Diving Physiology

Sources

- Joiner, J.T. (ed.). 2001. NOAA Diving Manual - Diving for Science and Technology, Fourth Edition. Best Publishing Company, Flagstaff, AZ.

Objectives

- After completing this training module you will be able to:
  - Describe the basic systems of the human body
  - Describe the process, mechanics, and control of respiration
  - Describe circulation, blood transport of oxygen and carbon dioxide, tissue gas exchange, and tissue use of oxygen

Objectives

- After completing this training module you will be able to:
  - List signs & symptoms and prevention / treatment strategies of respiratory problems associated with hypoxia, carbon dioxide toxicity, hyperventilation, shallow water blackout, carbon monoxide poisoning, excessive resistance to breathing, and lipoid pneumonia
  - Describe direct effects of pressure on descent associated with the ears, sinuses, lungs, and eyes

Objectives

- After completing this training module you will be able to:
  - Describe direct effects of pressure during ascent including reverse block, pneumothorax, mediastinal and subcutaneous emphysema, and arterial gas embolism
  - List four ways to help prevent lung overexpansion injuries

Objectives

- After completing this training module you will be able to:
  - Explain indirect effects of pressure during descent including inert gas narcosis, high pressure nervous syndrome, CNS oxygen toxicity, and whole-body oxygen toxicity
  - Differentiate between hypothermia and hyperthermia; listing signs & symptoms and prevention/management strategies

Objectives

- After completing this training module you will be able to:
  - Describe indirect effects of pressure during ascent associated with inert gas elimination, decompression sickness, aseptic bone necrosis, patent foramen ovale, and pregnancy
  - Describe concerns associated with the use of prescription and illicit drugs, smoking and alcohol use, and diving

General

- This module provides an overview of how the human body responds to the varied conditions associated with diving
- A knowledge of diving physiology contributes to diving safety and enables a diver to describe diving-related medical symptoms when they occur

Systems of the Body

Musculoskeletal System

- Bones provide the structure around which the body is formed and protection to the organs
- From a diving perspective bones are the last tissues to become saturated with inert gas

Musculoskeletal System

- Muscles also provide protection for vital organs
- The contraction of muscles causes movement
- Some muscles are controlled consciously, while others, like the heart, function automatically

Nervous System

- The nervous system includes the brain and spinal cord, referred to as the central nervous system (CNS), and a complex network of nerves

Nervous System

- The basic unit of the nervous system is the neuron, which has the ability to transmit electrochemical signals as quickly as 350 feet per second
- There are over ten billion nerve cells in the body, all originating in the brain or spinal cord

Nervous System

- The brain uses approximately 20% of the blood’s available oxygen supply, at a rate ten times faster than other tissues; its cells will begin to die within four to six minutes if deprived of that oxygen supply

Digestive System

- Consisting of the stomach, small and large intestine, the salivary glands, pancreas, liver, and gall bladder; the digestive system converts food to a form that can be transported to and utilized by the cells

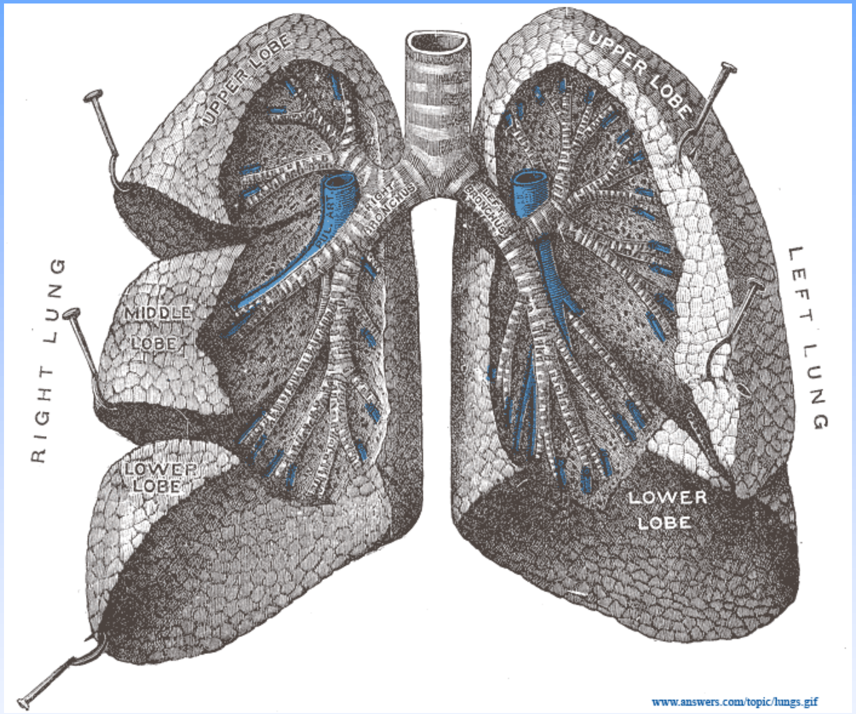
Respiration and Circulation

Process of Respiration

- Respiration is the process of getting oxygen (O_2) into the body, and carbon dioxide (CO_2) out
- Air is warmed as it passes through the nose, mouth, and throat; continuing down the trachea into two bronchi at the top of each lung

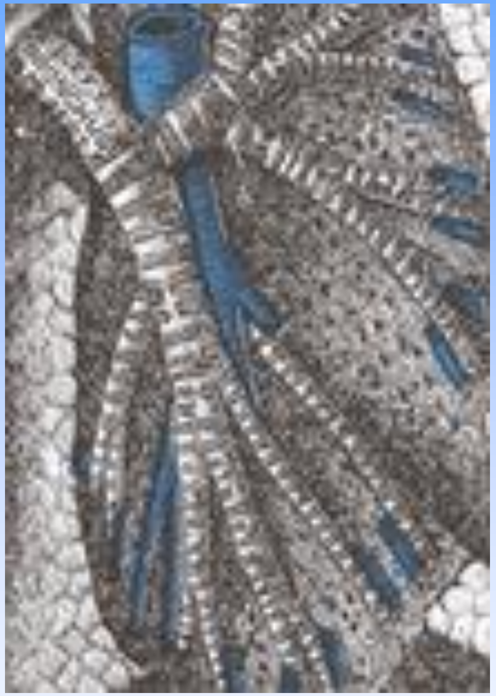
Process of Respiration

- These bronchi divide and re-divide into ten bronchopulmonary branches which make up the five lobes of the lungs; three for the right lung and two for the left (allowing room for the heart)



Process of Respiration

- In each lobe, the branches divide into smaller bronchioles



Process of Respiration

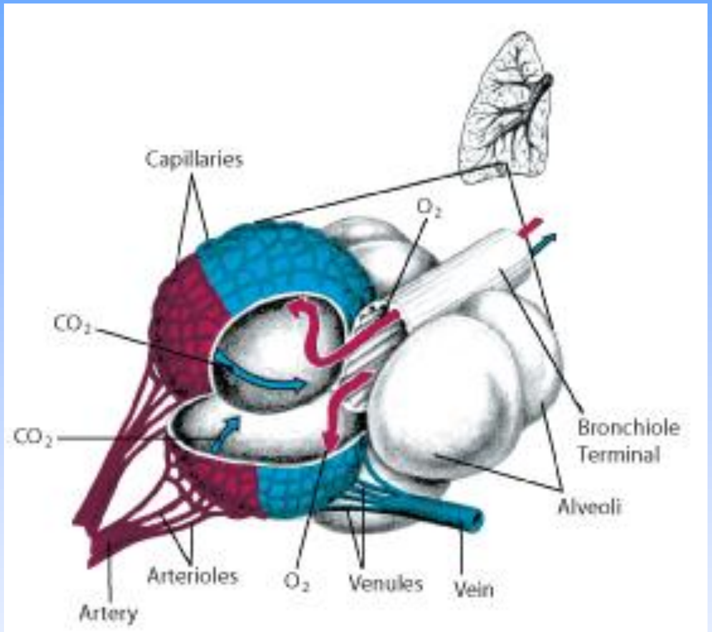
- Larger bronchioles have a muscular lining that can squeeze and relax to regulate how much air can pass
- Special cells lining the bronchioles secrete mucus to lubricate and moisten the lungs, and to trap dust and other particles for removal

Process of Respiration

- The bronchioles are honeycombed with pouches, each containing a cluster of tiny air sacs called **alveoli**
- Each alveolus is less than 0.04 inches (1 mm) wide and is surrounded by a network of capillaries
- There are about 300 million alveoli in each lung

Process of Respiration

- The single cell, semi-permeable, wall separating alveoli and capillary is where the gas exchange between lungs and blood flow takes place
- O_2 and other gases are absorbed by the blood and dissolved CO_2 and other gases are released



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Mechanics of Respiration

- Normal inhalation requires contractions of the inspiratory rib muscles (external intercostals) and the diaphragm

Mechanics of Respiration

- These contractions enlarge the chest cavity, pulling on the pleura surrounding the lungs which decreases pressure within the lungs by increasing lung volume allowing air to flow in

Mechanics of Respiration

- To exhale, the diaphragm and inspiratory muscles relax, pushing on the lungs by elastic recoil and pushing air out
- Exhalation can be increased by contracting the abdominal and expiratory chest muscles (internal intercostals)

Mechanics of Respiration

- Tidal volume – the volume of air breathed in and out; at rest it averages 0.5 liters
- Vital capacity – the largest volume exhaled after maximum inhalation; larger people generally have a larger vital capacity
- Inspiratory reserve – the amount you can forcibly inhale after a normal inhalation

Mechanics of Respiration

- Expiratory reserve – the amount you can forcibly exhale after a normal exhalation
- Residual volume – air left in lungs after exhalation; keeps lungs from collapsing

Mechanics of Respiration

- In addition to gas exchange, the lungs also work as filters for air passing into the lungs , and for the blood supply
- This filtration extends to small bubbles generated during diving ascents, but too many bubbles will overwhelm these pulmonary filters

Control of Respiration

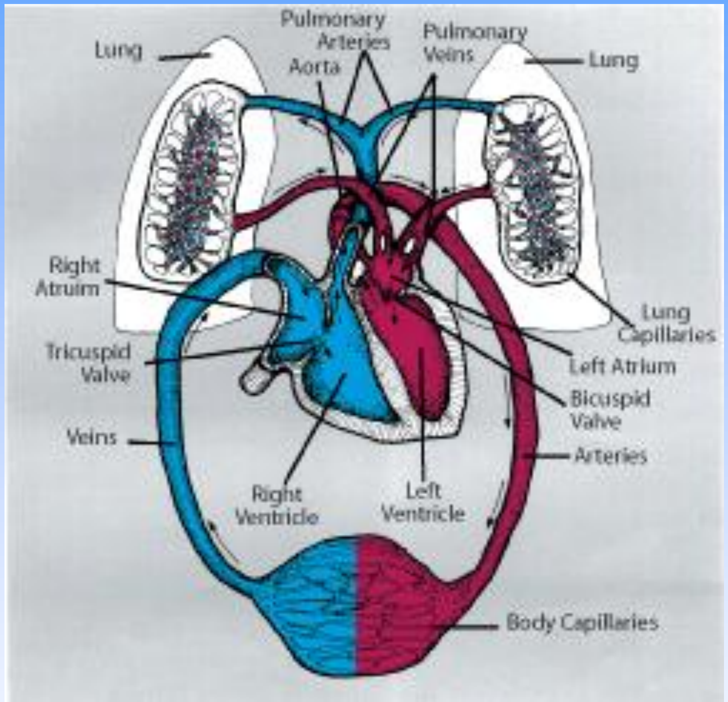
- The need to breathe is controlled by CO_2 levels in the body
- Rising production of CO_2 during exercise stimulates receptors in the respiratory center of the brain resulting in an increase in the ventilation rate

