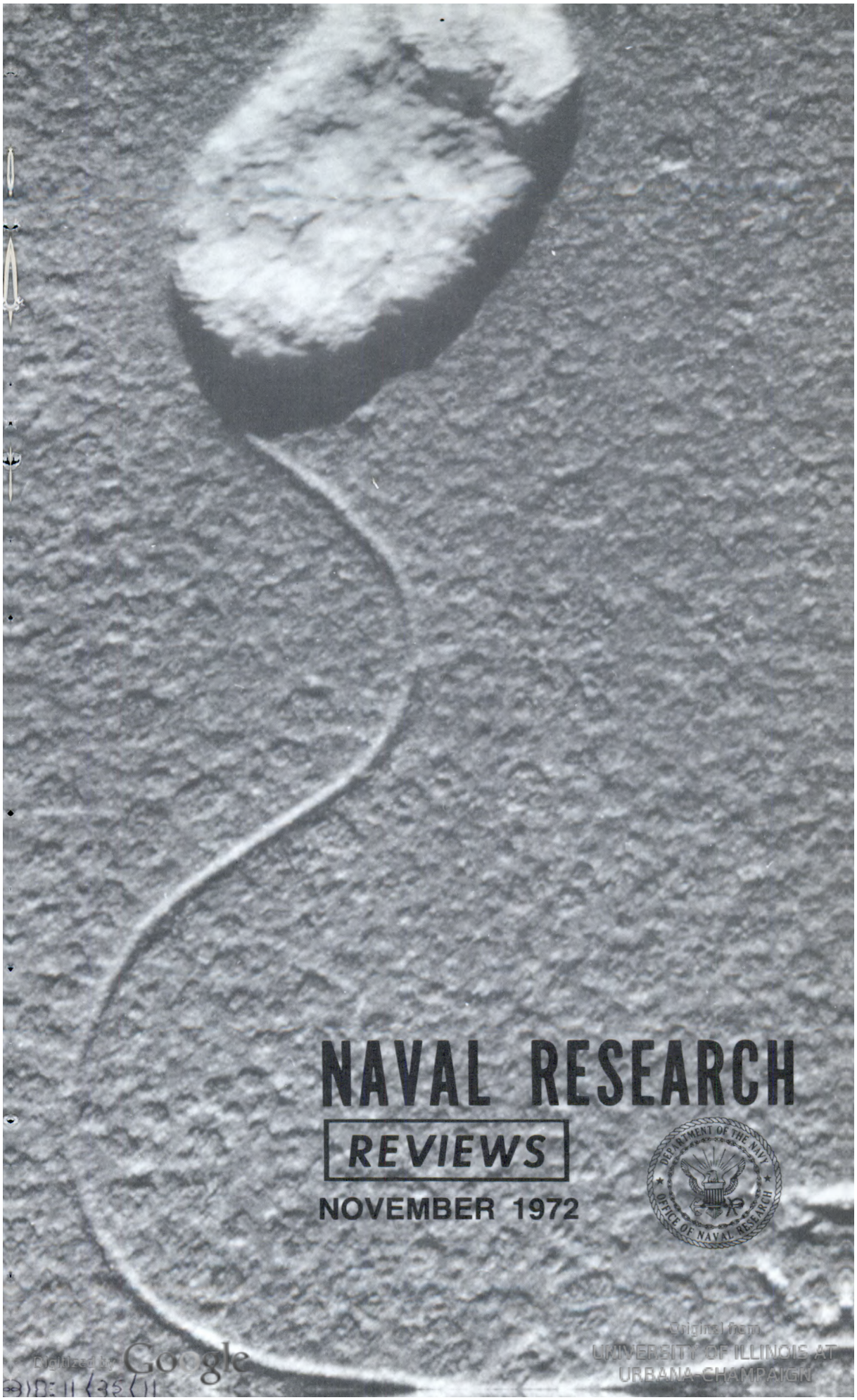
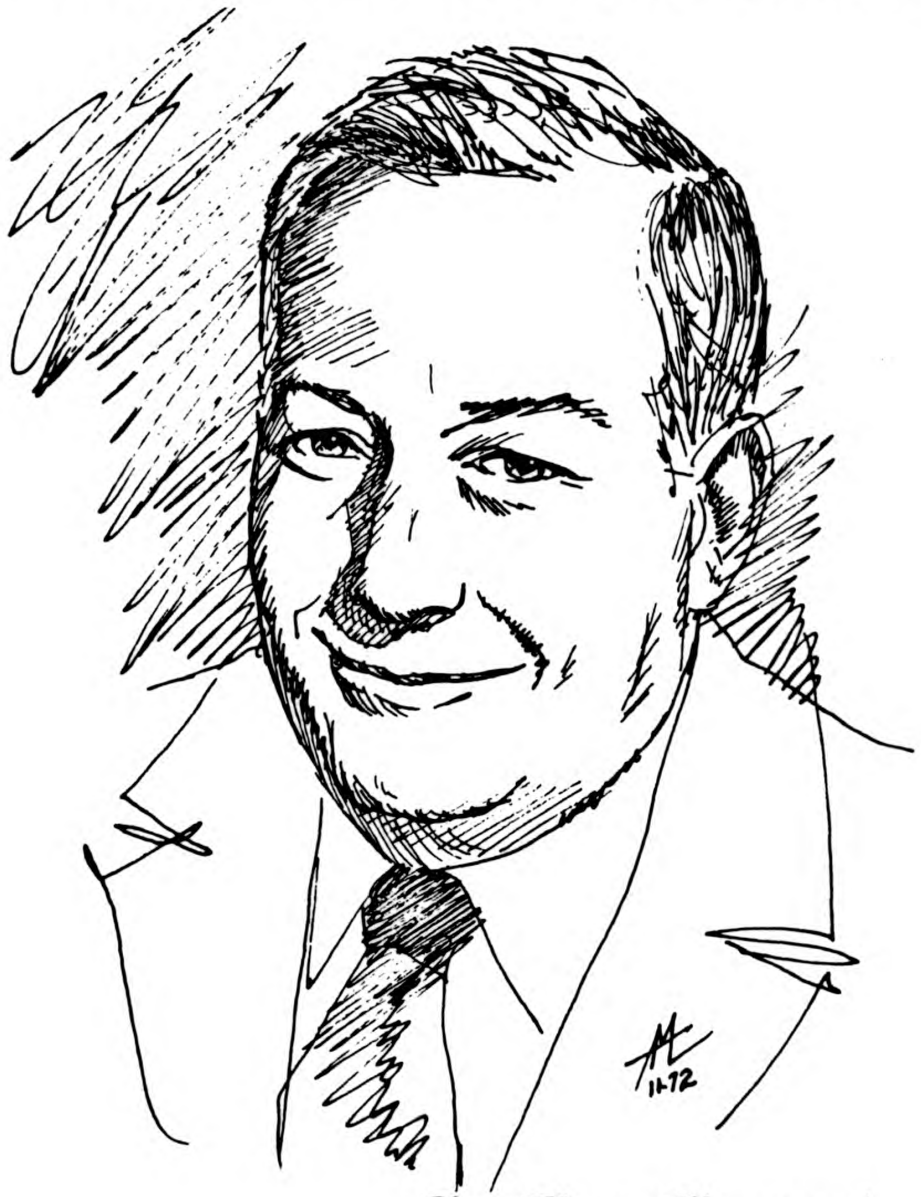


# PROFILES IN SCIENCE



*Dr. Harry Hoogstraal*

Since 1950 Dr. Hoogstraal has served as Head of the Medical Zoology Department, U.S. Naval Medical Research Unit No. 3, Cairo, Arab Republic of Egypt. His accomplishments have brought him recognition as the foremost authority on ticks and tick-borne diseases of man and animals. He has published 350 scientific papers on virtually every facet of ticks, tick-borne diseases and their epidemiology. His accomplishments will, to a large extent, be used as a basis for identification and ultimate prevention of a majority of the world's tick-borne diseases. He has had a distinguished career as a world-wide consultant, lecturer, educator, and board member and chairman in such organizations as the World Health Organization and the United Nations Food and Agriculture Organization. Dr. Hoogstraal received the Navy's 1971 Captain Robert Dexter Conrad Award for scientific achievement. He has, at various times, served as a technical consultant to the Army, Air Force, and other government and non-government agencies.

# Bacterial Chemotaxis, Marine Fouling, and Pollution

**Ralph Mitchell***
*Harvard University*

In a recent series of papers, J. Adler (1) reopened the question of chemoreception in bacteria. How do bacteria detect attractants, and how do they act when attracted? Answers to these questions will lead to a better understanding of pollutants on marine microorganisms.

Microbial chemoreception is an important ecological phenomenon. It is involved in the detection of potential food sources by marine bacteria, in particular, enabling the few bacteria living in the deep ocean to detect nutrients in the form of detritus. One might consider intermicrobial predation as a loop in the food chain by which nutrients are recycled. Both foreign and native microorganisms are continually being degraded by a native predator population. The predators seem to be able to detect and seek out their prey quite efficiently.

## Bacterial Chemoreception

The technique used in the laboratory to study bacterial chemoreception is simple. Figure 1 shows the typical apparatus. The potential attractant is placed in a capillary tube with the diameter of approximately 5 microns which is sealed at one end. Some motile bacteria, washed free of nutrients, are placed on a microscope slide in a buffer solution. The capillary is then placed in the solution of bacteria with the open end in contact with the bacteria. Next a cover slip is placed over the liquid to prevent contamination or evaporation. The tip of the capillary is observed under phase contrast microscopy. Within a few minutes, the material within the capillary beings to diffuse out into the bacterial suspension.

Bacterial attraction is immediately obvious; random motion stops and the bacteria orient themselves toward the capillary and begin to congregate around the tip of the capillary. Very soon a mass of bacteria begins to move into the capillary and within 15 or 20 minutes most of the bacteria, which were originally randomly distributed under the cover slip, congregate either in the capillary or around it. A typical positive reaction will result in the attraction of as many as 100,000 bacterial cells into the capillary within 20 minutes.

