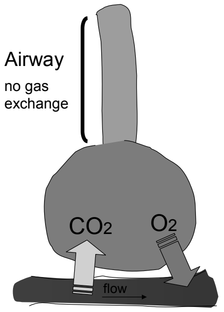
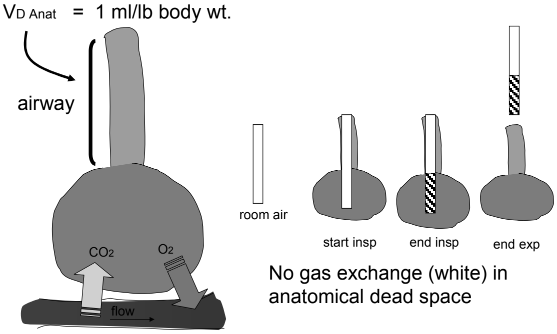
Gas exchange



Anatomical dead space

$V_{D\ Anat}$ = 1 ml/lb body wt.



No gas exchange (white) in anatomical dead space

Minute Ventilation:

V_E = breathing frequency (f) x tidal volume (V_T)

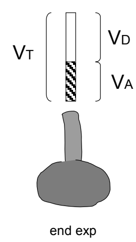
5 L/min = 10/min x 500 ml

Correction for $V_{D\ Anat}$:

V_E = f x (V_T – $V_{D\ anat}$)

3.5 L/min = 10/min x (500 – 150) ml

Estimating anatomical dead space



Volume x Fraction = Mass of Gas

Mass of Gas of V_T = sum of gas masses of V_A and V_D

$V_T \times F_ECO_2 = V_A \times F_ACO_2 + V_D \times F_DCO_2$

Since $F_DCO_2 = 0$

$V_A = (V_T \times F_ECO_2) / (F_ACO_2)$

Since $V_A = V_T - V_D$

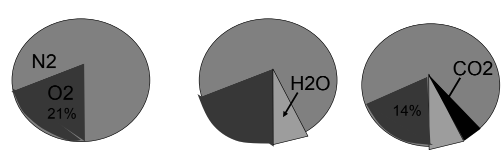
$$V_D = \frac{(F_ACO_2 - F_ECO_2)}{F_ACO_2} V_T$$

Partial pressure of a gas

Dalton's Law: in a mixture of gases, partial pressure (P_{gas}) of each gas contributes additively to total pressure (P_B) in proportion to the gas's fractional volume (F_{gas})

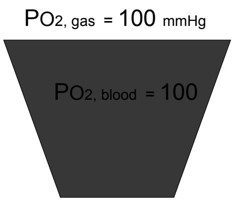
$$P_{gas} = P_B \times F_{gas}$$

Alveolar PO_2 is < Inspired PO_2

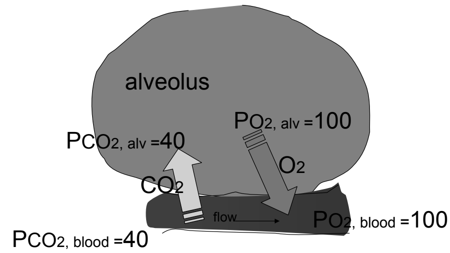


	dry room air	inspired air	alveolar gas
P_{O_2}	160	150	100
P_{CO_2}	0	0	40
P_{H_2O} (37°C)	0	47	47
P_{N_2}	600	563	573
Total (mmHg)	760	760	760

Henry's Law: at equilibrium, gas pressure above a liquid equals gas pressure in the liquid



Alveolar gas partial pressures determine blood gas tensions



Blood gas tension determines blood gas content

Concentration of gas dissolved per liter of blood (C) depends on gas solubility (α) and P_{gas} in blood

