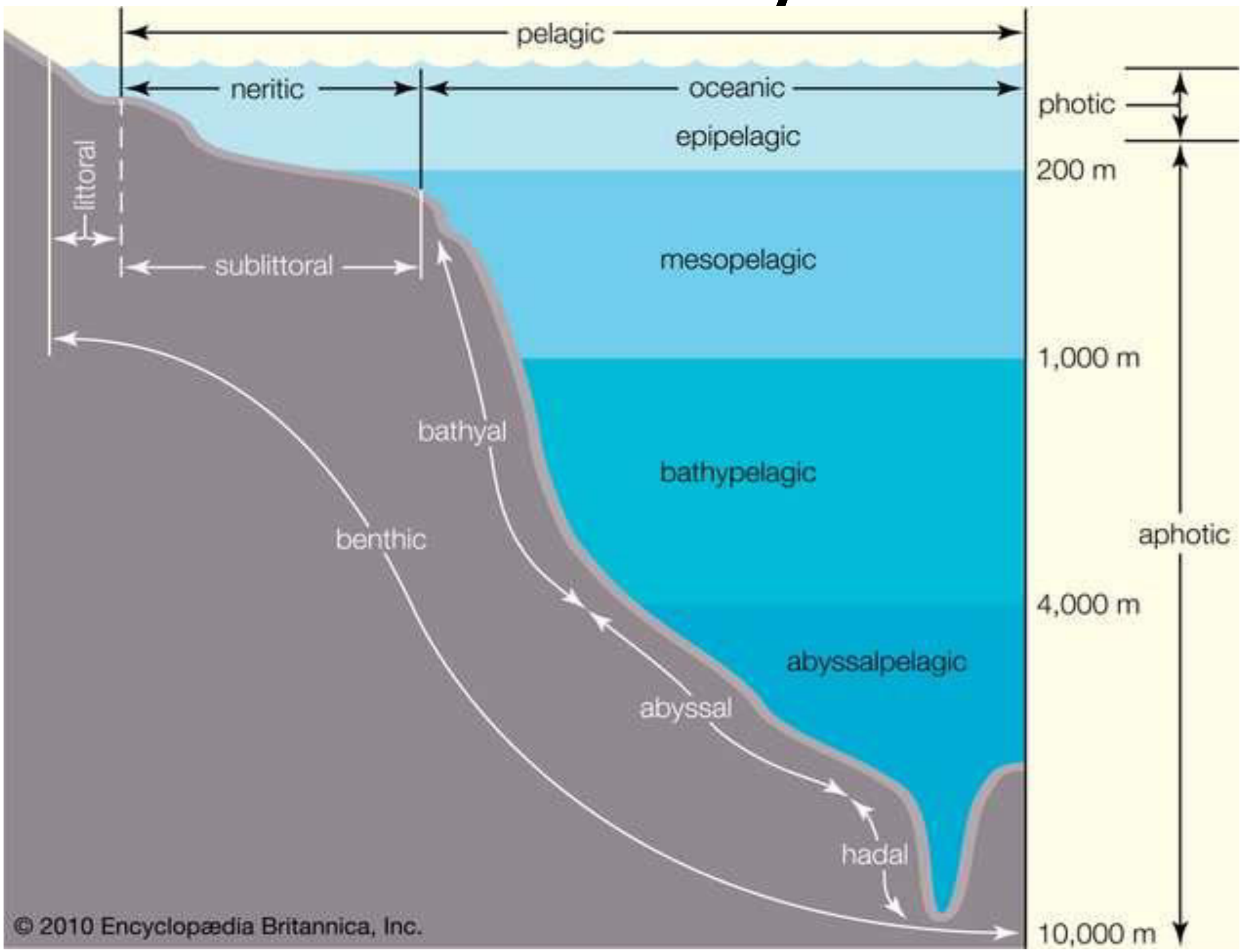
M.Sc 2nd year

4th unit Underwater

Marine Ecosystem



The **underwater environment** refers to the region below the surface of, and immersed in, liquid water in a natural or artificial feature (called a body of water), such as an ocean, sea, lake, pond, reservoir, river, canal, or aquifer.

