

Ocean Diver

The body and the effects of diving

Module objectives

Having introduced how air and water pressure affect divers in relation to basic and scuba equipment in OT1, this module looks in more detail at the human body and the effects of diving on it. Understanding the body provides a background to future modules on diving disorders, prevention and treatment. Diving with nitrox mixes is introduced.

Achievement targets

At the end of this module students should:

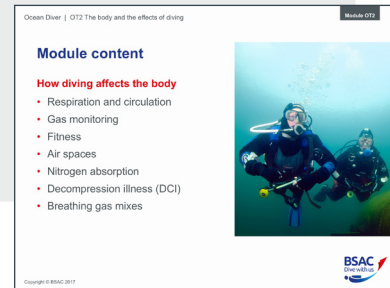
- Have a basic understanding of respiration and circulation
- Understand the need to monitor breathing gas
- Understand the need for general awareness and fitness before diving
- Understand what happens to air spaces in the body when diving
- Have a basic understanding of the effects of nitrogen on the body when diving
- Understand that management of nitrogen is crucial to minimise the risk of decompression illness (DCI)
- Have a basic understanding of breathing gas mixtures and the effect of oxygen on the body when diving

Additional visual aids needed

Instructors should enrich their teaching using additional visual aids: for example dive computers, BSAC dive tables, oxygen analyser, diving cylinder, and so on.

Module content

This session looks in more detail at the effects of diving on the human body.



How diving affects the body

A basic knowledge of how the human body's mechanisms of metabolism, respiration and circulation work under normal conditions will help you understand how diving affects these vital systems. You will also see how diving deeper and increasing ambient pressure leads to greater consumption of breathing gas, so it is vital to monitor your gas consumption at all times.

The module covers the following topics:

- **Respiration and circulation**
When underwater divers rely on their scuba equipment to sustain the key biological processes of respiration and circulation. It is important that divers understand these processes and their impact on gas consumption.
- **Gas monitoring**
Divers need to ensure that they have an adequate gas supply in the scuba cylinders at all stages of a dive. It is vital to monitor your gas consumption at all times.
- **Fitness**
Although a high level of personal fitness is not essential to be able to dive safely, it certainly helps to be in good shape for diving. General fitness will also affect how much gas you breathe and how you feel on a dive.
- **Air spaces**
The human body contains several air spaces, which can be affected by diving. It is important that divers are aware of the effects of going diving on lungs, ears and sinuses as there are various practical precautions to be taken to avoid discomfort and damage.
- **Nitrogen absorption**
It is important to gain a basic understanding of why and how the body absorbs nitrogen during a dive, as this needs to be managed to minimise the risk of decompression illness.
- **Decompression illness (DCI)**
Ocean Divers have limits placed on their diving, for safety and to allow skills to build up with experience, and these limits help to avoid problems resulting

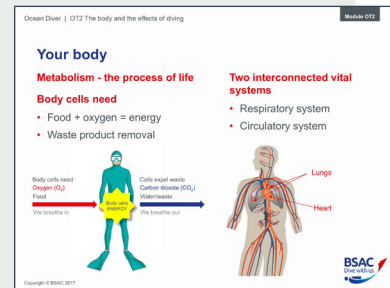
from nitrogen uptake, but students may hear more experienced divers planning decompression diving using tools such as tables and dive computers, and they need to begin to understand the process.

- **Breathing gas mixes**

Ocean Divers are qualified to use nitrox breathing gas mixes with up to 36 per cent oxygen in addition to air, to provide a safety factor in their early dives.

Your body

The human body is composed of trillions of cells, each with a particular function – they are the body’s building and storage blocks and they need energy to work. Metabolism converts the fuel in the food we eat into the energy needed to power everything we do.



Metabolism – the process of life

- **Food + oxygen = energy**

Body cells need food and oxygen to produce the energy that they need. Food is taken in via the digestive system and is broken down by a series of chemical reactions within the cells. Oxygen is a vital ingredient in this process.

- **Waste product removal**

The process of metabolism produces waste products such as water and carbon dioxide as well as energy. The body cells then excrete these waste products to prevent poisoning.

The body can store many of the substances it needs, for example body fat is an energy reservoir, but it cannot store more than a couple of minutes’ worth of the oxygen cells need. There needs to be a constant supply of oxygen to the cells and constant removal of the waste produced.

Two interconnected vital systems

The human body relies on two interconnected systems, which aid the metabolic process and carry gases and waste products around the body.

- **Respiratory system**

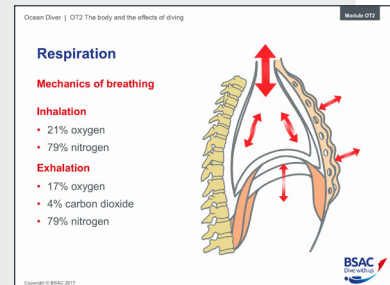
The respiratory system is responsible for drawing the breathing gas into the body and expelling waste gas. The primary organs of the respiratory system are the lungs, where the exchange of gases happens as we breathe.

- **Circulatory system**

This circulatory system pumps blood around the body to circulate and transport nutrients and blood cells around the body and to remove waste products.

Respiration

The lungs accomplish two things, first they transfer oxygen from the breathing gas to the blood and second, they transfer carbon dioxide from the blood to the expelled gas. There are sensors in the body that detect the build-up of carbon dioxide. When it reaches the level at which it could become poisonous to the body, the sensors activate a trigger response, which is the stimulus to breathe, and we expel carbon dioxide when we breathe out.



Mechanics of breathing

The chest forms a protective enclosure for the lungs where the ribcage and chest muscles form the sides and the diaphragm, an arched sheet of muscle, the base.

