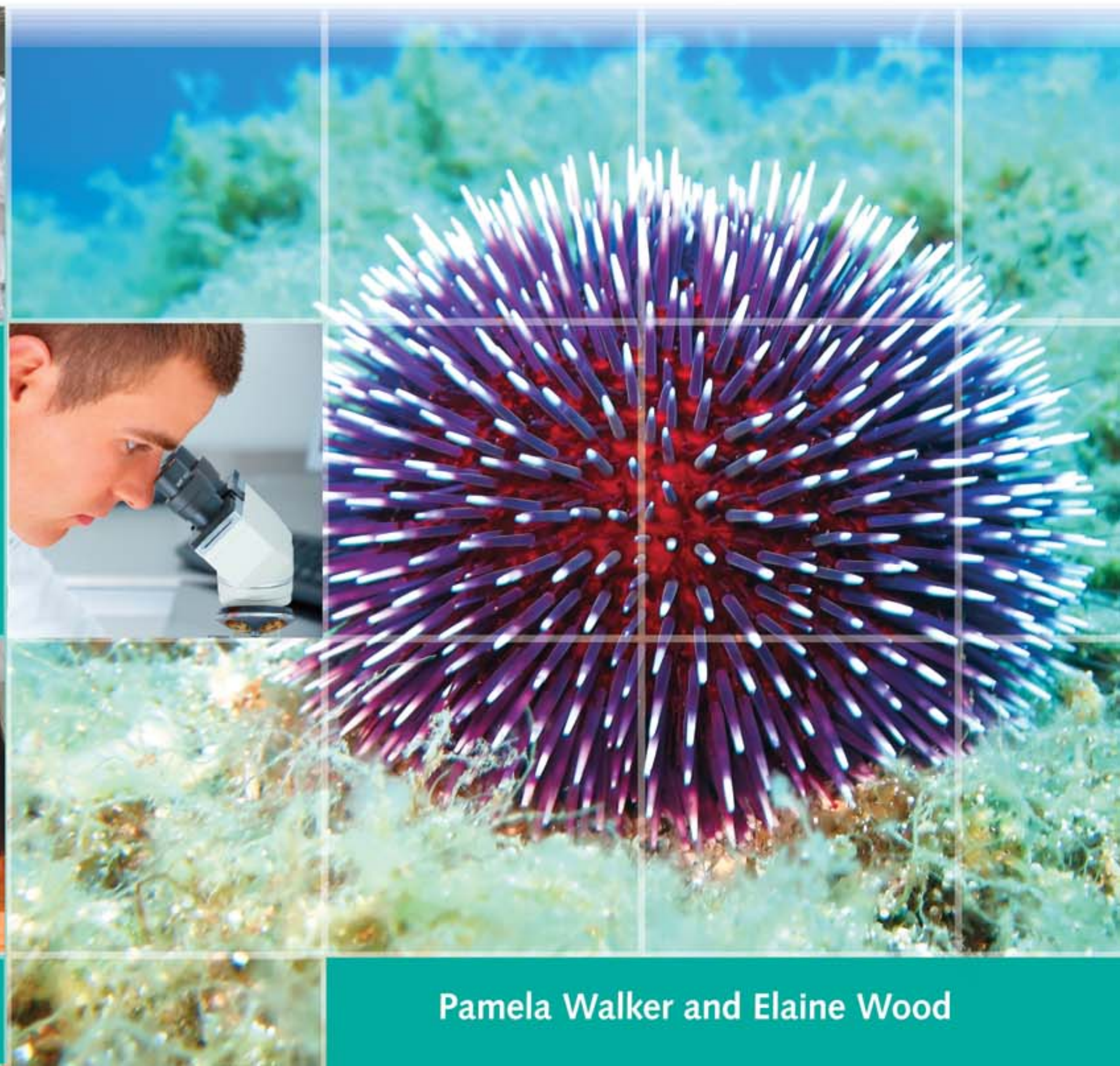
Facts On File Science Experiments

Marine Science Experiments



Pamela Walker and Elaine Wood

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Preface

For centuries, humans have studied and explored the natural world around them. The ever-growing body of knowledge resulting from these efforts is science. Information gained through science is passed from one generation to the next through an array of educational programs. One of the primary goals of every science education program is to help young people develop critical-thinking and problem-solving skills that they can use throughout their lives.

Science education is unique in academics in that it not only conveys facts and skills; it also cultivates curiosity and creativity. For this reason, science is an active process that cannot be fully conveyed by passive teaching techniques. The question for educators has always been, “What is the best way to teach science?” There is no simple answer to this question, but studies in education provide useful insights.

Research indicates that students need to be actively involved in science, learning it through experience. Science students are encouraged to go far beyond the textbook and to ask questions, consider novel ideas, form their own predictions, develop experiments or procedures, collect information, record results, analyze findings, and use a variety of resources to expand knowledge. In other words, students cannot just hear science; they must also do science.

“Doing” science means performing experiments. In the science curriculum, experiments play a number of educational roles. In some cases, hands-on activities serve as hooks to engage students and introduce new topics. For example, a discrepant event used as an introductory experiment encourages questions and inspires students to seek the answers behind their findings. Classroom investigations can also help expand information that was previously introduced or cement new knowledge. According to neuroscience, experiments and other types of hands-on learning help transfer new learning from short-term into long-term memory.

Facts On File Science Experiments is a twelve-volume set of experiments that helps engage students and enable them to “do” science. The high-interest experiments in these books put students’ minds into gear and give them opportunities to become involved, to think independently, and to build on their own base of science knowledge.

As a resource, Facts On File Science Experiments provides teachers with new and innovative classroom investigations that are presented in a clear, easy-to-understand style. Some areas of study in this multivolume set include forensic science, environmental science, computer research, physical science, weather and climate, and space and astronomy. Experiments are supported by colorful figures and line illustrations that help hold students' attention and explain information. All of the experiments in these books use multiple science process skills such as observing, measuring, classifying, analyzing, and predicting. In addition, some of the experiments require students to practice inquiry science by setting up and carrying out their own open-ended experiments.

Each volume of the set contains 20 new experiments as well as extensive safety guidelines, glossary, correlation to the National Science Education Standards, scope and sequence, and an annotated list of Internet resources. An introduction that presents background information begins each investigation to provide an overview of the topic. Every experiment also includes relevant specific safety tips along with materials list, procedure, analysis questions, explanation of the experiment, connections to real life, and an annotated further reading section for extended research.

Pam Walker and Elaine Wood, the authors of Facts On File Science Experiments, are sensitive to the needs of both science teachers and students. The writing team has more than 40 years of combined science teaching experience. Both are actively involved in planning and improving science curricula in their home state, Georgia, where Pam was the 2007 Teacher of the Year. Walker and Wood are master teachers who hold specialist degrees in science and science education. They are the authors of dozens of books for middle and high school science teachers and students.

Facts On File Science Experiments, by Walker and Wood, facilitates science instruction by making it easy for teachers to incorporate experimentation. During experiments, students reap benefits that are not available in other types of instruction. One of these benefits is the opportunity to take advantage of the learning provided by social interactions. Experiments are usually carried out in small groups, enabling students to brainstorm and learn from each other. The validity of group work as an effective learning tool is supported by research in neuroscience, which shows that the brain is a social organ and that communication and collaboration are activities that naturally enhance learning.

Experimentation addresses many different types of learning, including lateral thinking, multiple intelligences, and constructivism. In lateral thinking, students solve problems using nontraditional methods. Long-established, rigid procedures for problem-solving are replaced by original ideas from students. When encouraged to think laterally, students are more likely to come up with unique ideas that are not usually found in the traditional classroom. This type of thinking requires students to construct meaning from an activity and to think like scientists.

Another benefit of experimentation is that it accommodates students' multiple intelligences. According to the theory of multiple intelligences, students possess many different aptitudes, but in varying degrees. Some of these forms of intelligence include linguistic, musical, logical-mathematical, spatial, kinesthetic, intrapersonal, and interpersonal. Learning is more likely to be acquired and retained when more than one sense is involved. During an experiment, students of all intellectual types find roles in which they can excel.

Students in the science classroom become involved in active learning, constructing new ideas based on their current knowledge and their experimental findings. The constructivist theory of learning encourages students to discover principles for and by themselves. Through problem solving and independent thinking, students build on what they know, moving forward in a manner that makes learning real and lasting.

Active, experimental learning makes connections between newly acquired information and the real world, a world that includes jobs. In the twenty-first century, employers expect their employees to identify and solve problems for themselves. Therefore, today's students, workers of the near future, will be required to use higher-level thinking skills. Experience with science experiments provides potential workers with the ability and confidence to be problem solvers.

The goal of Walker and Wood in this multivolume set is to provide experiments that hook and hold the interest of students, teach basic concepts of science, and help students develop their critical-thinking skills. When fully immersed in an experiment, students can experience those "Aha!" moments, the special times when new information merges with what is already known and understanding breaks through. On these occasions, real and lasting learning takes place. The authors hope that this set of books helps bring more "Aha" moments into every science class.

Acknowledgments

This book would not exist were it not for our editor, Frank K. Darmstadt, who conceived and directed the project. Frank supervised the material closely, editing and making invaluable comments along the way. Betsy Feist of A Good Thing, Inc., is responsible for transforming our raw material into a polished and grammatically correct manuscript that makes us proud.

Introduction

Seen from the shore or the deck of a boat, the ocean is an immense world, gray and mysterious. Although the sea is home to millions of species, life there is essentially hidden from our view and from our easy access. Consequently, the sea reigns as the most unexplored region of Earth. Despite this, or maybe because of it, the marine environment is a captivating place that peaks our curiosity. In recent years, extensive research, which had to wait for the requisite technology, has revealed new discoveries and shown us that many more secrets are within our reach.

Marine science is multidisciplinary field that incorporates biology, chemistry, physics, geology, and environmental science. Research on the creatures in the sea is a biological science that includes the individual organisms, their interactions, and their ecosystems. The geology of the ocean examines hydrology, mineral cycles, and the seafloor. Scientists also study the watery environment's chemistry as well as the physics of waves and light. Because of global climate changes, understanding the ocean's ecology is an especially important part of marine research.

Marine Science Experiments is one volume of the new Facts On File Science Experiments set. The goal of this volume is to provide science teachers with 20 original experiments that convey basic principles of both physical and biological sciences related to the ocean. *Marine Science Experiments* is designed to help students understand the characteristics of the ocean and the marine life beneath the gray surface. Each experiment in the book is a proven classroom activity that broadens understandings of both scientific facts and the nature of science. Appropriate for both middle and high school classes, the investigations build on students' natural curiosity about the deep.

Experiments that are based on the biological sciences include "Taxonomy of Marine Fish," in which the Linnean system of classification is employed to identify fish by their physical characteristics. "Crowding in Fish" is an inquiry activity in which students develop a hypothesis and design an experiment to find out how the number of fish in a population affects the growth and development of individuals. In "Marine Plankton," students are introduced to some of the organisms that make up the marine plankton community. By microscopically examining organisms, students determine their feeding strategies and their positions in food webs.

“Salt Marsh Community” is an on-site experiment that guides learners through a field trip to a salt marsh to find, examine, and analyze the area’s residents. “Habitat Preference of Juvenile Fish” introduces the concept that not all habitats are equal and makes students aware of the advantages and disadvantages of different types of habitats for young fish. Organisms throughout the ocean have specific adaptations for their environment and lifestyles. In “Echinoderm Adaptations,” students examine a living starfish and make a model of its water vascular system.

In “Fertilization in Sea Urchins,” students learn more about the process of external reproduction, a common strategy in marine organisms. Most of the bioluminescent organisms on Earth are marine, yet few students have seen them. In “Bioluminescent Algae,” students examine glowing dinoflagellates and determine what stimuli make them flash. Fish live in all parts of the ocean, from the mud to the top of the water column. In “Fish Adaptations,” students learn about the structures and behaviors that enable animals to survive in every niche of the sea. “Which Seagrasses Do Marine Herbivores Prefer?” is an activity on the feeding preferences of two different species of marine herbivores. “Aquatic Herbicides Affect Nontarget Species” is an inquiry experiment in which students design procedures to find the effect of chemicals added to waterways on nontarget species.

The movement of water currents, the aerodynamics of waves, and the chemistry of water are elements of marine science that require understanding of some physics and chemistry. In “Staying Afloat,” students investigate the body shapes, sizes, and structures of planktonic organisms and create models that show adaptations to prevent sinking. The effects of temperature and salinity on water density and generation of ocean currents are evaluated in “The Oceanic Conveyer Belt.” The appearance of undersea life depends on the availability of light, a concept that students explore in “Ocean Regions.” Students use a hydrometer to measure variations in salt levels in “How to Measure Salinity.”

Marine geologists are interested in the structure and physical composition of the seafloor. One of the most useful geological tools is a seafloor map. In “Bathymetric Maps,” students research seafloor structures, make a model of some of these structures, and use the model to create a bathymetric map. Types of seafloor sediments are studied in “Ocean Sediments.” Students investigate techniques for acquiring sediment samples in “The Record in Ocean Sediments.”

One of the most timely areas of marine science is the study of ocean ecology and the impact of humans on the sea environment. "Bycatch During Fishing" helps students understand the source of bycatch and the problems involved in reducing the volume of bycatch. "Bioaccumulation in Killer Whales" demonstrates how toxins build up in the fatty tissues of sea mammals.

Not every student will have an opportunity to visit the sea and interact with it on a personal level, even though the ocean covers 70 percent of Earth's surface. Despite this, teachers can provide students with living and preserved sea organisms for observation and dissection. Classes can establish and maintain sea aquaria as miniature ecosystems, enabling students to learn about the ocean's significance in the biosphere. The authors of *Marine Science Experiments* hope that every science teacher will find experiments in this book that help them meet their classroom goals.

Safety Precautions

REVIEW BEFORE STARTING ANY EXPERIMENT

Each experiment includes special safety precautions that are relevant to that particular project. These do not include all the basic safety precautions that are necessary whenever you are working on a scientific experiment. For this reason, it is absolutely necessary that you read and remain mindful of the General Safety Precautions that follow. Experimental science can be dangerous and good laboratory procedure always includes following basic safety rules. Things can happen quickly while you are performing an experiment—for example, materials can spill, break, or even catch on fire. There will not be time after the fact to protect yourself. Always prepare for unexpected dangers by following the basic safety guidelines during the entire experiment, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual experiments. For one reason, we want you to take very seriously the safety precautions that are printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical.

Read the safety precautions here and at the beginning of each experiment before performing each lab activity. It is difficult to remember a long set of general rules. By rereading these general precautions every time you set up an experiment, you will be reminding yourself that lab safety is critically important. In addition, use your good judgment and pay close attention when performing potentially dangerous procedures. Just because the book does not say "Be careful with hot liquids" or "Don't cut yourself with a knife" does not mean that you can be careless when boiling water or using a knife to punch holes in plastic bottles. Notes in the text are special precautions to which you must pay special attention.

GENERAL SAFETY PRECAUTIONS

Accidents can be caused by carelessness, haste, or insufficient knowledge. By practicing safety procedures and being alert while conducting experiments, you can avoid taking an unnecessary risk. Be sure to check the individual experiments in this book for additional safety regulations and adult supervision requirements. If you will be working in a laboratory, do not work alone. When you are working off site, keep in groups with a minimum of three students per group, and follow school rules and state legal requirements for the number of supervisors required. Ask an adult supervisor with basic training in first aid to carry a small first-aid kit. Make sure everyone knows where this person will be during the experiment.

PREPARING

- Clear all surfaces before beginning experiments.
- Read the entire experiment before you start.
- Know the hazards of the experiments and anticipate dangers.

PROTECTING YOURSELF

- Follow the directions step by step.
- Perform only one experiment at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure there is adequate ventilation.
- Do not participate in horseplay.
- Do not wear open-toed shoes.
- Keep floor and workspace neat, clean, and dry.
- Clean up spills immediately.
- If glassware breaks, do not clean it up by yourself; ask for teacher assistance.
- Tie back long hair.
- Never eat, drink, or smoke in the laboratory or workspace.
- Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult.

USING EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives or other sharp, pointed instruments with care.

- Pull plugs, not cords, when removing electrical plugs.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Let your teacher know about broken glassware immediately.
- Do not use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Take care when working with any form of electricity.
- Use alcohol-filled thermometers, not mercury-filled thermometers.

USING CHEMICALS

- Never taste or inhale chemicals.
- Label all bottles and apparatus containing chemicals.
- Read labels carefully.
- Avoid chemical contact with skin and eyes (wear safety glasses or goggles, lab apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING SUBSTANCES

- Wear safety glasses or goggles, apron, and gloves when heating materials.
- Keep your face away from test tubes and beakers.
- When heating substances in a test tube, avoid pointing the top of the test tube toward other people.
- Use test tubes, beakers, and other glassware made of Pyrex™ glass.
- Never leave apparatus unattended.
- Use safety tongs and heat-resistant gloves.
- If your laboratory does not have heatproof workbenches, put your Bunsen burner on a heatproof mat before lighting it.
- Take care when lighting your Bunsen burner; light it with the airhole closed and use a Bunsen burner lighter rather than wooden matches.

- Turn off hot plates, Bunsen burners, and gas when you are done.
- Keep flammable substances away from flames and other sources of heat.
- Have a fire extinguisher on hand.

FINISHING UP

- Thoroughly clean your work area and any glassware used.
- Wash your hands.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Do not dispose of materials in the sink unless instructed to do so.
- Clean up all residues and put in proper containers for disposal.
- Dispose of all chemicals according to all local, state, and federal laws.

BE SAFETY CONSCIOUS AT ALL TIMES!

1. Taxonomy of Marine Fish

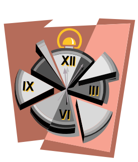
Topic

A taxonomic key can be used to identify marine fish.

Introduction

The *biodiversity* of living things on Earth is amazing. Because there are millions of different kinds of organisms, scientists classify all living things to facilitate study. The first and broadest level of classification is the kingdom. Carl Linnaeus (1707–78), an early *taxonomist*, put all living things in two kingdoms: Plantae and Animalia. The Fungi kingdom was added after scientists realized that mushrooms and their relatives were not plants. With the invention of microscopes, scientists were able to view one-celled organisms such as amoeba, so the kingdom Protista was established. The most recent kingdoms contain the smallest organisms, bacteria. The inhabitants of kingdom Archaebacteria are found in extreme environments. Common bacteria fall into the kingdom Eubacteria.

In the Linnean classification system, organisms are sorted in a hierarchical manner. Each kingdom is broken down into smaller groups called *phyla*. Further subdivisions include class, order, family, genus and species. The genus and species of an organism is used as its scientific name. Scientists draw on the evolutionary, biochemical, and physical characteristics of organisms to classify them. The physical characteristics are especially useful when identifying organisms in the field. *Taxonomic keys* are guides to help identify fish and other sea creatures from their physical traits. If you are looking at a fish that you cannot identify, you can use a taxonomic key to find its name. In the key, you read statements that describe two traits, then select the trait that fits the fish you are trying to identify. In this experiment, you will use a taxonomic key to identify some marine fish.



Time Required

30 minutes for Part A
30 minutes for Part B

Materials

- science notebook

Safety Note

Please review and follow the safety guidelines at the beginning of this volume.

Procedure, Part A

1. Examine the fish in Figure 1. Notice the locations of the dorsal, adipose, pectoral, pelvic, anal, and caudal fins. These fins are useful physical characteristics that can help identify fish. The dorsal fin may be soft along its entire length, or it may have a spinous section. Another identifier is the *lateral line*, which extends from the *operculum* to the caudal fin. Also notice the *barbels*, which are common in bottom-dwelling fish.
2. Examine the shapes of caudal fins shown in Figure 2. Characteristics of caudal fins are useful in identifying fish.

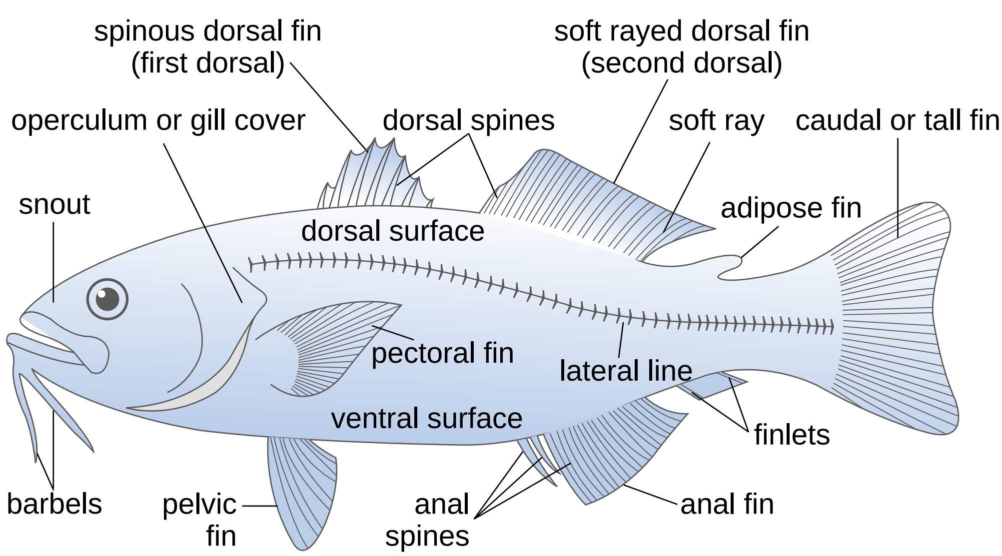


Figure 1

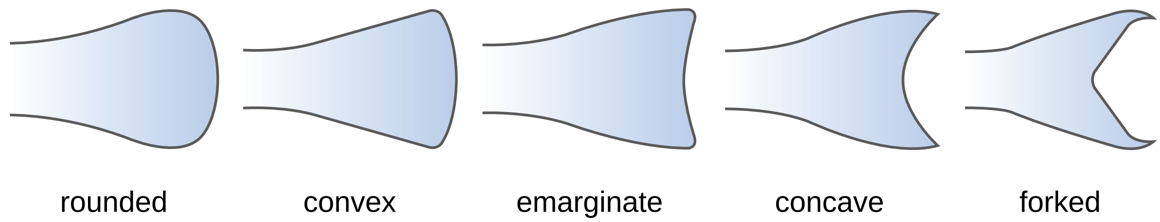


Figure 2

Caudal fins

3. Examine Fish 1 in Figure 3. Read statements 1a and 1b in the data table, Key to Marine Fish. Notice that statement 1a describes Fish 1. Statement 1a tells you to "Go to 2."
4. Read statements 2a and 2b. Fish 1 has a pelvic fin, so you select statement 2b, which tells you to "Go to 3."
5. Read statements 3a and 3b. The pelvic fin of Fish 1 extends from its head to tail. Therefore, you know that Fish 1 belongs to the family Nemichthyidae, a group commonly known as snipe eels.
6. Examine Fish 2 and use the "Key to Marine Fish" to find its family.
7. Repeat step 6 for Fish 3, 4, 5, 6, and 7.

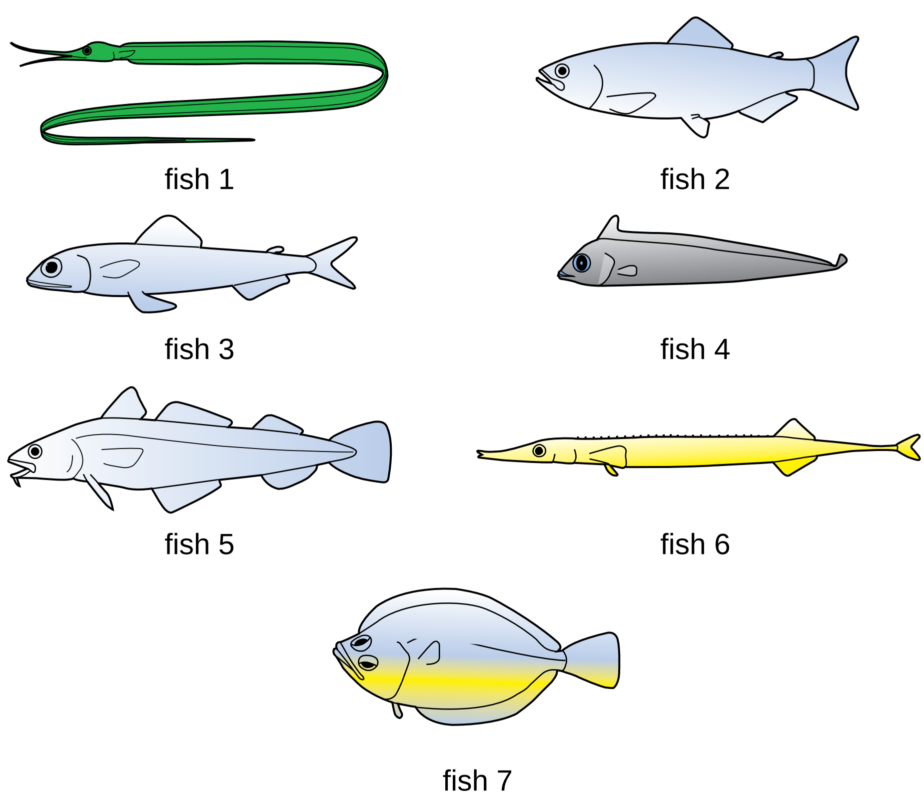
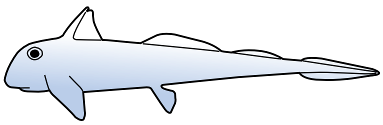


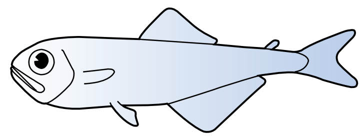
Figure 3

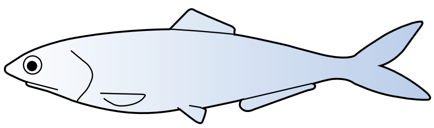
Data Table: Key to Marine Fish	
If	**Then**
1a. Dorsal fin extends from head to tail	Go to 2
1b. D'orsal fin does not extend from head to tail	Go to 4
2a. No pelvic fin	Family Trachipteridae (ribbonfish)
2b. Pelvic fin	Go to 3
3a. Pelvic fin extends from head to tail	Family Nemichthyidae (snipe eels)
3b. Pelvic fin does not extend from head to tail	Family Bothidae (f ounders)
4a. One short dorsal fin	Go to 5
4b. More than one dorsal fin	Family Gadidae (cods)
5a. Dorsal fin(s) preceded by bony spines	Family Aulorhynchidae (tubesnouts)
5b. Dorsal fin(s) not preceded by bony spines	4 Go to 6
6a. Tail forked	Family Synodontidae (lizardfishes)
6b. Tail concave, not forked	Family Salmonidae (salmon)

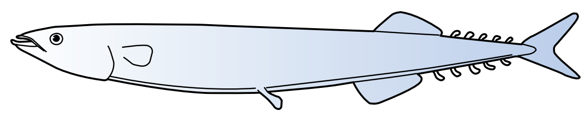
Procedure, Part B

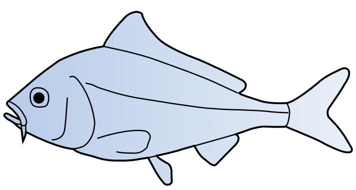
1. Examine the fish in Figure 4. Each fish is shown with its family name.
2. Create your own key to identify these fish.
3. Exchange keys with a classmate. Use your classmate's key to identify each fish.

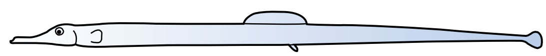

Family Chimaeridae (chimaeras)

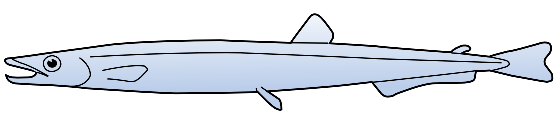

Family Myctophidae (lanternfish)

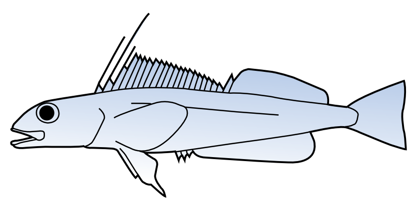

Family Engraulidae (anchovies)

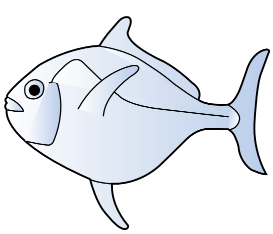

Family Scomberesocidae (sauries)


Family Cyprinidae (carp)


Family Syngnathidae (pipefishes)


Family Paralepididae (barracudinas)


Family Zaniolepididae (combfishes)


Family Lamprididae (opahs)

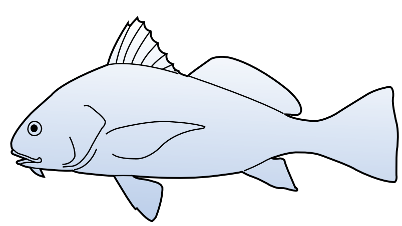

Family Sciaenidae (drums)

Figure 4

Analysis

1. Why do you think scientists use taxonomic keys?
2. List the family names of fish 2 through fish 7 in Figure 3.
3. What are some of the fish characteristics that you used to make your own fish key in part B?
4. What are some other characteristics of fish that you might use in making a taxonomic key?
5. Name five other marine organisms that could be identified with taxonomic keys.

What's Going On?

Fish are divided into two large groups: cartilaginous fish and bony fish. The first group includes sharks and rays, whose skeletons are made of cartilage. The second group is much larger than the first, and includes all other types of fish. All fish are *ectotherms*, meaning that their body temperature depends on the temperature of the water in which they are swimming. These aquatic animals get dissolved oxygen from the water through their gills.

Bony fish are covered with scales and a layer of mucus, which makes them slippery and reduces friction. Their gills are protected with an operculum. Along the length of the body of a bony fish is a lateral line, a canal just under the skin that detects movement in the water. The dorsal and ventral fins of a fish provide stability. Propulsion is provided by movement of the entire body, although the caudal fin helps the fish move forward. The paired pectoral and pelvic fins make it possible for the fish to move up and down in the water and come to a stop.

Connections

Fish are highly adapted for their environments and show variations in mouth size and shape, fins, and size and arrangement of eyes. A mouth at the end of a fish's snout is specialized for feeding in open water. On the other hand, if the mouth is angled downward and the upper jaw extends over the lower jaw, the fish feeds on the bottom. Strong jaws with teeth indicate a predator, whereas small, sucker shaped mouths are designed for eating plants or small organisms. Barbels around the mouth are *adaptations* seen on bottom-dwelling species because they provide input about objects they touch.

A long, eel-shaped fish is good at hiding in rocks and plants. Torpedo-shaped fish are fast swimmers. A round fish is difficult for predators to swallow, and a fish that is f attened on the belly side lives on the bottom. Many of the fast swimmers have large caudal fins to provide an extra push. Some fish have spines in or near their fins for protection. Fish with both eyes on the same side of the head catch prey by lying in wait on the bottom. Small eyes are found in open water fish and large eyes are typical of fish that live in deep water where light is minimal.

Want to Know More?

See appendix for Our Findings.

Further Reading

Dedicated Sharks Site. “Shark Classification.” Available online. URL: http://www.angelfire.com/hi2/haaitje/kindsofsharks/sharkclassification.html. Accessed June 11, 2009. A diagram is used to explain how sharks are classified.

Kazlev, Alan M. “Carl von Linné and the Linnean System of Nomenclature,” May 20, 2002. Available online. URL: http://www.palaeos.com/systematics/Linnean/Linnean.htm. Accessed January 25, 2010. The history and steps of Linnean classification are explained, and examples are provided on this Web site.

Marinebio. “The Naming of Life: Marine Taxonomy.” Available online. URL: http://marinebio.org/oceans/marine-taxonomy.asp. Accessed January 16, 2010. This Web page discusses the Linnean system and cites examples of marine organisms.

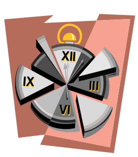
2. Crowding Among Fish

Topic

The number of fish in a population affects the growth and development of individuals.

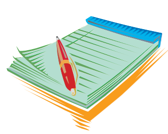
Introduction

Like all living things, fish require food, water, and space to survive. The amount of space available to fish affects their behavior, rate of growth, and rate of reproduction. Fish stake out *territories*, areas in which they live, hunt for food, and raise their young. In the wild, territories vary in size, depending on the species of fish. In some cases, several species of fish share territories. At other times, members of a species defend their territory, working hard to keep out intruders. In this experiment, you will find out how crowding and loss of territory affects the rate at which fish grow.



Time Required

55 minutes on day 1
30 minutes a day twice a week for 1 month



Materials

- 2 fish tanks with pumps
- fish tank divider or piece of screen
- 30 minnows
- fishnet
- fish food
- ruler
- access to dechlorinated water
- science notebook

Safety Note **Please review and follow the safety guidelines at the beginning of this volume.**

Procedure

1. Your job is to design and perform an experiment that determines how crowding affects the growth rate of fish.
2. You can use any of the supplies provided by your teacher, but you will not need to use all of them.
3. Answer Analysis question 1.
4. Keep in mind that to find out how crowding affects the rate of fish growth, you must have a *control group*, a group of fish that is not crowded. All other variables in the experiment, such as water temperature, amount of food, and availability of oxygen, must be the same for your experimental group and your control group.
5. Before you conduct your experiment, decide exactly what you are going to do. Write the steps you plan to take (your experimental procedure) and the materials you plan to use (materials list) on the data table. Show your procedure and materials list to the teacher. If you get teacher approval, proceed with your experiment. If not, modify your work and show it to your teacher again.
6. Once you have teacher approval, assemble the materials you need and begin your procedure.
7. Collect your results on a data table of your own design.
8. Answer Analysis questions 2 through 5.

