RAMA UNIVERSITY

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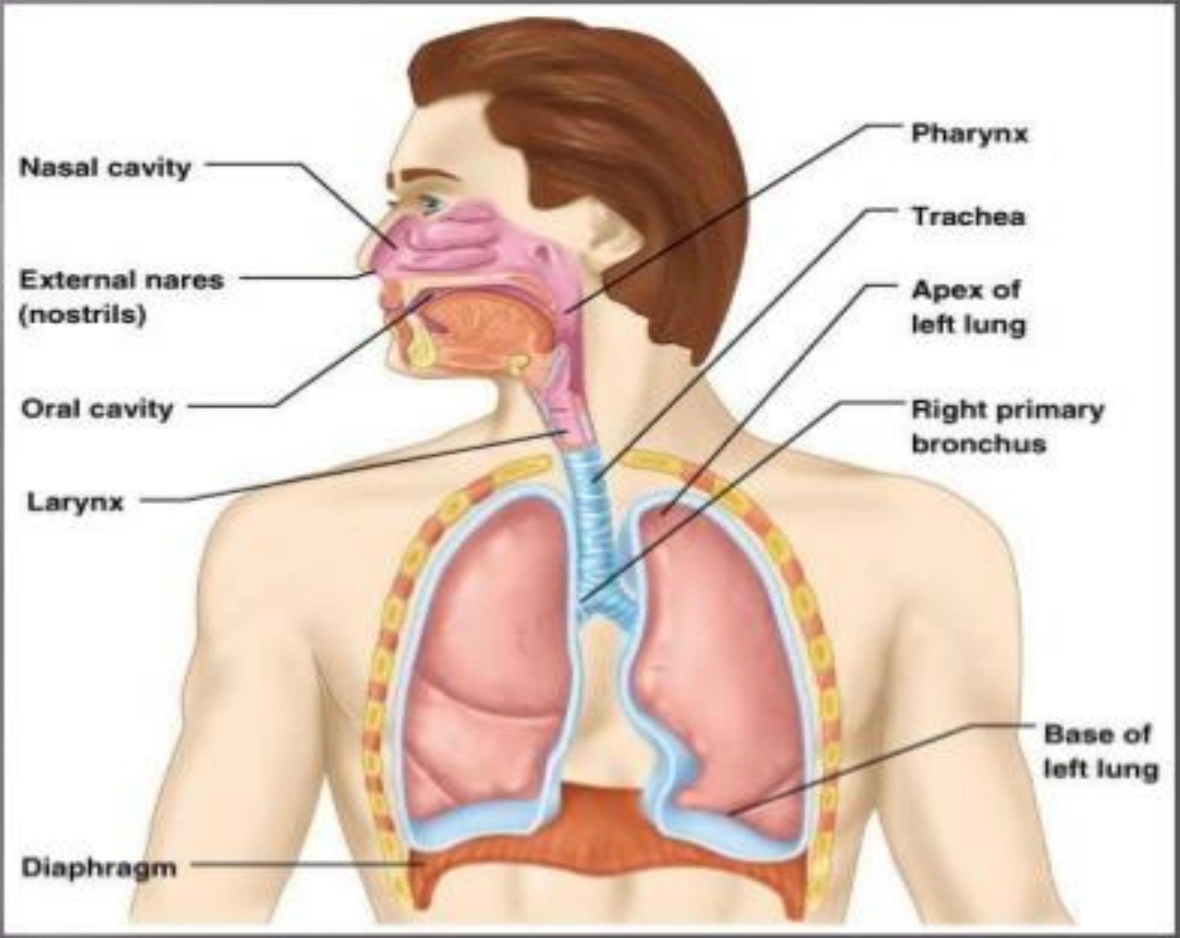
FACULTY OF ENGINEERING &TECHNOLOGY
DEPARTMENT OF BIOTECHNOLOGY

Organs of the Respiratory system

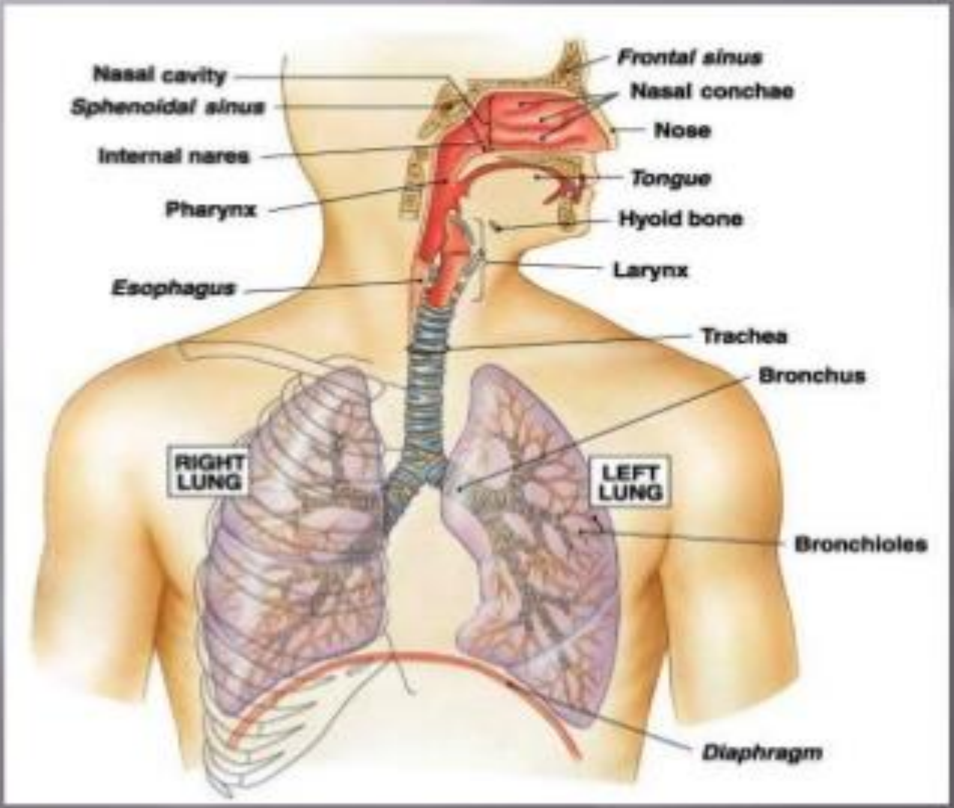
- Nose
- Pharynx
- Larynx
- Trachea
- Bronchi
- Lungs – alveoli



Respiratory System Functions

- Gas exchange: Oxygen enters blood and carbon dioxide leaves
- Regulation of blood pH: Altered by changing blood carbon dioxide levels
- Voice production: Movement of air past vocal folds makes sound and speech
- Olfaction: Smell occurs when airborne molecules drawn into nasal cavity
- Protection: Against microorganisms by preventing entry and removing them

Respiratory System Divisions



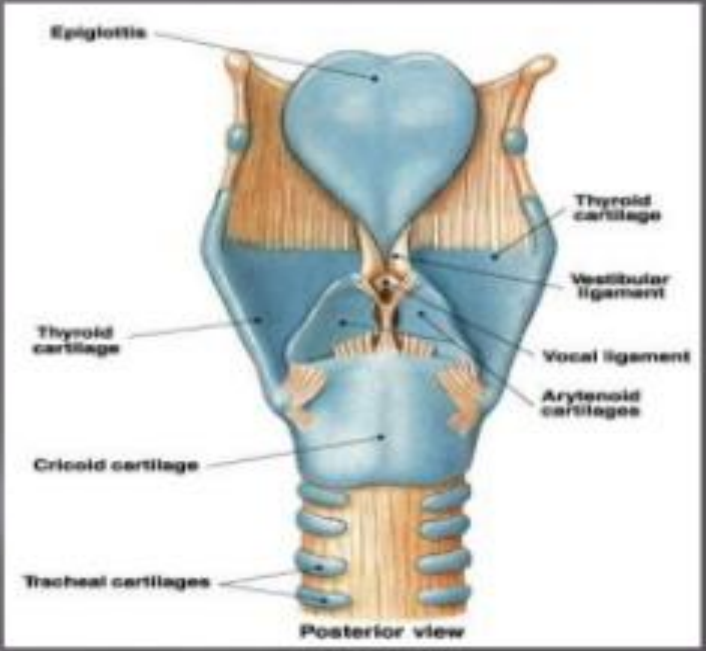
- Upper tract
  - Nose, pharynx and associated structures
- Lower tract
  - Larynx, trachea, bronchi, lungs

Nose and Pharynx

- Nose
  - External nose
  - Nasal cavity
    - Functions
      - Passageway for air
      - Cleans the air
      - Humidifies, warms air
      - Smell
      - Along with paranasal sinuses are resonating chambers for speech

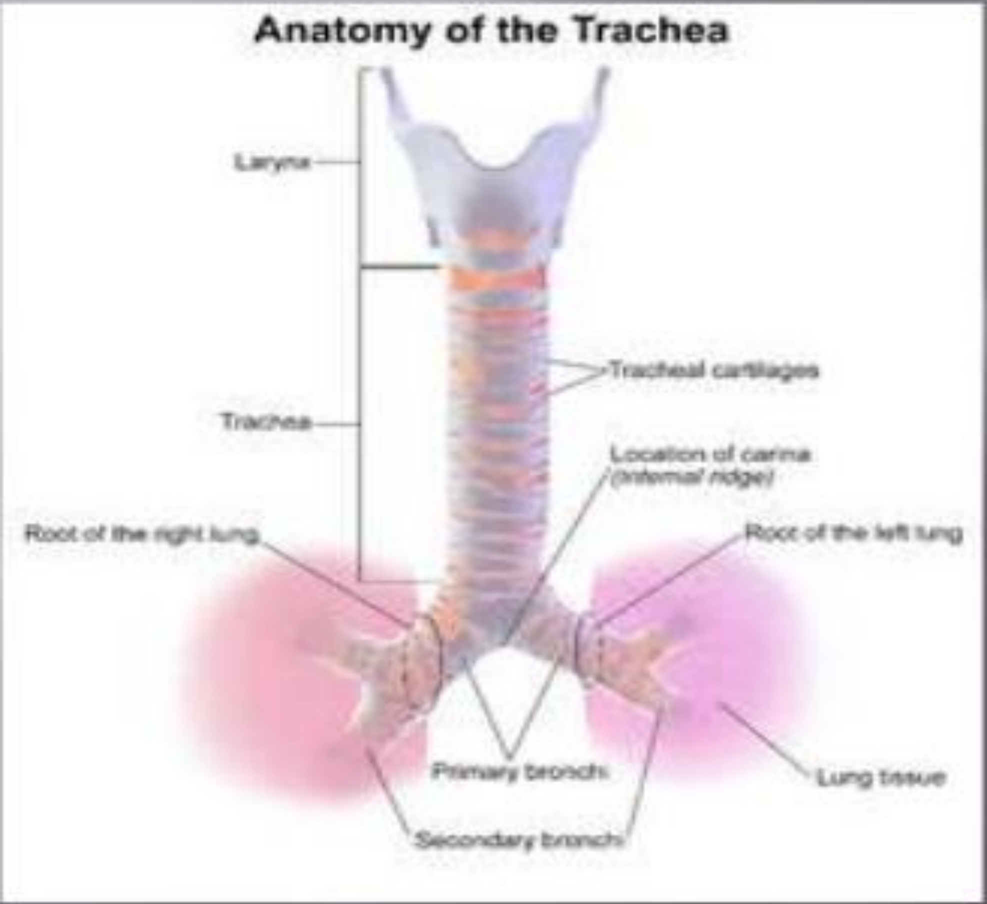
- Pharynx
  - Common opening for digestive and respiratory systems
  - Three regions
    - Nasopharynx
    - Oropharynx
    - Laryngopharynx

Larynx

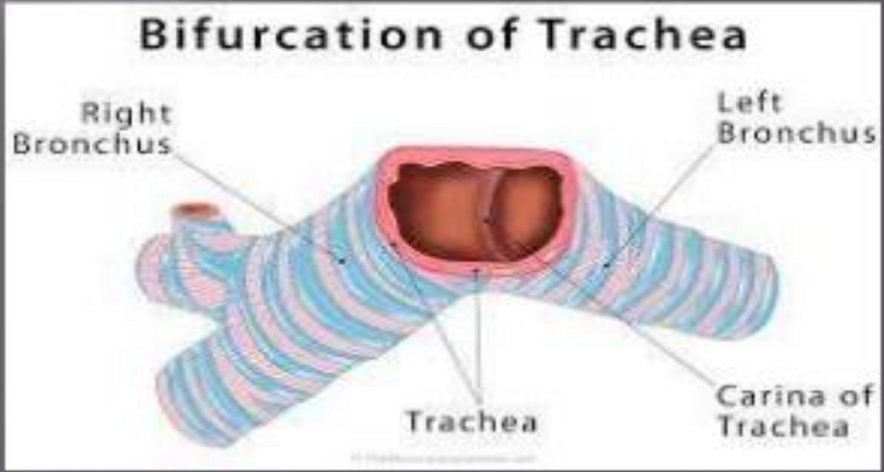


- Functions
  - Maintain an open passageway for air movement
  - Epiglottis and vestibular folds prevent swallowed material from moving into larynx
  - Vocal folds are primary source of sound production

Trachea



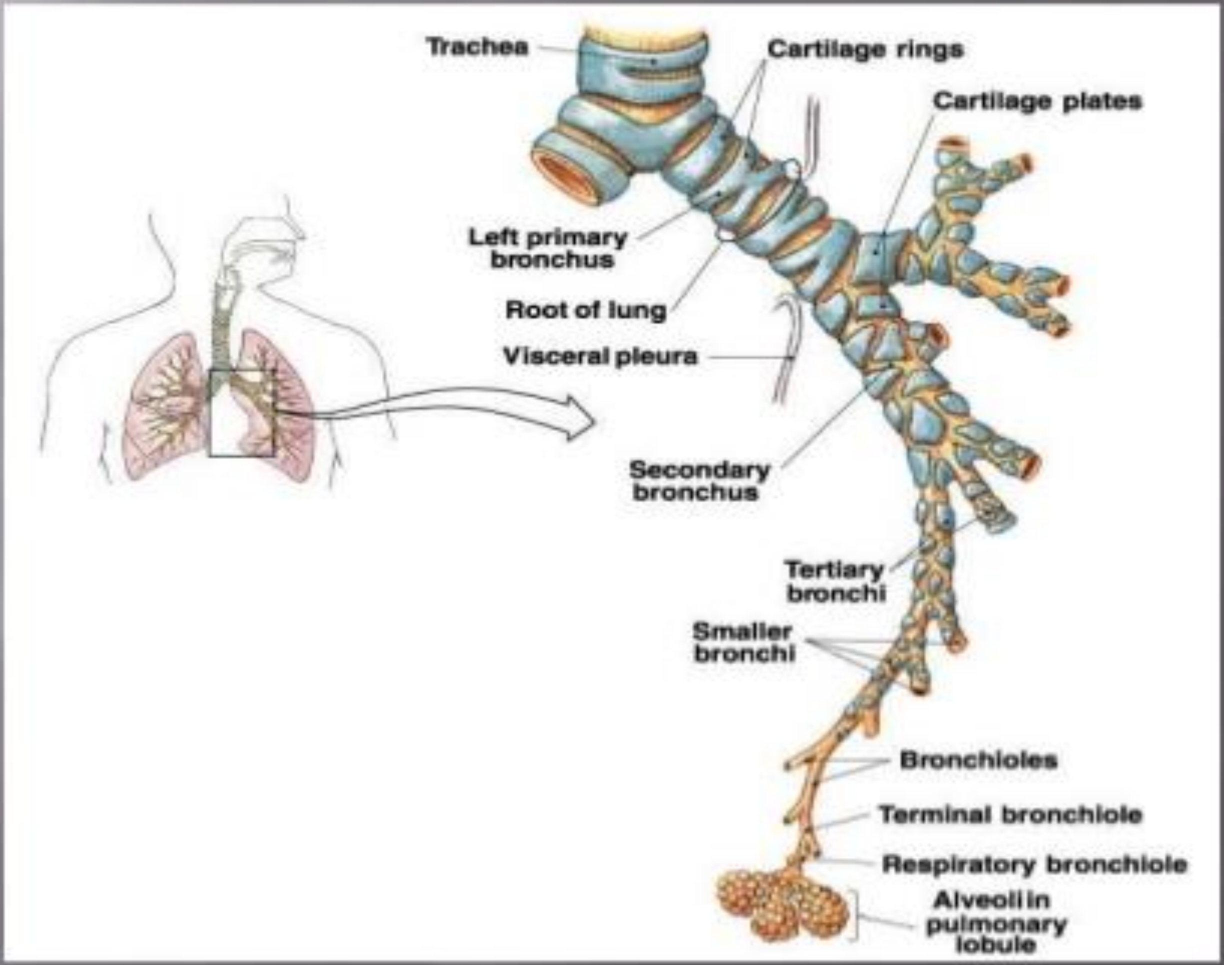
- Windpipe
- Divides to form
  - Primary bronchi
  - Carina: Cough reflex



Tracheobronchial Tree

- Conducting zone
  - Trachea to terminal bronchioles which is ciliated for removal of debris
  - Passageway for air movement
  - Cartilage holds tube system open and smooth muscle controls tube diameter
- Respiratory zone
  - Respiratory bronchioles to alveoli
  - Site for gas exchange

Tracheobronchial Tree



Trachea (Windpipe)

- Connects larynx with bronchi
- Lined with ciliated mucosa
  - Beat continuously in the opposite direction of incoming air
  - Expel mucus loaded with dust and other debris away from lungs
- Walls are reinforced with C-shaped hyaline cartilage

