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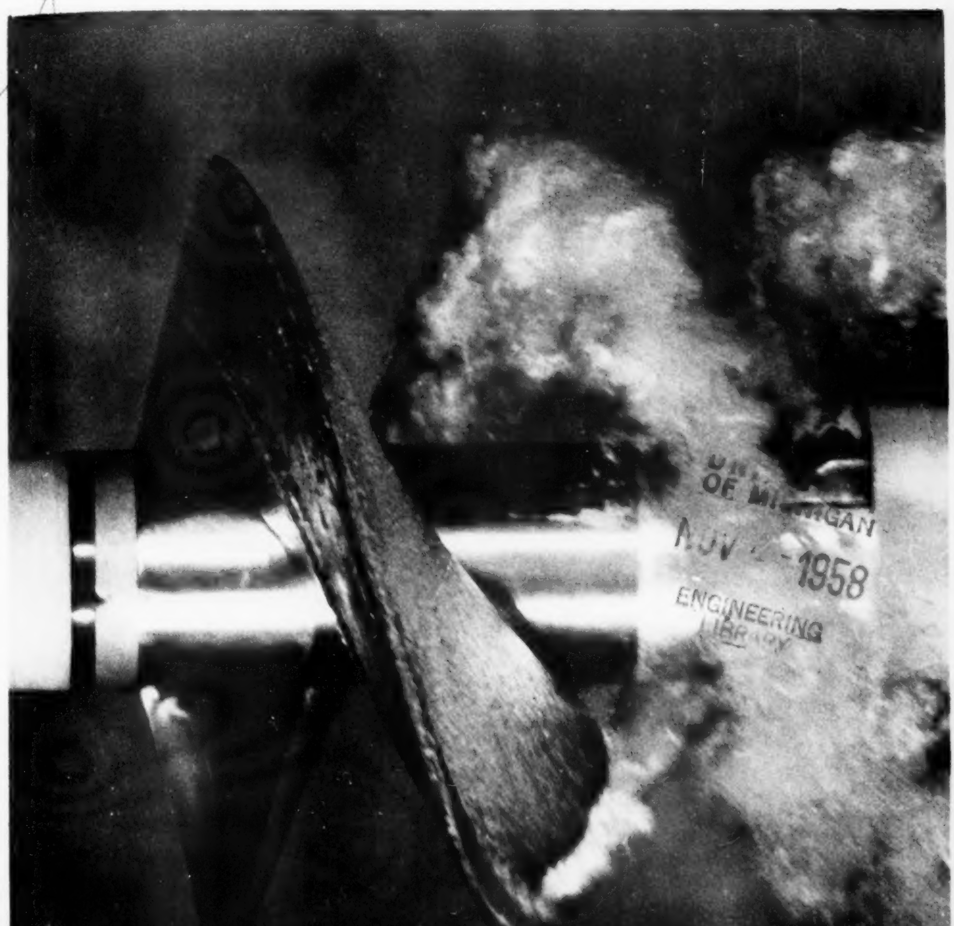
RESEARCH REVIEWS



DEPARTMENT OF THE NAVY
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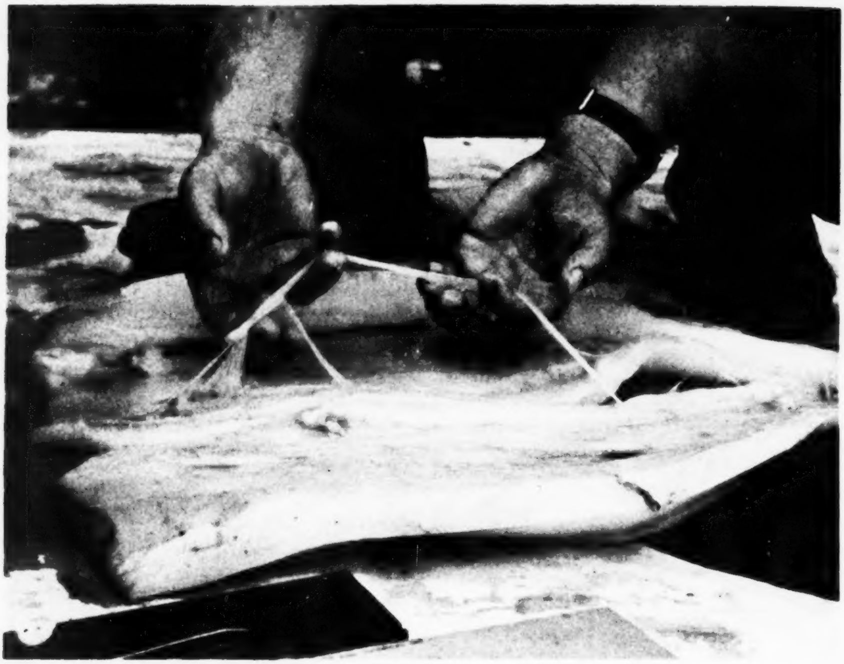

Dissected mantle of a large Chilean squid, showing giant fiber system. The stellate ganglion and its main nerve connections can be seen at left.

The Giant Squid and Nerve Research

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The nervous system has many functions. Well known to us are those having to do with the coordination of the body's activities, accomplished through the conduction of voluntary and involuntary messages, or "impulses," to the muscles, glands, blood vessels, heart, and other tissues. But there may also be others—not yet discovered—having to do with the formation of powerful hormones and chemical activators. Certain kinds of nerve cells are known to secrete hormones; a familiar example is the pituitary gland—actually a bit of specially differentiated nervous tissue—which secretes hormones that are essential to life.

Although much research has been done on the chemistry and physiology of nerves, our actual knowledge of the nature of the protein and other chemicals that constitute them is very small, smaller even than our knowledge of these elements in other tissues, such as muscle. When one considers that nervous and mental diseases are responsible for more hospital cases today than any other type of disease, it becomes clear that research at the basic level of molecular biology is badly needed.

In the quest for knowledge about nerves, the common squid has proved of great value because its nerve fibers are very large, ranging in diameter from 1/50 to 1/25 of an inch, as compared with from 1/10,000 to 1/1,000 of an inch for most animals. Large nerve fibers are useful to the squid because its body muscles must contract very rapidly to force seawater through its jet-like syphon. To obtain high velocity of conduction in the primitive type of nerve possessed by this animal, it is necessary for the fiber to have a very large diameter.

The difficulty encountered in the investigation of small nerve fibers is that one cannot be certain whether substances extracted are from the functioning nerve or from the surrounding connective tissue, blood vessels, or other material. But with the squid, one can be certain. By cutting the large fibers of this animal and extruding their contents, one can easily obtain the "pure" axoplasm (cytoplasm) of the neuron.

Because of their large size, squid nerve fibers were once thought to be blood vessels. In fact, it was not until early in this century that the suggestion was made that they might be nerve fibers instead of blood vessels. Proof of their true

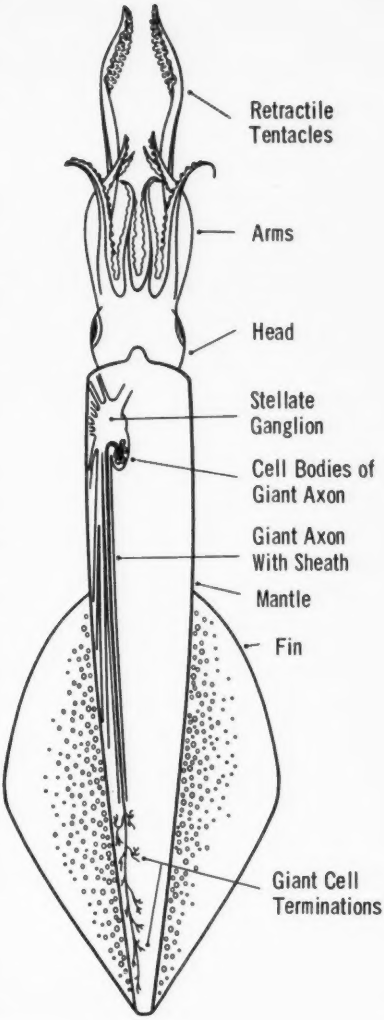
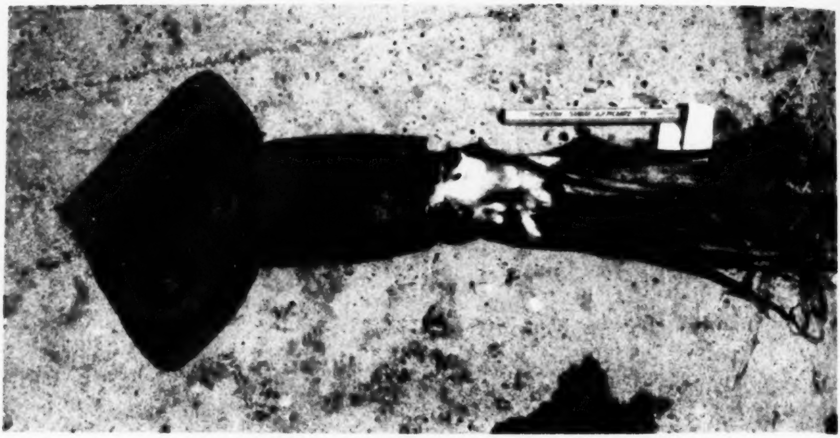


Diagram of common squid showing stellate ganglion and giant nerve fiber.

The M.I.T. squid truck.