Analysis

1. Write a hypothesis stating how you think crowding affects the growth rate of fish.
2. What is the control in this experiment?
3. Why must an experiment have a control?
4. Was your hypothesis correct? Explain why or why not.
5. If you were to conduct this experiment again, how would you improve it?

Data Table	
Your experimental procedure	
Your materials list	
Teacher's approval	

What's Going On?

In this experiment, you are using minnows, which are freshwater fish, whose responses to crowding are very similar to those seen in marine fish. One way to find out how crowding affects the growth of fish is to set up two small tanks, one with just a few fish and one with two or three dozen (see Figure 1). To measure the rate at which fish grow, you must first know the length of all the existing fish. Each fish can be gently removed from the tank with a net for a few seconds to find its length from tip of the snout to tip of the tail (see Figure 2). After measuring, the fish can be transferred to a small holding bowl until all fish have been measured. Excessive handling harms fish, so measurements must be taken quickly and without damaging the animals in any way.

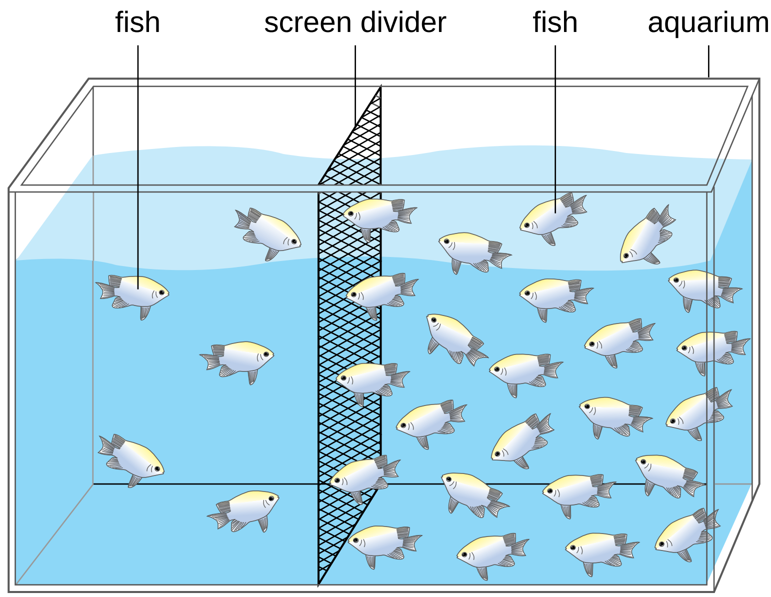


Figure 1

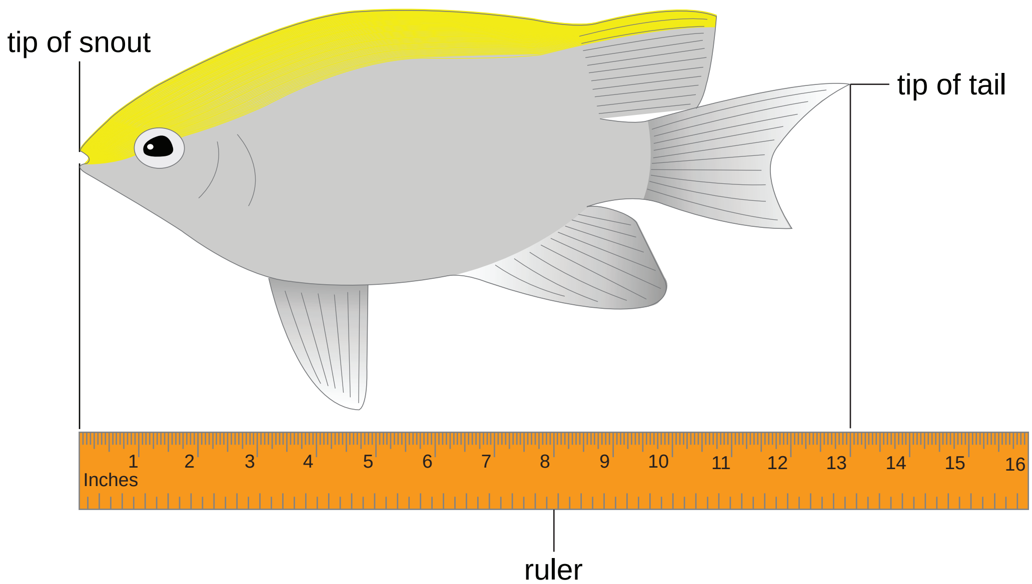


Figure 2

Some studies of fish populations have shown that fish are sensitive to crowding. Because there is less food for each individual, crowding slows or stops growth. In addition, fish in crowded situations tend to reproduce less often. Furthermore, closeness makes it easy to transfer disease and parasites from one fish to another.

In this experiment, you were able to count the number of individuals in both the control and the experimental populations. In the wild, scientists must use different techniques. One method, known as mark and recapture, traps animals, marks them with some identifying tag or label, then releases them back into the wild. Later, animals from the same population are captured again. The number of individuals recaptured can be used to estimate the population size.

Connections

In response to dwindling wild fish populations, some people are turning to fish farming, one type of *aquaculture*. Other types of animals raised in aquaculture include shrimp, oysters, and clams. Fish farming is the fastest-growing type of animal farming in the world. About one-half of all fish consumed are produced in aquaculture. Several marine species of fish are currently being farmed, including salmon, cod, f ounder, and tuna. Finding the optimal combination of water chemistry, physical location, space, sunlight, and population size is tricky for fish farmers.

On fish farms, large numbers of animals are fed and raised within a relatively small area. Such arrangements have a significant impact on the environment. Fish feces and pieces of uneaten fish food fall to the sediments below the pens. These pieces of organic matter affect the normal community of benthic organisms, those that live in the sediments. Oxygen-consuming bacteria f ourish on the waste and reduce the amount of dissolved oxygen available to sediment communities. Some organisms, especially mollusks, echinoderms, and crustaceans, die. Opportunistic species such as *polychaete worms* move in, changing the community.

Because large populations of fish produce tons of waste, the water chemistry of the area is affected. Water traveling through a fish farm picks up ammonia and loses oxygen. Changes in water chemistry affect *phytoplankton* in the area. In addition, outbreaks of diseases on fish farms can spread to wild fish populations. To combat disease, farmers use antibiotics, which are also released into the water and impact the environment.

Want to Know More?

See appendix for Our Findings.

Further Reading

Flores, Rosanna. "Observations of Territorial Behavior of *Stegastes fuscus*," 2003. Available online. URL: http://dominica.tamu.edu/student%20projects/Dominica%20Projects%20pdf%20copy/Flores_Rosanna.pdf. Accessed June 7, 2009. Flores conducted a study to document the behavior of *S. fuscus*, the dusky damselfish, when other fish species invade its territory.

Goldburg, Rebecca J., Matthew S. Elliott, and Rosamond L. Naylor. "Marine Aquaculture in the United States," Pews Ocean Commission, 2001. Available online. URL: http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Reports/Protecting_ocean_life/env_pew_oceans_aquaculture.pdf. Accessed May 3, 2009. In an extensive report, the authors discuss environmental problems that result from aquaculture.

Weber, Gregory, Scott Lankford, Jeff Silverstein, Roger Vallejo, and Timothy Welch. "Cortisol Response to Crowding Stress: Heritability and Association with Disease Resistance to *Yersinia Rackeri* in Rainbow Trout." Available online. URL: http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=204148. Accessed October 10, 2009. The authors explain how crowding stresses rainbow trout and makes them vulnerable to disease.

3. Marine Plankton

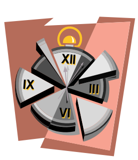
Topic

Plankton organisms are members of most marine food webs.

Introduction

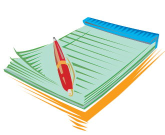
Have you ever gone swimming in the ocean and swallowed a mouthful of seawater? If so, you probably got a sip of *plankton* in that swallow. Plankton is a community of small, marine organisms that are primarily transported by water movement rather than by their own swimming ability. Organisms that make up plankton can be divided into two large groups based on how they get food: *Phytoplankton* are photosynthetic organisms such as diatoms and dinof agellates and, *zooplankton* are *heterotrophs* and include copepods, arrow worms, and jellyfish. A variety of plankton is shown in Figure 1.

All of the plankton organisms are members of an ecosystem. In every ecosystem, the Sun's energy is captured by *autotrophs*, organisms that contain *chlorophyll* and other pigments. Autotrophs make up the first *trophic*, or feeding, level of a food chain. Organisms that acquire energy by feeding on autotrophs make up the second trophic level. Members of the second trophic level provide energy to the third trophic level. In some plankton food chains, there can be as many as six trophic levels; all but the first are *heterotrophs*, organisms that cannot synthesize their own food. A group of interconnected food chains make up a *food web*. In this experiment, you will examine a sample of plankton, identify the organisms, and determine their feeding relationships.



Time Required

55 minutes



Materials

- plankton sample
- dissecting microscope

- compound light microscope
- microscope slides
- cover slips
- Petri dish
- science notebook

Safety Note

Please review and follow the safety guidelines at the beginning of this volume.

Procedure

1. Pour a small sample of plankton in one half of a Petri dish.
2. Place the sample on a dissecting microscope and turn on the light below the specimen.
3. Focus the microscope on low power and scan the Petri dish slowly to locate the organisms. As you are observing, notice the different kinds of organisms. Compare the organisms in the Petri dish to those in Figure 1 and identify as many as possible. Write the names of each type organism, and the number of organisms seen, in your science notebook. Make a note of any organisms that are not in Figure 1. Sketch these organisms in your science notebook.
4. Repeat step 3 using high power on the dissecting microscope.
5. If you see one organism eating another, make a note of it. (Preserved organisms will not be moving or eating.)
6. To see extremely small members of the plankton community, make a wet mount slide of the plankton sample and view it under the compound light microscope. Write the names of each type organism, and the number of organisms seen, in your science notebook.
7. In your science notebook, draw a food web of the organisms that you saw in the lab. Straight lines with arrows indicate the direction in which energy moves (from the organism being consumed to the consumer). When drawing your food web, use solid straight lines if you are certain of a feeding relationship. For example, if you saw a copepod eat a diatom, use a solid straight line with an arrow on one end. If you are not certain, but you think that a feeding relationship exists, use a dotted line.

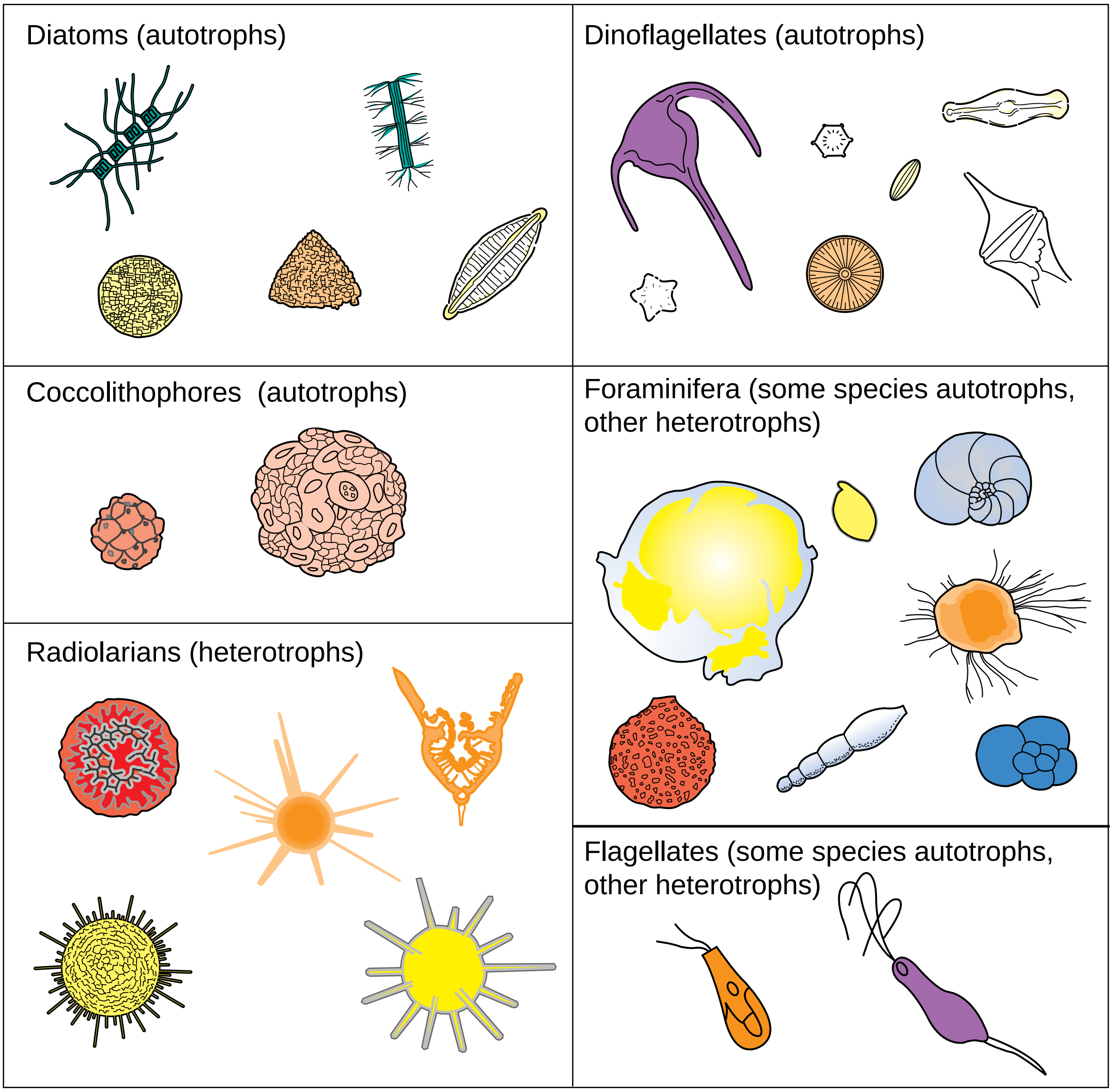


Figure 1

Some plankton organisms

Analysis

1. What kinds of organisms serve as the basis of the plankton food web?
2. Did you find more organisms on the first or second trophic level?
3. How do the photosynthesizers in the plankton ecosystem differ from photosynthesizers in terrestrial ecosystems?
4. Describe two ways in which members of the zooplankton move.
5. Some ecosystems are described as "closed" because they are self-sufficient and not inf uenced by other organisms. Ecosystems that are "open" are ones that interact with other ecosystems. Would you describe the plankton ecosystem as open or closed? Explain your reasoning.

What's Going On?

The species and numbers of plankton organisms found in a sample of sea water depend on where, how, and at what depth the sample was collected. A plankton net (Figure 2) is one of the best devices for collecting samples. Some nets are designed to be pulled by a person walking along the shore, while others are pulled by boats in the open ocean.

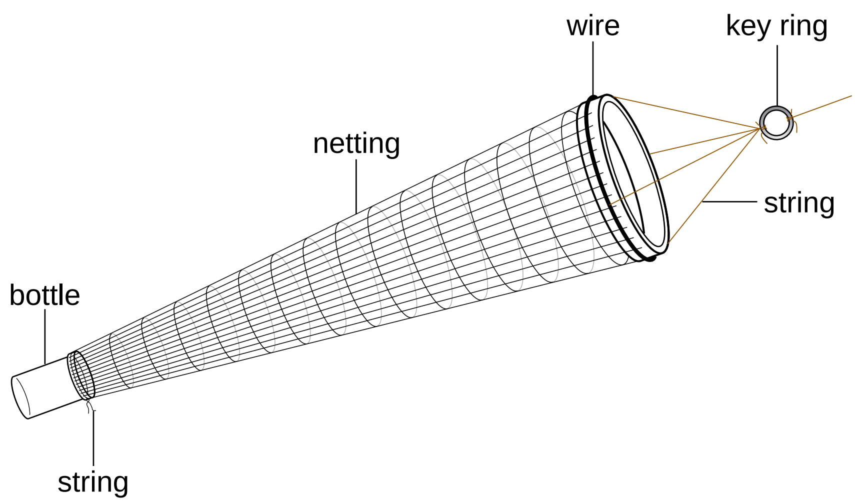


Figure 2

Plankton net

In the spring, when temperatures and hours of sunlight are increasing, phytoplankton populations grow rapidly. With plenty of food available, the zooplankton population also increases. When planktonic organisms die, they drop to the seaf oor, returning the nutrients tied up in their bodies to the ocean. Dead plankton also serve as food for bacteria and fungi, important decomposers in marine food webs. During summer months, seawater forms warm layers on top and cooler layers below. Because living plankton are at the top of the water column and the nutrients they need for growth are on the seaf oor, growth of the plankton community slows. In the fall, the water column undergoes mixing, bringing nutrients up from the seaf oor to the surface. This leads to another period of rapid growth. Growth slows in the winter when temperatures are cool and light levels are low.

Connections

Although marine phytoplankton are very small organisms, there are trillions of them living in the oceans. More than 50 percent of the

Earth's photosynthesis is carried out by marine phytoplankton. Like all photosynthetic things, they use carbon dioxide, as shown in the equation:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Phytoplankton remove 30 to 50 percent of the carbon dioxide produced by combustion of fossil fuels such as coal, oil, and gasoline. This means they take more than 3 billion tons (about 2,722 billion kilograms [kg]) of the gas from our atmosphere each year. In the process of photosynthesis, phytoplankton produce oxygen gas: More than 50 percent of the oxygen worldwide comes from phytoplankton.

The rate at which phytoplankton can carry out photosynthesis is influenced by water temperature. Photosynthesis slows when water temperatures increase to a critical temperature. Rising water temperatures are related to *global warming*, a general increase in the Earth's average surface temperature. Some scientists have suggested that "fertilizing" the ocean's phytoplankton with nutrients such as iron would increase the rate of marine photosynthesis and help slow global warming and provide even more oxygen. Others disagree, pointing out that we do not know the consequences of changing the ocean ecosystems.

Want to Know More?

See appendix for Our Findings.

Further Reading

Amber, Julie W., and Nancy M. Butler. "Microscopic Plants and Animals of the Ocean: Introduction to Marine Plankton," NASA, June 1, 2009. Available online. URL: http://phytoplankton.gsfc.nasa.gov/risingtides/pdf/RisingTides_page31-38.pdf. Accessed June 8, 2009. This Web page covers types of plankton and the organisms in planktonic food webs.

EurekAlert! "Iron and Biological Production in the High-Latitude North Atlantic," September 7, 2009. Available online. URL: http://www.innovations-report.com/html/reports/earth_sciences/iron_biological_production_high_latitude_north_135580.html. Accessed October 10, 2009. Scientists report that iron regulates plankton production in the North Atlantic.

Nature Works. "Plankton," New Hampshire Public Television, 2009. Available online. URL: http://www.nhptv.org/NATUREWORKS/nwep6d.htm. Accessed June 8, 2009. This Web page provides great descriptions and some clear line drawings of plankton organisms.

4. Salt Marsh Community

Topic

Life in a salt marsh is dictated by the movement of the tides.

Introduction

A salt marsh is an intertidal zone located between land and the sea or a *brackish* area, such as an *estuary* or bay. Living conditions for organisms in the salt marsh change with the tides. Areas are alternately f ooded and exposed to the Sun. The inhabitants, such as those shown in Figure 1, must be able to live in saltwater during high tide and avoid drying at low tide. Some organisms evolved by developing adaptations that help them survive these changing conditions. For example, *cordgrass* (Figure 2), the dominant type of plant, has special glands that excrete salt. Close examination will reveal tiny salt crystals along the length of the plant leaves.

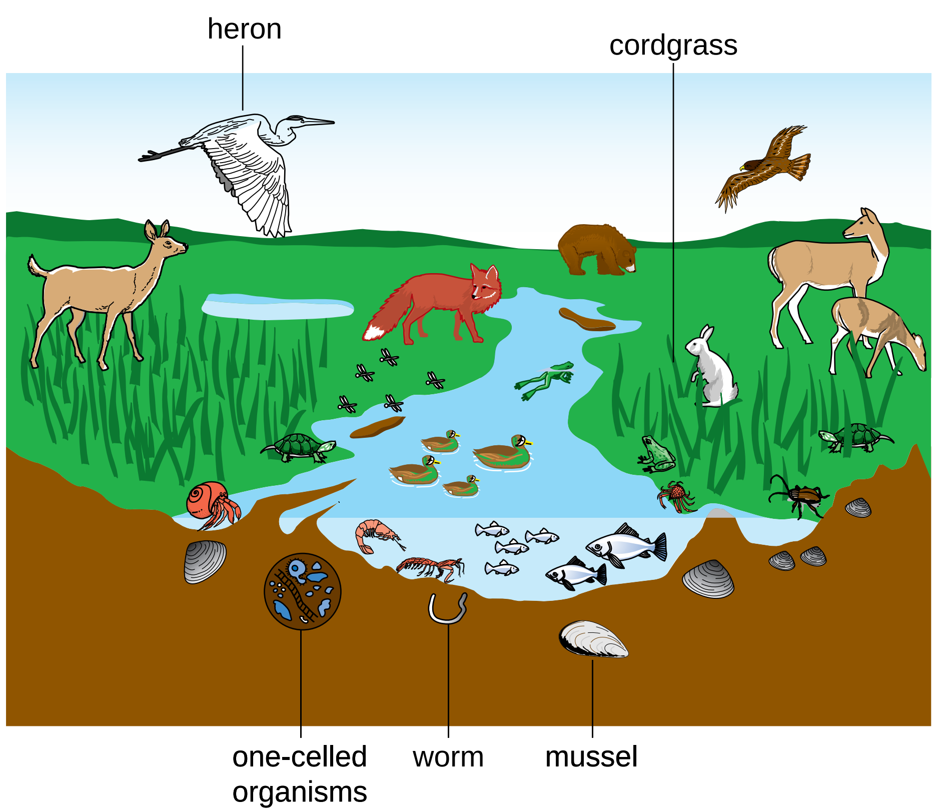


Figure 1

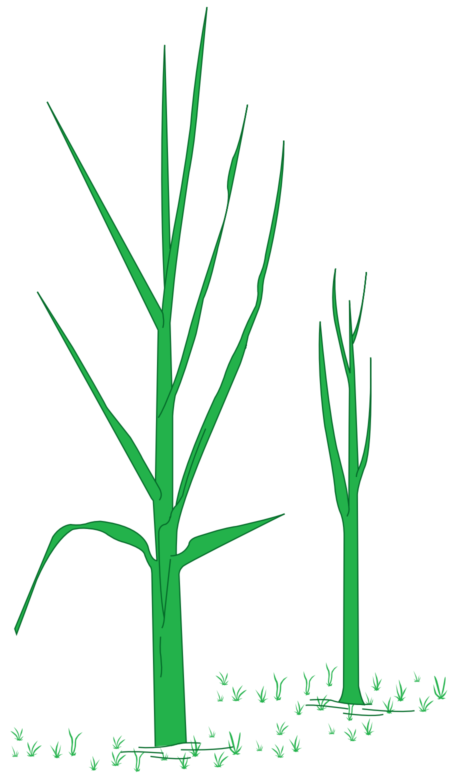


Figure 2
Cordgrass

Salt marshes have different zones based on how often they are flooded by the tides. Mudflats or sand flats, the areas closest to the water, are covered with sediment delivered with each incoming tide. The low marsh is the grassy region that is affected by normal tides. The high marsh is the adjoining, landward regions that are only flooded during extreme high tides. In this experiment you will examine the inhabitants of these zones of a salt marsh.

Time Required

90 minutes for part A
40 minutes for part B

Materials

- access to a salt marsh
- access to a dry outdoor area or a large room

- identification book on salt marsh organisms
- waterproof boots
- shovel
- screen or sieve
- hula hoop
- meterstick
- science notebook

Safety Note **Take care when working outdoors. Please review and follow the safety guidelines at the beginning of this volume.**

Procedure, Part A

1. Follow your teacher to a designated area of the salt marsh during low tide.
2. Observe the salt marsh. Notice that there is a high marsh region, the part that is only covered by high tide occasionally, and a low marsh, which is covered by high tide each day. In your science notebook, describe the differences in appearance in these two regions.
3. From the point where the plant life ends in the low marsh, measure about 10 feet (ft) (3 meters [m]) toward the water. Place the hula hoop on the mud at this point. In your science notebook, record all of the materials and organisms that you see on top of the mud inside the hula hoop. If you do not know the names of some organisms, sketch or describe them and look them up when you return to the classroom.
4. Dig into the mud to a depth of about 6 inches (in.) (15 centimeters [cm]) in one spot within the hula hoop. Place the mud on a screen and gently sieve it to find the organisms within. (Dip the screen into water to help clear away the mud.) Record the materials and organisms you find in your science notebook. When you are finished, replace the mud in the hole and leave the area as much like you found it as possible.
5. Move 10 ft (3 m) toward the water. Repeat steps 3 and 4 until you reach the water's edge.

6. In a dry location (outdoors or in the classroom), create a data table to organize your findings. Use books on salt marsh organisms to identify any specimens that you do not know.

Procedure, Part B

1. Your teacher will assign you a role to play as a component of the salt marsh ecosystem.
2. Follow your teacher to an outdoor area or a large room.
3. Designate the following regions of the outdoor area or large room: high marsh, low marsh, mudf ats, ocean.
4. Based on your role, go to the region of the salt marsh where you feel you should be located. If you and several other people have the same role, space yourself appropriately through the salt marsh.
5. When the teacher says, "The tide is coming in," the "saltwater" people will slowly move (as a tide) from the water location toward (but not into) the upper marsh. As saltwater moves in, some of the positions of other people will change. Some individuals will travel with the water. Others will move to avoid the water.
6. When the teacher says, "The tide is moving out," the "saltwater" people will slowly turn and move back to the water. As the saltwater moves out, some of the postions of other people will change. Some may travel with the water. Others may curl up or burrow in the mud to avoid drying.
7. After the tide has moved in and out one time, discuss the activity. Did everyone play their role as you expected them to? If not, discuss any changes that may need to be made, then repeat steps 5 and 6.
8. When the teacher says, "The tide is coming in, but it is unusually high," the "saltwater" people move slowly toward land because the tide will cover the mudf ats, low marsh, and high marsh.
9. When the teacher says, "The tide is moving out," the "saltwater people move back to the ocean.
10. After the tide moves out, discuss the activity. Suggest any changes that you feel need to be made to make the activity more accurate.

Analysis

1. Why do you find different kinds of plants in the high marsh and in the low marsh?

2. How do you think the incoming tide affects temperatures in the salt marsh during summer months? During winter months?
3. How might life in the salt marsh change if the cordgrass died?
4. Draw a food web of the salt marsh based on organisms in part B.

What's Going On?

Plant diversity in salt marshes is low because of the high salinity and the low-oxygen conditions of the soil. Cordgrass is one of the dominant salt marsh plants because of its adaptations to this unique environment. Some insects and a few other organisms feed on cordgrass directly. When cordgrass dies, it breaks off and becomes part of the *detritus*, the dead and decaying matter. Some decaying cordgrass stays in the marsh, but much is washed into the adjoining larger body of water where it provides nutrients to organisms living there.

The lives of many animals are interlinked with cordgrass. For example, mussels cling to the roots of the plant to avoid being washed out to sea with low tide. The mussels release phosphorous and nitrogen, two nutrients that are essential for plant growth. When the tide is in, mussels feed through a siphon, a tubelike structure that pulls water into the body where it is filtered for nutrients (see Figure 3). When the tide is out, mussels close their two shells, keeping their gills wet with trapped moisture. Another type of animal, fiddler crabs, feed on detritus that collects around the roots of cordgrass. As they search for food, they dig holes that keep the roots oxygenated. By increasing oxygen in the soil, the crabs also speed decomposition of organic matter, creating more detritus.

Connections

Economically, salt marshes are not very important. But from the environmental point of view, they are critical. Salt marshes are some of the most productive ecosystems on Earth. Cordgrass that grows in the marshes provides the basis for a food web that supports hundreds of types of living things. In addition, cordgrass provides hiding places and food for young fish and larval forms of many invertebrates.

The soil and plants in salt marshes serve as filters that remove pollutants from water. Some marsh plants break down toxins into harmless compounds, up to a point. There is a limit to how much pollution a marsh can handle. When toxin levels are extremely high, organisms

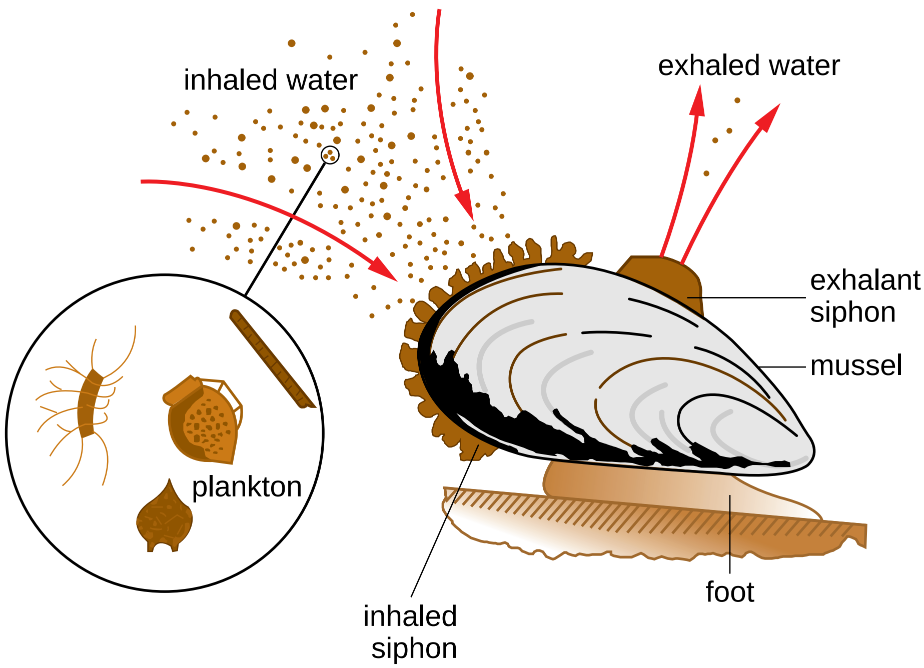


Figure 3

in the marsh suffer. Salt marshes also serve as natural buffer zones between the ocean and land. During storms, they slow storm surges and reduce erosion because the plants and their extensive root systems hold sediment, protecting inland areas.

Want to Know More?

See appendix for Our Findings.

Further Reading

EPA. "Marshes," October 21. 2008. Available online. URL: http://www.epa.gov/owow/wetlands/types/marsh.html. Accessed November 8, 2009. This Web site describes the characteristics and functions of marshes.

National Park Services. *Cumberland Island, An Ecological Survey of the Coastal Region of Georgia*, NPS Scientific Monograph No., 3, Chapter 4, "The Marshes," April 1, 2005. Available online. URL: http://www.nps.gov/history/history/online_books/science/3/chap4.htm. Accessed June 10, 2009. Written for the advanced high school student, this article reports in detail the types and number of organisms living in a Georgia salt marsh.

University of Florida. All About Wetlands, "Gulf Coast Salt Marshes." Available online. URL: http://wetlandextension.ifas.uf .edu/types/gulfcoastmarsh.htm. Accessed June 10, 2009. This Web page gives the basics of salt marshes, their inhabitants, and their locations and provides links to other excellent resources.

Wenner, Elizabeth. "Dynamics of the Salt Marsh," Sea Science. Available online. URL: http://www.dnr.sc.gov/marine/pub/seascience/dynamic.html. Accessed June 10, 2009. Wenner explains how cordgrass supports other organisms that make their homes in the salt marsh.

5. Habitat Preference of Juvenile Fish

Topic

Young fish select habitats where they can find food and avoid predators.

Introduction

When you open a menu in your favorite restaurant, you probably see a few seafood items. Seafood, which includes shrimp, crab, squid, and fish, is supplied to restaurants by commercial fishermen. In the United States, the Gulf of Mexico is a prime fishing region. Over the last several years, several commercially desirable fish species have been disappearing because of *overfishing*. Red snapper (Figure 1) is one of these species. The Gulf of Mexico Fisheries Management Council has set up guidelines to help restore red snapper to the gulf. For example, the council has established size limits so that fishermen will not remove young, immature fish. In addition, the council has set fishing quotas to prevent a few fishermen from taking all of the available catch. However, these strategies have not been enough. The council is now trying to protect the very young fish by supplementing their natural habitat. In this experiment, you will find out what kind of habitat is preferred by young fish.

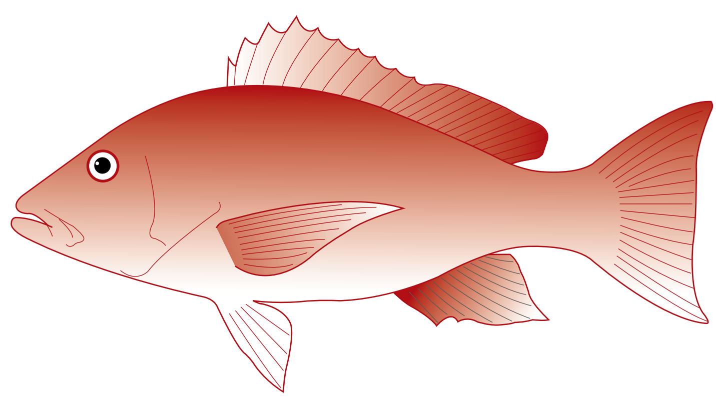
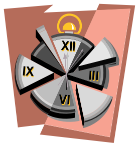


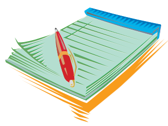
Figure 1

Adult red snapper



Time Required

30 minutes for part A
30 minutes for part B
30 minutes a day for 4 days for part C



Materials

- aquarium
- aquarium pump
- aquarium gravel
- 5 or 6 aquarium plants
- access to dechlorinated water
- fish food
- 5 or 6 sticks or dead stems, long enough to extend from the bottom of the aquarium to the top
- 10 small minnows
- clock or watch
- science notebook

Safety Note

Please review and follow the safety guidelines at the beginning of this volume.

