

# Chapter 24

# Ocean Water

## Chapter Outline

### 1 Properties of Ocean Water

Dissolved Gases

Dissolved Solids

Salinity of Ocean Water

Factors That Change Salinity

Temperature of Ocean Water

Density of Ocean Water

Color of Ocean Water



### 2 Life in the Oceans

Ocean Chemistry and Marine Life

Ocean Environments



### 3 Ocean Resources

Fresh Water from the Ocean

Mineral and Energy Resources

Food from the Ocean

Ocean-Water Pollution



## Why It Matters

Oceans are home to thousands of species and play a vital role in Earth's ecology. Important resources, including food and fresh water, come from oceans.



## Inquiry Lab

### Testing Temperature and Gauging Gases

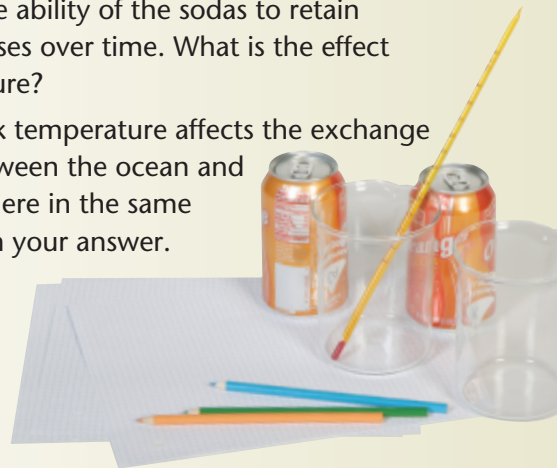


45 min

Open a **can of soda at room temperature** and a **can of chilled soda** at the same time. Use a **thermometer** to measure the temperature of the soda in each can. Pour the soda from each can into a **500 mL beaker**, and “swirl” the soda three times. Using a **stopwatch**, time how long it takes for the “fizziness” in each soda to die down. Return the cold soda to the refrigerator. Repeat the measurements on both sodas at 10 min intervals for the next 40 min. When you have collected all your data, use a **pencil** to plot your data on **graph paper**. Your graph should contain two lines: one for the warm soda and one for the cold soda.

#### Questions to Get You Started

1. Compare the ability of the sodas to retain dissolved gases over time. What is the effect of temperature?
2. Do you think temperature affects the exchange of gases between the ocean and the atmosphere in the same way? Explain your answer.

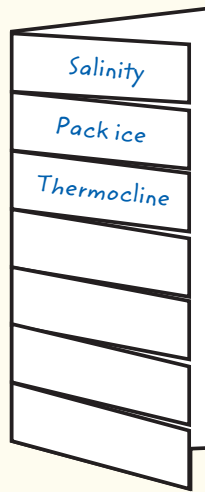


## FoldNotes

**Key-Term Fold** A key-term fold can help you learn the key terms in this chapter.

**Your Turn** Make a key-term fold, as described in **Appendix A**.

- 1 Write each key term from the Chapter Summary on the front of a tab. The first few terms are shown here.
- 2 As you read the chapter, write the definition of each term under the appropriate tab.
- 3 Use this FoldNote to study the key terms.



## Comparisons

**Analyzing Comparisons** Comparisons are often signaled in language by the use of a few key words or structures. The words *similar* and *dissimilar* can tell you whether the comparison is focused on similarities or differences. Often, a comparison describes one thing as *greater than*, *less than*, or *\_\_\_\_\_ than* another thing in some way.

**Your Turn** As you read Sections 1 and 2, fill out a table of comparisons like the one below. The sample entry is for the sentence, "The large amount of dissolved solids in ocean water makes it denser than pure fresh water."

| First thing | Second thing | Similarity or difference                | Signaling word or phrase |
|-------------|--------------|-----------------------------------------|--------------------------|
| ocean water | fresh water  | Ocean water is denser than fresh water. | denser                   |

## Note Taking

**Comparison Table** You can use a comparison table to organize your notes as you compare related topics. A table that compares mineral and energy resources found in the ocean has been started for you. It includes the following:

- topics that you are going to compare
- specific characteristics that you are going to compare

**Your Turn** Make a table like the one below. As you read Section 3, complete your table. Add columns and rows as needed.

|                    | Petroleum        | Nodules | Trace minerals           |
|--------------------|------------------|---------|--------------------------|
| Resources included | oil, natural gas |         |                          |
| Where found        |                  |         | dissolved in ocean water |
| Problems involved  |                  |         |                          |

For more information on how to use these and other tools, see **Appendix A**.



# Properties of Ocean Water

## Key Ideas

- Describe the chemical composition of ocean water.
- Describe the salinity, temperature, density, and color of ocean water.

## Key Terms

salinity      thermocline  
pack ice      density

## Why It Matters

Ocean water is a complex mixture of chemicals that supports a vast range of living organisms.

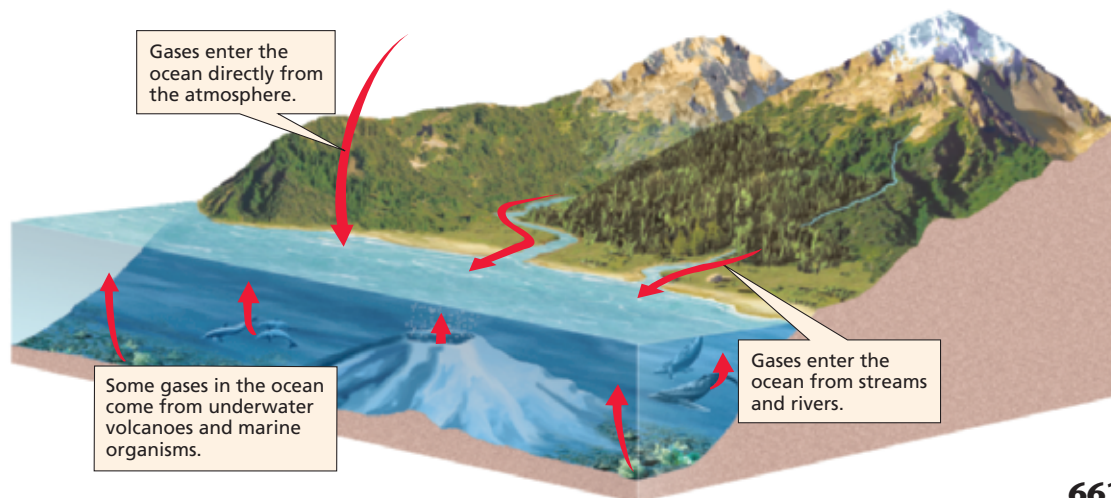
Pure liquid water is tasteless, odorless, and colorless. However, the water in the ocean is not pure. Many solids and gases are dissolved in ocean water. In addition to dissolved substances, small particles of matter and tiny organisms are suspended in ocean water. Ocean water is a complex mixture of chemicals that sustains a variety of plant and animal life. Scientists study various properties of ocean water to understand the complex interactions between the oceans, the atmosphere, and the land.

## Dissolved Gases

The two main gases in the atmosphere are nitrogen,  $N_2$ , and oxygen,  $O_2$ . These two gases are also the main gases dissolved in ocean water. While carbon dioxide,  $CO_2$ , is not a major component of the atmosphere, a large amount of this gas is dissolved in ocean water. Other atmospheric gases are also present in ocean water in small amounts.

Ocean water dissolves gases from a variety of sources, as shown in **Figure 1**. Gases may enter ocean water from water in streams and rivers. Some of the gases in ocean water come from volcanic eruptions beneath the ocean. Gases are also released directly into ocean water by organisms that live in the ocean. For example, many plants in the ocean make oxygen as a product of photosynthesis. However, most oxygen in the ocean enters at the surface of the ocean from the atmosphere.

**Figure 1** Gases can enter the ocean from streams, volcanoes, organisms, and the atmosphere.





## READING TOOLBOX

### Key-Term Fold

As you read this chapter, look for words in *italics*. These words, while not key terms, are also important. Add them and their definitions to the key-term fold you made at the beginning of the chapter, or make a new key-term fold.



## Temperature and Dissolved Gases

The temperature of water affects the amount of gas that dissolves in the water. Gases dissolve more readily in cold water than in warm water. You may have noticed this phenomenon when your glass of soda quickly goes “flat” on a warm day. The soda goes flat quickly because the  $\text{CO}_2$  that makes the soda bubbly escapes into the air. But if the soda is kept in the refrigerator, the soda will retain its fizz longer. Because cold water dissolves gases more readily, water at the surface of the ocean in cold regions dissolves larger amounts of gases than water in warm tropical regions does.

Gases can return to the atmosphere from the ocean. If the water temperature rises, smaller amounts of gases will remain dissolved, and the excess gases will be released into the atmosphere. For example, warm equatorial ocean water tends to release  $\text{CO}_2$  into the atmosphere, but ocean water at cooler, higher latitudes takes up large amounts of  $\text{CO}_2$ . Therefore, the ocean and the atmosphere are continuously exchanging gases as water temperature changes.

