RESPIRATORY SYSTEM

BASICS

Types of Respiration

- *External Respiration*: Exchange of respiratory gases between lungs and blood
- *Internal Respiration*: Exchange of respiratory gases between blood and tissues

Phases of Respiration

- *Inspiration*: During which the air enters the lungs from the atmosphere
- *Expiration*: During which the air leaves the lungs

During normal breathing, inspiration is an active process and expiration is a passive process.

Respiratory Tract

Respiratory Tract: The anatomical structure through which air moves in and out is the respiratory tract. It consists of:

- Nose
- Pharynx
- Larynx
- Trachea
- Bronchi
- Lungs

Division of Respiratory Tract

- *Upper Respiratory Tract*: This includes all the structures from nose up to vocal cords
- *Lower Respiratory Tract*: This includes trachea bronchi and lungs

Nose

Nose is further divided into external nose and nasal cavity.

Function of Nose

- Passageway for air
- Cleans the air
- Humidifies, warms air
• Smell
• Along with Para-nasal sinuses are resonating chambers for speech
• Olfactory stimuli (smell) are received.

**Pharynx**
The pharynx connects the nasal cavity with the larynx. Pharynx is a wide muscular tube which is common opening for digestive and respiratory systems. It has three regions:

1. Nasopharynx
2. Oropharynx
3. Laryopharynx

**Function of Pharynx**
Passage way for air and food

**Larynx**
Larynx or voice box is a short passage way that connects pharynx with the trachea. It lies within the midline of the neck.

**Functions of Larynx**
• 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

**Epiglottis**
This is a large leaf shape, piece of cartilage lying on the top of larynx. It prevents food to enter into trachea.

**Trachea (Windpipe)**
It divides to form
• Primary bronchi
• (cartilaginous ridge)
• Cough reflex

**Lungs**
Each lung is enclosed by a bilayer serous membrane called pleura or pleural sac. The two layers of pleura are visceral (inner lining) and parietal (outer) layer. The narrow space between two layers is called pleural cavity which contains pleural fluid. Pleural fluid act as lubricating agent and prevent fiction
between two layers. It also creates negative pressure within the interapleural space called interapleural pressure.

**Bronchus**
The trachea divides into **primary bronchi** called right and left bronchi. Each primary bronchus enters the lungs and divides into **lobar/secondary bronchi**. The left lung has two secondary bronchi. The right lung has three secondary bronchi. They further divide into **tertiary bronchi**. Each tertiary bronchus is called a segmental bronchus because it supplies a part of the lung called a bronchopulmonary segment. There are 10 bronchopulmonary segments in the right lung (3 in superior lobe, 2 in middle lobe, 5 in inferior lobe) and 8-10 segments on the left (4-5 in upper lobe, 4-5 in lower lobe). Each segment is separated from the others by a layer of connective tissue.

**Terminal Bronchiole**
Tertiary bronchi divide several times, when the diameter of bronchiole becomes 1mm or less it is called terminal bronchiole.

**Respiratory Bronchiole**
Terminal bronchioles continues or dived into respiratory bronchiole which has a diameter of 0.5mm

**Respiratory Unit**
The terminal portion of respiratory tract is where the exchange of gases occurs only. It includes

- Respiratory Bronchioles
- Alveolar duct
- Antrum
- Alveolar Sacs
- Alveoli
Each respiratory bronchiole divides into alveolar ducts. Each alveolar duct enters an enlarged structure called alveolar sac. The space inside the alveolar sac is called antrum. The wall of the alveolar sac contains the alveoli.

**Alveoli**

Each alveolus is like a pouch with the diameter of 0.2 to 0.5mm. It is lined with epithelial cells which are of two types:

- **Type I Alveolar Cells**: squamous epithelium forming about 95% of the cells. Form sites for gases exchange between alveoli and blood.
- **Type II Alveolar Cells**: cuboidal Epithelium forming about 5% of the cells. Secretes alveolar fluid and surfactant.

