

BASICS OF NEUROBIOLOGY

COCHLEAR AND VESTIBULAR SYSTEMS

ZSOLT LIPOSITS

Basics of Neurobiology: Cochlear and vestibular systems

CHARACTERISTICS OF THE COCHLEAR AND VESTIBULAR SYSTEMS

THE AUDITORY SYSTEM ENSURES THE SENSE OF HEARING. THE SYSTEM HAS TWO MAJOR CONSTITUENTS: THE EAR WITH THE COCHLEAR APPARATUS AND THE AUDITORY NEURONAL SYSTEM

SOUND CAUSES VIBRATION OF THE TYMPANIC MEMBRANE THAT IS TRANSMITTED VIA THE OTIC OSSICLES TO THE PERILYMPHATIC FLUID. IT GENERATES A SPREADING WAVE IN THE COCHLEAR DUCT FILLED WITH ENDOLYMPH

THE RESULT OF THESE EVENTS IS THE ACTIVATION OF HAIR CELLS IN THE ORGAN OF CORTI. THIS SIGNAL IS TRANSMITTED BY THE COCHLEAR NERVE TO COCHLEAR NUCLEI OF THE BRAINSTEM

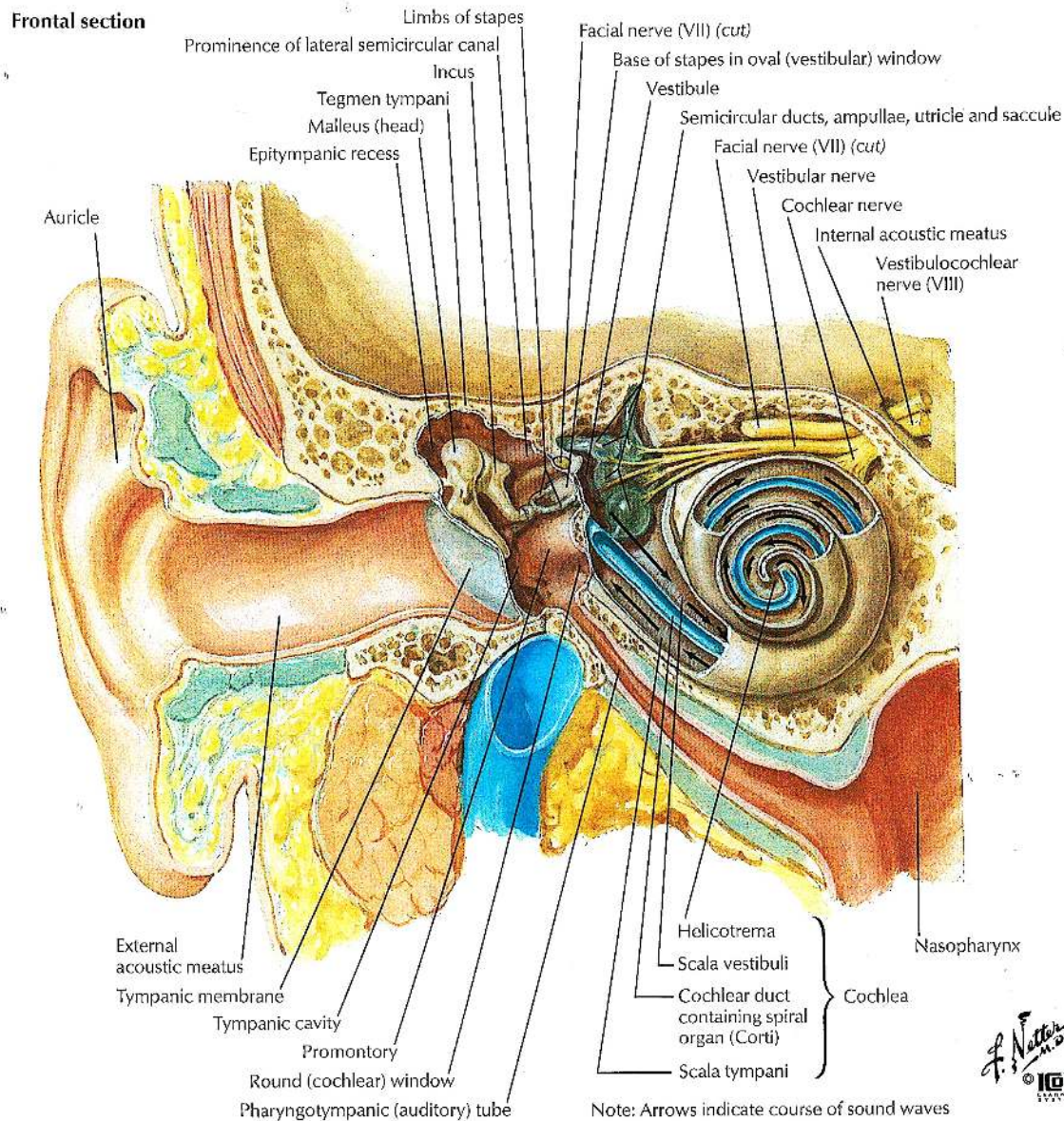
THE COCHLEAR NUCLEI PROJECT UPSTREAM AND SEND THE INFORMATION VIA BRAIN STEM AND METATHALAMIC STRUCTURES TO THE PRIMARY AUDITORY CORTEX LOCATED IN THE SUPERIOR TEMPORAL GYRUS

