Curriculum Units by Fellows of the National Initiative
2012 Volume VI: Asking Questions in Biology: Discovery versus Knowledge

Understanding Evolutionary Biology through Physical Adaptations in Insects

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Introduction

The natural world is my passion, and as a teacher, sharing it with my students is my gift to them. I spent summers backpacking for a week at a time with my family beginning at the early age of three months. I spent time swimming in lakes, reading books in the hammock, and gathering kindling for the evening's fire that would keep us warm. I learned to appreciate the red thimbleberries that grew in the dark forests. I remember learning about birds that also liked eating these berries, and how this helped the berry-bushes reproduce because the birds scattered seeds in the forest. I learned many valuable life lessons in the great outdoors, and I always felt a renewed appreciation for the basics of food, water, and shelter.

Many students are curious and respectful of nature. Some collect pill bugs and other small insects in plastic bottles to examine and share them with classmates; maybe these students will become future entomologists. But other students smash the life out of insects, and I will never forget the day that I euthanized a mealworm that had a small hole poked in it from a student's pencil. I want students to respect all life-forms, and to understand how they continually evolve in response to the environment. By grasping this idea, I believe that they will gain a better appreciation for the environment, all living creatures, and themselves.

Life science teaching for my second grade students has included raising mealworms and plants, and learning about adaptations as structures that have a purpose. While this is a good starting place for life sciences in the second grade it has always seemed simplistic to me. Adaptations indicate that an organism has changed in some way to better match its environment. If an organism has changed, what was there before the change arose? This unit is about answering two essential questions: How do organisms adapt? And why do organisms adapt? I will teach my students about evolution through observations, comparisons and games so that they better understand how adaptations cause organisms to differ from one another, and how this explains the biodiversity of life.

Objectives

In this unit, students will understand evolution by learning that 1) traits that improve a species match to their environment will be selected and passed onto their offspring, 2) traits that improve the fit to the environment are called adaptations, 3) adaptations arise from already existing material, and 4) all of life evolved.

To help clarify the often misunderstood topic of evolutionary biology, the background of this unit includes information about natural selection, a process which explains how and why adaptation occurs. I also explain what speciation is, and how it explains how different species arise. While speciation is not taught in my unit, I think it is important for teachers to understand and you may choose to foreshadow the idea for learners in your class who may be ready to grasp this concept. The fossil record is invaluable to the study of evolution and so I will also include this in my background information. *Why Evolution is True* by Jerry A. Coyne is an excellent book that is clearly written and includes diagrams and photographs of the fossil record.

While much of the emphasis in teaching focuses on getting the "right answers" this unit will value curiosity and questioning as essential for creating the next science literate generation. Stuart Firestein writes in his book *Ignorance How it Drives Science*, "Too much emphasis on the answers and too little attention to the questions have produced a warped view of science. And this is a pity, because it is the questions that make science such a fun game." Students will sketch, label, and write about what they notice and what they wonder. Asking questions is one of eight essential elements of the K-12 science and engineering curriculum from the new Framework for K-12 Science Education.

Students will compare and contrast the dragonfly from the order of Odonata with the house fly from the order of Diptera. I will guide the students in understanding how a physical adaptation arises from already existing material by focusing on two adaptations in these insects: the mouthparts and wings. Students will build a model of the dragonfly's mouthparts and the fly's proboscis. Building models is an essential practice for K-12 science and engineering curriculum in the new Framework for K-12 Science Education. All models are good for teaching some things but not others, and we will discuss how models help scientists think about the natural world. Students will participate in a game that shows how adaptations that are beneficial will increase in a population and thus learn about natural selection.

Background

Observing

Observing the natural world is the work of a scientist. As technology has improved, so have the observations that scientists make. Satellites, telescopes, and microscopes have all helped scientists observe our world and beyond. Richard P. Feynman writes that ". . . observation is the ultimate and final judge of the truth of an idea [1] ." Galileo recorded his observations using the help of a telescope to view the sun, moon, and planets, and concluded from his observations that the earth was not in the center of the universe, but rather the planets revolve around the sun.

Evolution

Age of the Earth and Early Life on Earth

Our earth and solar system are 4.6 billion years old. The first forms of life we know about are the prokaryotes which include archaea such as methanogens, and bacteria such as cyanobacteria (blue-green algae). Prokaryotes ruled the planet for 3.4 billion years, beginning one billion years after the earth's formation! These microbes are the most ancient life-forms that scientists have discovered.

The Fossil Record

The evidence contained in the fossil record led Darwin to observe that evolution had occurred in the past. While the fossil record was and still is incomplete, Darwin noticed that ancient fossils looked very different from modern species. He also noticed that the youngest fossils looked more similar to modern species. Fossils that were closer together in the fossil record were more similar and fossils that were further apart were less similar.

The majority of the fossils scientists discover come from the life that lived in our oceans and lakes. This is due to the way that fossils form in water with layers of sediments forming on top of the organism. This fossilization process must happen quickly before the dead organism becomes lunch for another creature, or simply rots away. Few plant or mammal fossils are discovered due to the necessity of water and the layering of sediments. Soft parts of plants and animals don't fossilize easily, so less is known about fragile organisms, like worms or jellyfish. Much more is known about species that have teeth and bones such as fish, and organisms with hard exoskeletons such as insects.

Geologists first began the work of finding, excavating and organizing fossils. Many fossils were found during canal excavations in England during the Industrial Age [2] . Geologists developed a system of ordering the fossils based on the similarities in the strata in different locations. While this made it possible to roughly estimate the age of the fossils, it was not an exact measurement. With the invention of measuring radioisotopes in igneous rock, exact dating became possible. If the fossil is not embedded in igneous rock, the layer or igneous rock closest to the fossil is measured and the age of the fossil is estimated.

Cells

Cells tie all living organisms together. Living organisms include animals and plants. Our cells contain DNA, which carries genetic information to future generations. DNA stands for deoxyribonucleic acid. DNA molecules are made up of nucleotides and these nucleotides are translated into proteins. The DNA in each human cell is split up into 46 chromosomes: 23 from the female and 23 from the male. This means that we receive 100% of our genetic information from the beings that made us, all things being fair 50% from each. Unless we have an identical twin, no one else possesses the exact same genetic material. This also means that we are more similar genetically to our parents and siblings because we share some of the same genetic information. Succeeding generations continue this same pattern and therefore genetic similarity diminishes. In the second generation, the offspring would share only 25% of the genes with the original progenitors. Within four or five generations there would be very little match between the original genes and the DNA of the offspring.

Natural Selection: Microevolution

Because most individuals in a population vary genetically from one another, variations exist within populations. Individual variation affects the ability to survive and reproduce in an environment. Those members of a species that are better adapted to their environment will have increased survival and/or reproductive rates, and through time these individuals will leave more offspring (fitness). Therefore, the genes responsible for specific adaptations, or traits that improve the match of an organisms to its environment, will be over-represented in the gene pools of future generations. This process of evolution is called natural selection.

When individuals within a species evolve new physical adaptations such as teeth or eyes, it can take hundreds, thousands, or even millions of generations, but natural selection can also happen more rapidly [3] .