**Respiratory Membrane**

Respiratory membrane is the membranous structure through which the exchange of gases occurs. The blood vessels form a capillary network by the endothelial cells beyond the terminal bronchiole. The alveolar membrane and capillary membrane together form the respiratory membrane. The respiratory membrane separates air in the alveoli from the blood capillary. Respiratory membrane has a surface area of 70sq m and thickness of 0.5 microns.

**Function of Respiratory Tract**

1. Respiration (Oxygen enters blood and carbon dioxide leaves)
2. Olfaction (Smell receptor present in nose)
3. Vocalization (Movement of air past vocal folds makes sound and speech)
4. Prevention of Dust Particles
5. Defense Mechanism
6. Maintenance of Water Balance
7. Regulation of Body Temperature
8. Regulation of Acid Base Balance (Altered by changing blood carbon dioxide levels)
9. Anticoagulant Function
10. Secretion of Angiotensin converting enzyme
11. Synthesis of hormonal substances

**Pulmonary Blood Flow to Lungs**

Lung receives the whole amount that is pumped out from right ventricle. The output of blood /min is same in both right and left ventricle (5 litres).
Lung Volumes
Lungs volumes are the volumes of air breathed by an individual during altered pattern of respiration. The lung volumes are dynamic and are of four types:

1. **Tidal Volume (TV)**
The volume of air breathed in and out of lungs in a single normal quiet respiration is called tidal volume. It is the normal depth of breathing. Normal value of TV is 500ml.

2. **Inspiratory Reserve Volume (IRV)**
An additional amount of air that can be inspired forcefully after the end of normal inspiration beyond tidal volume is called inspiratory reserve volume. Normal value of IRV is 3300ml.

3. **Expiratory Reserve Volume (ERV)**
The additional amount of air that can be expired out forcefully after normal expiration is called the expiratory reserve volume. Normal value of ERV is 1000ml.

4. **Residual Volume (RV)**
The amount of air remaining in the lungs even after forced expiration is called residual volume. The normal value of RV is 1200ml. It is significant because of two reasons:
   - It helps to aerate the blood in between breathing and during expiration
   - It maintains the shape of the lungs

Lung Capacities
Two or more lungs volumes together are called lung capacities. Lung capacities are of four types:

1. **Inspiratory Capacities (IC)**
   It is the maximum volume of air that is inspired from end expiratory position. It is the sum of tidal volume and inspiratory reserve volume. Normal value of IC = TV + IRV = 3800ml

2. **Vital Capacity (VC)**
   It is the maximum amount of air that is expelled out forcefully after a deep inspiration. Vital capacity is the sum of IRV, TV and ERV which has a normal value of 4800ml.

3. **Functional Residual Capacity (FRC)**
   It is the volume of air remaining in the lungs after normal expiration. FRC is the sum of ERV and RV which has normal value of 2200ml.

4. **Total Lung Capacity (TLC)**
   Total lung capacity is the amount of air present in the lungs after a deep inspiration. It includes all the volumes and has a normal value of 6000ml.
Spirometer
- Pulmonary volumes are recorded with the help of spirometer and the process of recording volume movements of air into and out of the lungs is called Spirometry.
- Spirometry is also used to determine the extent of impairment and assess the response to treatment.
- Pulmonary function test can also help to determine nature and severity of lung disease.

Respiratory Rate (RR)
Respiratory rate is the number of breaths taken within a set amount of time, typically 60 seconds.

Respiratory Minute Volume (RMV)
The amount of air breathed in and out of lungs every minute is called RMV. It is the product of TV and respiratory rate (RR). The normal value of $RMV = TV \times RR = 6000\text{ml/min}$

Ventilation
Movement of air into and out of lungs is called ventilation.

Pulmonary Ventilation
Pulmonary ventilation is a cyclic process by which fresh air enters the lungs and an equal volume of air leaves the lungs. It is the volume of air moving in and out of lungs per minute in quite breathing. It is also called respiratory minute volume (RMV). The normal value of pulmonary ventilation is $6000\text{ml/minute}$.

