Chapter 2

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PHYSICS

To understand the physical and physiological problems which can confront a diver, it is helpful to recall a few basic physical laws of nature. Only a brief and simplified review of the physics of diving is given in this text. For more detailed explanations, refer to the diving manuals.

PRESSURE

Some of the major physical hazards are related to the effects of pressure. Pressure is defined as force per unit area. i.e.

$$\text{PRESSURE} = \frac{\text{FORCE}}{\text{AREA}}$$

If a force is spread over twice the area, the pressure is halved.

This explains why, for example, wide tyres are preferable for driving on beaches. The weight of the vehicle (force) when spread over a large area causes less pressure on the sand. This vehicle is less likely to sink into the sand than one with narrow tyres.

Fig. 2.1

The effect of stilleto heels on soft wooden boat decks

Gases exert pressure because they are made up of lots of fast moving molecules. The greater the number and the faster they move, the greater the pressure.

Pressure on a Submerged Diver

The pressure acting on a submerged diver has two components:

1. The atmosphere above the water, termed **atmospheric pressure,**
2. The weight of the water above the diver, termed **hydrostatic pressure.**

Divers' depth gauges are calibrated only to read the hydrostatic pressure (the depth of water) and so they read zero at sea level. They do not read the 1 atmosphere (1 ATA) above them. Thus the "gauge pressure" is always 1 atmosphere less than the true or "absolute" pressure. We will now elaborate.

Atmospheric Pressure

The atmosphere above the earth is some 150 km high. Although air is very light, this amount of air has significant weight and exerts substantial pressure on the earth's surface.

ABSOLUTE PRESSURE	GAUGE PRESSURE	DEPTH of SEAWATER
1 ATA	0 ATG	Surface
2 ATA	1 ATG	10 metres (33ft)
3 ATA	2 ATG	20 metres (66ft)
4 ATA	3 ATG	30 metres (99ft)

Table 2.1
Pressure at Depth

Atmospheric pressure at sea level is referred to as "one atmosphere" or "one bar". It is the same as 101.3 kPa, 1 kg/cm^2, 760mm Hg and 14.7 psi. At higher altitudes, atmospheric pressure is reduced, a factor which has a significant effect on diving in mountain lakes (see Chapter 6).

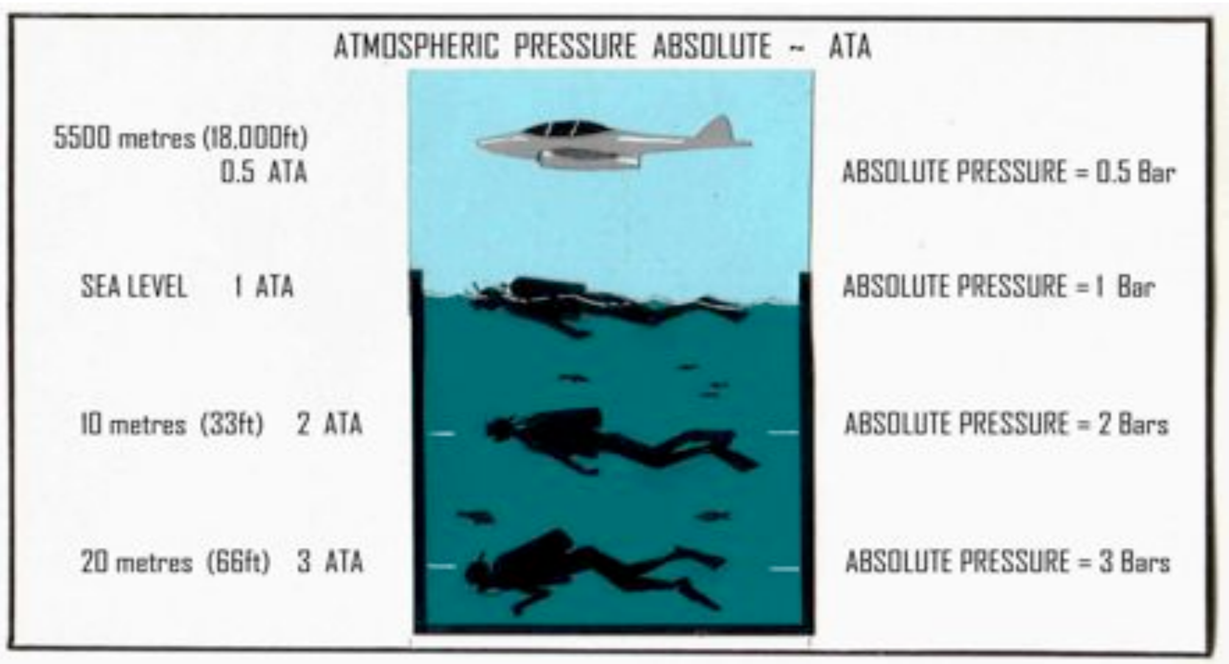

Fig. 2.2 Atmospheric and Hydrostatic Pressures (depth) added and thus converted to Absolute Pressure