Typical specimen of Chilean squid. The rule is 12 inches long.

identity came as a result of investigations conducted in the mid-thirties by Dr. J. Z. Young, then of Oxford, now head of the Anatomy Department of University College, London. Since that time, much research has been done on the giant nerve fibers of this animal, much of it at the Marine Biological Laboratory, Woods Hole, Mass. After World War II, this Laboratory developed (with ONR support) a specially equipped truck to being the squid from the shore to the Laboratory. A similar rig (see photograph on page 1) was adopted by a research group at M.I.T., and since 1950 it has operated almost daily during the summer between Sakonnet, Rhode Island, and M.I.T. More recently, an additional source of supply was opened up at Provincetown, Mass. The squid are dissected on the dock, and the extruded axoplasm is sent by air express to M.I.T. This procedure ir advantageous for work that does not require the use of live squid, as do experiments on the respiration and electrical activity of the living nerve.

From the M.I.T. investigations considerable information has been gathered on squid nerves and their constituents. Electron microscope examinations have been made, not only of the central core, or axon, with its "neurofibrils," but also of the thin mantle of living cells which surrounds the nerve fiber. Since the latter appears to stand between the core of the fiber and the external environment, it seemed urgent to examine the fine structure of the axon-sheath relationship. In addition, the chemical and gaseous metabolism of the sheath cells was investigated. This was done by slitting the fibers longitudinally and removing the axoplasm, then measuring the metabolism of the sheath cells by microvolumetric methods.

Over the last five years, several new substances have been isolated and identified in squid axoplasm. Among these are certain free amino acids which occur in extremely high concentrations, and a substance called isethionic acid (a close relative of taurine) which constitutes the chief anion of axoplasm.

In the spring of 1955 we began directing our attention to the large (6 to 8 feet long) squid which abound in the Humboldt current off the western coast of South America. With the financial aid of the Office of Naval Research, the National Institutes of Health, and the King Trust of Boston, and with the generous personal and financial aid of Mr. and Mrs. Louis E. Marron, an expedition was organized to secure and process squid in Chile.

Large numbers of squid were obtained by fishing off-shore, using lines fitted with several gang hooks. With the cooperation of Dr. P. Yanez, Director of the Marine Biological Station at Vina del Mar (a suburb of Valparaiso), a unit was set up at that station for procuring, processing, and shipping nerve material to Cambridge. Recently, arrangements were made to ship to Cambridge the chilled axoplasm from 200 to 300 large squid per week. This is equivalent to the amount of axoplasm obtained from 5,000 to 8,000 of our smaller New England squid. In addition, frozen dried axoplasm (in about one-gram lots) is sent regularly to our laboratory at M.I.T.

Dr. F. O. Schmitt (second from right), Mr. Louis E. Marron (extreme right), and assistants "fishing" for squid off Iquique, Chile.

From the frozen dried material we have already discovered and partly identified several new substances in the low molecular weight fraction. These include several new constituents in the acidic and the basic fractions and, most interestingly, at least five peptides which occur in the neutral fraction. The amino acids ornithine and citrulline, substances seldom found in proteins or in their hydrolytic cleavage products are found in several of them. Present also are strongly acidic groups which, since the peptides occur in the neutral fraction, suggest the possibility of a ring structure. These facts make it desirable to investigate the possibility that at least certain of the peptides may not have been derived from proteins but may have been synthesized as such. Certain pituitary hormones (for example, oxytocin, tyrocidin, and bacitracin) also belong to this class. Efforts are being made not only to determine the structure of each of these peptides, but also to obtain them in sufficient quantity to permit investigation of their possible biological properties.

Emphasis is being placed also on the isolation and characterization of the proteins of axoplasm, particularly those which compose the neurofibrils. For this investigation the axoplasm is extruded into chilled salt solution and sent in iced thermos jars to Santiago. There they are re-iced immediately before being sent by plane to the United States. Upon arrival at Miami, the jars are again iced and, after customs inspection, are forwarded to Boston, where they are brought immediately to the laboratory for chemical processing. In this way the temperature of the preparation is kept between 0^{o} and $5^{o}C.$, and the time elapsing between dissection of the squid in Chile and physicochemical fractionation of the axoplasm in Cambridge is usually less than 60 hours.

As soon as sufficient experience has been gained in the isolation of the proteins, it may be possible to complete the initial phases of the fractionation in Vina del Mar or Santiago, thus reducing the danger of deterioration of the preparation as well as the cost of its procurement.

Efforts are now being made, with squid caught near Provincetown, to determine if better results can be obtained if the axoplasm is processed immediately instead of after the unavoidable lapse of at least two days entailed in securing the material from Chile. Meanwhile, as much frozen-dried axoplasm as possible will continue to be collected in Chile so as to provide a source for the isolation and characterization of the low molecular weight fraction. As soon as individual constituents of special interest have been sufficiently well characterized, efforts will be made to obtain them or corresponding substances from the central nervous systems of mammals. It is believed that this will provide evidence of the universality of the constituents in nervous tissue. Of course, it will also lead to reductions in the expense of obtaining such substances, because a much larger source of supply can then be tapped.

Less Noise

The Navy recently took a big first step in overcoming one of the nation's biggest noise problems—the roar of jet aircraft. Relief to the eardrums will be provided by portable sound suppressors capable of reducing jet-engine noise prior to takeoff to a level comparable to that of conventional propeller-type aircraft. The suppressors will vary in size from 12 to 16 feet in length and from 6 to 12 feet in height, and they will weigh about 9,500 pounds each. They will be designed to fit against the exhausts of the jet engines.

Hurricane Buoys

A new method of locating hurricanes involving the use of anchored weather buoys is now being tested by the Bureau of Aeronautics in the central and western Gulf of Mexico. Under evaluation are methods of anchoring the buoys in the 12,000-foot-deep Gulf, transmission frequencies, seaworthiness, and reliability of the instrumentation. The buoys are designed to transmit for six months on a six-hour schedule without replacement of batteries. They are also engineered to withstand heavy seas.

If proved feasible, the new method will enable weathermen to detect hurricanes up to four days sooner than is now possible.

The Design of an Intelligent Automaton

Frank Rosenblatt
Cornell Aeronautical Laboratory, Inc.

An understanding of the physical mechanisms which underlie human experience and intelligence is unquestionably one of the greatest scientific challenges of our time. Although our interest in the nature of these processes is at least as old as that concerning many other questions which have confronted Western science and philosophy, we know no more about them than was known about physics in the pre-Newtonian period. We have some excellent descriptions of the phenomena, a number of interesting hypotheses, and a detailed knowledge about events in the nervous system. But we lack agreement on an integrated set of principles by which the functioning of the nervous system can be understood.

In spite of these facts there are several reasons for thinking that the problem might soon yield to theoretical investigation.

- The last few decades have seen the growth of electrophysiology and new advances in techniques of instrumentation. These have vastly improved our knowledge of the functioning of individual cells in the central nervous system.

- The development of digital computers and advanced mechanistic control systems which appear to perform in an "intelligent" manner have stimulated a large number of engineers and mathematicians to undertake, for the first time, serious studies of the methematical basis for thinking.

- The development of probability theory and the mathematics of stochastic processes provides new tools for the study of events in the nervous systems, where only the gross statistical organization is known.

In July 1957, the Information Systems Branch of the Office of Naval Research began supporting Project PARA (Perceiving and Recognizing Automaton) at the Cornell Aeronautical Laboratory. This project, which had been in progress at the Laboratory for more than a year, was concerned with the application of probability theory to the problem of memory and perception. Specifically, its aim was to design a physical system which could recognize different stimuli in a complex sensory environment and spontaneously form meaningful classifications of them. In undertaking the investigation the point of view was assumed that the organization of the sensory world of light, sound, temperature, pressure, and other elements is learned, in contrast to being immediately evident to the perceiving system. In other words, an organism equipped with visual apparatus and exposed to an environment of squares and circles would not be able to tell these forms apart unless it had learned to do so.

For the engineer or mathematician attempting to construct a system which will "learn to perceive," the principal difficulty is achieving "perceptual generalization." This is concerned with the way the perceiving system is able to recognize any member of a class of forms (for example, a man in any posture, angular orientation, or costume) even if it has not seen the particular form before. If the form (say a square) always appeared in the same position, angular orientation, and size, it would be a relatively simple matter to distinguish it, for it could be matched against such a form in a library of stored images. A physical system designed to function in this way would be extremely cumbersome, however, and would leave unsolved the more baffling problem of how non-rigid forms, and the projections of three-dimensional objects, such as a man or an ocean wave, could be recognized. Of course this problem relates to other sensory modalities as well; speech recognition, for example, is of particular interest.

Let us consider some features of the biological system which performs perceptual generalization with such amazing versatility. Figure 1a shows the basic organization of a mammalian brain. Note that the connections from the retina to the visual projection area are organized in such a way as to provide a sort of map of the visual field in the brain. Beyond this point, however, the connections appear to become increasingly random and "disorganized," so that in the association areas (which appear to be mainly responsible for learning and memory) it is no longer possible to relate a particular point to some specific location in the retina. The association cells of the brain are likely to respond to any one of a vast number of different stimuli, which may not even involve the same sensory modality, such as vision or hearing. Inputs to the association area tend to arrive at the surface layers of cells, while outputs emanate from the deeper layers. Note that there are feedback circuits between these layers, which are so organized that a cell in a deeper layer (which may send fibers to some particular part of the motor cortex) is more likely to feed back to the same outer-layer cells which caused its activity than to cells which take no part in its stimulation. When impulses arrive at the motor cortex, an intelligible order appears to have been restored. Thus, by means of the confusion of connections through the association area the brain has somehow "recognized" the visual stimulus and developed an output signal which is constrained to particular, relevant channels.

The big mystery is how the apparently unintelligible tangle of connections in the association area manages to record the fact that a beam of light or a landscape is actually seen, or a voice heard, and how the impulses from the stimulus are interpreted in such a manner as to enable the organism to select the appropriate response channel, and no other.

In Figure 1b is shown the organization of the perceptron—a man-made system whose "anatomy" is known to the last detail. Although this system now exists only in concept, it has been shown to be capable of the same functions of sensing, recognition, retention, and response selection as its biological counterpart. It consists of interconnected units capable of responding to appropriate signals, or impulses, and of delivering output signals analogous in many ways to nerve impulses.

