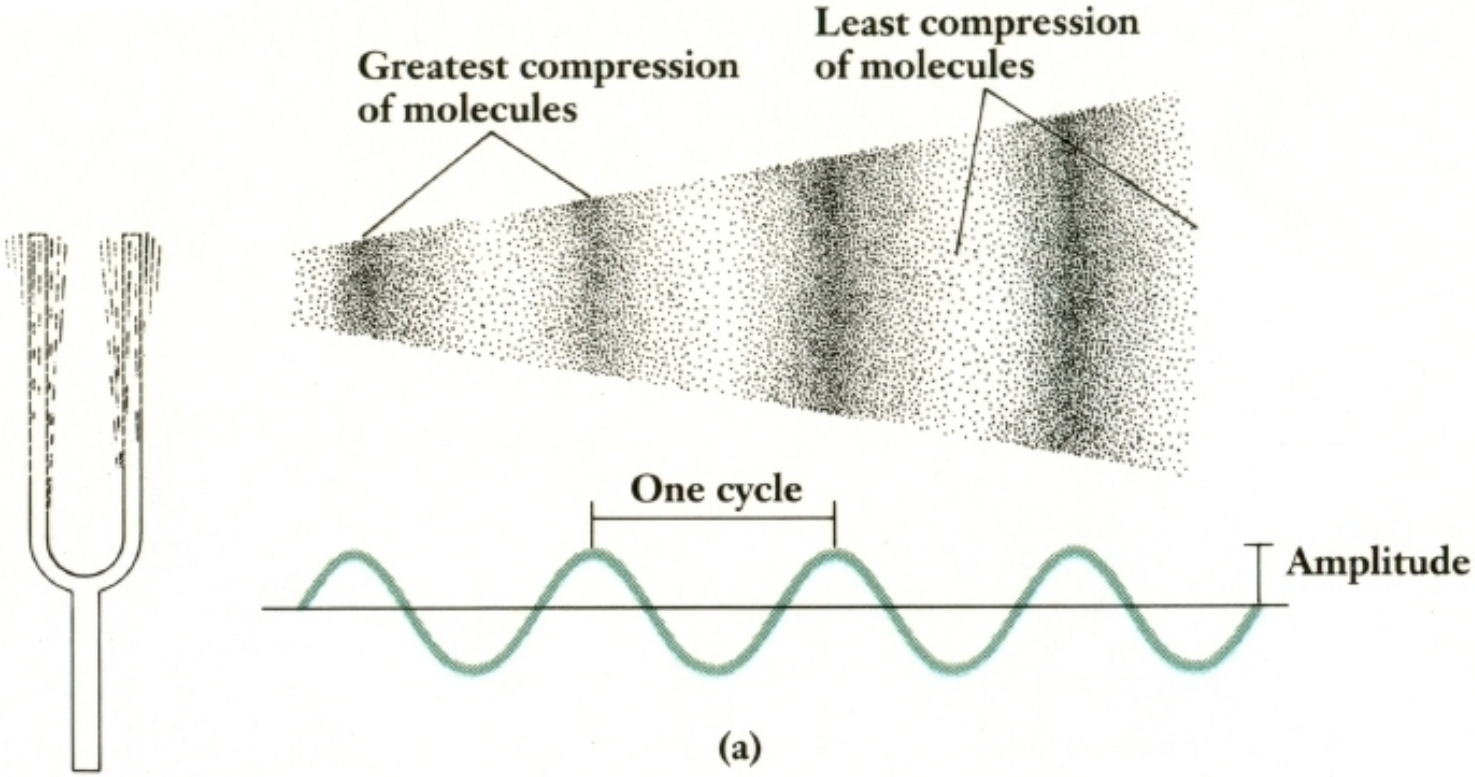
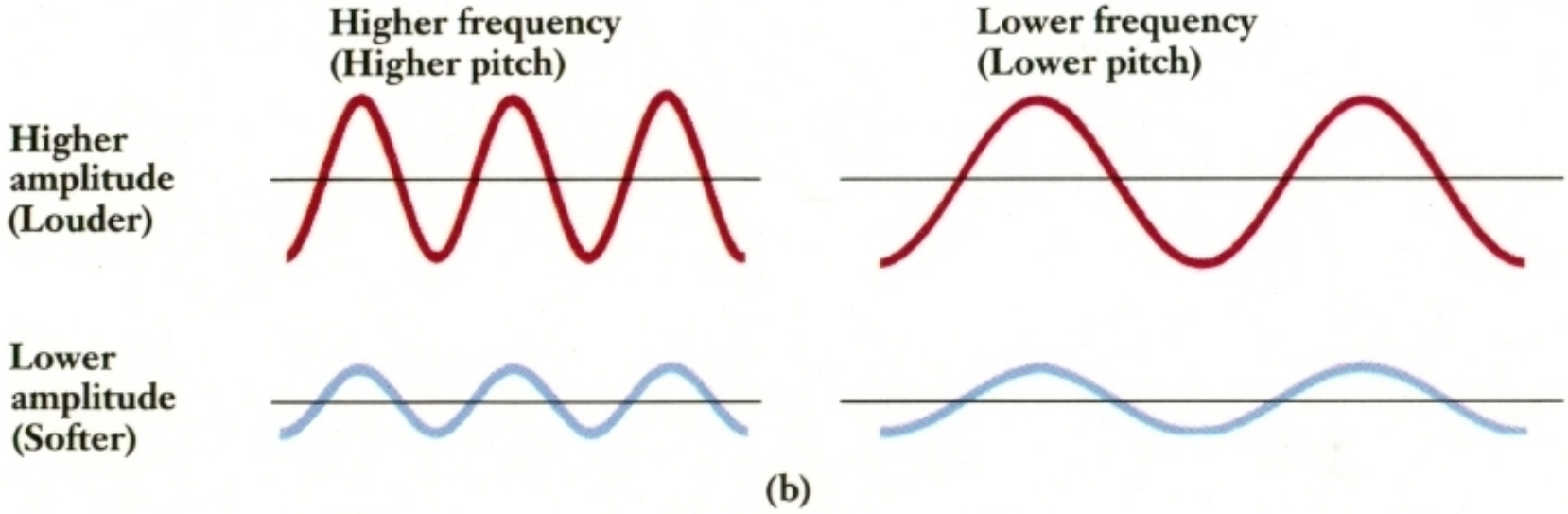
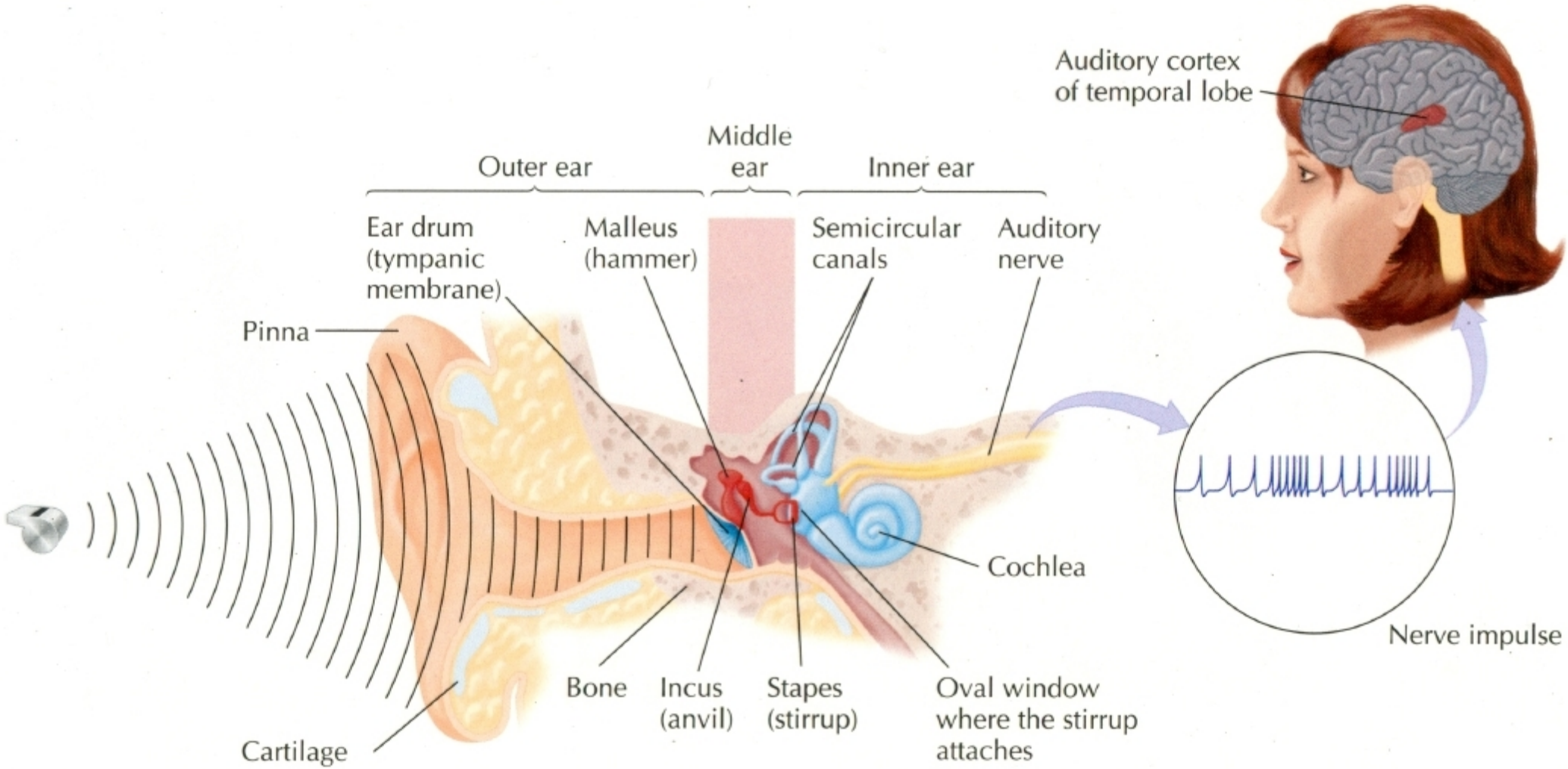
Physics of Sound

