


Diving Physiology

Objectives

1. Review Barotrauma
2. Review the parts of the body affected by diving
3. Review the physiological problems associated with descending
4. Discuss the physiological problems associated with ascending

Barotrauma

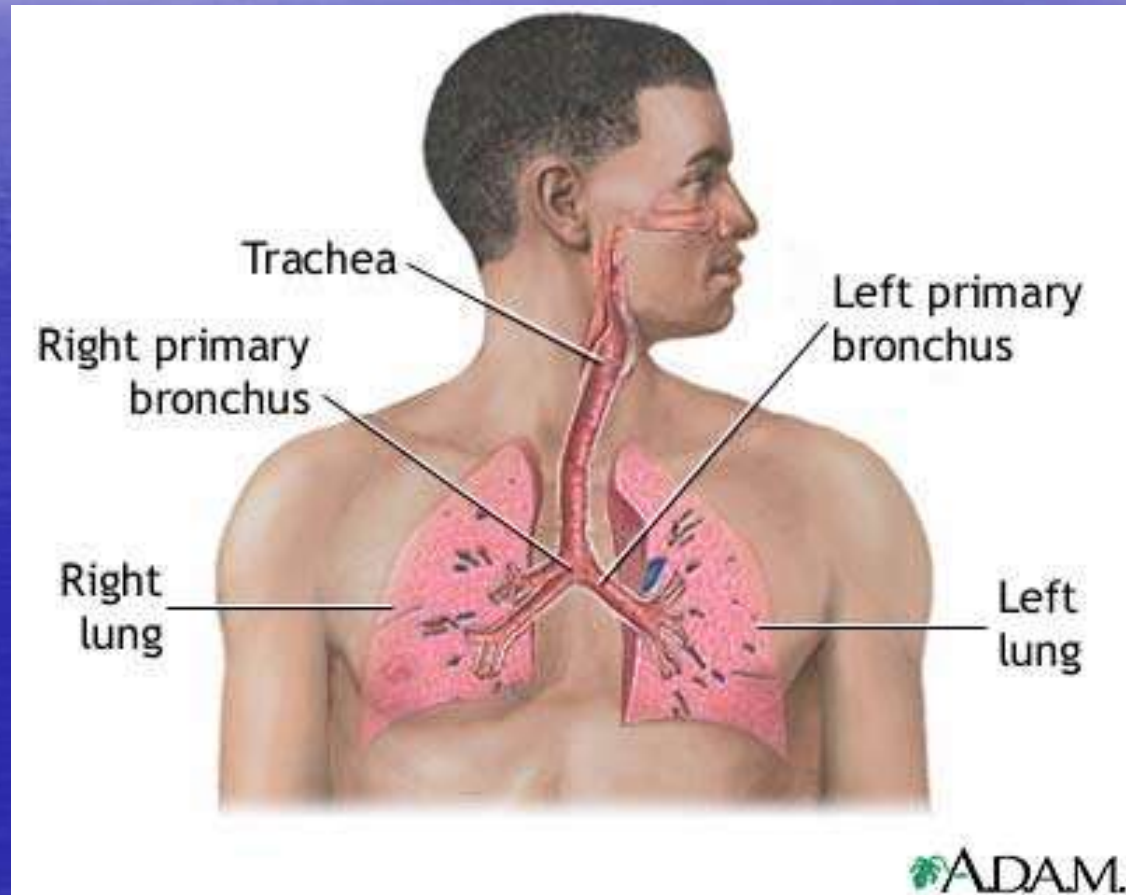
- An injury due to pressure.
- Two types of Barotrauma injuries:
 - Descent injury – pressure increase
 - Ascent injury – pressure decrease



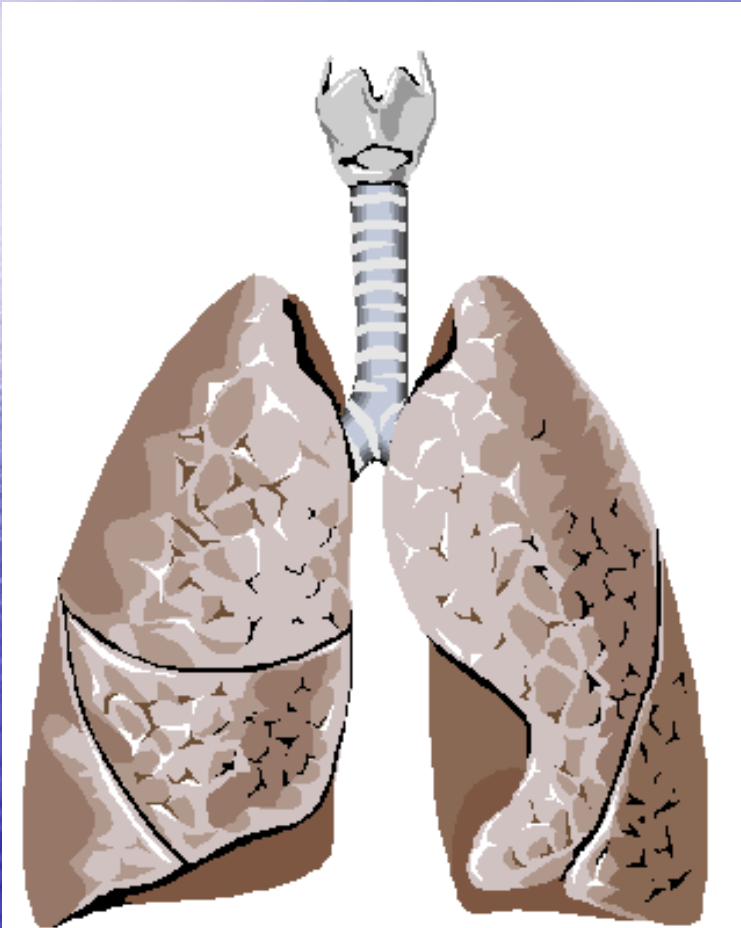
What parts of
my body are
affected when
diving?

