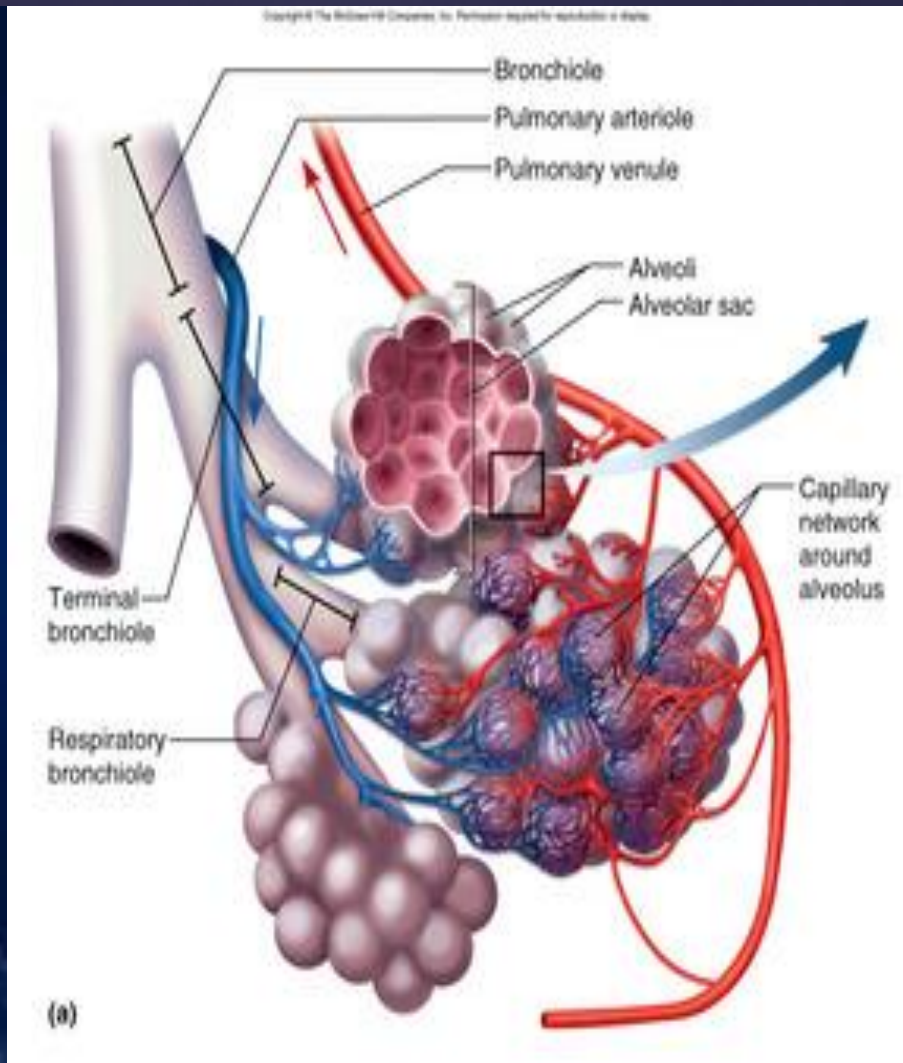
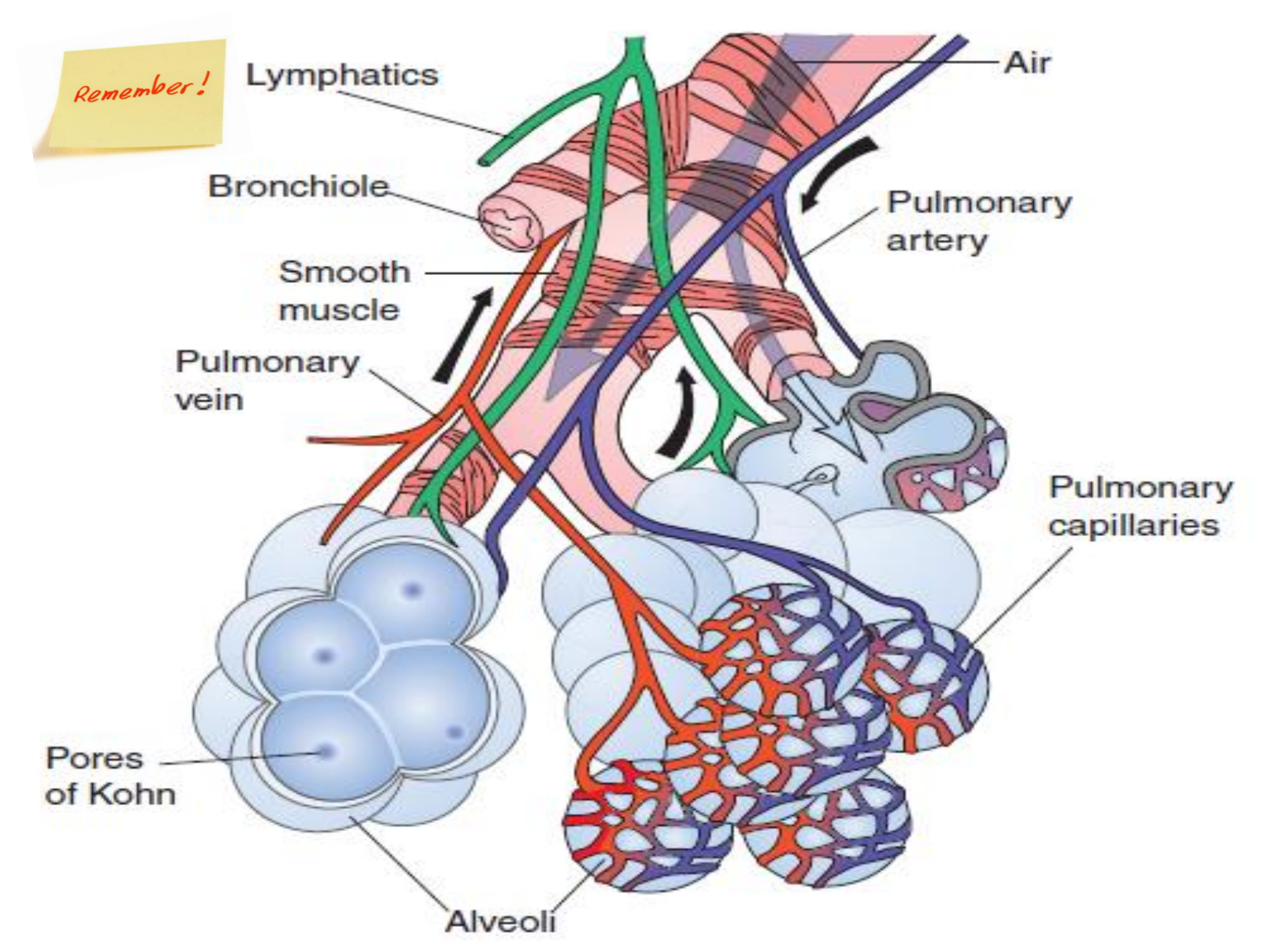
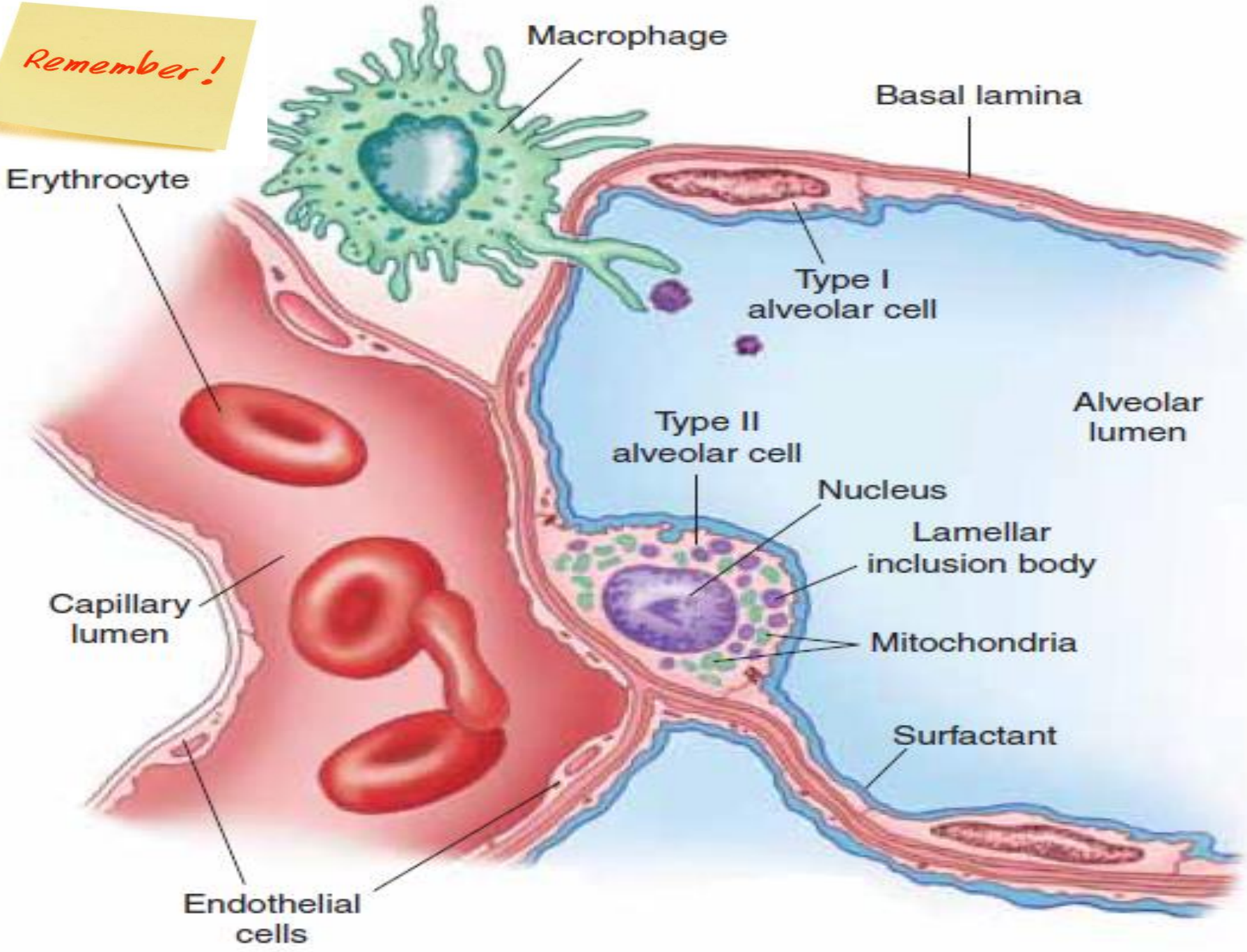
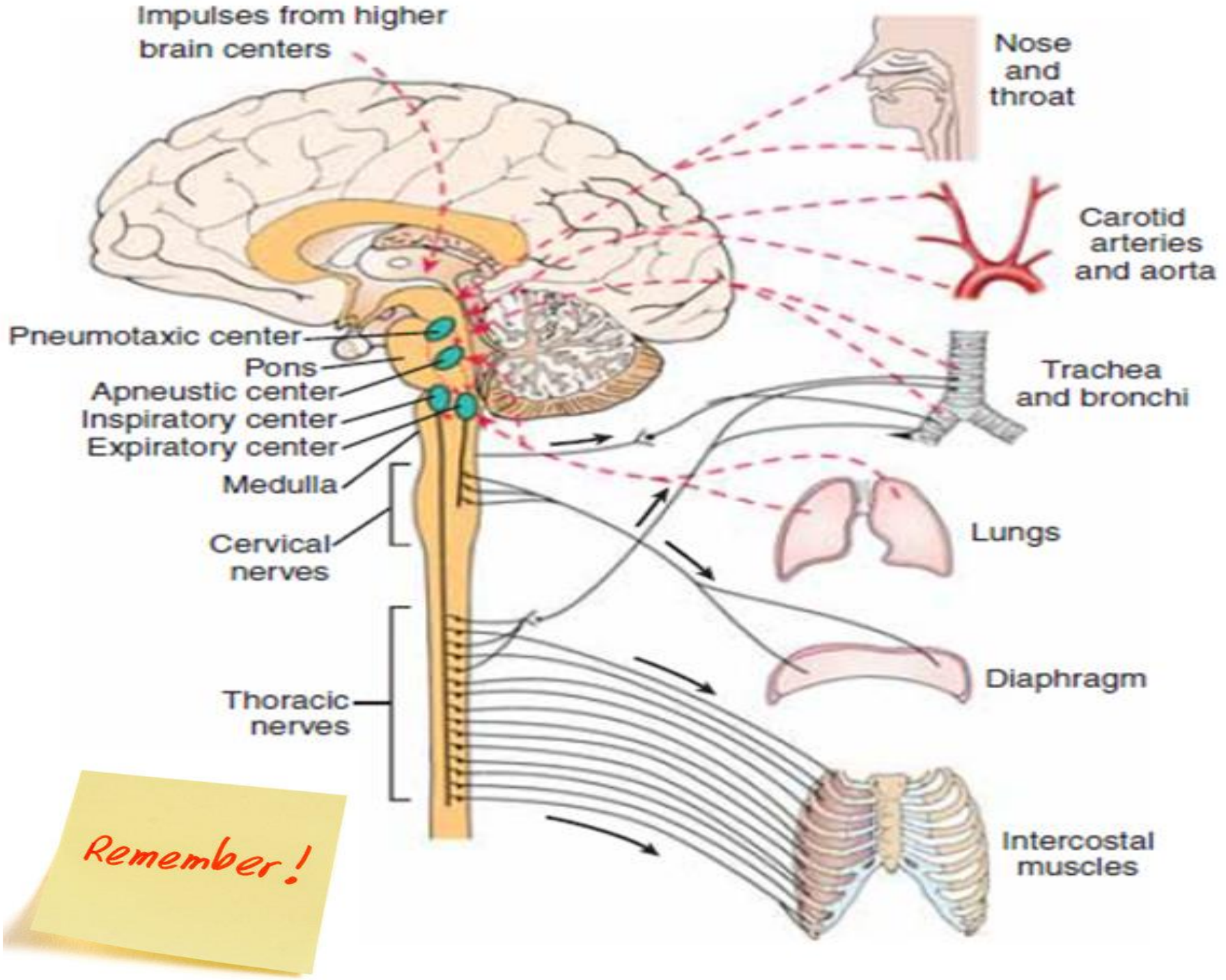
PATHOPHYSIOLOGY OF RESPIRATORY SYSTEM

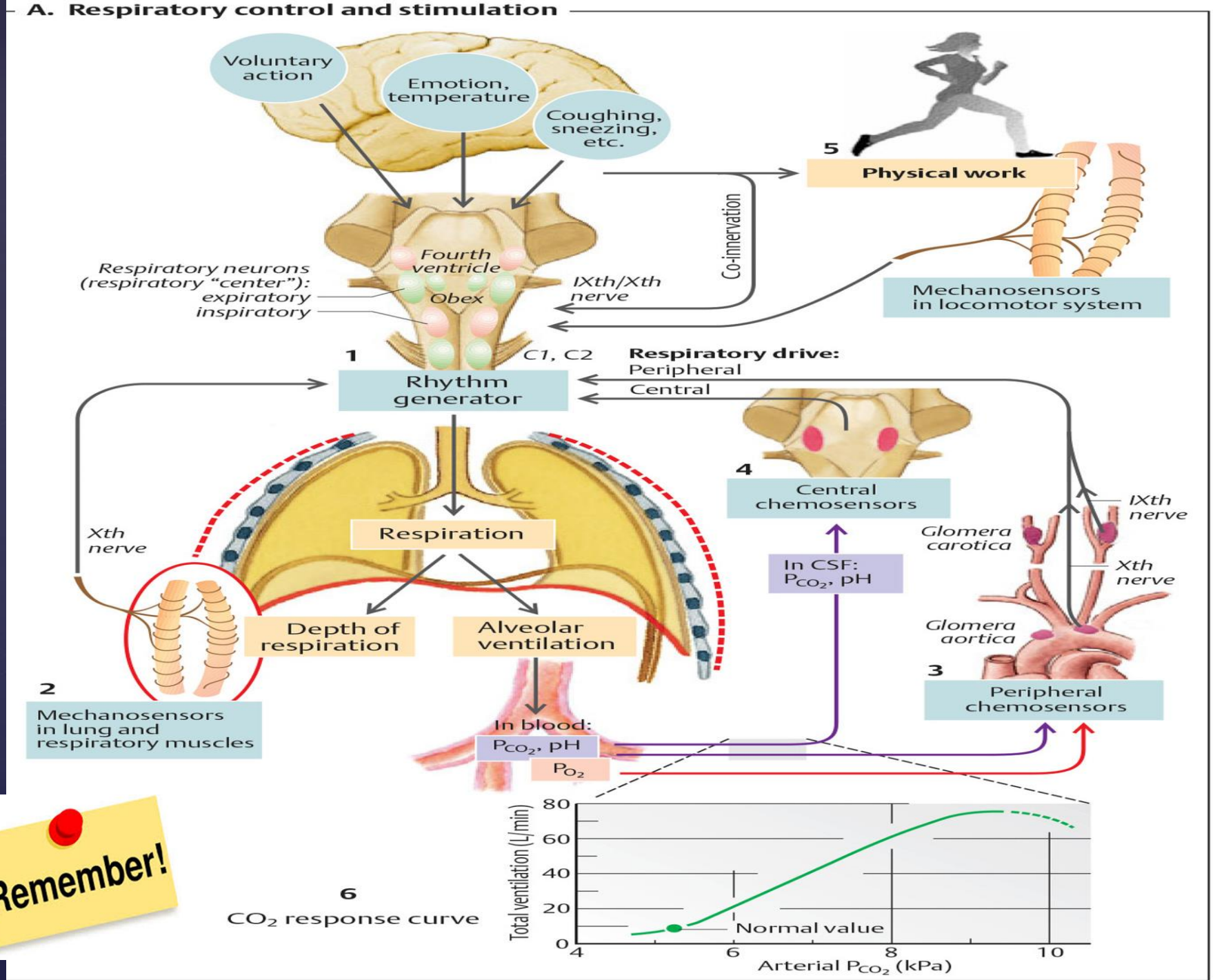



Remember!
Lymphatics
Air
Bronchiole
Pulmonary artery
Smooth muscle
Pulmonary vein
Pulmonary capillaries
Pores of Kohn
Alveoli

Remember!