While the basic organization of the perceptron is similar to that of a biological system, certain differences and simplifications should

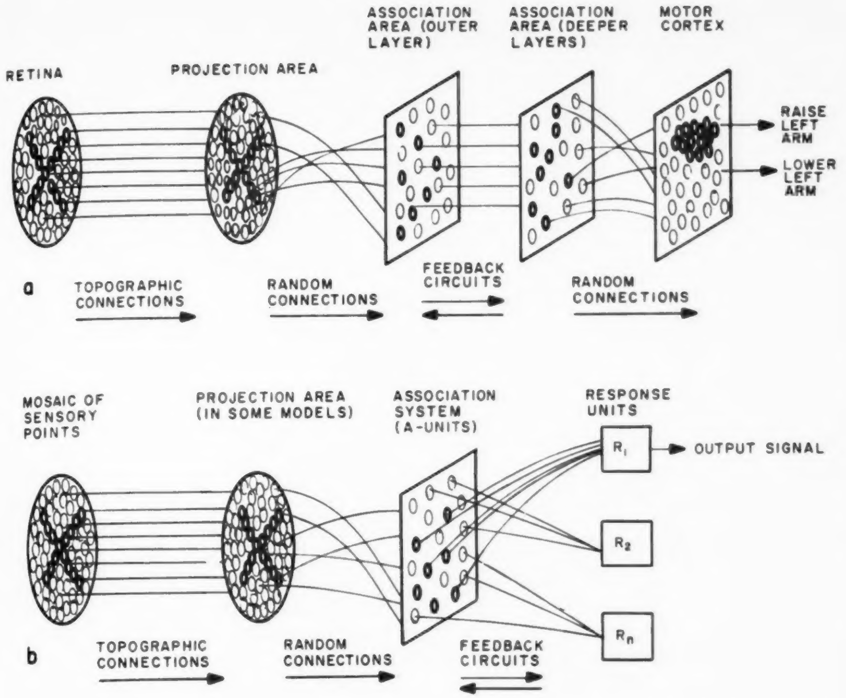


Figure 1--Comparison of the organization of a biological brain (a) and a perceptron (b). Dark areas indicate active cells responding to letter "X".

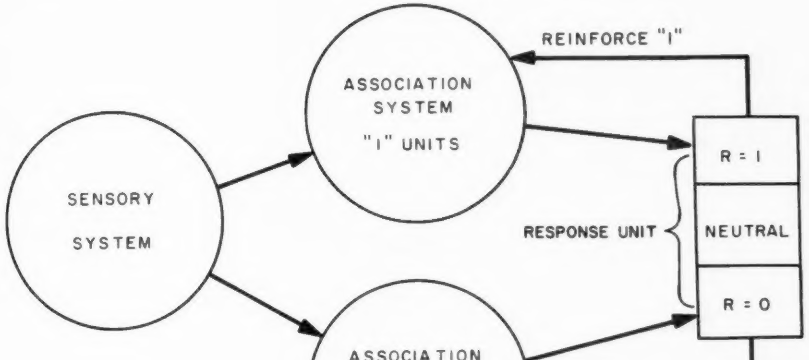


Figure 2--Detailed organization of a simple perceptron. This machine is capable of only two types of responses, R=1 and R=0. The association system contains sets of units, labeled "1" and "0", which give rise to the different responses. Arrows indicate direction of signals.

be noted. For one thing, the projection area, which is found in all advanced biological systems, is not essential for the perceptron, although it does serve important functions in some models. In simplified models, the "retinal" points are connected directly to randomly selected units in the association system. These association units (A-units) are transducers which have the peculiar property of increasing in value when activated. Second, the units effecting the responses (R-units) are typically binary devices which are either "on," "off," or in a "neutral" state. Third, the responses of the perceptron combine the functions of the second association layer with those of the motor cortex.

When a perceptron is first exposed to stimuli, its responses will be random and thus will have no meaning. As time goes on, however, changes which take place in the association system will cause responses to well differentiated classes of forms, such as squares, triangles, clouds, trees, and people. These changes, which occur whenever a cell is active, cause the cell to gain in "strength." Such gains act as "memory traces." Similar changes serving the same purpose are believed to take place in the nervous system.

The way in which these gains in strength occur is illustrated in Figure 2, a diagram of a very simple perceptron. The association system is divided into two parts, one tending to activate the response labeled R=1, the other tending to activate the response R=0. The response R=1 causes a feedback signal to be transmitted to units in the part of the association system giving rise to that response, while R=0 causes a feedback signal to go to those units giving rise to it. These feedback signals multiply the rate of activity of the A-units which receive them. Thus, the signals not only increase the slight original tendency of those units to maintain a particular response (R=1) for example), they also cause those units to gain in value at a greater rate than those giving rise to the other response (R=0). The actual value of the A-units is given as the solution of a differential equation, not treated here.

Now, let's experiment with this perceptron.

In Figure 3a we see what happens when we place the image of a square in front of the sensory system. Note that the stimulus affects an equal number of units in each part of the association system. (The areas occupied by these units are indicated by small open and closed circles.) It is assumed that either by accident or due to "forcing" by the experimenter the response R=1 occurs. Consequently, the set of units giving rise to that response is reinforced at a rapid rate. It is clear, therefore, that if we were again to show the perceptron this square, the signal from the units giving rise to the response R=1 would be stronger than that from the units giving rise to the response R=0. Thus the response R=1 would almost certainly be repeated.

In Figure 3b a second stimulus is shown to the perceptron, which still carries the residual effects of its previous experience. This time the stimulus is a circle, and it is assumed that the response R=0 occurs, either spontaneously or due to forcing by the experimenter. The added reinforcement is shown by the solid area in that part of the association

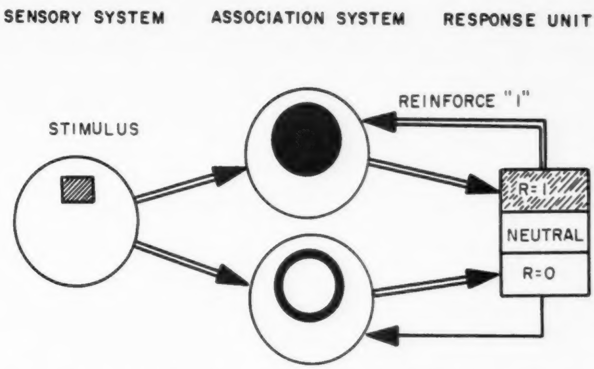
Figure 3--Some typical learning experiments made with a perceptron. Double lines indicate active connections. Areas covered by shading and hatching, and those enclosed by heavy outline, are active. Key to symbols appearing in association system is given below.

A group of A-units whose value is being increased as a result of reinforcement.

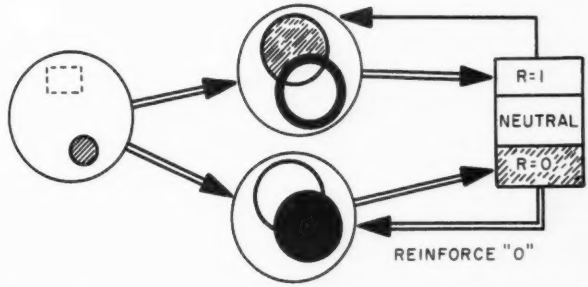
A group of A-units which is being stimulated, but not strongly enough to effect reinforcement.

A group of A-units having a high value owing to reinforcement during a previous experience.

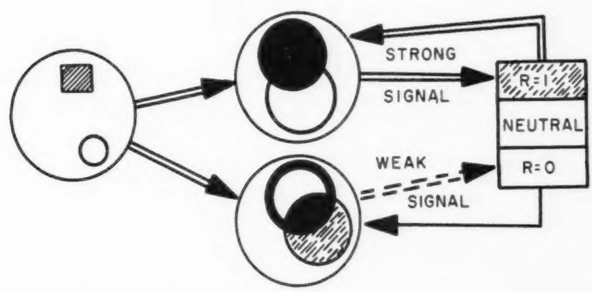
A group of A-units which was stimulated during a previous experience, but not strongly enough to effect reinforcement.



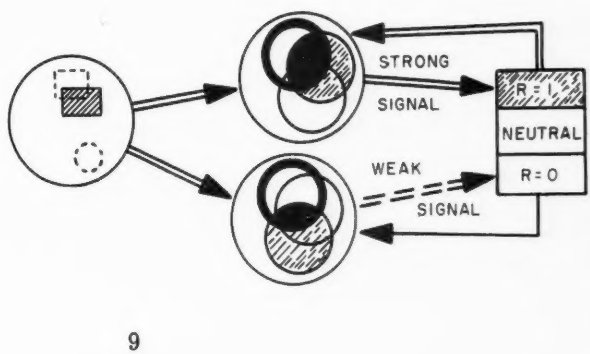
a A square is placed in front of sensory system.



b Then a circle.



c The original square is repeated



d Finally, a square selected at random is shown to sensory system, but in a different position from previous square.

