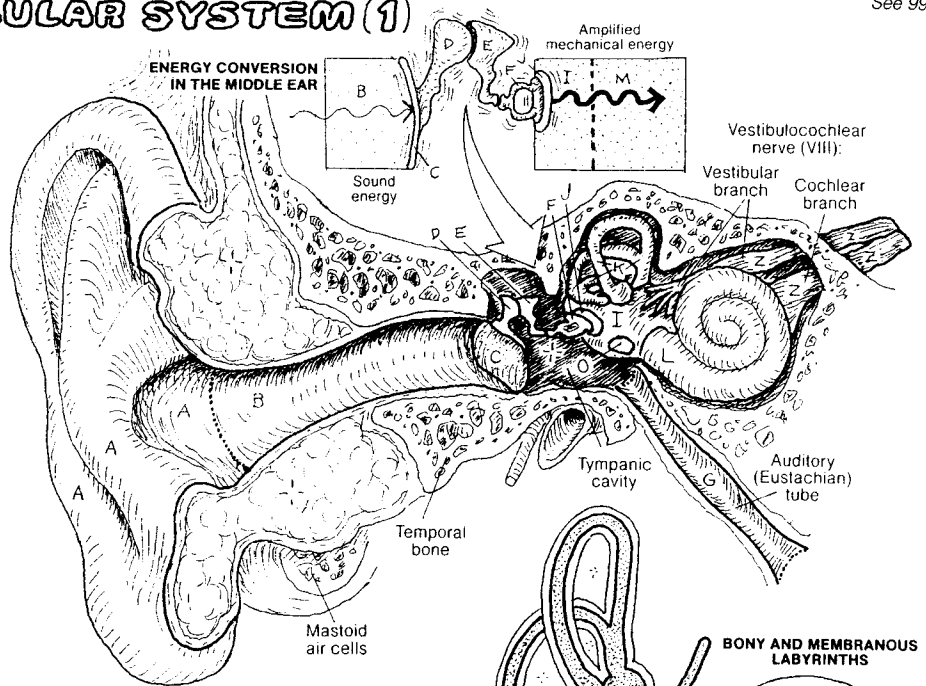


AUDITORY & VESTIBULAR SYSTEM (1)

CN: Use yellow for Z, and light colors for A, B, G, I, M, N, W, and X. The view of the internal ear is magnified in the upper illustration for coloring purposes. Color your way down the plate, beginning with the diagram at the top.



EXTERNAL EAR :-

- AURICLE **A**
- EXT. AUDITORY MEATUS **B**
- TYMPANIC MEMBRANE **C**

MIDDLE EAR :-

- MALLEUS (HAMMER) **D**
- INCUS (ANVIL) **E**
- STAPES (STIRRUP) **F**
- AUDITORY TUBE **G**

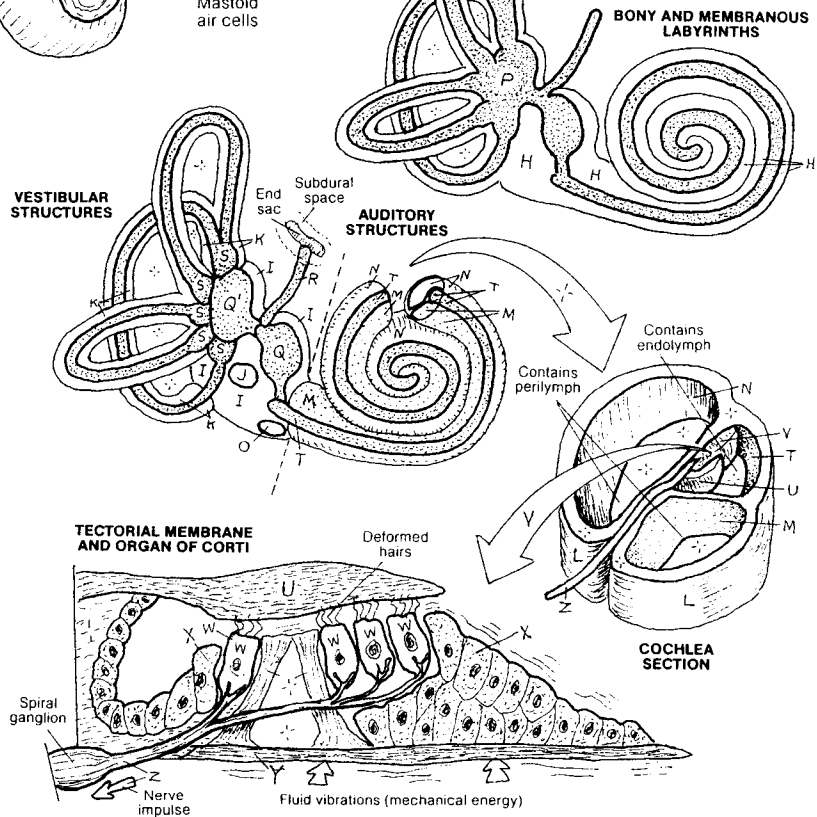
INTERNAL EAR :-

BONY LABYRINTH **H**

- VESTIBULE **I**
- OVAL WINDOW **J**
- SEMICIRCULAR CANAL **K**
- COCHLEA **L**
- SCALA VESTIBULI **M**
- SCALA TYMPANI **N**
- ROUND WINDOW **O**

