RESPIRATORY MECHANICS

Respiration - The composite of the mechanisms used by the body to provide O_2 to its component cells and to remove CO_2 from them while at the same time maintaining constancy of the internal environment.

Ventilation - Mass movement of inspired air(O_2) into the body from the environment and expired air(CO_2) from the body into the environment.

Transport - Movement of respiratory gases (O_2 and CO_2) between the lungs and the blood and the carriage of those gases by the blood.

Cell Respiration - Exchange of respiratory gases between the cells and the blood and extracellular fluid. Involves mainly **diffusion**.

VENTILATION

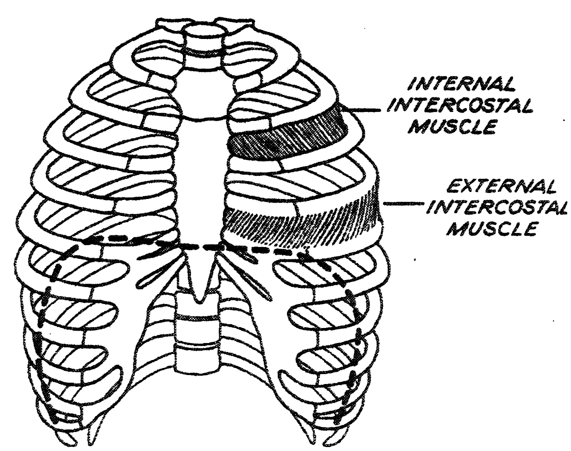
Because of the ribs the chest cannot expand or contract to any appreciable extent. Thus anything which increases the volume of the chest causes air to flow in, **inspiration**. Likewise anything which decreases the volume of the chest will cause air to flow out, **expiration**. In the body this is accomplished by muscles.

MUSCLES OF INSPIRATION
- Diaphragm
- External intercostals

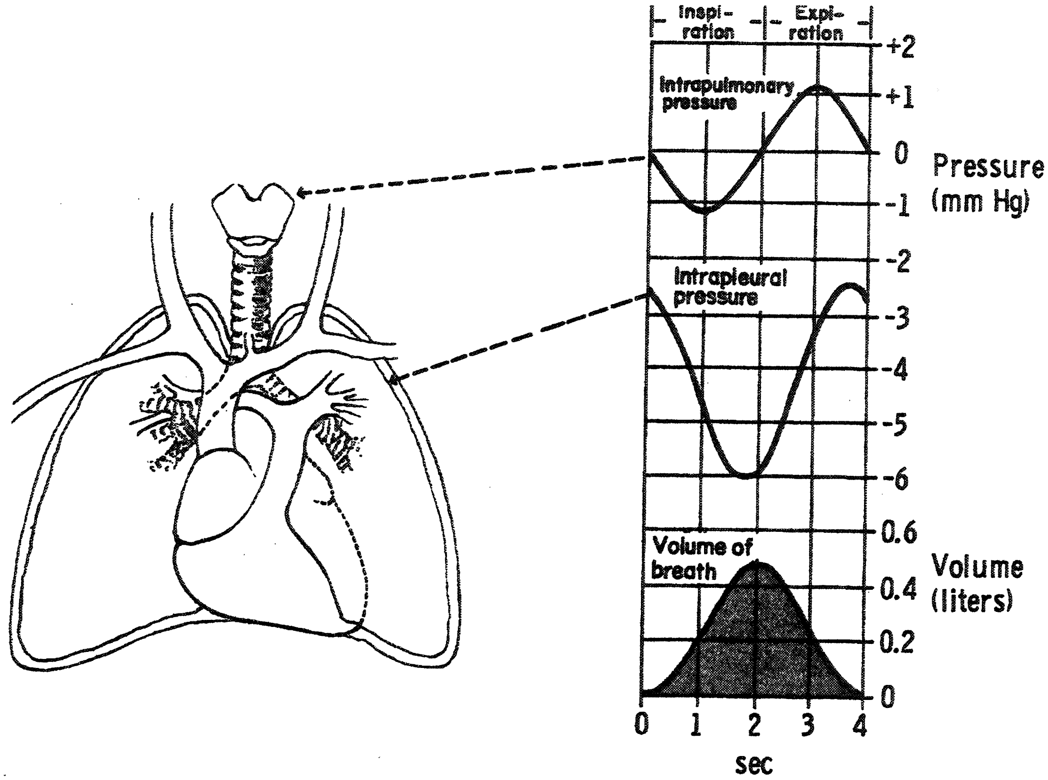
MUSCLES OF EXPIRATION *

Expiration is usually passive

- Internal intercostals
- Abdominal muscles



PRESSURES IN THE RESPIRATORY SYSTEM ASSOCIATED WITH VENTILATION.



