BIOL 260: Human Physiology

Spring 2020 TR, April 7-9

http://accounts.smccd.edu/staplesn/biol260/

1. THIS Week: Pulmonary Lab Data; Ventilation data. PhysioEx and IP!
2. QUIZ #5 – first attempt due Thurs. PM.
3. April 7-9: Finish Ch. 17, Ch. 18; & start 21.
4. CardioV Lab report #4 due by this weekend.

1

Ch. 18: Gas Exchange/Transport

Objectives: Students should be able to….

1. Ch. 18: ** Compare and contrast how oxygen and carbon dioxide are transported in the bloodstream, and the properties of each molecule that determine it's necessary mode of transport. *How do these properties determine where each gas enters or leaves the blood?*
2. ** Describe how ventilation is regulated by several neural, chemical, and higher brain (conscious/reflex) inputs. What are the results of these regulatory factors?
3. Identify and explain the functions of the muscle groups, cartilage, and mucosal tissues that produce vocalizations from the larynx. How is pitch controlled?

❖ *These objectives are your HOMEWORK between classes!!!*

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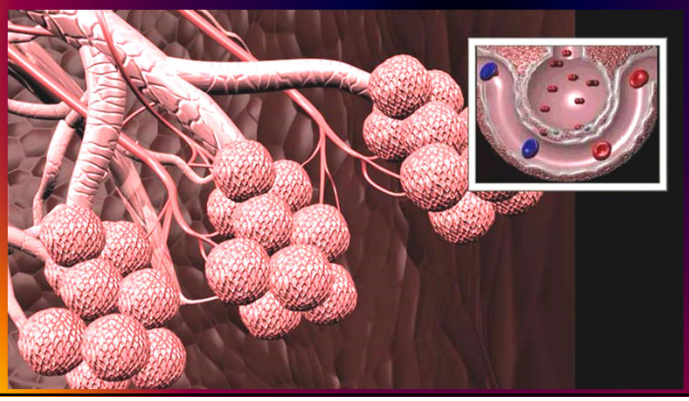
Chapter 18
Gas Exchange & Transport



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About Chapter 18

1. Getting CO_2 & O_2 dissolved for transport.
2. How oxygen is transported, role of hemoglobin.
3. How carbon dioxide is transported.
4. Regulators that sense and coordinate respiration with circulation for gas transport.

4

Overview of Respiratory Exchange

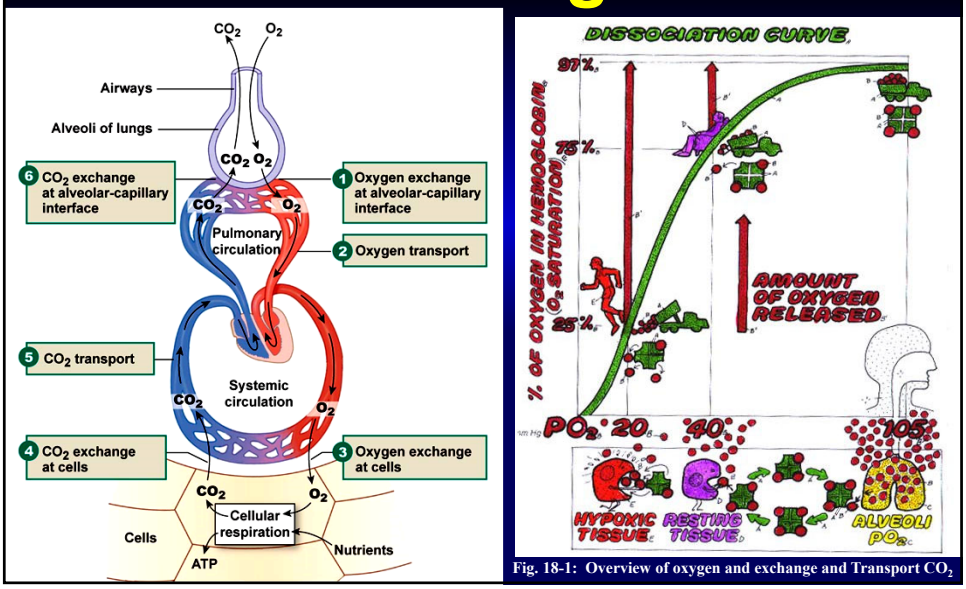

Fig. 18-1: Overview of oxygen and exchange and Transport CO_2

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18.1) Solubility of Gases

- **Pressure gradient**: lower at high altitudes
- **Temperature**: constant in warm blooded humans
- **Solubility** (solute & solvent): O_2 or CO_2 in water

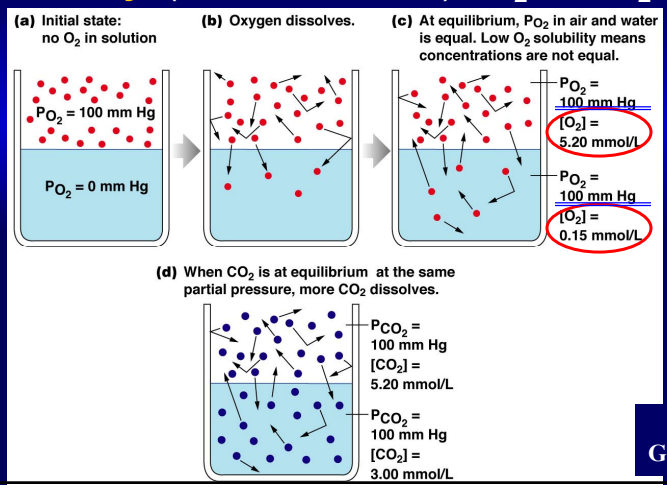

Figure 18-2: Gases in solution

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18.2) Gas Exchange in the Lungs and Tissues: Oxygen

1. Diffusion through thin alveolar cells.
   - ***Concentration/Pressure gradient = most important!!***
2. Down diffusion gradient into Blood (O_2).
   a) Higher in alveoli (100mm; 160 in air; 132 Denver).
   b) Lower in blood (20-100mm).
3. Diffusion from blood.
   a) Also down gradient (~100 mm in, 40 out).
   b) To ECF.
   c) To tissue cells (convert O_2 used to oxidize carbs to CO_2).

