South pacific underwater medicine society

Journal

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SUBSCRIPTIONS

Members pay $15 yearly. Associate membership for those neither medically qualified nor engaged in hyperbaric nor underwater related research is available for $10. The journal is sent up to four issues yearly to both full and associate members. Those resident outside the immediate Australasian area should write for the special terms available.

Treasurer: Dr P Rubinstein, 4 Highfield Grove, KEW.

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EDITORIAL

Those readers who appreciated the printer’s initiative in accidentally omitting the greater portion of last issue’s Editorial will be highly delighted by the present brevity. For this favour they can thank the contributors for being so forthcoming. It is regretted, naturally, that so few members have responded to the call for articles. It is known that some have contributed ably to other publications and it is hoped that they will now favour their fellow members.

The policy of reprinting important articles that have probably not been seen by most members is followed in this issue. Members are invited to comment, and indeed to suggest articles for possible later use. Members have been honoured by the ready permission to print articles from the third World Congress of Underwater Activities. This BS-AC sponsored meeting was held in October 1973 and the Proceedings are now in print. Both the BS-AC and the individual authors have been most helpful, for which we are most grateful. In addition to the two papers here printed there will be ones by Hannes Keller, Richard Tuson, Sgn Cdr John Rawlins RN and Prof. Johannes Kylstra. They will inform, amuse and stimulate your thoughts it is hoped.

It is planned to have a report of the Vila Conference in the next issue, together with a variety of other matters. So, dear reader, if you are not already a member, Join NOW!

HISTORY OF DIVING

Extracted with permission from *Diving and Subaquatic Medicine* (1975) by Edmonds, Lowry and Pennefather*

* Available from the Diving Medical Centre, 6 Hale Road, Mosman 2088)

The origins of *breathhold diving* are lost in antiquity. By 4,500 BC it had advanced from the first timid dive, into an industry that supplied the community with shells, food and pearls. During the ancient Greek civilisation sponge fishermen dived for this versatile marine product, and have continued to do so up till the present. In earlier days sponges were used by soldiers as water canteens and wound dressings, as well as for washing. Breathhold diving for sponges continued until the nineteenth century when helmet diving equipment was introduced, allowing the intrepid to gamble their lives in order to reach the deeper sponge beds. To the hazards of the sea were added an array of diving diseases - 'diver's palsy', 'burst lung', 'sponge fisherman's disease', 'blowup' and many more.

The ancient Greeks also laid down the first rules on the rights of divers in relation to the goods they salvaged. The diver was entitled to a proportion of the value and his share increased with depth. Many divers would prefer this arrangement to that offered by modern governments and diving companies.

In other parts of the world industries involving breathhold diving persist to this time. Notable examples include the Ama, or diving women, of Japan and Korea and the pearl divers of the Tuamotu Archipelago. The Ama have existed as a group for over 2000 years. Originally the male divers would catch fish and the women collected shell fish and plants. In more recent times diving has been restricted to the women with the men serving as tenders. Some attribute the change in pattern to better endurance of the women in cold water. Others pay homage to the folklore that diving affects the virility of males.

There is a long history of the use of divers for strategic purposes. Divers were involved in military operations during the Trojan Wars from 1194 to 1184 BC. They sabotaged enemy ships by boring holes in the hull or cutting the anchor ropes. Divers were also used to construct underwater defences designed to protect ports from the attacking fleets. The attackers in their turn used divers to remove the obstructions.

By Roman times precautions were being taken against divers. The anchor cables were made of iron chain to make them difficult to cut, and special guards with diving experience were used to protect the fleet against underwater attackers.

Some Roman divers were also involved in a rather different campaign. Mark Anthony's attempt to capture the heart of Cleopatra. Mark Anthony participated in a fishing contest held in Cleopatra's presence and attempted to improve his standing by having his divers ensure a constant supply of fish on his line. The Queen showed her displeasure at this subterfuge by having one of her divers fasten a salted fish to his hook.

There are many examples of the use of reeds and bamboos as a simple breathing tube or snorkel. Columbus reported that the North American Indians would swim towards wild fowl, breathing through a reed and keeping their bodies submerged. They were able to capture the birds with nets, spears or even with their bare hands.

The most skilled of the American native tribes came from Margarita Island. Travellers who observed them during the 16th, 17th and 18th centuries reported that the natives could descend to 30 metres and remain submerged for 15 minutes. They could dive from sunrise to sunset seven days a week. The divers attributed their endurance to tobacco! They also claimed to possess a secret chemical which they rubbed over their bodies to repel sharks. The Spaniards exploited the native divers for pearling, salvage and smuggling goods past custom. The demand for divers was indicated by their value on the slave market; prices up to 150 gold pieces were paid.

The history of diving with equipment is long and complex in the early stages it is mixed with legend. The exploits of Jonah are described with conviction in one text but there is a shortage of supporting evidence. Further reference is not made to him, on the technicality that he was an early submariner and not a diver. As his descent was involuntary he was at best a reluctant pioneer. Some claim that Alexander the Great descended in a diving bell during the 3rd century BC. Details of the event are vague and some of the fish stories attributed to him were spectacular. It is most unlikely that the artisans of the time could make glass as depicted in some of the illustrations of the ‘event’. This may have been a product of artistic licence, or evidence that the incident is based more in fable than fact.

Leonardo de Vinci sketched diving sets and fins. His set was really a snorkel that had the disadvantage of a large dead space. Another of his ideas was for the diver to have a “wine skin to contain the breath”. This was probably the first recorded design of a self-contained breathing apparatus. His drawings appear tentative so it is probably safe to assume that there was no practical diving equipment in Europe at that time.

Another Italian, Borelli, in 1680 realised that Leonardo was in error and that the diver’s air would have to be purified before he breathed it again. He suggested that the air could be purified and rebreathed by passing it through a copper tube cooled by the sea water. With this concept he had the basic idea of a rebreathing set. It might also be claimed that he had the basis of the experimental cryogenic rebreathing set which carries gas in liquid form and purifies air by freezing out carbon dioxide.

The first successful method of prolonging duration underwater, apart from snorkels, was the *diving bell.* This consisted of a weighted chamber, open at the bottom, in which men could be lowered under the water. The use of bells was initially limited to short periods in shallow water, until a method of supplying air to them was developed. The first fully documented use of diving bells dates from the 16th century.

In 1691 Edmund Halley, the English astronomer of comet fame, patented a diving bell which was supplied with air. With this development, diving bells became more widespread. They were used for salvage, treasure recovery and general construction work. Halley’s bell was supplied with air from weighted barrels, which were hauled from the surface. Dives to 20 metres for up to 1.5 hours were recorded. Halley also devised a method of supplying air to a diver from a hose connected to the bell. The length of hose restricted the diver to the area close to the bell. It is not known if this was successful. Halley was one of the earliest recorded sufferers of middle ear barotrauma.

During the second half of the 18th century, reliable *air pumps* that were able to supply air against the pressures experienced by divers were developed.

Several people had the idea of using these pumps for diving and developed what are now called open helmets. Air was pumped down to the diver and the excess air escaped round the bottom of the helmet. The diver could breathe because his head and neck were in air, or at least they ware until he bent over or fell. If this happened, or the hose or pump leaked, the helmet flooded and the diver was likely to drown.

In 1837 a naturalised Englishman, Augustus Siebe, produced his “closed dress” often called *standard diving dress* or *standard rig.* This equipment consisted of a rigid helmet sealed to a flexible waterproof suit. Air was pumped down from the surface into the helmet, and excess air bled off through an outlet valve. The diver could control his buoyancy by adjusting the flow through his outlet and thus the volume of air in his suit. This type of equipment, with a few refinements, is still in use.

There is some doubt about who designed the Siebe closed dress. It has been suggested that it was constructed by Siebe to designs supplied by one John Deane who had earlier experimented with an old suit of armour converted to a diving suit. Siebe certainly deserves the credit for marketing the firstacceptable equipment of this type. Several types of diving suits and a bell were used by the Royal Engineers on dives on the wreck of the “Royal George” which was a danger to navigation in Spithead anchorage. The Siebe suit was found to be greatly superior to the other designs. Siebe’s apparatus allowed the diver to bend over, or even lie down without the risk of flooding the helmet. Also, the diver could control his depth easily. A diver in an open helmet had to rely on his tenders to do this.

The first diving school was set up by the Royal Navy in 1843. Corporal Jones, who had gained his experience on the wreck of the “Royal George” was the instructor.

With the use of the Siebe closed dress and its rivals, cases of decompression sickness in divers were noted. This disease had already been observed in workers employed in caissons and tunnelling where the working area was pressurised to force out water. The history of decompression sickness is discussed in a later chapter but mention should be made here of the work of Paul Bert and JS Haldane. Paul Bert published a text book “La Pression Barometrique” based on his studies of the physiological effect of changes in pressure. His book is still widely used as a reference text although it was published almost a hundred years ago.

JS Haldane, a Scottish scientist, was appointed to a Royal Navy Committee to investigate the problem of decompression sickness in divers. At that time the Royal Navy had a diving depth limit of 30 metres. Deeper dives had been recorded; Greek and Swedish divers had reached 58 metres in 1904 and Alexander Lambert had recovered gold bullion from a wreck in 50 metres of water in 1885, but had developed partial paralysis from decompression sickness. Haldane deduced from Paul Bert’s results that a diver could be hauled safely to the surface from 10 metres with no evidence of decompression sickness. This involved halving the pressure. He deduced from this that a diver could be surfaced from greater than 10 metres in stages, provided that no stage involved a pressure reduction by a factor greater than two. This was tested on goats, and then men in chambers. Later, practical dives were undertaken which culminated in an open water dive to 64 metres in 1906. This work led to the publication of the first acceptable set of decompression tables as well as several practical improvements to the diving equipment used. Others extended this work and in 1914 US Navy divers reached 84 metres. The next year they raised a submarine near Hawaii from a depth of 93 metres. This was a remarkable feat considering that the salvage techniques had to be evolved by trial and error. The divers used air, so they were exposed to a dangerous degree of nitrogen narcosis as well as decompression sickness.

