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AEROSPACE/ OCCUPATIONAL MEDICINE

BAROMETRIC CONCERNS

Dr. John Campbell, DO, MPH, MFS

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Administrative Information

- Risk Assessment: Low
- Environmental Considerations: None
- Safety Considerations: None
- Evaluation: Pay Attention! This is Tested in Real Life of an Aviator and a 50 Question exam at the end of Aeromedical Training.

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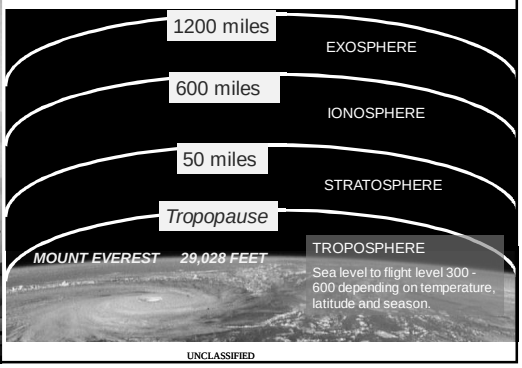
Physical Divisions of the Atmosphere



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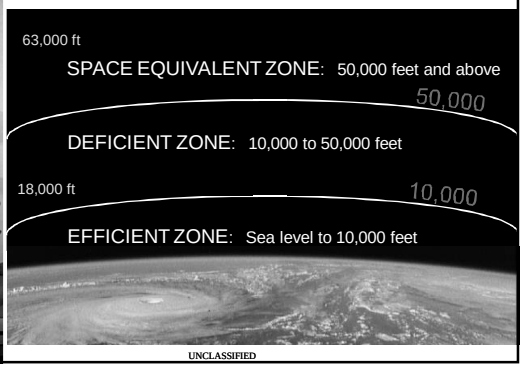
Physiological Zones of the Atmosphere



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Composition of the Air

- 78 % Nitrogen (N_2)
- 21 % Oxygen (O_2)
- 1 % Other
  - 0.03 % CO_2

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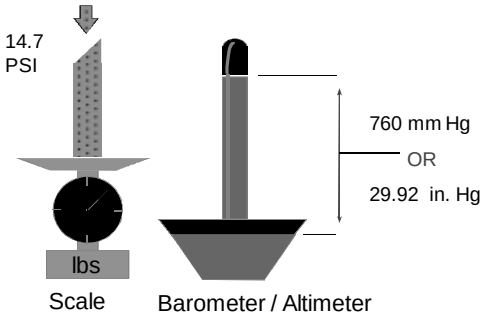
Sea Level Pressure



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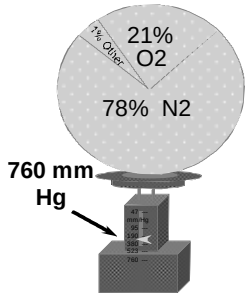
Composition versus Pressure



- Percent composition of the atmosphere remains constant
- But pressure decreases with altitude

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Significant Pressure Altitudes

Altitude	Pressure	
Feet	mmHg	Atmospheres
0	760	1
18,000	380	½
34,000	190	¼
48,000	95	1/8
63,000	47	1/16

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Dalton's Law

- The pressure exerted by a mixture of gases is equal to the sum of the partial pressures of each gas in the mixture

$$P_{Total} = P_1 + P_2 + ... + P_n$$

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Dalton's Law Examples

- SEA LEVEL
  - PO_2 = 0.21 X 760 mmHg = 160 mmHg
  - PN_2 = 0.79 X 760 mmHg = 600 mmHg
    - » P_{Total} = 760 mmHg
- 18,000 Ft
  - PO_2 = 0.21 X 380 mmHg = 80 mmHg
  - PN_2 = 0.79 X 380 mmHg = 300 mmHg
    - » P_{Total} = 380 mmHg

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Correction of Altitude, Alveolar O_2 Hb Saturation

Ambient Air

Altitude (feet)	Barometric Pressure (mmHg)	Alveolar Oxygen (PAO_2)	Hemoglobin Saturation % (Hb)
Sea Level	760	104	97
10,000	523	67	90
20,000	349	40	70
30,000	226	21	20
40,000	141	6	5
50,000	87	1	1

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Correction of Altitude, Alveolar O_2 Hb Saturation

100% Oxygen

Altitude (feet)	Barometric Pressure (mmHg)	Alveolar Oxygen (PAO_2)	Hemoglobin Saturation % (Hb)
Sea Level	760	673	100
10,000	523	436	100
20,000	349	262	100
30,000	226	139	99
40,000	141	58	87
50,000	87	16	15