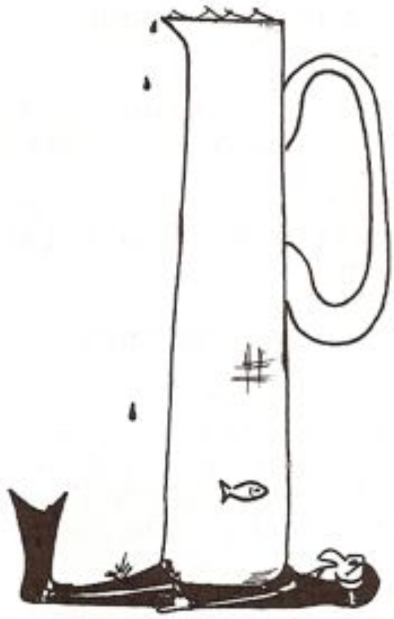

Fig. 2.3

Water is much denser than air and 10 metres (or 33 ft) of sea water exerts the same pressure (weight) as the whole 150 km of atmospheric air i.e. 1 ATA. For every additional 10 metres the diver descends, the water will exert a further pressure, equivalent to another atmosphere (1 ATA).

Common units of pressure (approximately):

1 ATMOSPHERE =	10 metres sea water
=	33 feet sea water
=	34 feet fresh water
=	1 kg/cm^2
=	14.7 lbs/in^2, psi
=	1 bar
=	101.3 kilopascals, kPa
=	760 millimetres mercury, mm Hg.

Absolute Pressure

The total pressure exerted on a diver at depth will be the pressure due to the atmosphere acting on the surface of the water (atmospheric pressure) plus the pressure due to the depth of the water itself (hydrostatic pressure).

The total pressure acting on the diver is termed the "absolute pressure". It is often expressed in terms of atmospheres and is called "atmospheres absolute" or "ATA".

To calculate the absolute pressure acting on a diver at a given depth in terms of atmospheres, divide the depth in metres by 10 (since every 10 m. sea water exerts 1 atmosphere pressure) and add 1 (the pressure of the atmosphere above the water).
e.g. the absolute pressure at 40 metres is [40 ÷ 10] + 1 = 5 ATA

(The depth in feet, divided by 33 + 1 also calculates absolute pressure, for those in the USA, e.g. the absolute pressure at 99 ft is 99/33 +1 = 4 ATA).

Gauge Pressure

As described above, hydrostatic pressure in diving is generally measured by a **pressure** or **depth gauge**. Such a gauge is normally set to register a pressure of zero at sea level and so it ignores the pressure due to the atmosphere (1ATA).

The pressure registered by a gauge at 10 metres sea water depth would thus be one atmosphere gauge (1ATG) or equivalent units. Gauge pressure is converted to absolute pressure by adding 1 atmosphere pressure.

Partial Pressure

With a mixture of gases, the proportion of the total pressure contributed by each of the gases is termed its partial pressure (its part of the pressure). The partial pressure contributed by each gas is proportional to its percentage of the mixture. Each gas contributes the same proportion to the total pressure of the mixture, as is its proportion in the composition of the mixture.

e.g. air at 1 ATA contains 21% oxygen, hence the partial pressure of oxygen is 0.21 ATA and
air at 1 ATA contains 78% nitrogen, hence the partial pressure of nitrogen is 0.78 ATA.

GAS LAWS

Gases behave in nature and in diving according to several laws. Knowledge of these laws is important to the diver because they influence the duration of the air supply and affect the gas containing spaces in the body such as the ears, sinuses and lungs. They also cause other diving illnesses.

Boyle's Law

This defines the relationship between pressure and volume. It states that the **volume of a given mass of gas varies inversely with the absolute pressure (if the temperature remains constant).**

Stated simply, for a given amount of gas, if the pressure is increased, the volume is proportionally decreased and vice versa. This means that if the pressure is doubled, the volume is halved and vice versa.

Stated mathematically: V varies as $\frac{1}{P}$ (where V = volume and P = pressure)

It follows that for a given amount of gas, the volume multiplied by the pressure always has a constant value.

i.e. $P \times V$ is constant.

So if a sample of gas has an original volume of V_1 and an original pressure of P_1, and either the pressure or volume are changed, the new volume V_2 and the new pressure P_2 will multiply out to the same value.

i.e. $\mathbf{P_1 \times V_1 = P_2 \times V_2}$

Fig. 2.4

This law can easily be demonstrated by a piston and cylinder such as a bicycle pump. If the piston is pushed into the cylinder half way, and the escape of gas prevented, the pressure in the cylinder will be found to have doubled. By this process, many litres of air can be crammed into a bicycle tyre but at the cost of an increase in pressure in the tyre (and hard work). Compressors work in this way, squeezing 2000 or more litres of air into a scuba cylinder – but at a high pressure.