THE VESTIBULAR SYSTEMS SENSES LINEAR ACCELERATION, DECELERATION AND ANGULAR ROTATION OF THE HEAD

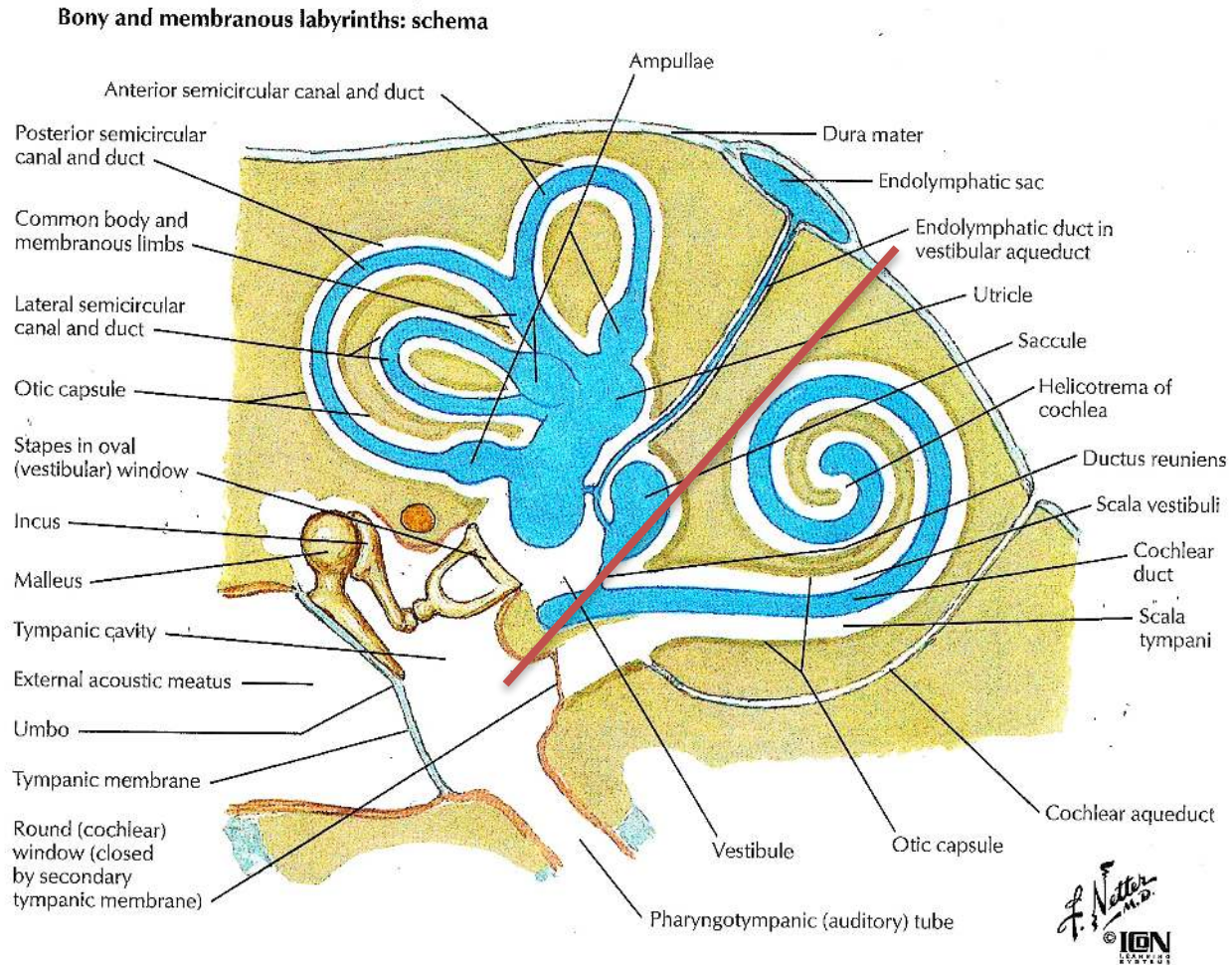
RECEPTORS ARE IN THE UTRICLE, SACCULE AND THE SEMICIRCULAR CANALS. THE GENERATED SIGNALS ARE CARRIED BY THE VESTIBULAR NERVE TO ITS NUCLEI FOR PROCESSING

THE SYSTEM IS INTERCONNECTED WITH MOTOR NUCLEI OF MUSCLES REGULATING THE MOVEMENTS OF EYE. THE VESTIBULAR INFORMATION IS ALSO FORWARDED TO THE CEREBELLUM AND THE SPINAL CORD

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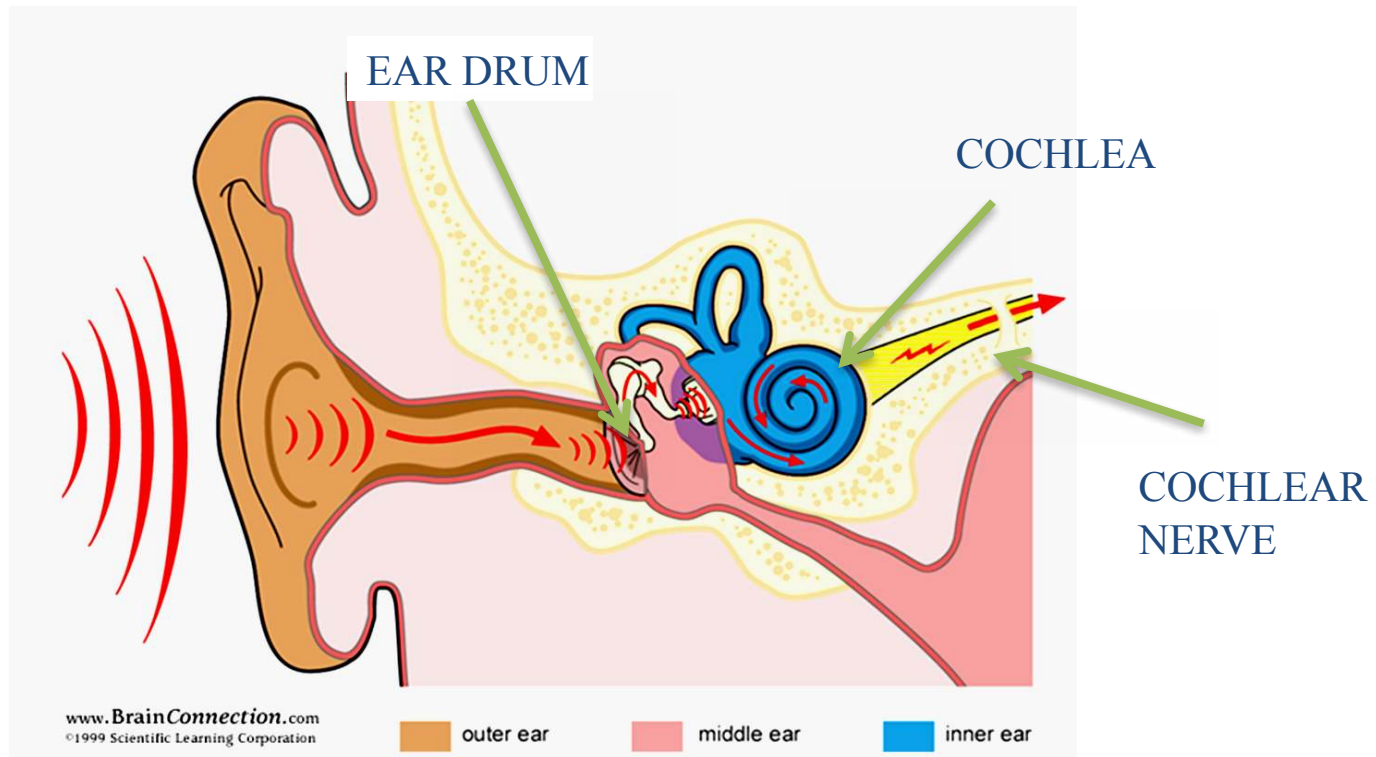