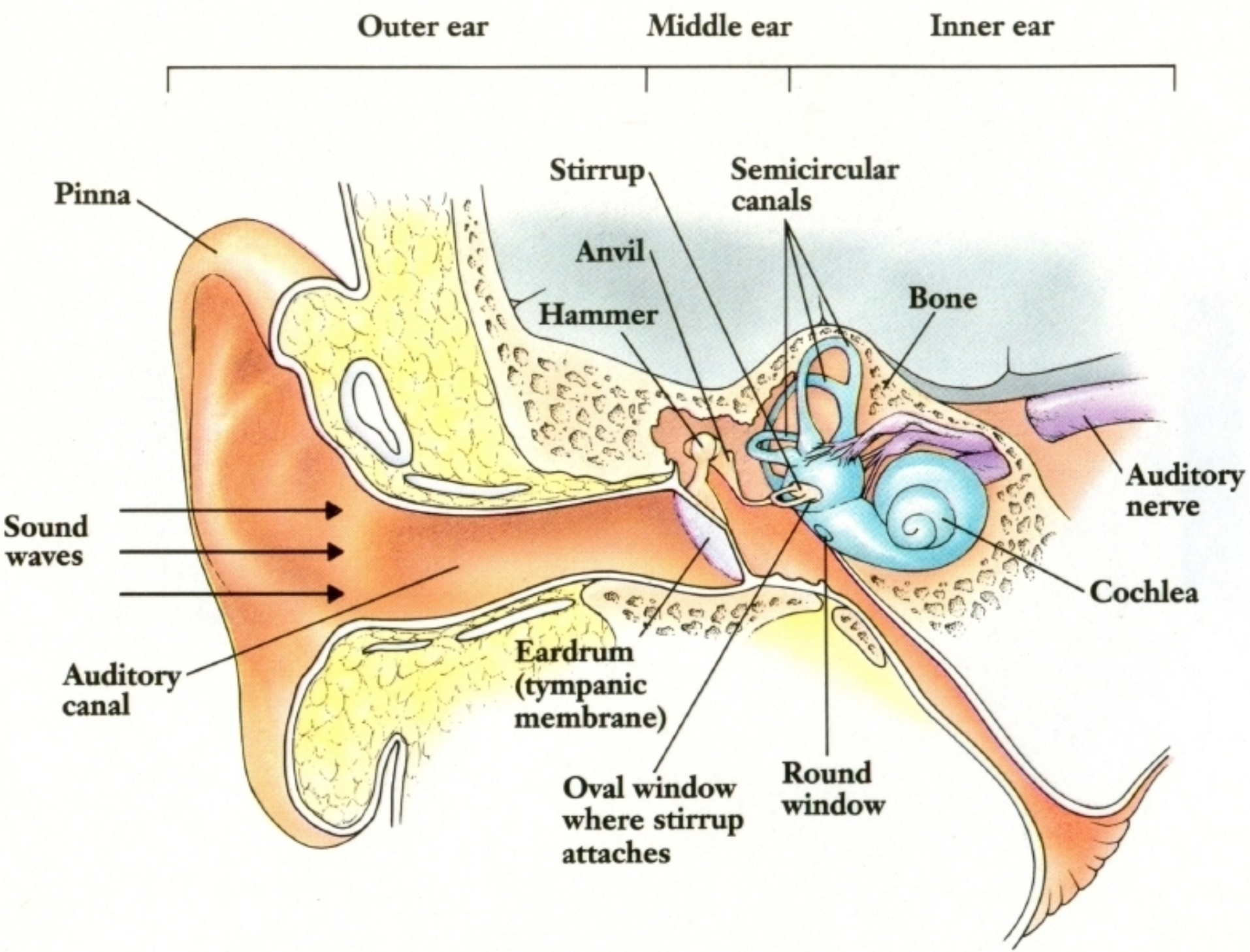


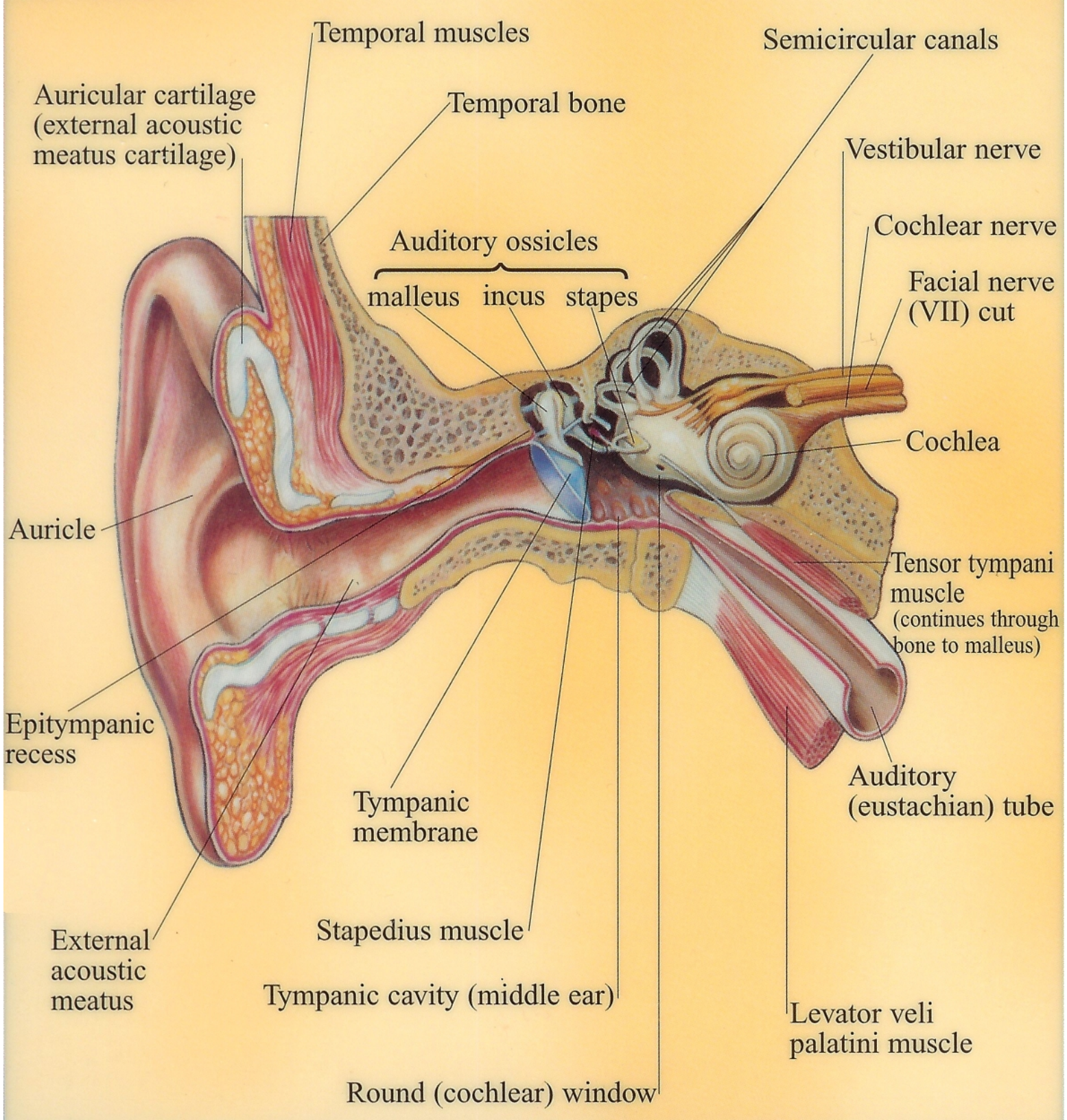


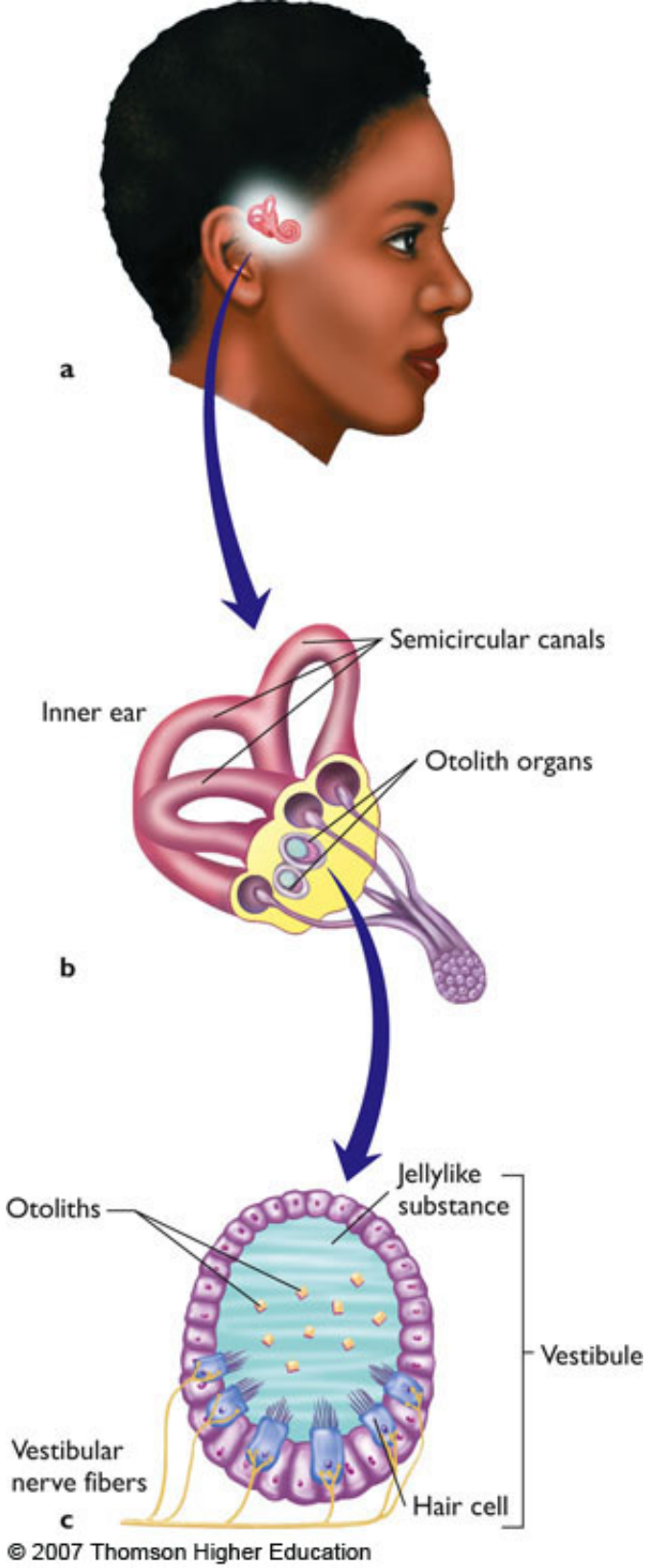
Human Hearing



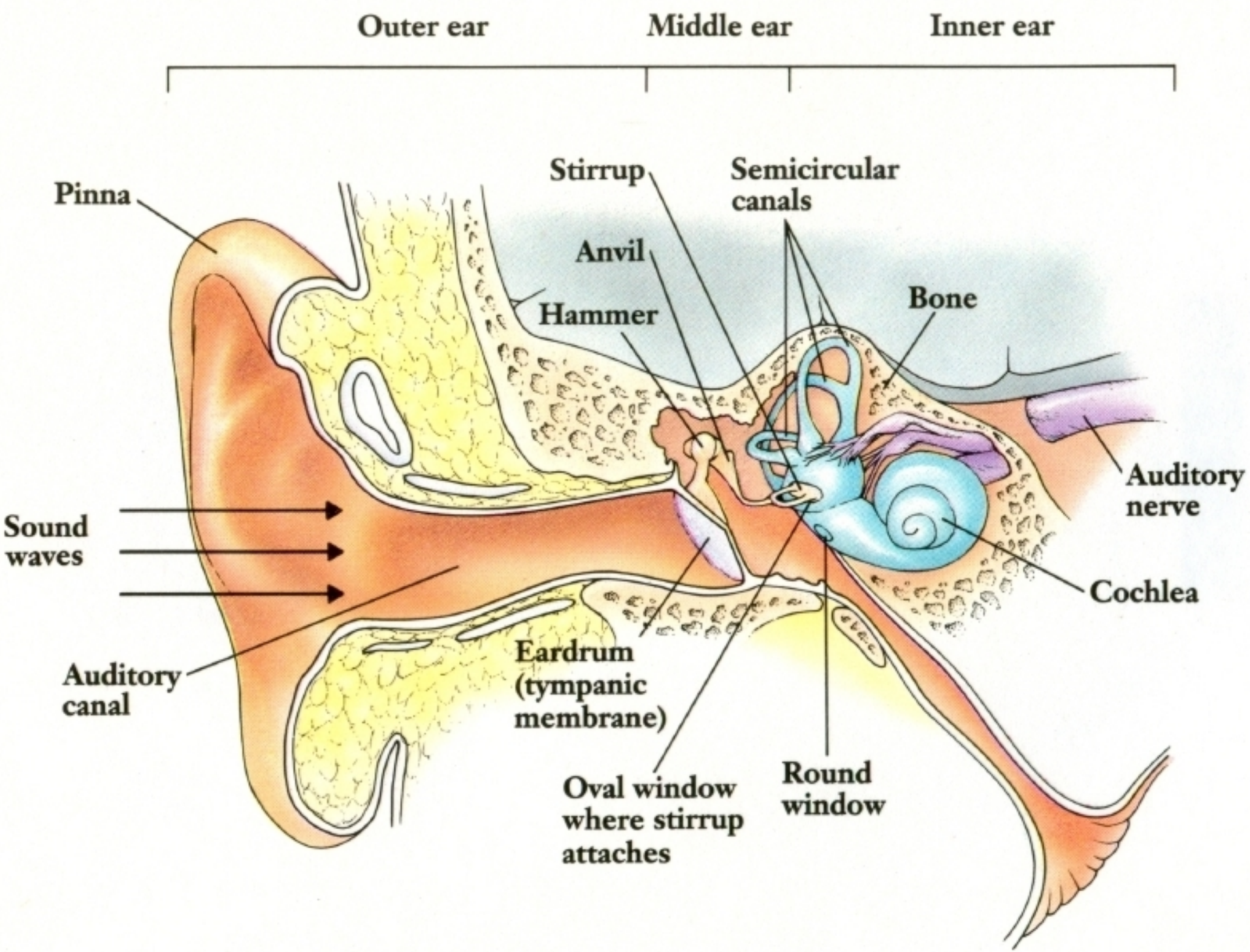
The Human Ear



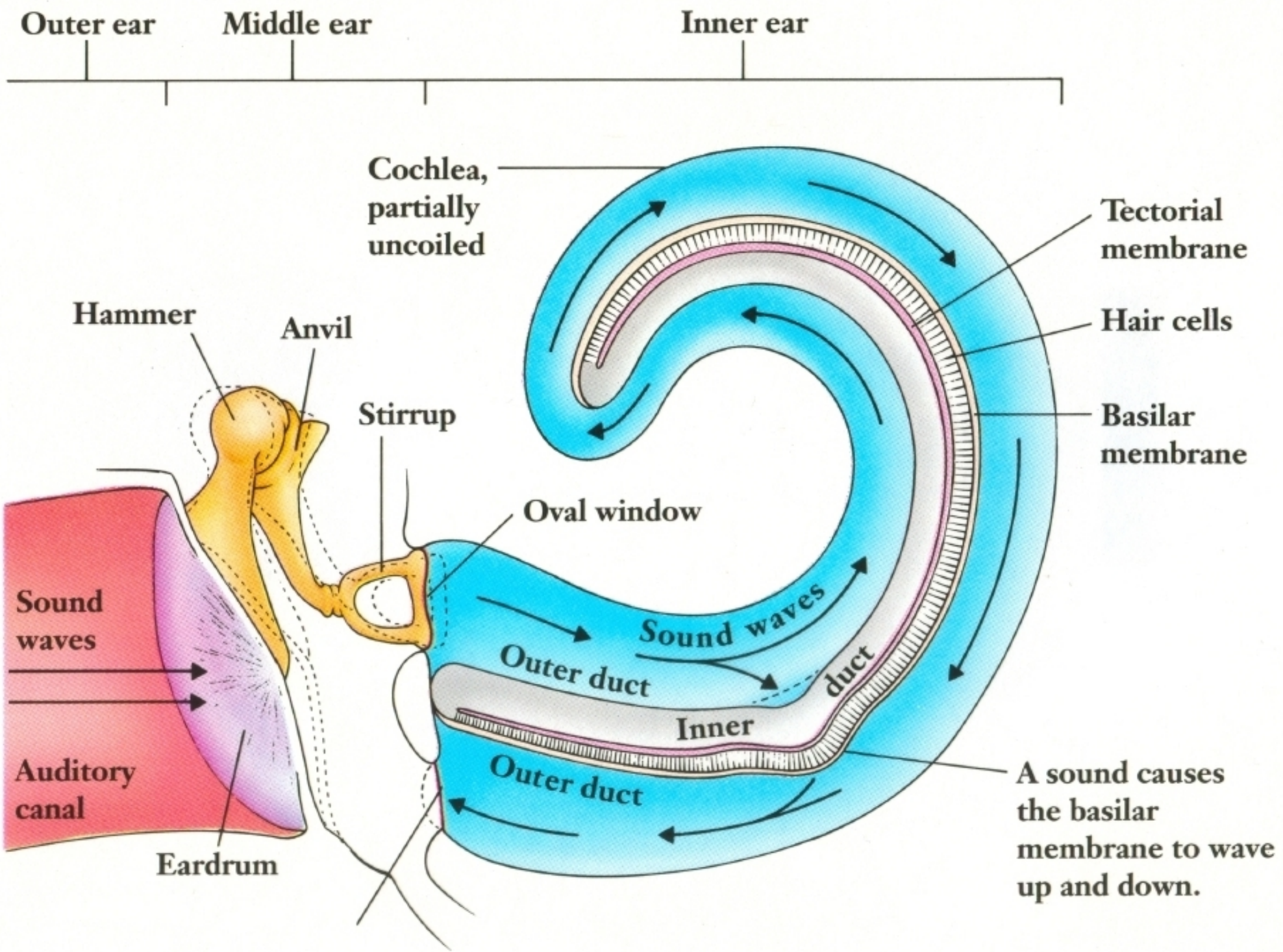

Temporal muscles
Semicircular canals
Auricular cartilage (external acoustic meatus cartilage)
Temporal bone
Vestibular nerve
Cochlear nerve
Auditory ossicles
malleus incus stapes
Facial nerve (VII) cut
Cochlea
Auricle
Tensor tympani muscle (continues through bone to malleus)
Epitympanic recess
Tympanic membrane
Auditory (eustachian) tube
External acoustic meatus
Stapedius muscle
Tympanic cavity (middle ear)
Levator veli palatini muscle
Round (cochlear) window



