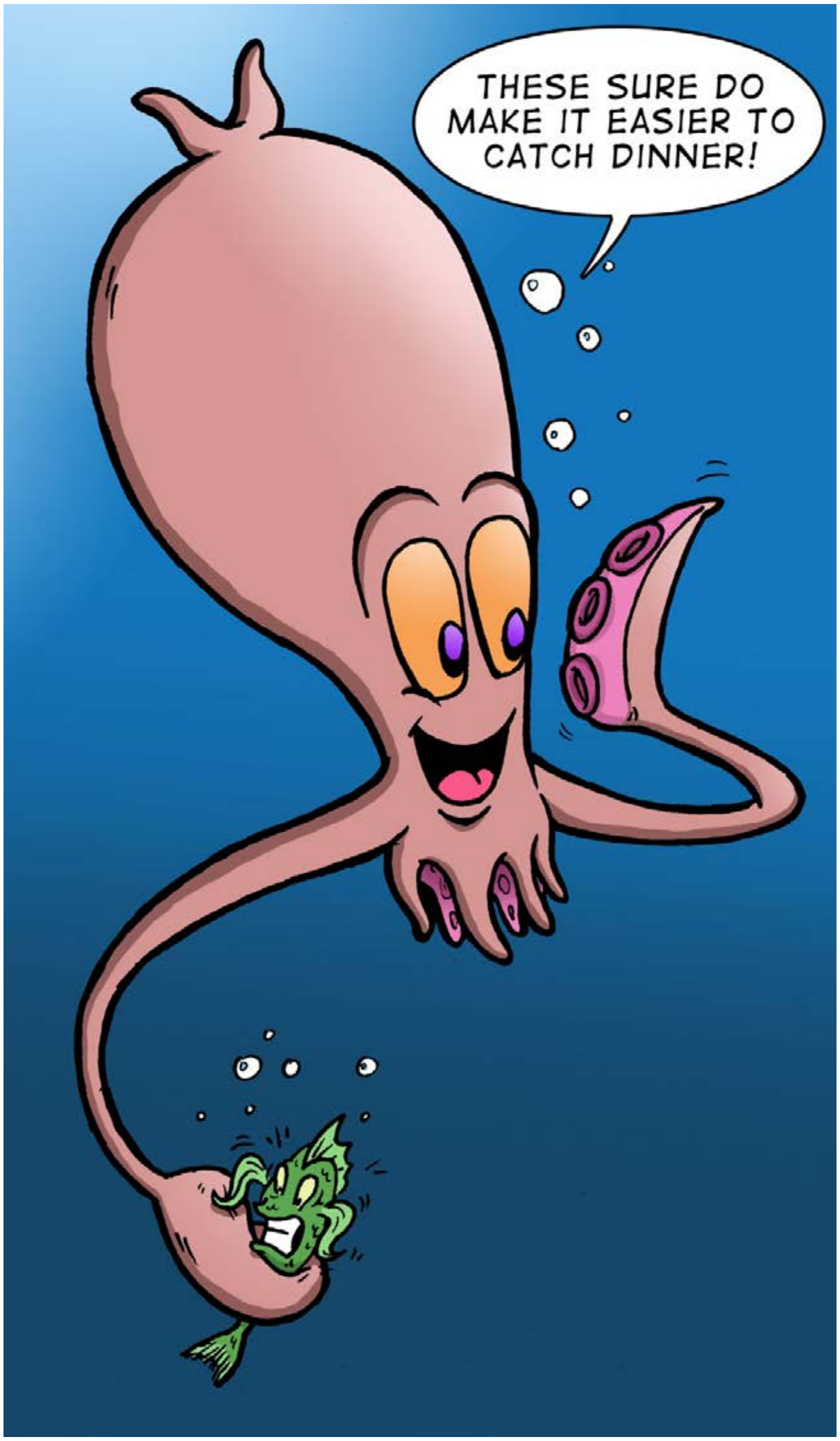
ADAPTATIONS
Teaching Module for Grades 6–12



Dear Educator,

We are pleased to present you with the second in a series of teaching and learning modules developed by the DEEPEND (Deep-Pelagic Nekton Dynamics) Consortium and their consultants. DEEPEND is a research network focusing primarily on the pelagic zone of the Gulf of Mexico, therefore the majority of the lessons will be based around this topic. Whenever possible, the lessons will focus specifically on events of the Gulf of Mexico or work from the DEEPEND scientists.

All modules in this series aim to engage students in grades 6 through 12 in STEM disciplines, while promoting student learning of the marine environment. We hope these lessons enable teachers to address student misconceptions and apprehensions regarding the unique organisms and properties of marine ecosystems. We intend for these modules to be a guide for teaching. Teachers are welcome to use the lessons in any order, use just portions of lessons, and may modify the lessons as they wish. Furthermore, educators may share these lessons with other school districts and teachers; however, please do not receive monetary gain for lessons in any of the modules. Moreover, please provide credit to photographers and authors whenever possible.

This second module focuses on adaptations of marine organisms, specifically discussing concepts of evolution. We have provided a variety of activities and extensions within this module such that lessons can easily be adapted for various grade and proficiency levels. Given that education reform strives to incorporate authentic science experiences, many of these lessons encourage exploration and experimentation to encourage students to think and act like a scientist.

Additional teaching modules, and materials such as animations, videos, and blog posts (kids and adults), will also be posted on the DEEPEND website as they become available (http://www.deependconsortium.org/). We hope you and your students dive into these materials and benefit from the adventure.

Sincerely,
K. Denise Kendall, Ph.D. on behalf of the DEEPEND Education and Outreach Team

DEEPEND
DEEP PELAGIC NEKTON DYNAMICS OF THE GULF OF MEXICO

GULF OF MEXICO RESEARCH INITIATIVE

NSU NOVA SOUTHEASTERN UNIVERSITY College of Natural Sciences and Oceanography

FIU Arts & Sciences FLORIDA INTERNATIONAL UNIVERSITY

USF UNIVERSITY OF SOUTH FLORIDA COLLEGE OF MARINE SCIENCE

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Resphera Biosciences

FAU FLORIDA ATLANTIC UNIVERSITY

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Marine Adaptations Background for Teachers

Marine environments, just like other environments, can have harsh living conditions. Organisms that reside in marine environments are faced with several survival challenges, including finding food for nourishment and finding shelter for protection from predators and their environment. Moreover, organisms that reside in marine habitats are also challenged in regulating salt intake, obtaining oxygen, counteracting water pressure, and changing temperatures. However, marine organisms possess features that enable them to deal with these challenges.

As we discovered in the marine environments module, the marine environment is diverse and composed of many habitats. The diversity of habitats in marine environments has led to an array of different organisms. Organisms that live in marine habitats exhibit adaptations that increase their chances of survival and reproduction in these environments. In this module we highlight some of these adaptations.

What is an adaptation?

An adaptation is a common inheritable trait of a species that increases survival chances, reproduction success, or function of an organism in its environment. This increase in fitness of an organism within a population drives the selective advantage that leads to the trait becoming more prevalent in the population in subsequent generations. It is important to note that fitness does not mean the largest and most powerful, rather it means having a greater chance of survival and reproductive success. While it may seem that adaptations are specifically formed or goal-directed for a purpose, they often arise from random mutations in the genetic code. In fact, an adaptation is an outcome of microevolution. Not all traits of an organism are adaptations, rather the characteristics of an organism are a combination of adaptations and other features. For example, some traits can be by-products of an adaptation, linked genes, or outcomes of other biological processes. Scientists often research if a trait is actually an adaptation by determining if the trait is heritable, increases reproductive success, and improves the individual's survival in the prevailing environment.

Adaptations can be sub-divided among three primary classifications: morphological, physiological, and behavioral; each of which provides unique attributes to organisms.

Morphological, or phenotypic, adaptations are those that impact the anatomical structure of the organism, as morphology deals with the physical features, both internal and external. A common example of morphological adaptation can be seen in the Galapagos Finches - their bill shapes accommodating for a range of diets. Variation in fin shape, body form, and gills are some examples of morphological adaptations present in marine organisms. For example, there is a wide array of caudal fin shapes including round (e.g., flounders), lunate (e.g., tuna), and heterocercal (e.g., sharks) which allow for differing speed and movement patterns.

