

PART 2: ADVANCED FREEDIVER COURSE



SNSIREC[®]
FREEDIVING

-20m
-66ft

-171m NoLimits



Francisco Pipin Ferreras

SNSI
FREEDIVING

SNSI
FREEDIVING

recognized by
Pipin Ferreras



A stylized, handwritten signature of Pipin Ferreras in white ink.

www.scubasnsi.com



CHAPTER 5

SAFETY EQUIPMENT



www.scubasnsi.com



CHAPTER 5

As you have learned in the *SNSI Freediver* course, when you perform deep freedives you must always use a guide rope. This is a reference point that will help you reach your desired depth, enable you to descend vertically in a straight line without wasting energy, and most importantly allow you to surface safely and easily. Moreover, your buddy can use the guide rope to track your dive and intervene promptly if necessary.

In this chapter we will explore how to tension the guide rope and how to ensure it is always within reach, regardless of the environmental conditions. On completion of this chapter you will know how to hold the guide rope, how to weight it correctly and how to attach it to the surface buoy. You will also learn how to use and prepare a safety lanyard.



THE GUIDE ROPE

Weighting

First of all, the guide rope must be weighted correctly. To do this, you need to know whether the guide rope needs to reach the bottom or if it can remain suspended in the water. The first situation usually arises when beginning the dive from the shore, as the guide rope needs to reach the bottom to create a point of reference throughout the duration of the dive, not just when descending and surfacing. In this case, the guide rope must be weighted more heavily as it needs to support the weight of the divers when they are holding onto the buoy at the surface. In fact, if there is a strong current forcing the divers away, the weight may plow across the bottom and cause the buoy to drift on the surface. This can cause serious harm to the marine ecosystem, damaging any sessile organisms (those attached to the seabed) that the weight accidentally comes into contact with. Furthermore, if the weight drifts and the buoy changes position, the freedive becomes more dangerous as it may result in



deeper water than intended or in the middle of a busy shipping lane, or even simply further away from the point of entry which makes returning to land difficult.

The above situations do not apply when diving from a boat. In this case, the reference point on the surface is the boat itself, which flies the dive flag. When diving from a boat, two ropes are attached to the buoy, one to connect the buoy to the boat and the other leading down under the water and acting as the guide rope. In this situation, the weight on the guide



rope has the simple purpose of keeping the rope taut and vertical, so less weight is needed.

To weight the guide rope you can use normal lead weights; these are usually heavier (2-3 kg / 4-7 lbs) than those worn on the weight belt meaning the freediver can use fewer actual weights. To position the weights you can use a normal weight belt, making sure that the quick-release function is locked and tie a knot at the end of the belt. However, it is better to use a special belt which has been specifically designed for this purpose; these belts don't have quick-release functions and therefore offer a more secure attachment to the guide rope. To attach the guide rope to the weights you can use the bowline knot described later in this chapter.

Bottom plate

During this *SNSI Advanced Freediver* course, you will dive to greater depths than you are used to. As such, it is very important that you learn how to establish the planned depth for each for each dive. To this end, a specific marker is positioned at the desired depth. This is a circular plate made of plastic, steel or aluminum that measures few tens of centimeters (4-10 inches) wide and less than a centimeter (0.5 inches) thick. The bottom plate also has other advantages: it reduces the risk of hitting your head or shoulders against the guide



rope weights or the seabed itself, and prevents the karabiner of the safety lanyard, described in more detail below, from getting caught on the knot on the weight belt when beginning the ascent back to the surface.

Knots

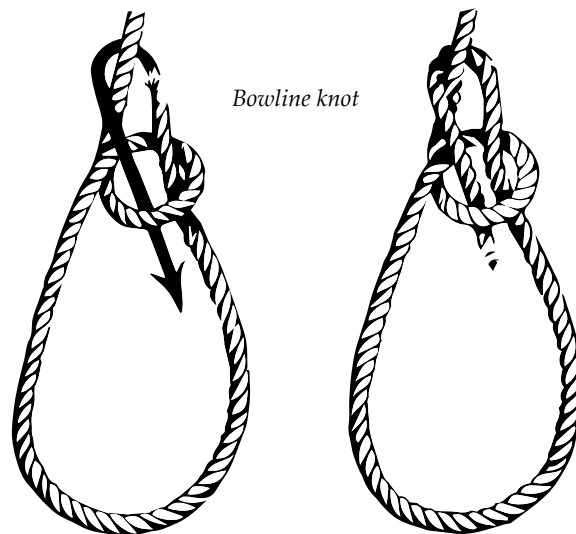
It is important to learn how to join the ropes securely or to attach them to objects such as the weights or the buoy. There are countless knots, all used for different purposes. For your aquatic activities, you need to learn three simple knots: the bowline knot, the square knot and the clove hitch.

Before we look at the individual knots, here are a few definitions of the elements of a knot:

- **Live** (also called working or running) **end**: this is the active part of the rope used when tying the knot.
- **Standing end**: this is the other end of the rope; it is generally under load or fixed to something, and is usually very long.
- **Turn**: when the live end is passed around the standing end to create a loop. Overhand turns are when the live end goes over the standing end, while underhand turns are when it goes under.
- **Eye**: this is the hole created after making a turn.
- **Bight**: a loop where the live end runs parallel to the standing end but in the opposite direction.

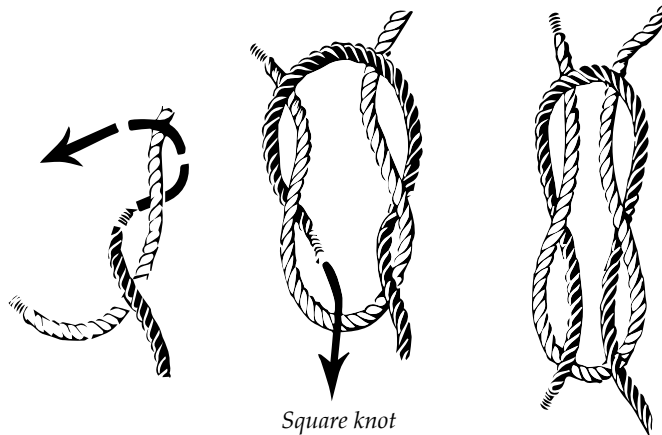
Your SNSI Freediving Instructor will help you learn how to tie these simple but useful knots.

The **Bowline** is a loop knot used to create a loop in the end of a rope, which can then be used to join to another rope. However, the knot is more commonly used to attach the rope to an object such as the tie-in loop on the weight belt. The main advantage of this knot is that it is very easy to untie even after being subjected to heavy loads (for example when the buoy has been buffeted up and down by the waves). This knot is tied in four simple stages: 1) create an eye in the rope by making an overhand turn (so passing the



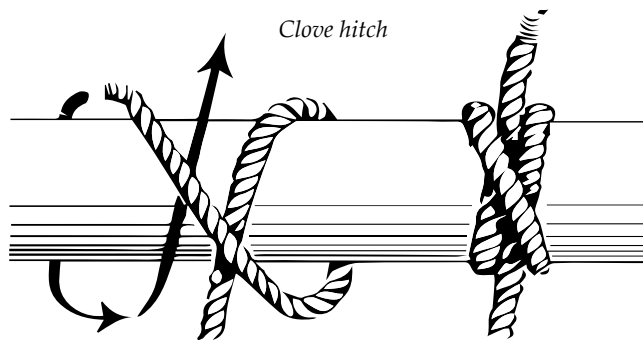
live end over the standing end); 2) pass the live end through the eye (from the bottom up); 3) pass the live end behind the standing end; 4) pass the live end back through the eye and pull.

The **Square Knot** (also known as the **Reef Knot**) is a joining knot that can be used to link two ropes. In a diving context, it may be used to attach the buoy line to the boat line in order to keep the buoy a certain distance away from the boat. This knot is tied in four simple stages: 1) Create a bight in rope one; 2) lay the live end of rope two across the bight (or curve) of rope one; 3) pass the live end of rope two underneath the bight; 4) make a bight in rope two, laying the live end of rope one across the bight and passing it underneath to complete the knot.



The **Clove Hitch** is a very simple knot that can be used when the rope is taut. This knot will enable you to tighten the guide rope correctly when the weight is on the floor, or to extend the guide rope to the correct length when the weight is suspended. This knot is tied in two simple stages:

1) Make an underhand loop around the object you wish to attach the rope to; 2) make an overhand loop with the live end.



SAFETY LANYARD

The safety lanyard is designed to keep you within close proximity of the guide rope, so that as you descend or ascend along it you will be able to maintain direction and not get too far away from the rope itself. Moreover, in an emergency your buddy will be able to



find you quickly and intervene promptly.

The safety lanyard is a Nylon or Cordura sling fastened to the wrist or ankle with an adjustable buckle or a very strong Velcro fastener equipped with a D-ring. The D-ring is connected to a sling (or stainless steel wire) measuring around one yard, the other end of which is equipped with a wide karabiner that can easily run up and down the guide rope. When you fin downwards, it is best to keep the safety lanyard attached to your wrist. However, if you are performing a free immersion, it is best to attach the lanyard to the ankle in order to keep your hands free and enable broader arm movements without getting caught on the karabiner running along the guide rope. During practice dives in open water, get your buddy to help you to move the safety lanyard into the most comfortable position possible before carrying out the exercise your instructor has outlined.

In later *SNSI Freediving* courses, you will learn that it is also possible to attach the safety lanyard at the waist using a specific belt. For safety reasons, it is not recommended to attach the lanyard to the weight belt because if you need to remove the weight belt in an emergency, you risk losing contact with the guide rope. For example, this position is useful when learning to freedive without fins as you will need your arms and legs free to frog kick.



AQUATIC EXERCISES

Frog kicks. Place your arms on a float, hold your head out of the water and look ahead. Move forward by only using your legs. Begin with your legs stretched out behind you and then bring your heels to your backside, keeping the knees together and bending them towards the bottom of the pool. When the legs are fully bent, move your heels so they are level with your sides and position your feet at right angles, with the toes pointing out. Make a circular motion with the legs to extend them back out behind you, feet together. Be careful never to let the knees come more than shoulder width apart. Use the full momentum of each kick before beginning the next one.

Underwater breaststroke. Lie on your stomach near the edge of the pool. Raise your legs, place your feet on the wall and push away from the edge of the pool. Point your head down and arch your back slightly to descend below the water surface. Glide through the water with your



Frog Kick



Underwater Frog Kick





arms stretched out in front, with the palm of one hand over the back of the other and keeping the elbows together. Tuck your chin into your chest, keeping your ears below your arms in order to achieve the most hydrodynamic position possible and to stay near the bottom when swimming. When the momentum from your push-off is coming to an end, perform a breaststroke stroke. Part your hands, pushing them so that they come alongside your thighs and using the momentum to propel you through the water. When this momentum ends, make a frog kick and at the same time extend your arms out in front of you, keeping the arms as close as possible to the body to reduce water resistance. Keep your head down with your chin tucked against your chest during each phase of the stroke.

Dynamic apnea without fins. Lie in the water and float with your face down, trying to find a position where you can relax all your muscles. Position yourself near the edge of the pool, facing in the direction of your dynamic apnea. Perform a preparatory breathing cycle and hold your breath! Raise your legs, place your feet on the wall and push away from the edge of the pool. Point your head down and arch your back slightly to descend below the water surface. When the momentum of the push-off comes to an end, begin to swim using the underwater breaststroke and frog kick, beginning with breaststroke arms. Remember to keep your chin tucked into your chest and to use the full

momentum of each stroke and kick. Follow the guide rope along the bottom or the line on the bottom of the pool.