Control of Respiration

- **Hyperventilation**, (an excessive ventilation rate) can lower CO_2 too far, reducing the drive to breathe to the point that one can become oxygen deficient (**Hypoxia**)

Circulation

- O_2 from the atmosphere enters the lungs and moves from the alveoli into capillaries. These capillaries join together into venules, which join to become the pulmonary vein



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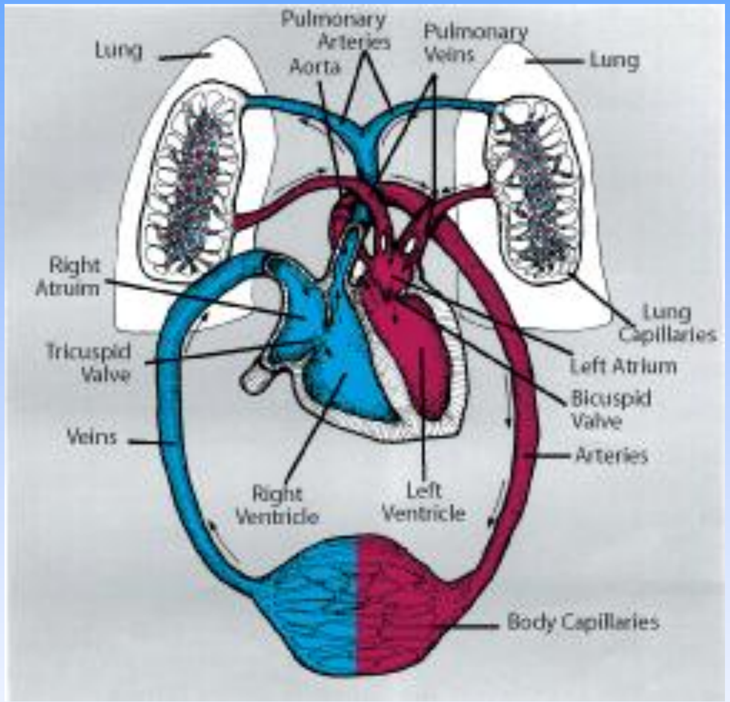
Circulation

- The pulmonary vein brings oxygenated blood from the lungs to the heart



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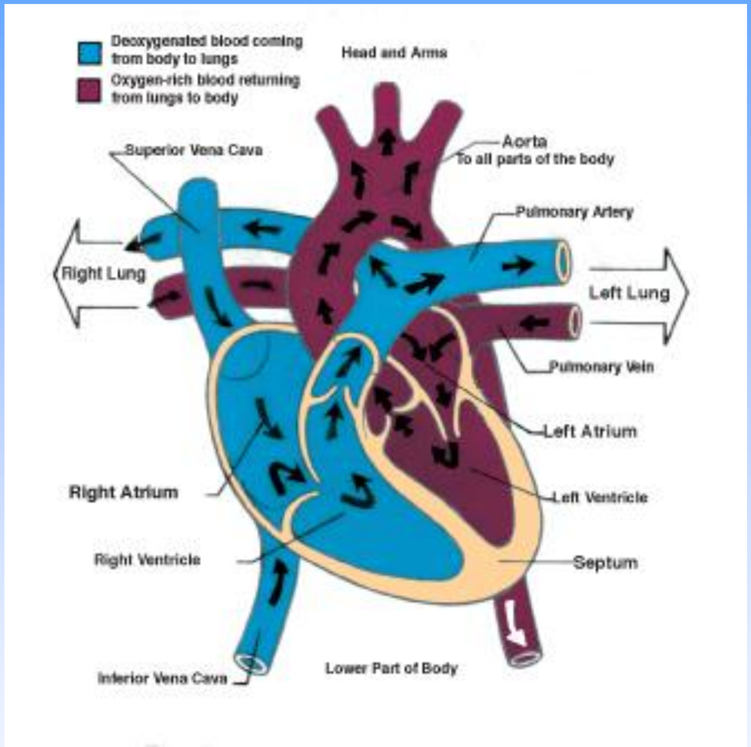
Circulation



- De-oxygenated blood enters the heart via the superior and inferior vena cava, flows into the right atrium, right ventricle, to the lungs via the pulmonary artery

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Circulation

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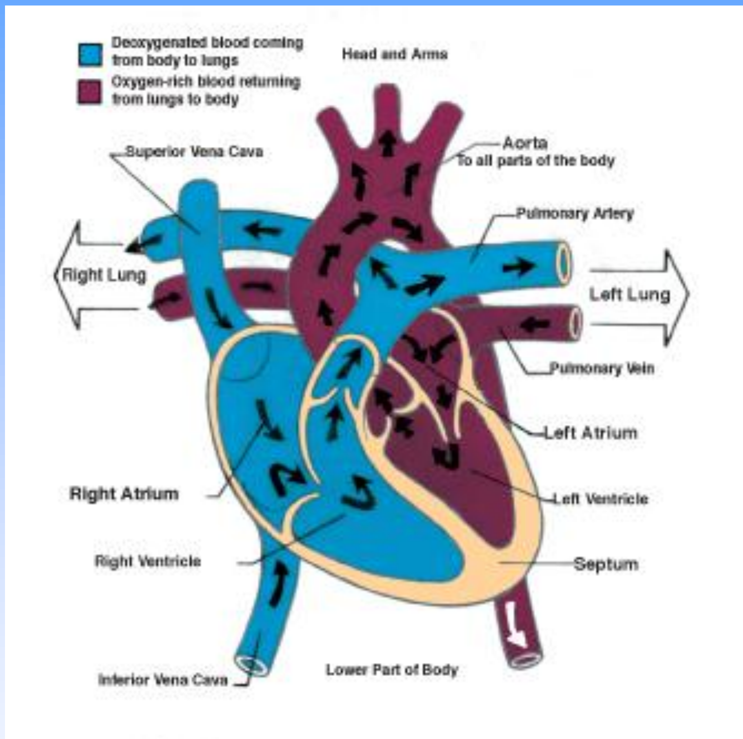

- Oxygenated blood flows from the lungs to the left atrium via the pulmonary vein, through the left ventricle to the body via the ascending and descending aorta

Circulation

- Arteries branch into progressively smaller arterioles that increase in number and decrease in size until they become capillaries

Circulation

- The human body has nearly 60,000 miles (100,000 km) of capillaries. They are so narrow, blood cells pass through them in single file

Circulation

- Another part of the circulatory system is the lymph system;
  - As blood passes through capillary networks, pressure inside capillaries pushes fluid out of the capillaries
  - The lymph system drains this extra fluid so it can return to the blood vessels to maintain proper blood volume

Blood Transport of O_2 and CO_2

- Oxygen (O_2) is transported in the blood by **hemoglobin**, a red protein molecule found inside red blood cells. At sea level, about 98% of the oxygen in the blood is carried by hemoglobin

Blood Transport of O_2 and CO_2

- Most carbon dioxide (CO_2) reacts with water in the blood cells and is transformed into bicarbonate ions, many of which diffuse into the blood plasma for transport to the lungs

Tissue Gas Exchange

- O_2 and CO_2 diffuse across tissues from areas of higher concentration to areas of lower concentration
  - O_2 moves from oxygenated blood into deoxygenated cells, while CO_2 moves from areas of high concentration in cells, to blood with lower concentrations of CO_2
  - The process is reversed at the lungs

Tissue Use of Oxygen

- The body only uses part of the oxygen supplied to it
- At rest, the body inhales approximately 21% oxygen and exhales about 16%

Tissue Use of Oxygen

- Usually about 25% of the oxygen used by the body is available for muscular activity; the balance produces heat and supports other metabolic functions

Tissue Use of Oxygen

- Unlike other areas of the body with varying blood supply, the brain needs a steady supply of oxygen
- If circulation slows or stops, consciousness may be lost in seconds, and irreparable brain damage may occur within four to six minutes

Tissue Use of Oxygen

- Aerobic fitness is the ability of lungs, heart, and blood to deliver oxygen, and the ability of the muscles and other cells to extract and use it
- People who are aerobically fit are able to deliver, extract, and use more oxygen when exercising

Tissue Use of Oxygen

- Average exercise increases the amount of oxygen needed by active tissues by about ten times
- Heavy exercise can increase the amount needed by about twenty times

Tissue Use of Oxygen

- Merely breathing in more oxygen does not affect how much one can use for exercise; only improvements in aerobic fitness through regular exercise can do that

Tissue Use of Oxygen

- Rapid-onset, short duration, intense activities such as sprints, hauling out of the water, or reacting to an emergency are anaerobic in nature and rely on the use of special stored fuel and glucose, not O_2

Tissue Use of Oxygen

- Regular exercise at high speed & intensity for short periods improves anaerobic capacity

Summary of Respiration and Circulation Process

- The six important, continuous phases of respiration include:
  1. Breathing air into the lungs (ventilation)
  2. O_2 and CO_2 exchange between air in the lung alveoli and blood
  3. O_2 transport by blood to the body tissue
  4. Releasing O_2 by blood cells, and extraction by body cells
  5. Use of O_2 in cells producing waste products including CO_2
  6. CO_2 transport by blood back to the lungs where it diffuses out of the blood and is exhaled

Respiratory Problems

Hypoxia

- Hypoxia results when tissue oxygen pressure drops below normal from an inadequate supply of oxygen
- Situations that may result in hypoxia include:
  - Breathing mixtures low in oxygen
  - Ascending to high elevation
  - Drowning, etc.

