# PULMONARY AND ALVEOLAR VENTILATION AND PERFUSION

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# OBJECTIVES

- Recall the functions of the lung
- Recall The Pulmonary and Systemic circulation
- Identify in depth the structure of the lung

  The function of Blood gas barrier
- Identify facts of ventilation

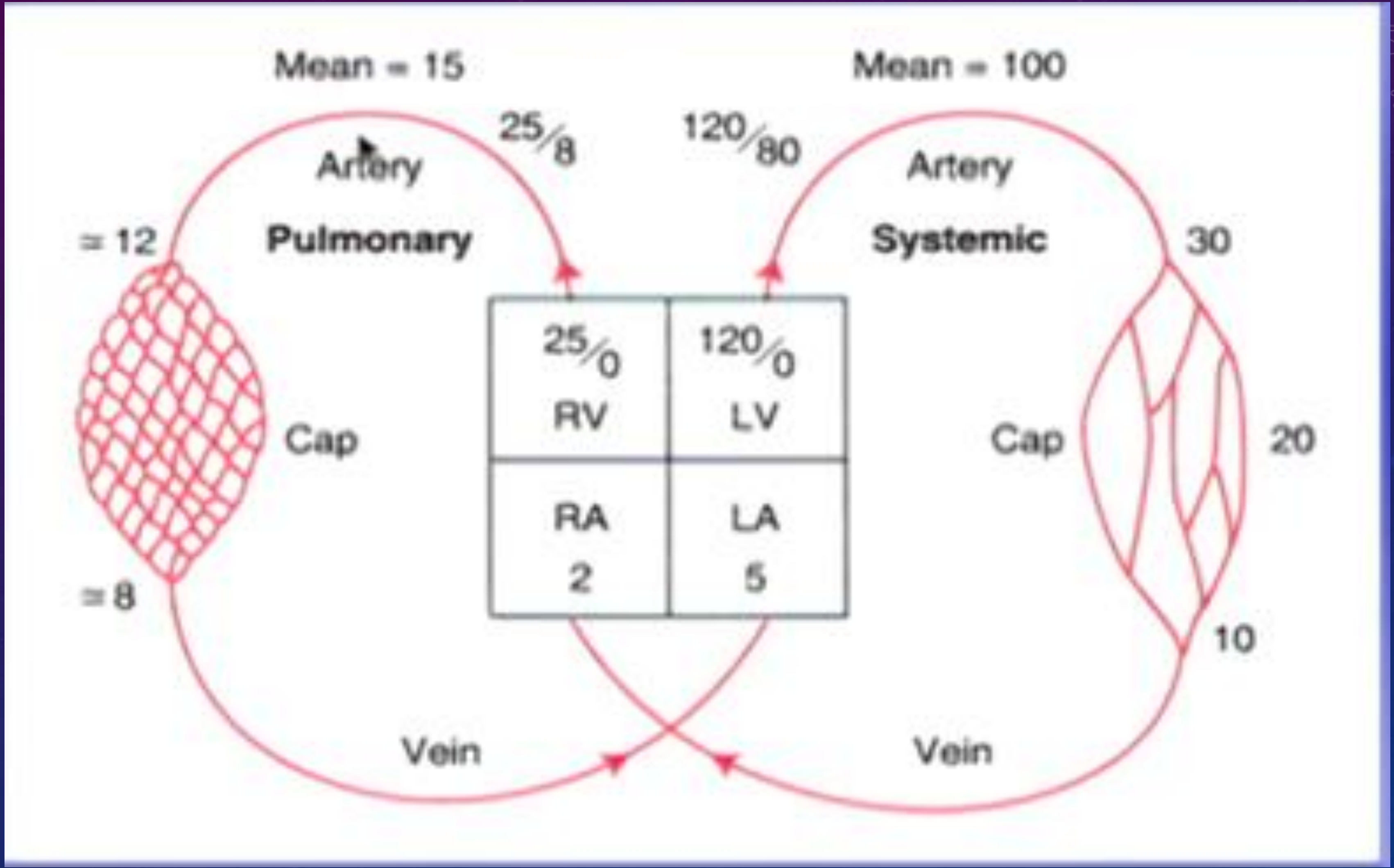
  Weibel model

  Volumes and flows in the lung

# STRUCTURE AND FUNCTION OF THE LUNG

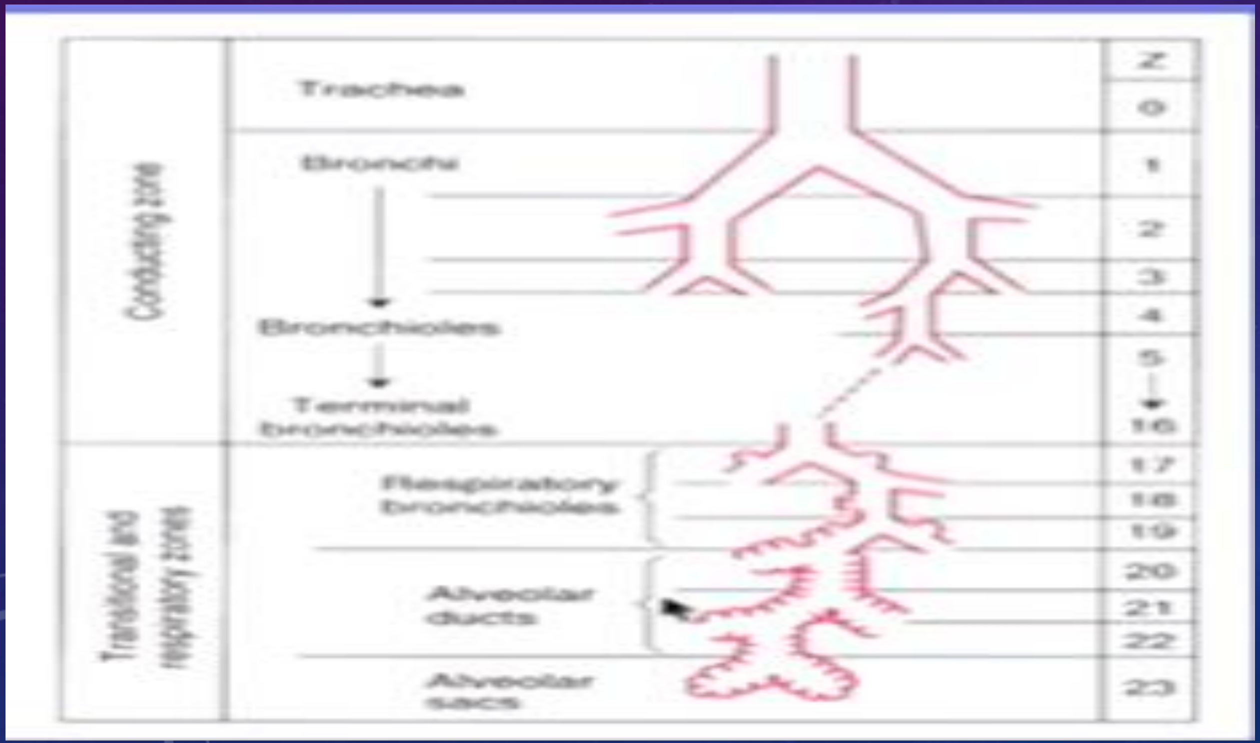
- The most important and the Primary function is gas exchange
- Filters unwanted material from the blood
- Metabolic functions
- Reservoir for blood

