

American College of Occupational and Preventive Medicine
2011 Annual Meeting, Orlando, Florida, November 2, 2011

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**AEROSPACE/ OCCUPATIONAL
MEDICINE**

BAROMETRIC CONCERNS

Dr. John Campbell, MFS

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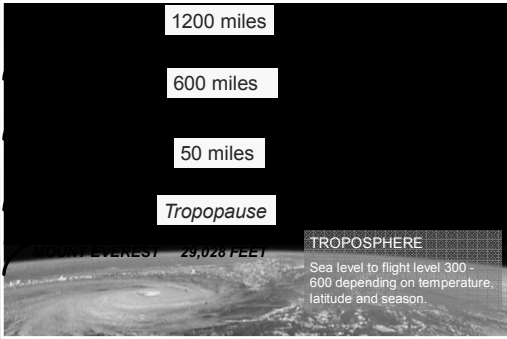
Administrative Information

- ◆ Risk Assessment: Low
- ◆ Environmental Considerations: None
- ◆ Safety Considerations: None
- ◆ Evaluation: 50 Question exam at the end of Aeromedical Training

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Physical Divisions of the Atmosphere



1200 miles

600 miles

50 miles

Tropopause

EVEREST 29,028 FEET

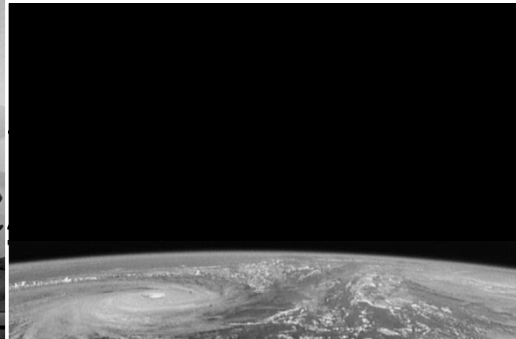
TROPOSPHERE

Sea level to flight level 300 - 600 depending on temperature, latitude and season.

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Physiological Zones of the Atmosphere



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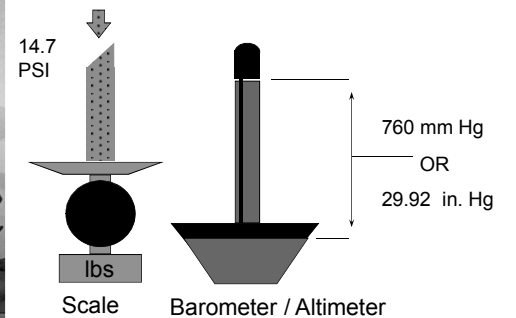
Composition of the Air

- ◆ 78 % Nitrogen (N₂)
- ◆ 21 % Oxygen (O₂)
- ◆ 1 % Other
 - ▶ 0.03 % CO₂

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Sea Level Pressure



14.7 PSI

760 mm Hg
OR
29.92 in. Hg

lbs

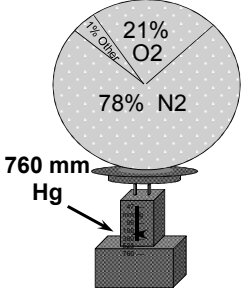
Scale Barometer / Altimeter

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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

$$P_{Total} = P_1 + P_2 + \dots + P_n$$

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Dalton's Law Examples

- ◆ SEA LEVEL
 - ▶ $PO_2 = 0.21 \times 760 \text{ mmHg} = 160 \text{ mmHg}$
 - ▶ $PN_2 = 0.79 \times 760 \text{ mmHg} = 600 \text{ mmHg}$
 - » $P_{Total} = 760 \text{ mmHg}$
- ◆ 18,000 Ft
 - ▶ $PO_2 = 0.21 \times 380 \text{ mmHg} = 80 \text{ mmHg}$
 - ▶ $PN_2 = 0.79 \times 380 \text{ mmHg} = 300 \text{ mmHg}$
 - » $P_{Total} = 380 \text{ mmHg}$

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Correction of Altitude, Alveolar O₂ 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 O₂ 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	88	87
50,000	87	16	15

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Functions of the Circulatory System