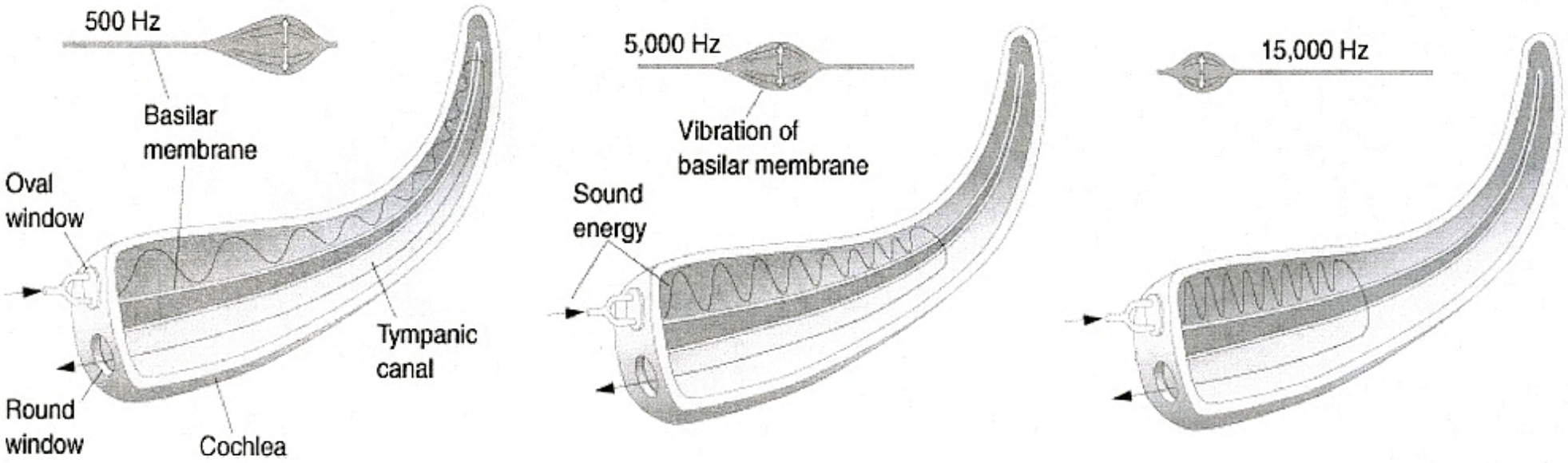
The Human Ear

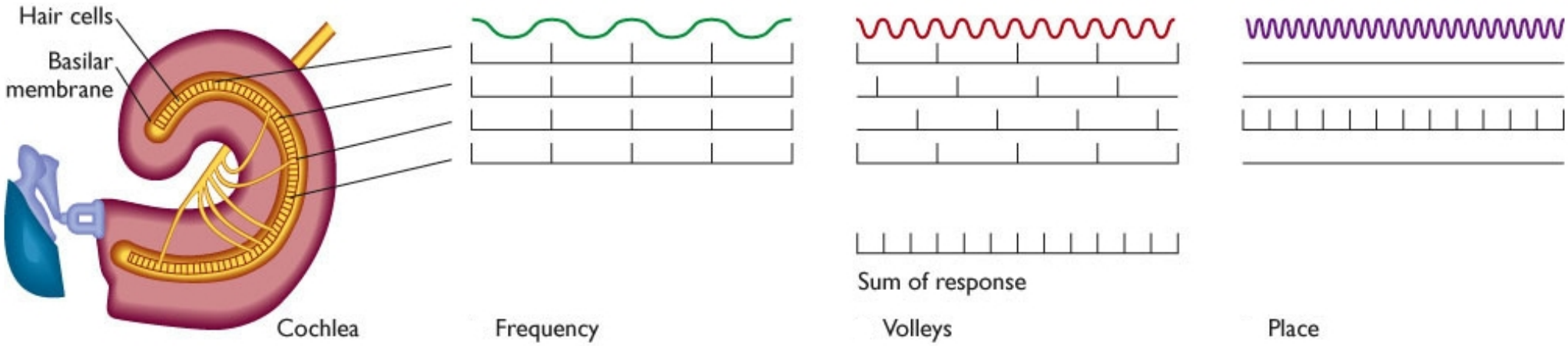


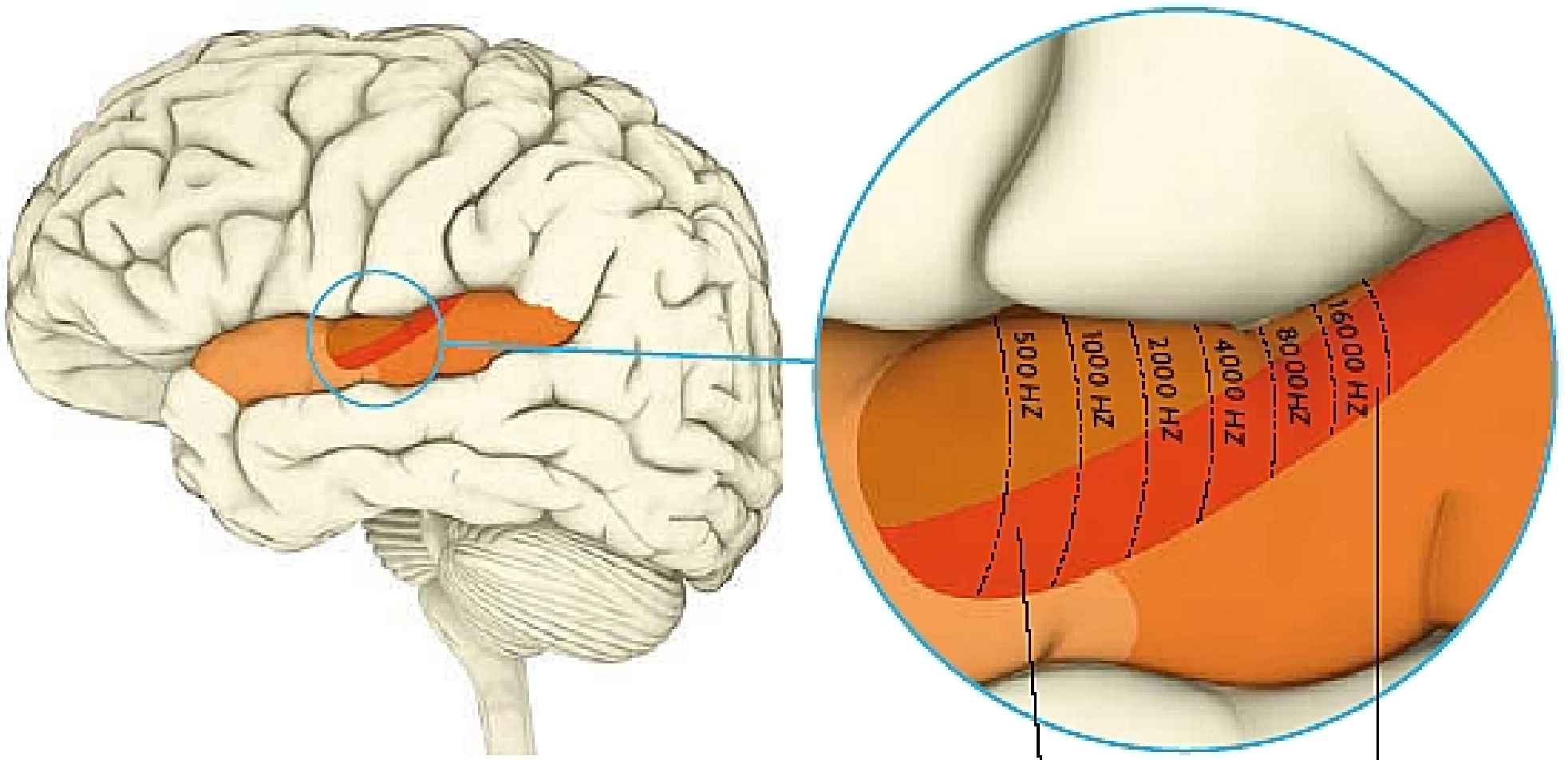
Auditory Transduction



Cochlear Vibration to Different Frequencies



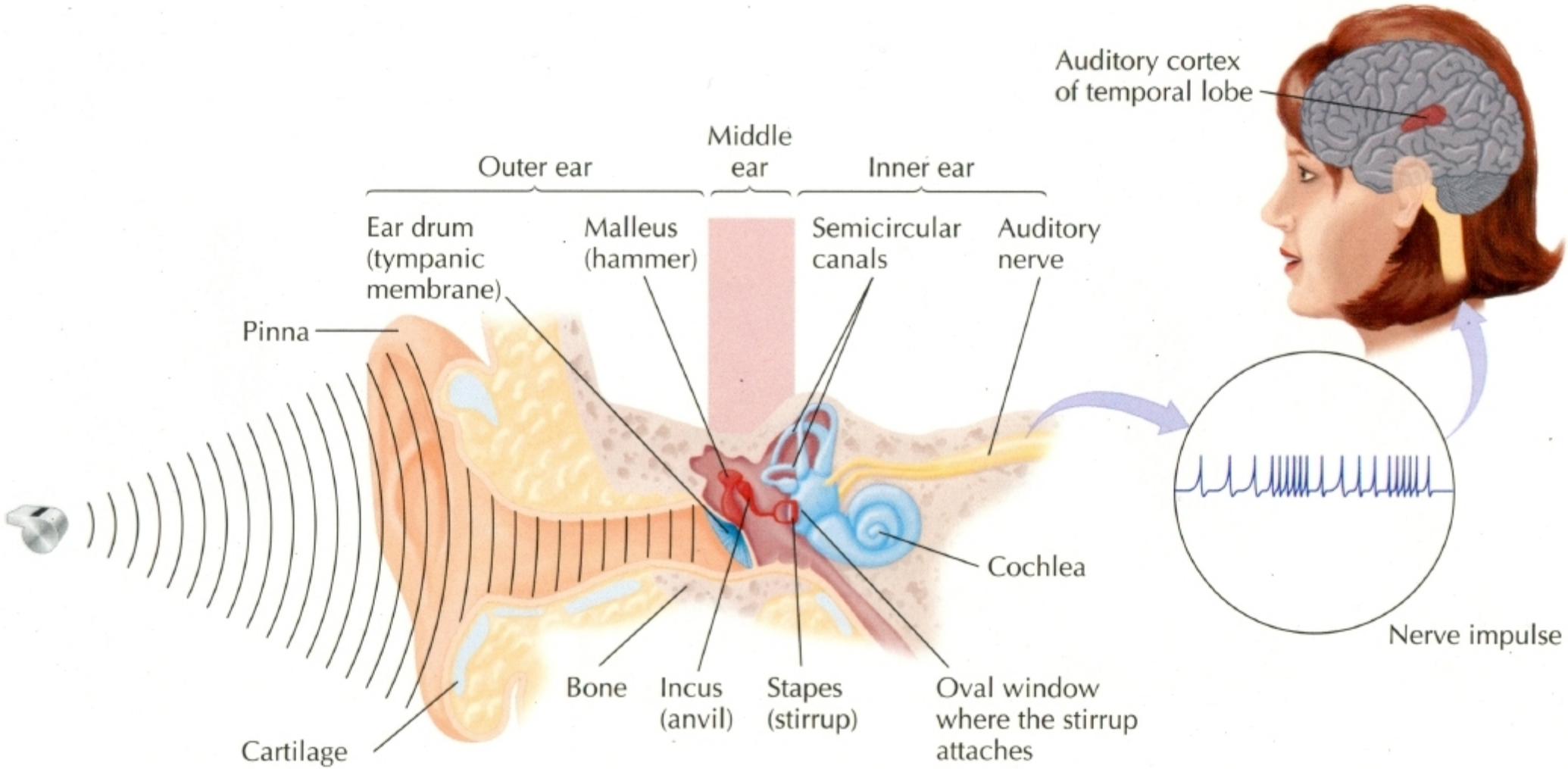

Hair cells
