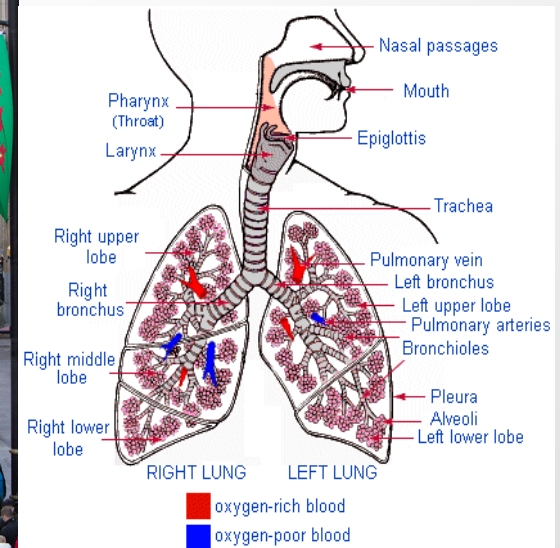
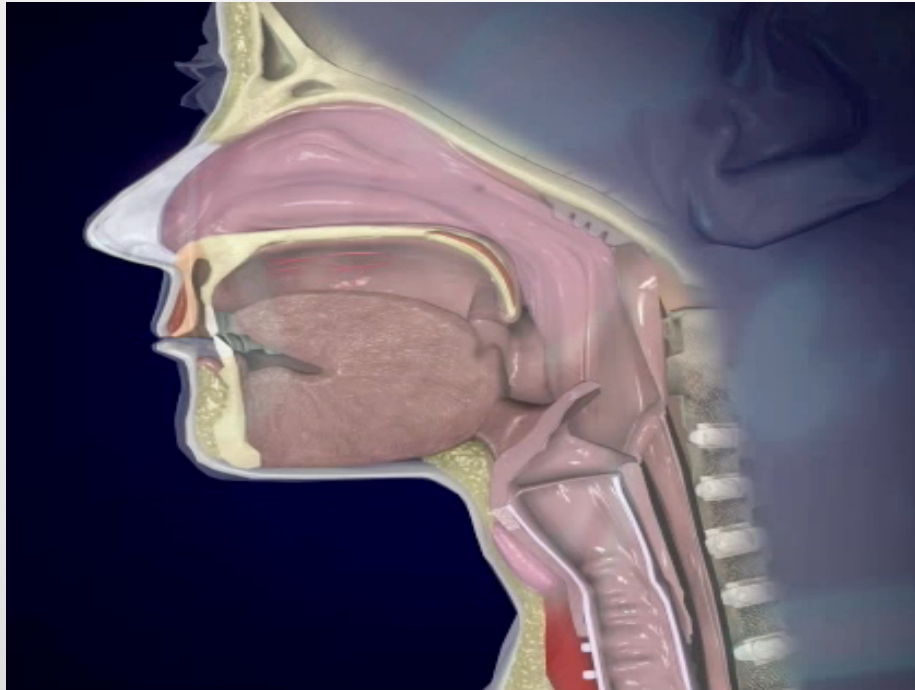


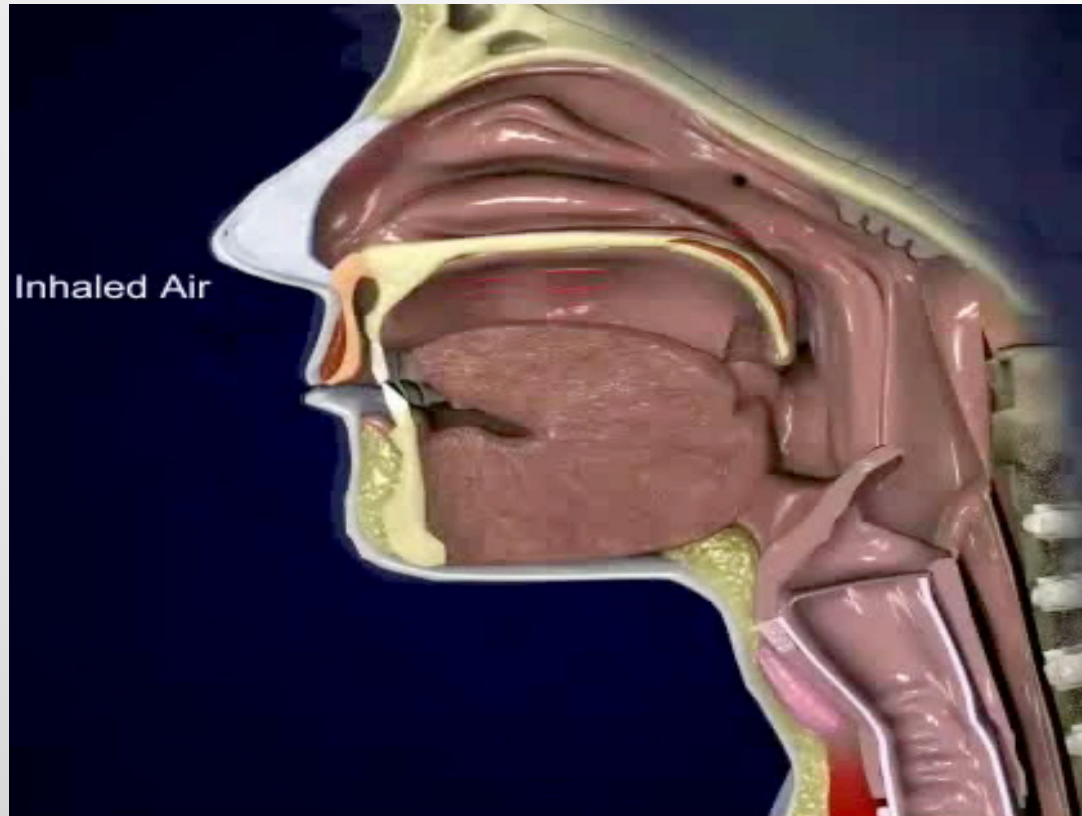
Human Anatomy & Physiology – Respiratory System