## The Ocean as a Carbon Sink

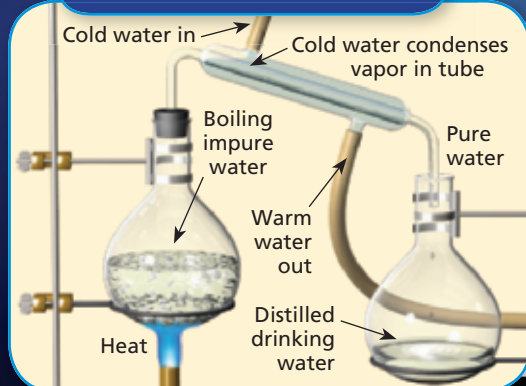
 The global ocean contains more than 60 times as much carbon as the atmosphere does. Dissolved  $\text{CO}_2$  may be trapped in the ocean for hundreds to thousands of years. Because of this ability to dissolve and contain a large amount of  $\text{CO}_2$ , the ocean is commonly referred to as a *carbon sink*. Because gaseous  $\text{CO}_2$  affects the atmosphere’s ability to trap thermal energy from the sun, the ocean is important in the regulation of climate. 

## Why It Matters

### Fresh Water in an Ocean of Salt

Each submarine crewmember needs about 20 liters of water per day. Carrying that much water would take up too much space, so submarines have distillation apparatus.

#### How Distillation Works



When distillation is completed, fresh water is collected in a tank.

## SCIENCE & SOCIETY



Some submarine distillation apparatus can produce between 38,000 and 150,000 liters of fresh water per day. This water is used by the crew and for cooling electronic equipment.

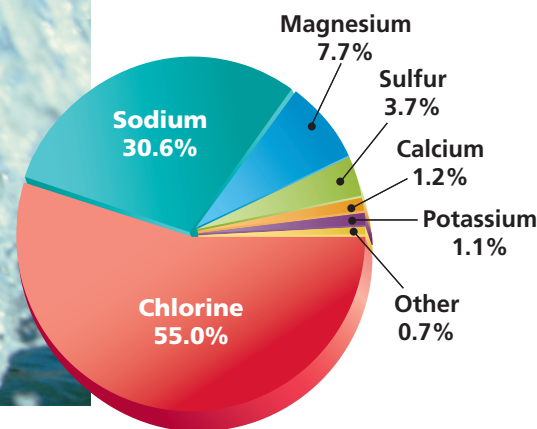
### YOUR TURN

#### UNDERSTANDING CONCEPTS

How else has modern technology allowed people to explore the ocean?



**Figure 2** Dissolved solids make up 3.5% of the mass of ocean water. More than 85% of these dissolved solids are sodium and chlorine.



## Dissolved Solids

Ocean water is 96.5% pure water, or  $\text{H}_2\text{O}$ . Dissolved solids make up about 3.5% of the mass of ocean water. These dissolved solids, commonly called *sea salts*, give the ocean its salty taste.

## Most Abundant Elements

Solids dissolved in ocean water are composed of about 75 chemical elements. The six most abundant elements in ocean water are chlorine, sodium, magnesium, sulfur, calcium, and potassium. The salt halite, which is composed of sodium and chloride ions, makes up more than 85% of the ocean's dissolved solids. The remaining dissolved solids consist of various other salts and minerals, as shown in **Figure 2**. *Trace elements* are elements that exist in very small amounts. Gold, zinc, and phosphorus are some of the trace elements that are found in the ocean.

## Sources of Dissolved Solids

Most of the elements that form sea salts come from three main sources: volcanic eruptions, chemical weathering of rock on land, and chemical reactions between sea water and newly formed sea-floor rocks. Each year, rivers carry about 400 billion kilograms of dissolved solids into the ocean. Most of these dissolved solids are salts. As water evaporates from the ocean, salts and other minerals remain in the ocean. Only a small fraction of these salts and minerals are returned to the land in the water that falls as rain and snow during the water cycle.

**Reading Check** How do dissolved solids enter the ocean?  
(See Appendix G for answers to Reading Checks.)

## Quick Lab

15 min

## Dissolving Solids



### Procedure

- Heat **200 mL of water** in a **beaker** over a **hot plate** until the water is about  $60^\circ\text{C}$ .
- Dissolve **table salt** in the water, 1 tsp at a time, until no more salt will dissolve. Record the total amount of salt that dissolves.
- Dissolve table salt, 1 tsp at a time, into **200 mL of water** that has been chilled in the refrigerator to about  $5^\circ\text{C}$ . Record the total amount of salt that dissolves.

### Analysis

- Which water sample dissolved the most salt?
- Describe what would happen to the dissolved salt in the hot water if the hot water was chilled to  $10^\circ\text{C}$ .



**salinity** a measure of the amount of dissolved salts in a given amount of liquid

## Salinity of Ocean Water

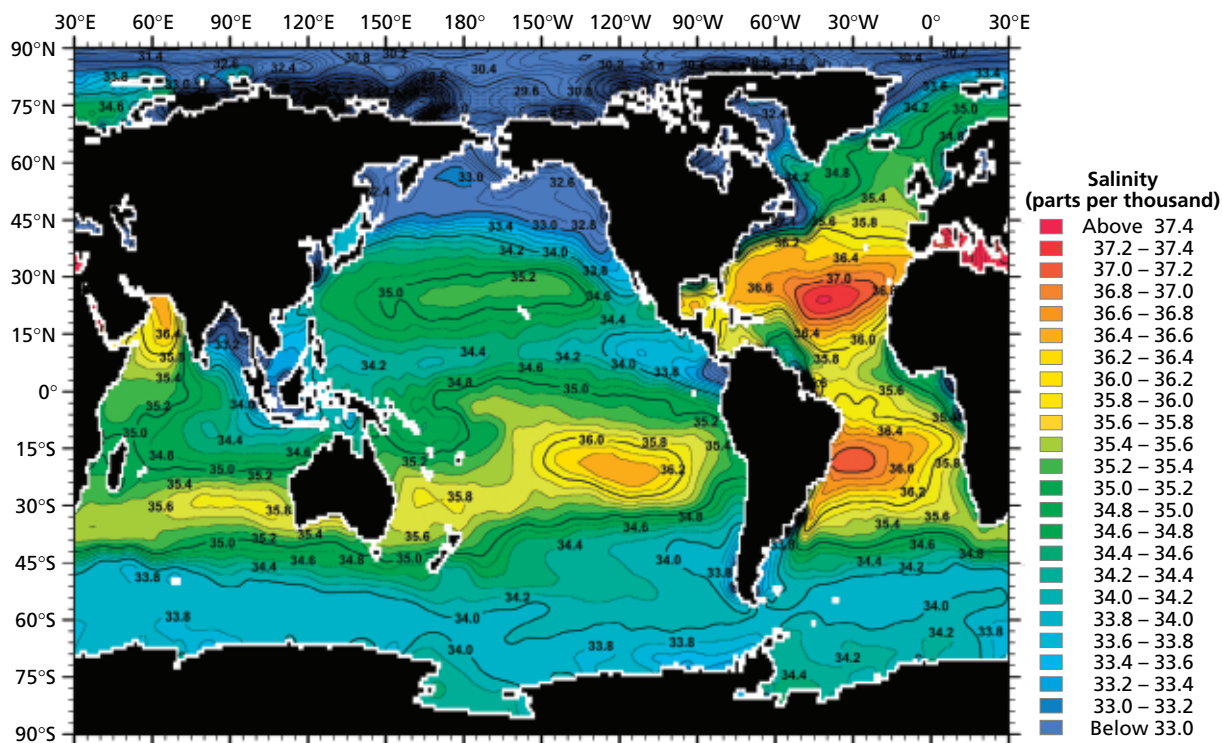
**Salinity** is a measure of the amount of dissolved salts and other solids in a given liquid. Salinity can be measured by the number of grams of dissolved solids in 1,000 g of ocean water. For example, if 1,000 g of ocean water contained 35 g of solids, the salinity of the sample would be about 35 parts salt per 1,000 parts ocean water. This measurement is written as *salinity* = 35 parts per thousand, or 35‰. Thus, the ocean is about 3.5% salts. However, fresh water is less than 0.1% salt or has a salinity of less than 1‰. Modern instruments measure salinity by recording the conductivity of water, or how easily electricity moves through the water. The higher the salinity of water, the better its conductivity.

## Factors That Change Salinity

Precipitation, such as rain and snow, is composed only of fresh water. When ocean surface water evaporates or freezes, only water molecules are removed from the ocean. Dissolved salts and other solids remain behind. Where the rate of evaporation is higher than the rate of precipitation, the salinity of surface water increases. Therefore, in equatorial water, where the rate of precipitation is highest, the salinity is lower than it is in subtropical water, where the rate of evaporation is highest.