Thorax

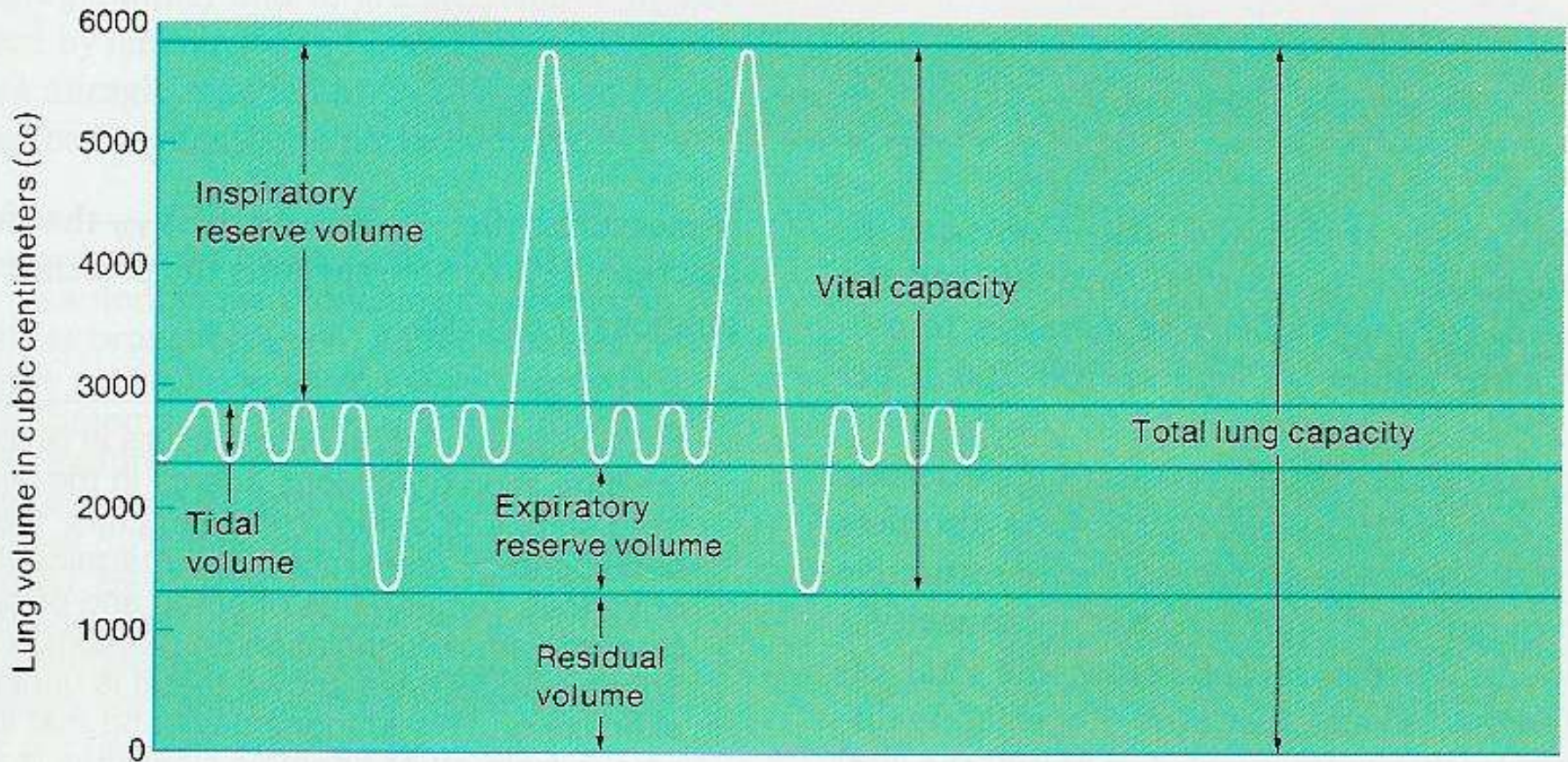
- Contains organs of respiratory system
- Trachea, bronchus, lungs
- Contains air
- Affected by changes in surrounding pressure



The Lungs



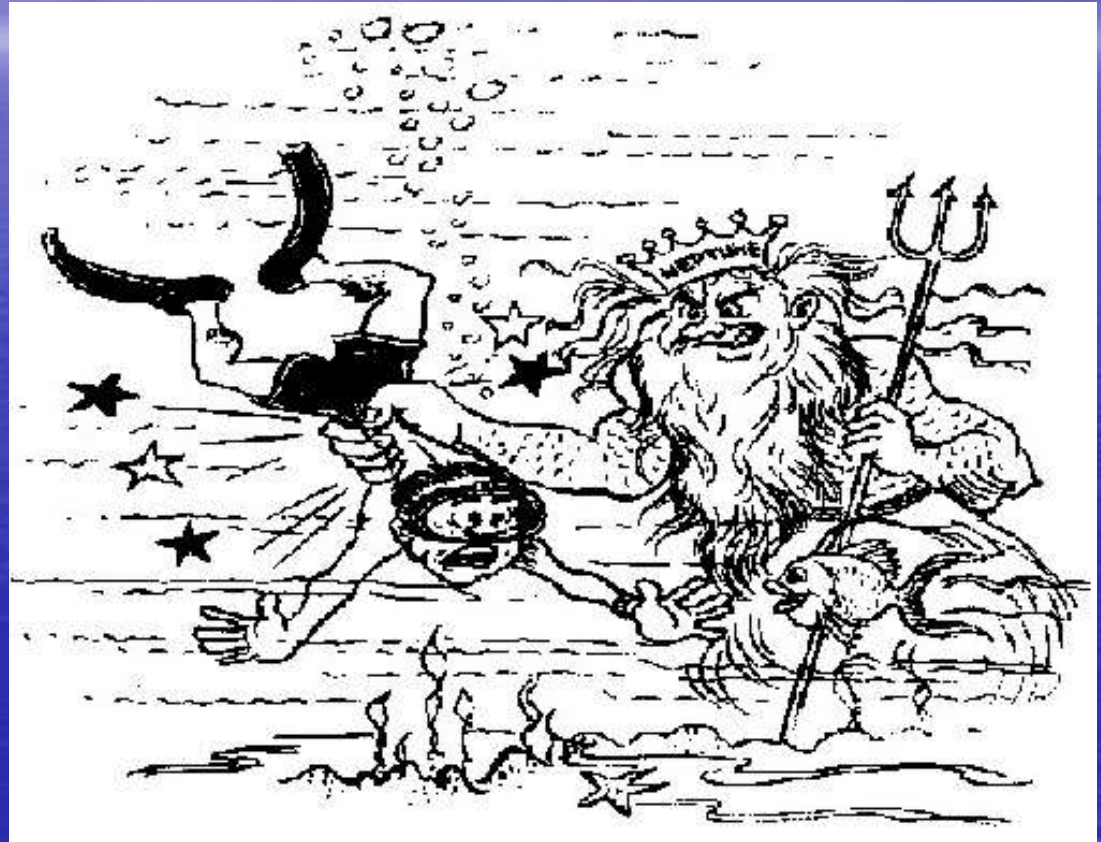
- Average lung capacity = 5.5 L
- Full capacity not normally used during respiration
- Respiration is a automatic process
- Triggered by increase in CO_2 levels



