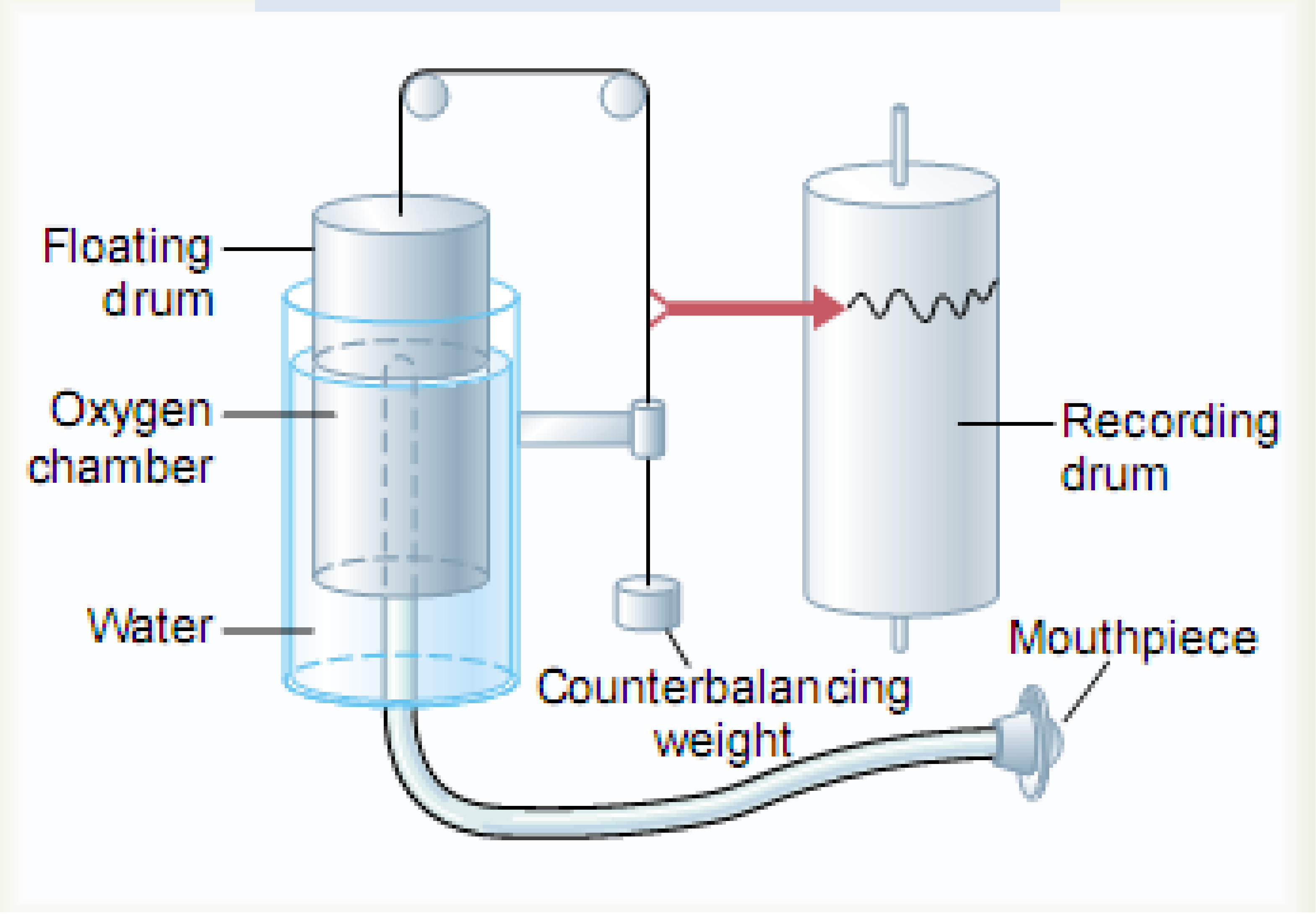
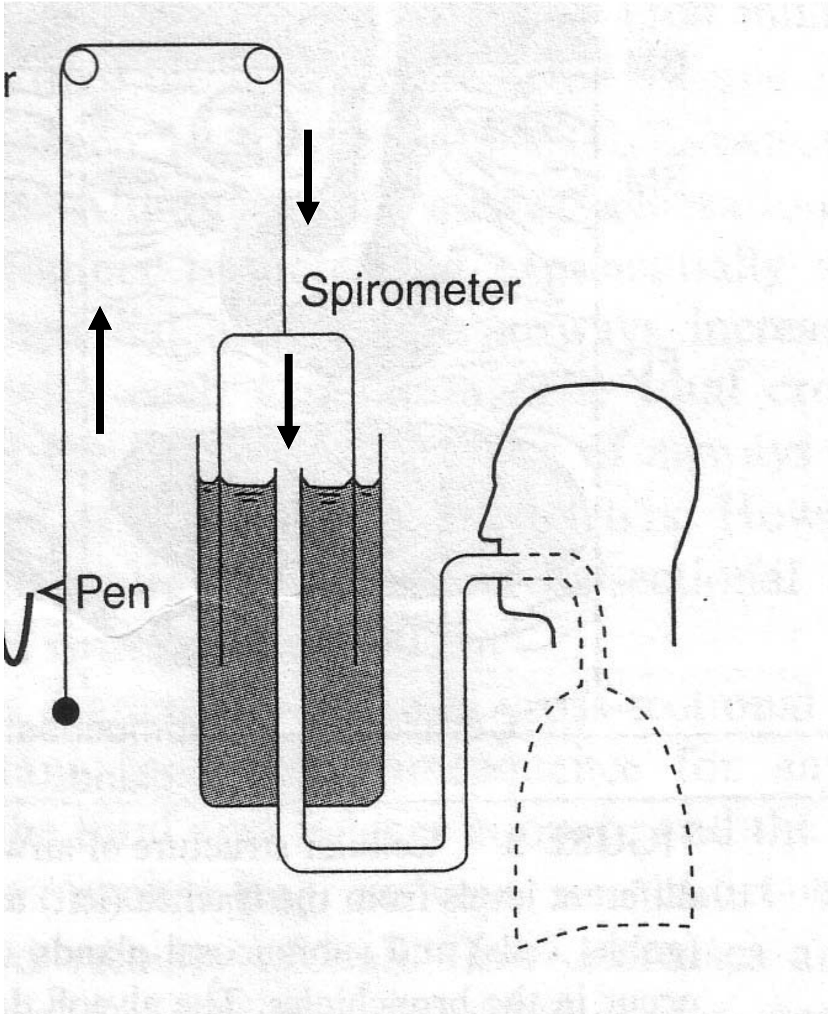
Respiratory Physiology

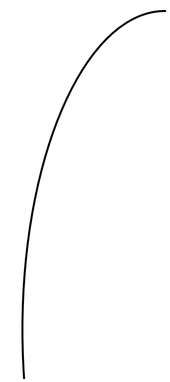
Dr. Lwin Aye Thet

SPIROMETER

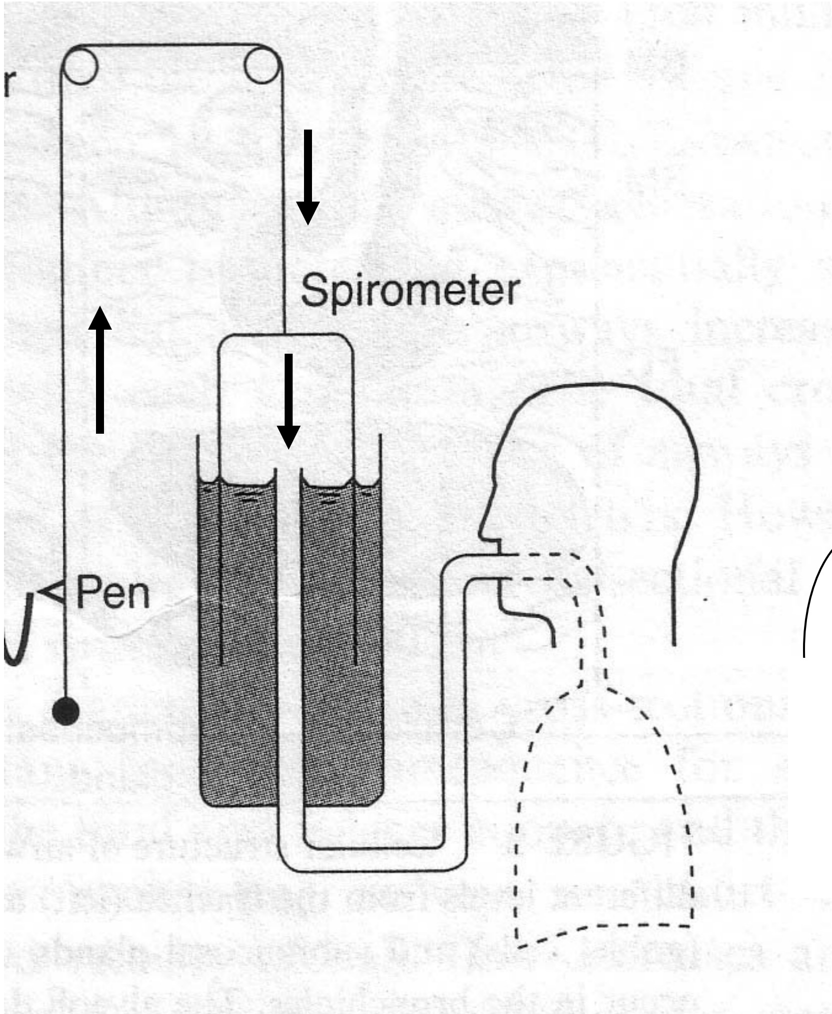

Floating drum
Oxygen chamber
Water
Counterbalancing weight
Recording drum
Mouthpiece