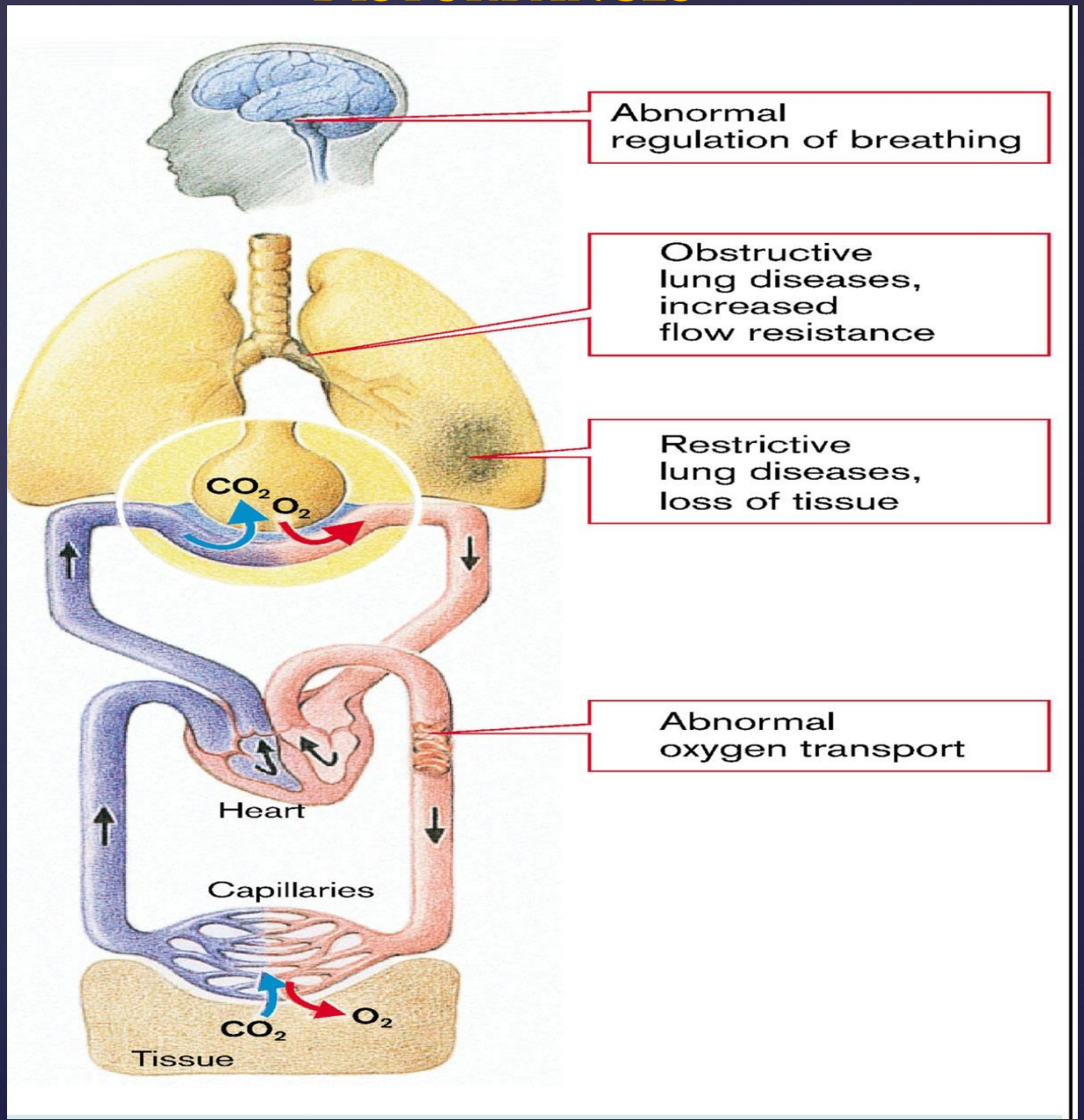

Macrophage
Basal lamina
Erythrocyte
Type I
alveolar cell
Alveolar
lumen
Type II
alveolar cell
Nucleus
Lamellar
inclusion body
Capillary
lumen
Mitochondria
Surfactant
Endothelial
cells

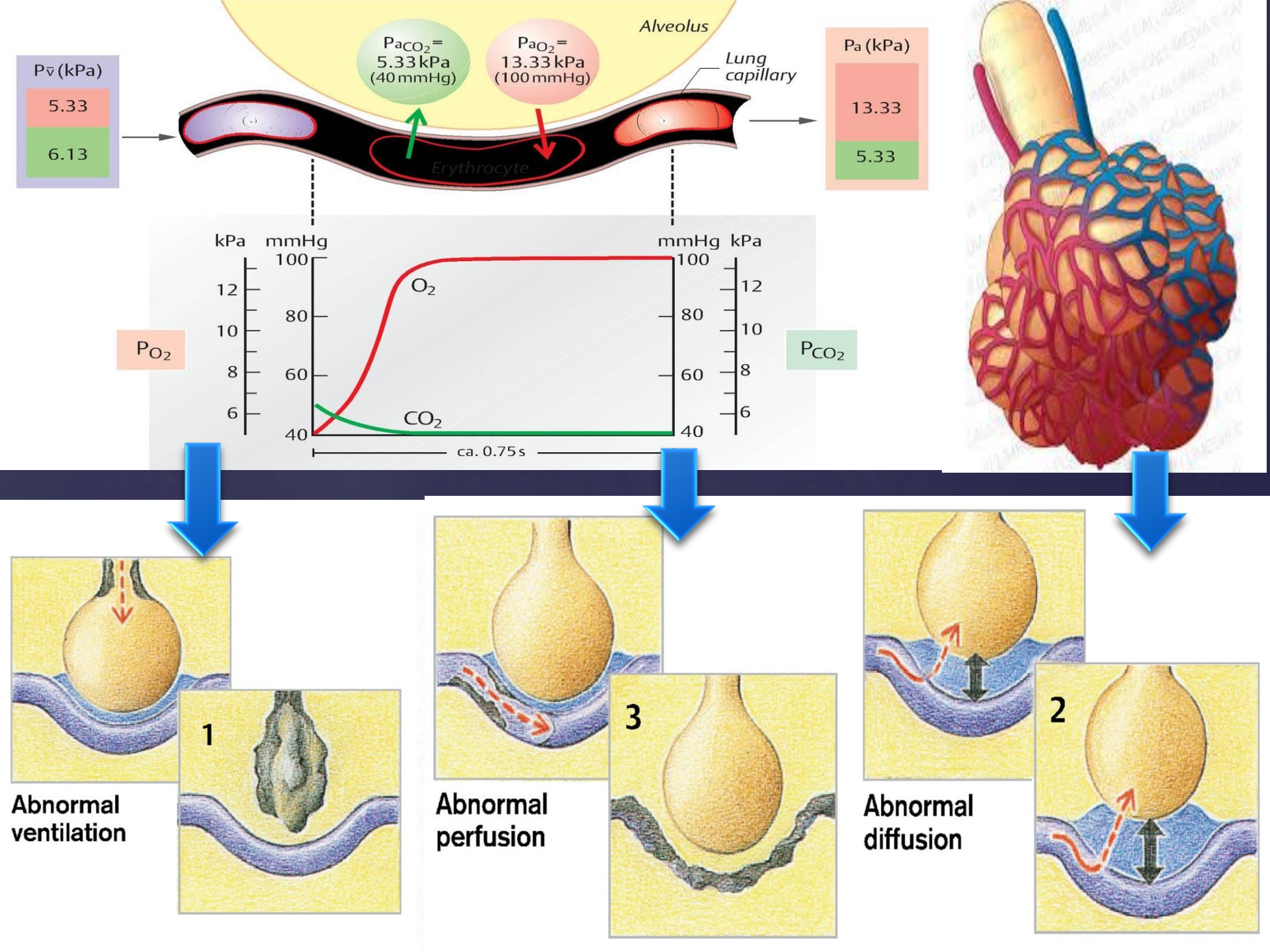

Impulses from higher brain centers
Nose and throat
Carotid arteries and aorta
Pneumotaxic center
Pons
Apneustic center
Inspiratory center
Expiratory center
Medulla
Trachea and bronchi
Cervical nerves
Lungs
Thoracic nerves
Diaphragm
Intercostal muscles
Remember!

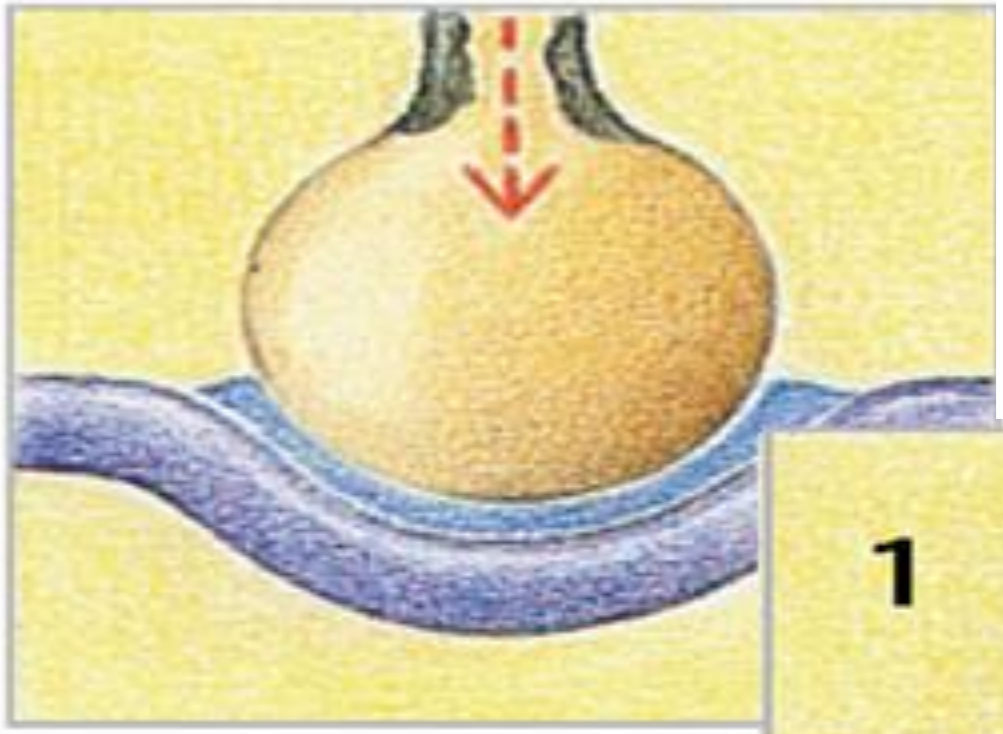

A. Respiratory control and stimulation
Voluntary action
Emotion, temperature
Coughing, sneezing, etc.
5
Physical work
Co-innervation
Fourth ventricle
Respiratory neurons (respiratory "center"):
expiratory
inspiratory
Obex
IXth/Xth nerve
Mechanosensors in locomotor system
1
C1, C2
Respiratory drive:
Peripheral
Central
Rhythm generator
4
Central chemosensors
Xth nerve
Respiration
In CSF: P_{CO_2}, pH
IXth nerve
Glomera carotica
Xth nerve
Glomera aortica
Depth of respiration
Alveolar ventilation
3
Peripheral chemosensors
2
Mechanosensors in lung and respiratory muscles
In blood:
P_{CO_2}, pH
P_{O_2}
Remember!
6
CO_2 response curve
Total ventilation (L/min)
80
60
40
20
0
Normal value
4
6
8
10
Arterial P_{CO_2} (kPa)

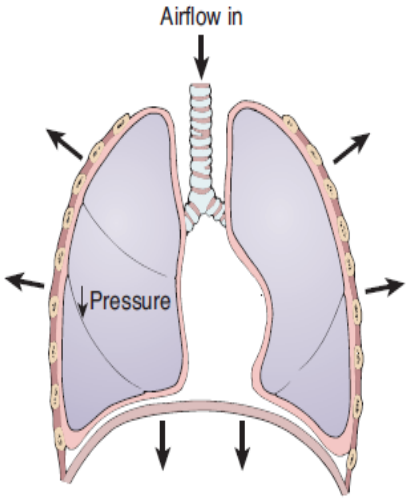
- DISORDERS OF ALVEOLAR VENTILATION
- DISORDERS OF LUNG PERFUSION
- DISORDERS OF LUNG DIFFUSION
- DISORDERS OF DISTRIBUTION IN THE LUNG

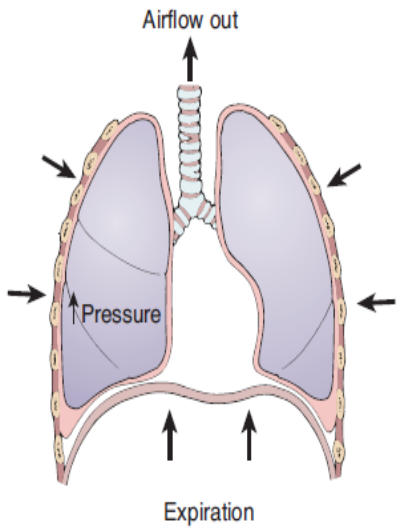
ETIOLOGICAL FACTORS INVOLVED IN RESPIRATORY DISTURBANCES

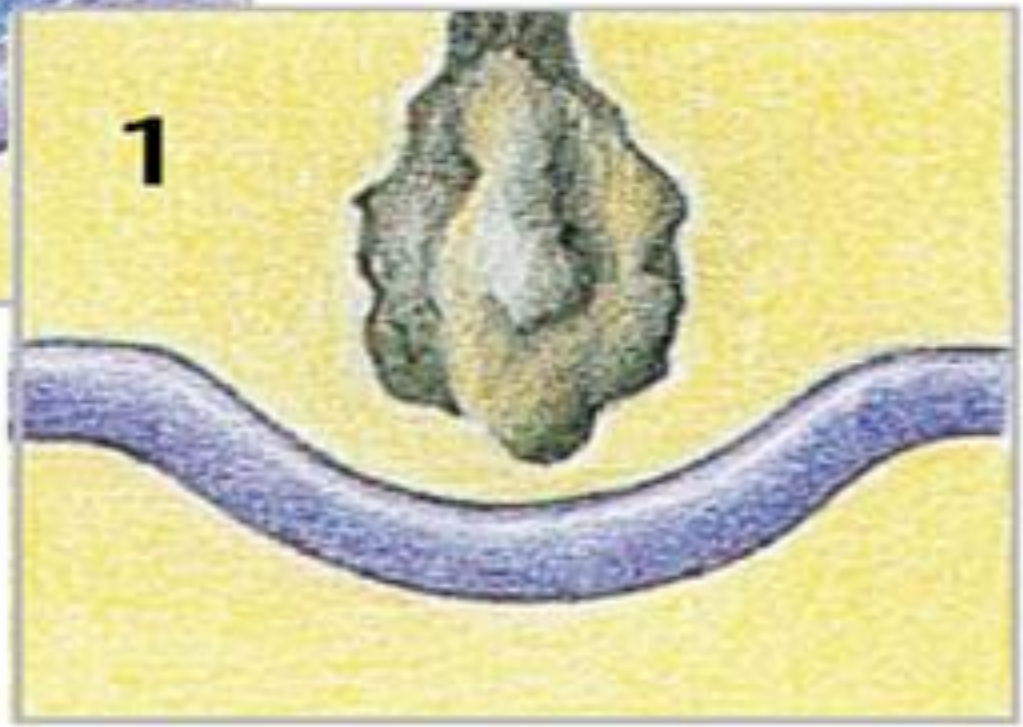



Alveolus
P_{aCO_2} = 5.33 kPa (40 mmHg)
P_{aO_2} = 13.33 kPa (100 mmHg)
Lung capillary
Erythrocyte
$P_{\bar{v}}$ (kPa)
5.33
6.13
Pa (kPa)
13.33
5.33
kPa
mmHg
100
80
60
40
12
10
8
6
O_2
CO_2
ca. 0.75 s
P_{O_2}
P_{CO_2}
1
Abnormal ventilation
3
Abnormal perfusion
2
Abnormal diffusion

