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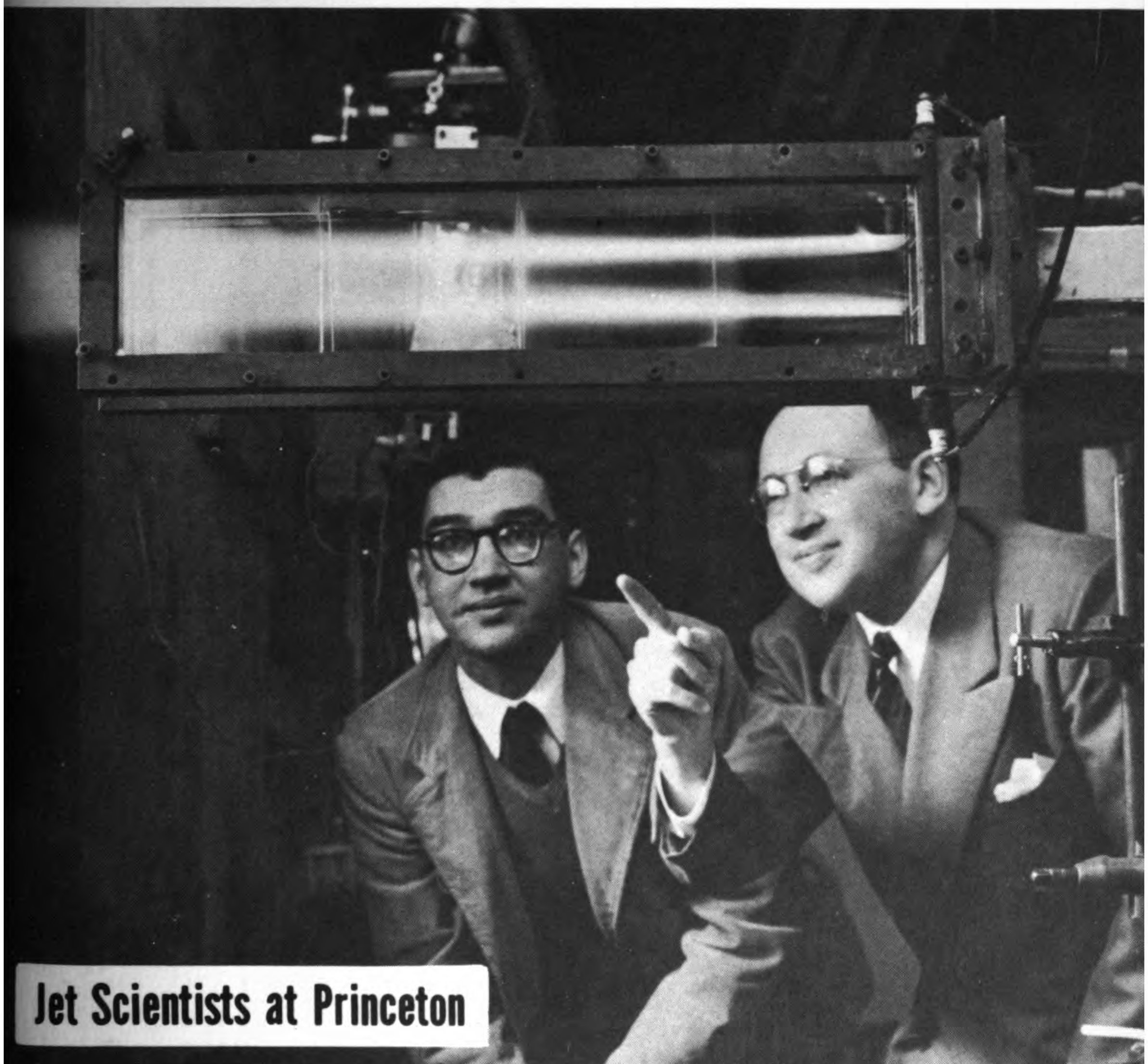
RESEARCH REVIEWS



Jet Scientists at Princeton

NAVEXOS P-510

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE NAVY

WASHINGTON, D. C.

COVER PHOTO: One of the many experiments underway at the Forrestal Research Center at Princeton University to advance commercial and scientific use of rocket and jet propulsion is being conducted by Sidney Reiter and Dr. Martin Summerfield. They are trying to find out how the qualities of a high-speed flame affect the burning of fuels in the combustion of a jet engine or rocket. For more about the Forrestal Research Center and the Navy's interest in its work see p. 10.

Approved by Bureau of the Budget, 14 February 1952

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A million dollars a month is a lot of money in anybody's language—and that is the sum which Kingsley Williams of the Naval Research Laboratory says it cost the Armed Forces merely to replace rotted tentage during World War II. This is just one example of the deterioration caused by tropical conditions, but Mr. Williams gives many others which show why it is vital for the Navy to find ways to hamper the natural forces which destroy huge amounts of vital equipment every year.

Forrestal Research Center Established 10

It is fitting that one of the great research laboratories of the country should be established in memory of James Forrestal, who had the vision to realize the importance of scientific research to national safety. Princeton has honored its son and trustee by setting up the Forrestal Research Center on the 800-acre tract formerly occupied by the Rockefeller Institute of Medical Research.

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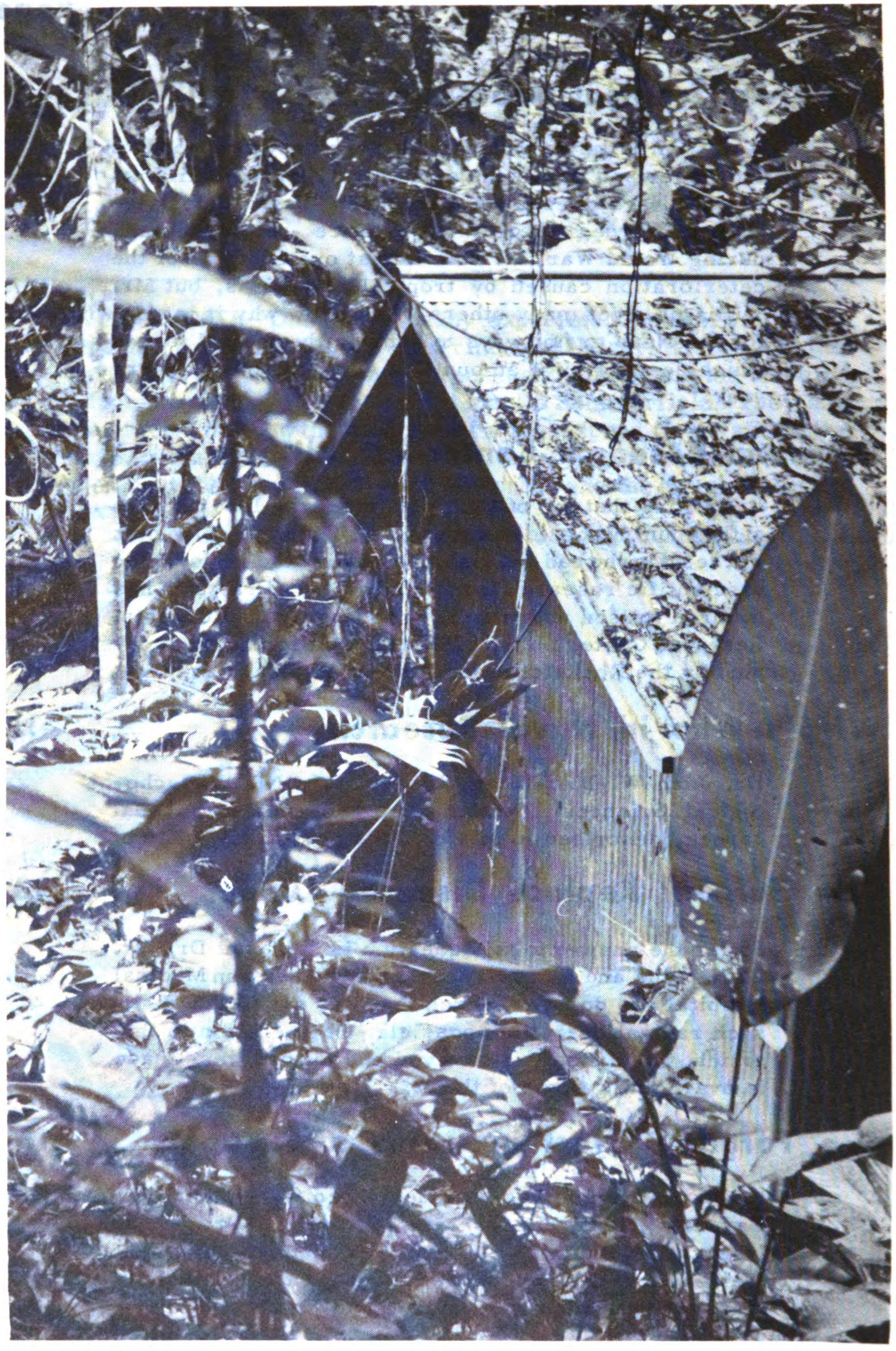
News of two seminars this month: one future and one past; also news of a unit anniversary.