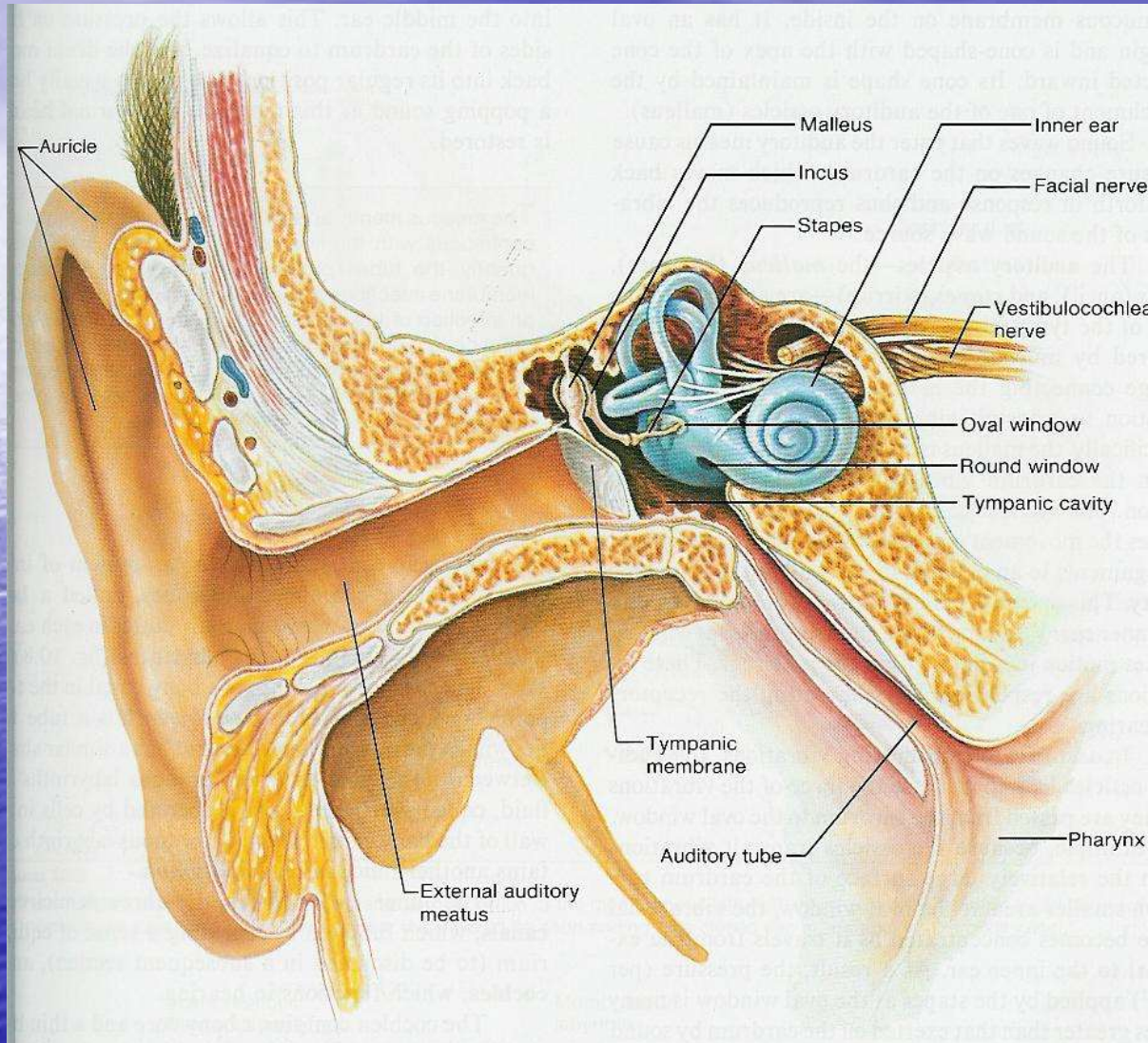
Total lung capacity is about 6 litres but you normally only exchange about .5 litres (Tidal volume) and there is about 1.2 litres you never exchange (residual volume)

Squeezes

- Boyle's Law
 - Squeeze results when the EXTERNAL pressure is greater than the internal pressure.
 - Reverse Squeeze results when the INTERNAL pressure is greater than the external pressure.



The Ears

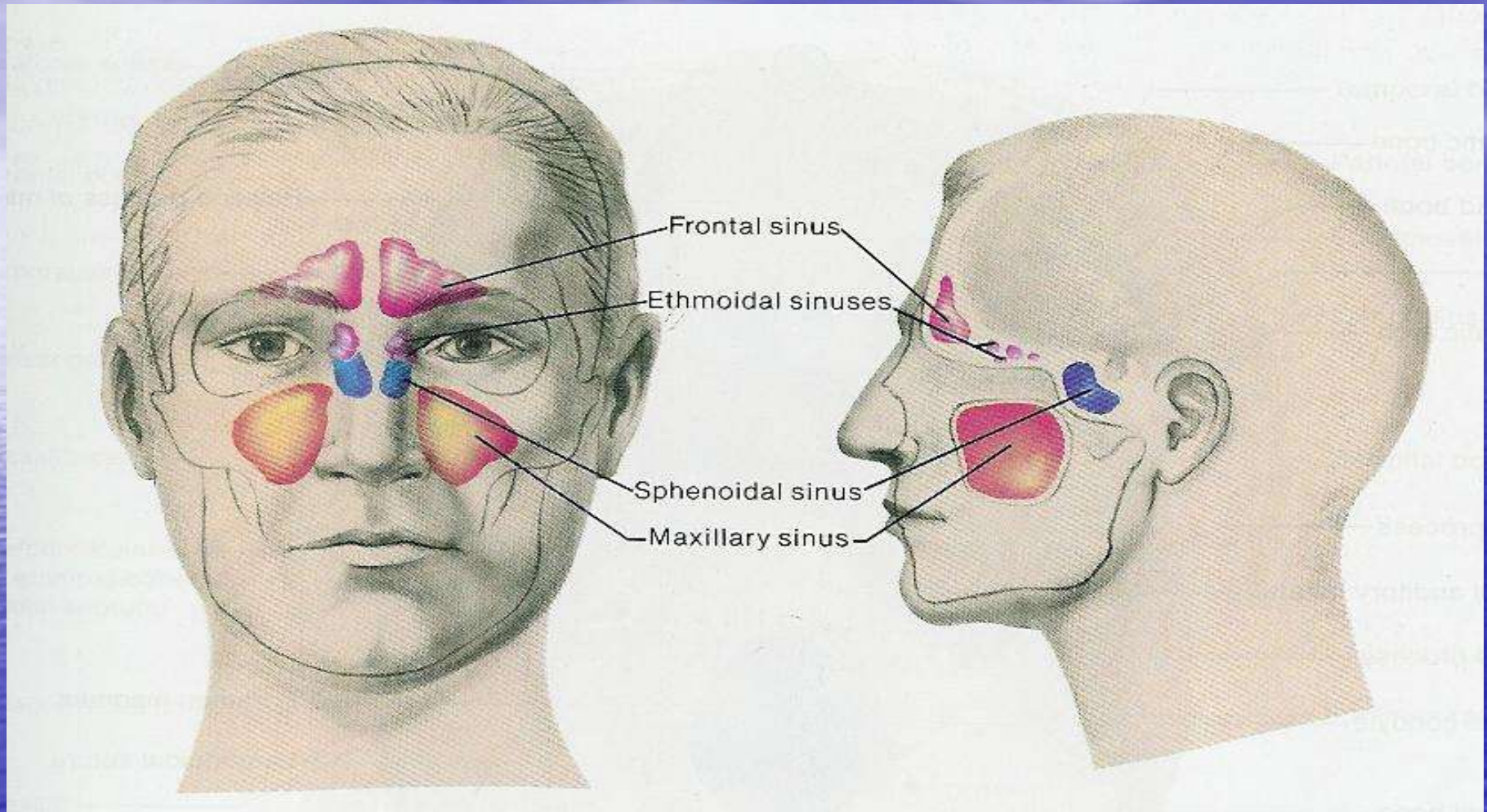


- **Outer Ear**
 - Tympanic Membrane (Ear drum)
- **Middle Ear**
 - Closed cavity
 - Eustachian tube (back of throat to middle ear)
 - Hammer, anvil, stirrup
- **Inner Ear**
 - **Corti, nerve center**