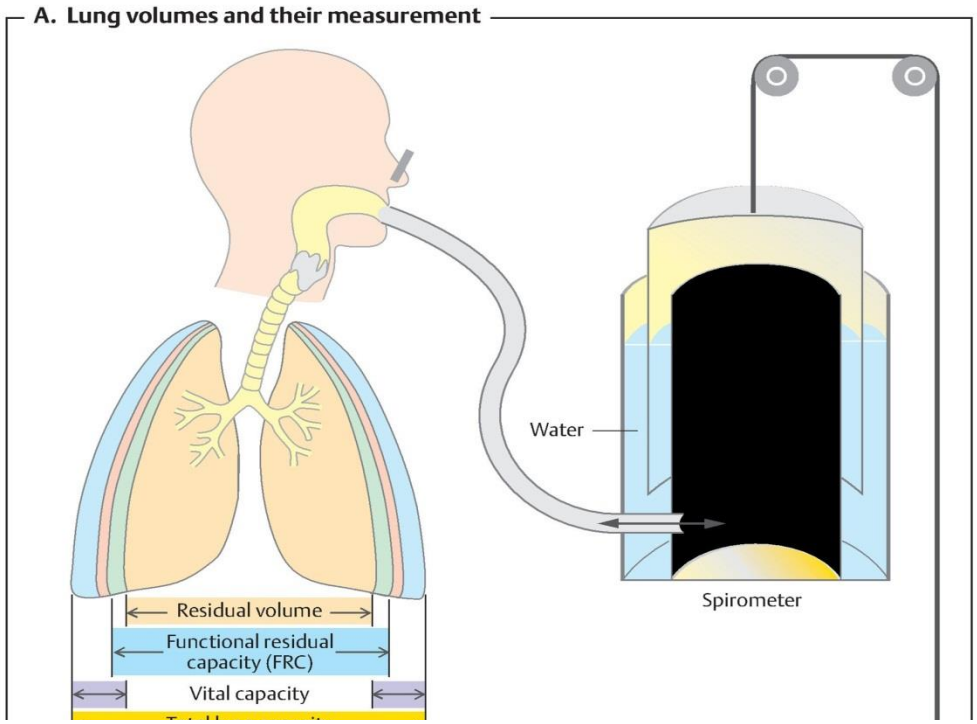








Abnormal ventilation



LUNG VOLUMES

VT (tidal volume) = 500 ml

IRV (inspiratory reserve volume) = 3200 ml

ERV (expiratory reserve volume) = 1200

RV (residual volume) =1200 ml

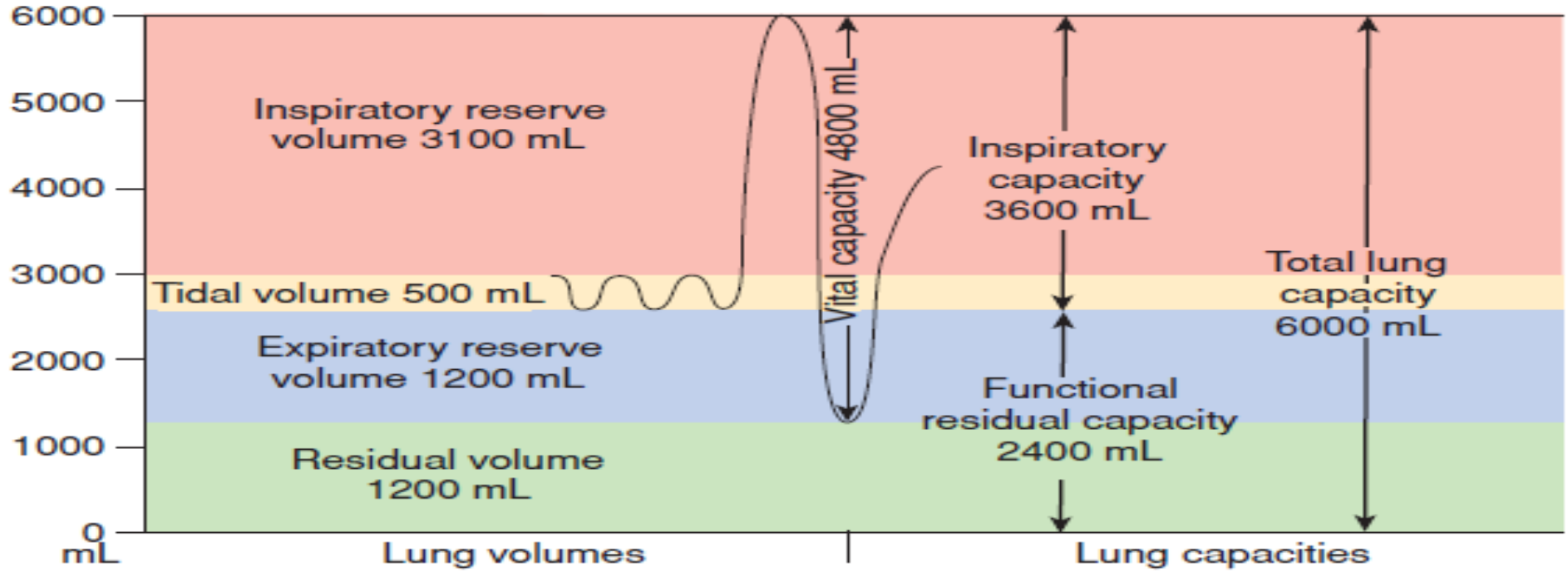
LUNG CAPACITIES

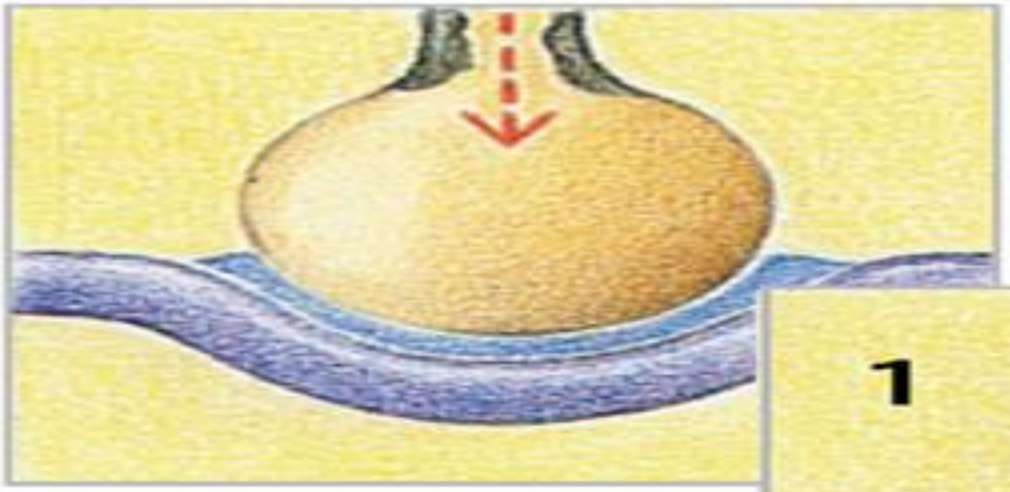
IC (inspiratory capacity) = VT+IRV =**3700 ml**

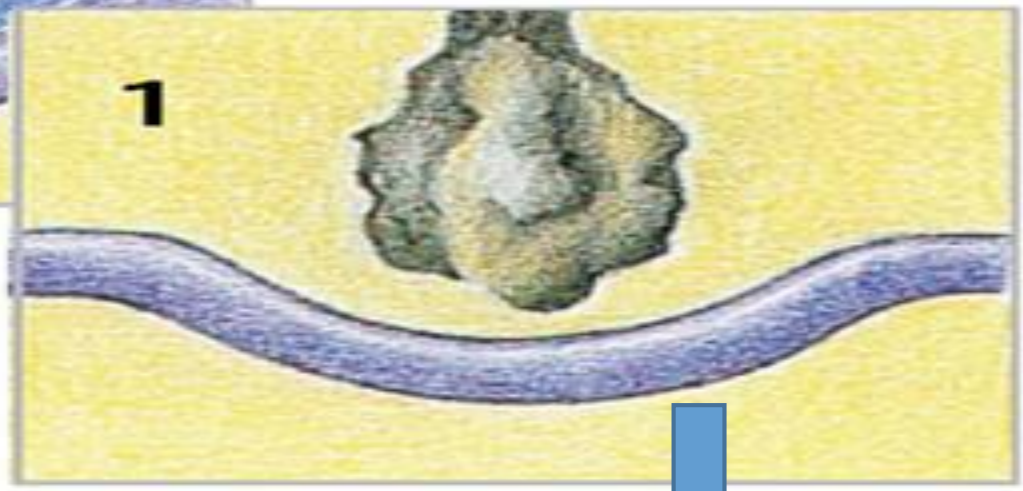
VC (vital capacity) = VT+IRV = ERV = 4700 – 5000 ml

FRC (functional residual capacity) = ERV + RV = 2700 ml

TLC (total lung capacity) = IC+ FRV = 6000 ml







Abnormal ventilation

Hyperventilation

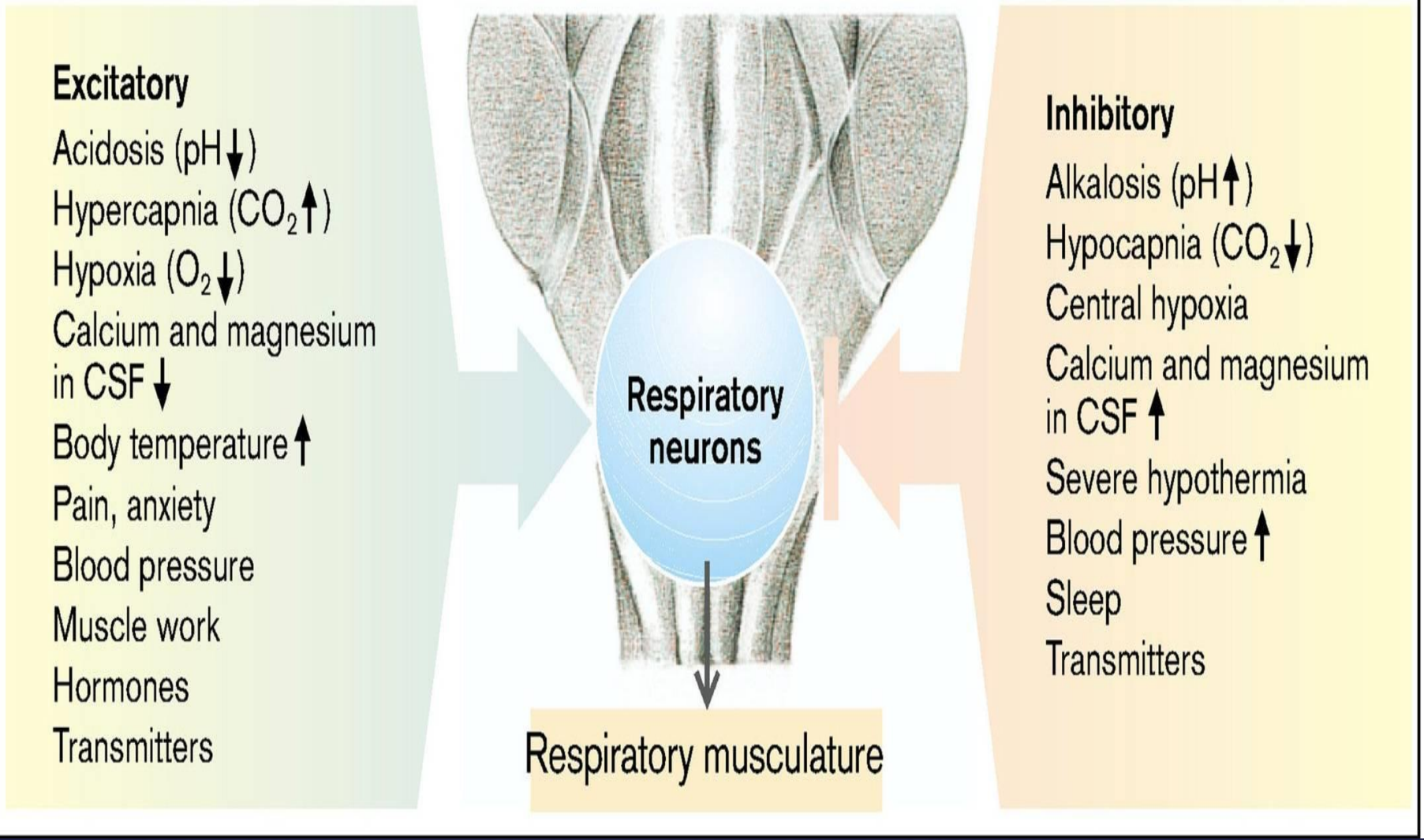
Physical effort
Acidosis
Inappropriate hyperreactivity of the respiratory centre

Hypoventilation

Damage of the respiratory centre
Disease of the respiratory muscles
Disturbances of neuromuscular transmission
Reduced thoracic mobility
Diseases of pleura
Restrictive lung diseases
Obstructive lung diseases

