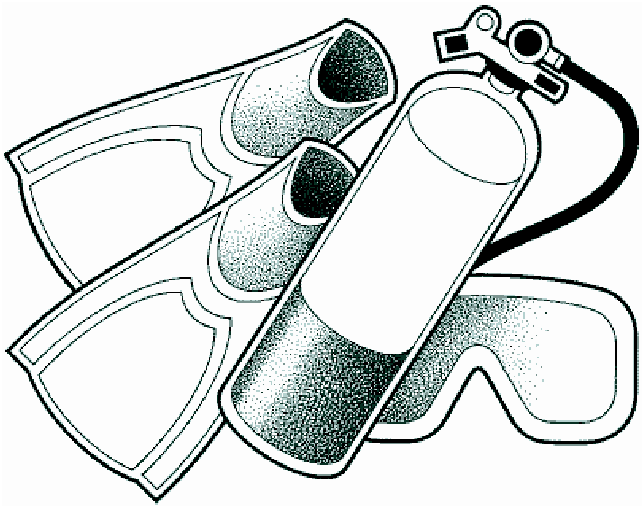
Principles of Scuba Diving



Murray MacCallum
m.maccallum@napier.ac.uk
scotsac.com

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Lecture 1
Basic Equipment, Signals and Surfacing Procedures

1. Basic Equipment

There are several basic pieces of equipment any diver needs. These are -:

- **A mask**
- **A snorkel**
- **A pair of fins** (NOT flippers!)
- **A weight belt**
- **A diving knife**
- **A buoyancy compensating device** (lifejackets and BCDs will be covered in the third lecture)

Masks

A mask is needed to see clearly underwater, and (typically) consists of four main parts.

The Frame
This secures the lens, the body and strap together, and is generally made of a hard wearing plastic

The Strap
This is either a split or single rubber or silicone strap, which holds the mask body against the wearer's face. The length of the strap can be adjusted by buckles and so tension the mask on the face, as required.

The Lens
This must be scratch- and shatter- resistant and is usually made of tempered glass. Avoid plastic, which tends to scratch and fog easily. The lens may be kept clear by application of an anti-fog solution.

The Body
This is usually made from soft rubber or silicone to form a waterproof seal against the diver's face. It encloses the eyes and nose and allows the wearer to pinch his nose in order to clear his ears while submerged. Drain valves may be fitted to aid mask clearing, but are unnecessary and become clogged with sand etc.

Many different types of mask are available. Take advice from an experienced diver or instructor. People who have eyesight problems can have corrective lenses fitted. Contact lens may be worn instead.

Silicone rubber is often used for the body of the mask. This material is non-allergic to body tissue and very long lasting. The translucent type of silicone also

allows light to enter the body of the mask. Silicone rubber also maintains its flexibility over a wide range of temperatures.
Since face shapes differ, a mask should be selected which will seal against the face and yet be comfortable. Test a new mask for correct fit by placing against your face without using the strap and inhaling through your nose. A correctly fitting mask should remain in place until you exhale through your nose. Also press the mask against the bridge of your nose, to ensure it doesn't hurt your nose too much. Look for masks with a good field of vision, both horizontally and vertically.
Generally, masks with a low internal volume are easier to clear and are less prone to mask squeeze.
The mask should be stored in the box provided when not in use.

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Fins

Fins are worn to propel the diver through the water by leg action alone, thereby leaving the hands free.

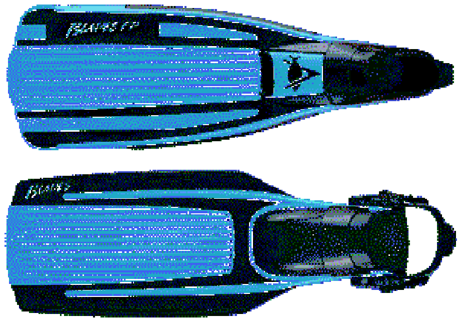
The fin is made of two parts – the shoe and the blade. The shoe needs to be made of soft rubber to ensure maximum comfort and freedom from chafing during prolonged use. The blade should have a graduated stiffness in order to transmit the power of the finning action of the legs and feet.

A harder material is used for the blade section and the stiffening ridges. Various rubber, plastic or fibreglass compounds are used in the blade.

Many designs incorporate slots or apertures in the area in front of the toes to reduce the effort required to move the fin through the water on the recovery stroke.

Since the fin which satisfies all the criteria for swimming in the pool may not be the best fin for use in the open water, and vice versa, many divers keep two pairs of fins – one for the open water and one for pool use.

There are two types of fin, open-ended and shoe-type. The open-ended (or **sea fins**) generally have a larger blade and are designed to fit over boots or booties, for use in the open water (always wear boots when trying



on this type of fin). A large and/or stiff blade will give more propulsion, but will be more tiring to use.

Shoe-type fins (pool and snorkelling/tropical use) are smaller, and are designed with a close fitting rubber shoe, which the foot fits into. Additional security can be obtained by using Y-shaped rubber fin retainers, which fit around the ankle and the fin clad foot.

Snorkels

A snorkel allows the user to breathe while lying on the front with the face in the water. This makes finning on the surface much easier, and also permits the wearer to continually look underwater from the surface.

In its simplest form, a snorkel consists of two parts – the mouthpiece, which is gripped by the teeth and forms a seal with the lips, and a rigid or flexible tube which points upwards over the semi-submerged head. The top of the tube is open and allows the user to breathe without risk of drawing in water.

The most common shapes of snorkels are either L or J shaped. A typical length will be 40-45cm. If the tube is too long, it will take too much effort to clear it, if it is too short, it will allow water in. The bore of the tube will be about 20mm. If it is too wide, too much effort will be needed to clear it. If it is too narrow, it will require too much effort to breathe.

Avoid snorkels that have complicated bends or valves at the open end. Some snorkels (purge-type) have valves at the lower end to aid clearing, which some people find useful.

Most snorkels are supplied with a retaining ring or clip to attach them to the mask strap (on the left side of the mask). Here it will always be ready for use. For normal diving, many divers prefer to have it stowed somewhere – perhaps in their knife strap, knee pad, or in their buoyancy control device – and remove it for use when required.

As with the mask, **the fit** of the snorkel on the wearer **is the most important consideration**.

Weight Belts

A wetsuit or drysuit will increase the diver's buoyancy, making it necessary to be weighted down so that neutral buoyancy can be attained. This is achieved by wearing lead weights around the waist on a suitable weight belt.

A vital part of the belt is the buckle. It must be a quick release type, ensuring that positive buoyancy can quickly be attained by a diver in an emergency situation only, by rapid jettisoning of the weight belt. It also makes the belt easy to remove, before climbing into the boat after a dive.

Many types of quick release buckle exist, so look for one which can be easily opened, even with thick gloves and cold hands, and which contrasts with the colour of the aqualung harness. It should allow the belt to come away quickly and easily without snagging. Avoid belts that are too long or too short.

The most popular types of belt in use are the **solid lead** type and the **shot** belt. The former is composed of lead blocks, threaded through a webbed nylon belt. The latter consists of lead shot contained in a hollow fabric belt, which is more comfortable to use. **The key issue is to never use more weight than you actually need**. A common problem with many divers is that they are over-weighted. Note that the amount of weight required varies with the type of suit used and whether the dive is taking place in fresh or salt water.

Some drysuit divers find the use of ankle weights helpful in maintaining a horizontal position in the water. This helps to prevent inversion and subsequently hazardous feet-first rapid ascent to the surface.
One development in weighting technology is the integration of weights with the BCD jacket. Releasing the weights in this system is by pull toggle.

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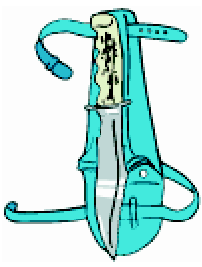
Diving Knifes

A diving knife is a mandatory piece of diving equipment. Its primary function is to enable the diver to cut him/herself (or buddy) free from line, rope or other entanglements. A secondary function is to provide the diver with a basic tool for probing, measuring and hammering.
Traditionally, knives were large and were worn on the calf or thigh, attached by means of a strap. Presently, there is a tendency to use a smaller knife, attached to the upper arm or BCD. The knife must be readily accessible by either hand.
The handle of the knife is normally made of hard or soft plastic or rubber and should be non-slip. It should be large enough to be held comfortably by a gloved hand.
The blade is made from stainless steel, to minimise corrosion. It requires regular sharpening and cleaning. A smear of oil can help prevent the blade rusting. Besides a cutting edge, it is advantageous if the blade has a saw edge and a line cutter as well.
The knife is contained in a plastic or rubber sheath, normally with some locking mechanism, and is attached in the manner(s) described previously. Some dry suits have special ‘knife pockets’ which, allow the implement to be fitted without using straps. Some divers attach a piece of cord between the knife handle and the sheath, to avoid loss. However, there is a tendency for this cord to become snagged during diving, unless care is taken with its design. **Note that is illegal to carry such knives unless on a diving trip.**



2. Underwater Signals

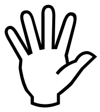
The OK signal

This is the classic diving signal. It is used both to enquire that all is well with the diver's buddy and to respond to the same enquiry about oneself. It is also in conjunction with other diving signals, to indicate that they have been received and understood. Thus, your dive leader will give you the OK signal from time to time to check that everything is well with you. Your response, if OK, would be to give the signal back immediately. If you're not OK, you give the appropriate signal from one of the other groups. If your buddy gives you any other signal you should respond with the OK signal if you agree and/or understand. Thus if your partner gives you the 'I'm out of air' signal, you give the OK signal to indicate that you acknowledge the signal and immediately go to them and administer air by an emergency method.

Normal Diving Signals

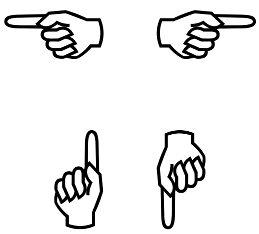
These are the signals which, together with the OK signal, will be given during the duration of a normal dive in which no untoward incidents occur. These are:

Up



Stop

Down



Direction

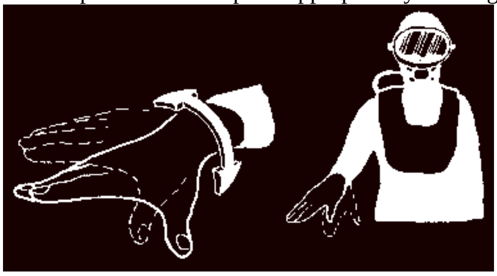
My contents gauge reads 50 bar or less

These, together with the OK signal, should form the some of signals used on a normal dive. The signal in the above set (my contents gauge reads 50 bar less) is the signal to terminate the dive and ascend to the surface.

Adversity signals

These signals are given when something is wrong and the dive partner *must* respond appropriately. The signals are:

I have no air



Something is wrong

I am in distress
(on the surface) (underwater)

I have no more air is given when the air supply fails, for whatever reason, and the buddy must, on seeing it, respond by sharing air or providing the spare mouthpiece of an octopus rig (or other secondary air supply). This is followed by a controlled ascent to the surface.

I'm in distress may be given for a variety of reasons, such as feeling unwell or in a state of panic or being snagged on a rock or wreckage. The signal requires the buddy to give the victim whatever assistance the situation demands.

Something is wrong is a signal used as either a statement or a question to another diver. If it is a statement it is followed by an indication of the source of trouble. If it is used as a question, it will be followed by the 'you' signal to ask whether the buddy is OK.

My air supply is giving me trouble [not shown] (normally indicated by pointing at the demand valve and giving the 'something is wrong' signal) This signal should be given when the air supply is constricted or erratic but while air is still available. It warns that sharing may become necessary (or some other type of emergency air provision employed) and invites the partner to examine his/her buddy's air system for some obvious cause of lack of supply, such as the pillar valve being incompletely turned on. If the problem is not immediately resolved then the dive should be terminated.

Information signals

These signals provide information which may be very valuable but which do not *necessarily* lead to any action by the buddy other than giving an OK signal. The signals are:

Danger

I'm out of breath

You or me?

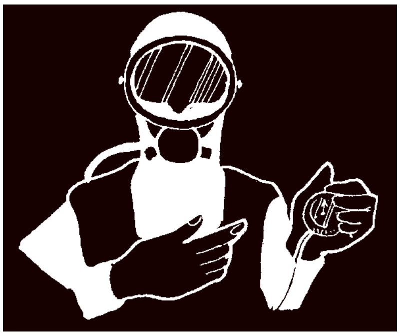
The **Danger** signal will be given whenever something is seen which might endanger you. For instance, sighting a hazardous marine animal or the remains of a fishing net would be a suitable occasion to use it. The signal is normally accompanied by the 'pointing' signal to indicate clearly the source of the danger. The normal response would be simply to keep clear of the problem.

I'm out of breath would normally be given to your buddy to indicate you want to slow down so that you don't become exhausted. Normally he or she will give the OK signal and slow down or stop.

You or me is simply a questioning signal to establish who should do something

Additional Information Signals

These are not official signals but are ones that are very effective so they have become widely used. They are:



Show me your contents gauge

I'm cold

I'm narcosed or giddy

Show me your contents gauge is the signal the dive leader should give from time to time, especially with trainees, to ensure that everyone in the group has enough air.

I'm Cold and **I'm narcosed or giddy** are signals which are used to convey to that the individual is either feeling chilled or that he/she is experiencing the effects of nitrogen narcosis (the 'narks'). The way of dealing with the former problem is to bring the dive to an end, whilst the effects of the second can be alleviated by ascending to a point where the symptoms are found to disappear. Both signals may be used in the 'enquiry' mode as well.

3. Surfacing Procedures

At the end of a dive, the surface should be approached in a smooth and controlled manner, with an arm outstretched above the diver, the hand forming an OK signal. The individual should be looking up towards the surface as the final approach is made, to ensure that there are no boats, windsurfers or other surface hazards in the vicinity. It is also a good idea to listen carefully, for the noise of boat engines, as the ascent is made. A final rotation, just prior to emerging from the water, gives safety coverage through 360^{o}

Lecture 2

Ears, Sinuses and the Effects of Pressure

Pressure

Air pressure is caused by the weight of air molecules in the atmosphere exerting a ‘pressing’ force. It is called **atmospheric pressure** and is measured in **bar**. In space, the absence of air means there is no pressure - thus it is 0 bar. The pressure gets higher and higher on approach of the earth’s surface, such that at sea level the pressure is 1 bar (sometimes called **1 atmosphere or 1 atm**). This is equivalent to 1 kg of force ‘pressing’ down on every square centimetre of surface. This pressure does not cause any discomfort, as it is ‘equalised’ (or the same) in all of the air spaces in a human body.

Entering the sea and going progressively deeper, the pressure is the combination of both the air and the water force, so it increases progressively. At 10 metres depth, the weight of water pressing on a body is equivalent to the pressure of the atmosphere at sea level. In other words, the pressure from 10 metres of water is equivalent to the pressure exerted by the whole atmosphere. Each 10 metres of water results in another bar of pressure.

Altitude or depth	Pressure
Top of atmosphere	0 bar
Sea level	1 bar
10 metres	2 bar
20 metres	3 bar
30 metres	4 bar, etc.

In air and water pressure acts in all directions, i.e. at 30m depth a body surface is subjected to 4 bar of pressure distributed uniformly.

Measuring Pressure

When measuring pressure, instruments are normally related to atmospheric pressure i.e. a simple gauge reads zero when the pressure is 1 bar, due to atmospheric pressure. Thus the pressure gauge on a diving cylinder might read 200 bar, when it is actually 200 bar above atmospheric pressure. This is called **gauge pressure**. The real pressure is 201 bar. This is called the **absolute pressure**. In the table above, absolute pressure is used.

NB: Absolute Pressure = Gauge pressure + Atmospheric pressure.

Partial Pressure – Dalton’s Law

Air is a mixture of gases, containing approximately 80% nitrogen, 20% oxygen (for the purposes of easy calculation). In reality, there are also small amounts of other gases including carbon dioxide etc.

Dalton’s Law of Partial Pressures states: in a container containing a mixture of gases like air, the pressure exerted by one gas in the mixture (partial pressure or pp) is the same pressure as that gas would exert, if it were by itself in the container with the same volume and temperature. For example, since air has 80% nitrogen and 20% oxygen, 80% of the pressure is caused by the nitrogen and 20% by the oxygen. Arithmetically:

Air at 1 bar pressure: Partial pressure of nitrogen = 80% of 1 bar = 0.8 bar
Partial pressure of oxygen = 20% of 1 bar = 0.2 bar.

Pressure and Volume – Boyles Law

Pressure varies inversely with volume, i.e. the greater the pressure, the smaller the volume will be.