Since water pressure increases with depth, the consequent reduction in gas volume becomes very important to the diver because his body has numerous air spaces.

Descent Problems: The air in the diver's middle ear and sinuses will contract in volume as the diver descends. If these volume changes are not compensated for by adding more air ("**equalisation**"), then pressure damage (**barotrauma**) to the tissues will result. For example:

If a 6 litre bag is filled at the surface (1 ATA) and taken to 20 metres depth (3ATA), the volume will be reduced by a factor of 3, to 2 litres.

$$P_1 \times V_1 = P_2 \times V_2$$
$$\therefore 1 \times 6 = 3 \times V_2$$
$$\text{i.e. } V_2 = 2 \text{ litres}$$

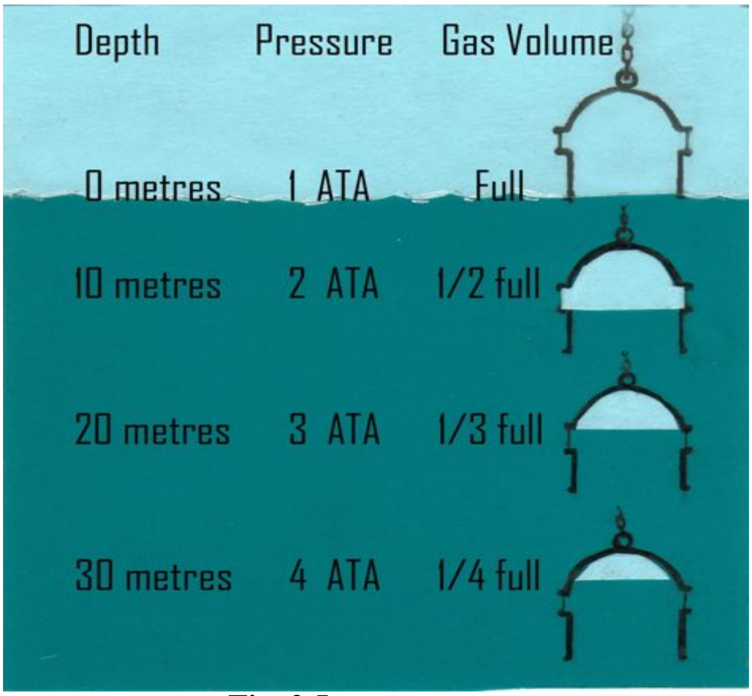

Fig. 2.5

In the same way, if a **breath-hold diver** takes a full breath at the surface and descends to 20 metres (3 ATA), the volume of air in his lungs may be reduced from 6 litres to 2 litres. The chest and lungs cope with compression better than distension. The limit for breath-hold diving is not known, but now has been shown to exceed 150 metres in certain individuals.

Ascent Problems. An average male diver's lungs may contain about 6 litres of gas. If a diver takes a full breath at 20 metres (3 ATA) from his scuba set and returns to the surface (1 ATA) without exhaling, the volume of gas in his lungs will increase from the 6 litre total lung capacity to 18 litres (6 × 3 litres).

This can be easily calculated this way:

$$P_1 \times V_1 = P_2 \times V_2$$

P_1 = 3 ATA, V_1 = 6 litres, P_2 = 1ATA, V_2 = ? litres

$$V_2 = \frac{P_1 \times V_1}{P_2} = \frac{3 \times 6}{1} = 18 \text{ litres}$$

The lungs would have to expand to 18 litres to accommodate this volume – well beyond their rupturing point, causing **burst lung** (**pulmonary barotrauma of ascent**).

An important practical observation of Boyle's Law is that **the greatest volume changes take place near the surface. This means that the greatest danger from barotraumas is near the surface — and this applies with descent as well as ascent.**