- Ocean waters are salty and contain minerals and dissolved gases. They also have a high heat capacity and vary in density depending on **temperature** and salinity.

Under water pressure

- This is due to an increase in hydrostatic **pressure**, the force per unit area exerted by a liquid on an object. The deeper we go under the sea, the greater the **pressure** of the **water** pushing down on us. For every 33 feet (10.06 meters) we go down, the **pressure** increases by one atmosphere .
- A wide variety of organisms, including bacteria, protists, algae, plants, fungi, and animals, live in the **sea**, which offers a wide range of marine habitats and ecosystems, ranging vertically from the sunlit surface and shoreline to the great depths and pressures of the cold, dark abyssal zone, and in latitude.

What is Scuba Diving?

- Self Contained Underwater Breathing Apparatus
- Underwater diving in which a diver uses a scuba set to breathe underwater.

Brief Information

• Scuba-diving is an underwater hobby.

•To scuba-dive, one must become certified through classes and hands-on-training through the organization PADI (Professional Association of Diving Instructors).

•Major equipment of a scuba-diver's gear is their regulator, tank, and BCD. The regulator and tank are used for breathing and the BCD controls buoyancy.

•The NUMBER ONE rule of scuba-diving is DO NOT hold your breath.

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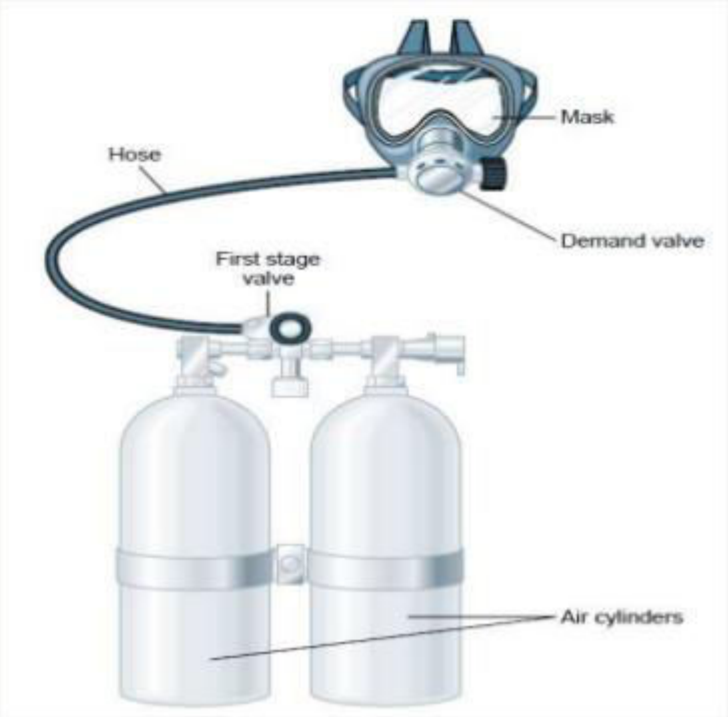
SCUBA DIVING

- ***Self-Contained Underwater Breathing Apparatus***

- (1) one or more tanks of **compressed air** or some other **breathing mixture,**
- (2) a **first-stage "reducing" valve** for reducing the very high pressure from the tanks to a low pressure level,
- (3) a **combination inhalation "demand" valve and exhalation valve** that allows air to be pulled into the lungs with slight negative pressure of breathing and then to be exhaled into the sea at a pressure level slightly positive to the surrounding water pressure,
- (4) a **mask and tube system** with small "dead space."


Mask
Hose
Demand valve
First stage
valve
Air cylinders

SCUBA DIVING

- The **first stage reducing valve reduces the pressure from the tanks** so that the air delivered to the mask has a pressure only a few mm Hg greater than the surrounding water pressure.