Arm strokes. Position yourself vertically in the water, taking care to keep your legs perfectly straight and close together. Position your elbows at ninety degrees and tuck them into your chest, keeping the upper part of your arm close to your body and the forearms in front of you. Keep your palms facing down and move the forearms out and then in, rotating the palm slightly to “capture” as much water as possible. As you move your arms out, rotate the palm outwards, then as they come back in, rotate the palm inwards. This technique will allow you to maintain your position perfectly.

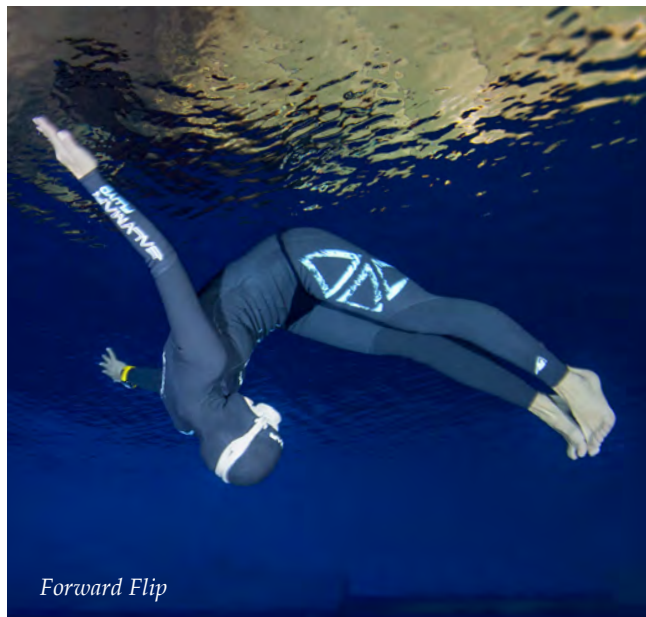
Leg-kicks. *Frog kick:* From a vertical position, bend your arms and keep your hands out of the water. Perform a frog kick to float, remembering to bend the ankles and keep the feet at a right angle to your legs. Be careful not to bob in the water: the water level should always be just below your shoulders. *Alternating kick:* From the same position as the previous exercise, alternate moving each leg. Push inwardly from the outside, so that as one leg pushes and moves in, the other is in the recovery phase and so moves out.

Complete strokes. Make each stroke with the legs and arms at the same time, first with the frog kick and then with the alternating kick.

Forward Flip. Descend a meter or so below the water using your preferred technique. Adopt a vertical position with your legs straight and together. With your arms extended alongside your body and your palms facing forward, bring your arms straight above your head, keeping them in front of your body, and at the same time roll your head forward to tuck your chin into your chest. Bring the arms back to the starting position, keeping them straight and position them alongside your body. Remember to keep the palms

parallel to the arm movements. Perform these two movements to rotate your body at least three or four times. Relax your abdominal and leg muscles; your entire body should follow the movement of your chest as your arms do the work.

Backwards Flip. Descend a meter or so below the water using your preferred technique. Adopt a vertical position with your legs straight and together. With your arms extended above your head and the palms facing forward, bring your arms down in front of your



Forward Flip



Backwards Flip



body and bring them to your side, at the same time roll your head back, tilting your neck towards your back. Bring the arms back to the starting position, keeping them straight and position them alongside your body. Remember to keep the palms parallel to the arm movements. Perform these two movements to rotate your body at least three or four times. Relax your abdominal and leg muscles; your entire body should follow the movement of your chest as your arms do the work.

Surface dive with the arms. Attach the safety lanyard then lie on your stomach with your snorkel on and your arms stretched out on the surface of the water in front of you. Push your arms towards your feet, positioning them alongside your body with your elbows bent, then immediately bring them above your head, keeping them straight and in front of your body. Tuck your chin into your chest and lower your shoulders. As your body bends downwards and your legs come out of the water, keep your legs vertical above your body. Repeat the first movement with your arms, pushing them towards your feet and keep them alongside your body; this final movement will take you completely under the water. Be careful to perform these movements at a safe distance from the guide rope to prevent getting tangled in the safety lanyard.

Two-legged surface dive. With the safety lanyard attached, lie on your stomach with your snorkel on and your arms relaxed towards the bottom. Put your

legs together, bring your heels towards your backside and bend your knees (keeping them together), then at the same time tuck your chin into your chest and lower your shoulders. When your heels are near your backside, extend your legs and push them out of the water, trying to keep the arms and legs in a line perpendicular to the water surface. As the weight of your legs pushes you downwards, start kicking as soon as you feel your fins enter the water. Be careful to perform these movements at a safe distance from the guide rope to prevent from getting tangled in the safety lanyard.

One-legged surface dive. The previous exercise can also be performed using one leg. This will help to save energy and use less oxygen. Lie on your stomach with your snorkel on and your arms relaxed, pointing down. Bend one leg, bring the heel towards your backside and bend the knee, then at the same time tuck your chin into your chest and lower your shoulders. When the heel is close to your backside, extend the leg out of the water. Try to keep your leg movement perpendicular to the surface of the water and in line with your arms. The other leg stays still and follows the movement of your body; when the weight of the raised leg pushes you downwards, the other leg will be dragged under the water. Begin to kick when both fins are in the water.

Turn-up and Ascending. When you reach your desired depth, it is important to change course before



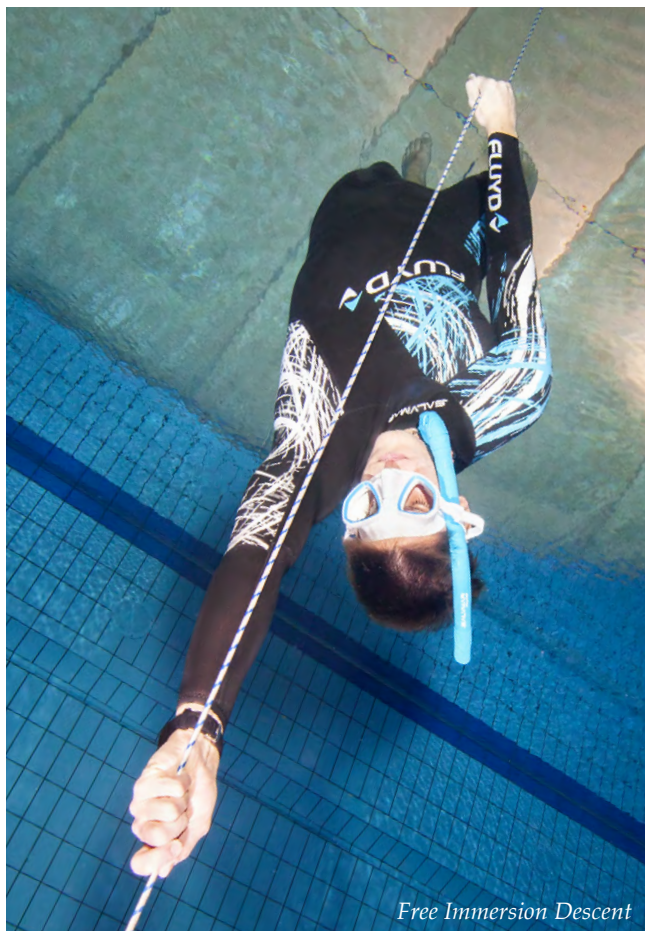


One-legged surface dive

returning to the surface. This maneuver must be as relaxed as possible to avoid wasting energy and using too much oxygen. When you reach the marker that signals your desired depth, gently grasp the guide rope and let the momentum pull your body downwards. Your body will then rotate the hand that is holding the rope. This allows gravity and inertia to bring you back to a vertical position with your head up, enabling you to conserve energy that can be used to surface in a relaxed manner. Before beginning to surface, check that the safety lanyard isn't caught on the bottom plate or the weights, make sure that your position is parallel to the guide rope and ensure that it is a safe distance away so as to be in easy reach but not present an obstacle.

Free Immersion Descent. You can also descend using just the strength of your arms, without using your fins. Hold on to the guide rope with one hand and pull yourself downwards, keeping your head facing down and looking at the rope. When the arm holding the rope is fully extended, extend the other arm down and grasp the rope. Repeat this movement to reach the desired depth. When you perform this movement, attach the safety lanyard to your ankle to keep your arms free and enable you to extend the arms completely between movements.



*Free Immersion Descent*

SUMMARY

This chapter has taught you how to prepare and manage your safety equipment. This will make you more independent and self-aware when organizing your freediving sessions and will help you to become a reliable diving buddy.

CHAPTER 5: STUDY GUIDE

1. The guide rope is essential because it enables you to:
 - ☐ Pull on it with your arms in an emergency.
 - ☐ Descend and surface in a straight line.
 - ☐ Keep the buoy anchored to the bottom.
2. The weight:
 - ☐ Can be placed on the seabed.
 - ☐ Can be suspended in the water.
 - ☐ Both.
3. The bottom plate should be positioned:
 - ☐ Above the weight.
 - ☐ On the seabed.
 - ☐ Two-thirds of the way down the guide rope.
4. The standing end is the part of the rope that is used to tie a knot.
 - ☐ True.
 - ☐ False.
5. The bowline knot:
 - ☐ Is a joining knot.
 - ☐ Is a stopper knot.
 - ☐ Is a loop knot.
6. The square knot:
 - ☐ Is a joining knot.
 - ☐ Is a stopper knot.
 - ☐ Is a loop knot.



7. The clove hitch:

- ☐ Joins two ropes.
- ☐ Can be used to attach the guide rope when weighted.
- ☐ Both.

8. The safety lanyard is designed to:

- ☐ Keep you attached to the guide rope.
- ☐ Keep you attached to your buddy.
- ☐ Attach the guide rope to the buoy.





CHAPTER 6

ADVANCED BREATHING



www.scubasnsi.com



CHAPTER 6

BREATHING

CHAPTER 6

In the *SNSI Freediver* course you learned how to increase total lung capacity by consciously controlling your respiratory muscles. As you read this chapter, you will understand how to add even more air to your lungs and use 100% of your lung capacity.

First, let's review the breathing techniques you have learned so far. The breathing cycle begins with diaphragmatic breathing to fill the lower third of the lungs with air; this part of the lung is responsible for most of the gaseous exchange in the body. For proper diaphragmatic breathing, you need to push the

abdomen muscles outwards and lower the diaphragm at the same time. When you have filled the abdominal section completely, continue to bring air into the central area of the lungs, filling the thorax region. To do this, continue to inhale while expanding the ribcage up and out. At the end of this inhalation process, you will have used around 70-80% of your lung capacity.

We will now look at how we can “pack” even more air in order to maximize the use of our total lung capacity.