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A. Oxygen Exchange in the Lungs and Tissues:

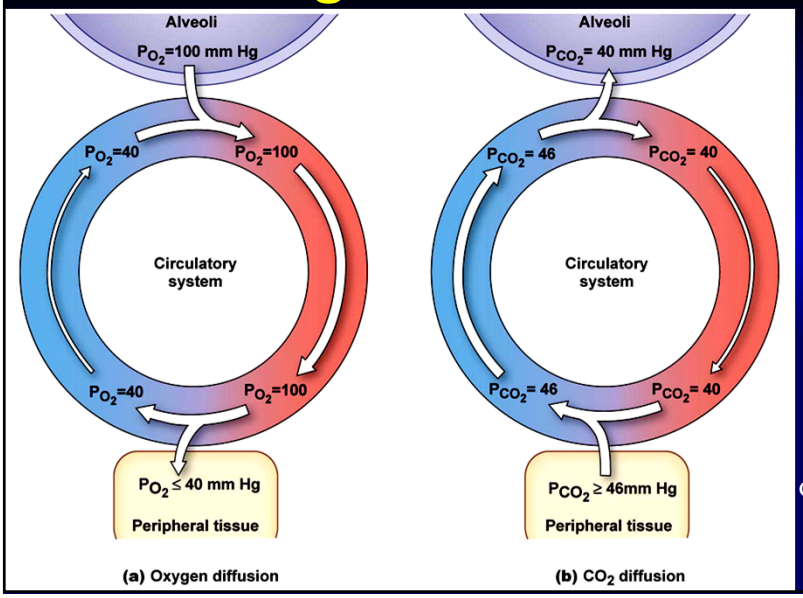

Figure 18-3: Gas exchange at the alveoli and cells

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B. Gas Exchange in the Lungs and Tissues: Carbon Dioxide

1. Diffusion out of cells (down diffusion gradient)
2. **Into blood**
   a) Buffer role – balance pH
   b) Conversions:
      - Plasma – **Bicarbonate**
   c) On **Hb**
3. Into alveolus & expiration

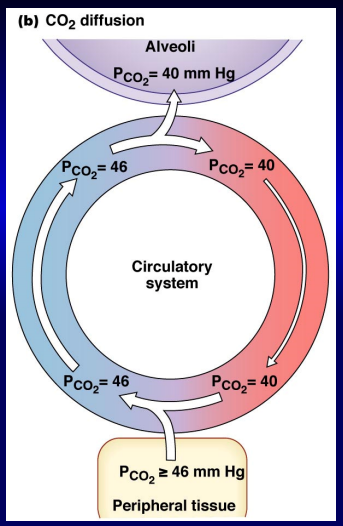

Figure 18-3b: Gas exchange at the alveoli and cells

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C. Alveolar Exchange and Diseases Related to Exchange

1. **Wet surface**
2. **Thin epithelia**
3. **Little ECF**

4. **DISEASES:**
   a) Emphysema – lost elasticity & surf. area
   b) Fibrotic Lung – less SA for exch.
   c) Pulmonary edema – increase diff. dist.
   d) Asthma – bronchoconstriction

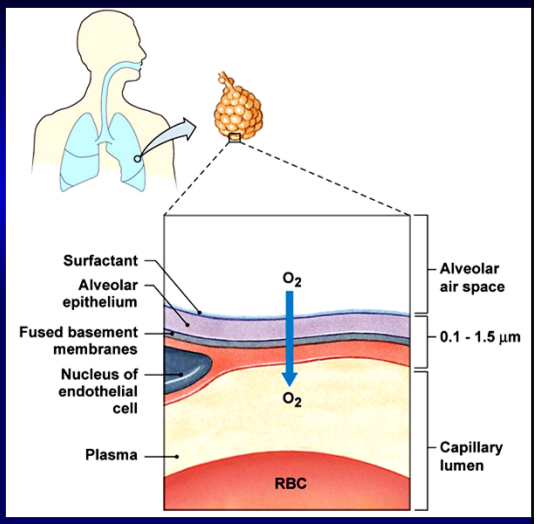

Figure 18-5: Oxygen diffuses across the alveolar and endothelial cells to enter the plasma

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Diseases Affecting Alveolar Exchange