Ear Squeeze

- Cause
 - Cold, sinus infection
 - Failure or inability to equalize properly on descent
 - External ear squeeze – dry suit hood, ear plugs
- Symptoms
 - Pain or pressure in ear
 - Vertigo (Dizziness), deafness (if ear drum *ruptures*)
 - Treatment
 - Stop your descent, ascend a few feet & try to clear.
 - If the pressure releases – continue to descend
 - If pressure does not release – ascend a few more feet & try again.
 - If your ears will not equalize, abort the dive!
 - Suspected rupture – warm compress and seek medical attention.
 - Move hood away from ears
- Prevention
 - Descend slow, equalize frequently.
 - Start equalizing the moment you begin descending
 - Never wear ear plugs.

The Sinuses



If you experience a pain around your eyes either your mask is too tight or you have a sinus squeeze.

The background is a smooth blue gradient, transitioning from a lighter blue at the top to a darker blue at the bottom. On the left side, there is a bright sun flare that creates a white and yellow glow, with rays of light extending across the sky. The overall effect is a serene, ocean-like atmosphere.

What can happen to my
body during descent?

Nitrogen Narcosis

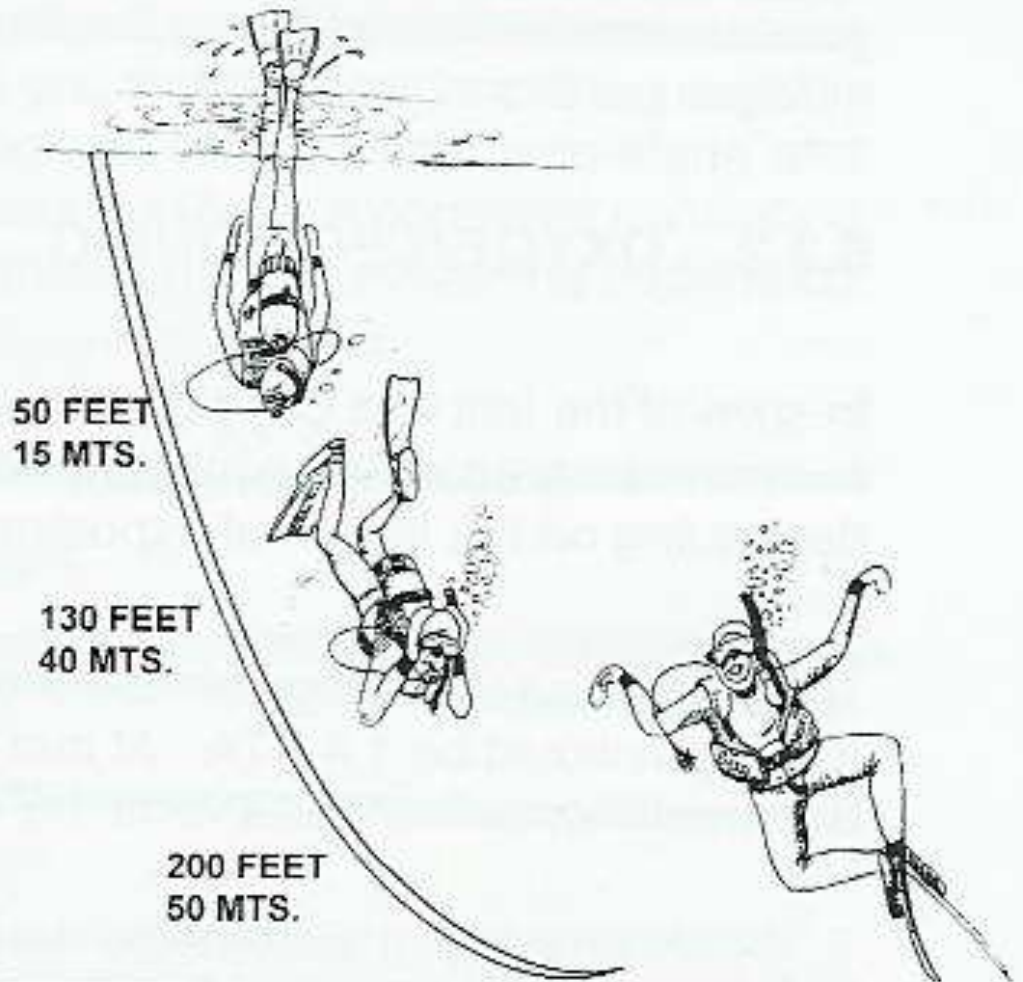
“Rapture of the Deep”



- Henry's Law
 - The amount of gas that dissolves in a liquid (blood) is directly related to the depth.
 - As pressure increases with depth more gas (N₂) will dissolve into the blood.

Cause

- The increase in Nitrogen on the CNS has a narcotic effect.
 - Diver loses ability to make clear decisions!
 - Effects are different for everyone.
 - Even two dives to same depth at differing times can have different effects!



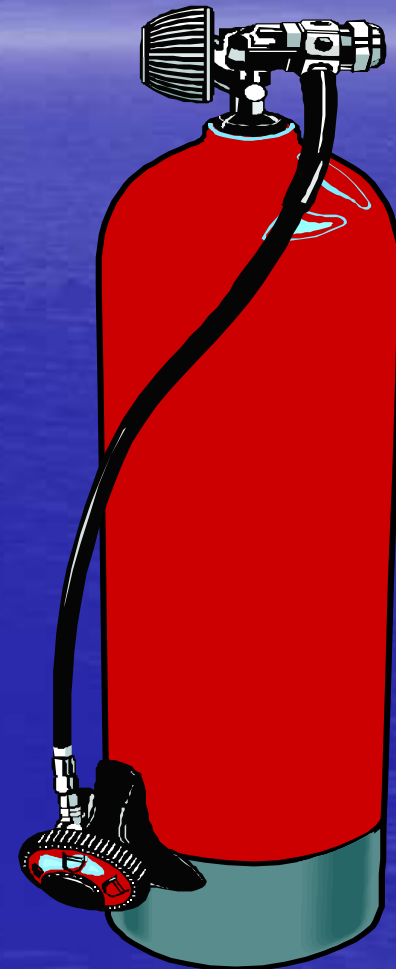
The Narcosis effects and how they vary with depth

- Symptoms
 - Euphoric
 - Depressive
 - Disorientation
 - Inability to concentrate
 - Claustrophobia
- “Drunkenness of the Deep”
 - Jacques Cousteau
- Martini’s Law
 - Every 50 Ft is equal to drinking one martini on an empty stomach!
- Treatment
 - Ascend!