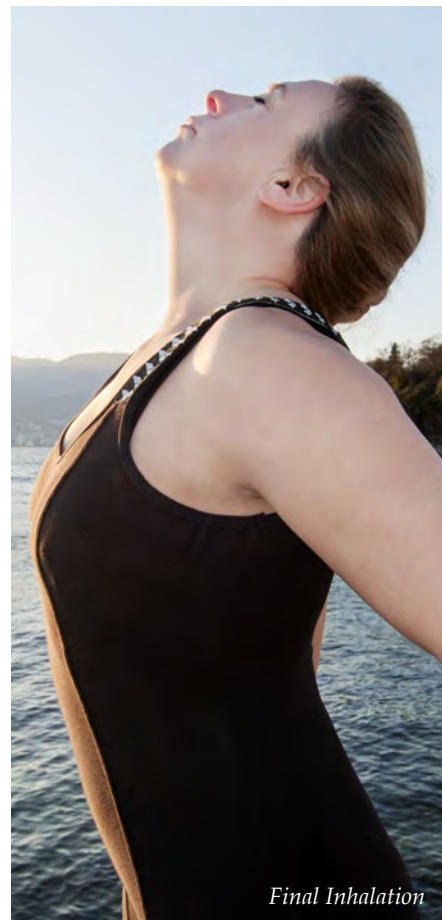


SUB-CLAVICULAR BREATHING

Sub-clavicular breathing is a type of shallow breathing that only utilizes the upper third of our lungs. Sub-clavicular breathing also uses the neck and the trachea to increase the volume of air we are able to inhale. Although this type of breathing is not very effective for efficient gaseous exchange, there are two reasons why it is important to learn to use it to prepare for deep-water freedives. On the one hand, adding more air to our lungs enables us to hold more oxygen in our body, which then moves into the part of the lung that processes the gaseous exchange so that the oxygen can be transported around the blood while we hold our breath. However, the main reason for using this breathing technique is to make more air available for when we need to equalize our mask and ears. Remember that as you descend, the air in your lungs is compressed by the hydrostatic pressure around you.

During the *SNSI Advanced Freediver* course, you will dive to 20 meters / 66 feet depth, where the pressure around you is 3 atmospheres / 44.1 psi; this reduces the air in your lungs by a third.

Let's look at the following example to better understand why this breathing technique is so important. If you manage to inhale 4.5 liters (0.16 ft³) of air, or 75% of your lung capacity, purely through diaphragmatic and thoracic breathing, by performing sub-clavicular breathing as well you will be able to inhale around 6 liters (0.21 ft³) of air. At 20 meters / 66 feet depth, the air in your lungs will increase from a volume of 1.5 liters / 0.05 ft³ (one third of 4.5 liters/ 0.16 ft³) to 2 liters / 0.07 ft³ (a third of 6 liters / 0.21 ft³). This means you still have half a liter more air in your lungs to use for equalization. Moreover, in the next chapter you will learn how to work out and increase your exact total lung capacity, another essential skill for freediving safely.



Final Inhalation



For correct sub-clavicular breathing, you need to push your shoulders up and back. As you will soon discover, during the last inhalation before the dive and at the apex of the breathing cycle, you will also need to extend your neck, tilting your head back to fully open the airways to allow you to inhale more air.

BREATHING CYCLES

Until now you have combined diaphragmatic and thoracic breathing to prepare for your dives. Now we are going to learn how to achieve the most efficient breathing cycle for freediving, using all three breathing techniques we have looked at so far (diaphragmatic, thoracic and sub-clavicular) in the right order, for the right length of time, and with the correct inspiratory and expiratory volumes.

Preparatory Breathing. Begin with abdominal breathing, inhaling and exhaling a normal volume of air and keeping the abdominal muscles relaxed. During this phase, you are preparing to enable air to flow correctly: you need to relax all the muscles in the body and take the time you need to focus and visualize the final objective. When you have returned to a normal breathing cycle (after a dive, for example), you must spend at least a minute performing normal and relaxing preparatory breathing cycles.

Breathing Sequence. After doing preparatory breathing for at least a minute, begin the breathing

sequence. A normal breathing sequence uses around 70-80% of your lung capacity. When performing the breathing sequence, it is very important to follow these stages in a precise order, beginning with abdominal breathing, moving onto thoracic breathing and then following the same order during exhalation, emptying the lower part of the lungs by the diaphragmatic method then breathing through the chest to empty the central and upper part. It is important to maintain a steady breathing rhythm; each inhalation should last 3-5 seconds, followed by 3-5 seconds of exhalation. You must repeat this procedure for at least two minutes, meaning you will realize around 15 - 20 complete breathing cycles.

Advanced Breathing Sequence. After completing the breathing sequence, begin the advanced breathing sequence. This includes all of the three types of breathing - abdominal, thoracic and sub-clavicular, and utilizes around 90-95% of your lung capacity. The advanced breathing sequence is similar to the normal breathing sequence, but at the end of each inhalation you must remember to inhale extra air into your throat through sub-clavicular breathing. After the inhalation, reverse the order as you would for a normal breathing sequence. Each inhalation should last around 3-5 seconds, followed by 3-5 seconds of exhalation and a pause of at least one second. You must repeat this procedure for at least two minutes, meaning you will make around 15 - 20 complete breathing cycles.



Final Inhalation. After completing the advanced breathing cycles, you are ready to take your final breath before you dive. The aim of this inhalation is to utilize 100% of your lung capacity. At the end of your final advanced breathing sequence, remember to breathe out forcefully in order to remove as much carbon dioxide from your lungs as possible. Once your lungs are empty, your final inhalation has two goals: to bring your oxygen levels to its maximum with a single breath, and to store as much air as possible to use for equalization.

TRAINING YOUR BREATH-HOLD TECHNIQUE

You have already discovered on the *SNSI Freediver* course that there are different ways to train your breath-hold ability, both on land and in the water, and how you don't need to make deep dives to practice. During this course, your instructor will help you to improve your performance by applying the new breathing techniques you have just learned to many of the exercises you have previously practiced.

Important Note. The first time you try these exercises, only do so under the supervision of your SNSI Freediving Instructor. This will assure your safety, as well as providing the opportunity to correct your techniques before you develop bad habits that might affect your performance.



Afterwards, you can repeat these exercises without your instructor, but always do so with your buddy and never on your own.

Exercises - Revision

Timed apnea. Lie face up in a relaxed position with your feet on the ground and legs bent. Complete one full breathing cycle: preparatory breathing, breathing sequence, advanced breathing sequence and final inhalation. *Now hold your breath!* Your instructor will time you to keep track of your performance.

Static apnea. Lie in the water and float with your face down. If you aren't wearing a wetsuit or this doesn't offer you enough buoyancy, you can use a float under your legs. Try to find a comfortable position, relaxing your muscles as much as possible. In this position, complete one full breathing cycle: preparatory breathing, breathing sequence, advanced breathing sequence and final inhalation. *Now hold your breath!* Your buddy will help you during this exercise, so agree on a signaling system for safety. For example, your buddy might signal to you every 15-30 seconds (depending on the scheduled length of the static apnea; the first few times you try, you will aim for 60 seconds and so your buddy will give a signal every 15 seconds, then once you have more experience and are aiming for two minutes of static apnea, your buddy can signal to you every 30 seconds) and you might respond with a gesture, such as a nod of the head or a

hand gesture. One of the most commonly used signals is to raise the index finger.

Dynamic apnea. Lie in the water and float facing down, trying to find a position where you can relax all your muscles. Position yourself near the edge of the pool, facing in the direction of your dynamic apnea. In this position, complete one full breathing cycle: preparatory breathing, breathing sequence and final breathing sequence. *Now hold your breath!* Raise your legs, place your feet on the wall and push away from the edge of the pool. Point your head down and arch your back slightly to glide below the water surface. You can use the flutter kick or dolphin kick for this exercise. Follow the guide rope or the line along the bottom of the pool. Your buddy will track you from the surface, carrying a floatation device in order to offer support or assistance if needed.

Diaphragmatic contractions

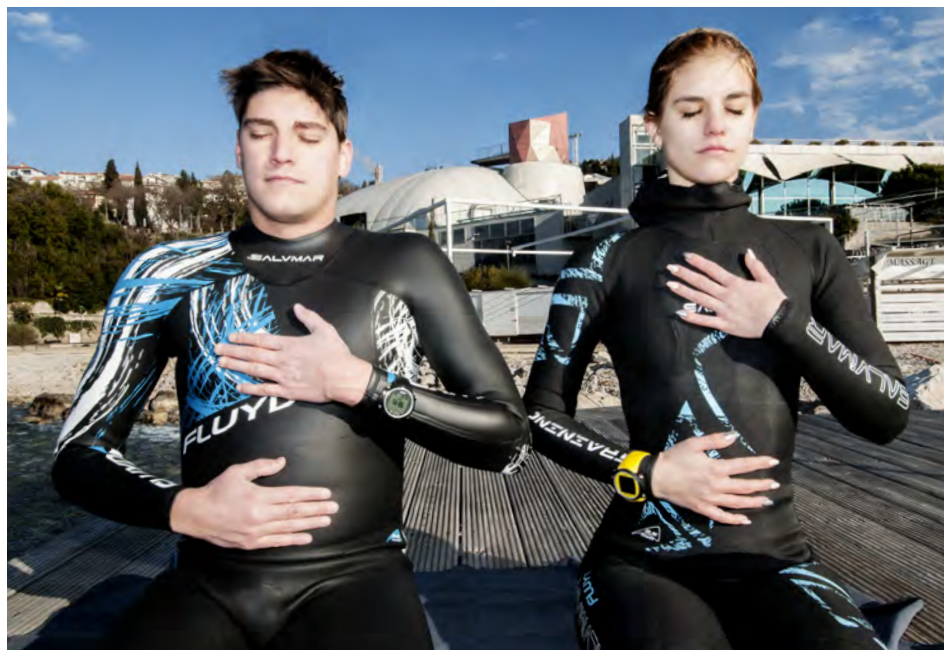
During the *SNSI Freediver* course, you learned how to stop holding your breath as soon as you felt your diaphragm contract. However, at this more advanced level you need to take your awareness of your body and its sensations to the next step. As you know, diaphragmatic contractions are an alarm bell and are one of the most important signals that our body sends during apnea. These contractions are involuntary and are caused by nerve impulses sent from the respiratory center in the brain. As you discovered on the *SNSI*



Freediver course, the breathing reflex occurs when the carbon dioxide levels in our body increase. This increase is perceived by certain receptors located mainly in our carotid arteries (the arteries that carry blood to the brain) and the aorta (the artery that leads away from the heart). The receptors stimulate the neurons in the respiratory center, which in turn sends nerve impulses to the diaphragm to make it contract. This increases the volume of the lungs and enables new air to enter the body. However, as your mouth is closed during apnea, bringing air into the lungs is impossible. Because of this, as the diaphragm contracts you will also feel your epiglottis contract as it is pulled downwards.

To become an advanced freediver, it is essential to learn how and when these reflexes occur and how to recognize them clearly and accurately. It is important to practice the exercises yourself in order to experience the sensations caused by diaphragmatic contractions first hand. You can practice the exercises

on land or in the pool and gradually become familiar with these sensations in a safe environment. By performing specific exercises, you can learn to induce diaphragmatic contractions quite rapidly in a decisive and unmistakable manner. When you carry out these exercises, pay attention not only to the contractions of the diaphragm in your abdomen, but also to the spasms of your epiglottis and the tension in your



thorax, as these sensations are directly caused by the diaphragmatic contractions.

Important Note. Again, your SNSI Freediving Instructor will supervise when you practice these exercises for the first time, offering assistance and thus assuring your safety. Your instructor can also correct your position and make sure you don't develop any bad habits that will affect your performance and safety. *It is essential to be closely monitored whenever you perform these exercises, even when you are practicing without your instructor.* Freediving is always carried out with a buddy, and this is even more important when practicing these exercises as you are pushing your physique to its limits. Only practice these exercises on land or in the pool.