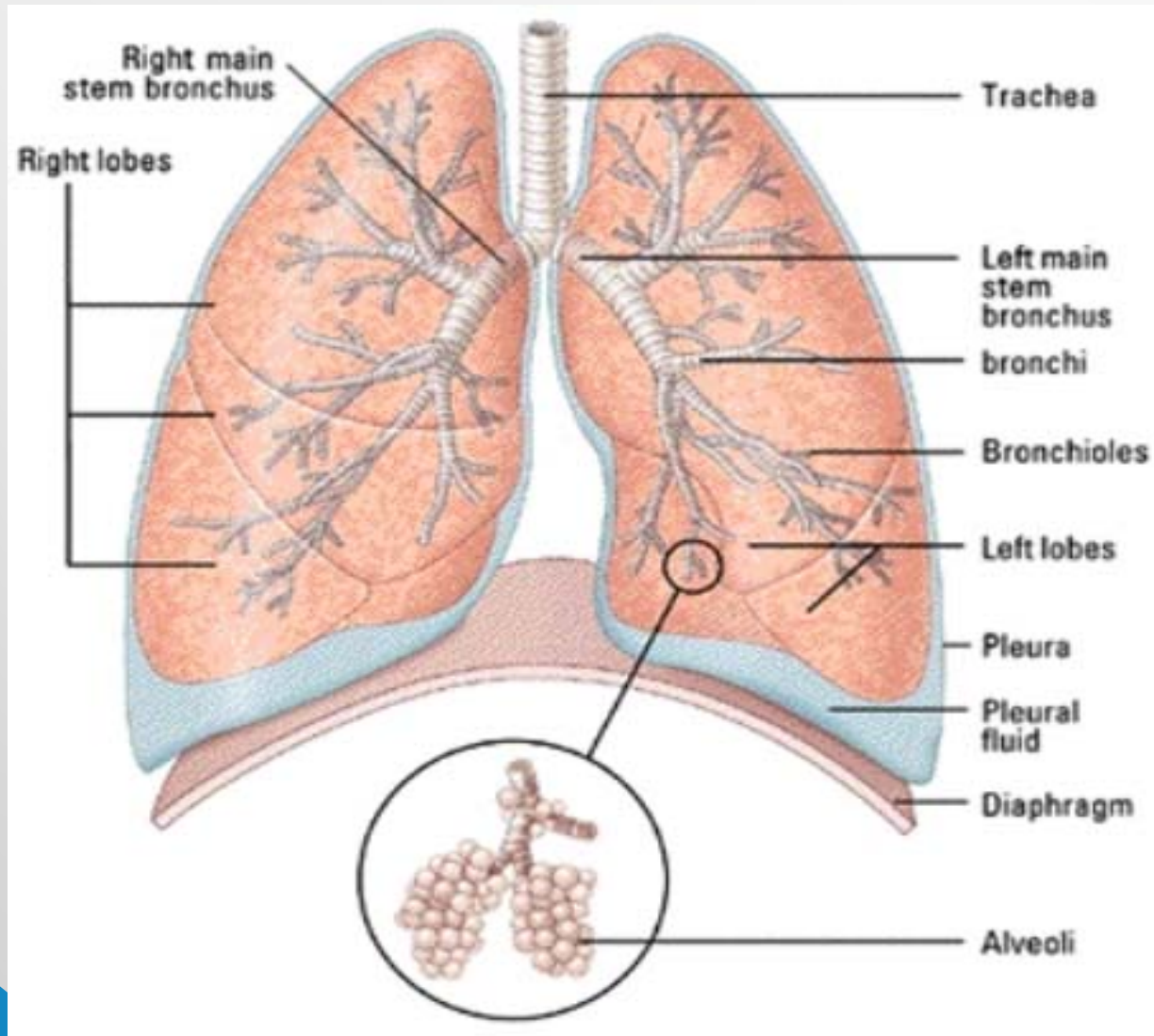
Upper Respiratory Tract



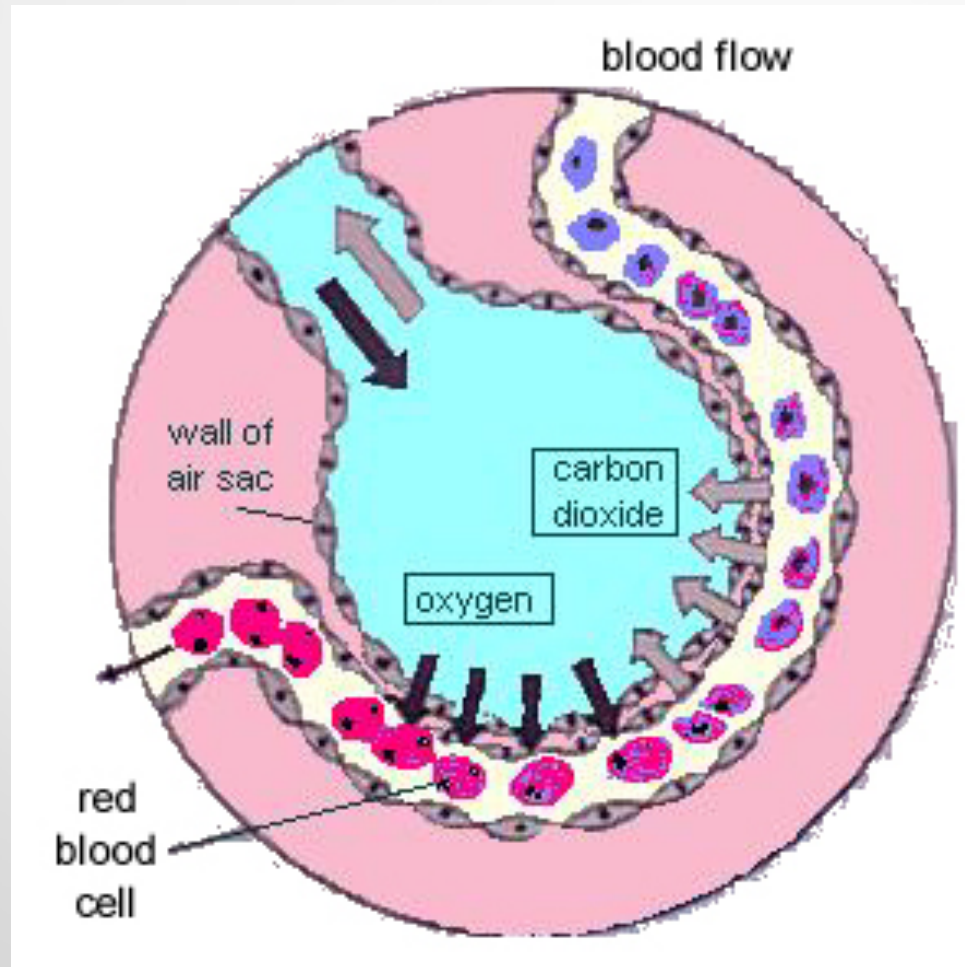
Dealing with the baddies



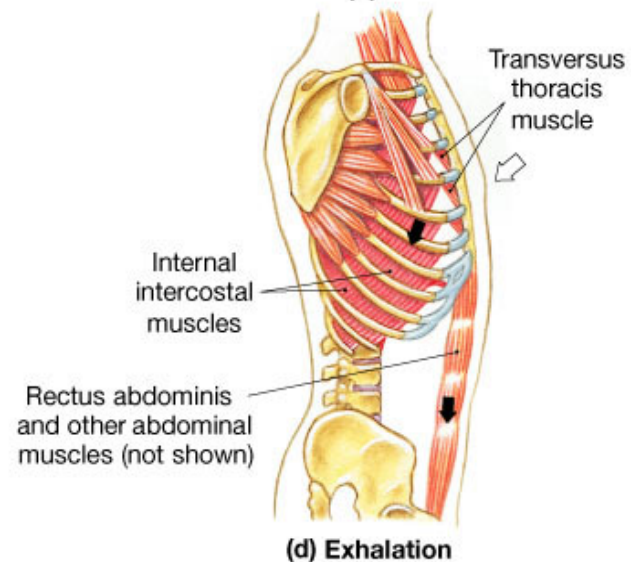
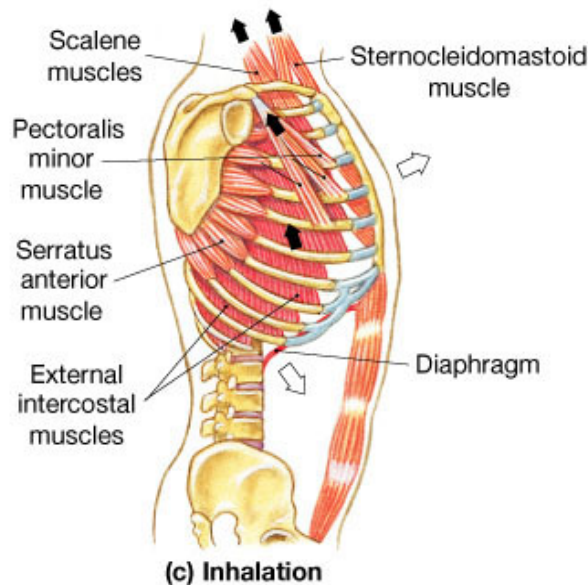
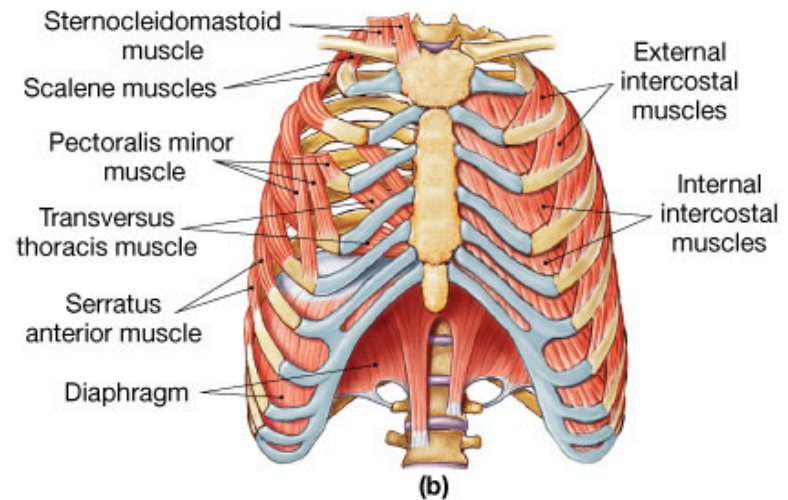
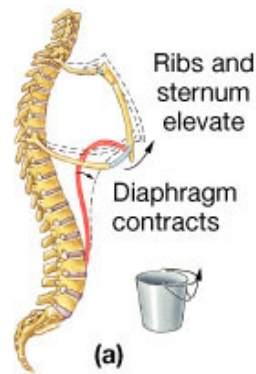
The Lungs



The Alveoli



The Respiratory Muscles



Pulmonary Ventilation

- The physical movement of air into and out of the lungs •
- Measured as VE – minute ventilation
- $VE = \text{Tidal volume} \times \text{breathing frequency}$