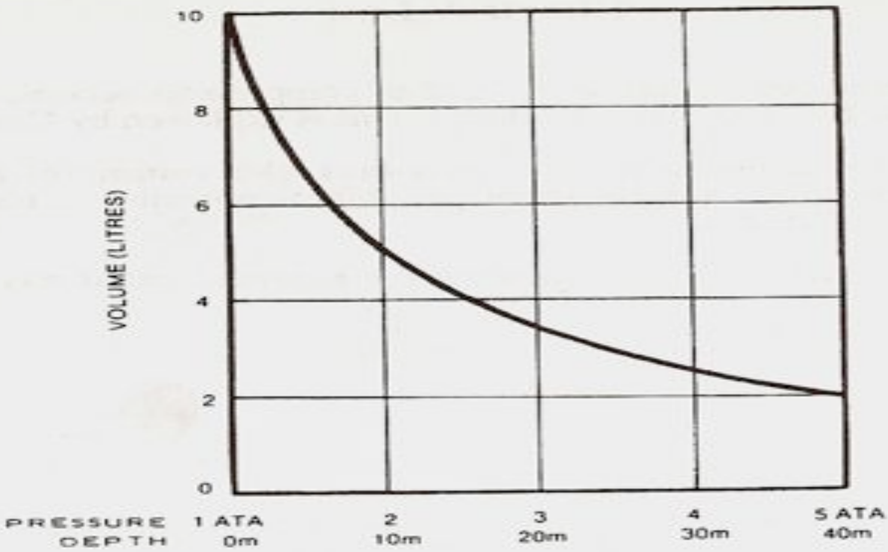

Fig. 2.6

This diagram shows changes in gas volume caused by pressure change at various depths. Note that maximal volume change is near the surface.

For example, if diver has a maximum of 4 litres of air in his lungs at 40 metres depth (5 ATA) and ascends 10 metres without exhaling (to 4 ATA), the volume in the lungs will increase to 5 litres:

$$
\begin{aligned}
P_1 \times V_1 &= P_2 \times V_2 \\
5 \times 4 &= 4 \times V_2 \\
\therefore V_2 &= 5 \text{ litres}
\end{aligned}
$$

Some people could possibly accommodate this expansion without lung damage.

If the same diver started at 10 metres depth (2ATA), and then ascended 10 metres to the surface (the same ascent distance as before), without exhaling, the pressure would change from 2ATA to 1ATA. The air in the lungs would expand from 4 to 8 litres. This would rupture his lungs.

Although the dives involved the same ascent distances, the volume change, and hence the danger, in response to Boyle's Law, is much greater near the surface.

Many divers are not aware of this and have a fallacious belief that if they confine their diving to shallow depths they will minimise the risk of barotrauma.

Buoyancy compensators are similarly affected by depth changes in response to Boyle's Law. **Wet suits** are also affected and lose their buoyancy and insulating properties with depth.

Charles' Law

Most divers will have noticed that bicycle pumps and air compressors become hot during use. As the volume of gas is compressed, heat is produced. This is explained by Charles' Law.

This Law states that **if the pressure remains constant, the volume of a given mass of gas varies directly with the absolute temperature** (absolute temperature is obtained by adding 273 to the temperature in degrees Celsius).

In other words, at a fixed pressure, if gas is heated it expands, and if gas is cooled its volume contracts.

Fig 2.7

Charles' and Boyle's laws can be combined into the **General Gas Law** : $\frac{PV}{T}$ is constant

For the non-mathematically minded this means that for a given amount of gas, the pressure multiplied by the volume, divided by the temperature, always comes to the same value – so if one of these factors is varied, it has an effect on the other two.

If a gas sample having $\frac{P_1V_1}{T_1}$ has one of these factors changed,

the new set of values $\frac{P_2V_2}{T_2}$ will multiply out to the same answer

i.e. $$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Fig. 2.8

Stated in another way; if a gas is compressed, its volume decreases and it gets hotter. If the gas is heated and the volume is prevented from expanding, the pressure rises.

The consequence of this law has lead to the demolition of several perfectly good automobiles (and divers!) following the storage of full scuba cylinders in the boot (trunk) in hot weather. Similarly, inflatable dive boats are often pressurised to the maximum and are then left in the sun. As the temperature rises, the pressure of the contained air progressively increases and then suddenly reduces – when the volume increases and when the boat explodes.

If gas is allowed to expand rapidly, it cools. Cooling from the expansion of previously compressed air, as it is breathed from a scuba cylinder, can lead to the regulator freezing up during cold water diving.

Problem: If the temperature of a scuba cylinder is 37˚C after being disconnected from the compressor. Its pressure gauge reads 199 ATG, what is the pressure after it has cooled to 17˚ C?

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

now because V_1 and V_2 are the same (the cylinder volume is unchanged), the equation can be written:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

and this can be rearranged to:

$$P_2 = \frac{P_1T_2}{T_1}$$

Substituting the figures: (note that the cylinder pressure is in ATG and needs to have 1 atmosphere added to get ATA, also that the temperatures have to be converted to degrees absolute by adding 273 degrees)

$$\therefore \; P2 = \frac{(199+1) \times (273+17)}{(273+37)}$$

$$= 187 \text{ ATA}$$

Dalton's Law

With a mixture of gases, the total pressure exerted by the mixture, is the sum of the pressures that would be exerted by each of the gases if it alone occupied the total volume. That is, the total pressure is the sum of the partial pressures.