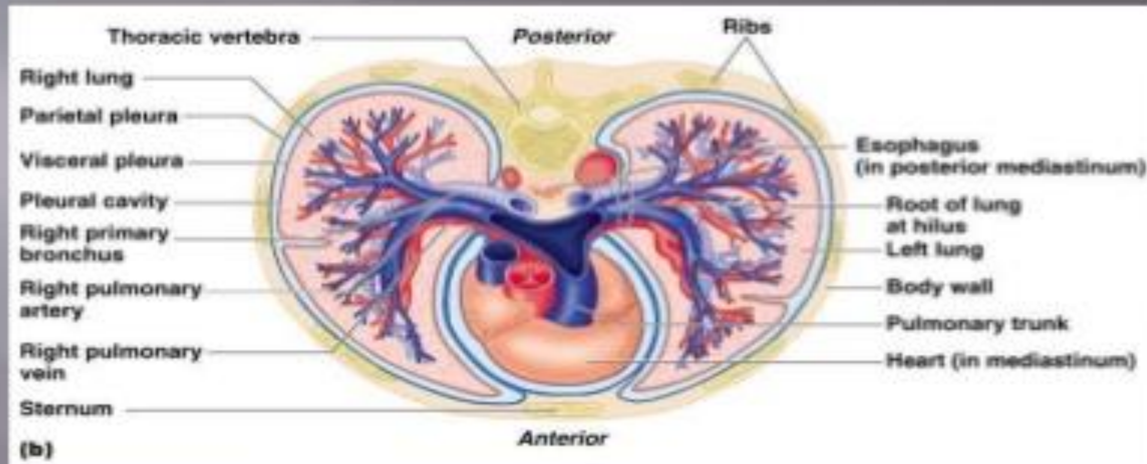
Primary Bronchi

- Formed by division of the trachea
- Enters the lung at the hilus (medial depression)
- Right bronchus is wider, shorter, and straighter than left
- Bronchi subdivide into smaller and smaller branches

Lungs

- Occupy most of the thoracic cavity
  - Apex is near the clavicle (superior portion)
    - Base rests on the diaphragm (inferior portion)
  - Each lung is divided into lobes by fissures
    - Left lung – two lobes
    - Right lung – three lobes

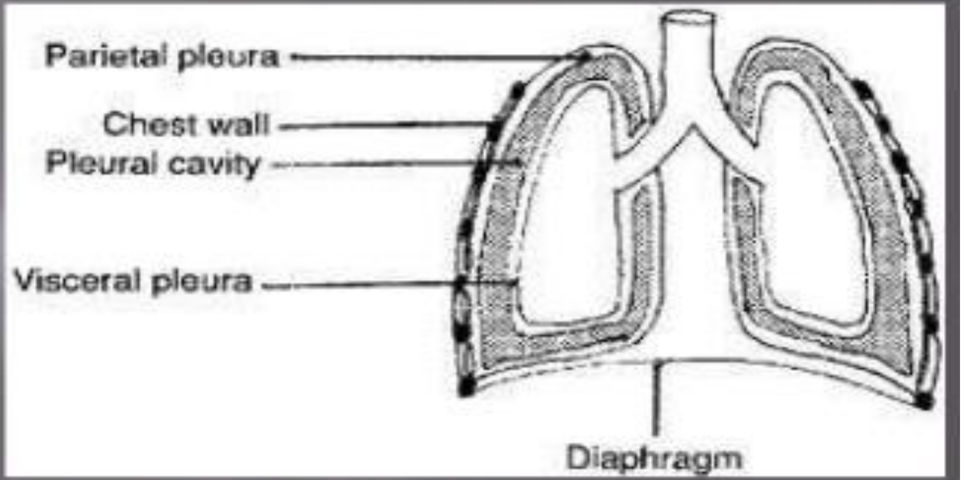
Lungs



Thoracic vertebra
Posterior
Ribs
Right lung
Parietal pleura
Visceral pleura
Pleural cavity
Right primary bronchus
Right pulmonary artery
Right pulmonary vein
Sternum
Esophagus (in posterior mediastinum)
Root of lung at hilus
Left lung
Body wall
Pulmonary trunk
Heart (in mediastinum)
Anterior
(b)

Coverings of the Lungs

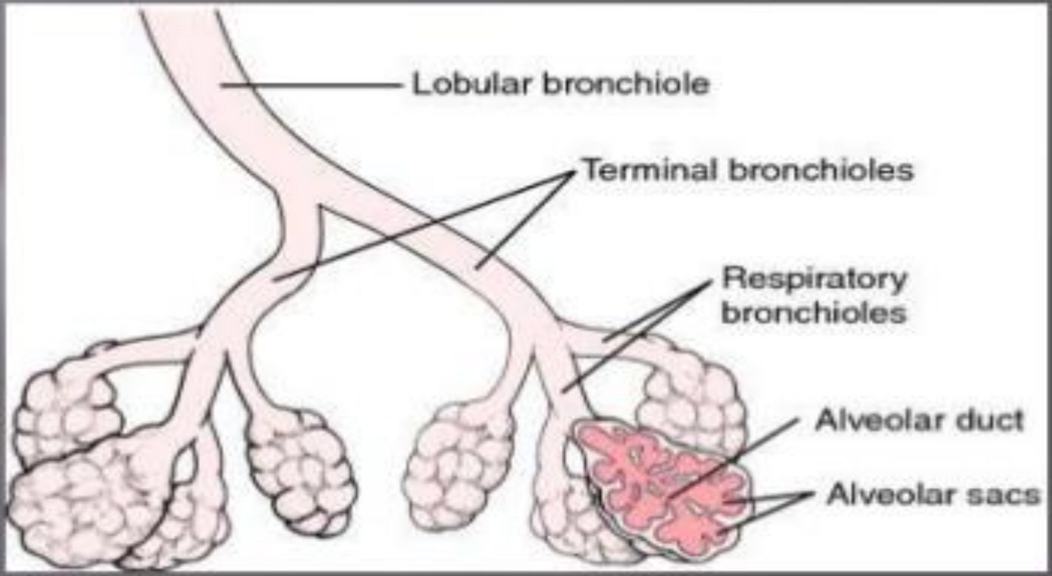
- Pulmonary (visceral) pleura covers the lung surface
- Parietal pleura lines the walls of the thoracic cavity
- Pleural fluid fills the area between layers of pleura to allow gliding



Respiratory Tree Divisions

- Primary bronchi
- Secondary bronchi
- Tertiary bronchi
- Bronchioli
- Terminal bronchioli

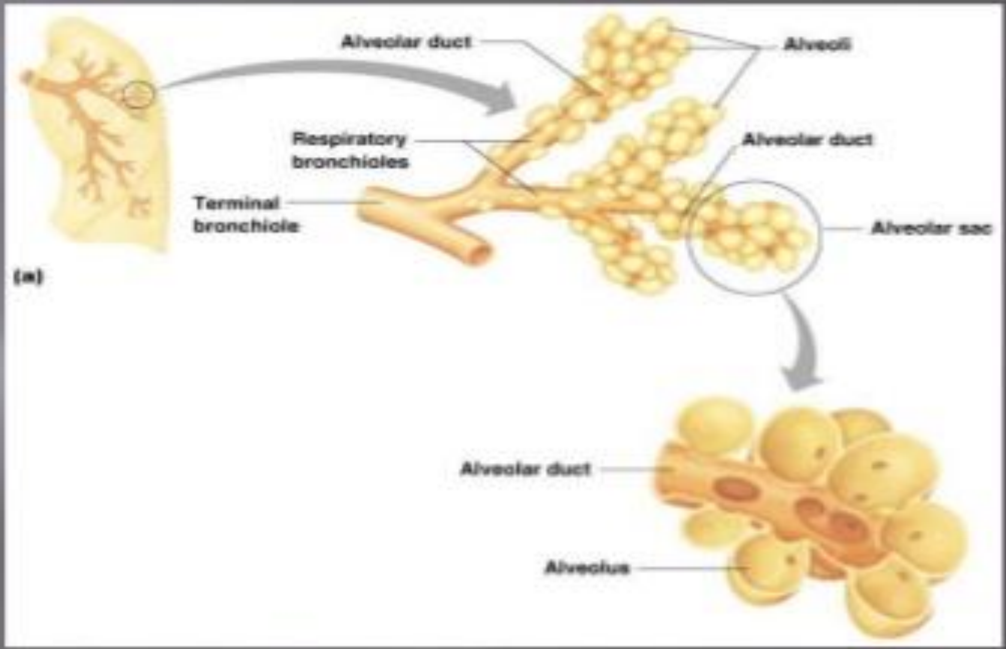
Bronchioles



- Smallest branches of the bronchi
- All but the smallest branches have reinforcing cartilage

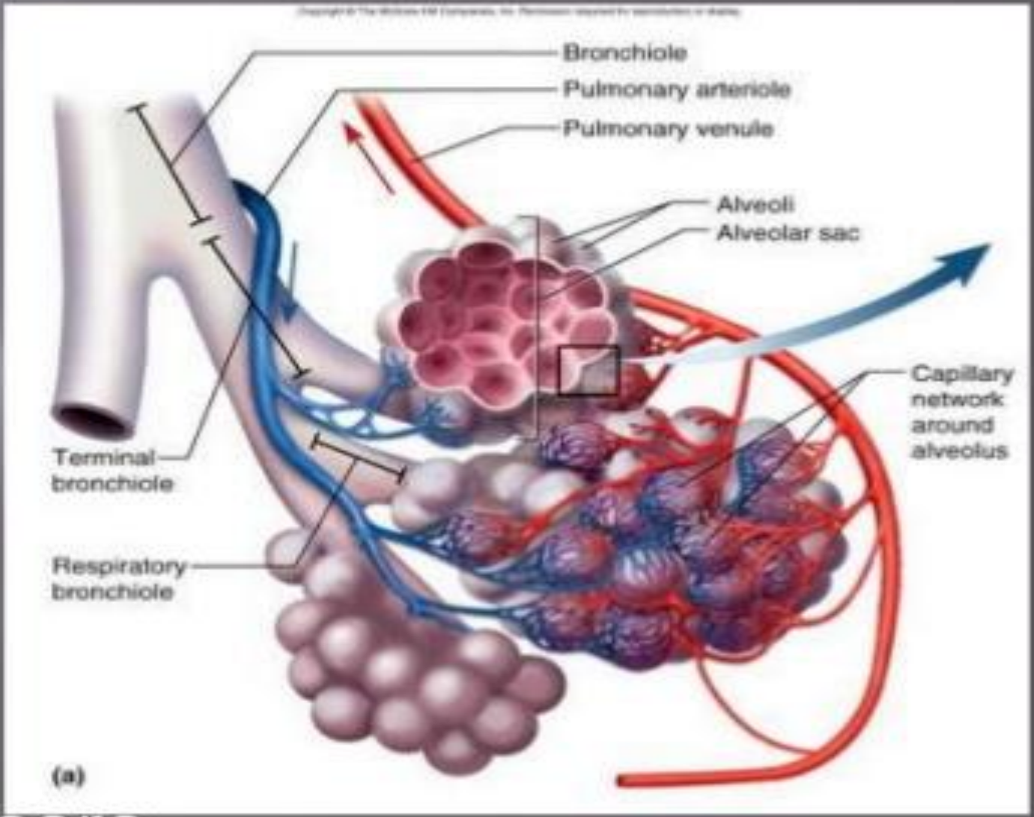
Bronchioles

- Terminal bronchioles end in alveoli



Alveoli

- Structure of alveoli
  - Alveolar duct
  - Alveolar sac
  - Alveolus

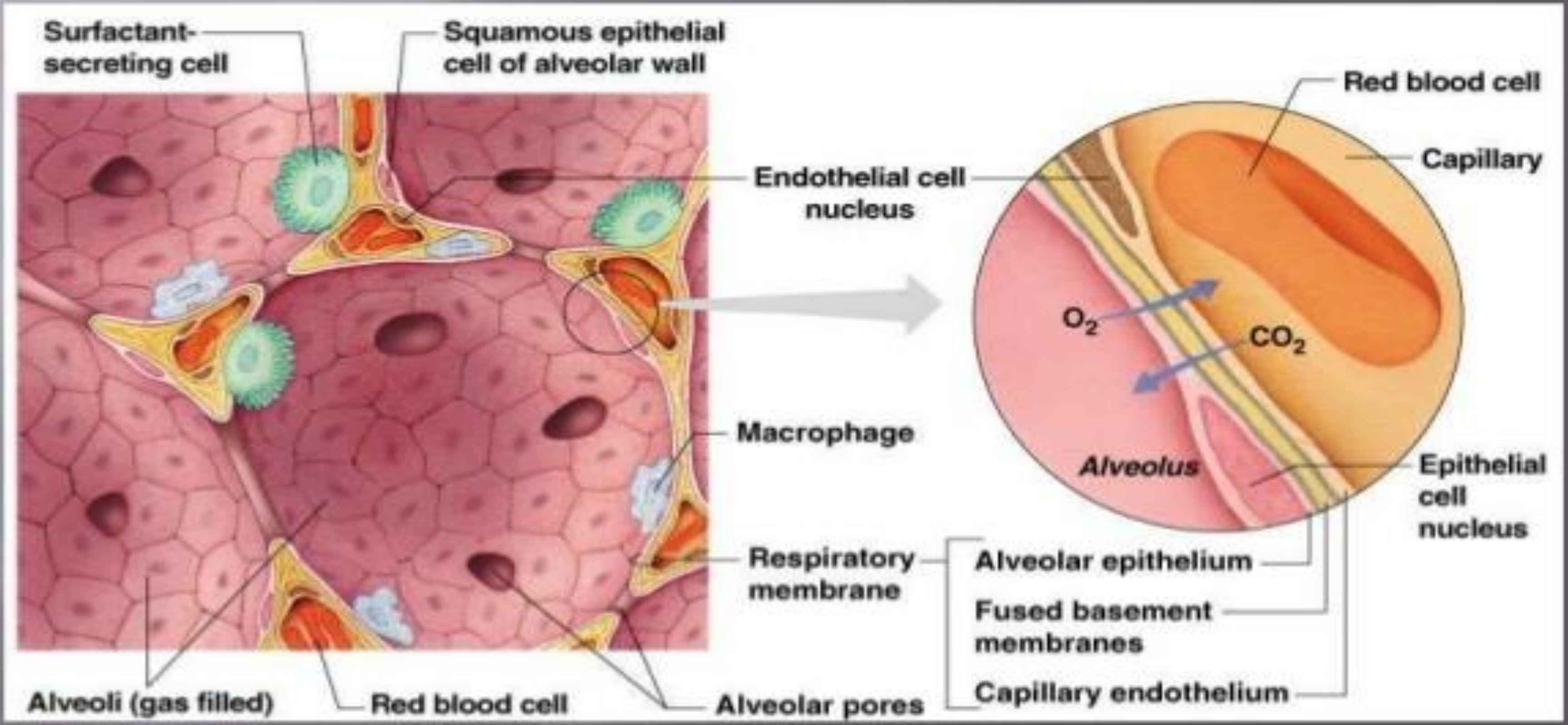


Gas exchange occurs here.

Respiratory Membrane (Air-Blood Barrier)

- Thin squamous epithelial layer lining alveolar walls
- Pulmonary capillaries cover external surfaces of alveoli
- The blood–air barrier (alveolar–capillary barrier or membrane) exists in the gas exchanging region of the lungs. It exists to prevent air bubbles from forming in the blood, and from blood entering the alveoli.

Respiratory Membrane (Air-Blood Barrier)



Events of Respiration

Pulmonary ventilation: O_2 into lungs from inspired air; CO_2 out of lungs from expired air.

External respiration: Gas exchange between alveoli and the capillaries.

Respiratory gas transport: Gasses are transported in blood (via vessels) to tissues.

Internal respiration: Gas exchange between blood and tissue cells in systemic capillaries

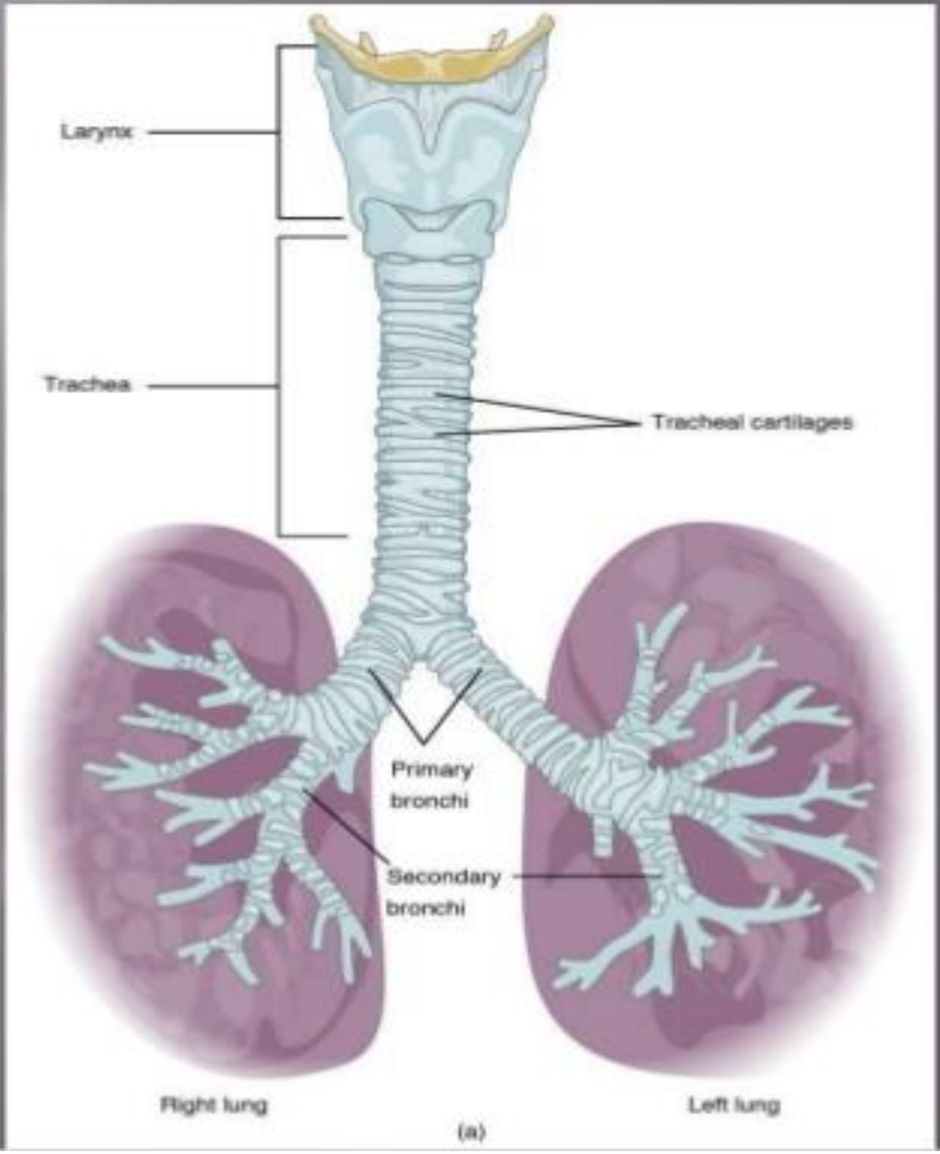
Cellular respiration.