CENTRAL DISTURBANCES OF VENTILATION

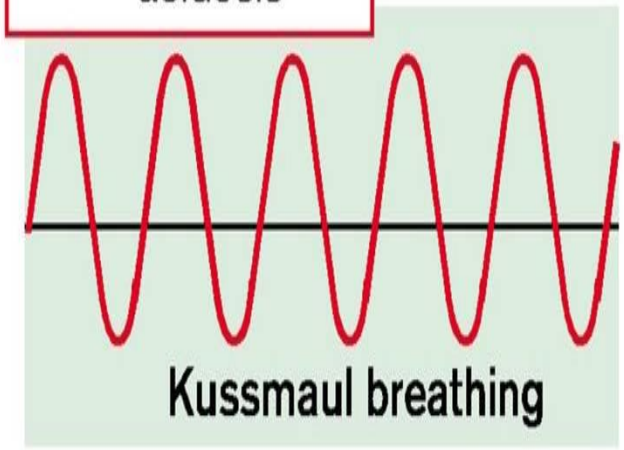
A. Modulators of Respiratory Neurons



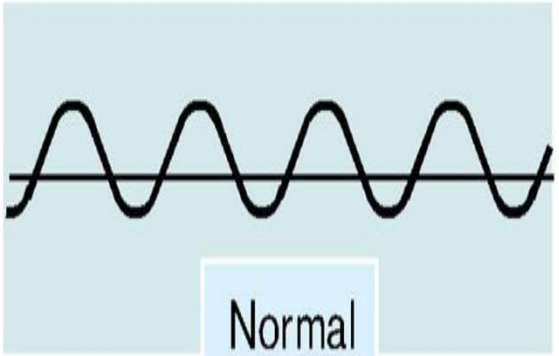
C. Pathological Patterns of Breathing

e.g. Metabolic acidosis

1



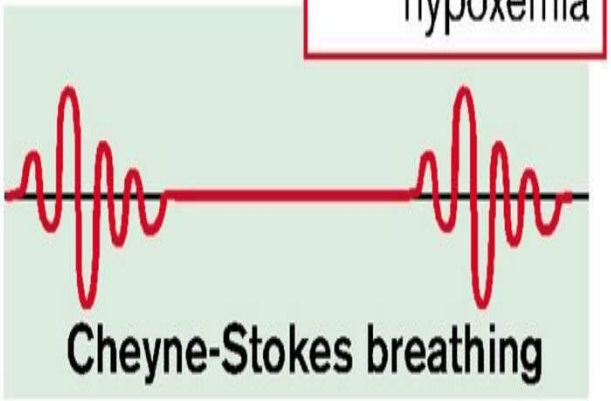
Kussmaul breathing



Normal

2

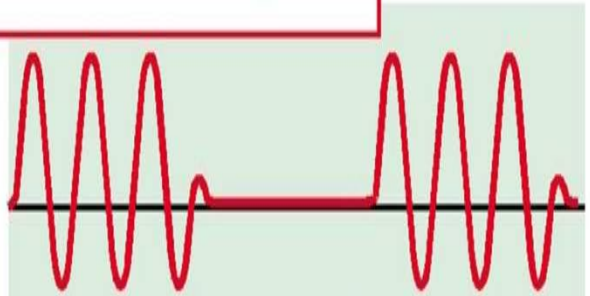
e.g. Sleep, drugs, hypoxemia



Cheyne-Stokes breathing

Neurons damaged

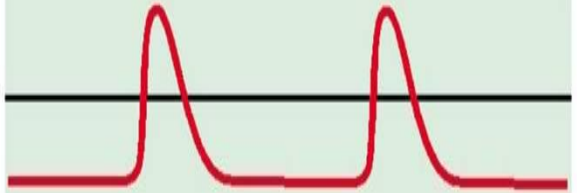
3



Biot breathing

4

Severely abnormal regulation

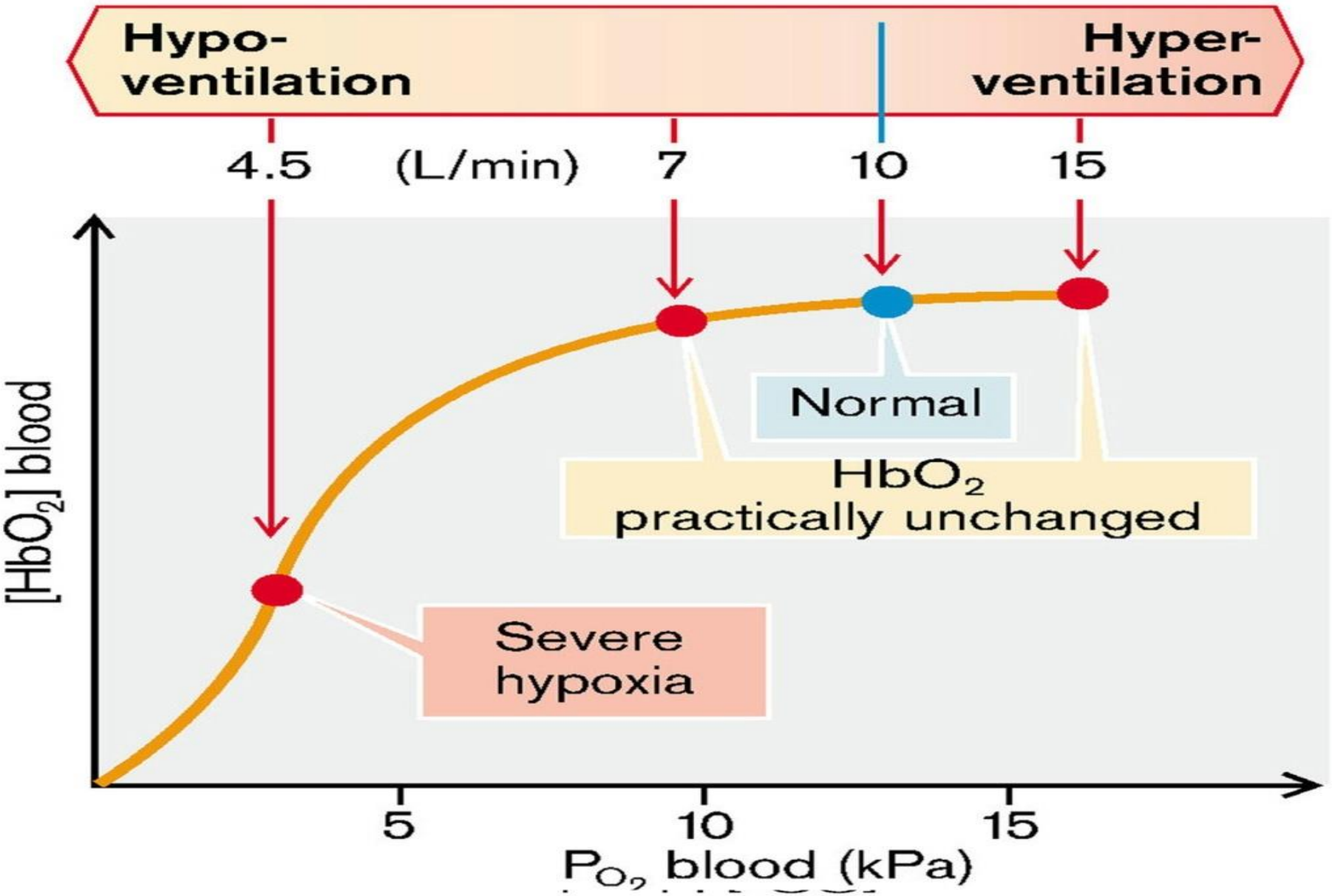


Gasping

PaO2 – pressure of O2 in the arterial blood = 100 mmHg

HYPOXEMIA

HYPEROXEMIA



HYPOXEMIA MANIFESTATIONS

RELATED TO DYSFUNCTION OF VITAL ORGANS

Mild hypoxemia produces few manifestations. There may be slight impairment of mental performance and visual acuity and sometimes hyperventilation;

Severe hypoxemia may produce personality changes, restlessness, agitated or combative behavior, uncoordinated muscle movements, euphoria, impaired judgment, delirium, and eventually, stupor and coma.

Profound hypoxemia can cause convulsions, retinal hemorrhages, and permanent brain damage. Severe persistent hypoxemia leads to paralysis of the respiratory centre and finally to arrest of ventilation – ***apnea***

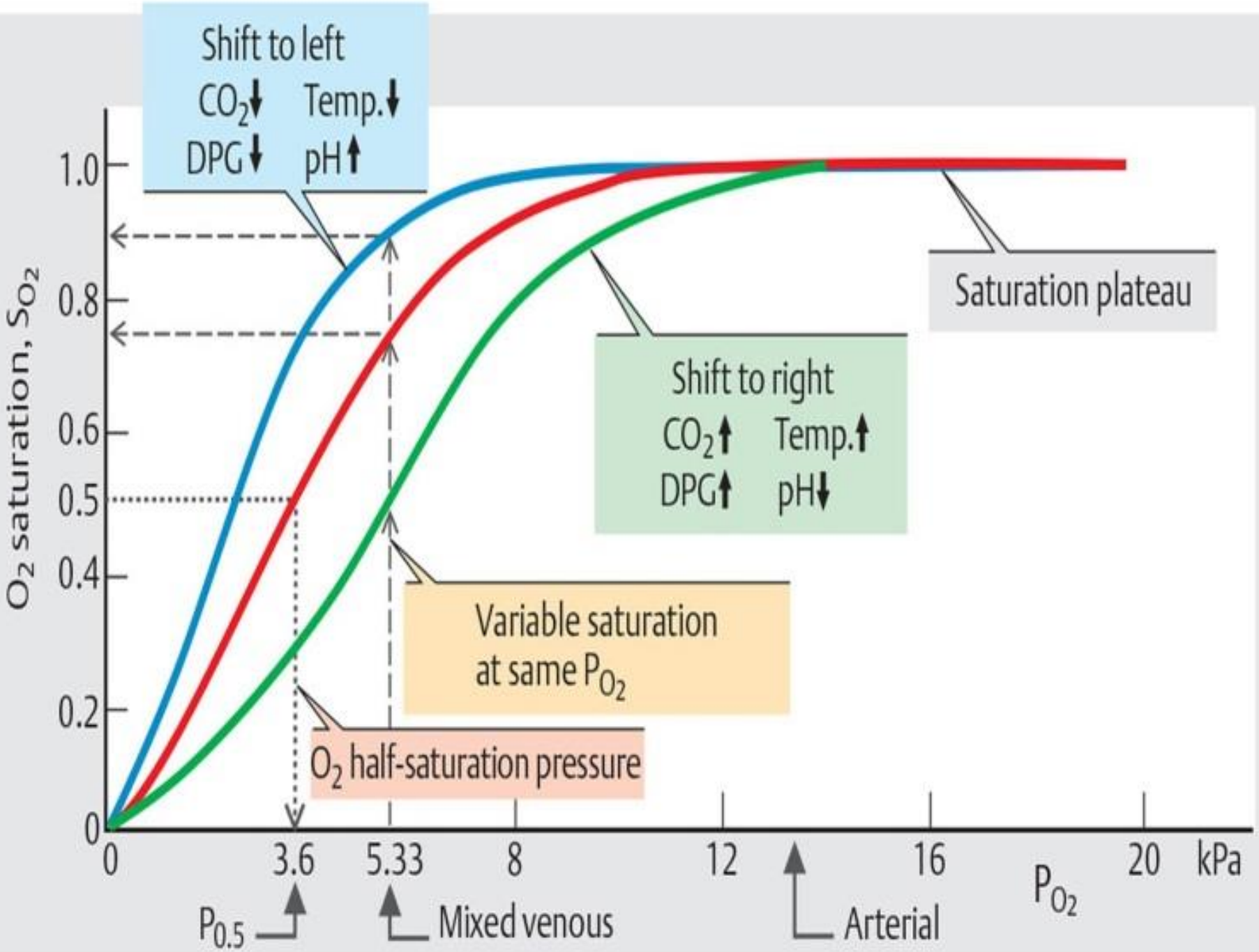
RELATED TO ACTIVATION OF COMPENSATORY REACTION

Recruitment of sympathetic nervous system compensatory mechanisms produces an increase in heart rate, peripheral vasoconstriction and a mild increase in blood pressure;

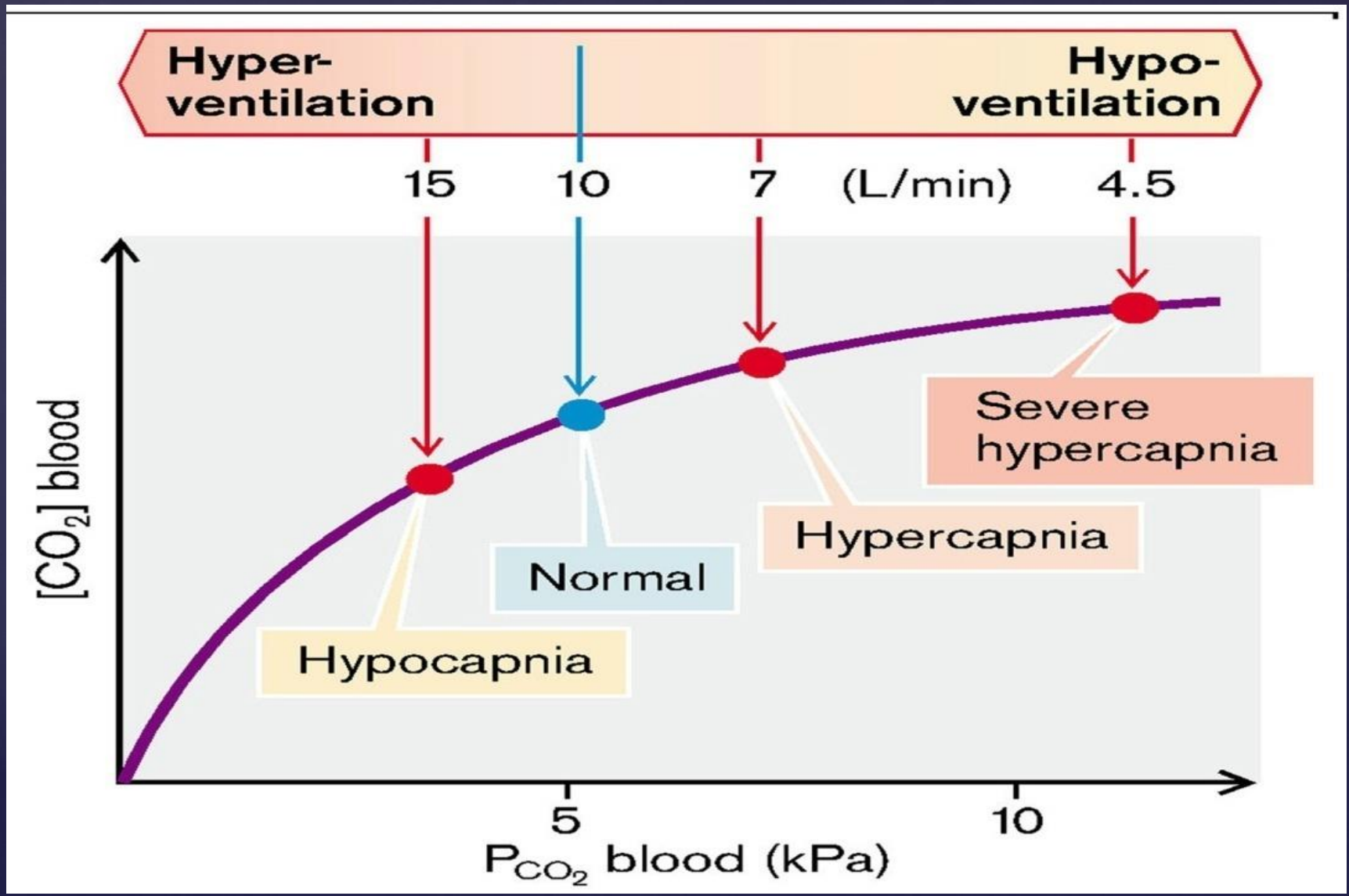
Hyperventilation results from the hypoxic stimulation of the chemoreceptors.

Increased production of red blood cells results from the release of erythropoietin from the kidneys in response to hypoxia;

Shift to the right in the oxygen dissociation curve as a means of increasing oxygen release to the tissues.

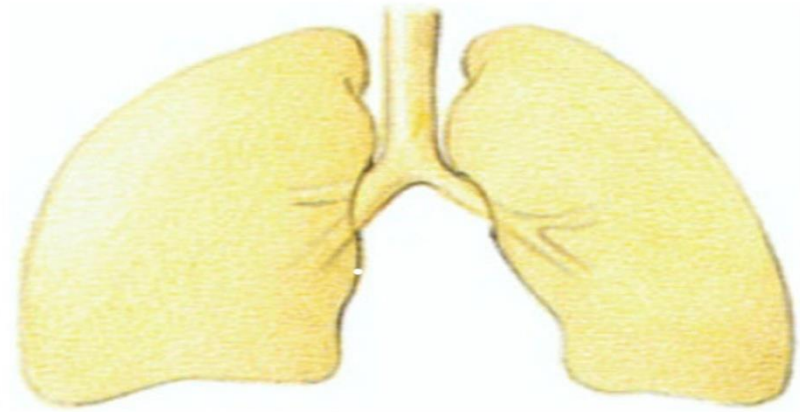

Shift to left
CO_2↓ Temp.↓
DPG↓ pH↑
Saturation plateau
Shift to right
CO_2↑ Temp.↑
DPG↑ pH↓
Variable saturation at same P_{O_2}
O_2 half-saturation pressure
O_2 saturation, S_{O_2}
1.0
0.8
0.6
0.5
0.4
0.2
0
0
3.6
5.33
8
12
16
20
kPa
P_{O_2}
$P_{0.5}$
Mixed venous
Arterial

CO_2 the most important parameter of ventilation.
$PaCO_2$ – pressure of CO_2 in the arterial blood = 40 mmHg
HYPERCAPNIA = $PaCO_2$ > 46 mmHg
HYPOCAPNIA = $PaCO_2$ < 40 mmHg

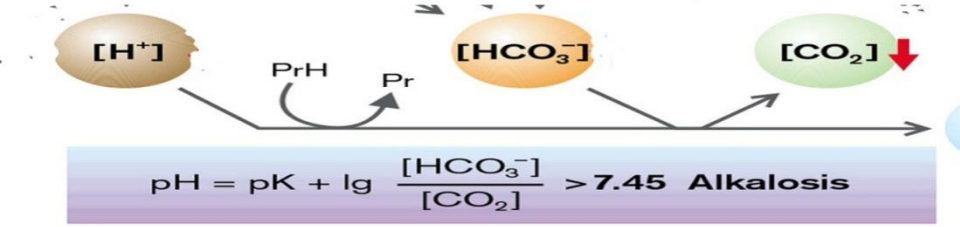


pH 7,35 - 7,45

Hyperventilation

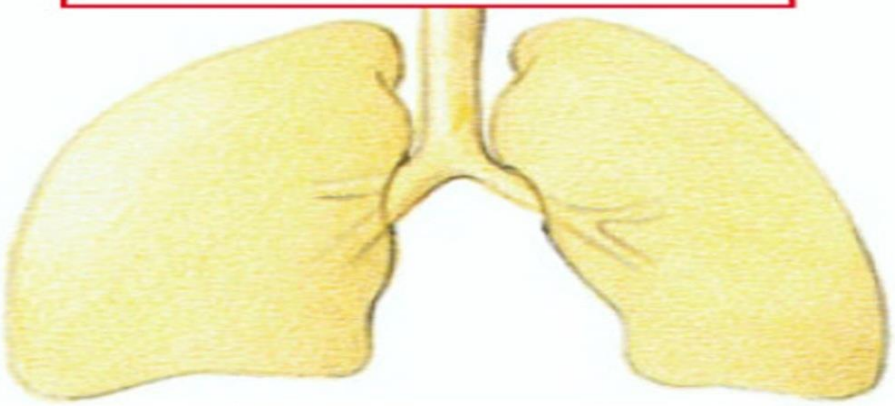


CO_2 output with expiration ↑↑

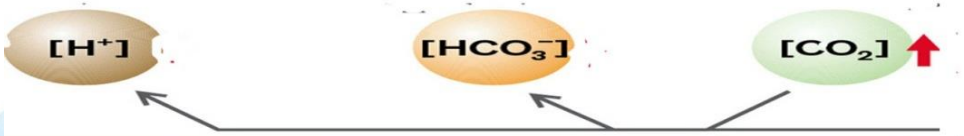


$$pH = pK + \lg \frac{[HCO_3^-]}{[CO_2]} > 7.45 \text{ Alkalosis}$$

Hypoventilation



CO_2 output with expiration ↓↓



$$pH = pK + \log \frac{[HCO_3^-]}{[CO_2]} < 7.35 \text{ Acidosis}$$

CYANOSIS

Represents bluish discoloration of the skin and mucous membrane that result from an excessive concentration of reduced or deoxygenated hemoglobin in the small blood vessels.

