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- **Lecture title: Regulation of respiration**

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- **Summary:** **The respiratory center: -** the rhythmic pattern of breathing and the adjustments that occur therein are integrated within portions of the brainstem known as the respiratory center.

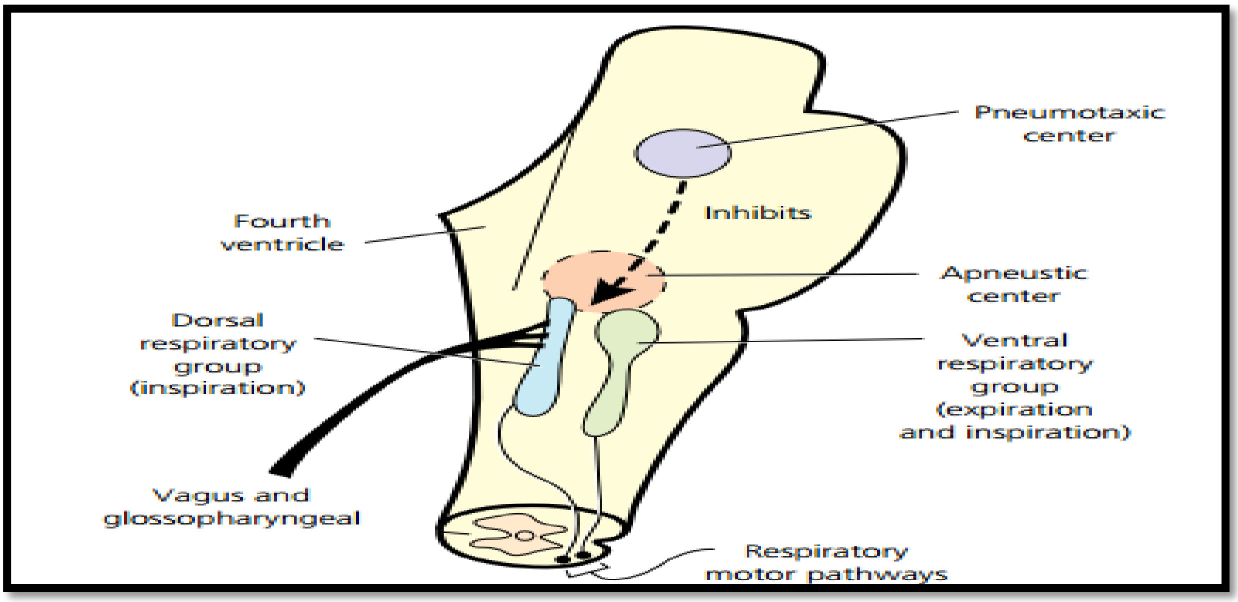
- **Regulation of respiration: -**

Pulmonary ventilation is regulated closely to maintain the concentrations of hydrogen ions, carbon dioxide, and oxygen at relatively constant levels while meeting the needs of the body under varying conditions. If either the hydrogen ion or the carbon dioxide concentration increases or if the oxygen concentration decreases, their levels will be returned to normal by increasing ventilation. **Conversely**, if either the hydrogen ion or carbon dioxide concentration decreases or if oxygen concentration increases, pulmonary ventilation will be decreased. This regulatory mechanism is controlled by changes in tidal volume, frequency of respiratory cycles, or both.

- **Neural control of respiration: -**
- **The respiratory center: -** the rhythmic pattern of breathing and the adjustments that occur therein are integrated within portions of the brainstem known as the **respiratory center.**
- Unlike many centers, it is not a collection of circumscribed nuclei but rather consists of regions within the medulla and pons associated with specific respiration-related functions. Four specific regions have been identified: -

1. The **dorsal respiratory group (DRG)** in the dorsal medulla
2. The **ventral respiratory group (VRG)** in the ventral medulla
3. The **pneumotaxic center (PC)** in the rostral portion of the pons
4. The **apneustic center** in the caudal pons.

- Neurons of the **DRG** are primarily associated with inspiratory activity and generate the basic rhythm of breathing which transmit sensory signals into the respiratory center from (1) peripheral chemoreceptors, (2) baroreceptors, and (3) several types of receptors in the lungs.
- The **VRG** has neurons that are associated with both inspiratory and expiratory activity but it is primarily responsible for expiration.
- The **PC** inhibits inspiration and therefore regulates inspiratory volume and respiratory rate. The primary function of the PC is to limit inspiration, thereby controlling the duration of the filling phase of the respiratory cycle. The pneumotaxic signal that controls the filling phase may be strong or weak. The effect of a strong signal is to increase the respiratory rate whereby both inspiration and expiration are shortened and which are coupled with a lesser tidal volume. The converse is true for a weak PC signal.
- The **apneustic center** is the least understood of all the regions of the respiratory center; consequently, there is no consensus as to its role



- **<u>Chemical control of respiration: -</u>**

Chemical regulation of breathing is part of the involuntary (autonomic) control of breathing. This mechanism is part of the bodies homeostasis to maintain an appropriate balance and concentration of CO_2, O_2, HCO_3^-

and pH. There are two types of chemoreceptors that react strongly to a change in the blood gases: **central** and **peripheral** chemoreceptors.