Inhalation

During inhalation, the diaphragm contracts and flattens downwards. At the same time, muscles lift the ribs up and outwards. This action increases the lung volume and draws gas in. You can get the students to inhale to feel this movement.

- **21% oxygen**
Inhaled air comprises approximately 21 per cent oxygen.
- **79% nitrogen**
Inhaled air comprises approximately 79 per cent nitrogen.

Exhalation

During exhalation, the diaphragm relaxes back to its arched position; the muscles relax allowing the ribs to return downwards and inwards. Lung volume reduces and expels gas. You can get the students to exhale to feel this movement.

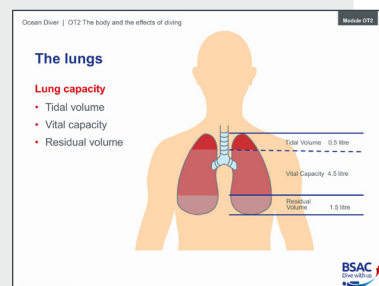
- **17% oxygen**
A proportion of the inhaled oxygen has been used by the body cells.
- **79% nitrogen**
Nitrogen plays no part in normal cell metabolism, it just washes in and out of the body. However, its presence in the body does affect a diver. This will be covered in more detail later in the module.

- **4% carbon dioxide**

The proportion of the inhaled oxygen used by the body cells is replaced in the exhaled gas by a waste product, carbon dioxide. The exhaled air contains four per cent carbon dioxide.

The lungs

It is helpful for divers to have a basic understanding of lung function as poor lung function can have significant impact on our ability to dive safely. Divers should seek medical advice should they suspect any issues with the health of their lungs.



Lung capacity

Lung size depends on body build so it varies from person to person but the average adult's lung capacity is six litres.

- **Vital capacity**

The maximum usable lung volume even with the deepest inhalation or exhalation is approximately four and a half litres. This is known as, the vital capacity.

- **Tidal volume**

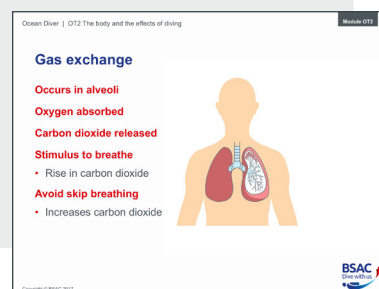
During normal quiet breathing, only a little of lung vital capacity is used, around half a litre, and this called the tidal volume.

- **Residual volume**

The lungs always retain an amount of air to stop them collapsing. This amount, known as the residual volume, is approximately one and a half litres and cannot be expelled, even by breathing out as hard as possible.

Gas exchange

Gas exchange is the process that transfers the oxygen drawn into the lungs to the blood for delivery to the body cells.



Occurs in alveoli

Air passes from the airway into its two branches (the bronchi), each entering a lung where they divide and sub-divide into ever smaller air tubes until they become as thin as a fine hair. At the end of each are microscopic bubble-shaped air sacs called alveoli.

There are about 300 million in each lung. This huge number means that all their surface areas combine to create a very large total surface area to cater for the body's demand for absorbing oxygen. Spread them out and they are about the size of a tennis court.

Surrounding the alveoli is a network of tiny blood vessels called capillaries. Gas exchange takes place through the very thin walls of the alveoli and capillaries. Gases always try to maintain a constant balance and tend to move, or diffuse, from a higher concentration to a lower concentration.

Oxygen absorbed

On inhalation, the alveoli contain oxygen at a higher concentration than that in the blood returning from the body cells and as a result oxygen diffuses into the blood to equalise this difference.

Carbon dioxide released

At the same time, carbon dioxide, the waste product of metabolism, is at a higher concentration in the blood than in the alveoli and so diffuses out of the blood into the alveoli to equalize the difference. Exhaling then expels the waste gas and this is replaced by fresh, oxygen-rich gas on inhaling.

Stimulus to breathe

When carbon dioxide reaches the level at which it could become poisonous to the body, sensors activate a trigger response in the lungs. This creates the stimulus to breathe.

- **Rise in carbon dioxide**

On dry land, there may be different lengths of time that individuals can hold their breath but, ultimately, they have to succumb to the stimulus to breathe to expel the carbon dioxide.

Avoid skip breathing

It is important to note here that although a diver may be breathing in a regular rhythm, there is a natural tendency to hold your breath when concentrating on a new task such as manoeuvring or adjusting buoyancy.

- **Increases carbon dioxide**

Remember that when you are underwater, you must never hold your breath – even just for a few seconds. This is called skip breathing and can result in carbon dioxide, which is now not being expelled properly, to reach elevated levels in your body. This may cause you to become unconscious underwater.

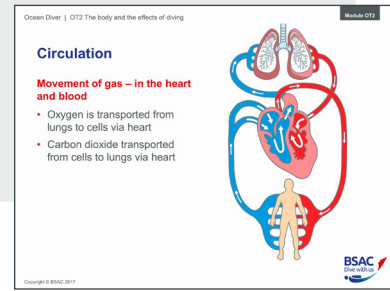
Circulation

It is the job of the circulatory system to transfer the oxygen and carbon dioxide between the cells and lungs.

Movement of gas – in the heart and blood

The heart pumps the oxygen-laden blood from the lungs to the body cells; carbon-dioxide-laden blood is returned from the body tissues to the lungs.

