

### **How Do We Hear?**

The human ear is an extremely good detector of sound. Even the best microphones can barely match the human ear's sensitivity to sound. The function of the ear is to change the vibrational energy of sound waves into electrical signals that are carried to the brain by way of nerves.

The sketch above indicates the structure of the human ear. Sound enters the passageway of the outer ear and strikes the Tympanum, or eardrum, causing it to vibrate. Inside the eardrum, there are three tiny bones, the hammer, the anvil, and the stirrup. These bones conduct the vibrations to the liquid-filled cochlea in the inner ear that transform the sound energy into electrical impulses that are sent to the brain.

At the entrance to the cochlea is the oval window. The amount of energy in the sound wave determines the amount of pressure that is exerted on the oval window, and the intensity of the sound that is heard.

Inside the cochlea is a fluid contained by a membrane that contains over 30,000 nerve endings. This membrane becomes gradually thicker and less taut through the cochlea. The thicker, less taut end is more sensitive to slower vibrations (low frequencies of sound), while the thinner, tighter end is more sensitive to rapid vibrations (higher frequencies of sound). This is analogous to a thick, loose rubber band that would vibrate slowly compared to a thin, tightly stretched rubber band that would vibrate more rapidly. Thus, the rate of vibration, or frequency, of the sound wave determines the part of the membrane and corresponding nerves that will be stimulated. This is the mechanism by which the human ear is able to distinguish sounds that vary in their frequency of vibration. Our perception of the highness or lowness of these frequencies is called pitch.

The human ear cannot hear all frequencies of sound waves. For example, you cannot hear sound from a person waving his hand back and forth, although the person is alternately compressing and rarefying air molecules around his hand. By the scientist's definition, sound is being produced. The range of frequencies of sound that can be detected by the human ear, known as the human range of audibility, varies from individual to individual but is typically between 20 and 20,000 Hertz. This means the lowest pitch sound that humans can hear is produced by a source vibrating about 20 times per second, and the highest pitch sound is produced from a source vibrating at about 20,000 times per second. Sounds produced from sources vibrating more rapidly than 20,000 times per second are known as ultrasounds. As a person ages, the membrane in the cochlea becomes brittle and the range of audibility decreases, especially in the region of higher frequencies.