15 Ocean Water and Ocean Life

Big idea

Water Planet

Q: What factors affect life in the ocean?

VIRGINIA SCIENCE STANDARDS OF LEARNING

ES.1.a, ES.1.c, ES.1.e, ES.2.c, ES.10.a, ES.10.c.
See lessons for details.

A humpback whale breaches off the coast of Vancouver Island in Canada.

INQUIRY
TRY IT!

HOW DOES SALINITY AFFECT THE DENSITY OF WATER?

Procedure

1. Pour 400 mL of fresh water into a 500-mL graduated cylinder. Pour 400 mL of salt water into a second 500-mL graduated cylinder. Precise measurement is important.

2. Gently place a small rubber ball or stopper in the fresh water. Record the new water level. Remove the object from the water and dry it off thoroughly.

3. Repeat Step 2 using the salt water and record your observations.

Think About It

1. **Calculate** What volume of fresh water was displaced by the object? What volume of salt water was displaced by the floating object?

2. **Draw Conclusions** As the density of water increases, the volume of liquid displaced by an object decreases. Which water is more dense—fresh water or salt water?

3. **Draw Conclusions** How does salinity affect the density of water?

15.1 The Composition of Seawater

ES.10 The student will investigate and understand that oceans are complex, interactive physical, chemical, and biological systems and are subject to long- and short-term variations. Key concepts include **a.** physical and chemical changes related to tides, waves, currents, sea level and ice cap variations, upwelling, and salinity variations.

Key Questions

What units are used to express the salinity of ocean water?

What are the sources of salt in ocean water?

What factors affect the density of ocean water?

What are the three main zones of the open ocean?

Vocabulary

- salinity
- thermocline
- density
- pycnocline

Reading Strategy

Preview Copy the table shown below. Before you read, preview the figures in this section and add three more questions to the table. As you read, write answers to your questions.

Questions About Seawater	Answers
What processes affect seawater salinity?	a. ?
b. ?	c. ?
d. ?	e. ?
f. ?	g. ?

WHAT IS THE difference between pure water and seawater? One of the most obvious differences is that seawater contains dissolved substances that give it a salty taste. Seawater consists of about 3.5 percent dissolved mineral substances that are collectively termed "salts." Although the percentage of dissolved components may seem small, the actual quantity is huge because the ocean is so vast.

These dissolved substances include sodium chloride, other salts, metals, and even dissolved gases. In fact, every known naturally occurring element is found dissolved in at least trace amounts in seawater. The salt content of seawater makes it unsuitable for drinking by land organisms or for irrigating most crops. Seawater is also corrosive to many materials. However, the ocean is full of life adapted to this environment.

Salinity

Salinity (*salinus* = salt) refers to the total amount of solid material dissolved in water. It is the ratio of the mass of dissolved substances to the mass of the water sample. Many common quantities are expressed in percent (%), which is parts per hundred. **Because the proportion of dissolved substances in seawater is such a small number, oceanographers typically express salinity in parts per thousand (‰).** The average salinity of seawater is 3.5% or 35‰. **Figure 1** shows the principal elements that contribute to the ocean's salinity. Most of the salt in seawater is sodium chloride, common table salt.

Sources of Sea Salts

What are the primary sources of dissolved substances in the ocean? **Chemical weathering of rocks on the continents is one source of elements found in seawater.** These dissolved materials reach the ocean through runoff rom rivers and streams at an estimated rate of more than 2.3 billion metric tons per year. **The second major source of elements found in seawater is from Earth's interior.** Through volcanic eruptions, large quantities of water vapor and other gases have been emitted into the atmosphere during much of geologic time. Scientists think that this is the principal source of water in the oceans. About 4 billion years ago, as Earth's temperature cooled, the water vapor condensed and torrential rains filled the ocean basins with water.

Certain elements—particularly chlorine, bromine, sulfur, and boron—were emitted from volcanoes along with the water. These elements occur in the ocean in much greater quantities than could be explained by weathering of rocks alone.

Evidence suggests that the composition of seawater has been relatively stable for millions of years. Material is removed at about the same rate that it is added. Organisms remove material as they build hard structures, such as shells. Materials also precipitate out of the water in sediment.

Processes Affecting Salinity Because the ocean is well mixed, the concentrations of the major components in seawater are fairly constant throughout the ocean. Surface salinity variation in the open ocean normally ranges from 33‰ to 38‰. Salinity varies depending on the amount of water in the solution.

Figure 2 shows some of the different processes that affect the amount of water in seawater, thereby affecting salinity. Some processes add large amounts of fresh water to seawater, decreasing salinity. These processes include precipitation, runoff rom land, and icebergs and sea ice melting. In areas of great precipitation, such as in the mid-latitudes and near the equator, salinity is below average.

Other processes increase salinity by removing large amounts of water from seawater. These processes include evaporation and the formation of sea ice. High salinities, for example, are found where evaporation rates are high, as is the case in the dry regions roughly between 25 and 35 degrees north or south latitude.

Surface salinity in polar regions varies seasonally due to the formation and melting of sea ice. When seawater freezes in winter, salts do not become part of the ice. Therefore, the salinity of the remaining seawater increases. In summer when sea ice melts, the addition of mostly freshwater decreases the seawater's salinity.

FIGURE 1 Salts in Seawater
This circle graph shows that 1000 grams of seawater with a salinity of 35‰ consists of 965 grams of water and 35 grams of salts and other solids dissolved in the water.

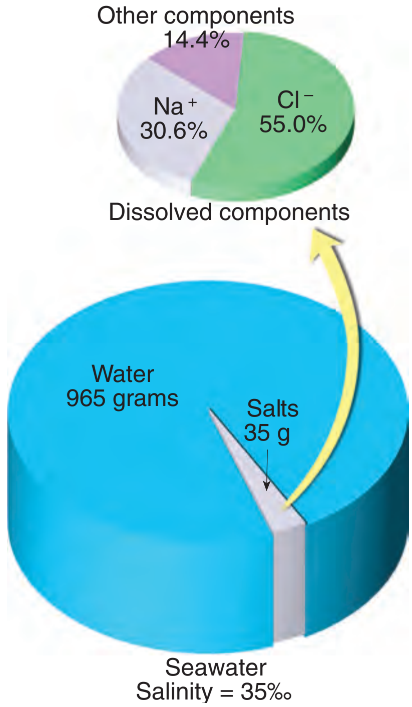
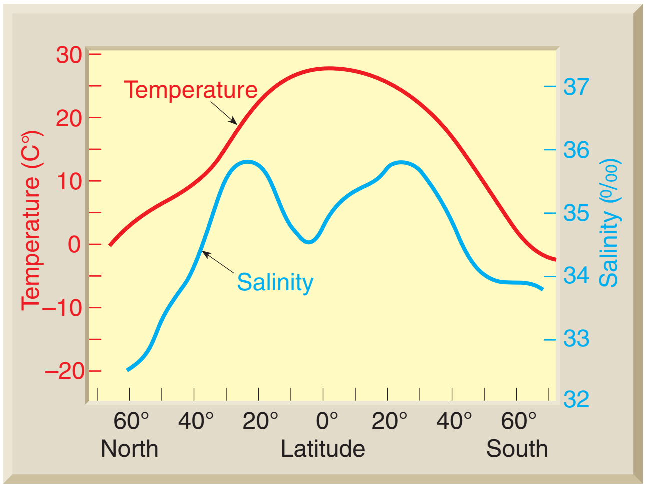


FIGURE 2 Natural Processes Affect the Salinity of Seawater
Apply Concepts *Which processes decrease the salinity of seawater? Which processes increase it?*

FIGURE 3 Effect of Latitude on Temperature and Salinity This graph shows the variations in ocean surface temperature (top curve) and surface salinity (lower curve) at different latitudes.
Interpret Graphs ***At which latitudes is sea surface temperature highest? Why?***

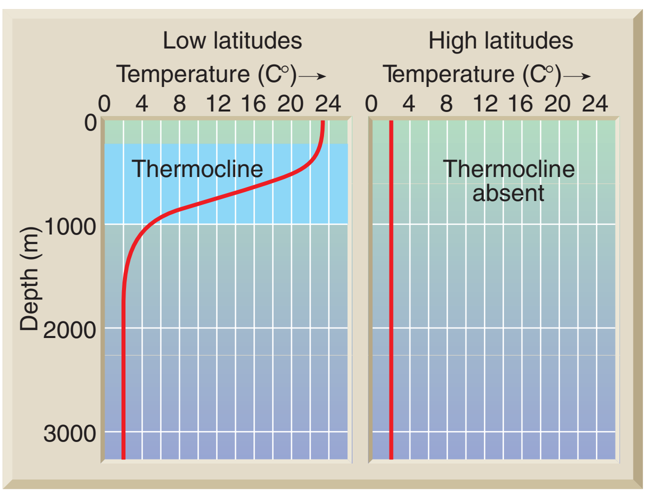


Ocean Temperature Variation

The temperature of the ocean contributes to global climate and is important to marine organisms. Latitude and water depth are two factors that influence the temperature of water masses.

Temperature Variation With Latitude **The ocean's surface water temperature is affected by the amount of solar radiation received, which is primarily due to latitude.** The graph in **Figure 3** shows this relationship. Due to the angle at which the sun's rays strike Earth, the intensity of solar radiation in high latitudes is much less than the intensity of solar radiation received in latitudes closer to the equator. Therefore, lower sea surface temperatures are found in high-latitude regions. Higher sea surface temperatures are found in low-latitude regions.