INSPIRATION

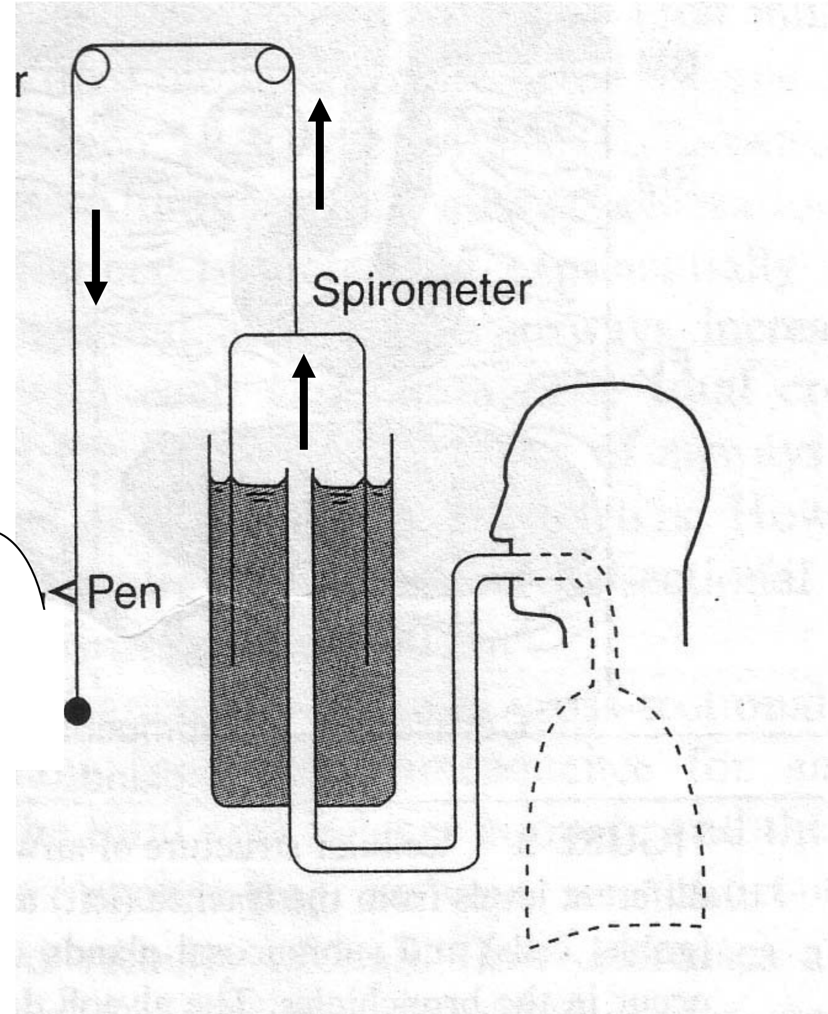


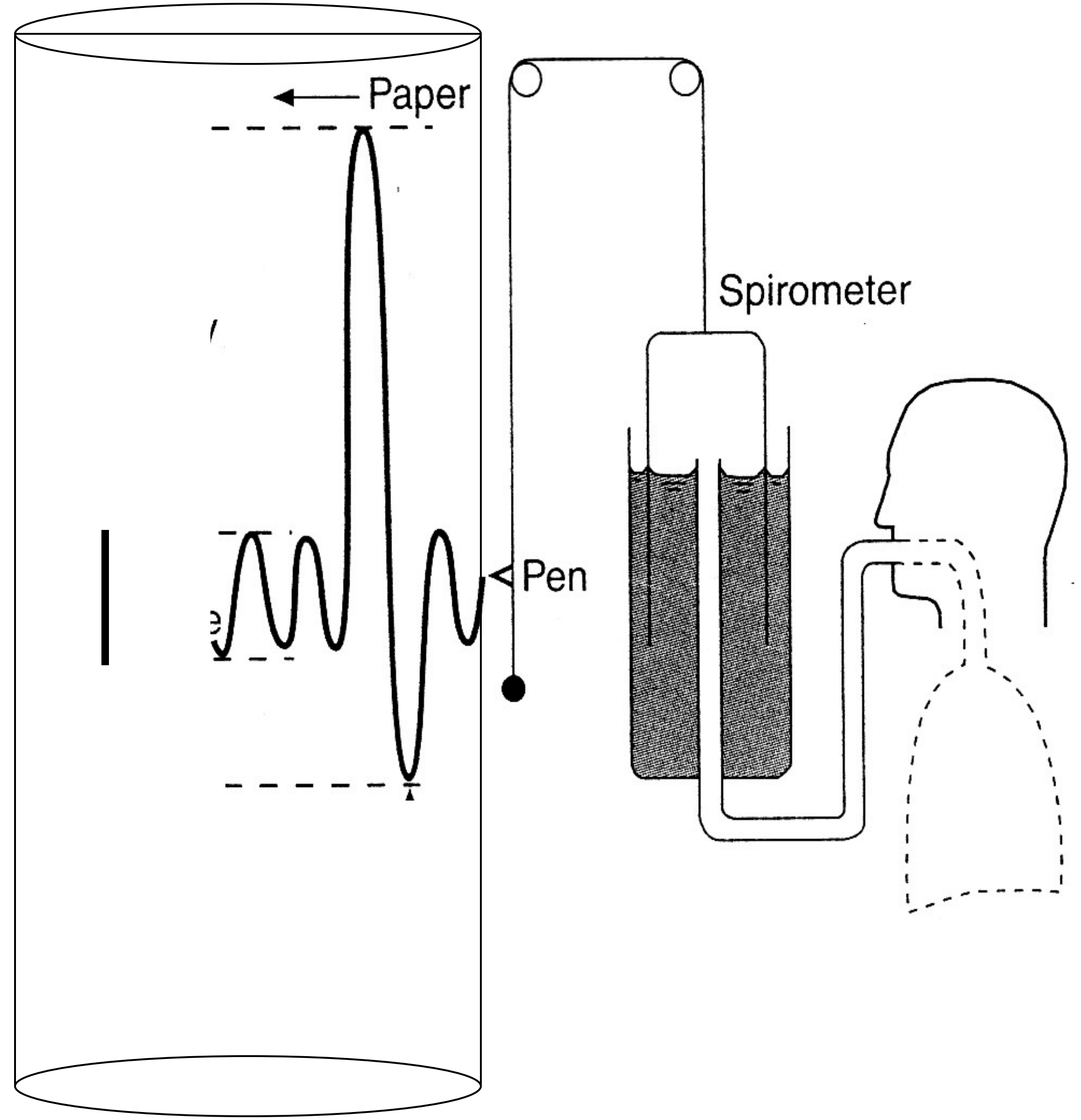


INSPIRATION



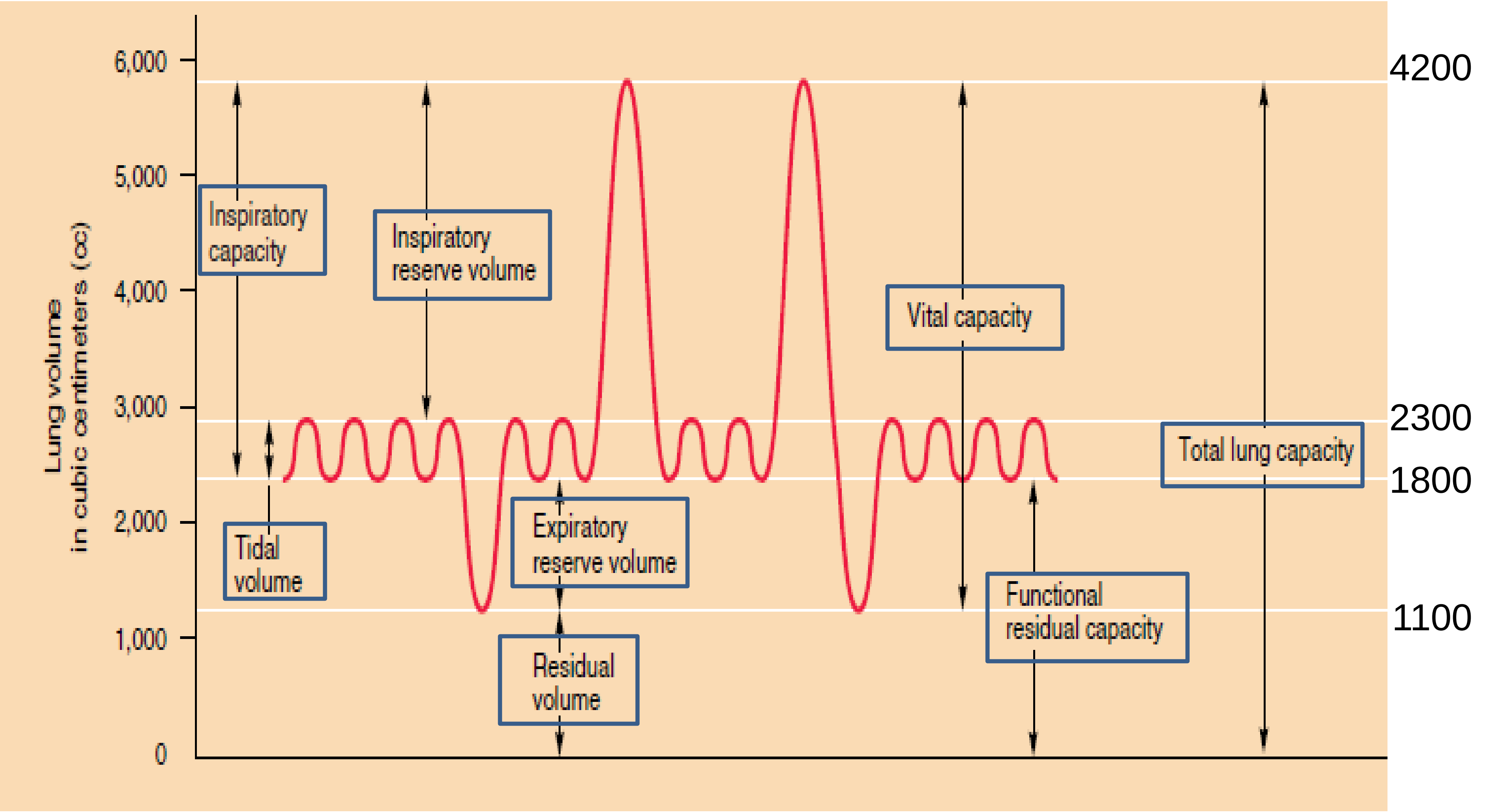
EXPIRATION



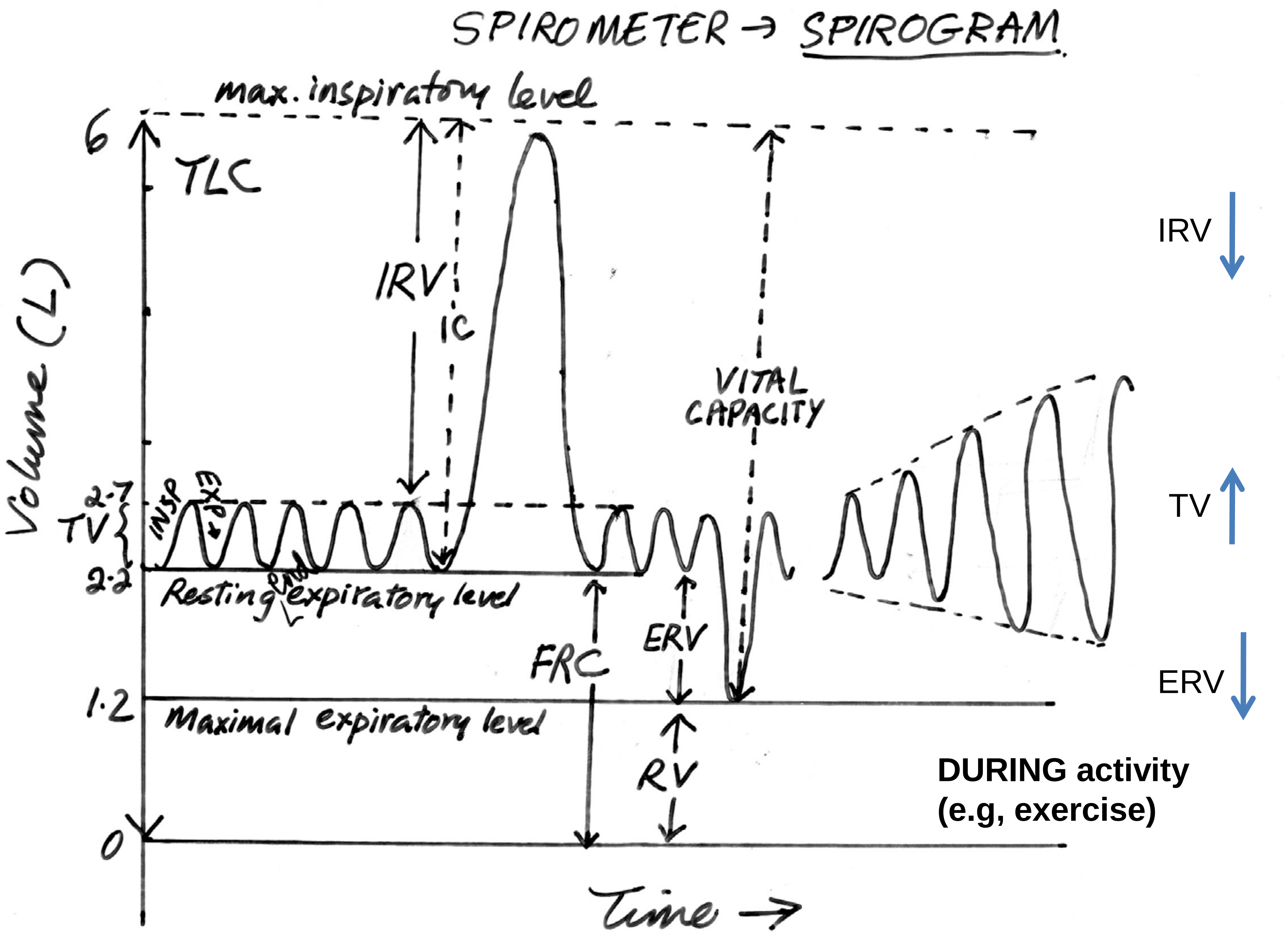

Paper
Spirometer
Pen

male

female



helium dilution



SPIROMETER → SPIROGRAM
max. inspiratory level
6
TLC
IRV
IC
VITAL CAPACITY
Volume (L)
2·7
TV
INSP
EXP
2·2
End
Resting expiratory level
FRC
ERV
1·2
Maximal expiratory level
RV
0
Time →
IRV
TV
ERV
DURING activity (e.g, exercise)

Dead space

- Primary function of lungs: gas exchange

- gas exchange: only in the terminal portions of the airways
  (alveoli equilibrated with pulmonary capillaries)

- Area (no gas exchange): dead space

Dead space

of two types

- (1) Anatomical dead space
  - volume of air occupying the space from the external nares to the terminal bronchioles, i.e. in the conducting zone
  - 150 ml in both sexes
  - approximately equal to BW in Ib
  - increased in tubing inhalation (e.g. diving)

- (2) Total dead space (Physiological dead space)
  - volume of gas not equilibrated with blood (e.g. lungs diseases)
  - diseases: Alveolar dead space

Normally: Anatomical DS = Physiological DS

Pulmonary ventilation (Respiratory minute volume: RMV)

$$\text{Pulmonary ventilation} = TV \times RR$$
$$= 500 \times 12$$
$$= 6\ L/min$$

Alveolar ventilation

$$\text{Alveolar ventilation} = (TV - DS) \times RR$$
$$= (500 - 150) \times 12$$
$$= 4.2\ L/min$$

Effect of variation in respiratory rate and depth on alveolar ventilation

RR = 30	RR = 10
TV = 200ml	TV = 600

Minute volume = 6 L/mim

Alveolar ventilation	Alveolar ventilation
= (200-150) x 30	= (600-150) x 10
= 1500 ml/min	= 4500 ml/min

Which is better?

rapid & shallow vs slow & deep

Resistance of the lungs and chest

1. Elastic resistance
   - resistance offered by stretching the elastic tissues of the chest wall and lungs **(65%)**
   (ST = 2/3 of ER)

2. Non-elastic resistance
   - resistance offered by the inelastic tissues of the lungs and the chest wall **(7%)**

3. Airway resistance
   - resistance to air flow offered by the respiratory passage **(28%)**

Work of breathing

Work

- is performed by the respiratory muscles in stretching the elastic tissues of the chest wall and lungs, moving inelastic tissues and moving air through the respiratory passages.

- can be calculated from relaxation pressure curves:

  Work = pressure x volume

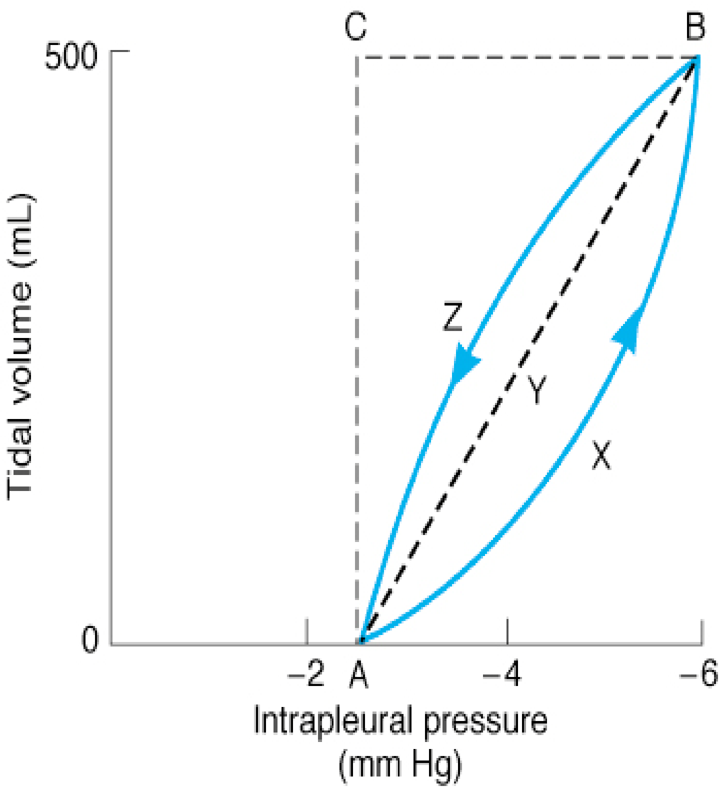
Work of breathing

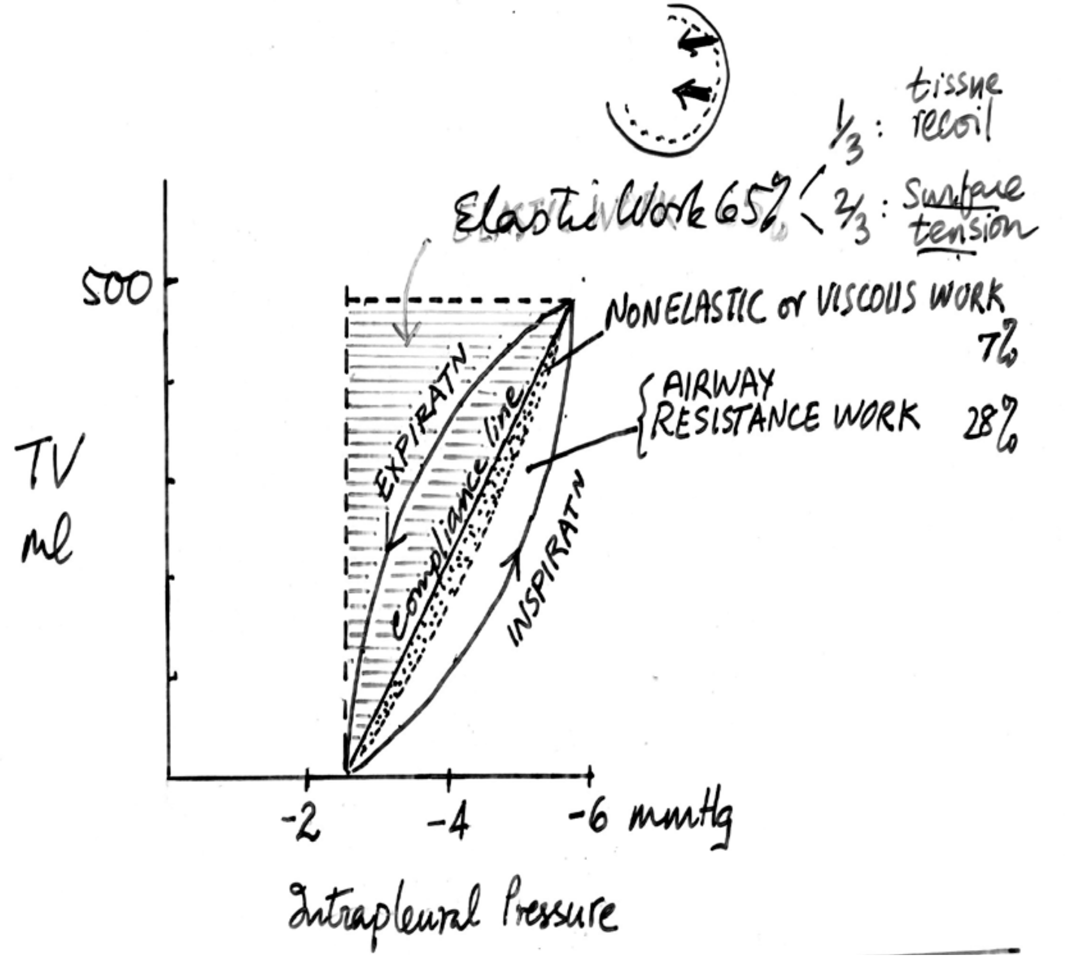
work = force x distance

force = pressure x area

work = pressure x area x distance

work = pressure x volume





Hysteresis loop

AXBCA

Total work of breathing
- 0.3 to 0.8 kgm-m/min

Work of breathing

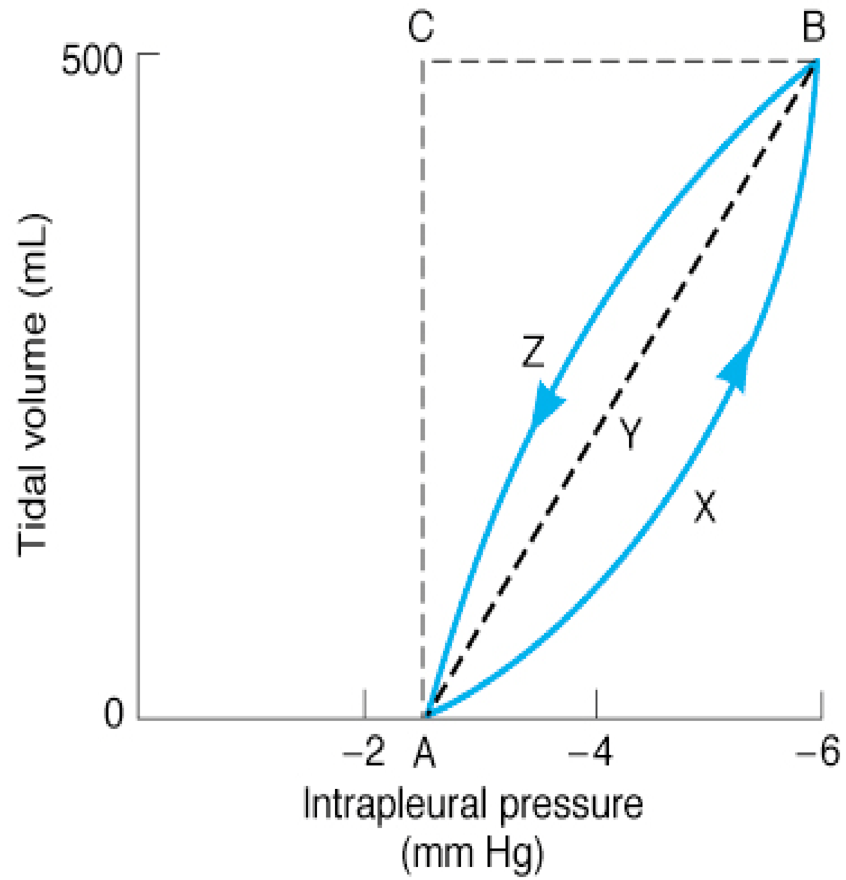
Increased: during exercise

Increased:

emphysema,
asthma,
congestive heart failure with
dyspnoea and orthopnoea

Compliance

- is the change in lung volume per unit change in airway pressure
- is slightly greater when measured during deflation than measured during inflation

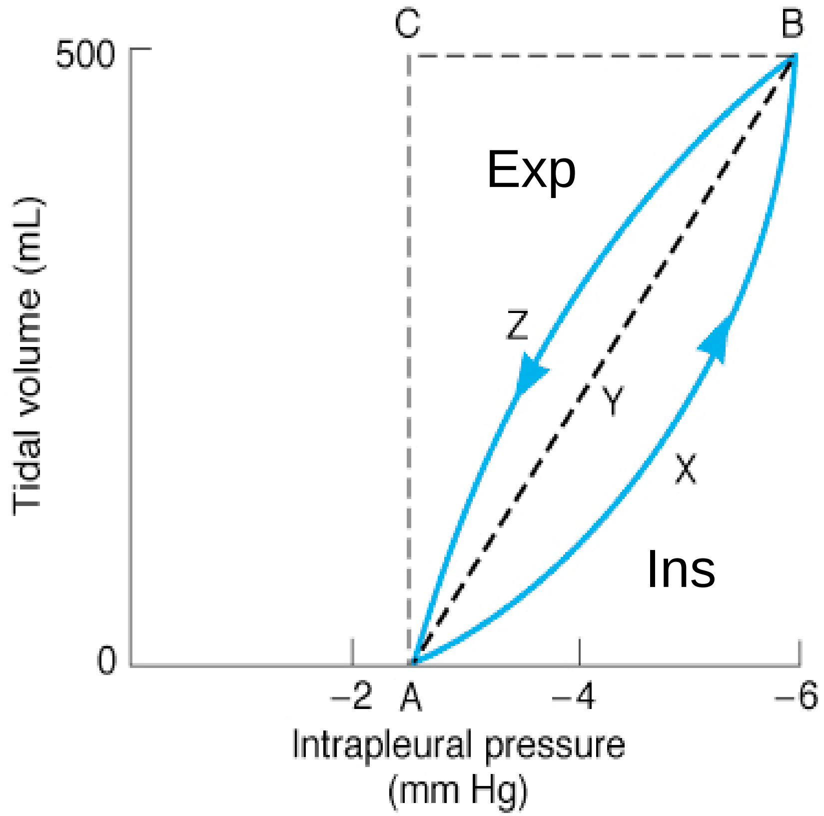


Compliance

- Compliance = ΔV / ΔP

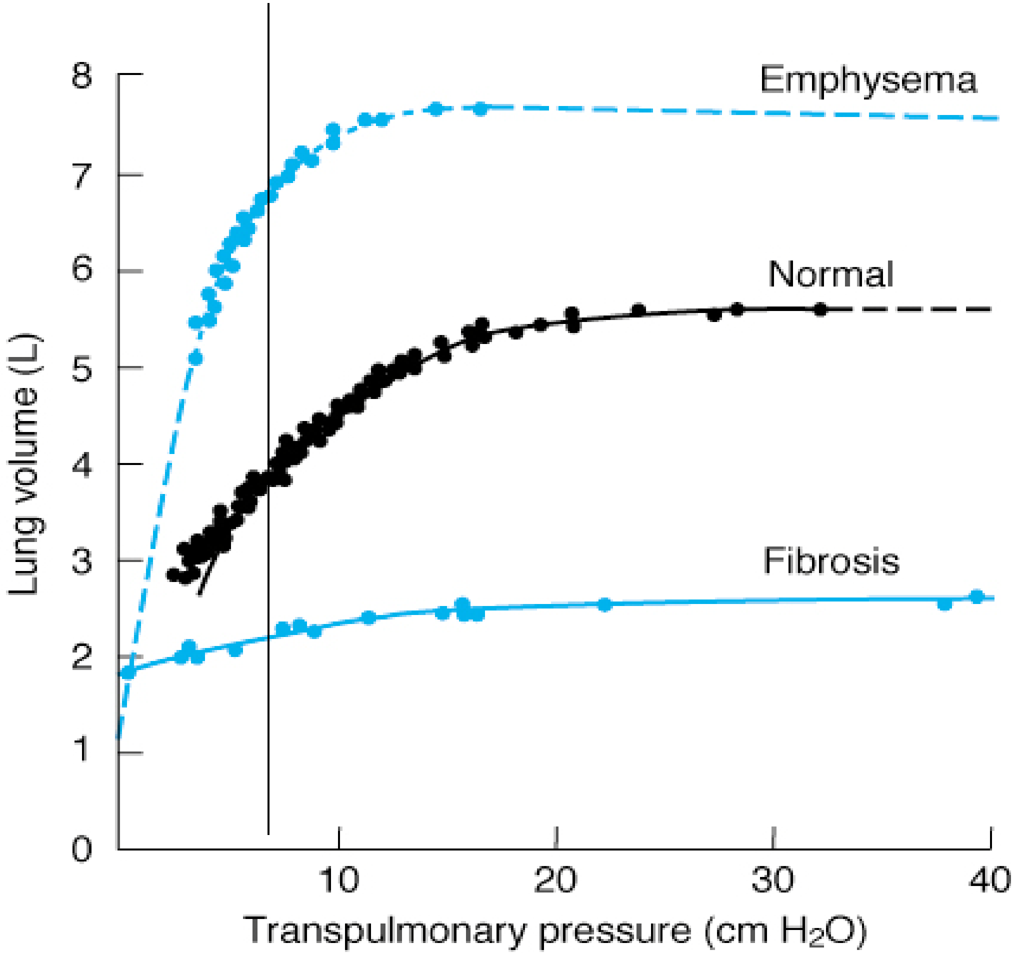
- Normal average value:
  0.2 L/cm water
  (0.09 to 0.26 L/cm water)

- **Compliance line - AYB**



as a measure of distensibility (stretchibility) of lungs and thorax

Compliance



Static expiratory pressure-volume curve

Compliance ↑

- emphysema

Compliance ↓

- pulmonary congestion
- interstitial pulmonary fibrosis
- surfactant deficiency

Compliance and ST

$$ST \;\; \alpha \;\; \frac{1}{\text{Compliance}}$$

Surfactant deficiency – ST $\uparrow$ – Compliance $\downarrow$

PULMONARY CIRCULATION

- Pulmonary vascular system is a low pressure distensible system
- Pulmonary arterial pressure is about **24/9** mmHg. Mean pressure is about **15** mmHg. (Recall that systemic arterial pressure = about 120/70mmHg).
- the volume of blood in the pulmonary vessels at any one time = about 1 L (Pulmonary reservoir)
- on lying down = is increased by 400 ml
  = 1000 + 400 = 1400 ml

PULMONARY CIRCULATION

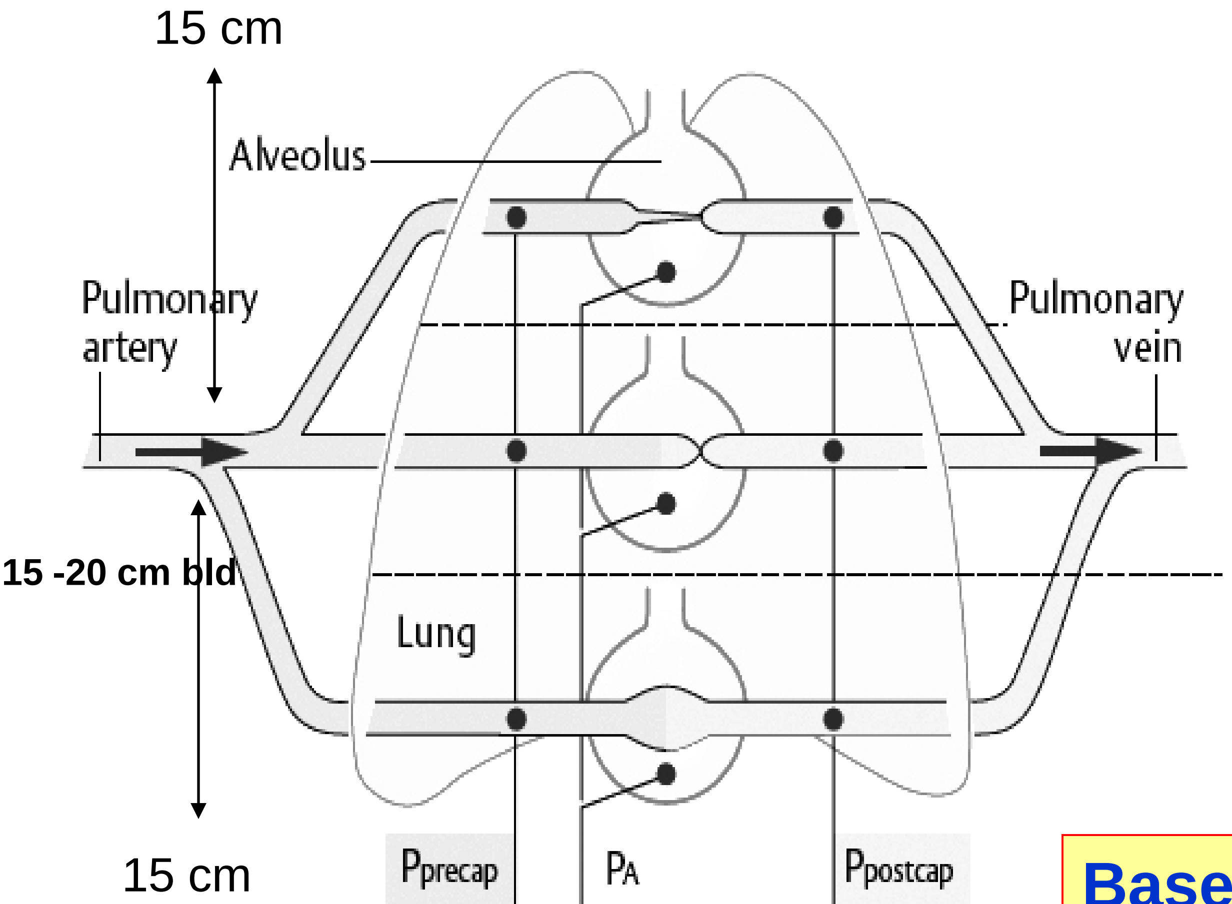
- Cardiac output (CO) of the right ventricle = Pul. BF = 5.5 L /min at rest.