Over most of the surface of the ocean, salinity ranges from 33‰ to 36‰. The global ocean has an average salinity of 34.7‰. However, salinity at particular locations can vary greatly, as shown in **Figure 3**. The salinity of the Red Sea, for example, is more than 40‰. The high salinity is due to the hot, dry climate around the Red Sea, which causes high levels of evaporation.

**Figure 3** The average surface salinity of the global ocean varies from one location to another. *What effect do river mouths tend to have on the salinity of the surrounding ocean water?*





## Temperature of Ocean Water

Like ocean salinity, ocean temperature varies depending on depth and location on the surface of the ocean. The range of ocean temperatures is affected by the amount of solar energy an area receives and by the movement of water in the ocean.

### Surface Water

The mixing, by waves and currents, of the ocean's surface water distributes heat down-ward to a depth of 100 to 300 m. Thus, the temperature of this zone of surface water is relatively constant and decreases only slightly as depth increases. However, the temperature of surface water does decrease as latitude increases. Therefore, polar surface water is much cooler than the surface water in the tropics, as explained in **Figure 4**.

The total amount of solar energy that reaches the surface of the ocean is much greater at the equator than in areas near the North and South Poles. In tropical water, an ocean surface temperature of about  $30^{\circ}\text{C}$  is common. The surface temperature in polar oceans, however, often drops as low as  $-1.9^{\circ}\text{C}$ . Because ocean water freezes at about  $-1.9^{\circ}\text{C}$ , vast areas of sea ice exist in polar oceans. A floating layer of sea ice that completely covers an area of the ocean surface is called **pack ice**. Usually, pack ice is no more than 5 m thick because the ice insulates the water below and prevents it from freezing. In the middle latitudes, the ocean surface temperature varies depending on the seasons. In some areas, the ocean surface temperature may vary by as much as  $10^{\circ}\text{C}$  and  $20^{\circ}\text{C}$  between summer and winter.

**Reading Check** What factors affect the surface temperature of the ocean?

**Figure 4** The surface temperature of tropical ocean water (right) can be as high as  $30^{\circ}\text{C}$ . However, the surface temperature of polar ocean water (left) is below the freezing point of fresh water.

**pack ice** a floating layer of sea ice that completely covers an area of the ocean surface



**thermocline** a layer in a body of water in which water temperature drops with increased depth faster than it does in other layers

## The Thermocline

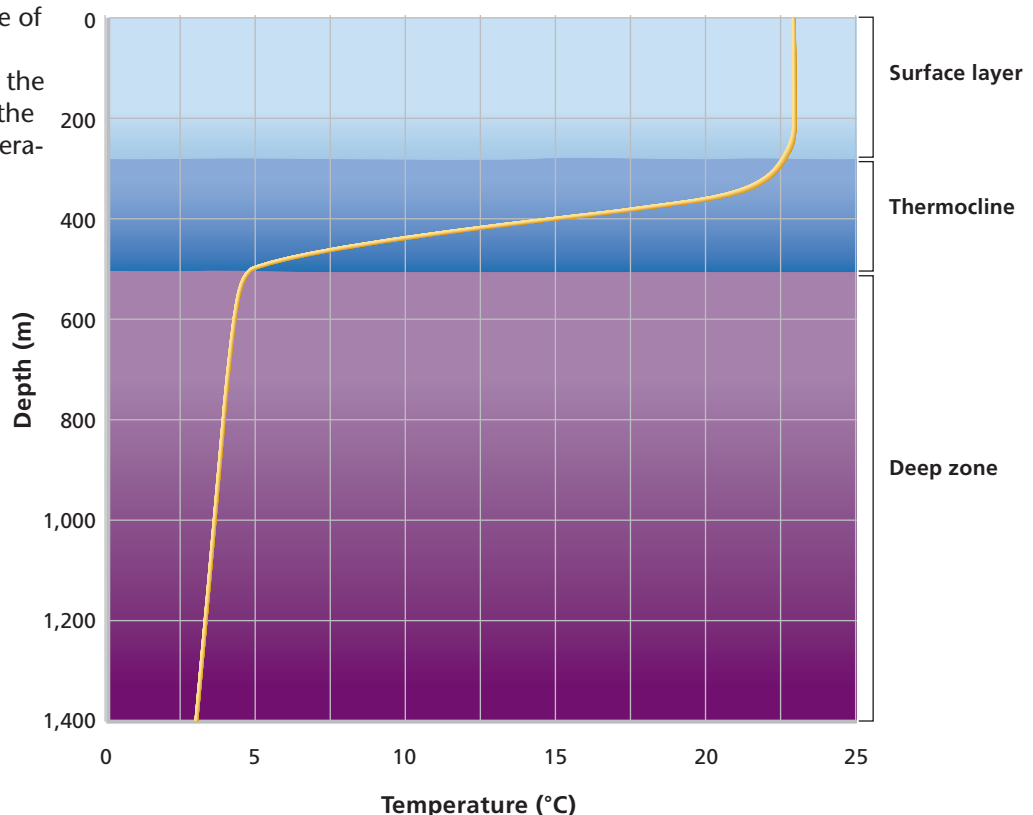
Because the sun cannot directly heat ocean water below the surface layer, the temperature of the water decreases sharply as depth increases. In most places in the ocean, this sudden decrease in temperature begins close to the surface. The layer in a body of water in which water temperature drops with increased depth faster than it does in other layers is called the **thermocline**.

The thermocline exists because the water near the surface becomes less dense as energy from the sun warms the water. This warm water cannot mix easily with the cold, dense water below. Thus, a thermocline marks the distinct separation between the warm surface water and the cold deep water. Below the thermocline, the temperature of the water continues to decrease, but it decreases very slowly, as shown in **Figure 5**. Changing temperature or shifting currents may alter the depth of the thermocline or cause the thermocline to disappear. Nevertheless, a thermocline is usually present beneath much of the ocean surface.

## Deep Water

In the deep zones of the ocean, the temperature of the water is usually about 2°C. The colder the water is, the denser it is. The density of cold, deep water controls the slow movement of deep ocean currents. This movement occurs when the cold, dense water at the poles sinks and flows beneath warm water toward the equator. Cold, deep ocean water also holds more dissolved gases than warm, shallow ocean water does.

**Figure 5** The temperature of ocean water decreases as depth increases. Just below the surface is the thermocline, the area where the water temperature decreases sharply.



## Density of Ocean Water

The mass of a substance per unit volume is that substance's **density**. For example,  $1\text{ cm}^3$  of pure water has a mass of 1 g. So, the density of pure water is  $1\text{ g/cm}^3$ . Different liquids have different densities, as shown in **Figure 6**. Two factors affect the density of ocean water: salinity and the temperature of the water. Dissolved solids, which are mainly salts, add mass to the water. The large amount of dissolved solids in ocean water makes it denser than pure fresh water. Ocean water has a density between  $1.020\text{ g/cm}^3$  and  $1.029\text{ g/cm}^3$ .

Ocean water becomes denser as it becomes colder and less dense as it becomes warmer. Water temperature usually affects the density of ocean water more than salinity does. Therefore, the densest ocean water is found in the polar regions, where the ocean surface is coldest. This cold, dense water sinks and moves through the ocean basins near the ocean floor.

**Reading Check** Explain why ocean water is denser than fresh water.



**Figure 6** This graduated cylinder contains six liquids that have different densities. From top to bottom, the liquids are corn oil, water, shampoo, dish detergent, antifreeze, and maple syrup. *Which liquid has the lowest density?*

THINK  
central

INTERACT ONLINE

Keyword: HQXOWAF6

**density** the ratio of the mass of a substance to the volume of the substance; commonly expressed as grams per cubic centimeter for solids and liquids and as grams per liter for gases

### Quick Lab

### Density Factors



20 min

#### Procedure

- 1 Fill a **deep, clear plastic container** half full with **room-temperature water**.
- 2 In a **1 L beaker**, mix  **$1/8$  cup of table salt**, a **few drops of red food coloring**, and 1 L of room-temperature water. Stir the mixture until the salt is dissolved.
- 3 Add the red saltwater mixture to the water in the clear plastic container. Record your observations.
- 4 In the **1 L beaker**, mix a **few drops of blue food coloring** with water that is  $8^{\circ}\text{C}$ .
- 5 Slowly add the cold, blue water to the clear plastic container in step 3. Record your observations.

#### Analysis

1. Describe what happened when you added the red salt water to the fresh water. Which is denser: fresh water or salt water?

2. What happened when you added the cold water to the room-temperature water? Which is denser: cold water or room temperature water?
3. What would you expect to happen if the blue water was heated, instead of cooled?
4. Based on your observations, where would you expect the water in the ocean to be the least dense? the most dense?
5. Describe water layering where a river empties into the ocean.







