

## HOW NOVEL ICEFISH GENES CAN IMPROVE HUMAN HEALTH

### OVERVIEW

This lesson serves as an extension to the Howard Hughes Medical Institute's short film *The Making of the Fittest: The Birth and Death of Genes* (<http://www.hhmi.org/biointeractive/making-fittest-birth-and-death-genes>). It also requires students to read and process detailed scientific information about two common human diseases that share some physiological similarities with certain icefish adaptations. It asks students to relate how studying the genetics of these icefish adaptations could help find treatments or cures for common human diseases.

### KEY CONCEPTS AND LEARNING OBJECTIVES

- Changes in the environment where a population lives can change which traits (and therefore genes) are favorable.
- The frequency of an allele in a population can change depending on whether the allele is advantageous, deleterious, or neutral.

Students will be able to

- consider different adaptations and propose explanations for why they arose.

### CURRICULUM CONNECTIONS

Curriculum	Standards
NGSS (April 2013)	HS-LS2-6, HS-LS4-2, HS-LS4-4, HS-LS4-5 HS.LS1.A, HS.LS2.C, HS.LS4.B, HS.LS4.C
Common Core (2010)	ELA-Literacy.RST.9-10.1, ELA-Literacy.RH.9-10.4, ELA-Literacy.RST.9-10.9, ELA-Literacy.RH.9-10.1, ELA-Literacy.W.9-10.1, ELA-Literacy.W.9-10.2, ELA-Literacy.W.9-10.7, ELA-Literacy.RST.11-12.4, ELA-Literacy.RST.11-12.8, ELA-Literacy.RST.11-12.9, ELA-Literacy.W.11-12.4, ELA-Literacy.W.11-12.7, ELA-Literacy.W.11-12.8
AP Biology (2012–13)	1.A.1, 1.A.2, 3.A.1, 3.C.1, 4.C.1
IB Biology (2009)	4.1, 4.3, 5.4, 6.2, 7.5

### KEY TERMS

evolution, mutation, natural selection, trait, variation

### TIME REQUIREMENTS

This lesson was designed to be completed within one 50-minute class period; the extension activity will require one or two additional class periods.

### SUGGESTED AUDIENCE

This lesson is appropriate for high school biology (all levels including AP and IB) and introductory college biology.

### PRIOR KNOWLEDGE

Students should know that traits can be inherited and that some traits provide organisms with a greater chance to survive and reproduce. They should know that specific genes code for the production of specific proteins and that mutations of these genes can have a positive, neutral, or negative impact on an individual's survival.



## *The Making of the Fittest: The Birth and Death of Genes*

HHMI  
BioInteractive.org  
**LESSON  
TEACHER MATERIALS**

### TEACHING TIPS

- Remind students that icefish are members of the Notothenioidei suborder. All notothenioids produce a protein that functions like antifreeze. Icefish, however, are unique among notothenioids in that they lack hemoglobin and red blood cells.
- Students should watch the short film before answering questions.
- You may want to show the film more than once, because after students start working on the questions, they might benefit from watching the film again.
- The extension activity asks students to complete an essay framework graphic organizer designed to help them learn to organize their work when given a writing assignment. This activity helps meet the literacy requirements addressed in the Common Core State Standards. Internet access or access to reference materials is required for research.

### ANSWER KEY

#### PROCEDURE STEP 1

As you watch the short film *The Making of the Fittest: The Birth and Death of Genes*, list the icefish adaptations below.

**The adaptations students may list include big jaw and many teeth, no scales, no red blood cells, watery blood, no hemoglobin, antifreeze proteins, and large gills.**

#### QUESTIONS

1. From the list of adaptations you recorded during the film in Step 1, (a) name the icefish traits that would be of direct interest to researchers investigating anemia in humans and (b) explain how each trait is related to anemia.

**a. Traits of interest are lack of hemoglobin and lack of red blood cells.**

**b. Red blood cells contain hemoglobin. They transport oxygen to the cells. Without an adequate number of red blood cells, oxygen transport is inadequate and the individual is diagnosed as being anemic. Another cause of anemia is too little hemoglobin. Hemoglobin is what makes it possible for red blood cells to transport oxygen. Consequently, even if the red blood cell count is sufficient, without adequate hemoglobin, the amount of oxygen transported to the cells is inadequate. A person with low hemoglobin is also diagnosed as being anemic.**

2. Below is a chart of icefish adaptations that the film does not mention. Using your knowledge of anatomy and physiology, place a check mark on the line in front of the three adaptations that most directly play a role in assuring that icefish tissues receive an adequate amount of oxygen.

**The three adaptations are large heart, large volume of blood, and wide blood vessels.**

3. Write a paragraph that explains how the adaptations you selected enable icefish tissues to receive an adequate amount of oxygen. **Possible explanations in the student paragraph may include but are not limited to the following:**

- Icefish have a large heart that is able to pump a large volume of blood with each beat.
- Fish of the same size but different species have a smaller volume of blood than icefish do. The icefish's greater blood volume allows more oxygen-rich blood to circulate and bring oxygen to the cells.
- There is less resistance to blood flow in wider blood vessels than in narrower vessels. With less resistance, the blood can reach the tissues more readily, with less energy consumed, and can deliver an adequate supply of oxygen.

4. Explain how understanding the evolution of the demineralization of the icefish skeleton might help scientists find an effective treatment or cure for osteoporosis. **Possible explanations may include but are not limited to the following:**

- Studying icefish should reveal more about the molecular and genetic aspects of bone loss in humans.
- Scientists can compare the genomes of closely related fish species to find out how the icefish genome changed as its bones lost minerals.

# The Making of the Fittest: The Birth and Death of Genes

- **The same or similar genes may regulate bone loss in humans. Whatever triggers the timing of demineralization in the icefish may also trigger the onset of bone loss in humans.**
- **If scientists learn to manipulate these genetic pathways in icefish, they may be able to apply this knowledge to humans.**

## EXTENSION ACTIVITY

You may wish to use the essay-outlining extension activity with your students. The framework provides students with a template that makes it easier for them to organize material for an essay. It also helps focus their research.

## Essay Framework

Essay Component	Description
Title	<i>"Icefish as Model Organisms"</i>
Proposal	<i>Antarctic icefish have evolved a unique set of adaptations, several associated with serious health problems in humans. A study of the icefish genome would provide information that scientists could use to understand and treat human disease.</i>
Definition of the model organism	<b>Model organisms are nonhuman, and scientists can use them to study specific biological events in humans, such as disease.</b>
Four examples of icefish adaptations and their associated human diseases	<b>No red blood cells/hemoglobin ... anemias Large heart or low blood pressure ... circulatory disorders Demineralized skeleton ... osteoporosis Abundance of lipids (fat deposits) ... lipid storage disorders Antifreeze gene ... perhaps heat or cold tolerance; thermal regulation</b>
Two examples of how the birth and death of genes are associated with the evolution of these adaptations	<b>The gene responsible for the production of hemoglobin has mutated and is no longer functional. This gene has died. The gene responsible for the production of antifreeze in icefish is the result of an existing gene being duplicated and mutations accumulating in the copy. The mutated gene produced a new protein.</b>
What scientists say about using the icefish as a model organism (provide three examples along with appropriate references).	<b>Students should check for articles that support this statement.</b>
Conclusion	<b>Students should provide a reasonable conclusion in support of the proposal stated above.</b>

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## FIELD TESTERS

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