- Mean velocity at the root of pulmonary artery = 40 cm/sec

- Traverse time at rest (pul. capillaries)= 0.75 second

- Traverse time during exercise = 0.3 second

Distribution of pulmonary blood flow (upright posture)



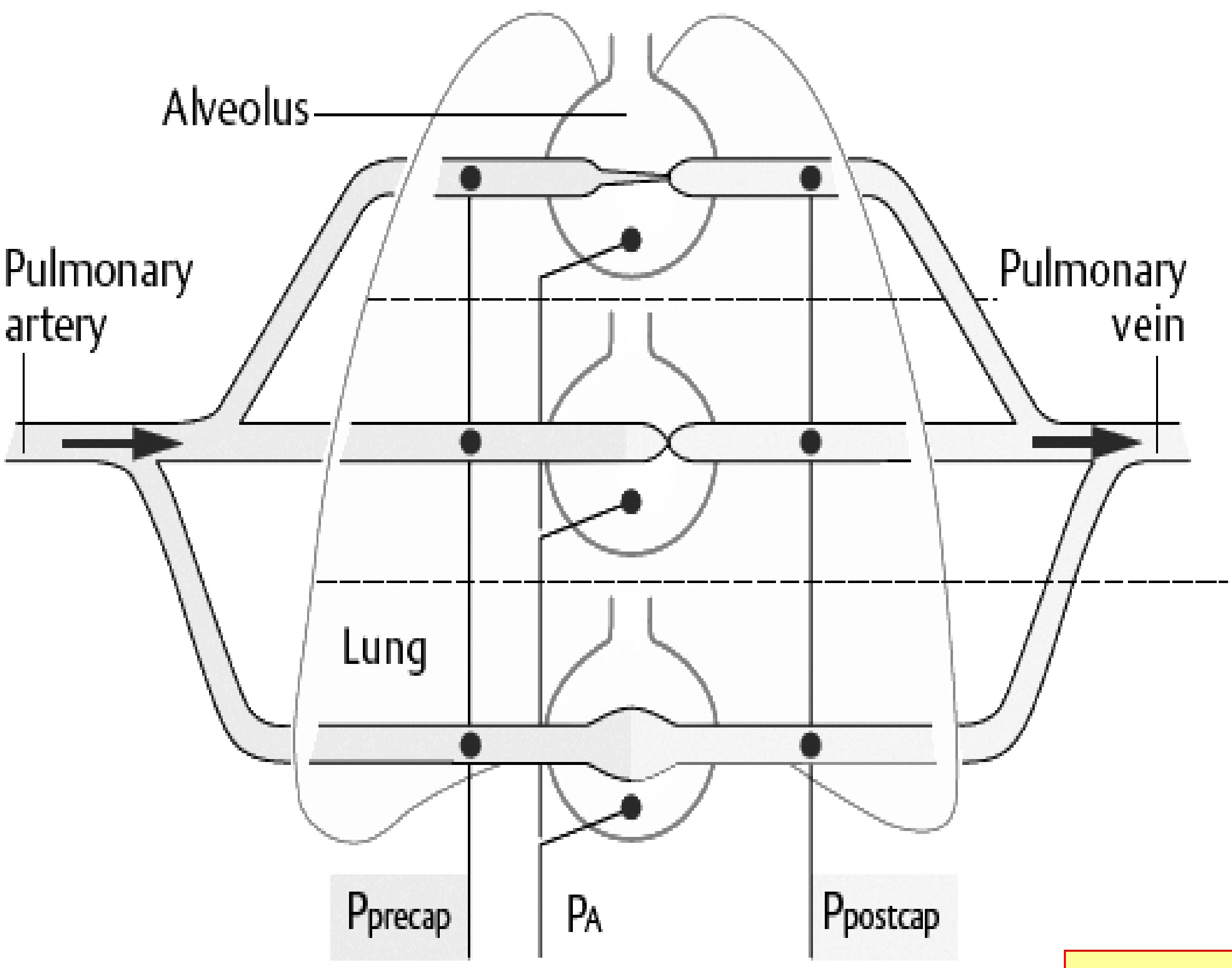
ZONE -1

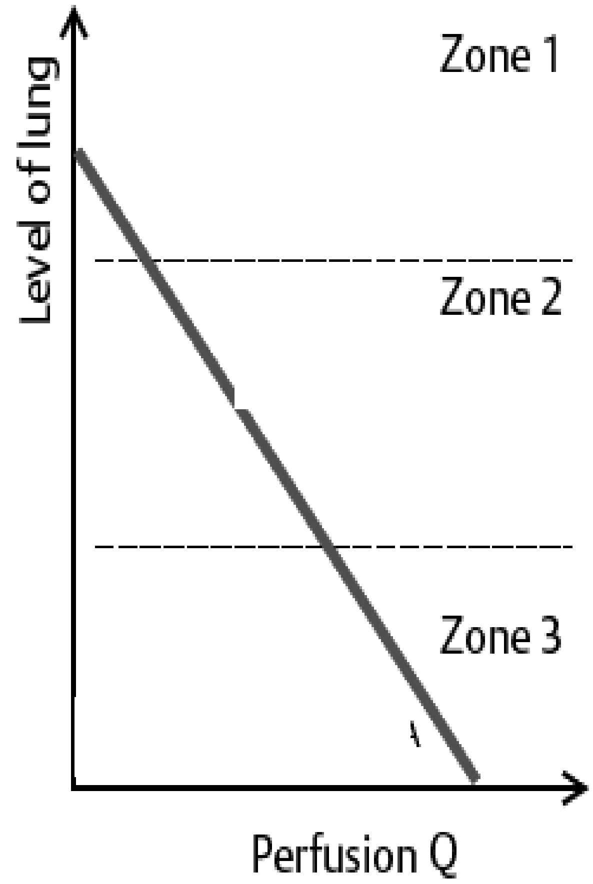
ZONE -2

ZONE -3

Base: better perfusion

Distribution of pulmonary blood flow (upright posture)



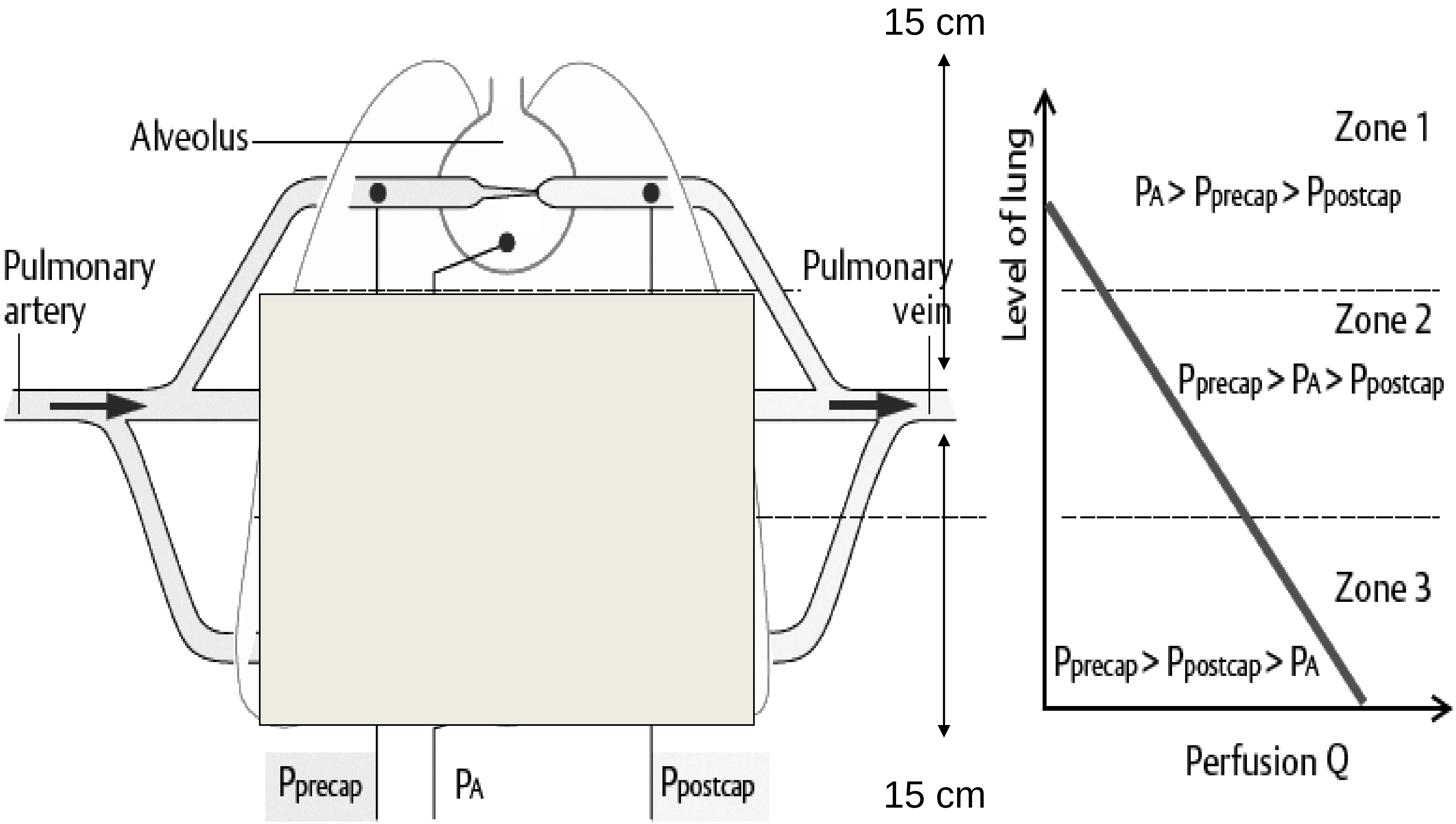


Base: better perfusion

Supine position: Posterior - better perfusion

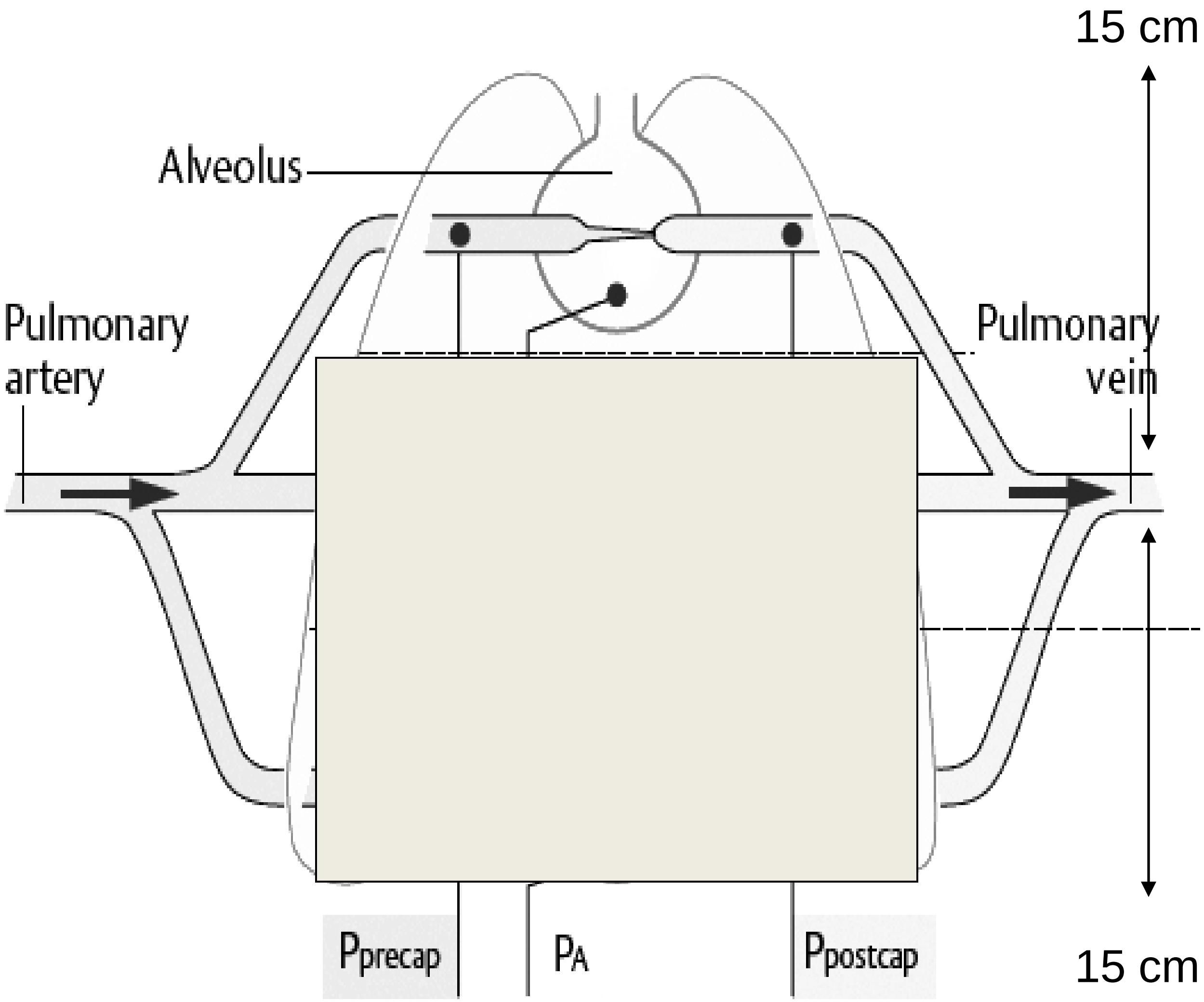
Distribution of pulmonary blood flow (upright posture)