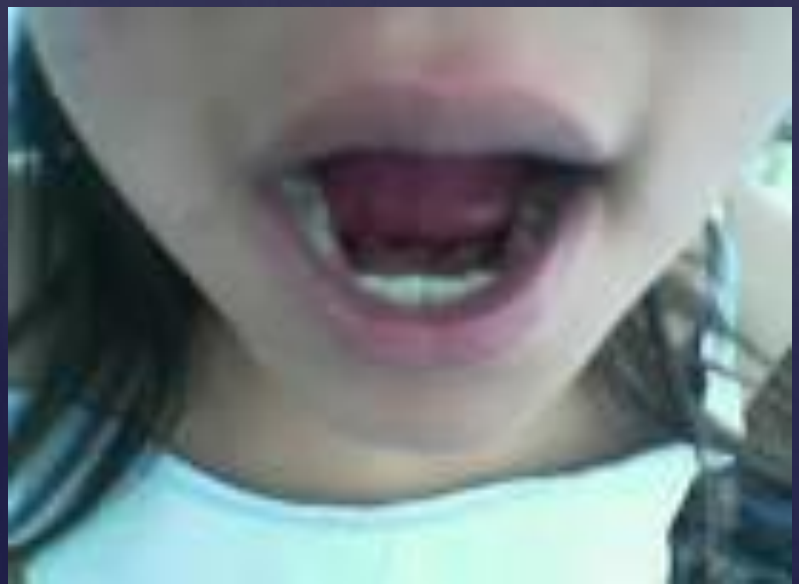
The degree of cyanosis is influenced by amount of cutaneous pigment, skin thickness and the state of cutaneous capillaries.

Persons with anemia are less prone to develop cyanosis (they have less hemoglobin to deoxygenate). On the contrary, persons with high hemoglobin level, as in case of polycythemia, may be cyanotic without being hypoxic.

CYANOSIS

CENTRAL

Evident in the tongue and lips. Caused by increased amount of deoxygenated hemoglobin or abnormal hemoglobin derivatives in the arterial blood (methemoglobin).



PERIPHERAL

Occurs in the extremities and on the tip of the nose and ears. Caused by slowing of blood flow to an area of the body, with increased extraction of oxygen from the blood. Results from vasoconstriction and reduced peripheral blood flow as in cold exposure, shock, heart failure or peripheral vascular disease.

DYSPNEA

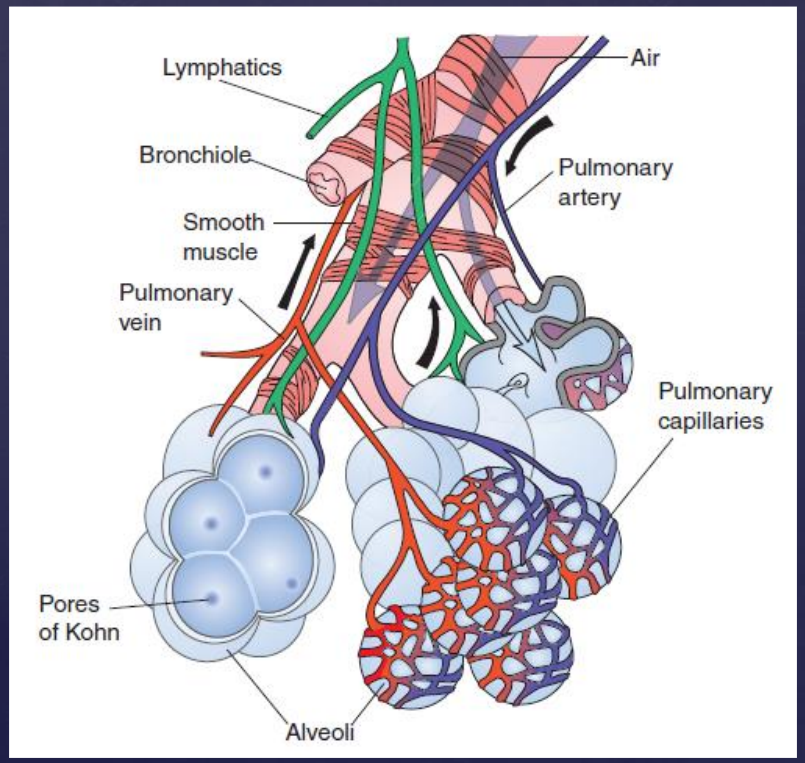
Changes of rhythm , amplitude and frequency of external breathing concomitantly with increased effort of respiratory muscles associated with a characteristic subjective feeling of lack of satisfaction from breathing process.

CENTRAL	*PULMONARY*	EXTRAPULMONARY
Changes in the excitability of respiratory centre and interrelations between inspiratory and expiratory neurons	Changes at the level of the lung parenchyma (fibrosis, inflammation, cancer) or airways (obstruction)	Can be *cardiac* dyspnea related to insufficiency of cardiac output (heart failure, heart defects with right-left shift etc…) and *extracardiac* which is characteristic for any type of hypoxia (except the cardiac hypoxia), anemia, metabolic acidosis.

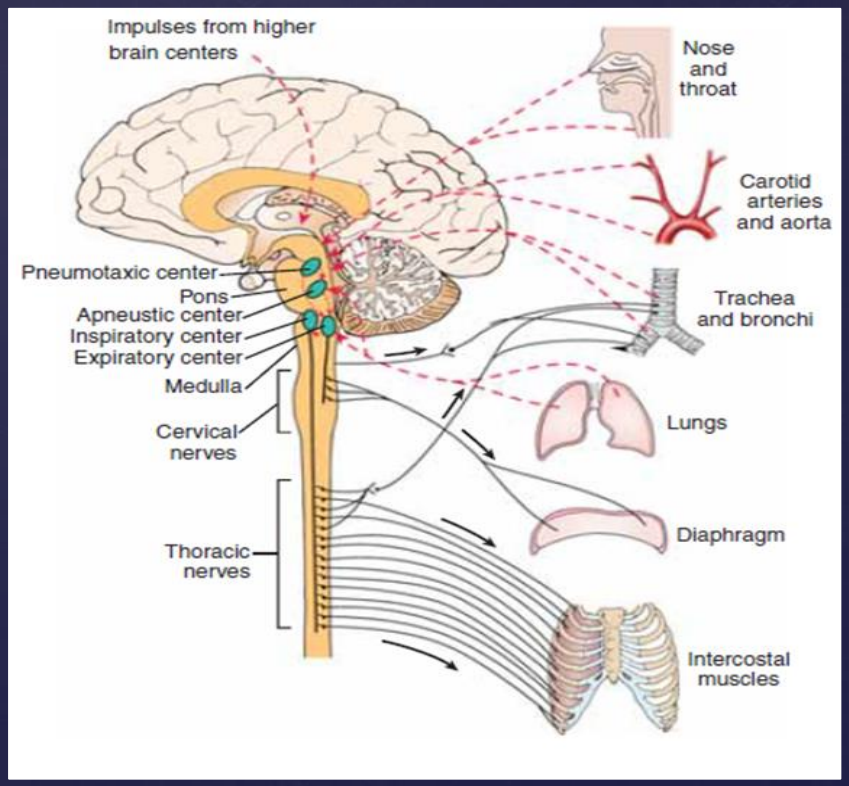
MECHANISMS OF DYSPNEA

Stimulation of lung receptors

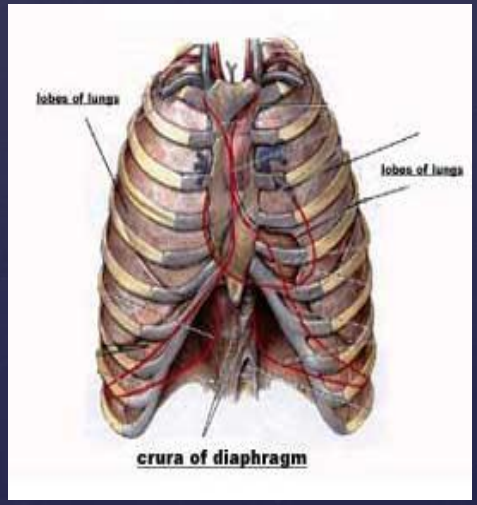
(stretch receptors, irritant receptors; juxtacapillary receptors)



Increased sensitivity to changes in ventilation perceived through central nervous system mechanisms;



Stimulation of neural receptors in the muscle fibers of the intercostals and diaphragm and of receptors in the skeletal joints, because of a discrepancy in the tension generated by these muscles and the TV that results. These receptors, once stimulated, transmit signals that bring about an awareness of the breathing discrepancy.



TERMS FOR DIFFERENT BREATHING ACTIVITIES

EUPNEA - normal breathing movements (frequency and amplitude)

HYPERPNEA – increased frequency and amplitude of breathing movements

HYPOPNEA - decreased frequency and amplitude of breathing movements

APNEA - arrested breathing

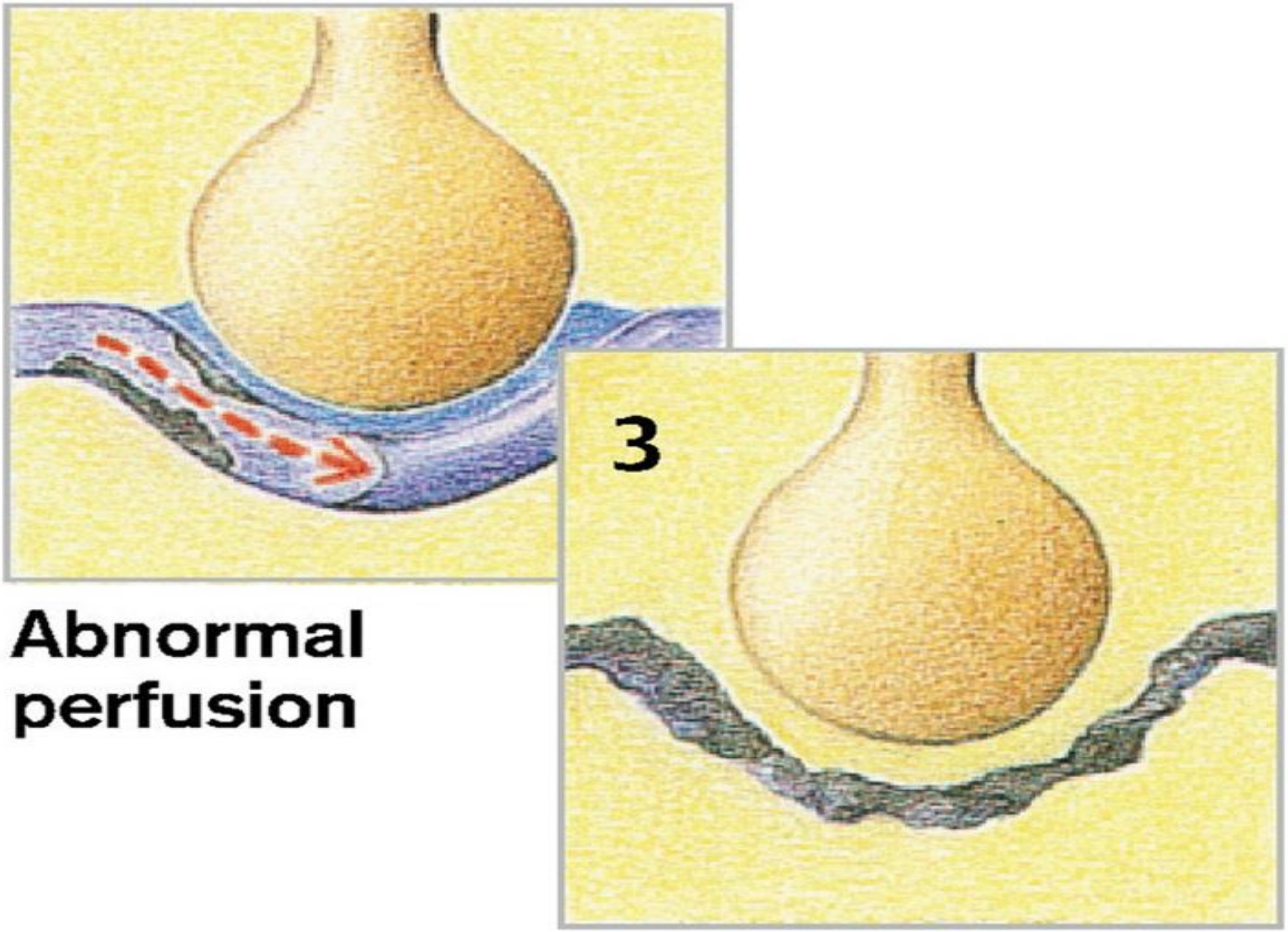
BRADYPNEA - decreased rate of breathing

TACHYPNEA - increased rate of breathing

DYSPNEA - labored breathing (subjective feeling)

