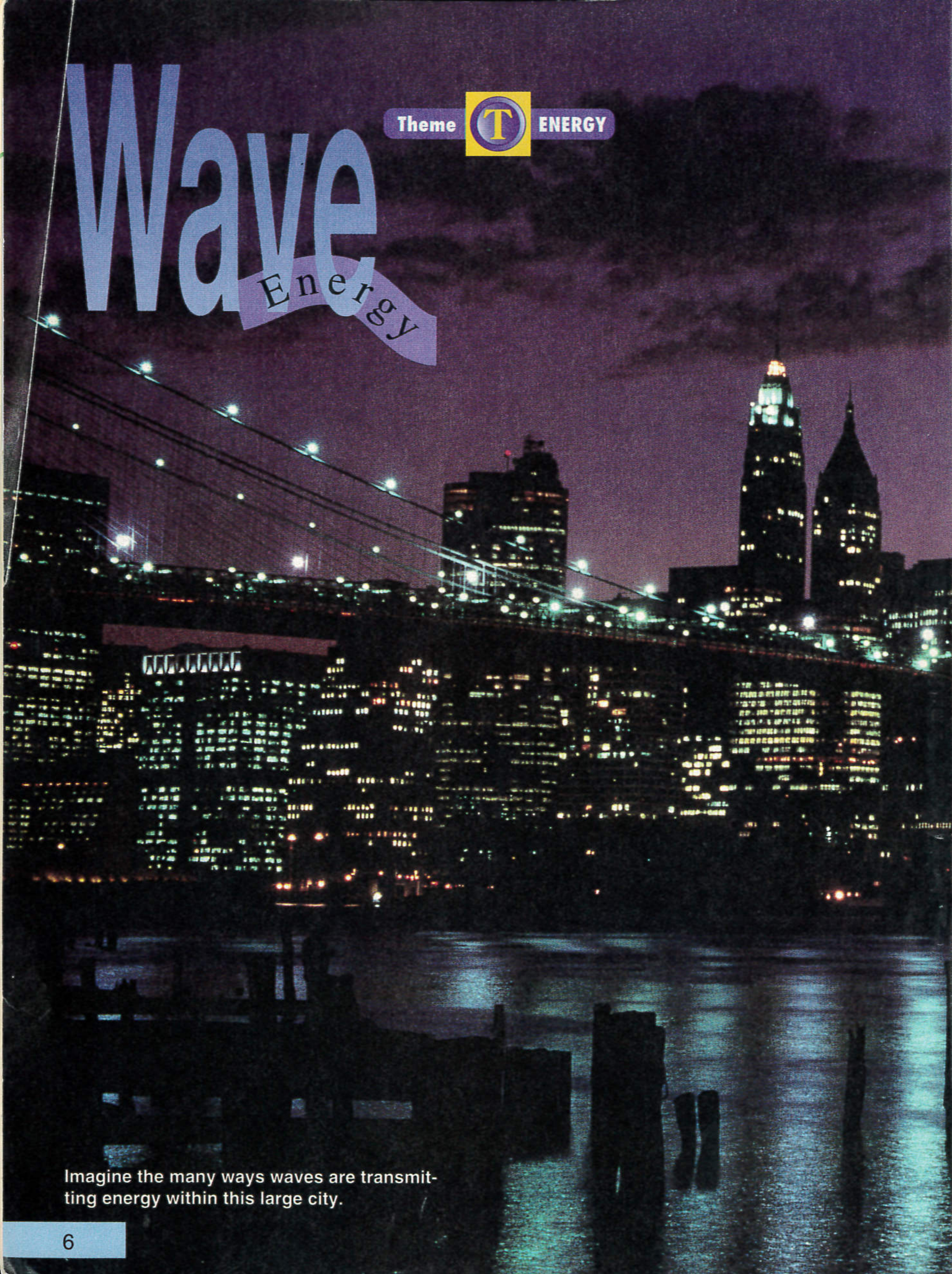
Wave Energy

Theme T ENERGY



Imagine the many ways waves are transmitting energy within this large city.

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Theme ENERGY

Imagine the many ways waves are transmitting energy within this large city.

Minds On! What is a wave? Can you think of any examples of waves? What do you think it would be like on Earth if waves didn't exist? In what ways would Earth be different? Could you live on, or visit, Planet Earth?