Intrapleural - pressure in pleural space between lung and chest wall.

Intrapulmonary - pressure inside of lung.

FACTOR AFFECTING VENTILATION

STATIC

Compliance = DV/DP — of lungs; of chest

Surface Tension of water

Law of Laplace - P=2T/r

Pulmonary Surfactant - reduces T and makes it proportional to r, body's way around Laplace's Law.

DYNAMIC

Resistance to air flow - $P = Q \times R$

for turbulent flow $P = Q_1R_1 + Q^2{}_2R_2$

$$R = \frac{8\eta L}{\pi r^4}$$

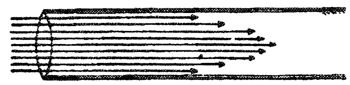
where L = length

η = viscosity

r = radius

TYPES OF AIR FLOW

LAMINAR

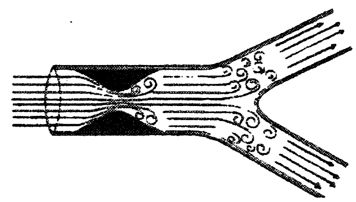


$P = K_1\dot{V}$

TURBULENT

$P = K_2\dot{V}^2$

TRACHEO-BRONCHIAL

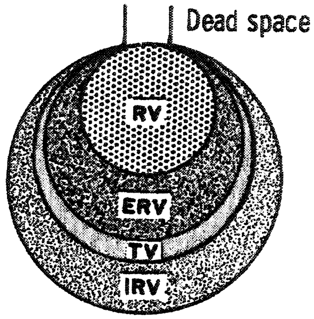


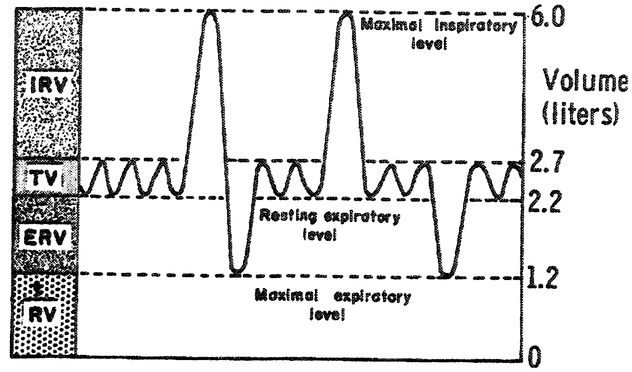
$P = K_1\dot{V} + K_2\dot{V}^2$

WORK OF BREATHING Work = Pressure x Volume

The body seeks to minimize the work of breathing, anything which increases the work of breathing (increased resistance or decreased compliance) will reduce the energy available to the rest of the body.

PULMONARY VOLUMES AND CAPACITIES





IRV = Inspiratory reserve volume   TV = Tidal volume
ERV = Expiratory reserve volume   RV = Residual volume

		Volume (liters) Men	Volume (liters) Women	
Vital capacity	IRV	3.3	1.9	Inspiratory capacity
Vital capacity	TV	0.5	0.5	Inspiratory capacity
Vital capacity	ERV	1.0	0.7	Functional residual capacity
	RV	1.2	1.1	Functional residual capacity
Total lung capacity		6.0	4.2	

Respiratory minute volume (rest): 6 liters/min
Alveolar ventilation (rest): 4.2 liters/min
Maximal voluntary ventilation (BTPS): 125-170 liters/min
Timed vital capacity: 83% of total in 1 sec; 97% in 3 sec
Work of quiet breathing: 0.5 kg-m/min
Maximal work of breathing: 10 kg-m/breath

TIDAL VOLUME - amount of air moved per breath.

MINUTE VOLUME - tidal volume x respiratory rate/min.

DEAD SPACE - volume of the parts of the respiratory system where gas does not interact with blood.

Anatomic - nose, trachea etc.

