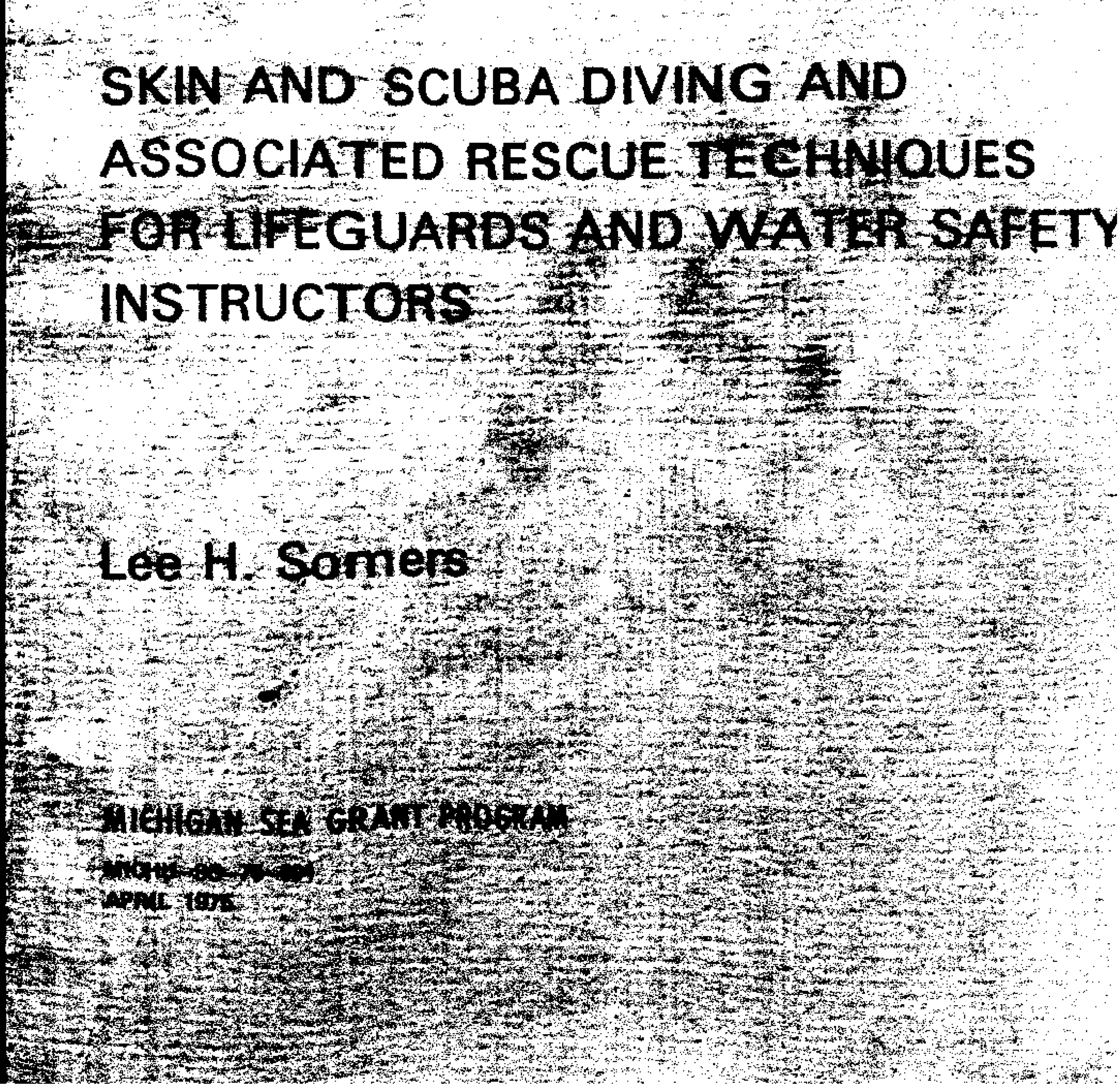

SKIN AND SCUBA DIVING AND ASSOCIATED RESCUE TECHNIQUES FOR LIFEGUARDS AND WATER SAFETY INSTRUCTORS

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SKIN & SCUBA DIVING AND ASSOCIATED RESCUE TECHNIQUES
FOR
LIFEGUARDS AND WATER SAFETY INSTRUCTORS

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PREFACE

This paper has been prepared to provide lifeguards and water safety instruction with a better understanding of skin and scuba diving and associated rescue techniques. A review of modern lifesaving texts reveals a limited amount of information on this subject. All lifeguard personnel working in pools and on beaches must be prepared to respond to a skin or scuba diving emergency.

Many of the ideas presented in this paper are based on the author's years of teaching scuba diving and supervising open water recreational and research diving. Some techniques and comments may conflict with other authorities in the field. There is a considerable need for more research and publication in the area of aquatic safety, and hopefully this paper will stimulate further work.

This paper has been prepared as a public service. As an economy factor, pictures and diagrams have been excluded. The reader is encouraged to seek skin and scuba diving training under the auspices of a certified scuba diving instructor, or at least, to contact a scuba diving instructor for special training in skin and scuba diving rescue techniques. The special physiological implications of skin and scuba rescue must be recognized. A successful rescue may still end in tragedy if the rescuer fails to administer proper first aid and seek immediate medical attention.

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INTRODUCTION

In recent years the art of skin diving, or swimming on and underwater using mask, fins and snorkel, has been introduced into American Red Cross lifesaving and water safety instructor courses. Skin diving equipment and skills are beneficial in some rescue situations and in shallow-depth underwater search and recovery. Unfortunately, the information on this subject contained in lifesaving and water safety instructor publications is relatively limited and imcomplete. Swimming and lifesaving instructors, unless trained in outside specialty courses, generally lack the specific knowledge of diving physiology and techniques to properly and safely instruct students in skin diving.

Furthermore, the instructor and prospective rescuer must have specific knowledge of the physical behavior of compressed gases and the physiological implications involved in the rescue and subsequent care of scuba (self-contained underwater breathing apparatus) diver. Improper rescue procedures and first aid for scuba diving accident victims may result in a number of medical complications leading to the possibility of permanent paralysis of various portions of the body or death.

This booklet is addressed primarily to the instructor. Hopefully, the information contained herein will better prepare instructors to provide safe and adequate instruction for their students. This booklet should not, however, be considered as a final source of information on the subject. It should be used in conjunction with a recognized lifesaving and water safety program and text. All instructors are also encouraged to seek specialized training in this area through one of several CNCA member organizations that specialize in training skin and scuba divers. These include the National Association of Underwater Instructors (NAUI), Professional Association of Diving Instructors (PADI), and the Young Men's Christian Association (YMCA). Addresses for the national headquarters of the organizations are included in the back of this booklet.

SKIN DIVING

A physically fit, veteran skin diver will generally be capable of breathhold dives to depths of 40 feet or more. Conditioned spearfishermen or persons who frequently make breathhold dives may dive to depths exceeding 90 feet. The current record breathhold dive exceeds 240 feet.

Breathhold diving or skin diving is a useful underwater search and rescue technique and a necessary part of training for diving with scuba. Proper use of mask, fins, and snorkel, surface swimming, surface dives, underwater swimming, pressure equalization, and rescue techniques are all necessary skills required for mastering scuba diving.

Breathhold diving is not without hazard. The diver must be an excellent swimmer and in reasonably good physical condition. An enthusiastic skin diver will frequently expose himself to more adverse conditions and greater physical strain than the casual swimmer. He will venture farther from shore under more hazardous environmental conditions for longer durations. The skin diver is subject to barotrauma of the ears and sinuses as any other diver; however, air embolism and related complications are only a problem if the diver breathes air while underwater from scuba, a habitat, or an air pocket under a rock, ledge, etc. Since breathholding can cause serious problems, the diver must thoroughly understand the potential hazards of prolonged breathholding under pressure.

The basic equipment for breathhold diving includes a mask, a snorkel, a pair of swim fins, and a floatation vest. The diver may use a weight belt to achieve a state of near-neutral buoyancy on the surface. Actually the diver should have slight positive buoyance at the surface. He should never wear sufficient weight to cause him to sink.

EQUIPMENT

FACE MASK

The face mask provides increased clarity and visibility underwater by placing an air space between the eyes and the water. The face mask, covering only the eyes and nose, is used for diving with scuba equipment with a mouth-piece or for skin diving. The face mask consists of a faceplate, a frame (face blank or body), and a headstrap. Faceplates of shatterproof, clear glass are recommended. Plastic faceplates are subject to discoloration, abrasive damage, and considerable fogging during dives. The frame is a flexible rubber carrier designed to hold the faceplate and provide a water-tight seal. The major portion of the frame would be of sufficient rigidity to hold the rubber plate away from the nose. The rubber edge should be soft and pliable enough to ensure perfect fit to the contour of the face and be comfortable; however, it must be sufficiently rigid to retain its shape. This edge may be fashioned of tapered neoprene rubber or thick foamed-neoprene rubber. A noncorrosive, plastic or metal retainer band is required to secure the faceplate in the frame. An adjustable rubber headstrap holds the mask to the diver's head. This strap should be approximately 1 inch wide and split at the rear of the head for better security and comfort. The headstrap should be secured to the metal retainer band or frame by metal strap anchors which facilitate adjustments and prevent slippage of the strap.

A mask may be equipped with a nose-blocking device to facilitate equalization of pressure during descent. Three basic types of nose-blocking devices are: (1) a foamed-neoprene rubber pad positioned below the nostrils for sealing off the nostrils by pushing upward on the mask, (2) finger pockets in the mask frame on each side of the nose to facilitate pinching the nostrils shut with the fingers, and (3) a formed nose pocket to facilitate pinching the nostrils. The rubber pad is recommended for use when diving with neoprene mittens and the nose pocket is desirable for divers who have difficulty equalizing pressure in ears and sinus during descent and ascent.

A mask may also be equipped with a purge valve, a device to facilitate clearing water from the mask. This purge device consists of a thin, circular, neoprene rubber check valve, generally protected by a vented plastic cover and housing. Underwater, this one-way check valve is held flush against its housing by increased water pressure. Exhalation through the nose forces water through the valve from inside the mask. Caution must be taken when selecting masks equipped with purge valves since many are subject to failure and leakage. The purge valve is a useful optional accessory. If the diver chooses to include this accessory, only high-quality masks with large check valves are recommended.

Facemask selection is a matter of individual preference, fit, comfort, and diver requirements. Masks are available in a variety of sizes and shapes, ranging from large, wrap-around models with side lenses for greater peripheral vision to small, lightweight, compact models with minimal internal volume.

Avoid plastic construction, extremely large-size masks, built-in snorkels, narrow headstraps, and goggles. Purge valves and nose-blocking devices are optional.

Those individuals who need to wear eyeglasses generally require some form of optical correction underwater. Large-size prescription lenses can be permanently bonded to most faceplates with optically clear opoxy by an optician specializing in underwater vision problems. Some skin diving equipment manufacturers provide a mask with a series of standard prescription lenses.

The mask should fit comfortably and form an airtight seal on the face. To test for proper fit, the mask is placed in position without securing the headstrap. The mask is properly sealed if, when the diver inhales through the nose, it will remain in place without being held.

