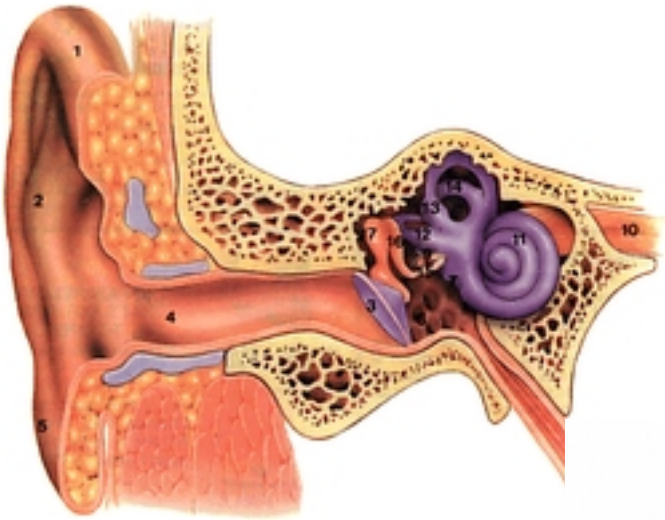
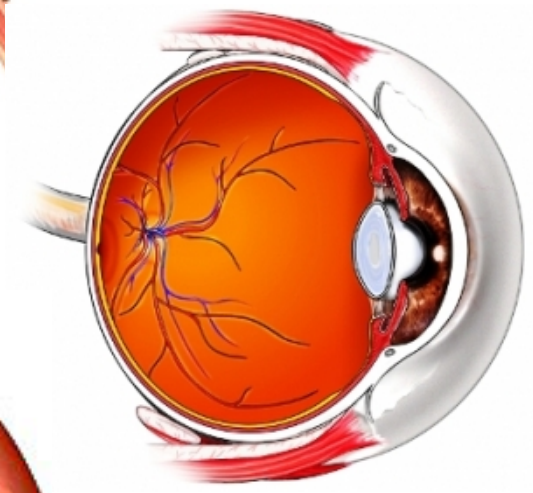
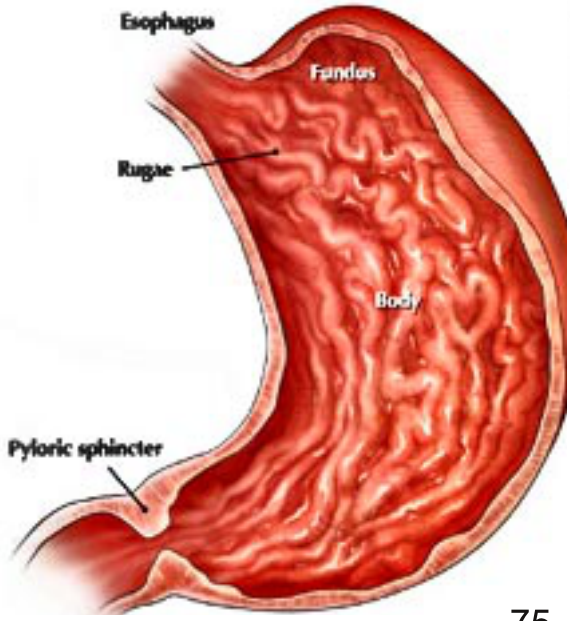
Chapter 3

Diving Medicine



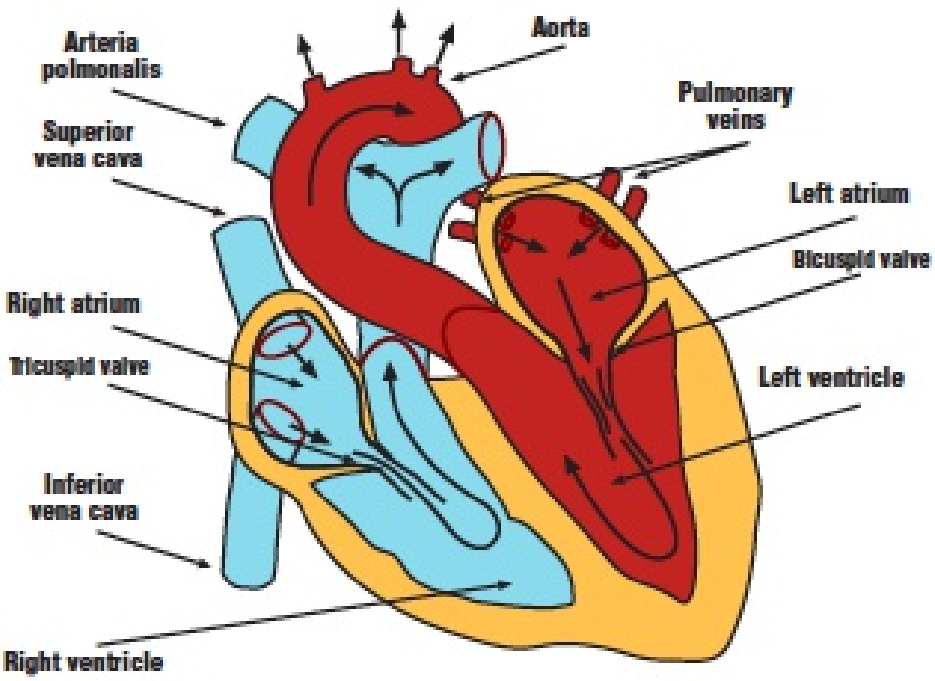




Why is it important to know diving medicine?

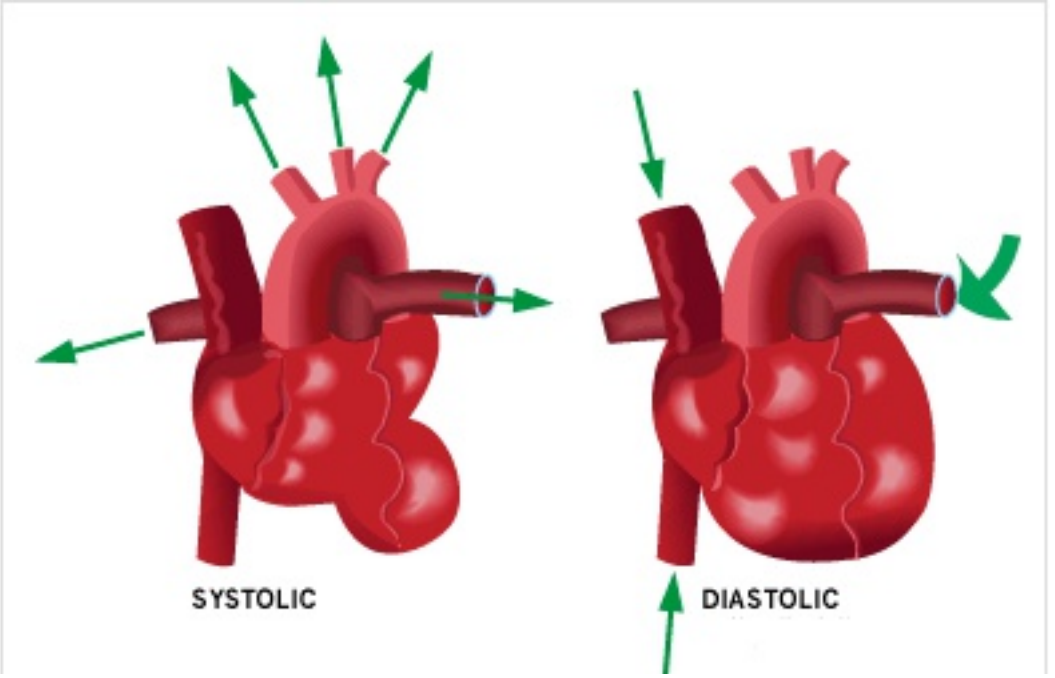
It is very important to understand this chapter because of your safety and the safety of your diving group. It is essential for good and effective handling of emergency situations.

The cardiovascular system



The function of the circulatory system is to transport and distribute oxygen and to remove remains of carbon dioxide. The central element of the circulatory system is the heart, which is divided vertically to the left and right side of the heart. The left side of the heart is responsible for the transportation of blood enriched with oxygen. The right side of the heart is responsible for the transportation of blood with carbon dioxide and poor in oxygen. Heart is horizontally divided into two parts - the atria and the ventricles. The lower two chambers of the heart are called ventricles. They are separated into the left ventricle and the right ventricle. The upper two heart chambers are called atria. Atria receive blood which is returning to the heart from the body and ventricles pump the blood from the heart to the body. The right ventricle pushes the blood towards the lungs via the pulmonary arteries, and returns the blood rich with oxigen through the pulmonary veins, which go to the left atrium. From there the oxygen rich blood goes into the left ventricles where it is pumped through the body via the arteries. When it delivers oxygen to cells, and takes the CO2 from them, it returns through the veins to the right atrium.

