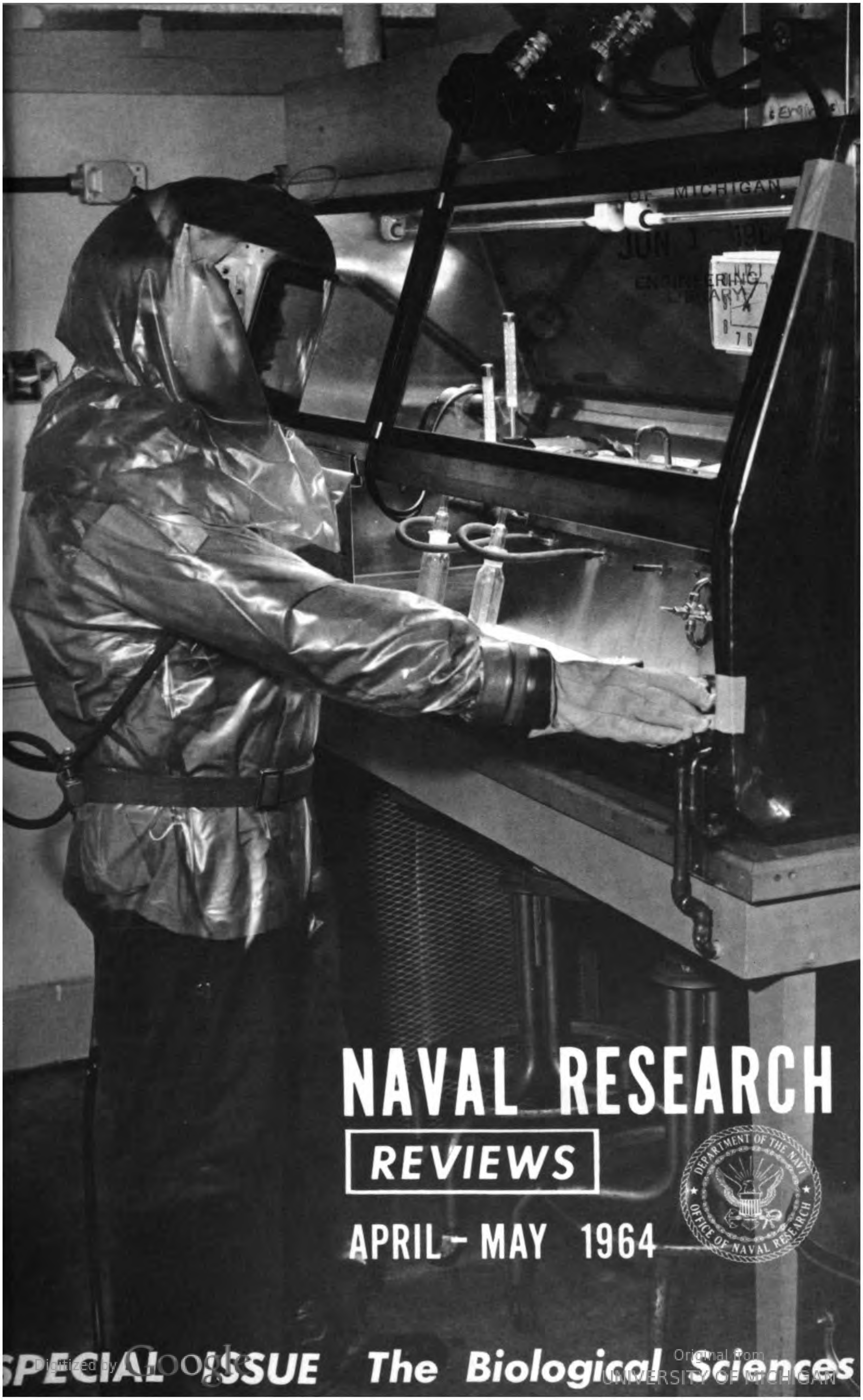


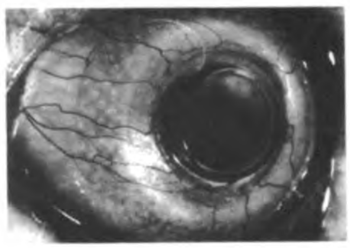
NAVAL RESEARCH REVIEWS

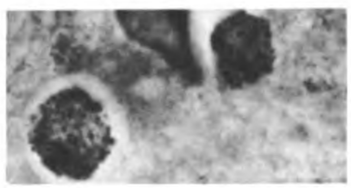
APRIL - MAY 1964

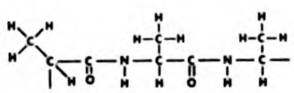
DEPARTMENT OF THE NAVY · OFFICE OF NAVAL RESEARCH

SPECIAL ISSUE The Biological Sciences

The Biological Sciences







FOREWORD

RADM L. D. Coates
Chief of Naval Research

So diffuse are the Navy's interests in the biological sciences, and so important is their bearing on Naval operations, the Office of Naval Research and the Navy bureaus are making an intense effort to gain new knowledge all across the biological frontier. More than a score of Navy laboratories now conduct programs in the biological sciences—ranging from investigations of tiny enzymes to studies of the entire human system. All of this work is aimed directly or indirectly at improving the readiness of our Fleet to meet every conceivable problem influenced by biological activity.

Obviously, the individual objectives within this large program must be coordinated if the Navy is to derive the maximum value from its investigations. Consequently, last fall, following several years of careful planning, the Office of Naval Research called together representatives of all Navy laboratories whose investigators are concerned with these problems. The five-day meeting, held at the Naval Medical Research Institute, National Naval Medical Center, Bethesda, Maryland, was highly successful. For the first time, the great wealth of biological research talent in the Navy was pooled for the benefit of each investigator and for the overall benefit of the Fleet. Although detailed reports of the proceedings were not prepared, abstracts were assembled ("Navy-Wide Workshop in Biological Sciences Research; ONR Symposium Report ACR-84").

Presented in this special issue of NAVAL RESEARCH REVIEWS *are generalized discussions of the research into which the Workshop probed. By no means do they tell the entire story of the Navy's investment in biology. However, they do tell some of the highlights of the story and give an indication of the tremendous impact that investment has on the welfare of man—in both peace and war.*

Biological Research in the Navy

Roger D. Reid
Director, Biological Sciences Division
Office of Naval Research

In the beginning, God created man and gave him dominion over every living thing upon earth and in the sea.

In the thousands of years that have passed since that beginning, man has claimed only part of his endowment. In the sense that he can visit any point on the earth's surface, even those at the greatest depths of the sea, he has, indeed, demonstrated his mastery over land and water. But in terms of his knowledge of the living creatures of earth, particularly those that dwell in the sea, he has hardly come to realize what mastery of them can mean, let alone exercise the control that was promised in the scriptures. Thus the Navy, which is concerned with marine life in terms of its effects on the Fleet's operations, and with man, who carries out those operations, often has been severely handicapped by the limited knowledge of life available to it.

Research in the physical sciences has led to wonderful developments in the ships, planes, weapons, and other vehicles and equipment used by our Navy. But as we admire these products, we are apt to forget that to a large extent their performance is determined by the roles played by man and many other organisms in their operation. For example—

- If the machines impose frequent or severe stresses on their crews, they may fail in their missions because of the breakdown of that part of their function assigned to man. Often, therefore, we must modify the design of a machine so that the causes of stress are reduced or eliminated.
- Injury, disease, and unusual environments may also incapacitate Navy men. As a consequence, these men cannot do their jobs or they do them poorly, and the weapons system of which they are a part becomes that much less effective. Thus, improved therapeutic and prosthetic devices applicable to these situations must be discovered and developed.
- Even knowledge of the lower forms of animal life can benefit the Navy. Some insects, for example, possess truly remarkable mechanisms for locating "targets," navigating, and communicating. Understanding how they perform these complex tasks may help engineers find ways to improve, miniaturize, and integrate electronic gear and other equipment vital to the Navy.
- Other little creatures cause fouling of marine gear or the deterioration of the metal and wood of expensive and intricate Navy equipment. By studying their activities we are able to devise methods of reducing or preventing this damage.

Long before Congress established the Office of Naval Research (Public Law 588, 79th Congress, August 1, 1946) to "encourage, promote, plan, initiate, and coordinate research," the Chief of Naval Operations and the heads of other Navy bureaus were working on problems involving biological systems. The effort was then very limited, however, and rarely took into account the possibility that new biological requirements would arise as a result of new operational or environmental conditions imposed by advances in engineering design and by other developments. The founders of the Office of Naval Research, in their wisdom, recognized these possibilities and provided for a Life Sciences Division, which was later divided into the Divisions of Biological Sciences and Psychological Sciences. Initially, these divisions supported programs that gave a broad interpretation to the "Navy's interest" clause. Later the National Science Foundation was established, and the research-granting activities of the National Institutes of Health of the U.S. Public Health Service were expanded. Nevertheless, ONR continued to serve as the Navy's strong basic-research arm for the support of mission-oriented programs to solve current problems as well as problems anticipated for the future. Coordinately, the Navy bureaus put the basic knowledge gained by ONR to work for the Fleet.

Here are a few examples of how this arrangement benefits the Fleet:

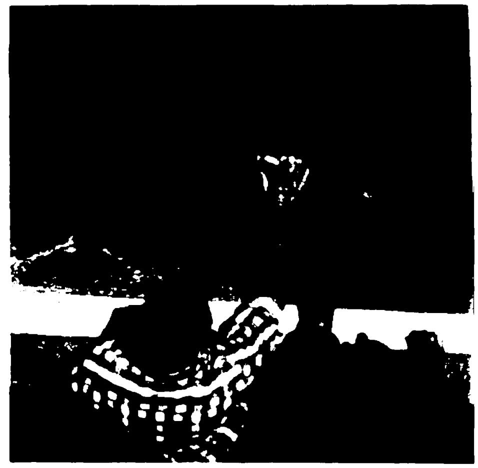
The Bureau of Medicine and Surgery, which is responsible for the health and selection of Naval personnel, sponsors some basic and much clinical research, evaluation, and development. Much of its research is conducted in its own laboratories—the Naval Medical Research Institute, the four Naval Medical Research Units, the Naval Radiological Defense Laboratory, and the laboratories at New London, Pensacola, Johnsville, and many other Naval stations and hospitals. By providing an understanding of man in the man-machine complex and as the host in the host-parasite relationship, ONR's basic research complements the applied research of the Bureau of Medicine and Surgery and helps it to solve problems affecting the health and welfare of Naval personnel.

The Bureau of Ships is concerned with the effects of radiation on men and with decompression, oxygen toxicity, nitrogen narcosis, and other physiological effects of diving. This bureau also studies the biological fouling of ships, mines, and other equipment. The role of various biological entities in antisubmarine warfare and the protection of ships at sea from biological or chemical agents that might be employed in an attack by an enemy have high priority in a number of Navy laboratories and offices, including the Experimental Diving Unit, Naval Mine Defense Laboratory, and Navy Oceanographic Office. Here, again, the Office of Naval Research provides invaluable assistance by bringing into the effort academically oriented scientists who add basic knowledge on which useful developments are based.

The Office of Naval Materiel is concerned with problems of biological deterioration of marine structures and fouling of gear. Progress in controlling these destructive organisms depends on improved understanding of their physiology, anatomy, taxonomy, and even their ecology. Navy laboratories which are coping with these problems include the Naval Applied Science Laboratory, Applied Oceanographic Group, Naval Civil Engineering Laboratory, Naval Ammunition Depot, Experimental Diving Unit, and Navy Electronics Laboratory. The Office of Naval Research provides basic information which is leading to great savings in materiel and improved performance of ships and gear.

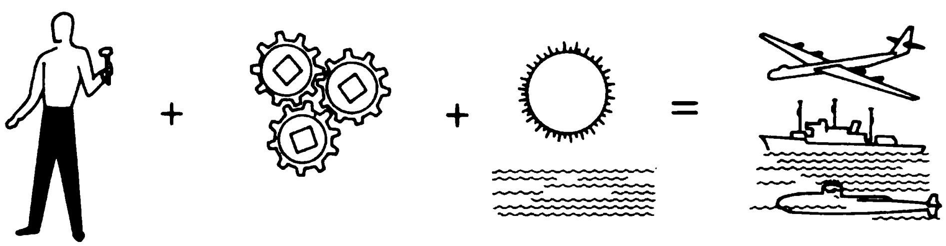
The Bureau of Naval Weapons is concerned particularly with the protection of Navy airmen from deleterious effects of acceleration, decompression, and fatigue. It is also investigating methods of ensuring proper orientation and preventing disorientation in Naval aviators, and it is studying the operational effects of anoxia. Finding solutions to these problems, on which a great deal

—*Continued on page 27*



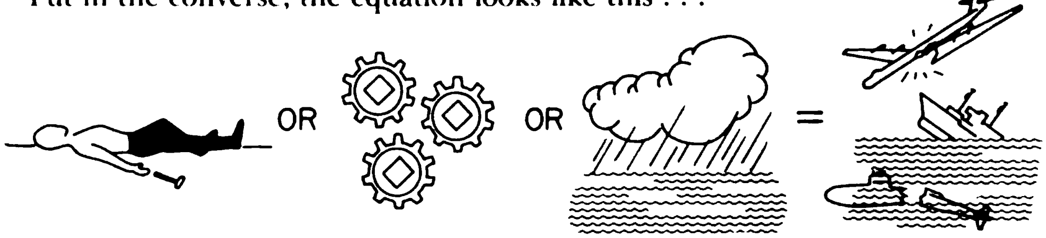
Marine Life: Friend and Foe of the Fleet

S. R. Galler
Head, Biology Branch
Office of Naval Research



In a few words, this equation reads: The combination of normal, healthy man and efficient operating machines functioning in a compatible environment is equivalent to an effective modern Navy.

Put in the converse, the equation looks like this . . .



. . . . which means that any factor that adversely affects the health of the man or the operating efficiency of the machine or that reduces the compatibility of the environment will reduce the ability of the Navy to perform its mission.

Together, these statements stand as the keystone of the Navy's mission-oriented, fundamental-research program in hydrobiology.

That the biological components of the marine environment – the Navy's principal operating medium – may influence greatly the effectiveness of Naval operations is a fact now accepted generally by the Navy's strategic and tactical planners. Far less well understood is the impact that a particular species or community of marine animals or plants, or both, may have on a Naval mission. Many years ago, therefore, the Navy set out to acquire, interpret, and translate (into the language of the Naval technician and line officer) basic scientific information about the biology of the oceans, including the interrelationships of the biota and the physical, chemical, and other factors of that environment, needed to predict and control the adverse effects of such entities on Naval operations.

Friend and foe of the Fleet: On facing page, a porpoise is readied for study which will help designers improve hydrodynamic features of Navy vessels; on this page, wood gribbles tunnel into a piling.

The "P's and Q's" of Hydrobiology

The adage, "One man's food is another man's poison," aptly describes one of our principal scientific interests in studying marine biology. The term "biological productivity of the seas" usually refers to the ability of a given ocean environment to produce and support marine organisms. The ultimate level of productivity is frequently reckoned in pounds, tons, or dollar value of commercially important organisms. However, there is another index of this productivity, one example of which is the dollar value of fuel oil required to overcome hull drag resulting from "hard" fouling growths, such as edible shellfish.

In order to develop means for minimizing such effects, one must identify the offending creatures and determine their normal biological and behavioral characteristics. In the pursuit of these objectives, which are obviously of great importance to the Navy, two other urgent research requirements become apparent: (1) the improvement of means of conducting basic research in marine biology and (2) careful research program planning and management.

The Naval Objectives

Prevention of marine fouling and deterioration. It is ironic that one of the Navy's newest technical obstacles stems from one of its oldest problems—the control of marine biological fouling and deterioration. Hundreds of learned scientific and technical publications have described the many types of damage caused by marine organisms, such as the fouling of hulls and salt-water intake by ocean vessels. Many other papers have been written about damage resulting from the penetration of wood, plastics, concrete, and other structurally important materials by shipworms, wood gribbles, and scores of other species. Yet in spite of the development of a number of effective chemical protective agents, the problem is far from solved. Indeed, it appears to be Medusa-like in character! Although hull surfaces can now be protected for as long as 24 months, newer requirements for long-lived antifouling agents for use on transducer domes, hydrophones, and optical instruments have increased in quantity and urgency.

Providing protection for acoustically active surfaces is complicated by the requirement that the protective agent not change the acoustic characteristic of the surface. Furthermore, effective agents must now be prepared to prevent fouling on large pieces of equipment placed in deep water for long periods of time. Such installations may serve as an oasis to animal life, attracting a large number of organisms, both mobile and fixed, which may seriously interfer with the operation of the equipment. Considering that deep-ocean fouling problems may be quite unlike those common to shallow coastal waters, with which we are more familiar, considerable new information will be required to protect this equipment satisfactorily. If ways are not found to obtain this information rapidly, occasions are sure to arise requiring us to make extrapolations from limited data, with the possible result that our conclusions will be incorrect.

