

Name: _____

Staying Warm in the Extreme: Metabolism of Baby Seals

Scenario: You have been hiking and wandered off the trail, and now you are lost! Immediately you reach for your phone, but you have no service. You look in your backpack to find you have a bottle of water, a chocolate protein bar, and a down jacket.

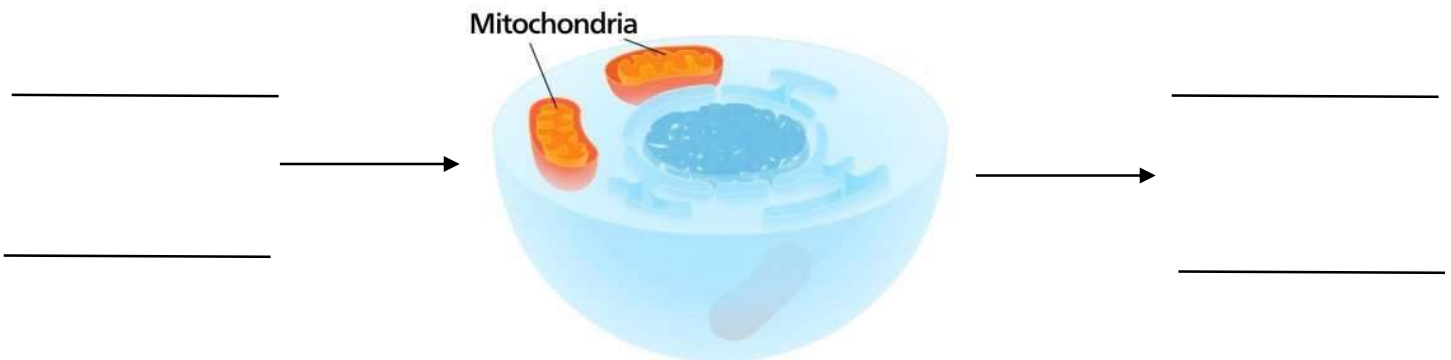


1. You are starting to get cold; the temperature is dropping below freezing. What item(s) do you use from your bag to stay warm and why?

Why do we need to stay warm?

Humans, along with other mammals and birds, are *homeotherms*, animals that maintain a constant body temperature; humans maintain a body temperature of 37°C (98.6°F). The term *homeostasis* means maintaining constant internal conditions, such as body temperature. If our bodies do not maintain homeostasis, our cells do not work properly, and things start to shut down (cells and eventually organs will die) if we don't correct it. Homeostasis works well in our bodies under normal conditions, but in extreme conditions we need to take action to make sure we can survive. When it comes to body temperature, the human body works like a thermostat that turns on the air conditioning when it's too hot or turns on the heater when it's too cold.

To aid in maintaining a stable body temperature, *endothermic* animals undergo the heat-producing reactions of *metabolism*. One of the chemical reactions of metabolism is *cellular respiration*, which breaks down glucose to generate heat. Using the word bank, label the reactants (going into the cell) and products (leaving the cell) in the process of cellular respiration in an animal cell: Glucose, Carbon Dioxide, Oxygen, Water (H₂O)



Scientists measure **metabolic rate** to understand how much energy an organism is using. One way to measure metabolic rate is to calculate the rate of cellular respiration,
 Glucose (C₆H₁₂O₆) + Oxygen (O₂) \longrightarrow Carbon dioxide (CO₂) + Water (H₂O) + HEAT + Energy.

- If you were a scientist and wanted to measure the metabolic rate of an organism, which do you think is the easiest molecule in the cellular respiration equation to measure: Glucose, Oxygen, Carbon Dioxide, or Water? Explain how you would measure it.

Though we don't have the equipment to measure your oxygen consumption in class, we can use **respiration rate** as a **proxy** for metabolic rate. When your metabolic rate increases, your respiration rate also increases to deliver oxygen to the body faster.

During exercise you use more energy, increasing your metabolic rate, and as a result you need to consume more oxygen. In this activity you will record data on your respiration rate before and after exercising, in Table 1 (below).

- Record the number of times you inhale for **60 seconds** while sitting still in your chair (at rest). Do **NOT** look at the timer during the 60 seconds, you may use a timer with a beeper or have a partner tell you when to begin and end counting.
- Repeat step 1 two additional times, and record the data in Table 1.
- Do 20 jumping jacks.
- Record the number of times you inhale for **60 seconds** while continuing to stand, immediately after you complete your jumping jacks. Do **NOT** look at the timer during the 60 seconds, you may use a timer with a beeper or have a partner tell you when to begin and end counting.
- Repeat steps 3 and 4 two additional times and record the data in Table 1.
- Calculate your mean number of inhales for both at rest and after exercise, and record those values in Table 1.

Table 1:

Trial Number	Number of inhales at rest	Number of inhales after exercise
1		
2		
3		
Mean (average of 3 trials)		

- Under which condition, at rest or after exercise, did you have a higher number of inhales?

4. Circle the correct terms to make the following a correct statement:

When organisms increase physical activity the amount of oxygen cells require increases, because the rate of cellular respiration **increases/decreases**. As the rate of cellular respiration **increases/decreases**, an organism's metabolic rate **increases/decreases**, and more heat is produced.

Weddell seals are the southernmost born mammals. They live in Antarctica, the coldest, driest continent on the planet. Weddell seals must survive in extreme weather conditions, including cold air temperatures and strong winds. Like humans, baby seals (pups) must maintain homeostasis with a body temperature around 37°C (98.6°F). Unlike humans, Weddell seal pups cannot put on a down jacket, eat a chocolate protein bar, or run around to stay warm. Instead, they have fur and blubber for insulation; they consume milk from their mom, which is really fatty (50% fat vs. 4% for whole cow's milk; heavy whipping cream is 30%); and they do not move around to stay warm, because they stay close to their mothers.