- **Oxygen is transported from lungs to cells via heart**
Oxygen diffused into the blood travels from the lungs to the heart and then to the cells in body tissues. The heart is the pump that continuously circulates the blood around the body.
- **Carbon dioxide is transported from cells to lungs via heart**
Given that inhaled air contains 21 per cent of oxygen, the 4 per cent used by the body may seem quite low, but the body cells cannot metabolise a higher concentration of oxygen. If the cells are working hard, the burn rate (also known as cell respiration) is faster with oxygen used and carbon dioxide produced more quickly. This increases the breathing rate and the heart pumps faster to speed up the blood delivering oxygen and removing carbon dioxide, but the percentages remain the same.



Breathing rate

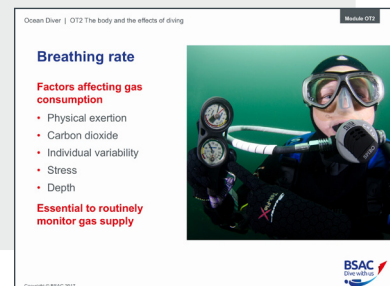
The breathing rate is of particular importance to divers, as its one of the factors that will determine how long they can stay underwater.

Factors affecting gas consumption

There are many variables that affect a diver's gas consumption so divers should be aware of them and their potential impacts for their personal risk assessment.

- **Physical exertion**
The harder a diver works while underwater, the more gas they will use. The greater the physical demand, the more oxygen the diver will require to sustain normal body functions. Physical demand is created in several ways.

Swimming fast will create more demand on a diver's body than swimming slowly and thus will require more gas. Swimming against a current is like running



uphill, if your equipment is not streamlined it increases drag and resistance in the water. All of these activities place greater physical demand on your body and thus use more gas, whether you are on land or at depth.

Physical demand affects each of us differently.

- **Carbon dioxide**

As mentioned above, higher than normal levels of carbon dioxide in the body result in the body increasing the breathing rate in an attempt to bring levels back to normal. Poor dive technique, smoking, illness and poor equipment can all result in elevated carbon dioxide levels.

- **Individual variability**

There are also a number of other variables. Not everyone's breathing rates are the same.

- **Stress**

Nervousness triggers a host of physiological responses, including an increase in pulse and breathing rates. Divers who are apprehensive and nervous use more air than someone who is confident and relaxed.

- **Depth**

The deeper in the water column a diver descends, the more gas they will use. This is because as a diver descends the ambient pressure — the pressure that surrounds them — increases and so the amount of gas needed to fill the lungs to the same volume also increases.

Essential to routinely monitor gas supply

For all divers, monitoring the use of breathing gas is crucial. All divers should carry the gas they need to complete the dive safely. They should also have a plan to access an alternative supply in case of a gas failure.

Fit to dive or exhausted?

Exhaustion is the inability to meet physical demands on the body, perhaps brought on by the effects of physical work and high breathing rates. During diving, there are several factors that can contribute to our level of dive fitness.

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Fit to dive or exhausted?

Physical fitness

- Working hard underwater
- Cold
- The night before
- Illness
- Mental fitness
- Tiredness
- Anxiety

Self-assessment

- You can always dive another day
- Peer pressure



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British Subaqueous Club

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Physical fitness

Although a high level of personal physical fitness is not essential to be able to dive safely, it certainly helps to be in good shape before diving. Divers should try to maintain a good fitness level especially when diving in more challenging temperate water environments. Specifically, divers should take care of the following points.

- **Working hard underwater**
Underwater work caused by hard finning will rapidly cause elevated breathing rates. This can be exacerbated by ill-fitting or restrictive equipment. In such circumstances, divers should stop and regain control of their breathing before continuing.
- **Cold**
Cold water can significantly reduce our ability to function underwater. Divers should always ensure that they have adequate thermal protection for the dive. If divers start to feel cold, then they should abort the dive and remove themselves from exposure to cold and windy conditions.
- **The night before**
A late night out drinking is likely to result in dehydration and a hang-over, which will impair both your mental capacity and physical ability to cope with the demands of diving. Besides, diving with a headache is not great.
- **Illness**
Diving when unwell can cause several problems – including increased breathing, dehydration, loss of concentration. In extreme cases, exercise has been known to trigger heart attacks even in seemingly young and healthy individuals. Colds can also prevent a diver from clearing their ears.

Mental Fitness

- **Tiredness**
Pre-dive tiredness resulting from perhaps a long week at work, long drive or combination of both can reduce a diver's ability to make good decisions when diving. Divers should always make sure they are well rested before diving.
- **Anxiety**
Inexperienced divers may well suffer a bout of anxiety or nerves prior to a dive. In extreme cases, this can reduce a diver's ability to cope with the dive itself. Divers should always look out for signs of stress and anxiety both in themselves and their buddy. This can also happen to experienced divers after a layoff from diving or if extending their diving experience outside of their normal comfort zone, for example on a deeper dive or in new conditions.

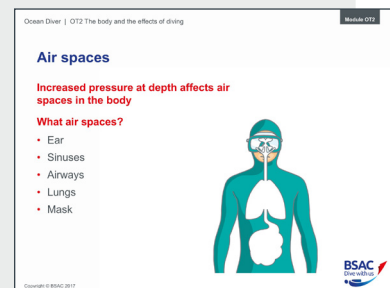
Self-assessment

Divers should always assess their personal fitness to dive. If either physically or mentally unwell, you should cancel your dive.

- **You can always dive another day**
However disappointing, there is always another day that you can go for a dive.
- **Peer pressure**
Divers should also take care to avoid being pressured into undertaking a dive for which they do not feel ready. No one will think any less of you if you decide that the conditions are too rough, the dive is too deep or that you just do not feel ready for the dive.