Procedure, Part A

1. Assemble the aquarium.
2. Fill the aquarium with dechlorinated water and turn on the pump.
3. Let the aquarium sit overnight.

Procedure, Part B

1. Divide your aquarium into three habitats: an open area, an area with plants, and an area with sticks (see Figure 2). To do so:

a. In one-third of the aquarium, secure one end of the plants in gravel.

b. In one-third of the aquarium, arrange the sticks or stems.

c. Leave one-third of the aquarium open.

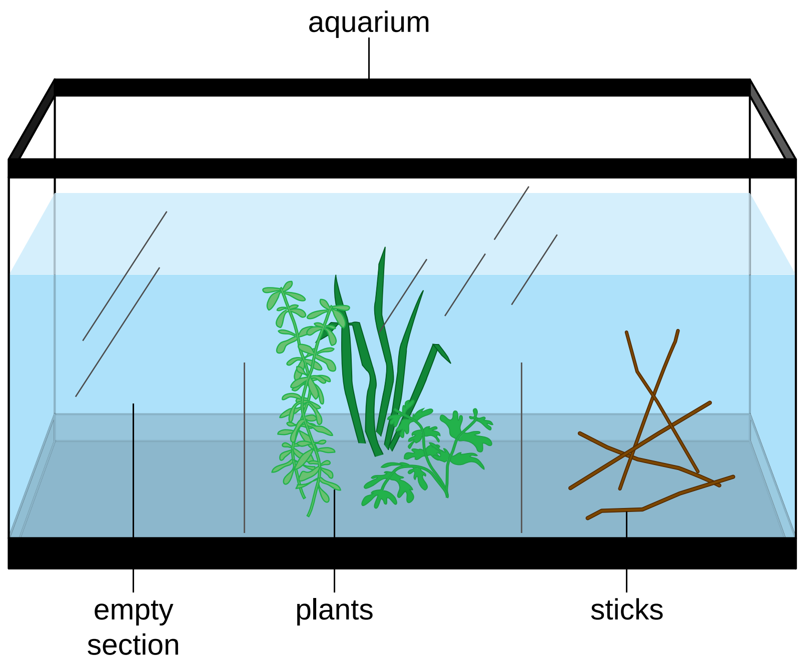


Figure 2

2. Introduce the minnows. Let the aquarium sit overnight.
3. Answer Analysis questions 1 and 2.

Procedure, Part C

1. In your science notebook, create a data table like the one on page 29, but extend yours to include 15 rows. Write the date and time at the top of the data table. Observe the minnows for 15 minutes at a time. Every minute, write the number of fish you see in each area of the aquarium in the correct column of the data table.
2. Repeat step 1 for three more days.
3. Analyze your results and answer the rest of the Analysis questions.

Data Table			
Minute	**Open habitat**	**Plant habitat**	**Stick habitat**
1			
2			
3			
4			

Analysis

1. In this experiment, you have created three different habitats in the aquarium. Which habitat do you think the minnows will prefer? Explain your reasoning.
2. In this activity, you are setting up a controlled experiment. Only one factor is being tested and all other factors are constant. Some of the constant factors in this experiment are temperature of the water, pH of the water, and amount of light falling on the aquarium. What is the factor being tested?
3. Was your prediction in Analysis question 1 accurate? Explain your answer.
4. Write a short paragraph explaining the results of this experiment.
5. Estuaries are regions of water where rivers enter the oceans. Because rivers carry many nutrients, estuaries tend to have a lot of plant growth and relatively shallow water compared to the open ocean. Would you expect to see more young fish in an estuary or in the open ocean? Explain your reasoning.

What's Going On?

In this experiment, you gave young fish the opportunity to select the habitat in which they felt most comfortable. For juvenile fish to survive, they must find plenty of food because they are going through a period of rapid growth. They also need to avoid predators, which include larger fish and birds. For this reason, areas that offer a place to hide and forage make perfect homes for young fish.

The minnows used in this experiment are juvenile freshwater fish. Their behavior is similar to that of marine fish. There are about 1,600 species of fish that are classified as minnows. Sold in bait and tackle shops, these animals are purchased by fishermen as bait. In the wild, minnows are forage fish, food for larger species. Minnows in turn feed on smaller organisms, so are important members of freshwater food webs.

Connections

Red snapper larvae drift in the *plankton* and live in the water column where they prey on *zooplankton*. Juvenile red snapper move to shallow water with sandy or muddy bottoms and plenty of protection. The adults live on the bottom in deep waters in areas where there are outcroppings such as ledges, caves, limestone formation, coral reefs, and artificial reefs. Like many other species of fish, red snapper travel in *schools* and hunt for smaller fish and crustaceans. The maximum age of red snapper in the Gulf of Mexico is 50 years and maximum weight is 50 pounds (lb) (23 kilograms [kg]).

Want to Know More?

See appendix for Our Findings.

Further Reading

Durbin, Edward. "Assessing Essential Fish Habitat and Connectivity of Reef Fish Otolith Microchemistry," 2008. Available online. URL: http://www.seagrantpr.org/research/research_files/projects_06_08/edward_durbin.html. Accessed October 10, 2009. Durbin studies the habitats of young fish by examining their otoliths, mineral deposits in the inner ear.

Gulf of Mexico Fishery Management Council. Available online. URL: http://www.gulfcouncil.org/. Accessed June 12, 2009. The council manages fisheries between state waters and the 200-mile (mi) (322-kilometer [km]) limit in the Gulf of Mexico. This Web site provides information on the marine environments in these fisheries.

Louisiana Fisheries. "Red Snapper FAQs Management." Available online. URL: http://www.seagrantfish.lsu.edu/faqs/redsnapper/index.html. Accessed June 12, 2009. The Louisiana Fisheries Web page explains laws that regulate fishing in the Gulf of Mexico.

Workman, Ian, Arvind Shah, Dan Foster, and Bret Hataway. "Habitat preferences and site fidelity of juvenile red snapper (*Lutjanus campechanus*)," *ICES Journal of Marine Science,* 59: S43-S50, 2002. Available online. URL: http://icesjms.oxfordjournals.org/cgi/reprint/59/suppl/S43.pdf. Accessed June 12, 2009. This article tells how the authors constructed ten small reefs of either oyster shell or polyethylene webbing and monitored juvenile red snapper at the sites.

6. Staying Afloat

Topic

The shapes of planktonic organisms help them stay afloat.

Introduction

At the surface of the water column, the ocean teams with life. Tiny, planktonic organisms drift with the current and wind. Plantlike organisms, the *phytoplankton*, capture the Sun's energy and convert it to food in the process of *photosynthesis*. As the basis for most marine food webs, phytoplankton are fed on by *zooplankton*, small drifting animals. Although zooplankton can move and swim weakly, their lives are dictated by movement of the water. Several species of phytoplankton and zooplankton are shown in Figure 1.

All planktonic organisms are highly adapted for their environment. If they could not stay in the upper part of the water column, these organisms would sink and die. Structurally, their *adaptations* include a flattened shape and long extensions that slow their rate of sinking. The bodies of some contain drops of oil which help them float in water. In this experiment, you will examine plankton and identify some the adaptations that keep organisms afloat. Then you will design plankton models that show "adaptations" for floating.

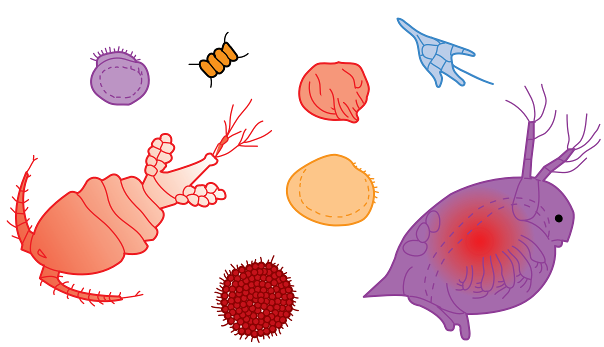
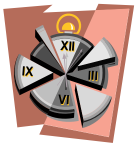


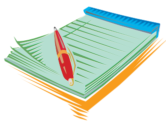
Figure 1

Phytoplankton and zooplankton



Time Required

45 minutes for part A
55 minutes for part B



Materials

- aquarium f lled with water
- sample of plankton (fresh or preserved)
- dissecting microscope
- Petri dish
- 2 marbles
- aluminum foil
- waxed paper
- modeling clay
- toothpicks
- pipe cleaners
- string
- stopwatch or watch with a second hand
- science notebook

Safety Note **Please review and follow the safety guidelines at the beginning of this volume.**

Procedure, Part A

1. Pour enough plankton into one-half of a Petri dish to cover the bottom of the dish.
2. Place the Petri dish on the stage of the dissecting microscope. Turn on the light beneath the sample. Adjust the microscope to low power. Focus the microscope, f rst using the coarse adjustment, then the f ne adjustment.
3. Sketch three different kinds of organisms in your science notebook.

4. Adjust the dissecting microscope to high power.
5. Sketch three different kinds of organisms in your science notebook.
6. Answer Analysis questions 1 and 2.

Procedure, Part B

1. Design and build a model of a planktonic organism. Your model must:
   a. support one marble
   b. be designed to stay afloat as long as possible
   c. not exceed a size of 6 by 2 inches (in.) (15 by 5 centimeters [cm]).
2. You can use any of the supplies provided by your teacher, but you do not have to use all of them.
3. When your model is complete, place it in the aquarium and time how long it takes to sink to the bottom. Record the time it takes your model to sink in your science notebook.
4. Record the sinking time for models created by your classmates.
5. Organize the sinking times of all models on a data table of your own design.
6. Answer Analysis questions 3 through 5.

Analysis

1. Describe the shapes of three planktonic organisms.
2. Why do planktonic organisms stay afloat in the water column?
3. Phytoplankton remain at the surface of the water because they need light to carry out photosynthesis. Why do you think zooplankton remain at the surface?
4. Describe the design of the model that sank most slowly.
5. What are some adaptations of planktonic organisms for staying afloat?

What's Going On?

Plankton live in the *photic zone*, the part of the ocean that receives sunlight (see Figure 2). Phytoplankton have several adaptations for staying afloat. Spines, spikes, bristles, and projections help keep them in the upper regions of the water column. Some have eyespots for detecting light and flagella for helping them swim toward the light. Their bodies are shaped so that they have a large surface area. Many have vacuoles that contain air or oil, making them more buoyant. Some species of phytoplankton form chains, ribbons, or spheres that float more easily than individual organisms. Like phytoplankton, zooplankton have a variety of fantastic shapes. These tiny animals may also have antennae or legs that increase their surface area and help them maneuver around and catch food.

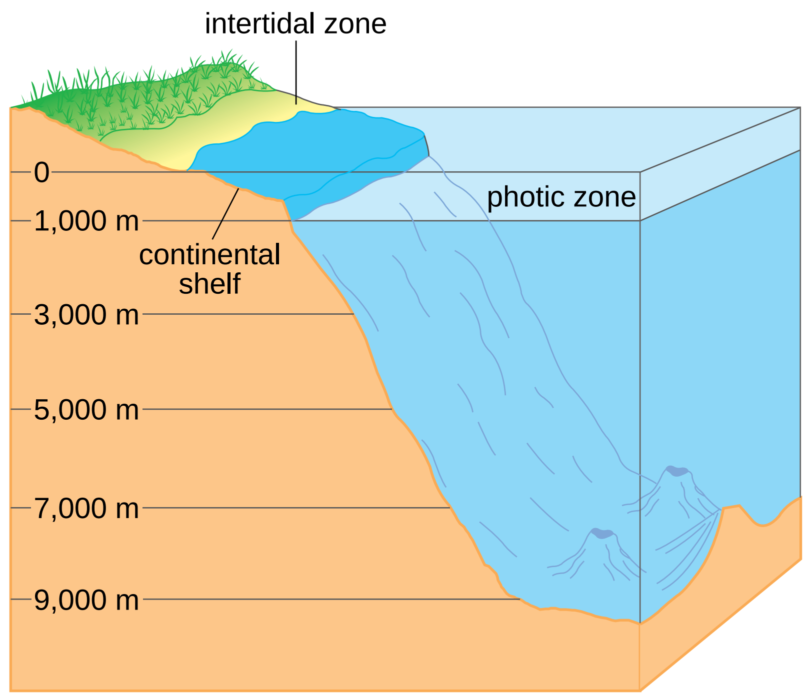


Figure 2

The photic zone is the part of the ocean that receives sunlight.

Connections

Terrestrial producers, which include plants such as grass and trees, have roots for absorbing nutrients and water and leaves for carrying out photosynthesis. These organs are connected to each other and other plant structures through a system of tubelike *vascular tissue* (see Figure 3). Phytoplankton lack the organs found in plants because they absorb nutrients directly from seawater. The projections and spines on phytoplankton maximize their surface area, facilitating absorption and exposure to sunlight.

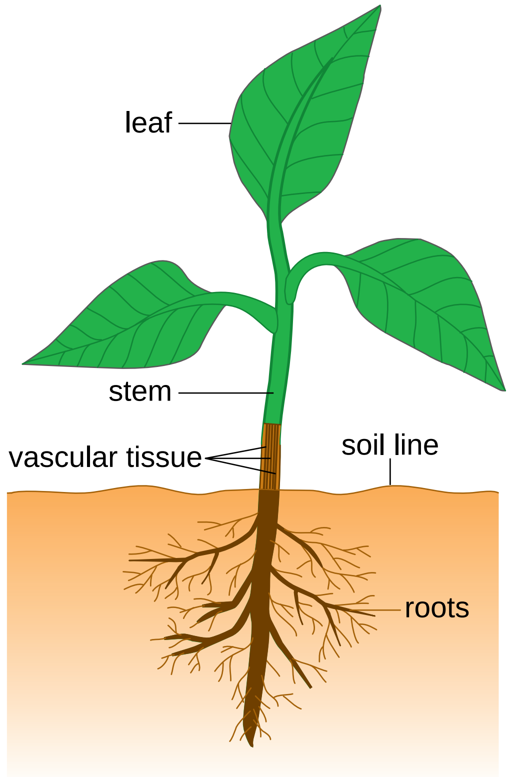


Figure 3

The photic zone varies slightly in different regions of the ocean. Factors that affect its depth include the clearness of the atmosphere, the angle at which light strikes the water, and the water's turbidity. As planktonic organisms die, they fall to the seafloor, recycling the nutrients in their bodies. These nutrients are returned to the water column by *upwellings*, vertical mixing of water.

Want to Know More?

See appendix for Our Findings.

Further Reading

Bigelow Laboratory for Ocean Sciences. Phytoplankton Background, 1998. Available online. URL: http://www.bigelow.org/foodweb/microbe0.html. Accessed June 30, 2009. This site provides simple descriptions of several types of plankton.

Florida Oceanographic Coastal Center. “Collecting Plankton.” Available online. URL: http://www.floridaoceanographic.org/teacher/plankton.pdf. Accessed October 10, 2009. This Web site provides great pictures of planktonic organisms.

Indiana University. “Diatom Home Page,” June 23, 1998. Available online. URL: http://www.indiana.edu/~diatom/diatom.html. Accessed June 30, 2009. This Web site has links to dozens of resources on plankton and other topics in marine biology.

Seafriends. “Plankton Classif cation.” Available online. URL: http://www.seafriends.org.nz/enviro/plankton/class.htm. Accessed June 30, 2009. This Web page shows the scientif c classif cation of organisms that make up plankton.

7. The Oceanic Conveyer Belt

Topic

Temperature and salinity affect the density of water and set up currents in the ocean.

Introduction

The ocean is in constant motion. The two major factors that create and drive ocean currents are winds and differences in water density. Winds, along with the Earth's rotation, create surface currents. From these currents, *eddies* spin off that carry water to other parts of the ocean. Eddies are large swirling regions of water that can be hundreds of miles wide.

Deepwater currents are set into motion by differences in water density that are due to temperature and *salinity*. Water near the equator is warmer than water near the poles because of the uneven heating of Earth's surface by the Sun (see Figure 1). Warming of equatorial waters causes rapid evaporation of water molecules, leaving salt molecules behind. These two factors cause the density-dependent movement of water known as the *thermohaline circulation*. In this experiment, you will observe the effects of temperature and salinity of water.

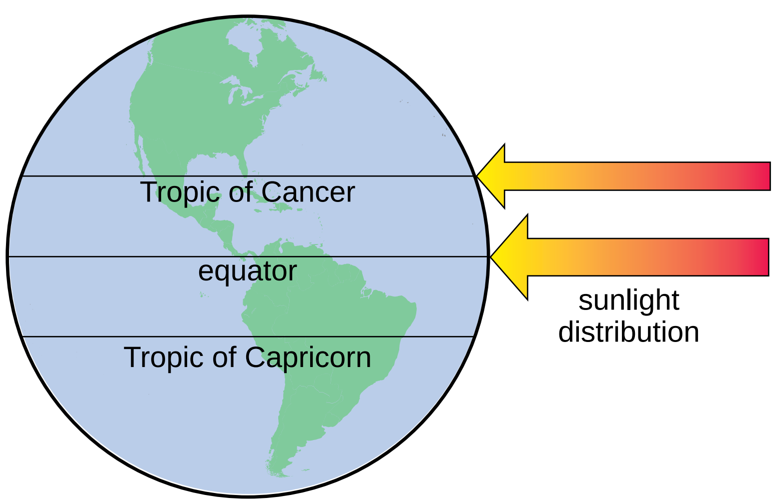


Figure 1

Equatorial zones receive more direct sunlight than other regions of the Earth.

Time Required

55 minutes

Materials

- glass dish (about 9 by 13 by 13 inches [in.]) (23 by 33 by 33 centimeters [cm])
- 5 or 6 ice cubes
- 2 Ziploc™ bags
- very warm water (about 1 cup)
- 2 clothespins
- access to tap water
- 2 small rocks
- 2 pipettes
- bottle of red food coloring
- bottle of green food coloring
- 2 Erlenmeyer flasks, 250 milliliters (ml)
- index card
- table salt (about 1/2 teaspoon [tsp])
- stirring rod
- science notebook

Safety Note **Take care when working with very warm water. Please review and follow the safety guidelines at the beginning of this volume.**

Procedure, Part A

1. Fill the glass dish with room-temperature water.
2. Let the glass dish of water sit for a few minutes until the water stops moving.
3. Put a few ice cubes and a small rock in one Ziploc™ bag.

4. Gently place the bag in the water at one end of the glass dish. Use a clothespin to secure the bag to the glass dish.
5. Place a rock in the other Ziploc™ bag, then carefully pour some very warm water into the bag.
6. Gently place the bag of warm water in the dish of water at the opposite end of the glass dish. Use a clothespin to secure the bag to the glass dish.
7. Use a pipette to put a drop of green food coloring in the water next to the bag of ice cubes.
8. Use the other pipette to put a drop of red food coloring in the water next to the bag of warm water.
9. Observe the drops of food coloring. In your science notebook, describe what happens to them.
10. Answer Analysis questions 1 through 3.

Procedure, Part B

1. Half f ll both Erlenmeyer flasks with water. Dissolve about 1/2 tsp of water and a few drops of food coloring in one flask. Stir to mix well.
2. Place an index card over the flask of salty, colored water. Carefully turn the flask upside down so that the index card is sealed by upward air pressure.
3. Position the inverted flask and card on top of the other Erlenmeyer flask.
4. Have a friend or lab partner gently remove the index card between the two flasks as you hold them in place.
5. Observe what happens when the two types of water meet. Record your observations in your science notebook.
6. Let the flask of water sit for about 5 minutes and continue to observe.
7. Answer Analysis questions 4 through 6.

Analysis

1. Draw the glass dish of water with the two ziploc™ bags and the two drops of food coloring. Label each item. Use arrows to indicate the movement of the drops of food coloring.

2. Based on your experimental results in Part A, which is denser, warm water or cold water? How do you know?
3. Imagine that you have a jar filled with room-temperature water. Into this jar you place an ice cube made with blue food coloring. What would you expect to see in the jar as the blue ice cube melts?
4. What happened when you removed the index card between the two Erlenmeyer flasks?
5. How did the flask of clear and blue water look after five minutes?
6. Based on your experimental results in Part B, which is denser, salt water or freshwater? How do you know?

What's Going On?

In this experiment, you examined the effects of temperature and salinity on the density of water. Water that is more dense sinks below water that is less dense. In Part A, you saw that dense cold water and less dense warm water can create a current. The presence of ice on one end of the glass dish and warm water on the other end set the water in motion; the cold water sank and the warm water moved toward the surface. Part B showed you that the higher the salinity of water, the higher its density because the salty water sank below the freshwater. These two factors, temperature and salinity, work together to create the currents in the oceans. Figure 2 shows the paths of the major ocean currents.

Currents are essential to support life in all parts of the water. When dense water sinks, it carries dissolved oxygen to deep parts of ocean. When warm water upwells, nutrients from the seafloor are carried to the surface. This global circulation is extremely slow. Water that sinks in the North Atlantic may not reach the sea surface in the Southern Hemisphere for thousands of years.

Connections

Some scientists fear that the thermohaline circulation may be in danger. *Global warming* is causing ice caps to melt at an unprecedented rate at northern latitudes. Ice is made up of freshwater. As this freshwater enters the northern oceans, it reduces the density of the ocean water. No one knows for sure how much extra freshwater is required to alter the current ocean conveyer belt. Oceanographer Ruth Curry at the Woods Hole Oceanographic Institution on Cape Cod, Massachusetts, has calculated

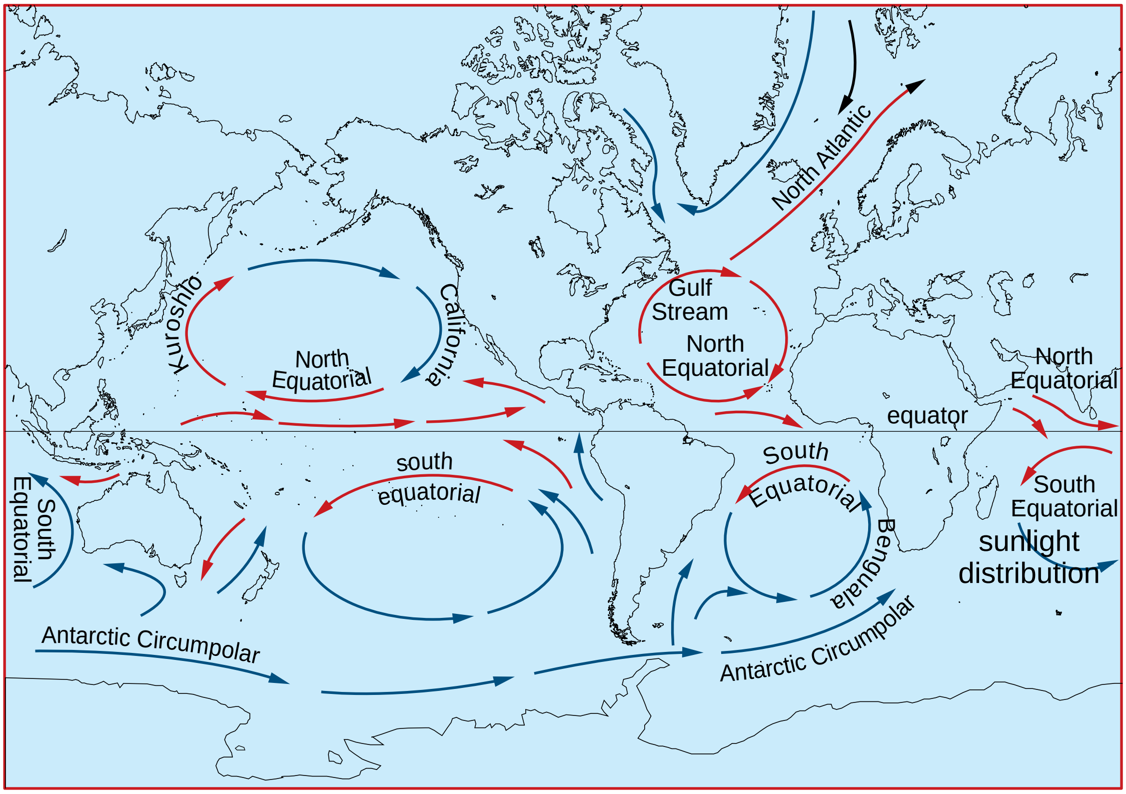


Figure 2

Major ocean currents. Blue indicates cool water; red is warm water.

that if freshwater continues to enter the northern oceans at today's rate, changes in currents could occur in about 200 years. However, not everyone agrees with Curry, pointing out that if global warming slows, the rate of freshwater release will also slow.

Want to Know More?

See appendix for Our Findings.

Further Reading

NOAA Paleoclimatology. "Thermohaline Circulation." Available online. URL: http://www.ncdc.noaa.gov/paleo/ctl/thc.html. Accessed October 10, 2009. The Web site includes a map showing the thermohaline circulation.

Roach, John. "Global Warming May Alter Atlantic Currents, Study Says," NASA, Ocean Motion and Surface Currents. *National Geographic*, June 27, 2005. Available online. URL: http://oceanmotion.org/html/impact/

globalwarming.htm. Accessed June 13, 2009. Roach reports on current research in changes in the global thermohaline circulation in this article.

Windows to the Universe. “Density of Ocean Water,” August 31, 2001. Available online. URL: http://www.windows.ucar.edu/tour/link=/earth/Water/density.html&edu=high. Accessed June 13, 2009. The Web site shows how the density of ocean water changes with depth.

Wunsch, Carl. “What is the Thermohaline Circulation?” *Science*, Vol. 298, November 8, 2002. Available online. URL: http://ocean.mit.edu/~cwunsch/papersonline/thermohaline.pdf. Accessed June 13, 2009. Wunsch distinguishes several different factors that affect ocean circulation.

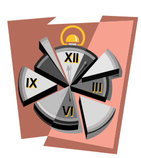
8. How to Measure Salinity

Topic

The salinity of water can be measured with a hydrometer.

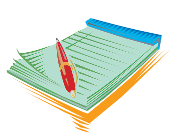
Introduction

Have you ever tasted ocean water? If so, you probably noticed its salty taste. Ocean water tastes salty because it contains dissolved minerals or salts. The term *salinity* refers to the concentration of dissolved salt. The salinity of water affects its *density*, a measurement of a substance's mass per unit volume. One way to measure density is as *specific gravity*, a comparison of the density of a material to the density of water at 39 degrees Fahrenheit (°F) (4 degrees Celsius [°C]). The specif c gravity of pure water is 1. If a substance is denser than pure water, its specif c gravity is more than 1. Specif c gravity of a liquid can be measured with a *hydrometer*. This instrument has a scale along its side that tells you the specif c gravity. To use a hydrometer, you place it in a liquid and read the scale. The denser the liquid, the higher the hydrometer floats in the liquid. In this experiment, you will measure the specif c gravity of water to determine its salinity.



Time Required

45 minutes



Materials

- 500 milliliters (ml) beaker of distilled water
- 500 ml beaker of standard saline water
- 500 ml beaker of sample A
- 500 ml beaker of sample B
- thermometer (Celsius)

- hydrometer
- science notebook

Safety Note **Please review and follow the safety guidelines at the beginning of this volume.**

Procedure

1. Place the thermometer in the beaker of distilled water. After 2 minutes, read the temperature on the thermometer and record it on Data Table 1.
2. Gently place the hydrometer in the beaker of distilled water. Do not let the hydrometer touch the sides of the beaker. When the hydrometer stops moving, read the specif c gravity on the side at the point where the stem of the hydrometer breaks the water's surface (see Figure 1). Read the measurement at water level, not at the top of the meniscus. Record the specif c gravity on the Data Table 1.

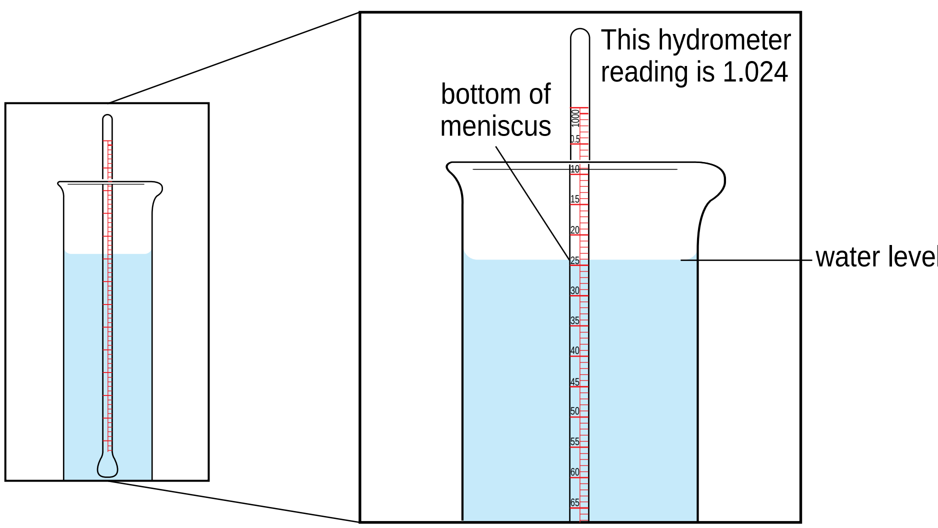


Figure 1

3. Refer to Data Table 2, which shows salinity as a function of specif c gravity and temperature. Find the temperature across the top of the data table and the specif c gravity on the left side. At the point where this row and column meet, read the salinity. Record the salinity on Data Table 1.

4. Repeat steps 1 through 3 two more times for a total of three trials with distilled water. Average the three salinities and enter the average salinity on the data table.
5. Repeat steps 1 through 4 with the standard saline water, sample A, and sample B.

Data Table 1

Sample	Temperature (°C)	Specific gravity on hydrometer	Salinity	Average salinity
Distilled water, trial 1				
Distilled water, trial 2				
Distilled water, trial 3				
Standard saline, trial 1				
Standard saline, trial 2				
Standard saline, trial 3				
Sample A, trial 1				
Sample A, trial 2				
Sample A, trial 3				
Sample B, trial 1				
Sample B, trial 2				
Sample B, trial 3				

Data Table 2							
	Temperature						
Specific gravity	**26.11˚C (79˚F)**	**26.66˚C (80˚F)**	**27.22˚C (81˚F)**	**27.77˚C (82˚F)**	**28.33˚C (83˚F)**	**28.88˚C (84˚F)**	**29.44˚C (85˚F)**
1.017	1.0193	1.0194	1.0196	1.0197	1.0199	1.0200	1.0202
1.018	1.0203	1.0204	1.0206	1.0207	1.0209	1.0210	1.0212
1.019	1.0213	1.0214	1.0216	1.0217	1.0219	1.0220	1.0222
1.020	1.0223	1.0224	1.0226	1.0227	1.0229	1.0230	1.0232
1.021	1.0233	1.0234	1.0236	1.0237	1.0239	1.0240	1.0242
1.022	1.0243	1.0244	1.0246	1.0247	1.0249	1.0250	1.0252
1.023	1.0253	1.0254	1.0256	1.0257	1.0259	1.0260	1.0262
1.024	1.0263	1.0264	1.0266	1.0267	1.0269	1.0270	1.0272
1.025	1.0273	1.0274	1.0276	1.0277	1.0279	1.0280	1.0282

Analysis

1. What is density?
2. Explain the relationship between density and specif c gravity.
3. Why can specif c gravity be used to determine salinity?
4. Rate the following bodies of water from most (4) to least (1) saline.

   _______ middle of a bay   _______ river

   _______ where river empties into bay   _______ ocean

5. Where do you think water is more saline, near the poles or at the equator? Explain your answer.

What's Going On?

Ocean water averages about 35 parts per thousand (ppt) of salt, which means that it is about 3.5 percent salt. In other words, if you had 1,000 cups of seawater, of those cups 35 would be salt and the rest would be water. Most of the salt is sodium chloride, or table salt, but a small percentage contains magnesium, sulfur, calcium, and potassium. The salinities of other bodies of water are shown in Data Table 3.

Data Table 3

Type of water	Salinity in ppt
Freshwater	0–1
Slightly saline water	1–3
Moderately saline water	3–10
Salt water	10–35

Water in bays and estuaries is a mixture of ocean water and freshwater from one or more rivers. This type of moderately salty water is described as *brackish*. Tides can influence the salinity of estuarine water. Salinity increases when tides are high and decreases when they are low. Heavy rains can also decrease the salinity of a bay or estuary.

Connections

All living things contain dissolved salts within their cells. In most organisms, cells contain about one-third as many salts as seawater. Plants and animals that live in water have special adaptations that help them maintain an ideal balance of salt and water in their cells. In freshwater environments, cells contain more salt than the environment. Therefore, water tends to move into the cells by *osmosis*, the diffusion of water through the cell's membrane. Freshwater organisms have mechanisms to get rid of excess water. In the ocean, cells contain less salt than the environment. Therefore, their cells tend to lose water. Marine animals have mechanisms for conserving water. For example, most marine organisms produce very little urine. Animals that eat saltwater plants or other saltwater animals tend to take in salt. To handle this, their bodies excrete the excess salt. Several species of marine birds have glands on their heads through which they sneeze out accumulated salt. Figure 2 shows a bird's skull with two prominent salt glands that concentrate sodium chloride so that it can be expelled.

