Level 2 Theory

Part 1

Starting Advanced Freediving

Objectives

After completing this part, you will be able to:
1. Understand the advanced freediving equipment
2. Describe how to best use oxygen through an understanding of how the body works during freediving
3. Know how to trigger the Mammalian Dive Reflex (MDR)
4. Describe all 4 main parts of the MDR

Advanced Freediving Equipment

The Level 2 Freediving course is for the diver who has already completed the Level 1 course, who has logged 8 or more dives, and who is now comfortable in the water and regularly dives to depths of 15-20 meters. It is suitable for someone who may have practiced diving in a pool and is looking for more in-depth information on deeper diving, or perhaps even wants to compete in freediving.

Freediving Level 2 focuses on depths between 20-30 meters and on advancing and adjusting the freediver's decompression technique. We also explore additional training and ways to improve your freediving style/technique and how long you can hold your breath.

We take a closer look at breathing and how to recover through breathing, belly breathing, stretching and flexibility. We practice stretching and preparing for the dive, as flexibility is key to deeper freediving. Belly breathing and relaxation techniques are also important, and we review them as well.

As with all types of diving, safety is paramount. Therefore, you may choose to include CPR and First Aid with your Level 2 freediving courses.

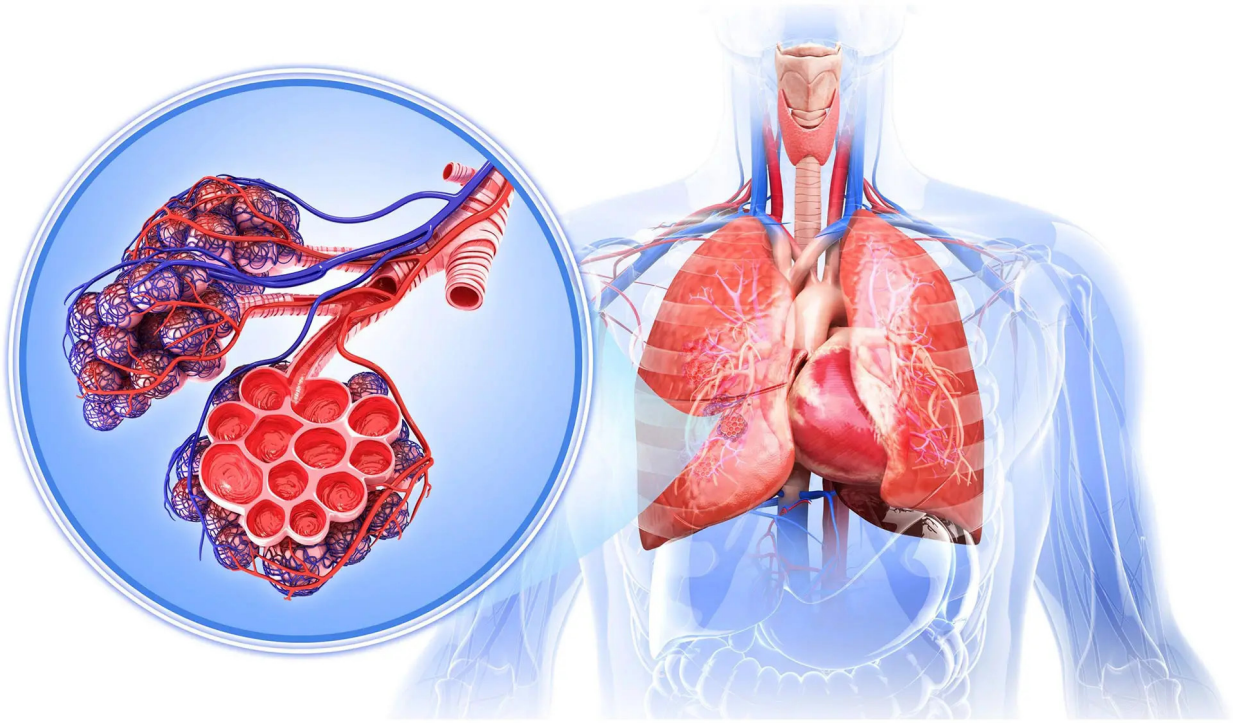
Ask your club about their CPR and First Aid program. Loss of consciousness and LMC (Loss of Motor Control) will be covered in more detail and depth. We also take a second look at safety and practical situations, and the Shallow Water Blackout (SWB) rescue depth is increased to 15 metres. Having completed Level 2, the diver is knowledgeable, flexible and comfortable in the water.

The right equipment for freediving makes diving an even more enjoyable experience, and you will find a lot of exciting specialist equipment at your dive centre. Your instructor will have a thorough knowledge of which equipment is best suited to your needs.

In Level 2 we will also take a look at monofins, nose clips, neck weights, specialist masks, diving without a mask and the use of fibre blades and different weight systems. We explain the uses and

benefits of all the new equipment and provide practical sessions to familiarise you with the equipment. Level 2 can also organise lessons in the pool and the ideals of freediving. All aspects will be explained and practised.

Advanced Freediving Physiology



The Respiratory System 1. Bronchi 2. Alveoli 3. Alveoli (magnification) 4 Capillary network around alveoli

The lungs are the most important organs of the freediver . The air we breathe at sea level (1 atm/bar) is a mixture of 21% oxygen (O2) and 79% hydrogen (N2). From that combination of gases, the body uses oxygen and creates carbon dioxide, a byproduct of oxygen use. Hydrogen is an inert gas and is therefore not used by the human body.

The respiratory system is controlled by the medulla oblongata in the hindbrain and by the proportion of CO2 (a byproduct of the body using O2) to control the rate of respiration.

The more O2 is consumed (i.e. during activity), the more CO2 is produced. Then a signal is sent from the medulla to the diaphragm to increase respiration and compensate for it.

At rest, the average adult takes 10-20 breaths per minute, depending on their age and health. This naturally increases during activity and decreases during total rest or sleep.

O2 Oxygen

Oxygen enters the body through the respiratory tract. The respiratory tract carries oxygen to the lungs through the mouth, nose, trachea, bronchi and bronchioles. CO2 follows the same path out of the respiratory tract. Inhalation and exhalation are controlled by the diaphragm, a large muscle that controls the breathing process and sits below the lungs. The lungs themselves resemble flexible sponges filled with thousands of tiny alveoli.

The bronchi divide into two tubes (one for each lung) and lead to the bronchioles – many small tubes (on average 30,000 per lung) that lead to the tiny air sacs, the alveoli.

Diffusion, an exchange of gases, occurs in the alveoli. The walls of the alveoli are incredibly thin, so only gas or liquid can penetrate them. Diffusion works on the principle that gas has a natural tendency to move from an area of high concentration to an area of lower concentration. There, the gas diffuses until the concentration of gas in both areas is equalized.