Hypoxia

Effects of Different Levels of Oxygen Partial Pressure	
PO_2 (atm)	Application and Effect
<0.08	Coma to ultimate death
<0.08-0.10	Unconsciousness in most people
0.09-0.10	Serious signs/symptoms of hypoxia
0.14-0.16	Initial signs/symptoms of hypoxia
0.21	Normal environmental oxygen (sea level air)
0.35-0.40	Normal saturation dive PO_2 level
0.50	Threshold for whole-body effects; maximum saturation dive exposure
1.6	NOAA limit for maximum exposure for a working diver
2.2	Commercial/military "Sur-D" chamber surface decompression, 100% O_2 at 40 fsw (12 msw) pressure
2.4	60% N_2/ 40% O_2 nitrox recompression treatment gas at six ata (165 fsw/50 msw)
2.8	100% O_2 recompression treatment gas at 2.8 ata (60 fsw/18 msw)
3.0	50/50 nitrox recompression treatment gas for use in the chamber at six ata

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Hypoxia

- Signs and Symptoms:
  - Frequently none (the diver may simply lapse into sudden unconsciousness)
  - Mental Changes similar to alcohol intoxication
  - Confusion, clumsiness, slowing of response
  - Foolish behavior
  - Cyanosis (bluish discoloration of lips, nail beds, and skin)
  - In severe cases, cessation of breathing

Hypoxia

- Prevention:
  - Avoid excessive hyperventilation before a breath-hold dive
  - Always know the amount of oxygen in the gas mixture being breathed

Hypoxia

- Treatment:
  - Get the victim to the surface and into fresh air
  - If victim is breathing, supplying a breathing gas with sufficient oxygen usually causes rapid reversal of symptoms
  - An unconscious victim should be treated as if they are suffering from gas embolism
  - CPR should be administered if necessary

Carbon Dioxide Toxicity

- Carbon dioxide excess (**Hypercapnia**) occurs from too much CO_2 in the breathing gas, or because CO_2 produced by the body is not eliminated properly

Carbon Dioxide Toxicity

- Full-face masks or helmets with too much dead space, **Skip-Breathing** to try to conserve cylinder air, and increased effort of breathing at depth are examples of conditions that can contribute to hypercapnia

Carbon Dioxide Toxicity

- Signs and Symptoms:
  - There may be no symptoms
  - If signs and symptoms are present, they may include:

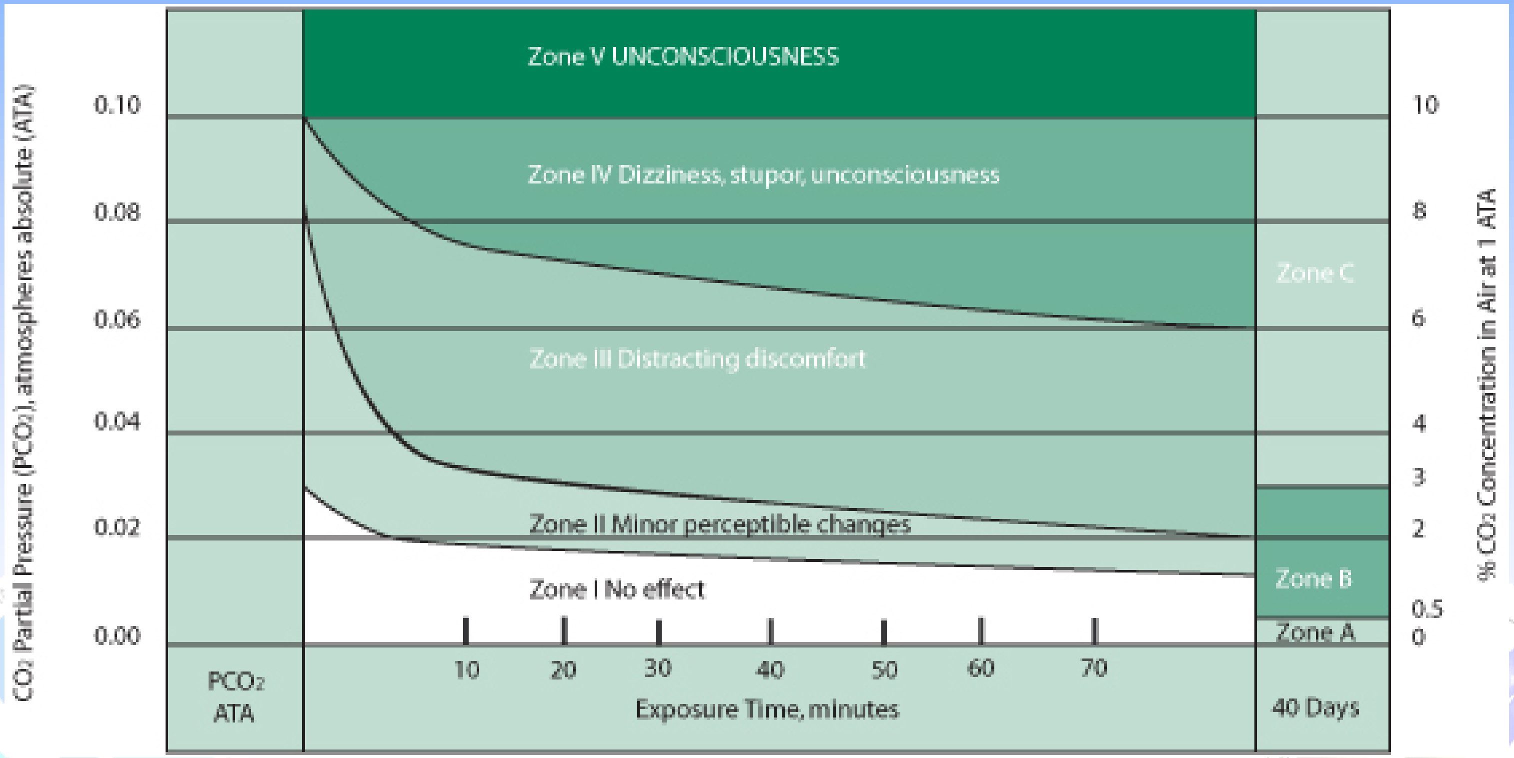
Carbon Dioxide Toxicity

- Signs and Symptoms:

- A feeling of air starvation and an overwhelming urge to breathe
- Headache
- Dizziness
- Weakness
- Perspiration
- Nausea
- A slowing of response
- Confusion
- Clumsiness
- Flushed skin
- UNCONSCIOUSNESS

Carbon Dioxide Toxicity

- The Relationship of Physiological Effects of CO_2 Concentration and Exposure Periods:



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Carbon Dioxide Toxicity

- Treatment:
  - If you experience symptoms stop, rest, breathe deeply, and ventilate yourself and your apparatus. Fresh breathing gas usually relieves symptoms quickly
    - Note: Headache form hypercapnia may persist for some time
  - An unconscious diver requires rescue

Hyperventilation

- Short term, rapid, deep breathing beyond the need for the activity
- Lowers the level of CO_2 in blood (hypocapnia or hypocarbia)

Hyperventilation

- Breath-hold divers often intentionally hyperventilate so they can stay underwater longer (see Shallow Water Blackout)
- Divers may also hyperventilate unintentionally during stressful situations

Hyperventilation

- Signs and Symptoms:
  - Rapid, deep breathing
  - Tingling fingers, lightheadedness, weakness, faintness
  - It is possible to go unconscious

Hyperventilation

- Treatment:
  - Take immediate steps to slow breathing rate
  - Hyperventilation is cause for terminating a dive and requires proper buddy skills to aid in identifying the problem and to assist the victim due to the possibility of unconsciousness

Shallow Water Blackout

- Hyperventilation lowers the amount of CO_2 in the blood, resulting in the urge to breathe being postponed

Shallow Water Blackout

- Breath-hold divers diving too deep for too long use up oxygen, but do not feel the urge to breathe,
- Upon ascent, reductions in ambient pressure reduce the partial pressure of oxygen in the body – this hypoxic condition can cause unconsciousness

Shallow Water Blackout

- Shallow Water Blackout can also be a concern in diving operations where compressed gas divers could find themselves breathing a hypoxic gas in shallow water

Shallow Water Blackout

- Prevention and good buddy skills are the keys to avoiding or responding to shallow water blackout
  - Do not hyperventilate prior to breath-hold diving
  - Know the partial pressure of oxygen (PO_2) and the breathable limits of your diving mixtures
  - Adhere to the buddy system and use proper buddy practices for the diving you are involved in

Carbon Monoxide Poisoning

- Carbon Monoxide (CO) disrupts the entire process of oxygen transport, uptake, and utilization by bonding with:
  - The hemoglobin in the blood;
  - The oxygen-transporting and storage protein of muscle (myoglobin);
  - And respiratory enzymes necessary for oxygen use in cells

Carbon Monoxide Poisoning

- Effects of CO increase with depth

Carbon Monoxide Poisoning

- CO contamination of a scuba cylinder can come from fumes drawn into the compressor intake
- Fumes can come from the exhaust of an internal combustion engine or from partial combustion of lubricating oil in a compressor not properly operated or maintained

Carbon Monoxide Poisoning

- Signs and Symptoms:
  - CO poisoning usually produces no symptoms until the victim loses consciousness
  - Some victims experience headache, nausea, dizziness, weakness, a feeling of tightness in the head, confusion, or clumsiness
  - Victims may be unresponsive or display poor judgment
  - Rapid deep breathing may progress to cessation of breathing

Carbon Monoxide Poisoning

- Signs and Symptoms:
  - The classic sign of "cherry-red" lips may or may not occur and is not a reliable diagnostic aid

Carbon Monoxide Poisoning

- Treatment:
  - Administer oxygen and seek medical attention
  - The treatment of choice is hyperbaric oxygen therapy in a recompression chamber

Excessive Resistance to Breathing

- "Work-of-breathing" is the amount of effort involved in inhaling
- If breathing resistance is high, breathing is more difficult

Excessive Resistance to Breathing

- Work-of-breathing increases with gas flow resistance in poorly tuned regulators, valves, and hoses, and from tight equipment
- Work-of-breathing also increases with depth as gas density increases

Excessive Resistance to Breathing

- The body compensates for high breathing resistance by reducing ventilation which in turn increases CO_2 retention
- To reduce work-of-breathing, breathe normally and keep equipment well tuned and maintained

Lipoid Pneumonia

- Lipoid Pneumonia can result if a diver breaths gas containing suspended petroleum vapor
- Prevent this problem by not allowing oil vapor in the breathing gas, and by ensuring only approved oil is used in compressors

Direct Effects of Pressure During Descent

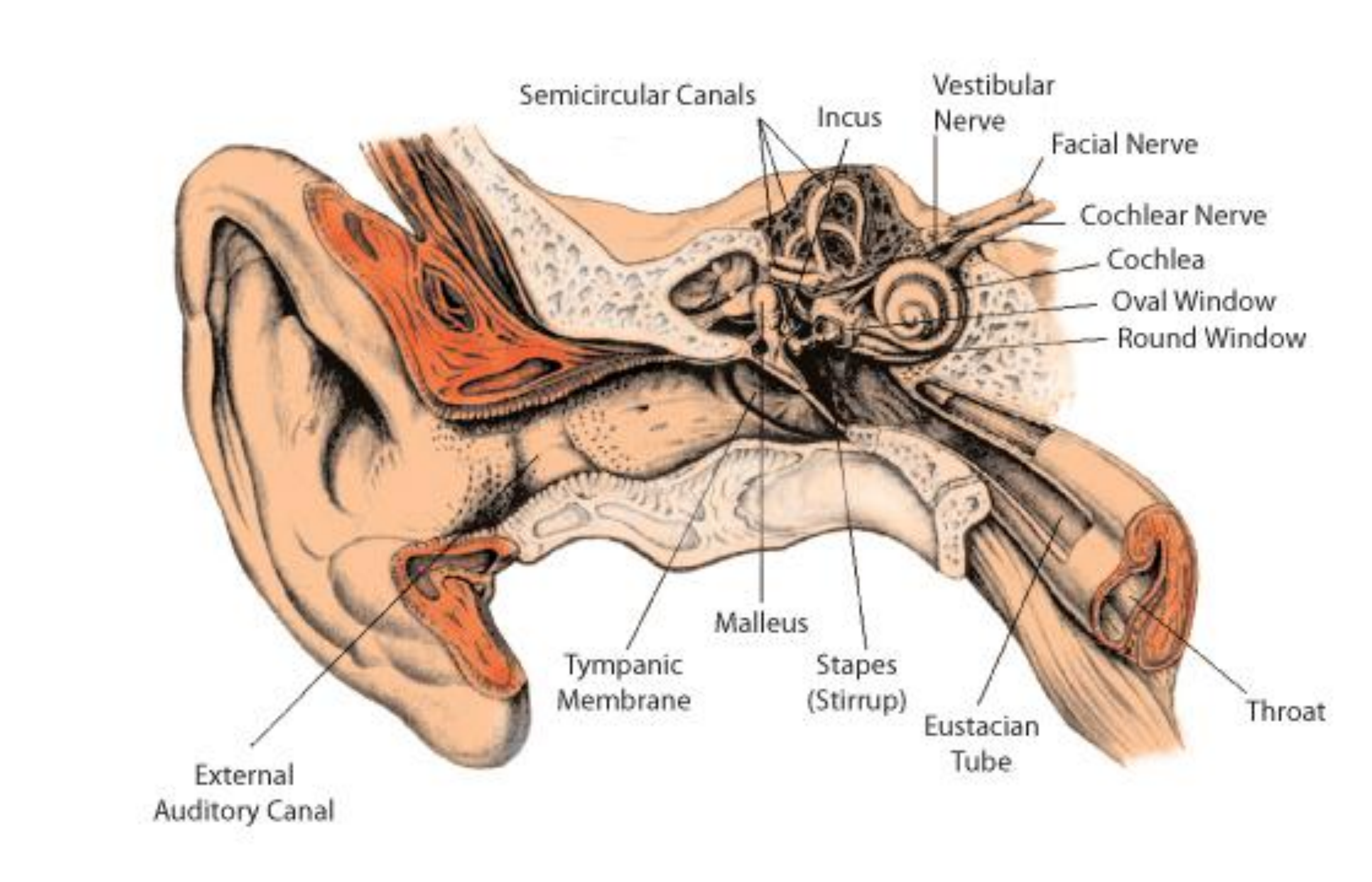
Direct Effects of Pressure During Descent