The rain-forest areas of the Canal Zone are filled with dense, jungle-like growth. Unfortunately for the Armed Forces the conditions which favor such thick vegetation also promote the growth of fungus, termites and other pests which ruin or seriously damage essential equipment.

Nature's Tropical Saboteurs

by
Kingsley Williams
Naval Research Laboratory

This is an article and not a sermon, but nevertheless I should like to choose as my text the second part of the 13th Chapter of the Book of Leviticus. In this section the scribe treats the matter of "leprosy of garments", the criteria for determining whether a garment be unclean or not, and the technique for disposing of unclean garments.

This text dramatically illustrates by its very antiquity the problem of biological deterioration. This "leprosy", which plagued the garments of the early Hebrews was not different in kind from what we moderns call mildew, rot, or fungus infection. With the change in nomenclature we have also achieved a somewhat better understanding of the nature of the problem, but we have not succeeded in eliminating it.

It has long been recognized that there are tremendous geographic variations in the rate of biological deterioration. This was dramatically demonstrated in the last war when literally billions of dollars of equipment which had proven quite satisfactory at Aberdeen Proving Ground wasted away at fantastically rapid rates when shipped to the South Pacific islands. Our bill for replacing rotted tentage alone has been estimated at a million dollars per month.

The common excuse for this tremendous waste was the climate. We all know what the weather is like in Aberdeen. On one day it may snow, on another it may be clear and warm. Monday may be bone-dry and Tuesday may be foggy all day. All we can safely say is that the weather is extremely variable.

In the tropical rain-forest areas the situation is different. Only two seasons are apparent: rainy and dry. Throughout the year the temperature ordinarily does not vary more than 20°, the humidity remains consistently above 55 percent, and rainfall is voluminous. The weather at Cristobal, C. Z. is probably the best documented of any rain-forest area and is quite representative of these areas. The mean temperature is extremely uniform and the range limited daily. Rainfall varies from a few hundredths of an inch in the dry season to as high as 44 inches in November, when seasons change. The relative humidity varies somewhat with the season but not nearly as drastically as it does in non-tropical areas.

Total rainfall at Cristobal runs to about 140 inches per year, though a few miles down the coast it totals nearly 200 inches annually. Most of this rain comes on quickly and the skies clear soon after it stops.

Kingsley Williams has just returned from a three-year tour of duty as Director of the Naval Research Laboratory's Tropical Exposure Station in Coca Sola, C. Z. This article was adapted from an informal talk which he gave before a chemistry colloquium held recently at NRL.

The average day in these areas is much like the delightful days we find in most of the United States in late spring, when conditions seem to be ideal for life of any kind. This is reflected in the lushness of life in the rain-forest areas.

With all this virulent but relatively short-lived growth, one expects to find vast quantities of fallen debris on the floor of the jungle—broken branches, dead leaves, flower parts and the like. In fact we do, but the quantities involved are not nearly as great as might be expected, because of the tremendous activity of those scavenging organisms, the fungi and termites.

Actually the scavengers—like the termites, molds, bacteria, cockroaches, and silverfish—play absolutely vital roles in the delicate cyclic balances of nature, for example in the carbon cycle and the nitrogen cycle. If their activities were suddenly to cease, life as we know it would come to a grinding halt.

Unfortunately for man, however, the perspective of these various beasts is quite limited, and their outlook so narrow that they fail to see that a piece of dead oak fashioned into an instrument case has increased in worth. To them, it is still just a good meal. It is because of this difference in point of view that men worry about biological deterioration. For we are constantly adopting organic materials for our own ends: wood, cotton, wool, linen, leather, paper. These and many more are derived from natural sources and sooner or later nature will reclaim them all.

We have found, however, that by various devious techniques we can retain custody of these items for relatively long periods. But in many cases, particularly in the tropics, these periods do not seem long enough to suit our convenience. Why?

Of considerable importance in the tropics are the fungi. These "beasts" are generally considered the lowest members of the vegetable kingdom. Since they are devoid of chlorophyl, they cannot synthesize their food from elemental sources. Their nutritional requirements are nearly the same as those of humans and they satisfy these requirements in the same way that humans do—by ingesting the dead remains of plants and animals. While the ability of any one species of fungus to digest organic materials is limited, fungi, as a class, are capable of utilizing virtually any such substance found in nature.

Reproduction of the fungi occurs through a wide variety of mechanisms, of which sporulation is the most important. A sporulating body of a fungus is shown in a diagrammatic sketch in Figure 1. These spores are very tiny and light so that they are dispersed even by gentle breezes.

When a spore lands on a leather boot, for example, it will promptly germinate if the conditions are right. The temperature should be somewhere in the range of 60° to 90°, the pH of the boot should not be too far from seven, an adequate supply of oxygen should be available and, most important, sufficient moisture must be at hand. If all these conditions are right, the spore will absorb water and send out a little shoot called

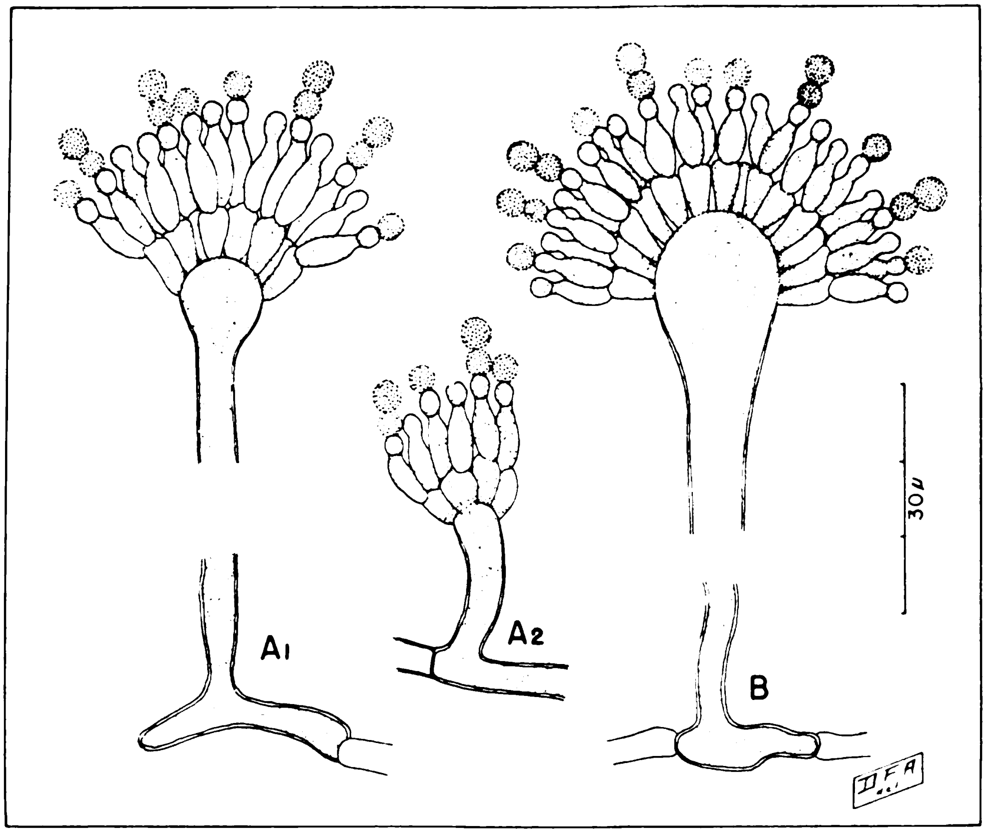


Figure 1. Sporulating mechanism of the fungus.

a hypha. The hypha grows longer, branches frequently and forms a mass of intertwining filamentary strands growing into and around the surface irregularities of the boot and forming what is called a vegetative mycelia. What usually appears to the eye is principally the reproductive mycelia with its innumerable sporulating bodies. These spores mature and are dispersed. Many are carried far beyond our observation but vast numbers fall back onto the boot, germinate and compound the evil. With this geometrically increasing growth, the time soon comes when the infection becomes obvious.

If we carefully wipe the boot off with a rag, growth will be slowed tremendously and if the wiping is coincident with a change in the weather we may feel that we have got rid of that particular infection. Actually a large part of the vegetative mycelia is left in the minute crannies on the surface of the boot and if, within a reasonable time, conditions again become favorable for growth, the infection may crop out anew. Even if unfavorable conditions persist for a long time there may be a recurrence of the growth.