- The breathing mixture **does not flow continually into the mask**.
- with each ***inspiration***, slight **extra negative pressure in the demand valve of the mask pulls the diaphragm of the valve open**, and this automatically releases air from the tank into the mask and lungs.

- In this way, **only the amount of air needed for inhalation** enters the mask.
- Then, on ***expiration***, the **air cannot go back into the tank** but expired into the sea.

SCUBA DIVING

- The most important problem in use of the SCUBA is the **limited amount of time** one can remain beneath the sea surface - only a few minutes are possible at a 200-foot depth.

- **tremendous airflow from the tanks is required** to wash carbon dioxide out of the lungs

- the **greater the depth, the greater the airflow in terms of quantity of air per minute that is required**, because the volumes have been compressed to small sizes.

DEEP-SEA DIVING

- When human beings **descend beneath the sea**, the pressure around them increases greatly.

- **To keep the lungs from collapsing**, air must be supplied at very high pressure to keep them inflated.

- This **exposes the blood in the lungs** also to extremely high alveolar gas pressure, a condition called ***hyperbarism***.

- Beyond certain limits, **these high pressures can cause great alterations** in body physiology and can be lethal.

Depth (feet)	Atmosphere(s)
Sea level	1
33	2
66	3
100	4
133	5
166	6
200	7
300	10
400	13
500	16

EFFECT OF HIGH PARTIAL PRESSURES

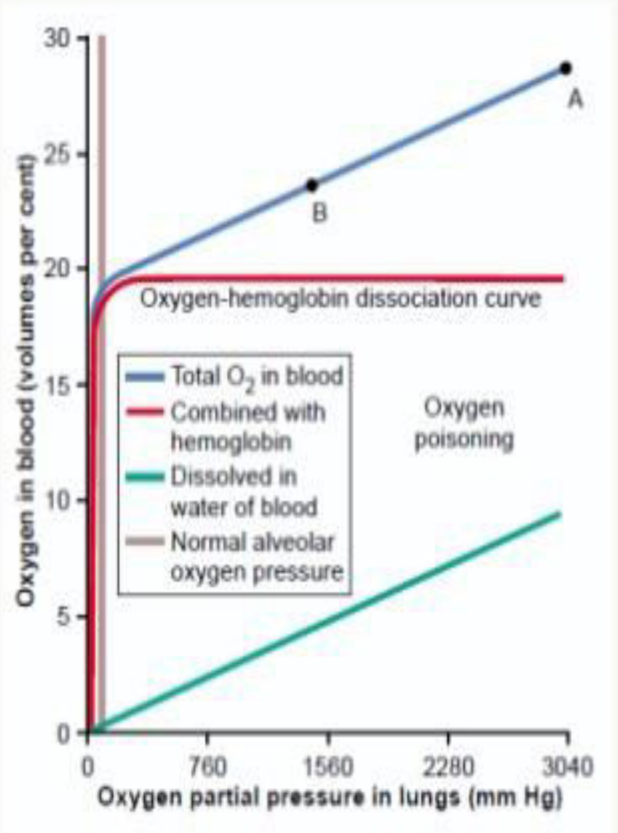
- ***Nitrogen Narcosis***
- When the diver remains beneath the sea for **an hour or more** and is breathing compressed air, the depth at which the first symptoms of mild narcosis appear is about ***120 feet*** - begins to exhibit cheerfulness and to lose many of his or her cares.
- At ***150 to 200 feet***, the diver becomes drowsy.
- At ***200 to 250 feet***, his or her strength decreases significantly, and the diver often becomes too clumsy to perform the work required.
- ***Beyond 250 feet*** (8.5 atmospheres pressure), the diver usually becomes almost useless as a result of nitrogen narcosis if ***he or she remains at these depths too long.***

NITROGEN NARCOSIS

- similar to those of alcohol intoxication, and for this reason it has been called **"raptures (joys) of the depths."**

- Nitrogen **dissolves in the fatty substances in neuronal membranes** and, because of its physical effect on altering ionic conductance through the membranes, ***reduces neuronal excitability***.