Ventilation across the faceplate is generally poor in any mask and the glass tends to fog easily. To minimize fogging, thoroughly smear the inside of the faceplate with saliva and rinse lightly prior to donning. Antifogging solutions such as mild liquid soap or a special commercial preparation may be applied to the inside of the faceplate. The faceplate should be frequently washed in detergent to remove oils and film that enhance fogging. If the mask fogs during use, admit a small amount of water into the mask and wash it across the fogged areas.

SWIM FINS

Swim fins increase the propulsive force transmitted from the legs to the water. Used properly, the swim fins conserve the diver's energy and facilitate all underwater movements. Swim fins are available in a variety of sizes and designs. Variations in characteristics include size and shape of foot pocket; size, shape, angle, and degree of stiffness of blade. Selection of fins is a matter of individual preference, mission requirements, fit, and physical condition. Performance depends upon fin design, the style of the diver's kick, and the force in which this style is applied to the water.

In general terms there are two styles of fins: swimming and power. Swimming-style fins are smaller, lighter weight and slightly more flexible than the power-style and used with a wider, more rapid kick of less thrust. The blade may have a greater angle. Some utilize an open vent or overlapping blade principle which is claimed to give the swimmer maximum thrust with minimum energy requirements. This style uses approximately as much force on the up-kick as on the downward kick. The swimming-style fin is less fatiguing for extensive surface swimming, less demanding on leg muscles, and more confortable. This type of fin is recommended for trainees. Power-style fins are longer, heavier, and more rigid than swimming fins. They are used with a slower, shorter kicking stroke with emphasis on the down kick. This style fin is designed for maximum power thrust of short duration with a sacrifice in comparative comfort, and is desirable for working divers who are required to swim while encumbered with multiple-cylinder scuba and heavy equipment. Many divers own both swimming-style and power-style fins. Buoyant and non-buoyant models are available in both styles; this factor doesn't generally affect the quality or performance of the fin.

Swim fins are available in open- or enclosed-heel models. Open-heel models are recommended for use with coral shoes or rubber boots. They are much easier to don and fit more comfortably. The open-heel models have either an adjustable strap or a one-piece nonadjustable strap. Adjustable strap models are designed to accommodate a wide range of foot sizes; however, they are less comfortable when worn without foot protection. The strap buckle must be sturdy and designed to hold the strap securely in place. Since open-heel fins have a closed toe section, the fin must be properly sized to prevent cramping of the toes. Open-heel fins are generally larger and stiffer than closed-heel models. Closed-heel fins are often used for diving in warmer climates where exposure suits and boots are not required. Even in warmer waters some divers prefer some sort of additional foot protection (socks or boots) to prevent chafing and blisters, especially if they wear fins for long periods of time.

Basically, the fin must fit comfortably. It must be properly sized to prevent cramping or chafing. Furthermore, the fin must match the individual's physical condition.

SNORKEL

The snorkel is a J- or L-shaped rubber or high-impact plastic tube which enables the diver to breathe while swimming on the surface, without moving his head. For efficient and easy breathing, the tube diameter should be 5/8 in or larger and not exceed 15 in in length. The mouthpiece should be pliable and nonrestrictive with a cross-section that is approximately equal to that of the tube. Snorkels with valve mechanisms are not recommended. Contoured, large-tube snorkels are popular with skin divers. These offer minimal resistance to breathing and swimming. A small rubber retainer is supplied with the snorkel to facilitate attachment to the mask strap.

FLOATATION VEST

A carbon dioxide or air-inflatable yoke-type floatation vest is desirable for skin divers. It is one of the diver's best safeguards against drowning, especially in rough seas or when highly fatigued. However, it should not be used as a substitute for swimming ability and physical fitness. The floatation vest must be designed so it can be inflated either by manual activation of the gas cylinder or by an oral inflation tube. The only acceptable floatation vest is the "yoke" type, which holds the diver's head clear of the water when inflated even if the diver is unconscious. Floatation vests should be lightweight, relatively compact, rugged comfortable, and provide amximum floatation. Neoprene-impregnated nylon is a desirable fabric. Some vests are fitted with multiple CO_2 cylinders, pressure relief valves, and large oral inflation rubes located at the back of the neck. The large diameter oral inflation tubes are desirable for they facilitate rapid inflation and deflation of the vest.

The compressed-air floatation vest is similar in design and construction materials to the CO_2 vest; however, it is bulkier and has a greater capacity and buoyancy. A compressed-air cylinder, refillable from a standard cylinder, provides gas for manual inflation. Some vests are fitted with a hose filler that connects directly to the scuba regulator. Others are equipped with manual CO_2 inflation systems. Most vests are fitted with pressure relief valves to facilitate purging excess gas during rapid ascent. A flexible tube is fitted to the vest at the back of the neck for oral inflation and manual deflation. The large compressed-air lifejacket should not be used by the movice scuba diver without specific training. Its capacity for rapid inflation and ascent demands respect and careful handling. This type of vest is considered by most to be too heavy and bulky for the skin diver.

Although many consider the floatation vest as a buoyancy compensation and floatation aid, it is also one important and essential piece of life-saving equipment. It should be maintained accordingly. Rinse and inspect the lifejacket after each dive. Periodically inspect and lubricate the activator mechanism. The gas cylinder should be checked prior to each dive and the cylinder threads lubricated. Periodic activation and inflation tests are recommended. The need for preventive maintenance is increased when vests are used as "buoyancy compensators". Water must be drained from the lifejacket following each dive and the inside rinsed, and activation tests must be performed more frequently. Periodically inflate the lifejacket and check for leaks by immersing it in water. Small holes may be repaired using an appropriate cement and pieces of similar material. Consult a local diving equipment supplier for material and instructions for repair of specific vests.

SKILLS

DONNING FACE MASK, SWIM FINS, SNORKEL, AND FLOATATION VEST

The face mask should fit the diver's face comfortably and hold its position on the face when the diver evacuates air from inside the mask by inhaling through his nose. If during inhalation, air leaks into the mask or the mask fails to hold to the diver's face, it either does not fit or there is some material such as hair, wet-suit hood, or mask strap preventing the entire edge of the mask from sealing. Prior to diving the faceplate should be coated with an antifog compound such as saliva, dishwashing soap, or a commercial preparation. Fogging underwater may be removed by admitting a small quantity of water into the mask, rinsing the faceplate, and purging the water from the mask. Some divers even retain a small volume of water in their masks for this purpose throughout the dive. The mask strap should be periodically inspected for signs of wear and adjusted so that the mask fits comfortably and snug, but not tight. A tight-fitting mask may cause discomfort or a headache, and a loose-fitting mask may easily be lost.

Prior to donning the mask, the diver should wet both the mask and his face to improve the sealing action. Then the mask is grasped by the faceplate retainer, positioned on the face, and secured by placing the strap behind the head. Generally the diver uses both hands for this procedure; however, donning the mask completely with only one hand must also be mastered. Test the seal by inhaling through the nose. Always hold the mask to the face when jumping into the water.

The selection of swim fins is based on fit, physical condition, and mission requirements. Prior to each dive, the fins, particularly the adjustable heel straps, are checked for signs of wear or damage. Adjustable straps and buckles must be secure. To facilitate donning, wet both the fin and foot. Grasp the fin by the side rib at the instep and slide onto the foot. Then position the heel strap. Don't don fins by pulling on the heel strap or the back of the foot pocket. Shoe-type fins may be more easily donned by turning the back of the foot pocket under the fin (inside out), sliding the fin onto the foot, and flipping the back of the pocket into place.

For breathhold diving, the snorkel is generally secured to the mask strap by a small rubber retainer. Prior to use, the snorkel should be inspected and cleared of foreign material (insects, sand, etc.), if necessary. To don, insert the mouthpiece into the mouth with the flange between the teeth. Adjust the retainer so that the snorkel is comfortable in your mouth, and the tube points slightly to the rear when the face is in the water in swimming position (looking down and slightly forward).

The floatation vest should be inspected prior to each dive to ensure that the gas cylinder is full, the activator is functioning properly, and that there are no tears or leaks. Don the vest and secure with the straps. The straps should be snug and comfortable, but not tight enough to induce restriction when breathing deeply.

SWIMMING WITH FINS

The kick used almost exclusively by skin and scuba divers is a modification of the standard flutter-type kick used by swimmers. Since swim fins greatly increase the efficiency of the flutter kick, the diver's version of this kick is much slower and the feet travel through a wider arc. The kick action is from the hip, with pointed toes and slight flexure in the knees. When used on the surface, the fins should not break the surface of the water throughout the entire motion. The body should stay relatively straight. If the hips tend to buoy up the legs, resulting in the feet breaking the water surface continuously, or if there exists a necessity of bending at the hips to keep the feet under, the diver should swim with his body straight but tilted downward at a slight angle to the water surface. A weight belt may be required to overcome hip buoyancy. Underwater the diver should relax and increase the arc of the kick. The legs may have to be spread slightly to avoid fins touching. Do not stiffen the knees, and avoid excessive body roll. Maintain a slow, steady rhythm. The diver should avoid excessive use of hands when swimming on the surface or underwater; he should trail them in a relaxed fashion at his side.

SURFACE DIVING TECHNIQUES

The breathhold diver or skin diver swims on the surface and breathes through a snorkel until he is ready to submerge. At this time he ventilates his lungs a few times, takes a full breath of air and executes a head- or feet-first surface dive. The head-first (jackknife) surface dive is performed by bending the body at the waist, thrusting the trunk well down, and bringing the legs out of the water into a vertical upward position. The weight of the legs above water should be sufficient to thrust the body downward; no other movement should be necessary until the fins are fully submerged. Then continue downward motion by kicking. As the diver submerges, he should start equalizing pressure in his ears.

Some divers prefer the feet-first surface dive. The diver prepares for the dive as above. To execute the dive, he drops his feet and assumes an upright vertical position with his head above the water. He then kicks strongly with his fins and at the same time brings his hands sharply to his sides. This action raises part of the diver's upper body above water. Now the toes are pointed, the diver relaxes, and drops vertically underwater. When submerged, turn on face or side and kick downward.

USING THE SNORKEL

The snorkel is positioned on the mask strap so that it is comfortable and not submerged during surface swimming. A normal breathing rhythm and volume exchange should be maintained. Avoid repeated hyperventilation or "skip" breathing (holding breath for long periods between inhalations). When the diver submerges, the snorkel will partially fill with water; however, in most cases, the entrapped air and pressure equalization will keep water from entering the diver's mouth.

During ascent, look up toward the surface and rotate the body 360 degrees to check for overhead obstructions. Keep the face pointed upward so that the top of the snorkel is slanted downward. Gently expel air into the snorkel while coming up. Because of the downward slant, the air will remain trapped in the tube and displace all the water. Start exhalation approximately two feet from the surface. When you reach the surface, roll into a swimming position and resume breathing. Because you exhaled underwater, cautious inhalation will bring fresh air upon reaching the surface. This procedure is considered far more desirable than the "blast" method of expelling water from the snorkel with a forceful exhalation.

ENTRIES

Whenever possible, skin divers should enter the water from a diving ladder or by jumping feet first from a low platform. Remember when performing all jump or roll entries to hold the face mask to the face to prevent loss. The diver must also check his impact area for obstructions, emerging divers, etc. The following entries should be mastered by skin divers.