Physiological adaptations are those that involve the metabolic processes of an organism. Some marine physiological adaptations include changes in muscle function, slowed heartbeat, and modified metabolism. For example, a polar bear's muscles are capable of functioning in the waters of the Arctic. Also consider, diving mammals, such as whales, have a slower heartbeat when diving. This slowed heartbeat allows the animal to reserve oxygen for breathing. Another physiological example is seen in deep sea fishes who have slowed metabolisms. It is believed that metabolic rates are decreased to save energy and since these fishes live in darkness they do not have to flee far to escape from predators. Conversely, other marine animals have increased metabolism. For instance, tuna must continuously swim and while they are swimming their mouths are open so they can continuously pump water over their gills. Accordingly, tunas have high blood pressure and greater amounts of hemoglobin to provide oxygen to muscles related to swimming.

Lastly, behavioral adaptations are actions taken by an organism that increases chances of survival. These actions can take place either individually or cooperatively. A well known example of cooperative behavior can be seen in ant colonies. Migration, communication, and hunting are a few examples of behavioral adaptations seen in marine organisms. For instance, sea turtles migrate between breeding grounds in tropical waters to feeding grounds in polar waters.

Now that we have covered the foundations of adaptations, let's take a deeper look at some of the adaptations found in marine plants and animals.

Marine Plants and Algae

Just like their land counterparts, photosynthetic organisms, such as plants and algae, that inhabit marine environments are the foundation of the marine food web. They provide food to organisms in higher trophic levels. Photosynthesis is a biochemical process that turns carbon dioxide and water into carbohydrates and oxygen. In order for marine plants and algae to photosynthesize, they must be able to access sunlight, carbon dioxide, and water. Marine plants (e.g., seagrasses, mangroves, and salt marsh bushes and grasses) and algae (e.g., seaweed, kelp, and ulva) inhabit marine environments penetrated by sunlight, where they either float along the surface or anchor to substrate.

Sargassum, a marine algae. Photo credit: Dante Fenolio.

The cell wall of marine plants and algae must allow carbon dioxide and water to enter while negating the entry of salt. This is because excessive salt concentration in the cell will cause plasmolysis, the process in which a cell loses water in a hypertonic solution. Moreover, since marine plants and algae access sunlight in the epipelagic layer they must be able to either float or secure themselves to substrate in the coastal region, which can experience harsh tidal changes and wind. Marine plants and algae tend to lack vascular tissue and are less rigid than their land counterparts. Marine plants and algae are supported by the water that encompasses them, and this allows them to move sinuously with the currents. Photosynthetic organisms inhabiting the epipelagic zone provide food for organisms living in deeper layers when they sink down through the water column. This sinking of dead photosynthetic organisms is part of the marine snow that encompasses all dead organic matter that falls to the ocean floor.

While marine plants and algae are similar in many aspects, they are both eukaryotes for example, there are also distinct differences between these two groups. Marine plants are members of the Kingdom Plantae while algae are members of the Kingdom Protista. Marine plants are multi-cellular organisms, whereas algae can be unicellular, colonial, or multi-cellular organisms. Anatomical differences are also noted between marine plants and animals. Marine plant anatomy includes the true roots, stems, shoots, leaves, and flowers. The anatomy of mutli-cellular algae includes the holdfast, stipes, bladders, blades, and fronds. The holdfast may resemble roots, but the only function of a holdfast is for attachment. Also, while both marine plants and algae perform photosynthesis, the location of these processes differ. In marine plants photosynthesis only occurs in the leaves, whereas in algae photosynthesis can take place in any cell.

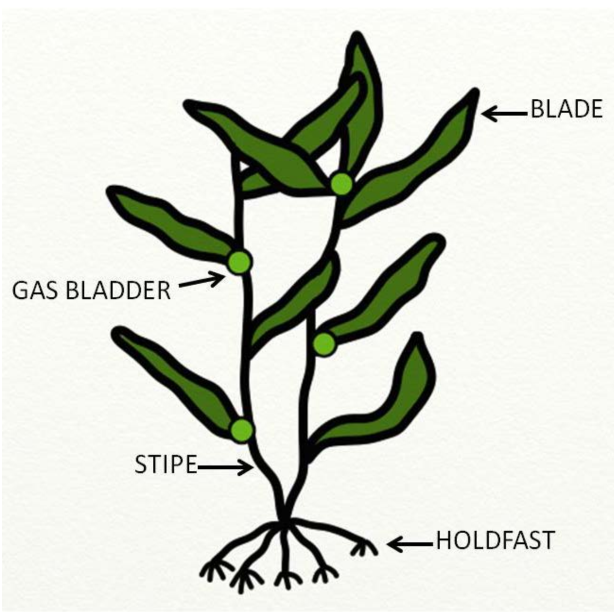


Diagram of multi-cellular algae anatomical structures.

Marine Animals

There is an amazing diversity of marine animals that live in the assortment of habitats in marine ecosystems. Although diverse, marine animals share common challenges living in marine habitats. This section will highlight some adaptations of marine animals.

Water intake and salt regulation

Water and salt intake of marine animals are closely linked, as these animals are surrounded by water with high salt concentrations. Many marine animals have specialized kidneys and gills that prevent saltwater equalization across membranes. Some animals take in seawater directly and then remove excess salt. For example, fish take in seawater and then eliminate salt through their gills. Similarly, seabirds will drink seawater and then eliminate the salt via salt glands draining through their nasal cavity. Other animals obtain water from sources other than the environment. One such example are whales which obtain necessary water from the organisms they eat.

Laughing Gulls on the Alabama Gulf Shore. Photo credit: Brad M. Glorioso.

Oxygen intake and hydrostatic pressure

While animals residing on land are surrounded by atmospheric oxygen, marine animals must either make contact with the atmosphere at the surface or rely on dissolved oxygen. Some marine animals will take in oxygen from the water, this is known as aquatic respiration. Aquatic respiration occurs either through the gills or directly through the skin. Meanwhile, other marine animals, such as whales, have collapsible lungs. These animals must resurface to breathe and while some oxygen will remain in their lungs at depth, a large fraction is relocated to muscles throughout the body which are capable of storing high amounts of oxygen. When the oxygen is relocated to muscles the lungs collapse again, thereby making the animal heavier. As a result, the animal sinks to lower depths without energy expenditure. These collapsible lungs also allow animals to change water depths without the ill-effects of hydrostatic pressure. Similarly, marine mammals, such as dolphins and whales, lack frontal cranial sinuses and, therefore, do not experience the tissue compression animals, like humans, would experience from hydrostatic pressure when diving.

Temperature regulation

Both ectothermic and endothermic animals occur in marine environments. The majority of documented marine animals are ectothermic. This means that their internal body temperature is determined by the external surroundings. However, marine mammals and birds are endothermic meaning they regulate their internal body temperature. The body temperature of endothermic animals remains relatively constant regardless of the surrounding temperatures. Marine environments tend to be colder than the preferred internal temperature of many of these marine mammals. Thus, some marine mammals have a layer of blubber which is a layer of fat and connective tissue located directly under the skin. This layer of blubber assists in insulation. The only truly endothermic fish in the ocean is the recently discovered opah, also known as the moonfish. While opah are the only true endothermic fish in the ocean, other fishes such as sharks and tuna maintain a body temperature greater than their surrounding through their lifestyle (e.g., constant swimming resulting in warm swimming muscles over which water must pass when entering the body).

Visibility

As we descend the water column we encounter visibility and light changes (details on this can be found in the Marine Environments module). Therefore, many marine animals do not rely on sight to transverse the waters or hunt. For example, some marine animals, like dolphins, use echolocation to navigate these dark waters. Other animals, like dragonfishes, have photophores that produce light.

Photophores on a dragonfish. Photo credit: Dante Fenolio.