Alveolar Ventilation
The alveolar ventilation is defined as the amount of air utilized for gaseous exchange every minute.

It is different from pulmonary ventilation as it indicated only the volume of air that is utilized for gaseous exchange. Some of air which is trapped in dead space is not utilized for gaseous exchange. The normal value of alveolar ventilation is $4200\text{ml/minute}$. It is measured as

$$Alveolar\ ventilation = (tidal\ volume - dead\ spaces) \times RR = (500 - 150) \times 12 = 4200\text{ml/min}$$

Dead Spaces
The part of respiratory tract where gaseous exchange does not take place is called the dead spaces. Dead spaces are of two types:

Anatomical Dead Space
It includes nose, pharynx, bronchi, bronchiole and all other conducting portion.
Physiological Dead Space
It includes the non-functioning alveoli and the air in those alveoli which does not receive adequate blood flow.

Inspired Air
Inspired air is the atmospheric air which is inhaled during inspiration.

Alveolar Air
The air present in the alveoli of lungs is called the alveolar air. It is partially replaced by inspired air during each breath.

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

Composition of Inspired, Alveolar and Expired Air

<table>
<thead>
<tr>
<th>Air (gases)</th>
<th>Inspired Air (ml %)</th>
<th>Alveolar Air (ml %)</th>
<th>Expired Air (ml %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>20.84</td>
<td>13.6</td>
<td>15.7</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>0.04</td>
<td>5.30</td>
<td>3.60</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>78.62</td>
<td>74.90</td>
<td>74.50</td>
</tr>
<tr>
<td>Water Vapour etc.</td>
<td>0.50</td>
<td>6.20</td>
<td>6.20</td>
</tr>
</tbody>
</table>

Partial Pressure of Inspired, Alveolar and Expired Air

<table>
<thead>
<tr>
<th>Air (gases)</th>
<th>Inspired Air (mmHg)</th>
<th>Alveolar Air (mmHg)</th>
<th>Expired Air (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>159</td>
<td>104</td>
<td>120</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>0.30</td>
<td>40</td>
<td>27</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>596.90</td>
<td>569</td>
<td>566</td>
</tr>
<tr>
<td>Water Vapour etc.</td>
<td>3.80</td>
<td>47</td>
<td>47</td>
</tr>
<tr>
<td>Total</td>
<td>760</td>
<td>760</td>
<td>760</td>
</tr>
</tbody>
</table>

MECHANISM OF REGULATION

Principle Purpose of Respiration
The principle purpose of regulation is to supply oxygen to the tissues and remove carbon dioxide. Respiration can be divided into four basic functional events:

1. Pulmonary ventilation
2. Diffusion of oxygen and carbon dioxide between the alveoli and blood
3. Transport of oxygen and carbon dioxide in blood (body fluids) to and from the cell.
4. Regulation of ventilation

**Pulmonary Ventilation**

This is inspiration and expiration of air, between the atmosphere and lungs.

- In this process there is an important factor called as pressure gradient exists.
- Air moves into the lungs when pressure inside lungs is less than that of atmospheric pressure.
- Air moves out from the lungs to atmosphere, when the pressure in lungs is greater.

**Mechanism of Pulmonary Ventilation**

**Inspiration**

During which the air enter the lungs from the atmosphere.

Principle muscles involved are diaphragm, and external intercostal.

- Contraction of diaphragm
- Increase vertical diameter of chest cavity (ribs pulled upward, sternum pushed forward)
- Expansion of Lungs
- Intra alveolar pressure and intra thoracic pressure decreases
- Air moves from atmosphere to lungs

**Expiration**

During which air leaves the lungs.