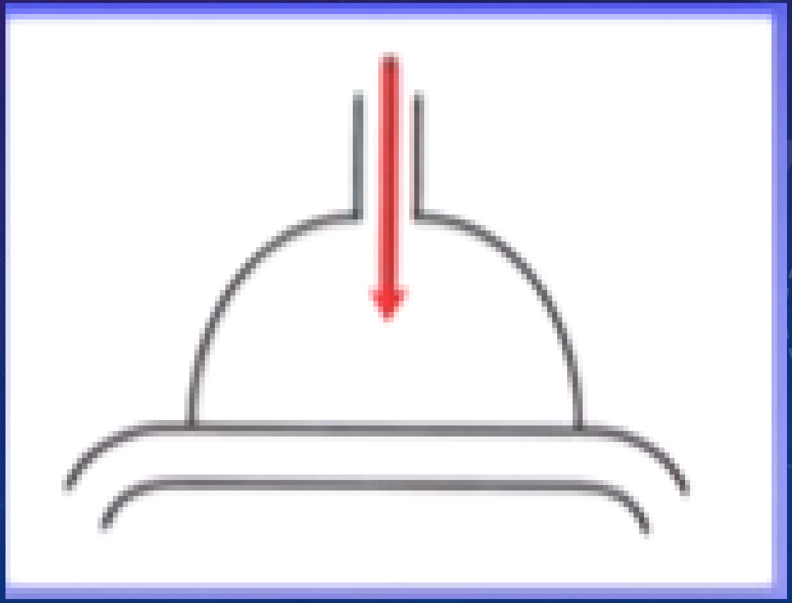
# Systemic and Pulmonary circulation



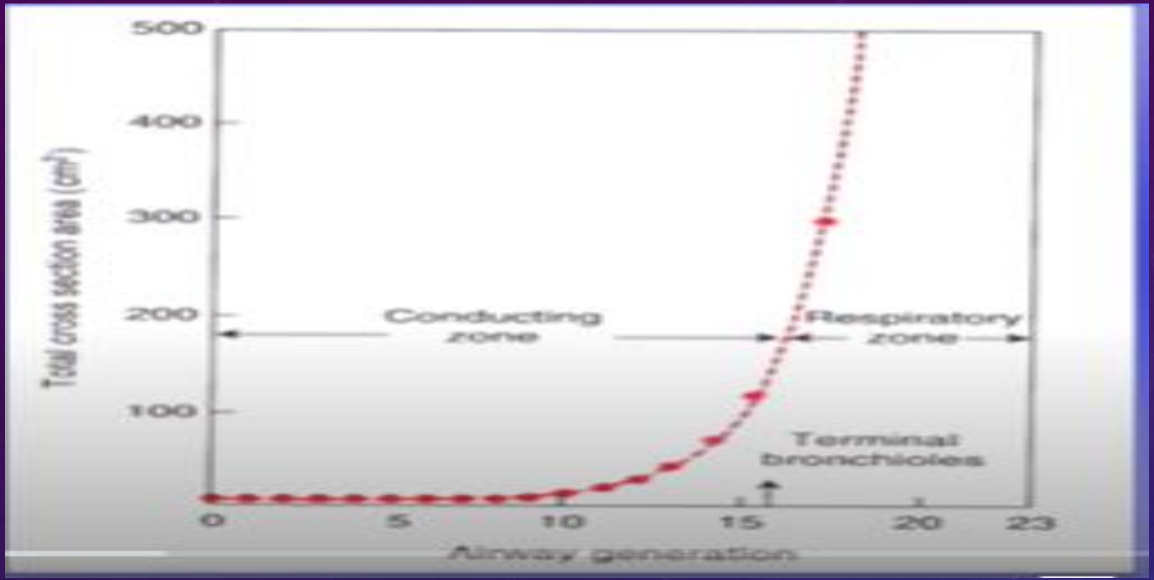
# FACTS OF VENTILATION

- Think of lung as symmetrical organ with the blood gas barrier in the middle air coming from one side by ventilation and blood coming to the other side by pulmonary circulation
- We are going to look at the two sytems the airway and the blood system in turn
- Swiss anatomist dr. weibel counted the air ways in the lung and measures their sizes and he came up with idealized airway model  called weibel model