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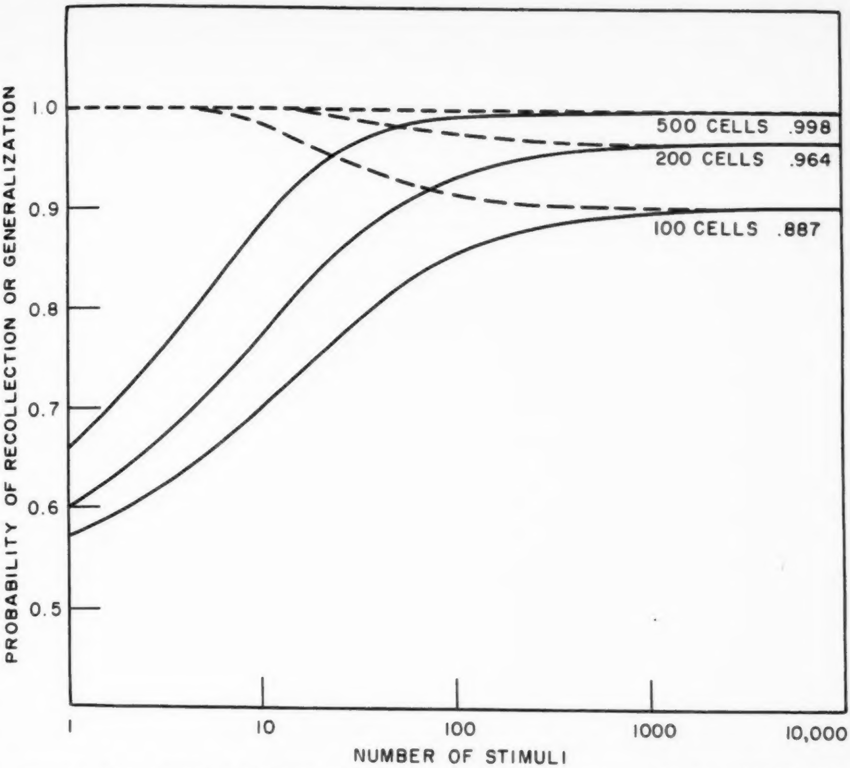
system responding to the circle. The question now is will the perceptron still give the "appropriate" response (R=1) if it is again shown the original square? This experiment is illustrated in Figure 3c. While some fraction of the reinforcement due to the circle is expected to carry over to the square, due to the intersections of the responding sets of A-units, the total reinforcement picked up by the units in that part of the association system giving rise to the response R=1 is greater than that picked up by the units giving rise to the response R=0, so that the appropriate response is expected to occur.

But the experiment shown in Figure 3c is, in a sense, a trivial one, since we obviously cannot afford to pre-train the perceptron to respond appropriately each time we show it a new square or circle. The critical question is asked in Figure 3d: What happens if we now show the machine a square which may or may not coincide in size and position with the square previously seen? Will it still tend to prefer the correct response, or will its response be entirely random? As indicated in the figure, the new square is likely to activate the set of A-units having the most members in common with the sets of A-units which have responded to other squares. While some reinforcement is expected to be picked up from both the previous square reinforcement and the previous circle reinforcement, the total reinforcement (solid area) in that part of the association system giving rise to the response R=1 is greater, and the appropriate response should occur.

It should be emphasized that the condition shown in Figure 3d can easily be reversed if the perceptron has been "trained" with only a single square and circle before testing. In order to make the perceptron's performance reliable, it must first see a sample of squares (say 100 or 200 in various positions and angular orientations) and a sample of circles, being forced by the experimenter to give the appropriate response to each.

The predicted performance of perceptrons having 100, 200, and 500 association cells in each part of the association system giving rise to a particular response is shown in Figure 4. The broken curves indicate the probability that the perceptron will give the correct response if it is shown, as a test figure, one of the identical stimuli that were used during the "training period," as in Figure 3b. The solid curves indicate the probability that the perceptron will give the appropriate response for any member of the stimulus class, picked at random, as illustrated in Figure 3d. A perceptron having 100 cells in each of the two parts of the association system and which has been trained with 100 squares and 100 circles should, theoretically, have a probability of about 0.92 of giving the correct response if it is shown one of the squares or circles that it has seen before. And it should have a probability of about 0.85 of giving the correct response to a square or circle which it may never have seen before. If learning experience is continued indefinitely, these probabilities converge to the same limit—0.887. This means that, in the limit, it makes no difference whether the perceptron has seen the particular stimulus before or not; it does equally well in either case. The mathematical proof of this statement constitutes proof of the machine's ability to form perceptual generalizations.



Curves showing the ability of three typical perceptrons to recollect and generalize. One of these perceptrons has 100 cells in each part of the association system giving rise to a particular response; another has 200 cells; and the third has 500 cells. Solid-line curves denote the perceptron's capacity to generalize; broken-line curves, its capacity to recollect.

As the number of association units in the perceptron is increased, the probability of correct performance increases. From Figure 4 it is clear that with an amazingly small number of units—as measured against the biological standard of a human brain, with its 10^{10} nerve cells—the perceptron is capable of highly sophisticated activity. This fact was well established, theoretically, by the fall of 1957. At that time a simulation program was started, on an IBM 704 computer, to find out how well the theory would hold up in practice. While the 704 cannot possibly rival the perceptron in speed and flexibility or performance, it is possible, by examining each connection and A-unit of the system in turn and computing the appropriate signals which would be transmitted in a physical network, to calculate the performance of a perceptron in response to a series of visual forms. A large number of such experiments were made, and virtually all main predictions of the theory were substantiated.

Nevertheless, one outstanding theoretical hurdle remained to be dealt with. While it is possible that a biological organism must "learn to perceive" in the sense indicated above, the important thing that characterizes biological systems is that they learn spontaneously, without a teacher. The perceptron, as described to this point, has an impressive capacity for learning and remembering concepts which are imposed on it by an experimenter; but as long as this is the only way in which it can learn, we have accomplished nothing more than the design of a particularly versatile recording device, capable of comparing new stimulus patterns with previously recorded prototypes and placing each stimulus in an appropriate class. But the classes themselves—the basic concepts with which the perceptron operates—would all be attributable to the human operator responsible for the machine's training.

In an approach to this probelm, the system was so modified that the A-units no longer responded only to those input signals which exceeded a given threshold (in the manner of biological nerve cells). Instead, their output was proportional in frequency or amplitude to the intensity of the input signal. This modification did not drastically alter the performance of the system, but it did permit a reformulation of the mathematical theory. This finally enabled us to answer the question of whether the perceptron could arrive at perceptual concepts spontaneously.

The answer is yes, provided that another modification—a slight, seemingly trivial one—is made. The change required is simply that the values of the A-units be allowed to decay at a rate proportional to their magnitude. The exponential decay which is thus introduced is characteristic of practically all biological conditions which need the continued application of energy for their maintenance. The effect of introducing the decay component is that instead of growing indefinitely, the values of the A-units tend toward a terminal equilibrium condition, which depends on the input signals and activity of the units. The characteristics of this class of perceptron are described in an "existence theorem," which is paraphrased below:

> There exists a class of perceptrons which, as time goes to infinity, tend toward a statistically stationary state, such that for each binary response (R=1, 0) the environment will be divided into two stimulus classes, such that all members of one class elicit the response R=1 and all members of the other class elicit the response R=0. The dichotomy will be one which tends to minimize the net error probability for the established responses. In general, a dichotomy which meets this condition is characterized by a substantial similarity between stimuli of the same class and a marked dissimilarity between stimuli of opposite classes.

Such a perceptron will form its own concepts, and these will tend to be "meaningful," that is, they will represent an organization of the environment on the basis of similarity and dissimilarity, in the sense these terms are generally used.

Within the reasonably near future it is hoped that a working model of this machine will be completed. The economical design of the model presents several difficult problems, but considerable headway has already been made in developing suitable components. That the effort shows much promise is indicated by this brief review of the main points which set the perceptron apart from other theoretical "brain models" that have been conceived:

● It is an economical system in the sense that it can operate successfully with a relatively small number of units.

● It is not designed to rigid logical specifications; thus the failure of a few units is not likely to cause a breakdown of the system.

● It does not recognize forms by matching them against a stored inventory of similar images or performing a mathematical analysis of characteristics. The recognition is direct and essentially instantaneous, since the "memory" is in the form of new pathways through the system, rather than in the form of a coded representation of the original stimuli.

● It does not violate any known information about the central nervous system. Its size, the logic of its connections, the degree of reliability required of individual units, the permissible random variation in its "wiring diagram," and the kinds of signals employed are all consistent with current anatomical and physiological data or the latest assumptions about these characteristics.

● It is the first system which has been proved capable of spontaneously organizing, conceptualizing, and symbolizing its environment along lines which bear some definite relationship to the human idea of "similarity." It does these things without human training or control.

The ultimate applications of the perceptron—if indeed such a system can be built economically—are difficult to predict. But it is fun to speculate what they might be. In principle, it could read both print and script and could respond to verbal commands as well. The possibility also exists that it could automatically translate words spoken in one language into written or spoken words in another language. Eventually, the coupling of a perceptron with a conventional digital computer might carry us over the remaining obstacles of grammar and syntax. In the distant future, automatic navigation and landing systems, automatic pilots, and various recognition systems might make use of the perceptron. The application of such a system to library research and data gathering for scientific purposes is also a possibility. Finally, coming at a time when the scientific exploration of outer space is just beginning, it might serve as a robot passenger capable of describing and classifying new environments, thus making possible the completion of many useful explorations under difficult environmental conditions.

Such speculation, however, takes us far beyond our immediate objectives. We must first extend the basic theory of the perceptron, which is still in its infancy. We must lower the cost of an A-unit by at least two orders of magnitude from the units which can now be built with conventional components. We must study the behavior of laboratory models in environments ranging from those consisting of simple geometrical forms to those which involve such complex problems as the discrimination of speech and human faces. And we must develop sensing devices suitable for providing visual and auditory inputs to the system.

As the perceptron program is a major undertaking having long-range goals, we should not expect practical applications soon. Nevertheless, whether the next stage requires two years or ten, it appears that with the perceptron a new field or research—relating both to engineering and to the theory of intelligent systems—is coming of age.

Links in a Vital Chain

"The free interchange of ideas among the scientists of the world is a subtle but important contributor to the advancement of scientific research. It is difficult to effect, however, requiring a lot of hard, painstaking work by many capable men. . . ."