Composition of inhaled and exhaled air

	<i>Inspired Air</i>	<i>Expired air</i>
<i>Oxygen</i>	About 20.9%	About 16.4%
<i>Carbon Dioxide</i>	About 0.03%	About 4.0%
<i>Nitrogen</i>	About 78.0%	About 78.0%
<i>Water Vapour</i>	Variable (rarely saturated)	Saturated
<i>Temperature</i>	Variable	About body temperature
<i>Dust Particles</i>	Variable but usually present	Little if any

Air movement

- Movement of air depends upon

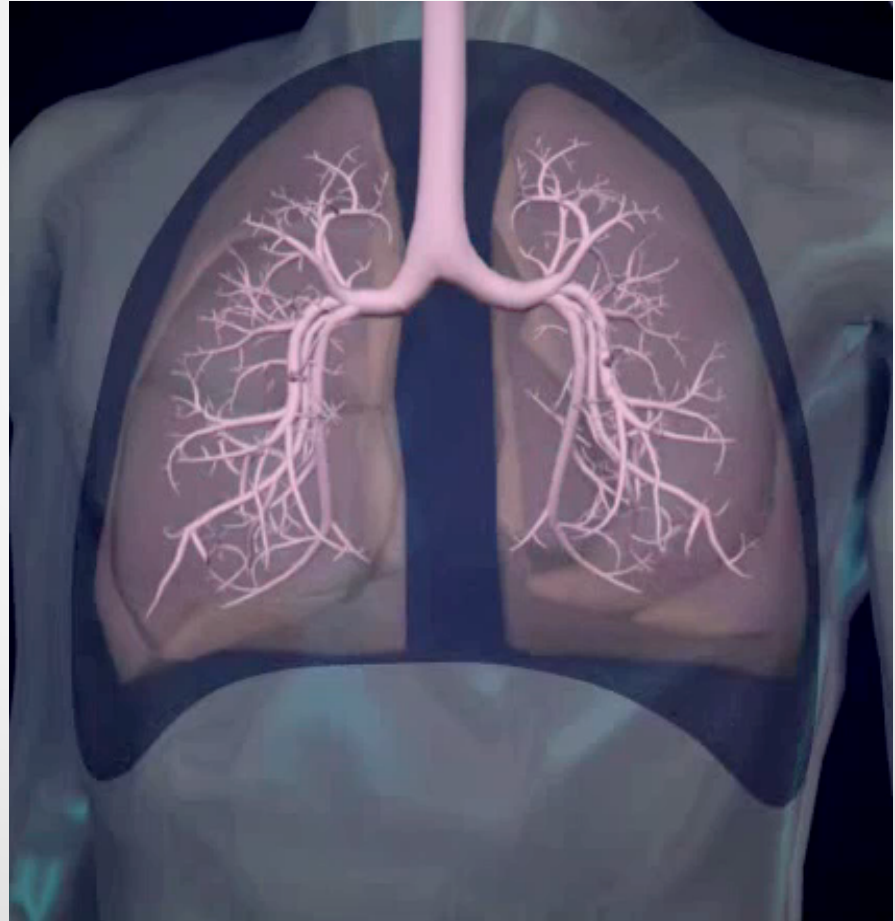
- Boyle's Law

Pressure and volume inverse relationship

In the lungs

- Volume depends on movement of diaphragm and ribs

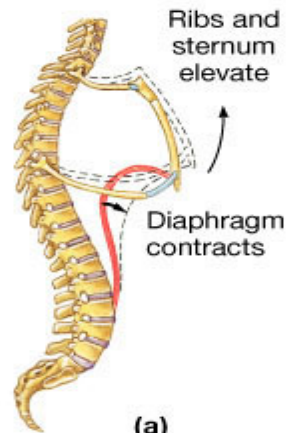
- Compliance – an indication of the expandability of the lungs



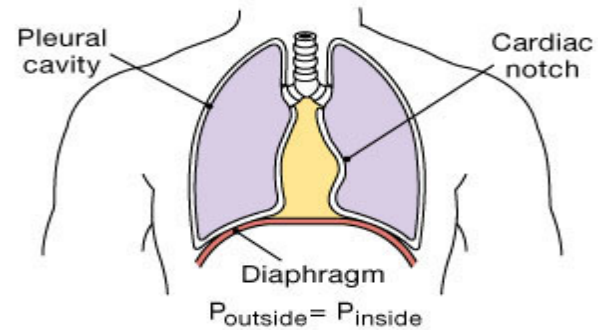
Pressure changes during inhalation and exhalation

- Relationship between intrapulmonary pressure and atmospheric pressure determines direction of air flow
- Intrapleural pressure maintains pull on lungs
 - Pressure in the space between parietal and visceral pleura

Mechanisms of Pulmonary Ventilation

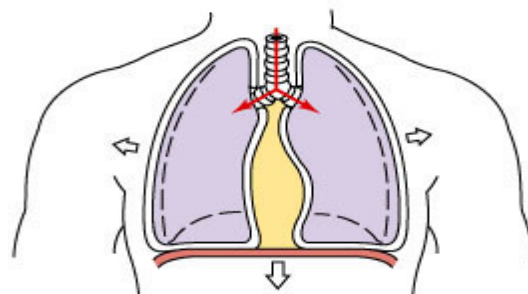


(a)



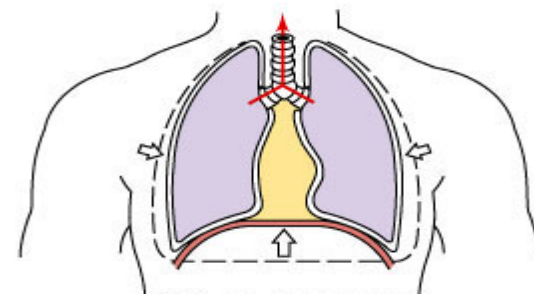
Pressure outside and inside are equal, so no air movement occurs

(b)



Pressure inside falls, so air flows in

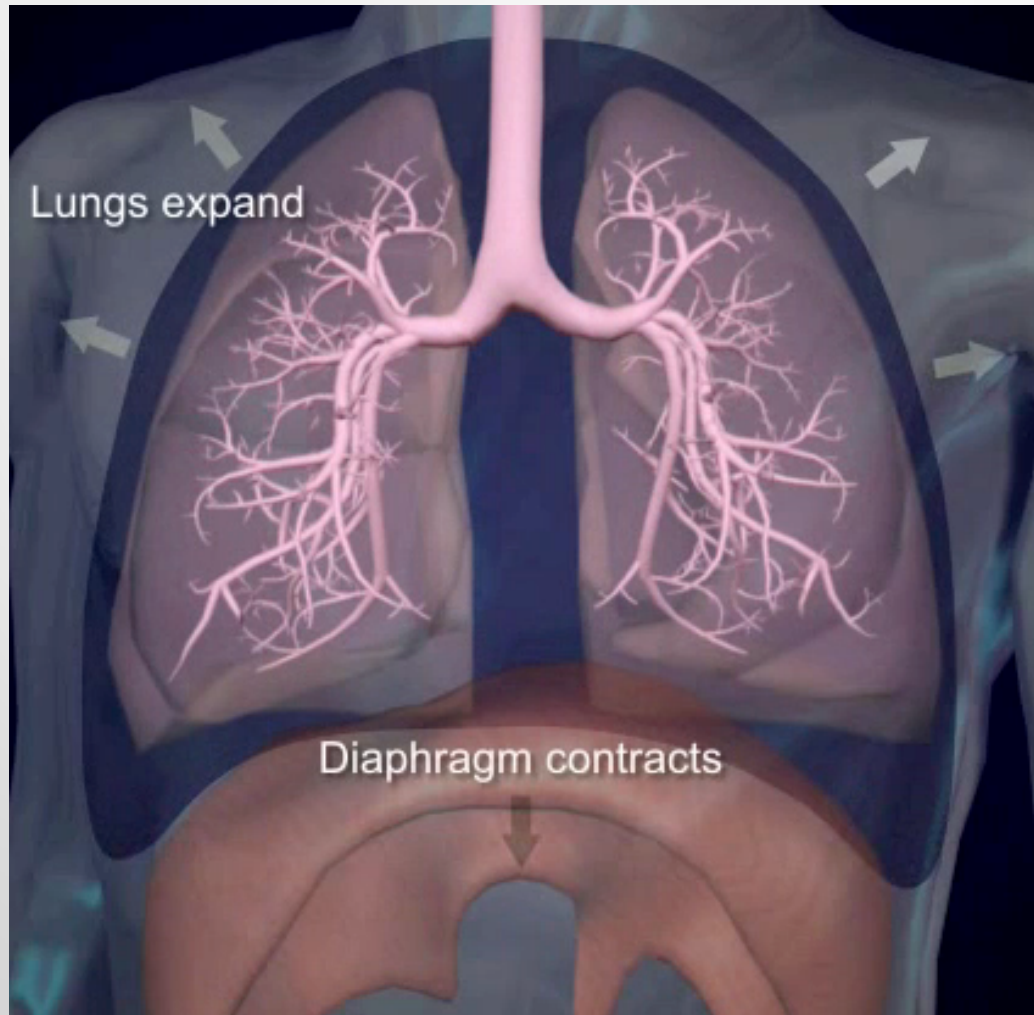
(c)