**Figure 7** Ocean water appears blue as far as 100 m below the surface.

### Academic Vocabulary

**affect** (uh FEKT) to change; to have an effect on; to influence

## Color of Ocean Water

Have you ever wondered why the ocean appears blue, as shown in **Figure 7**? The color of ocean water is determined by the way it absorbs or reflects sunlight. White light from the sun contains light from all the visible wavelengths of the electromagnetic spectrum. Much of the sunlight penetrates the surface of the ocean and is absorbed by the water. Water absorbs most of the wavelengths, or colors, of visible light. Only the blue wavelengths tend to be reflected. The reflection of this blue light makes ocean water appear blue.

### Why Is Ocean Color Important?

✿ Substances or organisms in ocean water, such as phytoplankton, can affect the color of the water. *Phytoplankton* are microscopic plants in the ocean that provide food to many of the ocean's organisms. Phytoplankton absorb red and blue light, but reflect green light. Therefore, the presence and amount of phytoplankton can affect the shade of blue of the ocean.

By studying variations in the color of the ocean, scientists can determine the presence of phytoplankton in the ocean. Because phytoplankton require nutrients, the presence or absence of phytoplankton can indicate the health of the ocean. If the color of an area of the ocean indicates that no phytoplankton are present, a lack of nutrients in the water may be preventing phytoplankton growth. ✿

## Section 1 Review

### Key Ideas

- 1. Describe** how water temperature affects the ability of the ocean water to dissolve gases.
- 2. Summarize** how freezing and evaporation affect salinity.
- 3. Describe** the composition of ocean water.
- 4. Define** *thermocline*.
- 5. Describe** how temperature and salinity affect the density of ocean water.
- 6. Explain** how the density of ocean water drives the movement of deep ocean currents.
- 7. Explain** why shallow ocean water appears to be blue in color.

### Critical Thinking

- 8. Making Inferences** Why does the surface temperature of ocean water in middle latitudes vary during the year?

- 9. Understanding Relationships** Why would surface water in the North Sea be more likely to contain a high percentage of dissolved gases than surface water in the Caribbean Sea would?

- 10. Predicting Consequences** If global temperatures increase, how would this change affect the ability of the ocean to absorb  $\text{CO}_2$ ?

- 11. Identifying Relationships** If an area of the ocean has a large decrease in phytoplankton, how would this change affect other ocean organisms? Explain your answer.

### Concept Mapping

- 12.** Use the following terms to create a concept map: *ocean water*, *salinity*, *temperature*, *density*, *dissolved solids*, and *dissolved gas*.

## Key Ideas

- Explain how marine organisms alter the chemistry of ocean water.
- Explain why plankton can be called *the foundation of life in the ocean*.
- Describe the major zones of life in the ocean.

## Key Terms

upwelling  
plankton  
nekton  
benthos  
benthic zone  
pelagic zone

## Why It Matters

Variations in sunlight, nutrients, and temperature create different zones in the ocean. These zones are filled with marine organisms especially adapted to the environment.

Most marine organisms depend on two major factors for their survival: sunlight and the essential nutrients available in ocean water. Variations in either of these factors affect the ability of aquatic organisms to survive and flourish.

## Ocean Chemistry and Marine Life

The chemistry of the ocean is a balance of dissolved gases and solids that are essential to marine life. Marine organisms help to maintain the chemical balance of ocean water. They do this by removing nutrients and gases from the ocean while returning other nutrients and gases to the ocean. For example, marine organisms, such as the giant kelp shown in **Figure 1**, absorb large amounts of carbon, hydrogen, oxygen, and sulfur. They also absorb other elements, such as nitrogen, phosphorus, and silicon. In addition, marine organisms return nutrients and gases to the ocean. For example, photosynthetic marine plants remove carbon dioxide from ocean water to produce oxygen.

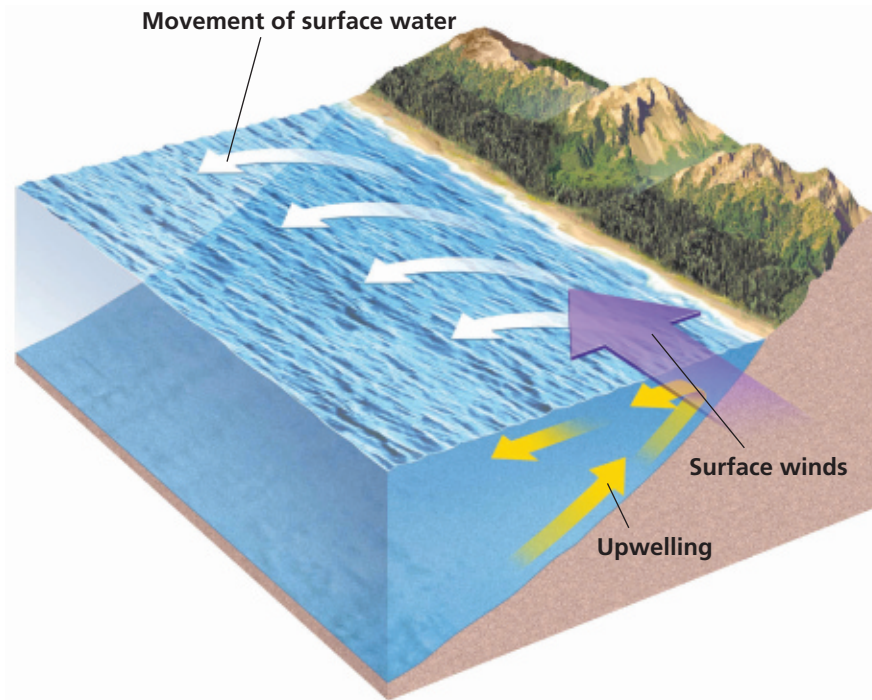
Marine organisms, such as the sea horse shown in **Figure 1**, also help to recycle nutrients in the ocean. During a marine organism's lifetime, the organism absorbs and stores nutrients from the ocean. These nutrients are eventually returned to the water when the organism dies. For example, bacteria in the water digest the remains of dead organisms. The bacteria then release the essential nutrients from the dead organisms into the ocean.

**Figure 1** Marine organisms, such as giant kelp and sea horses, help to maintain the balance of dissolved gases and solids in ocean water.





**Figure 2** Upwelling is caused by offshore movement of surface water. *How might stormy weather affect the process of upwelling?*



**upwelling** the movement of deep, cold, and nutrient-rich water to the surface

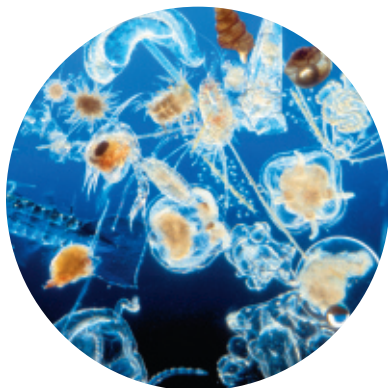
**plankton** the mass of mostly microscopic organisms that float or drift freely in the waters of aquatic (freshwater and marine) environments

**nekton** all organisms that swim actively in open water, independent of currents

**benthos** organisms that live at the bottom of oceans or bodies of fresh water

### Academic Vocabulary

**complex** (kahm PLEKS) having many parts or functions



**Figure 3** Plankton are so tiny that you need a microscope to see them.

## Upwelling

The distribution of life in the ocean depends on the way that life-supporting nutrients cycle in the ocean water. In general, all the elements necessary for life are consumed by organisms near the surface. Elements are then released back into the ocean water when the organisms die, sink to lower depths, and decay. Thus, deep water is a storage area for the nutrients needed for life. These nutrients must, however, return to the surface before most organisms in the ocean can use them.

One way that nutrients return to the surface is through a process called upwelling. **Upwelling** is the movement of deep, cold, and nutrient-rich water to the surface, as shown in **Figure 2**. When the wind blows steadily parallel to a coastline, surface water moves farther offshore. The deep, cold water then rises to replace the surface water that has moved away from the shore.

## Marine Food Webs

Because most marine organisms need sunlight as well as nutrients, most marine organisms live in the upper 100 m of water. Free-floating, microscopic organisms, called **plankton**, live within the sunlit zone. Plankton, shown in **Figure 3**, form the base of the complex food webs in the ocean. Plankton are consumed primarily by small marine organisms, which, in turn, become food for larger marine animals. These larger animals fall into two groups. All organisms that swim actively in open water, such as fish, dolphins, and squid, are called **nekton**. The organisms that live on the ocean floor are called **benthos**. Benthos include marine plants and animals, such as oysters, sea stars, and crabs, that live in sunlit, shallow waters.

# Ocean Environments

The ocean can be divided into two basic environments, or zones, as shown in **Figure 4**. These zones are the bottom region, or **benthic zone**, and the upper region, or **pelagic zone**. The amount of sunlight, the water temperature, and the water pressure determine the distribution of marine life within these zones.