- The body can withstand great hydrostatic pressure without experiencing barotrauma; liquid areas of the body are essentially incompressible and do not change shape or distort

Direct Effects of Pressure During Descent

- Air spaces are not affected as long as pressure inside the airspace is the same as pressure outside

Ears



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Ears

- The closed airspace of the middle ear is susceptible to Ear Squeeze, as pressure increases on descent and the volume in the airspace decreases

Ears

- Obstructing the external ear canal with ear plugs, earwax, or a hood can produce another closed airspace subject to pressure increase and "squeeze"

Ears

- Fullness or pressure in the region of the external ear canal; a Squeaking sound; Pain; and Blood or fluid from the external ear are all signs and symptoms of ear equalization problems
- If unchecked, these distortions could result in a ruptured ear drum

Ears

- Methods to equalize the pressure in the middle ear include:
  - Swallowing
  - Yawning
  - Using the Valsalva Maneuver – Pinch the noise closed and exhale gently against your fingers - avoid forceful blowing

Ears

- All of equalization techniques should be done early and often during the descent

Ears

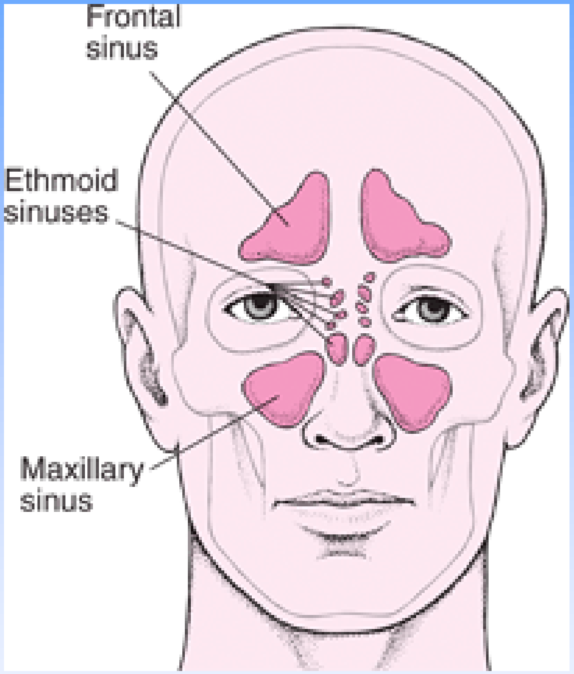
- Removing the obstruction of the external ear canal allows this space to equalize
- If you experience symptoms of an ear squeeze and cannot equalize, stop your descent, ascend to a shallower depth and try to equalize again
- If you cannot equalize, terminate the dive

Sinuses

- The term “sinus” can mean any hollow space or cavity in a bone, or a dilated area of blood vessel or soft tissue

Sinuses

- Here sinus refers to the four paired, mucus-lined, air cavities in the facial bones of the head



Sinuses

- Sinuses normally equalize when you exhale through your nose to equalize the pressure in your mask or when you Valsalva
- Nasal inflammation, congestion, deformities or other blockage can prevent equalization and cause a sinus squeeze

Sinuses

- Fullness or pain in the vicinity of the involved sinus or in the upper teeth; numbness of the front of the face; and bleeding from the nose are signs and symptoms of a sinus squeeze
- As with the ears, if you cannot equalize, terminate the dive

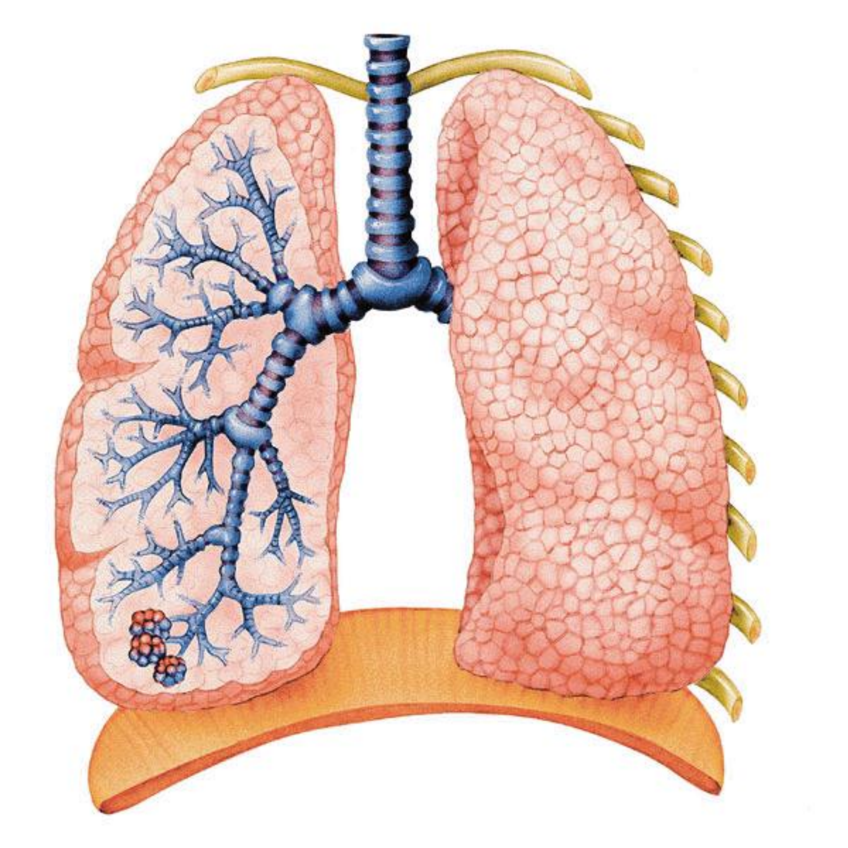
Sinuses

- Over the counter and prescription drugs can open sinus passages, but there is always a risk of them wearing off during a dive, allowing gas to be trapped on ascent
- Do not dive if you have congested sinuses

Sinuses

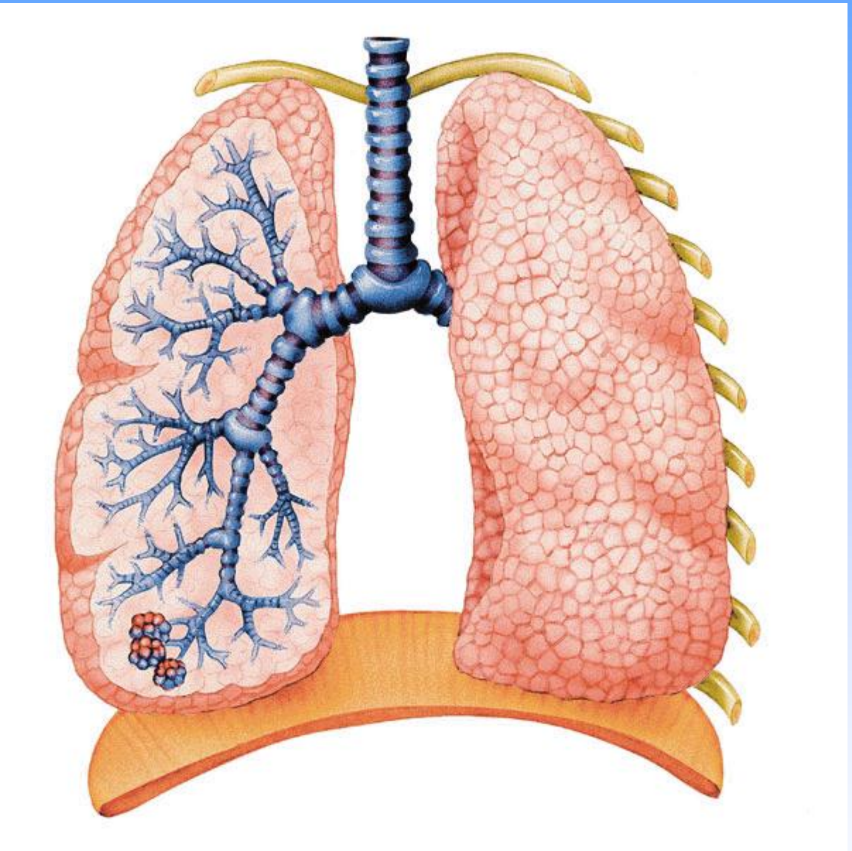
- Most symptoms of sinus barotrauma disappear within five to ten days
- Divers who experience symptoms for longer periods; or have severe pain, bleeding, or yellow or greenish nasal discharge should be seen promptly by a physician

Lungs



- On a breath-hold dive the lungs compress with increasing depth

Lungs



- This compression does not correlate completely to the pressure-volume relationship of Boyle's law due to the body's ability to shift blood into the thoracic blood vessels, maintaining larger than predicted lung volume

Eyes

- Non-compressible fluids in the eyes protect them from increasing water pressure, but without equalization, negative pressure in the mask creates suction that can cause swelling, bruising and bleeding

Photo courtesy Lester Quayle and Rita Barton

Eyes

- This condition, commonly called "eye squeeze" is easily avoided by exhaling into your mask through your nose during descent

Photo courtesy Lester Quayle and Rita Barton

Eyes

- Treatment includes applying ice packs to the damaged tissues and administering pain relievers
- For serious cases, seek the services of a physician

Photo courtesy Lester Quayle and Rita Barton

Direct Effects of Pressure During Ascent

Direct Effects of Pressure During Ascent

- During ascent, ambient pressure decreases and air in the body's air spaces expands
- When this gas vents freely there is no problem
- When expanding gas is blocked from venting, over-inflation occurs and an overpressurization injury can result

