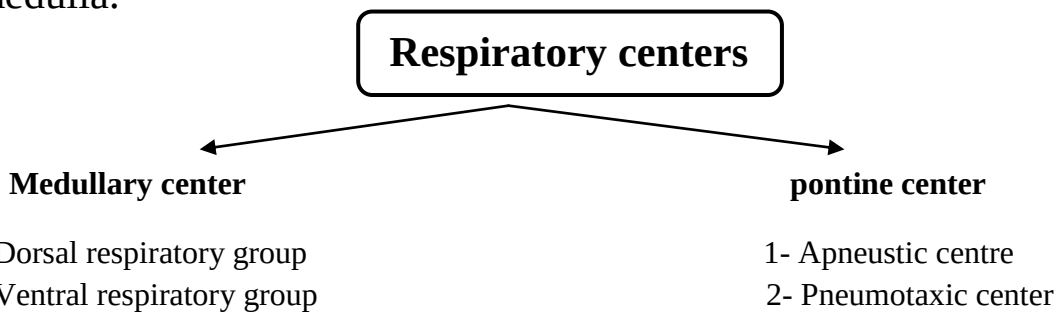
Control of Breathing

Spontaneous respiration depends completely on a collection of neurons in the brain stem called collectively the respiratory center. The neurons of the respiratory center are present in the pons and medulla.



I. Medullary centers

A) Inspiratory centre (Dorsal respiratory group)

- They are located in the dorsal portion of the medulla.
- The inspiratory center is responsible for **the basic rhythm** of ventilation.

B) Expiratory centre (Ventral respiratory group)

- They are located in the medulla, anterior and lateral to the inspiratory neurons.
- They are inactive during normal quite breathing since expiration is a passive process, but it is activated during forced expiration.

II. Pontine centers

A) *Apneustic center*

- Present in the lower third of the Pons.
- It continuously sends excitatory impulses to the medullary inspiratory center.
- It is called the pacemaker of respiration.
- It receives inhibitory impulses from the pneumatic center through the vagus.

B) <u>Pneumotaxic center</u>

- Present in the lower third of the Pons.
- Send inhibitory impulses to medullary inspiratory neurons, and Apneustic center.

N.B

- Stimulation of the centers on one side causes contraction of respiratory muscles on both sides of the body, due to interconnection between the centers on both sides.
- The neurons of the medullary centers are connected with the motor neurons of the diaphragm present in 3,4,5 cervical segments of the spinal cord and motor neurons of intercostal muscles in the upper (1-10) thoracic segments by descending tracts in the spinal cord.

Regulation of respiration

The activity of the respiratory center is regulated by: -

I. *<u>Nervous factors.</u>*
II. *<u>Chemical factors.</u>*

<u>I- Nervous regulation of respiration</u>

The activity of the respiratory centers is modulated by afferent impulses reaching it from other centers as well as from different parts of the body.

(1) Afferent impulses from higher centers

<u>A- From the cerebral cortex.</u>

The cerebral cortex regulates the voluntary ventilation, as voluntary hyperventilation and voluntary apnea.

a) **Voluntary hyperventilation** leads to Co2 wash from the alveolar air, leading to respiratory alkalosis.

b) **Voluntary apnea** leads to accumulation of Co2, after one minute of apnea, Co2 accumulate to a high level which can stimulate the respiratory center inspite of the effort made to inhibit it, this point is called the breaking point. The period of apnea can be prolonged by a preceding period of hyperventilation before breath holding; to increase O2 tension and decrease Co2 tension.

B- Afferent impulses from the hypothalamus

It can control respiration and affect the respiratory centers in the following conditions.

1- Pain:

- Mild pain leads to sympathetic stimulation and accelerated breathing.
- Sever pain leads to parasympathetic stimulation and slow breathing.

2- Temperature:

- Increased temperature stimulates respiration to get rid of some of excess heat through evaporation of water from lungs.

3- Emotions:

- Fear, anxiety and anger influence ventilation.
- Mild emotions stimulate sympathetic nervous system and stimulate respiration, while sever emotions stimulation parasympathetic nervous system leading to inhibition of respiration.

4- Sleep:

- At the begging of sleep respiratory rate is increased due to:-

a. Increase venous return.

b. Abdominal viscera hinder the descent of the diaphragm, stimulating the Golgi tendon and stretch receptors leaving it to stimulate of R.C.

- In deep sleep, the rate become slow but also become deeper.

(2)Afferent impulses from different systems

A- Afferent impulses from Respiratory system:-

i. ***Sneezing reflex:***

It is caused by irritation of the mucous membrane of the nose by foreign material which gives impulses along the trigeminal nerve to the respiratory center leading to deep inspiration followed by forced expiration which removes out the foreign material.

ii. ***Swallowing reflex:***

Breathing is inhibited during swallowing by impulses from the pharynx that pass through the glossopharyngeal nerve.

iii. ***Cough reflex:***

Stimulation of irritant receptors present in the airway, from trachea down to respiratory bronchioles by chemical or mechanical substance leads to reflex deep inspiration followed by deep forced expiration against closed glottis, which increases the intrapulmonary pressure that leads to sudden opening of the glottis and ejection of the foreign material.

