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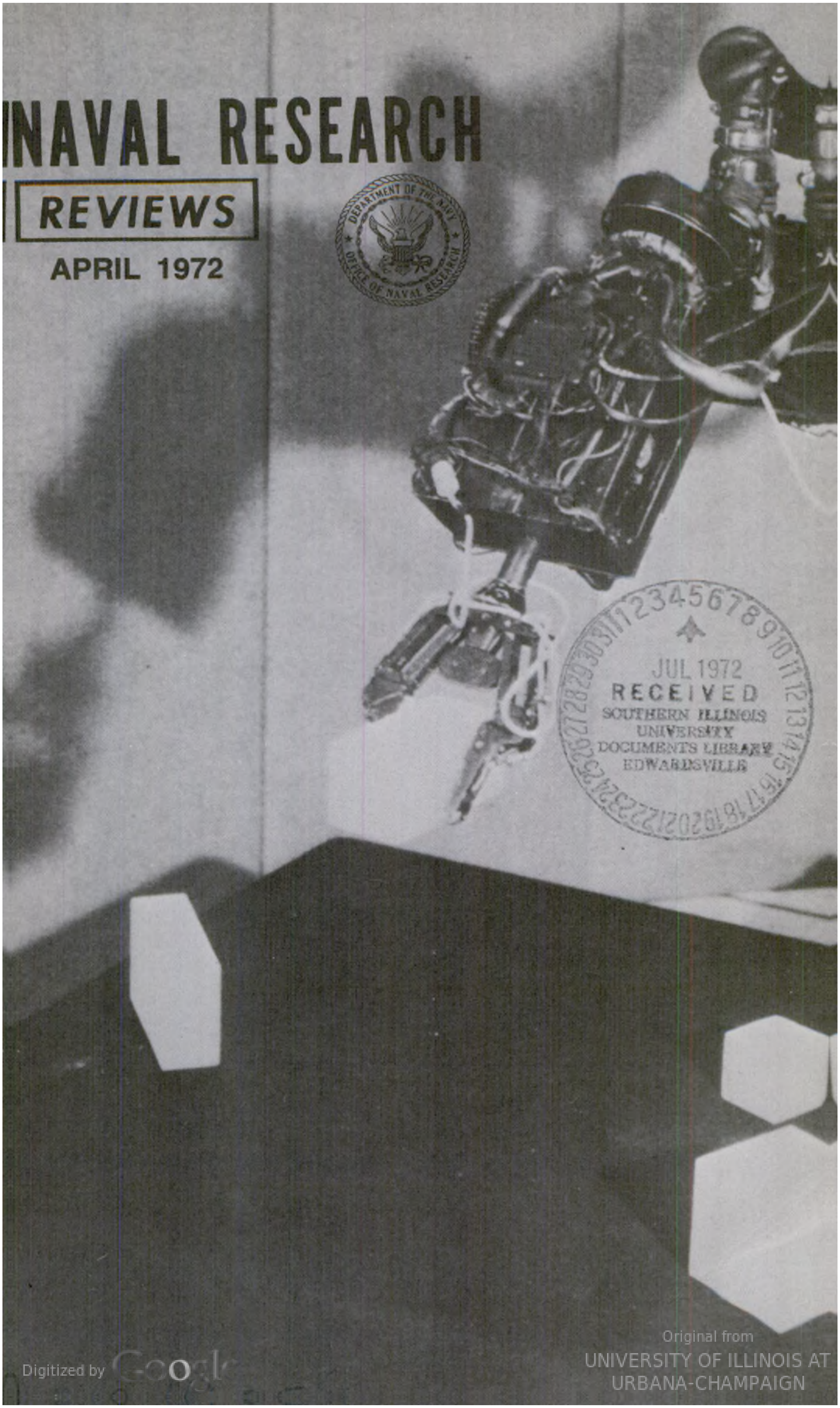

Nicholas J. Hoff

Nicholas J. Hoff, recently retired as the Chairman of Stanford University's Department of Aeronautics and Astronautics, is continuing as Professor Emeritus of that Institution his notable research contributions to the field of structural mechanics. The 160 and some papers he has published on virtually every facet of solid mechanics, many with ONR support, are characterized by their depth of physical understanding, thoroughness of execution and remarkable balance between theoretical development and practical importance of the results. This performance, coupled with his equally distinguished career as an educator and a University administrator of outstanding effectiveness, have won him numerous world-wide honors and awards, including active membership on the National Academy of Engineering. A most productive ONR chief investigator and technical advisor since 1947, chiefly in the areas of shell stress and stability analysis, and creep, Dr. Hoff has, at various times, similarly served all three U.S. Armed Services, NACA and NASA. Typical of Dr. Hoff's perceptive insight was his very successful extension of aircraft stiffened shell theory he had pioneered to effecting more sophisticated methods of analysis necessary for the design of deeper diving submarines.

Improvement in Ferro-Cement Structures

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Ferro-cement is a combination of reinforcing wire and cement mortar that can be used in thin shell construction. It is highly adaptable for boat hulls and other marine applications, and it is in this application that it has gained its widest acceptance.

Yet this material was found to have structural defects due to the presence of hydrogen gas bubbles in the cement mixture. The cause of these hydrogen bubbles and the exact nature of their effect on ferro-cement structures have not been previously studied. During a research program on the properties and microstructure of cements at the University of California, Berkeley, supported by the Office of Naval Research, experiments were conducted in the fabrication of ferro-cement panels which revealed what causes the formation of the gas bubbles and led to a solution to the problem that has been successfully tested. It has been demonstrated in these tests that the elimination of the bubbles results in a substantial increase in the strength and durability of ferro-cement structures.

A working definition of ferro-cement is that it is a thin shell of highly reinforced Portland cement mortar. Generally, the shells are in the range of 1/2-in. to 1-1/2-in. thickness, and the reinforcement is in the form of as many layers of steel mesh as possible for a given thickness with or without black steel reinforcing bars sandwiched midway between the layers of mesh. The resulting shell or panel is impregnated with a very rich Portland cement mortar. It might be thought that this is simply the well-known engineering material reinforced concrete. This is not the case. It has been thoroughly demonstrated that ferro-cement behaves in a manner so different from concrete reinforced with steel that it has to be considered as an entirely different material. Because the mesh is so finely and evenly distributed and subdivided throughout the entire cross section of the shell, there is a synergistic effect.

S. P. Shah observed that the fracture strength of ferro-cement primarily is dependent on the load carrying capacity of the mesh reinforcement. Shah notes that the modulus of elasticity of ferro-cement can be estimated from the wire mesh alone. However, for strain and cracking he

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finds a significant interaction between matrix and reinforcement. Shah found the specific surface of reinforcement, thus the total bonding area between mortar and steel, to be the most sensitive parameter as far as strain and cracking were concerned. The specific surface of reinforcement is considerably higher for ferro-cement than for reinforced concrete, and this is one of the factors that distinguishes one from the other.

Ferro-cement is used in thin wall (shell) applications where strength and rigidity are developed through form of shape. It has the distinct advantage of being moldable and of one piece construction. Other major advantages are its low cost and its nonflammable and low corrosive characteristics. The use in thin shells is possible because ferro-cement has relatively high tensile strength and essentially a homogeneous, crack-free behavior.

The colorful history of ferro-cement has been reviewed in several places, and it has many interesting sagas. Although its history goes back over 50 years, there is general agreement that the first serious research and development efforts were undertaken by the Italian Naval Administration in the Spring of 1943. Several motor-driven cargo vessels of 400 tons capacity were started by the firm of Nervi and Bartoli. Their construction was interrupted by the war, but there was renewed interest following the war. Some of the original vessels were finished, and several new ones were constructed. The operational experience of these vessels over a period of 10-20 years was judged highly successful.

Following his original investigations for the Italian Navy, Pier Luigi Nervi successfully used ferro-cement for buildings and other civil engineering structures. They have become landmarks of modern design. There are many potential uses of ferro-cement that could be developed in the future as more is learned about the material.

The durability of ferro-cement is particularly well-illustrated in the following passage from the Russian engineer, I. Ya Glan:

> "The following reinforced concrete (read ferro-cement) yacht 'Opyt' (Experience) in late autumn 1957 was torn from anchor during a severe storm and was thrown onto the rocks on the opposite shore. We were unable to remove the yacht because of the ice jam which had started. The entire autumn, the hull of the yacht was on the rocks, and during the winter it froze into the ice. In the spring, at first glance the hull of the yacht had a sad appearance. The sides were crumpled, but nevertheless the reinforced gratings proved to be undamaged. All that was required was the work of four men, a bag of cement and several buckets of river sand in order for the yacht hull to be repaired in one day."

The combination in ferro-cement of steel mesh and Portland cement mortar means that the design engineer must know about each material separately and their interactions. The solidification or hardening of Portland cement is the basic reaction in the fabrication of ferro-cement.

One of the primary roles of the mortar in ferro-cement is to cover and protect the reinforcing steel from corrosion and other environmental effects. Portland cement mortar will protect reinforcing steel if the mortar cover is thick, the permeability of the mortar is low, and the mortar-steel interface is free of discontinuities and voids. The permeability of the mortar can be controlled, but the thin layers of mortar may not be sufficient to give protection in all cases.

In an aggressive environment, such as that encountered by ferro-cement in its highly corrosive marine application, the mortar protection of the steel may be too low to prevent excessive corrosion. The danger of corrosion is highly enhanced in ferro-cement by the extreme thinness of the cover of mortar over the steel reinforcement. Also, it is known that the alternating conditions of wetting and drying of marine structures through sea spray and marine fog creates additional exposure hazards.

In order to minimize absorption, the exterior of a ferro-cement hull can be covered with a rather impermeable film of epoxy paint. However, this coating is subject to abrasion, deterioration, porosity, *etc*., and cannot be considered to be 100% effective. Any uncoated area will be subject to intensified local corrosion. Absorption or penetration will also occur from the interior of a hull structure from an accumulation of bilge water or other collected pools of water. This water will not only contribute directly to the corrosion of the steel but also indirectly by leaching out the natural protective constituents of mortar when the water is either high in sulfates (sea water) or when the water is soft (rain water).