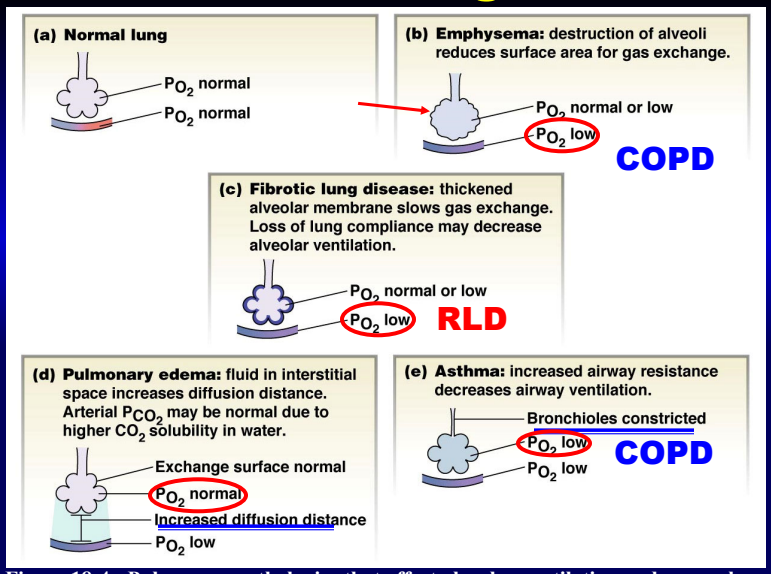

Figure 18-4: Pulmonary pathologies that affect alveolar ventilation and gas exchange

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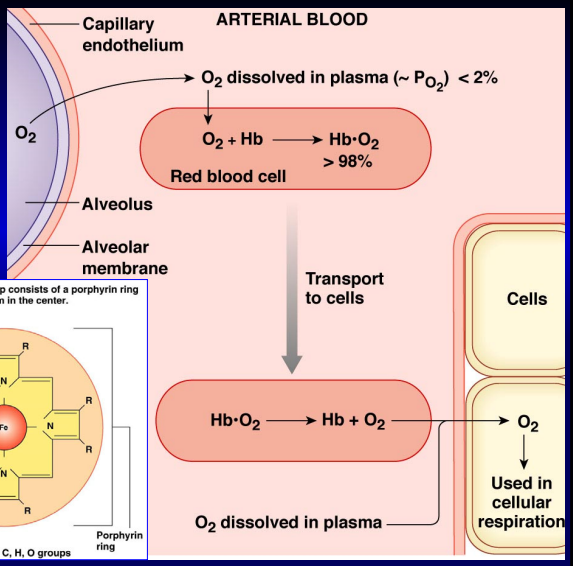
18.3) Gas Transport in the Blood: Oxygen

1. 2% in plasma
2. ***98%*** in hemoglobin (***Hb***)
3. Blood holds O_2 reserve



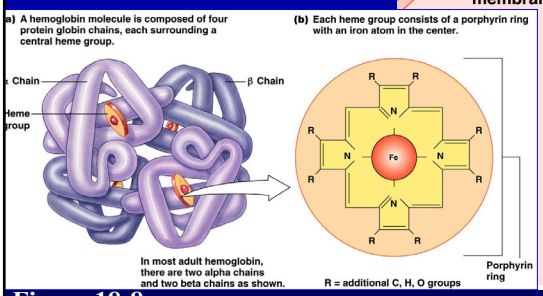


Figure 18-8

Figure 18-6: Summary of oxygen transport in the blood

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A. Oxygen Transport in the Blood

** Body needs = ~250 ml O_2/min. (50 ml/L x 5L/min CO avg. at rest) **

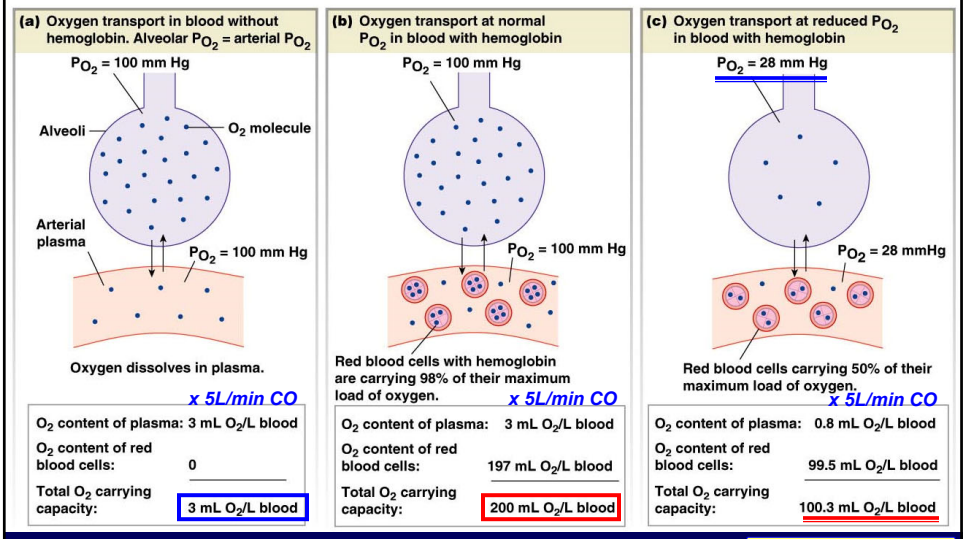

Figure 18-7: The role of hemoglobin in oxygen transport

Still 2X amt. needed at rest!