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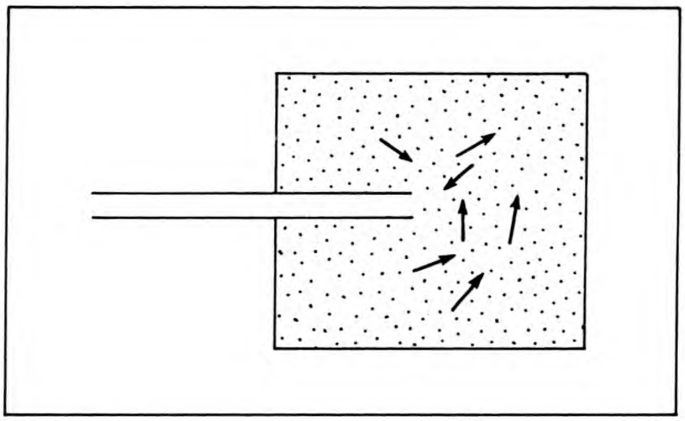
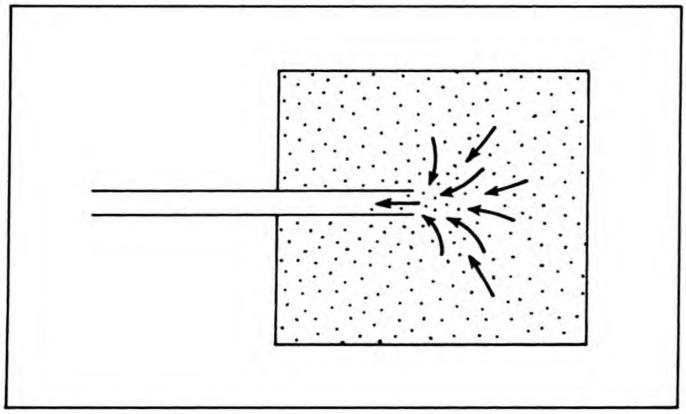
*Dr. Mitchell is Assistant Professor, Applied Microbiology, Engineering and Applied Physics, Harvard University. Dr. Mitchell's major interest is microbiology with emphasis on microbial interactions in water.



Bacteria move randomly when no attractant is present



Bacteria orient and move along gradient of chemical diffusing from capillary

*Figure 1 — Schematic representation of bacterial chemotaxis. In the top diagram the capillary contains artificial seawater. The bacteria move randomly and some enter the capillary. In the bottom diagram the artificial seawater in the capillary has been supplemented with an organic attractant. The bacteria rapidly orient to the attractant and huge numbers enter the capillary.*

Adler used this technique to study the response of the bacterium *Escherichia coli* to a variety of attractants. He found that glucose attracted the bacterium at concentrations as low as $10^{-7}$M. (molecular weight). Maximal attraction occurred at $10^{-3}$M. When the concentration of glucose in the capillary was increased to $10^{-1}$M. no attraction occurred; because the concentration of gluose in the suspension of bacteria became too high too rapidly, there was no significant diffusion gradient.

No apparent relationship exists between the ability of organic compounds to attract bacteria and ability of the latter to metabolize the

attractant. Galactose was attractive to this bacterium and it was metabolized. On the other hand, d-fucose, which is not metabolized by *E. coli*, is a strong attractant. Adler also isolated mutants of *E. coli*, which had lost the ability to metabolize galactose but had retained the chemoreceptors which enable them to detect that material. Thus bacteria may have the apparatus to detect and move towards organic compounds, but not the ability to metabolize them.

Chemoreception in microorganisms is not only confined to bacteria detecting nutrients; there are sexual attractants. For example female gametes of the fungus *Allomyces* produce a sperm attractant sirenin, which attracts sperm of the mold at a concentration as low as $10^{-10}$M. This attractant is known to be oxygenated sequiterpene. The water mold Acalya produces a steroid antheridiol, which induces hyphae on the male plant at a concentration of $10^{-10}$ g/ml. The stimulation of aggregation of amoeboid cells in the slime mold *Dictyostelium* by cyclic adenosine monophosphate is well known. A female substance, probably a protein, is produced by the green alga *Volvox*, which induces gonidia to develop into sperm packets. Because all of these signal substances are of high molecular weight, it is surprising that they are able to diffuse rapidly enough in water to affect behavior. Wilson (2) has pointed out that the diffusion coefficient of most water soluble substances in this range of molecular weights is in the order of $10^{-5}$ in water, compared to $10^{-2}$ in air. He suggests that natural currents play an important role in the distribution of chemical signals in aquatic systems.

The ecological significance of bacterial chemoreception has been a major aspect of the research in chemotaxis in the laboratory of Applied Microbiology at Harvard. The response of marine bacterial isolates to a broad range of chemicals were tested in order to determine the characteristics of the chemotactic response system. Sugars, organic acids, amino acids, and nucleotides were used as the attractants. All marine bacteria tested displayed chemotactic responses to some organic compounds. These responses were highly specific for each bacterium and the attractant was not necessarily metabolized. We never found a bacterium in the sea which was totally devoid of chemoreceptors. The threshold concentration for attraction was typically $10^{-8}$M, and maximal attraction was at $10^{-3}$M. The bacteria were attracted to the capillary within one to two minutes and usually attraction reached a peak within 10 minutes.

### Chemotaxis and Inter-Microbial Predation

The ability of marine animal predators to detect their prey is very highly developed. The prey frequently emits a chemical signal which is detected by the predator. In the microbial world there are a wide variety

of predator-prey relationships. This type of interaction allows microorganisms to feed on each other when non-living organic food sources are scarce, and also allows the recycling of food from old or starving microorganisms (3).

The destruction of enteric bacteria by indigenous predators in the sea is an important example of microbial predator-prey relationships. Enteric bacteria, native to the human intestine, are incapable of competing for nutrients when they enter the sea and are thus extremely vulnerable to attack. A wide range of microorganisms prey on these bacteria in the sea, including bacteria which enzymatically degrade the cell walls, tiny obligatorily parasitic bacteria called Bdellovibrios, and many different kinds of protozoa. The same fate awaits fungi which enter the sea in river estuaries or in run-off water. Since such fungi are foreign to the marine environment, they are not physiologically adapted to compete for nutrients and are also easy prey for microbial predators. Enzymatic degradation of fungal cell walls by marine bacteria appears to be the most common form of degradation.

Intermicrobial predation might be considered as a form of nutrient recycling. Nutrients which are tied up in the microbial cells are released by the action of the predator on the prey. This type of recycling is most important in the case of algae. We know that when estuaries become enriched with nutrients, there is a population explosion of algae. During algal growth, the nutrients are depleted from the water column. When some nutrient becomes limited, algal productivity slows down. Once again we have a microbial population, in this case the algae, which is under stress. Immediately a population of predators develops which decimates the algal population releasing the nutrients back into the water column. As in the case of the fungi, the most common predators on unicellular algae are bacteria which enzymatically degrade the algal cell wall.

Chemoreception is intimately involved in these microbial predator-prey relationships. For example, terrestial fungus *Pythium* produces cellulosic mats, which look extraordinarily like sheets of filter paper. When these mats are placed in sea water, a predator population quickly develops and degrades the mat within 3 to 6 days. The bacteria responsible for this degradation usually belong to the genus *Pseudomonas*, and are highly motile.

We tested for their ability to detect and move towards their fungal prey by placing pieces of fungal mycelium in buffer overnight. Fungal exudate accumulated in the buffer, which when placed in capillary tubes, strongly attracted the predator bacterium. The attractant was surprisingly specific, since a range of other bacteria were not attracted. The fungus has a cellulose wall and both cellulose and its oligo saccaride and monosaccaride units displayed a strong attraction for the predator bacterium.

It seems likely that autolytic products of the cell wall are excreted into the water and these attract predator bacteria. Predators further degrade the wall, releasing more products which in turn attract more predators. Thus the process of destruction of a fungus is a self-accelerating one. A similar process occurs in the destruction of native algae by marine bacteria. When the diatom *Skeletonema* is placed in non-sterile sea water in the dark, a large population of predacious bacteria are attracted. Metabolic products apparently are involved in this attraction process. The organism is stimulated to excrete large quantities of these products when placed under stress.

## Chemotaxis and Marine Fouling

Bacterial chemotaxis is also involved in the attachment of the primary bacterial film on surfaces. This film is essential for the settling of many different kinds of fouling larvae.

An example of the importance of chemotaxis in the formation of these bacterial films is shown in Table 1. Bacterial isolate MAV is attracted to maltose but cannot detect lactose. When a maltose solution is painted on a glass surface and the glass is placed in a culture of MAV there is a rapid growth of that bacterium on the surface. No such growth occurs on lactose covered surfaces. Similarly, bacterial isolate R3 is attracted to lactose and not to maltose. When surfaces are painted with lactose or maltose and are placed in a suspension of R3, only the surface painted with lactose develops a bacterial film.

## Bacterial Repulsion from Toxicants

It is ordinarily assumed that the primary bacterial film is prevented from forming on surfaces painted with toxic chemicals because they are killed by the chemical coming into solution. Our data show that this may not be the case. When low concentrations of copper and lead are placed in capillaries, marine bacteria display negative chemotaxis. That is, they are capable of detecting toxic chemicals and moving away from them before they are killed. It may be conceivable to design non-toxic anti-fouling paints which will act by repelling the essential primary bacterial film.

## Chemotaxis and Pollution

Another aspect of our research centered on the effect of sublethal concentrations of chemical pollutants on bacterial chemoreception. The addition of chemical pollutants to seawater seriously disturbs

TABLE 1
Chemotactic Responses and
Surface Growth of Two Motile
Marine Bacteria

| Response | Bacterium | Substrate | |
|---|---|---|---|
| | | Maltose | Lactose |
| Chemotactis | MAV | + | − |
| | R3 | − | + |
| Growth on surface | MAV | + | − |
| | R3 | − | + |

bacterial chemotactic responses. At very low concentrations the chemoreceptor activity of bacteria coming in contact with the pollutant is heightened so that more bacteria are attracted to substrates than in the absence of the pollutant. As the concentration of pollutant is increased the chemoreceptors become blocked and the bacteria lose their ability to detect attractants. Motility becomes random and no significant numbers of bacteria enter the capillaries. Ultimately the pollutant concentration becomes so high that the bacteria are killed.

These responses are typical for a wide range of bacteria and many different chemical pollutants. Chemicals tested include aromatic and aliphatic hydrocarbons, kerosene, and crude oil. Similar effects are observed with the herbicide 2,4-dichlorophenoxyacetic acid (2, 4-D) and a polychlorinated biphenyl compound (PCB).

The implication of this type of inhibition for marine microbial ecosystems is significant; apparently it is not sufficient to look for toxic effects of chemical pollutants on the marine microflora. Behavioral distortions occur at low concentrations of pollutants which may have far-reaching effects on marine processes.