In all the literature surveyed, there has never been any mention of the severe effects in ferro-cement caused by the presence of the dissimilar metals employed with fresh Portland cement mortar, and practical applications have not been recognized. The two dissimilar metals are the zinc coating of the galvanized mesh and the iron in the ungalvanized steel reinforcement bars. These metals in the presence of an electrolyte, in the form of Portland cement mortar, create an electrochemical (or galvanic) cell. Electron current flows from the zinc anode to the iron cathode with the electrolyte completing the circuit.

This galvanic cell action is present in hardened and fully cured mortar, but in this case it does not necessarily pose a problem because very low electron currents are present. As a matter of fact, the use of zinc has the benefit of providing cathodic protection to the steel; however, a very severe problem does exist when the mortar is fresh. Up until the time the mortar sets, a very large electron currents flow from the zinc anode to the iron cathode, where hydrogen ions acquire electrons and form hydrogen atoms, which is liberated as hydrogen gas H_2) along the surface of the black steel cathode.

The generation of this gas causes an expansive pressure on the mortar surrounding the bars and creates a gas filled void along the entire surface area of the cathodic steel bars. Therefore, after the cement paste has set, a continuous disrupted region will exist at the mortar-steel bar interface.

There are three very important deleterious results:

1. Poor mortar-to-bar bond strength—both chemical and mechanical (frictional).
2. Hydrogen embrittlement of the steel.
3. High corrosion probability from the continuous void along the bars.

Item one: The poor bond strength would affect the overall strength of the ferro-cement, that is, the impact strength, the tensile strength, and the strength in flexure. Although the extremely poor bond reduces the overall strength, many successful ferro-cement boats have been built with an apparently adequate strength—at least initially.

Item two: When high tensile steel is charged with atomic hydrogen (hydrogen ion in contact with steel) under the condition of cathodic charging, the steel is susceptible to hydrogen embrittlement. This condition could lead to a brittle failure of the steel.

Item three: The continuous voids along the bars will invite accelerated corrosion effects, particularly since there is little mortar cover in ferro-cement. Normally, in the extremely corrosive marine environment at least a 3-in. concrete cover is recommended. It is likely that the accelerated corrosion effect is the most critical result of the galvanic cell action.

A severe deterioration of the overall strength of ferro-cement would be the end result of items 2 and 3 above. It is beyond any doubt that the problem described is very serious and undesirable in ferro-cement.

Since black steel bars are imbedded in the middle of the ferro-cement shell, there would generally be at least a 1/4-in. of mortar cover over the black steel (1/8-in. cover over the galvanized mesh). This cover or layer of mortar would usually be sufficient to suppress the emergence of the hydrogen gas at the surface. In actual boat building practice the shell would normally have a more or less vertical surface, which would have the effect of increasing the suppressive force of the mortar over that of the expanding gas. This is the reason why this galvanic cell problem has gone unnoticed and unreported.

If a ferro-cement panel were to be placed horizontally, the gas could emerge at a soft or less dense location. This possibility would be guaranteed if the panel were to be vibrated or shaken, because the gas would then be agitated through the fresh mortar to the surface. There the gas would pop out in the form of an eruption or bubble, resulting in a miniature crater.

Indeed, it was through the horizontal fabrication of ferro-cement test panels, as described in the preceding paragraph, that the galvanic cell problem was first recognized by the authors during their research work in 1970. The acuteness of this problem was paramount while conducting extensive tests for strength and while experimenting with unique configurations of ferro-cement.

During this period, test panels 1/2-in. to 1-1/2-in. were fabricated with various layers of galvanized mesh and with 3/8-in. black steel bars, sandwiched midway between the mesh on 2-in. centers. Vibration of the panels allowed some of the generated gas to escape at various sites of low overhead resistance. At these sites vents formed, and on further vibration they collapsed and then new vents developed. Because the generation of gas is continuous as long as the cement paste has high conductivity, it was found that no amount of vibration at any frequency or amplitude will drive out all the trapped gas.

The surface of the mortar in contact with the reinforcing bars was observed to be highly pitted, but description of these conditions will be delayed until after the solution is described.

There are a number of possible solutions to the galvanic cell problem described above:

1. Eliminate dissimilar metals
   a. use of black steel (ungalvanized) reinforcing bars with ungalvanized mesh.
   b. use galvanized reinforcing bars with galvanized mesh.
2. Insulate the black steel bars with a protective coating.
3. Chemically passivate or inhibit the galvanic cell action.

The first solution, the most obvious, seemed to offer a good remedy. However, using all ungalvanized steel is not deemed to be desirable, because of the severe threat of corrosion in the highly corrosive marine environment.

There are, in fact, four main reasons for using galvanized wire or mesh in ferro-cement.

1. When the reinforcing is exposed to the elements for lengthy periods before the mortar is placed, galvanized wire will resist corrosion better than ordinary steel.

2. Field experiences and experiments at the University of California have shown that concrete with galvanized reinforcement resists an aggressive environment better and longer than concrete reinforced with black steel.

3. Once corrosion is initiated in ferro-cement, the zinc will corrode preferentially and will furnish cathodic protection to the steel. Work of T. Ishikawa, I. Cornet, and B. Bresler has shown that galvanized steel is anodic to black steel in concrete by about 0.5 volts and furnishes galvanic protection to steel in concrete in much the same way as it does in the atmosphere. Furthermore, corrosion may be slower in starting with galvanized steel, because zinc is somewhat more tolerant of chlorides than iron in the alkaline concrete environment.

4. Since the protective mortar cover is very thin (about 1/8-in.) in ferro-cement, the possibility of corrosion is very high. Therefore, black steel is very vulnerable, especially if any part of the steel reinforcement, bars or mesh, is left unprotected at the surface, for they would become focal points for the initiation of corrosion.

The use of galvanized bars and mesh was deemed to be a practical solution at a minimal cost, but subsequent tests have indicated that some dissimiliar metal characteristics remained because of the different purities of the zinc used in galvanizing or other factors. Care has to be exercised in applying a protective coating to bare spots caused by chipping or cutting of the bars. It should be realized that only mild steel reinforcing bars should be galvanized. However, today's most commonly used reinforcing bars in ferro-cement boat construction are not mild steel, but low carbon, cold drawn steel that is hard (springy) and or high strength (usually over 75,000 psi yield point). Galvanizing this steel will "stress relieve" the steel and cause it to become softer and weaker, therfore, galvanizing of other than mild steel bars is undesirable.

The second solution of insulating the black steel bars could be accomplished with a zinc rich paint or epoxy paint in order to prevent the galvanic currents. Care would have to be exercised in cleaning and preparing the bars for the coating in order to assure a good bond. During fabrication special care would have to be used in order not to scratch or otherwise damage the coating. This would be a tedious and somewhat uncertain method.

The third solution, a chemical cure, was considered to be the most expedient and dependable method if a chemical additive could be found that would eliminate or inhibit the electrochemical cell action. Bresler and Cornet have used chromium ions in solution as a means of passivating or inhibiting zinc and thereby reducing the galvanic cell effect of zinc and black steel in concrete. They have conducted experiments in which chromium trioxide (CrO_3), also known as chromic oxide, was added in very dilute concentrations of 100 to 300 ppm (parts per million) by weight to that of the water for their concrete mix. All of the mixes with these concentrations proved effective without any loss in the strength characteristics of the concrete.

Each of the possible solutions to the galvanic cell problem has been investigated in this study, but the use of chromium trioxide has proved to be the best solution. In the following sections the results of these experiments are described and the case for using chromium trioxide presented.

A series of ferro-cement specimens was prepared to investigate the possible solutions to the galvanic cell action described above to take place between the galvanized steel mesh and black (*i.e.*, ungalvanized) steel reinforcing bars. Two types of tests, a visual inspection test and a bending strength test, were designed to determine if the addition of chromium trioxide (CrO_3) to the mix of fresh mortar would reduce or eliminate the undesirable effects of the galvanic cell. In addition, the use of an all galvanized system, an all black iron system, and an epoxy coated black iron approach were investigated in the same way.

The visual inspection test consisted of two phases. The first phase was the fresh mortar test. Observations were made as to the apparent electrochemical action taking place in freshly cast ferro-cement specimens, with and without the CrO_3 admixture in the mortar, up until the final setting of the paste. The same test was made for the other treatments as well.

The second phase was the ferro-cement post cure test. This phase of inspection consisted of cutting open the fully cured ferro-cement specimens, casted in phase one, by use of a diamond saw, and then critically examining their internal structure. This test was made for all of the possible solutions to the problem.

Following the visual inspection tests the mechanical properties were investigated using a standard four point bending test (also called a flexure test) to determine what effect the galvanic cell problem has on engineering performance.

Visual observations were recorded during the first hour after the preparation of four test panels. Two panels contained CrO_3 and showed no bubbling or eruptions on the surface at all. This contrasted with the two panels without CrO_3 which exhibited active bubbling or spurting. It was clear that the addition of CrO_3 reduced the galvanic cell sufficiently to prevent the hydrogen bubbles from breaking through to the surface. This was particularly evident when the two panels with only one layer of mesh were compared. There is little resistance for the bubbles to break through and yet the specimen with CrO_3 showed no bubbling at all. The test panels were then, cured for 28 days at 100% relative humidity.

The fully cured ferro-cement specimens were cut with an 18-in. diamond saw, both at a right angle and longitudinally to the reinforcing bars, in order to observe the bonding characteristics of the mortar to the steel reinforcing bars. The longitudinal cuts were made top and bottom to the bars down to the surface of the bars, thereby allowing the ferro-cement to be "opened up" along the length of the bars. This allowed individual bars to be removed from the specimens (Figure 1).

The specimens without CrO_3 exhibited a continuous void along the entire length and circumference of the bars. There was evidence of very little contact between the mortar and steel. The surface of the mortar surrounding the bars was pocked, giving a spongy appearance.

