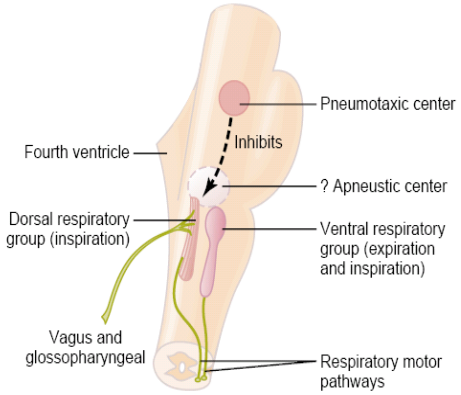
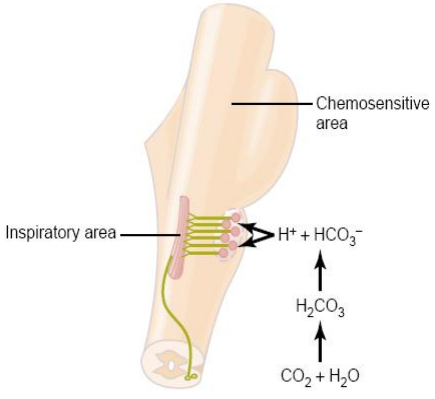
Unit II – Problem 6 – Physiology: Control of Breathing

- **There are 3 groups of neurons in brainstem which are concerned with regulation of respiration:**
  - **Dorsal respiratory group (in medulla oblongata):** most of neurons are located in (tractus solitaries). They receive information from the following nerves:
    - ✓ Vagus nerve (X).
    - ✓ Glossopharyngeal nerve (IX).

    Information are collected by the following receptors:
    - ✓ Peripheral chemoreceptors.
    - ✓ Baroreceptors.
    - ✓ Receptors from the lung.

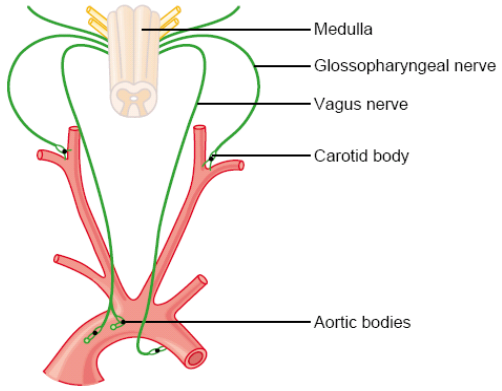
    Notice that this center results in INSPIRATION (the signal increases gradually to maximum and then wanes. When it ceases, expiration will occur).
  - **Pneumotaxic center**: located in nucleus parabrachialis in pons. It functions in limiting inspiratory duration and increasing respiratory rate.
  - **Ventral respiratory group**: it is located on each side of medulla oblongata in nucleus ambiguus and nucleus retroambiguus. These neurons are inactive in NORMAL breathing. When ventilation demand increases a lot, they will be activated thus contributing to both inspiration and expiration.
- **Pulmonary stretch reflex:**
  - Receptors in the smooth muscles of bronchi and bronchioles will inhibit the dorsal respiratory group and apneustic center (when they are over-stretched) resulting in termination of inspiration. By termination of inspiration they increase respiratory frequency.
- **Rhythmic ventilation:**
  - **Starting inspiration:**
    - ✓ Medullary respiratory center neurons are continuously active (spontaneous).
    - ✓ Respiratory center receives stimulations from:
      - ❖ Peripheral and central receptors.
      - ❖ Brain concerned with voluntary respiratory movements and emotion
    - ✓ Combined inputs from all sources cause action potentials to stimulate respiratory muscles.
  - **Stopping inspiration:**
    - ✓ Neurons receive inputs from pontine group and stretch receptors in lungs.
    - ✓ Inhibitory neurons are activated and relaxation of respiratory muscles results in expiration.
  - **Increasing depth of inspiration**: more and more neurons in dorsal respiratory group are activated.
- **Chemical control of respiration:**
  - **Central chemoreceptors:**
    - ✓ CO_2 or hydrogen ions elevation in the blood act directly on the respiratory center (act on both inspiratory and expiratory motor signals). Oxygen has very little (or no) direct effect.
    - ✓ The chemosensitive areas are located bilaterally beneath the ventral surface of medulla oblongata. Excitation of this area is mainly done by hydrogen ions. Since hydrogen ions do not cross

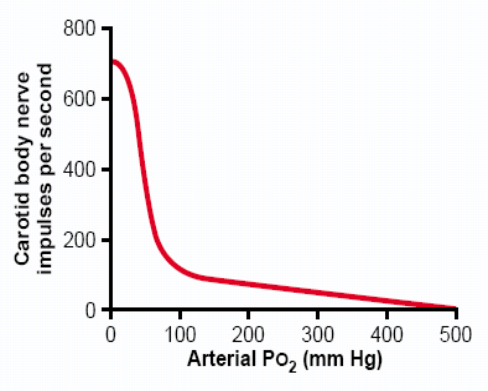
    

the Blood-Brain Barrier (BBB) easily thus high hydrogen ions level in the blood has less effect than a rise in blood CO_2.

