Hypoxia

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Breathe in "air"

↓

O_2

F_iO_2

100

P_aO_2

97%

S_aO_2

105

P_AO_2

arterial blood → Hb → O_2

lungs

TISSUE

CO_2

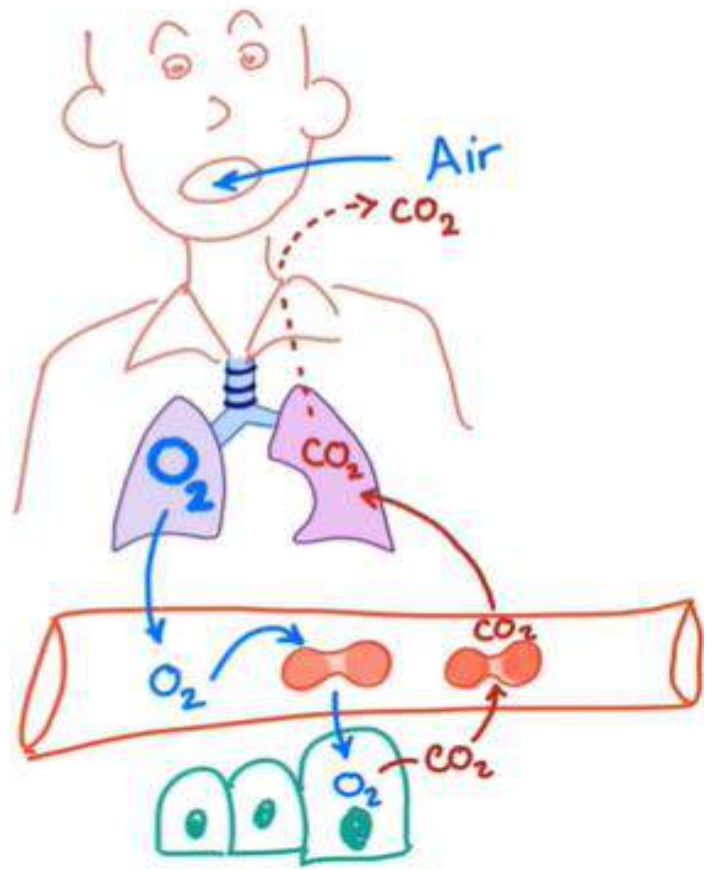
40 mHg

venous blood ← Hb

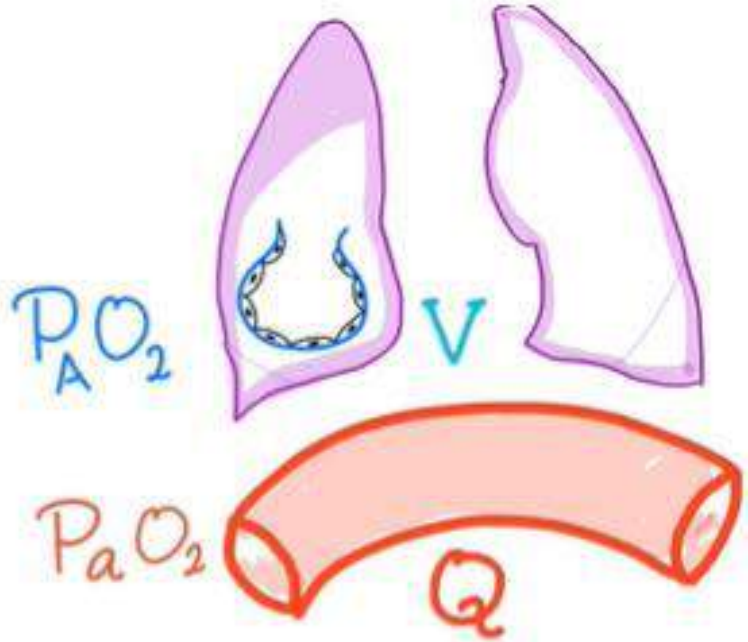
P_vO_2

CO_2

Breathe out



- Ventilation (V): getting air into the alveoli.
- Perfusion (Q): blood flow to the lung.