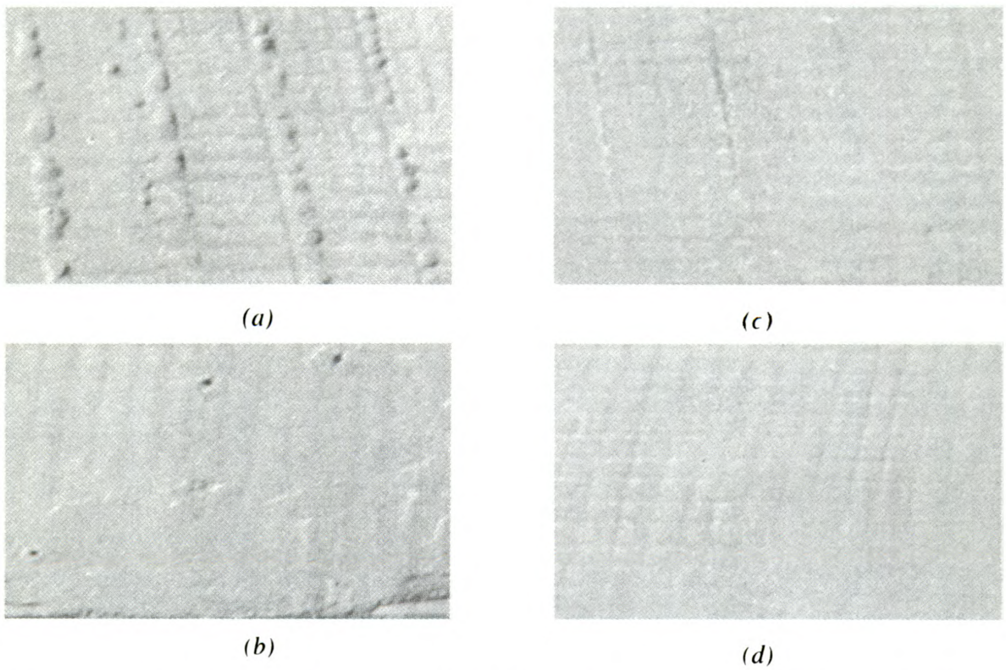

Figure 1 — Ferro-cement panels one hour after casting showing the effects of CrO_3 in suppressing the galvanic cell activity, (a) 1/2-in. thick specimen showing rows of bubbles along the reinforcing bars caused by the evolution of hydrogen, (b) 3/4-in. thick specimens showing the rather large vents randomly districted over the surface, (c) 1/2-in. thick specimen with CrO_3 shows no bubbles like those shown in (a), (d) 3/4-in. thick specimen with CrO_3 shows no vents like those in (b).

Few smooth areas could be found that would indicate that contact or bond had been made by the mortar to the bars. Entrapped hydrogen gas had completely encircled the bars and forced the mortar back from the surface of the bars.

The specimens with the CrO_3 admixture revealed a perfect impression of the deformed steel bars in the mortar. An excellent, void free bond existed along the entire length of each bar inspected.

The flexure tests were conducted on four ferro-cement panel specimens as described above. Two of the specimens contained CrO_3 and two did not. A Baldwin Universal Testing Machine of 60,000 pounds capacity was used with a linear differential transformer placed at mid-span to measure the deflection. A typical flexure test was made with a 1/2-in. thick ferro-cement specimen in place.

It was apparent that the presence of CrO_3 made a difference in the mechanical behavior of these panels. Both the apparent modulus and the ultimate strength were increased by using CrO_3.

It was interesting to note that the specimen with 6 layers of hardware cloth compared almost identically to the specimen with 8 layers of chicken wire for the specimens without CrO_3. The ultimate stress of these specimens, over 9,000 psi, were at the very top of the ultimate stress range for ferro-cement (approximately 5,000-9,000 psi) as reported by previous investigators.

The ferro-cement specimens with CrO_3 exhibited 59% and 43% greater strenths in flexure respectively for the hardware cloth and for the chicken wire reinforcements than for their counterparts without CrO_3. These strengths corresponded to stresses of 15,300 psi and 13,200 psi respectively. Subsequent tests with welded wire fabric show even better strengths using CrO_3.

The results of the visual tests showed that the chemical bond and the mechanical friction between the steel bars and the concrete was very low for ferro-cement without CrO_3. This fact was confirmed by the bending tests. Therefore, the bond strength (composite strength) between the bars and the concrete was considerably lower for ferro-cement not treated with CrO_3 and greatly reduced the fluctural strength.

It is probable that if plain bars (*i.e.*, smooth) would be used, those bars would most likely exhibit an even greater tendency to be pulled through the concrete, and failure would occur at even lower loads for mortar without the CrO_3 admixture. This is important for ferro-cement since smooth bar is often used.

The other possible solutions (all galvanized system, all black iron system, and an epoxy coated black iron) to the galvanic cell problem were investigated by visual observations on the freshly cast test panels and by cutting the panels open after a full cure cycle. There was little bubbling observed with any of the other systems, and it is interesting that the galvanic cell activity observed without CrO_3 present is confirmed to be due to the combination of galvanized steel mesh and ungalvanized steel reinforcing bars. This was true for the external examination of the freshly cast panels, but a study of the internal state of the cured specimens showed that both the all galvanized and all black iron samples had poor mortar/reinforcing-bar surfaces. A photograph of these specimens is shown, in Figure 2 and it is evident that there has been some activity at the reinforcing bar surface which had made a rough surface. It is probable that this is due to a galvanic cell caused by small differences in the material.

Recent tests with welded wire fabric showed that hydrogen gas was evolving from each of the junctions where a weld had been made. Both the all galvanized or all black iron system would be sensitive to small

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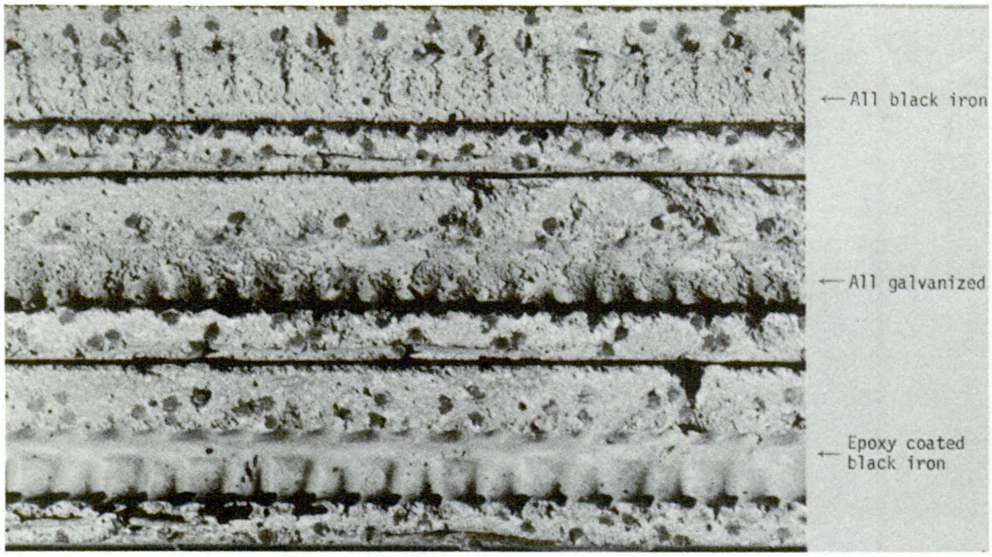

Figure 2 — The surface of the mortar is shown to be somewhat spongy where it was in contact with the reinforcing bar in both the all black iron and all galvanized systems. Note that the epoxy coated surface was protected, but that the deformations on the bar are smoothed over.

differences in material, and one would never be completely sure that some cells were not established by an unforeseen combination of materials. The CrO_3 solution appears to be the best solution available. The epoxy coating appeared to work rather well, except that it filled in some of the deformations on the reinforcing bar which would decrease its interlocking with the hardened mortar.

The galvanic cell between the plain steel and galvanized steel in ferro-cement is a problem which until this time appears to have been unknown. This has probably been active in most ferro-cement projects with the resulting lower strength and durability. The inspection and licensing authorities should be aware of the galvanic cell problem in ferro-cement, and all projects constructed in the past should be viewed as weakened by the evolution of hydrogen at the ungalvanized reinforcing bar. One of the most effective inspection procedures would be to remove specimens from the structure and look at the interface between the mortar and the plain steel.

For all future ferro-cement construction, we recommend that CrO_3 be added to the mixing water. Again the inspection and licensing authorities could require that CrO_3 be used during construction and that its use be noted in the permanent records of the vessel or structure.

The testing and inspection of ferro-cement vessel is a relatively new field and we recognize that the discovery of the galvanic cell problem has complicated the inspection of existent vessels and structures. Further experiments should be performed to determine how the durability of these vessels or structures is affected by the poor bond between reinforcing steel and the mortar. A non-destructive test method should be developed to help the surveyor determine the extent of bubble formation in an existing panel of ferro-cement. As it stands at this time, we can only recommend that test panels be cut from the vessel or structure and the interface inspected visually.

In the final analysis it is only in new construction that the galvanic cell problem can really be solved, and we believe that the addition of CrO_3 is the best possible solution. It's almost impossible to distinguish between a good or poor quality ferro-cement hull after it has been finshed. A ferro-cement vessel o structure must be made correctly the first time because it is almost impossible to go back an fix it later.

Navy Study Finds Prostaglandins Affect Red Blood Cells of Severely Injured

A Navy research study has turned up evidence that prostaglandins affect the red blood cells of persons severely injured or in shock in a way that appears to hamper blood circulation.

Prostaglandins are the mysterious family of compounds that affect a wide variety of bodily functions. They are known to be released from the brain and other tissues under varying degrees of stress. Their connection with blood circulation in wounded or injured persons has been indicated by the fact that high concentrations of the substance have been found in the blood of Vietnam casualities.

A study of the sensitivity of red blood cells to a type of prostaglandin known as E2 was made at the University of Pennsylvania School of Medicine as part of a program conducted by Dr. Howard Rasmussen and Dr. James Allen supported by the Office of Naval Research.