- **Central Chemoreceptors: -**

Central chemoreceptors are located on the ventrolateral surface of the medulla oblongata. They respond indirectly to blood PCO_2 but not to PO_2. CO_2 diffuses across the blood-brain barrier from blood to cerebral spinal fluid (CSF) while H^+ and HCO_3^- are unable to pass. As the blood CO_2 readily passes the blood-brain barrier into the CSF it will react with H_2O to make H_2CO_3, that will split into HCO_3^- and H^+.

$$CO_2 + H_2O \rightarrow HCO_3^- + H^+$$

An increase in H^+ concentration will directly stimulate the chemoreceptor neurons in the medulla oblongata. They will relay this information and cause an increase in ventilation which will lead to a decrease in CO_2. The central chemoreceptors are responsible for ~80% of the response to an increase CO_2 concentration.

- Peripheral Chemoreceptors: -

Peripheral chemoreceptors are located in carotid and aortic bodies that have neuro-epithelial cells that contact with sensory nerve terminals. They respond to changes in PO_2, PCO_2 and pH. When they are stimulated, K^+ channels close and Ca^{2+} channels open. This causes an increase in initiation of dopamine impulses to respiratory center via the glossopharyngeal nerves and an increase in ventilation. The peripheral chemoreceptors are responsible for ~20% of the response to an increase in PCO_2.

Panting: - is prevalent among many animal species, especially in dog. The respiratory center of the dog responds not only to the usual stimuli but also to body core temperature. The integration of these inputs permits the respiratory center to respond to metabolic needs by regulating alveolar ventilation and to dissipation of heat by regulating dead-space ventilation. Dead-space ventilation is increased by panting, which provides for cooling of the body by evaporation of water from the mucous membranes of the tissues involved. Studies have shown that there are three patterns of panting:

-. Inhalation and exhalation through the nose
2. Inhalation through the nose, exhalation through the nose and mouth.
3. Inhalation through the nose and mouth and exhalation through the nose and mouth

- Avian respiratory system: -

The avian pulmonary system consists of two functionally separate and distinct components: one for ventilation (trachea, bronchi, air sacs, thoracic skeleton, and muscles of respiration), and one for gas exchange (parabronchial lung).

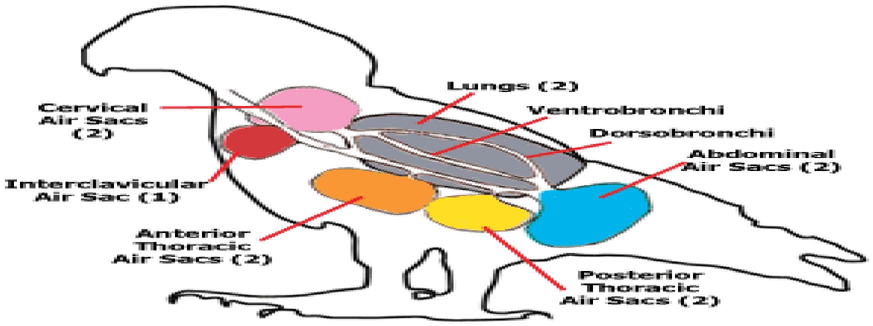
-The structure of the avian respiratory system is unique amongst the vertebrates, with small lungs that do not change volume during breathing, and nine large air sacs that act as bellows to ventilate the lung but do not participate directly in gas exchange

- In contrast to mammals, the avian thoracic cavity is essentially at atmospheric pressure (versus sub atmospheric), and there is no diaphragm to functionally separate it from the abdominal cavity

-The trachea has completed cartilaginous rings in most avian species and plentiful smooth muscle unlike the incomplete C-shaped rings of mammals.

- Air sacs: -

Birds have nine air sacs: two cervical, an unpaired clavicular, two cranial thoracic, two caudal thoracic, and two abdominal air sacs.



