Bubbles, Bubbles, Toils, and Troubles

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Objectives

- Discuss the effects of atmospheric pressure
- Review the most common gas laws and their effects on the body
- Discuss the concerns of “bubbles” in relationship to altitude
- Review treatment modalities for pressure related emergencies

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Atmosphere

- Layers of gases that surround the earth
  - Nitrogen ~78%
  - Oxygen ~21%
  - Argon ~1%
  - Tiny traces of other gases: CO2, Neon, Helium
- Bottom layer (troposphere) of the atmosphere is from the surface to 30,000 ft at poles to 56,000 ft at equator

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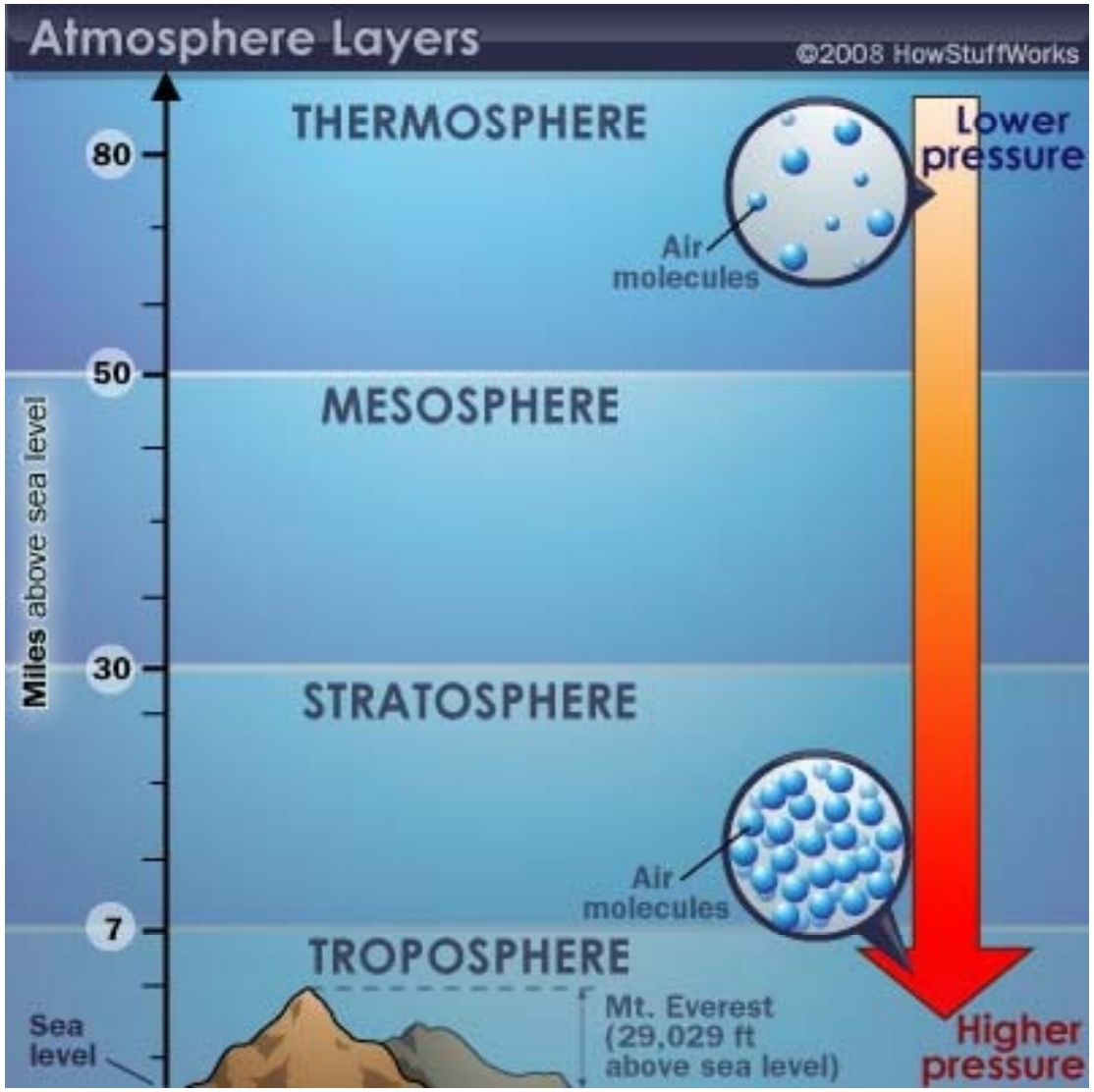

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Atmospheric Pressure

- Weight of air placed on a object
- Sea Level: 760 mm/hg
  - Why don't we feel it?
- Decreases as you increase elevation
- Increases as you go under water
  - Every 33 ft down is 1 atmosphere pressure
  - Max safe depth for divers is 133 ft

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Light versus Heavy

- Air
  - A 1 inch column of air from the sea to the top of the atmosphere weighs ~14 lbs
- 14 psi

- Water
  - The deeper a diver goes the greater the pressure for the water.
  - Water weighs 8 pounds a gallon
- Air spaces and dive gear will compress as pressure increases

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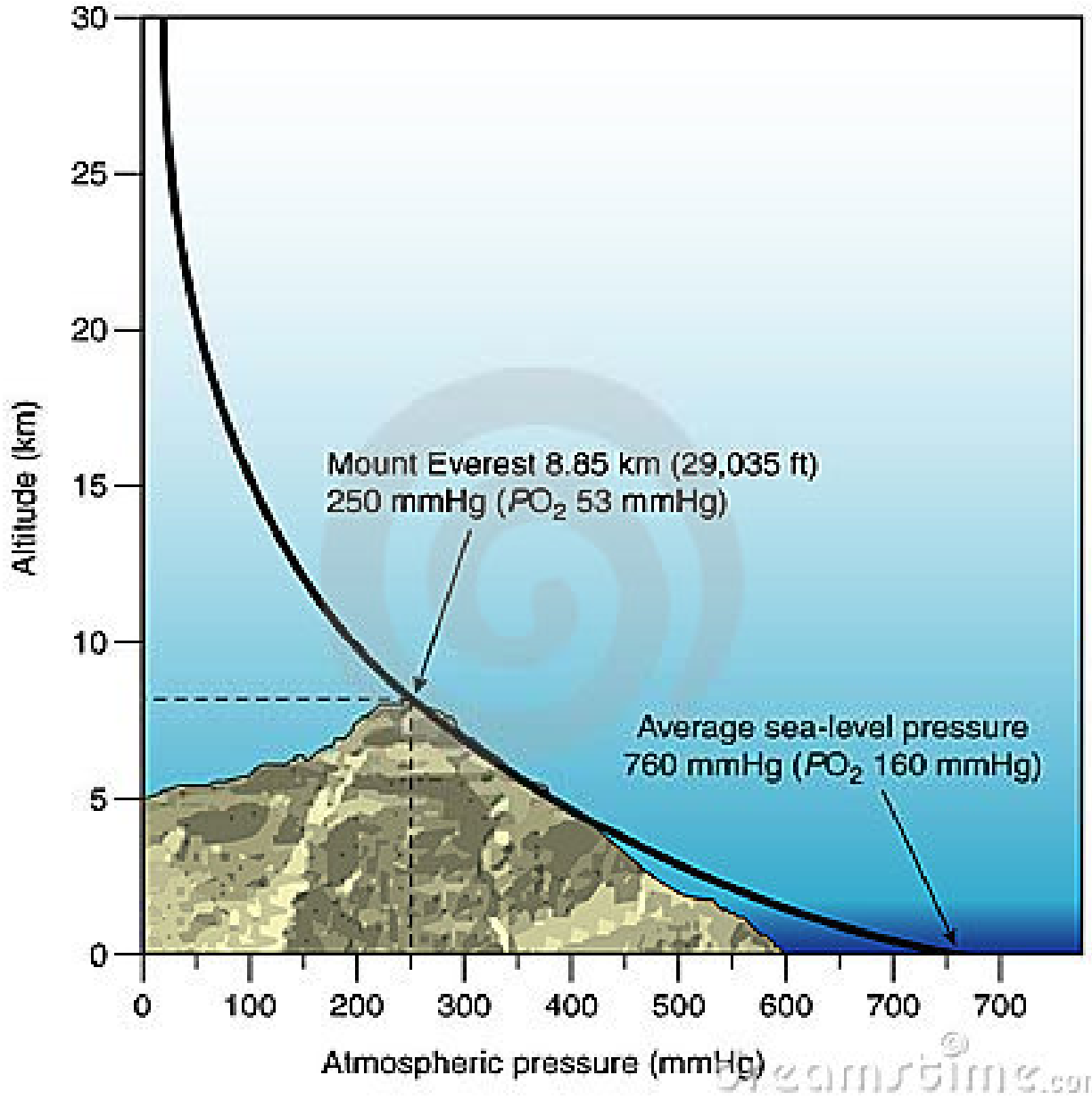
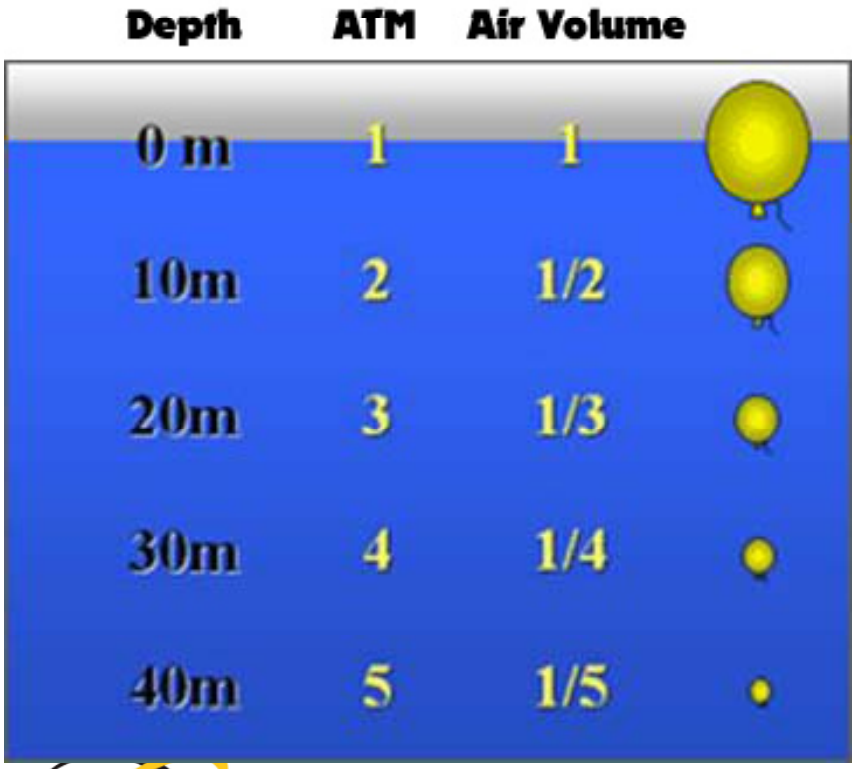