An example of natural selection in action comes from the medium ground finches living on the island of Daphne Major in the Galapagos. Medium ground finches feed on small soft seeds. In 1977, there was a drought and 85% of the individuals in this bird species died, because the drought caused no regrowth of plants that provided the small seeds on which the birds fed. Another food source was available, large seeds with a tough outer husk. Some of the finches began eating the larger seeds. It took great time and effort to eat these larger seeds and those who were unable to get enough food died. Most finches had a high mortality rate compared to the fewer large birds that happened to have the advantage of more powerful muscles and larger beaks. Those finches that had the slightly larger beaks and were thus successful in eating the larger seeds became more numerous. The drought caused natural selection to now favor larger beak size in medium ground finches. For this reason, beak depth in 1975 was about 9.5mm whereas in 1979, two years after the drought, it was about 10mm [4] . Larger beak size in medium sized finches is an example of an adaptation that leads to better survival and reproductive rates.

Another example is microbes such as viruses, which can evolve very rapidly because they experience large numbers of generations each day. A person who has received a flu vaccination at the beginning of a flu season may not find themselves protected from the flu. The explanation is that the influenza virus that is used to create the flu vaccine for immunization is chosen roughly a year before the flu season actually occurs, allowing enough time to create sufficient vaccine stocks to immunize large numbers of people. However, in this time period of a year the flu virus population can easily evolve to change, such that the flu vaccine is largely ineffective in protecting the public from the newly evolved virus strain.

Speciation: Macroevolution

Speciation is responsible for the great diversity of species in our nature. While natural selection tells us how populations of a species evolve, it does not tell us how different species arose. Estimations of species both living and extinct are between 17 million and 4 billion [5] . One definition of species is a group of organisms that can reproduce sexually and therefore belong to the same gene pool. (This definition does not work for the many species that reproduce asexually, like bacteria.) For example, humans belong to the same species called *Homo sapiens*. Although many differences exist in our outward appearances, humans can interbreed, which means we share the same gene pool and exist in the same species. Speciation happens when a species splits into two distinct species and they can no longer interbreed. The theory of geographic speciation says that in order for new species to arise they must have been geographically isolated, but this isolation can be a small distance. When species are geographically isolated they adapt through natural selection to their local environments. The environment of an organism might change or shift with droughts, continental drift, glaciers spreading, or mountains rising. Birds may eat from particular plants and drop them into new areas very different from the one where the bird originally ate them. Some species may wander far from their original homes and colonize new places. Today in our modern world species may be separated by highways or dams. These physically isolated populations of a species may develop new traits, such as different mating habits; thus, they may no longer recognize members of the original population as the same species and will no longer mate with them. Examples are changing preferences for where and when they may adapt to mate. Insects may choose to mate on a particular plant or when to mate such as a particular season. These processes will cause populations to only mate within their own gene pool, and eventually the two populations can become distinct species. However, different species may retain the ability to mate if they are not too distantly related, and may thus produce an offspring called a hybrid. One example is the offspring of a female horse and a male donkey which is a sterile hybrid called the mule. Some hybrids develop to adulthood but are sterile, whereas others may die prematurely and never reach adulthood.

Artificial Selection

Not all forms of life on earth are the result of natural selection. Humans are responsible for changing traits in some organisms because we have bred them through artificial selection, to possess certain traits we find valuable to us. Many examples are from domesticated animals such as dogs that are more docile than wolves, and plants that yield more fruit than their wild relatives. The great variety of dog breeds we see today are the result of humans choosing which traits they should possess, because we chose which male and female dogs should breed to create the desired traits in successive generations. Similarly, the varieties of colors and designs we see in many garden flowers are often the result of human tinkering. Genetically modified foods are the result of humans artificially selecting traits, and literally moving the DNA responsible for these traits into other plants. Problems with artificial selection arise because humans are choosing the trait(s), as opposed to the environment making the demand on the organism, which may not make an organism better suited to its environment. This can lead to organisms which lack resistance to disease, because we inadvertently removed these genes during the breeding and domestication processes.

Flies

Flies as Research Subjects

There are many reasons that various types of flies make excellent research subjects. First, depending on how you obtain your flies, the cost is cheap or even free. Flies are abundant in my backyard and kitchen, allowing them to be easily caught for week long observations in the classroom. The cost of feeding flies is very low since they consume very little food. Flies are small and therefore you can house many flies in a limited space. There are not restrictions to experimentation on flies like there are on humans or other mammals. Flies are easy to dispose of when they die compared with other specimens. People who are animal rights activists have less of a problem with experimentation on insects than they do with other animals. The main disadvantage of researching flies is that they can escape and can carry and spread bacteria to human food and make humans sick.

Drosophila melanogaster (fruit fly) from the Diptera order has been used since the early 1900s in genetic research studies. Flies reproduce quickly and in great quantities and scientists can study many generations of flies over short periods of time. Although very distantly related, flies and humans have many similarities which makes great research subjects. Sharmila Bhattacharya from NASA states that, "61% of known human disease genes have a recognizable match in the genetic code of fruit flies and 50% of fly protein sequences have mammalian analogues [6] ." It is amazing to think about how similar we are to the fly and yet the fly holds a low status in many people's minds.

Diptera and Odonata Adaptations Compared and Contrasted

The common house fly, sometimes referred to as "true fly," and the dragonfly both come from insect group. They share many similarities and some differences which make them perfect for learning how insects adapt to their environments. Dragonflies are from the order Odonata and are sometimes referred to as primitive flies because they have changed little over time. True flies are from the order Diptera and have more recently adapted in many environments.

In the Devonian period, 400-350 million years ago, the first spiders and primitive insects appeared. These first insects were wingless. The first winged insects were seen at the end of the Devonian. Odonata were first seen in the Permian period, which occurred 290-251 million years ago. Diptera were first seen in the Triassic period, which occurred 251-205 million years ago [7] . Insects make up 56% of all described species on Earth! In contrast, it is interesting to note that vertebrates make up only 2.7% of all described species [8] . 2.7% is a very small percentage!

Wings

Both flies and dragonflies have a thorax which includes the wings and three pairs of segmented legs. The dragonfly has two pairs of wings and the fly has one set of wings and structures called halteres. The true fly's halteres are an example of an adaptation that has evolved over time. Students will be able to see and compare this adaptation to primitive flies. Marc J. Klowden writes, "The evolutionary trend in insects has been towards a reduction in wing size and number" [9] . Primitive insects have two sets of wings. They flap these wing sets independently and at slightly different rates. The first set of wings, called the forewings, creates turbulence in the hind wings. Flying takes a large amount of energy and adaptations have evolved that make flying insects a better fit in their environments. Some species adapted and couple the wings sets, so that both sets flap at the same time. Other species, such as the true flies have eliminated the hind wings altogether, and instead evolved two knoblike appendages called halteres. The halteres help the fly to steer and balance. At the base of the halteres are hundreds of sensory organs called sensilla. The sensilla send information via nerve signals directly to the neurons that control the flight muscles. The halteres are an example of adaptive evolution, and they are also an example of how adaptations arise from already existing traits and structures (hind wings of primitive flies). Wings are such a successful adaptation, that only 0.06% of insects are wingless [10] .

