NAVSHIPS 250-538

U.S. NAVY DIVING MANUAL

JULY 1963

Navy Department
Washington, D.C.

U. S. NAVY DIVING MANUAL

PART 1

GENERAL PRINCIPLES OF DIVING

CONTENTS

PART 1

CONTENTS

TABLES AND ILLUSTRATIONS

CONTENTS

TABLES AND ILLUSTRATIONS—Continued

SPECIAL NOTE:

A publication is of value only insofar as it is maintained current and informative. The U.S. Navy Diving Manual (NAVSHIPS 250-538) must reflect all new developments and current procedures in the diving field.

All individuals and activities engaged in diving are authorized and requested to submit constructive criticism and recommendations for improvement of the manual direct to the:

Officer in Charge
U.S. Navy Experimental Diving Unit
NWP, Washington 25, D.C.

This same procedure is already in effect for submission of originals of activity diving logs (NAVSHIPS 1000) and copies of diving accident reports (NAVMED 816).

The Experimental Diving Unit is assigned responsibility for periodic assembly of the field recommendations into proposed numbered changes. These proposed numbered changes will also include information on equipment, techniques, and procedures as they are developed.

The Bureau of Ships is responsible for publication for approved changes to the U.S. Navy Diving Manual. Changes proposed by the Experimental Diving Unit will be forwarded to the Chief, Bureau of Ships via the Chief, Bureau of Naval Personnel and the Chief, Bureau of Medicine and Surgery for approval.

SECTION 1.1 INTRODUCTION

1.1.1 THE HISTORY OF DIVING

(1) History gives no record of the date when diving first began or who the first divers may have been, but man's curiosity probably led him into the water and under its surface at a very early stage. Like some of the native pearl and sponge divers who continue the primitive art, the first divers probably used no equipment at all except perhaps a stone to get them to the bottom more rapidly. Although unaided divers have achieved remarkable depths and durations of dive, it is not likely that the early divers often exceeded 1 or 2 minutes of submergence or 80 to 100 feet of depth.

(2) Written records provide accounts of some very ancient diving exploits. Most of these were connected with naval warfare. For example, Xerxes is said to have used combat divers; and over 400 years before Christ, Herodotus told the story of Scyllis, a famous Greek diver who was employed by Xerxes to recover treasure from sunken Persian ships. When the job was done, the conqueror decided to detain Scyllis but the diver went over the side during a storm, threw the whole fleet into confusion by cutting the anchor cables, and then completed his escape by swimming 9 miles to Artemisium. Alexander the Great used divers to destroy the boom defenses of Tyre about 333 B.C., and Aristotle wrote that Alexander himself descended in some sort of a diving bell. Divers were used in at least six naval battles and sieges between 400 B.C. and 1795 A.D. In the early 1800's Spanish warships still carried men whose duties were swimming and diving for the fleet, although no breathing appliances were used.

Early efforts

(3) Several of the ancient accounts indicate that crude means of supplying the diver with air were sometimes used. About 77 A.D., the historian Pliny referred to military divers who breathed through tubes which were supported at the surface by a float. In a famous treatise on warfare written about 375 A.D., Vegetius described diving hoods equipped with air pipes.

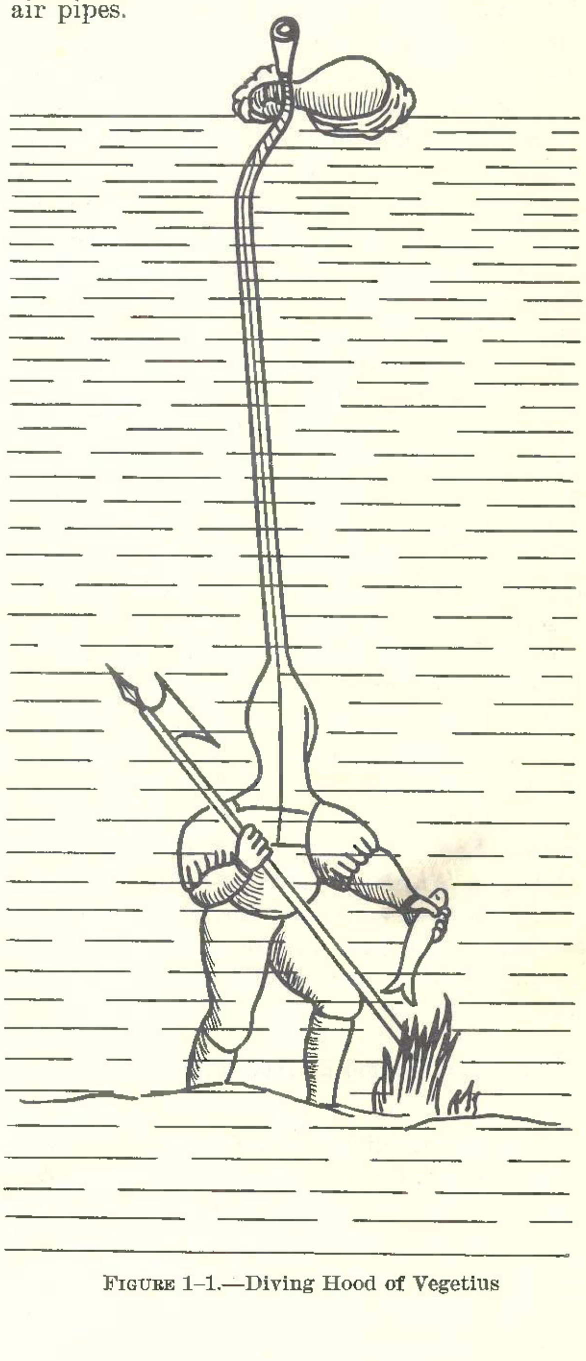


FIGURE 1-1.—Diving Hood of Vegetius

ʼing developments 1500 to 1800

4) Interest in diving increased after 1500, l many different rigs were designed. In 1, the book written by Vegetius in 375). was printed, and a drawing of the div- hood described by him (fig. 1–1) became first design for diving dress to be found a printed book. Even before this, the re- :kable artist Leonardo Da Vinci had :ched diving outfits and hand fins along h submarines and flying machines and other ·vels yet-to-come. In 1524, Vallo designed eather helmet which was slightly more anced than that of Vegetius. This one at t provided eye-ports, and its leather pipe reinforced with iron rings and held up a disk-shaped float. If they were ever t, such rigs could not have been used in er much over the diver's head. In 1680, elli proposed an outfit (see 3.1.1) which ld probably have been the first self-con- .ed diving apparatus—if it had been built if it could have been used, which is un- ly.

ʖ) Although little of the equipment de- ed before 1800 was very practical, the erwater accomplishments of the period ɜ surprising in many ways. A primitive ·kel submarine (propelled by 12 oarsmen) making regular trips on the Thames ınd London about the time the Pilgrims .ed in America. Diving bells and crude ng helmets were used for work on wrecks leep as 60 feet, and reasonably practical pumps were developed before the end of 1700's.

:ng developments 1800–1900

) The advent of compressors started the lopment of diving as we think of it today. ı the ability to maintain an air pocket nst greater and greater pressures for er and longer times came the physiological lems of working under pressure. As each lem was encountered, its solution was ht through the combined efforts of the .tists and the men willing to try again.

) The divers of the 1800's were true ad- ırers advancing into the unknown. They no knowledge of how well their equipment would work or against what tests it would be pitted. They had no knowledge of what the pressure, the compressed air, or the combination of all three would do to them. And the harbors around Europe were just as black then as they are now. We owe much to these individualists. (The most important development of this period, the "closed-dress" invented by Augustus Siebe in 1837, is discussed in pt. 2.)

(8) One of the most famous divers of the 1800's was Alexander Lambert. His most noted exploit took place when a tunnel, which was being built under the Severn River in England, flooded in 1880. Using the forerunner of oxygen rebreathing apparatus, he went alone down a vertical shaft and far into the tunnel through masses of floating debris. In order to shut an iron door so that the tunnel could be pumped out, he was forced to return to the surface to get a wrecking bar. On his second trip into the blackness, he finished the job. Three years later, the tunnel flooded again and Lambert was hired to repeat the job. He tried to use the same equipment, but this time he was poisoned either by the high oxygen pressure or by carbon dioxide. He barely managed to escape with his life, but he tried again the next day using a surface-supplied rig and was able to complete the job. In 1885, Lambert forced his way through three decks and into the strongroom of a wreck at 162 feet. He recovered nearly half a million dollars in gold, but the job gave him a case of the bends which forced him to retire. There were as yet no adequate decompression tables. These had to wait for the work of Professor Haldane and his associates in 1907. (See section 1.1.4.)

Diving in the U.S. Navy

(9) Not much is actually known about the beginning of diving in the United States Navy. Although good work evidently was done at shallow depths in the early days, very little was accomplished in deep diving. Largely as a result of the efforts of Chief Gunner George D. Stillson, an active development program was started in 1912 to check the practicability of Haldane's stage method of decompression

and to improve the standard Navy diving gear to permit deeper dives. Extensive tests were conducted in diving tanks ashore and later from U.S.S. *Walke* in Long Island Sound. The value of the work was evident in the salvage operations on the submarine U.S.S. *F–4* off Honolulu in 1915. On that job, divers descended to 304 feet—a depth which is probably a record for useful diving in the standard rig with air as the breathing medium.

(10) After the *Walke* tests, a diving manual was issued; and the Navy Diving School was established at the Naval Torpedo Station at Newport, R.I. This school was discontinued when the United States entered World War I. Personnel of the school and some of its graduates formed a nucleus for the overseas salvage division, which was established as a unit of the United States Naval Forces abroad. Throughout our participation in the war, these divers rendered valuable service in salvage operations along the French coast.

(11) The need for further development of diving was strongly emphasized by two tragic accidents which occurred in the mid-twenties. On 25 September 1925, U.S.S. *S–51* was rammed by the steamship *City of Rome* and sank in 132 feet of water off Block Island. Only three of the crew survived. At that time, only 20 Navy divers were qualified to dive deeper than 90 feet, and only six civilian divers on the east coast of the United States were willing to dive in 132 feet of water. Salvage operations commenced on 26 September 1925 but were interrupted by winter storms. The *S–51* was finally raised on 5 July 1926 and towed to U.S. Naval Shipyard, Portsmouth, N.H. The many difficulties encountered were made more serious by the fact that so few divers had been trained to work at such a depth.