## Benthic Zones

The shallowest benthic zone lies between the low-tide and high-tide lines and is called the *intertidal zone*. Shifting tides and breaking waves make this zone a continually changing environment for the marine organisms that flourish there.

Most of the organisms that live in the benthic zone live in the shallow *sublittoral zone*. This continuously submerged zone is located on the continental shelf and is populated by organisms such as sea stars, brittle stars, and sea lilies.

The *bathyal zone* begins at the continental slope and extends to a depth of 4,000 m. Because little or no sunlight reaches this zone, plant life is scarce. Examples of animals that live in the bathyal zone are octopuses, sea stars, and brachiopods.

The *abyssal zone* has no sunlight because it begins at a depth of 4,000 m and extends to a depth of 6,000 m. Organisms that live in the abyssal darkness include sponges and worms.

The *hadal zone* is confined to the ocean trenches, which are deeper than 6,000 m below the surface of the water. This zone is virtually unexplored, and scientists think that life in the hadal zone is sparse.

**Reading Check** Which benthic zone has the most marine life? Why?

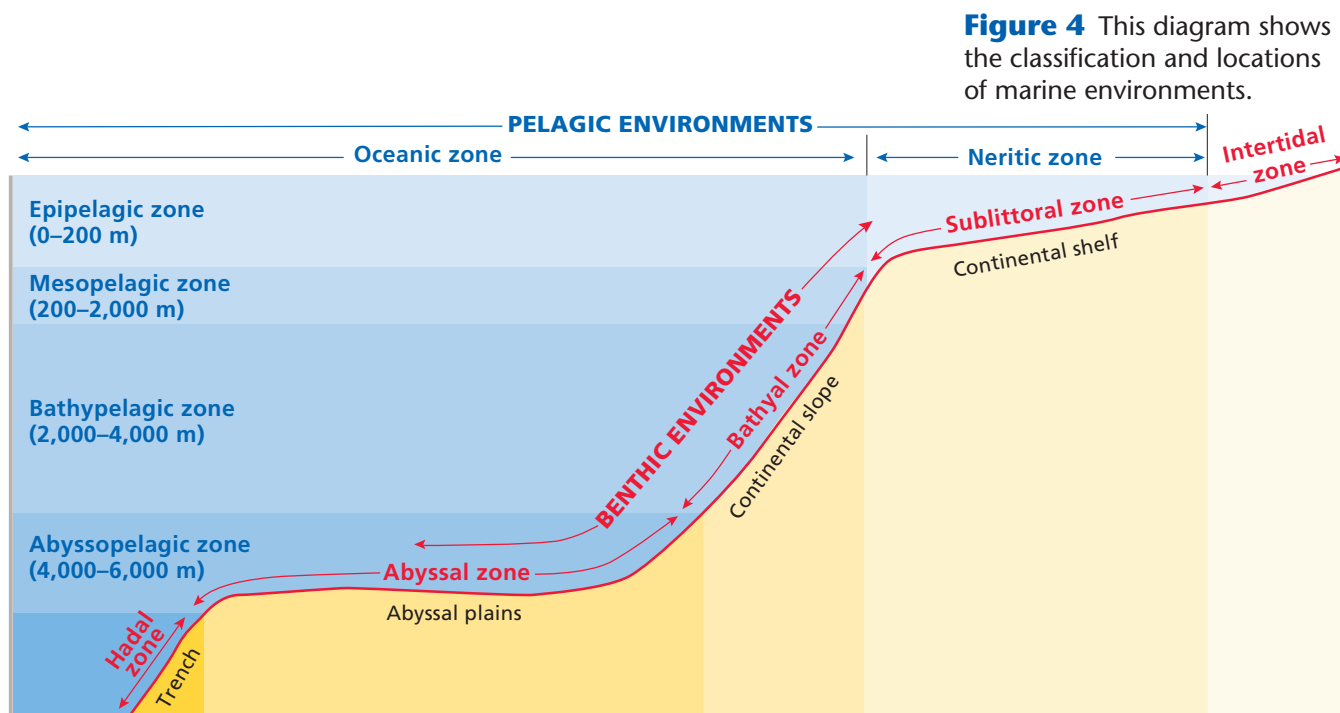
**benthic zone** the bottom region of oceans and bodies of fresh water

**pelagic zone** the region of an ocean or body of fresh water above the benthic zone

## READING TOOLBOX

### Comparison Table

As you read this page, complete a comparison table for the five benthic zones. Label the rows "Depth," "Sunlight," and "Marine life." See the Reading Toolbox at the beginning of this chapter if you need help getting started.





**Figure 5** Fish and marine mammals are examples of organisms that live in the pelagic zone.



SCILINKS

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Topic: Marine Life  
Code: HQX0912

### Pelagic Zones

The region of the ocean above the benthic zone is the pelagic zone. The area of the pelagic zone above the continental shelf is called the *neritic zone*. The neritic zone has abundant sunlight, moderate temperatures, and relatively low water pressure, which are ideal factors for marine life. Nekton fill the zone's waters and are the source of much of the fish and seafood that humans eat.

The *oceanic zone* extends into the deep waters beyond the continental shelf. It is divided into four zones, based on depth. The epipelagic zone is the uppermost area of the oceanic zone. It is sunlit and populated by marine life, such as the dolphins shown in **Figure 5**. The mesopelagic, bathypelagic, and abyssopelagic zones occur at increasingly greater depths. The amount of marine life in the pelagic zone decreases as depth increases. 🌿

## Section 2 Review

### Key Ideas

1. **Explain** the effects that marine organisms have on the chemistry of ocean water.
2. **Summarize** the process of upwelling, and describe its importance to marine organisms.
3. **Explain** how plankton form the base of ocean food webs.
4. **Identify** the two major environments, or zones, of the ocean.
5. **Compare** the sublittoral and neritic zones, and name some organisms found in each zone.

### Critical Thinking

6. **Analyzing Processes** How can the movement of wind currents alter the chemistry of an area of the ocean?
7. **Making Predictions** How would life in the ocean change if the area of all regions of upwelling decreased?

### Concept Mapping

8. Use the following terms to create a concept map: *pelagic zone*, *neritic zone*, *benthic zone*, *ocean environment*, and *oceanic zone*.

**Key Ideas**

- Describe three important resources of the ocean.
- Explain the threat that water pollution poses to marine organisms.

**Key Terms**

**desalination**  
**aquaculture**

**Why It Matters**

Resources from the ocean include fresh water, minerals, energy, and food.

The ocean supplies humans with a number of natural resources. It is a major source of food and minerals, and it provides a means of transportation. Furthermore, the growth of Earth's population has created new interest in the ocean as a source of fresh water.

## Fresh Water from the Ocean

The increasing demand for fresh water, for things such as drinking water, industry, and irrigation, can be met by converting ocean water to fresh water. One way of increasing the freshwater supply is through desalination, as shown in **Figure 1**. **Desalination** is the extraction of fresh water from salt water. Although desalination may provide needed fresh water, the process is generally costly.

### Methods of Desalination

One method of desalination is distillation. During *distillation*, ocean water is heated to remove the salts. Heat causes the liquid water to evaporate and leaves the dissolved salts behind. When the water vapor condenses, the result is pure fresh water. However, the process of evaporating liquid water often requires a large amount of costly heat energy.

Another method of desalination is *freezing*. When water freezes, the first ice crystals that form do not contain salt. The ice can be removed and melted to obtain fresh water. This process requires about one-sixth of the energy needed for distillation.

*Reverse osmosis desalination* is a popular method for desalinating ocean water. It includes the use of special membranes that allow water under high pressure to pass through, but block the dissolved salts.

**desalination** a process of removing salt from ocean water



**Figure 1** After salt water from the Persian Gulf has undergone desalination, much of the resulting fresh water is stored in these towers in Kuwait.

**Figure 2** Offshore oil rigs, such as this one in the Gulf of Mexico, produce about one-fourth of the world's oil.



### Academic Vocabulary

**extract** (eks TRAKT) to get or draw out something

## Mineral and Energy Resources

Salt is one mineral resource that can be obtained from the ocean. Other mineral and energy resources can also be obtained from the ocean. While some valuable minerals are easily extracted from the ocean, others are costly or difficult to extract.

### Petroleum

The most valuable resource in the ocean is the petroleum found beneath the sea floor. Offshore oil and natural gas deposits exist along continental margins around the world. About one-fourth of the world's oil is now obtained from offshore wells, such as the one shown in **Figure 2**. As a result of new drilling techniques, oil and gas can be extracted far offshore and from great depths.

### Math Skills

**Ocean's Gold** One cubic kilometer of ocean water contains about 6 kg of gold. If you must process 4 million liters of ocean water to get an amount of gold worth 4¢, how many liters of water would have to be processed to get an amount of gold worth \$1?