If, instead of wiping the infection off, we let it grow, the original mass of mycelia may literally drown in its own juices. The accumulation of waste (catabolic) products gradually slows down and eventually inhibits further growth. The chances are very good, however, that cessation of the original growth will permit a secondary invader to flourish, utilizing perhaps even the waste products of the first organism for its own purposes. Catabolic products may also be removed by rainfall, condensation, and insects, thereby permitting a revival of the original invader. The possible patterns of growth and decay are many, but the eventual result will be a complete digestion of the boot.

Total destruction, in the case of our boot, may take years, but sandbags, tents, and other materials may last only a few days or weeks. Camera and binocular lenses are often clouded and etched to uselessness by fungi and electrical insulating materials are seriously degraded by their depredations.

Even in cases where destruction or damage is not involved, the aesthetic sense of man is severely offended by the very presence of unwanted growth. The same man who delights in a moldy piece of Roquefort cheese will become very upset when he finds a bracket fungi on his shower curtain as shown in Figure 2.

We have already noticed that an adequate supply of moisture is essential to growth. By keeping materials dry it should be—and is—possible to eliminate, or at least minimize, fungus attack. All quarters in the Canal Zone and in most other tropical areas have built-in "hot-lockers"—a coat closet with a light bulb burning continuously near the floor. By storing bedding, shoes, photographic supplies and other highly susceptible materials in these lockers, it is possible to avoid damage.

Hot lockers are, of course, a bit impractical to carry with armies in the field. It has, however, proven feasible to package many items of military equipment in vapor-proof containers with small bags of dessicants (drying agents) so that during transportation and storage there is no danger whatever. Unfortunately proper packaging is a rather costly procedure, and it does not protect any material once it has been unwrapped and placed in service. It is necessary, then, to devise techniques or design to protect equipment.

Perhaps the most obvious solution is to replace fungi-susceptible materials with materials which do not nourish—in fact which poison—fungi. This approach has been satisfactorily applied to radios, cameras and the like. But economic, aesthetic and structural considerations prevent widespread use of this technique until we have developed synthetic fibers as satisfactory and as cheap as cotton, wool, hemp, and wood; consequently we must attend to the preservation of these materials. Many relatively efficacious fungicides and preservatives have been developed over the course of the years but as yet there is no panacea, and protection for any item must be tailored to suit its nature and anticipated function.

But enough of micro-organisms and on to something we can see. James Thurber has written a fable of an elephant who boasted he could lick in combat any animal in the world, and he did lick enough of them to get himself set up in a multi-story mansion as emperor of the beasts. He slept on the fifth floor and in the basement maintained a prize ring with an open challenge to any animal. One day he received a written invitation to battle and on the appointed hour he repaired to the prize ring where a tiny voice told him that it would not be long before he, the elephant, would be flat on his back there. The elephant searched for the source of the voice but was unable to find it and retired to his fifth-floor bed and went to sleep. A short time later the bedroom floor collapsed and the elephant fell through the five floors of his house to land on his back in the prize ring. Thurber draws the moral that the bigger they are the harder they fall, but I think a more appropriate moral is Never Underestimate the Power of a Termite.

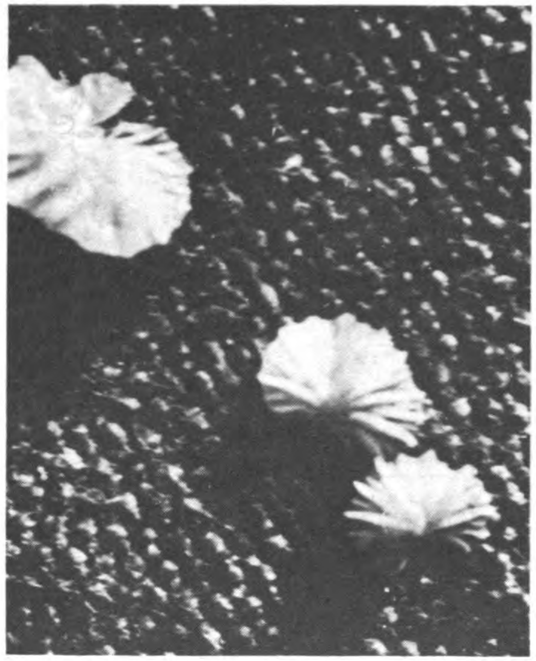


Figure 2. Bracket fungus on shower curtain.

Termites may get into a relatively undisturbed building or packing crate and completely destroy its usefulness before damage becomes apparent. Often their presence is not discovered until they have eaten so much underlying wood that ripples appear on the surface of the paint film. Part of the reason for this is that termites are remarkable engineers. They never accidentally eat through a board, though they may approach within a hundredth of an inch of the surface. Moreover, they will never destroy enough wood in a structural member to cause it to collapse of its own normal static loading. At the same time they don't leave much of a safety factor as an acquaintance of mine learned when he opened his Florida mansion for the winter season. He walked in the front door past his grand piano in the living room to the library, where he paused and turned around just in time to see the piano disappearing through the floor.

There are hundreds of varieties of termites (Figure 3), each with its own peculiarities. Many build magnificent edifices above the ground as we can see in Figure 4.

The tastes of termites include practically all cellulosic materials and they often seem to prefer paper, Celotex, cotton rope and the like to wood. They often show remarkable ingenuity in attaining their objective. Ordinary uncracked concrete is an effective barrier to them, though mortar can be penetrated by certain species. They often build mud tunnels across concrete, however. Fortunately they will not build around a sharp edge, and by laying a strip of metal flashing with its edges extending a few inches on either side of the footing of a building, it is possible to stall them off. In addition, a number of effective poisons which can be pressure-impregnated into timbers will deter them for many years.

In addition to the termites there are large numbers of boring beetles in the tropics—the furniture beetles, the powder post beetles and the death-watch beetles. These types bore fine tunnels into dry wood and their presence can usually be observed by an accumulation of sand-like sawdust immediately below their entrance holes.

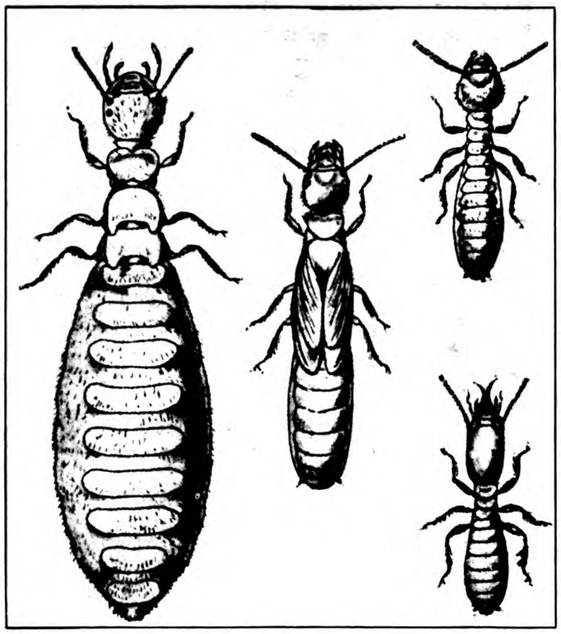


Figure 3. Termites: queen, nymph of winged female, worker, soldier.

Switching now to the seas bordering our rain forest, we find that wooden underwater structures are just as subject to attack as any fallen branch in the jungle. The termites of the sea are the flea-like limnoria and the shipworms, or teredos.

If we hang a piece of one-inch fir off the dock at Fort Sherman and examine it closely after a month we will find a few tiny holes, half a millimeter in diameter, certainly nothing to get excited about. If we replace the board in the water and examine it again after another month we find that there has been a tremendous increase in the number of those tiny holes. As the months go by the holes increase so greatly in number and become so closely packed that we can break down the walls between them with our thumb and rub off perhaps a few hundredths of an inch of