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# Directional Flight Behavior in a Mosquito

**Alvin M. Tanabe***
*University of California*

In 1969 the Naval Biomedical Research Laboratory (NBRL) added entomological studies to complement others in environmental biology and medical microbiology. These studies are part of the Office of Naval Research's Program in Preventive Medicine. This research may eventually allow man better control over the processes by which diseases, such as those caused by arbovirus, are transmitted to men by insects. The program is three-fold: (1) to determine the capacity of the mosquito vector to sense the presence of a host and to orient and move toward that host, (2) to determine the degree of attractiveness of different hosts to the mosquito. It this phase we will investigate the motivation of the vector to probe, feed, engorge and finally withdraw from the host. This new data on the fundamental biological aspects of insect vectors, will lead to the third phase of the program (3) improving control of insects of medical importance.

When the entomology program began in the fall of 1969, most of the mosquitoes found in California of medical importance as vectors had begun their hibernation period. Thus two strains of *Culex pipiens* from outside the laboratory sources were obtained. One strain was from Dr. R. Dadd of the Department of Entomology and Parasitology at the University of California, Berkeley, California, and the other from the Disease Vector Ecology and Control Center, Naval Air Station, Alameda, California.

Dadd's strain was an autogenous colony, that is, the adults did not require a blood meal before eggs were laid. At first the strain obtained from the Naval Air Station was believed to be a strict biting strain that required blood meals before it laid eggs but it too turned out to be autogenous. Because the former strain had been kept in a laboratory colony for a longer period, we began studies with the strain from the Naval Air Station because it was not overly inbred. This species of *Culex* mosquito occurs world-wide and is a serious pest in most areas. It is a recognized vector of arboviruses and filarial worms.

Our first studies of the insects' flight behavior stemmed from observations that their movement in a closed chamber was not random. Therefore, analytical techniques based on random flight could not be used

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investigationally. The studies on the directional flight behavior were conducted during the period from October 1969 to April 1971.

In early experiments flight behavior was observed using a large two-port olfactometer (a structure for bioassaying different olfactory substances that may influence directional flight behavior). Later the studies were carried out in a more sophisticated structure, an octagonal maze (Figure 1). The prototype maze was constructed out of carboard and the main interior chamber (called the arena) was uniformly sprayed with enamel. Later, the plastic maze (Figure 1) was used. Early directional flight patterns as a behavior attribute in mosquitoes had not been observed before, although directional movement of adults during dispersion had been described. The latter movement depended in many instances upon the speed and direction of the prevailing wind.

Even with uniform experimental conditions, there was a greater tendency of adults that had been released into the arena of the olfactometer to enter the traps aligned in the southern direction (when the ports were pointed in a north-south plane). When the olfactometer was

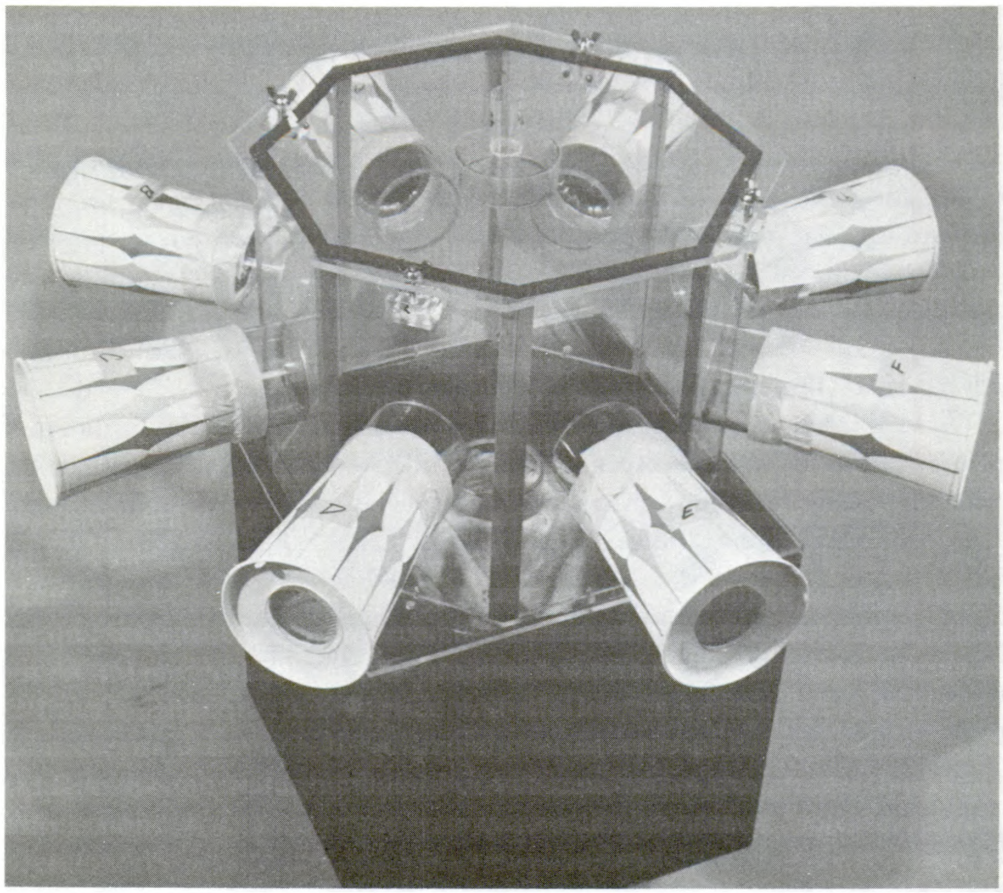

*Figure 1 — The octagonal maze used to study the flight behavior of mosquitoes*

turned so the ports were aligned in an east-west plane, the adults showed a bias in favor of the trap pointed west.

These findings brought up the question of whether there might be a tendency of adult mosquitoes to favor certain conditions. This possibility was studied further using a newly-designed octagonal maze in which traps could be arranged to point in the four cardinal compass directions as well as in four intermediate directions between the cardinal points.

From April 9, 1970 to June 13, 1970, there was a striking tendency of mosquitoes of both sexes to orient their flight to the northeast. This is depicted graphically in Figure 2. However, from June 15 to July 9, 1970, as the graph shows, there was a shift in the directional flight pattern to the northwest. This shift continued progressively, with increasing time, from northeast to northwest, to southwest, to southeast, to the northeast again, and finally to the northwest.

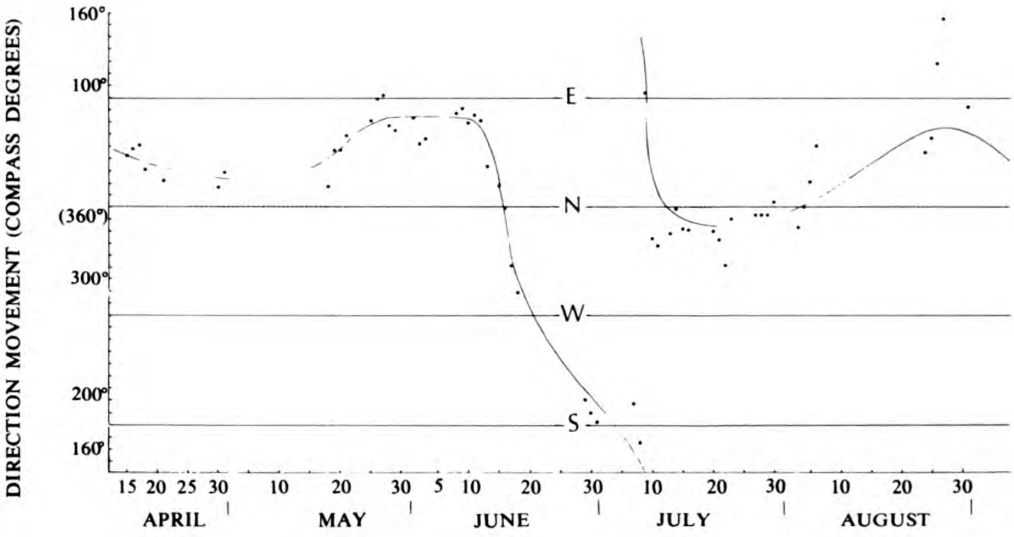


*Figure 2 — Graph depicting the mosquito flight pattern from April through August*

During August 1970, there was a shift back to the northeast and then back to the northwest during September to December after which the movement was toward the southwest. In brief, random flight movements were seldom observed.

Because many of our experiments were conducted in total darkness, it follows then that the directional orientation of the *C. pipiens* adults is essentially non-visual. It is possible that weak forces that were previously believed to lack sufficient energy for detection by organisms may be of importance in the orientation pattern and thus influence insect flight. Some of the possible sources of such stimuli have been proposed by others and include magnetic fields, electrostatic fields, atmospheric



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pressure and, possibly, the electric potential gradients (air ions) in the air.

Attempts to explain our observations with solar, lunar, or tidal variations failed. Even though the observations on the mosquito flight patterns have been restricted to the laboratory, it is not unreasonable to query its function and potential role in nature, especially as the implications for the understanding of migration of mosquito vectors are potentially significant in insect control.

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## Abstracts from Third International Congress on Marine Corrosion and Fouling

Persons interested in obtaining a copy of the abstracts from the Third International Congress on Marine Corrosion and Fouling held October 2-5, 1972 in Gaithersburg, Maryland, may do so by contacting Mr. Allen C. Jewett, Office of Naval Research, Code 443, Arlington, Virginia 22217. Copies are free.

## New Sea Photo Analysis Technique

The Naval Research Laboratory (NRL) has developed a new technique, called Sea Photographic Analysis (SPA), for the direct measurement of ocean-surface wave spectra to be used in pollution detection, as well as studies of wave growth and decay and radar clutter.

SPA used the diffraction pattern which results when coherent light illuminates a photographic transparency of the sea surface as a measure of the wave slope spectrum.

Since the ocean exhibits a surface roughness which is variable in both time and space, the independent mechanisms causing roughness variations (including surface contaminants) are difficult to isolate. The new NRL technique is being used in applications ranging from the documentation of the sea surface (surface truth) to measurement of wave growth and decay processes.

Recent optical measurements obtained by NRL using SPA at a tower off Mission Bay near San Diego, California, consisted of oblique photographs and wide-angle photography from which the ocean spectrum was analyzed as a function of time. Photographs were taken at 15-second intervals.