OXYGEN TOXICITY



ACUTE OXYGEN POISONING

- The extremely **high tissue Po2** that occurs **when oxygen is breathed at very high alveolar oxygen pressure** can be harmful to many of the body's tissues.

- breathing oxygen at 4 atmospheres pressure of oxygen (Po2 = 3040 mm Hg) will cause **brain seizures followed by coma** in most people within 30 to 60 minutes.

- The **seizures often occur without warning** and likely to be deadly to divers submerged beneath the sea.

CHRONIC OXYGEN POISONING

- Even **after about 12 hours of only 1 atmosphere** oxygen exposure,

- **lung passageway congestion, pulmonary edema, and atelectasis** caused by damage to the linings of the bronchi and alveoli begin to develop.

- The **air spaces of the lungs** are directly exposed to the high oxygen pressure,

- oxygen is delivered to the **other body tissues at almost normal Po2** because of the hemoglobin-oxygen buffer system.

CARBON DIOXIDE TOXICITY

- the diver has **no problem due to carbon dioxide toxicity** because depth alone does not increase the carbon dioxide partial pressure in the alveoli.

- **depth does not increase the rate of carbon dioxide production** in the body, and as long as the diver continues to breathe a normal tidal volume and expires the carbon dioxide as it is formed,

- **Alveolar carbon dioxide pressure** will be maintained at a normal value.

CARBON DIOXIDE TOXICITY

- In some types of rebreathing apparatuses, **carbon dioxide can build up in the dead space air of the apparatus** and be rebreathed by the diver.
- Up to an alveolar carbon dioxide pressure **(Pco2) of about 80 mm Hg**, twice that in normal alveoli, the diver usually tolerates this build-up by increasing the minute respiratory volume a maximum of 8- to 11-fold to compensate for the increased carbon dioxide.

- Beyond 80-mm Hg alveolar Pco2, the situation becomes **intolerable**, and eventually the **respiratory center begins to be depressed**, rather than excited, because of the negative tissue metabolic effects of high Pco2.
- The diver's **respiration then begins to fail** rather than to compensate.
- In addition, the diver develops severe **respiratory acidosis**, and varying degrees of **lethargy, narcosis** and finally even **anesthesia**

NITROGEN

- When a person **breathes air under high pressure for a long time**, the amount of nitrogen dissolved in the body fluids increases.

- Blood flowing through the **pulmonary capillaries becomes saturated with nitrogen** to the same high pressure as that in the alveolar breathing mixture.

- And over several more hours, **enough nitrogen is carried to all the tissues of the body to raise their tissue PN2** also to equal the PN2 in the breathing air.

NITROGEN

- Because **nitrogen is not metabolized by the body**, it remains dissolved in all the body tissues
- until the nitrogen pressure in the lungs is decreased back to some lower level, at which time the **nitrogen can be removed by the reverse respiratory process;**
- This removal often takes **hours to occur and is the source** of multiple problems collectively called ***decompression sickness***.

VOLUME OF NITROGEN DISSOLVED

- **At sea level**, almost exactly 1 liter of nitrogen is dissolved in the entire body.
- **less than half of this is dissolved in the water** of the body and a more than half in the fat of the body - because ***nitrogen is five times as soluble in fat as in water.***
- After the diver has become saturated with nitrogen, **the sea-level volume of nitrogen dissolved in the body at different depths** is as follows:

Feet	Liters
0	1
33	2
100	4
200	7
300	10

VOLUME OF NITROGEN DISSOLVED

- **Several hours are required** for the gas pressures of nitrogen in all the body tissues to come nearly to equilibrium with the gas pressure of nitrogen in the alveoli.
- The **blood does not flow rapidly enough** and the **nitrogen does not diffuse rapidly enough** to cause rapid equilibrium.
- The **nitrogen dissolved in the water of the body** comes to almost complete equilibrium in less than 1 hour,
- but the **fat tissue**, requiring five times as much transport of nitrogen and having a relatively poor blood supply, reaches ***equilibrium only after several hours***.