As the overall pressure increases (with descent underwater), so the partial pressure of each constituent gas increases.

e.g. if air contains approximately 21% oxygen (O_2) and 78% nitrogen (N_2), then in a sample of air at a given pressure, O_2 will contribute 21% of the total pressure and N_2 will contribute 78%.

AIR BREATHING

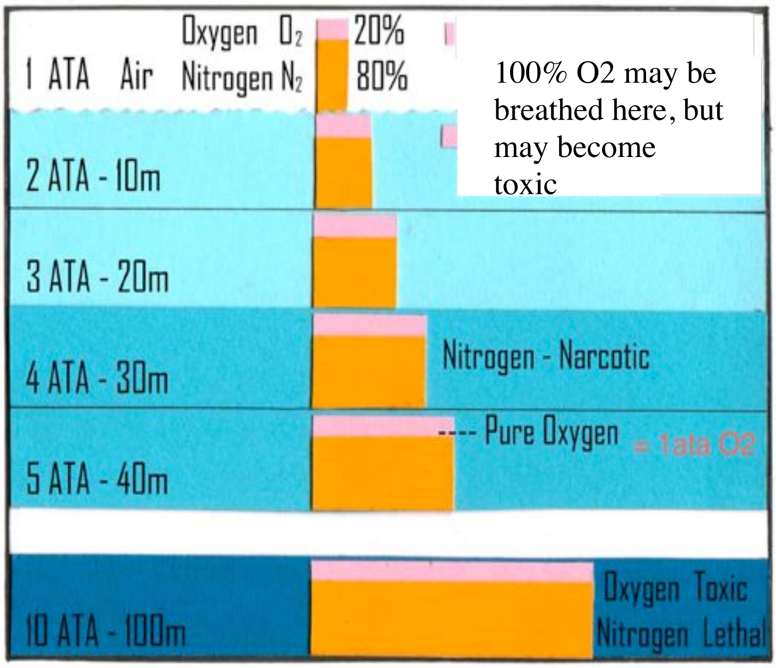

Fig. 2.9

At atmospheric pressure the partial pressure of O_2 in air is $^{21}/_{100}$ of 1 ATA. = 0.21 ATA

while the partial pressure of N_2 is $^{78}/_{100}$ of 1ATA = 0.78ATA.

To calculate the partial pressure of a gas, multiply the percentage of gas by the absolute pressure.

This law is important when considering the toxic effect of gases at depth or the use of O_2 for treatment purposes.

Problem: Since O_2 can cause convulsions when breathed at greater than 1.8 ATA, would it be safe to breathe a mixture of 50% O_2 and 50% N_2 at 30 metres (4 ATA) ?

The partial pressure of O_2 = 50% × 4ATA = 2ATA

This oxygen / nitrogen mixture would be potentially toxic at this depth.

Henry's Law

This law describes the dissolving of gas in a liquid and states that the **quantity of gas which will dissolve in a liquid at a given temperature is proportional to the partial pressure of gas in contact with the liquid.** This means that if the pressure of gas exposed to a liquid increases, then more gas will dissolve in the liquid.