Muscles involved:

- Internal intercostal
- external oblique abdominis
- Internal oblique abdominis
- rectus abdominis
- transverse abdominis
Relaxation of inspiratory muscle

- Decreased vertical and anteroposterior diameter of chest cavity
- Size of lung decreases (increased intra alveolar and intra thoracic pressure)
- Alveolar pressure increases

Air moves from lung alveoli towards atmosphere

Expiration

When the intrathoracic pressure is low, air (at atmospheric pressure) flows into the lung.

When the intrathoracic pressure is high, air (at atmospheric pressure) flows out of the lung.

**Thoracic movement during inspiration and expiration**

<table>
<thead>
<tr>
<th>INSPIRATION</th>
<th>EXPIRATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diaphragm descends</td>
<td>Diaphragm ascends</td>
</tr>
<tr>
<td>Ribs elevate and/or expand</td>
<td>Ribs descend and/or contract</td>
</tr>
<tr>
<td>Increased intrathoracic volume</td>
<td>Decreased intrathoracic volume</td>
</tr>
<tr>
<td>Decreased intrathoracic pressure</td>
<td>Increased intrathoracic pressure</td>
</tr>
<tr>
<td>'High pressure' exterior air flows into 'low pressure' lung.</td>
<td>'High pressure' air in lung flows out toward 'low pressure' exterior.</td>
</tr>
</tbody>
</table>

**EXCHANGE OF RESPIRATORY GASES**

In the lungs, exchange of respiratory gases takes place between the alveoli and the blood.

**Respiratory Unit**

The terminal portion of respiratory tract is where the exchange of gases occurs only. It includes

- Respiratory Bronchioles
- Alveolar duct
- Antrum
• Alveolar Sacs
• Alveoli

**Respiratory Membrane**
Respiratory membrane is the membranous structure through which the exchange of gases occurs. The blood vessels form a capillary network by the endothelial cells beyond the terminal bronchiole. The alveolar membrane and capillary membrane together form the respiratory membrane. The respiratory membrane separates air in the alveoli from the blood capillary. Respiratory membrane has a surface area of 70sq m and thickness of 0.5 microns.

The average diameter of pulmonary capillary is only 8 micron, which means that the red blood cells actually squeeze through the capillary having close contact with capillary wall. This facilitates the quick exchange of oxygen and carbon dioxide between the blood and alveoli.

**Diffusing Capacity**
Diffusing capacity is the volume of gas that diffuses through the respiratory membrane each minute for a pressure gradient of 1 mmHg.

**Factor Affecting Diffusing Capacity**
1. Pressure gradient
2. Solubility of gas in fluid medium
3. Total surface area of respiratory membrane
4. Molecular weight of the gas
5. Thickness of respiratory membrane

**TRANSPORT OF RESPIRATORY GASES**

**Transport of Oxygen**
- Oxygen is transported by the blood from alveoli to the tissue.
- The volume of oxygen in the arterial blood is 19 ml % and the partial pressure is 95 mmHg.
- The volume of oxygen in the venous blood is 14 ml % and the partial pressure is 40 mmHg.
- Oxygen is transported in blood in two forms:
  - As simple physical solution
  - In combination with hemoglobin
Transport of Oxygen as Simple Solution
Oxygen dissolves in water of plasma and is transported in this physical form. 3% of the total oxygen in blood is transported in this way which negligible, but becomes important during muscular exercise to meet the excess demand of oxygen.

Transport of Oxygen in Combination with Hemoglobin
- Oxygen combines with hemoglobin in blood and is transported as oxyhemoglobin. Maximum amount of total oxygen in blood is transported by this mean.
- One gram of hemoglobin carries 1.34ml of oxygen. It is called the oxygen carrying capacity of hemoglobin.
- The normal hemoglobin content in blood is 15 g% so the blood must carry 20.1 ml% of oxygen but the blood with 15 g% of hemoglobin carries only 19 ml% of oxygen which is called the oxygen carrying capacity of blood. It is because the hemoglobin in blood is only 95% saturated with blood.
- Oxygen combines with hemoglobin only as physical combination i.e. no oxidation take place. It is only oxygenation. It helps in readily release of oxygen when it is needed. Hemoglobin gives out oxygen wherever the partial pressure of oxygen is less.
- Oxygen combines with the iron in heme part of hemoglobin. Each molecule of hemoglobin contains 4 atom of iron. The iron of the hemoglobin is present in ferrous form. Each iron atom combines with one molecule of oxygen. After combination, iron remains in ferrous form only. This is why the combination of oxygen is called oxygenation only and not oxidation.