# Implication of weibel model

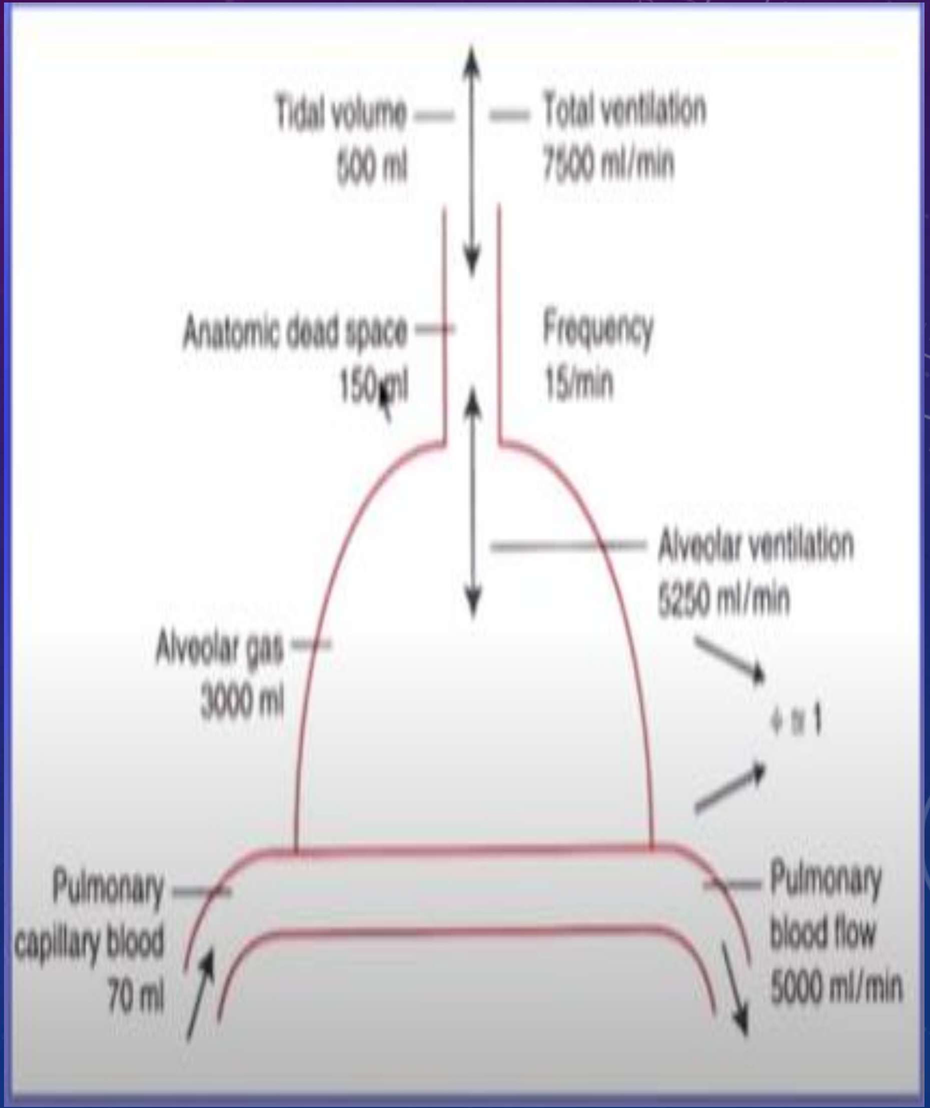



- ❑ Total cross section of each generation of airway plotted against the airway generation itself
- ❑ Over the first few generation the total cross sectional area doesn’t change at all
- ❑ Until we get to the region and there is a enormous increase in the cross sectional area; it is a little like trumpet where you have got a long initial part and the flaring at the end of the trumpet
- ❑ It has a very important implication in ventilation, the forward of velocity in enormous cross sectional area becomes very small by convection
- ❑ It turns anther mechanism of gas transfer takeover and that is diffusion
- ❑ Diffusion is the Predominant way of moving gas from terminal bronchi to alveoli
