Bonus: Climbing Mt. Everest

http://www.chemcollective.org/applets/everest/everest.php

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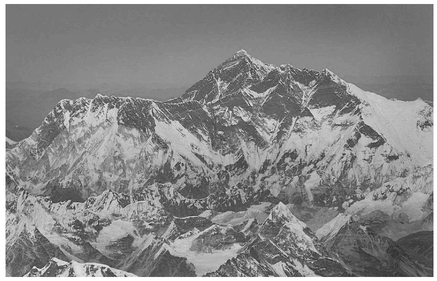

Your goal is to summit Mt. Everest, the world's highest mountain at 8,848 m (29,029 ft), before winter closes in. Your life will not be threatened in reality, but your virtual life may be lost in your attempt. A successful ascent of Everest will require you to manage a critical component of a complex physiological equilibrium involving oxygen, red blood cells, and hemoglobin, which relate acclimatization to altitude and the conditioning of your body to less and less available atmospheric oxygen as you ascend. You can adapt your body's production and basal level of hemoglobin in response to high altitudes and the lower partial pressures of oxygen, which are kinetically regulated and modeled by the Irydium Java applet.

The applet provides a simulation of climbing Mt. Everest and the body's response to the decrease in atmospheric oxygen. At sea level, air pressure is 760 torr and the atmosphere consists of 21% oxygen. This corresponds to a partial pressure of about 160 torr of oxygen. By the time air gets into your lungs and mixes with the air left from the last breath, the partial pressure of oxygen is about 100 torr. At the top of Mt. Everest, the amount of available oxygen has dropped by >65% to about 50 torr. If a person has spent their entire life at sea level and is then suddenly transported to the top of Mt. Everest, the decrease in atmospheric oxygen will almost certainly cause a medical condition known as hypoxia. This will lead to severe disorientation and possibly death. Hypoxia has contributed to a number of deaths including those in an Everest tragedy that occurred in May of 1996, which claimed the lives of 8 climbers, and was recounted by Jon Krakauer, who was among the climbers, in his book, ***Into Thin Air***. For more information on aspects of climbing Mt. Everest, see www.mountainzone.com.

Sherpa, is a Tibetan word for "eastern people", those who now live in eastern Nepal in the Himalayas near Mt. Everest. Since the first Mt. Everest expedition in 1921, they have served as expert mountaineering guides and were integral to many successful climbs including the first by Sir Edmund Hillary and Sherpa Tensing Norgay in 1953. Sherpas can survive a highly strenuous life at high altitudes because their bodies are accustomed to low oxygen levels. One aspect of this acclimatization is an increase in the concentration of red blood cells and the concentration of hemoglobin in the blood. Hemoglobin is a protein that binds oxygen in the lungs, transports it through the blood stream, and releases it where it is needed in the body as well as transferring it to myoglobin for storage. Since the kinetics of biochemical hemoglobin synthesis is slow, it takes significant time for a person to acclimatize to high altitude. Many climbers take along bottled oxygen for use in the "death zone" above 8,000 meters, where the last stretch near the summit can take up to 12 hours to complete. In this applet, you will climb Mt. Everest without bottled oxygen. [*Ed Viesturs has done it without oxygen five out of seven times*.] Instead, you will rest at each climbing camp long enough for your body to acclimatize, and increase hemoglobin until it is safe to move on to the next camp.

The applet uses a simplified model of your body's respiration where each hemoglobin molecule can bind 4 oxygen molecules. In your lungs, essentially all of the hemoglobin molecules have bound at least 3 oxygen molecules. We will consider the binding of the fourth oxygen molecule, which is governed by the equation,

$$Hb(O_2)_3 + O_2 \Leftrightarrow Hb(O_2)_4$$

The equilibrium expression governing this reaction is,

$$K = \frac{[Hb(O_2)_4]}{[Hb(O_2)_3]P_{O_2}} = 0.11\,\text{torr}^{-1}$$

In the applet, torr is used for the partial pressure of oxygen, and micromoles/liter (μM) for the concentration of $Hb(O_2)_4$ and $Hb(O_2)_3$. A micromole is 10^{-6} moles. Your body has a total of about 150 grams of hemoglobin per liter of blood. This corresponds to a concentration of about 2,600μM.

As you proceed up the mountain, the partial pressure of oxygen drops. You can determine the partial pressure at a particular camp by passing your mouse over that camp. (Be careful, because clicking on a camp takes you to that camp, and you may not yet have enough hemoglobin to survive at that altitude.) In this simulation, your body's optimal concentration of bound hemoglobin $[Hb(O_2)_4]$ is 2,400μM. If it drops below this level, your body will produce hemoglobin until the bound hemoglobin is optimal. If the concentration of bound hemoglobin drops below 2,300μM, you will pass out.

The applet oversimplifies the complex phenomena that occur to a human body at high altitude. The biggest simplification is the manner in which the body produces hemoglobin in response to a decrease in available oxygen. In the applet, we assume the rate is simply proportional to the amount of hemoglobin needed by the body. In reality, the time it takes to adjust to high altitude varies widely between different people and conditions.

The equilibrium between hemoglobin and oxygen has been highly simplified. The binding constants are different for each of the four oxygen molecules that hemoglobin can bind. The equilibrium constant value was chosen to reproduce the binding behavior in the pressure ranges of interest for this simulation.

To start the Irydium applet, click on Base Camp in the trail map. As you rest at base camp, your body produces hemoglobin. Your task is to rest at base camp long enough to have sufficient hemoglobin to survive at the next camp, and so forth up the mountain. If you rest too long, winter hits before you summit (180 days total), if you have too little hemoglobin you will become comatose and may die. If you reach the summit, an e-mail is to be sent to Dr. R. that affirms your accomplishment and an appropriate quiz bonus will be provided you.

Although it is possible to derive an equation, which relates the necessary amount of hemoglobin to the partial pressure of oxygen, it is not necessary to follow this approach to be successful. Using estimation and strategies such as linear interpolation can be highly productive and much more efficient than trial and error. (You have unlimited virtual lives.)

Good luck, and if you decide to attempt the real thing don't forget prayer flags, ~$75,000 for equipment, permits, guides and an offering to "*Holy Mother*", "Chomolungma", Tibetan for **Mt. Everest**.