FIGURE 4 Temperature and Depth These graphs show the variations in ocean water temperature with depth for low-latitude and high-latitude regions.
Apply Concepts ***Why is the thermocline absent in the high latitudes?***



Temperature Variation With Depth If you lowered a thermometer from the surface of the ocean into deeper water, what temperature pattern do you think you would find? Surface waters are warmed by the sun. They generally have higher temperatures than deeper waters. However, the observed temperature pattern depends on the latitude.

Figure 4 shows two graphs of temperature versus depth: one for low-latitude regions and one for high-latitude regions. The low-latitude graph shows high temperature at the surface. However, the temperature decreases rapidly with depth because of the inability of the sun's rays to penetrate very far into the ocean. At a depth of about 1000 meters, the temperature remains just a few degrees above freezing; it is relatively constant from this level down to the ocean floor. The **thermocline** (*thermo* = heat, *cline* = slope) is the layer of ocean water between about 300 meters and 1000 meters, where there is a rapid change of temperature with depth. The thermocline is a very important structure in the ocean because it creates a vertical barrier to many types of marine life.

The high-latitude graph in Figure 4 shows a very different pattern from the low-latitude graph. Surface water temperatures in high latitudes are much cooler than in low latitudes. Deeper in the ocean, the temperature of the water is similar to that at the surface, so the line remains vertical with no thermocline. A water column with no thermocline is called *isothermal* (*iso* = same, *thermo* = heat).

☑ **Reading Checkpoint** *What is the thermocline?*

Ocean Density Variation

Density is defi ed as mass per unit volume. It can be thought of as a measure of how heavy something is for its size. For example, an object that has low density seems lightweight for its size, such as a dry sponge. An object that has high density, such as cement, seems heavy for its size. Density is an important property of ocean water because it determines the water's vertical position in the ocean. Density differences cause large masses of ocean water to sink below other masses or to float.

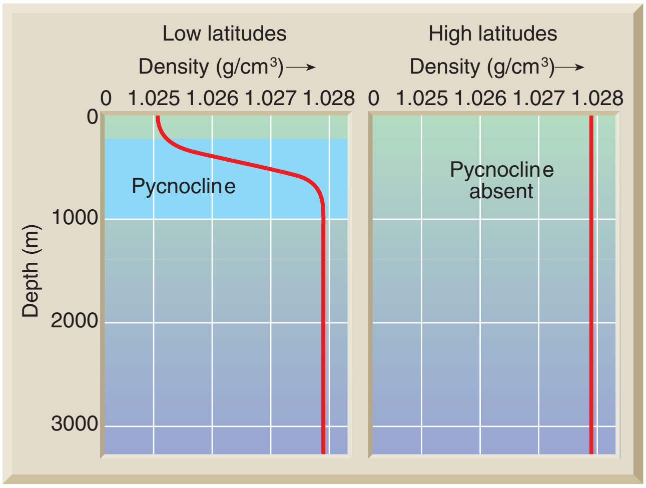
Factors Affecting Seawater Density

Seawater density is influenced by two main factors: salinity and temperature. An increase in salinity adds dissolved substances and results in an increase in seawater density. Although now a lake, the Dead Sea was once connected to the Mediterranean Sea. The salinity of the Dead Sea is ten times the average salinity of seawater. As a result, it has high buoyancy that allows swimmers, such as the one in **Figure 5,** to float easily.

An increase in temperature results in a decrease in seawater density. Generally, temperature has a greater influence over surface seawater density because the temperature of surface seawater tends to vary more than its salinity. Cold, polar regions with seawater that has high salinity contain the most dense seawater in the world.

FIGURE 5 Floating in the Dead Sea

FIGURE 6 Density and Depth The graphs show variations in ocean water density with depth for low-latitude and high-latitude regions. **Interpret Graphs** ***What is the difference between the low-latitude graph and the high-latitude graph? Why does this difference occur?***



Density Variation With Depth By sampling ocean waters, oceanographers have learned that temperature and salinity—and the water's resulting density—vary with depth. **Figure 6** shows two graphs of density versus depth. One graph shows the density for low-latitude regions and the other for high-latitude regions. The **pycnocline** (*pycno* = density, *cline* = slope) is the layer of ocean water between about 300 meters and 1000 meters where there is a rapid change of density. A pycnocline presents a significant barrier to mixing between low-density water above and high-density water below. A pycnocline is not present in high latitudes where the water column is about the same density throughout.

Reading Checkpoint *How does an increase in temperature affect the density of seawater?*

Ocean Layering

The ocean, similar to Earth's interior, is layered according to density. Low-density water exists near the surface, and higher-density water occurs below. Except for some shallow inland seas with a high rate of evaporation, the highest-density water is found at the greatest ocean depths. **Oceanographers generally recognize a three-layered structure in most parts of the open ocean: a shallow surface mixed zone, a transition zone, and a deep zone.** These zones are shown in **Figure 7.**

Surface Mixed Zone Because solar energy comes in contact with the ocean surface, water temperature is highest at the surface. The *surface mixed zone* is the area of the surface formed by the mixing of water by waves, currents, and tides. The surface mixed zone has nearly uniform temperatures. The depth and temperature of this layer vary, depending on latitude and season. The zone usually extends to about 300 meters, but it may extend to a depth of 450 meters. The surface mixed zone accounts for only about 2 percent of ocean water.

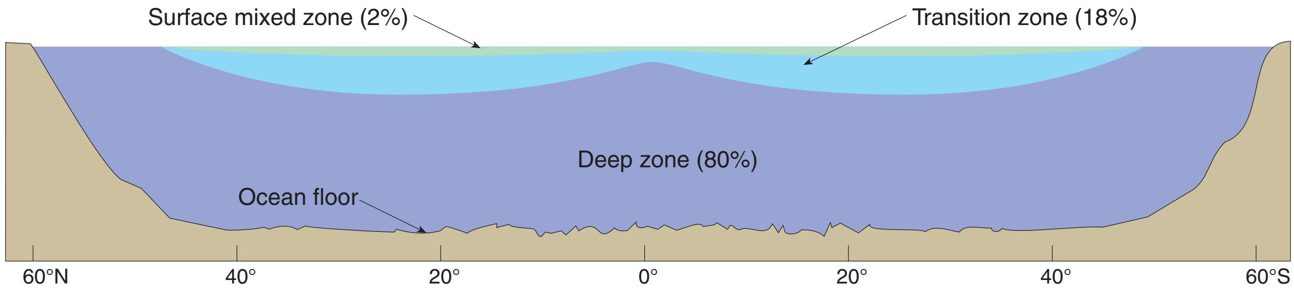


FIGURE 7 Ocean Zones Oceanographers recognize three main zones of the ocean based on water density, which varies with temperature and salinity. Note that the three layers do not form at high latitudes.

Transition Zone Below the sun-warmed surface mixed zone, the temperature drops abruptly with depth as was seen in Figure 4. Here, a distinct layer called the transition zone sits between the warm surface layer above and the deep zone of cold water below. The transition zone includes a thermocline and an associated pycnocline. This zone accounts for about 18 percent of ocean water.

Deep Zone Below the transition zone is the deep zone. Sunlight does not reach this zone, and water temperatures are just a few degrees above freezing. As a result, water density remains constant and high. The deep zone includes about 80 percent of ocean water.

In high latitudes, open ocean water does not form the three-layered structure shown in Figure 7. The three layers do not develop because there is no rapid change in temperature or density with depth. Therefore, good vertical mixing between surface and deep waters can occur in high-latitude regions. Here, cold, high-density water forms at the surface, sinks, and initiates deep-ocean currents that travel toward the equator.

15.1 Assessment

Review Key Concepts

1. What is salinity?
2. What units are used to express the salinity of ocean water?
3. What are the sources of salt in ocean water?
4. Explain the relationship between latitude and sea surface temperature.
5. What factors affect the density of ocean water?
6. What are the three main zones of the open ocean?

Think Critically

7. **Infer** Why does the salinity of seawater remain relatively constant over time?
8. **Summarize** Explain the general pattern of temperature variation with depth in low-latitude ocean water.

WRITING IN SCIENCE

9. **Describe** Write a paragraph that describes the different characteristics of the three zones of the open ocean. Include an explanation of why polar regions do not exhibit the same pattern of water layers.

15.2 The Diversity of Ocean Life

ES.10 The student will investigate and understand that oceans are complex, interactive physical, chemical, and biological systems and are subject to long- and short-term variations. Key concepts include **c.** systems interactions.

Key Questions

How can marine organisms be classified?

What is the difference between plankton and nekton?

In which area of the ocean can most benthos organisms be found living?

What factors are used to divide the ocean into marine life zones?

Vocabulary

- photosynthesis
- plankton • phytoplankton
- zooplankton • nekton
- benthos • photic zone
- intertidal zone
- neritic zone
- oceanic zone
- pelagic zone
- benthic zone
- abyssal zone

Reading Strategy

Build Vocabulary Copy the table below. As you read, add definitions and examples to complete the table.

Definitions	Examples
Plankton: organisms that drift with ocean currents	bacteria
Phytoplankton: a. ___?___	b. ___?___
Zooplankton: c. ___?___	d. ___?___
Nekton: e. ___?___	f. ___?___
Benthos: g. ___?___	h. ___?___

A WIDE VARIETY of organisms inhabit the marine environment. These organisms range in size from microscopic bacteria and algae to the largest organisms alive today—blue whales, which can be as long as three buses lined up end to end. Marine biologists have identified more than 250,000 marine species. This number is constantly increasing as new organisms are discovered. There are advantages and disadvantages to living in a marine environment. One advantage is that there is plenty of water. One disadvantage is that moving through water can be difficult. The success of marine organisms depends on their ability to avoid predators, fi d food, and cope with the challenges of their environment.