Oxygen Hemoglobin Dissociation Curve
The graph showing the relationship between the partial pressure of oxygen and the percentage saturation of hemoglobin with oxygen is called oxygen hemoglobin dissociation curve.

Normal Oxygen Hemoglobin Dissociation Curve
Under normal conditions the oxygen hemoglobin dissociation curve is ‘S’ shaped or sigmoid shape. The lower part of the curve indicates the dissociation of oxygen from hemoglobin. The upper part of the curve indicates the acceptance of oxygen by hemoglobin depending upon the partial pressure of oxygen.

Factor Affecting Oxygen Hemoglobin Dissociation Curve
The oxygen hemoglobin dissociation curve is shifted to right or left by various factor:
- Shift to Left: Indicates acceptance of oxygen by hemoglobin
- Shift to Right: Indicates dissociation of oxygen from hemoglobin

Factor Responsible for Shift to Right:
1. Decrease in partial pressure of oxygen
2. Increase in partial pressure of carbon dioxide
3. Increase in H+ concentration and decrease in pH (acidity)
4. Increase body temperature
5. Excess of DPG
**Factor Responsible for Shift to Left:**

1. In fetal blood: because, fetal hemoglobin has got more affinity for oxygen than the adult hemoglobin
2. Decrease in H+ concentration and increase in pH (alkalinity)

**Bohr’s Effect**

In the tissue due to continuous metabolic activities the partial pressure of carbon dioxide is very high and the partial pressure of oxygen is low. Due to pressure gradient, carbon dioxide enters the blood and oxygen is released from blood to the tissues. The presence of carbon dioxide in the blood decreases the affinity of hemoglobin for oxygen and further enhances the release of oxygen to the tissue and the oxygen dissociation curve is shifted to right. It is known as **Bohr’s effect**. All the factors which shift the oxygen dissociation curve to right enhance the Bohr’s effect.

**Transport of Carbon Dioxide**

- Carbon dioxide is transported by the blood from tissues to the alveoli.
- In the arterial blood, the volume of carbon dioxide is 48 ml% and the partial pressure is 40 mmHg.
- In the venous blood, the volume of carbon dioxide is 52 ml% and the partial pressure is 46 mmHg.
Carbon dioxide is transported in the blood in four ways:
- As dissolved form – 7%
- As carbonic acid - negligible
- As bicarbonates – 63%
- As carbamino compounds – 30%

**Transport of Carbon Dioxide as Dissolved Form**
- CO₂ diffuses into blood and dissolves in the fluid of plasma forming a simple solution. About 7% of total CO₂ is transported in this way.

**Transport of Carbon Dioxide as Carbonic Acid**
- Part of dissolved CO₂ in plasma combines with the water to form carbonic acid. Though CO₂ transported in this form, this reaction is very slow and it is negligible.

**Transport of Carbon Dioxide as Bicarbonate**
- About 63% CO₂ is transported as bicarbonate.
- From the plasma, the CO₂ enters the RBCs. In the RBCs, carbon dioxide combines with water to form carbonic acid. The reaction inside RBCs is very rapid, due to presence of an enzyme called carbonic anhydrase. The enzyme is present only in RBC not in plasma that is why the carbonic acid formed is at least 200 to 300 times more in the RBCs than plasma.
- The carbonic acid is very unstable. Almost all carbonic acid (99.9%) formed in RBCs, dissociates into bicarbonate and hydrogen ions. The content of bicarbonate ions in the cell increases more and more. The increased concentration of bicarbonate inside RBC causes diffusion of bicarbonate ions through the cell membrane into the plasma.