Mechanics of Breathing (Pulmonary Ventilation)

- Two phases
  - Inspiration – flow of air into lung
  - Expiration – air leaving lung

TRACHEA

- Trachea lies in midline of neck
- Extends from vertebral level C6 in the lower neck to vertebral level T4 in the mediastium where it bifurcates into a right and left main bronchus.



Larynx
Trachea
Tracheal cartilages
Primary bronchi
Secondary bronchi
Right lung
Left lung
(a)

SURFACE ANATOMY OF LUNGS

- Each lung is conical in shape
- It has:-
- APEX
- BASE
- THREE BORDERS
- TWO SURFACES

- APEX- it lies above the level of first rib. It reaches 2-5 cm above the medial one third of clavicle, just medial to supraclavicular fossa.
- BASE- rest on the diaphgram which seperates the right lung from the right lobe of the liver and the left lung from the left lobe of the liver, fundus of stomach and the spleen.

LEF

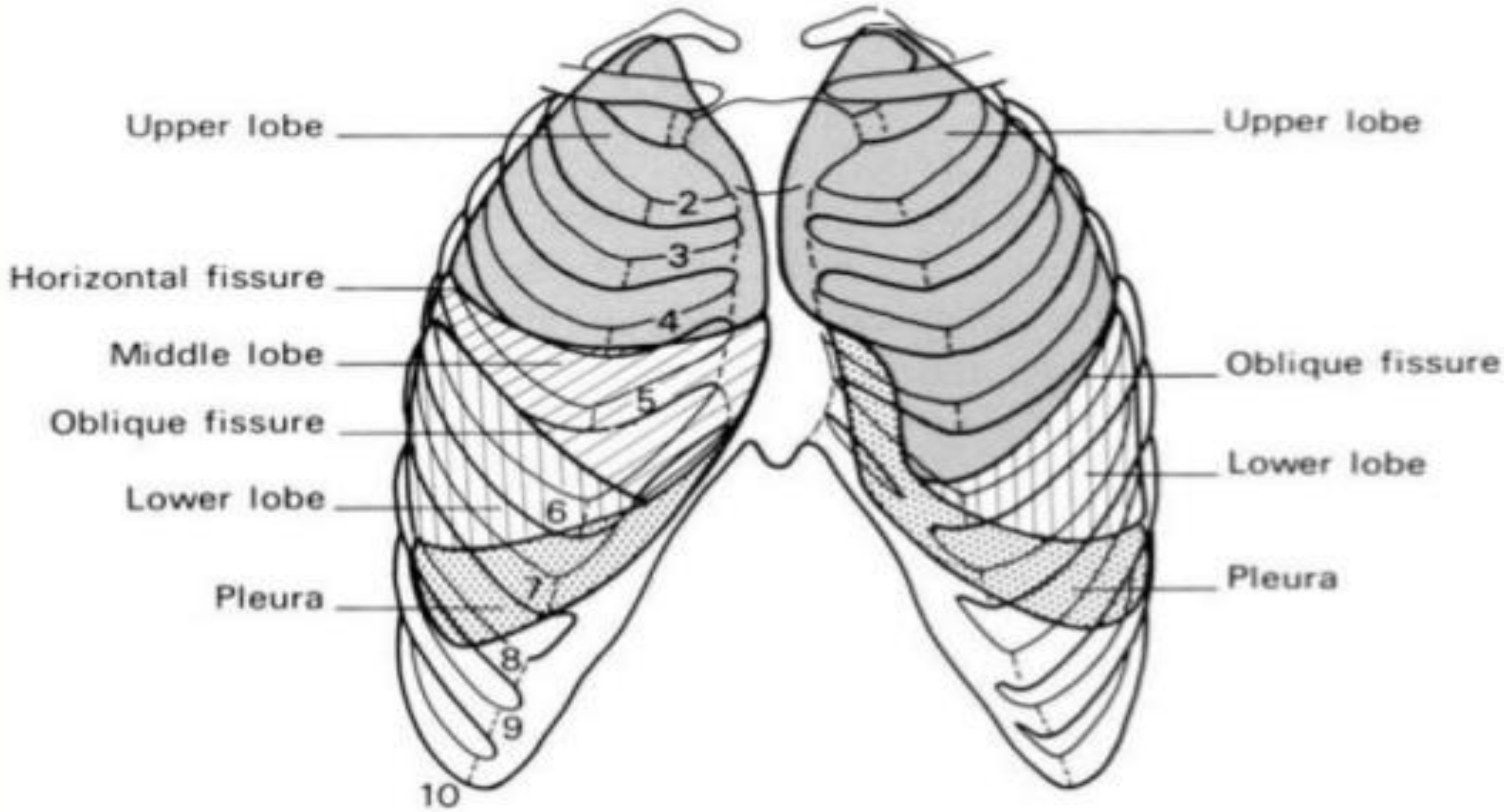
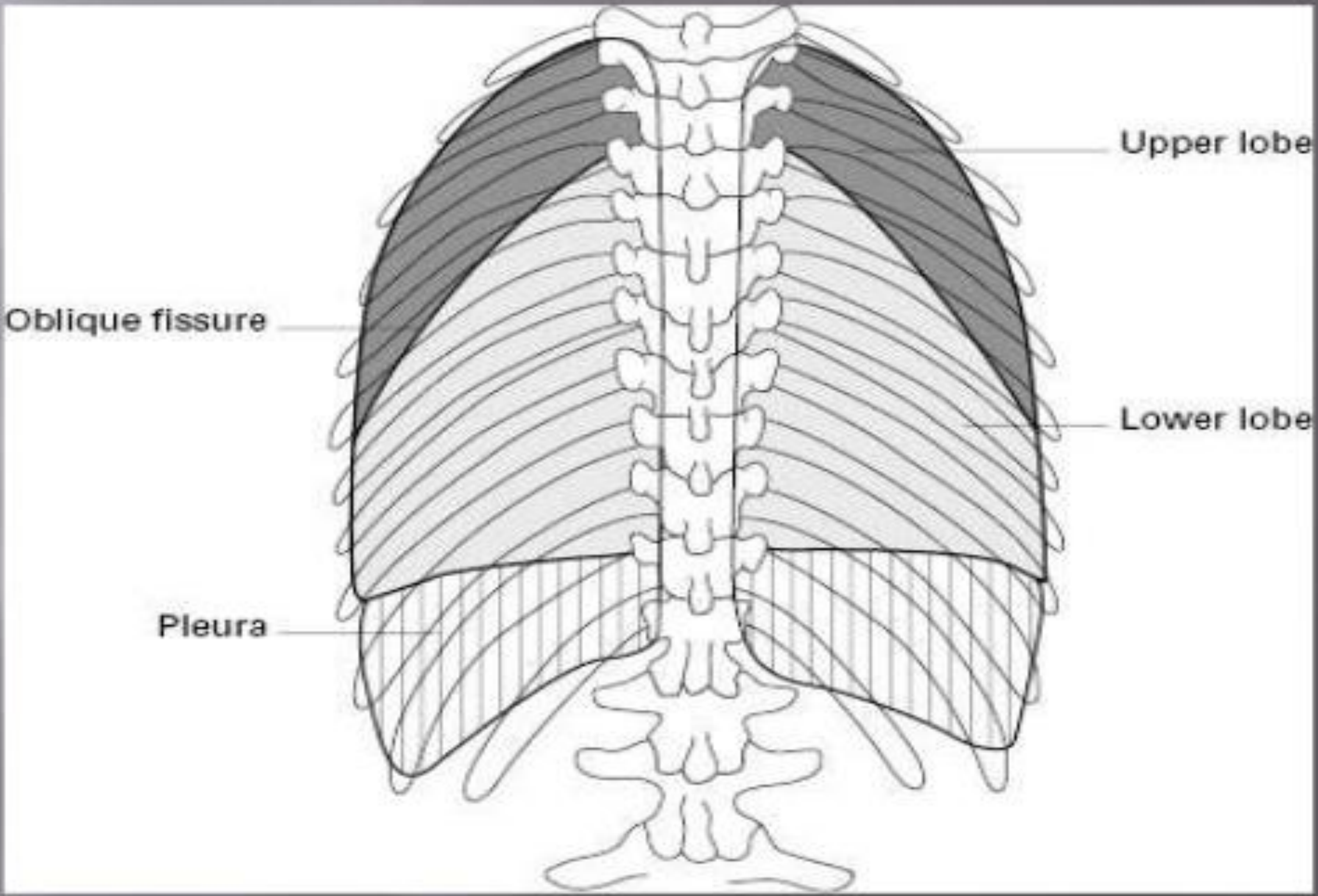
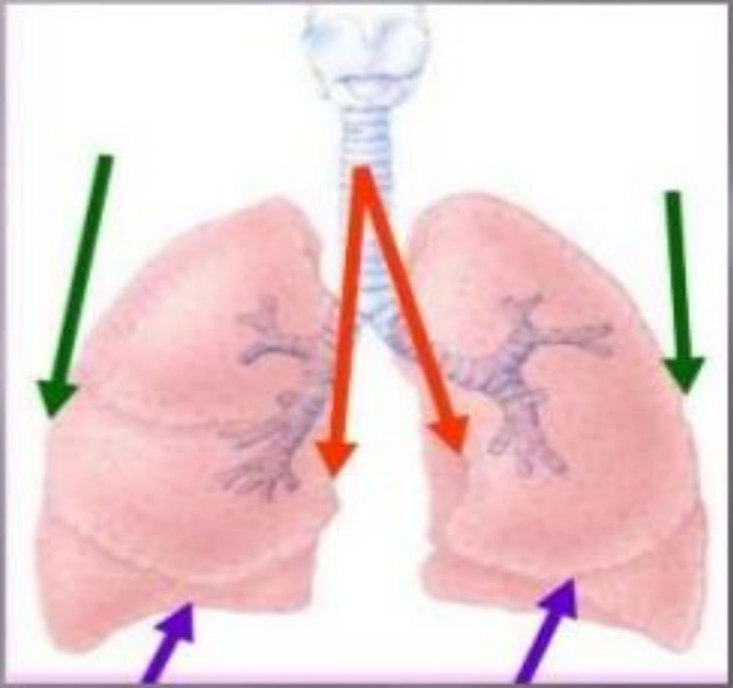


Fig. 2 The surface markings of the lungs and pleura—anterior view.


Upper lobe
Oblique fissure
Lower lobe
Pleura

- BORDERS
- ANTERIOR BORDER- right lung continues running downwards till the 6^{th} costochondral junction.
- ANTERIOR BORDER- left lung continues running downwards till the 4^{th} costal cartilage then curves laterally ½ inch forming the cardiac notch then descends downwards till the 6^{th} costochondral junction.

- INFERIOR BORDER- Is sharp and seperates the base from costal surface.
- POSTERIOR BORDER-Is rounded, thick and lies beside the vertebral column.



-Borders of the lung:

1- anterior border

2- posterior border

3- inferior border

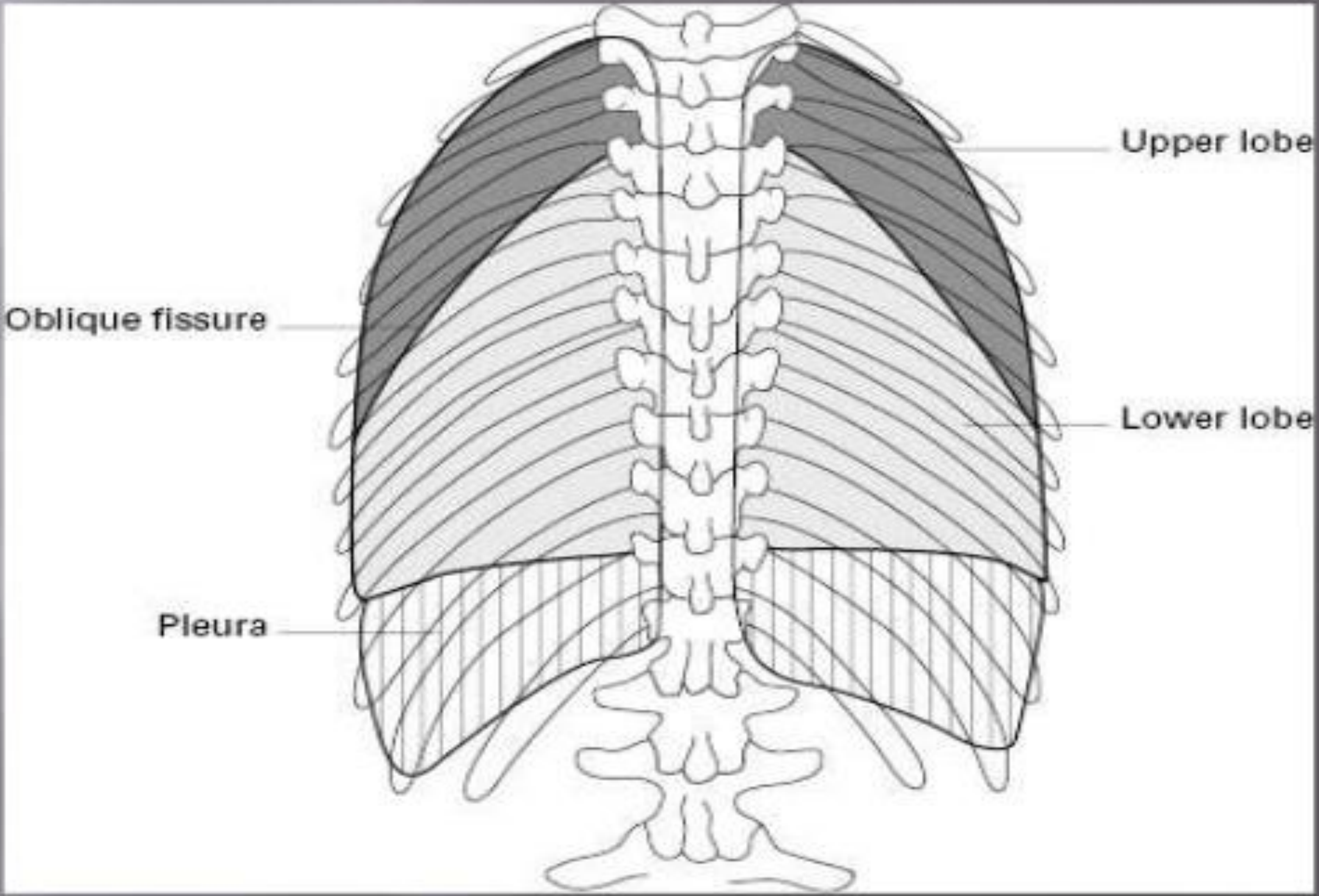
SURFACES

- COASTAL SURFACE- lies immediately adjacent to the ribs and intercostal spaces of the thoracic wall
- MEDIAL SURFACE- It is divided into two parts:

  a) Anterior(mediastinal part): Contains a HILUM in the middle(depression in which bronchi,vessels and nerves forming the root of lungs.

  b) Posterior(vertebral part): It is related to:

  -bodies of thoracic vertebrae, IV discs, posterior intercostal vessels.
- DIAPHRAGMATIC SURFACE


Upper lobe
Oblique fissure
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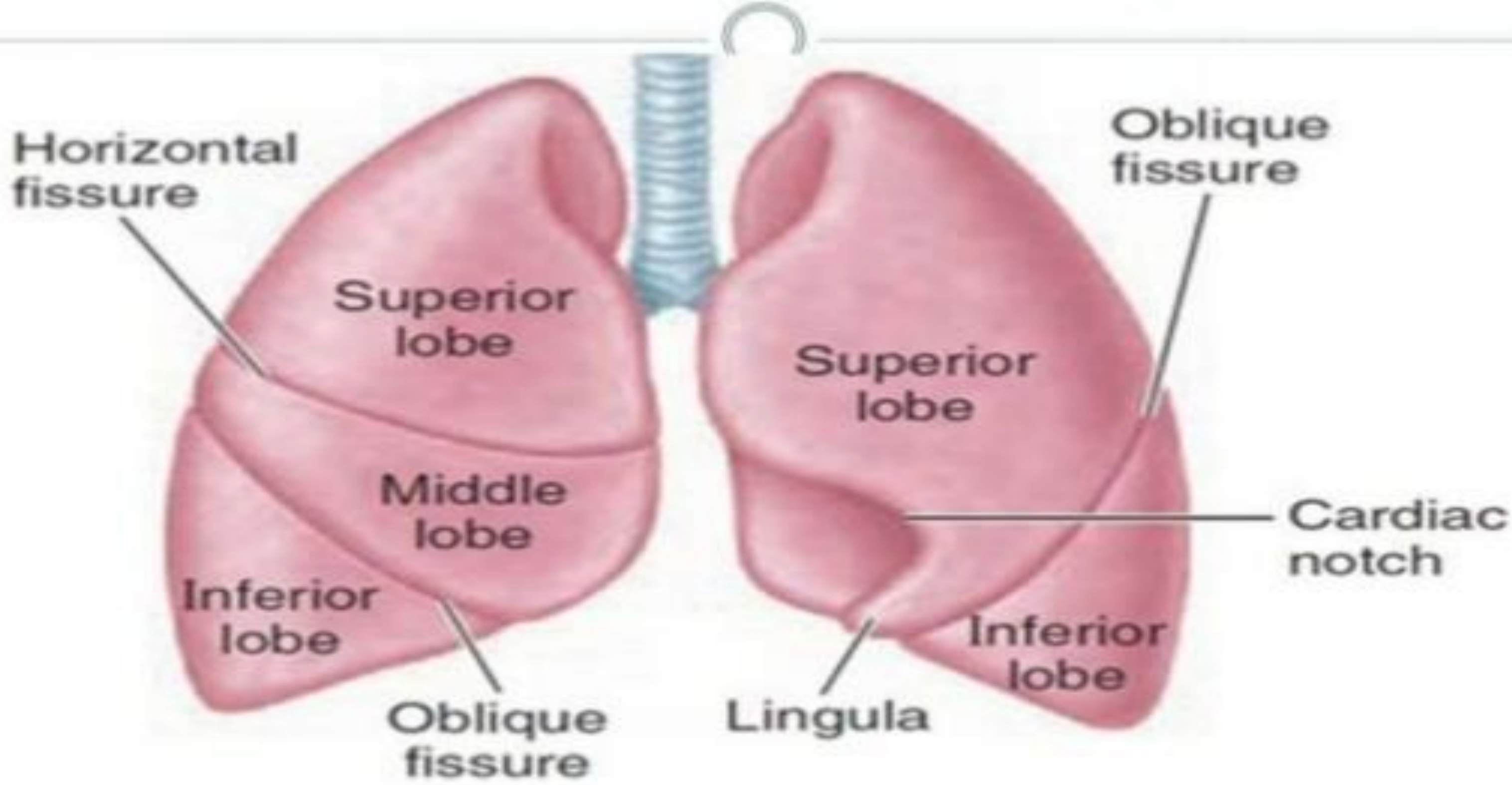
Lobes and fissures of lungs