The dragonfly and the house fly have different-sized wings. The dragonfly has larger wings than the fly. This means that the fly must beat its wings faster than the dragonfly because smaller size equals faster wing beats. The fly must use more energy to beat its wings and therefore this is an energetically expensive adaptation. Also, the fly can fold their wings vertically along their thorax while resting, unlike the dragonfly which cannot do so. If a dragonfly gets too hot while resting, it will raise its tail straight up in the air. In this position the dragonfly body absorbs less of the sun's rays and thus helps it regulate body temperature.

A lesson for teaching about the wings is not included, but I recommend teaching about the wings after fly observations and the building of the models of the dragonfly mouth in Lesson One and the house fly proboscis in Lesson Two. I will draw a simple line drawing of the dragonfly in front of my students, and they will help add labels to the diagram (See figure 2). Students will use their own observations of the fly and see the difference in the number of wings present in both insects. My goal for this lesson will be for students to see that the halteres of the house fly are an adaptation created from the material that was present in the second set of wings of primitive flies (See figure 1).

Figure 1

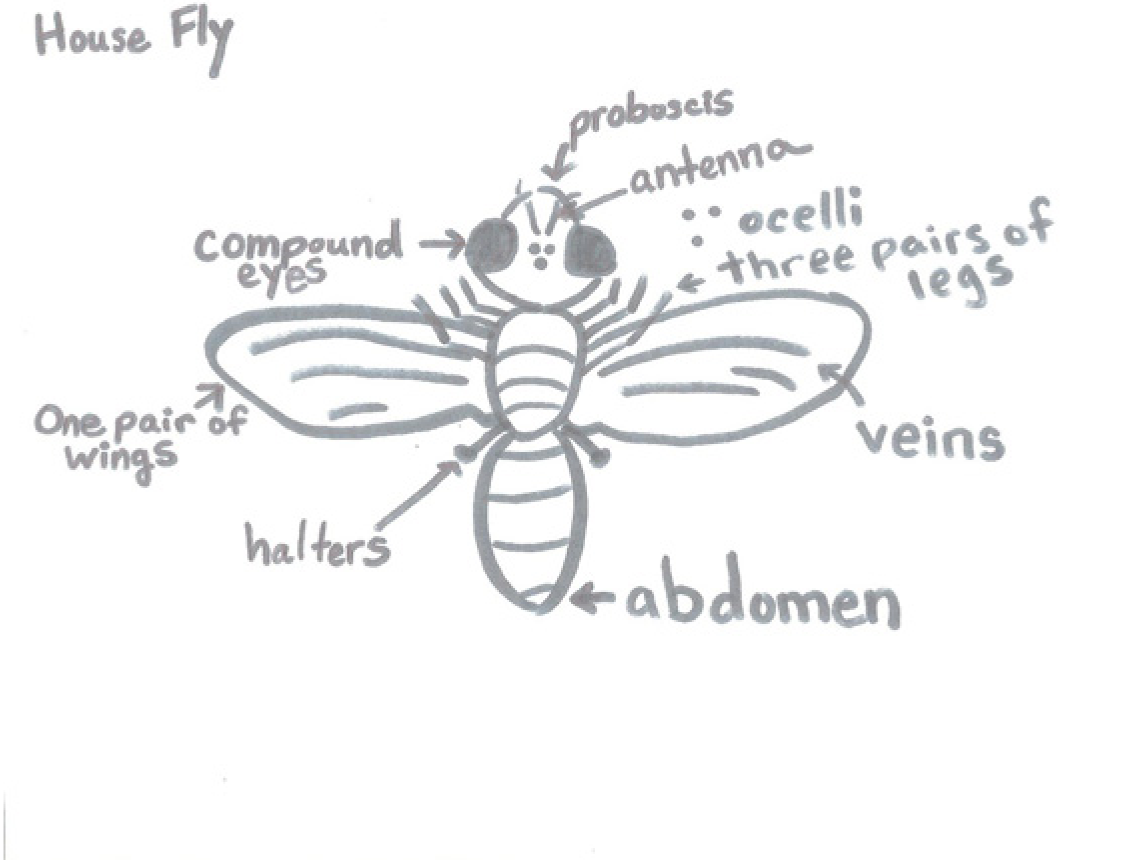

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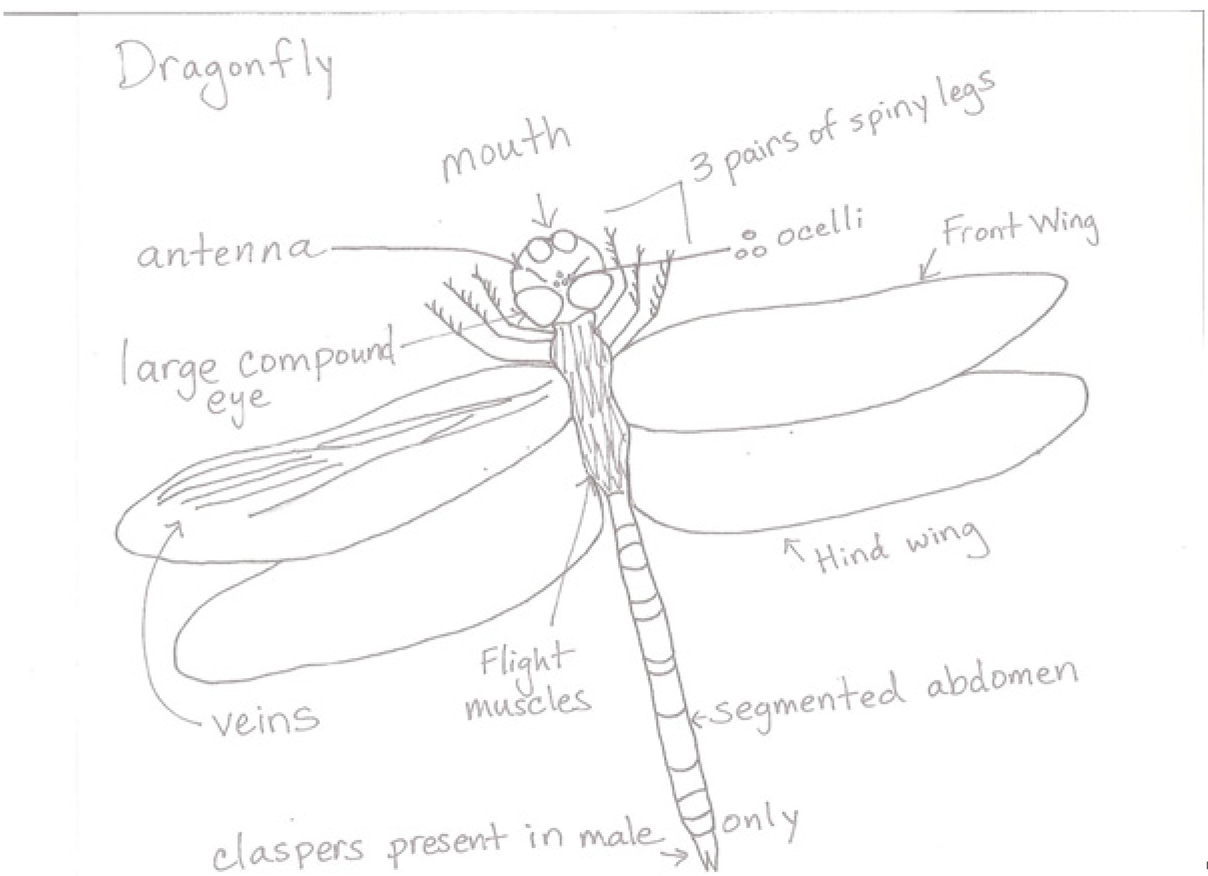
Figure 2



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Feeding

The dragonfly has a complex mouth structure that includes a bottom lip called the labium and an upper lip called the labrum. The palps are a sensory organ involved with taste. There are two sets of jaws which move laterally. The first set is called the mandibles and they are responsible for the chewing, tearing, and cutting of food. The second set of jaws, called the maxillae, include sensory palps like the labium.