Effects of Depth and Pressure



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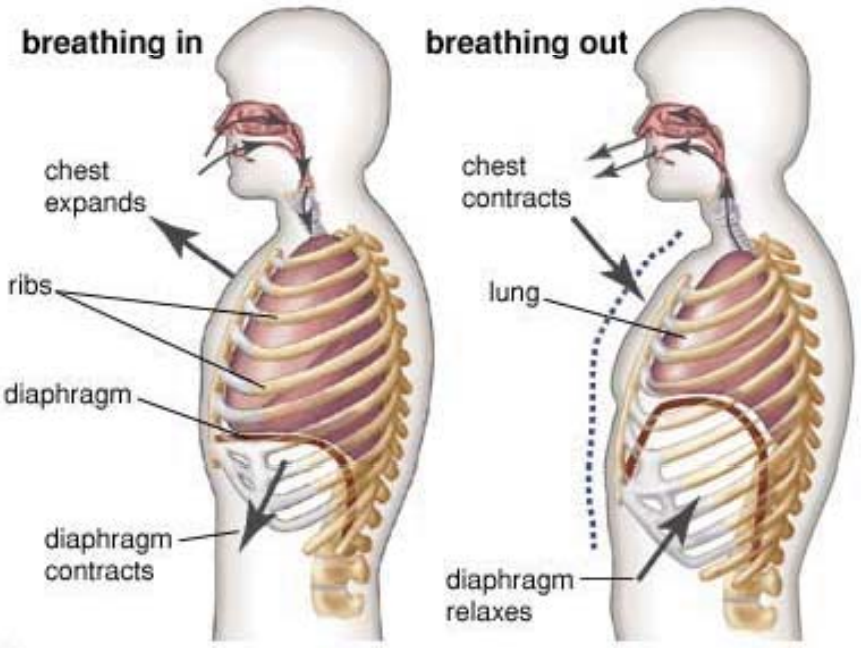
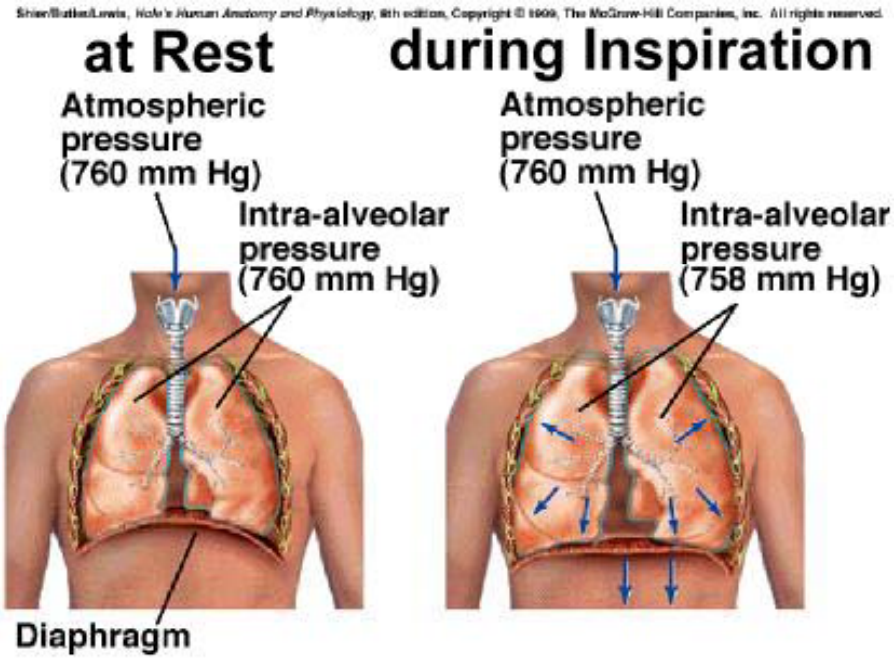
Taken to 3,000 meter

300 atmospheres

How we breathe?





Positive pressure versus negative pressure

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Lung Model

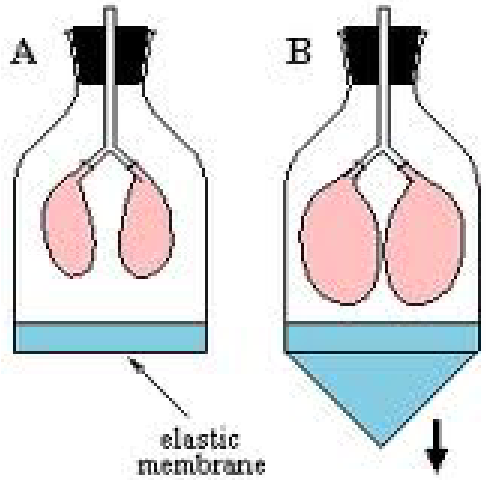

Figure 19 - A lung model

Positive pressure vs. negative pressure

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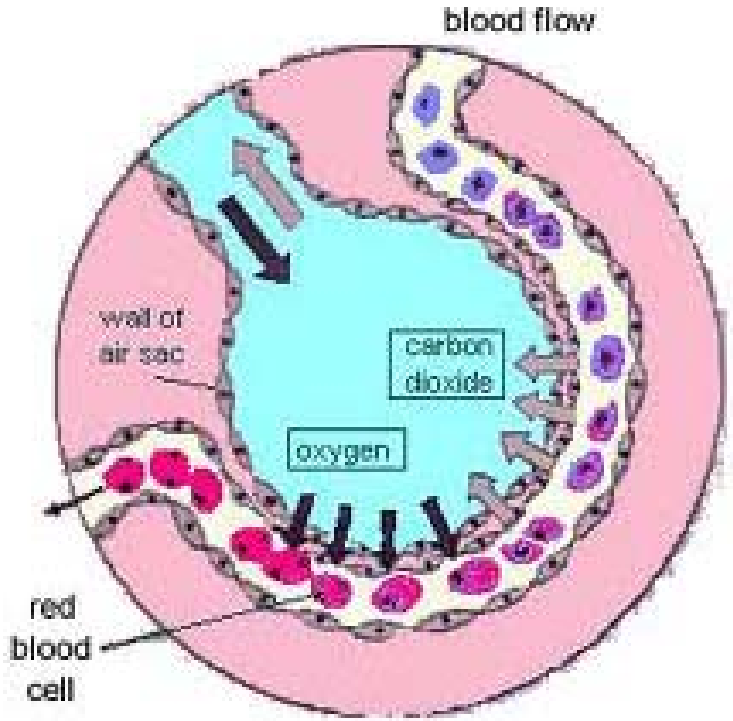
In vs. out, *what's the difference?*

- We breathe in….
  - 21% Oxygen
  - 78% Nitrogen
  - Tiny amount of Carbon Dioxide
- We breathe out….
  - 17% Oxygen
  - 78% Nitrogen
  - 5% Carbon Dioxide



Gas Law's

- Graham's Gas Law
  - Thomas Graham
  - Physical Chemist: Scotland
  - 1830's
- Dalton's Gas Law
  - John Dalton
  - British Physicist
  - 1801

Gas Law's

- Boyle's Ideal Gas Law
  - Robert Boyle
  - Irish Physicist
  - 1662
- Henry's Gas Law
  - William Henry
  - British Physicist
  - 1803

Graham's Gas Law

- Law of gaseous diffusion
- Gases diffuse or migrate from a region of higher concentration (or pressure) to a region of lower concentration (or pressure) until equilibrium is reached
- The physiological significance is in the explanation of gas exchange
  - Oxygen moves from the alveoli into the blood and from the blood into the tissues due to this phenomenon

