RESPIRATORY SYSTEM

Mohammad Saiful Islam
Phd (Japan) Post doc (Australia)
Dept. of Anatomy, Histology & Physiology
Sher-e-Bangla Agricultural University Dhaka

Respiration is the process by which gaseous exchange takes place between a living organism and its environment due to the differences in partial pressure of gases.

Types of respiration

Respiration is often classified into two types-

1. External respiration that involves exchange of respiratory gases between lungs and blood.
2. Internal respiration which involves exchanges of gases between blood and tissues

Phases of respiration

1. Inspiration during which the air enters the lungs from atmosphere
2. Expiration during which the air leaves the lungs.

Functions of respiratory system-

- The primary function of respiratory system is to transport of oxygen from the atmosphere to the tissues for metabolism and carbon dioxide from tissue to atmosphere as a metabolic end product.
- Other important functions of respiratory system are- thermoregulation, homeostasis, water balance in the body, anticoagulant activity, body defense, prevention of dust particles, secretion of angiotensin converting enzyme and removal of toxic volatile metabolic end product.

Pulmonary ventilation- It is a cyclic process by which fresh air enters the lungs and an equal volume of air leaves the lungs. It is also called respiratory minute volume (RMV). Normal value of pulmonary ventilation is 6000 ml/minute

Alveolar ventilation- It is the amount of air utilized for gaseous exchange in every minute. Normal value of alveolar ventilation is 4200 ml/minute

Dead space- It is defined as the part of the respiratory tract, where gaseous exchange does not take place. The parts of respiratory tract, which form the dead space are nose, pharynx, trachea, bronchi and branches of bronchi up to terminal bronchioles.

Type of dead space-

1. Anatomical dead space
2. Physiological dead space

Tidal volume- Tidal volume is the volume of air breathed in and out of lungs in a single normal quite respiration. Normal value of tidal volume is 500ml.

Inspiratory Reserve Volume- It is an additional volume of air that can be inspired forcefully after the end of normal inspiration. Normal value of inspiratory reserve volume is 3300ml.

Expiratory Reserve Volume-It is an additional volume of air that can be expired forcefully after the end of normal expiration. Normal value of expiratory reserve volume is 1000ml.

Respiratory cycle- It include both the acts of inspiration and expiration.

Respiratory frequency- It is the number of cycles or the number of breath per minute. It is an excellence indication of health status. The respiratory frequency is differs in different conditions, such as-body species, size, age, exercise, temperature, pregnancy etc.

Composition of alveolar air, inspired air and expired air-

Air	Inspired air	Alveolar air	Expired air
Gas		Content (ml %)	
Oxygen	20.84	13.60	15.70
Carbon dioxide	0.04	5.30	3.60
Nitrogen	78.62	74.90	74.50
Water vapor, etc	0.50	6.20	6.20
Total	100.00	100.00	100.00

Residual volume- It is the volume of air remaining in the lungs even after forced expiration. Normally lungs cannot be emptied completely even by forceful expiration.

It is significant because of two reasons-

1. It helps to aerate the blood in between breathing and during expiration.
2. It maintains the contour of the lungs.

Inspiratory Capacity- It is the maximum volume of air that is inspired after normal expiration. It includes tidal volume and inspiratory reserve volume. Normal value of inspiratory capacity is 3800ml.

Vital Capacity- It is the maximum volume of air that can be expelled out forcefully after a deep (maximum) inspiration. It includes inspiratory reserve volume, tidal volume and expiratory reserve volume. Normal value of vital capacity is 4800ml.

Functional Residual Capacity- It is the volume of air remaining in the lungs after normal expiration. It includes expiratory reserve volume and residual volume. Normal value of functional residual capacity is 2200 ml.

Total Lung Capacity- It is the volume of air present in the lungs after a deep inspiration. It includes all the volumes and its normal value is 600ml.

Inspired Air- It is the atmospheric air, which is inhaled during inspiration.

Alveolar Air-It is the air present in the alveoli of lungs. It is different from the inspired air because of-

1. The alveolar air is partially replaced by the atmospheric air during each breath
2. Oxygen diffuses from the alveolar air into pulmonary capillaries constantly
3. Carbon dioxide diffuses from pulmonary blood into the alveolar air constantly
4. The dry atmospheric air is humidified, while passing through respiratory passage just before entering the alveoli

Expired Air- It is the amount of air that is exhaled during expiration. It is a combination of dead space air and alveolar air.

Mechanism of Respiration in mammals

In case of inspiration- Enlargement of the thorax and lungs- accompanying inflow of air- decreased intrathoracic pressure.

backward movement of diaphragm (the principle muscle of respiration),

Forward and outward movement of ribs and external intercostales muscle.

the thoracic cage is enlarged and decreases the pressure in the thoracic cavity than the pressure in the environment or atmosphere, so air rushes into the lungs.

In case of expiration - the outflow of air by decrease in size of the thorax and lungs.