- if a person remains at deep levels for only a **few minutes**, not much nitrogen dissolves in the body fluids and tissues,
- if the person remains at a deep level for **several hours**, both the body water and body fat become saturated with nitrogen.

DECOMPRESSION SICKNESS

- ***Bends,***
- ***Compressed Air Sickness,***
- ***Caisson Disease,***
- ***Diver's Paralysis,***
- ***Dysbarism***

Definition

- Also called Decompression sickness(DCS), also known as divers' disease, the bends or caisson disease)
- Decompression sickness (DCS) occurs when the body is exposed to a sudden drop in surrounding pressure. DCS occurs most frequently during deep sea diving or when flying in a non-pressurized aircraft.

Divers Paralysis

- A disorder caused by the formation of nitrogen bubbles in the blood and tissues following a sudden drop in the surrounding pressure and characterized by joint pain, skin irritation, cramps, numbness, and, in severe cases, **paralysis**. It occurs especially in deep-sea **divers** when ascending rapidly from a **dive**

Dysbarism

- the complex of symptoms (as the bends, headache, or mental disturbance) that accompanies exposure to excessively low or rapidly changing environmental air pressure.

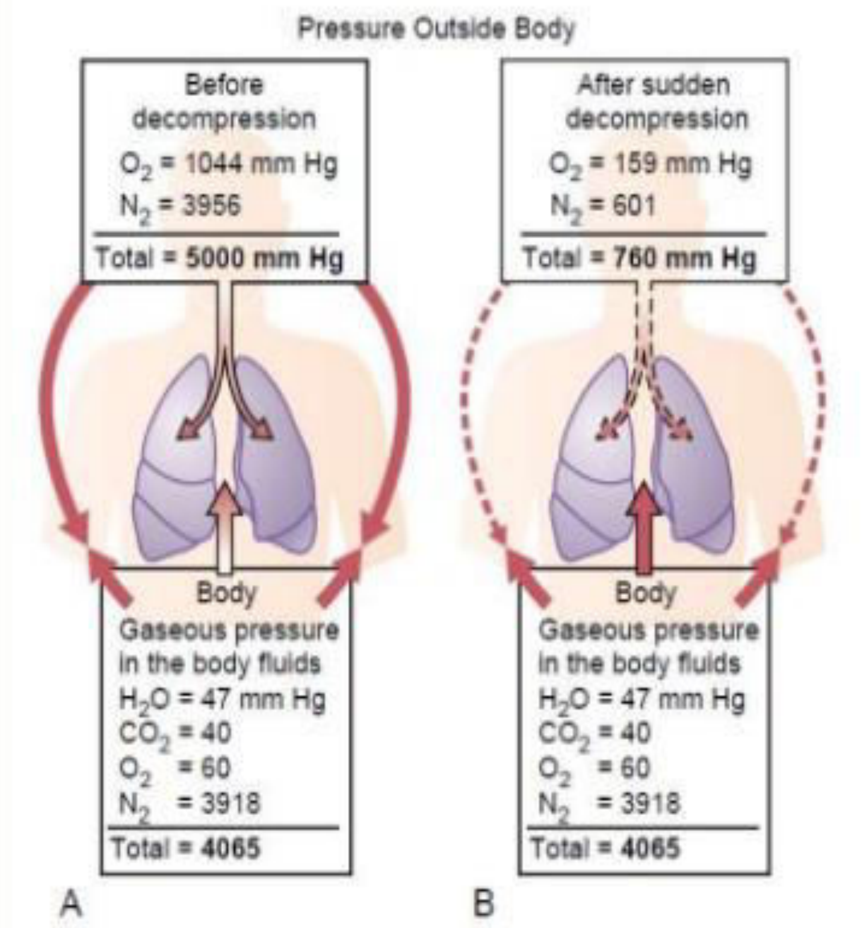
DECOMPRESSION SICKNESS

- If a diver has been **beneath the sea long enough** that large amounts of nitrogen have dissolved in his or her body