Consider a balloon full of air, which has been blown up at sea level. If this balloon was taken on a dive, it will be become smaller with depth, as the pressure acting on the balloon forces the air in the balloon into a smaller volume. (Conversely, if the balloon were taken up through the atmosphere, the pressure acting on it would decrease and the balloon would increase in size as the air within it expanded).
Mathematically:

$$P_1V_1 = P_2V_2$$

P_1 = Initial pressure
V_1 = Initial volume
P_2 = Final pressure
V_2 = Final Volume
(T constant)

Depth	Absolute Pressure	Partial Pressure O_2 (ppO_2)	Partial Pressure N_2 (ppN_2)	Volume
0 metres	1 bar	0.2 bar	O.8 bar	One
10 metres	2 bar	0.4 bar	1.6 bar	Half
20 metres	3 bar	0.6 bar	2.4 bar	Third
30 metres	4 bar	0.8 bar	3.2 bar	Quarter

This relationship between pressure and volume is fundamental to diving and is called **Boyle's Law.** The amount of gas that dissolves in a liquid with which it is in contact is proportional to the partial pressure of that gas. This is known as **Henry's Law.**
If at 30 metres depth a container was filled with air, the air would be compressed by the pressure acting at that depth (i.e. 4 bar). If an ascent was then made through the water to the surface, the pressure would decrease and the air in the container would expand. At 20 metres, it would be under 3 bar of pressure, so would have a third greater volume. At 10 meters it would be under 2 bar of pressure so would have twice the volume, and at the surface it would be under 1 bar of pressure and would have four times the volume. **This is what happens to all air contained within a human body.**

Pressure and Temperature – Gay-Lussac law

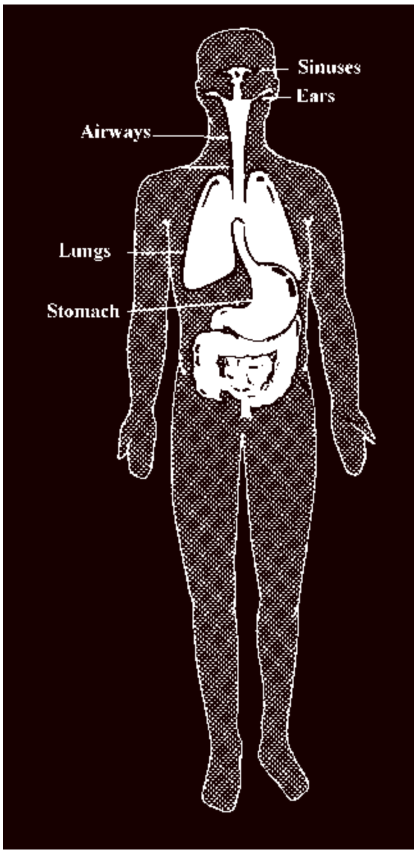
This law states that for any gas at constant volume, the pressure of the gas will vary directly with the absolute temperature i.e.

$$P_1/T_1 = P_2/T_2$$

P_1 = Initial pressure
T_1= Initial temperature
P_2 = Final pressure
T_2= Final temperature
(V constant)

Although the temperature of the sea can be regarded as largely constant, this law has a bearing on the surface where temperature variation occurs much more readily. This has an effect on any pressurised receptacle such as an air cylinder.

Air Spaces in the Human Body



Air is held in the human body in a variety of places. The main locations are: the ears; the sinuses; the respiratory airways; the lungs; the stomach and the gut. The rest of the human body can be assumed to be either liquid or solid and is not affected by pressure to the same degree.

Any compressible airspace in the diver's body will be affected by pressure and will vary in volume, according to Boyle's Law. As a diver descends, the increasing pressure will compress the air spaces in the body into a smaller volume (known as '**squeeze**'). Similarly, on ascent, the reverse occurs and the air spaces will expand as the pressure decreases.

Ears

This is felt particularly in the ears. The ears are very sensitive to pressure and will be affected within about 2 metres of leaving the surface e.g. the effect is noticed diving to the deep end of a swimming pool.

On descent, increasing external water pressure will force the air in the middle ear to compress, pushing the eardrum inwards and causing feelings of discomfort.

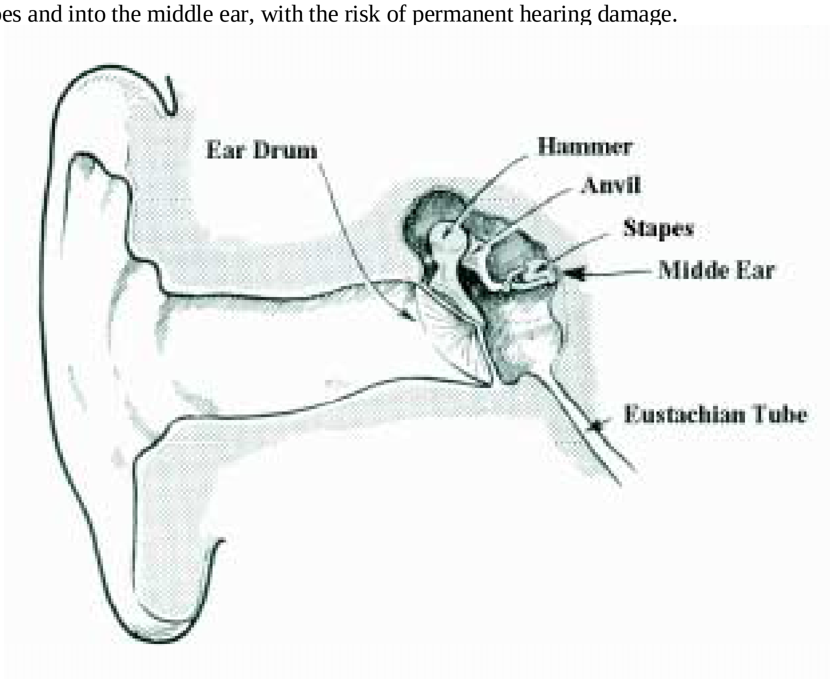
It is essential that the diver takes immediate action to equalise the pressure in the ears, as damage to the eardrum can occur very easily (**Aural Barotrauma**). This is normally achieved by the following method:

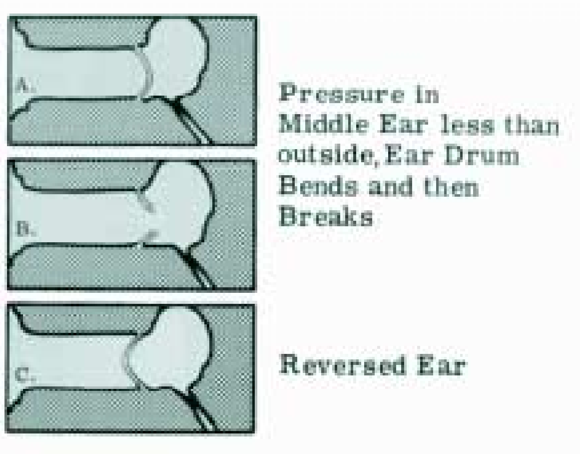
Holding the nose and blowing gently down through it. This is termed the **Valsalva manoeuvre**, or simply '**ear-clearing'**, and can be accomplished by using the nose pocket in the front of the mask. Air is forced into the middle ear through the Eustachian tube, such that the pressure on both sides of the eardrum is the same and the discomfort alleviated. Some individuals can achieve the same effect by swallowing hard, waggling their jaws or lifting the base of the tongue. It is important to remember not to use excessive force when attempting to clear, as it is possible to damage the eardrum by using this technique. **In the event that the ears will not clear**, the diver must first stop descending, ascend a few metres and try again until successful. It is best to descend in a head-up position to facilitate clearing.

During the dive, it can be necessary to equalise the ears regularly. On ascent at the end of the dive, the reverse happens: the air in the middle ear expands, pushing the eardrum outwards. Air should automatically be released through the Eustachian tubes back into the throat to equalise the pressure. Problems can sometimes occur with dive hoods that are very tight-fitting. Ear equalisation difficulties during ascent are, however, uncommon.

Ear-plugs should never be worn, as they effectively cause a pressure drop in the outer ear canal during descent, causing there to be pressure exerted on the drum from the middle ear.

Never dive with a cold or other respiratory infection. This makes the process of equalisation difficult, at best, **or** altogether impossible. Even if pressure damage does not occur, there is a possibility of forcing infection down the Eustachian tubes and into the middle ear, with the risk of permanent hearing damage.





Sinuses

The sinuses are air filled spaces inside the bone of the skull and are connected to the upper nasal passages. They exist to effectively reduce the weight of the skull and to protect against infection. They tend to equalise pressure automatically as long as they are healthy. In the event of a cold or any kind of nasal infection, hay fever or heavy catarrh, the passages connecting the sinuses (and ear) to the throat will be inflamed and may be clogged up or closed by mucus. **IF THIS IS THE CASE, DO NOT DIVE**. It is unlikely that the diver will be able to equalise the sinuses on the way down **or** on the way back up and this will result in painful pressure damage (**sinus barotrauma**). Using decongestant medicines may help an individual make a descent, but the implications of such tablets wearing off, prior to the conclusion of the dive, should be fully considered. Additionally, increased pressure may alter the medication's effects with potentially serious consequences.

Lungs

The air in the lungs will compress on the dive, and so will the total lung volume, on a 'breath-holding' (i.e. snorkel) dive. When breathing compressed air at ambient pressure, the lung volume remains constant, thus each breath taken will contain the same total amount of air as a breath at the surface.

On ascent, the air in the lungs will expand. If the diver has a cold, so will any pockets of air, which may be trapped in the lungs by mucus. Furthermore, if breath is held on ascent, there is a likelihood of pressure damage to the lungs, with potentially fatal consequences. This is **Pulmonary Barotrauma**. It is easy to avoid:

NEVER HOLD YOUR BREATH FOR ANY REASON
NEVER DIVE WITH A COLD
BREATHE NORMALLY AT ALL TIMES

Other Air Spaces

It is possible to have pain caused by air cavities in dental fillings (especially old fillings) This is **Dental Barotrauma**. It is rectified by a visit to the dentist and replacement of the filling(s). Mask squeeze is another potential problem. The air in the mask is a compressible space, and will be reduced in volume on descent. This can lead to discomfort if not equalised by breathing some air from the nose into the mask, on descent or at any time during the dive when the mask feels uncomfortable.

Lecture 3
Aqualung Use, Buoyancy Control & Buoyancy Aids

Buoyancy Control

Buoyancy control is probably the most important diving skill and is employed on every single dive. Successful mastery of this skill will make diving more enjoyable, comfortable and considerably safer. When diving, it is normally desirable to keep buoyancy **neutral**. A diver is **neutrally buoyant** if he or she slowly begins to sink when breathing out and gently ascends when breathing in. Thus, neutral buoyancy underwater is a essentially a state of weightlessness and is akin to flying. Objects which float in water are said to be **positively buoyant** and objects which sink are termed **negatively buoyant**.

A diver's **static** buoyancy is affected to a considerable degree by the equipment worn for diving and by the build and weight of the individual.

Control of **dynamic** buoyancy is achieved in two ways: **coarse buoyancy control** is achieved by the inflation or deflation of the **buoyancy aid** (**Adjustable Buoyancy Life Jacket (ABLJ**), **Buoyancy Control Device) or dry suit**; **fine buoyancy control** is achieved by the diver controlling the amount of air contained in the lungs. A degree of positive buoyancy can also be achieved by finning action: this is the principle of treading water.

Wetsuit or Semi-Drysuit diving

On the surface, wetsuits are very buoyant due to gas bubbles (nitrogen) trapped in the expanded neoprene rubber they are made of. As the diver descends the bubbles of gas compress and therefore the suit loses buoyancy. Thus a correctly *weighted* diver (i.e. neutrally buoyant) at the surface (with an empty buoyancy aid) will be negatively buoyant at depth (the diver will sink deeper). To combat this the buoyancy aid is partially inflated to regain neutral buoyancy. During the dive, neutral buoyancy is maintained by partially inflating and deflating the buoyancy aid as necessary.

Drysuit diving

1. *Membrane Drysuits*

The only factor that affects the buoyancy of a membrane drysuit is the air inside it. Any air in the suit on the surface will compress as the diver descends causing negative buoyancy and discomfort due to the suit pressing against the divers body. Therefore, instead of using the buoyancy aid to compensate for loss of buoyancy, more air is introduced into the suit to compensate instead. Neutral buoyancy is maintained by this introduction of air and dumping is carried out through a valve fitted to the suit. The most common type of dump valve is a diaphragm-type cuff dump valve, which allows air to escape when the divers arm is raised above shoulder height.

NOTE: In the case of drysuits, the ABLJ/Stabjacket is reserved for emergency use only, such as an equipment failure (e.g. suit tear), diver rescue or for providing additional floatation on the surface. It is potentially hazardous to use more than one method of buoyancy control at the same time.

2. *Neoprene Drysuits*

   The situation with neoprene drysuits is the same as with membrane drysuits, except there is the added complication that the suit's buoyancy changes with depth, as with wetsuits.

Other factors that affect buoyancy and should be taken into consideration are:

- ***Aqualung***

  Aluminium alloy tanks are more buoyant (less negatively buoyant) than steel ones, therefore more weight will be required for a dive with an aluminium alloy tank than with a steel tank. Also, a tank's buoyancy increases as the volume of air inside the tank decreases, so there will be a variation in buoyancy depending on the capacity of the cylinder.

- ***Breath Control***

  If the lungs are kept full during the dive, 1 or 2kg more buoyancy will be achieved as compared to the case when the lungs are empty. Note that it is dangerous to keep the lungs full, especially on ascent as there is the danger of pulmonary barotrauma, if the air contained is not expired. However, fine buoyancy control can be achieved by varying the amount of air in the lungs.

- ***Use of fins***
  Somewhere between 1.5 and 3kg of thrust from the fins is achievable over a sustained period.

- ***Weightbelt***
  Judge the weight to be put onto the belt, by taking into account the increase in buoyancy as the air is used up from the aqualung, as well as the size and material of the cylinder. Note that a dive in fresh water will require about a third less weight than in the sea. Essentially, a diver is correctly weighted if he or she can remain just neutrally buoyant at a depth of 3m, wearing full equipment and with virtually all air removed from the dry suit or buoyancy aid.

- ***Use of extraneous objects***
  Accessories will add to the diver’s total negative/positive buoyancy according to their characteristics. The use of devices such as a **Surface Marker Buoy (SMB)** or decompression marker buoy can result in increased positive buoyancy.

Use of Buoyancy Aids

A buoyancy aid uses the principle of displacing water with air to increase the diver's apparent volume, and therefore his or her buoyancy, in a controlled fashion. A buoyancy aid of some form should be worn for all dives in the open water.

Surface Life Jacket
This is a frontal vest, which is worn over the head and fastened by a waist strap and harness. Being intended for surface use only, the emergency inflation is by mean of firing a small CO_2 cylinder. An oral inflation tube is fitted for non-emergency use, such as a long surface swim, and also as a simple means of deflating the life jacket.
The problems associated with this type of lifejacket are:
There is no simple way of checking the contents of the gas cylinder before a dive, other than by weighing the cylinder
The size of the cartridge is designed to fill the jacket on the surface, giving about 15kg of buoyancy. At a depth of 30m the buoyancy provided would be under 4kg

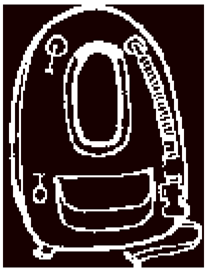
The Adjustable Buoyancy Life Jacket
The adjustable buoyancy life jacket (ABLJ) was, on introduction, a major contribution to more relaxed and safer diving.
The in-built emergency inflation system of the ABLJ is a small air cylinder of about 0.4l volume. When this cylinder is filled from a normal diving air supply (normal about 200 bar) it has about 80 litres of air available for inflation of the lifejacket.
To ensure that this supply is always available, the diver refills the small cylinder from the main diving cylinder at the start of *every* dive. This guarantees that there is a full emergency inflation system present. Air is fed into the jacket by opening the twist-grip valve on the small cylinder.

The ABLJ is usually fitted with an oral inflation tube with a valve-operated mouthpiece The tube is held above the head and the mouthpiece valve operated to allow the air in the jacket to escape.

For normal buoyancy control air is supplied to the jacket by a **direct-feed** from the aqualung (this is controlled by an inflation button, situated next to the mouthpiece).

Most ABLJ's are fitted with cord-operated vent valves (dump valves). These make the procedure of dumping air even easier – pulling the cord causes the air to escape. This valve may incorporate the excess pressure valve (needed to prevent over-inflation).

Since the small cylinder contains an appreciable quantity of breathable air, in the unfortunate circumstance of running out of air it is possible to breathe from the contents. This technique requires considerable practice to avoid

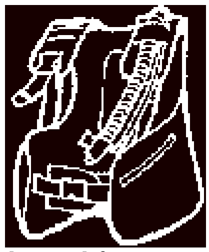


becoming over buoyant or breathing in water. Some ABLJ's are fitted with an automatic mouthpiece (a sort of basic demand valve) which makes emergency breathing much easier.

Stabilizer (STAB) Jackets or BCD
This is shaped like a waistcoat, and is usually attached to the diving cylinder. It can eliminate the need for a harness, and is very comfortable to wear. Many jackets have inflatable areas at the divers back, front and sides. While swimming horizontally, air for buoyancy adjustment will be located in the small of the back. When fully inflated, the air will be in the front of the jacket causing the diver to float face upwards. Stab jackets may use small air cylinders for emergency inflation and have direct feeds for routine buoyancy adjustment.

There are several types of stab jacket available:

The **waistcoat style** is shaped like a waistcoat and has buoyancy compartments on the back, on the front and above and below the shoulders.



The **conventional style**
is similar to the waistcoat style, except that there is no buoyancy over the shoulders. This gives conventional stab jackets a greater tendency to lift a divers face clear of the water on the surface, and to lie the person on their back, than with a waistcoat style stab jacket.