Reverse Block

- A reverse block of the ears or the sinus cavities can occur on any ascent but it is more likely to happen when the diver is congested
- Fullness, pressure, or pain in the sinuses and/or ears during ascent are symptoms of a reverse block

Reverse Block

- Swallowing, and wiggling the jaw are acceptable ways to try and clear a reverse block in the ears
- Inhaling gently against your fingers as you pinch your nose may help clear a reverse block of the sinuses or ears, but you should <u>NOT</u> Valsalva on ascent

Reverse Block

- Inhaling through the mouth and exhaling through the nose while remaining stationary or descending slightly in the water column may also help to clear a reverse block

Reverse Block

- Severe reverse block cases can produce bleeding or ruptures of the eardrum or sinus and require medical attention
- At some point you may be forced to ascend with a reverse block

Reverse Block

- Decongestants and nasal sprays may help open the blocked passages and return trapped pressure to normal, but preventing the condition by not diving when congested is the best course of action

Lungs

- Breathing normally during ascent will vent expanding gas without problem, unless there are lung lesions or conditions that obstruct air flow

Lungs

- Breath-holding or insufficient exhalation while breathing compressed gas can result in lung barotrauma; obstruction from chronic or acute respiratory disease, or bronchospasm with asthma can also cause a lung overexpansion injury

Pneumothorax

- The lungs are attached to the chest wall by a thin, paired membrane called the pleura
- The two pleural membranes lie so close to each other that they touch
- A watery fluid lubricates the layer between them and makes a suction between the layers which holds the lungs open

Pneumothorax

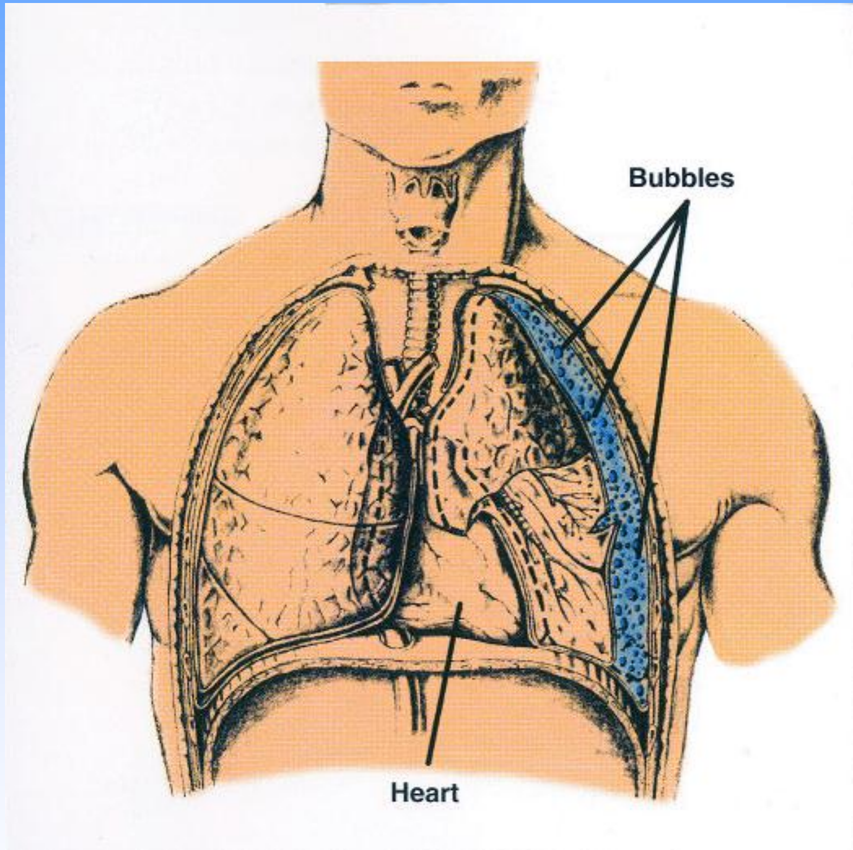
- Air rupturing the lung wall can vent into the pleural cavity creating a pneumothorax breaking the suction between the pleura

Pneumothorax

- There are two types of pneumothorax; simple and tension
  - A simple pneumothorax is a onetime leaking of air into the pleural cavity
  - A tension pneumothorax is a repeated leaking of air from the lungs into the pleural cavity; progressively enlarging the air pocket

Pneumothorax

- A large amount of air in pleural cavity prevents the lungs from expanding



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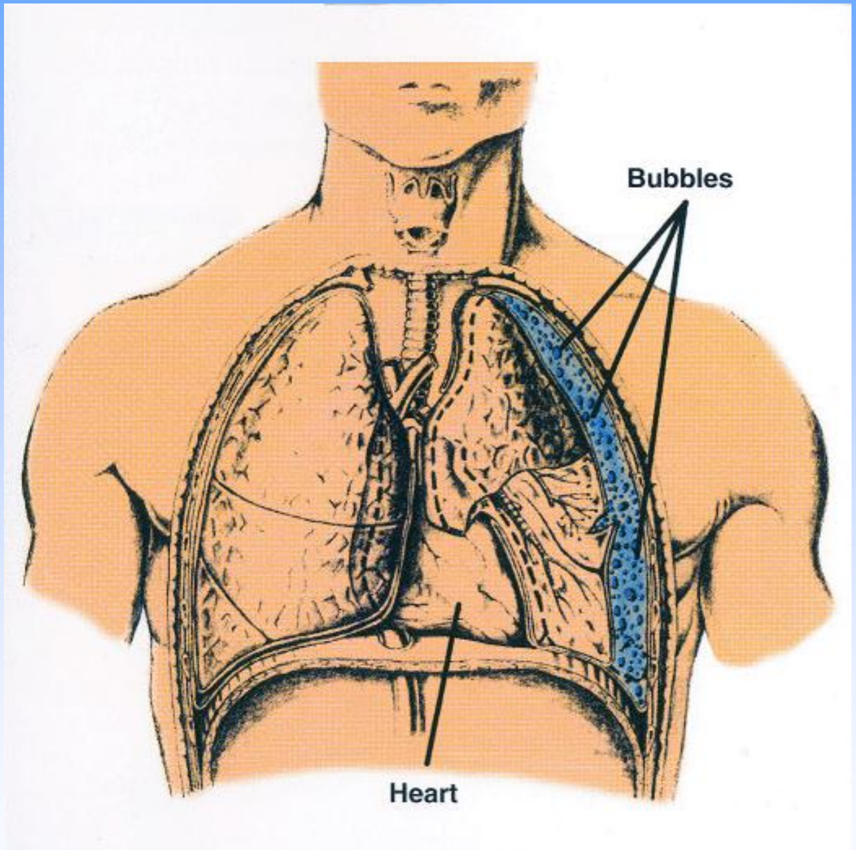
Pneumothorax

- A lung may collapse, the heart may push out of normal position causing sudden severe pain, difficulty breathing, and rarely, coughing frothy blood or death



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Pneumothorax

- Signs and Symptoms:

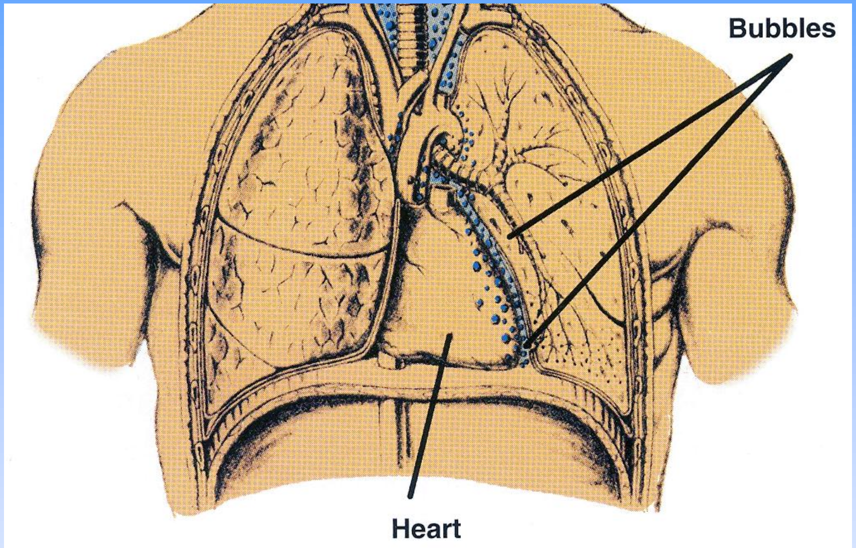
- Difficulty or rapid breathing
- Leaning toward the affected side
- Hypotension
- Cyanosis and shock
- Chest pain (deep breathing hurts)
- Shortness of breath
- Decreased or absent lung sounds on affected side
- Rapid, shallow breathing
- Death

Pneumothorax

- Treatment:
  - Position victim on injured side
  - Monitor for worsening symptoms
  - Monitor CABs (circulation, airway, and breathing)
  - Administer 100% oxygen and treat for shock
  - Transport immediately to a medical facility

Mediastinal Emphysema

- In mediastinal emphysema, air escapes from the lung into tissues around the heart, major blood vessels, and trachea



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Mediastinal Emphysema

- Signs and Symptoms:

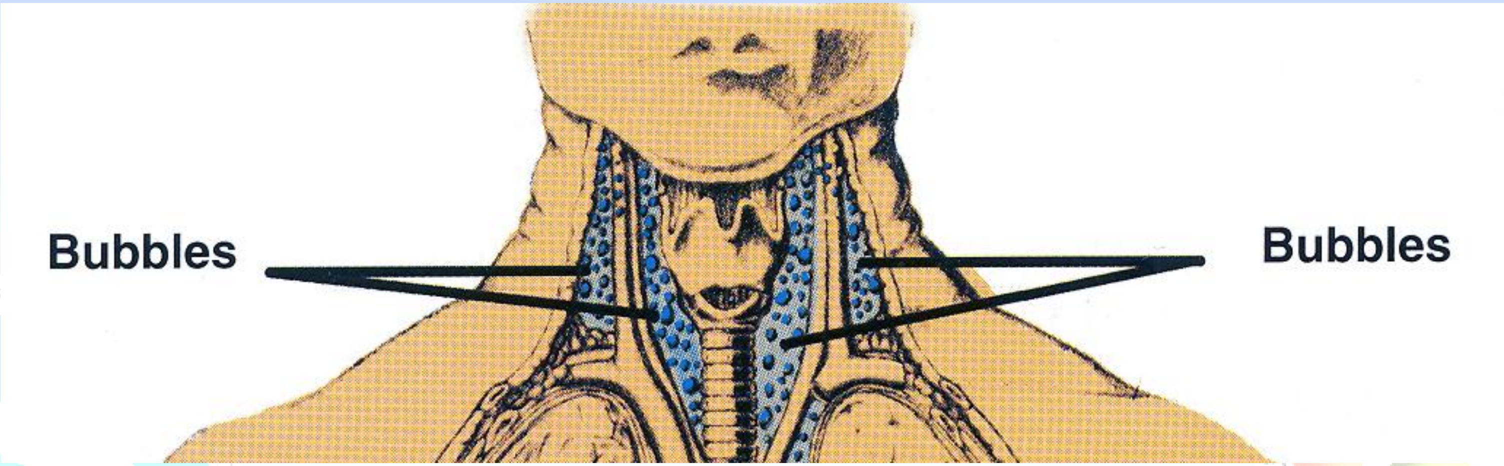
- Pain under the sternum that may radiate to the neck, collarbone, or shoulder
- Shortness of breath
- Faintness
- Cyanosis of the skin, lips, or nailbeds
- Difficulty breathing
- Shock
- Swelling around the neck
- A brassy quality to the voice
- A sensation of pressure on the windpipe
- Cough
- Deviation of the larynx and trachea to the affected side