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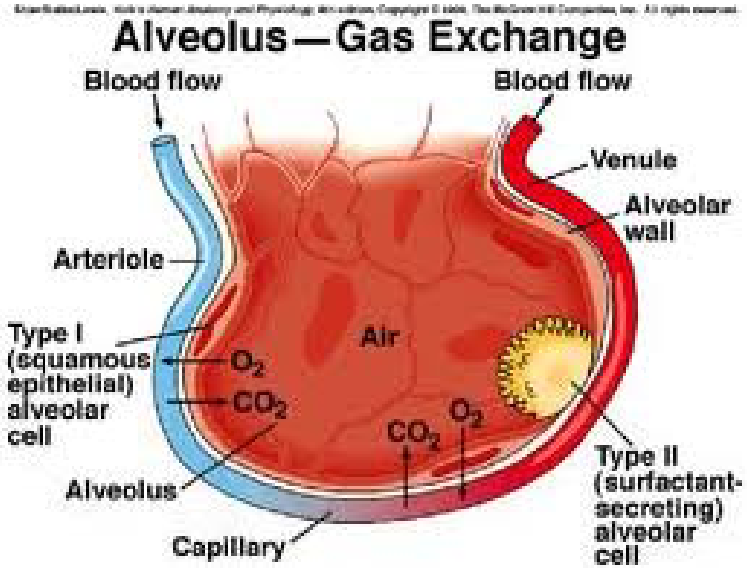
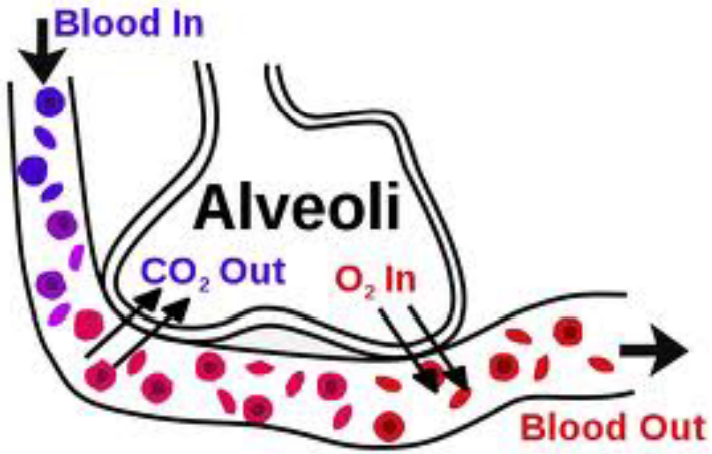
Graham's Law


Alveolus—Gas Exchange
Blood flow
Blood flow
Venule
Alveolar wall
Arteriole
Type I (squamous epithelial) alveolar cell
Air
O_2
CO_2
CO_2
O_2
Alveolus
Capillary
Type II (surfactant-secreting) alveolar cell


Blood In
Alveoli
CO_2 Out
O_2 In
Blood Out

Dalton's Law

- Describes the pressure exerted by a gas at various altitudes (pressures)
- Each gas present in the atmosphere contributes to the total
- The sum of the partial pressures is equal to the total atmospheric pressure

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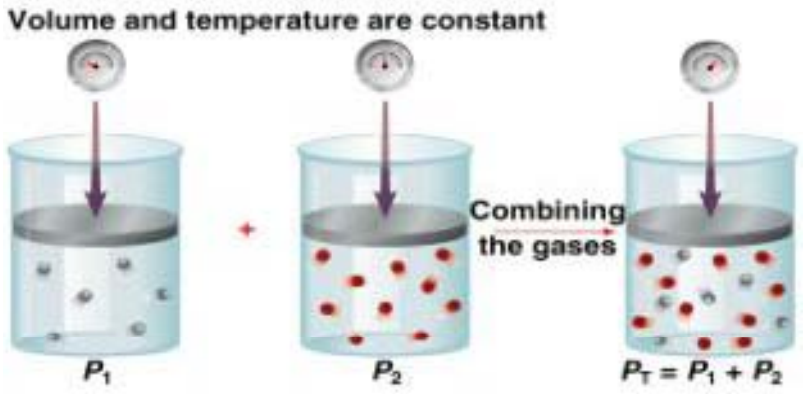
Dalton's Law

- As altitude increases – gases exert less pressure
- Explains the hypoxia that occurs with flight to higher altitudes
  - Example
  - Oxygen at sea level
    - O_2 = 21% and PO_2 = 21% x 760 mm Hg = 159.22 mm Hg
    - Oxygen at 8,000 feet
      - O_2 = 21% and PO_2 = 21% x 565 mm Hg = 118.65 mm Hg
- **THE PECENTAGE OF OXYGEN REMAINS THE SAME** with changes in altitude

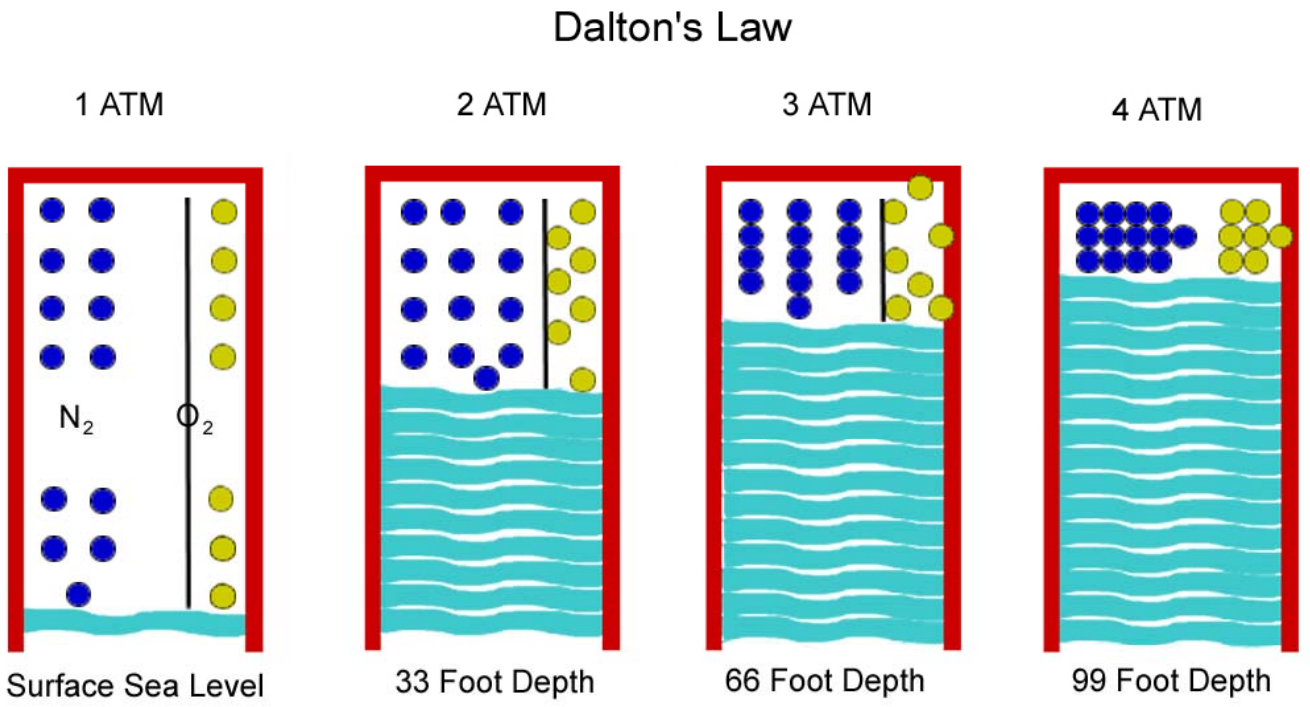
Dalton's Law

"Dalton's Gang"

- Dalton's Law Formula
  - Where
    - Pt = P1 + P2 + P3…Pn
      - Pt = total pressure
      - P1…Pn = partial pressures of constituent gases of the mixture



Dalton's Law



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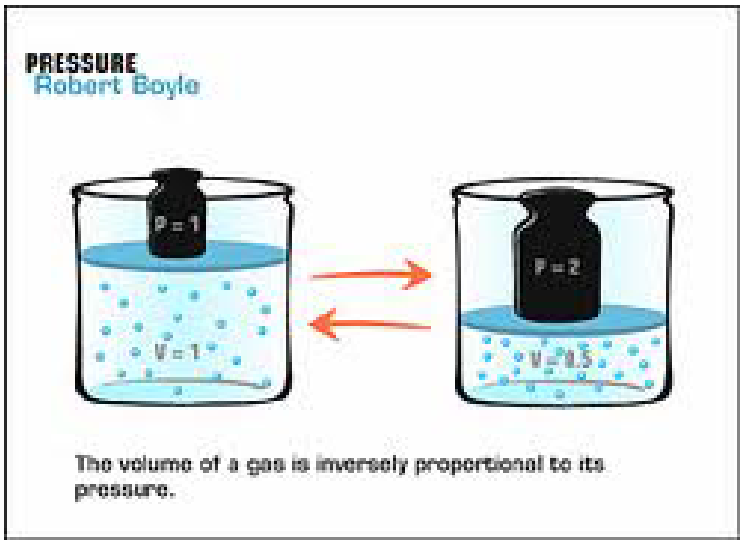
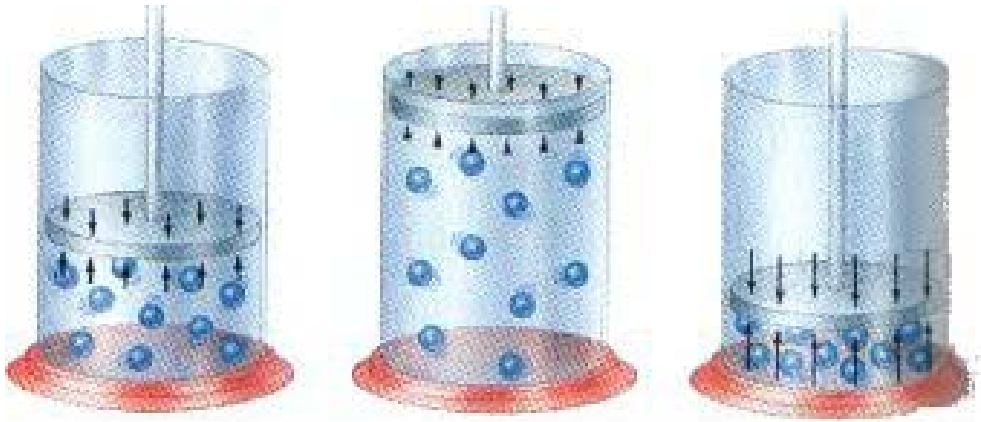
Boyle's Gas Law
"Bubbles"