- and the diver then **suddenly comes back to the surface of the sea,**

- significant quantities of ***nitrogen bubbles can develop*** in the body fluids either **intracellularly or extracellularly** and can cause minor or serious damage in almost any area of the body,

- depending on the **number and sizes of bubbles formed** - this is called ***decompression sickness.***


Pressure Outside Body
Before decompression
O2 = 1044 mm Hg
N2 = 3956
Total = 5000 mm Hg
After sudden decompression
O2 = 159 mm Hg
N2 = 601
Total = 760 mm Hg
Body
Gaseous pressure in the body fluids
H2O = 47 mm Hg
CO2 = 40
O2 = 60
N2 = 3918
Total = 4065
Body
Gaseous pressure in the body fluids
H2O = 47 mm Hg
CO2 = 40
O2 = 60
N2 = 3918
Total = 4065
A
B

SYMPTOMS ("BENDS")

- **gas bubbles blocking many blood vessels** in different tissues.

- At first, only the **smallest vessels are blocked by minute bubbles**, but as the <u>bubbles join, progressively larger vessels are affected</u>
- ***Tissue ischemia*** and sometimes ***tissue death*** are the result.

- The symptoms are ***pain in the joints and muscles of the legs and arms***, affecting 85 to 90 per cent of those persons who develop decompression sickness.

- <u>***The joint pain - "bends"***</u>

SYMPTOMS (CNS & "CHOKES")

- In 5 to 10 per cent of people with decompression sickness, nervous system symptoms occur, ranging from **dizziness** in about 5 per cent to **paralysis or collapse and unconsciousness** in as many as 3 per cent.
- The **paralysis may be temporary**, but in some instances, damage is permanent.

- about 2 per cent of people with decompression sickness develop ***"the chokes,"*** caused by massive numbers of microbubbles plugging the capillaries of the lungs;
- this is characterized by **serious shortness of breath**, often followed by **severe pulmonary edema** and, occasionally, **death**.

Treatment

- All cases of decompression sickness should be treated initially with 100% oxygen until hyperbaric oxygen therapy (100% oxygen delivered in a high-pressure chamber) can be provided. Mild cases of the "bends" and some skin symptoms may disappear during descent from high altitude
- It is beneficial to give fluids, as this helps reduce dehydration.
- The duration of recompression treatment depends on the severity of symptoms, the dive history, the type of recompression therapy used and the patient's response to the treatment.

NITROGEN ELIMINATION - DECOMPRESSION

- If a diver is **brought to the surface slowly**, enough of the dissolved nitrogen can usually be eliminated by expiration through the lungs to prevent decompression sickness.

- About **two thirds of the total nitrogen is liberated in 1 hour** and about **90 per cent in 6 hours**.

- **Decompression tables** have been prepared by the U.S. Navy that detail procedures for safe decompression.

NITROGEN ELIMINATION - DECOMPRESSION

- a diver who has been breathing air and has been on the **sea bottom for 60 minutes at a depth of 190 feet** is decompressed according to the following schedule:

- 10 minutes at 50 feet depth
- 17 minutes at 40 feet depth
- 19 minutes at 30 feet depth
- 50 minutes at 20 feet depth
- 84 minutes at 10 feet depth

- so, for a **work period on the bottom of only 1 hour**, the *total time for decompression is about 3 hours.*

