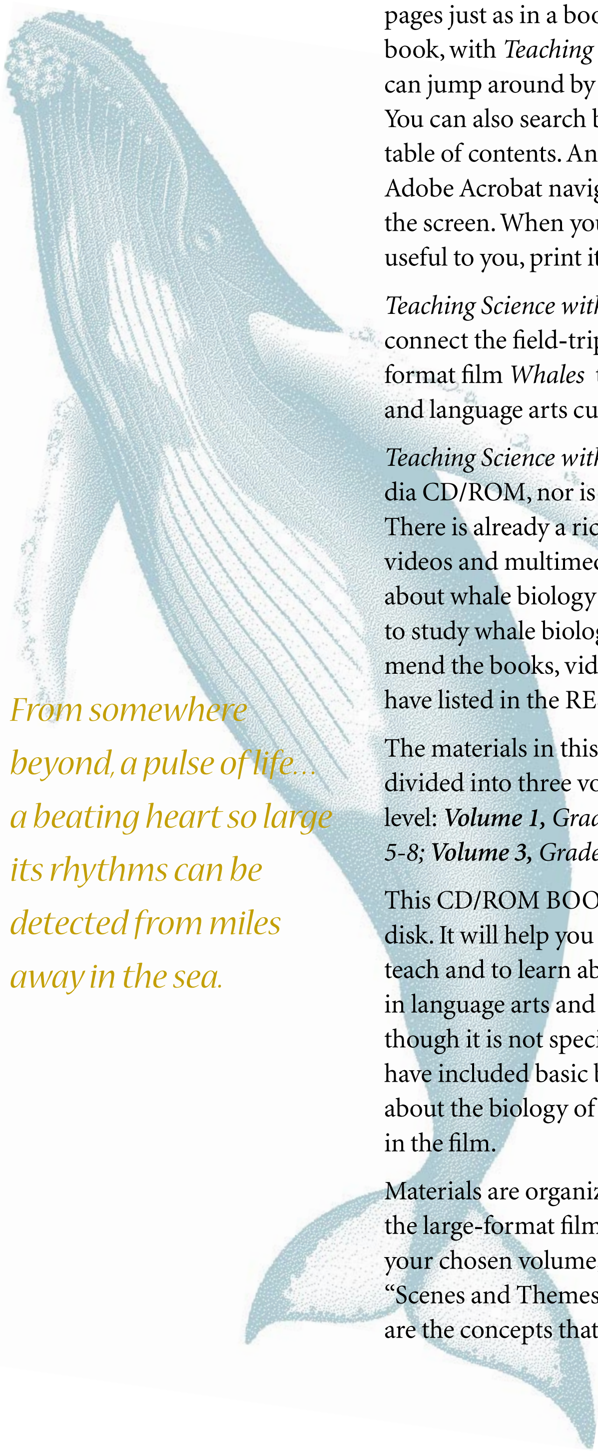
Teaching Science with Whales

A CD-ROM Book

Volume 1
Kindergarten–4th Grade

Welcome to Whales!



From somewhere beyond, a pulse of life… a beating heart so large its rhythms can be detected from miles away in the sea.

Welcome to the CD/ROM BOOK we call *Teaching Science with Whales* We hope that you find it helpful in teaching and learning science. The materials are produced here as illustrated text, with serial pages just as in a book. But unlike reading a book, with *Teaching Science with Whales* you can jump around by using hypertext buttons. You can also search by key word, or use the table of contents. And you can use the special Adobe Acrobat navigational tools at the top of the screen. When you find the material most useful to you, print it out and use it in class.

Teaching Science with Whales is designed to connect the field-trip experience of the large-format film *Whales* to the science, mathematics and language arts curricula of your classrooms.

Teaching Science with Whales is *not* a multimedia CD/ROM, nor is it a textbook on whales. There is already a rich assortment of books, videos and multimedia CD/ROMs specifically about whale biology and behavior. If you want to study whale biology in detail, we recommend the books, videos and CD/ROMs we have listed in the RESOURCES.

The materials in this CD/ROM BOOK are divided into three volumes based on grade level: ***Volume 1,** Grades K-4; **Volume 2,** Grades 5-8; **Volume 3,** Grades 9-12*

This CD/ROM BOOK is actually a book on a disk. It will help you to use the film *Whales* to teach and to learn about science, with exercises in language arts and mathematics, too. Although it is not specifically about whales, we have included basic background information about the biology of those species that appear in the film.

Materials are organized by selected scenes from the large-format film *Whales*. After you are in your chosen volume, you will see a selection of "Scenes and Themes". Listed next to each scene are the concepts that the scene can support.

Most of these concepts relate directly to the "content standards" and to the "fundamental concepts and principles" discussed in the *National Science Education Standards* (published by the National Academy Press of the National Academy of Sciences, 1996).

The "Whales & Words" concept choice relates to language arts and depends in part on the *Standards for the English Language Arts* (published by the National Council of Teachers of English and the International Reading Association, 1996).

The "Whale Biology" choice provides an overview of the biology and behavior of the whale species featured in the scene.

Backgrounders

Each Content Standard choice has a supporting article we call a "Backgrounder." Backgrounders can serve as refreshers for teachers to help prepare for the presentation of classroom activities. Backgrounders may serve as introductory materials for students. Backgrounders can complement information in other supplementary material and in text books.

Following each Backgrounder is a selection of "Activities". Students can perform these in class or do them as outside projects. Some Activities are lengthy and involved and require independent research. Others are simple and can be performed in groups. All Activities are designed to demonstrate or explicate the Content Standard cited in the Backgrounder.

In summary, the intent of *Teaching Science with Whales* is to connect the thrill of viewing the film *Whales* with classroom curricula in science, math, and language arts. Scenes from the film serve as inspirational springboards into both formal teaching settings and informal student activities.

How to use this CD-ROM

Getting Started

Teachers can browse for curriculum materials, and use the Backgrounders to prepare lessons. **Students** can browse the Backgrounders, and choose activities and lab exercises for research projects and science fair ideas.

The materials in this CD/ROM BOOK are divided into three volumes based on grade level:

Volume 1	*Grades K-4*
Volume 2	*Grades 5-8*
Volume 3	*Grades 9-12*

You are now in ***Volume 1***. If you would like to be in another Volume, close this document and open ***Volume 2*** or ***Volume 3***.

After you have read the information on this page, click on the forward arrow (located at the top of this page, at the left) to go to the "Table of Scenes." The 8 photos on this page are scenes from the large-format film *Whales*. Listed next to each scene are the concepts (or "themes") that the scene can support.

Here's how it works:

- Decide on one of the 8 scenes from the film and click on that image—you will be taken to a page with a larger-scale view of the scene
- Click on the forward arrow, or the "Theme Menu" button at the top of the page
- From the "Theme Menu," choose the theme you wish to explore by clicking on the name
- You are now on the Backgrounder page for that scene and theme

This material is designed to provide a background that relates the film scene with fundamental principles. The Backgrounder leads off with the fundamental principle from the National Standards.

- Read the Backgrounder, then go forward to review the "Activities Menu"
- Select an Activity and click on it
- When you have located the activity you want to use in class, print it out along with the Backgrounder for your future reference
- Use the material in class and photocopy the materials as needed

Document Navigation

There are a number of ways for you to navigate in this CD/ROM BOOK. You can click on the "buttons" at the top of the page, the highlighted bars in the menus, and the photos of the film scenes in the Table of Scenes. Within the text, there may be highlighted (colored) words that are "hot." You will know a word is hot when you pass the cursor over it—the hand will turn into a pointing hand (try it on the green sentence below). Click on the word(s) to go to linked information. You can also use the Adobe Acrobat navigation tools at the top, bottom, and left side of the window. When you find the material most useful to you, print it out and use it in class.

Click on these hot words for more detailed information on getting around in this document.

Printing

To print out the pages you want to use in class, choose the PRINT command and fill in the page number or range of pages you want to print. The page number is clearly marked in the upper left corner of the page. To find numbers of the pages you wish to print, choose the "Thumbnail and Page" viewing mode. At the left of your screen, you will see small versions of adjacent pages, numbered at the bottom. (If you need to see a thumbnail enlarged, click on it.)

Scene Menu

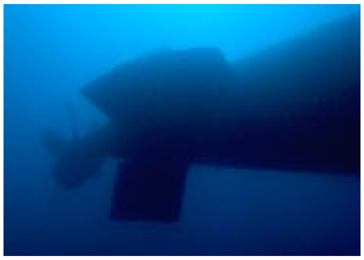
Table of Scenes

Choose a Scene

The following images are based on key scenes from the large-format film *Whales*. Each scene supports some of the National Science Education Content Standards. We have also added a Language Arts Section and basic information on the biology of featured whales.

Click on the image to first see a full-page view of the scene, then go forward a page to choose the "Theme" you wish to explore. The next page you'll see is the "Backgrounder" article that links the scene to class activities. Then select and print the pages you wish to use in class.

Submarine



This Scene supports the following Content Standards:

- *Life Science*

Debbie & Whales

This Scene supports the following Content Standards:

- *Science as Inquiry*
- *Nature of Science*
- *Whales and Words*
- *Whale Biology*

Blue Whales & Krill

This Scene supports the following Content Standards:

- *Life Science*
- *Science as Inquiry*
- *Whale Biology*

Mother & Calf

This Scene supports the following Content Standards:

- *Earth Science*
- *Whale Biology*

Eye of the Whale

This Scene supports the following Content Standards:

- *Life Science*
- *Physical Science*
- *Whales and Words*
- *Whale Biology*

Whale Graveyard

This Scene supports the following Content Standards:

- *Life Science*
- *Science as Inquiry*

Singing Humpback

This Scene supports the following Content Standards:

- *Life Science*
- *Physical Science*
- *Science in Society*
- *Whale Biology*

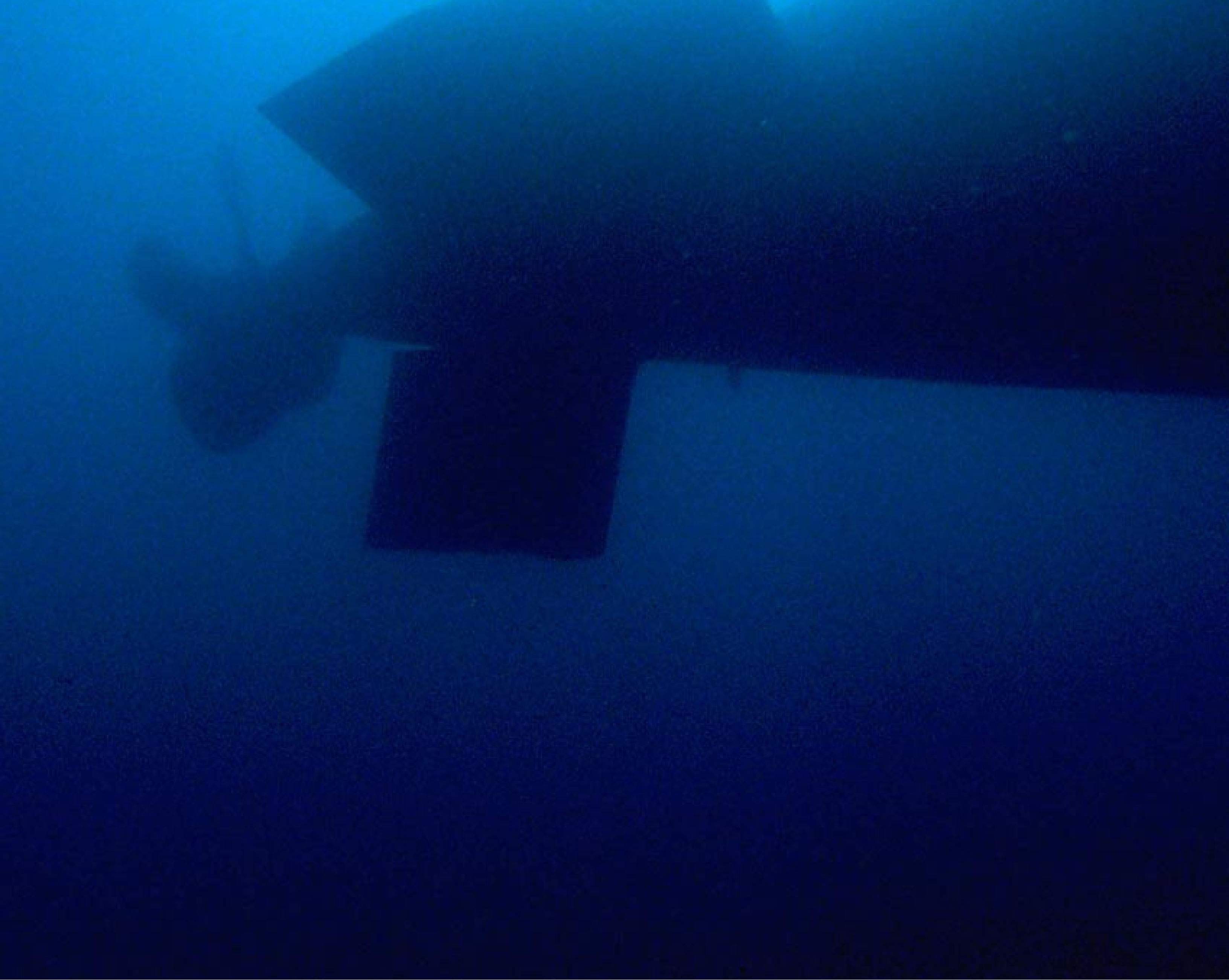
Bubble Nets

This Scene supports the following Content Standards:

- *Science as Inquiry*
- *Whale Biology*

Submarine

Engineers who design submarines are faced with problems similar to those already solved by fast-swimming animals in the sea.



Theme Menu

Submarine

Choose a Science Theme

The "Submarine Scene Resource" supports learning plans for the themes highlighted below. Press the highlighted bar for the theme you wish to explore.

Life Science
Physical Science
Earth Science
Science as Inquiry
Science in Society
Nature of Science
Whales & Words
Whale Biology

Backgrounder

Life Science

Submarine

"Characteristics of Organisms
Each animal has different structures that serve different functions in growth, survival and reproduction. For example, humans have distinct body structures for walking, holding, seeing, and talking." NS

Whales and Submarines

By comparing whales to submarines we can learn about adaptations to life in the sea. These include structures and systems for movement, diving, breathing, staying warm, storing energy, and communicating and navigating.

Convergent Evolution

Sometimes, unrelated or distantly related animals (e.g. sharks, and whales and porpoises) show similar adaptations to similar environmental problems. Biologists call this "convergent evolution." Outwardly the structures and adaptations look similar but close examination reveals that different structures may support similar functions.

In general, moving through the density of seawater requires a lot of effort. Less effort is needed if the moving object is streamlined rather than blunt or flattened.

Both whales and porpoises, and sharks (the kinds that live in open water, such as makos, gray reefs, great whites, tigers) can swim with relatively little effort. Their propulsive sources (their tails) are efficient mainly because their bodies are streamlined. In general, moving through the density of seawater requires a lot of effort. Less effort is needed if the moving object is streamlined rather than blunt or flattened. Fast-swimming open water sharks and porpoises show similarities in body shape and structure. Both have torpedo-shaped bodies. Their bodies are narrow at front and back and widest in the middle. Both have pointed or conical noses. Both have wing-like pelvic fins they use like airplane wings to dive or climb. Sharks and porpoises (and most whales) have dorsal fins to control pitch (rolling around the body axis). Both have body surfaces that are modified to reduce friction as they pass through the water. Porpoise-skin is very smooth. To the human touch, porpoise skin feels almost like an inflated tire inner tube. Shark skin, although noted for its roughness, is actually a successful adaptation for streamlining the surface of the shark's body. Shark skin is covered with tiny denticles (or "toothy-scales"). Each tiny denticle is ridged to direct water smoothly across its surface to the denticle behind it and so on. But shark skin is rough when rubbed the wrong way or when the sharp streamlining edges cut into flesh.

Whales, although much larger than fast-moving sharks and porpoises, usually have many of the same kinds of streamlining adaptations. Before scientists and photographers went underwater and began watching great whales swim, our main view of whales was based on their dead, flaccid carcasses hauled out of the sea and collapsed on a dock or ship's deck.

Until the early 1970s most paintings and drawings of live whales were based on dead whales. Artists drew them as fat and stubby creatures. Now, from underwater photographs and observations, we know them to be slim and gracefully shaped for ocean life.

Engineers and designers who design fast-moving submarines are faced with challenges similar to those of animals in the sea:

- high density of sea water;
- increasing darkness, cold, and pressure with increasing depth;
- removal of dissolved oxygen from seawater, or the ability to carry an air supply from the surface;

continued

Backgrounder

Life Science

Submarine *continued*

- long-distances between fuel (food) supplies;
- moving through featureless three-dimensions, with landmarks limited to the sea bottom or to current patterns.

A close look at a submarine can show many similarities to marine animals. These include strong streamlined hulls, hydroplanes for diving and climbing, strong, smooth skins, strong engines with large fuel supplies (compare blubber reserves in whales), propulsion systems that push from the rear, extended "breath-holding" capacity, use of submarine sound (SONAR) for navigation and communication.

Other kinds of human-built subs—bathyscaphs, bathyspheres, research subs—retain a cable connection to the surface. Most are slow and sluggish, sinking to the depth they want to investigate and moving around in a constrained manner, then returning to the surface. But subs that need to move fast and be maneuverable (like the new generation of Deep Flight research submersibles, end up looking a lot like sharks, porpoises and whales.

...subs that need to move fast and be maneuverable (like the new generation of Deep Flight research submersibles) end up looking a lot like sharks, porpoises and whales.

The streamlined shape of whales allows for efficient movement through water—a pointed object faces less resistance in water than a larger, flatter surface. Whales do not have external ears or hind limbs, making them more streamlined than most other marine mammals.

The rubbery tails or flukes whales have allow them to move very efficiently in water. Whale flukes move horizontally, their smooth, measured movements working much like a ship's propeller to drive them through water. Most fish, by contrast, swim by wriggling their bodies much like snakes do, and their tails move vertically from side to side.

The dorsal (topside) fin found on most whales (though not gray or humpback) is believed to act as a keel, keeping whales upright. Most boats also have keels. The flippers whales have are the equivalent to human arms and hands, and are critical to steering. Humpback whales have huge flippers which they also use for locomotion.

While whales spend much of their time in frigid waters, they have two physiological adaptations that help them to regulate their body temperature. First, they have a relatively low body surface area to volume ratio, which reduces their propensity for heat loss—the greater the surface area to volume ratio the more thermal conductivity occurs. The second adaptation is blubber, the thick layer of fat whales have to insulate them. Blubber is also used as a fuel source for whales when they are not in their feeding grounds.

Whales are also adapted to withstand extremely high water pressure while diving without damage to their organs or tissues. Water pressure increases 14 pounds per square inch with every 33 feet of depth, so a whale that is, for example, 800 feet underwater is exposed to 340 pounds per square inch of pressure.

Whales have very efficient respiration and circulation techniques. While land animals replace about 30% of their lung capacity with each breath, whales replace nearly 80% of their lung volume each time they inhale. Their red blood cells carry more oxygen than those of land animals, and this oxygen is stored in their muscle cells for use during prolonged dives. Whales also conserve oxygen by decreasing their heart rate and shunting blood to the brain and heart and away from other non-essential organs while diving.

continued

Submarine *continued*

. . . submarines use ballast that are filled with air or sea water in order to increase or decrease the subs density and cause it to sink or float, much as a whale displaces oxygen from its lungs in order to increase its density.

Many similar solutions are also seen in submarine design. Submarines have a streamlined shape. They use a rear propeller, comparable to a whale's fluke, to displace huge amounts of water and move forward or backwards in the water. They have hydroplanes (fins) on either side that deflect the flow of water around the hull and cause the submarine to ascend or descend under the power of its propellers. Submarines are well insulated and made of materials designed to withstand huge amounts of water pressure. And submarines use ballast that are filled with air or sea water in order to increase or decrease the subs density and cause it to sink or float, much as a whale displaces oxygen from its lungs in order to increase its density.

Whales drive themselves forward by pushing against the water with powerful strokes of the tail flukes. Pectoral fins act like hydroplanes to modify forward motion into climbing, diving and banking.

Blue Whales and Submarines

Perhaps the most exciting connection between blue whales and submarines has been made just recently. During the Cold War the U.S. Navy monitored the entire North Atlantic basin for Soviet submarine activity and locations using SOSUS (SOund SUrveillance System). SOSUS consist of a large array of underwater microphones buoyed throughout the Atlantic. A sound source (the propeller of a submarine, for example) is picked up by the hydrophones. Each hydrophone radio-transmits its signal to a central computer. The quality of the sound can be analyzed for distinctive characteristics—a unique "fingerprint" of the sound can be delineated. Every time that sound is heard on SOSUS, it can be identified.

SOSUS can also pinpoint the location of the sound. Travel times from sound source to three or more microphones (the location of which is plotted) can be used to calculate the sound source location.

SOSUS was developed to track enemy submarines. Since the end of the Cold War the U.S. Navy declassified the system and now allows its use by scientists to track whales. One individual blue whale "Old Blue" has been tracked for thousands of miles and many days. Its distinctive "voice" and SOSUS told scientists much about whale travels and navigation.

Thus technology based on the same physical adaptations of whales permits us to learn about whales themselves.

Submarine

Choose an Activity

The activities listed below will enable your students to experiment within the theme of "Life Science." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: Cucumber Whales

Activity 2: Whales & Submarines

Cucumber Whales

Activity 1

Group size

Individuals, pairs, or small groups

Time you'll need

1 hour or more

Materials you'll need

- *cucumbers*
- *large paper clips*
- *3' or more of string*
- *plastic lids from yogurt or ice cream containers, and/or a plastic milk jug*
- *scissors*
- *a knife (a plastic one will work)*
- *a sink, tub of water, or wading pool, at least 6" deep*
- *pictures of various whales, sharks and fishes*

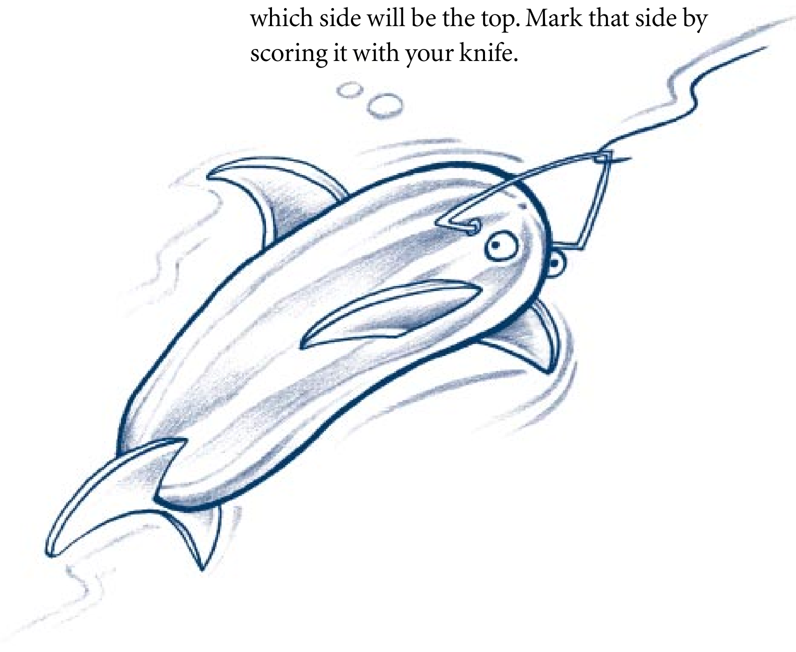
What to do

First, gather from books, posters or other materials an assortment of pictures of whales, sharks and fishes. Have everybody look closely at the pictures, then discuss possible reasons why marine animals have fins, flukes, or flippers and what they're used for. Do all animals have the fins the same size and in the same places? What are they used for? Do they move in the same directions? (Remember what you saw in the film.)

Each student or group is given a cucumber to act as a model of the body of a whale, fish, or shark.

After this discussion, design fins, flukes and/or flippers for your cucumber and cut them out of the plastic lids or milk jug. (Make them slightly bigger than you imagine them on the cucumber because part of each one will be stuck into the cucumber!) Try to make your cucumber as efficient a swimmer as possible.

After you've cut out your fins, flukes and/or flippers, straighten your paper clip, bend it in half, then bend the ends in 1/2" or more and stick them into your cucumber about 1" from the end. (See diagram) Attach a piece of string to the paper clip, then take your cucumber to your "test tank" (pond, pool, bathtub etc.) Let the cucumber float for a minute so you can tell which side will be the top. Mark that side by scoring it with your knife.



Take the cucumber out of the water. Score the cucumber with your plastic knife to make slots for where you want your plastic fins, flukes and flippers to be, then carefully insert each one.

Now put your cucumber back in the water. How well does it float now? Is the top still the top? What happens when you drag the cucumber through the water?

Take the cucumber out of the water, remove the paper clip, and use a knife to carefully whittle the end of the cucumber to form a pointed front end. Reinsert the paper clip and put the cucumber back in the water. Does it seem easier or harder to pull it through the water?

(To measure the amount of pull, you can attach the string to a small spring scale, available at fishing supply stores. As you pull on the scale, its spring pulls on the string, and the scale measures the amount of force that's pulling the cucumber sub.)

Take the cucumber out again, remove the paper clip, and cut the pointed front off the cucumber so that it has a round, flat front. Put the paper clip back in and try pulling the cucumber through the water. Does it feel any different?

What's happening?

Fins, flukes and flippers are critical to whales, sharks and fishes for swimming. There are many different combinations, sizes and placements of these on different animals, but they have essentially the same functions between species.

Whales have horizontal tail flukes that move up and down (vertically) to propel them through the water. They also have flippers, equivalent to human hands and arms, which are used for steering and for stopping. Humpback whales have very large flippers which they use for locomotion as well as steering. The dorsal (topside) fin on some whales probably acts as a keel to keep the whale from spinning around its long axis. But not all whales have dorsal fins. Why do you think some whales have them and some don't?

Whales & Submarines

Activity 2

Group size

Individuals or pairs

Time you'll need

A couple of hours for library research; a couple of hours to illustrate and write a report.

Materials you'll need

- *access to information on whale physiology and on submarines, e.g., encyclopedia*
- *pen and paper*

Objective

To compare and contrast whale anatomy and physiology with submarine structure and function.

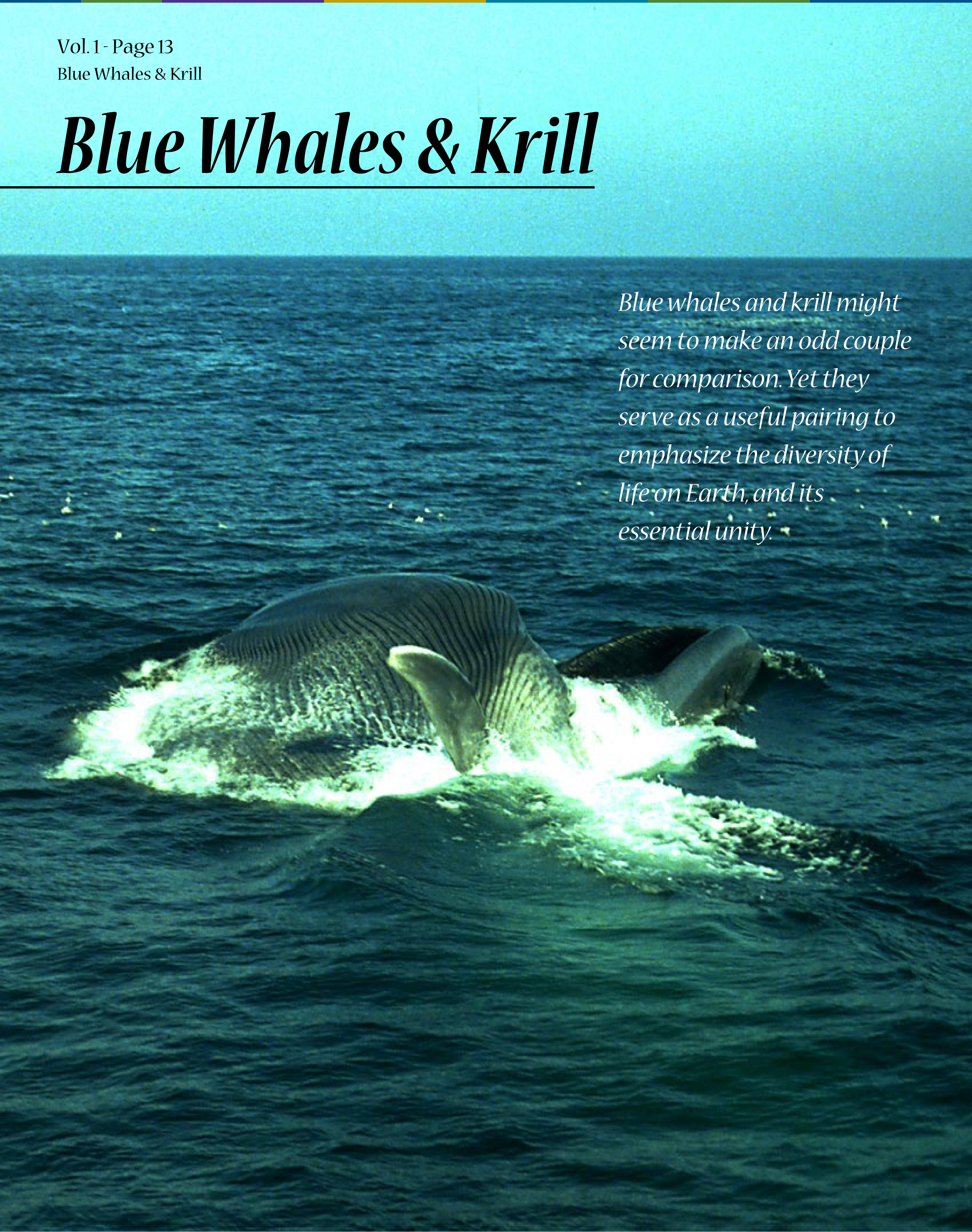
What to do

The first step is to visit the library. Find pictures of whales and submarines that define their various parts. Read as much as you can about how the various parts work.

Next, prepare a report on how whales and submarines are similar and how they are different. Do this in essay form and/or create a chart comparing various functions. Include drawings or photocopies of pictures of a whale and a submarine, and label as many of their parts as you can. Some things to specifically address in your report:

- How do they dive underwater?
- How long can they stay underwater? Why?
- How do they survive immense water pressure?
- How do they move? (forward, up, down, sideways)
- What happens if they stop moving?
- How are they fueled? (What do whales eat?)
- How do they know where they are going?
- How do they see in deep, dark, murky water?
- How do whales reproduce and evolve? Do subs reproduce and evolve? How?

Blue Whales & Krill



Blue whales and krill might seem to make an odd couple for comparison. Yet they serve as a useful pairing to emphasize the diversity of life on Earth, and its essential unity.

Theme Menu

Blue Whales & Krill

Choose a Science Theme

The "Blue Whales & Krill" supports learning plans for the themes highlighted below. Press the highlighted bar for the theme you wish to explore.

- **Life Science**
- Physical Science
- Earth Science
- **Science as Inquiry**
- Science in Society
- Nature of Science
- Whales & Words
- **Whale Biology**

Backgrounder

Blue Whales & Krill

"The Characteristics of Organisms

Organisms have basic needs. For example, animals need air, water, and food; plants require air, water, nutrients, and light. Organisms can survive only in environments in which their needs can be met. The world has many different environments, and distinct environments support the life of different types of organisms.