The study demonstrates that the E2 type "hardens" the red blood cells so that they become less pliable, thereby reducing their ability to push freely through the small capillaries. Since the red blood cells perform the vital function of supplying oxygen and nutrients to the essential tissues of the body, any retardation of the flow would likely inhibit recovery from serious injuries or shock.

The possibility also exists that reduced blood flow resulting from hardening of red blood cells is at least partly responsible for clinical or surgical shock, a little understood condition that frequently claims the lives of patients expected to recover from surgery. Previously it has been thought that this condition was related to pumping mechanisms involved in the blood flow.

Further research will investigate what other types of prostaglandins may affect red blood cells and what therapeutic measures might be taken to suppress the action of prostaglandins on them or decrease the hardening of blood cells.

Electron Microscopy of Sensory Receptors

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The house fly (*Musca domestica* L.) is cosmopolitan and a familiar pest to everyone. It is intimately associated with man and his activities and is therefore regarded as a "synanthropic" fly. Synanthropic flies are a nuisance and a threat to health since they readily transmit a variety of enteric diseases. Many diseases of military medical importance are transmitted by arthropod vectors. In particular, the Navy is concerned with reducing the presence of disease-breeding flies in the various environments in which naval personnel operate. The project support by the Office of Naval Research in this field provides knowledge which will enhance our ability to evaluate the epidemiological significance and vector potential of various species of insects.

Increasing human populations with the concurrent explosion of waste disposal problems assure the continuation of the fly problem. Fly breeding takes place in a variety of moist organic matter, notably man's garbage and the accumulated manure from man's livestock and poultry. Control of the fly larvae ("maggot") in these media is difficult in spite of modern insecticides. In many cases it is impossible due to the difficulty in obtaining adequate insecticide penetration and the existence of high levels of resistance to the chemicals. The obvious solution would appear to be sanitation, *i.e.* the frequent removal of breeding media. However, that often involves mere transfer of the problem from one site to another. For example, improperly managed sanitary landfills allow continuation of fly breeding in the waste materials. Handling of the fly breeding media must be accomplished in a manner that makes the waste unsuitable for continued development of the fly larvae. How to accomplish this depends on better knowledge of the behavior of fly larvae.

Behavior is mediated by sensory inputs and hence we have investigated the nature of the sensory receptors in the house fly larva. They have proved to be remarkably complex.

Gross Appearance

The fly egg hatches into a small larva (4 mm) which molts 3 times to produce a robust third-instar larva (1.5 cm) which later undergoes a

*Dr. Axtell is Professor of Entomology and Director of the medical entomology program at NCSU. Dr. Wang is Research Associate. This paper reports the first detailed study ever made of all the anterior sensory organs of the house fly.

complex metamorphosis to form a pupal stage within the thickened, darkened larval skin (now called a puparium or pupal case). The adult fly emerges from this case in 4-5 days.

The larva (Figure 1) in all stages is near-white, cone-shaped with a mouth and mouthhooks in the tapered anterior end and distinct openings for air exchange (spiracles) in the blunt posterior end. The major sensory organs are in the anterior portion which has a bilobed appearance (Figure 2). Three organs on each lobe are readily observed by scanning electron microscopy: (1) A cylindrical dorsal projection ("dorsal" organ), (2) a rosette of lobes pointing anteriorly ("terminal" organ) and a protuberance adjacent to the mouthhooks ("ventral" organ). The structure and probable functions of these organs will be described on the basis of our investigations on third-instar larvae using scanning and transmission electron microscopy.

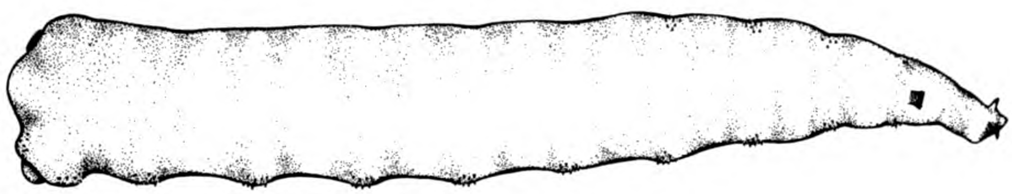

Figure 1 — Drawing of a house fly larva

Dorsal Organ

The dorsal organ consists of a dome and a cylindrical basal portion (Figures 3-5). The dome is about 15 μ (microns) in diameter and 16 μ high. The cylindrical portion is ca. 30 μ long and elliptical in cross-section ($25 \times 34\ \mu$). The dorsal organ is supplied by 35-41 bipolar neurons which together with their accessory cells from a ganglion in the interior of the lobe.

Five types of sensory seceptors were found in the distal part of the dorsal organ: (1) the dome, (2) a lateral pore receptor, (3) a scopodium-like receptor, (4) two contact chemoreceptors and (5) two other unclassified receptors. The last four types are located in the invagination between the dome and the cylindrical portion.

The dome is innervated by 21 bipolar neurons whose dendrites are grouped in 7 bundles of 3 dendrites each as they pass through the cylindrical portion of the organ (Figure 6). Upon reaching the dome, the dentrites branch profusely. As a result the peripheral lumen is filled with

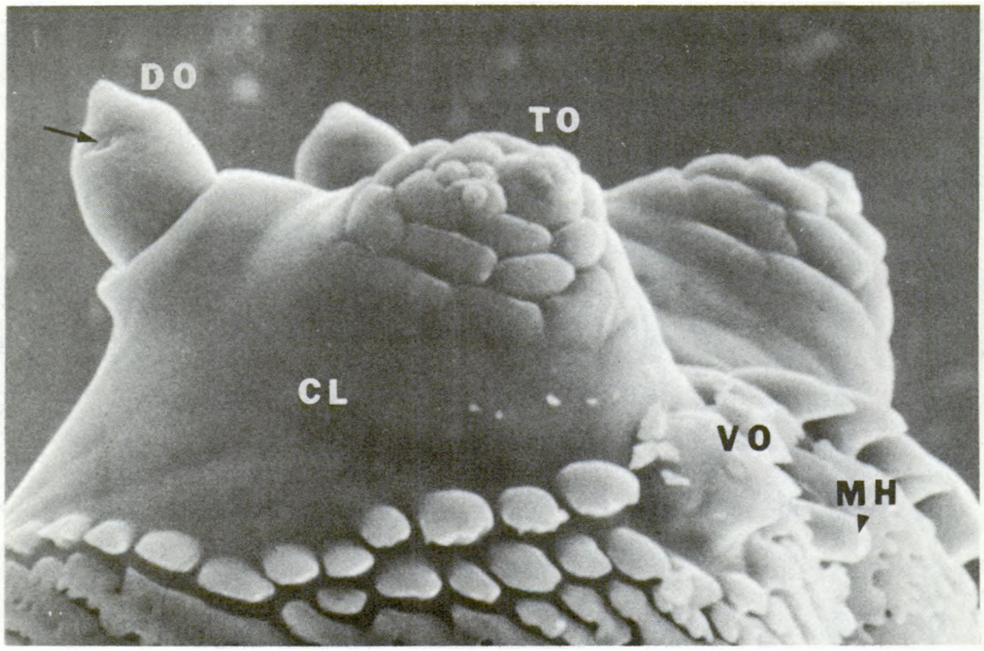

Figure 2 — Scanning electron micrograph of anterior end of a house fly larva showing the dorsal organ (DO), terminal organ (TO), ventral organ (VO), mouth hook (MH) and cephalic lobe (CL). Arrow indicates lateral pore receptor.

naked dendritic branches bathed in a fluid. The smallest branches are only 800 A in diameter. Stimuli may reach these dendritic branches from the exterior by means of numerous openings in the base of furrows in the surface of the dome (Figure 7). These furrows give the dome a striated appearance. A complex pore tubule system provides routes of communication from the furrows to the interior. The precise nature of stimuli transmission to the dendritic branches is not known, however. The dome appears to be an olfactory receptor.

Around the circumference of the base of the dome are 7 basal pores which are blocked and are not sensory receptors. They are apparently the openings through which the sheath surrounding the dendritic bundles are pulled out during the molting process.

The lateral pore receptor (Figure 8) has not been previously described in any fly larvae. It is an obvious structure when scanning electron microscopy is used. It is located laterally in the invagination between the dome and the cylindrical portion and is innervated by 2 bipolar neurons whose unbranched dendrites are exposed to the exterior by a single opening at the top of a protective cuticular tube. The lateral pore receptor appears to be a contact chemoreceptor although it may react also to strong odors.

In the invagination between the dome and the cylindrical portion are several other receptors. The scolopidium-like receptor is innervated by

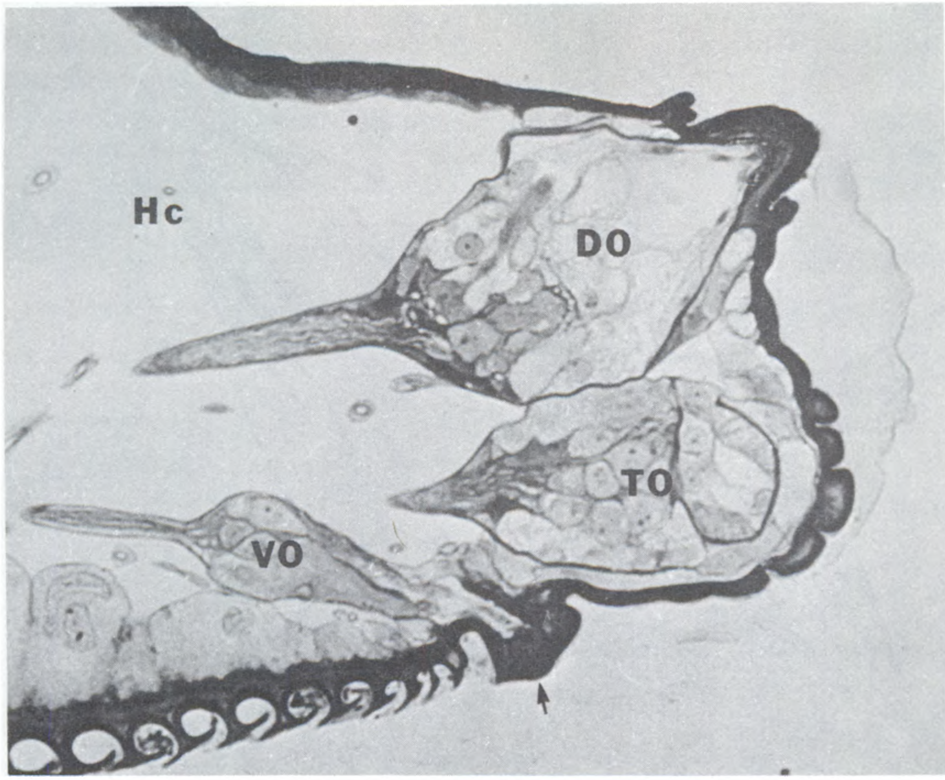

Figure 3 — Longitudinal section through the anterior portion of the fly larva showing the ganglia of the dorsal organ (DO), terminal organ (TO) and ventral organ (VO). Hc = haemocoel. Arrow indicates exterior openings of the ventral organ.