The diaphragm moves upward

The ribs moves inward and downward.

As a result the size of the thoracic cavity is decrease and the pressure in the thoracic cavity is greatly increased than that of the atmospheric pressure and air moves out from the lungs.

*** See the respiratory muscles from myology***

Surfactant

It is a surface acting material or agent secreted in alveolar epithelium that is responsible for lowering the surface tension of a fluid.

Sources-

- Type II alveolar epithelium cells in the lungs, which are called surfactant secreting alveolar cells or pneumocytes.
- Clara cells, which are situated in the bronchioles, also called bronchiolar exocrine cells.

Functions

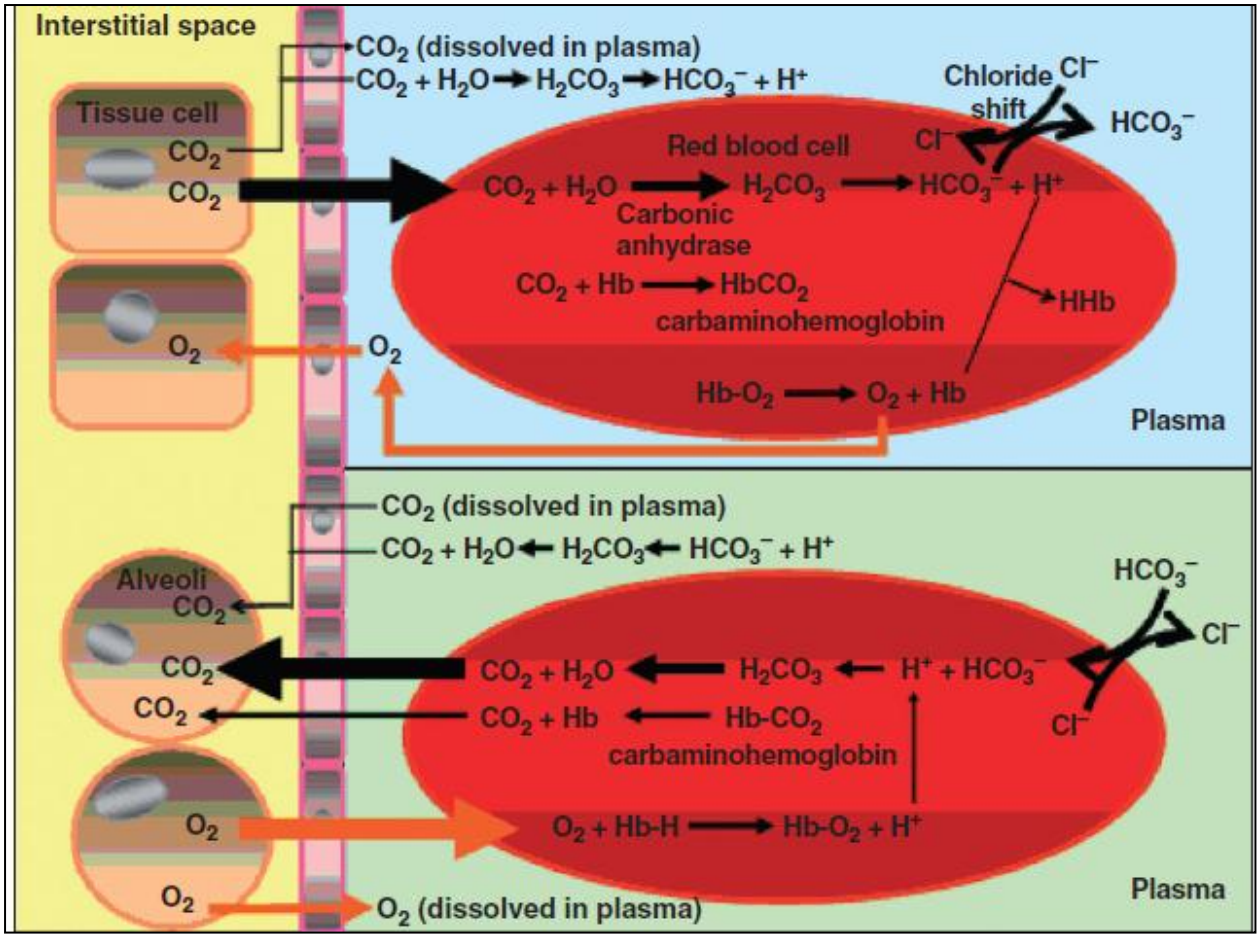
1. It reduces the surface tension in the alveoli of lungs and prevents the collapsing tendency of lungs.
2. It is responsible for stabilization of the alveoli, which is necessary to withstand the collapsing tendency.
3. It plays an important role in the inflation of lungs after birth.
4. It plays an important function in defense mechanism within the lungs against infection and inflammation