Although no unique signature was deduced in these tests, because of the superimposition of many effects (such as tides, magnitude and direction variations of the wind, *etc.*) there was immediate evidence of mild frequency dependence of the interaction. The results also showed temporal variations of the spectral amplitude in the range of wavelengths from about 3 cm to 1 m.

# Enzymes as Molecular Machines

**M. Weissbluth***
*Stanford University*

*Enzymatic activity promises to be one of the most important problem areas in contemporary bioscience research. The complex structure of enzymes is barely known; the nature of the enzymatic action which is crucial to all life processes is completely mysterious. In addition to unlocking one of the powerful secrets of the natural world, successful research on enzymes can have valuable spinoffs for the Navy, particularly in Navy medical science. Examples to date include hemoglobin behavior, drug detection, and membrane absorbtion phenomena.*

In an address before the American Physical Society in 1959, Richard Feynman (1) considered the problem of manipulating and controlling things on a small scale—really small scale, not what we normally regard as miniaturization, but at the level of atomic dimensions. Suppose, asks Feynman, we were able to realize in practice whatever is permitted by the laws of physics, how much volume would it take to store all the information that man has accumulated and which is now stored in an estimated 24 million books each the size of a volume of the Encyclopedia Brittanica. The answer, based on the estimate that 125 atoms are required to store one bit of information, is a cube of material 1/200 inch on a side—about the size of a barely visible speck of dust. What assurance is there, one may well ask, that such dense packing of information is possible, even in principle? All one needs to do, as Feynman recognized, is to look to the biological world. The DNA molecule, for example which carries all of our genetic information, uses approximately 50 atoms to store one bit. By comparison, the omniscient speck of dust is quite roomy.

We may go a step further. Instead of simply storing information let us ask what it takes to build a machine on a miniature scale. A machine must store a certain amount of information, but, the more important aspect is that it must be able to perform some operation *e.g.*, an airplane fiies, a lawn-mower cuts grass, *etc*. In other words, a machine is characterized by a fairly specific function. In the same address, Feynman dwells on the problems associated with building miniature machines,

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like a lathe reduced in size by a factor of 4000 or an electric motor 1/64 inch cube. But even more interesting, he speculates on machines that are only, say 100 atoms high. "I am," Feynman remarks, "inspired by the biological phenomena in which chemical forces are used in a repetitious fashion to produce all kinds of weird effects (one of which is the author)."

In this vein let us now pose the following question: Do we know of anything in the microscopic world of atoms and molecules that has the attributes of a machine? We wish to point out that such properties make their appearance among molecules with molecular weights of $10^4$ to $10^5$—not all molecules of that size but only those very special and remarkable molecules which act as biological catalysts and are known necessary to describe proteins which constitute a larger class of biological molecules containing both enzymes and non-enzymes.

Proteins are constructed of small organic molecules known as amino acids—these are the building blocks—of which there are some 20 different kinds; a typical one is shown in Figure 1 in which R stands for a chemical group (*e.g.* $-CH_3$, $-CH_2COOH$, *etc.*) which varies from one amino acid to another. Although each amino acid has a chemical name, let us simply label them by the first 20 leters of the alphabet, A ... T. The simplest protein is a linear chain of amino acids clipped together in a sort of head-to-tail fashion as illustrated in Figure 2. We might therefore represent such a chain by a sequence of letters, say, CBQRDO - - - NBP and there might be anywhere from less than a hundred to several hundred amino acids in the chain. The sequence is genetically controlled and must come out right. For example, if part of a chain has the sequence ... GRANDMA ... and there is a genetic defect which causes that part of the chain to come out ... GRANDPA ... the consequences can be serious. It is just such an error in hemoglobin that is responsible for sickle cell anemia as well as a host of other diseases.

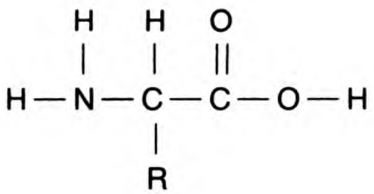

*Figure 1 – Amino acid*

We have represented an amino acid chain by a sequence of letters written in a straight line. This does not mean that the physical chain is strung out in a straight line; in fact it has a very complicated three-dimensional shape. There is no single shape (for conformation) for all chains—they are all different. However a particular amino acid chain under a prescribed set of external conditions *e.g.* pH, temperature *etc.*

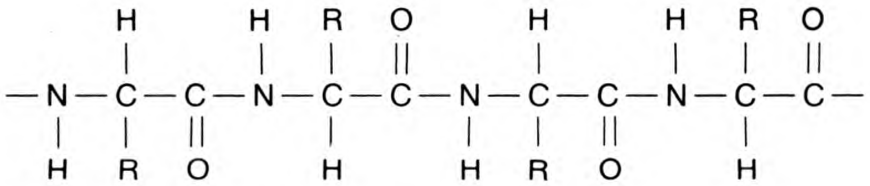

*Figure 2 — Amino acid chain or simple protein*

has a unique conformation which may nevertheless change when the external conditions are altered. A case in point is lysozyme, a very common enzyme which dissolves certain bacterial cells by attacking a complex sugar in the cell wall. Lysozyme is a protein; it consists of a single chain of amino acids folded into a complicated three-dimensional shape (Figure 3) with occasional cross-links (disulfide bridges or S-S linkages) between various points on the chain. Many proteins are of the single chain variety we have just described, but there are others that are composed of several chains. Such proteins are said to have several subunits and their three-dimensional shapes get even more complicated. Finally, some proteins may have metallic ions attached to them in various ways, or some other molecular groups which are not amino acids.

There are several thousand different kinds of enzymes; they are found in every living cell and their function is to catalyze the multitude of biochemical reactions required to sustain life. Their catalytic powers are exceedingly great; most enzymatic reactions proceed $10^8$ to $10^{11}$ more rapidly than the corresponding non-enzymatic reactions. Without assistance from enzymes, biochemical reactions could still go on but at such slow rates that life processes would cease. Just like any good machine which does not deteriorate significantly after executing a single operation, so the enzyme promotes a chemical reaction but does not get used up in the process. Enzymes are also highly selective; each one is responsible for catalyzing a specific type of reaction. This means that the enzyme must be capable of recognizing the molecule—sometimes only a specific region on a large molecule—where a particular biochemical change will be catalyzed. This the enzyme does very efficiently and is not easily fooled. Some molecules, for example, have isomers which have the same chemical formula but structurally, the molecule and the isomer are related like an object and its mirror image. The enzyme will recognize the difference and when a molecule is replaced by such an isomer, the enzyme will not respond. If one likens the cell to a factory, the enzymes correspond to the vast array of specialized machines one finds in a modern factory, only the cell and the enzymes are many times more complicated than any man-made system.

When examined in greater detail, it appears that the substrate—the generic name for substances upon which some change is wrought by an enzymatically-controlled reaction—comes in intimate contact with only

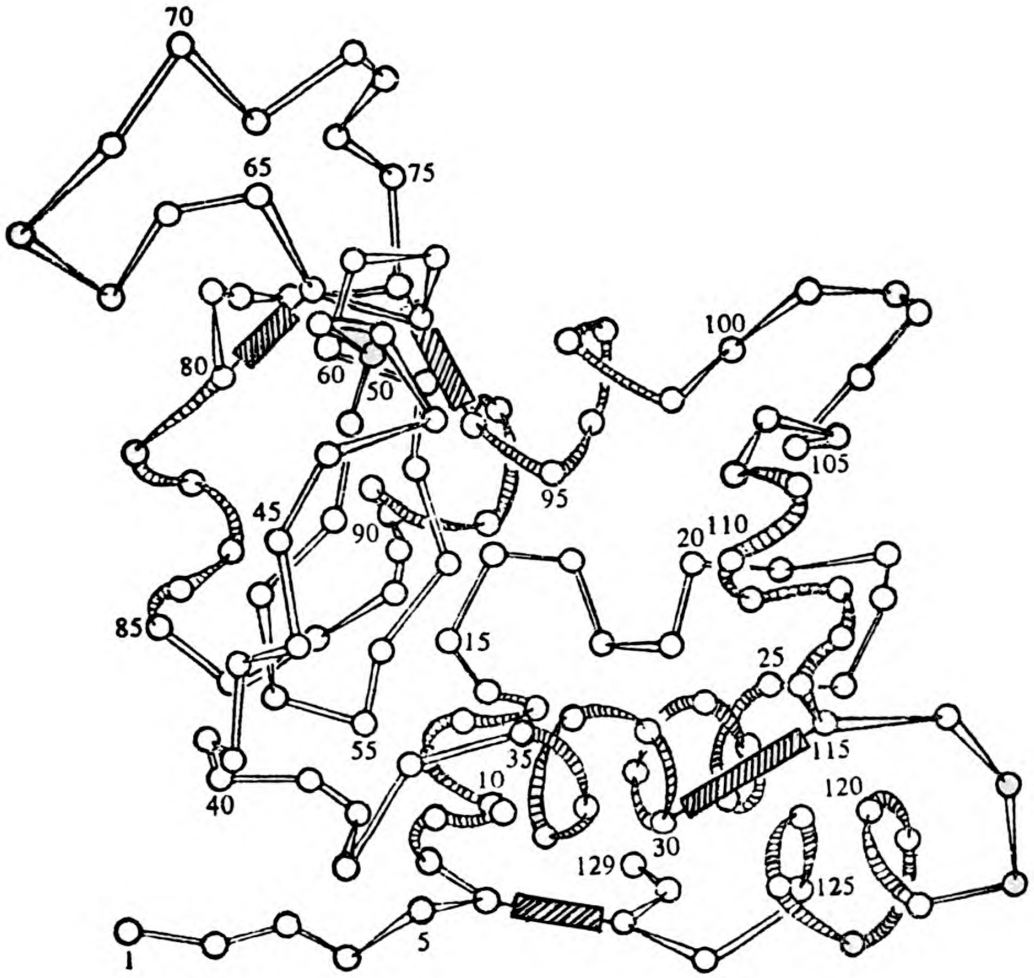


*Figure 3 — A schematic drawing of the conformation of lysozyme; the shaded rectangles represent disulfide bridges (5)*

a fairly small, localized region of the enzyme. Such a region is called an active site or catalytic site. But that is not all; frequently there is another localized region on the enzyme, quite distinct from the catalytic one—it may even be on another subunit—where a small molecule, again a very specific one, can be bound. When this occurs the activity of the catalytic site may, in some cases, be enhanced or, in other cases, inhibited. The second site which may be called a regulatory site thus exercises control over the catalytic site. It is as if the enzyme corresponded to a circuit; the catalytic site would then be the output element, the regulatory site, the control element, and the regulatory molecule (the one that binds at the regulatory site) would be analogous to a signal. Numerous variations on this basic theme have been identified including such things as the chemical analogue of feedback loops. All this points to the enzyme as a highly coordinated molecule in which one part somehow "knows" what is going on elsewhere.

