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ANTARCTIC ADAPTATIONS

Overview

This lesson focuses on adaptations as a driving force in evolutionary diversity. Adaptations are characteristics within a species that enhance its chances of survival and reproduction. Adaptations can be behavioral, structural, or functional. Students must understand that these adaptations are not acquired in the course of the organism's lifetime, but are inherited traits that have been passed down from those that survive and live to reproduce. Their beneficial aspects depend on the organism's environment. What is beneficial in one environment may be disastrous and selected out in another environment. Organisms that live in the Antarctic region have a wide range of adaptations that allow them to survive in extremely harsh conditions. By the same token, not all inherited traits are adaptations to a particular environment/climate. In studying specific organisms, students can identify and investigate these inherited traits. This activity will help students develop an understanding that adaptations arise through evolution and lead to the rich diversity in nature. This lesson focuses on evolution and homeostasis and can easily be incorporated into either concept. Teachers can also incorporate the role of mutations that aid in survival as well. Because this lesson involves pictures and descriptions of animals that often intrigue students, this lesson can stand on its own as well but it is preferable if students have some knowledge of evolution, natural selection, and adaptations. This is meant for high school students but can easily be modified for any level of learner.

Objectives

- Students will examine a wide array of adaptations that may be physical, structural, or functional.
- Students can compare/contrast inherited traits that

Materials

- Multiple sets of organism sheets
- Antarctic Fact Sheets
- (Ideally these sheets should be xeroxed on colored paper and laminated for reuse.)

are adaptations and those that are not adaptations.

- Students will gain a deeper understanding of homeostatic responses and related anatomical structures that allow survival in a polar region.
- Students will read about how Antarctic animals are very specifically adapted for life in the extreme cold.
- Students will broaden their understanding about marine life in Antarctica.

Beginning Question

How do specific adaptations increase the potential for survival?

Lesson Preparation

There is minimal preparation for this activity. Xerox the Organism sheets and Antarctic Animal Fact sheets. Divide the class into groups by animal or as a mixed group (see description below.) You may want to prep the students with a discussion on polar climates to gauge prior knowledge and to give them a foundation as they begin this activity.

This can be a one day activity or it can be stretched out over more than one class to allow students to do further research.

Procedure

This lesson is a good group activity and can be done in a couple different ways.

1. Jigsaw: Put all the students studying the penguin together to become penguin experts, all the whale experts together, etc. Then have students reassemble in groups where each animal is represented and the experts must teach the group about his/her animal. Each group should create a display or poster board for their presentation. Note: You may want to have each student use a different color marker to better monitor participation by the each member of the group.
2. Mixed Groups: Students can work in the same group throughout the activity. Give a full set of animals to each group. Have the students read each animal separately or as a group out loud to each other and, as a team, discuss each animal. Again, it is useful for students to create a visual representation of what they are learning, how the animals differ or overlap.

Post Lesson Activity

After the lesson you may want to watch the video link provided. It is an excellent 13 minute piece on the Antarctic icefishes and should be used after the lesson. To show this before the lesson may preempt student discussion and evaluation about adaptations in general and the icefish example in particular.

<https://www.hhmi.org/biointeractive/making-fittest-birth-and-death-genes>

Extension

An extension of this lesson could include some research on the impact of global warming in the Western Antarctic Peninsula and how this may affect the organisms featured in this lesson. You could also have students choose another environment and investigate environmental specific adaptations thus allowing them to compare and contrast adaptations in a wide range of environments.

End Product

Ideas for assessments:

- Poster displays are one form of assessment and nice to put up in the room or hallways.
- Can students identify if a trait or structure is an adaptation to environment or not? What inherited characteristics are not adaptations?
- Give students other animals or adaptations and have them link them to particular climates or habitats.
- Extrapolate changes in adaptations as climates warm.
- List which type of adaptation it is – structural, behavioral, functional.
- Discuss what it is about adaptation that make it so beneficial in the particular environment. Compare to other environments – would it continue to be beneficial? Neutral? Harmful?