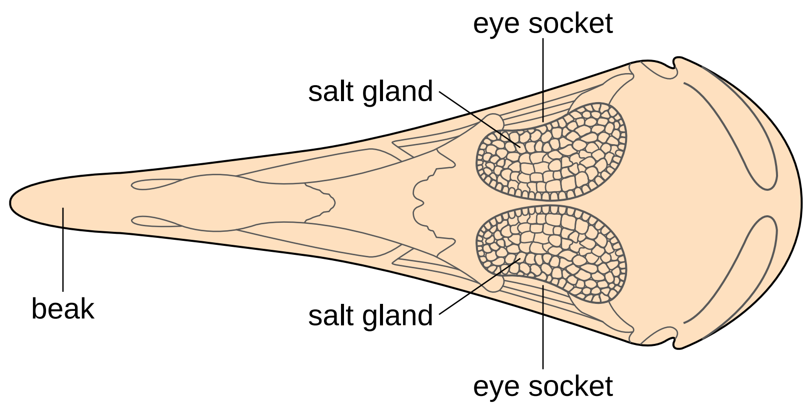


Figure 2

Want to Know More?

See appendix for Our Findings.

Further Reading

Science Daily. "Sea Salt Holds Clues To Climate Change," March 7, 2009. Available online. URL: http://www.sciencedaily.com releases/2009/04/090430115909.htm. Accessed June 13, 2009. Scientists can use the sea's salinity to help predict changes in climate.

Swenson, Herbert. "Why Is the Ocean Salty?" U.S. Geological Survey. Available online. URL: http://www.palomar.edu/oceanography/salty_ocean.htm. Accessed June 30, 2009. In this publication, Swenson explains how salts from the continents dissolve and f nd their way to the seas.

UPI. "NASA to measure ocean salinity from space," April 30, 2009. Available online. URL: http://www.upi.com/Science_News/2009/04/30/NASA-to-measure-ocean-salinity-from-space/UPI-20511241109240/. Accessed June 13, 2009. The ocean is so large that the salinity in many areas has never been measured. This news article reports that NASA is preparing satellites to take on this task.

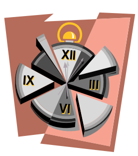
9. Bathymetric Maps

Topic

A two-dimensional map can show the three-dimensional nature of the ocean floor.

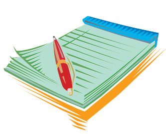
Introduction

A *bathymetric map*, or chart, is a two-dimensional drawing that shows the three-dimensional features of the seafloor. Each *contour line* on the map connects points of the same depth. Notice that the contour line in Figure 1 labeled 1,000 meters (m) connects all of the points that are this depth. The next contour line is labeled 2,000 m. The interval between these two lines is 1,000 m, telling you that the second contour line is 1,000 m deeper than the f rst. Wide spacing between contour lines indicates a gentle slope while closely spaced lines tell you that the slope is sharp. In this experiment, you will carry out some research on seafloor structures, make a model of some of these structures, and use the model to create a bathymetric map.



Time Required

25 minutes for part A
55 minutes for part B



Materials

- access to the Internet or reference books on seafloor structures
- metric ruler
- square-bottomed, quart-size plastic container
- clear transparency f lm
- marker (for transparency f lm)
- water (about 3 cups)

- scissors
- tape
- science notebook

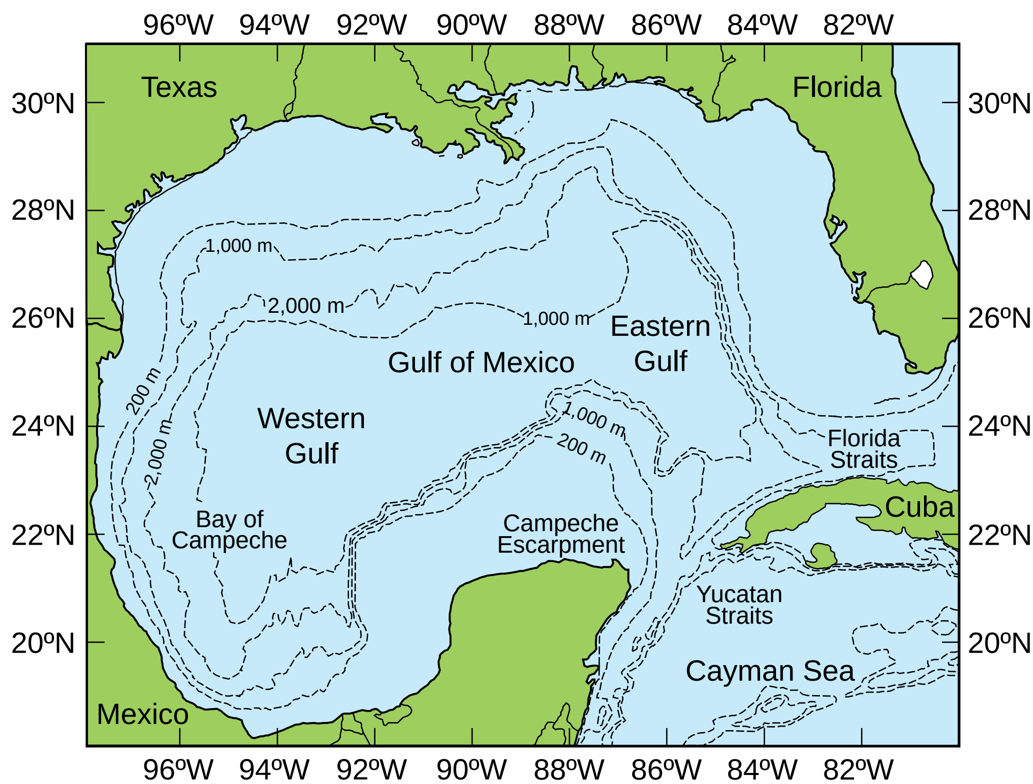


Figure 1

Safety Note

Please review and follow the safety guidelines at the beginning of this volume.

Procedure, Part A

1. Use reference books or the Internet to learn more about structures on the ocean floor. Specif cally, research:
   a. continental shelves
   b. abyssal plains
   c. seamounts
   d. mid-ocean ridges

e. trenches
f. canyons
g. guyots

Procedure, Part B

1. Use modeling clay to create a model of the seafloor that includes at least two features researched in part A. For example, your model could include the continental shelf and a trench or the abyssal plain and a seamount. Create your model inside the plastic container. The height of your model cannot exceed the height of the container.
2. Trim the transparency f lm to f t on the top of the plastic container. Cut a notch out of one corner of the f lm so that you can pour water into the plastic container.
3. Tape the f lm to the top of the plastic container.
4. Tape the ruler vertically to the outside of the plastic container with the largest number at the bottom of the container.
5. Gently pour water into the container through the opening left by the notch. Stop pouring when the depth of water reaches 1 centimeter (cm).
6. Look straight down into the container (through the f lm). Use the marker to draw on the transparency f lm the outline created where the water meets clay. This outline represents the f rst contour line of the topography of the seafloor that you have modeled. (Do not draw an outline of where the water meets the container.)
7. Read the water level on the ruler. Label the height of the water level on the line you drew.
8. Add another centimeter of water. Repeat steps 6 and 7.
9. Repeat steps 5 through 8 until the entire clay structure is submerged.

Analysis

1. What does a bathymetric map show you?
2. What is a contour line?
3. How many contour lines did you draw?
4. What depth of water does each contour line represent?
5. What are some possible uses of bathymetric maps?

What's Going On?

The outermost layer of the Earth, the crust, is made of two types of rock: (1) the rock that makes up the continental crust and (2) the rock found in the oceanic crust. The material making up the continental crust is relatively lightweight and floats higher on the mantle than the oceanic crust. Areas where ocean water covers the edges of the continents form the continental shelves, gently sloping, relatively shallow regions (see Figure 2).

Beyond continental shelves is the abyssal plain, a smooth, nearly flat expanse. Abyssal plains are immense, making up about 79 percent of seafloor worldwide. Volcanic eruptions on the plain can lead to mountain building, resulting in islands or seamounts, structures that do not break the surface of the water. Guyots are underwater volcanic mountains that have flat tops. Bisecting the oceans are the mid-ocean ridges, continuous mountain ranges that extend around the entire planet. Only about 2 percent of the ocean is made up of deep-water trenches, V-shaped, steep-sided canyons found along the continental slope. These structures give the seafloor a three-dimensional structure.

Connections

Bathymetric charts are similar to topographic maps, which show the elevations of landforms. The technology used to create bathymetric maps includes global positioning systems (GPS) and sonar. Sonar devices send out sound waves and measure how long it takes for them to bounce off a surface and return to a receiver. By knowing the speed of sound in water, equipment can calculate the distances to those structures.

Bathymetric maps are similar to road maps in that they are used in navigation. However, unlike road maps, they primarily show geological features (see Figure 2). These maps are important to the nautical navigator to avoid running aground or wrecking on submerged structures.

Before sailors had the electronic equipment available today, they determined depth by dropping a weighted rope from the boat. As the rope came in, they measured it; the length of rope between the hands of their outstretched arms was called a *fathom*. This unit of measurement is still in use today and has been standardized to 6 feet (ft) (1.8 meters [m]).

Want to Know More?

See appendix for Our Findings.

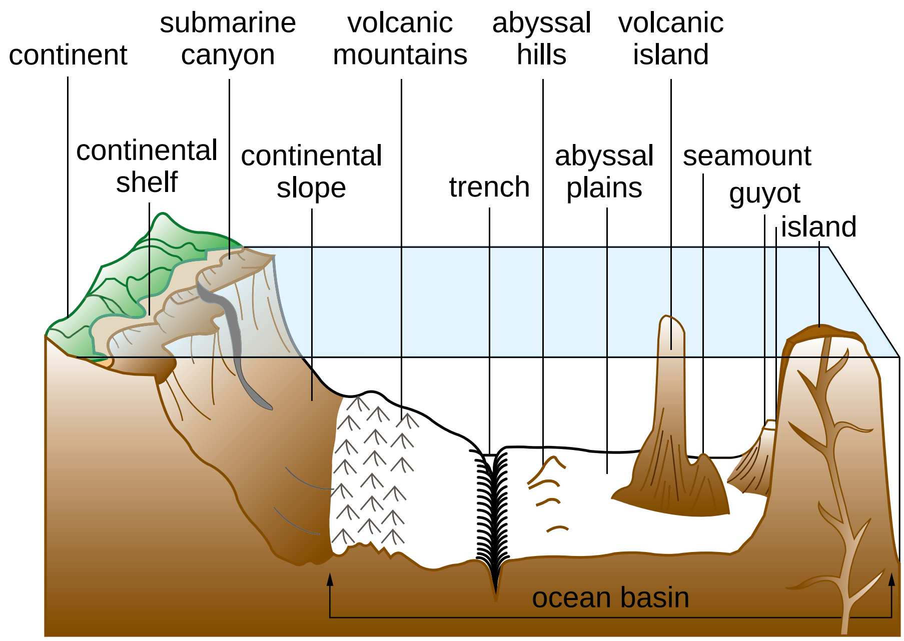


Figure 2

Further Reading

Gilman, Larry, and K. Lee Lerner. "Ocean Floor Bathymetry," 2007. *Water Encyclopedia*. Available online. URL: http://www.waterencyclopedia.com/Oc-Po/Ocean-Floor-Bathymetry.html. Accessed June 30, 2009. In this article, current and early techniques of studying the seafloor are explained.

National Geophysical Data Center (NGDC). "Marine Geology and Geophysics," April 13, 2009. Available online. URL: http://www.ngdc.noaa.gov/mgg/image/2minrelief.html. Accessed June 30, 2009. This National Oceanic and Atmospheric Administration (NOAA) Web site enables you to click on a region of the globe and see a relief image of that region.

Voyage to the Deep. "Seafloor Geology." Available online. URL: http://www.ceoe.udel.edu/deepsea/level-1/geology/geology.html. Accessed June 30, 2009. On this Web site you can learn more about seafloor structures such as deep ocean vents and the mid-oceanic ridge.

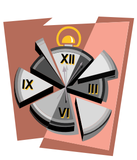
10. Ocean Sediments

Topic

The nature of the ocean bottom at any point on the seafloor is related to the distance from a source of sediment.

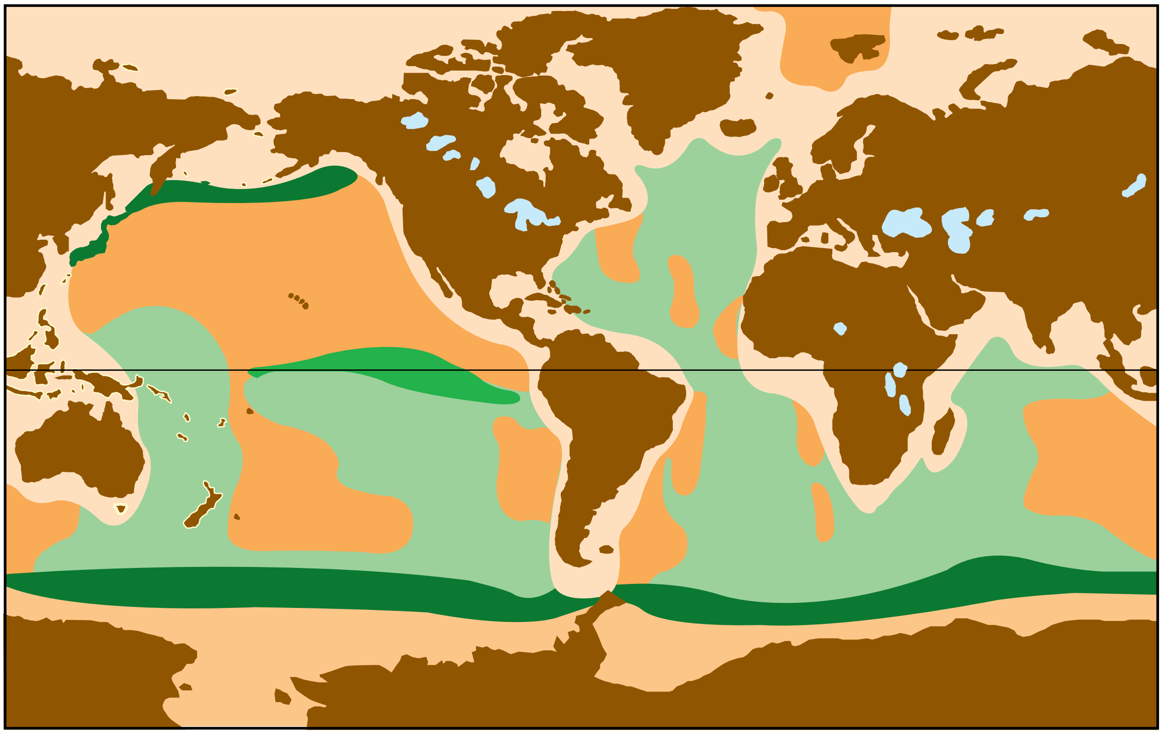
Introduction

The ocean floor can be divided roughly into two major types: soft bottom and hard bottom. Soft bottom floors are covered in layers of sediment, both f ne and coarse. The continental shelves and slopes have soft bottoms. The sources of the sediments vary, depending on geographic location. Much of the sediment is described as *lithogenic* or terrigenous because it comes from the erosion of rocks on land. Depending on the energy in the system, lithogenic particles may be carried far from their source. *Biogenic* sediments are made up of the shells of dead organisms. Some of these sediments are rich in calcium carbonate, which comes from the shells and skeletons of many marine organisms. Silica is contributed by two types of organisms*: foraminiferans*, tiny amoebalike organisms in shells, and *diatoms,* one-celled green algae in glasslike coverings. *Authigenic* sediments are materials that precipitated from biochemical reactions in the water. The sediments from volcanoes are described as *volcanogenic*, and those from outer space as *cosmogenic*. Figure 1 shows the continental shelves and areas of some deposits. Areas where currents are strong enough to remove all sediment and most parts of the deep ocean are rocky and described as having hard bottoms. In this experiment, you will determine how the distance from a source of lithogenic sediment affects the makeup of particles on the seafloor.



Time Required

55 minutes



Terrigenous deposits:

- continental margins
- glacial deposits
- clays

Biogenous deposits:

- calcium carbonate deposits
- silica deposits from radiolarians
- silica deposits from diatoms

Figure 1

General sediment distribution patterns

Materials

- oblong plastic tray or storage container
- samples of silt
- samples of sand
- samples of small gravel
- magnifying glass
- stopwatch
- cardboard
- spoons

- straws
- paper cups
- access to water
- science notebook

Safety Note **Please review and follow the safety guidelines at the beginning of this volume.**

Procedure

1. Your job is to design and perform an experiment that determines how closely to their source three types of suspended material (silt, sand, and small gravel) are deposited. Your experiment should compare the deposit of sediment under two circumstances: with currents and without currents.
2. You can use any of the supplies provided by your teacher, but you will not need to use all of them.
3. Answer Analysis questions 1 through 3.
4. Keep in mind that your experiment will need at least two setups. One setup will determine where each type of sediment falls when there are no currents. The other setup will determine where each type of sediment falls when currents are present. Your f ndings will be more accurate if you can carry out more than one trial of each setup.
5. Before you conduct your experiment, decide exactly what you are going to do. Write the steps you plan to take (your experimental procedure) and the materials you plan to use (materials list) on the data table. Show your procedure and materials list to the teacher. If you get teacher approval, proceed with your experiment. If not, modify your work and show it to your teacher again.
6. Once you have teacher approval, assemble the materials you need and begin your procedure.
7. Collect your results on a data table of your own design.
8. Answer Analysis questions 4 through 6.

Analysis

1. Complete the following statements to reflect you expectations in this experiment:
   a. When currents are present, _________ (small, medium-size, large) particles are deposited further from the source of sediment than _________ (small, medium-size, large) particles.
   b. When currents are not present, particles are deposited ___________________________________.

Data Table	
Your experimental procedure	
Your materials list	
Teacher's approval	

2. What are some sources of sediment?
3. Why is it advisable to carry out more than one trial in an experiment?

4. Were your expectations in this experiment correct? Explain why or why not.
5. On the outer edge of the continental shelf, sediment is made up of many f ne, silty particles. Why do you think this is so?
6. If you were to repeat this experiment, how could it be improved?

What's Going On?

In this experiment, you compared the deposit of particles in high- and low-energy systems. A low-energy system is one that has very little current or wave action. If you gently pour each type of sediment into water that is unaffected by energy, the sediment most likely piles up, with the smallest particles on top. If you pour the sediment into a high-energy system, one in which you create waves or current, the small gravel remains near the source, but the light-weight silt is most likely carried away from the source. Sand particles are probably found between the two other types of sediment.

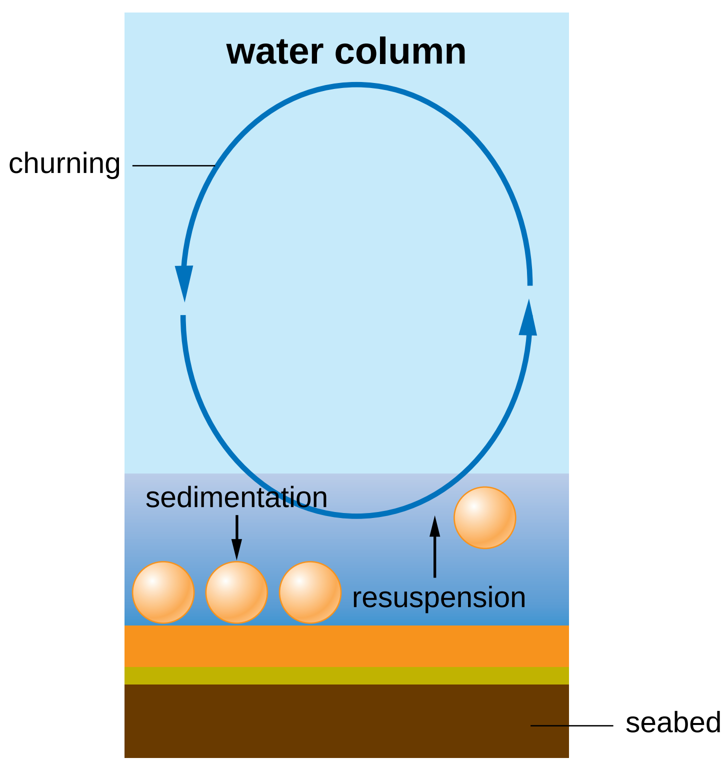


Figure 2

Waves continuously churn the water column, resuspending suspending sediment from the sea bed.

At any site on the continental shelf, the composition of sediment depends on the amount of energy present. Strong currents and waves keep f ne particles suspended so they are carried further from their source. Waves may be the dominant force in distributing particles because they continuously churn water at the shoreline and resuspend particles (see Figure 2). The only particles found along beaches are those of medium and coarse size; small particles are carried out to sea or held in the water column. In areas where currents and waves are weak, thick layers of f ne sediment may pile up.

Connections

Shelf sediments accumulate at the incredibly slow rate of about 11 inches (in.) (30 centimeters [cm]) every 1,000 years. The types of sediment found on the continental shelf vary with latitude and are determined by climate. At the equator and in subtropical regions where seas are warm and living things are abundant, there is lot of biogenic sediment. In temperate latitudes, lithogenic particles from river outflow are dominant. These deposits are rich in quartz and feldspar from erosion of granite. Near the poles, particles are derived from soil made from marine sediments deposited by glaciers and from sedimentary rock.

Want to Know More?

See appendix for Our Findings.

Further Reading

McDuff, Russell E. "Overview of Marine Sedimentation," Winter 2002. Oceanography 540—Marine Geological Processes. Available online. URL: http://www2.ocean.washington.edu/oc540/lec02-2/. Accessed July 1, 2009. This Web page provides excellent notes on the types of sediments found throughout the ocean.

Murray, Richard W. "Ocean Floor Sediments," 2007. *Water Encyclopedia*. Available online. URL: http://www.waterencyclopedia.com/Oc-Po/Ocean-Floor-Sediments.html. Accessed July 1, 2009. Murray explains the sources of ocean sediments and the activities that distribute these sediments in this article.

National Geographic Data Center (NGDC). "Total Sediment Thickness of the World's Oceans and Marginal Seas," March 31, 2009. Available online. URL: http://www.ngdc.noaa.gov/mgg/sedthick/sedthick.html. Accessed July 2, 2009. On this National Oceanic and Atmospheric Administration (NOAA) Web site, NGDC provides digital maps of the sediment in the world's seas.

11. The Record Written in Ocean Sediments

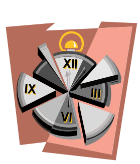
Topic

Marine sediments can be examined in core samples.

Introduction

What is on the bottom of the ocean? To collect ocean sediments, oceanographers do not have to go to the seafloor. Instead, they remain at the surface and use collection equipment that gathers samples. For example, a *dredge* is a wire bag that is pulled across the seafloor. Although large samples can be collected, the materials get mixed in the sampling bag, so layers of sediment cannot be distinguished. Grab samplers are metal jaws that bite into the sediment. Both dredging and grab sampling are best used to study sediments near the surface. Deeper samples are collected with corers, metal tubes that are pushed into the sediments. Corers have two advantages: they keep sediment layers intact, and they act as storage devices for the samples. Scientists examine the layers to find out the geological history of the ocean floor.

Some sediment is made from weathered rock and soil that eventually finds its way into the ocean. Sand, silt, and clay are three types of sediment distinguished by their size (see Figure 1). Sand, the largest particle, tends to sink quickly. Silt is a medium-size particle that is lighter and can travel further than sand. Clay particles are tiny, enabling them to remain suspended in the water. Other sources of sediment include particles from volcanic eruptions and the shells of dead organisms. Skeletons of *diatoms,* one-celled photosynthetic organisms covered in glasslike shells (see Figure 2), are found in regions beneath areas of high productivity. In this experiment, you will model ocean floor core sampling and analysis.



Time Required

55 minutes

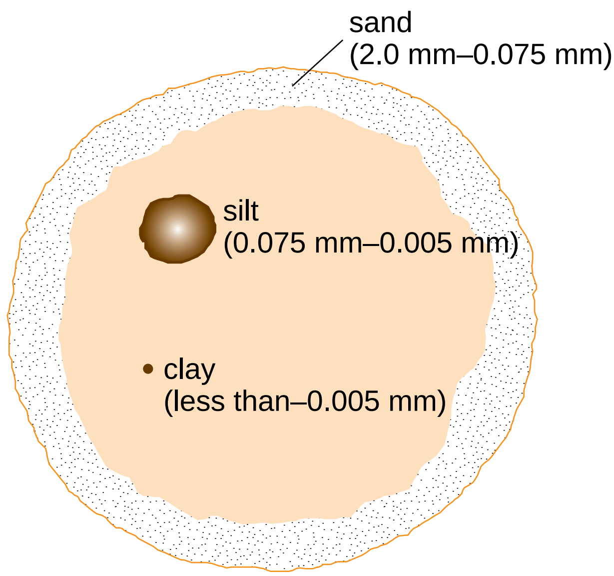


Figure 1

Soil particle sizes

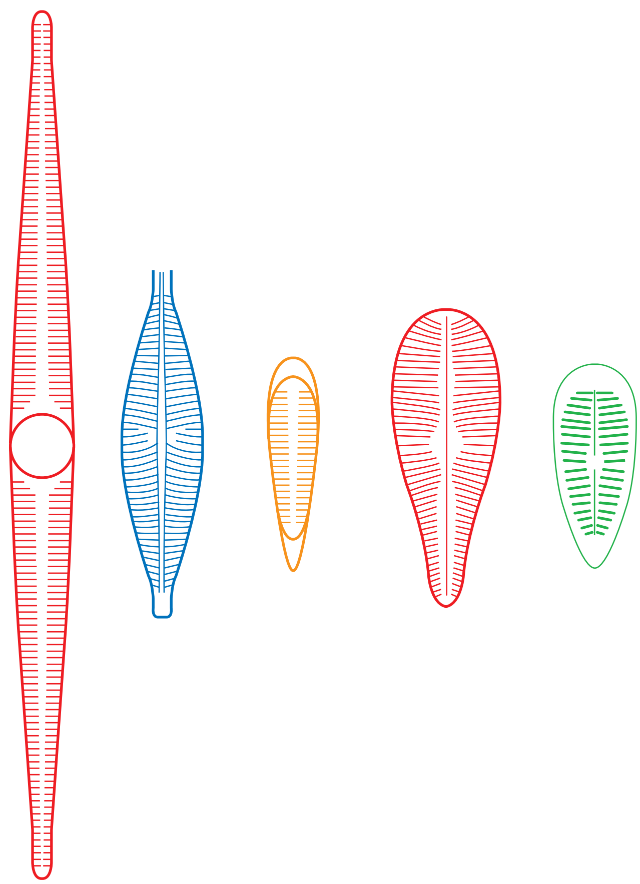


Figure 2

Diatoms viewed under a compound light microscope.

Materials

- 4 prepared containers of seafloor sediments (for the entire class) labeled A, B, C, and D
- 3 clear straws
- small ball of modeling clay
- scalpel
- dissecting microscope
- compound light microscope
- glass slide
- toothpick
- ruler
- science notebook

Safety Note **Take care when working with a scalpel. Please review and follow the safety guidelines at the beginning of this volume.**

Procedure

1. Take a core sample of seafloor sediment A. To do so:
   a. Carefully insert a clear straw into the sediment, taking care to avoid disturbing the areas surrounding the sampling location.
   b. Slowly and carefully remove the straw, then cover the end with clay to seal.
2. Repeat step 1 for samples B, C, and D.
3. Answer Analysis questions 1 and 2.
4. Draw and color each core sample in your science notebook.
5. Measure the length of each sample and the depth of each type of deposit in the sample.
6. Answer Analysis question 3.
7. Carefully use a scalpel to open the straw from sample A. With a toothpick, remove a little of the first layer of the sample and spread it on a microscope slide.

8. Examine the sample under the dissecting microscope, first on low power then on high power. Sketch and describe what you see.
9. Put a drop of water on the slide and add a cover slip. Examine the slide under low power on the compound light microscope. Sketch and describe what you see.
10. Repeat steps 7 through 9 with the other layers of the same sample.
11. Examine the core samples B, C, and D in the same manner.
12. Answer Analysis questions 4 through 6.

Analysis

1. What is the purpose of taking core samples of the ocean floor?
2. Describe the appearance of sediments in each of the four core samples. What can each of these samples tell you about the seafloor?
3. If sediment is deposited at the rate of 0.08 inches (in.) (2 millimeters [mm]) per year, how long did it take for samples A, B, C, and D to be deposited?
4. Researchers took a core sample of the ocean floor that is 13.1 feet (ft) (4 meters [m]) long. The present-day ocean floor layer is represented by the topmost layer of the core sample. How old is the bottom layer of the sample?
5. Generally, what do the different layers of a core sample tell you?
6. Describe the microscopic appearance of each layer of the four sediments.

What's Going On?

In this experiment, you modeled core sampling using prepared sediments. Each sediment sample is slightly different, indicating different regions of the ocean floor. Soil particles from *terrigenous* sources, those that originated on land, may range in size from gravel to clay. The smaller the particles, the further they can travel out to sea. Since heavy sediments cannot move far from their points of origin, their deposits show geologists the junctions of rivers and oceans in the past. By examining the positions of sand and gravel, scientists can clearly see that the ocean water level has varied over thousands of years. Additional evidence to indicate sea level fluctuations are found in the fossils of photosynthesizers. When sea levels are low, light can penetrate to the seafloor and photosynthetic organisms are abundant. Examining core samples enables scientists to glimpse other past events. The traces of once-living things also tell something about water temperature. When remains of living things are plentiful in the sediment, scientists know that the water temperatures were probably warm.

Connections

Core samples are used to study the history of Earth's climate. Climatologists have examined sediments from around the globe, focusing on layers that contain *foraminiferans*, one-celled organisms with calcite shells. Figure 3 shows shells of several types of foraminiferans. By inspecting the shells of these organisms taken from several locations, scientists have been able to determine the approximate temperature at the bottom of the ocean, the availability of nutrients in the water, and the direction of the ocean currents in the past.

This data led scientists to the conclusion that deep ocean currents changed their direction of flow 55 million years ago. The change was triggered by a period of global warming that lasted 20,000 years, an event known as the *Paleocene/Eocene Thermal Maximum* (PETM). The consequences of the PETM include mass extinction of deep-sea life and migrations of terrestrial animals, events that reduced and redistributed

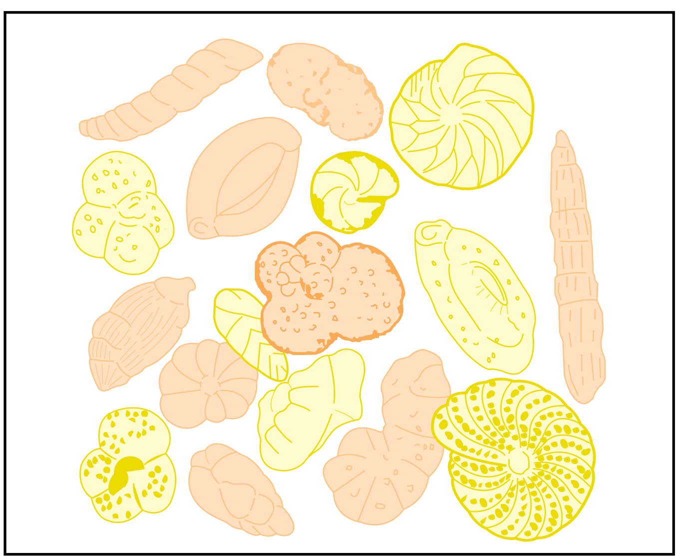


Figure 3

Foraminiferan shells occur in a variety of shapes.

biodiversity on a global scale. During the PETM, levels of atmospheric carbon dioxide were high, only slightly higher than those found today. The study is relevant to today's climate changes because it links global warming to other, serious alterations in Earth's ecology.

Want to Know More?

See appendix for Our Findings.

Further Reading

Columbia University. "Deep Sea Sample Repository," October 15, 2007. Available online. URL: http://www.ldeo.columbia.edu/res/fac/CORE_REPOSITORY/RHP1.html. Accessed August 11, 2009. Located in Palisades, New York, the repository is a storehouse for deep-sea cores taken from all the major oceans. This Web page explains how cores are taken, cared for, and analyzed.

Ohio State University. "Ocean Sediment to Reconstruct Record of Ancient Climate," *Huliq News*, June 6, 2009. Available online. URL: http://www.huliq.com/11/82295/ocean-sediment-reconstruct-record-ancient-climate. Accessed July 3, 2009. This article discusses analysis of core samples from the top 65.6 ft (20 m) of sediment in the North Atlantic Ocean that provides information about climate over the last 500,000 years.

Science Daily. "Global Warming Can Trigger Extreme Ocean, Climate Changes, Scripps-led Study Reveals," January 2006. Available online. URL: http://www.sciencedaily.com/releases/2006/01/060106002509.htm. Accessed July 3, 2009. This article reports on sediment research conducted by Flávia Nunes and Richard Norris, scientists at Scripps Institution of Oceanography at the University of California, San Diego, that links global warming to changes in deep ocean currents.

12. Bycatch During Fishing

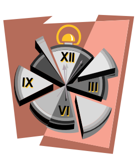
Topic

Some fishing techniques create more bycatch than others.

