Welcome to your PDA Open Water diver course.

Over two thirds of our planet’s surface is covered by water. You are about to discover a new world and we are looking forward to guide you on your first steps into this wonderful and adventurous world. We will teach you all the knowledge and skills you need for your underwater adventures. We wish you lots of fun and unforgettable experiences.

Your PDA Team

Who or what is PDA?

PDA is an international diving education organization, which means that your diving certification is recognized worldwide. We certify divers internationally through our different training programs, we provide teaching materials to students and instructors, set standards and monitor these and we teach and certify instructors, focusing on safe diving practices and fun.

What are you qualified to do after passing the Open Water Diver course?

After successfully completing your Open Water Diver course, you are certified to:
- Dive with a partner using scuba equipment to a depth of 20 meters
- Rent equipment
- Continue your dive training and participate in further dive activities

Course structure

The Open Water Diver course consists of three parts: the Knowledge development (8 to 10 hours), which supplies you with all the theoretical knowledge about diving that you need to know, the Pool training (2 to 3 sessions 3 hours each) where you will learn all relevant skills in the pool that are needed to follow safe diving procedures, and practice these until you have sufficiently mastered them. And lastly the Open water training (4 to 5 dives) where you will apply your knowledge and skills you have learned in a real underwater environment. At the end of your knowledge development you will take a final exam, this is a multiple choice exam following up on the most important aspects about diving that you have to know. The pass mark is 75% but you may retake the exam if you should score below that mark. After you have successfully participated in all three segments of the Open Water Diver course and have passed the final knowledge exam you will receive you internationally recognized certification in form of a PDA picture ID dive card. We will store your records and you can request a new ID card any time should your card get lost.
Requirements for certification

Here is a check list of all the requirements and prerequisites for your certification.

Administrative prerequisites:

✓ Complete and sign course sign-up
✓ Pay course fee
✓ Determine course schedule and dates
✓ Complete and sign release form
✓ Complete medical statement or hand in doctor’s physical
✓ Fill out equipment record file
✓ Set up record file

Requirements for certification and issuing of PDA dive ID card:

✓ Participation in all knowledge development classes
✓ Mastering all the practical scuba diving skills in the pool
✓ Conducting at least four open water dives under the direct supervision and guidance of a PDA instructor
✓ Passing the final exam
✓ Course fee paid in full
✓ Completed certification application including a passport picture
✓ Completed and signed release form
✓ Completed medical statement or a current doctor’s physical

Let’s get started...
# Table of contents

## 1. Water and Air  
- Characteristics of water  
- Water pressure  
- Pressure effects  
- Equalizing pressure  
- Reverse block  
- Rupture of the eardrums  
- Air – Volume –Pressure –Density  
- Breathing and Scuba diving  
- The lungs  
- Lung overextension injuries  
- Regulators  
- Snorkel  
- Dive tanks  
- Chapter 1 Knowledge review

## 2. See - feel - hear  
- Light  
- Behavior of light under water  
- Vision under water  
- Masks  
- Sound  
- Hearing under water  
- The ear  
- Thermal properties of water  
- Hypothermia  
- Hyperthermia  
- Diving suits  
- Chapter 2 Knowledge review

## 3. Buoyancy  
- Archimedes’ principle  
- Floating – sinking  
- Positioning your body under water  
- Why do I need weights?  
- Buoyancy control device  
- Different types of BCDs  
- Fins  
- Weight systems  
- Chapter 3 Knowledge review

## 4. Gases  
- What is air?  
- Dalton’s law of partial pressure  
- Nitrogen  
- Nitrogen narcosis  
- Decompression sickness  
- Oxygen  
- Oxygen toxicity problems  
- Carbon dioxide  
- Carbon monoxide  
- Chapter 4 Knowledge review

## 5. Dive planning and dive management  
- Diving as a team  
- Hand signals  
- Dive planning  
- General rules of recreational diving  
- Diving with a dive computer  
- Dive tables  
- The PDA dive table  
- Chapter 5 Knowledge review

## 6. The underwater world  
- Saltwater  
- Freshwater  
- Tides  
- Currents  
- Orientation and navigation  
- Interacting with aquatic life  
- Chapter 6 Knowledge review

## 7. Problem management  
- Problems and diving  
- Most common causes for problems  
- Surface problems  
- Under water problems  
- Out of air situations  
- Distressed diver  
- Panicked diver  
- Unresponsive diver  
- Near drowning  
- Injuries inflicted by aquatic life  
- Chapter 7 Knowledge review

## 8. Skills requirements  
- Overview of the OWD course’s practical skills
1 Water and air

Objectives for this chapter

✓ Explain the term atmospheric pressure
✓ Explain how pressure changes under water
✓ Determine the absolute pressure for any given depth
✓ Explain how to equalize
✓ Know what to do if you’re unable to equalize
✓ Explain what a reverse block is
✓ Explain the relationship between volume and pressure of gases
✓ Know the most important rule in scuba diving and why this rule is so important
✓ Name the parts of a scuba diving breathing regulator
✓ Name the most common materials used for dive tanks

Characteristics of water

Water (H_2O) is a compound between oxygen and hydrogen, one of the earth’s most common compounds. Water has a density of 1000 kg/m^3 at a temperature of 4 degrees Celsius and is about 800 times denser than air. Water can be found on earth in its liquid, solid and gaseous states. Furthermore a distinction is made between salt and fresh water. Saltwater has a slightly higher density of 1035 kg/m^3.

Water pressure

The pressure under water increases by 1 bar every 10 meters. There is a slight difference between fresh and saltwater which is so minor that for diving applications it can be disregarded. Atmospheric pressure + water pressure equals the surrounding pressure (absolute pressure)

The formula for the surrounding pressure is:

\[
(\text{Depth} / 10) + 1 = \text{PU (surrounding pressure)}
\]

Pressure effects

Unlike gases, liquids cannot be compressed. The human body consists between 55% to 70% of water which is why we only feel the effects of pressure in our body air spaces.

The main air spaces in our body are:

✓ Sinuses
✓ Lungs
✓ Ears
**Equalizing pressure - Equalization techniques**

- Valsalva method (squeezing and gently trying to exhale through your nose)
- Swallowing motions
- Moving your jaw

**How often and when?**

The first ten meters of your descend at least every meter. After that every time you start feeling a slight sensation of pressure on your ear drums. If you can’t equalize, discontinue your descend! Stop and slowly ascend until the discomfort and feeling of pressure in the air spaces eases, then equalize and continue your descent equalizing frequently. Never equalize forcefully or descend beyond feeling discomfort and pressure in the air spaces. If you are unable to equalize you have to abort the dive.

**What could prevent you from being able to equalize?**

The most common cause preventing equalization is congestion which can plug the air passages. This can be due to:

- hypothermia
- colds
- allergies

In rare cases deviations of the nasal septum can make equalization difficult or even impossible. This would also result in discomfort and problems while flying and driving at higher altitudes.

**Medication and equalization**

Generally you should not use medications, such as decongestants, for diving because they may wear off quicker under water, creating problems equalizing when you start your ascend.

**Reverse block - What is it?**

Expanding air can be trapped in an air space due to congestion during your ascend, creating a reverse block in the sinuses. In rare cases you might feel discomfort in your teeth due to expanding air trapped underneath dental fillings; however this is extremely rare since the quality in dental work has much improved over the last 20 years.

**Diving with ear plugs?**

Generally it is not advisable to use ear plugs while diving because they will make it impossible to equalize. However, there are special ear plugs, designed for recreational diving that enable equalization.
Rupture of the eardrum (perforated eardrum)

Our ears are sealed off to the outside by the eardrums, a very thin skin. Serious injury can occur if the pressure is not equalizes, the eardrums can strain or even tear.

Symptoms
Under water
⇒ Sharp pain
⇒ Vertigo
⇒ Nausea
⇒ Loss of orientation

Above water
⇒ Air escaping the affected ear
⇒ Impaired hearing
⇒ Dull to sharp pain

Treatment
⇒ Keep the ear dry
⇒ Discontinue to dive
⇒ Keep the ear clean
⇒ Seek medical treatment
⇒ Do not administer any medication without consulting a doctor

Air- Pressure - Volume- Density relationships

The Boyle-Mariotte law states that the pressure is inversely proportional to the volume of gases.

What does this mean?
If you fill an air balloon with 4 liters of air at a surrounding pressure of 1bar, tie it and expose it to a pressure of 2 bar, the pressure inside the balloon will also rise to 2 bar but the volume will decrease by a half. If you double the pressure of a gas, you halve the volume- if you halve the pressure of a gas, the volume will double.

Breathing and scuba diving - Breathing air at surrounding pressure

In order for us to be able to breather under water, our breathing regulator has to constantly adapt the pressure of the gas we are breathing according to the water pressure. We are breathing air under water which has a higher density than on the surface.

What is the correct breathing method under water?
Breathe as relaxed as possible, inhaling and exhaling deeply. You should not try to conserve air by holding your breath as this is not very efficient breathing and can lead to other problems.

The most important rule of scuba diving:
Breathe continuously, never hold your breath!
Does pressure under water affect the air in our lungs?

You know now that the pressure is inversely proportional to the volume of gases. A decrease in pressure therefore results in an increase in volume. If you took a deep breath at a depth of 20 meters and held that breath while ascending, the decrease in pressure would cause the volume of the air in your lungs to increase. At the surface, the volume of the lungs would have increased by times three, which could overextend or even burst your lungs. These injuries can be life threatening.

Breathing and overexertion

If you are overexerting yourself, your breathing rate will increase which can result in increased oxygen depletion in your body and can cause stress. Follow these simple steps to act appropriately:

Stop - Breathe - Think - Act

Stop the strenuous activity that led to overexertion, calm yourself down and take control of your breathing. Once you have regained control of your breathing devise a plan to safely continue your dive.

Correlation between depth and air consumption

Each diver has his or her own individual air consumption depending on various factors:

- Depth
- Water temperature
- Visibility
- Currents
- State of mind
- Physical condition etc.

One thing however is for certain, the deeper you dive, the more gas you will consume in the same amount of time. The increase of pressure in the depth causes the gas to be more dense and less in volume. At a depth of 30 meters and a surrounding pressure of 4 bar you will breathe 4 times as much air as compared to the surface (surface – 1 bar to 30 m – 4 bar). In other words, if your air supply lasts you for 60 minutes on the surface, that same air supply would last you for 15 min at a depth of 30 meters.
The lungs - The functioning of the lungs

The air you breathe travels through the respiratory tract to the lungs. Our lungs are one big air space, separated into two independent lobes. You may picture the lungs as a big sponge filled with many cavities (air sacs = alveoli). Between the alveoli you have tissue and vessels. All alveoli are surrounded by venous (oxygen depleted) and arterial (rich in oxygen) blood vessels. Another important structure of the respiratory organ are the bronchial tubes which connect to the upper air passages. The epiglottis lies inside the voice box (larynx) closing the upper end of the windpipe (trachea). The throat which includes the nasopharynx and the oral cavity connects the respiratory tract to the outside of the human body.

Which mechanism regulates our breathing?

Our cells need a constant flow of oxygen so they can produce energy, which we need to survive. Our cells use the oxygen to break down (burn) nutrients, mainly carbohydrates and fat to produce energy. This chemical reaction also produces carbon dioxide (CO2) which is transformed into bicarbonate and transported to the lungs via venous vessels and exhaled through the respiratory tract. Not the amount of oxygen in our cells, as often believed, but the CO2 and bicarbonate levels regulate our breathing. The breathing reflex, which causes us to inhale, is triggered once the CO2 and bicarbonate levels reach a certain level.

Lung overextension injuries

Overextensions of the lungs are among the most serious injuries that can happen to a scuba diver but are, at the same time, very easy to avoid. By never holding our breath and making sure our air passages are always open we can almost eliminate the risks of such an injury.