Diaphragmatic contraction exercises

Dry exercise:

Walking apnea. You have already practiced this exercise during the SNSI Freediver course. Now let's see how we can adapt it to focus on diaphragmatic contractions. Sit on a chair in a relaxed position with a straight back. Complete one full breathing cycle: preparatory breathing, breathing sequence, advanced breathing sequence and final inhalation. *Now hold your breath!* Stay in a relaxed position on the chair, continuing to hold your breath. When you feel the first contraction in your diaphragm, stand up and walk in a straight line at a slow and relaxed pace. Continue

to walk until you gain control of your diaphragmatic contractions. Try to take steps that are about the same length as the width of your shoulders. Your instructor and buddy will follow you closely when you are practicing this exercise, in order to offer you assistance if you should require it. They will also count how many steps you manage to take, so you will be able to see a measurable progress from one exercise to the next.

Contraction counting. Same as the previous exercise begin by sitting on a chair in a relaxed position with a straight back. Complete one full breathing cycle: preparatory breathing, breathing sequence, advanced breathing sequence and final inhalation. *Now hold your breath!* Stay in a relaxed position on the chair, continuing to hold your breath. When you feel the first diaphragmatic contraction, signal to your buddy then remain in a relaxed position, continuing to hold your breath until you feel fully comfortable with the diaphragmatic contractions this causes. While you hold your breath, try to count how many diaphragmatic contractions you experience.

Aquatic exercise:

Stimulating diaphragmatic contractions. This exercise aims to rapidly induce diaphragmatic contractions. Swim four pool lengths of freestyle, stopping for 20 seconds between each length. After another 20 seconds, swim a final length of freestyle, trying to breathe as little as possible (taking a maximum





of 2-3 breaths over the length). On reaching the end of the pool, where your buddy is waiting, breathe in deeply and begin to perform a static apnea. You will feel your diaphragm contract in less than half a minute; concentrate until you manage to control the contractions, focusing on the sensation. Your buddy will count during the apnea and will signal to you every 10 seconds; remember to respond with the familiar signal for static apnea.

Dynamic apnea. This exercise is useful to learn how much time you have to return to the surface after the first diaphragmatic contraction. Lie in the water and float face down, trying to find a position where you can relax all your muscles. Position yourself near the edge of the pool, facing in the direction of your dynamic apnea. In this position, complete one full breathing cycle: preparatory breathing, breathing sequence, advanced breathing sequence and final inhalation. **Now hold your breath!** Go underwater and grasp a pre-placed weight, then begin a static apnea on the floor of the pool. Stay in this position until you feel the first diaphragmatic contraction. Signal to your instructor that you are about to move. Let go of the weight and swim using the flutter kick, moving as quickly as possible and following the guide rope or the line along the base of the pool. Continue to swim for as long as you can hold your breath. Remember to swim quickly for the entire exercise and try not to lose speed at the end. Your instructor, and your buddy

when you practice this exercise afterwards, will follow you closely from the surface in order to offer prompt assistance if required.

AQUATIC EXERCISES

Turning. At the end of this *SNSI Advanced Freediver* course, you should be able to complete 35 meters (115 feet) of dynamic apnea with fins. It is therefore very likely that you will need to turn underwater at the end of the first length of the pool to swim in the opposite direction. It is important to learn the correct turning technique to avoid wasting too much energy and to help you achieve your goal of 35 meters (115 feet) more easily. As you approach the edge of the pool, place one hand on the wall, keeping it under the water, and extend the other arm down to your side. From this point there are two methods. For the first method (open turn), bring your knees to your chest and your heels to your backside. Tuck the legs under your body and rotate your torso by 180 degrees to point yourself in the new direction. The second method is called the flip turn and brings the legs over your body. With one hand on the wall of the pool, raise your heels and bring them towards your backside, keeping your knees away from your body. This allows you to rotate 180 degrees without your legs hitting the wall. Both techniques allow you to turn in either direction, depending on the position of

your hands; you must always rotate in the opposite direction to the hand against the wall.

SUMMARY

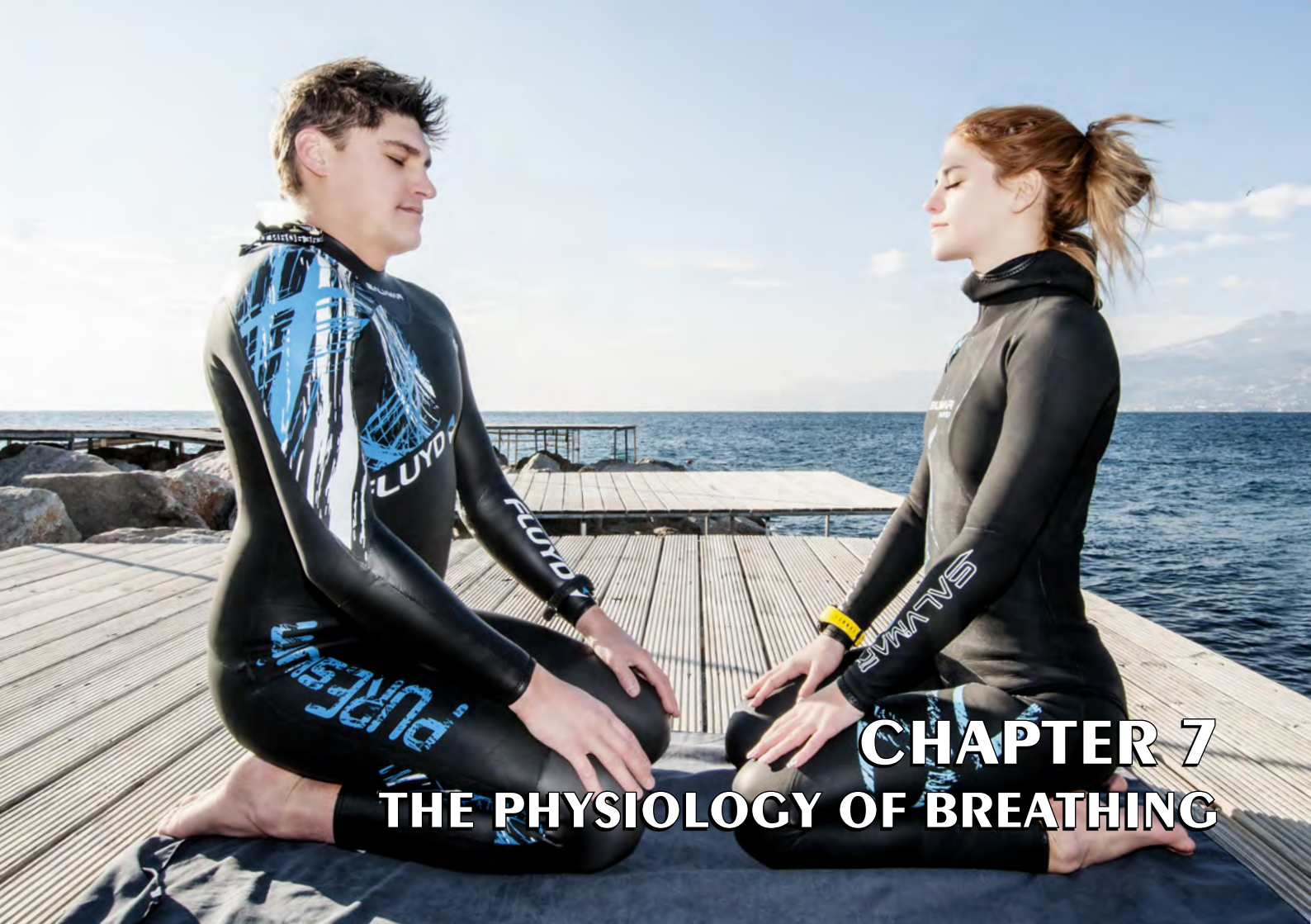
At the end of this chapter, you have increased your awareness of your true breathing potential and are now able to use the full extent of your lung capacity. However, this is not a magic formula that will transform you into an expert freediver and is just one more tool in your toolbox. As you have learned in the *SNSI Freediver* course, becoming a competent freediver requires training, perseverance and determination.



CHAPTER 6 STUDY GUIDE

1. Sub-clavicular breathing:
 - ☐ Is a type of shallow breathing.
 - ☐ Uses the upper third of the lungs.
 - ☐ Both.
2. Sub-clavicular breathing is an efficient way of stimulating gaseous exchange.
 - ☐ True.
 - ☐ False.
3. The advantages of sub-clavicular breathing are that:
 - ☐ It uses the lower third of the lungs and facilitates gaseous exchange.
 - ☐ It facilitates equalization.
 - ☐ Both.
4. Which type of breathing technique should you use when preparing to hold your breath?
 - ☐ Thoracic breathing.
 - ☐ Diaphragmatic breathing.
 - ☐ Both.
5. After holding your breath, preparatory breathing helps to re-establish the right levels of gas in the blood.
 - ☐ True.
 - ☐ False.
6. During the breathing sequence, the inhalation should last for:
 - ☐ 3-5 seconds.
 - ☐ The same length of time as the exhalation.
 - ☐ Both.
7. The normal breathing sequence uses:
 - ☐ 40-50% of your lung capacity.
 - ☐ 70-80% of your lung capacity.
 - ☐ 100% of your lung capacity.
8. The final inhalation uses:
 - ☐ 40-50% of your lung capacity.
 - ☐ 70-80% of your lung capacity.
 - ☐ 100% of your lung capacity.





CHAPTER 7

THE PHYSIOLOGY OF BREATHING



www.scubasnsi.com



CHAPTER 7

In the *SNSI Freediver* course you learned about gaseous exchange and what causes the breathing reflex. As part of the *SNSI Advanced Freediver* course, it is important that you understand exactly what is happening inside your body and which physical and physiological mechanisms enable you to live and breathe. Each breath we take uses various organs in our body, all with different shapes and functions but which are ultimately working towards the same objective: to carry oxygen to every single cell in our body and remove the carbon dioxide produced as we metabolize it. Each respiration is divided into various

phases: ventilation, or rather the movement of air from outside our body into our lungs; diffusion, or rather the transfer of the oxygen and carbon dioxide held in our lungs into the blood; and the transportation of oxygen from the lungs to our cells, and carbon dioxide from the cells to our lungs.

VENTILATION

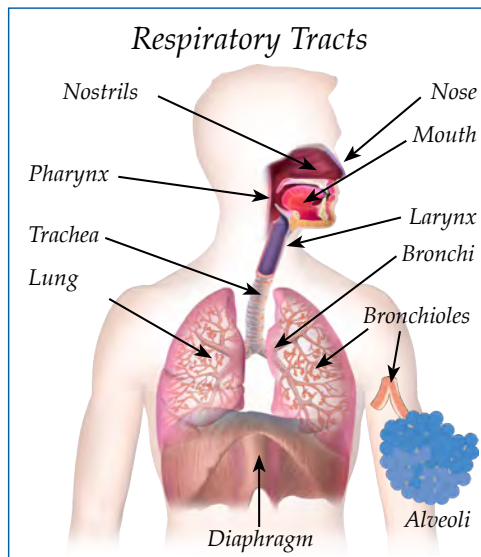
Our respiratory system is made up of the airways (or respiratory tracts), where gases are not exchanged, and the lungs, where gases are moved between the air and



our blood. The airways connect the external environment to our internal body systems and are subdivided into the upper respiratory tracts (nose and mouth, larynx and pharynx) and the lower respiratory tracts (trachea, bronchi and non-respiratory bronchioles), and form our physiological “dead space”. The main purpose of the respiratory tracts is to purify, heat up and humidify the air before it comes into contact with the blood, reducing the risk of toxic substances entering the blood supply and preventing our body from getting too cold. The final part of the respiratory system are the respiratory bronchioles, alveolar ducts and alveoli, where gaseous exchange occurs. The alveoli are tiny sacks that contain the air transported into our bodies via the respiratory tracts, and there are millions of them in each lung. They are formed of a very thin membrane surrounded by a dense network of capillaries. The alveoli and related capillaries form the basic part of the lung.