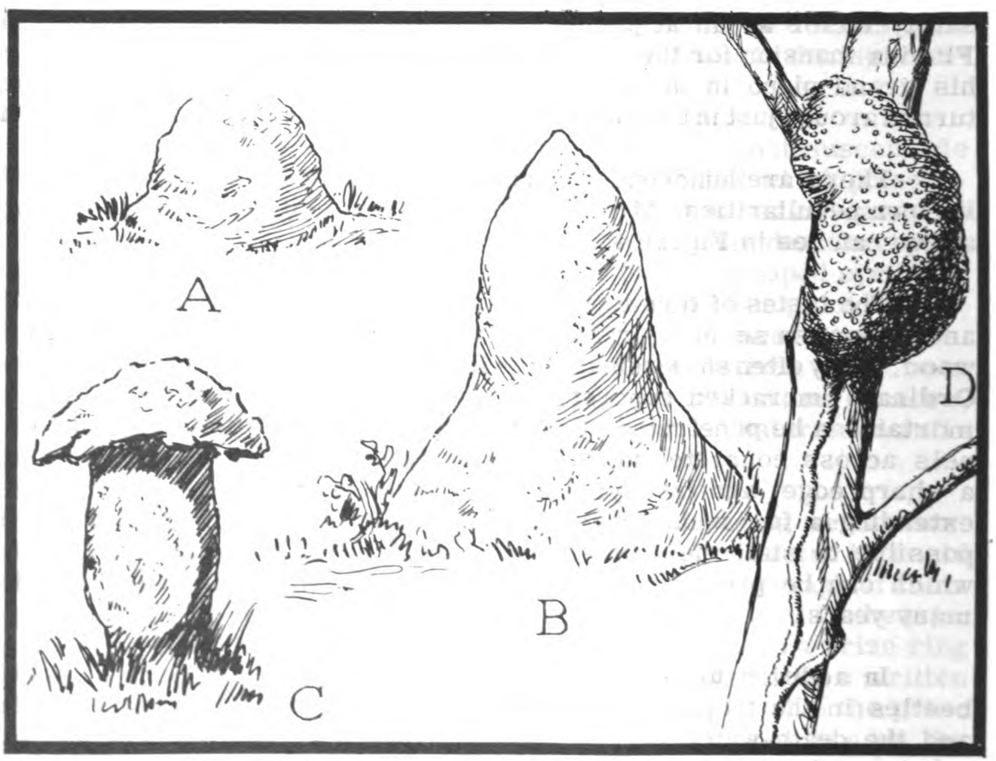


Figure 4. Termite houses: A is mound nest; B pyramid or steeple type; C mushroom type; D arboreal nest.

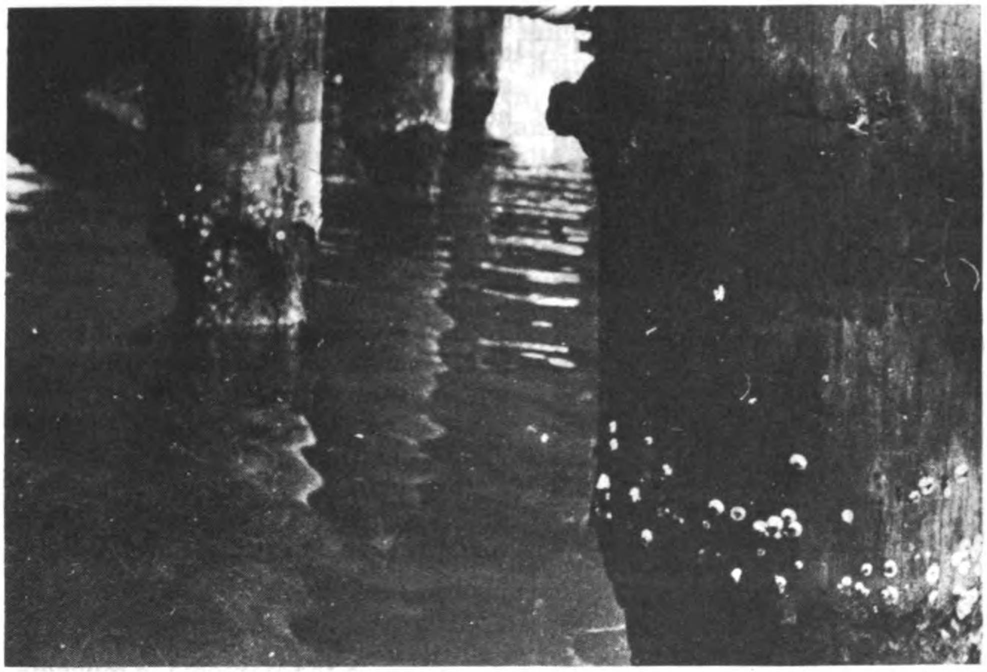


Figure 5. These piles, supporting the Fort Sherman Dock, show the work of the water flea.

the original surface. After only four or five months, the action of the water itself is enough to break down the walls separating the holes and the surface will gradually abrade away. After nine months the edges of our original board have completely disappeared and by the end of a year there is hardly enough left to recognize.

This is the work of the Limnoria—the water flea (Figures 5 and 6). He is equipped with legs which permit either crawling or swimming and with a lobster-like tail which permits rapid backward propulsion. Thus built and equipped, he is agile enough to skip from one point to another, eating into the wood at any one point only until his belly is full and then moving on to another tasty morsel. In some cases the rate of attack of Limnoria is as high as one inch a year and a twelve-inch piling under attack from both sides may be severed in six years.

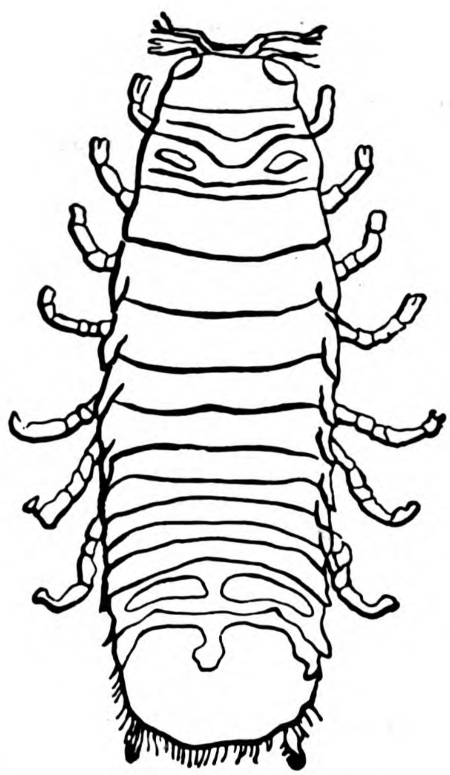


Figure 6. Here is the "beast" himself, prodigiously enlarged.

The Limnoria, however, is not the glamor boy of the sea termites. This honor is reserved for the teredo (Figure 8). The teredo is pretty much at the mercy of the currents

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until he encounters a piece of wood to which he attaches himself. He soon burrows into the wood and as he burrows he grows. Unlike the limnoria, his primary food is not cellulose, but plankton, which he takes in through an incurrent syphon. He remains permanently attached at the point of original entry throughout his life, using his shells as efficient cutting tools with which he digs an ever-increasing burrow, lining it with a thin calcareous lining as he goes. This sort of damage (Figure 7) was responsible for a disaster on Columbus's fourth voyage and today the total damage caused by these teredos runs into millions of dollars annually.

Another wood-inhabiting organism is the Martesia, a mussel-like bivalve which burrows into wood and grows up inside. These are smaller and less common than the shipworms and ordinarily do only limited amounts of damage. Of the many other forms of sea life, the barnacles and algae cause great consternation among shipowners, for they attach to ships' hulls in great profusion and cause enough drag to reduce seriously the operating efficiency and speed of the ships. Barnacles in addition, often rupture paint films to which they attach and leave that particular area subject to corrosion or borer attack.

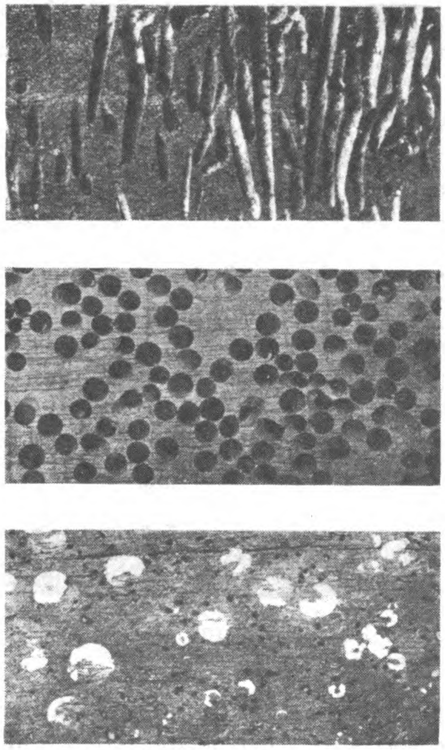


Figure 7. Wood attacked by teredo: Top, surface recently occupied by shipworm; middle, section parallel to surface shown above; bottom, vertical section through preceding figures.