- ❑ Very important implication in lung disease because it turns out that most of pollutant therefore deposit in this junction between the conducting zone and respiratory zone
- ❑ The pollutant is much small and massive compared to the airway particles for this reason the diffusion rate of pollutant like smoke for example is small

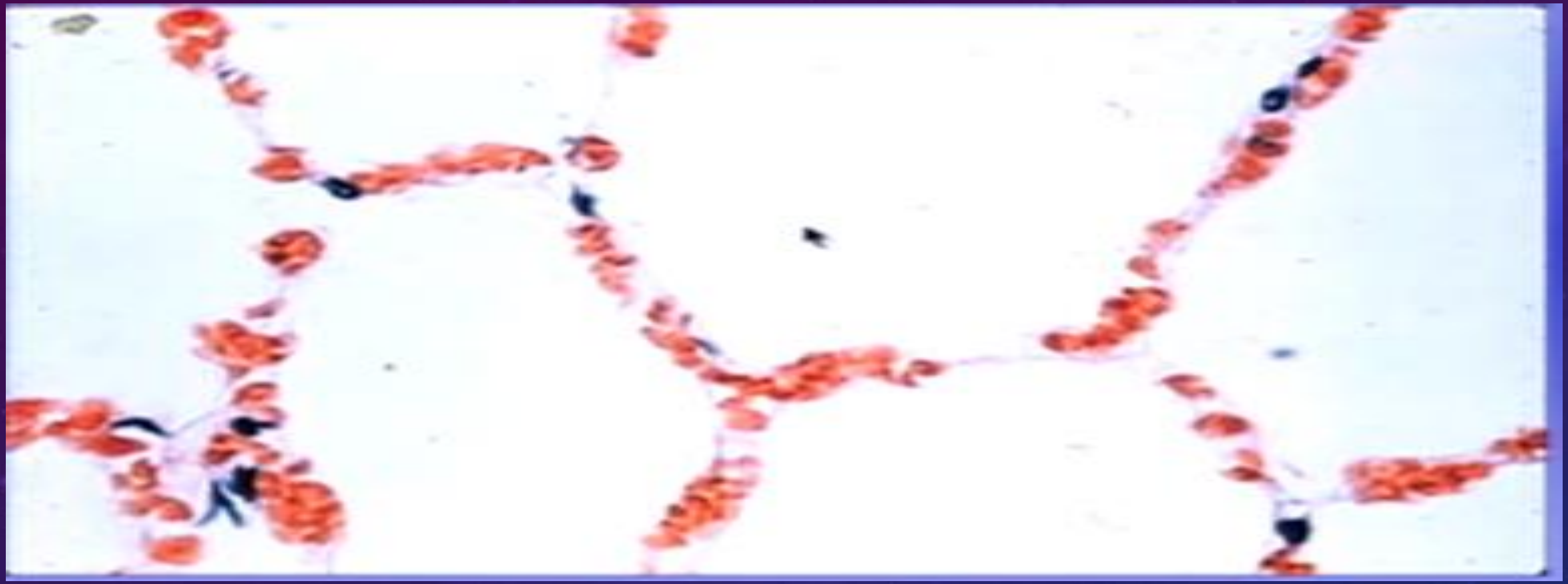
- The deposit of coal in a miner's lung  in autopsy
- The dust is deposit in terminal bronchiole and the peripheral  alveoli is  completely spared of dust
- Very important because we believe in bronchitis the first changes takes place in terminal bronchi
- Incidentally I should mention here as a caution ; it doesn't mean that the dust has not transported to some extent in alveoli but nevertheless  we know that the small air way is the region of the dust