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Functions of the Circulatory System

- Oxygen and nutrient transport to the cells
- Transport of metabolic waste products to organ removal sites
- Assists in temperature regulation
- Assists in maintaining acid-base balance

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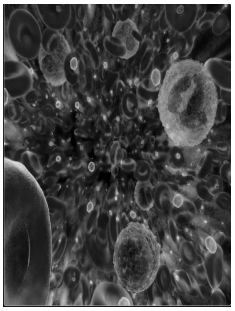
Components of Blood

- Plasma
  - 55% of whole blood
- White blood cells
  - Main function to fight infection or inflammation
- Platelets
  - Aid in blood coagulation
- Red blood cells
  - Transport approximately 98.5% of O_2 in the body



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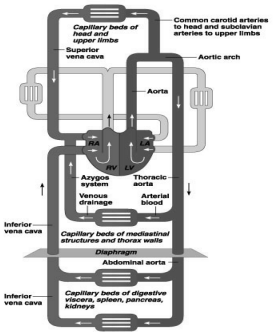
Components of the Circulatory System



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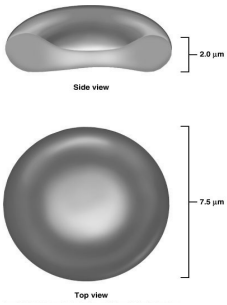
The Red Blood Cell

- The protein hemoglobin makes up about 97% of the dry mass of each red blood cell
- Hemoglobin has four oxygen binding sites
- Approximately 20% of the CO_2 in the blood is also transported on hemoglobin



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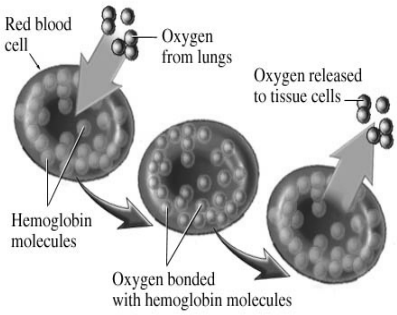
Hemoglobin and Oxygen Transport



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Functions of the Respiratory System

- Intake of Oxygen [O_2] Active Process
- Removal of Carbon Dioxide [CO_2] Passive Process
- Maintenance of body heat balance
- Maintenance of body acid base balance [pH]

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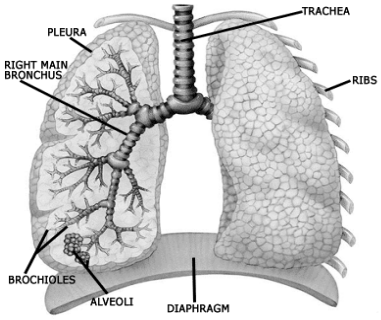
Components of the Respiratory System



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Phases of Respiration

- Inspiration is active
  - Raise chest wall
  - Lower diaphragm
    - Increases volume
    - Decreases pressure
    - Air is inhaled
- Exhalation is passive
  - Relax the chest
  - Relax the diaphragm
    - Volume collapses
    - Pressure increase
    - Air is expired

INHALATION – ACTIVE Phase

EXHALATION- PASSIVE Phase

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Law of Gaseous Diffusion

- Gas molecules of higher pressure move in the direction of gas molecules of a lower pressure

PO2 = 100mmHg ⟶ PO2 = 40mmHg

PO2 = 74mmHg ⟷ PO2 = 66mmHg

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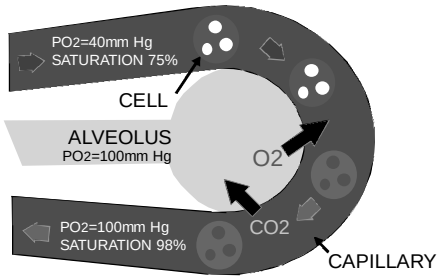
Oxygen Exchange Between Alveolus and Capillary Blood at Sea Level



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Hypoxia

- State of oxygen deficiency in the blood cells and tissues sufficient to cause impairment of function
- 4 Types
  - Hypoxic
  - Hypemic
  - Stagnant
  - Histotoxic

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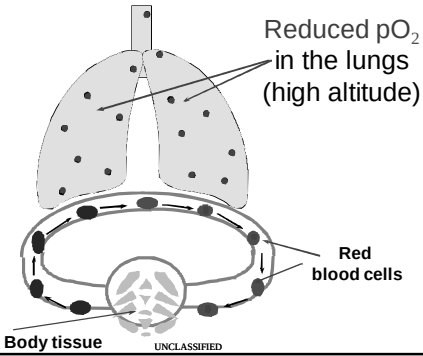
Hypoxic Hypoxia