Air spaces

The human body contains several air spaces, which can be affected by diving. Some of the air spaces are rigid while others are flexible. (The effect of pressure on both rigid and flexible air spaces was covered in OT1).



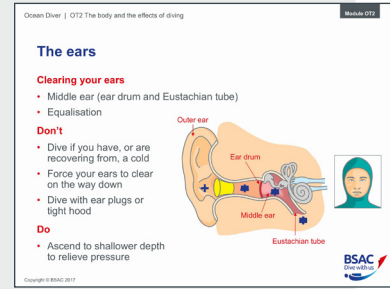
Increased pressure at depth affects air spaces in the body

What air spaces are affected?

- **Ear**
The ear is probably the body's most obviously affected air space. The eardrum creates a flexible air space in the middle ear, which is embedded in skull bone.
- **Sinuses**
The sinuses are rigid air spaces within the skull bone.
- **Airways**
These are relatively rigid structures, which link the atmosphere to the lungs.
- **Lungs**
The lungs are a flexible airspace. Remind students of the need to breathe normally at all times while using scuba equipment to avoid pressure injuries (see OT1).
- **Mask**
Our dive mask also creates an airspace. Failure to equalise the mask will result in 'mask squeeze'. This can be easily avoided. On descent, breathe a little gas into your mask from your nose. Do not over tighten mask straps, so that gas can easily escape from the mask on ascent.

The ears

The ear is divided into three sections: the outer, middle and inner ear. Thin membrane dividers separate each section. Sound waves are funnelled into the outer ear to the first of the membrane dividers, the eardrum, which vibrates in response to the sound waves. These vibrations are transmitted into the air space of the middle ear by a set of small interconnecting bones that arch across it to the next membrane divider. The middle ear air space connects with the back of the throat via the Eustachian tube. The vibrations pass into the fluid-filled inner ear as pressure waves. These are sensed by nerve endings and converted into messages for the brain to analyse. Also housed deep inside the inner ear are sensors that are important for the body's sense of balance and position.



Clearing your ears

- **Middle ear (ear drum and Eustachian tube)**

The middle ear is the most significant part of the ear for diving, as it is air-filled and affected by the pressure changes we experience underwater.

- **Equalisation**

In everyday life, the equalisation of pressure between the middle ear and ambient air pressure happens with involuntary swallowing of saliva which opens the Eustachian tube at the back of the throat. Sometimes a conscious effort is needed to equalise the ears, such as during the sudden increase in ambient pressure when a train rushes through a tunnel. Without clearing, the increased ambient pressure and lower pressure in the middle ear, causes the eardrum to flex inwards and cause discomfort. A conscious action to swallow or gently breathe out against a pinched nose, called a Valsalva manoeuvre, will open the Eustachian tube and introduce gas from the throat to equalise the middle ear.

Diving produces the same effect. Ears are very sensitive to the rapid increase in ambient water pressure on descent, so divers will need to equalise or 'clear' their ears at quite shallow depths and frequently during a descent. As ambient water pressure increases, the eardrum consequently flexes inwards. A Valsalva manoeuvre will equalise the pressure and allow the eardrum to return to normal. Ascending from a dive you don't normally need to clear your ears, as the expansion of gas in the middle ear will naturally open the Eustachian tube.

Problems can arise, even in shallow water, if there is a blockage. The most common is mucus congestion in the Eustachian tube preventing clearing: discomfort will be felt. Resolve this by ascending a little to relieve the discomfort and try ear clearing again. The blockage may clear allowing the diver to

continue down. However, the blockage could worsen during the dive. This will cause more problems on ascent and at the end of a dive you have to ascend. If the ears will not clear, ascend and either dive at a shallow depth (depending on the type of dive), where the ears are not affected, or abort the dive.

Don't

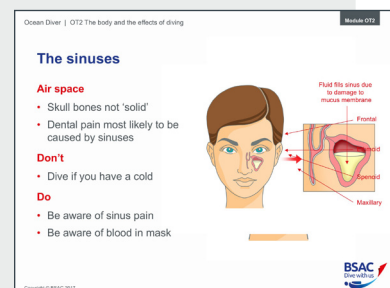
- **Dive if you have, or are recovering, from a cold**
This could result in you forcing your ear to clear and damaging your eardrum on the way down or getting reverse ear damage on the ascent when you cannot prevent the problem.
- **Force your ears to clear on the way down**
To force ear clearing or continue descending while still experiencing discomfort or pain is foolhardy. This will cause ear tissue damage and most likely burst the eardrum. Cold water entering the middle ear will upset the balance organs in the inner ear causing giddiness. Ear damage will curtail diving for some considerable time, affect hearing and, in severe cases, may stop diving altogether.
- **Dive with ear plugs or tight hood**
Less common is a blockage in the outer ear. A tight-fitting hood may block off the ear canal with trapped air between the blockage and eardrum. Equalising the middle ear by Valsalva action will push the eardrum towards the lower pressure with the resultant discomfort. Ensure water is free to enter the outer ear and never wear earplugs when diving.

Do

- **Ascend to shallower depth to relieve pressure**
This relieves the pressure on the ear and stops any pain. You can then assess whether it is possible to comfortably clear your ear and continue the dive or abort.

The sinuses

The sinuses are hollows deep inside the skull bone, above and below the eyes and around the ears. Their function is unknown but it may be that one of the main purposes is to lighten the skull. Air pressure within them normally equalises without any action.



Air space

- **Skull bones not 'solid'**
Embedded in bone, the sinuses are rigid air spaces, which are lined with a mucous membrane containing tiny blood vessels (akin to the lining of the nose).
- **Dental pain most likely to be caused sinuses**
The majority of dental pain experienced by divers is most likely to result from a sinus problem. However, nerves in dental cavities and broken fillings could also feel the effects of pressure when diving, and it is good to have regular dental check-ups.