We come now to the central question: How does an enzyme work? The short, simple, answer is that we just don't know. Even when all known chemical and physical mechanisms are allowed to operate under optimum conditions (2) we are still missing a factor of the order of $10^{10}$ in explaining any enzymatic reaction. The depth of our ignorance is truly enormous and it must surely mean that we are still lacking some crucial information or crucial concepts or both.

Current thinking concerning enzymatic activity has focussed on the conformation of an enzyme *i.e.* its three-dimensional shape or structure. Unfortunately, our knowledge in this regard is rather meager. The method which provides the most detailed structural information is x-ray diffraction but for molecules as large as most enzymes are, the method is difficult to apply. At the present time, the structures of less than a dozen relatively simple enzymes are known in detail (3). The best evidence for the importance of conformation has been found in hemoglobin whose structure has been determined to atomic dimensions and whose *modus operandi* is perhaps better understood than for other comparable biological molecules (4).

Hemoglobin, a constituent of red blood cells, performs the vital task of picking up oxygen in the lungs and delivering it to the tissues. Though not strictly an enzyme, hemoglobin nevertheless displays many of the characteristics of enzymes and for this reason it is thought that some of the processes observed in hemoglobin are sufficiently general to be applicable to enzymes, though the specific details may very well vary from one type of molecule to another. Each molecule of hemoglobin has four subunits and each subunit contains an amino acid chain plus a heme which is a relatively small organic structure containing one iron atom. Oxygen molecules become attached to the iron so that each subunit in hemoglobin has the capability of binding just one molecule of oxygen. In a rather remarkable fashion, the subunits cooperate with one another in the following sense: When an oxygen molecule becomes attached to one particular subunit, the probability of attachment of an additional oxygen molecule in a neighboring subunit is increased.

The cooperative phenomenon in hemoglobin has been under study for a long time. It is now believed that the basis for cooperativity resides in the transmission of conformational changes or "shape signals." Briefly, the way it goes is this (4): The attachment of an oxygen molecule to an iron atom belonging to one of the subunits produces a change in the position of the iron within the heme structure. The distortion spreads *i.e.* changes occur in the average positions of other atoms brought about, say, by changes in bond angles, rotation about certain bonds, *etc.* The sum total of these distortions constitute an overall alteration in shape, or conformational change, of the subunit. We therefore visualize that each subunit can reside in one of two possible conformations—one such

being when oxygen is bound to the subunit (oxy conformation) and the other when oxygen is not bound (deoxy conformation). The subunits are in close contact with each other so that when there is a conformational change in one subunit, the contact regions are affected. This loosens up certain constraints so as to make it easier for a neighboring subunit to acquire the oxy conformation which, presumably, is the more favorable conformation for the binding of oxygen.

We see, then, that conformational changes can act as signals which are propagated from one part of a large molecule to another in a manner analogous to the propagation of current or voltage wave forms among elements of an electric circuit. In the case of hemoglobin it has been possible to construct a fairly detailed formulation of these ideas (4) based on a large body of experimental information. For enzymes, that level of understanding has so far not been achieved though there is ample evidence that conformational changes must play a significant role (2).

Without a doubt, the problem of explaining the action of enzymes is one of the most important problems of modern science. A successful theory of enzymes may well have the same impact on biology as, say, the Maxwell theory of electromagnetism has had on physics. It is probably not too visionary to expect that developments of comparable importance in the biomedical field will follow from an understanding of enzymatic activity. Once we have the proper concepts with which to relate atomic arrangement and specific functions of an enzyme, we may even be in a position to design molecules to perform various tasks—biological and otherwise. Some of Feynman's microscopic machines may then not be so far out after all. It's a major scientific challenge not only for chemists and biologists, but perhaps even, eventually physicist and engineers.

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# Clean Water Ecology in the Polar Regions

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*The Office of Naval Research is sponsoring a series of biological tests and measurements in the Middle Salt Lagoon at Barrow, Alaska, which the Navy Arctic Research Laboratory uses for disposing raw sewage. The effects of sewage on public health, on lagoon ecology, and on the ecology of the part of the Arctic Ocean connected to the lagoon during brief periods in the melt season will be analyzed. When the effects of sewage disposal in a large arctic lagoon are known, better planning for arctic sewage treatment facilities will be possible.*

There is an old adage among those who frequent race tracks, which is subsequently ignored, that "horses don't bet on people, and that's why they never go broke." This philosophy can be extended to the sanitary microbiologist who does not "buck the odds" in determining if water supplies are safe to drink and do not contain enteric, pathogenic microorganisms. To achieve this aim he does not look for the pathogens directly, which if present are usually in low numbers and are quite fastidious in their nutritional and environmental requirements for growth; instead he seeks other microbes, called "indicator groups," which are almost universally found in intestinal habitats, occur in relatively large numbers, and grow more readily in a shorter period of time. However, even here he does not gamble but employes enrichment techniques for producing large populations from the initial samples or uses selective and differential media and filtration procedures for analyzing large quantities of water (usually 100 ml or more). Therefore, "potable water" in its most reliable sense means water that has not been polluted with feces, and therefore there is no danger that enteric pathogens are present.

Our interest in coliform bacteria in polar habitats goes back to 1955 while we were surveying potential water supplies for radar sites of the DEW LINE. Prior to this, in 1954 McBee and McBee (9) carried out a survey at Barrow to determine the distribution of thermophilic and coliform bacteria in soil and water habitats. For enumeration of the latter

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group they employed desoxycholate agar incubated at 35°C, and for consistency we have also followed suit, although other selective and differential media have been used in parallel studies. Where the incidence of thermophiles was high, the coliform counts were low or nonexistent, and they concluded that these thermophiles could not be of intestinal origin. However, many thermophilic species produce endospores which are more resistant to adverse nutritional and environmental conditions than vegetative forms and could, therefore, remain viable over long periods of time; both coliforms and thermophilic *sporeforemers* are found in the intestinal tract of man and other animals. To test longevity, we inoculated various soils and water at Barrow with pure cultures of both during 1956 and determined viability *in situ* (2). In comparison the death rate of coliform bacteria was greater in all cases, so that with time, it is possible to detect one group and not the other even if both come from the same source. It was realized that these results might have significance relative to the viability of enteric microorganisms among soil and water habitats in inland areas of Alaska where sewage is sometimes disposed of on the ground's surface; here coliform bacteria might be sought to detect possible ground pollution. This, then, was our first effort to study the viability of coliform bacteria in polar regions.

Our next opportunity to continue this work was during the United States Antarctic Research Program (USARP) of 1961-1962 and 1962-1963; our approach to the problem was more direct this time. We discovered that although areas around the heads (latrines) at McMurdo Sound had been contaminated recently during removal of the sewage barrels, they were completely free of coliform bacteria. Pony manure (dating from 1907-1913) found at Cape Royds and Hut Point was also free of these indicator organisms (3), although Meyer *et al* (10) found many non-coliform enteric bacteria in frozen human feces from both Scott's and Shackelton's Expeditions of 1907-1908 and 1911-1913, respectively. We were able to find a single coliform isolate in debris from Shackleton's dump at Cape Royds. It is not known if it has "historic" value because modern day visitors came to photograph penguins at this site, and a New Zealand party was living in the hut at the time. When this strain (Ro) was inoculated along with two human strains (Bo and Bu), it was more stable to the volcanic "soil" environment than the two human strains (3), but this was not the case when similar studies were carried out at Cape Hallett the next year (5). These results are summarized in Figure 1. These same three strains were tested at Barrow in all of the indigenous soil types; they showed varying degrees of stability, usually paralleling one another (Figure 2), but showed a slower rate of death than in the Antarctic habitats. When inoculated into a small tundra pond, however, neither the Bu nor Ro strains could be detected after two weeks when the initial concentrations were 3200 and 5400 per ml, respectively.

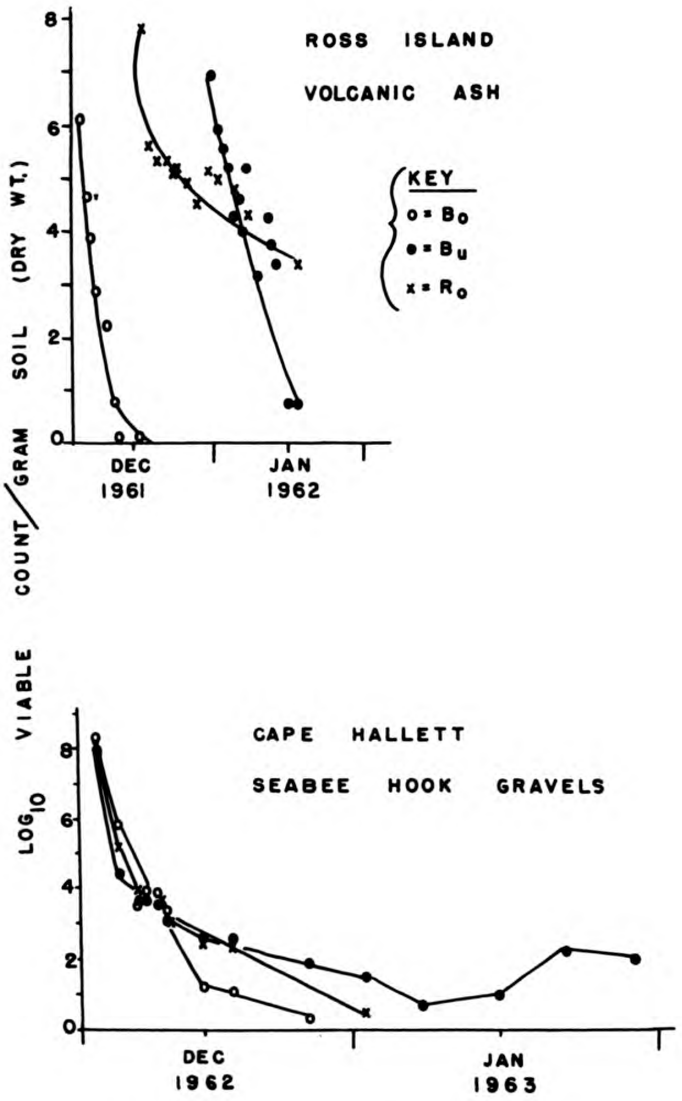


*Figure 1 — Viability of coliform bacteria in Antarctic habitats*

During the spring and summer of 1971, we initiated an ecological study of the Middle Salt Lagoon at Barrow the depository for sewage from the adjacent Naval Arctic Research Laboratory. We were interested in both the public health aspects of the operation as well as microfloral interactions which might affect mineralization and immobolization of sewage. The results of this preliminary work has been submitted as a technical report (4).