Biological interference with the propagation of acoustic energies underwater. Here, also, exists an increasingly urgent need for the basic data upon which to construct a system for the accurate prediction and classification of marine biological interference with the transmission and reception of acoustic signals underwater. The problem is being compounded rapidly by virtue – ironically – of the increased sensitivity of transducers and hydrophones, on the one hand, and by the greater ability of the modern ship and submarine to stay on station for extended periods of time, on the other. Unless we have substantially greater success in obtaining more complete marine bioacoustic information, especially on species identification and behavioral significance of the sound producers, our ship and submarine crews will be subjected to proportionally greater operational and psychological hazards.

Protection against obnoxious marine animals. A conservative estimate of the number of species of marine animals capable of harming man is more than 3000, separable into three categories – poisonous, venomous, and carnivorous. The problem of protecting a survivor at sea or an underwater swimmer engaged in a special operation is underlined by the following statistics. More than 250 species of sharks have been identified. Of these species, over 50 are known to be dangerous to man. They inhabit all of the oceans from 45°N. lat. to 45°S. lat.! The amount of fundamental ecological and behavioral information required to develop effective deterrents against all of these sharks is immense.

The problem of protecting Naval personnel against obnoxious marine animals is complicated by the fact that many servicemen like to fish and eat sea food. In a number of geographic regions, especially in the Central and South Pacific, certain highly prized food fishes sometimes ingest and accumulate substances which are toxic to mammals, including man. Occasionally, these fishes, when eaten, cause serious illnesses or death.

The venomous animals, such as the stone fishes, the sea snakes, and a great variety of invertebrates, represent a constant threat to the survivor at sea or the unwary swimmer or scuba diver.

Again, the requirements for effective prophylactic and therapeutic agents are likely to increase as new developments in underwater swimming equipment and techniques extend the depth and range man can travel by these means.

Protection against bioluminescent marine organisms. Many kinds of marine animals are capable of producing visible light when stimulated by mechanical means. In certain geographic regions, sufficiently dense concentrations of luminescent organisms are present throughout the year to serve as tourist attractions. For example, Phosphorescent Bay on the southwest coast of Puerto Rico attracts thousands of tourists because the passage of a boat through the water at night produces a wake sufficiently bright to allow one to read newsprint by its light.

One can easily imagine the valuable information an enemy would gain if he observed such wakes behind U.S. Navy vessels approaching his position at night. Although he could not see the ships or boats, he would know where they were and perhaps how many were attacking. As a matter of fact, during World War II, several Naval operations were compromised by bioluminescence – for example, as PT boats and landing craft unexpectedly stimulated light-producing organisms while assaulting enemy beaches; as a result, both men and boats were lost.

Although the fund of basic information on the biochemistry and physiology of bioluminescence has increased, the paucity of ecological and toxonomic data on the geographic and seasonal occurrence of bioluminescence seriously limits our ability to forecast accurately the onset of this phenomenon in regions of current or potential interest to the Navy.

Mechanical or electronic analogues of marine biological systems. In addition to wanting to guard against adverse influences of marine life, the Navy wants to know how it can utilize certain capabilities of these creatures to improve some of its own devices. If we learned how to construct mechanical or electronic analogues of some of the extraordinarily effective biological systems found in marine animals and plants, a number of important Navy requirements could be fulfilled. For example, many fishes, including salmon, are able to migrate over great distances, reaching their destinations with accuarcy. In the language of the Naval operations officer, these fishes can detect and identify targets at long range and navigate toward them with precision. Closely related to this phenomenon is the ability of schools of fish to perceive and respond rapidly to certain cues. Again, speaking operationally, such cues suggest a highly effective means of underwater communications.

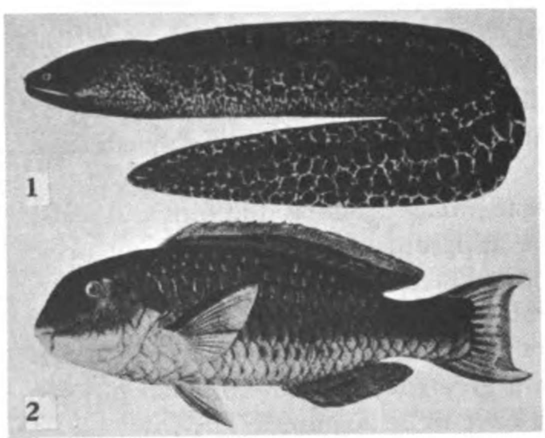
The swimming ability of certain marine mammals, such as dolphins and seals, is quite amazing. Remarkable, too, is the apparatus they utilize to hunt prey underwater. In these abilities, the marine architect and the sonar designer see highly effective propulsion mechanisms and sophisticated apparatus for target detection, target discrimination, and underwater communication. But in order to "borrow" them for Navy application, a great deal of fundamental physiological, biochemical, and biophysical data have to be acquired.

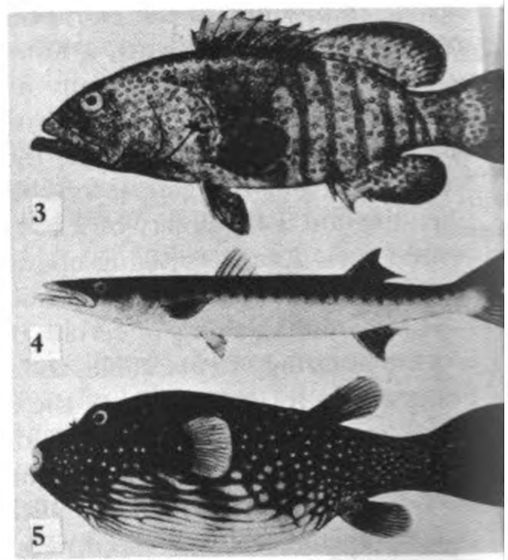
Requirements of Basic Research

In order to fulfill Naval requirements in the field of hydrobiology, several improvements in the ways we go about conducting fundamental research need to be made: in field and laboratory research facilities and equipment; in methods of collecting, retrieving, and interpreting basic data; and in interdisciplinary communication and collaboration.

Field and laboratory facilities and equipment. The lack of adequate field facilities for observing living organisms in their normal habitats over long periods of time has been one of the principal handicaps in establishing the validity of working hypotheses which describe the mediums of primary productivity, biological cycles, and other fundamentally important biological phenomena. Usually, the hypotheses are constructed from three kinds of data – laboratory data (which is now relatively reliable), collections of preserved specimens (which at present are inadquate), and field measurements (few of which have been made).

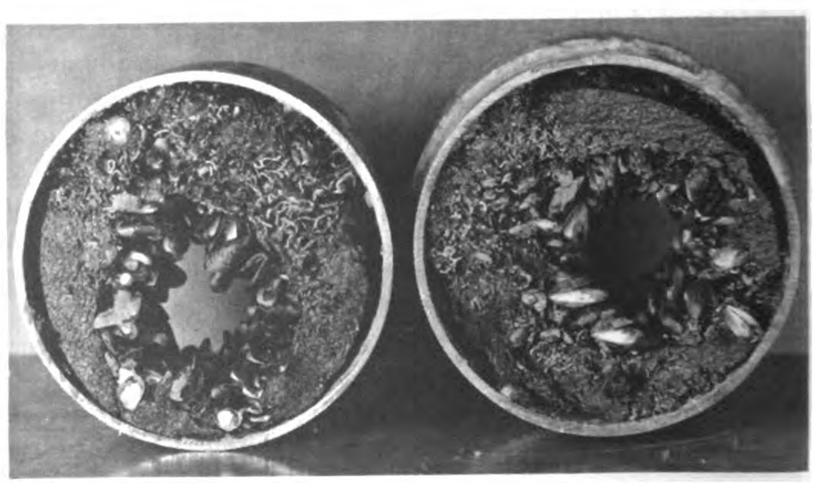
Photograph taken by light produced by bioluminescent bacteria.

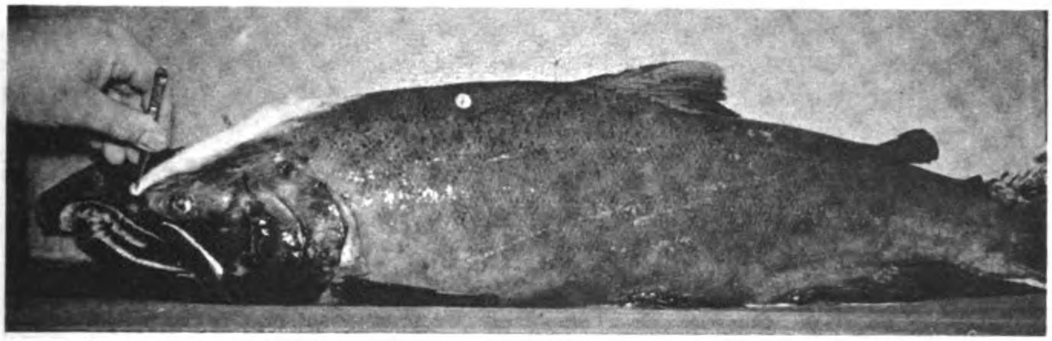




Some obnoxious fishes: 1, moray eel; 2, parrot fish; 3, sea bass, or grouper; 4, barracuda; 5, puffer.

Section of 6-inch pipe formerly located oyer boiler of a Navy ship. The pipe is almost closed by marine-fouling growth.

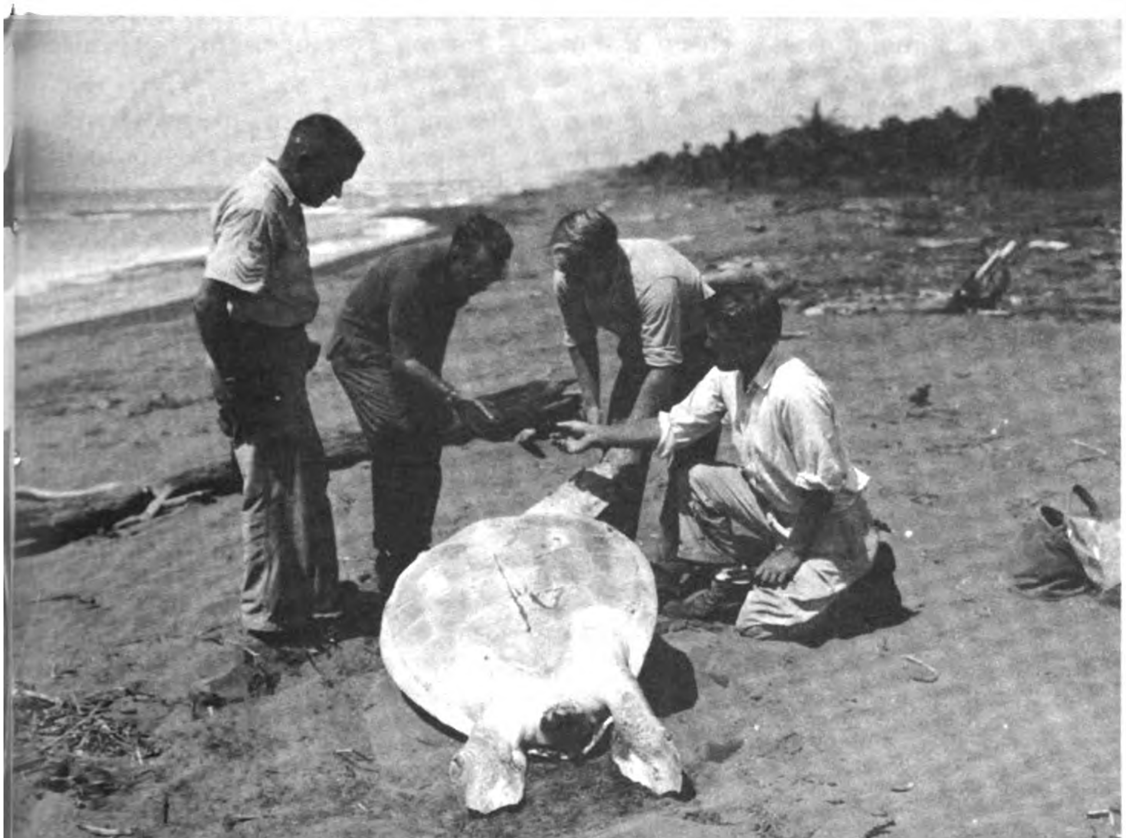




ôse of salmon is plugged as part of test of the ·h's reliance on his sense of smell in homing.

ıe author holds jaws and teeth of an 11-foot er shark, one of the species of shark ngerous to man.

green sea turtle is tagged on beach at rtuguera, Costa Rica, before being eased during study of his remarkable entation capabilities. During breeding ısons, this turtle migrates many hundreds miles in open water, reaching his destina-n exactly.



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Several means of improving the quality and number of our field observations have been considered – for example, the use of platforms of opportunity, such as commercial ships; of fixed unmanned field-observation posts; and of telemetry-type tags for instrumenting animals.

It is surprising to note that during a period when relatively liberal support is becoming available for the design and construction of ocean-going research ships and submersibles, little attention is being given to the design of laboratory pods and expendable or retrievable instrument packages for installation on commercial ships for the rapid, frequent, and reliable acquisition of field data. The use of our merchant-marine ships for field observations is not only feasible, but is even preferable to the use of research ships when the need is to obtain data on a seasonal basis from a given region. The cost of acquiring marine biological and oceanographic data is becoming prohibitive. Both manned and automated data-acquisition systems should be designed to match available propulsion systems, instead of relying almost entirely on the construction of new propulsion systems, such as oceanographic research ships, around the relatively inefficient data-collection systems now available.

Similarly, much more consideration should be given to the role of fixed, unmanned submarine observation posts, which may be cable-connected to a shore laboratory or controlled and interrogated by radio-buoy devices. An experimental fixed underwater audio-video observation station that has been in operation along the edge of the Gulf Stream off the island of Bimini in the Bahamas shows considerable promise for observing and recording a variety of biological and ecological phenomena over extended periods of time. The choice of acoustic hydrophones and television cameras for this installation was a fortunate one, because it allows for the incorporation of an array of secondary sensors for monitoring such environmental factors as temperature, pressure, and salinity both visually and acoustically.

Further, the utilization of fixed underwater audio-video platforms permits observations to be made of the results of subtle changes in an environment, such as those occuring in the local biota after the construction of artificial reefs.

Eventually, it should be possible to "pipe" information from a number of these posts simultaneously into several laboratories through a closed-circuit coaxial network or by way of orbiting satellites. Finally, we must consider developing transmitters that can be attached to fishes, elasmobranches, marine mammals, and other organisms so they can be interrogated while they are moving freely in their natural environments. In a few limited field experiments, radio transmitter beacons have been successfully attached to birds, marine turtles, and dolphins, suggesting that physiological and environmental data can be obtained from free-moving marine animals to which radio-frequency as well as sonic "tags" have been attached.

Methods of collecting, retrieving, and interpreting basic data. Great masses of potentially valuable unpublished biological research data are being overlooked by investigators because of the physical impossibility for one specialist or even a team of workers to evaluate and interpret them. The "modern" experimental biologists is beginning to need an accurate species identification of the organisms which he employs in his experiments. All too infrequently, however, is he able to obtain useful collaboration from the over-burdened toxonomist.

Even more infrequently is he aware of the distinct physiological varieties which may occur within the same species.

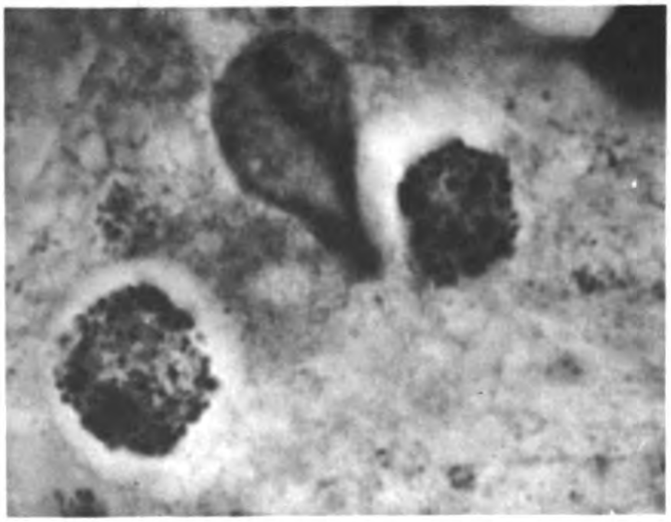
It is becoming apparent that the judicious use of computer programs may provide a rapid means of correlating and interpreting multidisciplinary data. For example, preliminary experiments in the new field of numerical taxonomy suggest that a wide variety of morphological, physiological, biochemical, and ecological characteristics of species and subspecies of marine animals and plants can be stored and collated. Ultimately, one should be able to insert into the computer "memory" a limited number of characteristics of an unidentified organism, then receive from the computer a list of species which the organism most closely resembles, thus greatly facilitating identification of the specimen. Such a system should lead to a stronger correlation of taxonomic and ecological information. Also, it should provide an effective means for interpreting paleontological and evolutionary hypotheses.