The development of *self-contained underwater breathing apparatus (SCUBA)* which allows the diver to carry his air supply with him rather than have it pumped down to him, dates back to the early nineteenth century. There is a brief report of an American engineer, Charles Condert, who made a type of SCUBA in which the air was stored in a copper pipe worn round his body. Details of the method used to control the air flow are unknown. He died while diving with his equipment in the East River in 1831.

Another early development was the Rouquayrol and Denayrouze device of 1865. This set was supplied with air from the surface in the same manner as the Siebe closed helmet suit, and was fitted with an air reservoir so that the diver could detach himself from the air hose for a few minutes. The first successful equipment with an independent air supply appears to have been developed and patented in 1918 by Ohgushi, a Japanese. This system could be operated with a supply of air from the surface or as a SCUBA with an air supply cylinder carried on the back. The diver controlled his air supply by triggering air flow into his mask with his teeth. Another SCUBA was devised by Le Prieur in 1933. In this set the diver carried a compressed air bottle on his chest and released air into his face mask by opening a tap.

In 1943 Cousteau and Gagnan developed the first SCUBA incorporating an automatic demand valve to release air as the diver inhaled. This valve was triggered by the diver’s breathing and so the diver was no longer required to operate a tap to obtain each breath of air. With this valve, which was pressure compensated so that changes in depth did not affect its function. Cousteau and Gagnan invented the SCUBA as we know it today.

During the time that these people were working to develop the modern SCUBA, others were working on rebreathing sets that supplied the diver with oxygen. They devised a closed circuit set that supplied the diver with pure oxygen and removed the carbon dioxide he produced. These sets are often called SCUBA, but they should be considered separately because of the difference in principles involved.

The first successful *rebreathing set* was designed by an Englishman, HA Fleuss, in 1878. This was an oxygen set in which carbon dioxide was absorbed by rope yarn soaked with caustic potash. Because of the absence of lines and hoses from the diver to the surface the set was used in flooded mines and tunnels where the extra mobility, compared to the standard rig, was needed. Great risks were taken with this set and its successors, because the work of Paul Bert on oxygen toxicity was not widely publicised. This equipment was the precursor of oxygen sets used in clandestine operations in both world wars and of other sets used in submarine escape, fire fighting and mine rescue.

The *military use* of divers in modern warfare had, until 1918, been largely restricted to the salvage of damaged ships, clearing of channels blocked by wrecks, and assorted ships’ husbandry duties. One significant clandestine operation conducted during the First World War was the recovery of code books and mine field charts from a sunken German submarine. This was of more significance as an intelligence operation, although the diving activity was also kept secret.

During the First World War, Italy developed a human torpedo or chariot that was used in 1918 to attack an Austrian battleship in Pola Harbour. The attack was a success in that the ship was sunk, but it coincided with the fall of the Austro-Hungarian Empire and the ship was already in friendly hands! The potential of this method of attack was not overlooked by the Italian Navy who put it to use in World War II with divers wearing oxygen rebreathing sets as underwater pilots. In passing, it is interesting to note that the idea of the chariot was suggested to the British Admiralty in 1909 and Davis took out patents on a small submarine and human torpedo controlled by divers in 1914. This, in turn, was pre-dated by a one-man submarine designed by JP Holland in 1875.

Diving research during the period of the Second World War was largely confined to improving equipment for use in offensive operations. Exploits of note included those of the Italian Navy, using divers to attack ships in Gibraltar and Alexandria. After a series of unsuccessful attempts with loss of life they succeeded in sinking several ships in Gibraltar harbour in mid 1941. Later that year three teams managed to enter Alexandria harbour and damage two battleships and a tanker. Even Sir Winston Churchill, who did not often praise his enemies, said they showed “extraordinary courage and ingenuity”.

In Gibraltar a special type of underwater war evolved. The Italians had a secret base in Spain, only six miles away, and launched several attacks that were opposed by a group of British divers who tried to remove the Italian mines before they exploded. On at least one occasion the British arrived before the Italians had left and an underwater battle ensued.

Divers from the allied nations made several successful attacks on enemy ships but their most important offensive role was in the field of reconnaissance and beach clearance. In most operations the divers worked from submarines or small boats. They first surveyed the approaches to several potential landing sites and after a choice had been made they cleared the obstructions that could impede the land craft. One of the more famous exploits of an American group was to land prematurely and leave a “Welcome” sign on the beach to greet the US Marines spearheading the invasion of Guam.

The research back-up to these exploits was largely devoted to improvement of equipment and the investigation of the nature and onset of oxygen toxicity. This work was important because most of these offensive operations were conducted by divers wearing oxygen breathing apparatus.

The use of *oxygen/nitrogen mixtures* for diving was originated by Siebe, Gorman and Co. Ltd. between the wars for use by the Royal Navy in conjunction with standard diving rig. It was based on an idea proposed by Sir Leonard Hill. The advantage of this equipment was that by increasing the ratio of oxygen to nitrogen in the breathing gas one can reduce or eliminate decompression requirements. It is normally used with equipment in which most of the gas is breathed again after the carbon dioxide has been removed; this allows reduction of the total gas volume required by the diver. The self-contained semi-closed rebreathing apparatus was a war-time advance and was first used extensively by divers clearing mines. This development was conducted by the Admiralty Experimental Diving Unit in conjunction with Siebe, Gorman & Co. Ltd. The change to a self-contained set was needed to reduce the number of people at risk from accidental explosions in mine clearing operations. The reduction, or elimination of decompression time was desirable in increasing the diver’s chances of survival if something went wrong. The equipment used was constructed from non-magnetic materials to reduce the change of activating magnetic mines and was silent for work on acoustically triggered mines.

The search for means to allow man to descend deeper has been a continuing process. By the early twentieth century deep diving research had enabled divers to reach depths in excess of 90 metres; at this depth nitrogen narcosis incapacitated most men.

After the First World War the Royal Navy diving research was designed to extend their depth capability beyond 60 metres. Equipment was improved, the submersible decompression chamber was introduced, and new decompression schedules were developed using oxygen breathing, to reduce decompression time. Dives were made to 107 metres, but nitrogen narcosis at these depths made such dives unrewarding and dangerous.

In 1919, an American scientist, Professor Elihu Thompson, suggested that nitrogen narcosis could be avoided by using helium as a replacement for nitrogen in the diver's gas supply. At that stage, the idea was hardly practical because helium cost over US$2,000 per cubic foot. Later the price dropped to about 3 cents per cubic foot, following the exploitation of natural gas supplies which contained helium. Research into the use of helium was conducted during the 1920's and 1930's; by the end of the 1930's compression chamber divers had reached 150 metres and a wet dive to 128 metres was rode in Lake Michigan. Between the two World Wars the USA had a virtual monopoly on the supply of helium, and so dominated research into deep diving,

The possibility of using hydrogen instead of helium in gas mixtures (for deep diving) was first tested by Arne Zetterstrom, a Swedish engineer. His pioneering work on the use of *hydrogen* in a diver's gas mixture has not been fully developed. He demonstrated that hypoxia and risks of explosion could be avoided if the diver used air from the surface to 30 metres, changed to 4% oxygen in nitrogen and then changed to 4% or less oxygen in hydrogen. In this manner the diver received adequate oxygen and the formation of an explosive mixture of oxygen and hydrogen was prevented. In 1945, Zetterstrom dived to 160 metres in open water. Unfortunately, an error was made by the operators controlling his ascent. They hauled him up too far and he died from hypoxia and explosive decompression sickness. The error was accidental and was not related to his decompression schedule. Interest in hydrogen for use in deep diving has not been great, but mice and monkeys have been pressurised to over 1000 metres on oxygen/hydrogen mixtures. The relative cheapness of hydrogen compared to helium, and the probability of a helium shortage, may mean that hydrogen will eventually be widely used in deep dives.

The cost of gas, combined with a desire to increase the diver's mobility, has encouraged the development of more sophisticated mixed gas sets. The most complex of these have separate cylinders of oxygen and diluting gas. The composition of the diver's inspired gas is controlled by the action of electronic control systems which regulate the release of gas from each cylinder. The first of these sets was developed in the 1950's, but they have been refined and improved since then.

One of the most important developing fields in diving since the Second World War is that of *saturation diving.* Behnke suggested that caisson workers could be kept under pressure for long periods and decompressed slowly at the end of their job rather than undertake a series of compressions, and risk decompression sickness after each. Bond and others adopted this idea for diving. The first of these dives involved tests on animals and men in chambers, then in 1962 Robert Stenuit spent 24 hours at 60 metres in the Mediterranean Sea off the coast of France.

Progress was rapid with both the French inspired Conshelf experiments and the American Sealab experiments seeking greater depths and duration of exposures. In 1965, the former astronaut Scott Carpenter spent month at 60 metres, and 2 divers spent 2 days at a depth equivalent to almost 200 metres. Unfortunately people paid for this progress. Lives were lost and there has been a significant incidence of bone necrosis induced by these experiments.

In most saturation diving systems, the divers either live in an underwater habitat or in a chamber on the surface. In the second case, another chamber is needed to transfer them under pressure to and from their work site. Operations can also be conducted from small submarines or submersibles with the divers operating from a compartment that can be opened to the sea. They can either move to a separate chamber on the submarine’s tender or remain in the submarine for their period of decompression. The use of this offers several advantages. The submarine speeds the diver’s movement around the work site, provides better lighting and carries extra equipment. Also, a technical expert who is not a diver can observe and control the operation from within the submarine.