C_{O2} = α x $P_{O2,\ blood}$

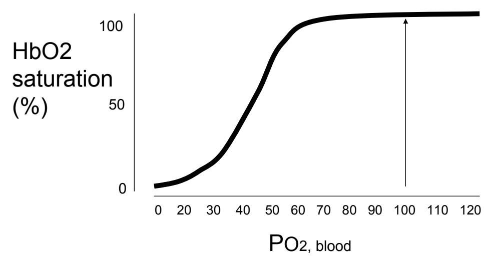
α, Solubility coefficient (ml O2/[liter.mmHg])

C_{O2} = 0.03 x 100

= 3 ml O_2/liter of blood

Dissolved gas → **= 0.3 ml O_2/100ml of blood**

The oxyhemoglobin dissociation curve



The O_2 carrying capacity of blood = Hgb-bound O_2 + dissolved O_2

$P_{O2,\ alv}$ → dissolved O_2 in blood

↓

$P_{O2,\ blood}$ → $HgbO_2$ saturation = 1.34 ml at 100%

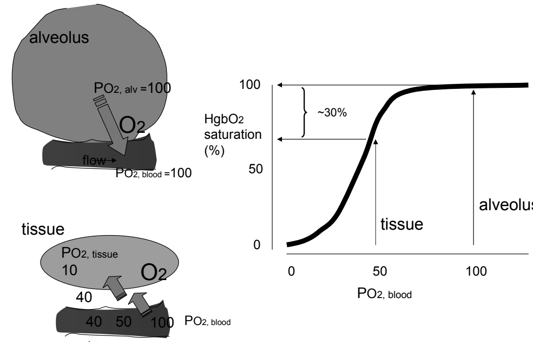
O_2 content in 1 liter of blood at $P_{O2,\ blood}$ of 100 mmHg

= ($HgbO_2$ sat [%] x 1.34 x [Hgb]) + (.03 x $P_{O2,\ blood}$)