(12) On 17 December 1927, the Coast Guard Cutter *Paulding* collided with U.S.S. *S–4* (SS–109) just to the southward of the extreme tip of Cape Cod. *S–4* immediately sank in 102 feet of water with all personnel on board. Divers reported signs of life in the boat 22 hours after the collision. The salvage vessel *Falcon* succeeded in ventilating the compartment, but bad weather forced her to cease operations. Rescue attempts were terminated on 24 December 1927. This accident underlined the need for some means of getting personnel out of a disabled submarine. On 27 December 1927, the salvage phase began. Again the work was hampered by a shortage of divers qualified to work at the depth involved. Only 24 were available. *S–4* was raised on 17 March 1928 by divers working from U.S.S. *Falcon.*

(13) Even before the loss of these submarines, there was concern over the possibility that rescue and salvage operations would be needed in much deeper water. Divers could not retain their mental clarity and effectiveness when breathing air at great depths, so some other breathing medium was needed. In late 1924, the Navy's Bureau of Construction and Repair (now the Bureau of Ships) joined with the Bureau of Mines in investigating the use of helium-oxygen mixtures. The preliminary work was conducted at the Bureau of Mines Experimental Station in Pittsburgh, Pa.

(14) Experiments on animals, later verified by studies with human subjects, clearly showed that helium-oxygen mixtures offered great advantages over air for deep dives. There were no undesirable mental effects, and there was reason to expect advantages in decompression time. In the early part of 1927, the experiment on the use of helium-oxygen had reached the stage where it was desirable to transfer the Experimental Diving Unit from the Bureau of Mines to the Navy Yard, Washington, D.C. (now the U.S. Naval Gun Factory), as a permanent activity under the Bureau of Construction and Repair (now Bureau of Ships). Its mission was to continue the investigation of helium-oxygen and other development work in diving practices and equipment. The Experimental Diving Unit has functioned accordingly up to the present time.

(15) The U.S. Naval School, Deep Sea Divers, was reestablished in 1926–27 at the Washington Navy Yard (Naval Gun Factory). This location was chosen with the view that its proximity to the Experimental Diving Unit would permit expeditious application of approved experimental findings to the standard training curriculum. The school is operated

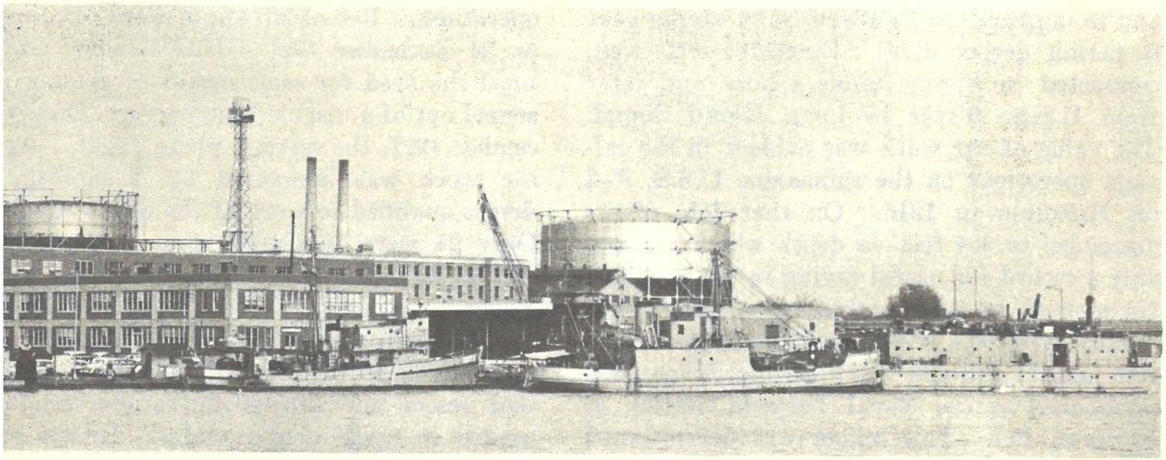


FIGURE 1-2.—U.S. Naval School, Deep Sea Divers.

URE 1-3.—Pressure tank, Experimental Diving
nit. The two wet-pressure tanks in the Deep Sea
ving School are used for training in deep diving;
ose in the Experimental Diving Unit are employed
the testing of decompression tables and for ex-
rimental dives.

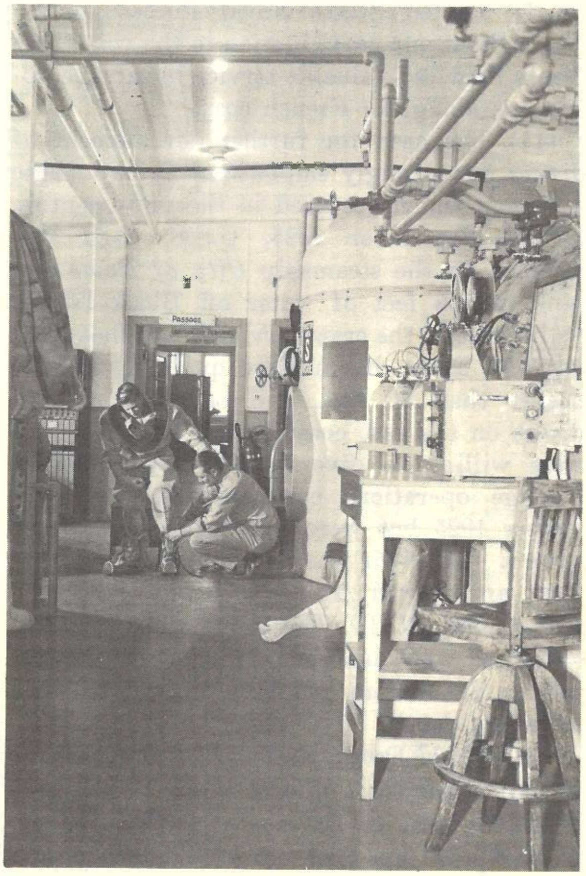


FIGURE 1-4.—"Igloo" and recompression chamber, Deep Sea Diving School. Above each pressure tank is an access chamber (igloo), and a recompression chamber (right) is connected to the igloo.

under the cognizance of the Bureau of Naval Personnel. The facilities of the Deep Sea Diving School (figs. 1–2 to 1–6) include two pressure tanks capable of withstanding 350 pounds working pressure and 525 pounds test pressure. Each pressure tank is directly connected to a recompression chamber. Two open tanks are also used for training purposes. Facilities on the Anacostia River outside the school proper include a converted 500-ton covered lighter (YFNX–9) which has been fitted with stations for eight divers. This also contains classrooms, shops, and a storeroom. Various service craft are also employed in training. Of these, the YDT–5 is used for helium-oxygen and air diving in a Potomac River field area. The YSD–39 is used for salvage projects with a sunken LCI in another field area. The YF–336 is used for demolition training off the Naval Powder Factory, Indian Head, Md. Other craft, such as a YDB and an LCPR, serve for local deep sea and scuba training. Among other training aids, a submarine rescue chamber is used for actual descents to a submarine false seat on the river bottom.

(16) The Experimental Diving Unit is equipped with two pressure tanks and recompression chambers which are duplicates of those installed in the Diving School. There are also modern workshops and an excellent laboratory. Both the School and Experimental Unit have gas-mixing rooms for helium-oxygen supply. The recompression chambers at the Experimental Diving Unit are also equipped for altitude experimental work. A great deal of work in altitude studies was done there at the start of World War II.

(17) The submarine disasters of 1925 and 1927 spurred not only further progress in diving but also developments in submarine escape and rescue methods. The years of experimentation which had been devoted to the

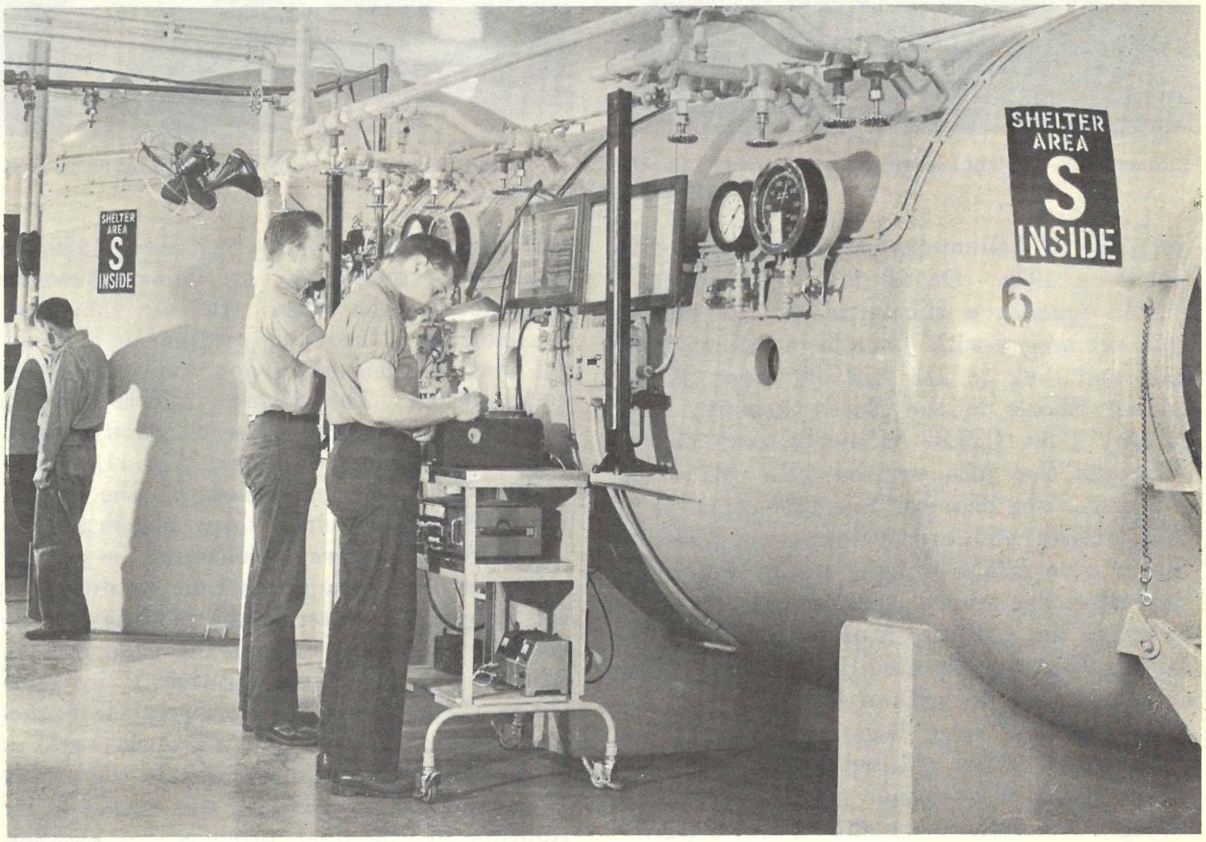
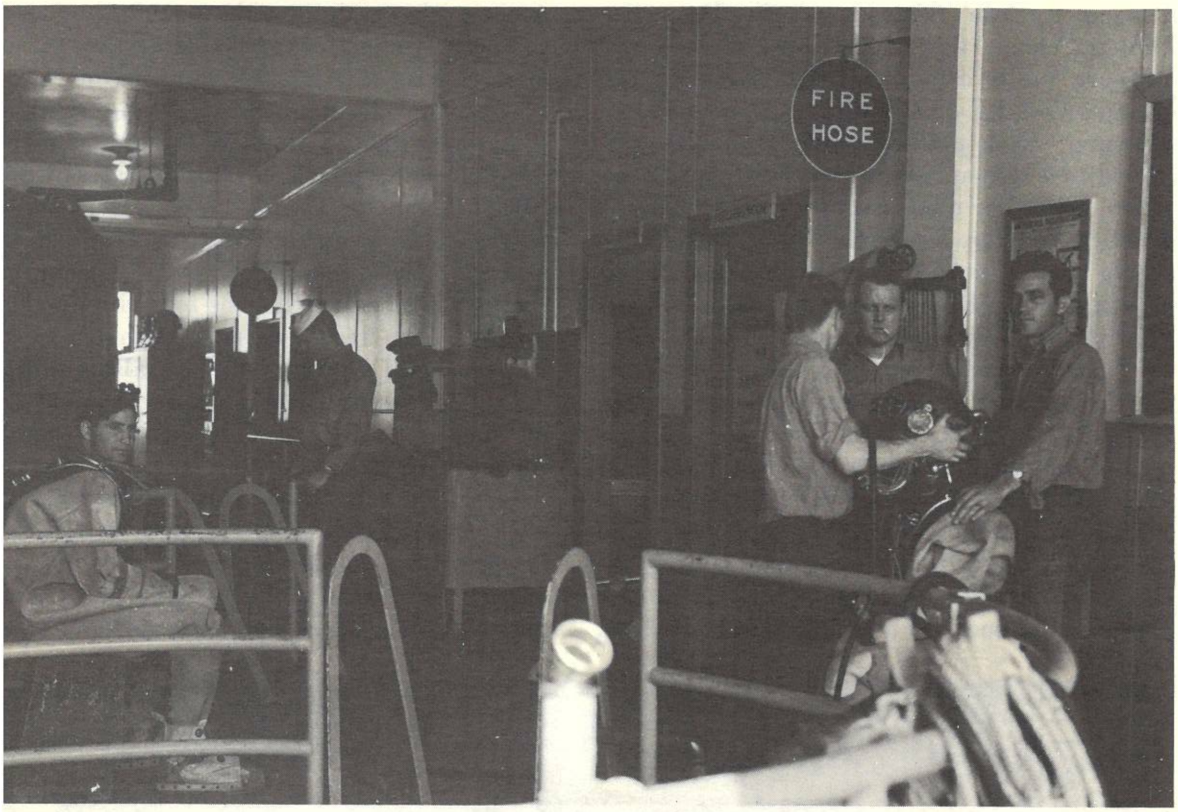