MEMBRANOUS LABYRINTH **P**

- SACCULE, /UTRICLE **Q**
- ENDOLYMPHATIC DUCT **R**
- SEMICIRCULAR DUCT **S**
- COCHLEAR DUCT **T**
- TECTORIAL MEMBRANE **U**
- ORGAN OF CORTI **V**
- HAIR CELL **W**
- SUPPORTING CELL **X**
- BASILAR MEMBRANE **Y**
- CRANIAL NERVE VIII **Z**



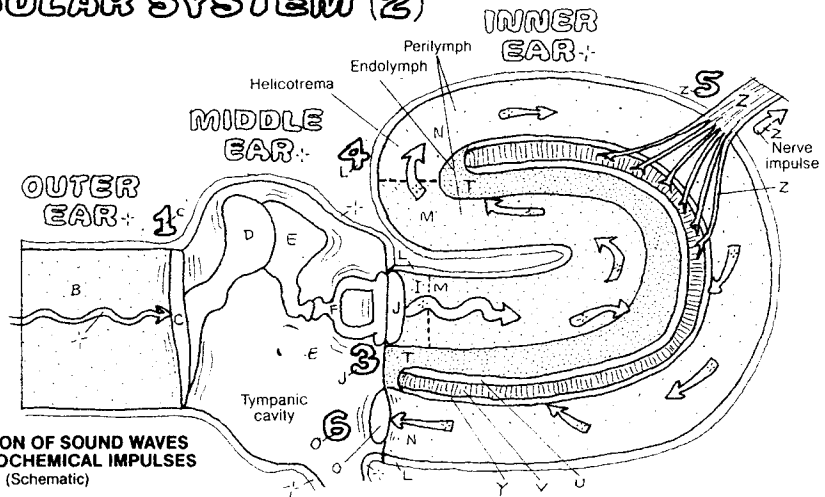
The ear is the organ of hearing and equilibrium (auditory and vestibular systems). It is organized into external, middle, and internal parts. The external ear includes the *auricle* (collector of sound energy) and the *external auditory meatus* or canal (a narrow passageway conducting sound energy to the *tympanic membrane*). This membrane, lined externally by skin and internally by respiratory mucosa, converts sound energy into mechanical energy by resonating in response to incoming sound waves.

The middle ear is a small area filled with much structure, including three small bones (*malleus*, *incus*, *stapes*) joined together by synovial joints. These ossicles vibrate with movement of the tympanic membrane, and amplify and conduct the mechanical energy imparted to them to the waters of the inner ear at the flexible, water-tight *oval window* (middle ear/inner ear interface). At the anterior-medial aspect of the middle ear cavity, the *auditory tube* runs to the nasopharynx, permitting equilibration of air pressure between nasal cavity (outside) and the middle ear. The internal ear, carved out within the petrous portion of the temporal

bone, consists of a series of interconnecting bony-walled chambers and passageways (*bony labyrinth*: *vestibule*, *semicircular canals*, and *cochlea*) filled with perilymph (extracellular-like) fluid. Within the bony labyrinth is a series of interconnecting membranous chambers and passageways (*membranous labyrinth*: *sacculle*, *utricle*, *cochlear duct*, and *semicircular ducts*), filled with endolymph (intracellular-like fluid). The *endolymphatic duct*, derived from the *sacculle*, ends in a blind sac under the *dura mater* near the internal auditory meatus (see Plate 25). It drains endolymph and discharges it into veins in the subdural space. Within the coiled, membranous *cochlear duct*, supported by bone and the fibrous *basilar membrane*, a ribbon of specialized receptor (*hair*) *cells* exists integrated with supporting cells, both covered with a flexible, fibrous glycoprotein blanket (*tektorial membrane*). This device (*Organ of Corti*) converts the mechanical energy of the oscillating tectorial membrane scraping against the receptor hair cells into electrical energy. The impulses generated are conducted along bipolar sensory (auditory) neurons of the *VIII cranial nerve*. (Continued on the next plate.)

AUDITORY & VESTIBULAR SYSTEM (2)

CN: Titles with subscripts 1, 2, and 3 require new colors; all other subscripts (A-Z) refer to titles and colors used on the preceding plate, which should be frequently referred to when using those same colors on this plate. (1) Color the numerals with the appropriate color as you follow the sequence of events in the simplified diagram to the right. See the previous plate for the more accurate anatomical structure. (2) Color the parts of the vestibular system concerned with the maintenance of dynamic and static balance.