Forms of lung overextension injuries:
- Pneumothorax (collapsed lung)
- Mediastinal emphysema (air inside the chest)
- Subcutaneous emphysema (air in the layer under the skin)
- Arterial gas embolism (gas bubbles in the blood vessels)

Symptoms
- Shortness of breath and difficulty taking deep breaths
- Dry cough
- Chest pain
- Breathing sounds
First aid treatment

- Administer medical oxygen
- Monitor the vital functions
- Immediately call an ambulance/medical assistance
- Position the patient in whichever position breathing works best

Equipment

Breathing regulator

The regulator is connected to the tank and supplies air to the diver which is regulated to match the surrounding pressure. Current models are all designed with a “fail-safe” mechanism.

Components

A set of regulators consists of the following parts:
The first stage brings the pressure from inside the tank down to intermediate pressure. The second stage, also referred to as the breathing regulator, has a lever operated valve which delivers air while inhaling through the mouthpiece. The valve will close once you stop inhaling and the airflow will stop. This is called on demand air flow. Inside the second stage the medium pressure is regulated down to match the surrounding pressure. Modern regulator set ups include an alternate air source, also called octopus. The octopus is an additional second stage used as a backup air source to supply your diving partner with air should he run out of air. Each of these components is connected to the first stage via medium pressure hoses, enabling air to flow from the tank through the first stage into the second stage/s. The inflator hose is another medium pressure hose which connects the first stage to the inflator located on your BCD (Buoyancy Control device generally called jacket). You can use your inflator to inflate your jacket with air from the tank. The pressure gauge hose is a high pressure hose guiding air straight from the tank to the pressure gauge, which measures the pressure in the tank and thus lets you know how much air you have left. It is very important to constantly monitor your pressure gauge under water. It can be located in a console with other instruments such as a compass, a depth gauge or a dive computer.

What should I look for in a regulator?

The most important feature for your regulator is that you can breathe easily and it fits comfortably into your mouth. Every major diving equipment manufacturer offers a range of regulators which are all suitable for recreational diving. One of the main differences, which is reflected in the price of the equipment, is whether a regulator is designed for warm water or cold water diving. Colder water temperatures require additional technical features inside the first stage that prevent the air flow from freezing up the first stage. Talk to your diving center or you scuba equipment retailer to find out which diving regulator meets your needs and is right for you.
Maintenance

Regulators are sturdy but you should still handle them with care, they keep you alive under water. Rinse your regulator after each dive, especially after you’ve been diving in salt water, making sure no water seeps into the first stage and into the hoses when you rinse your regulator. Do not leave it exposed to direct sunlight for extended periods of time. The UV light will corrode the hoses and plastic parts, reducing the life span of your regulator. Once a year you should have your regulator serviced by your dive center. Most manufacturers also recommend service after 100 dives, this number varies from manufacturer to manufacturer.

Snorkels

A snorkel enables you to swim on the surface with your face in the water, without having to raise your head to breathe.

Components

A snorkel basically consists of two components:

- Pipe
- Mouthpiece

Features

The pipe should not be longer than 40 cm (16 inches) and the tube’s diameter (bore) should be at least 2 cm (0.8 inches) to reduce breathing resistance. The mouthpiece should be made of non-allergenic silicone and should fit comfortably into your mouth. Some snorkels come with a silicone purge valve located at the lowest point of the snorkel designed to purge water through the bottom of the snorkel.

Maintenance

Rinse off saltwater and do not leave exposed to direct sunlight for extended periods.

Dive tanks or cylinders

The tank enables us to carry the gas we need to breathe under water. Breathing air compressors are used to fill tanks with high-pressurized air ranging to a pressure of 200 up to 300 bar. Every tank is equipped with a valve to open or close the air flow from the tank.

Materials

Scuba tanks are made most commonly from two different materials, steel or aluminum. For special purposes, tanks can also be made from a carbon composite material. Each material has different properties that need to be taken into account when deciding which tanks is right for you.

Steel

Most commonly used in Europe, tanks require only a cylinder thickness of 3-6 mm due to the strength of steel. The volume/weight ratio of steel tanks does not require
additional weights to equalize positive buoyancy. Steel tanks can be filled with up to 300 bar. However steel does not hold up against corrosion as well, especially in salt water.

Aluminum

Aluminum tanks hold up better against corrosion in salt water than steel tanks and are commonly used in diving hot spots around the world such as the Red Sea, the Maldives, the Caribbean, Asia. Requiring a much greater thickness, aluminum tanks are bulkier and heavier than steel tanks and their volume/weight ratio requires additional weights to counter the positive buoyancy of the tank. They can be filled with up to 225 bar.

Carbon – Composite materials

These cylinders are made of composite materials, the neck and the base of the cylinder are made of aluminum and the body is made of carbon. This reduces their weight by about 50% to comparable steel tanks, however this advantage is lost under water because you need to carry additional weights when diving with carbon tanks. Carbon tanks can be filled with up to 300 bar.

Sizes – air capacity

Cylinder or tank capacity is either expressed in liters or cubic feet (CF or CUF). Steel tank’s capacity is usually expressed in liters. Standard sizes are:

<table>
<thead>
<tr>
<th>Size</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 liter</td>
<td>10 liter</td>
</tr>
<tr>
<td>12 liter (long or short)</td>
<td>15 liter</td>
</tr>
</tbody>
</table>

The capacity of aluminum tanks is generally expressed in CUF or CF at a pressure of 200 bar. Most common sizes are:

<table>
<thead>
<tr>
<th>Size</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 CUF</td>
<td>5.66 liter</td>
</tr>
<tr>
<td>70 CUF</td>
<td>9.90 liter</td>
</tr>
<tr>
<td>80 CUF</td>
<td>11.31 liter</td>
</tr>
<tr>
<td>110 CUF</td>
<td>15.55 liter</td>
</tr>
</tbody>
</table>

Handling and transport

The Department of Transportation and similar national agencies establish regulations concerning the transport of pressurized containers, often considered hazardous cargo. Regulations vary by country and are not uniform. Each individual transporting dive tanks has to be familiar with and adhere to local laws. In addition to existing laws, a number of general rules should also be followed when transporting and handling diving tanks. Tanks are heavy and unstable when standing. To avoid injury or damaging your tanks never leave them standing unattended or unsecured and also secure them when lying down so they can’t roll. Always secure them properly inside a vehicle with the valve either facing sideways or backwards.

Filling your tanks

You should only have your tanks filled at trustworthy and certified Dive centers, Retail shops or Resorts. Unclean air can have serious impacts on your health. If there is an odor or taste to the gas in your tank, do not use it to go diving!
Maintenance

Diving tanks are subject to regulations that require periodic pressure tests. Regulations vary from country to country; your dive center can tell you the details of these regulations and usually offer visual inspections which should be performed annually in addition to the required hydrostatic tests. Make sure you do not store your tank empty, as it will draw in moisture potentially causing corrosion. Always store your tank standing and secured in a dry and cool place. After long periods of time you should empty the old air and refill the tank before using it to go diving.

Chapter 1 knowledge review

The pressure under water increases by 1 bar every ....

- A 13 meters
- B 10 meters
- C 4 meters
- D 6 meters

How high is the surrounding pressure at a depth of 30 meters?

- A 3 bar
- B 2 bar
- C 4 bar
- D 5 bar

What should you do if you are unable to equalize?

- A Keep trying head over heels.
- B Stop, ascend a little until the feeling of discomfort disappears.
- C Never use force to equalize.
- D Answers B and C are both correct.

Which is the most important rule of scuba diving?

- A Only use your snorkel at the surface.
- B Do not dive deeper than you are able to free dive.
- C Do not expose your regulator to the sun.
- D Breathe continuously – never hold your breath.

How much air will be in a balloon, after you filled it with 3 liters of air at a depth of 20 meters and let it rise to the surface?

- A 3 liters
- B 9 liters
- C 1 liter
- D The question can’t be answered with the given details.
Objectives for this chapter

✓ Explain why objects may appear larger and closer than on land
✓ Understand how light is absorbed by water and the consequences
✓ Know the most important feature of a dive mask
✓ Understand how sound travels under water
✓ Explain the difficulties of targeting the source of sound under water
✓ Know how to behave when you hear boat engine noises under water
✓ Understand how water conducts heat
✓ Explain why you need to wear a dive suit
✓ Explain the terms hypothermia und hyperthermia
✓ Know what to do in a case of hypothermia
✓ Know what to do in a case of hyperthermia

Light

Light is created by electromagnetic rays originating from the sun. The specter of visible light ranges between 380 Nm (nanometers) and 780 Nm of wavelength. Light travels at a speed of 300 000 km/sec.

Behavior of light under water

Water is about 800 times denser than air causing the light to travel much slower through water than through air. Light travels at a speed of 225 000 km/sec through water.

What is absorption?

As light travels through water, the water molecules absorb the light, converting it to thermal energy and other processes. Depth and the water’s visibility have an impact on the degree of absorption.
Refraction (light scattering)

The term refraction describes the optical effect that appears when light shifts its course slightly due to a change in velocity when entering a different medium. This effect can be noticed in two instances when scuba diving. The light scatters at the surface and off the particles in the water and it also changes speed traveling from the water to the air in our dive mask, causing refraction in both cases.

Vision under water

Why do objects appear larger and closer?

This effect is cause by the refraction of light entering our scuba mask. This makes objects look larger and closer by $1/3$.

What is optical reversal?

In waters with high visibility the effects of refraction can be reversed, meaning that objects will look further than they are.

Color vision

The white light we see is made up of all the colors mixed together. This absorption causes the colors to disappear one by one, starting with red and orange working its way up the color spectrum to yellow and on to green the deeper you dive. Blue is the last color to disappear. The natural colors will appear brownish dark after the light has been absorbed. If you want to enjoy the colorful underwater world you need to use an artificial light source (diving lamp).

The functioning of the eye

Light rays entering the eyes are refracted by the cornea, the lens and the vitreous body and captured by the retina. The refraction is measured in diopter. The human eyes need air to focus, this is why our vision is blurred under water without a mask.

How can the eyes suffer from a barotrauma?

The dive mask is an artificial air space on our body. Decreasing pressure during a descent creates a vacuum inside the mask. If we do not equalize the mask by letting air out of our nose the increasing vacuum can exert negative pressure on our eyes and the eye muscles, pulling them out of their sockets. This can cause blood vessels in the eye to rupture and lead to bruises around the eyes. This can be easily avoided by simply letting some air out of your nose while equalizing your ears, this will equalize the negative air pressure in your mask.
Equipment

**Masks**

Our eyes cannot focus in water, in order to see clear, we need air for our eyes to focus. Masks enable us to see clear under water.

**Components**

Masks generally consist of four components:
- The mask body or skirt
- The frame
- The glass or glasses
- The strap

**Features**

The most important thing when it comes to a dive mask is a proper and comfortable fit. Your dive center will help you try on different masks to make sure you find the one best suited for you. The glass lens should be made from tempered glass, which is less likely to shatter into sharp pieces should it break. The mask body or skirt should be made from non-allergenic silicone and should fit close against your face to form a good seal. The frame should be made from impact resistant plastic.

**Maintenance**

Do not leave your mask exposed to direct sunlight. Use the protective case that came with your mask to shield it from UV light and to maintain the shape of the mask skirt. Rinse it with freshwater especially after saltwater and pool dives.

**Visual correction masks**

If you need visual correction, some manufacturers offer visual lenses for their masks at a reasonable cost. Should your strength not be available, custom made lenses can be ordered from your optician.

**Sound**

Sound is energy travelling in waves through a medium; it travels through air at a speed of 343 m/s (1235 km/h). The higher the density of a medium, the faster sound will travel. Water is about 800 times more dense than air causing sound to travel at a speed of 1480 m/s, about 4.35 times faster than through air.
Hearing under water

How well can we hear under water?

We can hear very well under water due to the fact that sound travels much faster.

The ear - Directional hearing under water

Directional hearing under water however is more difficult. Our brain locates the source of sound by determining which ear is reached first by the sound and from this pinpointing a direction. Under water sound travels 4.35 times faster making it difficult for the brain to determine which ear is reached first. We might think we can tell which direction a sound is coming from, but are often mistaken. The brain will generally conclude that the sound is coming from somewhere above us.

How to behave when you hear a noise?