So began an article published in the May 1957 issue of Research Reviews entitled "On the Trail of Science in Europe," by D. M. Gates, then Deputy Scientific Director of ONR's London Branch Office (ONRL). The article went on to describe how a small staff of ONR scientists based in London go about gathering information on research developments in Europe in order to keep the Chief of Naval Research, the Department of the Navy, and other government agencies and government contractors informed of scientific progress in Europe, and to keep scientists of Europe informed of progress in America.

Since the article was written, 18 months have passed, many of them packed with important scientific achievements both here and abroad. These events have impressed on us as never before the value of scientific liaison across the Atlantic. Thus, it is fitting that we be reminded that ONRL continues to form a vital communications link between scientific institutions of the two continents.

Who are the men doing this important but little publicized work? They may be professors on leave from American colleges or scientific specialists on loan from ONR or other government scientific agencies. About half of the staff is renewed each year, making it possible to continually change the coverage within the scientific spectrum. Thus, the ONRL scientists now visiting the laboratories of Europe constitute a different crew from that which preceded them 18 months ago.

To indicate the nature of the work now going on out of ONRL, and to throw some light on the capabilities and background of the men doing it, the following information concerning the branch office's staff members is presented:

NAVAL COMMAND

NAME	POSITION	FIELDS OF SPECIALIZATION	INSTITUTION PREVIOUSLY REPRESENTED
Bennett, CAPT Bradley F., USN	Commanding Officer Assistant Naval Attache for Research	Nuclear physics Naval construction Metallurgy Health physics	
Anderson, CDR John B., Jr., USN	Executive Officer Naval Science Liaison Officer Mutual Weapons Development Program (MWDP) Officer	Aeronautical engineering	

NAVAL COMMAND (Continued)

NAME	POSITION	FIELDS OF SPECIALIZATION	INSTITUTION PREVIOUSLY REPRESENTED
Branscome, CDR James R., USN	Naval Science Liaison Officer MWDP Projects Officer	Armaments Undersea warfare Countermeasures	
Jerbert, CDR Arthur G., USN	Naval Science Liaison Officer MWDP Projects Officer	Pro submarine weapons Undersea warfare	
Palmer, CDR Charles A., Jr., USN	Naval Science Liaison Officer Stationed at Stockholm, Sweden	Upper atmosphere research	
Sherwin, CDR Sidney A., Jr., USN	BuShips Representative Naval Science Liaison Officer MWDP Projects Officer	Electronics (Ship and shore)	
Young, CDR Robert J., USN	Naval Science Liaison Officer MWDP Projects Officer	Airborne electronics Aeronautical engineering	
Spiel, LCDR Paul L., USN	Administrative and Personnel Officer		

SCIENTIFIC STAFF (for academic year 1958-59)

NAME	POSITION	FIELDS OF SPECIALIZATION	INSTITUTION PREVIOUSLY REPRESENTED
Page, Dr. Howard E.	Scientific Director	Human engineering Social psychology Personnel and training	ONR, Washington, D. C.
Dietz, Dr. Robert S.	Deputy Scientific Director IGY Coordinator	Earth sciences Diving Marine Geology	Naval Electronics Laboratory, San Diego, Calif.
Blachman, Dr. Nelson M.	Scientific Liaison Officer	Electronic physics Communication theory Computers	Electronics Defense Laboratory, Mountain View, Calif.
Farnsworth, CDR Dean, MSC, USNR	Scientific Liaison Officer	Psychology of vision Physiological psychology Spectrophotometry Illumination	USN Medical Research Laboratory, New London, Conn.

SCIENTIFIC STAFF (Continued)

NAME	POSITION	FIELDS OF SPECIALIZATION	INSTITUTION PREVIOUSLY REPRESENTED
Garabedian, Dr. Paul R.	Scientific Liaison Officer	Analysis Fluid mechanics Differential equations	Stanford University, Palo Alto, Calif.
Gordon, Dr. Alvin S.	Scientific Liaison Officer	Reaction kinetics Explosives Rocket fuels Propulsion	Naval Ordnance Test Station, China Lake, Calif.
Hadidian, Dr. Zareh	Scientific Liaison Officer	Enzyme systems Physiology Pharmacology	Medical School, Tufts University, Boston, Mass.
Irvine, Dr. John W.	Scientific Liaison Officer	Radiochemistry Inorganic chemistry Applied radioactivity	M.I.T., Cambridge, Mass.
Jonassen, Dr. Hans B.	Scientific Liaison Officer	Inorganic chemistry Metal organic complexes Polymers	Tulane University, New Orleans, La.
Ludwick, CAPT William E., DC, USN	Dental Liaison Officer	Preventive dentistry Tissue preservation and transplantation	ONR, Washington, D. C.
O'Donoghue, CAPT John A., MC, USN	Medical Liaison Officer	Radiobiology Health physics	BuMed, Washington, D. C.
Saaty, Dr. Thomas L.	Scientific Liaison Officer	Operations research Information theory Mathematics	EXOS, Navy Dept., Washington, D. C.
Sargent, Dr. Marston C.	Scientific Liaison Officer	Marine biology Oceanography Botany	Scripps Institution of Oceanography, LaJolla, Calif.
Tulin, Mr. Marshall P.	Scientific Liaison Officer	Hydrodynamics Aerodynamics Solid mechanics	ONR, Washington, D. C.
Webber, Dr. Robert T.	Scientific Liaison Officer	Solid state physics Magnetism Cryogenics	NRL, Washington, D. C.
Weertman, Dr. Johannes	Scientific Liaison Officer	Physical metallurgy Rheology Internal friction in metals	NRL, Washington, D. C.
Zaffarano, Dr. Daniel J.	Scientific Liaison Officer	Low energy Nuclear instrumentation Nuclear spectroscopy	Iowa State College Ames, Iowa

Adapting Training Methods to Trainee Aptitudes

Harold A. Edgerton
Richardson, Bellows, Henry & Company, Inc.
New York

For many years now the military services have been making good use of the fact that (a) people are different and (b) the differences can be measured. All of the services use intelligence tests and interest and aptitude tests to classify new recruits for various kinds of training. This is good as far as it goes. But can the principle be advantageously extended? For example, there is one kind of measurable difference which might be put to practical use after the recruit has received his training assignment. This generally overlooked difference is brought to light by the question, how does the individual trainee learn best?

It should not come as a surprise that trainees with different aptitudes may learn better and faster by different methods. For example, some may get more out of reading while others may get more out of listening to lectures. The surprising thing is that little attempt has been made to put this possibility to the test of practical usefulness.

The benefits can be very great. In a time of national emergency, for example, there may be a need to quickly train thousands of radar technicians. Is there any reason why the trainees must all go through exactly the same course of instruction? That is, even after intelligence, interest, and aptitude test scores have been used to select those who should be trained as radar technicians, could not the different patterns among such scores be used to separate the trainees for assignment to several different schools or courses, each organized to make the most of a different set of learning abilities?

This possibility was recently put to test in an experiment conducted by Richardson, Bellows, Henry and Company for the Office of Naval Research. The experiment was performed in the AN-P Course given at the Naval Air Technical Training Center, NAS, Jacksonville. Essentially, the purpose of this school is to give refresher training to Marine Corps airmen just before they are sent to their Class A schools for training for specific rates. The course included such subjects as mathematics, electricity, mechanics, and introduction to aviation.

For the experiment, the 169 trainees entering the school in the first two weeks of July 1957 were taught as completely as possible by the rote memory method, while the 158 trainees entering in the second two weeks of July were taught by the theory, or "why," method, using reasoning or explanation as an approach to the course materials. The purpose of the experiment was to find out if further analysis of the aptitude tests routinely given before the course might reveal different patterns of aptitudes for success in relation to the two different teaching methods. Success was to be measured by results on the regular examinations given in the course.

Various precautions were taken to insure the purity of the experiment. For example, it was determined that the members of the rote and "why" classes were similar in military background. It was also determined that their aptitude test results, including intelligence, were generally alike insofar as total test scores were concerned. Verification was also made of the fact that the two groups were really exposed to significant differences in teaching method. Thus, if an observer were to have visited each class every day he would have been able to record an average of 1.3 "why" explanations per hour given to the rote group, as compared with 4.2 for the why group. On the other hand, questionnaires on opinions about the course, administered to the trainees at the end of the course, showed that they were not consciously aware of the difference. The difference could not, therefore, be considered excessive.

The aptitude tests used were as follows:

- The Chicago Test of Primary Mental Abilities, with subtests on the number, verbal, space, word fluency, reasoning, and rote memory factors.
- A Marine Corps General Classification Test, with subtests on reading and vocabulary, arithmetic reasoning, arithmetic computation, and pattern analysis.
- The Naval Mechanical Comprehension Test.
- The Navy Vocational Interest Inventory, with subscores for a wide variety of military occupations.

The major course subjects applied to the study include mathematics, electricity, and aircraft familiarization.

The results of the experiment are as follows:

- The verbal factor of the Chicago Test of Primary Mental Abilities and the total score of the Marine Corps GCT contribute more to the examination scores on mathematics and electricity for the why method.
- The reasoning factor of the Primary Mental Abilities Test and the reading and vocabulary subtest of the GCT contribute more to the examination scores on mathematics and electricity for the rote method.
- Trainees who got high scores for memory on the Test of Primary Mental Abilities did not respond well to examination questions on aircraft familiarization when they were prepared for the examination by the "why" method of teaching. However, the memory factor of the Test of Primary Mental Abilities was found to be unrelated to examination results for rote teaching of this subject.
- High scores for word fluency on the Test of Primary Mental Abilities corresponded with high examination scores by those

taught aircraft familiarization by rote, but they bore little relation to the examination scores of those taught this subject by the "why" method.

- High scores for reading and vocabulary and for pattern analysis on GCT subtests corresponded with high examination scores by those taught aircraft familiarization by the "why" method but had little relationship with the examination scores of those taught this subject by the rote method.