Cardiac movement is divided into two phases: “systolic” and “diastolic”. The systole is a contraction which allows release of the blood, and the diastole allows the heart to be filled with blood.



Blood is carried by:

The main arteries - thick and wide,resistant to high blood pressure

The arteriole - small in width, regulate the flow of blood according to the requirements of the various organs

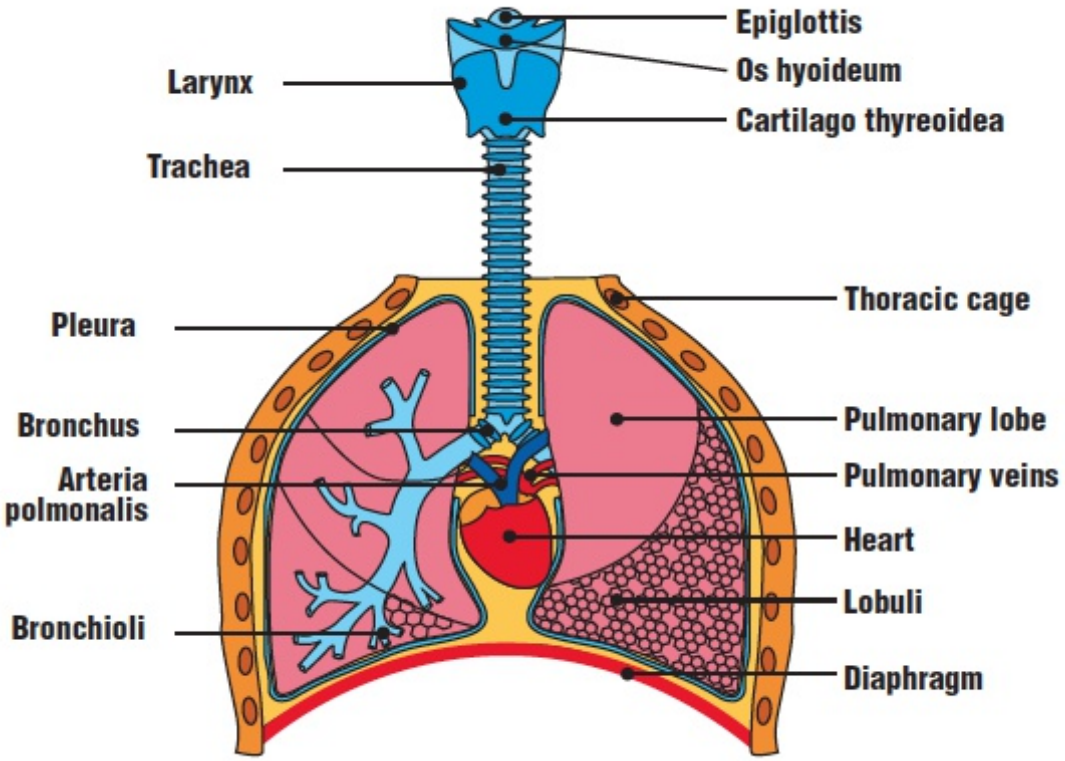
The capillaries - small blood vessels within the body tissues , that transports blood from arteries to veins (blood vessels that carry blood to the heart)

From the capillary the blood goes into the venule, from there into the larger veins, and finally to the veins that return to the heart.

The respiratory system

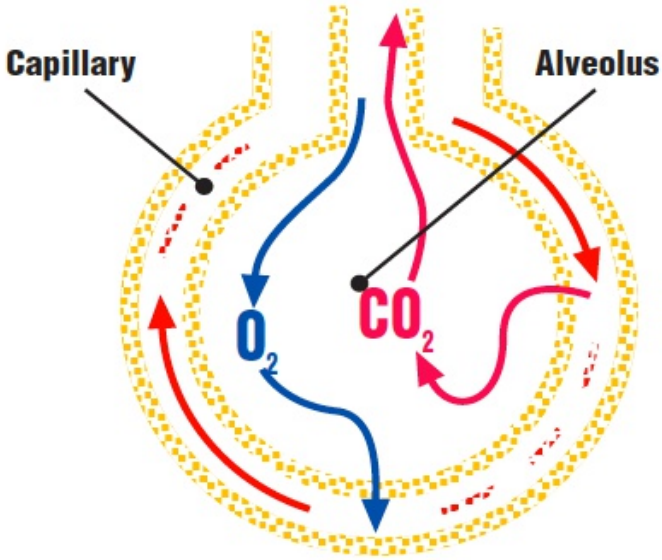
The function of the respiratory organs is gas exchange. Gasses are absorbed in the blood through the following: The respiratory airways (connect the lungs with the outside), the alveoli (the place where gas enters the bloodstream), lungsm and the capillaries (link the alveoli with the heart).

The respiratory airways are divided in two sections: upper and lower. The upper airways are nose, mouth, sinuses, pharynx and larynx. Their task is to carry air to the lungs while purifying and adding moisture to it. The lower airways are trachea, bronchi, bronchiole and alveoli. Respiratory exchange takes place over the and alveoli.



THE ALVEOLI AND THE CAPILIARIES

Alveoli are extremely small sacks, which grouped into alveoli branches make up the tissue of lungs. They have a vast surface area (between 40 and 100 square meters in adults). Over their surface area the exchange of gases in the body takes place. Oxygen is carried from the breathed air into the blood, because of the difference in partial pressure, through the membrane of the alveoli. When we breath in the air, the partial pressure of oxygen is bigger in the lungs than in alveolus, so the alveolus receive the oxygen to even up the partial pressure. While the blood receives oxygen from the alveolus, it releases the carbon dioxide into the alveolus, in order to release it from the body.



DIFFERENT PRESSURE
Capillary pCO_2 > Alveolar pCO_2
Alveolar pO_2 > Capillary pO_2

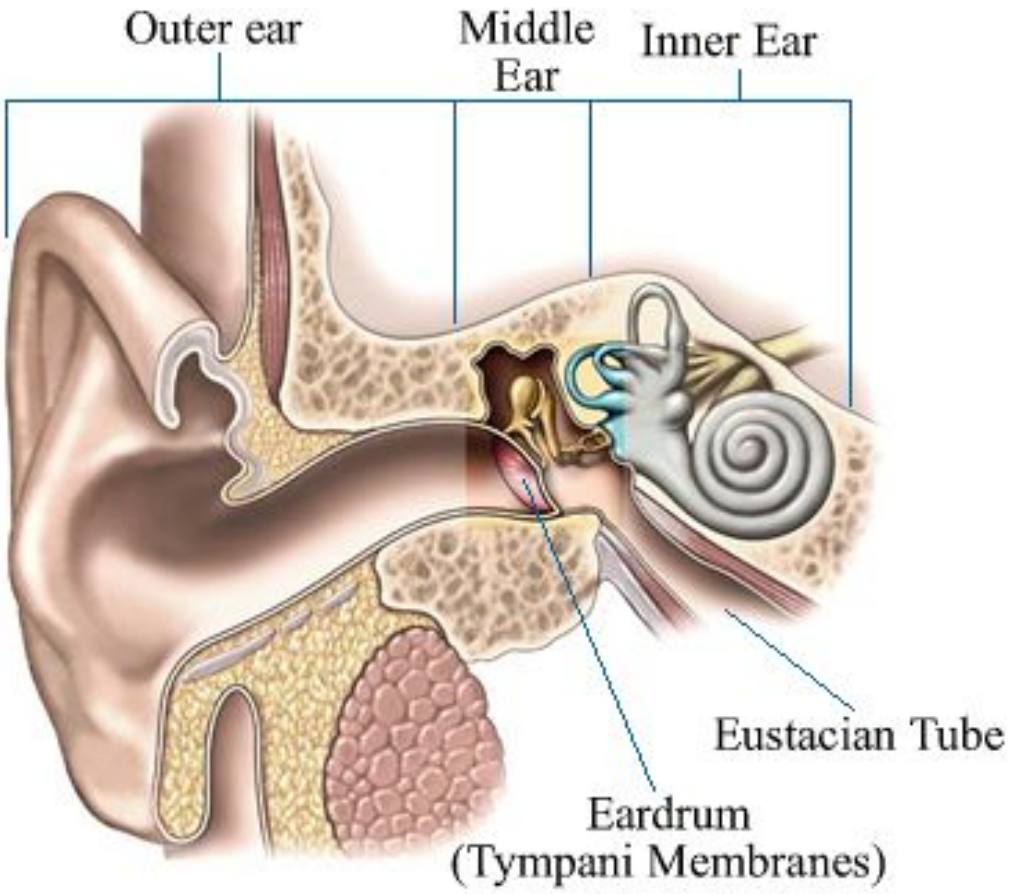
p is partial pressure

Hearing in water

Structure of a human ear

The three major parts of the human ear are the outer ear, the middle ear and the inner ear.

Sound travels from the outer ear to te middle ear and finally to the inner ear.