CO2 Carbon Dioxide

Carbon dioxide (CO2) is usually found in the atmosphere at a concentration of 0.03 – 0.04% in dry air. It is a byproduct of metabolism produced by the body when it uses oxygen. The pressure of carbon dioxide in the bloodstream is a very important factor in controlling breathing. There are chemo receptors in the body that use CO2 levels and act on them to create equilibrium. They also play a major role in triggering the diving reflex.

Cardiovascular System

The heart, blood vessels, arteries, and blood are all part of the cardiovascular system. The heart acts as a pump that circulates oxygen-rich blood throughout the body, through the arteries and to the tissues, where the oxygen is used and CO2 is produced and pumped back through the veins to the heart, which in turn pumps the blood back to the lungs, where it is circulated and exhaled.

Blood carries oxygen from the respiratory system to the cells, and when the heart pumps blood, it can be felt as the pulse that you can feel in different parts of the body. The pulse rate for an average adult at rest is around 60-80 beats per minute, depending on age and health.

The heart is divided into two sides. The left side is larger because it distributes oxygen-rich blood to the arteries, while the smaller right side pumps blood with low O2 values, rich in CO2, back to the lungs, which exhale CO2.

The Blood

The Blood is a mixture of red and white blood cells, plasma and platelets. The body of a typical adult contains 6 liters of blood, which makes up around 7-19% of the total body weight.

Red blood cells make up around 40% of the blood and contain hemoglobin (a protein that binds oxygen).

Newly oxygenated blood is a bright red color, while oxygen-poor blood with high levels of carbon dioxide is much darker – this is called venous blood.

The oxygen saturation of arterial blood is around 98%, but this level drops during freediving because you hold your breath and use oxygen.

After freediving, the oxygen saturation in the blood is restored through breathing.

N2 Nitrogen

Nitrogen has an atomic weight of 14, a molecular mass of 28 and makes up 79% of air. The substance is often considered physiologically inert, but can cause problems – decompression

sickness – for the freediver. If you have been scuba diving, wait at least 12 hours before freediving, and if you have dived repeatedly, you should wait 18 hours.

Breathing for freediving – Summary

Now we will take a second look at breathing for freediving.
• Relaxing breathing
• The last breaths
• Recovery through breathing
• Avoid over-breathing/hyperventilating 1. Relaxing breathing 2. 1-2 Last breaths 3. Time before freediving – approximately 2 minutes.

The diving reflex – Summary

The body has its own, built-in mechanism that can help you as a freediver – the diving reflex. When a mammal submerges its face in water, the reflex is triggered, maximizing the amount of time it can spend underwater and allowing the body to cope better underwater and with less oxygen. The reflex is an advantage for freedivers. The 4 main parts of the reflex are:

Bradycardia: Slows the heart rate by up to 50% in freedivers; can be triggered by immersing the face and holding your breath.
Peripheral Vasoconstriction: Contracts the blood vessels in the extremities of the body (arms and legs). This is a defense that the body uses, since blood is more important to use elsewhere when the body needs to conserve oxygen, such as in the lungs, heart and brain.
Blood shift: Creates a circuit with the heart, lungs and brain. Blood flows to the lungs to compensate for the pressure on the reduced spaces for air – to avoid squeezing the lungs – while the blood vessels swell to compensate for the reduced volume. This is very important for deeper freediving.
The Spleen: Contracts and releases more red blood cells into the bloodstream. The extra red blood cells can be used by the body, and the more you become a freediver, the more benefit you will get from the diving reflex.
Diuresis: A side effect of the diving reflex is that it increases the volume of thoracic blood, which sends excess plasma to the bladder to compensate. This makes you have to urinate more often.

Ways to trigger the diving reflex
• Breathing through a snorkel with your face in the water.
• Hold your breath dry or static (CO_2 triggers the reflex)
• Static at depth, e.g. 10m – a combination of immersing your face, holding your breath and using pressure to induce blood shift through an activity (freediving).
• Regular freediving / Freediving frequently
• Freediving training
The more you freedive, the faster and stronger the diving reflex will become.

Summary

Now you know how the freediving system works and what great equipment you can use to start enjoying diving. Ask your instructor for a consultation about equipment, information on sizes and materials and quality, and which equipment is best for you. Now we have looked at advanced freediving physiology, and you understand the process of diffusion and how the heart transports oxygen around the body. We have also shown you how to trigger the diving reflex and make your response as fast and as strong as possible, which is indispensable for anyone who wants to take diving to the next level.

Part 2

Advanced Freediving, Knowledge & Skills

Objectives When you have completed this part, you will be able to:
1. Understand the principle of correct balance f for freediving
2. Describe and demonstrate correct equalization techniques, such as Frenzel, for freediving
3. Identify the most important lung dimensions and explain residual volume
4. Describe the effects of pressure on the lungs and chest
5. Understand “Dalton’s Law” in relation to Shallow Water Blackout / unconsciousness / Loss of Motor Control.

Buoyancy

Archimedes’ Principle

An object partially or completely submerged in a fluid is lifted by a force equal to the weight of the fluid displaced by the object.

Changes in Buoyancy

1. Positive 2. Neutral 3. Negative (Free Fall)

According to Archimedes’ Principle, a freediver with a full breath and a mask has a positive buoyancy and must therefore make an effort to sink. The chest gradually decreases as they dive deeper, and the buoyancy becomes neutral around 10 meters deep. As they dive deeper, the chest decreases even more and after a certain time and at a certain depth, the diver becomes negatively buoyant.

If you are neutrally buoyant at a depth of less than 10 meters, it will be more difficult to resurface. Neutral buoyancy deeper than 20 meters makes it more difficult to dive. The ideal depth for neutral buoyancy is between 10-13 meters.

Freedivers can use these changes in buoyancy to conserve O2. When they swim up from 30-10 meters, they can let their buoyancy bring them to the surface without much effort. Using weights is essential for those who want to dive deeper, and should be done according to the planned depth. The weight needed for a diver wearing a 3mm two-piece diving suit and diving to 30 meters is significantly different from the weight needed for a diver without a suit who wants to dive to the same depth. All of these variables will be calculated, and you should keep a log for reference.