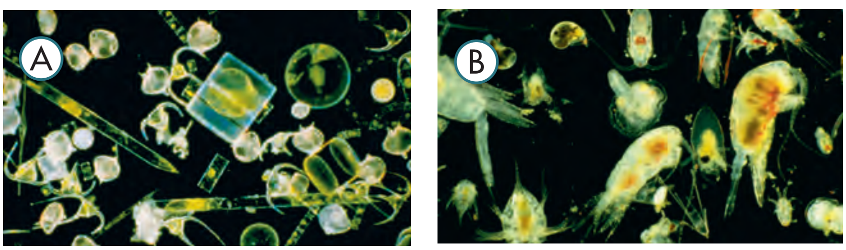
Classification of Marine Organisms

Marine organisms can be classified according to where they live and how they move. They can be classified as either plankton (floaters), nekton (swimmers), or benthos (bottom dwellers). Most marine organisms live in the sunlit surface of the ocean, where photosynthesis is possible. Organisms that perform **photosynthesis** use water, carbon dioxide, and energy from sunlight to produce carbohydrates for food. These organisms directly or indirectly provide food for the vast majority of marine organisms. Because oxygen is a waste product of photosynthesis, photosynthesizing organisms also are an important source of atmospheric oxygen.

Plankton

All organisms that drift ith ocean currents, including algae, tiny animals, and bacteria, are known as plankton (*planktos* = wandering). Many plankton can also swim, but either move very weakly or move only vertically.

FIGURE 8 Plankton Plankton are organisms that drift with ocean currents.



A This photograph shows a variety of phytoplankton from the Atlantic Ocean. **B** The zooplankton shown here include copepods and the larval stages of other common marine organisms.

Among plankton, the organisms that perform photosynthesis are called **phytoplankton.** Most phytoplankton, such as diatoms, are microscopic. Animal plankton are called **zooplankton.** Zooplankton include the larval stages of many marine organisms such as fish, sea stars, lobsters, and crabs. **Figure 8** shows members of each group.

Nekton **All animals capable of moving independently of the ocean currents, by swimming or other means of propulsion, are called nekton** (*nektos* = swimming). Nekton can determine their position within the ocean and in many cases complete long migrations. Nekton include most adult fish and squid, marine mammals, and marine reptiles. **Figure 9** shows examples of nekton.

Fish may appear to exist everywhere in the oceans, but they are more abundant near continents and islands and in colder waters. Some fish, such as salmon, swim upstream in freshwater rivers to spawn. Many eels do just the reverse, growing to maturity in fresh water and then swimming out of the streams to breed in the depths of the ocean.

Benthos **Organisms that live on or in the ocean bottom are called benthos** (*benthos* = bottom). **Figure 10** shows some examples of benthos. The shallow coastal ocean floor contains a wide variety of physical conditions and nutrient levels. Most benthos can be found living in this area. Shallow coastal areas are the only locations where large brown algae, often called seaweeds, are found attached to the bottom. These are the only areas of the seafloor that receive enough sunlight for the algae to survive.

Throughout most of the deeper parts of the seafloor, where photosynthesis cannot occur, animals live in perpetual darkness. They must feed on each other or on whatever nutrients fall from the productive surface waters. The deep-sea bottom is an environment of coldness, stillness, and darkness. Under these conditions, life progresses slowly. Organisms that live in the deep sea usually are widely distributed because physical conditions vary little on the deep-ocean floor.

FIGURE 9 Nekton Nekton include all animals capable of moving independently of ocean currents. **A** This squid can use propulsion to move through the water. **B** This school of grunts swims through the water with ease.
Infer ***Why do you think some organisms are classified as plankton during some stages of their lives and nekton during other stages?***

FIGURE 10 Benthos Benthos are organisms living on or in the ocean bottom. Benthic organisms include sea stars **(A)** and crabs **(B).**

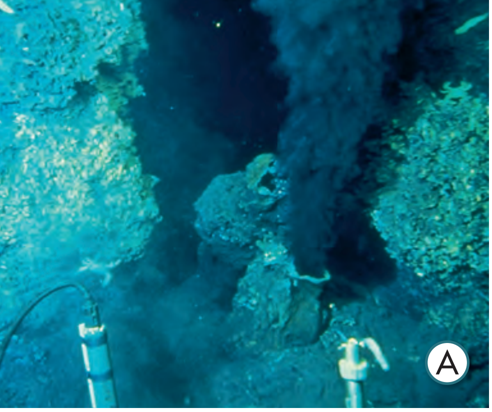


FIGURE 11 Hydrothermal Vents
A When super-heated water meets cold seawater, "black smoke" forms as minerals precipitate from the water. **B** Tube worms up to 3 meters in length are among the organisms that live on hydrothermal vents.

Hydrothermal Vents Among the most unusual seafloor discoveries of the last several decades have been the hydrothermal vents along the mid-ocean ridge. Here seawater seeps into the ocean floor through cracks in the crust.

The water becomes super-heated and saturated with minerals. Eventually the heated water escapes back into the ocean. When the hot water comes in contact with the surrounding cold water, the minerals precipitate out, giving the water the appearance of black smoke. These geysers of hot water are referred to as black smokers, such as the one shown in **Figure 11.**

At some vents water temperatures of 100°C or higher support communities of benthic organisms found nowhere else in the world. In fact, hundreds of new species have been discovered surrounding these deep-sea habitats since scientists found vents along the Galápagos Rift in 1977. Chemicals from the vents are an energy source for bacteria. These bacteria produce sugars and other foods that enable them and many other organisms to live in this very extreme environment.

Marine Life Zones

The distribution of marine organisms is affected by the chemistry, physics, and geology of the ocean. Marine organisms are influenced by a variety of physical factors. **Three factors are used to divide the ocean into distinct marine life zones: the availability of sunlight, the distance from shore, and the water depth.** The different zones in which marine life can be found are shown in **Figure 12.**

Availability of Sunlight The part of the ocean into which sunlight penetrates is called the **photic zone** (*photos* = light). The clarity of seawater is affected by many factors, such as the amount of plankton, suspended sediment, and decaying organic particles in the water. In addition, the amount of sunlight varies with atmospheric conditions, time of day, season, and latitude.

The *euphotic zone* is the portion of the photic zone near the surface where light is strong enough for photosynthesis to occur. In the open ocean, this zone can reach a depth of 100 meters, but the zone will be much shallower close to shore where water clarity is typically reduced. In the euphotic zone, phytoplankton use sunlight to produce food that directly or indirectly feeds most ocean life.

Although photosynthesis cannot occur much deeper than 100 meters, there is enough light in the lower photic zone for marine animals to avoid predators, find food, recognize other members of their species, and locate mates. Below this zone is the *aphotic zone,* where there is no sunlight.

Reading Checkpoint *What is the difference between the photic zone and the aphotic zone?*

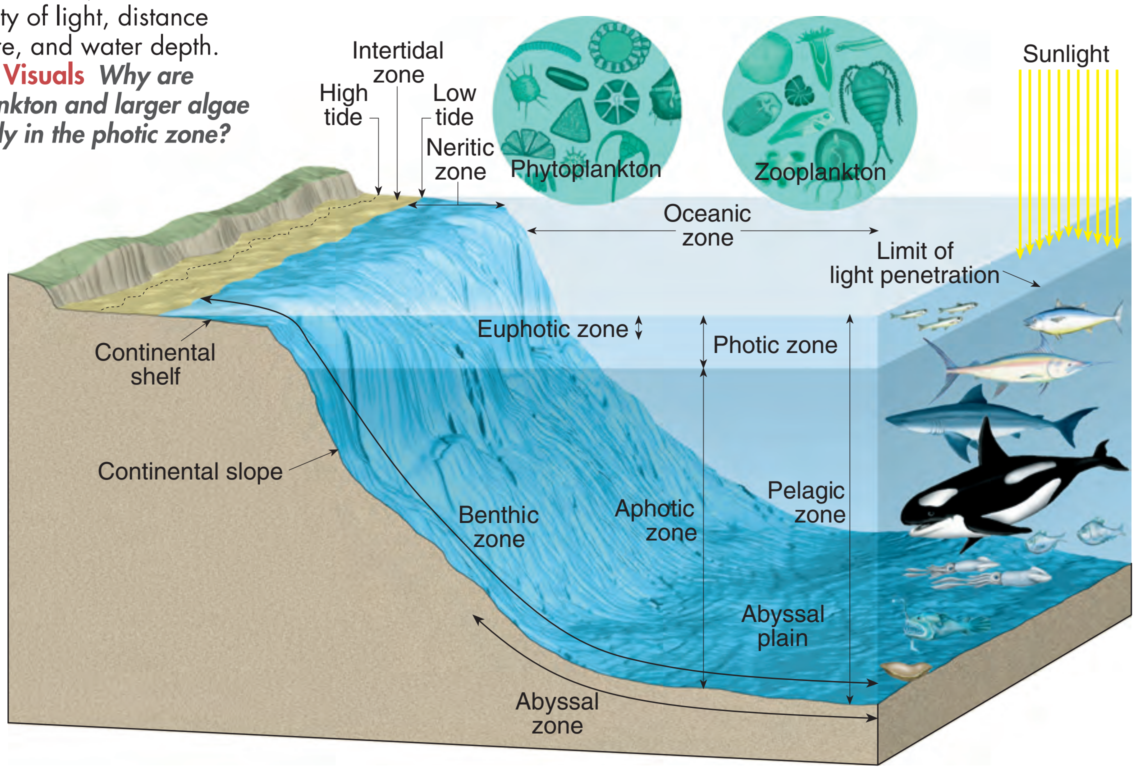
Distance from Shore Marine life zones can also be subdivided based on distance from shore. The area where the land and ocean meet and overlap is the **intertidal zone.** This narrow strip of land between high and low tides is alternately covered and uncovered by seawater with each tidal change. It appears to be a harsh place to live with crashing waves, periodic drying out, and rapid changes in temperature, salinity, and oxygen concentrations. However, the species that live here are well adapted to the constant environmental changes.