Introduction

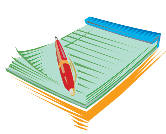
Marine fishermen supply our tables with fish, shrimp, scallops, crabs, oysters, and other delicacies from the sea. However, fishermen accidentally catch many organisms other than the target species. Animals that are unintentionally caught, and therefore discarded, are classified as *bycatch*. These organisms include mammals such as whales and dolphins, sea turtles, seabirds, small fish, and squid. The capture of these unwanted animals reduces their populations.

Not all types of fishing equipment yield the same volume of bycatch. Types of commercial fishing gear include gillnets (see Figure 1), trawl nets, and longlines. *Gillnets* are long, stationary sheets of webbing. Some hang in the ocean suspended by floats and others are weighed down so they will sink to the bottom. *Trawl nets* are large, rounded nets that are pulled behind a boat. *Longlines* consist of an extended central line to which smaller lines and hooks are attached. In this experiment, you will compare the bycatch of each fishing technique.



Time Required

45 minutes



Materials

- small fishbowl
- 50 pieces of large dried pasta
- 50 pieces of small dried pasta
- 100 sprinkles
- 20 Goldfish™ crackers

- tweezers
- spoon
- small scoop
- stopwatch or clock with a second hand
- science notebook

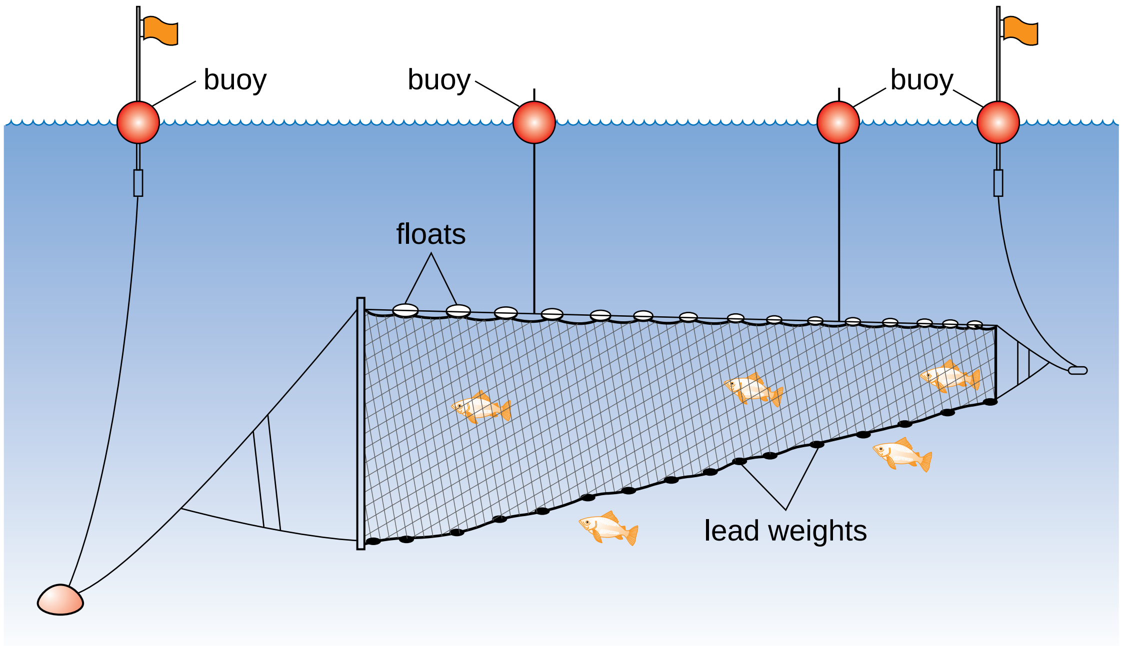


Figure 1

Gillnet

Safety Note **Please review and follow the safety guidelines at the beginning of this volume.**

Procedure

1. Work in groups of four. In this activity, the fishbowl represents the ocean, large pasta represents adult fish, small pasta represents young fish, sprinkles represent shrimp, and Goldfish™ crackers represent sea turtles. Put 50 pieces of large dried pasta, 50 pieces of small dried pasta, 100 sprinkles, and 20 Goldfish™ crackers in the fishbowl. Stir gently to mix.

2. You and two of your partners will “go fishing” 10 times. Each fishing trip will last 5 seconds. The fourth member of the group will keep time. One member of the group will fish with tweezers, which represents longlines. Another will fish with the spoon, which symbolizes a stationary gillnet. The third will fish with a scoop, which signifies a trawl net. Assign the stopwatch and fishing equipment to members of the group. The target animals for all fishermen are the adult fish.
3. Make three copies of the data table, one for each fisherman. Each fisherman will write his/her fishing tool on the blank at the top of the table.
4. Answer Analysis question 1.
5. Take 10 fishing trips. Your goal on these trips is to catch a total of 12 adult fish. To take a fishing trip:
    a. The timekeeper says “Go.” The fishermen work for 5 seconds with their tools to catch adult fish.
    b. Fishermen should try to avoid young fish, shrimp, and sea turtles.
    c. The timekeeper says “Stop” when time is up.
    d. All fishermen count and record the number of each type of animal they caught. Animals that are caught should be set aside.
6. Answer Analysis questions 2 through 9.

Analysis

1. Which type of fishing tool do you think will yield the most target animals? Which do you think will yield the most bycatch?
2. Which fishing tool produced the most bycatch of:
    a. shrimp ___________________
    b. young fish ___________________
    c. sea turtles ___________________
3. Why do you think it is important to avoid catching young fish?
4. What kind of fishing tool would you use to catch shrimp? How would you avoid bycatch?
5. If you need to sell 12 large fish at the fish market each day to earn a living, which tool(s) would yield enough catch?

6. Was it easier to catch adult fish at the beginning of the activity or toward the end of the activity? Why?
7. What do you think fishermen do with their bycatch?
8. Turtles have lungs, not gills, so they breathe air. What happens to turtles that are tangled in nets underwater for several hours?
9. Suggest three ways to reduce bycatch.

Data Table				
	Number of individuals caught using (tool) ____________			
Fishing trip	**Adult fish**	**Young fish**	**Shrimp**	**Sea turtles**
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

What's Going On?

All three fishing techniques represented in this experiment are indiscriminate in what they catch. Fishermen who use longlines bait the hooks, then drop the heavy lines overboard. Gillnets are difficult for animals to see, so they swim through them, and get caught. Once fish enter trawl nets, they cannot escape.

According to the United Nations Food and Agriculture Organization, one-fourth of the animals that are caught in nets are bycatch. This means that 25 percent of the sea life caught by fishermen is thrown away. Fish may be discarded either because they are the wrong species or because they are too young. If the young fish could be saved, they would help replenish depleted populations. When dolphins and sea turtles get caught in nets or on hooks, they cannot surface to get air, so they drown. Seabirds also drown when they dive for bait on the hooks of longlines.

Connections

Environmentalists and fishermen have been trying to solve the problems of bycatch, and they have made some progress. Some trawl nets have been equipped with escape hatches called turtle excluder devices (TEDs) through which turtles can find their way out (see Figure 2). A TED is a lattice of bars that is located at the top or the bottom of the trawl net. Small animals pass through the bars into a bag. When large animals like turtles strike a TED, they are expelled.

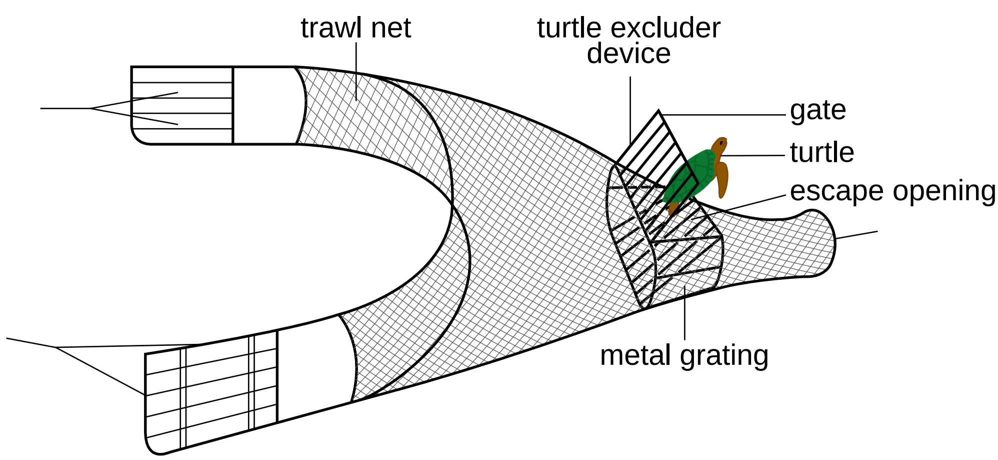


Figure 2

One fisherman who was especially concerned about the death of mammals in his gillnets bought a device that transmits a “pinging” sound like the one made when a school bus backs up. He attached this device to his nets and found that the number of porpoises in his nets dropped drastically. Other fishermen and marine biologists are advocating his discovery and promoting the use of pingers.

Want to Know More?

See appendix for Our Findings.

Further Reading

Greenpeace International. "Bycatch." Available online. URL: http://www.greenpeace.org/international/campaigns/oceans/bycatch. Accessed July 3, 2009. Greenpeace discusses the number of animals that are victims of bycatch each year on this Web page.

Oregon State University. "'Bycatch' Whaling a Growing Threat to Coastal Whales," June 23, 2009. Available online. URL: http://www.eurekalert.org/pub_releases/2009-06/osu-wa062309.php. Accessed July 3, 2009. Scientists have found that the number of bycatch whales in Japan is equal to the number of whales killed by the whaling industry.

Science Daily. "Excessive Bycatch of Cod Undermines Moratorium: Cod Bycatch Was at Least 70 Percent Higher Than Target Levels," May 7, 2009. Available online. URL: http://www.sciencedaily.com/releases/2009/05/090502102740.htm. Accessed July 3, 2009. As reported in this article, populations of cod, a favorite food fish, are declining, partially because of the large number of these animals in bycatch.

13. Bioaccumulation in Killer Whales

Topic

Killer whales accumulate toxins in their tissues because of their physiology and their positions at the top of food webs.

Introduction

Toxins, or poisonous substances, cause extensive damage to wildlife. Toxins do not occur naturally; they are all man-made. Although most toxins are designed for use on land, they eventually make their way into the oceans. The most serious problems are caused by toxins that are classified as *persistent organic pollutants*. One group of these pollutants is a class of about 250 chemicals that are collectively known as *polychlorinated biphenyls* (PCBs). The general chemical structure of PCBs is shown in Figure 1. These chemicals are very stable, so they do not break down over time. Because most PCBs are fat soluble, they are able to collect in body fat. Marine mammals like killer whales (*Orcinus orca)* (see Figure 2), are very susceptible to toxin accumulation because they have a lot of body fat. The buildup of toxins in tissue over a period of time is *bioaccumulation.* In this experiment, you will find out how PCBs accumulate in the tissues of animals.

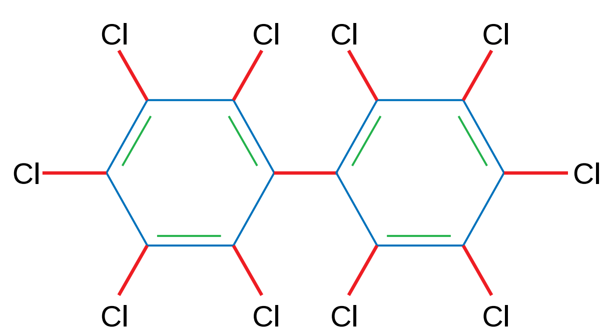


Figure 1

General chemical structure of PCBs

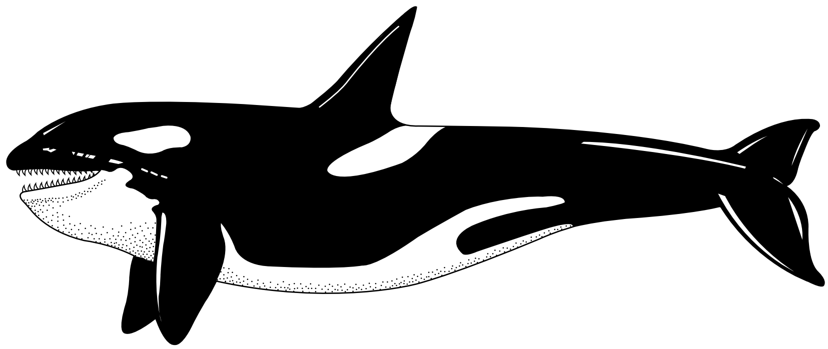


Figure 2

Killer whale, *Orcinus orca*

Time Required

35 minutes for part A
25 minutes for part B

Materials

- name cards
- masking tape
- sediment feeder cards
- access to an open area
- stopwatch or clock with second hand
- science notebook

Safety Note **Please review and follow the safety guidelines at the beginning of this volume.**

Procedure, Part A

1. You will play an animal in the killer whale *food chain*. Use masking tape to affix the card with your animal name to your shirt.
2. Follow your teacher to an open area. Your teacher will have the group form a large circle and will spread out cards labeled *sediment feeders*.

3. When your teacher gives the signal, students wearing the *zooplankton* labels enter the open area and "feed" by collecting cards labeled *sediment feeders*. Zooplankton should pick up only one card at a time. When the teacher says "stop," the "zooplankton" stop picking up cards but remain in their positions.
4. On the teacher's signal, zooplankton continue feeding and students wearing the *herring* labels enter the open area. Herring are small fish that feed on zooplankton. When a herring tags a zooplankton, the herring takes all the zooplankton's cards and labels. Zooplankton that are tagged must return to the circle. Untagged zooplankton continue eating sediment feeders. On the teacher's signal, all students stop moving and remain in their positions.
5. On the teacher's signal, zooplankton and herring continue feeding and students wearing the *seal* labels enter the feeding area. Seals are marine mammals that eat herring. To show this, a seal takes a herring's card and labels and the herring returns to the circle. On the teacher's signal, all students stop moving and remain in their current positions.
6. On the teacher's signal, zooplankton, herring, and seals continue feeding and the student wearing the *killer whale* label enters the feeding area. Killer whales are marine mammals that eat seals. When a killer whale eats a seal, the whale takes the seal's cards and labels and the seal returns to the circle. On the teacher's signal, all students stop moving.

Procedure, Part B

1. Return to the classroom. Each surviving organism stands in front of the class and displays his or her cards and labels. Notice that some of the labels have red dots. These dots indicate PCBs. Animals with very low levels of toxin survive. Those with moderate levels of toxin suffer damage to their immune and reproductive systems. Those with high levels of toxins die. To determine the number of healthy organisms and the number that survive with damage, examine the data table.
2. Organisms that died from excessive loads of toxins should sit down. The survivors and survivors with damage should form two separate groups in front of the class.

3. In your science notebook, record the number of survivors, survivors with damage, and organisms that died.

Data Table		
Organism	**Number of toxins**	**Outcome**
Zooplankton	3 or less	survives
	4 or 5	survives with damage
	6 or more	dies
Herring	4 or less	survives
	5 or 6	survives with damage
	7 or more	dies
Seals	5 or less	survives
	6 or 7	survives with damage
	8 or more	dies
Killer whales	6 or less	survives
	7 or 8	survives with damage
	9 or more	dies

Analysis

1. Why do marine mammals tend to accumulate PCBs?
2. In your own words, define *bioaccumulation*.
3. How many herring avoided being eaten by seals? How many of the surviving herring were damaged or killed by PCBs?
4. How many seals avoided being eaten by killer whales? How many of the surviving seals were damaged or killed by PCBs?
5. What factors affect the survival of killer whales?
6. How many steps exist in the killer whale food chain portrayed in today's experiment? In some whale food chains, there are more steps. For example, if herring are consumed by salmon, and

salmon are fed on by seals, the food chain gains a level. How might increasing the levels of the food chain affect the amount of toxin consumed by killer whales?

7. Killer whales become reproductively active between ages 15 and 20. Females usually produce one offspring every 5 years. How do PCBs affect the number of offspring produced by a group, or *pod,* of whales?

What's Going On?

Killer whales live in stable, female-led pods. By taking tissue samples using darts, scientists have determined that males have higher levels of PCBs than females. In calving, females pass some of their toxin load on their offspring. In addition, they also lose toxins in their fatty milk. For this reasons, calves begin their lives with relatively high levels of PCBs.

Much research has been conducted on orcas on the west coast of the United States. Three distinct groups live in the region: the northern resident pod, the southern resident pod, and the transients. In the northern pod, individuals average 46 parts per million (ppm) PCB. To put this in perspective, the tissues of an average human have 1 ppm PCB. Animals in the southern pod have an amazing 146 ppm. The difference is due to higher levels of pollution in southern waters. However, these numbers pale compared to those of the transients, who average 251 ppm. As their name suggests, transients travel extensively and are exposed to pollution globally. In addition, their diets are more varied, giving them more opportunities to take on toxins.

Connections

Polychlorinated biphenyls, first produced in 1929, were widely used in production of electrical equipment because they are resistant to heat, acids, and bases. The chemicals were also incorporated into paint, ink, adhesives, and surface coating. Before scientists determined that they are dangerous to humans and wildlife, about 2 millions tons of PCBs were produced. In 1976, a ban on PCB production was put in place. However, the toxins are still widespread in the environment because of improper disposal of PCB-laden products.

In the environment, PCBs bind strongly to particles in the sediment. Sediment particles are ingested by microscopic organisms, which serve as food for zooplankton and larger organisms. Eventually, PCB molecules are passed along food chains to marine mammals such as killer whales.

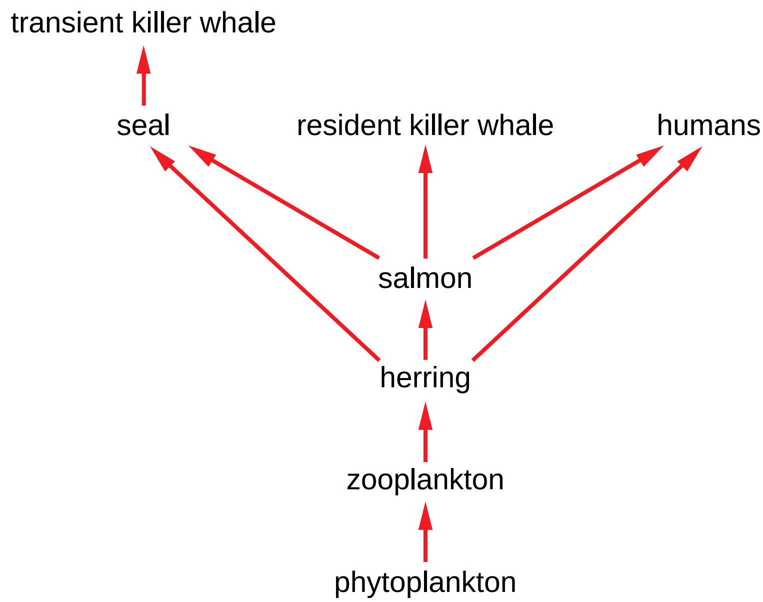


Figure 3

Want to Know More?

See appendix for Our Findings.

Further Reading

dolphins-world.com. "Killer Whale Facts," 2009. Available online. URL: http://orca.dolphins-world.com/. Accessed July 6, 2009. This Web page includes links to information on killer whale anatomy, socialization, and evolution as well as videos and photographs.

GreenFacts Digests. "Scientific Facts on PCBs," 2009. Available online. URL: http://www.greenfacts.org/en/pcbs/. Accessed July 6, 2009. The route of PCBs in the environment and the effects of these chemicals on the human body are explained on this Web page.

Lyke, M. L. "Killer Whales Are Full of Toxic Chemicals, New Study Says," October 25, 1999. *Seattle Post Intelligencer.* Available online. URL: http://www.seattlepi.com/local/whal25.shtml. Accessed July 6, 2009. This article discusses research conducted by the Institute of Ocean Sciences in Sidney, B.C., that indicates orca whales are some of the most contaminated animals in the world.

14. Ocean Regions

Topic

Regions of the ocean vary in physical characteristics.

Introduction

If you mixed all of the oceans together, the average temperature would be 39 degrees Fahrenheit (°F) (4 degrees Celsius [°C]) and the average depth 4,000 feet (ft) (4,267 meters [m]). However, very few areas exhibit these average characteristics. As one moves up and down through the water column, the physical characteristics of temperature, pressure, oxygen, nutrients levels, and light change. Organisms are highly adapted to live in the unique conditions at each level.

Temperature also varies with *latitude*. In equatorial regions, surface water temperatures may be as warm as 86°F (30°C) but at the poles, the temperatures are at, or very near, the freezing mark. Temperature also varies with depth; water near the surface is warmer than deep water.

With an increase in depth, water pressure increases. Every 33 ft (10 m) of water increases pressure by 1 atmosphere (atm). Despite the incredible amount of water pressure at depths of 3,281 ft (1,000 m) or more, many marine organisms make their homes in the bottoms of the deepest seas. Some are capable or migrating from deepwater to the surface every day with no ill effects. This ability to withstand high pressures is due to the physiology of fish and invertebrates, whose bodies are mostly water. Unlike air, water cannot be compressed, leaving fish largely unaffected by changes in pressure.

Chemical qualities of water, such as levels of oxygen and nutrients, are also diverse. Oxygen levels are high near the surface where mixing occurs and in very cold, deepwater. Mid-level regions of the ocean are usually oxygen poor. Nutrients are tied up within the bodies of living things. When organisms die, they fall to the seafloor, taking their nutrients with them. *Phytoplankton* living at the water's surface need nutrients to carry out photosynthesis, and they depend on upwellings of deepwater to bring these nutrients to the top.

Regions of the water column vary in the amount of light they receive. The upper or *photic* region, the first 656 ft (200 m), receives enough light to support photosynthesis. Sunlight is made up of the colors of the rainbow, and not all colors of light are able to penetrate water. Low-energy wavelengths of light, such as red and orange, are absorbed in water more easily than the high-energy blues. Therefore, blues penetrate deeper than the other colors (see Figure 1). The region from 656 ft (200 m) to 3,281 ft (1,000 m) is described as the twilight zone, an area where light penetration is minimal. Below 3,281 ft (1,000 m) is the dark zone where no light penetrates. In this experiment, you will see how the appearances of objects change with increasing water depth.

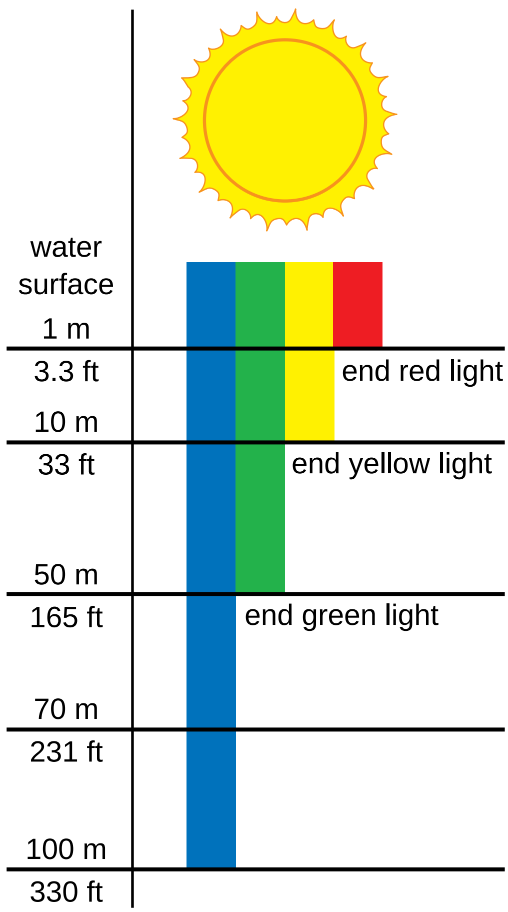


Figure 1

Time Required

45 minutes

Materials

- 6 strips of blue plastic (each strip about 5 inches [in.] by 1.5 in. [12.7 centimeters (cm) by 0.6 cm])
- scissors
- small squares of blue, green, red, and black construction paper
- sheet of black construction paper
- poster board (about the size of a sheet of notebook paper)
- tape
- photocopy of goggle pattern
- science notebook

Safety Note **Take care when working with scissors. Please review and follow the safety guidelines at the beginning of this volume.**

Procedure

1. Answer Analysis questions 1 through 3.
2. Cut out the goggles pieces from the photocopy of the goggle pattern (see Figure 2). Be sure to cut out the eyeholes.
3. Place the goggles pattern pieces on the poster board.
4. Trace the pattern on poster board.
5. Cut out the pattern pieces.
6. Cut two squares of blue plastic, one for each eyehole. Tape the blue plastic in the eyeholes. One layer of blue plastic represents a water depth of only a few feet.
7. Place the sheet of black construction paper on your desk top.
8. Randomly spread the squares of black and colored construction paper on the black construction paper.
9. Put on your goggles and observe the squares to find out how colors of objects appear in a few feet of water. Describe the colors of each square on Data Table 1.

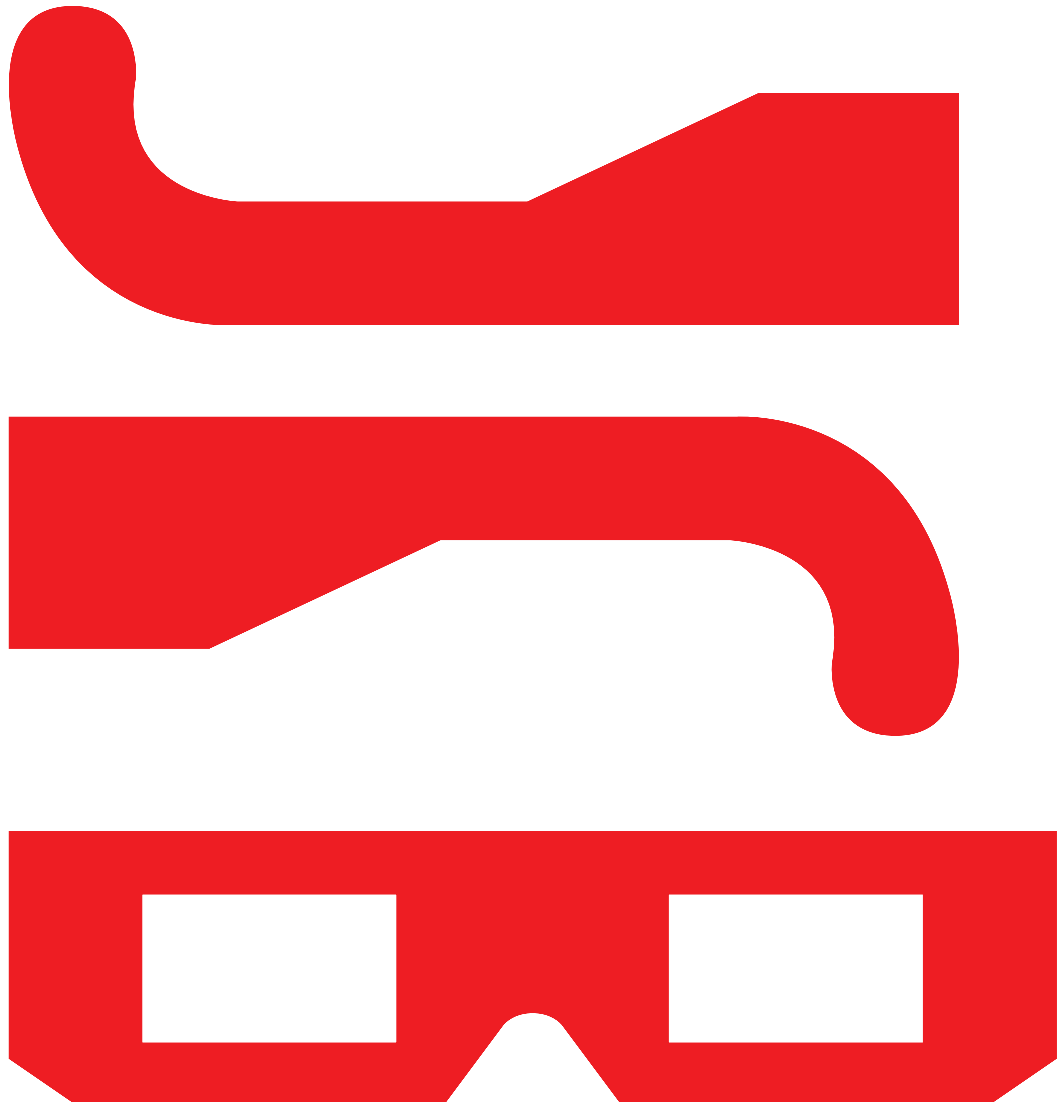


Figure 2

Pattern for goggles

10. Remove your goggles. Cut out two more squares of blue plastic. Tape a second layer of blue plastic on top of the existing layer. Two layers of blue plastic represent deeper water. Repeat step 9.

11. Continue adding layers of blue plastic to your goggles, observing and describing squares of paper until you have added 5 layers. Each addition layer of blue plastic represents deeper water.

12. Answer Analysis questions 4 through 7.

Data Table 1: Appearance of Paper Squares				
Layers of blue plastic	blue square	green square	red square	black square
1				
2				
3				
4				
5				

Analysis

1. What are the colors of the rainbow?
2. Grass is green because it reflects green light. What do you think happens to all of the other colors of light that strike grass?
3. If you observe grass in the moonlight, what is its color? Why?
4. How did the appearance of the squares of paper change with each additional layer of blue plastic?
5. What do the colored squares of construction paper represent in this experiment?
6. Based on Data Table 2, which color of light penetrates the deepest?
7. Some fish need to be visible at depth of 262 ft (80 m). What color would you expect these fish to be? Why?

What's Going On?

In this experiment, you used layers of blue plastic to represent layers of water in the ocean. Blue plastic blocks some of the light by absorbing colors other than blue. In the ocean, as on land, light makes it possible for animals to see. Many of the fish in the upper photic zone have distinctive colors or patterns on their bodies as well as keen eyesight.

Data Table 2	
Wavelength (color) of light	**Depth of penetration**
Red	16 ft (5 m)
Orange	49 ft (15 m)
Yellow	98 ft (30 m)
Green	197 ft (60 m)
Blue	246 ft (75 m)
Indigo	279 ft (85 m)
Violet	328 ft (100 m)

Fish depend on color to help them identify and attract mates, locate prey, and escape from predators. In shallow water, a red fish looks red. However, as depth increases, reds become invisible first, then oranges, yellows, green, and finally blues. Some of the fish that spend a lot of time in water of 246 ft (75 m) or more are blue because blue is one of the few colors visible at this depth. In 328 ft (100 m) of water, a red fish, like all others, simply appears black. As a result, fish that live in very deepwater are either darkly pigmented, or transparent, completely lacking pigment.

Light is a form of *electromagnetic radiation* and it has characteristics of waves. White light is a blend of several wavelengths. Red waves have the longest wavelengths and lowest energy, while violet waves have the shortest wavelengths and the highest energy. When white light strikes water, low energy waves are absorbed faster than high-energy waves. Data Table 2 shows the depth of penetration of each wavelength of white light.

Connections

In the deepest, darkest parts of the ocean, fish have adaptations for living without light. To signal mates or attract prey, some fish have special light organs called *photophores* that produce light through chemical reactions known as *bioluminescence*. A viper fish, for example, emits light on a lure-shaped organ that extends from its dorsal fin (see Figure 3). The flashing lure attracts smaller fish, making them easy prey for the viper. The viper fish and some other species have large, bulging eyes that help them gather any light wave emitted by other sea life.

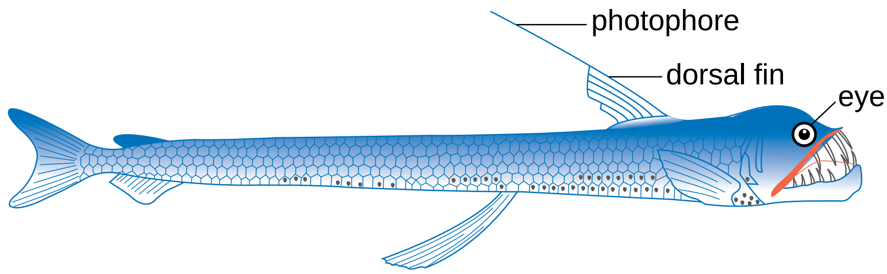


Figure 3

Viper fish

Want to Know More?

See appendix for Our Findings.

Further Reading

Chamberlin, Sean. “Light and Color of the Oceans,” 2009. Marinebio. Available online. URL: http://marinebio.org/Oceans/Light-and-Color.asp. Accessed August 16, 2009. Chamberlin explains the depth of penetration of different wavelengths of light on this Web page.

Goddard Earth Sciences Data and Information Services. “Ocean Color,” June 29, 2009. Available online. URL: http://disc.sci.gsfc.nasa.gov/oceancolor/additional/science-focus/locus/tutorials/module1.shtml. Accessed August 16, 2009. This NASA Web page explains how satellites determine and analyze sea surface temperature.

Johnsen, Sonke, and Heidi Sosik. “Shedding Light on Light in the Ocean,” 2004. Oceanus. Reprinted from *Oceanus* magazine, Vol. 43, No. 2. Available online. URL: http://www.whoi.edu/oceanus/viewArticle.do?id=2472. Accessed August 16, 2009. In this article, the authors use colorful diagrams and simple language to explain how light penetrates water and impacts living systems in marine environments.

15. Echinoderm Adaptations

Topic

Echinoderms possess a water vascular system that provides mobility and enables them to capture food.