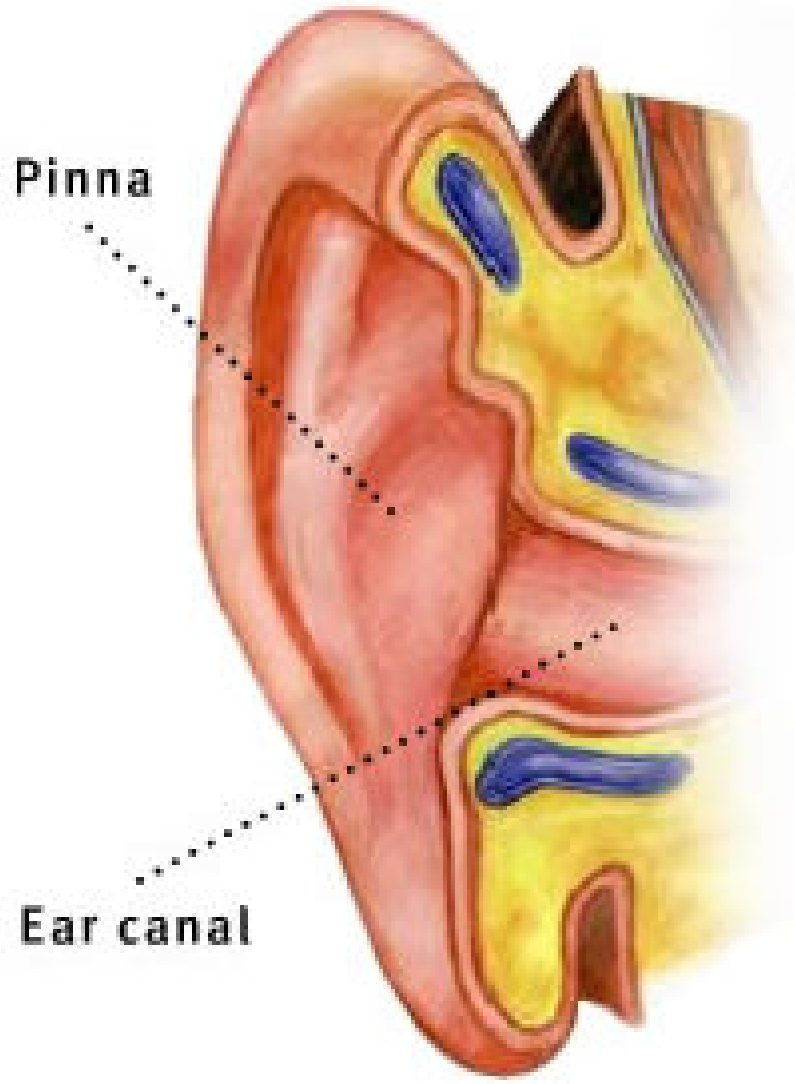


Outer Ear

The outer ear or external ear is a visible part of the ear. The outer ear consists of the following two parts:

Ear Flap (Pinna) - The sound waves enter the ear through the ear flap.

Ear Canal - The ear canal is about 2 cm in length. It increases the sound waves and channelizes them to the middle ear. Sweat glands are present in this canal. They secrete earwax.



Midddle ear

The middle ear is located between the outer ear and the inner ear. Outer and middle ear are separated by a thin membrane called tympanic membrane.

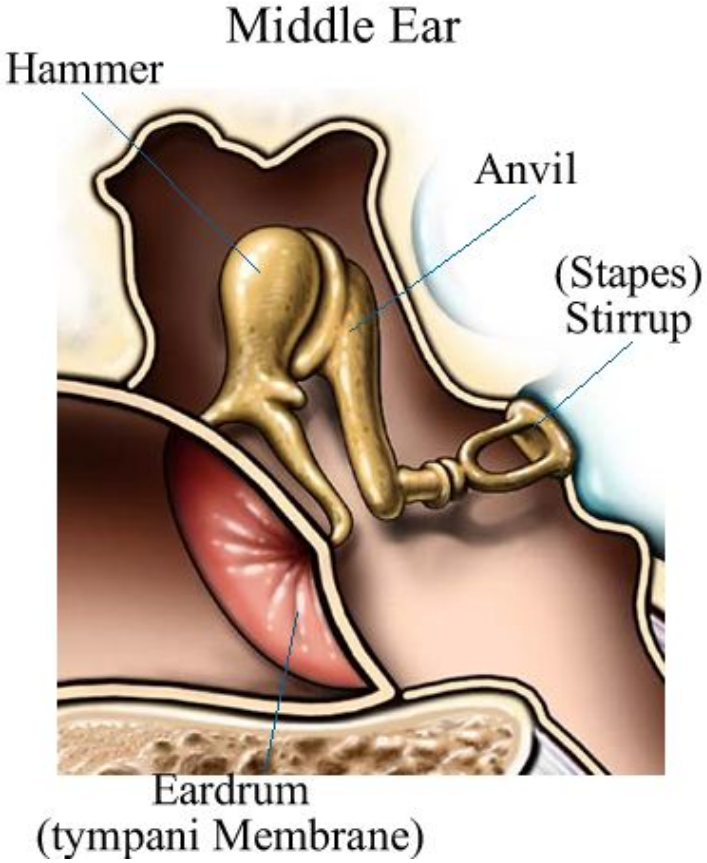
The middle ear is an air-filled cavity and consists of the following parts:

Eardrum - a thin membrane that presents a distinction between the outer ear and the middle ear. It vibrates as soon as it receives the sound waves

Hammer - is a tiny bone located next to the eardrum. The vibrations from the eardrum cause the hammer to vibrate.

Anvil - is another tiny bone next to hammer. It vibrates in response to the vibration of hammer.

Stirrup – similar to hammer and anvil, stirrup is a tiny bone in the middle ear. It also vibrates and passes the sound waves to the inner ear.



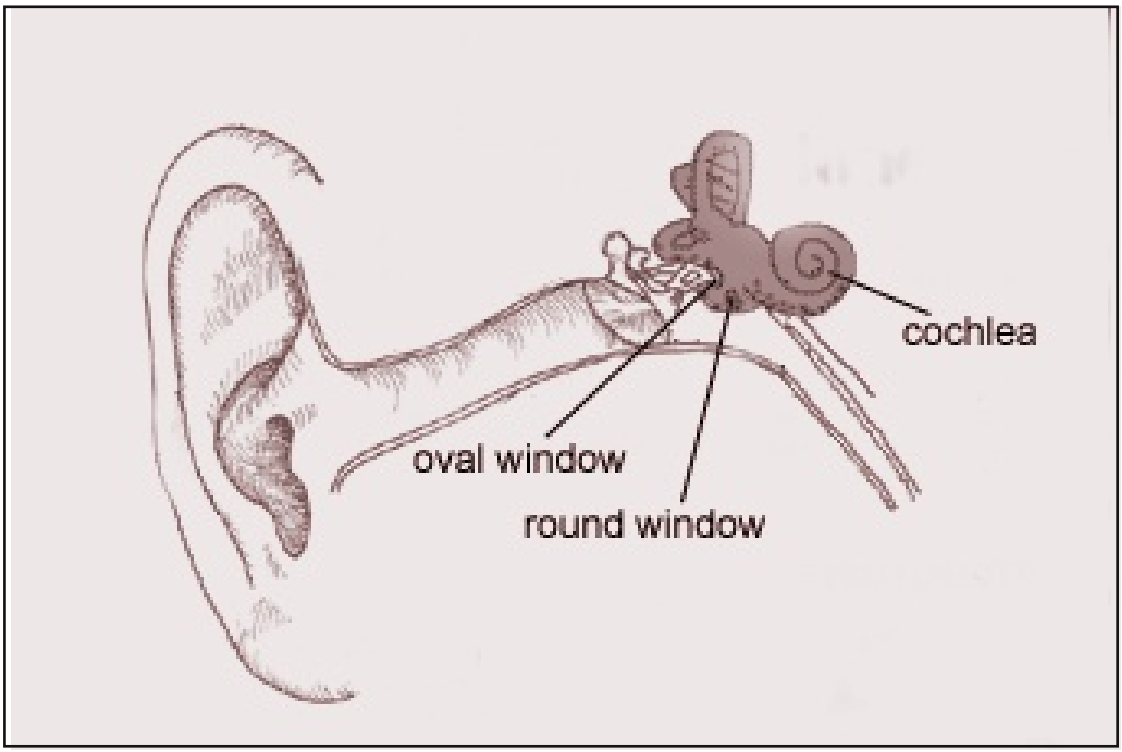
Inner ear

The inner ear is the inner part of the ear. It is filled with a water-like substance and consists of hearing and balancing organs. The inner ear consists of the following parts:

Cochlea - is a rolled structure that can stretch to about 3 cm. The membrane of cochlea consists of numerous nerve cells.