Imagine waking one morning in a world of total darkness. You're breathing heavily inside a spacesuit because oxygen and heat are missing from the atmosphere. The alarm clock doesn't glow or ring beside your bed. The radio is silent. No matter which dial you turn, the television channels remain blank. No voices call you to hurry and get dressed. How can you tell if it's time to get up for school? The silence is as total as the darkness. You feel your way to the kitchen, but the cupboards are empty. Every bit of food has vanished. In fact, in a world without waves, you might as well go back to bed. School will be canceled for the day...along with most life on the planet.

When many people think of waves, they think of ocean waves. However, islands aren't the only things surrounded by waves. You are surrounded and bombarded by them daily.

A wave is a disturbance that transfers energy. Energy is the ability to do work. The energy transmitted by ocean waves enables them to erode a sand castle on the beach, reshape a shoreline, or destroy a fishing village. The energy transmitted by sound waves brings music to our ears by causing our eardrums to move back and forth. It carries the voices of friends, the songs of birds, and the blaring warnings of fire alarms. It allows us to know when it's time to change classes. Light waves enable us to see and are indirectly responsible for our respiration and nutrition. They transmit the energy to make a potato grow, melt the snow, warm Earth, and make a flower blossom.

Large amounts of energy are being transferred by these water waves.

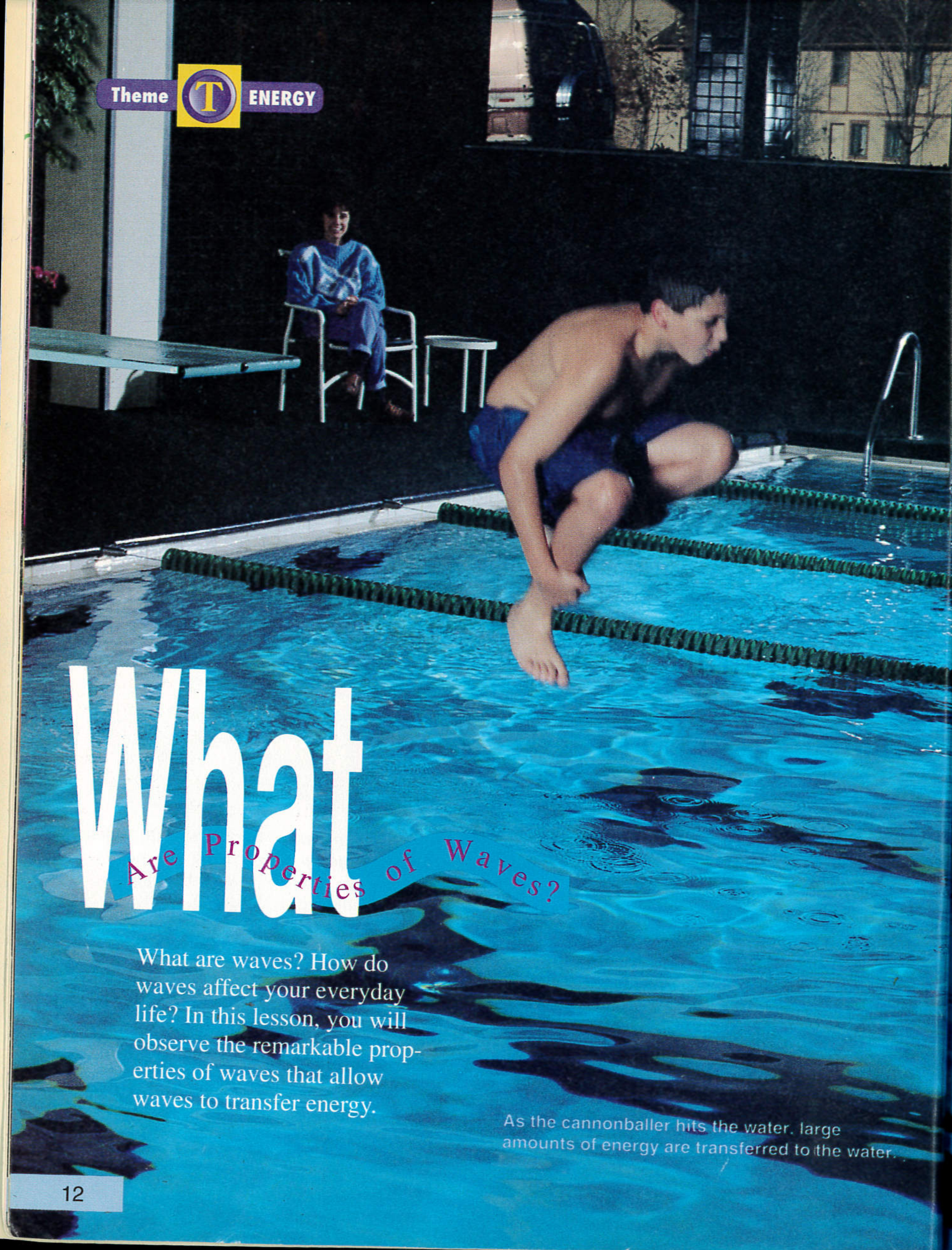
The sun radiates light energy in the form of waves.