Pulmonary cavities

Let's take a moment to consider these chambers



and try to give some definitions that will give you a better understanding of some of the concepts we will discuss later. As you saw on the SNSI Freediver course, your breathing, or rather the amount of air you intake into your body, is not always the same, and in fact to improve your freediving performance you are now able to store much more air than you would usually breathe in everyday life.

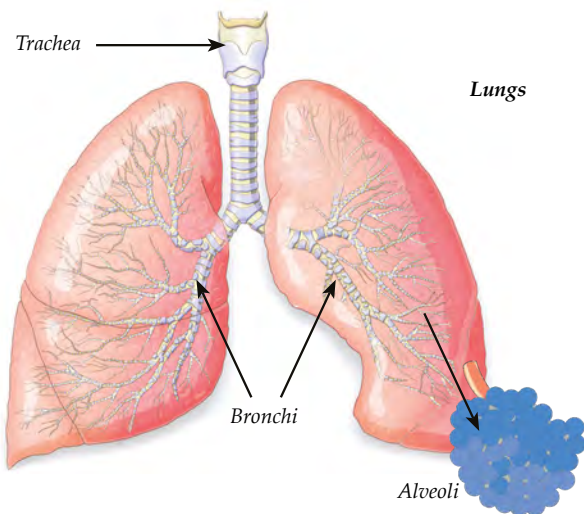
Tidal volume is the amount of air you inhale and exhale during an unforced breath, for example how you might breathe when reading, and is usually around

0.3-0.5 liters / 0.01-0.02 ft³.

Inspiratory reserve volume is the maximum amount of air that you are able to inhale into your lungs through extra force after taking a normal breath (2-3 liters / 0.07-0.11 ft³).

Expiratory reserve volume is the maximum amount of air that you are able to exhale from your lungs through extra force after taking a normal breath (1-1.5 liters / 0.04-0.05 ft³).

Vital capacity is the sum of the tidal volume, inspiratory reserve volume and expiratory reserve



muscles and the respiratory muscles themselves. The thoracic cage (or ribcage) is composed of the ribs which are supported by the spine behind and the sternum in front, and protects our lungs while enabling us to breathe. The main muscles that operate in the breathing process are the diaphragm, a large dome-shaped sheet attached to the inner edge of the lower ribs which separates the thoracic cavity from the abdominal cavity; the muscles between the ribs (intercostal muscles); certain muscles in the neck and the pectoral girdle.

As you have already learned on the *SNSI Freediver* course, the breathing reflex is provoked by the respiratory center in the brain and is activated by the level of carbon dioxide in the arterial blood. As soon as this level rises, the respiratory center uses the

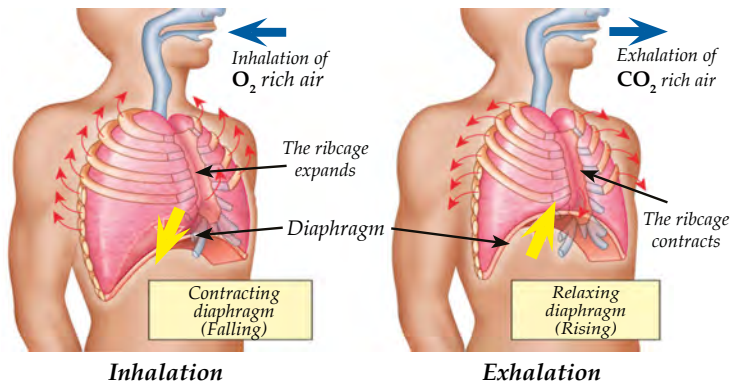
volume (3-5 liters / 0.11-0.18 ft³).

Residual volume is the amount of air left in your lungs after a forced exhalation (1 liter / 0.04 ft³).

Total lung capacity is the sum of your vital capacity and residual volume, and represents the total amount of air you can hold in your body after a forced inhalation.

The respiratory muscles

The neuromuscular system also plays a part in ventilation and is formed of a respiratory center in the brain, the nerves of the breathing



nervous system to activate our breathing muscles. The diaphragm and intercostal muscles vary the volume of the thorax and enable ventilation to occur. Inhalation is an active process. The contraction of the diaphragm pushes the muscle downwards, increasing the volume of the ribcage by extending the length. As the outer intercostal muscles contract, the ribs are pulled upwards and outwards, increasing the volume of the ribcage in a forward/backward direction. These movements increase the volume of the lungs which, according to Boyle's Law, causes the internal pressure to reduce, taking in air from outside through the respiratory tracts. Normal exhalation is a passive movement, resulting from the elastic recoil of the ribcage as the respiratory muscles relax. This reduction in volume pushes air out of the lungs. The diaphragm and outer intercostal muscles are the main muscles used for respiration, but during a forced inhalation or exhalation the inner intercostal muscles and other muscles in the neck that help to move the ribs may also be used.

GAS DIFFUSION

The air movements we have looked at thus far regard air masses. However, when it comes to the alveoli, the transfer is molecular, meaning that single molecules of the respiratory gases contained in the air in lungs are transferred to the capillaries through the

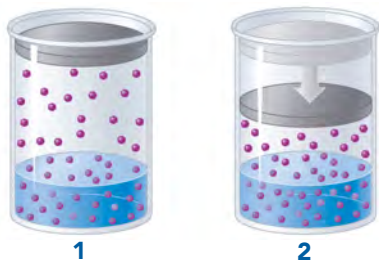
process of diffusion. To understand this phenomenon properly we need to discuss the laws of physics that govern gases.

In the *SNSI Freediver* course we learned about the law of partial pressures (Dalton's Law), which states that the sum of the partial pressures of individual gases in a mix is equal to the pressure of the mix itself. At the end of a complete inhalation, the air in our lungs contains 20.95% oxygen and 78.08% nitrogen, with the remaining percent composed of a mix of other gases, mainly argon, while carbon dioxide makes up just under 0.04%. According to Dalton's Law, at sea level the oxygen inside our lungs exerts a pressure of 159.22 mmHg (0.209 atm or 3.07 psi) while carbon dioxide exerts around 0.304 mmHg (0.0004 atm or 0.006 psi).

Henry's Law

Let's look at another law of physics that governs how gas behaves: Henry's Law. The gas laws you encountered in the *SNSI Freediver* course only apply to gases and mixed gases. However, there are also cases when a gas is present within a liquid, and we know that in certain situations gases dissolve (technically *becoming a solution*) in the liquid: for example, we know that fish process oxygen that has *dissolved* in the water and that all carbonated drinks like soda contain *dissolved* carbon dioxide. Many people find it difficult to understand how gases can dissolve into liquids. To





HENRY'S LAW
"A gas that exerts a certain pressure on the surface of a liquid becomes a solution when its pressure in the liquid is precisely equal to its pressure above the surface of the liquid."

the naked eye, a liquid doesn't appear to have any space for a gas to penetrate, yet we know that gases dissolve in liquid. We can see this every time we put a piece of ice in a carbonated drink. The bubbles that form are carbon dioxide coming out of the liquid. Although we can't see it in its dissolved form, the gas stays in liquid form until something causes it to change out of it. Another important concept is that a gas dissolved in a liquid continues to exert pressure. This pressure inside the liquid is defined as *gas tension*. The scientist William Henry studied how much gas can be absorbed by a liquid and what factors influence this process. His experiments proved that the quantity of a given gas that dissolves in a given liquid at a given temperature depends on the partial pressure of the gas and its affinity with that liquid. According to Henry's Law, temperature and pressure affect how much gas can dissolve in a liquid. As a concrete example, imagine that you have a glass of water that doesn't contain any dissolved gases. The glass is placed in a container

and a vacuum is created around it, meaning there are no gases in contact with the water. If air is inserted into the container and this comes into contact with the water, the molecules of the different gases in the mix begin to penetrate the liquid. The dissolved gas exerts its tension in accordance with Dalton's Law, and each component of the gas exerts its partial tension. The difference between the pressure of gas in contact with the liquid and the tension of the dissolved gas is called the pressure gradient. If this gradient is high, gas is absorbed rapidly by the liquid. However, as the molecules of gas dissolve in the liquid, the gradient diminishes and the molecules dissolve more slowly. The gas will dissolve in the liquid until its tension is equal to the pressure of the gas in contact with the liquid. Although molecules will continue to enter the liquid, the same number will exit from it, meaning they balance each other out and the quantity of dissolved gas does not increase. At this point the liquid is said to be *saturated*. Besides pressure, temperature also affects the absorption of gas in liquids. Heat speeds up the motion of the molecules in a liquid, and this rapid motion leaves less space for the gas molecules. We can see this phenomenon when we boil water. As the water heats up, small air bubbles form which collect on the bottom of the pan. This is caused by the increased motion of the water molecules pushing out the dissolved molecules of air. It is therefore logical that the colder a liquid is, the more gas that can be



dissolved in it. The molecules of a colder liquid move more slowly, creating space for a larger number of gas molecules.

Gaseous exchange

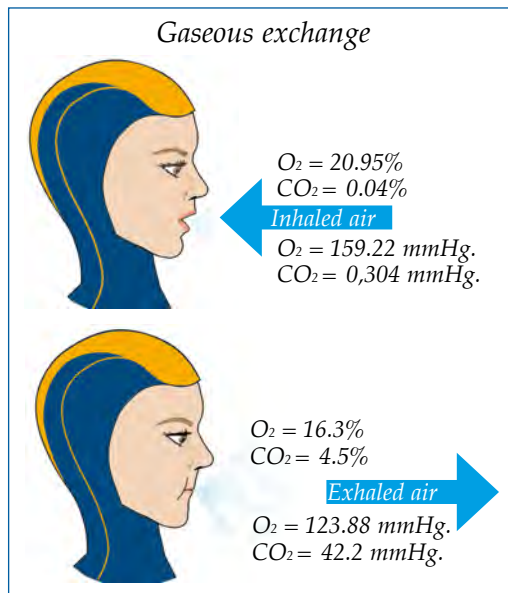
Gaseous exchange occurs thanks to the pressure gradient, or rather the difference between the partial pressure of the respiratory gas (oxygen or carbon dioxide) present in the alveolar air and the partial tension of the same gas in the blood. Henry's Law states that, like temperature, gas moves from areas of high pressure to areas of low pressure, following the pressure gradient.