OXYGEN

In the air: $F_iO_2 = 21\%$

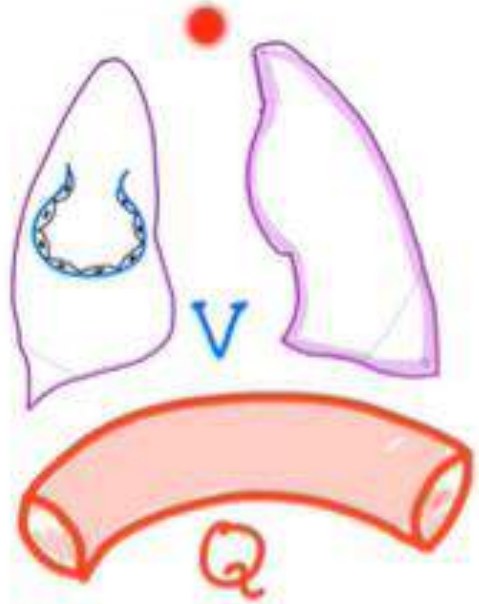
Partial pressure → $P_iO_2 = 150$ mmHg

In the alveoli: $P_AO_2 = 105$ mmHg

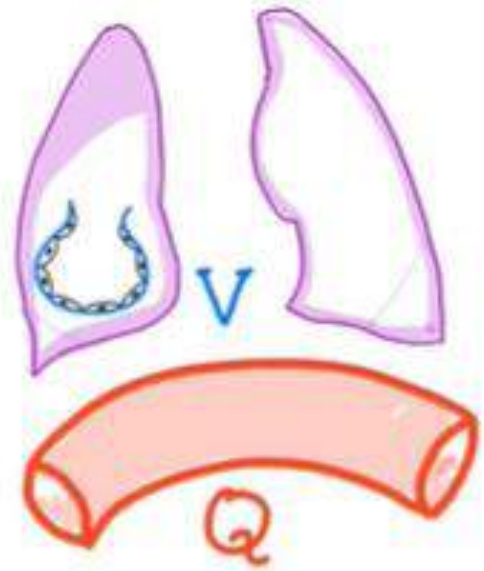
In the arterial blood: $P_aO_2 = 100$ mmHg

} A-a gradient

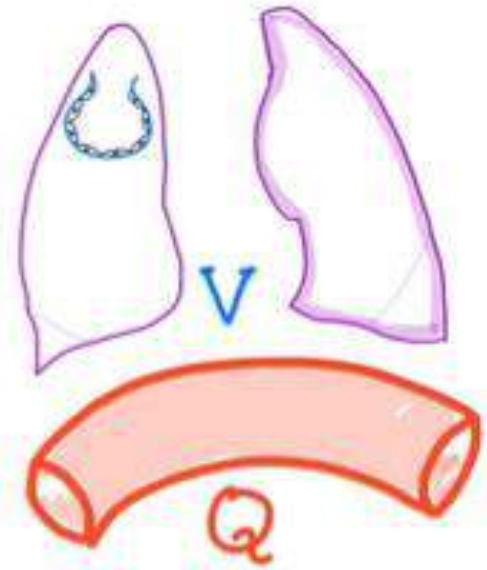
Normal "overall"



Normal base



Normal apex



$\frac{V}{Q}$ ratio 80%

↑ $\frac{V}{Q}$ < 80%

↑↑ Q "0.6"