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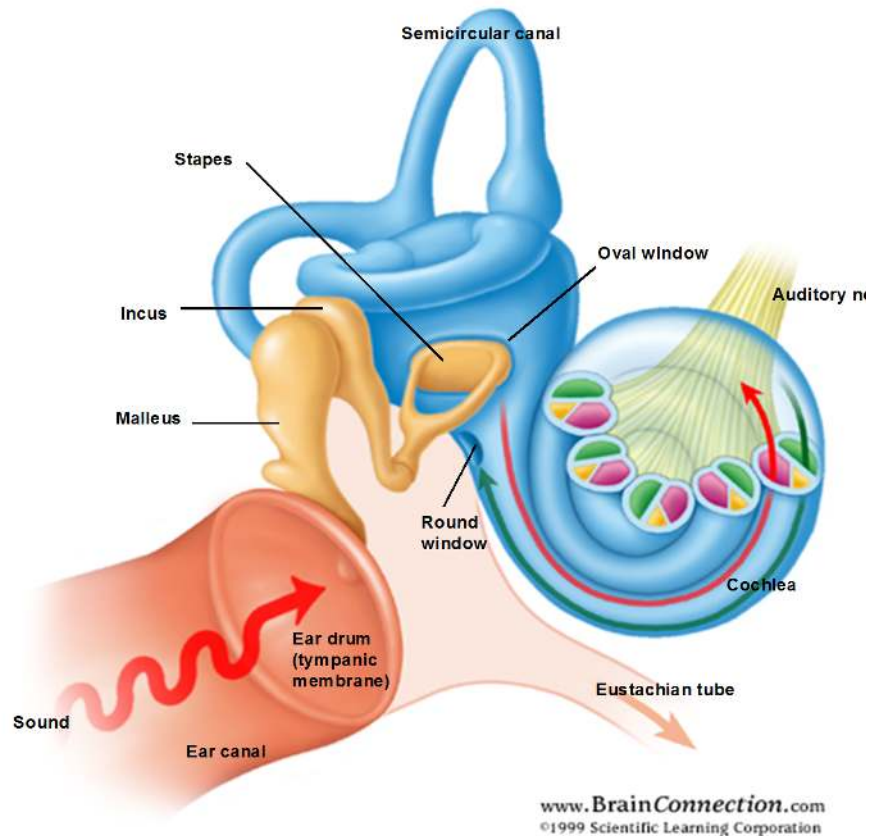
ORGANIZATION OF THE EAR



THE FIGURE DEPICTS THE OUTER, MIDDLE AND INNER PARTS OF THE EAR AND SHOWS THE PROPAGATION OF SOUND-EVOKED SIGNALS FROM THE EAR DRUM TO THE COCHLEA AND THEN TOWARD THE CENTRAL NERVOUS SYSTEM THROUGH THE COCHLEAR NERVE

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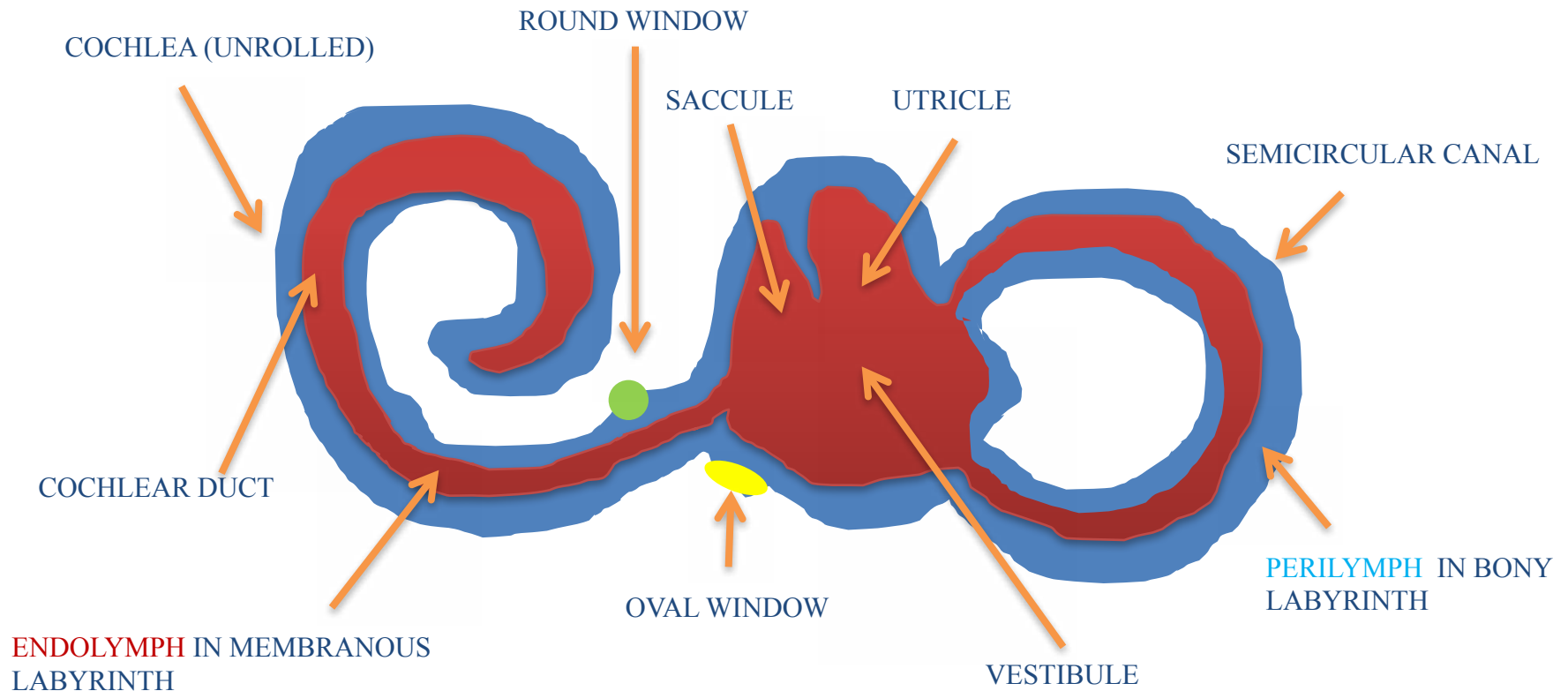
DETAILS OF SIGNAL PROPAGATION IN THE EAR