Operations involving saturation dives have become almost routine for work in deep water. The stimulus for this work is partly military, but the oher major requirement is the exploitation of oil and natural gas fields in deep water. The needs of the oil companies have resulted in strenuous efforts to extend the depth and efficiency of the associated diving activities. Diving firms are now prepared to sign contracts that may require them to work at 460 metres.

Man is pursuing other avenues in his efforts to exploit the sea. One involves diving in a suit in which the internal pressure is the same as sea level and there is the radical concept of liquid breathing.

Armoured diving suits withstand the pressure exerted by the water and allow the diver to avoid the hazards of increased and changing pressures. In effect the diver becomes a small submarine. The mobility and dexterity of divers wearing earlier armoured suits were limited and they were not widely used. The newer suits such as the British ‘Big Jim’ may become an accepted piece of diving equipment midway between a diver and a small submarine. They can be fitted with claws for manipulating equipment.

Experiments involving the *breathing of liquids* in which the lungs are flooded and the body supplied with oxygen in solution are still in the preliminary experimental stages. Some of the results obtained show promise; mice breathed liquids for up to 18 hours and the first human subject survived experiments involving flooding of one lung. Technical difficulties involving carbon dioxide transport have hindered development of this concept. The potential advantages of breathing liquids are the elimination of decompression sickness as a problem, freedom to descend to virtually any depth and the possibility of the diver extracting the oxygen dissolved in the water.

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Provisional Report on the 1974 Diving Deaths

Douglas Walker

Overview

The remarkably low number of fatal incidents that occurred in 1974 in association with underwater activities, eight in number, points to the paradox that in so patently hostile an environment so few come to serious harm. These brief case histories are presented to drew attention to the fact that failure to apply the commonly accepted rules for safe diving carries with it the occasional exaction of the supreme penalty, not withstanding the undoubted fact that a large number of divers survive the making of similar liberties with their underwater environment. Every mode of civil diving practice save deep sea professional diving has been represented this year and there are present indications that this group is in active hazard from the slowly developing crippling arthritis associated with dysbaric osteonecrosis.

The significant avoidable factors associated with these deaths are the same as those demonstrated in previous surveys. They are none the less tragic because others have trod the same paths to oblivion.

In brief, there were three breath-hold divers, two scuba divers and three hose supply divers (Hookah type). Causes involved included under-respect for the power of the sea, hyperventilation blackout, total ignorance of scuba apparatus used, the cutting of an air hose and failure to realise that deep sink-hole diving requires treating with great respect, for there are the risks of depth (narcosis) added to risk of being unable to ascend directly to the surface, entanglement, loss of visibility, etc.

Brief Histories

To ensure maintenance of confidentiality in this small series these reports include nothing not already of public knowledge. However, there is much to be learnt from a closer look at the events than is usually afforded to newspaper items.

Case 1 - (Breath-hold) The 22 year old victim tossed a coin to decide whether or not to call off the dive. Unfortunately for him the decision was made to chance the elements and make the dive. There was an 8-10 ft swell and visibility was poor underwater, but he was keen to do some spearfishing and managed to convince his buddy that he was sufficiently experienced for the conditions. They arranged that he should enter the water first and wait outside the surfline, and this plan was followed. When the buddy arrived at the appointed area he was unable to see any sign of the first diver so, after making a short search, he returned to the beach. After a fruitless search across the waves and along the shore he alerted the rescue services. They too could find no trace of the missing man. In fact the body was not recovered for six days. The victim was found to have bean wearing a home-made weight belt whose release mechanism was difficult to operate, a factor that would disadvantage him when seeking to alleviate his buoyancy problem in the rough water. His inexperience made him less able to extricate himself from water conditions he had mistakenly risked. It is well known that anyone in trouble in water becomes incapable of rational thought under the imperative desire to maintain their head above water. The disturbed, rapid, inefficient, shallow breathing reduces the buoyancy and increases panic. The possession of an efficient buoyancy aid could have been lifesaving despite all the other adverse circumstances.

Case 2 - (Breath-hold) This spearfisherman had a good reputation for his ability in the sport. He had ten years experience, though this was said to be the first time that he had worn a wet suit and a weight belt. He is known to have speared a 45lb Kingfish at 30 ft depth and kept with it when it fought hard. A fellow spearfisher saw the victim’s gun, and the attached fish, on the sea floor a short time after the kill. Then he observed the victim about 15 ft away from the gun, slowly sinking into a 50 ft trench. He was unfortunately unable to breath-hold dive sufficiently deep to reach the body so swam to summon help. Another diver was able to reach the body but was unable to raise it even after releasing the weight belt, having to procure a hookah hose before effecting the recovery. Naturally, by this time all hope of successful resuscitation had passed. This witnessed death was typical of the hyperventilation-blackout syndrome; a good diver over-extending himself in fighting a vigorous fish and then drifting gently to the sea floor, unconscious. Survival from such a circumstance is entirely dependent on the event being witnessed by someone immediately able to dive to the required depth, raise the body and perform effective resuscitation. Such factors did not operate here. The better the breath-hold spearfisher the greater the need for such a buddy.

Case 3 - (Breath-hold) This spearfisherman and his friend had received some training in Skin and Scuba diving early in 1973. He was said to be competent both as a swimmer and as a diver and to be aware of the dangers of pre-dive hyperventilation, though he still practiced it. On this occasion they were spearfishing about 20 ft from the rocks at the sea’s edge, the water being calm. The friend left the water with his third fish and became involved in conversation with two passers-by who were intending to go swimming in that area. One of these witnesses saw the victim at this time swimming normally on the surface. A short time later one of the men entered the water to examine a red float a little offshore. He was wearing goggles and the water was clear so he was able to see, to his great surprise, a diver lying quietly on his back on the sea floor in about 15-18 ft of water. A speargun was lying nearby and the facemask was still in position. After shouting the alarm to those ashore he dived and released the victim’s weight belt, thus enabling him to surface the body. Together with the help of the other swimmer, he brought the body ashore, chest compression resuscitation being performed, without success, both in the water and after landing. The period of submersion was very possibly too long for success to be expected but EAR might have been a better choice of method. This quiet death in calm water could also be a hyperventilation blackout. Once again, dive alone, die alone; ... and possibly unnecessarily.

There were two addenda to this story. First, one of those present was said to be a diving instructor yet he did not attempt EAR. Second, a surviving fragment of the onshore conversation taking place as the diver died: one of the strangers said, on seeing the size of the speared fish, “Why don’t you give it a chance to grow?” The reply made was “They are getting smaller all the time”.

Case 4 - (Scuba) The circumstances of this tragedy are almost unbelievable and it is hoped they will never be repeated. The victim was making an inspection of a submerged outlet valve in a shallow freshwater dam. He tried to do this by breath-hold diving but found it too difficult so thought to use scuba apparatus. It was no part of his duty, it would seem, to be a diver and in fact he was totally ignorant of diving. He borrowed a wetsuit and weight belt from someone and then approached a neighbour for the loan of a scuba tank and demand valve, refusing the offer of flippers because be intended to both enter and leave the water by walking. The owner of the equipment was aware of the total inexperience of the victim so showed him how to turn the air on and how to breath using the mouthpiece. There was no quick-release on the tank harness. Being not a fully equipped diver, he returned to the dam and his first ever dive.

At the dam he dressed and entered the water, there being handed a couple of loose spanners. He told his companion it would be only a short dive as he didn't have much air. The companion then rowed away on another job, losing sight of the diver. When he returned at the agreed time and was not met by his friend he searched for the air bubbles. Something in their character alarmed him so he made some breath-hold dives but was unable to locate him in the conditions of nil-visibility that always existed in the dam water. Being by now highly anxious for the safety of his fellow worker, he rowed ashore and called the Police. But by now the flow of bubbles had ceased.

The body was recovered by a brave policeman making breath-bold dives. The depth was 20 ft, the water cold and opaque and the victim dead when reached. When found he was noted to have his hands and forearms tied together by a line also attached to the two spanners. This line had apparently been on the underwater valve from a previous occasion and removed by the victim for use to prevent the possible loss of the spanners. The light nature of the line had done the rest, allowing it to float freely but uncontrollably around him. His mask was dislodged to behind his head and he had lost the mouthpiece of the demand valve. Not only was the tank harness without a quick-release, the weight belt was too long and he had the buckle to one side, so it would be difficult to reach even had he been experienced and had his hands free. The muddy bottom of the dam sloped such that a crawling escape to safety was impossible through slipperyness. He was alone, without air, his arms tied and without a lifeline to guide a rescuer. Even Houdini could not have escaped such a combination of self-inflicted circumstances.

Case 5 - (Scuba) This deep dive at Mount Gambier received the publicity usual to all such deaths. The circumstances of the dive were probably not unlike those associated with many dives with uneventful outcome, if one may judge from other incidents on file.

The two divers involved, of whom one died, were apparently experienced in scuba diving in the sea but their experience of deep diving and of cave/sink-hole diving is presumed to be slight. In this they were possibly typical of the majority of casual divers in these inland waters. There is some element of conjecture in the story of what occurred, no actual Inquest being held. The Coroner was content to accept the statements made to the Police in their investigation as adequate basis for a finding of death by misadventure. Such a procedure was his prerogative and completely proper but leaves some points relating to the incident undocumented.

In essence, this death occurred because the dive plan left no margin for safety there was no air-time to spare and no allowance for possible problems of nitrogen narcosis. Thus were the seeds of disaster sown.