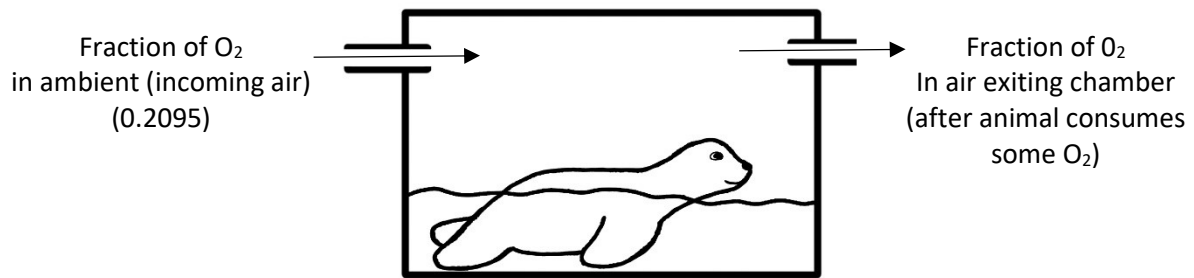
Starting at around 3 weeks old, Weddell seal pups start to face an additional extreme condition: they begin to learn to swim in not-quite-frozen ocean water, which is about -2.8°C (27°F ; note that seawater freezes at a colder temperature than freshwater). Scientists wondered which is more challenging for the pups to maintain homeostasis of body temperature, on top of the sea ice or in ocean water?

5. Do you think it requires more, less, or the same amount energy for Weddell seals to stay warm in ocean water (-2.8°C) compared to being on top of the ice, where temperatures can range from -40°C to $+10^{\circ}\text{C}$? Why?
6. Which additional variables do scientists need to control or account for to make sure they are only comparing the amount of energy being used by the seal pup in water versus air?

To determine if you were using more energy at rest or during exercise, you recorded your number of inhales, to reveal under which condition your body required more oxygen. To evaluate if Weddell seal pups were using more energy to stay warm in the water or air, the researchers also measured how much oxygen that the seals used. Instead of counting inhales, scientists used a device called a metabolic chamber.

The metabolic chamber is connected to sensors that record the following:

- The **flow rate** of air moving through chamber (500 L/min)
- Fraction of O₂ in ambient (incoming) air = 20.95% = 0.2095
(which is the same as the air around you!)
- Fraction of O₂ in air exiting chamber (after animal consumes some O₂)



Using the collected data, scientists can calculate the **oxygen consumption rate**, also referred to as **metabolic rate**, using the equation below:

$$\text{Metabolic Rate} = \text{Flow rate of air through chamber (500 L/min)} \times \left[\text{Fraction of O}_2 \text{ in ambient (incoming air) (0.2095)} - \text{Fraction of O}_2 \text{ In air exiting chamber (after animal consumes some O}_2\text{)} \right]$$

Below are the data scientists recorded for six 3-week-old Weddell seal pups. Using the equation above, you will be calculating their metabolic rates, both in and out of water, to determine if these pups use more energy to stay warm submerged in the cold ocean water or on the sea ice exposed to the Antarctic air.

Calculate the metabolic rate of the Weddell seal pups, using the equation above, when exposed to air. After you calculate the metabolic rate for each pup, calculate the mean metabolic rate.

Weddell Seal Pup	Fraction of O ₂ exiting Chamber	Calculated Metabolic Rate (L/min)
Mr. Goodbar	0.2085	
Twix	0.2081	
Smartie	0.2078	
Macaroni	0.2083	
King	0.2084	
Little Blue	0.2083	
Mean		

Calculate the metabolic rate of the Weddell seal pups, using the equation above, when submerged in water. After you calculate the metabolic rate for each pup, calculate the mean metabolic rate.

Weddell Seal Pup	Fraction of O ₂ exiting Chamber	Calculated Metabolic Rate
Mr. Goodbar	0.2080	
Twix	0.2080	
Smartie	0.2072	
Macaroni	0.2081	
King	0.2075	
Little Blue	0.2073	
Mean		

- In which condition, exposed to air or submerged in water, do Weddell seal pups have a higher metabolic rate? Use data as evidence to support your answer
- During this experiment you analyzed data of oxygen consumption because oxygen is required for cellular respiration, which is a chemical reaction of metabolism. Explain the pathway oxygen travels to get to cells to be used for cellular respiration.
- Returning back to the scenario at the beginning of the lab: How would eating a chocolate protein bar help you generate heat to stay warm?

Glossary:

Cellular Respiration – a set of reactions and processes in living cells, which convert chemical energy from oxygen and nutrients into other forms of energy

Endotherm – animal that uses its metabolism (internal energy) to maintain its body temperature (Mammals and birds are homeothermic endotherms.)

Flow Rate – movement of a fluid (air or water) per unit time

Homeostasis – maintaining constant internal conditions (**body temperature**, pH, water balance)

Homeotherm – animal that maintains ~constant body temperature

Metabolic Rate – energy expenditure per unit time in an organism

Metabolism – the sum of all chemical reactions in an organism

Oxygen Consumption Rate – the amount of oxygen (usually measured in liters or milliliters) an organism brings into its cells per unit time

Proxy – a measurement or process used in place of another

Rate – the measurement of something with respect to time elapsed

Respiration Rate – the rate at which breathing occurs, often measured as breaths per minute