- Scores on the Navy Interest Tests show that interests in mechanical activities are associated with high examination scores obtained by trainees taught by the rote method, while interests in electronic, clerical, and verbal activities are more likely to be associated with high examination scores obtained by those taught by the "why" method.

The major conclusion of the study was that the principle in question had been successfully demonstrated. That is, there is a relationship between trainee aptitude patterns and trainee response to different teaching methods in the same subject matter.

The degree of relationship will undoubtedly vary among different trainee groups taking different subject-matter courses. However, the practicality of determining this relationship, and putting it to use, is enhanced by the fact that the necessary data are readily available. All that is required, in effect, is a special re-analysis of the aptitude tests used for purposes of classification—against examination scores for a number of different classes.

The practicality of this procedure is also enhanced by the fact that many instructors have preferences for particular teaching methods and are likely to do a better job with the method of their choice. Variation in method permits some such choices to be made.

Finally, and as a word of caution, it should be noted that the degree of relationship will probably vary among different trainee-subject matter groups. For some groups the relationship will be too small for practical application. But for many others it will undoubtedly be large enough to be useful. In the latter case, the application of the principles discussed here will have an important bearing on the effectiveness of the training involved.

Dr. Harve J. Carlson has been appointed Head of the Microbiology Branch of ONR. He comes to the post from the ONR Branch Office in London. CAPT L. A. Barnes, Acting Head of the Branch for the past year, has been named Head of the Department of Bacteriology at the Naval Medical School, National Medical Center, Bethesda, Md.

Organizations with which Dr. Carlson has worked, in addition to the Navy, include the Idaho State Department of Health and Western Reserve University. At the latter, he conducted research on antibiotics and airborne infections. He holds the rank of Commander in the Naval Reserve.

On the Naval Research Reserve

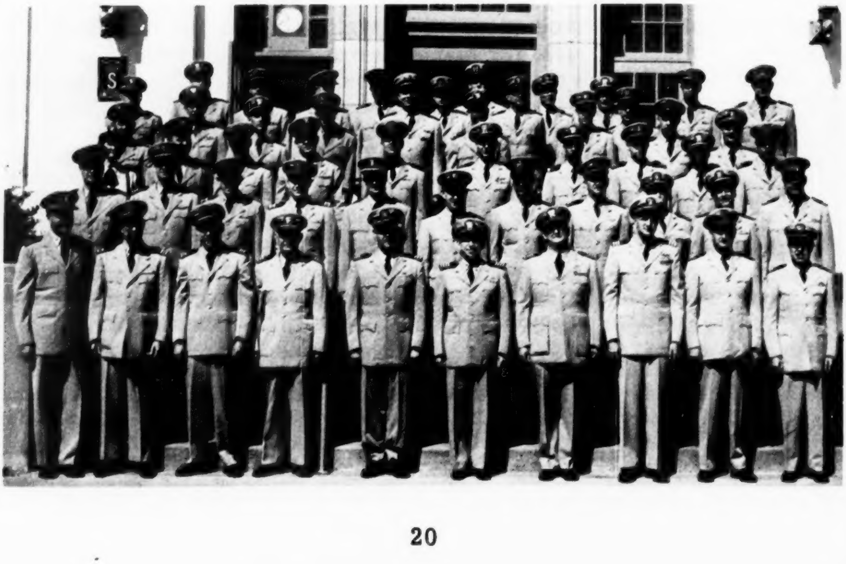
Seminar Held at NRL

Fifty Naval Reserve officers reported to the U. S. Naval Research Laboratory on August 18 to attend a two-week Research Reserve seminar. The officers were selected from reserve research units throughout the country because of their scientific backgrounds. The seminar, sixth of its kind, was the largest ever held at the Laboratory. Its mission was to familiarize Naval Reserve officers with the Laboratory's contributions to national preparedness. Information on research in each of the physical sciences was included.

The seminar was opened by CAPT Peter H. Horn, USN, Director of NRL, who introduced RADM Rawson Bennett, USN, Chief of Naval Research.

Naval Reserve Research Company 5-9, headquartered at NRL, was host at a luncheon on the opening day. LCDR C. F. White, USNR, executive officer of NRRC 5-9 and also an NRL employee, introduced the guest speaker, CAPT J. P. Aymond, USN, Special Assistant to the Chief of Naval Research for Research Reserve.

Each research division of the Laboratory arranged talks, demonstrations, and tours for the reserve officers. These included Nucleonics, Chemistry, Sound, Radar, Applications Research, Mechanics, Electronics, Metallurgy, Atmosphere and Astrophysics, Optics, Radio, Radiation, Solid State, and Project VANGUARD. In addition, the Engineering Services Division gave the reservists a view of the services they render. One day was spent on a field trip to the Chesapeake Bay Annex, which is located about 40 miles from Washington on the Chesapeake Bay. On this trip reservists saw some of the practical applications of NRL research. The officers also toured the VANGUARD Computing Center and the Naval Observatory.



"Naval War College Review"

Individual reservists of the Navy and Marine Corps Ready and Standby Reserves in the grade of lieutenant commander (major) are eligible to receive the Naval War College publication "Naval War College Review" gratis upon request.

This publication was established in 1948 under the title "Information Service for Officers" and assumed its present title in 1952. Its purpose is to provide officers of the Armed Forces selected material that has been presented to resident students of the Naval War College. It is published monthly, ten issues per academic year, September through June.

Subscription applications should be addressed to the Head of the Correspondence Courses Department, Naval War College, Newport, Rhode Island. They should include the following information: grade, service, designator, reserve status (ready or standby), and whether request is made for a new subscription or for a renewal. Officers desiring to renew their subscriptions must reapply each year.

Activation Dates of Research Reserve Companies

A search of the records in the ONR Branch Office in San Francisco has revealed the activation dates of the presently established Research Reserve companies in the Twelfth and Thirteenth Naval Districts. These companies and the dates they were formed are as follows:

TWELFTH NAVAL DISTRICT

12-1 (San Francisco)	August 6, 1948
*12-2 (Livermore)	November 2, 1955
12-3 (Stanford)	December 6, 1948
12-4 (Fresno)	January 27, 1949
12-5 (Berkeley)	April 1, 1949
12-6 (Davis)	August 8, 1949
12-7 (Logan)	June 4, 1953
12-8 (Monterey)	February 20, 1952

THIRTEENTH NAVAL DISTRICT

13-1 (Seattle)	December 13, 1948
13-2 (Richland)	December 15, 1948
13-3 (Pullman)	March 14, 1949
13-4 (Portland)	April 18, 1949
13-5 (Corvallis)	January 27, 1949
13-6 (Idaho Falls)	April 20, 1953

*Actually NRRC 12-2 was first activated on August 2, 1948, but was subsequently disestablished in 1950 when the majority of the unit volunteered for and were ordered to active duty.

Roster of Research Reserve Companies

ALABAMA

AUBURN
NRRC 6-2
Room 318, Ross Chemistry Laboratory
Alabama Polytechnic Institute
1900, 1st and 3rd Monday
LCDR James E. Land

HUNTSVILLE
NRRC 6-17
Naval Reserve Training Facility,
Canal and Barnett Streets
1900, alternate Tuesdays
CDR Hubert M. Tatum

ARIZONA

PHOENIX
NRRC 11-6
USN&MCRTC, 2042 W. Thomas Road
2000, 2nd and 4th Thursday
(No meetings in July)
CDR Archie P. Kelley

TUCSON
NRRC 11-7
USN&MCRTC, 1100 South Alvernon Way
2000, 1st and 3rd Thursday
CDR Albert E. Hamilton

CALIFORNIA

LOS ANGELES
NRRC 11-1
USN&MCRTC, 851 Chavez Ravine Road
2000, 1st and 3rd Tuesday
CDR Carl T. Cobbs

PASADENA
NRRC 11-2
USNRTC, 2727 Paloma Street
2000, 1st and 3rd Thursday
LCDR Harold S. Cook, Jr.

LOS ANGELES
NRRC 11-3
Lecture Room 103, 3rd Floor
U. C. L. A. Medical Center
2000, 1st and 4th Monday
CDR Joseph Cryden

COMPTON
NRRC 11-4
USN&MCRTC, 600 North Alameda
2000, 2nd and 4th Wednesday
CDR Gerald E. Myers

SAN DIEGO
NRRC 11-5
USNRTC, Camp Decatur
1930, 2nd, 3rd and 4th Tuesday
LCDR Richard B. Woolley

POINT MUGU
NRRC 11-8
Building 36, Naval Air Missile Test Center,
1645, 1st and 3rd Wednesday
CDR Elmer M. Holk

AZUSA
NRRC 11-9
Aerojet - General Corporation
2000, 2nd and 4th Wednesday
CDR Donald D. Snodgrass

VENTURA
NRRC 11-10
N-6, Ventura College
1930, 2nd and 4th Wednesday
(No meetings in July)
CDR James V. Iliff

SANTA MONICA
NRRC 11-11
USN&MCRTC, 3400 Airport Avenue
2000, 1st and 3rd Monday
CDR Lehman M. Rosholt

SAN FRANCISCO
NRRC 12-1
1000 Geary Street, 3rd Floor
1930, 2nd and 4th Monday
CAPT Ray H. Parker

LIVERMORE
NRRC 12-2
Radiation Laboratory
University of California
1645, every other Wednesday
LCDR Vernon M. Field

STANFORD
NRRC 12-3
Room 126, Electronics Research
Laboratory, Stanford University
2000, every other Wednesday
CAPT Robert M. Fincher

FRESNO
NRRC 12-4
Room 119, Agriculture Building
Fresno State College
2000, 2nd and 4th Thursday
Varied dates, 1st quarter
LCDR James A. Ryles

BERKELEY
NRRC 12-5
Room 147, Cory Hall
University of California
1930, 2nd and 4th Wednesday
LCDR Clarke L. Coldren

DAVIS
NRRC 12-6
Room 1006, Haring Hall
University of California
2000, 1st and 3rd Tuesday
Varied dates, 1st quarter
LCDR Trimble R. Hedges

MONTEREY
NRRC 12-8
Room 530, Building 235
USN Postgraduate School
2000, every other Wednesday
Varied dates, 1st quarter
CAPT Lawrence E. Kinsler

COLORADO

FT. COLLINS
NRRC 9-12
Room 220, Chemistry Building
Colorado A&M College
1900, 2nd and 4th Thursday
LCDR Harry E. Troxell

BOULDER
NRRC 9-12
University of Colorado
1900, 1st and 3rd Tuesday
LT William F. Utlaut

CONNECTICUT

NEW HAVEN
NRRC 3-5
NROTC, Naval Science Laboratory
Hammond Laboratory, Yale University
14 Mansfield Street
2000, 2nd and 4th Thursday
CDR Joshua H. Goldman

HARTFORD
NRRC 3-5
(Contact officer-in-charge for time and place of meeting)
CDR Kenneth I. Boone

NEW LONDON
NRRC 3-12
USNRTC, Building 137
US Naval Submarine Base
2000, alternate Tuesdays
LCDR John A. Wheeler, Jr.