Mediastinal Emphysema

- Treatment:
  - Monitor CABs
  - Administer oxygen and monitor for shock
  - Transport to the nearest medical facility

Subcutaneous Emphysema

- Subcutaneous emphysema results from air forced into tissues beneath the skin of the neck
- It can be associated with mediastinal emphysema or can occur alone



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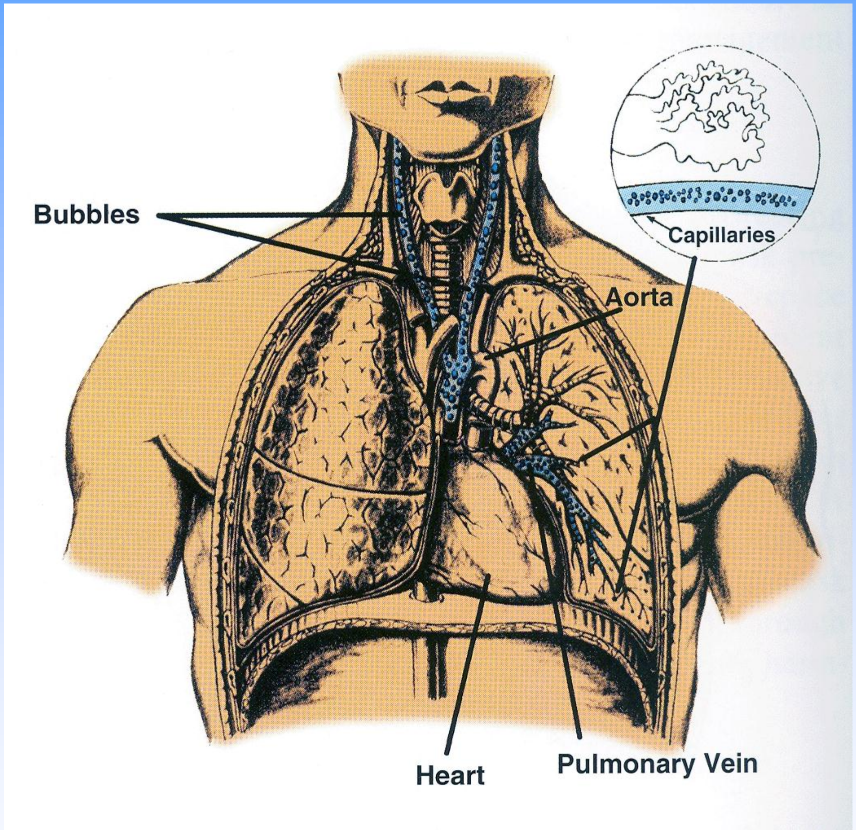
Subcutaneous Emphysema

- Signs and Symptoms:
  - Feeling of fullness in the neck area
  - Swelling or inflation around the neck and upper chest
  - Crackling sensation when skin is palpated
  - Change in sound of voice
  - Cough

Subcutaneous Emphysema

- Treatment:
  - Unless complicated by gas embolism, recompression is not normally required
  - Administer oxygen and have the diver seen by a physician

Arterial Gas Embolism



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- An arterial gas embolism (AGE) occurs when a bubble of gas causes a blockage of blood supply to the heart, brain, or other vital tissue

Arterial Gas Embolism

- Symptoms of an AGE usually occur immediately or within five minutes of surfacing
- One, a few, or all symptoms may be present
- AGE is **LIFE THREATENING,** and **REQUIRES IMMEDIATE TREATMENT**

Arterial Gas Embolism

- Signs and Symptoms:

- Chest pain
- Cough or shortness of breath
- Bloody, frothy sputum
- Headache
- Visual disturbances including blindness (partial or complete)
- Numbness or tingling
- Weakness or paralysis
- Loss of, or change in, sensation over part of body
- Dizziness
- Confusion
- Sudden unconsciousness
- Respiratory arrest
- Death

Arterial Gas Embolism

- Treatment:
  - Establish and maintain CABs
  - Initiate CPR if necessary
  - Administer 100% oxygen with the diver in the supine or recovery position
  - Transport to nearest medical facility and initiate recompression treatment ASAP

Minimize the risk of lung overexpansion injuries by:

- Never holding your breath when diving compressed gases
- Ascending slowly (30 feet per minute [9 meters per minute]) while breathing normally
- Not diving with a chest cold or obstructed air passages
- Carrying sufficient quantities of gas to complete the dive

Emergency Transport Considerations

- Decreased ambient pressure associated with plane flight or ground transportation ascending over mountain passes can aggravate lung overexpansion injuries, AGE, and DCS

Emergency Transport Considerations

- If air transportation is required, an aircraft capable of being pressurized to sea level is preferred
- A helicopter or unpressurized aircraft should be flown as low as safely possible

Stomach and Intestine

- Gas overexpansion injuries of the stomach or intestines are rare
- Belching or heartburn can be experienced

Stomach and Intestine

- To prevent gastrointestinal (GI) barotrauma, breathe normally, don't swallow air, and avoid large meals and gas-producing food and drink before diving

Stomach and Intestine

- Should GI distress occur on ascent, descend to relieve discomfort, and slowly re-ascend
- If surfacing is necessary before relieving pressure, over-the-counter anti-gas preparations may be helpful
- In extreme cases, seek medical attention

Teeth

- Tooth squeeze is not common, but prevention is worth keeping in mind
  - Keep teeth clean, have cavities filled and ill-fitting crowns replaced
  - Before undergoing dental work, inform the dentist that you are a diver

Contact Lenses

- Bubbles have been found in the film of tears beneath contact lenses after ascent
- Affected divers experienced soreness, decreased visual acuity, and the appearance of halos around lights for about two hours after ascent

Indirect Effects of Pressure During Descent

Inert Gas Narcosis

- Inert gas narcosis is a state of altered mental function ranging from mild impairment of judgment or euphoria, to complete loss of consciousness produced by exposure to increased partial pressure of nitrogen and certain other gases

Inert Gas Narcosis

- Narcosis is often first noticed at approximately 100 ft (31 m) when breathing compressed air
- Impairment increases with depth and there is wide variation in susceptibility from diver to diver

Inert Gas Narcosis

- Signs and Symptoms:
  - Loss of judgment and skill
  - A false feeling of well being
  - Lack of concern for tasks or safety
  - Inappropriate laughter
  - Euphoria

Inert Gas Narcosis

- CO_2, fatigue, anxiety, cold, alcohol, medications that might cause drowsiness or reduce alertness can contribute to and compound the effects of narcosis
- Narcosis rapidly reverses with ascent

Narcotic Effect of Compressed Air Diving		
Feet	**Meters**	**Effect**
0-100	**0-30.5**	**Mild impairment of performance on unpracticed tasks. Mild euphoria.**
100	**30.5**	**Reasoning and immediate memory affected more than motor coordination and choice reactions. Delayed response to visual and auditory stimuli.**
100-165	**30.5-50.3**	**Laughter and loquacity may be overcome by self control. Idea fixation and overconfidence. Calculation errors.**
165	**50.3**	**Sleepiness, hallucinations, impaired judgment.**
165-230	**50.3-70.1**	**Convivial group atmosphere. May be terror reaction in some. Talkative. Dizziness reported occasionally. Uncontrolled laughter approaching hysteria in some.**
230	**70.1**	**Severe impairment of intellectual performance. Manual dexterity less affected.**
230-300	**70.1-91.5**	**Gross delay in response to stimuli. Diminished concentration. Mental confusion. Increased auditory sensitivity, i.e., sounds seem louder.**
300	**91.5**	**Stupefaction. Severe impairment of practical activity and judgment. Mental abnormalities and memory defects. Deterioration in handwriting, euphoria, hyperexcitability. Almost total loss of intellectual and perceptive faculties.**
300	**91.5**	**Hallucinations (similar to those caused by hallucinogenic drugs rather than alcohol).**

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High Pressure Nervous Syndrome

- High pressure nervous syndrome (HPNS) occurs at depths greater than 400 fsw (123 msw)
- It was first noted in the 1960s using helium/oxygen breathing mixtures
- HPNS becomes worse with increasing pressure and rate of compression

High Pressure Nervous Syndrome

- HPNS is characterized by dizziness, nausea, vomiting, postural and intention tremors, fatigue and somnolence, sudden muscle twitching, stomach cramps, intellectual and psychomotor performance decrements, and poor sleep with nightmares

High Pressure Nervous Syndrome

- Adding a small amount (5-10%) of nitrogen into the breathing mixture reduces HPNS
- Slow compression, stage compression with long intervals, and careful personnel selections can also prevent or reduce HPNS

Oxygen Toxicity

- There are two types of oxygen toxicity for which divers must be concerned:
  - CNS Oxygen Toxicity (Central nervous system)
  - Whole-Body Oxygen Toxicity

CNS Oxygen Toxicity

- CNS oxygen toxicity can occur at the high end of PO_2 exposures (typically above 1.6 atm)
- The end result may be an epileptic-like convulsion not damaging in itself, but could result in drowning

CNS Oxygen Toxicity

- Susceptibility is highly variable from person to person and even from day to day in a given individual

CNS Oxygen Toxicity

- Susceptibility is increased by factors that cause an increase in internal PCO_2 such as exercise, breathing dense gas, or breathing against resistance
- Immersion, dramatic changes in temperature, and physical exertion also increase susceptibility

CNS Oxygen Toxicity

- Signs and Symptoms are easily remembered with the acronym **CONVENTID**

CNS Oxygen Toxicity

- **CON** – Convulsion
- **V** – Visual disturbance, including tunnel vision
- **E** – Ear ringing
- **N** – Nausea
- **T** – Tingling, twitching or muscle spasms, especially of the face and lips
- **I** – Irritability, restlessness, euphoria, anxiety
- **D** – Dizziness, dyspnea

CNS Oxygen Toxicity

- The use of “air breaks” to reduce or postpone CNS oxygen toxicity incidence is common practice in hyperbaric treatments

CNS Oxygen Toxicity

- The concept of air breaks has been extended to diving situations where supplemental oxygen or high oxygen content mixtures are used for decompression
- In these types of exposures a five minute air break every 20 minutes is recommended

CNS Oxygen Toxicity

- The use of oxygen exposure limits for single dive exposures and exposure to high PO_2 during a 24-hour period have been found to be effective in preventing CNS oxygen toxicity

CNS Oxygen Toxicity

- It should be noted that these “limits” like those associated with dive tables do not guarantee safety if adhered to
- Exceeding the limits may not produce a problem, but does increase the risk

CNS Oxygen Toxicity

- The NOAA Oxygen Exposure Limits should be used to determine your dive time limits for a given PO_2

