Science Unit: ***Living with Oxygen***

Lesson 2: ***Oxygen Consumers – Mammalian Diving Response***

School Year:	2012/2013
Developed for:	J.W. Sexsmith Elementary School, Vancouver School District
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Grade level:	Presented to grade 7; appropriate for grades 6 – 7 with age appropriate modifications
Duration of lesson:	1 hour and 20 minutes (2 hours is preferable)

Objectives

1. Reinforce the basic concepts of hypothesis-driven science.
2. Understand the body's need for oxygen and what affects the physiology of respiration.
3. Understand the physics of pressure and how this relates to the circulatory system.
4. Learn the basic physiology of the mammalian diving response.
5. Develop and test hypotheses on the mammalian diving response in humans.

Background Information

The mammalian diving response is a combination of physiological reflexes that occur when an animal initiates a dive. When an animal's face enters the water and respiration ceases, the heart rate slows down (bradycardia). Blood vessels supplying nonessential organs are constricted, redirecting blood to the oxygen-requiring brain and heart. When the heart supplies fewer organs with blood, it can beat more slowly and still maintain adequate blood pressure to the brain, the most metabolically sensitive organ.

Diving bradycardia is an easily measured component of a group of reflexes that together constitute the "diving response." This response to diving is observed in seals, penguins and whales, but also seen to a lesser degree in humans.

Vocabulary

Bradycardia:	A slower than normal heart rate. The heart usually beats between 60 and 100 times a minute in an adult at rest. If you have bradycardia (brad-e-KAHR-de-uh), your heart rate will be fewer than 60 times per minute.
Apnea:	Cessation of breathing.
Reflex:	An involuntary and nearly instantaneous movement in response to a stimulus.
Vasoconstriction:	The narrowing (constriction) of blood vessels by small muscles in their walls. When blood vessels constrict, blood flood is slowed or blocked.
Periphery:	The outermost part of the body or one of its organs or parts.
Hemoglobin:	An iron-containing protein in a red blood cell that binds and releases oxygen.
Myoglobin:	An iron-containing protein in muscle that binds and releases oxygen.
Hematocrit:	The percentage of blood that is made up of red blood cells.

Materials

- Omron automatic blood pressure/heart rate cuff (available at London Drugs, Shoppers Drug Mart, Safeway, etc)
- Plastic dish pans (~10 litres)
- Snorkel
- Bleach solution (5 ml bleach/L water for disinfecting snorkels and for the buckets)
- Bleach
- Towels
- Thermometers
- Tap water
- Ice

In the Classroom

Introductory Discussion

1. Last lesson, we talked about the importance of oxygen and how the respiratory system works. You came up with some hypotheses regarding the factors that would affect maximum breath hold ability.
    - Show the data from last week's lab and discuss the results.
    - What was the maximum breath hold ability observed in your class?
    - Can you guess what the maximum breath hold for a human is? (22 minutes, 22 seconds, June 5, 2012 – Tom Sietas).
    - What animal do you think has the record for the longest dive? (female Northern elephant seal). What do you think the duration of this dive was? (Longest recorded dive duration is 119 minutes in 1995; new data/record to be published in 2013/14).
    - What factors or features do you think contribute to the diving ability of a seal? (Higher hematocrit; large spleen to store more red blood cells, higher blood volume; more profound bradycardia; higher muscle myoglobin).
2. The mammalian diving response is a suite of events that occur when a mammal submerges in water. The two main stimuli that trigger the diving response are: apnea (cessation of breathing) and facial immersion (a combination of pressure, temperature and the sensation of water on the face – stimulates trigeminal nerve).
    - How would you test this response?
    - Would it be possible to separate out the effects of facial immersion from the response to breath hold? (Lead the students to identifying the experimental condition of 1) breath hold; 2) facial immersion alone (snorkel); 3) breath hold and facial immersion.
    - What other factors might change the diving response? (Stress – "fight of flight" response; temperature of water; position of body; training/acclimation, etc).
3. The experimental design.
    - Set up one station per four students.
    - Each station has a dishpan, thermometer, towels, snorkel, a beaker with disinfectant, bucket of crushed ice, and an Omron blood pressure cuff.
    - Have the students try to achieve a set temperature using the crushed ice (between 10 and 15˚C will provide a greater diving bradycardia than water at room temperature).
4. Describe the control condition where each student is seated with the left arm extended on the table, flat palm.

- Have the students measure blood pressure and heart rate in the control situation during a breath hold (no hyperventilation).
- Facial immersion without breathhold is performed in the same position (seated with left arm extended). The student is instructed to put their face in the water and BEGIN BREATHING through the snorkel (the immediate response will be to hold their breath, so emphasize that they must breathe). Once the student has begun to respire, the blood pressure measurement can be initiated.
- Facial immersion with breathhold is performed in the seated position with left arm extended. No snorkel is used and the student is required to hold their breath during the measurement. Some students will have difficulty maintaining a breathhold for the duration of the measurement. For consistency, instruct all students to "pre-load" the blood pressure cuff by initiating the measurement prior to the student placing their face in the water. The cuff takes approximately 10 seconds to inflate. Once inflated, the student can then be instructed to place their face in the water, thus reducing the required breathhold time.

5. Students are made aware that their participation is voluntary and if they have any concerns about facial immersion, they may opt to be a data recorder and not participate as a subject.

Science Experiment

Experiment Title: The mammalian diving response in humans.

Purpose of Experiment: To provide practical knowledge of experimental design and identify the components which contribute to the diving response.

Experimental Treatments: Control, facial immersion, facial immersion with breath hold.

Prediction or Hypothesis: Facial immersion will result in a greater bradycardia than breath hold alone. Facial immersion with breath hold will result in the greatest bradycardia. Blood pressure will increase in response to facial immersion.

Methods and Instructions:

All tests are conducted in the same posture: leaning over the lab bench with elbows resting on the lab bench and the head down.

- Students should work in groups of four. Each student takes a turn being the experimental subject.
- At the beginning of a test that requires holding the breath, students should take a deep but not maximal breath and then hold it. Students should not hyperventilate before holding their breath.
- Before conducting any test using water, students should measure the temperature of the water and adjust it by adding warm tap water or ice. Temperature should be 15°C for the initial simulated dive.
- For immersion tests, subjects should immerse the face up to the temples.
- Allow several minutes for heart rate to return to normal between tests.
- Ensure that the snorkels are rinsed in the bleach solution between subjects.
- Ensure that the basins are rinsed and disinfected between students.
- Test subjects will appreciate being tapped on the back every 10 s by the timer in order to keep track of time and remain calm during immersion.

Closure Discussion

What's happening: The two stimuli (apnea and facial immersion) provide feedback to the body in different ways. Why do you think humans have a diving response? Can you think of other environmental conditions where this response would be beneficial?

- Do you think you would show the same response if your body is immersed in water (think about walking into a pool or the ocean)?
- Do the variables provide an additive response (i.e., is the response to facial immersion and breathhold greater than the response of each single stimuli)?

References

Hiebert, Sara M, and Burch, Elliot. 2003. Simulated human diving and heart rate: Making the most of the diving response as a laboratory exercise. Adv Physiol Educ. Vol. 27, no. 3. 130-145.