Basilar membrane
Cochlea
Frequency
Sum of response
Volleys
Place



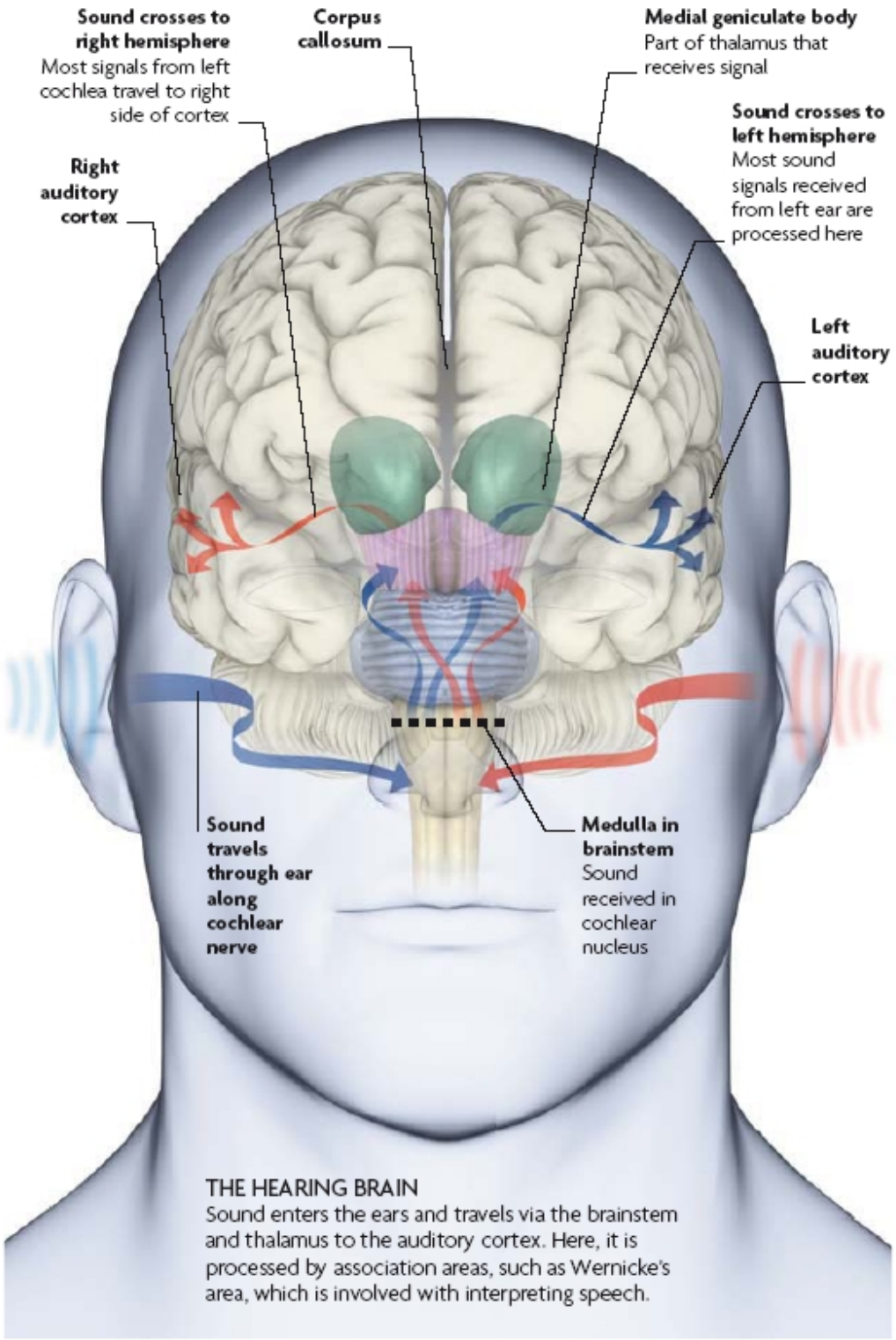
PERCEIVING SOUND FREQUENCIES

In the primary auditory cortex, neurons are sited according to the frequency each responds to, as are the sensory cells in the cochlea.