Like students in your school, or shoes in a shopping mall, waves come in all different kinds and sizes. But despite their differences, waves share some common characteristics.

A wave transfers energy, but not matter, along its path. What is the difference, then, between energy and matter? Matter is anything that takes up space and has mass. Matter makes up everything in the universe that can be touched or shaped, grown or built. Energy is the ability to do work, and it moves in waves through matter or space. Energy carried by waves is transferred to whatever stops a wave.

Water waves and sound waves are caused when something disturbs a medium. A medium is simply the substance or matter that a wave moves through. Water is the medium of an ocean wave. Sound waves travel through solids, liquids, and gases. Your voice travels through the air as well as through solids and liquids. Beluga whales click and squeak to communicate underwater. You can feel the beat of music through a wall. Earth is the medium of seismic (earthquake) waves.

Some waves are different, however. They can travel and transmit energy in the absence of any medium. These waves are called electromagnetic (i lek′trō-mag net′ik) waves. Light waves, radio and television signals, microwaves, and X rays are all examples of electromagnetic waves. They can transmit energy through a vacuum, including outer space.



What Are Properties of Waves?

What are waves? How do waves affect your everyday life? In this lesson, you will observe the remarkable properties of waves that allow waves to transfer energy.

As the cannonballer hits the water, large amounts of energy are transferred to the water.

Have you ever been floating on an inner tube, eyes closed, basking in the sun, when someone on the diving board yells "Cannonball!" and plunges into the pool? Your eyes pop open. You see waves moving toward you across the surface of the water, and you grab the sides of the inner tube. But something strange happens. You probably don't tip over. You are not swept to the side of the pool. Instead the waves slide past you, bobbing you up and down and back and forth, as they appear to move on across the water. You and your inner tube are still in about the same place in the pool.