# Volumes and flows in the lung

- The tidal volume; is the volume of air expired or inspirited in normal breath
- A big disparity between the volume of gas and the volume of blood
- This has to do incidentally with the fact that the diffusion phase in the gas phase are much faster than diffusion rates in the liquid phase
- Volume per unit time or ventilation ; assume the breathing rate is 15 breath per a minute
- If the tidal volume is 500 ml and the frequency is 15 then ventilation rate is 7500ml/min but not all of that gas gets to the region of the lung some of them is left behind the dead space
- So the amount of gas in the alveoli is going to be 500ml less 150 times the 15 which gives us 5250ml/min ventilation rate
- The cardiac out put of the right heart is 500ml/min; this is very interesting because despite the disparity  between the volumes of alveolar gas  and the volume of blood capillary at any instant in time , the volume reaching the blood gas per a minute on the gas side and the blood side are approximately the same
- The ratio of ventilation to pulmonary blood flow is about one  and we are going to give much more in ventilation / perfusion

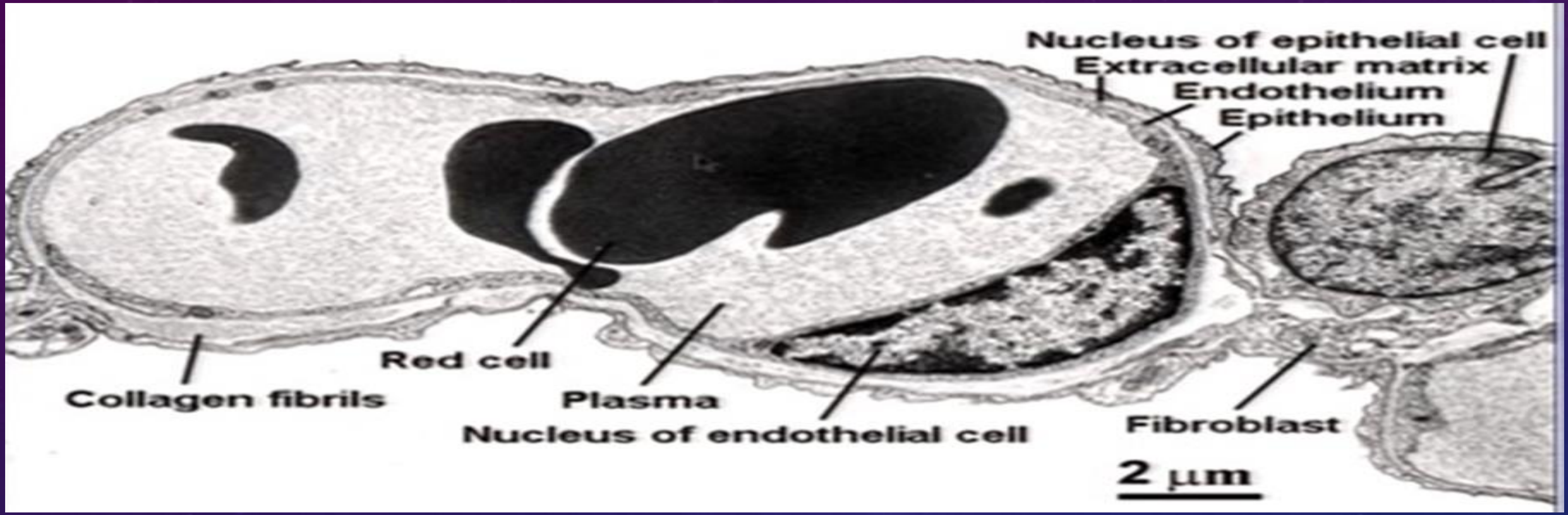


# Alveoli and Capillaries



- Light micrograph taken from rapidly freezing lung
- Alveolar spaces and capillaries
- Blood gas barriers separates the blood from the capillary side and the gas from the alveolar space where the blood gas exchange occur
- Blood gas barrier is extremely thin we cant identify it from light micrograph like this

# Electron micrograph of Pulmonary Capillary

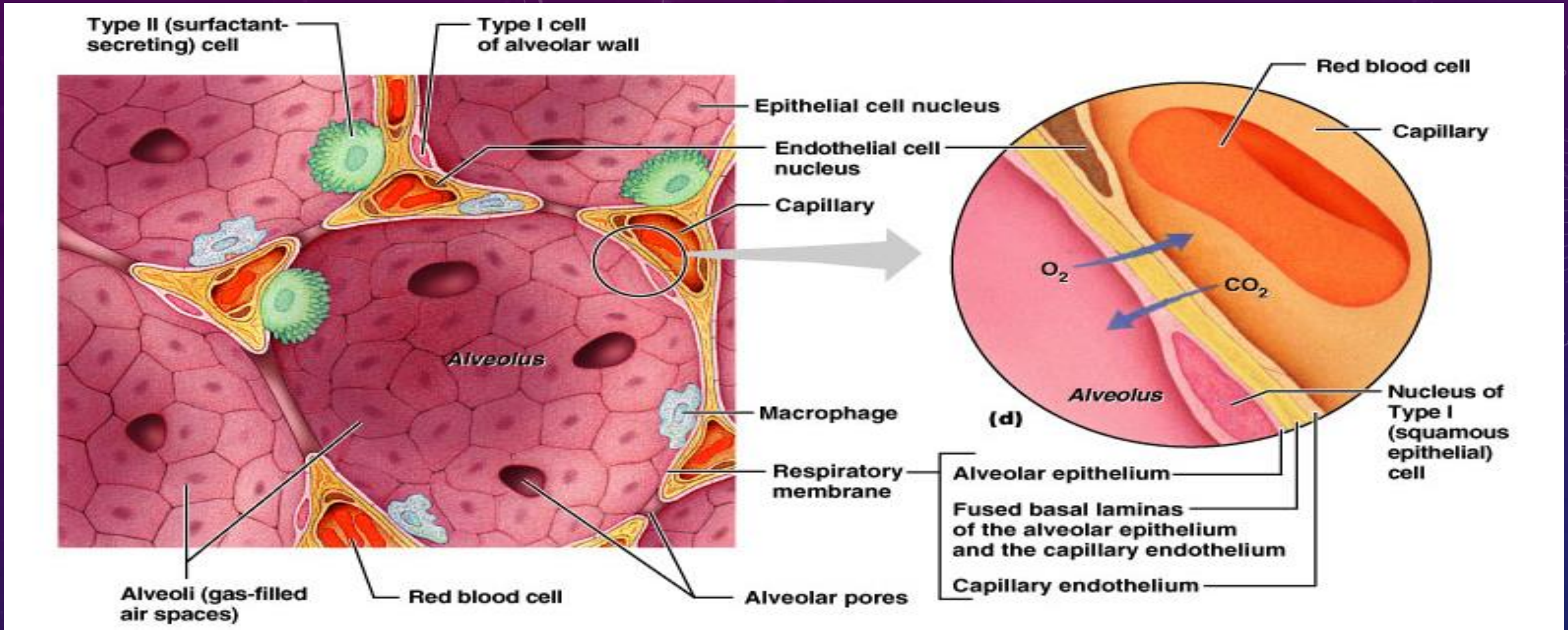



- ❑ the capillary and alveolar wall which is running across the slide here
- ❑Alveolar gas on both side of the capillary
- ❑Inside the capillary red blood cells and plasma
- ❑ the wall of the capillary is the blood gas barrier blood from one side and gas on the other
- ❑The scale of the blood gas barrier is one third of micron