Oxygen Poisoning

- Henry's Law
 - The amount of gas that dissolves in a liquid (blood) is directly related to the depth.
- Dalton's Law
 - The pressure exerted on a gas is equal to the sum of its Partial Pressures.
 - At certain pressures each gas can become harmful to the body!





- Causes

- Breathing pure O_2 at a depth > 20 feet (1.6 ATM) can have serious pulmonary consequences!
- Regular air is toxic at 250 feet
- Beyond this depth a diver runs the risk of O_2 poisoning!



- Symptoms

- Nausea, dizziness, twitching, cramps, shivering, depression, euphoria, tunnel vision, hallucinations...

- Treatment

- Fresh air at surface

- Prevention

- Risk of O_2 poisoning is remote as depth limit for recreational divers well above depth where O_2 poisoning can occur.

Carbon Dioxide Poisoning



- Cause
 - Hyperventilating due to anxiety
 - Skip breathing
- Note that carbon dioxide is what triggers our need to breath



- Symptoms

- Headaches
- Dizziness
- Choking feeling
- Nausea
- Unconsciousness
- Coma
- Death
- ***Blue red lips, ears and nails

Carbon Monoxide Poisoning



- Cause
 - CO (Exhaust fumes – bad fill)
 - Colorless
 - Odorless
 - Tasteless
 - CO binds to hemoglobin much more readily than O₂
 - Decreases function of hemoglobin to transfer O₂ to body
 - 0.2% serious effects
 - 1% fatal

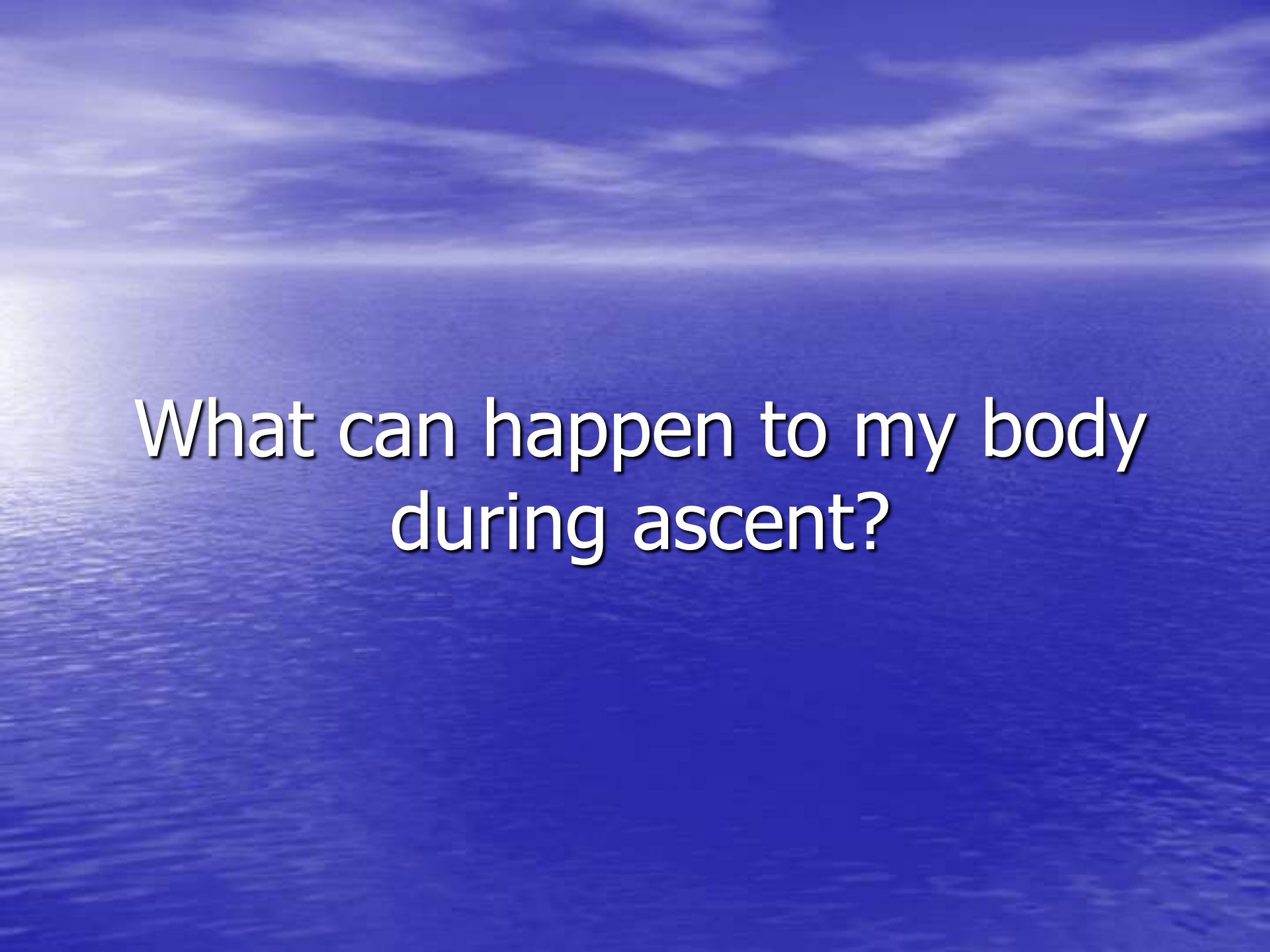


- Symptoms
 - Headaches
 - Dizziness
 - Choking feeling
 - Nausea
 - Unconsciousness
 - Coma
 - Death
 - ***Cherry red lips, ears and nails

Treatment for both carbon dioxide and monoxide poisoning:

- Pure O²
- Fresh air
- AR
- Medical attention



The background of the slide is a photograph of a bright blue sky with wispy white clouds. On the left side, there is a bright sun flare that creates a white and yellow glow. Below the sky is a deep blue ocean with visible ripples on the surface. The text is centered in the middle of the image.

What can happen to my body
during ascent?

Remember!

- Boyle's Law
 - As pressure increases, gas volume decreases
 - As pressure decreases, gas volume increases



- Causes

- Breath-holding during ascent **
- Out of air – rapid ascent
- Too fast ascent
- Skip breathing
- Lack of training
- Unconsciousness
- Loss of regulator



- Panic: Glottis closes and lungs become a sealed unit. Air in lungs expand during ascent. A decrease in pressure of only 4 feet can cause a rupture in the alveoli causing air bubbles to move into the blood stream.