FIGURE 1–5.—"Igloo" and recompression chamber, Experimental Diving Unit. The unit's recompression chambers are used for equipment evaluations and experidental "dry dives" as well as for treating decompression sickness. They are equipped with special instruments for both depth and high altitude pressures.



ɜURE 1–6.—Students learn diving techniques in Deep Sea Diving School open tanks before going on to river diving and pressure tanks.

:hnique of helium-oxygen diving paid div-ɜnds in 1939. On 23 May of that year, S.S. *Squalus*, a submarine of the newest pe, submerged with its main induction valve en and sank in 243 feet of water off the e of Shoals in the North Atlantic. On May 1939, U.S.S. *Falcon*, veteran of the *51* and *S–4* jobs, arrived with the rescue amber. The chamber was first attached to e forward hatch of the *Squalus*, and 33 sur-vors were safely brought aboard *Falcon* in ur trips. The rescue chamber was then at-:hed to the after hatch of the *Squalus*, and ɜ sad word was reported that all was flooded d there were no signs of life.

(18) Salvage work began immediately on *Squalus*. This resulted in the first field perimental application of helium-oxygen ring. The divers were able to think clearly d work efficiently when breathing helium d oxygen mixtures at the 243 foot depth. rface decompression with oxygen was also used successfully. On 13 September 1939, the *Squalus* was towed into port following months of heroic salvage work. Had air alone been available for a breathing medium, it is doubtful that the demanding job could have been accomplished. The *Squalus*, rechristened the *Sailfish*, was restored to service and contributed to the victory of World War II.

(19) With the expansion of the United States Navy to include ships specifically designed for ship salvage work and the requirements of diving under wartime conditions, it was necessary to increase the facilities for the training of divers. About the time this expansion was under consideration, a fire broke out in U.S.S. *Lafayette* (formerly the French liner *Normandie*) while it was docked at Pier 88, North River, in New York. In the process of extinguishing the fire, she was capsized. The righting of the liner provided an excellent opportunity for establishing a diving school where practical experience for ship salvage personnel could be obtained. In addition to

the experience that could be obtained on the U.S.S. *Lafayette*, the large number of other diving jobs in the harbor increased the advantages of the location. The Naval Training School (Salvage) was established on a permanent basis in September 1942 to provide for the increased need for divers. During 1946, the school, as the U.S. Naval School, Salvage, was transferred from Pier 88, New York, to Bayonne, N.J. This school was authorized to train and designate salvage divers. In the summer of 1957, the school was disestablished at Bayonne, and the courses for salvage divers and salvage diving officers were moved to the school at Washington.

(20) In addition to the Naval School, Deep Sea Divers, there are diving activities within the fleet and at various naval shipyards which are authorized to train and designate divers second class.

(21) During and after World War II, the Experimental Diving Unit continued the improvement of helium-oxygen equipment and techniques. Dives as deep as 561 feet were made using helium-oxygen gear in the wet pressure tanks. Research in other aspects of diving also continued. One notable advancement was development of tables for surface decompression after air dives, using oxygen to shorten the decompression time appreciably. The Unit's work in recent years has reflected the growing importance of diving with self-contained underwater breathing apparatus (scuba). Many types of such equipment have been developed and tested, and numerous physiological studies concerning the unusual problems of self-contained diving have been conducted.

(22) The military potential of self-contained diving was demonstrated conclusively during World War II. In 1947, the first submersible operations platoon was organized in Underwater Demolition Team Two for the purpose of applying scuba to UDT (Underwater Demolition Team) operations. Men assigned to the platoon were trained in many skills such as underwater reconnaissance, underwater long distance swimming, and the application of these and other techniques to offensive and defensive operations. At the present time, self-contained diving finds many applications in the work of Underwater Demolition Teams and Explosive Ordnance Disposal Units and has proved advantageous for many other underwater jobs. In 1954, the U.S. Naval School, Underwater Swimmers, was established in Key West, Fla., specifically for the training of SCUBA divers.

(23) Divers today are doing more kinds of underwater work and doing it at greater depths, for longer times, and with far greater safety than would have been thought possible a hundred years ago. The progress of the next century may be even more impressive. Certainly, the Navy's efforts to increase the scope and safety of diving will continue.

1.1.2 TYPES OF DIVING EQUIPMENT

(1) The Navy employs several different types of diving equipment depending on the circumstances and the job to be done. A brief description of the types of gear presently in use in the Navy is presented here. Details concerning them will be found in part 2 (Surface-supplied Diving) and part 3 (Self-contained Diving) of this manual. Details concerning special tools and accessories used with both types of diving equipment are provided in part 4 (Diving Accessories).

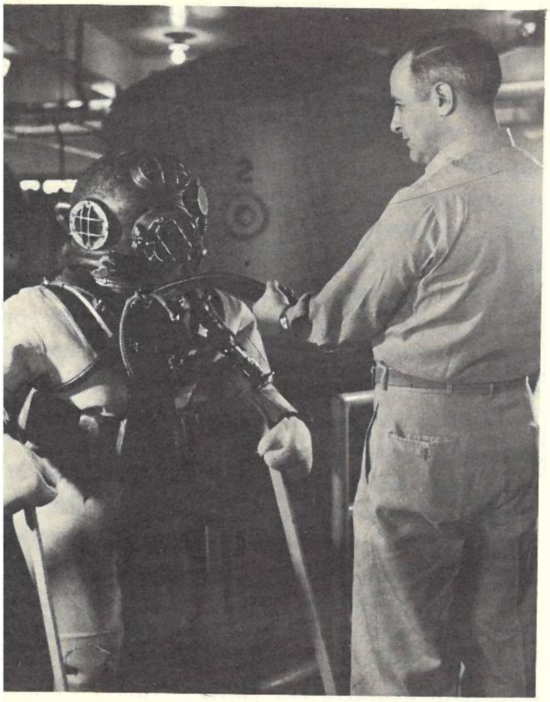
Surface-supplied apparatus

(2) All of the types in this category are supplied with air or some other suitable breathing medium through a hose from the surface. They are used mainly where the diver's work is confined to a rather small area and where stability rather than great mobility is important. Great depths and other special conditions may also require use of surface-supplied rigs. The fact that air supply duration is not limited is a definite advantage of this type of equipment.

(3) *The deep sea diving outfit* (fig. 1–7) consists of a helmet and watertight dress, weighted belt and shoes, supply hose and control valve, non-return valve, and exhaust valve. The belt and shoes overcome the positive buoyancy of the dress and helmet. The hose supplies the air to the diver, and he controls the quantity with the control valve. The non-return valve prevents the escape of air from the dress back up the hose in the event that

e supply pressure drops due to rupture of e hose or any other accident. The exhaust lve is spring-loaded and adjustable. The lance between control valve and exhaust lve settings governs the pressure in the suit d thus controls the degree of inflation and e buoyancy.

(4) The essential part of the *lightweight ving outfit* (fig. 1–8) is a full face mask. iis is supplied with air from the surface rough a hose of the type generally used r oxygen. A nonreturn valve and control lve are mounted on the right side of the isk, and an exhaust valve is provided on e left side. This mask can be used alone desired, allowing the diver almost as much eedom, within limits, as with self-contained paratus. A light, flexible dress is provided r use with the mask when desired. Since air ters and exhausts direct from the mask thout entering the dress, there is no excess buoyancy with this rig. The weights pro- led can therefore be much lighter than with deep sea rig, and they are equipped with juick release fastening to permit them to be



URE 1–7.—Surface-supplied apparatus: deep sea diving outfit.

FIGURE 1–8.—Surface-supplied apparatus: lightweight diving outfit.

dropped rapidly in an emergency. A lifeline attached directly to the diver's body completes the lightweight outfit.