Interdisciplinary communication and collaboration. Effective communication between the hydrobiologist and his colleagues in the mathematical, physical, and engineering sciences who will be called upon to translate biological data into mechanical and electronic devices is essential to the success of a mission-oriented fundamental-research program in hydrobiology. Unless the original experimental protocol is designed to yield data in a form that can be translated into terms useful to the physical scientists – and this is rarely done – the data will remain always within the province of the biologist and thus will not go far toward advancing the objectives of the program. The requirement for multidisciplinary communication is therefore of paramount importance to hydrobiology if the objectives of that science – in both basic research and development – are to be fulfilled.

Research Program Management

Because of its interdisciplinary nature, the Navy's program in hydrobiology sponsored by ONR is especially dependent for its success on the whole-hearted collaboration of investigators in a wide variety of research institutions. That the program has been singularly successful in this regard is attested to by the fact that more than 300 scientists representing universities, private laboratories, industrial establishments, and Naval and other Government laboratories are contributing to it through more than 120 individual research projects. Although the great majority of these projects are being undertaken in the United States, some are being conducted abroad because of the uniqueness of certain foreign marine environments.

It is particularly noteworthy that this program has been constructed entirely from research projects selected by ONR from proposals presented voluntarily by scientists in universities, industry, and Naval laboratories. It is this practice which gives the program its greatest strength and promise. It permits the scientist whose proposal has been selected to receive ONR support to pursue his intellectual endeavors without Government orientation or direction. At the same time and through the same process of selection, it permits ONR's hydrobiologists to obtain basic scientific data directly relevant to their program objectives. This marriage of science and the Navy is producing knowledge of the biota of oceans and estuaries which is of great importance not only to the Navy but to many other facets of our National welfare.



Microscopic view of part of a chick endodermal cell containing microorganisms responsible for trachoma, a disease of the human eye. The trachoma agent occurs here in colonies (the two spherical bodies). The tear-shaped object is a slightly distorted cell nucleus. Magnification: 1900X. See also photo on page 16.

Microbiology in Naval Affairs

R. F. Acker
Head, Microbiology Branch
Office of Naval Research

The lowly microbe is indeed one of God's miraculous creatures. He is so small that he cannot be seen with the naked eye, and yet he is a bold and often deadly invader of the human body. The products of his cell machinery are sometimes harmful to man because they help the microorganism break down the human body's defenses to disease. But the battle is not entirely one-sided. Man can "turn the tables" on some of the invaders – by purposely extracting the harmful products of their cell machinery and "firing" them back into the human body to fight disease. So microorganisms play a dual role in our lives. On the one hand they are beneficial, and on the other, harmful. On one occasion we are desirous of preventing their multiplication, and on another we may wish to foster their activities.

Microorganisms and microbiology are important to the Navy because of that service's far-flung activities, which bring its personnel into contact with the diseases of foreign lands, some of which have no counterpart in the United States. In their travels, our sailors and marines encounter bacteria which cause bacillary dysentery, fungi which cause ringworm, viruses which cause strange fevers and aching in the limbs, and many other harmful microorganisms. Coping with such diseases as they affect Naval personnel is the prime concern of the Bureau of Medicine and Surgery, the Naval Medical Research Institute (NMRI) in Bethesda, and the Naval Medical Research Units (NAMRU) in various parts of the world, and it is an important concern of the Office of Naval Research. Not only does the Navy apply existing knowledge to the problem, but it also seeks to learn, through research, how to prevent disease, how to control the microbes' harmful activities, and how best to treat or cure a patient who is already infected.

Even some of the "common" diseases become important to the Navy because of the environmental conditions under which sailors and marines must operate. In a submarine, for example, personnel must function efficiently in small, closed spaces for long periods of time. In such an environment, microorganisms and the diseases they cause are transmitted quickly from one person to another. For this reason the Office of Naval Research supports investigations at its Naval Biological Laboratory on airborne infectious diseases.

Host-Parasite Relationships

To help solve problems of disease prevention, treatment, and cure, ONR has developed a program of research on host-parasite relationships. It supports research on specific diseases, such as rheumatic fever and influenza, as well as studies of how the human defense mechanisms can be improved to prevent the contracting of disease. An important aspect of the program is its coordination with research carried on by the in-house Navy laboratories in the pursuit of solutions to special problems.

Because rheumatic fever is a disease which affects young recruits, it deserves special attention. We know that it is caused by a tiny spherical bacterium called *Streptococcus,* but we do not know which factors in the human body or in the makeup of the germ itself are responsible for infection. For this reason, ONR supports the work of immunologists who carefully disassemble the rheumatic fever microbe to find out which parts are "antigenic," that is, which parts can be utilized in the production of a vaccine. If such a vaccine is developed, the antigenic parts will be injected into the bodies of human beings. Within the body they will stimulate the formation of "antibodies," which will render the individual immune to the disease. In the solution of such problems, ONR cooperates and coordinates with the Naval Medical Research Unit No. 4 at Great Lakes, Illinois, and with the Naval Medical Field Research Laboratory at Camp Lejeune, North Carolina, where Navy and Marine recruits provide "populations" which are stable for several weeks at a time and which are subjected to similar environmental influences.

Other studies of the human immune mechanisms are conducted in laboratory animals by university researchers to find out when and how the immune response first appears. The investigators want to know what conditions bring it about and whether these conditions arise as part of the maturation process in the animal or whether they result from exposure to "outside," or environmental, influences. Still other workers are investigating the role of the white blood cells in the immune process. We have known for years that the white blood cells are capable of surrounding and engulfing foreign bacteria and viruses that find their way into the blood stream. ONR is seeking to determine what kind of chemical action kills germs which invade the body, and it wants to know if all microbes which are engulfed are actually killed, or if some survive and multiply within the white blood cells.

You will remember in the early history of microbiology and immunology that Edward Jenner performed the first "vaccination" by rubbing some cowpox virus into the arms of subjects who were later exposed to smallpox. Because the harmless cowpox was related to the harmful smallpox, a vaccine could be prepared to protect man from smallpox. Virologists are now finding that other "pairs" of viruses show remarkable promise for providing this same kind of protection. For example, injection of bovine diarrhea virus into swine protects against the lethal virus responsible for hog cholera. Similarly, injection of measles virus of humans into dogs will protect these animals against lethal canine distemper. By following these important leads, it is entirely possible that man will one day be protected from many dread viruses by other viruses which cause no disease whatsoever in man.

At Taipei, Taiwan (Formosa), research personnel of NAMRU No. 2 and NMRI are making good progress toward the development of a vaccine to be used against trachoma, a virus disease of the eyes which often leads to blindness. Trachoma is relatively rare in the United States, but has occurred in the Middle East for centuries. One preliminary vaccine that has been tested in preschool-age children in rural Taiwan has been found to reduce the incidence of trachoma by 60 percent. By modifying the vaccine, it is probable that its effectiveness will be improved further. Naval personnel on duty in the Middle East will thus have a means of protection against trachoma.

Microbial Genetics

Microbial genetics is the study of changes which take place in the characteristics of microorganisms as the result of alterations in their genetic make-up. Its importance to the Navy is that it provides a means of improving the effects of the microorganisms used in vaccines. One of the earliest discoveries made in this field was of a process called "transformation." It was found that bacteria contained genetic material in the form of nucleic acid, and that when this material was taken from one kind of bacteria and mixed with intact cells of another kind, a change, or transformation, occurred. The recipient cells took on some special characteristic of the cells from which the nucleic acid was extracted. Viruses, which also have an heridity-control center containing nucleic acid, have in addition a protein coat which controls and kind of immunity that is engendered in an animal or human who receives the virus in his body, either by accident or intent. One can see the implication here. It may be possible to modify a disease-causing organism so that it becomes harmless but still retains the ability to produce immunity. We would say, then, that such an organism was still immunogenic, but no longer pathogenic.

At the Naval Biological Laboratory, a group of workers is concentrating on the use of so-called "infectious nucleic acid" from viruses. They find that nucleic acid can be extracted from poliomyelitis virus and purified. This purified nucleic acid can then be used to "infect" special mammalian cells grown in bottle culture. These cells succumb to the infection just as they would if attacked by the original virus. They finally produce new poliovirus progeny. It is true that the process is not as efficient as infection by intact virus, because fewer progeny virus are produced. But it is remarkable, nevertheless, that *any* progeny viruses can be produced in this way.

Another example of microbial genetics is the study of microbial susceptibility and resistance to antibiotic substances. We know that bacteria which have been subjected to antibiotics are not always killed or inhibited. Oftentimes resistant bacteria develop which are genetically different from the parent strain. One ONR-sponsored investigator has found that the development of antibiotic-resistant bacteria can be prevented if the antibiotic is combined with another drug at the time it is administered to a patient. Combined therapy involving two antibiotic substances is not new, but combined therapy involving one antibiotic and another unrelated substance *is* new. The approach shows great promise—in fact, it may lead to a major medical breakthrough.

Marine Microbiology

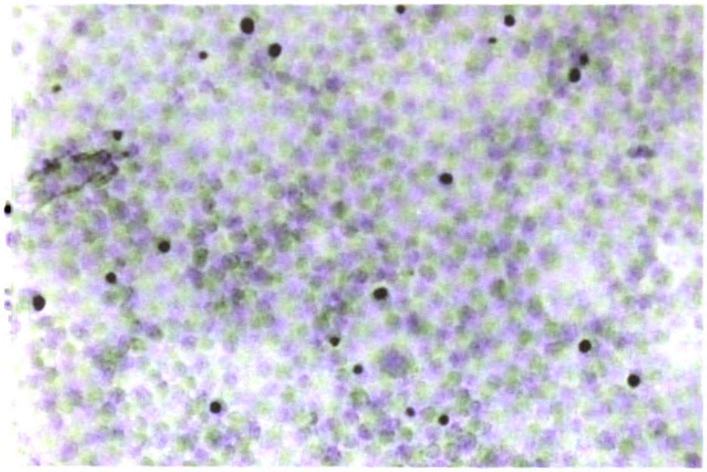
We have seen so far that the over-all Navy effort in microbiology is enhanced by cooperation and coordination between offices, bureaus, and laboratories. This complementary pursuit of goals is advantageous particularly to the ONR program in marine microbiology. The program includes investigations of microorganisms which cause rusting and corrosion of metals in the marine environment and of microbial transformations of compounds containing nitrogen, sulfur, carbon, and phosphorus. The transformations are of interest because they are the key to our understanding of the "cycling" of these elements in the ocean. We hope eventually to be able to explain these processes as well as we can now explain the similar "cycling" which occurs in the soil. In the oceanic environment these elements are assimilated by marine plants and animals into living tissue. Wastes from dead and decaying marine plants and animals are in turn "dissimilated", or decomposed, by microbial activity into simple chemical compounds or elements. Such processes are part of the natural orderliness of the universe; by exploring them we will one day learn many of the important secrets of the sea—how Nature maintains a balance of life there, how man can tap ocean resources without endangering this balance, and how he can obtain greater quantities of food, chemicals, and other elements of value and thus improve his own way of life.

Contamination of Jet Fuels

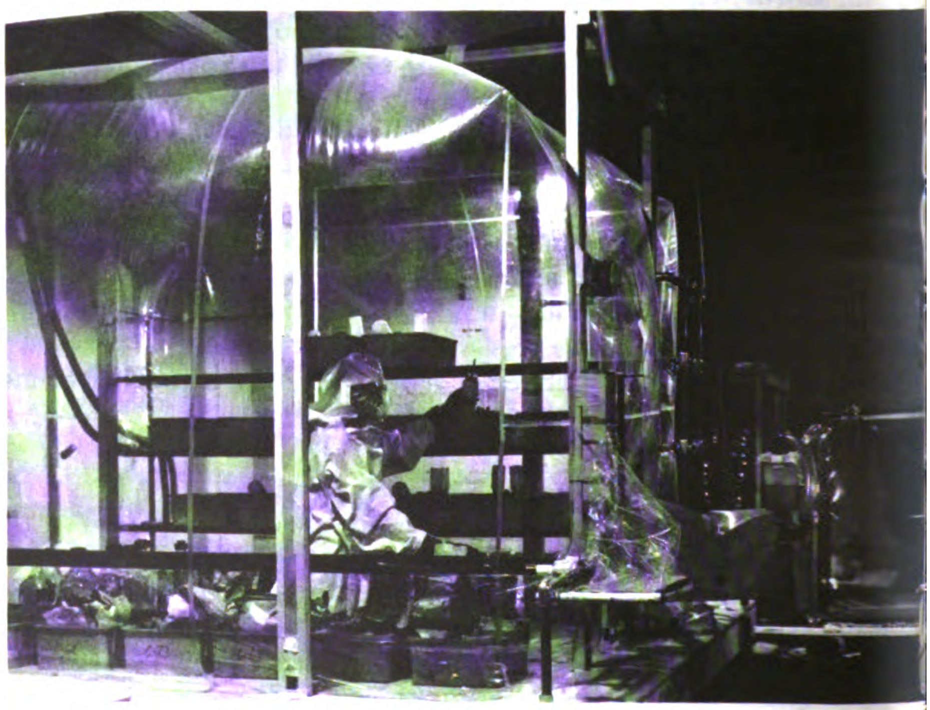
In addition to its long-range research programs, the Navy must give attention to practical problems of immediate significance. One such problem is the microbial contamination of jet aircraft fuels. Because contaminated fuel receives dissolved impurities from the microbial growth which it harbors, it is injurious to jet engines; the impurities clog fuel lines, corrode vital metal parts, or burn poorly and inefficiently. As a consequence, flights have to be delayed, dollars are lost, and lives are jeopardized. Furthermore, in war emergencies, entire ships and airdromes are endangered when their aircraft cannot fly.

Efforts to prevent and control microbial fuel contamination are being made by the Bureau of Ships, Bureau of Weapons, and by the Office of Naval Research through its Naval Research Laboratory. At NRL a group of scientists has found that some kinds of fuel contamination are attributable to molds—the same sorts of organisms we see commonly as woolly outgrowths on moldy bread or fruit. Certain molds possess the metabolic machinery to utilize hydrocarbons in fuel as nutrients for their own development and growth. They do require oxygen, however, and thus do not develop in the depths of tanks which air and oxygen cannot reach.

In other cases, the offending microorganisms belong to a group of bacteria which can live in the absence of free air or oxygen. These bacteria utilize oxidized sulfur compounds, which they convert to free sulfur or hydrogen



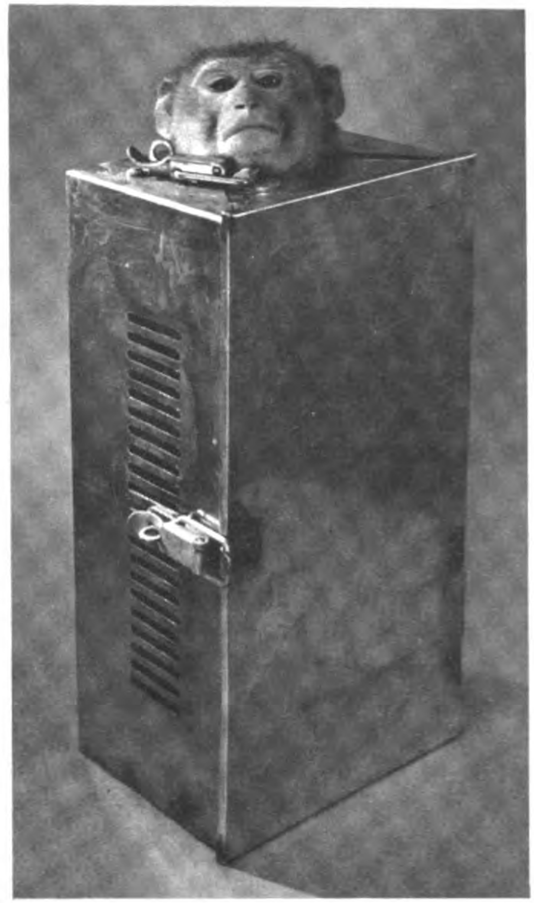
Monolayer of mammalian cells heavily infected by microorganisms which cause trachoma, a disease of the human eye. The microorganisms occur in colonies (small black spots). By counting the colonies a determination of the degree of infection can be made. Magnification: About 200 X. See also photo on page 12.



A technician wearing a pressurized plastic suit attends infected monkeys at NBL.