An excellent method of entering the water from a low platform is to simply sit on the platform with the feet in the water, hold the mask to the face, tuck chin, and roll forward in a somersault fashion. The shoulder will hit the water first.

The step-in or stride entry is used from a dock, platform, or boat dock. Hold the mask firmly against the face and look straight ahead. In a smooth motion, bend slightly forward at the waist and step off with a wide stride; do not look down. As the body strikes the water and starts to submerge, make a sharp scissor-type kick and sweep free arm downward. This entry resembles the standard feet-first lifesaver's entry.

When working from small boats, it is generally desirable to sit on the gunnel with the back to the water and feet in the boat. To enter, simply press the mask to the face, tuck chin, and fall backwards.

PHYSIOLOGY OF SKIN DIVING

The human body is designed to function in a gaseous atmosphere of approximately 20 percent oxygen and 80 percent nitrogen at a pressure of about 15 lb/in^2. Significantly decreasing or increasing the pressure exerted on the body or changing the partial pressure of the breathing medium can induce radical physiological changes. Prolonged breath-holding while subjecting the body to significant pressure changes, as during skin diving, can result in unconsciousness without significant warning signs to indicate the onset of complications. Subsequently, the diver may drown.

The human body contains several rigid or semirigid air-containing spaces which, because of restricted openings, are subject to mechanical damage when unequalized pressure exists. The air-containing structures of the body are the middle-ear spaces, the paranasal sinuses, the lungs and airways. With the exception of these air-containing spaces, the entire body consists of fluids and solids, which for all practical purposes within the limits of sport diving are incompressible. The middle ear and sinuses are line with membranes containing blood vessels. Changing external pressure is transmitted via the blood vessels and body tissues to the membrane lining of these air spaces. Unless the pressure in these spaces is equal to the ambient pressure, a pressure differential exists causing baratrauma, or pressure injury.

MIDDLE EAR SQUEEZE

The middle ear is connected with the throat by the Eustachian tube , which functions to drain and ventilate the middle ear. When Eustachian tube blockage (by mucus or congestion, tissue overgrowth, local inflamation and swelling) prevents pressure euqlization in the middle ear, painful aerotitis media, or "middle ear squeeze," may occur, with possible tympanic perforation (rupture of the eardrum). The diver will experience discomfort and pain in the first few feet of descent. Further descent will result in increasing pain, with stretching of the eardrum and dilation and eventual rupture of the blood vessels in both the tympanic membrane and the lining of the middle ear.

Actual rupture of the eardrum may occur with a pressure differential of as little as 5 lb/in^2, at a depth of about 10 ft. Generally a slight restriction of the Eustachian tube can be overcome by maneuvers for "clearing the ears" such as swallowing, yawning, or exhaling against closed mouth and nostrils (Valsalva maneuver). Variations in ability to ventilate the Eustachian tube may in some instances by an anatomical factor of the individual's tube size. Inability to equalize pressure may be due to swelling. This condition may result from upper respiratory infections (colds) or seasonal allergies. The use of spray, drop, or oral decongestants to shrink nasophoryngeal mucus membrane may be used under medical direction. Currently only prescription medications are recommended. Indiscriminate use of non-prescription decongestants in diving may induce unacceptable abnormal reactions. The diver is cautioned to use the Valsalva maneuver with discretion. Increased intrathoracic pressure produced during the maneuver will result in hypotension in the normal individual. This is primarily due to impairment of venous return to the heart and the potential of the pulmonary stretch reflexes inducing certain cardiac arrhythmias. Some physiologists suggest that the combination of these two influences is probably responsible for the syncope (fainting) that may occur upon doing the Valsalva maneuver. Moreover, too vigorous a Valsalva maneuver could result in inner ear trauma from too sudden a pressure change, either by shearing forces or rupture of blood vessels in the inner ear when the stapes foot plate is pulled externally by the sudden pressure change during inflation of the middle ear. This condition could result in vertigo and/or hearing loss. Obviously, the implications to skin diving are that a prolonged and intensive Valsalva maneuver could possibly result in unconsciousness and subsequent drowning.

When a diver surfaces after experiencing ear squeeze, he may spit blood which has drained to the throat through the Eustachian tubes. If drainage and/or discomfort persist, a physician should examine the injury and prescribe treatment. A diver should not re-enter the water until healing is complete. Antibiotics may be indicated to combat infection.

The most frequent and most serious complication of aerotitis media is temporary or permanent impairment of auditory acuity. Research has shown that, although capable of equalizing pressure in the middle ear, many subjects develop complications by letting the increasing pressure "get ahead" of them one or more times and then equalizing only after some damage has been done. A diver should not wait for pain as a signal to equalize pressure in his ears. The equalization maneuvers should start immediately when the diver begins his descent or at least at the first sensation of pressure change on the ear. Pain is an indication that barotrauma already is present. Continued descent after initial ear pain is felt and pressure equalization maneuvers are unsuccessful will generally result in eardrum rupture. When the eardrum ruptures, a sudden relief in pain may be experienced. If the diver's ears are exposed directly to the water, the entry of cold water into the middle ear may cause a violent upset of the sense of balance. The diver may experience extreme vertigo (dizziness) because of thermal effect on the inner ear and semicircular canal and may also become nauseated and vomit. This reaction usually subsides in a minute or so as soon as the water in the ear warms to the body temperature. Blood is generally present in the external auditory canal. Except in the presence of infection, healing takes place in a few days to a few weeks, depending on the severity of the injury. During this time, diving is prohibited and water should not be allowed to enter the external auditory canal. Antibiotics may be necessary, especially if the diver has been in polluted water.

SINUS SQUEEZE

Blockage of the sinus ostia (openings) results in aerosinusitis, or sinus squeeze, with painful edema and hermorrhage in the sinus cavities. These cavities are located within the skull bones and are lined with mucous membrane continuous with that of the nasal cavity. The mechanism is much the same as that described for aerotitis media. With normal gas pressure within the sinus cavity and an excess pressure applied to the membrane lining via the blood, a vacuum effect is created within the cavity. Unless the pressure is equalized, severe pain and damage to the membrane will occur. A diver who has experienced sinus squeeze will often surface with blood in his mask or will notice a small amount of blood and mucus discharge from his nose following the dive. Sinus squeeze can be avoided by refraining from diving when there is nasal congestion as a result of an allergy, cold, or infection. If discomfort develops in the sinus areas during descent, it may be relieved by the Valsalva maneuver; if not relieved, terminate the dive. Following aerosinusitis, infection may develop, as indicated by persistent pain and discharge; medical attention and systemic antibiotics are generally necessary. On ascent, the ears and sinuses generally vent the expanding gas without much difficulty. However, blockage may occasionally result from mucus or swelling of tissue injured during descent and result in a reverse ear or sinus squeeze. In the event of symptomatic developments during ascent, descend slowly to facilitate pressure equalization. The after effects of vasonconstrictors used prior to descent may produce tissue swelling in individual cases, and consequent Eustachian tube or sinus ostia restriction.

THORACIC SQUEEZE

As a diver descends while holding his breath, the flexible portion of the thorax is compressed and the diaphragm elevated. Consequently, the air within the lungs and airways is compressed and the system assumes a more "expiratory" position. Until recently it was indicated in the literature that no difficulty is experienced until the position of maximal expiration is reached; then the volume of air equals the residual volume of the lungs plus the volume of the airways. Beyond this point, further descent while breathholding may result in pulmonary congestion, edema, and hemorrhage in the lungs. The diver may experience a sensation of chest compression, breathing difficulties, and possible chest pain. This condition is generally called thoracic squeeze.

Physiologists have shown that during breathhold dives to greater depths, blood is forced into the thorax, replacing air and resulting in a significant decrease in residual volume. Using the impedance plethysmograph, measurements of thoracic blood volume displacements were made during breathhold dives to depths of 130 ft. These measurements confirmed that a significant shift in blood volume into the thorax does take place. Furthermore, several skilled skin divers successfully dived to depths of 230 ft or more. These are considerably greater depths than could be predicted on the basis of total lung volume/residual volume ratios. Based on total lung volume/residual volume ratios, the depth threshold of one diver who reached 231 ft would have been 90 ft. Theoretically, a blood shift of 980 ml into the thorax was necessary, with a corresponding replacement of air and reduction of his residual volume to approximately one-half that measured. Underwater photographs taken during a 240 ft dive show pronounced caving in of the thorax, compression of the abdomen, and skinfolds flapping around the chest.

EQUIPMENT-INDUCED SQUEEZES

Gas-containing structures attached to the surface of the body are potential sources of local "squeeze". Failure to equalize pressure under the diver's face mask during descent can result in damage to the skin and particularly to the eyes. The mechanism of damage is similar to that of middle ear or sinus squeeze. The most easily damaged tissues are those covering the eyeball and lining of the eyelids and the spaces around the eyeball. Excessive pressure differential may cause conjunctival and even retrobulbar (behind the eyeball) hermorrhage with tension on the optic nerve and possible loss of vision. Subcutaneous hemorrhage and swelling of the facial tissue under the mask may be evident. The condition is avoided by the diver simply admitting air into his mask through his nose.

External ear squeeze can occur where the mechanism and consequences are essentially like those of middle ear squeeze. Damage to the tympanic membrane (eardrum) may be equally severe, though the force is applied in the opposite direction. Hemorrhagic blebs (blood blisters) may form close to the eardrum and blood drain from the external auditory canal. The common foamed-neoprene wet-type suit generally eliminates these hazards; however, there is potential hazard with thin, tight-fitting hoods. Ear plugs are contraindicated in diving not only because of the possibility of external ear squeeze but also because the unequalized pressure may force the ear plugs deep into the external auditory canal.

IMPAIRED CONSCIOUSNESS DURING BREATHHOLD DIVING

Prolonged voluntary breathholding while swimming underwater can result in loss of consciousness and subsequent drowning. Case studies of near drownings and deaths resulting from loss of consciousness while swimming underwater have shown that the loss of consciousness was due to hypoxia. Hyperventilation is a common practice among underwater swimmers, i.e., skin divers, sponge and pearl divers, etc. By hyperventilation the swimmer can significantly deplete the carbon dioxide (CO_2) stores of the body. The partial pressure of CO_2 (pCO_2) in the nerve tissue regulating respiration appears to be the primary stimulus to respiration, with comparatively little stimulus derived from low oxygen partial pressures (pO_2). While swimming underwater the diver uses O_2 and produces CO_2; however, since the CO_2 is used for replacement of the subnormal body CO_2 stores, there is insufficient CO_2 stimulus for respiration. When the oxygen consumption is increased, the pO_2 commands the diver to surface for air. Loss of consciousness can result from hypoxia (or anoxia, which has nearly the same meaning) with little specific warning. The victim may actually continue his activity between the time of loss of consciousness and final collapse.

This condition is further complicated by increased ambient pressure and ascent from depth. Controlled experiments to study the mechanism of hypoxia and carbon dioxide retention during breathholding dives shows that the alveolar oxygen tension (pAO_2) decreases linearly, but remains high enough to completely re-oxygenate the blood during most of the dive. However, staying on the bottom longer than 90 sec yields significantly low pAO_2 and arterial O_2 tension (paO_2). The low pAO_2 and the Bohr effect (the greater the $paCO_2$, the lower the hemoglobin O_2 saturation is) results in a significant fall in O_2 saturation; thus, the blood cannot carry as much O_2 from the lungs to the tissue as before. Some divers have been reported to have lost consciousness at the bottom, and they possibly have contracted the dangerous combination of a low pAO_2 and a very high $pACO_2$.