Seaward from the low-tide line is the **neritic zone.** This zone covers the gently sloping continental shelf. The neritic zone can be very narrow or may extend hundreds of kilometers from shore. It is often shallow enough for sunlight to reach all the way to the ocean floor, putting it entirely within the photic zone.

Although the neritic zone covers only about 5 percent of the world ocean, it is rich in biomass and number of species. Many organisms fi d the conditions here ideal because photosynthesis occurs readily, runoff rom the land supplies nutrients, and the bottom provides shelter and habitat. This zone is so rich with life that it supports 90 percent of the world's commercial fisheries.

Beyond the continental shelf is the **oceanic zone.** The open ocean reaches great depths. As a result, surface waters typically have lower nutrient concentrations because nutrients tend to sink from the photic zone to the deep-ocean floor. This low nutrient concentration usually results in smaller populations than are found in the more productive neritic zone.

FIGURE 12 Marine Life Zones
The ocean is divided into marine life zones, based on availability of light, distance from shore, and water depth. **Interpret Visuals** ***Why are phytoplankton and larger algae found only in the photic zone?***



INQUIRY APPLY IT!

Q: *How do deep-sea organisms find their way around without sunlight?*

A: More than half of deep-sea organisms—including fishes, jellies, crustaceans, and deep-sea squid—are bioluminescent, which means they can produce light. These organisms produce light through a chemical reaction in specially designed structures or cells called *photophores*. Some of these cells contain luminescent bacteria that live symbiotically within the organism. In a world of darkness, the ability to produce light can be used to attract prey, define territory, communicate with others, or avoid predators.

Water Depth A third method of classifying marine habitats is based on water depth. These three zones—the pelagic, benthic, and abyssal—are shown on the previous page in Figure 12. Open ocean of any depth is called the **pelagic zone.** Animals in this zone swim or float freely. The photic part of the pelagic zone is home to plankton and nekton, such as tuna, sea turtles, and dolphins. Giant squid and other species that are adapted to life in deep water inhabit the aphotic zone.

The **benthic zone** includes any sea-bottom surface regardless of its distance from shore. It is mostly inhabited by benthos such as giant kelp, sponges, crabs, sea anemones, sea stars, and marine worms that attach to, crawl upon, or burrow into the seafloor.

The **abyssal zone** is a subdivision of the benthic zone. The abyssal zone includes the deep-ocean floor, such as abyssal plains. This zone is characterized by extremely high water pressure, consistently low temperature, no sunlight, and sparse life. Food sources at abyssal depths typically come from the surface, such as decaying particles that steadily "rain" down. These particles provide food for filter feeders, brittle stars, and burrowing worms. Other food arrives as large fragments or entire bodies of dead organisms that sink from the surface. These pieces supply meals for fish that are actively seeking food, such as the grenadier, tripodfish, and hagfish.

15.2 Assessment

Review Key Concepts

1. How can marine organisms be classified?
2. What is the difference between plankton and nekton?
3. In which area of the ocean do most benthic organisms live?
4. What factors are used to divide the ocean into marine life zones?
5. Why is the neritic zone rich in living things?
6. What are two reasons that scientists were surprised to find so many different forms of life on hydrothermal vents?

Think Critically

7. **Infer** Why do many fish in the abyssal zone locate food through chemical sensing?
8. **Infer** Organisms that live in the intertidal zone must deal with harsh and changing conditions. What types of adaptations would benefit organisms living in this zone?

BIGIDEA WATER PLANET

9. Make a table to organize the information about marine life zones presented in this section. Include the basis by which the zone is classified, any subdivisions of the zone, and the characteristics of each zone.

15.3 Oceanic Productivity

ES.10 The student will investigate and understand that oceans are complex, interactive physical, chemical, and biological systems and are subject to long- and short-term variations. Key concepts include **c.** systems interactions.

LIKE OTHER ECOSYSTEMS on Earth, organisms in the marine environment are interconnected through the web of food production and consumption. Marine producers include phytoplankton, larger algae such as seaweeds, and bacteria. Consumers include crabs, clams, sea stars, fish, dolphins, and whales. Why are some regions of the ocean teeming with life, while other areas seem barren? The answer is related to the amount of primary productivity in various parts of the ocean.

Primary Productivity

Primary productivity is the production of organic compounds from inorganic substances through photosynthesis or chemosynthesis. Recall that photosynthesis is the use of light energy to convert water and carbon dioxide into energy-rich glucose molecules. **Chemosynthesis** is the process by which certain microorganisms produce organic molecules from inorganic nutrients using chemical energy. For example, bacteria in hydrothermal vent communities use hydrogen sulfide as an energy source. These bacteria are producers that support the hydrothermal vent communities.

Two factors influence a region's photosynthetic productivity: the availability of nutrients and the amount of solar radiation, or sunlight. Primary producers need nutrients such as nitrogen, phosphorus, and iron. Lack of nutrients can be a limiting factor in productivity. Thus, the most abundant marine life exists where there are ample nutrients and sunlight. Oceanic productivity, varies dramatically because of the uneven distribution of nutrients throughout the photic zone and the availability of solar energy due to seasonal changes.

Key Questions

What factors influence a region's photosynthetic productivity?

Describe the transfer efficiency between trophic levels.

How do food webs show the relationships among organisms in an ecosystem?

Vocabulary

- primary productivity
- chemosynthesis
- trophic level
- food chain
- food web

Reading Strategy

Identify Main Ideas Copy the table below. As you read, write the main idea of each topic.

Topic	Main Idea
Productivity in polar oceans	a. ___?___
Productivity in tropical oceans	b. ___?___
Productivity in temperate oceans	c. ___?___

FIGURE 13 Great Barrier Reef The abundance of life found in coral reef communities is supported by high levels of primary productivity.

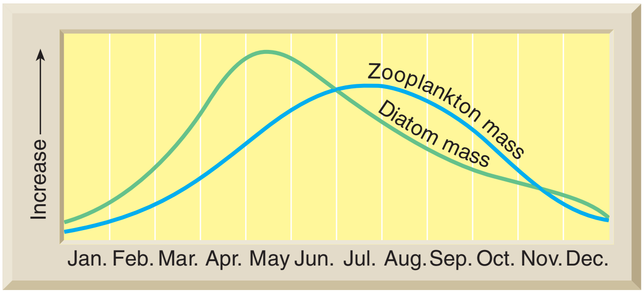


FIGURE 14 Productivity in a Polar Ocean One example of productivity in polar oceans is illustrated by the Barents Sea. **Interpret Graphs** *Describe the relationship between the zooplankton and phytoplankton populations.*

Productivity in Polar Oceans Polar regions such as the Arctic Ocean's Barents Sea, off he northern coast of Europe, experience continuous darkness for about three months of winter and continuous sunlight for about three months during summer. Productivity of phytoplankton, mostly single-celled algae called diatoms, peaks there during May. This trend is shown in the graph in **Figure 14.** During May the sun rises high enough in the sky so that sunlight penetrates deep into the water. The increase in available light results in an increase in the diatom population. Zooplankton now have a greater food source than before and their population also increases. As Figure 14 shows, the zooplankton biomass peaks in July and continues at a relatively high level until winter darkness begins in October.

Recall that density and temperature change very little with depth in polar regions and mixing occurs between surface waters and deeper, nutrient-rich waters. In the summer, however, melting ice produces a thin, low-salinity surface layer that does not readily mix with the deeper waters. This lack of mixing between water masses is crucial to summer productivity, because it helps prevent phytoplankton from being carried into deeper, darker waters. Instead, they are concentrated in the sunlit surface waters where they reproduce continuously.

Because of the supply of nutrients rising from deeper waters, high-latitude surface waters typically have high nutrient concentrations. **The availability of solar energy, however, is what limits photosynthetic productivity in polar areas.**

Productivity in Tropical Oceans You may be surprised to learn that productivity is low in tropical regions of the open ocean. Because the sun is more directly overhead, light penetrates much deeper into tropical oceans than in temperate and polar waters. Solar energy also is available year-round. However, productivity is low because a permanent thermocline prevents mixing between surface waters and nutrient-rich deeper waters. **Figure 15** shows how water masses are separated in the tropics. The thermocline is a barrier that cuts off he supply of nutrients from deeper waters below. **Productivity in tropical regions is limited by the lack of nutrients.** These areas have so few organisms that they are considered biological deserts.