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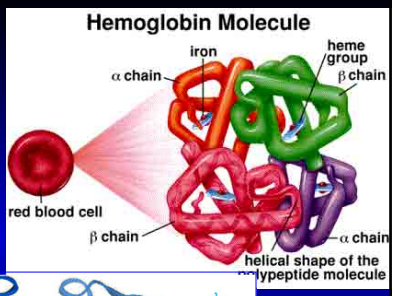
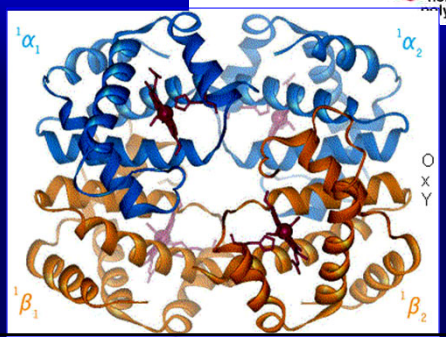
B. Hemoglobin Transport of Oxygen: Disassociation Curve

1. 4 O_2-binding sites per Hb molecule
2. *98% saturated in alveolar arteries*
3. **Resting cell P_{O2} = 40 mm Hg**
4. **Working cell P_{O2} = 20 mm Hg**
5. More unloaded with more need
6. *75% in reserve at normal activity*





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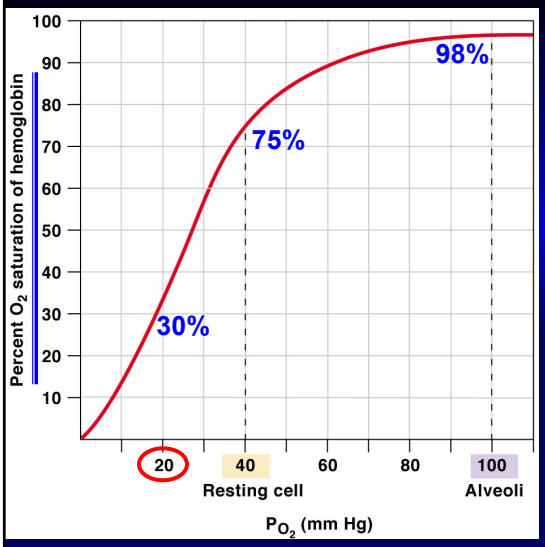
Hemoglobin Transport of Oxygen: Disassociation Curve



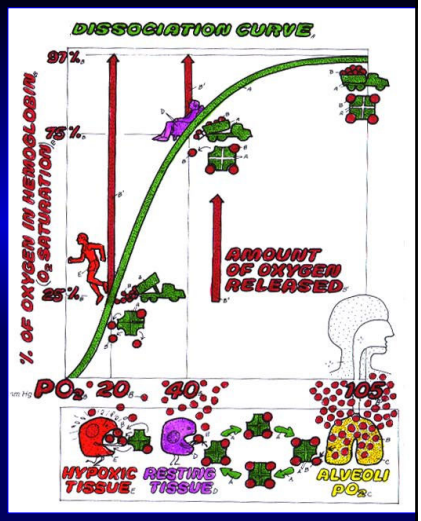


Figure 18-9: Oxygen-hemoglobin dissociation curve

http://people.eku.edu/ritchisong/RITCHISO//301notes6.htm

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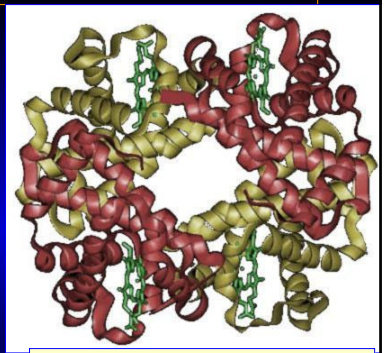
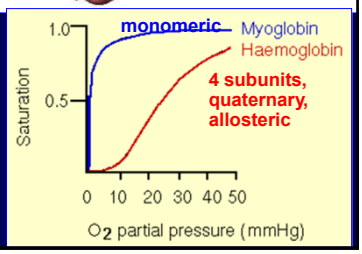
C. Factors that Modify Hb Transport of Oxygen

1. ***Bohr effect:*** *pH ↓ causes ↓ O_2 binding -releasing it*
2. ***2,3-DPG:*** ↑ O_2-release *(response to high altitude, hypoxia)*
3. **↑ P_{CO_2}:** decreases O_2 binding → releasing O_2
4. *(Temperature affects the curve but doesn't vary in humans; = homeothermic!)*





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Factors that Modify Hb Transport of Oxygen

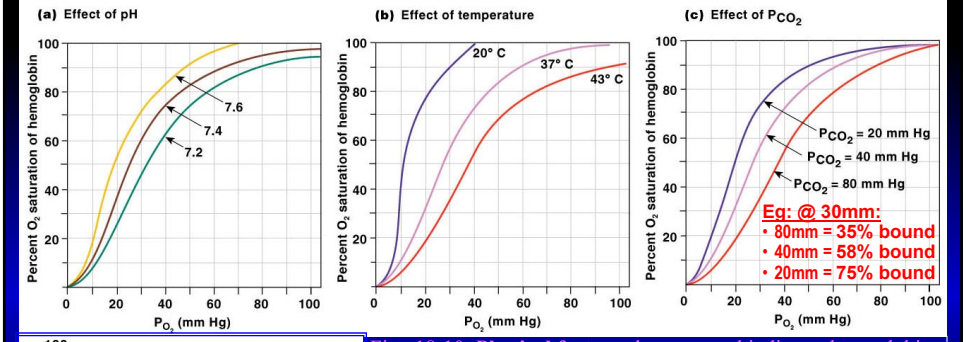
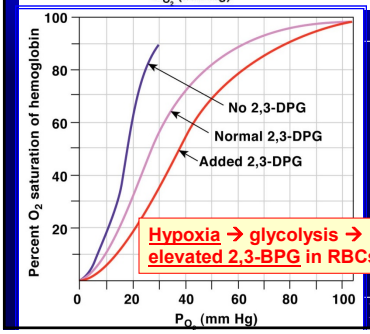


Fig. 18-10: Physical factors alter oxygen binding to hemoglobin



Hypoxia → glycolysis → elevated 2,3-BPG in RBCs.