**Chloride Shift or Hamburger Phenomenon**
In plasma, plenty of sodium chloride is present. It dissociates into sodium and chloride ions. When negatively charged bicarbonate ions moves out of RBCs into the plasma, to maintain the electrolyte equilibrium he negatively charged chloride ions move into the RBCs. It is called chloride shift or Hamburger phenomenon. Band 3 protein is responsible for exchange of ions.

**Reverse Chloride Shift**
The bicarbonate ion is converted back into carbon dioxide which has expelled out. When the blood reaches the alveoli, sodium bicarbonate in the plasma dissociates into sodium and bicarbonate ions. A bicarbonate ion moves into the RBCs. It makes chloride ions to move out of the RBCs into the plasma where it combines with sodium and forms sodium chloride. It is called reverse chloride shift.
- At the same time, oxygen also enters the RBC. It displaces hydrogen ion from hemoglobin. The hydrogen ion combines with bicarbonate ion and forms carbonic acid which dissociates into water and carbon dioxide. The carbon dioxide is expelled out.
Transport of Carbon Dioxide as Carbamino Compounds

- About 30% of carbon dioxide is transported as carbamino compounds. Carbon dioxide is transported in blood in combination with hemoglobin and plasma proteins. Carbon dioxide combines with hemoglobin to carbamino hemoglobin or carboxhemoglobin. And it combines with plasma proteins to form carbamino proteins. The carbamino hemoglobin and carbamino proteins are together called **carbamino compounds**.
- The carbon dioxide combines with proteins or hemoglobin with loose bond so that carbon dioxide is easily released into alveoli where the partial pressure of carbon dioxide is low.

Carbon Dioxide Dissociation Curve

The relationship between the partial pressure of carbon dioxide and the quantity of carbon dioxide that combines with blood is demonstrated by graph called carbon dioxide dissociation curve.

Factor Affecting Carbon Dioxide Dissociation Curve

**Haldane’s Effect**

Combination of more amount of oxygen with hemoglobin displaces carbon dioxide from hemoglobin. This effect is called Haldane’s effect. So it cause shift of carbon dioxide dissociation curve to right.

**Causes of Haldane’s effect**

1. The highly acidic (hemoglobin due to combination of oxygen with hemoglobin) has low tendency to combine with carbon dioxide. So carbon dioxide is displaced from blood.
2. Because of the acidity, hydrogen ions are released in excess. The hydrogen ions bind with bicarbonate ions to form carbonic acid. Carbonic acid in turn dissociates into water and carbon dioxide and is released from blood to alveoli.

**Significance of Haldane’s effect**

1. The release of carbon dioxide from blood into alveoli of lungs
2. Uptake of oxygen by the blood

REGULATION OF RESPIRATION

Respiration is a reflex process. Voluntary control of respiration is possible but only for short period of about 40 seconds (voluntary apnea).

The pattern of respiration is regulated by two mechanisms

1. Nervous or neural mechanism
2. Chemical mechanism

Nervous Mechanism

Nervous mechanism regulates respiration by reflex process. It includes respiratory, afferent nerves and efferent nerves.
**Respiratory Center**
Respiratory Centers are group of neuron, which control the rate, rhythm and force of respiration. These centers are situated in reticular formation of brainstem on either side. Depending upon the situation in the brain stem they are classified into two groups

1. **Medullary Group**
   a) Inspiratory center
   b) Expiratory center
2. **Pneumotaxic Center**
   a) Pneumotaxic center
   b) Apneustic center

**Inspiratory Center**
The inspiratory center is situated in the upper part of medulla oblongata. It is formed by inspiratory neurons, which are otherwise called **dorsal group of respiratory neurons**.

**Function**
Inspiratory center is concerned with inspiration. It receives sensory impulses from peripheral receptors, chemoreceptor, pulmonary receptors through vagus and glossopharyngeal nerves. These impulses from periphery help the center in the regulation of respiration. It stimulates the contraction of inspiratory muscles and causes prolonged inspiration.