### Nodules

Potato-shaped lumps of minerals, called *nodules*, are found on the abyssal floor of the ocean. Nodules are a valuable source of manganese, iron, copper, nickel, cobalt, and phosphates. However, the recovery of nodules is expensive and difficult because they are located in very deep water. Because country borders are observed only close to land, the question of who has the right to mine minerals from the ocean floor can be difficult to answer.

### Trace Minerals

The ocean is also the main source of magnesium and bromine. However, the concentration of most other useful chemicals that are dissolved in the ocean is very small. The extraction of minerals found only in trace amounts is too costly to be practical.



## Food from the Ocean

Of all the resources that the ocean supplies, the one in greatest demand is food. Seafood, which is an important source of protein, can be harvested through fishing or through aquaculture.

### Fishing

Because fish are a significant food source for people around the world, fishing has become an important industry. But when the ocean is overfished, or overharvested, for a long period of time, fish populations can collapse. A collapsed fish population may damage the ecosystem and threaten the fishing industry. To prevent overharvesting, many governments have passed laws to manage fishing.

### Aquaculture

Another way to deal with the high demand for seafood is by farming aquatic life. **Aquaculture** is the raising of aquatic plants and animals for human use or consumption. Catfish, salmon, oysters, and shrimp are already grown on large aquatic farms. Similar methods are used to breed fish and seaweed in ocean farms, such as the one shown in **Figure 3**. A major problem for aquaculturalists is that ocean farms are susceptible to pollution and may themselves be a local source of pollution.

Under the best conditions, an ocean farm can produce more food than an agricultural farm of the same size does. For example, in agriculture, only the top layers of soil can be used. In contrast, ocean farms can use a wide range of depths to produce food. Someday, the nutrient-rich bottom water may be pumped to the surface as a way of fertilizing aquatic farms.

 **Reading Check** List the benefits and problems of aquaculture.

### READING TOOLBOX

#### Analyzing Comparisons

As you read about food from the ocean, look for comparisons. Create a comparisons table similar to the one that you started at the beginning of the chapter.

SCILINKS

[www.scilinks.org](http://www.scilinks.org)

Topic: Ocean Resources

Code: HQX1065

**aquaculture** the raising of aquatic plants and animals for human use or consumption

**Figure 3** Aquaculture establishments, such as this seaweed farm in Madagascar, provide a reliable, economical source of food.





**Figure 4** Pollution can damage the ocean's ecosystem and make seafood unsafe to eat.

## Ocean-Water Pollution

The ocean has been used as a dumping ground for many kinds of wastes, including garbage, sewage, and nuclear waste. Until recently, most wastes were diluted or destroyed as they spread throughout the ocean. But the growth of the world population and the increased use of toxic substances have reduced the ocean's ability to absorb wastes and renew itself.

Productive coastal areas and beaches are in the greatest danger of being polluted because they are closest to sources of pollution, as shown in **Figure 4**. Pollution has destroyed clam and oyster beds, sea birds have become tangled in plastic products, and beaches have been closed because of sewage and oil spills.

Besides being found in coastal waters, pollutants can be found in most other areas of the ocean. Traces of mercury, the insecticide DDT, and lead from gasoline have been detected in the ocean. In some areas of the world, concentrations of pollutants are so high that the fish have become unsafe for humans to eat. Recognizing the effects of dumping wastes in the ocean, scientists and governments have been working to reduce pollution. For example, the use of DDT has been banned in the United States and the use of leaded gasoline has been greatly reduced. 🌿

## Section 3 Review

### Key Ideas

1. **Describe** three methods of desalinating ocean water.
2. **Explain** why distillation can be an expensive method of desalination.
3. **List** two important mineral resources in the ocean.
4. **Identify** the most valuable resource that can be obtained from the ocean.
5. **Define** the term *aquaculture*, and explain why aquaculture is important.
6. **Explain** why beaches are especially vulnerable to ocean pollution.

### Critical Thinking

7. **Making Inferences** Describe how the mining of nodules may create problems between countries.
8. **Predicting Consequences** How does pollution of the ocean affect the fishing industry?
9. **Analyzing Relationships** How could humans be affected if microscopic marine organisms absorbed small amounts of mercury?

### Concept Mapping

10. Use the following terms to create a concept map: *desalination, distillation, freezing, reverse osmosis, petroleum, aquaculture, fishing, salt, ocean resource, and pollution.*



# Searching for Sunken Treasure

Shipwrecks full of ancient treasure are not just the stuff of pirate stories. Under some conditions, ocean water can preserve ships and their contents. These artifacts are valuable not just to treasure hunters but to maritime archaeologists, giving them a fascinating insight into days gone by. Sonar, video, and an understanding of how the properties of ocean water affect wood and metals—these tools all help scientists solve the mysteries of how ships sank and what they were used for. In this way, scientists learn more about how people lived in the past.



FORENSIC  
SCIENCE



Many factors affect how a ship decays including water temperature, currents or wave action, the material a ship is made from, and the presence of marine animals.

## Sonar Imaging



Side-scan sonar produces images of objects on or under the ocean floor (left). The acoustic reflections from the ocean floor are recorded in a series of "slices" that together form an image (right).



The ocean is not kind to all shipwrecks. Shipworms and bacteria devour wooden wrecks, while dissolved salts attack iron-based metal ships.

YOUR  
TURN

## DRAWING CONCLUSIONS

Explain which combination of water properties you think would be the most destructive to a sunken ship.

## ONLINE RESEARCH

Research more about how scientists study shipwrecks. What can be learned from studying shipwrecks?



## What You'll Do

- **Measure** the temperature and density of water.
- **Analyze** the effects of temperature and salinity on the density of water.

## What You'll Need

beaker, 250 mL  
 clay, modeling  
 freezer (optional)  
 gloves, heat-resistant  
 graduated cylinder, 100 mL  
 hot plate  
 pencil, grease, red  
 pencil, grease, yellow  
 ruler, metric  
 scissors  
 straw, plastic  
 table salt  
 teaspoon  
 thermometer  
 water, distilled

## Safety



### Step 8

# Ocean Water Density

The density of ocean water varies. It is affected by the salinity of the water and the temperature of the water. Furthermore, the salinity of an area of the ocean is affected by the rate of evaporation or freezing and by the addition of fresh water and salts. The temperature of the ocean is determined by the amount of solar radiation that reaches Earth's surface. In this lab, you will observe the effects of temperature and salinity on the density of salt water.

## Procedure

- 1 Make a hydrometer (an instrument used to measure the density of water) by filling 5 cm of one end of a straw with modeling clay.
- 2 Pour 100 mL of distilled water at room temperature into a glass jar or beaker. Float the straw upright in the jar. If the straw does not float upright, cut off the open end at 1 cm intervals until it floats upright.
- 3 Use a red grease pencil to mark the water level on the straw. Remove the straw from the water, and draw a continuous line around the straw at the mark.
- 4 Use a yellow grease pencil to draw lines around the straw at 1 cm intervals above and below the red line. The red line will be used as a reference point.
- 5 Add 2 tsp of salt to the water, and stir until all the salt has dissolved. Draw a table similar to **Table 1**. Measure the water temperature, and record the measurement in your table.
- 6 Place the hydrometer in the salt water. In your table, record the density by counting the marks above or below the red line to the water's surface. The higher the hydrometer floats out of the water, the more dense the water.
- 7 Turn the hot plate on low. Place the beaker of salt water on the hot plate. **CAUTION** Wear heat-resistant gloves.
- 8 Hold the thermometer in the water. Do not let the thermometer touch the bottom of the beaker.



- 9 When the temperature of the water reaches 25°C, turn off the hot plate. Immediately place the hydrometer in the water. Record the relative density in your table.
- 10 Repeat steps 7 to 9, and heat the water until it is 30°C.
- 11 Turn the hot plate on high. Heat the salt water until it begins to boil. Boil the water for 5 min. Turn off the hot plate.
- 12 Place the hydrometer in the water. Draw a table similar to **Table 2**. Measure the density of the water, and record the measurement in your table.
- 13 Boil the water for another 5 min. Measure and record the density of the water.
- 14 Repeat step 13. Once the water is cool, measure the amount of water that remains in the beaker.

## Analysis

1. **Analyzing Data** In which trial was the water the most dense? In which trial was it the least dense? Explain your answers.
2. **Identifying Trends** As the temperature of water increases, does the density of the water increase or decrease?
3. **Making Inferences** Based on your observations, infer the density of polar ocean water, and compare it with the density of equally saline water near the equator. Explain your answer.
4. **Analyzing Processes** Why did the amount of water in the beaker change? Explain why boiling the water affected its density.
5. **Forming Hypotheses** How would you expect the density of the water to change if the water was frozen instead of boiled? Explain your answer.