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This lesson was adapted and modified from the BSCS biology curriculum

Standards

Next Generation Science Standards (NGSS):

Any of these can be incorporated depending on the way you want to carry out the lesson.

- HS-LS4-2. Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
- HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations.
- HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

Illinois and National:

- 11.A.4c Collect, organize and analyze data accurately and precisely.
- 12.B.4a Describe processes by which organisms change over time using evidence from comparative anatomy and physiology, embryology, the fossil record, genetics and biochemistry.
- 12.A.4c Compare physical, ecological and behavioral factors that influence interactions and interdependence of organisms.

CRS:

- 20-23 Select a simple hypothesis, prediction, or conclusion that is supported by a data presentation or a model
- Identify key issues or assumptions in a model

Antarctic Icefish

Scientific name: *Chaenocephalus aceratus*

C. aceratus are found only in the Southern Ocean.

The majority of Notothenioids (fish in the sub order notothenioidae) live at seawater temperatures between of -2°C and 4°C , but some sub-polar species inhabit waters that may be as warm as 10°C . They can be found near Bouvet Island, Scotia Sea and the northern Antarctic Peninsula. They inhabit depths between 16 ft/5m to 2500ft/770m deep. Their maximum length is about 28in/70cm and maximum weight can reach up to 8lbs./3.7kg.



These fish have no swim bladder, an internal gas filled organ that helps fish to maintain buoyancy. Hence, they are demersal (living near the bottom of the sea). Icefish feed on fish and krill. They have very large heads, spoon shaped lower jaws and large toothy mouths. Larger fish, fur seals and gentoo penguins are predators of the icefish.

Icefish have evolved a variety of interesting physiological and biochemical adaptations that either permit survival in, or are possible only because of, the generally cold, stable seawater temperatures of the Southern Ocean. They are unique among vertebrates (animals with a backbone) in that they lack hemoglobin – red blood cells. Hemoglobin is usually used to transport oxygen around the body, but in these fish, oxygen is transported in the blood plasma. They have white blood. This lack of hemoglobin is believed to be a result of a mutation about 5 million years ago. This mutation neither helped them, nor hurt them because of the high oxygen content of the cold waters of the Southern Ocean. The oxygen is absorbed and distributed directly by the plasma. These fish must expend twice as much energy in cardiac output per second than the notothenioids with higher hemoglobin concentration. They contain a much greater number of mitochondria in their cells. Mitochondria is the organelle in the cell that processes oxygen and uses it to generate energy in the form of ATP. In addition, icefish have no scales, which is thought to help promote oxygen uptake through the skin.



Ice fish blood in vial is white



Compare the ice fish (white-blooded) gills to the red-blooded fish.

Southern Elephant Seal

Scientific name: *Mirounga leonine*



Southern elephant seals are the largest of all seals. Males can be over 20 feet (6 meters) long and weigh up to 8,800 pounds (4,000 kilograms). Like fur seals, they show a strong sexual dimorphism (difference in size between the males and females), females grow to about 2.8m (9ft) and 900kg (2000lb). Southern elephant seals live in the brutally cold sub-Antarctic and Antarctic waters but are rich in the fish, squid, and other marine foods these seals enjoy. Southern elephant seals breed on land but spend

their winters in the frigid Antarctic waters near the Antarctic pack ice.

Their powerful sleek bodies are encased in blubber and taper down into a tail. Blubber helps insulate seals in polar conditions. In response to the cold Antarctic temperatures, a seal's blood vessels constrict and cut off the warm blood sent to skin that touches the ice surface. That means a seal's skin gets very cold (close to freezing). This fridge-friendly feature means that the seal's blubber can insulate the animal's internal organs without fighting to keep the exposed skin warm. All the energy is used to protect the seal's critical parts and pieces, like its heart and brain.