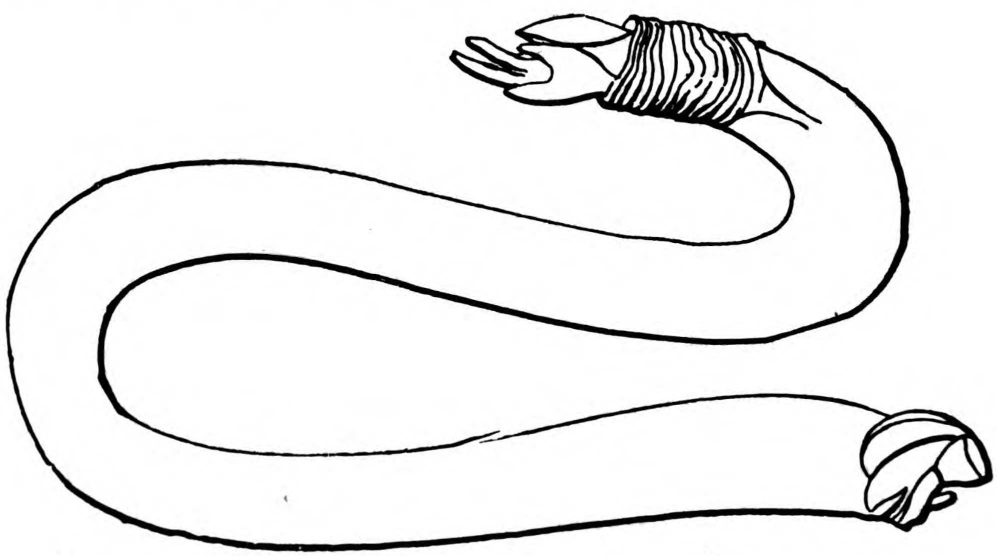


Figure 8. The teredo, or shipworm, as he is popularly known.

Before returning to land, we might point out that marine pilings are often favorite roosting spots for pelicans, gulls, and terns and soon become covered with excreta which, whether corrosive in themselves or encouraging decay by micro-organisms, cause a rapid wasting away of the tops of the piles, commonly called pelican rot.

Coming back to shore, we find in the tropics many of the same destructive animals with which, we, as Washingtonians, are familiar. The cockroach is far more ubiquitous in the tropics than here. While the average run of roaches is about the same size as those in this area a few species run to such a size that they just fit into half-pint mayonnaise-jars.

Mice and rats are less common in the tropics than might be expected, because of the abundance of their natural enemies—snakes, predatory cats and hawks. The rodents behave there as here, gnawing through Celotex, cardboard, wood, or even lead to reach some tasty bit of food. Ants, while frequently a great nuisance, are not generally in themselves destructive of materials. Many species, however, nest in infrequently disturbed communications equipment, switch boxes, fire alarm boxes and the like. The grass or litter of their nests is kept continually wet and leads to rapid corrosion of nearby metallic objects. These sorts of equipments are also favorite hangouts for mud-daubers, wasps, and hornets, which seldom do any damage to the equipment but are often very discouraging to the operators.

Lizards seem to be particularly fond of transformer vaults and quite often manage to bridge across high-voltage terminals, causing arcs which do a great deal of damage to the transformers. The majority of power failures in the Canal Zone are probably due to this sort of cause—lizards, snakes, sloths and even occasional monkeys bridge circuits and blow breakers all the way across the isthmus several times a year.

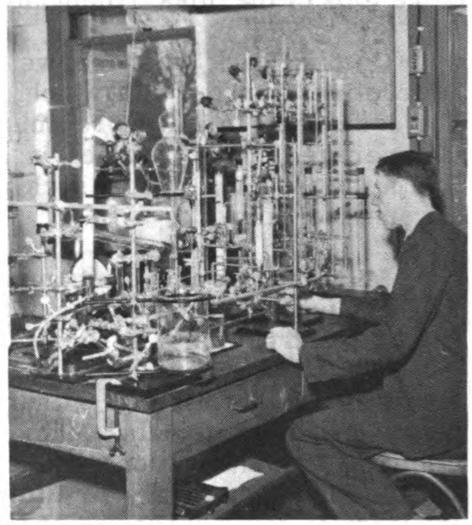
This has been an admittedly casual and very incomplete survey of biological deterioration in the tropics. If it has suggested to you the magnitude and diversity of the problems involved and has in some small measure indicated the fascination of the rain forests, it has accomplished its purpose.

Acknowledgment: Figures 4, 7 and 8 are taken from Volume 5 of the Smithsonian Series (Insects, Their Ways and Means of Living by R. E. Snodgrass), permission of the Series Publishers, Inc. Figure 6 comes from Woods and Other Organic Structural Materials by C. H. Snow (McGraw Hill Book Co., Inc.).

Orr Reynolds On Special Research Project

Dr. Orr Reynolds, Director of ONR's Biological Sciences Division, has started a six-months' leave of absence and is serving for that period as Executive Secretary of a group appointed by the American Physiological Society to explore the science of physiology and the possibility of increasing its value to the welfare of the Nation. Financial support of the study is provided by the National Science Foundation. Dr. Reynolds' offices are in the Dupont Circle Building in Washington, D. C. During his absence from ONR Dr. John P. Lindsay will serve as Acting Director of the Biological Sciences Division.

Forrestal Research Center Established



Some of the researchers who will work on jet propulsion problems at the Center: at left, Drs. C. D. Perkins, J. V. Charyk, Luigi Crocco, and M. Summerfield; at right an unidentified scientist in the laboratory for Chemical Kinetics, where factors related to jet propulsion are investigated.

For many years Princeton University's most distinguished intellectual "neighbor" was the Rockefeller Institute of Medical Research, a branch of the great New York establishment. Its research effort was devoted primarily to plant and animal pathology, but during the recent war the facilities and program were expanded to include many allied studies. Shortly after the war the Institute decided to move all of the personnel and specialized equipment to New York. A magnificient tract of 800 acres, and dozens of laboratory buildings were thus left without a tenant.

Recently the University acquired the entire property and has named it the James Forrestal Research Center. Thus Princeton was able to find suitable housing for its many Armed Forces research projects and at the same time honor one of its most distinguished alumni. Although the initial purchase was arranged through a private endownment fund, the operation of the Center would be impossible without government contracts—many of which were sponsored by ONR and other naval agencies.

By now, all graduate research projects in Princeton's scientific, engineering and mathematics departments have been moved to the Center. A small hangar has been built and an airstrip is under construction.

The Center was dedicated last month by Robert A. Lovett, Secretary of Defense.

Who's Who in Naval Research

Big, good-natured Dr. John W. MacMillan is an ex-football player and intercollegiate championship boxer and looks like he could still do both. For the past six years, however, he has been devoting most of his energies to the guidance of psychological research at ONR.

Back in 1946, Dr. (at that time LCDR) MacMillan was about to take off for his native Canada on a well-earned terminal leave from the Navy. But before departing from Washington he decided to visit the newly-organized Office of Research and Inventions. They took one look at his record as an aviation psychologist and persuaded him to "stick around for a week or two." ORI became ONR and Dr. MacMillan stayed on to become Director of the Psychological Sciences Division. He still has to take his well-earned leave.

How does one get to be an aviation psychologist? In MacMillan's case, by first acquiring a thorough education in psychology, then by learning to be a competent pilot and finally by years of applied research with pilots as subjects. That, in a nutshell, was his preparatory career.

Born in Toronto in 1908, he first went to Upper Canada College and then transferred to the University of Toronto, graduating in 1932. He went on for further study at Cornell, where he won a Russell Sage fellowship and obtained his doctorate in psychology in 1939. With that under his belt, he accepted a teaching position at the University of Maryland. The peculiar problems of aviators began to interest him when—in connection with the Civilian Pilot Training Program—the National Research Council asked the University of Maryland Psychology Department to undertake research on pilot tension. As part of the experiments, Dr. MacMillan made a guinea pig of himself to see how quickly a person can be taught to fly. He soloed in <u>two</u> hours and—through special arrangement with CAA—obtained a license in sixteen.

In 1942 MacMillan was called into the Navy and received a direct commission (LTJG, as a psychology specialist) in the Hospital Corps. He spent two years at primary and advanced training fields, helping to set up training programs and instructing instructors in the psychology of teaching youngsters how to fly. Late in '44 he was sent to the Pacific area to work directly with combat pilots. Aboard carriers and ashore, he followed the fighting from the Marianas and through the Philippines and Iwo to Okinawa, studying the behavior and combat performance and noting the emotions, tensions and social problems of the naval pilots—in the hope that his findings would help to improve selection and training techniques. After V-J Day he returned to Washington and spent six months preparing a voluminous annotated bibliography on Human Factors in Engineering Design for the Bureau of Medicine and Surgery.

As a division director, his present job is much more comprehensive in its scope, covering all phases of psychology of possible interest to the Navy. There are three main programs of contract research projects. One deals with selection, classification and training, not just for flyers, but for all naval jobs. A second, under the general heading of "physiological psychology" covers the visual and auditory standards for different kinds of jobs, and is concerned with human-engineering problems or the design of equipment for the most effective performance of the man-machine combination. The third program is, broadly, human relations: what qualities make a good leader, how leadership can be developed, what human and social elements go into the creation of team spirit, what morale is and the like.

Dr. MacMillan still lives with his wife and family (three teenagers: two boys and a girl) in University Park, Md. in the house they bought while he was teaching in the University. He sneaks away occasionally for a game of golf and manages to squeeze in, at least once a year, a trip to a cottage on an Ontario lake. His favorite pastime there is small-boat sailing.