Sea Level - 1 ATA (Vol. = 1 or 100%)

33FT. - 2 ATA (Vol. = 1/2 or 50%)

66FT. - 3 ATA (Vol. = 1/3 or 33 1/3%)

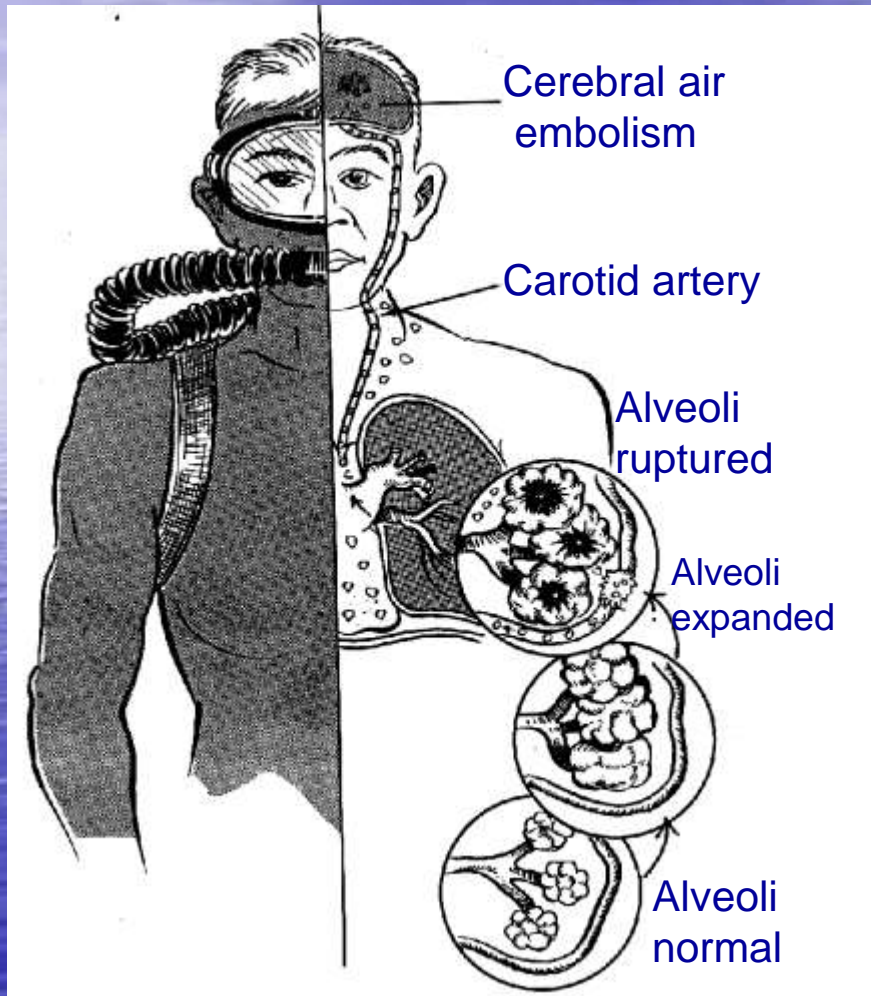
99FT. - 4 ATA (Vol. = 1/4 or 25%)

132FT. - 5 ATA (Vol. = 1/5 or 20%)

267FT. - 10 ATA (Vol. = 1/10 or 10%)

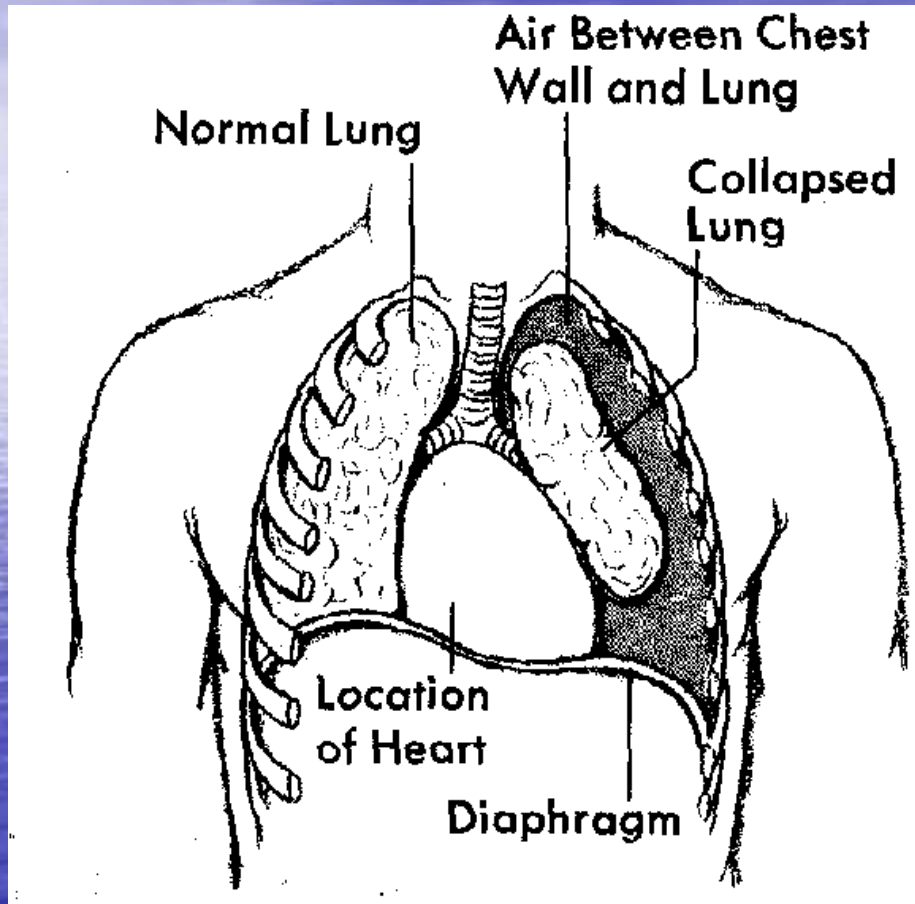
Boyle's law applied to depth versus volume and pressure

Air Embolism



- Alveoli rupture causing air bubbles to enter blood stream.
- Bubble may travel to brain or heart and may cause stroke or MI
- Symptoms
 - Sharp pain in chest
 - Blood from mouth
 - Dizziness
 - LOC
 - Blurred vision
 - Staggering
 - Paralysis

Pneumothorax



- Results from ruptured alveoli
- Air escapes into pleura which encloses the lungs
- Lung may collapse

- Symptoms
 - Pain in chest (may be one-sided)
 - Difficulty breathing – rapid, shallow
 - Cyanosis