Shortly after reaching the bottom a diver may experience a subjective "breaking point" approach sensation due to increased $paCO_2$ stimulus plus stimuli elicited from smaller lung volume. This sensation is easily overcome by the willpower of trained breathhold divers. The expert skin diver can actually condition himself to voluntarily or involuntarily ignore the breaking-point sensation (or urge to breathe) and over a period of time become inured to the subsequent pCO_2 buildup that would drive the average person to the surface for air. During ascent, a relief of the breaking-point sensation is experienced because the lung volume increases and the $pACO_2$ falls, even though oxygen may actually diffuse from the alveoli to the blood at a slower rate due to $pACO_2$ decrease. Since the pAO_2 may fall below the venous pO_2, the possibility for O_2 transfer from the blood to the lungs is present. Blood oxygen stores may be depleted rapidly. If during ascent, blood deprived of oxygen arrives at the cerebral cortex, and diver may lose consciousness with little or no warning before or just as he reaches the surface. Unconsciousness during ascent when the diver is below the "buoyance point" is a potentially fatal condition. Ironically, many competitive skin divers wear lead weight belts, making them negatively buoyant for effortless descent.

Most authorities condemn both competitive breathholding exercises and contests, and anyone who wears excessive weights, even under the auspices of a good organization. Unfortunately, competitive breathholding contests are a common occurrence in nearly every American swimming pool. One such experience involved a 16-year-old male in excellent physical condition participating in a contest conducted in a swimming pool. Wearing a face mask and weight belt the young man settled to the bottom of the pool and remained there for 9 min in full view of almost 200 spectators. Finally, he was hauled to the surface unconscious and not breathing. His breathing was successfully returned; however, subsequent examination and electro-encephalorgrams revealed no cortical activity. In other words, this young man was now doomed to lead the life of a vegetable for the rest of his days.

Neurological phenomena, including unconsciousness as a result of decompression sickness, may occur from repeated breathhold dives to great depths. The increase in the paN_2 is high at about 20 m depth. Although the volume of N_2 absorbed during each dive may be small, the increase in tissue pN_2 (ptN_2) could account for the occurrence of N_2 containing bubbles in the tissue following many repetitive and rapid alterations in ambient pressure. Fortunately, such cases are rare, probably because most human divers cannot breathhold dive deep enough nor often enough to contract decompression sickness.

The dreaded disease of Tuamotus pearl divers is "taravana". These pearl divers are true skin divers; they use no breathing apparatus or air supply for their underwater work. Yet, many of those stricken with "taravana" exhibit symptoms like those of classic decompression sickness--vertigo, paralysis, unconsciousness, and insanity. These divers may make as many as 6-14 dives/hr to depths up to 150 ft and stay submerged an average of 1 min and 35 sec. This schedule is continued daily throughout the pearl diving season. On one exceptionally good diving day (good weather and seas), one investigator observed that 47 divers were stricken with "taravana". Thirty-four of the 47 suffered vertigo, nausea, and dizziness, and 11 surface paralyzed or unconscious and were rescued. Of the 11, six were partially or completely paralyzed, two were "mentally affected", and two young men died.

It has been suggested that hypoxia is the principal cause of "taravana," with its effects on the central nervous system and brain accounting for the many and varied symptoms. Mangareva divers space their dives 15 min apart, instead of the 4-8 min used by the Tuamotus divers, and do not suffer from "taravana". Certainly hypoxia explains many of the symptoms, and it should also be stated that continuous daily and seasonal exposure of brain tissue cells to hypoxia conditions could possibly result in cumulative and irreversible brain damage. However, decompression sickness is also an equally significant explanation, especially when considering the cumulative underwater time and depth.

SKIN DIVER RESCUE

Since skin divers spend more time in the water under more hazardous conditions than do most swimmers, it is essential that they know the fundamentals of lifesaving and water safety. One of the first principles of water safety is fulfilled by the "buddy system"--never swim or dive alone. Divers have another important factor in their favor--the floatation vest. Through the "buddy system" and the use of a floatation vest, most situations can be resolved.

The additional equipment used by skin divers modifies, to some degree, lifesaving techniques. The fact that the "buddy" is generally always in the water, near the victim, lessens the use of reaching or throwing assist. It is a known fact that most divers get into trouble at the surface, rather than at depth. In "trouble" situations the "buddy" is normally obligated to render all assistance possible. Frequently, "trouble" situations may develop into panic situation.

TROUBLE SITUATION

In the "trouble" situation, the diver is simply having difficulty in keeping afloat, but he has not lost control of himself. The victim may rescue himself by jettisoning his weight belt, inflating his floatation vest, or regaining physical control of the situation. In this situation the "buddy" or rescurer can do several things. First, encourage self-rescue by talking to the potential victim. Repeatedly call to the victim to drap his weight belt and inflate his floatation vest. Be calm, do not panic the victim. If there is a float to push to the victim or other means of avoiding contact, the rescuer should use it. Otherwise the rescuer must move in, staying behind the victim; if possible. The safest and simplest means of aid is to reach around and inflate the victim's floatation vest and/or release his weight belt. If he is not wearing a vest of if this method is not feasible the rescuer should support him at the surface from behind by gripping him firmly under the arm to support while talking to him and thus enabling him to get his breath. If the victim is wearing a weight belt, the rescuer should jettison it. The rescuer should reassure the victim and keep calm. A calm reassurance can often prevent a panic situation.

PANIC SITUATION

Panic is a sudden unreasoning and overwhelming fear which attacks people in the face of real or fancied damger. Panic is the diver's most deadly hazard and is a contributory cause of practically all water accidents. A panic situation is dangerous to both victim and rescuer. The rescuer must know what he is doing and apply all his skill and training to avoid personal danger. The will to aid sometimes ends tragically for both victim and rescuer. The first impulse of a panic-stricken swimmer will be to "climb" the rescuer and get himself out of the water. The rescuer must retain his common sense, good judgement, and reasoning, and must not let the fictim get hold of him--stay clear. While the victim is violently thrashing in his panic, these movements will probably keep him afloat. When he tires, the rescuer can move in from behind and proceed with the rescue as in the "trouble" situation. The rescuer must be sure to keep the victim facing away from his so the victim cannot grab him. By holding the diver firmly under the arm the rescuer can both hold him up and control him. He should inflate the victim's vest and jettison the weight belt as soon as possible.

APPROACH

If it is necessary to approach the victim from the front, the rescuer should swim to within 6-8 ft of him. He should do a surface dive and approach the victim underwater, grasping him at the knees and turning him around. From the moment the rescuer makes contact with the victim, he should keep hold of him and control him. He should not drag the victim underwater as he moves up to a support or carry position. As the rescuer moves up he should release the victim's weight belt and inflate his vest. When approaching from the rear, the rescuer should be in a position to move quickly out of the victim's reach in case he turns. He should use the underarm grasp and control if necessary.

EQUIPMENT AIDS

The fact that divers are equipped with mask and fins can greatly facilitate rescues. The addition of the floatation vest simplifies the situation considerably. The rescuer should not inflate his personal floatation vest or drop his weight belt until the situation is in hand and he knows he will not have to go underwater to approach or maneuver his victim. If he does inflate his vest and finds that he must go back underwater, he can remove it and leave it for a float, or deflate it. The rescuer must remember to drop his own weight belt if faced with anything but a very short tow.

TOWING

Once the victim is under control, the rescuer should tow or push him to safety. The simplest method of towing the victim is for the rescuer to grasp the collar of the victim's inflated vest and swim on his side or back, towing the victim at arm's length. He should take care not to kick the victim. The important thing is to keep the victim's head above water. The rescuer should keep control of the victim at all times. If the victim is struggling, the rescuer should not let the victim turn on him. An alternate method of towing is the head carry. The rescuer can use his personal floatation vest (inflated) when doing this carry. The rescuer places a hand on each side of the head. The palms cover the victim's ears, the fingers and extended along the jaw and the thumbs are placed on the temples. He holds firm and depresses his wrist to tilt the victim's head back. The rescuer holds his arms straight and swims on his back. The "fin-push" is considered a far more acceptable procedure than the conventional tired swimmer's carry. With weight belt off and vest inflated, simply have victim rest on his back, legs straight, and push him by the feet or fins.

ASSIST

As previously stated, the fact that the "buddy" is generally in the water, near the victim, lessens the possibility of a reaching or throwing assist. However, it should be stated that if at all possible, direct contact with the victim should be avoided. If near a pier, boat, etc., the rescuer should reach for the victim with a towel, pole, or whatever may be handy. If the victim is too far away for a reaching assist, the rescuer should throw him a rope, ring buoy, etc. If the rescuer reaches for the victim, he should keep low and firmly placed so the victim will not poll him in. The prone position is best.

RELEASES

If, for some reason, the victim gets a hold on the rescuer, the rescuer must know how to break it. Holds can sometimes be prevented by blocking the arm, grasping it, and turning the victim around; go directly to a control and carry position. At other times it may be necessary to block the victim by ducking underwater, placing a hand on the victim's chest and pushing him away. When the victim acutally gets a hold on the rescuer, the rescuer should not panic. He sink, think, and act. If the victim gets a front head-hold on the rescuer, he should submerge, grasp the victim's arm (on the side closest to his head) at the elbow, and push up. He should bring his other hand over the victim's arms, between his own head and the victim's, and push the victim's head away. When the victim breaks, retain the hold on his arm, turn him, and control him. An alternate method of escape is for the rescuer to sink, place both of his hands on the victim (grasping his sides), and push outward and upward, while turning his own head to the side. When the victim breaks, turn and control him. If the victim gets a rear head-hold, the rescuer should sink, grasp the lower elbow and wrist, and push up on the elbow and down on the wrist. As the rescuer frees himself, he should move under the victim's arm (retaining hold) and control him. If the victim grabs his arm, the rescuer should release the hold with a quick twisting jerk of his arm. The rescuer should use leverage to advantage in all breaks. Conventional, lifesaving release procedures apply in most situation, but may be complicated by the presence of hood, mask and snorkel.

SUBMERGED AND UNCONSCIOUS SKIN DIVER

An unconscious, submerged skin diver must be surfaced as rapidly as possible and artificial respiration procedures started immediatley. The rescuer should dive to the victim, release his weight belt, inflate the floatation vest and pull the victim toward the surface by grasping his arm or vest collar. In shallow water the buoyancy of the vest and wet suit (if worn) will generally lend considerable assistance to the surfacing procedure.

Assuming that the victim does not begin breathing upon surfacing, mouth-to-mouth resuscitation must be started immediately--in the water. The most common method of administering in-water mouth-to-mouth resuscitation has been nicknamed the "do-si-do" method. This term was derived from the position similarity to the do-si-do in square dancing. The basic procedure is as follows:

1. An inflatable floatation vest is vital to success in this procedure. Inflate it immediately. Although most people advocate immediate release of the victim's weight belt, some feel that it helps position the body better if left in place when the victim is wearing a full wet suit. Some authorities indicate that the rescuer should also release his belt once the victim has been surfaced; other find it difficult to swim with a full wet suit and no weight belt. Students should be encouraged to practice both procedures and form their own opinions.