Transport of Respiratory gases

Transport of oxygen

O_2 is transported from alveoli to the tissue by the blood in two forms

a) In physical solution: O_2 dissolves in water of plasma and is transported in this physical form. The amount of O_2 transported in this form is very little, only 3% of the total O_2 is transported in this form. Under normal condition, 0.3 ml of O_2 is carried by 100ml of plasma of arterial blood and 0.15 ml of O_2 is carried by 100ml of plasma of venous blood
b) In combination with hemoglobin: O_2 combines with hemoglobin in blood and is transported as oxyhemoglobin. The transport of O_2 in this form is important because, maximum amount (97%) of oxygen is transported by this method. O_2 combines with the iron in heme part of hemoglobin. Each molecule of hemoglobin contains 4 atoms of iron and each iron atom combines with one molecule of O_2. The iron of the hemoglobin is present in ferrous form. After combination, iron remains in ferrous form only. So, this way of combination is called oxygenation and not oxidation.



The maximum quantity of O_2 which the blood can carry term the O_2 capacity, depends upon the amount of Hb in the blood. The Hb content in the blood is about 15 gm/100ml and 1 gm of Hb can carry 1.34 ml of O_2. So, 15 gm can carry 15×1.34=20.1 ml% of O_2 but oxygen carrying capacity of blood is only 19 ml% because the Hb is saturated with O_2 about 95

Oxygen Hemoglobin dissociation curve

It is the curve that demonstrates the relationship between partial pressure of O_2 and the percentage saturation hemoglobin with O_2. Normally in the blood, hemoglobin is saturated with O_2 only up to 95%. The saturation of hemoglobin with O_2 depends upon the partial pressure of O_2. When the partial pressure of O_2 is more, hemoglobin accepts O_2 and when the partial pressure of O_2 is less, hemoglobin releases O_2.

Under normal conditions, the oxygen hemoglobin dissociation curve is S shaped or sigmoid shaped. The lower part of the curve indicates dissociation of O_2 from hemoglobin. The upper part of the curve indicates the acceptance of oxygen by hemoglobin.