Whenever we want to identify and locate the source of sound under water, we have to establish visual confirmation.

Boat engine noises

Whenever you hear noises potentially originating from motorized boats and water crafts you should be very cautious. Immediately descend to a safe depth well beneath the water surface. This will put a safe distance between you and any boats’ propellers. Remain at a safe depth until the noise has disappeared. In areas with frequent boat traffic always dive close to shore or along the reef. Regulations require divers to carry a diver’s buoy and/or flag which is well visible above the surface, indicating the location of the divers under water. Always employ a safety buoy when surfing in the open water. Do not approach boats from underneath unless they are sitting at anchor. Otherwise approach boats on the surface from a safe distance establishing contact with the crew before swimming closer to the boat.

Things that may affect your hearing under water

⇒ Air inside the outer ear
⇒ Hood

Thermal properties of water

Water conducts heat 25 times faster than air, due to its density which is 800 times higher than air.
Why does our body cool down faster while diving than when we are swimming or snorkeling?

When swimming or snorkeling, parts of the body remain above the water surface (the head, shoulders and parts of the back). In addition to the complete submersion we are breathing pressurized air which is cooler and drier than the air above the surface. Our body needs to warm and moisten the air that we breathe under water. This requires energy drawing from our body’s warmth and fluids.

**Hypothermia**

How can hypothermia occur?

The most common mistake is to wait too long before aborting the dive due to feeling cold. If you are cold under water and start to shiver and cannot control the shivering it is past time to stop the dive and leave the water to warm up. Not choosing the appropriate suit for your dive can quickly lead to feeling cold under water.

**Symptoms**

- Shivering in an uncontrollable manner
- Lips and fingernails turning blue
- Pale skin
- Slow reaction
- Loss of temperature feeling
- Coordination problems
- Weakness in the legs and arms

**Treatment**

- Dry off and put on warm clothes as quick as possible
- Stay in a dry and warm place
- Do not drink alcohol
- Drink warm beverages

**First aid**

Do not use hot water in an attempt to warm up the victim. This could lead to a widening of the blood vessels and too much cold blood could be transported to the body’s core, intensifying the hypothermia. Continuously monitor the vital signs and consciousness of the victim. If there is no state of shock, administer warm beverages.

**Hyperthermia**

How can hyperthermia occur?

Because water has a cooling effect on our body, hypothermia usually occurs before we enter the water. If we wait too long in the heat of the day suited up in our dive gear, before we jump into the water, our body can quickly overheat. The dive suit disables our bodies to regulate our body temperature by sweating. We sweat inside our suit but air cannot evaporate the sweat and cool us off, so we continue to sweat and to overheat.
Symptoms
- Blushing of the face
- No sweat
- Accelerated pulse
- Shallow breathing
- Dry and warm skin
- Disorientation

Treatment
- Immediately take off dive suit
- Find a cool and shaded area
- Cool off with water or a shower
- Drink plenty of cold fluids
- Do not drink alcohol

First aid
Use a cold towel to cool off the neck and the head, wipe down the body with cold towels. Monitor the vital functions and consciousness of the victim. If the victim is responsive administer fluids and electrolytes.

Equipment
Diving suits
Diving suits protect us from the cold by reducing heat loss but also serve various other functions, from sun protection and protection from abrasions to looking fashionable.

What is neoprene?
Neoprene is actually a brand name from the company DuPont used to refer to chloroprene rubber. Neoprene is very flexible and resistant. Neoprene used for diving suits is foamed by pressing gas (usually nitrogen) into liquid chloroprene rubber. Countless tiny gas bubbles are trapped inside the neoprene delivering great insulation.

Function of a dive suit
Dive suits provide warmth under water by creating a thin layer of water between the skin and the neoprene and by insulating this layer from the outside water temperature. The skin warms this thin layer of water and the warm water reflects heat back to the skin. Dive suits have to fit tight, otherwise the layer of water could be too large and drain warmth from the skin without effectively reflecting it back, and the water layer can move easily every time the diver moves, causing it to cool off and exchange water with the cool surrounding water.

Different styles and types of diving suits
The diving environment dictates which type of suit can be used. The colder the water the better the insulation required from the suit. The main difference lies in the thickness of the neoprene used for the suit, one other difference lies in the layer of water between the suit and the skin.
Body suits or tropical overall
1- 3 mm strong overalls made from neoprene, lycra or nylon are primarily worn in warm, tropical waters. Heat insulation is not the main consideration when it comes to warm waters but body suits also provide sun burn protection as well as protection from scrapes and abrasions as well as jelly fish stings.

Shorty suits
A dive suit made from neoprene 3 - 5 mm strong with short legs and short arms, this suit is also used for warm water.

Long John suits
Are overall pants made of neoprene, which are generally worn under a long sleeve jacket. Long john suits are used in moderate water temperatures and usually 5 to 7 mm strong.

Wet suits
Wet suits are the most common dive suits, a single overall made of 5 or 7 mm strong neoprene with either a front or back zipper. Wet suits can be used for many water temperatures, depending on the thickness of the neoprene and they can be complemented with an ice vest worn over the overall to add insulation for colder temperatures under 18 C (65 F).

Semi-dry suits
A newer version of the wet suit reduces the flow of water inside the suit by sealing off the arms and legs. Water will still enter the suit through the neck and the zipper, but it is kept inside the suit making the heat exchange between the skin and the water more efficient. This enables you to either reduce the neoprene thickness for your dive suit or to dive in colder waters as low as 10 C (50 F) than with regular comparable wet suits. This feature is mostly standard in modern dive suits.

Dry suits
Are made from neoprene but can also be made from different materials such as codura, nylon or trilaminate. They provide insulation in a different way than wet suits, as the name already suggests it, a dry suit does not use a layer of water between the skin and the suit, but a layer of air. The suit cannot allow any water to enter the area between suit and skin for this to work. Dry suits are equipped with gas proof zippers, either on the back or in the front and have neck and wrist seals to keep the water out. The boots are attached to the suit. They are worn with undergarments, anything worn between your skin and the water inside a dry suit reduces heat loss. Air is trapped between your skin and the suit, creating another artificial air space that is affected by the surrounding pressure.
Dry suits have a second inflator hose connected to the suit (usually in the chest area) to add air and a valve (usually located on the left arm) to release air in order to equalize pressure changes. Using a dry suit comes with some additional challenges and you need to master additional skills before you should use a dry suit in your open water dives. You can take the Dry Suit Diver specialty course during your Open Water diver course to learn these necessary skills.

Maintenance - neoprene
Rinse with fresh water after pool and saltwater dives. Do not leave neoprene exposed to the sun for longer periods. This can cause the gas bubbles trapped inside the neoprene to diffuse out of the material and will reduce the insulation provided by the material and its flexibility causing it to tear. You can machine wash neoprene suits at up to 40 C without tumbling cycle and there are antibacterial neoprene detergents. Use a broad clothes hanger for your dive suit to maintain the form when drying.

Dry suits
Dry suits come at a more complex design and a higher price point. Maintenance should be taken more serious, especially the wrist and neck seals and the gas proof zipper require special attention. The seals should be cleaned and covered with talcum powder after every dive. Use wax to keep the zipper smooth and never bend it. Store your dry suit in a dry and cool place.

Dive suit accessories - Hoods
We lose approximately 75% of our body heat through our head. Wearing a neoprene hood reduces the heat loss and keeps us warm longer under water.

Gloves
Gloves are worn under water to protect from scrapes and abrasion and the can provide insulation. In warm water you would wear lightweight gloves that provide no insulation (reef gloves), for colder water, neoprene gloves or even mitts also provide insulation and warmth.

Wet suit boots
Wet suit boots provide insulation for the feet in colder water, but also protection when walking on rocky terrain to or from the dive site. Wet suit boots are made of neoprene up to 7 mm strong and should reach above the ankles to ensure a seamless connection with the legs of the dive suits.

Neoprene socks
Provide additional insulation in cold water or can be worn with full foot fins. They are usually 2 - 3 mm strong.

Undergarments
Undergarments worn under wet suits provide additional insulation by reducing water flow inside the suit and they make it easier to get into and out of your wet suit. They are usually made of either thin neoprene or lycra.
Under water we perceive objects to be...
- □ A far away and small.
- □ B about 30% closer and larger.
- □ C very blurry.
- □ D present that are not (optical illusions).

How much faster does sound travel in water compared to air?
- □ A 26 times faster.
- □ B 4.35 times faster.
- □ C 0.6 times faster.
- □ D 12.34 times faster.

Why do we wear a dive suit under water?
- □ A The bright colors of our suit make us more visible under water.
- □ B Neoprene can protect against shark bites.
- □ C To protect our body from hypothermia.
- □ D To cushion our back against the dive tank.

When we hear boat engine noises under water, we should...
- □ A surface immediately to see which boat it is.
- □ B remain at a safe depth until the noises have disappeared.
- □ C stay close to the shore or the reef when surfacing.
- □ D Both answers B and C are correct.

What should we do when we start to shiver uncontrollably?
- □ A Abord the dive and get out of the water.
- □ B Swim faster to get warm again.
- □ C Snuggle up to your dive partner to keep warm.
- □ D Remain still until the shivering stops.
3. Buoyancy

Objectives for this chapter

 ✓ Explain Archimedes’ principle
 ✓ Name the different types of buoyancy which are relevant for scuba diving
 ✓ Know the differences between fresh and salt water when it comes to diving
 ✓ Explain the function of the lungs as a buoyancy control device
 ✓ Know how to position yourself correctly under water depending on the situation
 ✓ Know the most common techniques for swimming under water
 ✓ Name the pieces of equipment that are used to control buoyancy
 ✓ Know how to determine the correct amount of weights

Archimedes’ principle - Buoyancy, upward and downward movement

Archimedes’ principle is one of the most important laws of physics when it comes to scuba diving. Archimedes was a Greek mathematician and physicist who lived around 300 b.C.:

„A body immersed in a fluid is buoyed up by a force equal to the weight of the displaced fluid. “

How do volume and weight influence buoyancy?

Positive buoyancy - A body immersed in a liquid will experience upward movement and float if it weighs less than the fluid it displaces.

Neutral buoyancy - A body immersed in a liquid will neither float nor sink but hover if it weighs the same amount as the fluid it displaces.

Negative buoyancy - A body immersed in a liquid will experience downward movement and sink to the bottom if it weighs more than the fluid it displaces.

Differences salt water – fresh water

Since the force of buoyancy depends on the weight of the liquid that is displaced, salt water will create a larger force of buoyancy than fresh water because salt water is heavier than fresh water. A body that is neutrally buoyant in fresh water will be positively buoyant or floating in salt water. As a consequence we will require more weights when diving in saltwater than we do in fresh water.
The relevance of different types of buoyancy for scuba diving

**Floating:** Positive buoyant – upward movement
We start every dive on the surface, floating and when we end our dive, ascending back to the surface.

**Sinking:** Negative buoyant – downward movement
We need downward movement to descend beneath the surface and to reach our desired depth.

Neutral buoyancy- hovering at a certain depth
This is the desired state during the dive. If we are neutrally buoyant we can conserve energy by not having to counter upward or downward movement to remain at the chosen depth.

**Positioning your body under water**

**During the descend**
Always descend feet first. Diving down head over heels can lead to vertigo and loss of orientation. Descending feet first will make it easier for you to control your buoyancy through your BCD and keep visual contact with your dive team.

**During the dive**
Maintaining a horizontal and level position under water reduces the water resistance and helps you conserve energy when swimming under water.

**Streamlining**
Apart from positioning yourself horizontally it is also important to keep your hoses and equipment tucked in close to your body to reduce water resistance. This will also protect your equipment from damage not to be dragged on the bottom or caught on objects.

**How to move under water**
Try to avoid any exertion under water. Pace yourself and move slowly and steadily. It is not a race and the faster you swim, the faster you will use up your air supply, cutting your time under water short. Try to keep your arms still and close to your body, use your legs to move your body.