B- Afferent impulses from cardiovascular system

(DISCUSSED LATER)

C- Afferent impulses from skeletal muscles

- Active and passive movement of the joints stimulates respiration by afferent impulses from proprioceptors in muscles, tendons and joints which stimulate respiratory center.
- This effect help increased ventilation during exercise.

D- Afferent impulses from the viscera.e.g.(yawning and hiccup)

II- Chemical regulation of Respiration

Ventilation is regulated by the concentration of O2, CO2 and H+ in the arterial blood. This regulatory function is done through the chemoreceptors.

- ***There are two types of chemoreceptors: -***

1) Peripheral chemoreceptors.

- **Site:-**

a. Carotid bodies, at the bifurcation of the common carotid arteries.
b. Aortic bodies, located at the aortic arch.

- **Innervations:-**

Impulses from carotid bodies are carried in the carotid sinus nerve, which is a branch of the glossopharyngeal nerve, while impulses from aortic bodies are carried in the vagus nerve.

- **Blood supply:-**

The carotid and aortic bodies have a rich blood supply, and their response to changes in blood gases is very fast.

- ❖ These receptors respond to decreased arterial PO2, decreased pH, and increased CO2 concentration.
- ❖ Peripheral chemoreceptors are more sensitive to decreased O2 tension.

2) Central chemoreceptors

➢ **Site:-**

- They are located in the medulla oblongata close to the medullary respiratory centers.
- It has a direct connection with the inspiratory centers.
- These receptors are stimulated by increased CO2 level, and the mechanism of its activation is through H+ ions.

N.B: ***H+ ions do not easily pass through the blood brain barrier (BBB), but it stimulates the central chemoreceptors as follow:***

CO2 enter the C.S.F of the medulla, and then react with H20 to give carbonic acid which rapidly dissociates into HCO3 and H+

$CO2 + H2O \rightarrow H2CO3 \rightarrow HCO3 + H$ ions

- The released H ions stimulate respiration through stimulation of the central chemoreceptors.
- Central chemoreceptors are more sensitive to changes in CO2 and H+ concentration.

N.B

If respiratory depression is treated with pure O2, peripheral chemoreceptors will be inhibited leading to more respiratory depression. A gas mixture of 95% O2 and 5% CO2 is given instead to stimulate the central chemoreceptors by the CO2.

Ventilatory response to CO_2

The increase in Co2 tension of arterial blood stimulates respiration and increases pulmonary ventilation, while a decrease of CO_2 tension inhibits respiration.

- If 4% CO_2 is breathed the respiratory minute volume is doubled, and the CO_2 tension in alveolar air is almost not changed.
- If 10% CO_2 is breathed the respiratory minute volume is increased 10 times, but the CO_2 tension in alveolar air rises to 50 mmHg.
- Increased CO_2 percentage above 10% does not result in significant increase in respiratory minute volume but CO_2 tension in alveolar air rises rapidly, with increased CO_2 tension in arterial blood and H+ ion concentration rises.

❖ **Mechanism:** increased CO_2 tension in arterial blood will stimulate R.C through respiratory chemoreceptors.

a- Central chemoreceptors:-

- As discussed above CO_2 diffuses through the (BBB) into the cerebrospinal fluid (C.S.F) passing the cells of the chemoreceptors.
- CO_2 is converted into H+ ions.
  $CO_2 + H_2O \rightarrow \quad H_2CO_3 \rightarrow$ H+ and HCO_3.
- The H+ ions stimulate the chemoreceptor cells (H+ ions receptors) which stimulate the neurons of the respiratory center.
- On the other hand hyperventilation lowers the CO_2 tension in alveolar air, CO_2 in arterial blood and CO_2 tension in the CSF. This lowers the H+ concentration in the C.S.F. leading to inhibition of R.C leading to increased CO_2 tension in alveolar air and arterial blood to the normal level.

(b) Peripheral chemoreceptors:-

These receptors are sensitive to decreased O2 tension and to a lesser extent to increased H+ ion concentration and to increased CO2 tension of arterial blood.

Ventilatory response to H+ ion concentration

H+ ion concentration in the blood is proportional to the ratio of

$$\frac{free\ CO2}{Bicarbonate}$$

Increased H+ ion concentration in arterial blood as in metabolic acidosis stimulates R.C, while decrease in H+ ion concentration will inhibit the R.C.

❖ **Mechanism:-**

Increased H+ ion concentration stimulates peripheral chemoreceptors, which send impulses along afferent fibers in the vagus and glossopharyngeal nerves to stimulate respiratory center.

Ventilatory response to O2 lack

Respiration is stimulated by a decrease in O2 tension in arterial blood, when alveolar O2 tension drops due to:-

a) breathing gas mixture with low oxygen content at sea level.
b) ascent to high altitudes.

❖ **Mechanism:-**

- Through stimulation of the peripheral chemoreceptors O2 lock will stimulate the respiratory center and increase pulmonary ventilation.
- Moderate decrease in O2 tension in arterial blood sufficient to stimulate the peripheral chemoreceptors has no action on the central chemoreceptors.
- Marked decrease in O2 tension in arterial blood will inhibit R.C if the peripheral chemoreceptors are denervated.

N.B

- Drop of O_2 tension in arterial blood is a weaker stimulus for the R.C than the rise in CO_2 tension in arterial blood. The R.C is stimulated when O_2 tension in arterial blood drops below 60 mmHg.