The Doppler Effect Have you ever been passed by a car with its horn honking? If so, you probably noticed the sudden change in pitch—sort of an *EEEEEOOoooowwn* sound—as the car sped past you. The pitch you heard was higher while the car was approaching than it was after the car passed. This is a result of the Doppler effect. For sound waves, the **Doppler effect** is the apparent change in the frequency of a sound caused by the motion of either the listener or the source of the sound. **Figure 7** explains the Doppler effect. Keep in mind that the frequency of the car horn does not really change; it only sounds like it does. The driver of the car always hears the same pitch because the driver is moving with the car.

Figure 7 *The Doppler effect occurs when the source of a sound is moving relative to the listener.*

a The car moves toward the sound waves in front of it, causing the waves to be closer together and to have a higher frequency.

b The car moves away from the sound waves behind it, causing the waves to be farther apart and to have a lower frequency.

c A listener in front of the car hears a higher pitch than a listener behind the car.

Loudness Is Related to Amplitude

If you gently tap a bass drum, you will hear a soft rumbling. But if you strike the drum with a large force, you will hear a loud *BOOM*! By changing the force you use to strike the drum, you change the loudness of the sound that is created. **Loudness** is how loud or soft a sound is perceived to be.

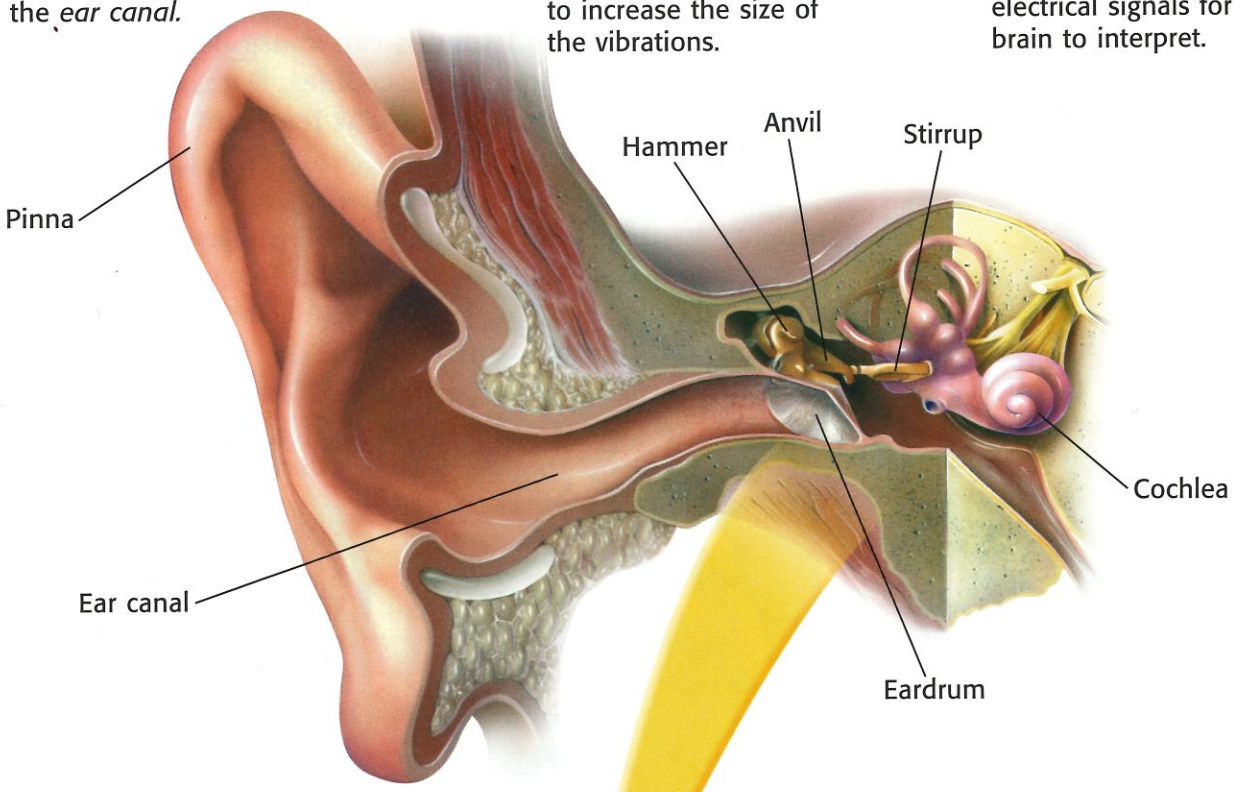
Energy and Vibration The harder you strike a drum, the louder the boom. As you strike the drum harder, you transfer more energy to the drum. The drum moves with a larger vibration and transfers more energy to the surrounding air. This increase in energy causes air particles to vibrate farther from their rest positions.