**Swimming styles**
- Flutter kick (leg kick used in crawl swimming)
- Frog Kick (similar to the breast stroke kick)
The lungs used as a buoyancy control device

Besides the mechanical devices we use to regulate our buoyancy, the jacket and the weights, our lungs offer us a natural way to control our buoyancy. Our breathing enables us to efficiently make smaller adjustments to our buoyancy under water. By taking deeper breaths, we increase our body’s volume and thus the amount of water displace, becoming slightly more positive buoyant and we can reverse this effect by exhaling deeply, decreasing our volume. You will learn these skills under water during your pool dives.

Why do I need to carry weights under water?

We need to carry weights under water to counter the positive buoyancy from our neoprene suit and other pieces of equipment. Without weights we would not be able to achieve negative buoyancy to descend underneath the surface. If you carry too little weight, you will either not be able to descend or you will have to battle positive buoyancy by kicking harder, using up more air and potentially causing problems during your safety stop at the end of your dive. Having too much weight will also increase your energy and air consumption because you will face greater water resistance. As you can see, it is important to determine the proper amount of weights for your dive.

Factors that influence how much weight you need

Fresh water or salt water?

Salt water has a greater density than fresh water which results in greater buoyancy. We need about 5% more weights when diving in salt water with the same equipment as in fresh water.

The size and the material of our dive tank

When determining the amount of weight we need we have to take the size and the material of our dive tank into consideration. The larger the volume of our dive tank, the heavier the tank and the less weight we need to carry. Steel tanks are much smaller than aluminum tanks with the same air capacity volume and therefore displace less water and have more negative buoyancy. Diving with aluminum tanks requires you to carry additional weight than when diving with steel tanks.

Diving suit

The foamed structure of neoprene gives your dive suit a lot of positive buoyancy, the thicker the suit the more weight you need.

How to determine the right amount of weight?

You could use a rule of thumb and take 10% of a divers weight as the amount of weight needed, however that does not take all the aforementioned factors into consideration, it can be used as a starting point. To correctly determine your right amount of weight, enter the water with all your equipment. Release all the air from your jacket in water too deep to be standing and breathe constantly through your regulator. Refrain from moving and the water should be somewhere close to your nose, you have the right amount of weight.
If you sink beneath the surface, you are carrying too much weight, if your head is above water, you are not carrying enough weight. The more experienced you become the less weight you will need. It is a good idea to keep track of the amount of weight you need when diving with different equipment and in different environments. You can enter this information into you diving log book after each dive.

**Equipment**

**Buoyancy control device (Jacket, BCD, Wing etc.)**

Modern buoyancy control devices serve two main purposes:
- Safely securing the dive tank to the diver
- Regulating upward and downward movement by buoyancy control

Every jacket (buoyancy control device) consist of a carrying device for the tank, a hard back plate with a locking mechanism, and an expandable bladder which can be inflated and deflated under water, either using air from the lungs or the inflator which is connected to the tank.

**Different types of BCDs**

Bcd is simply the abbreviation of the term buoyancy control device and is used for all types of floatation devices used in scuba diving.

**Buoyancy vest, Scuba diving jacket or adv-jacket (adjustable diver jacket)**

Recreational divers most commonly use this this style of bcd. Shaped as a jacket or vest, they come with adjustable shoulder and belly straps. These bcds are generally used to dive a single tank, some manufacturers allow the use of twin tanks. adv-jackets are usually available in sizes XS-XXL and the expandable bladder offers a volume ranging from 5 to 20 liters depending on jacket size. The shape of the bladder lets the air expand over an area covering the back, reaching around underneath the arms to the sides of the belly.

**Wing-jacket**

The main difference between wing-jackets and adv jackets is the bladder, which is shaped like a wing and only located on the back of the jacket. This offers the advantage that the expanding bladder does not restrict movement of the arms and the upper body.
Tec-jacket

So called Tec-jackets are wing jackets which are suitable to be used for diving with several tanks. The bladder has a larger volume and all fastening clips are made from stainless steel. Tec-jackets are more robust and durable than regular wing jackets, which comes at a higher price point.

Back plate harness with wing

This system consists of a back plate, either made from aluminum, steel or a compound material like carbon, equipped with a locking mechanism. A wing bladder will be added separately in between the back plate and the dive tank/s depending on the flotation volume required. These systems can accommodate single or multiple tanks with a flotation volume ranging from 12-100 liters.

Side mount system

This is a newer system which enables the diver to carry the tanks on his sides rather than on his back. Mostly used by wreck and cavern divers these systems can also be suitable for recreational divers.

Features of these different bcds

ADV jackets

are generally very comfortable and offer several pockets for divers to store small gadgets. A cushioned back plate made from plastic can be easily adjusted. ADV jackets require more weight because of their positive buoyancy (2-4 kg), modern jackets offer the option of weight integrated systems, allowing the diver to store the weight inside the jacket rather than carrying it on a belt worn around the belly.

Wing-jackets

are more expensively manufactured and present the top segment of recreational diving jackets. Integrated weights, cushioned back and shoulder areas and various quality clips and pockets are standard.

Tec-jackets

are very robust and durable jackets, less tailored to be comfortable tec-jackets are very versatile and functional. Integrated weight system comes standard.

Back plate harness with wing

is by far the most purist system able to adopt to the diver’s needs. The high adjustability and the possibility to add pockets and clips anywhere allow countless configurations and can grow with the challenge.
Integrated weight system or not?

Integrated weight systems reduce the direct strain of the weights on the back and the spine. Weight belts pull down on the hip while the bcd lifts up from under the shoulder, putting strain on the lower back which can be avoided using an integrated weight system.

Maintenance

Rinse with fresh water after pool and saltwater dives. Do not leave your jacket exposed to the sun for longer periods. Before storing your jacket for longer periods of time you should rinse the inside of the bladder with warm water and use an antibacterial disinfecting solution. The inflator should be serviced every two years or every 100 dives by a professional dive or service center.

Fins

Styles

Full foot fins

fit like rubber slippers and are often referred to as snorkeling fins. They do offer little insulation and protection for the feet and are usually used only in warm water.

Open heel fins

have an open heel pocket allowing you to slip in your dive boots. An adjustable strap ensures a proper fit with your dive boots. They are also referred to as adjustable strap fins.

Which fin is right for me?

Your physical ability, your size and where you plan to dive help you find the right fins for you. If you plan on diving in warm waters, full foot fins should fit snugly but comfortably on your bare feet without binding. Open heel fins should fit your dive boot inside the pocket and the pocket should come up to your ankle, if it does not come up that high, choose a larger size. For both full foot and open heel fins, the larger and stiffer the blade of the fin, the more physical strength you need to use it.

Maintenance

Rinse with fresh water after pool and saltwater dives. Do not place heavy objects on your fins to avoid deformation of the rubber foot pockets. Store your fins in a dry and cool place. Check the adjustable straps for rips and tears before diving, always keep a replacement strap with your dive gear.
Weight systems

Weight belts
are 5 cm (2 inches) wide belts made from nylon or codura with a quick release buckle. The weights are threaded onto the belt, variations of belts have pockets for the weights. The quick release buckle enables you to ditch the weight belt in an emergency with only one hand by simply pulling on the loose end of the belt. Weight belts have the longest history as weight systems.

Weight-vests
have weight pouches to store the weight and are worn like a vest over the shoulders. This shifts the weight from the hips to the shoulders making it more comfortable to be carried on land.

Integrated weight systems
are a more modern approach to weight systems and integrate the weight system with your jacket. Weight belts often shift and can be uncomfortably to wear, integrated systems eliminate these problems. They also come with a quick release system, enabling the diver to ditch the weights with only one hand in an emergency.

Hazardous material advisory
Lead is a very poisonous metal. It is especially toxic to the human organs and the nervous system. Children especially should be protected from exposure to lead. European regulations prohibit the use of lead shot, lead bars are still ok to be used. Ideally your lead weights should be coated as this reduces the impact of your lead on the environment and the exposure of lead to humans and especially children. When handling uncoated lead make sure to wash your hands afterwards and make sure children do not lick their hands after handling uncoated lead.

Maintenance
Store your lead weights out of the reach of children and pets.
Chapter 3 - Knowledge review

Which law of physics describes the buoyancy of object immersed in fluids?

- A Einstein's law.
- B The principle of buoyant objects.
- C Archimedes' principle.
- D Dalton’s law.

What happens to an object which is neutrally buoyant in salt water when it is placed in fresh water?

- A It will float.
- B It will sink to the bottom.
- C It will remain neutrally buoyant.
- D Unable to predict with the given information.

Which pieces of equipment affect the amount of weight needed?

- A The dive suit.
- B The fins.
- C The jacket.
- D Answers A and C are both correct.

The lungs are an important aid to buoyancy control.

- A Correct
- B False

Any weight system used for scuba diving has to...

- A be yellow.
- B be equipped with a quick release mechanism.
- C be coated.
- D weight at least 4 kg.
4. Gases

Objectives for this chapter

✓ Name the major gases in the air we breathe
✓ Explain the constitution of the air we use for scuba diving
✓ Understand Dalton’s law
✓ Know what nitrogen narcosis is
✓ Name the symptoms of nitrogen narcosis
✓ Know how to behave when showing signs of nitrogen narcosis
✓ Know how to avoid nitrogen narcosis
✓ Describe what decompression sickness is and what causes it
✓ Name the symptoms of decompression sickness (DCS or the bends)
✓ Know the first aid procedures for DCS
✓ Know how to avoid DCS
✓ Explain why oxygen is important for the human body
✓ Explain what is meant by oxygen toxicity problems
✓ Name two definite symptoms of oxygen toxicity problems
✓ Describe the greatest danger resulting from oxygen toxicity problems
✓ Know how to avoid oxygen toxicity problems
✓ Know the first aid procedures for oxygen toxicity problems
✓ Describe the effects of carbon dioxide
✓ Explain the terms hypercapnia and hypocapnia
✓ Describe the effects and dangers of carbon monoxide
What is air?

The term air is used to describe the gas mixture that has formed inside the atmosphere that surrounds our planet. A mixture is a combination of two or more substances such that each substance retains its own chemical identity, no new substance is being created. Air is a mixture from several gases, the main components being nitrogen, oxygen, argon and carbon dioxide.

Composition of air:

- 78,084 % nitrogen (N)
- 20,942 % oxygen (O)
- 00,934 % argon (Ar)
- 00,038 % carbon dioxide (CO₂)
- 00,002 % trace gases such as xenon, krypton, radon, helium, methane and carbon monoxide.

To simplify matters for recreational scuba diving we assume the composition of air to consist of 21% oxygen and 79% nitrogen.

Dalton’s law of partial pressure

To fully comprehend how gases have an effect on the human body, it is important to understand that it is the gases’ partial pressure that is important and not their percentage of the mixture. Dalton’s law defines a gas’ partial pressure as:

“In a mixture of non-reacting gases, the total pressure exerted is equal to the sum of the partial pressures of the individual gases.”

\[ P_{\text{total}} = p_1 + p_2 + \ldots + p_n \]

As you have learned, the atmospheric pressure at sea level is 1 bar. If we apply Dalton’s law to the total pressure of 1 bar of air, we can conclude the partial pressures to be:

\[ 0,21 \text{ bar } O + 0,79 \text{ bar } N = 1,0 \text{ bar } P_{\text{Gesamt}} \]

To calculate the partial pressure of a gas \( P_x \) for a given surrounding pressure (total pressure= \( P_{\text{tot}} \)), we have to multiply the partial volume of the gas's percentage \( V_x \) with the total pressure.

\[ P_x = V_x \times P_{\text{tot}} \]

Example: What is the partial pressure of Oxygen \( P_O \) at a depth of 20 meters with oxygen at 21%? Solution: Surrounding pressure at 20 meters (depth/10) + 1 bar = 3 bar total pressure. 21% oxygen partial volume equals 0.21. This leads us to 0.63 bar \( P_O \).

\[ P_O = V_x \times P_{\text{tot}} \]

\[ P_O = 0,21 \times 3 = 0,63 \text{ bar } P_O \]

The partial pressure of oxygen at 20 meters is 0.63 bar while the volume percentage remains 21%.
Nitrogen (N)

Nitrogen, as you have learned, holds the largest fraction of the air we breathe. Under normal conditions, inside the human body, it remains inert, meaning it is chemically inactive and does not have any impact on our body. If the conditions are altered like the surrounding pressure when scuba diving, nitrogen can start to affect our body.