2. Assuming that the victim is to the right of and facing the rescuer, the rescuer will reach between the victim's arm and body (as if swinging elbows with the victim). The rescuer's right hand may then grasp the victim's hair to facilitate tilting the head back, grasp the collar of the floatation vest, or reach under the victim's back to provide support. Students should be encouraged to practice various hand positions and determine which they like best. Pulling the head back over the collar of the vest aids in opening the victim's air passage.

3. Using the left (free) hand, remove the victim's mask and seal his nose.

4. The victim may be easily rotated toward the rescuer who places his mouth over the victim's and begins routine mouth-to-mouth rescue breathing.

5. After lung inflation, the rescuer may allow the victim to rotate back to the level position. He should listen and observe for exhalation. If difficulties are encountered the rescuer may have to poll the head back further or clear matter from the mouth or airway.

6. The rescuer should attempt to maintain a normal 12 breath per minute rhythm for adults. The critical factor is, however, to get air into the victim as soon as possible and to continue ventilating the victim even if conditions dictate an irregular pattern.

7. Between inflations, the rescuer should call for additional assistance. Another swimmer can push the victim by grasping his fins or legs while the rescuer continues resuscitation. If no other assistance is available, the rescuer may start toward shore (or boat) with his victim under tow without changing positions. With practice the rescuer may quite successfully tow the victim and give resuscitation simultaneously. On the surface, the rescuer may cover the victim's mouth as the waves break over.

An alternate method of administering resuscitation in deep water is the mouth-to-snorkel method. Although some advocate this as the most desirable method, the majority of diving instructors prefer the previously described procedure. This method is impossible with some modern snorkel designs. Students may experiment with both methods and formulate their own conclusions. The mouth-to-snorkel method is administered as follows:

1. The victim is turned face-up, vest inflated, and head tilted sharply back with a chin pull to open the airway.

2. The water is drained from a snorkel and its mouthpiece is inserted into the victim's mouth. The fingers and palm of the rescuer's chin pull hand are used to seal the mouth and the thumb and forefinger of the same hand pinch the victim's nostrils shut.

3. The rescuer controls the other end of the snorkel tube with his free hand. He places the tube into his mouth and inflates the victim's lungs.

4. When the rescuer removes his mouth from the snorkel he should be able to hear the air flow back from the victim's lungs.

5. Continue at a normal mouth-to-mouth resuscitation rate while towing the victim to shore.

SCUBA DIVER RESCUE

The rescue and subsequent care of a person who is using scuba (self-contained underwater breathing apparatus) is a far more complex procedure than the non-diver may realize. The fact that the victim has been breathing air under pressure leads to a host of complications. Any of the following conditions may lead directly or indirectly to near-drowning in scuba diving:

- Contaminated air supply
- Overexertion
- Exhaustion
- Abnormal breathing

- Loss of mask or fins
- Unsuccessful "buddy breathing" attempt
- Adverse surface conditions
- Lung barotrauma
- Improperly fitted wet suit
- Decompression sickness
- Panic
- Cold stress
- Anxiety

PHYSIOLOGY OF SCUBA DIVING

In order to better understand the complications that arise in scuba diver rescue, one must first be familiar with the behavior of gases under varying pressure conditions. Pressure is the amount of force applied per unit area. At sea level the earth's atmosphere exerts a pressure of nearly 15 pounds per square inch (lb/in^2) or one atmosphere (atm). This is the weight of the earth's atmosphere. Water, on the other hand, is nearly 800 times as heavy per unit volume as air. Consequently, when one submerges in water the pressure exerted on the body increases about 1/2 lb/in^2 per foot of descent. At a depth of only 33 feet of seawater (FSW) the diver is experiencing a pressure increase equal to that of the entire earth's atmosphere. Now he is at an ambient or absolute pressure of 2 atmospheres or nearly 30 lb/in^2. This pressure increase explains the ear and sinus discomfort associated with skin and scuba diving if pressure equalization is obstructed.

The scuba diver breaths air at ambient pressure. Consequently, when swimming at 33 FSW and breathing from the scuba, the diver inhales compressed air at twice the pressure as at the surface. This means that there are twice as many molecules of gas compressed into the same amount of lung space as at the surface. As long as the healthy diver continues normal breathing and does not hold his breath as he swims up toward the surface the expanding air will exit from the lungs through the airways without complications. However, if in panic the conscious diver holds his breath (the normal response of an untrained person) and swims rapidly to the surface or the untrained rescuer brings the victim to the surface without venting his excess air from the lungs, lung barotrauma is almost inevitable.

LUNG BAROTRAUMA

Cerebral gas embolism is a severe occupational hazard associated with diving. Since air is the most common breathing medium for divers, the term "air" embolism is used most frequently. According to the U.S. Navy, air embolism is probably second only to drowning as a cause of scuba diving fatalities. Other authorities suspect air embolism as a prime cause of scuba fatalities.

In a diminishing pressure situation, e.g., a diver ascending from depth, the air in the lungs expands because of the decreasing external pressures. If the normal exhalation route of the expanding gas is interrupted either voluntarily, as in breathholding, or involuntarily, from local respiratory tract obstruction, the intra-polmonary pressure progressively distends alveoli and ruptures of alveoli ensue. Localized partial or complete bronchial obstructions include "ball-valving" bronchial lessions, mucus, broncho-spasms, etc. Bronchial mucus and irritants, particularly tabacco, are prime offenders. From the point of rupture the gas may dissect along bronchi and enter the mediastinum to create <u>mediastinal emphysema</u>. A diver with mediastinal emphysema may experience such manifestations as substernal pain, breathing difficulties, and even collapse due to direct pressure on the heart and great vessels. Cyanosis may be evident.

From the mediastinum, the gas frequently migrates into the subcutaneous tissues (<u>subcutaneous emphysema</u>), most often in the neck and supraclavicular region. This will add manifestations evident by enlargement of the neck, voice changes, breathing difficulties, and crepitation (cracking sensation) upon palpation of the neck and supraclavicular region. If there is a weakened area on the surface of the lung, such as alveolar emphysematous blebs, rupture may take place into the pleural space with the development of a pneumothorax. A pneumothorax is an infrequent but serious complication of diving. This may result in partial or total collapse of the lung on the side involved. As the diver continues ascent, the air entrapped in the pleural space expands at the expense of the collapsing lung and may eventually cause displacement of the heart. This is an extremely serious complication because both breathing and circulation are impaired. Manifestations include chest pressure and pain, breathing difficulties, and cyanosis.

The most serious consequence of alveolar rupture is the release of gas bubbles into the pulmonary circulation, and via the pulmonary vein, left heart, aorta and carotids, into the cerebral circulation. The cerebral area is most frequently affected since the diver is usually in an erect or head up position, and the bubbles tend to rise. Any bubble too large to pass through an artery will lodge and obstruct circulation to adjacent areas or organs. This obstruction is the embolus.

The wide clinical spectrum of symptoms and signs associated with <u>cerebral air embolism</u> include headache, vertigo, cranial nerve involvement, visual, auditory, and speech disturbances, loss of consciousness, coma, paralysis, convultions, loss of vital signs, and death. Death results from coronary and/or cerebral occlusions with cardiac arrhythmias, respiratory failure, circulatory collapse, and irreversible shock. The onset of symptoms is dramatic and sudden, usually occurring within seconds of surfacing, or even prior to surfacing. Many cases occur without development of any symptoms prior to unconsciousness; the diver may or may not experience discomfort or pain in the chest prior to or during alveoli rupture. The tearing of lung tissue often results in bloody froth at the mouth; however, the absence of bloody froth does not preclude the possibility of air embolism.

DECOMPRESSION SICKNESS

The term "decompression sickness" refers to the "signs, symptoms and basic underlying pathological processes caused by rapid reduction in barometric pressure from high pressure to one atmosphere, or from any higher to any lower level of pressure". The basic underlying pathologic process in decompression sickness is the local formation of bubbles in body tissue, both intravascular and extravascular. The resulting symptoms vary widely in nature and intensity depending on the location and magnitude of bubble formation. When the diver is breathing air, the primary constituent of these bubbles is nitrogen with a small fraction of carbon dioxide.

To understand the basic causes of the bubble formation phenomenon, it is necessary to examine what happens to air when breathed under increased ambient pressure. In accordance with the laws of partial pressures, the amount of a given gas that will dissolve in a given liquid is determined by the percentage of that gas in the total mixture and by the ambient pressure. When the pressure on the gas mixture is increased, a pressure gradient exists between the tensions of the dissolved and undissolved phases of the gas. This gradient drives each gas into solution in proportion to its partial pressure until an equilibrium is established between the dissolved and undissolved phases of the gas. If ambient pressure is then decreased, the tension of the gas in the dissolved phase exceeds that of the gas phase, and the pressure gradient is reversed. The factor of time for equilibrium to be established in either direction is a principal factor in the discussion of decompression sickness.

Nitrogen is the only principal component of air that is inert; it therefore is unaltered in the respiratory process and, for all practical purposes, quantitatively obeys purely physical laws. Consequently, at gaseous equilibrium, the partial pressure values of nitrogen in the alveolar air, venous and arterial blood, and body tissues are identical. Oxygen and carbon dioxide are actively functional in the metabolic processes and, under ordinary diving circumstances, the metabolic cushion renders the tissue tensions of these two gases of little significance in the mechanism of bubble formation.

The symptoms of decompression sickness are variable in their nature and intensity, depending on the location and size of the bubbles. Localized pain is the most predominant symptom, occurring in about 89 percent of all cases, and is the only symptom in roughly 68 percent of cases. The onset of pain, sometimes linked to that of a severe toothache, is often gradual with fairly rapid increase in severity; untreated, it almost invaribly progresses to an "unbearable" stage. The location of the pain is usually rather localized at first and extends centrifugally to involve a progressively larger area. Generally, the pain is neither aggravated nor alleviated by a motion or local palpation. Joints and tendinous structures are the most common location of pain symptoms.

Localized skin rash and itching is experienced fairly often by divers during or immediately following decompression. A peculiarly irregular, modified "rash" is the most common type of skin lesion related to decompression sickness. The distribution tends to be related to subcutaneous fat deposits and is characteristically found, in order of frequency, in the pectoral region, back of the shoulders, upper abdomen, forearms, and thighs. Recompression causes complete disappearance of the visible lesion; however, tenderness may persist for several days. The underlying pathologic changes and mechanism of skin lesion production in decompression sickness are clear.

Transient blurring of vision and other visual disturbances are a more serious manifestation of decompression sickness. Visual disturbances are probably secondary to vasomotor decompensation and shock and are rarely of CNS origin.

Central nervous system manifestations are probably the most serious consequence of inadequate decompression. The great variety of bubble formation sites yields a comparable variety of disturbances, sometimes bizarre, often multiple, and certainly unpredictable. Theoretically, bubble formation can produce almost any symptom. Damage may be extensive or confined to minute structures. Most CNS lesions occur in the spinal cord, particularly in the lower segment; cerebral damage is relatively rare. Quadriplegia, paraplegia, and paralysis of a single or several extremities in every combination have been reported. Early vasomotor collapse and shock are associated with the more serious manifestations. Various body organs and functions may be affected. Permanent residual damage may result in loss of bowel and bladder control and/or some degree of residual paresis in one or both of the lower extremities.