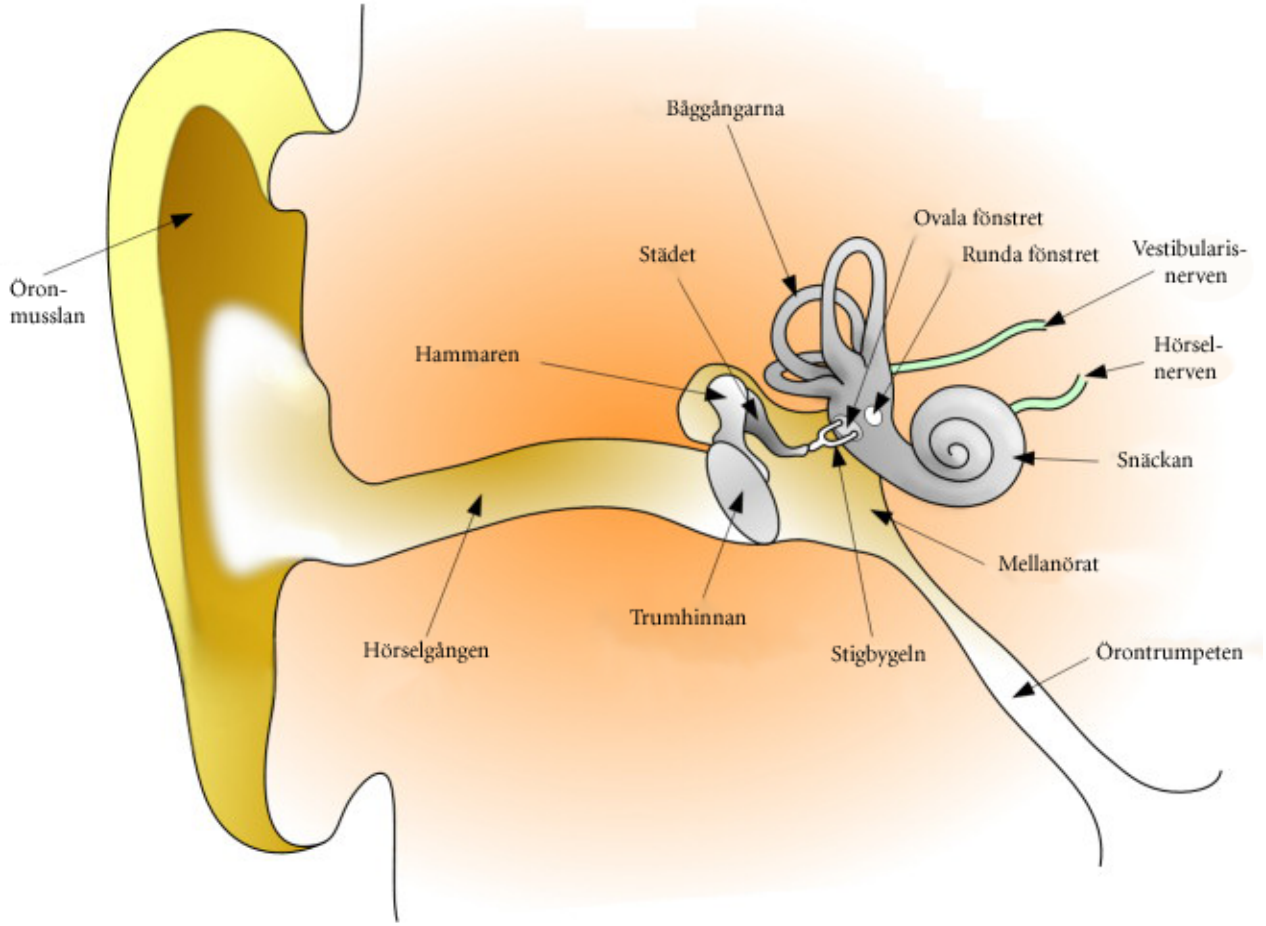
Whether you dive in salt or fresh water will make a difference when it comes to buoyancy, as will different types and thicknesses of wetsuits. Proper buoyancy should be recorded in your log, and remember that when choosing a dive belt, it should be made of rubber that can conform to your body and not slip as you dive. You should avoid using too much weight – instead, start with less weight and gradually add more to find the perfect buoyancy for the depth you are freediving at.

Negative Buoyancy (Free Fall)

Just beyond the point where the diver reaches neutral buoyancy, they begin “free fall.” At this point, the diver stops swimming downward and glides, conserving oxygen. Free fall should be smooth and hydrodynamic. Practice makes perfect, so it is important to know when you reach neutral buoyancy in order to make the transition to free fall.

During freefall, your buoyancy changes from positive to neutral and then negative. When you swim back to the surface, it goes the other way, from negative to neutral and then positive. Always use appropriate weights – “never neutral over 10m”.

Advanced Pressure Equalisation Techniques



As you start diving deeper, smoother and faster, your lungs will approach their residual volume. That’s when it’s time to focus on more advanced pressure equalisation techniques and a more serious approach to helping your ears.

Did you know that alcohol and dairy can cause mucus problems? Or lying down right before or between dives can cause blood to pool in the veins of your nose and/or the eustachian tubes, making it harder to equalise?

Did you know that divers who force their way down can have their eustachian tubes blocked and locked if they don’t equalise? While some freedivers seem to have steel tubes in their ears that never get blocked, fogged up, pressed or pinched, equalization is a major problem for many.

Pressure Equalization Strategy and Knowledge

A freediver’s position in the water column is incredibly important when diving downwards, as is the knowledge of effective pressure equalization to make diving as safe and comfortable as possible. Both factors help the diver avoid barotrauma, which is not only the most common diving accident, but also the most avoidable.

Beginners or infrequent divers often have minor or partially blocked eustachians, do not equalize pressure properly, or are still learning about equalization. Remember that the process of equalization begins at the surface, which helps you in two ways.

First of all, it allows you to see potential problems before the dive, and it also creates a cushion of air behind the eardrum that allows air to enter the inflated eustachian tube during the dive.

Without pre-compression equalization, the eustachian tube can become blocked and locked during a dive at as little as 1 msw, forcing the diver to blow harder to try to re-inflate it. This makes late-compression equalization nearly impossible.

An accelerated dive increases the risk of barotrauma – by the time the diver's body is underwater, the ears are already at a depth of 1.5 meters. Unless you are one of the lucky divers who can equalize anywhere, it will not be a comfortable dive, and trying to equalize pressure while upside down can cause dizziness and disorientation.

The Eustachian Tube

Thanks to the Eustachian Tube, it is possible to perform comfortable pressure equalization. It not only brings in air that equalizes the pressure in the middle ear, but also allows the body to get rid of secretions – mucus. It is located high up in the throat, approximately at the level of the nostrils, and is half surrounded by bone. The other half is partially covered by a C-shaped piece of cartilage that allows the tube to be affected by gravity even when the body is upside down, as well as by the swallowing reflex and pressure changes from the respiratory system when using pressure equalization techniques.

It is usually closed if you are not swallowing, when it opens and closes, which is the small clicking sound you hear in your ears when you eat or drink.

How open and large the Eustachian Tube is varies from diver to diver, and some never have problems with pressure equalization. However, this is not the case for most people, who must use some air to handle volume changes in the middle ear and sinuses as they equalize pressure.