SOUND CAUSES VIBRATION OF THE TYMPANIC MEMBRANE WHICH IS TRANSMITTED BY A CHAIN OF TINY BONES, THE **MALLEUS**, **INCUS** AND **STAPES** TO THE OVAL WINDOW OF THE COCHLEA. THE BASIS OF THE STAPES TRANSMITS THE SIGNAL TO THE PERILYMPH, A FLUID FILLING THE **SCALA VESTIBULI** AND **SCALA TYMPANI** COMPARTMENTS OF THE COCHLEA. THE SCALA VESTIBULI STARTS AT THE OVAL WINDOW AND THE FLUID FILLED MEMBRANOUS TUBE WINDS AROUND THE VERTICAL AXIS OF THE COCHLEA, THEN IT TURNS DOWNHILL AND CONTINUES AS SCALA TYMPANI WHICH ENDS AT THE MEMBRANE COVERING THE ROUND WINDOW. SCALA TYMPANI AND SCALA VESTIBULI SURROUND THE MEMBRANOUS TUBE **COCHLEAR DUCT** WHICH IS FILLED WITH ENDOLYMPH

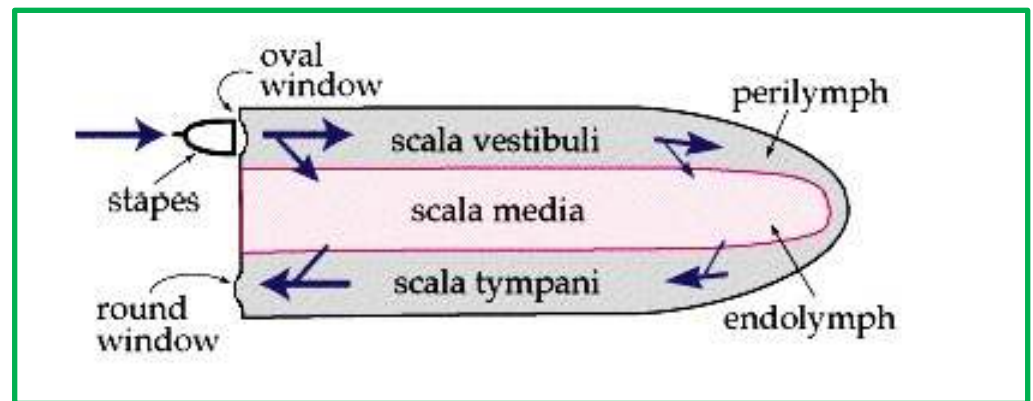
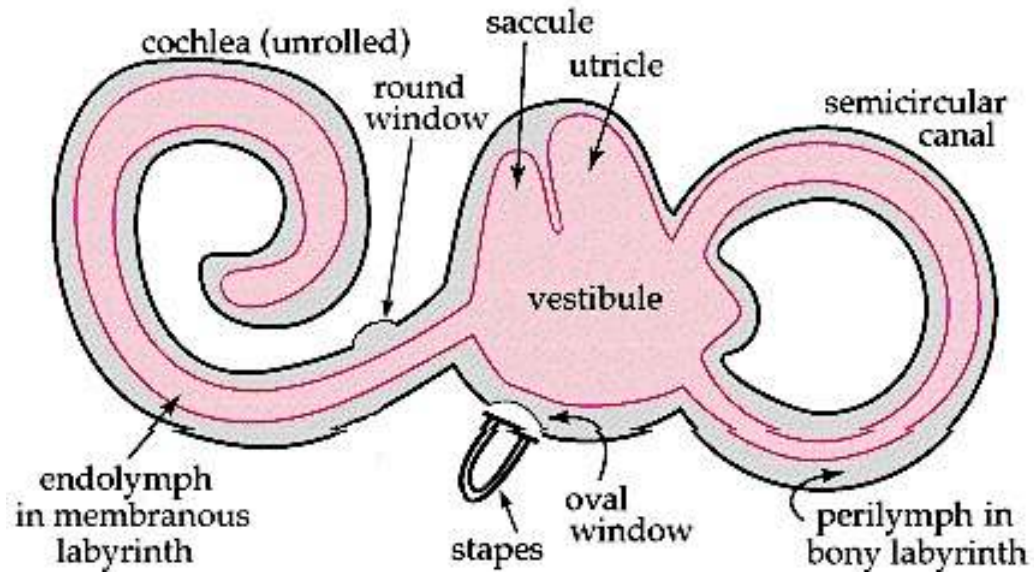
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FLUID COMPARTMENTS OF THE BONY AND MEMBRANOUS LABYRINTHS



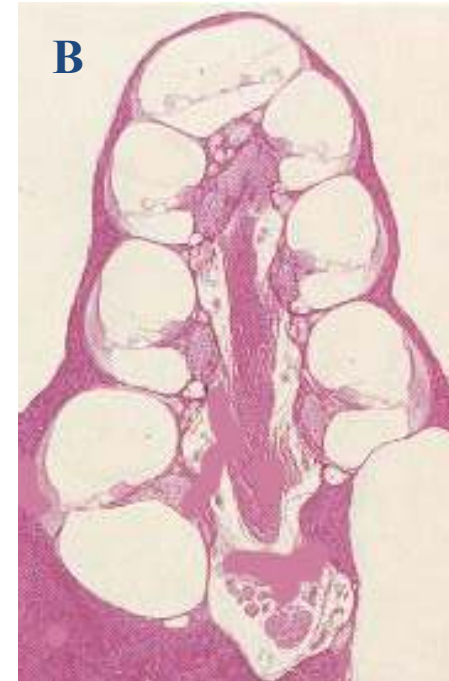
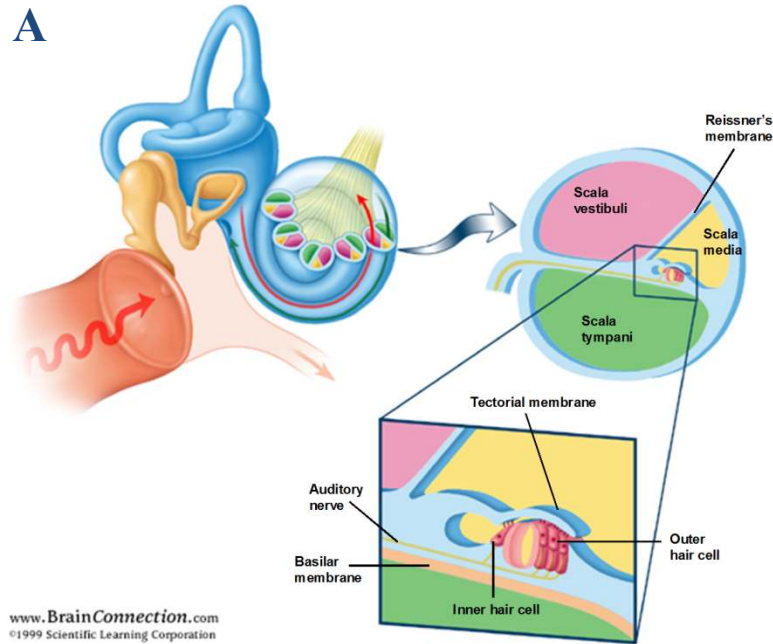
NOTE THAT THE ENDOLYMPHATIC COMPARTMENT IS SURROUNDED BY THE PERILYMPHATIC FLUID SYSTEM