**Expiratory Center**
The expiratory center is situated in medulla oblongata anterior and lateral to inspiratory center. It is formed by expiratory neurons which are otherwise called **ventral group of respiratory neurons**.

**Function**
 Normally expiratory center is inactive during quiet breathing and it becomes active during forced breathing or when the inspiratory center is inhibited. When active it stimulates expiratory muscles and causes prolong expiration.

**Pneumotaxic Center**
It is present in the dorsolateral part of reticular formation upper pons.

**Function**
The primary function of pneumotaxic center is to control medullary respiration. It always controls the inspiratory center through Apneustic center. It inhibits the inspiratory ramp so that the duration of inspiration is controlled. Indirectly the pneumotaxic center increases the respiratory rate by reducing the duration of inspiration.

**Apneustic Center**
The Apneustic Center is situated in reticular formation of lower pons.

**Function**
This center increases the depth of inspiration by acting directly on the inspiratory center.
Efferent Pathway
The nerve fibers from the respiratory center leave brainstem and descend in the anterior part of lateral columns of spinal cord. It terminate on the motor neurons from where two sets of nerve fiber arises

1. Phrenic nerve fibers, which supply the diaphragm
2. Intercostal nerve fibers, which supply the intercostal muscles.

Vagus nerve also contains some efferent fibers from the respiratory centers.

Afferent Pathway
Impulses form peripheral chemoreceptors and baroreceptors are carried to the respiratory centers by the branches of glossopharyngeal and vagus nerve.

Role of Medullary Center

Inspiratory Ramp

- Inspiratory center is responsible for the normal rhythm of respiration. The neurons of this center discharge impulses intermittently at regular intervals ad the impulses cause inspiration.
Normally, during inspiration, the inspiratory center inhibits expiratory center; and during expiratory center, expiratory center inhibits the inspiratory center. Thus the medullary respiratory centers control each other.

The significance of inspiratory ramp signal is that there is slow and steady inspiratory so that the filling of lungs with air is also steady.

**Role of Protine Center**

- The medullary respiratory center is under the influence of protine centers. The Apneustic center always accelerates the activity of inspiratory center and the stimulation of this center cause prolong inspiration.
- The pneumotaxic center inhibits the Apneustic center and restricts the duration of inspiration.

**Factor Affecting Respiratory Center**

1. Impulses from higher centers (cerebral cortex)
2. Impulses from stretch receptors of lungs: Hering-Breuer Reflex
3. Impulses from 'J' receptor of lungs (have sensory nerve endings of the vagus nerve)
4. Impulses from irritant receptor of lungs (harmful chemical)
5. Impulses from baroreceptors (change in blood pressure)
6. Impulses from chemoreceptors (condition like hypoxia)
7. Impulses from proprioceptors (change in position of body)
8. Impulses from thermo-receptors (change in environmental temperature)
9. Impulses from pain receptors
10. Cough reflex
11. Sneezing reflex
12. Deglutition reflex (swallowing of food)

**Hering-Breuer Reflex**

During inspiration when there is stretching of lung tissues due to expansion, the stretch receptors are stimulated and produce impulses. The impulses are carried vagal afferent fibers to respiratory centers. The impulses actually inhibit the inspiratory center and so inspiration stops and expiration starts. This reflex is a protective reflex because it restricts the inspiration and limits the over stretching of lungs.