1 bipolar neuron and a "tubular body" in the dendritic tip which appears to be exposed to the outside. This receptor appears to have both mechano- and chemoreceptive functions. The two other receptors which have dendritic tips exposed to the exterior through a single opening are probably contact chemoreceptors. The fifth receptor type we have designated "unclassified" because each have 2 dendrites exposed to the exterior but one may be a chemoreceptor and the other (due to the presence of a tubular body) may be a mechanoreceptor. Perhaps additional receptors occur in the invagination but we did not find them!

From this description of the dorsal organ it is obvious that it is a complex organ. Its major function is apparently olfactory reception but considerable contact chemoreception and mechanoreception must occur.

Terminal Organ

The terminal organ is the most anterior projection of each lobe and appears as a cluster of knobs and papillae surmounting an area of lobes on the body surface. A large ganglia underlies the organ. The terminal

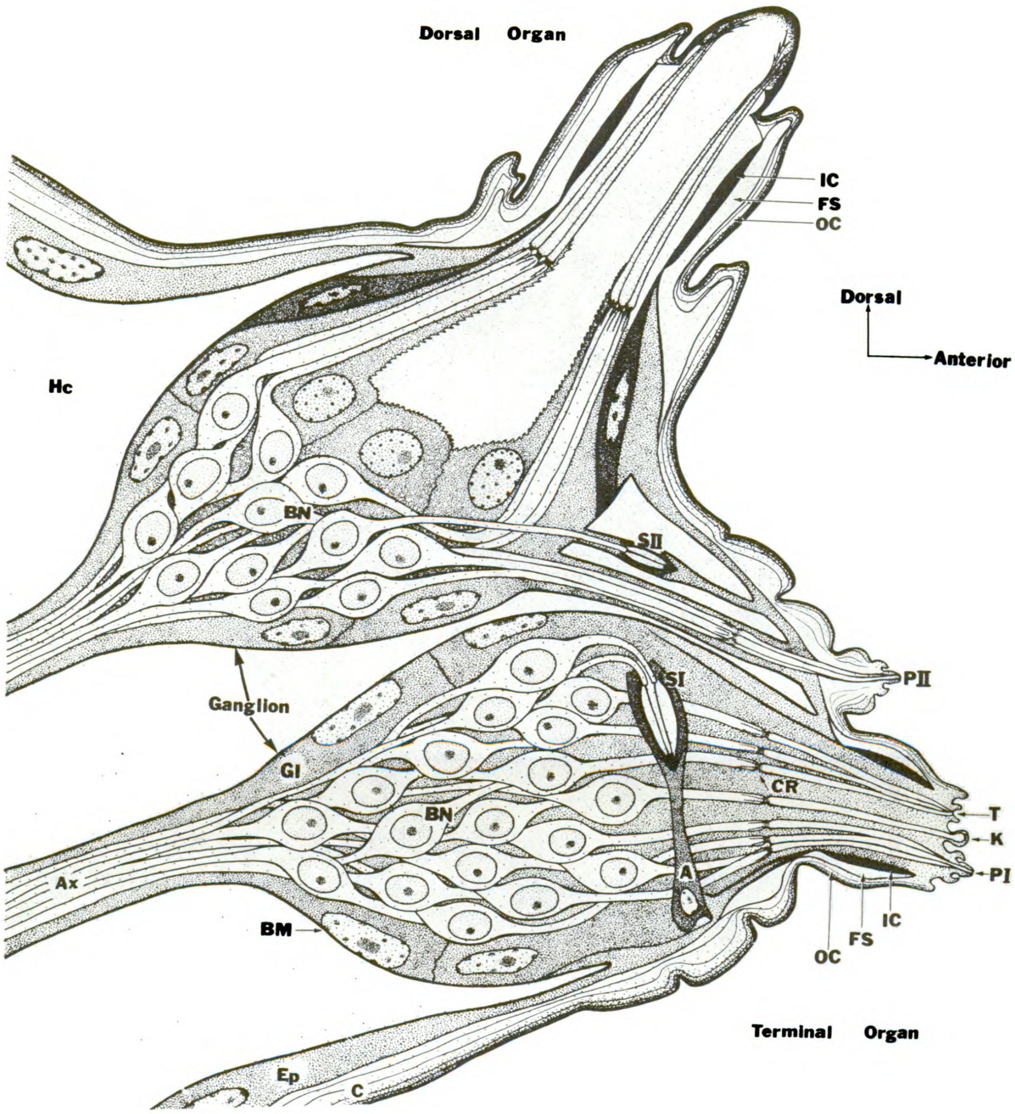

Figure 4 — Drawing of a longitudinal section through the dorsal and terminal organs. A, attachment cell; Ax, axon; BM, basement membrane; BN, bipolar neuron; C, cuticle; CR, ciliary region, Ep, epidermis; FS, fluid-filled space; Gl, glial cell; Hc, Haemocoel; IC, inner cuticular ring; K, knob sensillum; OC, outer cuticular ring; PI, papilla sensillum in the distal group; PII, papilla sensillum in the dorso-lateral group; SI, scolopidium in the ganglion of the terminal organ; SII, scolopidium in the dorso-lateral group; T, pit sensillum.

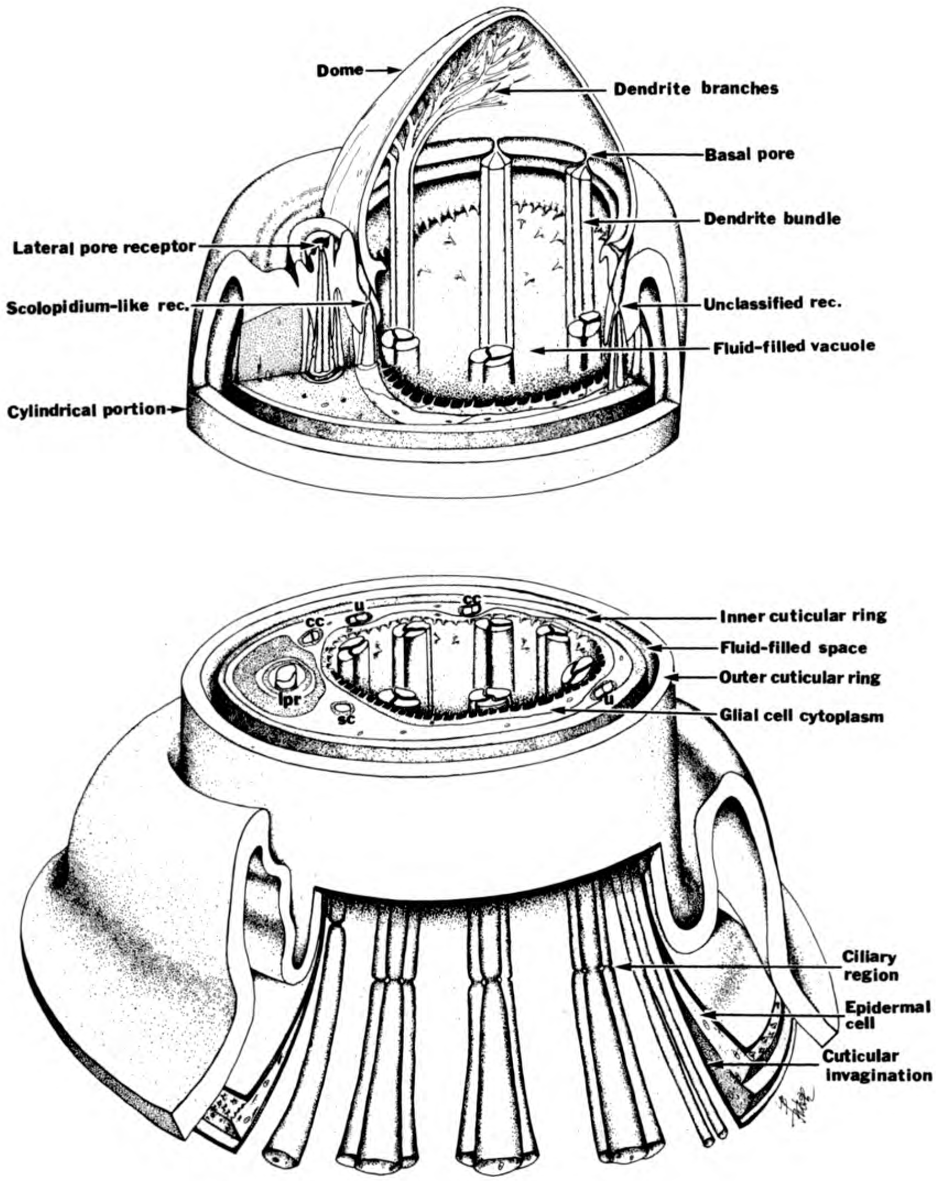

Figure 5 — Diagram of the dorsal organ showing the distribution of receptors. cc, contact; lpr, lateral pore receptor; sc, scolopidium-like receptor; u, unclassified receptor.

organ is even more complex than the dorsal organ and contains at least 6 different types of sensory receptors arranged in two clusters (Figures 9 and 10): A distal group and a smaller dorso-lateral group.