How the Human Ear Works

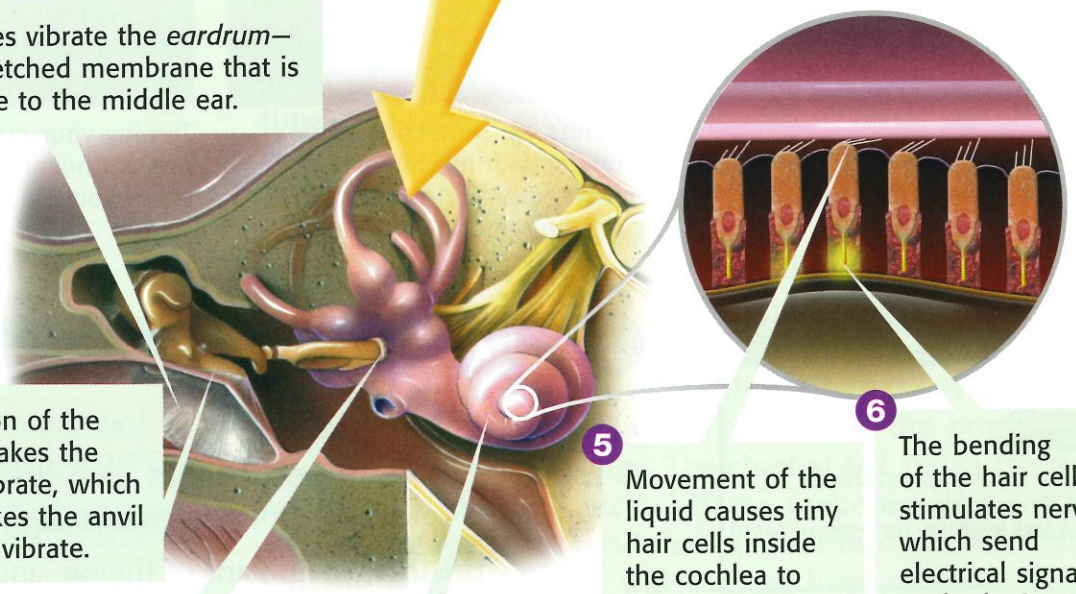
a The **outer ear** acts as a funnel for sound waves. The *pinna* collects sound waves and directs them into the *ear canal.*

b In the **middle ear,** three bones—the *hammer, anvil,* and *stirrup*—act as levers to increase the size of the vibrations.

c The **inner ear** is where vibrations created by sound are changed into electrical signals for the brain to interpret.



1 Sound waves vibrate the *eardrum*—a lightly stretched membrane that is the entrance to the middle ear.



2 The vibration of the eardrum makes the hammer vibrate, which in turn makes the anvil and stirrup vibrate.

3 The stirrup vibrates the *oval window*—the entrance to the inner ear.

4 The vibrations of the oval window create waves in the liquid inside the *cochlea.*

5 Movement of the liquid causes tiny hair cells inside the cochlea to bend.

6 The bending of the hair cells stimulates nerves, which send electrical signals to the brain.