61: THE EAR

The ear can be divided into three main areas: the outer ear, the middle ear, and the inner ear. The outer ear is what we think of as the "ear." Technically, the outer ear also includes the ear canal, or auditory canal, most of which we cannot see. The technical word for just that outer flap of skin we call our ear is the **pinna**. The pinna is a complicated looking shape and we might wonder if there is anything significant about this shape. Scientists think that the shape of the pinna might help to collect and direct sound waves into the ear canal, especially the sound of the human voice. There are names for the various parts of the pinna. The only names we'll learn here are the **lobe** (which you already know), the **helix** (curly outside rim), the **antihelix** (curly inner shape), and the **tragus** (that flap you push on when you want to close your ears and not hear something).

The outer ear ends at the **eardrum**, also called the **tympanic membrane**. The eardrum is a thin, round membrane stretched across the end of the canal. It is not completely flat, but is slightly cone-shaped, bending in to the middle ear. The eardrum vibrates when sound waves hit it. The sound waves are passed along to the parts of the middle ear.

Sound is made of mechanical pressure waves that travel through the air. Very high sounds are made of waves that are short and travel quickly. The highest sound a human ear can hear has a wave speed, or frequency, of about 16,000 waves per second. (Some charts list 20, 000 as the upper limit.) Low sounds are made of waves that are long and travel more slowly. The lowest sounds our ears can hear have a frequency of about 20 waves per second. The unit of measurement for sound is **hertz, Hz**. Hertz means waves, or "cycles," per second. So we can say that humans can hear a range of sound from 20 Hz to 20,000 Hz. Many animals can hear much higher frequencies. Cats can hear sounds that mice make at about 75,000 Hz. Brown bats can only hear high sounds from 10,000 to 90,000 Hz. Don't bother talking to a bat because your voice is so low (100-200 Hz) that it can't hear you!

The middle ear, on the other side of the eardrum, begins with the **malleus** bone, also called the "hammer." ("Malleus" is Latin for "hammer.") The ends of this bone touch the eardrum and pick up vibrations. The vibrations move the malleus back and forth. The malleus is connected to the **incus**, or "anvil." ("Incus" is Latin for "anvil." The anvil is a tool used by a blacksmith. It is heavy block that the hammer strikes.) Connective tissue ligaments hold these bones in place. At the end of the incus we find the tiny **stapes** *(stay-peas)*. The stapes is often called the "stirrup" because it does indeed look like a stirrup on a horse saddle--the part where your foot rests. ("Stapes" is Latin for "stirrup.") These three bones of the middle ear are the smallest bones in the body. They transfer the vibrations from the eardrum to the inner ear where they will be turned into electrical signals.

The space around these bones is not filled with fluid, but is an air space. Problems might arise if the air pressure inside this space is higher or lower than the air pressure outside of the head, so there is a thin tube that connects the middle ear to the outside world. This tube is called the **Eustachian tube**, named after the scientist who discovered it in the 1500s, Bartolomeo Eustachi. The Eustachian tube is only a few millimeters in diameter and is flattened shut most of the time. When you go up in an airplane, the air pressure around you drops, and the high pressure air in the middle ear must escape through the Eustachian tube. We often experience this sudden opening of the tube as a "popping" sensation inside our ears. Divers experience the opposite, with the pressure around them suddenly increasing. They must make a yawning motion in their nasopharynx region in order to open the Eustachian tube and let the pressure equalize.

The end of the stirrup (stapes) is where the inner ear begins. The stirrup touches an oval area called the **oval window**. The oval window is part of a structure that has two parts, the **cochlea** and the **vestibular system**, but looks like it is just one part.

The **cochlea** gets its name from the Greek word for snail shell, "kohklias." The cochlea sits inside a "pocket" of bone in much the same way that the pituitary gland does. The cochlea is a set of coiled tubes that are filled with fluid. This fluid absorbs the vibrations that come in through the oval window. If you straightened out the cochlea and cut a cross section, it would look like two tubes stuck together. Vibrations enter through the top tube and leave through the bottom one. The end of the bottom tube touches the outside of the cochlea at a place called the **round window**. The oval window and round window work together, pulsing in and out as vibrations travel through the fluid. When the oval window presses inward, the round window pops out, and vice versa.

Between the tubes we find the **organ of Corti**. This long and thin little "organ" has cells that vibrate to certain frequencies. These cells are located on the **tectorial membrane**. When the organ of Corti is flexed up and down by the sound vibrations the tectorial membrane rubs "hairs" at the ends of **hair cells**. This causes the hair cells to depolarize and release neurotransmitters that will start an action potential in the dendrites of nearby neurons. (The inner hair cells are the ones that send signals to the brain.) The neurons get bundled as they exit the cochlea and become the **cochlear nerve** that goes into the brain. In the brain these electrical signals will be interpreted as sounds. High sounds are picked up by the first part of the cochlea, closer to the oval window. Low sounds are picked up near the center of the spiral.

The other part of the inner ear is the **vestibular system**. (In Latin, a "vestibule" is an entrance hall.) This is what gives us our sense of balance. The main body of the system is the **vestibule**. There are also three C-shaped tubes called **semi-circular canals**. The canals contain fluid that sloshes back and forth as we move our head. Each canal senses a different motion of the head: 1) up and down in a "yes" motion, 2) back and forth in a "no" motion, and 3) when the head tips down toward a shoulder. All together, the semi-circular canals are sometimes called the **labyrinth**. We saw this word in the lesson on the sinus. (The word labyrinth is a very general word and can be applied to any part that has a complicated, maze-like structure.) Sensor cells on the inside of the semi-circular canals are connected to neurons that send signals to the brain. As the fluid moves around the brain gets information on which way the head is tipped.