IMMERSION

- Immersion of the human body in water has effects on the circulation, renal system and fluid balance, and breathing, which are caused by the external hydrostatic pressure of the water providing support against the internal hydrostatic pressure of the blood. This causes a blood shift from the extravascular tissues of the limbs into the chest cavity, and fluid losses known as immersion diuresis compensate for the blood shift in hydrated subjects soon after immersion. Hydrostatic pressure on the body due to head out immersion causes negative pressure breathing which contributes to the blood shift.[

- The blood shift causes an increased respiratory and cardiac workload. Stroke volume is not greatly affected by immersion or variation in ambient pressure but slowed heartbeat reduces the overall cardiac output, particularly due to the diving reflex in breath-hold diving. Lung volume decreases in the upright position due to cranial displacement of the abdomen due to hydrostatic pressure, and resistance to air flow in the airways increases significantly because of the decrease in lung volume. There appears to be a connection between pulmonary edema and increased pulmonary blood flow and pressure which results in capillary engorgement. This may occur during higher intensity exercise while immersed or submersed. Negative static lung load due to hydrostatic pressure difference between ambient pressure on the chest and breathing gas supply pressure can cause a reduction in compliance of the soft lung tissues leading to increased work of breathing.

Exposure

- Cold shock response is the physiological response of organisms to sudden cold, especially cold water, and is a common cause of death from immersion in very cold water, such as by falling through thin ice. The immediate shock of the cold causes involuntary inhalation, which if underwater can result in drowning. The cold water can also cause heart attack due to vasoconstriction; the heart has to work harder to pump the same volume of blood throughout the body, and for people with heart disease, this additional workload can cause the heart to go into arrest. A person who survives the initial minute of trauma after falling into icy water can survive for at least thirty minutes provided they don't drown. However, the ability to perform useful work like staying afloat declines substantially after ten minutes as the body protectively cuts off blood flow to "non-essential" muscles.

Exposure Cont…..

- Hypothermia is reduced body temperature that happens when a body dissipates more heat than it absorbs and produces. Hypothermia is a major limitation to swimming or diving in cold water. The reduction in finger dexterity due to pain or numbness decreases general safety and work capacity, which consequently increases the risk of other injuries. Body heat is lost much more quickly in water than in air, so water temperatures that would be quite reasonable as outdoor air temperatures can lead to hypothermia in inadequately protected divers, although it is not often the direct clinical cause of death.

Breath- hold diving

- Breath-hold diving by an air-breathing animal is limited by the physiological capacity to perform the dive on the oxygen available until it returns to a source of fresh breathing gas, usually the air at the surface. When this internal oxygen supply is depleted, the animal suffers an increasing urge to breathe caused by a buildup of carbon dioxide in the circulation, followed by loss of consciousness due to central nervous system hypoxia. If this occurs underwater, it will drown. Breath-hold diving depth is limited in animals when the volume of rigid walled internal air spaces is occupied by all of the compressed gas of the breath and the soft spaces have collapsed under external pressure. Animals that can dive deeply have internal air spaces that can extensively collapse without harm, and may actively exhale before diving to avoid absorption of inert gas during the dive.[20

Breath-hold cont….

- Breath-hold blackout is a loss of consciousness caused by cerebral hypoxia towards the end of a breath-hold dive, when the swimmer does not necessarily experience an urgent need to breathe and has no other obvious medical condition that might have caused it. It can be provoked by hyperventilating just before a dive, or as a consequence of the pressure reduction on ascent, or a combination of these. Victims are often established practitioners of breath-hold diving, are fit, strong swimmers and have not experienced problems before