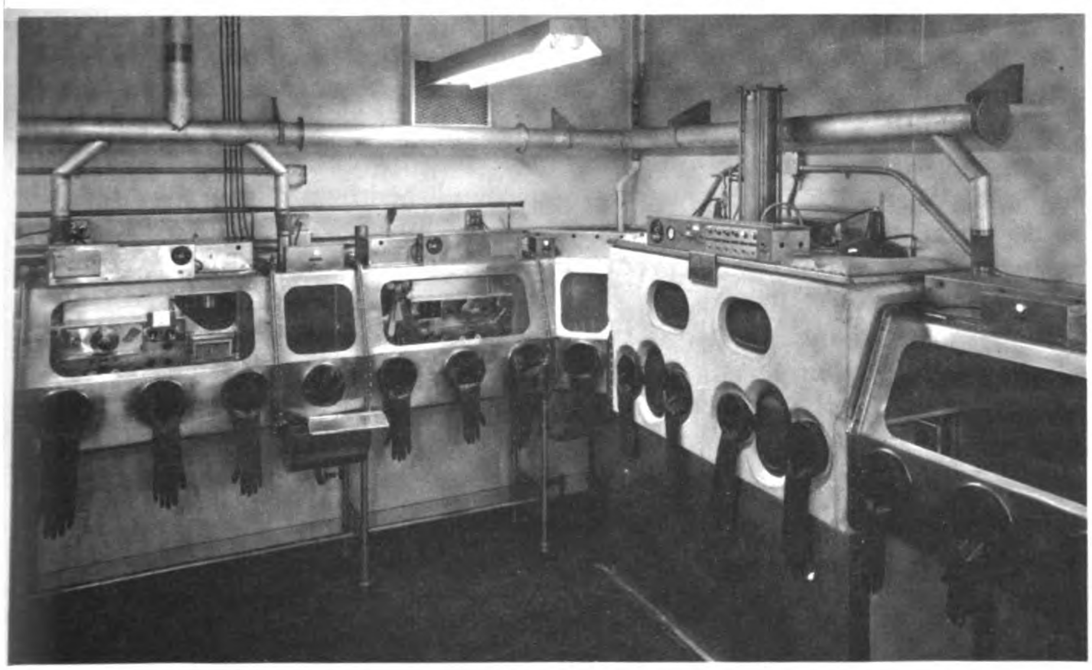
A technician performs intra-peritoneal in-noculation of a mouse during study at NBL.

large plastic jacket isolator at LOBUND Laboratories, iiversity of Notre Dame. As many as 180 breeding nale mice can be housed in this isolator, which keeps imals in germ-free state.



The head of a monkey protrudes from special restraining cage which permits respiratory exposure.

A completely sealed system used at NBL for handling infectious material which readily becomes airborne.



sulfide, both of which are highly corrosive in fuel. The Bureau of Ships, with the help of advisors from NRL and ONR, has successfully introduced ship-keeping procedures which prevent this insidious kind of bacterial contamination. This is another example of Navy-wide cooperation in the solution of an important problem.

Biological Warfare

No discussion of our microbiological effort would be complete without mention of biological warfare defense. In this priority area ONR cooperates with the Army, the Air Force, and several Navy in-house laboratories such as the Naval Applied Science Laboratory and the U.S. Naval Weapons Laboratory.

The objective of our nation's BW effort is to prepare for potential attacks of several sorts. First, it is possible that microbial disease agents will be disseminated against our agricultural crops. The agents, in this case, would be fungi, bacteria, or viruses which invade healthy plant tissue and cause destruction. Second, it is possible that agents will be disseminated against our meat-producing animals and fowl. Such agents would be expected to infect these creatures by the respiratory route, that is, by the breathing of the organisms in aerosol form, or possibly through purposefully contaminated food or water. Finally, a potential aggressor may choose to release BW agents to produce disease in military or civilian personnel. The methods employed for mass infection would be essentially the same as those used against domestic animals, but the agents might be more carefully selected. In some instances, the choice would favor microbial agents capable of producing only incapacitating diseases. In other instances an aggressor might choose especially virulent organisms which could cause serious disease and death.

Our first biological warfare defense objective is to provide a means for detection and identification of pathogenic microbes *before* they can cause disease. For this purpose, devices are being developed which will detect unusual increases in microorganisms carried through the air. These devices will also serve to identify, within a few minutes, the kinds of airborne microorganisms that might be dispersed by an enemy. Instruments and devices used for detection and identification need to be sufficiently compact and portable to be handled under a variety of conditions on land or on board ship. The second objective of BW defense is to provide protection for our servicemen on duty when a BW attack occurs. This may be accomplished by use of suitable masks and protective clothing, but especially by development of vaccines which will render personnel immune to predictable warfare agents. In the latter regard, the Naval Biological Laboratory plays a major role. Scientists at NBL have already succeeded in developing vaccines which could provide protection against BW attack by certain agents. [See also "Preparing for Biological Warfare," this issue.]

Having now been apprised of the remarkable scope of activity of the ubiquitous microbe in Naval affairs, the reader can well appreciate the Navy's "need to know" concerning the harnessing of harmful and beneficial microbial powers. Through the Office of Naval Research, the Office of Naval Material, and the Navy's in-house laboratories, significant strides will be made toward this important goal.

Preparing for Biological Warfare

COL Ward K. Shaub

Senior Warfare Officer
Office of Naval Research

On the 19th of February, 1945, an amphibious task force of the United States Navy sent its Marines ashore in an assault on the island fortress of Iwo Jima. In this action the troops of the famed Fifth Amphibious Corps, Fleet Marine Force, Pacific, annihilated the strongly entrenched Japanese garrison of 23,000 fanatic fighting men in one of the bloodiest battles of World War II. The price tag for this eight square miles of island, so urgently required in carrying the war toward the Japanese mainland, was high in terms of human lives—5,500 Marine, Navy, and Army personnel killed in action, about 19,000 U.S. fighting men wounded, and almost the entire Japanese garrison removed from the active-duty roster.

Since the end of World War II, some military strategists have theorized that if certain chemical or biological weapons, or both, had been used against the Japanese on Iwo Jima prior to the landing of the Marines, the small but important island could have been captured at but a fraction of the price that was actually paid. Although consideration of what might have been cannot change what happened, it can give us greater insight concerning our preparations—offensive and defensive—for future engagements of this kind. In view of the many scientific breakthroughs that have been made in chemistry, biochemistry, and microbiology on both sides of the Iron and Bamboo Curtains, we cannot afford to ignore the powerful chemical and biological weapons now in existence.

The Army is interested in these weapons because of their potential application to land warfare. The Air Force is studying BW and CW agents adaptable for delivery in the earth's atmosphere—its medium of operation. The Navy is preparing for this type of warfare for the same reasons the Army and Air Force are, and for another important reason as well:

- The Marines of our Fleet Marine Forces landing in amphibious assault face the same BW and CW problems ashore as does the Army.

- Our Fleet includes both Navy and Marine Corps aviation units whose interests in the dispersal of BW and CW agents in the atmosphere are similar to those of the Air Force.

- The ships of the Fleet, even when dispersed, consist individually of high concentrations of personnel, which, if unprotected, present choice targets for biological and chemical attack by an enemy.

Within the framework of Department of Defense coordination of the chemical and biological RDT&E effort, the Navy pulls its oar. From basic research through development of hardware, it employs its resources to the understanding and control of those agents that might be dispersed in the vast sea environment. Because many approaches and many stages are involved in preparations for offensive and defensive BW and CW warfare, much overlapping and interlocking of interests occurs among the Navy bureaus. Careful coordination of the effort is therefore required.

The Bureau of Yards and Docks devises defensive techniques and provides material and equipment for shore-based stations and installations.

The Bureau of Supplies and Accounts develops protective clothing and procures and distributes material and equipment.

The Bureau of Naval Personnel trains men in the use of equipment and in the application of BW and CW techniques, and it assigns personnel to BW and CW "battle stations."

The Bureau of Ships plans and prepares for defensive and offensive shipboard operations.

The Bureau of Naval Weapons develops BW and CW hardware for application to the marine environment.

The Marine Corps develops hardware to be used during amphibious operations.

The Bureau of Medicine and Surgery prepares defensive measures and carries out prophylactic and therapeutic research for application to the recovery of personnel after BW and CW attack.

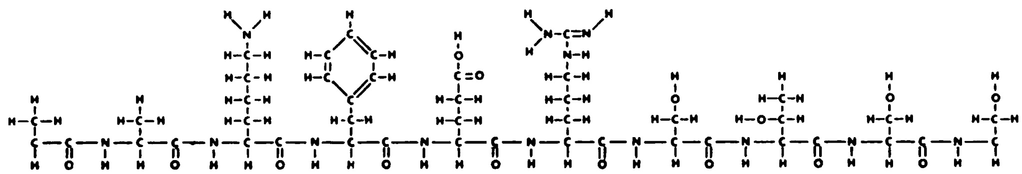
The Office of Naval Research, through its research programs and resources, provides the dimension of depth to the overall effort. Under the cognizance of ONR, the Navy laboratories contribute to the preparations through both basic research and development.

One excellent example of ONR's profitable involvement in BW is the research conducted for the past 14 years at the Navy Biological Laboratory, Oakland, California. NBL is supported and staffed jointly by the University of California, the Navy, and other Government agencies and is administered by the University under contract with ONR. Naval Medical Research Unit No. 1 of the Navy's Bureau of Medicine and Surgery shares the location of the Laboratory and actively collaborates in its work. NBL develops techniques for the diagnosis, control, and prevention of infections or disease of epidemic proportions that can be caused in man, animals, and plants by microorganisms disseminated in the air. While this research has obvious applications to defense against biological warfare waged by an enemy, it is also valuable in pointing the way to better control and treatment of infectious diseases that impair the health of the general public and of military servicemen during peacetime. For example, NBL, NMRU No. 1, and the University have produced a vaccine that protects animals against cocidiomycosis, or valley fever, an infection of the lungs and other parts of the body that is endemic in the Southwestern United States. This vaccine modifies the lethal nature of severe infections in animals, and it holds out the promise of preventing the occurrence of the disease in humans. (See "Microbiology in Naval Affairs," this issue.)

In any broad consideration of defense against chemical and biological warfare, one of the most critical problems is early warning. The potency of exotic biological and chemical agents that might be dispersed in wartime and the inability of the senses to perceive many of them solidly underline the need for rapid detection by instruments. A system that signals instantly the presence of such agents is essential to trigger immediate group defensive actions, such as the donning of life-saving masks and protective clothing, and to warn personnel to enter shelters and to initiate timely damage-control measures.

Related closely to early warning is the requirement of rapid identification of specific agents. Ordinary diagnostic methods are too slow to meet the need for immediate medical treatment of mass casualties.

—Continued on page 42



Biochemistry: Who Needs It?

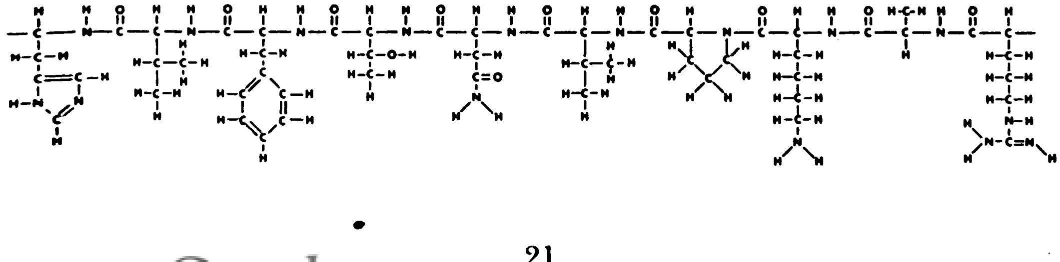
Robert K. Jennings
Head, Biochemistry Branch
Office of Naval Research

It takes no training. The newest "boot" in Great Lakes can digest a hamburger sandwich. From its proteins, carbohydrates, and fats, he can break out the amino acids and other chemical building blocks he needs and reassemble them into the muscle, mind, and elbow grease the Navy demands of him. He makes use of enzymes and metabolic pathways; his health, his ability to deal with hardships, and his ability to recover from injury and disease depend on things like hormones and antibody molecules—but he doesn't need to know all that. He can do very well with the help of Nature and intuition.

As far back as records go, navies have moved through an atmosphere, across a hydrosphere and within a biosphere. Time was when—knowing nothing of the atmosphere—sea captains paid good money for bags full of favorable winds to be released when wanted. Time was when sailors prayed to the waters and gave them libations. Time was when drinking water went ropy in the scuttle butt, so that the men had to "hold their noses while they drank the water and cut it off with scissors when they were done."

Early sailors may have felt that they had knowledge and mastery of the sea. They were at least vaguely aware of the air and its forces. The presence of life within the drinking water and, indeed, the very timbers of the ship was not even suspected. Still, like the "boot" with the hamburger, they did very well. Missions were accomplished. Nature, intuition, and empirical observation can carry a man a long way.

Today, at the Naval Medical Research Institute, at the Naval Research Laboratory, at the Naval Radiological Defense Laboratory, in Cairo, on Formosa, and in various other places, the Navy has a very considerable investment in biochemical research. The Navy also supports many scientists in the laboratories of universities, hospitals, and pure research institutes studying such seemingly non-nautical subjects as the structure of protein molecules and the generation of electric currents by living cells. Surely, thinking along the lines indicated above, it is very reasonable to wonder, "why"?



A little additional speculation will, of course, provide at least a partial answer. Nature and intuition probably did lead a caveman to grasp a fallen branch and to use it as a weapon or as a rake to pull in a bit of food fallen beyond arm's reach. The cave man may have seen in the branch the principle of arms or of tools. Beyond this point, however, research in increasing degrees of sophistication was necessary to develop the concept of the spear into the arrow, the projectile, and finally the Polaris missile, or the principle of the tool into the lever, the wheel, the motor, and finally the submarine which makes the missile effective. An enemy who had travelled this path only so far as Nature and common sense would carry him would have had little chance against an adversary who had completed the journey and learned to apply the forces of Nature as he saw fit.

Better questions, then, would be: Will knowledge of the way in which the biosphere operates provide concepts which may be developed into technological power, just as the arrow has been developed by research? Are there forces at work in living things which can be controlled and channeled purposefully in fulfilling Naval missions? Can knowledge of the biosphere be as important as knowledge of the sea and air?

One way to answer such questions is to let the reader judge for himself from an account of some of the biochemical research now in progress under Naval sanction. The account will necessarily be brief and spotty, missing important projects and perhaps seeming to emphasize some relatively minor matters. The examples are chosen, not because they are the brightest and best, but rather to give some feeling for the kind of knowledge which is being generated and for the relationship of biochemical research to other areas of scientific effort.

We might start by considering the studies of Asiatic cholera which are being carried on at the Naval Medical Research Unit on Formosa. Cholera is a rapid killer, but one to which meat-eating Westerners are not particularly prone. It plays havoc with native populations in many parts of the world where U.S. Naval forces must operate, and on occasion it has swept westward and struck at Europe and America as well.

Empirical observation of the disease long ago suggested that its worst effects were due to the enormous outpouring of fluid from the body, as though the intestines had been rendered suddenly porous by the cholera vibrio. This thought led to replacement of the fluid as a first consideration in treatment. Water alone was found not to be enough, however. It became apparent that the salts, which were washed away with the fluid, must be replaced as well.

As research has become more precise, it has become apparent that the remedy is not that simple. Studies showed that more is involved than mere leakage. So the research now underway in the Formosan laboratory is concerned with the physical and chemical mechanisms which result in the active transport of sodium ions across a membrane, such as the wall of the gut. A convenient membrane for use in laboratory studies is the skin of a frog; hence we find Navy scientists studying cholera with materials and concepts which seem very far removed indeed from the relatively simple problems of sanitation and vaccination that a layman might expect to be the concern of cholera research.

Among other matters, scientists at NMRI are studying the chemistry of muscle action. Muscle fibers contract, of course, when they are stimulated by impulses reaching them along nerve fibers. Under some conditions the delivery of the stimulus can be impeded. There are drugs which render the stimulus more effective. Some diseases and some poisons act by blocking the nerve stimulus altogether. Other agents can act to produce much greater motive power than a muscle normally delivers. If this research is successful—if we can come up with a real understanding of the mechanisms involved in the chemical events taking place where nerve and muscle fibers join—several benefits may accrue. We may be able to deal more effectively with poisons an enemy might employ against us; we may be able to treat diseases which incapacitate men today; and we may even learn how to create men who are temporarily superhuman in their strength and muscular control to deal with emergencies without being harmed. This much is clear: The problem is one which involves an understanding of the movement of sodium ions across membranes in living systems.