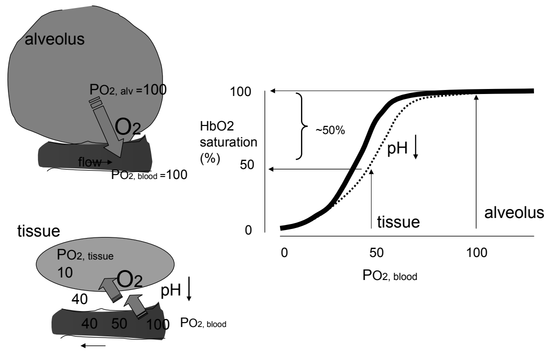
= (0.98 x 1.34 x 150 [g/l]) + 3

= 200 ml O_2/liter of blood

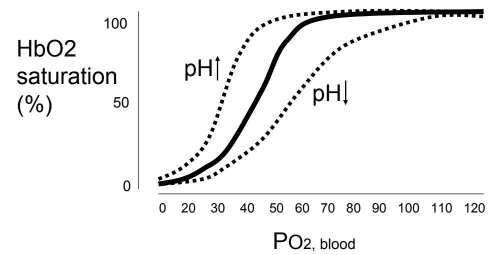
How tissues get O_2



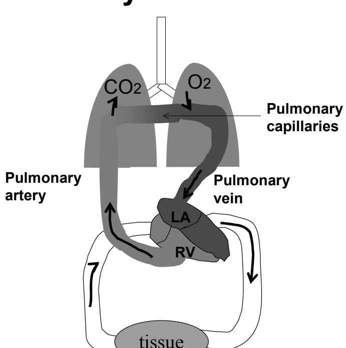
Low pH unloads O_2 better



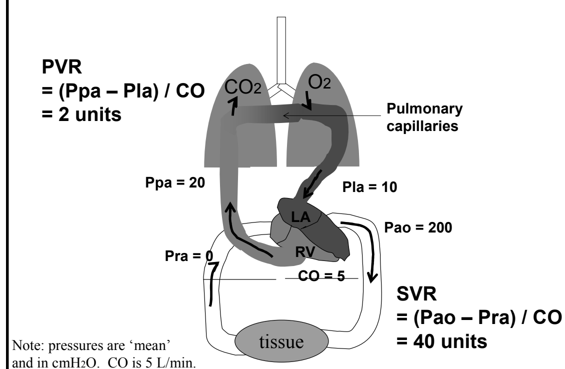
The oxyhemoglobin dissociation curve



The pulmonary circulation

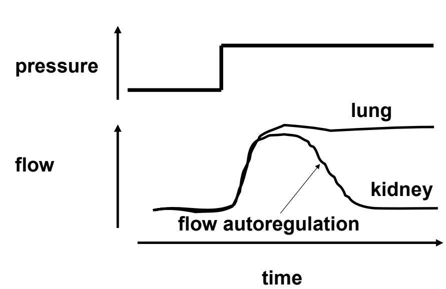


PVR is <<< SVR

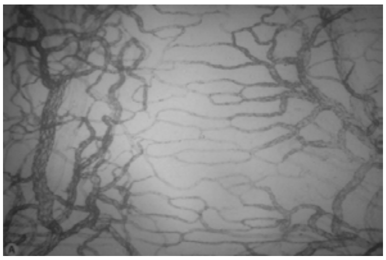


The lung has low vascular resistance

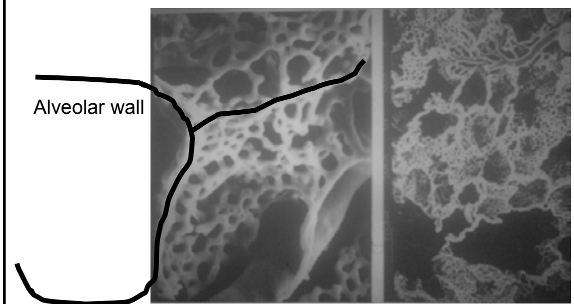
The lung has low vascular tone



Systemic capillaries



Lung capillaries



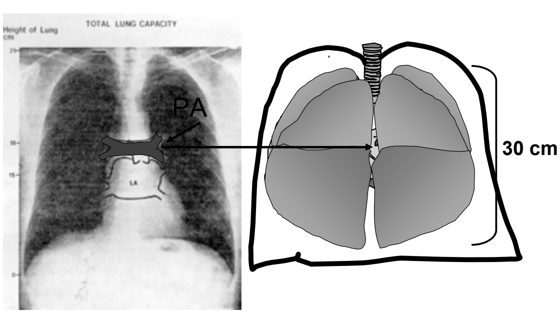
Lung capillaries

The lung's low vascular resistance is due to

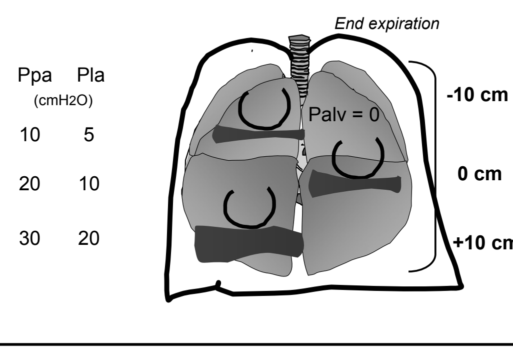
1. Low vascular tone

2. Large capillary compliance

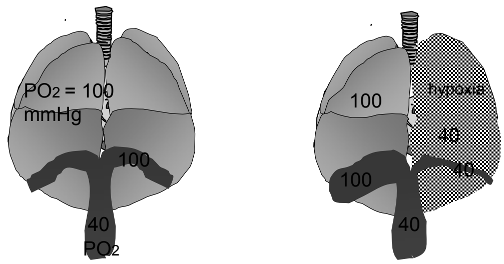
PA enters mid lung height



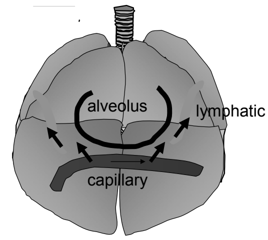
Gravity determines highest blood flow at lung base