The dragonfly has many adaptations that make it an excellent hunter. Dragonflies locate their prey mainly by using their large compound eyes to locate prey. The dragonfly's legs are covered in spines and they use their spiny legs like a basket to catch food and can even eat while flying! The dragonfly hunts for a wide variety of insects including mosquitoes, flies, bees, butterflies, and moths and they may even eat smaller dragonflies. They can fly for miles in search of food and can fly backwards, forwards, up and down, and hover in mid-air. The dragonfly can turn quickly in the length of its own body.

The fly has a proboscis which contains tubes that deliver saliva to solid food and break it down into a liquid, so the fly can easily ingest the liquid as food. The proboscis has little resemblance to the dragonfly mouth. The labium, or bottom lip was the material for the proboscis. The proboscis is retracted when the fly is not eating. The fly eats nectar from flowers, rotting food, meat, fruits, vegetables and feces.

Young Feeding Habits of Nymphs and Larvae

The nymph is the second stage of a dragonfly's life cycle. The nymph eats insects, minnows, tadpoles, and mosquito larvae with the help of a folding lip that is made up of two hinged pieces with sharp palps or pincers. This folding lip is half the size of the young nymph and can be shot forward "in a matter of milliseconds to seize prey which, for larger nymphs, may include frogs and even small fish [11] ." The palps help the young dragonfly nymph to catch prey quickly. The nymph lives in the water for three months to six years and breathes through gills in the end of the abdomen. The folding lip of the nymph dissolves and fuses together and becomes the labium of the dragonfly's mouth.

At the second stage of life flies are called larvae and they are also referred to as maggots. Larvae are often pale and wormlike and eat with mandibles. Often eggs are laid in or near a food source, such as a decaying animal. See Visual Resources for a video of a dead rabbit being eaten by larvae. The mussel shell I found outside my home had a small piece of decaying meat in which a female fly laid her eggs. The larvae feed on different food sources than adults and therefore the larvae and adult fly do not compete for the same food resources. This difference helps larger numbers of young to develop to an age of maturity where they can reproduce and continue the cycle of life.

Size

One characteristic of insects is that they are small, which has its costs and benefits. Insects can live in a great variety of ecological niches compared to larger organisms. For example, an oak tree can support hundreds of different insect species [12] . Their small size, along with their light rigid exoskeleton, allows insects to be blown around with decreased incidence of being seriously hurt. The reason for this is that insects have a larger surface area compared to their volume. Objects that have greater mass will fall faster than those with lighter mass, due to a difference in air resistance. The larger surface area creates some issues for the insect in terms of regulating temperature, however it is more difficult for insects to stay cool and it takes lots of energy to stay warm. Insects take advantage of microclimates within their environment to regulate their temperature. To stay cool in hot environments insects will take shelter underground, under rocks or near plants and trees where shade creates more tolerable conditions. Some insects in hot desserts have adapted long legs and run quickly to escape the heat radiating from the earth beneath them. Dragonflies will glide using their large wings to stay cool while flying. Insects can also cool off by bringing increased haemolymph (body fluid of insects, analogous to blood in humans) into their abdomens. To warm up before flying, insects will beat their wings.

Larger insects than those present today have been found in the fossil record. 300 million years ago some species in the Odonata had a one meter wing span. While most insects today are small, it doesn't mean that they will always remain that way. Natural selection could favor larger insects in the future.

Exoskeletons Versus Interior Skeletons

Insects possess a rigid exoskeleton made of chitinous cuticle covered with hair. The cuticle has many layers. The bottom layer is the epidermis, followed by layers of cuticle that get progressively stronger because the proteins become denser at the upper layers of cuticle. The very top layer, called epicuticle, is hard and has wax in it which helps insects retain water inside of their bodies, which have a tendency to get too warm. The epicuticle does not form in areas of the insect's body where flexibility is needed, like in joints and jaws. I will include this information as students build the dragonfly mask.

In contrast, it is helpful to think about vertebrates who have a boney skeleton and skin. We are able to feel because our skin allows us to feel sensations. We can feel the wind and the rain. The fly has chitinous cuticle which is hard, therefore it would be unable to sense or feel its environment without the help of hair which serves a sensory function. My students will experiment by blocking the sensation of wind coming from a fan in the classroom with a plastic or cardboard shield on the arm/face to see why the hair on the fly is such an important adaptation that all insects have in common.

Compound Eye and Ocelli

All insects have eyes that are made of individual light receptors called ommatidia. The more ommatidia an insect has the better that insect's visual acuity. The dragon fly may have more than 10,000 ommatidia [13] . A Libellula dragonfly has 30,000 ommatidia. A housefly may have 4,000 ommatidia [14] . Some ants may have only one or two ommatidia. In addition to the compound eye, both the housefly and dragonfly have three ocelli that are simple eyes that detect light. The fly and dragonfly feed during the day when there is light. Some night insects have a greater ability to be sensitive to light. All orders of insects have color vision [15] . I plan to build a model of the compound eye with my students. Under Resources, see Stephanie Bailey's page from the University of Kentucky's Department of Entomology for ideas about how to build a compound eye.

Fecundity

The ability for organisms to reproduce is what keeps the species going. Insects typically have a great ability to reproduce rapidly. Houseflies lay 100-150 eggs at a time. Housefly eggs are laid in a food source and the estimates of the numbers of eggs laid in one lifetime are 500 to 1,000. See Visual Resources for a video of a fly emerging from their pupa stage, which is the third stage of their life cycle. The dragonfly lays hundreds to thousands of eggs, usually on or near plants in water. Please see Visual Resources for a fantastic video that shows the process of the dragonfly's life cycle.

Benefits of Insects

The presence of dragonflies near freshwater is often a sign that the environment is healthy. Instead of using pesticides to treat the water in some tropical areas, nymphs are placed in the water to eat mosquito larvae. Fly larvae are decomposers and they clean up dead organisms, both large and small.