(5) *Helium-oxygen equipment* (fig. 1–9) is basically the same as the standard deep sea outfit. The helmet is modified by the installation of a means of conserving the helium-oxygen mixture by recirculating it through a carbon dioxide absorbent. The exhaust system is provided with a special check-valve arrangement which makes it almost impossible for water to enter.

Self-contained underwater breathing apparatus (Scuba)

(6) The term "self-contained" indicates that the diver carries his breathing medium with him in cylinders and can thus be independent of surface connections. Three types of self-contained apparatus are in present use. Each type may include more than one make or model of unit, but the basic principles and characteristics are essentially the same for all units within the type.

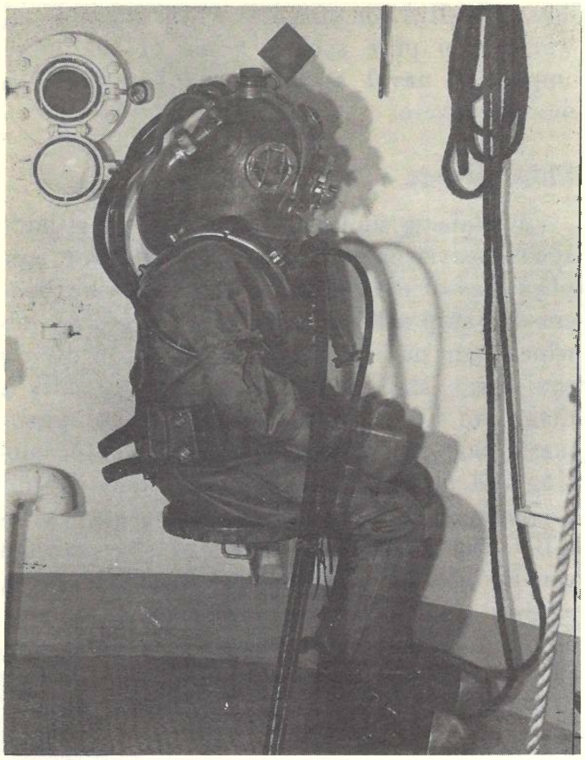


FIGURE 1–9.—Surface-supplied apparatus: helium-oxygen equipment.

(7) *Demand Type* (open circuit scuba) (fig. 1-10) is the simplest type and the one most frequently used. The diver carries large cylinders which are normally charged with compressed air. A special type of regulator supplies air on demand when the diver inhales, and the air is exhausted into the water when he exhales. No rebreathing takes place. The fact that air flows only in response to inhalation requirements helps conserve the supply, but the limited duration of the amount the diver can carry is the principle drawback of demand type gear.

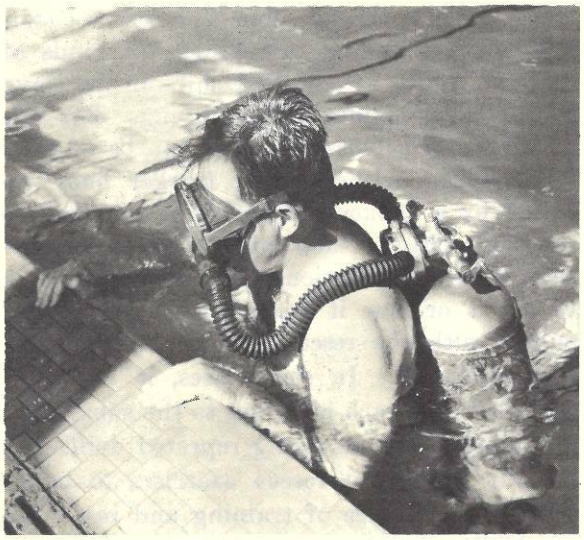
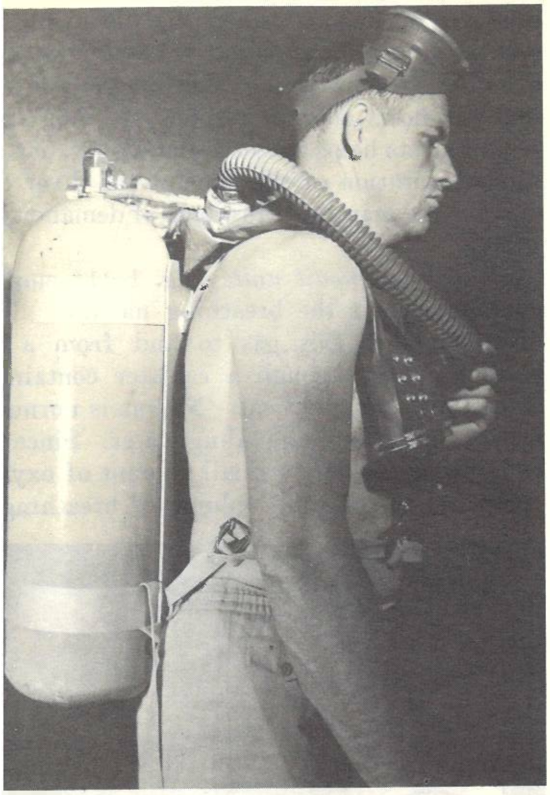


FIGURE 1–10.—Self-contained apparatus: open-circuit scuba.

(8) *Closed-circuit units* (fig. 1–11) employ pure oxygen as the breathing medium. The diver breathes this gas to and from a rebreathing bag through a canister containing carbon dioxide absorbent. No gas is normally exhausted to the surrounding water. Since the body consumes only a small amount of oxygen compared to the total volume of breathing, a relatively small gas supply suffices. Closed-circuit scuba also has the advantage of freedom from bubbles and noise, which can be very important in some tactical applications. (See 1.1.3(8).) The main drawback is the severe limitation of safe depth of use imposed by the possibility of oxygen poisoning.

FIGURE 1–11.—Self-contained apparatus: closed-circuit scuba (Lambertsen amphibious respiratory unit "LARU").

(9) *Semiclosed-circuit scuba* (fig. 1–12) was developed to permit conservation of gas by



URE 1–12.—Self-contained apparatus: semiclosed-circuit scuba (experimental "LES" unit).

reathing without the necessity of using re oxygen. The apparatus is basically like sed-circuit scuba, but a continuous flow of as mixture is provided to assure that neither ygen lack nor excessively high oxygen levels ll develop. The diver rebreathes the major rtion of the gas, but a certain amount is ntinually exhausted from the system. Much eater durations can be achieved than with mand type. Generally, mixtures of nitrogen d oxygen (i.e. air with added oxygen) or lium and oxygen are used. This can some-nes provide an added advantage by shorten-g the decompression time required.

.3 APPLICATIONS OF DIVING

(1) Most of the developments in diving mmed from the need to accomplish some ecific kind of underwater work. As diving elf progressed, and as new tools and tech-ques were developed, more and more types underwater activity became possible. To-day, men dive for purposes which range from warfare to pure sport. Some of the more important naval applications of diving are described here.

Ship salvage

(2) Raising sunken ships or repairing damaged ones is one of the most important applications of diving in the Navy today. Present-day ship salvage work is a specialized job which can put to use most types of diving equipment and almost every special skill a diver can have. It can require use of pneumatic tools, use of explosives, underwater cutting and welding, and other techniques as well as the specific know-how of salvage work itself. The underwater phases of ship salvage usually consist of repairing damaged ships, raising sunken ships, refloating grounded ships, and clearing harbors. The Navy has several types of salvage ships, most of which are equipped with divers and several types of diving equipment. These ships are capable of performing all varieties of ship salvage work from simple underwater repairs to major refloating operations.

Submarine rescue

(3) Each submarine squadron has a submarine rescue ship (ASR) fully equipped and ready to go to the aid of a submarine in distress. Each carries a submarine rescue chamber and is prepared to perform all kinds of diving. ASR's are the only ships in the Navy equipped for helium-oxygen diving. The role of diving in submarine rescue can be of vital importance. Although the marker buoy released by a sunken submarine is intended to carry the chamber-downhaul cable to the surface, unusual conditions may require a diver to rig it or free it from obstruction. Difficulties with the rescue chamber itself could require diving. In some cases, it would be necessary to attach air hoses to the submarine. In addition to conducting repeated drills and periodic simulated rescue exercises to maintain a high degree of training and readiness, the ASR's provide many useful services, diving and other, to their squadrons and the fleet.

Search and recovery

(4) Practice torpedoes and many other objects must often be located and recovered. All types of underwater search are tedious and time-consuming unless the location is accurately known and the underwater visibility exceptionally good. Even though the use of drags, sonar gear, or electromagnetic detection equipment is often effective and more efficient in search than diving, a diver usually must verify contacts. Where these methods cannot be used, searching becomes wholly the diver's job. Once the object is located, a diver usually must rig lifting lines or other means of raising it.

Inspection and repairs

(5) All types of diving equipment can be utilized for inspections and repairs. Diving inspections are usually conducted more easily and efficiently with scuba equipment because of the diver's mobility. Inspections usually made by Navy divers are ship bottom inspections which may be required for reasons such as suspected damage, leakage, routine checks of sonar equipment, and sea suction troubles. In time of war, bottom inspections would also include search for underwater ordnance. Much repair work on underwater parts of floating equipment can be accomplished by the use of divers, thus eliminating the expense and loss of time necessary for drydocking. This repair work is ordinarily minor although some major repairs have been effected in emergencies. Ship repair work often accomplished by divers includes changing propellers, replacing zincs, minor patching, clearing fouled propellers, straightening bent propeller blades, blanking off sea chests, and repairing minor damage to sonar equipment. Divers are also called upon to repair pipelines, tunnels, bridges, cable moorings, piers, and other structures.

Construction

(6) Navy divers are not usually utilized in construction work, but much work is accomplished by divers in building tunnels, bridges, caissons, and occasionally wharfs and piers.

Tactical diving

(7) Although history indicates that divers were used in war in very early times, tactical diving in military operations is comparatively new in modern warfare. It was developed into a very potent weapon of both offense and defense during World War II. Developments in self-contained underwater breathing apparatus made this application practicable.

(8) Many of the characteristic operations of Underwater Demolition Teams can be conducted without diving equipment, but the ability to approach enemy beaches without surfacing is highly advantageous. In bottom reconnaissance or in location and demolition of underwater obstacles, the operations are primarily diving tasks. Development of surface detection equipment may make it impossible to use surface swimmers because of danger to the men and the probability of giving advance warning of a projected invasion. With self-contained equipment, detection is less probable; and the swimmers retain the advantages of freedom and the ability to make direct observations. Direct attacks on ships require self-contained equipment for work beneath the ships as well as for undetected approach and safe departure. Landing parties with the ability to approach submerged can make successful raids even on closely guarded installations.