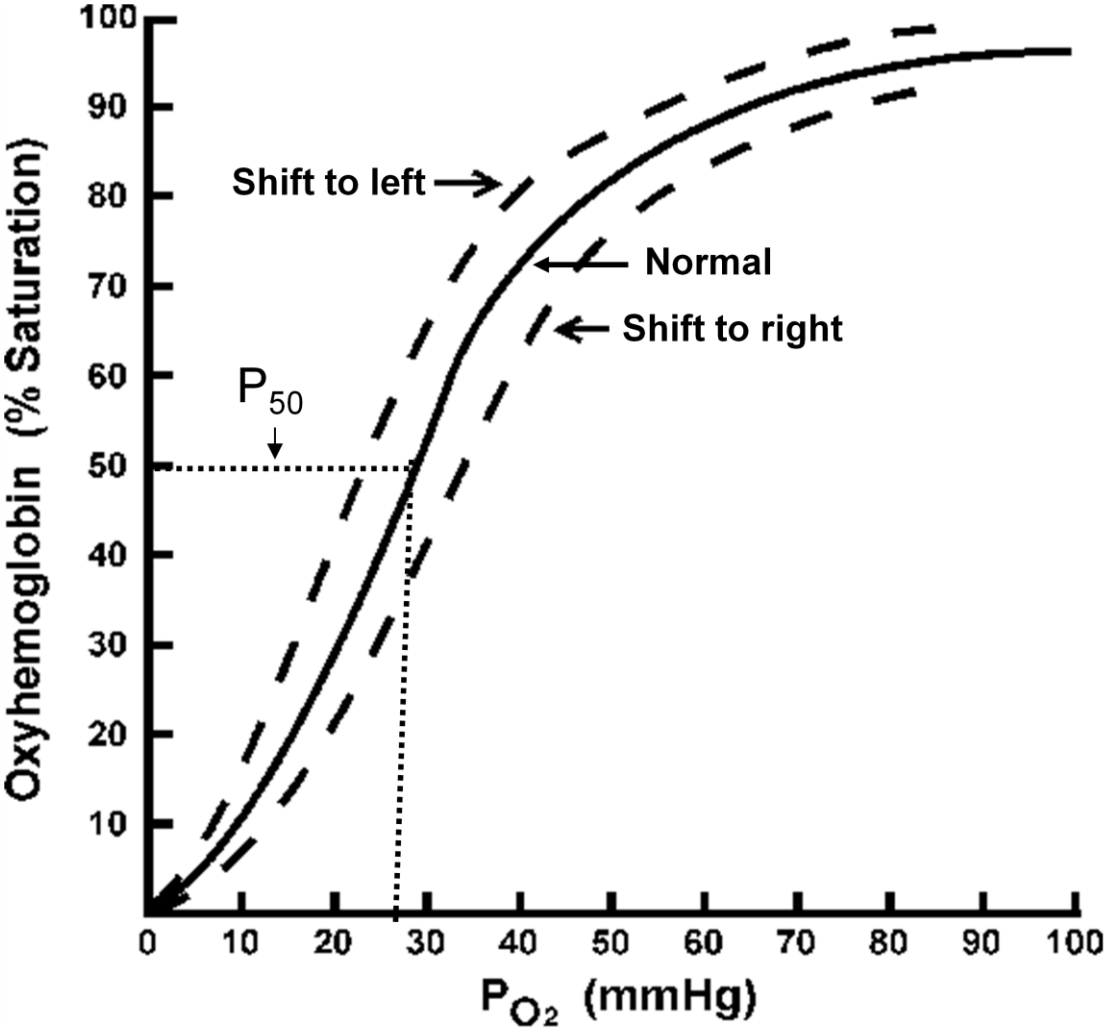


Fig. Oxygen Hemoglobin dissociation curve

Transport of CO_2

CO_2 is transported in the blood in four ways.

 # As simple solution

 # As carbonic acid

 # As bicarbonates

 # As carbamino compounds

1. Transport of CO_2 as simple solution: CO_2 diffuses into blood and dissolves in the fliud of plasma forming a simple solution. It is about 7% of total CO_2 in the blood.
2. Transport of CO2 as carbonic acid: Part of dissolved CO2 in plasma combines with water to form carbonic acid but this reaction is very slow and it is negligible
3. Transport of CO2 as bicarbonate: About 63% of CO2 is transported as bicarbonate. From plasma, the CO2 enter the RBCs and combines with water to form carbonic acid. In the RBCs, the reaction is at least 200-300 time faster than that of Plasma due to the presenc of an enzyme called carbonic anhydrase.
4. Transport of CO_2 as carbamino compounds: About 30% of CO_2 is transported as carbamino compounds. CO_2 is transported in blood in combination with hemoglobin and plasma protein. CO_2 combines with hemoglobin to form carbamino hemoglobin or carbhemoglobin. And, it combines with plasma proteins to form carbamino proteins. The carbamino hemoglobin and carbamino proteins are together called carbamino compounds.

Chl**oride shift or Hamburger Phenomenon-** The carbonic acid produced inside the RBC is very unstable and easily dissociates into bicarbonate and hydrogen ions. So, more and more bicarbonate is formed inside the RBC which is diffuse into the plasma through the cell membrane. The chloride ions diffuse in the opposite direction to maintain the ionic equilibrium. The movement of chloride ion into the erythrocytes is term the chloride shift or Hamburger Phenomenon.