In the larger distal cluster there are 4 types of receptors which have been named from their gross appearance as papilla, pit, knob and spot sensilla. Internally there is a scolopidium receptor which apparently measures stresses.

The three papilla sensilla have a single pore opening to the exterior. One papilla is innervated by 5 bipolar neurons and the other 2 by 3

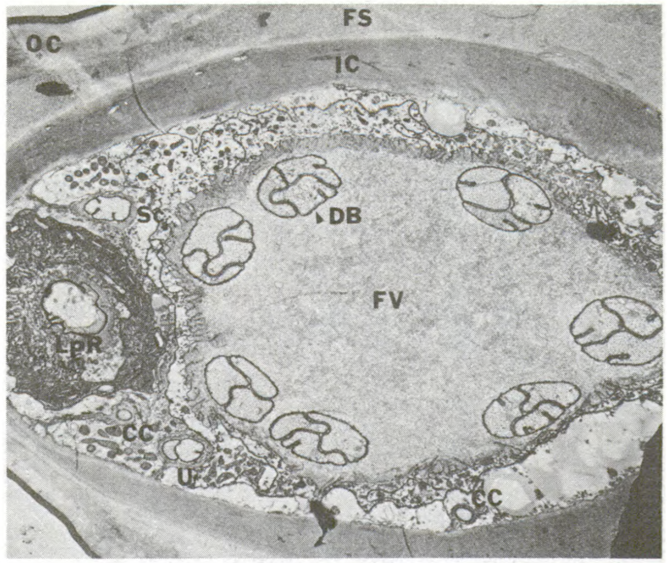

Figure 6 – Cross section of the cylindrical portion of the dorsal organ showing the 7 bundles (DB) of 3 dendrites and dendrites (LPR) of the lateral pore receptor.

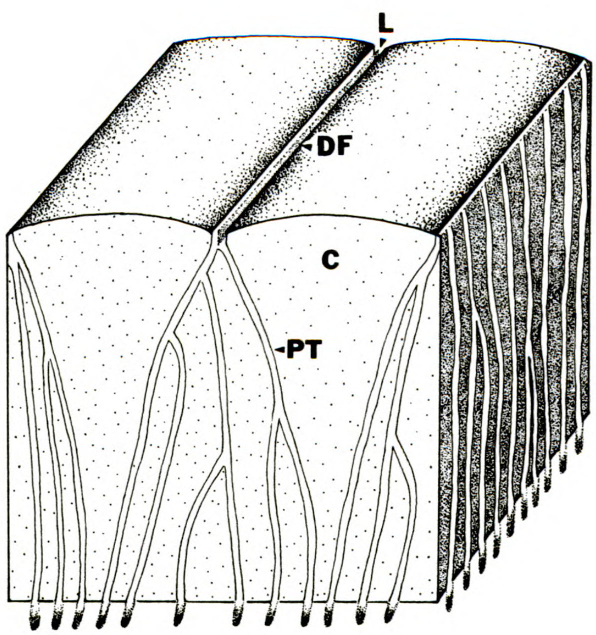

Figure 7 – Drawing of the arrangement of furrows (DF) and pore tubules (PT) in the cuticular wall (C) of the dome portion of the dorsal organ.

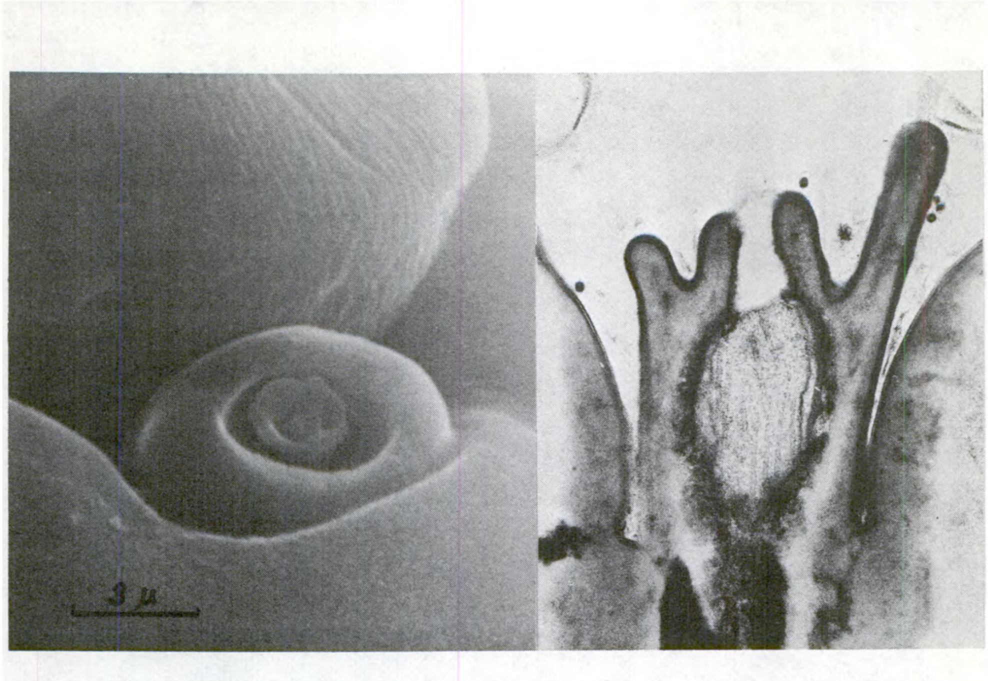

Figure 8 — Lateral pore receptor. Left, scanning electron micrograph showing exterior appearance of the lateral pore and the striated surface of the dome. Right, transmission electron micrograph showing a transverse section through the lateral pore receptor.

bipolar neurons each. One of the dendritic tips ending near the pore has a "tubular" body indicating a mechanoreceptor. The other dendritic tips lack such a structure and extend further towards the pore opening suggesting a contact chemoreceptor.

The five pit sensilla each have a pore in the center. They are innervated by 2-5 bipolar neurons. In two of the sensilla there is a tubular body in one of the dendritic tips. The other dendrites lack such a structure and extend further towards the pore opening. This suggests that the pit sensilla are contact chemoreceptors and two of them have an additional mechanoreceptive function.

The two knob sensilla differ in size but each is innervated by 1 bipolar neuron. A pore opening was found at the base of the knob portion of the sensillum but this is probably similar to the basal pore in the dorsal organ. The dendrite ending in the smaller knob contains a granular material while the ending in the larger knob is filled with lamellae. We are not able to suggest a function for the knob sensilla.

The spot sensillum is innervated by 1 bipolar neuron. The dendritic tip has a "tubular body" and communicates to the outside through a fine pore. This suggests both contact chemoreception and mechanoreception.

The dorso-lateral group of sensilla contains a papilla type, a modified papilla type; a spot sensillum and a scolopidium. The papilla sensillum is like the ones in the distal group except that it is innervated by 3 bipolar neurons whose cell bodies are located in the ganglia of the dorsal organ instead of the terminal organ. The modified papilla sensillum is innervated by only 1 dendrite whose cell body is located in the haemocoel not in

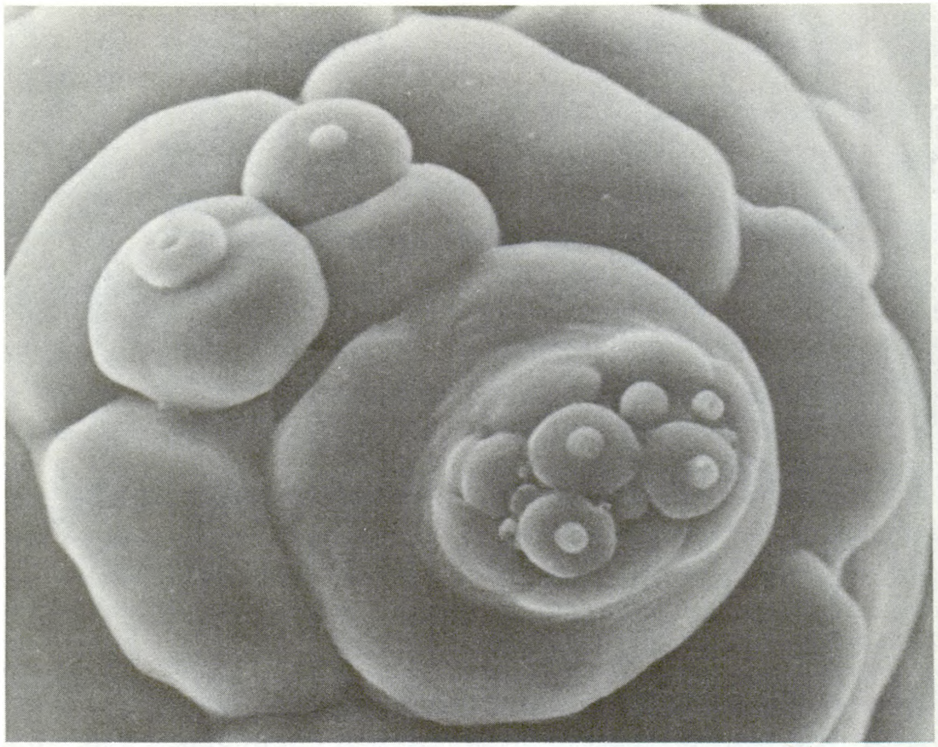

Figure 9 — Scanning electron micrograph of the terminal organ of the house fly larva

the ganglion of either the dorsal or the terminal organ. The dendritic tip has a tubular body and is exposed to the outside through a pore. Adjacent to this modified papilla sensillum is a spot sensillum whose structure is like the one in the distal group. Near the papilla sensillum is an internal scolopidium to measure stresses. It is innervated by only 1 bipolar neuron whose cell body is located in the ganglia of the dorsal organ.

These receptors in the terminal organ suggest that this complex structure has major importance as a contact chemoreceptor and a mechanoreceptor. Specific subfunctions are perhaps performed by the various types of sensilla. The two internal scolopidium provide a means of detecting stresses in two different planes.