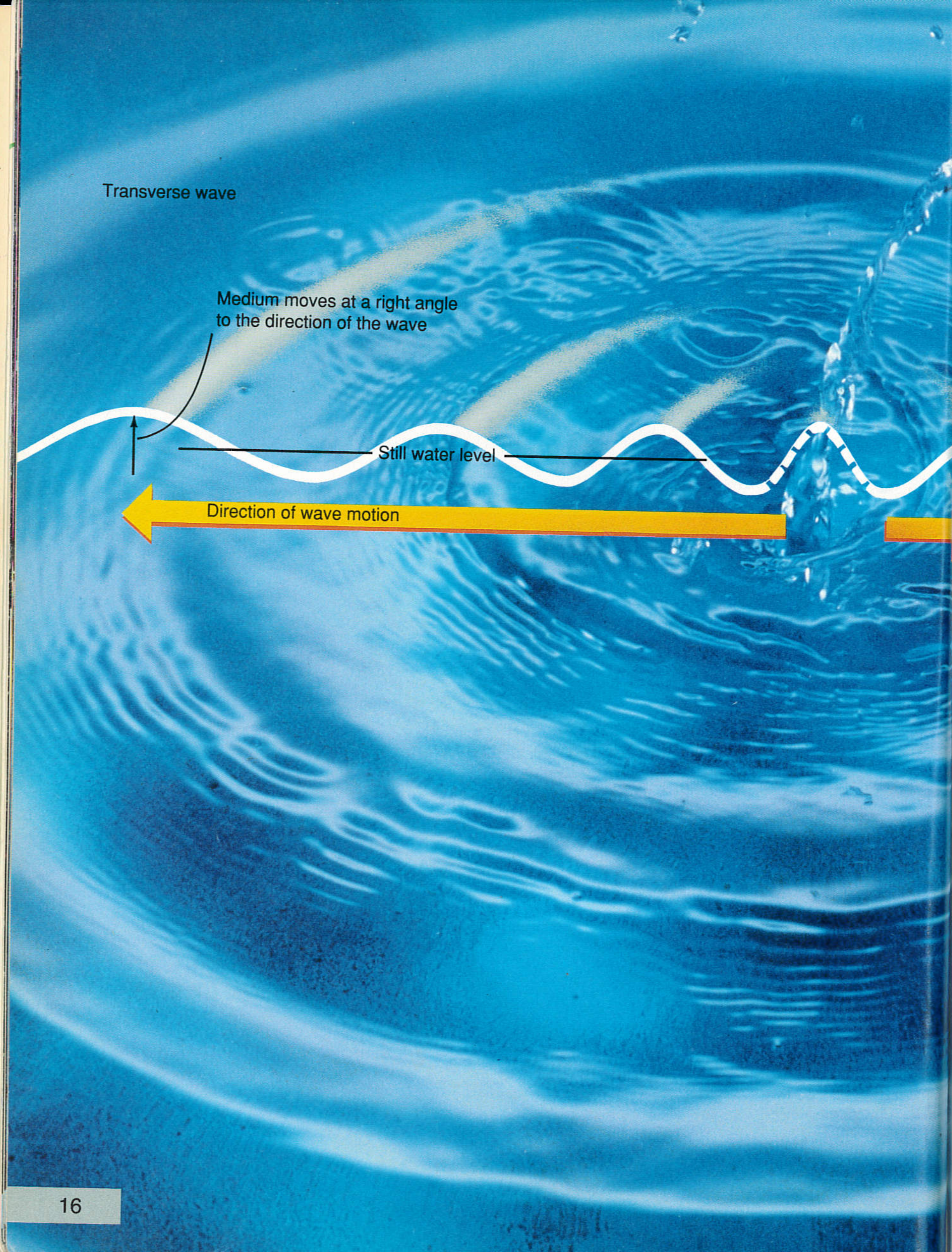
What do you think happened? Why didn't the waves push you to the side of the pool? Recall that a wave is a disturbance that transmits energy and not matter. Changes occur in matter when energy is transferred to it. Because energy can do work, it can move matter.

Both you and your inner tube are matter. So how did you change? You pretty much stayed in the same place in the pool instead of moving in the direction of the wave energy. The energy of the wave, however, caused you to move up and down in the pool. Wave energy was transferred to your up-and-down motion. Water is matter, too. How do you think the water was moved by the wave? The wave energy worked on the water by moving it repeatedly up and down as this energy passed along the surface. From these observations, what can you conclude about how energy is transferred?

Minds On! Think about floating in a pool on an inner tube. In your ***Activity Log*** on page 2, make a stick-figure side-view sketch of yourself on the tube, bobbing up and down in the water. Draw a wave that has passed under you and is moving away from you across the surface of the pool. Now, draw a straight line in the direction that both you and the inner tube are moving. Then draw a straight line in the direction the wave is moving. Extend the lines so they meet, or intersect. How would you describe the angle formed by the intersection of these two lines? How did the wave move you up and down at a right angle (90°) to its own motion?●

Water transfers energy from one place to another by wave movement.

Think again about the waves created in the pool when the cannonballer hit the water. How would these waves compare to those that would be created by someone gracefully diving into the water headfirst? The diver would also create water waves. Even though both of these sets of waves were created in the same medium—the water in the pool—they varied in size and shape. How do you think waves can change their shape and size as they transmit energy from one place to another? The source of a wave is the disturbance that sets it in motion or, in these examples, persons jumping into or diving into water. Wind is most frequently the source of water waves. You will act as the source of waves in the next activity as you investigate the properties of waves. You will also find out how the properties of waves, such as size and shape, can vary.



Wave Properties

Water transmits energy in the form of waves. As you discovered in the example of the inner tube floating in water, matter is not transmitted by waves. A water wave can be modeled by a transverse (trans vûrs′) wave. In a **transverse wave,** the matter in the medium moves at right angles to the direction the wave travels. Water was the medium of the waves in the pool. You and the inner tube were disturbed by the water because you were resting on the water. As a result, you were displaced in an up-and-down direction, while the waves moved energy across the surface of the pool. Observe how matter and energy move in the waves you create in the activity to the right. ⇨

When you walk to school or to the store, you may cross a number of blocks between your house and your destination. If the blocks are the same size, you encounter intersections at regular intervals. You walk a block and come to an intersection. You walk the same distance again and come to another intersection, over and over. There is a regular pattern to the route you are taking.

