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Respiratory System

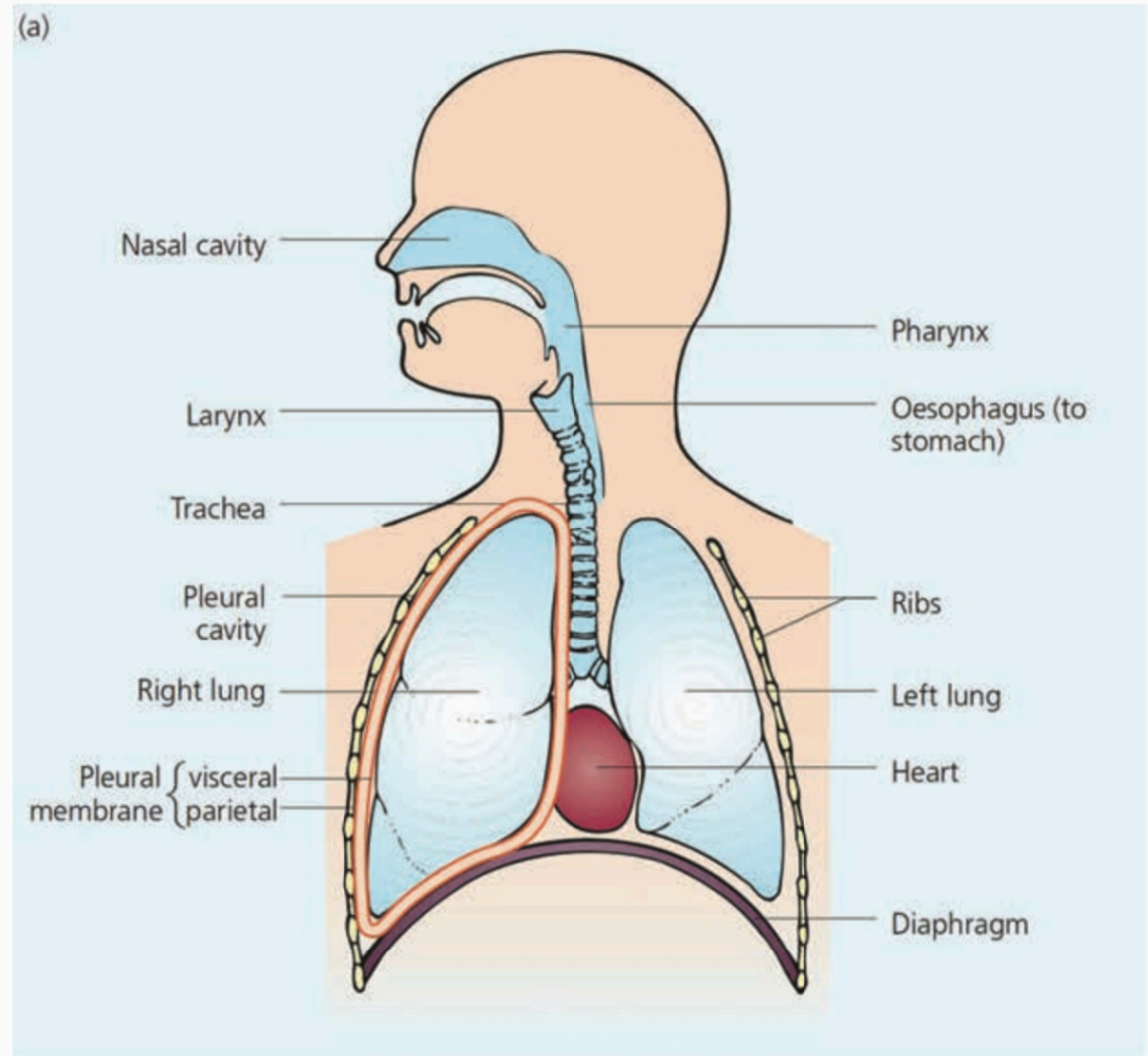
Based on Chapter 9, Sturgeon (2018)