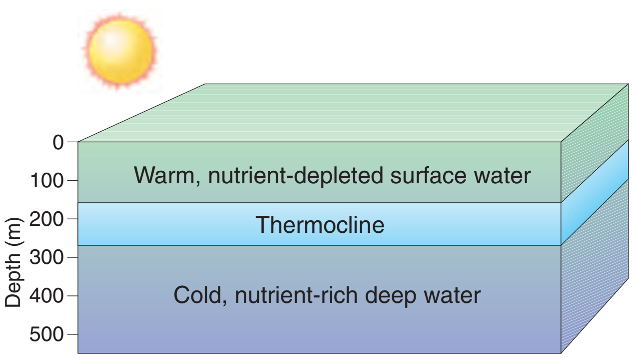


FIGURE 15 Water Layers in the Tropics The permanent thermocline in tropical oceans prevents the mixing of surface and deep water masses. Productivity is limited by the amount of nutrients in surface waters.

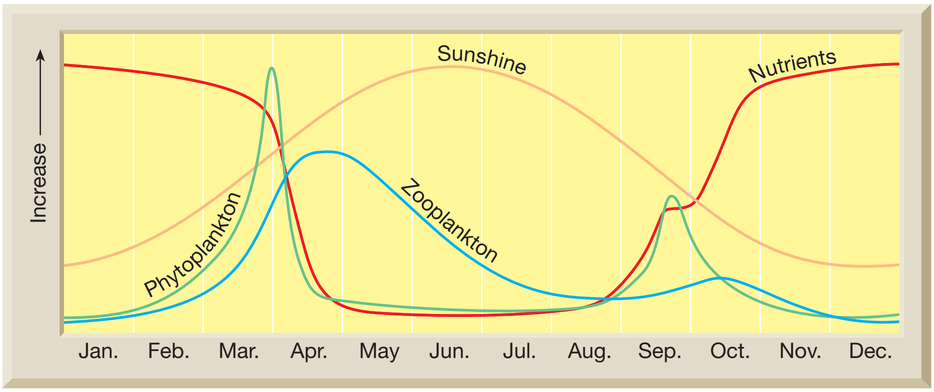


FIGURE 16 Productivity in Northern Hemisphere, Temperate Oceans The graph shows the relationship among phytoplankton, zooplankton, amount of sunshine, and nutrient levels for surface waters.
Interpret Graphs *What happens to phytoplankton in the spring and in the fall?*

Productivity in Temperate Oceans Productivity is limited by available sunlight in polar regions and by nutrient supply in the tropics. **In temperate regions, which are found at mid-latitudes, seasonal changes influence levels of sunlight and nutrient supply which, in turn, influence productivity.** These relationships are shown in **Figure 16.**

▶ ***Winter*** Productivity in temperate oceans is very low during winter, even though nutrient concentration is highest at this time. The reason is that solar energy is limited because days are short, and the sun angle is low. As a result, the depth at which photosynthesis can occur is so shallow that phytoplankton populations are low.

▶ ***Spring*** The sun rises higher in the sky during spring, allowing photosynthesis to occur at greater depths. A spring bloom of phytoplankton occurs because solar energy and nutrients are available. Eventually, a seasonal thermocline develops and traps algae in the euphotic zone. The algae consume nutrients in the euphotic zone and the supply is quickly depleted. Productivity decreases sharply. Even though the hours of daylight, and thus available sunlight, are increasing, productivity during the spring bloom is limited by the lack of nutrients.

▶ ***Summer*** The sun rises even higher in the summer, so surface waters in temperate parts of the ocean continue to warm. A strong seasonal thermocline develops that prevents the mixing of surface and deeper waters. Nutrients depleted from surface waters cannot be replaced by those from deeper waters. Throughout summer, the phytoplankton population remains relatively low.

▶ ***Fall*** Solar radiation decreases in the fall as the sun moves lower in the sky. Surface water temperatures drop and the summer thermocline diminishes. Nutrients return to the surface layer as increased wind strength mixes surface waters with deeper waters. These conditions produce a fall bloom of phytoplankton, which is much less dramatic than the spring bloom. The fall bloom is very short-lived because sunlight becomes the limiting factor as winter approaches.

PLANET DIARY

For an activity on **Photosynthesis in the Oceans,** visit PlanetDiary.com/HSES

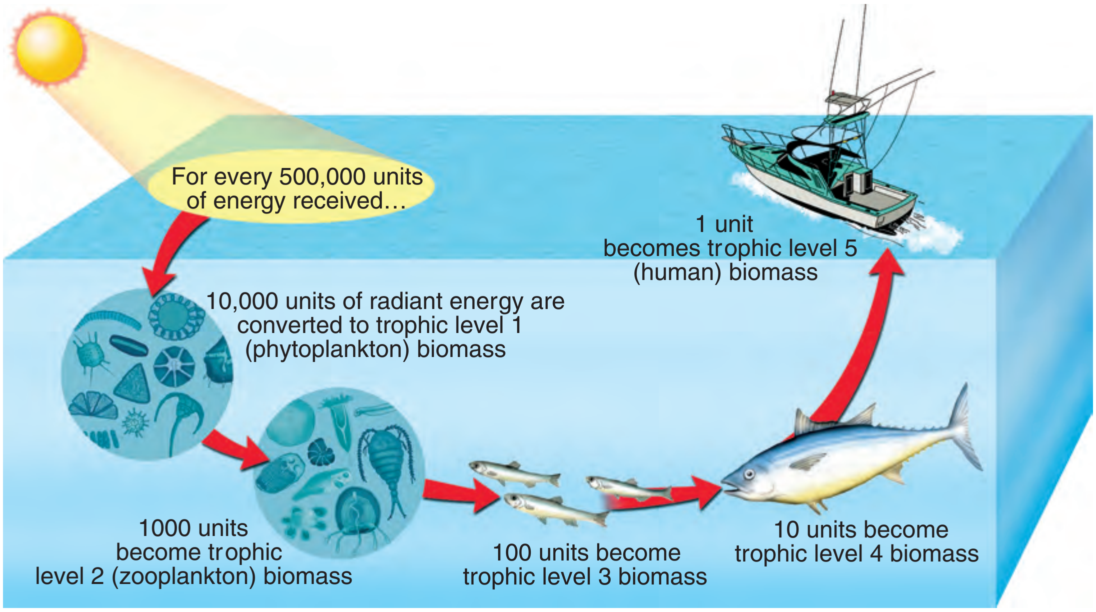


FIGURE 17 Energy Flow in an Ecosystem For every 500,000 units of radiant energy input available to the producers, only one unit of mass is added to the fifth trophic level.
Calculate ***What is the average transfer efficiency for phytoplankton? What is it for all of the other trophic levels?***

Oceanic Feeding Relationships

Phytoplankton, plants, and bacteria are the main oceanic producers. As producers make food available to the animals of the ocean, energy passes from one feeding population to the next. Only a small percentage of the energy taken in at any level is passed to the next one because energy is lost as heat at each level. As a result, the producers' biomass in the ocean is many times greater than the mass of top consumers, such as sharks.

ACTIVE ART

For: Ocean Food Web activity
Visit: PearsonSchool.com
Web Code: czp-5153

Trophic Levels Chemical energy stored in the mass of the ocean's producers is transferred to the animal community mostly through feeding. Zooplankton are herbivores (*herba* = grass, *vora* = eat) that consume phytoplankton. Larger herbivores feed on brown algae and marine plants that grow attached to the ocean bottom near shore. The herbivores are eaten by carnivores (*carni* = meat, *vora* = eat). Smaller carnivores are eaten by larger carnivores, and so on. Each of these feeding stages is called a **trophic level.**

Transfer Efficiency **The transfer of energy between trophic levels is very inefficient.** The transfer efficiencies of different primary producer species vary, but the average is only about 2 percent. This means that 2 percent of the light energy absorbed by primary producers is stored as chemical energy in food and made available to herbivores. **Figure 17** shows the passage of energy between trophic levels through an entire ecosystem—from the solar energy used by phytoplankton to a top-level carnivore, humans.

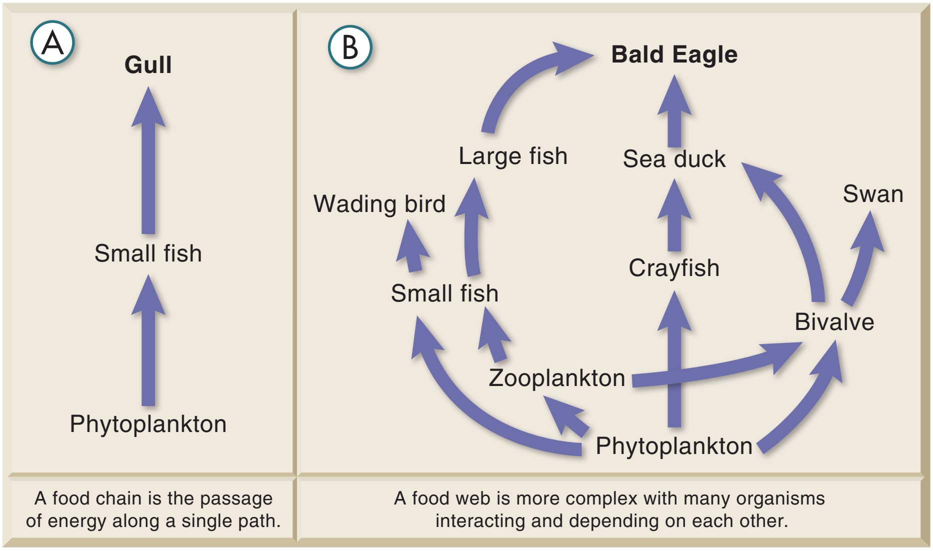


FIGURE 18 A Food Chain and Food Web of the Chesapeake Bay
A A food chain is the passage of energy along a single path. **B** A food web is a complex series of feeding relationships with many organisms interacting and depending on each other.