Physiologic - any area where air/blood interaction is not optimal.

ALVEOLAR VENTILATION - (tidal volume - dead space) x RR

INSPIRATORY RESERVE VOLUME (IRV)

EXPIRATORY RESERVE VOLUME (ERV)

RESIDUAL VOLUME (RV)

VITAL CAPACITY

TOTAL LUNG VOLUME

TRANSPORT OF GAS BY THE BLOOD

Table 35-1. Gas content of blood.

Gas	ml/100 ml of blood containing 15 gm hemoglobin			
	Arterial Blood (PO_2 95 mm Hg; PCO_2 40 mm Hg; Hb 97% saturated)		Venous Blood (PO_2 40 mm Hg; PCO_2 46 mm Hg; Hb 75% saturated)	
	Dissolved	Combined	Dissolved	Combined
O_2	0.29	19.5	0.12	15.1
CO_2	3.0	47.0	3.5	51.5
N_2	1.04	0	1.04	0

OXYGEN

O_2 dissolved in blood

O_2 bound to hemoglobin

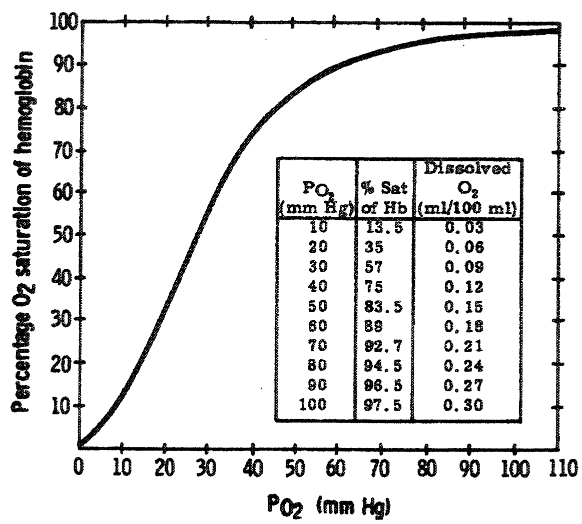
