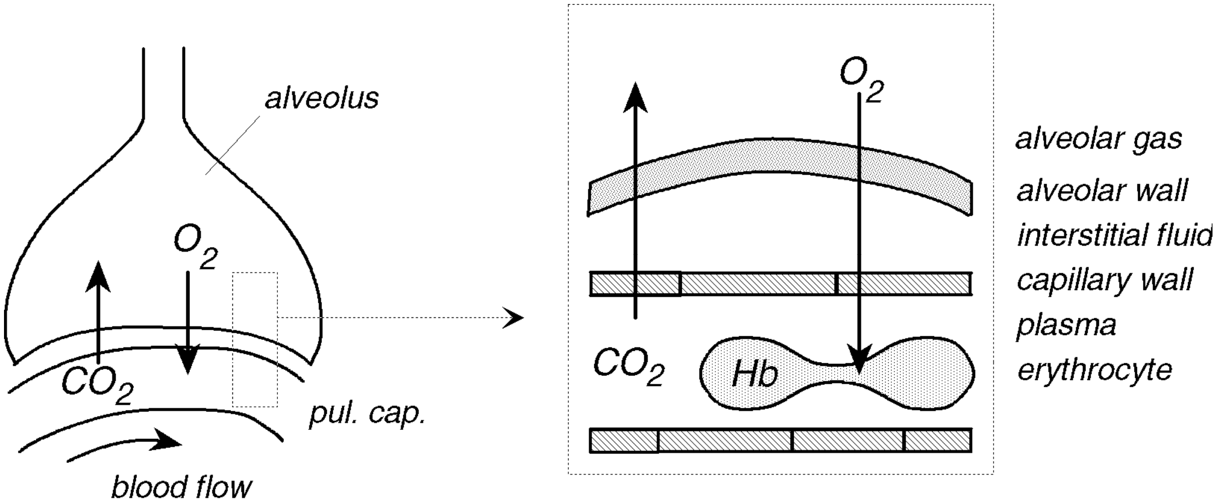
ALVEOLAR-CAPILLARY EXCHANGE

A. Mechanism

1. Simple diffusion through tissue and fluids



B. Characteristics of Alveolar-Capillary Diffusion

1. Driving force: <u>partial pressure</u> difference between alveoli and pulmonary capillary blood <u>for each gas</u>

2. Rate of diffusion: Product of <u>driving force</u> and <u>ease of diffusion</u>

3. Gases diffuse independently, according to each gas's partial pressure difference and ease of diffusion

4. Ease of diffusion depends on

   a. Area: the alveolar area available for diffusion (i.e., in contact with pulmonary capillary blood) is very large (order of 70 m^2)

      Note effect of degenerative lung disease
      Note effect of pulmonary embolism

   b. Distance: even though gas must pass through several compartments, all are normally thin (even interstitial space), so total diffusion distance is small

      Note effect of pulmonary edema

ALVEOLAR-CAPILLARY EXCHANGE (continued)

B. 4. Ease of diffusion (continued)

c. Diffusion Coefficient: depends on molecular weight of the gas (not normally a major factor) and its water solubility (major factor)

Note diffusion coefficient of CO_2 >> O_2 because of much greater solubility of CO_2

C. Equation

$$\text{Rate} = D \times \Delta P$$

e.g.

$$\dot{V}_{O_2} = D_{O_2} \left(P_{A\,O_2} - P_{\text{pul cap}\,O_2} \right)$$

where
ΔP = partial pressure difference
D = Diffusing Capacity (combined diffusion and rx. rate)
V' = Rate of gas movement (e.g. ml/min)
P_A = Alveolar partial pressure
$P_{\text{pul cap}}$ = Pulmonary capillary partial pressure

Note utility of adding oxygen to inspired air for patients with low D_{O2} -- but also note problem of oxygen toxicity