One micron= millionth of meter or thousandth of millimeter

Red blood cells =seven micron in diameter ; visible on light microscope less than one micron we need micrograph

- ❑ The blood gas barrier is polarized so on side ; the capillary side is thinner than the alveolar side
- ❑ A barrier that is thin is rather fragile and of the pressure in the capillary rises to abnormally high levels you can get ultrastructure changes and leak fluid into alveolar spaces and that's situation is called stress failure



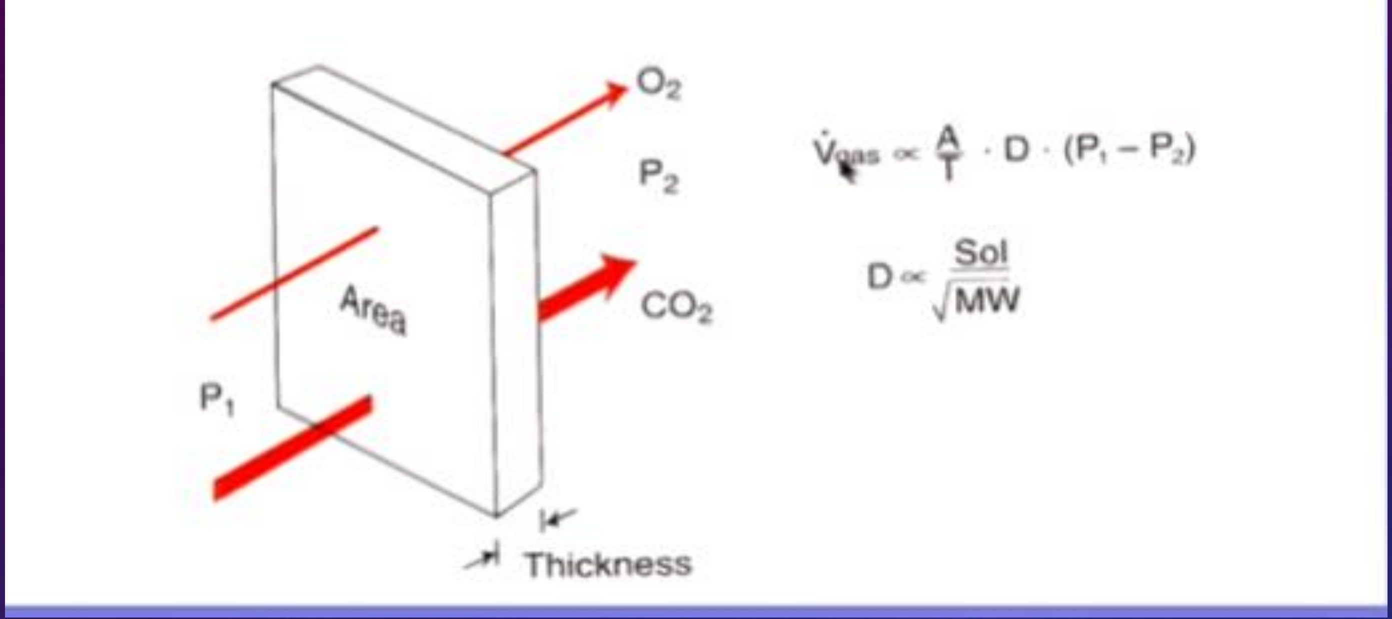

- Alveoli surrounded by fine elastic fibers
- Alveolar macrophages – free floating "dust cells"
- Note type I and type II cells and joint membrane
- Type 4 collagen responsible for the strength of basement membrane

▪air-blood barrier (the respiratory membrane)

is where gas exchange occurs

Oxygen diffuses from air in alveolus (singular of alveoli) to blood in capillary.Carbon dioxide diffuses from the blood in the capillary into the air in the alveolus

# Ficks law of diffusion through a tissue sheet




- ❑ if you have a tissue sheet like a postage stamp then the volume of gas which moves a cross the sheet is proportional to the area of the sheet and proportional to the constant which is called the diffusion constant and the difference of partial pressure between one side of the sheet and the other