Each plant or animal has different structures that serve different functions in growth, survival, and reproduction." NS

It is likely that the shrimp-like animals called krill have relatives still unknown to us. It is even possible that blue whales may have toothed cousins we have yet to discover.

Blue whales and krill might seem to make an odd couple for comparison. Huge and tiny; bluish gray and red; vertebrate and invertebrate; mammal and shrimp; predator and prey. Yet they serve as a useful pairing to emphasize the diversity of life on Earth, and its essential unity.

How Many Animals?

Nearly two million kinds of living organisms have been scientifically described and named. Scientists think there may be millions more that we still haven't recognized and discovered. Some of these undiscovered creatures may be large; a new kind of shark 15 feet long (5.2 m) came to light in 1976. Some may be small; the canopy of tropical rainforests is a rich source of new species for insect biologists. Some may be microscopic; newly discovered forms of bacteria are now known to be the basis of food chains in the hydrothermal vent areas of the deep sea.

It is likely that the shrimp-like animals called krill have relatives still unknown to us. It is even possible that blue whales may have toothed cousins we have yet to discover. (A new species of beaked whale was named in 1963.)

Meeting the Challenges of Life in Different Ways

Within the millions of species in the animal kingdom (distinguished from plants, fungi, protista, and various kinds of bacteria) we can so far distinguish about 30 distinct groups, or phyla (or, phylums). The members of each phylum share a set of distinguishing physical characteristics. The fundamental characteristics of a phylum's physical plan distinguish it from all others. The phylum's unique type of body plan has evolved to meet the challenges of life.

Basically all animals are engaged in similar activities in order to exist. All animals feed—they obtain, digest, and assimilate food. All animals circulate nutrients and gases within their bodies. They dispose of wastes generated by cellular activity. All animals coordinate internal activities using neural and sometimes endocrine systems. They grow, avoid being eaten, and most importantly for their species—they reproduce.

As even a quick review of animals shows—take a look at a blue whale and a krill-shrimp, for example—there are a wide variety of ways to solve these problems. All are based on essential similarities at the cellular level.

Classifying the Millions

Humans have long tried to order this vast diversity of life. A first step in organizing anything complicated is to name the parts, in this case the kinds of animals. Naming animals is an important and basic task in most human cultures. This importance is revealed in many creation myths. In *Genesis*, the creation story of Judaeo-Christian culture, God gave Adam the task of "naming the birds of the air, the fish of the sea." In the *Kumulipo*, a creation-chant of Hawaii, creatures of land and sea are named as their creation is recounted.

continued

Backgrounder

Life Science

Blue Whales & Krill *continued*

A scientifically useful system of naming and organizing living things must reflect the relationships and similarities and differences among them.

But naming is not enough to comprehend the biodiversity of the world. A scientifically useful system is based on grouping animals according to genetic relationship (presumed or proven) and shared origin. Aristotle, the Greek rational philosopher who lived from 384-322 BC, tried to develop a systematic naming system to help understand the natural world.

Today's scientific speciality of biological nomenclature is called *taxonomy*. Taxonomists use a bionomial system of naming. Bionomial means "two-named" and refers to the universal use of *genus* and *species* to form the basic scientific name of an animal or plant. The bionomial system used by all biologists dates from 1758. That important year saw the publication of a landmark book called *Systemae Naturae*, written by Swedish botanist Karl von Linné (latinized to Carolus Linnaeus). Although Linnaeus was a botanist, he named many kinds of animals, including whales. The modern scientific name for the blue whale, *Balaenoptera musculus*, dates to Linnaeus' book.

A scientifically useful system of naming and organizing living things must reflect the relationships and similarities and differences among them. Linnaeus looked long and hard at the sexual parts of flowers to develop his classification of plants. Good classifications require careful study of the structure, biology, and behavior. Today's taxonomists and evolutionary biologists now add the tools of genetic analysis to reveal and confirm relationships.

At the fundamental level of the scientific system of biological classification is the *species*. A species is a population of interbreeding individuals. These individuals are reproductively isolated from (cannot interbreed with) other animals, including some that might be related to them. Genetically related species are classified together within a *genus*.

Whale Classification

The blue whale is classified in the genus *Balaenoptera*, as *Balaenoptera musculus*. Closely related to blues, but reproductively independent of them are other species of whales also classified in the genus *Balaenoptera*. These include fin whales, *Balaenoptera physalus*; sei whales, *Balaenoptera borealis*; Bryde's (pronounced 'broods) whale *Balaenoptera edeni*; and minke whales, *Balaenoptera acutorostrata*.

Humpbacks are somewhat similar to blues but have some distinctive differences. Based on these differences, they are classified in a distinct genus, *Megaptera*. Scientists recognize the shared ancestry of the two genera, *Balaenoptera* and *Megaptera,* by classifying them in the same family, Balaenopteridae.

Gray whales are different enough from blues and humpbacks that scientists classify them in a separate family, Eschrichtiidae. Yet, because they are more closely related to blues than to any toothed whale, blues and grays are grouped together in the order Mysticeti. Toothed whales are in another order, Odontoceti.

All whales, toothed and baleen, are more closely related to seals and sheep and humans than to fish or snakes, so they are grouped in the class Mammalia. Thus all the species within a group, whether class or genera, are considered to be genetically related (i.e., have a shared ancestry). The smaller the group in which two species are included, the closer their relationship. Species in the same genera are thus closely related. Species in different orders are distantly related, and in different classes even more distantly related.

Classification and inference of relationships are based on many kinds of evidence from biochemistry to behavior. Scientists may

continued

Backgrounder

Blue Whales & Krill *continued*

All whales, toothed and baleen, are more closely related to seals and sheep and humans than to fish or snakes, so they are grouped in the class Mammalia.

disagree on their interpretations of complex data. One taxonomist's family grouping may be another's genus grouping. But such disagreement is more about what to call the category, than a conflict in the basic principle of relationship.

Summary of the Classification of some Baleen Whales

Phylum Chordata (mostly Vertebrata—animals with backbones)

Class Mammalia (haired vertebrates that feed their young with milk);

- Order Mysteceti, baleen whales
  - Family Balaenopteridae, rorqual whales
    - Genus *Balaenoptera*
      - blue whale *Balaenoptera musculus*
      - sei whale *Balaenoptera borealis*
    - Genus *Megaptera*
      - humpback whale *Megaptera novaenglandiae*

Activities Menu

Life Science

Blue Whales & Krill

Choose an Activity

The activities listed below will enable your students to experiment within the theme of "Life Science." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: Which is a Whale?

Activity 2: Whale Works

Which is a Whale?

Activity 1

Group size
Individuals or pairs

Time you'll need
20 minutes or more

Materials you'll need
• copies of the activity page
• crayons or colored pencils

Objective
To learn the characteristics of mammals and the difference between whales and fishes.

What to do
First, review with your class the defining characteristics of mammals:

- Mammals are "warm-blooded." They keep a constant, high body temperature independent of their surroundings. Hair helps insulate land mammals; blubber helps insulate marine mammals (whales, seals, sea lions).
- Mammals give live birth.
- Mammals nurse their young. Mother whales produce milk that is very rich in fat; this helps their calves to develop thick layers of blubber quickly.
- Mammals take in oxygen from the air through their lungs. Whales breathe air in and out through the blowholes located on the top of the heads. When a whale needs oxygen, it surfaces, clears its blowhole of water, exhales, then takes a long deep breath of air into its lungs.
- Even whales and dolphins have at least some hair. Adult whales rarely have hair, though some young whales may have a few bristles on the tops of their heads.

Whales are not fish. Fish are different in these ways:

- Fish take in oxygen from the water through their gills.
- Fish have scales.
- Fish are "cold-blooded," that is, their body temperature is the same as the termperature of the water they are in.
- Fish move their tails from side to side; whales move theirs up and down.

After discussing these differences, hand out copies of this activity page, **Which is a Whale?**

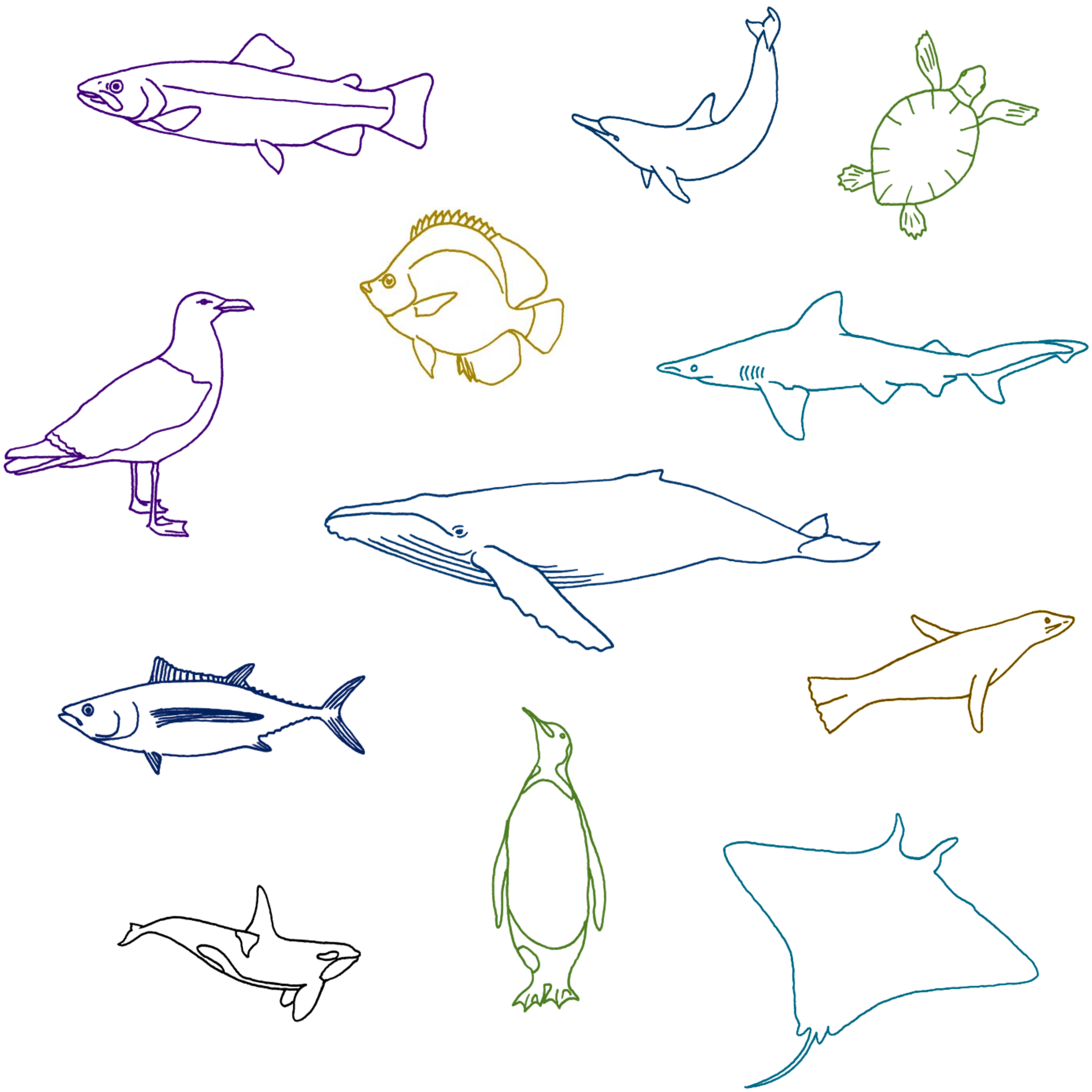
Ask students to draw **blue circles** around the whales, and **red squares** around the fish.

continued

Which is a Whale? *continued*

Activity 1

Draw BLUE CIRCLES around all the whales on this page.
Draw RED SQUARES around all the fish on this page.



Whale Works

Activity 2

Group size

Individuals or small groups

Time you'll need

20-30 minutes

Materials you'll need

- *copies of this page*
- *pencils or pens*

What to do

Part 1

Complete the sentences below with one of the words in this list.

ears	flippers
blowholes	flukes
dorsal fin	baleen

Blue whales have ___________ in their mouths that strains food from the water.

Whales use their ___________ to turn.

Whales have small ___________ on the outside. They hear most things by having sounds travel through their bodies to their inner ears.

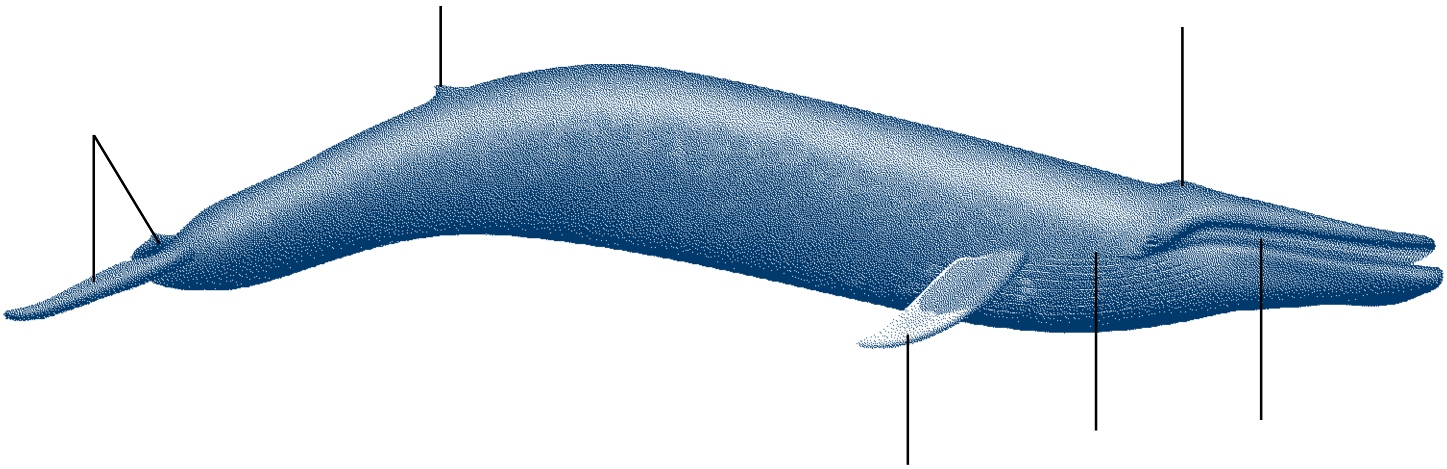
The ___________ some whales have helps keep them upright in water.

Whales breathe through their ___________ .

Whales move their ___________ up and down to swim.

Part 2

Here's a picture of a blue whale. Write the name of each part next to the line that points to that part.



Backgrounder

Science as Inquiry

Blue Whales & Krill

"Employ Simple Equipment and Tools to Gather Data and Extend the Senses

In early years, students develop simple skills, such as how to observe, measure, cut, connect, switch, turn on and off, pour, hold, tie, and hook. Beginning with simple instruments, students can use rulers to measure length, height, and depth of objects and materials; thermometers to measure temperature; watches to measure time; beam balances and spring scales to measure weight and force; magnifiers to observe objects and organisms; and microscopes to observe finer details of plants, animals, rocks, and other materials. Children also develop skills in the use of computers and calculators for conducting investigations."

NS

"When you can measure what you are speaking about, and express it in numbers, you know something about it … when you cannot express it in numbers … you have scarcely, in your thoughts, advanced to the stage of science."

Lord Kelvin

Biologists that study whales need special skills and special equipment, such as ships and boats, subs, cameras, scuba and diving gear, underwater microphones. Some even use satellites to listen for signals from whales that they have tagged with small radio transmitters. But to use such equipment and instruments, and to express and analyze the results, scientists need more than words. They need mathematics.

Math and Measure

Much of scientific mathematics involves measurement. Some scientists like to paraphrase the Scottish physicist, William Thomson, Lord Kelvin (1824-1907) and say, "If you can't measure it, you can't talk about it." Mathematics is obviously essential to experimental science. But it is no less useful in the study of wild animals—their biology, behavior and ecology. Just counting the number of individuals in an area is essential information. It sounds deceptively easy to answer a question like "How many whales visited Hawaii in December 1996? How many were male, female, calves?" But in practice, it is very difficult to arrive at a reliable number. Before scientists learned to recognize individual animals by markings on their bodies and tail it was even harder. Practically, it was difficult to even see whales. Counting from an airplane adds error—are the same whales or different ones included in a count? Still, reliable numbers (data) are the treasure that scientists seek.

We need math to describe the size of whales. "It's big!" is not a scientific way to describe a blue whale or a spider, especially to someone who has never seen either one. But when we know that a spider is 6 inches long, it's big. And a blue whale 100 feet long is big too! (But first of course we need to know what an inch, a centimeter, a foot, or a meter is. Learning to use measurement systems is a part of science, too.)

Mathematical Models

Often, the use of mathematics is most helpful to scientists when it is framed in a mathematical model. Scientists use many kinds of "models" to study and describe the world. Rarely are they actually the kind of model we often think of—a small three dimensional model of a whale. Of course, such a model could be useful to a scientist studying the streamlining of a whale's body.

But a more common kind of mathematical model looks like this:

$$Y=0.00151X^{2.49}$$

This specific mathematical model helps to estimate the weight (in tons) of a blue whale when we know its length (in feet).

In general, a mathematical model helps to analyze a real situation in the natural world by describing it in terms of equations. A model

continued

Backgrounder

Science as Inquiry

Blue Whales & Krill *continued*

Mathematical models are also tools to test ideas. They are frequently used to estimate how many fish (or whales) fishermen can catch without reducing the population.

may help us estimate a condition in nature when we cannot directly measure it. Models can also help us test whether our assumptions are correct about how a part of nature works.

Let's consider one such model, expressed in the equation above. How can we know how much a blue whale weighs? Catching one, weighing it, and letting it go again seems very impractical. Killer whales are smaller (although still very big) and are commonly weighed at the oceanariums where some live. But weighing blue whales is another matter. Our estimates of the weights of the largest blue whales are based on records from the days of factory whaling.

The largest blue whale ever recorded was a female 100 feet long (31 m) killed in the Antarctic ocean. She was too big to weigh on the ship. Her total weight was estimated by weighing individual parts of her body, cut apart on the whaling ship, and totaling them. The total was increased by about 10% to allow for the blood and body fluids lost during sectioning.

Now, it is illegal to kill blue whales. Say we see one swim next to our whale watching boat off California. By comparing it to the length of our boat, we know it is 80 feet long (24.4 m). About how much does it weigh? Our mathematical model, based in part on the data recorded from many dead blue whales, will help us to estimate its weight.

The general relation between weight and length is represented by the equation $\mathbf{Y=aX^b}$, where **Y** is body weight, **X** is body length, **a** is a constant specific to the kind of animal in consideration, and **b** a coefficient, (variable according to body shape). The constant "**a**" can be estimated by plotting length/weight data for a sample of animals; the larger the sample, the better the estimate of "**a**." Using the equation, the mathematical model, for an 80-foot whale we can calculate the estimated body weight to be 83 tons (81,000 kg).

Forecasting with Models

Mathematical models are also tools to test ideas. They are frequently used to estimate how many fish (or whales) fishermen can catch without reducing the population. Such models are used to support economic policies, as well as advance science. At present, there is an international argument about whether there are enough minke whales (a close relative of blue whales) to support an increased whaling effort by Norway. (While science can help estimate and forecast changes in the numbers of minke whales, value judgments about whether whaling is "good" or "bad" are outside the realm of science.)

Fishery scientists try to estimate whether a population of whales (or fish, or shrimp) is growing, declining in numbers, or staying the same. If it is growing, there may be judged to be a surplus of animals available for harvest. If fishermen take more than this surplus, the population will decline. If they take less it will probably grow. To make such forecasts and estimates, scientist need to know a lot about the population of animals. To make good estimates of a safe catch size, a fishery mathematical model needs to include:

- the population size now in the catch area;
- the annual rate of increase, e.g., how many calves are born and survive; and, how many whales swim into the catch area from another ocean;
- the annual rate of decrease, e.g., how many whales die of disease, are killed by predators, or swim to another ocean and out of the catch area;
- the "buffer" that the population need to survive an abnormal year of storms or famine;
- the food requirements for a growing population, e.g., are the animals eaten by the whales in abundant supply, are they scarce, increasing or decreasing;

continued

Backgrounder

Science as Inquiry

Blue Whales & Krill *continued*

- the age structure of the population, e.g., how many are males, females, immature; at what age do females breed; how many young does a female have in a lifetime; how long does she live.

Accurately estimating population size is difficult. All of the estimates are subject to error and they are compounded in a complex model.

It might seem relatively simple to gather the data to construct such a model. But it is difficult. We are just beginning to learn about reproductive rates in most whales. Accurately estimating population size is difficult. All of the estimates are subject to error and they are compounded in a complex model. Proponents of renewed minke whaling say that good data support the model. Many others say that we need many more observations and more data to test the model. If our estimates are in error we could threaten the population rather than "harvesting its surplus."

These are just two examples of mathematical models involving whales. There are many others described in scientific journals. But we hope it's clear that to say anything scientifically meaningful about whales, scientists need mathematics.

Activities Menu

Science as Inquiry

Blue Whales & Krill

Choose an Activity

The activities listed below will enable your students to experiment within the theme of "Science as Inquiry." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: Big as a Whale

Activity 2: Big Eaters

Activity 3: How Many Whales?

Activity 4: How Big Are Whales?

Science as Inquiry

Big As A Whale

Activity 1

Group size

20 or more (can be modified for fewer)

Time you'll need

One hour or more

Materials you'll need

- *pencil & paper*
- *a measuring tape*
- *a scale (optional)*
- *a large outdoor space (optional)*
- *calculator, if permitted*

Objective

To measure and calculate average height and weight of the group; to consider the size of a blue whale relative to other animals (including humans).

What to do

Stage 1: Measuring and Calculating

First, make a chart with the names of everyone in your group in one column, then create columns for height and weight. Measure everyone in your group then, if you have a scale, weigh them.

Calculate the average height and weight of your group. (To calculate an average, add up all the heights—or weights. Divide that sum by the number of heights—or weights—that comprise the sum.

For fun, create your own unit of measurement!

Call it the **Myclassmates Unit**.

One **Myclassmates Unit** of weight = the average weight you measured and calculated.

One **Myclassmates Unit** of length = the average height you measured and calculated.

Stage 2: Comparing

How many **Myclassmates** long is 90 foot long blue whale?

How many **Myclassmates** does an 80 ton blue whale weigh?

Stage 3: How Big Is a Blue Whale?

Complete the following chart to get an idea of just how big an 80 ton blue whale is:

Animal/Avg. Weight	How many to make an 80 ton blue whale?
Killer Whale/5 tons	
Grizzly Bear/1,200 pounds	
Emperor penguin/66 pounds	
Bald eagle/15 pounds	

Big Eaters!

Activity 2

Group size

Individuals

Time you'll need

15 minutes or more

Materials you'll need

- *pen and paper*
- *calculator, if permitted*

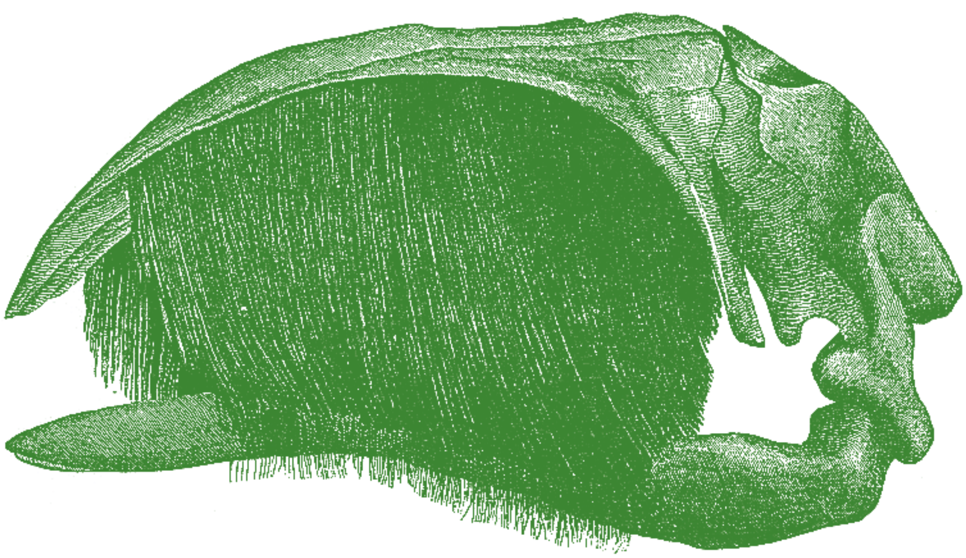
Objective

To estimate the amount of food necessary to sustain baleen whales

Problem 1: How much do baleen whales eat?

Blue whales generally consume around 3% of their weight in food each day, when they are on the feeding grounds. Their primary food source is krill, which they strain out of sea water with their baleen. Given that, calculate the following:

1. How many kilograms of krill does a blue whale that weighs 80,000 kilograms eat in a day?
2. If 10 krill weigh 150 grams, how many krill will it take to sustain the blue whale for a day?
3. If there is a kilogram of krill in every cubic meter of water, how many cubic meters of water must the blue whale filter in that day?



Science as Inquiry

How Many Whales?

Activity 3

Group size

Individuals or small groups

Time you'll need

10-15 minutes

Materials you'll need

- *copies of this page*
- *pens and pencils*

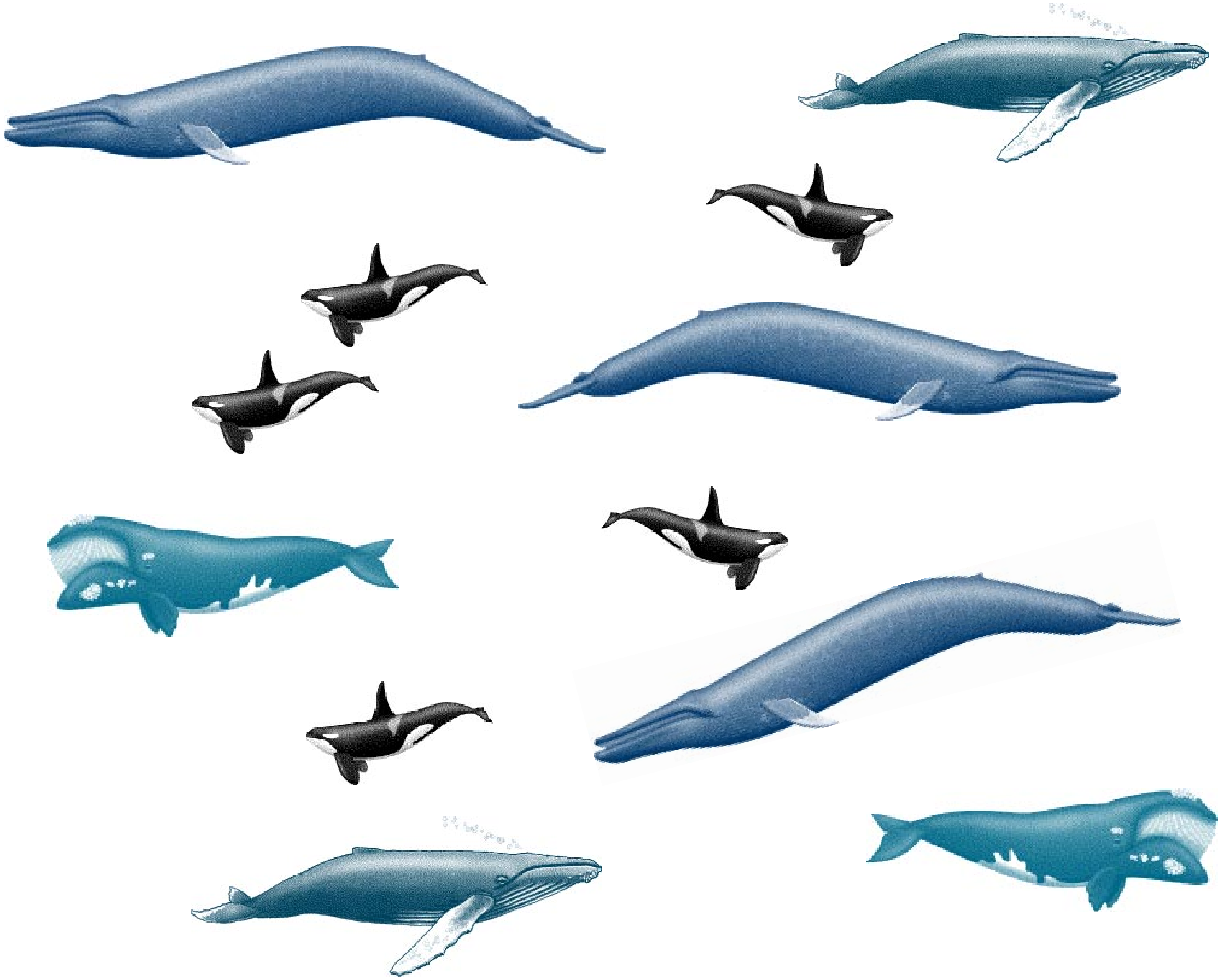
Count how many whales are on this page.
Write the number on this line. ____________

Draw a circle around all the BLUE WHALES on this page.
Count the number of BLUE WHALES.
Write the number on this line. ____________

Draw a circle around all the RIGHT WHALES on this page.
Count the number of RIGHT WHALES.
Write the number on this line. ____________

Draw a circle around all the ORCAS (KILLER WHALES) on this page.
Count the number of ORCAS (KILLER WHALES).
Write the number on this line. ____________

Draw a circle around all the HUMPBACK WHALES on this page.
Count the number of HUMPBACK WHALES.
Write the number on this line. ____________



How Big Are Whales?

Activity 4

Group size

Any size

Time you'll need

30 minutes or more

Materials you'll need

- *a long (up to 100') piece of rope*
- *different colors of marking pens and/or tape*
- *measuring tape(s)*

Objective

To compare the sizes of humans and whales.

What to do

Here are the average sizes of several species of whale:

Bottlenose dolphin	10 feet	(3 meters)
Killer whale	25 feet	(7.5 meters)
Humpback whale	40 feet	(12 meters)
Right whale	55 feet	(17 meters)
Blue whale	90 feet	(27.5 meters)

For younger students, teachers should take the 100' rope and mark these measurements using color coded tape or pen marks before class begins. For older students (those able to add two-digit numbers and measure accurately), select a team to measure and mark the rope.