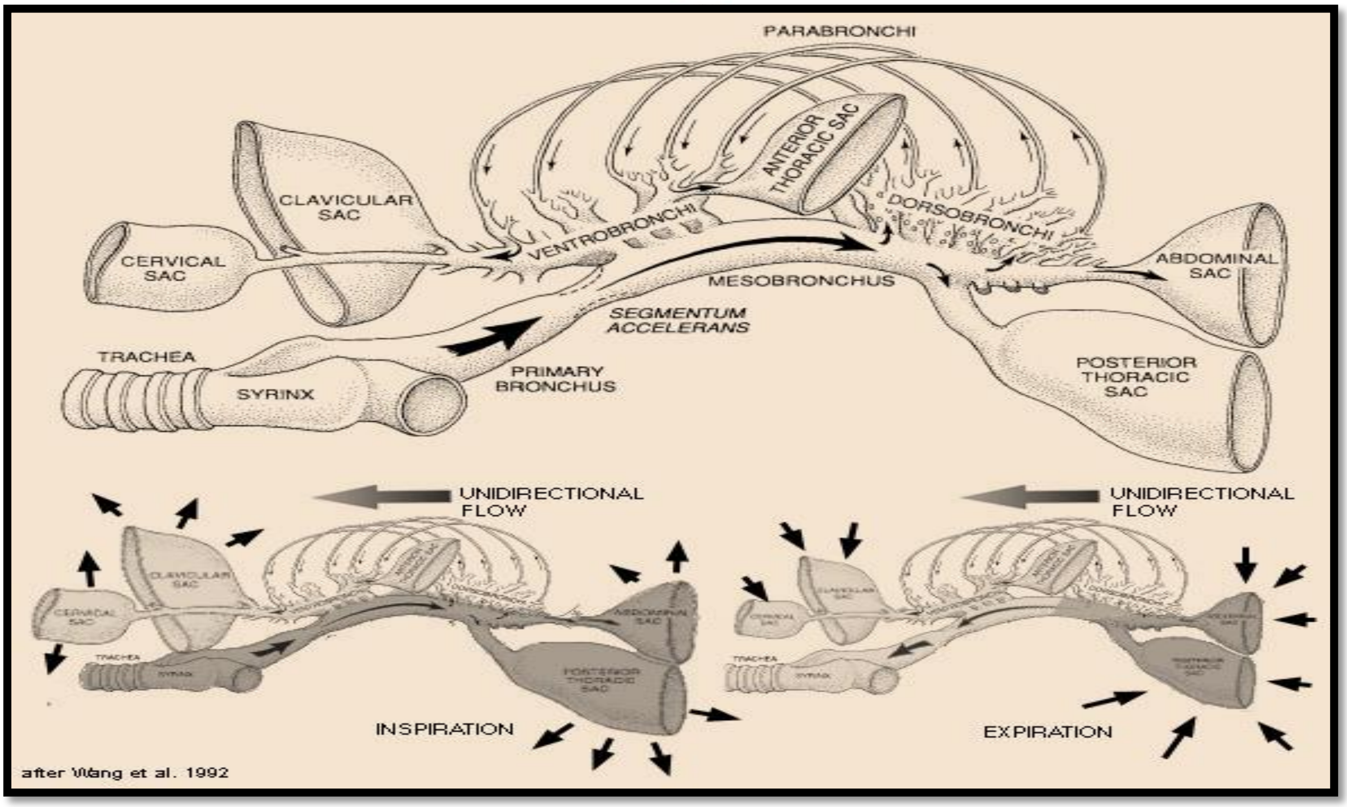
- Birds do not possess a muscular diaphragm, but depend on cervical, thoracic and abdominal muscles for inspiration and expiration, both of which are active processes requiring muscular contraction
- The air sacs permit a unidirectional flow of air through the lungs. Unidirectional flow means that air moving through bird lungs is largely 'fresh' air & has a higher oxygen content. In contrast, air flow is 'bidirectional' in mammals, moving back and forth into and out of the lungs. As a result, air coming into a mammal's lungs is mixed with old air (air that has been in the lungs for a while) & this 'mixed air has less oxygen. So, in bird lungs, more oxygen is available to diffuse into the blood.

- **Respiratory cycle in birds: -**

1- During the first inspiration, the air travels through the nostrils, also called nares of the bird, which are located at the junction between the top of the upper beak and the head. The fleshy tissue that surrounds them, in some birds, is called cere. As in mammals, air moves through the nostrils into the nasal cavity. From there it passes through the larynx and into the trachea. Air moves through the trachea to the syrinx; it passes through the syrinx and then the air is divided in the tow as the trachea divided. The air does not go directly to the lung, but instead travels to the caudal (posterior) air sac. A small amount of air will pass through the caudal air sac to the lung.

2- During the first expiration, the air moved from the posterior air sac through the ventrobronchi and dorsobronchi into the lung. The bronchi continue to divide into small air capillaries. Blood capillaries flow through the air sac capillaries and this is where the oxygen and carbon dioxide are exchanged.

3- When the bird inspires the second time, the air move to the cranial air sacs.


PARABRONCHI
ANTERIOR THORACIC SAC
CLAVICULAR SAC
CERVICAL SAC
VENTROBRONCHI
DORSOBRONCHI
ABDOMINAL SAC
MESOBRONCHUS
SEGMENTUM ACCELERANS
TRACHEA
SYRINX
PRIMARY BRONCHUS
POSTERIOR THORACIC SAC
UNIDIRECTIONAL FLOW
UNIDIRECTIONAL FLOW
INSPIRATION
EXPIRATION
after Wang et al. 1992