They have loosely interlocked vertebrae which make them flexible enough to surf the waves and navigate ice and rocky shores. Seals have slits for nostrils that naturally close under water – and they shut even tighter with increased water pressure. They can hold their breath for up to two hours and can dive up to a mile down into the water. Instead of fighting the intense pressure at increased depths they let their lungs completely collapse. They store the oxygen in their blood and muscles and expel the air. Seals have more blood than land animals of a similar size, plus more hemoglobin to carry oxygen.

Seals have flattened corneas and pupils that can open wide to let in light while swimming. Unlike land animals, a seal's eyes consist only of rods (sensory cells) that work great in low light, plus they don't have cones (other sensory cells) to detect color.

Some seals get their fill of water by eating fish with low salt content. For those with diets higher in salt, they rely on their kidneys, which act like natural desalinization machines! They can extract fresh water from salt water as well as urinate high concentrations of salt. Elephant seals were aggressively hunted for their oil, and their numbers were once reduced to the brink of extinction. Fortunately, populations have rebounded under legal protections.

Gentoo Penguins

Scientific name: *Pygoscelis papua*

Gentoo penguins are about 30 to 35 inches (75 to 95 centimeters) tall and generally weigh around about



13 pounds (6 kilograms). Krill is their primary food source as are small fish. They feed at sea but breed on the mainland. Their short overlapping feathers, rounded bodies, small extremities and an ability to store a layer of fat under their skin for insulation serve as a defense against the cold. They also huddle closely together when it is extremely cold.

Penguin wings are paddlelike flippers used for swimming. The motion of the flippers resembles the wing movements of flying birds, giving penguins the appearance of

flying through water. The wing and breast muscles are well developed, to propel penguins through water. Having solid, dense bones helps penguins overcome buoyancy.

Although it is more energy efficient for penguins to swim under water than at the water's surface, they must come to the surface to breathe. Many species of penguin *porpoise* - leap in and out of the water, like dolphins or porpoises. When porpoising, penguins can continue breathing without interrupting forward momentum. They maintain a steady speed of 7 to 10 kph (4.3-6.2 mph). Porpoising also may confuse underwater predators.

Like marine mammals, during deep dives, the penguin heart rate slows and the temperatures of a penguin's peripheral areas (limbs and skin) drop during a dive while those of the core regions (heart, deep veins, and pectoral muscle) are maintained at the normal temperature.

Penguins have glands under the eyes that help rid the body of excess salt. The secretion of salt and fluid often collect as droplets on the bill and are shaken off. These glands are so effective that penguins can drink sea water without ill effects. Feathers provide waterproofing critical to penguins' survival in water that may be as cold as -2.2°C (28°F) in the Antarctic. Tufts of down on feather shafts trap air. This layer of air provides 80% to 84% of the thermal insulation for penguins. The layer of trapped air is compressed during dives and can dissipate after prolonged diving. Penguins rearrange their feathers by preening. The dark plumage of a penguin's dorsal surface absorbs heat from the sun, which increases body temperature.

A penguin's circulatory system adjusts to conserve or release body heat to maintain body temperature. To conserve heat, blood flowing to the flippers and legs transfers its heat to blood returning to the heart. This *countercurrent heat exchange* helps ensure that heat remains in the body. If the body becomes too warm, blood vessels in the skin dilate, bringing heat from within the body to the surface, where it is dissipated.

Humpback Whale

Scientific name: *Megaptera novaeangliae*

Adult males measure 40-48 feet (12.2-14.6 m), adult females measure 45-50 feet (13.7-15.2 m). They weigh 25 to 40 tons (22,680-36,287 kg). They are a dark bluish color and their skin has many little bumps on it which is how it got its name.

Humpback whales feed on krill, small shrimp-like crustaceans, and various kinds of small fish. Each whale eats up to 1.5 tons (1,361 kg) of food a day. During feeding, large volumes of water and food can be taken into the mouth because the pleated grooves in the throat expand. As the mouth closes water is expelled through the baleen plates, which trap the food on the inside near the tongue to be swallowed.



Humpbacks are powerful swimmers, and they use their massive tail fin, called a fluke (see the picture to the left), to propel themselves through the water and sometimes completely out of it. These whales, like others, regularly leap from the water, landing with a tremendous splash. Scientists aren't sure if this breaching behavior serves some purpose, such as cleaning pests from the whale's skin, or whether whales simply do it for fun.