Food Chains and Food Webs A **food chain** is a sequence of organisms through which energy is transferred, starting with the primary producer. A herbivore eats the producer, then a carnivore eats the herbivore. The chain culminates with the "top carnivore," which is not usually preyed upon by any other organism.

Figure 18A shows a simple food chain. Feeding relationships are rarely as simple as this food chain suggests. More often, top carnivores in a food chain feed on a number of different animals, each of which feeds on a variety of organisms. These feeding relationships form a **food web. Figure 18B** shows a food web found in the Chesapeake Bay.

Food webs are used to evaluate relationships in ecosystems because they show how the success or failure of one population could affect other populations. For example, what could happen to small fish if a disease struck crayfish? With fewer crayfish to eat phytoplankton, small fish and zooplankton would have more food. If the zooplankton population also grew in size, the small fish could have a great increase in food supply.

15.3 Assessment

Review Key Concepts

1. What factors influence a region's photosynthetic productivity?
2. Describe the transfer efficiency between trophic levels.
3. Identify one food chain in the food web shown in Figure 18B.
4. What limits primary productivity in tropical oceans? Why?

Think Critically

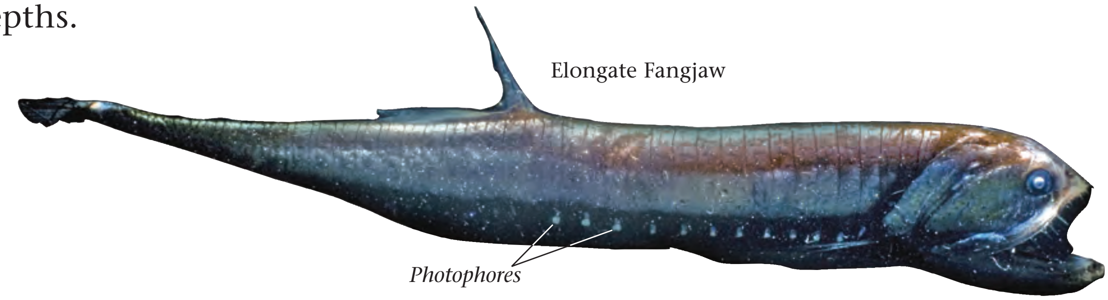
5. **Compare and Contrast** Compare and contrast photosynthesis and chemosynthesis. Give examples of organisms that perform each process.
6. **Draw Conclusions** Explain why producers are the first trophic level in a food chain or food web.

MATH PRACTICE

7. **Calculate** If 700,000 energy units are received by phytoplankton in the ocean surface, approximately how many energy units will reach a consumer that is in the fourth trophic level of a food chain?

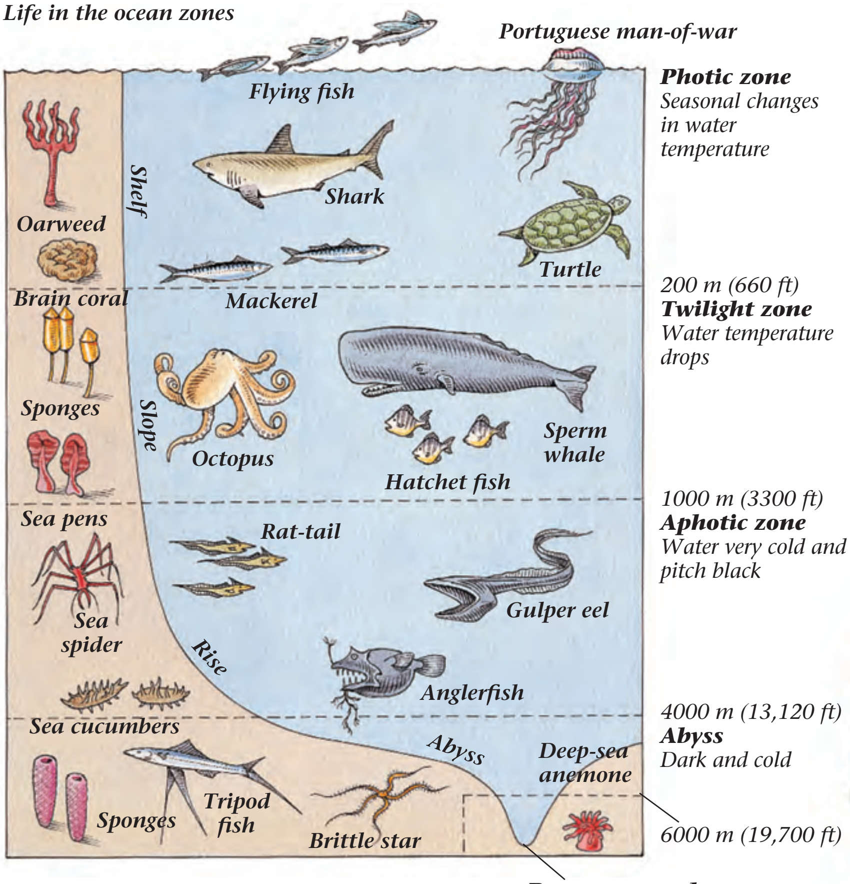
Ocean Life

The world's oceans cover almost three quarters of Earth's surface and are home to a vast array of life. Below the surface, the oceans become increasingly cold and dark. Even so, living things, ranging in size from giant whales to microscopic floating organisms called **plankton,** thrive at every depth. Some jellyfish and turtles float or swim near the surface. Whales and squid often swim in the ocean's middepths. A whole host of unusual creatures swim or crawl around the deep and dark ocean depths.



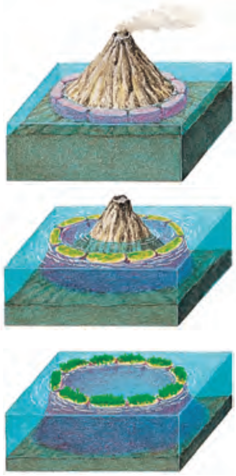
▲ BIOLUMINESCENCE
Some fish, such as this elongate fangjaw (above), have special organs called photophores that give off a glow. In this process, called **bioluminescence,** fish use the light to recognize members of their own species or as lures for attracting prey.

Life in the ocean zones



▲ VERTICAL ZONES
Oceanographers divide the oceans into zones based on depth. Each zone is home to living things that are adapted to survive at that depth. For example, deep-water animals cope with darkness, very cold temperatures, and pressures that would crush a human. Some creatures can survive in more than one zone. In addition, some organisms live exclusively on or near the seafloor, while others float or swim in the water column.

A school of chromis swims among coral off the coast of the Maldives in the Indian Ocean.



Growth of a coral atoll

1. Coral starts to grow around a volcanic island.

2. As the volcano becomes dormant, it gets cooler and denser, causing the island to gradually sink. Sand collects on the growing coral reef and forms land.

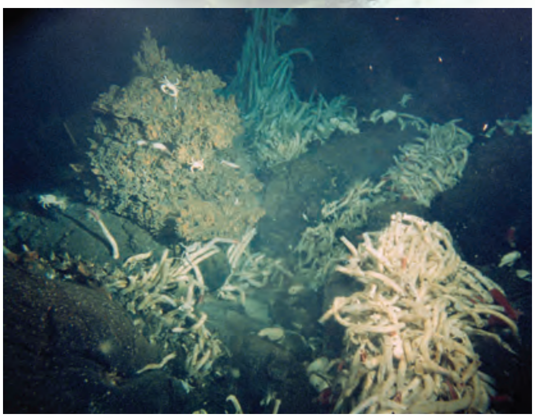
3. The island disappears. Vegetation grows on the atoll that remains.

▲ CORAL REEFS
A coral is a tubular soft bodied animal with tentacles. Most corals attach to a surface and build reefs in the warm, shallow, brightly lit waters of the continental shelf. Other reefs are ring-shaped **atolls** around a lagoon of shallow water. Atolls grow over millions of years.

Australian sea lions are marine mammals that breathe air, feed at sea, and breed on land.

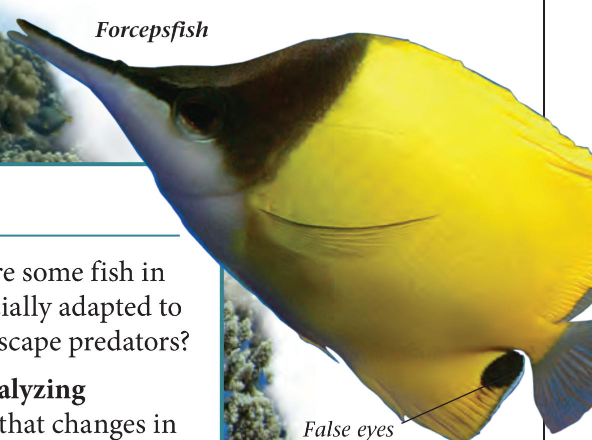
▲ PHOTIC ZONE
Sunlight supports the growth of algae, sea grasses, and other plants on which some sea creatures feed. Marine mammals, squid, fish, and other animals have to be strong swimmers to move in the surface currents. Sea grasses and coral reefs provide food, shelter, and breeding sites for a variety of creatures.

