4.6.2

Chemicals that Regulate Ventilation

Carbon Dioxide

Carbon dioxide is the most influential and tightly controlled chemical regulator of ventilation. Carbon dioxide crosses the blood brain barrier (H+ can't cross the blood brain barrier) and H+ levels elevate by the same reaction catalyzed by carbonic anhydrase in red blood cells as discussed previously and shown below.

Elevated brain extracellular fluid (or Cerebral Spinal Fluid) H+ concentrations are detected by chemoreceptors in the medulla oblongata. About 80% of carbon dioxide homeostasis at rest is maintained by this central detection. There are many neural connections from the chemoreceptors to the medullary regulatory center. High levels of carbon dioxide in the blood **(hypercapnia)** and consequently H+ ions in the brain, will result in increased rate and depth of ventilation while low levels **(hypocapnia)** will have the opposing effect. This way, arterial blood traveling from the heart to the tissues is always maintained in the normal $PaCO_2$ range of 37 - 43 mm Hg. A change of 5 mm Hg in the partial pressure of carbon dioxide will have a profound effect on ventilation - essentially doubling the breathing rate. Peripheral chemoreceptors in the carotid arteries and aortic arch also respond to changes in carbon dioxide levels but are only responsible for about 20% of carbon dioxide response under resting conditions. Peripheral chemoreceptors play a larger role during exercise.

Let's test your understanding. While sitting in the library reviewing about chemicals that regulate ventilation, you notice your friend Richie across the room. Richie wished he would have studied more and now is stressed about his BIO 461 respiratory exam coming up. Becoming more anxious, he starts to hyperventilate. As he does so, you consider what will happen to the carbon dioxide blood levels in his blood and brain. You have studied diligently and know that hyperventilation may lead to hypocapnia which can cause vasoconstriction of cerebral vessels, cutting off some blood supply, possibly leading to dizziness and fainting. As he complains of dizziness you tell him to breath into a paper bag. You understand that this will increase the amount of carbon dioxide in his inhaled air and help bring his blood carbon dioxide levels back up. Congratulations! You saved the day. Now back to work.

Oxygen

There are also chemoreceptors for oxygen in the carotid arteries and aortic arch. The oxygen partial pressure in arterial blood under normal conditions is 95 mm Hg. Low levels of oxygen in the blood is known as **hypoxemia**. As discussed previously, the manner in which hemoglobin was created to bind to oxygen is truly magnificent. Remember the oxygen-hemoglobin dissociation curve. The top of the curve is quite flat. Even if oxygen partial pressures drop to 80,70 or even 65, hemoglobin is still highly saturated (see the table 1 below). It is not until levels drop to around 60 mm Hg, that oxygen on its own really starts to stimulate an increased breathing rate. Supplemental oxygen for patients (i.e. COPD patients) doesn't generally need to be given until partial pressure levels go below 65 mm Hg. Due to the unique way hemoglobin binds to oxygen, 70-100 mmHg can be considered "normal".

Oxygen partial pressure (PO_2)	**Oxygen Saturation**
100 mm Hg	98%

Oxygen partial pressure (PO_2)	Oxygen Saturation
80 mm Hg	95%
60 mm Hg	89%

Table: Percent saturation of hemoglobin with oxygen at certain arterial blood oxygen partial pressures.

Oxygen Saturation Moniter

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A **pulse oximeter** (Pictured above) is a noninvasive method to quickly determine oxygen saturation (Note: this device does NOT measure PaO_2). The device is placed on a translucent part of the body like a fingertip or earlobe and utilizes differences in light absorbance between oxyhemoglobin and deoxygenated hemoglobin to determine percent oxygen saturation of hemoglobin. A saturation of 90-95% is considered the normal range for patients without a pulmonary disorder or disease.