Don't

- **Dive if you have a cold**
A blockage, generally the result of a cold or infection, can result in sinus squeeze. Without equalisation, the mucus membrane lining the sinus swells and its small blood vessels may tear and bleed, flooding the air space. If the bleeding continues this, will increase the pressure and force the blockage out together with excess blood. To prevent sinus problems, do not dive with a cold, congestion or infection.

Do

- **Be aware of sinus pain**
If a diver experiences sinus pain during a descent (caused by damage to the mucous membrane nerve endings) they should abort the dive. If, after diving, sinus pains occur with regularity, the diver should seek medical attention.
- **Be aware of blood in mask**
Although it might appear alarming, a slight nosebleed during or after a dive is a common sign of a mild sinus blockage.

Quiz 1

Instructors should routinely check for transfer of knowledge to the students. This can be done by asking an open questions such as:

What is the percentage of oxygen in exhaled air?

- 17 per cent

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Quiz 1

What is the percentage of oxygen in exhaled air?



- 17%

The stimulus to breathe is provided by which gas?

- Carbon dioxide

Why should you not dive with a cold?

- May result in pain, and ruptured ear drums

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The stimulus to breathe is provided by which gas?

- Carbon dioxide

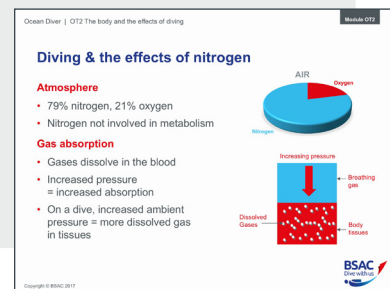
Why should you not dive with a cold?

- May result in pain, and ruptured ear drums

Correct any incorrect answers and reteach the relevant areas if necessary.

Diving and the effects of nitrogen

To understand the effects of the underwater environment on divers, remind students that normally we are attuned to the Earth's surface conditions.



Atmosphere

- **79% nitrogen, 21% oxygen**
The air we breathe is approximately 79 per cent nitrogen and 21 per cent oxygen.
- **Nitrogen not involved in metabolism**
Nitrogen is an inert gas, which is breathed in and expelled from the body. Nitrogen in the body tissues reaches equilibrium with nitrogen in the atmosphere. At atmospheric pressure nitrogen has no adverse effects, however increased pressure underwater makes nitrogen loading an important consideration for divers.

Gas absorption

- **Gases dissolve in the blood**
Gases dissolve in the blood and are carried to and from the body tissues.
- **Increased pressure = increased absorption**
Increasing the pressure of a gas increases its absorption into a fluid. (Pushes more in)
- **On a dive, increased ambient pressure = more gas dissolved in tissues**
Increased ambient pressure on a dive results in gas breathed at higher pressure, results in more gas dissolved in blood and in the tissues.

Nitrogen absorption

Divers need a basic understanding of the process of nitrogen absorption when diving.

On the surface

- **Nitrogen in body is in balance with the atmosphere**

On the surface before a dive, the body is in equilibrium with nitrogen in the atmosphere, the body cannot absorb any more nitrogen.

On a dive

- **Nitrogen absorbed by tissue – on-gassing**

The increase in ambient pressure on a dive pushes more nitrogen into the body. This is known as nitrogen on-gassing.

- **Going deeper or staying longer increases body's uptake of nitrogen**

The increase in ambient pressure results in even more nitrogen dissolving into the body.

- **Different tissues absorb nitrogen at different rates**

The human body is made up of a number of different tissues: muscle, bone, skin, and so on. Each of these tissues absorbs nitrogen at different rates.

- **Fast tissues – good blood supply**

Tissues that have a good blood supply, such as the brain or heart, absorb nitrogen quickly and are known as fast tissues.

- **Slow tissues – poorer blood supply, fatty tissues**

Tissues that have a poor blood supply, such as bones, or have a high fat content, absorb nitrogen more slowly and are known as slow tissues.

The different tissues will accumulate nitrogen at different rates but eventually, given long enough, they would all become saturated at the new ambient pressure and we would be in equilibrium with our new surroundings.



Nitrogen release

Now let us look at why this increased body load of nitrogen is a problem for divers.

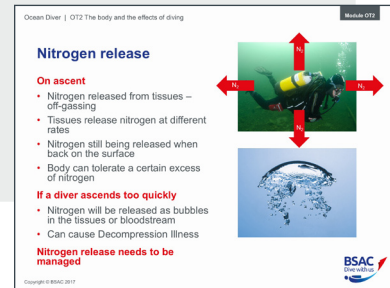
On ascent

- **Nitrogen released from tissues – off-gassing**
As the ambient pressure reduces during the ascent phase of a dive, nitrogen is released from the tissues – this is known as off-gassing.
- **Tissues release nitrogen at different rates**
Just as nitrogen on-gasses at different rates, it also off-gasses at different rates.
- **Nitrogen still released when back on the surface**
The ascent phase of a dive is a relatively short period of time for the tissues to release nitrogen compared with the preceding part of the dive when the body has been absorbing nitrogen. So even after completing a dive and when the diver is back on the surface, the nitrogen continues to off-gas until it reaches a state of equilibrium with the atmospheric pressure – the body's normal state.
- **Body can tolerate a certain excess of nitrogen**
The body can tolerate a certain level of excess nitrogen, but once this has been exceeded, the dissolved gas will begin to come out of solution by forming bubbles of nitrogen gas in the tissues or the blood.