NRL Develops Ceramic Paper Suitable for Electrical Insulation

Chemists at the Naval Research Laboratory have added another product to the growing list of synthetics they have developed which are potentially valuable for electrical insulation. The new material can be easily and cheaply made from domestic materials.

The paper is made by conventional paper making methods from a substance that closely resembles rock-wool and is essentially aluminum silicate or any similar clay. In the process developed at NRL, the black impurities which comprise about 60 percent of the basic material are removed in a fractionating box or "riffler," leaving about 30 percent in a fluffy white fibrous form and 10 percent in a granular form that appears suitable for thermal insulation. The fibrous material can be made into paper only because of the fineness of its fibers; individual strands are less than 40-millionths of an inch in diameter.

For paper-making purposes, bentonite clay, a material similar to fuller's earth, is added to the fiber. When the fiber is bonded with suitable resins, it can be laminated into fireproof panels, easily machined or drilled and capable of withstanding temperatures to 2,500° F. Such panels would be useful for switchboard panels and similar installations where resistance to fire plus electrical insulation is needed.

Can Surgery Replace Diseased Lungs?

by

Wilford B. Neptune and Charles P. Bailey
Hahnemann Medical Hospital

For many years the replacement of diseased or destroyed parts of the body with healthy parts, obtained from a donor, has been an appealing idea. A very limited success has been attained in some attempts at this type of surgery. Skin grafts have aided the recovery of burn victims in certain cases. And the now famous "eye bank" has helped a few people regain their sight by contributing the corneas from healthy eyes for transplantation to those whose sight has been clouded by cataracts or other ailments. Transplanted blood vessels have been used for some time successfully, even though the donor vessel is ultimately replaced by the recipient's own tissue; in such cases the donor tissue serves a useful purpose until it is supplanted. Nevertheless, surgical attempts to replace parts of the body have met with great difficulties and in most cases have ended in failure.

Being primarily concerned with diseases of the chest, we were interested in the idea of transplanting lungs. Such a procedure, if possible, would prove of great benefit to people with destroyed or poorly functioning lungs resulting from pulmonary tuberculosis, bronchiectasis (dilation of the bronchial tubes), and emphysema (swelling caused by air). Moreover, since the lung is mainly a group of blood vessels, we were hopeful that the procedure might be possible.

In the first part of the work, we removed a lung from an experimental animal and then restored it. Although this operation has been previously reported by others, we repeated the work to develop a technique to follow in the later experiments. We now have a dog whose left lung was completely removed and then reimplanted and who now has been under observation for 8 months. Repeated examination of the air passages by means of a bronchoscope; X-ray examination of the lungs; and lung function studies, including intake of air and utilization of oxygen, all show the dog to be normal.

After this, we started to work on transplantation of lungs from one dog to another. The usual pattern of events is similar to

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Wilford B. Neptune, a Fellow in research surgery at the Hahnemann Hospital and Medical College, has had wide experience in thoracic surgery. A graduate of the Ohio State University College of Medicine, he served residencies in general surgery, medicine, and thoracic surgery before coming to Hahnemann.

Charles P. Bailey is Associate Professor of thoracic surgery at Hahnemann, where he originally received his M. D. Previously he was in private practice, first in medicine and then in thoracic surgery.

Measuring the Faraday Effect in Gases and Vapors

by

L. R. Ingersoll
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When plane polarized light traverses material in a magnetic field, parallel to the lines of magnetic force, the plane of polarization suffers a (generally small) rotation. This is called the Faraday effect after its discoverer, and is similar to the "natural rotation" shown by dextro- and laevo-rotary substances such as sugars. It is apparently exhibited by all gases, liquids and (isotropic) solids and is proportional to the length of the light path as well as to the strength of the magnetic field. Like other fundamental properties of matter, measurements of its values help to answer some of the questions relating to the structure of matter, interaction of atoms and molecules, and electronic considerations.

Inasmuch as gases represent the simplest state of matter and usually are considered a good starting point when it comes to explaining many phenomena, it might reasonably be expected that a knowledge of the Faraday effect in gases and vapors would be helpful to the theorist. Unfortunately, however, the value of the Verdet constant—i.e., the magneto-optic rotation per centimeter of light path, per unit of field strength—is so small in gases (about 10^{-5} minutes of arc) that only relatively few measurements have been made. Moreover, most of these were accomplished under high pressure, where polymerization is possible—and all several decades ago. Our knowledge in the case of vapors, except for a few exceptions, is practically nil. The apparatus described here was developed to make measurements of this sort on gases and vapors, and to get certain other data which will be explained later.

In taking up the problem it was first necessary to decide on the method of attack. The great bulk of Faraday effect measurements have been visual. These, like polarimetry measurements on sugar solutions, have, in general, involved the turning or setting of a polarimeter eyepiece until the two halves of the field of view are of equal brightness. This setting, which must be made before and after excitation of the magnetic field, may be determined under ideal conditions with an accuracy of a minute or so of arc. If there is some "depolarization", however,—such as may occur with long light path and many reflections—the accuracy may be considerably less.

Since it was necessary to improve considerably on the above limits of accuracy (in some of our experiments the total measured rotation has

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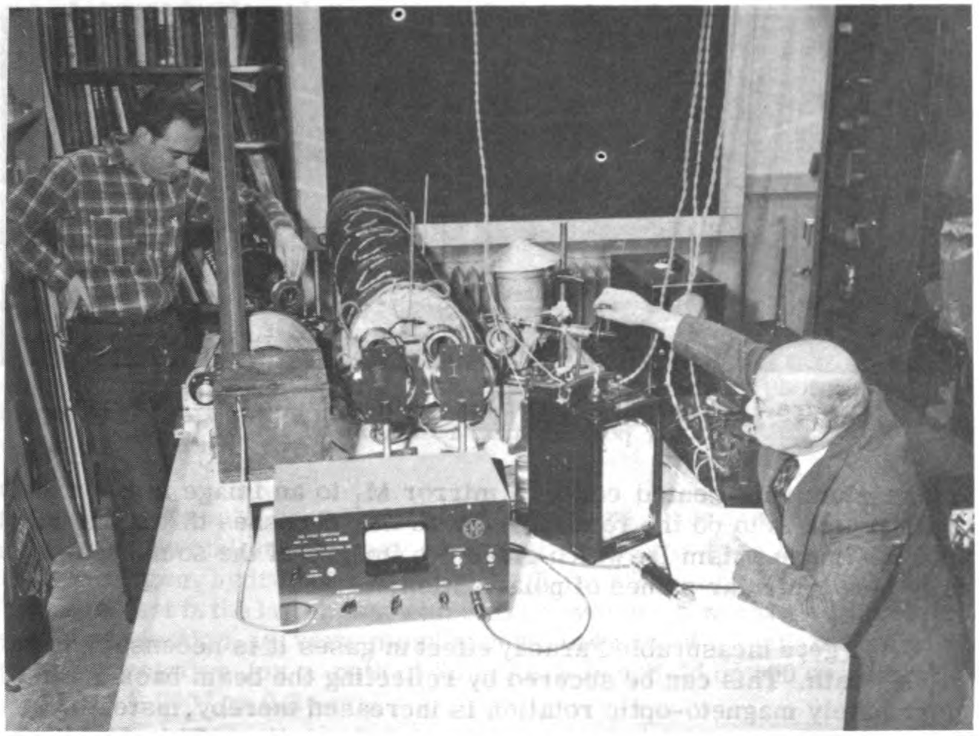


Figure 1. General view of Faraday effect apparatus

been less than a minute) it was decided to give up any idea of visual measurements. We resolved to use instead some radiation-measuring device such as a bolometer, thermopile, or phototube—building on the experience the author has had in infrared Faraday measurements. With such a receiver it is possible to measure small magneto-optic rotations directly, i.e., in terms of a galvanometer or other meter deflection rather than through a series of before-and-after-field-excitation readings.

The fundamental principle of the method adopted is very simple. If plane-polarized light falls on a double-image prism, whose planes make an angle of 45° with the original plane, the two beams which result will be of equal intensity. If, however, the original plane suffers a slight rotation, one of the beams will be increased in intensity and the other diminished. The relative change in intensity can be readily shown to be $\pi/45$ times the rotation in degrees, which means 1 part in 859 for a rotation of 1' and 1 in 51,600 for 1". To measure rotations of this order of magnitude it is necessary to measure relative changes of intensity of the two beams of only hundredths or even thousandths of one percent.

