New England Aquarium

Protecting the blue planet

Mammalian Dive Response Laboratory Investigation

Answer Key

PRE-LAB QUESTIONS

1. Hypothesize how submerging your face in cold water while holding your breath may impact your resting heart rate.

Answers may vary but students should hypothesize that the heart rate may change based on this experience. SCAFFOLDING: If you need a starter sentence, you can use: I hypothesize that the cold water and holding my breath will make my heart rate _____ because…

Their heart rates should decrease. The diving response lowers the blood pressure and heart rate and shunts blood to vital organs.

VIDEO LINK:
Mammalian Dive Reflex – Heartrate
www.youtube.com/watch?v=00RKh6NRMqc

2. Hypothesize what may happen to your heart rate, blood pressure, and energy levels if you tried to exercise while fully submerged in cold water.

Answers may vary but students should hypothesize that the heart rate may change based on this experience.

Their heart rates and blood pressure should increase with activity since they may have experienced this during exercise where they are not holding their breath. Students should indicate that they may not be able to do so for very long because eventually their cells are going to run out of oxygen.

3. Use your textbook, if needed, to answer this question. **During cellular respiration, what substance builds up in the body when there is a lack of oxygen?** To demonstrate this, perform a wall sit. Stand against the wall, keeping your back flat against the wall. Lower yourself down and walk your feet out until your knees and quads are at a 90-degree angle. Hold that position for several minutes until you feel this substance building up in your quadriceps. This substance is building up due to a lack of free oxygen in your muscles.

Lactic acid or lactate.

Fermentation will begin, as the muscles are not oxygenated. Glycolysis, or anaerobic respiration, can supply energy to the cells when oxygen is not available. Fermentation allows glycolysis to continue to generate cellular energy in the form of ATP. As you may expect, fermentation cannot sustain the cell's energy for very long given the fact that eventually that fermentation can be quite painful if the muscles are not allowed to rest and re-oxygenate. That burning sensation in your legs is lactic acid building up in your muscles. Lactic acid

can be toxic; therefore fermentation cannot go on for long periods of time. The lactic acid must be cleared from the muscle tissue, which happens during aerobic respiration. This is a special adaptation that allows our muscles to perform intense activity in short bursts that requires recovery time.

ARTICLES:

- *Article: Why Does Lactic Acid Build up and Why Does it Cause Sore Muscles? http://www.scientificamerican.com/article/why-does-lactic-acid-buil/*
- *Research shows that Weddell seals can reduce their lactate buildup by performing short active dives, which are easier to recover from. http://sitkawhalefest.org/wordpress/wp-content/uploads/2013/12/paper.pdf*
- *This maximizes their cellular respiration.*

4. Marine mammals such as dolphins, whales, and seals can hold their breath for extended periods of time while exerting energy during hunting, mating, or migrating.

a. How does this impact their heart rate?

Answers may vary but students should hypothesize that the heart rate may change based on this experience.

The animals are holding their breath, which would lead to a decreased heart rate, but at the same time they are exercising, which would increase their heart rate. In order to overcome the drop in heart rate from holding their breath, the energetic activity increases their heart rate in order to deliver oxygen to the peripheral structures like the flipper and fluke.

ANATOMY EXTENSION:
Diving mammals have anatomical adaptations that allow them to perform these deep dives while holding their breath. You can compare these with humans in an extension activity.

Aortic bulb, high volume of blood, Vena cava, muscles near diaphragm to regulate deoxygenated blood flow to heart, increased hemoglobin and myoglobin

b. How might the fermentation stage of the Krebs cycle differ in marine mammals compared to humans?

Answers may vary depending on the student's background on the Krebs cycle.

Look for logical abilities of organisms that spend most of their time underwater:

- *ability to hold their breath*
- *lactic acid does not "bother" the marine mammals*
- *bigger muscles may help diffuse the lactic acid*
- *water pressure may have an impact*

BACKGROUND INFORMATION:
The Weddell seal and other seals are able to store more oxygen in their muscle tissue due to higher amounts of myoglobin, an oxygen storage protein. This allows them to hold their breath for longer periods of time without running low on oxygen needed for cellular respiration. In addition they are able to tolerate higher levels of lactic acid in their muscles, which does not get released into the bloodstream until the animal comes up for a breath. At this time, the aerobic respiration pathways clear the lactic acid through the liver and during the animal's recovery time.

POST-LAB QUESTIONS

1. **What happened to your heart rate when you held your breath out of water?**

   Students should observe that their rates decreased, but it may not be very drastic. If they did not, students should explain their results. Possible explanations: nervous/adrenaline, not holding breath long enough, improper heart rate measurement, resting heart rate was not truly resting.

2. **Was your result in #1 different when you held your breath underwater?**

   Students should observe that their rates decreased even more while submerged in the cold water. If they did not, students should explain their results. Possible explanations: nervous/adrenaline, not holding breath long enough, water temperature was not cold enough, improper heart rate measurement, resting heart rate was not truly resting.

3. **What variable changed and how did that impact your result?**

   The temperature around their face went from room temp or warmer to cold-water bath. In addition, their nostrils and mouth were submerged.

4. **On average, did the class data follow the same trend as your individual results? Explain.**

   The class data should follow the trends of individuals. If you have any students who are asthmatic or have recently moved from a high elevation, you may find their results to be different. It may be worth discussing with the students.

5. **Why is it better to use class data than just your information?**

   More data is always better to rule out outliers.

6. **What would the results have been if you were actively swimming while submerged?**

   Students should conclude that activity would deplete their stored oxygen more quickly and increase their heart rate. They may also add that lactic acid buildup may happen faster. Since humans do not have the exact same mechanism for clearing lactic acid buildup like Weddell seals, their bodies may become toxic rapidly.

7. **Hypothesize why the mammalian dive response is present in humans even though we do not live in aquatic environments as adults?**

   This is likely an artifact of early mammalian evolution. Being able to conserve oxygen stores is crucial to our survival. Individuals who could not maintain and utilize sufficient oxygen stores in their body would likely have perished. Cellular respiration mechanisms date back even further as detailed in the Endosymbiotic Theory when single-celled Eukaryotes enveloped prokaryotic organisms, which eventually became the mitochondria.