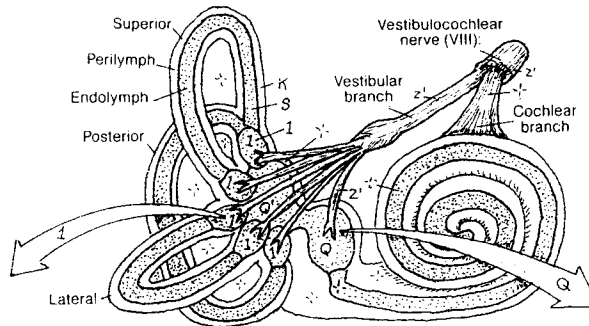
CONVERSION OF SOUND WAVES TO ELECTROCHEMICAL IMPULSES
(Schematic)

In review: the external ear collects sound waves and rifles them to the *tympanic membrane*, which converts the sound energy into mechanical energy. The linkage of *ossicles* increases the amplitude of the energy and transmits the force to the *oval window* of the bony labyrinth of the inner ear. Vibratory movements of the *stapes* in the window are transmitted to the perilymph of the *vestibule* of the bony labyrinth, creating wave-like motions of the fluid. These waves spread throughout the vestibule, then enter and move through the *scala vestibuli* of the *cochlea* to the *helicotrema* at the apex of the cochlea (2½ turns) and on around to the *scala tympani*, which

terminates at the *round window*. Here, fluid waves and vibrations are dampened. The fluid motion in the *scala vestibuli* vibrates the roof of the membranous *cochlear duct*, creating endolymph waves in the cochlear duct. This motion stirs the *tectorial membrane*, which rubs against and bends the hair-like processes of the *receptor (hair) cells*, depolarizing them and inducing electrochemical impulses. These impulses are conducted by the sensory neurons of the cochlear division of the *VIII cranial nerve*. Stimulation of the hair cells from the apex of the cochlea to the base produces a continuum of increasingly high-pitched sound perceptions.

VESTIBULAR SYSTEM/EQUILIBRIUM

- AMPULLA:**
CRISTA:
 CUPOLA₂
 HAIR CELL_{w'}
 NERVE FIBER_{z'}
 SUPPORTING CELL_{x'}

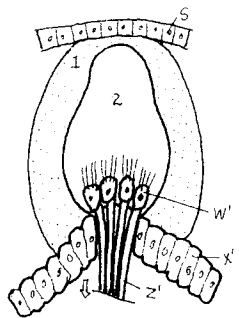


- SACCLE, UTRICLE:**
MACULA:
 GELATINOUS LAYER₂
 OTOLITH₃
 HAIR CELL_{w'}
 NERVE FIBER_{z'}
 SUPPORTING CELL_{x'}

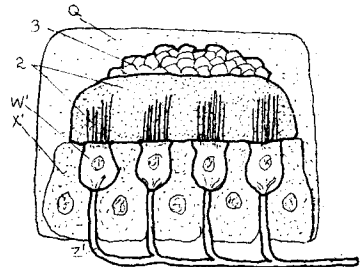
SEMICIRCULAR CANAL_k SEMICIRCULAR DUCT_s

In review: the vestibular system is located in the inner ear. The bony *semicircular canals* are oriented at 90° to one another. Within these canals are the membranous *semicircular ducts*. Directly communicating with the utricle at one end, each duct terminates at the other end in an *ampulla*. Within the *sacculle/utricle* and the ampullae are sensors responsive to fluid (endolymph) movement. Each ampulla has a hillock of cells (*crista* or *crest*) consisting of *receptor (hair) and supporting cells*. The hair-like processes of these receptor cells are embedded in a top-heavy, gelatinous *cupola* (like an inverted cup). Movement of endolymph in response to head turning, and especially rotation, pushes these cupolas, bending the hair cells and causing them to depolarize, generating an electrochemical impulse. The impulses travel out the vestibular part of the *VIII nerve* to the vestibular nuclei in the lower brain stem. When the body is rotated rapidly, horizontal, oscillatory eye movements occur (*nystagmus*). These eye movements are mediated by ampullary sensory input to the brain stem. Such movements represent the brain's attempt to maintain spatial orientation (by momentary visual fixation) during head and/or body rotation. Sensations of rotational movement in the absence of body rotation are called vertigo.

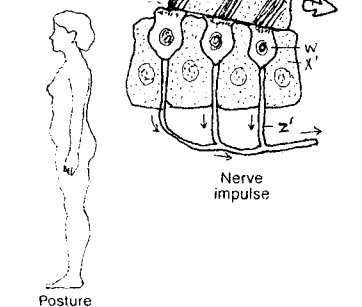
Within the utricle/sacculle, *hair cells* and their *supporting cells* are covered with a *gelatinous layer* in which are embedded small calcareous bodies (*otoliths*). Movement of the endolymph induces movement of the gelatinous layer against the hair cells, with responses identical to those of the ampullary receptors. Receptor activity in the utricle/sacculle is influenced by linear (horizontal and vertical but non-rotational) acceleration of the body. Vestibular receptors have strong neural connections with cranial nerve nuclei concerned with eye movements and with postural motor centers.



ROTATIONAL MOVEMENT
(Dynamic balance)



LINEAR MOVEMENT
(Static balance)



Posture