(9) Adequate *defense* may also require self-contained diving. Divers may prove to be the only effective defense against individual attacks on shipping. Direct interception of swimmers and underwater hand-to-hand combat are not very probable, but periodic ship-bottom search may be essential. The slow progress of a diver encumbered with surface connections makes self-contained apparatus very desirable for such jobs. Locating and inactivating mines present similar problems If the type of mine or its position precludes working from the surface, diving is the only alternative. The limitations of speed and mobility imposed by surface connections may dictate the use of self-contained equipment.

(10) In situations where proximity to the enemy would expose a surface vessel to undue

nger, self-contained diving may provide the ly way to accomplish a variety of under-ıter jobs in war. The many possible tactical plications of diving, especially with self-ntained gear, include even operations under-ken by land forces. Destruction or con-uction of bridges are examples.

.4 PHYSICS AND PHYSIOLOGY

(1) The forces which act upon a diver derwater are explained by the science of *ysics*, which deals with the behavior of all ıds of matter. The effects of these forces on body are explained by *physiology*, which concerned with the body's functions and its ponse to various conditions. Both of these ences developed within fairly recent times. chimedes explained buoyancy many cen-ies ago, but little was known about pres-e and its effects until Robert Boyle did his periments in the 1600's. Practically nothing s known about the composition of air or n the existence and importance of oxygen il Priestley's work in the late 1700's. Un-standing of the body's vital functions like athing and the circulation of blood devel-d even more slowly. It is not surprising t progress in diving was at a standstill for usands of years without such knowledge l that even brilliant men designed rigs ich could not possibly have worked.

2) The first real progress in diving came ut mainly through increased knowledge of sics and advancements in invention and nufacturing. For example, divers could not beyond very shallow depths until workable air pumps and hoses became available and were applied. This did not happen until around 1800, about the time steam engines began to be used extensively. Some of the most serious problems of diving naturally did not arise at all until this kind of progress made it possible for men to be exposed to high pressures. Decompression sickness was unheard of until caissons were put into use after 1840. In the years which followed, scores of men were killed or maimed by decompression sickness before the great French physiologist, Paul Bert, experimented with animals and applied existing knowledge to explain this condition in the 1870's. Improvement in decompression methods and the beginnings of recompression treatment followed his work, but needless deaths and suffering continued until investigators like Haldane put the matter on a firmer basis in the early years of our own century. Much the same sequence of events also took place with nitrogen narcosis, oxygen poisoning, and other diving problems.

(3) Today's divers have no cause to look down on their "ancestors" in diving for their ignorance. The average person today, although he enjoys all the benefits of science, knows little more about physics and physiology than they did. In diving, we still face many problems which are unsolved because of our own lack of knowledge. The least every diver can do is to learn the essentials of what is known in these sciences as they apply to diving. The next two sections of this manual are presented to help him do this and to dive more safely and effectively as a result.

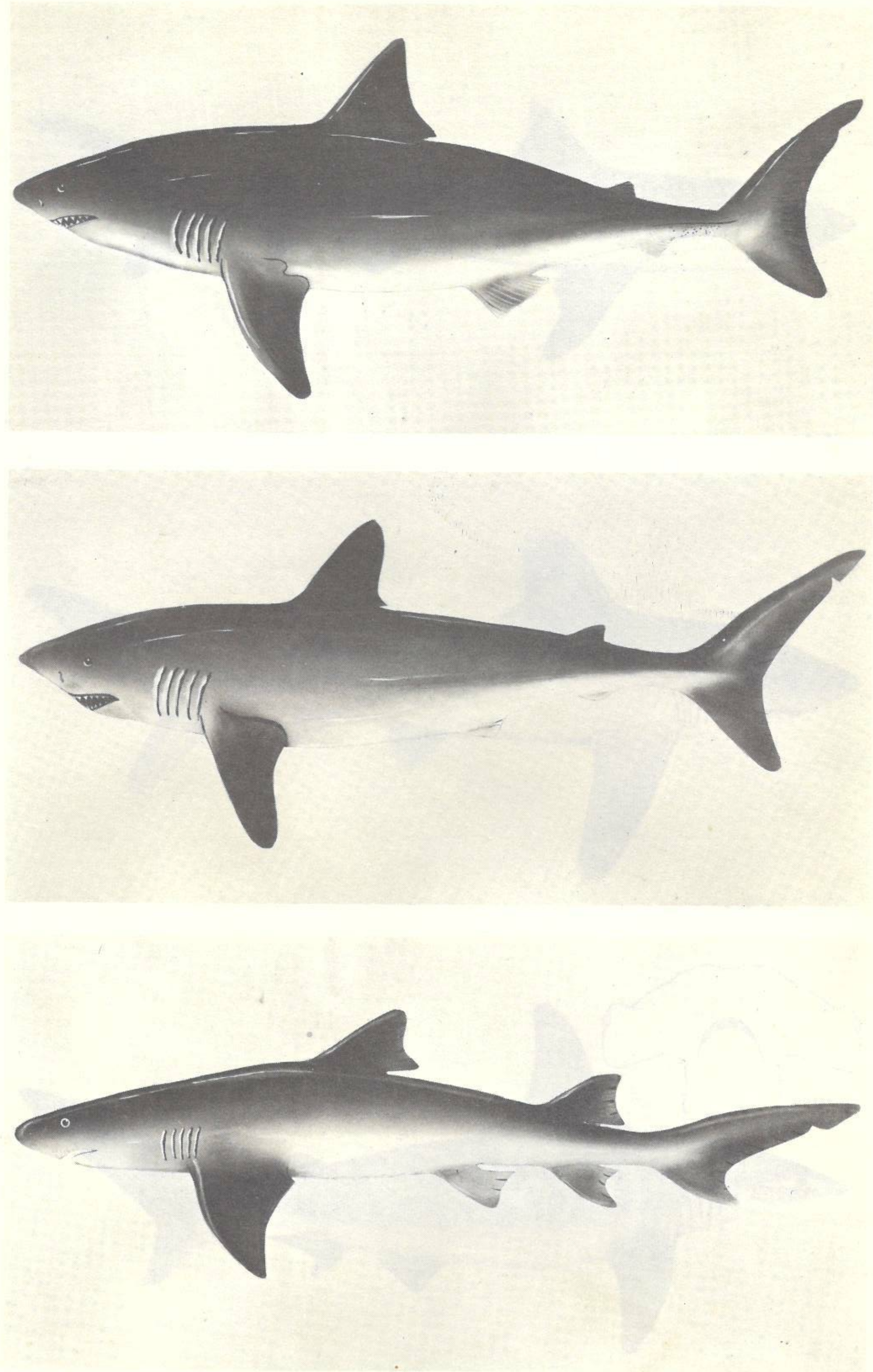


FIGURE 1-36A.—White shark, mako shark, tiger shark.

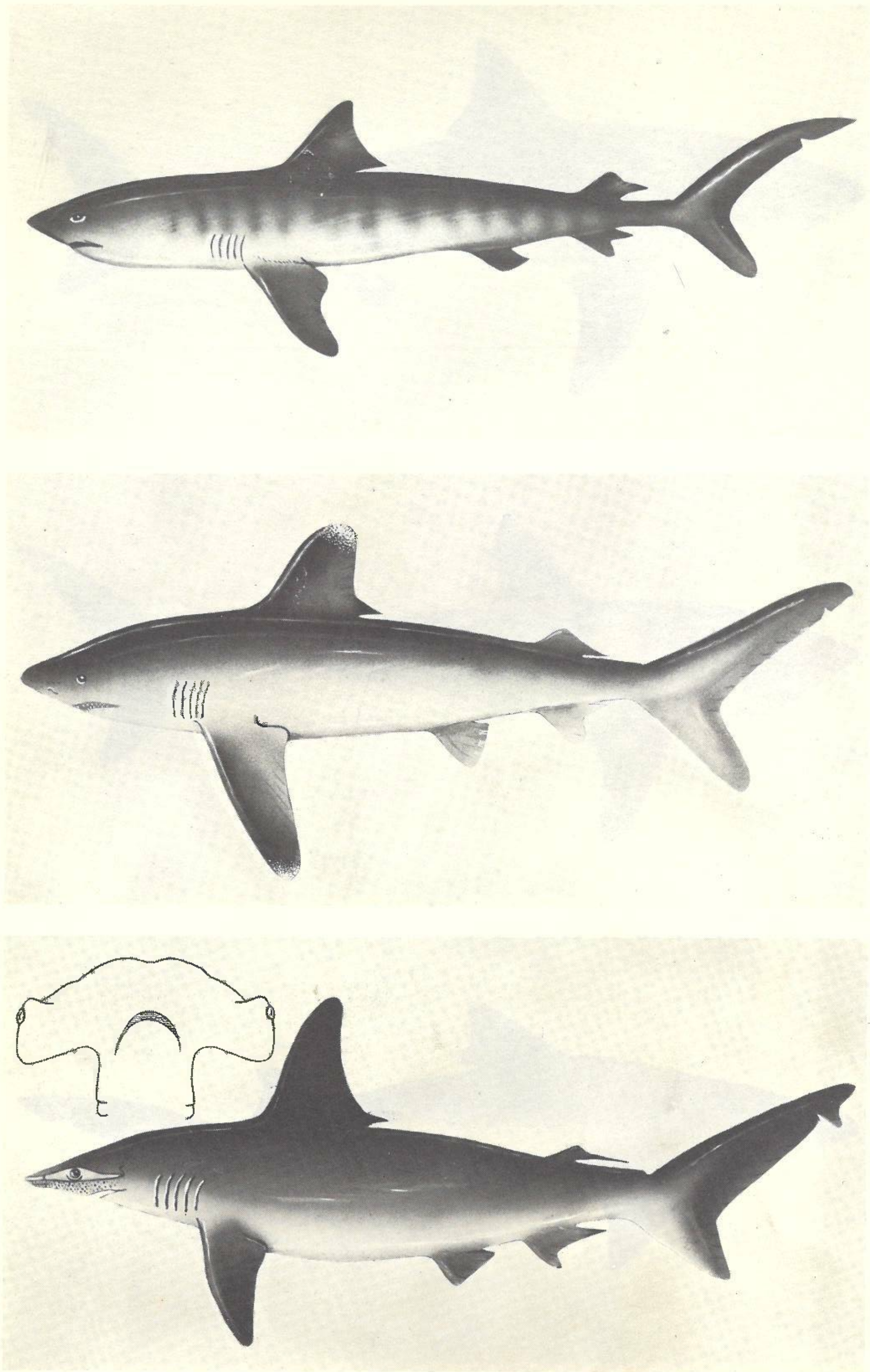


FIGURE 1–36B.—Lemon shark, white-tipped shark, hammerhead shark.