Starting Technique – The Valsalva Maneuver

The Valsalva Maneuver consists of pinching the nostrils and blowing gently into them while tensing the muscles in the cheeks (pinch & blow). The method is effective and you can feel the effect through a "pop" or a heightened sensation in the eustachian tube. The Valsalva Maneuver is usually the first method new freedivers learn, and it is very easy to perform. In principle, it is the diaphragm that pushes air into the eustachian tube, which means that the maneuver must be performed gently and not aggressively. As the lungs are compressed at depth, the Valsalva Maneuver becomes more difficult to perform. For the level 2 freediver, the Frenzel method is much more suitable for deeper diving.

The Optimal Technique – The Frenzel Maneuver

The Frenzel Maneuver uses the air in the mouth/throat to equalize pressure by closing the epiglottis. You can perform the maneuver by pinching your nostrils and lifting the back (thickest) part of your tongue, which compresses the air in the back of your throat and pushes it up into the eustachian tube. There are a few steps to learning the Frenzel Maneuver properly.

The Frenzel Maneuver is the most effective method for freedivers, as it requires less effort/energy and does not require the diaphragm to push air into the eustachian tube. Because the maneuver uses the tongue/cheek instead, it can be repeated many times without much effort. To perform the maneuver, the palate must be relaxed, the epiglottis must be closed, and the air must be controlled by the tongue. It takes time to learn the steps, and you should practice until you know them by heart.

Your instructor can guide you through a hands-on demonstration of the Frenzel Maneuver.

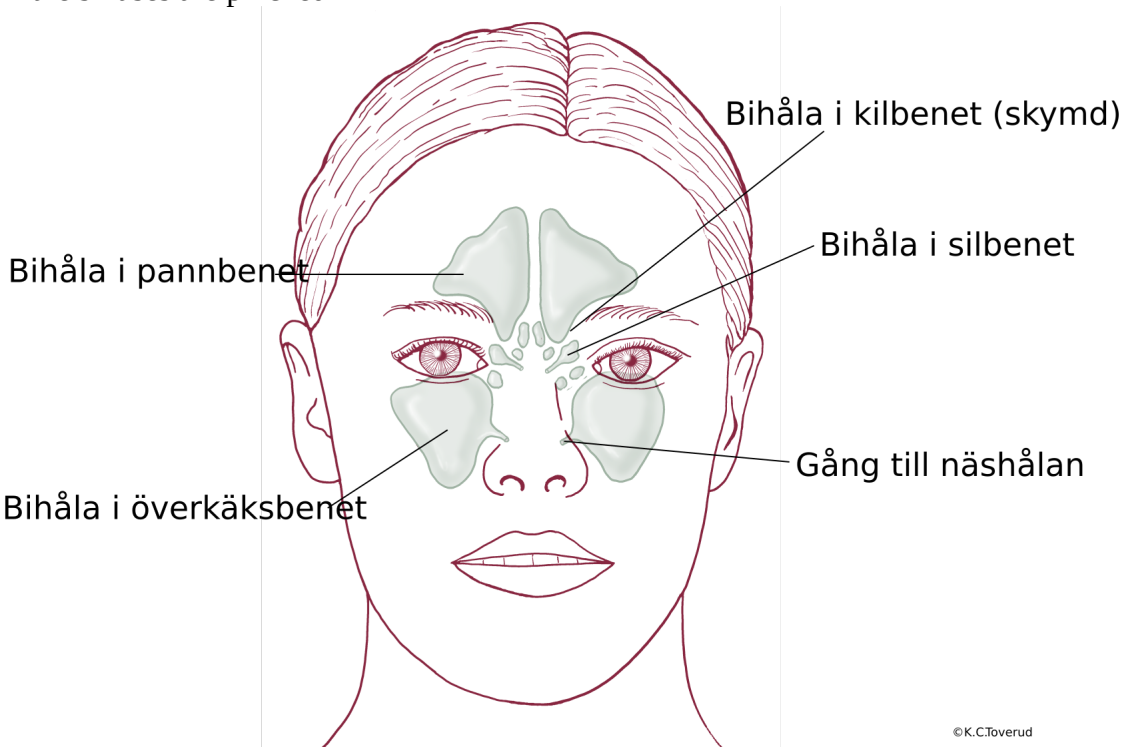
Pressure equalization with the Frenzel technique is essential for deeper and safer freediving. When you can do it correctly, you will notice that your freediving improves. Take the time you need to practice and learn the Frenzel maneuver perfectly.

Equalization – problems

Although the Valsalva maneuver is the most common technique, a forced maneuver or too high a pressure can damage the inner ear. If you dive too fast, the Toynbee maneuver and to some extent the Frenzel maneuver can both cause you to swallow air. Since the stomach cannot absorb oxygen, the substance is wasted and can cause discomfort when you return to the surface. To achieve any real depth with freediving, pressure equalization is indispensable, and should be treated as one of the most important skills to practice.

Practice makes perfect, but despite this, pressure equalization is an afterthought for many freedivers when they are training.

If the sinuses are pinched



There are spaces for air in the sinuses, which are needed to equalize the pressure in the water. If this does not happen, the diver may feel pressure or pain in the area.

The sinuses usually equalize the pressure with the eustachian tube, but if the diver is congested or has had a cold, this can interfere with the process during diving. In such cases, you should not dive.

Reverse blockage

On the way to the surface, the diver may feel that air is trapped in the ear or sinuses. If the expanding air cannot be vented, the pressure in the space increases, causing discomfort. The discomfort can also be a sign of an injury - from mild to extreme. Injuries to the sinuses can occur suddenly and lead to damage to the inner ear.

If this happens to you, immediately slow down on the way to the surface. If possible, stop by grabbing the rope. You can sometimes relieve the discomfort by moving your jaw or swallowing. Then continue to ascend with caution. It is not recommended to freedive when you are stuffy.

When the hood is tight

A good freediving suit is waterproof, which can cause problems with pressure equalization. If there is no water inside the suit's hood, a small air bubble in the outer ear can prevent pressure equalization. In this case, simply insert a finger under the hood and let the water replace the air bubble.

When the mask is tight

Remember to check that you can use the mask for pressure equalization by regularly letting air move from your nose into the mask.