NOAA Oxygen Exposure Limits		
PO_2 (atm)	Maximum Single Exposure (minutes)	Maximum per 24 hr (minutes)
1.60	45	150
1.55	83	165
1.50	120	180
1.45	135	180
1.40	150	180
1.35	165	195
1.30	180	210
1.25	195	225
1.20	210	240
1.10	240	270
1.00	300	300
0.90	360	360
0.80	450	450
0.70	570	570
0.60	720	720

CNS Oxygen Toxicity

- The chart shows the maximum single dive exposure and the accumulated daily limits at a given PO_2

NOAA Oxygen Exposure Limits		
PO_2 (atm)	Maximum Single Exposure (minutes)	Maximum per 24 hr (minutes)
1.60	45	150
1.55	83	165
1.50	120	180
1.45	135	180
1.40	150	180
1.35	165	195
1.30	180	210
1.25	195	225
1.20	210	240
1.10	240	270
1.00	300	300
0.90	360	360
0.80	450	450
0.70	570	570
0.60	720	720

CNS Oxygen Toxicity

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1.40	150	180
1.35	165	195
1.30	180	210
1.25	195	225
1.20	210	240
1.10	240	270
1.00	300	300
0.90	360	360
0.80	450	450
0.70	570	570
0.60	720	720

- If more than one dive is planned to the maximum single dive exposure of a PO_2 of 1.6, a surface interval of at least 90 minutes is advised

CNS Oxygen Toxicity

- If one or more dives using a PO_2 less than 1.6 reach or exceed the maximum single exposure limit, the diver should spend a minimum of two hours at a normoxic PO_2 (normal oxygen, air)

NOAA Oxygen Exposure Limits		
PO_2 (atm)	Maximum Single Exposure (minutes)	Maximum per 24 hr (minutes)
1.60	45	150
1.55	83	165
1.50	120	180
1.45	135	180
1.40	150	180
1.35	165	195
1.30	180	210
1.25	195	225
1.20	210	240
1.10	240	270
1.00	300	300
0.90	360	360
0.80	450	450
0.70	570	570
0.60	720	720

CNS Oxygen Toxicity

NOAA Oxygen Exposure Limits		
PO_2 (atm)	Maximum Single Exposure (minutes)	Maximum per 24 hr (minutes)
1.60	45	150
1.55	83	165
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1.45	135	180
1.40	150	180
1.35	165	195
1.30	180	210
1.25	195	225
1.20	210	240
1.10	240	270
1.00	300	300
0.90	360	360
0.80	450	450
0.70	570	570
0.60	720	720

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- If the Maximum 24-hour Limit is reached in a 24-hour period the diver must spend a minimum of 12 hours at normoxic PO_2 before diving again

Whole-Body Oxygen Toxicity

- Whole-Body oxygen toxicity is a slow developing condition resulting from exposure to above normal PO_2, generally at levels below those causing CNS toxicity but above a PO_2 of 0.5 atm

Whole-Body Oxygen Toxicity

- Whole-Body oxygen toxicity is of little concern to divers doing no-stop dives, even when breathing oxygen-enriched mixtures (nitrox), but it may be seen during intensive diving operations or long oxygen treatments in a hyperbaric chamber

Whole-Body Oxygen Toxicity

- Signs and Symptoms:
  - Pulmonary irritation resulting in chest pain or discomfort, coughing, inability to take a deep breath without pain or coughing, development of fluid in the lungs, and a reduced vital capacity

Whole-Body Oxygen Toxicity

- Signs and Symptoms:
  - Non-pulmonary symptoms include skin numbness and itching, headache, dizziness, nausea, effects on the eyes, and a dramatic reduction of aerobic capacity during exercise

Whole-Body Oxygen Toxicity

- The risk of developing Whole-Body Oxygen Toxicity is unlikely when using nitrox
- Procedures have been developed for managing this risk when the diver will be conducting many dives over more than a three day period, and where exposures get lengthy

Whole-Body Oxygen Toxicity

- The REPEX method uses the single dose Oxygen Tolerance Unit (OTU) to track extended operational exposures

REPEX Oxygen Exposure Chart for Tolerable Multiple Day Exposures		
Exposure Days	**OTU Average Dose**	**OTU Total Dose**
1	850	850
2	700	1400
3	620	1860
4	525	2100
5	460	2300
6	420	2520
7	380	2660
8	350	2800
9	330	2970
10	310	3100
11	300	3300
12	300	3600
13	300	3900
14	300	4200
15-30	300	As required

Whole-Body Oxygen Toxicity

- The total for a given exposure period is given in the third column

REPEX Oxygen Exposure Chart for Tolerable Multiple Day Exposures		
Exposure Days	OTU Average Dose	OTU Total Dose
1	850	850
2	700	1400
3	620	1860
4	525	2100
5	460	2300
6	420	2520
7	380	2660
8	350	2800
9	330	2970
10	310	3100
11	300	3300
12	300	3600
13	300	3900
14	300	4200
15-30	300	As required

Whole-Body Oxygen Toxicity

- The OTU Calculation Table provides Per Minute OTU units for a range of PO_2s

OTU Calculation Table

PO2 (atm)	OTU Per Minute	PO2 (atm)	OTU Per Minute	PO2 (atm)	OTU Per Minute
0.50	0	1.05	1.08	1.55	1.85
0.55	0.15	1.10	1.16	1.60	1.92
0.60	0.27	1.15	1.24	1.65	2.00
0.65	0.37	1.20	1.32	1.70	2.07
0.70	0.47	1.25	1.40	1.75	2.14
0.75	0.56	1.30	1.48	1.80	2.21
0.80	0.65	1.35	1.55	1.85	2.28
0.85	0.74	1.40	1.63	1.90	2.35
0.90	0.83	1.45	1.70	1.95	2.42
0.95	0.92	1.50	1.78	2.00	2.49
1.00	1.00				

Indirect Effects of Pressure During Ascent

Inert Gas Elimination

- Assuming your body remains at a constant pressure long enough the gases your body absorbs are at equilibrium with the surrounding pressure

Inert Gas Elimination

- Increasing ambient pressure causes the body to absorb or “on-gas”
- Decreasing ambient pressure causes the body to eliminate or “off-gas”

Inert Gas Elimination

- Nitrogen, the inert gas making up the largest percentage of the air we breathe, is of particular concern to divers
- The rate at which nitrogen on-gases and off-gases is measured in tissue or compartment half-times

Inert Gas Elimination

- “Half-times” refer to the time in minutes necessary to uptake or eliminate enough nitrogen (or other gas) to fill or empty half the area with gas
- “Tissue” or “compartment” refers to body areas that on-gas and off-gas at the same rate

Inert Gas Elimination

- Similar compartments can be scattered throughout the body
- Theoretical tissues are further differentiated as being "slow" or "fast" tissues depending on their capacity to absorb the dissolved gas

Inert Gas Elimination

- The speed of a given tissue group depends on the blood supply and the makeup of the tissue

Inert Gas Elimination

- Fatty tissues are examples of slow compartments
- They hold more gas than watery tissues, and take longer to absorb and eliminate gas

Inert Gas Elimination

- Fast compartments usually build higher amounts of nitrogen after a dive than slower ones because they on-gas more in the same time period

Inert Gas Elimination

- When a compartment fills to capacity, it is called “saturated”
- On most dives there is not enough time for total saturation
- Faster compartments may become saturated, while slow compartments may be practically empty, while still others are somewhere in between

Inert Gas Elimination

- Differences in solubility and rates of gas diffusion give different gases different half-times
- Helium is much less soluble in tissues than nitrogen, but it diffuses faster; allowing helium to reach equilibrium faster than nitrogen

Inert Gas Elimination

- On ascent the diver’s tissues, especially slow compartments, may continue to absorb nitrogen
- During ascent, ambient pressure can drive nitrogen into slow tissues, even as higher pressure, fast compartments off-gas

Inert Gas Elimination

- After ascending to the surface (or a shallower depth), it may require 24 hours for equilibration due to half-time gas elimination

Inert Gas Elimination

- No matter how much gas a compartment starts with, it takes six half-times to empty or fill
- For practical purposes 99% is completely saturated or de-saturated

Inert Gas Elimination

- For practical applications like calculating decompression tables, off-gassing is considered to proceed at the same half-time rate as on-gassing
- Safety stops and slow ascent rates (30 fsw [9 msw]) are recommended to allow for proper off-gassing

Inert Gas Elimination

- Decompression requirements are dictated by the off-gassing of inert gases

Inert Gas Elimination

- By breathing 100% oxygen, the inert gas gradient is significantly increased. This can result in an increase in the rate that inert gases are eliminated from the body
- Switching to gases with higher contents of oxygen at appropriate depths can shorten required decompression times

Decompression Sickness

- Decompression sickness (DCS, aka “the bends”) is the result of inadequate decompression following exposure to increased pressure

Decompression Sickness

- If the diver ascends too quickly, the nitrogen absorbed by the diver's body during a dive can come out of solution and form bubbles in the body's fluids and tissues

Decompression Sickness

- The exact trigger for bubble formation is not understood and <u>adhering to accepted decompression limits and proper ascent rates is no guarantee of avoiding symptoms of DCS</u>

Decompression Sickness

- So called silent bubbles have been known to form after dives; producing no symptoms
- Bubbles that do produce symptoms can affect the lymphatic and circulatory systems, damage nerves, and trigger immune system reactions

Decompression Sickness

- The major determinants of risk of DCS are depth, time at depth, ascent rate, and multiple dives
- Individual variation is also a factor, but this area is poorly understood

Decompression Sickness

- Fatigue, dehydration, smoking, alcohol consumption, and carbon dioxide retention may predispose a diver to DCS
- Environmental factors including chilling at the end of a dive, heavy work, and the use of heated suits have also been identified as possible predisposing factors

Decompression Sickness

- It has been common to describe decompression sickness as one of three Types, or to categorize it by the area of involvement and the severity of symptoms

Decompression Sickness

- Type I includes skin itching or marbling; brief, mild pain called “niggles,” which resolve typically within ten minutes; joint pain; lymphatic swelling, and sometimes included extreme fatigue

Decompression Sickness

- Type II DCS is considered to be respiratory symptoms, hypovolemic shock, cardiopulmonary problems, and central or peripheral nervous system involvement

Decompression Sickness

- Type III includes arterial gas embolism and is also called decompression illness (DCI)

Decompression Sickness

- Categorizing DCS by area involved and severity of symptom includes:
  - Limb Bends
  - Central Nervous System (CNS) DCS
  - Cerebral Decompression Sickness
  - Pulmonary DCS
  - Skin Bends
  - Inner-Ear Decompression Sickness

Decompression Sickness

- **Limb Bends** – Dull, throbbing, deep pain in the joint or tissue; usually in the elbow, shoulder, hip, or knee
- Pain onset is usually gradual and slowly intensifies
- In severe cases limb strength can be affected
- In divers, upper limbs are affected about three times as often as lower limbs

Decompression Sickness

- **Central Nervous System (CNS) DCS –** May cause muscular weakness, numbness, "pins and needles," paralysis, loss of sensation, loss of sphincter control, and, in extreme cases, death

Decompression Sickness

- **Central Nervous System (CNS) DCS –** Symptoms are often different from the usual history of traumatic nerve injury
- Strange neurological complaints or findings <u>should not</u> be dismissed as imaginary

Decompression Sickness

- **Cerebral Decompression Sickness** – May produce almost any symptom: headache, visual disturbance, dizziness, tunnel vision, tinnitus, partial deafness, confusion, disorientation, emotional or psychotic symptoms, paralysis, and unconsciousness