** TIPs:
- A RIGHT-shift in a curve means looser binding (more release at lower P_{O_2}).
- A LEFT-shift in a curve means tighter binding (less release) of O_2.

- NOTE: Actual chemical name is BIS-phosphoglycerate. Common (but inaccurate) name is DI-phosphoglycerate.

Figure 18-11: 2,3-BPG alters Hb affinity for O2

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D. Fetal Hemoglobin (gamma subunits)

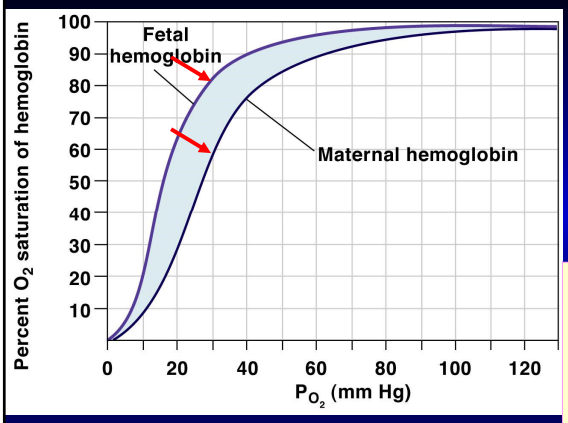
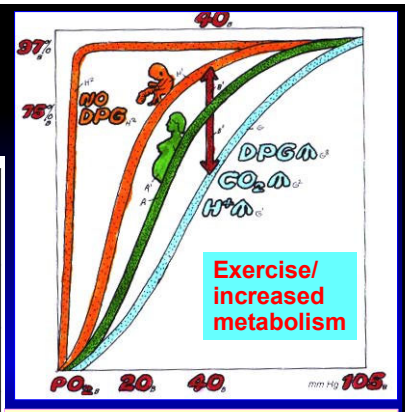
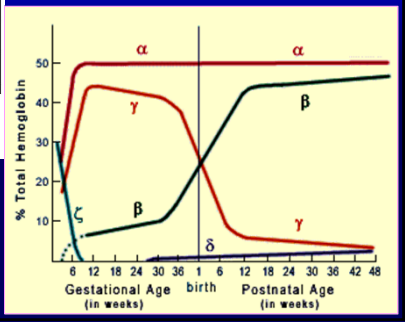


Figure 18-12: Fetal Hemoglobin: Differences in binding from Maternal Hb.

http://people.eku.edu/ritchisong/RITCHISO//301notes6.htm





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E. Summary of Oxygen Transport

- *How many of these choices are likely to be variable?*

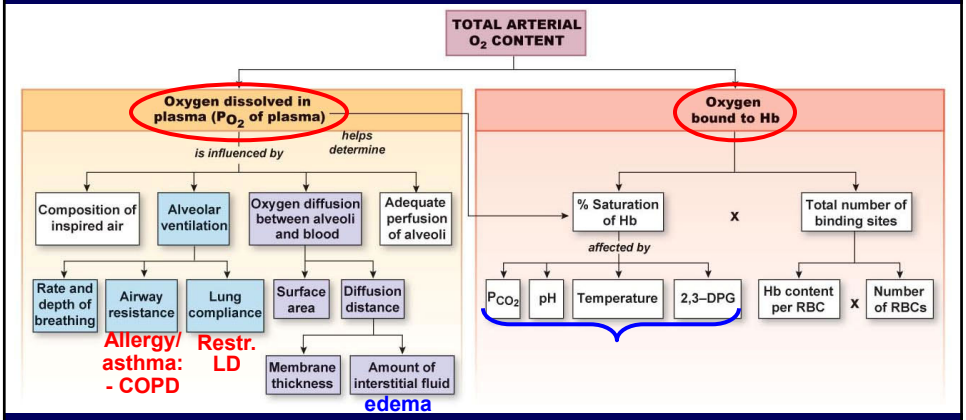

Figure 18-13: Factors contributing to the total oxygen content of arterial blood

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18.4) Gas Transport in the Blood: Carbon Dioxide

1. ***Hypercapnia:*** Excess CO_2 in blood
   - Leading to:
     - ***acidosis, CNS depression, & coma!***
2. **7% dissolved in plasma,**
3. **23% bound to Hb &**
   - Hemoglobin also binds H+
   - Hb and CO_2: ***CarbAminoHemoglobin***
4. **70% as HCO_3^-**, acts as a pH buffer [H^+]

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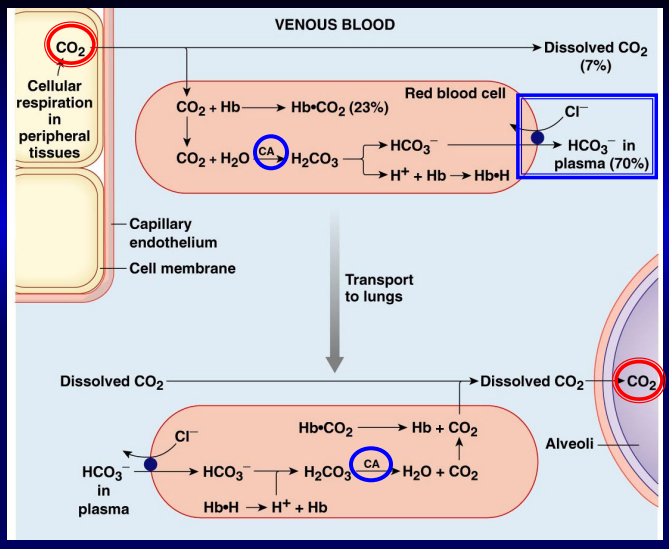
A. Carbon Dioxide Transport in the Blood



"Chloride Shift"!!