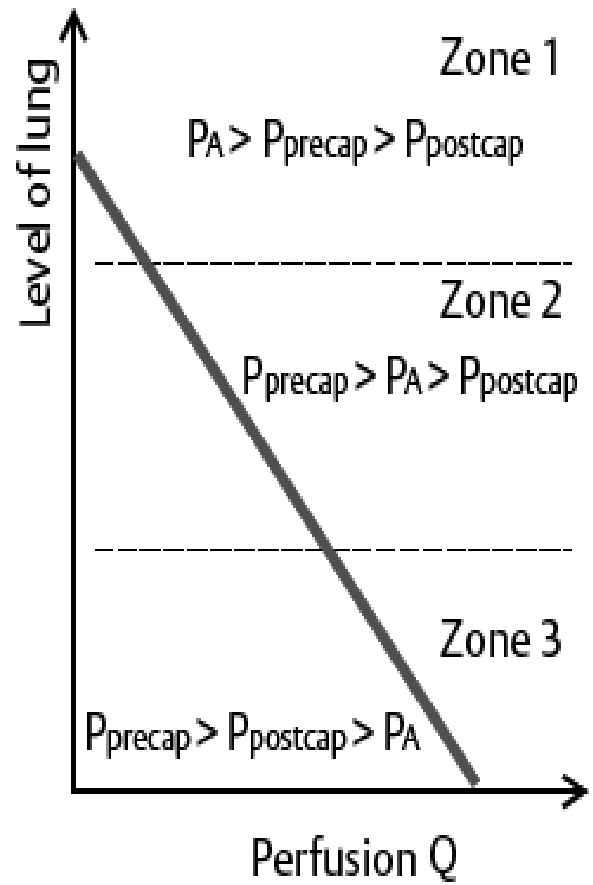
$$Q = \frac{P_A - P_B}{R}$$



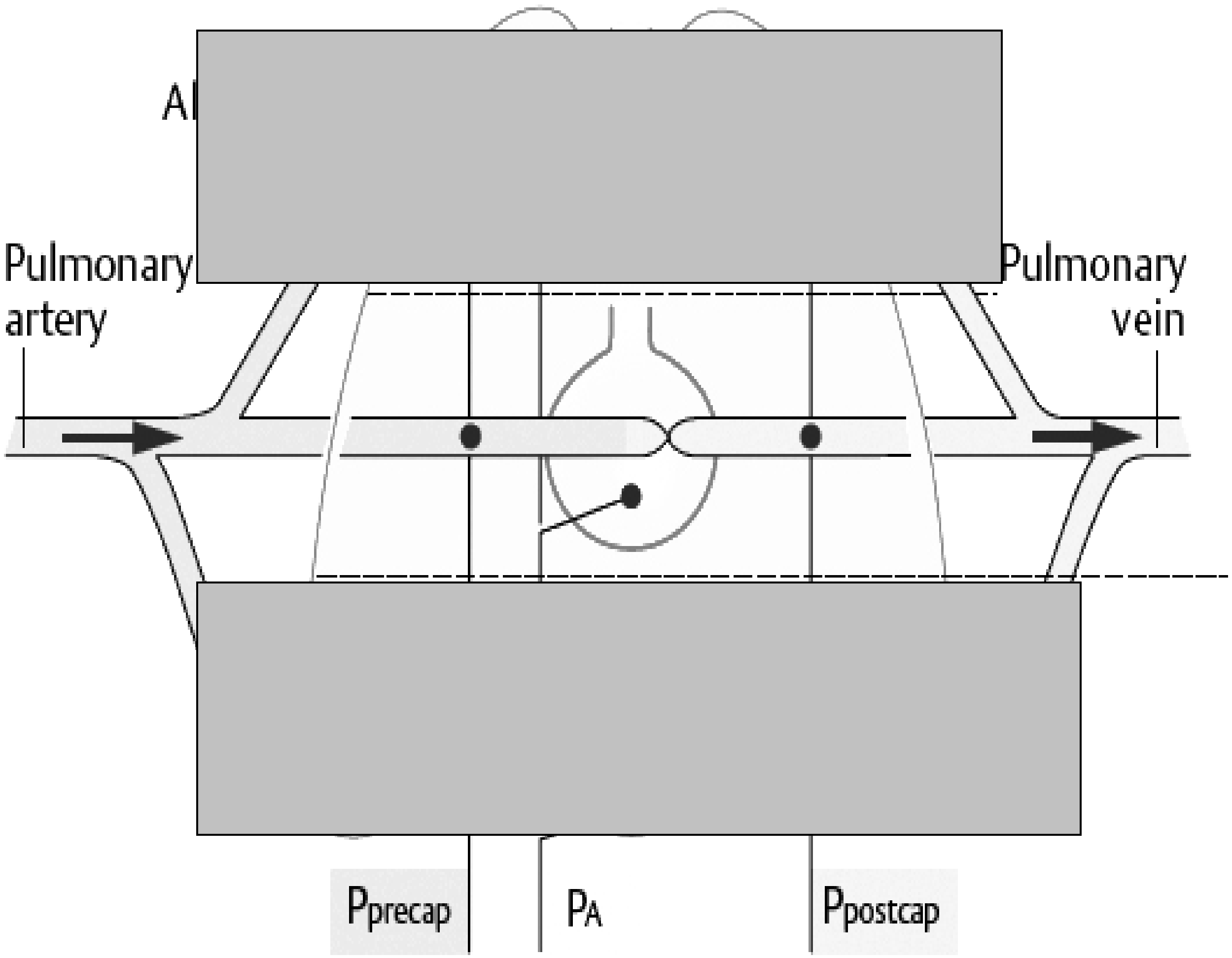
Distribution of pulmonary blood flow (upright posture)

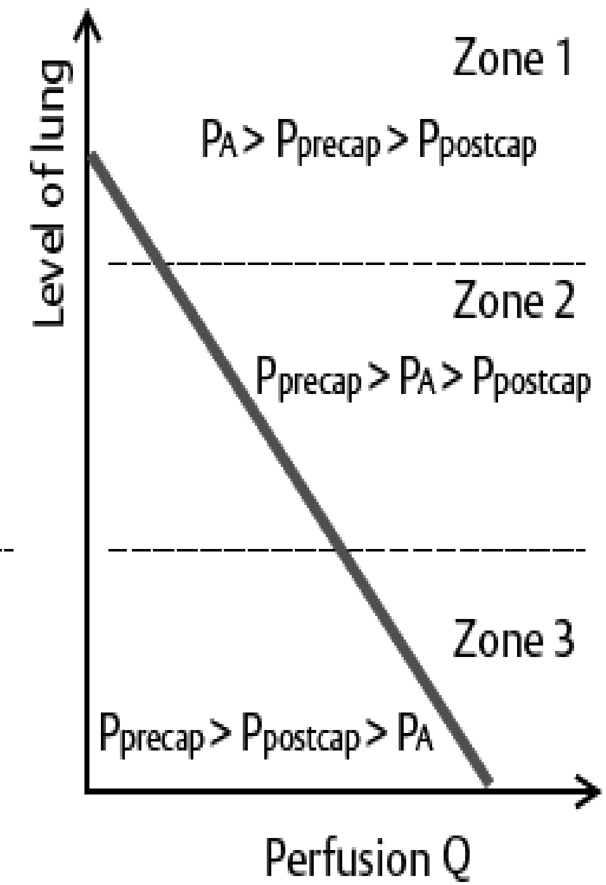
$$Q = \frac{P_A - P_B}{R}$$



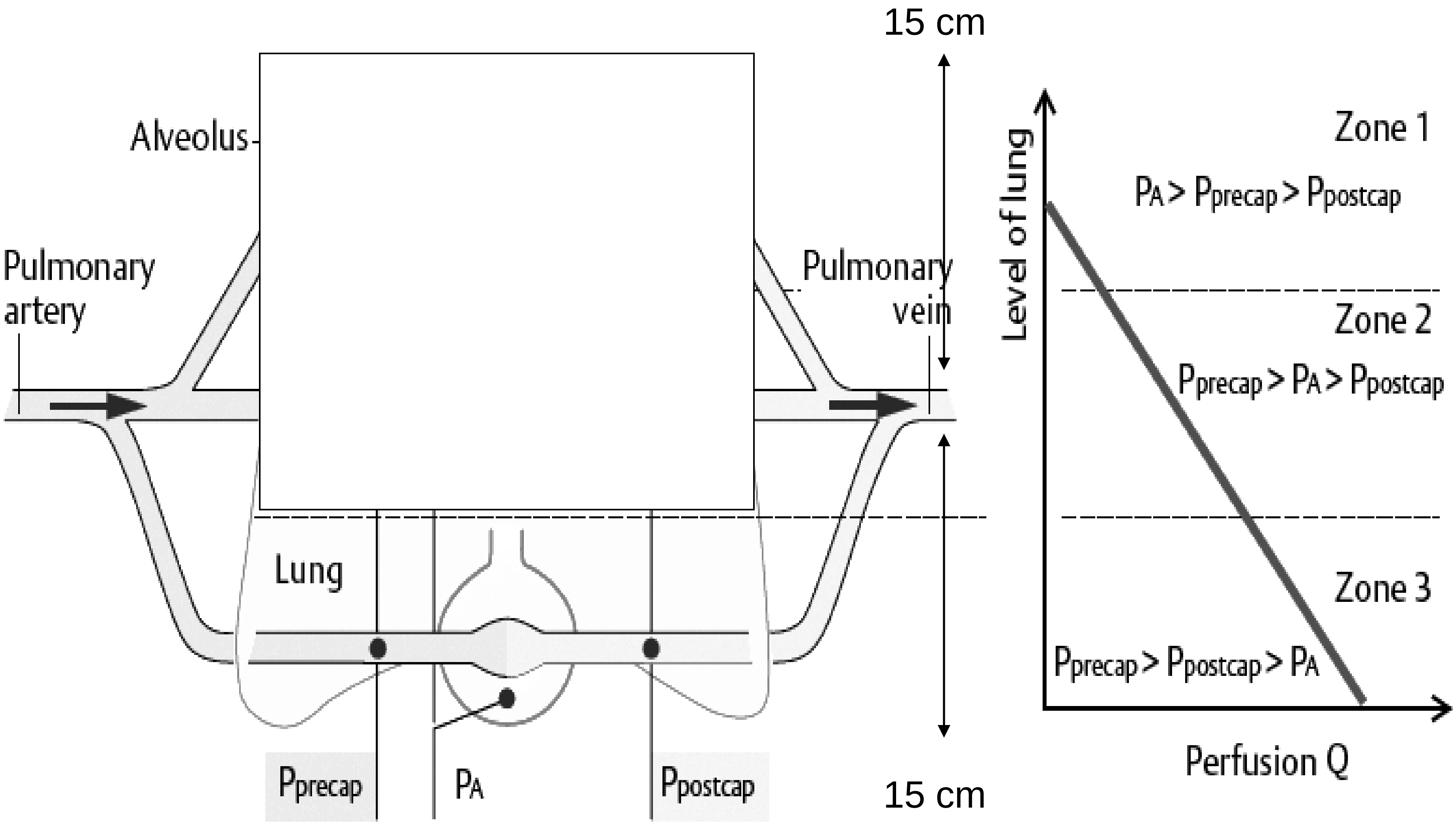


Distribution of pulmonary blood flow (upright posture)

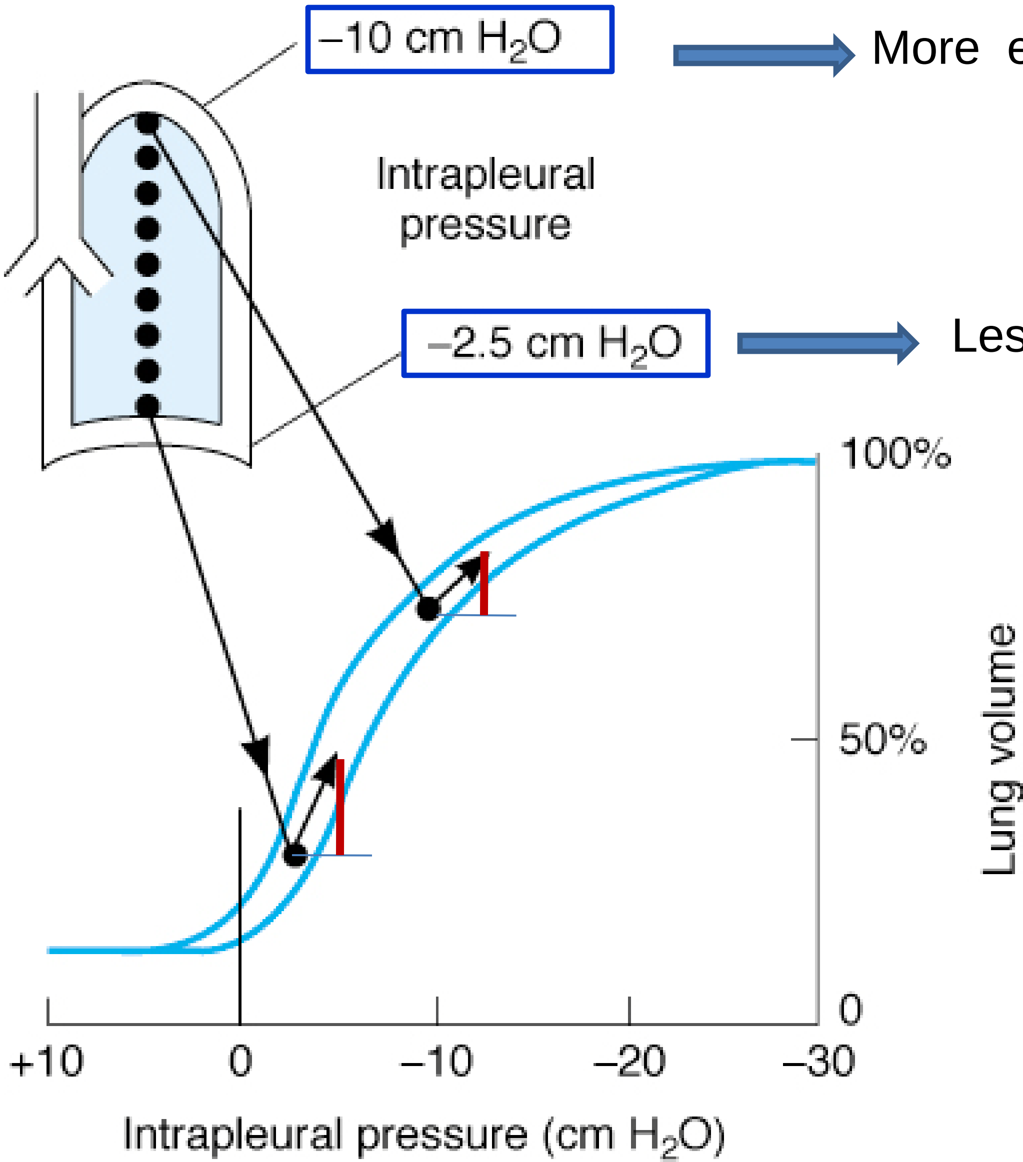




Distribution of pulmonary blood flow (upright posture)



Break



More expended (more stiffness)

Less expanded → Greater ventilation

UPRIGHT POSTURE

Ventilation

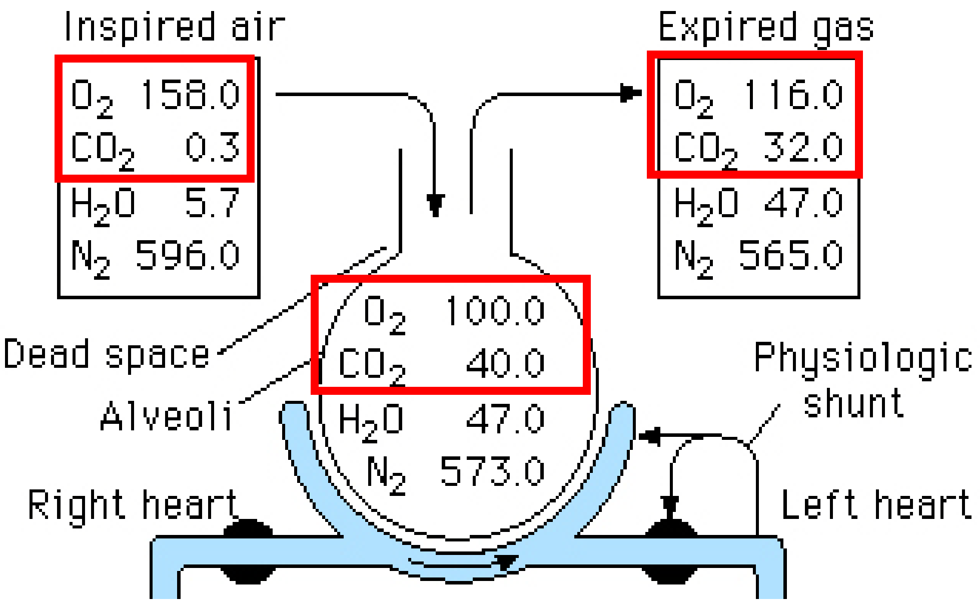
Base > Apex

UPRIGHT POSTURE

Ventilation (V) : Base > Apex

Perfusion (Q) : Base > Apex

Ventilation



Inspired Air = 1 ATM (760 mmHg)