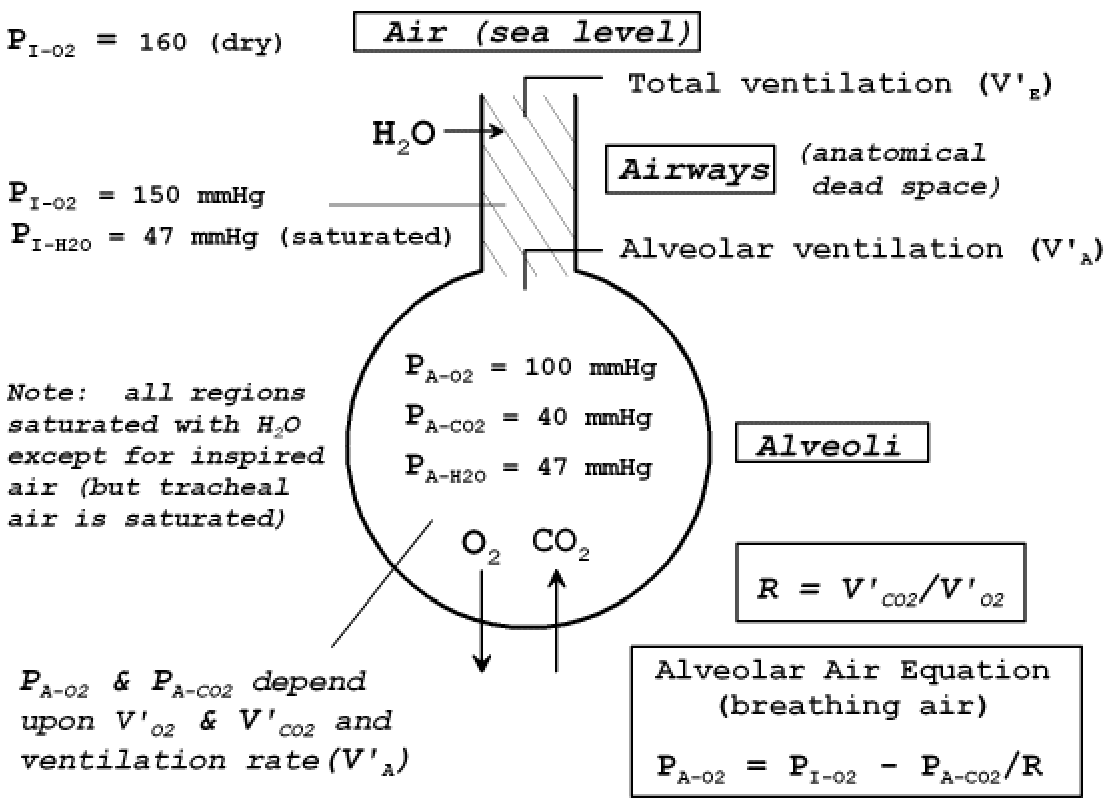
NOTATION

SYMBOLS	SITE	GAS
V = volume	I = inhaled (inspired)	O_2 = oxygen
V'= rate or flow	E = exhaled (expired)	CO_2 = carbon dioxide
P = pressure	A = alveolar	N_2 = nitrogen
F = fraction (percent)	B = barometric	H_2O = water vapor
C = content (concentration)	a = systemic arterial blood	CO = carbon monoxide
R = V'_{CO_2} / V'_{O_2}	v = systemic venous blood	
f = resp. frequency (breaths/min)	c = capillary blood	

Examples:

$P_{A\text{-}CO2}$ = alveolar partial pressure of carbon dioxide
$C_{a\text{-}O2}$ = content (concentration) of oxygen in systemic arterial blood
V'_{O2}= oxygen consumption rate

GAS COMPOSITION CHANGES DURING VENTILATION



A. Inspired (Inhaled) Air

1. Assume breathing dry air: mixture of O_2 (21%) and N_2 (79%); if air not dry, variable amount of H_2O vapor, depending on relative humidity and temperature (generally less than 2%; in tropics up to 6%)

B. Inspired Air, saturated or wet or moist (Tracheal Air)

1. Inhaled air is saturated with water as it passes along the moist airways

2. Water content depends on temperature; at core (deep) body temperature of 37C (typical of lungs), P_{H2O} is 47 mmHg

3. As a result of addition of water, O_2 and N_2 are diluted

C. Alveolar Air

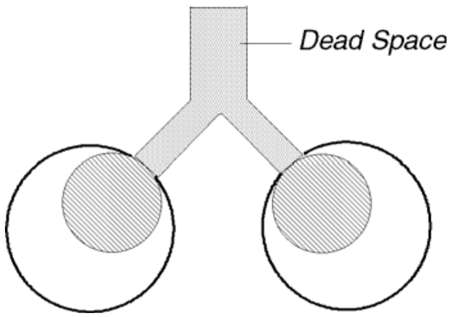
1. Inhaled air is split; some enters the alveoli and some remains in the airways (anatomical dead space)

GAS COMPOSITION CHANGES DURING VENTILATION (continued)

C. Alveolar Air (continued)

2. Dead Space

   a. Define V_D: volume ventilated but not exchanging with pulmonary capillary blood



   b. Typical value: 150 ml (about 30% of resting tidal volume)

   c. <u>Wasted</u> <u>Ventilation</u>: ventilation of dead space ($V_D = f \times V_D$)

3. Alveolar Ventilation

   a. Define: rate of ventilation of alveoli

   b. Equation: $V'_A = f \times (V_T - V_D) = V'_E - V'_D$

ALVEOLAR VENTILATION = TOTAL VENTILATION - WASTED VENTILATION

4. Alveolar gas composition

   a. O_2 decrease, due to oxygen uptake; usually about 50 mmHg drop

   b. CO_2 increase, due to carbon dioxide production; generally 40 mmHg

   c. O_2 drop and CO_2 increase are proportional and depend on metabolic rate versus alveolar ventilation

   Metabolism $\Uparrow \Rightarrow P_{O2} \Downarrow$ & $P_{CO2} \Uparrow$
   Ventilation $\Uparrow \Rightarrow P_{O2} \Uparrow$ & $P_{CO2} \Downarrow$

   Note: In exercise, the appropriate response of respiratory regulation is to increase alveolar ventilation in proportion to the increase in metabolic rate

D. Exhaled (Expired) Air

1. Mixture of Alveolar Air and Tracheal Air that remained in the Dead Space

2. <u>End-tidal gas</u>. In a clinical setting, it is possible to estimate the mean alveolar gas concentrations by measuring the composition of the gas exhaled at the end of expiration as this gas comes almost entirely from the alveoli; this is termed the <u>end-tida</u>l gas