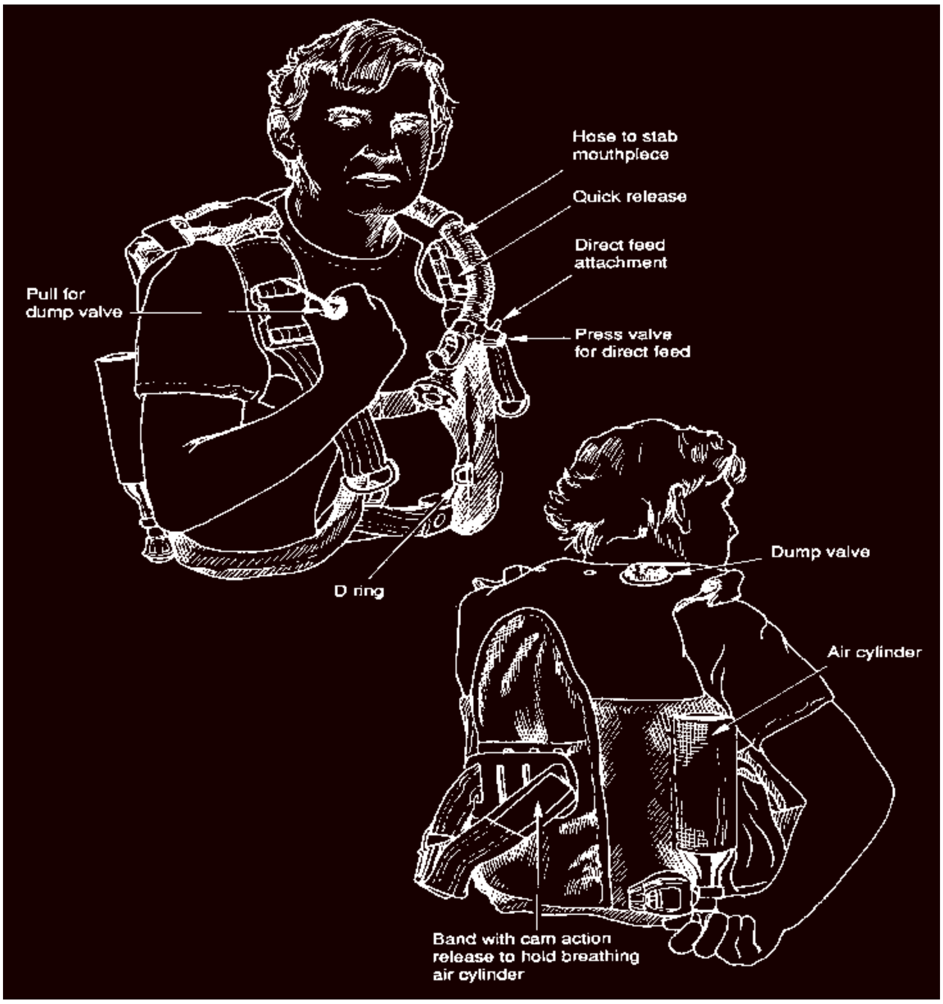
The **wings style** stab jacket (below) is designed for more specialist divers ('technical' divers) who use several different mixes of air on a dive, and

consequently need several tanks. The buoyancy is all provided behind the diver, and hold him or her in a horizontal position whilst diving. A lot more buoyancy is provided with wings to compensate for the weight of the extra tanks. The drawback about wings is they have a tendency to hold a diver face down on the surface.

Direct Feed
The use of a direct feed inflator removes the need for oral inflation and is found on every BCD. A hose is connected to the medium pressure side of the first stage of the diving regulator, with it's other end connected via a quick release connector to a valve in the mouthpiece of the oral inflation hose. Whenever the diver needs to put air into the jacket, a simple push on the direct-feed button accomplishes this.

Oral Inflation
The jacket is normally fitted with an oral inflation tube, allowing easy inflation and venting. This is a fairly long tube, corrugated for flexibility, which has an easy to operate valve at the open end. Holding the tube above the head and operating the valve allows air to escape from the jacket should this be necessary, for example when moving into shallow water or surfacing. Most models of jacket with oral inflation also have the provision for emergency inflation by using a special cylinder.
Since it is now possible to fully inflate the lifejacket at depth and then come to the surface, causing the air in the jacket to expand, such devices are fitted with an over-pressure valve to prevent rupture of the inner bag.

Air-Inflated Drysuit
The drysuit is also used as a buoyancy control device. Air is fed to the suit by another, low-pressure, direct-feed from the main cylinder. An ABLJ or STAB jacket must always be worn. Diving with a dry-suit requires additional training to ensure that it is operated in a safe manner



Assembly and Testing of the Aqualung

Assembly

Assemble all the equipment required:

- A tank, full
- An ABLJ (Adjustable Buoyancy Life Jacket) and Backpack; or a Stabjacket
- A regulator and demand valve
- An Emergency Air Cylinder
- A weight belt

Filling of the Emergency Air Cylinder

- Fit the Emergency Air Cylinder (EAC, or Fenzy Bottle) over the pillar valve of the tank and tighten, making sure the EAC is seated properly. Also ensure the small purge button is facing away from you and anyone else.
- Slowly open the EAC valve fully, and turn it a quarter turn back.
- SLOWLY open the pillar valve of the main cylinder, keeping one hand on the EAC to make sure it doesn't heat up excessively.
- Once airflow is inaudible, close both the EAC valve and pillar valve fully.
- Press the purge button on the EAC to release the pressure between the EAC and pillar valve. If you cannot manage, get an experienced person to assist you. NEVER use a rock or weightbelt.
- Remove the EAC from the pillar valve. If it is stiff, or tight, press the purge button again to ensure the pressure is released.

Fitting of the ABLJ

- Having filled the EAC, place it into the mounting sleeve on the back of the ABLJ
- The correct order of fitting of the equipment is:
  1. ABLJ
  2. Aqualung
  3. Weightbelt
- Place the ABLJ over the head, and adjust the strap that comes between the legs. This should not be too tight, as subsequent inflation will make it uncomfortable to wear.
- Connect the waist strap, and adjust. This should be fairly tight. Ensure that none of the straps are twisted.

Assembly of the tank and regulator

- Fit the tank to the backpack or stabjacket as tightly as it will go. Make sure the hole in the pillar valve where the air comes out is facing where the back of the head will be. Ensure that the O-ring is in place and in serviceable condition.
- Fit the regulator (demand valve) to the pillar valve of the tank, making sure the regulator is seated correctly on the O-ring.

- Hold the **contents** gauge with the glass facing away from you or anyone else. Holding it against the ground or the side of the tank is a good idea. They have been known to explode. GENTLY turn on the pillar valve (anti-clockwise). Never look at the contents gauge while turning the air on. Wait until the hissing of air has stopped. Also never look at the pillar valve when the air is turned on, as the O-ring of a incorrectly-placed regulator might shoot out at you. If there are any obvious leaks turn off the air and reseat the regulator, making sure the regulator is **fully purged first.**
- Check the regulator will supply breathing air from the mouthpiece. 'Taste' the air, as contaminants due to a faulty compressor may be noticeable. If the pressure of the cylinder is appreciably below the working pressure of the cylinder (shown on the contents gauge) of 150 – 200 bar discuss this with your dive leader, as it may be necessary to obtain another cylinder with more air in it.
- Turn off the air and examine the contents gauge. The indicating needle should remain in its original (pressurised) position. If it falls towards zero, it is an indication of a leak in the system and should be investigated further. If all is well, breathe from the regulator. After two to five breaths the valve should resist giving air and the contents gauge should read zero. If the regulator continues to give air, there is a major leak in it and it is unsafe to dive with. This again would have to be rectified prior to proceeding.

Fitting of the Aqualung

- Ensure that the backpack or stabjacket is fitted as tightly as possible, and that both of the shoulder straps are connected.
- Left the aqualung onto your back. It is quite heavy, you may want to get someone to help you.
- Lie it along your back, and ensuring the straps are not lying over the ABLJ, pull the shoulder straps as tight as possible.
- Connect the waist strap, and pull it as tight as is comfortable.
- Stand upright, and the tank should not slip in the harness. If there are any direct feeds to be connected, connect them now.
- Ensure again that none of the straps are twisted, or lying over the ABLJ.

Fitting the Weight Belt

- To fit the weight belt, lie it on the ground in front of you, with the buckle on one side, and the free end on the other, in a straight line, belt side up.
- Step over the belt, and bend over so that the tank is lifted off your lower back.
- Staying in that position, bend down and hold the ends of the belt.
- In one smooth motion, lift the belt from the ground onto your hips, so it lying beneath the tank.
- Do up the weight belt.
- Remember, the weight belt should be the last piece of equipment fitted, so that in an emergency it is the first thing to come off, and there is nothing trapping it.

Also remember that the waist strap of the aqualung and the weight belt, should be done up in opposite directions so that the wrong one is not inadvertently opened in an emergency.

Additional Information for STAB Jacket Wearers

It is common practice for STAB-Jacketed divers to fit their weightbelts before fitting their STAB jacket & aqualung. This is acceptable providing the weightbelt can be easily released at all times, especially in an emergency situation.

Testing

The Buddy Check

The buddy check is carried out once the diver and his or her buddy are fully kitted and ready to enter the water.
The basic routine is:

- Check that all straps are done up correctly and ensure that the weight belt and aqualung waist straps are distinct and separate.
- Ensure that the air is turned on. A couple of breaths should be taken from the regulator, whilst checking the contents gauge for any fluctuations. Any change of indication means that the air supply is not functioning properly.
- Ensure that any drain valves are closed securely.
- Ensure that all their direct feeds are working properly. Establish where the relevant dump valves are.
- Ensure the EAC is fitted correctly and working properly by GENTLY opening the twist-grip valve and observing that the ABLJ/Stabjacket begins to fill.
- Ensure that the drysuit (if worn) zip is properly closed
- Check the presence and location of all other essential items of diving equipment

Lecture 4

Burst Lung and Ascent in Emergency

Pulmonary Pressure Damage

Boyle's Law states that pressure varies inversely with volume, so that for a fixed mass of gas, at constant temperature, the pressure increases as the volume decreases, and vice versa.

A diver breathes air at ambient pressure. Hence at a pressure of two bars (10m), twice the amount of air is taken into the lungs, to fill them to their normal capacity, as would be on the surface. For a diver who maintains normal lung volume during a dive, over expansion of the lungs on ascent (i.e. failure to exhale while ascending), is a real danger. It can force air into the blood stream or can cause lung tissue to rupture, trapping air in pockets in the chest cavity. This condition is not preceded by any warning signals, as with the ears, as the 'full to bursting' sensation (*Hering-Breur reflex*) is very weak in human beings. The results of this are dramatic and often fatal. Injuries of this sort are collectively referred to as 'burst lung'.

1. **PULMONARY TISSUE DAMAGE**
   This is the rupture of a few alveoli and is in itself not overly serious. It always precedes 2,3 and 4. Symptoms include breathing difficulties, coughing and bloody sputum.

2. **AIR EMBOLISM**
   An ***embolism*** is a blockage of circulation. The alveolar membrane can stretch, allowing tiny bubbles of air to enter the capillaries and thus the bloodstream. The circulation will carry these bubbles - which unite into larger bubbles - to the brain, heart and other vital organs where they could lodge, blocking further blood flow and thus oxygen supply. This is, in effect, a stroke and death can occur within seconds. Symptoms usually appear rapidly after surfacing: giddiness; numbness; paralysis; visual disturbances; respiratory difficulties; heart failure and death are all associated with this type of injury. N.B. This can occur from as little as 3m depth.

3. **SPONTANEOUS PNEUMOTHORAX**
   In some cases the alveolar tissue may suffer a major tear, allowing considerable quantities of air to escape outwards and become trapped between the lung sac and chest wall. As the ascent continues, the pressure of the trapped air will be greater than that of the air in the lungs, and this will cause the lung sacs to collapse. The lungs will then be starved of oxygen. Symptoms (in addition to the above) include severe pain on breathing, shortness of breath, coughing of blood and swollen appearance of chest cage.

4. **INTERSTITIAL EMPHYSEMA**
   Larger bubbles of air that escape from torn lung tissue can travel inwards between the lung sacs, into the vicinity of the heart and the major blood vessels. This trapped air will also have a serious effect on normal respiration. Symptoms include shortness of breath, swollen appearance of skin at base of neck and also those of air embolism.

It should be mentioned that air embolism may also be present in cases of pneumothorax and emphysema. Burst lung conditions can also include effects and symptoms of hypoxia, since normal respiration is upset, i.e. blueness of lips, ear lobes, finger nail beds, and unconsciousness.

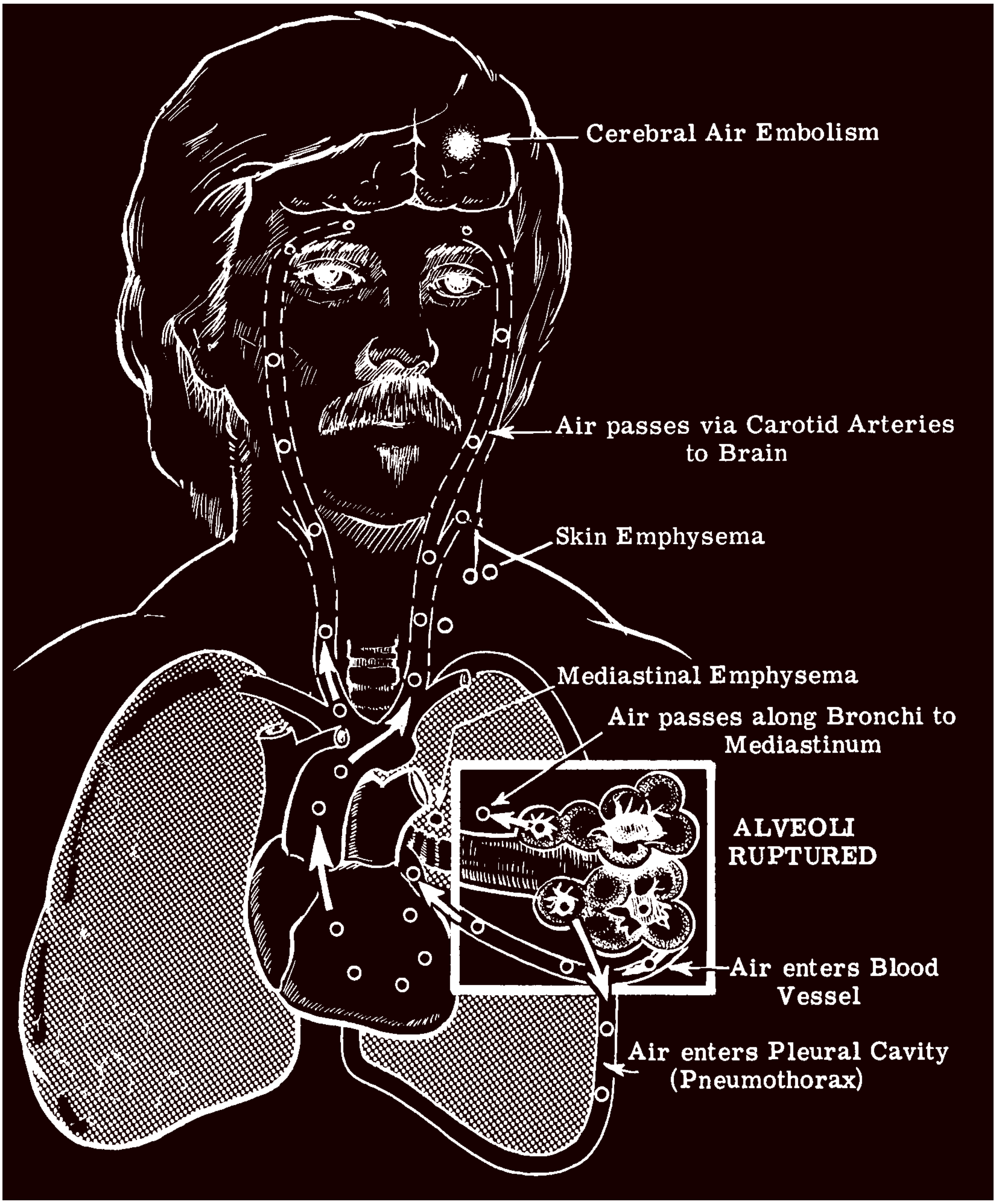
TREATMENT FOR BURST LUNG

In all cases, normobaric oxygen should be administered immediately to the victim. The only successful treatment for air embolism is immediate recompression in a chamber. Pneumothorax and emphysema may require minor surgical treatment. Consequently, professional medical assistance should be sought immediately. The victim should be placed with the head lower than the feet, to encourage air away from the heart and brain. If breathing difficulties are experienced, they can be alleviated by administering EAR.

PREVENTION

Every diver should successfully undertake a proper medical examination. Diseased lungs are weakened and are therefore more susceptible to damage. During colds, mucous clogs lungs and increases the risk of lung damage if diving is conducted.
Most importantly:

ALWAYS BREATHE NORMALLY: NEVER HOLD YOUR BREATH


Cerebral Air Embolism
Air passes via Carotid Arteries to Brain
Skin Emphysema
Mediastinal Emphysema
Air passes along Bronchi to Mediastinum
ALVEOLI RUPTURED
Air enters Blood Vessel
Air enters Pleural Cavity (Pneumothorax)

ASCENT PROCEDURES

NORMAL ASCENTS

This is the standard situation at the end of a dive.

1. The diver exchanges ‘go up’ signal with buddy. ‘OK’ signals are also exchanged.
2. Both divers fin *gently* upwards whilst monitoring depth gauge/computer, buddy and small bubble ascent rate.
3. A rate of 10m/min should not be exceeded. Normal breathing must be maintained at all times. The divers should look up for surface obstacles or other hazards above (e.g. jellyfish).
4. In a poor visibility situation, the diver should hold his/her hand above the head and hold on to buddy.
5. As the divers pass the 10 m point, the ascent rate should be carefully controlled.
6. On surfacing, the divers should check all around (360 ^{0} circle) for approaching vessels.
7. The divers should exchange ‘OK’ signals with each other and the boat or shore cover. BCDs may be inflated.

EMERGENCY ASCENTS

These occur most often through poor dive practice and not due to equipment failure. Running out of air is the most common reason.

(i) Assisted Ascent

This procedure assumes that the buddy is in close proximity and his/her attention can be attracted quickly.

1. The distressed diver gives the “I am out of air” signal.
2. The assisting diver (AD) approaches from the right (due to position of regulator) as quickly as possible. The AD takes hold of buddies aqualung pillar valve or harness with left hand (diver being assisted takes buddies harness with right hand).
3. AD takes 2 breaths, places DV in buddies mouth and purges it.
4. Assisted diver takes two breathes and returns it to buddy.
5. When regular rhythm is established, donor gives “up” signal and checks rates of ascent.

NB AD will have to release mouthpiece at some point so that air may be dumped for a controlled ascent rate. Each diver **must** breathe out between inspirations.

(ii) Free Ascent (should never be practised)

Used when contact with buddy cannot be made. This method is dependant on calm, controlled technique for its success.

1. The diver immediately begins to fin steadily upwards.
2. If this is found to be difficult, the weightbelt can be jettisoned.
3. The diver should remove mouthpiece and exhale gently and continuously through pursed lips.
4. As the diver approaches 10m, it is essential to start breathing out more rapidly to avoid serious pressure damage.