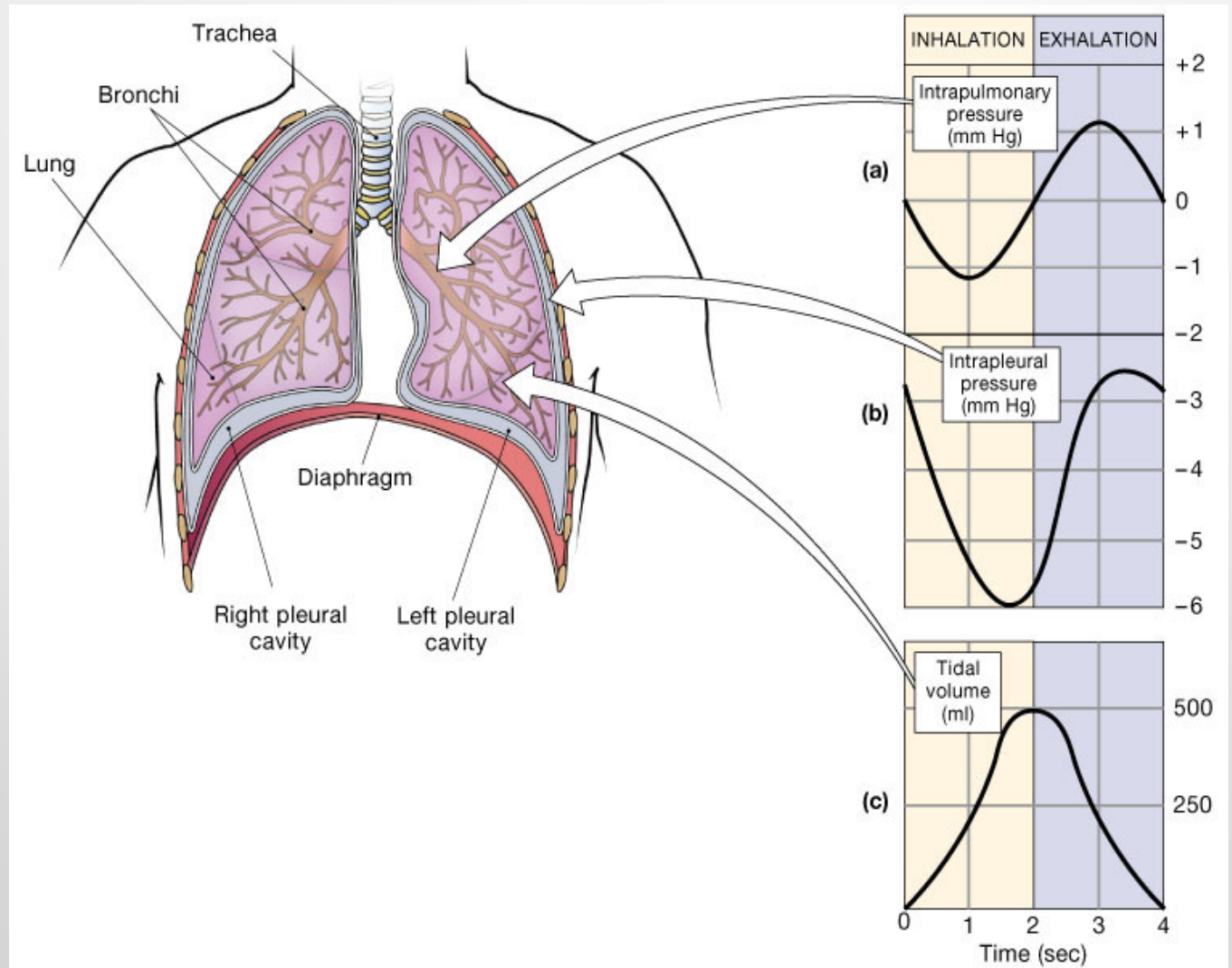
Pressure inside rises, so air flows out

(d)

Mechanics of Breathing



Pressure Changes during Inhalation and Exhalation



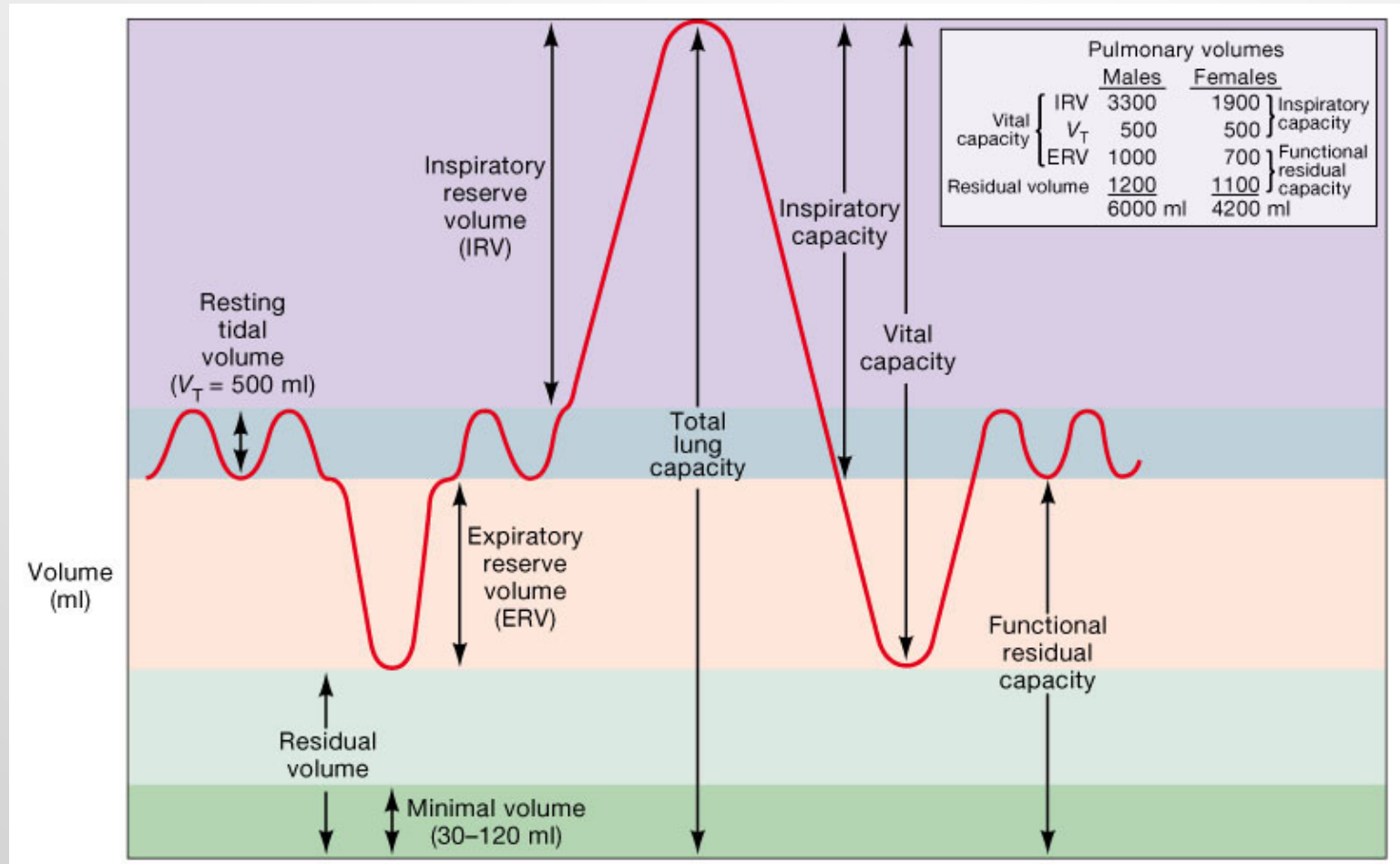
Mechanisms of breathing

- Quiet breathing (eupnea)
 - Diaphragm and external and internal intercostals muscles
- Forced breathing (hyperpnea)
 - Accessory muscles

Respiratory volumes

- Alveolar volume
 - Amount of air reaching the alveoli each minute
- Tidal Volume (V_T)
 - Amount of air inhaled or exhaled with each breath
- Vital capacity
 - Tidal volume plus expiratory and inspiratory reserve volumes
- Residual volume
 - Air left in lungs after maximum exhalation

Respiratory Volumes and Capacities



Types and size Lung Volumes

■ Tidal Volume (500 ml)

- The amount of air that enters the lungs during a normal, quiet inspiration.