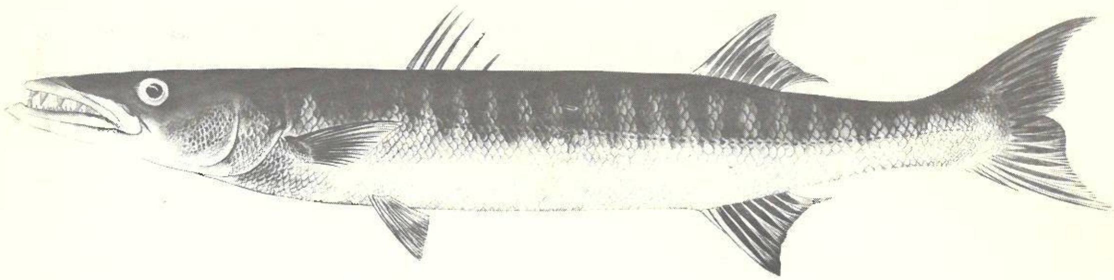


FIGURE 1-37.—Great barracuda.

(b) Barracuda wounds can be differentiated from those of a shark since the former are straight cuts, where as those made by the shark are curved like the shape of their jaws. The barracuda will strike at any speared fish that a diver may be carrying. They should be treated with respect.

Groupers

(5) Some of the giant groupers attain a length of 12 feet and a weight of more than 700 pounds. They are frequently found lurking around rocks, caverns, old wrecks, etc. They are curious, bold, and ravenous feeders. Their feeding characteristics coupled with their large size make them a potential danger to the skin diver. Several fatal attacks have been reported.

Moray eels

(6) Moray eels (see fig. 1–38) are seldom found except in tropical and subtropical seas. They may attain a length of 10 feet. Morays are bottom dwellers, commonly found lurking in holes and writhing through crevices under rocks and corals. They seldom attack unless provoked, but provoking them is not difficult. When encroaching upon their habitat by reaching into dark holes and crevices, one should move with great caution. The moray's narrow jaws are armed with strong knifelike or crushing teeth which can inflict severe lacera-

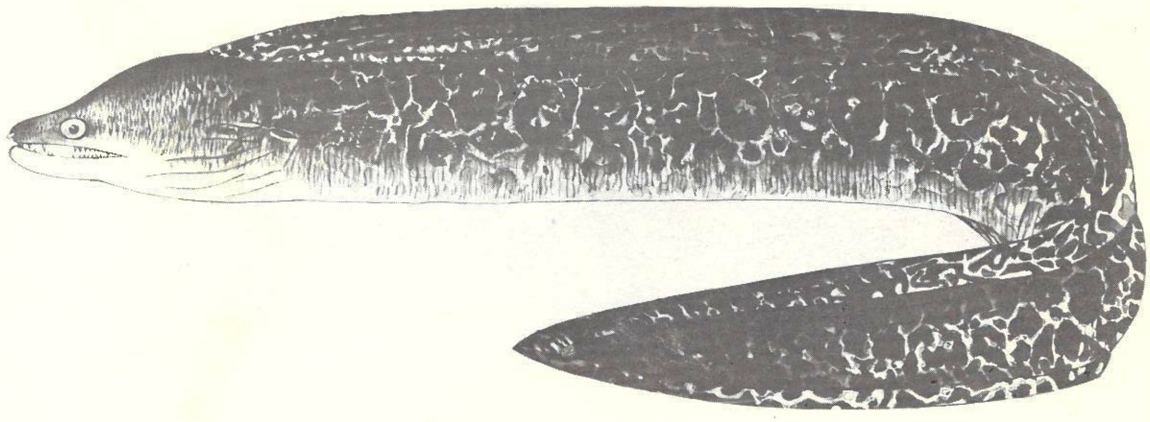


FIGURE 1–38.—Moray eel.

ons. The jaws frequently maintain their rip until death.

iller whales

(7) The killer whale (see fig. 1–39) has a eputation of being a ruthless and ferocious east. It is found in all oceans and seas, opical and polar alike. The killer whale is aracterized by a bluntly rounded snout, a gh black top fin, a white patch just behind d above the eye, and the striking contrast the jet black color of the head and back ith the snowy white underparts. Killer hales hunt in packs of 3 to 40 individuals, eying on other warm blooded marine anials. They are fast swimmers, will attack ything that swims, and have been known come up under ice flows and knock seals d people into the water. If a killer whale seen in the area, the diver should get out the water immediately.

a lions

(8) Sea lions are curious, fast swimmers, d have been known to nip at skin divers. eep away from sea lions especially during eeding time or when young are in the water.

a urchins

(9) Sea urchins (see fig. 1–40) abound on e ocean floor and cling to rocks in tropical and temperate zones; they are also found in great numbers in coral reefs. Injury from the spines is the most common effect of contact with a sea urchin, but some types have a venom apparatus and produce poisoning as well. (See par. 18 of this article.)

Corals

(10) Corals can also produce both wounds and poisoning. They are discussed in paragraph 15 of this article.

Barnacles, mussels

(11) Certain shellfish, such as barnacles and mussels, that grow on rocks, pilings, wrecks and the like, are sharp and can cause deep cuts when a diver is forced against them.

Giant clams

(12) Tridachna, or so-called giant or killer clams, abound in tropical waters. Some of them attain huge proportions, weighing several hundred pounds. Although accidents from them are rare, one should learn to recognize them and avoid catching a foot or hand between the two valves. Drownings have occurred from divers accidentally stepping into the open shells and becoming trapped. In order to release the victim, a knife must be inserted between the shells to sever the clam's adductor muscle.

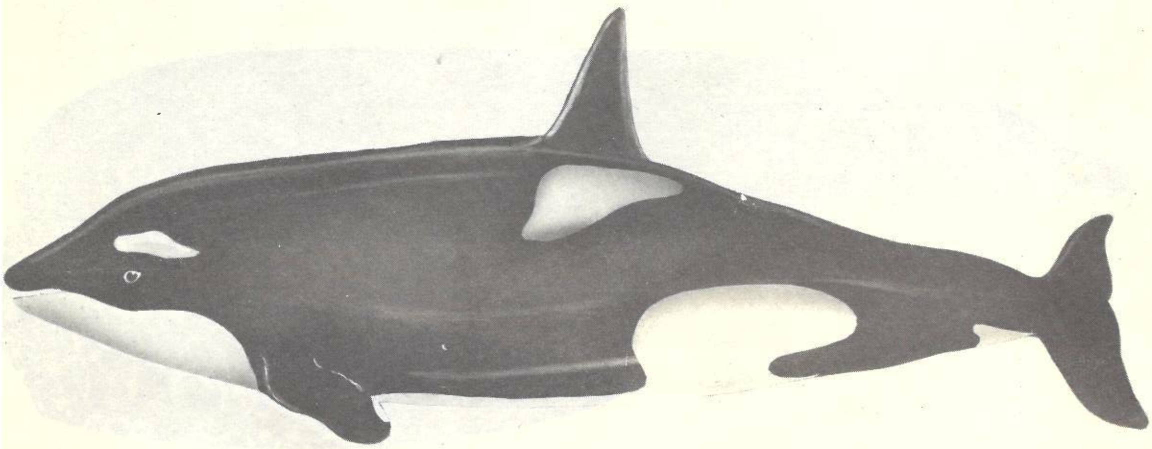


FIGURE 1–39.—Killer whale.

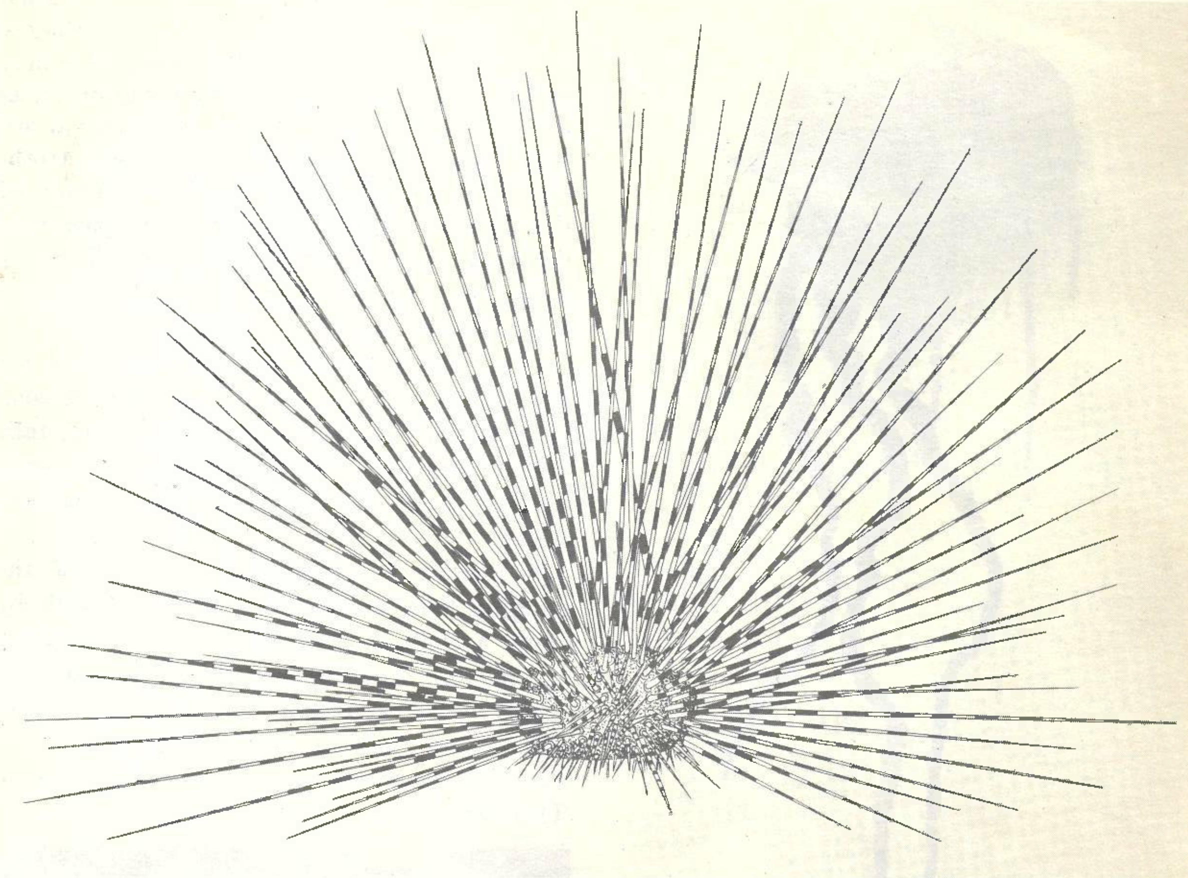


FIGURE 1–40.—Sea urchin (long-spined).