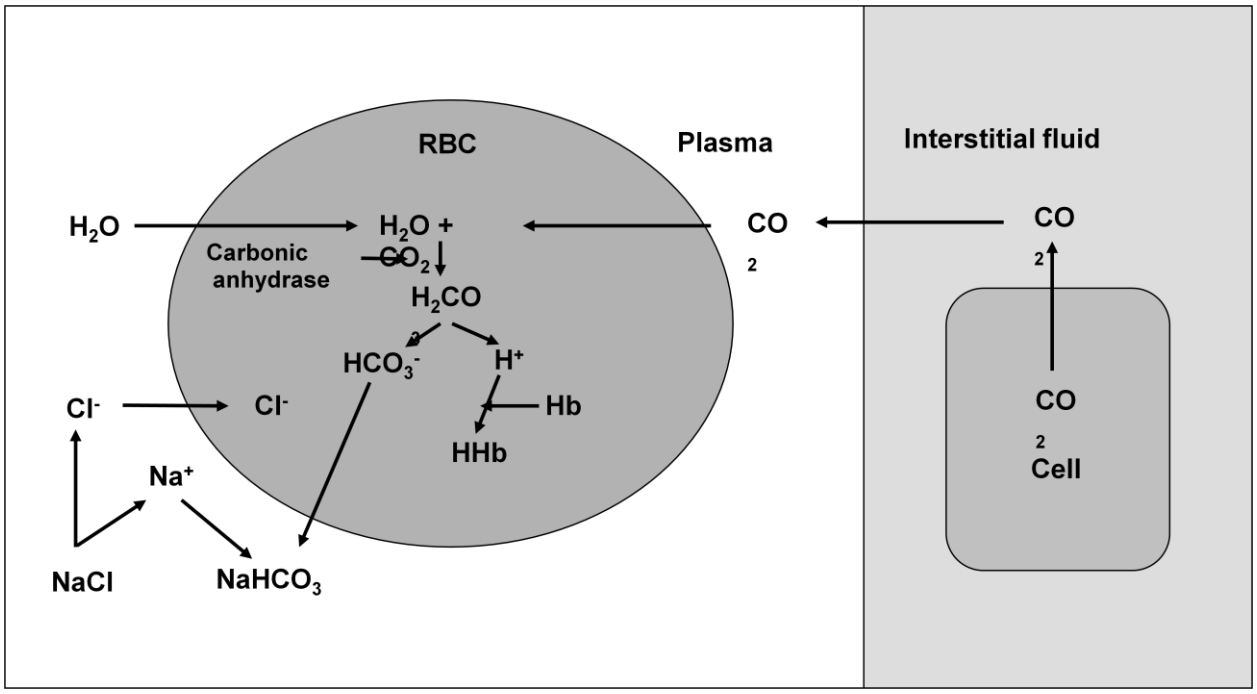


Fig. Chloride shift or Hamburger Phenomenon

Activities during respiration-

There are 7 types of activities during respiration-

The movement of air into the lung, that is respiration

The passes of O_2 from the lung alveoli to capillary beds

O_2 is transported by the blood to all the cells of the body

O_2 enter into the cells, utilized it and production of CO_2, that is cellular respiration

CO_2 enter into the blood

CO_2 enter into the lung from blood

The movement of CO_2 out to the lung, that is expiration

Exchange of respiratory gases-

The exchange of respiratory gases takes place due to partial pressure difference of the gases, permeability of the membrane and chemical reaction in the blood.

Table Partial pressure and content of O_2 and CO_2 in alveoli, capillaries and tissues

Gas	Arterial end of pulmonary capillary	Alveoli	Venous end of pulmonary capillary	Arterial end of systemic capillary	Tissue	Venous end of systemic capillary
PO_2 (mmHg)	40	104	104	95	40	40
O_2 content (ml %)	14	-	19	19	-	14
PCO_2 (mmHg)	46	40	40	40	46	46
CO_2 content (ml %)	52	-	48	48	-	52

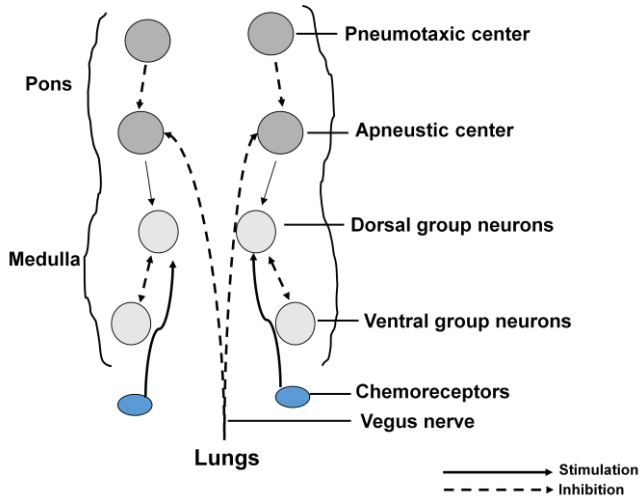
Regulation of respiration

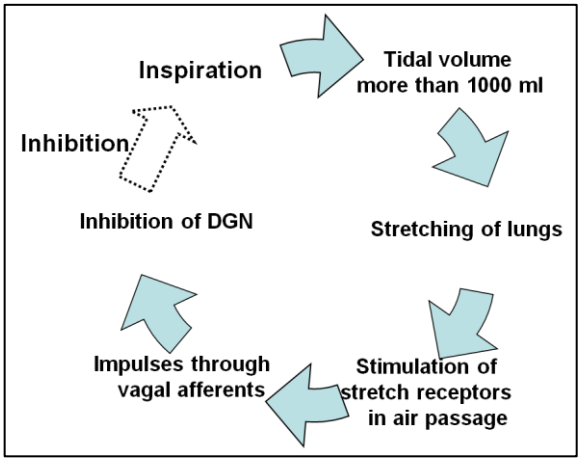
Respiration is subjected to variation even under normal physiological conditions. Example-Emotion and exercise increase the rate and force of respiration. Rest and sleep decrease the rate and force of respiration. But the altered pattern of respiration is brought back to normal within a short time by some regulatory mechanisms in the body.