As part of the sampling protocol, standard potability tests (1) were also included using larger than normal samples (usually four to five, 100 ml quantities). The results presented in Table 1 show that during the early part of the summer most of the samples were negative despite the continuous addition of sewage from the Laboratory. At this time, the runoff

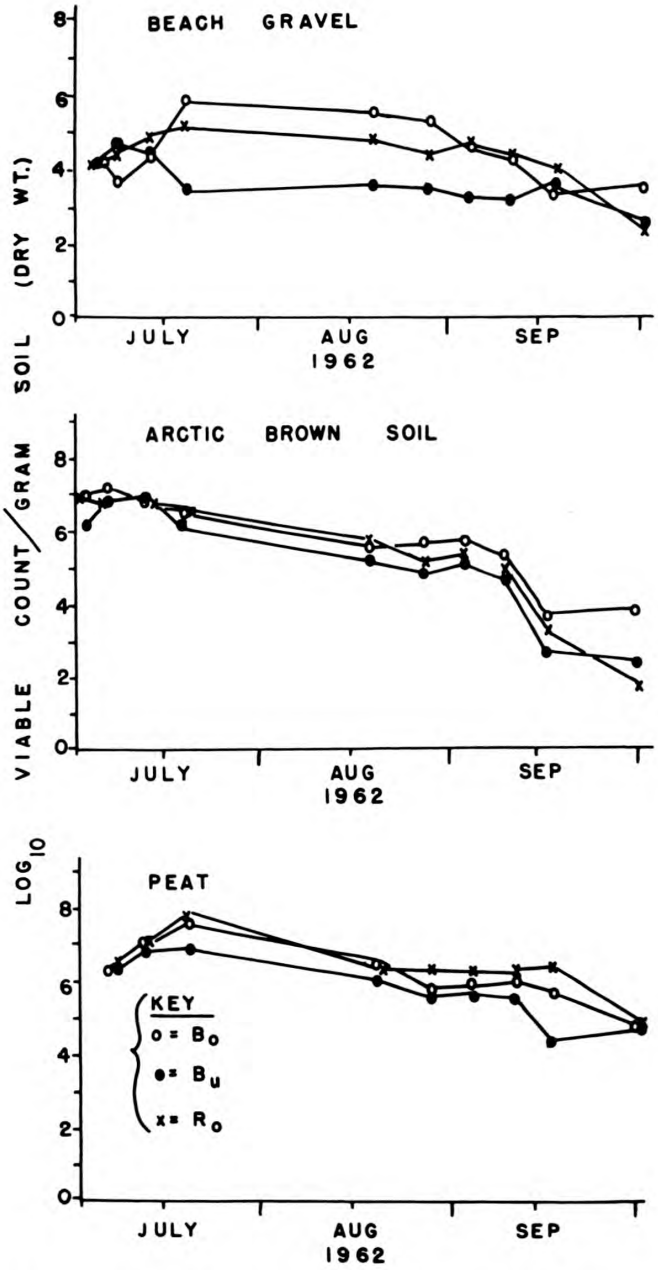


*Figure 2 — Viability of coliform bacteria in Arctic soils*

was in progress, the Lagoon was confluent to the nearby sea, and the large ice cover was melting. Once the channel to the sea had been closed (July 11) and the Lagoon was ice-free, the trend was reversed, and the majority of samples were positive for coliforms. Later sampling under the ice during March, 1972, showed a low incidence of these microorganisms. When pure cultures of indicator organisms, coliform bacteria and fecal streptococci, were employed *in situ* rapid death was observed for both, while an indigenous *Pseudomonas* species, tested in

TABLE 1
Results of Standard Potability Tests, 1971-1972
(100 ml Water Per Sample)

| | Date | Source | Total Number of Samples | Total Number Positive (Completed Test) | Total Number Negative (Preseumptive Test) |
|---|---|---|---|---|---|
| 1971 | June 7 | Runoff | 5 | 2 | 3 |
| | 8 | Lagoon | 5 | 1 | 4 |
| | 9 | Lagoon | 5 | 4 | 1 |
| | 10 | Lagoon | 3 | 1 | 2 |
| | 15 | Runoff | 4 | 1 | 3 |
| | 16 | Runoff | 4 | 1 | 3 |
| | 17 | Runoff | 4 | 0 | 4 |
| | 18 | Runoff | 4 | 0 | 4 |
| | 19 | Runoff | 4 | 1 | 3 |
| | 20 | Runoff | 2 | 1 | 1 |
| | 22 | Lagoon | 4 | 3 | 1 |
| | 25 | Lagoon | 4 | 1 | 3 |
| | 29 | Lagoon | 3 | 2 | 1 |
| | July 1 | Lagoon | 4 | 2 | 2 |
| | 3 | Lagoon | 4 | 2 | 2 |
| | 6 | Lagoon | 4 | 2 | 2 |
| | 10 | Lagoon | 4 | 1 | 3 |
| | 12 | Lagoon | 4 | 2 | 2 |
| | 15 | Lagoon | 4 | 0 | 4 |
| | 23 | Lagoon | 4 | 1 | 3 |
| | 26 | Lagoon | 4 | 3 | 1 |
| | 31 | Lagoon | 4 | 3 | 1 |
| | Aug. 1 | Lagoon | 4 | 2 | 2 |
| | 6 | Lagoon | 4 | 4 | 0 |
| | 9 | Lagoon | 4 | 3 | 1 |
| | 13 | Lagoon | 4 | 4 | 0 |
| | 17 | Lagoon | 4 | 4 | 0 |
| | 21 | Lagoon | 4 | 3 | 1 |
| | 23 | Lagoon | 4 | 4 | 0 |
| 1972 | Mar. 17 | Lagoon | 5 | 1 | 4 |
| | 19 | Lagoon | 5 | 2 | 3 |

parallel with the others, showed greater stability to the Lagoon environment (Figure 3).

These preliminary studies have raised some questions concerning the enteric flora of the Lagoon that should be answered. The relative stability of coliform bacteria and other indicator organisms *versus* enteric pathogens has been studied in temperate regions in a number of different habitats and has been reviewed by several workers (8, 11). Although there is no consistent pattern of stability, in most habitats coliform bacteria usually live longer than do the enteric pathogens. "Coliform removal" in sewage lagoons has also been used as an index of concomitant death of enteric pathogens. For example, work done on the bottom sludge of the sewage lagoon at Fort Yukon has shown a fecal coliform count from 4,900 to 130,000 per gram of sludge while no *Salmonella* could be detected (6).

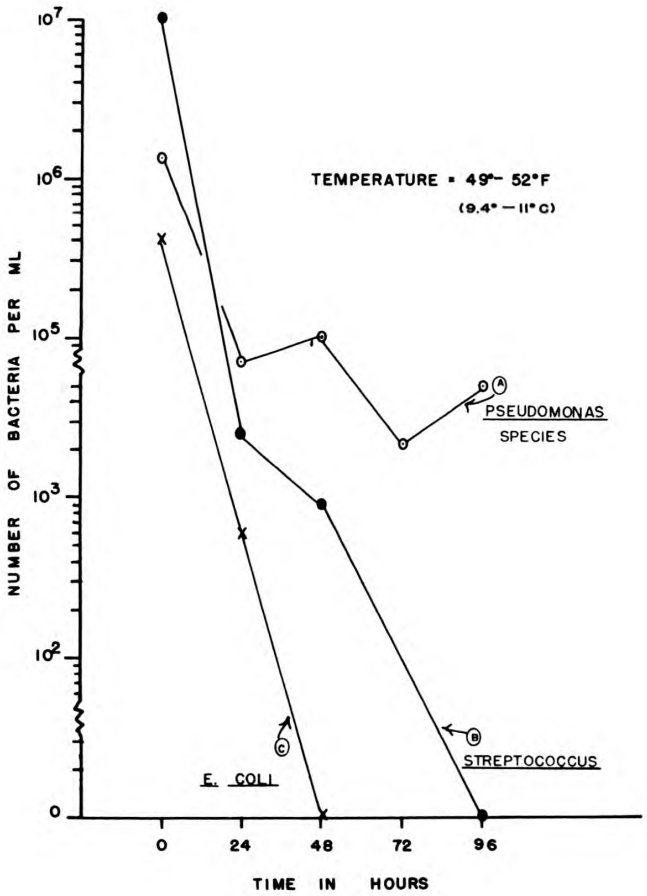


*Figure 3 — Stability of indicator microorganisms in the Middle Salt Lagoon. All microorganisms were isolated from the Lagoon. The Streptococcus was enumerated on B phenyl ethanol agar and the pseudomonad on plate count agar*

With the higher incidence of enteric infections among residents of northern areas compared to temperate regions (7), the probable source of infection, should receive further attention. Because of the high cost of fuel and construction, dwellings are small, and people live in close proximity which perhaps contributes to the communicability of these diseases and/or it may be that under certain environmental conditions enteric pathogens remain viable longer than the sought-for indicator groups. Although the pattern is erratic, the incidence of enteric disease appears to be higher right after runoff, perhaps because organisms from thawed feces enter the water supplies. Dogs have been implicated as intermediate hosts, but this has become less of a problem because of the increased popularity of the snowmobile.

Since past studies as well as ours have shown great variation in the stability of coliform bacteria, it would be presumptious to assume that the death of enteric pathogens would directly parallel that of the indicator groups in every case. Because of the very nature of these enteric pathogens, mandatory viability studies under a number of different conditions will have to be carried out, not *in situ*, of course, but under simulated laboratory conditions. Future work should also include sampling of large quantities of Lagoon water to detect possible resident members of the *Salmonella* and *Shigella*. The Middle Salt Lagoon represents an extremely good model for part of this study since large quantities of sewage are being added on a continuous basis. Only after studies of this type have been completed can indicator organisms be used or rejected as indices of safety; for polar habitats other metabolic groups may also have to be sought out as more appropriate indicators.