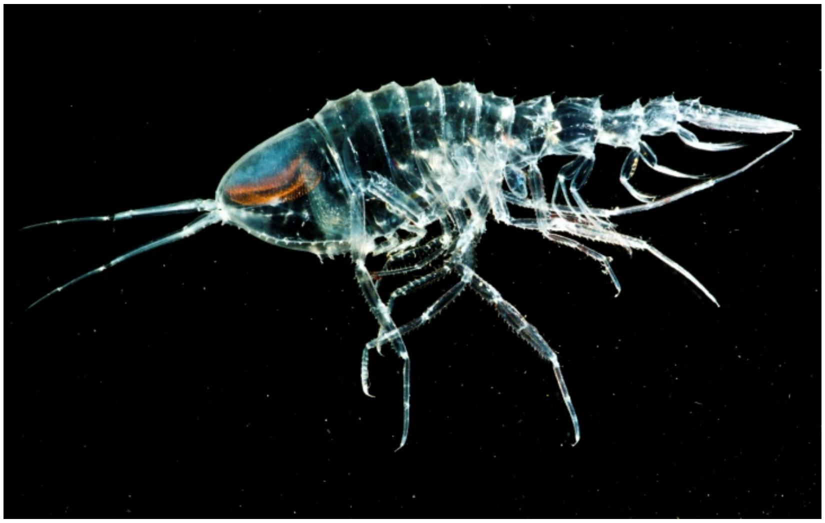
Obtaining food

Marine animals portray a diversity of feeding strategies. Sessile marine animals, such as sponges, tend to be filter feeds which take advantage of microorganisms being suspended in the water column. Some motile marine animals, like sharks, are active predators while others, such as siphonophores, practice a sit-and-wait behavior. Active predators can either feed off of detritus they seek in the sediment or stalk prey. Many animals that are sit-and-wait predators in the deep sea are bioluminescent, attracting their prey with lighted lures like the anglerfish below.

Anglerfish with bioluminescent lure. Photo credit: Dante Fenolio.

Evading predators

Many marine habitats offer limited hiding places, particularly in the open ocean. Consequently, several marine species have adaptations that enable them to evade predation. Many marine animals are camouflaged. For example, some animals, such as many fish species, in the epipelagic zone exhibit countershading. Countershading is a coloration pattern where the ventral side is lighter and the dorsal side is darker. This type of coloration helps an organism blend into its background. From above, a fish appears dark and blends into the darkness of the ocean depths below. From below, a fish appears lighter and blends into the relative brightness of the water column above toward the surface. Predators, such as sharks, also employ countershading to camouflage them as they track and stalk their prey. Other marine animals, like cookiecutter sharks, use counter-illumination to hide from predators. Similar to countershading, counter-illumination helps the animal blend into the surroundings. Counter-illumination is the use of bioluminescence to match the brightness of the background. Another example of marine animal camouflage is seen in many of the invertebrates, which are primarily transparent making them more difficult to find.



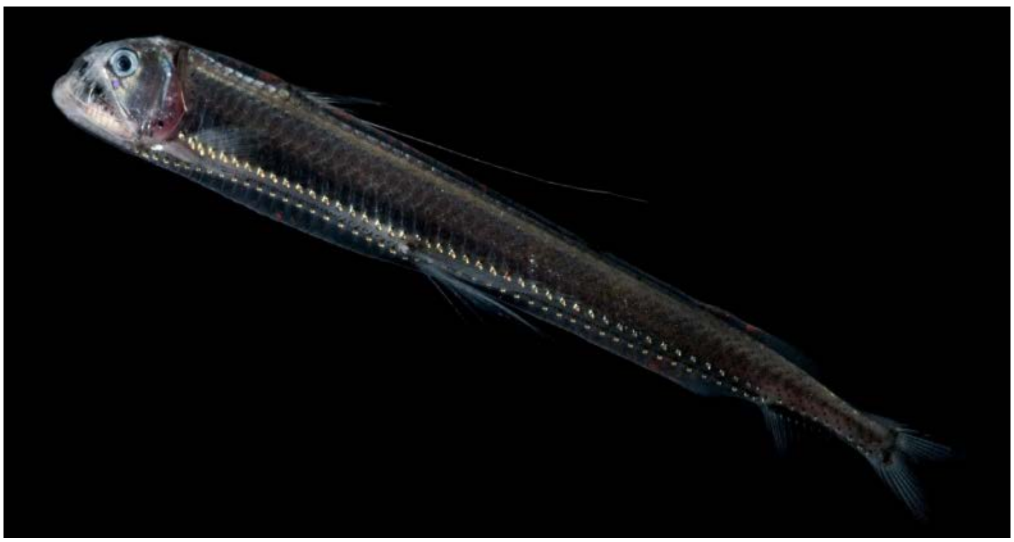
Giant amphipod with transparent body coloration. Photo credit: Dante Fenolio.

Other marine animals, like squids, are capable of making quick escapes from predators. Squid can use jet propulsion to navigate out of harm's way. This is accomplished by drawing water into the mantle cavity through an opening in the head. Pressure builds inside this cavity when all orifices are sealed with the exception of the siphon. The thick muscles of the mantle contract and force water out through the siphon with enough force to propel the squid in a short burst of movement. This is similar to the way that air is expelled from a deflating balloon.

Squid capable of jet propulsion. Photo credit: Dante Fenolio.

Movement

The body shape of marine animals is diverse as the localities and movement needs of species varies. The density of sea water allows large animals to reside in the environment without the presence of strong limbs that would be necessary for life on land. Therefore, the body shape of many marine animals is slim and sleek making them more aerodynamic. This body shape allows them to glide through the water more easily. Moreover, the variety of fish tail shapes determine the acceleration and maneuverability of the animal and can provide insight to where and how the animal lives. Consider this, bottom-dwelling fishes tend to have tails nearly half the length of their bodies allowing for increased leverage for propulsion while fishes living within the water column have thin, small, tails ideal for moving quickly. Other bottom-dwelling fishes, like flounders, often have a flattened body shape and therefore swim on one side. To aid in this swimming technique these fishes often have taller pectoral fins.



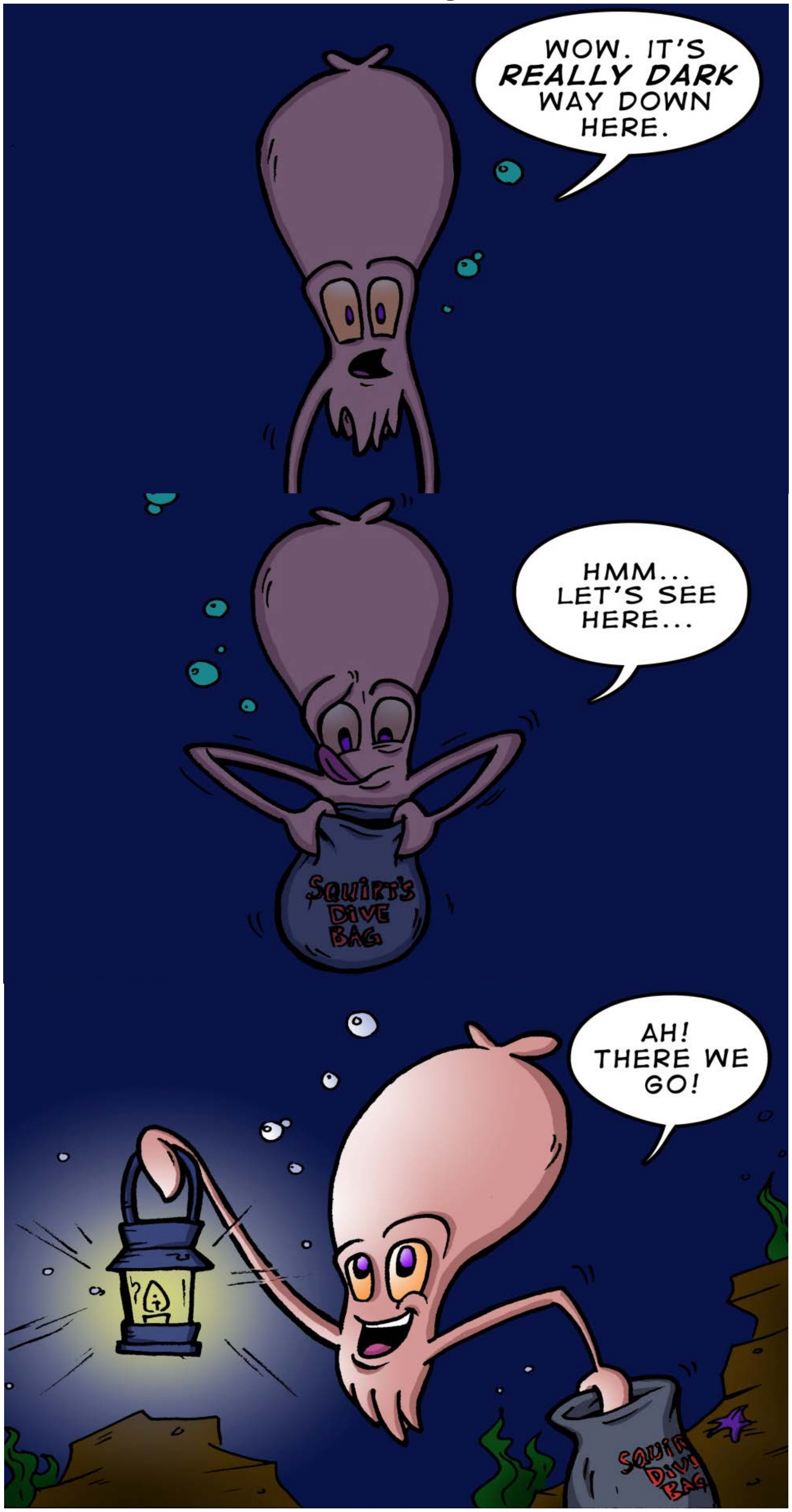
Chauliodus sloani, a narrow bodied fish. Photo credit: Dante Fenolio.