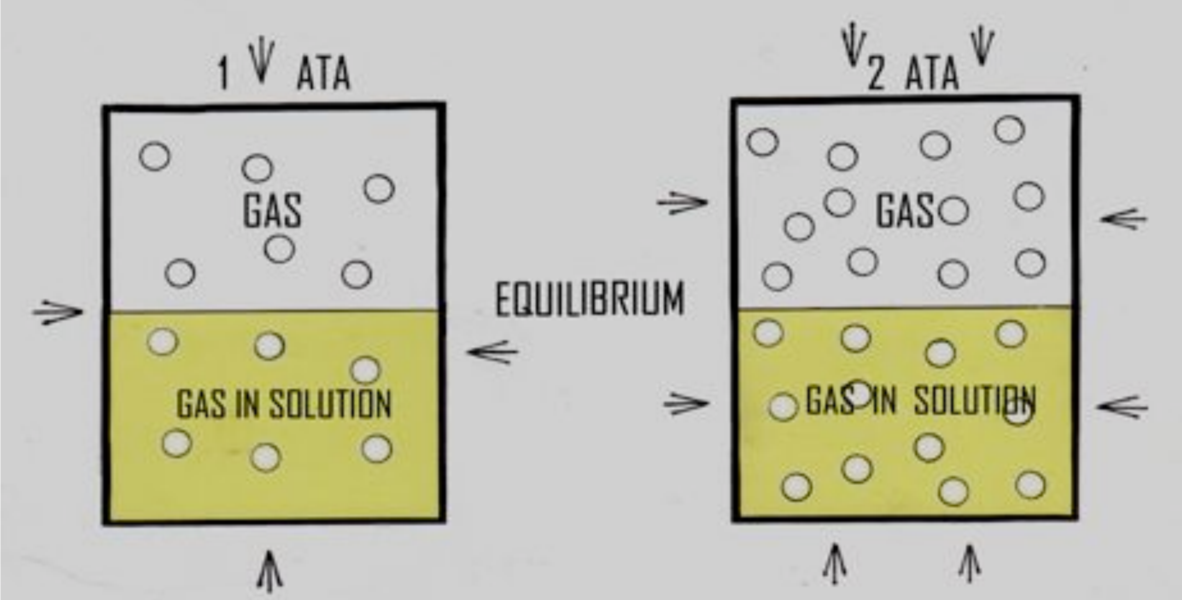

Fig. 2.10
This diagram shows how more gas molecules are dissolved in a liquid as the pressure of the gas exposed to the liquid is increased from 1 to 2 ATA.

An example of this law can be seen whenever a fizzy soft drink bottle is opened. During the manufacture of these drinks, carbon dioxide is dissolved in the liquid under pressure and the lid on the bottle maintains the pressure. When the bottle is opened and the pressure released, the liquid will not allow as much gas to be dissolved and so the excess gas is released from solution in the form of bubbles.

At sea level (1ATA) the human body contains approximately 1 litre of N_2 dissolved in the tissues. Whenever a diver breathes compressed air at depth, more N_2 will dissolve in the body because the partial pressure of N_2 in the air being breathed is increased. This is the cause of **nitrogen narcosis**.

Under certain circumstances, when the diver returns to the surface this N_2 can come out of solution in the form of bubbles. These bubbles cause tissue injury which is the basis of **decompression sickness** ("bends").

Fig. 2.11

Diffusion of Gases

If a diver were to pass wind in a confined room, all the occupants of the room would soon be aware of the fact but, fortunately, not necessarily the source.

This process of distribution of gas is termed diffusion. It is caused by the rapid random movement of gas molecules to all parts of a contained space. Gas molecules, being only single or small groups of atoms, are able to easily diffuse through watertight membranes such as blood capillaries or cell walls. This process allows O_2 and other gases to pass from the lungs to the blood and tissues, and then back.

GASES OF IMPORTANCE TO DIVERS

Air

Air consists of a mixture of O_2 + N_2 + a trace of carbon dioxide (CO_2), and minute amounts of rare gases. Rare gases such as Neon (Ne), Argon (Ar) and Xenon (Xe), and Hydrogen (H_2) exist in trace amounts only.

The approximate composition of air is:

Oxygen (O_2)	**—**	**21% by volume**
Nitrogen (N_2)	**—**	**78% by volume**
Carbon Dioxide (CO_2)	**--**	**0.04% by volume**
Others	**--**	**< 1 % by volume**

Some less reputable suppliers of air fills for scuba tanks provide free additives to the compressed air, such as dust, oil, hydrocarbons, rust, water vapor and carbon monoxide (CO).

Oxygen – O_2

This is a colourless, odourless, tasteless gas which is indistinguishable from air to breathe.

It is essential for metabolism and maintenance of life yet in quantities exceeding those in air it is **toxic** to man. Its proportion in air (21% or more specifically, a partial pressure of 0.21 ATA at sea level) is critical. A little more than this causes O_2 toxicity, a little less will not support human life. For this reason most gas mixtures breathed by deep divers contain an inert gas – usually either N_2 or helium (He), mixed with O_2 to ensure that the O_2 composition is maintained at a partial pressure close to 0.2 ATA (0.16 – 0.40 ATA).

O_2 supports combustion vigorously and can cause normally non-flammable substances (such as the occupants of a recompression chamber) to burn brilliantly if it is present at a sufficiently high partial pressure.

Divers should be aware of the potentially explosive and combustible properties of oxygen, as they may require to use it in first-aid, or be inadvisably enticed into diving with high oxygen mixtures.

Nitrogen – N_2

This gas, which is the major constituent of air, is also colourless, odourless and tasteless. N_2 dissolves well in body fluids and tissues, causing **narcosis** at depth and **decompression sickness** when it bubbles out of solution, after ascent.

It is termed an "**inert gas**" because it does not take part in human biochemical processes. The Creator appears to have included this gas in air to prevent us from developing O_2 toxicity, and to reduce the fire hazard.

Divers vary this N_2/O_2 ratio (in Nitrox, oxygen enriched air or mixed gas diving) in an attempt to improve on nature, extend diving durations, and reduce narcosis.

