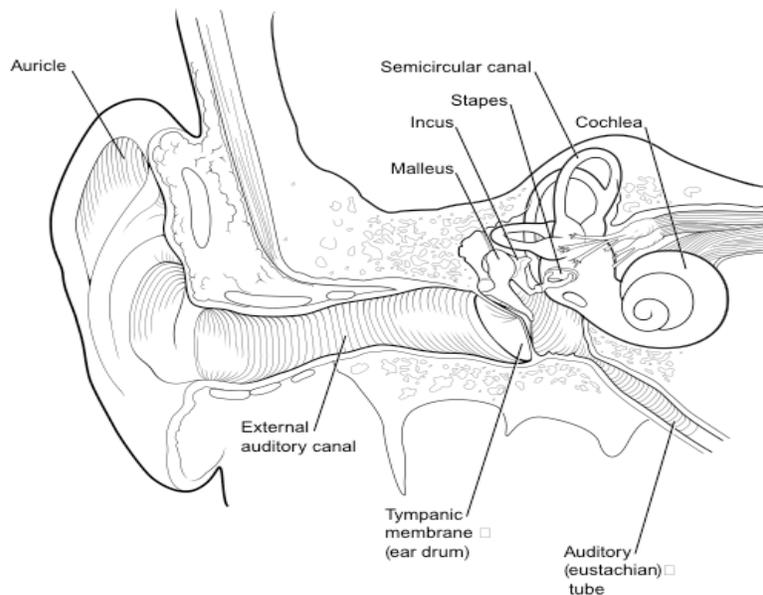


## Ears and Human Hearing

We need our ears to hear! But the process of ‘hearing’ is actually a result of several steps. Ears do three things. First, they focus the sound waves into the middle and inner ear. Then they convert the sound waves to tiny electrical signals. And finally, the electrical signals travel through nerves to the brain, where they’re interpreted as sounds.

The ear consists of 3 main parts: The Outer Ear, the Middle Ear, and the Inner Ear.



The part of the ear we all recognize is the Outer Ear. The curly part is called the *auricle* or *pinna*. Its purpose is to gather sound waves and focus them into the eardrum. The auricle points forward and to the side. Its curves are designed to help us *locate* the sound. We recognize reflective patterns from the auricle, and these patterns tell us where the sound is coming from. To *locate* means to identify where in space the sound is coming from.

One of the most obvious location techniques is right-left, or horizontal location. Your brain determines the horizontal position of a sound by comparing the information coming from your two ears. If the sound is coming from your left, it will arrive at your left ear a little bit sooner than it arrives at your right ear. And the sound will be a bit louder in your left ear than your right ear. This difference is interpreted by the brain as ‘the sound is coming from the left’.

In human beings, the auricles face forward, so we hear sounds in front of us better than sounds behind us. Our auricles are almost immovable. Some animals, on the other hand, have auricles which can be swiveled around. Dogs and cats are able to point their ears in several directions, which allows them to focus in on specific sounds all around them.

### The OUTER EAR

The **auricle**, or **pinna**, guides the sound waves into the **ear canal**. The ear canal is where earwax is produced. The earwax, though a little gross, is actually very important for keeping the ear clear of dust and dirt.

At the end of the canal, the soundwaves hit the **tympanic membrane**, more often called the **eardrum**. The eardrum is a thin bit of tissue about 10 millimeters wide.

The eardrum is very stiff, and very sensitive. Even *very* small changes in air-pressure will cause the eardrum to move back and forth. The eardrum is attached to a small muscle which keeps it pulled inwards. This helps to keep the eardrum tight and responsive to vibration.

The eardrum is a lot like the diaphragm of a microphone. It moves inwards and outwards in response to vibrations in the air. And the frequency and waveshape of the vibrations is faithfully reproduced by the eardrum.

### The MIDDLE EAR

This is where we find the **ossicles**, a set of 3 tiny bones. In fact, these are the smallest bones in the body!

First, there is the **malleus**, also called the **hammer**. Then comes the **incus**, sometimes called the **anvil**. And finally, the **stapes**, usually called the **stirrup**.

The hammer is joined to the center of the eardrum, but on the inner side of the ear. When a sound causes the eardrum to vibrate, it moves the hammer back and forth, kind of like a lever. The other end of the hammer is attached to the anvil, which is attached to the stirrup. The other end of the stirrup rests against the cochlea, in the inner ear. The connection is made through something called the **oval window**.

The entire system of middle ear bones act like a piston, pushing in and pulling away from the oval window. These pushing and pulling motions,

exact duplicates of the sound wave, cause pulsations in the fluid in the cochlea.

The purpose of the ossicles is to amplify the signal as it travels into the inner ear. It works because of a difference in size between the eardrum and the stirrup. The eardrum has a surface area of about 55 square millimeters, but the end of the stirrup that is touching the oval window has a surface area of only 3.2 square millimeters. The sound waves are hitting every square mm of the eardrum, applying force equally over the membrane. All of this energy is transferred from the eardrum through the middle ear to the stirrup. When you concentrate the sound energy from a large surface onto a smaller surface area, the pressure is much greater. It is 'amplified'.

In fact, the pressure that is transmitted to the cochlear fluid is about 22 times stronger than the pressure felt by the eardrum!

### The INNER EAR

The **cochlea** is a spiral shaped tube deep inside the ear. It contains a membrane called the **basilar membrane**, which is a rigid surface, like a guitar fretboard, that runs the length of the cochlea. When the stirrup bone vibrates back and forth, it pushes and pulls on one end of the basilar membrane, through the oval window. This causes a wave to travel along the surface of the basilar membrane. The wave is similar to ripples traveling across water.

The basilar membrane is made of 20,000 to 30,000 reed-like **fibers** that sit across the cochlea tube. Near the oval window, the start of the signal path, these fibers are short and stiff. Towards the other end, the fibers are longer and more flexible.

When the sound wave reaches the fiber that match its frequency, the fiber is 'fired' like a gun. This burst of energy causes little hairs around the fiber to move back and forth.

When they move, they cause an electrical impulse to travel through the **cochlear nerve**. This impulse is sent into the brain, and interpreted according to frequency (how far along the basilar membrane did the release occur) and amplitude (how strongly did the hairs vibrate). Then the magic occurs, as our brains interpret these impulses as speech, or music, or noise, or anything else!