Breathing is controlled by – I) the concentration of chemical components in body fluid and II) nervous system

**I) Chemical Regulation**

Concentration of $O_2$, $CO_2$ and $H^+$ in blood regulate breathing

1) Concentration of $O_2$

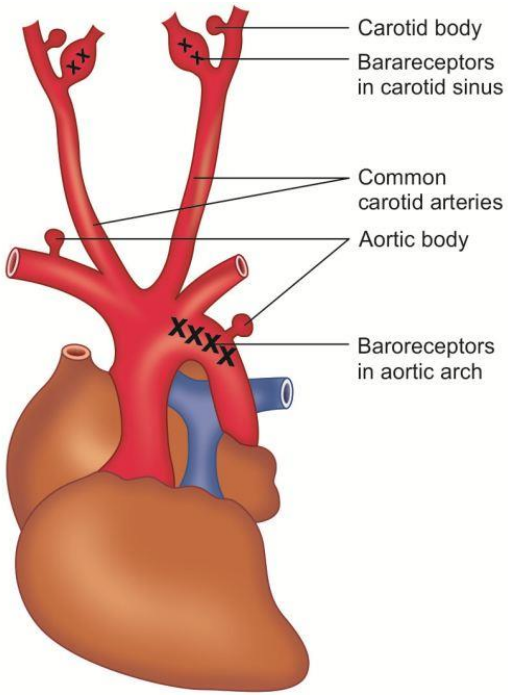
i) When the concentration of $O_2$ i.e., $[O_2]$ in arterial blood falls below normal (70 mmHg), the chemo-receptors in carotid body and aortic body become strongly stimulated.

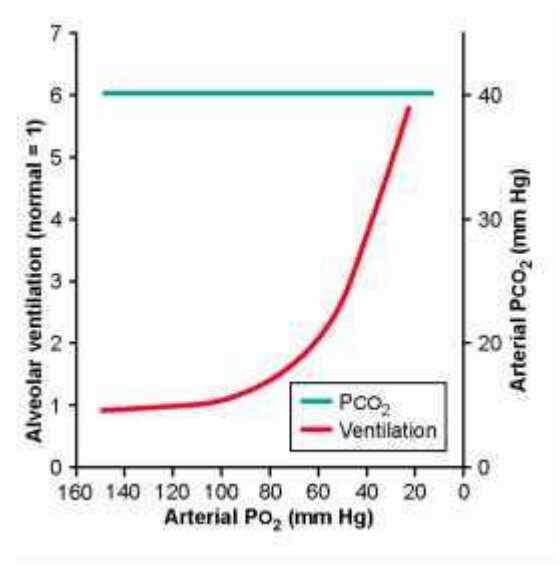
ii) The action potential is transmitted via glossopharyngeal and vagus nerve to dorsal respiratory group and the centre is activated.

iii) The motor impulse is reached to diaphragm and external intercostals muscles. Consequently, these muscles contract and alveolar ventilation increases.

iv) Therefore, breathing rate (R) varies inversely proportional to the concentration of $O_2$ ($[O_2]$) or partial pressure of $O_2$ in blood ($P_{O2}$)

$R \alpha \frac{1}{[O2]}$ or, $R \alpha \frac{1}{PO2}$




2) Concentration of $CO_2$

i) An increase in the concentration of $CO_2$ in arterial blood (> 38 – 42 mmHg) excites the chemo-receptors in carotid body and aortic body and action potentials are generated.

ii) These sensory impulses are transmitted to dorsal respiratory group via glossopharyngeal and vagus nerve.

iii) Simultaneously, high concentration of $CO_2$ above normal excites chemo-sensitive area in medulla oblongata forming $H^+$s from $H_2CO_3$.

$$CO_2 + H_2O \xrightarrow{\text{Carbonic anhydrase}} H_2CO_3$$

$$H_2CO_3 \rightarrow H^+ + HCO_3^-$$

iv) Subsequently, the dorsal respiratory group is stimulated and this leads to rise of breathing rate (R).