■ Inspiratory reserve volume (3100 ml)

- During a forced inhalation the volume of air over and above the tidal volume.

■ Expiratory reserve volume (1200 ml)

- During forced expiration the volume of air expired over and above the tidal volume.

■ Residual volume (1200 ml)

- Even after forced expiration some air remains in the lung structures. This prevents the lungs from collapsing. (note because of the residual volume staying in the lungs at all time it has a lower oxygen and higher carbon dioxide content than inspired air. Hence the mixing of newly inspired air and residual volume means that the concentration of oxygen at the alveoli is lower than that in atmospheric air).

Lung Volumes

■ Vital capacity (4800 ml)

- The maximum amount of air that can be exhaled after a maximal inspiration. It is equivalent to tidal volume + inspiratory reserve + expiratory reserve.

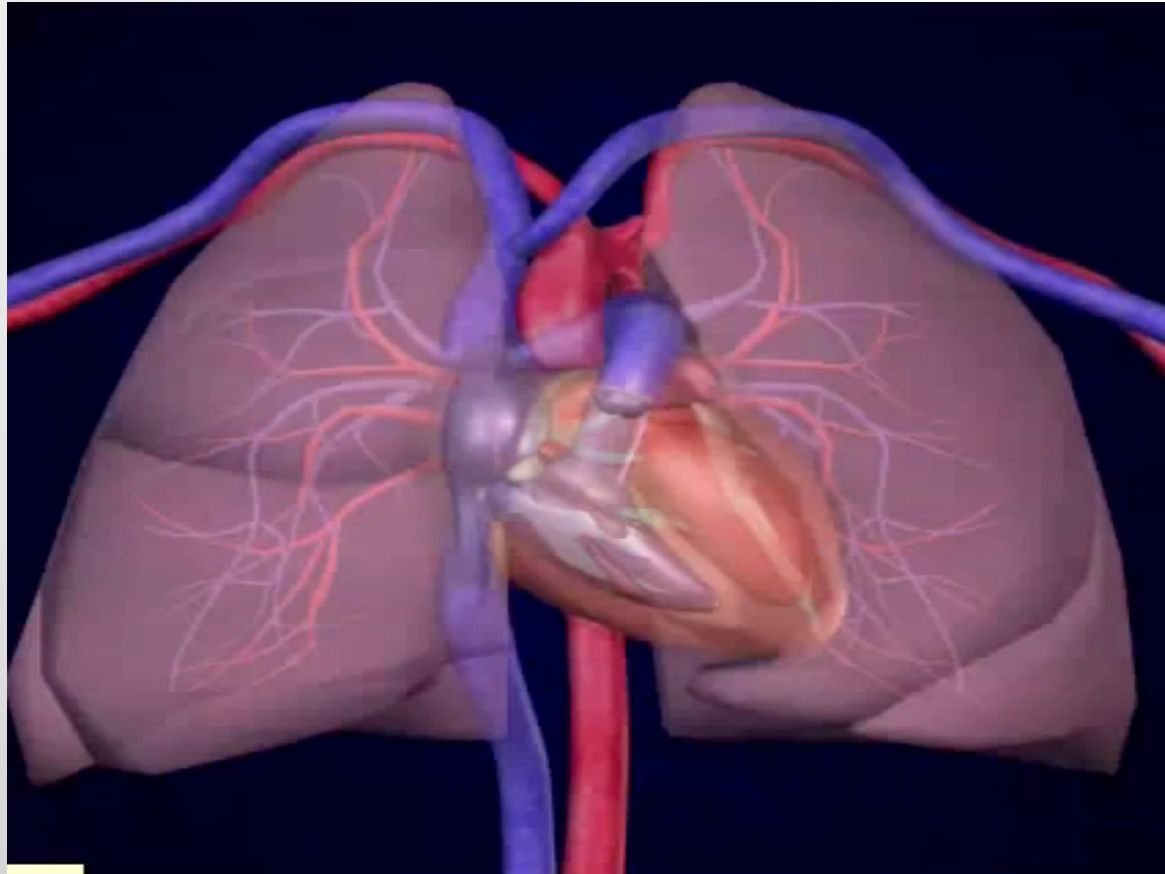
■ Total Lung capacity (6,000 ml)

- This is the total maximal volume of air that can be contained in the lungs and is equivalent to the vital capacity + residual volume.

■ Dead Space (150 ml)

- This is the amount of air that is contained in the lungs but never reached the alveoli. It is the volume of the bronchial tree (trachea, bronchi and bronchioles)

Pulmonary Circulation



Gas Exchange ($O_2 - CO_2$)

The gas laws

- **Dalton's Law and partial pressure**

Individual gases in a mixture exert pressure proportional to their abundance

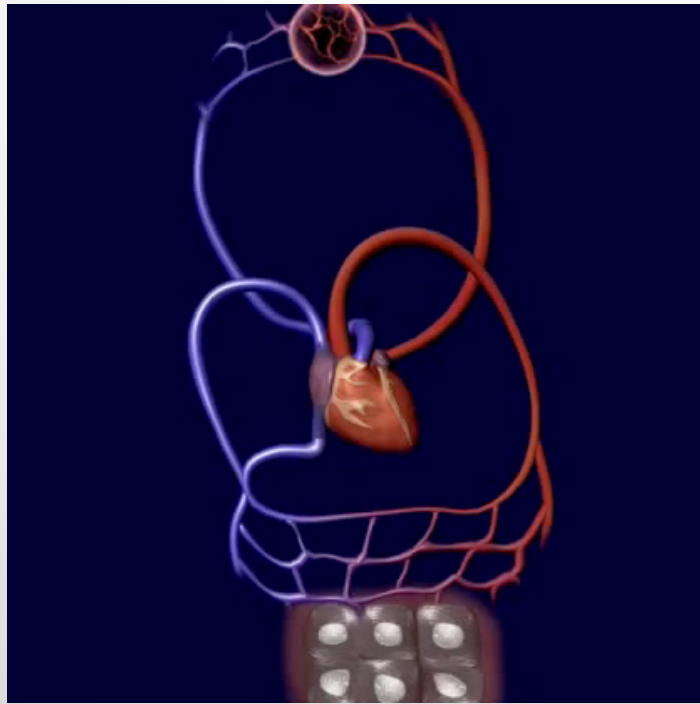
- **Diffusion between liquid and gases (Henry's law)**

The amount of gas in solution is directly proportional to their partial pressure

Diffusion and respiratory function

- Gas exchange across respiratory membrane is efficient due to:
 - Differences in partial pressure
 - Small diffusion distance
 - Lipid-soluble gases
 - Large surface area of all alveoli
 - Coordination of blood flow