DELAWARE

WILMINGTON
NRRC 4-5
USNRTC, Foot of Madison Street
2000, alternate Mondays
CDR Donald MacCreary

DISTRICT OF COLUMBIA

NRRC 5-8
National Academy of Sciences
2102 Constitution Avenue, N. W.
2000, 1st and 3rd Thursday
CDR James W. Smith

NRRC 5-9
Auditorium, Building 28
4555 Naval Research Laboratory
Overlook Avenue, S. W.
1630, 1st and 3rd Wednesday of 1st quarter; 1st and 3rd Friday of 2nd, 3rd, and 4th quarters
LCDR Ernest W. Peterkin

FLORIDA

GAINESVILLE
NRRC 6-4
USNRTC, 1300 N.E. 8th Avenue
1915, 1st and 3rd Tuesday
LCDR Leon N. Henderson

ORLANDO
NRRC 6-8
USNRTC, West Livingston Avenue
2000, 1st and 3rd Tuesday
LCDR Percy F. Hurt

CORAL GABLES
NRRC 6-10
Building 521, Room 523
University of Miami
2030, 1st and 3rd Thursday
CDR Norman R. Buchan

FT. WALTON BEACH
NRRC 6-15
Ft. Walton Beach Elementary School
Eglin Highway
1900, alternate Mondays
CAPT Carl Kyselka

MELBOURNE
NRRC 6-16
Conference Room, Building 425
Patrick Air Force Base
1630, 1st and 3rd Monday
LT James R. Petters

GEORGIA

ATLANTA
NRRC 6-1
Conference Room
Georgia Institute of Technology
1930, alternate Thursdays
CDR James D. Baer

ATHENS
NRRC 6-9
Room 112, Baldwin Hall
University of Georgia
1900, 1st, 3rd, and 4th Mondays
(No meetings in summer)
CAPT Francis E. Johnstone

IDAHO

IDAHO FALLS
NRRC 13-6
Army Reserve Training Center
1930, 2nd and 4th Thursday
LCDR Mark Baum

ILLINOIS

CHICAGO
NRRC 9-1
Navy Pier Campus
University of Illinois
1900, 2nd and 4th Tuesday
LCDR B. J. Jaskoski

URBANA
NRRC 9-2
"E" Law Building, University of Illinois
1930, 2nd and 4th Tuesday, except August (1st and 2nd Tuesday) and September (3rd and 4th Tuesday)
CDR Walter C. Jacob

PEORIA
NRRC 9-2
Library, Northern Regional Research Laboratory
1930, 2nd and 4th Mondays
LCDR R. G. Dworschack

DECATUR
NRRC 9-2
USNRTC, Decatur
2nd and 4th Wednesday
LT John E. Housiaux

FOREST PARK
NRRC 9-23
Naval Ordnance Plant
7500 West Roosevelt Road
1930, 2nd and 4th Wednesday
LCDR Remo Puricelli

INDIANA

LAFAYETTE
NRRC 9-7
219 Poultry Building
Purdue University
1900, 2nd and 4th Tuesday
LCDR Audra E. Bell

IOWA

AMES
NRRC 9-5
NROTC Building
Iowa State College
1900, 1st, 2nd, and 3rd Wednesday
LT Robert K. Larson

DES MOINES
NRRC 9-13
USN&MCRTC, Ft. Des Moines
1930, every Wednesday
CDR Harris M. Golden

IOWA CITY
NRRC 9-19
Field House, University of Iowa
1930, every Thursday
LT Marvin S. Thostenson

WATERLOO
NRRC 9-24
USNRTC, 200 Riverside Drive
1930, 1st and 3rd Wednesday
CDR John O. Chellevold

KANSAS

LAWRENCE
NRRC 9-20
104 Military Science Building
University of Kansas
1930, every Monday
(No drills July and August)
LCDR Harold W. Haight

LOUISIANA

NEW ORLEANS
NRRC 8-1
NROTC Building
Tulane University
1930, alternate Tuesdays
LT Robert J. DeMint

BATON ROUGE
NRRC 8-2
Agricultural Center, 218
Louisiana State University
1630, 2nd and 4th Wednesday
(No meetings in August)
LT Alva B. Watts

MARYLAND

FREDERICK
NRRC 5-3
Fort Detrick
1930, 1st and 3rd Tuesday
LCDR H. L. Baier

BALTIMORE
NRRC 5-4
Board of Education Building
3 East 25th Street
2000, 1st and 3rd Thursday
CDR Raymond A. Kempf

BETHESDA
NRRC 5-10
Conference Room, NMRI
Naval Medical Center
2000, 2nd and 4th Tuesday
CDR Urner Liddel

ANNAPOLIS
NRRC 5-11
USN Engineering Experiment Station
2000, alternate Tuesdays
CDR E. N. McWhite

MASSACHUSETTS

CAMBRIDGE
NRRC 1-1
Room 4-270, M.I.T.
77 Massachusetts Avenue
1930, 1st and 3rd Monday
CAPT Robert W. Hart

WOODS HOLE
NRRC 1-2
Woods Hole Oceanographic Institute
1930, 1st and 3rd Tuesday
LCDR John W. Stimpson

AMHERST
NRRC 1-3
Gunness Laboratory, Room 10-11
University of Massachusetts
1930, 1st and 3rd Tuesday
LCDR Archibald L. Hepworth

WORCESTER
NRRC 1-5
Stratton Hall
Worcester Polytechnic Institute
2000, 1st and 3rd Monday
(No meetings in July and August)
LCDR Samuel H. Coes

MICHIGAN

ANN ARBOR
NRRC 9-3
112 North Hall, University of Michigan
1930, 1st and 3rd Monday
(Varied dates in July, August and September)
LCDR Joseph J. Keeley

MIDLAND
NRRC 9-15
Midland Library
1900, 2nd and 4th Tuesday
LCDR Walter C. Broad

EAST LANSING
NRRC 9-16
Room 306, Electrical Engineering Building
Michigan State College
1930, 1st and 3rd Monday
(No meetings in August)
CDR Marshall B. Burt

MINNESOTA

MINNEAPOLIS
NRRC 9-6
Room 321, Mechanical Engineering Building
University of Minnesota
1930, 2nd and 4th Monday
LCDR Neil B. Coil

MISSISSIPPI

GULFPORT
NRRC 6-5
USN&MCRTC, Broad Avenue
1930, 1st and 3rd Wednesday
LCDR John S. Luter

MISSOURI

ST. LOUIS
NRRC 9-8
101 Crow Hall
Washington University
2000, 2nd and 4th Wednesday
CDR Walter L. Wilkins

ROLLA
NRRC 9-9
203 Mechanics Hall
Missouri School of Mine & Metallurgy
1900, Mondays
(No meetings in July and August)
LT John M. Brewer

NEBRASKA

LINCOLN
NRRC 9-22
208 Plant Industry Building
University of Nebraska
1930, Wednesdays
LT Harold J. Ball

NEW HAMPSHIRE

HANOVER
NRRC 1-7
Wentworth Hall, Dartmouth College
2000, 1st and 3rd Tuesday
(No meetings in July and August)
CDR George Z. Dimitroff

NEW JERSEY

PORT NEWARK
NRRC 3-13
USN&MCRTC, Building 213
Naval Reserve Industrial Shipyard
1930, 1st and 3rd Wednesday
LCDR Norton L. Jeffers

PRINCETON
NRRC 4-1
Gayot Hall and various buildings
at Princeton University
2000, alternate Wednesdays
CDR Raymond R. Goldberg

NEW MEXICO

ALBUQUERQUE
NRRC 8-7
USN&MCRTC, 1805 Yale Avenue, SE
2000, 1st and 3rd Wednesday
LCDR Jack M. Houston

LOS ALAMOS
NRRC 8-9
Lecture Room, Administration Building
Los Alamos Scientific Laboratory
1700, 1st and 3rd Tuesday
CDR Alvin R. Lyle

NEW YORK

NEW YORK
NRRC 3-1
Room 301, 30 East 42nd Street
1900, 2nd and 4th Wednesday
CDR Frank E. Kulman

POUGHKEEPSIE
NRRC 3-1
(Contact officer-in-charge for time and place of meeting)
LT Jerome L. Krumpelman

LONG ISLAND
NRRC 3-2
Engineering Building
USN Training Device Center
Sands Point, Port Washington
1930, 2nd and 4th Monday
CDR Alphonse A. Chester

BUFFALO
NRRC 3-3
USN&MCRTC, 3 Porter Avenue
2000, 2nd and 3rd Monday
LT Eugene S. Hiller

ROCHESTER
NRRC 3-4
Room 202, Gavett Hall
University of Rochester
2000, 1st and 3rd Tuesday
LT Kenneth W. Kimpton