O_2 = 20.98%: 0.21 x 760 = 160 mmHg

CO_2 = 0.04%: 0.0004 x 760 = 0.3 mmHg

Ventilation – perfusion Relationship

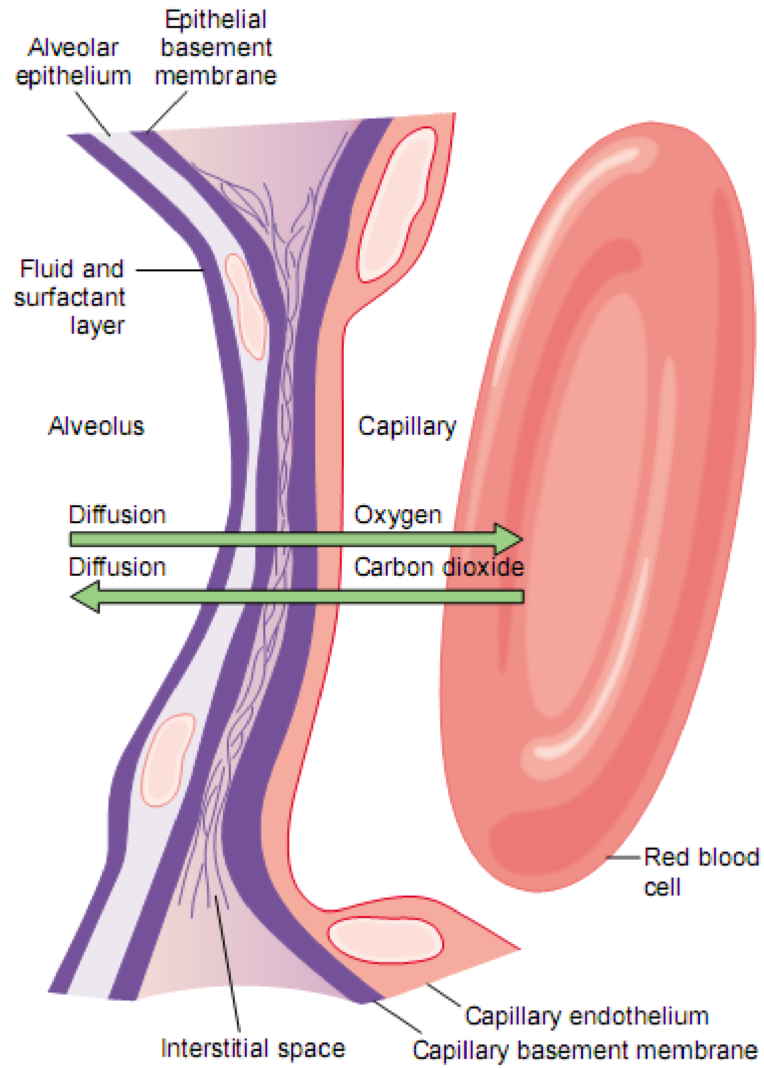
For adequate respiration: air and blood delivered to the lungs:
proper proportion

Each minute at rest:

Alveolar ventilation: about 4 L/min

Perfusion (CO): about 5 L/min

V:Q ratio = 4/5 = 0.8 (overall)



UPRIGHT POSTURE

Ventilation (V) :

Base > Apex

Perfusion (Q) :

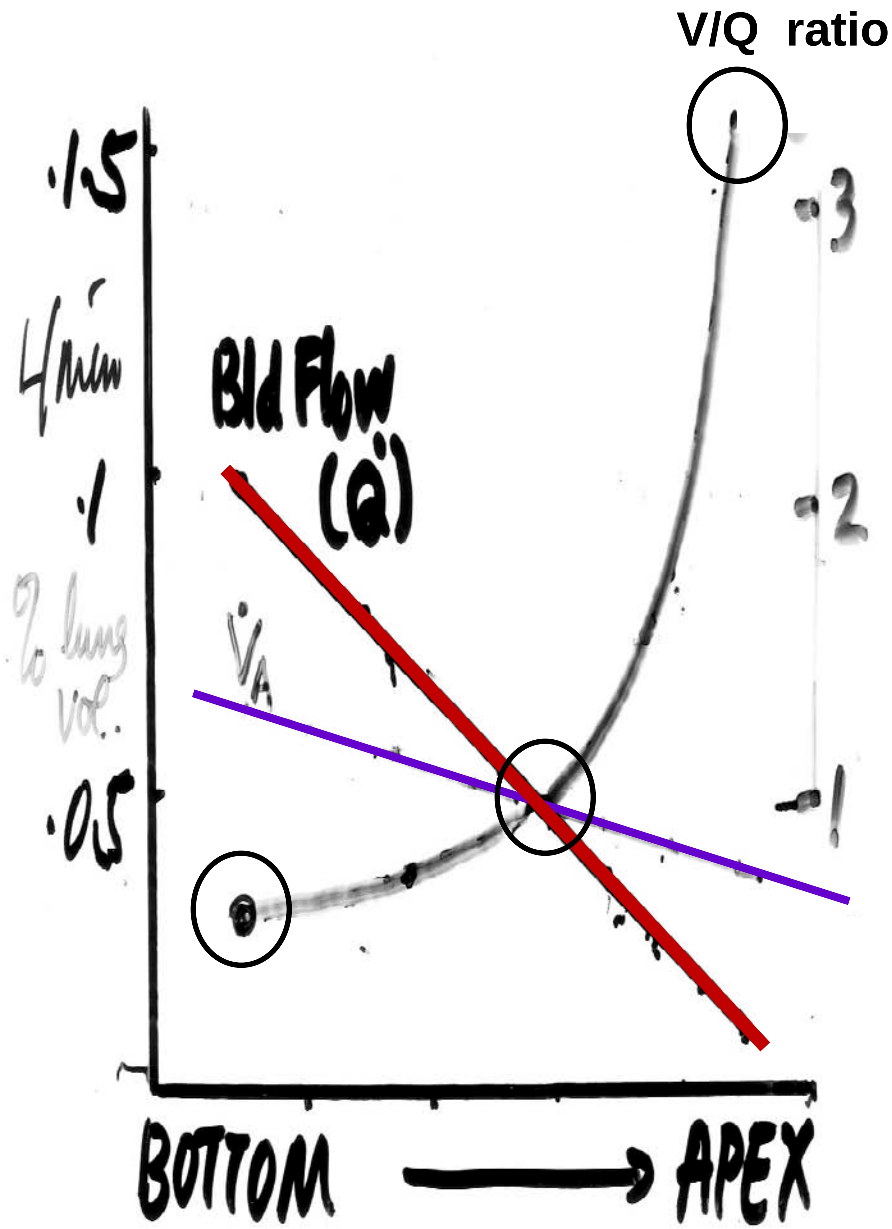
Base > Apex

V:Q

Base = 0.63

Apex = 3.3

Base < Apex



Gas exchange: absolute < V-Q ratio

Top

- V:Q ratio = 3.3
- OVERVENTILATED in relation to blood flow

WASTED VENTILATION

Base

- V:Q ratio = 0.63
- UNDERVENTILATED in relation to blood flow

WASTED PERFUSION

V-Q ratio

WASTED PERFUSION

(e.g. Base of Lungs)

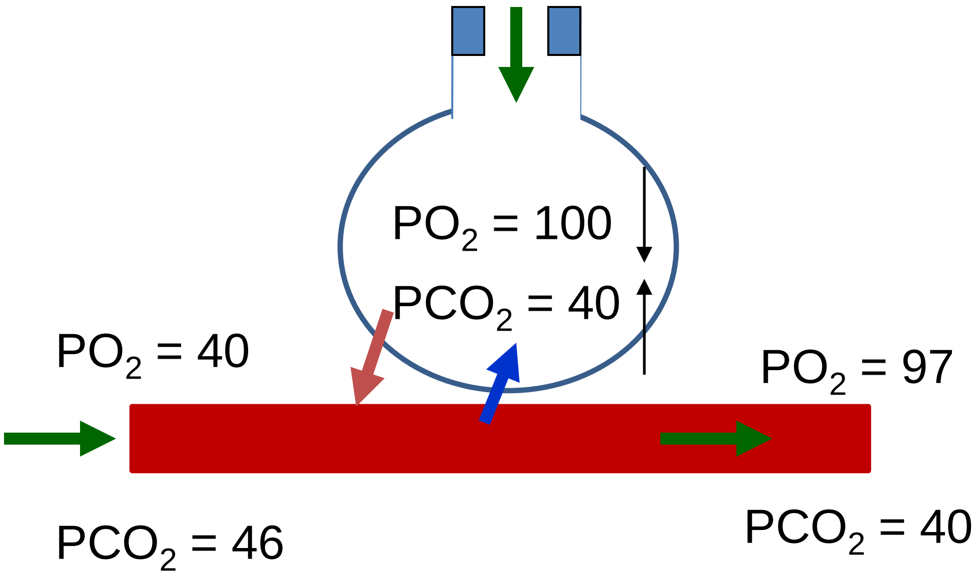
V < Q

Alveolar PO_2 = falls

Less O_2 delivered

Alveolar PCO_2 = rises

Less CO_2 expired



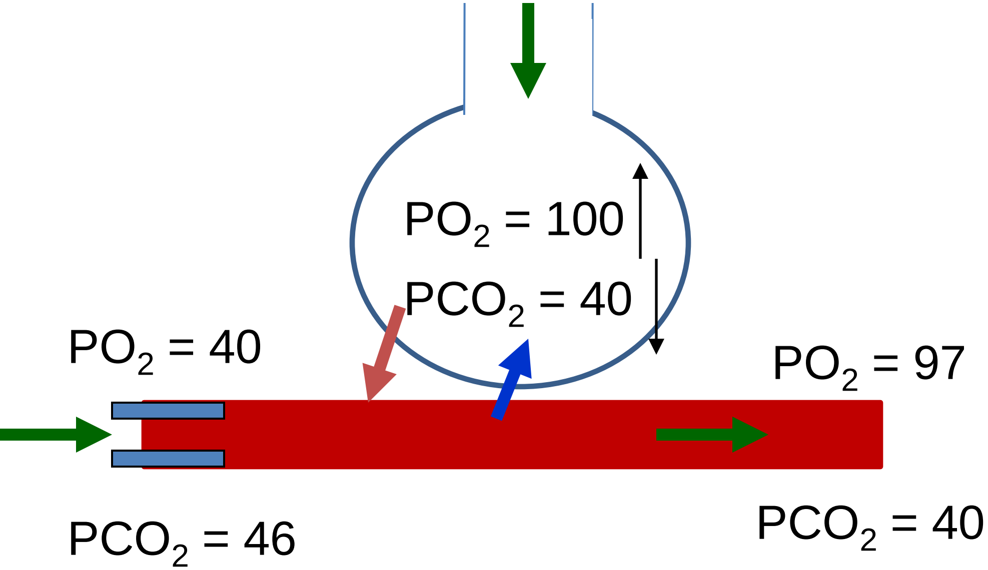
WASTED VENTILATION
(eg. Top of lungs)

V > Q

V-Q ratio

Alveolar PO_2 = rises — Less O_2 enters the bld

Alveolar PCO_2 = falls — Less CO_2 is delivered

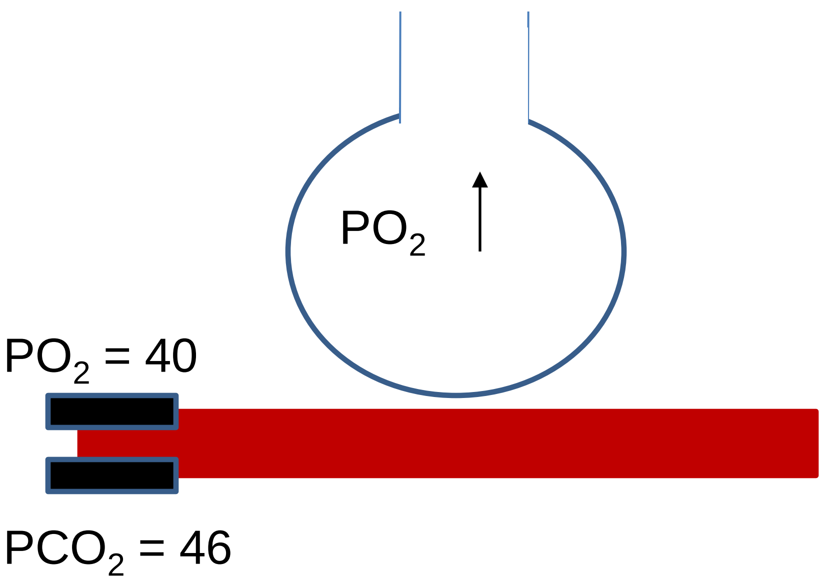


V-Q ratio

WASTED VENTILATION

Alveolar PO_2 = rises

Alveolar PCO_2 = falls



Top alveoli :