Nitrogen narcosis

Breathing air at a high surrounding pressure results in an increased partial pressure of nitrogen, which can cause nitrogen narcosis. The increased partial pressure of nitrogen causes nitrogen to dissolve into nerve cell membranes, causing temporary disruption in nerve transmission, causing narcosis. First symptoms and signs of nitrogen narcosis can appear at a depth of 30 meters when diving with regular air. The recommended depth limit for recreational diving therefore is set at 30 meters. However certain catalytic factors can increase the risk and lead to nitrogen narcosis at lower depths.

Symptoms and signs of nitrogen narcosis

The following symptoms are listed in order of their appearance, with increasing pressure.

- Euphoria
- Overestimation of your own abilities
- Impaired perception
- Reduced reaction
- Irrational behavior
- Attention deficit
- Coordination problems
- Tunnel vision
- Ringing in the ears
- Dizziness
- Impaired hearing
- Fear
- Halluzination
- Unconsciousness

The progression in the signs and symptoms of nitrogen narcosis is directly related to an increase in pressure, a progression is unlikely at constant pressure.

Catalytic factors that contribute to nitrogen narcosis at lower depths

- Cold temperatures
- Darkness, reduced visibility
- Hypercapnia (excess carbon dioxide)
- Stress
- Fear
- Exertion

How to react to signs and symptoms of nitrogen narcosis?

If you detect signs and symptoms of nitrogen narcosis in yourself or your dive partner, you should not descend any deeper but should decrease your depth by slowly ascending a few meters. You will quickly notice the signs and symptoms to fade, as the decreasing pressure lowers the partial pressure of nitrogen, canceling its impact on your body.
How to help your dive partner

If you suspect your dive partner to be impacted by nitrogen narcosis, get his attention and establish visual contact with him and signal him to ascend together with you. Repeat your requests until he reacts to it and you have decreased your depth. Unless there is a clear emergency refrain from handling your dive partner’s equipment and buoyancy control devices. You do not know exactly which symptoms he has and how he might react to your interference, you could spark fear or loss of control in your partner.

Mutual surveillance

It is advisable to agree on mutual surveillance techniques with your partner when diving at depths where nitrogen narcosis seems probable. For example you could agree on a number beforehand that has to be added to a random number symbolled under water, the time it takes your partner to solve the equation gives clues to whether he might be affected by nitrogen narcosis. Generally you have to be aware of the physiological fact that nitrogen narcosis will eventually appear with increasing depth, no matter how experienced the diver is.

How to avoid nitrogen narcosis.

- Do not dive deeper than 30 meters
- Reduce your planned depth in less than optimal and potentially exhausting conditions, such as darkness, cold water or currents
- Dive with nitrox
- Stay focused under water

Decompression sickness - DCS (the bends)

Since our body is mostly made up of liquids, it has the ability like any liquid to store gases, in direct relation to the surrounding pressure. Breathing air at the same pressure as the surrounding pressure, we constantly absorb some of the gases that we breathe under water and store them inside our tissue. This process is called the saturation of gases. Nitrogen is the relevant gas when breathing under water as it is not consumed by our body as compared to oxygen, which is used in our cells to produce energy and converted into Co2 which is then transported out of our body. Our body starts absorbing and storing nitrogen when we descend and the saturation process continues until we start ascending. The decreasing surrounding pressure causes the stored nitrogen to leave our body again. Gases diffuse towards lower pressure, when we descend the partial pressure of nitrogen outside our body rises and is higher than inside our body, nitrogen starts to enter our tissue. When we ascend, the pressure decreases and the partial pressure of nitrogen inside our body is higher than outside, the nitrogen starts to leave our body. The larger the gradient, the faster the gas will try to diffuse. This can create problems when scuba diving. If we ascend too fast, nitrogen rushes into our blood stream and could form gas bubbles, leading to serious medical consequences by blocking off vessels. This is called a decompression sickness. It is extremely important to ascend slowly to give our body enough time to reduce the nitrogen. The maximum speed should not exceed 10 meters per minute when ascending. At the end of each dive we make a safety stop at a depth of 5 meters for 3 minutes, this enables our body to further reduce nitrogen (the largest pressure increase/decrease happens in the first 10 meters).
Signs and symptoms of DCS.

Nitrogen that rushes into our bloodstream could form bubbles which can form in different places in the body. Depending on the severity of the signs and symptoms we differentiate between Type 1 and Type 2 DCS. Symptoms usually occur within 5 to 20 minutes after the dive, but sometimes it might take up to 6 hours until the peak of the symptoms is reached.

DCS Type I

- Tingling skin (divers fleas)
- Dull ache
- Skin rash
- Weakness and fatigue
- Joint and limb pain
- Sickness and vomiting

DCS Type II

- Shock
- Impaired hearing
- Loss of eyesight
- Slurred speech
- Paralysis
- Difficulty breathing
- Unconsciousness
- Death

Recreational dives are no-decompression dives

The amount of nitrogen that is absorbed by your body depends on how long and how deep you dive. No-decompression limits tell you how long you can stay at a certain depth and still be able to ascend straight to the surface, adhering to the maximum speed and the safety stop. These are so called no-decompression dives. If you overstay a no-decompression limit, your body has absorbed more nitrogen than the tissue can safely absorb and there is a high risk for DCS. In this case you have to make decompression stops at predetermined depths to allow your body to reduce the nitrogen before reaching the surface. These dives are called decompression dives or saturation dives and require additional training.

How to avoid DCS

- Always stay within your no-decompression limits
- Do not exceed the recommended depth limit of 30 meters
- Always ascend slowly, no faster than 10 meters/minute
- Always make a safety stop
- Use nitrox
- Make sure you are well hydrated before diving

Progression of DCS

It can take up to 6 hours from the first signs to the peak of DCS, depending on the dive/s that lead to DCS. A worsening of the symptoms can generally be expected during the progression in this time.
First aid

If a diver is suspected to be suffering from DCS, the first thing you should do, once he is safely out of the water, is to have him breathe pure oxygen. Every dive center and diving vessel is equipped with pure oxygen for emergencies. The victim should drink fluids to stay hydrated if he or she is respondent. Do not take any medication unless a physician is consulted first. The victim's vital functions should be constantly monitored. A back position with raised legs is advisable, unless the patient prefers a different position which allows him to be more comfortable. Any DCS II has to be treated in a pressure chamber and under medical surveillance. The symptoms of a DCS are generally reversible, if treated within 8 hours in a pressure chamber; therefore it is very important to not delay the victim's transport to a facility where he can be treated. Immediately arrange for medical transport, informing them that a diving accident has occurred, which has relevance for the preparation of his transport and his treatment. Make sure to supply all available date of the dive/s that lead to the DCS to the medical team, including the diver's dive computer if he had one.

What is a pressure chamber treatment?

Inside a pressure chamber the surrounding pressure is increased, to raise the partial pressure of nitrogen inside our body. This causes the nitrogen bubbles in our blood stream that potentially have blocked vessels, to be absorbed back into our cells. Our body now can reduce the nitrogen levels in the tissues while the pressure inside the chamber is slowly lowered. Depending on the severity of the DCS, this process has to be repeated up to 20 times. The patient is continuously monitored by a medical team. In order for the pressure chamber treatment to be as successful as possible, the medical team has to have all the diving data of any dives 36 hours prior to the accident. Dive chamber facilities can read this data from any dive computer.

Wet recompression

In the early days of scuba diving before compression chambers were available, wet recompression was used to force the nitrogen bubbles back into the tissue. What this meant was that the diver who had the accident was brought back down to a certain depth until the symptoms had subsided and then he was slowly brought back to the surface. This includes great risks for the victim and the helpers and wet recompression should not be used in any case.
**Oxygen (O)**

Oxygen is vital to humans and most other creatures for nearly all metabolic processes; it supplies the human body with energy. The effects of oxygen on our organism are also affected by the surrounding pressure and the resulting partial pressure of oxygen ($P_o$).

There are three states of oxygen saturation in our body:

- **Normoxic** – Body is supplied with sufficient amounts of oxygen. $P_o$ of 0.21 bar.
- **Hypoxic** – A $P_o$ lower than 0.21 bar can lead to an undersupply of oxygen in our body, for example at high altitudes when mountaineering.
- **Hyperoxic** – A $P_o$ higher than 0.21 bar can lead to an oversupply of oxygen. Oxygen can become toxic for our cells above a partial pressure of 1.6 bar.

**Oxygen toxicity problems**

**Causes of oxygen toxicity?**

An increased $P_o$ higher than 1.6 bar can lead to CNS (Central Nervous Syndrome), an oxygen toxicity problem also referred to as the Paul Bert effect. It is a condition resulting from the harmful effects of breathing molecular oxygen at increased partial pressures which leads to a higher production of hydroxyl radicals which can initiate a damaging chain reaction within cell membranes.

**Signs and symptoms**

Some of the signs and symptoms of central nervous system oxygen toxicity can be very similar to the ones of nitrogen narcosis, such as visual changes (tunnel vision), ringing in the ear (tinnitus), nausea, irritability (anxiety, confusion, etc.) and dizziness. There are two symptoms however that are clear indicators for oxygen toxicity:

- Twitching (especially of the lips and facial muscles)
- Seizures and intense muscle contractions leading to cramping

**Effects of oxygen toxicity and how to react**

The greatest danger from oxygen toxicity is drowning. Twitching and cramping of facial muscles, especially the lips, can cause a diver to lose control over the breathing regulator. Once the regulator is no longer inside the mouth, the breathing reflex will eventually force the diver to inhale water leading to drowning. Should you suspect signs or symptoms of oxygen toxicity in your dive partner it is very important that you reduce the $P_o$ immediately by ascending to shallower depths. Should your dive partner have lost the regulator, replace it immediately. It may take up to two hours for the symptoms to wear off.

**How can you prevent oxygen toxicity?**

- Refrain from diving at depths that exceed a $P_o$ of 15 bar
- Refrain from diving with Nitrox without the proper training
Generally the critical $P_o$ limits are beyond the recreational dive depths. When diving with regular air, the $P_o$ becomes critical at a depth of 66 meters, far deeper than recreational divers are advised or allowed to dive. Diving with oxygen enriched air mixtures (Nitrox) can move the $P_o$ limits to a shallower depth. Diving with Nitrox requires additional training and is mandatory before you can safely dive with oxygen enriched air mixtures.

**Rescue and first aid**

- Make sure the breathing regulator stay in the diver’s mouth
- Overextend the victim’s head to allow expanding air to escape the lungs
- Slowly ascend together with the victim
- Immediately transport the victim out of the water and remove all equipment
- Position victim safely so he can not harm himself during any seizures
- Do not administer fluids or food as long as the seizures continue
- Constantly monitor the victim

**Carbon dioxide - $CO_2$**

When converting oxygen into energy, our cells emit carbon dioxide as a metabolic product, which has a very important function for our body. Carbon dioxide is transformed into bicarbonate so it can be transported in our bloodstream. Once a threshold is reached, the breathing reflex is triggered in our brain, causing us to exhale carbon dioxide and inhale fresh oxygen.

**What is hypercapnia?**

An increased production and/or a reduced exhalation of carbon dioxide can lead to excess of carbon dioxide in our body, a state called hypercapnia. This can occur in divers trying to conserve air by breathing less. First signs of hypercapnia are increased and shallow breathing, sometimes in connection with headaches. Increased carbon dioxide will lead to a more frequent breathing reflex and potentially the feeling of not getting enough air. This can lead to increased stress and in worst cases to unconsciousness.