Ventral Organ

The ventral organ appears as a lobe on each side and anterior of the mouthhook. It is a relatively simple structure. There are 4 pores opening to the exterior (Figure 11). Each represents a sensilla, three of which are innervated by 1 bipolar neuron and the other by 2 bipolar neurons. A dendritic tubular body was found in one case and probably occurs in

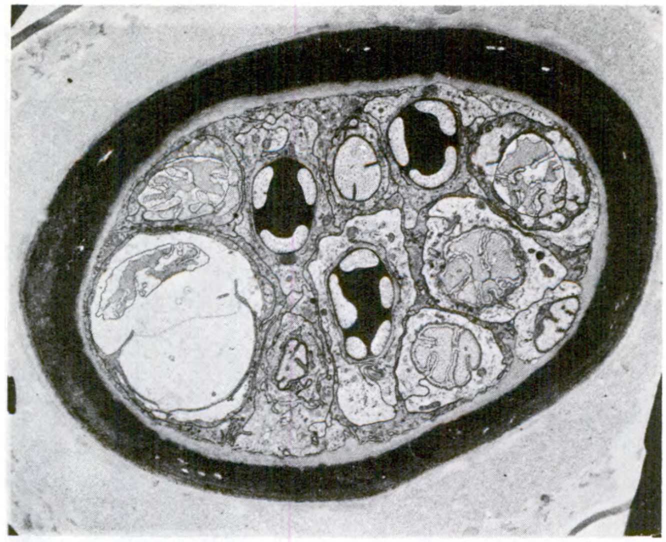

Figure 10 — Cross section through the distal group of the terminal organ showing dendrites innervating the various receptors.

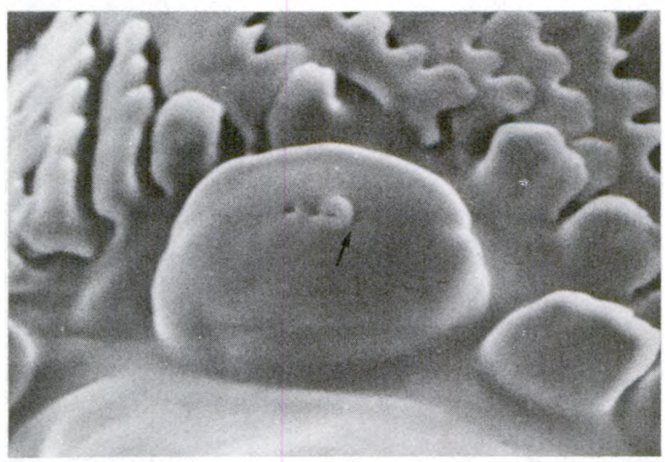

Figure 11 — Scanning electron micrograph of the ventral organ of the house fly larva showing pore openings (arrow).

the other sensilla (Figure 12). The ventral organ must be a contact chemoreceptor with additional provision for mechanoreception.

This elucidation of the structures of the fly larva enable us to suggest functions on the basis of resemblance to known sensory receptors in other insects. Experimental evidence (electrophysiological and behavioral) are now needed to fully document the role of the various types of receptors. The complexities of the larval sensory organs are now known. This makes possible more refined experimental approaches to fly behavior and control.

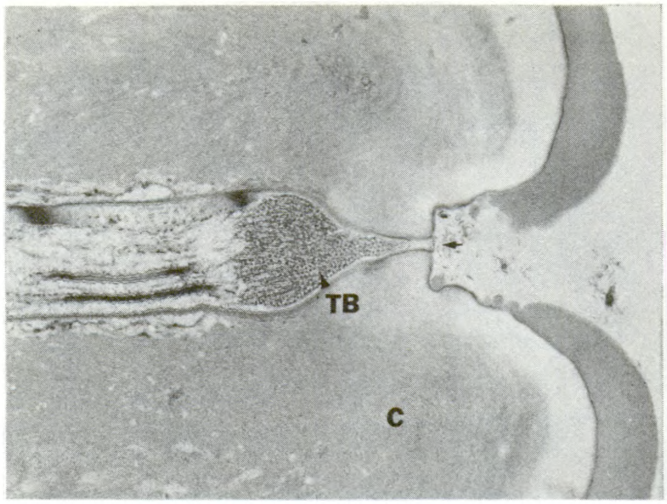

Figure 12 — Longitudinal section through a pore in the ventral organ showing the underlying dendrite with tubular body (TB).

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Wang, I-Wu Chu and R. C. Axtell. In press. "Fine Structure of the Terminal Organ of the House Fly Larva, *Musca domestica* L," *Z. Zellforschung*.

ONR Sponsored Meetings

International Chalon Conference to be held in Augusta, Michigan June 5-7, 1972. For additional information, please contact Dr. A. B. Callahan, code 444, Office of Naval Research Arlington, Va.

Advanced Study Institute, Physics and Chemistry of Upper Atmospheres, to be held at the University of Orleans, Orleans, France July 31-August 11,

(Continued on Page 24)

On the Naval Research Reserve

Report from Boston

NRRC 1-1, Boston, Massachusetts draws its members from three states: Maine, New Hampshire, and Massachusetts; its 25 current members represent a wide spectrum of technological talent. The Company is growing. In the first half FY 72, it gained more members than it lost, and is actively recruiting.

In addition to its regular members, there are 19 affiliates from the Army, Navy, Air Force, Coast Guard and Marine Corps adding to the depth of group discussions and panels.

An exciting project is now underway to provide a fresh new look at branch office mobilization contigency plans. NRRC 1-1 will start from the ground up to develop current and projected technology and industry profiles of the Northeast Region and couple this with the Office of Naval Research mobilization requirements. The answers obtained on this project may well effect the future of many Research Companies, particularly the diversified units near the branch offices.

Reserve Company Helps the Fleet

Commander, Destroyer Development Group has been assigned the task of Fleet Introduction of the AN/SQS-35 Independent Variable Depth Sonar (IVDS) jointly by the Commanders of the Cruiser-Destroyer Forces of the U.S. Atlantic and Pacific Fleets. The task includes defining towed body behavior, characteristic performance of the system, and development of tactics and operating doctrine for this sonar system, which is the Navy's newest operational sonar system. Naval Reserve Research Company 1-2 is assisting Commander, Destroyer Development Group in the above task by taking raw data from exercises conducted in connection with tests for the sonar system and placing this data in computer readable format so that it can be used in arriving at conclusions that will be incorporated into recommendations for fleet use.

Promotion Selections

Congratulations are extended to officers listed below who were selected for promotion by the Fiscal Year 1972 Reserve Selection Board.

There were one thousand eight hundred and ten Naval Reserve line officers selected for promotion to Lieutenant Commander. Twenty were members of the Research Reserve Program:

	NRRC		NRRC
Aument, William A.	4-5	Harris, Jerry L.	6-6
Biondi, Enrico F.	12-3	Hoehing, Herbert O.	3-3
Cauthen, William R.	6-19	Hunter, Roger B.	9-6
Collins, Curtis A.	8-13	Lowenstein, Jack	4-1
Collins, James A.	9-21	Paul, Martin A.	5-11
Draper, William H.	6-9	Poust, Roy N.	1-1
Drescher, Allen J.	1-1	Richards, Charles	13-1
Erickson, Bernard J.	9-12	Romanoli, Peter J.	4-1
Fonseca, Anthony	3-1	Shelton, Jon A.	5-10
Guberman, Herbert D.	6-3	Stowers, Richard A.	11-5

Eleven of the officers were from the new field and nine from the old. Other statistics based on the records of the Research Reservists selected for promotion are:

Date of Birth		Date of Rank		Designator	
Earliest	3-19-27	Earliest	3-1-58	1105:14	1405:3
Latest	7-21-42	Latest	12-1-67	1355: 1	1825:1
				1356: 1	

(*Continued from Page 22*)

1972. For further information, please contact either Dr. Dardis, code 421 or Dr. T. P. Quinn, code 418 both of the Office of Naval Research, Arlington, Virginia.

The Pharmacolgy of Temperature Regulation Symposium, to be held at the Sheraton Hotel, San Francisco, California. For additional information, please contact Dr. L. M. Libber, code 441 of the Office of Naval Research, Arlington, Virginia.

IV International Biophysics Congress to be held in Moscow, USSR August 7-14, 1972. For additional information, please contact Dr. Martin A. Garstens, Office of Naval Research, Arlington, Virginia. Phone OX2-4219.

Twenty-Ninth U.S. Navy Symposium on Underwater Acoustics, to be held at the New London Laboratory, Navy Underwater Systems Center, New London, Connecticut October 31, 1-2 November, 1972. For additional information, please contact Mr. M. Lasky (468) Office of Naval Research, Arlington, Virginia. Phone: OX2-4206.

Research Notes

Navy Study Indicates Regular Marijuana Use Disrupts Sleep Patterns

A Navy study has provided a preliminary indication that chronic use of marijuana significantly disrupts normal sleep patterns.

The study is part of a broad research program on brain functioning and behavior underway at the University of Texas Medical Branch, Galveston, sponsored in part by the Office of Naval Research. The overall goal of the program is to develop psychophysiological measurements that may help to predict performance and behavior of naval personnel.

In exploratory experiments in which the effects of animals of the chronic use of marijuana on brain functioning and behavior were studied, the Texas team of scientists under the direction of Dr. Ernest Barratt noted significant changes in electroencephalogram (EEG) patterns during both waking and sleep periods. At the same time, the animals became more lethargic, less interested in playing or being petted as well as undergoing definite changes in their sleep records.

This led to experiments designed to explicitly explore the specific effects of regular marijuana use on sleep. The EEG results clearly indicated that the animals received significantly less "slow-wave" or stage four sleep as a result of the chronic administration of marijuana. It was also discovered that the sleep changes did not return to normal for at least 30 days following cessation of marijuana usage.

Stage four is the deepest level of sleep in terms of arousal threshold. It is significant in that scientists generally believe it is this stage during which the restorative biological processes occur. For example, one series of studies has recently shown that secretion of human growth hormone is significantly related to this stage of sleep.