The feeling of air starvation may well diminish slightly if the breath is held BRIEFLY until the residual air in the lungs expands with the fall in the surrounding water pressure. Another breath may be obtained from the regulator for the same reason.

There will be enough oxygen in the bloodstream to supply muscles, carbon dioxide will be removed, therefore there should be no undue desire to breath. After this (or any) type of emergency ascent, the diver should be observed for any signs of pressure damage or decompression sickness.

(iii) Buoyant Ascent (should never be practised)

Most ABLJs and STAB jackets are fitted with direct feed and (occasionally) an emergency air cylinder, which can be used to bring a diver to the surface in an emergency.

1. The weight belt must not be removed as it maintains correct body position.
2. The ABLJ/STAB emergency cylinder tap is opened, or the direct feed button is depressed, **just sufficiently** to begin the ascent.
3. As the ascent commences, the tap/direct feed should be turned off.
4. The diver should lean back, breathe out and look towards the surface.
5. The ascent rate may be controlled by venting the ABLJ/STAB/drysuit. Care must be taken not to vent excessively such that the diver becomes negatively buoyant and starts descending again.

NB Full inflation of an ABLJ/STAB induces an ascent rate of 120m/min, which could cause explosive decompression and air embolism.

Lecture 5
Respiration, Hypoxia & Anoxia, Drowning & Hyperventilation

Respiration

What is Respiration?

Respiration is the process by which **OXYGEN (O_2)** is transported from the air that is breathed to the body tissues, and by which **CARBON DIOXIDE (CO_2)** produced in these tissues is vented to the air. This process becomes clear when the composition of inhaled (breathing in) and exhaled air (breathing out) is examined.

% Composition	Inhaled Air	Exhaled Air
Nitrogen, N_2	78	78
Other	≈ 1	≈ 1
Oxygen, O_2	21	16
Carbon dioxide, CO_2	Trace	5

It is apparent that whilst the air has been in the lungs, some of the oxygen has been used and a small amount of carbon dioxide added. Note that nitrogen is not involved in this process (i.e. it is ***non-metabolic***), so that its contribution remains unaltered. It is important for other reasons (e.g. it is responsible for nitrogen narcosis and decompression sickness).

Why is Respiration necessary?

In the same way that a fire needs oxygen to burn, i.e. to release the chemical energy in the fuel (e.g. coal), a human body needs oxygen to release energy from food. Carbon dioxide is a waste product of this process and needs to be removed from the body. The process is known as *metabolism* i.e.

Food + O_2 = Energy + CO_2 + waste products

How is breathing accomplished?

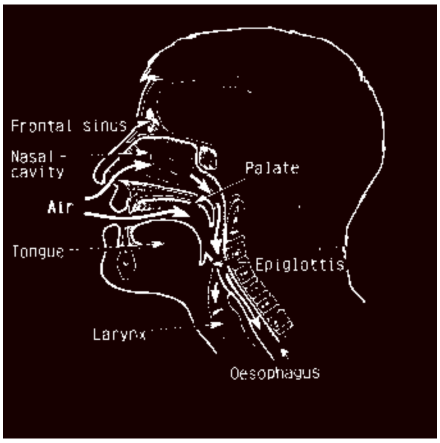
Air is drawn into the lungs by the action of intercostal muscles and the diaphragm. To breathe in, the rib cage is pulled up and the diaphragm down. This increases the volume of the lungs, causing the internal pressure to fall and air to move in to fill the space. Breathing out is the reverse of this action. The lungs are 'squeezed' by letting the rib cage fall and pulling the diaphragm up, which results in the air being pushed out.

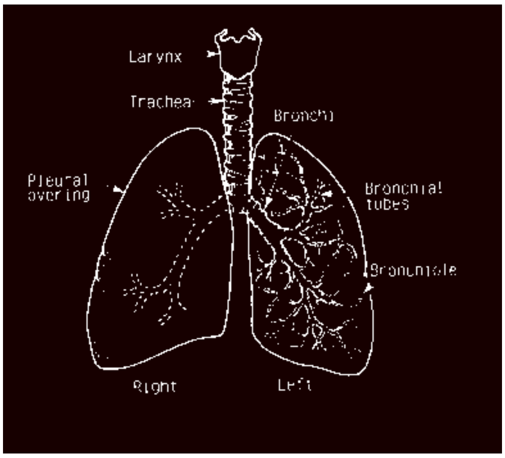
Airways

The path by which air enters the lungs is as follows:

Mouth & Nose => Larynx => Trachea => Bronchi => Lungs (Alveoli).

It leaves in the reverse direction

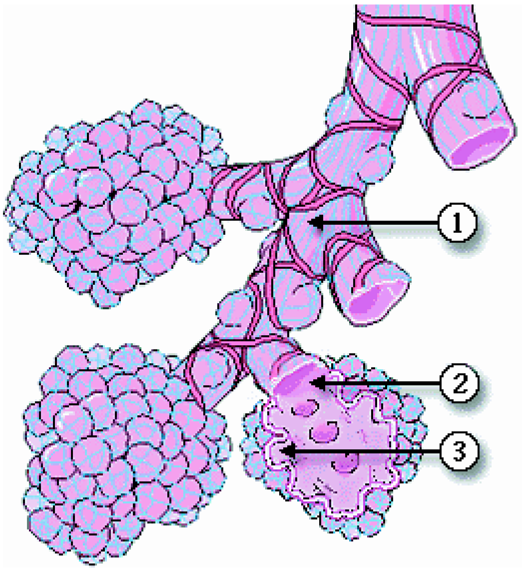




The Lungs

The lungs are the organs where the exchange of gases between the atmosphere and the blood takes place. They occupy, along with heart, almost all of the chest cavity. The lungs are rather dense organs, similar in structure to a sponge. The holes in this 'sponge' are represented by air spaces, within which air is continually moving in and out and the structure of the sponge is the small blood vessels, called **CAPILLARIES**, which contain de-oxygenated blood. These air spaces are actually microscopic sacs, called **ALVEOLI**. Their function is to allow the transfer of

O_2 and CO_2 between the air in the sac and the de-oxygenated blood surrounding it, with O_2 moving from the air to the blood and CO_2 from the blood to the air. The lungs are completely filled with alveoli, providing a surface area equal to the size of a tennis pitch over which gaseous exchange can occur.



(1) Respiratory Bronchiole (sometimes called terminal bronchiole)
(2) Alveolar duct
(3) Alveoli

The Blood Stream

Oxygen is transported round the body via the blood. It is principally carried via **RED BLOOD CELLS**. These are shaped like discs, to maximise their surface area and so make gaseous exchange easier. The cells are full of a compound called **HAEMOGLOBIN**, which has a strong affinity to oxygen. When oxygen comes into contact with a molecule of haemoglobin, it seizes it and forms a molecule of **OXYHAEMOGLOBIN**. This moves around the body to where it is needed, whereupon the oxygen is released and the molecule reverts to being haemoglobin. Oxygen also dissolves in the blood plasma and is transported in that way. Carbon dioxide is also transported via the blood, mostly in solution.

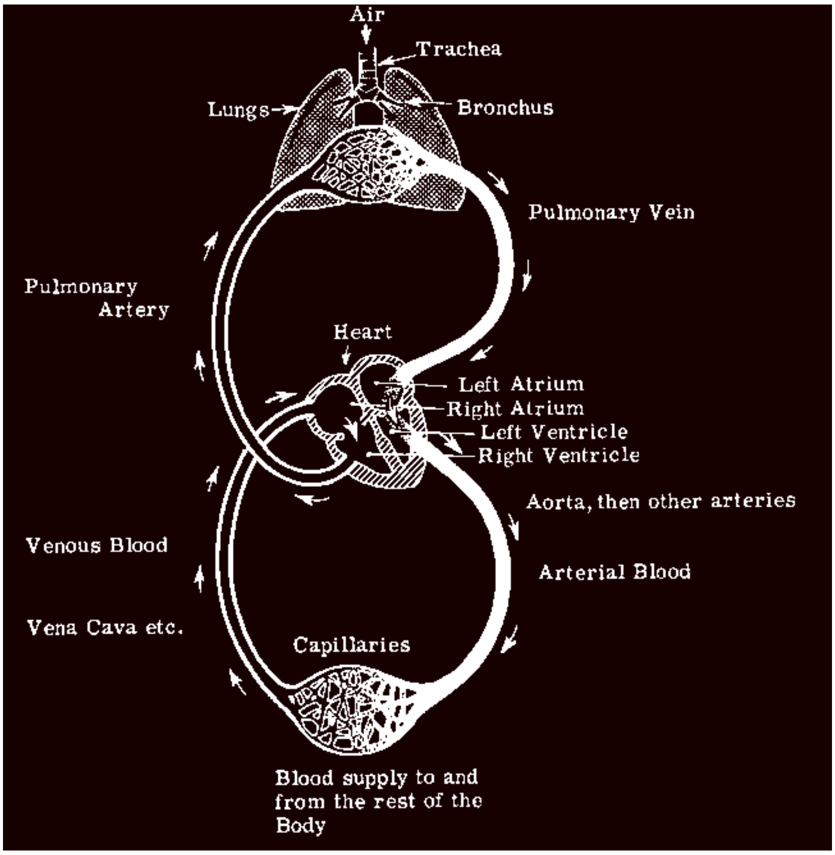
The Circulatory System

Blood is transported around the body by means of a highly efficient pump: the heart. It circulates blood within a closed circuit system known as the **CIRCULATORY SYSTEM**. This circulation takes oxygenated blood (oxygen rich, little carbon dioxide) from the lungs to those tissues which require it and de-oxygenated blood (oxygen depleted, carbon dioxide rich) back to the lungs, where the CO_2 is vented and more O_2 is captured.

Where does the desire to breathe originate?

The breathing rate (i.e. the number of breaths taken per minute) varies depending on the work rate. Thus the harder the work rate, the more air is taken. This occurs because energy is being burned faster and so there is a need to consume more oxygen.

The trigger for the breathing action is not, however, the amount of oxygen in the blood, but rather its pH. Carbon dioxide dissolves in the blood to form a weak acid called **CARBONIC ACID** (CO_2+ water). The more carbonic acid in the blood, the lower the pH, and the greater the desire to breathe.



Hypoxia & Anoxia

What Are Hypoxia & Anoxia?

It has already been established that a body's demand for oxygen varies proportionally with the workload. ***Hypoxia*** describes a situation where an insufficient amount of oxygen is received. This term can apply to the entire body or to specific organs e.g. the brain. It is defined as a **partial lack of oxygen**. If steps are not taken to increase the supply of oxygen, ***Anoxia*** can result, which is the **complete absence of oxygen**. Body cells cannot survive without oxygen. Brain cells are particularly sensitive and can die within as little as 4 minutes.

How It Can Occur?

Hypoxia can occur for a number of reasons:
- There is an obstruction of the airway
- There is too little oxygen in the breathing gas (i.e. partial pressure < 0.14 atm);
- The lung(s) are damaged or diseased e.g. a burst lung;
- Carbon monoxide poisoning has occurred (**CARBOXYHAEMOGLOBIN**);
- The heart is unable to pump with sufficient force to supply all the body tissues
- An extraordinary incident such as hyperventilation or drowning

Symptoms - Subjective/Objective

There are many symptoms of hypoxia, depending on its severity:
- drowsiness
- lack of co-ordination
- headache
- increased respiration and pulse rate
- lips/nails/ear lobes turning blue **(cyanosis)**
- unconsciousness and death

Treatment

Restore a supply of oxygen (at least 0.16 Bar absolute) as soon as possible, using pure oxygen if available. If the victim is not breathing, EAR and perhaps ECM will be necessary.

Drowning

Drowning prevents oxygen from reaching the body tissues i.e. it causes hypoxia. The term, strictly speaking, should only be applied if death occurs. Individuals who inhale water but are resuscitated have experienced a ***'near drowning'*** situation. Drowning is the ultimate cause of death in most diving fatalities.

Types of Drowning

- **Blue or Dry Drowning**

  No water enters the lungs as a result of an **EPIGLOTTAL SPASM**, which seals off the trachea. However, water may enter the stomach. Hypoxia will occur and, unless breathing is restored, anoxia will result followed by death.
- **White or Wet Drowning**

  This is a much more severe, and more likely to be fatal, form of drowning, in which water enters the lungs. There are two types:

  Seawater Drowning: Water is removed from the blood by osmosis, leading to **HAEMOCONCENTRATION.** This can put a great strain on the heart.

  Freshwater Drowning: This is the more severe situation. Water rapidly enters the bloodstream, again by osmosis, causing **HAEMODILUTION**. This causes the red blood cells to burst and subsequent heart fibrillation, leading to rapid death from hypoxia or heart attack.

Treatment

Clear the airway, and apply EAR/ECM as necessary. Always seek professional medical help: secondary drowning ,due to the lungs filling up with fluid because of damage to the alveolar membrane, can occur up to twelve hours after the original incident.

Hyperventilation

How Does It Occur?

The object of ***hyperventilation***, before a breath-holding dive, is to increase the length of time the diver can remain underwater. It may be accomplished by taking a series of very deep breaths prior to breath-holding and commencing the dive. This, in effect, significantly reduces the level of CO_2 in the body and only marginally increases the O_2 level. Thus the CO_2 breathing trigger is at an artificially low level at the start of the dive. During the dive, especially with the diver finning hard, O_2 is being used up rapidly. However, the desire to breathe is suppressed due to the low level of CO_2 The outcome of this is that the secondary receptors in the heart and brain detect the lack of O_2 , before the CO_2 trigger is reached. The diver then lapses into unconsciousness.

Why Does It Happen?

After the first two or three breaths the haemoglobin in the blood is saturated with oxygen. Subsequent breaths add no more oxygen, but remove more and more CO_2 from the bloodstream, increasing the pH of the blood. When the dive begins, the body starts to use up the available oxygen, generating CO_2 in the process. However, because the amount of CO_2 in the blood was reduced to a low level by hyperventilating, it does not build up to the level at which a breathing reflex is triggered until well after the diver has used up all the available oxygen in the blood. As a result the individual become seriously hypoxic and finally anoxic. The problem is exacerbated with depth and is common in persons engaged in commercial spear-fishing.

What is the Safe Way to Swim Underwater?

Take only 2 medium deep breaths, at most, **before setting off on a breath-holding dive.** Never overwork or linger at depth. Snorkel divers, like their aqualung counterparts, should always operate in pairs. One should remain on the surface whilst his/her buddy is diving. The divers should arrange to be buoyant from 10m upwards, as problems normally occur on ascent or at the surface.

Principles of EAR

When somebody has stopped breathing, they will become increasingly hypoxic, and finally anoxic. To prevent certain death it is essential to commence Expired Air Resuscitation (EAR) on the victim as soon as possible. The aim is twofold:

1. To provide the casualty with the oxygen that they cannot provide themselves;
2. The air that is expired contains more carbon dioxide than is breathed in, so that it is more likely to trigger a breathing reflex in the victim and cause them to start breathing again.
3. The normal procedure is to give **two breaths every 10 seconds**, either mouth-to-mouth (on land) or mouth-to-nose (in water).

Lecture 6
Exhaustion, Hypothermia & Protective Clothing

Diving is a physically intensive sport where exposure to temperature extremes, above and below the water, are experienced. The nature of the sport presents health risks associated with exhaustion and hypothermia. It is thus important that divers are able to recognise the signs and symptoms of both conditions, as well as knowing how to deal with them.

Exhaustion

Exhaustion is a condition that is more easily recognised than defined, but may be described as a point where the individual is unable to respond adequately, either physically or mentally, to further demands. Within the context of diving, exhaustion may (most commonly) be due to **physical exertion**. It may also be attributed to **mental/physical fatigue** or the **effects of depth and hypothermia. It is characterised by deep, laboured breathing**.

Exhaustion is a condition which must be avoided by divers because they are submerged in an alien environment which will not support life. Hence an inability to cope can lead to death by drowning.

Avoidance and Treatment

Physical Exertion: Hardworking muscles (lifting/finning) may become overloaded, causing ***lactic acid*** to be released. Lactic acid creates a dull ache in the muscles and increases the blood's acidity. This stimulates the breathing reflex in the same way as CO_2. The result is laboured breathing which will continue after the exertion has ceased, which allows the body to reclaim the oxygen debt built up by the exertion. It follows logically that it is in the interests of the individual to maintain a reasonable level of fitness for diving.

Avoid exhaustion by finning at a comfortable pace. If a diver should become breathless, a signal should be made to his/her buddy ('out of breath') and finning should cease. If there is a swell, tide or a strong current, it is better to find a secure object to hold on rather than expending energy against the elements. If submerged, it is essential to keep track of the depth and time. If there is nowhere secure, it is preferable to drift while carefully monitoring the depth/time/buoyancy. The diver should concentrate on controlling the breathing to a deep, slow rhythm.

Once the diver feels comfortable again and has regained normal breathing, an 'OK' signal can be given to the buddy and the dive continued. It is important that the sequence of activities which contributed to the initial exhaustion is not repeated. Thus, it may be necessary to conclude the dive at this point.

If normal breathing cannot be regained, then the dive must be terminated. Appropriate signals should be exchanged and the divers should make a controlled ascent to the surface. In a severe situation, diver rescue may be necessary.

When the surface is reached, the condition of the exhausted diver should be monitored. ABLJ/STAB jackets should be fully inflated. If conditions permit, the mask and demand valve should be removed. Appropriate signals, depending on the severity of the situation, should be given to the shore/boat cover. After regaining the shore/boat, rest and perhaps hot drinks should be administered and the individual's condition monitored. **Shock** can occasionally follow exhaustion.

Hypothermia: loss of body heat results not only in physical discomfort but also in slow mental reactions and loss of muscle power. It is an important, and often unrecognised, underlying cause of exhaustion and a contributing factor in many accidents. To continue with a dive whilst feeling chilled is not only foolhardy but also dangerous.