- High V:Q ratio

- Wasted ventilation

- Predilection of tuberculosis in the apex of the lungs

Normal lungs

Top

- V:Q ratio = 3.3
- OVERVENTILATED in relation to blood flow

- **WASTED VENTILATION**

BASE

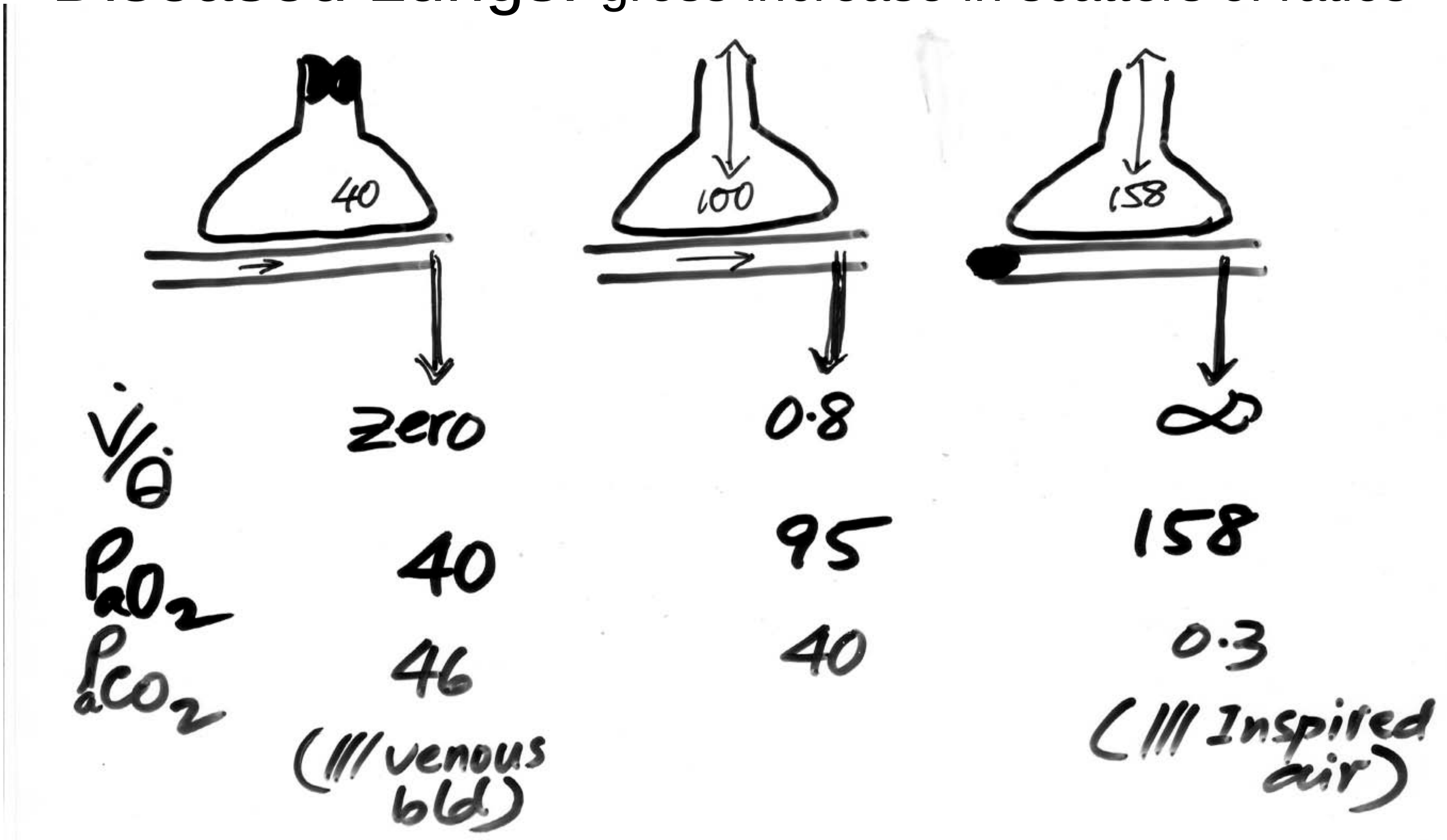
- V:Q ratio = 0.63
- UNDERVENTILATED in relation to blood flow

- **WASTED PERFUSION**

Magnitude of wastage

- Even in normal lungs: +
- Diseased lungs: +++

Diseased Lungs: gross increase in scatters of ratios



Mismatched or imbalance between V and Q

HYPOXIC HYPOXIA

UPRIGHT POSTURE

Ventilation (V) :

Base > Apex

Perfusion (Q) :

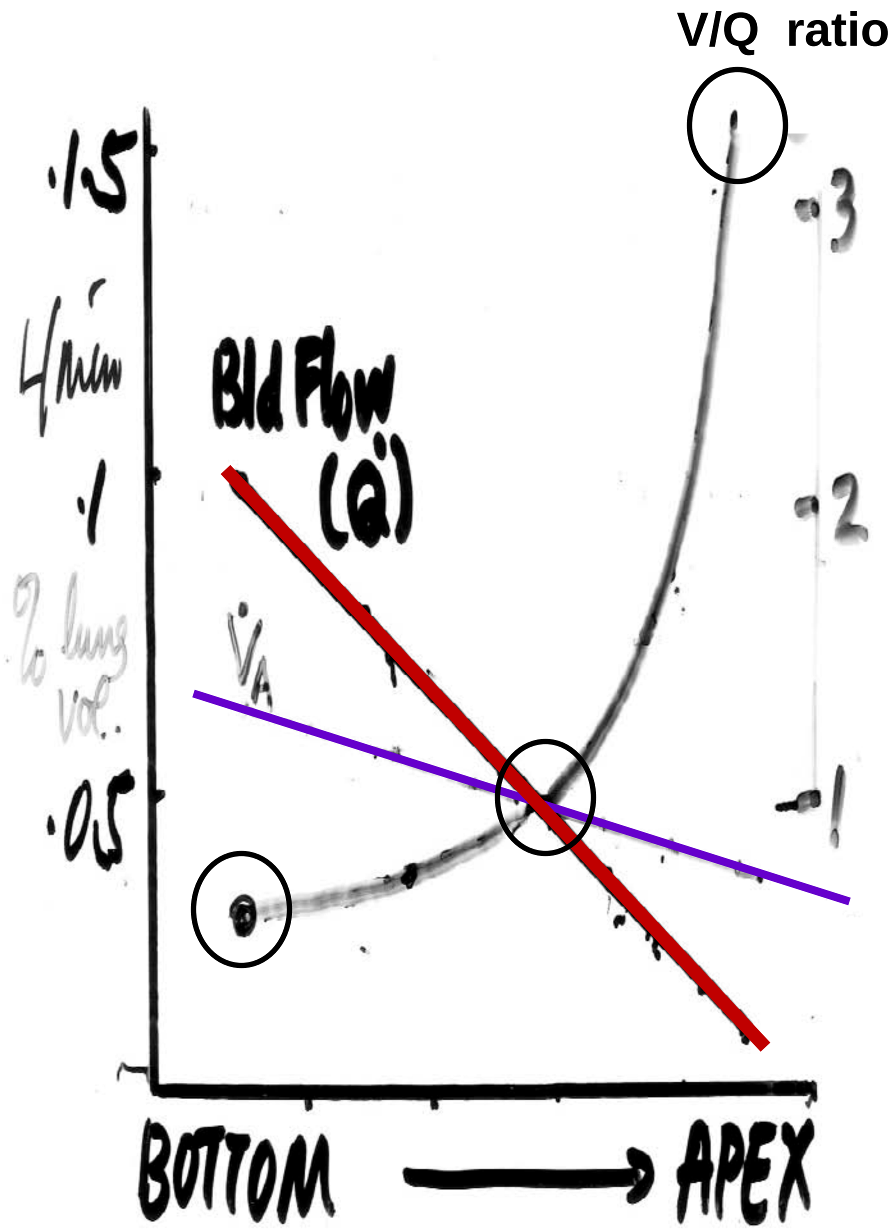
Base > Apex

V:Q

Base = 0.63

Apex = 3.3

Base < Apex

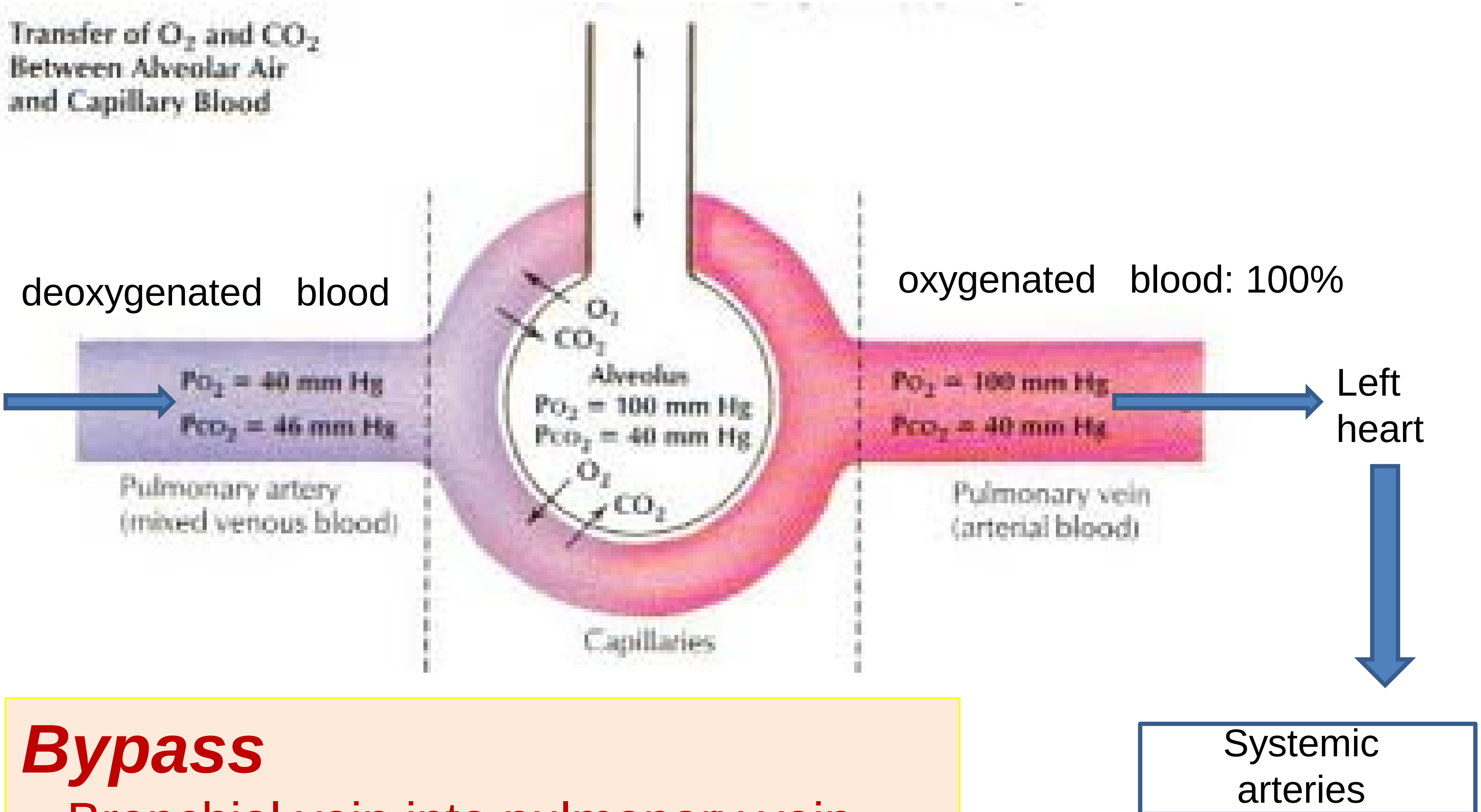


Physiologic Shunt

- Pulmonary arteries: deoxygenated blood

- Pulmonary veins: oxygenated blood

Physiologic Shunt



Bypass
- Bronchial vein into pulmonary vein
- Coronary arteries into chambers

Control of Pulmonary circulation

- Neural control: Sympathetic vasoconstrictor nerve fibres from cervical sym. ganglion
- Humoral control: pulmonary arterioles
  - NA: VC
  - AT II (angiotensin II): VC
  - Ach: VD
  - Isoproterenol: VD
- Humoral control: pulmonary venules
  - Serotonin, histamine, endotoxin

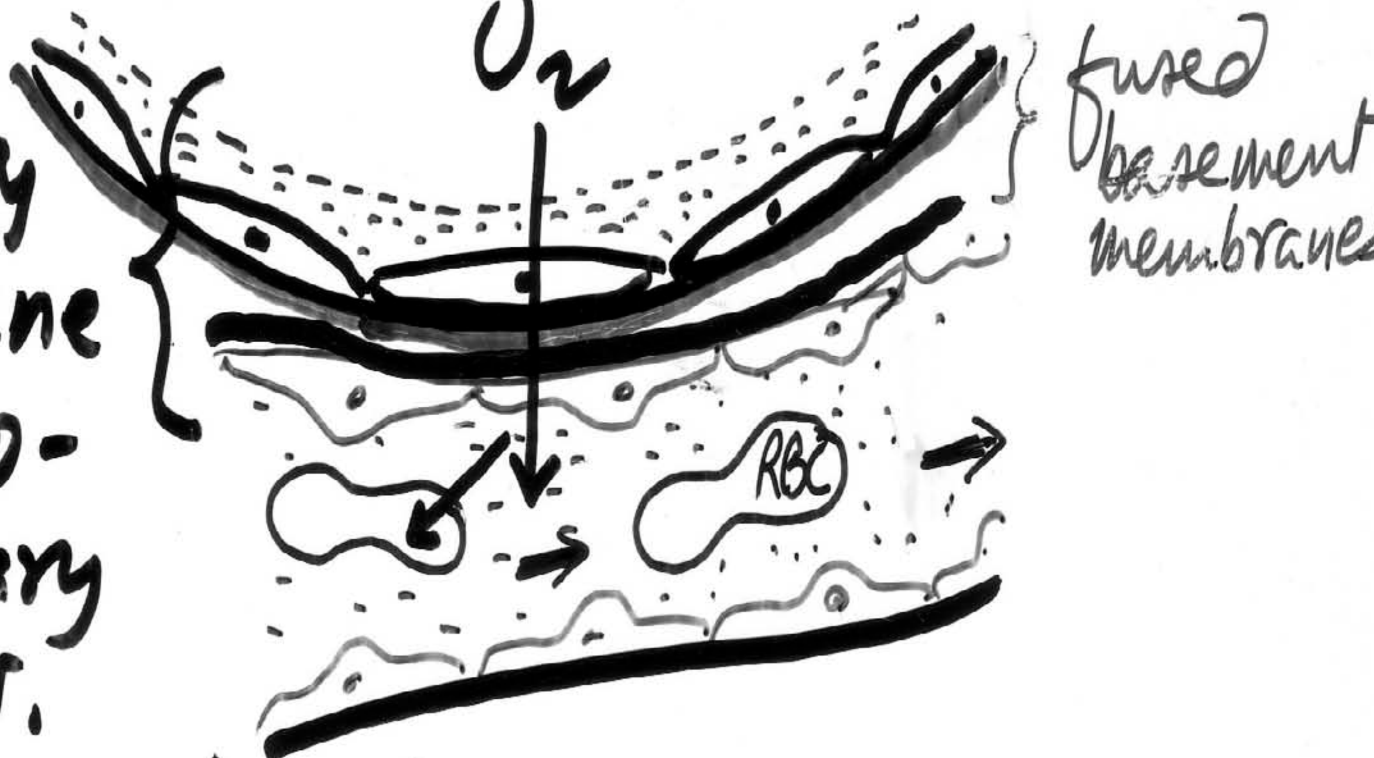
Local hypoxia and hypercapnia (VDM)