**What is hypocapnia?**

Free divers often employ a technique where they reduce the level of carbon dioxide (hypocapnia) in their blood in order to delay the breathing reflex. Lowering the bicarbonate levels in your blood by specifically exhaling carbon dioxide can lead to oxygen depletion in your cells before the breathing reflex is triggered by the rise in bicarbonate. This situation would result in unconsciousness because the cells in our body and in our brain have too little oxygen. This is called a pool blackout and if a common cause for drownings.
Carbon monoxide - CO
Carbon monoxide is a gas without any odor and can be very dangerous; it is the product of many oxidation and fermentation processes. Carbon monoxide inside our body will bind to hemoglobin, which is responsible for transporting oxygen, and block any oxygen molecules. It has a 320 times higher affinity to hemoglobin than oxygen. A partial pressure of carbon monoxide of 0.01 bar can be lethal within minutes. Smoking also increases carbon monoxide levels in our body and reduces our oxygen transport efficiency.

Signs and symptoms of CO poisoning
- Dizziness
- Vomiting
- Head ache
- Tiredness
- Red lips
- Red finger and toe nailbeds

How to avoid CO poisoning.
Make sure your diving tanks are filled at dive centers and resorts with properly maintained compressors. Portable compressors that are powered with fuel should have a long air intake hose away from the exhaust fumes. Your tank should be inspected at regular intervals and free from condensates or fatty residue on the inside.

Rescue and first aid
- In order to ensure free passage of air, the victim should lay on the side in the recovery position
- Check the airways
- Administer pure oxygen
- Transport victim to a medical facility as soon as possible
Chapter 4 – Knowledge review

To simplify calculations, for recreational diving, air is considered a mixture of...

- A 36% oxygen and 64% nitrogen.
- B 32% oxygen and 68% nitrogen.
- C 21% oxygen and 79% nitrogen.
- D 23% oxygen and 77% nitrogen.

Dalton’s law states that...

- A the total pressure of a gas mixture is equal to the sum of the partial pressures of the individual gases.
- B the sum of a gas mixture always equals 1 bar.
- C each partial pressure equates the percentage of the gas.
- D no more than two gases form a mixture.

The gas responsible to narcosis at great depths is...

- A carbon dioxide.
- B argon.
- C nitrogen.
- D hydrogen.

You can avoid decompression sickness by always...

- A ascending to the surface slowly, no faster than 10 meters per minute.
- B staying within your no-decompression limits.
- C carrying out a safety stop of 3 minutes at a depth of 5 meters.
- D All the above answers are correct.

The greatest danger of oxygen toxicity under water is...

- A a laughing fit.
- B euphoria.
- C cramping.
- D drowning.
5. Dive planning and dive management

Objectives for this chapter

✓ Explain why recreational diving is a team sport and which points are parts of good dive planning
✓ Know the most common underwater signals for recreational diving
✓ Know the most important rules of recreational diving
✓ Understand the most important functions of diving computers
✓ Know the rules for diving with a dive computer
✓ Explain what a dive chart is
✓ Know how to apply the rules of diving with a dive chart
✓ Explain the differences when it comes to diving with a dive computer or a dive chart

Diving as a team – why we should never dive alone.

Safety - The main concern when it comes to recreational diving. As a team you will be able to address and solve any problems that you might encounter under water. Other benefits that come from diving with a partner:

⇒ You can document and back your experience in your logbook
⇒ Shared memories of great experiences
⇒ More fun

Hand signals

Verbal communication under water is only possible with the help of complicated technical equipment and therefore not practical in recreational diving. To be able to communicate with you dive partner we use hand signals that carry different meaning. The following are the most common hand signals and are generally used internationally. They may vary sometimes, make sure to review hand signals before every dive with your dive team. Beyond these most common dive signals there are many more signals, often dive partners develop their own signals to increase their communication and fun under water.
OK (?!)

Surface ok

Surface ok

Ok with glove

Something is not right

Problems equalizing

I am cold

Out of air

Surface help

Surface need assistance

Descend go deeper

Ascend go higher

Look

Stop

Slow/Calm down

Level out

https://commons.wikimedia.org/wiki/File:Dive_hand_signals.
Which way?  Lead-follow  Stay together  Turn around

Check your air  Half tank 100 bar  Reserve 50 bar  Give me air

Danger  I don’t know  Boat  Think

Hold hands  Safety stop  Abort dive
Dive planning

Important points of consideration when it comes to dive planning

Orientation at the dive site

- Gather all necessary information about your dive site
- Have someone explain the local conditions to you
- Is the weather decent enough for the planned dive
- Are the conditions under water decent, such as visibility, current, waves, etc.
- Determine where and how you will enter and exit the water

The dive

- Determine your maximum dive time
- Determine your maximum dive depth
- Determine which route or course you will follow
- Determine the objective for the dive
- Determine the point of return, as in remaining pressure in your tank

Who has which responsibilities during the dive?

- Orientation
- Monitoring time and depth
- Monitoring the remaining pressure in the tank for the point of return
- Who is leading the way?

Common procedures

- Review the most important hand signals
- Always check your and your partner’s equipment before entering the water
- Emergency procedures – Missing dive partner
- Where is pure oxygen?
- How and who to contact in an emergency?
- Where is the next pressure chamber?
General rules for recreational diving

Check your equipment before every dive

Every diver is responsible to check his or her equipment before every dive to ensure it is functioning properly, no matter if it is personal or rental equipment.

Mandatory buddy check

Dive partners check each other’s dive equipment before entering the water, ensuring proper function and or usage of:

- the buoyancy control device (does it inflate and deflate)
- weights (proper amount of weights, is the quick release unobstructed)
- air supply (how much air is in the tank, does the regulator work)
- straps (all straps securely fastened, bcd and tank straps)
- fins and masks (masks defogged, all straps in decent condition)
- and instruments (dive watch, depth gauge, pressure gauge all functioning)

Maximum depth for Open Water Diver – 20 meters!

Maximum depth for experienced recreational divers- 40 meters!

At optimal conditions!

- Good visibility
- no strong current
- warm water
- good local knowledge of the dive site

Recommended depth limit for experienced recreational divers – 30 meters!

Diving within the reach of daylight

Do not dive inside caves or wrecks outside the reach of daylight. The added distance to the surface may not exceed your maximum dive depth. In conclusion, if a wreck is situated at a depth of 10 meters, an OWD diver is only allowed to penetrate the wreck for a maximum of 10 meters, with a constant direct view of the entrance and daylight.

Maximum ascend speed

10 meter per minute, in a case of emergency the maximum ascend speed is 18 meters per minute.

Safety stop

Every dive at a depth of 10 meters or more should have a safety stop carried out at a depth of 5 meters for 3 minutes before surfacing. This safety stop is mandatory for dives of 30 meters or deeper.

Repetitive dives

Any dive following a previous dive within 24 hours is considered a repetitive dive. The depth of a repetitive dive should not exceed the depth of the preceding dive. Our body might still have nitrogen stored in the tissue from the preceding dive/s and multiple repetitive dives can increase the risk of DCS.
Recreational diving is no-decompression diving!

No-decompression diving

means you are able to ascend to the surface at any time with a maximum speed of 10 meters per minute. Your body has not absorbed the nitrogen threshold that would require a decompression stop.

No decompression dives!

Decompression diving are dives that go deeper and/or last longer than your no-decompression limits and do not allow a direct ascend to the surface but require a decompression stop to allow your body to reduce the nitrogen level to prevent DCS.

Safety stops are not decompression stops!

If a safety stop is not carries out, the diver does not have to worry about consequences. If a decompression stop is not carried out, the diver is at a high risk of DCS.

Gas reserve

Once your tanks reaches an air pressure of 50 bar you should have started your ascend and be carrying out your safety stop at 5 meters. Never empty your tank to avoid “out of air situations” under water! An empty tank will draw moisture which will reduce the life span of your tank.

Diving with a dive computer

Dive computers are commonly used in recreational diving and combine several mandatory instruments; they keep your dive time, monitor your depth and calculate the nitrogen your body is absorbing. Some models can receive the air pressure from a transmitter on the tank and also function as pressure gauges. Another advantage in addition to the convenience they offer is that they monitor your actual dive and use this data to calculate dive limits, as compared to dive tables that use theoretical estimated data to calculate dive limits. Computers calculate the “runtime decompression”, they always use the current depth to calculate nitrogen absorption and deliver very accurate dive limits. However this also means that their calculations are far more progressive that dive table calculations, which would be more conservative and give you a bigger safety cushion. Both dive computers and dive tables employ the same logarithms to determine dive limits.

Which data should be supplied by your dive computer?

You should be able to access the following information under water:

📅 Current depth
📅 Maximum depth
📅 Dive time
📅 Remaining no decompression time
📅 Ascending speed or speed warning
📅 Decompression warning
📅 Decompression stops
📅 Safetystop
📅 Maximum depth warning
📅 Dive time warning
📅 Water temperature
Open Water Diver Manual

You should be able to access the following information above water:

- Remaining no fly time
- Time/Time zones
- Date
- Stored dives - logbook function
- Surface interval

Different types of dive computers

- No decompression dive computers
- Decompression dive computers
- Nitrox dive computer
- Gas blends dive computer

A distinction is also made whether the Dive computers connects to the air supply or not.

- No air integration: computer is not connected to the air supply
- Air integrated dive computer: dive computer is connected to the air supply via
  - a high pressure hose
  - a transmitter

Air integrated dive computers also function as pressure gauges and can calculate you air consumption to determine the remaining dive time.

General rules for diving with a dive computer

- Read and understand your dive computers manual. Make sure you know how to activate all functions and set all alarms.
- Make sure you know which information the display reads and what they mean.
- Each dive partner should have their own dive computer. If a diver does not have a dive computer he must stay at a slightly lower depth than the diver with the computer at all times.
- Never switch dive computers with you partner in between dives or diving days!
- Never exceed the dive limits of your dive computer, even if your dive computer offers you the option of decompression dives, stay within the no decompression dive limits!
- Should your dive computer fail during a dive, stay at a lower depth than your partner and continue the dive, make a safety stop and wait at least 6 hours before diving again. Should your partner not have a dive computer, you have to abort your dive, make your safety stop and ascend with your partner.
- If you have to switch dive computers in between repetitive dives, wait at least 6 hours before diving again.
- Always check your dive computer and especially the battery level before diving.
- Ensure your dive computer has switched on when you descend beneath the surface.
- Obey the no fly times of your dive computer after your dive. Generally it is advisable to wait 24 hours after diving before air travel.
Dive tables

General rules for using dive tables:

- The maximum speed for ascending is 10 meters per minute.
- When planning repetitive dives, the first dive should always be the deepest.
- Any dive shallower than 12 meters is considered to be 12 meters deep.
- The dive table shows increasing depths at 3 meter intervals.
- Always use the next larger depth if your depth is not shown.
- Always use the next longer dive time if your time is not shown.
- Die PDA dive table cannot be used for multilevel dives.
- The minimum surface interval is 10 min, should the interval be less than 10 min it has to be considered a continuation of the dive.
- A surface interval of at least one hour between repetitive dives is recommended.
- Dives carried out under strenuous conditions (poor visibility, currents, cold water) should employ the next larger depth and dive time in the table than actually planned for calculations.
- Die PDA dive table can only be used for dives at altitudes up to 300 meters above sea level. For higher altitudes special high altitude diving tables have to be used.
- Avoid progressive dives that are close to the limits of the dive table.
- A safety stop of 3 minutes at 5 meters is mandatory for every dive.
- You might have to carry out a decompression stop to avoid DCS, should you overstay your dive limit or ascend too fast.
- Wait 24 hours after diving before flying.
- Wait at least 6 hours after diving before driving or travelling to high altitudes.
The PDA dive table consists of three tables:

- Table 1: Pressure group (nitrogen saturation)
- Table 2: Surface interval
- Table 3: Repetitive dive
Table 1 – Pressure group (nitrogen saturation)

The depth is indicated on the left side of the table either in meters or feet, starting at 12 meters (40 feet) going to 39 meters (130 feet). Choose your planned depth and follow this column to the right where the dive times are located. Dive time limits are marked in red and should not be exceeded. After you have located your dive time in the column of your depth you follow the column downward underneath your dive time. This will lead to a letter (from A-L). This letter stands for your pressure group at the end of the dive and reflects the nitrogen saturation of your body. Letter A would symbolize low levels of nitrogen whereas L would be a lot of nitrogen.