The lungs and residual volume

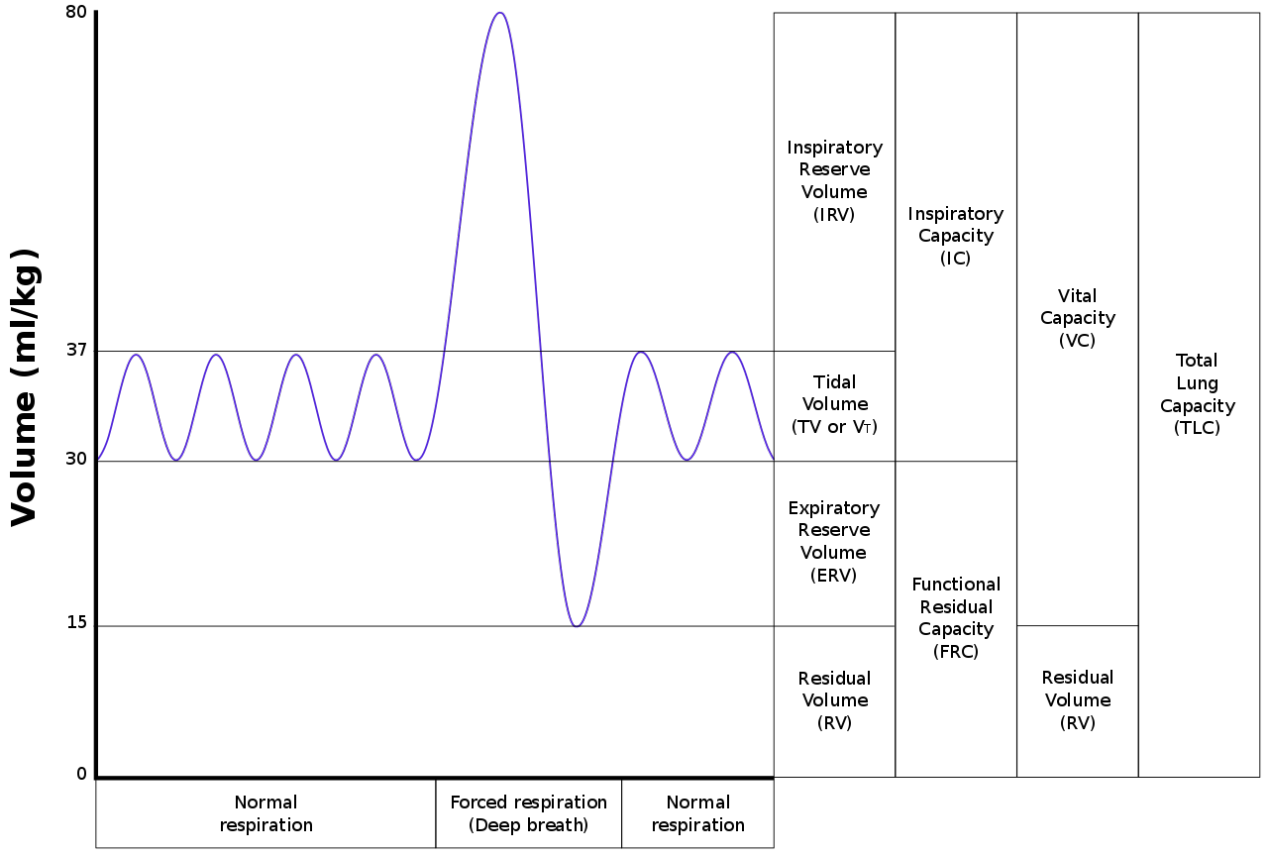
The lungs are a flexible organ n that contain air. Therefore, they obey the natural laws of pressure and compression – Boyle’s law. If the temperature is constant, the volume of gas is inversely proportional to the absolute pressure.

As depth and pressure increase, the volume of air decreases.

The lungs are relatively flexible, unlike other air spaces in the body such as the chest and surrounding tissue, the sinuses and the middle ear. As depth increases, the lungs will gradually shrink until they reach the residual volume (RV). At such depths, the normal Valsalva technique does not work, which can instead cause excessive pressure on the lungs. If this happens, the diver should stop diving.

Diving below the residual volume requires a lot of training. Once the residual volume is reached, it becomes very difficult to remove air from the lungs to equalize the pressure, which is why air must be taken from the mouth at this depth. Therefore, it is extremely important to equalize the pressure with the Frenzel maneuver for deeper dives. This puts pressure on the diaphragm and lungs, and the diver must learn to equalize the pressure with only the air in the mouth and above the closed glottis.

Lung capacity



“Total lung capacity”
(TLV) IRV + TV + ERV + RV The total volume of the lungs (the volume of air in the lungs after a complete inhalation).
“Vital capacity”
(VC) IRV + TV + ERV The largest volume of air that can be consciously moved into and out of the respiratory system.
“Tidal volume”
(TV) The volume of air that a person normally breathes in and out (average: 500ml). “Residual volume” (RV) The volume of air that remains in the lungs after a maximum exhalation.
“Expiratory reserve volume”
(ERV) The volume of air that can be exhaled after a normal exhalation. “Inspiratory reserve volume” (IRV) The maximum volume of air that can be inhaled in addition to TV.
“Functional residual volume”
(FRC) ERV + RV “Functional residual volume” (FRC) The volume of air that remains in the lungs after passive exhalation.
The residual volume is usually 20-25% of the total lung capacity. The depth at which the diver achieves RV depends on the relationship between total lung capacity and residual volume.

Stretching for freediving

There are a number of exercises that can reduce RV and increase VC.
• Stretching the rib cage or muscular structure makes the chest more flexible, which can increase the volume of air that can be inhaled – vital capacity.
• The stronger the “blood shift” that is produced, the more of the lungs are taken up by the enlarged blood vessels. This reduces TV and allows the lungs to be compressed without damage.
• Fully stretching the lungs increases vital capacity and flexibility of the chest and diaphragm, and the lungs' ability to expand more easily when inhaling.

• When stretching the lungs on exhalation, residual volume is reduced by making the diaphragm more flexible and able to reach further into the chest, reducing RV.

The exercises are described in detail by your instructor, who will also demonstrate a practical review, as well as the benefits and safety precautions that should be taken by Freediving Level 2 divers.

Making the chest and body more flexible is another of the most important factors when it comes to freediving. You can practice this on land, through yoga, or by stretching before freediving to maximize your potential.

Stretching the chest and diaphragm

The exercises should be done on an empty stomach (in the morning or evening before diving). Make sure to increase your inhalation as you stretch progressively. There is a risk of unconsciousness when stretching your lungs to full capacity, so also make sure there are no sharp objects nearby. This also applies to stretching your diaphragm. It is a slow and gradual process – don't exhale too much until you are comfortable with the exercises.

The exercises are described in detail by your instructor, who will also demonstrate a practical demonstration and the benefits and safety precautions to take for them.

At what depth do I reach residual volume?

If you know your total lung capacity and your residual capacity, you can calculate the depth at which you reach residual volume using Boyle's Law.

The average adult male has a lung capacity of 6 litres.
The average adult female has a lung capacity of 4 litres.

We know that the average adult human has a residual volume of 25% of their total lung capacity. This means that we can calculate the depth at which you reach residual volume.

Depth	**TLC 4L**	**TLC 6L**	**TLC 9L**	**TLC 11L**
10m (2 BAR)	2L	3L	4L	5L
20m (3 BAR)	1,33L	2L	3L	3,66L
30m (4 BAR)	1L	1,5L	2,25L	2,75L

In the examples above, residual volume is reached at 30 meters, 25% of TLC.

We can recalculate and imagine that we have reduced the residual volume to 20% of TLC through exercises and stretching for free diving.

