The diffusion capacity of lung to gases

- **Definition:** The volume of gas which is diffused/min/1mmHg difference in partial pressure of the gas.
- **Measurement:** The diffusion capacity for CO (D_{LCO}) is measured as an index of diffusion capacity because its uptake is diffusion limited.
  - D_{LCO} is proportional to the amount of CO entering the blood (V_{CO}) divided by P_{CO} in the alveoli (P_{ACO}) minus the partial pressure of CO in the blood entering pulmonary capillaries ≈ zero (except in habitual smokers)

$$D_{LCO} = \frac{V_{CO}}{P_{ACO} - P_{aCO}} \longrightarrow D_{LCO} = \frac{V_{CO}}{P_{ACO}}$$

- **Factors:** same factors that affect rate of gas diffusion through the respiratory membrane affects diffusion capacity of the lung
  - It is directly proportional to the surface area of alveolo-capillary membrane and inversely proportional to its thickness.

⊙ Normal value

- D_{LCO} at rest is 25mL/min/mmHg (Diffusion coefficient = 0.8)
  - ☞ It increases to three fold during exercise because of capillary dilation and an increase in the number of active capillaries
- D_{LO_2} = D_{LCO} = 25mL/min/mmHg (Diffusion coefficient =1)
  - ☞ ↑ D_{LO_2} in Exercise
  - ☞ ↓ D_{LO_2} Diseases (fibrosis of alveolar walls)
- D_{LCO_2} = 400ml/min/mm Hg (> D_{LO_2}) (Diffusion coefficient =20)
  - ☞ High solubility of CO_2 in cell membrane (CO_2 retention is rarely a problem in patients with alveolar fibrosis even when the reduction in diffusion capacity for O_2 is sever)

Effect of V/Q on alveolar gas concentration

- Ratio of alveolar ventilation(V) to pulmonary blood flow (Q)
  - Matching ventilation and perfusion is important to achieve the ideal exchange of O_2 and CO_2
  - Normal V/Q (whole lung) at rest is 0.8 (4L/min ÷ 5L/min)

Ventilation	Normal	Zero	Normal
Perfusion	Normal	Normal	Zero
V/Q	Normal	Zero (0 ÷ 5)	Infinity(4 ÷ 0)
Situation	Normal	Complete airway obstruction →shunted blood	Pulmonary artery obstruction → dead space
Gas exchange	Optimal	No gas exchange	No gas exchange
Alveolar:Po_2 mmHg Pco_2 mmHg	Po_2 = 100 Pco_2 = 40	Po_2 = 40 Pco_2 = 46	Po_2 = 149.7 Pco_2 = 0.3