## Extension

**Evaluating Hypotheses** Place a beaker of salt water in a freezer until a crust of ice forms. Break up and remove the ice from the water, and record the density of the remaining water. Is the water more or less dense than it was before it was frozen? Explain.

| Temperature (°C) | Density (cm above or below the red line) |
|------------------|------------------------------------------|
| 25               |                                          |
| 30               |                                          |
|                  |                                          |
|                  |                                          |
|                  |                                          |
|                  |                                          |
|                  |                                          |

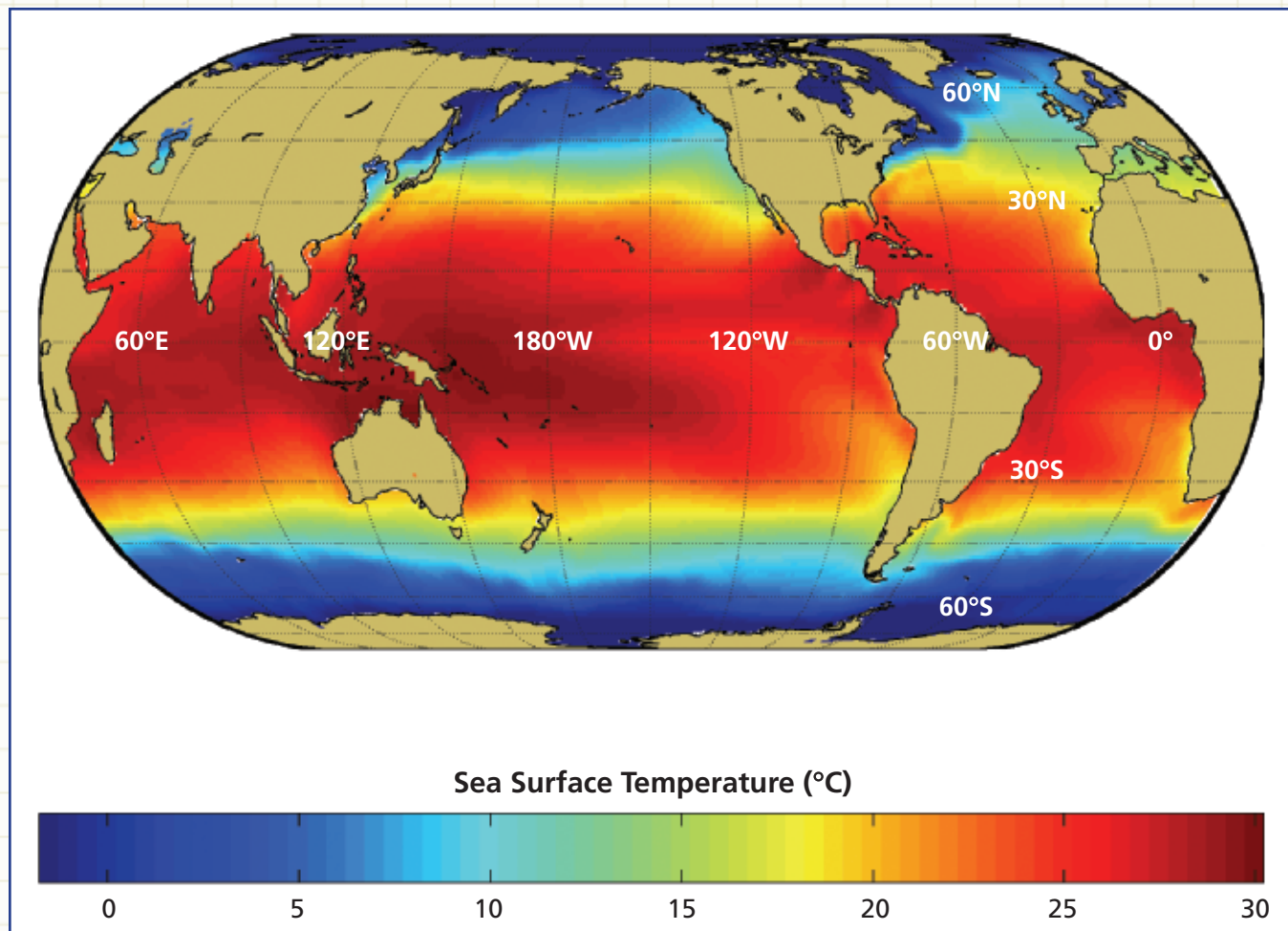
**Table 1**

| Minutes of boiling | Density (cm above or below the red line) |
|--------------------|------------------------------------------|
| 5                  |                                          |
| 10                 |                                          |
| 15                 |                                          |
|                    |                                          |
|                    |                                          |
|                    |                                          |
|                    |                                          |

**Table 2**



## Sea Surface Temperatures in August



### Map Skills Activity

This map shows global sea surface temperatures in the month of August. Latitude is shown in 15° intervals. Longitude is shown in 30° intervals. The latitude of New York City is 41°N 74°W. Use the map to answer the questions below.

- Analyzing Data** Estimate the sea surface temperatures off the east coast of Florida.
- Identifying Relationships** Identify areas of the globe that receive the most solar energy.
- Inferring Relationships** At which locations would you most likely find pack ice?
- Making Comparisons** Where would you expect to find higher surface salinity values: off the coast of North Africa or off the coast of the southern tip of South America?
- Analyzing Relationships** As latitude increases, surface temperature decreases. How would you expect the density of surface water to change as latitude increases? Explain your answer.
- Making Predictions** Off the coast of New York City, would you expect the density of the ocean water to increase or decrease in December, compared with the density of the water in August? Explain.

**Section 1****Section 2****Section 3****Key Ideas****Properties of Ocean Water**

- › Dissolved solids make up 3.5% of the mass of ocean water. Ocean water also contains dissolved gases, such as oxygen, carbon dioxide, and nitrogen.
- › Salinity is a measure of the amount of dissolved salts in ocean water. The temperature of ocean water is dependent on depth and latitude. The density of ocean water is dependent on temperature and salinity. The color of ocean water is affected by the presence of phytoplankton.

**Life in the Oceans**

- › Marine organisms help to maintain the chemical balance of ocean water by using nutrients for life processes and by returning the nutrients to the water after death.
- › Plankton form the base of complex ocean food webs by acting as food for other marine organisms.
- › There are two major zones of life in the ocean: benthic and pelagic. Each zone supports different types of organisms.

**Ocean Resources**

- › The ocean is valuable as a source of fresh water, minerals, and food.
- › Ocean-water pollution threatens both marine organisms and humans by damaging food resources in the ocean.

**Key Terms**

salinity, p. 664  
pack ice, p. 665  
thermocline, p. 666  
density, p. 667

upwelling, p. 670  
plankton, p. 670  
nekton, p. 670  
benthos, p. 670  
benthic zone, p. 671  
pelagic zone, p. 671

desalination, p. 673  
aquaculture, p. 675



- 1. Comparison Table** Make a comparison table to describe the similarities and differences between ocean water and pure fresh water.



### USING KEY TERMS

Use each of the following terms in a separate sentence.

2. *thermocline*
3. *upwelling*
4. *desalination*

For each pair of terms, explain how the meanings of the terms differ.

5. *salinity* and *density*
6. *plankton* and *nekton*
7. *benthic zone* and *pelagic zone*
8. *upwelling* and *aquaculture*

### UNDERSTANDING KEY IDEAS

9. The amount of dissolved salts in ocean water is called the water's
  - a. salinity.
  - b. nekton.
  - c. plankton.
  - d. density.
10. When liquid water is warmed, its density
  - a. increases.
  - b. decreases.
  - c. remains the same.
  - d. doubles.
11. Although most of the wavelengths of visible light are absorbed by ocean water, the one wavelength that is most often reflected is the color
  - a. violet.
  - b. green.
  - c. yellow.
  - d. blue.
12. Drifting marine organisms are known as
  - a. plankton.
  - b. benthos.
  - c. nekton.
  - d. sea stars.

13. Marine animals that can swim to search for food and avoid predators are called
  - a. phytoplankton.
  - b. zooplankton.
  - c. nekton.
  - d. benthos.
14. Which of the following ocean environments experiences the most change?
  - a. intertidal zone
  - b. abyssal zone
  - c. bathyal zone
  - d. neritic zone
15. Which of the following methods is *not* used for producing fresh water by desalination?
  - a. distillation
  - b. evaporation
  - c. reverse osmosis
  - d. aquaculture
16. Lumps of minerals on the ocean floor are called
  - a. nekton.
  - b. nodules.
  - c. benthos.
  - d. plankton.
17. Aquaculture is another name for
  - a. desalination.
  - b. distillation.
  - c. ocean farming.
  - d. rapid temperature changes.

### SHORT ANSWER

18. Describe the process of upwelling, and explain its effects on marine life.
19. What are the six most abundant elements that are dissolved in ocean water?
20. How are temperature, salinity, and density related?
21. Describe how an oil spill would affect a fishing industry.
22. List three important resources from the ocean, and describe how they are obtained.
23. What effects does ocean pollution have on humans?