Strategies

Biology Picture Walk

A picture walk is a fun and interactive way to introduce students to a new topic of study. It does take time to build a picture file for specific topics, but the bonus is they can be used year after year. You can collect pictures of all kinds of animals and plants from sources such as National Geographic magazine. You can also collect physical examples, such as plants, shells, and plastic figures. Arrange the pictures on poster sized paper. While the students look at the pictures and physical objects they will write observations, thoughts, and questions on the Post-it notes and stick them to the poster. I emphasize placing the Post-it notes beside the pictures, rather than on top, so others can see the pictures. I discuss what to do when an area is crowded and how to move onto another poster and return later. I invite the students to go on an observation walk for about 15 minutes. Come together and share thinking. Share with students that biology is the study of life. "Bio" is the root word for "life." A biologist is a scientist who studies living things. There are many specialty scientists and for this unit I will discuss that an entomologist is a scientist who studies insects. I plan on inviting an entomologist or entomology PhD student from a local university to visit my classroom.

Informational Posters

I will copy Figures 1 and 2 onto transparencies and then project them onto a large paper. I will trace the images lightly in pencil. To assist students in learning the different parts of the body, I will trace each part of the body in a different colored marker and label the body parts. In small groups the students will create their own posters of figures 1 and 2.

Assessment

Pre-assessment and post assessment will be the same. I will give students a blank piece of paper and one with lines or any formatted paper students use for writing. Ask students to draw and write about what they know about flies and dragonflies. I will be looking for evidence that students understand about the different adaptations of the mouthparts and the wings present in the dragonfly and house fly. I will continue to reinforce learning about natural selection. Noticing the variety that exists within a species is an important concept and one that can be easily reinforced by observing insects and plants.

Key Vocabulary

Antennae: a sensory organ in insects involved in an insect's ability to smell its food.

Abdomen: the last section of the insect's body and the place where digestion and reproduction take place.

Compound Eye: An eye made up off many hexagonal shaped lenses.

Cuticle: the hard exoskeleton made up of dense protein layers.

Diptera: house flies belong to the order of Diptera

Haemolymph: a liquid that transports nutrients and waste in insects and is analogous to blood in humans.

Head: the head contains the compound eyes, mouthparts, and the ocelli.

Labrum: an insect's upper lip.

Labium: an insect's lower lip. Contains a pair of palps.

Larvae (plural of larva): the second stage of the fly's life cycle. They are wormlike and have mandibles to eat. Synonym: maggots.

Mandibles: first set of jaws in dragonflies that move laterally.

Maxillae: second set of jaws in dragonflies that move laterally and contain palps.

Nymph: second stage (after eggs) of the dragonfly's lifecycle.

Ocelli: part of an insect's sensory organs that detects light. Both the fly and dragonfly have three arranged in a triangular shape.

Odonata: dragonflies belong to the order of Odonata.

Ommatidia: individual hexagonal shaped lenses present in the compound eye.

Palps: a pair of sensory organs in insects involved in taste. See Figure 4.

Proboscis: the fly's mouthpart that has tubes that carry the saliva to food to liquefy it before sucking it back up. See Figure 5.

Thorax: the middle section of insects that houses the flight muscles, legs, and wings.

Lesson One: Three Dimensional Movable Dragonfly Head Model

Question

What are the parts of the dragonfly's mouth and how do they work?

Objectives

The learner will build a three dimensional model of the dragonfly's mouth with the help of a partner.

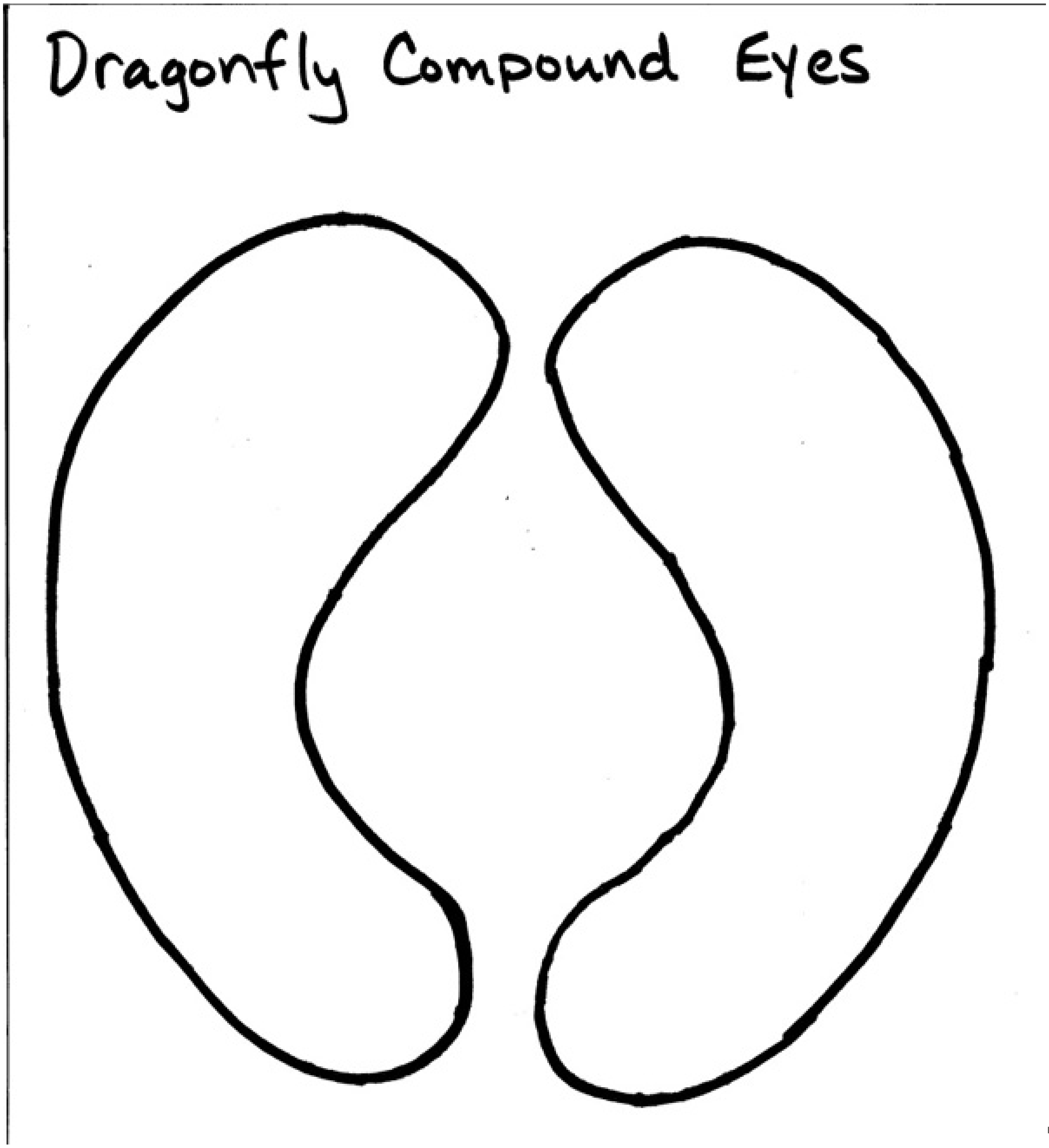
Pre-teach Scissor Safety

Before beginning a project with scissors, remind students about scissor safety.