The dive was to 200 ft using single 72 cft cylinders plus one reserve cylinder hung at 30 ft. A 220 ft long shot line was used and the victim wore a reel line on his belt. This was to be a bounce dive and in fact the ascent was started after only 20-30 seconds at maximum depth. Both the shot end reel lines were attached to the surface buoy. Before leaving the 200 ft level the second diver switched on his reserve. Ascent was uneventful and hand contact was maintained till 150 ft depth. Here, where the light could be seen above, the diver wearing the reel found his ascent suddenly arrested. His companion was by now low on air end having difficulty in breathing and this may have similarly affected the victim as their rate of air consumption was usually similar. The buddy assumed that a line had snagged so tried to pull him free. When this failed he never thought to try to cut the line, shortage of air requiring him to ascend to the waiting air reserve, there to decompress. At this time thought of the need to avoid decompression sickness over-rode all other considerations. When decompression steps were completed, be surfaced and gave the alarm. It seems reasonable to assume that his failure to rethink his assistance pattern when the tugging failed was an example of the narrowing of perception, or "tunnel thought", with obsessive concentration on one fact to the exclusion of all others. This would be typical of nitrogen narcosis and increased by the panic stimulus of air shortage. Had the line in fact come free this incident would have been soon forgotten by both those involved. Had more air been available the victim might have cut himself free.

Case 6 - (Hookah) The fatal and unexpected Shark attack on this Abalone diver could not have been foreseen or prevented. It is presumed that a white pointer mistook him for a seal, for he was gathering abalone from the sea floor with his legs floating upwards when the attack occurred. The first that the man in the boat knew about it was when the diver surfaced unexpectedly and called for help. Until he had pulled him back to the boat and was attempting to get him aboard he did not see the shark or realise that an injury had occurred. At this time the victim still lived but death from shock and haemorrhage occurred before shore was reached. There is no note that any attempt was made to give first aid but most of the blood loss may have occurred while still in the water, so not preventable. Seals had been seen in the area previously, though not at the time of the attack. That the risk of attack is low may be gauged from the rapidity with which the vacant fishing licence was applied for and taken up.

Case 7 - (Hookah) There were two divers here on separate hoses from an air compressor in the boat. The owner of the boat and the equipment became the victim, though the only experienced person present. He had bought the equipment new about two years previously and kept it in good condition. Though by this time practiced in its use he may never have received any formal diving training. The other diver was totally inexperienced save for a quick lesson in a pool in the use of hookah apparatus, while the friend left in the boat was a non-diver who was without prior experience with the compressor. The two did not keep together underwater, the novice making the valid point that as the other had a speargun he intended to keep out of the way. Water conditions were good and depth 20 ft.

After a few minutes the victim surfaced, shouted, sank and then resurfaced. The man in the boat correctly interpreted this as a call for help and used the hose to pull him back to the boat. He was apparently conscious till within 8-10 ft of the boat. By this time the other diver had come across the speargun and one flipper on the sea bed and surfaced with them. When he observed what was occurring he dropped his find and went to give assistance. Finding it impossible to get the victim into the boat by pushing from the water while the other tried to lift, he came aboard and together they managed to bring the body inboard. In both this and the previous case great difficulty was experienced in getting a helpless diver back into a boat. It was noted that the victim's demand valve was then functioning normally and the novice at no time had any air supply problem. The total dive time was only 8 minutes. EAR was given but the victim was already dead. Air Embolism was the cause of death but why the diver made an emergency ascent is quite inexplicable. He was certainly aware of the need for exhaling on ascent, having instructed the novice to this effect. Once again, the extreme ease with which one can use hookah apparatus without training has been illustrated, as also the mode of death (air embolism so typical of fatalities in this diving group and the rapidity with which it can occur).

Case 8 - (Hose supply) Neglect of precautions is possibly inevitable when undertaking routine procedures. Only the occurrence of the inevitable accident brings a return of a more alert appreciation of the value of correct routines. Such was here the case. This was a normal harbour job of removing a broken pile. The surface barge was required to move slightly and the order given. Unfortunately on this occasion the diver had obtained an excessive length of free hose from his surface tender and it had drifted, unsuspected, under the barge. When the propeller started to revolve it immediately tightened the hose around itself. This not only cut off the diver’s air, it also violently jerked him. He was thus in no condition to close his inlet valve to retain his air. It is easy to note the faults in hose management, the risks of unprotected propellers and the incorrectness of having a revolving propeller with a diver in the water nearby. The sins were venal, the penalty mortal. This case is reported in the hope that it will alert others to consider their diving practices.

Discussion

These cases illustrate once again the extremely short span of time it requires for death to occur. None of these victim did anything that others may not have done without a fatal outcome, yet all save the shark victim broke clearly recognised guidelines for safe diving. The reader is urged to consider his own diving practices to see whether, should he too prove mortal, others would say of him “What an unnecessary thing it was that led to him dying’.

The breath-hold divers continue to hyperventilate and few inevitably black-out. In the absence of rapid rescue and resuscitation they will drown. Those most at risk are the spearfishermen seeking to excel. The inexperienced divers under-respect the sea’s power and risk simple drowning. That so few in fact do drown may be a tribute to the buoyancy given by a wet suit, though there is no proof of this.

That Scuba divers require training is now generally accepted, and Case 4 shows the possible consequences of lending equipment to the untrained. The lender in this case obviously is ignorant of every principle of safe scuba diving. Case 5 illustrates the trueism that still waters and deep lead men to folly. Once again, it is clear that every dive plan should include a very generous element of safety. To have air available is a great comfort in time of trouble. Perhaps if tank fills were charged by quantity actually supplied rather than by tank size divers would not mind returning from a dive with air remaining unused. It is time that those intending to dive in sink-holes/caves ensure that at least the dive leader is alert to the special risks end precautions of this type of diving and adjust their dive plan accordingly. To dive deep without adequate air and without allowance for nitrogen narcosis is suicidal.

One should remember always that the diver without a line may get lost, one with a line get snagged. The only ready remedy to the deep-dive menace would seem to be if some public spirited person put a notice on the shaft wall saying “200 ft; please sign here” ... at 100 ft.

Hookah diving is another diving discipline that merits special attention from diving instructors, despite the absurd simplicity of the equipment, for the only thing that goes seriously wrong for the diver is the abrupt cessation of his air supply. But this little matter explains the relationship of air embolism with hookah diving fatalities.

It is apparent that a thorough knowledge of the first aid treatment of Haemorrhage and of Resuscitation may be required at short notice. It should therefore be a required skill.

It is the writer’s opinion that role of the Coroner in making verbal examination of witnesses, based on their statements to the investigating police, fulfils an important need. He can often elucidate points left unclear in statements and obtain information not thought significant to the basic investigation as to whether the death was misadventure or culpable, but of importance and basic to consideration of the preventable factors present in the incident’s evolution. The Coroner has a key position in the Safety Team. He can also, where necessary, prevent ill-formed “Experts” from having it all their own way, a difficult, skilled and important task. The holding of inquests is as relevant to today’s problem as it was to those of times long past when the Office was initiated. Nothing better has yet evolved for the investigation of the generality of accidental deaths. This investigation certainly rests heavily on the work of Coroners.

Acknowledgments

All those who have supplied information are thanked. Special thanks are given to the Attorney General’s Departments in all States for their continued assist.

Request for Incident Reports

Without a continued supply of information concerning incidents associated with diving there cannot be progress in further improving the safety of diving, for dangers will remain unrecognised and uncorrected. Although this report concentrates on fatalities, reports of all types of non-fatal incidents are equally required. All are treated as confidential. YOUR reports could help improve the safety of future divers. Please send reports, or queries, to the following address:

Dr DG Walker
PO Box 120
NARRABEEN NSW 2101

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PANIC
Dr Arthur J Bachrach (Oceans 2000, 1973)

For some time Glen Egstrom and I have been working (on a somewhat negative aspect of diving - the destructive problem of panic. My remarks today are, in effect, a distillation of our work. About 120 sports) divers are killed each year in the United States and, of them, cave diving produces 25 - 30 deaths in Florida alone. There are perhaps two million divers, so this would not appear to be much of a statistic, but if you compare this with the five deaths each year in an equally popular high-risk sport - skiing - you will see why we wish to examine what is killing our divers.

The problem of panic has three elements: training, which needs to be improved in many ways; physical condition, which is becoming more and more a source of concern for us; and finally, equipment.

Most deaths occur at shallow depths or on the surface and are to be associated in very large measure with loss of control - panic. Most of the divers pulled out of the California waters still have their weight-belts on, yet when you look into the training progress it would seem to be automatic that a person should jettison his weight-belt to save his life. Certainly, they have enough air left in their tanks, but frequently the mouthpiece has been spat out, implying that there has been a loss of control on the part of the divers.

This is not only true for sports divers, it also applies to a number of deep divers. Commander Carpenter will certainly remember concerns expressed by some of the divers on Sealab II: about scorpion fish, loss or failure of equipment, failure of CO_2 sensors. These are things that are beyond the control of the diver but, above all, his greatest concern must be a personal loss of control, which would mean that it was beyond the diver’s capability to handle a problem.

Competence and self-confidence seem to be the two things that are important in controlling panic. When an individual, who is basically a land mammal_wearing strange equipment, is in trouble in the water, he will begin to struggle - clawing the water, with his head held back, struggling to keep out of the water. He has spat out his mouthpiece and still has his weight-belt on. The hard struggling results in keeping the head higher but also increases the weightload, and the body responds by increasing the heart and respiration rates. Therefore, the individual rapidly reaches the state where he cannot possibly sustain this excessive workload, and becomes exhausted. It has been estimated that an individual can sustain a workload like this for less than a minute, and exhaustion can bring an additional psychological stress which will mean he may or may not be able to perform another manoeuvre such as ditching the weight-belt or inflating a flotation device.

We have a theory, which is unproven, that it may well be psychologically antagonistic for a diver, with his hands up and trying to keep his head out of the water, to put his hands back into the water to release his weight-belt or to pop the CO_2 cartridge. It could be that in engineering equipment, it would be more practical to have such a safety feature on the shoulder or closer to the head.