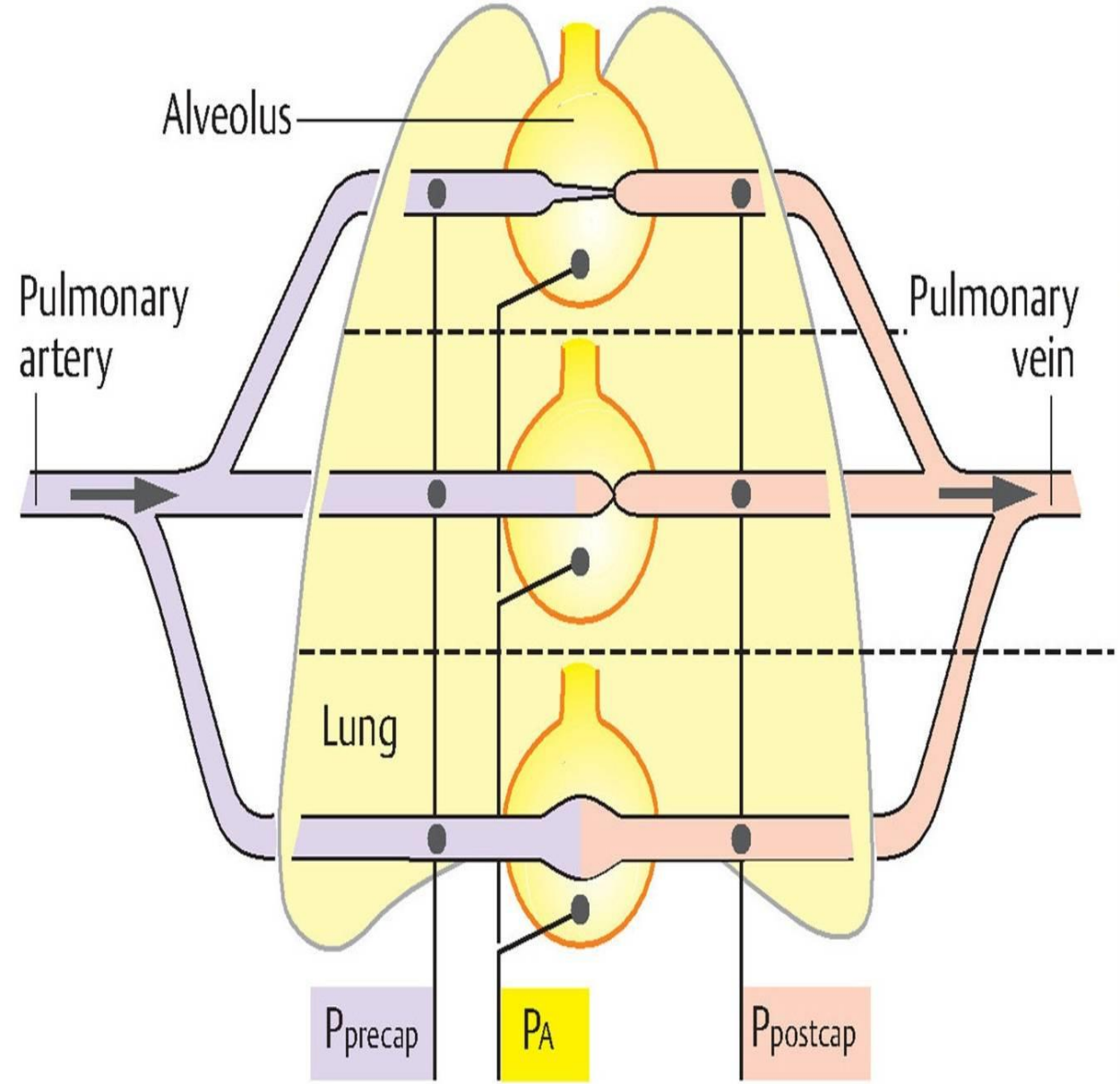
ASPHYXIA – inability to breath due to airway obstruction

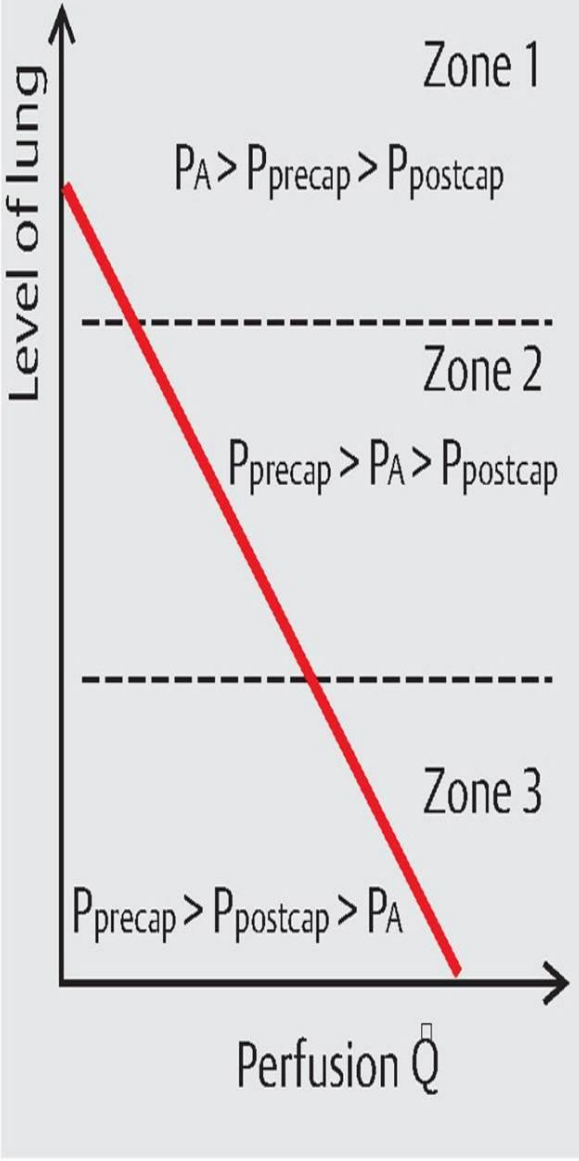
ORTHOPNEA – labored breathing, except in the sitting or upright position

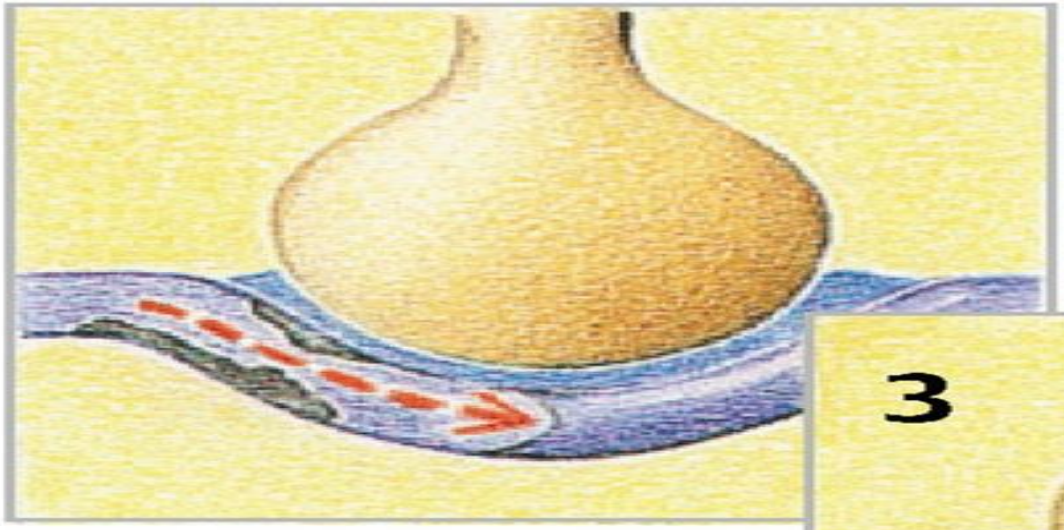


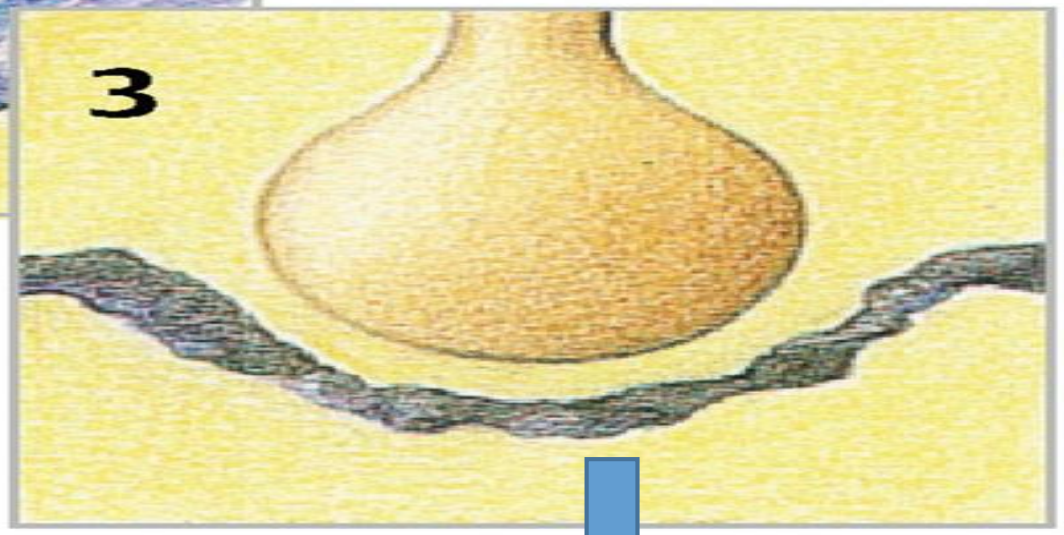
Abnormal perfusion

A. Regional blood flow in the lung (upright chest position)









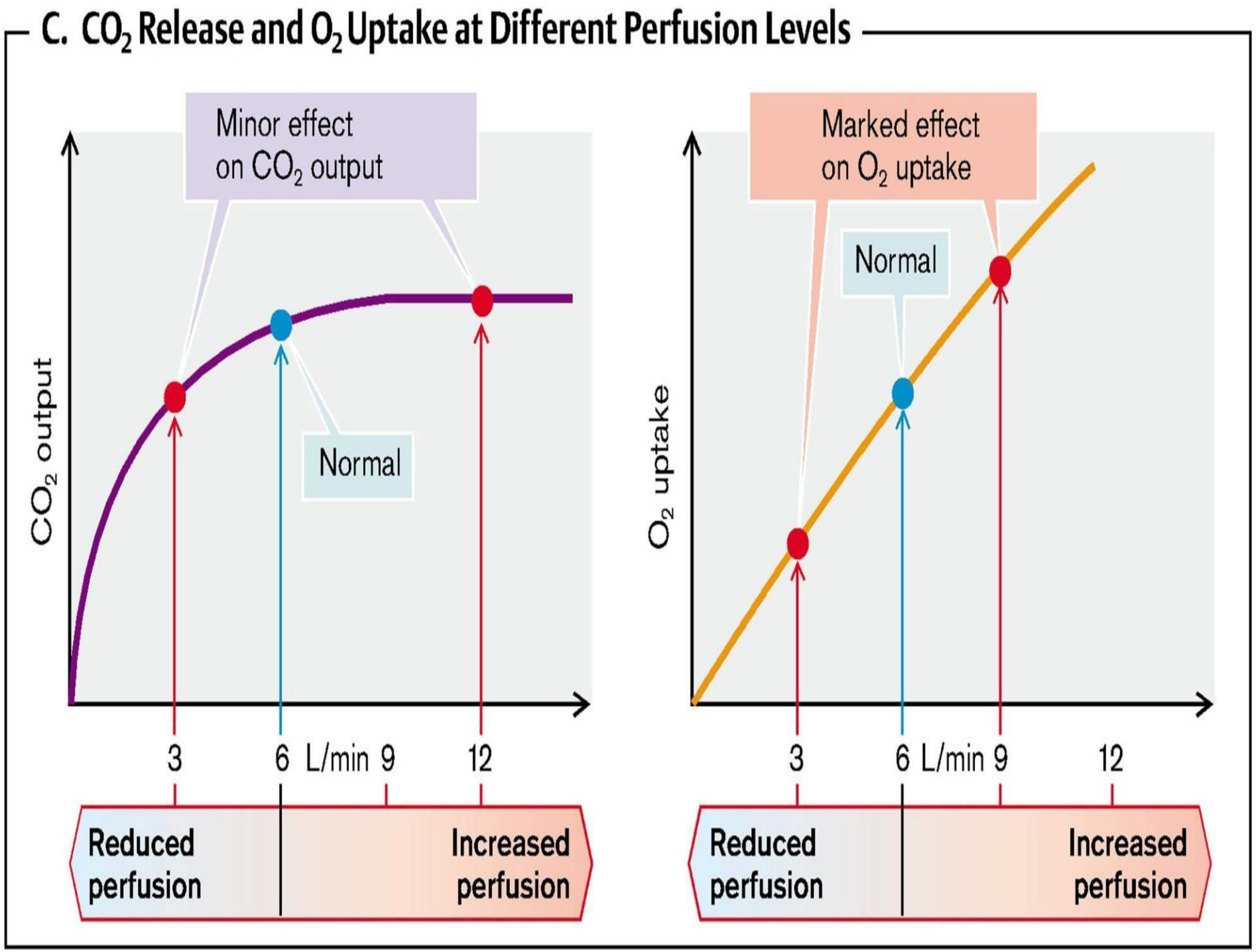
Abnormal perfusion

INCREASED PERFUSION

PHYSICAL EFFORT

REDUCED PERFUSION

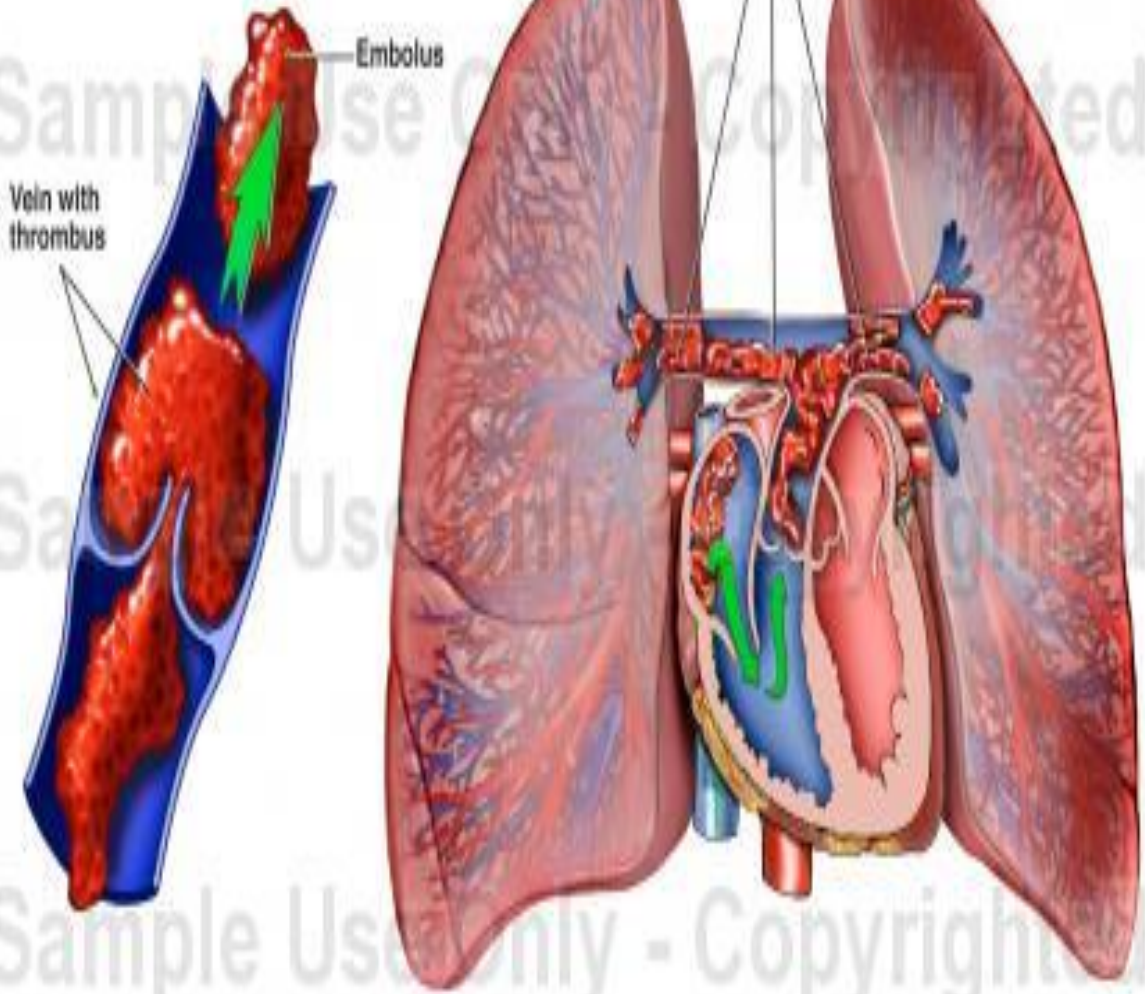
HYPOVOLEMIA
HEART FAILURE
CIRCULATORY FAILURE
PULMONARY EMBOLISM
OCLUSSION OF LUNG VESSELS
VASOCONSTRICTION OF LUNG VESSELS