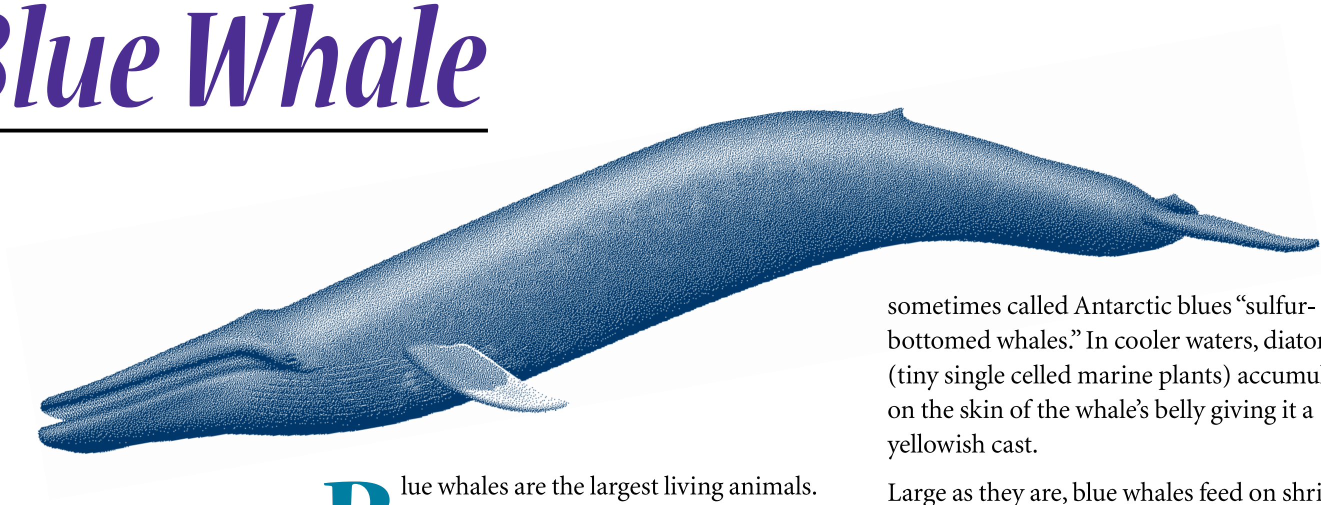
Place a measuring stick or tape measure on a wall or in a doorway, and have students measure one another. Have the students guess how many of them it would take to create a line as long as each of the whales.

If you have a big indoor or good outdoor space, lay the rope down on the ground. Have students lie on the ground head to toe until they create a line as long as a blue whale. Walk down the rope and point out the different whale sizes so students can compare their size to the sizes of different whales. Have students walk, march, dance, etc. around the length of the blue whale to experience the scale of size.

Backgrounder

Whale Biology

Blue Whale



Blue Whale
Balaenoptera musculus
(Mysticeti—Baleen Whales)
The largest animals living on Earth eat shrimp shorter than your eyebrow. Of course it takes a lot to make a meal for a whale that weighs as much as 8 school buses. In Whales*, you will see blue whales feeding in the rich ocean off California.*

A single krill -shrimp may weigh only about half an ounce (about 15 grams). But in a single day, when food is abundant, an adult blue whale may ingest eight tons (around 7,300 kg) of krill.

Blue whales are the largest living animals. Everything about them is big. A heart the size of a small car pumps blood to a tail almost 100 feet (30 m) to the rear. An adult blue whale weighs at least 88 tons (80,000 kg). Compare that to an elephant that may weigh 4.5 tons (4,000 kg).

Look at it this way: if a relatively small blue whale (about 60 feet long) stood straight up in the water, a human snorkeler would have a hard time diving down to see its tail.

A century or more ago, the world's oceans were home to more than 300,000 blue whales. By 1960, worldwide whaling by factory ships using harpoons with explosive heads had reduced blue whale populations to less than 20,000. They are now protected internationally. However, DNA analysis of whale meat in Asian markets has revealed blue whale flesh for sale labeled as another species.

Blue whales are long, relatively slim whales with a small dorsal fin set far back on the body. At birth, a blue whale calf is already 23 feet long (7 m). It will suckle milk from its mother for about eight months. When it is weaned, the young calf will be about 49 feet long (15 m), having added about 200 pounds of weight per day (90 kg). At adulthood (reached after 10 years of growth) males are slightly shorter (74 feet long; 22.5 m) than females (79 feet long; 24 m).

Despite their name, blue whales are more light gray than blue and often mottled with grayish or whitish splotches. Old-time whalers sometimes called Antarctic blues "sulfur-bottomed whales." In cooler waters, diatoms (tiny single celled marine plants) accumulate on the skin of the whale's belly giving it a yellowish cast.

Large as they are, blue whales feed on shrimp-like animals called krill (usually *Euphausia superba)* about the size of a baby's finger. A single krill -shrimp may weigh only about half an ounce (about 15 grams). But in a single day, when food is abundant, an adult blue whale may ingest eight tons (around 7,300 kg) of krill. Krill aggregates in dense swarms within 328 feet (100 m) from the surface. Blue whales seem to be relatively shallow feeders since they eat almost exclusively krill. Blue whales can be seen offshore from coastlines in California, Mexico, and NE Canada. But blues are much more a whale of the open sea than humpbacks and right whales, which aggregate in shallower nearshore waters during at least part of the year.

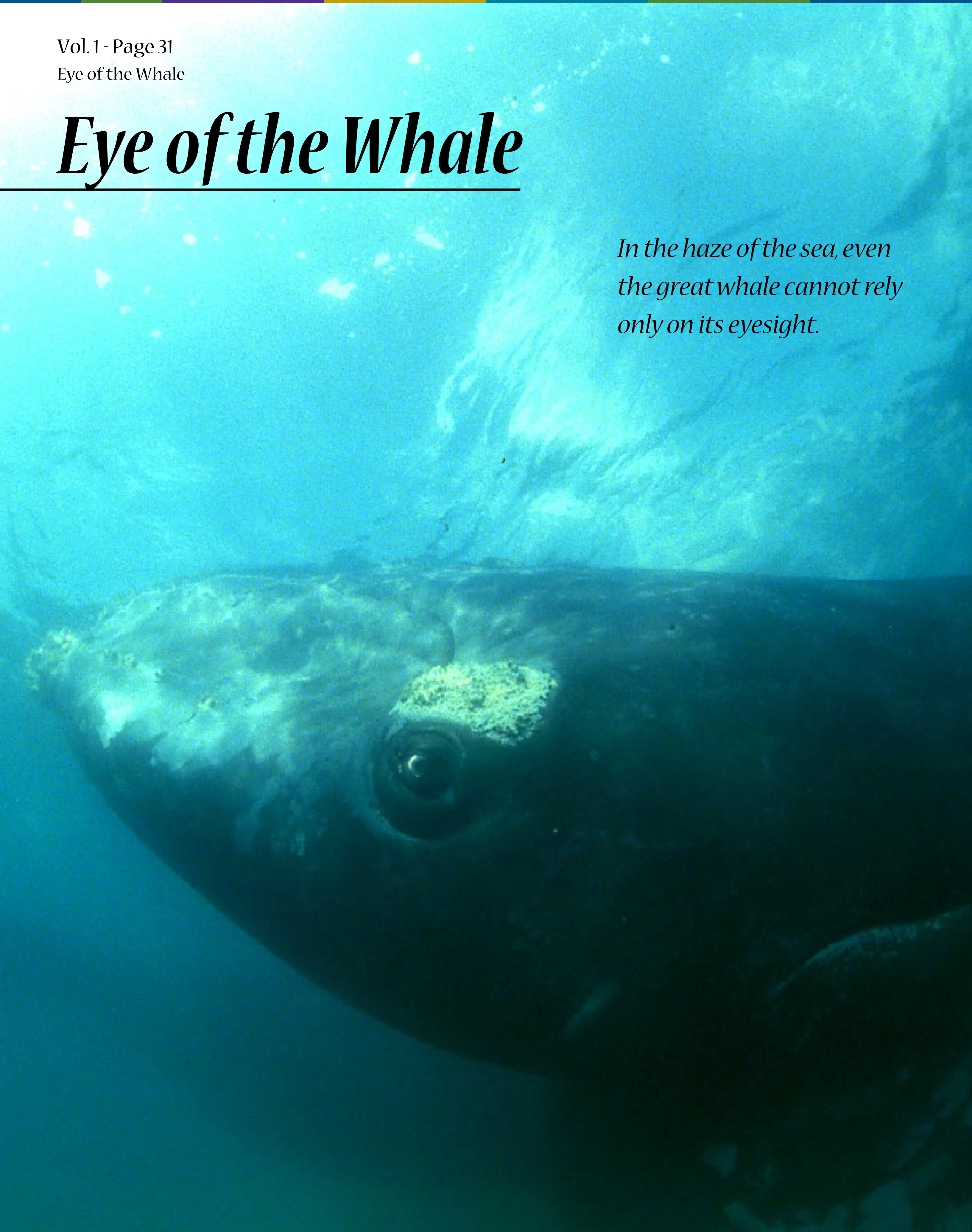
Although blue whale populations are still much reduced due to whaling, they occur throughout the world oceans. In the north Pacific most blue whales appear to summer from Baja California, and southern and central California through the Gulf of Alaska and the Aleutian Islands. This population winters in the open waters of the tropical Pacific.

In the Atlantic, blues summer from the Gulf of St. Lawrence and Greenland north to the pack ice edges and from Iceland and the British Isles and southern Norway to Murmansk and Spitsbergen.

For North Americans the best places to see blue whales are off southern and central California, and inside the Gulf of St. Lawrence where they can be seen from cliff tops in late summer and early fall.

Eye of the Whale

In the haze of the sea, even the great whale cannot rely only on its eyesight.



Theme Menu

Eye of the Whale

Choose a Science Theme

The "Vision Scene Resource" supports learning plans for the themes highlighted below. Press the highlighted bar for the theme you wish to explore.

Life Science
Physical Science
Earth Science
Science as Inquiry
Science in Society
Nature of Science
Whales & Words
Whale Biology

Backgrounder

Life Science

Eye of the Whale

"Characteristics of Organisms
Each animal has different structures that serve different functions…in survival…for example, structures for seeing."

NS

All organisms have sensory structures that give them information about their environment. Survival depends ultimately on the ability to respond to such information.

Every sense organ is a specialized structure consisting of one or more receptor cells and accessory tissues. Receptors are classified according to the nature of their stimulus. Most animals are equipped with mechano-receptors (touch), chemo-receptors (smell and taste), and photoreceptors (sight). Receptors and their cells not only have diverse functions and structures, but also connect in different ways with nerves. All receptors, however, generate nerve impulses. In the vertebrate eye, the receptor cells are the rods and cones, and the accessory structures are the cornea, lens, iris and retina. Receptor cells connect to central brain processing centers via the optic nerves.

The eye is a camera that not only forms a picture but also transmits it in code to the brain via the optic nerves.

Vertebrate animals—those with backbones such as mammals, birds, reptiles, amphibians, and fish— rely heavily on the sense of sight. Vertebrate visual systems are complex and involve components from cellular to the organ level. Marine mammals— such as whales— have eyes adapted for seeing underwater and occasionally in air.

Anatomy of the Eye

The vertebrate eye is like a camera that forms a picture. The visual system transmits the image in biochemical code to the brain via the optic nerves. The human eye is similar to the eyes of other mammals, whales included.

Here's how your eye (and a sheep's and a cow's) works:

Light reflects or is generated from objects in the world and enters your eye through the cornea, the tough, clear tissue covering the front of your eye. Because the tissue of the cornea is much denser than air, light is refracted as it passes into your eye. This initial refraction begins the focusing process. Light then passes through the pupil, the dark hole at the center of the iris.

The muscular iris expands or contracts to regulate the amount of light transmitted through the pupil.

Your eye's lens then focuses the corneally refracted light to make an image on your retina, a thin layer of light-sensitive cells that lines the back of your eyeball. These cells, the rods and cones, send electrical impulses to the brain via the optic nerve. The brain interprets these signals as images.

Anatomy of the Camera

Like a human eye, a camera has three main parts:

- a focusing system (lens)
- a way to control the amount of light coming in (aperture and shutter)
- a light sensitive chemical layer that records images (film)

A camera has an adjustable aperture like a "pupil." The size of the hole is measured in f-stops. A still camera's shutter opens very briefly to allow light into the camera and then shuts. (Typical shutter speeds are 1/60th to 1/250th of a second.) Light hits the chemical suspended in the emulsion of film, carried on a plastic strip. When light in a human eye strikes the retina's nerve cells, it chemically changes them. When light hits a camera's film, it changes the chemicals in the emulsion. These changes are "developed and fixed" by another series of chemical treatments.

continued

Backgrounder

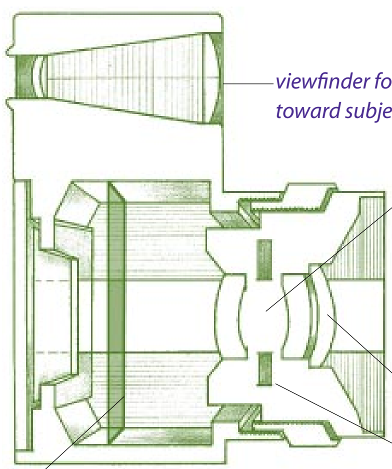
Life Science

Eye of the Whale *continued*

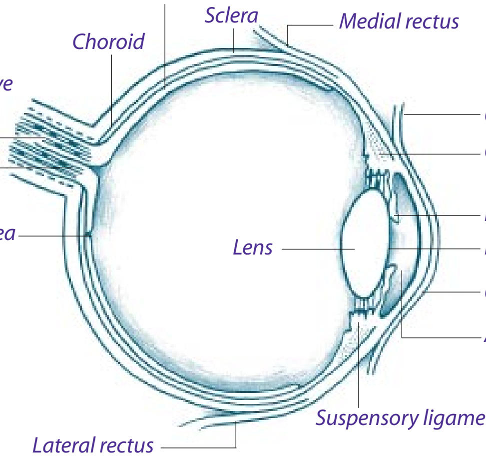
There is a basic difference between the way that a human eye (or sheep or cow eye) and a camera focus the incoming light. A camera focuses by moving the lens system closer or farther away from the film.

In a human eye a single lens is focused by muscles that tighten and stretch the lens into a flatter shape, or relax and let it form a thicker shape. As humans age, their ability to focus their eyes changes. The lens becomes harder and less flexible and the muscles that stretch it weaken. That's why almost everyone over a certain age wears glasses to read.

CAMERA



HUMAN EYE



Vision in the animal world varies widely, from simple photoreceptors to complex eyes. Starfish have photoreceptors on their tube feet that simply perceive light and the direction of its source. Earthworms and sea urchins have areas called eyespots, clusters of photosensitive cells, that detect light. Eyespots in protozoa or flatworms are photoreceptors rather than eyes because they are incapable of forming images. The development of a lens which could concentrate light on a group of photoreceptors was an essential evolutionary step from photoreceptors to true eyes.

Only three of the major phyla of animals have developed well-formed, image-resolving eyes: the arthropods (insects, spiders and crabs), cephalopods (octopus, squid), and vertebrates. There is no anatomical, embryological or evolutionary connection between the three different types of eyes in these phyla. However, the chemistry of the visual process is very nearly the same for each of them. In all three the pigments which absorb the light that stimulates vision are made of vitamin A, in the form of its aldehyde, called retinal, joined with specific retinal proteins called opsins.

The complexity, size and placement of an animal's eyes are critical to its survival. Insect eyes are very different from human eyes. They can have two types of eyes, simple or compound. Sometimes they have both.

The simple eye is a small, rounded, clear lens which can distinguish only light and dark, and only sometimes sees color. These are found on caterpillars or on the foreheads of adult insects.

continued

Backgrounder

Life Science

Eye of the Whale *continued*

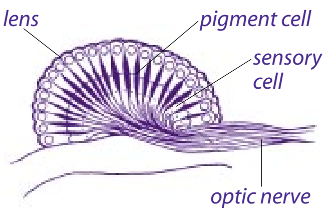
The compound eye is made up of hundreds of tiny pieces placed together in a honeycomb pattern. Each of these pieces is shaped like a long, pointed tube. The broad end of each "tube" reaches the outside of the eye and contains a clear lens. The thin end is joined to a special type of cell that converts light into electrical signals, each color of light producing a different signal. The compound eye, therefore, sees the world as a sort of jigsaw puzzle of tiny images, each tube producing a tiny part of the overall picture. This adaptation allows insects extreme peripheral vision, which helps them to detect predators.

The lenses in the insect's compound eyes do not move, so they do not produce sharp images. The most they produce is a fuzzy pattern of light, dark and color. Many insects can only see if an object moves or if it is very close to them. Insect's compound eyes have lots of tiny hairs, knobs, or pits on them. These are special sense organs that insects use to smell, taste, and feel, something no other animal can do with their eyes.

Whale eyes show many modifications to life in the sea. The difference between refractive indexes of the whale's cornea and seawater are slight, so little focusing of the light beam takes place at the seawater/cornea interface. As a result,the whale's lens is thicker and rounder. Whales seem to lack interocular muscles, suggesting that focusing is either less important or is accomplished differently. The sclera of the whale's eye is much thicker, perhaps as an adaptation to pressure, or to provide insulation from intense sound. Much more research is needed on the eyes of whales.

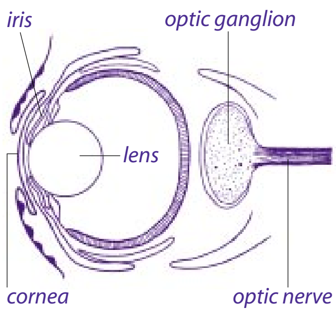
Compound eyes

insect



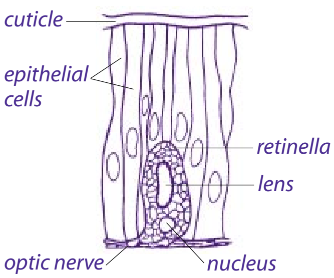
Camera eyes

octopus



Light-sensitive cells

epidermal light-sensitive cell—flatworm or annelid



Eye of the Whale

Choose an Activity

The activities listed below will enable your students to experiment with their sense of vision within the theme of "Life Science." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: Afterimages

Activity 2: Fish Bowls

Activity 3: The Biggest Whale in the World

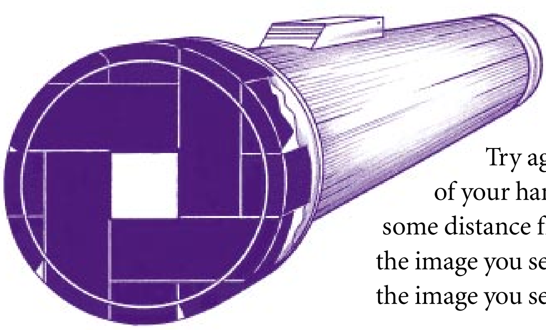
Afterimages

Activity 1

Group size
Individuals

Time you'll need
30 minutes or less

Materials you'll need
- *a flashlight*
- *white paper*
- *opaque black tape (electrical or photo tape)*
- *a blank wall*



Objective

In this activity students will learn how prolonged stimulation of the retina creates afterimages and how the perception of those afterimages varies depending on distance. They will also be encouraged to experiment with adaptation to light and dark.

What to do

Tape a piece of white paper over the lens of a flashlight. Cover most of the paper with strips of opaque tape. Leave an area in the center of the lens uncovered so that light can shine through. This area should be a recognizable shape, such as a square or triangle.

In a darkened room, turn the flashlight on, hold it at arm's length, and shine it into your eyes. Stare at one point of the brightly lit shape for about 30 seconds, then stare at a blank wall and blink a few times. Notice the shape and color of the image you see.

Try again, first focusing on the palm of your hand and then focusing on a wall some distance from you. Compare the size of the image you see in your hand to the size of the image you see on the wall.

Close your left eye and stare at the bright image with your right eye. Then close your right eye and look at the white wall with your left eye. You will not see an afterimage.

What's happening?

You see because light enters your eyes and produces chemical changes in your retina, the light-sensitive lining at the back of your eyes. Prolonged stimulation by a bright image (here, the flashlight) desensitizes part of the retina.

When you look at the white wall, light reflecting from the wall shines onto your retina. The area of the retina that was de-sensitized by the bright image does not respond as well to this new light input as the rest of the retina. Instead, you'll see a negative afterimage, a dark area that matches the original shape of the light source. An afterimage may remain for 30 seconds or longer.

The apparent size of the afterimage depends on the size of the image on your retina and also on how far away you perceive the image to be. When you look at your hand, you see the negative afterimage on your hand. Because you hand is near you, you see the image as relatively small – no bigger then your hand. When you look at a distant wall, you see the negative afterimage on the wall. But it is not the same size as the afterimage you saw on your hand. You see the afterimage on the wall as much bigger – large enough to cover a considerable area of the wall.

The afterimage is not actually on either surface but on your retina. The actual afterimage does not change in size; only your interpretation of its size changes.

This helps explain the common illusion that the moon is larger when it is on the horizon than when it is overhead. The disk of the moon is the exact same size in both cases, and its image on your retina is the same size. So why does the moon look bigger in one position than in the other?

One explanation suggests that you perceive the horizon as further away than the sky overhead. This perception might lead you to see the moon as a large disk when it is near the horizon (just as you saw the afterimage as larger when you thought it was on the distant wall), and as a smaller disk when it is overhead (just like the smaller afterimage in the palm of your hand).

Negative afterimages do not transfer from one eye to the other. This indicates that they are produced on the retina and not in the visual cortex of the brain where signals would have been fused together.

continued

Afterimages *continued*

Activity 1

Further exploration

For up to 30 minutes after you walk into a dark room, your eyes are adapting. At the end of this time, your eyes may be up to 10,000 times more sensitive to light than they were when you entered the room. We call this improved ability to see night vision.

Night vision is caused by the chemical rhodopsin, which is contained in the rods and cones of your retina. Rhodopsin, commonly called visual purple, is a light-sensitive chemical composed of vitamin A and the protein opsin.

You can use the increased presence of rhodopsin to take "afterimage photographs" of the world. Here's how:

Cover your eyes to allow them to adapt to the dark. Be careful that you do not press on your eyeballs. It will take at least 10 minutes to store up enough visual purple to take a "snapshot."

When enough time has elapsed, uncover your eyes and look at a well-lit scene for half a second (just long enough to focus on the scene), then close you eyes again. You should see a detailed picture of the scene in purple and black. After a while the image will reverse to black and purple. You may take several "snapshots" after each 10-minute adaptation period.

Fishbowls

Activity 2

Group size
Pairs or small groups

Time you'll need
30 minutes or more

Materials you'll need
- *4 pieces of white posterboard or paper*
- *1 piece each of bright red, blue and green construction or contact paper*
- *a black marker*
- *glue or a glue stick*

What to do
Cut a simple fish shape out of each of the pieces of colored paper, then glue each one to the center of a piece of white posterboard or paper. Draw a small eye on each fish with your black marker. On the fourth white board draw a fish bowl.

Place the boards in a well-lit area. (Bright lighting is a significant factor in making this effect work well.)

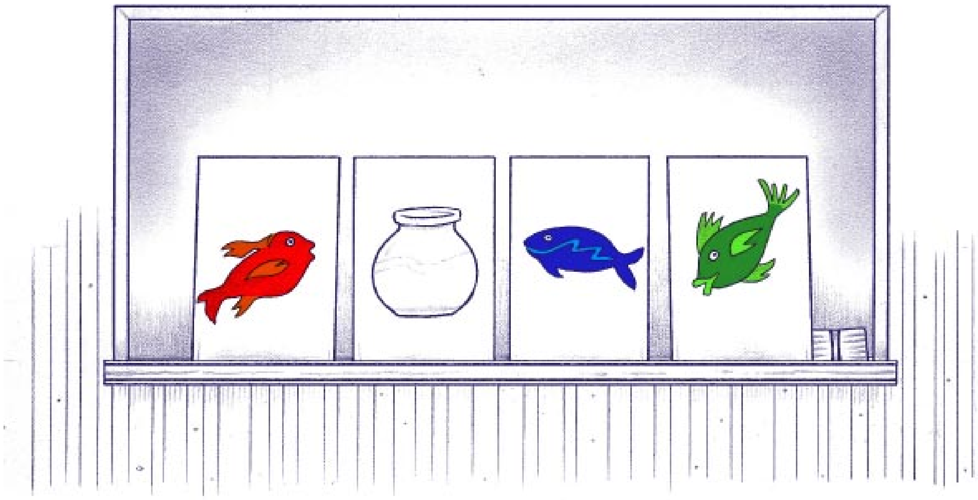
Stare at the eye of the red fish for 15 - 20 seconds and then quickly stare at the fish bowl. You should see a bluish-green (cyan) fish in the bowl! Now repeat the process, staring at the green fish. You should see a reddish-blue (magenta) fish in the bowl. Finally, stare at the blue fish. You should see a yellowish fish in the bowl.

What's happening?
The ghostly fishes that you see are called afterimages. An afterimage is an image that stays with you even after you have stopped looking at the object.

The changes in the color of the fish you see are simple to explain. The back of your eye is lined with light sensitive cells called rods and cones. Cones are sensitive to colored light, and each of the three types of cones is sensitive to a particular color range. If one or more of the three types of cones becomes fatigued to the point where it responds less strongly than it normally would, the color you perceive from a given object will change.

So, when you stare at the red fish, the image falls on one region of your retina. The red-sensitive cells in that region start to grow tired and stop responding to red light. The white board with the bowl on it reflects red, blue and green light to your eyes (since white light is made up of all these colors). When you shift your gaze from the red fish to the white board, the fatigued red-sensitive cells don't respond to the reflected red light, but the blue-sensitive and green-sensitive cones respond strongly to the reflected blue and green light. As a result, you see a bluish green or cyan fish.

When you stare at the green fish, your green-sensitive cones become fatigued. Then, when you stare at the white board your eyes respond only to the reflected red and blue light, so you see a red-blue or magenta fish. Similarly, when you stare at the blue fish the blue-sensitive cones become fatigued and the reflected red and green light combines to form a yellow fish.



Life Science

The Biggest Whale in the World

(It takes good eyes to see it!)

Activity 3

Group size
Individuals or small groups

Time you'll need
10 minutes

Materials you'll need
• green and blue crayons

What to do

Find these words and color them blue. Some letters may be in more than one word.

KRILL	SEA	FOG	SPOUTS
WAVE	FOOD	EYE	

B	L	U	E	K	S
W	A	V	E	R	E
F	O	O	D	I	A
O	E	Y	E	L	G
G	W	H	A	L	E
S	P	O	U	T	S

Now find the hidden name of the biggest whale. Color the letters green and write the name on the line below.

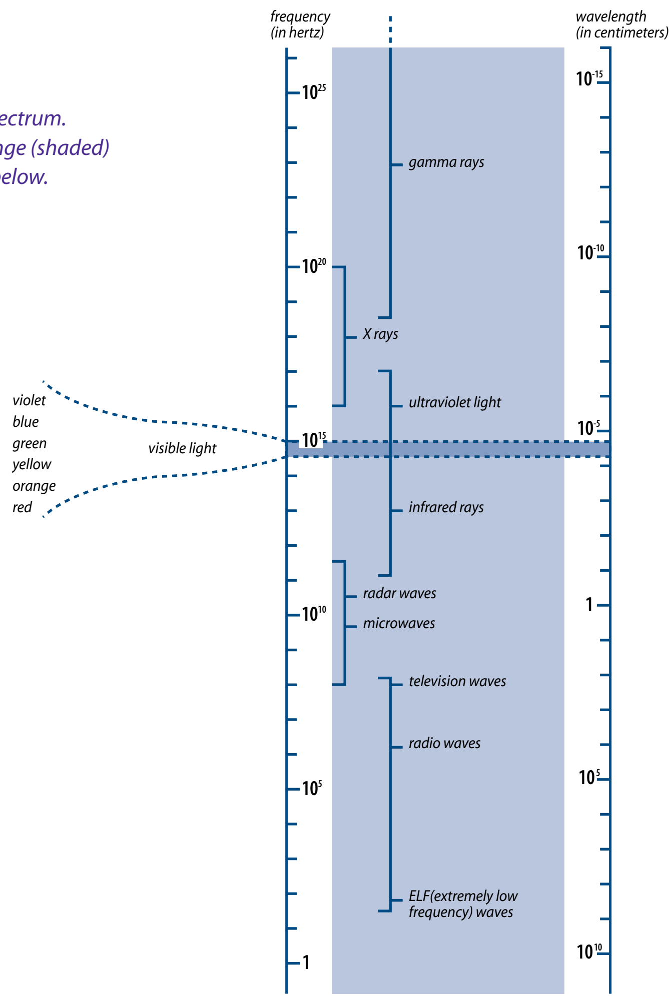
____

Eye of the Whale

*"**Light, Heat, Electricity, and Magnetism***
Light travels in a straight line until it strikes an object. Light can be reflected by a mirror, refracted by a lens, or absorbed by an object."

All organisms have sensory structures that give them information about their world. Survival depends ultimately on an animal's ability to interpret and respond to such information. Light is an important source of information about the environment. Almost every kind of organism responds to light in some way. Most vertebrate animals (i.e., animals with backbones, like fish, frogs, snakes, birds, whales, cows and humans) have well developed organs for sensing light—eyes. To understand how eyes work, we must also understand light and its qualities.

Electromagnetic Spectrum.
The small visible range (shaded) is shown enlarged below.



What is Light?

Light is a type of electromagnetic radiation. Visible light (light we humans can see) is a relatively small band of energy within the much wider electromagnetic spectrum. Light travels in electromagnetic waves, as do other forms of energy, including radio waves, microwaves and ultraviolet waves.

Much of the electromagnetic spectrum is invisible to humans. Animals vary in their ability to see certain wavelengths. For example, humans cannot see ultraviolet light but many insects can.

All wavelengths of the electromagnetic spectrum travel at the speed of light. Each class of waves has different ranges of wavelengths. Radio waves and microwaves have relatively long wavelengths. X-rays and gamma rays have shorter wavelengths .

Light's Speed

An important quality of light is the speed at which it travels. Einstein showed that the speed of light in the vacuum of space, symbolized by "*c*," is a universal constant, about 186,000 miles per second, or 300,000 km/s. (That is the "*c*" in his famous equation $E=mc^2$; what do "*E*" and "*m*" stand for?).

But animals live in air and water, not in space. While light travels at "*c*" in space, it travels more slowly in the dense atmosphere of earth. The speed of light is affected by the density of the material through which it travels. Light travels more slowly in air, in water, in glass. Light is changed when the density of the material through which it is traveling changes.

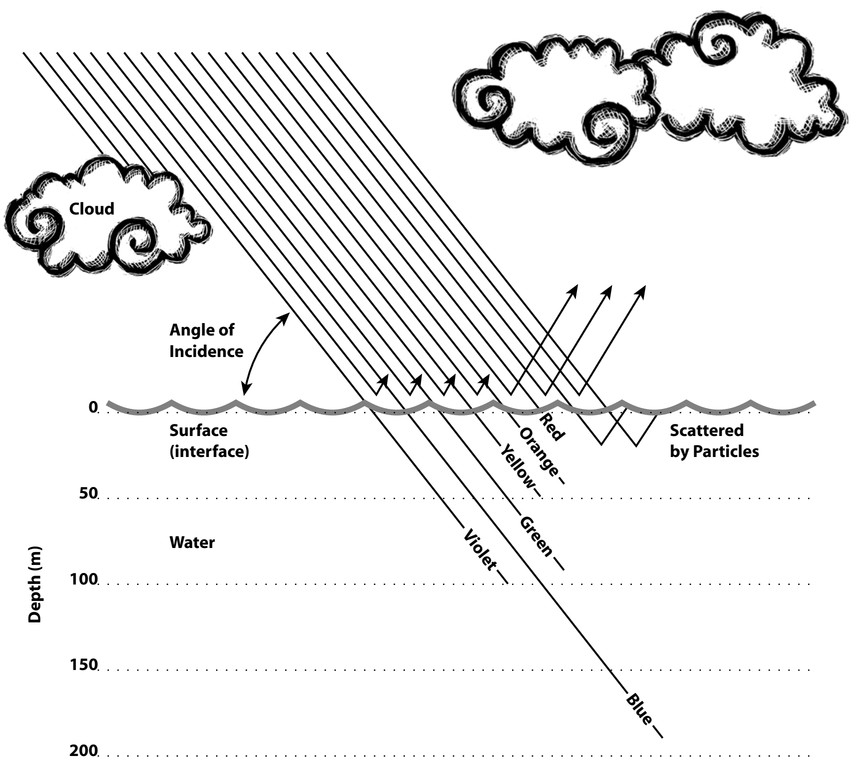
continued

Eye of the Whale continued

For example, when sunlight strikes water suspended in the air—mist or rain—several things happen. Light can be **reflected** back in the direction it was traveling; it can be **scattered** (i.e., reflected among water and dust particles), and it can be **refracted**. Refraction is the bending of light as it changes speed in passing from one transparent material to another.