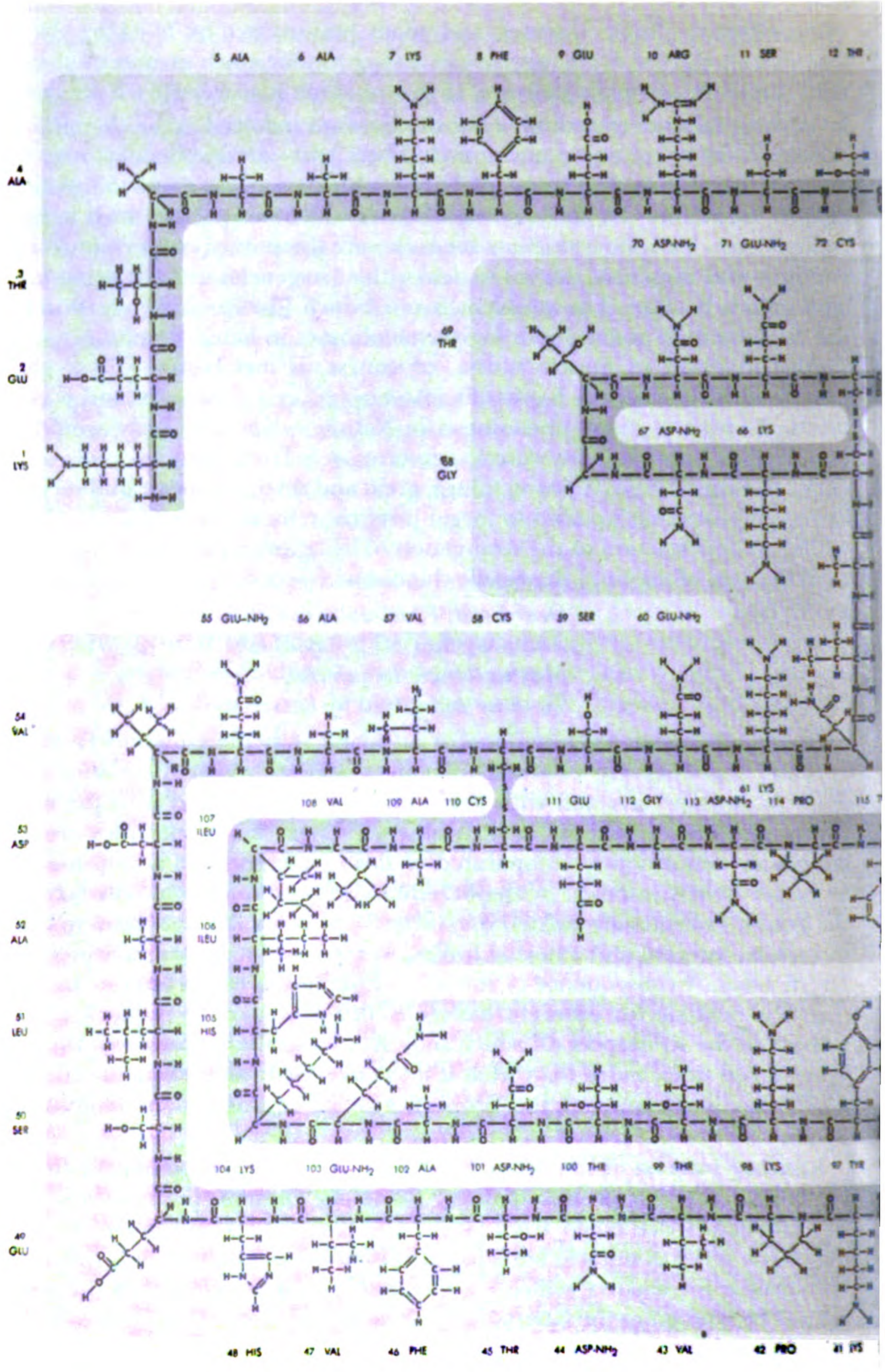
Also involved in muscle action, of course, is metabolism—those chemical events which transform foodstuffs into energy, cell substance, and waste products. As with so many phenomena in Nature, what takes place would not be expected to happen if we were to reason purely from what we know of chemistry. The metabolism of living things, great and small, has been studied so much in recent years that we tend to forget just how remarkable it really is. Once in a while, an appreciation of the strangeness of living processes does break through, as in the case of the English organic chemist who recently enunciated this prayer:

Dear Lord, I fall upon my knees
And pray that all my syntheses
May no longer be inferior
To those conducted by bacteria.

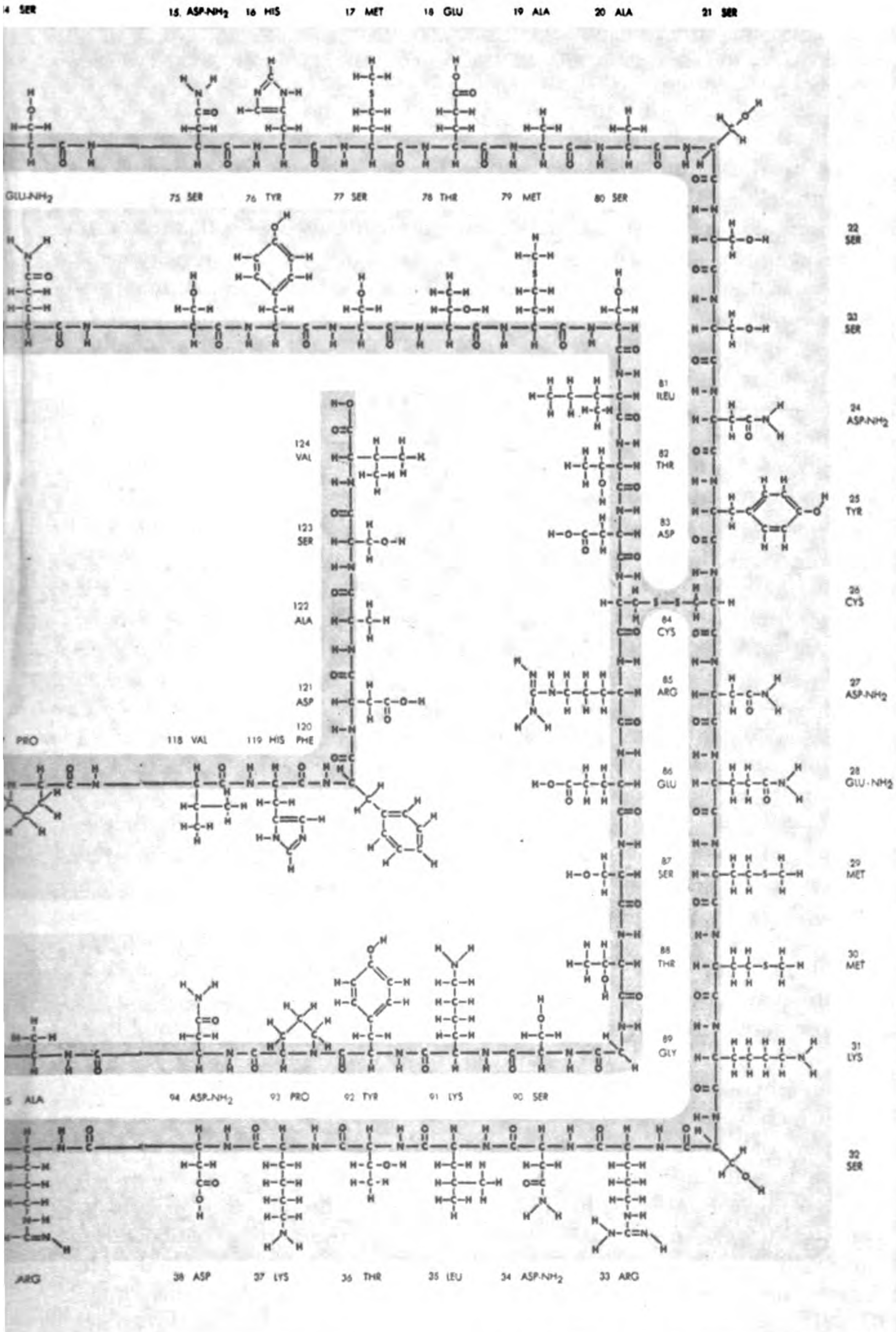
In the chemical machinations of all living cells the common factor is the enzyme. Enzymes are essentially organic catalysts which force substances to react in certain ways and with great rapidity as compared with the reactions which could be carried out in their absence. Characteristically, they are protein molecules—enormously complicated chains of amino acids bound together in an order strictly imposed by the hereditary instructions chemically recorded in the genes. Enzymes are twisted into orderly spirals or tangled skeins in response to various internal and external forces; so their surfaces may vary in many different ways. A consequence of the infinite variability of the enzyme molecule is that it is possible for different molecules of this class to be highly specific with respect to the substances on which they act and to the action which they foster. What a cell does, more than what it looks like, determines what a cell is. What a cell *does* is the sum of the properties of its enzymes. (See diagram, pages 24-25.)

Another interest of importance at NMRI is the cultivation of cells away from the creature which produced them. Curiously enough, the tissues studied in this laboratory are taken from birds. The reason these tissues were chosen is that birds serve as suitable hosts for a number of parasites, such as the organism responsible for malaria, which are dependent of living cells; thus the organism cannot be studied in the laboratory without a suitable host. In other laboratories and for other purposes, the biochemistry involved in the cultivation of cells and tissues, some of which come from human sources, is being studied under ONR support.

Such cultures develop characteristics which are not exactly like the cells and tissues found in the body. Some of the changes resemble those observed in cancerous cells. When enough has been learned about the factors which control the growth and differentiation of, let us say, skin cells, it may be possible to have



Molecule of ribonuclease, an enzyme that digests the cellular substance ribonucleic acid (RNA), is diagramed in two dimensions to show complexity of the enzyme. In this structural formula are 1,876 atoms: 587 of carbon (C), 909 of hydrogen (H), 197 of oxygen (O), 171 of nitrogen (N) and 12 of sulfur (S). The backbone of the chain of amino acid residues is in the darker shaded area; the side



chains characteristic of the various amino acids are in the lighter shaded area. The amino acid residues are numbered from 1 to 124, beginning at the amino end of the chain. Abbreviations for amino acids appearing in the diagram are indicated on next page. Reprinted with permission. Copyright (c) 1961 by Scientific American, Inc. All rights reserved.

Abbreviations for amino acids appearing in diagram on preceding two pages: ALA, Alanine; ARG, Arginine; ASP, Aspartic Acid; ASP-NH_2, Asparagine; CYS, Cystine; GLU, Glutamic Acid; GLU-NH_2, Glutamine; GLY, Glycine; HIS, Histidine; ILEU, Isoleucine; LEU, Leucine; LYS, Lysine; MET, Methionine; PHE, Phenylalanine; PRO, Proline; SER, Serine; THR, Threonine; TYR, Tyrosine; VAL, Valine.

"skin farms" to which the physician can turn for replacement parts when large numbers of casualties are brought to him after natural or man-made holocausts.

A technological barrier to this capability remains in the curious fact that our bodies can recognize themselves. Boarders are repelled and foreign tissue is rejected, even though it is possible to move bits of one's own skin about from place to place and have it take hold and grow nicely.

Chemically speaking, the response of a host to invasion by germ, parasite, or foreign tissue is the production of antibodies. Like enzymes, antibodies are protein molecules possessed of great specificity. This characteristic can be both a blessing and a curse.

Immunological specificity can be useful to the chemist. It allows him, for example, to pass forensic judgment as to whether a blood spot on the clothing of a murder suspect is from the victim or from some other man or animal. On the other hand, it imposes on the reluctant sailor the necessity of undergoing some 15 different "shots," each one for protection against a different germ. And it limits the ability of the surgeon to switch skin, limbs, or organs about from one person to another or to make tissue and organ banks a commonplace part of his armamentarium.

It follows that a considerable part of the research effort in biochemistry supported by the Navy, in-house and out, is directed toward understanding the structure and function of protein molecules. To gain this understanding it is necessary to learn something of how the molecules are produced, and this effort takes the scientist into the rapidly developing study of nucleic acids—the chemical couriers of heredity. Curiously, this study is intimately linked with the nature and properties of viruses.

The list of Navy interests in biochemistry could go on, far beyond the reasonable limits of this article. But, perhaps what has been said will suffice to give some insight into the nature of biochemical research and the ways in which it may serve the Navy.

The reader may still have reservations. For example, would not our bacteriologists work out answers as to how the cholera vibrio does its dirty work? Wouldn't our physiologists explain the nature of nerve-muscle interactions and the factors which control them?

The answer, of course, is that the biochemist is not really studying cholera after all. He is studying such things as ion transport across membranes, an activity which may be involved in cholera, paralysis, muscular control, and in such seemingly unrelated processes as respiration and the nutrition of bacteria. He is not really studying the metabolism of cells in culture or in the body. He is cataloging the properties of macromolecules. These properties may range from the services of the enzymes, which—like the eunuch in a harem—can arrange important matters which are of no apparent concern to himself, to those of the antibodies which can serve their master or destroy him.

Broken down in this way, the biochemistry which is suitable for support by the Navy deals with the biosphere, as oceanography deals with the hydrosphere and as physics deals with the world of energy within which Naval operations are carried out.

In the Office of Naval Research, certain questions are asked: Will the work which is going on in a particular laboratory contribute to our understanding of the relationships between the chemical structure of macromolecules and their ability to conduct the processes called "life"? Will it elucidate the ways in which living material transforms energy, turning sunlight into the latent energy in food and causing microorganisms to glow in the wake of a vessel, or switches on the many other remarkable processes we observe in living things? Or will it serve to explain how such factors as pressure, radiation, and magnetic fields affect the biochemical or biophysical performance of protoplasm?

If one or more of these questions can be answered in the affirmative, then here is "blue ground," in which it is reasonable to hunt for the factual "diamonds" that will be of value to the Navy. It is a characteristic of basic research that the greatest pay-off comes from instruction in matters we did not know in advance we needed to know about.

Not all basic-research problems arise in the minds of scientists. Some arise as feedback from technical obstacles to the accomplishment of an objective or the development of a desired capability. In general, such problems will be referred to in-house laboratories, and the eventual utility to the Navy will be relatively easy to discern. Hence, in-house research programs may often be described with some justification in such terms as "cholera studies" or "respiration under pressure." Even so, if the work is truly basic it will serve the stated purpose but will also make endless contributions to other fields as well, some useful to the Navy and some unrelated to Naval tasks.

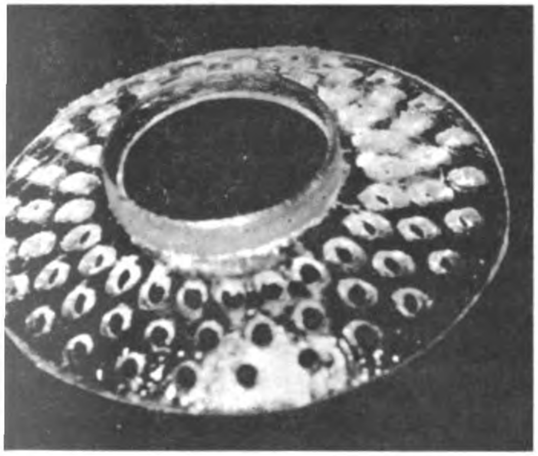
Because basic biochemistry is more properly akin to fertile soil in which research projects in the biological and medical sciences may grow than to seeds specifically intended to grow into individual technological fruits, the uninitiated may sometimes fail to see the pertinence of basic biochemistry to the continuing success of the Naval forces. But, unless the Navy is to operate in the biosphere with an ignorance as profound as that which existed with respect to the hydrosphere in 1492, the answer to our question—"Biochemistry: Who needs it?" must be, "The Navy does—for one!"

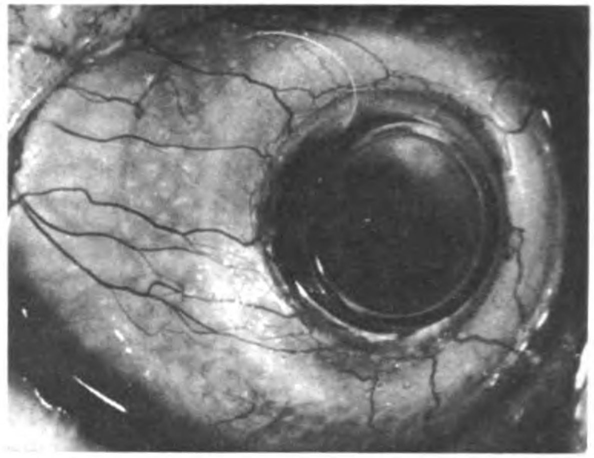
Biological Research in the Navy—Continued from page 3

of "in-house" research at the Air Crew Equipment Laboratory, Naval Medical Center, Naval Research Laboratory, Naval School of Aviation Medicine, and elsewhere is being conducted, is being expedited by the basic research in physiology sponsored by the Office of Naval Research. Other problems of considerable practical importance to the Bureau of Weapons are the delivery of weapons of limited warfare and the biological contamination of jet fuels.

The biological-research objectives enumerated here are but a few of those recognized in the Navy. Through close coordination between the Navy's scientists in her own laboratories and investigators at universities and in other private laboratories supported by the Office of Naval Research, progress in attaining these objectives is assured.

By pursuing this approach into the future, we shall not only guarantee that our Navy will continue to be the world's best, but we shall also help man to gain dominion over the living things of the sea and on the earth as the Creator intended.





Left, artificial cornea fabricated of methylmethacrylate. Right, the plastic cornea as it appears after implantation in a rabbit's eye.