Echiostoma barbatum, another narrow bodied fish. Photo credit: Dante Fenolio.

Conclusions

With the diversity of habitats present in marine environments comes a plethora of adaptations in marine animals. This background information has merely brushed the surface of the amazing diversity of adaptations that have evolved in the many disparate groups of organism that reside in marine environments. We have hit on a few key categories and highlighted a sampling of organisms, and we strongly encourage you and your students to continue this exploration in more depth. With more in-depth exploration you and your students are likely to find intriguing and mind-boggling details about the plants and animals of marine environments.

Marine Environments Background for Students



What is an adaptation?

An **adaptation** is a common inheritable trait of a species that increases survival chances, reproduction success, or function of an organism in its environment. **Inheritable** means it can be passed from parent to offspring. If an adaptation increases an individual's fitness within the population then that trait is likely to become more common in the population. **Fitness** means having a greater chance of survival and reproductive success. While it may seem that adaptations are formed for a purpose, they are not. Adaptations come from random mutations in the genetic code. The genetic code is the information that makes an organism! For example, the genetic code determines your eye color.

Not all traits of an organism are adaptations. Organisms are a combination of adaptations and other features. Scientists often research if a trait is actually an adaptation by determining if the trait is heritable, increases reproductive success, and improves the individual's survival in the current environment.

Types of adaptations

There are three main types of adaptations: morphological, physiological, and behavioral. **Morphological** adaptations are those that impact how an organism looks, both inside and outside. For example, the shape of a bird's beak is a morphological adaptation. A bird's beak shape determines what type of food it eats. **Physiological** adaptations are those that involve the metabolic processes of an organism. For example, the rate at which a dolphin's heart beats is a metabolic processes. When dolphins dive their heartbeat slows down; this is a physiological adaptation that saves energy. Lastly, **behavioral** adaptations are the actions taken by an organism that increase chances of survival. Sometimes the animal takes these actions alone, but other times these actions are done with others. Have you ever seen birds migrate? This is a behavioral adaptation.

Marine Plants and Algae

Marine plants and algae are the foundation of the marine food web. They provide food to organisms in higher tropic levels. Many plants and algae inhabit marine environments that are penetrated by sunlight. They do this by either floating in the **epipelagic** zone or anchoring to substrate. The epipelagic zone extends from the water surface to about 200 meters in depth. Sunlight penetrates the epipelagic zone, so these marine plants and algae are able to photosynthesize. **Photosynthesis** is a biochemical process that turns carbon dioxide and water into carbohydrates and oxygen. In order for marine plants and algae to photosynthesize they must be able to access sunlight, carbon dioxide, and water. The cell wall of marine plants and algae must allow carbon dioxide and water to enter while keeping out salt. If lots of salt gets into the plant or algae's cells then the plant/algae will lose water and shrivel up. When plants and algae die, they sink to the ocean floor where they are decomposed or eaten by awaiting animals.

Sargassum, a marine algae. Photo credit: Dante Fenolio.

Marine Animals

Many different kinds of marine animals live in the marine environment. But even with this diversity of animals, many marine animals share common difficulties to living in these habitats. Organisms that reside in marine environments are faced with several survival challenges including finding food for nourishment and finding shelter for protection from predators. Moreover, organisms that reside in marine habitats are also challenged in regulating salt intake, obtaining oxygen, counteracting water pressure, and changing temperatures. Let's take a closer look at how marine animals deal with some of these common challenges.

Water intake and salt regulation

All animals require water to survive. Since marine animals are surrounded by salt water they need to either get rid of salt they take in or use other methods to get water without salt. Some fish take in seawater and then remove excess salt through their gills. Other animals, like seabirds, drink seawater and then filter salt through salt glands which exit pores at the base of their nose. Lastly, some marine animals, like whales, get the water they need from their food.

Laughing Gulls on the Alabama Gulf Shore. These birds drink seawater and then expel the salt. Photo credit: Brad M. Glorioso.

Oxygen intake

Marine animals need oxygen to survive. Some marine animals get their oxygen directly from the water through a process called aquatic respiration. Aquatic respiration occurs through either the gills or directly through the animal's skin. Other marine animals must come to the surface to breath. Have you noticed the blowhole that many marine mammals, like dolphins and whales have? These marine mammals have collapsible lungs. When the animal breathes the lungs expand. Then, the oxygen is relocated to muscles for storage and the lungs collapse again.

Temperature regulation

Both ectothermic and endothermic animals live in marine environments. Ectothermic means that the internal body temperature of an animal is determined by the external surrounding. An example of an ectothermic land animal is a snake, like this black-masked racer found in Louisiana.

Black-masked racer, an ectothermic land animal. Photo credit: Matthew L. Niemiller.

Endothermic means that the body temperature of an animal is regulated so it stays relatively constant regardless of the external surrounding. An example of an endothermic land animal is you!

Most marine animals are ecothermic, but there are a few exceptions. Marine mammals are endothermic. Many marine mammals have a layer of blubber that helps them regulate their internal body temperature. Blubber is a layer of fat and connective tissue that is located directly under the animal's skin. The only documented known endothermic fish is the recently discovered opah, also called a moonfish.

Visibility

As we dive deeper from the ocean surface to the ocean floor, the amount of light that penetrates the water decreases. At depths of about 800 meters we encounter complete darkness. Therefore, many marine animals do not rely on sight to navigate the waters and find food. For example, some marine animals, like dolphins, use echolocation to find their way. Echolocation is the use of sound waves to determine where objects are. For echolocation the animal sends out sound waves by producing a noise; when the sound wave hits an object it is reflected back to the animal. The quicker the sound waves are returned the closer the object is.

Other animals, like dragonfishes, have photophores. **Photophores** are organs that produce light and can be used for communication and hunting. Some dragonfish photophores produce red light. Many deep sea animals cannot see red light, but the dragonfish can and as a result the dragonfish can use this red light to hunt.

Photophores on a dragonfish can be used for communication. Photo credit: Dante Fenolio.

Obtaining food

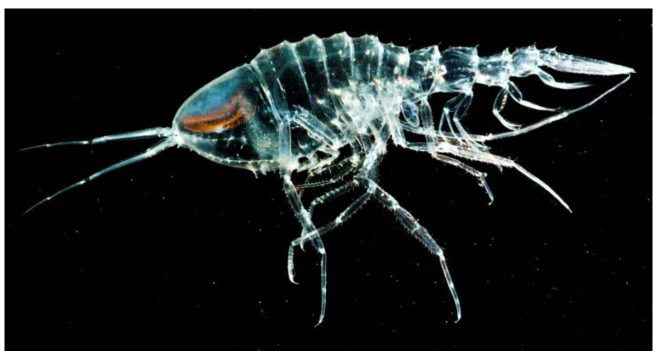
Many feeding strategies are used by marine animals. Sessile marine animals are animals that cannot move, such as sponges. Sessile marine animals are usually filter feeders. This means that they filter water that passes by them and eat little organisms that are floating in the water column.