To achieve this accuracy is obviously difficult, but it has been done fairly satisfactorily in the apparatus shown in Figures 1 and 2. Light from a tungsten lamp S, preferably of the single ribbon or strip filament type, is focussed by the

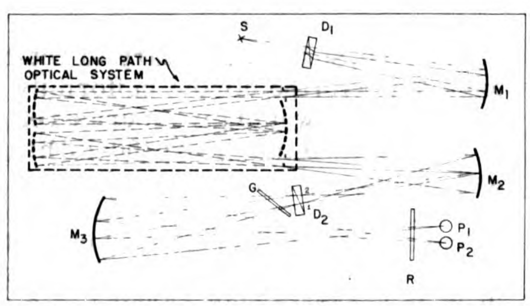


Figure 2. Diagram of Faraday effect apparatus

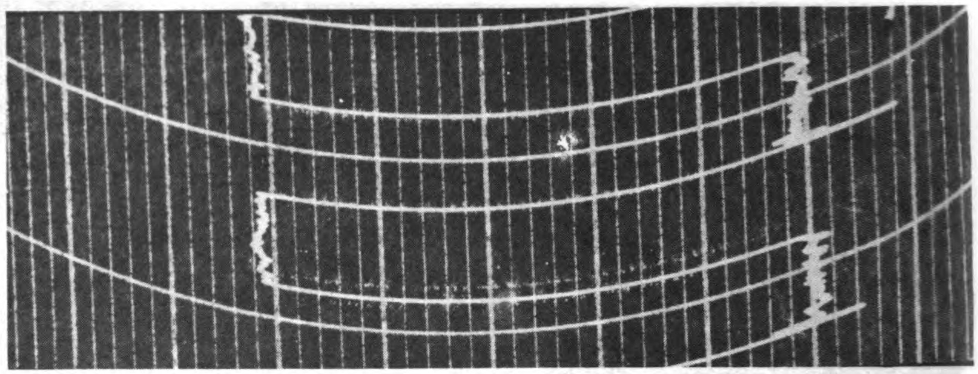


Figure 3. Reproduction of recording miliammeter record for polarization rotations of 1'.

glass aluminum-coated concave mirror M_1 to an image in the medium (gas) which is to do the rotating. On its way it passes through a calcite double-image prism D_1 which gives <u>two</u> images of the source, of mutually perpendicular planes of polarization.

To get a measurable Faraday effect in gases it is necessary to have a long path. This can be secured by reflecting the beam back and forth; fortunately magneto-optic rotation is increased thereby, instead of being cancelled, as would be the case for natural rotation. This "folding" is done in the present case by the White three-mirror method as indicated. The three mirrors, one of which is a nine-inch-diameter mirror cut in half, are in a large brass tube six feet long, around which is a wire helix used to produce the field.

After leaving the tube, the beam of light is reflected through a second double-image prism D_2, with planes oriented at 45° relative to D_1, and through a special rotating polaroid R onto two 929 phototubes, one beam falling on each tube. Now, considering only one of the two phototubes at a time (actually a single tube would do, but two are much better), it is easy to see that if the two components of the beam produced by the second double-image prisms are equal, the light passing through the polaroid will have constant intensity as the polaroid rotates. But if, due to a rotation of the plane of polarization of the original beam, the components produced by the second double-image prism are unequal, the light passing through the polaroid will vary in intensity as the polaroid rotates. This flicker of the beam intensity results in an electrical impulse which is amplified and gives a current; this, after rectification actuates a recording milliammeter.

The amplifier used responds to a "chopping" frequency of 10 cycles per second, so it is necessary to rotate the polaroid at 5 rps and this has to be done with the utmost uniformity and without any vibration or irregularity which would give spurious effects. To accomplish this the polaroid is mounted in a heavy (50-lb) brass disk or wheel, carefully balanced and turning in large precision ball bearings driven by a synchronous motor. To prevent small vibrations of this wheel from affecting the rest of the apparatus it is carried by a strut from an overhead beam resting on the walls of the room. The rest of the apparatus is mounted on a 2500-lb concrete slab, carried on a six-legged table, each of whose legs is cushioned from the floor by a specially designed vibration damper.

A reproduction of a section of the record for a rotation of 1' is given in Figure 3. This indicates a signal-to-noise ratio approaching 100, so a rotation of 1", and perhaps even less under the most favorable conditions, might be given as the limit of sensitivity or accuracy. This is a very small angle, considerably less than one millionth of a revolution. It is believed that this sensitivity is at least an order of magnitude larger than that of any previous polarimetric arrangement operating under comparable conditions.

The wavelength (about 5000A) at which most of the measurements have so far been made is determined only roughly by the spectral response of the 929 phototube used with a tungsten lamp. A monochromator is being arranged, however, and with this and a variety of phototubes and polaroids it is expected that the visible spectrum and near-infrared can be reasonably well covered.

Measurements on a variety of gases are already under way with this apparatus and preliminary comparative results have been obtained for air, oxygen, hydrogen and helium. It is interesting to note that the Faraday effect in the latter gas, which has never been worked with before in this connection, is very minute, being only about a tenth that of air. The total rotation for a path of 20 meters in a field of 100 oersteds is only about 0.003° or 0.2'.

While the main work planned for this apparatus will be with gases and vapors—perhaps even including water vapor at ordinary temperatures—the first complete investigation accomplished with it has been of quite a different sort. This was, in effect, an attempt at finding the smallest (short period) change in the earth's magnetic field which can be detected through the Faraday effect. Because of its extraordinary transparency in the blue-green, pure water was chosen as the rotating substance, and this, with the three-mirror arrangement, was contained in an open-top aluminum tank instead of the brass tube. The Verdet constant for water in the blue-green is approximately 0.02' per centimeter oersted, so a path of 20 meters in a field of 0.6 oersteds (about the earth's field) would give a total rotation of 24'. If a rotation of 1" could be determined, this would mean that a change in the earth's field of 1 part in 1440 might be detected by an arrangement of this sort. This, of course, is not set as a definite limit, because the use of larger mirrors would be possible, and because continued experimentation always effects small improvements. Nevertheless it at least gives an idea of the order of magnitude which seems reasonably possible with this method.

Research Reviews

Research Reviews endeavors to report briefly highlights of technical progress in research by naval laboratories and contractors and the development of important naval research facilities. Articles which meet these broad criteria and possess a good degree of readability are welcomed. Manuscripts and changes of address should be sent to Code 250, Office of Naval Research, Washington, D. C.

On the Naval Research Reserve

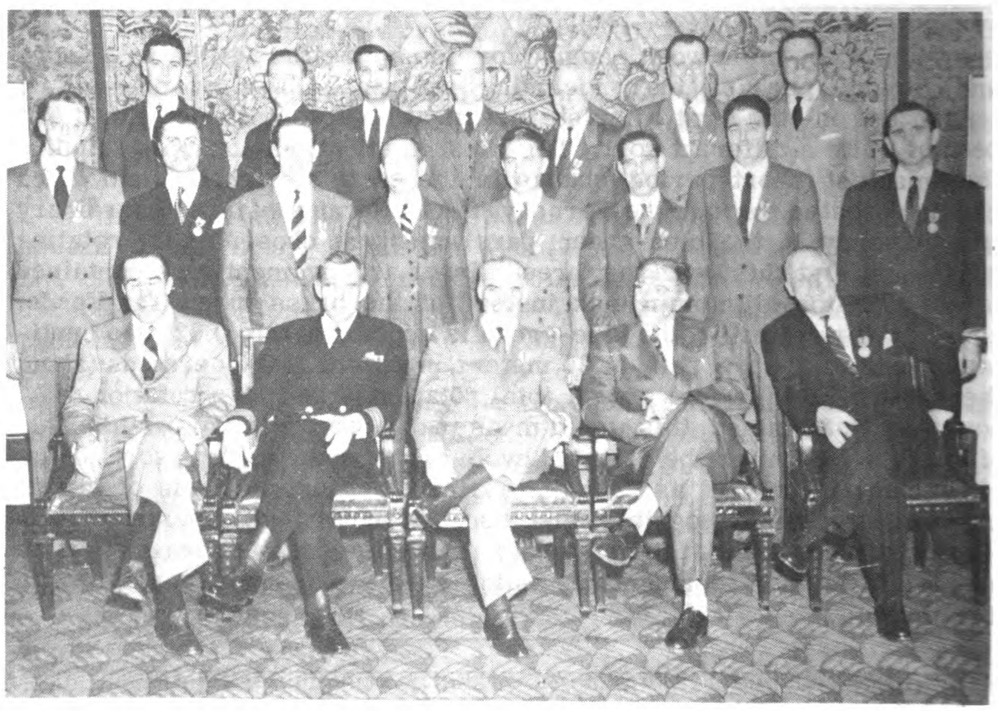
Psychological Warfare Seminar Scheduled 4-18 August

Applications should be submitted immediately for a two-week seminar scheduled to begin 4 August at the University of North Carolina on the subject of Psychological Warfare. Reservists must have secret clearance, for the conference will be at this security level.

Unit 4-4, located at the university, will be in charge of conducting the seminar. The sessions will include lectures by qualified personnel and project studies will be assigned to panels chosen from members of VNRR units attending.

Members of units attending the seminar should report to the Inspector-Instructor, University of North Carolina, prior to 1800 3 August 1952.