Mechanics of Breathing (Pulmonary Ventilation)

- Completely mechanical process
- Depends on volume changes in the thoracic cavity
- Volume changes lead to pressure changes, which lead to the flow of gases to equalize pressure

Mechanics of Breathing (Pulmonary Ventilation)

- Two phases
  - Inspiration – flow of air into lung
  - Expiration – air leaving lung

Inspiration

- Diaphragm and intercostals muscles contract
- The size of the thoracic cavity increases
- External air is pulled into the lungs due to an increase in intrapulmonary volume

Inspiration

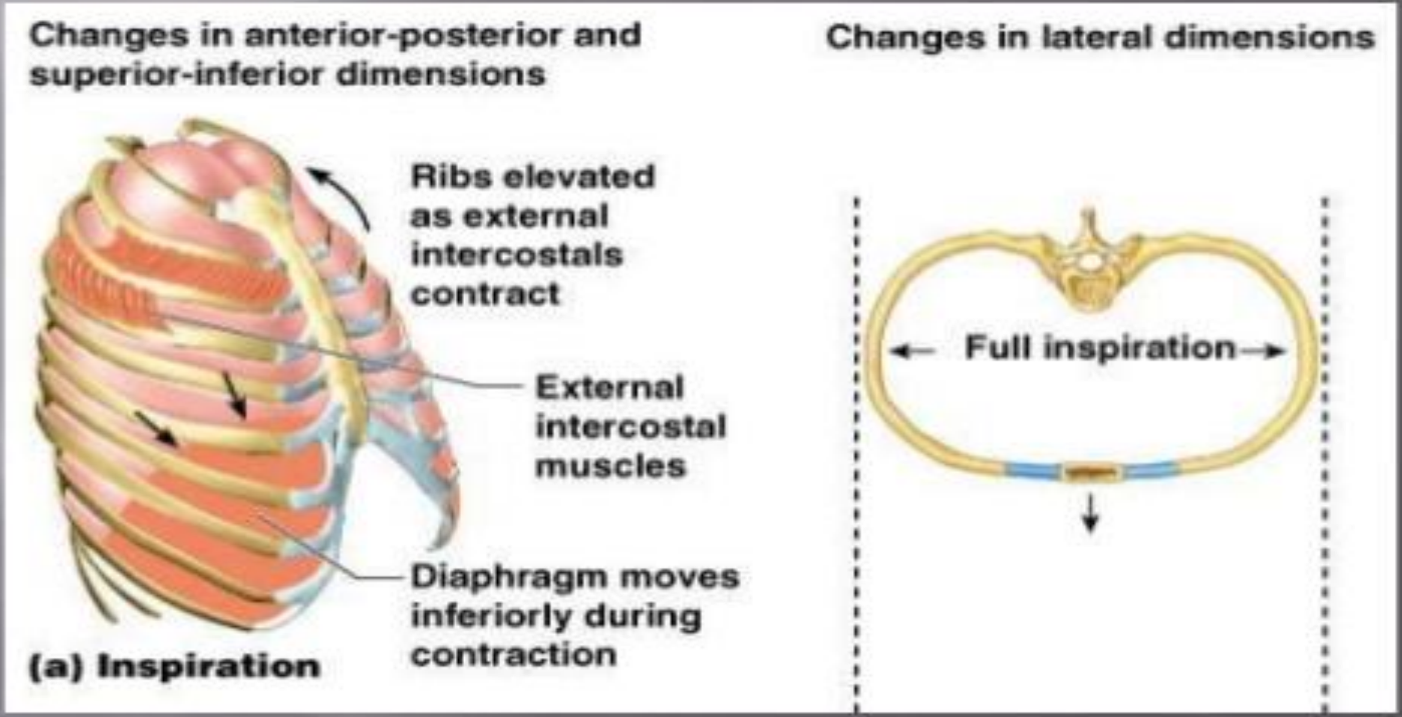


Figure 13.7a

Exhalation

- Largely a passive process which depends on natural lung elasticity
- As muscles relax, air is pushed out of the lungs
- Forced expiration can occur mostly by abdominal recti, which have the powerful effect of pulling downward on the lower ribs and internal intercostal muscles depress the rib cage

Exhalation

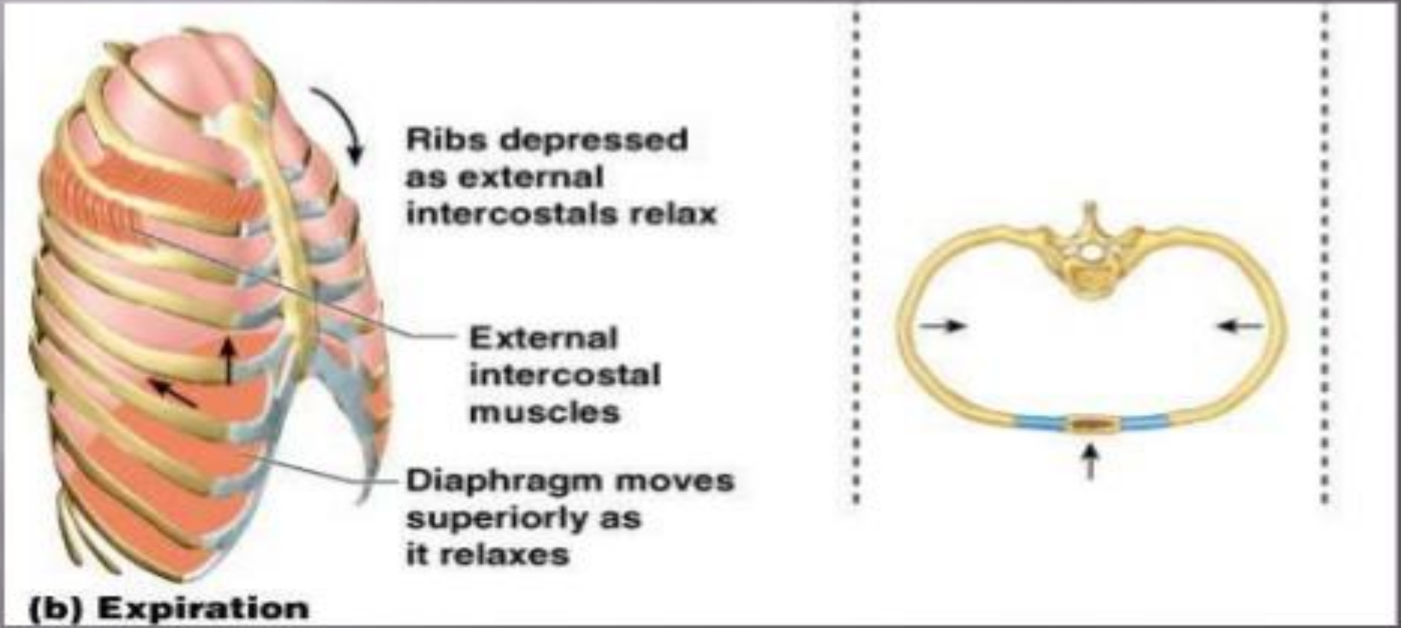


Figure 13.7b

Lung recoil It is due to **Elastic recoil** and surface tension.

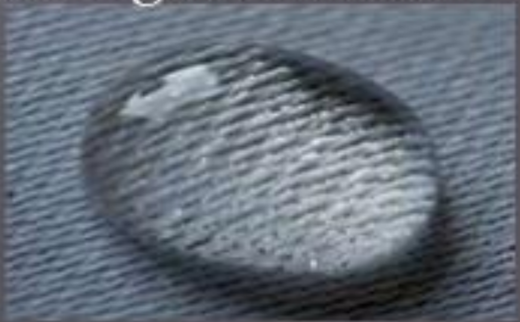
Elastic recoil:

Elastic forces of the lung tissue it is determined mainly by elastin and collagen fibers.

Surface tension:

It is the elastic tendency of a fluid surface which makes it acquire the least surface area possible.

As the air inside the lungs is moist, there is considerable surface tension within the tissue of the lungs. Because the alveoli are highly elastic, they do not resist surface tension on their own, which allows the force of that deflate the alveoli as air is forced out during exhalation by the contraction of the pleural cavity.



Surfactant

Surfactant: Reduces tendency of lungs to collapse
It is secreted by special surfactant-secreting epithelial cells called type II alveolar epithelial cells

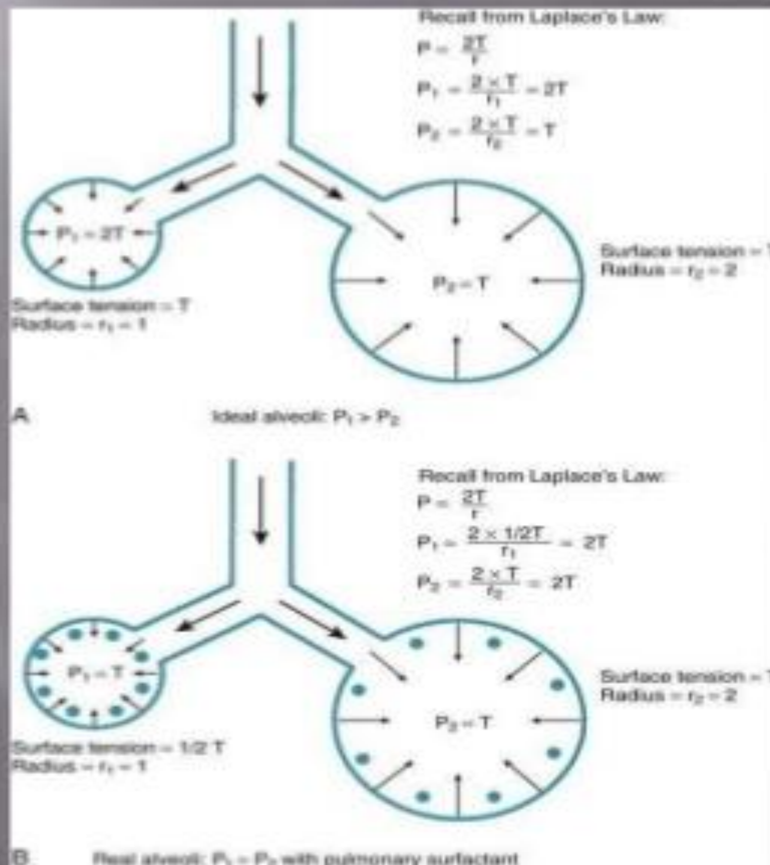
Role of surfactant

During Inspiration

- When alveoli expand, surfactant molecules move apart.

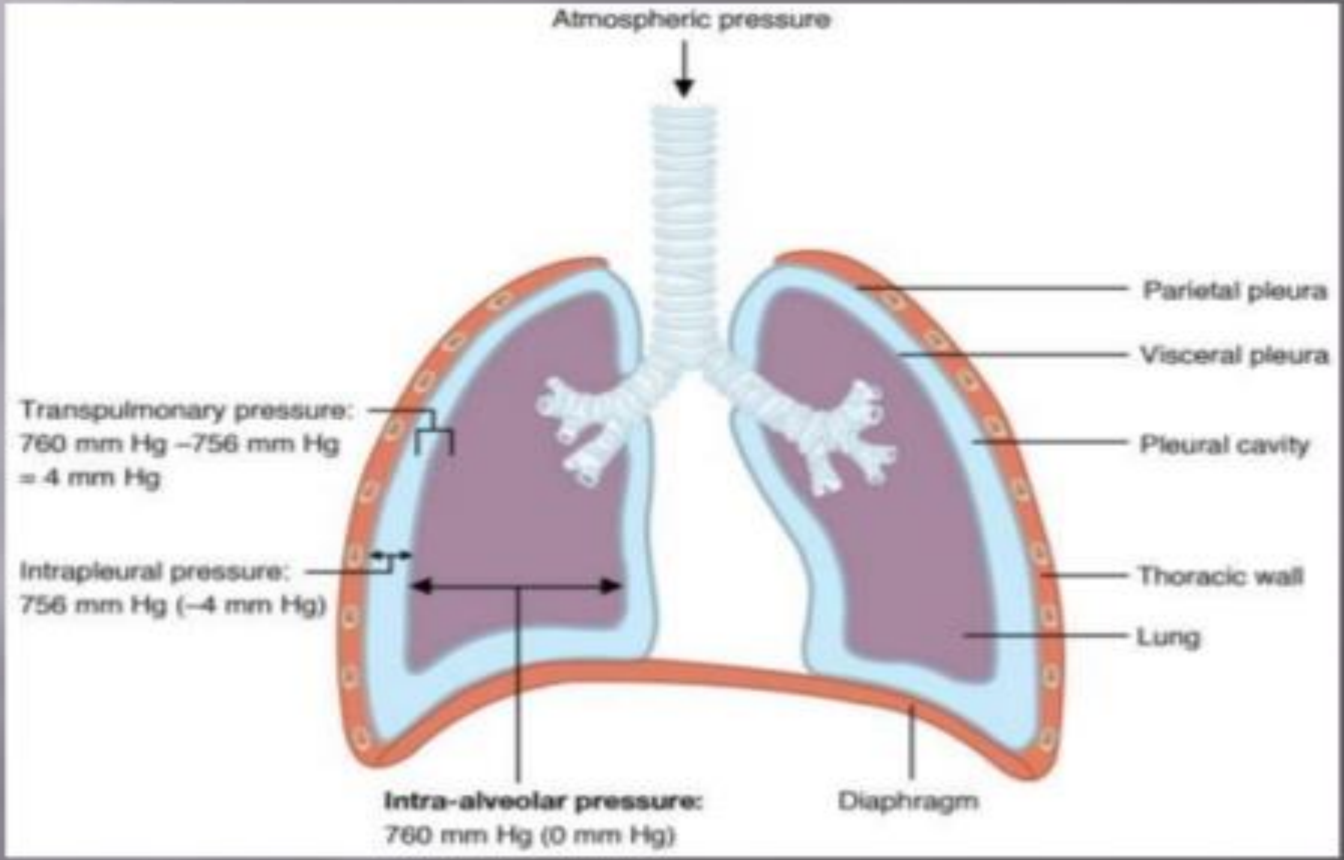
During Expiration

- When lungs shorten, surfactant molecules move together and become concentrated → surface tension is reduced



Recall from Laplace's Law:
$P = \frac{2T}{r}$
$P_1 = \frac{2 \times T}{r_1} = 2T$
$P_2 = \frac{2 \times T}{r_2} = T$
$P_1 = 2T$
Surface tension = T
Radius = r_1 = 1
$P_2 = T$
Surface tension = T
Radius = r_2 = 2
A
Ideal alveoli: $P_1 > P_2$
Recall from Laplace's Law:
$P = \frac{2T}{r}$
$P_1 = \frac{2 \times 1/2T}{r_1} = 2T$
$P_2 = \frac{2 \times T}{r_2} = 2T$
$P_1 = T$
Surface tension = 1/2 T
Radius = r_1 = 1
$P_2 = T$
Surface tension = T
Radius = r_2 = 2
B
Real alveoli: $P_1 = P_2$ with pulmonary surfactant

Pleura



Pleural fluid produced by pleural membranes
Acts as lubricant
Helps hold parietal and visceral pleural membranes together

TRANSPULMONARY PRESSURE

The difference between the alveolar pressure and the pleural pressure, this is called the transpulmonary pressure.