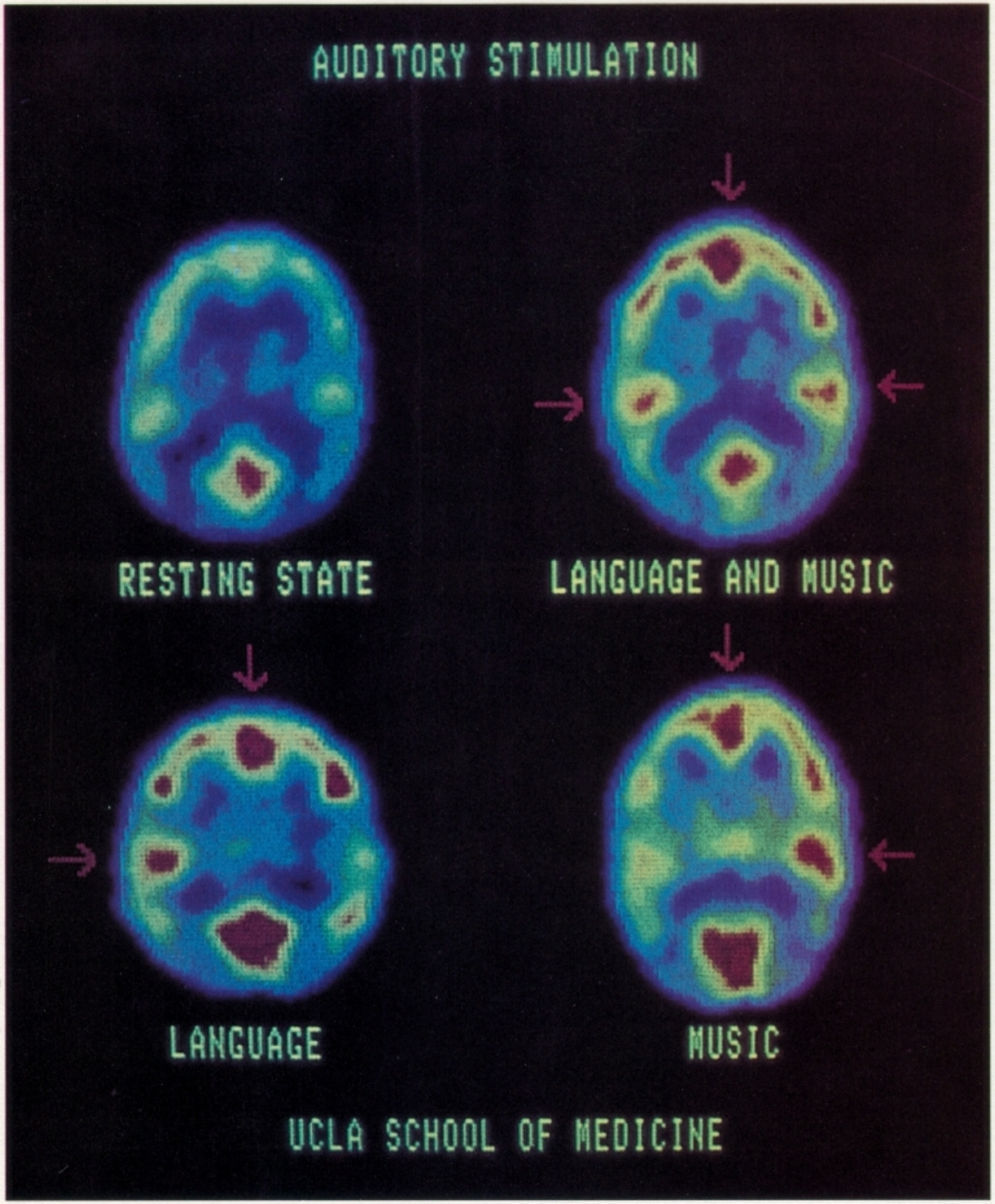
Human Hearing



Auditory Pathway

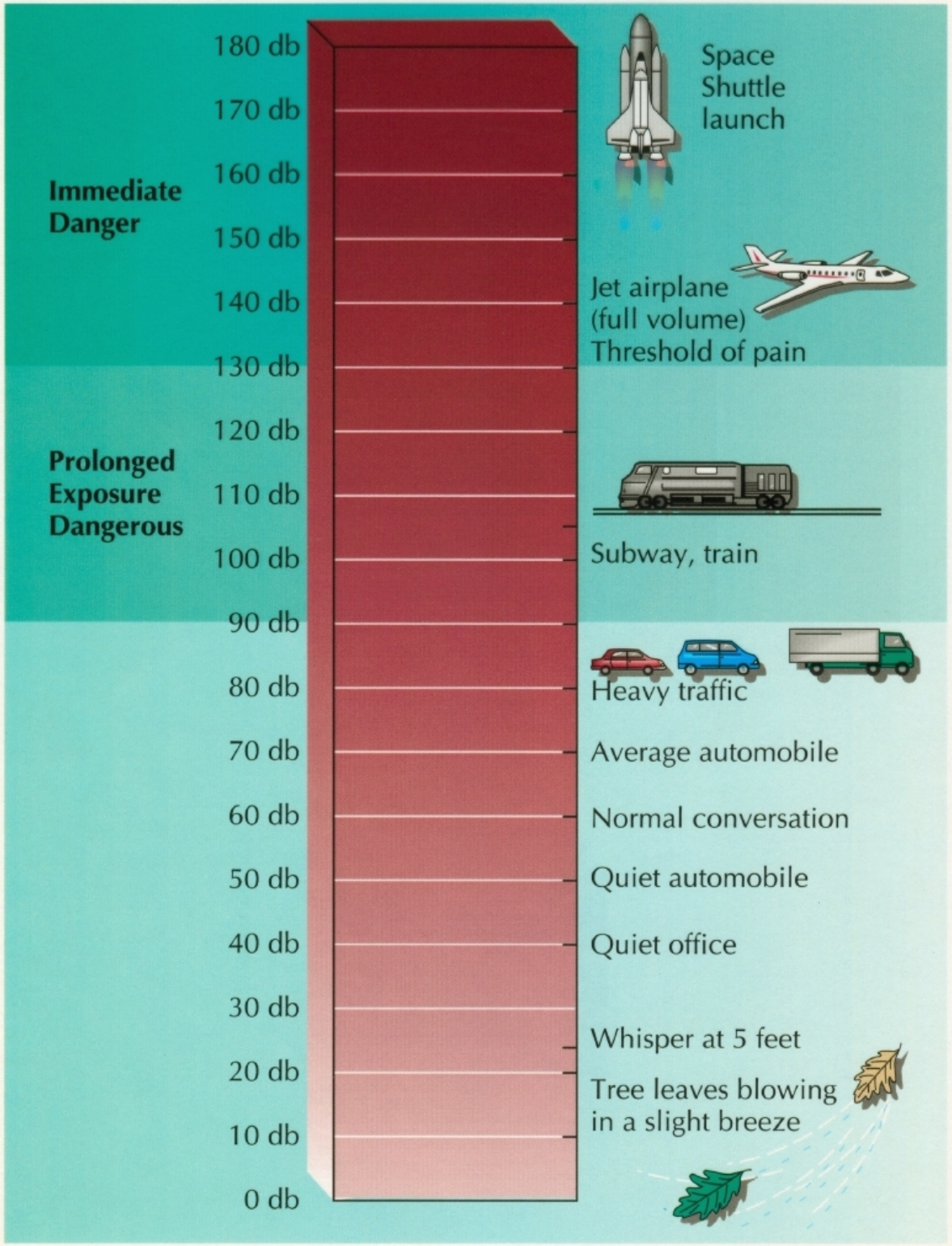


Areas of Excitation During Auditory Stimulation



Mazziotta, et. al./Science Photo Library/Photo Researchers.