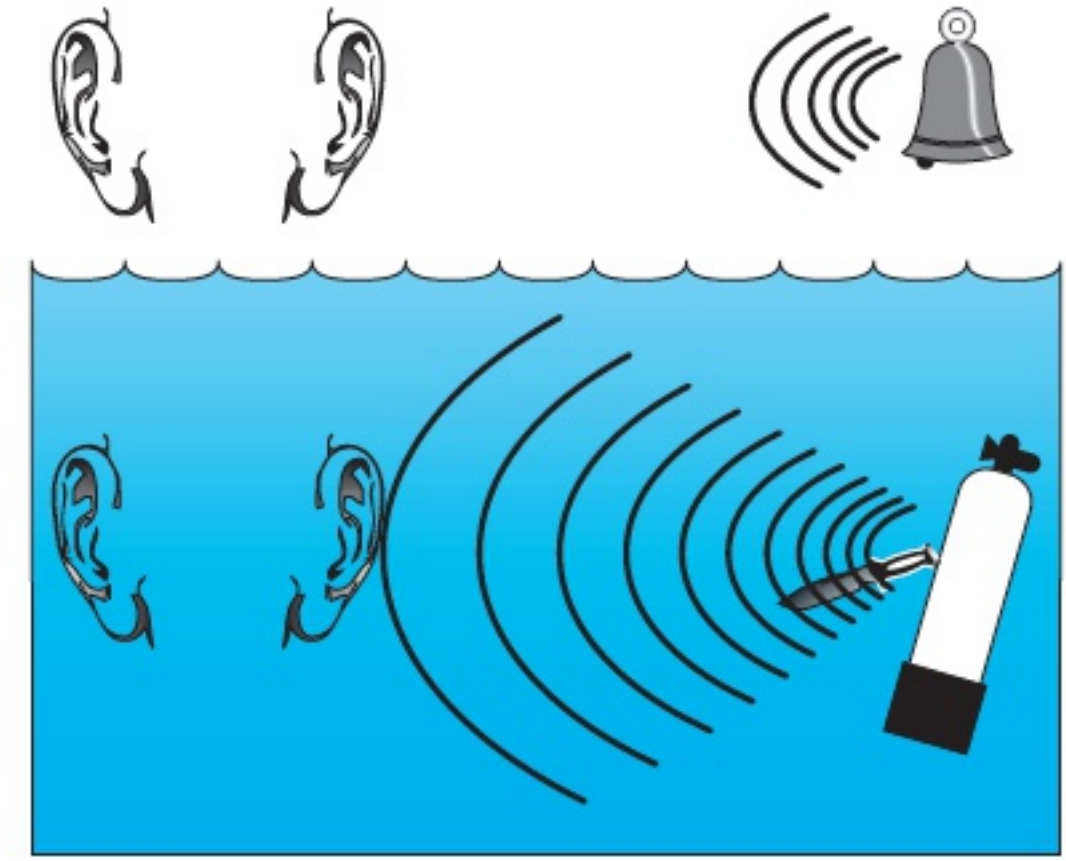
Semicircular Canals - are fluid-filled loops, attached to the cochlea and help maintaining the balance.

Auditory Nerve - the electrical impulses, generated by the nerve cells, are then passed to the brain.



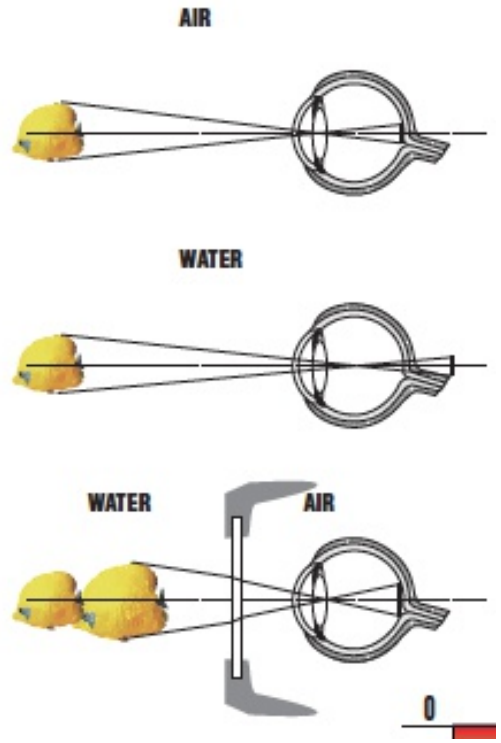
Hearing in water

Underwater sounds are transmitted much more quickly because water has a greater density than air. While the speed of sound in air is 330 m/s underwater is 1500 m/ s. Sounds made to call attention, like hitting a knife on metal can be heard at great distances. In the atmosphere the sound is received through the above explained ear parts. In the water because of the speed of sound we receive the sound waves over our scull and get completely surrounded by sound. Thus we can not determine the direction of the sound. Pay attention on the noises and if you hear an engine while ascending wait for the sound to go away.

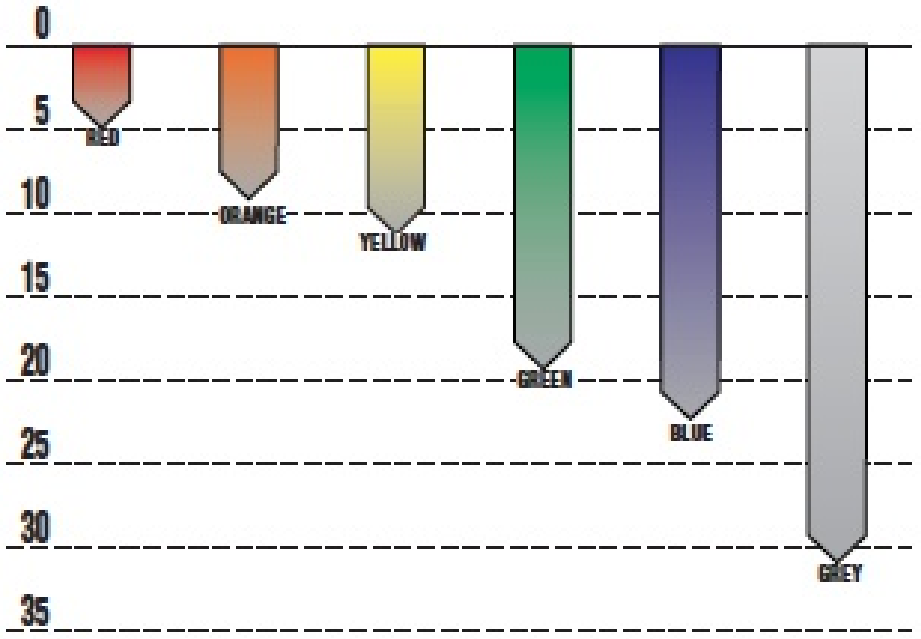


Sight in water

Sight doesn't present a major problem in diving. However, when the eyes are in direct contact with water the vision is unfocused, everything is blurry because the rays of light coming from the viewed object undergo a index of refraction different to that of the air. To be able to see clearly underwater we need our eyes to be in contact with air, that is wear a mask. However because the bigger index of light refraction objects underwater seem closer and bigger for about 1/3 and closer for about 1/4.

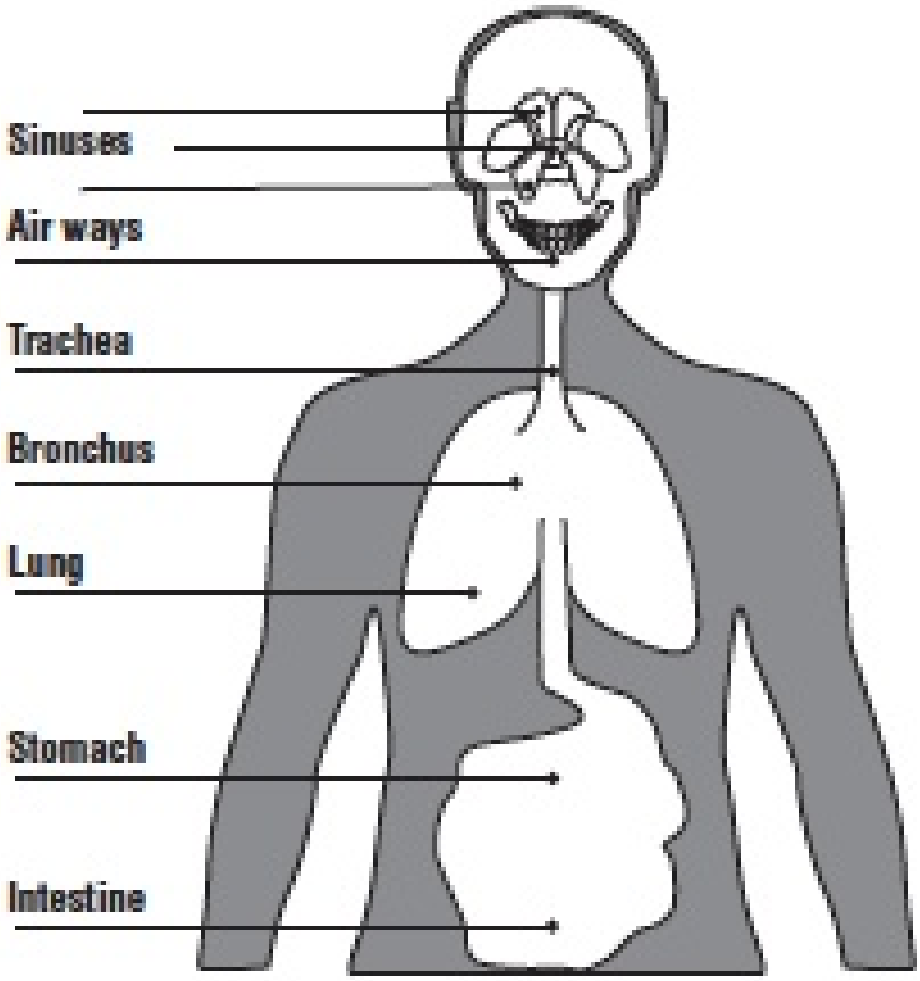


As water absorbs light the colors are lost. The warm colors are lost first. In order to see colors underwater a diving light must be used.