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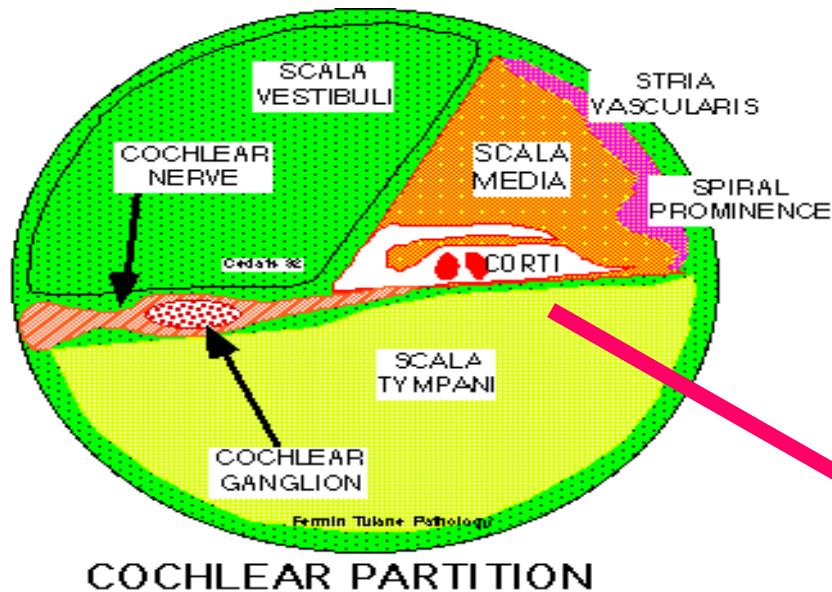
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THE STRUCTURE OF THE CORTI ORGAN



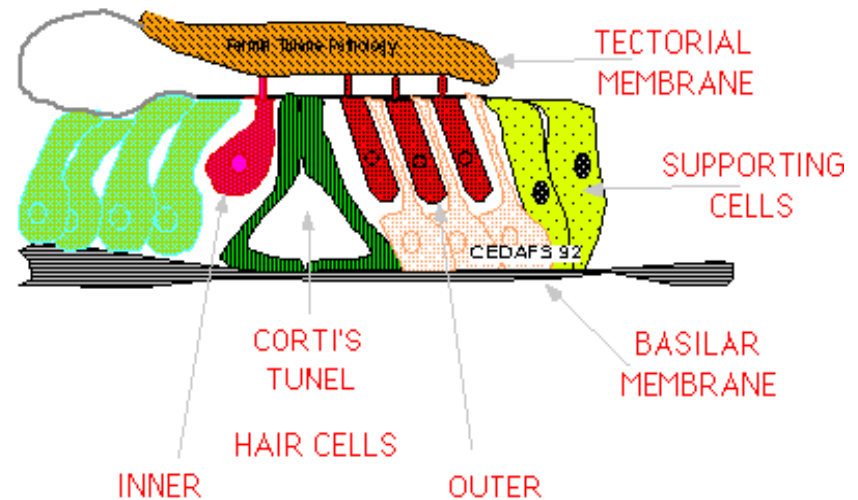
A. THE ORGAN OF CORTI IS SITUATED WITHIN THE COCHLEAR DUCT. IT IS BUILT BY SENSORY EPITHEL HAIR CELLS AND SUPPORTIVE EPITHEL CELLS. THE SENSORY CELLS PICK UP THE SIGNAL OF THE SPREADING ENDOLYMPHATIC FLUID WAVE. NEURONS OF THE COCHLEAR GANGLION CONVEY THE INFORMATION TO AUDITORY CENTERS OF THE BRAIN STEM. **B.** HISTOLOGY OF THE COCHLEA

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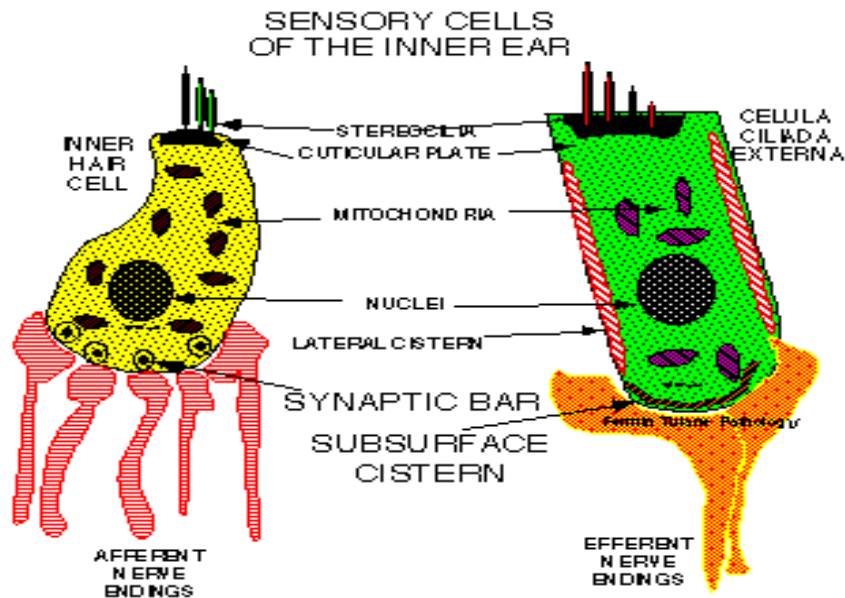


