hhmi | BioInteractive

Icefish Blood Adaptations: Viscosity

Activity
Educator Materials

OVERVIEW

This hands-on lab activity serves as an introduction to the BioInteractive short film *The Making of the Fittest: The Birth and Death of Genes*. It explores a key adaptation introduced in the film: the low blood viscosity of icefish. The lab serves primarily as an engagement exercise to motivate students into thinking about why viscosity might be an important adaptation before they watch a film that explains the process. For a similar activity exploring another adaptation from the film, see "Icefish Blood Adaptations: Antifreeze Proteins."

Most fish would freeze to death in the Southern Ocean around Antarctica, because the temperature of the water there (–1.8°C/28.8°F) is below the freezing point of their blood. However, icefish and all other notothenioids (a group containing many Antarctic fish species) have an "antifreeze" protein in their blood that prevents it from freezing. So, as other species of fish died off in Antarctic waters, notothenioids thrived and diversified.

In addition to having antifreeze proteins, icefish do not produce red blood cells or hemoglobin. As a result, their blood is less viscous and can flow easily even at very cold temperatures. However, having no hemoglobin greatly reduces the amount of oxygen that a given volume of blood can carry. Icefish compensate for their lack of hemoglobin with a variety of other adaptations, including a large heart, wide blood vessels, large gills, and no scales. These adaptations increase their blood flow and the amount of oxygen that diffuses into their blood.

In this activity, students create a model of icefish blood and explore its properties through a simple lab. The lab demonstrates that less viscous blood is easier to pump — a property that benefits icefish survival by increasing the flow of blood (and thus oxygen delivery) to tissues.

KEY CONCEPTS

- Traits may be advantageous, disadvantageous, or neutral. Changes in the environment where a population lives can affect which traits (and therefore genetic variations) are advantageous.
- Adaptations are not always “perfect” solutions, and some adaptations may also confer disadvantages.
- Blood’s viscosity affects the rate at which blood circulates throughout the body.

STUDENT LEARNING TARGETS

- Explain the importance of different adaptations (in particular, low blood viscosity) to the survival of icefish.
- Use models to make scientific claims based on evidence and reasoning.

CURRICULUM CONNECTIONS

Standards	Curriculum Connection
NGSS (2013)	HS-LS4-2, HS-LS4-4
AP Bio (2015)	1.A.1, SP1
IB Bio (2016)	5.2
AP Env Sci (2013)	II.C
Common Core (2010)	ELA.RST.9-12.3, WHST.9-12.9
Vision and Change (2009)	CC1, DP1

KEY TERMS

adaptation, evolution, hemoglobin, natural section, oxygen, red blood cell, trait, viscosity

TIME REQUIREMENTS

- One 50-minute class period is recommended for completing the lab and questions. Additional time may be needed if students watch the film in class.
- See TEACHING TIPS below for alternative strategies.

SUGGESTED AUDIENCE

- High School: Biology (General, AP/IB)
- College-level: Introductory Biology

PRIOR KNOWLEDGE

Students should know that:

- some traits are inherited
- traits can have positive, negative, or neutral effects on the fitness of an individual
- blood carries oxygen to tissues, which is essential to the survival of many animals

MATERIALS

For each group of students:

- 100 mL of corn syrup (i.e., Karo syrup)
- 100 mL of tap water
- two clear plastic cups or beakers
- two 60-mL syringes (without needles)
- felt-tipped marker

For the entire class:

- *The Making of the Fittest: The Birth and Death of Genes* video
- graduated cylinder

PROCEDURE

In this lab, you'll test two mystery solutions, A and B. One solution models the blood of a "normal" fish. The other solution models the blood of an icefish.

1. Get cups of solutions A and B from your teacher.
2. Using your marker, label one syringe "A" and the other syringe "B."
3. Fill syringe A with 40 mL of solution A, and syringe B with 40 mL of solution B.
4. Pick up one syringe in each hand. Hold syringe A over the cup for solution A, and syringe B over the cup for solution B.
5. Push both syringes at the same time, with the same force, until they are both empty. Observe how each solution responds to being pushed.
6. Repeat steps 3 through 5 until everybody in your group has had a turn.