Mental Fatigue or Stress can also lead to exhaustion. Late nights, early starts, responsibility/organisation and equipment assembly are all factors in the exhaustion equation. Particularly problematic are dives late in the day and/or at the end of a diving weekend.

Deep diving and Decompression diving will make a diver more susceptible to exhaustion. As depth increases, so does air density and consequently breathing resistance. At 30m, the diver's maximum ventilation rate is halved and the ability to eliminate CO_2 diminished. Thus, at depth, it becomes increasingly important to avoid heavy exertion in any form. Such behaviour is not only wasteful of air, but leads to exhaustion underwater. It can also lead to an increased likelihood of N_2 narcosis and decompression sicknesss.

Summary

Exhaustion Avoidance:

- **Minimise exertion whilst diving.** The effects of tide, current and surface wind/swell should be taken into account. This will not only avoid the diver becoming exhausted, but is essentially good diving technique.
- **Maintain a reasonable level of physical fitness.**
- **Do not dive if feeling tired, cold or unwell.**
- **Signal to dive buddy as soon as the effects of exertion are noticed.**
- **Take extra care at depth.**

Hypothermia

Hypothermia is the depression of temperature in the body core. The temperature of UK seawater can vary from 4 -16^0 C and the temperature in freshwater lakes and water-filled quarries can be as low as 0^0 C. Water conducts heat 25 times better than air, so it is apparent that divers are particularly vulnerable to the condition of loss of body heat or hypothermia. The normal human body core temperature is 37 degrees C. The body is extremely sensitive to changes in deep core temperature and a drop of as little as 1^0 C will cause shivering and discomfort. The rate of heat loss is related to the surface area of the body and the rate of heat production is related to body volume. Therefore, smaller individuals such as children are more susceptible to hypothermia because their surface area to body volume ratio is small. The extremities (hands, feet etc.) are less dependent on temperature and hence have a less extensive blood supply and can withstand mild coldness. This results in less heat being lost from these extremities, due to the reduced blood flow. This, in turn, increases the level of blood in the body core (***CBV: Central Blood Volume***) which increases the blood pressure and, consequently, the load on the heart. The body senses this and attempts to reduce the blood level by passing more water through the kidneys i.e. urine production is increased.

Signs & Symptoms

Core temperature is crucial and a fall of only 1-2 degrees C brings a flood of homeostatic mechanisms into place in an attempt to counteract further temperature reduction:

* Shivering - muscular respiration releases heat.
* Metabolic rate increases - to release heat.
* Goose pimples - body hairs trap air for thermal insulation.
* Vasoconstriction - blood vessels contract and minimise outflow from the body’s core.

Core Temperature Degrees C.	Symptoms
35-36	Sensation of cold, numbness, ‘goose pimples’, controllable and then uncontrollable shivering occurs. Metabolic & respiratory rate increases.
34-35	Heart, metabolic, and respiratory rates begin to decrease, causing confusion, lethargy and behavioural changes.
33	Amnesia begins, **shivering stops** and muscles become rigid. Mental confusion and communication difficulties. Semi-consciousness occurs.
30	Unconsciousness, pupil dilation, irregular respiration.
28	Respiration ceases, ventricular fibrillation.
25	Death

It should be stressed that there are considerable individual differences in the experience of and variability in reactions of different people to cold. Factors such as weight, fitness levels and overall health will effect the susceptibility to hypothermia.

Preventing Hypothermia

- Be aware of the signs & symptoms of hypothermia.
- Wear adequate protective clothing during the dive i.e. a wetsuit, semi-drysuit or drysuit.
- Wear windproof and waterproof clothing, especially on the head, to prevent coldness **before and after** a dive.
- Be aware of the effects of wind chill.
- Take hot, high-energy drinks to help maintain body heat level.
- Terminate the dive if the feeling of cold persists.

Treatment

- Prevention of further heat loss is crucial. Remove from cold and protect from wind chill.
- **For mild cases:** if a dry location is available (i.e. not the case in an open boat), the casualty should change into warm clothing. They should be gently re-warmed by hot drinks and/or the use of an exposure blanket or even by others warming the victim with their own body heat.
- **For serious cases**: serious hypothermia is a life-threatening situation and requires urgent admission to hospital. Professional medical assistance should be sought immediately. It may be necessary to give CPR if the victim has no pulse and has ceased breathing. Handling of the casualty should be kept to a minimum. They should lie still with the feet raised to contain the blood within the body's core and so prevent shock, caused by a fall in blood pressure. An exposure blanket/other body warming method should be used, concentrated on raising the casualties core temperature. The victim should be reassured and closely monitored until help arrives.

DO NOTS:

- **Do not give alcohol.** It causes blood vessels to dilate and permits cold peripheral blood to return to the body's core.
- **Do not apply local heat or rub extremities.** Cold blood may rush into the torso and cause a further drop in the core temperature. This is a major factor in 're-warming' deaths and results in the heart being stopped either by the surge of cold blood or a reduction in blood pressure, due to peripheral vessel dilation. It is known as ***afterdrop***.

Protective Clothing

Protective Clothing protects the diver against the effects of:
*** Cold** *** Abrasion** *** Pollution** *** Hazardous creatures**

Wetsuits, Semi-Drysuits & Drysuits

A ***Wetsuit or Semi-Drysuit*** traps a thin layer of water between the suit and wearer's body, which warms and so provides thermal protection. If the suit does not fit snugly then the warmed water will be constantly flushed away and replaced with cold water, resulting in reduced thermal performance. No special training is required prior to use in the open water.

Drysuits are waterproof suits which have seals at the neck and wrists, thus (theoretically) excluding water entirely. Insulation is provided by wearing some sort of thermal underclothing, depending on the drysuit type. Drysuits are much warmer than wetsuits as air is a better insulator than water. They are also normally more expensive to buy. Since drysuits are used for buoyancy control, special training is required prior to use in the open water.

Type	**Material**	**Features**	**Comments**
Wetsuit	Closed-cell, expanded foam neoprene. No additional neck and ankle seals. Integral hood.	Inherently buoyant. Buoyancy varies with depth as material compresses.	Usually at least 7mm thick for diving in UK waters, which can restrict mobility. Normally two piece construction: jacket and 'long johns'. Suit offers little protection to cold out of water, especially to wind chill, thus requires extra protective clothing to be worn (e.g. a cagoule). Long drying time. Easy to effect minor repairs. Boots (wet) are additional.
Semi-Drysuit	Closed-cell, expanded foam neoprene with neoprene wrist and ankle seals. Integral hood.	Inherently buoyant. Buoyancy varies with depth as material compresses.	As above. Additional seals help prevent suit 'flushing' (flow of water through suit).
Membrane Drysuit	Normally a tri-laminate (nylon/rubber/nylon) or vulcanised rubber material. Neck and wrist seals normally of latex rubber. Shoulder or cross-body dry zip with integral boots.	No inherent buoyancy. Full thermal undersuit must be worn.	Excellent thermal protection both in and out of water. Short drying time. Slightly less resistant to puncturing and more difficult to effect minor repairs than neoprene types. Excellent mobility out of water. Some drag in water. May require ankle weights. More expensive than wet or semi-drysuit.
Neoprene Drysuit (Standard)	Closed-cell, expanded foam neoprene. Shoulder or cross-body dry zip with integral boots. Latex or neoprene wrist/neck seals.	Inherently buoyant. Thermal underwear (or similar) must be worn underneath suit. Buoyancy varies with depth as material compresses.	Excellent thermal protection both in and out of water. Long drying time. Durable and very resistant to puncturing. Easy to effect minor repairs. Reduced mobility out of water. Low drag in water. More expensive than wet or semi-drysuit.
Neoprene Drysuit (Crushed or Compressed)	Compressed or crushed expanded foam neoprene. Shoulder or cross-body dry zip with integral boots.	Little inherent buoyancy. Full thermal undersuit must be worn.	Excellent thermal protection both in and out of water. Medium drying time. Durable and very resistant to puncturing. Easy to effect minor repairs. Excellent mobility. Reduced drag in water. More expensive than wet or semi-drysuit.

Sea Temp ^{0}C	**Survival Time in Hours Naked Swimmer**	**Survival Time in Hours Wet Suited Diver**
4	2	10-50
10	4	>50
16	8	

Lecture 7
Rescue, Lifesaving &Artificial Respiration

***The circumstances under which a diver may be required to perform a rescue are wide and varied. Thus the following information should be regarded as a set of guidelines which may be adapted to suit any particular situation and not as a rigid procedure in itself. The overriding point is that* under no circumstances must the rescuer's own safety be compromised.**

Rescue

1. Rescue Overview

Key Stages

I. Assess the situation calmly and objectively.
II. ***Initiate rescue procedure*** i.e.assist the casualty to the surface (if underwater) as quickly and safely as possible.
III. Commence resuscitation as soon as possible.
IV. Obtain professional medical assistance immediately.
V. Administer aftercare treatment to the casualty whilst recovering.

Contributory Factors

- ***Stress: uneasiness; panic***
- ***Physical Disablement***: injury; entrapment
- ***Illness***: decompression sickness; O_2/CO_2 poisoning
- ***Equipment Failure***: air supply; loss of weight belt

Detection

- ***General Appearance***: rapid breathing; erratic behaviour; buoyancy problems; staring eyes
- ***Response to signals***: abnormal and/or erratic
- ***Underwater Position***: vigorous treading of water; lying on face/back

Prevention

- ***Fitness***: physical and mental fitness for purpose
- ***Skill Level***: adequate preparation for situation
- ***Equipment***: level of maintenance; familiarity
- ***Planning:*** type of site; conditions; dive groups

2. Rescue Procedure

General

- A ***buoyancy device*** can describe either an ABLJ or a STAB jacket.
- Given the number of different methods of achieving buoyancy, divers should be aware of the main buoyancy method being used by the buddy **- this must be established during the buddy check**.
- Avoid using more than one method to achieve buoyancy as this could cause confusion and problems during ascent.
- The rescuer should maintain individual buoyancies such that the casualty is **always more positively** buoyant than the rescuer.
- The rescuer should attempt to pull the casualty's head back during the ascent, as this will help any expanding air in the lungs to escape. Squeezing the diaphragm is also beneficial in achieving the same result.
- If using an 'inflation' method of rescue, only inflate the buoyancy device/drysuit a small amount at a time until the ascent has started and then monitor the ascent rate carefully.
- Good access to the air dumping mechanism is essential so as to maintain a safe ascent rate. *Do not over dump,* as this might result in the rescuer and/or casualty descending towards the bottom.

Approaching the Casualty

- Victim may be conscious or unconscious: the latter case is more straightforward to deal with.
- If victim is panicking, wait until calm returns before intervening.
- Always approach the casualty from behind.

Recovering the Casualty

- If the rescue is performed underwater, then the casualty must first be brought safely to the surface.
- The normal method used is the ***buoyant lif***t (*see below) as it minimises the effort on the rescuers part.
    1. The rescuer should establish neutral buoyancy in both divers.
    2. The casualty should be firmly held in a position that allows close situation control and provides good access to **both** buoyancy control devices (or drysuits). A side/frontal position is preferred and eye contact can help in reassuring the victim.
    3. The ascent should be initiated by the rescuer gently finning upwards. Some air may be added to the casualty's BCD/drysuit to facilitate the initial rise off the bottom.
    4. As the ascent begins, any inflation ceases and preparations must be made to vent air from the BCD/drysuit. **The casualty must always be more positively buoyant than the rescuer.**
    5. Special vigilance, with respect to buoyancy control, is required in the region from 10m to the surface.
- Once the surface is reached, the casualty's BCD (**not drysuit**) may be substantially inflated.
- The distress signal should be given to the boat/shore.
- **Expired-Air Resuscitation (EAR)** must be given **immediately** if the casualty is not breathing or has breathing difficulties. The casualty's regulator and mouthpiece should be first removed and a firm hold re-established. The neck should be gently extended. EAR should be administered **mouth-to-nose at a rate of two breaths every 10 seconds.** Its delivery is greatly facilitated if the victim's body is tilted towards the rescuer.
- The casualty may be towed to the shore/boat by the rescuer. An unconscious casualty may be towed by the rescuer grasping the chin with one hand in an ***extended-arm tow,*** which maintains the neck extension, whilst the other hand is placed on the neck or shoulder-blades to steady the victim.
- Note that towing is a very strenuous activity, particularly in adverse conditions and/or when combined with EAR. The pace should be judged to fit the situation and the stamina of the rescuer. Some compromise may be necessary, but the **priority must be to maintain the administration of EAR** to a non-breathing casualty.
- Once the boat/shore is reached, the casualty should be removed from the water. Assistance should be given from boat/shore personnel, whilst the rescuer maintains control from the water. The victim's heavy equipment should be removed to make recovery easier.
- Once on the boat/shore, the casualty's condition should be carefully monitored and the emergency services alerted as necessary. The incident details should be recorded. EAR must be maintained for the non-breathing casualty and **External Chest Compression (ECC)** may be required if the victim's heart has stopped. A breathing casualty should be placed in the recovery position and kept warm until medical assistance arrives. Give O_2 and treat for shock**. Do not give anything by mouth.**

* Should a casualty's BCD or drysuit fail to provide sufficient buoyancy due to a malfunction or a shortage or absence of air, an alternative method of recovering the casualty to the surface must be considered i.e.

- ***The casualty's weight belt may be ditched.*** This will make the ascent nearly impossible to control.
- ***The rescuer's buoyancy is used to lift the casualty***. It is essential that the casualty is held firmly at all times, as a loss of contact will almost certainly result in irretrievable separation.
- ***The rescuer swims the casualty to the surface***. This is known as the ***dead lift*** method and can be very strenuous for the rescuer.

A rescuer must therefore decide on one of the above options and act accordingly, providing that they do not place themselves in serious danger.

Lifesaving &Artificial Respiration

1. Overview

The three basic objectives for rescuers are:

1. To preserve life
2. To prevent the condition worsening
3. To promote recovery

The task of the amateur lifesaver is to do the **minimum necessary** with whatever facilities are at hand and to achieve the above objectives until such time as professional assistance arrives.

The priorities for the lifesaver are:

- Remove the casualty from danger.
- Restore heartbeat, if stopped.
- Restore breathing, if stopped.
- Stop major bleeding
- Treat for any other conditions (e.g. decompression sickness).
- Treat for shock.
- Send the casualty for further professional treatment.

As noted from previous, any form of prolonged oxygen starvation will cause brain damage and eventual death. It is thus essential that all efforts be made to re-establish this crucial gas supply, by a combination of ***Expired-Air Resuscitation (EAR)*** and ***External Cardiac Compression (ECC).***

2. Expired Air Resuscitation (EAR)

EAR is a simple technique that allows a casualty's lungs to be ventilated with air from the rescuer's lungs. This is possible because the air that is expired still contains 16% Oxygen, enough to maintain life. The casualty will automatically expel this air, in turn, due to the natural elastic recoil of the rib cage.

EAR is an easy technique to apply and can be done with little training. It may be used in almost any situation and gives much greater and more controlled ventilation of the lungs than do other methods. It can be applied to persons of any age and does not place a heavy physical demand on the rescuer. EAR can be performed either **mouth to mouth**, or **mouth to nose**. The important issue in both cases is to form a good seal so that expired-air (EA) may be efficiently transferred

Assessing the Need for EAR

- The subject is not breathing.
- The victim's skin has a blue-grey appearance (**cyanosis**), particularly at the lips, ear lobes and nail beds.
- The pulse is erratic and slow.

Procedure

1. Supporting the head, **turn the casualty onto their back.**
2. If on dry land, kneel beside the casualty.
3. **Check for cardiac arrest** (see relevant section on next page).
4. **Open casualty's mouth and remove any debris**. Check also that the tongue has not been swallowed and therefore might impede EA delivery.
5. By exerting gentle pressure under the casualty's chin, **extend the neck to open the air route to the lungs.**
6. **Two full breaths of EAR should be given**, by either mouth-to-mouth (on land), or mouth-to-nose (in water).
7. **Examine the chest after each breath to ensure it is rising**. This implies that air is getting into the lungs.
8. If on dry land, it is best to remove any obstructions over the casualty's chest, i.e. ABLJ, or any tight clothing (e.g. drysuit neckseal) if it appears restrictive to breathing.
9. If any obstructions have been removed, give another two breaths.
10. **Check carefully for a pulse** (see relevant section on next page).
11. **Continue giving two breaths of EAR every 10 seconds**, until the casualty starts breathing on their own, or until expert help arrives.

- **Note 1**: the casualty may be sick during the above process. If this happens they must be moved onto their side, supporting and extending their head, until vomiting ceases. Their mouth must be cleared before continuing with EAR.
- **Note 2**: If the chest fails to rise, there may be an obstruction or other blockage. An attempt may be made to clear this by turning the casualty on their side and administering three sharp blows between the shoulder blades or, if this fails, by manual abdominal thrusts (casualty on back). Both of these methods may induce vomiting as per Note 1.

3. External Cardiac Compression or Heart Massage (ECC or ECM)

Administering EAR by itself is futile if the heart is not pumping the oxygen around the body. If the heart has stopped it must be restarted by using a compression technique to activate the muscle and re-induce blood circulation in the subject.

Assessing the Need for ECC

The casualty will normally exhibit the symptoms of respiratory failure already detailed.
Signs of cardiac arrest:

- ***The casualty has no detectable pulse.*** Check for the pulse by using the fingers, **NOT** the thumb, at the carotid artery in the throat (adjacent to the windpipe).
- ***The casualty's eyes are widely dilated*** and do not respond to light.
- ***The casualty is not breathing.***
- ***The casualty has an ashen pallor.***

Important Note: it is essential that the above diagnosis be as accurate as possible. If ECC is performed in error, on a functioning heart, it may be stopped. Other situations encountered in cold-water diving, such as hypothermia or the effects of drowning, may mask the presence of a pulse.