Figure 18-14: Carbon dioxide transport in the blood

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B. Review of Respiratory Exchange & Transport

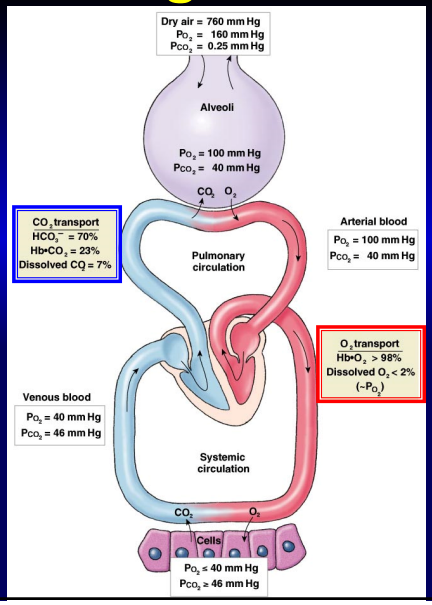

Figure 18-15: Summary of gas transport

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18.5) Regulation of Ventilation: Central Pattern Generator

1. Integrates input from cortex, limbic & chemoreceptors
2. ***Rhythmic contractions of ventilation***
3. ***In Brain stem: Central Pattern Generator***
   - **a) Unstable V_m pacemaker cells**
     - Rhythmic pattern of breathing arises from a network of spontaneously discharging neurons
   - **b) Pons & Medulla**
     - Respiratory neurons in medulla control inspiration and expiration
     - Neurons in the pons modulate ventilation
   - – ** *Ventilation is subject to modulation by chemoreceptor-linked reflexes and by higher brain centers* **

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A. Regulation of Ventilation: *Central Pattern Generator*

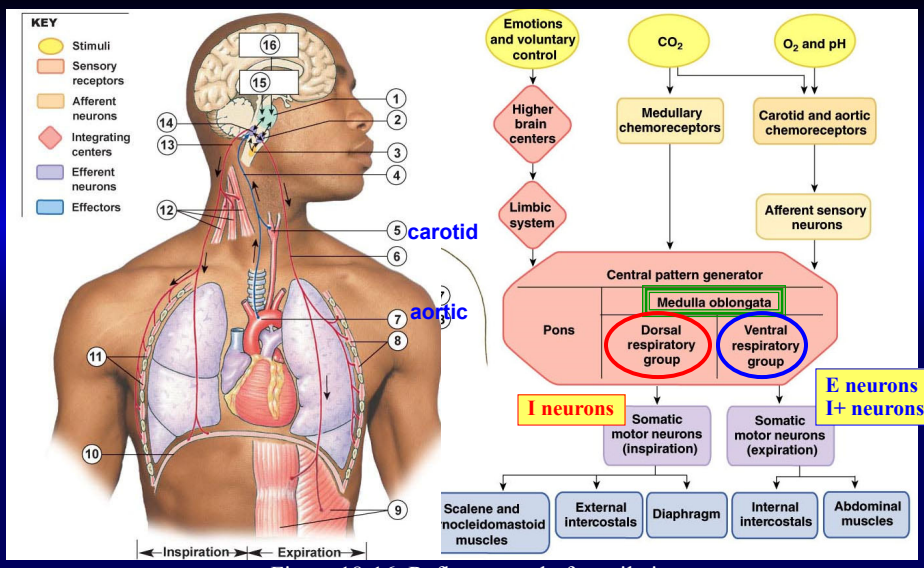

Figure 18-16: Reflex control of ventilation

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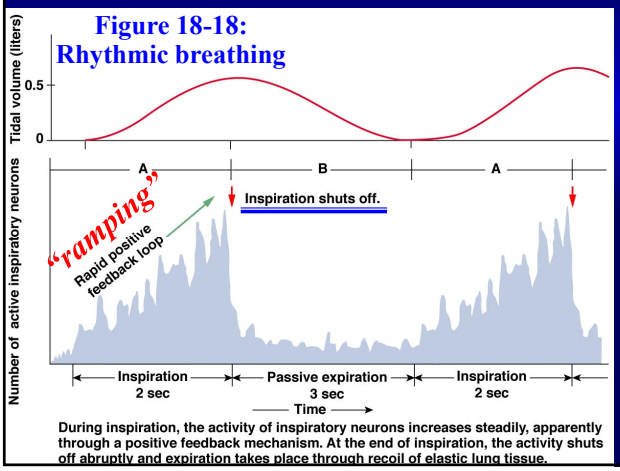
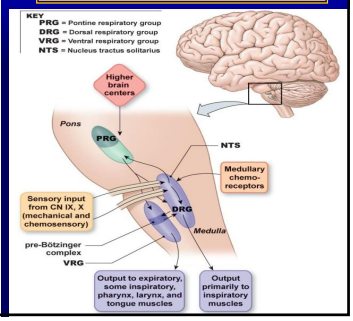
B. Regulation of Ventilation: Pons Center

1. ***Dorsal Respiratory Group*** – inspiration.
2. ***Ventral Respiratory Group*** – forced breathing.