- ❑Inversely proportional to the thickness of sheet

- ❑So we need thin sheet as possible and large area as possible

The blood gas barrier is phenomenally thin and the area is about 50 to 100 square meters enormous area that is generated by 500 million alveoli and in each walls of the alveoli you get these capillaries with their blood gas barrier

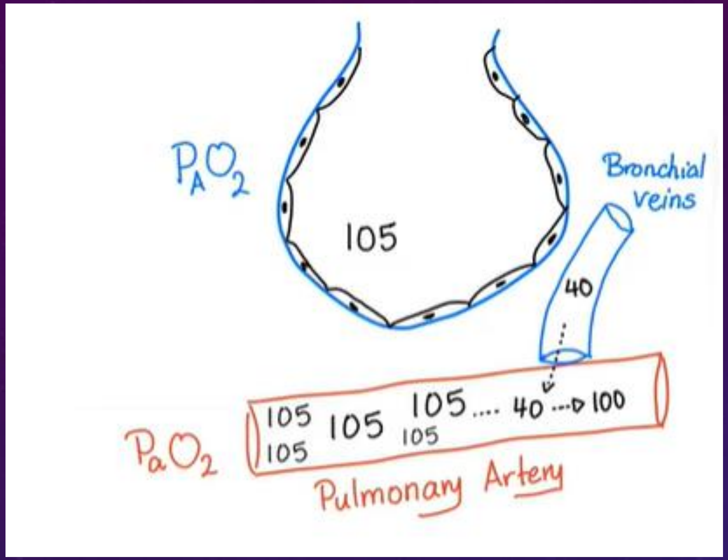
# FEV1/FVC RATIO

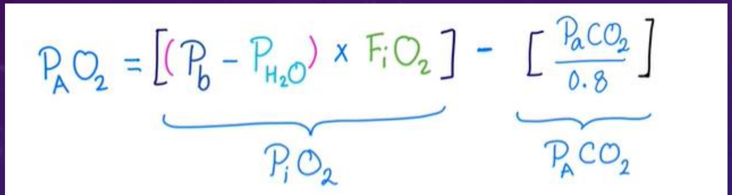
FEV1/FVC ratio: 4L/5L=80%

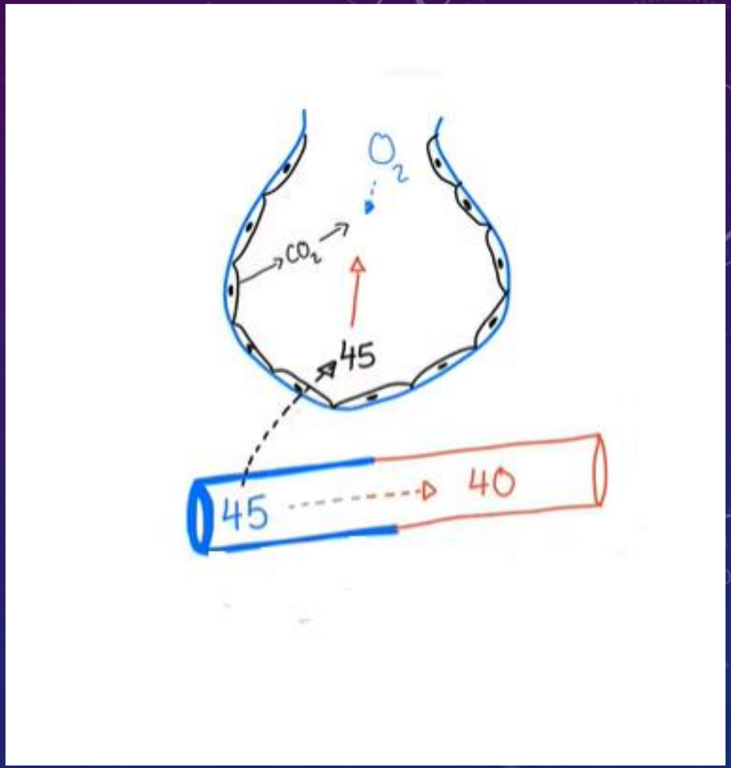
FEV1: the amount of air quickly and forcibly exhale in 1 second

FVC: the amount of air quickly and forcibly exhale after maximum inhalation ( timed)

- 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)




A-a GRADIENT NORMAL EXTRINSIC RESTRICTIVE LUNG DISEASE

A-a GRADIENT ABNORMAL INTRINSIC RESTRICTIVE LUNG DISEASE

| 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. |

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!