Trawsnewid Addysg; Trawsnewid Bywydau
Transforming Education; Transforming Lives



www.uwtsd.ac.uk

Anatomy



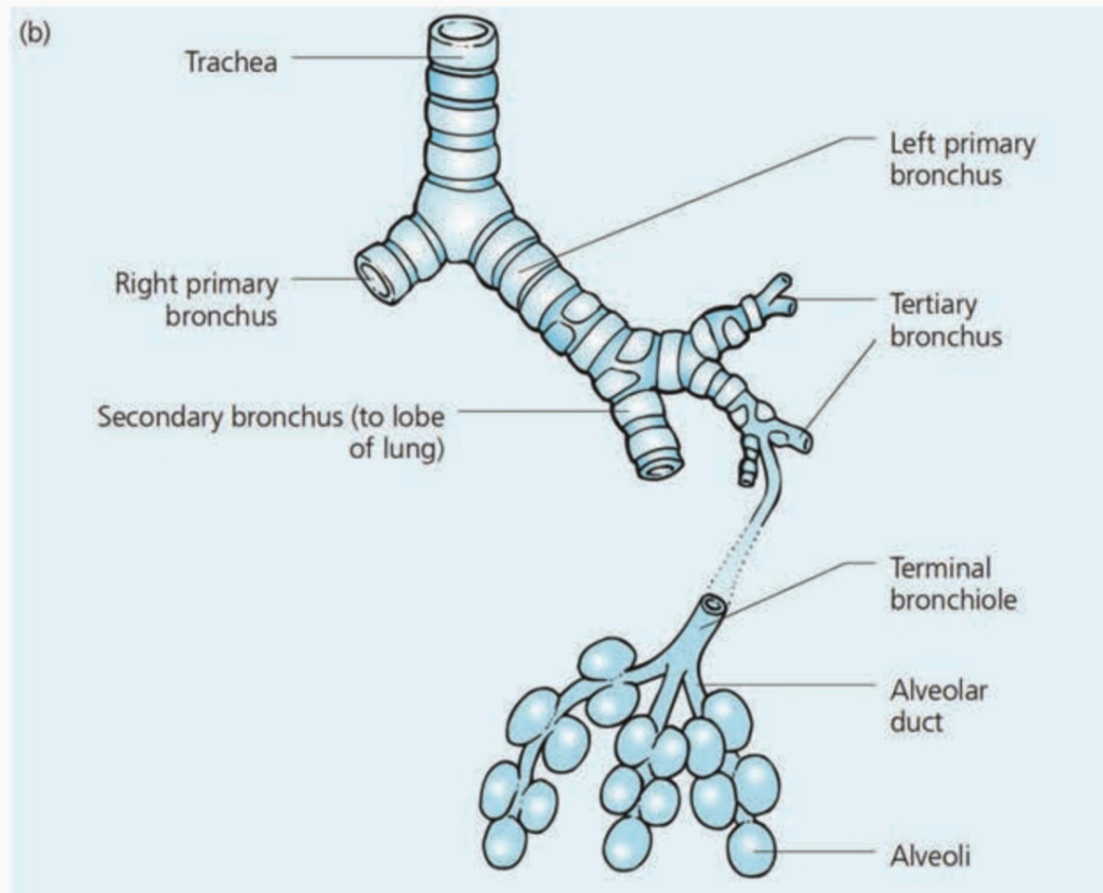


Figure 9.1 (a) Upper respiratory tract and thoracic cavity. (b) Lower respiratory tract and alveoli.

Respiration

- Three types of respiration:
 - External
 - Internal
 - Cellular

External Respiration

- Takes place at lungs
- Involves exchange of Oxygen from atmosphere into blood, and Carbon Dioxide from blood into atmosphere.

Internal Respiration

- Takes place within body
- Involves exchange of Oxygen from blood to tissues, and Carbon Dioxide from tissue to blood.

Cellular Respiration

- Occurs within cells.
- Involves production of ATP through oxidative phosphorylation (aerobic respiration)
- Takes place within mitochondria.