Color

The color of visible light depends on its wavelength. Sunlight, which we call white light, is a mixture of many wavelengths and therefore, many colors. As far as human perception is concerned, white light can be approximated quite well by a mixture of just three colors, out of the many. These three colors, loosely called red, green and blue, are given the name "additive primary colors." Mixing these colors can fool the eye into perceiving any color we wish. (This is how a color television tube works.)



Different colors (wavelengths) of light are bent by different amounts. Long wavelength light is refracted more than short wavelength light. As sunlight passes through a glass prism or mist in the sky, for example, the many colors (different wavelengths) are spread out into the multicolored band we call the rainbow.

Sunlight in the Sea

Dust and water vapor in the air affect light , as a rainbow demonstrates. But the much greater density of seawater affects light even more than air does. Much of the sunlight shining on the sea surface is reflected. The sunlight that does enter the sea is scattered and absorbed. Light bounces among the water molecules and is scattered far more than in air. Water molecules struck by light rays absorb their energy and vibrate as the light's energy is converted to heat. The light energy of some colors is converted into heat nearer to the surface than the light energy of other colors. Red is absorbed first; blue persists much deeper. Light persists longer in clear water. In cloudy water, light is absorbed sooner by suspended particles and microscopic plants and animals. Eventually all the light is absorbed and darkness prevails. A whale swimming at 330 feet deep (100m) in Alaskan waters sees very little and must rely on sound for sensing the environment. At the same depth in the clearer waters of Hawaii, a whale can sense the blue twilight of the ocean.

Scientists know much more about the eyes of land animals, such as humans, sheep and cows, than they know about the eyes of whales and dolphins. Although comprised of the same basic parts and plans, whale eyes show many adaptations to living in water. Many of these are correlated with the effects of seawater on light. The following activities are designed to encourage experiments into the nature of light. To understand how vision works— in whales or in humans— we need to understand the characteristics of light.

Activities Menu

Physical Science

Eye of the Whale

Choose an Activity

The activities listed below will enable your students to experiment with their sense of vision within the theme of "Physical Science." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: Mirror, Mirror

Activity 2: Fire in the Water

Activity 3: Disappearing Glass Rods

Activity 4: Splitting Sunlight

Mirror, Mirror

Activity 1

Group size

Adult demonstrator with one or more students

Time you'll need

30 minutes or more

Materials you'll need

- *two pieces of mirror, about 6" x 6" (you can get safe, plastic mirrors cut to size at plastic supply houses, or you may use glass mirror tiles. If you use glass, bind the edges of the tiles with duct tape to decrease the likelihood of injury)*
- *duct tape*
- *a piece of cardboard, 12" x 12" or larger*
- *a protractor*
- *a pen or pencil*
- *a coin, or any small object*

What to do

Place the two pieces of mirror side by side, face down, and tape them together. Stand the mirrors up with the hinge at the corner of your cardboard, reflective sides facing in. Place a small object on the cardboard between the mirrors. Move the mirrors so they are at different angles and note how many images of your object you see.

What's happening?

When you put an object between two mirrors, light from that object bounces back and forth between the mirrors before it reaches your eyes. Each time the light bounces off a mirror an image is formed. The number of images you see depends on the angle of the mirrors. A smaller angle means the light will bounce back and forth more times, so you'll see more images.

Optional

On one corner of your piece of cardboard, use a protractor to mark the following angles: 180°, 90°, 60°, 45°, 36°, 30° and 20°.

Demonstrate this rule: The number of images you see equals 360 divided by the angle of the mirrors minus one. At 90° , for example, you should see three images: 360/90-1=3.

Note

This is a good activity to introduce experimentation using simple apparatus, and to introduce the idea that light waves travel in a straight line until they strike another substance.

Even if younger students are not ready for the protractor, they can still benefit from the concept of "angles," easily demonstrated with the hinged mirrors. The adult demonstrator can pre-mark angles on a sheet of cardboard as described in the Optional Exercise. Students can match the hinged mirrors to the angles, then place the object between them and count the number of images they see. Are there more images with bigger angles or with smaller angles?

Fire In The Water

Activity 2

Group size

Adult demonstrator with student group

Time you'll need

30 minutes or less

Materials you'll need

- *a clear water-glass, 3/4 full of water*
- *a candle (a small votive works best because it will stand on its own, but a regular candle no taller than your glass will work if secured)*
- *a clean sheet of glass, approximately 5" x 7" (this can be taken from a picture frame)*
- *a piece of cardboard, at least 12" x 18"*
- *some modeling clay or FunTak®*
- *some matches or a lighter*

What to do

On a table, place the candle, the glass, and the jar with water about 6" apart, as shown in the diagram. The candle and plate glass can be secured with modeling clay or FunTak.

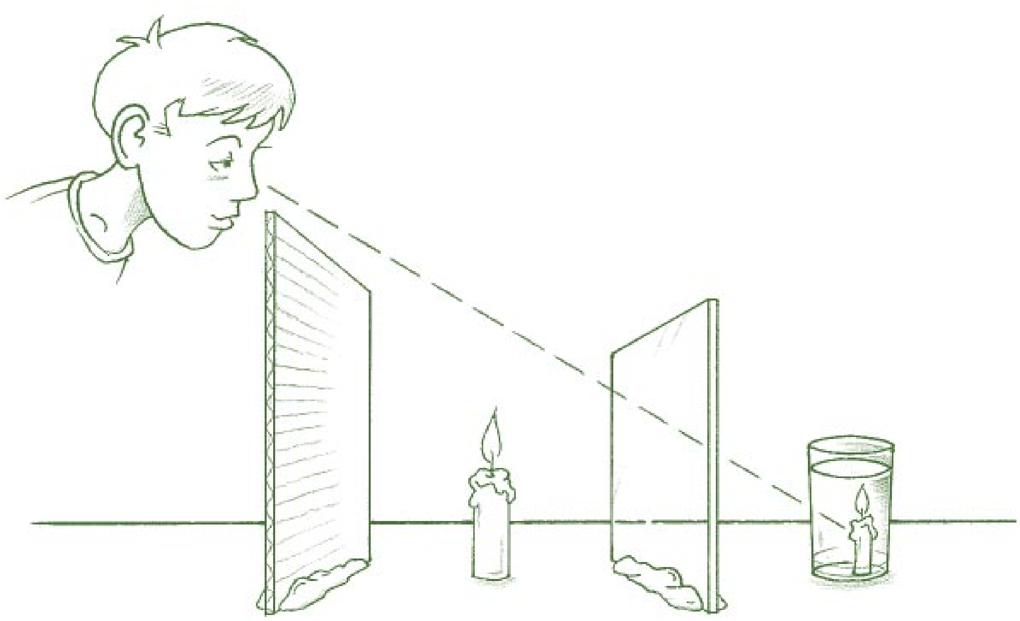
Place the cardboard on the edge of the table closest to you, and secure it with modeling clay or FunTak. Be sure that it is high enough to block your view of the candle when you stand at the edge of the table and low enough that you can see the glass plate and the jar.

Stand at the edge of the table and look over the cardboard so you see the jar of water through the glass plate, but you can't see the candle. Have your partner carefully light the candle. Do you see a candle burning underwater? (If this image does not appear, adjust the distances between the jar and the candle until it does. If the flame is above the water level of the jar, either add more water or use a shorter candle.

Next, have your partner empty the water from the jar, then put the jar back in its place. Have your partner then slowly pour water back into the jar while you look through the glass plate at the jar. As the water rises you'll expect the candle flame to be extinguished. But what happens? Let your partner try this experiment, too!

What's happening?

In this experiment, the clear glass plate acts as both a window and a mirror. You see the jar of water when you look through the glass plate, but you also see the reflection of the candle onto the glass plate. These two images combine to create the illusion of fire under water!



Disappearing Glass Rods

Activity 3

Group size

Adult demonstrator with student group

Time you'll need

15 minutes or more

Materials you'll need

- *Wesson™ oil. (regular, not lite, because of the refractive index)*
- *One or more Pyrex® stirring rods or other small, clear glass objects*
- *A beaker*
- *Optional: a glass eyedropper, a glass magnifying lens*

What to do

Pour some Wesson oil into the beaker. Immerse a glass object in the oil. Notice that the object becomes more difficult to see. Only a ghostly image of the object remains.

Experiment with a variety of glass objects, such as clear marbles, lenses, small glassware. Some will disappear more completely than others.

You can make a glass eyedropper disappear before your eyes by immersing it then sucking oil up into the dropper!

If you immerse a magnifying lens in the oil you may notice that it does not magnify images when it's submerged.

What's happening?

When light traveling through air encounters a glass surface at an angle, some of the light reflects. The rest of the light keeps going, but it bends or refracts as it moves from the air to the glass. You see a clear glass object because it both reflects and refracts light.

When light passes from air into glass, it slows down. It is this change in speed that causes the light to reflect and refract as it moves from one clear material (air) to another (glass). Every material has an index of refraction that's linked to the speed of light in the material. The higher a material's index of refraction, the slower light travels in that medium. The refractive index of air is 1.0; the refractive index of Wesson oil and Pyrex is 1.474.

The smaller the difference in speed between two clear materials, the less reflection will occur at the boundary and the less refraction will occur for the transmitted light. If a transparent object is surrounded by another material that has the same index of refraction, then the speed of light will not change as it enters the object. No reflection and no refraction will take place, and the object will appear invisible.

Wesson oil has nearly the same index of refraction (n) as Pyrex glass (n=1.474). Different glasses have different indices of refraction. In Wesson oil, Pyrex disappears, but other types of glass remain visible. A lot of laboratory and home glassware is made from Pyrex glass.

For most Pyrex glass, the matching of the refractive index with Wesson oil is not perfect because glass can have internal strains that make its index of refraction vary at different places in the object. Even if you can match the index of refraction for one part of a Pyrex stirring rod, the match will not be uniformly perfect. That is why a ghostly image of the rod remains with even the best index matching.

Incidentally, clear acrylic plastics (e.g., Plexiglas, Lucite) have almost the same refractive index as seawater so there is no bending of light as it passes from the plastic into seawater.
The huge viewing windows in large public aquariums and oceanariums can be 12 inches thick. But because they are made of acrylic, they afford a very clear view of the water and ocean life they enclose.

Physical Science

Splitting Sunlight

Activity 6

Group size

Adult demonstrator with one or more students.

Time you'll need

20 minutes or more

Materials you'll need

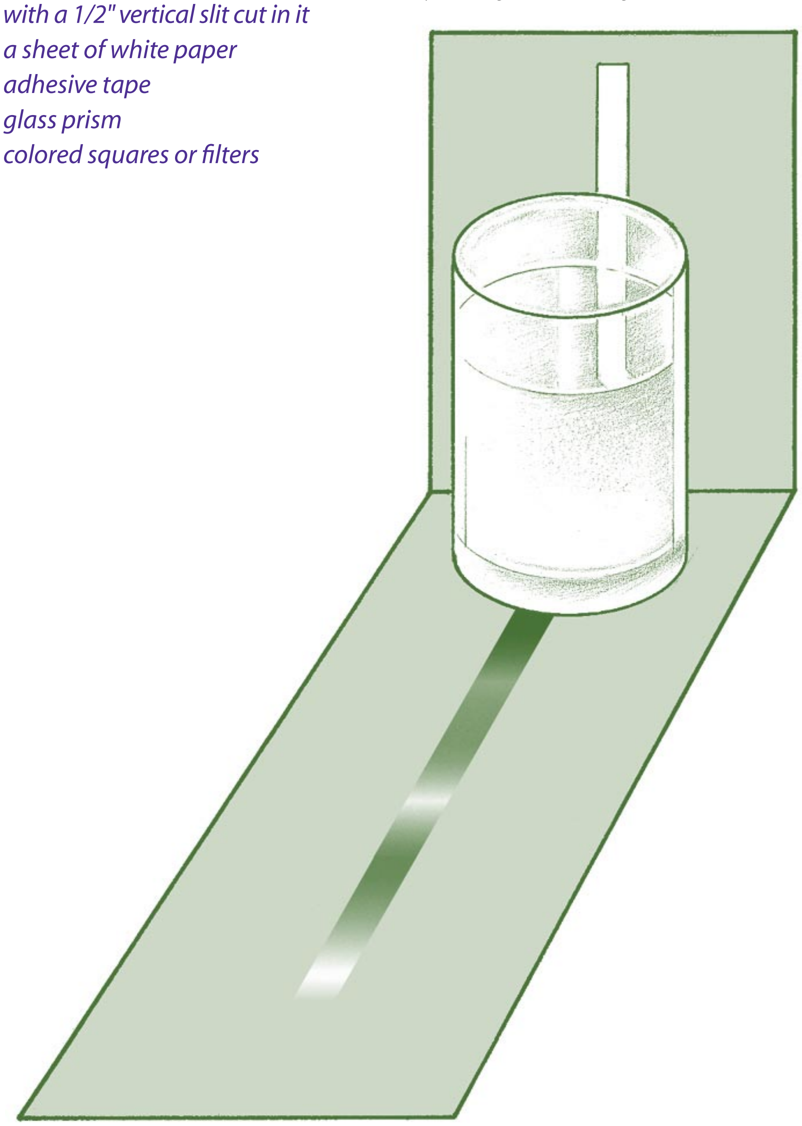
- *a straight-sided, clear water-glass, or jar*
- *a piece of posterboard (or other rigid, thick paper) slightly larger than the glass, with a 1/2" vertical slit cut in it*
- *a sheet of white paper*
- *adhesive tape*
- *glass prism*
- *colored squares or filters*

What to do

Fill a jar with water, then tape the card with the slit in it to the outside of the jar. Place the sheet of white paper close to a sunny window, then stand the jar on it. What do you see?

What's happening?

The color of the visible spectrum is projected on your sheet of white paper. As sunlight passes through the slit in the card it is refracted by the water in the glass. Light with long wavelengths, like red, is bent more than light with short wavelengths, like violet, so the colors separate as they emerge from the glass.



Further research

Visible light that appears white to our eyes, such as sunlight, is actually a mixture of colors—a range of wavelengths. Prove this to yourself by performing another simple test:

Instead of a water-filled jar, use a glass prism to focus sunlight on a piece of white paper so that the light waves are refracted (bent) into a range of colors (called the color spectrum). Creating this spectrum works best if you focus the light onto a piece of white paper which is in a shaded spot.

- Record the order of the colors.
- Back in the room, use crayons, colored pencils, etc. to draw a color spectrum.
- How does a prism refract light?
- Which wavelengths (colors) are the longest? shortest?

Color can also be produced by the reflection and absorption of light. Try this simple test:

In bright light record your observations when combining plastic squares colored by pigments. DO NOT LOOK DIRECTLY AT THE SUN; Let light shine through the squares. Use white paper behind colored squares for best results.

Record the results below:

1. blue + yellow = ____________________
2. red + blue =____________________
3. blue + green = ____________________
4. blue + magenta = ____________________
5. red + yellow = ____________________
6. orange + blue = ____________________
7. red + green = ____________________
8. all colors = ____________________

Backgrounder

Eye of the Whale

"Language Arts Standard 5
Students employ a wide range of strategies as they write, and use different writing process elements appropriately to communicate with different audiences for a variety of purposes."

NS

Successful storytellers, whether they are writers or speakers, must make many decisions and answer, in their own minds, many questions about how they will tell their stories.

Observing and reporting about the world can be done in at least two ways:

1. by describing it in the third person (e.g., "As the killer whale approached, the humpback whale swam away rapidly.")

or,

2. by taking the personal point of view of another person— or creature, (e.g., "When I heard the frightening clicks and whistles of that hungry killer whale, I turned and swam away as fast as I could!")

Both choices require knowledge about the person or creature—e.g., where it lives, what dangers and opportunities it faces. Telling the story in the first person also requires imagination and the creation of a 'voice' for that other person or creature.

Successful storytellers, whether they are writers or speakers, must make many decisions and answer, in their own minds, many questions about how they will tell their stories.

Examples of such questions include:

What is my purpose in telling the story—to make the audience (my readers) laugh? be frightened? think clearly? be angry? be sad? be happy? learn new ideas and facts? adopt new attitudes? take some action?

The answers, in turn, create other questions about methods, such as:

What is my "point-of-view" as the story teller?

What "voice" shall I use?

What atmosphere and mood do I want to establish?

The scene linked to this Backgrounder and its activities strengthens a discussion of Point-of-View and Subjective-Objective Balance.

While we are looking at the whale in this scene, it is looking back at us (or at least at the camera operator who serves as our surrogate.) This staring whale can stimulate student-writers to consider and discuss the question of point-of-view. Related issues include the objective voice *vs* the subjective voice; and the need for research and disciplined imagination.

A writer must clearly understand her or his choices and commit to them.

Consistency in point of view and in the balance of objectivity and subjectivity are essential in good writing. A third-person narrator can straightforwardly report generally accepted formal explanations of the actions he or she describes. Such reporting is likely to be objective.

However a third-person narrator can also describe actions and events in ways that slyly or openly influence the reader's opinion of the subject. Such reporting is subjective.

continued

Eye of the Whale continued

An example of a narrative written from the first-person point of view follows:

"Call me Ishmael. Some years ago—never mind how long precisely—having little or no money in my purse, and nothing particular to interest me on shore, I thought I would sail about a little and see the watery part of the world. It is a way I have of driving off the spleen, and regulating the circulation.

Moby Dick Herman Melville

Here is an example of a narrative written from the third-person point of view:

"The great fish moved slowly through the night water, propelled by short sweeps of its crescent tail. The mouth was open just enough to permit a rush of water over the gills. There was little other motion: an occasional correction of the apparently aimless course by the slight raising or lowering of a pectoral fin—as a bird changes direction by dipping one wing and lifting the other.

The eyes were sightless in the black, and the other senses transmitted nothing extraordinary to the small, primitive brain."

Jaws Peter Benchley

Eye of the Whale

Choose an Activity

The activities listed below will enable your students to experiment with their sense of vision within the theme of "Whales & Words." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: His Name Might Be Ishmael

Activity 2: The Whale of Argentina

His Name Might Be Ishmael

Activity 1

Group size

From a single student to entire class

Time you'll need

30-60 minutes, or a homework

Materials you'll need

Samples of good writing in first-person and third person narrative, e.g., the Melville and Benchley selections in the accompanying Backgrounder.

What to do

- Teachers read the selections provided or other stories about whales.
- Lead a discussion about writer's point-of-view. Ask students to tell who is talking? What can you tell about him or her? Is it a man or woman?
- Ask students to re-tell the story in an alternative point-of-view. (i.e. if original is written in the first person, re-tell it in the third person).

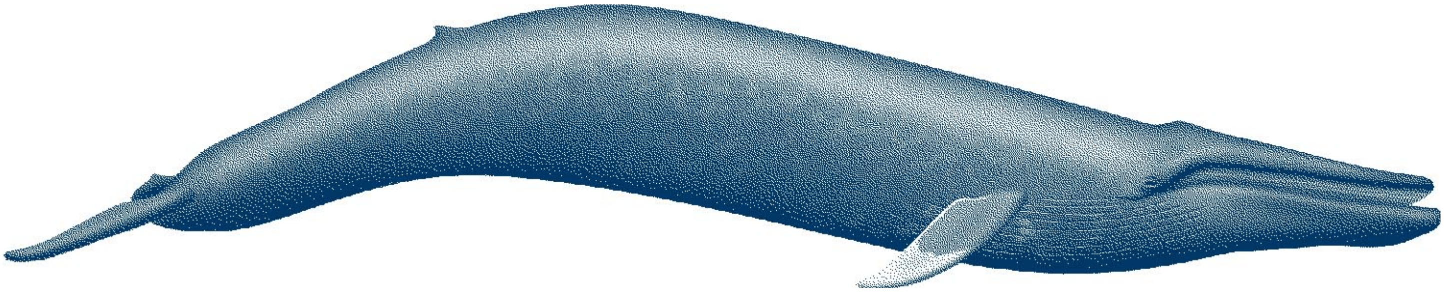
Ask the group to discuss such issues as:

When statements change from first-person to third-person, does the story change? For example is there any difference in "Call me Ishmael."; "My name is Ishmael."; "His Name Was Ishmael."; and "His Name Might be Ishmael."?

Is it harder to tell a story or a third-person story?

How can you think like a whale (and write in the first-person narrative) if whales don't think? Or do they? Do we know? What kind of guesses must you make to write from the point-of-view of another person or creature?

Which stories do students like better—first-person or third-person?



The Whale of Argentina

Activity 2

Group size
Individuals or small groups

Time you'll need
10 minutes

Materials you'll need
• green and blue crayons

What to do

Find these words and color the letters in them blue.

CALF **TAIL** **BONNET**
WHITE **BALEEN**

B	A	L	E	E	N
O	A	T	A	I	L
N	Y	C	A	L	F
N	W	S	L	A	P
E	W	H	I	T	E
T	R	I	G	H	T

Color the letters in the name of the Whale of Argentina green. Write the name on the line below.
Where is Argentina? Find it on a map or globe.

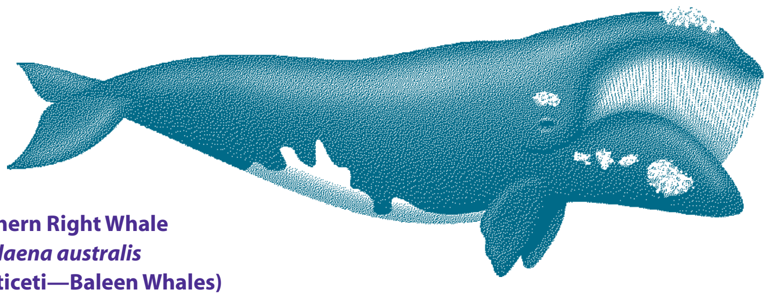
____

Backgrounder

Southern Right Whale

The eye in this scene belongs to a Southern Right Whale filmed on the winter courting and nursery grounds in southeastern South America, near Peninsula Valdez on the Patagonian coast of Argentina.

Southern Right Whales have no dorsal fin. Their upper jaws are strongly arched and the lower jaws are strongly bowed. The upper jaws bear long dense plates of baleen. The throat has no obvious grooves. Large rough white bumps (called *callosities)* are obvious on their chins, sides of the head, and near the eyes. The largest callosity, in front of the twinned blowhole is called the "bonnet."



Southern Right Whale
Eubalaena australis
(Mysticeti—Baleen Whales)
Right whales were once abundant in the world's oceans. Now they number in the hundreds. Perhaps the best place to see them is in Peninsula Valdez, Argentina. The Whales *film crew and scientist Roger Payne and colleagues journeyed to this remote area of Patagonia to film the right whales you will see. Watch for the unusual young white whale calf.*

Right whales may reach 51 feet long (15.5 m) and weigh 66 tons (59,400 kg). Newborn calves are about 15-20 feet long (4.5-6 m). The skin of Right Whales is black or dark brown with white patches on the throat, belly and sides. Rarely, calves are born white. They grow darker with age.

Much of what we know about the behavior of these whales has been learned by Roger Payne and his colleagues at Peninsula Valdez on the central coast of Argentina. Right whales come here in the southern winter arriving in shallow, sheltered waters in July. They leave in November and swim south toward Antarctica. Recent studies show they may aggregate around areas in the open ocean where currents converge and food is abundant. Right whales are specialized feeders. They seem to prefer copepods (small crustaceans) and take krill as a second choice.

Right whales once were abundant in the Atlantic and Pacific Oceans but whaling reduced world populations to extremely low numbers. Some biologists consider the northern hemisphere populations to be a separate species, the Northern Right Whale *(Eubalaena glacialis)*.

In the North Atlantic, the right whales survive in small numbers, migrating seasonally from Florida and the Gulf of Mexico to the Gulf of St. Lawrence, Nova Scotia, and Newfoundland. Recently United States government agencies have required the U.S. Coast Guard to take special care to protect right whales along the Atlantic seaboard. Ship collisions and net entanglements are constant threats.

Once abundant, right whales in the Pacific are even scarcer with only a handful of sightings from Washington, Oregon, California and Baja California. A single sighting was made recently in Hawaii.

Singing Humpback

An animal hearing in air can localize sound, aided in part by the density difference between air and tissue. But with no density difference, sound localization is impossible in water.

Theme Menu

Singing Humpback

Choose a Science Theme

The "Sound Scene Resource" supports learning plans for the themes highlighted below. Press the highlighted bar for the theme you wish to explore.

Life Science

Physical Science

Earth Science

Science as Inquiry

Science in Society

Nature of Science

Whales & Words

Whale Biology

Backgrounder

Life Science

Singing Humpback

"The Characteristics of Organisms

The behavior of individual organisms is influenced by internal cues (such as hunger) and by external cues (such as a change in environment). Humans and other organisms have senses that help them detect internal and external cues."

NS

Sound is one of the primary ways we communicate our thoughts, ideas and wishes, and the way we gain information about a lot of things in our environment, living and non-living. Our ears are the receivers of sound—without them sound would simply be vibrations in the air.

The human ear is a very complex organ, comprised of the outer ear, the middle ear, and the inner ear.

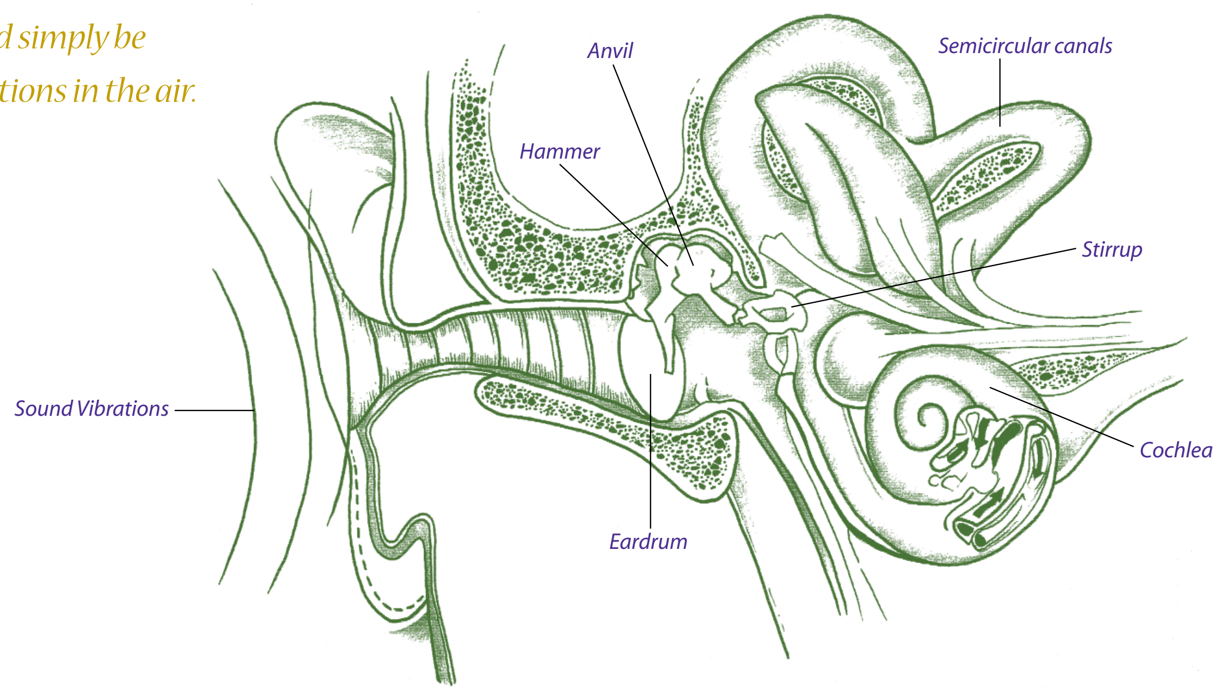
The outer ear has the auricle, the part that sticks out from the head, and the canal.

The middle ear begins with the eardrum (sometimes called the tympanum). The ear drum is skin stretched tautly across the auditory canal, much like a skin stretched across a drum. It is so thin that even the smallest sound waves causes it to vibrate. These vibrations swing a tiny bone called the hammer against another bone called the anvil. The anvil then shakes another bone called the stirrup. The Eustachian tube off the middle ear connects the ear to the throat and serves to balance air pressure on both sides of the eardrum.

The cochlea of the inner ear is coiled like a snail and lined with tiny hairs. It is also filled with liquid, making it an excellent transmitter of sound waves. Vibrations sent from the middle ear to the cochlea stimulates the tiny hairs, which then send impulses to the brain via the auditory nerve. These impulses are interpreted by the brain as sounds.

continued

Our ears are the receivers of sound—without them sound would simply be vibrations in the air.



Backgrounder

Life Science

Singing Humpback *continued*

As aquatic animals, whales are faced with different opportunities and different problems for sending and receiving sounds. Sound travels farther and faster in seawater than in air. However the density of living tissue—bone, flesh, blood—is very close to water.

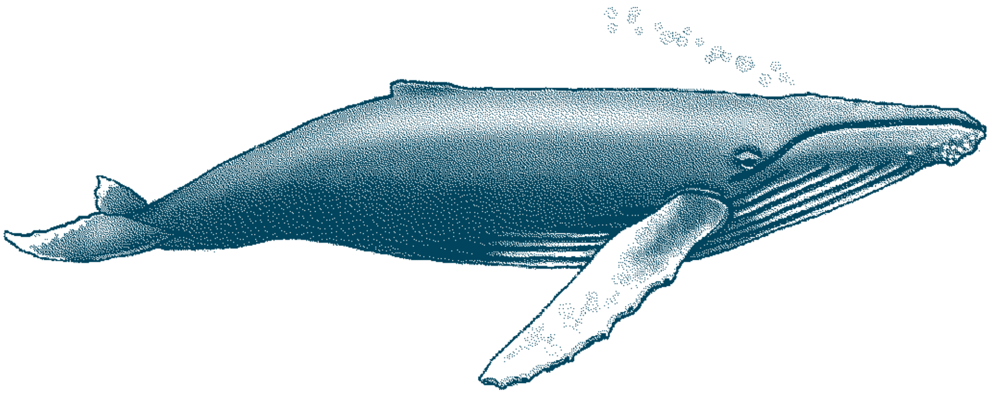
An animal hearing in air can localize sound, aided in part by the density difference between air and tissue. But with no density difference, sound localization is impossible in water. Whales and dolphins have adapted to this problem with elaborate foam-filled sinus cavities that surround the middle and inner ears. These create an air barrier—a density difference—and localization of sound is possible.

In addition, the bones of whale inner ears are heavier and more rigid than those of land mammals. This helps protect the ear during deep dives and permits the fine resoultion of higher frequencies in water.