Following work at the Royal Naval Physiological Laboratories at Alverstoke, Peter Bennett and I, working at Duke University, conducted further research into the subject of apprehension as experienced during deep dives. We prepared a special analysis of a tremor and with diver-operated force transducers measured the psycho-physiological changes experienced by divers in a chamber at 870 ft.

The results showed that the professional divers, who had been saturated for a while and were resting and waiting to travel to 1000 ft, produced peaks at 3-5 Hertz. The normal frequency at which this takes place being 10 Hertz, this suggested a pathological tremor which does not necessarily mean that the individual has suffered any permanent brain changes, but that he was experiencing what we may loosely call ‘apprehension’.

As they began to compress to 1000 ft, the tremor and their level of performance returned to normal, suggesting that the divers’ stress had been experienced prior to travelling on compression.

During an evaluation of the Mk XII, which is a system that the US Navy may adopt to replace the old Mk V copper diving helmet, we listened to a diver’s heartbeat while working a UCLA pipe puzzle in very clear, warm water with a three-quarters of a knot current. As the telemetry recorded back through the 60 ft deep water, Glen Egstrom, with whom I was preparing the preliminary data, remarked that the diver probably hadn’t been in the water for a while. On checking with the Director, we found that the diver had not been in the water for about six months. What gave Glen this suggestion was that we were peaking 184 beats at one point where he was working the old Mark V on the pipe puzzle. The normal moderate workload would probably be about 140, and the marked increase in heartbeat suggested that the diver was not in good physical condition, had not been in the water for a while, and was not functioning effectively.

If we study this aspect of stress, knowing that it is normal both to professional and sports divers, we would assume that training is reflected in competence. Competence is also a reflection of physical condition, and if you have a diver who is what we call in the United States, FOB (fat, old and balding) he should not be in the water, or at least the dive instructor should be aware that there are going to be problems.

We feel that swimming pool training is not sufficient for ocean divers and that specialities such as cave diving also require further training. There is a need for intermediate kinds of training in between pools and oceans - perhaps in controlled coves or quarries, or some area where an individual can get into more open water than the controlled, safe aspects of the swimming pool.

How automatically one performs a task is very relevant to the experience of apprehension and panic. It is important that a task be learnt to the point where a diver no longer has to give it much thought, so that he is relaxed and not continually concentrating on moving the equipment, or himself, through the water.

There is an important aspect of training which I think relates very definitely to the psychological problems that we meet in sports divers, and that is the aspect of condition. Any individual who thinks that he is going to compete by saying that he has gone further on less air than another diver, is a dangerous diver; he should be competing with himself in terms of his own skills and abilities, and not in terms of depth and air consumption. With regard to this aspect of competition, one should be aware and cognizant of the fact that one of the main motivators of human nature and behaviour is the fear of looking foolish, and it is important that dive instructors stop individuals from taking chances, or from getting into situations in which they may get into trouble because they don’t dare not to go.

We have talked about transportation - the means of getting down to the particular brand of diving in which we are interested, the equipment, and certainly the social aspects of diving, all of which are important aspects of training and the enjoyment of the task. Finally, let me turn to the task itself, which is one of the problems in sports training that has still not been resolved. We have trained people to use equipment to get down to depths, but we have never trained them really systematically to do anything.

To help control apprehension and panic a diver should have a function, whether it be underwater archaeology, shell collecting, observation, photography or ,whatever, so that he is not just down there listening nervously to the harmonics of his regulator, but rather, absorbed in taking photos or in doing something purposeful.

Herb Prosser believes that hyperventilating is one of the least recognised but most important causes of drowning. Certainly, the diver who is clawing the water and trying to get fresh air instead of tank air may hyperventilate, which causes all sorts of physiological changes including, possibly, passing out within very short period of time.

We also feel that there is some evidence that hyperventilation and hypoglycaemia have similar types of physiological effects and it may well be that some dietary aspects of hyperventilation and control may be important, so that beer may not be the best thing to have just before a dive.

Let me turn to one other aspect of what happens when an individual gets into a panic situation. Under stress, an individual's narrowing of perception is quite marked, he begins to focus in an almost tunnel fashion, losing peripheral vision to a very marked extent. Not only is the vision narrowed but his problem-solving capabilities are also narrowed. Picture a diver whose reserve valve had been accidentally pushed down while he was working among rocks: he may start to breathe a last hard breath and put his thumb on the handle of the pull release. Nothing happens because his reserve is already pulled: a non-coping response occurs - he keeps pulling, with no results, and begins to panic. Once you have this stereo-typed response, any problem-solving becomes almost impossible. There was a case in Tucson, Arizona some years ago of a woman diver who was drowned in 12 ft of water in a lake on a golf course. When she was pulled out she not only had on her weight-belt, she was clutching a bag of golf balls. This is non problem-solving behaviour and very hazardous, but it happens, and this is one of the things we are puzzled by in psychology.

We know a good deal about experienced and inexperienced stress responses. Some years ago a couple of psychologists did some work on sky divers and found that the experienced sky divers were frequently apprehensive about going out and doing a jump. The interesting thing about their research was that the apprehension occurred usually on the morning of the jump and if they felt sufficiently apprehensive they would call and cancel, whereas the novice would peak their anxiety just before the ride to the jump site. So, there was a temporal difference in the apprehension of the two types of divers. Again, there may be some factor about looking foolish and not wanting to cancel. I have a feeling that there may be this parallel between sky and scuba divers: the gallows humour that you see on the way to a dive site may well be the kind of apprehension release that the novice divers require. Probably, the experienced scuba diver who didn't feel too comfortable about going out, doesn't go whereas the novice diver tries to overcome it and peaks his anxiety just before he is about to dive. These are things that a dive instructor should be aware of and do something to control: to cure the need for foolhardy face-saving and to be thankful for sinuses and colds, because they always provide an excuse for getting out of a dive.

Finally, I would like to mention what I think is going to happen with regard to sports diving in the future, and I'm going to say a couple of things which I am sure are controversial. I know that there is an argument about controlled emergency ascent or free ascent: many of us believe that there is a very critical need for training in these areas, and the US Navy and the Royal Navy are not very positive about this. However, for many of us interested in sports training, the controlled emergency ascent is a very important potential lifesaver.

Secondly, I foresee that there will be less and less training in sharing (buddy breathing) and more and more development of equipment similar to, but more efficient than, the octopus rig. Buddy breathing not only causes concern about the buddy who is running out of breath and the return of one's regulator, but is also an inefficient method with which to handle this emergency situation.

Diving is a fine sport. With proper physical conditioning, equipment and training the individual can expect much excitement and pleasure in diving - but let's be certain the excitement is of the positive kind.

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Brief Profile

Dr Arthur J Bachrach is the Director of the Behavioural Sciences Department of the Naval Medical Research Institute, Bethesda, Maryland.

His diving research activities are largely concerned with deep dives and have been centred around experimental methods of assessing behavioural and physiological changes in divers.

He has been involved in research on the 1000 ft Westinghouse chamber dive in 1971 and, as Visiting Investigator at the Institute of Environmental Medicine, a 1200 ft chamber dive after that. In 1973, he collected tremor data on the Navy/Taylor 1600 ft chamber dive.

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NOTES TO CONTRIBUTORS (BUT NOT OURS!)

The Editor of the Federation of Australian Anarchists' "Bulletin" has advised pressure groups seeking space in his publication in the following words:-

> "Comrades - only articles which provide interest for the people who type out these articles will be typed on stencils. If you think your articles are boring and egotripping then would you type them on stencils and then forward them to the city that is currently publishing the bulletin."

This information was noted in The Australian, 20th May 1975. Neither the Editor of The Australian nor of this Newsletter are making any comments.

DIVER NARCOSIS, FROM MAN TO CELL MEMBRANE

Prof. W Paton

(Oceans 2000, 1973)

I think there are nine hurdles in the divers' Grand National and, of these, there are two that may or may not prove to be insurmountable obstacles, anaesthesia by inert gases and the effects of pressure per se.

Firstly, to bring out two points about anaesthesia:

Some time ago we at the Medical Research Council did some work on carbon dioxide intoxication: three colleagues and I breathed carbon dioxide at 20 per cent, 15 per cent, 12 1/2 per cent and 10 per cent in oxygen, meanwhile signing our names continuously. Delicate changes in our hand-writing became apparent almost immediately, and finally we reached a stage of total illegibility - at which point we were in fact unconscious, failing to respond to commands, and amnesic.

What I want to point out here is that even though we were unconscious, we were still trying to do the tasks allotted to us, still trying to write. So a person can be quite fundamentally affected and yet still persist in his previous behaviour.

The second point is that even when completely unconscious in these conditions, we were far from being at a state of surgical anaesthesia. There is a great difference between the quantities of narcotic of these anaesthetic drugs that will affect a man's operational efficiency - his judgement, resourcefulness or ability to adhere to a programme - and the amounts necessary to attain surgical anaesthesia.

The reason that most of us believe that anaesthesia is effected by molecules getting into the fatty part of the body is that if you measure the tendency of gases to go into fat, and correlate this with the potency of the gases, you get an extraordinary correlation which deviates from the expected by, perhaps, about 20 per cent, and I think one should rely on this to show that it is a fatty, as opposed to watery, part of the body that is really involved at the molecular level.

Comparison of Rank Order of Inert Gases Low

	Low				**High**
Decompression sickness (1/Poo for mice)	He	N_2	Ar	SF_6	N_20
Water solubility	SF_6	He	N_2	Ar	N_20
Fat solubility	He	N_2	Ar	SF_6	N_20
Total body solubility	He	N_2	Ar	SF_6	N_20

Poo is the maximum pressure from which a rapid decompression to atmospheric pressure is possible without hazard after long exposure.

Comparison of the liability of various gases to produce decompression sickness with their water and fat-solubility, showing the best correlation with fat solubility (or total body solubility, to which fat solubility makes the major contribution with most gases).