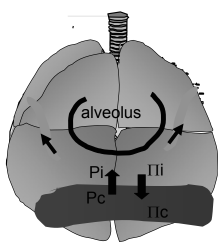
Hypoxic pulmonary vasoconstriction



Capillary filtration determines lung water content



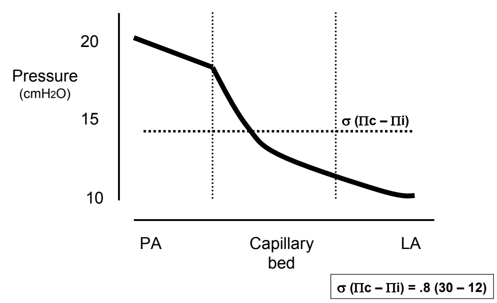
The Starling equation describes capillary filtration



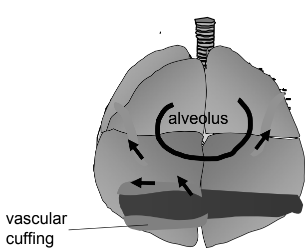
$$FR = Lp \times S \, [\, (Pc - Pi) - \sigma \, (\Pi c - \Pi i) \,]$$

FR	filtration rate
S	capillary surface area
Pc	capillary pressure
Pi	interstitial pressure
σ	reflection coefficient
Πc	plasma colloid osmotic pressure
Πi	interstitial colloid osmotic pressure

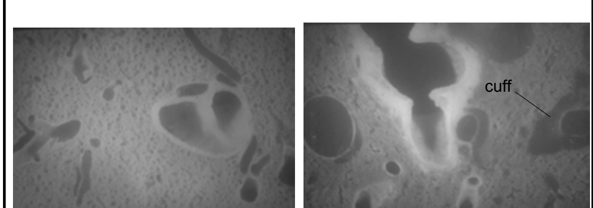
Keeping the alveoli “dry”: Large capillary pressure drop



Keeping the alveoli “dry”: Perivascular cuff formation



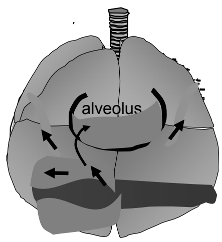
Perivascular cuffs in early pulmonary edema

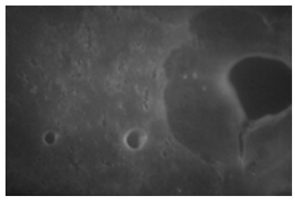


Normal lung

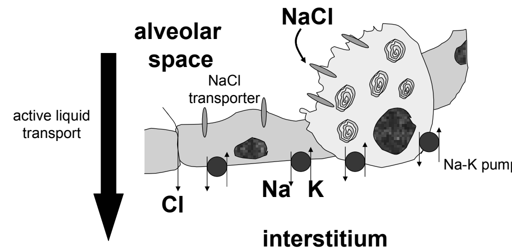
Early pulmonary edema

The ultimate insult: alveolar flooding





Keeping the alveoli "dry": active transport removes alveolar liquid



SUMMARY

Features of the pulmonary circulation designed for efficient gas exchange:

1. Accommodate the cardiac output
   * low vascular tone
   * high capillary compliance

SUMMARY

Features of the pulmonary circulation designed for efficient gas exchange:

2. Keep filtration low near alveoli
   * low Pc
   * vascular interstitial sump

SUMMARY

Features of the pulmonary circulation designed for efficient gas exchange:

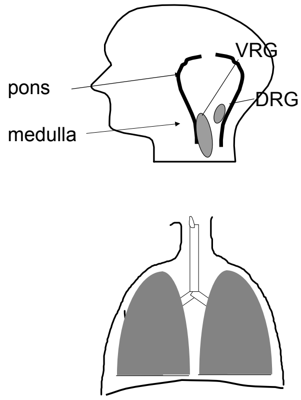
3. Keep liquid out of the alveoli
   * active transport
   * high resistance epithelium

Control of Breathing

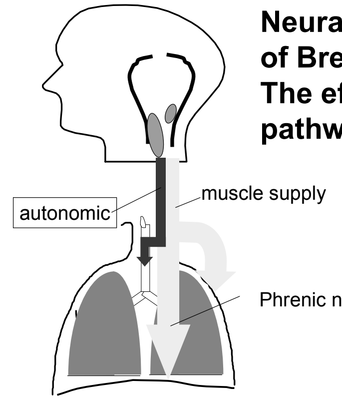
Central neurons determine minute ventilation (V_E) by regulating tidal volume (V_T) and breathing frequency (f).