If a diver ascends too quickly

The dissolved gas will rapidly come out of solution and bubbles of nitrogen gas will begin to form in the body tissues

- **Nitrogen bubbles in the tissues or bloodstream**
The principle of fast gas bubble release from a solution can be demonstrated, or referred to, with a bottle of fizzy drink. Open the top too quickly and in equalising the pressure in the bottle with the ambient pressure, bubbles can be seen forming in the liquid and rising to its surface.
- **Can cause decompression illness**
Most of the nitrogen bubbles pass to the lungs and the gas is released through the alveoli. However, the presence of bubbles can slow down the off-gassing process and can distort or damage tissues or block the blood vessels. This can cause oxygen starvation to tissues downstream of the blockage resulting in further tissue damage. This is called decompression illness (DCI).

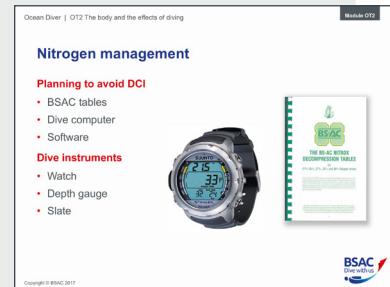


Nitrogen release needs to be managed

Changes in the body's load of nitrogen are inevitable during dives. It is the management of nitrogen absorption and release that is very, very important for divers.

Nitrogen management

To help us manage our nitrogen exposure we have several tools (decompression look-up tables, dive computers and software programs) that we can use to predict the absorption and release of nitrogen based on our exposure time and depth. These help us to plan our dives safely and to minimise the risk of DCI.



Planning to avoid DCI

All these tools are mathematical models with inbuilt parameters that should neither be ignored nor over-ridden. The essential parameters are depth (pressure), time and gas mix.

- **BSAC tables**
Although many divers now use dive computers, understanding the principles of tables will help with understanding computers. The tables are a matrix of depths and dive times, which describe how long and how deep a diver can safely go.
- **Dive computer**
Wrist or console-mounted dive computers are available from a wide range of suppliers. A dive computer can be thought of as an 'automated' table, which constantly calculates the safe time a diver can stay down. Before using such a device, you should carefully read the instruction manual and follow the advice provided for your model. Failure to adhere to these instructions could result in DCI
- **Software**
Divers can also get software programs for home computers, tablets or phones, which can create bespoke dive plans/tables. At this level of their training divers would not be expected to use software programs to create bespoke dive plans, but it is likely that they may be exposed to more experienced and qualified divers using such tools.

Dive instruments

To dive a plan using tables, a diver will need a depth gauge, watch and dive slate as a reminder of the dive plan.

- **Watch**
A diving watch is used to monitor the time spent underwater. Both digital and analogue versions are available.
- **Depth gauge**
Depth gauges are used to monitor depth. Both mechanical and digital gauges are available and both offer maximum depth indicators. Digital gauges do not necessarily offer greater accuracy over analogue versions.
- **Slate**
Write your plan down on a slate, do not try to remember it.

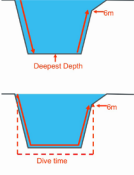
Decompression procedures

Both tables and computers will define a set of standard procedures to be followed when diving a plan that has been generated by that tool. The following items are based on the BSAC tables, but most dive computers will specify similar parameters.

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Decompression procedures

- Slow controlled ascents**
 - 15m/min maximum to 6m
 - 1 min for last 6m
 - Note computers may provide different rates
- Ascent check depth**
 - Brief pause to check plan adherence
- No-stop diving**
- Safety stops**
 - Typically 3 min at 6m
 - Note if conditions are not suitable then should be omitted.



Deepest Depth

Dive time

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Slow controlled ascents

Control of an ascent is very important in the management of nitrogen release. The last 10m is where there is the greatest ambient pressure change.

- **15m/min maximum to 6m**
The BSAC tables specify a maximum ascent rate of 15m a minute – up to 6m.
- **One min for last 6m**
On BSAC tables, the ascent from 6m to the surface should take a minute.
- **Note computers may provide different rates**
Dive computers will often specify slightly differing rates, with 10m per minute all the way to the surface being common across a wide range of devices.

Ascent check depth

This is a feature of the BSAC tables

- **Brief pause to check plan adherence**
The ascent check depth of 6m is rather like a traffic light. Divers need to slow their ascent before the check depth to ensure fine buoyancy control at 6m where dive time is checked against the plan.

No-stop diving

Ocean Divers carry out no-stop diving to a maximum depth of 20m. This is to introduce them to diving with minimum risk, enabling divers to get really comfortable with their buoyancy control on ascent before undertaking more adventurous diving.

Very long or deep dives will cause more nitrogen to be absorbed and it may not be safely eliminated during a direct ascent to the surface. These dives require decompression stops – where a diver will stop at various points during ascent for a number of minutes to allow greater nitrogen release.

Ocean Divers cannot carry out dives requiring mandatory decompression stops. Dives involving decompression stops will require the diver to maintain accurate control of their buoyancy at the ascent check depth for three or more minutes.

Safety stops

Students may hear the term safety stop. This is where divers stop at 6m for a short period of time before ascending to the surface. This is an additional safety precaution.

- **Typically, 3 min at 6m**
It is custom and practice within BSAC to conduct safety stops at 6m, but it should be noted that many diver computers will indicate shallower depths – 3 or 5m are common options.
- **Note if water conditions are not suitable then safety stops should be omitted**

Using nitrox

Nitrox is a breathing gas mixture made up of oxygen and nitrogen, where the percentage of oxygen is greater than 22 per cent.

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Using nitrox


What is nitrox?