The next question is, of course, what do we mean by a fatty part of the body? Membranes are an important class of fatty material. All our cells have a limiting membrane which is a sheet of fatty molecules with a water-attractive head, and pairs of peripheral tails that dip down like double leaflets. One can envisage the anaesthetic molecule - whether it is chloroform, xenon or nitrogen - getting among these leaflets and disorganising them.

There is another sort of potential hydrophobic or fattiness and that is the lumps - macromolecules - in the membranes, which transport glucose, carry ions and mediate the responses to drugs. Crystallographers have found that these big protein molecules (macromolecules) can coil in a variety of ways so that the water-attractive areas of the molecule and the hydrophobic or fatty components may localise in regions. If this occurs, there is a sort of binding force between the similar fatty materials and it has been suggested that the fatty region may even hold the molecule in position in the membrane. Now, if one inserted an intrusive molecule which has an affinity for fat, it might disorganise the binding which holds the macromolecules.

The next step in our researches both supported this theory and brought us into the field of very high pressures. In our work at Oxford with Brian Smith, Ray Smith and Keith Miller we queried as to whether helium or neon could anaesthetise if pressure were increased sufficiently, and we wanted to be able to compare the effects of pressure applied through a gas (which would dissolve in the body), with pressure applied hydrostatically.

For our experiments we chose the Crested Italian Newt, which is amphibious. The newt, like us, if turned on its back, tends to right itself and if the animal is completely normal it has a hundred per cent response to this rolling reflex.

At pressures of up to 120 - 150 atmospheres, the newt only just began to be affected by neon. A similar experiment with helium produced roughly the same results with the newt 50% affected at about 150 atmospheres. This might have been “anaesthesia”.

Next, we exposed the same animal to water - in which there are no strange gas molecules. This time the newt responded fully at 100 atmospheres pressure but again began to be affected at 120 atmospheres upwards. We concluded, therefore, that if helium and neon are anaesthetics one cannot prove this because the pressure takes effect first.

Then we came to an interesting question: suppose one combined high pressure and anaesthesia, would they add or even mutually potentiate, or mutually antagonise? We began by exposing the newt to about 30 atmospheres of nitrogen; this virtually blotted out its ability to right itself. Then the pressure was further raised using helium, regarding this as equivalent to hydrostatic pressure; the animal presently recovered as the pressure was increased until it practically got back to normal. However, eventually the pressure effect re-established itself and the newt was roughly fifty per cent paralysed, but not as originally, at approximately 150 atmospheres, but at about 250 atmospheres. It looked as though pressure could antagonise anaesthesia, which would support the general theory of the molecule getting into the fatty material, thus impairing its function.

It is known that when anaesthetic dissolves, membranes expand very slightly; at a surgically anaesthetic concentration they expand by about 0.5 per cent. If one estimates thermodynamically how much pressure is needed to neutralise this expansion, one finds that it agrees closely with the pressure we needed to antagonise anaesthesia. Thus, it looks as though expansion is linked to anaesthesia, and if you can prevent the expansion (by pressure) you prevent anaesthesia.

One might think the pressure simply drove the nitrogen molecules out of the membrane; but analysis shows that this effect (which can be calculated) cannot account for it. Instead it appears that in general the entry of inert molecules into the membrane expands it, that anaesthesia occurs when this expansion reaches a certain critical level (estimated as around 0.5%), no doubt because of some disorganization of the structure, and that reversing this expansion by sheer hydrostatic pressure reverses the anaesthesia.

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Brief Profile

Professor William DM Paton has been Professor of Pharmacology, University of Oxford since 1959.

After qualifying in medicine in 1942, and undertaking progressively more important radical jobs, his scientific research work began in 1944 when he joined Sir Lindor Brown's team on diving and submarine physiology at the National Institute of Medical Research.

Although later attracted into pharmacology, and distinguishing himself in that field, he has remained associated with high pressure work since then.

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PHYSICAL FITNESS EXERCISES

Proposed new unit of measurement:

There are unconfirmed reports that the SUM are shortly to issue details of new Fitness Standards based on the 50 yards sprint measurement unit proposed by the Victorian Minister for Youth, Sport and Recreation, Mr Brian Dixon. He had noted the general lack of interest by the public in improving their health through jogging or cycling, even by the use of stationary cycles. It is his hope that people will be induced to undertake indoor athletics on a regular basis. That the RAN should be in the van of this experiment is only natural.

A $30,000 study has revealed that people can be considered in regard to their attitude to this matter to fall into five groups. Group 1 "the drifters", comprises the 59% who prefer food and listening to records to making the effort. Group 2, about 19%, feel inadequate regarding their athletic performances following failures during their school life. Group 3 was called "the self improvers" and was the 11% who thought their athletic activities were worthwhile as a way of looking good. The fourth Group, about 6%, gave an impression of great activity but talked rather more than they performed. Only 5% were in the "super-tuned young lions" category who are really active and get on with it, finding the inactivity of others surprising.

Mr Dixon, who is a regular morning runner and father of four children, admits to being in the "super-tuned" group. He says that his Department must now take a new approach to physical fitness. "We need to emphasise activity as fun, and just incidentally as useful", he said, adding that he believed that sexual intercourse as physical activity had the fitness value of a 50 yard sprint. "If you are a bedroom athlete there is no reason why your recreational activities can't be enjoyed", he said.

Promulgation of the new tests is eagerly awaited.

DIVING BLIND
Robert R Given, PhD

First of all, let me tell you that I am not professionally orientated toward working with the blind or handicapped, although I do find it most interesting and rewarding. I am a marine Biologist, and in that capacity was asked some years ago to lead a group of children through an “intertidal experience”. Now leading 50 children (ages 6-15) over wet rocks and trying to tell them something at the same time is challenge enough, but when they are in various stages of blindness, muteness and deafness, in addition to severe mental problems, I nearly gave up. Fortunately, there were many counsellors to keep them going and from hurting themselves, so I could concentrate on trying to show them something. My first impression was one of extreme disappointment, because they seemed to be paying absolutely no attention, and I thought I was getting nowhere. Then one of the student counsellors took me aside and explained to me just how these kids do respond, what to look for, how to get and capture their attention, even for a fleeting moment, and in essence to just “hang loose” and do what comes naturally. After that, it went beautifully - the kids would bring me things - anything - and we would talk about it until they lost interest, then go to something entirely different. I learned to live for that moment, and not to fret because they were not listening enraptured and taking copious notes, as I expect my university students to do. Later in talking again to the counsellors, they said that some of the kids had responded that had not shown any emotion in months. It was all in knowing what to look for in them, rather than in thinking of my own ego and how I thought they should react. The other thing that impressed me was how the kids look after each other, and even acted as “translators” for me to some child that was most interested in a crab or piece of seaweed but just couldn’t understand what I was trying to show him. They seem very concerned about each other, and are always looking around to see that a friend is alright, or that they all saw the animal or plant being shown at the moment.

My experience with the blind has also been quite a learning experience for me. We have a very active Lions International Club here on Catalina, and as you know, Lions are sight-oriented. Several years ago, in co-operation with some local yachtsmen and the southern California blind organizations, a group of about 15 (10-20 years old) came to Catalina for a weekend. They rode horseback, milked a cow, and did some nature study. Then they visited our Marine Laboratory, where we had some seawater tanks set up with plants and animals that they could “see” (feel), guided on a one-to-one basis by our own sighted Students. They “looked” through microscopes, “saw” things in the tanks, asked about colors, shapes, “does it bite”, etc.

As a result of the success of that, we decided to try something different last year. We heard that the local Braille Institute was teaching some of the blind kids to swim and snorkel dive. Their youth director and I worked out the idea of a “Braille Trail”, so they could dive down and “see” the animals and plants, using their newly-acquired snorkelling skills. We particularly wanted them to lose any fear of the water, and of kelp or other things brushing against them underwater, so we decided to keep it shallow, even within “standing-up” depth, at least at first. Now this is all trial-and-error, remember, and I will point out our pitfalls and modifications as I continue my tale.

As a general plan, we decided to establish a series of 9 or 10 “stations” in the shallow water, over a rocky bottom in a sparse kelp bed. The stations were to be buoyed lines attached to the bottom, and connected to each other with a floating polypropylene line. The divers could move from one to the next, along the lateral line, then dive down the buoyed line to the bottom and feel the animal or plant there.

Each station was composed of a rubber tyre inner tube, on the top of which had been lashed a 3 foot diameter plywood disk, to form a sort of raft. On this disk was taped a legend about the animal or plant to be “seen” there. One legend was done in braille, on waterproof paper, the other on the same paper in large type, for the partially sighted. The idea was that they would move along the line to each station, reach up and read or feel the legend, then dive down to the bottom of the line where the animal or plant would be waiting to be “seen”. The setting up of the trail went well, and we had a long string laid out, with stations about 30 feet apart, in a line parallel to shore in about 5 or 6 feet of water. Then we sent a blind diver out - a sharp kid, about 12 years old - as a scout to run the trail and see what it was like. His comments were as follows:

1. Depth - fine.

2. Systems of lines and floats - good.

3. Braille legend could not be read-water was too cold (70°F) and fingertips got numb and insensitive (mistake #1).

4. Organisms supposed to be at bottom of line had moved away (mistake #2).

Another comment, which shows the sense of humor these people can have about their handicap - “water was murky and I couldn’t see a thing!!” So, even with those comments, we sent the group of about 20 divers through anyhow (they had had about an hour in the laboratory, feeling and “seeing” the animals and plants in the aquaria, and being told what to look for). They had a great time, but all had about the same comments - could not read the braille, and the animals had moved away from the station. Se we said, okay, why not help us figure out a way to do it so it works better. They really liked this, and after much messing around and conversation, we finally ended up with this. String a surface line out between two points - can be as long as you want. Have “rest” floats along the way. Blind students pair up with one of our sighted students, and they snorkel along the line together. When the sighted student sees something underwater, they dive down together, and the sighted student “shows” it (puts hand on it, or picks it up and hands it to) to the blind student. This put a very personal touch to it, and greatly simplified the logistics of fooling with the wooden disks, etc. This thing can be set up essentially anywhere, and any sighted person can be trained in a very short time to recognize the organisms. The pretraining in the laboratory is important.