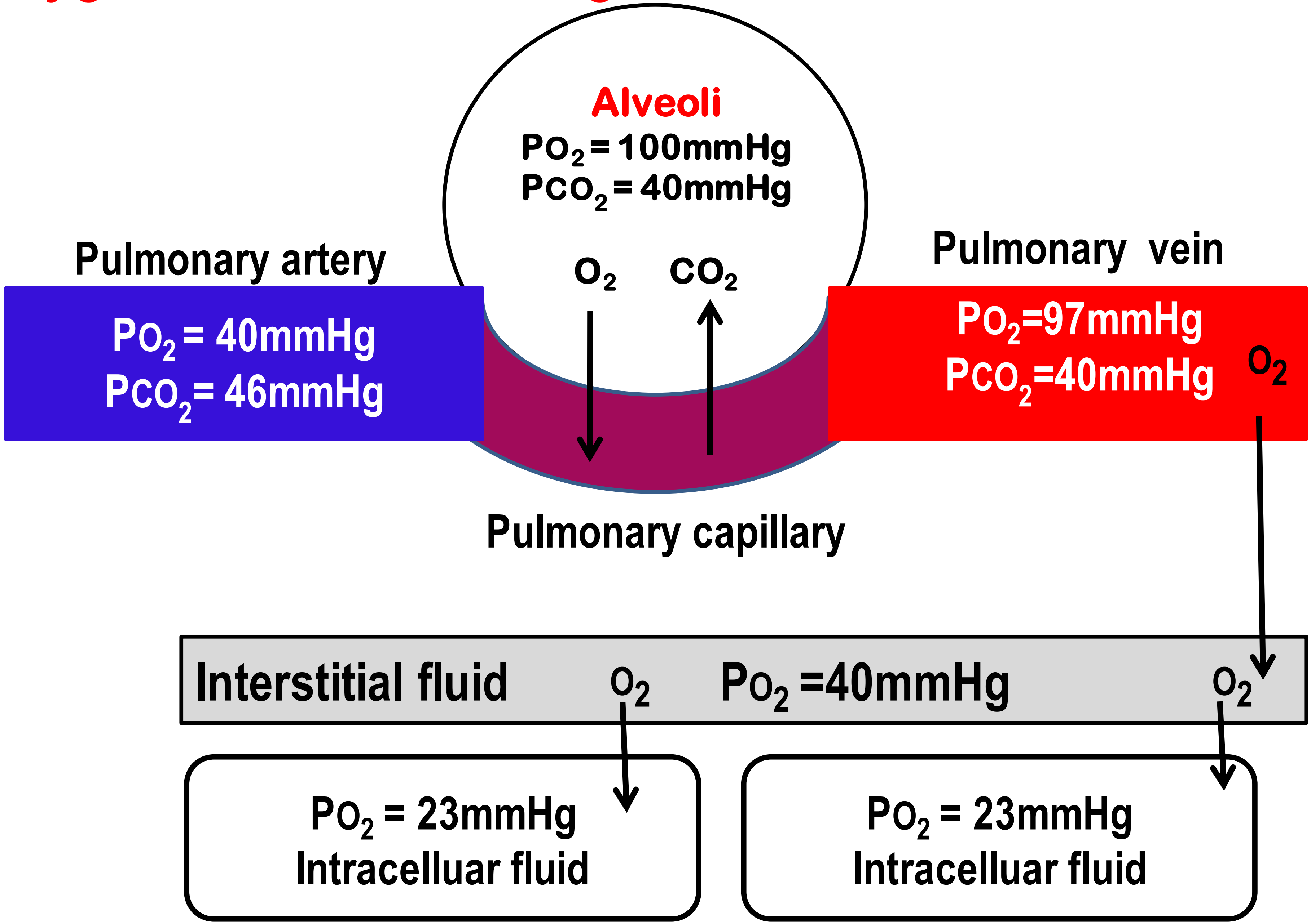
Lecture 7

Transport of O_2 and CO_2 between the lungs and the tissues:

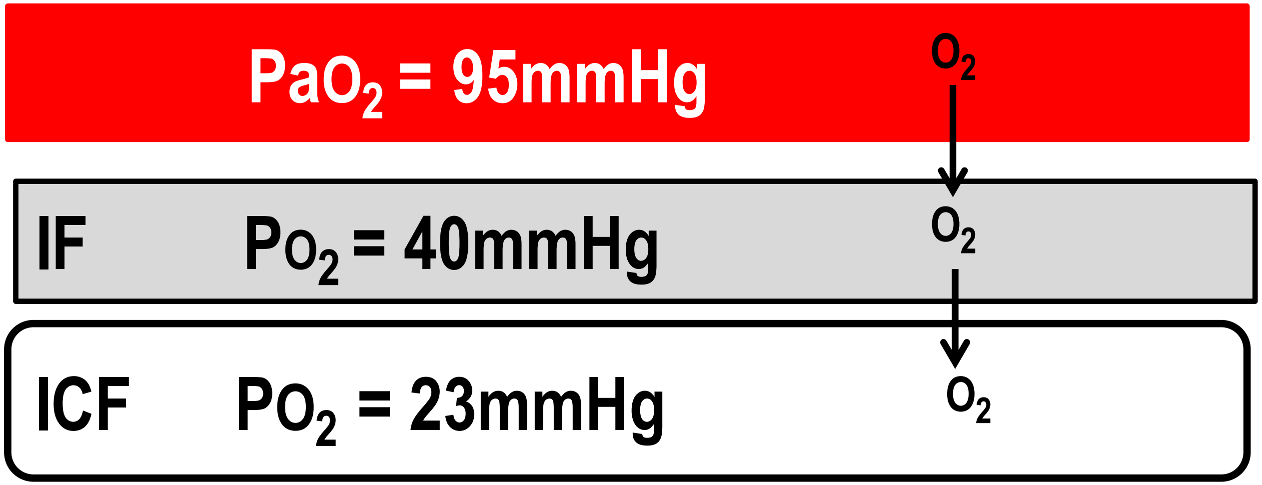
Objectives

- The manner in which O_2 flows downhill from the lungs to the tissues and CO_2 flows downhill from the tissues to the lungs.
- The reaction of O_2 with Hb & O_2-Hb dissociation curve.
- The important factors affecting affinity of hemoglobin for O_2 and physiological significance of each.
- The reactions that increase the amount of CO_2 in the blood, The CO_2 dissociation curve for arterial and venous blood.