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## Novel Chemical Laser System

Chemists at the Naval Research Laboratory have developed a laser system involving the insertion of an oxygen atom (from ozone photolysis) into a partially-halogenated methane molecule to produce an energy-rich halo-methanol.

These halogenated alcohols, which contain a halogen atom and hydroxyl group both attached to the same carbon atom, are extremely unstable, decomposing almost instantaneously into carbonyl compounds and highly excited halide molecules which lase.

The importance of chemical lasers lies in this transformation of chemical energy into laser radiation. The present state of the art is such that the energy required to initiate the chemical reactions generally exceeds the useful output.

However, chemical lasers can provide laser radiation of otherwise unobtainable wavelengths, as well as needed information on the energy partition among the various reaction products.

## Computerized Design for Miniature Microwave Components

The Naval Research Laboratory's Electronics Division has developed a computer-aided method for designing broadband directional couplers as a miniature microwave component using planar transmission lines on high dielectric ceramic materials.

Until now, the development of broadband couplers that use such structures has been impeded by an inability to attain sufficiently tight coupling with coupled-line configurations that lend themselves to standard thin-film fabrication techniques.

The NRL method, programmed in Fortran IV for use on the CDC 3800 digital computer at the NRL Computation Center, uses a moment solution to compute the impedance and phase velocity for each of the even and odd modes of an arbitrary configuration of coupled transmission lines. Dielectric inhomogeneities in the system are handled in this treatment.

# On the Naval Research Reserve

## Reflections on Active Duty for Training (ACDUTRA)

The following comments were submitted by a Research Reservist following an ACDUTRA period at one of the ONR Branch Offices.

If there is sufficient time to communicate with a reporting reservist, and it can be verified that the reservist is currently pursuing research in a field directly related to one or two on-going ONR funded research projects, the reservist may be asked to do some "homework" prior to reporting. Following a tour of ACDUTRA, the reservist should be encouraged to write up a detailed, though brief, summary of the state of the art of his field of research. In an ideal case, this may coincide with an on-going research program that he has actually reviewed. A major contribution, *via* this post-visit report, might be considered as a Contributory Support Program function and if the quality is sufficiently high, the awarding of drill credit might be in order. This type of approach might have the effect of drawing reservists into a Contributory Support role and thus make a two week ACDUTRA tour more than a "visit."

I believe that the presence of competent ACDUTRA personnel accompanying a staff member on a visitation program serves a very useful function. It provides the reservist with a look at how ONR funded research is carried out. One has an opportunity to directly compare the quality of execution of an ONR contracted research program as compared to the execution of other agency funded projects.

One very important result of an ACDUTRA tour with a Branch Office such as this one, and participation in a visit program, is that one's professional horizons are broadened. The day-to-day, year round execution of a specialized research project does not allow much time for broadening of one's scientific background. Furthermore, the exposure to only one university on a daily basis tends to keep one oriented to only one school of thought. The opportunity for a student like myself, to visit other universities and to be exposed to people who have different ways of approaching engineering problems, is unique. There is no way that I could have had the opportunity to discuss different aspects of my field with such a variety of researchers, had it not been for this tour of ACDUTRA. For this opportunity I am very grateful.

In the case of reservists, like myself, who are graduate students pursuing advanced degrees, the monetary aspects of ACDUTRA are important to note. The Research Reserve Program is essentially a non-pay participation in the reserve, and is closely linked to centers of higher learning. Since graduate students, on the average, have small annual incomes any additional income can be made quite useful. However, there is one aspect of this that is often ignored. As a result of

additional monies through ACDUTRA, a reserve student's proportion of time spent on part-time non-academic work is reduced. This directly results in more available time for scholarly pursuits and thereby raises the quality of the research being accomplished in pursuit of an advanced degree.

In these days where patriotism is not a virtue admired by the mass media, the active involvement in the Naval Establishment serves to remind one of his obligations and responsibilities to his country. The dedication to their work, and pride in performance, that was observed in this Office is in excess of normal job requirements. This attitude can only be explained as a pride in being a member of a Navy team and just plain old-fashioned patriotism."

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## NRL's Two Wavelength Laser Technique Applicable to Many Laser Studies

A new technique recently developed at the Naval Research Laboratory allows two wavelength selections simultaneously in either inhomogeneously or homogeneously broadened lasers. The technique has been found applicable to other investigations in this area of science.

Dr. Herschel S. Pilloff of NRL's Chemistry Division developed the technique whereby two laser beams can be produced simultaneously, and collinearly with perpendicular polarizations.

In his early investigations he applied the technique to pulsed nitrogen ($N_2$) laser pumped dye lasers which features continuous wavelength tunability throughout the entire optical gain region of the particular dye solution used.

There are many reasons why a tunable two-wavelength laser is important to scientists. Particularly this is so, if both output beams are perfectly collinear and collimated so that the complete spatial overlap is maintained even when both beams are focused to very small spot sizes.

The $N_2$ laser-pumped dye laser was selected for the investigations because it offered continuous wavelength tunability throughout the visible spectrum (using different dye solutions) and as comparatively large tuning ranges from a single dye solution up to a maximum range of 1760 A.

However, after more detailed study, Dr. Pilloff now says there are other areas that the application of this technique could be used by scientists.

He said these could include infrared difference frequency generation in birefringent nonlinear crystals, two photon spectroscopy, optical double resonance, excited state spectroscopy, photoselection and others known to scientists.

# Research Notes

## Biological Degradation of Trinitrotoluene (TNT)

The Naval Biomedical Research Laboratory (NBRL), Oakland, California, is conducting research to develop an effective and practical system for degrading trinitrotoluene (TNT) wastes using microorganisms. This research is being conducted for and is funded by NAVORD. Dr. Robert J. Heckly and Mr. William Won have isolated nine different bacterial types from mud and water samples obtained from the U.S. Naval Ammunition Depot at McAlester, Oklahoma. Two of these isolates have been found to actively metabolize or degrade TNT. The TNT at concentrations of 100 parts per million was completely degraded within 50 hours when inoculated with these organisms. Work is currently in progress to determine the optimum conditions for degradation and they are also chemically and chromatographically analyzing the degradation products to determine the completeness of degradation.

This information is expected to permit the design and construction of treatment facilities to remove TNT from the effluent water from munitions processing or storage facilities.

## NRL Chemists Develop Protective Coatings with Fluoro-Condensation Polymers

Naval Research Laboratory scientists (NRL) have developed a family of novel coating materials through the use of fluoro-condensation polymers that are expected to find important uses in the military, as well as to private industry.

These materials, with some properties similar to those of the well known Teflon, were developed recently as spray-paint protective coatings for Navy aircraft.

The new coating should reduce aircraft maintenance costs for the Navy, since it is very readily cleaned of common aircraft surface contaminants, and will not wash off when the planes are cleaned with strong chemical agents.

The Cornell Aeronautical Laboratory is using the product in their environmental chamber as a protective coating against ultraviolet rays and because it is resistant to particle generation and is easily cleaned. The work at Cornell is sponsored by the Environmental Protection Agency and the Office of Naval Research, in their continuing quest for answers to pollution problems.

One of the important potential uses of the new materials is expected to be in the medical world, to provide protective coatings or moldings for implantation of artificial organs (prosthetics) into the human body. This use has not been developed yet.

There are a host of other uses for the polymeric materials, including composite marine application structures using matrix plastics, because of their

durability and resistance to seawater. Some are considered important as future barrier films for complex instrumentation parts. Certain of these materials are considered better than those now in use because they are effective, can withstand higher temperatures. They also would reduce costs, since the parts may be cleaned without damage to the films.

It has long been known that large amounts of fluorine in organic materials impart that unusual properties to them. Public appreciation of the singular qualities of polytetrafluoroethylene (Teflon) has prompted numerous efforts to synthesize other polymers of comparable heat stability, surface properties, *etc. via* heavy fluorination. However, the lack of availability of suitable difunctional intermediates and the distraction from pure fluorocarbon behavior caused by the presence of functional groups has stymied many of these efforts before practical materials could be realized.

## Fire-Fighting Development


Naval Research Laboratory chemists have developed new chemical agents, equipment, and techniques that have proven to be very effective in controlling gasoline and other fuel fires. The system is presently in use on aircraft carrier flight decks, at Naval and Air Force Air stations, at commercial airports and as an additional method for fire departments to fight certain oil or gasoline fires. The photo shows the system being tested at sea on the flight deck of an aircraft carrier where the flick of a switch will put the fixed nozzles to work spraying an

NRL-developed chemical agent dubbed "light-water" to work to smother flames and to keep them from reigniting. The chemical agents, even though they are heavier than the fuels, will form a floating film cover over the liquid fuel which prevents its evaporation and burning. Many of the ships also have an NRL-developed firefighting agent called Purple-K-Powder which is most effective in quenching the flames of highly flammable liquid fires. The agent, carried in a tank by a mobile unit, is often used to douse fires on flight decks of ships and then "light-water" sprayed over it to keep the flames from reigniting. There are at least 80 commercial airports using the twin-agent flame-quenching technique, as well as Naval Air stations, Air Force stations and fire departments. The system can be adapted for helicopter use.

## First Extragalactic Carbon Monoxide Found

Dr. Philip R. Schwartz of the Naval Research Laboratory and Drs. William J. Wilson and Eugene E. Epstein of the Aerospace Corporation, Los Angeles, teamed up recently to locate huge clouds of carbon monoxide in a nearby galaxy called M-33.

This was the first time detection of an extragalactic molecular emission line had been noted by radio astronomy, and indicates that the presence of complex molecules in the interstellar medium is not unique to our own galaxy.

The finding that carbon monoxide also exists outside the Milky Way was made through the use of the National Radio Astronomy Observatory's 36-foot radio telescope at Kitt Peak in Arizona.

The astronomers probed regions of ionized hydrogen in two nearby spiral galaxies, M-31 and M-33 perhaps similar to our Milky Way galaxy.

The discovery of carbon monoxide in another galaxy, means that at least one other galaxy is similar to ours in that both contain complex molecules in their interstellar gas.