SYRACUSE
NRRC 3-6
USNRTC, Syracuse
2000, 1st and 3rd Monday
LCDR John B. Simeone

SCOTIA
NRRC 3-7
USNRTC, Scotia
2000, 2nd and 4th Thursday
CDR Thomas J. Gair

NEW YORK
NRRC 3-8
Room 301, 30 East 42nd Street
1900, 2nd and 4th Tuesday
CDR Leo J. Murphy

UPTON
NRRC 3-9
Brookhaven National Laboratory
1930, 2nd and 3rd Wednesday
CAPT John S. Medd

MASSENA
NRRC 3-10
Court Room, City Hall
1930, 1st and 3rd Monday
LCDR Lucius M. Hale

NORTH CAROLINA

CHAPEL HILL
NRRC 6-6
105 Abernathy Hall
University of North Carolina
1930, Wednesdays
LCDR Quentin W. Lindsey

OHIO

COLUMBUS
NRRC 4-7
Ohio State University Research Foundation, 1314 Kinnear Road
1930, 2nd and 4th Thursday
LCDR Daniel Howland

CLEVELAND
NRRC 4-8
USNRTC, 1089 E. Ninth Street
2000, 1st and 3rd Monday
CDR Viktor Schreckengost

DAYTON
NRRC 4-9
USN&MCRTC, 410 Gettysburg Avenue
1930, 2nd and 4th Monday
LCDR William E. Kremer

CINCINNATI
NRRC 4-11
Room 54, Albers Hall
Xavier University
1900, 2nd and 4th Tuesday
LCDR Louis J. Pecora

OKLAHOMA

BARTLESVILLE
NRRC 8-8
American Legion Building
1930, 1st and 3rd Tuesday
CDR E. O. Box, Jr.

STILLWATER
NRRC 8-13
Room 2, Union Building
Oklahoma State University
1930, 2nd, 3rd, and 4th Thursday
(No meetings in August)
CDR Dariel E. Howell

OREGON

PORTLAND
NRRC 13-4
USN&MCRTC, Swan Island
2000, 1st and 3rd Tuesday
LCDR William H. Rice

CORVALLIS
NRRC 13-5
Room 132, Food Technology Building
Oregon State College
1930, 2nd and 4th Monday
LCDR Wayne V. Burt

PENNSYLVANIA

PHILADELPHIA
NRRC 4-2
Franklin Institute
20th Street & Parkway
1930, alternate Thursdays
(No meetings in July and August)
CDR John C. MacFadyen

PITTSBURGH
NRRC 4-3
Room 1112, Engineering Hall
Carnegie Institute of Technology
2000, alternate Thursdays
LT Richard Atherton

STATE COLLEGE
NRRC 4-4
Room 200 A, Engineering "E"
Campus, Pennsylvania State University
1900, alternate Mondays
CDR Henry H. Chisman

BETHLEHEM
NRRC 4-6
USNRTC, Spring Garden and Rodgers Streets
1900, 2nd and 4th Tuesday
LCDR William A. Green

WILLOW GROVE
NRRC 4-12
Technical Training Building
US Naval Air Station
1930, alternate Tuesdays
(No meetings in July and August)
CDR Bradley C. Algeo, Jr.

RHODE ISLAND

PROVIDENCE
NRRC 1-2
NROTC Building, Brown University
1930, 1st and 3rd Wednesday
LCDR Peter F. Merenda

KINGSTON
NRRC 1-2
Room 200, Ranger Hall
University of Rhode Island
1930, 1st and 3rd Tuesday
LCDR Pierre F. Smith

SOUTH CAROLINA

CLEMSON
NRRC 6-11
Physics Building, Clemson College
1930, Wednesdays
LCDR William G. Miller

AIKEN
NRRC 6-13
Red Cross Building, Laurens Street
1900, 2nd and 4th Thursday
CDR Loren T. Palmer

SOUTH DAKOTA

BROOKINGS
NRRC 9-11
Room 330, Agricultural Hall
South Dakota State College
2030, 2nd and 4th Wednesday
(Varied dates in July and August)
LCDR Gerald B. Spawn

RAPID CITY
NRRC 9-11
Chemistry Building
South Dakota School of Mines
2000, 1st and 3rd Tuesday
LCDR Willard J. Martin

TENNESSEE

OAK RIDGE
NRRC 6-3
Room 245, Oak Ridge High School
1930, 2nd and 4th Wednesday
CDR Burl Zimmerman

TULLAHOMA
NRRC 6-12
Conference Room, Arnold Engineering Development Center
1930, 2nd and 4th Tuesday
LT Arthur H. Hinners, Jr.

NASHVILLE
NRRC 6-18
George Peabody College
21st Avenue South
2000, 1st and 3rd Monday
CDR S. B. Sudduth

TEXAS

COLLEGE STATION
NRRC 8-3
Biological Science Building
Texas A&M College
1930, 2nd and 4th Monday
CDR Norman F. Rode

HOUSTON
NRRC 8-4
Science Building
University of Houston
2000, alternate Wednesdays
CAPT Robert W. Talley

AUSTIN
NRRC 8-5
Room 223, Experimental Science Building
University of Texas
1900, Mondays
LCDR Richard B. Eads

GALVESTON
NRRC 8-6
USNRTC, Galveston
1930, 1st and 3rd Monday
LT Lauro Gutierrez-Vela

DALLAS
NRRC 8-12
USN&MCRTC, 9638 Bachman Boulevard
2000, 1st and 3rd Tuesday
CDR Louis F. Connell, Jr.

UTAH

LOGAN
NRRC 12-7
Faculty Lounge
Utah State Agricultural College
2000, 2nd and 4th Thursday
(Varied dates in 1st quarter)
CDR Oliver B. Cope

VIRGINIA

NEWPORT NEWS
NRRC 5-1
USN&MCRTC
73rd Street and Warwick Road
1930, 1st and 3rd Tuesday
CDR Gilbert T. Strailman

BLACKSBURG
NRRC 5-2
310 New Agricultural Building
Hutcheson Hall, VPI Campus
2000, Mondays
LCDR James B. Eades, Jr.

RICHMOND
NRRC 5-5
2 North Conference Room
Department of Biology & Genetics
Medical College of Virginia Hospital
1700, 2nd and 4th Monday
CDR Charles M. Preston

WASHINGTON

SEATTLE
NRRC 13-1
Fisherman's Terminal, Department of Fisheries, 4015 20th Avenue West
1930, 1st, 2nd, and 3rd Monday
LCDR Raleigh Moreland

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RICHLAND
NRRC 13-2
Court Room, 2nd Floor Headquarters Building
Camp Hanford
1900, 2nd and 4th Tuesday
LCDR Roy S. Peterson

PULLMAN
NRRC 13-3
Room 39, Holland Library
Washington State College
1930, 2nd and 4th Monday
(Varied dates in 1st quarter)
CDR Claud C. Lomax, Jr.

WEST VIRGINIA

SOUTH CHARLESTON
NRRC 5-6
USNRTC, South Charleston
1930, 1st and 3rd Thursday
LT Arthur C. Bowbeer

WISCONSIN

MILWAUKEE
NRRC 9-4
USN&MCRTC, Milwaukee
2nd and 4th Monday
CDR Horace F. Burr

MADISON
NRRC 9-14
University of Wisconsin
1930, alternate Mondays
(No meetings in July and August)
CDR Marshall W. Keith

Military Pay-Raise Benifits

The military pay raise voted in the last session of Congress is of considerable benefit to reservists on inactive duty as well as to those members of the armed forces serving on active duty. These benefits may be realized now as well as later, upon retirement.

Reservists will be given an increase in pay for inactive duty in a drill pay status as well as for active duty for training performed with pay. The pay-raise legislation also increased the amount of retirement pay for reserve personnel retired under the authority of Title 10, U. S. Code, Chapter 67 (formerly Title III, Public Law 810, 80th Congress). Tables showing the pay schedule for each drill period and for active duty, as provided by the new law, may be found in "The Naval Reservist," July 1958. A thorough coverage of the effect of the raise on retirement pay, as well as requirements for retirement for reserve personnel, may be found in the August 1958 issue of the same publication.

Non-Electric Fish Inhibitor

Down at the Navy Underwater Sound Reference Laboratory, Orlando, Florida, fish are a problem. The creatures are not particularly noisy by above-the-water standards, but in a placid lake their grunts, whistles, and gnashings can seriously interfere with the tests of underwater sound gear. The Laboratory's engineers tried every method they could think of--repellant chemicals, electric shockers, ultra-high-frequency emitters—but none of them kept the curious fish at a respectful distance.

Beneficial suggestor Rudolph Schnell, who likes to fish during the noon hour, thinks he has the problem licked. He punched a few holes in a can of "Puss 'n Boots" cat food (unit cost about 10 cents) and suspended it in the lake at some distance from the test pier. Ergo, the fish are attracted to the cat food and away from the sound gear. Not only that, the lunch-time fishermen--by dropping their lines near the cat food—have boosted their catch from a meager four or five a day to between twenty and thirty.

In This Issue

COVER PHOTO: This "super-cavitating" propeller represents a significant breakthrough in propeller development. Designed at the David Taylor Model Basin, under an ONR contract, the new screw operates at high rotation speeds where other propellers merely churn the water.

RESEARCH REVIEWS endeavors to report briefly highlights of technical progress in research by Navy laboratories and contractors and the development of important naval research facilities. Articles which meet these broad criteria and possess a good degree of readability are welcomed. Manuscripts and changes of address should be sent to Code 740, Office of Naval Research, Washington, D. C. ... Research Reviews is listed for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. Subscription price: $1.50 per year in U. S. and Canada; $2.00 per year, foreign; $0.15 per individual copy. Use of funds for printing this publication was approved by the Director of the Bureau of the Budget, February 12, 1958.