Mediastinal Emphysema

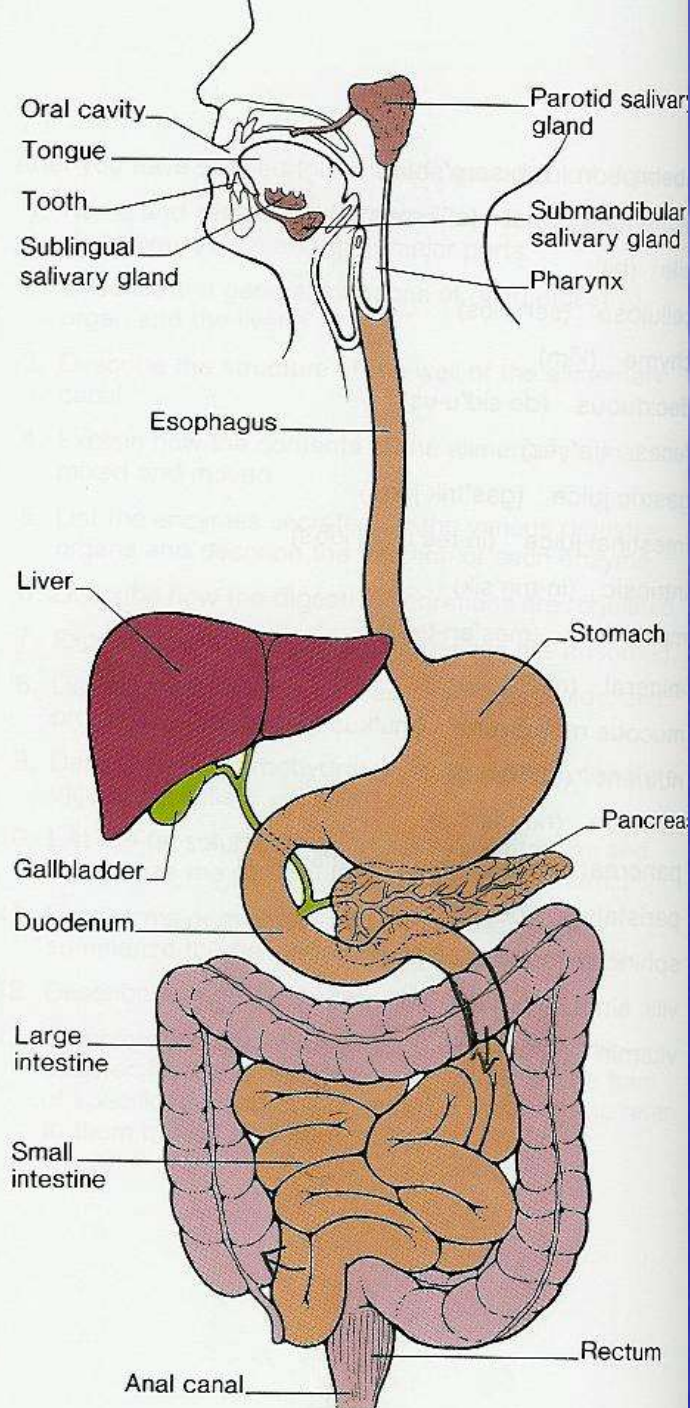
- Air bubbles do not enter blood stream
- Air enters the interior thoracic cavity surrounding the heart called the mediastina
 - Pain in mid chest
 - Difficulty breathing
 - Cyanosis (restriction of circulation)

Subcutaneous Emphysema

- Air bubbles do not enter blood stream
- Air travels to the neck & shoulder area under the skin
 - Fullness in neck
 - “Rice Crispies” under the skin
 - Voice change – difficulty with speech



- Treatment for all of these
 - Lay flat on back
 - AR and CPR if required
 - Seek medical attention
 - 100% O₂ & Recompression Therapy
- Prevention
 - Breathe normally – even if out of air try to breathe **
 - NEVER HOLD YOUR BREATH WHILE ASCENDING
 - Ascend no faster than your bubbles (60 feet per minute)



Stomach / Intestinal Gas Expansion



- Causes
 - Eating gas producing foods prior to dive
 - Swallowing air
- Symptoms
 - Bloating feeling on ascent
 - Slight restriction in breathing after ascent
- Treatment
 - Relax and allow normal body processes to eliminate excess gas!
- Prevention
 - Avoid gas producing foods prior to dive

Decompression Illness (DCI)

- Refers to two types of trauma that can occur to the body when the surrounding pressure decreases (on ascent):
 - Arterial gas embolism
 - Bubbles in the blood stream
 - Decompression sickness
 - *Nitrogen* Bubbles in the tissues

Decompression Sickness



- “Bends” – style of walk called the Grecian Bend used in ancient Greece
- “Caissons Disease” – booths used by workers digging tunnels under rivers to stay dry.

Involves 3 Gas Laws



- Boyle's Law
 - As pressure increases, gas volume decreases
 - As pressure decreases, gas volume increases
- Henry's Law
 - The amount of gas that dissolves in a liquid (blood) is directly related to the depth.
- Dalton's Law
 - The pressure exerted on a gas is equal to the sum of its Partial Pressures.
 - At certain pressures each gas can become harmful to the body!

- DCS may hit randomly
- May be mild to severe
- It occurs in approximately 1000 US scuba divers each year *
- DCS Type I and II
 - DCS I means that the diver has joint and / or muscle pain and that the examining physician has found no indication of any symptoms of DCS II prior to beginning treatment. *
 - DCS II symptoms include neurological symptoms, such as numbness, tingling, muscle weakness or bladder problems. Sometimes with DCS II, cardiorespiratory problems can also occur. *



* DAN website

Causes



- Rapid ascent
- No safety stops
- Deep, long dives
- Cold water
- Fatigue
- Age
- Physical fitness
- Illness
- Excessive exertion at depth
- Obesity (Fat absorbs 5X as much N₂ as muscle)
- Dehydration
- Medications
- Alcohol
- Saw tooth dive profile
- Exposure to altitude or flying too soon after diving

Symptoms

- 50% of DCS accidents are detected within 30 minutes
- 90% within 6 hours
- 98% within 24 hours
- Denial ***
- Joint pain **
- Numbness or tingling **
- Muscular weakness *
- Inability to empty a full bladder *
- Itching
- Blotchy rash
- Pain in arms, legs or trunk
- Sweating
- Chest Pain
- Coughing, choking – cyanosis
- Shock, LOC
- Loss of speech, hearing or vision
- Dizziness
- Paralysis

Immediate Treatment

- Never take the victim back down to depth
- 100% O₂ therapy
 - Early O₂ administration may reduce s/s dramatically
- Prevent the diver from getting cold
- Hydrate (non-alcoholic)
- AR or CPR if required
- Seek medical attention – Recompression Therapy
 - Call DAN hotline for nearest hyperbaric chamber 1-919-684-4DAN
 - If air transport required cabin pressure is maintained near sea level and not to exceed 800 feet
 - Obtain the dive history
 - Perform a basic neurological exam – see handout

Hyperbaric Chamber

- Involves taking the victim down to pressures where the symptoms are relieved and the bubbles return to solution
- Then the victim is returned to atmospheric pressure slowly, allowing the Nitrogen to off gas naturally through the lungs
- Pure O_2 is administered intermittently

Hyperbaric Chamber

Moose Jaw (1 – 306 – 694 – 0200)



Prevention



- DCS is affected by age, fitness, alcohol use, exertion, hot showers after diving.
- Ensure proper hydration.
- Avoid excessive physical exertion before and after diving.
- Keep warm.
- Increase your physical fitness.
- See a diving physician with any concerns.
- Increase your confidence and experience in diving by taking further courses.