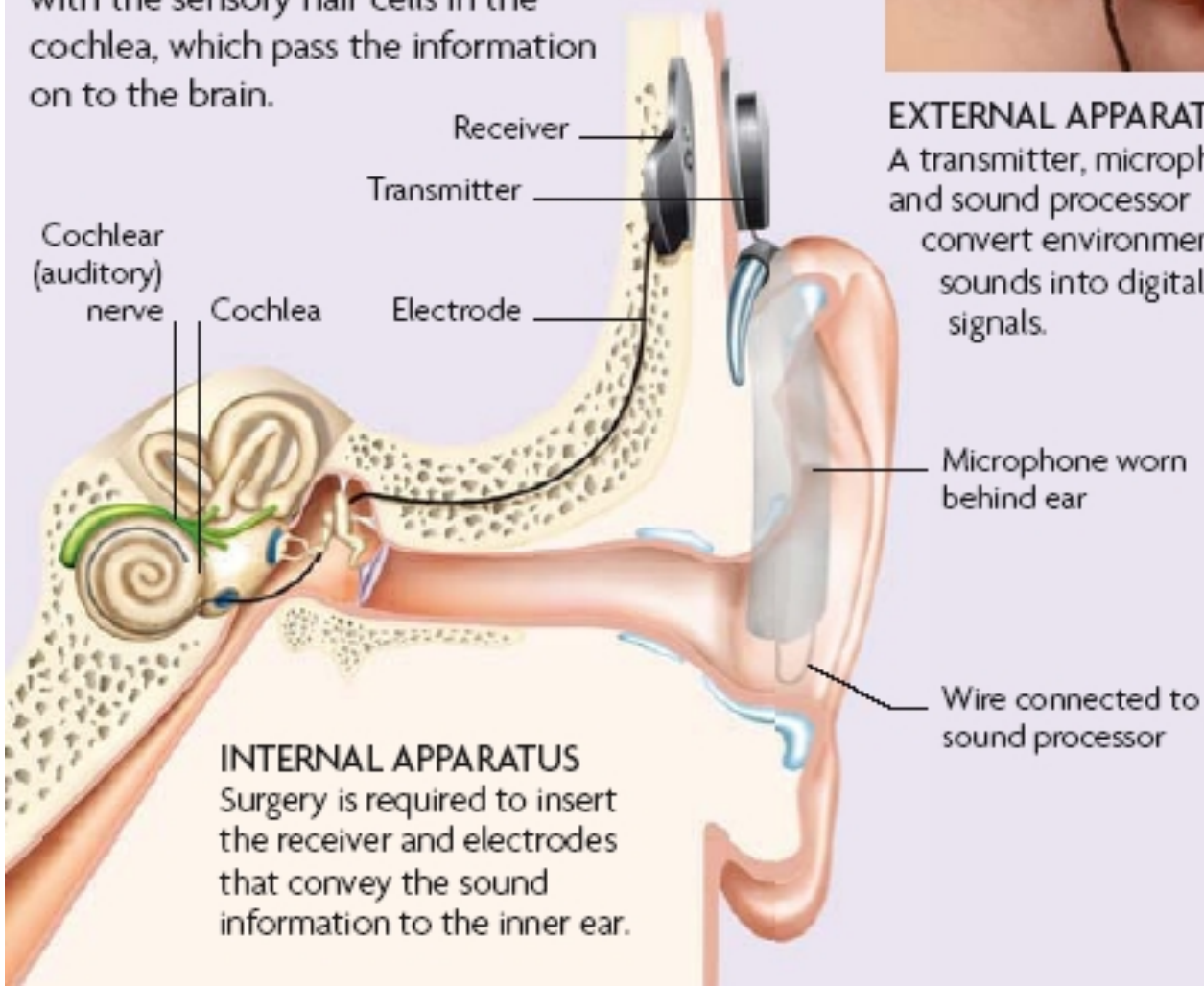
Sound Intensity Levels: The Decibel Scale



THE COCHLEAR IMPLANT

Rather than restore hearing, this device helps the wearer have a perception of sound with no time lag, which can help with lip-reading. A microphone picks up sounds and passes them to a sound processor, which turns them into digital electrical signals. The transmitter conveys the signals, in the form of radio waves, to the implanted receiver, located beneath the skin. This receiver communicates via electrodes with the sensory hair cells in the cochlea, which pass the information on to the brain.

EXTERNAL APPARATUS
A transmitter, microphone, and sound processor convert environmental sounds into digital signals.



INTERNAL APPARATUS
Surgery is required to insert the receiver and electrodes that convey the sound information to the inner ear.

HEARING

HEARING INVOLVES MECHANICAL VIBRATIONS FROM THE ENVIRONMENT—SPEECH, MUSIC, AND EVERYDAY NOISE—TRAVELING THROUGH THE OUTER, MIDDLE, AND INNER EAR. THE VIBRATIONS ARE TRANSFORMED TO ELECTRICAL SIGNALS, WHICH TRAVEL TO THE BRAIN TO BE INTERPRETED AS SOUND.

PATHWAY OF SOUND

The ear is a complex, exquisitely designed instrument for the capture of sound and its transport to the brain. Once mechanical vibrations from sound sources reach the inner ear, they are transformed into electrical impulses that shoot along the cochlear nerve to the brainstem. Here, they follow complex pathways up to the thalamus before arriving at the auditory cortex. Processing in the brain allows perception of the meaning, direction, and volume of a sound.

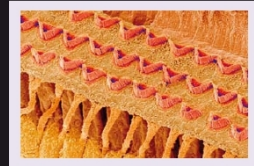
1 The outer ear
Sound waves are caught in the funnel-like curves of the outer ear that comprises the exterior "flap" of the pinna and the auditory canal.

2 The auditory canal
The sound waves continue along the 1in-(2.5cm)-long auditory canal, which extends from the concha (inner curve) of the outer ear to the eardrum and is lined with tiny hairs that protect it from the entry of foreign objects.

3 The eardrum
The eardrum, or tympanic membrane, vibrates as sound waves enter the auditory canal. It is a thin layer of fibrous tissue that forms a barrier between the outer ear and the middle ear.

4 Ossicles
Vibrations are passed on to a set of tiny bones called ossicles (see p.88), which act as a chain of levers. The stapes pushes and pulls on the oval window at the entrance to the cochlea, transmitting sound to the inner ear.

5 The cochlea
The cochlea contains three fluid-filled ducts. The vestibular canal transmits sound vibrations (blue) to the basilar membrane of the organ of Corti. Residual vibrations (red) travel back along the tympanic canal to the round window.



HAIR CELLS
Each hair cell is topped by about 100 projections called cilia. It is the movement of these in response to vibrations that generates electrical signals.

6 The organ of Corti
Mechanical vibrations of sound are transformed into electrical signals by hair cells in the organ of Corti, which is the main organ of hearing and is located in the cochlea (see p.88).

7 The cochlear nerve
Sound impulses are transported from each hair cell in the organ of Corti via cochlear nerve endings that join together to form the nerve responsible for transmitting signals to specialized groups of neurons in the brainstem.

8 Cochlear nuclei
The cochlear nerve branches to connect to the two cochlear nuclei on the same side of the brain as the ear where the sound originally entered. After this, neural pathways branch and ascend in ways that are not yet fully understood.

9 The superior olive
Cells in the ventral cochlear nucleus send signals up to the superior olives on both sides of the brainstem. Here the brain interprets the direction of sounds (see p.90). The superior olive then sends signals on to the midbrain.

10 The inferior colliculus
All the ascending auditory pathways—some of which bypass the superior olives—converge upon the inferior colliculi at the top of the brainstem and their input is then passed on toward the thalamus.

11 The thalamus
Nerve impulses are received and processed by specialized neurons in the medial geniculate nucleus of the thalamus. These signals are then sent to the primary auditory cortex, which also feeds information back to the thalamus.

12 The primary auditoy cortex
The characteristics of a sound input are finally interpreted, after intermediate processing at the primary auditory cortex, which works with other cortical areas on sound perception.

HOW THE BRAIN HEARS
A sound begins as a wave of vibrations that is picked up by the trumpet-shaped outer ear. Vibrations travel through the middle ear before being converted into electrical signals by the organ of Corti. There are thought to be several nerve pathways that sound impulses take through the brainstem (see p.90) to reach the thalamus and primary auditory cortex for processing into the conscious perception of a sound.