- TPP can be measured by performing oesophageal manometry

Pneumothorax : In this an abnormal collection of air in the pleural space between the lung and the chest wall. https://www.hamilton-medical.com/en_IN/Solutions/Transpulmonary-pressure-measurement.html

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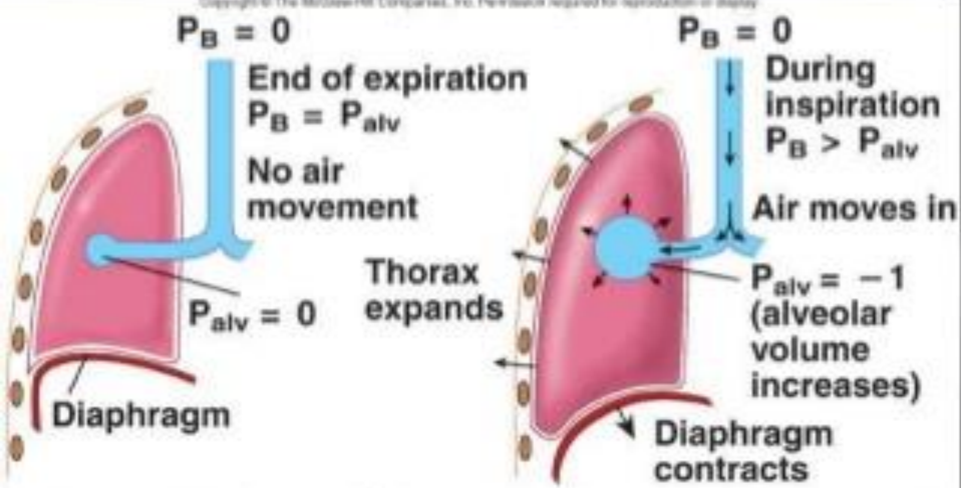
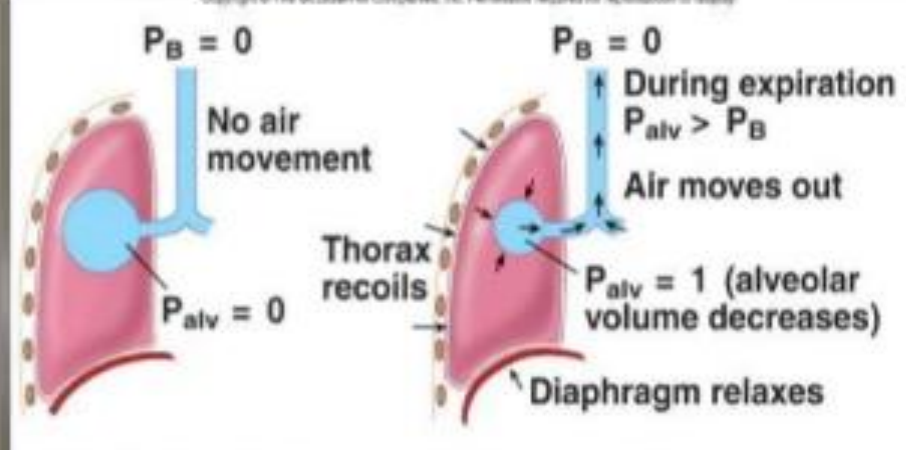
Alveolar Pressure Changes



1. Barometric air pressure (P_B) is equal to alveolar pressure (P_{alv}) and there is no air movement.

2. Increased thoracic volume results in increased alveolar volume and decreased alveolar pressure. Barometric air pressure is greater than alveolar pressure, and air moves into the lungs.



3. End of inspiration.

4. Decreased thoracic volume results in decreased alveolar volume and increased alveolar pressure. Alveolar pressure is greater than barometric air pressure, and air moves out of the lungs.

Compliance

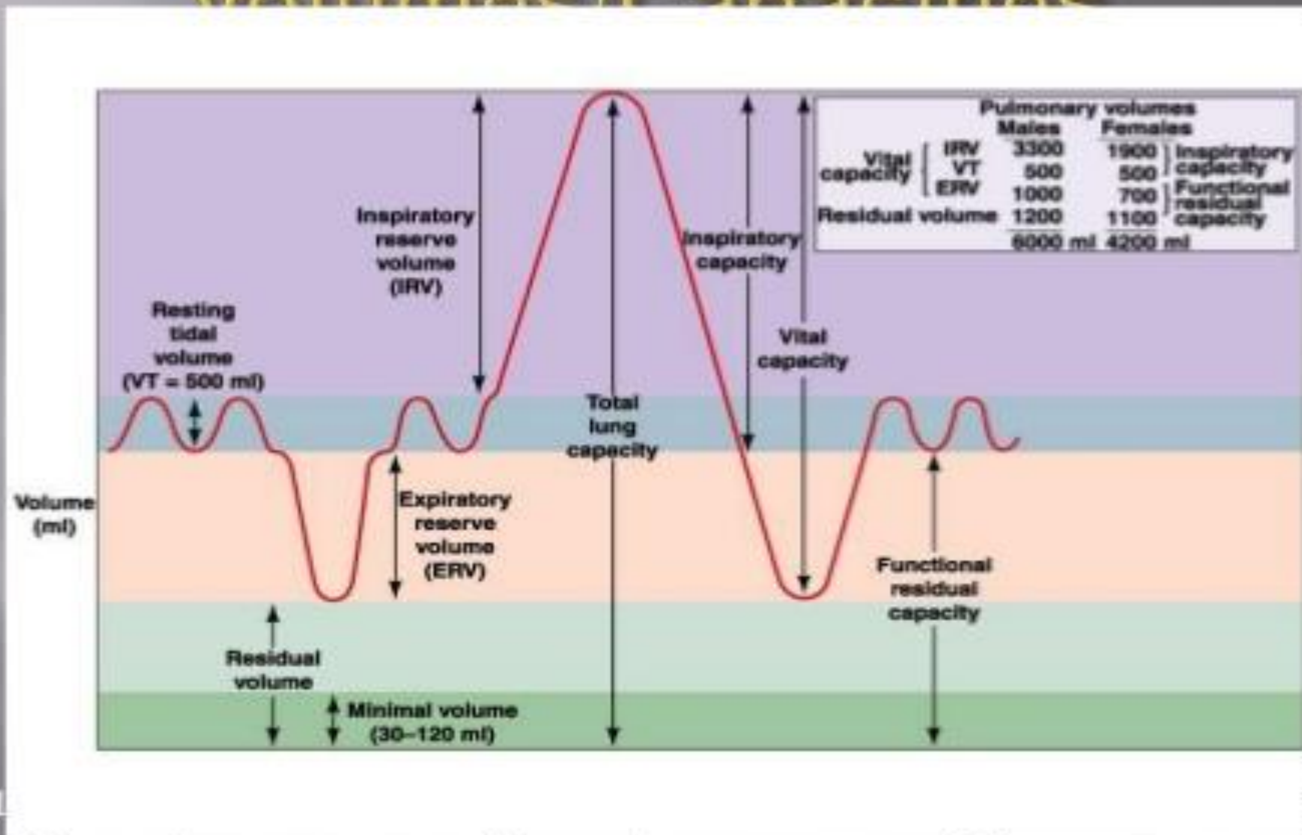
Measure of the ease with which lungs and thorax expand

A lower-than-normal compliance means the lungs and thorax are harder to expand

Pulmonary Volumes

- Tidal volume : Volume of air inspired or expired during a normal inspiration or expiration , Usually 500 millilitres in the adult male
- Inspiratory reserve volume: Amount of air inspired forcefully after inspiration of normal tidal volume , It is usually equal to about 3000 millilitres
- Expiratory reserve volume: Amount of air forcefully expired after expiration of normal tidal volume It is usually 1100 millilitres
- Residual volume: Volume of air remaining in respiratory passages and lungs after the most forceful expiration. It is usually 1200 milliliters.

Spirometer and Lung Volumes/Capacities



All pu … to 25 percent less in women than in men, and they are greater in large and athletic people than in small and asthenic people.

Pulmonary Capacities

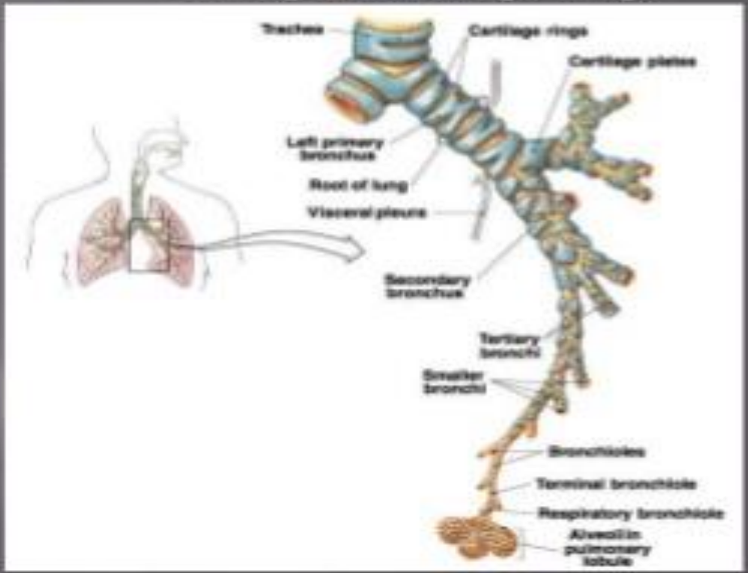
- Inspiratory capacity: Tidal volume plus inspiratory reserve volume (about 3500 milliliters)
- Functional residual capacity: Expiratory reserve volume plus the residual volume (about 2300 milliliters)
- Vital capacity: Sum of inspiratory reserve volume, tidal volume, and expiratory reserve volume (about 4600 milliliters)
- Total lung capacity: Sum of all volume (about 5800 milliliters)

Minute and Alveolar Ventilation

- Minute ventilation: Total amount of air moved into and out of respiratory system per minute
- Respiratory rate or frequency: Number of breaths taken per minute. It is about 12 breaths per minute.
- Anatomic dead space: It is the total volume of the conducting airways from the nose or mouth down to the level of the terminal bronchioles, and is about 150 ml on the average in humans.
- Alveolar ventilation: How much air per minute enters the parts of the respiratory system in which gas exchange takes place

Functions of the Respiratory Passageways

multiple cartilage rings



less extensive curved cartilage plates

One of the most important problems in all the respiratory passageways is to keep them open and allow easy passage of air to and from the alveoli.

The bronchioles are not prevented from collapsing by the rigidity of their walls. Instead, they are kept expanded mainly by the same transpulmonary pressures that expand the alveoli

Cough Reflex

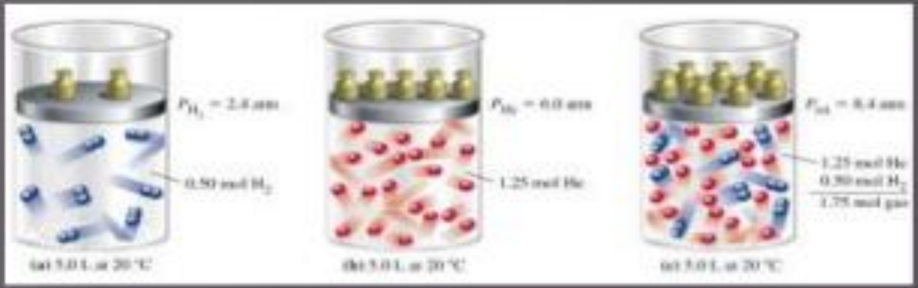
- The bronchi and trachea are so sensitive to light touch that very slight amounts of foreign matter or other causes of irritation initiate the cough reflex

Sneeze Reflex

The sneeze reflex is like the cough reflex, except that it applies to the nasal passageways instead of the lower respiratory passages. The initiating stimulus of the sneeze reflex is irritation in the nasal passageways.

Physical Principles of Gas Exchange

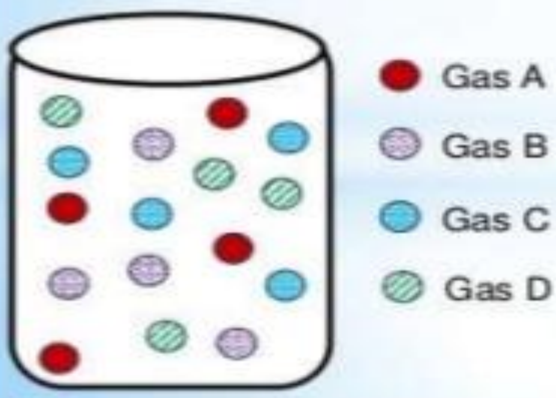
- In respiratory physiology, one deals with mixtures of gases, mainly of oxygen, nitrogen, and carbon dioxide.
- The rate of diffusion of each of these gases is directly proportional to the pressure caused by that gas alone, which is called the partial pressure of that gas.



*Dalton's Law of Partial Pressures

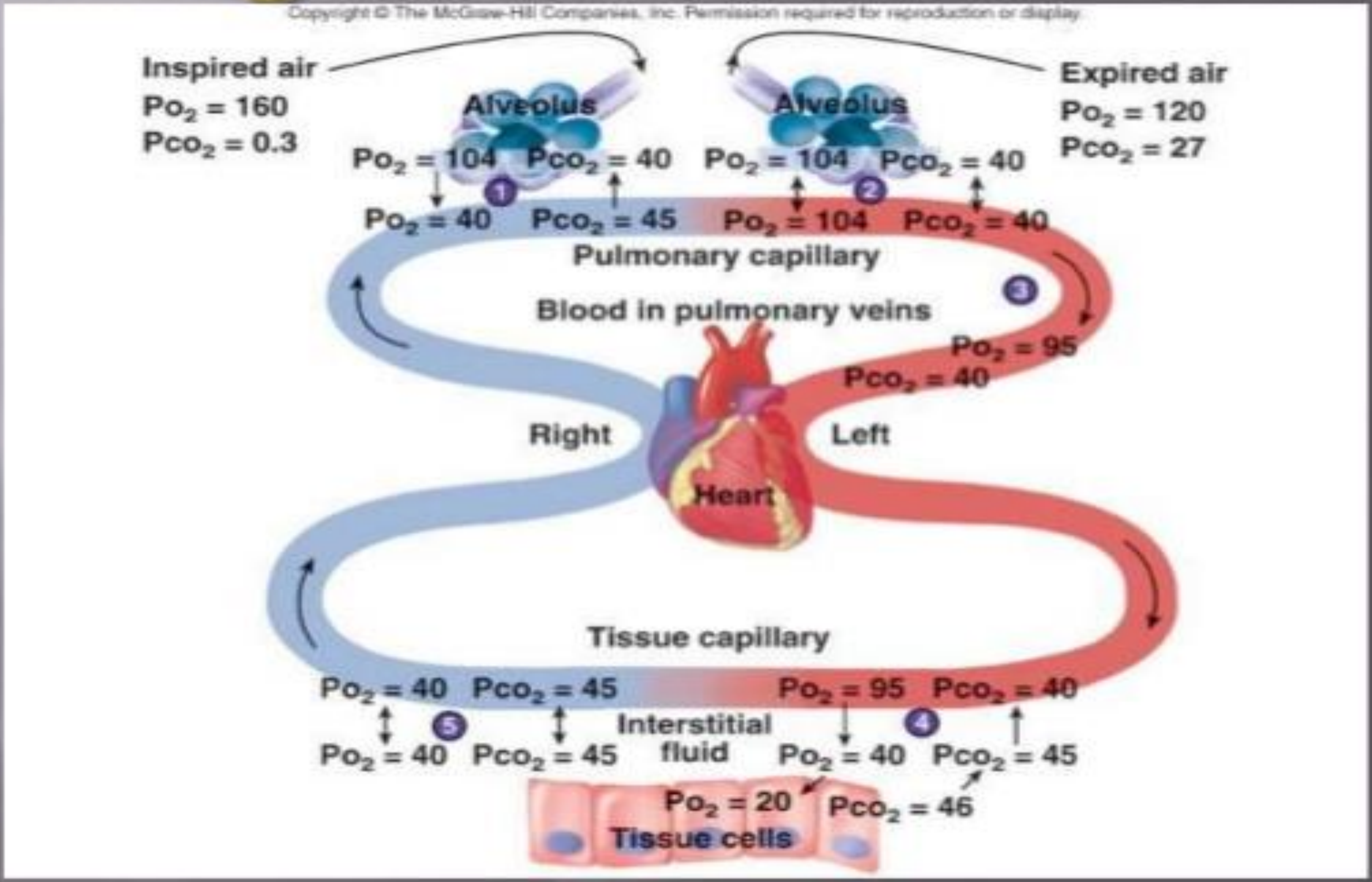
Now, let's do the same thing for the mixture of gases…
We can write an equation to calculate the total pressure of all four gases in the container as

$$P_{Total} = \frac{n_A RT}{V} + \frac{n_B RT}{V} + \frac{n_C RT}{V} + \frac{n_D RT}{V}$$



- Diffusion of gases through the respiratory membrane
  - Depends on membrane's thickness,
  - the diffusion coefficient of gas,
  - surface areas of membrane,
  - partial pressure of gases in alveoli and blood
- Relationship between ventilation and pulmonary capillary flow
  - Increased ventilation or increased pulmonary capillary blood flow increases gas exchange
  - Physiologic shunt is deoxygenated blood returning from lungs