Plan the Dive.....

- Ensure you have an accurate and reliable instrument to measure time and depth.
- Review your dive profile using your dive tables – include safety margins....
 - Dive tables used by recreational SCUBA divers were originally designed for young, fit, military Navy divers. Use the tables conservatively.
 - Note that different dive computers may be more or less conservative.

.....and Dive the Plan

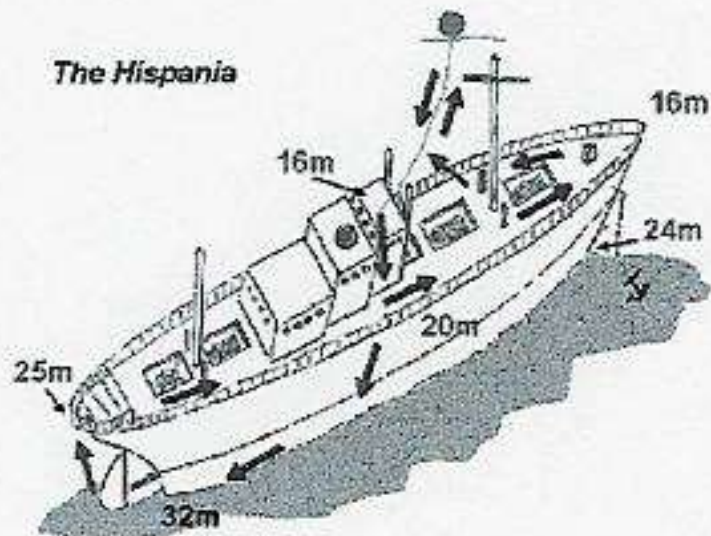
- Do the deepest dive first.
- Avoid dives that require decompression stops. Stay within the no decompression limits.
- If necessary, adhere to all decompression stops.
- Slow your ascent rate: Never exceed 60 ft/min ascent rate.
- Do a 3 – 5 min safety stop on all dives below 40 feet.

Extend the surface interval between dives

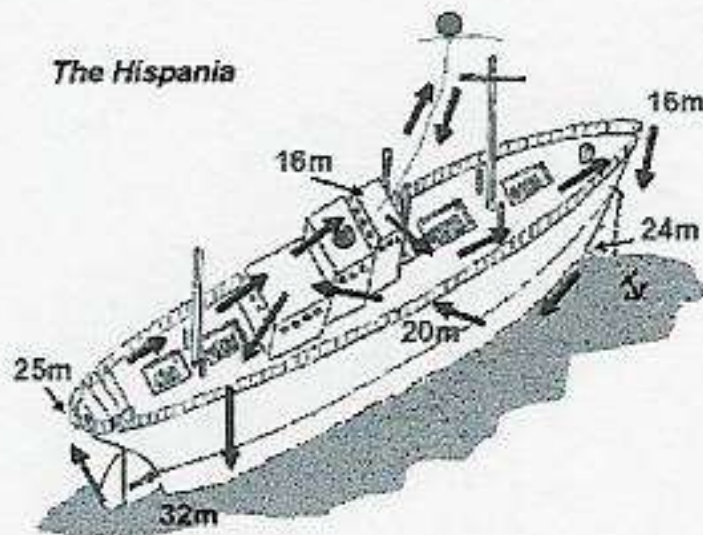
- Nitrogen bubbles form faster on the second dive and are quickly added to the bubbles formed on the previous dive.
- Allowing longer surface intervals between dives gives your body more time to off-gas.
- Dive within the limits of the dive tables or use the planning mode of your dive computer.
- Shortening the duration of your dives may also help prevent DCS.

Avoid Saw Tooth & Rectangular Dive profiles

- Dive profiles that involve ascending and re-descending (saw tooth) or remaining at the same depth (rectangular) or work progressively deeper throughout the dive increase the risk of DCS.
- Choose a dive profile that involves descending to your maximum depth at the start, staying for a short time, and following a gradual ascent for the rest of the dive.



Example of dive profile that may reduce risk of DCS.



Example of dive profile more likely to result in DCS

Consecutive Diving and Flying

- Do not do more than 3 dives per day.
- If doing several consecutive days of diving, take a day off every 3 to 4 days.
- Do not fly for 24 hours after your last dive.

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Other Related Physiology

Hypothermia



- Heat transfer is 25 times faster in water than in air
- Cause
 - Inactivity in cold water
 - Inadequate exposure suit
 - Excessive exposure
 - Alcohol & drug use
- Symptoms
 - Shivering
 - Cyanosis
 - Difficulty concentrating
 - Fatigue
 - Slurred speech
 - Cramps /pain in limbs
 - Unconsciousness

- Treatment

- warm shower (not hot!)
- Warm dry clothing
- Blankets on torso (Warming too quickly can result in cardiac problems)
- Warm fluids
- Windproof clothing
- Fire
- CPR in extreme cases – Medical attention



- Prevention

- Adequate exposure suits
- Limit bottom time
- Abort the dive
- Portable shelters

Heat Exhaustion / Stroke



- Causes
 - Excessive exertion / exposure to heat
- Symptoms
 - Exhaustion: Restless, faint, nausea, cold & clammy skin, sweating, rapid pulse
 - Stroke: Collapse, dry skin, rapid & shallow breathing, high body temp >38 degrees C

- Treatment

- Lie in cool place
- Cool victim in cold water
- Salted water
- Heat Stroke: Seek medical aid

- Prevention

- Avoid excessive exertion in heat
- Organize dressing procedure
- Avoid excessive exposure to heat when dressed
- Cool in water when dressed

Hypoglycemia

Low blood sugar

- Cause
 - Inadequate nutrition
- Symptoms
 - Dizzy
 - Nausea
 - Fatigue
 - Possible unconsciousness
- Prevention
 - Adequate diet prior to diving
 - Quick energy foods



Sunburn

- Symptoms
 - Redness, blisters
- Treatment
 - Aloe lotion
 - Do not break blisters
- Prevention
 - Sunscreen SPF 15 or higher
 - Avoid excessive exposure
 - Cover up with light clothing



Alcohol / Drug Use



- Avoid alcohol prior to and immediately after diving
- Alcohol affects judgment and heat production / loss
- May lead to vomiting underwater or possible drowning
- Can contribute to DCS

Be Safe
Dive Safe