Similarly, waves can have regular patterns. Imagine riding a roller coaster shaped like the waves you just made in the pan. The car you are riding in clanks to the very top of the first hill, then races down. Before you can catch your breath and stop screaming, you are racing up the next hill. Again and again, up and down, your car moves over a regular pattern of rising and falling tracks. If you could imagine the feeling of this ride without the forward motion, you would feel as if you were bobbing up and down on a water wave.

TRY THIS **Activity!**

Waves Transfer Energy

How can you demonstrate the transfer of energy by waves?

What You Need

small cork
rectangular pan
water
***Activity Log* page 5**

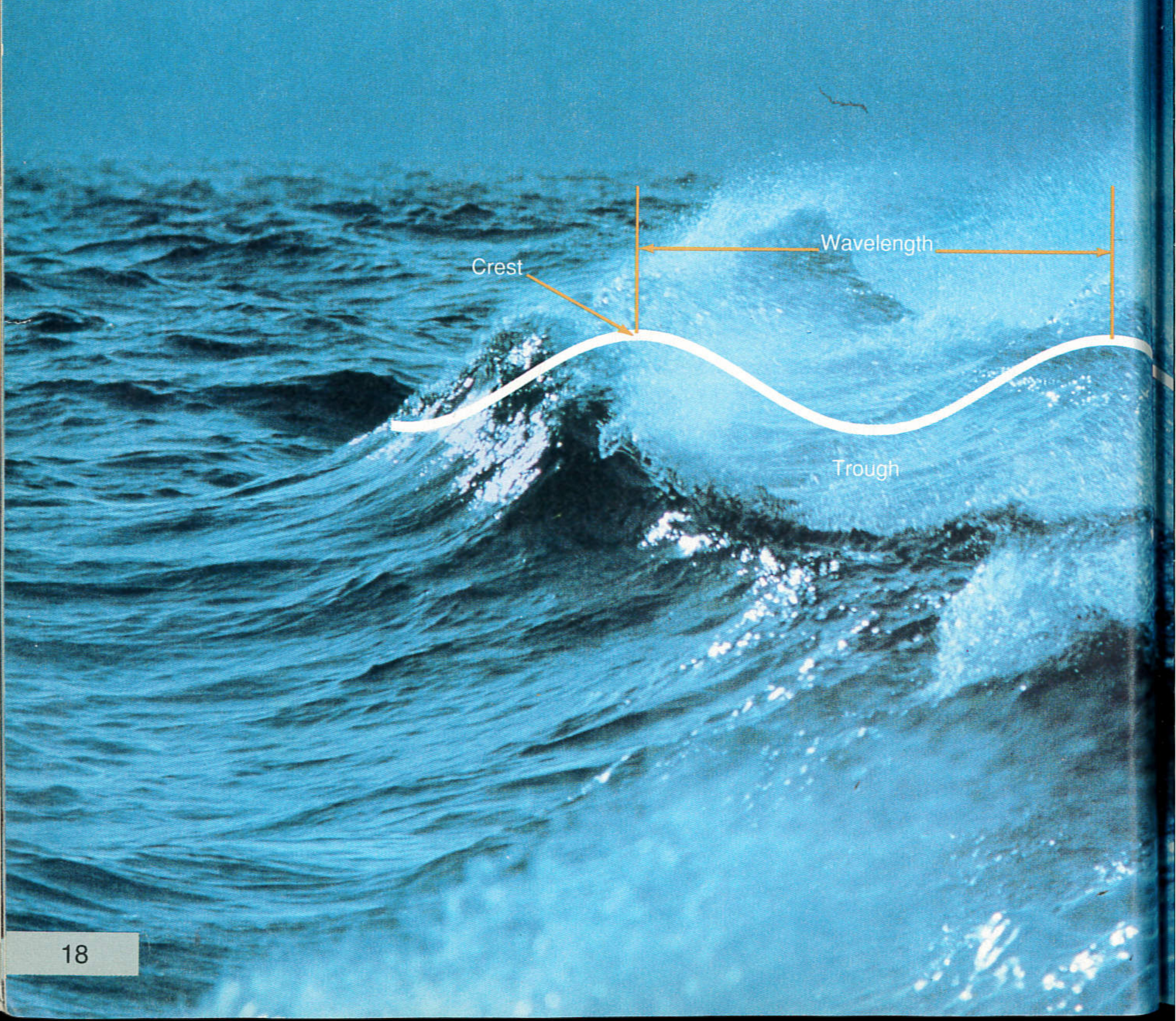
1. Put a small cork into a small rectangular pan of water.
2. To produce waves, pick up one end of the pan an inch or so and then lower it quickly back to the table. It will slosh a bit at first. Repeat this motion several times until a pattern is established.