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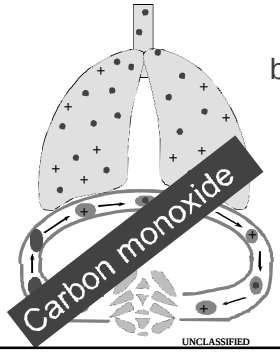
Hypemic Hypoxia



Inability of the blood to accept oxygen in adequate amounts

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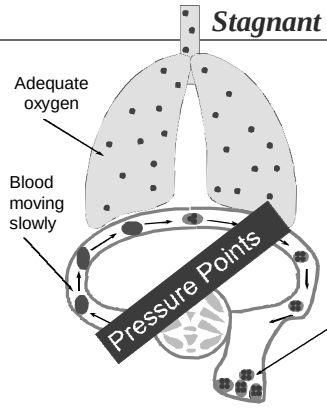
Stagnant Hypoxia



Reduced blood flow

Red blood cells not replenishing tissue needs fast enough

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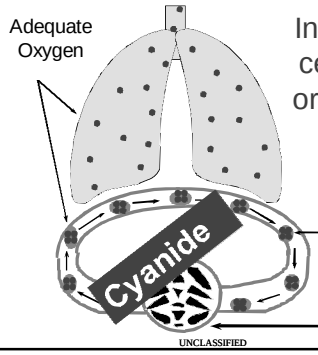
Histotoxic Hypoxia



Inability of the cell to accept or use oxygen

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Symptoms of Hypoxia (what you might feel)

- Air hunger
- Apprehension
- Fatigue
- Nausea
- Headache
- Dizziness
- Blurred vision
- Hot & cold flashes
- Euphoria
- Belligerence
- Numbness
- Tingling
- Denial

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Signs of Hypoxia (what you might see)

- Hyperventilation
- Cyanosis
- Mental confusion
- Poor judgment
- Lack of muscle coordination

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Stages of Hypoxia

- Indifferent Stage
- Compensatory Stage
- Disturbance Stage
- Critical Stage

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Indifferent Stage

- Altitudes: Sea Level - 10,000 feet
- Symptoms: decrease in night vision @ 4000 feet
  - acuity
  - color perception

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Compensatory Stage

- Altitudes: 10,000 - 15,000 feet
- Symptoms: impaired efficiency, drowsiness, poor judgment and decreased coordination

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Disturbance Stage

- Altitudes: 15,000 - 20,000 feet
- Symptoms:
  - Decreased memory, impaired judgment, decreased reliability, poor understanding
  - Personality: happy drunk versus the mean drunk
  - Blurred vision, increased sense of touch & pain, impaired hearing
  - Poor coordination, erratic flight control, slurred speech, illegible handwriting

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Critical Stage

- Altitudes: 20,000 feet and above
- Signs: loss of consciousness, convulsions and death

WARNING! *When hemoglobin saturation falls below 65% serious cellular dysfunction occurs; and if prolonged, can cause death!*

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Factors Modifying Hypoxia Symptoms

- Pressure altitude
- Rate of ascent
- Time at altitude
- Temperature
- Physical activity
- Individual factors
- Physical fitness
- Self-imposed stresses (D.E.A.T.H.)

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Time of Useful Consciousness (TUC)

Altitude	Time of Useful Consciousness
43K+ Feet	9-12 seconds
40K Feet	15-20 seconds
35K Feet	30-60 seconds
30K Feet	1-2 minutes
28K Feet	2 ½ -3 minutes
25K Feet	3-5 minutes
22K Feet	8-10 minutes
18K Feet	20-30 minutes

- The TUC's shown for a crew member flying in a pressurized cabin are reduced approximately one-half following sudden loss of pressurization such as in an RD
- RD = Rapid Decompression

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Hypoxia

- Prevention
  - Limit time at altitude
  - Pressurized cabin
  - Minimize self imposed stressors
  - 100% O_2

- Treatment
  - Descend to a safe altitude
  - 100% O_2

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Hyperventilation

- An excessive rate and depth of respiration leading to the abnormal loss of CO_2 from the blood
- Emotional
  - (fear, anxiety, apprehension)
- Pressure breathing
- Hypoxia