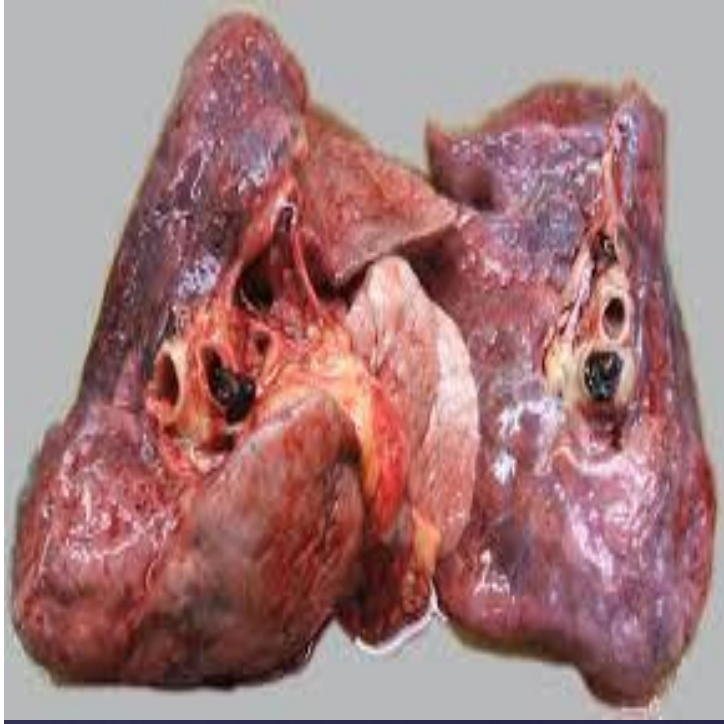

C. CO_2 Release and O_2 Uptake at Different Perfusion Levels
Minor effect on CO_2 output
Normal
CO_2 output
3
6
L/min
9
12
Reduced perfusion
Increased perfusion
Marked effect on O_2 uptake
Normal
O_2 uptake
3
6
L/min
9
12
Reduced perfusion
Increased perfusion

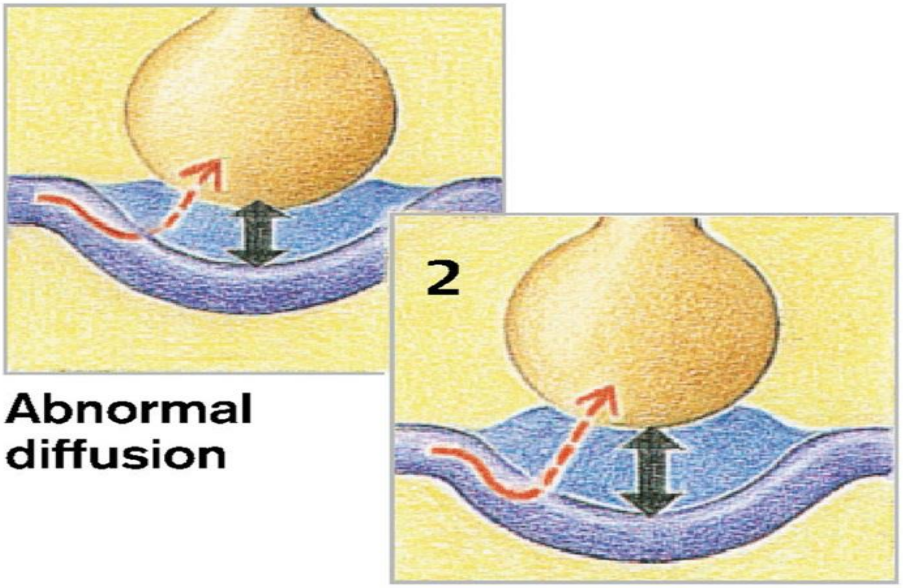
Mechanism of Pulmonary Embolism

Cut-away view through vein with an embolus breaking off and traveling up towards the heart and lungs

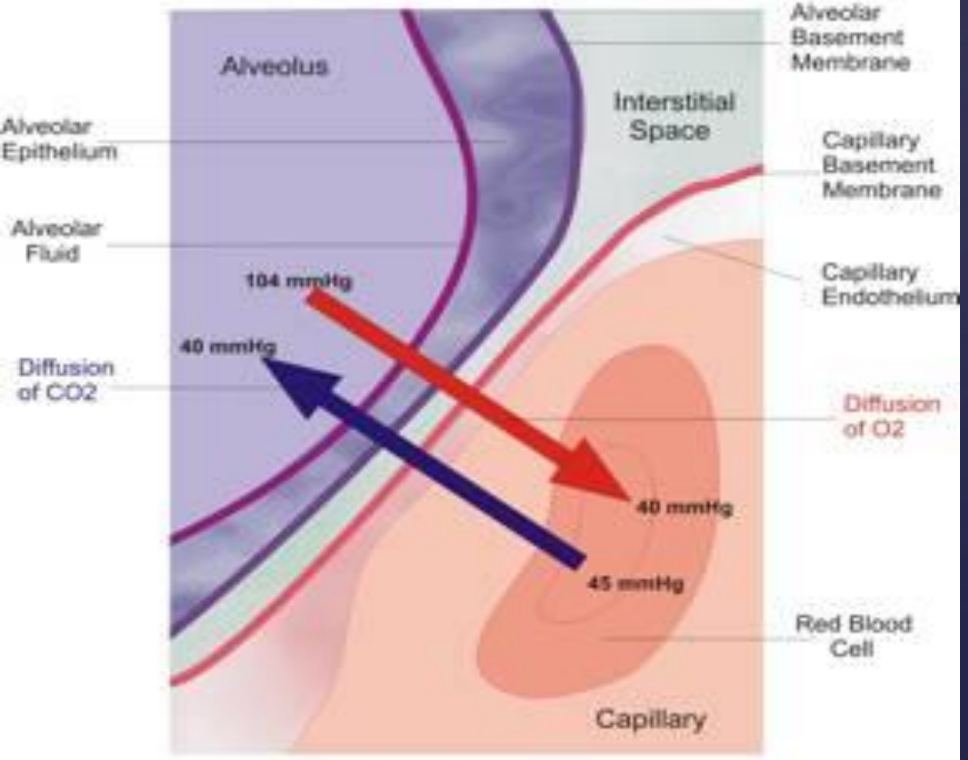
Blood clots occluding the right and left pulmonary arteries



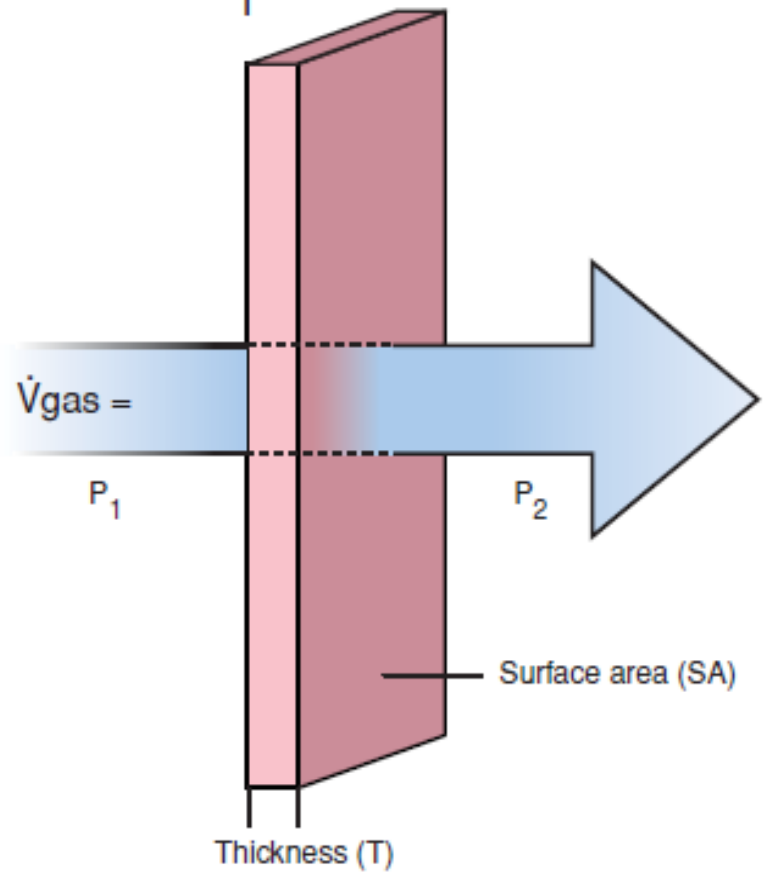




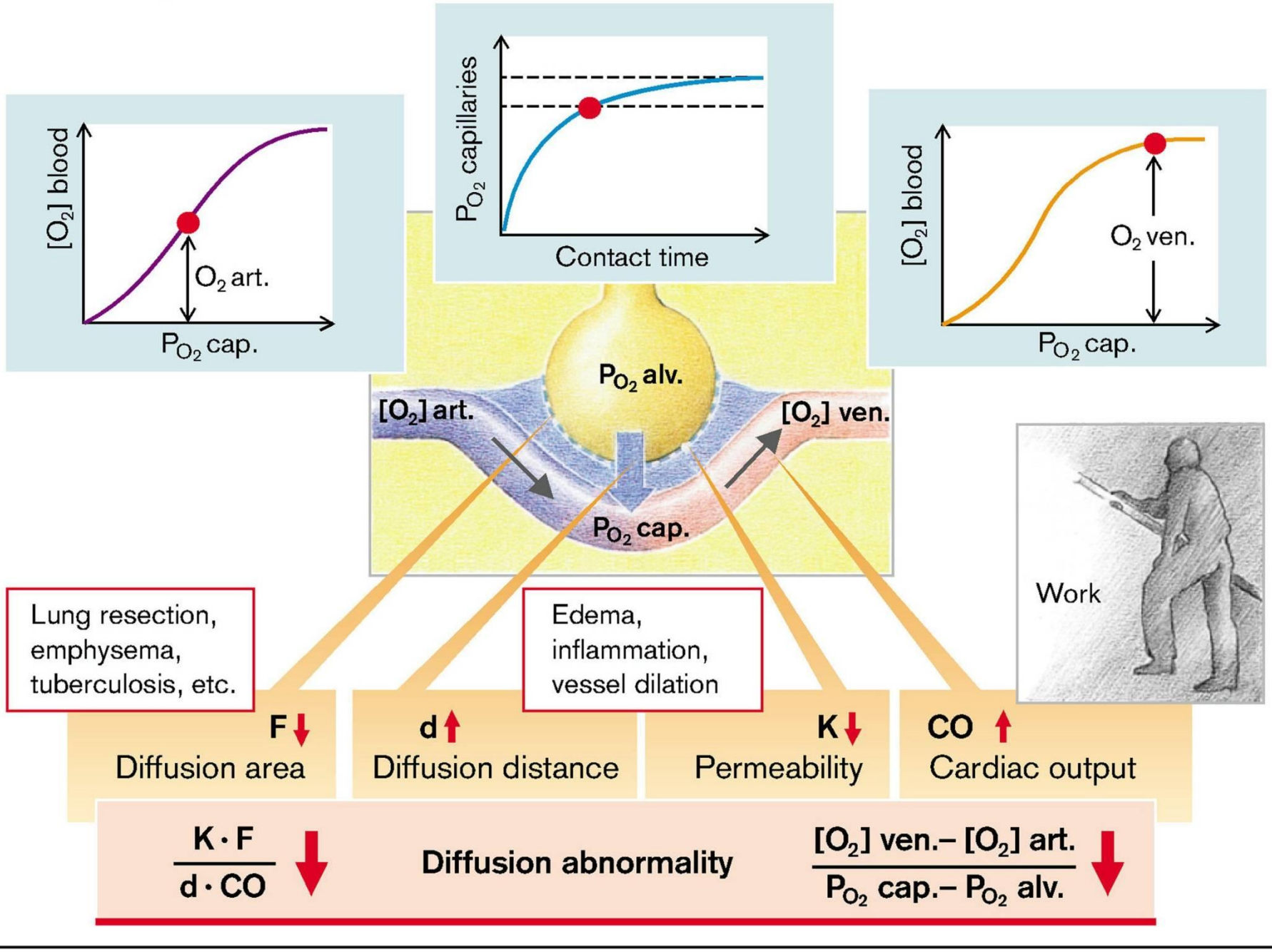
Abnormal diffusion



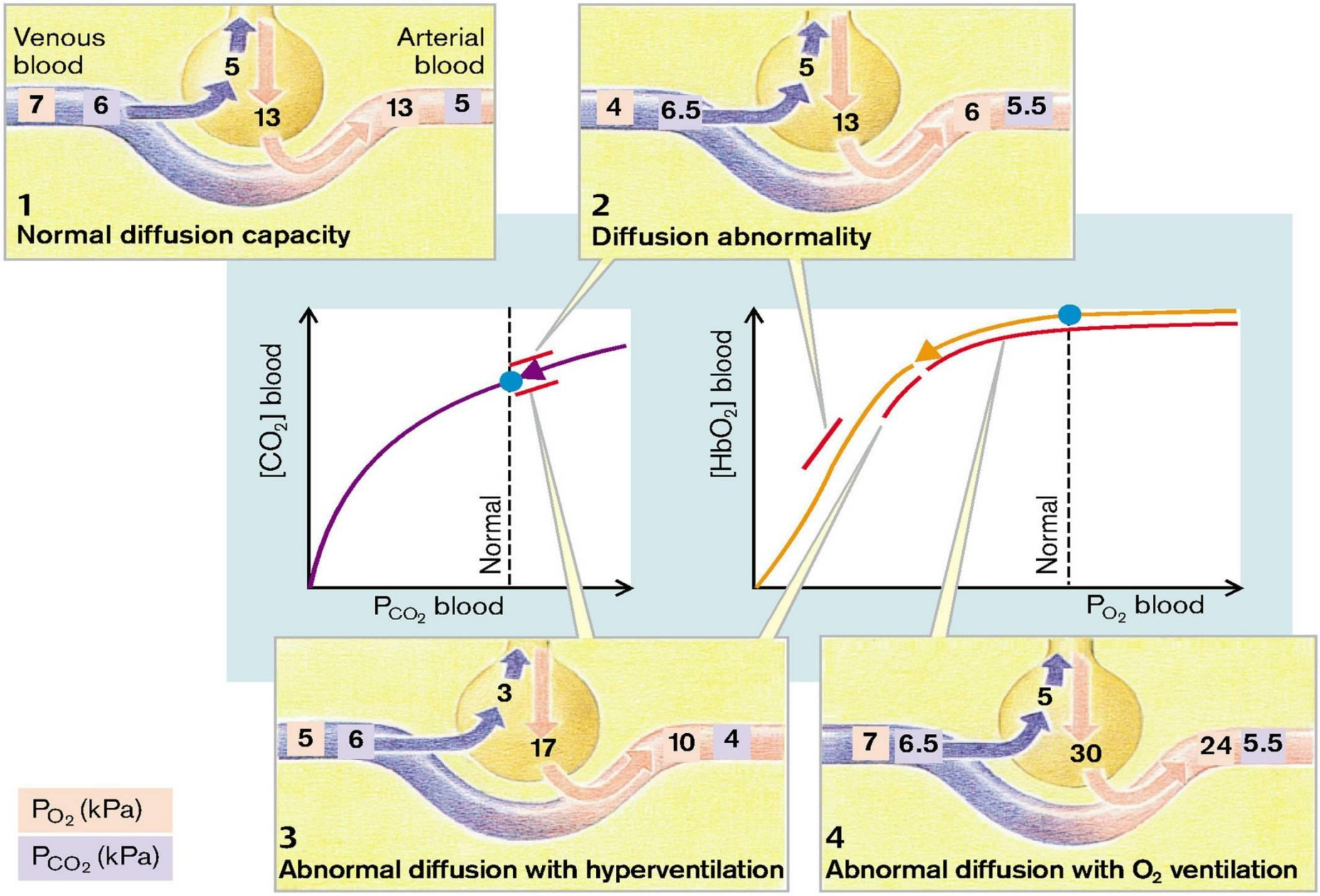
$$\dot{V}gas = \frac{SA \times D\,(P_1 - P_2)}{T}$$