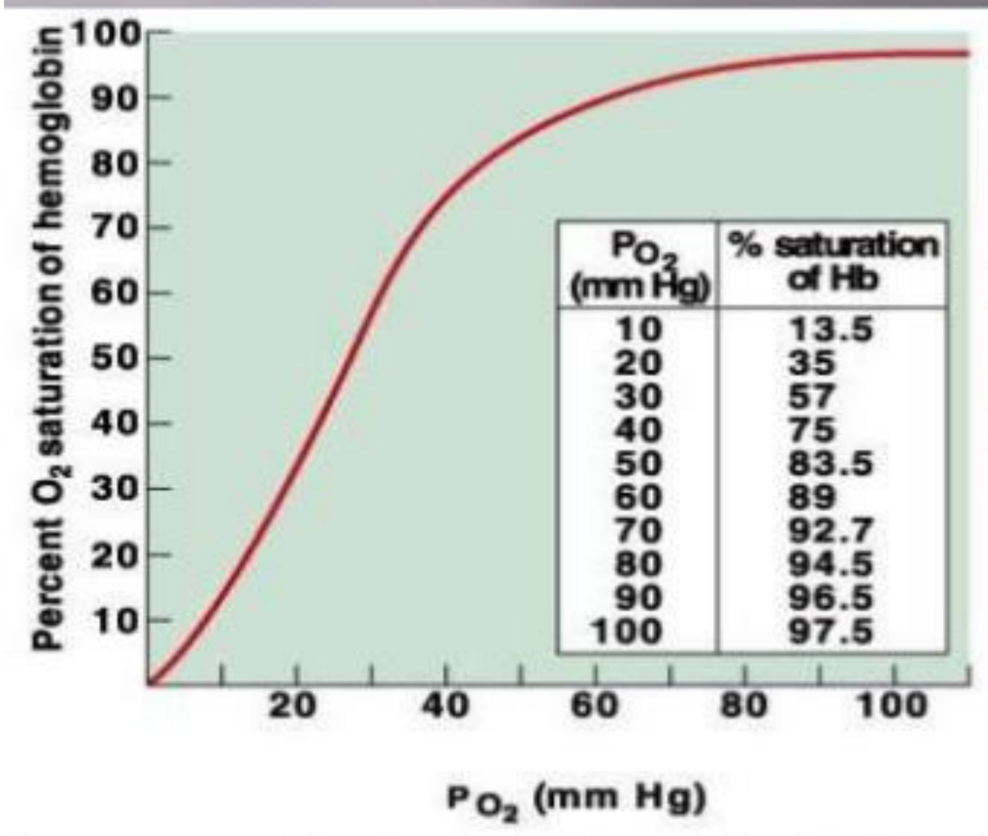
Changes in Partial Pressures



Hemoglobin and Oxygen Transport

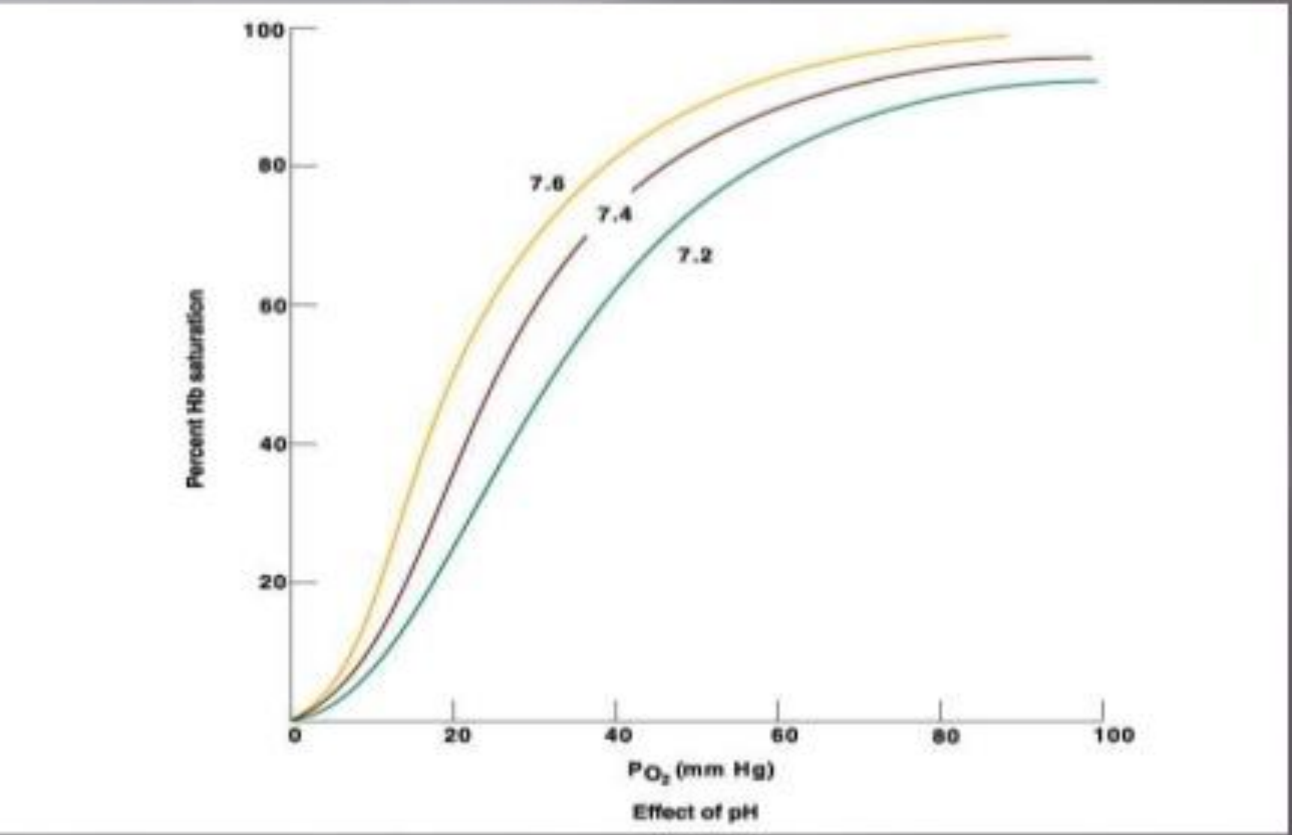
- Oxygen is transported by hemoglobin (98.5%) and is dissolved in plasma (1.5%)
- Oxygen-hemoglobin dissociation curve shows that hemoglobin is almost completely saturated when $P0_2$ is 80 mm Hg or above. At lower partial pressures, the hemoglobin releases oxygen.
- A shift of the curve to the left because of an increase in pH, a decrease in carbon dioxide, or a decrease in temperature results in an increase in the ability of hemoglobin to hold oxygen

Oxygen-Hemoglobin Dissociation Curve at Rest



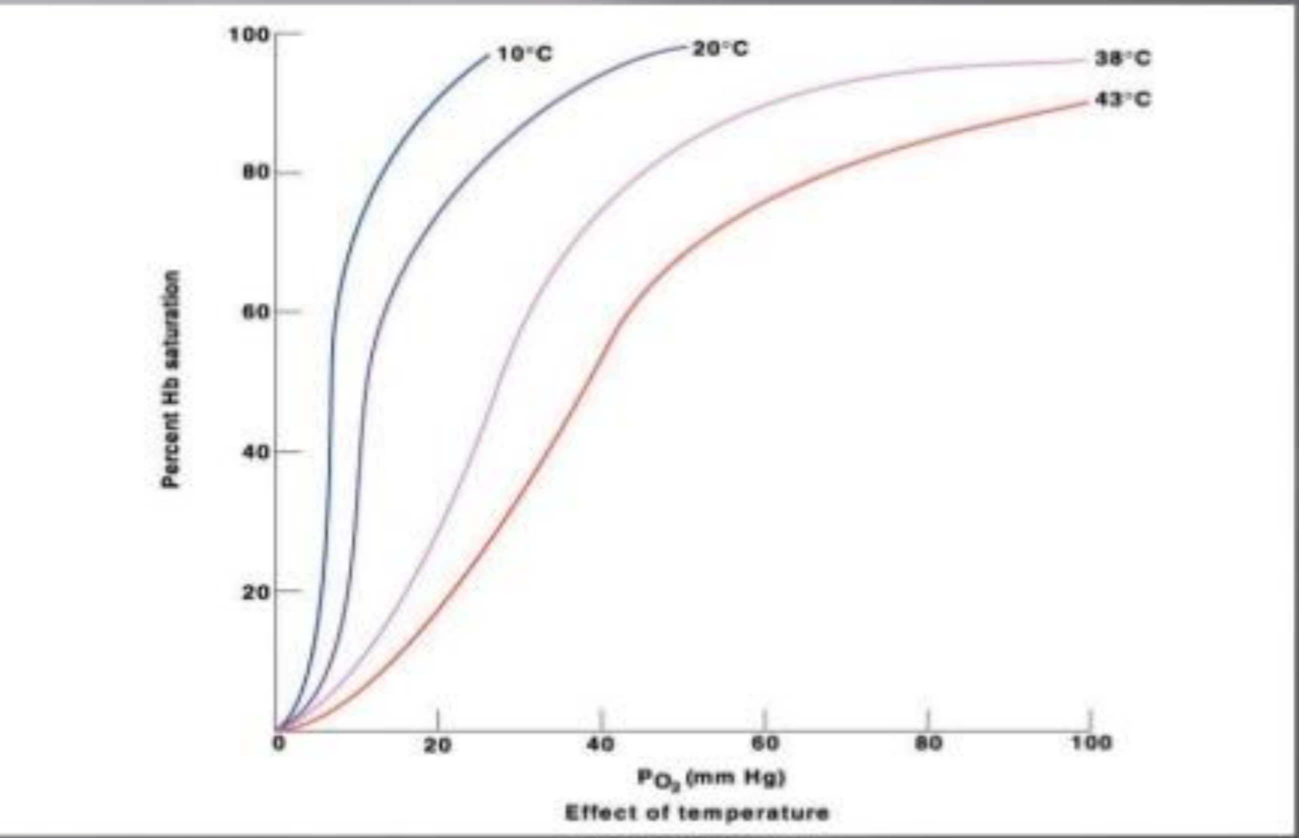
P_{O_2} (mm Hg)	% saturation of Hb
10	13.5
20	35
30	57
40	75
50	83.5
60	89
70	92.7
80	94.5
90	96.5
100	97.5

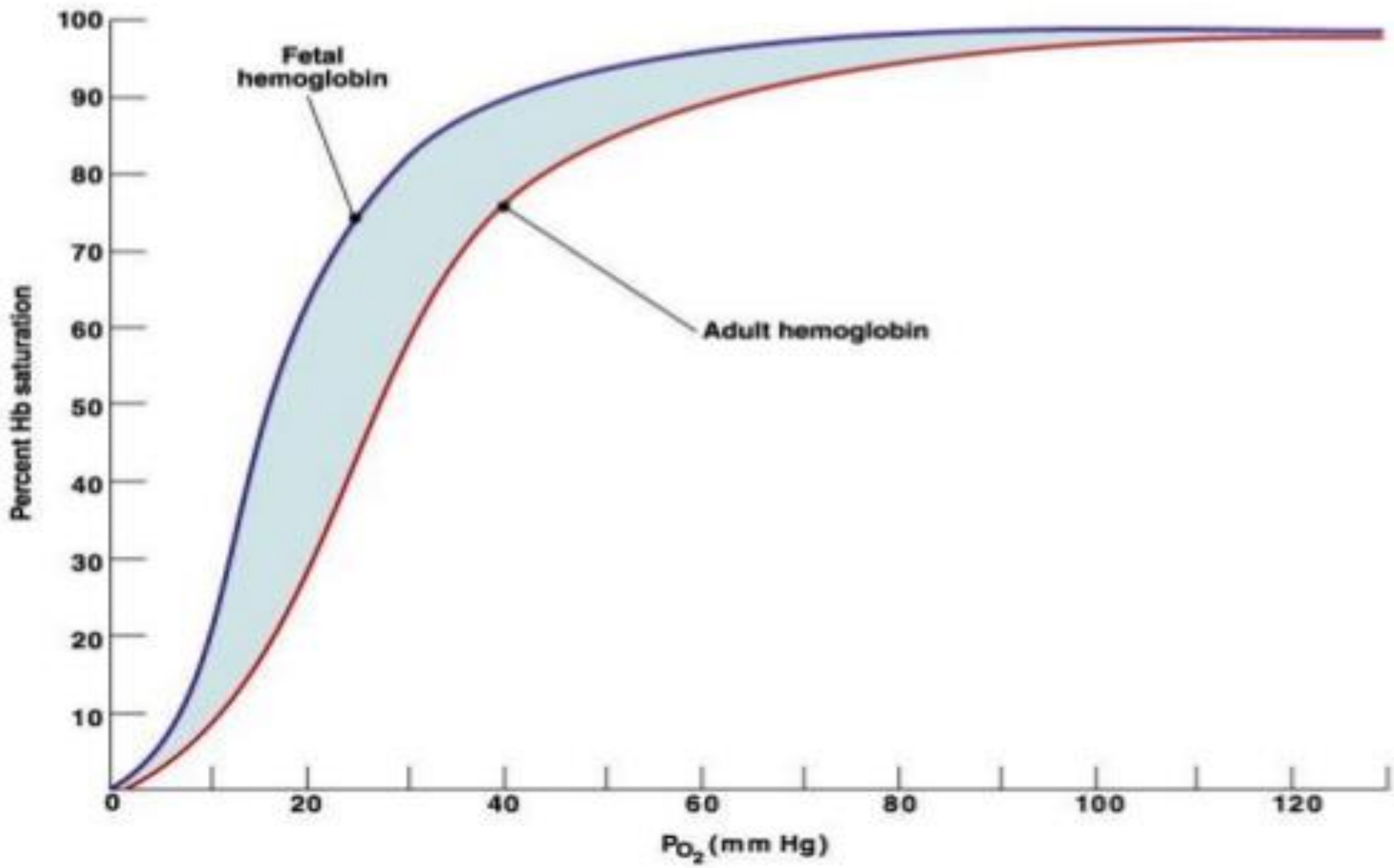
Bohr effect:



100
80
60
40
20
Percent Hb saturation
7.6
7.4
7.2
0
20
40
60
80
100
P_{O_2} (mm Hg)
Effect of pH

Temperature effects:





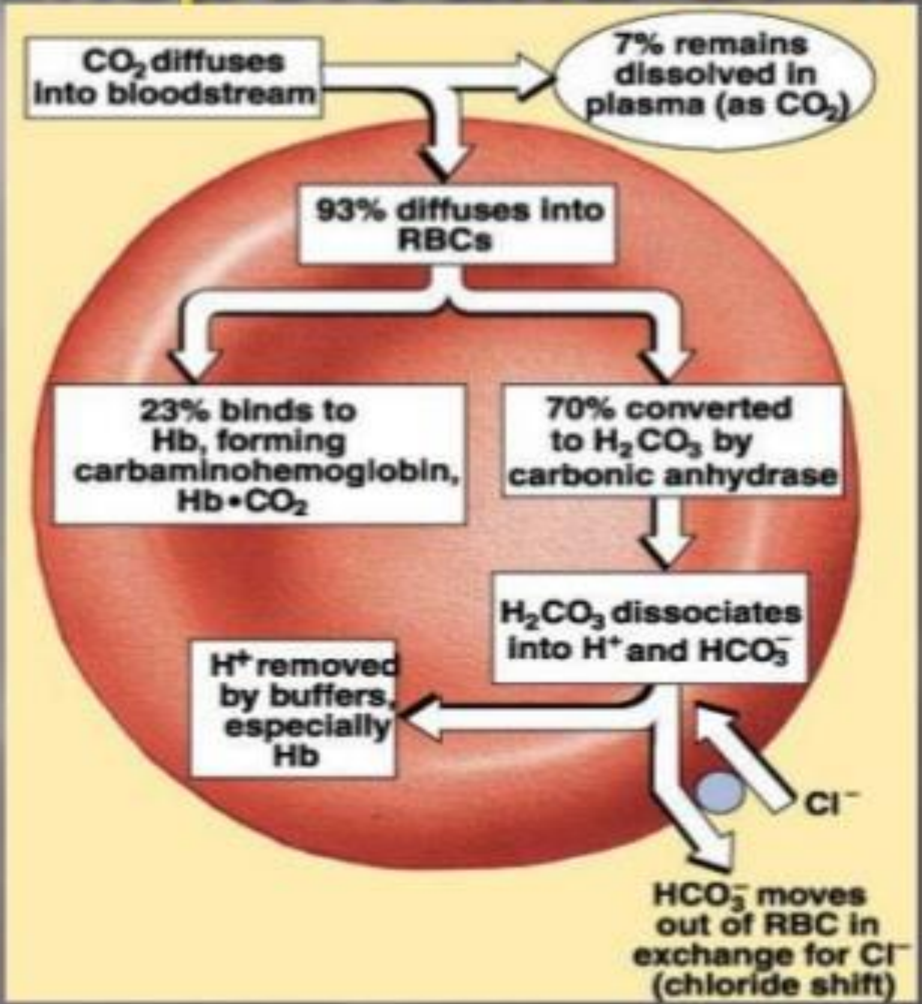
Fetal hemoglobin
Adult hemoglobin
Percent Hb saturation
100
90
80
70
60
50
40
30
20
10
0
20
40
60
80
100
120
P_{O_2} (mm Hg)