The pattern of respiration is regulated by two mechanisms-

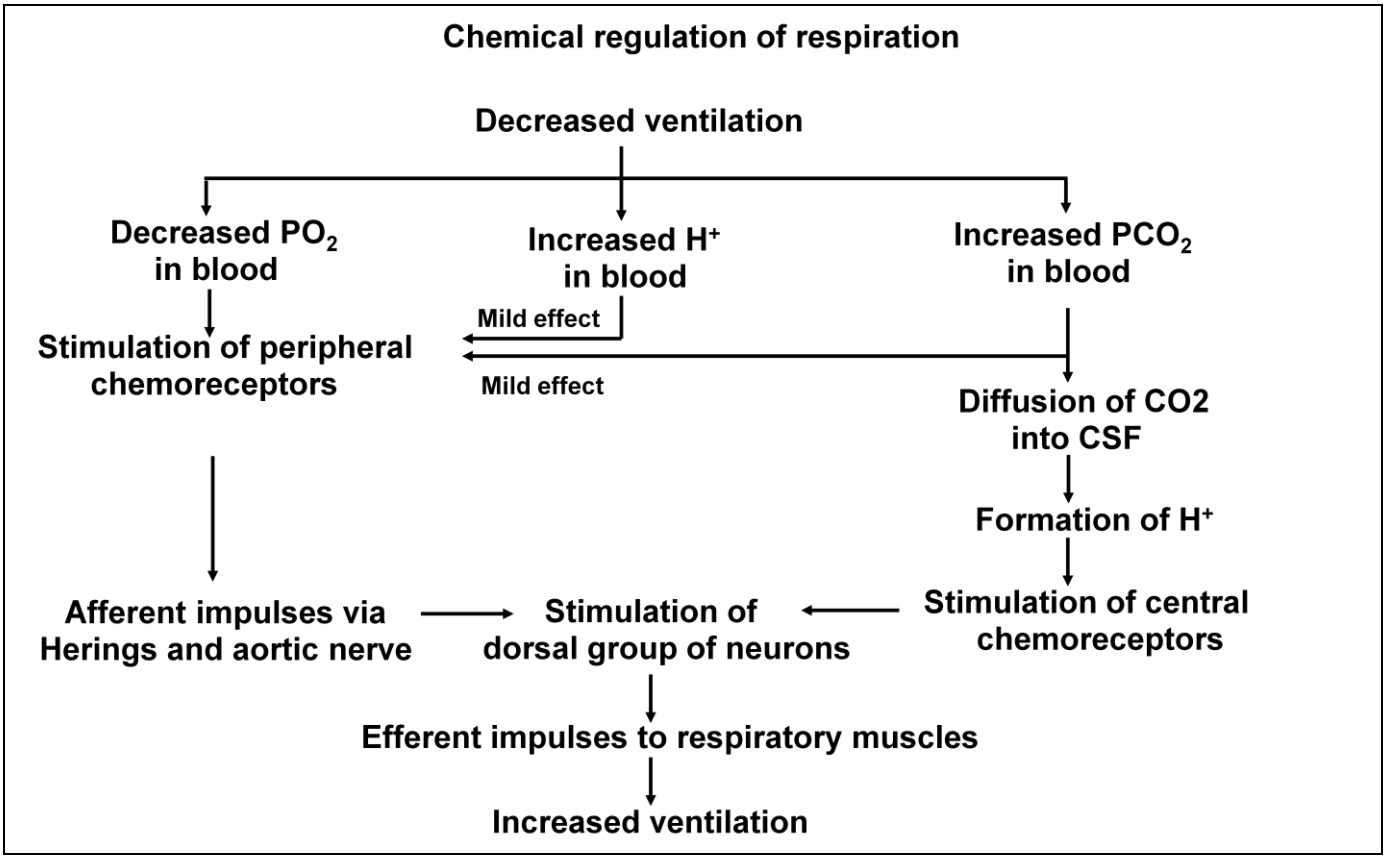
 # Nervous or neural mechanism

 # Chemical mechanism





Hering-Breuer reflex-It is a protective reflex that restricts the inspiration and prevents over stretching of lung tissues. It is initiated by the stimulation of stretch receptors which located on the wall of bronchi and bronchioles.



Disturbances of respiration

Eupnea- It refers to the normal respiration

Apnea - It is defined as temporary cessation of breathing.

Causes- Voluntary effort, After hyperventilation, Obstruction of respiratory tract.

Hyperventilation- It means increased pulmonary ventilation due to forced breathing.

Causes- Exercise

Hypoventilation- It is the decrease in the pulmonary caused by decrease in rate or force of breathing.

Causes- Administration of some drugs

Hypercapnea- Is the increased carbon dioxide content of blood.

Causes- Asphyxia, Air containing excess CO_2

Hypocapnea- Is the decreased carbon dioxide content of blood.

Causes- Hypoventilation

Asphyxia- It is the condition characterized by combination of hypoxia and hypercapnea due to obstruction of air passage.

Causes- Strangulation, Hanging, Suffocation from inhalation of coal gas etc.

Dyspnea- It means difficulty in breathing.

Causes- Severe muscular exercise, Pneumonia, pulmonary edema,

Pneumothorax, cardiac disorder etc.

Cyanosis- It is defined as diffused bluish coloration of skin and mucus membrane due to excessive concentration of reduced hemoglobin in the blood.

Causes- Hypoxia, poisoning leading to formed altered hemoglobin etc.

Atelectasis- It refers to partial or complete collapse of lungs.

Causes- Deficiency or inactivation of surfactant, Obstruction of bronchus or bronchiole etc.

Pneumothorax- It is the presence of air in pleural space.

Causes- Damage of chest cavity.

Pneumonia- It is the inflammation of lung tissues followed by the accumulation of blood cells, fibrin and exudates in the alveoli. The affected part of the lungs becomes consolidated.

Causes- Bacterial or viral infection, inhaling noxious chemical substance

Bronchial asthma- It is the respiratory disease characterized by difficult breathing with wheezing.

