HISTORY OF DIVING

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* 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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