- A fixed number of air molecules. Remains constant
- As elevation increases the volume expands
- Boyle's = Bubbles





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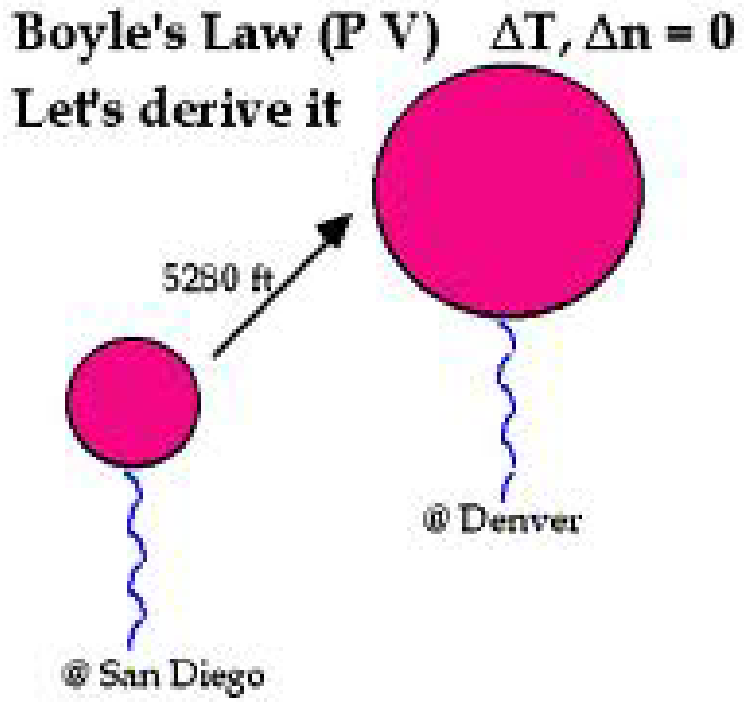
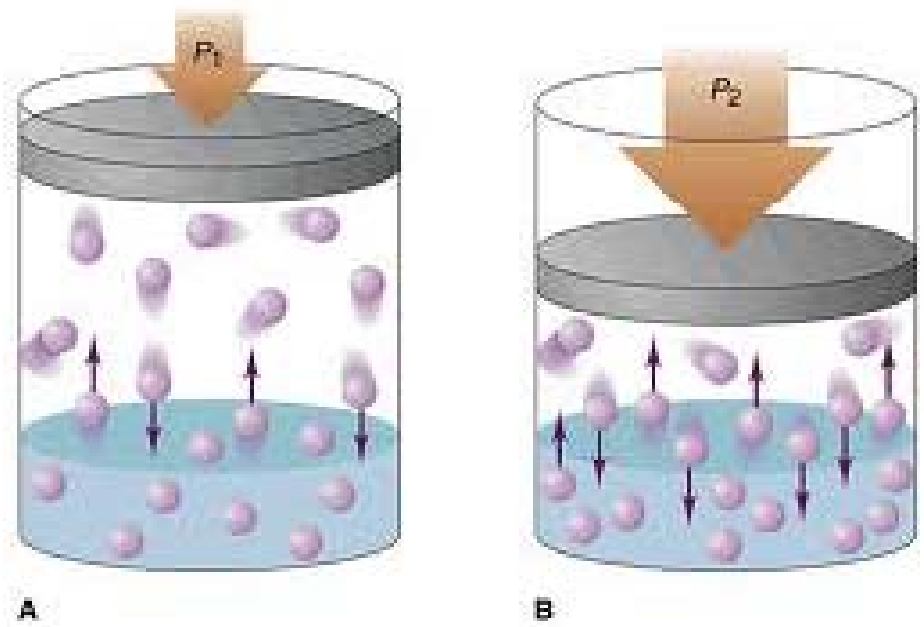
Boyle's Law



Inverse relationship
P(increase) → V (decrease)
Boyle's Law: $V = K_B / P$

Henry's Gas Law

Henry's Gas Law



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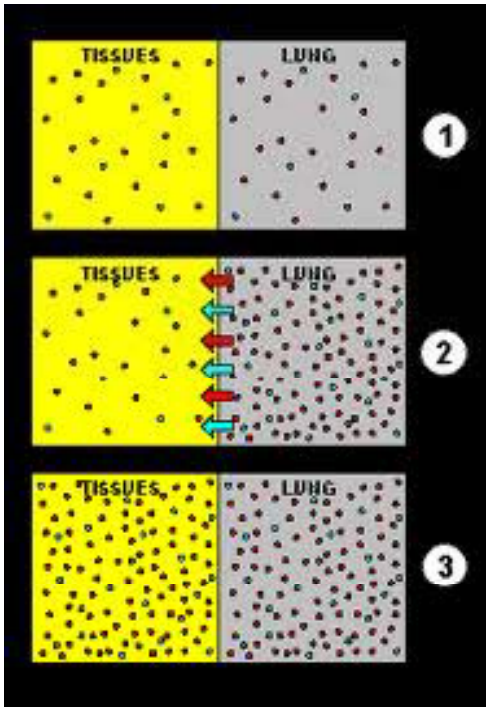
Henry's Law and SCUBA Diving



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Pressure on the body: The ups and downs

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Places where air gets trapped

- Chest
- Stomach
- Intestines
- Head
- Joints
- Fatty tissue

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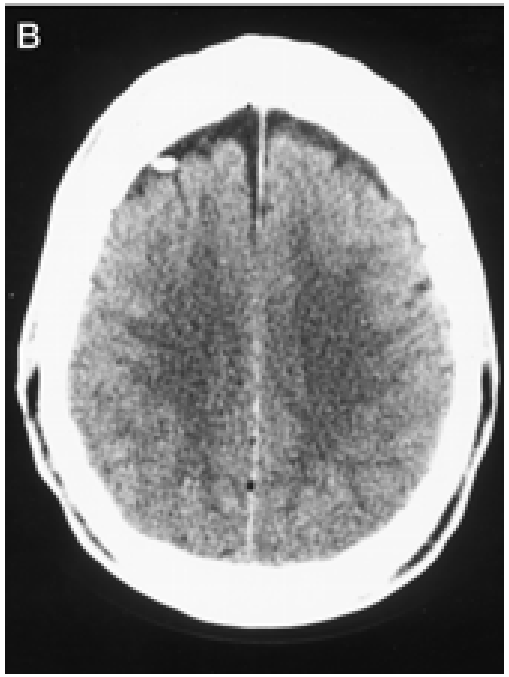