The outer ear of whales is greatly modified for life in water. Whales have no earflaps only a tiny, barely visible slit. The ear canal is blocked by a heavy keratin (waxy protein) plug to keep water out. The outer ear canal may not be an important pathway for sound, as it is in our ears.

It is likely that most sounds reach the whale's inner ear through jawbones and fatty deposits around the inner ear.

Scientists are still investigating how whales receive and transmit sound.



Singing Humpback

Choose an Activity

The activities listed below will enable your students to experiment with their sense of hearing within the theme of "Life Science." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: Sounds Like. . .

Activity 2: Highs & Lows

Activity 3: Stereo Sound

Sounds Like…

Activity 1

Group size
Individuals or small groups

Time you'll need
10-15 minutes

Materials you'll need
- *copies of this page*
- *pens or pencils*

What to do

Choose words from the list to complete each sentence. For fun, make the sound described in the sentence.

LOUD HIGH SOFT LOW

Sample
A cat's yowl sounds __LOUD__ and __HIGH__ .

1. A lion's roar sounds __________ and __________ .
2. A train whistle sounds __________ and __________ .
3. Thunder sounds __________ .
4. A dog's bark sounds __________ and __________ .
5. A car motor sounds __________ and __________ .
6. In the movie *Whales*, the whale songs sounded __________ and __________ .

What is your favorite sound?

Circle the words that tell about it.

LOUD HIGH SOFT LOW

Highs and Lows

Activity 2

Group size

Individuals, pairs, or small groups. Can be done as a teacher demonstration with younger students.

Time you'll need

20 minutes or more

Materials you'll need

- *6 small-mouthed glass bottles of same size*
- *water*
- *metal spoon or rod*

Objectives

- *To distinguish between higher pitched and lower pitched tones.*
- *To learn how frequency affects pitch.*

What to do

Pour increasing amounts of water into each bottle. Gently tap each bottle with the spoon or rod to sound a tone. Do different bottles make different sounds? How are they different? Which bottle makes the highest sound? Which one makes the lowest sound? Talk about the difference in how "low" sounds different from "high."

What's happening?

All sounds are created by vibrations. The number of times an object moves back and forth (vibrates) in a second of time is called the frequency of the sound. The greater the frequency, the higher the pitch. When the bottles are tapped with the spoon or rod, the glass vibrates. Water in the bottles slows down the vibration so the more water the slower the glass vibrates. The bottle with the most water vibrates the slowest, so its frequency and pitch are the lowest.

Stereo Sound

Activity 3

Group size

Teacher acts as demonstrator to small groups. Each student should have a chance to listen to the tubes.

Time you'll need

30 minutes or less

Materials you'll need

- *A 3' length of flexible hose measuring 1" or more in diameter (vacuum hose works well)*
- *Two 10" length of 1" x 2" wood*
- *A piece of wood (for the base) measuring about 2" x 4" x 6"*
- *2' of wire*
- *glue, nails, or screws*

Objective

To explore how human ears determine the sources of sound.

What to do

Fasten the two 1" x 2" pieces so that they form a T, then fasten the bottom of the T to the center of the base.

Hang the hose from the T's cross bar with wire so that it hangs freely and balances. (See illustration)

A student keeps eyes closed and holds the hose up so one end is in each ear. Have teacher or another student tap on the hose with a pencil or pen. Can you tell whether the tapping is closer to your right ear than your left ear? Have your friend tap in a lot of different places and try to guess where on the hose he's tapping. Can you tell where the center of the hose is? How far from the center does the tapping have to be for you to distinguish a different noise in each ear?

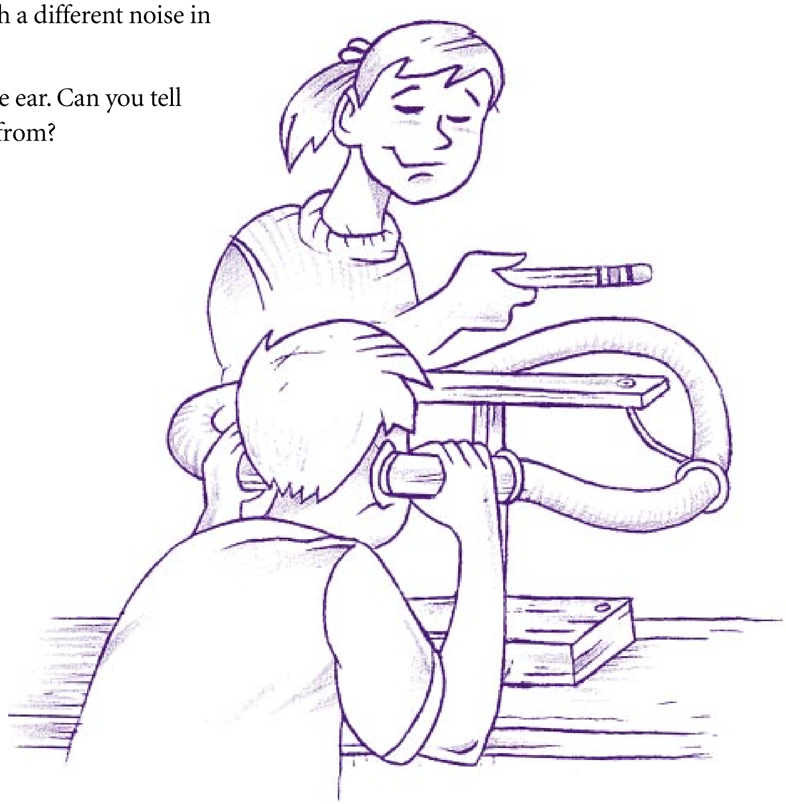
Try listening with only one ear. Can you tell where the tapping comes from?

What's happening?

When you use two ears, you compare the differences in volume, arrival time, and pitch of a sound. If a sound source is directly in front of or behind you, your ears will hear those properties as being equal. Your ears and brain use the differences in a sound to locate its source.

If your friend taps the hose to the left of center while you are listening with both ears, the sound will reach your left ear slightly before it reaches your right ear.

If you listen with only one ear you will not be able to tell whether the tapping is on one side or the other of the middle. You can tell when the tapping is very close or very far away from your ear.



Backgrounder

Physical Science

Singing Humpback

"Position and Motion of Objects
Sound is produced by vibrating objects. The pitch of the sound can be varied by changing the rate of vibration."

All humpbacks make sounds but apparently only the males sing. No one yet knows how they make their distinctive melodies.

Whales and dolphins, like other vertebrates, have evolved complex mechanisms of communication. Most of these involve sound. Birds sing; frogs croak; wolves howl; people talk. The extent of the sounds of birds, wolves and people is limited by the thinness of air. But the greater density of seawater affords whales and dolphins a medium that carries their sounds much farther and faster.

The humpback in the scene that supports this unit is an adult male singing on the wintering grounds in Hawaii. All humpbacks make sounds but apparently only the males sing. No one yet knows how they make their distinctive melodies. We do know that they don't have vocal cords such as we humans use for speaking and singing.

"Songs" are defined as a series of discrete notes formed into long , complex and repeated patterns. Perhaps these complex sound trains are related to courtship and competition with other males.

However they make them and for whatever reasons, humpbacks produce powerful, haunting patterns of notes that can be heard by sailors on the deck of a quiet boat, and literally can be felt by swimmers near the singing whale.

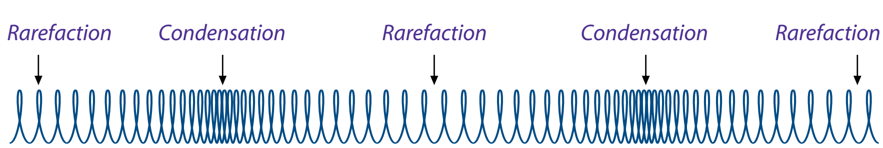
All sounds— whether from bells, birds, buzzers or whales— are created by vibrations. The reception and interpretation of sounds depends on those vibrations reaching the organs of hearing (e.g., ears) or mechanical devices such as microphones.

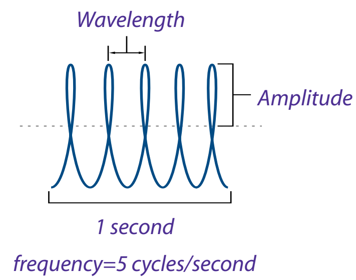
When, for instance, a note is played on a piano, the piano mallet hits the piano string and makes it vibrate. Those vibrations are transmitted to the sounding board. It pushes a lot of air as it vibrates and thus generates sound waves, which travel through the air. Some of these sound waves are intercepted by your ear. The vibrating air sets your eardrum into vibration. A series of bones and other sturctures in your ear transform the vibrations into electric nerve signals. The auditory nerve transmits the signals to your brain where they are interpreted as a piano note.

Sound can travel through solids in the form of transverse waves, which vibrate crosswise to the direction of wave motion (something like water waves) and longitudinal, or back-and-forth, waves, which vibrate parallel to the direction of wave motion, In fluids (liquids like water and gases like air), however, only longitudinal waves can travel.

Longitudinal waves (also called compression waves) move by alternately squeezing and stretching, much like a coiled spring might move.

continued





Backgrounder

Physical Science

Singing Humpback *continued*

Whales and dolphins make high-frequency "clicks" that bounce off objects. These underwater echoes give them information about the size, texture, speed and distance of objects .

As the piano sounding board pushes into the surrounding air, it compresses the air. As it moves back, air rushes in to follow it and the air is rarefied (becomes less dense). The distance between successive compressions (or between successive rarefactions) is called the **wavelength**. The distance through which any little bit of air is moved as it is first pushed and then rushes back is twice the **amplitude**. The number of waves that pass a given point per second is called the **frequency**. Frequency is measured in a unit called the hertz (Hz). 1 Hz is equal to one complete vibration per second. In old books, you will sometimes see the same thing called a hertz. The hertz is named after the German physicist Heinrich Hertz (1857-1894), who was the first to make accurate measurement of the frequency of electromagnetic waves.

Sound waves travel very slowly compared to the speed of light, but they are still very fast. And, they can travel through liquids, solids and gases. Some materials are better conductors than others. Through dry air at room temperature, sound can travel at a speed of about 340 meters per second or 760 miles per hour. Common liquids and solids transmit sound at a much greater velocity than air does. In water, for example, sound waves travel almost five times faster than they do in air.

We perceive sound in terms of three essential characteristics: **Pitch**, **loudness**, and **quality**. You can differentiate between a bass drum and a piccolo because of differences in their pitches and sound qualities. Pitch is determined by the frequency of vibrations: the greater the frequency, the higher the pitch. Frequency is usually measured in hertz (Hz) or cycles per second. Young people can hear sounds over the frequency range from about 20 Hz to about 18,000 Hz. Sound having frequencies above the range of human hearing is called ultrasound. Many animals can hear in the ultrasonic frequency range; these include dogs, dolphins, and bats. For frequencies between thousands of hertz, it is often convenient to use the unit kHz; 1 kHz=1000 Hz. At much higher frequencies yet, ultrasonic signals that are made to pass through humans or animals can be used to form images of internal organs and fetuses in a manner similar to the way that X rays are used. When passed through structures, they can detect cracks. Frequencies used are in the megahertz (MHz) range; 1MHz=1,000,000 Hz.

The **loudness** that we perceive depends on the **intensity** of the sound, which depends on the amplitude. Loudness is often measured in **decibels** (dB). The faintest sound that a normal human can hear in the mid-frequency range (about 3 kHz) is defined to be 0 dB. Extended exposure to sound louder than 100 dB can cause hearing loss in humans. Even a very short-term exposure to sound at 120 dB can cause intense pain and immediate hearing loss.

Almost all persons experience a partial loss of hearing as they age, beginning at about age 20-30. Sensitivity to high-frequency sound tends to diminish first. Unfortunately, extended exposure to loud sound can produce the same effect in quite young persons. Audiologists have observed large numbers of young people (18 or younger) whose audiograms look like those of 60-year-old people because they have listened to loud music like that at rock concerts and on headphones.

Bouncing sound (also called **echolocation**) is a method used on ships in charting ocean depth. Whales and dolphins use echolocation to sense information about objects and animal around them. To measure ocean depths, ships use oscillators to produce sound waves that travel through the water. An instrument called a fathometer records the time it takes for the sound waves to echo back from the ocean floor. With that information, ocean depth can be estimated. The deeper the water, the longer the travel time.

Singing Humpback

Choose an Activity

The activities listed below will enable your students to experiment with their sense of hearing within the theme of "Physical Science." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: Jumping Rice!

Activity 2: Highs and Lows

Activity 3: See Your Friends With Your Ears

Jumping Rice!

Activity 1

Group size
Individuals or pairs

Time you'll need
20 minutes

Materials you'll need
- *a bowl*
- *a rubber band (big enough to go around the lip of the bowl)*
- *a metal saucepan or cookie sheet*
- *a piece of heavy plastic (thick plastic wrap or a garden trash bag will work well*
- *a handful of cooked rice*
- *a large spoon*
- *scissors*

What to do
Cut a square piece of plastic a little larger than the top of your bowl. Stretch the plastic over the bowl, then put the rubber band around the lip of the bowl to hold the plastic in place.

Sprinkle a few grains of rice on top of the plastic. Hold the pan up close to your "drum" and bang on the bottom of the pan with your spoon. Does your rice jump?

What's happening?
All sounds are created by vibrations or sound waves. When you bang your spoon on your pan, the pan vibrates and so does the air around it. The sound waves that reach your ear cause you to hear the banging of the pan. The sound waves that hit the drum skin make it vibrate, causing your rice to jump up and down!

Highs and Lows

Activity 2

Group size

Individuals, pairs, or small groups. Can be done as a teacher demonstration with younger students.

Time you'll need

20 minutes or more

Materials you'll need

- *6 small-mouthed glass bottles of same size*
- *water*
- *metal spoon or rod*

Objectives

- *To distinguish between higher pitched and lower pitched tones.*
- *To learn how frequency affects pitch.*

What to do

Pour increasing amounts of water into each bottle. Gently tap each bottle with the spoon or rod to sound a tone. Do different bottles make different sounds? How are they different? Which bottle makes the highest sound? Which one makes the lowest sound? Talk about the difference in how "low" sounds different from "high."

What's happening?

All sounds are created by vibrations. The number of times an object moves back and forth (vibrates) in a second of time is called the frequency of the sound. The greater the frequency, the higher the pitch. When the bottles are tapped with the spoon or rod, the glass vibrates. Water in the bottles slows down the vibration so the more water the slower the glass vibrates. The bottle with the most water vibrates the slowest, so its frequency and pitch are the lowest.

See Your Friends with your Ears

Activity 3

Group size
12 or more

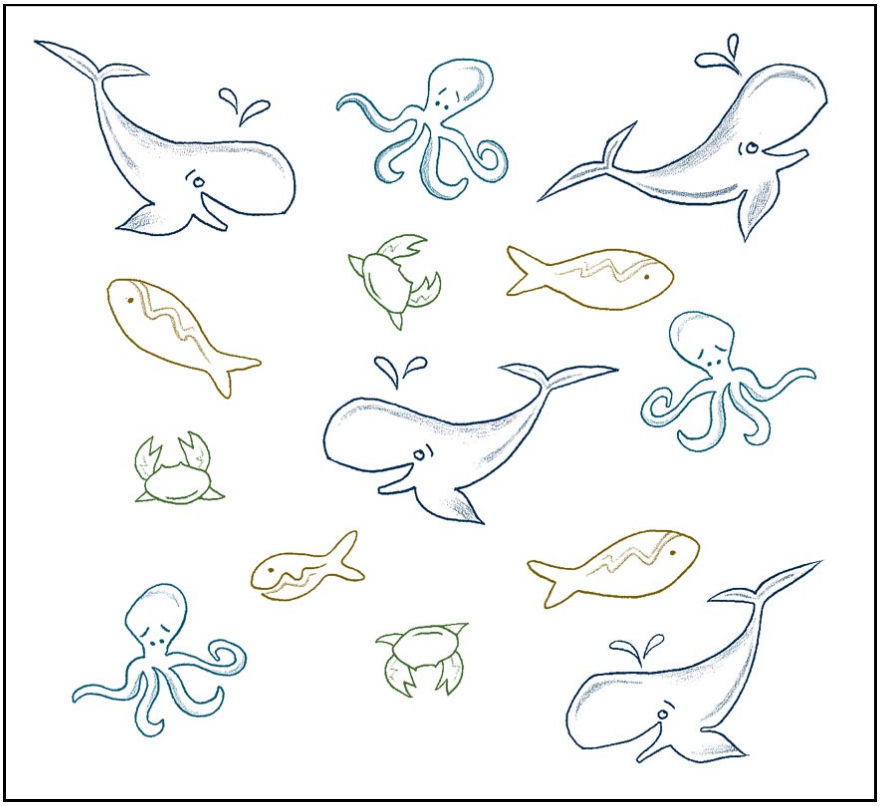
Time you'll need
45 minutes or more

Materials you'll need
- *4 noisemakers (dry beans in film canister work well)*
- *4 bandannas or paper bags (to be used as blindfolds)*
- *a large open space*

Objective
To explore using hearing rather than sight to identify other "species."

What to do
Go outside to your activity area and discuss the boundaries of it and the rules for this activity before you start.

Select four people to be whales, then blindfold each one of them and give them each a noisemaker. Divide the rest of your class into groups of three or more. Have each of those groups choose another animal or ocean object to be—dolphins, rocks, squid, etc. Ask each of those groups to determine a noise that they will make to identify themselves. (i.e. all the dolphins will whistle and all the rocks will snap their fingers).



Once the groups have determined their identifications, have them all scatter themselves throughout the activity area. Remind them that they are to pick a spot and freeze there throughout the activity.

Then the teacher or group leader walks each of the blindfolded whales to a spot in the activity area. When all four "whales" are in position, the game begins.

The challenge of this game is for the whales to find one another. To do this, they can make sounds with their noisemakers to identify themselves, and must listen to the other noises in the area to try to identify their fellow whales. When the four whales have found one another they can remove their blindfolds. This activity can then be repeated using another group as whales until everyone has had a turn to be a friend-finding whale!

What's happening?
Humans rely heavily on their sense of sight for identifying things – particularly their friends. Because seeing in dark, deep water is difficult, whales rely heavily on their sense of hearing to locate and identify things in the ocean.

All cetaceans (dolphins, whales and porpoises) use clicks, squeaks, barks, grunts, cries, screams, chirps and/or whistles to communicate with one another. Different species have different languages, and sometimes different dialects within a language. These languages are used to identify and communicate with other whales within a population about navigation, feeding, mating and other things.

Backgrounder

Science in Society

Singing Humpback

"Understanding About Science and Technology
People have always had problems and invented tools and techniques (ways of doing things) to solve problems. Trying to determine the effects of solutions helps people to avoid some new problems." NS

The sounds that whales and the animals that live around them create have probably not changed significantly in a hundred years. But as human technology has advanced, we have added many new sounds to whale's world.

What does a humpback whale hear in the sea? Do blue whales listen for messages sent across thousands of miles? Scientists are getting better answers to these questions as research proceeds, but one thing is fairly certain: what whales hear in today's ocean differs markedly from what their great-great-great-great-grandparents heard a century ago.

The sounds that whales and the animals that live around them create have probably not changed significantly in a hundred years. But as human technology has advanced, we have added many new sounds to whale's world. Some sounds have been intentionally introduced to the sea. Others are incidental to the primary reason for their cause.

Noise in the Sea

Noise from ship and boat engines were the first additions to the world of whales by humans. For centuries humans depended on the technology of wind-driven boats and ships. These vessels, although probably detectable by some whales and dolphins, were relatively quiet. Then came the steam engine, the diesel electric engine, the nuclear reactor engine. Propellers, driven by ship engines are audible for long distances underwater, even to human ears.

A busy coastline where whales visit annually, for example, near Lahaina, Maui; San Diego, California; Cape Cod, Massachusetts; Long Island, NY, or Acapulco, Mexico, may be filled with the sounds of passenger ships, freighters, jet skis, power boats, and the occasional submarine. All these vessels influence our quality of life in some way. But how do their sounds effect the lives of whales? And if we find that some sounds or all of them are harmful to whales, what can or should we do about it?

Noises from ships and boats are only part of today's acoustic environment for whales. Sounds of coastal construction like pile-driving, dredging and blasting have been joined by newer sounds from technologies such as SONAR, seismic exploration, and military and civilian experiments.

Sound in the Sea

SONAR (for Sound Navigation and Ranging) was developed during World War II as a way to detect submarines using sound. SONAR has been improved for finding schools of fish, sunken objects, and to map the bottom.

Sound was first used to measure depth in 1919. The same basic principle is still used in today's sophisticated technology. The first depth recorder was developed by the U.S. Navy about 80 years ago. The "Hayes Sonic Depth Finder" sent sound waves to the sea bottom. The travel time of the reflected signal returning from the sea floor indicated depth. In 1927 a similar device was marketed for civilian use under the name Fathometer.

Modern systems employ a transmitter that produces a powerful electric signal.
A transducer converts electrical energy into an acoustic pressure wave aimed at a target, often the sea floor. The reflected echo is received, converted to electrical energy, timed and recorded or displayed.

Today, almost every sea-going vessel, from small outboard driven fishing ships to water-ski boats to container ships, is equipped with some kind of SONAR device for depth sounding or fish finding.

continued

Singing Humpback *continued*

Recently, scientists have planned experiments that involve underwater sounds loud enough to be heard halfway around the world.

Sound signals are also used to find oil and minerals under the sea floor. Acoustic signals (often very high energy, i.e., loud) penetrate the sea floor and the crust beneath it. Travel times of the recorded signals reveal the density of the material comprising the crustal structure and can reveal oil deposits.

Experiments in the Sea

Experiments are now underway that involve underwater sounds loud enough to be heard halfway around the world. The ATOC Experiment (for Acoustic Thermometry of Ocean Climate) aims to measure temperature change in the ocean by using sound sent across entire ocean basins. Timing the arrival of sound waves from a remote source may give good information about the temperature of the world's oceans. The results could verify or change our assumptions about global climate change.

Good data, however, will require loud sounds to be made many times. What will such sounds do to whales and other marine mammals? Do we need to find out before the experiment? And what if the sound are harmful to whales? Should we cancel the research?

All of these new sounds, from SONAR to ATOC, are produced by technologies that contribute to our overall economic and social benefit. However, they may also affect the lives of whales in harmful ways. Its seems intuitive that widespread, intense noise may hurt whales. But to find out for certain, more research must be done.

If it turns out that the well-being of whales is endangered, what can and should we do about it? This is, indeed, a case where "social values influence the direction of technological development."

Warning All Whales

Of course, technology can be used with the intention of protecting whales, too. The following news item from Australia discusses an interesting combination of technology in human relationships with large marine animals.

In many areas of Australia, swimmers are protected from shark attack by long nets stretched across swimming beaches. (Such nets are not meant to catch whales.)

Netting Sharks and Warning Whales

BRISBANE, 10/16/96

Acoustic alarms would be fitted to all shark nets along the Queensland coast after two humpback whales were trapped in the protective barriers today, a Department of Primary Industries (DPI) spokesman said.

Both animals were freed but one of the whales, a calf, was stranded in shallow water for seven hours before being reunited with its mother off the Sunshine Coast north of Brisbane. Staff from Sea World on the Gold Coast and Underwater World on the Sunshine Coast worked all morning to free the animal and succeeded soon after midday.

DPI fisheries resource protection general manager Dan Currey said the acoustic alarms, which had been used on nets in areas where whales were commonly seen, would now be fitted to all nets. "The alarms have been very successful and we believe that fitting these to all shark nets in Queensland will minimize the risk of this happening again," Mr. Currey said.

Both whales were swimming safely off shore about 7 pm (AEST).

Singing Humpback

Choose an Activity

The activities listed below will enable your students to experiment with their sense of hearing within the theme of "Science in Society." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: Well, Well, Willie. Whales!

Well, Well, Willie. Whales!

Activity 1

Group size
small or large group

Time you'll need
20 minutes

Materials you'll need
- *accomplished reader*
- *paper and pencil*
- *radio*

Objectives
- *To recognize a specific consonant set and sound.*
- *To concentrate on a sound source and extract quantitative information from it.*
- *To demonstrate the effect of background noise.*
- *To stimulate discussion about the effects of human-made sound in the world of whales.*

What to do

An accomplished reader reads the following story. (The story can be shortened for younger listeners.) Listeners mark down (we suggest in "fences and gates," groups of five) every time they hear a "wh" sound (Hint: there is one "wh" sound made by letters other than "wh"). Count the total of "wh" sounds.

Turn on a radio tuned to voices (e.g., news, commercials, etc.) Do the exercise again. Was it easier or more difficult to listen to the reader and hear the "wh" sounds? Were the counts the same? Was there greater or lesser error in the counts with the radio on? How is this exercise similar to what whales endure in an ocean area filled with human-made sounds like SONAR and engine noise?

Wanda White was a wonderful woman who walked west from Walla Walla, Washington.

Wanda wanted Willy Wilson to watch whales with her at the west wall of Whistler's Wardrobe (a wharf where the wind whistled in winter).

Whereas wildlife gave Willy the willies and he was wont to whimper, Wanda worried Willy would wail.

Wednesday, Wanda wakened and walked with Willy west, where the wharf was. Wanda wondered, would Willy wail while whales wandered in their wayfaring, whale way?

With wit, Wanda watched westward where whales were.

"Well, well, Willy. Whales," whispered Wanda.

Wanda watched in wonder while wily whale males waltzed and whistled with their wayfaring wives. (One whale watched Wanda.)

Willy watched and watched and watched...when,

Wonder of Wonders!

Willy Wilson —without worry—whooped wildly, "Whales! Whales! Wahoo for whales!"

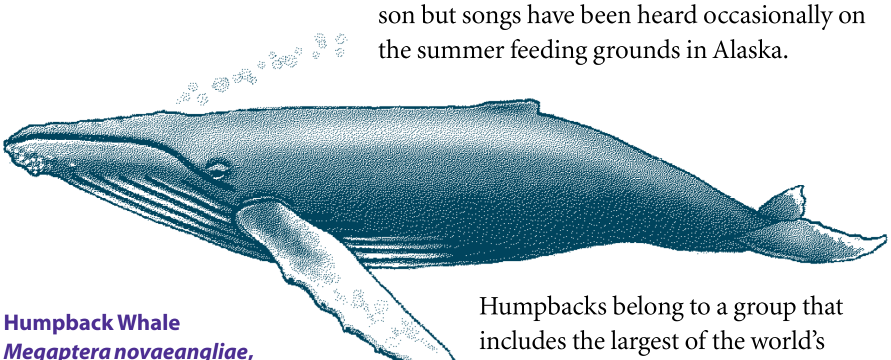
Backgrounder

Whale Biology

Humpback Whale

Unlike some whales that seem to slip beneath the surface when they dive, a humpback—well—humps its back, extends its tail in the air and then dives.

Humpbacks whales are famous for their long, haunting and complicated songs. In *Whales* we see a lone male humpback hanging motionless in the mid-water and hear him sing his plaintive song. Scientists need more research in order to know what these songs are really for—courtship, perhaps, or warnings to competing males? No one is certain how humpbacks produce their songs. Roger Payne and Scott McVay first discovered in 1971 that humpbacks sing long and complex songs. Later scientists learned that only males sing, although all humpbacks make sounds. Roger Payne is still studying whale songs, and we see him in *Whales* recording their melodies. Singing occurs mainly during the breeding season but songs have been heard occasionally on the summer feeding grounds in Alaska.



Humpback Whale
***Megaptera novaeangliae*, (Mysticeti—Baleen Whales)**
Adult males are famous for their songs. In Whales, *we hear them singing in Hawaii. Scientist Debbie Ferrari has studied mothers and their calves among the islands for more than 20 years. After they leave Hawaii in the Spring, humpbacks migrate to Alaska to eat all summer. Watch them catch fish with a net of bubbles and a mouthful of baleen.*

Humpbacks belong to a group that includes the largest of the world's baleen whales. Loosely called "rorquals," all whales in this group (blue whales, fin whales, sei whales, minke whales, Bryde's whales) are slender and streamlined. Humpbacks are the stoutest of the group.

Rorquals have many grooves on the throat, extending from the chin to behind the pectoral (or, arm) fins. Once thought to aid in streamlined swimming, grooves instead act like accordion pleats to expand the mouth. Humpbacks have 14-35 grooves, the fewest of any rorqual.

Sometimes names aren't much help in identifying an animal, but humpbacks are an exception. Both the scientific and the common name give us some tips for distinguishing them from other whales. Unlike some whales that seem to slip beneath the surface when they dive, a humpback—well—humps its back, extends its tail in the air and then dives. The habit of extending its tail before it dives turns out to be very helpful to whale biologists. Individual whales can be identified by the bumps, scallops and white and dark patches on their tail fins, or flukes.

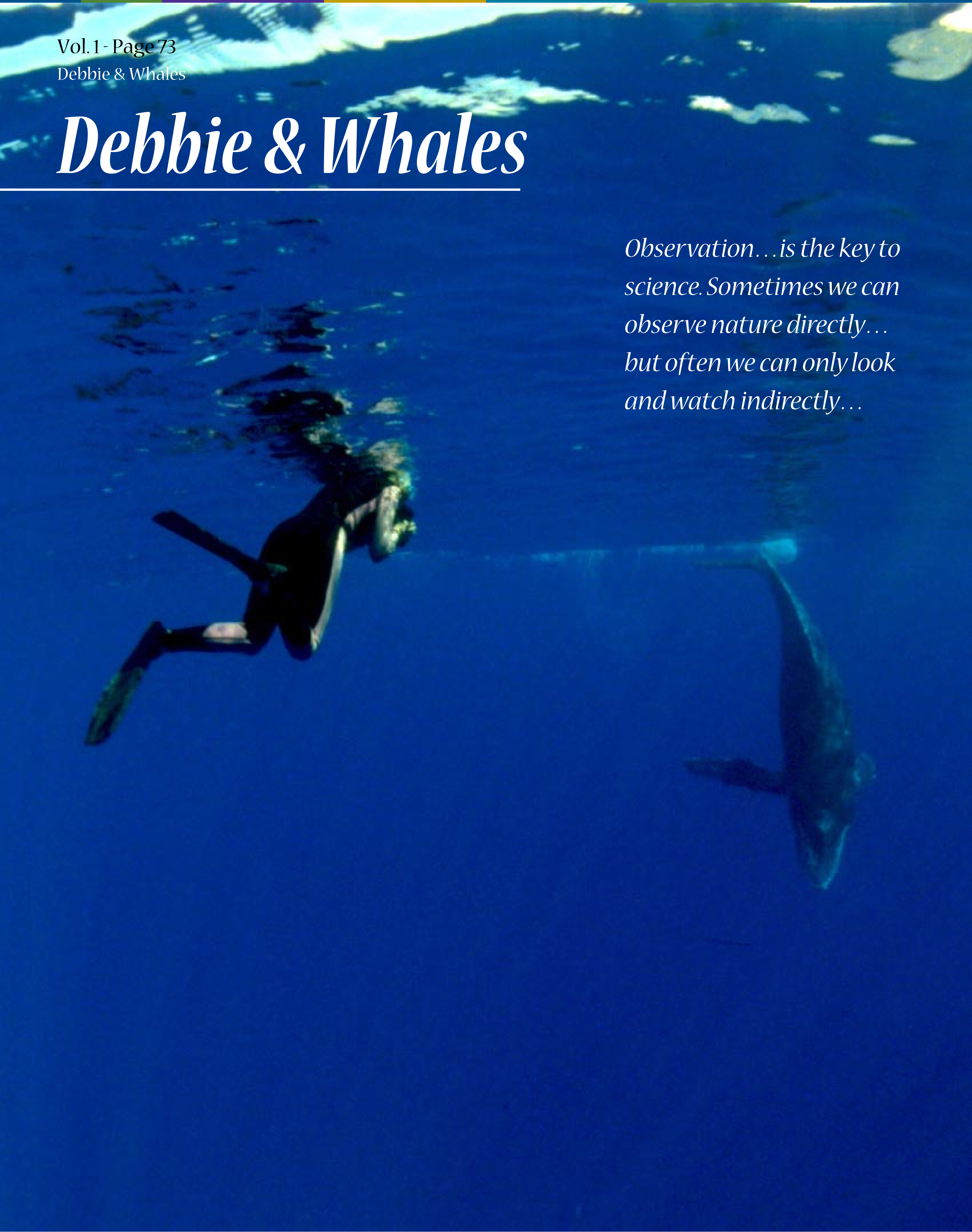
Humpbacks also have distinctive pectoral, or wing fins. These fins are almost a third as long as the whale's body, longer (relatively) than any other whale. *Megaptera* means giant fin. The species name *novaenglandii* comes from their unfortunate history with the whalers of the east coast of the United States and the coast where they were once abundant.