Introduction

Echinoderms are a group of spiny-skinned marine animals that include starfish, brittle stars, sand dollars, sea cucumbers, and sea urchins. These animals display the unusual characteristic of *radial symmetry,* with appendages that extend from a central point, like spokes on a wheel. Most animals, including humans, are *bilaterally symmetrical*, having two sides that are mirror images. Echinoderm appendages, or rays, generally occur in multiples of five. They are able to grasp objects because of an internal *water vascular system*. Within their central disc (see Figure 1), an echinoderm has a vascular ring that surrounds the digestive system. Radial canals extend from the central ring, traveling through each appendage. Attached along the radial canals are small, saclike *ampullae* that end in *podia,* or feet, that can form suction cups. By removing water from its podia, the animal creates suction that lets it hold objects. To let go, the animal releases water through the tiny feet. Externally, the podia are located along grooves or *ambiculacra* on the underside of each appendage. One of the best-known types of echinoderms is the starfish. In this experiment, you will examine a living starfish and make a model of its water vascular system.

Time Required

35 minutes for part A
55 minutes for part B

Materials

- living starfish in saltwater aquarium
- shallow plastic container (that will hold a starfish)

- magnifying glass
- plastic cup
- modeling clay
- straws
- rubber tubing
- rubber bands
- paper clips
- paper cups
- access to water
- science notebook

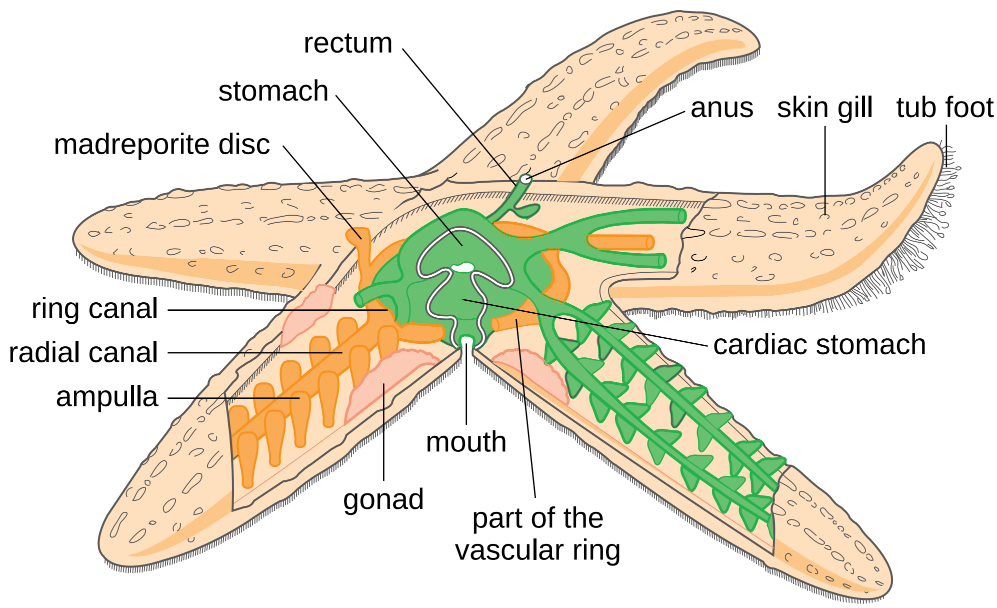


Figure 1

Starfish

Safety Note Take care when working with living organisms. Wash hands thoroughly after handling marine animals. Please review and follow the safety guidelines at the beginning of this volume.

Procedure, Part A

1. Gently lift a starfish from the saltwater aquarium and place it in a shallow plastic container of saltwater.
2. Examine the dorsal (upper) surface of the living starfish. Locate the central disc, the middle portion of the animal, and the rays that extend from the disc.
3. Find the *madreporite disc* (see Figure 1), a round structure that may resemble a bump or wart.
4. Use the magnifying glass to examine the spiny dorsal skin. Examine the bumpy structures on the skin.
5. Gently turn the starfish so that its ventral (under) side is up.
6. Locate the mouth in the central disc.
7. Observe the ambulacral grooves extending down each appendage. Along the grooves are the tube feet.
8. Locate the tube feet and gently touch them with one finger.
9. Return the starfish to the aquarium.

Procedure, Part B

1. Notice the components of the water vascular system in Figure 2: the ring canal, radial canals down each appendage, the ampullae, and the tube feet.
2. Make a model of a starfish's water vascular system. Your model can be either a structural one that simply shows the parts of the system or a functional one that shows how regulating water in the tubes enables starfish to grasp and release objects. While making your model, keep these points in mind:
   a. You can use any of the supplies provided by your teacher, but you probably will not need all of them.
   b. You must be able to explain what the parts of your model represent.

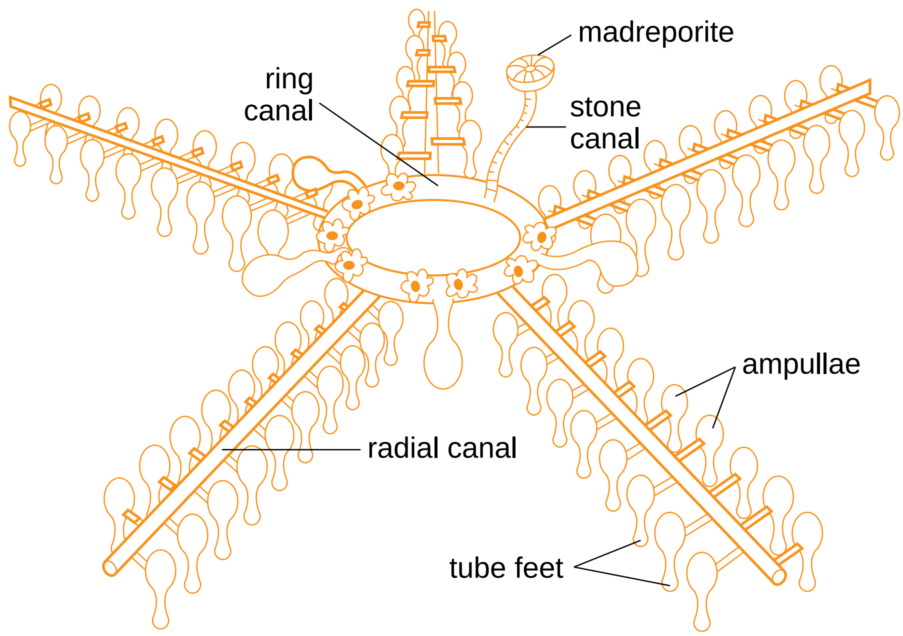


Figure 2

Analysis

1. What are some of the basic characteristics of all echinoderms?
2. Describe what you saw when you examined the dorsal surface of the starfish with a magnifying glass.
3. Did you notice any structures on the starfish that might detect light or odors?
4. How might a starfish use its appendages to attach to a rock? How might it let go of the rock?
5. Explain what the parts of your model represent.

What's Going On?

Despite the fact that starfish lack brains, eyes, noses, hands, or feet, they are very successful animals that have existed on Earth for hundreds of millions of years. The tube feet of starfish give them mobility to explore the seafloor in search of food. Plus, the tube feet have other functions. Sensory nerves located on the tube feet enable these invertebrates to learn about their environment. The information they gather is supplemented by eyespots on the tip of each appendage. Although eyespots do not see images the way eyes do, they are light-sensitive organs that detect the presence and movement of light.

When you touch a starfish, you may notice that it feels hard, and its skin is bumpy and prickly. Starfish have internal skeletons made of material that is similar to bone. The interlocking calcium plates of the skeleton protect the soft internal organs. The hard skeleton is covered by thick skin. Protruding from the skin are bumps called *dermal branchiae* that absorb oxygen. In addition, pincherlike *pedicellaria* can remove things that might try to hitch a ride on the starfish. The large, colored dot on the dorsal surface is the madreporite, a sievelike part of the water vascular system that takes in water. Nearby is another bump, the anus.

Starfish are predators that eat a variety of small animals including clams, mussels, snails, and barnacles. To open a clam, the starfish surrounds its victim and attaches to both shells with its tube feet. The animal slowly pulls the two shells apart. Once there is a small opening between the shells, the starfish extrudes its stomach through its mouth and into the clam. The stomach produces digestive enzymes that kill the clam and break down its tissues. Once digestion is complete, the stomach absorbs the prey. By the time a starfish finishes its meal and returns its stomach to the original position, there is nothing left but two clam shells.

Connections

If a starfish loses an appendage, it can grow another one through *regeneration*, the ability to replace missing organs. Some species of echinoderms have even more amazing powers of regeneration. *Linckia* can regenerate an entire animal from one appendage. If *Linckia* gets torn apart, five new starfish will be produced. In this case, regeneration is a type of *asexual reproduction*.

In most echinoderms, the primary type of reproduction is sexual. Males and females release their *gametes* into the water, where *fertilization* occurs. The developing embryos form part of the *zooplankton*, drifting with the currents and gathering food by beating their tiny *cilia*. Developmentally, starfish fall into a group known as *deuterostomes*, organisms whose embryos show bilateral symmetry. Later, larvae settle to the seafloor and grow into the adult forms.

Want to Know More?

See appendix for Our Findings.

Further Reading

Holmes-Farley, Randy. "Reef Alchemy," *Reef Keeping,* 2009. Available online. URL: http://www.reefkeeping.com/issues/2004-05/rhf/index.php. Accessed July 8, 2009. Farley explains how to maintain proper physical parameters in saltwater aquaria.

Kalakaua Marine Education Center. "Invertebrates of Hawai'i," September 28, 1996. Available online. URL: http://www2.hawaii.edu/~tissot/inverts/asteroid.htm#AP. Accessed July 7, 2009. This Web site names, briefly describes, and provides photographs of several species of echinoderms.

Starfish. "Invertebrates: Multi-celled animals (metazoan)," May 21, 2009. Available online. URL: http://www.starfish.ch/reef/echinoderms.html. Accessed July 7, 2009. The authors of this Web site describe the unique characteristics of echinoderms and explain how they develop from bilateral larvae.

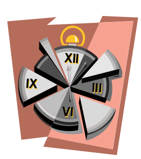
16. Fertilization in Sea Urchins

Topic

Sea urchins reproduce sexually by external fertilization.

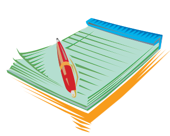
Introduction

Sea urchins are *echinoderms*, a group of spiny skinned animals that include starfish and sea cucumbers. Echinoderms are either male or female. Distinguishing the two sexes can be a little difficult, although in some species, males have less color than females. Echinoderms fertilize their eggs externally. Both eggs and sperm are released into the water, then sperm swim to eggs and fertilize them. Within minutes, the fertilized eggs or *zygotes* begin to undergo a series of cell divisions that lead to the development of small larvae. The larvae float in the *plankton*, feeding and undergoing changes for several months. Eventually they settle to the bottom and form a sphere-shaped, spiny animal with the same form as the adult. From birth to adulthood may take two to five years, depending on the species. In this experiment, you will remove egg and sperms from two adult sea urchins and watch the gametes carry out *fertilization*.



Time Required

55 minutes for part A
45 minutes for part B



Materials

- artificial seawater (about 1.3 gallons [gal] [5 liters (L)])
- 2 milliliters (ml) 0.5M potassium chloride (KCl)
- beaker (mouth of beaker should be slightly smaller than the sea urchin)
- aluminum foil
- half a Petri dish (either top or bottom)
- 1 ml syringe

- plastic wrap
- 50 ml beaker
- transfer pipette
- micropipette
- thermometer
- glass depression slide
- cover slip
- test-tube rack
- 2 test tubes
- labels
- science notebook

Safety Note **Take care when working with the syringe. Potassium chloride (KCl) is dangerous if you accidentally inject it into your body. Take care when when working with living organisms. Wash hands thoroughly after handling marine animals. Please review and follow the safety guidelines at the beginning of this volume.**

Procedure, Part A

1. Carefully remove a male sea urchin from the holding container and turn it upside down. You are looking at the mouth of the sea urchin. Induce the release of sperm by using the syringe to inject a total of 1 ml of 0.5M KCl solution into the sea urchin, 0.5 ml on each side of the mouth. Avoid injecting the solution into the mouth (see Figure 1). Very gently shake the sea urchin for a minute to mix the KCl.
2. Place the male sea urchin, mouth-side down, into one half of a clean, dry Petri dish. Off-white sperm should appear on the urchin in minutes. Gently collect the sperm with a clean transfer pipette. Place the sperm in a test tube, cover the test tube with plastic wrap, and store on ice or in the refrigerator. (Sperm can be stored for 2 to 5 days at 39 degrees Fahrenheit (°F) [4 degrees Celsius (°C)]).
3. Return the male sea urchin to the holding container.
4. Carefully remove a female sea urchin from the holding container and turn it upside down. Induce spawning in the female sea urchin by injecting 1 ml of 0.5M KCl into the body, 0.5 ml on each side of the mouth. Very gently shake the sea urchin for a minute to mix the KCl.

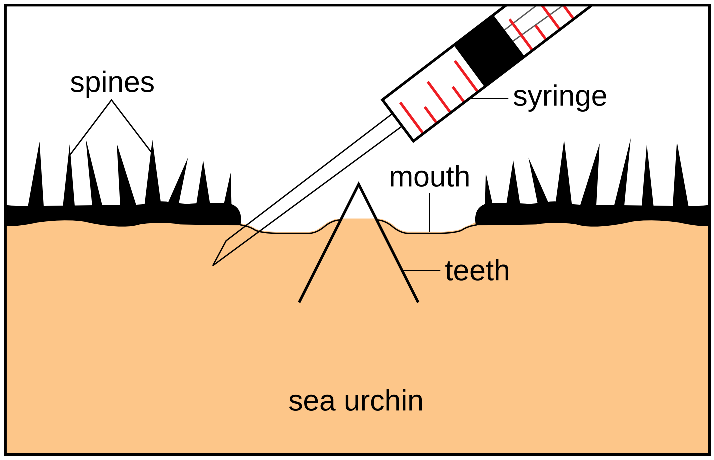


Figure 1

5. Place the female sea urchin, mouth-side down, on the top of a beaker filled with artificial seawater. The water should contact the sea urchin, but the body should be supported by the mouth of the beaker. If additional support is needed, use strips of aluminum foil to hold the sea urchin in place. Water temperature is important. If using sea urchins *L. variegatus*, the seawater should be room temperature. If using *S. purpuratus* and *L. pictus*, the water should be below 57°F (14°C).
6. Tan-to-orange-color eggs will be shed into the water over the next several minutes. When the sea urchin stops shedding eggs, return her to the holding container.
7. Give the eggs a few minutes to settle in the beaker of artificial seawater. When eggs are settled, pour off the artificial seawater and replace with fresh artificial seawater. This “washing” helps remove the jellylike coat from the eggs.

Procedure, Part B

1. Use a pipette to transfer some eggs to a 50-ml beaker.
2. Use a micropipette to dilute the sperm by adding 5 ml of sperm to 15 ml of artificial seawater in a separate test tube.
3. Place a drop of eggs on a glass depression slide.
4. Place the slide on the stage of a compound light microscope and examine under low and medium power. Draw what you see in your science notebook.

5. Add a drop of sperm. Cover the slide with a cover slip. Examine the slide and observe until a *fertilization membrane* forms (see Figure 2).

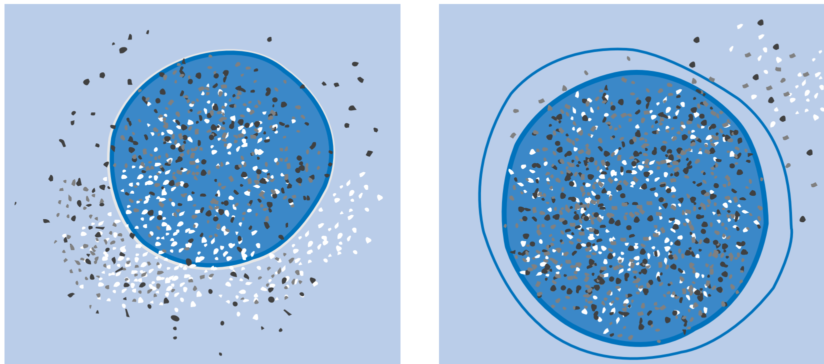


Figure 2

The egg on the left is surrounded by sperm. The egg on the right has developed a fertilization membrane.

Analysis

1. Describe the appearance of the sea urchin's mouth.
2. In your own words, define *spawning*.
3. After the injection of KCl, where did sperm appear on the male sea urchin?
4. After injection of KCl, where were eggs released by the female sea urchin?
5. Estimate the number of sperm that you saw on the microscope slide.
6. How can you tell that an egg has been fertilized?
7. Both the sperm and egg are described as haploid (1N) cells because they each have one-half set of chromosomes. Do you think that a fertilized egg is haploid or diploid? Explain your reasoning.

What's Going On?

Fertilization begins when a sperm swims to an egg and comes in contact with its jellylike covering. The *acrosome*, a structure on the head of the sperm, releases enzymes that break down the egg's jellylike covering. At the outer surface of the egg, sperm proteins and egg receptors bind. This binding ensures that only sperm of the same species can fertilize the egg. The plasma membrane of the sperm fuses with that of the egg, and the egg becomes impermeable to other sperm. The outer layer of the egg separates from the egg's plasma membrane, and the space between the two fills with water, forming a fertilization membrane. The nucleus of the sperm fuses with the egg's nucleus, pooling the genetic information of both parents.

Over a period of several hours, the zygote begins the process of *cleavage*. First, the zygote undergoes a mitotic division, forming two cells. Each of these cells undergoes a second mitotic division, producing four. The process of division continues, but the zygote does not increase in size. Eventually, cleavage leads to the development of a hollow ball of cells, the *blastula*, that has a fluid-filled cavity (see Figure 3). During the second phase of development, *gastrulation*, some of the cells begin to specialize and three distinct layers form: endoderm, mesoderm, and ectoderm. These layers *differentiate* into the tissues that will form the young sea urchin larva. The ectoderm forms epidermis, nerve tissue, and several other tissue types including the lining of the mouth. The endoderm forms the lining of the digestive, respiratory, reproductive, and urinary tracts, the endocrine organs, and the digestive glands. The mesoderm develops into the skeletal, muscular, circulatory, excretory, and reproductive systems.

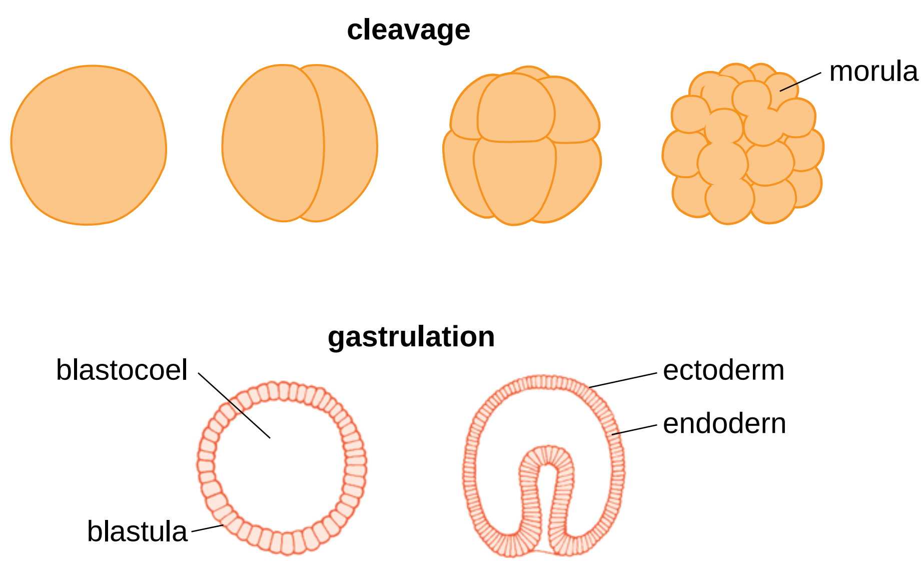


Figure 3

Connections

Sea urchins are relatively small echinoderms, measuring 1.2 to 3.9 inches (in.) (3 to 10 centimeters [cm]) in diameter. Spines on the animal provide protection as well as camouflage from predators. Urchins can be found in seas worldwide: Their habitats include tide pools, grass beds, wave-exposed shores, coral reefs, and kelp forests. During the day, urchins wedge themselves between rocks or partially cover their bodies with sediment or grass to avoid predators. At night, they feed by crawling slowly along the sea floor looking for food. The mouth, a bony structure made of five teeth or plates on the underside, scraps up algae.

Want to Know More?

See appendix for Our Findings.

Further Reading

Hart, Stephen. "Evo Devo Learns a Larval Lesson." NASA Astrobiology Institute, March 21, 2001. Available online. URL: http://nai.nasa.gov/news_stories/news_detail.cfm?ID=181. Accessed January 19, 2010. This article discusses the possible adaptive advantages of a radially symmetrical animal producing a bilaterally symmetrical larva.

ScienceDaily. "Restricting the Gene Pool," October 15, 2003. Available online. URL: http://www.sciencedaily.com/releases/2003/10/031015030557.htm. Accessed July 8, 2009. This article discusses how proteins and protein receptors on the gametes of sea urchins help sperm recognize eggs of the same species, preventing cross species fertilization.

Virtual Urchin. "Urchin Anatomy." Available online. URL: http://virtualurchin.stanford.edu/anatomy.htm. Accessed July 11, 2009. By mousing over a sea urchin diagram on this Web page, one can examine a body system and learn it functions.

17. Bioluminescent Algae

Topic

Some species of algae produce light by the process of bioluminescence.

Introduction

Dinoflagellates comprise a varied group of unicellular protists: There are hundreds of species of dinoflagellates, and each is unique. All dinoflagellates have two *flagella,* which enable them to swim (see Figure 1). In some species, the organism is protected by plates made of *cellulose*. Some species contain light-capturing pigments and are photosynthetic. Others are *symbiotic*, living with a marine host such as coral, sponges, and flatworms. A few species are parasites of small organisms in the *plankton*, fish, and other organisms. About half of the species are *heterotrophs,* eating bacteria and other protists in the plankton. An infamous group of dinoflagellates produces toxins that can sicken and kill fish, marine mammals, and even humans. These organisms contain red pigments, so when their populations experience periods of rapid growth, they change the color of the water to red, earning the title "the red tide."

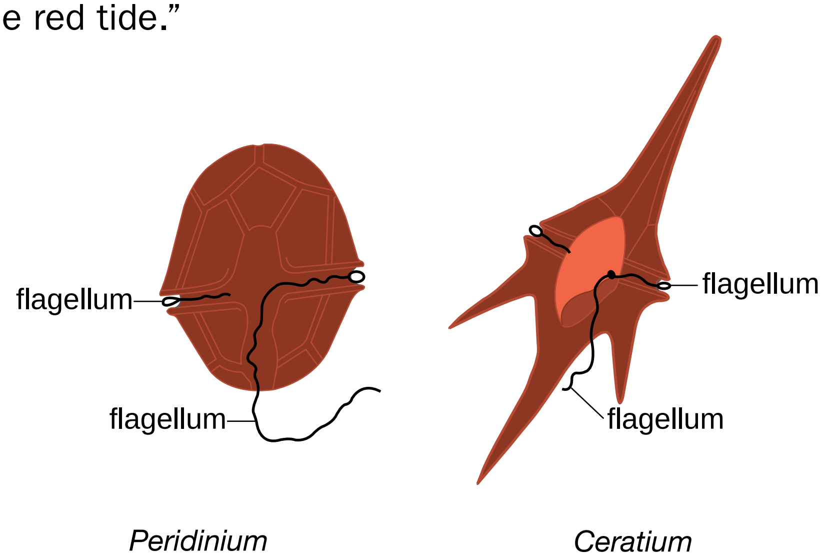
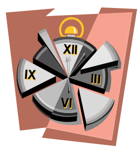


Figure 1

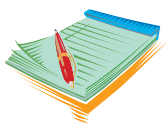
Dinoflagellates such as *Peridinium* and *Ceratium* have flagella.

Some species of dinoflagellates can produce light in a chemical process similar to one used by fireflies. The ability of a living thing to produce light is known as *bioluminescence*. The light produced is generally bluish-green, but yellow, red, and other colors have been observed. Most of the organisms that can carry out bioluminescence are marine. In this experiment, you will examine bioluminescence in dinoflagellates.



Time Required

55 minutes



Materials

- small vial of bioluminescent dinoflagellates (such as *Pyrosystis fusiformis*)
- compound light microscope
- slides
- cover slips
- dropper
- access to a room that can be darkened
- science notebook

Safety Note

Please review and follow the safety guidelines at the beginning of this volume.

Procedure

1. Gently set a vial of dinoflagellates on your desk top.
2. In a darkened room, examine the vial without touching it. Answer Analysis question 1.
3. Gently shake the vial. Answer Analysis question 2.
4. Turn on the classroom lights. Prepare a wet-mount slide of dinoflagellates. To do so:
   a. Transfer a drop of dinoflagellates from the vial to a slide.
   b. Cover the drop with a cover slip.

5. Place the slide on a compound light microscope, turn on the microscope light, and focus on low power. Observe organisms for a minute or two. Sketch what you see in your science notebook.
6. Without disturbing the slide, turn off the microscope light and the room lights. Leave both off for about two minutes.
7. While the lights are off, look through the eyepiece of the microscope. Watch the dark slide for a minute or two. Answer Analysis question 3.
8. While observing through the eyepiece, gently tap the slide to disturb the organisms.
9. Answer Analysis questions 4 through 7.

Analysis

1. Describe the vial of dinoflagellates as it sat on your desk.
2. Describe the vial of dinoflagellates after shaking.
3. Describe what you saw as you observed the darkened slide.
4. Describe what happened when you tapped the slide.
5. Based on your observations, what causes dinoflagellates to bioluminesce?
6. Define *bioluminescence* in your own words.
7. Describe an experiment you could perform to learn more about bioluminescent dinoflagellates.

What's Going On?

Why do dinoflagellates produce light? No one knows for sure, but scientists have some ideas. In this experiment, you saw that a disturbance causes the organisms to glow. On stormy nights at the coast, observers may witness spectacular light shows in choppy or wind-whipped surface water. As producers and small heterotrophs, dinoflagellates are low on the marine food chain, serving as food for small fish. Bioluminescence may be a unique form of protection from predators. When predators invade a colony, the entire group begins flashing. Research indicates that these flashes work like burglar alarms, signaling larger fish to come eat the invaders.

Connections

Each tiny flash of light that a dinoflagellatte produces only lasts for milliseconds. The group of chemicals responsible for each flash is known as *luciferins*. All biological chemical reactions require enzymes, and the particular enzyme that catalyzes luciferin is luciferase. When luciferin reacts with oxygen, it is *oxidized* to form light energy and oxyluciferin (see Figure 2). Once a molecule of luciferin is oxidized, it cannot flash any more until is *reduced* to form luciferin again.

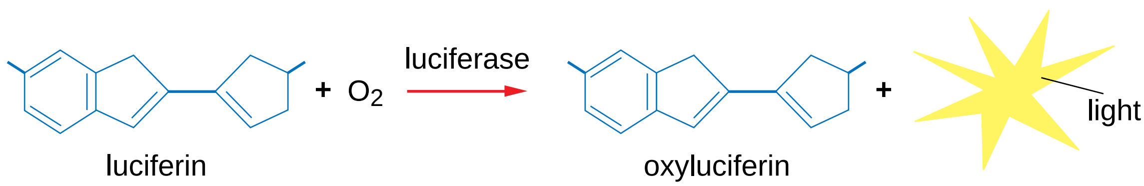


Figure 2

Bioluminescence is a useful tool in genetic engineering. Genes that direct luminescence can be linked to genes of interest, then the group of genes inserted in a target organism. If luminescence occurs, the researcher knows that the gene of interest is also in place. Speculation on the future uses of bioluminescence varies from simple to amazingly complex. The implantation of bioluminescent genes in fir trees could create Christmas trees that do not need lights or glowing trees that could border highways to light the way for travelers. One day consumers may be able to purchase glowing fish for the aquarium, or light-producing kittens and puppies as novelty pets.

Want to Know More?

See appendix for Our Findings.

Further Reading

Haddock, S. H. D., C. M. McDougall, and J. F. Case. “The Bioluminescence Web Page,” May 11, 2009. Available online. URL: http://www.lifesci.ucsb.edu/~biolum/. Accessed July 12, 2009. This Web site provides literature and unpublished data on research related to bioluminescence.

Hastings, Woodland, Wayne Schultz, and Liyun Liu, "Dinoflagellate Bioluminescence and Its Circadian Regulation," February 2, 2009. Available online. URL: http://www.photobiology.info/Hastings.html. Accessed July 12, 2009. This advanced article on bioluminescence explains the biochemistry and importance of circadian rhythms.

San Diego Natural History Museum. "Lights Alive." Available online. URL: http://www.sdnhm.org/kids/lightsalive/. Accessed July 12, 2009. This student-friendly Web site provides pictures and information about several types of bioluminescent organisms.

Wilson, Tracy V. "How Bioluminescence Works," 2009. Available online. URL: http://animals.howstuffworks.com/animal-facts/bioluminescence.htm. Accessed October 10, 2009. Tracy explains how several types of animals produce light.

18. Fish Adaptations

Topic

Marine organisms are uniquely adapted for their habitats.

Introduction

All fish have similar basic characteristics. Because they live in water, they rely on gills to supply their bodies with oxygen. Most have fins and a tail to propel them through their watery world. Fish are cold-blooded animals; this means that their body temperatures change with the temperature of the environment.

Each species of fish is uniquely adapted for its habitat and way of life. For example, puffer fish are small animals that maneuver slowly through the water. When threatened, the fish fill their stomachs with water until they look like finned balls. The heads of anglerfish are crowned with a long piece of flesh that glows, which they use as a lure to attract prey. Four-eyed butterfly fish (Figure 1) have large, dark spots surrounded by white rings near their tails that help them confuse their predator. The lionfish are brightly colored and covered in protective, venomous spines. In this experiment, you will learn more about fish adaptations and put what you learn to use to design a marine fish.

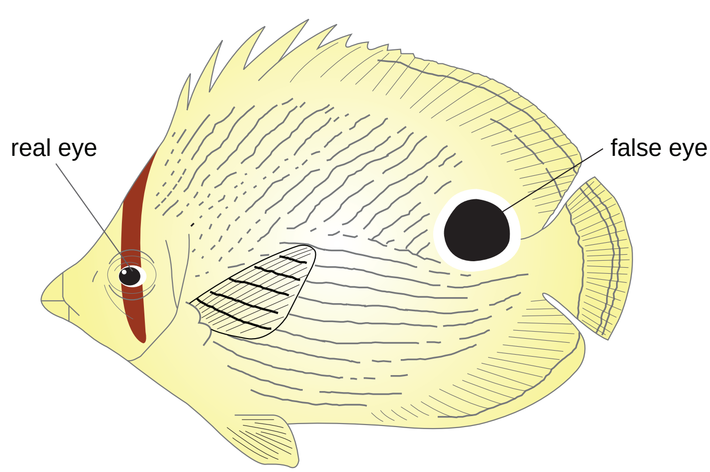


Figure 1

A four-eyed butterfly fish has false "eyes"on its flanks.

Time Required

45 minutes for part A
45 minutes for part B

Materials

- access to the Internet or reference books on marine organisms
- construction paper
- cardboard
- scissors
- glue
- tape
- colored markers or pencils
- science notebook

Safety Note **Please review and follow the safety guidelines at the beginning of this volume.**

Procedure, Part A

1. Use the Internet or reference books to learn about adaptations.
2. Answer Analysis question 1 through 9.

Procedure, Part B

1. Ask your teacher for a description of a marine fish habitat.
2. Read the description of the habitat.
3. You may use any of the supplies provided by your teacher to design a fictitious fish that would be adapted to the marine habitat you have been assigned. Keep in mind the characteristics of all fish and the special needs of the one you are designing.

   Also remember that almost all fish must avoid predators. In designing your fish, consider the size and shape of its mouth, the size and position of its eyes, the structure of its fins, its body shape, and its coloration.

4. Write a one-page report that explains your fish and how it adapted to its environment.

Analysis

1. What are some of the uses of coloration in marine organisms?
2. Which coloration would you expect to see on a fish whose predators swim above it: dark on the top and light on the bottom or light on the top and dark on the bottom? Explain your reasoning.
3. Fish have six to eight fins. What are the functions of each fin? How are a fish's fins adapted for their environments?
4. Some fish live alone, while others live in schools. What is the advantage of schooling?
5. Describe three fish adaptations for feeding.
6. How might the mouth and stomach of a fish that eats once a month be different from one that feeds every day?
7. What are some variations in the sizes, shapes, and positions of fish eyes?
8. What kind of body shape would you find in:
   a. a fish that is difficult to swallow?
   b. a bottom-feeding fish?
   c. a fast-swimming fish?
   d. a fish that lies flat on the bottom?
   e. a fish that hides in rock and crevices?
9. Some fish have large, false eye spots. What is the advantage of such spots?

What's Going On?

In fish, patterns of pigmentation and coloration of skin are important adaptations for both predators and prey. Prey animals have a variety of color patterns to help them avoid detection. Some fish are camouflaged so that they blend in with the environment. The skin of rays, for example, is the color and texture of the sea floor.

Counter shading, a type of coloration that is dark on the dorsal side and light on ventral surface (see Figure 2), also helps camouflage fish. Animals looking down into the water cannot see fish that are dark on the top against the dark ocean floor. Likewise, these same fish are difficult to see when predators or prey are looking up through the water because their light colored bellies blend in with the sunlit surface.