Pulmonary Ventilation:

Inspiration *(continued)*

- Lung volume ↑, intrapulmonary pressure ↓
 - Boyle's law regarding pressure versus volume
 - At constant temperature, pressure and volume inversely proportional
- Air passively rushes in due to pressure difference
- Forced breathing uses additional muscles
 - Scalenes, sternocleidomastoid, pectorals
 - Raise ribs even farther

Pulmonary Ventilation: Expiration

- Usually passive process
 - Inspiratory muscles relax
 - Lung volume ↓, intrapulmonary pressure ↑
 - Air forced out of lungs
- Active process (forced breathing)
 - Internal intercostals pull ribs down
 - Also, latissimus dorsi, quadratus lumborum
 - Abdominal muscles force diaphragm back up

(continued)

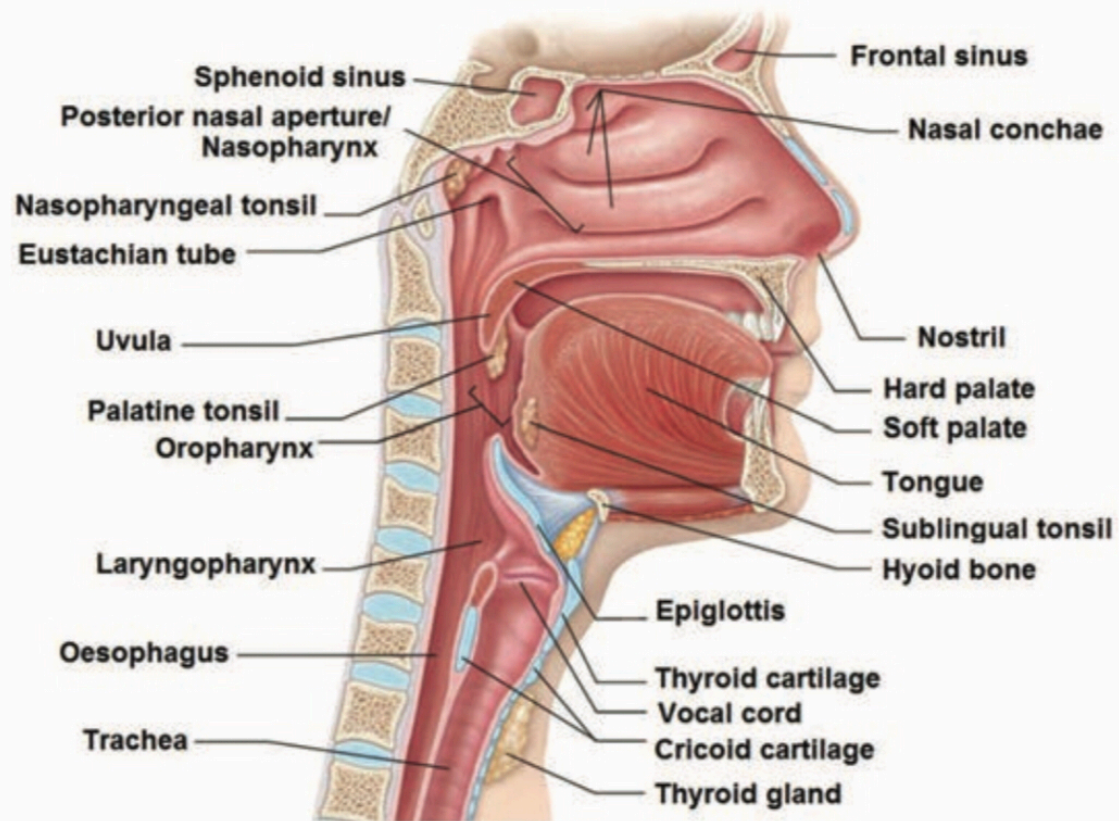
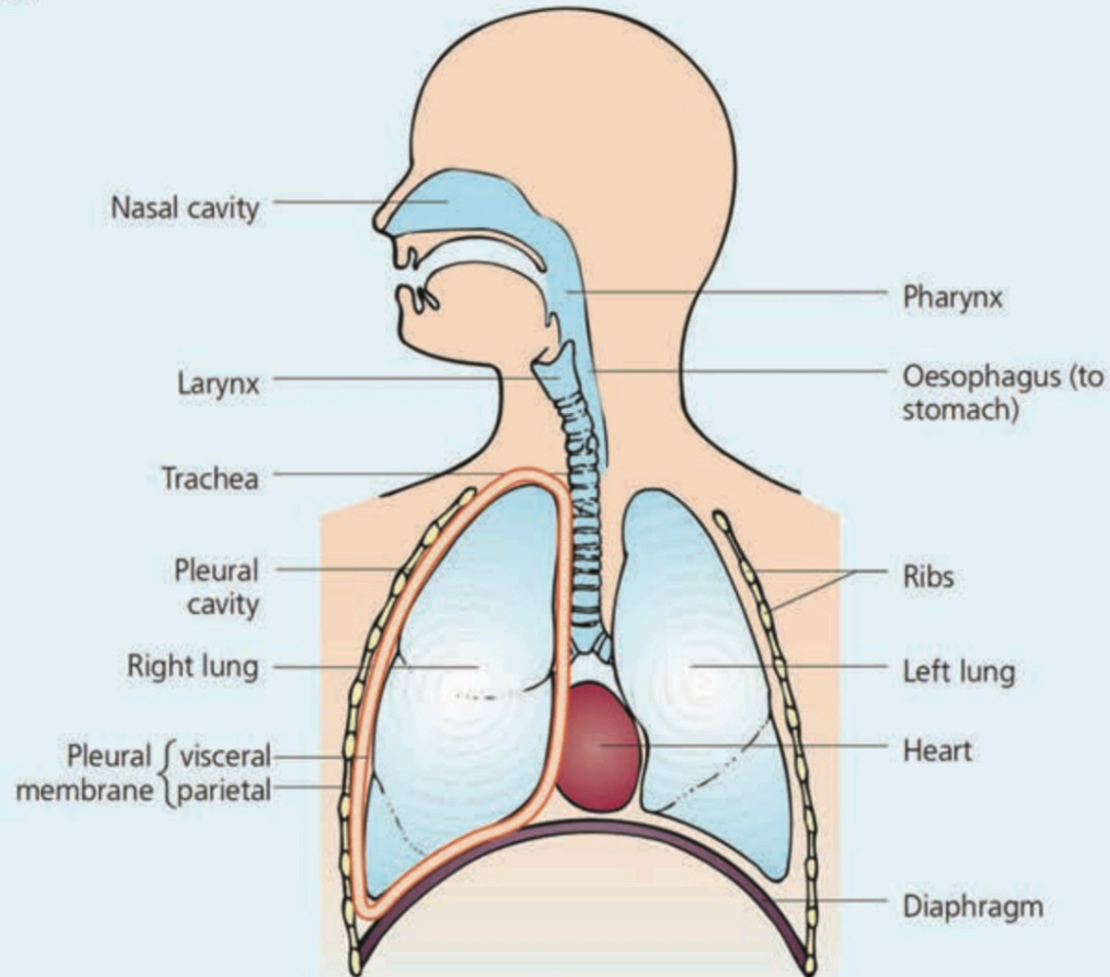