$R \alpha [CO_2]$ or, $R \alpha P_{co2}$

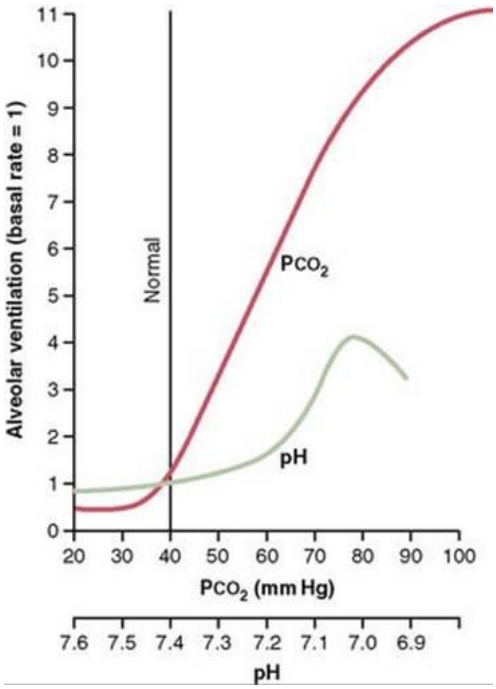
3) Concentration of $H^+$

i) Increase in concentration of $H^+$ in arterial blood (pH > 7.35 – 7.45) excites chemo-receptors in carotid body, aortic body and chemo-sensitive area together.

ii) Successively dorsal respiratory group is stimulated.

iii) As a result, alveolar ventilation increases proportionately.

$R \alpha [H^+]$




**II) Neural Regulation**

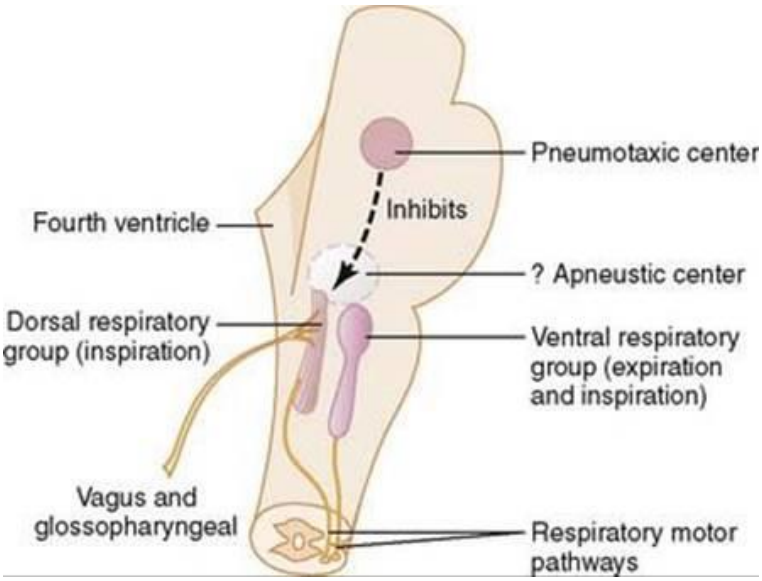
Breathing is primarily regulated by nervous system. It normally adjusts the rate of alveolar ventilation almost exactly to the demand of the body. The partial pressure of $O_2$ and $CO_2$ are hardly altered in arterial blood even during heavy exercise and respiratory stress.