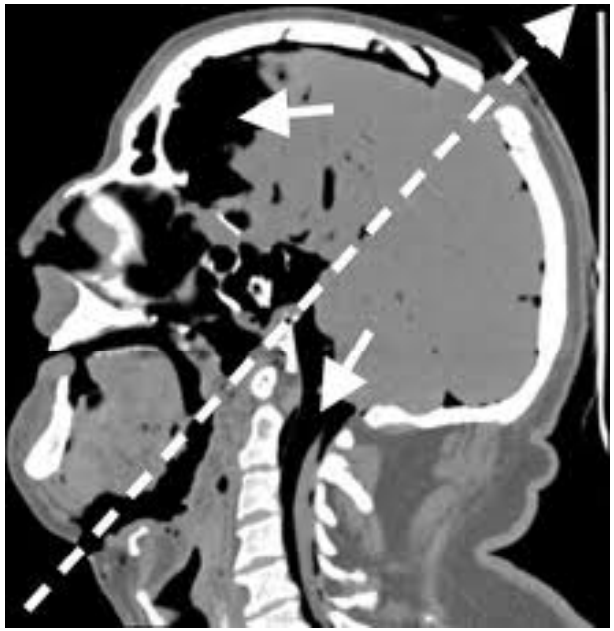

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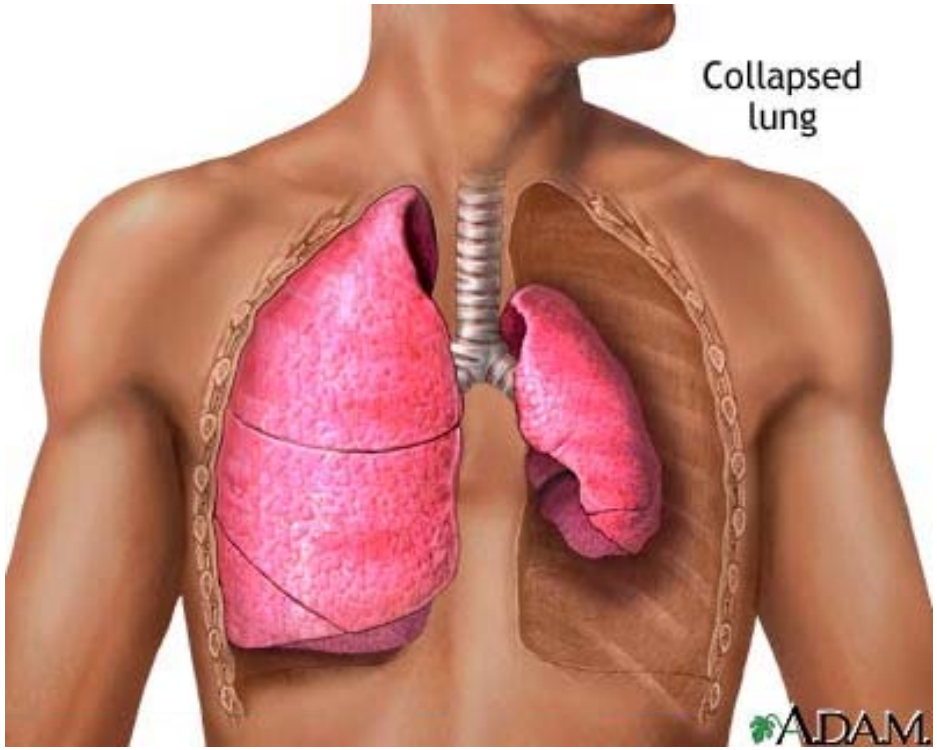
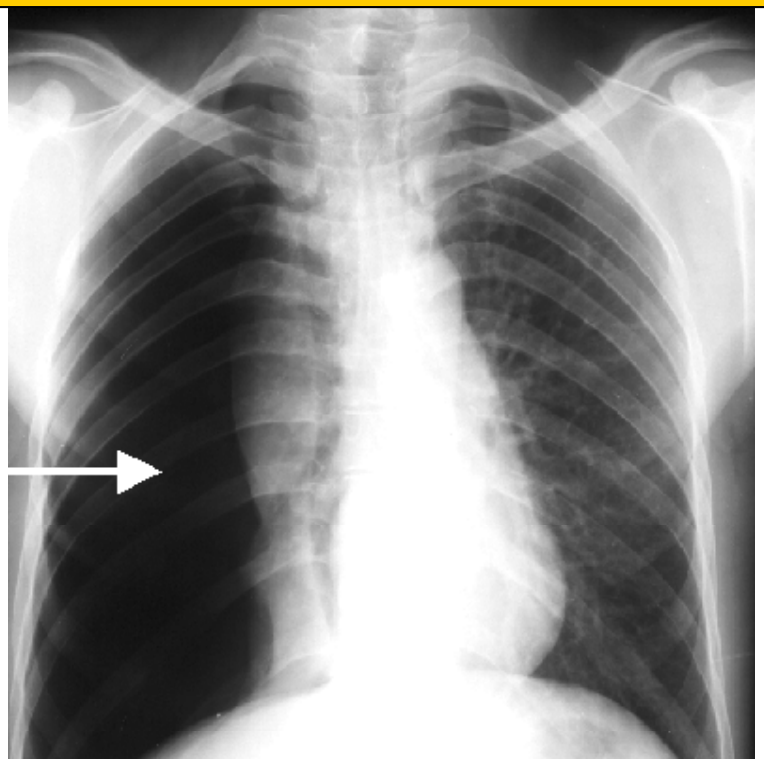
Concerns with air in your chest





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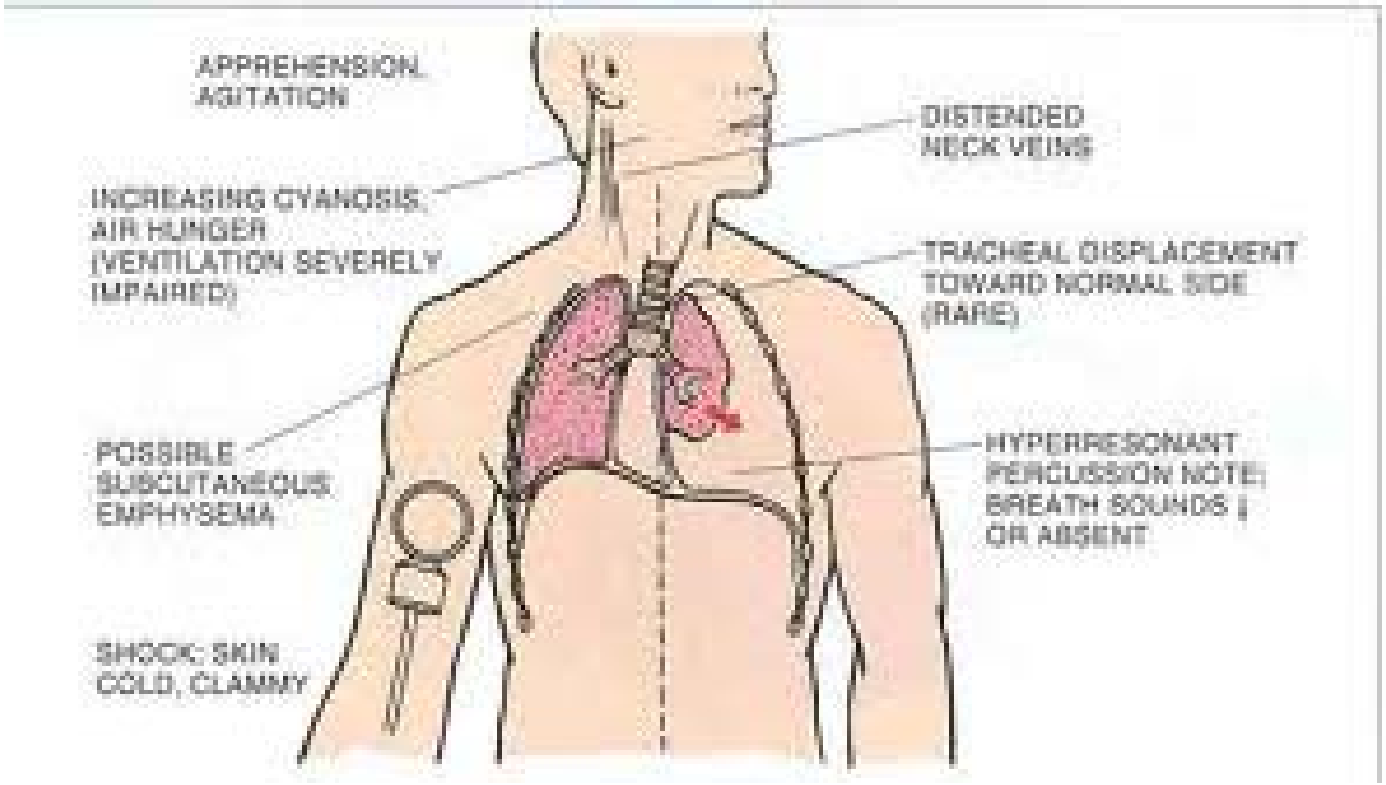
Tension Pneumothorax Concerns



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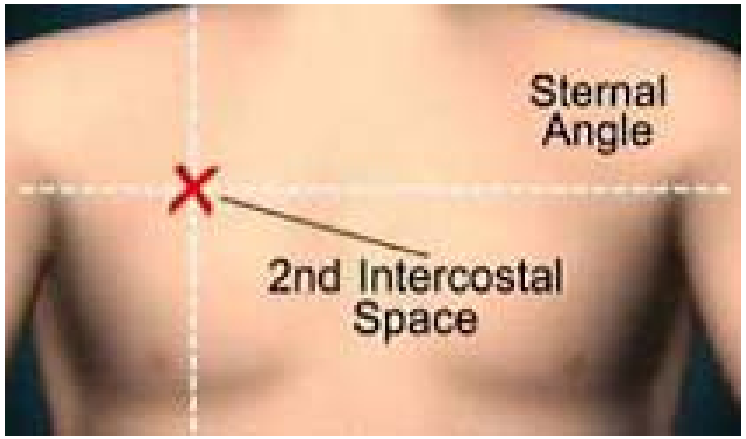
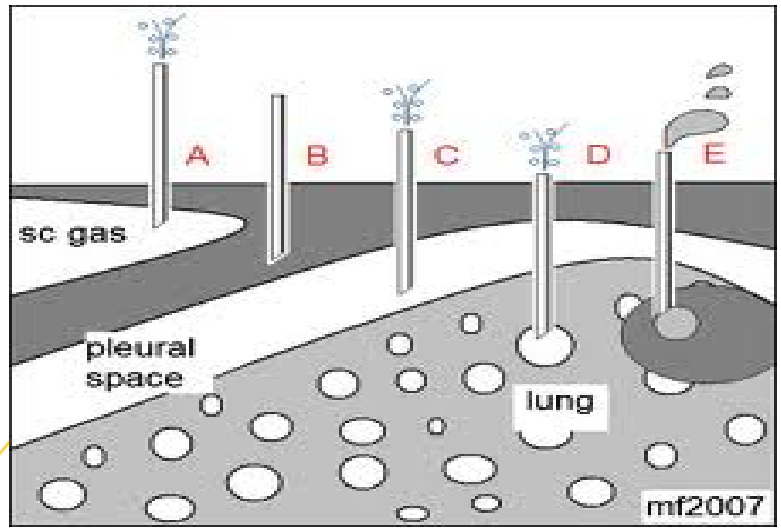
Needle Decompression