Materials

One 8 or 9 inch paper plate per student (thin inexpensive paper plates work well), 3 different colors of construction paper (this should be uniform for every student so that color can be used to refer to the structures of the mouth, as in the "yellow mandibles"), 2 brass brads per student, scissors, pencil, hole punchers, 4 pipe cleaners, glue and one compound eye template (See Figure 3) cut out of cardboard or stiff paper for each group of four students to share, or use Figure 1 and copy onto paper.

Figure 3



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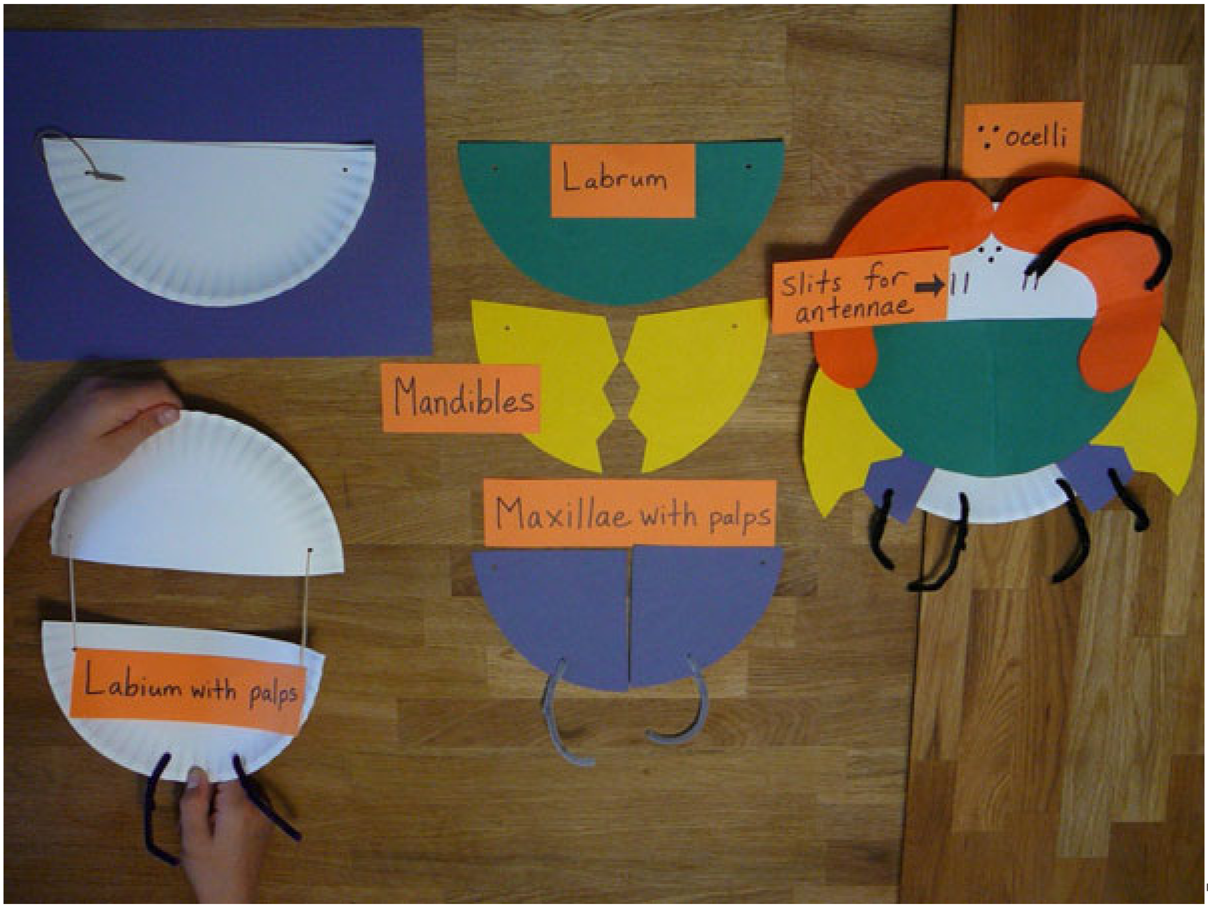
Prepare the paper plates ahead of time with a pair of vertical cuts for each antennae using the brass brads and placing about a quarter from the top of the plate towards the middle and about 2 inches apart horizontally. See figure 4.

Figure 4



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Directions

1. Give each student a paper plate and give each pair of students three different colors of construction paper. Have students take turns using the paper plate as a template and tracing the circle on all three papers and set aside.

2. Fold the plate in half and then open and cut along the fold.

3. Take the two halves and place together and use a hole punch to make two holes on opposite ends of the half circles (total of four circles with doubled plates). The holes will be more uniform if students slide the hole-punch onto the paper plates till it stops, then punch. See figure

4. Cut open 2 rubber bands (or use thin elastic) and place through the holes. Leave slack in the rubber band. This is the model of the dragonfly's lower lip called the labium. It moves longitudinally and can move very quickly. Young nymph dragonflies catch their food with their labium.

5. The labium also has palps which are involved in taste. Add the palps by punching two holes and placing half a pipe cleaner in each one.

6. Have students take three papers and cut out the three circles. Fold the circles in half and cut each one. Each student should have 3 different colored half circles.

7. Have students punch holes on opposite sides of the paper half circles, just as they did with the plates.

8. Next, students will fold one of the colors in half (for two fourths) to create the maxillae (singular: maxilla). Place the maxillae on top of the lower lip. The maxillae move laterally, or sideways, and are the second pair of jaws. Once the mask is built, it will be easy for the students to see this as the second jaw.

9. Cut a pipe cleaner in half and attach to each maxilla by punching a hole. These are the palps and they are sensory organs that help the dragonfly taste and smell their food.

10. Now the students will form the first jaw by folding another half circle in half (two fourths) and this time making a jagged cut. These jaws are responsible for cutting, chewing, tearing and carrying food. They move laterally, like the maxillae.

11. Keep the last half circle intact and place on top of all mouthparts. This top covering is like the upper lip and it is called the labrum which moves longitudinally in an up and down motion. The labrum is useful for pulling food into its mouth. Use the two brads to attach the mouthparts to the top half of the plate through the same hole the rubber band is wrapped through. The bottom lip of the dragonfly should be able to move freely.

13. Now the students will add the large compound eyes of the dragonfly. Have students trace the compound eye template or cut out a copied set of compound eyes from Figure 1. Have them apply a small amount of glue only to the top part of the eye because you don't want glue on or near the mouthparts because you want them to be able to move freely.

14. Students will add three dots in the shape of an upside down triangle between the eyes near the top of the head to form the ocelli, which are 3 simple light receptive organs.

15. Form the antennae located between the eyes using two pipe cleaners. Feed a folded in half pipe cleaner through the two slits (part of preparation) and twist together. Do the same on the other side. See completed mask in Figure 2. The antennae have olfactory receptors which allow the dragonfly to smell its food.

Introduce the names of each structure while building each one, and save the labeling of the structures for another day. It is important that the focus of this first lesson be on the function of the mouthparts and not on the vocabulary. Briefly introduce each one and move onto the next structure. In Lesson Two, the teacher and students will construct a model of the housefly's mouth. These two models can then be used to compare the two insects feeding habits. Many insects share similar mouthparts as the dragonfly.

Independence

Allow students to construct the model with a buddy class and teach the other students what they've learned about the structures on the dragonfly's head and mouth.