HYDROTHERMAL VENTS ▶
On the deep ocean floor, hot, mineral-rich water gushes from cracks, called **hydrothermal vents.** Bacteria feed on chemicals in this water, forming the basis of a food chain that does not rely on sunlight and plants. Giant tube worms, clams, and blind white crabs are some organisms that live around these vents.



Worms and crabs near a hydrothermal vent.

BRIGHT COLORS
Many fish that live in the photic zone have bright colors that attract mates and confuse predators. Complex coloration makes it hard to detect the outline of a fish. Some fish have eyespots, or false eyes. As a predator attacks the false head, the fish darts off in the opposite direction. ▼



Forcepsfish

False eyes

Assessment

1. Key Terms Define **(a)** plankton, **(b)** bioluminescence, **(c)** atoll, **(d)** hydrothermal vent.

2. Ecosystems Why does most photosynthesis occur near the ocean surface but not near the deep ocean floor?

3. Physical Processes How can the emergence of a volcano lead to the growth of coral and the formation of an atoll?

4. Ecosystems How are some fish in the photic zone specially adapted to attract mates or to escape predators?

5. Think Critically **Analyzing Processes** Suppose that changes in the environment cause a decline in the population of photosynthesizing marine organisms and corals. How might that environmental change also cause damage to populations of fish, marine mammals, and other sea creatures?

INQUIRY
EXPLORATION LAB

How Does Temperature Affect Water Density?

Problem How can you determine the effects of temperature on water density?

Materials 100-mL graduated cylinders (2), test tubes (2), beakers (2), food coloring or dye, stirrer, ice, tap water, graph paper, colored pencils

Skills Observe, Graph, Infer, Draw Conclusions

Connect to the Big idea Ocean water temperature varies from equator to poles and with depth. Both temperature and salinity affect the density of seawater. However, seawater density is more sensitive to temperature changes than it is to salinity. Surface water cools in the polar regions, sinks, and moves toward the tropics.

Procedure

Part A

1. In a beaker, mix cold tap water with several ice cubes. Stir until the water and ice are well mixed.
2. Fill a graduated cylinder with 100 mL of the cold water from the beaker. The graduated cylinder should not contain any pieces of ice.
3. Put 2 to 3 drops of dye in a test tube and fill it 1/2 full with hot tap water.
4. Pour the contents of the test tube slowly into the graduated cylinder and record your observations.
5. Add a test tube full of cold tap water to the second beaker. Mix in 2 to 3 drops of dye and a handful of ice. Stir the solution thoroughly.
6. Fill the second test tube 1/2 full of the solution from Step 5. Do not allow any ice into the test tube.
7. Fill the second graduated cylinder with 100 mL of hot tap water.
8. Pour the test tube of cold liquid slowly into the cylinder of hot water. Record your observations.
9. Clean the glassware and return it along with the other materials to your teacher.

Part B

1. Copy the graph on the next page onto a separate sheet of graph paper.
2. Using the data in Table 1, plot a line on your graph for temperature. Using a different colored pencil, plot a line for density on the same graph.

Analyze and Conclude

1. **Observe** What differences did you observe in the behavior of the two water samples in Part A? Which water sample was the most dense in each experiment?
2. **Infer** How does temperature affect the density of water?
3. **Draw Conclusions** If two water samples of equal mass had equal salinities, which sample would be more dense: water sample A, which has a temperature of 25°C, or water sample B, which has a temperature of 14°C?

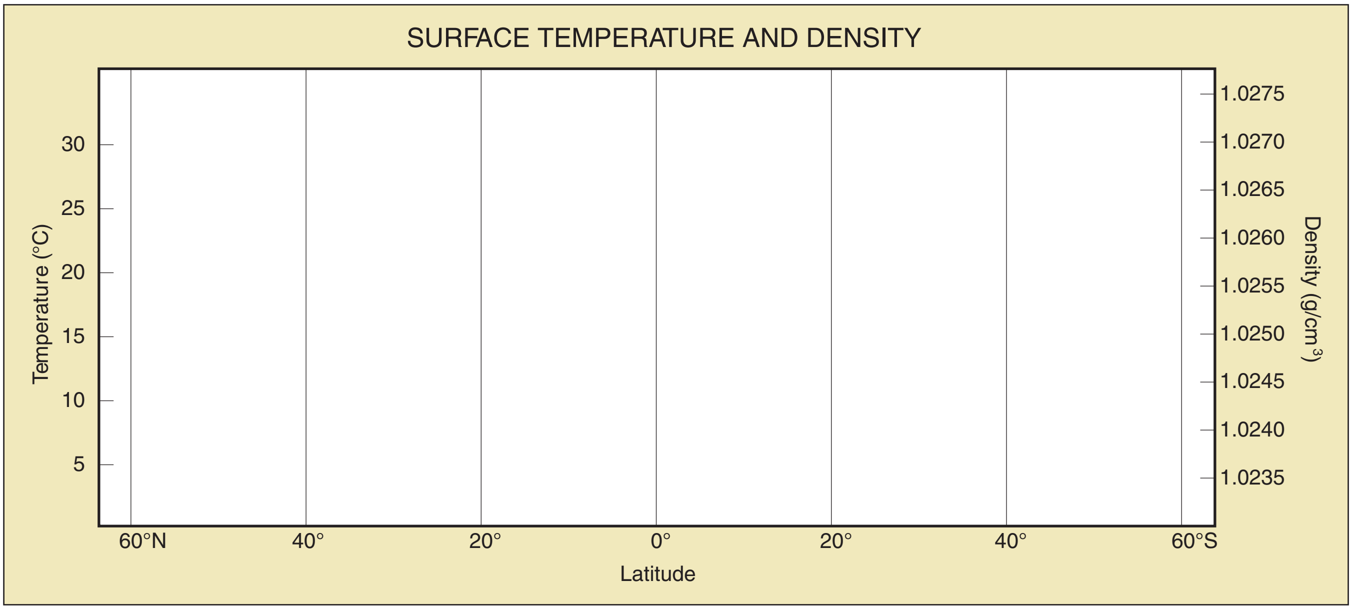


Table 1 Idealized Ocean Surface Water Temperatures and Densities at Various Latitudes

Latitude	Surface Temperature (C)	Surface Density (g/cm^3)
60N	5	1.0258
40N	13	1.0259
20N	24	1.0237
0	27	1.0238
20S	24	1.0241
40S	15	1.0261
60S	2	1.0272

4. Interpret Graphs Describe the density and temperature characteristics of water in equatorial regions. Compare these characteristics to water found in polar regions.

5. Infer What is the reason that higher average surface densities are found in the Southern Hemisphere?

6. Communicate Write a lab report describing your procedures in this experiment and how you reached your conclusions.

ES.1 The student will plan and conduct investigations in which **a.** volume, area, mass, elapsed time, direction, temperature, pressure, distance, density, and changes in elevation/depth are calculated utilizing the most appropriate tools; **c.** scales, diagrams, charts, graphs, tables, imagery, models, and profiles are constructed and interpreted; and **e.** variables are manipulated with repeated trials. **ES.2** The student will demonstrate an understanding of the nature of science and scientific reasoning and logic. Key concepts include **c.** observation and logic are essential for reaching a conclusion.

15 Study Guide

Big idea Water Planet

15.1 The Composition of Seawater

Because the proportion of dissolved substances in seawater is such a small number, oceanographers typically express salinity in parts per thousand (‰).

Chemical weathering of rocks on the continents is one source of elements found in seawater.

The second major source of elements found in seawater is from Earth's interior.

The ocean's surface water temperature is affected by the amount of solar radiation received, which is primarily due to latitude.

Seawater density is influenced by two main factors: salinity and temperature.

Oceanographers generally recognize a three-layered structure in most parts of the open ocean: a shallow surface mixed zone, a transition zone, and a deep zone.

salinity (422)
thermocline (424)
density (425)
pycnocline (426)

15.2 The Diversity of Ocean Life

Marine organisms can be classified according to where they live and how they move.

Plankton are organisms that drift ith ocean currents, including algae, animals, and bacteria.

All animals capable of moving independently of the ocean currents, by swimming or other means of propulsion, are called nekton.

Organisms that live on or in the ocean bottom are called benthos.

Three factors are used to divide the ocean into distinct marine life zones: the availability of sunlight, the distance from shore, and the water depth.

photosynthesis (428)
plankton (428)
phytoplankton (429)
zooplankton (429)
nekton (429)
benthos (429)
photic zone (430)
intertidal zone (431)
neritic zone (431)
oceanic zone (431)
pelagic zone (432)
benthic zone (432)
abyssal zone (432)

15.3 Oceanic Productivity

Two factors influence a region's photosynthetic productivity: the availability of nutrients and the amount of solar radiation, or sunlight.

The availability of solar energy limits photosynthetic productivity in polar areas.

Productivity in tropical regions is limited by the lack of nutrients.

In temperate regions, which are found at mid-latitudes, seasonal changes influence levels of sunlight and nutrient supply which, in turn, influence productivity.

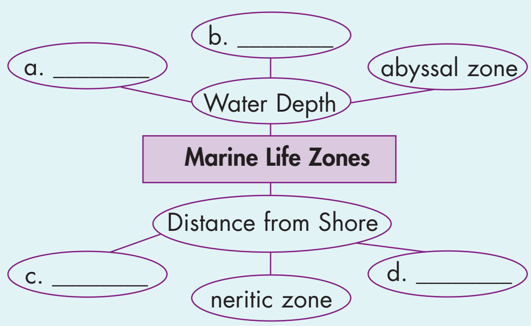
The transfer of energy between trophic levels is very inefficient.