Humpback whales are found throughout the world's oceans. There are populations on both sides of the Pacific and Atlantic oceans. In the North Pacific, populations winter (on the west side) around the Marianas, Bonin, and Ryuku Islands and Taiwan. The eastern Pacific stocks winter in Hawaii and on the American coast and nearshore islands and in the Sea of Cortez and mainland Mexico. Northwest Atlantic humpbacks winter in the West Indies and summer from New England (another link to their species name) to Baffin Island. In the Eastern Atlantic, they winter near the Cape Verde Islands and northwest Africa, and summer north of Norway.

Humpback whales spend spring, summer and early autumn in high latitudes, well away from the equator. Here they feed and little mating activity takes place. But in late autumn, humpbacks set forth on their long annual migration to tropical waters closer to the equator where they court, mate and calve. Typically, wintering areas are found around islands and reefs. Recent evidence suggests that not all individuals may migrate every year. Adult females have been reported over-wintering in Alaska and the Gulf of Maine.

Debbie & Whales

Observation…is the key to science. Sometimes we can observe nature directly… but often we can only look and watch indirectly…



Theme Menu

Debbie & Whales

Choose a Science Theme

The "Debbie & Whales Scene Resource" supports learning plans for the themes highlighted below. Press the highlighted bar for the theme you wish to explore.

- Life Science
- Physical Science
- Earth Science
- Science as Inquiry
- Science in Society
- Nature of Science
- Whales & Words
- Whale Biology

Backgrounder

Science as Inquiry

Debbie & Whales

"Science as Inquiry
Scientists use different kinds of investigations depending on the questions they are trying to answer. Types of investigations include describing objects, events, and organisms; classifying them; and doing a fair test (experimenting).
Scientists develop explanations using observations (evidence) and what they already know (scientific knowledge). Good explanations are based on evidence from investigations."

NS

Much of what we know of whale behavior and ecology (what they eat, how they eat, who eats them, etc.) has been learned by biologists working on or in the sea follwoing and watching whales.

In its most basic form, science is watching nature to get hints about how the world works. Observation—watching, listening, smelling, touching—is the key to science. Sometimes we can observe nature directly, e.g., an ant carrying a crumb across the table. But often we can only look and watch indirectly, e.g., recording the songs of humpbacks whales when we can't see the singers or their whale audience.

The more indirectly we look, the more tools and instruments we require. We can watch the moon with just our eyes, but if we want to know a little about the surface of the moon, we need telescopes. If we want to know a lot about the surface of the moon, we need spacecraft and lunar landers.

The Basics of Science

Science is more than just watching nature and telling others about it, although that is its foundation. Scientists work according to a basic scientific method. The method involves at least five fundamental activities:

1. observation, direct or indirect with instruments;
2. reading the works of other scientists who have watched a similar phenomenon and who have measured it and written about it and tried to explain it;
3. crafting hypotheses (conditional explanations) that can be tested by experiment or continued observation;
4. experimentation and quantitative observation—direct attempts to prove or disprove the conditional explanation or hypothesis; and, an essential part of science,
5. documenting methods and results in writing and mathematical representations (and many other ways, including photography); and, interpreting the results within a larger theory so that the process of scientific inquiry can continue.

Many people think of scientists as white men in white lab coats who work with apparatus in a laboratory. Certainly this is part of science. But scientists are also women and men of all ages and racial and social backgrounds. Much of science is done in the wilds of nature as well as laboratories. Some science is done in people's own backyards. Charles Darwin, one of the first modern field biologists, is well known for the observations he made while travelling around the world on the *H.M.S. Beagle* during 1831-1836. But when he retired to his home in England, he learned a lot about the biology and behavior of earthworms by watching them in his own backyard.

Field Biology

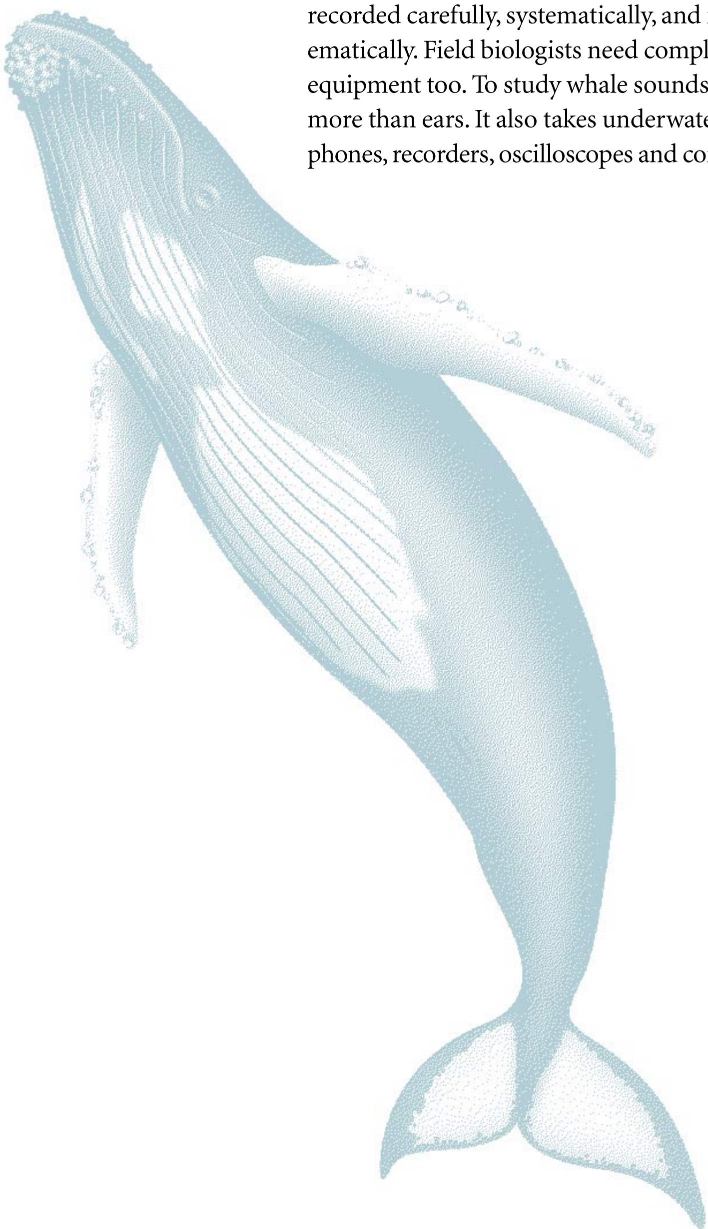
Field biology is the observation of nature in the wild outdoors where the animals and plants and the communities they form are found. "Field" is the general word for where the animals are, whether it be a corn field in Kansas or the Gulf Stream in the Atlantic Ocean. Much of what we know of whale behavior and ecology (what they eat, how they eat, who eats them, etc.) has been learned by biologists working on or in the sea following and watching whales.

continued

Backgrounder

Science as Inquiry

Debbie & Whales *continued*



Basic Skills

All scientists (whether they work in a lab or use SCUBA tanks) must have certain basic skills and traits: mathematics, ability to talk and write about their results, patience, curiosity, as well as an understanding and devotion to the scientific method

Some kinds of science involve much experimentation, apparatus, and laboratory support. Field biologists rely on observations of wild animals in nature. Even so, their results must be recorded carefully, systematically, and mathematically. Field biologists need complicated equipment too. To study whale sounds requires more than ears. It also takes underwater microphones, recorders, oscilloscopes and computers.

In the Field with Whales

In the last thirty years or so, scientists have changed the way we study whales. When there was a world-wide fishery hauling thousands of dead and dying whales from the sea every year, biologists examined the anatomy of whales and learned a lot about dead whales. Today, we recognize whales to be marvelous living creatures that we can best know by watching alive. (We can still learn a lot by examining whales that die of natural causes likes stranding on beaches).

The study of living creatures, whether they are whales in the sea, pandas in the bamboo forests of China, ravens in Canadian woods, mountain goats in the Rocky Mountains, or gorillas and chimps in Africa, requires many of the same skills and qualities. High among them is patience.

Watching animals takes a lot of time. Watching whales requires a tolerance for sea sickness, cold water, and boredom. It also requires the dedication of continuing a study year after year.

Today we have a variety of techniques from photography to DNA analysis to help us learn how whales live. But the main tool of scientists and naturalists is patience and dedication. Be there with the whales; that's how to learn about them.

What We'd Like to Know

We asked some whale researchers what questions they would like to answer or have answered in the next 10-20 years. Here are some of their questions (maybe you could help answer them someday):

- *How do humpback males produce their sounds?*
- *Are the human-made sounds in the sea from ships, SONAR, science experiments, and oil-drilling harming the whales and interfering with their own sounds or injuring their ears or driving them nuts from the constant buzzing?*
- *How do humpbacks navigate and find their way from, say, Hawaii to Alaska?*

Activities Menu

Science as Inquiry

Debbie & Whales

Choose an Activity

The activities listed below will enable your students to experiment within the theme of "Science as Inquiry." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: Name That Whale

Activity 2: Humpback Word Search

Name That Whale

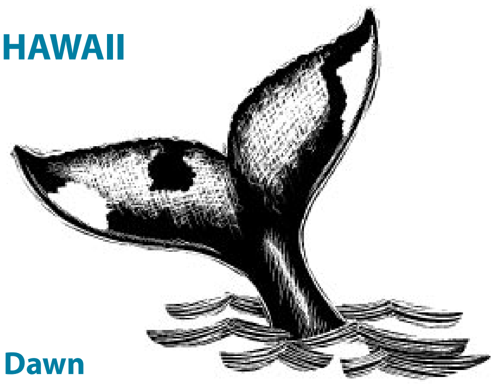
Activity 1

No other whale has exactly the same shaped or patterned tail. Each whale has different white spots, or black patches, or different margins.

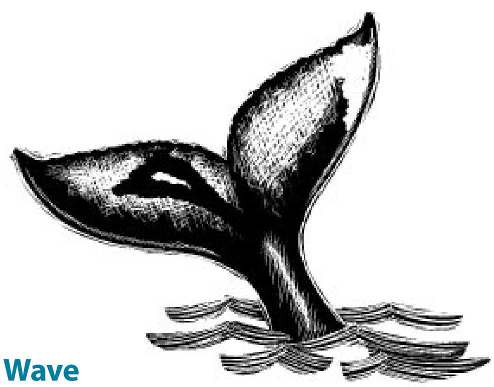
Scientists have learned that each hump back whale has a unique pattern on the tail. No other whale has exactly the shaped or patterned tail. Each whale has different white spots, or black patches, or different margins.

Scientists take photos of whales' tails in Hawaii in the winter. They give each whale a different name. In summer, other scientists take pictures of whales' tails in Alaska. They compare the two sets of photos. Scientists can tell when a whale they saw in Alaska goes to Hawaii by comparing the tail pictures. Find the Hawaiian whales in Alaska. Write the name beneath the same whale's tail.

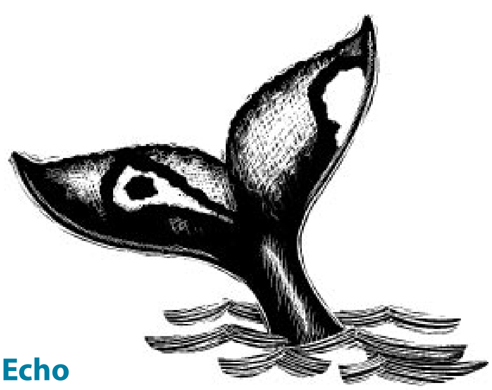
HAWAII



Dawn

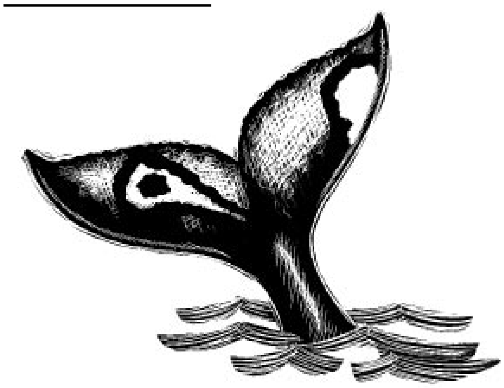


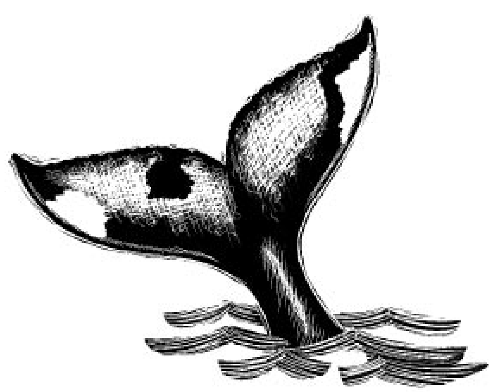
Wave



Echo

ALASKA





Science as Inquiry

Humpback Word Search

Activity 2

Group size
Individuals or small groups

Time you'll need
20 minutes

Materials you'll need
- *copies of this page*
- *pencils and pens*

What to do

Find these words. Each one has something to do with humpback whales.

Hints
- some letters may be used in more than one word
- one word is backwards
- one word is upside-down

BALEEN
BLOWHOLE
KRILL
HAWAII
PLANKTON
FLUKE
ALASKA
MIGRATE

B	E	N	O	T	K	N	A	L	P
S	T	W	O	L	B	A	L	E	L
E	A	E	K	U	L	F	C	H	A
K	R	I	A	L	L	O	L	M	A
N	G	R	H	A	W	A	I	I	L
R	I	A	A	K	H	E	G	I	A
C	M	L	W	A	O	N	B	G	S
W	O	A	P	S	L	L	I	R	K
I	B	A	L	E	E	N	R	E	A
C	E	L	O	H	V	F	G	T	I

Make up sentences that use these words. For example: *Blue whales eat KRILL. KRILL are tiny, red shrimp.*

Backgrounder

Nature of Science

Debbie & Whales

"Understanding About Science and Technology
Women and men of all ages, backgrounds, and groups engage in a variety of scientific and technological work." NS

Some people say that scientists, artists, and children—each in their own ways—try to make sense of the world, and then tell others about what they have found. While they all may share the joy of discovery, their methods and manner of telling others differ greatly.

A child can revel in the wonder of his or her discovery. A artist can present a work of art to the world with no justification other than the personal, subjective worth of the creative act. But a scientists is bound to present evidence for her or his discovery. Such evidence must be verifiable by others, and needs to be expressed in ways that are measurable, predictive, and in the best case, explanatory.

Surveys show that many people distrust scientists and science. But it is not the discovery of knowledge (i.e., science) by scientists that presents risk. Rather it is the application of the knowledge (i.e., technology) that can be scary.

Think of a scientist as a gold miner. Both work hard—searching, digging, following the maps made by others, exploring new territory, getting lucky, discovering the joy of finding a valuable nugget (of gold or of knowledge).

Then the *real* work begins. The discovered "nugget"—gold or fact—must be dug out, tested and refined. Is it really what it seems? Do others agree it is gold when they test it? Can the nugget lead to a larger deposit of ore, of knowledge? And when a rich lode is discovered, "Eureka!" is the cry, I have found it! The California prospector of 1849 made his shout from excitement and pride. The scientist, may be excited too, but the announcement of her discovery to other scientists (in person, and in published journals) is also a professional obligation.

Many scientists—usually working together—go well beyond the discovery and verification of "gold nugget discovery." They become artisans of their discovered material. Just as a jeweler refines gold, and casts and shapes and assembles it into a elaborate clock,—scientists fit their nuggets of refined discovery into intricate, ingenious, intellectual constructions that can be used to find the way to other discoveries. These intellectual "models", hypotheses, theories help explain how the world works.

As we consider how discovered knowledge is crafted into larger explanations of the world, it is important to distinguish between science and technology.

Science is ordered, verifiable discovery (and the process of making and verifying the discovery).

Technology is the use and application of scientific knowledge to influence or change events, actions and conditions that involve human activities.

Surveys show that many people distrust scientists and science. But it is not the discovery of knowledge (i.e., science) by scientists that presents risk. Rather it is the application of the knowledge (i.e., technology) that can be scary.

Scientists and gold miners both can use the technological applications of science (dynamite, electron microscopes, for example) to increase their chances of discovery. A gold prospector needs some basic tools and skills to support his search—pickax, shovel, compass, maps, mule, pan. A scientist on the road to discovery requires basic skills and tools, too: mathematics, good writing, access to scientific papers, measurement and recording devices, and many, many more, varying with the scientific discipline and subject matter.

Probably most '49er gold prospectors were men with beards and dirty long-underwear. And in 1849, the year of the California gold rush, most scientists were men too. But today, scientists are a varied lot, men and women of all colors, races and ethnic backgrounds. We still need more scientists and we need more scientists that are women and from minority groups.

Debbie & Whales

Choose an Activity

The activities listed below will enable your students to experiment within the theme of "Nature of Science." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: Meet a Whale Biologist

Activity 2: Future Science

Meet a Whale Biologist

Activity 1

Teacher or Parent

Read aloud to student group and discuss:

- *What is a scientist?*
- *Do you know any scientists?*
- *Would you like to be a scientist?*
- *Why or why not?*

Like the humpback whales she studies, Debbie Glockner-Ferrari visits the Hawaiian Islands from November to April. Every year for the past 25 years, she has returned to meet up with her big friends. When the whales leave to go north to their summer feeding grounds in early May, Debbie and her family return to the mainland United States to process their field notes and to earn enough money to come back next year.

Debbie Glockner-Ferrari *is the biologist in the scene that supports this section.*

Unlike many whale researchers, with permanent jobs at Universities and government agencies, Debbie is a self-taught scientist. Well, she started out to be self-taught. Then the whales began to teach her. Her published studies impressed older, established scientists who helped her learn the arcane skills of science.

One of Debbie's major accomplishments is her discovery that male and female humpback whales can be distinguished underwater. Until Debbie found that females have a melon-shaped bulge in front of the genital pit, whale researchers could not tell the sex of a living whale unless it was a nursing mother.

Debbie's special interest in humpbacks has been and continues to be their courtship, reproduction, and calving behavior. Like all field biologists working by observing living animals, Debbie has found her most useful single tool—an extension of her own sharp eyes and memory— is photography. By relentlessly photographing individual whales, trading these photographs with colleague whale researchers in other parts of the Pacific Ocean, she has tracked her Hawaiian friends over the Pacific and over the years.

"The 1996 season was a wonderful year for us in Hawaii. We saw Sasha with her new calf. We first met her in 1979 and she had a calf that year too, so we know Sasha is at least twenty-two years old. It's a real thrill to come back every year and recognize friends that we made 20 years ago. There is a real satisfaction to conducting field work year after year in what anthropologists would call a 'longitudinal study'— i.e., watching a group of animals year after year. In fact, I almost feel like an anthropologist returning to a village to renew old friendships and to see how children have grown and matured."

After working singly on whale studies for five years, Debbie met and married her partner in research, Mark Ferrari. Their 6-year old daughter Chantelle (named for the singing of humpback whales) joins them in the field. Mark and Debbie's friends kid them about their family and the whales sharing the waters of Maui for their courtship, reproduction and childbearing.

The clear waters of Hawaii are an ideal place to study whales using photography and observation. In the two decades that Debbie has been conducting research in Hawaii and the waters off Maui, she estimates she has taken more than 30,000 pictures of perhaps five hundred individual whales.

Future Science *an exercise in imagination*

Activity 2

Group size:

Individuals to small groups with teacher or parent

Time you'll need:

15-30 minutes

Materials you'll need:

- *drawing pads*
- *crayons*
- *color photos of animals from magazines*

What to do

Adult reads "Meet a Whale Biologist" in Activity 1. This will give students a sense of what whale researchers do, and inspire thinking about how many things we still do not know about whales (and other animals).

Each student chooses an animal picture and pretends to be a scientist. Students studying that animal take turns describing the questions he or she would try to answer and explains these to the group.

Examples:

- What does it eat?
- How old is it?
- Explain how you would find out.

Each student describes him- or herself as a future scientist. Here is a list of good questions for adults to ask the "imaginary scientists":

- Where did you go to school?
- What did you study?
- Do other people work with you? What kinds?
- What skills do you use in your research?
- What kinds of instruments or technology do you use?
- Do you write about your work?
- Where and how do you get money for your salary and your research costs?
- Who is most interested in your work?

Backgrounder

Debbie & Whales

"Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts. They draw on their prior experience, their interactions with other readers and writers, their knowledge of word meaning and other texts, their word identification strategies, and their understanding of textual features (e.g., sound-letter correspondence, sentence structure, context, graphics)." NS

Writing…results from a person (the writer) trying to tell other people (the readers) the writer's thoughts about the world and how it appears to him or her.

All scientists, whether they study whales or stars, must read and write well and often. They read many different kinds of writing:

- journal articles by other scientists;
- instructions about how to work a new instrument, camera, or computer;
- books written many years ago that may contain clues about the subject they study today;
- e-mail messages from colleagues who have just seen a whale do something wonderful;
- poetry, stories, and children's fables may help scientists to understand what they see in the world.

Writing, after all, results from a person (the writer) trying to tell other people (the readers) the writer's thoughts about the world and how it appears to him or her. Such views of the world range from simple to complex.

Writing About Whales

The ways in which the writer writes about the world can be equally diverse. Consider these writings about whales.

Hannah is 8. Here is what she wrote about a whale.

> "My dad took me on a boat. We saw a whale up close.
>
> The whale blew hard. Its breath was wet and it stunk."

D.H. Lawrence, a British poet, wrote a 38-line poem in 1928 called *Whales Weep Not*. One stanza says,

> "And enormous mother whales lie dreaming suckling their whale-tender young
>
> and dreaming with strange whale eyes wide open in the waters of the beginning and the end..."

This prayer of an Indian from the Kwakiutl tribe of the Northwest coast of North America (collected and translated by anthropologist Franz Boas) addresses a dead stranded killer whale,

> "Oh, it is great how you lie there on the ground, great supernatural one.
>
> What has made you so unlucky? Why, great and good one, are you lying here on the ground?
>
> Friend, supernatural one, why have you been unlucky, friend, for I thought you could never be overcome..."

In the *Sierra Club Handbook of Whales and Dolphins*, whale biologist Dr. Stephen Leatherwood wrote of strandings in a different style (but is the content so different?).

> "...some strandings may be caused by parasite infections that interfere with the animals' biosonar navigational system or their sense of equilibrium. Large areas of brain damage due to parasitic flukes have been found...many cetologists...salvage cetacean carcasses from beaches and investigate possible explanations of how they got there. So far a good general answer has not been found.

In a recent scientific paper, whale biologists reported on the age and sex of western North Atlantic right whales:

> "We evaluated the identification records of 188 identifiable right whales (60% of the

continued

Debbie & Whales *continued*

For whatever purpose a scientist writes or reads, he and she must have and use the basic skills and knowledge of grammar, word-origin, sentence structure, and clear presentation and argument.

known population) collected between 1980 and 1992, for which the age, sex and reproductive state (of adult females) were known. The mean annual identification frequency of adult females was significantly lower than that of adult males ($p < 0.001$), juvenile females ($p < 0.001$) and juvenile males ($p = 0.028$). Amongst cows, non-parous animals were seen significantly less often than parous ones ($p < 0.003$)…"

All of these writers had something they thought was important to say about whales. Yet all of them were writing for different audiences for different purposes. The same person, for example, a whale scientist, may read all of the above writings and get important information from each of them. But the reader has some idea from where the writer viewed the world and, as he reads, will interpret the sense and meaning with that knowledge in mind.

Good Reading—Good Writing

Good writers are good readers. Good readers can be good writers. To be a good writer and a good reader a person must:

- practice both often;
- learn basic skills, such as how words and sentences are built;
- write in a way that is simple and direct, and clear and persuasive;
- collaborate with the reader, or writer, i.e., know something about what the writer is attempting or what the reader expects.

Writing and reading skills are basic to all professions. To a scientist they are essential—and used for many purposes and for many audiences.

- Scientists write grant proposals to get money for research ("Dear National Science Foundation, I need $50,000 to charter a ship because…").
- Scientists write letters to non-scientists to ask support and permission. ("Dear Farmer, I would like to watch the ravens in your corn field for a year.")
- Scientists explain their work to people who may know very little about their work. ("Dear Students, My daughter Maria has asked me to explain to her fellow fourth graders what my job is…")
- Scientists report their results to other scientists for verification and consideration. ("This paper presents data that support the hypothesis that some adult humpback whales, known to be born in Hawaii, consistently overwinter in Alaska.")

For whatever purpose a scientist writes or reads, he and she must have and use the basic skills and knowledge of grammar, word-origin, sentence structure, and clear presentation and argument.

Learning and practicing these skills begins best in pre-school and continues throughout life. No one is too smart or too old to use the dictionary, to learn a new word, or to learn to be more simple and more direct. Start now, no matter what grade you are in.

Debbie & Whales

Choose an Activity

The activities listed below will enable your students to experiment within the theme of "Whales & Words." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: Backbone Letters

Activity 2: Well, Well, Willy. Whales!

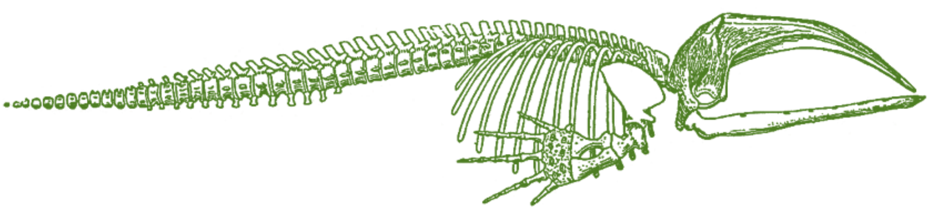
Backbone Letters

Activity 1

***Note:** this activity is designed for a teacher to use with a class.*

Debbie Ferrari is the scientist swimming with the whales in the scene that leads to this activity. Like all successful field biologists, Debbie learns by paying very close attention to the animals she studies. She watches, listens, counts and measures. She learns to see patterns in the behavior of the whales she studies. By knowing these patterns, she can predict the way whales may act that she has yet to meet.

Skeleton of a Southern Right Whale.



Imagine that the "animals" you are studying are words. Take some time to watch, and to listen to words. Inspect them, take them apart, and see how they work.

The lessons you learn will help you predict the way that new words you haven't even seen yet may act when you encounter them.

Like all successful field biologists, Debbie learns by paying very close attention to the animals she studies. She watches, listens, counts and measures.

Think about this—

Every whale has a backbone. The muscles of the whale attach to the backbone and make it strong and flexible. Just as every whale that Debbie studies has a backbone, every word that you study has "backbone letters."

"Backbone letters" are A, E, I, O, U, and sometimes Y. Backbone letters are usually called **vowels**.

There are "muscle and fat" letters in words, too. These are the rest of the letters in the alphabet. They are usually called **consonants**. The "backbone letters in "whale" are "**a**" and "**e**'; the muscle and fat" letters are "**w**", "**h**" and "**l**."

• • •

Sometimes the backbone letter "**e**" looks like a tail at the end of the word. It doesn't make any sound and so may appear to have no use. But, like the whale's tail gives it power, the ending vowel "**e**" can give power to the rest of the word. Look at the silent "**e"** on the end of "mate." It doesn't make a sound. But by being at the end of the word, "**e**" changes the sound of the "**a**" before it.

When an "e" ends a word after a muscle letter like "t", it makes the vowel before the letter "say its name" (or become a "long" vowel).

Because the "e" is there—

the "a" in "mate" says "ay"; without the tail of "e", the "a" in "mat" says "eh"

the "i" in "site" says its name; but the "i" in "sit" says "ih";

the o in "rote" says its name; but the "o" in "rot" says "ah."

Without the backbone "e" at the tail, the backbone letter in front of the ending muscle letter is short and you say it more at the back of your mouth than the front of your mouth.

• • •

Muscle letters (consonants) sometimes act together to change the sounds of the backbone letters (vowels) near them. Even thought we don't say the muscle letters, they do make us say the backbone letter in front of them differently.

Look at "might." We don't sound the "g" or "h" but they act together to make the backbone letter in front of them say its name. Without the "gh" "light" is "lit" and the backbone letter "i" sounds very different.

Can you think of more examples when muscle letters change the sound of backbone letters near them?

• • •

The biology and behavior of whales is complicated. But if we look closely at a whale, how it is made and what it does, it gets easier to understand whale biology. Writing and reading, spelling and pronunciation are also complicated. But if we look at words carefully, reading and writing, spelling and pronunciation get easier.

Well, Well, Willy. Whales!

Activity 2

Group size
small or large group

Time you'll need
20 minutes

Materials you'll need
- *accomplished reader*
- *paper and pencil*
- *radio*

Objectives
- *To recognize a specific consonant set and sound.*
- *To concentrate on a sound source and extract quantitative information from it.*
- *To demonstrate the effect of background noise.*
- *To stimulate discussion about the effects of human-made sound in the world of whales.*

What to do

An accomplished reader reads the following story. (The story can be shortened for younger listeners.) Listeners mark down (we suggest in "fences and gates," groups of five) every time they hear a "wh" sound (Hint: there is one "wh" sound made by letters other than "wh"). Count the total of "wh" sounds.

Turn on a radio tuned to voices (e.g., news, commercials, etc.) Do the exercise again. Was it easier or more difficult to listen to the reader and hear the "wh" sounds? Were the counts the same? Was there greater or lesser error in the counts with the radio on? How is this exercise similar to what whales endure in an ocean area filled with human-made sounds like SONAR and engine noise?

Wanda White was a wonderful woman who walked west from Walla Walla, Washington.

Wanda wanted Willy Wilson to watch whales with her at the west wall of Whistler's Wardrobe (a wharf where the wind whistled in winter).

Whereas wildlife gave Willy the willies and he was wont to whimper, Wanda worried Willy would wail.

Wednesday, Wanda wakened and walked with Willy west, where the wharf was. Wanda wondered, would Willy wail while whales wandered in their wayfaring, whale way?

With wit, Wanda watched westward where whales were.

"Well, well, Willy. Whales," whispered Wanda.

Wanda watched in wonder while wily whale males waltzed and whistled with their wayfaring wives. (One whale watched Wanda.)