- There are three different mechanisms behind blackouts in freediving:[26]
- **Duration-induced hypoxia** occurs when the breath is held long enough for metabolic activity to reduce the oxygen partial pressure sufficiently to cause loss of consciousness. This is accelerated by exertion, which uses oxygen faster or hyperventilation, which reduces the carbon dioxide level in the blood which in turn may:
  - increase the oxygen-haemoglobin affinity thus reducing availability of oxygen to brain tissue towards the end of the dive (Bohr effect),
  - suppress the urge to breathe, making it easier to hold the breath to the point of blackout. This can happen at any depth.[27][26]
- **Ischaemic hypoxia** is caused by reduced blood flow to the brain arising from cerebral vasoconstriction brought on by low carbon dioxide following hyperventilation, or increased pressure on the heart as a consequence of glossopharangeal insufflation (lung packing) which can reduce blood circulation in general, or both. If the brain used more oxygen than is available in the blood supply, the cerebral oxygen partial pressure may drop below the level required to sustain consciousness. This type of blackout is likely to occur early in the dive.[26][28]
- **Ascent-induced hypoxia** is caused by a drop in oxygen partial pressure as ambient pressure is reduced on ascent. The oxygen partial pressure at depth, under pressure, may be sufficient to maintain consciousness but only at that depth and not at the reduced pressures in the shallower waters above or at the surface

Ambient Pressure Change

- There are two components to the ambient pressure acting on the diver: the atmospheric pressure and the water (hydrostatic) pressure. A descent of 10 m (33 feet) in water increases the ambient pressure by an amount approximately equal to the pressure of the atmosphere at sea level. So, a descent from the surface to 10 m (33 feet) underwater results in a doubling of the pressure on the diver. This pressure change will reduce the volume of a gas filled space by half. Boyle's law describes the relationship between the volume of the gas space and the pressure in the gas.

Ambient Pressure Change cont…

- Barotrauma is physical damage to body tissues caused by a difference in pressure between a gas space inside, or in contact with the body, and the surrounding gas or fluid.[13] It typically occurs when the organism is exposed to a significant change in ambient pressure, such as when a diver ascends or descends. When diving, the pressure differences which cause the barotrauma are changes in hydrostatic pressure

- The initial damage is usually due to over-stretching the tissues in tension or shear, either directly by expansion of the gas in the closed space, or by pressure difference hydrostatically transmitted through the tissue. Tissue rupture may be complicated by the introduction of gas into the local tissue or circulation through the initial trauma site, which can cause blockage of circulation at distant sites, or interfere with normal function of an organ by its presence.[13] Barotrauma generally manifests as sinus or middle ear effects, decompression sickness (DCS), lung overpressure injuries, and injuries resulting from external squeezes

- Barotraumas of descent are caused by preventing the free change of volume of the gas in a closed space in contact with the diver, resulting in a pressure difference between the tissues and the gas space, and the unbalanced force due to this pressure difference causes deformation of the tissues resulting in cell rupture

- Barotraumas of ascent are also caused when the free change of volume of the gas in a closed space in contact with the diver is prevented. In this case the pressure difference causes a resultant tension in the surrounding tissues which exceeds their tensile strength. Besides tissue rupture, the overpressure may cause ingress of gases into the tissues and further afield through the circulatory system.[13] This pulmonary barotrauma (PBt) of ascent is also known as pulmonary over-inflation syndrome (POIS), lung over-pressure injury (LOP) and burst lung. Consequent injuries may include arterial gas embolism, pneumothorax, mediastinal, interstitial and subcutaneous emphysemas, not usually all at the same time.

Breathing under pressure

- Provision of breathing gas at ambient pressure can greatly prolong the duration of a dive, but there are other problems that may result from this technological solution. Absorption of metabolically inert gases is increased as a function of time and pressure, and these may both produce undesirable effects immediately, as a consequence of their presence in the dissolved state, such as nitrogen narcosis and high pressure nervous syndrome,[35][36] or cause problems when coming out of solution within the tissues during decompression.[37]
- Other problems arise when the concentration of metabolically active gases is increased. These range from the toxic effects of oxygen at high partial pressure,[38] through buildup of carbon dioxide due to excessive work of breathing and increased dead space,[39] to the exacerbation of the toxic effects of contaminants in the breathing gas due to the increased concentration at high pressures