2021-1-15 Explain perfusion limited and diffusion limited transfer of gases in the alveolus.

Diffusion through tissues is described by Fick's law of diffusion

$Rate\ of\ Diffusion = \frac{\Delta P \times A \times s}{T \times \sqrt{MW}}$, where:

- ΔP is the pressure gradient across the membrane
- A is the area of the membrane
- s is the solubility of the substance
- T is the thickness of the membrane
- MW is the molecular weight of the substance

- The rate of diffusion of a gas through a tissue is:
  - directly $\propto$:
    - surface area of the barrier
    - solubility of the gas
    - concentration gradient (partial pressure difference)
  - Inversely $\propto$:
    - Membrane thickness
    - Square root of MW

Diffusion vs. perfusion limited

Transfer of gases can be diffusion or perfusion limited dependent on the rate limiting step

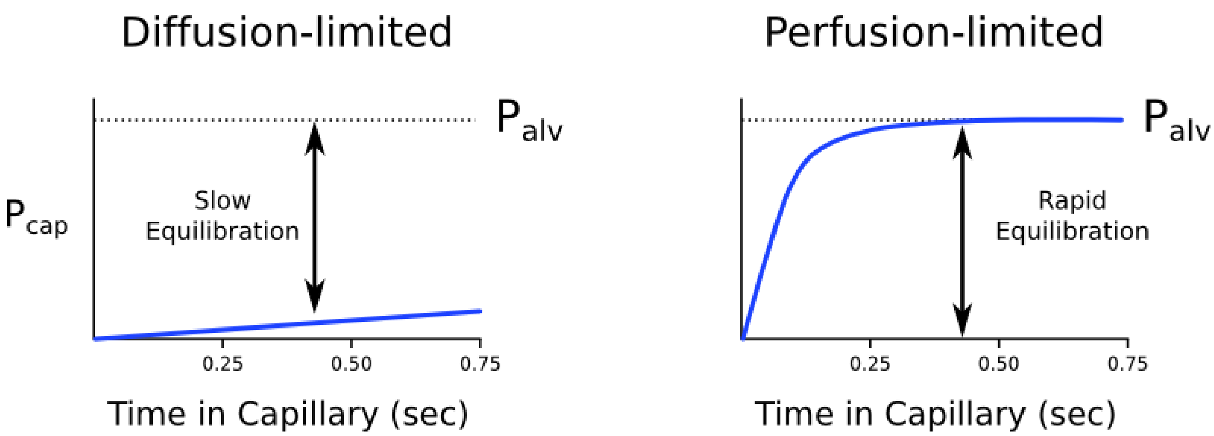
Diffusion limited

- Occurs in gases which do not reach equilibration of Pa and PA
- The rate of gas diffusion across the alveolar membrane limits its transport away from the lung
- Rate limiting step = rate of diffusion
- E.g. CO
  - CO binds so avidly to Hb (250x that of O2) → virtually no CO dissolved in plasma → PaCO rises only slightly
  - Even when RBC traversed entire length of pulmonary capillary, there is still substantial partial pressure difference across alveolar-capillary barrier → equilibrium of PaCO and PACO never reached

Perfusion limited

- Characterized by complete equilibration i.e. Pa = PA
- amount of gas transferred between alveolus and capillary = dependent on amount of blood passing through the capillary
- rate limiting step = rate of blood flow
- E.g. N_2O
  - N2O rapidly diffuses across alveolar-capillary barrier
  - Insoluble; does not bind to Hb; only carried in plasma in dissolved form
  - $PaN_2O = PAN_2O$ (<0.07sec); well before RBC has traversed pulmonary capillary
  - ↑diffusion rate will not ↑ blood transport away from the lungs → limiting factor = rate of blood flow/ perfusion

- - e.g. CO_2 (ventilation limited i.e. perfusion limited in reverse)



http://www.pathwaymedicine.org/diffusion-limited-gas-exchange

<u>Is the transfer of O2 perfusion or diffusion limited?</u>

- Can behave as both perfusion and diffusion limited
- O_2 diffusion takes 0.25s; pulmonary capillary transit time is 0.75s
- Normal conditions
  - Transfer of O_2 across the alveolar capillary barrier is perfusion limited
  - Equilibrium is reached between alveolar and capillary PO_2 before the RBC has traversed the pulmonary capillary
- Conditions where transfer of O_2 may become diffusion limited
  - Disease of the alveolar capillary barrier
    - Pulmonary fibrosis: thickening of alveolar-capillary barrier → ↓rate of diffusion
    - Exercise: ↑CO → ↓RBC transit time
    - Altitude: ↓ PaO_2

<u>Examiner Comments:</u>

36% of candidates passed this question.

This question required detail on those factors affecting gas exchange at the level of the alveolus. A description of the components of the Fick equation was expected - and how this related to oxygen and carbon dioxide transfer at the alveolar capillary membrane. The rapid rate of equilibration (developed tension) was the limiting factor in of blood/alveolar exchange that rendered some gases perfusion limited (examples - N_2O, O_2 under usual conditions but not all) and the slower rate of others diffusion limited (examples CO and O_2 under extreme conditions e.g., exercise, altitude). Estimates of time taken for each gas to equilibrate relative to the time taken for the RBC to travel across the interface was also expected for full marks. CO_2 despite rapid equilibration and higher solubility was correctly described as perfusion limited (unless in disease states). Better answers described CO_2 as ventilation limited. Some answers also correctly included the component of interaction with the RBC and haemoglobin. Ventilation/perfusion inequalities over the whole lung were not asked for and scored no marks.