Other manifestations include respiratory distress ("chokes"), headaches, nausea, and fatigue. The "chokes" is a rare but interesting symptom of delayed development of substernal distress, often described as burning. The condition is aggravated by deep inspiration and subsequent burning pain in all phases of respiration and an uncontrollable urge to cough. As the pain intensifies and spreads, respiration becomes difficult, and coughing more severe. The victim becomes cyanotic, very apprehensive and progresses into clinical shock with subsequent loss of consciuosness on occasion. The condition can be fatal if untreated. Headache, nausea, and fatigue generally are considered to be nonspecific reflex phonomena secondary to the conditions previously discussed. Marked fatigue, often out of proportion to the physical exertion expended, is frequently experienced following deep dives, particularly if the decompression has been marginal. The onset of fatigue is generally 2-5 hr after surfacing and is characterized by an overpowering urge to sleep. The underlying mechanisms responsible are not known; however, fatigue is frequently considered a minor manifestation.

HYPERVENTILATION SYNDROME IN SCUBA DIVERS

Hyperventilation initiated by anxiety and/or physical stress may result in unconsciousness or muscle spasms as possible consequences of excessive depletion of carbon dioxide with subsequent acid-base imbalance in the blood and body. The diver may not be aware of his pending problem. In the water this can result in drowning. Some individuals are more susceptable to low CO_2 tension (hypocapnia) than others, however, loss of consciousness and muscle spasms could probably be induced in almost anyone with sufficiently prolonged hyperventilation.

Scuba divers should be aware of the problems associated with hyperventilation. If a diver notices that he is involuntarily hyperventilating, he should take immediate steps to slow his breathing rate. A scuba diver should notify his "buddy" and, if feasible, promptly ascend. When he reaches the surface, he should inflate his vest. He should not attempt to swim to the boat or shore unaided since unconsciousness may be imminent. A tender should continuously monitor the diver's breathing for signs of hyperventilation. If the diver starts to hyperventilate, he should be asked to stop work and rest. Holding his breath for short periods will aid in replenishing low CO_2 levels and possibly avert further complications.

HYPERPNEA-EXHAUSTION SYNDROME

Various problems in diving such as equipment manfunction, reaction to venomous marine animal wounds, cold stress, exhausting swims, etc. may cause a diver to panic. A frequent manifestation of panic is rapid, shallow breathing hyperpnea, resulting in insufficient ventilation of the lungs. Subsequently there is an accumulation of carbon dioxide in the lungs, blood, and body tissues (cypercpnea). The diver's situation is further complicated by possible decrease in buoyancy due to inadequate inflation of the lungs. The onset of the phyerpnea-exhaustion syndrome is indicated by rapid shallow breathing, dilation of the pupils, inefficient swimming movements, and signs of exhaustion. The diver will experience anxiety and exhaustion. Collapse from exhaustion, unconsciousness, and subsequent drowning may follow. Divers exhibiting the signs or symptoms of this manifestation would immediately terminate the dive, surface, drop the weight belt, and inflate the vest. Diving partners should watch for signs of distress. This condition is probably responsible for many problems and near drownings while the scuba diver is swimming on the surface.

OVEREXERTION AND EXHAUSTION

Nearly everyone has experienced the "out-of-breath" feeling from working too hard or running too fast. It is possible for a person to exceed his normal working capacity by a considerable margin before the respiratory response to overexertion is apparent. The end result is generally shortness of breath and fatigue. On land, this presents little problem.

Underwater (under increased ambient pressure), the problem of exertion is modified by several factors and is considerably more serious. Even the finest breathing apparatus offers some resistance to the flow of air. As the depth increases, so does the density of the air, and consequently it moves through the body's airways with greater resistance to flow.

When shortness of breath and fatigue are brought on by overexertion, the diver may not be able to get enough air. The feeling of impending suffocation is far from pleasant, and it may lead the inexperienced diver to panic and a serious accident.

Man's ability to do hard work underwater has definite limitations, even under the best of conditions. Many situations can lead to exceeding these limits. They include:

- Working against strong currents
- Prolonged heavy exertion
- Wasted effort
- Breathing resistance, especially with poorly designed and maintained breathing apparatus
- Carbon dioxide build-up
- Insufficient or contaminated breathing medium
- Excessive cold or inadequate protection

The diver will realize that he has overexerted himself by labored breathing, anxiety, and a tendency toward panic.

If the diver feels the typical "air hunger" and labored breathing starting to appear, he should do the following:

1. Stop, rest, and ventilate to get a maximum flow of air by holding the scuba mouthpiece in place and pushing the purge bottom on a single-hose unit. With a double-hose unit, he should turn on his back to obtain a free flow of air during the inhalation phase. Do not exhale against the free flow. Breathe deeply.

2. Inform his "buddy".

3. Do not shoot to the surface. Terminate the dive with a slow, controlled ascent.

4. When he reaches the surface, he should inflate his vest and return to the boat or shore. If too exhausted, he should signal for an immediate "pick-up".

The "buddy" should:

1. Render all possible assistance.

2. Watch for signs of panic that might lead to a serious underwater accident.

3. Assist the victim to the surface.

4. Remove the victim's scuba equipment if it is causing apparent additional stress on the surface.

CAROTID SINUS REFLEX

Pressure on the carotid arteries in the neck region can stimulate the heart to reduce blood flow to the cerebral area. Consequently, symptoms similar to those of hypoxia will be evident and eventually the diver will lose consciousness. This condition may be enduced by a tight-fitting hood and/or suit collar.

COLD STRESS

A survey of civilian diving activities in the United States indicates that 83 percent of all divers are in water below 60° F, 60 percent of all divers are in water between 60° F and 40° F, and 25 percent of all divers are in water below 40° F. Of these dives, 44 percent have a duration of 90 min or longer and 33 percent have a duration of 45-90 min. In diving, the major cause of physiological depletion is cold stress. Cold is a major limiting factor relative to diver performance, comfort, and safety.

Initially upon submergence in cold water there is a mobilization of the body's heat generation and insulation resources to resist the cold. This response is characterized by immediate cooling of the body's surface layers, vascoconstriction, metabolic rate increase with possible increase in core temperature, respiration increase, and a decrease in heart rate. Continued exposure results in localized cooling, with the hands and feet exhibiting the most rapid rate of heat loss.

The hands and feet cool rapidly because they have the greatest skin surface area to mass ratio of all body regions, little or no subcutaneous fat, and somewhat poorer circulation. The diver's finger dexterity, tactile discimination, and kinesthetic sensation diminish, with subsequent reduction in his ability to perform manual skill tasks. Loss of manual skill, even by degrees, results in a deteriorated state of efficiency and safety. The diver's ability to make critical value judgements and handle emergency situations is impaired. The diver is, however, still capable of performing certain tasks. For example, a diver may adapt by using the side of his hand to thread a nut onto a bolt instead of his impaired fingers. Also, individual variations in susceptibility to cold and discomfort, skill level, and motivation play a major role in diver performance under cold stress.

Cooling of the hands and arms results in a marked decrease in muscle strength. A 50 percent reduction in grip strength can be expected when an unprotected subject is immersed in 50° F water for 1 hr. The diver's ability to board a boat or ascend a diving ladder without assistance may be impaired. Tenders and surface personnel must be prepared to render assistance.

Cold stress causes deterioration in motor and mental processes. Visual perception, sensory motor coordination, and anticipation (purely a mental process) are affected to various degrees. The loss of mental agility (problem-solving ability) and memory impairment are symptomatic of severe cold stress. Cold stress may limit the amount of information that one can retain and can also be responsible for erroneous recollection, both vital factors in scientific observations. At this point man is not only useless as a working diver, but he is a hazard to himself and his colleagues.

Further exposure can lower core temperature (normal: 98.6° F ± 1°) and skin temperature (normal comfort: 91.5° F to 87.8° F). When core temperature drops to 97° F, the central nervous system's neuroregulatory capacity is affected, and severe pain followed by nerve damage is indicated when skin temperature drops below 55° F.

FIRST AID CONSIDERATIONS IN SCUBA DIVING RESCUE

Probably the most serious mistake in dealing with diving accidents is the failure to recognize air embolism or decompression sickness. In many incidences these may be indistinguishable from each other; however, they both require the same first aid measures and recompression. In the more serious situations, although permanent damage of some degree can be expected in all untreated cases, death is generally the consequence of failure to recompress. Air embolism or decompression sickness must be considered in diagnosis of almost any abnormal sign or complaint presented by a person who has been underwater with breathing apparatus.

Unconsciousness, during or following a dive, presents a particular problem of diagnosis and management. However, one practical rule can be given: an unconscious diver must be considered a victim of air embolism or decompression sickness until proven otherwise by medical personnel. These conditions can coexist with seemingly more obvious causes of unconsciousness such as apparent or "technical" drowning and injury to the head. Spontaneous recovery doesn't rule them out if neurologic defects remain.

Respiratory arrest from any apparent cause must also be managed the same as unconsciousness if the victim has been using underwater breathing apparatus. However, obviously the standing rule for first aid if the diver is not breathing must be to administer artificial respiration immediately and continue while the victim is being transported to a recompression chamber, has regained natural breathing, or has been pronounced dead by medical personnel. All divers and personnel connected with diving operations must know how to apply mouth-to-mouth artificial respiration. Using a floatation vest or float, artificial respiration can be administered while the diver is still in the water and being returned to the base of operation. A mechanical resuscitator may have advantages. However, do not wait for the resuscitator. Start manual artificial respiration immediately while the resuscitator is being brought to the scene and readied by qualified personnel. Even though apparently normal, a victim resuscitated at the scene must be encouraged to seek medical attention and observation because he may later collapse and possibly die due to progressive lung damage.

Neurologic disorders short of unconsciousness must likewise be considered as resulting from air embolism or decompression sickness in almost every case. Nearly the entire spectrum of central or peripheral nervous symptom involvement manifestations can be produced or simulated by these conditions. Air embolism nearly always manifests itself during ascent or within a few minutes after surfacing, and the symptoms are usually major. Decompression sickness, however, may become evident many hours after the dive and may involve anything from minor local defects to unconsciousness and convulsions.

Bloody froth, coughed up or seen at the nose or mouth, signifies lung injury. When a diver using underwater breathing apparatus exhibits this symptom, particularly if associated with neurologic disorders, he is probably a victim of air embolism. In breathhold diving, bloody froth generally indicates thoracic squeeze.