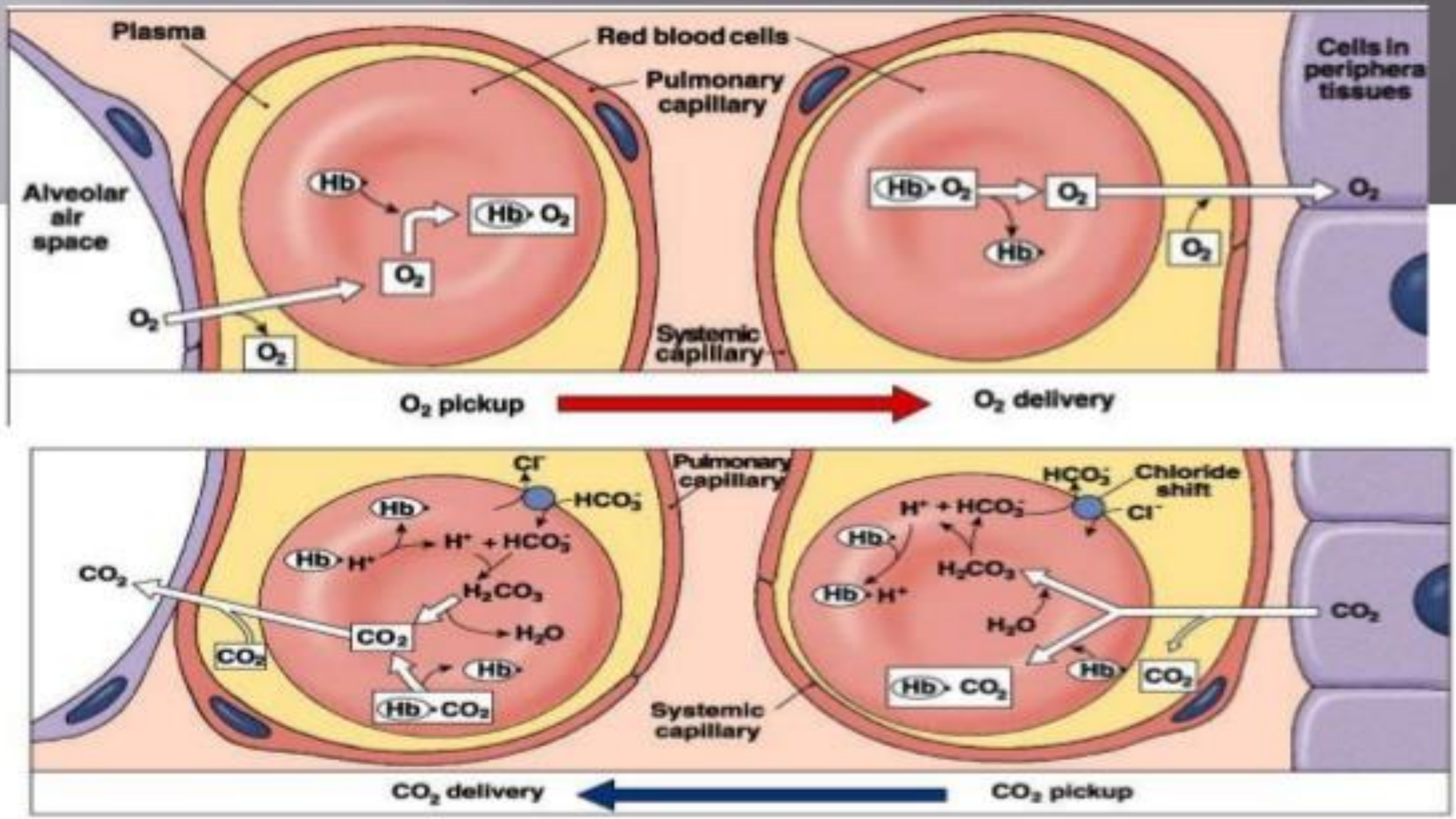
Transport of Carbon Dioxide

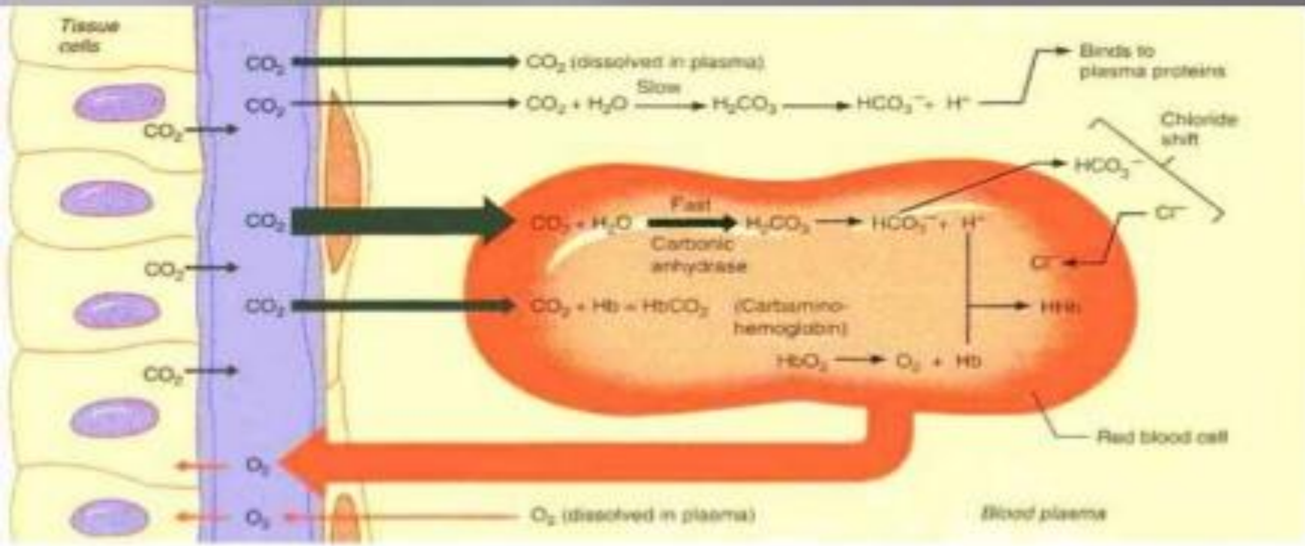
In lung capillaries, bicarbonate ions and hydrogen ions move into RBCs and chloride ions move out. Bicarbonate ions combine with hydrogen ions to form carbonic acid. The carbonic acid is converted to carbon dioxide and water. The carbon dioxide diffuses out of the RBCs.

Increased plasma carbon dioxide lowers blood pH. The respiratory system regulates blood pH by regulating plasma carbon dioxide levels

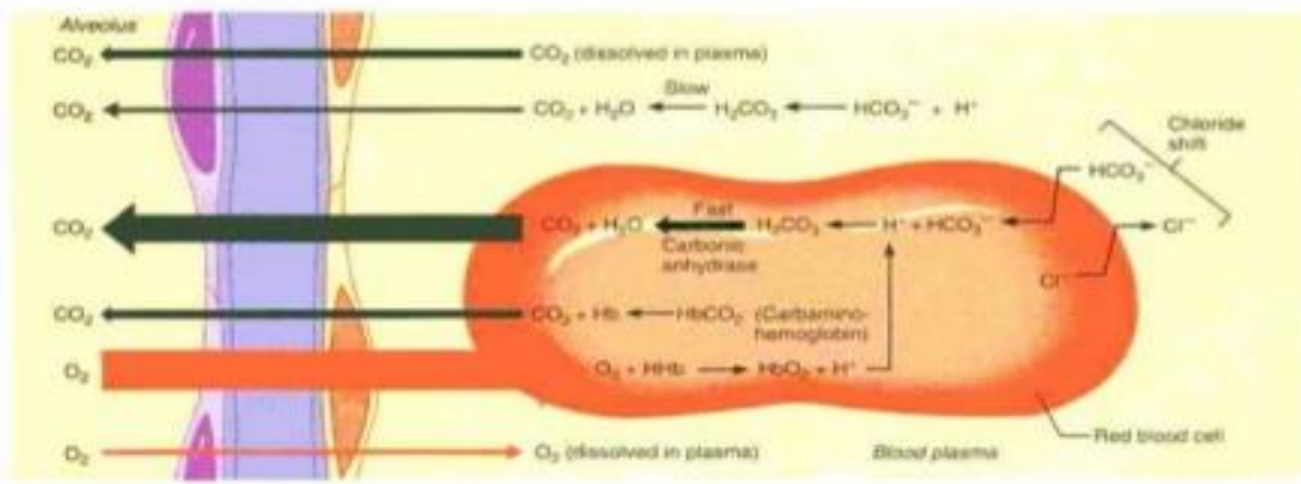
CO_2 Transport and Cl^- Movement




Plasma
Red blood cells
Pulmonary capillary
Cells in periphera tissues
Alveolar air space
Hb
$Hb \cdot O_2$
O_2
Systemic capillary
O_2 pickup
O_2 delivery
Cl^-
HCO_3^-
Pulmonary capillary
Chloride shift
$H^+ + HCO_3^-$
$Hb \cdot H^+$
H_2CO_3
H_2O
CO_2
$Hb \cdot CO_2$
Systemic capillary
CO_2 delivery
CO_2 pickup

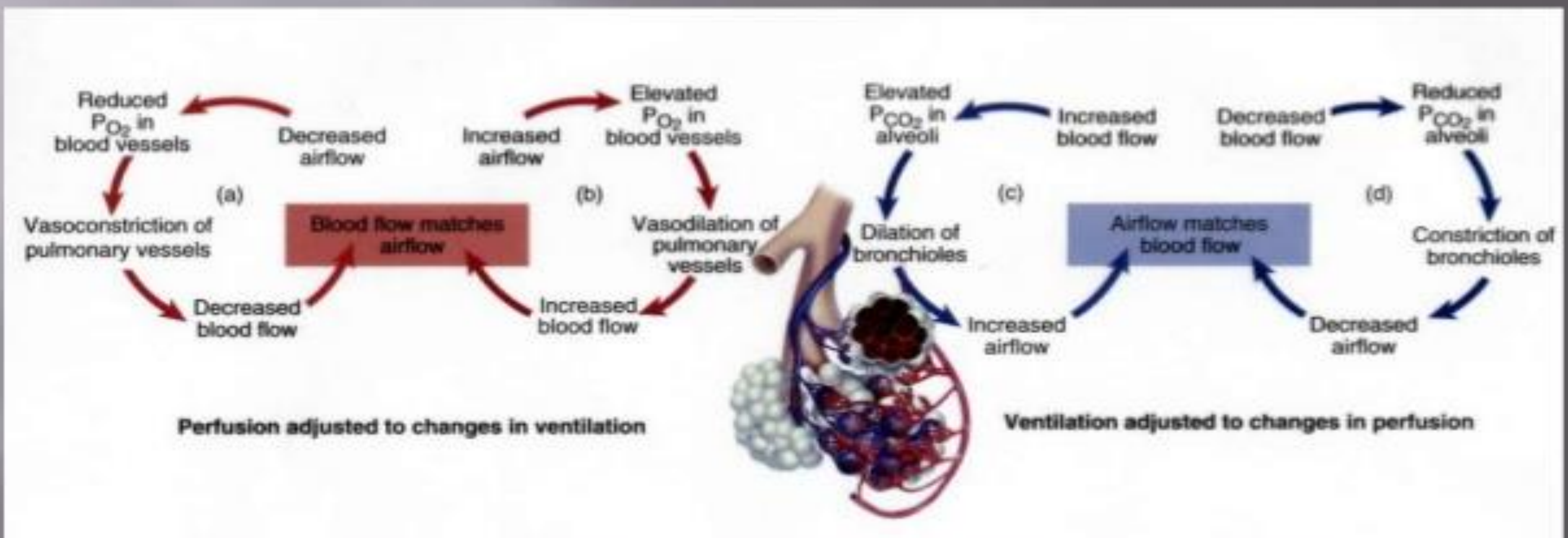


(a) Oxygen release and carbon dioxide pickup at the tissues



(b) Oxygen pickup and carbon dioxide release in the lungs

Ventilation-perfusion coupling:



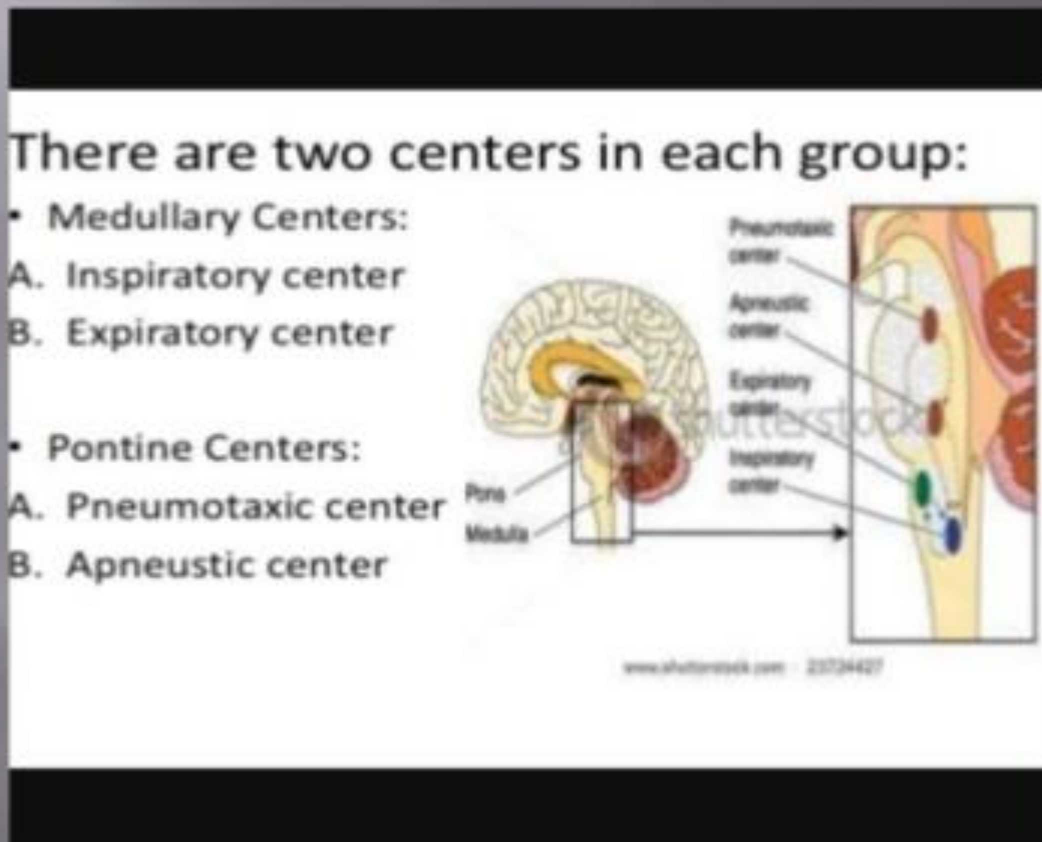
- Normal rate of respiration in adults is 12-16/min ,with tidal volume of 500ml.This rate and depth of respiration i.e total pulmonary ventilation can be adjusted to the requirements of the body.
- The size of thorax is altered by the action of the respiratory muscles ,which contract as a result of nerve impulses transmitted to them from centers in the brain and relax in absence of nerve impulses.
- These nerve impulses are sent from clusters of neurons located bilaterally in the medulla oblongata and pons of the brain stem .This widely dispersed group of neurons collectively called the respiratory center .

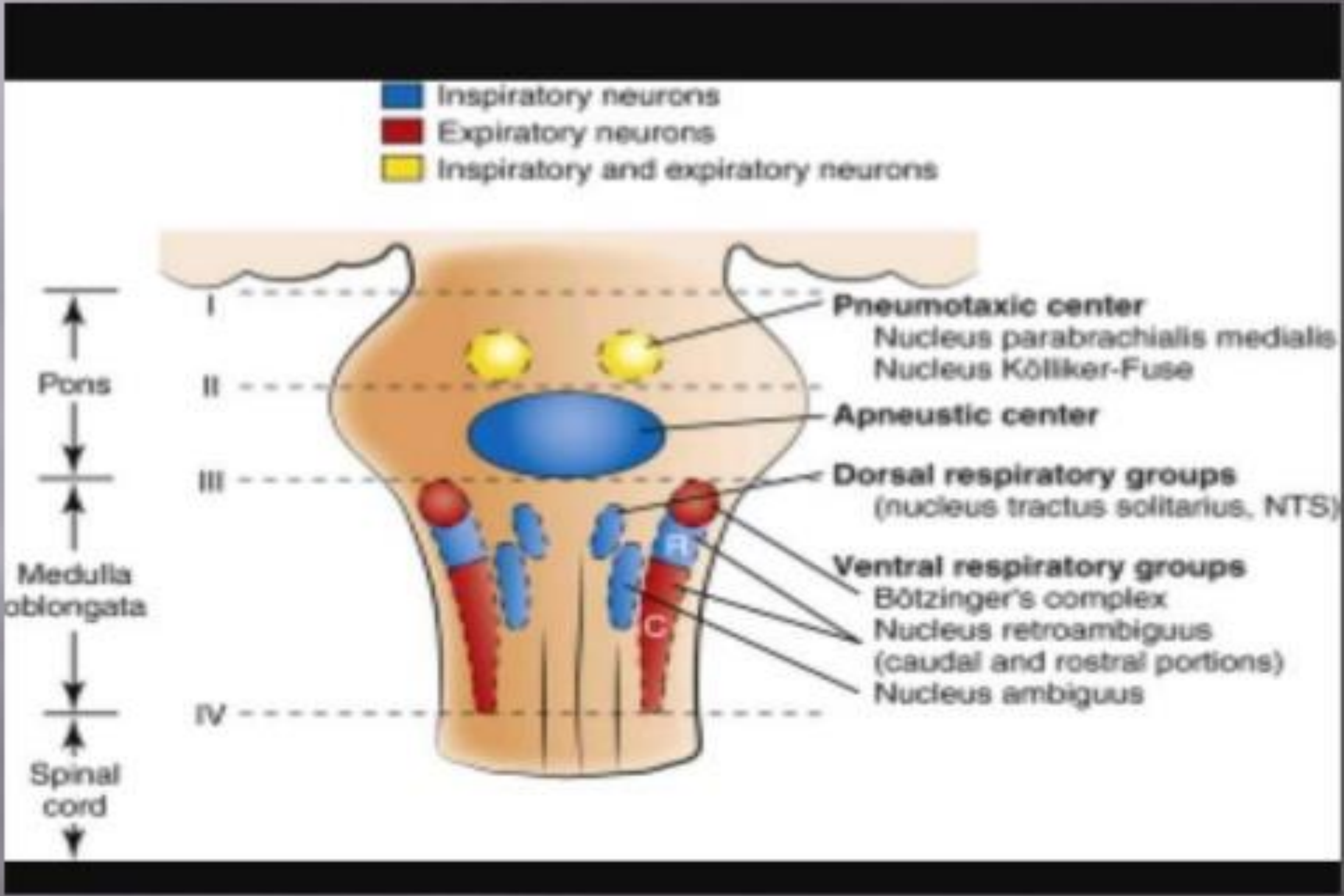
- This rhythmic discharge from the brain that produces spontaneous respiration is regulated by 2 mechanisms:-

1) NERVOUS REGULATORY MECHANISM
2) CHEMICAL REGULATORY MECHANISM

NERVOUS REGULATORY MECHANISM

- TWO SYSTEM:-
- AUTOMATIC CONTROL :Medullary rhythmicity area in the medulla oblongata.
- Pneumotaxic area in pons.
- Apneustic area in pons .
- VOLUNTARY CONTROL : via cerebral cortex .


There are two centers in each group:
• Medullary Centers:
A. Inspiratory center
B. Expiratory center
• Pontine Centers:
A. Pneumotaxic center
B. Apneustic center
Pneumotaxic center
Apneustic center
Expiratory center
Inspiratory center
Pons
Medulla



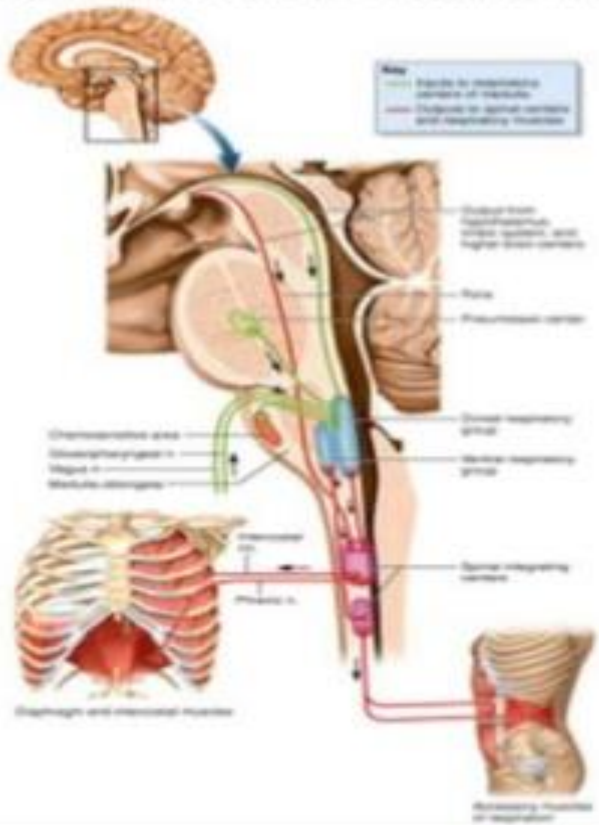
Inspiratory neurons
Expiratory neurons
Inspiratory and expiratory neurons
Pons
Medulla oblongata
Spinal cord
I
II
III
IV
Pneumotaxic center
Nucleus parabrachialis medialis
Nucleus Kölliker-Fuse
Apneustic center
Dorsal respiratory groups
(nucleus tractus solitarius, NTS)
Ventral respiratory groups
Bötzinger's complex
Nucleus retroambiguus
(caudal and rostral portions)
Nucleus ambiguus
R
C

AUTOMATIC CONTROL OF RESPIRATION

- Composed of neurons in medullary rhythmic area(MRA)in medulla oblongata, pneumatoxic & apneustic area in pons.
- MRA (Medullary rhythmic area) located in ventrolateral medulla overlying olivary nucleus .There are two types of respiratory neuron I and E neuron.