Effects of high pressure on human organism

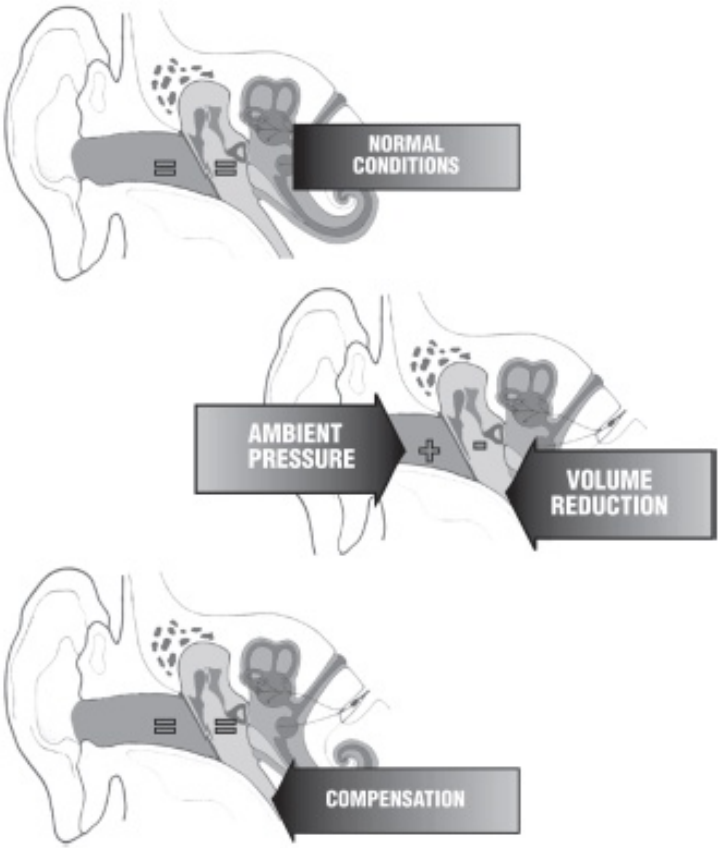
If the ambient pressure increases, gas at that pressure is introduced into organs. In order to compensate the volume of the organ doesn't change. When the pressure is reduced this gas under pressure expands and must be able to be released, in order to avoid an increase in volume of the organ. The respiratory airways are compensated automatically because they are in contact with the air at ambient pressure through the air breathed through the regulator. We feel the change in pressure only in body parts filled with air because air is compressible, and water is not.

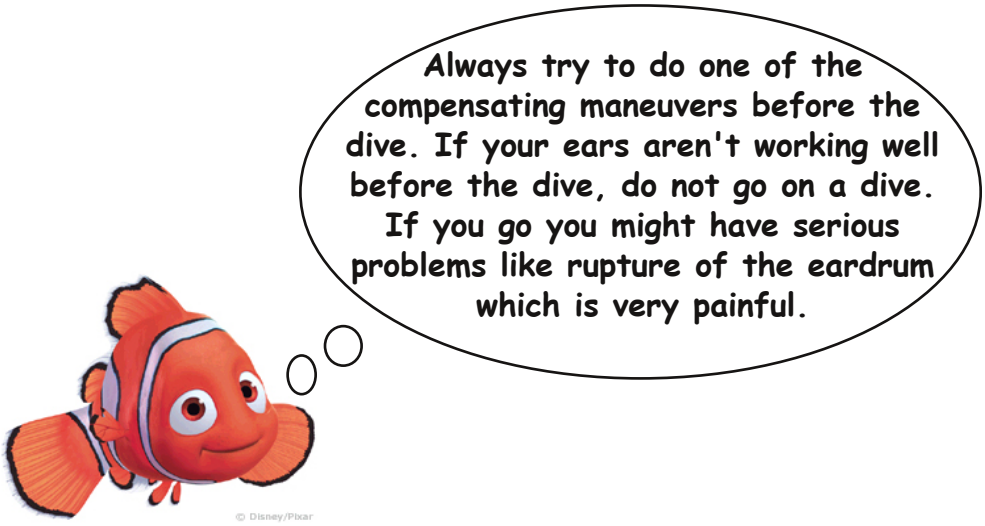


Body parts filled with air

Reduction of volume

The rising external pressure causes a reduction in volume of air-filled organs. In the stomach and intestine this variation in volume doesn't normally present any problems but in the ear it causes the crash of the Eustachian tube. Namely, lowering down the pressure in the middle ear during descent affects the eardrum- it is being turned inwards because the higher external pressure. On ascent the air in the middle ear expands, and if not compensated the eardrum turns outwards. The volume of air in the middle ear has to be kept in balance by adding air through the eustachian tube (usually called compensation), for which there are several ways. The most common and effective methods for achieving compensation are Valsava (pinching one's nose shut and blowing through it) and Fresnel maneuver (closing the nose and moving the tongue upwards). Compensation must be carried out before the ear start to hurt: too long a wait can result in reduction in the volume of the air inside the middle ear and that can make the maneuver difficult or hardly possible at that moment.





Disorder and barotrauma of the middle ear

Barotrauma is an injury caused by the changes in pressure to different air filled cavities in the body. The most common kind of ear barotrauma experienced by recreational divers is the middle ear barotrauma. Middle ear barotrauma is caused by the inability of the diver to clear the space in the middle ear through the Eustachian tube. Ear barotrauma is the usually an injury to timpanic membrane, in form of rupture, bruising and stretching. Common causes of an ear barotrauma are ineffective equalization techniques, congestion, exceedingly forceful equalizations, or skipped equalizations. An ear barotrauma can occur at any depth, but is most common at shallow depths where the pressure change per a foot is the greatest.

A middle ear barotrauma may occur on descent. Lowering down the pressure in the middle ear during descent affects the eardrum- it is being turned inwards because the higher external pressure. On ascent the air in the middle ear expands, and if not compensated the eardrum turns outwards.

Signs and Symptoms of a Middle Ear Barotrauma

On Descent:

Build up of pressure, pain, inability to equalize

If a diver continues to descend without equalizing, the eardrum will rupture. This is usually followed a flow of water into the middle ear which can cause fainting. You can prevent that by going on a smaller depth and trying to equalize. If you do not suceede, ascend

On Ascent:

The signs are the same as on the descent. Try to go a bit deeper and equalize the pressure if possible. Release the pressure if it is possible, by moving the jaw, and trying to open the eustachian tube with movements of tongue and back of the throat.

After the Dive:

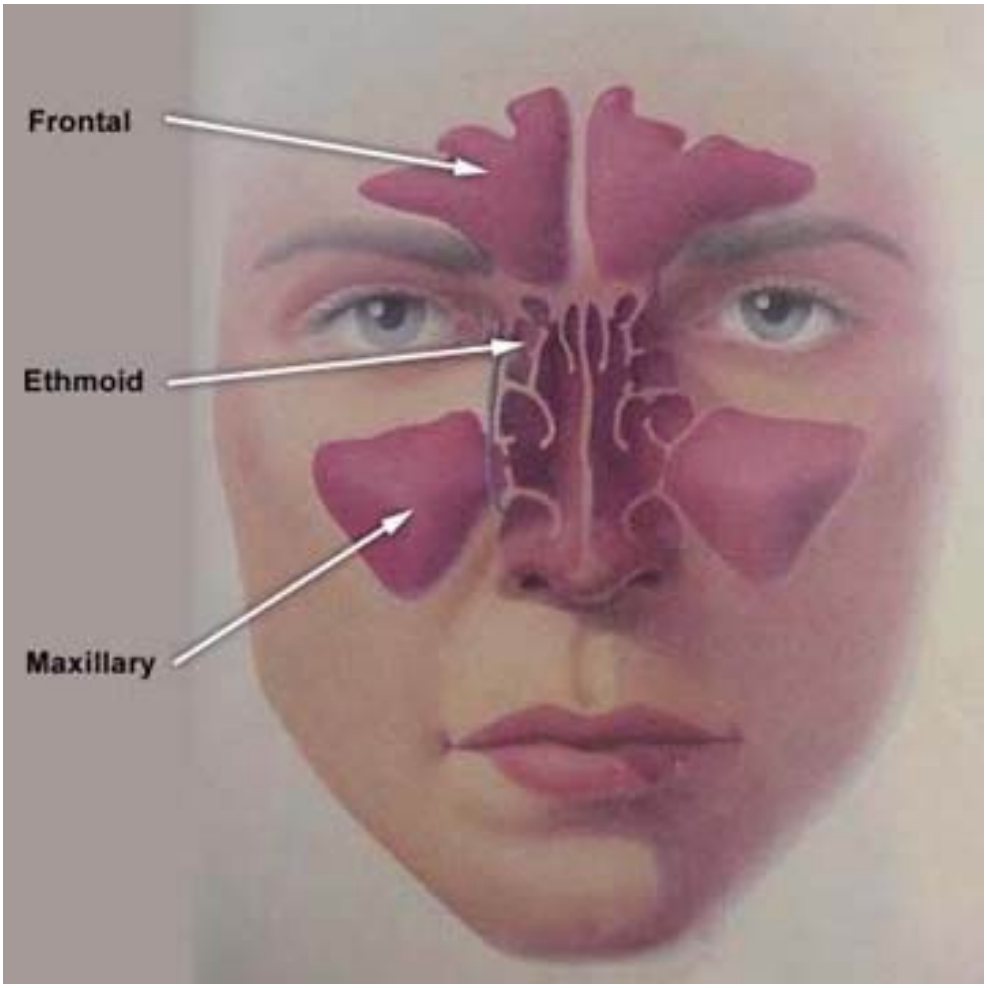
Middle ear barotrauma may be recognized after a dive by the feeling of water in the ears that does not go away. This is caused by the accumulation of blood and body fluids in the eardrum and middle ear, not by water.

Bad hearing, dizziness, popping or crackling sounds while moving the jaw, soreness of the eustachian tubes and ears, squeaking noises during equalization, and fluid leaking into the throat from the eustachian tubes are all signs of a middle ear barotrauma.

If you notice these problems during a dive stop, tell that to your buddy and dive leader! After the dive go see a doctor! Do not panic! This problem is treatable, but until it is completely treated do not dive!

Sinus squeeze

Your sinuses are air-filled cavities. When you ascend or descend, the pressure in each sinus must adjust to match the air pressure in the nose. For those with healthy normal sinuses, this occurs automatically. But if the sinus openings are plugged by polyps, mucous, or congestion, "sinus squeeze" occurs. Mild cases can be treated by simply slowing your ascent and descent, and blowing gently into your nose - just as you do to equalize the pressure in your ears. More severe cases may require use of decongestants in pill form. If sinus problems are chronic, your doctor can prescribe a steroid nasal spray to decrease swelling and sensitivity in the nose.



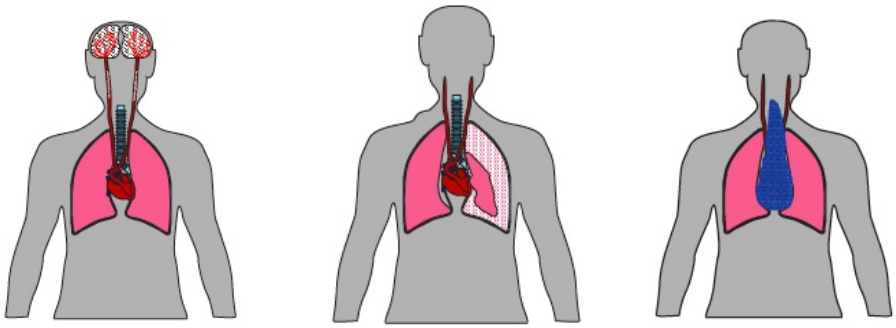
Sinuses

Teeth barotrauma

Teeth barotrauma can occur if air gets trapped in a hole in a tooth and can not get out on ascent. As the air expands the tooth starts to hurt and bursts. This can cause fainting.This does not happen in healthy teeth. You can prevent this by regularly going to the dentist.

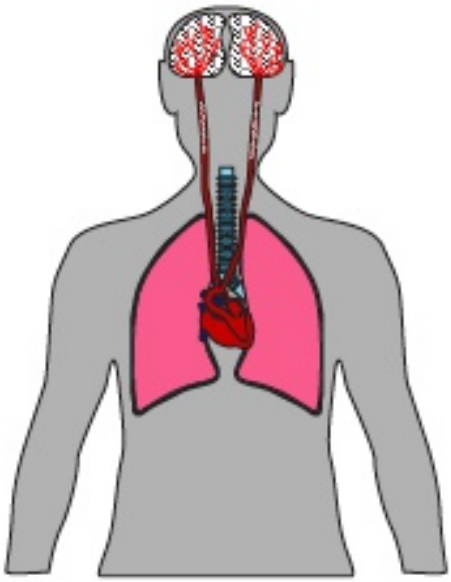
Pulmonary barotrauma

During ascent the air in the lungs expands. If breath is held during ascent in scuba diving this expansion of the air first enlarges the lungs to their maximum, and then causes a growth of the pulmonary alveoli. If a diver continues to ascend without breathing out, the result can be a pulmonary barotrauma (a trauma of the lungs caused by pressure). In this case the alveoli can break and the bubbles released can end up in the blood stream, or in the spaces surrounding the lungs. The prevention of this medical state is regular and continuous breathing. Never hold your breath during ascent, even in the pool. The seriousness of a pulmonary stretching depends on the effect of pressure on the pulmonary alveoli. The most serious case is when bubbles come in to the blood stream. The consequences of passing bubbles from the lacerated alveoli to the neighboring tissues may be: pneumothorax, mediastinal emphysema or subcutaneous emphysema.



Air embolism sindrome

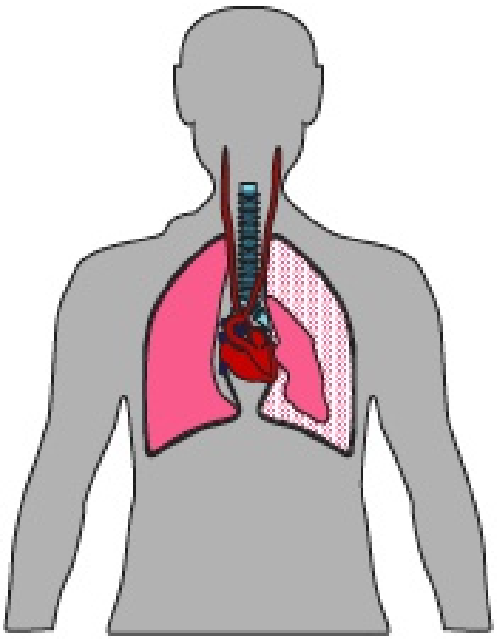
The bubbles escaping from the ruptured alveoli, once they reach the bloodstream are pushed along the aorta. They can reach any part of the body and may stop in the small vessels. This can block circulation of the blood, and therefore of oxygen in the areas below the embolus. Symptoms and effects:
dizziness, blurry vision, breathing problems, heart disturbances, and paralysis.



Pneumothorax

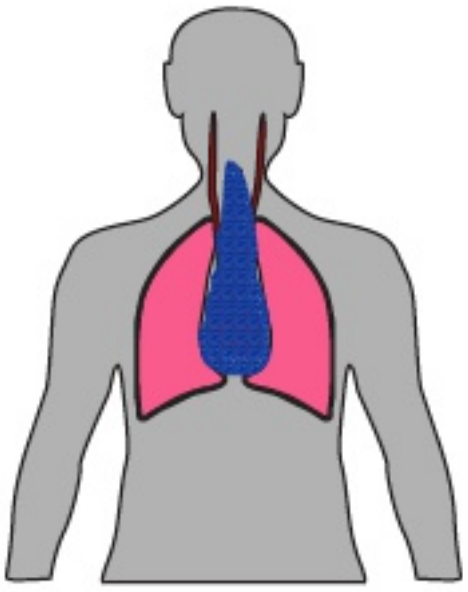
If the alveoli and pulmonary membrane rupture and air gets in the space around the lungs Pneumothoraxs occurs.

The symptoms of pneumothorax consist of intense chest pain along with coughing of blood and difficulty in breathing.