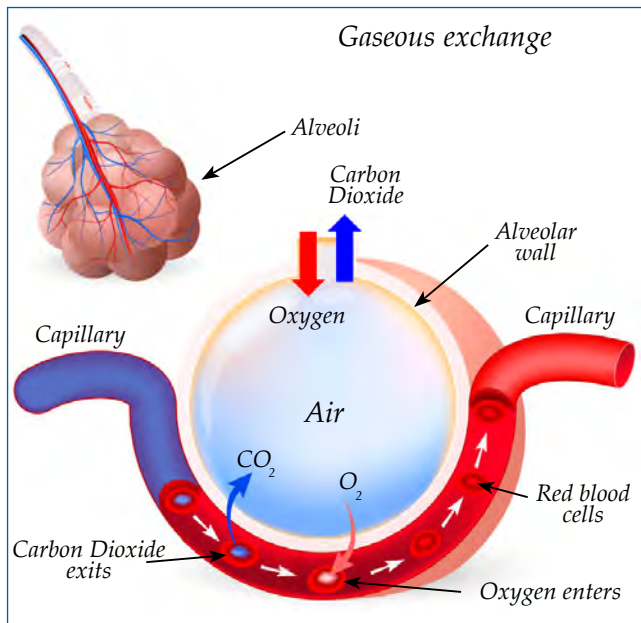
The blood circulating in the alveolar capillaries reaches the lungs from the periphery of the body. As it has already delivered oxygen to the cells, this blood has low oxygen levels and high carbon dioxide levels. As such, the partial pressure of oxygen in the blood is less than the partial pressure in the alveolar air, while the partial pressure of carbon dioxide is greater. There is therefore a difference in pressure, the gradient, between

the gases contained in the blood which reaches the alveoli and the gases contained in the air inside the alveoli themselves. As such, a certain amount of oxygen transfers from the alveoli to the blood, while a certain amount of carbon dioxide transfers from the blood to the alveolar air.

This exchange can occur thanks to the specific structure of the alveoli and their capillaries. The walls of the alveoli are very thin and are formed of a single layer of cells. These are surrounded by a very high number of capillaries that often come into contact with one another in the alveolar wall. The capillaries are also very small, meaning that only one red blood cell can pass through at a time. Red blood cells carry oxygen and contain a substance called hemoglobin, which is able to chemically bind itself to many types of gas. Hemoglobin has a close affinity with oxygen, and in fact most of the oxygen that is transferred from the alveoli into the capillaries binds with it very quickly.

When blood releases carbon dioxide and collects oxygen, it transforms from venous blood





to arterial blood. Now let's look at the difference between these two types of blood and the route they take through our bodies to transport carbon dioxide and oxygen respectively.

GAS TRANSPORTATION

The cardiovascular system transports oxygen, nutrients and waste products around the body. It is formed of the heart, which maintains blood circulation;

the *blood vessels* (arteries, veins and capillaries), which contain the circulating blood; and the blood itself which carries the dissolved oxygen, the nutrients and the waste products.

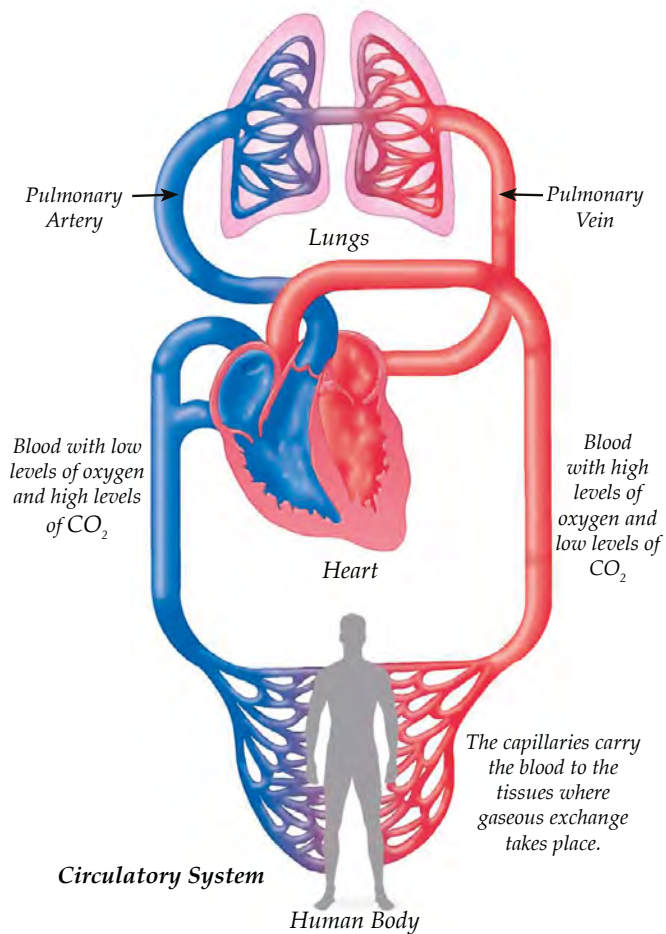
The *heart* is a hollow involuntary muscle, meaning it works without our conscious control, which contracts rhythmically and acts as a pressure and suction pump, pushing and drawing blood to and from the different parts of the body.

The heart is located in the thoracic cavity between the lungs and rests on the diaphragm which separates it from the abdominal cavity. This is composed of four cavities: two upper cavities, known as atria, and two lower cavities, known as ventricles. The heart is also divided lengthwise: the right side of the heart is formed of the right atrium and right ventricle, while the left side of the heart is formed of the left atrium and left ventricle.

The two sides do not communicate with one another, but each atrium communicates with the corresponding ventricle below through a one-way valve, the tricuspid (right) and mitral (left) heart valves. The atria receive the blood from the periphery of the body, with blood coming from the tissues entering the right atrium and blood coming from the lungs entering the left atrium.

The ventricles push the blood out of the lungs and pump it into the blood vessels. The right ventricle pushes the blood from the right atrium to the lungs,





while the left ventricle pushes the blood from the left atrium to the tissues.

The atria have thinner walls than the ventricles and dilate as blood flows into them while simultaneously pushing it through the valves and into the ventricles. At this point the ventricles contract and pump the blood away. At the end of the phase when the ventricles contract (*systole*), the heart muscle relaxes and the two cavities extend to allow the chambers to fill with blood (*diastole*).

The *blood vessels* are divided into categories based on their position in relation to the heart and their direction of circulation. The ventricles push the blood towards the periphery of the body through the *arteries*, while the atria receive the blood through the *veins*. Therefore we can deduce that the blood flowing through the arteries has a centrifugal, or outwards, motion, while the blood in the veins has a centripetal, or inwards, motion.

As they get further away from the heart, the arteries branch out significantly; these narrower arteries are known as *arterioles*. The arterioles then branch into even narrower vessels called *arterial capillaries*, and these flow into the *venous capillaries* which in turn flow into the larger veins. The *capillaries* are where the arterial and venous systems meet. Blood vessels can also be distinguished by their difference in structure. In the arteries, the outer wall is formed of muscular tissue which is able to contract to support the pumping

action of the heart and modify the width of the lumen (the hollow channel inside the artery), affecting the speed of the blood flow. The veins contain special valves which prevent gravity from causing the blood to flow in the opposite direction between one heart beat and the next.

The two blood circuits

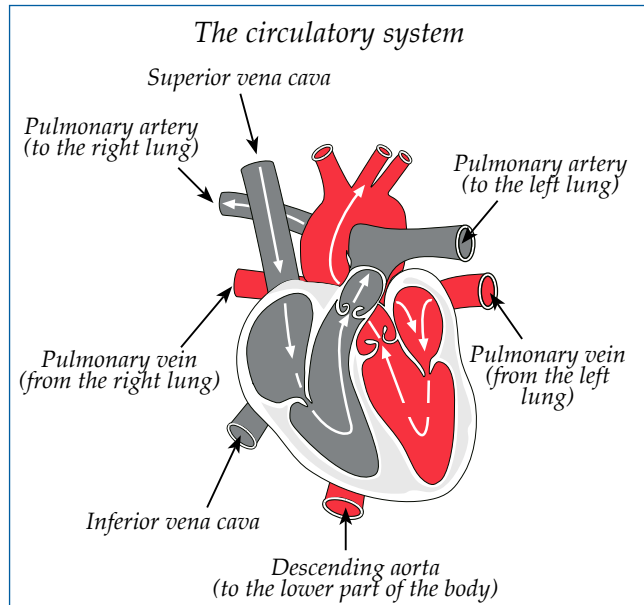
Although they are in direct contact with one another, the right and left sides of the heart are responsible for two different circulatory systems, the large circuit and the small circuit.

The *large circuit* begins from the left ventricle and pushes oxygenated blood through the aorta to every part of the body through a vast network of arteries and arterioles. Thanks to the elastic arterial walls, the blood pumped by the contracting ventricle is carried at a speed of 9 meters (30 feet) per second. In the arterioles, the speed reduces to one millimeter per second to facilitate the gaseous exchange between the blood and the cells of the tissues.

On reaching the cells, the arterial blood releases its nutrients and oxygen and collects the waste substances. It then flows into the veins which carry it to the right atrium, where it passes through the tricuspid valve into the right ventricle to enter the *small circuit* (or pulmonary circulatory system).

As mentioned above, the blood is now carrying the waste products, including carbon dioxide, and is

pushed through the pulmonary artery to the lungs, where it splits into numerous different branches leading into a dense network of microscopic arterioles that cover the walls of the pulmonary alveoli. After becoming oxygenated and releasing the carbon dioxide into the pulmonary capillaries, the blood enters the veins. These become increasingly wide until separating into the four pulmonary veins which carry the blood to the left atrium. Here, the blood moves

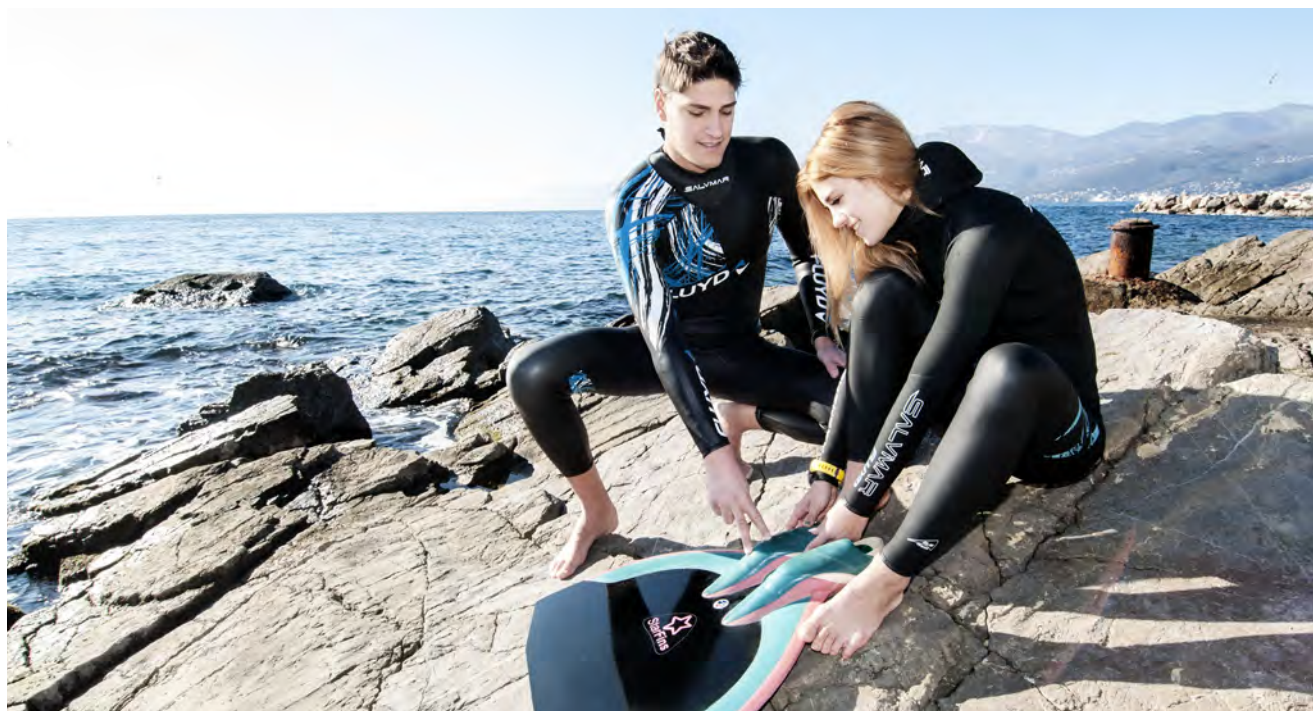


into the left ventricle and the *large circuit* begins again.