↓↓ $\frac{V}{Q}$ > 80%

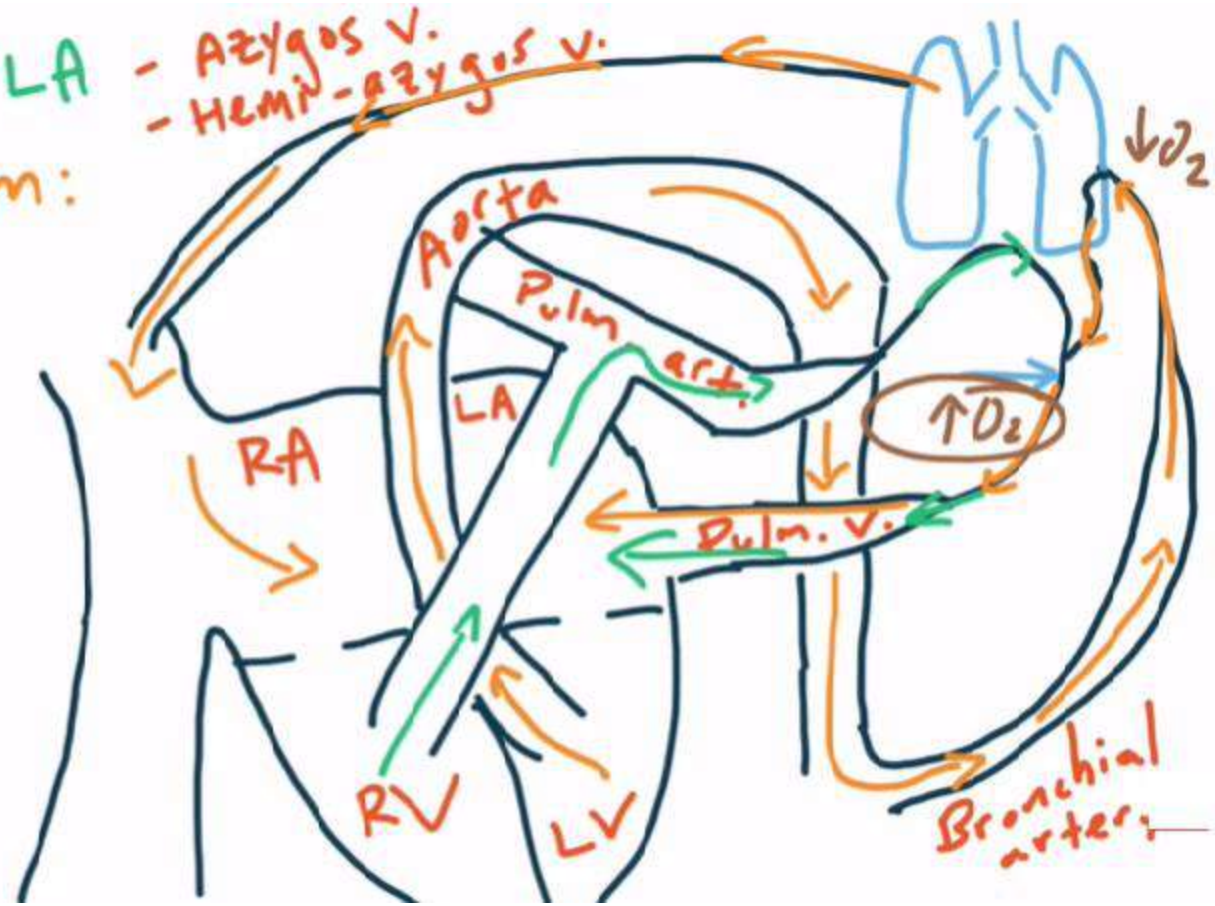
↓ Q "3"

Pulm: RV → LA

Bronchopulm:

LV → LA

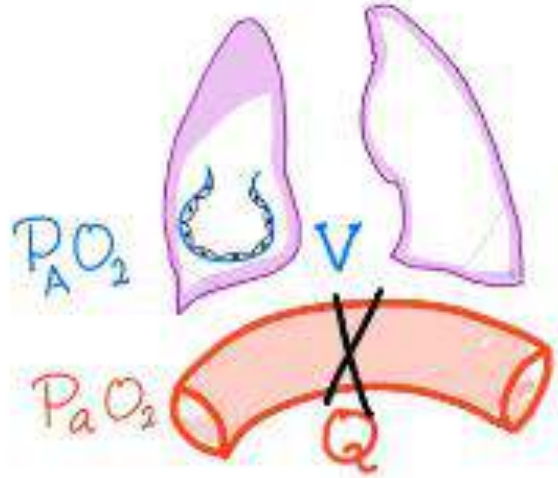
LV → RA



Normal

Ventilation defect

Perfusion defec



$\frac{V}{Q}$ ratio = $\frac{4 L/min}{5 L/min}$ = 0.8 = 80%

Ideally $\frac{V}{Q}$ = 100% = 1

V = Q

$\downarrow\downarrow \frac{V}{Q}$ < 80%

e.g. zero

$\frac{V}{\downarrow\downarrow Q}$ > 80%

e.g. ∞

	Normal	Decreased ventilation (e.g. Obstrutive lung disease) 	Decreased perfusion (e.g. pulmonary artery embolus) 
V/Q ratio	0.8	decrease "<0.8"	increase ">0.8"
PAO2	**105** (alveolar air is like the arterial blood)	40 mmHg (alveolar air is like the venous blood) because no gas exchange happened, blood came and blood went "**shunting**"	152 mmHg (alveolar air became similar to atmospheric air) Dead space
PaO2	**100**	40 mmHg [Hypoxemia]	<100 mmHg (because there is no gas exchange) [Hypoxemia]
PvO2	40 mmHg	40 mmHg	40 mmHg
PACO2	**40** (alveolar air is like the arterial blood)	**46** mmHg	0 (alveolar air became similar to atmospheric air)
PaCO2	**40**	40	<40 (due to hyperventilation)
PvCO2	46	**46**	46
		In response: • ***hypo***xia —> vasoconstriction—> force the blood to the well ventilated areas. • i.e. when the bronchus is closed —> close the vessel.	In response: • ***hypo***capnia—> alkalosis —> vasoconstriction —> to keep the CO2 in —> acidosis (to try to compensate the alkalosis) • i.e. when the vessel is closed —> close bronchus.

Patient A "normal"

- RR = 12/min, TV = 500 mL
  - Pulmonary ventilation = respiratory rate x tidal volume = 12 x 500 = 6 liters.
  - Alveolar ventilation = respiratory rate x (tidal volume - dead space) = 12 x (500-150) = 12x350 = 4.2 liters.

Patient B "increased respiratory rate"

- RR = 30/min, TV = 200 mL
  - Pulmonary ventilation = respiratory rate x tidal volume = 30 x 200 = 6 liters.
  - Alveolar ventilation = respiratory rate x (tidal volume - dead space) = 30 x (200 - 150) = 1.5 liters.

Patient C "increased tidal volume"

- RR = 6/min, TV=1,000 mL
  - Pulmonary ventilation = respiratory rate x tidal volume = 6 x 1000 = 6 liters.
  - Alveolar ventilation = respiratory rate x (tidal volume - dead space) = 6 x (1000-150)= 5.1 liters.

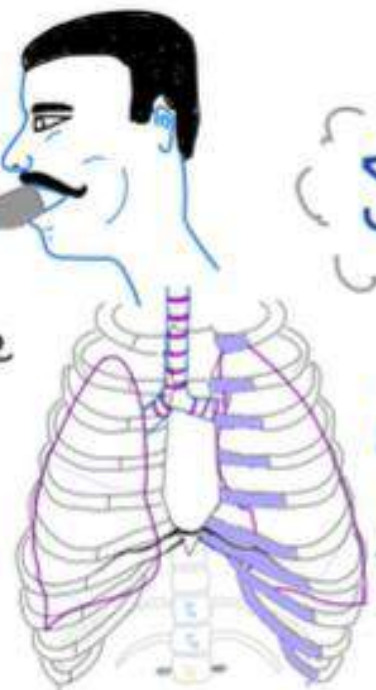
Therefore, increasing the tidal volume is a better way to achieve more alveolar ventilation than increasing the respiratory rate.