$V_E = V_T \times f$

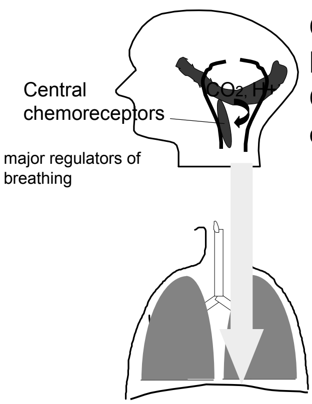
Neural Control of Breathing – Respiratory neurons



Neural Control of Breathing – The efferent pathway



Control of Breathing by Central chemoreceptors



CO_2, H+

↓

Central chemoreceptors

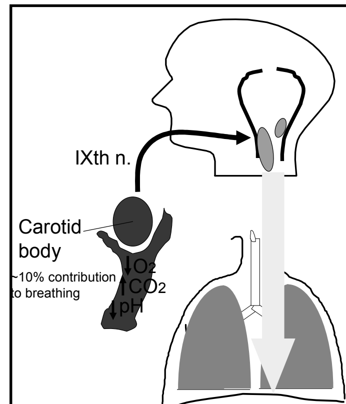
↓

Resp neurons

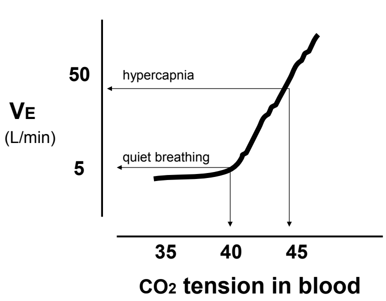
↓

V_E

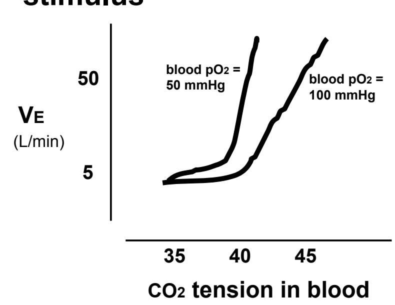
Chemical Control of Breathing – Peripheral chemoreceptors

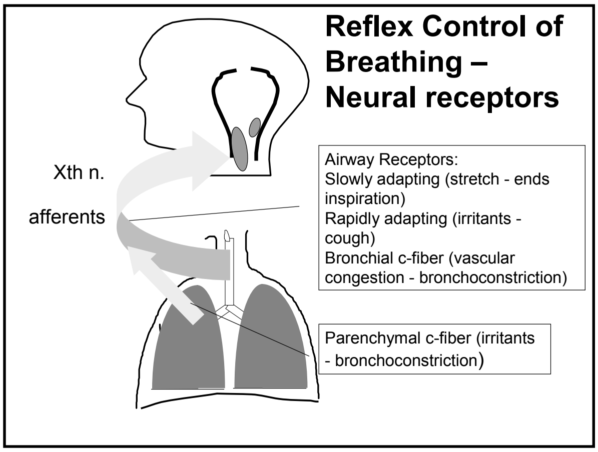


CO_2 drives ventilation



Hypoxia is a weak ventilatory stimulus




Reflex Control of Breathing – Neural receptors
Xth n.
afferents
Airway Receptors:
Slowly adapting (stretch - ends inspiration)
Rapidly adapting (irritants - cough)
Bronchial c-fiber (vascular congestion - bronchoconstriction)
Parenchymal c-fiber (irritants - bronchoconstriction)