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Hyperventilation Symptoms

- Tingling sensations
- Muscle spasms
- Hot and cold sensations
- Visual impairment
- Dizziness
- Unconsciousness

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Hyperventilation (Corrective Actions)

- Don't panic
- Control your breathing
- Check your oxygen equipment - it may be hypoxia

Can incapacitate an otherwise outstanding, healthy aircrew member

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Hyperventilation or Hypoxia? Distinguishing Factors

- Above 10,000 feet possible hypoxia
- Below 10,000 feet probably hyperventilation
- Cyanosis occurs only in hypoxia
- Muscle cramps occur only in hyperventilation

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Check on Learning

- What are the four types of Hypoxia?
  - Hypoxic hypoxia, Hypemic hypoxia, Histotoxic hypoxia and Stagnant hypoxia
- What are three causes of Hyperventilation?
  - Anxiety, Pressure Breathing, and Hypoxia
- How do you distinguish between hyperventilation and hypoxia?
  - Below 10,000 ft assume hyperventilation
- What are the names of the three Physiological Zones of the atmosphere?
  - Efficient Zone, Deficient Zone and Space Equivalent Zone

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Gas Dysbarism

Syndrome resulting from the effects, excluding hypoxia, of a pressure differential between the ambient barometric pressure and the pressure of gases within the body

Two Types: Trapped Gas and Evolved Gas

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Boyle's Law

- The volume of a gas is inversely proportional to its pressure; temperature remaining constant

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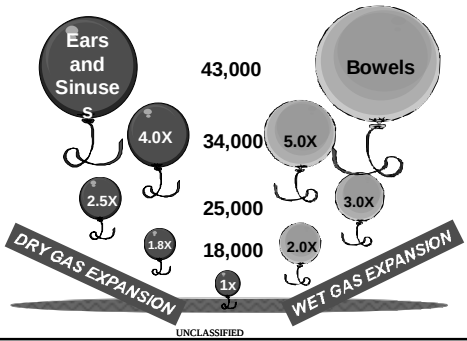
Gas Expansion



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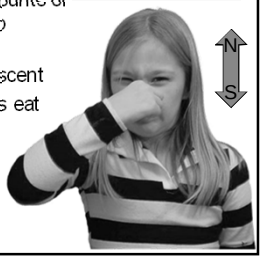
Prevention of Abdominal Gas

- Avoid soda and large amounts of water just prior to going to altitude
- Don't chew gum during ascent
- Keep regular bowel habits eat your fiber
- Off-gas as necessary



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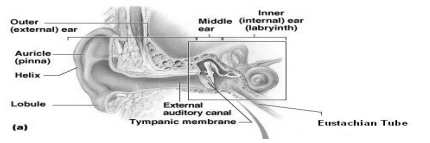
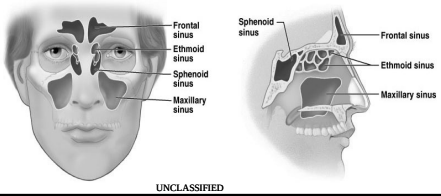
Ear and Sinus Blocks





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Treatment of Ear/Sinus Blocks

- On the ascent (rare)
  - Land and refer individual to flight surgeon
- On the descent (most common)
  - Stop the descent of the aircraft and attempt to clear by valsalva
  - If unable to clear, climb back to altitude until clear by pressure or valsalva
  - Descend slowly and clear ear frequently during descent

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Barodontalgia

- Tooth pain due to gas expansion
  - Usually isolated to one tooth and always on the ascent
  - New decay under a filling
  - Trapped air under crown
  - Gum abscess: dull pain
  - Inflamed pulp: sharp pain
- Land and refer to dental

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Evolved Gas Dysbarism (a.k.a. Decompression Sickness)

- Occurs due to the reduction in atmospheric pressure
- As pressure decreases, gases dissolved in body fluids are released as bubbles
  - like taking the top off a soda bottle

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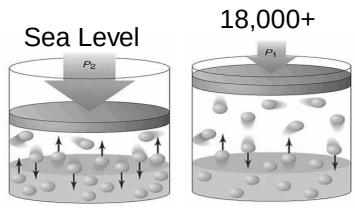
Henry's Law



The amount of gas dissolved in a solution is directly proportional to the pressure of the gas over the solution

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Evolved Gas Disorders

- Decompression Sickness (DCS)
  - Type I
    - Bends
    - Skin manifestations
  - Type II
    - Chokes
    - Central Nervous System - CNS

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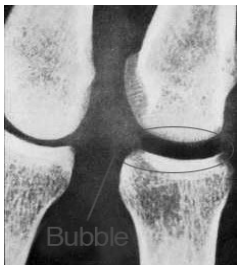
The Bends

- N_2 bubbles become trapped in the joints
- Onset is mild, but eventually painful!