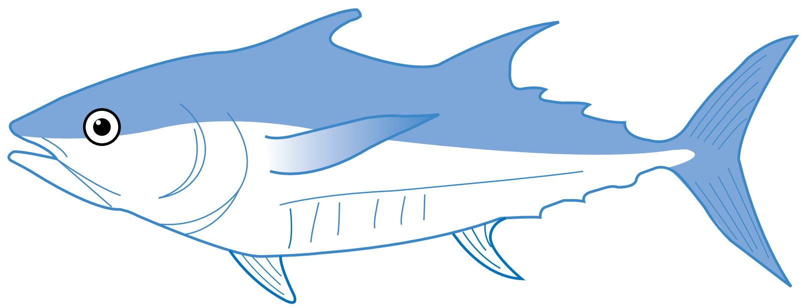


Figure 2

Fish with counter shading are dark on the dorsal surface and light on the ventral side.

Another adaptation for avoiding predators is disruptive coloration, a pattern of color that confuses predators. Some species of angelfish have dark vertical lines that make them look less fishlike (see Figure 3). A different type of disruptive coloration makes it hard for predators to distinguish the head end of the animal from the tail end. For example, the large eye spots on the tails of some species disorient their predators. If a predator strikes at a prey's tail instead of its head, the prey can avoid serious injury or even manage an escape by swimming forward very quickly.

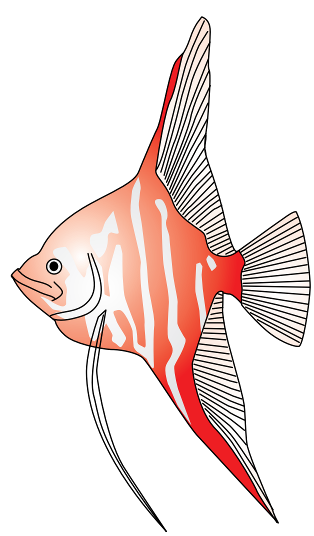


Figure 3

Vertical stripes confuse predators.

Connections

Some fish have extreme adaptations for avoiding predators or finding prey. Many types of fish manufacture toxins. To advertise their dangerous weapons, poisonous animals are often brightly colored. Scorpion fish, catfish, and stingrays are just a few of the fish that deliver toxins through spines. A stingray has a stiff spine on its tail that can be raised to deter a predator. Poison glands along the groove of the spine or at the base of the spine provide the toxin.

Some fish, especially rays and sharks, can sense electric fields. These animals possess gel-filled canals in their heads that can pick up weak electric fields produced by prey. Research indicates that these fish may also able to sense Earth's electromagnetic fields and use their electric-detecting organs to help them navigate. Other species of fish are capable of generating an electric shock to stun their prey. Electric eels also use electric fields to locate prey, communicate, and navigate.

Want to Know More?

See appendix for Our Findings.

Further Reading

Marine and Environmental Education and Research, Inc. "Fish Body Forms and Lifestyles," Available online. URL: http://www.meer.org/M23.htm. Accessed July 19, 2009. This Web site delineates the six basic categories that adaptations of fish lifestyles fall into: rover predators, ambush predators, surface-oriented fishes, bottom fishes, deep-bodies fishes, and eel-like fishes.

Muska, Karen. "Adaptations in the Coral Reef: Specialized Adaptations," 2001. Available online. URL: http://www.kmuska.com/ocean/adaptations_pg2.html. Accessed July 19, 2009. Muska provides text, video footage, and colorful photographs on fish marine adaptations.

Worsley School OnLine. "The Angler Fish," 2001. Available online. URL: http://www.worsleyschool.net/science/files/angler/fish.html. Accessed July 19, 2009. This Web page shows some unique adaptations for survival the anglerfish has developed for its deep water habitat.

19. Which Seagrasses Do Marine Herbivores Prefer?

Topic

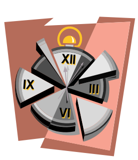
Some marine herbivores show a preference for specific types of seagrasses.

Introduction

The term *seagrass* is used to describe any number of marine *angiosperms* that grow submerged in shallow ocean waters. Seagrasses are descended from terrestrial plants; like these land-based ancestors, seagrasses have true roots and *vascular* tissues, and they produce sugars by means of *photosynthesis*.

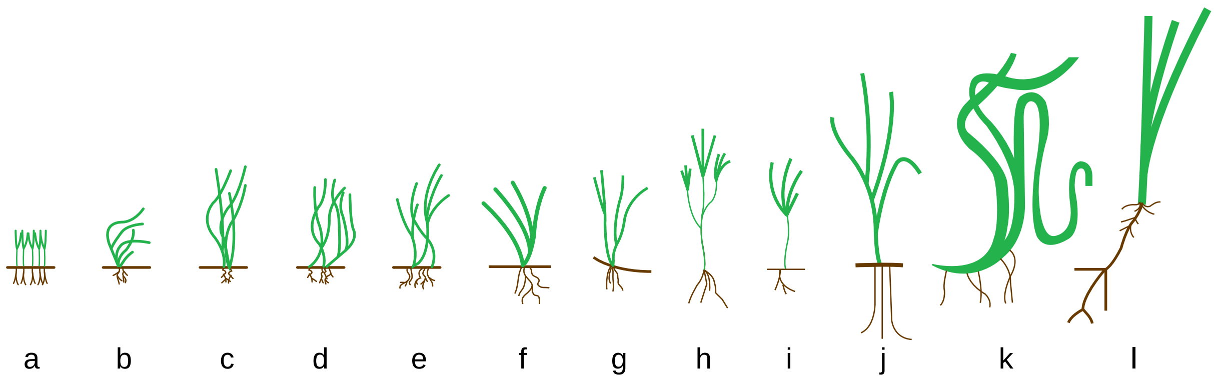
Seagrass beds are found near the shore and around coral reefs, where they provide shelter and nursery areas. Because seagrass beds are highly productive, the plants serve as the primary food source for fish and many other sea organisms such as crustaceans, echinoderms, and mollusks.

Several different varieties of plants are known as seagrasses. The varieties differ in color, shape, height, and nutritional value. Some common types of seagrass include turtle grass *(Thalassia testudinum),* manatee grass *(Syringodium filiforme),* shoal grass *(Halodule wrightii),* Johnson's seagrass *(Halophila johnsonii),* paddle grass *(Halophila decipiens),* and star grass *(Halophila engelmannii)*, among others (see Figure 1). Most seagrass beds are made up of several different types of grasses mixed together. This mixture provides a variety of food types for marine herbivores. In this experiment, you will present two different marine herbivores with two types of seagrass to see if either of the marine herbivores show a preference for one type of grass over the other.



Time Required

45 minutes on day 1
20 minutes each day for 3 consecutive days



a. Halophila
b. Halodule
c. Ruppia
d. Zostera/heterozostera
e. Phyllospadix
f. Cymodocea
g. Syringodium
h. Amphibolis
i. Thalassodendron
j. Thalassia
k. Enhalus
l. Posidonia

Figure 1

Types of seagrasses

Materials

- 2 saltwater aquariums, 10- to 20-gallons (gal) (38- to 76-liters [L]), (set up with dechlorinated water, a filter, aquarium salt, a thermometer, and a heater and allow to cycle for about 72 hours before beginning the experiment)
- 2 varieties of seagrass
- 2 different types of marine herbivores (such as fish, snails, crabs, sea urchins, or shrimp)
- ruler
- scissors
- 2 lengths of braided ropes, each about 1.5 feet (ft) (46 centimeters [cm]) long and about 0.25 inch [in.] [0.6 cm] in diameter or smaller
- 4 small weights, nuts, or other heavy objects that can be attached to rope to keep it submerged
- graph paper
- pencil
- colored pencils or markers

- marking pen
- science notebook

Safety Note **Take care when working with living organisms. Wash hands thoroughly after handling marine plants and animals. Please review and follow the safety guidelines at the beginning of this volume.**

Procedure

1. Label the saltwater aquariums as “Tank 1” and “Tank 2.”
2. Introduce one type of marine herbivore to Tank 1 and the other herbivore to Tank 2. The organisms in Tank 1 will be referred to as “Herbivores 1” and those in Tank 2 as “Herbivores 2.” Record the species names in your science notebook.
3. Attach a weight to each free end of one rope.
4. Using a permanent marker, make a mark near the weight at one end of the rope.
5. Use a ruler to measure 12 in. (30.5 cm) from the first mark and draw another mark. The segment of rope between the marks is the experimental zone.
6. Obtain approximately equal amounts of the two types of seagrass and separate the plants into individual blades. One species of seagrass will be referred to as “Grass A,” and the other as “Grass B.” Record the types and names in your science notebook.
7. Untwist the braided portion of the rope at one of the marks designating the experimental zone. Place the end of one blade of Grass A into the space between the strands of the untwisted rope and then release the rope, allowing it to tighten around the grass and holding it in place (see Figure 2).
8. Untwist the rope 0.5 in. (1.3 cm) from the blade of Grass A and insert the end of a blade of Grass B. Continue inserting grass blades into the rope every 0.5 in. (1.3 cm), alternating grass types, until the second mark is reached. Be sure that all blades of grass are facing in the same direction.
9. Trim the seagrass with scissors so that each piece stands up 3 in. (7 .6 cm) from the rope.

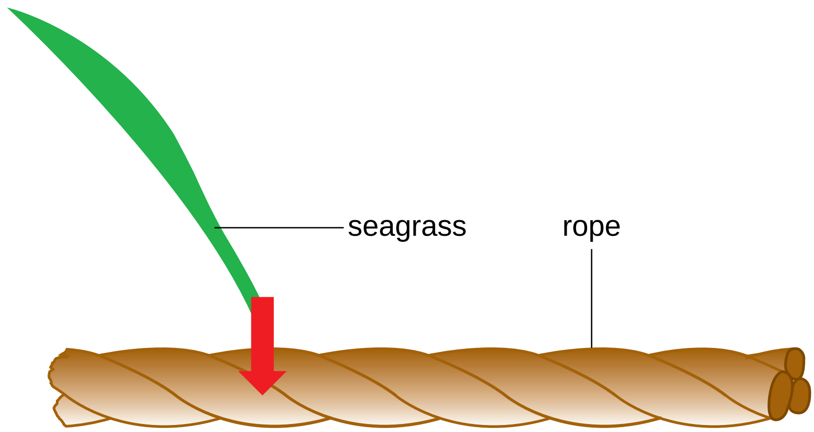


Figure 2
Inserting seagrass blades into rope

10. Repeat steps 4 through 9 with the remaining piece of rope.
11. Carefully place one rope containing seagrass into Tank 1 and the other into Tank 2, stretching the two weights apart so that the rope makes a straight line across the bottom of each tank.
12. After 24 hours, measure the seagrass on the rope in Tank 1. Noting that each piece began as 3 in. (7.6 cm) long, record the total length of each grass type that was eaten. (For example, if there is a piece of Grass A that is now 2 in. (5 cm) long, 1 in. (2.5 cm) was eaten.) Record the total amount of Grass A and Grass B eaten from Tank 1 on Data Table 1.
13. Measure the seagrass on the rope in Tank 2. Record the total amount of Grass A and Grass B eaten from Tank 2 on Data Table 2.
14. Repeat steps 12 and 13 twice more, recording the total amount of each variety of grass eaten every 24 hours for a total of 3 days. Record the findings on Data Tables 1 and 2.

Data Table 1

	Amount of seagrass eaten in Tank 1				
Species	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Total**
Grass A	0				
Grass B	0				

Data Table 2					
	Amount of seagrass eaten in Tank 2				
Species	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Total**
Grass A	0				
Grass B	0				

Analysis

1. Which types of seagrass did you choose to use in this experiment? Draw a sketch of each and describe the differences between them.
2. What were the control factors in this experiment? Why were these important?
3. Plot the results of your measurements on two different line graphs to depict the amount of each grass eaten on days 1 through 4. Create one graph for Tank 1 and another for Tank 2. On each graph, show the two types of seagrass in different colors so that they can be distinguished.
4. Did Herbivore 1 show preference for one type of seagrass over the other? How do you know?
5. Did Herbivore 2 show preference for one type of seagrass over the other? How do you know?
6. The term *opportunistic feeder* refers to an organism that will eat any food that is available to it. Does this term apply to either of the herbivores tested in this lab? Why or why not?

What's Going On?

There are many organisms that commonly feed on seagrasses. Herbivores eat seagrass to obtain energy. Since most seagrasses have similar nutritional values, this factor does not play a major role in food selection. Instead, herbivores tend to select a type of food with which they are familiar. They may occasionally venture out and try a new type of plant, but will usually return to their traditional food.

Although many marine herbivores develop preferences for the type of food in their particular habitat, most of them have the capability to be opportunistic feeders. This means that they will eat whatever type of food is available when they are grazing. Some organisms only resort to opportunistic feeding when there is a limited availability of food. Others spend most of their lives as opportunistic feeders, but the reasons among different species vary. Some animals have limited mobility, so their only options are the seagrasses around them. Other animals have very high metabolic rates, so must feed continuously to support their bodies' energy needs.

Connections

A common misconception is that seagrasses are a type of seaweed. However, this is not the case. Generally, the term *seaweed* refers to different varieties of algae and kelp that are actually in the protist kingdom and not the plant kingdom. Although algae and plants are both photosynthetic organisms and they look very similar, they have several distinct differences. Most plants have true specialized tissues, roots, stems, leaves, and they are able to bear seeds for reproduction. Algae do not have these specialized tissues or structures, although most have structures that resemble plants in many aspects. For instance, large algae have holdfasts to secure them in place to the seafloor, but the structures are not absorptive like the true roots of plants. Algae may also have blades that look similar to leaves, but they are not specialized organs like leaves in plants.

Want to Know More?

See appendix for Our Findings.

Further Reading

Florida Department of Environmental Protection. "What Are Seagrasses?" June 20, 2008. Available online. URL: http://www.dep.state.fl.us/coastal/habitats/seagrass. Accessed October 10, 2009. This Web site describes the roles of seagrass in marine ecosystems and provides figures of several species.

Hill, K. “Smithsonian Marine Station at Fort Pierce; Seagrass Habitats,” June 28, 2002. Available online. URL: http://www.sms.si.edu/IRLspec/Seagrass_Habitat.htm. Accessed August 2, 2009. Hill lists the species of organisms that are commonly known as seagrass, and discusses characteristics of the group.

Science Daily. “Native Plant Eaters Have Gourmet Palates.” September 12, 2005. Available online. URL: http://www.sciencedaily.com/releases/2005/09/050912124317.htm. Accessed August 2, 2009. This article reports on research by the Georgia Institute of Technology that indicates aquatic herbivores may prefer exotic plants to native species.

South Florida Aquatic Environments. “Seagrass Species Files.” Florida Museum of Natural History. Available online. URL: http://www.flmnh.ufl.edu/Fish/southflorida/seagrass/profiles.html. Accessed August 2, 2009. Photographs and illustrations on several species of seagrass are provided on this Web page.

20. Aquatic Herbicides Affect Nontarget Species

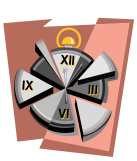
Topic

Algicides or herbicides can impact nontarget species in waterways.

Introduction

A pond can be an aesthetically pleasing part of the landscape. Goldfish or koi and some varieties of aquatic plants are some of the most common organisms found in small ponds. However, if left alone, these decorative landscapes can become overrun with algae and pond weeds. In a short time, pond water turns green and weeds choke out many of desired organisms. For this reason, people often treat their ponds with algicides or aquatic herbicides to control the unwanted invaders. In many cases, these chemicals do more harm than good because they affect the nontargeted species as well as those they were meant to kill.

Because there are many different types of plants and algae that can live within a pond (see Figure 1), there are also many different types of algicides and aquatic herbicides. These are chemically classified in two ways: (1) *narrow-spectrum* chemicals only affect a few specific types of organisms; (2) *broad-spectrum* algaecides and herbicides affect multiple species of plants or algae. Within each general group, consumers have other choices. Some formulations damage the target organisms' basic metabolism. Others interfere with *photosynthesis;* thereby, stopping the production of food. Still others mimic natural plant hormones and inhibit growth of stems or roots. Other types of chemicals cause disintegration of the plant cell walls. Problems develop when the addition of chemicals affects the health of other organisms within a body of water. In this experiment, you will develop a procedure to determine if a particular algicide or herbicide has negative effects on nontarget species.



Time Required

55 minutes on day 1
10 to 20 minutes on follow-up days for a period of about 2 weeks

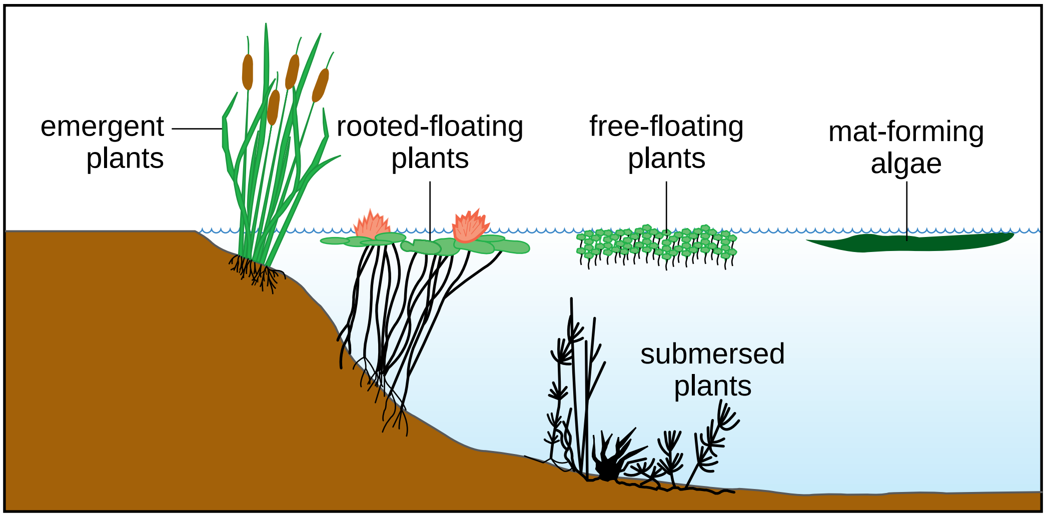


Figure 1

Types of aquatic plants and algae

Materials

- access to the Internet
- 2 aquariums, 10- to 20-gallons (gal) (38- to 76-liters [L]), (set up with filter, pump, dechlorinated water, thermometer, and heater)
- pH meter or pH test kit
- 2 UV sunlamps
- variety of aquatic plants and algae, which may include but are not limited to the following:
  - planktonic algae/cyanobacteria
  - filamentous algae
  - *Chara*
  - *Nitella*
  - water lily
  - spatterdock
  - water shield
  - Eurasian water milfoil
  - pondweed
  - duckweed

  - watermeal
  - *Elodea*
- aquatic algicides and herbicides, which may include, but not limited to the following:
  - Simazine
  - Quat/polyquat
  - Glyphosate
  - Fluridone
  - 2,4-D
  - Endothall
  - Diquat
  - Triclopyr
  - Imazapyr
- science notebook

Safety Note **Wash hands thoroughly after handling aquatic species and applying algicides or herbicides. Take care when working with chemicals of any type. Please review and follow the safety guidelines at the beginning of this volume.**

Procedure

1. Your job is to design and perform an experiment to find out if aquatic algicides and herbicides affect the health of nontarget species of plants and algae.
2. You can use any of the supplies provided by your teacher, but you may not need to use all of them.
3. Use the Internet to research the action of the algicides and herbicides provided by your teacher. Determine the targeted species that each chemical is designed to control and write a description of how it affects the target organism in your science notebook.
4. Before you conduct your experiment, decide exactly what you are going to do. Write the steps you plan to take (your experimental procedure) and the materials you plan to use (materials list) on the

data table. Show your procedure and materials list to the teacher. If you get teacher approval, proceed with your experiment. If not, modify your work and show it to your teacher again.

5. Once you have teacher approval, answer Analysis question 1. Then, assemble the materials you need and begin your procedure.
6. Collect your results on a data table of your own design.
7. Answer Analysis questions 2 through 5.

Data Table	
Your experimental procedure	
Your materials list	
Teacher's approval	

Analysis

1. Which types of plants or algae are most likely to be controlled by the chemicals that you will apply to your aquarium habitat? Which species are not targeted by these chemicals?
2. What criteria did you use in this experiment to assess the health of the species within the aquarium habitat?

3. Did the herbicide or algicide you used affect the targeted species? How?
4. Were there any effects to the nontargeted species within the habitat? If so, describe them.
5. What are some management techniques that can be used to control unwanted algae or pondweeds other than introducing chemical herbicides or algaecides?

What's Going On?

Most people assume that narrow-spectrum herbicides and algicides will only affect the species that they intend to control. However, in many cases the overall health of an aquatic community will be affected by the introduction of chemicals. Many pesticides can be toxic to fish and make water unsafe for drinking or absorption by plants. Even if chemical herbicides and algicides directly affect only the targeted species, they may indirectly affect other organisms within the habitat by lowering the overall water quality. Often, after the targeted species has been killed by chemical herbicides, the dead organisms remain in the water. This may allow toxic nitrogenous wastes to build up or cause an accumulation of bacteria that feed on the dead organisms. Very large populations of bacteria deplete the oxygen in the water, which negatively affects the other organisms that are living there.

Although there are ways to control pesky weeds and algae within a body of water without the use of chemical agents, they are not nearly as fast acting. Weeds can be uprooted and removed from the water. Additionally, introduction of natural predators to the habitat can control many types of plants and algae. Introducing fish, snails, and crustaceans that feed on algae and weeds can help control the amount of algae within the environment, although they will most likely not eliminate them completely.

Connections

Chemical fertilizers, herbicides, and pesticides are often used on crops to help them grow stronger and healthier and to increase their yield. Although these chemical additives may have benefits for the crops themselves, they can also cause a great deal of damage to the marine environment. Environmental effects from chemicals on crops often do extend well beyond the area directly surrounding the cropland. In fact, the devastating effects may multiply as the chemicals build up in areas far removed from the original crop where they were applied.

One example of the far-reaching effects of crop chemicals can be seen in the Gulf of Mexico near the mouth of the Mississippi River. The central region of the United States is well known for its farmland. Farmers in the central plains apply fertilizers and pesticides to their crops to create bigger and more productive plants. The majority of these applied chemicals are absorbed into the soil or plants, but a significant portion wash away when it rains. The runoff from the central United States usually ends up in the Mississippi River. By the time the water from the Mississippi makes it to the Gulf of Mexico, it has accumulated a heavy chemical load. Like plants, algae grow best when chemical nutrients are available. The Mississippi runoff creates huge *algal blooms* that cover the surface of the ocean and prevent sunlight from reaching the organisms below. When the algae die, they sink to the bottom where they are broken down by billions of bacteria. Eventually the bacteria use all the oxygen in the area. Animals that can move away do so, but the immobile ones die. The area where this devastation occurs is known as a *dead zone*. Figure 2 shows the huge dead zone in the Gulf of Mexico just beyond the mouth of the Mississippi.

Figure 2

Gulf of Mexico dead zone

Want to Know More?

See appendix for Our Findings.

Further Reading

Algone. "Algaecides in Your Aquarium." Available online. URL: http://www.algone.com/algaecides.php. Accessed August 2, 2009. This Web site discusses algaecides that can be used in aquariums.

Department of Ecology, State of Washington. "Aquatic Plant Management: Aquatic Herbicides." Available online. URL: http://www.ecy.wa.gov/programs/wq/plants/management/aqua028.html. Accessed August 2, 2009. The Department of Ecology Web site helps citizens understand how their practices affect the local ecosystems.

Purdue University. "Why Aquatic Herbicides Affect Aquatic Plants and Not You!" Available online. URL: http://www.btny.purdue.edu/aquatic/aquaticherb.html. Accessed August 2, 2009. This Web site provides a video that discusses the chemical action of herbicides.

Scope and Sequence Chart

This chart aligns the experiments in this book with some of the National Science Content Standards. (These experiments do not address every national science standard.) Please refer to your local and state content standards for additional information. As always, adult supervision is recommended and discretion should be used in selecting experiments appropriate to each age group or to individual students.

Standard	Grades 5–8	Grades 9–12
Physical Science		
Properties and changes of properties in matter	8	8
Chemical reactions	18	18
Motions and forces	7	7
Transfer of energy and interactions of energy and matter	14	14
Conservation of energy and increase in disorder		
Life Science		
Cells and structure and function in living systems		
Reproduction and heredity	2, 16	2, 16
Regulation and behavior	2, 5, 19	2, 5, 19

Standard	Grades 5–8	Grades 9–12
Populations and ecosystems	3, 19, 20	3, 19, 20
Diversity and adaptations of organisms	1, 3, 4, 6, 15, 17, 19	1, 3, 4, 6, 15, 17, 19
Interdependence of organisms	3, 4, 12, 13	3, 4, 12, 13
Matter, energy, and organization in living systems	3, 4	3, 4
Biological evolution		
Earth Science		
Structure and energy in the Earth system	9, 10, 11	9, 10, 11
Geochemical cycles	7	7
Origin and evolution of the Earth system		
Origin and evolution of the universe		
Earth in the solar system		
Nature of Science		
Science in history		
Science as an endeavor	all	all

Grade Level

Title of Experiment	Grade Level
1. Taxonomy of Marine Fish	6–12
2. Crowding Among Fish	6–12
3. Marine Plankton	6–12
4. Salt Marsh Community	6–12
5. Habitat Preference of Juvenile Fish	6–12
6. Staying Afloat	6–12
7. The Oceanic Conveyer Belt	6–12
8. How to Measure Salinity	6–12
9. Bathymetric Maps	6–12
10. Ocean Sediments	6–12
11. The Record Written in Ocean Sediments	6–12
12. Bycatch During Fishing	6–12
13. Bioaccumulation in Killer Whales	6–12
14. Ocean Regions	6–12
15. Echinoderm Adaptations	6–12
16. Fertilization in Sea Urchins	9–12
17. Bioluminescent Algae	6–12
18. Fish Adaptations	6–9
19. Which Seagrasses Do Marine Herbivores Prefer?	6–12
20. Aquatic Herbicides Affect Nontarget Species	9–12

Setting

The experiments are classified by materials and equipment use as follows:

- Those under SCHOOL LABORATORY involve materials and equipment found only in science laboratories. Those under SCHOOL LABORATORY must be carried out there under the supervision of the teacher or another adult.
- Those under HOME involve household or everyday materials. Some of these can be done at home, but call for supervision.
- The experiments classified under OUTDOORS may be done at the school or at the home, but call for supervision.

SCHOOL LABORATORY

3. Marine Plankton
6. Staying Afloat
7. The Oceanic Conveyer Belt
8. How to Measure Salinity
11. The Record Written in Ocean Sediments
15. Echinoderm Adaptations
16. Fertilization in Sea Urchins
17. Bioluminescent Algae
20. Aquatic Herbicides Affect Nontarget Species

HOME

1. Taxonomy of Marine Fish
2. Crowding Among Fish
5. Habitat Preference of Juvenile Fish
9. Bathymetric Maps

10. Ocean Sediments
12. Bycatch During Fishing
13. Bioaccumulation in Killer Whales
14. Ocean Regions
18. Fish Adaptations
19. Which Seagrasses Do Marine Herbivores Prefer?

OUTDOORS

4. Salt Marsh Community

Our Findings

1. TAXONOMY OF MARINE FISH

Idea for class discussion: Ask students how they identify unknown birds that they may see at a bird feeder. Point out that today they will use similar techniques to identify fish.

Analysis

1. Scientists use taxonomic keys to identify unknown organisms.
2. Fish 2, Salmonidae; Fish 3, Synodontidae; Fish 4, Trachipteridae; Fish 5, Gadidae; Fish 6, Aulorhynchidae; Fish 7, Bothidae
3. Answers will vary. Students may use any traits, such as the absence or presence of fins, the shape of the caudal fin, and mouth shape and position.
4. Answers will vary but could include size (of adults), color, and texture (types of scales).
5. Answers will vary but could include kelp, octopuses, clams, sharks, and whales.

2. CROWDING AMONG FISH

Idea for class discussion: Find out how many students raise fish in aquariums in their homes. Discuss some of the basics of setting up an aquarium.

Analysis

1. Answers will vary, but students should include a statement that reveals what they expect to see as a result of this experiment.
2. Answers will vary, but students should discuss a group of fish that were not crowded.
3. A control is important because it provides data against which experimenters can compare their findings.
4. Answers will vary.
5. Answers will vary.

3. MARINE PLANKTON

Idea for class discussion: Discuss the meaning of the term *plankton* and the prefixes *phyto-* and *zoo-*.

Notes to the teacher: If you live near the ocean, you can collect plankton with a net. If not, you can order preserved plankton from biological supply houses.

Analysis

1. Answers will vary but could include diatoms, dinoflagellates, and coccolithophores.
2. In an ecosystem, there are more organisms on the first trophic level than on any other levels.
3. Answers will vary. Plankton photosynthesizers are primarily one-celled organisms such as diatoms, dinoflagellates, and flagellates. On land, photosynthesizers are much larger and include grass, shrubs, and trees. Many marine photosynthesizers have flagella, which enable them to move.
4. Answers will vary. Some organisms have cilia, that gently sweep the water and provide movement. Others use body undulations or swimming appendages (legs and antennae) to propel themselves.
5. The plankton ecosystem is open. Fish feed on some of the small crustaceans and worms. In addition, seaweed or dead grass from shore may act as producers in the system.

4. SALT MARSH COMMUNITY

Idea for class discussion: Ask if any students have visited a salt marsh. Help them understand the difference in a salt marsh and a beach.

Notes to the teacher: Photocopy the table on pages 129 through 131 and cut it into strips so each student has a role to play. The left side of the strip states the name of the role and the right side gives an explanation. Some roles appear several times because they make up a large part of the salt marsh ecosystem. There are enough strips for a class of 30. You can add or eliminate strips to fit your needs.

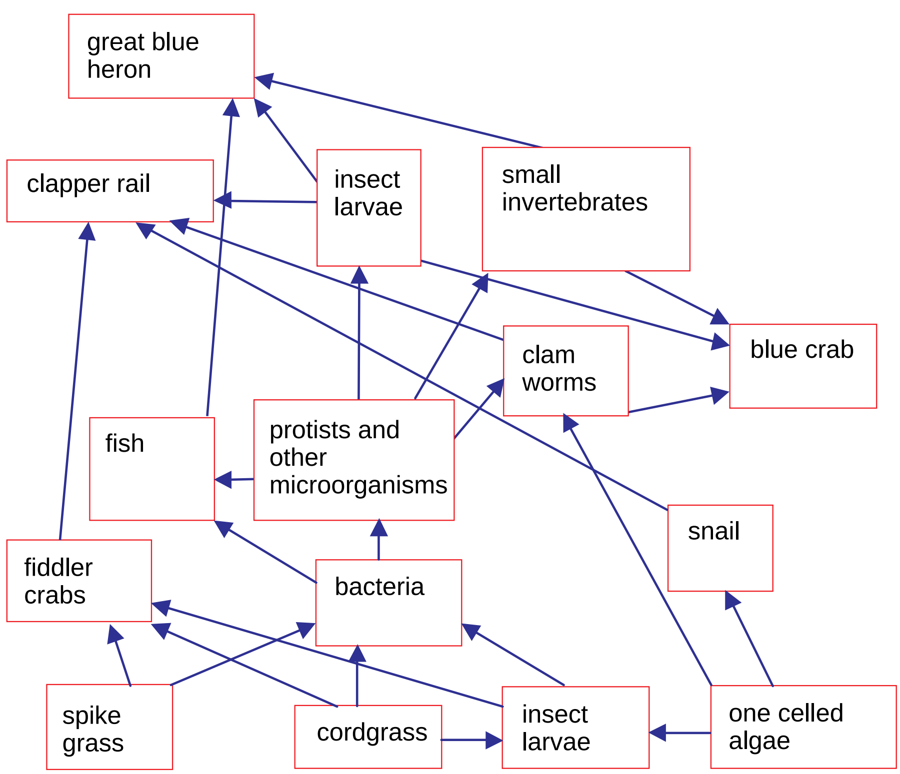
Detritus—all over marsh	Dead plant and animal matter. Provides food for plants, bacteria, and other microorganisms.
Detritus—all over marsh	Dead plant and animal matter. Provides food for plants, bacteria, and other microorganisms.
Detritus—all over marsh	Dead plant and animal matter. Provides food for plants, bacteria, and other microorganisms.
Detritus—all over marsh	Dead plant and animal matter. Provides food for plants, bacteria, and other microorganisms.
Saltwater	Water carries nutrients and living things in as the tide rises. Carries out decaying vegetation.
Saltwater	Water carries nutrients and living things in as the tide rises. Carries out decaying vegetation.
Saltwater	Water carries nutrients and living things in as the tide rises. Carries out decaying vegetation.
Saltwater	Water carries nutrients and living things in as the tide rises. Carries out decaying vegetation.
Saltwater	Water carries nutrients and living things in as the tide rises. Carries out decaying vegetation.
Cordgrass—lives in low marsh	Provides food for insects, snails.
Cordgrass—lives in low marsh	Provides food for insects, snails.
Marsh hay—lives in high marsh	Provides food for insects.
Marsh hay—lives in high marsh	Provides food for insects.