Properties of Hemoglobin

Reaction between O_2 and hemoglobin

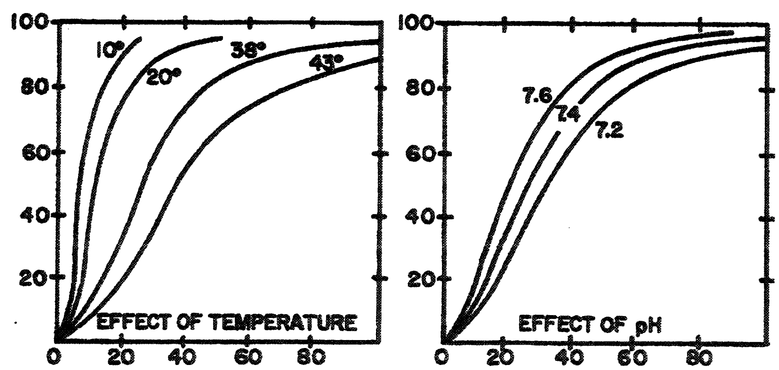
effect of temperature

effect of CO_2

effect of pH



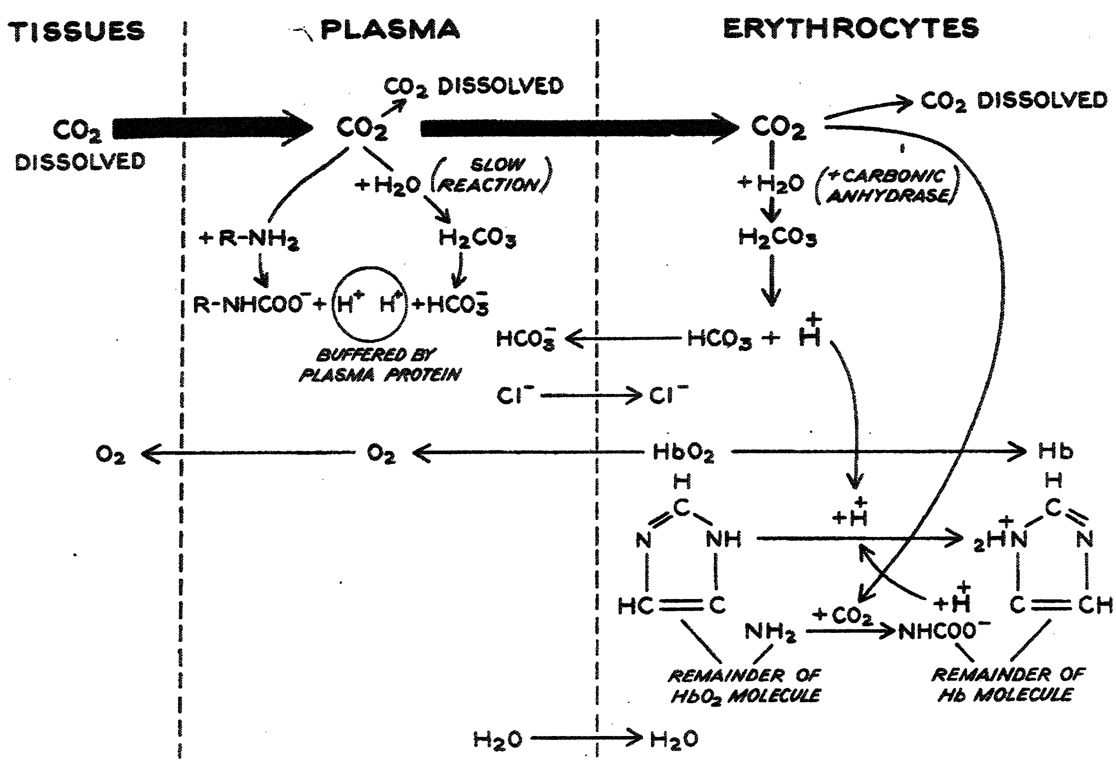
PO_2 (mm Hg)	% Sat of Hb	Dissolved O_2 (ml/100 ml)
10	13.5	0.03
20	35	0.06
30	57	0.09
40	75	0.12
50	83.5	0.15
60	89	0.18
70	92.7	0.21
80	94.5	0.24
90	96.5	0.27
100	97.5	0.30



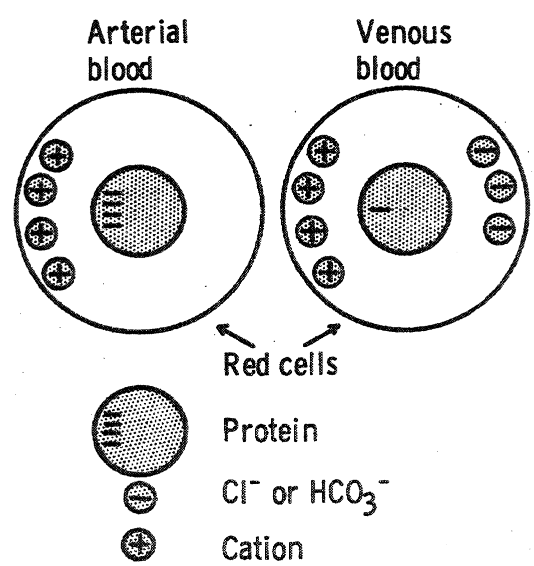
CARBON DIOXIDE (CO_2)

Henderson-Hasselbach Equation- $pH = pK_a + \log\frac{(HCO_3^-)}{(H_2CO_3)}$

- CO_2 dissolved in plasma
- CO_2 bound to hemoglobin and other proteins
  - effect of carbonic anhydrase
  - effect of O_2 - Haldane effect
  - effect of H^+ - Bohr effect
  - Chloride shift