In the examples below, residual volume is reached at 40 meters, 20% of TLC.

Djup	**TLC 4L**	**TLC 6L**	**TLC 9L**	**TLC 11L**
10m (2 BAR)	2L	3L	4L	5L
20m (3 BAR)	1.33L	2L	3L	3,66L

30m (4 BAR)	1L	1,5L	2,25L	2,75L
40m (5 BAR)	0,8L	1,21L	1,81L	2,2L

Advanced Freediving Overview

The Instinct to Breathe

When we hold our breath, we temporarily stop releasing CO2, which causes a build-up of carbon dioxide in the cells, blood and lungs. The concentration of CO2 in the body causes the reflex to breathe. You can use oxygen more efficiently by training for freediving, or by simply doing exercises where you hold your breath properly.

Hyperventilation

Hyperventilation is simply when you breathe too much. An old myth is that you can become a better freediver by lowering your body's CO2 levels. In fact, the opposite is true. Below you can see real examples of the disadvantages hyperventilation has on a freediver.

Disadvantages of hyperventilation

• Blood does not conserve O2 when it has low CO2 levels, and therefore the volume of air you can hold in your lungs decreases.
• Low levels of CO2 make arterial blood alkaline, which increases the pH above normal (7.4 pH) and makes the bond between hemoglobin and oxygen too strong. This in turn causes O2 in the blood to not be released to the tissue, which is known as the Bohr effect.
• When CO2 levels are low, blood flow to the brain is also reduced, causing vasoconstriction, which reduces the supply of oxygen to the brain and can cause fainting and reduce the ability to hold your breath.
• Increases heart rate.

Hyperventilation significantly reduces the chances of apnea.

Effects of pressure on the lungs and chest

Changes in the chest According to Boyle's law, the lungs are compressed as depth increases. The lungs respond to the pressure of the environment. When you dive deeper, they are compressed, and the volume of air decreases in size. When you swim to the surface, on the other hand, they expand, and the volume of air returns to its original size.

Once the chest has been compressed to the residual volume, it cannot decrease any further. This means that the blood is directed to the blood vessels in the lungs. These blood vessels swell, reducing the residual volume even more. This is a direct reaction of the diving reflex.

When the lungs are squeezed

The lungs can be squeezed if a freediver is not flexible enough, or does not have sufficient training before diving.

This can happen during deep dives, and sometimes even at shallower depths. The symptoms are wheezing, shortness of breath, and the feeling that you cannot breathe fully. In some cases, you may also cough up traces of blood (the airways and trachea can also be squeezed). If this happens, you should get out of the water and stop freediving for the day. If possible, breathe 100% oxygen for 5-10 minutes and consult a doctor.

How to avoid a lung squeeze

• Dive only when you have fully inhaled
• Stretch your chest and stay flexible
• Don't dive when you are cold or stressed
• Gradually increase the depth you dive to; don't go too deep too quickly
• Dive regularly • Flexibility and relaxation are very important to avoid squeezing your lungs
• Don't stretch at depth
• Give your body time to adapt to the depth

Your skills as a freediver

The depth that is safe for a freediver depends on their total lung capacity and the smaller volume of remaining air. With the right skills and training, you can freedive within your own limits and gradually increase the depth you can dive to.

Freedivers are well-trained athletes with trained, flexible bodies trained for this particular sport. For a level 2 freediver, the depth they dive to should be increased gradually, and it should be a slow process. As the diver gradually increases depth, the lungs can adapt to the new depths at a good pace.

Divers who go too deep, too fast, risk lung compression and other pressure-related injuries. Flexibility and relaxation are important factors in avoiding these problems. You learn these skills by safely and progressively increasing depth, time and distance.

Enjoy safe and fun freediving. Ask your instructor about social diving experiences such as clubs or trips.

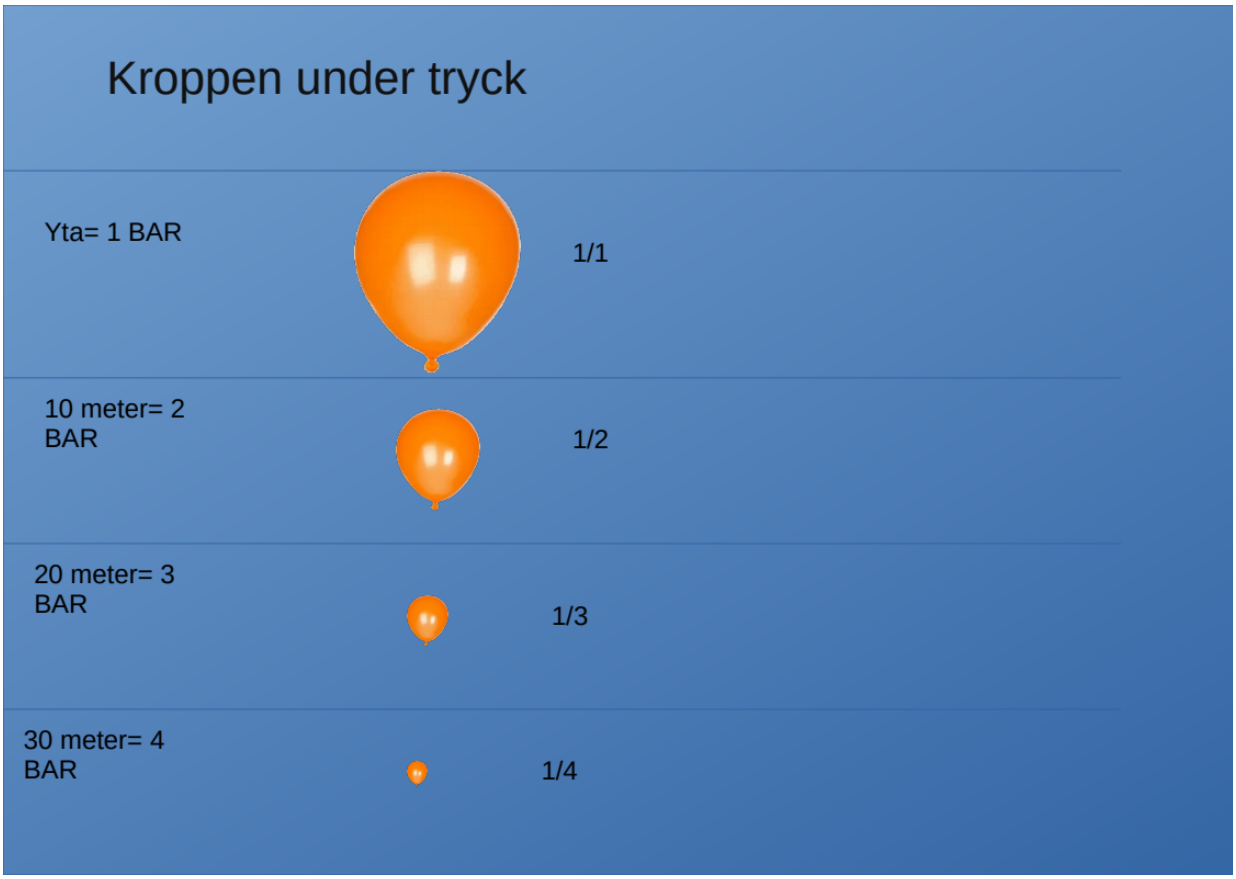
Did you know?

