Mountains in the Sea Exploration

It's a Roughy Life

Focus
Physiological adaptations in deep-sea fishes

Grade Level
9-12 (Life Science/Chemistry)

Focus Question
How do physiological differences among groups of deep-sea fishes reflect different strategies for surviving in the deep-sea environment?

Learning Objectives
Students will be able to make inferences about aspects of the natural history of deep-sea fishes based upon information about the biochemical composition of different fish species.

Students will be able to discuss the significance of anaerobic respiration, and describe circumstances under which the capacity for anaerobic respiration would be advantageous

Materials
- ❒ Blackboard, overhead projector, or marker board
- ❒ Copies of "Body Composition and Biochemical Data on Benthopelagic, Benthic, and Seamount-Associated Fishes," one for each student

Audio/Visual Materials
None

Teaching Time
One 45-minute class period

Seating Arrangement
Classroom style, or groups of 4 - 5 students

Maximum Number of Students
30

Key Words
Seamount
New England Seamounts
Bathypelagic
Benthopelagic
Benthic
Orange roughy
Anaerobic metabolism
Aerobic metabolism
ATP
Lactic acid

Background Information
Seamounts (also called "guyots") are undersea mountains that rise from the ocean floor, often with heights of 3,000 m (10,000 ft) or more. Compared to the surrounding ocean waters, seamounts have high biological productivity, and provide habitats for a variety of plant, animal, and microbial species. Seamounts are formed by volcanic processes, either as isolated peaks or as chains that may be thousands of miles long. In the Atlantic Ocean, the New England Seamounts form a chain of more than 30 peaks that begins near the coast of New England and extends 1,600 km to the southeast. Some of the peaks are more than 4,000 m above the deep-sea floor, similar to the heights of major peaks in the Alps.

Bear Seamount is the closest of the New England Seamounts to the coast of the United States, and rises from a depth of 2,000 - 3,000 m to a summit that is 1,100 m below the sea surface. Previous investigations have found numerous invertebrates, including cephalopods, crustaceans, and more than a hundred other species in 10 different phyla. These investigations also found more than 100 species of fishes, some of which are commercially important. Several species discovered at Bear Seamount were previously unknown to science.

Deep-sea fishes can be loosely categorized as bathypelagic (fishes that live in deep water and do not typically associate with the sea floor), benthopelagic (fishes that live in deep water near the sea floor), or benthic (fishes that live on the sea floor). Exploration of seamounts has led to the recognition of a fourth group of "seamount-associated" fishes that live near the seamount surface but are morphologically and biochemically different from other bathypelagic fishes.

Many deep-sea fishes (such as the sea dragon and anglerfish) look very strange when compared to fish species from shallower waters. Often, they appear to be mostly mouth and teeth, with eel- or blob-like shapes and greatly reduced fins. The metabolism of these fishes is only ten percent or less of shallow-water species. Because deep-water fish species often have much less muscle and bone tissue, fat and protein in their tissues is greatly reduced and their flesh has a watery consistency. These features are probably adaptations to scarcity of food in the deep-sea environment. Because deep-sea fishes live in almost total darkness, the ability to swim in strong rapid bursts is less advantageous than in shallower waters where predators can visually locate prey species. Reducing the capacity for rapid swimming in deep water fishes therefore would not make these fishes much more vulnerable to predators. Reduced swimming capacity, though, would greatly reduce food requirements because rapid swimming requires lots of muscles, and muscles require lots of energy, and that energy has to come from food consumed by the fish.

Deep-water fishes are not generally considered to be commercially important because the lack of protein and watery flesh makes them unattractive as food for humans. In the 1980's, however, fishermen discovered large populations of a very different type of deep-water fish living between depths of 700 - 1,200 m. These fishes had firm, tasty flesh and high content of protein and lipids. Moreover, these fishes occurred in large aggregations around seamounts and plateaus near Australia and New Zealand. One of these fishes, the orange roughy (*Hoplostethus atlanticus*), is now common in North American markets.

In this lesson, students will research some characteristics of benthopelagic, benthic, and seamount-associated fishes, and will use their research to make inferences about the life-history strategies of these species.