Oxygen flow from the lungs to the tissues

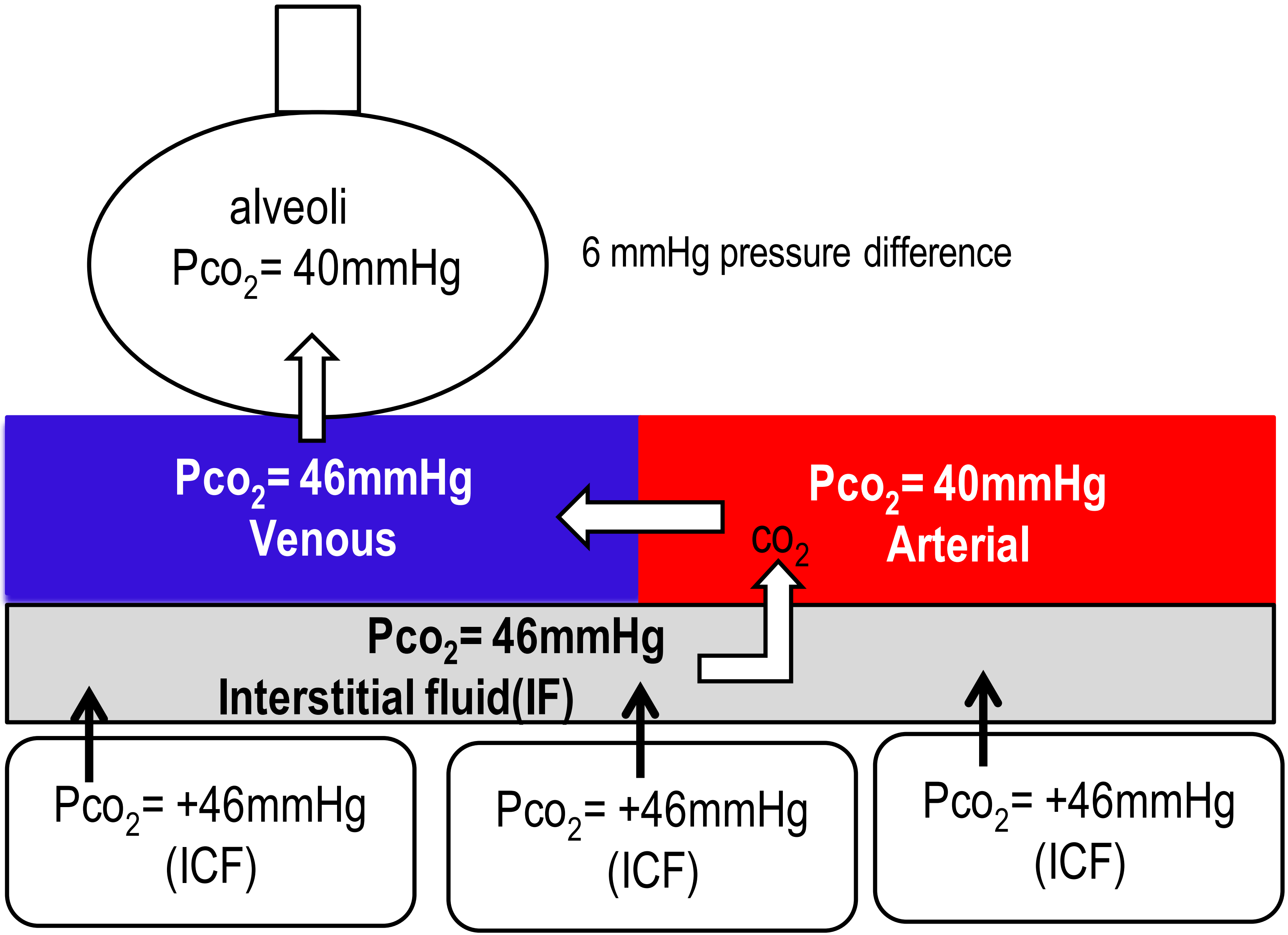


Factors affecting interstitial fluid (IF) Po_2 =40mmHg

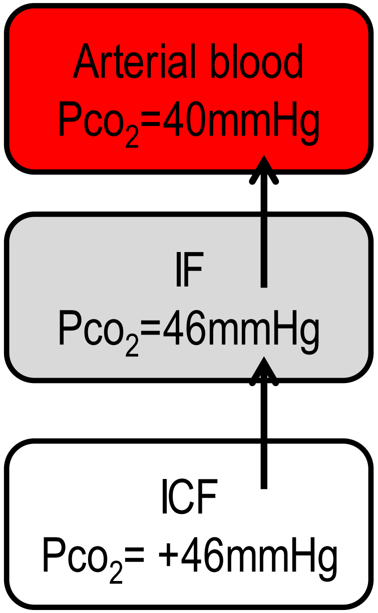


Factor		IF Po_2(mmHg)
Blood flow	↑Q	↑ Po_2
Hb concentration	↓Hb	↓ Po_2
Tissue metabolism	↑ Metabolism	↓ Po_2

Diffusion of CO_2 from the cells to the tissue capillaries and from the pul. capillaries to the alveoli:



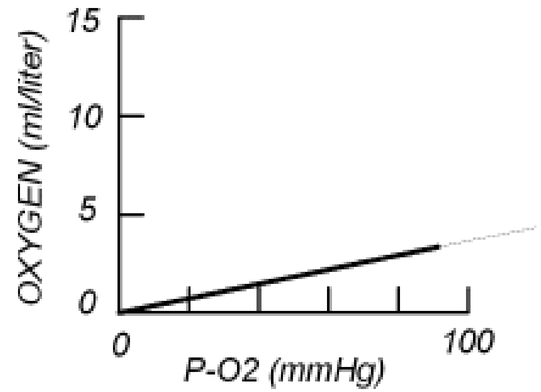
Effect of tissue metabolism and blood flow on interstitial Pco_2 (46mmHg):



Factor		Interstitial Pco_2 (mmHg).
Blood flow	↓ Q	↑ Pco_2
Metabolism	↑ Metabolism	↑ Pco_2

Oxygen Transport:

1) 98.5 % combines with Hb (Hb increases the O_2 carrying capacity of blood 70-fold).
2) 1.5 % dissolved in plasma



Transport of oxygen in dissolved form

- 1.5 % of O_2 is transported in the dissolved form.
- Dissolved O_2 α PO_2 (0.003ml/dL blood/mmHg PO_2).