VRG:
- Active expiration
- Greater than normal inhal'n



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C. Regulation of Ventilation: Peripheral Chemoreceptors

1. ***Carotid & aortic bodies***: O_2, CO_2 & H^+ receptors
   – Specialized ***glomus cells***
2. Medullary CO_2 receptor (really H+ !!)
3. **Low $[O_2]$, high $[CO_2]$ & high *$[H^+]$ (low pH)* → ↑ ventilation.**

- Central chemoreceptors
  – Changes in CO_2, *but adapt!!*

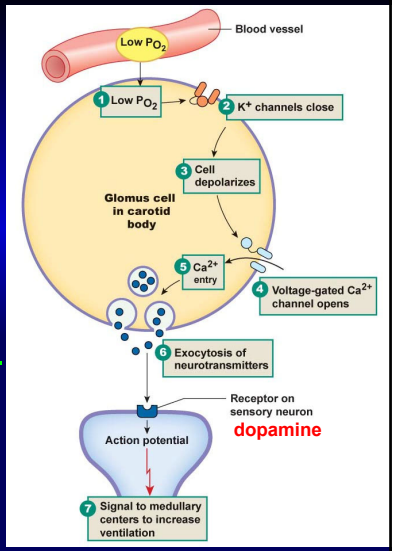

Figure 18-18: Carotid body oxygen sensor releases neurotransmitter when PO_2 decreases

Figure 18-19

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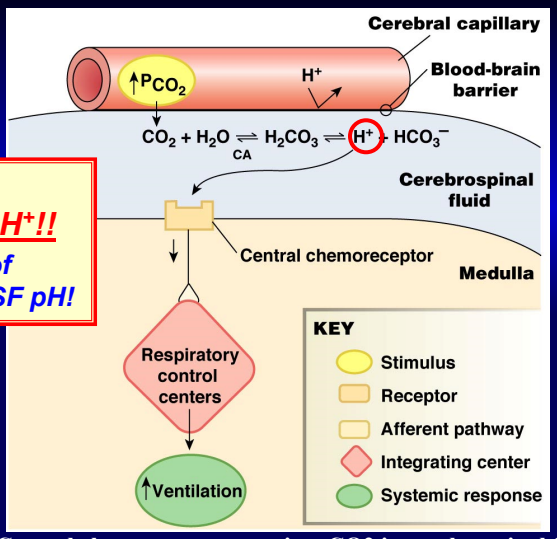
D. Regulation of Ventilation: Central Chemoreceptors



Medullary CO_2 receptor: really H^+!!

- ***Indirect* sensing of plasma CO_2 by CSF pH!**

Figure 18-20: Central chemoreceptor monitor CO2 in cerebrospinal fluid

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E. Summary of Regulatory Ventilation Reflexes

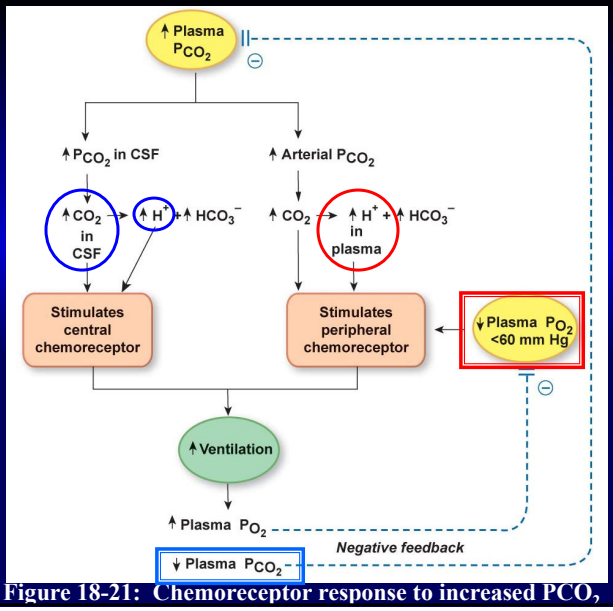

Figure 18-21: Chemoreceptor response to increased PCO_2

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18.6) Protective Reflexes

1. **Bronchoconstriction** - parasympathetic
   a) **Irritant receptors**
      - Bronchoconstriction
      - Sneezing
      - Coughing
   b) **Toxic particles**
   c) **Irritating particles** (i.e. pollen, allergens)
2. ***Hering-Breuer Reflex*** prevents over-inflation (V_T > 1000 mL)
   - *Stretch receptors in lungs → brain stem → ↓Insp*
3. Unconscious reflexes take over voluntary breathing – also: coughing, sneezing.
4. ***Choroid plexus*** (exocrine in brain) → secretes ***bicarbonate*** into **CSF** (chronic acid).
   - ***Adapt to chronic acidosis***; dangerous (depend on peripherial pH/CO_2 receptors)

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Ch. 18: Summary

1. **Oxygen** is transported bound to **Hb** and this is affected by temperature, pH, CO_2, and DPG.
2. **Carbon dioxide** is transported in plasma, bound to Hb and acts as the buffer bicarbonate.
3. Respiration is regulated by **CNS central pattern generator**, *pons center* and *peripheral carotid and aortic receptors.*
4. **Feedback reflexes** coordinate circulation and ventilation to maintain blood O_2, CO_2, and H^+ concentrations.