- A breathing gas with >22% oxygen


Nitrox mix defined by the Oxygen content

- Nitrox 32 – 32% oxygen + 68% nitrogen
- Nitrox 36 – 36% oxygen + 64% nitrogen

Nitrox 32



Nitrox 36



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Nitrox mixes, because they generally contain a greater percentage of oxygen, contain a correspondingly lower percentage of nitrogen. This helps to reduce nitrogen absorption.

What is nitrox?

- A breathing gas with >22% oxygen**
Ocean Divers may use nitrox mixes with up to 36 per cent oxygen in addition to air.

Nitrox mix defined by the oxygen content

- Nitrox 32: 32% oxygen + 68% nitrogen**
Nitrox 32 contains 32% oxygen.
- Nitrox 36: 36% oxygen + 64% nitrogen**
Nitrox 36 contains 36% oxygen

Nitrox benefits

There are a number of benefits associated with the use of Nitrox 32 or 36 as your diving gas in comparison with air (Nitrox 21).

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Nitrox benefits


Advantages of less nitrogen

- Reduced risk of DCI when used with air table or computer
- Some divers find it reduces fatigue

Disadvantages

- Nitrox divers can still suffer DCI
- Some methods of cylinder filling can expose cylinders to 100% oxygen
 - Cylinders need periodic cleaning
- Oxygen toxicity



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Advantages of less nitrogen

- Reduced risk of DCI when used with air table or computer**
You can use nitrox to provide a greater safety factor against DCI: Air tables and computers (air) assume 79% N₂, however, nitrox mixtures >21% oxygen have less nitrogen, therefore giving less exposure to nitrogen.
- Some divers find it reduces fatigue**
Divers often report that they feel less tired when diving on nitrox, but there is limited evidence to support this claim.

Disadvantages

On the flip side, there are some disadvantages of using nitrox

- **Nitrox divers can still suffer DCI**
Divers are still exposed to nitrogen. Staying over time, rapid ascents, being unfit, drug/alcohol abuse, and all other usual causes of DCI cannot be ignored.
- **Some methods of cylinder filling can expose cylinders to 100% oxygen**
In such cases, cylinders must be in oxygen service
- **Cylinders need periodic cleaning**
Certain equipment may be dedicated for the use of Nitrox in excess of 40%. This may mean additional expense for annual cleaning and certification (oxygen service). Care needs to be exercised that the dedicated equipment is not accidentally contaminated.
- **Oxygen toxicity**
Increased percentage of oxygen in the breathing gas, may lead to oxygen toxicity.

Oxygen toxicity

Although very unlikely to affect Ocean Divers, the following explains what oxygen toxicity is. While there are actually two types of oxygen toxicity, this section concerns only acute oxygen toxicity.

Acute oxygen toxicity can occur when oxygen is breathed in a combination of high percentage and high pressure. This risk increases with higher oxygen percentages, deeper depths and longer duration dives.

(Note: Sports Diver training covers the concept of partial pressures. This is an important concept but is too complex for Ocean Diver students)

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Oxygen toxicity

Risk increases with

- Depth
- Dive duration
- Percentage of oxygen

Avoidance

- Observe maximum operating depth (MOD)

Signs and symptoms

- Sight or hearing disturbance
- Muscular twitching
- Convulsions
- Unconsciousness

Treatment

- Abort the dive and return to surface

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Risk increases with

- **Depth**
As the depth increases and the pressure increases, the body is subjected to higher levels of oxygen, which in turn raises the toxicity risk. Oxygen toxicity determines a maximum operating depth (MOD) for a particular mix, but staying within that MOD does not guarantee freedom from oxygen toxicity.
- **Dive duration**
The length of time that oxygen is breathed at high pressures is also a major consideration.

- **Percentage of oxygen**
Richer nitrox mixes also carry a higher risk of oxygen toxicity.

Avoidance

It is essential that oxygen percentages are checked by analysing the cylinder contents both at the filling station, and then again just before the nitrox mix is used. This ensures that divers know exactly what mixture they are breathing.

- **Observe maximum operating depth (MOD)**
Knowing the percentage of oxygen in the mix allows the diver to accurately know the MOD of their mix. Do not exceed the MOD. Ocean Divers should also stay within their 20m depth limit.

Signs and symptoms

The following signs and symptoms do not necessarily happen in any order and some may not happen at all.

- **Sight or hearing disturbances**
Visual or auditory disturbances, including dizziness or nausea, can occur.
- **Muscular twitching**
Muscular twitching of the face, lips, or fingers may be seen.
- **Convulsions**
In serious cases convulsions or fits may occur, which lead to a significant risk of drowning when underwater.
- **Unconsciousness**
Unconsciousness may result with potentially serious consequences.

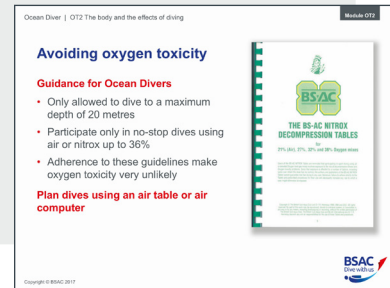
Treatment

Remind students that prevention is better than cure. Ocean Divers are restricted to 20m maximum depth and to nitrox mixes of up to 36 per cent, which should largely eliminate the risk of oxygen providing you follow the rules. In the event of an oxygen toxicity incident

- **Return to the surface, abort the dive**
This may require the buddy to execute a rescue if convulsions or unconsciousness has occurred.

Avoiding oxygen toxicity

To ensure that Ocean Divers can safely use nitrox there are a number of controls have been put in place to minimise the risk posed by oxygen toxicity.