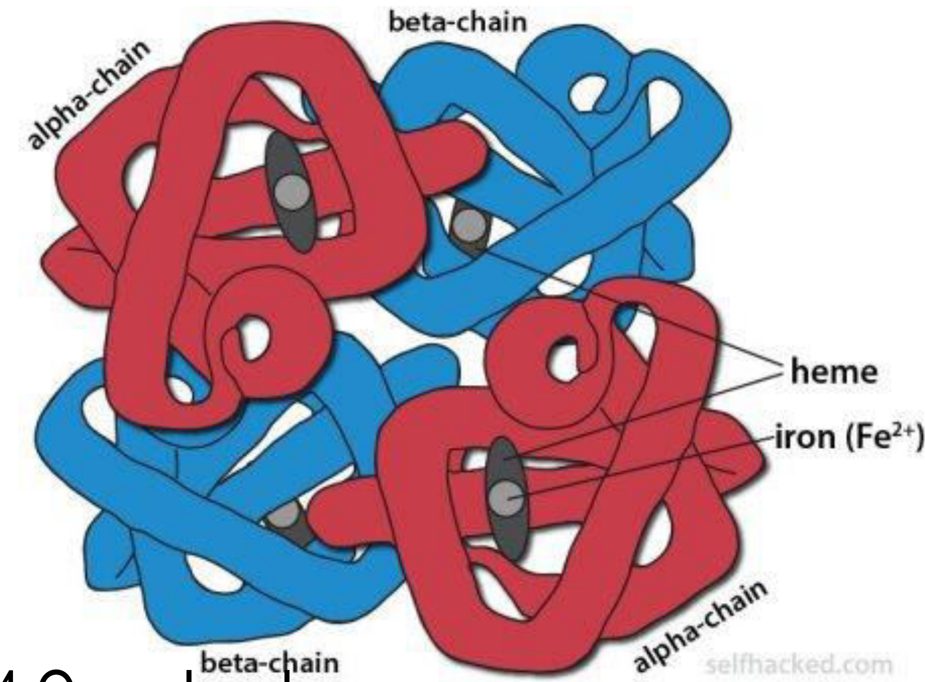
	Arterial blood (PO_2=95mmHg)	Venous blood (PO_2=40mmHg)	O_2 transported to tissues by each 100 ml of blood
O_2 content (ml /dL blood)	(0.003 ×95)= 0.29	(0.003 ×40)= 0.12	0.29-0.12= 0.17ml

- The volume of dissolved O_2 although very small, is of great functional importance for, it is the gas in solution alone that exerts the partial pr
  - It is the PO_2 in blood that determines the quantity of O_2 that will combine with hemoglobin.

Transport of O_2 in combined form

Reaction of Hb & O_2

Hb			
Heme		Globin	
Porphyrin	Fe^{+2}	2α	2β

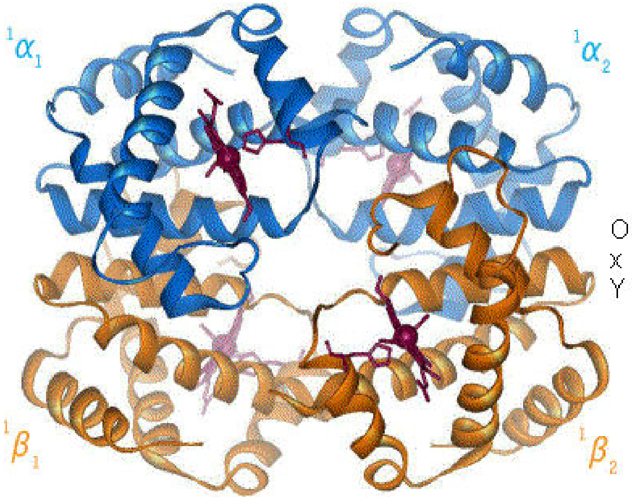


- MetHb: iron oxidized (Fe^{+3})
- Carboxy-Hb: COHb
  - Hb molecule can transport up to 4 O_2 molecules.
  - When $4O_2$ are bound to Hb →100 % saturated
  - ↑ Saturation →↑Hb affinity