Causes- Inflammation of the air passage, allergic condition, pulmonary edema.

Pulmonary edema- It is the accumulation of serous fluid in the alveoli and the interstitial tissue of lungs.

Causes- Pneumonia, Sulfur poisoning etc.

Hypoxia- It is defined as reduced availability of O_2 to the tissues.

Types-

Hypoxic hypoxia- It means the decreased oxygen content in the blood.

Causes- High altitude, Asthma, Pneumothorax, Pulmonary edema etc.

Anemic hypoxia- It is the condition characterized by the inability of blood to carry enough amount of oxygen.

Causes- Any condition that causes anemia can cause anemic hypoxia.

Stagnant hypoxia- It is the hypoxia caused by decreased velocity of blood flow.

Causes- Congestive heart failure, Hemorrhage, Surgical shock etc.

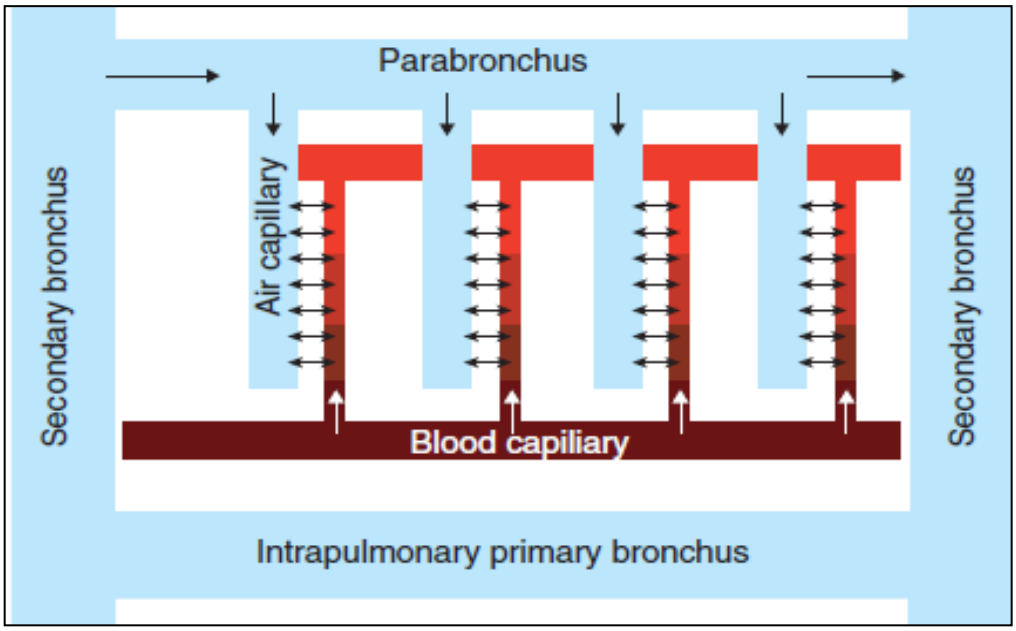
Histotoxic hypoxia- It is the type of hypoxia produced by the inability of tissues to utilize oxygen.

Causes- Cyanide poisoning, Sulfide poisoning

Avian Respiration

- The avian respiratory system has a unique structure compared to others
- Bird lungs are inelastic and therefore do not change volume during respiration.
- Gas exchange in birds occurs in air capillaries.
- Birds lack diaphragm,
- The movement of the ribs and the sternum are important in changing the abdominal pressure in order to move air in and out of the air sacs,
- The lungs do not expand; instead, air sacs act as bellows to move air in and out of the lungs.
- Gas exchange occurs in the lungs, but not the air sacs.
- Thoracic cavity is at atmospheric pressure instead of negative pressure as in mammals.
- Although birds have a larynx, but sound is generated in the syrinx (diverticulum of trachea).
- The avian lung is a rigid structure located in the thoracoabdominal cavity.
- The trachea extends from the larynx to the syrinx, and it is composed of complete tracheal cartilages
- The lungs of birds are unilobed and deeply imprinted by the thoracic vertebrae.

- The primary bronchus passes through the lung
- Within the lung, it gives off many small groups of secondary bronchi
- Then give rise to hundreds of parabronchi.
- Most of these are arranged in tightly parallel loops, and others form more irregular loops.
- Parabronchi are the site of gas exchange.



- The primary and secondary bronchi do not participate in gas exchange.
- The parabronchi also called tertiary bronchi, which originate from the secondary bronchi. There are two types of parabronchi.
  - Paleopulmonic parabronchi: gas flow is unidirectional.
  - Neopulmonic parabronchi: gas flow is bidirectional.
- Branches of Parabronchi: atria> infundibula>air capillaries.
- The air capillaries intermesh with pulmonary blood capillaries, the site of gas exchange

Air sac

- Air sacs are thin membranous structures connected to the primary or secondary bronchi via ostia/foramen.
- Air sacs are poorly vascularized.
- They do not participate in gas exchange,
- Function of airsacs in respiration: to move air through the lungs so that gas exchange can occur in the parabronchi.
- Diverticula from airsacs enter various bones (pneumatic bones) and bones become light.
- In domestic chicken there are 8 airsacs.