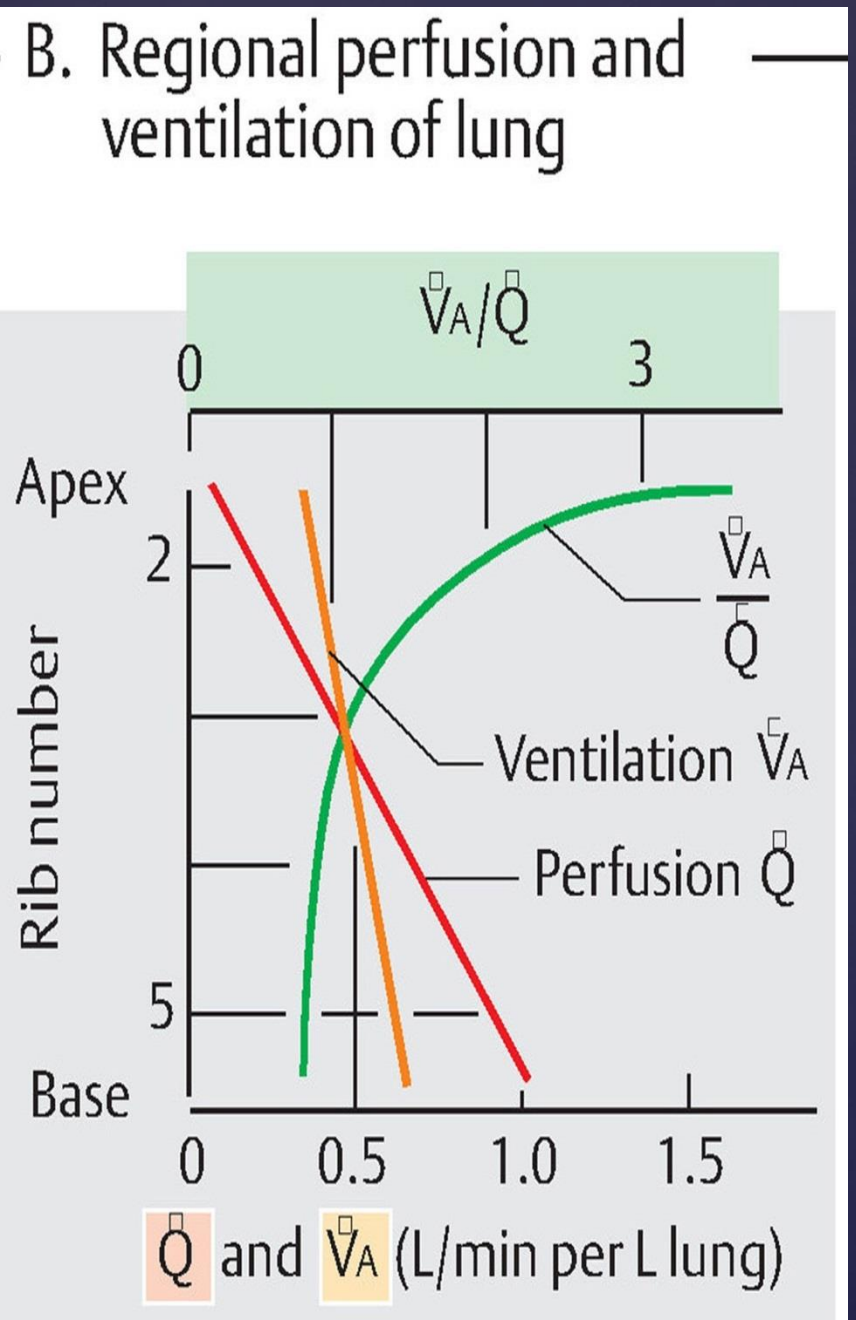
A. Development of Diffusion Abnormalities

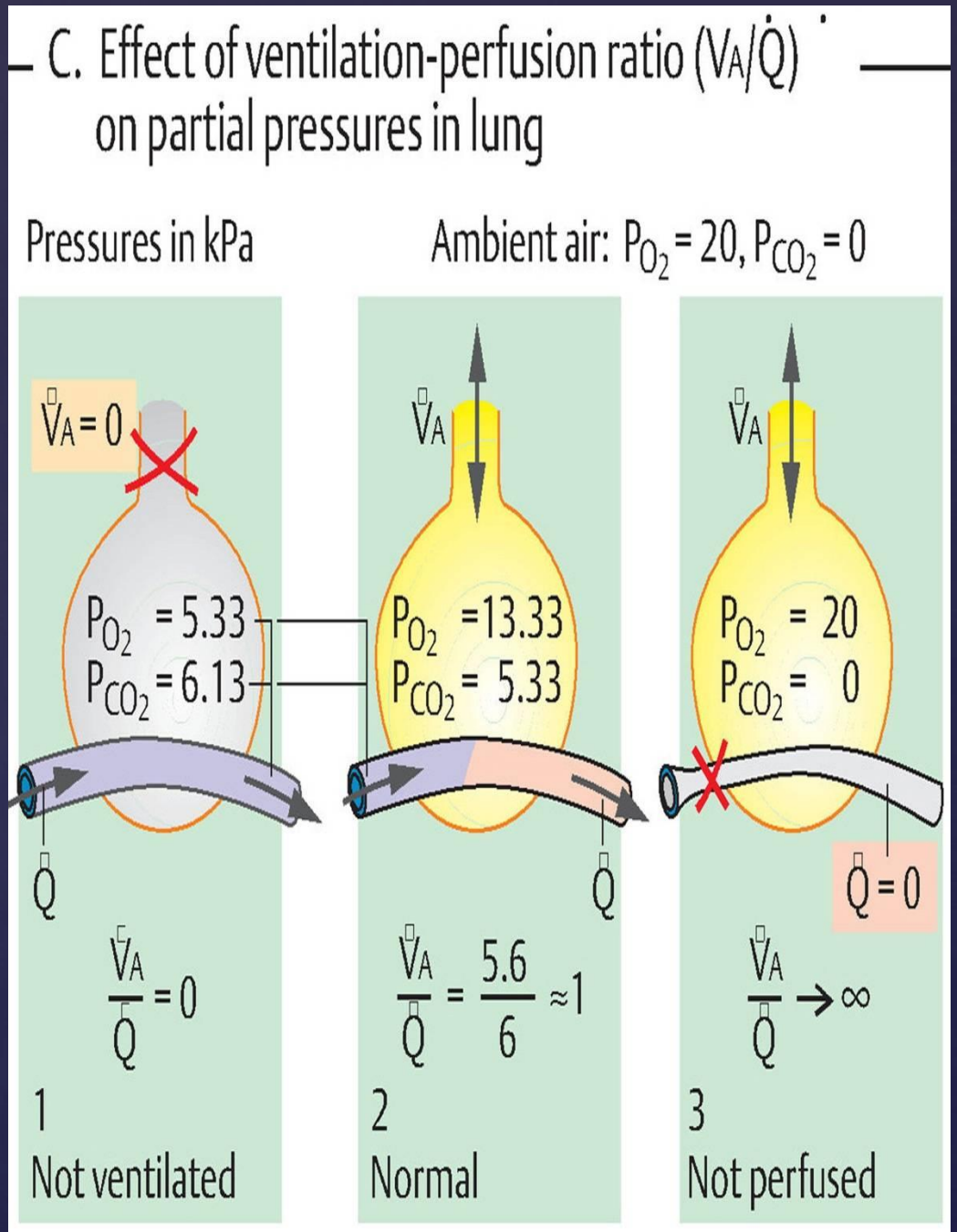


B. Abnormal Diffusion: Concentrations of CO_2 and HbO_2 in Blood

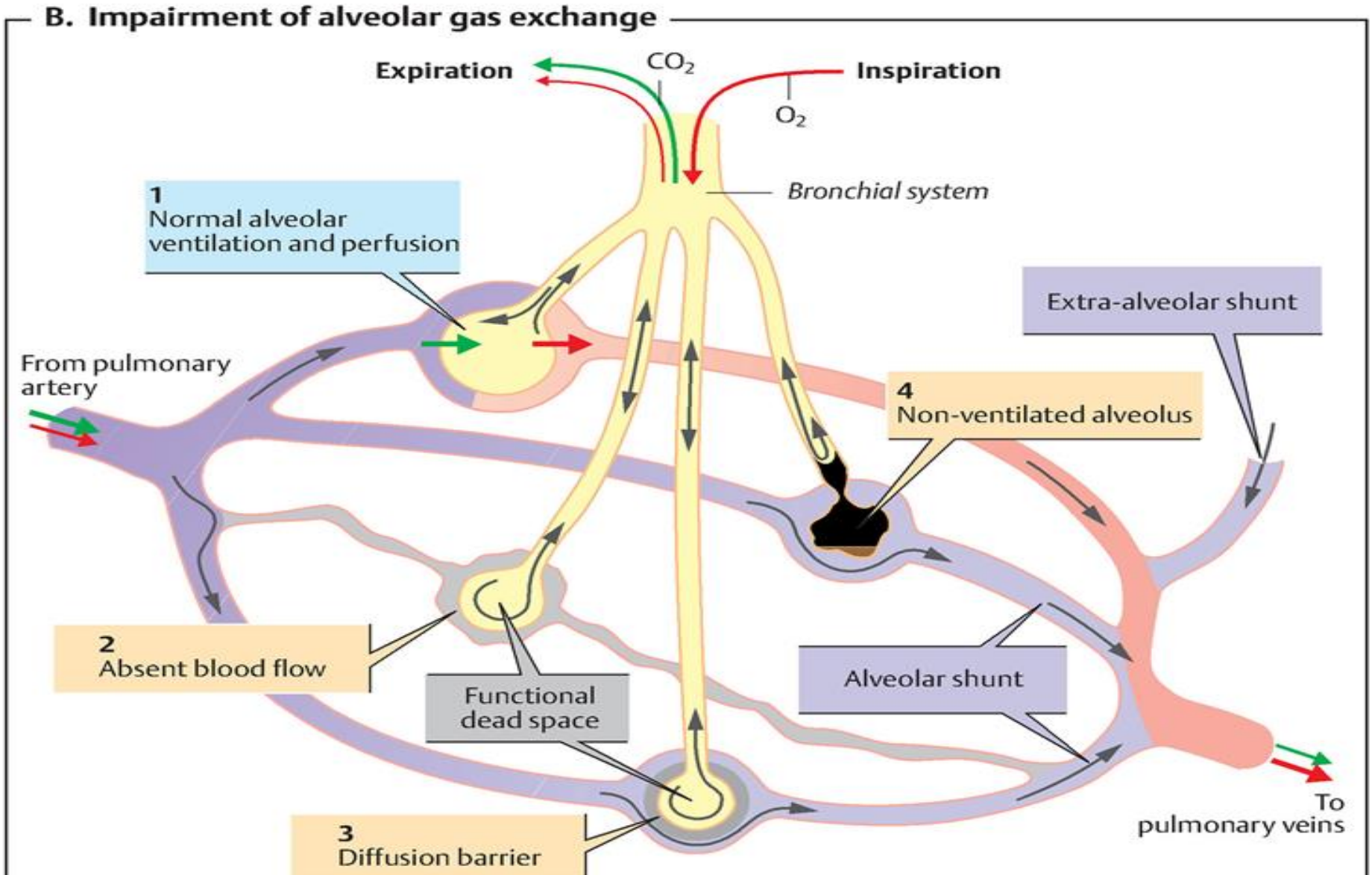


DISTURBANCES OF DISTRIBUTION

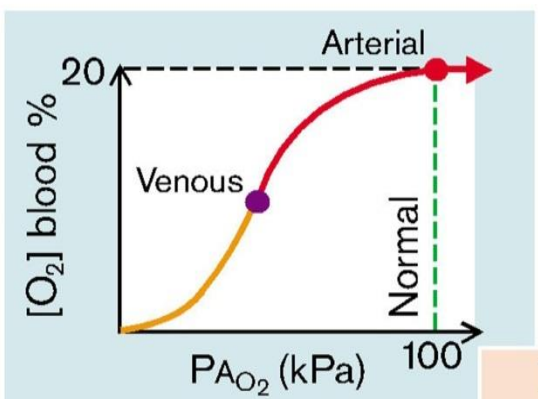


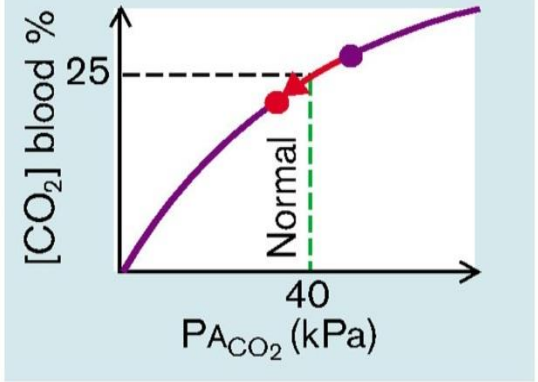


ABNORMAL DISTRIBUTION – condition when the ratio of ventilation to perfusion in individual alveoli deviates to a functionally significant extent from that in the whole lung.

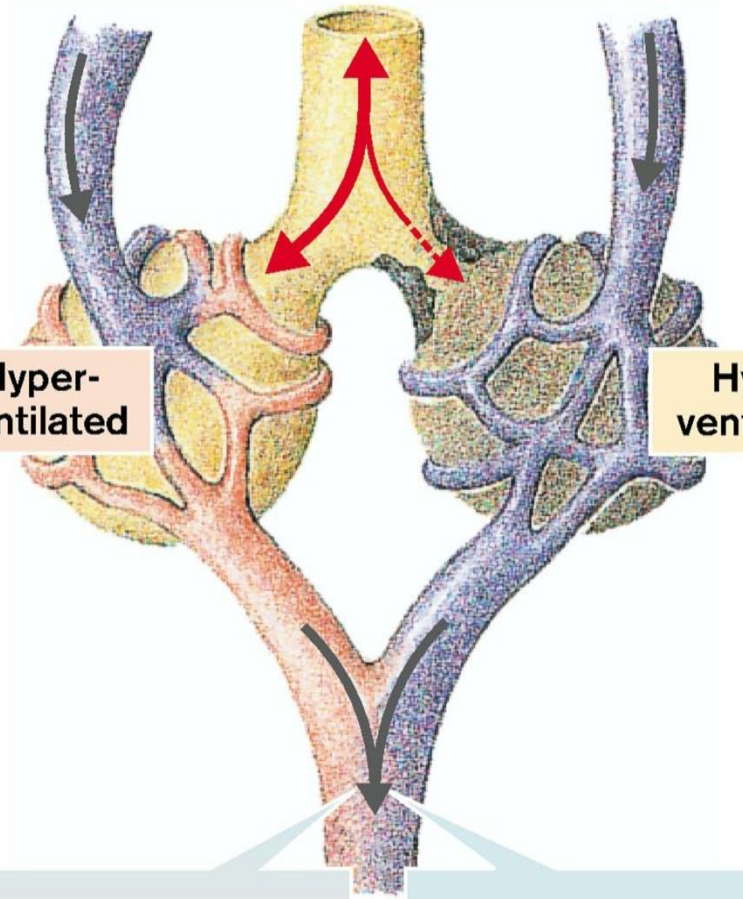


A. Effects of Abnormal Distribution on O_2 Uptake and CO_2 Release

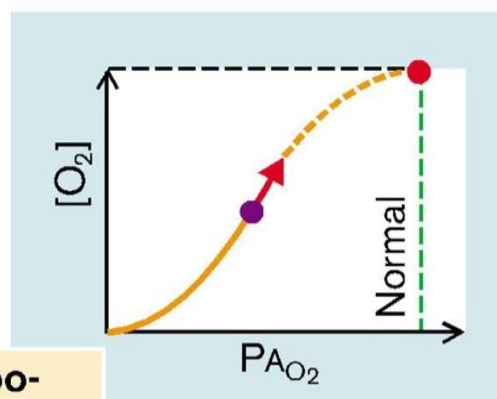


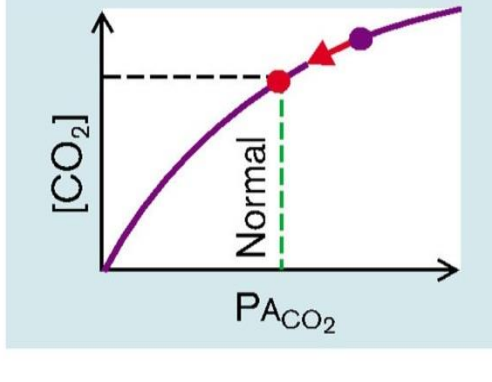


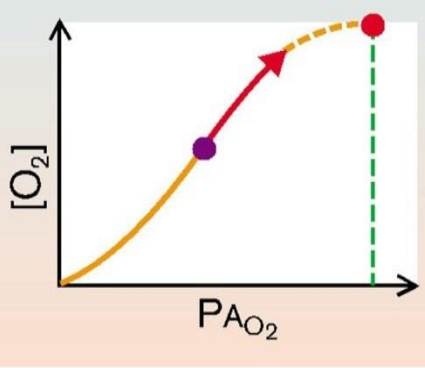
Hyper-ventilated



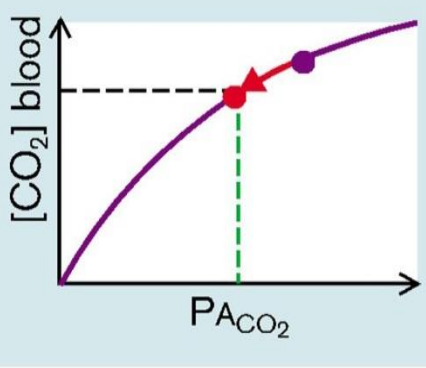
Hypo-ventilated







Hypoxemia



Normocapnia


Thank
you