Willy watched and watched and watched...when,

Wonder of Wonders!

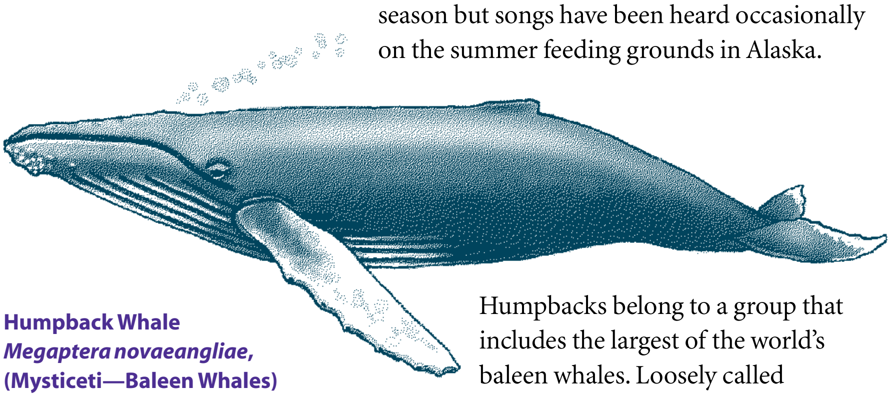
Willy Wilson —without worry—whooped wildly, "Whales! Whales! Wahoo for whales!"

Backgrounder

Humpback Whale

Unlike some whales that seem to slip beneath the surface when they dive, a humpback—well—humps its back, extends its tail in the air and then dives.

Humpbacks whales are famous for their long, haunting and complicated songs. In *Whales* we see a lone male humpback hanging motionless in the mid-water and hear him sing his plaintive song. Scientists need more research in order to know what these songs are really for—courtship, perhaps, or warnings to competing males? No one is certain how humpbacks produce their songs. Roger Payne and Scott McVay first discovered in 1971 that humpbacks sing long and complex songs. Later scientists learned that only males sing, although all humpbacks make sounds. Roger Payne is still studying whale songs, and we see him in *Whales* recording their melodies. Singing occurs mainly during the breeding season but songs have been heard occasionally on the summer feeding grounds in Alaska.



Humpback Whale
***Megaptera novaeangliae*, (Mysticeti—Baleen Whales)**
Adult males are famous for their songs. In Whales, *we hear them singing in Hawaii. Scientist Debbie Ferrari has studied mothers and their calves among the islands for more than 20 years. After they leave Hawaii in the Spring, humpbacks migrate to Alaska to eat all summer. Watch them catch fish with a net of bubbles and a mouthful of baleen.*

Humpbacks belong to a group that includes the largest of the world's baleen whales. Loosely called "rorquals," all whales in this group (blue whales, fin whales, sei whales, minke whales, Bryde's whales) are slender and streamlined. Humpbacks are the stoutest of the group.

Rorquals have many grooves on the throat, extending from the chin to behind the pectoral (or, arm) fins. Once thought to aid in streamlined swimming, grooves instead act like accordion pleats to expand the mouth. Humpbacks have 14-35 grooves, the fewest of any rorqual.

Sometimes names aren't much help in identifying an animal, but humpbacks are an exception. Both the scientific and the common name give us some tips for distinguishing them from other whales. Unlike some whales that seem to slip beneath the surface when they dive, a humpback—well—humps its back, extends its tail in the air and then dives. The habit of extending its tail before it dives turns out to be very helpful to whale biologists. Individual whales can be identified by the bumps, scallops and white and dark patches on their tail fins, or flukes.

Humpbacks also have distinctive pectoral, or wing fins. These fins are almost a third as long as the whale's body, longer (relatively) than any other whale. *Megaptera* means giant fin. The species name *novaeanglandii* comes from their unfortunate history with the whalers of the east coast of the United States and the coast where they were once abundant.

Humpback whales are found throughout the world's oceans. There are populations on both sides of the Pacific and Atlantic oceans. In the North Pacific, populations winter (on the west side) around the Marianas, Bonin, and Ryuku Islands and Taiwan. The eastern Pacific stocks winter in Hawaii and on the American coast and nearshore islands and in the Sea of Cortez and mainland Mexico. Northwest Atlantic humpbacks winter in the West Indies and summer from New England (another link to their species name) to Baffin Island. In the Eastern Atlantic, they winter near the Cape Verde Islands and northwest Africa, and summer north of Norway.

Humpback whales spend spring, summer and early autumn in high latitudes, well away from the equator. Here they feed and little mating activity takes place. But in late autumn, humpbacks set forth on their long annual migration to tropical waters closer to the equator where they court, mate and calve. Typically, wintering areas are found around islands and reefs. Recent evidence suggests that not all individuals may migrate every year. Adult females have been reported over-wintering in Alaska and the Gulf of Maine.

Mother & Calf

Baleen whales, pregnant for almost a year, provide a long period of maternal care—at least three months of lactation on the nursery grounds followed by a long escorting period.

Theme Menu

Mother & Calf

Choose a Science Theme

The "Mother & Calf Scene Resource" supports learning plans for the themes high-lighted below. Press the high-lighted bar for the theme you wish to explore.

- Life Science
- Physical Science
- Earth Science
- Science as Inquiry
- Science in Society
- Nature of Science
- Whales & Words
- Whale Biology

Backgrounder

Life Science

Mother & Calf

"Life Cycles of Organisms
Plants and animals have life cycles that include being born, developing into adults, reproducing, and eventually dying. The details of this life cycle are different for different organisms." NS

Successful reproduction produces offspring that have a good chance of surviving, in turn, to reproduce.

The scene of a humpback mother and her calf departing the nursery grounds for a long trek to faraway feeding areas has been repeated by many generations of whales over thousands of years. The close ties between mother and young and the care and learning that result are adaptations for survival. Maternal care is vital for mammals, but the amount and kind of such care varies widely for vertebrates in general.

Marine vertebrates (back-boned animals that live in the sea, including fish, sharks and whales) have a variety of strategies and adaptations to assure reproductive success. Successful reproduction produces offspring that have a good chance of surviving, in turn, to reproduce.

Strategies

The many reproductive strategies of marine vertebrates can be generally grouped into two kinds:

I. Production of many young, with little if any maternal care;

II. Production of fewer young that receive some, or much, parental care. Parental care can be divided into:

   A. pre-hatching or pre-birth; and,

   B. post hatching or post-birth.

Let's look at these groupings in more detail

I. High Production / No Care

Most fishes use the strategy of producing many, many tiny young. The chances of some surviving are increased by the great number produced. In all but a few species, eggs and sperm are "broadcast" into open water. Once the egg is released into the water, the mother provides no care. Some fishes (damsel fishes are one example) place their eggs in nests and guard them until they hatch.

Broadcast eggs are fertilized and float in the currents as part of the plankton. When the nutrition from the yolk is exhausted, the young fish hatches. The resulting free-swimming transparent larval forms continue to live in the plankton feeding on zooplankton. After days or weeks, the tiny larval forms transform into juveniles and settle to the bottom or school in mid water.

II. Low Production/ High Care
A. pre-birth care/ no post-birth care

Surf Perches and Sharks and Rays
Not all fish broadcast their eggs into open water. The surf perch family, found in abundance in the coastal waters of California and Japan, give birth to live juveniles. The number of young produced is limited by the size of the mother and her ability to carry developing young. During gestation, maternal nutrients are transferred to the developing young via capillary systems in the greatly expanded fins of the young and the ovarian tissue of the mother.

All sharks and rays either give birth to live young or lay eggs. Each egg hatches into a single juvenile—a miniature adult. Sometimes the hatching occurs inside the mother and she continues to nourish the embryos (one to dozens, depending on the species and the size of the mother) until they fully develop and are born. Any maternal care is limited to gestation

continued

Backgrounder

Life Science

Mother & Calf *continued*

Seals and sea lions are mammals and mothers suckle their young with milk. Even before weaning, mothers leave their young alone in a colony while they go out to sea to forage.

and pre-birth behavior, such as migration into pupping grounds where predation is lower than the open sea, or the placement of eggs in safe places, such as in cracks and or beneath rocks.

Sea Turtles and Sea Snakes
Sea turtles lay eggs. Their maternal care is limited to pre-hatching behavior. Sea turtles may migrate for hundreds or thousands of miles to nesting beaches. The female leaves the water and digs a large hole in the beach above the wash of the waves. Here she deposits the eggs, buries them and leaves. There is no maternal care after they hatch. The young are on their own to find the sea and move on.

Sea snakes give birth to live young. There is no maternal attention after birth. Care is limited to gestation and delivery of the young in a safe area of the reef.

B. pre-birth care/ no post-birth care

Seahorses and Cardinal Fish
Some fishes afford both pre-birth care and some post-birth care. In seahorses, and their pipefish relatives, the male retains the juveniles in a pouch on his belly. The young go forth to feed and return to shelter until they have grown to a size at which their survival is more likely. Male cardinal fish, found on most tropical reefs, provide protection for their young within their mouths. The young come and go in a manner similar to the sea horses using their father's pouch.

Sea birds
Sea birds provide significant care for their very few young (often only one), from incubation of the egg to care of the young until it is able to fly and feed on its own. In some species—boobies, frigate birds, and terns—parents alternate care. One parent will incubate the young while the other parent forages—sometimes far at sea.

Seals and Sea Lions
Seals and sea lions are mammals and mothers suckle their young with milk. Even before weaning, mothers leave their young alone in a colony while they go out to sea to forage. There is no care from the fathers in the colony, but there may be significant teaching by adult males and females when the juveniles enter the water.

Toothed Whales
(Dolphins, Porpoises, and Orcas)
After a lengthy gestation, dolphins receive substantial post-birth care immediately from birth and during the nursing period. A mother gives birth to a single calf (rarely to twins). Calves are born tail first, so that they continue to receive oxygen from their mother as long as possible. Mothers and accompanying adults assist the newborn in reaching the surface where it takes its first breath. As juveniles and young adults, dolphins receive significant care from the group in which they live.

Baleen Whales
Baleen whales, pregnant for almost a year, provide a long period of maternal care—at least three months of lactation on the nursery grounds followed by a long escorting period. During migrations of thousands of miles, there may be significant teaching of the young by adults. Many species of toothed whales such as dolphins and killer whales include young in large family groups. Baleen whales, as far as we know don't form such social groups and mother and calf are fairly independent of large group interactions.

Mother & Calf

Choose an Activity

The activities listed below will enable your students to experiment within the theme of "Life Science." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: Moms and Babies

Moms and Babies

Activity 1

Group size
Individuals or small groups

Time you'll need
15-20 minutes

Materials you'll need
- *copy of this page*
- *pencil or pen*

What to do

These mothers feed milk to their babies:

SEAL	WHALE	MOUSE
GOAT	HORSE	DOLPHIN
BEAR	MONKEY	

These mothers lay eggs. The yolk feeds the baby inside the egg:

TUNA	SNAKE	FROG
LIZARD	SHARK	TURTLE
HAWK	PENGUIN	

Draw a square around the animals that feed their babies milk.
Draw an oval around the animals that lay eggs.

SEAL	TURTLE	HAWK
HORSE	MONKEY	WHALE
SHARK	GOAT	BEAR
PENGUIN	LIZARD	FROG
SNAKE	MOUSE	TUNA
DOLPHIN		

Backgrounder

Earth Science

Mother & Calf

"Properties of Earth Materials

Earth materials are solid rocks and soils, water, and the gases of the atmosphere. The varied materials have different properties that make them useful in different ways… The sun provides the light and heat necessary to maintain the temperature of the earth."

The major currents of the world bear names, as the persistent geographic features they are.

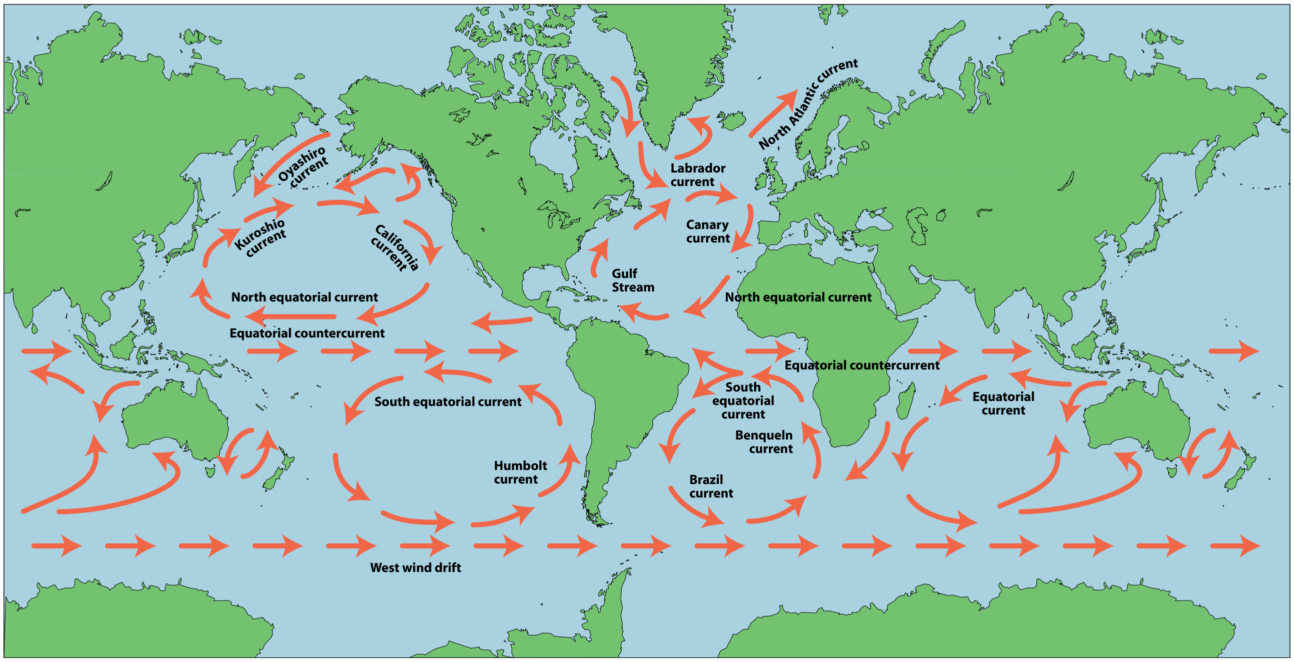
The Moving Ocean

When baleen whales leave their seasonal courting and breeding grounds to travel to productive areas rich with food, they swim through thousands of miles of ocean. It is not a uniform ocean. Its waters are complex combinations of currents moving in all directions—east, west, north, south, and up and down.
As whales travel through these moving waters, they encounter water masses of different temperatures and salinity (i.e., salt and chemical content).

Currents

Currents form in the oceans for several reasons. The chief influence on currents is energy transferred from wind blowing on the sea surface. The major ocean current systems are produced by the major wind belts around the globe. These winds are generally steady and persistent in direction. They are caused by differential heating of atmospheric air masses. As winds blow across the face of the spinning Earth, they are deflected by the earth's rotation. This deflection of direction is called the *Coriolis effect.* As the Earth rotates from west to east, the spinning of the planet causes a slight displacement of the moving air— to the right in the Northern hemisphere, and to the left in the Southern hemisphere. Prevailing winds push surface waters into motion, producing slow but massive laterally moving currents that transport great volumes of water across great distances. Currents affect the distribution of marine animals and primary producing plant cells. Currents also influence weather and

continued

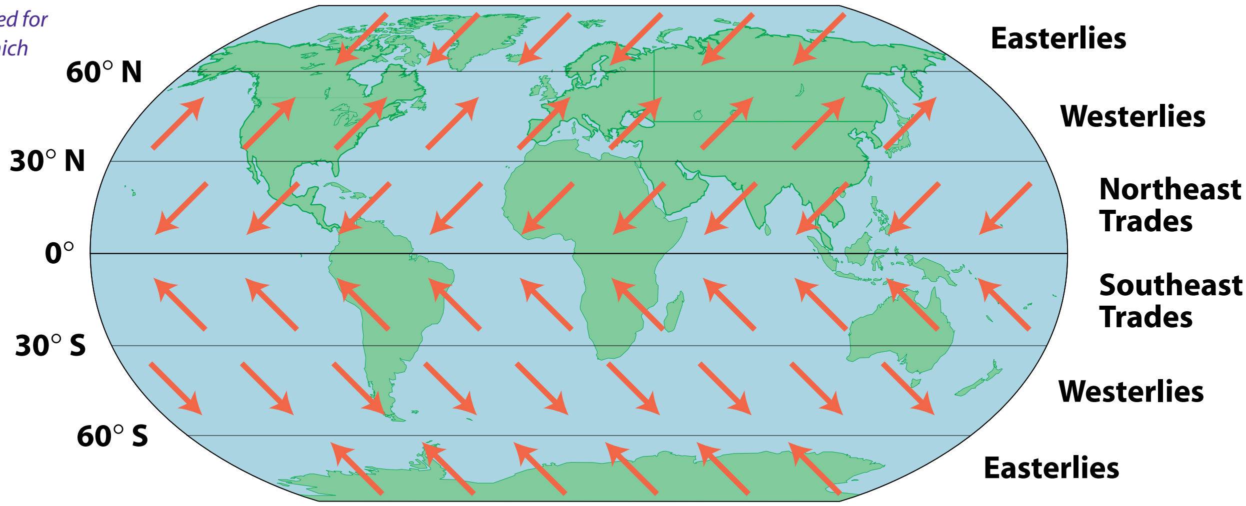


Backgrounder

Earth Science

Mother & Calf *continued*

Major wind belts of the earth and their prevailing directions. *(Note: winds are named for the direction* ***from*** *which they are blowing.)*



climate by transferring heat energy from one area to another. Warm currents carry and release heat; cold currents absorb heat.

The force of the wind on the surface of the sea also affects deeper layers of water. Each layer receives a decreasing amount of energy. As a result a current's velocity is reduced with depth. The depth at which wind stress fails to impact motion is usually within the upper hundred meters.

…the trade winds, blowing toward the Equator in both hemispheres, push water toward the Equator from east to west. Thus, net water movement is east to west.

The presence of the continents and other land masses also affect currents. For example, the trade winds, blowing toward the Equator in both hemispheres, push water toward the Equator from east to west. Thus, net water movement is east to west. Water piles up on the western side of ocean basins (e.g. against Asia in the Northern Pacific; against South America in the South Atlantic) and flows along the coasts away from the equator.

Differences in water density are important factors in both shallow and deeper currents. Tides drive currents along coastal embayments. But winds influence surface currents and are the main drives of global current patterns. To fully understand current patterns, it helps to realize that the seawater of the world's oceans is made up of a number of different water masses, based on density differences due to different temperatures and salinity.

Salinity

The range of salinity, or dissolved salts, in the sea is smaller than the wide range of temperatures. Salinity is usually expressed as "parts per thousand = ‰" rather than percent (= "parts per hundred = %"). Open ocean sea water in most of the world varies from 34-37‰(which also equals 3.4% to 3.7%) and averages 35‰. Inshore and in enclosed areas, fresh water runoff from rivers can depress salinity to 0‰. In hot, enclosed areas of high evaporation such as the Red Sea and Persian Gulf, salinity may rise to 40‰.

Temperature

The temperature range of seawater affects the density of seawater far more than differences in salinity. The salt content of seawater depresses its freezing point below the fresh water freezing point of 0° C (32° F) to -1.9° C (28.5° F) for seawater of salinity of 35‰.

continued

Backgrounder

Earth Science

Mother & Calf *continued*

Movement in the deep-water mass (below the mixed layer and the thermocline) is isolated from the wind. But it is influenced by changes in surface water.

Seawater temperature decreases with increasing depth and increasing latitude. Near-freezing seawater occurs in polar seas and in the deep sea.

In sun-heated tropical waters, seawater is often 20°-30° C (68°-86° F) throughout the year. Below the warm sun-heated water of the surface, temperature falls rapidly with depth, most markedly between 16-986 feet (5-300 m.). This depth zone of most rapid temperature decline (the depth of which varies with latitude and area) is the called the *thermocline*. Below the thermocline, water temperature continues to decrease with depth but at a much slower rate. In effect, one can consider the water mass below the thermocline to be essentially the same temperature. Tropical waters have a thermocline year-round. Temperate waters have a thermocline in the summer. Cold polar waters lack a thermocline; temperature is essentially the same from surface to bottom.

The upper water mass of the oceans, the area above the thermocline, is in constant motion, with currents and waves. Waves range in size from ripples to large ocean swells. We can easily see them.

Currents are water movements that transport water masses horizontally or vertically. Masses of a given density (combination of temperature and salinity) tend to move at different rates than other water masses and maintain their integrity. Mixing does occur at boundaries.

Upwelling

Vertical movement of water results from the sinking of colder denser water from the surface to deeper layers. Upwelling water, in which nutrients have concentrated, flows upward in certain areas. Along the eastern margins of ocean basins wind driven surface currents flow toward the equator along the coast. Simultaneously the rotation of the Earth tends to displace the moving surface waters offshore. Deeper water flows upward to replace the surface water moving offshore.

Deep Water Movement

Movement in the deep-water mass (below the mixed layer and the thermocline) is isolated from the wind. But it is influenced by changes in surface water. Denser seawater (colder and/or saltier) sinks in seawater of less density. For surface water to sink into the deep water mass it must increase in density. This can happen in two ways. Sun-heated tropical water increases in salinity due to evaporation. The Gulf Stream in the Northern Atlantic transports warm high saline water northward. Near Iceland and Greenland, it meets the southward flowing, cold Labrador current. Mixing of the water masses forms cold, saline—and denser—water that sinks to form North Atlantic deep water. This mass moves very slowly south over time. Eventually, perhaps a century after it sinks, it surfaces in the Antarctic region.

Weather Effects

One key to the ocean's effect on weather is the very high heat capacity of water. Heat capacity refers to the quantity of heat required to raise the temperature of 1 gram of substance 1 C°. In other words, once water is heated up, it retains heat even as air temperature drops.

Sun-heated land cools off faster after dark than does seawater. This gives rise to the onshore-offshore effect of local winds. During the day, land heats up quickly. The adjacent ocean heats up slowly. Hot air over the land rises; cooler air from the sea rushes in to fill in behind it. We feel this as a daytime onshore breeze. At night the land cools quickly. Air over the warmer ocean rises; cool air from land fills in behind it We feel this as nighttime offshore breeze. This is one example of ocean's effect on local weather.

Activities Menu

Earth Science

Mother & Calf

Choose an Activity

The activities listed below will enable your students to experiment within the theme of "Earth Science." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: Cold Water Currents

Activity 2: Salty Waters

Activity 3: Cold Water, Colder Air

Cold Water Currents

Activity 1

Group size

Demonstration to be led by an adult

Time you'll need

20 minutes or more (though colored ice cubes must be frozen ahead of time)

Materials you'll need

- *water*
- *dark blue food coloring*
- *ice cube tray and freezer*
- *ground pepper*
- *rectangular glass baking dish (or a small rectangular aquarium)*
- *a glass, bowl, or measuring cup*

Objective

To observe how temperature differences in ocean waters affect currents.

What to do

Fill the glass, bowl, or measuring cup with water and mix in the dark blue food coloring. Fill the ice cube tray with the colored water and place it in the freezer.

After the blue ice cubes are frozen, fill the glass baking dish or aquarium half full with warm tap water. Sprinkle some ground pepper onto the surface of the water. Does the pepper move? What is the direction of the surface current of the water?

Next, take one of the blue ice cubes and place it in the water at one end of the glass dish, or aquarium. Watch the direction of the blue water as the ice cube melts. In which direction is it flowing? Does the blue water stay on the bottom or float to the top? Did the moving pepper change directions?

Now empty your aquarium and re-fill it with clear, warm water and sprinkle it with pepper. This time put a colored ice cube in each end of the glass dish. What do you observe?

What's happening?

You've just made a basic model of the Earth's oceans: cold at each end (the poles) and warm in the middle (the equator). Water at the equator receives more direct sunlight and is warmer than water at the poles. Polar waters receive only slanting sunlight in the summer and no sunlight in the winter. Cold water is heavier than warm water so the colder, heavier waters in polar regions sink to the ocean floor and flow along the bottom to the equator. These flows are called density currents. Cold water is denser than warm water.

Salty Waters

Activity 2

Group size

Demonstration to be led by an adult

Time you'll need

30 minutes

Materials you'll need

- *a wide-mouthed jar (a mayonnaise jar will do) or a large glass measuring cup*
- *two large glasses of water*
- *red food coloring and green food coloring*
- *a carton of table salt*

Objective

To observe how dissolved salt (salinity) affects the density of water.

What to do

In one glass of water, add about a half teaspoon of salt (or 2 grams) and a few drops of red food coloring. Mix it well, then pour it into the jar. Let the mixture stabilize. What do you observe?

In the other glass, dissolve 3 teaspoons (or about 12-15 grams) of salt and a couple of drops of green food coloring. Slowly pour this mixture into the jar. What happens? Let the mixture sit for a while. Does it eventually mix together? How can you tell?

What's happening?

Heavier, or denser, water sinks to the bottom in lighter, or less denser water. Two major factors influence the density of water:

1. temperature, and

2. salt content.

In this activity, all of the water is at the same temperature so it does not affect the density. However, the water with more salt (higher salinity) is heavier, denser, than the water with less or no salt.

In the ocean, salinity is due to many chemicals beside just the salts in table salt. All sorts of conditions affect salinity in the oceans. Fresh water flowing in from rivers, lakes and ice-melts make ocean water less salty. Evaporation in hot places, like the Red Sea, make sea water saltier. Water becomes heavier as it becomes saltier, and sinks below less salty water.

Earth Science

Cold Water, Colder Air

Activity 3

Group size

Demonstration to be led by an adult
Students can record data

Time you'll need

About an hour

Materials you'll need

- *2 large glass jars with lids (e.g., mayonnaise jars)*
- *2 thermometers (best if scaled in both Fahrenheit and Celsius scales)*
- *a large jug of water (about 1 gallon, or 4 liters) at room temperature*
- *a refrigerator or freezer*
- *graph paper*
- *a watch or clock*
- *pens or pencils with green and blue ink/lead*

Objective

To observe how air and water are affected by temperature changes.

What to do

Put one of the thermometers in an empty jar and screw on the lid. After 2 or 3 minutes, note the temperature on the thermometer. Record the temperature of the air inside the jar on your paper.

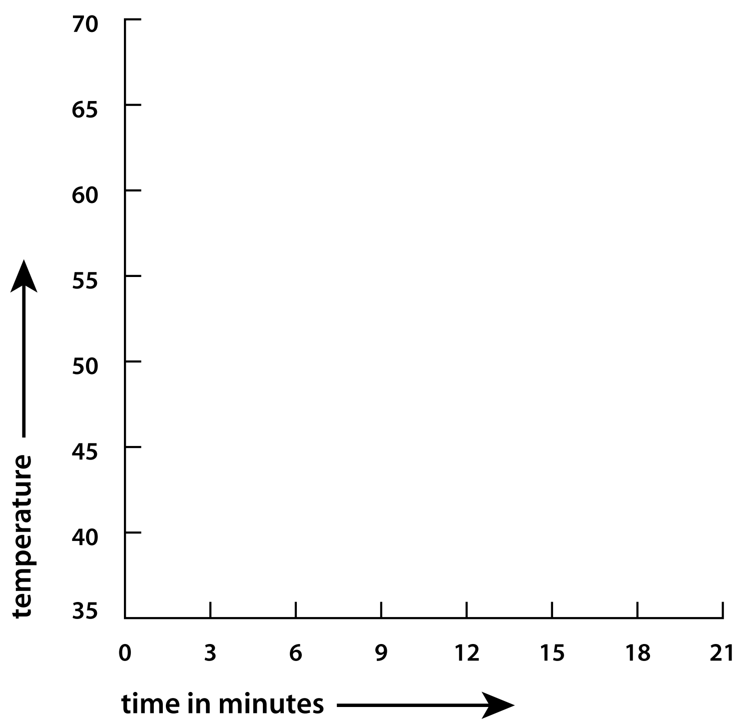
Fill a second jar with water from the jug. Immerse a second thermometer in the jar of water, then screw on the jar lid.

Place both jars in the refrigerator and record the temperatures shown on the two thermometers every three minutes for 21 minutes (or more). Plot your results on a scale similar to the one shown below. Plot the temperature of the air in green and the temperature of the water in blue.

What do you notice?

What's happening?

Temperature changes happen much more quickly in air than they do in water. The temperature of the atmosphere changes much more quickly than the temperature the ocean. Air that gets blown across the sea tends to be either warmed up or cooled down, depending on the temperature of the ocean. This is a major reason why coastal areas tend to be cooler than inland areas in the summer and warmer than inland areas in the winter.



Backgrounder

Humpback Whale

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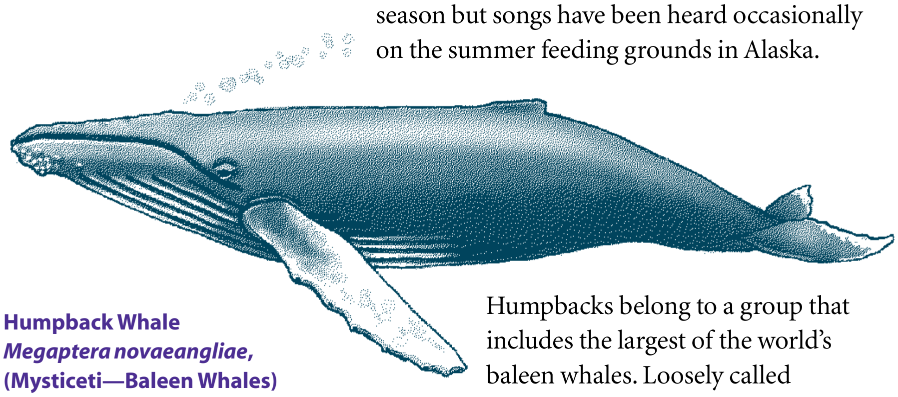

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Sometimes names aren't much help in identifying an animal, but humpbacks are an exception. Both the scientific and the common name give us some tips for distinguishing them from other whales. Unlike some whales that seem to slip beneath the surface when they dive, a humpback—well—humps its back, extends its tail in the air and then dives. The habit of extending its tail before it dives turns out to be very helpful to whale biologists. Individual whales can be identified by the bumps, scallops and white and dark patches on their tail fins, or flukes.

Humpbacks also have distinctive pectoral, or wing fins. These fins are almost a third as long as the whale's body, longer (relatively) than any other whale. *Megaptera* means giant fin. The species name *novaenglandii* comes from their unfortunate history with the whalers of the east coast of the United States and the coast where they were once abundant.

Humpback whales are found throughout the world's oceans. There are populations on both sides of the Pacific and Atlantic oceans. In the North Pacific, populations winter (on the west side) around the Marianas, Bonin, and Ryuku Islands and Taiwan. The eastern Pacific stocks winter in Hawaii and on the American coast and nearshore islands and in the Sea of Cortez and mainland Mexico. Northwest Atlantic humpbacks winter in the West Indies and summer from New England (another link to their species name) to Baffin Island. In the Eastern Atlantic, they winter near the Cape Verde Islands and northwest Africa, and summer north of Norway.

