21.10C: Chemoreceptor Regulation of Breathing

Chemoreceptors detect the levels of carbon dioxide in the blood by monitoring the concentrations of hydrogen ions in the blood.

Learning Objectives

- Describe the role of chemoreceptors in the regulation of breathing

Key Points

- An increase in carbon dioxide concentration leads to a decrease in the pH of blood due to the production of \( \text{H}^+ \) ions from carbonic acid.
- In response to a decrease in blood pH, the respiratory center (in the medulla) sends nervous impulses to the external intercostal muscles and the diaphragm, to increase the breathing rate and the volume of the lungs during inhalation.
- Hyperventilation causes alakalosis, which causes a feedback response of decreased ventilation (to increase carbon dioxide), while hypoventilation causes acidosis, which causes a feedback response of increased ventilation (to remove carbon dioxide).
- Any situation with hypoxia (too low oxygen levels) will cause a feedback response that increases ventilation to increase oxygen intake.
- Vomiting causes alkalosis and diarrhea causes acidosis, which will cause an appropriate respiratory feedback response.
Key Terms

- **hypoxia**: A system-wide deficiency in the levels of oxygen that reach the tissues.
- **central chemoreceptors**: Located within the medulla, they are sensitive to the pH of their environment.
- **peripheral chemoreceptors**: The aortic and carotid bodies, which act principally to detect variation of the oxygen concentration in the arterial blood, also monitor arterial carbon dioxide and pH.

Chemoreceptor regulation of breathing is a form of negative feedback. The goal of this system is to keep the pH of the blood stream within normal neutral ranges, around 7.35.

Chemoreceptors

A chemoreceptor, also known as chemosensor, is a sensory receptor that transduces a chemical signal into an action potential. The action potential is sent along nerve pathways to parts of the brain, which are the integrating centers for this type of feedback. There are many types of chemoreceptors in the body, but only a few of them are involved in respiration.

The respiratory chemoreceptors work by sensing the pH of their environment through the concentration of hydrogen ions. Because most carbon dioxide is converted to carbonic acid (and bicarbonate) in the bloodstream, chemoreceptors are able to use blood pH as a way to measure the carbon dioxide levels of the bloodstream.

The main chemoreceptors involved in respiratory feedback are:

1. **Central chemoreceptors**: These are located on the ventrolateral surface of medulla oblongata and detect changes in the pH of spinal fluid. They can be desensitized over time from chronic hypoxia (oxygen deficiency) and increased carbon dioxide.
2. **Peripheral chemoreceptors**: These include the aortic body, which detects changes in blood oxygen and carbon dioxide, but not pH, and the carotid body which detects all three. They do not desensitize, and have less of an impact on the respiratory rate compared to the central chemoreceptors.

Chemoreceptor Negative Feedback

Negative feedback responses have three main components: the sensor, the integrating sensor, and the effector. For the respiratory rate, the chemoreceptors are the sensors for blood pH, the medulla and pons form the integrating center, and the respiratory muscles are the effector.

Consider a case in which a person is hyperventilating from an anxiety attack. Their increased ventilation rate will remove too much carbon dioxide from their body. Without that carbon dioxide, there will be less carbonic acid in blood, so the concentration of hydrogen ions decreases and the pH of the blood rises, causing alkalosis.

In response, the chemoreceptors detect this change, and send a signal to the medulla, which signals the respiratory muscles to decrease the ventilation rate so carbon dioxide levels and pH can return to normal levels.

There are several other examples in which chemoreceptor feedback applies. A person with severe diarrhea loses a lot...
of bicarbonate in the intestinal tract, which decreases bicarbonate levels in the plasma. As bicarbonate levels decrease while hydrogen ion concentrations stays the same, blood pH will decrease (as bicarbonate is a buffer) and become more acidic.

In cases of acidosis, feedback will increase ventilation to remove more carbon dioxide to reduce the hydrogen ion concentration. Conversely, vomiting removes hydrogen ions from the body (as the stomach contents are acidic), which will cause decreased ventilation to correct alkalosis.

Chemoreceptor feedback also adjusts for oxygen levels to prevent hypoxia, though only the peripheral chemoreceptors sense oxygen levels. In cases where oxygen intake is too low, feedback increases ventilation to increase oxygen intake.

A more detailed example would be that if a person breathes through a long tube (such as a snorkeling mask) and has increased amounts of dead space, feedback will increase ventilation.

**Respiratory feedback:** The chemoreceptors are the sensors for blood pH, the medulla and pons form the integrating center, and the respiratory muscles are the effector.