As you have just discovered, the claim that “arterial blood carries lots of oxygen while venous blood carries lots of carbon dioxide” is not wholly accurate. In fact, it applies to the entire circulatory system with two main exceptions: the pulmonary artery and the pulmonary veins. In fact, on the *small circuit*, the

pulmonary artery transports the blood with high levels of carbon dioxide from the heart to the lungs where it is oxygenated, then the pulmonary veins carry the oxygenated blood to the heart.

We have seen how oxygen (and carbon dioxide in the opposite direction) is transferred from the outside environment to the individual cells in our body. Here,



oxygen diffuses from the peripheral capillaries to individual cells through a diffusion process in much the same way as it transfers between the alveolar air and the blood in the capillaries of the alveolar walls.

When oxygen enters the cells, cellular respiration occurs; this is a metabolic process which, thanks to the presence of the oxygen itself, burns nutrients such as sugar and fatty acids to produce energy.

We will explore this concept in more detail in subsequent levels of the *SNSI Freediving* program when we discuss different training techniques.

AQUATIC EXERCISES

Surfacing with a partially flooded mask. Perform a surface dive, fin to the bottom and perform a turn-up. Now allow a little water to enter your mask, pulling the upper silicone rim of the mask away from your forehead slightly. Fin up the guide rope then on reaching the surface, empty your mask as you learned on the SNSI Freediver course, pulling the mask away

from your face with both hands.

Surfacing without a mask. Perform a surface dive, fin to the bottom and perform a turn-up. Now take off your mask and put it around your neck. Fin up the guide rope then on reaching the surface, put your mask back on. Position the strap on the nape of your neck and bring your mask to your face, ensuring that no part of your clothing or hair becomes caught under the silicone of the mask.

SUMMARY

In this chapter you have learned what happens in your body on each and every breath, gaining an understanding of the body's physiological processes and the organs behind them. This will increase your knowledge as an advanced freediver, enabling you to dive with complete self-awareness of your body and the mechanisms that freediving provokes, and consequently discovering your personal limits and how to manage them safely.





CHAPTER 7: STUDY GUIDE

1. Respiration is made up of
 - ☐ 2 phases.
 - ☐ 3 phases.
 - ☐ 4 phases.
2. Gaseous exchange takes place:
 - ☐ In the lower respiratory tracts.
 - ☐ In the trachea.
 - ☐ In the alveoli.
3. Total lung capacity is the sum of:
 - ☐ The inspiratory and expiratory reserve volumes.
 - ☐ The tidal volume and residual volume.
 - ☐ The vital capacity and residual volume.
4. As you inhale:
 - ☐ The diaphragm contracts and the intercostal muscles relax.
 - ☐ The diaphragm contracts and the intercostal muscles contract.
 - ☐ The diaphragm relaxes and the intercostal muscles contract.
5. During diffusion, oxygen moves:
 - ☐ From the lungs to the blood.
 - ☐ From the blood to the lungs.
 - ☐ In both directions.
6. The right atrium receives:
 - ☐ Blood from the tissues.
 - ☐ Blood from the lungs.
 - ☐ Oxygenated blood.
7. Diastole means the contraction of the ventricles.
 - ☐ True.
 - ☐ False.
8. The arteries:
 - ☐ Always carry high levels of oxygen.
 - ☐ Always carry blood in a centrifugal (outwards) motion.
 - ☐ Both.



CHAPTER 8

PHYSIOLOGICAL ADAPTATIONS



www.scubasnsi.com



Although humans have adapted to live on land, we can nonetheless recognize our marine ancestry. All known life forms alive today evolved from the first organisms that developed in the so-called “primordial soup”, the ocean that covered the Earth around 3 billion years ago. The physiological mechanisms and adaptations that our body undergoes when we go underwater are so pronounced and effective that some academics have put forward the hypothesis that humans evolved, or at least spent some of their evolutionary history, in an underwater environment, the so-called “the aquatic monkey theory”.

Humans are aquatic animals not only from a phylogenetic perspective (which refers to the origin of the species as a whole), but also in terms of ontogenesis (meaning the origin of each individual). In fact, the fetus develops in an aquatic environment, namely the amniotic fluid inside the mother's womb. This is why for the first six months of their lives, newborn babies are entirely comfortable underwater. Newborns do not swallow water, instinctively closing their mouths and, most importantly, their epiglottis, which separates the digestive and respiratory systems by sealing the

trachea. They also keep their eyes open and are able to coordinate their arms and legs to move short distances in the water. The adaptations and behaviors we see in newborn babies originate from the diving reflex. This phenomenon has been extensively studied in marine mammals which have adapted to swim underwater, such as seals, whales and dolphins; these animals have a particularly well-developed diving reflex, but the mechanism is in fact present in all mammals, including humans, and it is this reflex that enables us to make deep freedives.

Now let's try to gain a better understanding of what the diving reflex is and what physiological adaptations it induces in our bodies.

THE DIVING REFLEX

During your *SNSI Freediver* course, you probably noticed that you were able to hold your breath longer when performing static apnea in a pool than you could on dry land. The reason for this improved performance is the so-called diving reflex, which kicks in when we are immersed in water and mainly causes changes to our cardiovascular systems, such as a slower heart rate, peripheral vasoconstriction and higher blood pressure. In particular, the diving reflex is sparked when cold water comes into contact with our face; immersing other parts of the body in water does not provoke the same

physiological response. This contact stimulates the thermal receptors located on the forehead, around the eye-sockets and on the cheekbones which are connected predominantly to the trigeminal and vagus nerves. These receptors then stimulate the nerve centers which control our heart rate, blood pressure and the vascular tone of our blood vessels. The purpose of these physiological changes is to protect our body in what it considers to be a new and hostile environment. In fact, these alterations help us to conserve oxygen, in particular from our extremities, in order to redirect it to our vital organs (brain, heart and liver), as well as to reduce heat loss resulting from contact with water.

Bradycardia, the result of stimulation of the vagus nerve, causes a 10% to 50% reduction in heart rate in humans and an even more dramatic response in certain marine mammals, dropping to 80% to 90% in seals. It also reduces the amount of oxygen required by the entire body. Peripheral vasoconstriction reduces capillary diameter and limits blood flow to the extremities; hands and feet are the first to be affected, followed by the arms and legs. These effects enable the body to conserve the right amount of oxygen for the heart and brain, at the expense of organs which are more resistant to ischemia.

Another effect of the diving reflex is spleen contraction, triggered when the body's oxygen

levels fall. In fact, during immersion the spleen continues to contract and releases more red blood cells which, despite the fact that partial pressure gradient is limited, enables the blood to transfer more oxygen molecules from the lungs into our circulation, making them available for metabolic functions. Furthermore, this greater number of red blood cells significantly aids recovery after freediving, quickly restoring normal blood oxygen levels to the body.

The speed and intensity of the diving reflex depend on the temperature of the water and physical fitness. Frequent freediving in water accelerates the onset of the diving reflex and amplifies its effects.

THE BLOOD SHIFT

When freediving was first practiced as a recreational sport, the physical limit of freediving was widely discussed. In fact, many doctors believed that the human body would not be able to support the pressure of the water beyond certain depths. Many freedivers, including the Italian Enzo Maiorca, often dived against medical advice, knowing that according to medical opinion at the time, they were putting their lives in danger.

However, all of these freedivers succeeded in their endeavors and today athletes reach depths that are 4 or 5 times greater than those believed





possible in the past. These achievements are made possible by another physical mechanism called the *blood shift*.

As a concept, the doctors' beliefs were not wrong. In fact, they believed that as if we were to descend deeper underwater, the water pressure would compress the air in the respiratory tracts, in turn reducing the volume of the lungs and causing the ribcage to collapse. During the descent, the total lung capacity, or rather the amount of air held inside the lungs after a forced inhalation, reduces and on reaching a certain depth attains its residual volume, namely the amount of air that can never be expelled from the lungs even by a forced exhalation. Theoretically, continuing to descend beyond this point could cause serious lung injuries. As such, the depth at which total lung capacity is reduced to the residual volume would therefore be the maximum depth a diver could reach. Given that on average, the residual volume is around a quarter of total lung capacity, the pressure of 4 atmosphere (58.8 psi bar) reached at 30 meters (99 feet) depth would reduce the volume of the lungs to their residual volume.

In practice however, freediving champions have proven that this limit doesn't check out. This is because of peripheral vasoconstriction, when a large quantity of blood in our arms and legs is redirected back to our chest, mainly in the pulmonary artery. This causes blood pressure to rise

and the pulmonary capillaries in the alveolar walls to thicken, consequently reducing the air spaces in the alveoli themselves and drastically reducing the residual volume. To put it simply, the reduction of the volume of air in the lungs is equalized by the greater quantity of blood in the walls of the alveoli.

However, this physiological adaptation can cause problems for freedivers when diving or surfacing.

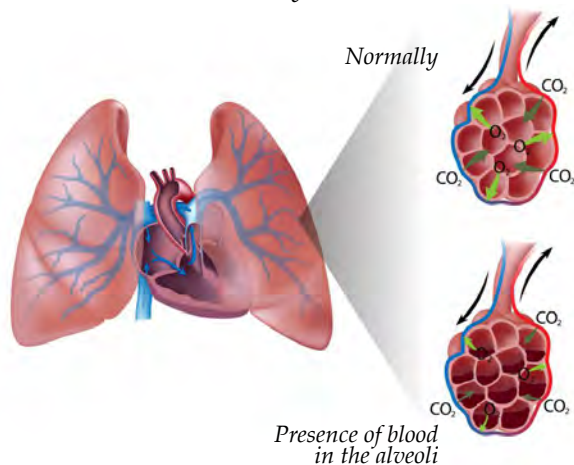
Hemoptysis

Hemoptysis is the presence of blood in the respiratory tract and some divers experience this during their freedives. The causes behind this problem are not completely clear, although the issue has been widely debated in the medical field and there are currently two schools of thought which have assigned two different physiological causes to the phenomenon: *pulmonary edema* and *lung overexpansion*.