CORTI ORGAN

ORGAN OF CORTI

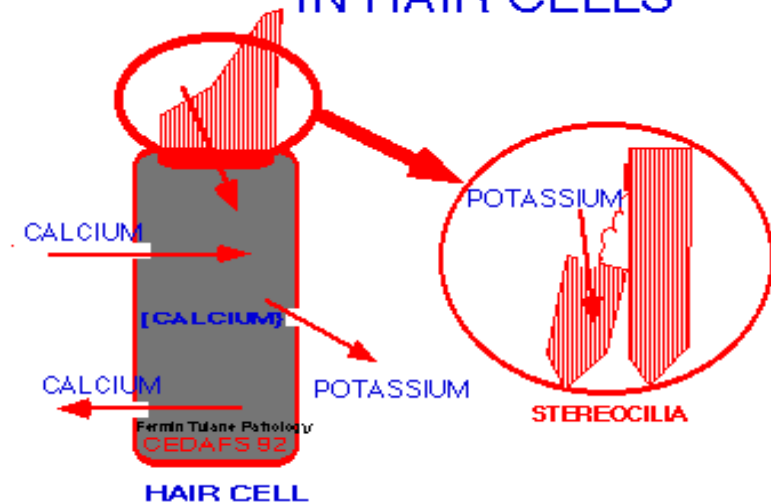


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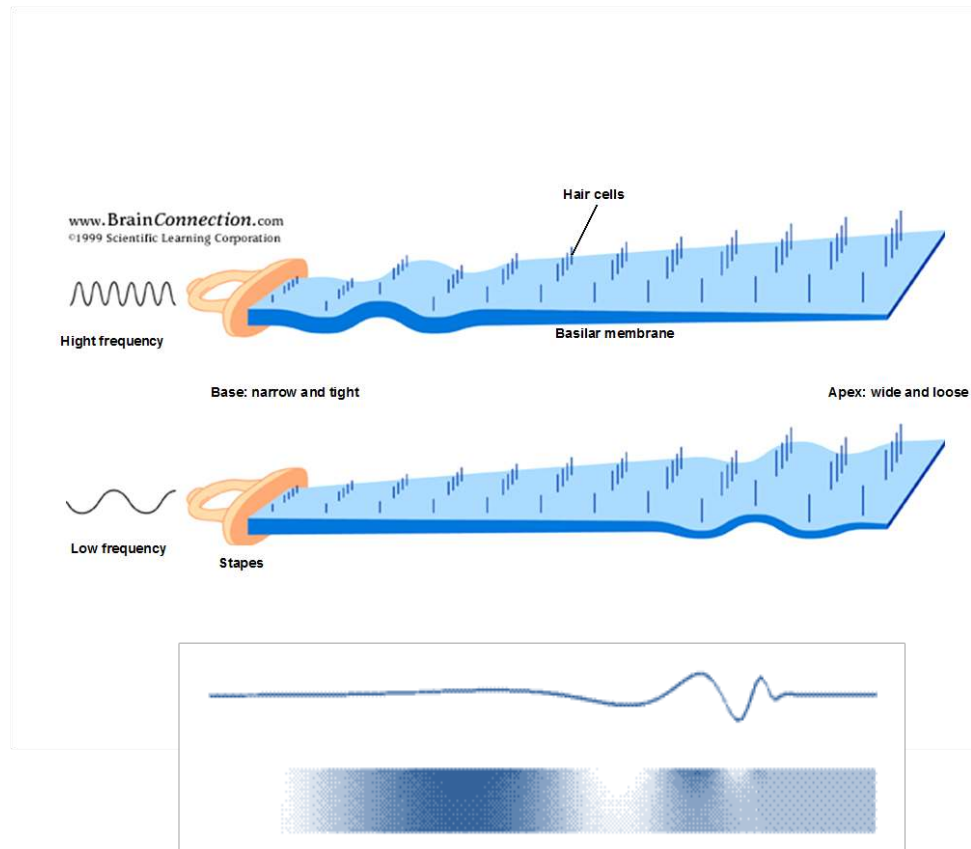
HAIR CELLS

POSSIBLE TRANSDUCTION IN HAIR CELLS



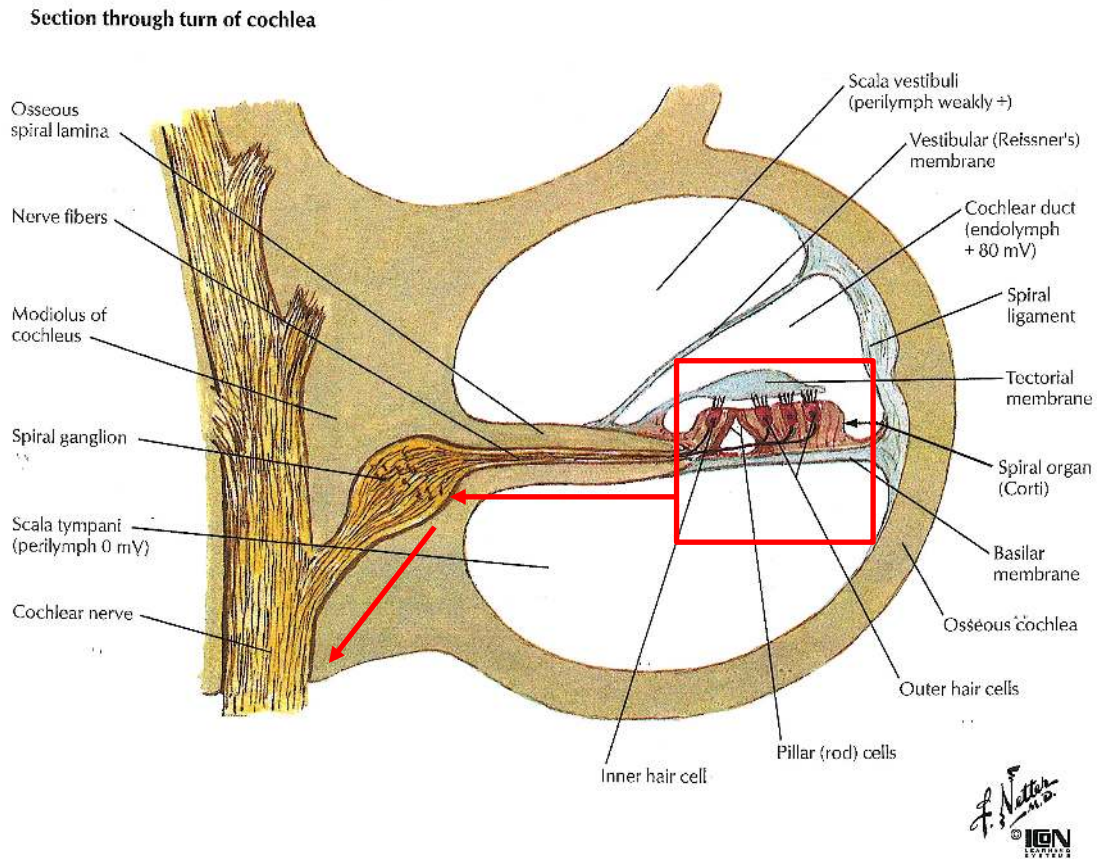
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VIBRATION OF THE BASILAR MEMBRANE, HAIR CELL ACTIVATION