Example: Depth of the dive 19 meters (have to use 21 m), dive time 33 minutes (have to use 35 min) will lead you to the pressure group G.
Table 2 surface interval

This table takes into account the rate at which we reduce the nitrogen levels from each pressure group at the surface. Follow the arrow underneath your pressure group letter to the time frame matching your surface time (intervals showing from-to time frames). From the time frame that matches your surface interval, follow the column to the left where you will find your new pressure group symboling your adjusted nitrogen level.

Example: You had the pressure group G after your last dive and are taking a 2 hours surface interval. You find the matching time frame: 2 hours- 2 hours and 58 minutes, and follow the column to the left. Your new pressure group is D, the nitrogen level in your body has decreased from G to D.
Table 3 repetitive dives

This table enables you to determine your remaining dive time limits and your residual nitrogen time. From your pressure group move along the column to the left to the depth of your next planned dive. The red number indicates your remaining dive time for the corresponding depth, above it the blue number indicates your residual nitrogen time. You have to add the residual nitrogen time to your actual dive time after the dive to find your new pressure group after the repetitive dive.

```
<table>
<thead>
<tr>
<th>Depth</th>
<th>Group</th>
<th>Remaining Dive Time</th>
<th>Residual Nitrogen Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>A</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>B</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>20</td>
<td>C</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
```

Example: After our surface interval and the pressure group D we want to make another dive to a depth of 21 meters. We follow pressure group D to the left to the corresponding depth and find our remaining dive time of 25 min. We know now we could stay up to 25 min at 21 meters. Our actual dive time is 23 minutes. Do determine our pressure group after this dive, we have to add the blue number, our residual nitrogen time from the first dive, to the dive time of 23 minutes from the second dive. This gives us a theoretical dive time of 43 minutes at a depth of 21 meters, which reflects the nitrogen level in our body after these two dives. We can now use table 1 to look up our pressure group.
Chapter 5 – Knowledge review

What is a buddy check?

- A When you push your partner into the water.
- B You check your dive partner’s equipment before entering the water.
- C You check your dive partner’s diving certification.
- D You ask your partner if the equipment has been checked.

What is the recommended maximum depth for recreational diving?

- A 15 meters
- B 20 meters
- C 30 meters
- D That depends on the region you are diving in.

What is a safety stop?

- A Interrupting your ascend at a depth of 5 meters for at least 3 minutes.
- B Stop every 5 meters during your ascend to check on your dive partner.
- C Stop whatever you are doing when you have a problem.
- D Stop at your depth when you hear boat engine noise.

Which are important rules when it comes to diving with a dive computer?

- A Every dive partner should have his own dive computer.
- B Every dive computer should have Wi-Fi.
- C Make sure your dive computer has activated before descending.
- D Both answers A and C are correct.

What is the maximum speed ascending to the surface?

- A 18 meters per second.
- B 10 meters per minute.
- C 1 meter per second.
- D 18 meters per minute.
6. The underwater world

Objectives for this chapter

✓ Explain how currents are formed
✓ Name the different types of currents relevant to scuba diving
✓ Explain how a thermocline is formed
✓ Explain what sediment is
✓ Know what affects the tides
✓ Understand the aspects of natural navigation
✓ Know what a compass is and how it can be useful under water
✓ Explain how to behave responsible under water

Saltwater

Between 96% and 97% of all the water found in liquid state on earth is salt or brackish water. About 70% of the earth’s surface is covered with water.

Fauna

The majority of the 300,000 scientifically identified species that live in water are found in salt water. The majority of these live in and around coral reefs.

Flora

The flora under water, especially in salt water is much less diverse than on land. Seagrass, kelp and mangroves are among plants that grow in salt water.

Coral reefs

Coral reefs are built by little creatures called corals. Reef building corals are members of the hard corals family, which use minerals from the ground and the water to build an exterior skeleton of calcium carbonate for protection. Corals typically live in compact colonies and are capable of building structures large enough to create and influence ecosystems. Coral reefs are the largest structures on earth constructed by animals and are estimated to encompass a total area of 600,000 km². Coral reefs are fragile and under stress from environmental changes. Coral reefs are generally divided into four classes: fringing reefs, barrier reefs, atolls and patch reefs. Tropical coral reefs need a constant water temperature water of 20 C to survive, however water that is too warm will kill them over time.
Fresh water

Only about 3% of the earth’s water is fresh water and about 2/3 of it can be found frozen as ice on glaciers and the polar caps. Only about 0.3% of it is located on the surface in lakes or rivers.

Fauna

Only 520 of the 10,000 identified fish species are found in Europe. Other than fish we can find different species of mussels, snails, crabs and even rays, dolphins and snakes.

Flora

Plants are more abundant than in salt water because salt is difficult to deal with for most plants. There are three different types of fresh water plants: plants that float on the surface, plants that are partially submerged and plants that grow under water. In addition to that we have plants that grow in the shore zone. Most plants are not winter proof and are reappearing each spring.

Thermocline

A thermocline, sometimes called metalimnion, is a thin but distinct layer of water in which the temperature changes more rapidly with depth than it does in the layers above or below. These temperature changes found in fresh water are created by layers with different water density. Haloclines which are found in salt water are created by layers with different salt content and through tides and currents. A thermocline can change the temperature by up to 10°C within a few cm.

Waters bottom

Fresh water bodies often receive a large input of organic matter (leaves, plants, pollen, etc.) which collects at the bottom and form a layer of sediment unless carried away by a current. This layer of sediment is often very soft and fine and easily disturbed, which can heavily affect the visibility under water. In rare cases you will find a gravel or rocky bottom in standing fresh water.

Tides

Tides are water movements in the oceans caused by the gravitational forces of the moon, the sun and the earth’s rotation that cause the sea levels to rise and fall periodically. The lowest point of the amplitude is called low tide and the highest point of the amplitude high tide. The two intertidal zones are called flood tide for rising sea levels and ebb tide for falling sea levels. The gravitational force of the sun is approximately half as strong as the moon’s gravitational force. The earth rotates once around the sun in 24 hours and the moon takes 24 hours and 50 mins to rotate the earth. This results in the intertidal period between two high and low tides to lasts 12 hours and 25 minutes. Tide charts are used to predict the daily times for high and low tide. The rise in sea levels cause by the moon is roughly 30 cm but the resulting currents and the topography of a coast can lead to a much larger rise of the water of up to 14 meters in certain locations.
Currents

Oceanic currents are caused by wind, tides and differences in the water’s density. We differentiate between constant currents such as the Gulf Stream or the Aghulas Currents, and temporary currents. Temporary currents that appear along a coast line or a reef affect divers more often; they are mostly driven by tides and winds.

- Onshore currents are driven by high tides when the rising water pushes towards the shore and by onshore winds.
- Offshore currents are driven by low tides through the receding water and by offshore winds as well as by rivers flowing into the ocean.
- Longitudinal currents flow alongside the coastline or a reef and are in most cases driven by wind.
- Rip currents are specific kinds of water currents that are usually found near beaches. They are strong, localized and rather narrow currents of water created by the topography of the area, where water that has been pushed towards the beach is funneled back out to the ocean. Rip currents always flow out at a right angle to the beach.

Orientation and navigation

Natural navigation

Navigation and orientation under water without the help of technical devices is called natural navigation. Different natural clues can be used to orientate ourselves under water:

- The sun: we can determine the compass direction with the location of the sun and the time of the day.
- Grooves in the sand: grooves in the sand on the bottom usually run parallel to the shoreline.
- The surf: the direction the waves are travelling usually points to the shore.
- Formations: we can use distinctive formations under water to help with orientation.
- Topography: the topography under water can help us determine where we are, if carefully studied before the dive.

Compass navigation

One very useful technical device for orientation is the compass. With a compass under water, you can:

- determine the direction
- set a course and follow it
- pinpoint a target and reach it
- easily navigate a return course
A compass consists of three components:

- The compass rose is located inside a transparent, oil filled casing situated on a needle. The magnetic needle aligns with the north.
- The rotating set ring sits on top of the casing and is marked with 360 degree intervals to set a course.
- The orienting arrow and the direction of travel arrow are used to pinpoint a target and read the degrees of the course from the set ring.

General rules for the use of a compass:

- Keep the compass needle horizontally so it can rotate freely. In a more vertical position the needle might not be able to align properly with the north.
- Keep metal objects away from the compass as they can interfere with the magnetic needle.
- Make sure your entire body points straight in the direction of travel, keep the compass in both hands in front of your body or form a square with your arms and the hand holding the compass, this will prevent you from adjusting your course with your arm only and not your body.

Interacting with aquatic life

We are simply guests under water and should behave the way good guests are expected to behave without doing anything that could harm our hosts.

- Always maintain neutral buoyancy and keep a distance from the bottom and the reef.
- Do not touch anything unless you have to, to ensure your safety. Gloves to not permit you to hold on to rocks or corals, or to touch any aquatic life.
- The ocean is not a petting zoo, refrain from touching any aquatic life, it could hurt you or you could do permanent damage to it.
- Do not collect any shells under water, they may appear dead but can still serve as housing for under water creatures.
- Do not break off any corals, if it should happen unintentionally leave the pieces where they are. Possession of corals is a criminal offense in many parts of the world.
- Always try to minimize your impact on the underwater world and the environment.

Take nothing but pictures...

Leave nothing but air bubbles!
Chapter 7 - Knowledge review

When do onshore currents usually occur?

☐ A  Always in the afternoon.
☐ B  Between 8 and 10 am.
☐ C  During incoming tide.
☐ D  In the evenings.

What is useful for natural navigation?

☐ A  Grooves in the sand on the bottom.
☐ B  Fish and their locations.
☐ C  The position of the sun.
☐ D  Answers A and C are both correct.

What drives the tides?

☐ A  Under water volcanic activity.
☐ B  Sea quakes.
☐ C  Gravitational forces from the moon and the sun.
☐ D  Wind and waves.

Why would you use a compass under water?

☐ A  To determine the direction.
☐ B  To locate your dive partner after you’ve been separated.
☐ C  To follow a set course.
☐ D  Answers A and C are correct.

Touching and petting aquatic life under water...

☐ A  can sometimes be necessary.
☐ B  should be avoided at all times.
☐ C  is important for the animals’ well-being.
☐ D  No answer is correct.
7. Problem management

Objectives for this chapter

✓ Know the most important points to avoid problems
✓ Name the most common causes for problems when diving
✓ Know the most common problems that could occur on the surface and how to react to them
✓ Know the most common problems that could occur under water and how to react to them
✓ Know how to deal with a diver in distress and how help him
✓ Know what to do when a diver is in panic
✓ Know what to do when a diver is unconscious
✓ Be familiar with first aid for near drowning victims
✓ Know how to treat injuries caused by aquatic life

Problems and diving

How can I avoid problems?

▷ Do not overestimate your abilities
▷ Take time to properly plan and prepare for your dive
▷ Check your equipment before entering the water
▷ Always dive within your limits
▷ Monitor your gauges constantly during the dive
▷ Dive in a team

What are the most common causes for problems?

▷ Overestimating ones abilities
▷ Wrong evaluation of the conditions
▷ Group pressure
▷ Not properly checked equipment
▷ Underestimating potential risks

problem → stress → exhaustion → loss of control → panic → accident
How to react to the most common problems that can occur on the surface:

Not enough positive buoyancy
- Inflate your jacket, either orally or using the inflator hose
- Ditch your weights

Currents
- Signal for help
- Try to get out of the current by swimming laterally to the current
- Inflate your signal buoy
- Stay together with your dive team
- Use acoustic and visual signaling devices
- Keep calm

Cramping
- Signal your partner for help
- Stretch out the affected area trying to relieve the cramping

Exhaustion
- Signal for help early
- Conserve energy and try to relax
- Keep calm

Waves
- Keep your mask on your face
- Keep your regulator in your mouth
- Turn your back into the waves
- Signal for help
- Inflate your signal buoy

The most common problems under water and how to react to them:

Exhaustion
- Stop
- Find a stable position, holding on to something or lying on the bottom
- Control and calm down your breathing
- Signal your partner for assistance
Entanglement

- Keep calm.
- Wait for your partner.
- If necessary take off your jacket to free yourself and put your jacket back on. Do not take the regulator out of your mouth.
- Do not try to struggle free.
- Be very careful using your dive knife. Do not cut anything that you cannot see.