Carbon Dioxide – CO_2

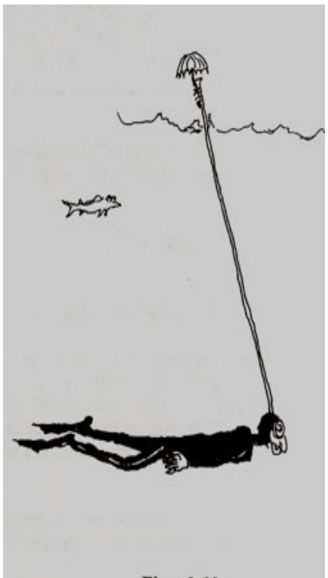

Fig. 2.12

This gas is also colourless, odourless and is said to be tasteless. However if a diver inhales a mouthful of CO_2 from a buoyancy vest inflated from a CO_2 cartridge it will be found to taste very nasty, due to its formation of carbonic acid in water.

CO_2 is a by-product of cellular metabolism and we exhale approximately 5% of CO_2 in our breath.

If a diver rebreathes some of his exhaled gas by using faulty breathing equipment or an excessively long snorkel the CO_2 will accumulate in the body leading to toxicity. These effects are discussed further in Chapter 22.

Carbon Monoxide – CO

This gas is colourless, odourless and tasteless. It cannot be detected by a diver and even in trace amounts can cause loss of consciousness or death.

It is usually produced as a product of incomplete combustion of carbon containing compounds and is a constituent of internal combustion engine exhausts and cigarette smoke.

Air contaminated by carbon monoxide, if supplied in scuba cylinders or by surface supply to divers, may have lethal results (see Chapter 23).

Helium – He

This is a colourless, odourless, tasteless gas, which is very light and very expensive. It is obtained from underground natural gas sources found in North America and elsewhere.

It is used to dilute O_2 in gas mixtures breathed at great depths because it has little tendency to produce narcosis (e.g. Heliox may be 90% He + 10% O_2, or any other proportion).

Due to its very low density it readily escapes through small leaks in pipes and valves making it difficult to retain. It is also a very effective conductor of heat, causing serious problems with **hypothermia**.

The low density of He alters the normal process of speech production causing "**Donald Duck**" like speech when a diver breathes this gas.

Hydrogen – H_2

This is a very lightweight gas that can replace N_2 to reduce narcosis at depth. Unfortunately it can combine explosively with O_2 and the resultant water (H_2O) is not sufficient to 'put out the diver'. It is sometimes used with very low O_2 percentages, at great depths, by skilled professional divers. It shares many problems with He.

Inert Gases:

Neon – Ne, Argon – Ar, Radon – Rn, and Xenon – Xe

These are more biologically inert gases which are present only in trace amounts in the atmosphere. They are of no importance to recreational divers.

Oil Gases

Because of lubrication needs in the compressor, oil vapors and hydrocarbons can be produced which may then contaminate the air supply. See Chapter 24.

BUOYANCY

It is important for divers to understand the factors affecting buoyancy. These are:

Density

Density is defined as **mass per unit volume** (density = mass ÷ volume).

For our purposes, mass can be considered to be the same as weight, so density is equivalent to weight per unit volume.

A substance is more dense than another if the same volume has more weight. Try lifting a bucket of water and then a bucket of lead, to illustrate this.

Specific Gravity

Specific gravity (S.G.) is the density of a substance compared to the density of fresh water which is given a value of one.

Lead has a specific gravity of 13.5 so it is 13.5 times as dense as water.
e.g.1 litre of water will weigh 1 kg., while the same volume of lead will weigh 13.5 kg.

The concept of specific gravity is important since the specific gravity of a substance determines whether it will float or sink in water.

Fig. 2.13

A substance with a specific gravity greater than 1 (i.e. denser than water) will sink. Lead, with a specific gravity of 13.5, does not float well, whereas oil, with a specific gravity of 0.8, floats easily — producing an oil slick.

The human body has a specific gravity of slightly greater than 1, depending on its content (fat has a specific gravity less than 1, and bones are greater than 1) but the air content of the lungs provides enough buoyancy to allow most people to float.

Archimedes Principle

The ancient Greek, Archimedes (apparently while reclining in his bath), discovered that when an object is immersed in a fluid, it appears to be lighter, and that the apparent loss of weight (or **buoyancy**) is equal to the weight of water displaced by the object.

Fig. 2.14

That is – the buoyant effect will be equivalent to the weight of fluid of equal volume to the immersed object.

Depending on whether the weight of fluid displaced is greater than, equal to or less than the weight of the object, an object immersed in the fluid will either float, remain suspended or sink. Even an object which sinks will still appear to be lighter than it would out of the fluid.

Sea water is denser than fresh water because of the salt content, so a greater weight of sea water will be displaced by an object. Hence objects in sea water are more buoyant than in fresh water.

Air (in the abdomen, buoyancy compensator and wet suit) contributes to buoyancy. Unfortunately air in these compartments varies in volume in response to the pressure changes with varying depth, making constant buoyancy adjustments necessary. This is usually accomplished by adding air to, or releasing it from, the diver's buoyancy compensator.