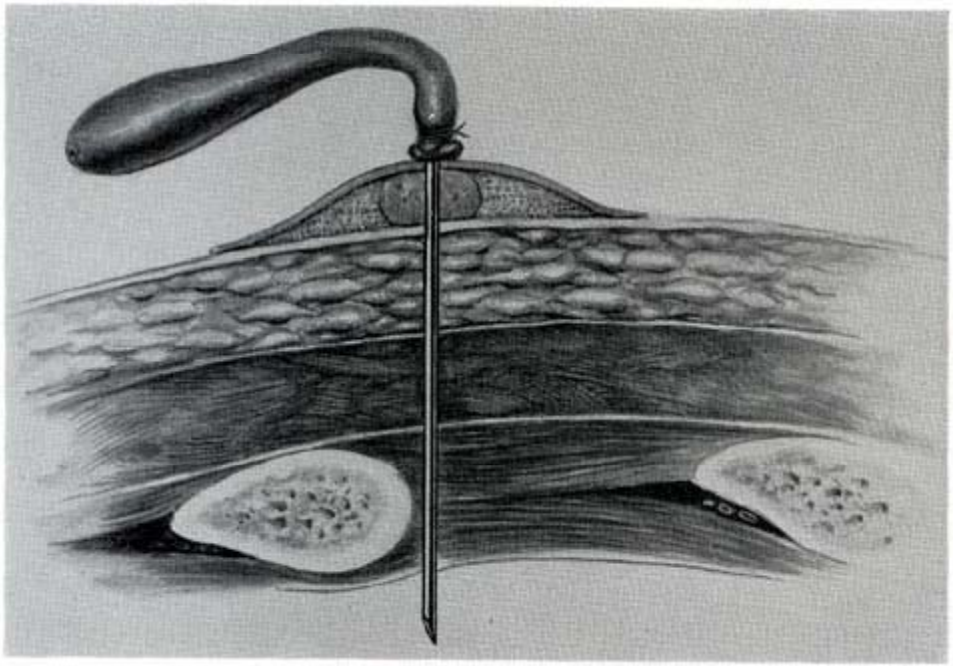
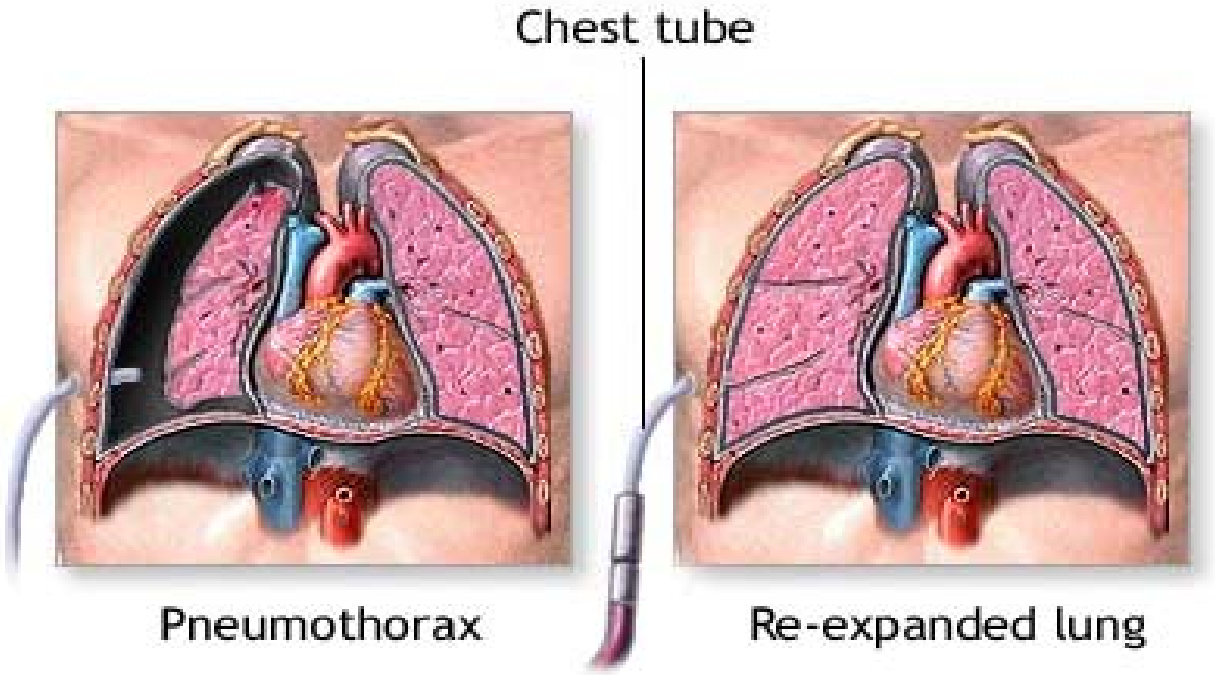


FIGURE 32.—Management of tension pneumothorax. Needle introduced through second interspace anteriorly, through cork, with finger cot flutter valve in situ.

How is the pressure relieved?



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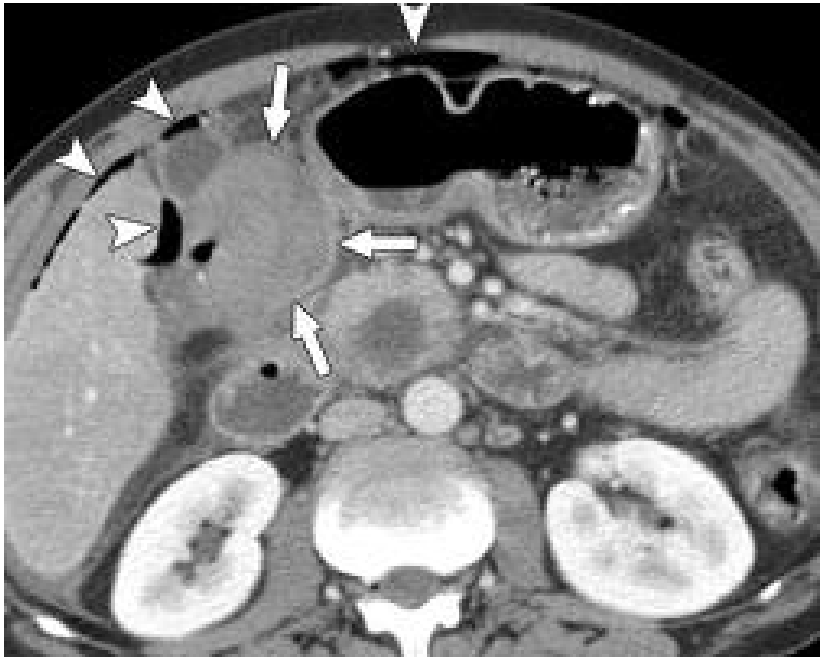
A.D.A.M.

Air in the belly



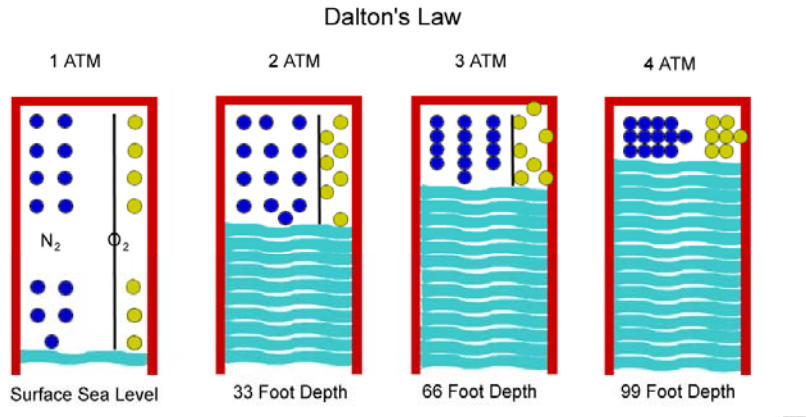
Consider
OGT/NGT

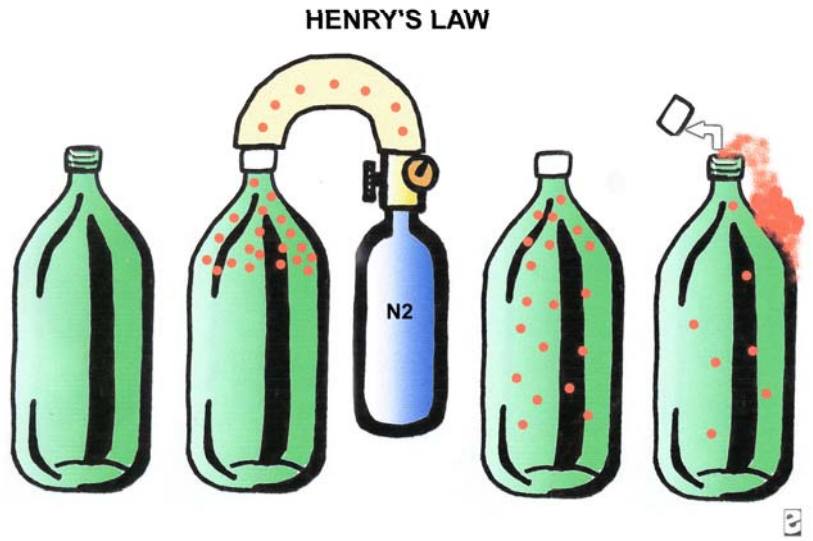
Decompression Sickness

- When you breathe compressed air with nitrogen. It gets trapped in your tissues under pressure as you descend and re-expands as you ascend.
- Nitrogen bubbles are trapped in your tissues/joints causing the symptoms of the “bends”