Extension

Students will take the model home and teach family members or friends about the structures of the dragonfly's head. Students will write down questions from parents. These questions could lead to whole class investigations or independent student investigations.

Lesson Two: True Fly Proboscis Model

Question

How does the house fly eat?

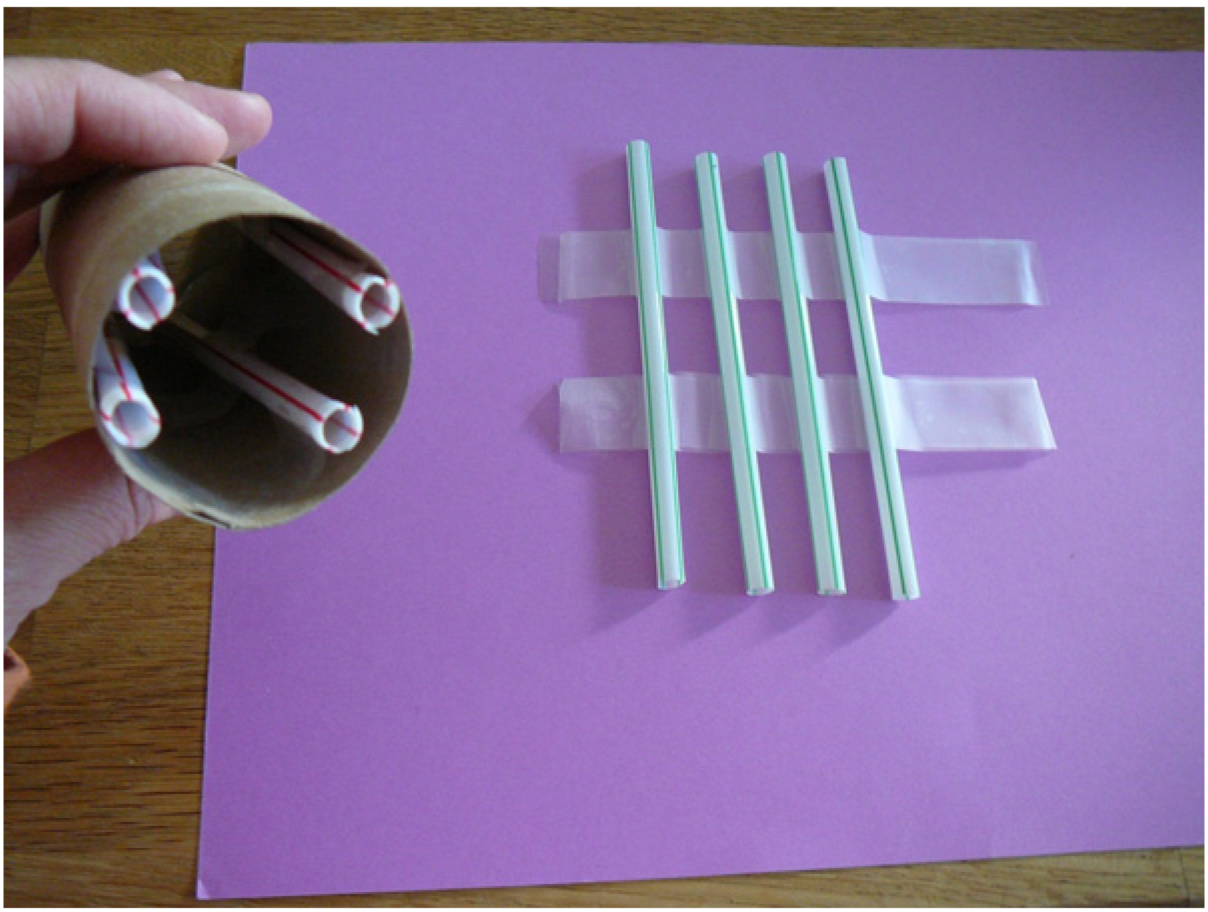
Objective

Students and teacher will build a simple model of how a fly eats with its proboscis.

Materials

One paper or toilet roll for each student, about 6 inches tall and 2 inches in diameter, 4 or 5straws cut to the same height as the black tube, and clear tape. See figure 5.

Figure 5



Directions

1. Tape the straws together with a little space between.

2. Place the straws inside the tube and tape.

3. Explain that this is a model of the house fly's proboscis which is folded under the fly's head and extended

when it is eating. The straws in the model represent the tubes that carry the house fly's saliva to solid food. These tubes are called the pseudotracheae. The food is dissolved by the fly's saliva and the fly sucks in the liquid food with muscles in the upper part of the proboscis. Label the muscles on a piece of tape and place near the top of the model. The fly can only drink liquids. It has no structures for chewing its food like the dragonfly. The labium, or bottom lip which is also present in the dragonfly, has been adapted to form the proboscis. The other mouthparts present in the dragonfly are no longer recognizable in the true fly.

Discussion

Sit in a circle with the students and have students think, pair, and then share with the group about the question. Why did the housefly evolve to have a proboscis? Some ideas to discuss and think about: The proboscis allows the fly access to a variety of foods. House flies don't have to hunt for live food to get a blood meal, like horse flies.

Independence

Allow students to construct the proboscis model with a buddy class and teach the other students what they've learned about the structures of the fly's proboscis.

Extensions

1. Students will use 3-5 straws and drink liquid like a fly through multiple straws.

2. Compare the mouthparts of other insects. Students will look at the curved tube proboscis of butterflies and moths or the piercing and sucking mouthparts of the mosquito.

3. Students will create their own mouth adaptation for a fly. In what environment is your fly using their structure? Have students do a brief presentation using a model.

Lesson Three: The Natural Selection Game

Question

How does an adaptation arise in a population?

Objective

The learner will understand how an adaptation that allows an organism to be more fit in its environment will increase in a population, because individuals with the adaptation will become relatively more numerous in the population.

Materials

For a class of 20 have 20 of each item: forks, spoons, knife, and chopsticks. Have a bowl full of each of the following uncooked rice, cooked pasta, and skittles or M & M's (this may be done one bowl of food each day for three days, or all 3 on one day depending on the age and focus of the students). Students should each have a small cup to gather their food.

Explanation of game

Each utensil represents an adaptation. Students will take turns gathering food with their adaptation. The ones who have significantly less food will die or go extinct if all of members of the group with the same adaptation fail to get enough food. Depending on what the food source is, you might give a food goal for each student or pair of students, for example, "You must collect a full cup of noodles."

Directions

1. Pass out an equal number of each adaptation to students.

2. Take turns gathering food. For larger classes, you may have students work as partners.

3. The adaptations that gather the least amount of food are "dead." Once they step away from the group have them be the next generation born to the organisms whose adaptations are successful. Example: If I am a student who is using the knife to gather M & M's, and I fail to meet the food goal for the round, then I would "die."

4. Continue the game until only one or two adaptations exist.

Discussion

Sit in a circle and discuss what happened during the game. Let students know that this is an example of natural selection. An organism that is better suited to its environment will survive and live to reproduce. The adaptation depends on the demands the environment places on the organism.

Extensions

1. Have students create their own adaptations and surprise them with the food source or have students bring a food source and use the same adaptations.