The animal experiments are currently being extended by experiments relating chronic marijuana usage to sleep among human subjects. The normal sleep patterns of these subjects are checked for about four days to establish baseline values. Their sleep patterns are then recorded during ten successive days of marijuana smoking plus a one-week recovery period. Surveys show that at least two to five percent of marijuana users smoke pot at least once daily.

After seven days of daily marijuana usage, the subjects studied to date were found to have significantly less stage three and four sleep. During the recovery week, the loss of these stages of sleep was still significantly below their predrug baseline levels. In addition, the subjects spontaneously complained of being tired and sluggish at this time without any questioning by the experimenter. Although such behavioral effects of marijuana have been noted in the past by clinical observers, this is the first scientific confirmation of a possible link to regular marijuana usage.

If these preliminary findings with humans are borne out by more extensive testing and if they continue to be consistent with the results from the animal research, it could mean that individuals who use marijuana several times a week will find their sleep does not provide the rest and restorative process that humans require.

Navy Studies New Exercise Technique That Takes Less Time

A Navy study of an experimental exercise technique promises to reduce considerably the time and effort necessary for individuals to maintain physical fitness.

The study, underway at the Ohio State University Research Foundation, under the direction of Dr. Donald K. Mathews, is sponsored by the Office of Naval Research. Called the Interval Training Program (ITP), it is a system of conditioning in which the person exercises for brief but regularly repeated periods alternated with approximately equal periods of rest or relaxation.

The interest of the Navy in this research is to reduce the time now spent by naval personnel to keep in good physical condition. ITP exercises also can be performed almost anywhere, including aboard submarines and space-limited ships, and requires no special equipment. Another advantage is that it can increase a person's energy potential more rapidly than other methods of conditioning.

Physical fitness is achieved by exercise or stressful work that increases the body's energy supply or work capacity and maintains it at a high level. Energy is generated in the body by adenosine triphosphate (ATP) required for short bursts of intense activity and by oxygen needed for continuing or prolonged exertion. Anaerobic training increases the body's store of ATP while aerobic training improves the body's ability to utilize its oxygen supply.

Although the ITP concept is not new, the Ohio State research program is the first scientific attempt to understand the physiological effects of interval training and to devise the most efficient exercise program to increase the body's overall energy supply through both anaerobic and aerobic mechanisms. This has led to an experimental seven-week exercise program during which a total time of less than four hours is spent in actual exercising.

In a typical exercise program in the experiment, the subjects ran in place for about 30 seconds and rested for about the same amount of time, repeating the cycle 20 times. Running speed varied depending on the subject's condition, with more rapid running achieved as conditioning improved. As the subjects moved from a relative sedentary state to one of considerable fitness, their cardiac output and the physical manifestations of the cardiac cycle were monitored.

It was found that the subjects, who performed this 20-minute regimen just three times a week for seven weeks significantly improved their anaerobic and aerobic capacities. Their mean work capacity increased 60 percent.

It was also determined that there was no advantage in performing the exercise more than three times a week. Subjects who did the training four times a week, in fact, showed only a slight improvement over those who exercised twice a week.

It was further discovered that once the seven-week program was completed, which achieved the desired level of fitness, a maintenance program of only once a week was required to maintain that level.

A field trial of ITP conditioning will be conducted this summer at the U.S. Naval Aerospace Medical Institute, Pensacola, Florida. One group of men will be given the ITP while another group will participate in the regular Navy system of physical training. A training manual will be prepared that will be adaptable to a variety of Navy situations.

Navy Awards Contract for Robot Research to New MIT Laboratory

An Artificial Intelligence Laboratory has been established at the Massachusetts Institute of Technology under a contract with the Office of Naval Research, with initial funding of $1 million provided by the Advanced Research Projects Agency.

The immediate goal for the new laboratory is to conduct research on techniques that will endow robot-like devices with human-like learning, viewing, and manipulative capabilities. It is intended that the robots will be able to survey their environment, move about in it, and also understand natural English instructions in relation to performing tasks within that environment. The robots would not only see (*via* television) and hear but would also have a sense of touch.

Such devices, which would be remotely controlled by computer, are expected to be able to supplant or supplement man in performing essential military tasks in hostile or stressful environments. Examples of applications are deep sea exploration, bomb demolition and intelligence data collection.

The Artificial Intelligence Laboratory, which is under the direction of Dr. Marvin Minsky, will also be concerned with understanding the principles of both artificial and natural intelligence. The work in artificial intelligence will concentrate on robot development, including vision, mechanical manipulation and advanced automation. In the area of natural intelligence the objective will be to design models of structures involved in "common-sense thinking" along with the development of the capability of robots to understand meanings in everyday language.

Other research will explore tradeoffs between time, memory size and processor parallelism within the robot system. All three areas will be initially pursued in connection with a "block world," with the blocks representing an environment of objects of varying sizes, shapes and colors.

Work at MIT under a previous ONR contract resulted in a machine with an arm and hand-like manipulator that can distinguish blocks of various sizes and shapes by sight and feel. When instructed, the manipulator can pile several blocks one on top of another according to their exact order of descending size. The machine system can also interpret statements and commands even when language is used that might be ambiguous, incomplete or ungrammatical.

Measuring Pollution Samples

Naval Research Laboratory Scientists, working under an Environmental Protection Agency contract, have developed a simple, fast, and inexpensive technique for monitoring and measuring pollution samples, from either the air or water, through an advance in x-ray spectrometry.

L. S. Birks and J. V. Gilfrich of NRL's X-Ray Optics Branch who are principal investigators in the research and Dr. J. Wagman, project officer at EPA's National Environmental Research Center in North Carolina, reported that particulate or precipitate samples filtered from air or water require no specimen preparation and can be placed immediately in the x-ray equipment for measuring of harmful elements.

The NRL improvement has increased the detectability of pollutants by more than 10 times thus making it easier to investigate violations of the pollution regulations.

Advances made by NRL in the past year, Mr. Gilfrich said, make it likely that x-ray spectrometry may become the workhorse for analysis of particulate pollutants throughout the nation. Because the x-ray method is nondestructive, the samples can be retained as evidence for legal prosecution of pollution cases.

In a recent general review to be published by the American Chemical Society, Mr. Birks suggested that the technique as it now stands should be a significant improvement over other methods for analyzing particulate pollutants.

Agena Satellite Experiment Seeks Answers to Interference with Long-Distance Radio Signals

A Lockheed experiment is probing the ionosphere more than 400 miles above the Earth's surface. It is exploring ionospheric processes which sometimes result in the loss or impairment of long-distance radio communications, especially in the case of radio signals that pass through the polar regions.

A new and promising experimental instrument aboard the satellite transmits radio signals to the Earth's surface where they are reflected back to the satellite, which then records the amplitude of the reflected signal.

The purpose of the experiment is to understand changes produced in the Earth's ionosphere when solar storms send streams of high-energy particles into the Earth's atmosphere. These high-energy particles, mostly protons and alpha particles, penetrate the atmosphere down to the D-region of the ionosphere. This is a layer about 30 miles thick lying roughly between 20 and 50 miles in altitude above the surface of the Earth.

Lockheed scientists and technicians at the Lockheed Space Sciences Laboratory in Palo Alto have only begun to analyze the data recorded aboard the satellite and relayed to Earth since launch of the satellite last October. Even so, the scientists headed by Dr. Richard G. Johnson say the experiment package and the Agena are performing as programmed.

The experiment package was built under contract with the Office of Naval Research, and the Agena was launched by the Air Force Space and Missiles Systems Organization (SAMSO) from Vandenberg AFB, Calif.

The instrument that transmits the radio signals to the Earth surface is called the Earth-Reflecting Ionospheric Sounder (ERIS). ERIS measures the amplitude of the radio waves that return to the satellite, thus giving a clue to the effects of the additional particles in the ionosphere.

Also part of the experiment package are 19 individual instruments to collect data on proton, alpha and electron particles from the sun that pass the satellite on their way to the upper atmosphere.

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Cooperating with the experiment are three Earth-surface sites that use high-frequency electronic signals sent into space and other observing techniques to coordinate with the satellite. The signals emanate from incoherent backscatter sounders, high-frequency radars, ionosondes, and other techniques that include optical systems, rocket probes, and radio receivers.

Two of the sites are in Canada—at Ft. Churchill, Manitoba, and at Edmonton, Alberta—and the third is at Fairbanks, Alaska.

Normally long-distance radio signals travel around the Earth between the surface and the ionosphere, which constantly shifts its altitude above the Earth. As they circle the Earth, the radio waves are reflected or refracted by the ionosphere at its various altitudes depending on whether the radio waves are high or low frequency.

Occasionally changes in the ionosphere caused by the penetration of the high-energy particles generated by solar storms produce communication problems, ranging from total blacktout to static so intense that only part of the message can be understood.

Total mission life for the Agena and its payload is expected to be at least six months. However, Johnson expects his instruments will function much longer. He noted that a previous satellite experiment operated in orbit for 18 months.

The long mission life is made possible by the near circular 400-mile orbit, the excellent performance of the experimental package, and abundant power from the solar panels, including an experimental solar panel, aboard the spacecraft.

Scientific data gathered in orbit is transmitted to tracking stations located around the world. Equipped with 11 antennas, the Agena uses 800 telemetry channels to return data to the experimenters. The spacecraft is capable of responding to 248 different, real-time ground commands. Two high-speed tape recorders record and play back information acquired during flight.

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Ferro-Cement Structures .... KENNETH A. CHRISTENSEN 1
ROBERT BRADY WILLIAMSON

A way to substantially improve the strength and durability of ferro-cement structures has been developed under an ONR contract. Ferro-cement is very useful for boat hulls and other marine applications.

Electron Microscopy of Sensory Receptors .... RICHARD C. AXTELL 12
I-WU CHU-WANG

This ONR project has produced the first microscopy study of the sensory organs of the housefly larva. Only by understanding the makeup of the larva can better ways be found to control this disease carrying insect.

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Research Notes 25

Shown here is the arm of a robot which is being created at Massachusetts Institute of Technology. The robots will be able to survey their environment, move about in it, and also understand instructions in relation to performing tasks. See page 27.

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