Other marine animals are capable of movement; these animals are considered motile. Some motile marine animals, like sharks, are active predators. Active predators stalk and catch their prey. While there are active predators in marine environments, there are also motile marine animals that practice a sit-and-wait method of hunting. These predators often have quick responses when prey swim by or they have a way to attract prey to them. For example, the anglerfish that lives in the deep sea is bioluminescent. This anglerfish has a lighted lure that attracts prey to it, like the lure on a fishing line.

Anglerfish with bioluminescent lure. Photo credit: Dante Fenolio.

Evading predators

Many marine habitats have limited hiding places, especially out in the open ocean. Many marine animals have adaptations that help them evade predation. One key adaptation is camouflage. Some animals, like fishes in the epipelagic and mesopelagic zone exhibit countershading. Countershading is a coloration pattern where the ventral (bottom) side of the animal is lighter and the dorsal (upper) side of the animal is darker. This type of coloration helps the animal blend into the waters. From above, the fish appears dark and blends into the darker waters below. At the same time, from below the fish looks lighter and blends into the brighter waters above. Other animals use counter-illumination to hide from predators. These animals, like the lanternfish, use bioluminescence on their stomachs to hide their shadows. They light up to exactly match the light that their bodies are blocking. Many invertebrates are transparent, essentially clear, making them more difficult to find.



Giant amphipod with transparent body. Photo credit: Dante Fenolio.

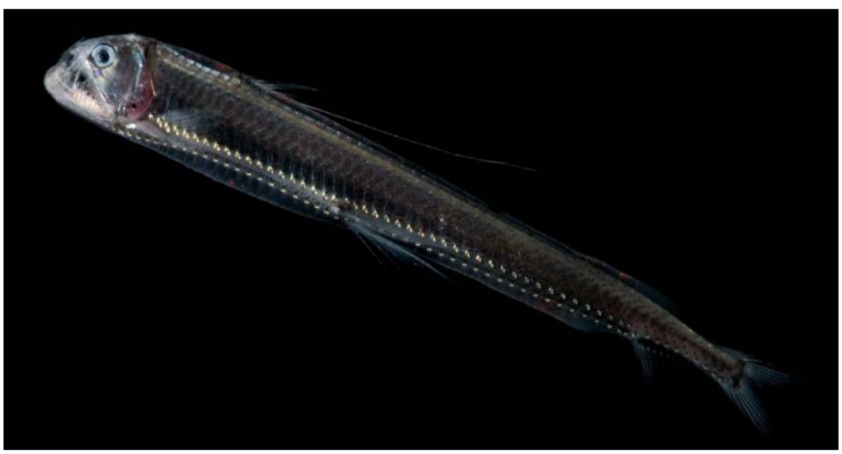
Another adaptation is the ability to make quick escapes from predators. Squids can use jet propulsion to navigate out of harm's way. They use water to give them short bursts of quick movement.

Squid capable of jet propulsion. Photo credit: Dante Fenolio.

Movement

The body shape of marine animals is diverse as the localities and movement needs of species vary. The density of seawater allows large animals to reside in the environment without the presence of strong limbs that would be necessary for life on land.

The body shape of many marine animals is slim and sleek making them more aerodynamic. This body shape allows them to glide through the water more easily. Marine animals have a variety of tail shapes, which determine the acceleration and maneuverability. The tail shape of fishes can tell us where and how the animal lives. Bottom-dwelling fishes tend to have tails nearly half the length of their bodies, allowing for increased leverage for propulsion, while fishes living within the water column have thin, small, tails ideal for moving quickly. Other bottom-dwelling fishes, like flounders, often have a flattened body shape, so when they swim they turn on one side. To aid in this swimming technique these fishes often have taller pectoral fins.



Chauliodus sloani, a narrow bodied fish. Photo credit: Dante Fenolio.

Echiostoma barbatum, another narrow bodied fish. Photo credit: Dante Fenolio.

Evolutionary History!

Objective
Students will learn about evolutionary histories of some marine animals.

Next Generation Science Standards applicable to activity and extensions
- MS-LS4-2. Apply scientific ideas to construct an explanation for the anatomical similarities and difference among modern organisms and between modern and fossil organisms to infer evolutionary relationships.
- HS-LS1-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
- 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.

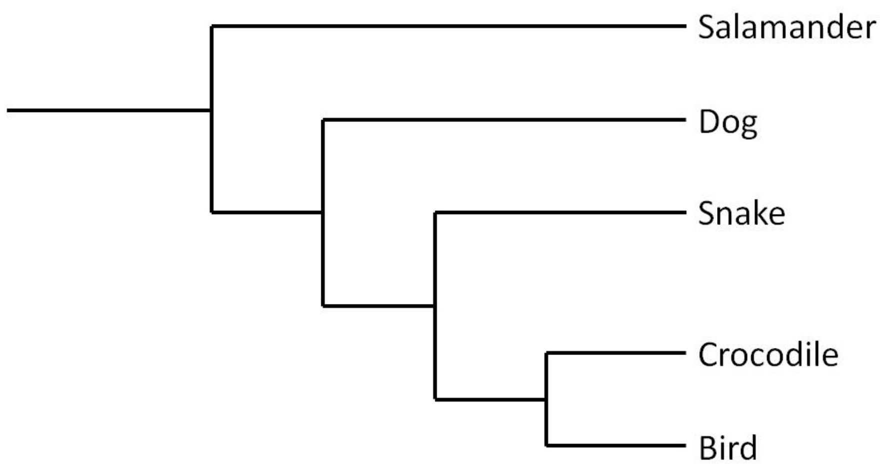
Supplies
- Worksheets
- Pens/pencils

Lesson
In this lesson students will learn about models of evolutionary histories - cladograms and phylogenies. First, students will obtain information about the use of evolutionary models, how to read them, and the limitations of these models. Then, students can complete one or both of the associated worksheets. The first worksheet asks students to reconstruct the evolutionary history of six marine animals using traits. The second worksheet uses the same six marine animals, but has students use genetic data to compare the evolutionary histories.

This lesson can be expanded by having students research different marine plants and animals and reconstruct their evolutionary histories while identifying ancestral and derived traits. These reconstructed histories can be created as 3D models, posters, or sketches. Students can compare and contrast their histories with their peers.