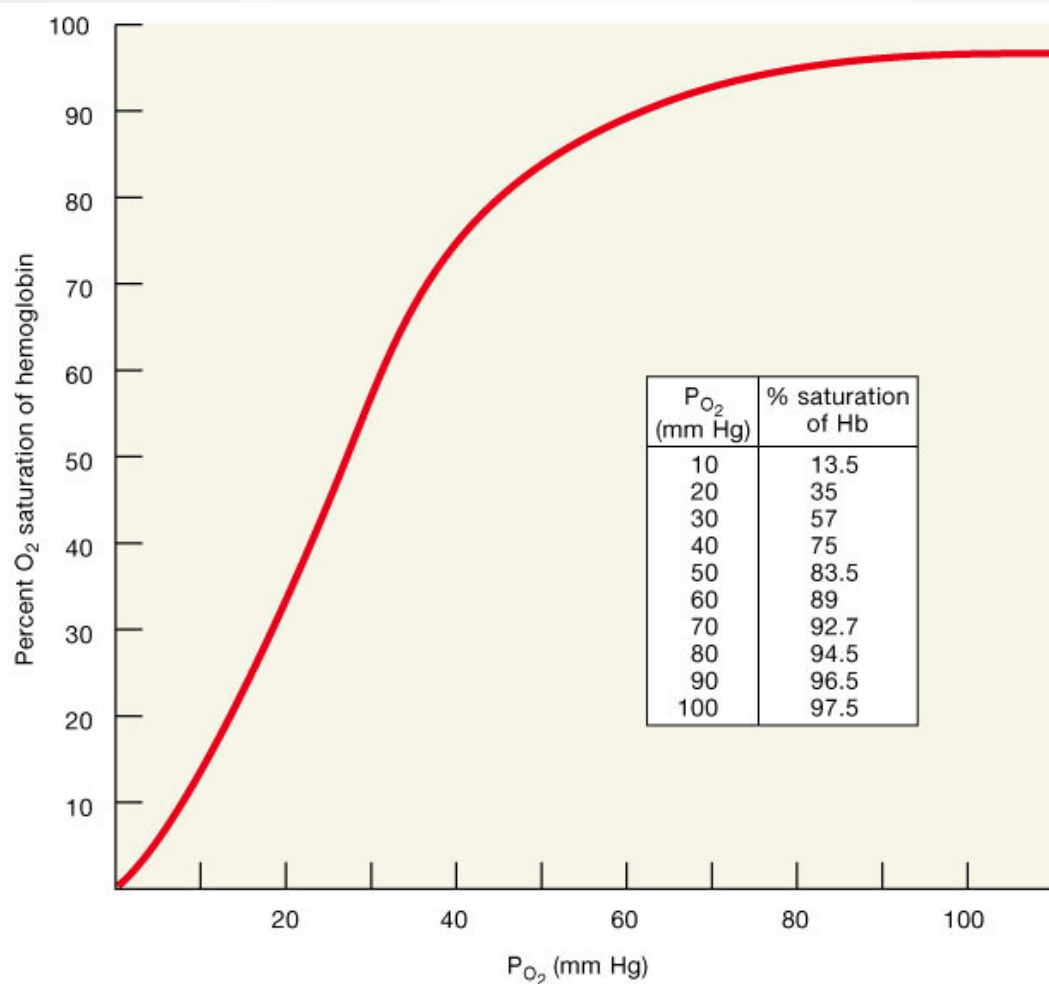
Respiratory Processes and Partial Pressures in Respiration



Oxygen transport

- Carried mainly by RBCs, bound to haemoglobin
- The amount of oxygen haemoglobin can carry is dependent upon:
 - PPo_2
 - pH
 - temperature
 - barometric pressure
- Fetal haemoglobin has a higher O_2 affinity than adult haemoglobin

The Oxygen-Hemoglobin Saturation Curve



Diffusion of Oxygen

- Oxygen diffuses from the alveoli into the blood capillaries under the influence of partial pressures.

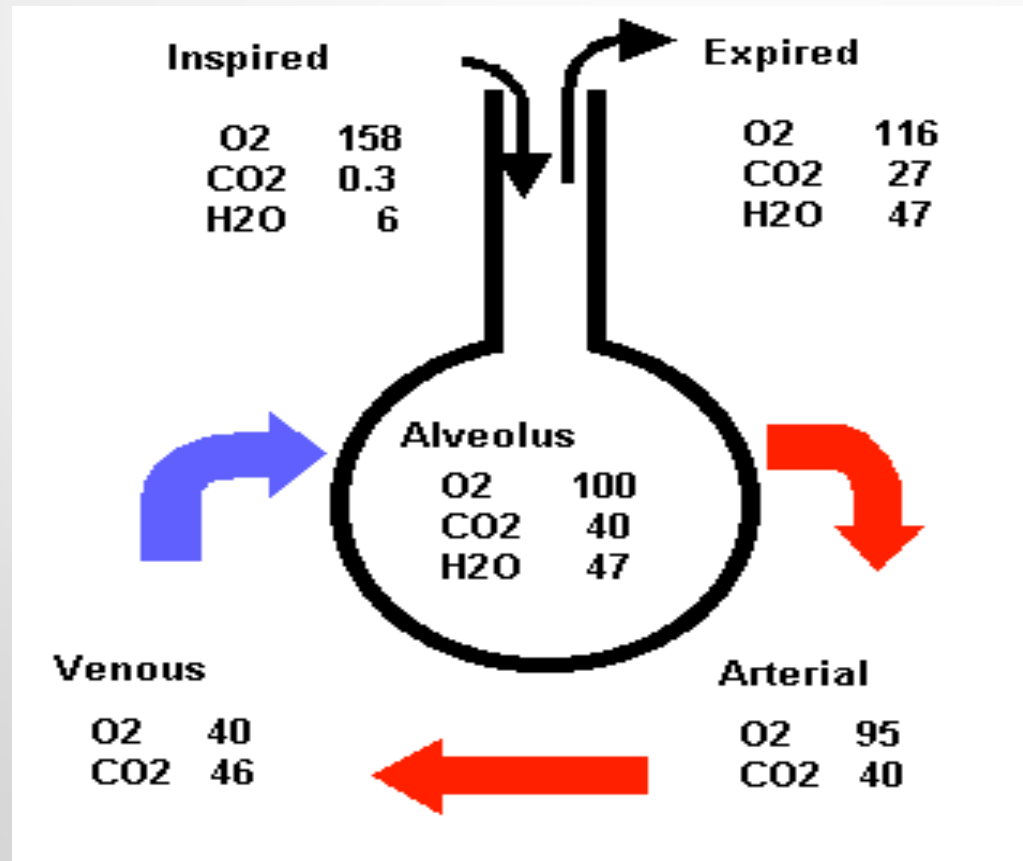
Diffusion

- “The movement of atoms or molecules from a high concentration to a lower concentration until equilibrium is reached”.
- An increase in temperature increases the rate of diffusion.
- A higher concentration gradient increases the amount transferred not the speed.

Partial Pressure (PP)

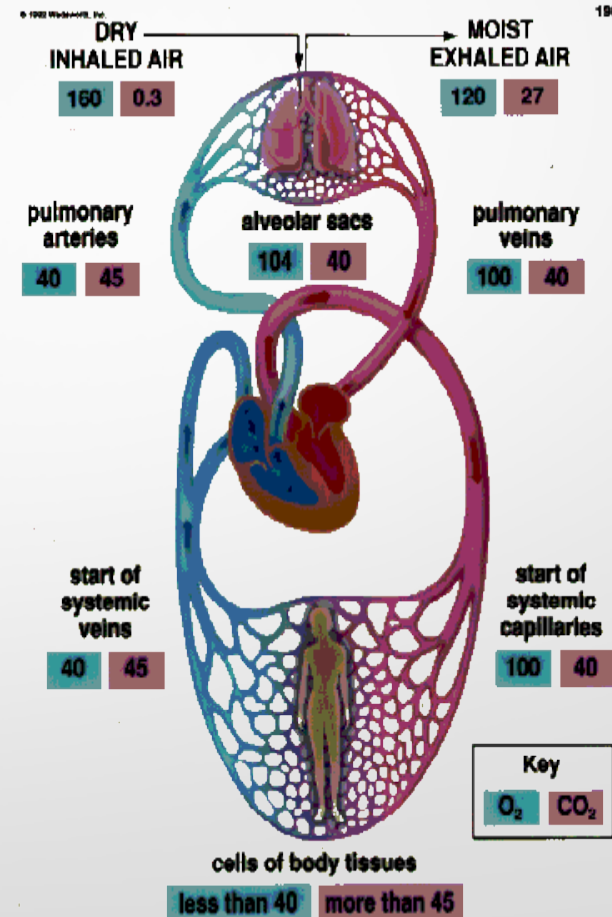
- The pressure a gas exerts on a container is dependent on the volume of gas within the container. When the gas is made from several other gases then the partial pressure is the relative pressure exerted by the component gases and is proportional to the relative volume of the component within the whole.

Partial pressures of oxygen and carbon dioxide during respiration and gas exchange (all values in mmHg)



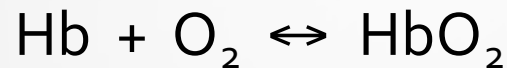
Partial pressures at various locations around the body.

A large gradient exists between alveolar air and pulmonary capillary blood for oxygen and small gradient exists for carbon dioxide. When combined with the specific diffusive capacities (oxygen being less soluble than carbon dioxide results in a much reduce uptake for oxygen) for each gas, these partial pressure gradients result in similar diffusion profiles. As blood flows through the pulmonary capillaries, the partial pressure of oxygen and carbon dioxide reaches an equilibrium after approximately 0.25 seconds under resting blood flow of 5lts/min.



Oxygen transport

- Oxygen is transported in the blood combining with the protein haemoglobin, located on the surface of the red blood cell, to form oxyhaemoglobin.



- Haemoglobin consists of four globin units (polypeptide chains) each having a haeme group containing iron (Fe^{+2}). Each of these globin and haeme units can bind with one molecule of oxygen (1 g of haemoglobin bind with 1.34 ml of oxygen).
- At rest and during exercise blood leaving the lungs is 98+% saturated with oxygen which can be represented in an oxygen

98% Saturation ?