Unconsciousness, respiratory arrest, neurologic disorders, and certain associated manifestations are indicative of air embolism. Symptoms are dramatic and sudden in onset, and brain damage or death can result in a matter of minutes; recompression is the only proper treatment. However, in applying first aid, dramatic relief from symptoms of air embolism may be seen with the victim turned slightly on left side, in a 15 degree head-down position. This technique is successful in increasing intravenous pressure, dilation of the venous system and capillary bed of the brain, dislodgement and dispersion of emboli, and restoration of circulation. The tilt technique is not considered as a substitute for recompression, but as a slight modification of the standard position used in first aid for a victim of shock. The resultant intracranial vascular pressure increase may be paramount in the prevention of permanent brain damage. The victim is kept in this position while enroute to a recompression facility, and resuscitation may be accomplished in this position if necessary. Be alert for vomiting. Administer oxygen to the victim throughout transport if possible. Mediastinal and subcutaneous emphysema and pneumothorax are often associated with air embolism. If symptoms of these conditions are indicated, consider the diver as a victim of air embolism and take appropriate first aid measures. If the victim has difficulty breathing in the tilted position, lower the body back to a horizontal position; lowering the head only over the edge of the stretcher may be beneficial. If head injury is evident use tilt position only at a doctor's direction. The proper action for almost all diving casualties can be summarized in four simple statements:

1. If the diver isn't breathing, start artificial respiration immediately.

2. Acquire medical attention at once (unless the injury is a mild or simple condition).

3. If the diver is injured, give appropriate first aid (combat shock; head down, tilt position).

4. If there is any possibility of air embolism or decompression sickness, arrange for immediate transportation to a recompression facility; keep victim in a head down position, slightly on his left side and administer oxygen, if available.

RECOMPRESSION AND THE RECOMPRESSION CHAMBER

It is absolutely essential that a victim of decompression sickness or an air embolism be treated by recompression as soon as possible following the appearance of symptoms. In cases of decompression sickness prompt and adequate treatment will generally preclude the development of residual damage. It is well established that the incidence of slow or incomplete response to treatment and the magnitude of residual damage are directly proportional to the length of time between the first appearance of decompression sickness symptoms and the beginning of recompression procedures. In cases of air embolism, the brain is frequently involved; when it is, the symptoms are usually extremely serious and unless the victim is recompressed immediately, death or permanent damage may follow even a short delay. Transportation to the nearest facility equipped with a recompression chamber must be made by the most rapid means available. When the distances are great, an ambulance is generally not the most rapid transportation available. Under such circumstances, efforts should be made to obtain a helicopter or other airborne conveyance. Flight at low altitude will not appreciably aggravate the victim's condition and is of minor consequence when the alternative is delay.

All the technical and theoretical details of treatment by recompression will not be reiterated here. The purpose of recompression is to provide prompt and lasting relief from symptoms of decompression sickness and air embolism. Recompression procedures are designed to reduce the bubbles to a size at which they become asymptomatic and to ensure that no bubble becomes symptomatic upon subsequent decompression. Procedures must be such that no new bubbles form in the process. Proper treatment must be conducted under the auspices of specially trained personnel. Improper or inadequate attempts by untrained personnel to recompress a victim may result in even more severe damage than the initial manifestations.

There are a number of important considerations in the application of recompression treatment to decompression sickness. It is important to treat even doubtful cases, since failure to treat can result in serious complications. As previously stated, the recompression must be prompt, since delay further complicates treatment and recovery.

The layman is cautioned against attempting to administer recompression. Such action without supervision by a licensed physician can involve risk, not only of harm to the victim but of legal complications, both civil and criminal. Attempts to recompress the victim by submerging him underwater at the dive site are considered fruitless and hazardous. Do not attempt in-water treatment.

A recompression chamber is a chamber in which a diver may be put back under pressure for treatment of decompression sickness or air embolism or for surface decompression procedures. The chamber is generally constructed of metal and has a working pressure of at least 75 lb/in^2. Maximum working pressure capability and size will depend on mission requirements. A double-lock chamber with two separate compartments capable of being pressurized independently and with enough space to accommodate two divers and an attendent in the main compartment is recommended. Double-lock chambers generally have an inside diameter of 48 in or more. The chamber should be equipped with oxygen breathing equipment which is designed to prevent excessive accumulation of oxygen in the chamber. The air and oxygen supply system will depend on the installation, size, and type of chamber.

EMERGENCY PROCEDURES FOR MICHIGAN AREA

When air embolism or decompression sickness is suspected, follow these procedures after giving necessary immediate first aid:

1. Determine if the victim is carrying a badge, card, or other object which identifies him (her) as a diver or compressed-air worker.

2. Follow instructions on the badge or identification card to contact his project physician and remove him to the project treatment facility at the address shown on the card.

If the victim cannot be so identified--

3. Contact the nearest state police post, sheriff's office, or municipal police and advise that office of the nature of the accident and exact location. Request medical assistance and transporation.

4. Request that the police contact the Michigan State Police Operations Office in Lansing for the location and availability of the nearest hyperbaric chamber. This is necessary since a chamber may be already in use or have been moved to another location to support a diving operation. The Michigan State Police Operations Office will give you the location of the nearest available chamber.

5. Establish communications, if possible, with the physician in charge at the chamber facility which has been assigned to you. Explain the symptoms and answer all questions clearly and precisely. Follow the physician's instructions for first aid. Emergency medical information and services for diving accident victims are available at The University of Michigan Hospital Emergency Room (313/764-5102). Physicians specialized in hyperbaric medicine may be contracted through The University of Michigan Hospital Radiopage Service (313/764-4244); ask for Radiopage No. 146. Physicians in other areas can acquire emergency information and chamber locations from the U.S. Navy Experimental Diving Unit in Panama City, Florida (904/234-4355) on a 24-hour/day basis.

6. Promptly follow instructions for transporting the victim to the chamber facility. If the victim is some distance from the chamber, the physician may decide to transport the patient by air, although this could aggravate the situation. If the distance is not too great, the physician will probably decide to transport the patient by ground routes. The decision, however, is the physician's. The State Police will contact the nearest air transport facility if necessary.

RESCUE TECHNIQUE

The basic elements of diver rescue have been previously discussed in the section on skin diving. When rescuing a distressed scuba diver one must consider the additional complications imposed by the presence of the scuba and special floatation equipment, and the special physiological problems previously discussed.

CONSCIOUS, TROUBLED SCUBA DIVER ON THE SURFACE

To a rescuer the distressed scuba diver may appear as only a very fatigued swimmer. The broad spectrum of physiologic and psychological stress factors that may accompany an abnormal scuba diving situation do require special attention, even at the initiation of the rescue attempt. The psychological stress imposed by exhaustion, abnormal breathing, adverse surface or underwater conditions, and cold can cause the diver to forget even the most basic technique of self-rescue. The verbal rescue may be all that is required. Simply approach the victim and calmly direct him to inflate his vest, release his weight belt, and relax. Do not lose visual contact since the victim may lose consciousness from the physiological changes induced by abnormal breathing and sink silently below the surface. Even with immediate recovery, resuscitation attempts may be unsuccessful.

If the victim does not respond, approach as described in the skin diving section, inflate the vest and drop the weight belt. Constantly talk to and reassure the victim that he is going to be all right. Relax and stabilize the situation. If there is apparently still air in the scuba, encourage the victim to replace the mouthpiece and breath from the scuba while swimming or resting on the surface. This is especially true in rough water. The presence of the scuba cylinder may, on the otherhand, complicate the rescue procedure. Once the belt has been dropped and vest inflated, it is generally best to remove an empty cylinder if the victim must be towed. Cylinder removal may be complicated by the fact that on some units an inflation hose leads from scuba regulator to the floatation vest. This hose must be manually disconnected from the vest. If the vest inflation mechanism is functioning properly, air will not leak from the vest when the inflator is disconnected; if not, air will discharge and the inflator hose connection will have to be re-inserted to stop the discharge or loss of air. Unfortunately, there is no standardization of inflation mechanisms for scuba diver floatation vests. Each manufacturer seems to use a different type and location of the inflation mechanism. The rescuer may have to study the victim's equipment in order to properly inflate the vest. Persons who anticipate being placed in situations which may involve the rescue of scuba divers are encouraged to seek diver training themselves and routinely visit diving equipment suppliers to update themselves on the vast variety of floatation vests and inflation mechanisms being used.

With the advent of vest inflation directly from the scuba air supply, many vests appeared on the market without small "emergency" self-contained

CO_2 or air cylinder inflation mechanisms. Consequently, if the victim's scuba air supply is exhausted, the vest may be inflated only by oral means. A highly distressed victim may be incapable of self-oral inflation. Therefore the rescuer will have to move in and orally inflate the vest. This is a difficult and potentially hazardous situation for the rescuer. If the victim panics at this point, the rescuer is in a very awkward position. If possible, and providing that the vest has a long hose, move behind the victim to inflate his vest. This is a better position to take defensive action.

Some divers use a scuba system which incorporates the scuba, weights, and floatation device all into one unit. In this situation the scuba must be retained in order to retain the floatation. Weights contained in the backpack may be dropped by pulling a pin mechanism on the backpack. The rescuer should stabilize the situation, inflate the buoyancy unit to full capacity (orally or with air from the scuba), and use it as a float or raft for the distressed diver.

This type of scuba system may produce complications in self-rescue if the diver is exhausted. Rumors of divers being held in a face down position and unable to regain a position to hold their head clear of the water when the floatation device is fully inflated have been circulated throughout the diving community. Unfortunately, in either equipment design or rescue procedures objective research has not kept pace with the introduction of new scuba diving equipment on the public market. Rumors may be without foundation or they may be very accurate. In any event, they cannot be ignored and both divers and potential rescuers of divers must constantly upgarde their knowledge of equipment.

When necessary, and possible, the scuba should be removed. The victim may then move toward safety under his own power and the rescuer may tow the scuba. If the rescuer has to render aid to the victim, the scuba should be discarded. It is very difficult and inefficient to tow a scuba equipped victim. Unfortunately, distressed scuba divers sometimes place a higher value on their equipment than their lives. Tests have shown that in scuba diving rescue, the speed and efficiency of towing can be improved nearly three fold if the scuba of both the rescuer and victim are discarded.

Once the victim has been returned to safety the rescuer's responsibilities are not terminated. He must assess the physical state of the victim and attempt to determine if the victim is suffering from conditions such as lung barotrauma, decompression sickness, carbon monoxide poisoning, etc. An unattended rescued scuba accident victim may pass into unconsciousness and even die within minutes or up to several hours after initial rescue as a result of physiological complications. The victim must be observed and, if any abnormality at all is present, a physician consulted. Above all, the rescuer must inform the first aid and medical personnel that the victim was participating in scuba diving at the time of the accident. Accompany the victim, if possible, to the hospital or at least attach an accident description to his clothing.

UNCONSCIOUS SCUBA DIVER ON THE SURFACE

The rescuer may encounter an unconscious scuba diver floating on the surface. In this case the victim may have dropped his weight belt and even inflated his vest prior to losing consciousness. Unconsciousness may have been induced by factors such as cardiac arrest, decompression sickness, air embolism, contaminated breathing air, etc. Also, it is not inconceivable that the fatigued victim could have been unable to maintain his head above water sufficiently to breath because of improper use of his equipment. In any case, the rescuer should immediately take action to position the individual and, if necessary, start mouth-to-mouth resuscitation. Discarding the scuba may be necessary, but should not delay the initial resuscitation procedures. Handling the divers equipment has been discussed previously. Tow the victim to shore or boat as instructed in the section on skin diving and take appropriate action to cope with the near-drowning and diving induced injuries.