Decompression Sickness

- **Pulmonary DCS** – aka the Chokes accounts for about 2% of DCS cases
- Symptoms include: pain under the breastbone on inhalation, coughing that can become paroxysmal, and severe respiratory distress that can result in death

Decompression Sickness

- **Skin Bends** – Come in two forms: harmless simple itchy skin after hyperbaric chamber exposure, or rashy marbling on the torso that may warn of serious DCS

Decompression Sickness

- **Inner-Ear Decompression Sickness** – aka Vestibular DCS or Ear Bends
- Signs and symptoms include vertigo, tinnitus, nausea, or vomiting

Decompression Sickness

- **Inner-Ear Decompression Sickness –**

Ear Bends occur more often after deep dives containing helium in the breathing mixture; particularly after switching to air in the later stages of decompression

Shallow water and/or air divers are not immune

Decompression Sickness

- While you can do everything correctly and still suffer DCS, prevention can be enhanced if you:
  - Ascend slowly (30 ft/min [9 m/min])
  - Make safety stops
  - Use longer surface intervals
  - Plan the dive, dive the plan and have a backup plan
  - Maintain good physical fitness, nutrition, and hydration

Decompression Sickness

- First aid and treatment of DCS includes:
  - Administering 100% oxygen by demand/positive-pressure valve or non-rebreather mask at 15 Lpm constant flow with the injured diver in the supine or recovery position

Decompression Sickness

- First aid and treatment of DCS includes:
  - Interviewing the victim and their dive buddy to collect information on the dive(s) within the past 24 hours
  - Making the victim comfortable
  - Monitoring vital signs and addressing issues as necessary

Decompression Sickness

- First aid and treatment of DCS includes:
  - Re-hydration of the victim (fluids by mouth should only be administered to fully conscious persons)
  - When appropriate, conducting a field neurological examination

Decompression Sickness

- First aid and treatment of DCS includes:
  - Contact with a physician schooled in hyperbaric medicine and transport to a chamber for recompression
  - The Diver's Alert Network [DAN] is available for information or emergency assistance
    - emergency (24/7) at 919-684-9111
    - information (normal business hours) at 919-684-2948

Aseptic Bone Necrosis

- Aseptic bone necrosis is an occupational hazard of professional divers and others exposed to hyperbaric stresses

Aseptic Bone Necrosis

- Surfaces of the long-bone ends can die when bubbles formed during decompression obstruct blood flow resulting in pain, spasm around the joint, and finally, disabling arthritis

Aseptic Bone Necrosis

- The hip and shoulder are most often affected
- Bone necrosis is seldom seen in the elbows, wrists, or ankles, and lesions occurring in the shafts of the long bones rarely cause symptoms or disability

Aseptic Bone Necrosis

- Lesions in the hip are often bilateral and the joint can degrade to the point of total collapse
- The only treatment known to have any degree of success is surgical repair or replacement of the joint

Patent Foramen Ovale

- The foramen ovale is a flap-like opening in the septum wall separating the right and left atria of the heart, normally open in a developing fetus
- This opening allows fetal blood to bypass the non-functional lung (since fetal gas exchange takes place in the mother)

Patent Foramen Ovale

- Within a year after birth the foramen ovale closes in most people
- However, in an estimated 20-30% of the general population the foramen ovale remains partially or fully open and is termed a Patent Foramen Ovale (PFO)

Patent Foramen Ovale

- In normal activities at sea level a PFO poses no problem and most people with PFO are unaware they have the condition
- PFO can cause severe problems for divers by allowing bubbles accumulated during a dive to be shunted from one side of the heart to the other, bypassing the lungs

Patent Foramen Ovale

- PFO has been implicated in a number of otherwise unexplained cases of DCS/DCI

Pregnancy and Diving

- Specific safety guidelines regarding pregnancy and diving are difficult to provide based on existing experiences of humans and animal studies, but it is the consensus of the diving medical community that there are risks for both the mother and the fetus with diving during pregnancy

Pregnancy and Diving

- Women should not dive during pregnancy

Hypothermia

Effects of Cold

- Chilling, even if not life threatening, increases fatigue and reduces dexterity making it difficult to do useful work and impacts on diver safety

Effects of Cold

- Susceptibility to chilling increases with dehydration, fatigue, hunger, and illness
- Being out of shape, underweight, a smoker, or using drugs or alcohol also increase susceptibility to chilling

Signs and Symptoms of Dropping Core Temperature

Core Temperature		
ºF	ºC	Symptoms
CHILLING		
98.6	37	Cold sensations, skin vasoconstriction, increased muscular tension, increased oxygen consumption
97	36	Sporadic shivering suppressed by voluntary movements, gross shivering in bouts, further increase in oxygen consumption, uncontrollable shivering
MODERATE HYPOTHERMIA		
95	35	Voluntary tolerance limit in laboratory experiments; mental confusion, impairment of rational thought, possible drowning, decreased will to struggle
93	34	Loss of memory, speech impairment, sensory function impairment, motor performance impairment
91	33	Hallucinations, delusions, partial loss of consciousness; in shipwrecks and survival history, 50% do not survive; shivering impaired
SEVERE HYPOTHERMIA		
90	32	Heart rhythm irregularities, motor performance grossly impaired
88	31	Shivering stopped, failure to recognize familiar people
86	30	Muscles rigid, no response to pain
84	29	Loss of consciousness
80	27	Ventricular fibrillation (ineffective heartbeat), muscles flaccid
79	26	Death

Effects of Cold

- A diver experiencing any of the following should terminate a dive and begin re-warming:
  - Loss of dexterity and grip strength
  - Difficulty performing routine tasks, confusion, or repeating tasks or procedures
  - Intermittent shivering, even though routine tasks can still be performed
  - Behavioral changes in a buddy that may indicate existing or approaching hypothermia

First Aid for Hypothermia

- Severe hypothermia is life-threatening and needs to be treated by trained medical personnel
- First aid includes:
  - Monitoring and addressing the diver's CABs (circulation, airway, and breathing)
  - Handling the victim extremely gently
  - Preventing further heat loss
  - Activating EMS

Thermal Protection

- A wetsuit does not stop heat loss, it merely slows it
- Diving in water temperature below 50°F (10°C) usually requires a drysuit

Thermal Protection

- Body fat, the body's ability to generate heat, the ability to constrict blood vessels to the limbs to shunt and save heat, physical conditioning, and regular cold exposure are important contributors to cold tolerance and protection

Prevention of Hypothermia

- Check air and water temperature before diving
- Wear adequate thermal protection for conditions
- After the dive, get out of wet cloths
- Move to a warm protected area
- Dry your hair
- Wear a hat
- Drink warm liquids between dives
- Be adequately nourished, well hydrated, and avoid alcohol and caffeine
- Repetitive dives should not be made until diver is completely re-warmed

Prevention of Hypothermia

- For maximum cold water performance, divers should swim in cold water on a regular basis to improve cold tolerance

Hyperthermia

Overheating & Hyperthermia

- Overheating can be problematic in diving
- A rise in core temperature of as little as 7.5°F (3.2°C) will make most people convulse
- Thermal protection necessary for in-water exposures can complicate normal thermal regulation leading to serious hyperthermic conditions

Types of Heat Stress

- **Heat syncope** – The sudden loss of consciousness due to heat
- It is usually experienced by individuals with prolonged exposure to a hot environment to which they are not acclimatized, or who have been moving about in extreme heat while dressed in heavy garments

Types of Heat Stress

- **Heat cramps** – A mild response to heat stress in the form of muscle cramps
  - Cramping usually occurs in the legs, arms, or abdomen
  - Best treatment is rest, oral fluids, cooling down, ice, and stretching and massaging the muscles

Types of Heat Stress

- **Heat exhaustion** – A serious problem in which hypovolemia (low blood volume) results from fluid loss
  - Signs & Symptoms include profuse sweating, nausea, vomiting, a weak and rapid pulse, ataxia (lack of coordination), low blood pressure, headache, dizziness, altered mental state, and general weakness

Types of Heat Stress

- **Heat exhaustion**
  - Severe cases require intravenous (IV) fluids, aggressive cooling, and medical attention

Types of Heat Stress

- **Heat stroke** – A serious, life-threatening emergency
  - The body's capacity to cool itself has failed
  - The skin becomes hot and dry, core temperature can soar above 105°F (40.8°C) leading to convulsions, delirium, and coma
  - If unchecked, permanent brain damage or death can occur

Types of Heat Stress

- **Heat stroke**
  - Victims must be removed from the hot environment, cooled aggressively, taken to an emergency medical facility and given IV fluids

Overheating & Hyperthermia

- To reduce the risk of overheating:
  - Drink water and juices liberally and before becoming thirsty
  - Avoid alcohol, coffee and other diuretics
  - Avoid drugs that increase susceptibility to overheating

Overheating & Hyperthermia

- To reduce the risk of overheating:
  - Maintain good physical condition
  - Acclimate gradually
  - Minimize exposure by efficient pre-dive preparations and cooling down as needed

Thermal Stress Irrespective of Ambient Temperature

- Hypothermia and Hyperthermia can occur irrespective of ambient temperature
- Monitor and address thermal issues as soon as possible to have the best chance of avoiding these conditions

Drugs and Diving

Prescription Drugs

- The hyperbaric environment may change how some drugs act in the body
- Specific concerns include:
  - How the body absorbs, metabolizes, and excretes the drug

Prescription Drugs

- The hyperbaric environment may change how some drugs act in the body
- Specific concerns include:
  - Possible physical effects of the type of breathing gas, increased density of the gas, water temperature, and other environmental factors

Prescription Drugs

- The hyperbaric environment may change how some drugs act in the body
- Specific concerns include:
  - Side effects; acceptable side effects on the surface may lead to accidents if experienced underwater

Prescription Drugs

- Beta blockers, motion sickness medications, antihistamines, amphetamines, tranquilizers, sedatives, hypertensive drugs, and decongestants are commonly used, but may affect a diver's performance, the ability to thermoregulate, and diver safety

Prescription Drugs

- Consult with a physician knowledgeable in diving medicine before diving while using prescription drugs

Smoking

- Cigarette smoke contains poisons including hydrogen cyanide, nitrox oxides, and carbon monoxide
- Smoking has detrimental affects on the respiratory and cardiovascular systems that are undesirable in diving

Smoking

- Smoking reduces the oxygen carrying capacity of the blood and may predispose the diver to DCS
- Smoking is not recommended and should be discouraged

Illicit Drugs & Alcohol

- Alcohol, barbiturates, and marijuana are commonly abused nervous system depressants
- Depressed motor function is hazardous underwater

Illicit Drugs & Alcohol

- Cocaine and other commonly abused CNS stimulants render a diver incapable of properly responding to an emergency, and can increase the likelihood of an oxygen toxicity seizure

Illicit Drugs & Alcohol

- Alcohol is a diuretic and may accelerate and multiply the effects of nitrogen narcosis
- Alcohol predisposes a diver to thermal stress
- There appears to be a relationship between the number of drinks consumed and the severity of DCS
- You should not dive when under the influence of alcohol or illicit drugs

Diver's Alert Network [DAN

– DAN is available for emergency assistance
    • emergency (24/7) at 919-684-9111