Bone x-rays that show the effects of rapid decompression on the body
Left=normal bone, right=bone with bubble

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Skin Manifestations

- N_2 bubbles form under skin along nerve tracts
- Tingling and itchy sensation (paresthesia) and possibly a mottled red rash

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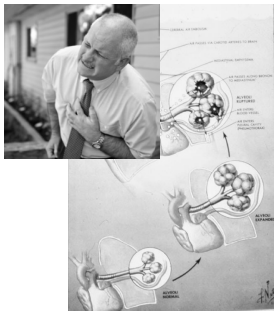
The Chokes

- N_2 bubbles block smaller pulmonary vessels
- Burning sensation in sternum
- Uncontrollable desire to cough
- Sense of suffocation ensues



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CNS

- N_2 bubbles trapped in brain or against spinal cord
- Paralysis, visual disturbances, one-sided tingling

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Factors Influencing the Development of Evolved Gas Disorders

- Rate of ascent
- Altitude
- Body fat content
- Age
- Exercise
- Duration of exposure
- Repeated exposure

WARNING ! *Evolved gas disorders are considered serious medical conditions; medical treatment and advice must be sought immediately!*

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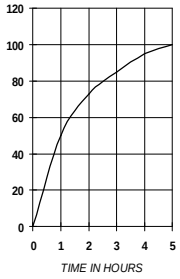
Decompression Sickness Prevention



- Denitrogenation
  - Required by AR 95-1 for all unpressurized flights above 14,000 feet
  - Prebreath 100% 0_2 for 30 minutes prior to flight and en route to altitude
- For pressurized flight maintain cabin pressurization at or below 10,000 ft PA

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Decompression Sickness Treatment

- Descend
- 100% Oxygen
- Land at nearest location where qualified medical assistance is available
- Compression greater than 1 atmosphere absolute

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Scuba Divers Beware!

- 24 hour restriction between diving and flying!!!!!

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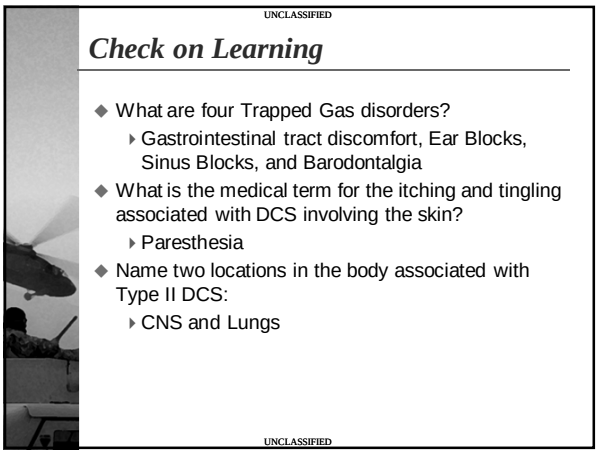
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Check on Learning
What are four Trapped Gas disorders?
Gastrointestinal tract discomfort, Ear Blocks, Sinus Blocks, and Barodontalgia
What is the medical term for the itching and tingling associated with DCS involving the skin?
Paresthesia
Name two locations in the body associated with Type II DCS:
CNS and Lungs
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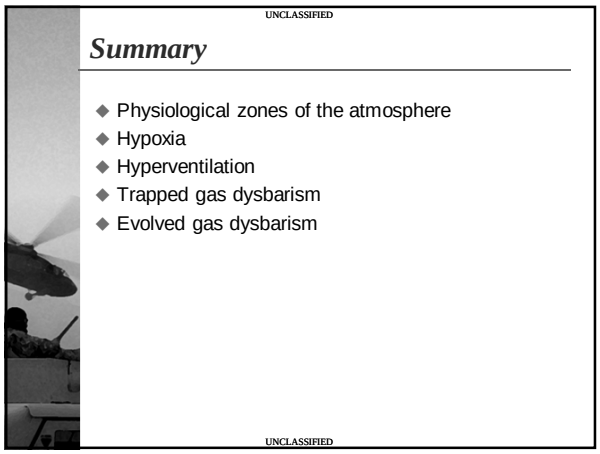
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Summary
Physiological zones of the atmosphere
Hypoxia
Hyperventilation
Trapped gas dysbarism
Evolved gas dysbarism
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