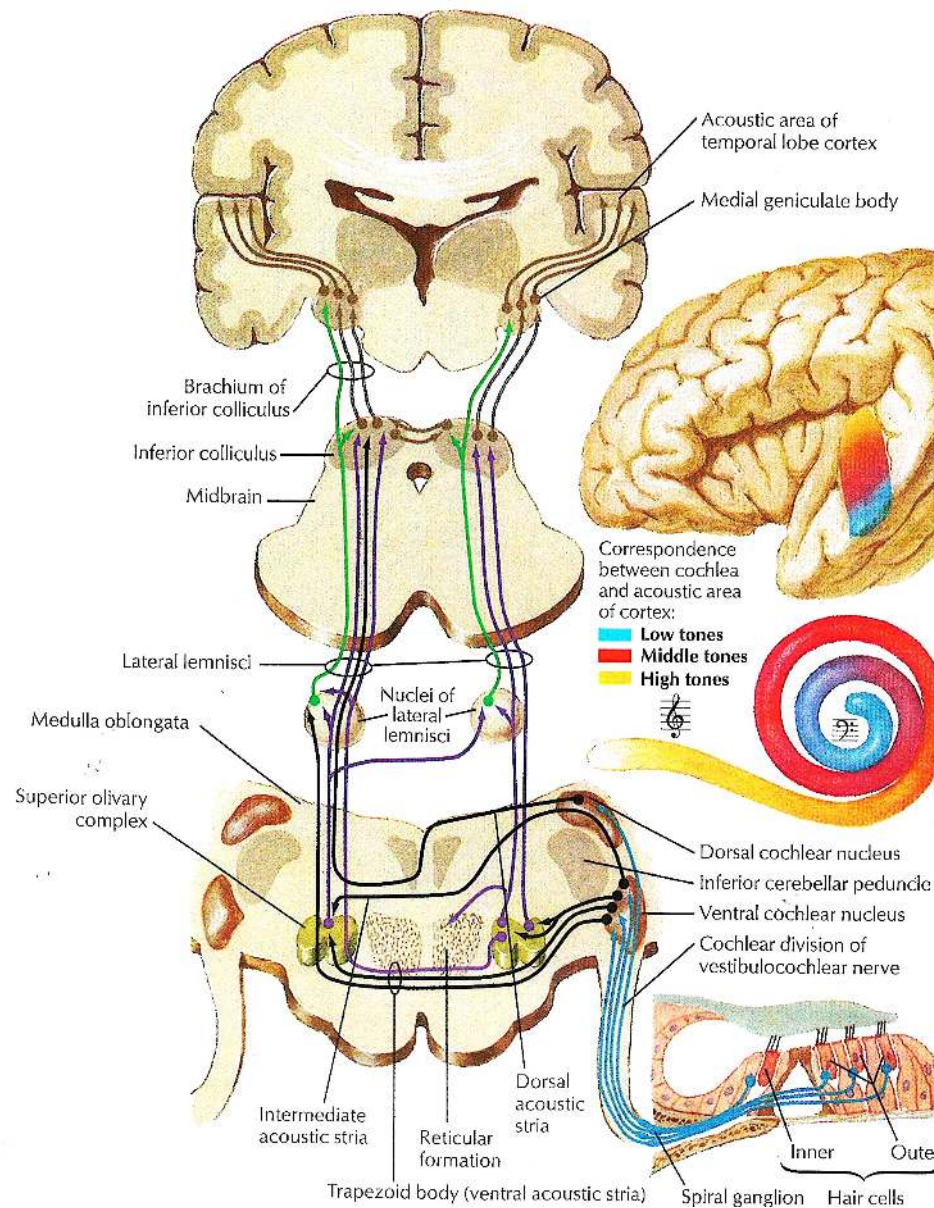


DEPENDING ON THE PITCH OF THE SOUND, A PARTICULAR REGION OF THE BASILAR MEMBRANE VIBRATES WITH A MAXIMAL INTENSITY. SIGNALS AT HIGH FREQUENCY GENERATE VIBRATIONS AT THE BASE OF THE MEMBRANE, WHILE SOUNDS AT LOW FREQUENCY INITIATE MOVEMENT AT THE WIDER AND LOOSER APICAL PART OF THE BASILAR MEMBRANE. THE EVOKED MOVEMENT RESULTS IN BENDING OF THE HAIRS OF SENSORY EPITHEL CELLS TOWARD THE STEREOCILUM WHICH, IN TURN, CAUSES DEPOLARIZATION AND INCREASES THE RELEASE OF TRANSMITTERS FROM HAIR CELLS. THIS EVENT ACTIVATES THE PERIPHERAL PROCESSES OF COCHLEAR GANGLION NEURONS