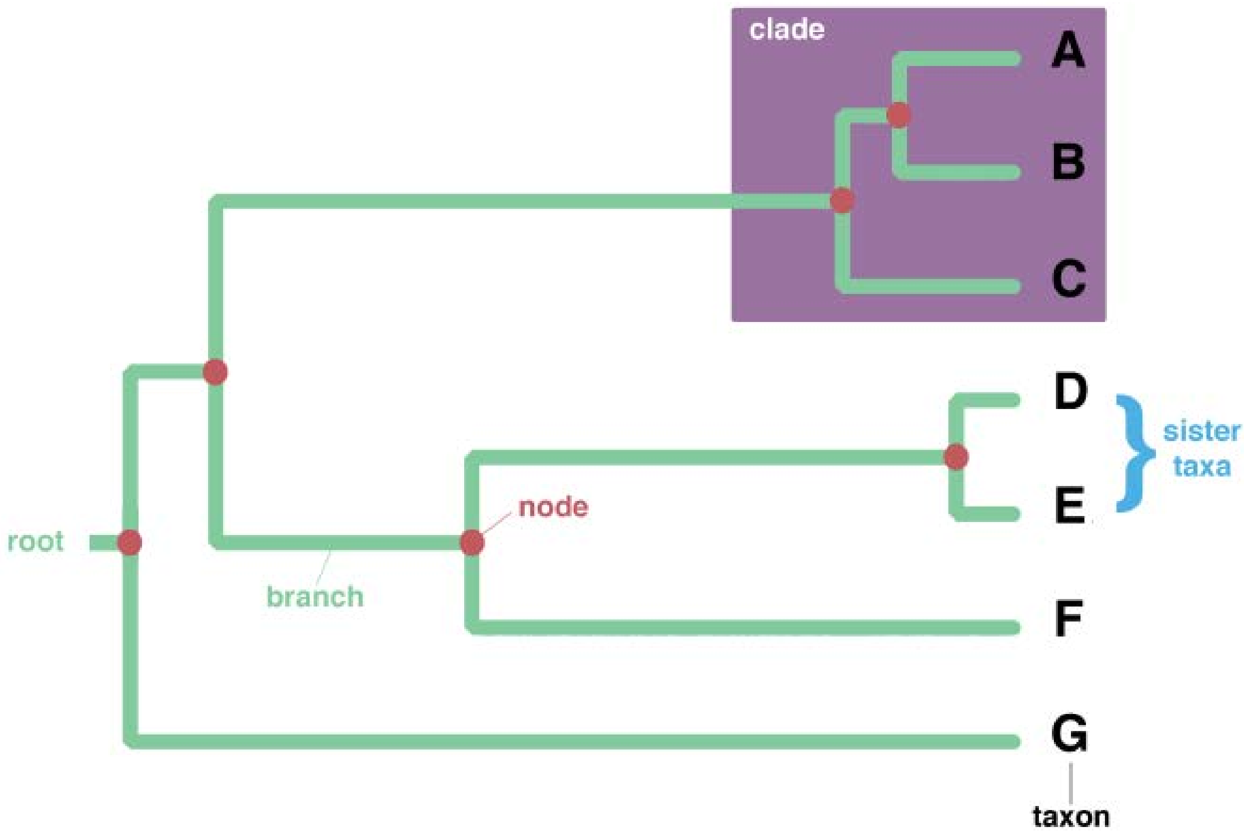
Interpreting Evolutionary Histories

Scientists use models, like cladograms and phylogenetic trees, to depict the evolutionary history of organisms. Cladograms and phylogenies can be created from data, such as morphology (body shape), DNA (nuclear DNA, chloroplast DNA, mitochondria DNA), and paleontology (fossils). This means that these models can be used to determine the relatedness of organisms, similar to the way we use a pedigree to determine family histories.



These models can be used to infer ancestral (shared) and derived (more recent) traits. **Ancestral traits** are inherited from an ancestor, whether in the distant past or more recently. When inherited from an ancestor in the distant past this trait should be shared by a large number of species, whereas if the trait first appeared more recently it should be shared by fewer species. It is important to note that ancestral does not mean a trait is more primitive, nor does it mean that the species is more primitive. A **derived trait** is present in an organism, but was absent in the last common ancestor of that group. Species will have a mixture of ancestral and derived traits, and similarly, the traits which are ancestral and derived are dependent on the group.

There are multiple ways to draw these models, but the interpretation of them are the same: 1.) Every line represents the particular organism of interest, 2.) The distance between lines represents how closely related organisms are, and 3.) Connected lines represent a common ancestor. Terminology often associated with these models include: root, branches (speciation events), nodes (common ancestor), tips (modern living organisms), and clades (tips that all share a common ancestor; monophyletic).



There are limitations to these models. Scientists may not always be able to show extinctions or models can become confused by issues such as convergent evolution (emergence of a trait in unrelated lineages). Given these results, most of these models are created from multiple sources of data.

Name: ______________________ **Date:** ________________

Evolutionary History Interpretation

You will now practice creating and interpreting a phylogeny of your own. Use the matrix below of characters of various marine animal groups to recreate the evolutionary history of the organisms. Note: convergent evolution can occur.

Traits	**Organisms**					
	Jellyfish	Squid	Sponge	Shark	Starfish	Flatworm
Bilateral Symmetry		X		X		X
Coelom		X		X	X	
Deuterostome				X	X	
Multicellularity	X	X	X	X	X	X
Notochord				X		
Protostome		X				X
Radial Symmetry	X				X	
True Tissue	X	X		X	X	X

Name: ______________________ **Date: ________________**

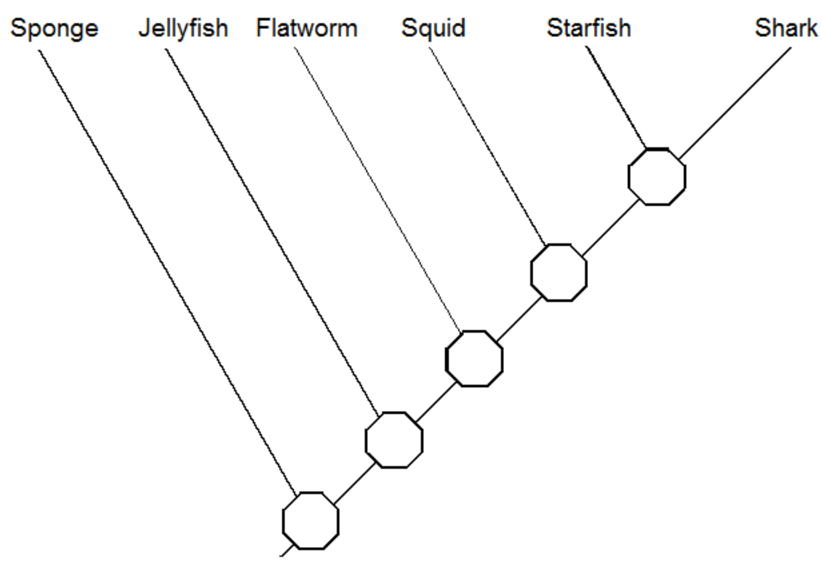
Genetic Data

We have obtained genetic data from six marine animals. Below is a table of what the base sequences from the same gene in each animal. Use these data to answer the questions below.

1. What prediction would you make regarding the similarity of DNA sequences between each of the six animals based on the cladogram you created in activity one?

2. Now, compare the DNA sequences of the species. Record the number of differences in the DNA sequence between each group in the octagons located at the nodes on the cladogram below.

Shark	T	T	T	A	T	C	G	A	A	G	T	C	T	A	A	G	A	T	A	G	T	T
Flatworm	T	G	G	A	T	A	C	T	A	G	C	A	T	A	A	G	A	A	A	C	G	T
Sponge	T	G	G	A	T	A	A	T	A	T	G	T	C	A	A	G	A	G	A	C	A	T
Squid	T	G	T	A	T	A	A	C	A	G	T	C	C	A	A	G	A	C	A	G	C	T
Starfish	T	T	T	A	T	C	G	A	A	G	T	A	T	A	A	G	A	T	A	G	T	T
Jellyfish	T	A	G	A	T	A	C	T	C	G	T	G	C	A	A	C	A	T	A	T	A	T



3. Based on the DNA sequences you just examined, do the data support your predictions?

Colored Vision!

Objective

Students will explore the effects of color on vision as light is absorbed in aquatic systems.

Next Generation Science Standards applicable to activity and extensions

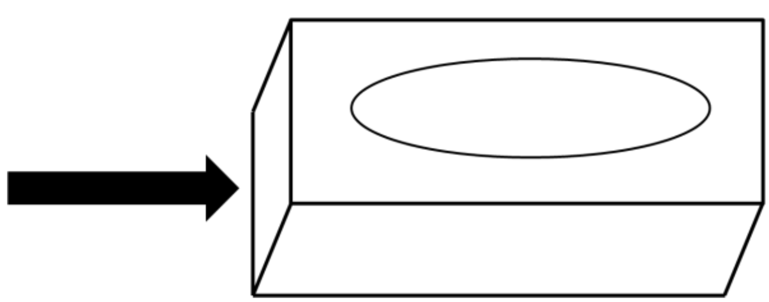
- MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
- MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
- MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect 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.