This summer we plan to add another wrinkle — a couple of inflatable children’s wading pools, filled with seawater and stocked with plants and animals, so the blind kids can sit around the edges and reach their hands and pick up the animals, turn them over, etc. Then, if they want to, they can go out on the “trail” and do it in real life. Again, Lions will be helping out, as will some of our local town kids and students from the Laboratory.

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<u>Brief Profile</u>

Robert Given is Assistant Director of the USC Marine Laboratory at Avalon, California. This article is taken from a letter describing his interest in blind children. A most remarkable achievement by both the sighted and handicapped participants is modestly revealed.

IDLE THOUGHTS - NEVER TRUST A BUBBLE!

Oh for the days of Innocence when all was crystal clear and a quick sideways glance at an open soda water bottle was a full and adequate refresher course on the cause and treatment of Decompression Sickness (DS). The man who first said that a little learning was a dangerous thing should have thought out the consequences of trying to find out more once one has discovered the Good, the True, the Pure Faith. Perhaps one should never seek too eagerly for those extra facts once one "knows", for no Scientific theory is entirely complete and nowhere is this more apparent than in medical matters. The risks implicit in seeking knowledge have been known since the time of Adam, who lost his sinecure through being curious. And now the Pundits of Hyperbaria have cast aspersions on the parentage of DS. Is nothing to be sacred: Should any Gentle Reader, a relic of the simpler days of diving, choose to avoid the pain of meeting heresies striving to become orthodoxies, such scruples can be met by reading no further.

The change in thought owes its origin to many factors. First there is the inescapable and undesirable fact of life that the most faithful and devoted servant of The Tables may suffer a rogue case of DS while many who carelessly flout orthodox advice appear (unjustly!) to suffer no immediate retribution. Salt is rubbed into this sore point when it is additionally noted that their continued diving to the same pattern increases their resistance to suffering acute DS symptoms, though should they take a few days absence from diving their resistance becomes like that of ordinary humanity. That they are probably quietly acquiring bone damage is of little comfort, for even the virtuous can suffer from such damage, though hopefully to a greatly reduced severity. Then there is the observation from olden times that on occasion even spinal bends could resolve without recompression, such treatment being unavailable to sponge divers and the early caisson workers. Hyperbaric Oxygen is helpful at pressures found ineffective if air is used for breathing, so simple reduction of bubble size cannot alone be invoked as sole treatment mode. The failure of immediate recompression to guarantee primary total cure of DS is similarly suggestive of factors operative that transcend the purely physical space-occupying effect of bubbles. And there is that great Mystery that all true believers in The Bubble must accept unquestioningly, the Supersaturation of Blood by Nitrogen that defies the turbulence of a fluid (blood) containing many cells likely to disturb any equilibrium.

The incrimination of bubbles with decompression was first noted by Robert Boyle in 1670, nearly two centuries before the first recorded case of any decompression affliction in man. Philp has noted the evolution of thought in the matter of DS from that time. Starting from a belief in the mechanical effects of bubble size there followed consideration of a bubble-blood interaction causing red cells sludging in the fine blood vessels and the formation of emboli and petechial infarcts. End proposed that such emboli were the primary factor in DS. In 1942 the aggregation of platelets around gas bubbles in experimental animals was noted and suggested as a more likely cause of local occlusion in regions of sluggish circulation in small vessels, either with or without the addition of fibrin. However, a further 20 years or so elapsed before this idea was really considered.

Work on rats and other animals subjected to severe DS has demonstrated the beneficial effect of intravenous Heparin. This has been linked with its lipaemia clearing effect because other surfactant agents are also effective while anticoagulants are not. The circulating platelet count falls after decompression and exercise at altitude especially in test rats fed on a high-fat diet. For this reason it has been suggested that intravascular bubbles might trigger platelet aggregation and the coalescence of plasma lipids, contributing to obstruction of the blood vessels and leading to the haemo-concentration noted in experimental animals. Platelet aggregates and microthrombi in the lung vasculature have been demonstrated in dogs after decompression. The slow intravenous infusion of air into anaesthetised rabbits caused a progressive fall in circulating platelets which was rewarded by simultaneous intravenous low molecular weight dextran, a substance known to inhibit platelet and red-cell adhesion. Disseminated Intravascular Coagulation (DIC) has been suggested as a complication of bubble induced changes in the blood. Examination of divers has confirmed the fall in platelets and the occurrence of haemoconcentration even in the absence of DS after a 300 ft dive with the ascent controlled by the Pneumatic Analogue Computer. It has been shown by several workers that the platelet count falls for a days after a very safe dive to 100 ft, this dive profile having been used without the occurrence of bends on 100 open sea dives, being a 1 hour dive and stage-compression over 122 minutes. In one case there was no post dive platelet reduction, this man showing a lack of the platelet release reaction, ie. the ability of platelets to release their granular constituents in response to aggregation agents such as Adenosine Diphosphate was deficient. This abnormality may be associated with a mild bleeding disorder and is similar to changes induced by ingestion of aspirin.

An unexpected problem facing researchers using animals arises from their inexpertise in the field of veterinary science, coupled apparently with a lack of qualified advice when needed. Martin tells of one occasion when he had to rely on “consensus opinion” to evaluate the effectiveness of treatment. This was the case of a goat used for a 1,000 ft simulated dive which was noted three days later to be suffering from probable spinal bends. As the alternatives were to “put down” the victim or try some treatment, he thought to try the effect of intravenous Heparin about which he had recently been reading. The clinical response was gratifying, the goat recovering the ability to walk. The reality of the improvement was confirmed by the acceptance of the victim by the other goats, who would have molested a sick animal. It may be a little less than reassuring that some small part of the evidence in favour of the use of Heparin in DS is based on the no-butt of a herd of goats!

The influence of Carbon Dioxide on the occurrence of DS was noticed at least as early as 1887 in Caisson workers, being confirmed by later workers. This is another fact implicating biological factors in addition to purely physical factors in the consideration of the behaviour of inert gas bubbles in body fluids. Carbon dioxide is known to increase the incidence and severity of agglutination, while an increase in Oxygen will decrease or reverse the process. Such observations are consistent with platelet function being of practical significance in DS and are in line with the experience of divers.

Hallenbeck has detailed the progression of studies concerning the causes of the observed clinical picture of DS. These now centre on the changes that result from the denaturation of globular protein molecules exposed to any gas-liquid interface, the bubble-blood interface being an important instance of such circumstances. The underlying derangement in DS is still thought to be the nucleation of bubbles, this having two major categories of effect. Firstly, there is the mechanical effect of bubbles in the blood vessels, the long accepted cause which is the rationale for recompression therapy, and secondly, such bubbles may trigger pathologic reactions indirectly through interfacial effects. The interface has a 40 - 199A layer of electromagnetic forces that tend to orient exposed globular proteins so that their hydrophilic groups are in blood while their nonpolar groups protrude into the gaseous phase. This molecular reorientation disrupts the native secondary and tertiary configurations of globular plasma proteins. As biological specificity of function is related to structure, a functional alteration will result. This can generate a far reaching sequence of patho-physiologic events that may play a major role in the production of clinical DS. Both increased and decreased enzyme activity can result from the interfacial exposure of globular protein. A process causing extensive and indiscriminate enzyme alteration would be very disruptive to enzyme systems that normally exist in a state of dynamic equilibrium. Kinin, complement, coagulation and fibrolytic systems would theoretically be vulnerable and their haphazard disruption could be a factor in the individual and temporal variability of response to a single dive profile that is so characteristic of decompression sickness.

The occurrence of spinal symptoms in DS points to venous rather than arterial factors, as arterial bubble emboli would preferentially reach the Brain. The exact site of bubble formation remains uncertain but Guyton’s work suggests that interstitial fluid pressure and intralymphatic pressure average 7 mm Hg below ambient pressure when measured at one atmosphere, so there is reason to suppose that bubbles might nucleate in such areas at an early stage. Arturson has observed intralymphatic bubbles during decompression in dogs. Inert gas tensions in capillary and venular blood are high post-dive relative to arterial blood and flow in them is intermittent: doppler studies suggest that venous bubbles occur prior to arterial bubbles. Once formed they will begin to exert the above noted effects. Some authorities believe that practically any decompression from a depth greater than 30 ft is going to involve bubble formation whether or not there are symptoms.

The lung has a very central role in DS, one important feature being its activity as what could be termed a metabolic organ. Serotonin, histamine and prostaglandins are inactivated as well as released by lung tissue (autologous clot emboli in dogs caused serotonin release and consequent intrapulmonary vasoconstriction). The consequences of a lung dose rate of bubbles and products of bubble surface activity that exceeds the lung’s capacity for bubble elimination and metabolic degradation of injurious substances are several. The cumulative effect on pulmonary vessels of arriving bubbles, altered blood proteins (including fibrin clots), cellular aggregates, vasoactive substances and fat emboli is at least two fold, having mechanical and reactive elements. The reactive increase in pulmonary vascular resistance is due to vasoconstriction mediated by the locally released and blood-borne vasoactive substances and perhaps also by vascular reflexes. Smooth muscle active agents that provoke bronchospasm also cause an indirect reactive increase in pulmonary vascular resistance by decreasing transmural capillary pressure. Several studies bear on such changes. Histamine causes bronchospasm, decreased transmural capillary pressure, increased airways pressure and consequent increased pulmonary vascular resistance in an isolated lung preparation experiment. Lysozome release from leucocytes may well contribute to pulmonary endothelial damage and interstitial oedema, as in “shocklung” .