Getting separated from your partner

- Search under water for up to one min. (in optimal condition, otherwise less than 1 min).
- Slowly swim to the surface and wait there to reunite with your dive partner.

Out of air situation – different possible scenarios and how to react to them.

You notice you are about to run out of air:

- Immediately start your ascend
- Do not remove any equipment or weights.
- Do not make a safety stop
- Stay within the maximum speed when ascending
- Inflate your jacket once you are at the surface and wait for your partner

You ran out of air but your partner is close by:

- Signal your partner “I’m out of air”
- Locate your partner’s octopus and pull it towards you
- Switch your own regulator for the octopus
- Clear the water from the octopus and start breathing
- Establish physical contact with your partner, holding on to him or his jacket
- Signal each other “OK” and “Start ascending”
- If you have enough air for the two of you, carry out a safety stop
- Once you have reached the surface, return the octopus to your partner and orally inflate your jacket

You ran out of air and you are closer to the surface than to your partner:

- You do a controlled swimming emergency ascend
- Do not remove any equipment or weights, keep the regulator in your mouth
- Start swimming towards the surface. Try to stay within the maximum speed if possible
- Maintain control of your airways and allow expanding air to escape from your lungs
- Overextend your head and either whistle or hum
- Do not make a safety stop
- Once you have reached the surface, orally inflate your jacket
- Wait for your partner
Open Water Diver Manual

You ran out of air, you cannot see your partner and are too deep for a controlled swimming emergency ascend:

- You have to do an emergency ascend
- Create positive buoyancy by dropping your weights
- Start swimming hard to the surface
- Maintain control of your airways and allow expanding air to escape
- Inflate your jacket on the surface
- Immediately signal for help
- Breathe pure oxygen for at least 20 min
- Monitor any symptoms for the next 6 hours for a potential DCS or lung overexpansion
- Immediately seek medical treatment should you show any symptoms
- Do not dive for 24 hours

**Currents**

- If possible try to get out of the current by swimming laterally to the current.
- Swim close to the bottom where currents are generally less strong.
- If you’re diving along a wall, stay close to the wall to protect you from the current.
- If you are starting to feel exhausted, find a spot that is protected from the current and rest. If you have to hold on the something try to create as little damage as possible.
- Set a current anker if you have one.
- Your personal safety comes before protecting the underwater environment.
- If the currents is too strong and there is a potential danger of you getting swept away, abort the dive, inflate your signal buoy and surface.

**Distressed diver**

There are many factors that can lead to a diver in distress:

- Difficulties maintaining neutral buoyancy
- Increased air consumption
- Exhaustion
- Having lost your orientation
- Being separated from your dive partner
- Problems with your diving equipment
- Actual or imagined threats posed by aquatic life

**Signs of Stress are:**

- Accelerated breathing
- Attention deficit
- Uncoordinated motions
- Not responding to signals
- Wide eyes

Ultimately it does not matter what caused the stress, what matters is that you are able to react quickly and appropriately to avoid any stress potentially leading to panic. Stress is our body’s natural reaction to a potentially dangerous situation. Adrenaline is released, our blood pressure is increased, heart rate and breathing are accelerated to increase our performance potential. Our brain will also be more active and all this increased activity can lead to panic, if the cause of the stress is not eliminated. Panic is
a state where we are no longer in control of our actions and instinct takes over, which should be avoided. If we fell distressed, we have to located and eliminate the causing factors. If we encounter another diver showing signs of stress we should try to have a calming effect on him and communicate to him that you are here to help. Very often this will already be enough to reduce the stress level and enable the person to regain control of the situation. Each individual situation and person will require a different approach to relieve stress and eliminate the causing factors.

In any situation, always: **STOP - CONTROL YOUR BREATHING - THINK - ACT**

**Panicked diver**

Stress can lead to panic and results in fear causing us to lose control of our actions. Our brain will shut down our conscious decision making ability and instinct will take over to have increased reflexes in potential dangerous situations. A state of panic can be either passive or active but any person move between these two stages. In a diving situation, a panicked diver always poses potential dangers to rescuers. Dealing with a panicked diver either on the surface or under water is difficult and requires extensive training and experience. The Rescue Diver Course will help you develop the necessary skills to help other divers and yourself in such situations. Your personal safety always comes first, only attempt to help someone if you feel safe. A panicked diver will likely try to grab a hold of you, putting you in danger. You should avoid this by not approaching a panicked diver from the front.

**Unresponsive diver – on the surface**

An unresponsive diver on the surface who is unconscious has to be transported out of the water as quick as possible. Do not waste time checking his vital signs. Depending on how far you have to transport the diver you may want to consider removing your and the victim’s weights and jackets before transporting him to the shore or a boat. If you have been properly trained you can administer mouth to mouth rebreathing while you drag the diver to the shore or to a boat. Once out of the water immediately contact emergency services and then start CPR.

- **under water**

If we encounter an unresponsive diver under water who is unconscious, it is important to bring the victim to the surface as quick as possible. When ascending together with the unconscious diver, make sure you stay within the maximum speed to avoid putting yourself at risk. Rather let go of the unconscious diver than ascending too fast, if he is being pulled to the surface by expanding air in his jacket. Transport the unconscious diver from behind, keeping one arm around his waist and one on his chin, so you are able to overextend his head. This will ensure that expanding air from his lungs can escape and will not cause additional damage. This will also enable you to kick your legs to start swimming towards the surface. Try to use the victim’s jacket to control buoyancy by letting out air as you ascend. If the unconscious diver still has the regulator in his mouth, make sure it stays there by pinning it down with your hand on his chin. If he has lost his regulator, do not waste any time trying to replace it. Once you have reached the surface, make sure you are both positively buoyant. Proceed as you would with an unconscious diver on the surface.
Near drowning

If a person has inhaled larger quantities of water, they are considered “near drowning victims”. Such a person might appear to be feeling fine but should nevertheless be monitored and not be left alone, as his state could lead to a so called “dry drowning”. Dirt particles or saltwater may have been inhaled and remain in the lungs, causing our organism to produce fluids to wash away these particles, which can result in problems breathing and even respiratory arrest. Immediately find a doctor or a hospital should problems breathing occur following a near drowning incident.

Injuries inflicted by aquatic life

are very rare and in most cases are caused by defensive actions and not by attacks. We differentiate three different types of injuries:

- Bites
- Puncture or stab wounds
- Burns

Bites

can lead to bacteria entering the wounded area and cause heavy infections. It is important to clean and to disinfect the wound and put a sterile bandage over it. Should the affected are show signs of infections like redness, swelling, localized pain, consult a doctor immediately.

Puncture or stab wounds

can be inflicted by aquatic life possessing spines and thorns, often poisonous for protection (i.e. the dragonfish, the stonefish or the stingray). These spines or thorns do not only cause puncture or stab wounds but also transmit proteins which can be extremely dangerous, in some cases even lethal for the human body. Sharp pain, heavy swelling and color changes in the affected areas are first signs. As first aid, expose the affected areas to hot water (50 C ) for as long as it is bearable. The heat can break down the protein. Immediately go to a doctor or hospital should you experience a fever or tissue color changes

Burns

are caused through skin contact with certain jellyfish and stinging plankton. Very few jellyfish species are capable of inflicting dangerous stings, most will cause skin irritations and redness with skin itching. Treat affected areas by rinsing them with warm salt water. Should there still be tentacles on your skin, either remove them carefully with a credit card or with gloves or a wet towel. Refrain from rubbing or scratching which could result in so far undamaged stinging cells to cause further burns. Also do not use vinegar or urine to treat the affected areas. Urine does not help at all and vinegar only helps with certain species and can make the injuries worse for other species. In cases of strong skin irritation, nausea or difficulties breathing, see a doctor immediately.
Chapter 7 - Knowledge review

How can you avoid problems when scuba diving?
- A By eating healthy.
- B Stay within your limits.
- C Check your equipment before every dive.
- D Answers B and C are correct.

What are the most common causes for problems?
- A Over estimating your own abilities.
- B Group pressure
- C Wrong evaluation of the conditions (i.e. currents).
- D All answers are correct.

What factors can lead to a distressed diver?
- A Equipment problems
- B Frequent monitoring of the dive gauges.
- C Over exertion
- D Both answers A and C are correct.

Which dangerous situation could result from a near drowning incident?
- A Decompression sickness
- B Carbon monoxide poisoning
- C Dry drowning
- D Strong flatulence

Injuries cause by aquatic life are generally a result of...
- A boredom.
- B an unprovoked attack.
- C a defensive reaction.
- D the animals desire to play.
8. Skills requirements

In this chapter we will talk about the exercises we use to teach you the practical skills which are necessary to practice scuba diving safely. You will do these exercises in the pool and apply the skills during the open water training dives. The following is simply an overview of all these skills. Your PDA instructor will explain and demonstrate these skills to you before you start practicing them. Once you have mastered these skill you will apply them in the open water dives.

Assembling and inspecting your scuba equipment
- Attach the tank to the jacket
- Attach the regulator to the tank
- Connect the inflator hose with the inflator
- Turn on the air by opening the valve
- Check your air pressure
- Check that your jacket inflates properly
- Check your jackets overpressure valves and quick releases
- Inspect your regulator and the alternative air source
- Check the remaining pieces of equipment (suit, boots, fins, mask and snorkel and dive computer)

Gearing up your equipment
- Put on your dive suit
- Put on your boots
- Put on your dive computer
- If you are using one, put on your weight belt
- Put on your scuba gear (jacket, tank and regulators) with the help of your dive partner
- Have your mask, snorkel and fins in your hands

Buddy Check – check the equipment of your geared up dive partner
- Buoyancy control device
- Straps
- Weights
- Air supply and instruments
- Mask, snorkel and fins

Different techniques to enter the water:
- Large forward step
- Backwards roll
- Entering shallow water

Weight check
- You should sink in to about your nose with an empty jacked and regular breathing
Proper technique for descending
- Five points descend
- Techniques for equalizing pressure

Taking the regulator out of your mouth and putting it back in under water
- Clear the water from your regulator by exhaling
- Clear your regulator by pushing the purge button

Recovering your regulator
- Sweep and recover
- Reach and recover

Flooding and clearing your mask
- Partially flood your mask and clear it
- Completely flood your mask and clear it
- Take your mask off, put it back on and clear it

Take off your jacket and put it back on
- Under water
- At the surface

Using your partner’s alternate air source
- Stationary octopus breathing
- Swimming octopus breathing
- Using one regulator with alternate breathing

Controlled swimming emergency ascend
- Simulated controlled emergency ascend from a depth of 10 meters max.

Buoyancy control – neutral buoyancy
- Pivoting on your fins
- Hovering
- Using your lungs as a buoyancy control device

Removing your weight system and putting it back
- Under water
- At the surface
- Using the quick release system of your weights at the surface

Out of air situation
- Breathe from a regulator in a simulated out of air situation

Free flowing regulator
- Breathing from a free flowing regulator
Recovering an unresponsive diver from the bottom

⇒ Recovering an unresponsive diver from a depth of 10 meters max.

Using a compass

⇒ Set a course
⇒ Get a bearing and set a course for that bearing
⇒ Swim a straight course on the surface
⇒ Swim a straight course and the return course under water

Proper technique for ascending

⇒ 5 Points ascend
⇒ Safety stop

Snorkel techniques

⇒ Switch from breathing through your snorkel to your regulator at the surface
⇒ Snorkel with your scuba gear for at least 50 meters

Procedures after the dive

⇒ De-assembling your equipment and cleaning it
⇒ De-Briefing
⇒ Logbook entry

Congratulations on all the knowledge and the skills you have acquired!

Enjoy your scuba diving adventures and wonderful experiences under water!

Your PDA-Team