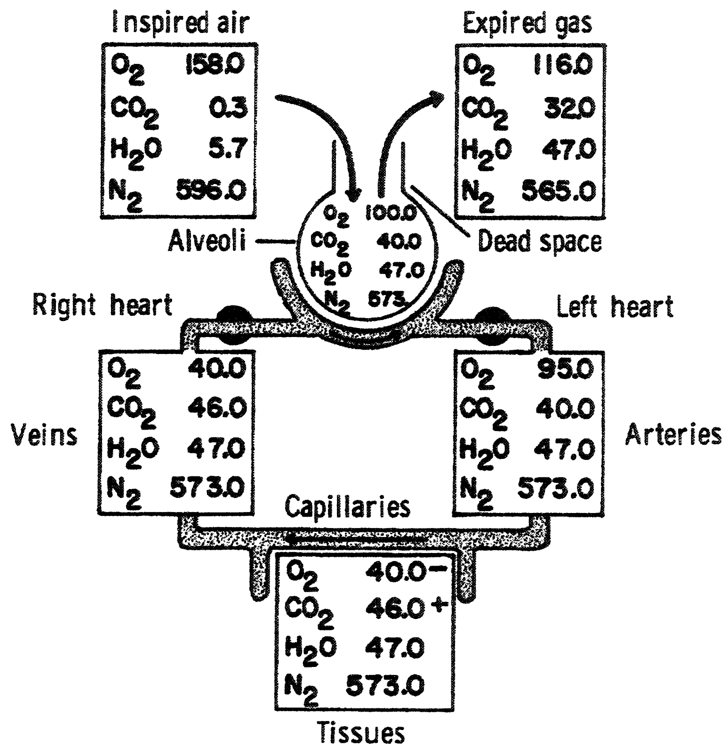


Osmotic effects



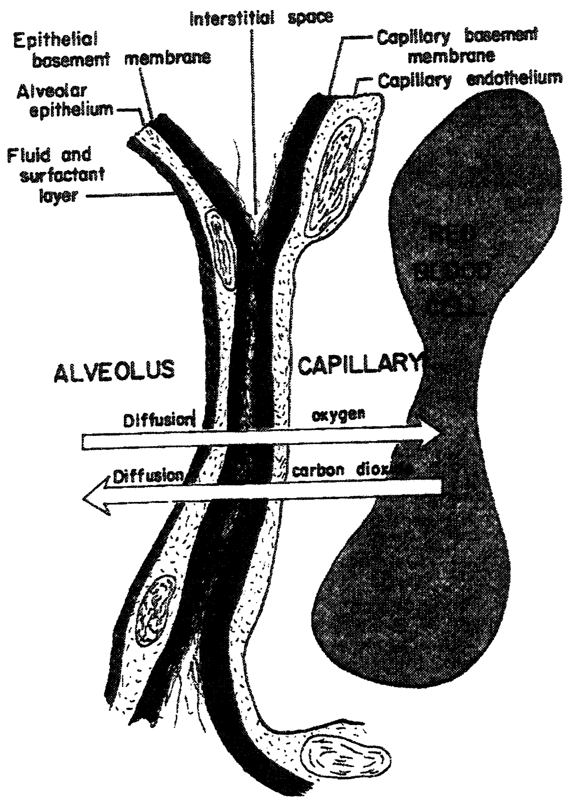
EXCHANGE OF RESPIRATORY GASES

Factors influencing Gas Exchange in lungs.