Pulmonary vasoconstriction

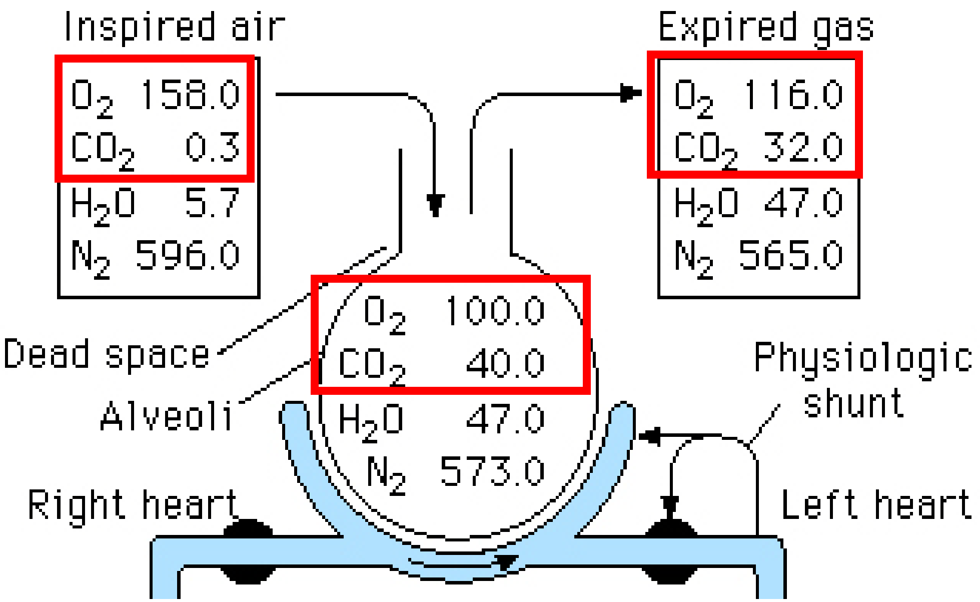
PULMONARY GAS TRANSFER

- Pulmonary membrane (Alveolar-capillary membrane)
- It is a very thin membrane across which O_2 and CO_2 diffuse.
- It consists of:
  1. Capillary endothelium
  2. Fused basement membranes of 1 and 3
  3. Alveolar epithelium
  4. A layer of thin film of fluid lining the alveoli

Pulmonary Membrane
= Alveolo-Capillary membr.
= blood-gas barrier



Ventilation

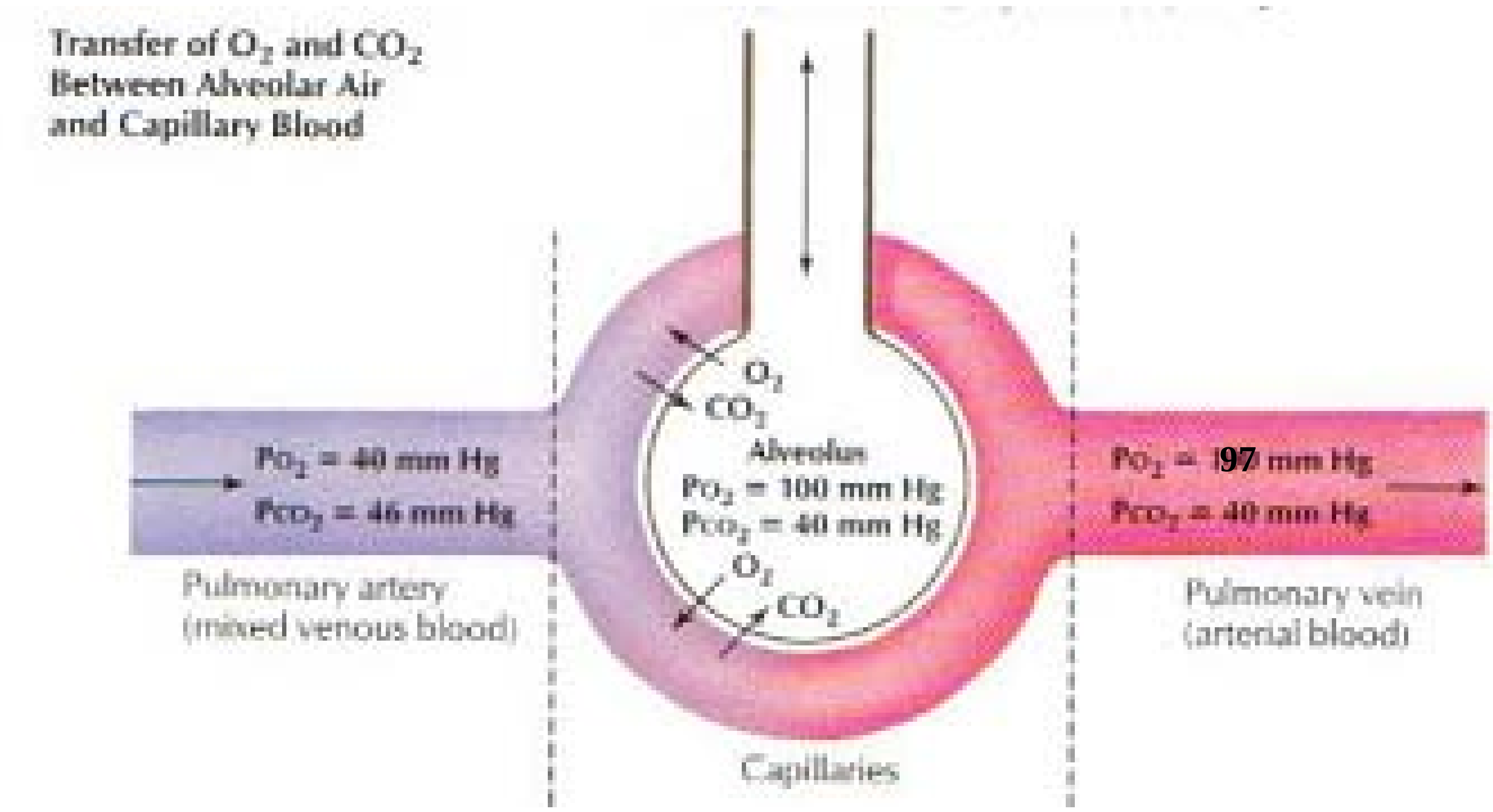


Inspired Air = 1 ATM (760 mmHg)

O_2 = 20.98%: 0.21 x 760 = 160 mmHg

CO_2 = 0.04%: 0.0004 x 760 = 0.3 mmHg

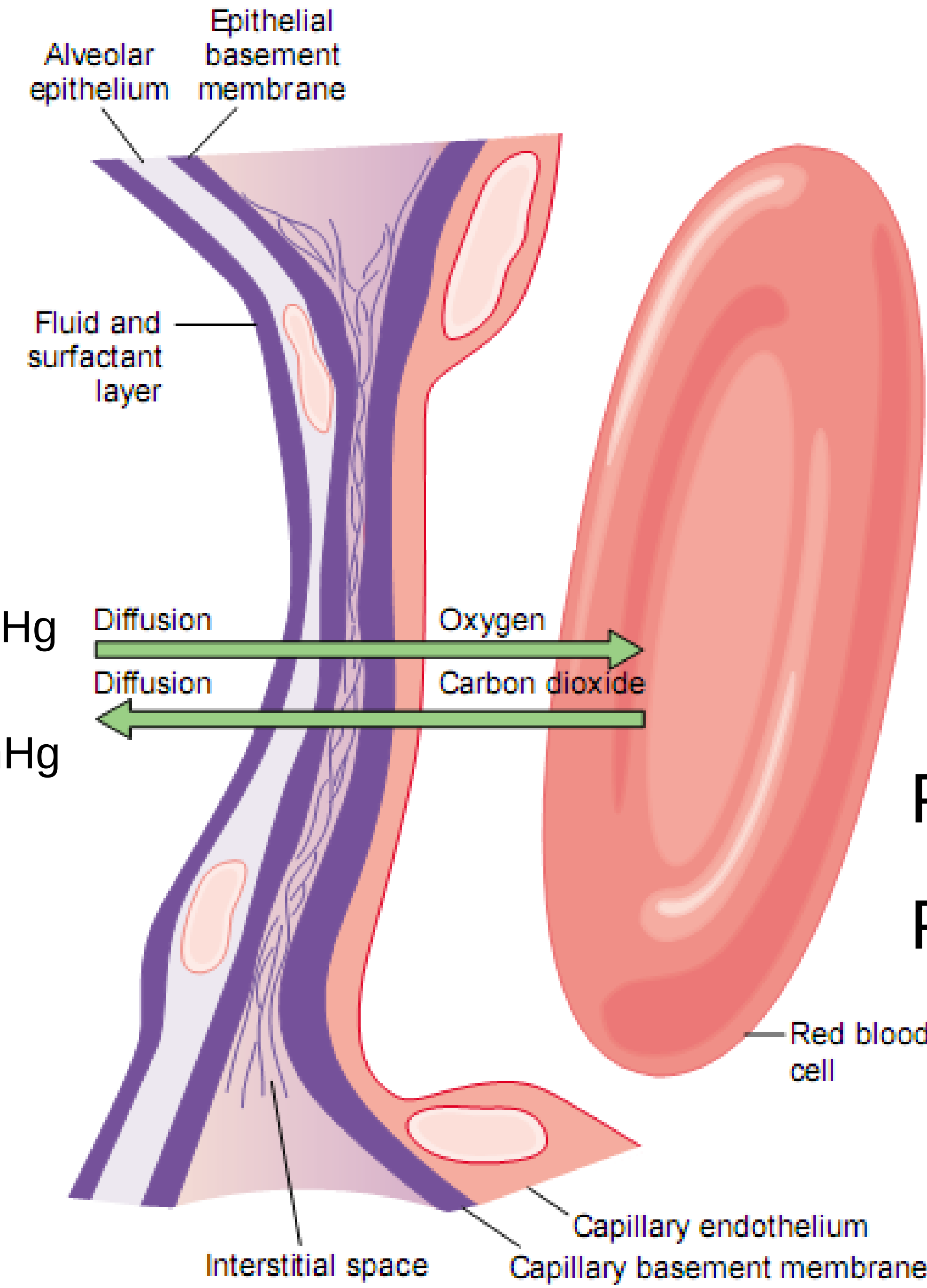
Pulmonary gas exchange (transfer)



Alveolus

$P_{O_2} = 100$ mmHg

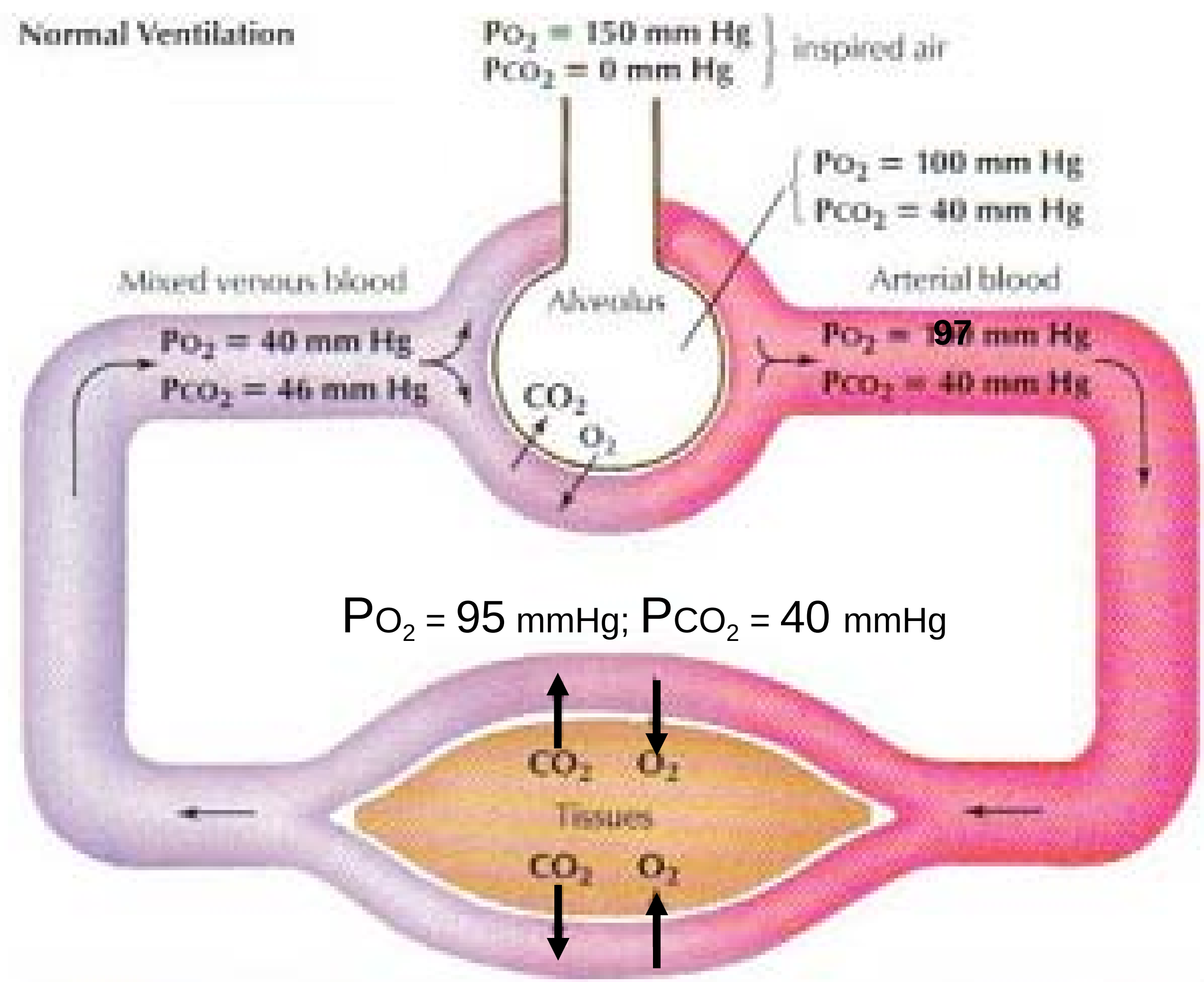
$P_{CO_2} = 40$ mmHg



capillary

$P_{O_2} = 40$ mmHg

$P_{CO_2} = 46$ mmHg



P_{O_2} = 95 mmHg;
P_{CO_2} = 40 mmHg

P_{O_2} = 40 mmHg

P_{CO_2} = 46 mmHg

Tissue gas exchange

Diffusing Capacity

- Diffusing capacity (a Transfer factor) is the amount of gas which crosses the alveolar membrane per minute per mmHg difference in partial pressure gradient between alveolus and blood in the pulmonary capillary.
- Normal values of diffusing capacity
- For O_2 : TO_2 = 20 - 30 ml/min/mm Hg
- For CO_2 : TCO_2 = 500 ml/min/mmHg

- DC is directly proportionate to **surface area** of A-C membrane and inversely proportionate to **thickness**

Factors affecting Gas Transfer

Gas diffusion is DIRECTLY proportionate to

- partial pressure gradient
- area of diffusion
- membrane permeability
- gas solubility
- amount of Hb
- rate of uptake of gas by Hb
- temperature (to a limit)

Factors affecting Gas Transfer

Gas diffusion is INDIRECTLY proportionate to

- molecular weight of the diffusing gas
- length of the diffusion path

  (eg. thickness of the alveolar membrane)

Gas transport

O_2 transport

- Forms: dissolved, combined with Hb (**oxyHb**)
- At rest: 250 ml of O_2 /min (from blood to tissues)

CO_2 transport

- Forms: dissolved, combined with Hb (carbamino compound), **HCO_3**
- At rest: 200 ml of CO_2 /min (from tissues to lungs)

Thank you