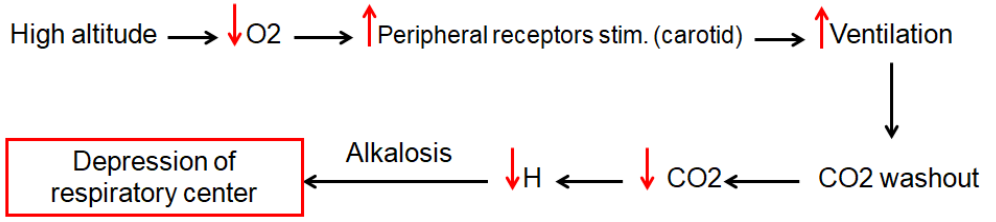
- ✓ CO_2 can pass BBB easily. When it passes, it reacts with water of interstitial fluid of medulla oblongata and ultimately liberating hydrogen ions which stimulates the chemosensitive area.
- ✓ The excitatory effect of high blood CO_2 gradually declines over the next 2 days. This is because of:
  - ❖ Readjustment of hydrogen ions in the blood by the kidney (increasing HCO_3 formation).
  - ❖ The HCO_3 itself diffuses through BBB and combines directly to hydrogen ions adjacent to respiratory neurons. Thus CO_2 has only acute effect.
- ✓ Stimulation of central chemoreceptors is responsible for about 70% of the increase in the rate and depth of respiration in response to increased CO_2. Carotid and aortic bodies are responsible for the other 30% of the response to raised CO_2. They also increase ventilation in response to a rise in level of hydrogen ions or a large drop in PaO_2 (to below 60 mmHg).

- **Peripheral chemoreceptors:**
  - ✓ Especially important to detect low levels of oxygen (can be stimulated by high CO_2 or hydrogen, but the central effects of these is much higher than peripheral effect.
  - ✓ The peripheral receptors are located mainly in the carotid bodies (glossopharyngeal nerve), and to lesser extent in the aortic bodies (vagus nerve). Carotid and aortic bodies are so small and the blood flow in them is so quick so that oxygen pick up is very little and the blood in them can be considered always arterial (not venous).
  - ✓ The frequency of discharge in the carotid bodies is very sensitive when PO_2 ranges between 30 and 60 mmHg. The mechanism by which low PO_2 is stimulating these receptors is quite unknown.

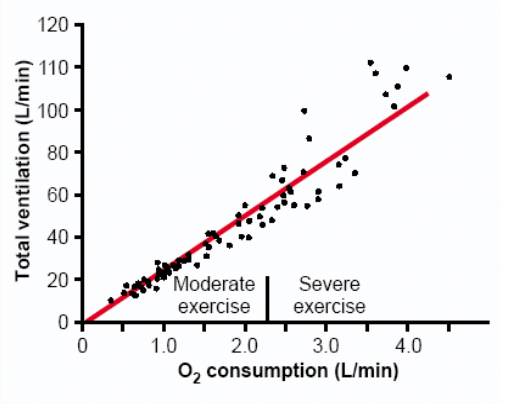


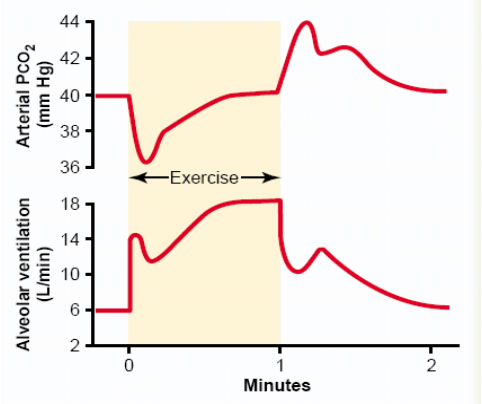


  - ✓ **Chronic breathing of low O_2 (acclimatization):** a mountain climber can breath more deeply if he climbs slowly over a period of days rather than a period of hours. In the first two days, the control of respiration is done by CO_2 and H ions. After two days, 4/5th of respiratory center sensitivity will be lost and hypoxia will be the main drive of the respiratory center to increase alveolar ventilation.



- ✓ Respiration during exercise:
  - ❖ The O_2 consumption and CO_2 production may be 20 folds, but the arterial PO_2, PCO_2 and pH remain almost exactly normal. This is because the alveolar ventilation increases exactly the same manner of O_2 consumption.
  - ❖ How is this? ventilation cannot be increased by the high levels of CO_2, hydrogen ions or hypoxia, because it even increases before any change in these factors. It is believed that a neurogenic signal is stimulating the brainstem respiratory center the same time these signals stimulate the skeletal muscles to make the exercise.





- ✓ The degree and intensity of the neurogenic signal during exercise is a learned response. With repeated exercise, the brain will know how much it needs in any type of exercise to stimulate respiration to keep the arterial PCO_2 constant around 40 mmHg. The cortex is involved in this learning process.

- **Other factors which control/regulate breathing:**
  - Voluntary control.
  - Pulmonary Irritant receptors in epithelium of trachea, bronchi, bronchioles which cause coughing and sneezing.
  - J-receptors in alveolar walls juxtaposition to pulmonary capillaries which are excited by capillary engorgement and pulmonary edema. When stimulated, they give sensation of dyspnea.
  - Effect of brain edema and increased intracranial pressure (causes depression of respiratory center). This condition is treated by hypertonic solution as Mannitol.
  - Anesthesia depresses respiration.
- **Sleep apnea:**
  - **Cessation of respiration during sleep. It may occur many times during the night. It is caused by:**
    - ✓ Obstructive causes (muscles of pharynx relax during sleep leading to obstruction of air passages). This type is characterized by SNORING.
    - ✓ Central sleep apnea: caused by brain damage or stroke. No SNORING.