Animals that inject venom

(13) Venomous marine animals are for the most part slow moving or tend to remain in one spot. In some instances, as with stonefish, scorpionfish, and stingrays, they are well-camouflaged and exceedingly difficult to distinguish from their surroundings. In other instances they are spectacularly colored and attract attention, as in the case of zebrafish and some jellyfish. Favorite colors of many venomous creatures are combinations of black and orange.

Jellyfish

(14) Forms of marine life commonly clumped under the term "jellyfish" are found in large numbers in all oceans, in bays, and in the tidal portions of rivers. At times, they concentrate to such a degree that contact by a swimmer is almost inevitable.

(*a*) The stings of the most dangerous types, the Portuguese man-of-war (see fig. 1–41) and the sea wasp (see fig. 1–42) can have extremely serious effects. Both of these organisms are rather small in size, seldom exceeding 6 inches in diameter of the central portion. The tentacles may reach a length of 50 feet. The Portuguese man-of-war is largely an inhabitant of tropical waters. The sea wasp is found in the waters about northern Australia and the Philippines and in the Indian Ocean. The sea wasp is considered the most dangerous type.

(*b*) *Method of stinging.*—Stinging is produced by a series of specialized cells which are located largely on the tentacles. Contact with these cells sets off a trigger-like mechanism which ejects a tiny thread tube from a venom filled cell. Many thousands of these micro-

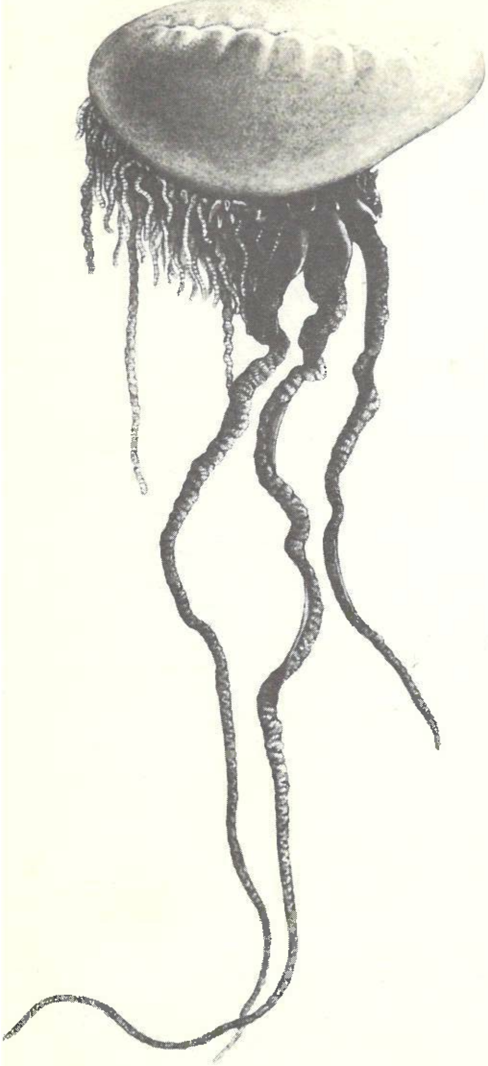


FIGURE 1-41.—Portuguese man-of-war.

›pic cells are to be found on the tentacles a single jelly fish.

(*e*) *Symptoms.*—The symptoms of jellyfish .ngs vary according to the species of jellyfish, e extent and duration of contact, the site of e sting, and the health of the victim. Symp-ms vary from an immediate mild prickly or .nging sensation like that of a nettle sting an intense burning, throbbing or shooting .in which may render the victim unconscious. ıe area coming in contact with the tenta-›s usually becomes red followed by the appearance of welts (puffy patches of skin), blisters, swelling, and small skin hemorrhages. In severe cases in addition to shock, there may be muscular cramps, abdominal rigidity, loss of the senses of touch and temperature, nausea, vomiting, severe backache, loss of speech, frothing at the mouth, sensation of constriction of the throat, respiratory difficulty, paralysis, delirium, convulsions, and death. The sea wasp has been known to kill a man within 5 minutes or less.

(*d*) *Treatment.*—If stung yourself, call for help at once and get out of the water as soon as possible. If helping another victim, take action promptly. Have someone else seek medical assistance; proceed rapidly with these steps;

1. Remove tentacles and as much of the stinging fluid as possible. (Protect hands by using a cloth, a stick, seaweed, or a handful of sand; try to avoid spreading the material.) Apply weak ammonia or saturated sodium bicarbonate (baking soda) solution if available; otherwise rub area gently with wet sand. Then wash area with fresh water.

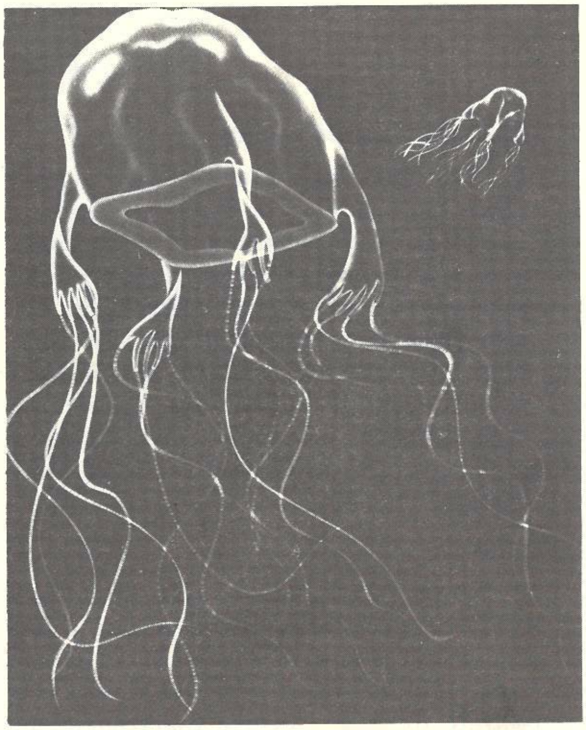


FIGURE 1-42.—Sea wasp.

2. Attempt to reduce local reaction. Use cortisone ointment, antihistamine cream, or local anesthetic ointment if available. Otherwise, try olive oil, sugar, soothing lotions, or ethyl alcohol. Apply cold compresses.

3. Try to check general reaction and shock. Keep victim lying down; elevate feet. Give artificial respiration if needed. Give oral antihistamine preparation if victim is conscious.

4. Medical personnel may use the following if considered necessary: epinephrine for "allergic shock," adrenocortical preparations for local and general reaction, morphine for pain (unless respiration is depressed), careful intravenous injection of calcium gluconate for muscular cramps, and respiratory and cardiac stimulants. Intravenous fluids for shock. (Note that there is no specific antidote.)

(*e*) *Prevention.*

1. Be alert to avoid contact when possible.

2. Wear well-fitting underwear or a rubber suit especially for night operations or when jellyfish are thickly congregated.

3. Remember that tentacles of some forms stream considerable distance from "body" and that stings can be inflicted even by detached and broken tentacles or "dead" jellyfish washed up on the beach.

Corals

(15) Divers who must work about reefs frequently sustain cuts and abrasions from contact with coral formations. The injuries are generally superficial, but they are usually very slow in healing and can cause loss of much manpower in operations. While some forms of coral inflict only a dirty wound, others produce additional injury and reaction by means of stinging cells similar to those of jellyfish.

(*a*) *Symptoms.*—Even without the stinging effect, a coral wound can be unusually painful and troublesome. Especially under unfavorable living conditions, even a simple scratch, left untreated, can become a pus-forming ulcer surrounded by a painful reddened area. The initial effect of a coral sting "coral poisoning" is a violent reaction with pain and itching in and around the wound and reddening and welt-formation in the surrounding skin. Severe general reactions, like those seen with some jellyfish stings, are not frequent.

(*b*) *Treatment.*

1. Rinse area with baking soda solution or weak ammonia if available, otherwise with clean water.

2. Use cortisone ointment or antihistamine cream on the wound and give antihistamine by mouth to help reduce initial pain and reaction.

3. As soon as pain begins to subside, cleanse wound thoroughly with soap and water to remove all foreign material. Apply an antiseptic and cover wound with a sterile dressing.

4. In a severe case, give patient bed rest with elevation of affected limb. Apply kaolin poultices or wet dressings of magnesium sulfate solution in glycerine.

(*c*) *Prevention.*—Wear gloves, shoes, and other appropriate protective gear when working around coral.

Octopus

(16) While large specimens of octopus may exceed 25 feet in span, those found at usual diving depths are generally much smaller. They tend to be inquisitive rather than vicious. (See fig. 1–43.)

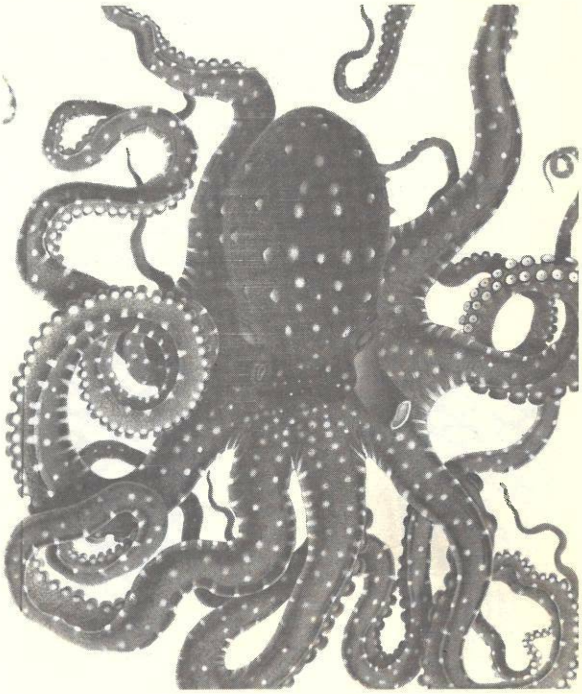


FIGURE 1–43.—Octopus.

(a) One possible danger of contact with an opus lies in the fact that even a relatively all one might trap a diver underwater if could get a good grip on him and a rock the same time. Clothing like wool underar will hinder attachment of the suction cups. ce underwater caves, crevices and wrecks favorite haunts of the octopus, these are t avoided when possible.

(b) The octopus has a well-developed venom paratus associated with its beak and proes injurious effects by biting. Symptoms ude a stinging sensation with swelling, ness, and heat in the area about the wound. ath has been reported. There is no specific atment.