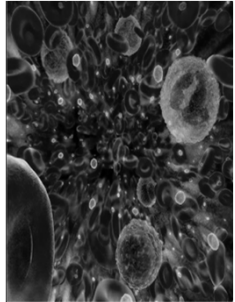
- ◆ Oxygen and nutrient transport to the cells
- ◆ Transport of metabolic waste products to organ removal sites
- ◆ Assists in temperature regulation
- ◆ Assists in maintaining acid-base balance

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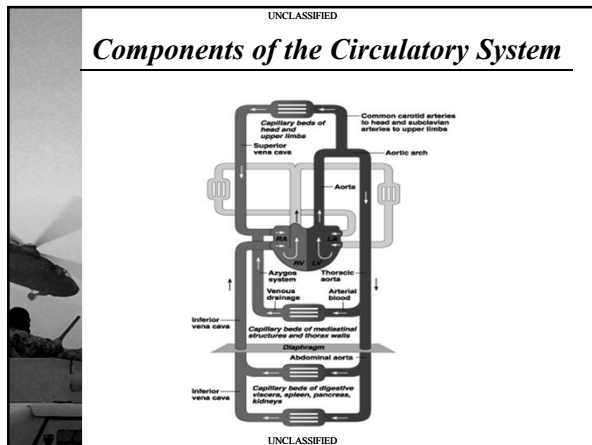
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Components of Blood

- ◆ 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 O₂ in the body



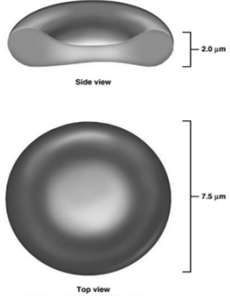
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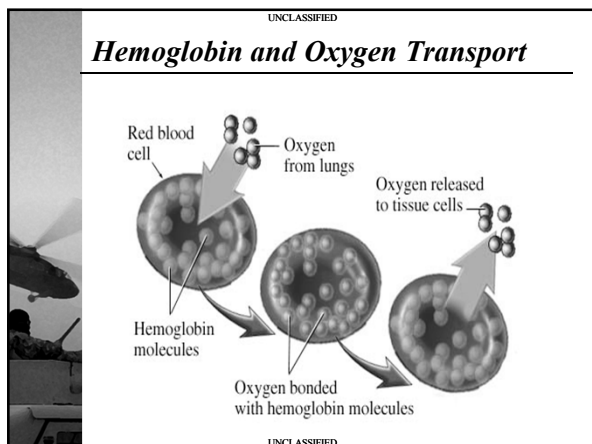
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The Red Blood Cell

- ◆ 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 CO₂ in the blood is also transported on hemoglobin