TEACHING TIPS

- Have students work in groups of 2 to 4.
- To maximize class time, prepare solutions A and B ahead of time for each group of students.
    - For solution A (models "normal" fish blood), pour 100 mL of corn syrup into a cup. Label this cup "Solution A."

 - For solution B (models icefish blood), pour 100 mL of water into a cup. Label this cup “Solution B.”
- After students complete Questions 1 and 2, have them watch the short film *The Making of the Fittest: The Birth and Death of Genes* before doing Question 3. The film and Question 3 can be assigned as homework.
- Be on the lookout for the common misconception that natural selection gives organisms what they need and eliminates unneeded traits. Natural selection does not guarantee that organisms will get what they need. Natural selection only affects whether the traits already in a population become more or less common, based on how advantageous those traits are in the population’s environment.

ANSWER KEY

1. Describe how solutions A and B responded to being pushed. Was it easier or faster to push one solution than the other?

Solution B was easier and faster to push than solution A.

2. Solutions A and B differed in a property called viscosity.

   a. Define “viscosity” in your own words.

Viscosity is a fluid’s resistance to flow — how thick and sticky it is.

   b. Which solution, A or B, had a higher viscosity?

Solution A

   c. Remember that solutions A and B model different types of blood. Would the blood modeled by solution A or B be easier to pump through the body? Support your answer with evidence from your observations.

It was easier and faster to push the syringe with solution B, so the blood modeled by solution B would be easier to pump through the body.

   d. Make a guess about how blood viscosity is related to the ability to survive at very low temperatures.

Student answers may vary. Some students may guess that more viscous blood is less likely to freeze.

3. To learn more about icefish blood, watch the BioInteractive short film *The Making of the Fittest: The Birth and Death of Genes*. As you watch, pay attention to any mentions of adaptations involving blood viscosity. Use what you learn from the film to answer the questions below.

   a. How do red blood cells affect the viscosity of blood at cold temperatures?

Red blood cells make blood more viscous (thicker) when it's cold.

   b. Which would have a higher viscosity at cold temperatures, icefish blood or “normal” fish blood? Why?

"Normal" fish blood would have a higher viscosity. That's because it has many red blood cells, and icefish blood doesn't have any red blood cells.

   c. Make a claim about which solution, A or B, modeled blood from an icefish, and which modeled blood from a “normal” fish. Use the properties of the solutions and information from the film to provide evidence and reasoning for your claim.

Icefish blood is less viscous (more watery) than "normal" fish blood. Solution B was less viscous than solution A. So solution B modeled blood from an icefish, and solution A modeled blood from a "normal" fish.

   d. Explain how an icefish’s blood viscosity is an adaptation to the Antarctic environment.

Icefish blood is less viscous than the blood of other animals when it's cold, so it's easier to pump through the body. This is an adaptation because it makes it more likely for icefish to survive and reproduce in the Antarctic environment.

   e. Do you think this trait would be advantageous in a warmer environment? Justify your answer.

Probably not. In a warmer environment, blood can flow more easily even when it has red blood cells. So, having less viscous blood with no red blood cells wouldn't be as much of an advantage.

(Students with more chemistry background may also realize that the lack of red blood cells could become a disadvantage at warmer temperatures. Because icefish don't have red blood cells, they must absorb oxygen from the water through their skin. However, warmer water has lower concentrations of oxygen.)

4. "Normal" fish blood contains hemoglobin, but icefish blood does not.
   a. What is hemoglobin, and what is its function in the body?

Hemoglobin is a protein that delivers oxygen throughout the body.

   b. According to the film, how do icefish survive without hemoglobin?

Icefish absorb oxygen from the water through their scaleless skin.

   c. Icefish have other adaptations that were not mentioned in the film, including a large heart and wide blood vessels. Explain how these adaptations might help an icefish survive without hemoglobin.

A larger heart pumps more blood, and wider blood vessels let more blood flow through. These adaptations help blood circulate through the icefish's body more quickly. This makes it easier for the blood to deliver oxygen to cells, even without hemoglobin.

   d. Think about the model with solutions A and B that you tested earlier. Propose two modifications to this model to simulate the adaptations from 4c.

Student answers may vary. One modification could be using a bigger syringe B to model the larger icefish heart. Another modification could be connecting tubes to the syringes to model blood vessels; syringe B should get connected to a wider tube to model the wider icefish blood vessels.

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