The Management of Trauma

Joseph F. Saunders
Head, Medicine and Dentistry Branch
Office of Naval Research

In most cases the conflict between health and disease is carried on between elements too small to be seen...In the so-called metabolic errors there is a failure of some chemical process, the essential elements of which are too small to be observed by even the most powerful modern microscopes...The great advances of the foreseeable future will almost certainly come from increased knowledge of the body considered as a chemical factory.

—R. S. MORISON IN "MAN'S KNOWLEDGE OF THE MODERN WORLD"

In recent decades, basic insight gained into the dynamic events of metabolism has concerned the production, conversion, and utilization of energy and the ways in which cellular material is built up and broken down. Because most of this knowledge has been acquired through studies made in the "normal" environment, it has not provided Navy medical biologists with the background they need concerning the biochemical events that take place in cells as the result of injuries and diseases. Rapid changes in Naval technology and the wide geographic range of Naval operations require that these researchers think in terms of injuries arising from the exposure of men to unusual tactical, environmental, chemical, physical and biologic conditions.

These scientists want to learn—

• The nature of injuries which affect metabolic processes in terms of local aberrations in morphologic integrity and biochemical functions of cells, tissues, and organs.

- How the organism reacts initially to injury.
- What means will be most expedient for effecting repairs of injured tissues.
- What factors are involved in repair mechanisms, both natural and artificial (an example of the latter is skin grafting to replace tissue damaged by burns).
- What can be done to minimize the extent of the damage.

A continuing responsibility of the Navy is the pursuit of a coordinated multidisciplinary research program revolving around these questions. Thus the medical-research effort of the Office of Naval Research is coordinated and integrated with the efforts of all Naval laboratories. A good illustration of the way this policy is effected is the recent Navy-wide Workshop in Biological Sciences, which pooled a significant part of the data accumulated by all Navy medical research groups. Here are a few examples of investigations described at the meeting:

The Navy Applied Science Laboratory in Brooklyn reported on the importance of the use of skin simulants, such as plastics, and mathematical models in the determination of energy inputs to the skin from thermal stress. Participants from the Naval Medical Research Institute (NMRI) described: (1) physiologic investigations of thermal and circulatory changes evoked by frozen tissues; (2) trauma caused by drugs and its effect on the muscular response of personnel exposed to "sealed" military environments; (3) the biochemical events leading to cell death and ultimate kidney failure following trauma; and (4) the application of microcalorimetry to the determination of the driving forces of chemical change in antigen-antibody interaction, biologic energy-donors, such as ATP and creatinine phosphate, and other biologically important compounds. A facet of the program of the Navy Tissue Bank was described in which efforts are being made to determine the nature of the homograft reaction, the nature of the "homograft antigens," and the histochemcial mechanisms of homograft rejection. In addition, a discussion was held of the studies being carried out at the U.S. Naval Radiological Defense Laboratory on ways of improving skin homograft tolerance by irradiation and subsequent administration of antimetabolites.

Through such exchanges of information, the programs of ONR and the Navy laboratories are catalyzed, enabling Navy medical scientists to augment practical approaches toward problem solution by reference to a large pool of basic data. Conversely, these meetings point out obstacles that bar the solution of problems in the Navy laboratories, thereby stimulating, through contract research, the pursuit of leads that may accelerate efforts to find solutions.

Two research programs have been established by ONR to obtain information at the fundamental level which will help medical researchers in the Navy deal effectively with trauma. These programs concern cryobiology and transplantation biology.

Cryobiology

The cryobiology program is directed along three principal lines:

- The development of pure scientific principles for future application to "projected" problems, especially in extraterrestrial life studies.

- The acquistion of knowledge that has an immediate application to recovery from disease and injury, such as improved surgical techniques in which tissues are destroyed by freezing rather than "conventional excision."

- The furtherance of our understanding of the intricate mechanisms which govern the complex biologic behavior of man in a variety of environments.

Since the beginning of this century, scientists have frozen many kinds of animal and human cells outside the bodies to which they belonged. One of the earliest curiosities about the reaction of individual cells to extreme cold centered on how cancer cells would react when reduced greatly in temperature. Rat tumor cells were treated in liquid air at about −148°F. After 30 minutes the cells were rewarmed and inoculated into rats to test their viability. The cells grew into tumors, proving that they had not been killed by the extreme cold. Normal tissue cells have also survived this kind of treatment. Human skin, for instance, has been frozen to almost −110°F and has remained useful for experimental surgical grafting. Such developments have led to a relatively new field of scientific endeavor—cryobiology—which holds enormous promise for man's future health.

In the Navy's cryobiology program, progress has been impressive in studies of the long-term preservation of whole blood, blood components, and other tissues. A procedure utilizing nitrogen in the liquid and vapor states has been developed whereby blood can be preserved indefinitely at temperatures of −320°F and −275°F respectively. A pint of human blood can be frozen in approximately 75 seconds, stored for several years, then thawed in a 110°F water bath in about 75 seconds; it is thereupon available for direct transfusion. Should the clinician desire to transfuse red blood cells, those cells can be separated from the thawed blood, resuspended in a physiologic medium, such as albumin solution, and transfused.

This blood program, which was initiated by ONR, is now of international scope. In addition to the basic and basic-applied effort in centers in the United States (San Francisco's Presbyterian Medical Center, Yale University, Ann Arbor Veterans Hospital, and Roswell Park Memorial Institute) collaborative studies are underway in the Royal Army Medical College in London, the Central Laboratory of the Netherlands Red Cross, and recently in the laboratories of the French Army Center for Transfusion and Reanimation. The immediate concern of the British Army Medical Service is the evaluation of the ONR blood-preservation process for application to actual battlefield conditions. Additional information that will eventually be applied to the perfection of the process is being contributed by such laboratories as the American Foundation for Biological Research (effects of rapid freezing on leucocytes), the Bjorksten Research Laboratories (the effects of low temperature on the protein components of the erythrocyte), the University of Pennsylvania (the hemoglobin-haptoglobin relationship), and by many others.

The program in cryobiology is related closely to the one in transplantation biology. Studies dealing with the cryobiologic arrest of the activities of important tissue enzyme systems are underway in order to learn more about the relation of these systems to tissue-graft acceptance and rejection. Thermal and electrical conductivities of various tissues and fluids are being explored at cryogenic temperatures to determine whether alterations occur which may or may not affect adversely the function of these tissues and fluids when they are utilized to perform their endowed biologic function. These studies will contribute substantially to the solution of some of our current problems as well as equip us to cope with the problems that are not yet recognized but which may arise in the future.

Transplantation Biology

Transplantation biology encompasses studies dealing with the conservation and transplantation of tissues; host-donor interactions; suppression of the "immune response" and the inducing of tolerance through the administration of immunosuppressive agents; the intermediary metabolism of tissues, particularly the recognition of the reacting substances and the tissue reaction centers; transplantation genetics; and the development of tissue substitutes. In essence, the program represents a concerted effort of the various disciplines in the fundamental biologic and clinical sciences which may one day lead to the development of really effective methods of transplantation therapy for many of man's maladies.

An example of ONR's contribution in this area of tremendous promise is the successful transplantation of chimpanzee kidneys into humans by a Tulane University medical team. Until recently, the major obstacle in the path of this medical revolution was the biochemical defense system of the host which protects his body against what it discerns as harmful—for instance, infectious microorganisms. Perhaps it is this same system that causes the body to reject transplanted foreign tissues. This defense mechanism, in the case of the chimpanzee kidneys, was temporarily overcome or paralyzed by the use of antimetabolites or immunosuppressive drugs. The particular agent used in these studies was an antidiuretic containing radioactive mercury. Although the mechanism responsible for inducing tolerance in the patient is not understood completely, it is believed that the radiation from the drug countered the normal defensive systems of the host.

Sometime in the future it may be possible to use plastic materials as tissue substitutes or as artificial organs more efficiently and more effectively than preserved human tissues and organs. As part of an ONR-supported study, a plastic material—methylmethacrylate—has been used for the fabrication of artificial corneas. Having satisfied transplantation and immunologic criteria in experimental animals, these corneas are now awaiting trials in humans who are hopelessly blind because of opaque or disease-laden corneas of the otherwise normal eyes. Perhaps this material and other materials will prove to be more suitable than preserved human skin as a temporary biologic dressing for burns. Testimony for such speculation is corroborated by the commonly successful replacement of blood vessels by artificial ducts made of such materials as nylon, orlon, vinyon-N, and a number of other materials. Another positive step in this direction is the recently reported beneficial burn therapy which calls for immersion of the seriously burned patient in silicon solution.

Until more is known about the discrete chemistry of transplantation antigens, about the biochemical changes occurring in the sensitized cells which take part in host defense, and about the mechanism of graft destruction, no one can predict how soon the replacement of injured, diseased, and even aging organs with healthy ones surgically transferred from humans or animals will become common practice. Nevertheless, advances are continuing. For example, further cancer research may lead to many of the answers. As mentioned previously, frozen-preserved tumor cells that were transplanted into rats developed into tumors instead of being rejected in the manner that normal replacement tissues are cast off by the body. It is believed that one of the reasons such tolerance to malignant tissue exists is that the cancerous cells secrete some substance or combination of substances that suppress or paralyze indefinitely the host defense systems and thereby induce tolerance. Although considerations such as these are purely speculative, the meticulous experimentation which will follow them may provide the answers we are seeking. Lending support to this postulate is the belief that human beings are host to many malignancies during their normal lives and that some individuals are genetically endowed to overcome them whereas others are genetically deficient in these respects and therefore succumb to the invaders. Although the Navy does not support cancer research *per se*, it studies cancer to obtain solutions to important Navy problems such as those of transplantation biology.

Cryobiology can contribute significantly in such studies. For instance, frozen sections (−94°F) of grafted tissue and adjacent host tissue taken two days after implantation of the graft show that significant changes occur in some enzyme systems. Such findings are evidence that other subtle metabolic changes may also be detectable cryobiologically. After such detection, tissues in which these short-lived or transient reactants have been suspended can be subjected to a battery of biochemical and physical analyses to determine their characteristics as well as to identify their favorable or unfavorable biologic function.

The Future

All of the obstacles to the preservation of life at low temperatures are apparently involved in ice-crystal formation, subsequent tissue dehydration, electrolyte imbalance or concentration, and aberrations of morphologic and molecular architecture. Through further research we may be able to avoid the biologic damage caused by these changes. In essence, cryobiology presents us with previously unrealized opportunities for studying fundamental life processes which defy analysis and appraisal at temperatures at which human beings and other organisms live normally.

A union of scientific forces between cryobiology and transplantation biology shows promise of enabling medical scientists to establish the real identity of the "immunologic factor," or antigen, and to determine the nature of the stimulating substance or substances and the location of the tissue-reaction center and the effector mechanism leading to the transplantation reaction (acceptance or rejection). The precise chemical nature of the transplantation antigen is not known. Identifying it will require a coordinated effort in the biochemical, immunogenetic, and clinical sciences. The fundamental properties of tissue and the specific sites of its reaction to normal and abnormal stimuli, including those which are presented during surgery and disease, must be elaborated. Basic exploration of immunologic parameters, particularly in relation to tissue injury, must be expanded. And every possible avenue of approach must be utilized to determine why a host rejects a graft and what can be done to overcome such barriers to successful and rapid restoration of injured and diseased persons to healthful and useful lives.

Leonard M. Libber
Head, Physiology Branch
Office of Naval Research

Causes and Effects of Physiological Stress

Physiology is the study of biological function at the cellular, tissue, organ, and system levels. During Naval operations, a variety of stresses having adverse effects on the body at one or more of these levels can occur, seriously affecting the performance of aviation, submarine, shipboard, and Marine Corps personnel. Physiological research conducted within the Navy's own laboratories or under contract to the Office of Naval Research is aimed at reducing these effects as much as possible.

The physiological stresses to which Navy personnel are exposed can be grouped into about six major categories, depending on their physical or chemical causes: temperature, acceleration, radiation, magnetism, pressure, and noxious agents.

High Temperature

One major concern to Navy physiologists is the adjustment of the human body to temperature in the hot, dry climate of deserts. Assuming that adequate drinking water is available, a period of one to two weeks is required for a man to acclimatize to the desert environment. After this time, he is able to work strenuously with a minimum effect on heart rate, respiration rate, blood pressure, and body temperature, and without excessive loss of body electrolytes. At one time, physiologists thought that if a person became acclimatized to humid, tropical conditions, he could adjust rather easily to the desert. However, a well-conducted field study reported in 1962 by the British revealed that troops artificially acclimatized to hot, moist conditions did not perform much better during the first four days in the desert than totally unacclimatized troops. Naturally acclimatized troops, on the other hand, performed far better than either of the other groups.

However, in this modern era when troops are transported from one climatic area to a totally different one in a matter of hours, personnel can be expected to be called into battle before any natural acclimatization can occur. No chest-mounted air conditioners exist at present to help these people escape the heat, and even if they did, they would probably be so cumbersome they would impair performance rather than enhance it. Far more suitable would be the administration of a drug or the application of some other rapid technique that would assure acclimatization in minutes or hours rather than in days or weeks—"instant acclimatization," as it were. Survivors of airplane crashes or forced ejections into desert environments could also benefit by such procedures. But to achieve this capability, much basic research in thermoregulatory mechanisms, circulatory and respiratory responses, electrolyte and water conservation, metabolic pathways, and other processes will be needed.

At the Naval Medical Research Institute at Bethesda, a physiologist who has had a long-standing interest in these problems has been experimenting on human temperature control by means of the human gradient calorimeter, a device that responds quickly to temperature changes in the body (see "Inventions," this issue). During the Biological Sciences Research Workshop, this investigator—T. H. Benzinger—described the use of this research tool in exploring his concepts regarding the role of the hypothalamus, or "temperature eye" of the brain. The hypothalamus is very sensitive to small changes in the temperature of the blood that circulates through it. According to Benzinger, when the temperature of this blood increases sufficiently, it triggers a whole series of body responses, including increased blood flow to the skin and sweating.

The question now needing to be answered is—how does the hypothalamus transmit its information to the nervous and chemical messengers of the body? The Office of Naval Research is supporting investigations of techniques whereby various drugs are injected directly into one of the internal spaces—the third ventricle—of the brain. The hypothalamus, which forms part of the floor of this space, is closely associated with cells normally containing adrenaline and serotonin. During periods when the body temperature was artificially raised, the intraventricular injection of adrenaline caused the temperature to drop, while the injection of serotonin made the temperature rise. These findings suggest that the normally occurring adrenaline and serotonin are continuously "bucking" each other in maintaining the temperature of our bodies at a relatively constant level.

Low Temperature

Adaptation to cold does not pose a critical problem to troops in the field because of the availability of light-weight protective clothing and equipment. But it does pose a problem to the survivors of aircraft crashes in the arctic. If a downed flyer could go into a hibernating state to adapt to a severe drop in peripheral and deep body temperatures, he might stay alive long enough to be rescued. Unfortunately, however, the means of inducing hibernation in humans probably will not be found. Nevertheless, mechanisms closely related to hibernation are certainly worthy of research. For example, we might very profitably study the peculiar adaptability of certain ethnic groups. The Alacaluf Indians who live at the southern tip of South America are one such people. In the past, these Indians have lived almost completely nude in a climate in which both snow and sleet are likely to occur, even in summer. In Charles Darwin's report on his visit to this land, he described a seminude woman, carrying a naked baby at her breast, who waded out to meet his boat. The water was icy cold, and snow was beating down, yet neither mother nor child appeared to be uncomfortable. Such utter disregard for conditions we would consider to be intolerable may indicate that these Indians have a different hereditary legacy than other people.

Acceleration

With each passing day, man is improving the capacity of his machines to transport him at higher and higher speeds – in the sea, on land, in air, and in space. As a result, the physiological stresses associated with acceleration continue to be important subjects of research. These stresses are caused by several different kinds of acceleration – linear, radial, angular, and sinusoidal, occurring either separately or in combination.

Linear acceleration occurs along a relatively straight path during such events as catapult launch, landing arrest, seat ejection, parachute opening, and airplane crashes. It is characterized by a rapid build-up to a short-duration (milliseconds), high-peak increase in speed, and it causes injury by mechanically overloading the tissues.

Radial acceleration causes the body to travel through a curved path about a single point or to shift from one curved path to another about several points, as in aerobatics. The primary effects are related to the pooling of the blood supply and the displacement of internal organs. The redout and blackout experienced by aviators during various maneuvers are caused by radial acceleration, which is characterized by a slow onset and relatively long duration (seconds).

Angular acceleration occurs when there is rotation of the body or its parts about the body's axes – for example, during tumbling and windmilling prior to parachute opening, whiplash of the neck and head, and swaying of the body (which gives rise to motion sickness). This type of acceleration also is slower in onset and of longer duration than linear acceleration.

Sinusoidal acceleration occurs as the result of high-frequency vibrations experienced in land vehicles traveling over rough terrain, in aircraft flying in turbulent air, and in seagoing vessels when shaken by underwater blasts. It is usually characterized by a relatively low-peak G-load, short duration, and rapid repetition in a cyclic manner. Sinusoidal acceleration may cause fatigue or set up resonances in the body which tear tissues and organ-suspending ligaments.