3. Observe the cork.
4. Observe the motion of the water. What is moving across the pan? How can you be sure the waves are transmitting energy and not matter as they move?
5. Record all observations in your ***Activity Log.***

The top of each hill, like the top of a wave, is called the **crest** (krest). The **trough** (trôf) of a wave is its lowest part and is similar to the valley between two hills. If you stopped the roller coaster on one hill and measured the distance to the exact same point on the next hill, the distance measured would be the length of one wave, or **wavelength.** Similarly, the wavelength of a water wave is the distance from crest to crest, or trough to trough, of two neighboring waves.

Another property of a wave is its frequency (frē′kwən sē). **Frequency** is simply the number of times something occurs in a given time period. To understand frequency, think about a newspaper route. The people on your route only subscribe to the Sunday paper. Therefore, you deliver papers once every seven days. The frequency of your newspaper deliveries is one time per week. Now suppose that you talk all of the people on your route into subscribing to the daily paper as well. The frequency of your deliveries increases to seven times per week.

Now, let's look back at the spring toy activity you did. What happened as you moved your wrist faster and faster? What can you say about the frequency of those waves? What happened to the size of the waves?



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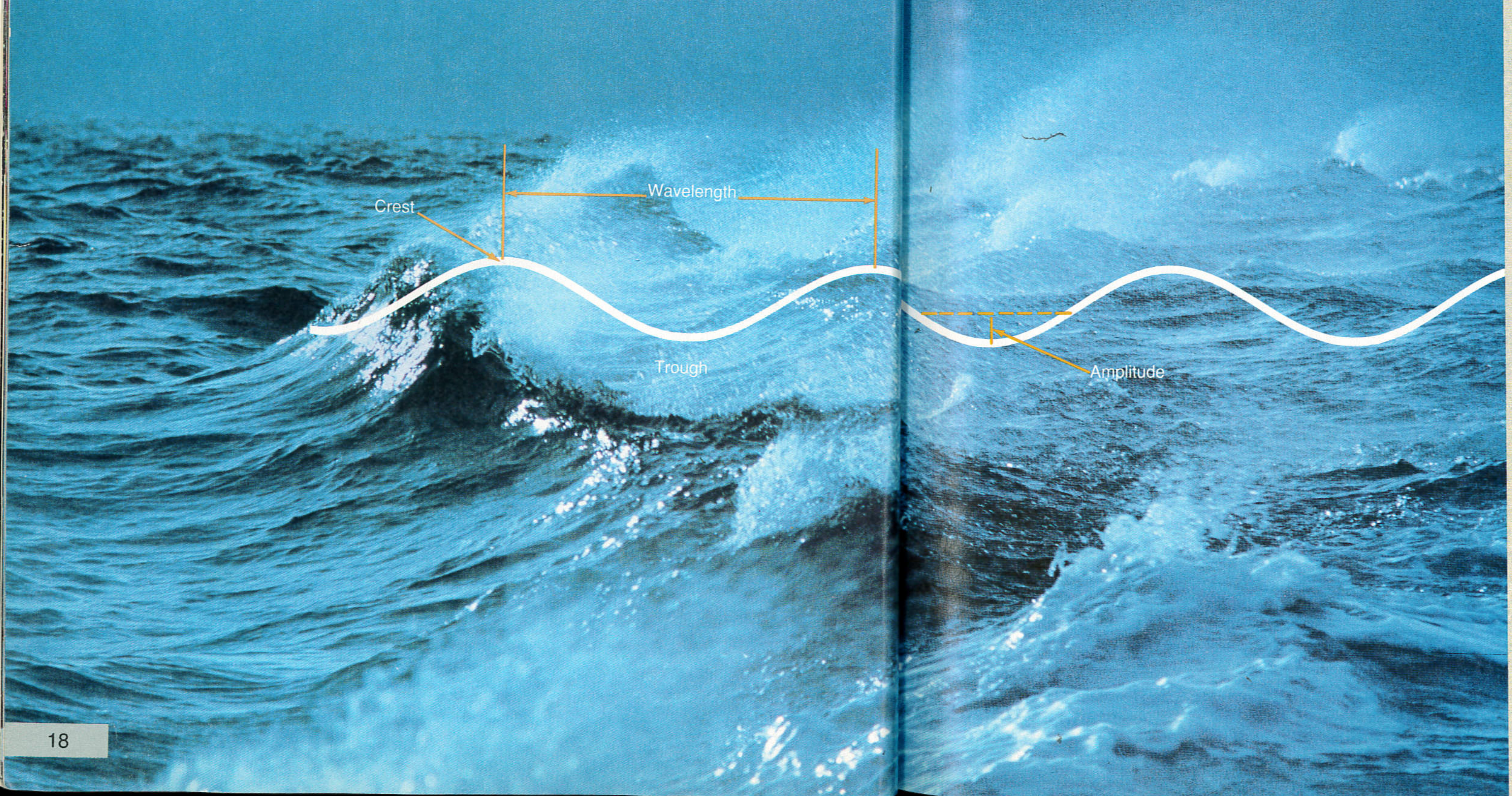
The amount of energy you used when you shook your wrist back and forth also affected the spring toy waves you made by changing their height, or amplitude (am′ pli tüd′). **Amplitude** is one-half the height of the wave from the crest to the trough. If you had measured the height of the spring toy during the activity, you would have found the amplitude of a transverse wave. The amplitude of a wave is related to the amount of energy put into the wave. In the activity, if you put a lot of energy into the spring toy by shaking it hard, you created waves with large amplitudes. If you put less energy into the spring toy, the waves had a smaller amplitude. As you can see, the amplitude of a wave is not determined by the wave's length or frequency. Do the activity on this page to find out what happens to water waves when you put more energy into them.