Procedure

1. Lay the casualty on their back on a firm surface.
2. **Check for a pulse**: see above
3. **Locate the base of the sternum** and place the heel of one hand (with the other hand on top) approximately two fingers width above this point.
4. **Pressure should be applied through a forward rocking motion** keeping the arms straight. The sternum should be depressed a distance of about 4-5cm for the average adult. Rocking back will release pressure on the chest and allow blood to fill the heart again.
5. **ECC should be combined with EAR** (known as ***Cardiopulmonary Resuscitation*** **(CPR))** and performed at a rate of about **15 compressions every 10 seconds**, interspersed with two breaths as before.
6. **Always continually check to ascertain if a pulse** has been re-established. **If a pulse is detected ECC should cease immediately.**

- **Note 1:** The force required for ECC is considerable - about half the bodyweight of the victim. This obviously implies that a **proportionally much reduced pressure** is necessary for children etc.
- **Note 2: Conducting CPR by oneself is extremely tiring**. Assistance should therefore be sought, with the two rescuers synchronising their efforts, one giving EAR and the other ECC.

Assessment

- Return of a spontaneous respiration and a strong, regular pulse.
- Change of appearance from blue-grey to a more normal skin colour.
- Pupils react to light i.e. contract.

Further Assistance

Dial 999, or broadcast a mayday on a VHF radio on channel 16. Ask for the coastguard and explain that there is a diving emergency. Give the casualty's symptoms, incident location and other information as requested.

Aftercare

Once the casualty has re-commenced full respiration, the following should be carried out.

1. Place casualty in the recovery position.
2. **Check regularly** to ensure that breathing (and heart activity) is maintained.
3. The casualty may be wrapped in something warm. **DO NOT** apply artificial heat.
4. Speak to the casualty and re-reassure them, if they are conscious.
5. Ensure that help is coming, but do not leave the casualty alone.
6. **DO NOT** give any food or fluids for at least two hours.
7. **The casualty must always be seen by a doctor, preferably at a hospital, where further observation can take place as necessary.**

Lecture 8
Principles of the Aqualung and Air Endurance

Aqualung Principles

The ‘aqualung’ or SCUBA (an acronym for **S**elf **C**ontained **U**nderwater **B**reathing **A**pparatus), is the main equipment with which safe underwater breathing may be carried out. Its invention is credited to the late diving pioneer, Jacques Cousteau, who developed the first apparatus for self-contained underwater breathing in the late 1940’s. The ***set*** comprises a **cylinder** of breathing air under high pressure, which is subsequently reduced to ambient pressure through the **regulator**. Other parts of the aqualung are the **O-ring, backpack**, **protective mesh**, **handle** and the **cylinder boot**.

The Cylinder or Tank

General
Cylinders store compressed air at extremely high pressure. They are conventionally made from **steel** or **aluminium alloy** and come in various colours, sizes and working pressures. Due to the high pressures present within a tank**, great care** must be taken in handling and storage.

Steel cylinders have a thin wall of 4-5 mm thickness. Aluminium alloy tanks have thicker walls of around 11 mm. However, for the same cylinder capacity, the steel tank will probably be lighter due to this thickness variation, even although aluminium alloy is actually a lighter material. As a further result, the aluminium tank will also be bulkier. Steel tanks normally change from substantially negatively to slightly negatively buoyant between full and empty (note that air weighs 1.2 grams per litre). Aluminium tanks will change from slightly negatively to positively buoyant over the same range. This is an important factor when considering the amount of weight to be carried on the weightbelt.

Steel tanks are more prone to test failure due to corrosion as they suffer from a progressive ‘rusting’ process. Aluminium tanks are affected by oxidation, which results in the formation of a coating which arrests the corrosive action, so preventing further deterioration. Both types can be painted to offset these corrosion effects and to act as a visible indicator underwater. Yellow and white are popular colours.

A steel cylinder has a ***rounded bottom*** due to the process of manufacture. This means that it must be fitted with a rubber ‘boot’, in order that it may stand upright. An aluminium cylinder has a ***flat bottom*** and may or may not be fitted with a boot. Either type, if left standing unattended, should be placed on its side as a safety measure.

Aluminium is a softer material than steel and, consequently, is more prone to superficial damage. First-stage cylinder, or pillar, valves are normally made of brass which can corrode into the aluminium, due to electrolytic action. This can cause seizure of the valve in the cylinder threads unless it is periodically removed and cleaned.

The **capacity**, **working pressure** and **material** used in manufacture classify a cylinder. **Working Pressure (WP**) is the operational pressure of the cylinder, measured in BAR. Tanks usually have working pressures in the range 150-232 BARS, although some newer types can take up to 300 Bar. Cylinder capacities (termed their ‘**water capacity**’, in litres) range from 0.7L (emergency BCD cylinder) to 18L (extra large main diving cylinder).

Cylinders are normally fitted with a plastic mesh, to protect their outer surface from damage. To aid transportation, cylinders may have a handle fitted underneath the pillar valve.

Tanks when filled will heat up. Therefore it is important to fill tanks as slowly as practicable to maximise the available air, due the variation of pressure with temperature. Fully charged cylinders should not be stored in an environment that can be exposed to high temperatures e.g. a car boot or standing in direct sunlight for any length of time.

Cylinder Regulations
Cylinders made in the UK have to meet the requirement of BS 5045 Part 1 (steel) or Part 3 (aluminium alloy). All cylinders must carry markings on their ‘shoulders’. Typical markings are:

- **Manufacturer's Mark and Serial Number**
- **Specification (i.e. BS 5045 Part I or Part 3)**
- **Date of Manufacture and other test dates**
- **Water Capacity (WC) or Volume (VO)**
- **Cylinder Weight**
- **Working Pressure (WP)**
- **Test Pressure (TP)**

Cylinders must be **visually inspected every two years** from new and **hydraulically tested every four years**, by suitably-qualified persons, at a special test station.**This is a requirement for all diving cylinders, including small emergency cylinders (which are often neglected). It is illegal (and dangerous) to fill a cylinder which is out of test.**

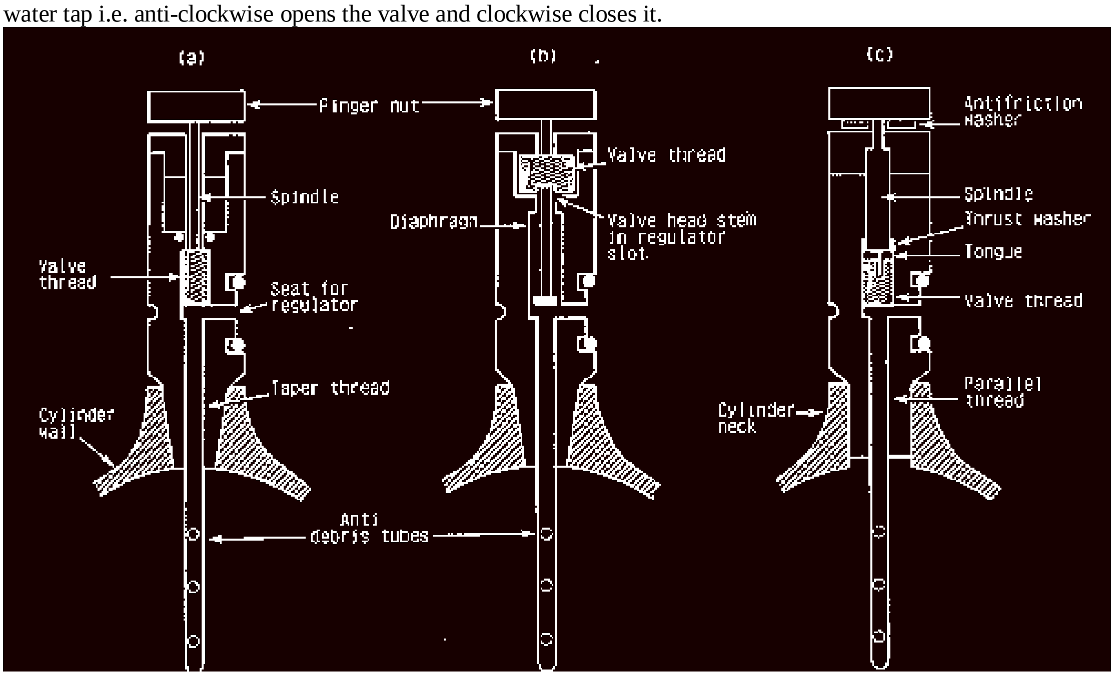
In a visual inspection, the cylinder is inspected internally and externally for damage, scores, pitting, corrosion and thread damage, all of which can cause failure. Light corrosion may be removed by special cleaning processes.

The hydraulic test consists of measuring the cylinder diameter when empty, filling it with water and then hydraulically pumping it up to its **Test Pressure**. The **expansion** of the cylinder is measured. When the pressure is released the expansion should return to normal. If the permanent expansion is **more than 5 % of the diameter,** the cylinder will fail the test.

Satisfactory performance in all aspects of the test means that the cylinder is fit for further use and it will be issued with a ***test certificate*** and the shoulder of the cylinder will be ***stamped with the date of test*** and the test house stamp. The BS 5430 regulation requires that the test house destroy any cylinder which fails the test.

Cylinder Valve

The cylinder valve (cross flow or pillar valve) is screwed into the cylinder neck with either a parallel thread, sealed with an O-ring, or on older tanks with a taper thread sealed with PTFE tape. It is normally opened and closed like a water tap i.e. anti-clockwise opens the valve and clockwise closes it.



Pillar Valves: (a) Unbalanced; (b) Glandless; (c) Balanced

The most common type of contemporary pillar valve is the ***balanced*** type. This type is so termed due to the action of high pressure air on both sides of the valve when it is in the open position.

The other types may be encountered on older cylinders: the ***unbalanced*** type has high pressure air acting on the inner valve and so is difficult to open or close when the tank is full; the ***glandless*** type is similar but is designed such that there is less wear on the valve parts. All valves have an ***anti-debris tube***, which extends deep into the cylinder and so prevents dust, rust etc. from reaching the valve mechanism when the cylinder is inverted.

An O-ring is used to form a seal so that the diving regulator can be connected to it using an A-Clamp, or for higher pressure (up to 300Bar), a screw DIN clamp. The O-Ring should always be inspected for damage prior to connecting the A-clamp.

In operation the valve should be opened fully anticlockwise and turned back a quarter turn. When closing the valve, excessive force should not be used as this can damage the valve seat. If there is any stiffness in the operation of the valve or it fails to turn off or on properly, then the equipment officer or other experienced person should be informed.

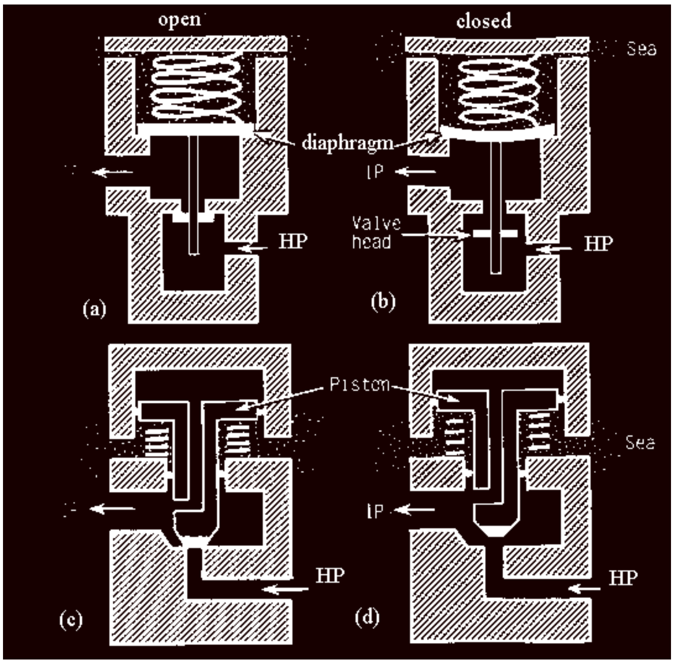
Note: The screw DIN fitting is the standard connection in some countries, so when travelling abroad it is important to establish ask what type of tank fittings are employed if it is intended to use a UK-pattern regulator.

The Demand Valve or Regulator

The demand valve (or regulator) supplies air to the diver on demand i.e. when required. All modern regulators reduce air from cylinder pressure to ambient pressure in two stages and are therefore called **two stage** regulators. They may be ***balanced*** or ***unbalanced*** by design.

The **first stage** is attached to the cylinder and is normally constructed from plated brass. The **second stage** is the part which contains the breathing mechanism and is made of a lightweight durable material (e.g. plastic). Both valves operate in relation to the ambient pressure and the pressure downstream of the valve.

<u>First Stage Valves</u>



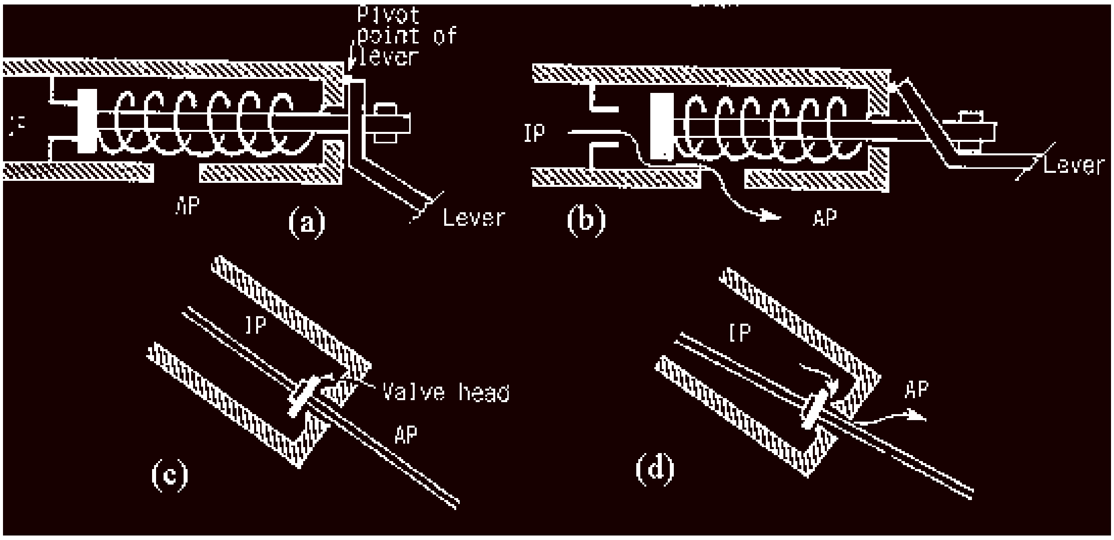
First stage valves in open & closed modes: (a) and (b) show the diaphragm type; (c) and (d) show the balanced (or piston) type

When the diver inhales the pressure in the intermediate hose drops allowing the first stage valve to open and air then flows from the cylinder into the intermediate hose until the pressure reaches a pre-set level of around 5 to 12 bar above ambient.

The ***diaphragm*** type first stage operates simply by allowing the drop in **intermediate pressure (IP)** to lift the valve, allowing air to flow from the **high pressure (HP)** side to the IP outlet. However, as the IP rises, the valve is returned to its seat and the airflow ceases. This is an ***'upstream'*** type valve.

In the more modern ***balanced*** configuration, both ends of the valve stem are exposed to IP air. This results in less force being exerted on the valve stem as it is returned to the seat. Water, at ambient pressure, pushes the valve away from its seat as the diver inhales, so allowing air to pass through. This configuration is fail-safe by design and consequently modern regulators of this type are highly reliable. In the event of a component failure, the system would revert to free-flow operation (i.e. continuous air).

Second Stage Valves



Second stage valves: (a) and (b) show piston types; (c) and (d) are tilt valve mechanism

When the diver is not inhaling the pressure inside the mouthpiece is the same as the pressure outside and the second stage valve is closed. When the diver inhales the pressure inside the mouthpiece drops slightly and the second stage valve opens allowing air to flow to the diver. When the diver exhales the pressure increases inside the mouthpiece and the exhaust valve opens allowing the expired air out.

The above shows (a & c) the valve closed and the (b & d) the valve open situations for both types. Both valves operate by virtue of a large thin diaphragm, which senses the difference between the ambient water pressure and the diver's inhalation or exhalation pressure.

The modern configuration is the ***piston*** type. It operates when a lever attached to the diaphragm is moved by the inhalation action. This pulls the valve against the spring and allows air to pass through to the mouthpiece. Exhalation causes the diaphragm to move outwards and allows the lever and spring to close the valve

In the ***tilt*** valve, the diaphragm acts directly on the valve stem, which is rocked by the inhalation/exhalation action, so opening and closing the valve. In high-performance second stage valves, the diaphragm may be replaced by a metal piston, which can be ***balanced*** as with the comparable first stage valve. Some ultra high-performance regulators even offer servo assisted breathing.

The first stage on a regulator will have high pressure (HP) and intermediate or low pressure (IP)/(LP) outlets. The cylinder contents gauge is connected to a HP outlet. The IP outlets are for connecting the second stage, an **octopus rig** (a spare second stage) and **direct feed** hoses for ABLJ's, drysuits etc.

All second stage regulators have a **purge button** that may be depressed to manually open the air inlet valve. This can be used to test the device prior to diving, to expel water and debris from inside the second stage and to relieve the inter-stage pressure prior to disassembly of the aqualung. Th exhaust valve location varies with different regulator types, but is conventionally at the bottom of the mouthpiece and angled away from the diver's field of vision.

Aqualung Care and Maintenance

Cylinders

The outside of the cylinder should be rinsed in clean, fresh water after use. The pillar valve may be momentarily opened to discharge any water from the air outlet point. Never store cylinders empty, as this will allow corrosion to flourish. A pressure level of 50 Bar is adequate. Tanks should be **stored** in an upright position, as this will allow any moisture to gather at the bottom. Inspect the O ring regularly and replace if it shows any sign of damage.
Whilst transporting cylinders, care should be taken not to damage the outer surface in any way, through improper handling or movement during carriage. Transportation by air requires that cylinders must be empty of air, which is an undesirable state. It is rarely necessary, however, as dive centres abroad normally have an adequate supply of tanks for hire.