Several Naval laboratories have installed unique and costly equipment to study the effects of acceleration. One of these devices is the human centrifuge at the Aviation Medical Acceleration Laboratory. It consists, in part, of a rotating 50-foot arm and a gondola; the human subject sits in the gondola, which is attached to the outer end of the arm. Various flight profiles can be programmed electronically into the machine so that realistic radial G-loads can be imposed on the subject.

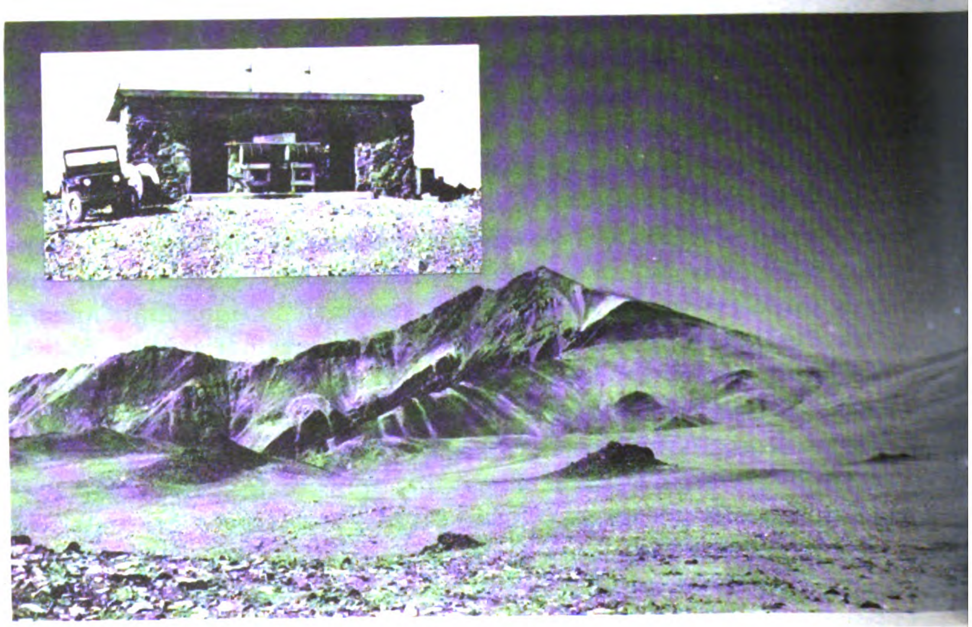
The Naval School of Aviation Medicine at Pensacola utilizes several machines for radial- and angular-acceleration studies. One of them, a disorientation device, is like a giant cement mixer that spins its human occupant about two of his body axes at the same time and at fairly high speeds. During the Biological Sciences Research Workshop, F. E. Guedry of the School discussed research conducted on the responses of the three semicircular canals in the head to angular accelerations. These canals are responsible for sensing acceleration

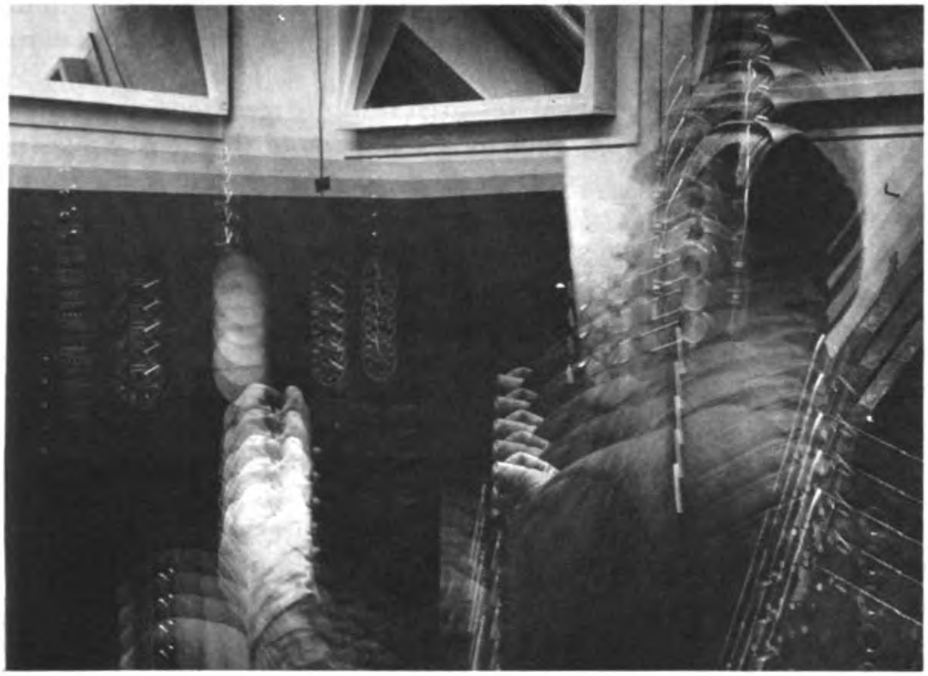
Navy man explores crevasse as part of an assignment. Before his work is done, he may experience the debilitating effects of intense cold and of hypoxia.

Multiple photographic exposur showing a subject being vibrated over a vertical distance of about inches. Pilots and other aircraft-crew members may be severely shaken by similar vibrations during actual flight.

A Navy ballonist awaits prepara-tions for journey into strato-sphere. He may experience ex-tremes in temperature and violen accelerations before the capsu in which he rides comes to re again on earth.

The 14,000 foot high White Mountain in California and the Navy-supported physiological research station at its summit. Several other Navy-supported stations are located at other high altitudes on the mountain.





A Navy deep-sea diver adjusts his air-control valve while descending from a submarine rescue vessel. He could be subject to any of several harmful effects of high pressure.

in three different planes. If two or more of the canals are stimulated simultaneously, various physiologically and psychologically distressful situations develop, such as motion sickness, vertigo, and illusions.

D. E. Goldman of the Naval Medical Research Institute reported on investigations of the effects of vibration on animals. He has found that most injurious or stressful effects occur in the frequency range of 2 to 20 cycles per second. An ONR contractor working on the dynamic relationship between the lungs and the chest wall of the dog augmented these findings by determining that the natural resonating frequency of the lung-thorax system is 8 cycles per second.

Linear accelerators at the Aerospace Crew Equipment Laboratory include an ejection-seat tower and a horizontal catapult. These devices have been utilized in developing safer, more efficient ejection seat systems, body restraint devices, and aircraft seating configurations. E. Hendler of that Laboratory described various studies being conducted for NASA. One of the investigations involved the determination of the human tolerance threshold to negative G impact accelerations. Such experiments can be very hazardous if inaccurate criteria are used in establishing the tolerance threshold.

Radiation

Just as different types of acceleration evoke well-defined physiological responses, so also do some forms of radiation. The ionizing type of radiation, such as that produced by x-ray machines, the klystron tubes of radar devices, radioactive fallout, and other sources, can influence genetic characteristics and induce pathological states in the cells and tissues; it does not, therefore, fall within the scope of stress physiology. Nonionizing radiation, on the other hand – for example, that emitted by ultrasonic, laser, and electromagnetic sources – may cause considerable physiological stress.

Ultrasonic energy is dissipated rapidly in air but can be transmitted some distance through water. However, the power required to cause harmful effects at a distance is relatively high, so it is not likely that weapons designed to emit such energy would be very practical. Devices designed to produce ultrasound over short ranges have been used clinically for the visualization of soft tissues that can't be seen by x-ray and for various types of bloodless surgery. Lasers, which produce an intense beam of pure monochromatic light in a narrow cross-sectional area, may some day be used in communications systems. Even though lasers are in the infancy of their development, they are still dangerous, particularly to the eyes when the proper safety precautions are not taken. As yet, neither ultrasonic nor laser instruments pose any physiological problems from the operational standpoint.

Electromagnetic devices produce the most dangerous radiation. At the end of World War II, the average power density of the strongest pulsed radar was of the order of a few kilowatts. At the present time, the Navy is building for shipboard use radar devices that operate in the megawatt range – a 1000-fold increase in average power density! Furthermore, this equipment is so designed that in order to obtain the desired coverage, part of the deck and access areas might be swept by the beam. Of course, all areas in which the safety limit of 10 mw/cm² is exceeded will be kept off limits to personnel. But this safety limit has been based on the average energy outputs of devices that produce less power. It does not take into account the fact that during the duty cycle of the high-powered equipment very short, very intense emissions will occur. Although this duty cycle may give the same average power density per unit of time as the longer duration, lower intensity duty cycle of the older radar devices, the effects may not be the same. As yet, we have no biological information on the effects of the high-powered devices, because they are still in the design and prototype stages and, therefore, are not available for biological studies.

Magnetism

All organisms from single-cell amoeba to complex, multi-celled humans have developed in the presence of the earth's magnetic field. Working in conjunction with the Naval Research Laboratory, D. Beischer of the Naval School of Aviation Medicine has been conducting a series of intriguing experiments on humans and animals in near zero magnetic fields as well as in some very high alternating magnetic fields. Some of the findings were described by him at the Biological Sciences Research Workshop. Although the research was stimulated by NASA's interest in what might happen to an astronaut in a particular magnetic field, the results may prove to be of great value to many other scientists interested in basic biological processes.

Low Pressure

The general problem of equipping Navy men to function efficiently in environments to which they are not accustomed includes considerations of their adaptation to pressure changes. We have only to think of the mountain ranges along and within the borders of our potential enemies to see that the necessity for airlifting marines to battlegrounds at high altitudes might arise. During the recent invasion of India by the Communist Chinese, Indian troops found themselves suddenly occupying mountain passes 19,000 feet high. Because of the intense cold and the hypoxia, these troops performed very poorly, and the Chinese swarmed into India. Altitude acclimatization is time consuming, taking several days even at lower levels than those to which the Indian troops were moved. For the human body to adjust to an altitude of 18,000 feet (the highest level at which full acclimatization can occur), several months are required. The Chinese troops presumably were acclimatized to the high altitude before starting the invasion.

Since 1947, the Office of Naval Research has been supporting a high-altitude research station on White Mountain in California. During these years, the station's laboratories, located at various levels on the 14,000-foot mountain, have grown in size, number of facilities, and scientific use. Many basic studies on altitude adaptation have been conducted here by investigators from all parts of the United States. The station is operated by the University of California.

High Pressure

The effects of high pressure need to be investigated more thoroughly than they are at present. In order to extend human diving capability to its greatest potential in both depth and duration, we are looking for ways to prevent such harmful effects as oxygen toxicity, inert-gas narcosis, carbon-dioxide poisoning, the bends, and excessive body heat loss.

G. F. Bond, officer-in-charge of the Naval Medical Research Laboratory at New London, presented to the Biological Sciences Research Workshop his concepts of an underwater habitation to be used instead of a surface ship to support divers working for days or weeks at ocean depths of several hundred feet. The use of his capsule (called "Sealab") would obviate the need for frequent decompressions between dives, and thus would reduce diving hazards. Even though the prolonged exposure would cause the tissues to be so saturated with gases that a relatively long decompression period would be required, the new diving technique should be of great practical value to underwater salvage and construction projects.

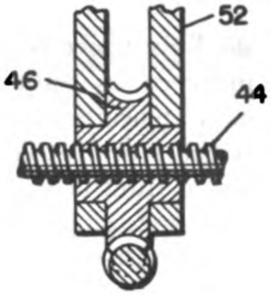
Improved equipment and procedures are needed also to enable men to dive quickly into the ocean, sometimes to depths as great as 1000 feet, to carry out such assignments as inspecting or deactivating underwater weapons and rescuing trapped submarines. For many years, the Office of Naval Research has been supporting basic research on this subject to enrich the scientific body of knowledge and, thereby, help Navy laboratories develop more advanced techniques, equipment, and diving tables. CDR Robert Workman of the Experimental Diving Unit described the problems encountered by divers and some of the new diving equipment being designed and tested, pointing out particularly the physiological considerations. One of the difficulties experienced in this work is the tendency of engineers to design operational devices without regard for the physiological shortcomings of the human. Thus the equipment often fails to serve its purpose. For example, recently the Navy purchased several one-man open vehicles that were to be driven underwater by electric power. The vehicle was designed to operate continuously for three hours, but when it was field-tested in 54°F water, the rider's hands became numb and practically useless within three-quarters of an hour, even though he wore gloves. One can imagine how well the rider would have performed in the 28°F Arctic Ocean.

Noxious Agents

A final physiological problem of concern to the Navy is the exposure of personnel to noxious agents that might be introduced aboard ship — for example, the carbon dioxide that builds up in closed quarters, the radioactive materials that accumulate after a thermonuclear explosion, and the poison gases that could be used in wartime. Positively charged ions in the air might also have detrimental effects. Many such hazards can be prevented by the proper selection of counteractive materials, the use of purifying systems, the exercise of good sanitation, and the development of suitable protective gear.

The philosophy of the Office of Naval Rsearch is to support basic research through contracts with academic and industrial experts in all of these areas of operational stress that cannot be undertaken conveniently by Naval laboratories. As we learn more about the nature of these stresses — their causes and effects — the means will be found either to avoid them entirely or to protect man adequately against them.

INVENTIONS



Many inventions arise from the Navy's in-house and contract research program in the biological sciences. Although professional opinion may vary as to the desirability of filing patent applications covering these concepts, there are many reasons for doing so that are unrelated to the motive commonly believed to be most important – profit. For example, patent coverage of a medical instrument may be necessary to protect the investment made to get the device into the market. It may be considered desirable, also, because of the ethical control which the patent allows to be exercised – as, for example, to discourage malpractice in the application of the invention. Furthermore, the granting of a patent enables the inventor, if he wishes, to dedicate his concept to the public, thereby assuring that its benefits to society are not diminished, as they might be if the invention became the exclusive property of individuals.

Measuring Body Temperature

The inventions of Dr. Hans Benzinger, a world authority on human calorimetry, are among the most important of those made by Navy inventors working in the biological sciences. Although his efforts have been directed to a field of basic research from which one would expect few concepts to be patented, he has never failed to recognize a practical application of new knowledge or a better solution to a problem. Thus, while Dr. Benzinger has been employed by the Navy, he has produced about a dozen inventions.

One of the patents issued to Dr. Benzinger is on a device for measuring body temperature (U. S. Patent No. 3,054,397), otherwise known as the ear thermometer. This invention is based on the determination that the hypothalamus, which is located in the forebrain, is the human thermostat. The temperature of the tympanic membrane – the most accessible point near the hypothalamus – is monitored by means of a thermocouple inserted into the auditory canal so that it contacts the membrane. The direct current flowing in the thermocouple leads is measured by a galvanometer calibrated to indicate temperature. At present, the technique is applicable only to the laboratory; more extensive use awaits the development of miniaturized reading equipment. (See "The Causes and Effects of Physiological Stress," this issue.)

Another of Dr. Benzinger's inventions, patent protection for which is now being sought, is a microcalorimeter capable of measuring the magnitude and rate of heat flow produced by chemical or biochemical reactions.

High-Speed Dentist's Drill

Out of the Navy's biological sciences program have come several inventions that have had considerable impact on dentistry. One of them is a high-speed dental drill. This device is constructed by placing a high-speed rotor or turbine in the handpiece, as contrasted with the practice, at the time the invention was made, of placing the motor at some distance from the handpiece and relying on gears and pulleys to drive the cutting head. The rotor is driven by compressed fluid at a speed of several hundred thousand revolutions per minute. High-speed operation is advantageous because it enables the dentist to cut into a tooth without applying much pressure. Also, the driving fluid, upon being expelled by the rotor, cools the cutting tool, protecting the tooth structure and minimizing discomfort to the patient. The invention, which is covered by U. S. Patent No. 2,994,129, issued several years ago, was made by Paul H. Tanner and Oscal P. Nagel.

Dental Mirror

Another invention that solves a problem for dentists is the "Thin Replaceable Back Surface Mirror and Holder" (U. S. Patent No. 3,031,932), conceived by Emanuel Kafig and Raymond L. Long, technicians at the Naval Medical Research Laboratory. The mirror is prepared by cementing a thin glass element, coated with a reflective backing, to a disc of magnetic material. The mirror's holder is recessed and provided with a permanent magnet, which keeps the mirror in place. Removal and replacement of the mirror surface can, therefore, be accomplished quickly and economically.

The Pump-Oxygenator

An improved pump-oxygenator was invented by Professor Samuel C. Collins and Dr. Ernest M. Barsamian while they were working under an ONR contract with the Massachusetts Institute of Technology. Devices of this type play life-saving roles by carrying on the vital functions of the heart and lungs during critical surgery and other emergencies affecting those organs. Some of the advantages of the improved pump-oxygenator are that it requires only a small amount of blood for "pumping"; it can be operated by a single technician, in contrast with other equipment which requires the services of many skilled opertors; the unit can be constructed at low cost; it can be sterilized in the assembled state; and it is so designed that it does not produce foam in the blood. The patent application for this invention is now pending in the U. S. Patent Office.