SUBMERGED DIVER RESCUE

In the handling of submerged scuba divers we will consider both the possibility of a distressed conscious diver and the non-breathing victim lying on the bottom. In the case of a distressed conscious diver, the victim's diving "buddy" or another nearby scuba diver would probably be placed in the role of the rescuer. In the event of equipment failure or loss or exhaustion of air supply, the trained diver may choose <u>self-rescue</u> by making an emergency ascent.

Learning the technique of a "controlled emergency swimming ascent" or "free ascent" (without assistance from another diver or floatation vest) is an important part of scuba training; however, this ascent can be hazardous and difficult to accomplish safely in situations of stress.

Unless the breathing apparatus is entangled, the diver should not abandon it even though it may appear useless. He must exhale prior to the start of the ascent and continue to exhale throughout the ascent to prevent lung barotrauma. The head should be extended back. This allows maximum opening of the throat area and a good overhead view. The diver should swim to the surface, constantly being aware of possible entanglements or obstructions, and of the serious consequences of holding his breath. The mouthpiece may be left in place. The weight belt should be dropped if the diver is having difficulty swimming to the surface. Definitely drop belt at the surface to facilitate staying afloat.

In desperate emergency situations where the diver feels that he may pass out, etc., it may become necessary to make a "positive-buoyancy ascent" and risk entanglement, injury, and air embolism. This is accomplished by dropping the weight belt <u>and</u> inflating the floatation vest (only high-capacity lifejackets are dependable). The ascent may be slow at first and will become more rapid as the wet suit or vest expands, especially near the surface. Positive-buoyancy ascents are to be used only in a life-or-death situation and no others. Remember, in all emergency ascents, exhale continuously throughout; the possibility of air embolism is always present. Routine practice of open-water free ascents and, especially, positive buoyancy ascents is considered as a high potential risk and is discouraged.

Upon reaching the surface after emergency ascent, or when in trouble at the surface following normal ascent (rough water, exhausted, etc.) jettison the weight belt (if not done previously), inflate the floatation vest and signal for aid.

When not in difficulty, swim for the craft or shore base. If the breathing apparatus interferes with swimming, the diver should remove the equipment and tow it to safety while swimming on his back (jacket inflated or deflated) or on his front with a snorkel. The diver may have to discard his equipment if he faces a long swim to safety.

The technique of controlled emergency swimming ascents should be described, demonstrated and practiced in the swimming pool. Many scuba diving instructors introduce the free ascent procedure during the skin diving phase of a course. The student learns the proper body position and exhalation techniques. He practices the procedure by breathhold diving (no scuba) to the bottom of the pool, exhaling, and making a simulated free ascent to the surface. This same procedure may also be used for simulated ascents from depth by having the student ascend parallel to the bottom of the pool from deep to shallow water; the exercise is later repeated while the student is using scuba. These training techniques eliminate the possibility of lung barotrauma during initial introduction of the procedure (skin diving phase). In healthy, medically qualified scuba diving students, these practice procedures, when used under strict supervision in a pool, minimize the potential of lung barotrauma. Most important, when properly used these techniques can physically and psychologically prepare the diver for handling real underwater emergencies.

Frequently, the diving "buddy" must rescue his distressed partner underwater. "Buddies" must learn to work together and should know and understand a standard set of signals. They should be in visible range at all times and observe each other. In poor visibility a short buddy line may be required. The diver should signal his "buddy" at the first sign of trouble. If your "buddy" shows signs of distress, get to him at once whether he signals or not. The hardest job for a "buddy" will be in the presence of panic. You may be able to do no more than take him to the surface at once. In handling a panicked person underwater every effort must be made to keep the mouthpiece in place. In ascent, the possibility of lung barotrauma exists. It may be necessary to tilt the victim's head far back to facilitate exhalation, especially in panic situations. Never strike the victim in the stomach or chest; this procedure could cause lung barotrauma. Position yourself behind the victim to reduce potential personal risk and facilitate controlling the victim.

It may be necessary for scuba divers to share air (buddy breathe) in the event of air supply exhaustion or equipment malfunctions. There are several methods of sharing air and the diver must use the best adapted to the situation. Generally, air sharing is necessary only for direct ascents. The divers simply face each other and exchange the mouthpiece of the operative scuba while making a slow, controlled ascent. Get the situation under control and attempt to establish rhythm before ascending. When sharing air with a single-hose regulator, the diver providing the air should be slightly to the left (when facing the stricken diver). A normal procedure is for each diver to take two medium, quick breaths on each cycle. Do not fill your lungs and then hold your breath while your "buddy" is taking a breath. Remember as you are ascending that you must continue to exhale as you rise to prevent lung barotrauma. The diver supplying the air should always retain control of the mouthpiece with his right hand and grasp the harness of the victim with his left hand. Do not cover the regulator purge button. He is generally in a better position to regulate breathing cycles and to control the ascent than the diver who has experienced air supply failure. Also, most divers remove neck straps from their regulators; these straps may significantly hamper use of the regulator for sharing air.

When working in caves or under ice, divers may find it necessary to move horizontally before ascending to the surface. In this case the diver wearing scuba containing air swims with his left side down. The distressed diver swims on his right side, holding his "buddy's" harness with his left hand and exchanging the regulator with his right.

An alternate method of lateral swimming is for the "buddy" with the air supply to swim face down. The other diver swims directly above him holding onto the neck of the air cylinder. The diver on the bottom passes the regulator up and the top diver places it back in view of the bottom diver. These methods may be used for both double- and single-hose regulators. Another method of lateral swimming while sharing air with a single-hose regulator is to have the divers swim side by side in a prone position.

Sharing air under emergency conditions is difficult even for the best trained and most experienced divers. Divers should practice the skill frequently. Many individuals feel that buddy breathing is a more hazardous emergency procedure for divers than the controlled emergency swimming ascent. A number of single and double drownings (and incidences of lung barotrauma) have been directly attributed to unsuccessful attempts at buddy breathing under stress situations. A buddy breathing ascent will generally take considerably longer, two to five times, than a free ascent. The use of free ascent procedures in shallow water and inclusion of diver carried auxiliary breathing units (octopus rig, pony bottle, etc) for deeper diving is increasing in popularity. Proper training and diver discretion are key factors in handling emergency situations underwater.

The potential rescuers of an unconscious submerged diver encompasses a much larger group of individuals. Any swimmer, skin diver or lifeguard operating in an area of scuba diving activity may find him or herself in a situation of recovering an unconscious scuba diver. This is especially true in recreational pools and beach areas where scuba diving is permitted.

Assume that the rescuer is not equipped with scuba and that the victim is in water that is shallow enough to reach by normal surface diving techniques.

The rescuer should dive to the victim, and proceed as follows:

1. Position the victim so that his head may be extended back, thus opening the airway as in mouth-to-mouth resuscitation. This can generally be best accomplished by getting behind the victim and pulling his head back by grasping his hood or hair with one hand and supporting him under the arm with the other hand.

2. With the free hand, reach around and release the victim's weight belt and, if the victim cannot be pulled from the bottom, inflate his floatation vest. If the victim can be surfaced without vest inflation or considerable delay, do so.

3. Maintain the victim in the upright head held back position throughout ascent. This is vital for the prevention of air embolism or other lung barotrauma. It may be necessary to swim the victim up if his vest does not inflate and he is not wearing a wet suit. Some advocate placing both arms around the victim's chest or abdominal area and squeezing. This practice is difficult when the victim is wearing scuba.

4. Do not take time to remove the scuba unless it is entangled in rope, net, weeds, etc. or it is significantly inhibiting handling the victim.

The scuba diver may find himself in a similiar position of victim recovery, only at a much greater depth. The techniques of recovery are basically the same except for the following considerations:

1. Floatation vest inflation is at the discretion of the rescuer. If the victim is buoyant when the weight belt is released, the rescuer may have better control if he does not inflate the vest until he reaches the surface.

2. Scuba removal may make surfacing the victim faster, depending on the depth, type of scuba harness, etc.

3. The rescuer must not endanger himself; keep in mind the need for exhalation throughout the ascent.

4. If the victim's vest is inflated and the ascent gets "out of control", the rescuer is probably better off if he releases the victim and takes care of himself. Recent research has shown that the airway in an unconscious diver may, in fact, remain sufficiently open to allow adequate venting in such situations as rapid buoyant ascent of an unconsious diver. Studies show that the rescue of a diver from 30 feet can be accomplished in about 1/2 to 1/3 the time.

Some divers advocate positioning the victim in a face down--feet up position and placing the regulator against his mouth to faciliate purging water from the airway. At this time research and documented successful experience using this technique is not sufficient to endorse it as a "standard" procedure. A relatively significant amount of time is consumed in positioning, airway purging, and ascenting in an "abnormal position". Time is of greatest essence in successful rescue and resusitation.

Once the victim is on the surface, inflate the vest and immediately start mouth-to-mouth resuscitation. Do not take time to remove equipment. If necessary, systematically remove the divers scuba equipment without interupting resuscitation procedures. Frequently, it may be best to remove both the victim's and your sucba. Use the resusitation techniques previously described.

RESCUE OF A VICTIM FROM A SUBMERGED CAR

Another type of underwater resuce is the recovery of a live victim from a submerged car. The technique for opening the vehicles door or window is discussed briefly in publications of the American Red Cross. Basically, water pressure will initially prevent the opening of the door. The victim will generally find a pocket of air in the uppermost portion of the car as water fills the car. Once the car is nearly filled with water and the remaining air is trapped and compressed the inside and outside pressure will equalize. The victim may then take a breath, submerge and open a door. At this point the victim exits the vehicle and ascends to the surface while exhaling all the way. If a rescuer is attempting recovery of the victim, conscious or unconscious, he must make certain that the victim exhales during the ascent. The victim has breathed air under pressure, just as a scuba diver. Lung barotrauma is very probable if proper precautions are not taken. After the victim has been rescued, in addition to other required first aid, this person must also be handled as a scuba diving accident victim would be handled.

CONCLUSIONS

This booklet contains information of skin diving equipment and techniques, diving physiology and skin and scuba diver rescue. It is intended as a supplementary text to better prepare water safety and lifesaving instructors for teaching skin diving and diver rescue. A relatively complete understanding of diving physiology is very important so that the potential rescuer understands the special complications involved in diver rescue. For more details on the subject of skin and scuba diving and an extensive list of technical references on many of the items covered in this booklet, consult the *Research Diver's Manual* by Lee H. Somers (available from the Publications Office, Michigan Sea Grant Program, 4113 Institute of Science and Technology Building, The University of Michigan, Ann Arbor, Michigan, 48105), *The New Science of Skin and Scuba Diving* (available from the Association Press, 291 Broadway, New York, N.Y., 10007 or your local bookstore), or *Skin and Scuba Diving* by John L. Cramer (Bergwall Productions, Inc., Garden City, New York, 11530).

For further information on skin and scuba diving contact:

- National Association of Underwater Instructors
  22809 Barton Road
  Grand Terrace (Colton), California, 92324

- Michigan Sea Grant Program
  Underwater Technology Laboratory
  4113 IST Building
  University of Michigan
  Ann Arbor, Michigan, 48105

- Professional Association of Diving Instructors
  P.O. Box 177
  Costa Mesa, California, 92627

- YMCA: National Scuba Program
  1611 Candler Building
  Atlanta, Georgia, 30303