2. Have students research an adaptation.

Standards

California Life Sciences Standards for Second Grade

Life Science 2c. Students know many characteristics of an organism are inherited from the parents. Some characteristics are caused or influenced by the environment.

Life Sciences 2d. Students know there is variation among individuals of one kind within a population.

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas

Structure and Function: Grade Band Endpoints for LS1.A

By the end of grade 2. All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air. Plants also have different parts (roots, stems, leaves, flowers, fruits) that help them survive, grow, and produce more plants.

Growth and Development of Organisms: Grade Band Endpoints for LS1.B

By the end of grade 2. Plants and animals have predictable characteristics at different

stages of development. Plants and animals grow and change. Adult plants

and animals can have young. In many kinds of animals, parents and the offspring

themselves engage in behaviors that help the offspring to survive.

Information processing: Grade Band Endpoints for LS1.D

By the end of grade 2. Animals have body parts that capture and convey different

kinds of information needed for growth and survival—for example, eyes for light,

ears for sounds, and skin for temperature or touch. Animals respond to these

inputs with behaviors that help them survive (e.g., find food, run from a predator).

Plants also respond to some external inputs (e.g., turn leaves toward the sun).

Resources

Bailey, Stephanie. "University of Kentucky Entomology for Kids." University of Kentucky. http://www.uky.edu/Ag/Entomology/ythfacts/bugfun/cmpdeye.htm (accessed July 31, 2012). Instructions for building a model of the compound eye.

"BioKIDS - Kids'Critter Catalog, Diptera, true flies, including mosquitos." BioKIDS - Kids' Inquiry of Diverse Species. http://www.biokids.umich.edu/critters/Diptera/ (accessed July 31, 2012). Information on Diptera.

"Comparative anatomy and homologous structures." Welcome | EQUELLA. http://tle.westone.wa.gov.au/content/file/c0a7f9da-2dc9-b549-578a-0f1a8921d148/1/bio_science_3b.zip/content/004_evidence/page_05.htm (accessed July 31, 2012). Good resource for learning about evolution and insect mouthparts.

Coyne, Jerry A. *Why Evolution Is True*. New York: Viking, 2009. Excellent resource for understanding evolution and great photos and diagrams.

Dawkins, Richard. *The Selfish Gene*. 30th Anniversary ed. Oxford: Oxford University Press, 2006. Dawkins writes about a theory for evolution based on the gene.

Dethier, V. G. *To Know a Fly*. San Francisco: Holden-Day, 1962. A look into a lab that studied and conducted various experiments flies.

Feynman, Richard P. *The Meaning of It All: Thoughts of a Citizen Scientist*. Reading, Mass.: Addison-Wesley, 1998. This is an edited interview with Feynman and in it he gives ideas about how science might be taught by telling analogous stories.

Firestein, Stuart. *Ignorance How It Drives Science*. New York: Oxford University Press, 2012. A book that discusses how scientists value ignorance over knowing facts.

"First Year Biology." The University of Sydney School of Biological Sciences Online Learning. http://bugs.bio.usyd.edu.au/learning/ (accessed July 31, 2012). Excellent resource for insect mouthparts and close up photos of the compound eyes, ommatidia, antennae, and the labium of the dragonfly.

Grant, Peter R., and B. Rosemary Grant. *How and Why Species Multiply: The Radiation of Darwin's Finches*. Princeton: Princeton University Press, 2008. A look at evolution happening on the islands of the Galapagos with color pictures of the finches, their adaptations and scientists doing work in the field.

"Hexapoda the insects, part 3." *www.bumblebee.org Home Page*. N.p., n.d. Web. 2 Aug. 2012. http://www.bumblebee.org/invertebrates/Hexapoda3.htm#eyes>. Excellent pictures and information about insects.

"Insect mouthparts - Amateur Entomologists' Society (AES)." Amateur Entomologists' Society (AES) - The gateway to entomology. http://www.amentsoc.org/insects/fact-files/mouthparts.html (accessed July 31, 2012). A valuable resource for insect mouthparts and mouthpart modifications.

Klowden, Marc J. *Physiological Systems in Insects*. San Diego: Academic Press, 2002. A book about the physiology of insects.

Mackean, D G. "Insect Life-Cycles, Information." Biology and Teaching Resources. http://www.biology-resources.com/insects-01.html (accessed July 28, 2012). The best downloadable diagrams and information about the housefly.

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Roberts, Royston M. *Serendipity: Accidental Discoveries in Science.* New York: John Wiley, 1989. A collection of stories about how scientists make discoveries.

"The Fruit Fly in You - NASA Science." NASA Science. http://science.nasa.gov/science-news/science-at-nasa/2004/03feb_fruitfly/ (accessed August 2, 2012).

"Welcome to Evolution 101!" Understanding Evolution. http://evolution.berkeley.edu/evolibrary/article/evo_01 (accessed July 31, 2012). Good website for learning about speciation with visuals.

Student Resources

Dixon, Norma. *Focus on flies*. Markham, Ont.: Fitzhenry & Whiteside, 2008. Excellent resource for students about flies.

McEvey, Shane. *Dragonflies*. 2001. Reprint, Pennsylvania: Chelsea House Publishers, 2002. Excellent student resource with many photographs of dragonflies.

McLaughlin, Molly. *Dragonflies*. New York: Walker and Company, 1989. Excellent photographs of the dragonfly emerging from nymphal case and nymphs eating and catching food.

Visual Resources

1. The birth of the fly http://www.youtube.com/watch?v=F3njusp5y. Video on You Tube that shows flies emerging from their pupas.

2. Rabbit decomposition time-lapse (higher resolution) http://www.youtube.com/watch?v=C6sFP_7Vezg&feature=related. This is a time lapse video that shows a dead rabbit being decomposed by larvae.

3. *Life in the Undergrowth* with David Attenborough. This is a two disc DVD set put out by the BBC that I highly recommend. The second section of Taking to the Air begins with mayflies and includes wonderful footage of damselflies, nymphs, dragonflies and dragonfly fossils.

Endnotes

1. Richard P. Feynman, in *The Meaning of it All*, 15.
2. Jerry A. Coyne, Chapter Two, in *Why Evolution is True*, 23.
3. Jerry A. Coyne, Chapter One, in *Why Evolution is True*, 4.
4. Peter R. Grant and B. Rosemary Grant, Chapter Five, in *How and Why Species Multiply*, 53.
5. Jerry A. Coyne, Chapter Two, in *Why Evolution is True*, 22.
6. NASA Science News, 2003.
7. George C. McGavin, Part One in *Essential Entomology*, 18-19.
8. George C. McGavin, Introduction in *Essential Entomology*, 1.
9. Marc J. Klowden, Chapter 10, in *Physiological Systems in Insects*, 294.
10. George C. McGavin, Part One in *Essential Entomology*, 32.
11. George C. McGavin, Part Three in *Essential Entomology*, 81.
12. George C. McGavin, Introduction in *Essential Entomology*, 33.
13. George C. McGavin, Part One in *Essential Entomology*, 43.
14. Bumblebee.org, 2012.
15. George C. McGavin, Part 1 in *Essential Entomology*, 34.