Rheologic disturbances result from bubble surface activity. Fat embolism can cause mechanical obstruction of blood flow and has been noted in DS by several observers. Bubbles can not only accelerate clotting by platelet aggregation but also can accelerate it in the absence of platelets by the activation of a plasma factor, presumably Hageman. Experiments at sea level have shown in-vitro that lipids can be released from proteins and provoke a syndrome overlapping clinical disseminated intravascular coagulation (DIC). When plasma proteins were deprived of their lipid content, platelet and red cell aggregation and “gastrauma” induced reactions were eliminated. Further, the nitrogen uptake of blood samples from identical subjects when compared in a gaseous environment and invitro at identical hyperbaric air exposures showed uptake to be 1.6 times greater after a fatty meal than at basal conditions. After a standard compression-decompression manoeuvre at 4 - 100A the infusion of lipidic substances resulted in a linear relationship between the amount of lipids infused and gas desaturation. At sea level experimental fat emboli compromise the microcirculation of the lung. Fat emboli are now thought to originate from locally produced triglycerides and not from bone marrow cells, their formation being influenced by enzyme activity, colloid defects, osmotic pressure and an increase in lymph production and flow. Platelet aggregation is favoured by the appearance of plasma low-density lipoproteins, these inducing changes in platelet electro-phoretic mobility.

A new element in the discussion is the possibility of air microemboli from the lungs, the mechanism by which local minimal pulmonary overpressure (‘microlung’) occurs being as described in the last issue by Prof. Walder. Such small bubbles may have a “seeding” effect, for though they are too small to cause arterial obstructive symptom when first formed they are capable of growth after passage through tissues containing increased tensions of dissolved gas, thereafter behaving in the same way as bubbles arising from decompression of the tissues themselves. It has been suggested that some cases of submarine “escape lung” accidents with symptoms similar to DS occurring within one to several minutes after surfacing are of such astiology. When intrapulmonary pressure increases to 80 mm Hg and drops suddenly 10 seconds later, bubbles appear in the vascular system of experimental animals. The passage of air through intact lung walls has been observed in experimental animals since 1883. The conscious man can safely raise his intrapulmonary pressure to 300 mm Hg because of the support from the thoracic cage, but any areas of air trapping give rise to pressure inequalities. Indeed it is entirely possible that small numbers of arterial gas emboli occur during the normal and apparently safe decompression of a diver who has been exhaling normally on ascent.

It has been noticed that any diver who does not feel like a hearty meal on completion of a strenuous dive is a likely candidate for DS within the hour. Disproportionate fatigue is a symptom often preceding more severe ones. It may be significant that both anorexia and fatigue are symptoms noted by physicians in association with disorders of the pulmonary circulation.

In that severe pulmonary manifestation of DS, ‘the chokes’, inhalation may be limited by a sharp “catch”. Sometimes it is first noticed when the diver lights up a cigarette and attempts to inhale, a test long used by Greek sponge divers after surfacing. Substernal distress, debilitating malaise, bronchospasm and pallor, apprehension and sweating may all occur. Usually in divers it follows fairly soon after rapid decompression from a relatively deep dive but delays of several hours are not uncommon, particularly if limb bend pains have been left untreated. While most believe that these symptoms result from pulmonary bubble embolism there is also the possibility of surface absorption effect on the bronchial tree (of skin bends), the burning sensations being the result of direct mucosal damage.

In conclusion one can hardly better summarise present views than to reproduce verbatim part of the article by Ricci and Massa: ‘It is our belief that the pathophysiology of some cases of DS rests with a combination of factors, namely haemodynamic and humoral changes, pulmonary stasis or hypertension and the impact of CSF pressure and circulation upon the venous return in the vertebral canal surrounding the spinal cord. We do not unequivocally support the theory claiming growth and fusion of bubbles locally or through an embolization via the arterial system. We maintain that there is overlap between some cases of pulmonary stasis, congestion and hypertension (chokes) with spinal paralysis and shock. The possibility of minute alveolar ruptures in pulmonary overpressure and the establishment of a “microlung” after moderate overinflation were described long ago and also recently with the classical symptoms of “traumatic air embolism”. Even when spinal cord impairment is acute and severe, we cannot deny an asymptomatic pulmonary etiology and primitive arterial embolization, via spinal cord afferents, cannot be excluded”.

It is but an idle thought, but it seems to be a lucky break for divers that recompression therapy was discovered empirically before the full complexity of the problem in DS were suspected!

This report was based on the Proceedings of a Symposium on Blood Bubble Interaction in Decompression Sickness (December 1973) (DCIEM 73-CP-960)

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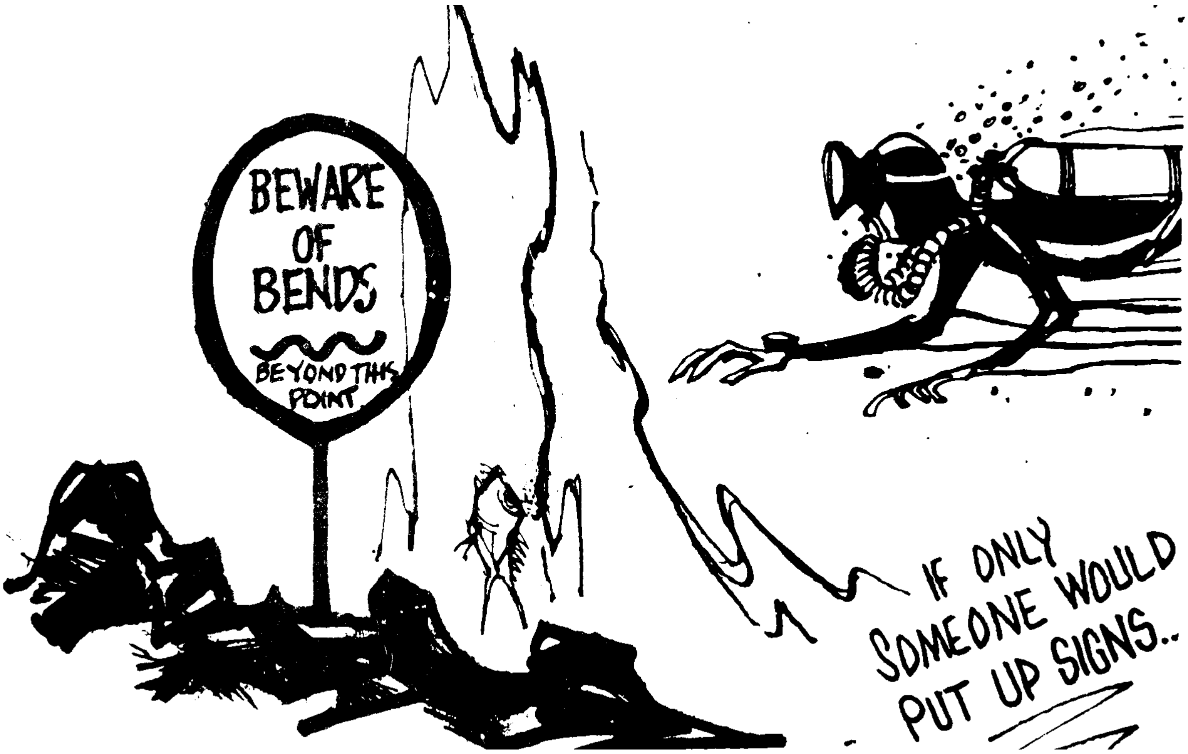
AIR FOR SOLO DIVER

The intrepid divers who went seeking the Loch Ness Monster tried to be prepared against every eventuality, even the rather unlikely one of actually finding their quarry. Although the search was cluttered with sophisticated electronic equipment there were still some nice human touches. Divers involved were issued with tiny harmonicas that would fit into their breathing tubes (sic), so that if the monster suddenly appeared and was unfriendly they could sooth it with an instant imitation of Larry Adler.

(*The Australian*, 16 November 1970)



Notice of Proposed SPUMS Meeting in Melbourne

Members are advised that plans are being considered regarding the holding of a meeting following the AGM of the Australian Society of Anaesthetists in Melbourne. The date would be 31st October, 1975 and the Chairman, Dr Phil Rubenstein. Subject to amendment, the program will be as follows:

9.30 - 10.00	Oxygen Toxicity	John Knight
10.10 - 10.35	Hyperbaric Medicine	Gavin Dawson
10.45 - 11.30	Visit Prince Henry's Hyperbaric Chamber	
	Morning Tea	
11.30 - 11.40	Dysbaric Osteonecrosis in Melbourne	Gordon Donnan
11.45 - 12.15	The Oil Rig Diver in Bass Strait	Geoff Macfarlane
12.30 - 1.30	Lunch in Cafeteria	
2.00	Visit to Melbourne Metropolitan Board of Works Recompression facilities at Lower Dandenong Road, Braeside. (Gavin Dawson will review the experience at Prince Henry's Hospital, Melbourne)	

The proposed venue is the Clinical Lecture Theatre at Prince Henry's Hospital.

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1976 UNDERWATER MEDICINE SYMPOSIUM IN NEW ZEALAND

The first International Symposium on underwater medicine in New Zealand is to be held 8-14 February 1976 in Auckland and Tukukaka. It is now in the early stages of planning and will be the Annual Scientific Meeting of SPUMS and run by the New Zealand members. Those wishing to present papers or to obtain further information should write to Dr Noel Roydhouse, Ch.M., 118 Remuera Road, Auckland, 5 New Zealand.

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Copies of the Proceedings of this symposium can be obtained from the BS-AC. Further particulars regarding cost by writing to:-

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REFERENCE BOOKS IN DIVING SUBAQUATIC MEDICINE
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6 Hale Road
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