The saturation is only 98% as;

1. Blood from the bronchioles drains into the pulmonary vein without passing through the pulmonary capillaries.
2. Blood drains from coronary vein into left ventricle
3. Average inequality between the lungs VE / Q – ventilation / cardiac output

If the blood is fully saturated (98%) even during maximal exercise it implies that the capacity and functioning of the lungs is not a limiting factor in aerobic exercise.

Plasma Oxygen

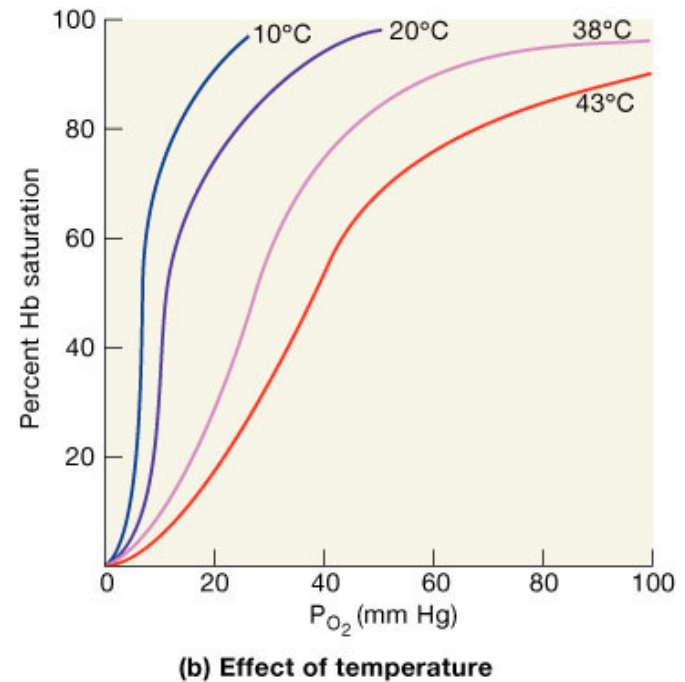
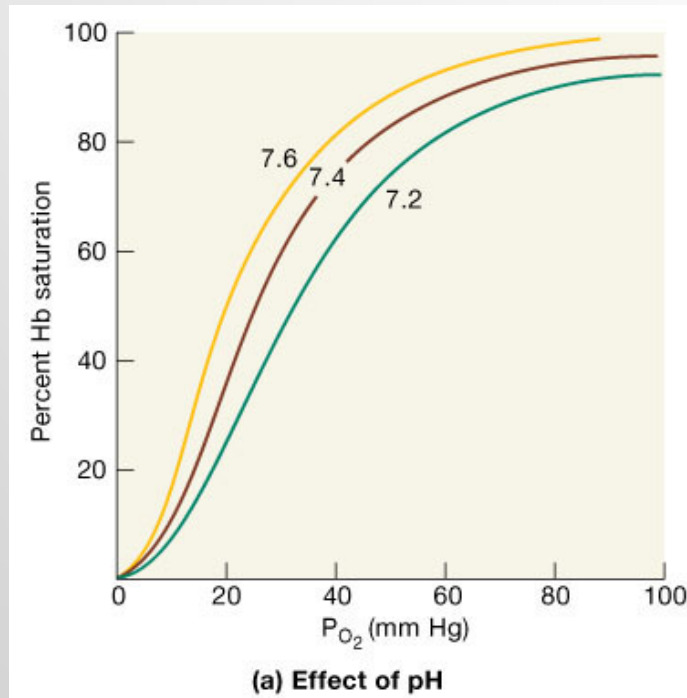
- Some oxygen is also transported in the plasma which is an important regulator in ventilation, i.e. low oxygen concentrations in the plasma stimulate an increase in ventilation.
- Repeated or long term exposure to low levels of plasma oxygen cause by endurance training or living / training at altitude stimulate an increase in the secretion of erythropoietin from the kidneys. This stimulates an increase in red blood cell production and haemoglobin concentrations. Long term training may induce a hypervolemic response which will reduce concentration.

Haemoglobin concentration

- Males 14 – 18 g / 100 ml blood
- Females 12 – 16 g / 100 ml blood

This means that males are able to transport more oxygen than females and implies that they should be generally better at aerobically stressful activities.

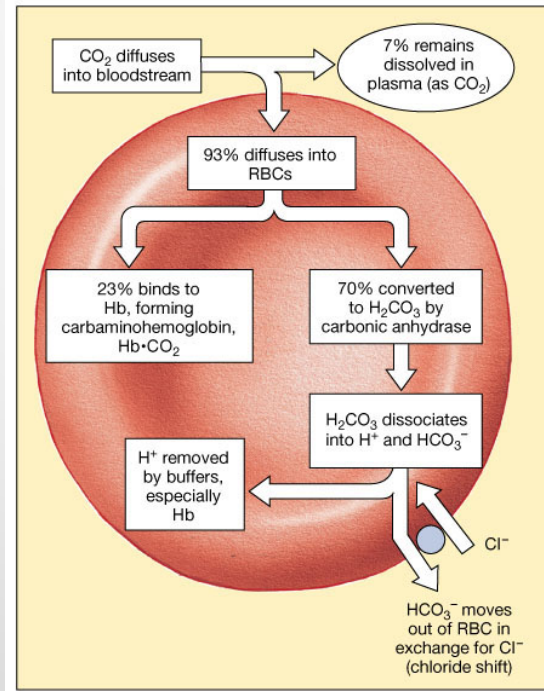
The Effect of pH and Temperature on Haemoglobin Saturation



Transport of Carbon Dioxide

- Solution – 5-7% dissolved in plasma
- Combined with haemoglobin
- Combined with water to form bicarbonate in plasma and r.b.c.

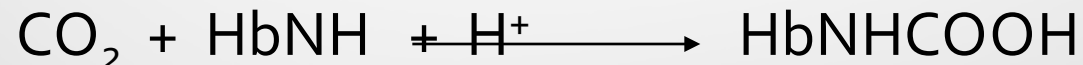
Carbon Dioxide Transport in Blood



Combined with Haemoglobin

- Carbon dioxide reacts with amino acids in blood proteins, especially globin in haemoglobin, forming carbamino compounds. This reaction requires an additional hydrogen proton, thereby assisting in the buffering process.

Combination of haemoglobin with carbon dioxide

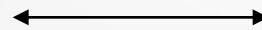


- This reaction is reversed as PCO_2 is lowered. CO_2 moves into solution then into the alveoli. Also as oxygen binds with haemoglobin, carbon dioxide is removed (Haldane effect) which facilitates the removal of CO_2 by the lungs.

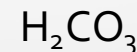
Role of Carbonic Acid

- An enzyme carbonic anhydrase, found on the surface of red blood cells combines CO_2 and water (H_2O) in reversible reaction forming carbonic acid.

formation of carbonic acid

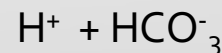
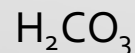


Carbonic anhydrase



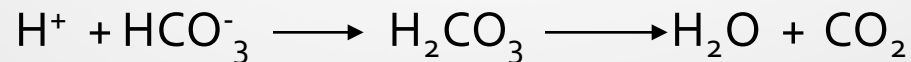
- The carbonic acid then dissociates a hydrogen proton forming bicarbonate.

Carbonic acid dissociation to bicarbonate and a hydrogen proton



- The hydrogen is buffered by haemoglobin preventing a decrease in pH. The bicarbonate diffuses from the red blood cell into the plasma.
- To maintain ionic balance Cl^- moves into the red blood cell (chloride shift).
- When the blood reaches the lungs the CO_2 leaves the blood lowering PCO_2 change the equilibrium recombining bicarbonate with hydrogen and the subsequent carbonic acid splits to CO_2 and H_2O .

Formation of carbonic acid and subsequently carbon dioxide and water in the alveolar capillaries.



- The carbon dioxide moves into the alveoli and the water retained by the body.
- As the concentration of bicarbonate in the plasma is lowered chlorine move back from the red blood cells.