Preparing for Biological Warfare—Continued from page 20

Of course, another important need is the establishment of techniques for mass prophylaxis—ideally by active biological immunization.

On the BW and CW "fronts" facing the Navy, scientists and engineers are making steady gains. As has been pointed out, some of their products have already been used to curb or prevent the spread of diseases occurring under normal conditions. Thus, whether the future brings war or allows peace to continue, we can look forward to further advances in this important field of research and development that are sure to save many lives, both in and out of the Navy.

On the Naval Research Reserve

Nuclear Sciences Seminar

The 46 Naval Reserve officers who reported to Brookhaven National Laboratory, Upton, New York, on March 1, found a full schedule of Sunday activities awaiting them. Administrative processing was handled first, and then the group was taken on an orientation bus tour of the 3655-acre Laboratory site. The bus tour was followed by a get-acquainted party.

The Nuclear Sciences Seminar program, entitled "A Workshop In Health Physics," was started with welcoming addresses by RADM R. Mason, USN, Commandant of the Third Naval District, and by Dr. C. Falk, Associate Director of the Laboratory. CAPT Hoffman, USN, Deputy Chief of Naval Research, was the speaker at the opening-day luncheon. He gave a most interesting talk on the activities of the Office of Naval Research.

Each morning, staff members of the Laboratory's Health Physics and Medical Departments lectured on radiation safety, and in the afternoons, tours and exercises were conducted. The reservists visited a reactor, a hot laboratory, the Medical Research Center, and the Brookhaven Alternating Gradient Synchrotron—the world's largest "atom smasher." Exercises included calibrating and reading film badges; actual decontamination of equipment; a radiation survey at a small reactor; and use of emergency breathing equipment.

CDR L. A. Baker, Jr., USNR, who in civilian life is the Laboratory's Manager of Safety Services, served as the Commandant's representative in directing the seminar. LCDR S. J. Tassinari, USNR, Commanding Officer of NRRC 3-9 and an analytical chemist at the Laboratory, was Administrative Officer; LT C. Raseman, USNR, Group Leader in the Nuclear Engineering Department, was Program Officer; and LTCOL E. J. Bergin, USAR, the Laboratory's Supervisor of Staff Services, was the Duty Officer.

Experimental Leadership Training Program

A conference was held at the Office of Naval Research Branch Office, Chicago, on February 14 and 15 to evaluate the progress of a pilot program for leadership training in Research Reserve companies.

Participants included CAPT Charles H. Bowman, USNR, NRRC 9-2, Urbana, Ill.; CAPT John K. Sterrett, USNR, NRRC 9-26, Colorado Springs, Colo.; CDR Bernard Schmidt, USNR, NRRC 9-7, Lafayette, Ind.; LCDR Richard Hood, USNR, NRRC 9-4, Milwaukee, Wis.; LCDR Leon Jameton, USNR, NRRC 9-8, St. Louis, Mo.; LCDR William Johnston, NRRC 9-25, Indianapolis, Ind.; LCDR Roger Oesterreich, USNR, NRRC 9-1, Chicago, Ill.; LT Melvin Larsen, USNR, NRRC 9-5, Ames, Iowa; and representatives of the ONR Branch Office, Chicago.

The pilot group was formed in August 1963 to test the experimental program which had been developed under CAPT Bowman's supervision at Urbana. The unique feature of the program is that the case studies employed are concerned with practical situations that could arise in ONR management activities. The case studies represent typical situations the individual member of a research company would encounter upon mobilization, and they stress the basic leadership principles outlined in NAVPERS 15924.

While it is premature to predict the final results of the pilot evaluation study, the indications are that a program of this kind might be highly worthwhile in the Research Reserve curriculum. As stated by CAPT Sterrett, "The program not only provides a stimulating means of leadership training within the unit, but also serves to focus attention on things going on in the ONR organization. Speaking as the commanding officer of a new company, I have found this program to be most helpful in orienting our members to ONR."

In their reports on progress of the study within their companies, the conferees revealed that various methods of incorporating the discussions were used. If the experimental program is approved for general curriculum usage, it is anticipated that local autonomy in this regard would be encouraged.

The emphasis throughout the studies is to find approaches to good methodology for dealing with problems of human relationships, rather than to find solutions to the problems themselves. The pilot group believes that there are no "pat" answers to leadership problems.

Final reports of the study and recommendations for future use are expected to be completed in late spring.

Seminars Planned for Fiscal Year 1965

Eleven Research Reserve seminars are planned by the Office of Naval Research for fiscal year 1965. Final approval of the plans must be given by the Bureau of Naval Personnel. Further information will then be promulgated officially in the BUPERS Instruction 1571.4 series. This instruction is expected to be available in May 1964. The titles, places, and dates of the seminars now planned are as follows:

	1964
Nuclear Sciences, Idaho Falls, Idaho	August 3
Aerophysics, Denver, Colo.	August 3
Applied Research, Albuquerque, N. Mex.	August 10
Electronic Computers, College Station, Tex.	August 24
Space Science, Moffett Field, Calif.	September 14
West Coast Seminar, San Diego, Calif.	October 19
Nuclear Sciences, Oak Ridge, Tenn.	November 30
	1965
Research Reserve Seminar, ONR, Washington, D.C.	January 25
Training Devices Seminar, Port Washington, N.Y.	May 24
Naval Research Laboratory, Washington, D.C.	June 7
Research Reserve Seminar, Boston, Mass.	June 14

Promotion Selections

Five hundred and ten Naval Reserve line officers have been selected for promotion to captain, and 427, to commander by the Fiscal Year 1964 Reserve Selection Boards. Of these numbers, 23 Research Reservists were selected for captain, and 12 for commander. Congratulations are extended to these officers.

FOR CAPTAIN

	NRRC		NRRC
Barnet, Fredrick R.	5-10	Park, Willie E. (C.O.)	6-11
Clayton, John H.	6-6	Preston, Roger Guy	12-2
Depue, Leland A.	5-9	Radford, Robert M. (C.O.)	6-13
Hallett, Byrne E.	9-25	Ross, Malcolm D.	9-3
Hession, John J.	4-3	Shostak, Arnold A.	5-8
Johnson, Ernest P. Jr. (C.O.)	8-1	Smith, Richard W.	12-5
Johnson, Walter F. Jr.	9-16	Traina, Dominick R.	5-9
Johnson, William H. (C.O.)	12-2	Twaddle, Herbert G.	8-4
Kelly, Leroy B.	11-2	Winter, Philip H.	5-8
King, James R. (C.O.)	12-3	Zellmer, Ernest J.	5-8
Klein, Paul M. Jr.	12-1	Zimmerman, Burl	6-3
Marboe, Robert F.	4-4		

Statistics based on the records of the Research Reservists selected for promotion are as follows:

Date of Rank	*Designator*		*Year of Birth*
Earliest 7-1-55	1105:12	1405:5	Earliest 1908
Latest 1-1-58	1355:1	1455:5	Latest 1922
Median 7-1-57			Median 1915

All officers selected for captain were in Ready Reserve status. Twenty of the 23 selected were in the zone for the first time, and 3 were selected from the old field. The educational levels of the officers selected were as follows: Doctor's degrees, 3; Master's, 7; and Bachelor's, 13.

FOR COMMANDER

	NRRC		NRRC
Bachmann, Clarence R.	3-2	Huus, Helen	4-2
Eades, James Beverly Jr.	5-2	Lake, Dale Jr.	3-14
Hagist, Warren M. (C.O.)	1-2	Nall, Julian C.	5-8
Hansing, Frank D. (C.O.)	5-10	Salwak, Stanley F.	9-7
Holz, Peter P.	6-3	Staples, Carlton W.	3-5
Housiaux, John E.	9-4	Sutherland, John Arthur II	13-1

Statistics based on the records of the Research Reservists selected for promotion are as follows:

Date of Rank	*Designator*		*Year of Birth*
Earliest 4-1-52	1105:8	1405:1	Earliest 1913
Latest 6-1-59	1355:1	1455:1	Latest 1926
Median 7-1-57		1515:1	Median 1921

All officers selected for commander were in Ready Reserve status. Three of the 12 selected were in the zone for the first time, and 9 were selected from the old field. The educational levels of the officers selected were as follows: Doctor's degrees, 6; Master's, 3; and Bachelor's, 3.

Qualifying for Promotion

It is to the advantage of the officers selected for promotion to qualify for promotion within one year of the date on which the President approved the report of the selection board (Feb. 20, 1964, for officers on the captain list and Feb. 29 for those on the commander list). By qualifying within the one-year period, these officers will be entitled to pay and allowances of the new grade for that year. If more than a year is taken to qualify, the entitlement for pay and allowances of the new grade will date from the officer's appointment in that grade. The maximum time limit for qualifying for promotion is one fiscal year following the fiscal year of selection.

The physical examination for promotion may now be taken as soon as the official letter of notification of selection has been received, even though the officer may not have completed the professional requirements at that time.

Quota for Army Reserve Seminar

The U.S. Army Research and Development Unit, Oak Ridge, Tennessee, will conduct a seminar in Nuclear Sciences August 9-22, 1964. A quota of five individuals has been offered to the Navy for attendance at this seminar.

The purpose of the meeting is to provide Reserve officers having a scientific or technical background with up-to-date information in the field of nuclear science. Particular attention will be given to nuclear power reactors and their technology and to other military applications of nuclear science. Radiation and radiation effects will be emphasized.

Officers interested in attending the seminar should apply through regular Navy channels. Reserve Assistants at ONR branch offices may request quotas on an individual basis from ONR, Washington.

General Excellence Award Presented to NRRC 6-18

The Hon. James H. Wakelin, Jr., Assistant Secretary of the Navy (Research and Development), honored Naval Reserve Research Company 6-18, Nashville, Tennessee, by presenting the company with the General Excellence Award on March 17, 1964. The award, which was established by the Chief of Naval Research in 1960, was made to NRRC 6-18 in competition with the 118 Research Reserve companies throughout the United States.

The presentation ceremony took place at a banquet at the Richland Country Club, Nashville, Tennessee. Among the distinguished guests at the ceremony were RADM L. D. Coates, USN, Chief of Naval Research, and RADM L. R. Daspit, USN, Commandant, Sixth Naval District. At the dinner Secretary Wakelin presented a plaque emblematic of the General Excellence Award to NRRC 6-18. Receiving the award for the company was CAPT W. D.

McClurkin, USNR, Commanding Officer. Secretary Wakelin commended the company for its outstanding achievement—a result of the excellent training which it conducted throughout the year.

Present at the ceremony, in addition to the 38 members and their wives, were CAPT D. J. Mooney, Jr., USNR, Special Assistant to the Chief of Naval Research for Research Reserve; CAPT W. J. Moran, USN, Naval Aide to Secretary Wakelin; and CAPT G. Roper, USNR, Assistant Chief of Staff for Naval Reserve and Training, Sixth Naval District.

In winning this award for fiscal year 1963, NRRC 6-18 is the third company to be so honored; the other two winners were NRRC 13-6, Idaho Falls, Idaho, for fiscal year 1961; and NRRC 3-9, Upton, New York, for fiscal year 1962. The names of all of the winning companies are inscribed on a permanent plaque which is displayed prominently in the Office of Naval Research, Washington, D.C.

Pictured at the General Excellence Award ceremonies are, left to right, RADM L. R. Daspit, USN; Hon. James H. Wakelin, Jr.; CAPT W. D. McClurkin, USNR; and RADM L. D. Coates, USN.

Space-Science Seminar

The one-day Space-Science seminar, presented by Naval Reserve Research Company 9-8, St. Louis, Missouri, with the assistance of the McDonnell Aircraft Company, was held March 14, 1964, at the company plant. Approximately 140 Reserve officers were in attendance, of which 87 were active members of the following Naval Reserve Research companies: NRRC 8-1, New Orleans, Louisiana; NRRC 8-4, Houston, Texas; NRRC 9-4, Milwaukee, Wisconsin; NRRC 9-7, Lafayette, Indiana; the host unit, NRRC 9-8, St. Louis, Missouri; NRRC 9-10, Evanston, Illinois; NRRC 9-13, Des Moines, Iowa; NRRC 9-14, Madison, Wisconsin; NRRC 9-18, Decatur, Illinois; NRRC 9-23, Forest Park, Illinois; and NRRC 9-26, Colorado Springs, Colorado. The following officers from the ONR Branch Office, Chicago, were also in attendance: CAPT C. L.

Dillard, USN, Commanding Officer; CDR O. D. Hughes, USNR, Reserve Assistant; and LTJG E. G. Bartell, USNR, Assistant for Research Reserve.

The seminar was opened with a welcome by CAPT R. G. Freeman, USN, Bureau of Naval Weapons representative. Mr. C. M. Forsyth, Vice President of the McDonnell Company, presented an overview of activities of the company. Following his presentation, various members of his staff discussed in more detail specific projects presently underway: Mr. B. H. Collopy discussed the F-4B Phantom; Mr. R. S. Rippe presented a discussion of the two-man spacecraft development report on the Gemini mock-up; and Mr. E. Ziha demonstrated the Gemini docking simulator. A tour of the plant, which provided a view of the F-4 final assembly, followed these presentations. In the afternoon Mr. J. Davie made a presentation on automation, and the seminar was closed by Mr. R. Sohn, who outlined future plans of the company.

Members of NRRC 9-26, Colorado Springs, Colorado, were supplied transportation to the seminar by Commander, Naval Forces, Continental Air Defense Command, with CDR G. K. Ebbe, USN, in charge. Present also from Colorado Springs was CAPT D. McCampbell, USN, Deputy Chief for Programs, NORAD. CAPT McCampbell is a holder of the Congressional Medal of Honor.

Trying out the new two-man Gemini space capsule is CAPT F. L. Mickle, USNR, Training Officer, NRRC 9-26. Watching the dry run are other NRRC 9-26 members – left to right, LCDR A. S. Ormond, LCDR R. E. Ward, CDR M. F. Sanders, and CDR S. A. Oellerich.

Weekend Seminar Held at Houston, Texas

Members of Naval Reserve Research Company 8-4, Houston, Texas, sponsored the Second Annual National Aeronautics and Space Administration – Manned Spacecraft Center Seminar over the weekend of April 3-5. General arrangements were under the direction of LCDR M. G. Gugenheim, USNR, Commanding Officer of the Reserve company.

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Mr. Louie G. Richard of NASA's MSC (2nd from left), shows members of NRRC 8-4 features of the seat to be used in the Gemini spacecraft. Reserve officers, left to right, are LT Robert J. Ward, USNR, seminar coordinator; CDR Malcom E. Fisher, USNR, registration chairman; LCDR M. G. Gugenheim, Jr., USNR, Commanding Officer of NRRC 8-4.

CAPT D. J. Mooney, Jr., USNR, Special Assistant to the Chief of Naval Research for Research Reserve, opened the seminar Friday evening with a discussion of matters of current interest to Reserve officers, including future plans of the Research Reserve program.

The Saturday session, which was held at the Naval Reserve Training Center, consisted of briefings by authorities from NASA's Manned Spacecraft Center. The NASA aerospace engineers who spoke and the subjects of their talks were: Mr. Arthur H. Hinners, Chief, Flight Acceleration Branch, "Environmental Testing"; Mr. Herbert E. Smith, Flight Crew Support Division, "Simulation and Crew Training"; Mr. Eugene H. Brock, Chief, Computation and Data Reduction Division, "Computer Science"; Mr. Andre J. Meyer, Jr., Chief of Gemini Office of Project Administration, "Gemini Program"; Dr. John Billingham, Chief of Environmental Physiology Branch, "Life Support Systems"; Mr. John H. Boynton, Mission Analysis Division, "Appollo Program"; and Mr. Jerry L. Modisette, Chief, Radiation and Fields Branch, "Space Environments."

A tour and inspection of the Manned Spacecraft Center at Clear Lake was held on Sunday. The Reservists had an opportunity to view the test division, operations directorate, computer center, spacecraft simulator and astronaut trainer.

One hundred and seventy-five Reservists took advantage of this opportunity to acquaint themselves with the latest developments at NASA's MSC. These Reservists included not only members of local drilling units but also members of companies from neighboring states.

IN THIS ISSUE

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The Biological Sciences

A broad program of Naval biological research — ranging from investigations of tiny enzymes to studies of the entire human system — is being conducted in many university, industrial, and Navy laboratories. Highlights of the work, which are reported throughout this special issue, reveal the tremendous impact Navy interest in biology is having on the welfare of man.

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important Naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 740, Office of Naval Research, Washington, D.C., 20390. The magazine is listed for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.50 per year in the U.S. and Canada; $2.00 per year, foreign; $0.15 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

EDITOR: Richard D. Olson

NAVEXOS P-510

Symbolic of the sophistication of biological research of the 1960's is this experiment in aerobiology underway at the Navy Biological Laboratory. Wearing a protective plastic pressure suit, a technician readies special equipment for the exposure of experimental animals to infection by airborne microorganisms