Spike grass—lives in high marsh	Provides food for insects.
Spike grass—lives in high marsh	Provides food for insects.
One-celled algae	Provides food for microscopic organisms.
One-celled algae	Provides food for microscopic organisms.
Bacteria	Decompose dead plant and animal matter.
Bacteria	Decompose dead plant and animal matter.
Bacteria	Decompose dead plant and animal matter.
Fungi	Decompose dead plant and animal matter.
Clam worm—burrows into marsh mud	Comes out during high tide to look for food. Eats other worms, dead fish, algae.
Mussel—lives in low marsh half-burrows in mud	Filter feeder that eats suspended plant and animal matter. Breathes with gills. Shells closes when the animal is exposed to air.
Clapper rail—lives in high marsh	At low tide, feeds on fiddler crabs, worms, and other small animals.
Salt marsh snail—lives in high marsh	Eats dead grass and algae on the mud. When tide is out, hides under mats of dead grass and hay. Has lungs but can be submerged for an hour or two.
Raccoon	Feeds on small animals at low tide.

Great blue heron	When tide is low or is going out, feeds on fish, shrimp, insects in the shallow water.
Killifish	Moves in and out with the tides. Eats larvae of insects, small animals, plants.
Blue crab	Moves into marsh with tide. Stays submerged—has gills. Eats worms, snails, oysters, other small animals.
Fiddler crab	Aerates sand as it looks for detritus to eat.

Analysis

1. Plants in the high marsh, are rarely covered with saltwater. Those in the low marsh are covered 6 or more hours a day.
2. In summer, water cools the marsh: In winter, it warms the marsh.
3. The nutrients in cordgrass support several types of animals. Cordgrass roots help stabilize mussels and other organisms. Without cordgrass, many types of animals could no longer survive.
4. Answers will vary. A possible food web is the following:



5. HABITAT PREFERENCE OF JUVENILE FISH

Idea for class discussion: Ask students, "If you were a young fish, where would you prefer to live?" Have them defend their answers.

Notes to the teacher: Minnows can be found in bait and tackle shops.

Analysis

1. Answers will vary. Students might suggest that the minnows prefer the area with plants because it provides protection from predators.
2. The factor being tested is what type of environment juvenile fish select: open, plant, or sticks.
3. Answers will vary depending on students' experimental results.
4. Answers will vary depending on students' experimental results.
5. Young fish prefer estuaries to the open ocean. Estuaries provide hiding placing from predators as well as plenty of food.

6. STAYING AFLOAT

Idea for class discussion: Ask how many students can float on their back in a swimming pool. Have one or two explain their techniques for staying afloat. Relate their techniques to those used by plankton.

Analysis

1. Answers will vary depending on organisms selected.
2. The bodies of planktonic organisms are adapted to float in the upper level of the water column.
3. Zooplankton feed on phytoplankton.
4. Answers will vary based on the model designs.
5. Planktonic organisms have many adaptations for staying in the top of the water column, including projections and large surface area to body size.

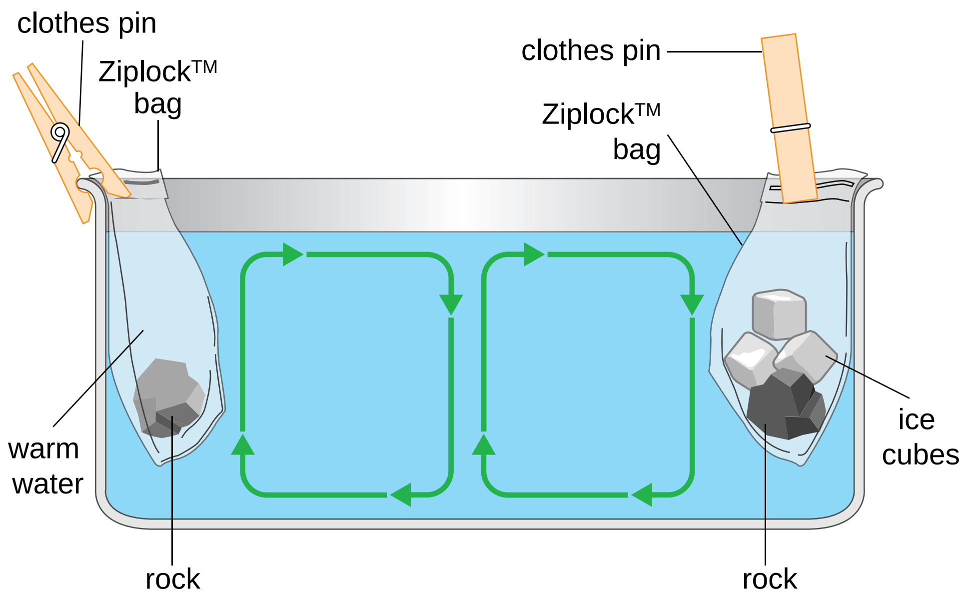
7. THE OCEANIC CONVEYER BELT

Idea for class discussion: Ask students to define *conveyor belt* in their own words and to provide some examples of conveyor belts.

Relate the students' ideas to the concept of conveyor belt-type activity in the ocean.

Analysis

1. Answers will vary, but could look something like the following:



2. cold water. Cold water moved to the bottom of the dish and warm water moved to the top.
3. The cold, blue melt water will sink to the bottom of the jar.
4. The blue water rushed into the flask of clear water and sank to the bottom.
5. The clear water was layered on top of the blue water.
6. saltwater. Saltwater sank to the bottom of the flask.

8. HOW TO MEASURE SALINITY

Idea for class discussion: Ask students if it is easier to float in the ocean or in a swimming pool. Find out how much students understand about the effects of salinity on buoyancy.

Note to the teacher: Prepare standard saline water by placing 17.5 grams (g) table salt in a 500-milliliter (ml) beaker. Add distilled water to the 500-ml line. Stir to dissolve.

Prepare sample A by using the same procedure with 8.7 g of table salt. Prepare sample B by using the same procedure with 4.3 g of table salt.

Laboratory groups can share beakers of distilled water, standard saline water, sample A, and sample B.

Check the accuracy of the hydrometers using distilled water.

Analysis

1. Density is a measurement of mass per unit volume.
2. Specific gravity compares the density of a substance to the density of water.
3. Specific gravity increases as the concentration of dissolved solids increases. If temperature is taken into consideration, specific gravity can be converted to salinity.
4. middle of a bay, 3; river, 1; where river empties into bay, 2; ocean, 4
5. Answers will vary. Water near the equator is slightly more saline because of evaporation.

9. BATHYMETRIC MAPS

Idea for class discussion: Ask students what the seafloor looks like. Point out that the mental images they have of the seafloor are probably related to bathymetric maps they have seen.

Analysis

1. A bathymetric map shows the topography of the seafloor.
2. A contour line connects all points of the same depth.
3. Answers will vary based on the maps students draw.
4. 1 centimeter (cm)
5. Answers will vary. Students might suggest that ships use them to avoid shallow areas, scientists use them for research, or fisherman use them to find areas where fish might live.

10. OCEAN SEDIMENTS

Idea for class discussion: Ask students what kinds of soil particles they are likely to find at the beach. Ask why there is more sand than clay or silt on the beach.

Analysis

1. a. small; large; b. near the source, with small ones on the top

2. Sources of sediment include erosion, shells, and bodies of dead organisms; precipitates from biochemical reactions; volcanic particles; and particles from outer space.
3. The results in only one trial could have been a fluke and not a reflection of what can usually be expected.
4. Answers will vary.
5. Silt is lightweight and can remain suspended in water much longer than larger particles. If a current is present, silt can be transported to the edge of the continental shelf.
6. Answers will vary.

11. THE RECORD WRITTEN IN OCEAN SEDIMENTS

Idea for class discussion: Ask the class how scientists know what life was like on ancient Earth. Relate their comments to the same type of geological studies that are done in the sea.

Note to the teacher: Prepare four plastic storage containers (about 6 by 6 by 4 inches [in.] [15.2 by 15.2 by 10 centimeters (cm)]) with different mixtures of sediments to represent four different regions of the seafloor. Use sand, silt, and clay to represent materials that have eroded from land. Include ash (or sand particles tinted black) with the other layers to indicate volcanic material. Diatomaceous earth can be used to represent layers of diatom shells. Dampen each sample so that the layers will hold together when students take cores.

Analysis

1. Core samples show the layers of sediment on the ocean floor.
2. Answers will vary depending on preparations.
3. Students should measure the depth of their sediments in inches (in.) or millitmeters (mm), then divide by 0.08 in. (2 mm) to find the number of years required to create the sediments.
4. 2,000 years
5. They tell you that conditions have changed in the area. For example, an abundance of diatom shells indicates a time when algae were common. Volcanic sand tells you that a volcano recently erupted.
6. Answers will vary with sediment samples. Students should be able to distinguish silt, clay, and sand particles by size and ash by color. They can find pieces of diatom shells in the diatomaceous earth.

12. BYCATCH DURING FISHING

Idea for class discussion: Find out how many students have ever been fishing. Discuss the difference in their intended catches and their actual catches.

Analysis

1. Answers will vary. A scoop (trawl net) will yield the most target fish and the most bycatch.
2. Answers will vary, but the most likely answers are: (a) shrimp, scoop (trawl net); (b) young fish, scoop (trawl net); (c) sea turtles, scoop (trawl net)
3. If you catch young fish, they will not have the opportunity to become adults and have offspring.
4. Answers will vary. Trawl nets are used commercially to catch shrimp.
5. Answers will vary, but the fisherman with tweezers (longlines) may not have 12 fish to take to market.
6. It was easier to catch adult fish at the beginning. There were more animals available to catch.
7. Answers will vary. Fishermen generally discard their bycatch.
8. Turtles that are tangled in nets drown.
9. Answers will vary.

13. BIOACCUMULATION IN KILLER WHALES

Idea for class discussion: Discuss the terms *food chain* and *food web* and relate them to marine environments.

Notes to the teacher: This is a whole-class, teacher-led activity. For a class of 30, write “sediment organisms” on 50 index cards, “zooplankton” on 16 index cards, “herring” on 10 index cards, “seals” on three index cards, and “killer whale” on one index card. Put a red dot on half of the cards. Do not tell students yet, but the red dot represents PCBs in the environment.

Analysis

1. The bodies of marine mammals contain a lot of fat (blubber).
2. Answers will vary. Bioaccumulation is the build up of a toxin in the tissues of an organism.

3. Answers will vary based on classroom results.
4. Answers will vary based on classroom results.
5. The levels of toxin in killer whales affect their abilities to survive.
6. six (counting the killer whales). Increasing the levels of feeding in a food chain would increase the toxins consumed by killer whales.
7. PCBs affect both the ability of killer whales to survive and their reproductive rate. Since whales have a slow reproductive rate, any further reduction can seriously impact the future of the pod.

14. OCEAN REGIONS

Idea for class discussion: Show students how a prism breaks light into its colors. Review the relationship of light color and wavelength.

Notes to the teacher: Blue overhead projector film is a good source of blue plastic for the goggles.

Analysis

1. red, orange, yellow, green, blue, indigo, and violet
2. All colors except green are absorbed by the grass.
3. grey. In low light, colors are not transmitted.
4. Answers will vary based on experiment results.
5. The squares of paper represent organisms of different colors.
6. violet
7. blue. Blue light penetrates to a depth of 289 feet (ft) (85 meters [m]).

15. ECHINODERM ADAPTATIONS

Idea for class discussion: Show the students a suction cup and ask them to explain how it works.

Notes to the teacher: If a living starfish is not available, a preserved one will serve the purpose.

Analysis

1. Echinoderms are spiny-skinned animals that have radial symmetry and tube feet.

2. Answers will vary. The dorsal surface, which is bumpy, has tiny pairs of pincers on it.
3. Answers will vary. Some students might have noticed the eyespots at the end of each appendage.
4. By removing water from its podia, the animal creates suction and can grasp objects, including a rock. To let go of the objects, the animal releases water through the tiny feet.
5. Answers will vary depending on the models.

16. FERTILIZATION IN SEA URCHINS

Idea for class discussion: Discuss the differences and similarities in internal and external fertilization.

Note to the teacher: Instant Ocean™ is a product that can be used to create an appropriate saline solution for sea urchins. Or, you can use the following recipe to prepare artificial seawater:

Ingredient	Volume
NaCl	24.72 gram (g)
KCl	0.67 g
$CaCl_2.2H_2O$	1.36 g
$MgCl_2.6H_2O$	4.66 g
$MgSO_4.7H_2O$	6.29 g
$NaHCO_3$	0.18 g
dH_2O	to 1 liter (L)

To prepare 0.5 M KCl, mix 3.73 g KCl with 100 milliliter (ml) dH_2O.

Keep in mind that sperm quickly lose their viability once introduced to seawater.

Analysis

1. Answers will vary. The mouth is a centrally located cavity bordered by fused calcium plates.
2. Answers will vary. Spawning is the release of eggs.
3. Sperm appeared on the dorsal side.
4. Eggs were released from the ventral surface into the seawater.
5. Answers will vary.
6. The egg develops a fertilization membrane.
7. A fertilized egg is diploid; it contains a half set of chromosomes from the egg and a half set from the sperm to make a full set.

17. BIOLUMINESCENT ALGAE

Idea for class discussion: Ask for a show of hands of students who have seen fireflies. Have pairs of students discuss their ideas about how fireflies produce light. Ask one or two students to discuss their ideas with the class. Use these ideas to introduce bioluminescence in other organisms.

Notes to the teacher: *Pyrocystis noctiluca* is a bioluminescent dinoflagellate that can be purchased from biological supply houses. If you want to maintain a culture for some time, you can purchase culture medium such as Alga-Gro™, a seawater medium for marine species. Maintain the organisms on a cycle of 12 hours light, 12 hours dark. Cool-white fluorescent lamps, aquarium lights, or grow lights work well.

In the ocean, dinoflagellates photosynthesize during the day and bioluminesce at night. These activities are controlled by a light-dependent circadian rhythm. To use the organisms in class, you will need to reset their daily rhythm so that you can observe bioluminesce in the daytime. You can include this resetting as part of the class activity, or do it before class. To reset, alter their light exposure schedule by one hour a day until they are in their dark cycle during the school day. Keep in mind that dinoflagellates are most active about two hours into their dark schedule.

Analysis

1. Nothing happened in the vial of dinoflagellates as it sat on the desk.
2. Shaking caused some dots of light to appear.
3. Nothing appeared on the darkened slide.

4. Tapping caused dots of light to appear.
5. A disturbance can cause dinoflagellates to bioluminesce.
6. Bioluminescence is the production of light through biochemical reactions within living things.
7. Answers will vary. Students might suggest experiments to see if changes in pH or nutrients affect bioluminescence.

18. FISH ADAPTATIONS

Idea for class discussion: Have three different students describe three different fish. Ask for details, such as size, color, and shape of mouth. Compare the students' descriptions. Find out whether students know that the differences in species are due to adaptations.

Notes to the teacher: Photocopy the table on page 141 and cut it into strips. Each strip describes a marine environment and some activities or characteristics of a fish. Give each student or lab group one of descriptions. Change descriptions if you want students to focus on one type of adaptation or one area of the ocean.

Analysis

1. Answers will vary but should include coloration to avoid predators (such as camouflage or warning coloration) and coloration to attract mates.
2. Dark on the top and light on the bottom because a fish that is dark on the top blends in with the bottom and is less obvious to predators looking down into the water.
3. Answers will vary. Fins make it possible for fish to move up and down and forward and backward in the water.
4. Schooling may help deter predators by presenting a more formidable mass of fish than one single animal can present.
5. Answers will vary. Fish that scrape algae from rocks have sharp, beak-like mouths. Predators that catch smaller fish have large mouths with teeth. Fish that eat along the bottom have sucker-shaped mouths.
6. Fish that feed daily have smaller mouths and digestive systems than those that feed only once a month.
7. Fish that have eyes on one side of the head lie on the bottom. Fish with small eyes are generally residents of shallow water, while large-eyed fish a more often found in deep water.
8. a. round; b. flat on the ventral surface; c. torpedo shaped; d. flattened; e. ribbon or eel shaped

Warm, shallow, open water; fish is bottom feeder, swims slowly
Warm, shallow water, grassy habitat; fish chases small prey, fast swimmer
Warm water rocky bottom; fish preys on small fish, strong swimmer
Warm water, estuarine habitat; fish eats dead plants and animals on seafloor, slow swimmer
Warm water intertidal zones; fish catches small fish in the shallows, maneuvers quickly through water
Warm deep, open water; fish eats medium-size fish, fast swimmer
Warm water; fish is small in size, can make itself difficult for prey to swallow
Warm water; fish feeds off the bottom, senses prey in the turbid water
Warm water, coral reef; fish has poisonous barbs, eats coral
Warm water; fish lives on sandy bottom, ambushes prey
Warm, shallow water; fish can change colors
Cold, shallow water, grassy habitat; fish eats dead plants and animals
Cold, shallow water; fish preys on small fish that swim below it
Cold, shallow water; fish preys on medium-size fish that swim above it
Cold, shallow water; fish eats plankton
Cold, shallow water; fish eats jellyfish
Cold, deep water; fish preys on small fish
Cold, deep water; fish is fast swimmer, preys on medium-size fish
Cold, deep water; fish is slow swimmer, eats crabs and worms
Cold, deep water; fish is slow swimmer, ambushes prey
Cold, deep water; fish is slow swimmer, lives on rocky bottom, hides and waits for prey

9. large spots that look like eyes and scare away predators. If the spots are near the tail, a predator may strike toward the tail where it does less damage than it would striking near the head.

19. WHICH SEAGRASSES DO MARINE HERBIVORES PREFER?

Idea for class discussion: Ask students if they have ever waded in submerged grasses near the ocean shore. Point out that grasses do not usually grow along a sandy beach. Draw some parallels between the roles of terrestrial and aquatic grasses.

Analysis

1. Answers, drawings, and descriptions will vary depending on seagrass chosen. See Figure 1 on page 109 for pictures of some common seagrasses.
2. Answers will vary but may include: water temperature, salinity, location of food, length of grass, presence of only one type of herbivore in each tank. Control factors are important in a scientific experiment to ensure that there is only one factor that is being adjusted so that it can be determined if that particular factor is causing the results of the experiment to change.
3. Graphs will vary. Students should have two separate graphs, one depicting the results from Tank 1 and the other from Tank 2. Each graph should have the days listed on one axis and the amount of grass eaten (in inches [in.] or centemeters [cm]) on the other. There should be separate plots and lines for each species of seagrass with each species represented in a different color. All parts of the graphs should be labeled, and a key should show what the different colors represent.
4. Answers will vary based on student results. Students should use the amount of each type of seagrass eaten as evidence to support their claim.
5. Answers will vary based on student results. Students should use the amount of each type of seagrass eaten as evidence to support their claim.
6. An opportunistic feeder is an organism that will eat whatever type of food is available to it. Generally, opportunistic organisms will not show a preference toward one type of food over another. Therefore, if any of the organisms ate equal amounts of each type of grass, they are most likely opportunistic.

20. AQUATIC HERBICIDES AFFECT NONTARGET SPECIES

Ideas for class discussion: Ask students if they have seen an aquarium or pond with thick green scum. Discuss the origin of the scum and ask how students would remove it.

Notes to the teacher: Some common algaecides/herbicides are included below for reference.

- *Quat/Polyquat.* Algaecides that contain liquefied ammonium salts. Lower the water tension, cover algae, and split open cell walls. Too much can cause the water surface to appear soapy.
- *Simazine.* Algaecide that penetrates the cell and destroys photosynthesis mechanisms. Long lasting; frequent use not recommended. Affects plants in the same way it does algae.
- *Glyphosate (Rodeo™, AquaMaster™, and AquaPro™).* Broad-spectrum herbicide; controls floating-leaved plants like water lilies. Does not work on underwater plants such as Eurasian water milfoil. Nonselective but takes weeks to show effects. May require re-application.
- *Fluridone (Sonar™ and Whitecap™)*. Slow-acting, broad-spectrum herbicide. Affects Eurasian water milfoil and other underwater plants. May take 6 to 12 weeks before the dying plants decompose. Some pondweeds are minimally affected by low concentrations.
- *2,4-D (Aquakleen™ and Navigate™).* Fast-acting, systemic, selective herbicide. Affects broad-leaved species. May negatively affect fish.
- *Endothall (Aquathol™).* Fast-acting, nonselective contact herbicide. Destroys vegetation but not roots. Can effectively treat small areas when applied to limited area. Not effective on elodea.
- *Diquat (Reward™)*. Fast-acting, nonselective contact herbicide. Destroys vegetative part of plants without killing roots. Useful on submersed aquatic plants. Can be used for spot treatments. Not effective in dense algal blooms.
- *Triclopy TEA (Renovate3™)*. Relatively fast-acting, systemic, selective herbicide. Affects Eurasian water milfoil and other broad-leaved species. Useful as a spot treatment. May cause eye and skin irritation to fish and humans while swimming.

- *Imazapyr (Habitat™)*. Broad spectrum, slow-acting herbicide. Controls emergent plants like spartina, reed canarygrass, and phragmites. Also affects floating-leaved plants like water lilies. Does not work on submerged underwater plants.

Analysis

1. Answers will vary based on the herbicide used as well as the plants and algae that are in the aquarium. See list on page 143 for commonly affected plants and algae.
2. Answers will vary based on student procedure. Some possible answers include comparison to control tank, size of plant leaves, color of the algae or plant, and amount of new growth.
3. Answers will vary based on student results. Students should describe what happened to the targeted species over the course of the experiment.
4. Answers will vary based on student results. Students should describe any effects on the nontarget species in the aquariums.
5. Answers will vary. Some possible answers include: introducing a natural predator such as snails, shrimp, and algae-eating fish and removing the problem plants and algae regularly.

Glossary

acrosome structure on the head of the sperm that contains enzymes

adaptation characteristic due to natural selection that helps organisms survive in their environment

algal bloom proliferation of algae in waterways, often due to the addition of fertilizers

algicide chemical that kills unwanted species of algae in waterways and aquariums

ambiculacra groove extending from the central disk of an echinoderm

ampulla saclike enlargement of a gland or canal

angiosperms large group of vascular plants whose reproductive structures are flowers

aquaculture farming plants and animals that live in water

asexual reproduction type of reproduction that requires only one parent

authigenic of rocks or minerals that were formed at the place where they were found

autotroph organism that makes its own food

barbels tactile, whiskerlike extensions on the heads of some types of fish that provide information to the fish about the environment

bathymetric map map that shows the ocean floor and indicates depth

bilateral symmetry type of symmetry in organisms that can be divided into two equal halves by a plane

bioaccumulation accumulation of chemicals such as pollutants in the tissues of living things

biodiversity large number and range of species within an ecosystem

biogenic produced by a living thing

bioluminescence production of light by chemical reactions in the tissues of an organism

blastula stage of development of an animal zygote in which a single layer of cells surrounds a fluid-filled cavity

brackish water a mixture of salt and fresh water

bycatch unintended catches that are accidentally captured by commercial fishing equipment such as nets

cellulose tough, complex carbohydrate that makes up the cell walls of plants

cilia small, hairlike projections from cells that move materials or provide locomotion

cleavage the division of a cell in the early stages of development

contour line line on a bathymetric map that connects points of equal depth

cordgrass one of several genera of *Spartina*, a tough grass found in brackish areas

cosmogenic originating in space

cyanobacteria also known as blue-green algae, a large group of prokaryotic photosynthesizers that contain blue as well as green photosynthetic pigments

dead zone region in a body of water that is depleted of oxygen and can only support anaerobic organisms

density mass of an object per unit volume

dermal branchiae projections of the body of an echinoderm that aid in respiration

detritus dead, particulate organic matter

deuterostome group of animals that includes echinoderms and vertebrates that is distinguished by development in which the first embryological opening becomes the anus

diatoms group of unicellular algae whose cell walls contain silica

differentiate to become specialized for a specific function

dinoflagellates group of unicellular algae with two flagella and cell walls that contain cellulose

dredge instrument that collects materials by dragging

echinoderm group of spiny-skinned animals that include starfish and sea urchins

ectotherm animal whose body temperature varies with the environment; cold-blooded animal

eddy current of water moving in a circular pattern

electromagnetic radiation energy that travels in a wave and has both magnetic and electrical characteristics

estuary coastal body of water where a river drains into the sea

fathom measurement of water depth; 6 feet (ft) (1.8 meters [m])

fertilization union of a sperm with an egg

fertilization membrane membrane that forms around a fertilized egg, preventing penetration of other sperm

flagellum tail or whiplike structure on a cell that is used for locomotion

food chain feeding relationships in an ecosystem that show how energy is transferred from producers to consumers

food web all of the overlapping food chains in an ecosystem

foraminiferan unicellular marine organism that makes a shell by secreting calcium carbonate or by gluing together particles of sand

gamete sex cell; sperm or egg cell

gastrulation process in the early development of an embryo in which a three-layered gastrula develops from a blastula

gill net flat net suspended in the water that traps fish by their gills

global warming an overall increase in Earth's temperature caused by the accumulation of gases in the atmosphere that trap heat

guyot flat-topped, undersea mountain of volcanic origin

herbicide chemical used to kill unwanted plants

heterotroph organism that is not capable of making its own food

hydrometer instrument used to determine the specific gravity of a liquid

lateral line sensory organ in fish and amphibians that can detect vibrations in the water and the movements of other organisms

lithogenic originating from the rock on Earth

longline long, central rope or line to which are attached baited hooks

luciferins group of light-emitting compounds found in organisms that are able to bioluminesce

madreporite disc structure on the dorsal surface of an echinoderm that takes in water for the water vascular system

operculum hard, bony flap that covers and protects the gills of fish

opportunistic feeder organism that uses the food found in almost any environment

osmosis the movement of water molecules from an area of high concentration to an area of low concentration

Paleocene/Eocene Thermal Maximum period of rapid global warming that took place 55 million years ago and caused dramatic changes in climate

pedicellaria jawlike appendage on the dorsal surface of an echinoderm that removes parasites

photic of the area in the ocean that receives enough light to carry out photosynthesis

photophore light-emitting organ that can be found in several types of marine animals

photosynthesis biochemical process in which chlorophyll traps the Sun's energy and uses it to make glucose

phytoplankton free-floating, small algae that can be found on the surface of fresh water and in marine environment

plankton free-floating, small organisms, including algae, small animals, and protists, that can be found on the surface of freshwater and in marine environments

pod group of marine mammals such as whales or dolphins

podium animal structure that functions as or resembles a foot

polychaete any of the segmented worms that have pairs of fleshy, bristled appendages on each body segment

polyvinyl chlorides (PVCs) synthetic material made of repeating units of vinyl chloride that is used to make a variety of products

protist member of the kingdom Protista, a group of single or multicellular eukaryotes that includes protozoans, algae, and slime molds

radial symmetry type of body symmetry in which all planes of the organisms are arranged around a central axis

regeneration the process of developing organs later in life to replace missing ones

salinity the amount of salt in a solution

specific gravity ratio of the density of a material to the density of water

symbiotic of the long-term relationship between two organisms of different species

taxonomist scientist who classifies living things into groups based on their characteristics, structures, behavior, and origins

terrigenous derived from weathering processes on the land

territory area occupied by an animal, mating pair of animals, or group of animals that is defended against intruders

thermohaline circulation global circulation of ocean water driven by differences in water density

toxin poisonous substance produced by a living thing

trophic referring to a feeding level in a food chain

turtle exclusion device (TED) modification to a trawl net that allows turtles and other large animals to find their way out of the net

upwelling the movement of cold, dense, nutrient-rich water from deep in the ocean to the surface

vascular tissue conducting tissue that allows a plant or animal to transport water and nutrients to tissues

volcanogenic of volcanic origin

water vascular system network of water-filled tubes in echinoderms that provide locomotion and aids in respiration

zooplankton free-floating, small animals and animal larvae that can be found on the surface of fresh water and in marine environments

zygote diploid cell formed by the fusion of an egg and a sperm

Internet Resources

The World Wide Web is an invaluable source of information for students, teachers, and parents. The following list is intended to help you get started exploring educational sites that relate to the book. This list is just a sample of the Web material that is available to you. All of these sites were accessible as of January 2010.

Educational Resources

Anthoni, J. Floor. "Oceanography: waves," 2000. Available online. URL: www.seafriends.org.nz/oceano/waves.htm. Accessed January 23, 2010. Anthoni's article on the behavior of ocean waves is written for the advanced high school student.

"Arctic Marine Geography, Climate, and Sea Ice," April 29, 2009. Available online. URL: http://www.uaf.edu/accap/documents/AMSAArcticMarineGeographyClimateSeaIce.pdf. Accessed January 23, 2010. This Arctic Marine Shipping Assessment, written for navigational purposes, reviews current knowledge in the region's seafloor and ice and provides useful information for anyone interested in marine science.

Classroom BATS. "Virtual Plankton Tow." Available online. URL: http://www.coexploration.org/bbsr/classroombats/html/virtual_plankton_tow.html. Accessed January 23, 2010. Classroom BATS, the Bermuda Atlantic Time-series Study, is a program of the Bermuda Biological Station for Research that focuses on the ocean's role in global environmental change. The BATS Web site provides excellent photographs and descriptions of planktonic organisms.

Coghlan, Andy. "Fishing fleets squander half their catches." *New Scientist*. April 15, 2009. Available online. URL: http://www.newscientist.com/article/dn16946-fishing-fleets-squander-half-their-catches.html?DCMP=OTC-rss&nsref=online-news. Accessed January 23, 2010. In this article, Coghlan reports on research done by the World Wildlife Federation on the amount of bycatch produced by the fishing industry.

Gardiner, Lisa. "Earth's Oceans," Windows to the Universe, September 31, 2008. Available online. URL: http://www.windows.ucar.edu/tour/link=/earth/Water/ocean.html. Accessed January 23, 2010. Gardiner's Web site discusses waves, currents, coral reefs, ocean life, and other topics related to marine science.

HowStuffWorks. “The Geography of Oceans,” 2009. Available online. URL: http://geography.howstuffworks.com/oceans-and-seas/the-geography-of-oceans8.htm. Accessed January 23, 2010. Ocean geography, properties of seawater, submarine topography, and transmission of energy in oceans are some of the topics discussed in this easy-to-read article.

Lee, Henry II. “Methods for Assessing Sediment Bioaccumulation in Marine/Estuarine Benthic Organisms.” National Sediment Bioaccumulation Conference. Available online. URL: http://www.epa.gov/waterscience/cs/library/lee.pdf. Accessed January 23, 2010. Written for the advanced student, this paper explains how toxic materials impact on marine ecosystems.

MacRae, Andrew. “Dinoflagellates,” Available online. URL: http://www.geo.ucalgary.ca/~macrae/palynology/dinoflagellates/dinoflagellates.html. Accessed January 23, 2010. MacRae describes several types of dinoflagellates and provides excellent photographs on this Web site.

Marinebio. Available online. 2009. URL: http://marinebio.org/MarineBio/index.asp. Accessed January 23, 2010. This Web site supplies accurate information on marine organisms and promotes marine conservation.

Massengale’s Biology Junction. “Echinoderms.” Available online. URL: http://www.biologyjunction.com/Echinoderm.ppt. Accessed July 19, 2009. Massengale, a biology teacher, differentiates the characteristics of different classes of echinoderms on this Web site.

MyFWC.com. “Fish Identification – Saltwater,” 2009. Available online. URL: http://myfwc.com/WILDLIFEHABITATS/SaltFishID.htm. Accessed January 23, 2010. Sponsored by the Florida Fish and Wildlife Conservation Commission, this Web site provides descriptions and illustrations of many marine fish.

Ocean World, June 11, 2009. Available online. URL: http://oceanworld.tamu.edu/index.html. Accessed January 23, 2010. Developed and maintained by the Jason Education Project at Texas A & M University, this Web site provides information on fisheries, weather, coral reefs, and more marine topics.

Office of Naval Research, Science and Technology Focus. “Ocean in Motion: Waves – Characteristics.” Available online. URL: http://www.onr.navy.mil/Focus/ocean/motion/waves1.htm. Accessed January 23, 2010. The parts and behavior of waves are explain with great illustrations on this Web site.

Parmentier, Jan. “Growth of a Starfish, Microscopy-UK.” Available online. URL: http://www.microscopy-uk.org.uk/mag/indexmag.html?http://www.microscopy-uk.org.uk/mag/art98/janstar.html. Accessed January 23, 2010. In this article, Parmentier describes the larval stages of starfish and shares some of her own excellent photographic images.

ScienceDaily. “Marine Science News,” 2009. Available online. URL: http://www.sciencedaily.com/news/plants_animals/marine_biology/. Accessed January 23, 2010. ScienceDaily is a Web site that reports on news and research related to science. This page contains articles about marine biology.

U.S. Environmental Protection Agency. “Polychlorinated Biphenyls (PCBs),” June 25, 2009. Available online. URL: http://www.epa.gov/epawaste/hazard/tsd/pcbs/index.htm. Accessed January 23, 2010. This Web site provides information on the production and disposal of PCBs as well as the impact of these chemicals on human health and the environment.

U.S. Geological Survey. “Coastal and Marine Geology Program,” December 3, 2008. Available online. URL: http://marine.usgs.gov/. Accessed January 23, 2010. The U.S. Geological Survey’s Coastal and Marine Geology Program studies issues related to coastal, deep, and estuarine waters and publishes reports on its Web site.

U.S. Geological Survey Science Center for Coastal and Marine Geology, May 8, 2009. Available online. URL: http://woodshole.er.usgs.gov/. Accessed January 23, 2010. The Woods Hole Coastal and Marine Geology Team conducts research on a variety of marine science topics. Reports of their research and other news related to marine science are available on the Web site.

Periodic Table of Elements

1 — atomic number
H — symbol
1.008 — atomic weight

Numbers in parentheses are the atomic mass numbers of radioactive isotopes.

1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57-71*	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89-103‡	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Ds (271)	111 Rg (272)	112 Uub (285)	113 Uut (284)	114 Uuq (285)	115 Uup (288)	116 Uuh (292)		118 Uuo (294)

*lanthanide series	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
‡actinide series	89 Ac (227)	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

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