Figure 9.2 Upper respiratory tract.

(a)



150 million alveoli

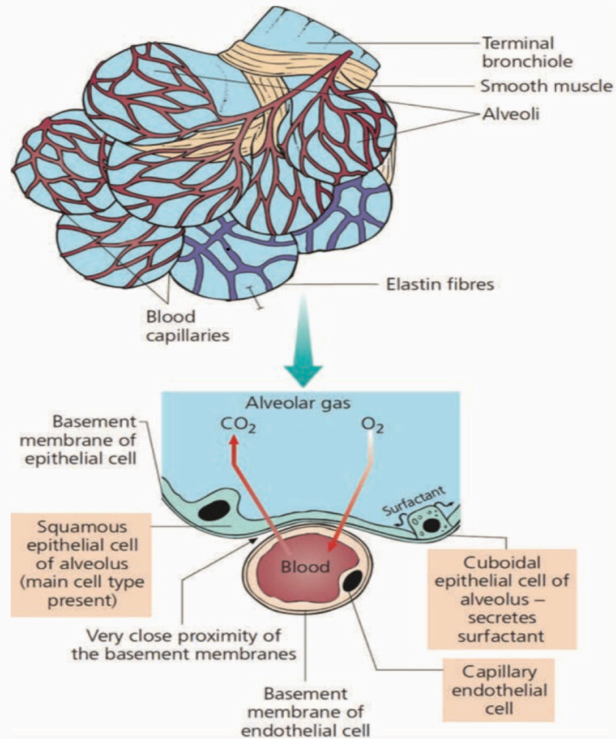
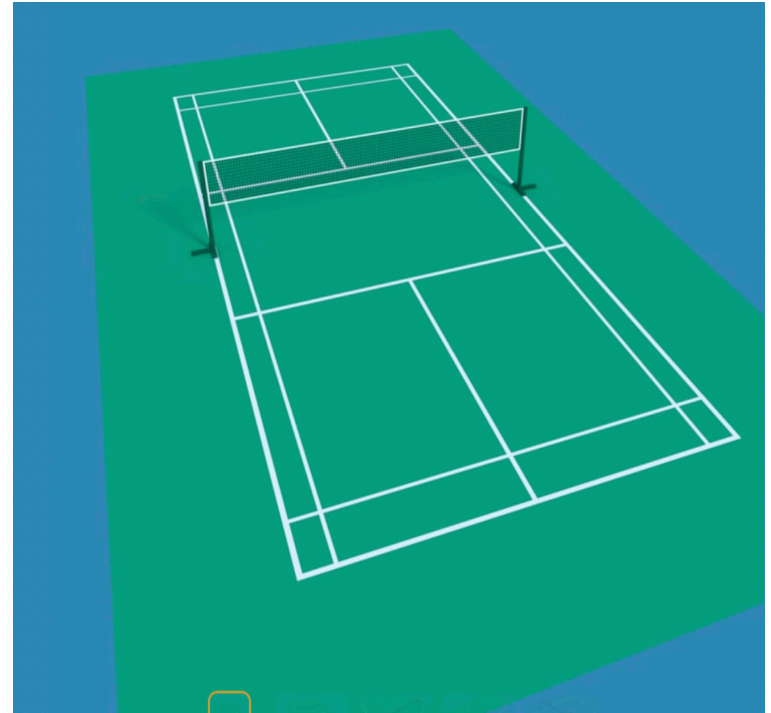


Figure 9.4 Alveoli and gaseous exchange.



Pulmonary Diffusion:

Partial Pressures of Gases

- Air = 79.04% N₂ + 20.93% O₂ + 0.03% CO₂
 - Total air P: atmospheric pressure
 - Individual P: partial pressures
- Standard atmospheric P = 760 mmHg
 - Dalton's law: total air P = PN₂ + PO₂ + PCO₂
 - PN₂ = 760 x 79.04% = 600.7 mmHg
 - PO₂ = 760 x 20.93% = 159.1 mmHg
 - PCO₂ = 760 x 0.04% = 0.2 mmHg

(continued)

Pulmonary Diffusion:

Partial Pressures of Gases *(continued)*

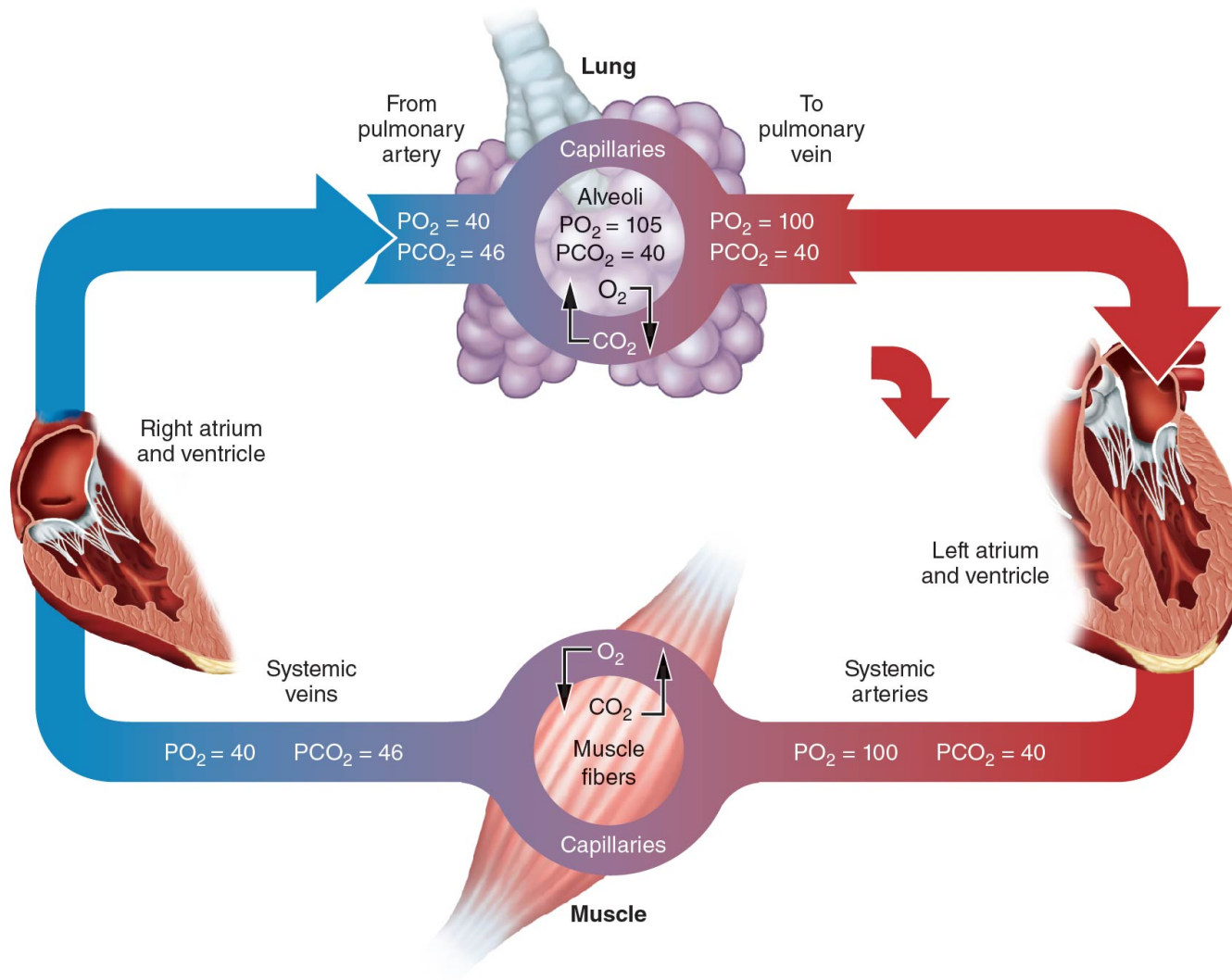
- Henry's Law: gases dissolve in liquids in proportion to partial P
 - Also depends on specific fluid medium, temperature
 - Solubility in blood constant at given temperature
- Partial P gradient most important factor for determining gas exchange
 - Partial P gradient drives gas diffusion
 - Without gradient, gases in equilibrium, no diffusion

Gas Exchange in the Alveoli:

Oxygen Exchange

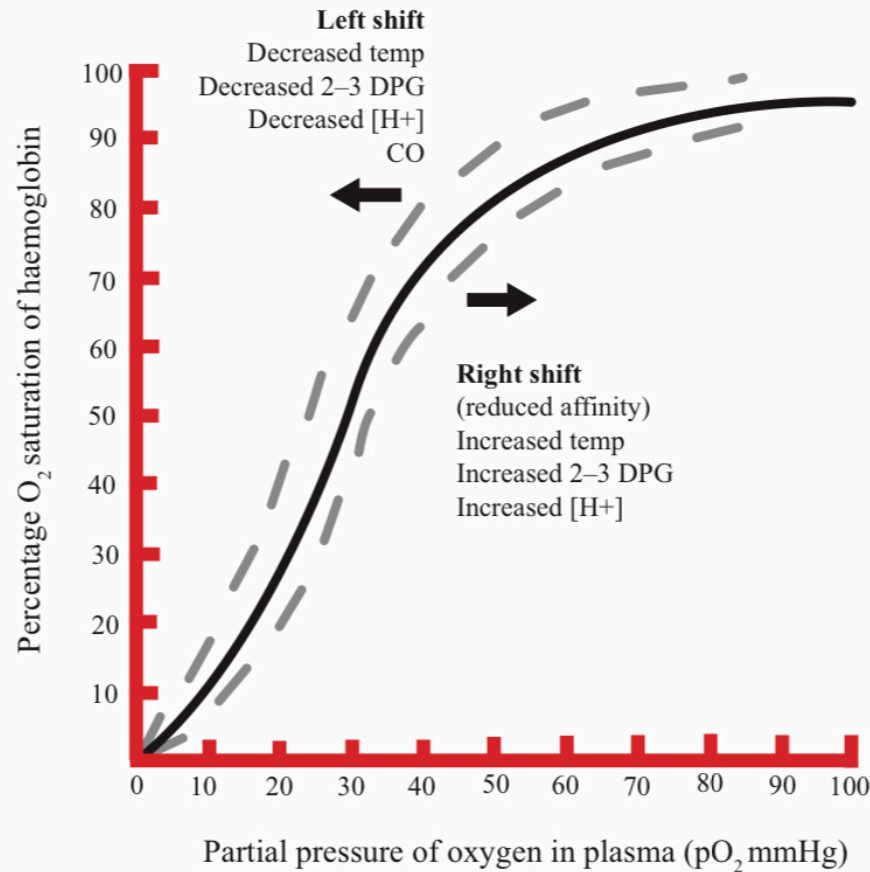
- Atmospheric $PO_2 = 159$ mmHg
- Alveolar $PO_2 = 105$ mmHg
- Pulmonary artery $PO_2 = 40$ mmHg
- PO_2 gradient across respiratory membrane
 - 65 mmHg (105 mmHg – 40 mmHg)
 - Results in pulmonary vein $PO_2 \sim 100$ mmHg

(continued)



Transport of Oxygen in the Blood

- Can carry 20 mL O₂ / 100 mL blood
- ~1 L O₂ / 5 L blood
- >98% bound to hemoglobin (Hb) in red blood cells
 - O₂ + Hb: oxyhemoglobin
 - Hb alone: deoxyhemoglobin
- <2% dissolved in plasma



pO_2 (mmHg)	% saturation of Hb
10	13.5
20	35.0
30	57.0
40	75.0
50	83.5
60	89.0
70	92.7
80	94.5
90	96.5
100	97.5

Figure 9.5 Oxygen-haemoglobin dissociation curve.

Carbon Dioxide Transport

- Released as waste from cells
- Carried in blood three ways
 - As bicarbonate ions
 - Dissolved in plasma
 - Bound to Hb (carbaminohemoglobin)

Carbon Dioxide Transport: Bicarbonate Ion

- Transports 60 to 70% of CO₂ in blood to lungs
- CO₂ + water form carbonic acid (H₂CO₃)
 - Occurs in red blood cells
 - Catalyzed by carbonic anhydrase
- Carbonic acid dissociates into bicarbonate
 - $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{HCO}_3^- + \text{H}^+$
 - H⁺ binds to Hb (buffer), triggers Bohr effect
 - Bicarbonate ion diffuses from red blood cells into plasma

Carbon Dioxide Transport:

Dissolved Carbon Dioxide

- 7 to 10% of CO_2 dissolved in plasma
- When PCO_2 low (in lungs), CO_2 comes out of solution, diffuses out into alveoli

Carbon Dioxide Transport: Carbaminohemoglobin

- 20 to 33% of CO_2 transported bound to Hb
- Does not compete with O_2 -Hb binding
- Hb state, PCO_2 affect CO_2 -Hb binding
 - Deoxyhemoglobin binds CO_2 easier versus oxyhemoglobin
 - $\uparrow \text{PCO}_2 \rightarrow$ easier CO_2 -Hb binding
 - $\downarrow \text{PCO}_2 \rightarrow$ easier CO_2 -Hb dissociation

Respiratory Drive

- The rate and depth at which we breath is controlled by respiratory centres of brain.
- Chemoreceptors provide information on chemical composition of blood.
- CO_2 , O_2 and H^+ are monitored.
- If CO_2 and H^+ levels rise, breathing increases.

Crash course videos

- <https://youtu.be/bHZsvBdUC2I>
- <https://youtu.be/Cqt4LjHnMEA>