Divers go to considerable lengths to vary their buoyancy to help them submerge, to stay at a given depth, or to ascend or stay afloat in an emergency.

PHYSICAL EFFECTS OF THE ENVIRONMENT

Temperature

Body heat is a form of energy, the level of which can be estimated by measuring the body temperature.

Heat energy flows from areas of high temperature to areas of low temperature. The heat transfer which is important to the diver is **thermal conduction** (or transfer of heat by direct contact), and may cause **hypothermia** (low body temperature).

Since normal body temperature is 37°C and oceanic water temperature is commonly 12–20°C, the diver is almost always immersed in water at a lower temperature than his body. Usually the water temperature decreases with depth, but there may be layers of water at different temperatures (thermoclines) – especially in still water.

Cold water creates a strong temperature gradient along which heat flows from the body, resulting in a continuous heat loss into the water. This process is assisted by water having a high capacity to conduct and absorb heat.

Since the maintenance of normal body temperature is essential for physiological functioning, the diver needs to take steps to minimise heat loss. This may be achieved by inserting a layer of air (which is a poor conductor of heat) between the diver and the water. It is conveniently contained in minute cells in a wet suit or under a rubber skin in a dry suit.

Light and Colour

Substances that transmit light have a tendency to slightly alter the path of the light rays which pass through them. This process is termed **refraction**. The degree to which they do this is termed the refractive index. Each time light passes through an interface between substances with different refractive indices, its path is bent.

When a diver views objects underwater, light must pass through the water, the face mask glass, and the air in the mask before it reaches his eyes. The light rays are refracted at each of these interfaces and the distortion makes objects appear larger and closer by a factor of about 25%.

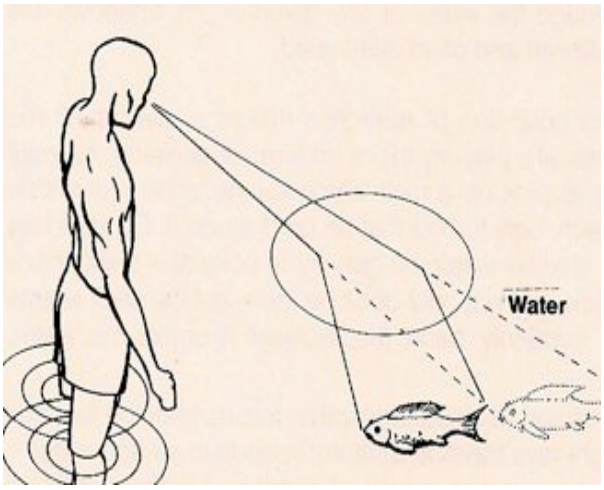

Fig 2.15 The fish appears closer, because the light rays are refracted at the air/water interface

Until the diver adapts to this distortion, it may be difficult to judge size and distances. This creates practical difficulties with simple tasks such as spear fishing.

Light rays are scattered by particles in the water making shadows less pronounced and reducing the ability to see clearly over large distances.

Clear focusing of the eye depends heavily on the refraction of light rays passing between the air in front of the eye and the cornea (the clear surface at the front of the eye). If the eyes are opened underwater without a face mask, the absence of this air/cornea interface results in very blurred vision.

Water absorbs colours to differing degrees. In clean oceanic water, red is absorbed in the first metre, orange in the first five metres, yellow in the first ten, and green and blue at greater depths. This explains why most things, regardless of their colour on the surface, appear to be coloured shades of blue or green at depths beyond about ten metres.

Inshore waters often contain yellowish products of vegetable decay which absorbs most colours except green. As a result, clean oceanic water appears blue, while inshore and estuarine water appears green from the surface.

Because deep water is lit mainly by blue and green light, coloured corals and fish at these depths look less brilliant unless illuminated by a torch or camera flash.

For safety reasons, it is advisable to wear conspicuously coloured diving equipment. However, the absorption of light underwater needs to be considered when choosing these colours. Red, for instance, which is easily visible on the surface, appears black at depth because of the significant absorption of red light by the water.

Fluorescent orange or **yellow** paint or fabric affords better visibility because the fluorescent dye actively emits light of its own colour and also provides a good contrast against natural aquatic backgrounds.

Sound

Sound waves in air are usually reflected at the air–water interface, and therefore shouting instructions to submerged divers is not of much value. Underwater, the sound wave travels much faster than in air, and this makes localisation of the source much more difficult. An example of this is the concern experienced when divers hear outboard engines, but cannot identify the distance or direction of the boat.

Altitude

If exposed to altitude (less than 1 ATA) a variety of effects may endanger the diver. Some equipment may be affected e.g. pressure gauges, and the diving profile needs to be modified to prevent pulmonary barotrauma and decompression sickness (see Chapter 6).