Partial Pressure of Gases = %gas x total atm. pressure

Composition of alveolar air - pO_2 = 100, pCO_2 = 40



Diffusion - alveolar-capillary membrane

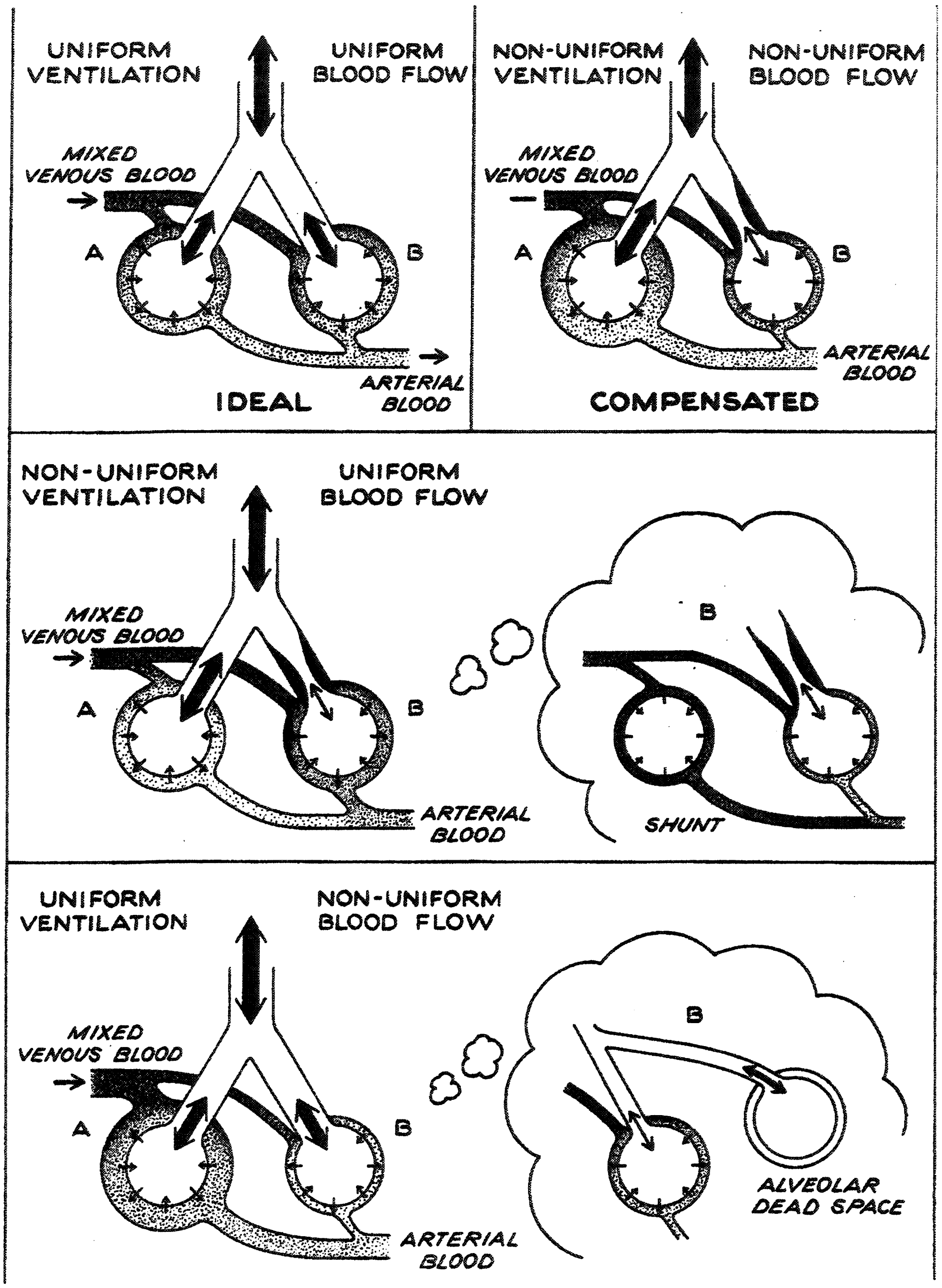
$$Q = \frac{D_C \, \Delta P \, A}{L}$$

where D_C - diffusion constant

ΔP - partial pressure difference

A - area for diffusion

L - distance for diffusion



Ventilation-Perfusion Ratio - V/F = 4/5 = 0.8

Increased V/F = dead space

Decreased V/F = shunt

Factor influencing Gas Exchange in the Tissues

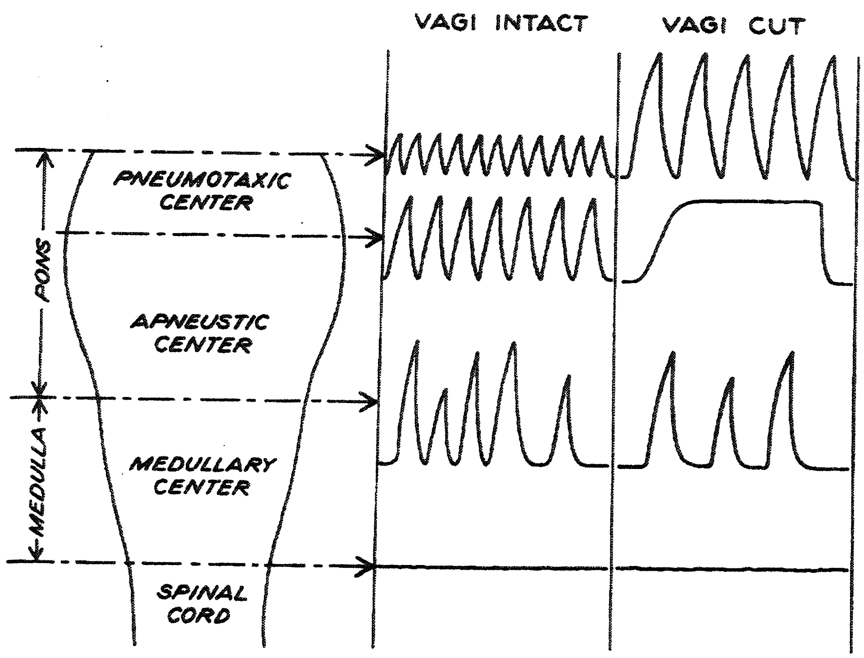
- Partial Pressure difference - controlled by tissue
- Diffusion distance (L) - controlled by vasculature
- Area for diffusion (A) - controlled by vasculature

