Science Unit: *Living with Oxygen*
Lesson 1: *Experimental Design – Breath Hold Ability*

School Year:	2012/2013
Developed for:	J.W. Sexsmith Elementary School, Vancouver School District
Developed by:	Sheila Thornton (scientist); Duncan Kay and Danielle Conrad (teachers)
Grade level:	Presented to grade 7; appropriate for grades 6 – 7 with age appropriate modifications
Duration of lesson:	2 hours

Objectives

1. Review the concept of hypothesis-based science.
2. Understand the difference between continuous and discrete variables.
3. Explore the concepts of causation and correlation.
4. Learn the basic physiology of breathing and oxygen transfer.
5. Develop and test hypotheses on possible variables that affect breath hold ability.

Background Information

This is the first lesson in the unit, “Living with Oxygen”. This unit focuses on oxygen as the basis of life on Earth. In this lesson, we will explore the concept of hypothesis-based research and how we apply experimental design to explain and validate observations. We will examine the difference between correlation and causation, as well as define the different types of variables that we may encounter.

What is oxygen?

Oxygen is a chemical element with symbol O and atomic number 8. At standard temperature and pressure, two atoms of the element bind to form dioxygen, a colorless, odorless, tasteless gas with the formula O_2. This substance is an important part of the atmosphere, and is necessary to sustain most life. The atmosphere of Earth is a layer of gases that is retained by Earth's gravity, and is composed of ~20.95% oxygen, 78.05% nitrogen, and small amounts of other gases, including carbon dioxide (CO_2).

Why do we need oxygen?

Oxygen is a vital component of our metabolic pathway. Energy that is stored in the bonds of molecules (food) is transferred to an organism through a number of biochemical pathways. For the body to use this energy, it is transferred to a molecule called ATP (adenosine triphosphate). We call this the “universal currency” in the body (I ask the students to name different currencies used in other countries, and then use the analogy of going to a bank or currency exchange in order to transfer its value into Canadian dollars, so they are able to purchase items within Canada). Oxygen is the final step in this energy transfer process. Without oxygen, metabolic processes in the cells of most organisms will cease.

Physiology of breathing

In order to supply sufficient oxygen to meet the metabolic needs of an organism, the body extracts oxygen from the environment. In mammals, this is achieved via a process called **respiration**. See Human Anatomy – Lesson 3 and 4 for background information on circulation and respiration.

http://scientistinresidence.ca/science-lesson-plans/human-anatomy-how-do-we-move/.

We have a number of sensors and feedback mechanisms that ensure we maintain a constant supply of oxygen to the body. There are two main types of sensors: oxygen and carbon dioxide (CO_2) sensors. To ensure sufficient oxygen is maintained to the brain, CO_2 sensors located in the carotid arteries (the main artery to the brain) monitor the blood for CO_2 content. If a mammal's respiration is insufficient to clear out the CO_2, these sensors act as an early warning system and will initiate an increase in respiration to ensure that a decrease in oxygen does not occur.

Experimental Design

During the session, we will measure lung volume, body mass, breath hold ability and one other variable to be decided upon by the students (examples may include variables such as shoe size, birth month, eye colour, etc). If time allows, an additional experimental variable (hyperventilation prior to breath hold) may be added to illustrate the function of CO_2 sensors in the carotid arteries. Students will be provided with the data set at the end of the session and a lab report, including graphs of the relevant data, will be assigned.

Vocabulary

Word:	Brief definition
Hypothesis	(plural *hypotheses*) A proposed explanation for a phenomenon. For a hypothesis to be a **scientific hypothesis**, the scientific method requires that one can test it. Scientists generally base scientific hypotheses on previous observations that cannot satisfactorily be explained with the available scientific theories. A *scientific hypothesis* is a proposed explanation of a phenomenon that still has to be rigorously tested.
Correlation	A mutual relation of two or more things or variables. A correlation may be either positive (when the value of one variable increases, the value of the other variable increase), or negative (when the value of one variable increases, the value of the other variable decreases). For example*, Studies find a negative correlation between number of hours of TV per week and grades.*
Causation	The relationship between an event (the *cause*) and a second event (the *effect*), where the second event is understood as a consequence of the first. In common usage, causality is also the relationship between a set of factors (causes) and a phenomenon (the *effect*). Though the causes and effects are typically related to changes or events, they could also be objects, processes, properties, or other variables.
Variable	A term used to describe something that can be measured and can also vary. In scientific experiments, variables are used as a way to group the data together. Variables can be grouped as either discrete or continuous variables.
Discrete variable	Variables that can have only a certain number of different values between two given points. For example, in a family, there can be one, two, or three children, but there cannot be a continuous scale of 1.1, 1.5, or 1.75 children.
Continuous variable	Variables that can have an infinite number of different values between two given points. As shown above, there cannot be a continuous scale of children within a family. If height were being measured though, the variables would be continuous as there are an unlimited number of possibilities even if only looking at between 1 and 1.1 meters.
Metabolism	The sum of the chemical and physical changes occurring in tissue, consisting of **anabolism** (those reactions that convert small molecules into large), and

catabolism (those reactions that convert large molecules into small).

Spirometer — An apparatus used to measure the volume of air inspired (breathed in) and expired (breathed out) by the lungs.