Putting it all together

- Dalton: Descend and pressure builds
- Henry: Ascend too rapidly and nitrogen is off gassed too quickly





DCS Symptoms

- Numbness
- Dizziness
- Weakness
- Nausea
- Pain
- Headaches
- Itching
- Visual disturbances

- Emergency treatment
  - 100% Oxygen
  - Fluids: PO or IV
  - Transport to decompression chamber
- Low altitude
  - CPR PRN
  - *Take gear, if possible*

Trendelenburg position is no longer recommended. Actually increases ICP

Take dive gear if possible

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Decompression Chamber

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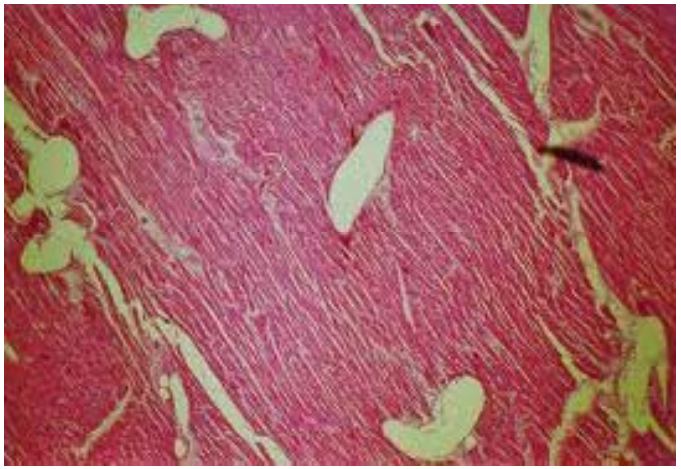
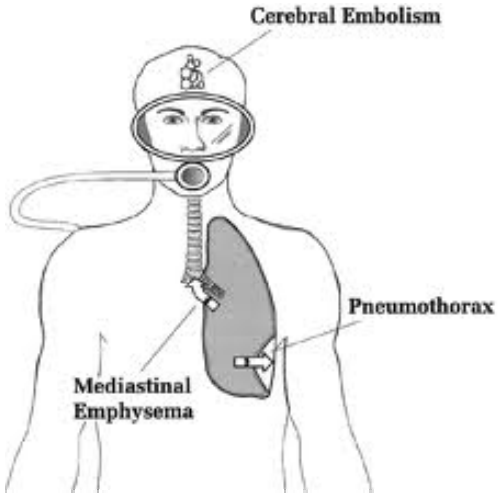
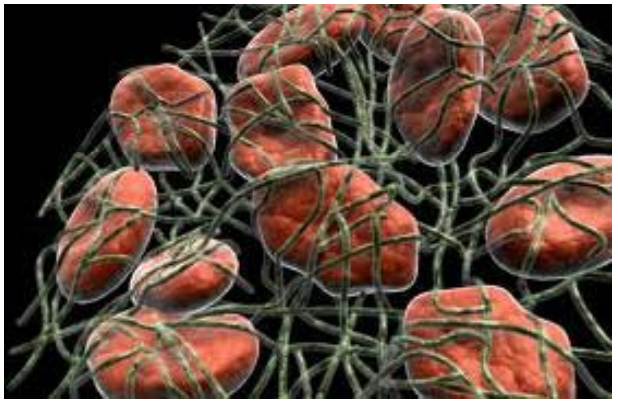
Other SCUBA related emergencies

- Air embolism
- Pneumothorax
- Nitrogen narcosis







Dive Computers

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SCUBA vs. Free Diving

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Altitude Illness/Sickness

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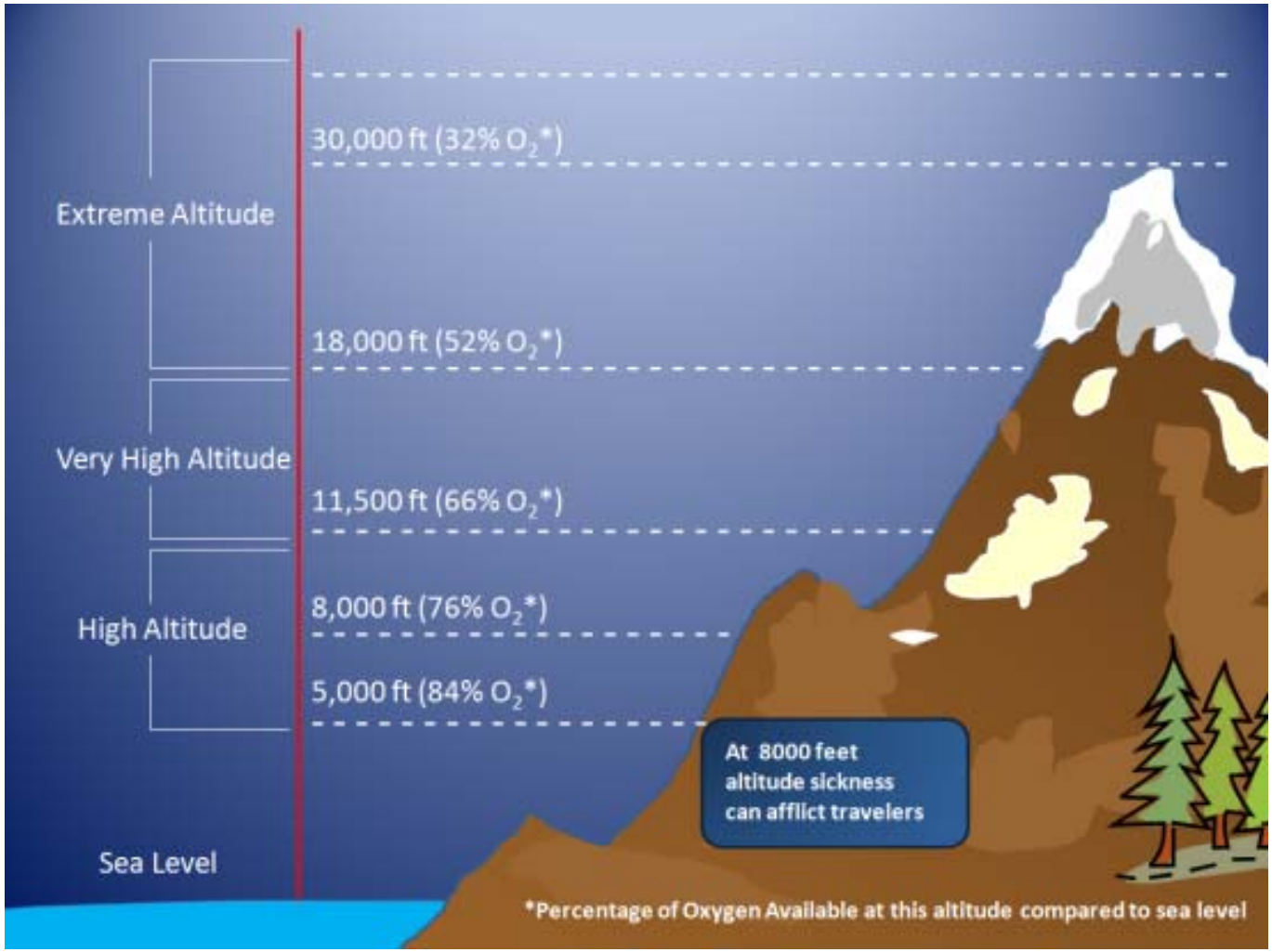
Affects of altitude on O2%



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How does Altitude Sickness Occur?