(c) Stabbing deep between the eyes is the method of killing an octopus.

ne shells

17) Cone shells. (See fig. 1–44.) Cone lls are a favorite of shell collectors because their attractive patterns. There are more 1 400 species and all of them contain a aly-developed venom apparatus. Several of tropical species have caused human deaths. living shell contains a slug-like animal ch may crawl out. If the animal is dised, microscopic venom filled teeth may be denly moved from the inside of the animal he proboscis (trunk), where they can be zed as a stinging apparatus. Avoid comin contact with the soft parts of the animal.

a) *Symptoms.*—The stings are of the punc- variety. Localized ischemia (shutting-n of blood supply), cyanosis (blueness), or a sharp stinging or burning sensation, are usually the initial symptoms. Numbness and paresthesias (abnormal sensations) begin at the wound site and may spread rapidly, involving the entire body particularly about the lips and mouth. In severe cases paralysis may follow. Respiratory distress is usually absent. Coma may ensue and death is said to be due to heart failure.

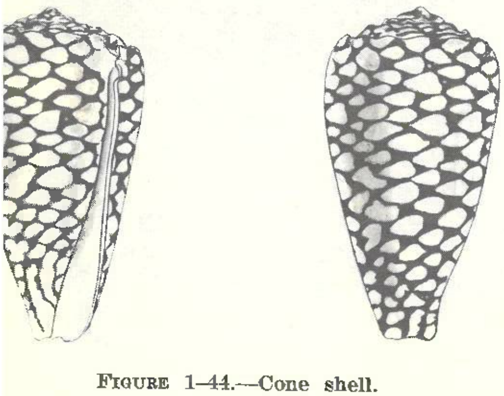


FIGURE 1–44.—Cone shell.

(b) *Treatment.*—There is no specific treatment. Cases of cone shell stings should be managed like venomous fish stings. (See par. 22 of this article.)

Sea urchins

(18) Sea urchins (see fig. 1–40) exist in numerous species and vary in characteristics such as length and shape of the spines. In most cases, the spines are solid, have blunt rounded tips, and do not inject venom. A few have long, slender, hollow spines that are sharp and dangerous. The sharp tips permit easy penetration, but small barbs and extreme brittleness cause the spines to break off when removal is attempted. Some sea urchins also have small, venom-carrying pincers. These are generally spread over the surface of the shell and may appear buried near the base of the spines. They are on stalks and can be extended. The pincers consist of sharp, stonelike jaws enclosed within a venom gland.

(a) *Symptoms.*—Penetration with the spines may result in an immediate and intense burning sensation followed by redness, swelling, and aching. Weakness of the legs, anesthesia (loss of body sensation), swelling of the face, and irregularities in the pulse have been noted. Secondary infection may result. Severe cases may produce an intense radiating pain, faintness, numbness, generalized paralysis, loss of voice, respiratory distress, and even death.

(b) *Treatment.*—When sea urchin spines are broken off in the skin, remove as many as possible with forceps, then cleanse the area, and cushion it with a large, loose dressing. If any evidence of infection appears, seek medical attention promptly. Spines of some types will be absorbed within 24 to 48 hours; otherwise, surgical removal will be required. When a venomous type of sea urchin is involved, remove the pincers from the wound promptly since they remain active for several hours and continue to inject venom into the wound. Management of the case is otherwise like that for venomous stings in general. (See par. 22 of this article.)

(*c*) *Prevention.*—Do not touch or handle sea urchins that have long, needle like spines. Be cautious in contacts with the short-spined variety because of the venomous pincers. Since shoes, gloves, suits, and the like afford little protection against the sharp spines, contact must simply be avoided whenever possible.

Sting rays

(19) There are many varieties of rays, and many of them are venomous. One example is the round stingray which is shown in figure 1–45. Varieties usually encountered can sometimes reach a length of 3 or 4 feet.

(*a*) The exact nature of the venom apparatus varies from species to species, but it usually consists of a spine covered by a skin-like sheath. The spine is located on the upper side of the tail at a variable distance from the base of the tail.

(*b*) Stingrays are generally found lying on the bottom in shallow water. They are usually well camouflaged and are often partly covered by sand. The main danger to a swimmer or diver is that of stepping on one. When stepped-on, the ray strikes upward with its tail and drives the spine deeply into the foot or leg. This usually produces a ragged, dirty wound. Often all or part of the sheath of the spine remains in the wound. The venom produces severe pain, and if present in large quantities can cause generalized effects.

(*c*) *Symptoms.*

1. Local pain develops within four to ten minutes.

2. Fainting and weakness are common.

3. Within 30 minutes, the pain increases in intensity and may affect the entire lower leg.

4. In about 90 minutes, the pain reaches its maximum, is extremely severe, and may involve the whole limb.

(*d*) *Recognition* is aided by these observations:

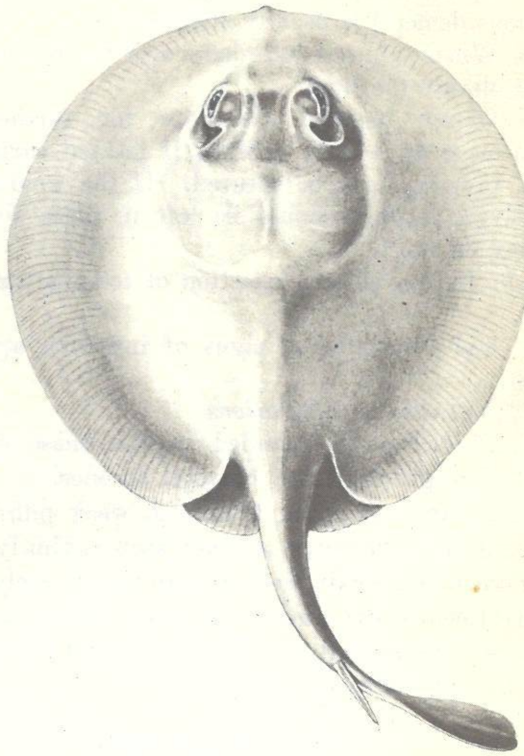


FIGURE 1–45.—Round stingray.

1. A puncture or lacerated wound on the upper portion of the foot or ankle. (Victim may recall that he stepped on something soft and slippery.)

2. Pain within a few minutes, increasing in intensity and finally affecting the entire limb.

3. Shock symptoms, with fainting, nausea, and weakness.

4. Muscular spasms of the affected limb.

(*e*) *Treatment.*—Since fainting is common, get victim out of the water promptly. Commence treatment at once.

1. Wash wound with sterile saline solution if this is available, otherwise cold, clean water.

2. Try to remove any remaining portions of the stinger sheath.

3. Soak in plain water, as hot as can be tolerated, for at least 30 minutes. Use hot compresses on areas that cannot be immersed. (Heat is believed to destroy the venom.)

4. If pain is severe and fails to respond to heat treatment, local injection of 0.5 to 2 percent procaine can be tried. If local measures

l to relieve pain, intramuscular or intra-
ıous demerol is usually effective.
›. When pain has subsided, cover the wound
ɫ elevate the limb.
ᵎ. Obtain medical assistance for further
ıtment of wound. (Most, if treated early
ɫ properly, can be sutured. If the wound
large, a drain should be left in place for
ay or two.)
7) Give a booster injection of tetanus tox-
.
. Use antibiotics if signs of infection ap-
r.
f) Special considerations.
. If victim is wounded in the chest or
omen, get him to a hospital at once.
 If signs of shock (fainting, weak pulse,
ing blood pressure) appear, keep victim ly-
down and obtain medical help immediately.
eatment is the same as for shock from other
ses with special emphasis on maintaining
liovascular tone.)

Venomous fishes

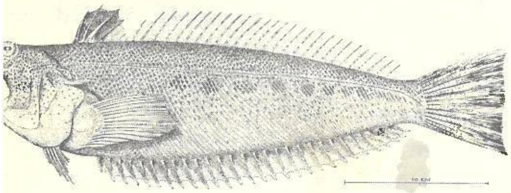
(20) Fishes that inflict poisonous stings are found throughout the world but are most common in tropical waters. They tend to be quiet in their habits. Injury is produced by contact with poison-bearing spines. A diver should learn to recognize the most important venomous fish groups mentioned here. (Symptoms and treatment of stings from these species are discussed in paragraph 22 of this article.)

(*a*) *Horned sharks.*—These include bullhead sharks, the spiny dogfish, and some less common species. The venom organs consist of two spines on the each one in front of each back fin.

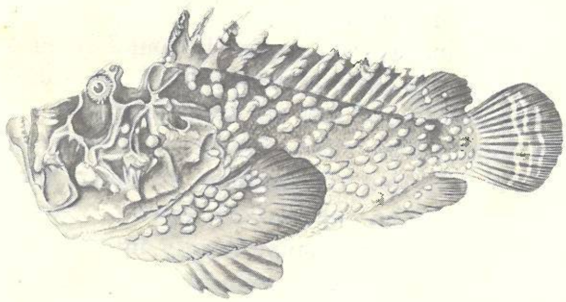
(*b*) *Catfish.*—Are largely found in fresh water. Their venom apparatus consists of spines on the back and behind the gills. The venom is believed to have effects on the nerves and the blood.

(*c*) *Weeverfish.*—(See fig. 1–46) are small and found only along the eastern Atlantic and

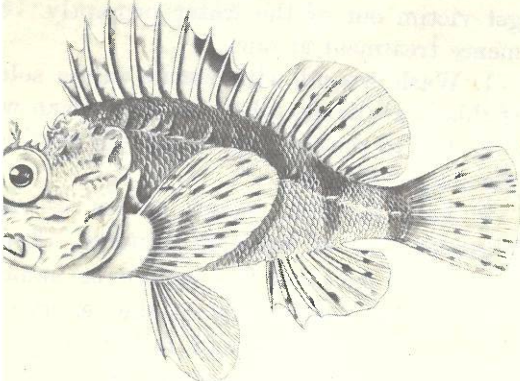
FIGURE 1–46.—Venomous fishes.



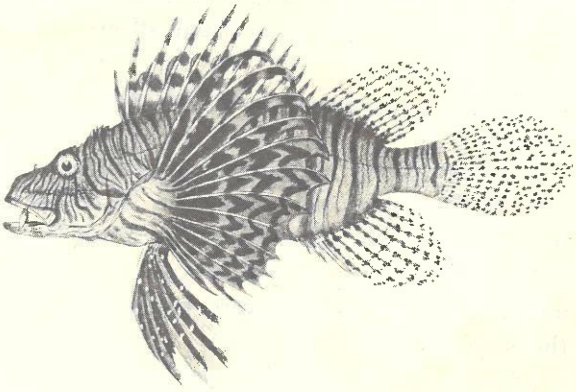
Weeverfish



Stonefish



Scorpionfish



Zebrafish