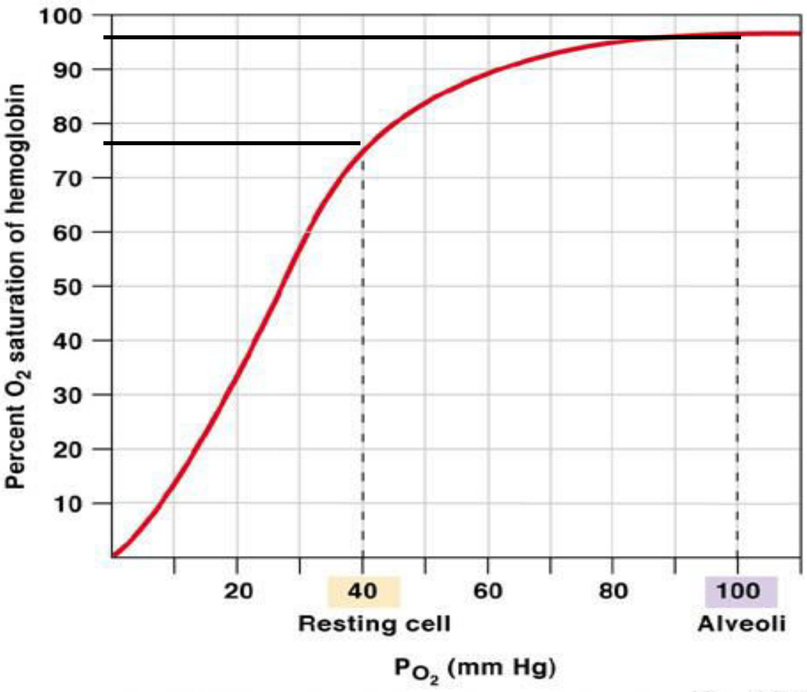
$$Hb\ (deoxy\text{-}Hb) + O_2 \underset{lungs}{\overset{tissues}{\leftrightarrows}} HbO_2\ (oxy\text{-}Hb)$$

$$Hb_4 + O_2 \leftrightarrows Hb_4O_2$$
$$Hb_4O_2 + O_2 \leftrightarrows Hb_4O_4$$
$$Hb_4O_4 + O_2 \leftrightarrows Hb_4O_6$$
$$Hb_4O_6 + O_2 \leftrightarrows Hb_4O_8$$

- The oxygenation and deoxygenation are rapid (<0.01 sec).
- In deoxygenated Hb, the globin units are tightly bound in a tense (T) state, which reduces the affinity of the molecule for O_2



- When O_2 first bound →the bonds holding the globin units are released → relaxed (R) state → exposes more O_2 binding sites → ↑in O_2 affinity.
- In tissues, these reactions are reversed, releasing O_2.



The amount of oxygen in the blood:

- 100% O_2 (PO_2=760mmHg) → Hb 100% saturated with O_2 (each gm of pure Hb (1.39ml O_2) → (normal Hb contains 1.34 ml O_2)
- Each dL of blood contains (15 (Hb%) × 1.34 ml = 20.1ml of O_2)

	Arterial blood, PO_2=95mmHg, Hb saturation 97%	**Venous blood, PO_2=40mmHg, Hb saturation 75%**	**Amount of O_2 carried to tissues by each dL of blood (rest)**
Combined O_2 ml/dL	20.1× 0.97= 19.5	20.1× 0.75= 15.1	19.5-15.1 = 4.4
Dissolved O_2 ml/dL	0.003 × 95= 0.29	0.003 × 40= 0.12	0.29 -012 =0.17
Total O_2 ml/dL	19.8mL of O_2/dL	15.2mL of O_2/dL	19.8-15.2 = 4.6

250 mL of O_2 /min is transported from the blood to the tissues at rest (4.6×5600/100≈250mL).