Food webs are used to evaluate relationships in ecosystems because they show how the success or failure of one population could affect other populations.

primary productivity (433)
chemosynthesis (433)
trophic level (436)
food chain (437)
food web (437)

Think Visually

Use the information in the chapter to complete the web diagram on marine life zones.



15 Assessment

Review Content

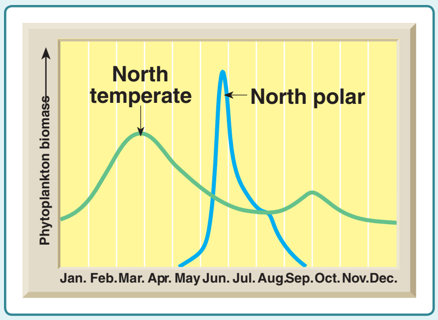
Choose the letter that best answers the question or completes the statement.

1. The most abundant salt in seawater is
   - **a.** calcium chloride.
   - **b.** magnesium chloride.
   - **c.** sodium chloride.
   - **d.** sodium fluoride.
2. Which process does NOT lead to a decrease in the salinity of seawater?
   - **a.** runoff rom land
   - **b.** precipitation
   - **c.** evaporation
   - **d.** sea ice melting
3. Which term refers to the layer of water in which there is a rapid change of temperature with depth in the ocean?
   - **a.** pycnocline
   - **b.** abyssal zone
   - **c.** thermocline
   - **d.** isothermal line
4. Which is NOT a zone in the three-layered structure of the ocean according to density?
   - **a.** surface mixed zone
   - **b.** deep zone
   - **c.** transition zone
   - **d.** intertidal zone
5. Organisms that drift ith ocean currents are
   - **a.** nekton.
   - **b.** plankton.
   - **c.** neritic.
   - **d.** pelagic.
6. Which term describes the upper part of the ocean into which sunlight penetrates?
   - **a.** neritic zone
   - **b.** intertidal zone
   - **c.** oceanic zone
   - **d.** photic zone
7. Phytoplankton are usually found in the
   - **a.** benthic zone.
   - **b.** photic zone.
   - **c.** abyssal zone.
   - **d.** aphotic zone.
8. The use of light energy by organisms to convert water and carbon dioxide into organic molecules is
   - **a.** chemosynthesis.
   - **b.** decomposition.
   - **c.** photosynthesis.
   - **d.** consumption.
9. During which season does primary productivity reach its peak in polar oceans?
   - **a.** spring
   - **b.** summer
   - **c.** fall
   - **d.** winter
10. In temperate oceans, primary productivity is limited by
    - **a.** nutrients and oxygen concentration.
    - **b.** nutrients and water temperature.
    - **c.** sunlight and oxygen concentration.
    - **d.** sunlight and nutrients.

Understand Concepts

11. Why is salinity expressed in parts per thousand instead of percent?
12. What is the principal source of water in oceans? Why did scientists reach this conclusion?
13. Explain how the salinity of water in polar regions varies seasonally.
14. What is the range of salinity for surface waters in the open ocean?
15. Is there a thermocline present in high-latitude ocean waters? Why or why not?
16. Compare and contrast phytoplankton and zooplankton.
17. What factors may affect the depth of the photic zone in any given area of the ocean?
18. What is the oceanic zone? What limits the amount of production in the oceanic zone?
19. What is the difference between the pelagic zone and the benthic zone?
20. How does the permanent thermocline in tropical oceans affect primary productivity in those areas?

Copy the diagram onto a separate sheet of paper and use it to answer Questions 21 and 22.



21. Draw a line on the graph that correctly represents the productivity of tropical oceans year-round.
22. Draw a line on the graph that represents the changes in zooplankton population in north temperate oceans throughout the course of a year.
23. What is the difference between a food chain and a food web?

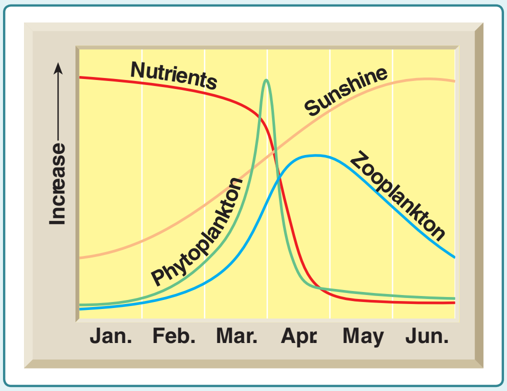
Think Critically

24. Relate Cause and Effect In the Red Sea, evaporation values are higher than the values of precipitation and river runoff, particularly in summer months. Do you think that the salinity of the water here is higher or lower than average ocean water salinity? Why?

25. Draw Conclusions Water Mass A is 2°C with a salinity of 34.50‰. Water Mass B is 2°C with a salinity of 34.00‰. Water Mass C is 2°C with a salinity of 34.78‰. Order the water masses from lowest density to highest density. Which water mass will be nearest the surface? Which will be closest to the bottom?

26. Relate Cause and Effect Explain how the phytoplankton productivity in polar waters is related to the fact that density and temperature change very little with depth in polar waters.

Use the figure below to answer Questions 27–29.



27. Apply Concepts The graph shows the productivity in temperate oceans in the Northern Hemisphere for the fi st half of the year. Describe what is happening to the phytoplankton and zooplankton populations in the graph. Explain what factors are affecting productivity.

28. Infer Describe what the graph would look like if it were extended through December. How is it different than the January through June portion?

29. Draw Conclusions How would this graph be different if it were for a temperate ocean in the Southern Hemisphere?

Concepts in Action

Use the table below to answer Questions 30 and 31.

Depth (m)	Temperature (C)
0	23
200	22.5
400	20
600	14
800	8
1000	5
1200	4.5
1400	4.5
1600	4

30. Interpret Data An oceanographer recorded the temperature data in the table above for an area of ocean water. Graph the data on a sheet of graph paper. What feature exists between 400 and 1200 meters?

31. Apply Concepts For which area of the world ocean would this temperature variation with depth be present? What processes cause this to occur?

32. Form a Hypothesis It has been observed that some species of zooplankton migrate vertically in ocean water. They spend the daylight hours at deeper depths of about 200 meters and at night move to the surface. Formulate a hypothesis that might explain this behavior.

Performance-Based Assessment

Design Equipment Imagine you have been asked to collect marine plankton samples from surface waters near the coast. Recall that many plankton are microscopic or nearly so and that by definition, plankton drift ith currents. Design a piece of equipment that will allow you to collect the plankton so that they can be brought to the lab and examined under a microscope. Include the materials you will use to construct the equipment, a drawing of it, and an explanation of how it should be used in the field.

Virginia SOL Test Prep

Tips for Success

Watch for Qualifiers The words *best, least,* and *greatest* are examples of qualifiers. If a question contains a qualifier, more than one answer will contain correct information. However, only one answer will be complete and correct for the question asked. Look at the question below. Eliminate any answers that are clearly incorrect. Then choose the remaining answer that offers the best explanation for the question asked.

Which factor has the greatest influence on the density of surface water in the ocean?

A temperature
B pressure
C salinity
D oxygen

(Answer: A)

Choose the letter that best answers the question.

1 **The total amount of solid material dissolved in water is known as—**
A sediment load
B salinity
C total dissolved solids
D density ES.10.a

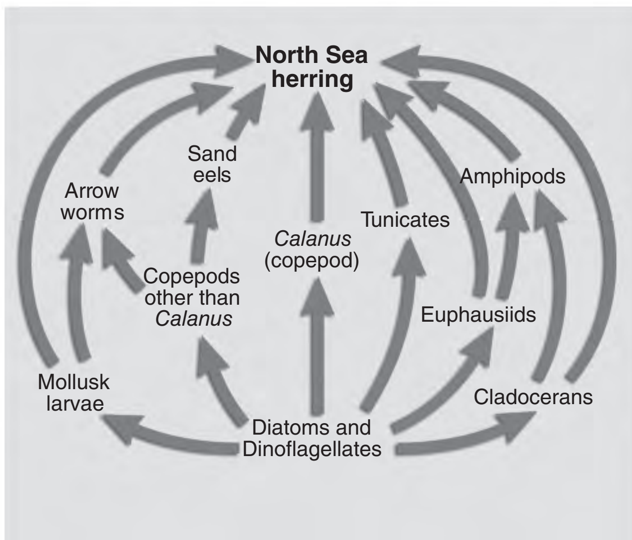
2 **Thermoclines in oceans are best developed at—**
F lower latitudes
G higher latitudes
H both high and low latitudes
J regions close to continents ES.10.a

3 **Which term describes a rapid change in density with depth?**
A thermocline
B halocline
C isocline
D pycnocline ES.10.a

4 **Animals capable of moving independently of ocean currents, by swimming or other means of propulsion, are called—**
F benthos
G plankton
H nekton
J pelagic ES.10.c

5 **During which season is productivity the greatest in temperate waters?**
A spring **C** fall
B summer **D** winter ES.10.c

6 **Which of the following changes would occur to the food web below if the population of copepods was killed by a bacterial disease?**
F The sand eel population would decline because the copepods are their only food source.
G The mollusk larvae population would decrease because the arrow worms would depend more heavily on that food source.
H Neither F nor G.
J Both F and G. ES.10.c



If You Have Trouble With . . .

Question	1	2	3	4	5	6
See Lesson	15.1	15.1	15.1	15.2	15.3	15.3