**Chemical Mechanism**

**Chemoreceptor**

Chemoreceptors are sensory nerve endings, which are highly sensitive to chemical changes in blood. Chemoreceptors are stimulated by following changes in blood constituents:

1. Hypoxia
2. Hypercapnea
3. Increased hydrogen ion concentration
Types of Chemoreceptors
1. Central Chemoreceptor
2. Peripheral Chemoreceptor

Central Chemoreceptor
- The chemoreceptor present in the brain are called the central chemoreceptor.
- Central chemoreceptors are situated in the deeper part of medulla oblongata, close inspiratory center. The chemoreceptors are in close contact with blood and cerebrospinal fluid.
- The main stimulant of central chemoreceptors is the increased hydrogen ion concentration. However, increases in hydrogen ion concentration in blood cannot stimulate the central chemoreceptor as it does not pass blood-brain barrier.
- If carbon dioxide increases in blood, it can easily cross the blood-brain barrier and enter cerebrospinal fluid. There, the carbon dioxide molecules combine with water to form carbonic acid. Since carbonic acid is unstable, it immediately dissociates into hydrogen ion and bicarbonate ion.
- The hydrogen ions now stimulate the central chemoreceptors which send stimulatory impulses to inspiratory center causing increases rate and force of breathing.

Peripheral Chemoreceptors
- It is present in the carotid and aortic region. Reduction in partial pressure of oxygen is the most potent stimulant for the peripheral chemoreceptors which send impulses through aortic and sinus nerves when the partial pressure of oxygen is low. These impulses reach the respiratory center (inspiratory center) and stimulate them.

DISTURBANCES OF RESPIRATION
Eupnea: Normal Breathing
Trachpnea: The increase in rate of respiration
Bradpnea: The decrease in rate of respiration
Polypnea: Rapid, shallow breathing
Apnea: Temporary arrest of breathing
Hypernea: Increase in pulmonary ventilation due to increase in rate of force of respiration
 Hyperventilation: Abnormal increase in rate and force of respiration
Hypoventilation: Decrease in rate and force of respiration
Dyspnea: Difficulty in breathing
Periodic breathing: The abnormal respiratory rhythm
**Hypoxia**: reduce availability of oxygen to the tissues

**Hypercapnea**: increase carbon dioxide content in blood

**Hypocapnea**: Decrease carbon dioxide content in blood

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**HISTOLOGY OF RESPIRATORY SYSTEM**

**Normal Lung**

- Sections of lung tissue have the appearance of fine lace because most of the lung is composed of thin-walled alveoli. The alveoli are composed of a single layer of squamous epithelium.
- Between the alveoli you may see a thin layer of connective tissue and numerous capillaries also lined with simple squamous epithelium.
- Bronchioles can be recognized by the fact that they are lined by ciliated columnar epithelium (larger bronchioles) or by cuboidal epithelium (smaller bronchioles leading to alveoli).
- Remember that bronchioles are tubes and may be sectioned either transversely (across) or longitudinally.

**Pharynx**

- The pharynx connects the nasal cavity with the larynx.
- Depending on the extent of abrasive forces on the epithelium, the pharynx is either lined with respiratory epithelium (nasopharynx or epipharynx) or with a stratified squamous epithelium (oropharynx or meso- and hypopharynx), which also covers the surfaces of the oral cavity and the oesophagus.
- Lymphocytes frequently accumulate beneath the epithelium of the pharynx.
- Accumulations of lymphoid tissues surrounding the openings of the digestive and respiratory passages form the tonsils.
- The nasal cavity and pharynx form the upper respiratory passages.

**Epiglottis**

- It consists of a plate of elastic cartilage covered on both sides by mucosa.

**Epithelium:**

- Anterior (lingual) surface and upper part of posterior (laryngeal) surface are covered by stratified squamous epithelium.
- Lower half of the posterior surface is covered by the respiratory epithelium.
**Bronchi**

- The histological structure of the epithelium and the underlying connective tissue of the bronchi correspond largely to that of the trachea and the main bronchi. In addition, bronchi are surrounded by a layer of smooth muscle, which is located between the cartilage and epithelium.

**Bronchioles**

- Bronchioles are the terminal segments of the conductive portion.
- At the transition from bronchi to bronchioles the epithelium changes to a ciliated columnar epithelium, but most of the cell types found in the epithelium of other parts of the conductive portion are still present.
- Glands and cartilage are absent. The layer of smooth muscle is relatively thicker than in the bronchi.