1. Cervical sac-1
2. Clavicular-1
3. Cranial thoracic air sac-paired
4. Caudal thoracic air sac-paired
5. Abdominal air sac (largest)- paired

Ventilation and Gas Exchange

Inspiration – air passes through the lungs and either enters:

- The caudal air sacs and inflates them, or
- The parabronchi, where gaseous exchange takes place; this air then passes into the cranial air sacs and inflates them.

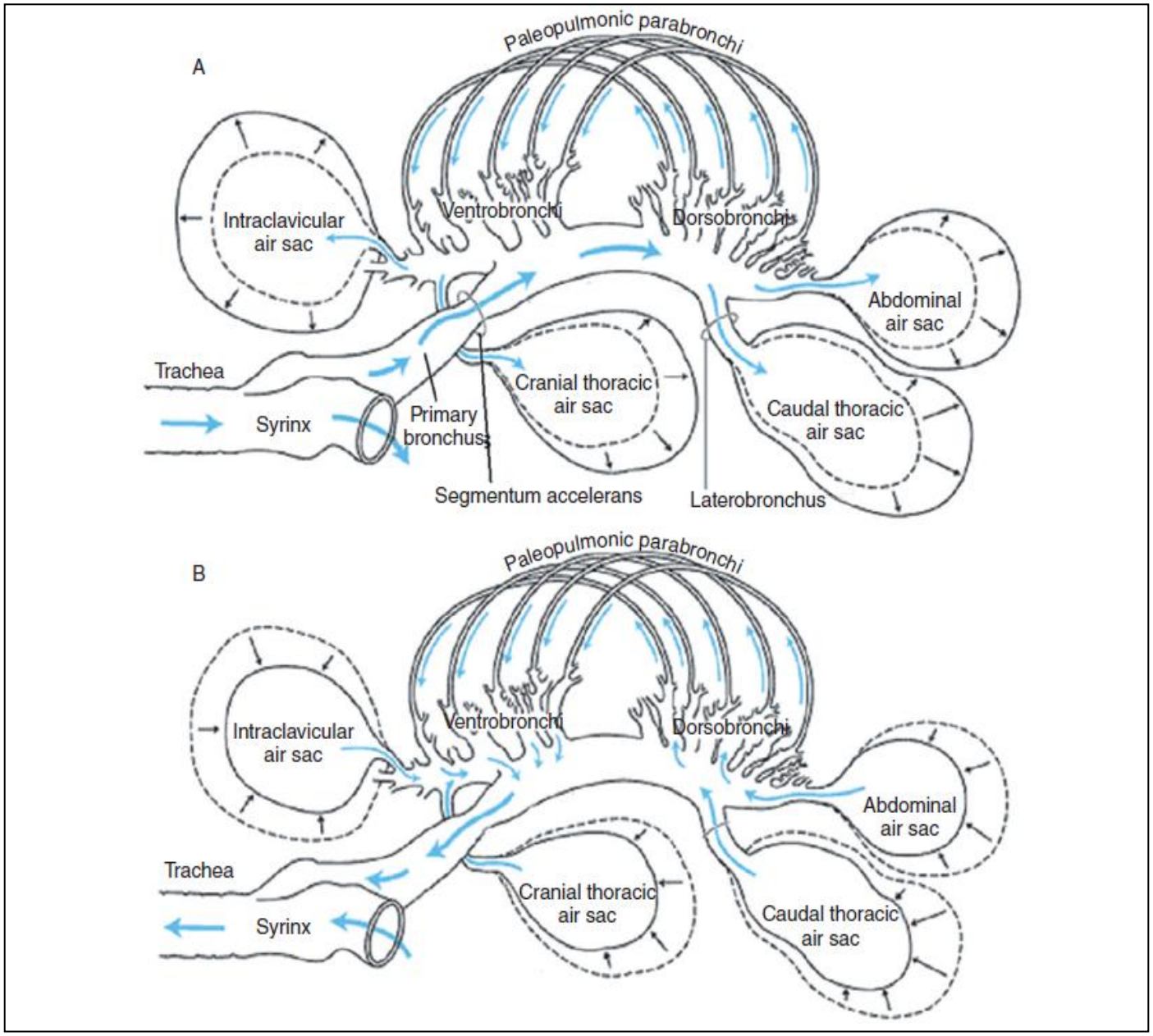


Fig. 1 Mechanism of respiration in bird. A: Inspiration B: Expiration

Expiration

- The abdominal muscles contract, squeezing air from the caudal air sacs back into the parabronchi, where further gaseous exchange takes place
- Air in the cranial air sacs passes straight through the lungs and out