## CRITICAL THINKING

- 24. Predicting Consequences** If climatic conditions over the ocean caused upwelling and wave action to stop, what would happen to marine life? Explain your answer.
- 25. Identifying Relationships** How would a significant and global decrease in sunlight affect plankton and other marine organisms?
- 26. Applying Concepts** If you were to start an aquatic farm, in which zone of marine life would you locate your farm? Explain your answer.
- 27. Making Inferences** When oceanographers first explored the deep-ocean basin along mid-ocean ridges, they discovered a variety of marine life, including sightless crabs. Explain why sightlessness is not a disadvantage to these crabs.

## CONCEPT MAPPING

- 28.** Use the following terms to create a concept map: *fishing, marine life, plankton, fish, color, dissolved gas, dissolved solid, desalination, salt, ocean water characteristics, and aquaculture.*

## MATH SKILLS

### Math Skills

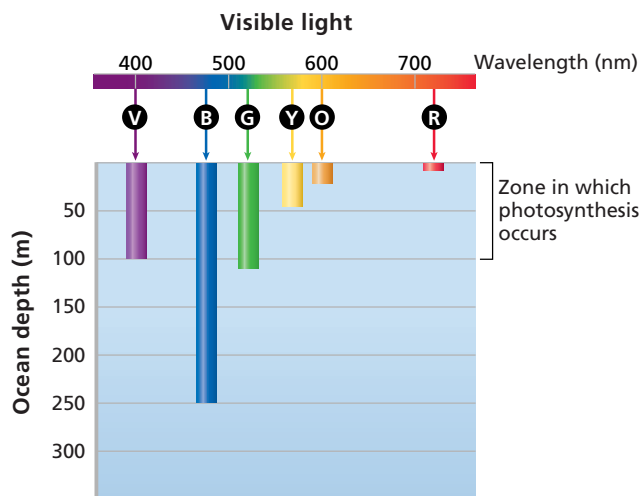
- 29. Using Equations** Using the equation  $\text{density} = \text{mass} \div \text{volume}$ , determine the mass of a  $3 \text{ cm}^3$  sample of ocean water if the water's density is  $1.027 \text{ g/cm}^3$ .
- 30. Making Calculations** What percentage of dissolved salts would be present in water that has a salinity of 40‰?
- 31. Making Calculations** A 1,000 g sample of ocean water contains 35 g of dissolved solids. Magnesium makes up 7.7% of the 35 g of dissolved solids. How many grams of magnesium are in the 1,000 g sample of ocean water?

## WRITING SKILLS

- 32. Creative Writing** Write a descriptive essay about the deep-ocean waters of the oceanic zone. Your essay should include a description of the marine organisms in this zone, as well as a description of what life is like for these marine organisms.
- 33. Writing from Research** Research the new foods that are being produced through aquaculture and the nations that are investing in this method of farming. Write a short essay that describes these foods, where they are grown, and their nutritional values.

## INTERPRETING GRAPHICS

The graph below shows the depths at which different wavelengths of light penetrate ocean water. Use this graph to answer the questions that follow.



- 34.** Estimate the depth at which yellow light can no longer penetrate ocean water.
- 35.** Which colors can penetrate ocean water to a depth of 50 m?
- 36.** Would an object that is painted red appear red at a depth of 50 m? Explain your answer.



## Understanding Concepts

Directions (1–5): For each question, write on a separate sheet of paper the letter of the correct answer.

- Organisms that live on the ocean floor are called  
**A.** benthos. **C.** plankton.  
**B.** nekton. **D.** phytoplankton.
- Which process cannot be used to remove salt from sea water to make the water safe for drinking?  
**F.** distillation  
**G.** freezing  
**H.** reverse osmosis  
**I.** adding fresh water
- The temperature of ocean water is dependent on all of the following except  
**A.** depth.  
**B.** the amount of solar energy that the ocean water receives.  
**C.** water movement.  
**D.** the number of organisms living in the ocean water.
- As the temperature of ocean water increases from 10°C to 30°C, how does the water's density change?  
**F.** It increases.  
**G.** It decreases.  
**H.** It remains the same.  
**I.** It is impossible to predict.
- Which of the following is a barrier to the mining of mineral nodules?  
**A.** Mining rights for the ocean floor have not yet been determined.  
**B.** Nodules contain only traces of minerals and therefore are not worth the effort to gather.  
**C.** Nodules are readily accessible and therefore not valuable.  
**D.** Nodules primarily contain elements that are dangerous to humans.

Directions (6–7): For each question, write a short response.

- What is the cause of deep ocean currents?
- What is the name of the top layer of ocean water that extends to 300 m below sea level?

## Reading Skills

Directions (8–10): Read the passage below. Then, answer the questions.

### The Effects of El Niño

The interaction between the ocean and the atmosphere can profoundly affect weather conditions. Occurring, on average, every four years and lasting about 18 months, El Niño is one event that triggers global weather changes. El Niño is characterized by changes in wind patterns that allow warmer water from the western Pacific Ocean to surge eastward. Normally, east-to-west winds cause warm water to accumulate in the western Pacific Ocean. During El Niño, the trade winds weaken and warm water shifts east. Sea surface temperatures from the coast of Peru to the equatorial central Pacific rise. The warm water causes the thermocline to sink and contributes to the formation of convective clouds, which cause heavy rains that shift eastward at the same rate as the water. In areas on the western coast of the Pacific Ocean, droughts become common.

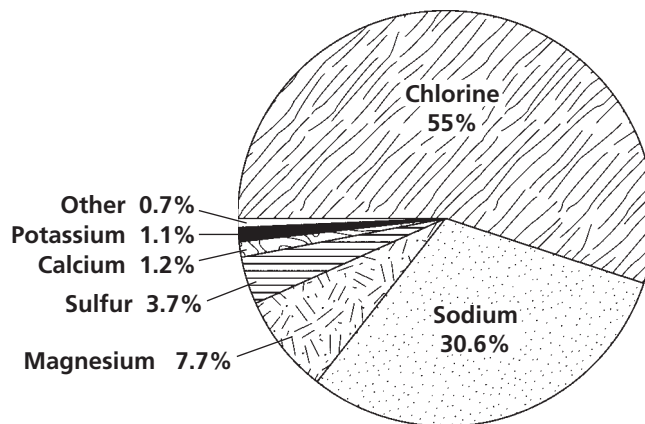
- According to the passage, which of the following statements is not true?  
**F.** During El Niño, the trade winds weaken and warm water shifts eastward.  
**G.** El Niño is one event that triggers global weather changes.  
**H.** An El Niño weather event lasts about two years on average.  
**I.** An El Niño event leads to the formation of convective clouds that shift eastward.
- Which of the following statements can be inferred from the passage?  
**A.** An El Niño event is usually followed by a weather event that moves cold water westward.  
**B.** The changes caused by El Niño directly affect the weather in the United States.  
**C.** El Niño causes severe disruptions to international trade and travel.  
**D.** El Niño weather cycles are a relatively recent phenomenon.
- During an El Niño weather event, what happens to the thermocline? What effect might this have on upwelling?

## Interpreting Graphics

Directions (11–13): For each question below, record the correct answer on a separate sheet of paper.

Use the pie graph to answer questions 11 and 12.

**Solids Dissolved in Ocean Water**



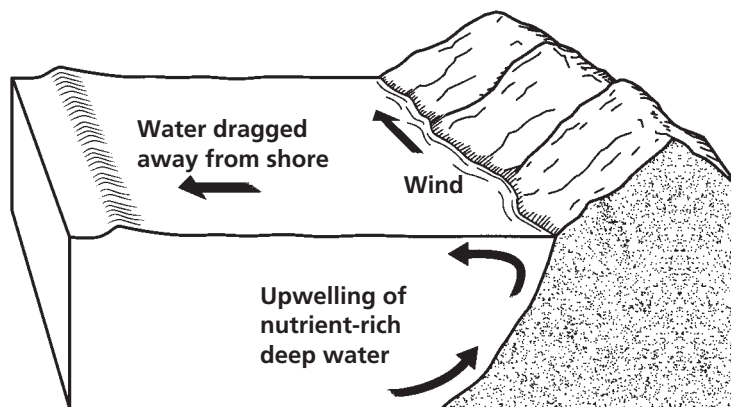
**11.** The two elements that make up the largest percentage of the dissolved solids combine to make what common solid found in ocean water?

- F.** sand
- G.** salt
- H.** siliceous ooze
- I.** calcareous ooze

**12.** Identify the two elements that are most abundant in ocean water. What are the sources of these elements?

The diagram below shows the basic mechanics of upwelling. Use this diagram to answer question 13.

**Mechanics of Upwelling**



**13.** During summer months, beaches may sometimes close because of the appearance of large phytoplankton blooms. How might an upwelling contribute to these beach closings during warmer months?

### Test Tip

Scan the answer choices for words such as *never* and *always*. Such words are often used in statements that are incorrect because they are too general.