Supplies

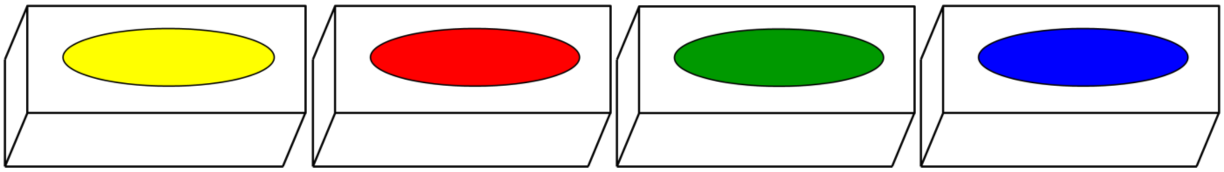
- Tissue boxes
- Box cutter
- Colored cellophane
- Flashlights
- Strong tape (e.g., gorilla tape, duct tape, etc.)
- Objects of various colors to view in boxes (e.g., candies, cards, cut-outs, etc.)

Lesson

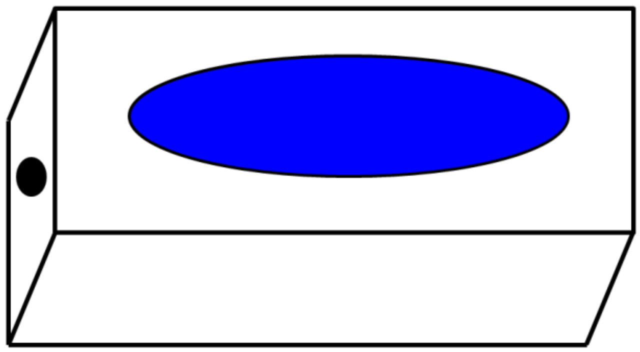
When light strikes an object some wavelengths are absorbed while others are reflected. The wavelengths reflected from an object are what gives the object its color. In this demonstration students will investigate the effects of color on vision. Viewing boxes will need to be prepared by the teacher prior to the demonstration. To create viewing boxes you will need large tissue boxes, strong tape, colored cellophane, flashlights, and a box cutter. You will need one tissue box for each color of cellophane you have. First cut one of the short sides of the tissue box to create a flap by cutting along the side and top edges while leaving the bottom edge intact. Short side noted in the diagram below by the arrow.



Now cover the tissue hole with cellophane, one color per box. Secure the cellophane with tape by reaching into the flap and taping it on the interior.



Now, on the flap cut a circle the size of the end of your flashlight (you will use this cutout to illuminate the interior).



After you put objects into the box you will secure the flap by taping it securely. Your viewing boxes are ready to use! Simply illuminate the interior of the tissue box by inserting the flashlight into the hold and turning it on. Then peer through the cellophane opening.

An extension of this lesson is to have students create marine animals from clay or construction paper. These recreations should be as realistic as possible. Then students should view their animals in each viewing box to observe the effects of light on their animal.

Name: ___________________________ **Date:** _________________

Absorbed Light!

Light penetrates marine waters until about 800 meters in depth. As this light enters the water, wavelengths are absorbed and some wavelengths are scattered. Longer wavelengths, like red light, are absorbed the fastest as they have the lowest energy level. While shorter wavelengths, like violet, are scattered away. This leaves primarily blue light, which can reach deeper depths.

Question: How does the color of light affect how objects look?

Write a **hypothesis**:

Experimental protocol:

1. Gather a variety of objects to view in different lighting conditions.
2. Use a viewing box to observe the object in each lighting condition.
3. Record whether or not you can see the object under each color.

Data table:

	Viewing Box Color				
Object	**Red**	**Blue**	**Yellow**	**Green**	**White**

Results: Analyze your data. How does light affect the appearance of the objects?

Conclusions: Do your results support your hypothesis? Provide support for your conclusions.

Insulated!

Objective
Students will explore insulating materials in order to obtain a deeper understanding of temperature regulation.

Next Generation Science Standards applicable to activity and extensions
- MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
- MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
- MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
- MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- 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.

Supplies
- Graph paper
- Writing utensils
- Stop watch
- Thermometers
- Glass jars (e.g., pint size mason jars)
- Warm water (~90 ^{o}C)
- Measuring cup
- Clay
- Insulating materials (e.g., towels, jacket, fat [e.g., Crisco, vegetable oil], feathers, aluminum foil, etc.)
- Plastic baggies

Lesson
Many endothermic marine animals have a layer of blubber below their skin. This blubber acts as an insulator, similar to a jacket that keeps you warm in the winter. In this lesson students explore the effectiveness of different insulating materials.

Prior to class you will need to drill a hole in the center of each jar lid. The hole must be large enough to fit the thermometer snuggly. It is okay if the hole is too large as the hole can be sealed and thermometer can be secured with clay. Alternatively you can use aluminum foil to cover the tops of the jars, but it is important to tape any tears to prevent heat loss.

Warm water will need to be available for students during class, I have found that the easiest and safest way to provide water is through the use of an electric water boiler.

To set up the experiments students will fill each jar of their set-up with equal amounts of water (ideally between 1/2 and 3/4 full). Students will immediately secure the lid to the jar and insert the thermometer. Modeling clay should be molded around the thermometer to ensure that the hole is air-tight. Students should then wrap the jar in the insulating material (e.g., a towel, feathers, fat, etc.). Students can compare different insulating materials or they can compare different amounts of the same insulating material in their experimental set-up. I found that the cleanest and most effective way to secure insulating material is to put the jar in a plastic bag filled with the insulating material. If using a plastic bag for one insulating material it is important to use the bag for all materials to negate for any isolation provided by the bag. Note: Using fat will be messy, but this most closely mimics blubber.

For data collection purposes students should record the initial water temperature and the water temperature every minute for 10–30 minutes depending on your class length. The length of data collection can be modified to fit your class time. After all data have been collected students should graph their results and draw conclusions.

An extension if this lesson is to have students compare land animals to marine animals in terms of temperature regulation and structure. Students should conduct research on insulating properties common to land animals. Students can set-up an experiment with other insulating properties they discover in their research to determine the effects of these properties on temperature change.

Name: _________________________ **Date: ________________**

Insulated?

Many marine animals are endothermic and rely on a layer of blubber to help regulate body temperature.

Materials:

- Graph paper
- Writing utensils
- Stop watch
- 4 Thermometers
- 4 Glass jars (e.g., pint size mason jars)
- Warm water (~90 ^{o}C)
- Measuring cup
- Clay
- Insulating materials: paper towels, fat, and feathers
- Plastic bags

Question: How efficient are diverse insulating materials?

Write a **hypothesis**:

Conduct an experiment:

1. Fill all four glass jars with equal volumes of water. The jars should be somewhere between 1/2 and 3/4 of the way full.
2. Put the lid on each jar and insert the thermometer. Use the clay to secure the thermometer and seal any opening around the thermometer.
3. Place each glass jar inside of a plastic bag. Seal one bag without an insulating material. This is your control. In each of the other bags place an insulating material around the jar and seal the bags.
4. Record the initial water temperature in each jar. Then, record the water temperature in each jar at selected minute intervals.
5. Plot your data on a graph using the graph paper and draw conclusions. Compare your results with other groups.

Data:

	Treatment			
Time	**Control**	**Paper Towels**	**Fat**	**Feathers**
0				

Conclusions:

Insulated?

Many marine animals are endothermic and rely on a layer of blubber to help regulate body temperature.

Materials:

- Graph paper
- Writing utensils
- Stop watch
- 4 Thermometers
- 4 Glass jars (e.g., pint size mason jars)
- Warm water (~90 ^{o}C)
- Measuring cup
- Clay
- Insulating materials
- Plastic bags

Question: How efficient are diverse insulating materials?

Write a **hypothesis**:

Conduct an experiment:

1. Fill all four glass jars with equal volumes of water. The cups should be somewhere between 1/2 and 3/4 of the way full.
2. Put the lid on each jar and insert the thermometer. Use the clay to secure the thermometer and seal any opening around the thermometer.
3. Place each glass jar inside of a plastic bag. Seal one bag without an insulating material. This is your control. Select your insulating materials. In each of the other bags place an insulating material around the jar and seal the bags.
4. Record the initial water temperature in each jar. Then, record the water temperature in each jar at selected minute intervals.
5. Plot your data on a graph using the graph paper and draw conclusions. Compare your results with other groups.

Data:

	Treatment			
Time	**Control**			
0				

Conclusions:

Echolocation!

Objective
Students will explore the use of echolocation by marine animals.