• It is high CO_2 levels – not low oxygen levels – that trigger the instinct to breathe.
• As you dive deeper, your buoyancy changes from positive to negative and finally negative.
• The diving reflex and its effects can be a great help to the freediver.

Freediving is a fun and exciting sport for all ages. With the right training, knowledge and equipment, freediving can offer hours of exciting underwater adventures. The ocean is your playground, and freediving is the most natural way to meet all the fascinating creatures that live below the surface. Enjoy your experience and share your freediving with your loved ones.

Advanced knowledge of pressure

Boyle's Law & Dalton's Law “Boyle's Law states that if temperature is constant, the volume of a gas is inversely proportional to the absolute pressure.”
• You should be aware that air pressure increases with altitude and that water pressure increases with depth.



• Since water is thicker than air, pressure increases more rapidly as you dive downward
• The human body is mostly made up of water. During freediving, the pressure of the water is felt most in the air spaces of the body (the lungs, sinuses, and middle ear) and in the mask.

depth (meter)	BAR		Ambient pressure BAR	Volume of a sealed container	Density of the gas
0	1	1		1	1x
10	2	2		1/2	2x
20	3	3		1/3	3x
30	4	4		1/4	4x

Boyle's Law

Boyle's Law of Pressure and Volume

Every time you freedive, you must be able to deal with the effects of increased water pressure underwater. That's why it's important to understand the different types of pressure that exist, and the changes between the surface and depth.

When it comes to pressure, Boyle's Law is one of the most important laws of nature. It explains the relationship between gas and pressure: At constant temperature, the volume of a gas decreases at the same rate as the surrounding pressure increases.

What does it mean for you as a freediver?
• Understanding atmospheric pressure. The air pressure at sea level is defined as 1 BAR.
• The pressure increases by a value of 1 BAR for every ten meters of depth. A diver at a depth of 10 meters is at 2 BAR, 3 BAR at 20 meters, etc.
• The volume of air decreases in relation to the pressure as depth increases

The air we breathe at sea level (1 BAR) is a mixture of gases (21% oxygen / 79% nitrogen).

The body requires oxygen to stay alive, while nitrogen is an inert gas (not used by the body).

Dalton's Law and Shallow Water Blackout

Dalton's Law states that the total air pressure is the sum of the individual partial pressures of each gas. The partial pressure of a gas, such as oxygen, is the pressure that the gas exerts at a specific volume and temperature if all other gases are removed. The partial pressure of oxygen is denoted pO2.

First, let's take a look at how Dalton's law affects freediving and blackout in shallow water. The pressure of O2 is a concentration/percentage (partial pressure of O2 at sea surface = 0.21).

When the freediver descends, the partial pressure of O2 is the same as at sea surface; 0.21 (at 1 BAR).

Summary

In this section, we have looked at the many benefits of proper weight use for freediving, especially for freefall. We have also shown how advanced pressure equalization techniques work, such as the Frenzel maneuver, and more efficient and safe ways to dive.

We also show how important flexibility is for the chest, lung measurements and volumes that allow you to calculate the depth you can dive, what pressures affect you as a freediver and how you can enjoy this fun and safe sport with the right information and knowledge.

Dalton's law of partial pressure and how it relates to blackouts at low tide or the inability to control your muscles shows the simple mathematics behind them. Remember that although blackouts at low tide or loss of control of your body are rare, it is important to be prepared and ready for your safety.

Part 3

Take your freediving to the next level

Objectives

After completing this part, you will be able to:
1. Understand the different types of freediving
2. Understand how to prepare for freediving
3. Understand all the benefits of not diving alone
4. Know two ways to train for freediving
5. Know the correct safety precautions for freediving

Freediving as a Sport

Competitive freediving is one of the world's most exciting water sports, where you compete against yourself or your friends with exciting challenges.

How does freediving work as a competition?

At the competitive level, freediving consists of a number of events or disciplines. The competitive part of the sport is where divers compete to achieve the greatest depth, longest time or distance while freediving. It is a test of physical fitness and mental control.

There are different types of competitive freediving depending on whether you dive with fins, without fins, with a rope or without any equipment. There are also competitions that are not based on the depth you dive to (in a pool).

Competitions are held for fun. You do not have to dive at a shallow depth to enjoy the atmosphere of the competitions or to challenge yourself and your friends. See freediving as a fun experience.

Depth

Contact Weight (CWT). The diver uses fins or a fin and must dive down and up with the same weight.

Constant Weight Without Fins (CNF). The diver uses no equipment and uses the breaststroke to swim down and up. They must also use the same weight when they dive and swim back up.

Free Immersion (FIM). The freediver dives down and swims up with a fixed line. The weights must be the same when they dive down and swim up, which can be done feet or head first. Some divers use a mixture or both.

Variable Weight (VWT). The freediver dives down with a weight or other device and swims up with fins, using to pull the rope, or under its own power. VWT is not usually done for competitions.

Non-Deep Dynamic (DYN/DNF). Usually done in a pool (50 meters long), where the freediver swims a horizontal distance in a single breath. This type of diving can be done with or without a fin, with a mono-fin or stereo-fins. The perfect dynamic performance is achieved by a good balance between O2 and the amount of energy used, as well as hydrodynamic techniques for swimming underwater.

Static (STA). The diver takes as big a breath as they can while lying face down in the water. As soon as their face is underwater, their breath begins to be timed. Due to the psychological aspect, many divers consider static to be the most difficult of the disciplines.

Speed Apnea. A freediver competes to be the fastest underwater with dynamic apnea – from 50 to 100 meters.

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Freediving – Calm, Peaceful, and Fun

Freediving encourages a cool head and a relaxed attitude. Anyone who is worried about how they will perform, or who is too serious, will find it difficult to relax in the water. Fear and anxiety release adrenaline, which increases the heart rate and causes rapid, shallow breathing. With practice and confidence, you can improve your mental state and it is important that you know what your limitations are when it comes to freediving. Relax and find your rhythm, and most importantly – have fun. It will make you a better freediver.

Freediving is linked to many wonderful experiences and emotions. The mysterious underwater world is fascinating and offers many surprises and unexpected discoveries. It is a place where we can feel free. Where you can move as you please.

The attitude of a freediver depends on how motivated and positive they are, and affects how much they can enjoy diving.