Materials

- Stop watch/clock
- Tygon tubing (min ½" or 12 mm)
- Bathroom scale
- Clamp to hold tygon tubing to the side of aquarium
- A PVC hose adapter appropriately sized for the disposable mouthpieces
- Disposable mouthpieces (West Care Medical Ltd (604-540-8288 or other medical supply location)

- Aquarium (minimum 15 gallon/55 litre)
- Beaker (minimum 3 litre – plastic or glass container with graduated volume marks; may require a 5+ litre container for older students with a high lung volume)

In the Classroom

Introductory Discussion

1. Have the students stand up and on the count of three, JUMP in the air.
   - What would you say if I observed that, at the exact moment you landed, a 6.3 magnitude earthquake occurred in Peru (a country generally not known for its seismic events)? Is this correlation or causation? (Run a PowerPoint slide of a seismograph exactly when they land – simple method is an image of a seismograph, animated to appear with "wipe left, medium speed"; use two or three different images for repeats).
   - How would you test this?
   - How many times would you have to test this to accept or reject the hypothesis?
2. If you were a scientist testing this hypothesis, imagine what a graph of your data would look like.
   - Would these data be continuous or discrete?
   - Would you use a bar graph, scatter plot, pie chart?
3. Introduce the topic of oxygen and its role in life.
   - Provide information on the basic biochemistry
   - Discuss ATP and the universal currency analogy
   - Emphasize that this biochemical pathway is highly conserved between species
4. Work with students to develop an experimental design to explore relationships between breath hold ability and other variables.
   - Lead them to selection of body mass and lung volume as possible correlates

- Encourage them to suggest/hypothesize other variables that may be correlative/causative

5. Undertake an experiment to determine how maximum breath hold ability correlates with variables (body mass, lung volume, etc).
   - Set up three stations – breath hold, body mass, and lung volume – for students to collect data
   - Collate data at the end of the session for analysis

Science Activity/Experiment

Experiment Title: Factors that affect breath hold ability

Purpose of Experiment: To provide practical knowledge of experimental design, and to introduce the concept of oxygen consumption

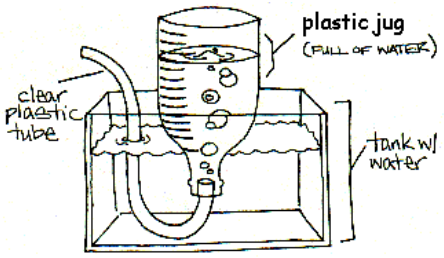
Experimental Variables: Maximum breath hold, body mass, lung capacity

Prediction or Hypothesis: Use your prior knowledge of lung function and the requirement for oxygen to predict what may correlate with breath hold ability.

Safety considerations: Students will be provided with a disposable mouthpiece for use with the spirometer. Each student will be given a number; all data collected will be associated with their number rather than their name. Students will be given the option as to whether they would like to participate as a subject for data collection. If hyperventilation is performed prior to maximum breath hold measurements, no more than three breaths should be taken in rapid succession. All breath hold and lung volume exercises are to be performed in the seated position.

Methods and Instructions:

STATION 1 – Lung Volume using a simple spirometer



1. Fill a ~15-20 gallon (60+ litre) aquarium with water.
2. Place an overturned container (minimum 3 litre) into the aquarium. Ensure the container has graduated markings indicating volume (mls).
3. Clamp a hose (1/2" tygon tubing) to the side of the aquarium. Fit a PVC connector to the end of the pipe.
4. Place the other end of the hose in the water underneath the overturned container.
5. Provide each student with a disposable mouthpiece (label with student's name). Have the student sit in front of the aquarium and place the disposable mouthpiece in the PVC connector.
6. Instruct the student to take a full breath of air, and exhale slowly and steadily into the hose until they are unable to exhale any further.

7. Hold down the overturned container and observe the maximum displacement (lung volume).

STATION 2 – Breath hold

1. Using a timer or a clock with a second hand and working in pairs, one student is instructed to take a full inhalation and the other student will begin timing. At the beginning of the expiration, student timing the breath hold shall make note of the end of the breath hold event, and record the time to the nearest second. The student should record 3 breath holds, and the average will be used during the data analysis.

2. If the experiment includes a hypothesis on oxygen/CO_2 sensors, the student will hyperventilate by taking three breaths in rapid succession prior to the breath hold measurement, and compare the average maximum breath hold values to the control (non-hyperventilation) data.

STATION 3 – Body mass

1. Using a standard bathroom scale, each student will weigh themselves and record their body mass. You can assign each student a number for use in gathering data and take the opportunity to discuss privacy issues and data collection. Ask permission to gather data from the students and emphasise that participation as a subject is voluntary.

Closure Discussion

What's happening at Station 1 (spirometer): When you blow the air out of your lungs into the tube, the air forces water out of the beaker. The amount of water that is forced out of the bottle is equal to the air that you exhale out of your lungs. This is called "displacement" – you displace a measurable amount (i.e., a volume) of water with a measurable amount (i.e., a volume) of air.

At Station 2: When you hyperventilate prior to breath hold, you clear the "dead space" (trachea) of accumulated CO_2, and reduce the stimulation to the carotid body chemoreceptors (CO_2 sensors). This should decrease the urge to breathe and increase the maximum breath hold time.

Some questions to ask the class:

1. Of the variables that we measured today, which ones are continuous and which ones are discrete?

2. Based on our earlier discussions, which variables do you anticipate will be correlated with breath hold ability? Will these correlations be positive or negative?

3. Given the results of today's experiment, what features might you expect to see in an animal that can undertake extensive breath hold events (for example, a diving seal)?

Resources

Online ordering of mouthpieces: http://www.vernier.com/products/accessories/spr-mp/

A good article on the process of experimental design:
http://www.longwood.edu/cleanva/images/sec6.designexperiment.pdf

Practical strategies for science classrooms and competitions. Cothron, J. H., Giese, R. N., & Rezba, R. J. (3rd Ed.). (2000). Dubuque, IA: Kendall/Hunt Publishing Company.