Learning Procedure

1. Explain that seamounts are the remains of underwater volcanoes, and that they are islands of productivity compared to the surrounding environment. Although seamounts have not been extensively explored, expeditions to seamounts often report many species that are new to science and many that appear to be endemic to a particular group of seamounts.

2. Be sure students are familiar with the function of anaerobic and aerobic metabolism, and the distinctions between them. Both processes provide the energy to power muscle contractions that produce locomotion. This energy is provided in the form of adenosine triphosphate (ATP). In aerobic metabolism, carbohydrates, fats, and/or proteins react with oxygen to release the energy stored in the chemical bonds of these substances and transfer that energy to ATP molecules. In anaerobic metabolism, ATP molecules are formed by

the release of energy in the chemical bonds of carbohydrates (but not fats or proteins) through chemical reactions that do not involve oxygen. A by-product of anaerobic metabolism is lactic acid, which builds up in muscle tissues, impairs further contractions, and produces physical discomfort or pain.

Aerobic metabolism is used by muscle cells until the cardiovascular system can no longer provide adequate oxygen. At this point, anaerobic metabolism takes over and continues to provide ATP until lactic acid buildup prevents further muscle contractions. Once exercise is reduced or stopped, aerobic processes take over again, and excess lactic acid is metabolized by liver and muscle cells. Anaerobic respiration is particularly important to animals that periodically require intense exertion (such as in fishes that must chase their food or swim rapidly to avoid being food for something else).

3. Have each student group examine data in the table titled "Body Composition and Biochemical Data on Benthopelagic, Benthic, and Seamount-associated Fishes," and make inferences about the life history habits of each species based on these data. Students should recognize that species with higher energy densities, higher levels of LDH, and/or higher respiratory rates probably engage in intense muscular activity more frequently than species that do not share these characteristics. The seamount-associated species has a respiratory rate that is more than 20 times that of the other species, reflecting the need for these fishes to deal with strong and variable currents in the vicinity of seamounts.

4. Have students visit http://www.fishbase.org, to obtain additional information about one or more of these species to add to their inferences based on biochemical data.

5. Have each group present and discuss their inferences, reasoning, research data and conclusions.

The BRIDGE Connection

www.vims.edu/bridge/ - In the Navigation toolbar, click on "Ocean Science Topics." In the "Ocean Science Topics" menu, click on "Biology," then on "Bony Fishes."

The "Me" Connection

Have students describe the relative importance of aerobic and anaerobic metabolism in their own lives, and describe circumstances under which their muscles have obtained energy through anaerobic pathways. Have students describe how their bodies felt when they were making intensive use of anaerobic pathways, and provide physiological or biochemical explanations for these feelings.

Connections to Other Subjects

Language Arts, Chemistry

Evaluation

Have students prepare written reports prior to group discussions in Step #5.

Extensions

Have students visit http://oceanexplorer.noaa.gov to find out more about the New England Seamount Expedition.

Resources

http://www.fishbase.org - a searchable database of life history information on more than 24,000 fish species.

Koslow, J. A. 1996. Energetic and life-history patterns of deep-sea benthic, benthopelagic, and seamount-associated fish. Journal of Fish Biology, pp. 54-74. The journal article on which this activity is based.

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science

- Chemical reactions

Content Standard C: Life Science

- Matter, energy, and organization in living systems

For More Information

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Student Handout

Body Composition and Biochemical Data on
Benthopelagic, Benthic, and Seamount-Associated Fishes

Species (1)	% Water	% Protein	% Lipid	Energy Density (2)	LDH (3)	Respiration (4)
Sebastolobus altivelis (Bn)	81	15	4	1.20	25	0.0027
Coryphaenoides acrolepis (Bp	83	16	0	0.91	154	0.0024
Coryphaenoides armatus (Bp)	83	17	0	0.97	53.1	0.0032
Coryphaenoides carapinus (Bn)	85	12	3	0.94	4.7	-
Hoplostethus atlanticus (SA)	76	13	10	1.67	79	0.07

(1) Bp = Benthopelagic; Bn = Benthic; SA = Seamount-associated
(2) Energy available from lipids and proteins in fish tissues (kcal per gram wet weight)
(3) Lactate dehydrogenase, an enzyme involved in anaerobic respiration
(4) Oxygen consumption (ml per gram body weight per hour)