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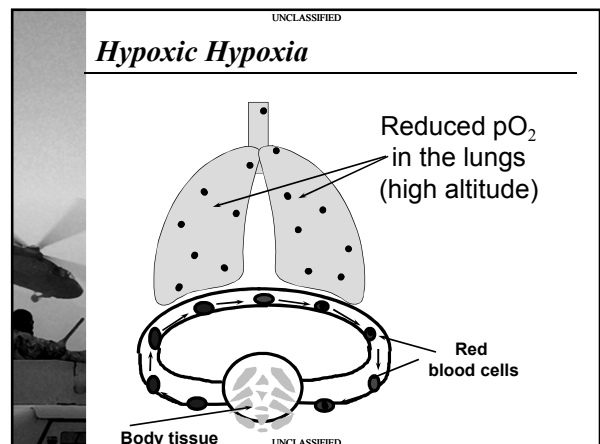
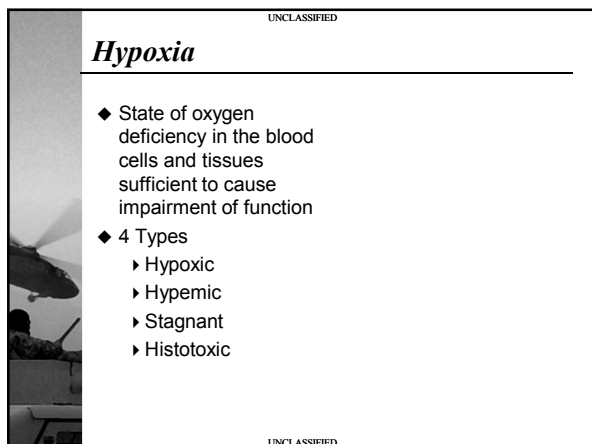
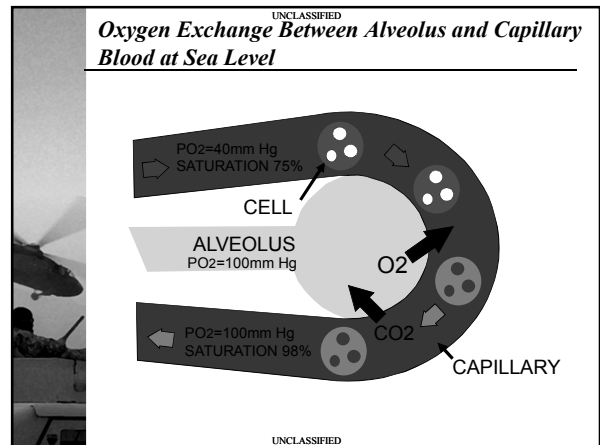
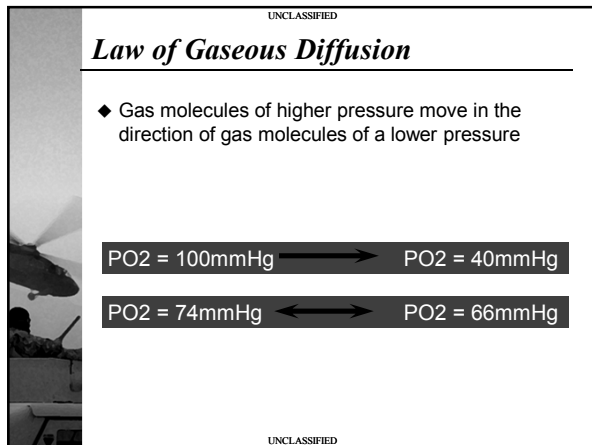
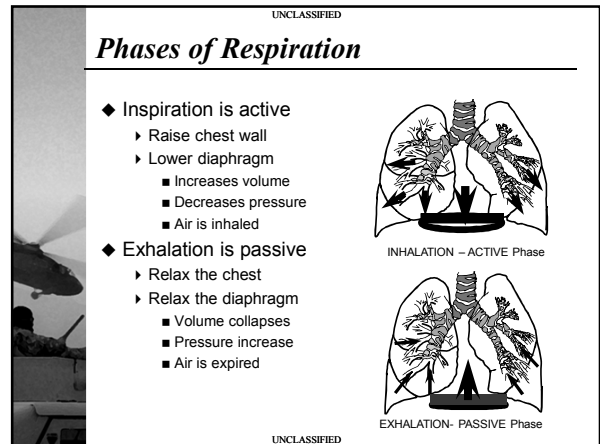
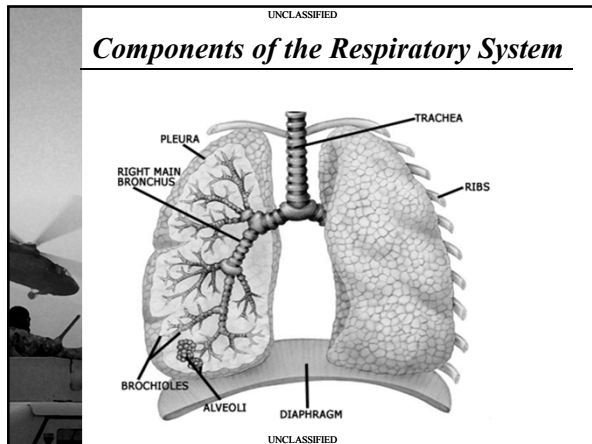
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Functions of the Respiratory System

- ◆ Intake of Oxygen [O₂] Active Process
- ◆ Removal of Carbon Dioxide [CO₂] Passive Process
- ◆ Maintenance of body heat balance
- ◆ Maintenance of body acid base balance [pH]