Pulmonary Circulation

- Low Pressure - Low Control - High Compliance
- Non-Pulmonary Functions
  - Metabolism
  - Filtration
  - Heat Exchange
  - Communication

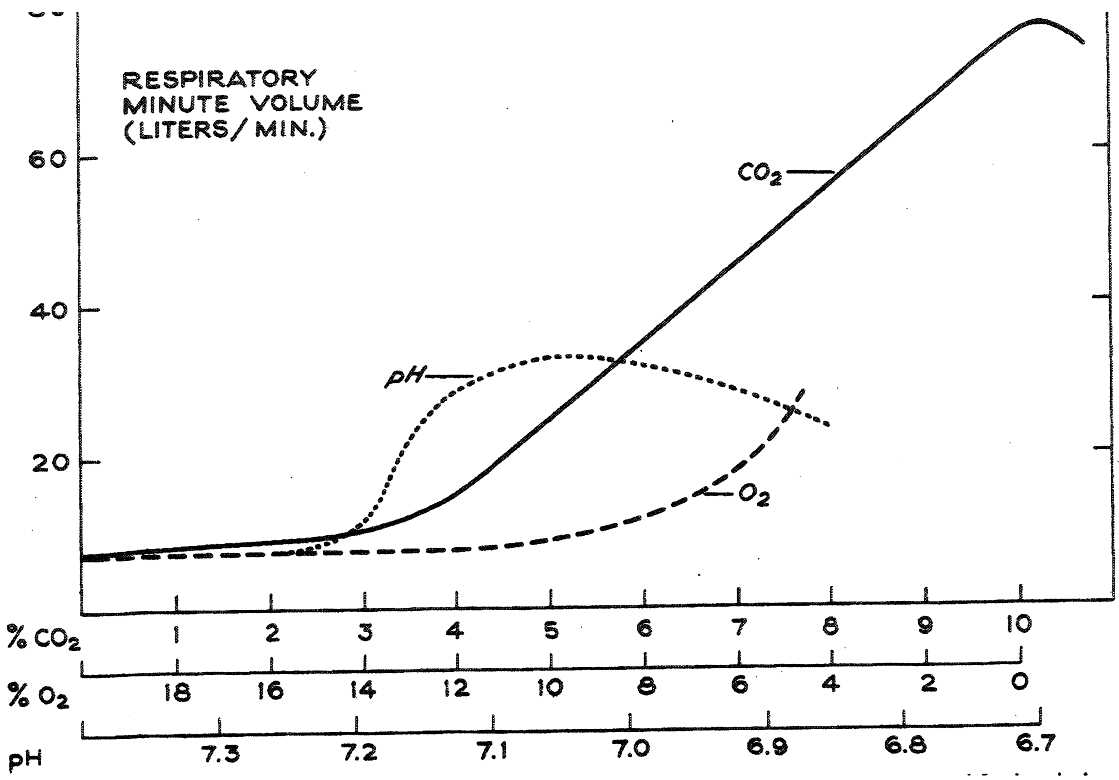
CONTROL OF RESPIRATION

Central control of respiration
Respiratory Center - medulla oblongata



FACTORS INFLUENCING RESPIRATORY CENTER

- High CNS influences - speech, emotion
- Pontine influences
  - Pneumotaxic center
  - Apneustic center
- Vagus Nerve (mechanoreceptors)
  - Hering-Breuer Reflex
- Oxygen - (chemoreceptors)
  - carotid and aortic bodies



Carbon Dioxide (chemoreceptors)

- peripheral
- central
  - 4th Ventricle
  - choroid plexus

Hydrogen ion

Baroreceptors

Thermorecptors

Smell