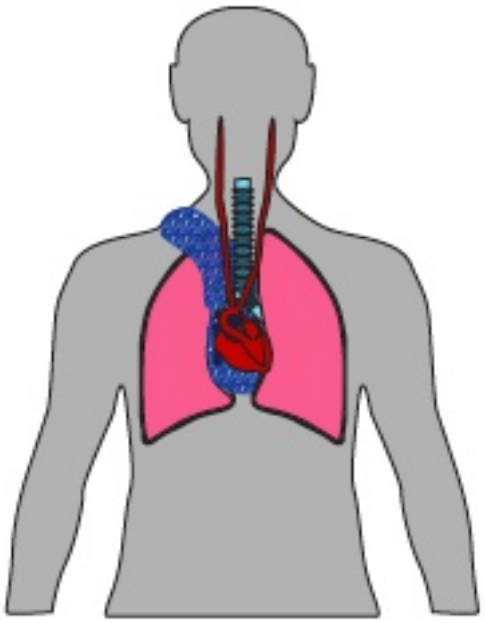
Mediastinal emphysema

If the alveoli and pulmonary membrane rupture and air gets trapped between the tissues around the heart and the major blood vessels mediastial emphysema occurs. The first symptom is a pain in the inside of the rib cage. In addition, the trapped air that presses against the lungs, the heart, and the large blood vessels, causes breathing difficulties and possible loss of consciousness.



Subcutaneous Emphysema

If the alveoli and pulmonary membrane rupture and air penetrates under the skin around the lungs or the neck subcutaneous emphysema occurs. The symptoms are a “sense of swelling” at the neck and a change in the sound of the voice.



Squeeze

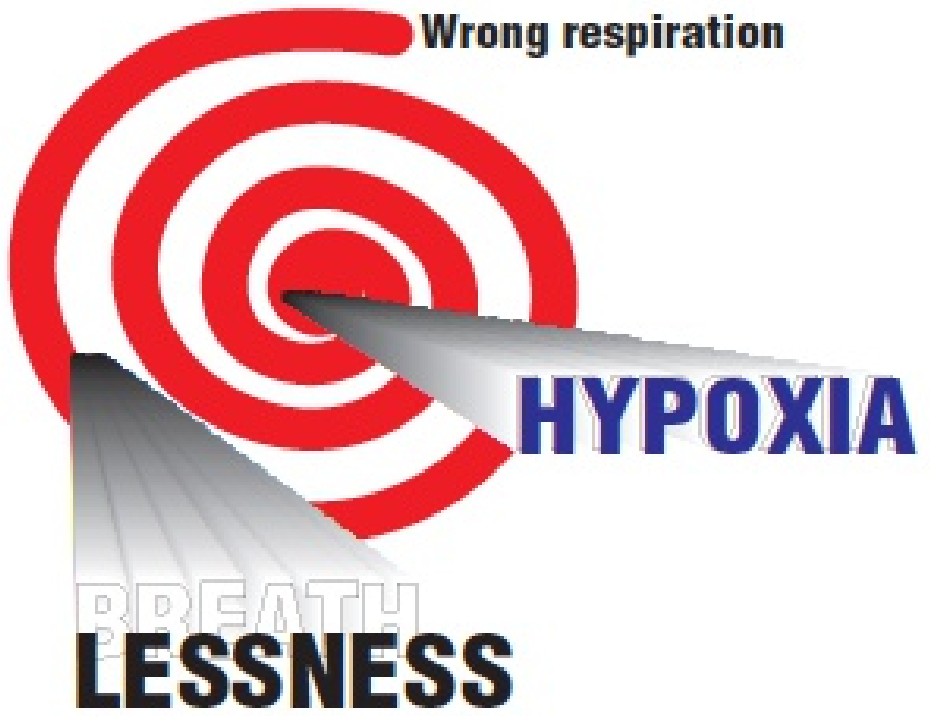
It is always necessary to compensate the mask, as you go deeper underwater the volume of the air inside the mask is reduced and it is pressed into the soft tissues of the face. This can be avoided by blowing air through the nose into the mask. This maintains a constant internal volume. If this is not done, then small blood vessels around the eyes burst. It can cause bruising, blood spots over the white of the eye, and swelling. It rarely causes injury inside the eyeball. This condition isn't dangerous. See the doctor immediately if there is loss of vision, twinkling lights, shadows in your vision, or increasing pain. Wet suit squeeze occurs when increasing the external pressure leads to decrease in thickness of neoprene suits, which then adheres firmly to our skin. The first preventive measure of protection from this nasty phenomenon is the use of neoprene suits of an appropriate size. Tight wetsuit can cause squeeze and discomfort. Also, ALWAYS put water in your wet suit to prevent squeeze becuase water is not compressible and will not change its volume during the dive!

Mask squeeze

Gas related problems in diving

Hypoxia

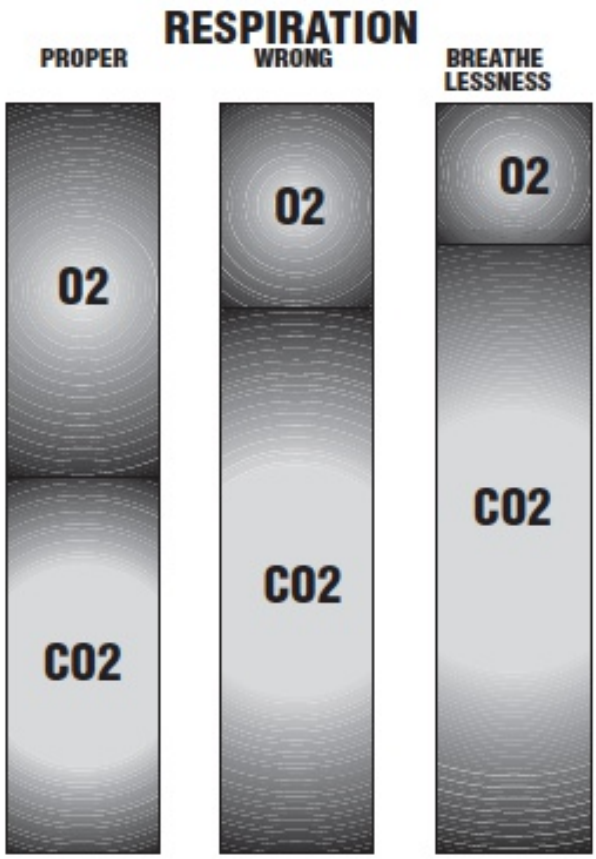
Hypoxia is a situation when there is not enough oxygen for all cells of the body. When scuba diving, hypoxia can occur after a sudden interruption of the air supply (too long dive, or malfunction in equipment) or can develop gradually if we do not breat regurarily (effect of excessive physical work or incorrect breathing). The symptoms of hypoxia are inability to concentrate and impaired movement. The diver suffering from hypoxia should be taken to the surface as soon as possible, treated with oxygen and, if necessary, given artificial respiration.



Hypercapnia

Hypercapnia is a condition where there is too much carbon dioxide (CO2) in the blood. Hypercapnia occurs in shallow and fast breathing, often due to physical work. Hypercapnia normally triggers a reflex which increases breathing and access to oxygen. A failure of this reflex can be fatal. Hypocapnia is the opposite of hypercapnia, and happens in hyperventilation in apnea (breath hold diving).

It is very important to breathe normally. Breathe slowly, not with full lungs, but not shallow. Find your rhythm of breathing. You are breathing properly if you are relaxed and do not have "a hunger for air"

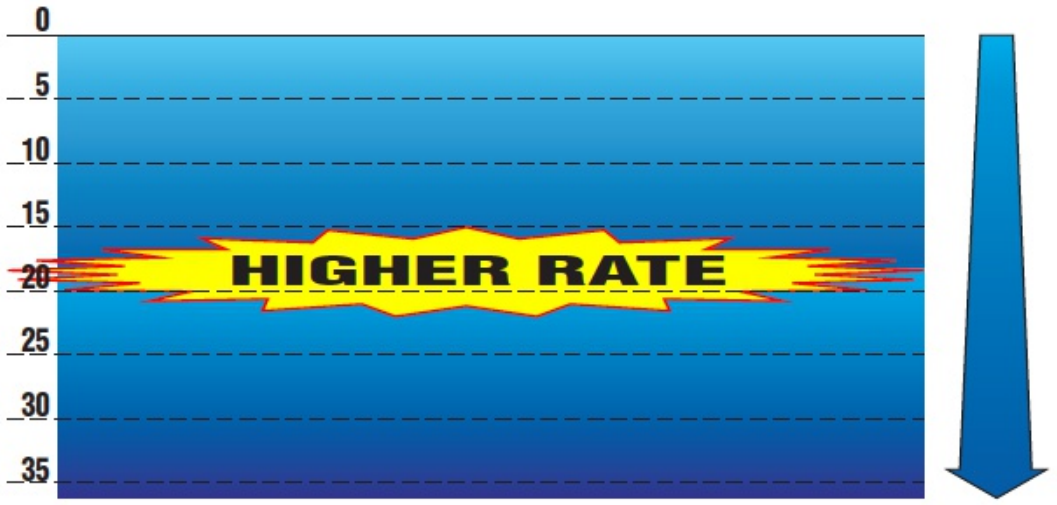


CO Poisoning

CO poisoning is happens when a diver breaths air that contains an excessive amount of CO. This happens if the breathing mixture was not prepared properly by people who work on diving compressors (machines which fill diving cylinders). Symptoms are feeling of warmth in the face and headache. It is necessary to ensure the casualty is immediately given pure air, or even better pure oxygen because CO poisoning can develop into loss of consciousness and coma.