Guidance for Ocean Divers

The depth limit of 20m for Ocean Divers combined with the no-stop limit and choice of the standard gas mixes not exceeding 36 per cent virtually eliminate the risk of oxygen toxicity at this stage.

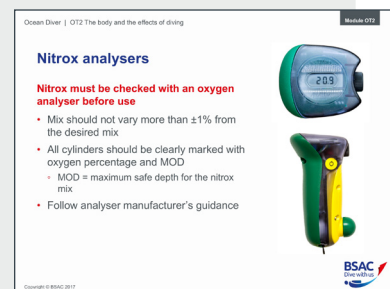
- Only allowed to dive to a maximum depth of 20m
- Participate only in no-stop dives using air or nitrox up to 36%
- Adherence to these guidelines make Oxygen toxicity very unlikely

Plan dives using an air table or air computer

In addition, Ocean Divers should treat nitrox as air when it comes to dive planning for increased safety over increased dive time. Sport Diver training covers the option of using nitrox to extend dive time.

Nitrox analysers

There are a wide variety of oxygen analysers available on the market, and the methods of operation of each are likely to differ, however, there is a generic principle of operation. We will go through an example (by kind permission of Analox.com) of such a generic principle of operation. It is important therefore, to follow the manufacturer's instructions for the proper use of the instrument in each case.



Nitrox must be checked with an oxygen analyser before use

Remind students that oxygen percentages should always be checked before use.

- Follow manufacturer's guidance
Always read the manufacturer's instructions for the analyser and follow these carefully.
- Mix allowed to vary $\pm 1\%$ from the stated mix
In September 2006, British Standard BS 8478:2006 was introduced defining

what diver grade oxygen and nitrox is and what the measurement tolerances should be for a particular range of nitrox breathing mixes. This defines the standard for commercially supplied nitrox. For general measurements on site, if analysis shows that the mix is more than 1 per cent different from the mix desired, then the mix must not be used and the filling station requested to adjust the mix or refill the cylinder

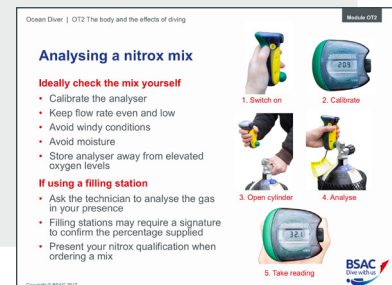
Example: The desired mix is nitrox 32

Acceptable readings are between 31 and 33 per cent. Outside this is unacceptable.

- **All cylinders should be clearly marked with oxygen percentage and MOD**
When using nitrox, all cylinders must be labelled with the percentage of oxygen contained and its MOD.
- **MOD = maximum safe depth for the nitrox mix**
- **Follow analyser manufacturer's guidance**
Always read the manufacturer's instructions for the analyser and follow these carefully.

Analysing a nitrox mix

Remind students to follow the guidance provided in the manufacturer's instructions. Wherever possible check the mix immediately before diving.



Ideally check the mix yourself

- **Calibrate the analyser**
Start by calibrating the analyser to ensure it provides an accurate result. Switch on the gas analyser and do an air calibration. This is essential before use.
- **Keep flow rate even and low**
Very slowly open the cylinder valve until the gas is heard gently hissing out. Present the analyser to the cylinder valve outlet and hold firmly to prevent gas escaping. Close the pillar valve after a short period (this will depend upon the analyser type). Take a reading. Care must be taken here to ensure that the cylinder gas reading is taken and not the surrounding, ambient air. Record the analysis: non-stable or erratic readings points towards analyser failure. Your analysis must be within plus or minus one per cent of your target mix.
- **Avoid windy conditions**
Try to avoid taking measurements in windy conditions. The high airflow could

result in inaccuracy.

- **Avoid moisture**
Water vapour will reduce the life of your oxygen sensors and could result in imprecise results.
- **Store analyser away from elevated oxygen levels**
Again, this would reduce the life of the oxygen sensor.

If using a filling station

Although the best advice is to check the fill yourself, many divers will not have access to their own analyser and will rely on the analysis of their gas provider.

- **Ask the technician to analyse the gas in your presence**
Although breathing gas suppliers are rigorous in controlling breathing gas mixtures, experience shows that it is possible for a mixture to be supplied which does not correspond to the cylinder markings or desired mix. All breathing gas mixtures should be checked on receipt and re-checked immediately before assembling the scuba unit.
- **Filling stations may require a signature to confirm the percentage supplied**
Many filling stations will show you the analyser and the percentage. Typically, they will then request a signature to confirm that you have accepted the mix provided. Note that you will normally be required to present your nitrox qualification when requesting and signing for a fill.

Quiz 2

Instructors should routinely check for transfer of knowledge to the students. This can be done by asking an open question such as:

What are the signs and symptoms of oxygen toxicity?

- **Sight or hearing disturbances**
- **Muscular twitching**
- **Convulsions**
- **Unconsciousness**

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Quiz 2


What are the signs and symptoms of oxygen toxicity?

- Sight or hearing disturbances
- Muscular twitching
- Convulsions
- Unconsciousness

What are the advantages of nitrox?

- Reduced risk of DCI when used with air table or computer

?



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What the advantages of nitrox?

- Reduced risk of DCI when used with air table or computer

Correct any incorrect answers and reteach the relevant areas if necessary.

Summary

Recap the module objectives and provide students with opportunity to ask questions.

The body and the effects of diving

- Respiration and circulation
- Gas monitoring
- Fitness
- Air spaces
- Nitrogen absorption
- Decompression illness (DCI)
- Breathing gas mixes