Unit 3-8 Celebrates Second Anniversary



When Unit 3-8 in New York City celebrated its second anniversary recently these people were on hand to mark the occasion. Back row, left to right: ENS H. J. Aibel, LT M. H. Redish, LT R. E. Sandt, LCDR W. H. Van Benschoten, CDR H. Jacobziner, LT G. N. Blair, LT R. A. Sincerbeau, Middle row, left to right: ENS G. Hetzel, LT S. V. Kilbourn, LCDR S. Frost, LCDR B. Powell, LT R. F. Timm, LCDR R. W. Culbert, LTJG T. M. Moran, LTJG A. M. Voutsas. Front row, left to right: LCDR M. J. von der Heyde, Executive Officer, CDR J. E. Graham, Reserve Program Officer, 3rd and 4th Naval Districts, CDR A. Weeks, Unit Commanding Officer, Willy Ley, flying missiles expert, and CDR H. D. Rose, Program Officer for the Unit.

LCDR W. L. Morris is CO of Newly Activated Unit 13-6

Officers of the new unit, left to right: LCDR A. C. Lankford, Program Officer; LCDR D. J. Mallon, Executive Officer; LCDR R. Dart, Representative, COM 13; LCDR W. L. Morris, Commanding Officer; LCDR D. R. Larson, Personnel Officer; CDR F. L. Edmondson, Director, Naval Research Reserve.

A new unit, mainly staffed by physicists and chemists and headed by LCDR W. L. Morris, has been added to the growing ranks of the Research Reserve. VNRRU 13-6 in Idaho Falls was recently activated with CDR F. L. Edmondson, Director of the Naval Research Reserve, on hand to explain to the new members the training opportunities available to them. Other speakers present at the activation included LCDR R. W. Dart, officer in charge of the VNRR program for the Thirteenth Naval District, Seattle, and LCDR A. Schultz, also of the Thirteenth Naval District. LCDR Dart outlined the research reserve programs at other units in the district and supplied recent information on activities of the whole Research Reserve organization.

LCDR W. L. Morris announced that the group will be open hereafter for all naval reservists in the area who wish to join. Meetings will be held on the first and third Thursdays of each month in the Tautphaus Park armory.

VNRRU 1-1 Instructor Promoted

In promotion ceremonies conducted at Headquarters, First Naval District, CDR H. Wray Rohrman, USNR, Research Reserve Program Officer, recently administered the oath to LCDR Thomas B. Dowd, USNR, Instructor of VNRRU 1-1, Boston, Massachusetts.

LCDR Dowd has served as Instructor of VNRRU 1-1, Boston since its activation 21 February 1949. He was graduated from the College of the Holy Cross in 1941 and received his Master's Degree at Boston College in 1947. Before becoming associated with the Office of Naval Research, Boston, in June 1947, as Scientific Research Coordinator (Physics), he was an instructor of Physics at Boston College and at Georgetown University.

During World War II, after indoctrination at the University of Notre Dame, he served from April 1942 to December 1945 with sea duty aboard mine sweepers in the Pacific.

Research Reservists at SDC Seminar Hear Talks by ONR, SDC, UN Notables

"One of the most successful seminars in recent years", was Research Reserve Director CDR F. L. Edmondson's verdict on the activities at the Special Devices Center which last month attracted scores of research reservists from all over the country. Top men from ONR and SDC and notables from the United Nations combined their talents in the presentation of facts about their respective organizations. VNRRU members left feeling that they had absorbed a lot of information that was going to be extremely valuable to them.

The reservists got a comprehensive picture of ONR from the people who were the best qualified to give it to them. RADM C. M. Bolster, the Chief of Naval Research, was on hand to greet the officers and to explain the aim and scope of ONR's activities. Other ONR staff members who provided more details to fill out RADM Bolster's picture of ONR were Dr. Mina Rees, Head of the Mathematics Division, and CAPT C. W. Shilling, Special Assistant for the Bio Sciences. CAPT T. B. Haley, Director of the Special Devices Center, spoke to the reservists and then handed the program over to members of his staff who, on the succeeding days of the seminar, told the officers practically everything there was to know about synthetic training devices.

Another high point of the seminar was the visit to the United Nations at Lake Success where Mrs. Eleanor Roosevelt, U.S. Representative to the Human Rights Commission, gave an analysis and appraisal of the work of the UN. Later the reservists heard about the program of technical assistance from Willem Brand, Far East Area Officer and Miss Claire de Hedervary, Europe and Near East Area Officer.

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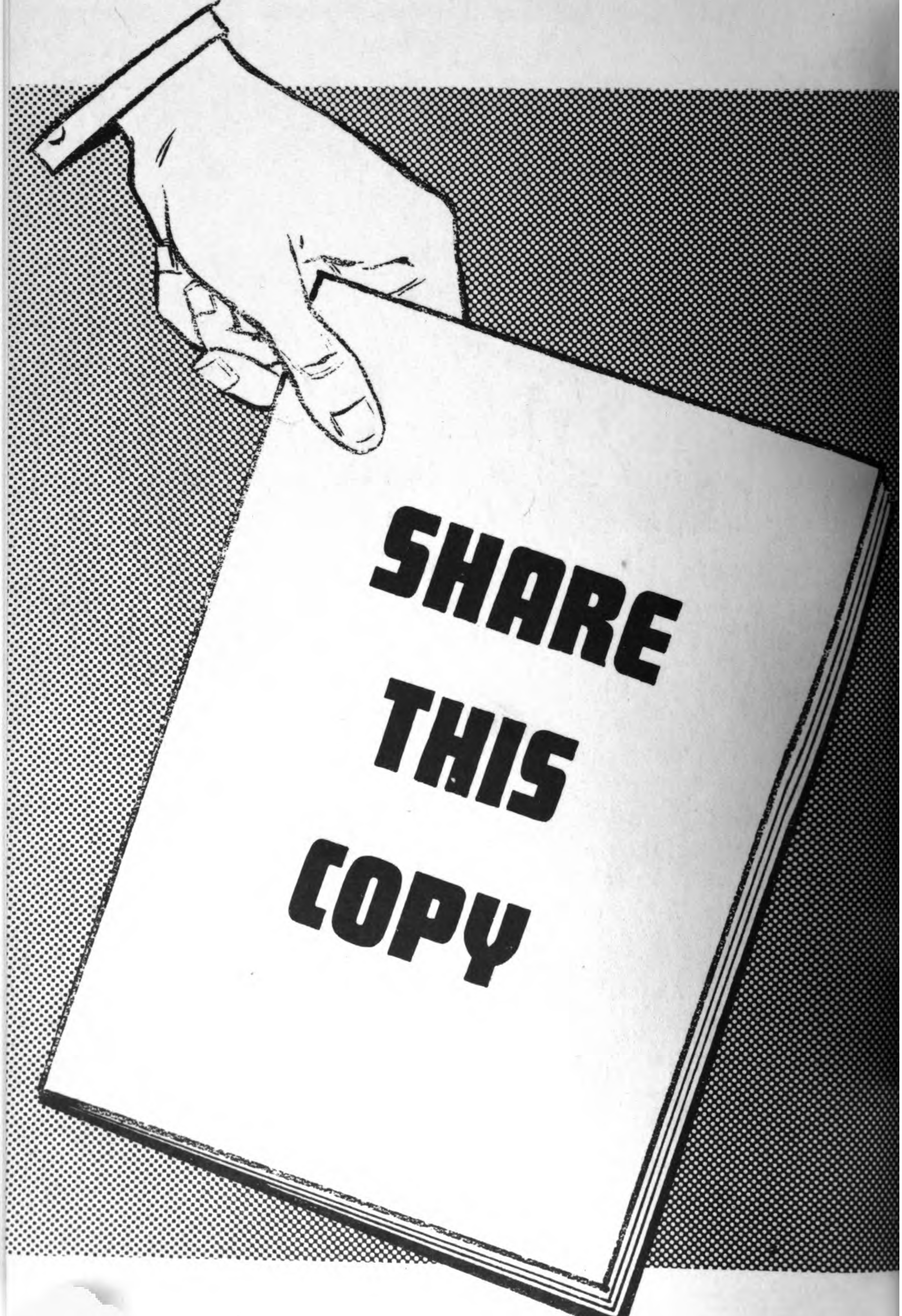
VNRR Day at the United Nations

Mrs. Roosevelt speaks to the Research Reserve Seminar Group at the United Nations. Seated near her are left to right: Mr. A. W. Cordier, Assistant to Trygve Lie, LT R. W. Dibling, SDC Training Officer, and Miss Jane Weidland, Liaison Officer, UN Department of Public Information.

Research Reservists are shown outside of the United Nations Building shortly after hearing the talk by Mrs. Roosevelt. They spent an entire day getting acquainted with various phases of the activities of the UN organization.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