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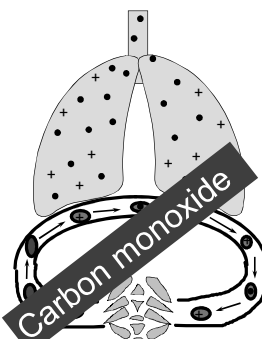
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Hypemic Hypoxia



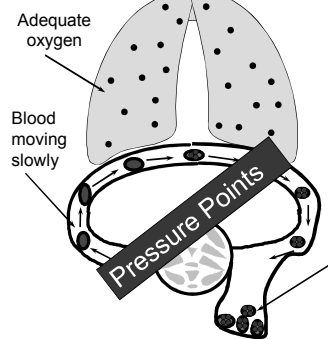
Inability of the blood to accept oxygen in adequate amounts

Carbon monoxide

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Stagnant Hypoxia



Adequate oxygen

Blood moving slowly

Pressure Points

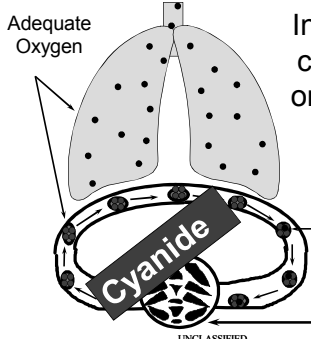
Reduced blood flow

Red blood cells not replenishing tissue needs fast enough

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Histotoxic Hypoxia



Adequate Oxygen

Inability of the cell to accept or use oxygen

Cyanide

Red blood cells retain oxygen

Poisoned tissue

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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

<ul style="list-style-type: none"> ◆ Pressure altitude ◆ Rate of ascent ◆ Time at altitude ◆ Temperature 	<ul style="list-style-type: none"> ◆ 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 1/2-3 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% O₂



- ◆ Treatment
 - ▶ Descend to a safe altitude
 - ▶ 100% O₂

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Hyperventilation

- ◆ An excessive rate and depth of respiration leading to the abnormal loss of CO₂ 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

<ul style="list-style-type: none"> ◆ Above 10,000 feet possible hypoxia 	<ul style="list-style-type: none"> ◆ Cyanosis occurs only in hypoxia
<ul style="list-style-type: none"> ◆ Below 10,000 feet probably hyperventilation 	<ul style="list-style-type: none"> ◆ 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

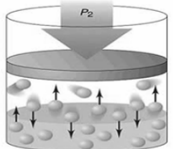


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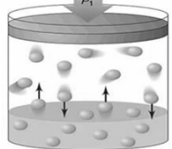
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Henry's Law

Sea Level



18,000+



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

- ◆ N₂ 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

- ◆ N₂ bubbles form under skin along nerve tracts
- ◆ Tingling and itchy sensation (paresthesia) and possibly a mottled red rash



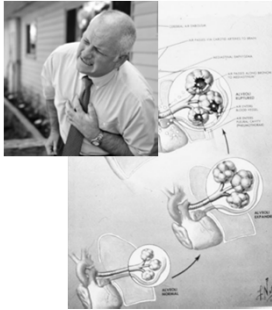
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The Chokes

- ◆ N₂ bubbles block smaller pulmonary vessels
- ◆ Burning sensation in sternum
- ◆ Uncontrollable desire to cough
- ◆ Sense of suffocation ensues




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CNS

- ◆ N₂ 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

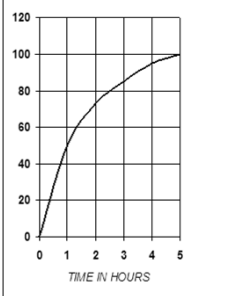
- ◆ Rate of ascent
- ◆ Altitude
- ◆ Body fat content
- ◆ Age
- ◆ Exercise
- ◆ Duration of exposure
- ◆ Repeated exposure

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% O₂ 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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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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Summary

- ◆ Physiological zones of the atmosphere
- ◆ Hypoxia
- ◆ Hyperventilation
- ◆ Trapped gas dysbarism
- ◆ Evolved gas dysbarism

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