Regulators

The regulator is an essential piece of life-support equipment and, consequently, it is imperative that is maintained in first rate condition. Avoid dropping it or placing in sand etc. It must be rinsed carefully with clean, fresh water after diving and the ***dust cap*** replaced over the first stage inlet when diving is completed. Air from the cylinder may be used to blow away water and debris from this inlet, prior to fitting the dust cap.
It is highly recommended that a specialist technician services the regulator at regular intervals (annually for a regulator in active use). HP and IP/LP outlet hoses should be inspected periodically and replaced if they show any signs of damage, bulging or perishing. ***Hose protectors*** are useful in protecting the metal unions at the hose ends and to reduce the amount of bending at these points.

Air Endurance

The amount of air that a diver breathes in a minute is affected by:

- **Lung capacity**
- **Amount of effort being expended**
- **Current depth**
- **Mental state**
- **Physical fitness**
- **Diving experience**

Normal air consumption, for an average person at rest on the surface, is approximately 10 litres/minute. For an average person swimming on the surface, the rate may be considered to be around **25 litres/minute**. It should be noted that all air endurance evaluation should be regarded as **a rough guide only.**

Since pressure increases by 1 Bar for every 10 metres of water, so air consumption increases with depth i.e.

Consumption Rate (l/min)	**Depth (metres)**				
	10	**20**	**30**	**40**	**50**
20	*40*	*60*	*80*	*100*	*120*
25	*50*	*75*	*100*	*125*	*150*
30	*60*	*90*	*120*	*150*	*180*

Thus, at 30 metres, an average diver would require **4 Bar x 25 l/min = 100 l/min** of air.
If it was intended to spend 15 minutes at this depth, then **15 min. x 100 l/min = 1500 litres of air** would be required.

A diving cylinder has a fixed amount of air contained within it. This amount is dependent on the capacity of the cylinder and the pressure of the air within. The **maximum capacity** of such a cylinder would be:

Water Capacity x Maximum Working Pressure = Total Air Capacity

For example, a 15 litre cylinder at its maximum working pressure of 232 Bar would contain:

15 l x 232 Bar = 3480 litres of air

If the cylinder is not at its maximum WP, perhaps due to having been used on a previous dive, then the air it contains will be given by:

Water Capacity x Gauge Pressure = Available Air

Thus, if the contents gauge read 100 Bar, then the cylinder would contain:

15 l x 100 Bar = 1500 litres of air

These calculations can now be used to assess the amount of air that is required for a particular dive:

<u>Example 1</u>
Assume a dive is to be undertaken to 26 metres with 20 minutes total dive time. How much air is required?

25 litres/min. x 3.6 Bar x 20 minutes = 1800 litres

As this would give only just enough air for the dive, it is necessary to have a reserve supply of approximately 25% of the cylinder's capacity. Thus the total air required is:

1800 litres ÷ 0.75 = 2400 litres

If a 12 litre cylinder was available and was charged to 232 Bar, this would give:

12 litres x 232 Bar = 2784 litres

which is adequate for the dive in question.

<u>Example 2</u>
A dive is planned to 30 metres. What would be the maximum dive time if a 12 l cylinder at 200 Bar was available?

Lecture 9

Decompression Sickness and its Avoidance

Introduction

As a direct consequence of human beings breathing compressed air for more than two centuries, a unique record of the effects of the **potency** of **pressurised nitrogen** and the **toxicity** of **pressurised oxygen** has been complied.

Of these afflictions, the most common and yet imperfectly understood is **decompression sickness (DCS),** which occurs as a result of prolonged exposure to **pressurised N_2**. The affects of this aliment were first noticed in 1877, after workers involved in the construction of the St.Louis Bridge complained of pains in their joints. This resulted in these individuals walking with a slight stoop, which was similar to a posture adopted by fashionable women of the time. This affectation was known as the 'Grecian bend' and has given the illness its familiar name – **the 'bends'**.

Inert Gas Absorption and Elimination

Around the same time that the effects of DCS were first noticed, it was also observed that people exposed to hyperbaric (high-pressure) air behaved as if intoxicated by alcohol. This condition is now known as **Nitrogen Narcosis.**

To consider fully the effects of these conditions on the diver, it is first necessary to understand the effects of inert gas absorption and release in the human body.

Gases are soluble in fluids, therefore it may be stated that the amount of gas that dissolves in a fluid, termed its **solubility**, is dependent on:

- **The partial pressure of the gas in contact with the fluid (Henry's Law).**
- **The nature of the gas.**
- **The nature of the fluid.**
- **The temperature of the fluid.**

From the above, it should be noted that all factors may be regarded as variable. The partial pressure of the gas will **vary with depth of water**, the nature of the gas is dependant on the **type of gas** in question, the nature of the fluid varies with different **fluid-based body tissues** and the temperature of the medium (water) varies with season, weather etc. In essence, only the latter factor can be considered near constant.

In the case of N_2, some body tissues will absorb and release the gas more rapidly than others and thus become saturated sooner. This **differing rate of absorption depends on the fat content of the tissue and the blood supply** to it. Therefore, tissues with a **high blood supply and low fat content** (e.g. the brain, heart, muscles etc.), will **saturate very quickly**, whereas those with a **high fat content and poor blood flow** (e.g. cartilage, tendon etc.) will **saturate slowly**. These two tissue types are termed **'fast'** and **'slow'** respectively.

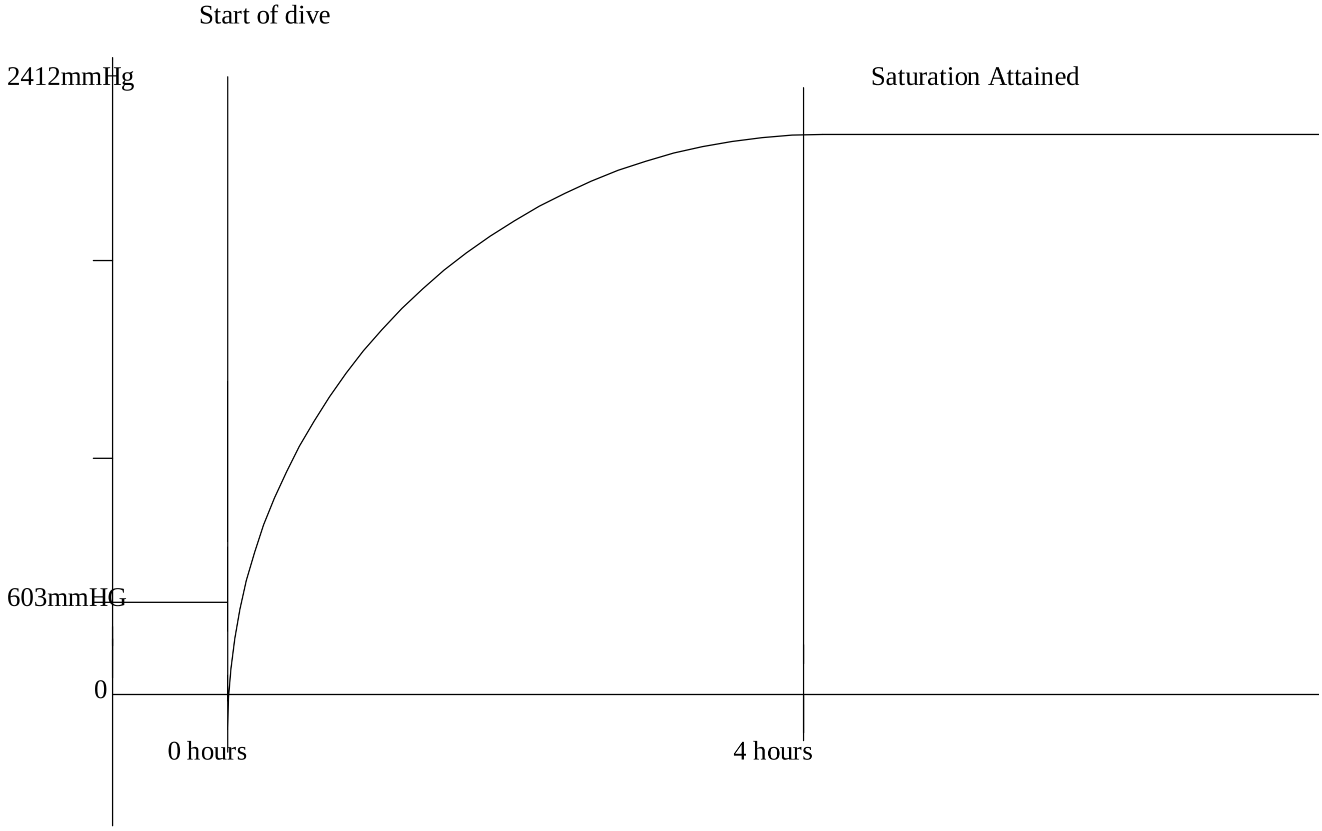
Furthermore, N_2 becomes more soluble as temperature decreases and exertive activity, which increases the respiratory rate, delivers extra N_2 to the body tissues.

The table below shows the **solubility and diffusibilty** of various gases in water:

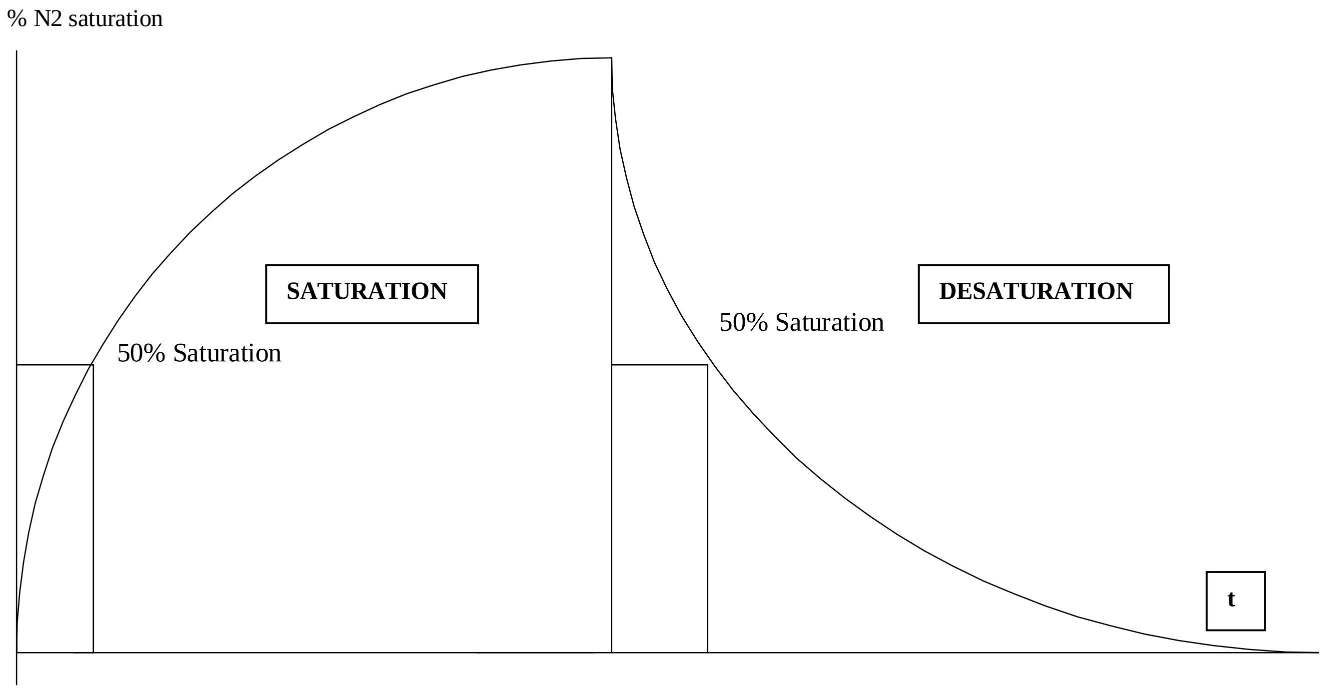
GAS	SOLUBILITY	DIFFUSIBILITY
Nitrogen	0.0127	2.01
Oxygen	0.0241	2.2
Helium	0.0087	5.9
Argon	0.028	2.22
Neon	0.0096	2.01

Note that the **diffusibility** of a gas is its ability to move from one medium to another (e.g. a fluid to air).

The diagram below shows the rate at which N_2 saturation is approached in a dive to 30m depth. Before the dive the body is saturated with N_2 at a partial pressure of 603mmHg. When the dive starts at 0 Hours (the diver is assumed to reach 30m immediately and remains at that depth for the duration of the dive). The divers body is unsaturated at this point because of the increase in ppN_2 in the breathing gas to 2412mmHg, but as time passes the diver absorbs more and more N_2 (as shown by the curve) until the ppN_2 in the body reaches 2412mmHg and the diver is again saturated with N_2.



At the end of a dive the reverse process occurs. As the ambient pressure is reduced the partial pressure in the lungs decreases. The blood now has a higher N_2 level than the air in the lungs, so N_2 passes from the blood into the lungs and is expired. This process continues as the blood, with it's continually reducing N_2 level, passes through the body tissues and collects N_2 from them. As already stated, some tissues will release their N_2 more slowly than others. This process is illustrated below.



Note that from the previous diagram that the **time** to reach **half saturation** point is **shorter** than the time taken to reach **half desaturation** point. If the ascent is made slowly enough then the pressure gradient between the N_2 in the tissues and the N_2 in the breathing gas is not excessive (< 2:1) and no gas bubbles form. It may be necessary to stop on the ascent so as not to exceed this differential. However, if the ascent is made too rapidly, then the pressure gradient of N_2 may reach a level where the blood or particular tissues are said to be **supersaturated.** At this point dissolved gas will begin come out of solution and form bubbles.

N_2 Narcosis

This complex phenomenon is thought to occur as a result of pressurised N_2 exerting a force on the nerve cells in the brain. It impairs the transmission of impulses in the central nervous system and effects all divers at depths **greater than approximately 30m.**

The symptoms of N_2 narcosis are over confidence, impaired reasoning, confusion, giddiness, delayed response to signals and euphoria. At extreme depth unconsciousness and death will occur**. These effects are exacerbated with alcohol, fatigue, heavy exertion, poor visibility and cold.** There is considerable variation in individual susceptibility to N_2 narcosis and it is possible to develop a tolerance to its effects by repeated exposure to depth

The effects of N_2 narcosis are immediately relieved by ascending to a shallower depth, after giving the appropriate signal to his/her buddy.

DCS: Symptoms

As already established, rapid ascents will cause bubbles to form in body tissues due to the high N_2 gradient between them and the breathing gas. These bubbles can form in any part of the body and cause damage to tissues and blood vessels. The effects of this are known as decompression sickness.

DCS is classified into two types:

- **Type 1: pain in and around the joints, skin itching and rashes.**
- **Type 2: numbness, paralysis, respiratory difficulties, impaired vision, unconsciousness and death.**

Type 2 DCS is the more serious case as it represents damage to the **Central Nervous System (CNS).** In many cases the damage caused is irreparable and can be fatal e.g. bubbles in the lungs – known as a gas embolism or **'the chokes'.**

These symptoms typically appear after the diver has surfaced, usually within one hour after the end of the dive. However, in some cases symptoms may not develop until more than 24 hours after the dive terminated.

The likelihood of DCS occurring is influenced by: rate of ascent (slow is best); repetitive diving; deep diving; flying (or ascending to a higher altitude) after diving; CO_2 level; exertion; fitness level; obesity; PFO presence; fatigue; anxiety; cold; alcohol; drug use and dehydration. The probability of its occurrence is reduced by repeated exposure to depth.

DCS Treatment

The definitive treatment for decompression sickness is immediate recompression in a designated chamber, followed by gradual decompression. This prevents the formation of any additional gas bubbles and reduces in size those that have already formed. To aid this process, the casualty breathes as high a partial pressure of O_2 as is possible.

This treatment can only be carried out in a specially equipped medical centre with a recompression chamber and staffed by qualified personnel. **Under no circumstances should recompression be attempted by the diver re-entering the water.**

In terms of first aid at the diving site, it is essential that the authorities are alerted as soon as possible. This involves contacting the coastguard, either by VHF radio or by dialling 999. The coastguard will ask for details of the symptoms as well as precise aspects relating to the dives performed. The strategic accident management will then be in the hands of the specialists.

The casualty should be kept warm and laid flat with the feet slightly raised and, if possible, O_2 should be administered. Mild pain relieving drugs may be given (e.g. aspirin) Note that the divers buddy is also at risk of developing DCS. He or she should be closely monitored and may be required to accompany the affected diver to the recompression chamber.. **These first aid measures in no way replace the expert treatment of DCS by recompression.**

Decompression Tables

Decompression tables are a set of tables used to plan a dive. The tables that are used by the Scottish Sub Aqua Club are the **Buhlmann** tables. There are several other types available, such as **RNPL** (Royal Navy Pressure Limits) tables and the **BSAC-88** tables, all of which differ slightly, although the general principle is the same**. Dive Computer**s may also be used to plan dives and calculate decompression requirements.

Instructions are provided with each set of tables. To use the tables correctly some key terms must be defined:

Dive time — The total duration of the dive i.e. the time from leaving the surface to regaining the surface at the end of the dive.

No Stop Time — The maximum time that a diver can spend at a given depth, without incurring any decompression stop time.

Surface Interval — The time spent on the surface between the end of one dive and the start of another.

Bottom Time — The time between leaving the surface at the start of the dive and commencing the ascent to the surface (normal profile)
OR
The time from leaving the surface to reaching the 9m mark at the end of the dive (irregular profile).

All decompression tables work on a square profile basis. A square profile dive assumes that the diver descends directly to the deepest part of the dive and remains there until the ascent begins. Figure 1 shows an example of a dive which falls into the second category of definition of bottom time i.e. time from the surface until 9m. Figure 2 shows an example of a square profile dive and Figure 3 illustrates a square profile dive with two decompression stops.