Pulmonary edema

As you have just seen, as the depth of a dive increases, a large quantity of blood is recalled from the periphery of the body to our chest to prevent it from collapsing. This causes the lumen (the inside space) of the pulmonary capillaries to increase and results in a sharp increase in blood pressure. These processes cause the walls of the capillaries to extend in response to the modifications of the *blood shift*. Consequently, the cells that form the walls of the

Pulmonary Edema



capillaries become slightly further apart, increasing the permeability of the wall itself. When freediving, the ambient pressure increases proportionally to the depth, and the air in our lungs adapts to the increased pressure by reducing its volume. In this way, the intrathoracic pressure is maintained at the same level as the hydrostatic pressure until total lung capacity is reduced to the residual volume. The volume cannot be reduced below this limit because of the rigidity of the thorax, and consequently this creates a slight depression in the lungs that, combined with the greater permeability of the

cell wall and the higher blood pressure, can cause blood to pass from the circulatory system to the lungs, resulting in pulmonary edema. The first sign of pulmonary edema is hemoptysis, which can be recognized by the traces of blood in the saliva. If this occurs, you must end the diving session immediately and not dive again that day. In serious cases of pulmonary edema, divers may have difficulty breathing (shortness of breath), rattling lungs and a persistent cough with frothy, pink or blood-streaked saliva. In these cases, pure oxygen should be given as first aid and the diver should be hospitalized immediately.

As explained above, pulmonary edema is possible when a depression is created in the lungs following an ineffective *blood shift*. As we know, this phenomenon is a physiological adaptation that our body undergoes in response to an increase in ambient pressure, and so we need to allow adequate time for the process to occur correctly. For deep freedives, it is important to warm up well before each session and reach the maximum depth of the dive gradually. If you have not dived for a long time, it is also recommended to make multiple dives before diving to your maximum level.

Lung overexpansion

When resurfacing from a dive, the reduction in water pressure causes an increase in the volume of



the air inside your body cavities, including your lungs (Boyle's Law). It can take a few hours for the amount of blood that has been transferred to the thoracic cavity during the *blood shift* phenomenon to be redistributed around the body after diving. This means that when resurfacing from a dive, the pulmonary capillaries are still "swollen" with blood and consequently prevent the alveoli from expanding completely in response to the reduction in ambient pressure. In other words, the volume of your lungs immediately after a freedive is smaller than it was when you began the dive, but the amount of air in your lungs is still the same as the amount you breathed in before the dive. This overexpansion of the lungs can create micro-lacerations in the alveolar wall, causing a small amount of blood to enter the lungs (thus explaining the flecks of blood in the saliva which indicate hemoptysis).



However, lung overexpansion can also cause serious damage to the lungs, such as pulmonary barotrauma (also known as lung over-pressure injury) when the lung walls rupture as gas enters the circulatory system. If the lung tissue tears and air bubbles enter the bloodstream, the diver may suffer a pulmonary embolism, which occurs when one or more air bubbles block the blood supply to any part of the body, including the brain. The symptoms of pulmonary embolism can be slight, such as numbness in the limbs or temporary loss of sight, speech and hearing, or may cause the diver to lose consciousness.

This scenario is unlikely to occur at the depths reached during this *SNSI Advanced Freediver* course, but it may be more of a risk as you dive to deeper depths during more advanced courses. Consequently, it is essential that you learn to surface with your glottis open,

enabling any excess air to escape from your lungs without damaging them. The symptoms of a lung overexpansion injury are immediate and include difficulty breathing (shortness of breath), coughing and blood in the mouth and throat. The seriousness of these symptoms depends on the extent of the damage to the lung tissue. In this scenario, the first response should be to administer pure oxygen at ambient pressure. The injured diver must then be taken to hospital for tests and to assess the extent of the damage.

Diuresis

Diuresis is also affected by the *blood shift*. In fact, high blood pressure in the thorax and heart can result in the production of diuretic hormones that aim to reduce the build-up of pressure.

This can result in the diver becoming dehydrated, particularly given that during your diving sessions you will be spending a long time in the water. It is important to remember to drink enough before entering the water and to continue to hydrate throughout the diving session.

AQUATIC EXERCISES

Easing a cramp on the surface. On the surface, ask your buddy to simulate a cramped calf muscle. Get him to grasp the buoy with one hand and hold



him heel with the other, bringing the affected leg parallel to the water surface and placing the heel on your thigh. Place one hand over the knee to prevent it from bending then with your other hand, push the fin blade towards your buddy. After a few moments, massage the affected calf with the hand that was on the knee.

Surfacing using the arms. If you experience cramp when making a freedive descent, you need to be able to surface despite the pain in your leg. One way of doing this is to swim to the surface using breaststroke arms. Perform a surface dive, fin to the bottom and perform a turn-up. Now simulate a cramp and return to the surface, staying close to



the guide rope and doing underwater breaststroke. Remember to pause between each stroke to fully utilize the momentum. Obviously, try not to move your legs or fins when surfacing.

Surfacing with a single fin. Another method of returning to the surface with a cramp is to use the free immersion technique. Perform a surface dive, fin to the bottom and perform a turn-up. Now take off one fin and lay it on the bottom of the pool. Grasp the guide rope with one hand and pull upwards, looking at the rope. When the arm holding onto the guide rope is fully extended along your body, extend the other arm towards the surface and grasp the rope. Repeat this movement to reach the surface. On reaching the surface, breathe, perform a correct breathing sequence then descend using the free immersion technique to retrieve your fin. Put your fin back on and return to the surface by whichever technique you prefer.

Loss of Motor Control and Blackout Management. If you notice that your buddy or a nearby diver is showing the first signs and symptoms of LMC or seems to have lost consciousness, the first thing to do is to call for help. Next, approach the unconscious diver and roll him onto his back, facing up. The first step is to improve him buoyancy, so unbuckle the weight belt. Remove his mask and, if necessary, his snorkel. Position yourself behind the unconscious diver, placing both hands on the sides

of his head with your palms pressed against his ears, placing your middle or ring fingers below his lower jaw (be careful not to press the other fingers against the soft skin below the chin). Apply slight pressure to enable you to tilt his head backwards to open the airways. Blow energetically on his mouth and repeat: "Breathe! Breathe! Breathe!". If he does not respond, you must begin to administer rescue breaths. Position yourself behind the unconscious diver, placing both hands on the sides of his head with your palms pressed against his ears, placing your middle or ring fingers below his lower jaw (be careful not to press the other fingers against the soft skin below the chin). Apply slight pressure to enable you to tilt his head backwards to open the airways. Begin by giving two rescue breaths to attempt to interrupt the laryngospasm and kick-start the breathing reflex. If this doesn't work, you need to drag the unconscious diver to the shore, blowing in the airways every 5 seconds. Count one thousand and one, one thousand and two, one thousand and three, one thousand and four, administer a rescue breath, then repeat until reaching the shore.

Shallow Water Blackout Rescue. If you notice signs of Shallow Water Blackout while watching your buddy, swim towards him and approach him from behind his right side. Position your left hand below his left armpit and use your right hand to unbuckle the weight belt. Grasp the injured diver under the





armpits and bring him to the surface, keeping your arms extended above you so his body is above yours to make you more hydrodynamic and to stop anything from getting in the way of your fins. Call for help as soon as you reach the surface. Remove his mask and, if necessary, his snorkel. Position yourself behind the unconscious diver, placing both hands on the sides of his head with your palms pressed against his ears, placing your middle or ring fingers below his lower jaw (be careful not to press the other fingers against the soft skin below the chin). Apply slight pressure to enable you to tilt his head backwards to open the airways. Blow energetically on his mouth and repeat: "Breathe! Breathe! Breathe!"

If they do not respond, you must begin to



administer rescue breaths. Position yourself behind the unconscious diver, placing both hands on the sides of his head with your palms pressed against his ears, placing your middle or ring fingers below his lower jaw (be careful not to press the other fingers against the soft skin below the chin). Apply slight pressure to enable you to tilt his head backwards to open the airways. Begin by giving two rescue breaths to attempt to interrupt the laryngospasm and kick-start the breathing reflex. If this doesn't work, you need to drag the unconscious diver to the shore, blowing in the airways every 5 seconds. Count one thousand and one, one thousand and two, one thousand and three, one thousand and four, administer a rescue breath, then repeat until reaching the shore.



SUMMARY

In this chapter you have learned about the physiological adaptations that your body initiates each time you dive underwater while holding your breath, enabling you to dive further and improve your freediving performance. You have also learned the effects these adaptations have on your body and the symptoms and conditions these can cause. You now know how to act and how to plan your diving sessions correctly to create a safe environment for your freedives.





Once you have finished this course,
you are ready for the next adventure:

The SNSI Deep Freediver Course.

Visit the SNSI website or ask your SNSI Freediving Instructor for more information.

www.scubasnsi.com



CHAPTER 8: STUDY GUIDE

1. The diving reflex kicks in:
 - ☐ When you hold your breath.
 - ☐ When your face comes into contact with water.
 - ☐ When your body goes underwater.
2. The diving reflex:
 - ☐ Slows the heartbeat.
 - ☐ Lowers blood pressure.
 - ☐ Reduces breathing frequency.
3. Peripheral vasoconstriction is useful as it helps us to:
 - ☐ Use less oxygen.
 - ☐ Reduce heat loss.
 - ☐ Both.
4. When the spleen contracts, it:
 - ☐ Reduces oxygen consumption.
 - ☐ Produces more red blood cells.
 - ☐ Increases oxygen consumption.
5. The theoretical diving limit is linked to:
 - ☐ The collapse of the lungs.
 - ☐ Partial pressure of oxygen.
 - ☐ Both.
6. Hemoptysis is:
 - ☐ The presence of blood in the respiratory tracts.
 - ☐ The collapse of the lungs.
 - ☐ A pulmonary embolism.



- 7.** What occurs after a pulmonary edema?
- ☐ Blood moves from the alveolar capillaries to the lung.
 - ☐ The saliva is flecked with blood.
 - ☐ Both.
- 8.** Lung overexpansion is caused by:
- ☐ The permeability of the alveolar wall.
 - ☐ The blood shift.
 - ☐ The oxygen concentration.



go to **SNSI**PRO



UNDERWATER **LIFE** PROJECT

DIVE WITH US INTO A GREAT GLOBAL PROJECT

Our initiatives:

- **Mangroves Study** Campaign: The only tree that grows in seawater.
- “**Mission *Hippocampus***”: A census of the seahorse population in the Mediterranean.
- Support for the Università di Bologna for the study and research into **Balanophyllia Europea**.
- Census of **Caulerpa Taxifolia**: The algae is constantly monitored as it is damaging to the environment.
- **Save the Manatees** project in Cuba.
- The **Underwater Biodiversity in the Mediterranean** Project



- The **STE Underwater Biodiversity** project in the Red Sea.
- “**Deep Clean**” aimed at cleaning up the seabed.

Code for C-Card application

Only available in
the printed manual



If you love nature, adventure and sports that require physical and mental dexterity, then this program is for you!

You may be reading this manual for pleasure, to satisfy your curiosity about freediving or to learn more about the SNSI certifying body and our dynamic, modern teaching system.

However, if you are reading it as part of one of the many SNSI training programs, you should be aware that this is only part of a broader course aimed at teaching safe and enjoyable freediving and scuba diving practices. To learn to dive, you must receive additional in-water training with an SNSI Freediving Instructor, and a book is no substitute for the knowledge, experience and safety that only an SNSI instructor can impart.

Join us and you will embark on the never-ending journey of a lifetime, full of discoveries, adventures and memories you will treasure forever!