i) Breathing is controlled by three respiratory centre-

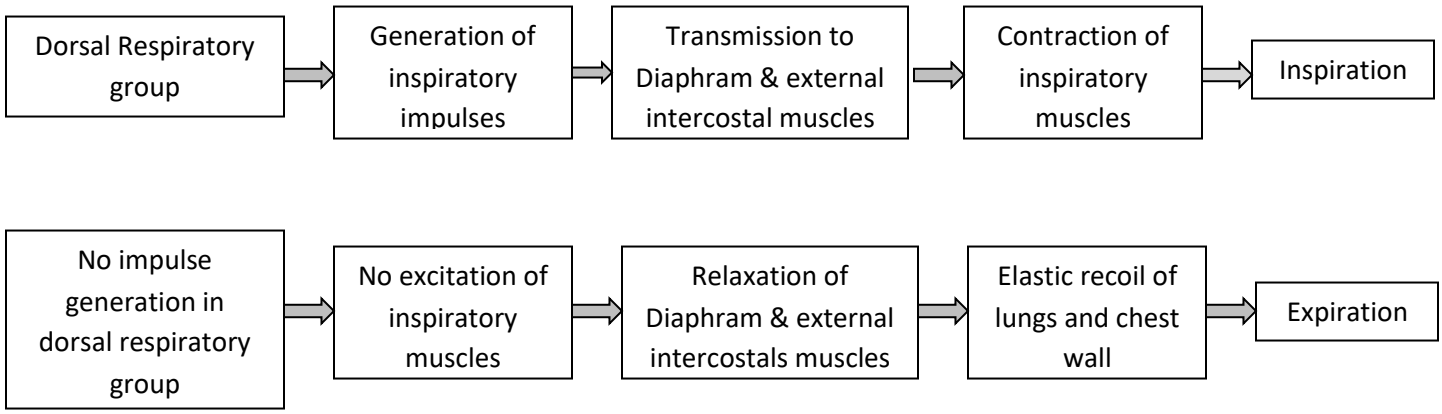
a) A dorsal respiratory group located in dorsal portion of medulla oblongata, which causes inspiration.

b) A ventral respiratory group located in ventro-lateral part of medulla oblongata, which causes expiration.

c) A Pneumotaxic centre located in superior portion of pons, which controls rate and depth of breathing.

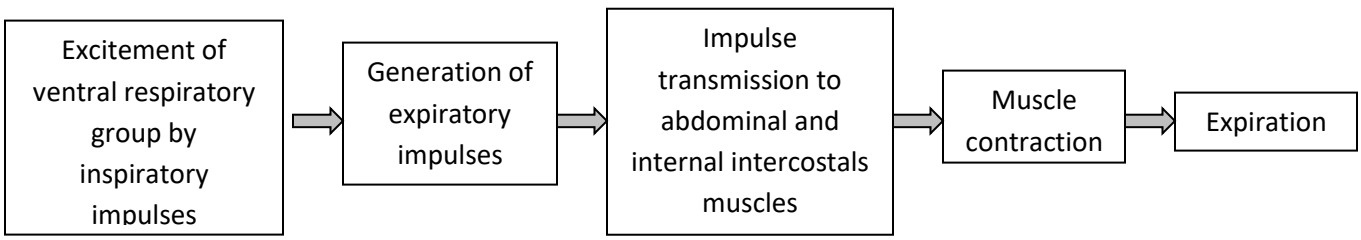



ii) The dorsal respiratory group of neurons plays a fundamental role in control of respiration. The basic rhythm of respiration (i.e., neuronal action potentials) is generated mainly in the dorsal respiratory group of neurons. These action potentials are transmitted diaphragm and external intercostals muscles. As a result, these inspiratory muscles contract and inspiration begins. After 3 seconds of inspiration, the generation of action potentials are ceased which turns off excitation of inspiratory muscles but allows elastic recoil of lungs and chest wall. This initiates expiration. Next, the inspiratory signals begins again for another cycle and this cycle repeats.




iii) The neurons of ventral respiratory group remain inactive during normal quiet respiration. Expiration is controlled by dorsal group of neurons.

iv) To perform high level of pulmonary ventilation, ventral group of neurons are stimulated by inspiratory signals generated from dorsal group. Expiratory neuronal impulses are transmitted to internal intercostal and abdominal muscles and they contract. This leads to powerful expiration.



v) A Pneumatic centre transmits impulses to the dorsal group of neurons to suppress from generating inspirational impulses and thus controls the rate and depth of pulmonary ventilation. A strong pneumotactic signal can increase the rate breathing to 30-40 breaths/min. whereas, a weak pneumatic signal may reduce the rate to only 3-5 breaths /min.

vi)The stretch receptors in bronchial and bronchiolar muscles transmit neuronal impulses through vagus nerve to dorsal respiratory group when the lungs become overstretched and the dorsal respiratory group is suppressed. Consequently, inspiration as well as expiration are controlled.