Figure 1

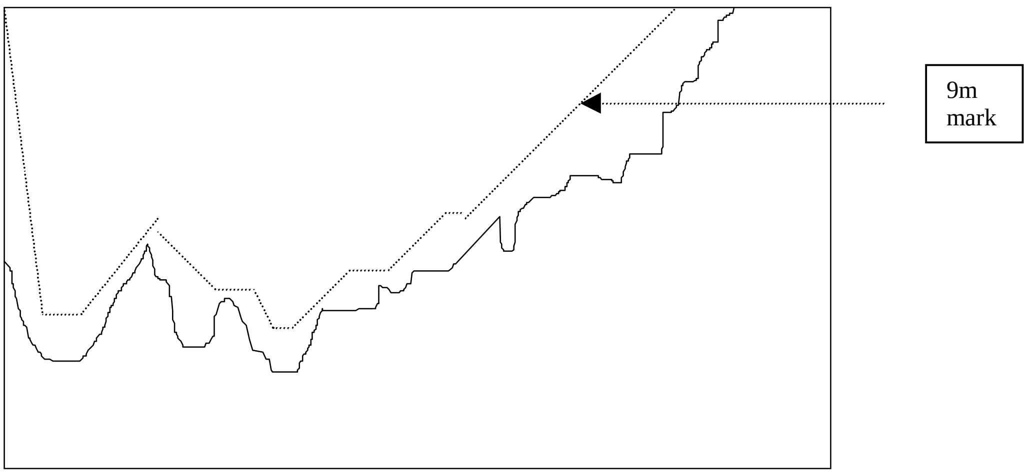


Figure 2

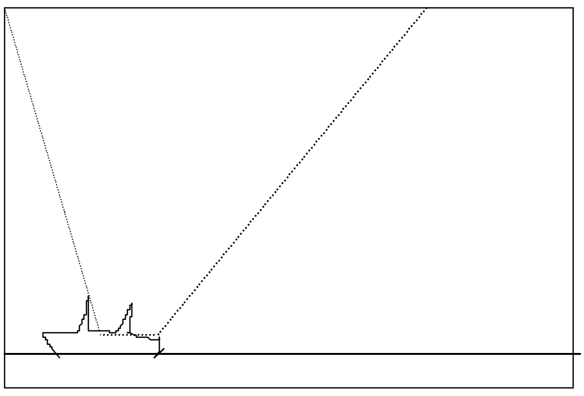
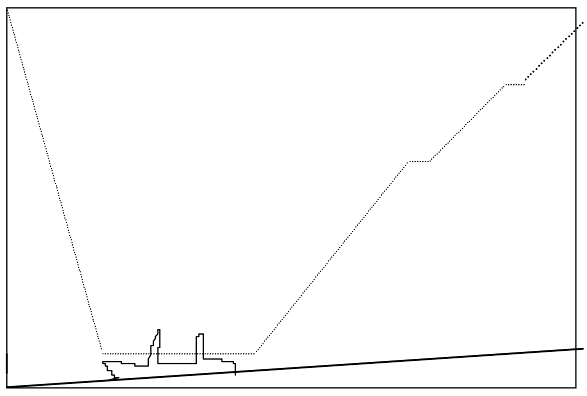


Figure 3



Buhlmann Air Decompression: Table 1

Depth (m)	Bot.Time	Stop 9	Stop 6	Stop 3	RGL		Depth(m)	Bot.Time	Stop 9	Stop 6	Stop 3	RGL
12	125			1	F		**33**	14			1	D
	150			4	G			20			4	E
	180			10	H			25		2	7	F
	210			17	H			30		4	11	G
	240			23	K			35		6	17	G
15	75			1	G			40	2	8	23	G
	90			7	G			45	4	11	28	H
	105			10	H			50	5	15	31	H
	120			16	H		**36**	12			1	D
	150			27	H			15			3	D
	180			39	K			20		2	5	E
18	51			1	F			25		4	9	F
	60			5	F			30	2	5	15	G
	70			11	G			35	3	8	18	G
	80			18	G		**39**	10			1	D
	90			21	H			15			4	E
	105			27	H			20		3	7	F
	120		2	35	K			25	2	4	12	G
21	35			1	E			30	3	7	18	G
	40			2	E			35	6	10	23	G
	50			8	F		**42**	9			1	D
	60			16	G			12			4	D
	70			24	H			15		1	5	E
	80		2	26	H			18		4	6	F
	90		6	30	H			21	2	5	10	F
	105		11	38	K			24	3	6	16	G
	120		17	44	K			27	4	7	19	G
24	25			1	E		**45**	9			3	E
	35			4	F			12			5	E
	40			8	F			15		3	5	E
	50			17	G			18	2	4	9	F
	60		4	24	G			21	3	5	13	G
	75		10	29	H			24	4	6	18	G
	90		16	39	K		**48**	9			3	E
	105	3	23	45	K			12		2	5	E
27	20			1	E			15		4	6	F
	30			5	F			18	3	4	10	F
	35			10	F		**51**	9			4	D
	40		2	13	G			12		3	6	E
	45		3	18	G			15	2	4	8	F
	50		6	22	G			18	4	5	13	F
	60		11	26	H		**54**	9		1	4	D
	75	2	18	36	H			12	1	4	6	E
30	17			1	D			15	3	4	10	F
	25			5	E		**57**	9		2	5	D
	30		2	7	F			12	2	4	8	E
	35		3	14	G							
	40		5	17	G							
	45		9	23	G							
	50	1	10	28	H							
	60	3	13	35	H							

All times in minutes **RGL: Repetitive Group Letter**

Dives requiring decompression stops below 12m are not tabulated. **<u>Ascent rate: 10m/min</u>**

Table 2: Surface Interval Table

								N_2 Unload (hrs)	Fly After (hrs)
							A	2	2
						B	20	2	2
					C	10	25	3	3
				D	10	15	30	3	3
			E	10	15	25	45	4	3
		F	20	30	45	75	90	8	4
	G	25	45	60	75	100	130	12	5
H	50	65	95	130	180	240	340	24	7
K	180	240	300	360	420	480	560	39	14

Note: all times in minutes unless otherwise stated

Table 3: Residual Nitrogen Time

Next Dive Depth (m) →	9	12	15	18	21	24	27	30	33	36	39	42
A	25	19	16	14	12	11	10	8	8	7	7	6
B	37	25	20	17	15	13	12	11	10	9	8	7
C	56	37	29	25	22	20	18	16	14	12	11	10
D	81	57	41	33	28	24	21	19	17	15	14	13
E	105	82	59	44	37	30	26	23	21	19	17	16
F	130	111	88	68	53	42	35	30	27	24	21	19
G	154	137	115	91	72	57	47	40	35	31	27	25

Instructions For Use

1. Select the planned depth in Table 1 and then locate the corresponding desired bottom time. If the planned depth is not tabulated, choose the **next deepest** value. Similarly, if the desired bottom time falls between the tabulated figures, select the **greater time**. Read along the row to find the decompression requirement for the dive.

2. To calculate a **repetitive** dive (**maximum 3 dives per day**), take the RGL code (this is the nitrogen loading from the preceding dive) from the previous dive and enter Table 2 at the corresponding **row** (i.e. at the same letter). Read along this row until the time that relates to the **surface interval** (i.e. the time since the end of the first dive) is reached. If the ***actual*** time of this surface interval falls between two tabulated row values, choose the **smaller number** (i.e. the smaller interval). Read **upwards** in the **column** to find the entry letter code for Table 3.

3. Enter Table 3 at the row letter from the previous stage. Read along this row until the **column intersection point** with the **planned depth** for the next dive is reached. If the required depth falls between the two tabulated values, select the **lower value** (this will carry the greater penalty). This **penalty time** must now be **added** to the intended bottom time for the dive being planned.

4. Re-enter Table 1 and assess the decompression requirements for the depth, bottom time and **penalty** in question for the next dive.

Summary

- Use Table 1 to calculate the decompression requirements for the planned dive, based on the depth and bottom time. Obtain the RGL for the next dive.
- Use the RGL in Table 2 to establish the entry letter for Table 3, based on the surface interval.
- Use Table 3 to evaluate the penalty from the previous dive. Add this to the intended bottom time for the next dive and calculate decompression requirements as previously. If this dive is required to incur only the ***minimum*** decompression time (i.e. 1min @ 3m), then this penalty time must be **subtracted** from the minimum available bottom time for that depth. This is now the new bottom time for a minimum decompression dive.

Buhlmann Tables: Examples

Example 1

(a) Dive A is to be to 30m with 15 minutes of bottom time. Calculate the decompression requirements.
(b) Dive B is to be conducted to a depth of 27 m, following a surface interval of 38 minutes from the end of A. Only the minimum decompression requirement is to be incurred. Calculate the available bottom time for this dive.

Example 2

A dive starts at 09.00 and has a maximum depth of 32 m with a bottom time of 28 minutes. At what time will the divers surface after following the correct procedures?

Example 3

Following 2 above, the divers re-enter the water at 12.00 for a dive to 25m, with an intended bottom time of 23 minutes. Calculate the decompression requirements.

Lecture 10
Maintenance of Diving Equipment
&
Open Water Dive Procedure

Maintenance of Diving Equipment

1. General Equipment Maintenance

What is meant by equipment maintenance?

Equipment maintenance means maintaining all diving equipment in a safe working condition. This involves:

- Cleaning
- Repair and Maintenance
- Storage

Why is it necessary?

Diving equipment is regularly submerged in salt water, so unless it is properly cleaned, maintained and stored, it will start to decay or rust and become unsafe. Chlorinated water, as in the swimming pool, or dirty freshwater will have a similar effect. Equipment maintenance is therefore necessary to:

- Keep the equipment in safe working order.
- Prolong its operational lifetime.

How and when should it be done?

In general

- Avoid exposure to hydrocarbons such as oil, petrol, grease, suntan lotion etc.
- Avoid contact with underwater obstacles (e.g. abrasive rocks, wrecks etc.) and sand/grit.

After every dive

- Wash in plenty of clean fresh water to:
  - Prevent salt building up
  - Remove sand and grit
- Allow to air dry
- When dry, store in a cool dry place, preferably in darkness (silicone decomposes in sunlight).

After every few dives

- Perform regular visual inspection and check:
  - Generally for signs of wear and damage.
  - Rubber straps and hoses for sign of perishing (‘cracking’ effect)
  - Webbing and suit seals for signs of fraying.
  - Buckles for correct operation.

2. Specific Equipment Maintenance

Demand Valves

An essential piece of life-support equipment: thus should be maintained with particular care.

- At the end of each dive, carefully use HP air from the cylinder to blow away water and debris from the first stage inlet.
- Replace the dust cap on the first stage before washing / storing.
- Rinse carefully after every dive, preferably soaking overnight in fresh water.
- Servicing is recommended every year by qualified technicians, or after every 50 dives, whichever comes first.
- Check carefully for damage to hoses, mouthpieces and direct feed connections.

ABLJs and Stabjackets

- After use, rinse the inside as well as outside with clean fresh water.
- Periodically rinse the inside with a weak disinfectant solution to kill any bacteria.
- Check for leaks before and after every dive.
- Treat the Emergency Air Cylinder (EAC) the same as a main cylinder.
- Re-grease the purge button on EAC after every 15 or so dives.
- Inspect webbing regularly for damage e.g. caused by the weightbelt rubbing.

Tanks

- Always fit a boot.
- Fit a cover, either webbing or neoprene, to prevent damage to the external finish.
- Maintain paintwork.
- Do not overtighten pillar valve
- Check the condition of the o-ring before and after every dive.
- Servicing is required by law every two years (see test date)
- Never completely empty a tank.

Drysuits

- Close zip and wash outside of suit after every dive
- Check all seams and seals regularly for deterioration
- Dust neck and wrist seals with talc after rinsing and drying.
- Keep the zip clean and lubricated, using beeswax or special zip cleaner/lubricant.
- Check inflation/dump valves for correct operation.
- Avoid contact with hydrocarbons, which cause perishing of seals
- Avoid folding, especially zip, during storage. Hang to store.

Wetsuits

- Wash suit inside and out in fresh water
- Dry the suit completely, avoiding direct sunlight.
- Clean and lubricate zips.
- Examine the suit regularly for tears and damage.
- If possible, avoid folding – hang like a drysuit, or lie flat.

Torches

- If using rechargeable batteries, follow the recommended maintenance schedule
- Apply silicone grease to o-ring on a regular basis.
- Do not use for extended periods of time out of water.

3. Conclusions

- Maintaining all items of diving equipment is essential to ensure safety.
- Wash equipment in clean fresh water after every dive, air dry and store away from direct sunlight.
- Follow appropriate maintenance/service schedule.

Open Water Dive Procedure

The following are guidelines for open water diving. Individual Clubs may operate slightly different procedures.

1. Pre-Dive Preparation

This is a briefing session, in which dive groups (normally pairs of divers) are formed and Dive Leaders appointed. The order of diving and the responsibilities of the individuals concerned are established (i.e. Dive Marshal, Safety Officer, Shore Cover etc.) The details of the site are discussed: depth; bottom terrain; tidal influences; dive time; anticipated visibility; exit and entry points; other hazards etc. The current weather conditions are taken into consideration: this may cause a major change to the intended diving and necessitate the usage of an alternative dive plan.

2. Equipment

A useful method to remember what equipment is required is to consider the various categories:

***Protective equipment*:**	Drysuit/wetsuit, boots, gloves, hood, swim trunks or swimsuit, undersuit.
***Basic Equipment*:**	Mask, snorkel, fins
***Safety Equipment*:**	ABLJ or STAB Jacket, knife, weightbelt, depth gauge, watch.
***Breathing Equipment*:**	Cylinder, harness, Demand Valve
***Ancillary Equipment*:**	Surface Marker Buoy (SMB), compass, torch etc. (as required)

Check the equipment as it is gathered it and pack it logically into a suitable bag. It is also important not to forget the vital after dive items - food, hot drinks, warm clothes, waterproofs, towel, log book/training schedule and some money!

3. Kitting Up

The order for kitting up will vary due to a number of factors e.g. depending what equipment is being used. However a standard sequence would be:

- Charge and fit the emergency ABLJ/STAB cylinder.
- Attach the STAB jacket to the main cylinder, checking the cylinder O ring at the same time.
- Fit the regulator to the STAB/cylinder.
- Turn the air on slowly and check the cylinder contents.
- Check the operation of the regulator by breathing from it.
- Turn the air off and verify that there are no leaks in the system.
- Put on the diving suit.
- Fit all ancillary equipment
- Fit the weight belt.
- Turn on air and fit the STAB jacket and cylinder.
- Ensure that all straps are free of twists and that the weight belt buckle is easily accessible.
- Fit the mask, fins and snorkel just prior to commencing the dive.

4. Buddy Checks

This is an essential aspect of safe diving. It is normally the last opportunity to visually appraise the dive partners equipment and finalise the conduct of the dive. This final buddy-to-buddy briefing, led by the Dive Leader or instructor, covers the following and is characterised by the mnemonic **SEEDS**:

SAFETY: breathe normally/ avoid over-exertion/ ear clearing/underwater hazards/ boats and surface hazards/ tidal effects/ separation and emergency procedures.

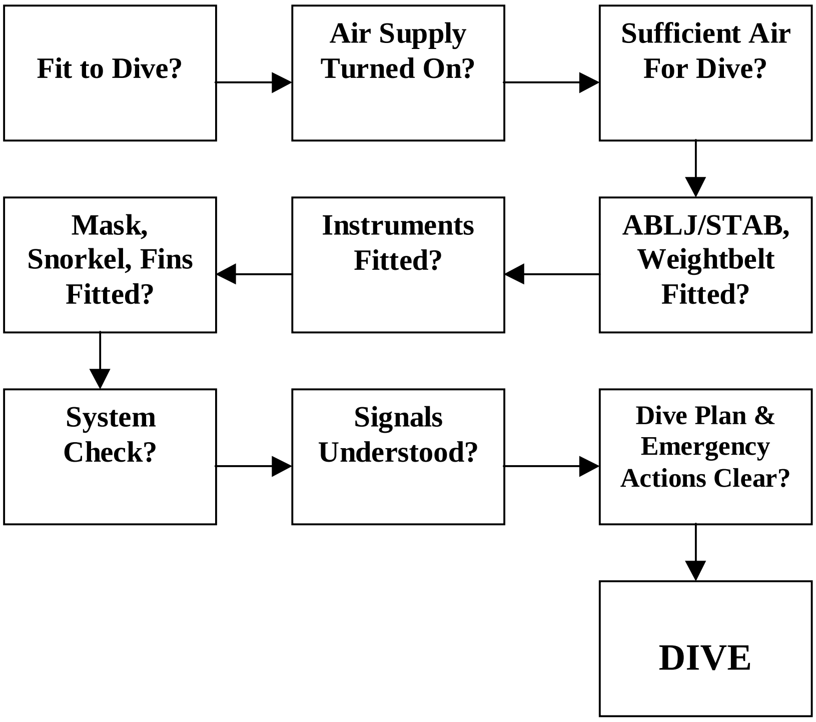
EXERCISE: dive purpose (pleasure, exploration, drift, night, wreck etc.)/ bottom type/ duration/ depth/ buoyancy requirements/ air checking procedures/ skills to be performed/ surfacing procedures/ entry and exit procedures.

EQUIPMENT: air contents check/ABLJ/STAB operation/drysuit (if worn) operation and valve type/ instruments/ weightbelt release.

DISCIPLINE: relative position of dive leader and buddy/specific duties.

SIGNALS: signals to be used during dive/at surface/ in low visibility.

The previous may be illustrated by reference to the following chart:



ALWAYS: PLAN THE DIVE – DIVE THE PLAN

5. After the Dive

Once the dive is over and the divers have safely exited the water, the Dive Leader should make a report to the Dive Marshall, who records the details of the dive. The divers then assist each other in the removal of their equipment and get themselves into dry clothing. This is now a time for relaxation and (non-alcoholic!) refreshment. A debriefing session should take place, in which the aspects of the dive are discussed. Logbooks and training records should be completed and then signed by the appropriate parties.

Safe Diving!