Gas absorption/generation balanced by capillary rates of delivery/removal

- Homeostatic mechanisms maintain balance
- Local regulation of gas transport and alveolar function include
 - Lung perfusion
 - Alveolar capillaries constrict in low oxygen
 - Alveolar ventilation
 - Bronchioles dilate in high carbon dioxide

Respiratory centers of the brain

- Medullary centers

- Respiratory rhythmicity centres set pace

- Pontine centres – provide input to the medullary centers

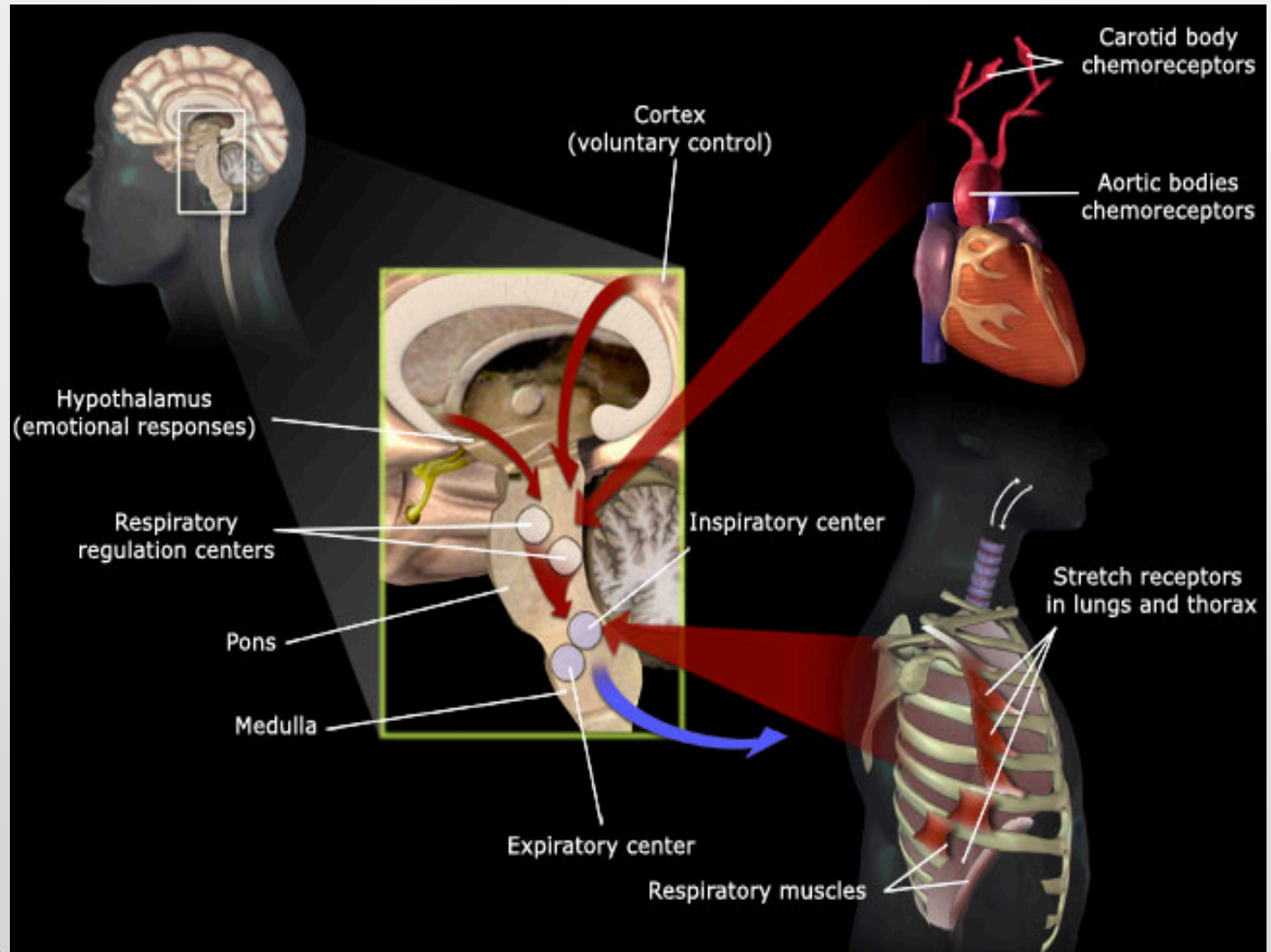
PNEUMOTAXIC CENTRE

- inhibits inspiratory centre both directly and by inhibiting apneustic centre
- limits time of inspiration and prevents over-inflation
- provides the 'fine tuning' of respiration

APNEUSTIC CENTRE

- stimulates inspiratory centre
- not very important unless pneumotaxic centre destroyed

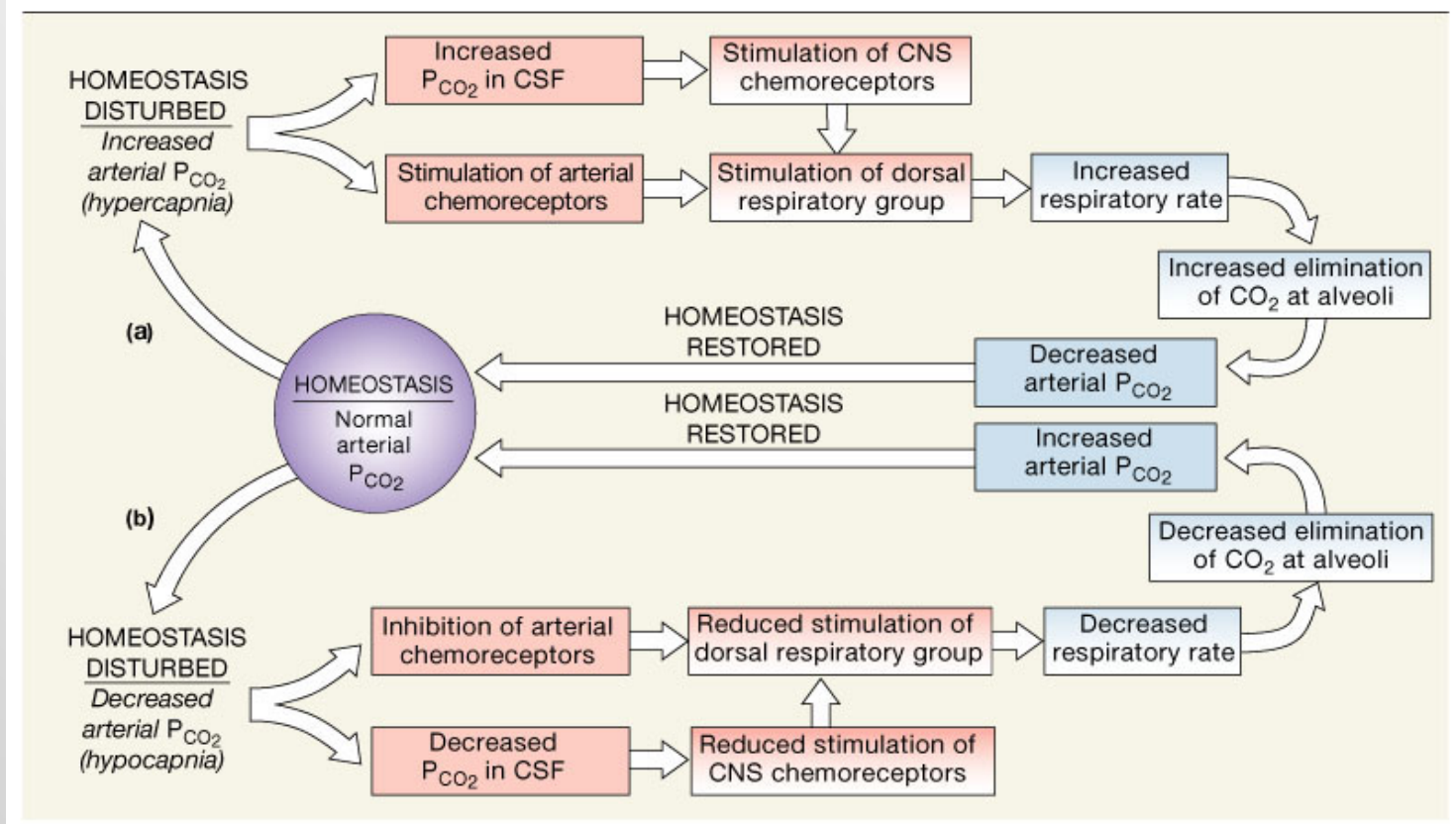
Respiratory Centers and Reflex Controls



Respiratory reflexes

- Respiratory centers are modified by sensory information including
 - Chemoreceptor reflexes
 - Level of carbon dioxide
 - Baroreceptors reflexes
 - Hering-Breuer reflexes
 - Prevents over-inflation
 - Protective reflexes

The Chemoreceptor Response to Changes in P_{CO_2}



Voluntary control of respiration

- Regulation of respiratory rate is dependent upon:
 - Conscious and unconscious thought
 - Emotional state
 - Anticipation

General Information

- Lung volumes are not particularly effective in predicting athletic performance. It is the efficiency of exchange of oxygen and carbon dioxide between the lungs and the blood which is more important.
- Smoking interferes with lung volumes. The irritation from smoke cause mucus secretion restricting air flow. One cigarette can reduce vital capacity by 10 - 15%.