TRY THIS **Activity!**

Tank Waves

What can you observe about the characteristics of waves in a wave tank? Oceanographers frequently study the motions of waves with wave tanks. You can easily create your own wave tank.

What You Need

tall, narrow glass jar with lid
cold water
blue food coloring
vegetable oil
***Activity Log* page 6**

Find a tall, narrow glass jar. Fill it one-third full of cold water. Add a few drops of blue food coloring, close the lid, and swirl the jar to mix the color evenly. Then, carefully fill the jar to the top with vegetable oil. Screw the lid on tightly. Hold the jar horizontally and move it gently back and forth to simulate the motion of water waves. Next, use more of a rocking motion to put more energy into the waves without changing their wavelengths and frequencies. In your ***Activity Log,*** describe what happens to the amplitude of the waves as you apply more energy to them.

Factors That Affect Wave Motion

So far in this lesson, we have seen characteristics of waves using water as the medium in which the waves transfer energy. Water, however, is not the only medium in which waves can transfer energy. Waves can conduct energy through solids, liquids, and gases. Some waves can even transfer energy through a vacuum, which is empty space! You will read about all of these waves in the lessons that follow.

All of the waves that you study in this unit have common characteristics that you have already identified in water waves. These characteristics are wavelength, frequency, and amplitude. You can determine the speed of three sets of water waves in the Math Link.

Math Link

Wave Speed

The speed of a wave can be found by multiplying its frequency times its wavelength. Imagine you are sitting on the edge of a dock watching waves go by. Ten wave crests are passing every minute. The wavelength of these waves is three meters. Suddenly the sky grows cloudy. The breeze picks up. Now 20 wave crests are passing you each minute. If the wavelength remains the same, what has happened to the wave speed? What if the frequency increased to 30 wave crests per minute, but the wavelength shrank by one-third? How would the wave speed change?

Look at the diagram on this page. Notice that waves can have the same wavelengths and different frequencies. If you multiply the frequency of a wave by its wavelength, you determine the speed of the wave. What's the speed of each of the waves in the diagram? What happens to the speed if the frequency doubles and the wavelength remains the same? What happens to the frequency if the wavelength decreases and the speed remains the same? Another factor that affects the speed of a wave is the density of the material through which it is moving. For example, light waves travel faster through air than through glass.

You've observed, with a spring toy and water, how waves transmit energy without transporting matter in the direction of the wave. But can you describe how energy moves through waves? In the next activity, you'll make a wave machine and use it to demonstrate what happens to the matter and energy in waves in a medium other than water.