- Air is "thinner" at high altitudes. When you go too high too fast, your body cannot get as much oxygen as it needs. This causes the headache and other symptoms of altitude sickness
- Lower pressure at altitude
- As low as 8,000 feet can cause mild sickness

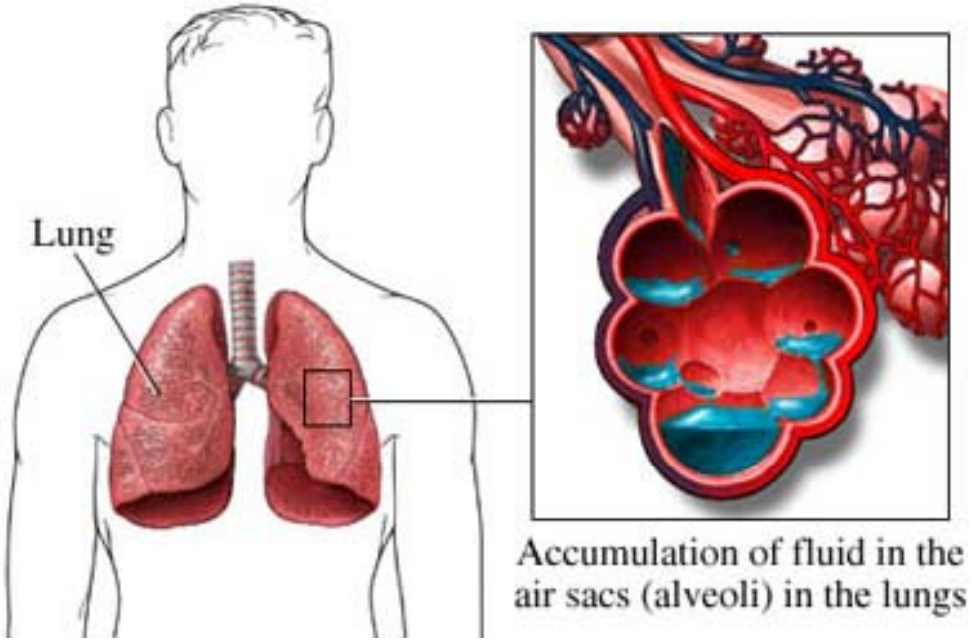
Symptoms of Altitude Illness

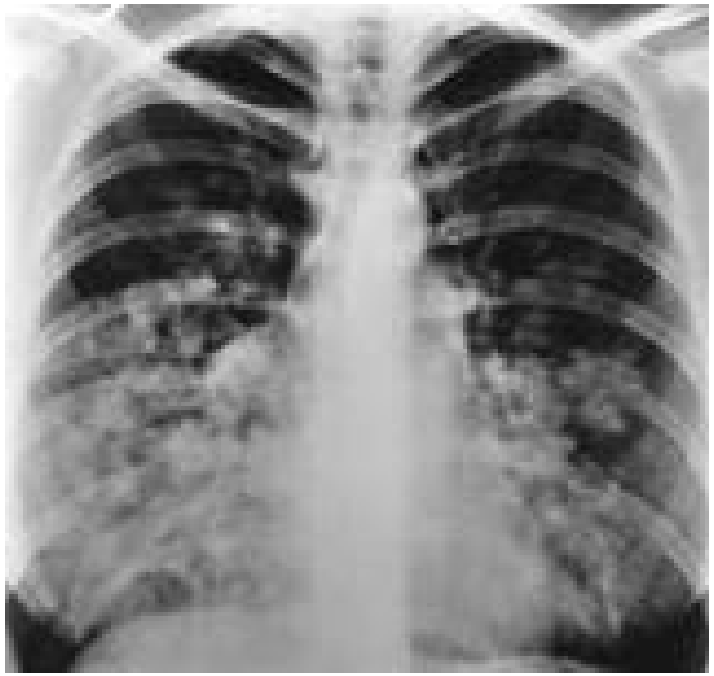
- Headache (headache)
- Fatigue (physical exhaustion)
- Sleep Disorder
- Nausea and Vomiting
- Digestive Disorders
- Agitation
- Vertigo

Severe symptoms

- Affects your lungs and brain
- Neuro symptoms: confused, not being able to walk straight (ataxia), feeling faint,
- Pulmonary symptoms: cyanosis of lips or fingernails.
  - Pulmonary edema (can be severe) and difficulty breathing
  - H.A.P.E.
    - Not enough atmospheric pressure to overcome pulmonary HTN and increase permeability of the vascular endothelial cells

H.A.P.E.





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Altitude Illness Treatment

- Mild symptoms: Accumulate or decrease altitude till symptoms improve.
- Moderate to severe symptoms:
  - Rest
  - Descend as quickly as possible/pressure bags
  - O2
  - Procardia/Nifedipine: Helps to decrease pulm HTN
  - Diamox (acetazolamide): Binds to bicarb to decrease the alkalosis that occurs with hyperventilation r/t altitude.
  - Diuretics: Lasix and Bumex

Why do I worry about pressure when fly a patient or go to high altitude by ground?

- Expansion
  - Tubes needed
  - ETT/Gastric
  - Watch pt closely
- Oxygen
- Fly low
- Pressurized planes

Altitude Considerations: ETT Cuff

- Careful with cuff pressure
- Consider a cuff manometer
  - Adults ~25mm/Hg

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Altitude Considerations: Devices

- PA Catheter: “Swan Ganz” Cath
- Wedge concerns

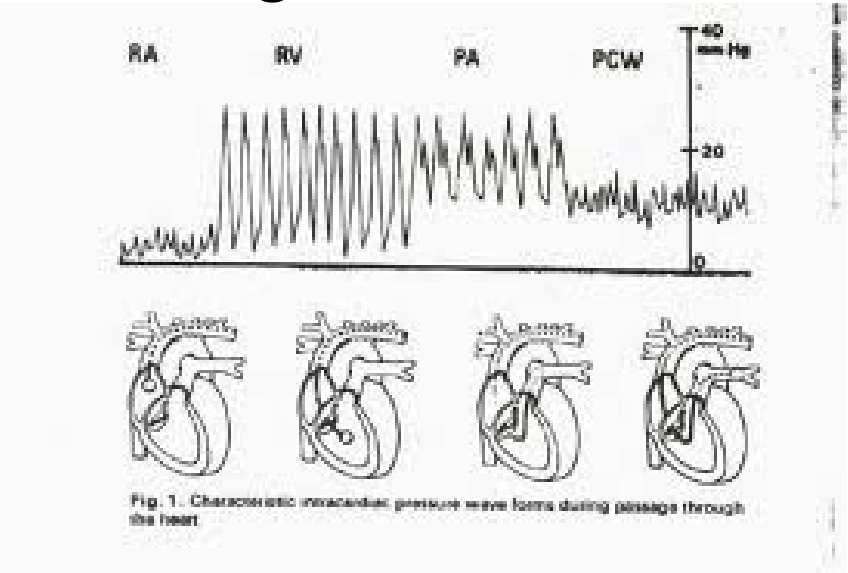
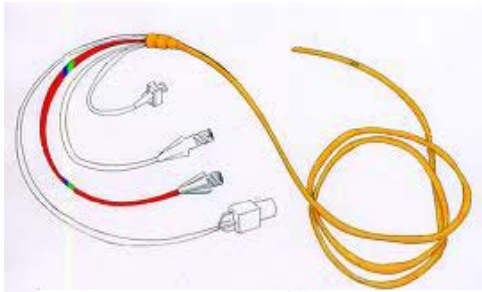
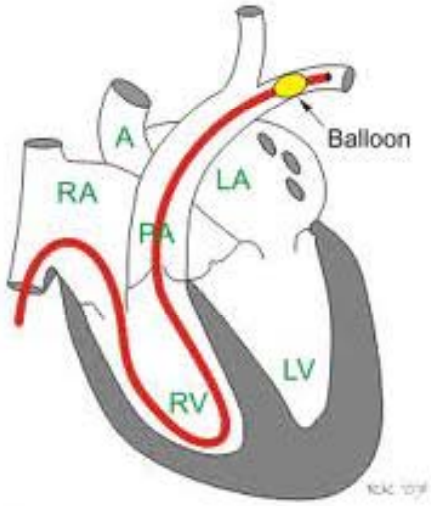


Fig. 1. Characteristic intracardiac pressure wave forms during passage through the heart.

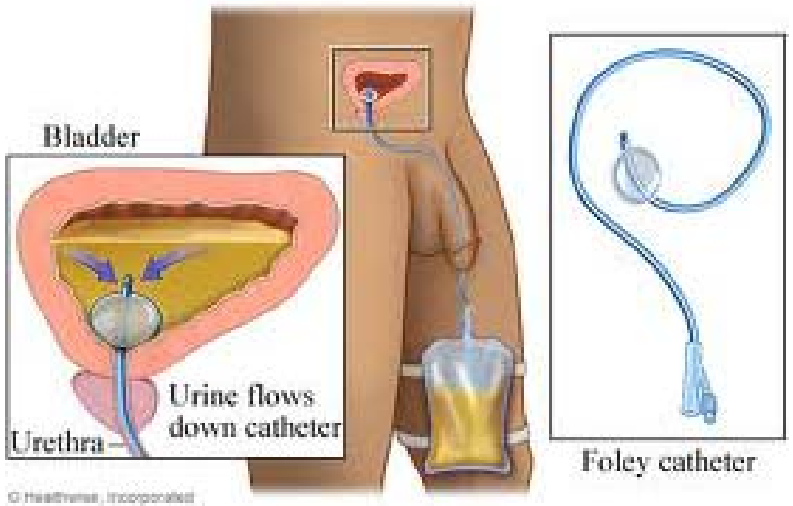




Balloon-tipped, Swan-Ganz catheter for measuring pulmonary capillary wedge pressure (PCWP).

Altitude Considerations: Devices

- Urinary Catheters
  - Fluid filled balloon
- Gastric Bags
  - "Burp"
  - Leaking
  - Rupture



Summary

- Understanding the effects of pressure on the human body prepares the provider to anticipate problems before they arise
- Altitude considerations need to be taken into account on all patients that are flown or ground transported at elevation.

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