Nitrogen narcosis

Nitrogen narcosis is an effect of nitrogen under higher pressure on the brain which occurs to divers who go below 30 meters, due to the laws of partial pressures. The condition causes loss of motor function and ability to make reasonable decisions. The diver acts like he is "drunk", as with alcoholic beverages. Factors which increase the possibility of nitrogen narcosis are cold, stress, heavy work, CO2 retention, and hang over. This condition does not have any permanent consequences.



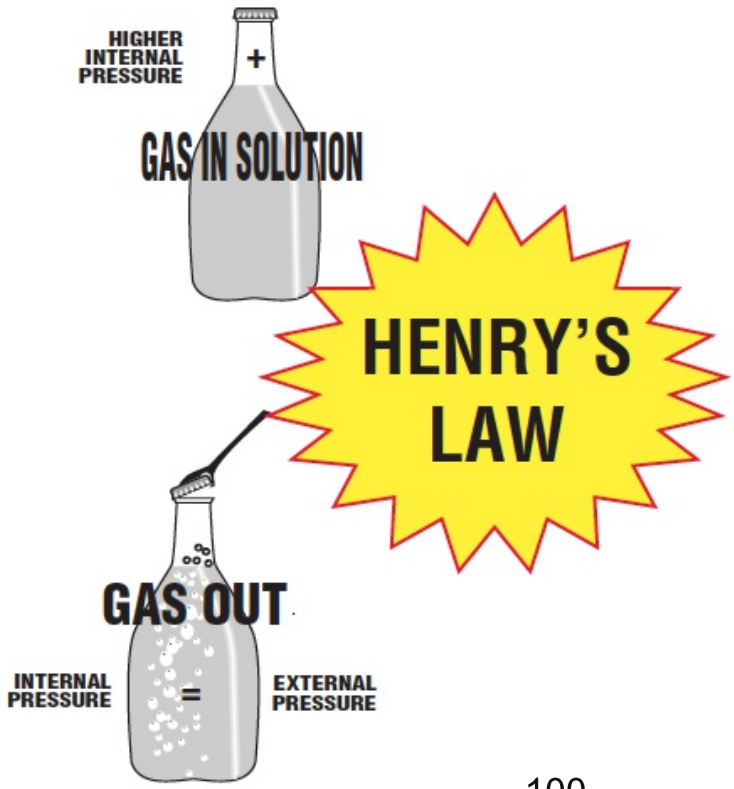
It has been stated that narcosis results in the feeling of one martini for every 15 meters

If you notice strange behavior of your buddy he might have nitrogen narcosis. Treatment of nitrogen narcosis is immediate controlled ascent to the surface, with the buddy or dive master observing the diver for unusual behavior. On the surface, administration of O2 and temporary brake in diving.

The divers affected by narcosis often do some funny things like start to chase pretty fishes, hear fish sing or talk, give their regulator to fish...It is said that you are the same under narcosis as when drunk due to alcohol beverages.

Decompression sickness

As we have seen during descent, the increase in pressure results in a rise in the partial pressure of the
gas breathed. According to Henry's Law the pressure in the tissues increases at the same rate. These percentages vary directly proportional to the depth. Also, the longer spent at a given depth the more gas absorbed in the tissues. On ascent, maintaining a rate of 8-10 meters a minute the excess nitrogen is released from the blood through the lungs, at a partially higher pressure. According to the length and depth of the dive decompression stops (stops at one depth) are made according to the deco tables. If you ascend too quickly the nitrogen cannot be released quickly enough and bubbles form in the divers body. This leads to Decompression Sickness. The symptoms differ based on the affected tissue. It usually appears shortly after surfacing. The symptoms of DCS (decompression sickness) can even present two days after surfacing. Flying soon after diving may cause this disease. On most diving watches you have "no fly interval", the interval of time you are not allowed to fly unless you want to get this terrifying disease.



Skin decompression sickness

It ranges from a mild rash to an measles like rash or a bluish marble like pigmentation of the skin. The spotting is a sign of a severe DCS and is caused by a bubble blocking the blood vessels of the skin. Medical help NEEDS TO BE SOUGHT IF ANY symptoms are seen, because these symptoms might be hiding serious neurological problems.

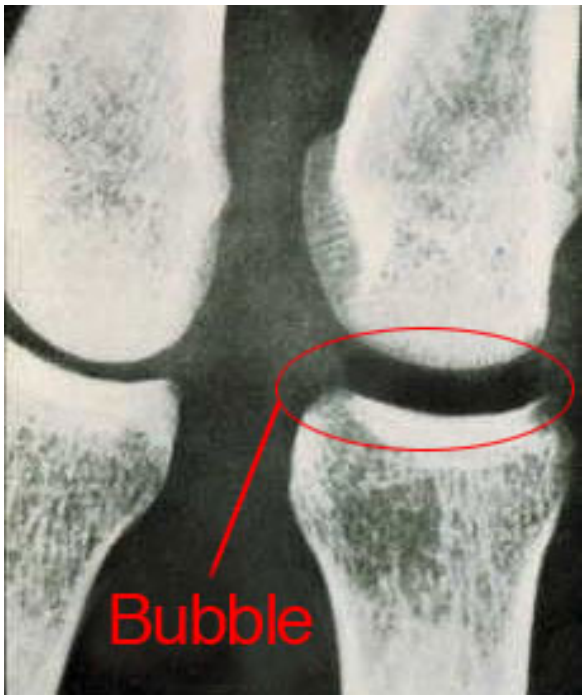
Marbling of skin

Joint decompression sickness

It usually starts as a feeling of tenderness or numbness at or near a joint, soon becoming a sharp, penetrating ache. The joint may swell and become red. The pain increases over the next 12 or 24 hours and will be temporary relieved by exerting pressure on the affected joint. Medical help must be sought, because serious neurological DCS may also be present.

DCS type two is most common in the shoulder.

Joints



Affected joint

Central nervous system decompression sickness

The brain and spinal cord and are very sensitive to bubbles in the blood stream. The symptoms for a CNS Decompression sickness are various and diverse. Some possible effects are; extreme fatigue, numbness, confusion and disorientation, partial or total paralysis, loss of bladder function and blurry vision. Death can be the result of a CNS DCS. This is the most common type of DCS among sport divers and is usually associated with lack of decompression stops (divers stop at a certain depth according to the decompression tables or a dive computer in order to exhale the excess nitrogen out of their system).

FIRST AID

Contact the nearest Recompression Facility. 100% Oxygen must be given to the casualty as soon as possible after the accident and during the journey to the hyperbaric chamber (a room that allows an individual to breathe 100% pure oxygen at greater than 1 standard atmosphere of pressure). The application of pure oxygen guarantees greater oxygenation of the tissues and helps to lessen the risk of damage. The casualty needs to drink fluid at a rate of about 1 liter per hour because hydration helps the blood volume and reduces the risk of more bubbles forming.

It is very important to recognize the mentioned diseases if an accident happens. The faster you react the more chance of smaller consequences for the casualty. Communicate and collaborate. The whole diving group must work as a team to help the person in need. If you are just a begginer, you will not be in charge of first aid, but remember maybe the casualty will be your buddy and you will have to tell the dive master what is wrong and help your buddy surface safely . Thus, this chapter is very important for your safety and the safety of your diving team.

Diving associations

In order to become a certified diver you need to pass a training of one of diving associations. There are levels in each association marking the progress in knowledge, skills and experience of a diver. There are many diving associations, but here are just a few of them:

CMAS

World Confederation of Underwater Activities (CMAS) offers many levels and courses from beginner to advanced. CMAS trainings are very educational and respected. CMAS certification is very hard to get (believe me, I know it from experience. It is not one of those fast courses, but a long and very educational course). There are three diving stars and trainer stars. Of course there are additional courses for wreck diver, speleo diver and so on.

PADI

Professional Association of Diving Instructors (PADI) was founded in 1967. PADI offers many levels of courses and a quick learning course within a week for diving on small depths. This association is widely spread on attractive locations like Egypt so people could dive on holidays.

NAUI

National Association of Underwater Instructors (NAUI) offers curriculum guides and certification. The NAUI association offers a good training course which is said to be one of the best training courses of all.

SSI

Scuba Schools International (SSI) was founded in 1970. It offers school-based scuba diving education and scuba certification. An SSI certification card is accepted at all dive shops for rentals and diving packages.

PDIC

Professional Diving Instructors Corporation (PDIC) is a training association which offers education programs at every level from open water to Advanced Instructor.

Every beginner needs to have some basic practical diving skills which are taught in training courses of all diving associations. Those basic skills will be discussed in the next chapter.

Scuba diving flag