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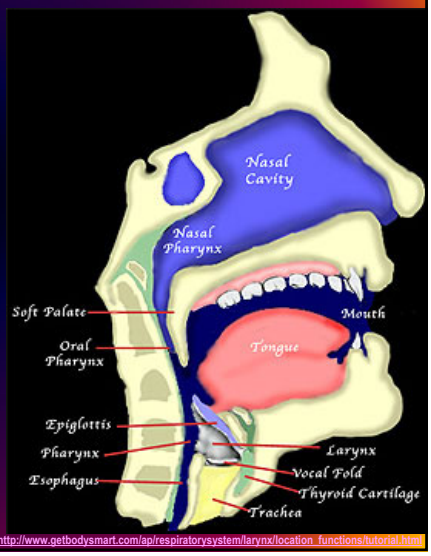
Vocal Physiology: The Larynx

- The ***larynx*** ("voice box") sits atop the ***trachea*** (windpipe) in the throat (pharynx).
- The ***epiglottis*** covers the airway during eating/ drinking.
- ***Vocal folds*** ("cords") also close airway during ***eating***, and for support of ***abdominal pushing.***
  - Lifting, giving birth, etc.…



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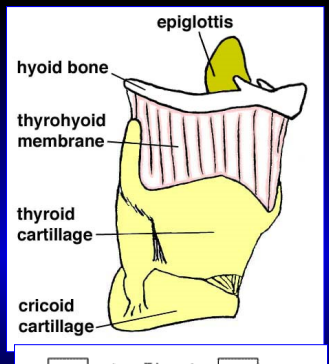
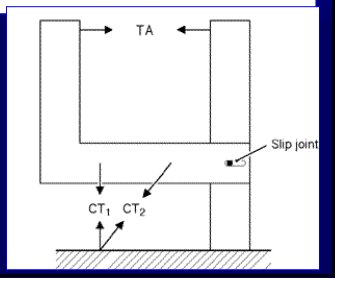
Internal anatomy of the Pharynx: Movable Cartilages

- **Movable cartilages:**
  - muscles in the larynx push and pull cartilage forward and back,
  - ***adducting*** (moving together) &
  - ***abducting*** (moving apart) the vocal folds for ***PHONATION.***
- **Muscles** adjust tension of folds, and tilting of thyroid cartilage
  - Controls phonation (sound production).
  - Controls pitch (frequency of sound).
- **Air flow** = the vocal generator!
  - ***Highly controlled exhalation!!!***
  - Controlled at diaphragm, intercostals, and abdominal muscles.





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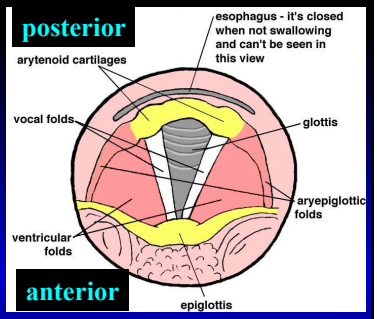
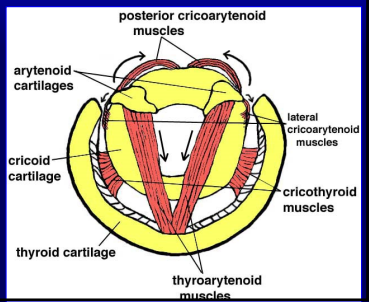
Internal anatomy of the Pharynx: Vocal Muscles

- ***Vocal Folds*** = mucosal tissues controlled by laryngeal muscles
- ***CricoThyroid Muscles (CT)***
  - Help lengthen the folds to raise the pitch (speak/sing higher)
- ***ThyroArytenoid muscles (TA)***
  - With mucosal epithelium, make up folds themselves
  - Shorten folds to lower the pitch (speak/sing lower)
- ***Tissues must be healthy and MOIST for proper phonation!!***





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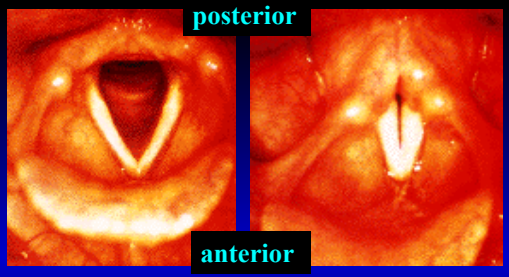
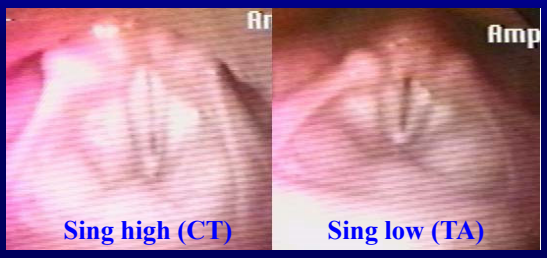
Phonation: CT & TA

Abducted for breathing (apart)



Adducted for phonating (together)

- Tiny puffs of air → vibrations/sound!!
- (buzzing -- without chambers of head/sinuses, throat, and palate)



http://www.ucdvoice.org/anatomy-of-the-human-voice/

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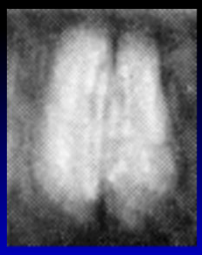
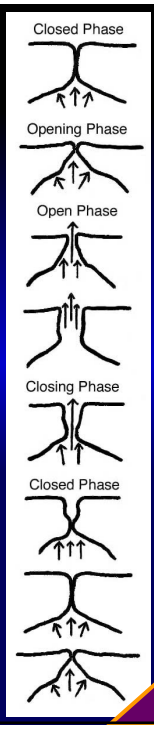
Phonation: Glottic Cycle



*** https://youtu.be/-XGds2GAvGQ

Some informative websites for your further edification:

- http://www.yorku.ca/earmstro/journey/index.html
  - (Great comprehensive site on vocalizing and breath control/diaphragm.)
- http://www.lionsvoiceclinic.umn.edu/page2.htm
  - (comprehensive information on the workings of the human voice, namely the larynx!)
- http://www.ucdvoice.org/anatomy-of-the-human-voice/
  - good summary of vocal function, with a cool video of a larynx (top view, down into throat) vocalizing, and then breathing.



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