A motivated and enthusiastic person who has the right attitude will be able to enjoy freediving the most.

The most dangerous thing that can happen in the water is panicking. Why is it so dangerous?
• A person who panics starts breathing too quickly (hyperventilating). This makes them dizzy and can lose consciousness.
• A diver who panics quickly is a sure sign that they are uncomfortable, which can be dangerous for them. Feeling like they can't breathe can cause panic and breathing or cardiopulmonary problems.
• A freediver who panics can also be a danger to other freediver's – it's best to get them out of the water as quickly as possible.
• Remember to enjoy freediving – it will reward you with hours of underwater exploration and adventure and – most importantly – positive memories.

Always dive with a friend or partners. Dive with your and your partner's limitations in mind. Always remember: Never dive alone!

Dive Buddy

"One up, one down" – swimming with a partner is a safety measure, and the most important factor when it comes to safe diving.

Diving with a partner is both important and social. A partner can make your experience safer, more enjoyable and more relaxed.
Your partner can help with:

• Putting on wetsuits and equipment
• Fixing ropes and other equipment
• Helping with countdowns
• Warming up
• Increasing safety on the surface and at depth.

Ideally, the person you are diving with should be at the same level as you when it comes to freediving. We need to keep both our partner's and our own skills in mind when diving with others.

Communication

The partner's main job is to be able to see the other freediver throughout the dive. Communication between divers is important and includes depth, time and recovery for the dive. There are a number of things that need to be communicated to each other for safety.
Something as simple as a misunderstanding can jeopardize the safety of the dive.

On the surface

Your partner can keep an eye on you as you dive and look out for hazards such as boats or other water traffic and animals (like jellyfish). They can also provide countdowns, help you with relaxation, equipment, support and positive feedback. All of this will make your freediving experience more positive and enjoyable.

The partner's job continues once you have surfaced again, as there is a risk of blackout or LMC once you have surfaced from a deeper dive and do breathing exercises to recover. Therefore, it is important that your partner is alert until you have fully recovered (at least 30 seconds).

Once you have completed your recovery and breathing, you can signal OK to your partner.

At depth

Your partner is very important when you have dived to depth. They are responsible for keeping an eye on you from the surface and making sure the dive is going well. They should also meet you when you swim back up and where you are at risk of blackout. Although there is no rule written in stone, it is a good idea to meet your partner at a third of the total depth, so if you dive to 30 meters, your partner can meet you at 10 meters and keep an eye on you all the way back to the surface.

This is good practice and reassuring for you as you swim up.

As a partner of a freediver, you are part of a team. Compliments and encouragement are always welcome, and the better you can communicate with your partner, the more fun and safe your freediving will be. In fact, a partner can help you with all aspects of your diving.

Freediving – safety

How to deal with a blackout

As a freediver, you must know first aid. You must also know how to deal with blackouts in shallow water, blackouts and loss of muscle control if they happen when you are nearby.

You should regularly practice first aid and CPR. Surface rescue and blackout assistance should be routine for a responsible freediver.
We recommend that you train in first aid and CPR

What happens when you freedive?

The body has an amazing response when you black out in the water – laryngospasm, when the muscles close the throat. Laryngospasm prevents water from entering the lungs and means that for a short time an unconscious diver underwater can be rescued.

Signs and symptoms of loss of motor control (LMC)

You can notice reduced oxygen levels and lose control of your body. This can be seen through
• Head nodding, shaking, tunnel vision, uncoordinated movements
• The freediver exhales air, blackout, The freediver stops using his fin
• Blue lips / face (cyanosis)

Remember that the majority of freedives are actually safe and do not involve any incidents. Here are a few practical tips that you can use to reduce the risks.

How to avoid blackout/LMC/blackout in shallow water and reduce the risks
• Do not hyperventilate – do not take more than 1-2 last breaths. You should exhale longer than you inhale.
• Dive within your limits. Gradually increase the time, depth, or distance you dive.
• Do breathing exercises to recover after diving.
• Don’t stay underwater until you desperately need to breathe.
• Instead, start swimming to the surface while you still feel comfortable, and take your time doing so.
• Communicate with your partner and always use the “1 up, 1 down” system.
• Rest for several minutes. Rest three times as long between dives as the dive takes. It takes time to get your heart rate back to normal.
• Wear a wetsuit that fits you and is the right thickness for the temperature of the water you will be diving in. (Water reduces body temperature 25 times faster than air).
• Ideally, you should use a suit designed for freediving.

A blackout or loss of muscle control can also occur above the surface, as the oxygen you have left in your body may be so low that your body cannot get it into your bloodstream quickly enough – and if you do not use the correct breathing technique for recovery.

• Adjust your weights so that you have positive buoyancy at the surface and negative buoyancy at depth. For example, a diver with a 7 mm suit and neutral weight at the surface will be 6 kg overweight when they start to swim back to the surface from a depth of 20 meters.
• Always use weights so that you have positive buoyancy at the surface. After a passive exhalation, the diver should still float at the surface.
• Make yourself as streamlined as possible – with long fins and a low-profile mask – to reduce the energy you have to use.
• Also dive with an experienced mentor or partner.

Rescue/Response/CPR

When rescuing another diver, whether conscious or unconscious, you must get them to the surface and out of the water as quickly as possible. It is impossible to give them first aid while they are still in the water.

When you begin a rescue, it is important to maintain control at all times and to be in control of the situation. If you lose control during the rescue, two lives could be in danger. Always protect yourself first and help your buddy second. Risking two lives is not an excuse for a heroic effort to save one.

Never attempt a rescue unless you have all the equipment, including a mask, fins, snorkel, and something to float on—such as a buoyancy aid or buoyancy suit. If you can't see well, breathe, or float, you can't help without putting yourself in danger.

Rescue

The rescue phase consists of the following actions
• Bringing a blacked-out diver to the surface
• Keeping the airway clear of water
• Physically supporting the diver

Respond

The second phase consists of the following actions
• Removing the mask/equipment that obscures the face (nose clip, etc.)
• Tilting the diver's head back to open the airway
• Blowing air into the face (cranial nerve)
• Lightly tapping the cheeks with your finger to trigger a reflex/response
• Guiding them through breathing repeatedly

Resuscitate

The third phase, resuscitation, consists of the following actions

If the person is not breathing, your actions should be determined by the distance to the shore or boat. Open the airway and give the person two quick breaths before you begin to move them toward the shore or boat. If you have to swim a long distance and have not been able to restore breathing, continue to give them a breath every five seconds until you reach the shore or boat. This will of course be easier with the help of another freediver.

If during the rescue you find that you cannot handle the other person due to their weight, release their or your own weight belt. If the diver does not regain consciousness after you have attempted to revive them with two breaths, immediately take them to shore and call an ambulance.

If the freediver regains consciousness, you should give them moral support and tell them what happened and that they should not dive again that day.