Next Generation Science Standards applicable to activity and extensions

- MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
- MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
- MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- 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.

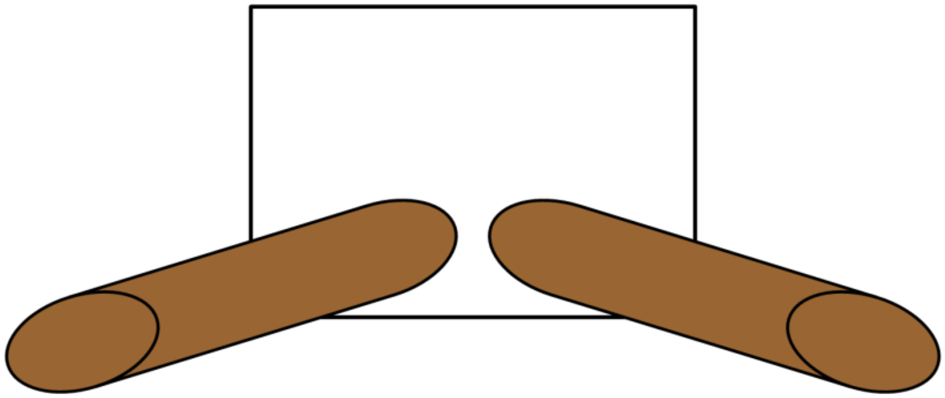
Supplies

- Paper towel and toilet paper rolls
- Protractor
- Noise maker (e.g., buzzer, radio, alarm clock, or etc.)
- Cardboard piece (~30 by 45 cm)
- Foam board (~30 by 45 cm)
- Fabric (~30 by 45 cm)

Lesson

In this experiment students explore how sound can bounce from surfaces. Students can observe how sound bounces from different surfaces (hard and soft surfaces), from different angles as well as from different distances (paper towel roll versus toilet paper roll). The students should determine what their independent variable will be (e.g., surface type, sound angle, or distance sound travels) prior to writing a hypothesis.

This experiment is best performed in pairs. One students will hold the reflective surface (e.g., cardboard piece, foam board, fabric) while another student serves as the observer and recorder. The reflective surface should be held upright on a flat desk, table, or the floor. Then students should place their distance roll at a specified angle in front of the reflective surface. See set-up example.



There should be a 6-cm gap between the reflective surface and the roll. At the end of one roll students should place the noise maker. Then the observer should place his/her ear at the end of the other roll and listen. The observer should record how well he/she can hear the noise maker. The sound travels along the first tube and is reflected from the reflective surface into the other tube. Students should repeat with their remaining treatments. After all data have been collected students should analyze the data and then draw conclusions. If pairs chose different independent variables they can present their results to other pairs of students.

An extension of this activity can be conducted by mimicking the use of echolocation by dolphins in the classroom. One student should be the dolphin while all other students are fish. The dolphin should be blindfolded leaving the ears uncovered. In order for this extension to be safe all sharp edges should be covered with padding and the blindfolded student should have a safety guide assigned to them (either the teacher or another student). Alternatively, this activity can be completed outdoors in an open field. The fish should disperse around the classroom. The fish should remain in this spot for the entire activity. Once all fish are in place and the dolphin is blindfolded the hunting should being. The teacher should point to different fish (one by one or multiple at a time). When the teacher points the fish should make noise (e.g., clap). The dolphin should try to navigate toward the noise. If the dolphin tags a fish then the fish is caught. Rotating the students in the role of dolphin will allow them all to experience how listening can be used to locate prey and navigate.

Name: _________________________ **Date: ________________**

Echo-lo-what?

Some marine animals use echolocation to navigate through dark marine waters and to find food. Echolocation is the use of reflected sound waves to determine the location and distance to an object.

Question: What factors can affect the reflection of sound waves?

Dependent variable:

Independent variable:

Write a **hypothesis**:

Experimental design:

Data:

Conclusions:

Salted Plants!

Objective
Students will explore the effects of saltwater on plants.

Next Generation Science Standards applicable to activity and extensions
- MS-LS1-2. Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.
- MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
- MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Supplies
- Freshwater plants (e.g., *Elodea*)
- Seawater plants (e.g., seagrass) , algae (e.g., seaweed)
- microscope
- microscope slide and cover slips
- Plastic pipettes
- Salt water (salty like the ocean - make using either table salt or instant ocean)
- Distilled water
- Tissues

Lesson
In this experiment students will explore the effects of salt concentration in aquatic systems on seawater and freshwater plants. Plants move water in and out of cells via active and passive transport means. This transfer of water maintains an ideal pressure level which allows land plants to support themselves against the pull of gravity and aquatic plants to support themselves against the effects of water pressure. When plants are placed into saltwater the high concentration of salt outside of the cell membrane causes water to move out of the cell, unless the plant has an adaption that prevents this from happening. Students will observe the effects of salt concentration in an aquatic environment on plants adapted for freshwater and seawater environments.

Students will remove a single leaf from the freshwater plant and place it on a microscope slide. After which, students will cover the leaf with a cover slip. Students should focus the leaf under high power. Students should use a plastic pipette to place a drop of distilled water on the left side of the cover slip. They should then use a tissue to draw water across the slide between the cover slip and the slide. Students should document what the plant cells look like. Then, using a plastic pipette students should place a drop of salt water on the left edge of the cover slip. They should then use a tissue to draw water across the slide. Students should document what is happening to cells inside the leaf (e.g., water flowing in and it bursting, no water movement, or water flowing out and it shriveling). It may take a bit to see the movement. Students should repeat this with the seawater plant. Students should analyze their data and draw conclusions about the effects of salinity on plant cells. When plants are not in use it is important to keep them under growth lights.

For an extension, students can discuss if any of their plants have adaptations that enable them to live in a specific environment by observing the leaves closely using a compound microscope or hand lens. Students can also conduct this experiment using new leaves and higher concentrations of salt water if desired. For this extension, students will explore the independent variable of water salt concentration.

Name: ___________________________ **Date: _________________**

Salted Plants!

Plants move water into and out of their cells through active and passive transport. Today you will perform an experiment to determine the effects of water type on plants from freshwater and seawater environments.

What effect do you think water type has on freshwater plants?

What effect do you think water type has on seawater plants?

Conduct the experiment:

1. Remove a single leaf from the freshwater plant and place it on a microscope slide.
2. Cover your leaf with a cover slip and focus the leaf under high power on your microscope.
3. Place a drop of distilled water on the left side of the cover slip. Then use a tissue to draw water across the slide between the cover slip and the slide.
4. Document what the plant cells look like in the data table (e.g., water flowing in and it bursting, no water movement, or water flowing out and it shriveling).
5. Now, place a drop of salt water solution on the left edge of the cover slip. Use a tissue to draw water across the slide.
6. Document what is happening to cells inside the leaf. It may take a bit to see the movement.
7. Repeat this process with the seawater plant.

Data table:

	Freshwater Plant	Seawater plant
Distilled water		
Salt water		

Conclusions: Use your data to draw conclusions about the effects of water type on freshwater and seawater plants.

Culmination

Objective

Students should be able to synthesize information learned in this module and apply it to a real life scenario.

Lesson

This lesson provides students with a means to summarize their learning. This lesson can also be used as an assessment tool providing insights into student mastery of content in relation to adaptations of marine organism.

Students should be assigned a specific depth of the marine environment to research. Students should document the chemical and physical properties of this depth (the Marine Environments module can provide some useful information). Students should then be randomly assigned a marine organism, this can be completed by cutting out strips of paper, writing organisms on the strip, and having students pull strips out of a bucket. Then, students should research their organism. During which, students should identify and features that would allow the organism to live at their assigned depth and any features that would hinder survival. Students should then recreate their organism so it is capable of surviving at the assigned depth. Students can then present their original and recreated organisms to the class.

References and resources for teachers and students

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Dr. K. Denise Kendall is a graduate of the Department of Ecology and Evolutionary Biology at the University of Tennessee-Knoxville (2013). She holds a Florida Professional Teaching Certificate (Biology 6-12) from the University of West Florida. Dr. Kendall is committed to the advancement of science education in K-12 and higher education through the integration of authentic scientific experiences into course curricula.