Whales are mammals. This means they are warm blooded and must regulate their temperatures to help stay warm in the cold Antarctic waters of the Southern Ocean. A couple of adaptations that have helped deal with this problem include a fatty layer of blubber under their very thick skin and reducing the amount of blood going to areas in contact with the cold water.

Once way to escape predators and search for food is to dive deep down into the sea. They are able to dive very deep into the water without the side effect called “the bends” because as they descend they exhale instead of inhale like we do. They expel air from their lungs, and therefore do not absorb excess nitrogen. Other adaptations to marine living include: a slower heartbeat during dives, reduced blood flow to non-vital organs, unusually high hemoglobin count in blood, and an unusually high myoglobin count in muscles. Hemoglobin and myoglobin carry oxygen that is needed by the animal.

Because their feeding, mating, and calving grounds are close to shore and because they are slow swimmers, the humpback whales were an easy target for early whalers. The International Whaling Commission (IWC) gave them worldwide protection status in 1966.

Octopus

Scientific name: *Pareledone turqueti*

P. turqueti is a species of benthic octopus with a circumpolar Antarctic distribution. They are invertebrates in the cephalopod class. This species has a wide depth range, occurring from shallow waters to 4,000 m deep. They can grow up to 15cm in mantle length (which does not include the long tentacles) and have very smooth skin covered by low granular bumps. They have two eyes and 8 arms that are covered with strong suction cups which help get a strong grip on their prey. They feed on fish, mollusks and other cephalopods and polychaetes (type of marine worm). Octopuses are venomous. They



usually inject their prey with paralyzing saliva before dismembering it into small pieces with their beaks. They are preyed upon by seals and large Patagonian toothfish.

Octopuses have very keen sense of touch and excellent eye sight, however they are color blind. Their main sensory organs are their eyes. Their retinas and optic lobes are highly developed. An octopus has an amazingly complex brain which allows it to think, learn, and problem solve. Because

they have no skeleton, they are vulnerable to predators. This also means they can squeeze into just about any size of crevice or hole to hide or to live. An octopus can escape prey through jet propulsion. Water is shot out of the mantle cavity very fast through the siphon. This allows the octopus to get quick bursts of speed to elude predators or catch prey. It can release a cloud of ink into the water. The ink sac is only used if the octopus feels threatened. The octopus can contract muscles around the ink sac releasing the black substance behind it, temporarily blinding their enemy or obscuring the vision of its potential predator.

Octopuses have special skin cells that allow them to change colors. This helps them camouflage themselves or help to scare off potential predators. They can blend in both by changing color but also by allowing their skin to take on the appearance of different textures as well. It is thought that one function of these special skin cells is to serve as a means of communication between octopuses.

Octopuses are not warm-blooded animals, yet the speed with which their nerves transmit signals depends on temperature. Those living in cold water use slightly different proteins than octopuses living in tropical waters, even though the proteins of both begin with the same gene. Antarctic octopods also have a specialized blue pigment in the blood that allows them to survive temperatures that often drop below freezing. This respiratory pigment in their blood is called hemocyanin and has the effect of making the octopods' blood blue. Hemocyanin contains copper, which is the responsible ion for binding oxygen. Hemoglobins contain iron instead, which gives our blood a red color.

Suggested Vocabulary Words

You may want to create a vocab list ahead of time. You can give them a list with the definitions already prepared or students can look them up on their own. Depending on age range you might have students try to figure them out in the context of use. Some of these words are defined in the text as they show up.

Benthic
Buoyancy
Crustacean
Demersal
Desalinization
Dissipate
Dorsal
Encase
Hemocyanin
Hemoglobin
Mantle (of octopus)
Mitochondria
Myoglobin
Notothenioid
Pectoral
Plumage
Polychaete
Preening
Sexual Dimorphism
Swim Bladder
Venomous
Whale Fluke