Medullary Respiratory Centers

- Ventral Respiratory Group: Sets the underline breathing rate .It activates the
  - Diaphragm stimulated via the Phrenic Nerve
  - External Intercostals stimulated via the Costal Nerves
- Dorsal Respiratory Group (DRG): receives input from multiple areas.
  - It modulates the breathing rate of the VRG so it can adapt to various situations.



Function of MRA to control basic rhythm of respiration .

↓

Inspiratory & expiratory area within MRA

↓

During quiet breathing inhalation lasts for about 2sec and exhalation for about 3 sec .

↓

Nerve impluse generated in inspiratory area → Establish basic rhythm of breathing

↓

Active insp. area generate nerve impluse for about 2 sec .

↓

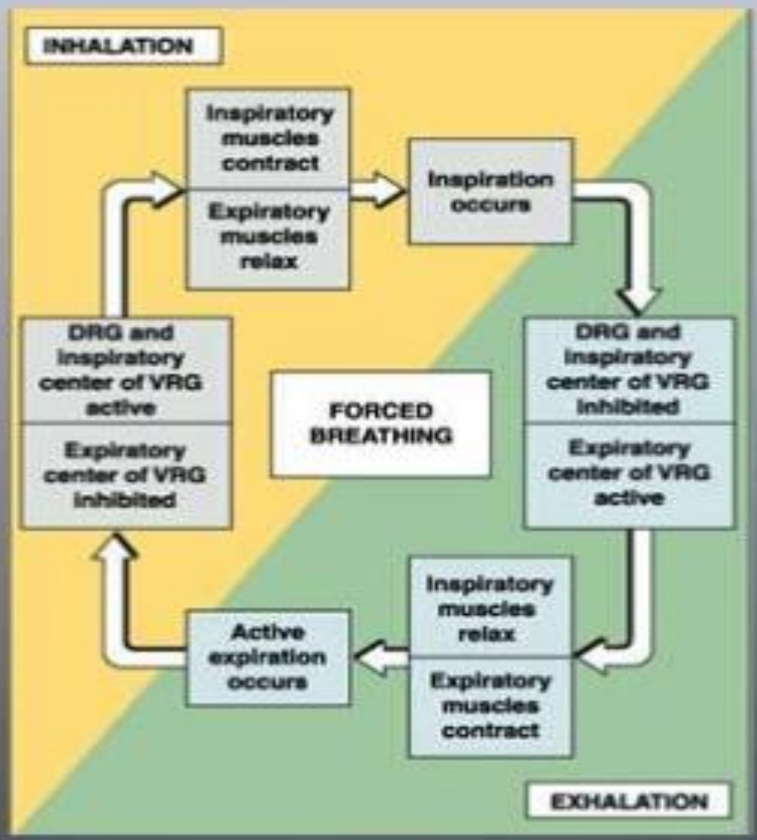
Impluse propogated to ext IC muscles via IC nerve and diagram via phrenic nerve

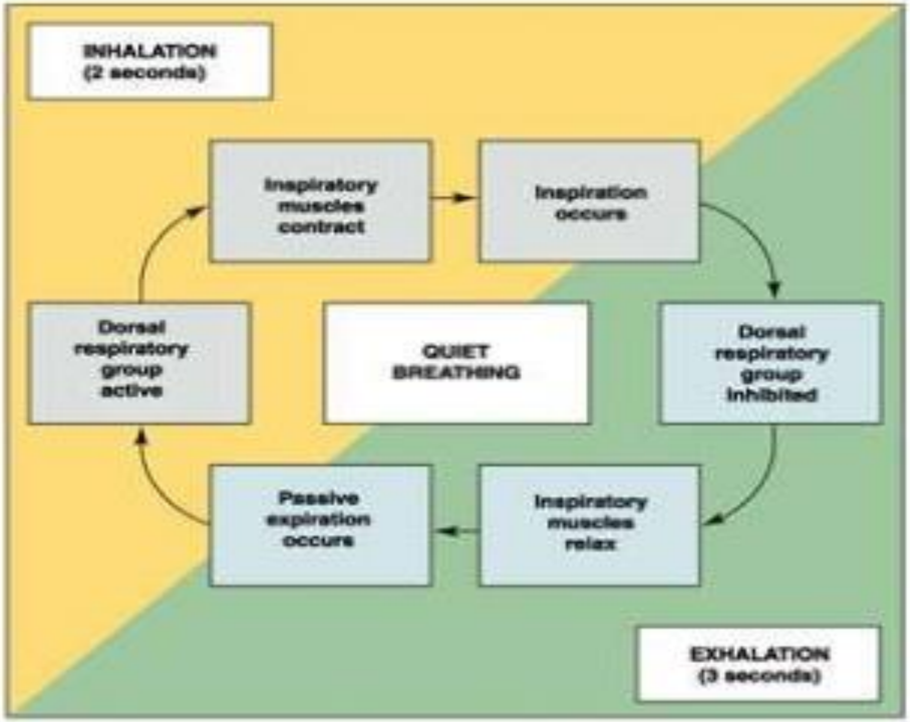
- When nerve impluse reach diaphragm and ext IC muscles → muscle contract and inhalation occur .
- At the end of 2sec → insp. area become inactive → nerve impulse ceases → with no impulse arriving daiphragm and ext.IC muscles relax for about 3 sec ,allowing passive elastic recoil of lung ,thoracic wall and the cycle repeats .

- Neurons in exp. Area remain inactive during quiet breathing .However during forceful breathing nerve impulse from insp.area activate the exp.area.

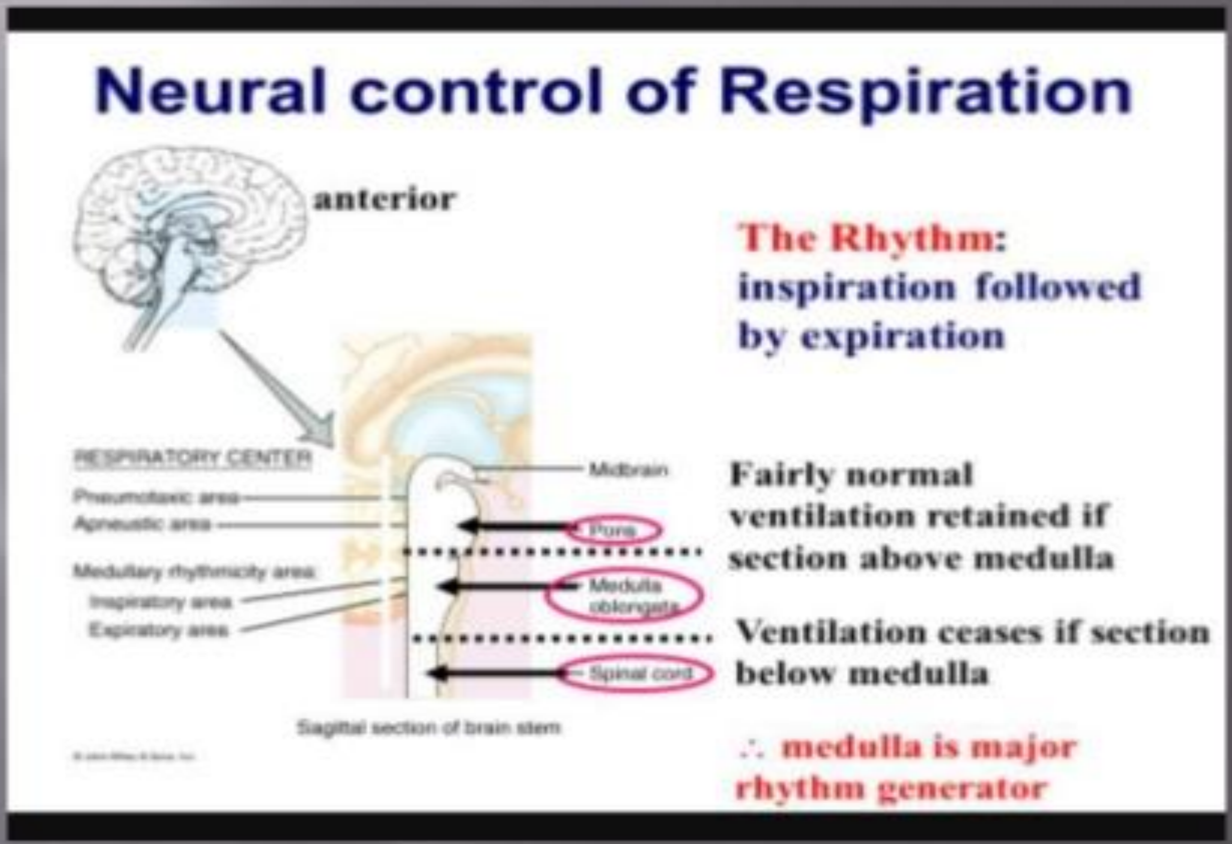
↓

- Impulses from the exp. area cause contarction of int.IC muscle and abdominal muscle which decrease size of thoracic cavity and causes forceful exhalation .


INHALATION
Inspiratory muscles contract
Expiratory muscles relax
Inspiration occurs
DRG and inspiratory center of VRG active
Expiratory center of VRG inhibited
FORCED BREATHING
DRG and inspiratory center of VRG inhibited
Expiratory center of VRG active
Inspiratory muscles relax
Expiratory muscles contract
Active expiration occurs
EXHALATION



INHALATION
(2 seconds)
Inspiratory muscles contract
Inspiration occurs
Dorsal respiratory group active
QUIET BREATHING
Dorsal respiratory group inhibited
Passive expiration occurs
Inspiratory muscles relax
EXHALATION
(3 seconds)


Neural control of Respiration
anterior
The Rhythm: inspiration followed by expiration
RESPIRATORY CENTER
Pneumotaxic area
Apneustic area
Medullary rhythmicity area:
Inspiratory area
Expiratory area
Midbrain
Pons
Medulla oblongata
Spinal cord
Fairly normal ventilation retained if section above medulla
Ventilation ceases if section below medulla
Sagittal section of brain stem
∴ medulla is major rhythm generator

PNEUMOTAXIC AREA

- Help to coordinate transition between inhalaton and exhalation (in upper pons) .Transmit inhibitory impulses to inspiratory area.These impulses shorten the duration of inhalation .When the pneumotaxic area is more active ,breathing rate is more rapid.

APNEUSTIC AREA

- This is in lower pons. This sends stimulatory impulses to the inspiratory area that activate and prolong inhalation .The result is long deep inhalation.
- When pneumotaxic area is active ,it overrides signal from the apneustic area.

CORTICAL INFLUENCES ON RESPIRATION

- Cerebral cortex has connections with respiratory center, we can voluntarily alter our pattern of breathing .We can refuse to breathe for short period of time.
- Voluntary control is protective as it enables us to prevent water or irritating gases entering from lungs.This ability to not to breathe is limited by the build up of CO_2 and H^+ in the body.
- When Pco_2 and H^+ conc. Increase to a certain level ,the inspiratory area is strongly stimulated , nerve impluses are sent along phrenic and IC nerves to respiratory muscles ,and breathing resumes.

CHEMICAL REGULATION OF RESPIRATION

- Some chemical stimuli modulate how quickly and deeply we breathe.The respiratory system functions to maintain proper levels of CO_2 and O_2 and is very responsive to changes in the levels of these gases in body fluids .
- There are some sensory neurons that are responsive to chemicals called chemoreceptors .Chemoreceptors in 2 locations monitor levels of CO_2,H^+,O_2 and provide input to respiratory center .

- 2 types of chemoreceptors :-
- CENTRAL CHEMORECEPTORS :-Are located near medulla oblongata in CNS. They respond to changes in H^+ conc. Or pCO_2 or both in CSF .
- PERIPHERAL CHEMORECEPTORS :-Are located in the aortic bodies(clusters of chemoreceptors located in the wall of the arch of aorta) and cartoid bodies (oval nodules in the wall of the left and right common carotid arteries .These are part of PNS and are sensitive to changes in Po_2,H^+,Pco_2 in blood .
- Axons of sensory neurons from the aortic bodies are part of the vagus nerve and those of carotid bodies are part of right and left glosdopharyngeal nerves.

Peripheral chemoreceptors:

The receptors are present in peripheral portions of the body that's why called as peripheral chemoreceptors.

Situation:

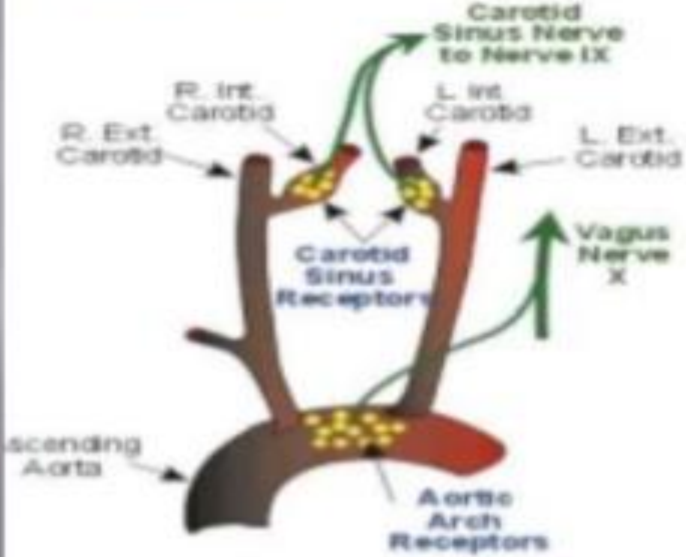


Figure 1. Location and innervation of arterial baroreceptors.

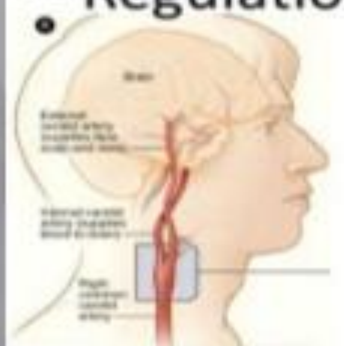
Action:

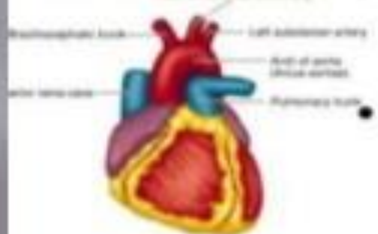
- They are very sensitive to reduction in partial pressure of oxygen.
- Whenever, the partial pressure of oxygen decreases these chemoreceptors become activated and send impulses to inspiratory center and stimulate them.
- Thereby increases rate and force of respiration and rectifies the lack of oxygen.

- Normally ,P_{CO_2} in arterial blood is 40 mmHg .Slight increase in it cause condition called hypercarbia or hypercapina. ⟶ Central chemoreceptors are stimulated by both high P_{CO_2} and the rise in H^+.
- When P_{O_2} in arterial blood falls from normal level of 100mmHg but is still above 50mmHg ,peripheral chemoreceptors are stimulated .Deficiency of O_2 depresses activity of central chemoreceptors and inspiratory area which then don't respond to any input and send fewer impulses to muscles of inhalation .As a result breathing rate decreases.

- Chemoreceptors participate in a negative feedback that regulates level of CO_2,O_2 and H^+in blood ,as a result of increased H^+ ,Pco_2 input from the central and peripheral chemoreceptor causes inspiratory area to become highly active .Rate and depth of breathing increases called hyperventilation, allows the inhalation of more O_2 and exhalation of more CO_2 until level of Pco_2 and H^+ are lowered to normal.
- If arterial Pco_2 is lower than 40mmHg – hypocapnia and hypocarbia, both the chemoreceptor are not stimulated therefore impulses are not sent to inspiratory area.As a result the area sets to it own pace until CO_2 accumulates and rises above 40 mmHg .The inspiratory area is stimulated more strongly when Pco_2 level rises above normal and Po_2 fall below normal.

Regulation of Breathing in Controlled Chemoreceptors





- Chemoreceptors sense a chemical change in blood composition
  - Inc. or dec. of H+ in blood
- When an inc. of H+ is detected → medulla to breathes more
- When a dec. of H+ is detected → medulla breathes less

PROPRIOCEPTOR STIMULATION OF RESPIRTION

- EXERCISE ↑ rate and depth of breathing ,even before changes in Po_2,Pco_2,H^+level occur.

- Main stimulus for these changes is input from propiroceptors which mointor movement of joint and musles → nerve impulse from propiroceptors stimulate inspiratory area of the medulla oblongata.

- At same time axon collateral of UMN that originate in primary motor cortex also feed exctitatory response to inspiratory area.

Neural control of breathing and CO_2 homeostasis.(2016)

- Recent advances have clarified how the brain detects $CO_2$to regulate breathing (central respiratory chemoreception).These mechanism are reviewed and their significance is presented in the general context of CO_2/pH homeostasis via breathing .
- At rest resp. chemoreflexes initiated at peripheral and central sites mediate rapid stabilization of arterial $PCO_2$and PH .
- Specific brainstem neurons (retrotrapezoid nucleus,serotonergic) are activated by PCO_2 and stimulate breathing .

- RTN neurons detect CO_2via intrinsic proton receptors ,synaptic input from peripheral chemoreceptors and signals from astrocytes .
- Respiratory chemoreflexes are arousal state dependent whereas chemoreceptor stimulation produces arousal .
- When abnormal these interactions lead to sleep disorderd breathing .During exercise ," central command " and reflexes from exercising muscles produce the breathing stimulation required to maintain arterial PCO_2 and ph despite elevated metabolic activity .