Humpback whales spend spring, summer and early autumn in high latitudes, well away from the equator. Here they feed and little mating activity takes place. But in late autumn, humpbacks set forth on their long annual migration to tropical waters closer to the equator where they court, mate and calve. Typically, wintering areas are found around islands and reefs. Recent evidence suggests that not all individuals may migrate every year. Adult females have been reported over-wintering in Alaska and the Gulf of Maine.

Whale Graveyard

*The lives of great whales
depend on the sun.
The deaths of great whales
give life to creatures in the
dark deep sea.*

Theme Menu

Whale Graveyard

Choose a Science Theme

The "Whale Graveyard Scene Resource" supports learning plans for the themes highlighted below. Press the highlighted bar for the theme you wish to explore.

Life Science
Physical Science
Earth Science
Science as Inquiry
Science in Society
Nature of Science
Whales & Words
Whale Biology

Backgrounder

Life Science

Whale Graveyard

"The Characteristics of Organisms
Organisms have basic needs. For example, animals need air, water and food; plants require air, water, nutrients, and light. Organisms can survive only in environments in which their needs can be met. The world has many different environments, and distinct environments support the life of different types of organisms." NS

Most of the plant life in the ocean is tiny, single-celled and floating near the sea surface. Such tiny plant forms, generically called phytoplankton, form the basis of most marine food webs.

The lives of great whales depends on the sun. The deaths of great whales give life to creatures in the dark deep sea. Life, death; darkness, light; surface, depth. What links these contrasting elements?

Sunlight and Life

Almost all life on earth depends on the ability of green plants to use the energy of the sun to make food. Plants use the process of photosynthesis to make energy-rich organic molecules (starch, sugars) from inorganic materials (carbon dioxide, water). To do so, they must have sunlight and nutrients, (iron, nitrogen, potassium, phosphorus).

Most of the plant life on land is relatively large and rooted in the ground—grasses, shrubs, trees. Most of the plant life in the ocean is tiny, single-celled and floating near the sea surface. Such tiny plant forms, generically called phytoplankton, form the basis of most marine food webs.

Blue whales (20 meters long or so) eat shrimp-like krill (50 mm long or so). Krill eat phytoplankton (microscopic). Phytoplankton photosynthesize food. From sunlight to blue whales in the three steps is an amazing transformation of energy into matter.

Phytoplankton is not evenly distributed in the ocean, in part, because light is not evenly distributed. Plants need light to survive. Seawater scatters and absorbs light. The more particles suspended in seawater the more light is absorbed. In clear tropical waters enough sunlight to support photosynthesis may penetrate to 100-150 m. In coastal waters, where soil run-off may cloud the sea, light is absorbed quickly and plants photosynthesize in only the upper few meters.

Phytoplankton are not evenly distributed even within the light-filled surface layers. Single-celled plant-life blooms in areas where currents concentrate the nutrients they need to grow. When such blooms occur, they absorb light and reduce the depth of photosynthesis. Tropical waters are very clear—not only because of having fewer suspending particles, but because nutrients are in short supply and phytoplankton don't bloom

In areas where great blooms of phytoplankton cover square kilometers of ocean surface, feeding animals also swarm. The nutrient rich waters of Antarctica and the California coast (to name just two areas) support great seasonal fields of marine plants. The plant-eating krill-shrimp grow here in phenomenal numbers, coloring great expanses of water with their red bodies. It is here that blue whales gather to seine the shrimp-filled water

Life in the Dark

If plants need sunlight to grow and if it's dark in the deep sea, what do deepsea animals eat?

Until some important discoveries were made in the 1970's, marine scientists thought that all animals in the deep sea depended on food that drifted down from the productive upper layers. Such material takes the form of dead organisms, fecal material, and cast off exoskeletons

continued

Backgrounder

Life Science

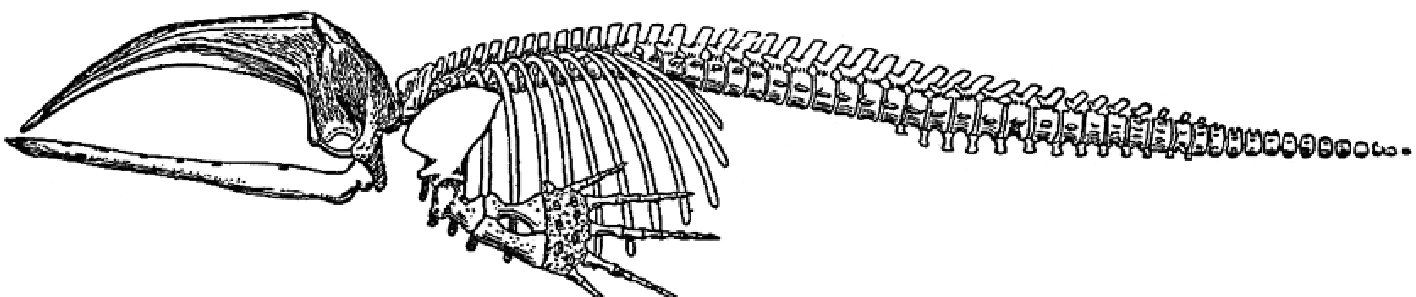
Whale Graveyard *continued*

(from shrimps and their relatives for example). A dead whale carcass sunken to the bottom is a rich food resource for many kinds of animals, from starfish to sharks and hagfish.

In the 1970s, scientists discovered new communities of animals on the sea bottom about 3,000 meters deep. Their food webs are independent of plants and the energy of sunlight. Instead, the basis of these food webs are bacteria. Communities of animals— clams, worms, crabs, shrimps, octopus, fish— live around volcanic vents in the sea floor. The vents gush forth very hot, chemically rich water. Bacteria use the energy from the sulfide chemicals in the hot water to produce food. Animals eat the bacteria, much like surface animals eat phytoplankton.

More recently, scientists have found that whale carcasses sunken to the sea floor provide oases for the bacteria-eating animals of the vent areas. Some bacteria convert the fatty substances of the whale body into sulfide-rich compounds. (When bacteria do this in shallower water, we can smell the strong rotten-egg odor of hydrogen sulfide if we pull up a chunk of the "rotting" whale carcass.) The sulfide-loving bacteria of the vent areas colonize the whale carcass. They provide a food source for vent-animals even far from the actual vents.

Thus, dead sunken whales provide a distribution path for vent animals as well as providing food for deepsea bottom dwellers. The energy of sunlight and plants, the energy of sulfides and bacteria, the food webs of the surface and the sea floor, all are combined on the body of a dead whale.



Skeleton of a Southern Right Whale

Whale Graveyard

Choose an Activity

The activities listed below will enable your students to experiment within the theme of "Life Science." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: Culturing Green Water

Activity 2: What Whales Eat

Life Science

Culturing "Green Water"

Activity 1

Group size:

Any size—to be demonstrated and led by an adult

Time you'll need:

30 minutes for preparation; 2 weeks for occasional observation and analysis

Materials you'll need:

- *pond water (collected from a local lake or pond)*
- *two 1-liter glass jars or small aquariums*
- *some freshly hand-cut hay or grass, or a pond plant (from a lake or pond, or from the pet store)*
- *two fluorescent grow lights*
- *a microscope (optional)*
- *a pen and paper*

Objective

To observe the greening of the pond water (i.e., the growth of phytoplankton) over time and understand the process of photosynthesis.

What to do

First, take a small sample of your pond water and look at it under a microscope. [Note: You may use tap water, but let it sit in an open container for several days first to make sure any toxic chlorine, put into the water to disinfect it, goes away] Can you see living organisms? Write or draw descriptions of them on a piece of paper.

Now place equal parts of the water and the hay or plant in each of your jars or aquariums. Take notes on the appearance of the water at this time: Is it clear? If not, what color is it? Can you see through it?

Hang one grow light over one of the jars and leave the light on at all times. Place the second jar under the other grow light *only* for four hours per day. The other 20 hours of the day this jar should be completely shielded from light by being wrapped in heavy paper or placed in a closet or cupboard.

On a daily basis, record your observations about any changes in each of the two jars over a two week period. At the end of the two weeks, draw a picture of what happened.

What's happening?

Most plants on land are big and rooted to the ground, like trees, shrubs and grasses. Plants in both fresh water and in the sea are mostly very tiny single cells. (There are some larger, attached plants in fresh water and the ocean, too.) All plants, large or small, in water or on land, depend on a green chemical called chlorophyll to make food. Plants use energy from the sun to make their own food through photosynthesis (this word literally means "making" (= synthesis), with light (= photo). In the process of photosynthesis, plants use carbon dioxide, water, nutrients, and sunlight to produce oxygen, sugar and energy. The sugar molecules then combine to form starch and cellulose, energy-rich organic molecules that are food for the plants. One of the critical chemicals for photosynthesis is chlorophyll, which is bright green.

When you leave your pond water and plant exposed to sunlight for a couple of weeks, the tiny plants in the water thrive and produce more and more cells that contain chlorophyll. As the number of cells increase, the water gets greener and greener.

The amount of sunlight that plants in the ocean receive is extremely important to the survival of marine animals. Blue whales depend on small shrimp, called krill, for their food. In turn, krill eat tiny free-floating single-celled marine plants called phytoplankton. The phytoplankton in the sea are related to the green plant cells in your aquarium. Phytoplankton make their food through photosynthesis, so they thrive in places where there is abundant sunlight and where the sea is rich in nutrients. Latitude, season, and water clarity all affect how much sunlight is absorbed by the ocean.

Further exploration

What would happen if you put your glass of pond water in a dark room now? Would it stay as green as it was after two weeks in the sun? Have you ever left a blanket or board or anything on your lawn for a few days? What happens to the grass underneath? Why?

What Whales Eat

Activity 2

Group size

Individuals or small groups

Time you'll need

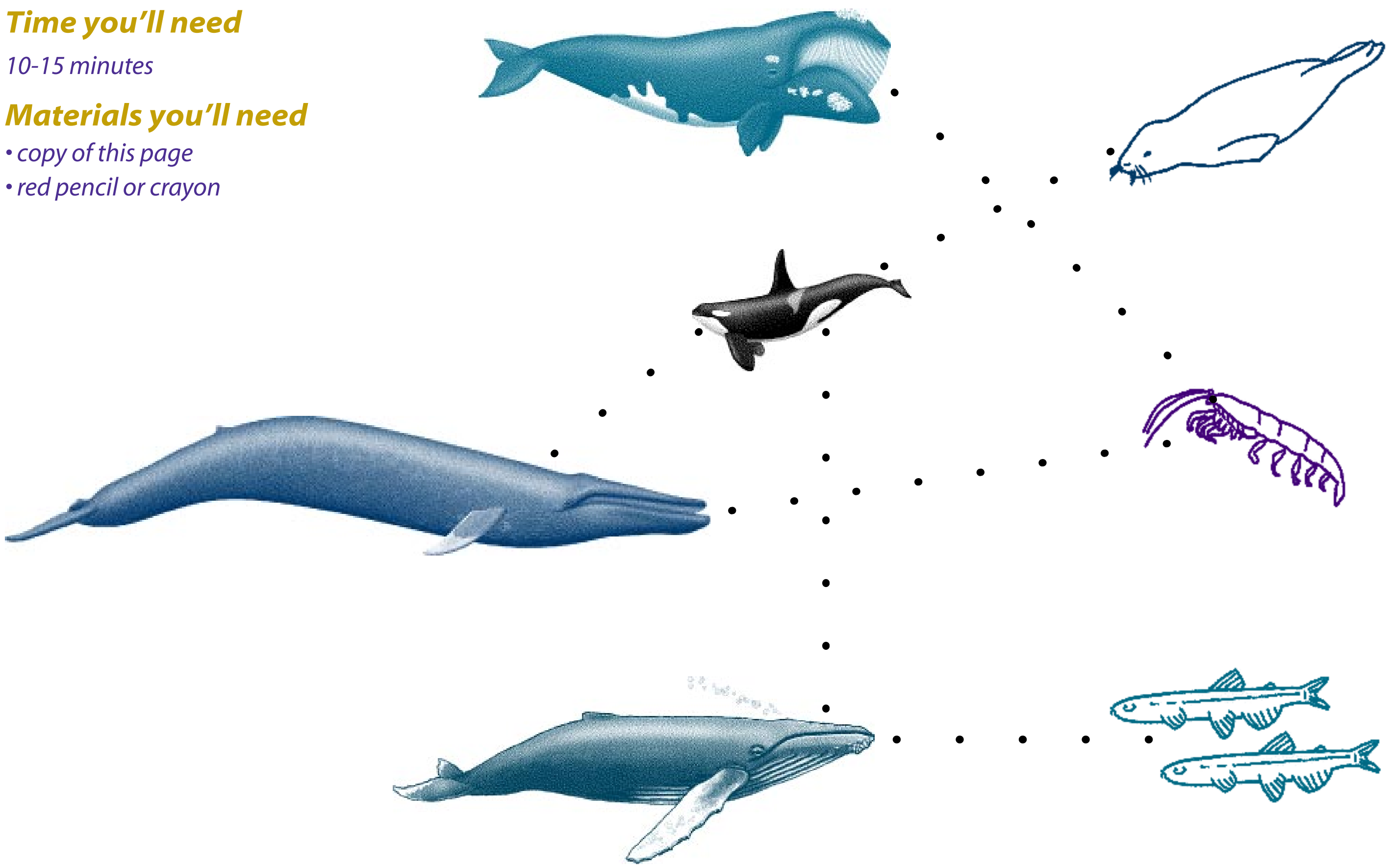
10-15 minutes

Materials you'll need

- *copy of this page*
- *red pencil or crayon*

What to do

Connect the dots with a red line from the whale to its favorite food



Connect the dots to see the way each whale eats:

gulps • • • • • • • • **Humpback whale**

bites • • • • • • • • **Orca whale**

skims • • • • • • • • **Right whale**

Bubble Nets

In Whales, *we see several humpback whales feeding on schooling fish at or near the sea surface. This behavior was first reported nearly a century ago and is still under study.*

Theme Menu

Bubble Nets

Choose a Science Theme

The "Bubble Nets Scene Resource" supports learning plans for the themes highlighted below. Press the highlighted bar for the theme you wish to explore.

Life Science
Physical Science
Earth Science
Science as Inquiry
Science in Society
Nature of Science
Whales & Words
Whale Biology

Backgrounder

Science as Inquiry

Bubble Nets

*"**Understanding About Science and Technology***
People have always had questions about their world. Science is one way of answering questions and explaining the natural world." NS

Complex ideas can often be easily expressed by using metaphors, similes or adopted phrases. Because scientists must practice skepticism, the intended (and inadvertent) meaning of words must be rigorously considered.

The Value of Skepticism

Measurement, functional equations, and other numerical descriptions and expression of ideas are essential in communicating about science. Words, of course, are also useful—perhaps unavoidable—but we need to be aware of their weaknesses and pitfalls. Complex ideas can often be easily expressed by using metaphors, similes or adopted phrases. Because scientists must practice skepticism, the intended (and inadvertent) meaning of words must be rigorously considered.(Of course, the same skepticism needs to be applied in evaluating mathematical expressions, too, but this Backgrounder and supporting activities focuses on verbal expression.)

Scientists evaluate a scientific explanation by asking:

Is that statement accurate?

On what information do I base its accuracy?

Do I or the person who made the statement have sufficient information to rely on the statement as an accurate explanation?

If not, what information, definition, or clarification do I need to be confident of its reliability?

The Seduction of Words

Words can mislead. We can get so accustomed to a phrase from regular use that we grow overly confident that we understand it and that our understanding is "true." Scientists need to be very careful in their use of words and metaphors. Every word needs to be clearly defined. Even if the word seems to need no definition, the connotations, nuances and logical implications of its use must be considered.

Consider some examples. "Survival of the Fittest." This time-worn phrase is supposedly convenient shorthand for Charles Darwin's theory of evolution. But does its briefness and familiarity mislead us? Is it an accurate abbreviation likely to be comprehended by persons new to the idea? Does "fit" refer to physical condition? Does it mean that the "survivor" bests the non-survivor in some direct confrontation?

In *Whales*, we see several humpback whales feeding on schooling fish at or near the sea surface. This behavior was first reported nearly a century ago and is still under study. Many people call this feeding activity "bubble netting." It is a convenient and vivid metaphor. But—could it be misleading? Do we know enough about the behavior to call it that?

Let's examine the phrase, "bubble netting": "Bubble" certainly seems warranted. The exhalations of whales are released at depth and during swimming.

What about "netting"? That chosen word implies many concepts for which we as yet have no quantified data (although scientists are trying to collect measured observations). The resulting bubbles seem to consistently form a circular pattern that apparently entraps schools of fish. But "netting" implies behavior that may be learned. Do we know whether whales teach other whales to perform this behavior? Or do all whales know how to feed by using bubbles instinctively? Do all humpbacks feed in this manner, or do only whales in a certain area feed this way?

continued

Backgrounder

Science as Inquiry

Bubble Nets *continued*

Many kinds of animals seek food in groups for reasons other than feeding. For example many songbirds forage in groups in order to avoid predators, female lions forage in groups to protect cubs from aggressive males.

"Netting" also implies the construction or adaptation of an external device. In fact, one leading whale scientist has written (perhaps seduced by the word more than by facts) that the use of bubbles in humpback feeding can be considered to be "tool-making behavior."

Using that phrase, in turn, implies a clear and commonly held definition for "tool." But does everyone who uses the word "tool" mean the same thing by it? To some definers of the word, a tool is a tangible object. Can a bubble be a tool? If it is, then is the bark of a border collie (also produced by exhaled air) the use of a "tool" to influence the behavior of sheep? Or does a "tool" need to be tangible, like the sticks used by ants, woodpeckers, or chimpanzees? Does a "tool" need to a *modified* natural object (like an adze) or just a found object employed in a novel way (like a stick for digging out grubs)?

"Bubble netting" sometimes involves more than one whale. Humans netting fish often form groups to help spread and retrieve a seine net. Does the term "bubble netting" inadvertently imply team-work by whales? In *Whales*, a group of humpbacks rush to the surface at the same time, gulping herring that have concentrated into a dense group as a result of the bubbles released by one or more of the whales. Some scientists have called this "cooperative feeding" and have described the members of the group as acting like members of a basketball team with one whale setting up the play and the others repeatedly playing the same position.

This is a pleasing metaphor. But what data do we need to substantiate it? Are the whales "cooperating" or are they in the same place at the same time because the prey are concentrated there? Some scientists discriminate between "cooperative foraging" (which implies a functional relationship) and "group foraging" (purely a descriptive term). Many kinds of animals seek food in groups for reasons other than feeding. For example many songbirds forage in groups in order to avoid predators, female lions forage in groups to protect cubs from aggressive males. Alternatively, individuals may forage in groups simply because prey is so heavily concentrated that large numbers of predators can feed without undue competition.

"Cooperation" should involve some sort of coordination of activity, allowing an increase in individual energy intake rates, or a decrease in variability in energy intake rates. In order to demonstrate cooperation, individual energy intake rates for individuals foraging alone versus those foraging in groups, should be determined.

Scientists are working to collect observations that will help substantiate or correct the kind of assumptions and complex hypotheses contained in the deceptively simple phrase "bubble netting."

Activities Menu

Science as Inquiry

Bubble Nets

Choose an Activity

The activities listed below will enable your students to experiment within the theme of "Science as Inquiry." Press the corresponding bar for the activity you wish to explore. You can return to this page to select a different activity by clicking the "Activities Menu" button at the top of any activity page, or you can scroll through the activities using the forward and backward arrows. When you have completed all of the activities, click on the "Theme Menu" button to choose a different theme to explore.

Activity 1: A Whale in Alaska

Science as Inquiry

A Whale In Alaska

Activity 1

Group size
Individuals or small groups

Time you'll need
10 minutes

Materials you'll need
• blue crayons

What to do

Find these words and color the letters in them blue. (Some letters can be used more than once.)

BUBBLE	THAW	WHITE	NET
TAIL	WAVE	BAY	

W	H	I	T	E	M
B	U	B	B	L	E
T	M	A	N	E	T
H	P	Y	O	U	A
A	B	A	C	K	I
W	A	V	E	O	L

Now find the hidden name of the whale that's in Alaska in the summer. Color the letters in it green and write the word on the line below.

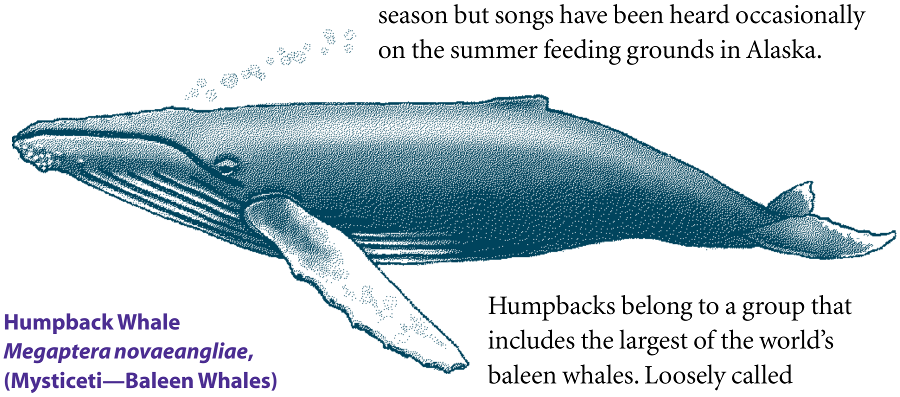
____

Backgrounder

Humpback Whale

Unlike some whales that seem to slip beneath the surface when they dive, a humpback—well—humps its back, extends its tail in the air and then dives.

Humpbacks whales are famous for their long, haunting and complicated songs. In *Whales* we see a lone male humpback hanging motionless in the mid-water and hear him sing his plaintive song. Scientists need more research in order to know what these songs are really for—courtship, perhaps, or warnings to competing males? No one is certain how humpbacks produce their songs. Roger Payne and Scott McVay first discovered in 1971 that humpbacks sing long and complex songs. Later scientists learned that only males sing, although all humpbacks make sounds. Roger Payne is still studying whale songs, and we see him in *Whales* recording their melodies. Singing occurs mainly during the breeding season but songs have been heard occasionally on the summer feeding grounds in Alaska.



Humpback Whale
***Megaptera novaeangliae*, (Mysticeti—Baleen Whales)**
Adult males are famous for their songs. In Whales*, we hear them singing in Hawaii. Scientist Debbie Ferrari has studied mothers and their calves among the islands for more than 20 years. After they leave Hawaii in the Spring, humpbacks migrate to Alaska to eat all summer. Watch them catch fish with a net of bubbles and a mouthful of baleen.*

Humpbacks belong to a group that includes the largest of the world's baleen whales. Loosely called "rorquals," all whales in this group (blue whales, fin whales, sei whales, minke whales, Bryde's whales) are slender and streamlined. Humpbacks are the stoutest of the group.

Rorquals have many grooves on the throat, extending from the chin to behind the pectoral (or, arm) fins. Once thought to aid in streamlined swimming, grooves instead act like accordion pleats to expand the mouth. Humpbacks have 14-35 grooves, the fewest of any rorqual.

Sometimes names aren't much help in identifying an animal, but humpbacks are an exception. Both the scientific and the common name give us some tips for distinguishing them from other whales. Unlike some whales that seem to slip beneath the surface when they dive, a humpback—well—humps its back, extends its tail in the air and then dives. The habit of extending its tail before it dives turns out to be very helpful to whale biologists. Individual whales can be identified by the bumps, scallops and white and dark patches on their tail fins, or flukes.

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Humpback whales are found throughout the world's oceans. There are populations on both sides of the Pacific and Atlantic oceans. In the North Pacific, populations winter (on the west side) around the Marianas, Bonin, and Ryuku Islands and Taiwan. The eastern Pacific stocks winter in Hawaii and on the American coast and nearshore islands and in the Sea of Cortez and mainland Mexico. Northwest Atlantic humpbacks winter in the West Indies and summer from New England (another link to their species name) to Baffin Island. In the Eastern Atlantic, they winter near the Cape Verde Islands and northwest Africa, and summer north of Norway.

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Resources

HELP FOR TEACHERS

The Exploratorium Science Snackbook Series **in four volumes (1995-1996)**
John Wiley and Sons

National Science Education Standards (1996)
National Research Council
National Academy Press
Washington, DC

Standards for the English Language Arts (1996)
National Council of Teachers of English
Urbana, Illinois

WHALE BOOKS

Whales, Dolphins, and Porpoises (1992)
Mark Cawardine
Dorling Kindersley, Inc
New York

Whales, Dolphins and Porpoises (1995)
James.D. Darling, Charles "Flip" Nicklin, and others
National Geographic Society
Washington, DC

The Book of Whales (1985)
Richard Ellis
Alfred A. Knopf, Inc.
New York

Whales for Kids (1990)
Tom Wolpert, Flip Nicklin
Northwood Press, Inc.

Sierra Club Handbook of Whales and Dolphins (1983)
Stephen Leatherwood and Randall R.Reeves
Sierra Club Books
San Francisco

WHALE VIDEOS

Magnificent Whales (1988)
Smithsonian Books and Marine Mammal Fund
Washington, DC

Blue Whales: Largest Animal on Earth (1995)
ABC/Kane Productions
Los Angeles

WHALE CD/ROMs

In the Company of Whales (1993)
The Discovery Channel CD/ROM
(Macintosh and Windows)

WHALE AND SCIENCE WEB SITES

Web sites change frequently. New ones are added. Old ones change or go away. A good way to find whale web sites is to use one of the several good search engines (e.g., Yahoo, Alta Vista) and search for "whale." At the time we prepared this list, the following were current addresses.

Teaching Science with Whales
http://www.oceancurrent.com

Whalenet
http://whale.simmons.edu

Song of the Whale
http://www.easynet.co.uk/ifaw/pic.htm

The High North Alliance—Voice of Norway's Whalers
http://www.highnorth.no/

National Science Foundation
http://www.nsf.gov/

National Institute for Science Education
http://www.wcer.wisc.edu/NISE/

National Wildlife Federation
http://www.nwf.org

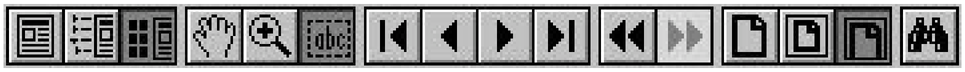
Destination Cinema, Inc
http://www.whalesfilm.com

SCIENCE SUPPLIES (prisms, etc.)

Edmund Scientific, Barrington, NJ
telephone: 609-547-8880
e-mail: scientifics@edsci.com

Document Navigation

Adobe Acrobat Toolbar

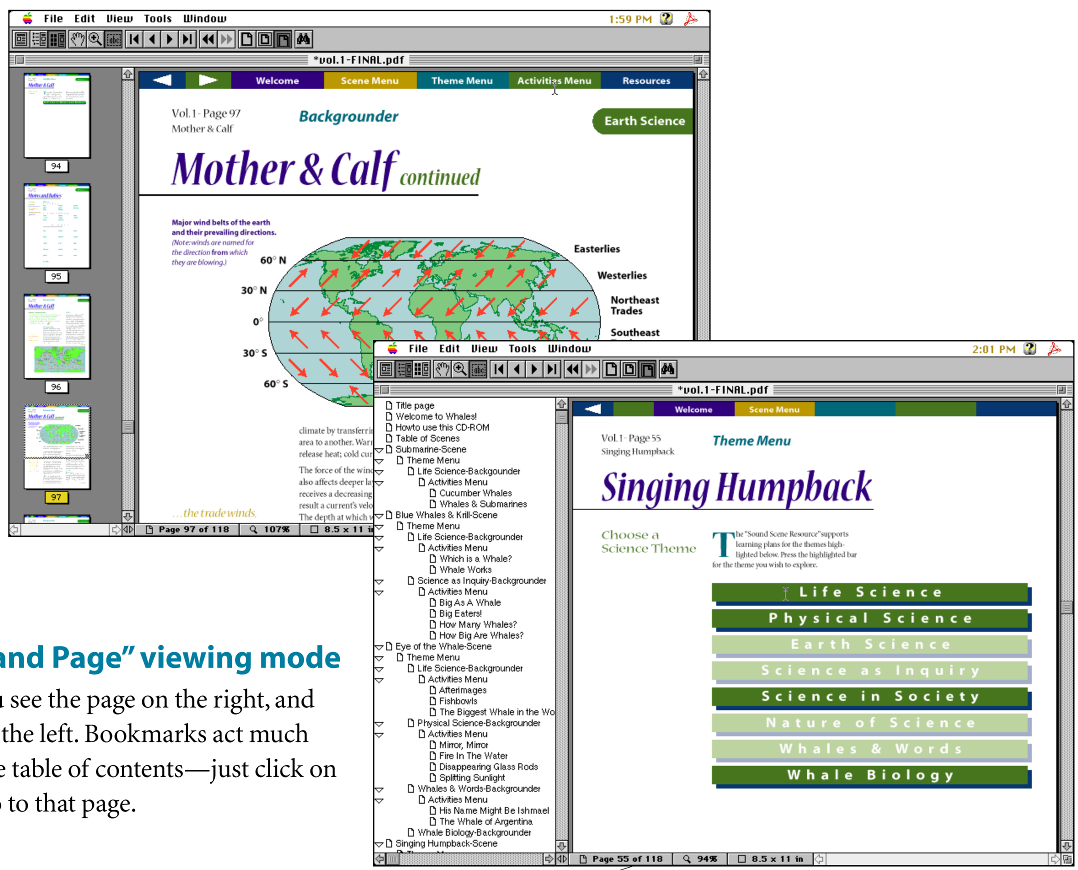


a. b. c. d. e. f. g. h. i. j. k. l. m. n. o. p.

a. *view page only*
b. *view bookmarks and page*
c. *view thumbnails and page*
d. *scroll around the page "manually"*
e. *zoom in, or—holding down Option (Mac) or ALT (Windows) key—zoom out*
f. *select text (to copy to a text file)*
g. *go to beginning of document*
h. *go back one page*
i. *go forward one page*
j. *go to end of document*
k. & l. *toggle between page you last viewed and page you are presently viewing*
m. *view page at 100% (full size)*
n. *fit entire page in window*
o. *fit page width to window*
p. *search document by key word*

"Thumbnails and Page" viewing mode

In this mode, you see the page on the right, and "thumbnails" of each page on the left. Thumbnails are small pictures of each page for quick reference. The page number is shown at the bottom of the thumbnail. Click on the thumbnail to go to that page. You can also click on different areas of the thumbnail to view that area in the right side of the window.



"Bookmarks and Page" viewing mode

In this mode, you see the page on the right, and "bookmarks" on the left. Bookmarks act much like an interactive table of contents—just click on the heading to go to that page.

click here to open a dialog box where you can enter the number of the page you wish to view

click and hold for a pop-up menu, or click for a dialog box, to select the degree of magnification or the fit of the page in the window

click and hold for a pop-up menu, or click for a dialog box, to select your preference for viewing the document: single pages, continuous single pages, or continuous facing pages

Teaching Science with Whales

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For information on *Teaching Science With Whales,* contact:
Leighton Taylor & Associates
1677 Sage Canyon Road, St. Helena, CA 94574
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For information about the large-format film *Whales,* contact:
Destination Cinema
4155 Harrison Blvd., Ogden, UTAH 84403
801-392-2001
http://www.whalesfilm.com

For information about more educational resources on nature and environmental issues, contact:
Christopher Palmer
National Wildlife Federation
8925 Leesburg Pike, Vienna, VA 22184
703-790-4077
http://www.nwf.org

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This publication was developed and produced with the understanding that it will be provided either free or at cost to all interested students, teachers, parents, and other educators.