Of the many interstellar molecules found in our galaxy, carbon monoxide is by far the most abundant and most widely distributed due to its simplicity and stability.

Complicated molecules such as formaldehyde and methanol are formed in various regions of the galaxy, possibly in cool stars or on interstellar grains. These may be broken down and dispersed by a variety of processes until eventually this very stable carbon monoxide "debris" remains and is distributed about the galactic disk like neutral hydrogen.

If the same molecular formation and destruction mechanisms which operate in our galaxy are present in other galaxies with similar structures and stellar populations, the detection of extragalactic molecules would not be surprising. And carbon monoxide is the most "expected" molecule. Carbon monoxide was found in the Milky Way about two years ago.

Until now only an unconfirmed detection of the hydroxal radical (OH) in absorption had been reported, despite the efforts of many radio astronomers to detect many molecules. The detection of carbon monoxide is thus doubly important since being essentially a "daughter," its spectral lines signal both its presence and the presence of its more complex "parents."

Many scientists believe ammonia and formaldehyde came together to form the earth's atmosphere and its ocean, and are the basic building blocks of life.

One light year is the equal of almost six trillion miles, and M-33 is about 1.5 million light years from the center of the Milky Way galaxy. This means that, even though M-33 is a neighboring galaxy it is eight million trillion miles away.

Laboratory scientists, including Dr. Schwartz, are now attempting to detect the presence of ammonia in M-33 through the use of the telescope at NRL's Maryland Point Observatory.

## U.S. and French Submersibles to Explore Mid-Atlantic Depths

Deep diving research submersibles from France and the United States will plumb the depths of the mid-Atlantic Ocean for the first time, in a three-year international scientific program announced today by the Commerce Department's National Oceanic and Atmospheric Administration (NOAA) and the Woods Hole Oceanographic Institution (WHOI).

The program, called FAMOUS (French-American Mid-Ocean Undersea Study), will make a detailed study of the Mid-Atlantic Ridge in an area some 200 miles south of the Azores. The submerged ridge is a major feature of the earth's surface but has not yet been studied at close range. First-hand study of the ridge is expected to furnish direct knowledge of how the earth's continents and oceans were formed, information that bears directly on the formation of metallic ore deposits and oil accumulation.

The Mid-Atlantic Ridge is a giant undersea mountain range that extends from the Arctic Ocean the entire length of the North and South Atlantic, and continues around Africa into the Indian Ocean. It is at an average depth of 7,200 feet, with a maximum depth of about 12,000 feet.

Up until now, man's knowledge of the ocean floor has been obtained from indirect measurements from surface ships and deep-sea coring and dredging. By using submersibles, scientists will obtain samples direct from the rift valley in the center of the Atlantic ridge, much as the astronauts went to the moon to obtain samples of its surface.

The submersibles will also emplace instruments on the ocean floor to provide a continuous supply of precise data on the dynamics of seafloor spreading and the emergence of new crustal material.

FAMOUS is one of several scientific programs being undertaken as a result of a bilateral agreement between France and the United States. United States coordination in the field of oceanography is the responsibility of NOAA. Scientific coordination of FAMOUS is being handled by WHOI, with financial support from the National Science Foundation, the Office of Naval Research, and NOAA.

The scientific program follows a plan recommended by an international group of scientists convened by the National Academy of Sciences at Princeton in January 1972 under the sponsorship of the United States Office of the International Decade of Ocean Exploration. Focus of the study is exploration of the

mid-ocean rift system, which comprises a network of cracks in the seafloor up to 10 miles wide and two miles deep, virtually girdling the globe. A major objective of the research is to obtain evidence of volcanic-like activity apparently causing seafloor spreading and the gradual drifting of North America and Europe away from each other.

Co-Scientific Leaders for U.S. participation in the mid-Atlantic study are Dr. George Keller, Director of the Marine Geology and Geophysics Laboratory at NOAA's Atlantic Oceanographic and Meteorological Laboratories, Miami, and Dr. James Heirtzler, Chairman of the Department of Geology and Geophysics at the Woods Hole Oceanographic Institution.

Following two years of site surveys and training, a fleet will assemble at the site selected, in the summer of 1974. The French bathyscaphe *Archimede* and French submersible *SP-3000*, the American submersible *Alvin*, and four surface ships will carry out the most extensive deep ocean manned submersible study ever undertaken. Some 40 dives will be made at that time, with special missions for each submersible. The submersibles will do detailed mapping of the area, collect special bottom samples, and place instruments on the seafloor.

Each of the deep-diving research vehicles will have special assignments to make best use of their differing capabilities. The *SP-3000*, which has a high degree of maneuverability, will be used for rapid visual reconnaissance and for studies within the rift valley of the midocean ridge. *Archimede*, a bathyscaphe designed for maximum depths and heavy payloads but in relatively gentle terrain, will explore the fracture zones of the seafloor. The highly maneuverable *Alvin*, owned by the Office of Naval Research and operated by WHOI, will explore both terrains as well as the rift valley wall.

In describing the FAMOUS project, Dr. James Heirtzler said that ships and personnel from France, Great Britain, Canada, and several institutions in the United States, including the Woods Hole Oceanographic Institution, Scripps Institution of Oceanography, University of Rhode Island, Naval Research Laboratory, NOAA's Atlantic Oceanographic and Meteorological Laboratories, and others, will work together in exploring the related area.

"A regional site survey has been completed by aircraft and surface ships," said Dr. Heirtzler. "Additionally, last month a French team conducted a field trip in Iceland to study some of the volcanic features believed similar to those of the mid-ocean ridge. Late in August, *Alvin* conducted training dives in the Gulf of Maine with a team which included a participating French scientist. One purpose was to test instrumentation and techniques to be used in the Mid-Atlantic Ridge Study over somewhat similar seafloor terrain."

Survey work of the region was carried out in August by the University of Rhode Island's research vessel *Trident*, and in September by the French oceanographic research vessel *Jean Charcot*. Further surveys will be undertaken in October by Woods Hole's *Atlantis II;* and later in the year by the U.S. Naval Ship *Mizar*. The surveys will include accurate measurements from surface and deeply-towed instruments and extensive sonar and bottom photographic mapping operations.

Next year, additional survey work will be done by naval research ships, Woods Hole's *Knorr*, and the British oceanographic research vessel *Discovery*, utilizing a huge long-range side-scan sonar system of the United Kingdom's National

Institute of Oceanography. The French bathyscaphe *Archimede* also will make an initial reconnaissance dive in the area.

A special training program is already underway for the scientific divers. This includes practice dives in all three submersibles, field trips by divers and pilots to Iceland and Eastern Africa where similar terrain is located, and workshops for establishing priorities on the types of observations to be made during the various dives. Navigation and sampling instrumentation is being developed that will be interchangeable among the submersibles.

Presently, *Alvin* can dive to 6,000 feet, and a new ballast system was installed last spring at Woods Hole as an initial step towards operation at greater depths. This coming winter a new titanium personnel sphere, provided by the U.S. Navy, will be installed to replace the existing steel sphere. The new sphere, which will hold the three-man crew, could virtually double *Alvin's* deep-diving capabilities.

The National Oceanic and Atmospheric Administration was created in October 1970 by President Nixon's reorganization of Federal environmental activities, to improve man's comprehension and use of the earth's physical environment and its oceanic life.

## Taking a Televised Look at the Sun

For the first time in history man will have an opportunity to conduct close-up real-time observations of sun flares and other solar phenomena through the use of an ultraviolet TV monitor to be on SKYLAB '73. Dr. Richard Tousey of the Naval Research Laboratory (NRL) is the principal investigator for this experiment.

SKYLAB, the United States' first orbiting manned space station, is scheduled for launch for the National Aeronautics and Space Administration in the spring of 1973. If all goes according to plan, three crews of three men each will visit SKYLAB over a period of almost eight months, and will conduct a varied series of scientific experiments.

The solar phenomena, which man cannot see from earth, will be observed in both the low and high solar atmosphere, and parameters compared to include form, dynamics of motion and evolution.

The real-time TV displays will be available not only to the SKYLAB astronauts, but will also be relayed to the ground to allow scientists to observe the sun continuously in extreme ultraviolet wavelengths.

It is possible that some of the real-time data gathered on the phenomena of the solar activity may be piped into the living room of the world's populace through commercial television channels.

Solar activity, such as solar flares, often cause disruptions to radio and television communications as well as navigational instruments and other electronics here on earth.

NRL scientists are the principal investigators for six experiments scheduled to fly aboard the orbiting space station and, in addition, are providing technical assistance for a seventh.

Of the six NRL instruments, four will observe solar activity at various wavelengths. A fifth experiment will be to record heavy atomic nuclei present among incoming cosmic rays, and the sixth will look back at Earth to photograph both the upper atmosphere's ozone layer and the twilight airglow.

Dr. Tousey is the principal investigator in the four solar activity experiments. The first experiment, the extreme ultraviolet coronal spectroheliography, is designed to record in great spatial detail the emission pattern of the Sun's entire chromosphere and corona. It will also provide maps of various layers in the solar atmosphere by observing selectively the appropriate lines of extreme ultraviolet radiation. In addition the experiment is designed to record the development of solar flares; record changes in flare temperatures, and see the effects of solar flares extending up through the Sun's atmosphere.

Two other solar experimental instruments will be the Chromospheric Spectrograph and Extreme Ultraviolet Monitor. The first is designed to obtain, in great spectral detail, the emission characteristics of small isolated areas of the Sun. It will provide information on changes in the spectrum crossing from the photosphere, to the chromosphere, to the corona, and derive from this data a detailed temperature and density model. The models are located in the Apollo Telescope Mount section of SKYLAB.

The Extreme Ultraviolet Monitor—which will provide the real-time TV pictures of the Sun in the 171-500 angstrom band will show the Sun's actual emission pattern in the wavelength ranges to be studied both by the first two experiments mentioned. It will enable the astronauts to point the second experiment at extreme ultraviolet features of interest that are not visible in Hydrogen Alpha or in white light.

The final experiment to be pioneered by Dr. Tousey, will be to obtain x-ray/UV Solar Photography. This experiment will record on photographic film the detailed energy spectrum of x-ray and ultraviolet radiation from normal and explosive areas in the solar atmosphere. This experiment will be located in the Orbital Workshop of SKYLAB, rather than on the Apollo Telescope Mount.

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**Caption for Cover Picture**

*An electron micrograph of a typical motile marine bacterium involved in bacterial chemotaxis. See page 1.*

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