- But, everything is good within limits.
  - If you increase the tidal volume too much —> the alveoli will expand tremendously (inspiration) and then collapse (expiration)…This big difference, repeated over and over again, can lead to INFLAMMATION!

Cause of hypoxia	Example	A-a gradient	Effect of oxygen therapy (100% oxygen)
Atmospheric	High altitude	Normal	Excellent; Oxygen can COMPLETELY cure it. (100% effective therapy)
Hypoventilation	Decreased respiratory rate (e.g. Obstructive)	Normal	Very good; Oxygen therapy will help with the hypoxia (but won't cure the hypercapnia)
Diffusion defect	Pulmonary fibrosis, pulmonary edema	High	Very good: increase in PAO2 –> increase in PaO2
Hemoglobin defect	Anemia, methemoglobinemia	Normal	Ok: oxygen therapy will NOT increase the oxygen saturation or the hemoglobin saturation, but it can increase the dissolved oxygen (PaO2) a little which can be the difference between life and death.
Ischemia	Thrombus, embolus, tissue edema, bad vessels in a peripheral organ (not lung).	Normal	Ok: oxygen therapy will NOT increase the oxygen saturation or the hemoglobin saturation, it won't remove the clot, but it can increase the dissolved oxygen (PaO2) a little
Shunt	intrapulmonary shunt, or intracardiac (Rt-to-Lt) shunt	High	No effect.

Patient (A)

Spirometer



S.O.B

Chest wall disease

Extrinsic Restrictive lung disease (extrathoracic)

A-a

↓ ↓

ABG

↓ PaO_2 → ↓ SaO_2

↓ lung volumes & capacities

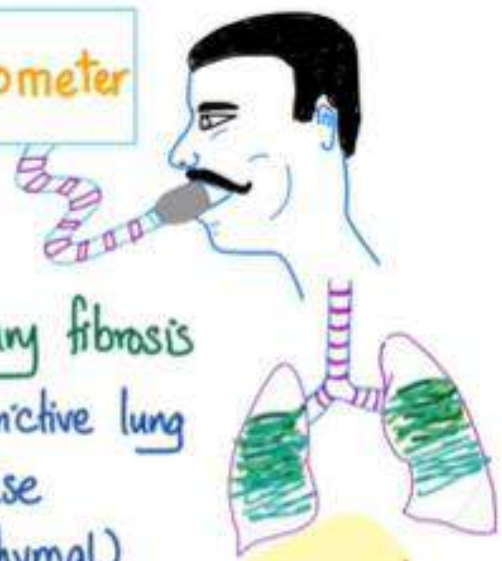
↓ FEV_1, ↓ FVC, ↑ FEV_1 / FVC ratio

or nl

Spirometer

Patient (B)

Spirometer



Pulmonary fibrosis

Intrinsic restrictive lung disease (parenchymal)

Oximeter

↓ PaO_2 → ↓ SaO_2

↓ lung volumes & capacities

↓ FEV_1, ↓ FVC, ↑ FEV_1 / FVC ratio

or nl

FEV1/FVC ratio

- FEV1: the amount of air that you can quickly and forcibly exhale in 1 second after maximal inhalation (timed).
- FVC: the amount of air that you can quickly and forcibly exhale after maximal inhalation (timed).
- FEV1/FVC ratio: FEV1 divided by FVC
    - Normally, it's 80% (4L/5L).

In brief:

- low FEV1/FVC ratio —> obstructive lung disease
- low TLC —> restrictive lung disease.
- high FEV1/FVC ratio —> restrictive lung disease
- low FEV1/FVC ratio and low TLC —> mixed lung disease (obstructive + restrictive)