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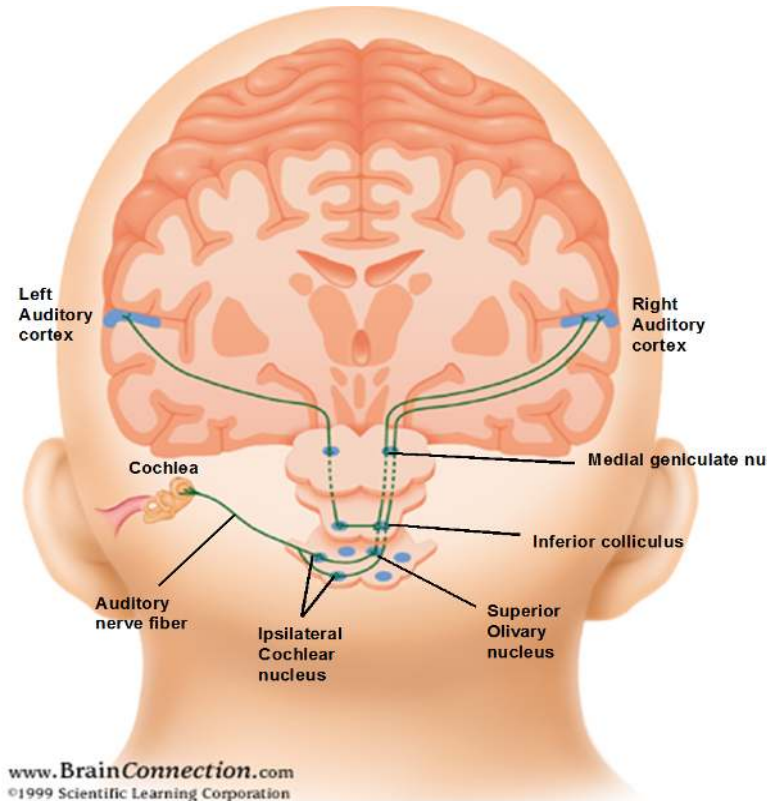
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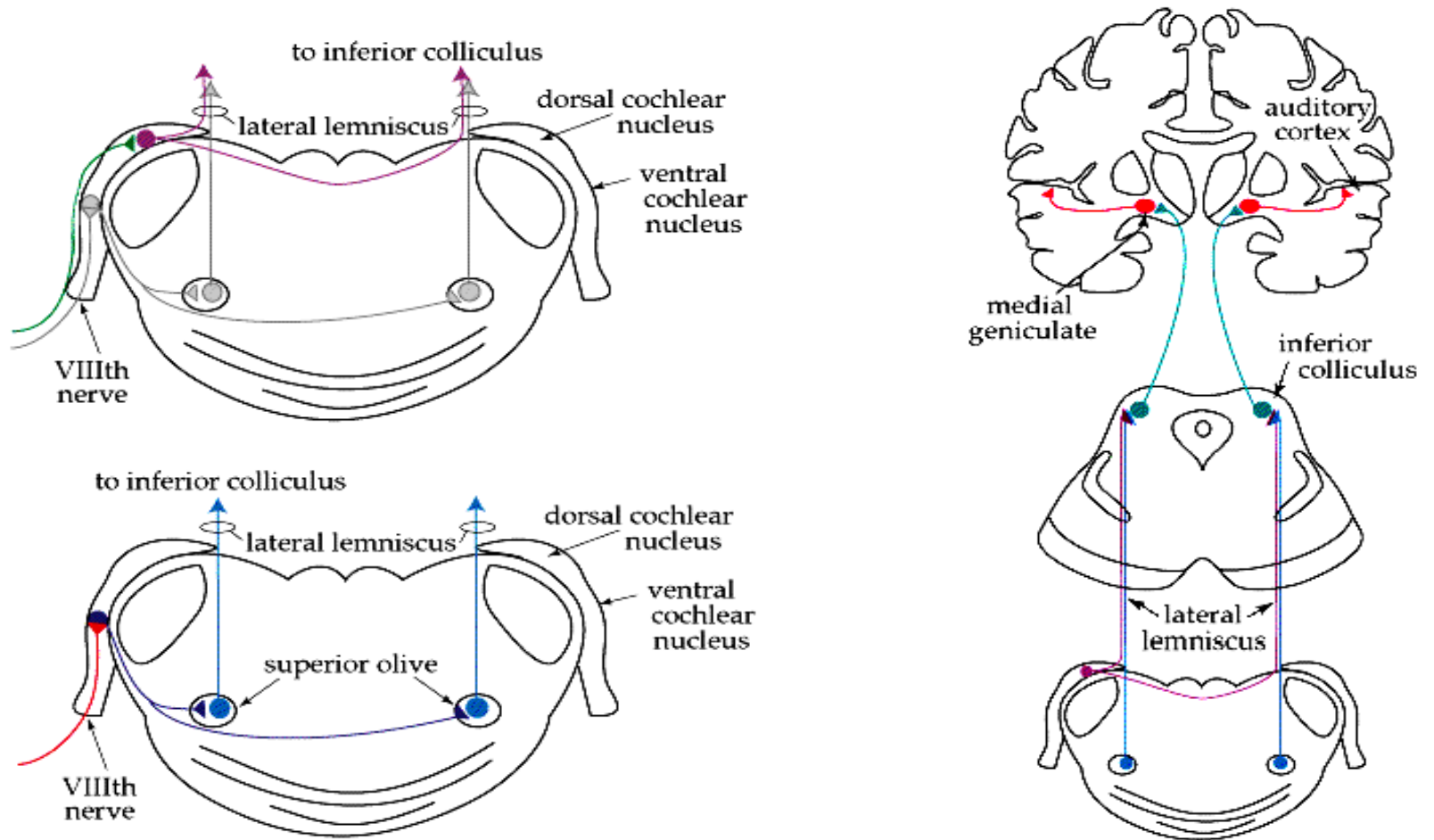
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THE AUDITORY PATHWAY

THE CENTRAL PROCESSES OF COCHLEAR GANGLION CELLS TERMINATE IN THE DORSAL AND VENTRAL COCHLEAR NUCLEI OF THE BRAIN STEM. THE COCHLEAR NUCLEI COMMUNICATE WITH THE SUPERIOR OLIVE FROM WHERE THE AUDITORY FIBERS ASCEND TO THE INFERIOR COLLICULUS FORMING THE LATERAL LEMNISCUS. THIS NUCLEUS RELAYS THE INFORMATION TO THE MEDIAL GENICULATE BODY OF THE THALAMUS. THE FINAL ACOUSTIC RADIATION REACHES THE PRIMARY AUDITORY FIELD (A1) OF THE SUPERIOR TEMPORAL GYRUS. THE AUDITORY CENTER HAS A TONOTOPIC ORGANIZATION, THE APEX OF THE COCHLEA PROJECTS TO THE ANTERIOR PART OF THE FIELD, HIGH FREQUENCY SOUNDS ARE REPRESENTED AT THE POSTERIOR POLE. BEHIND THIS REGION IS THE SENSORY SPEECH AREA OF WERNICKE

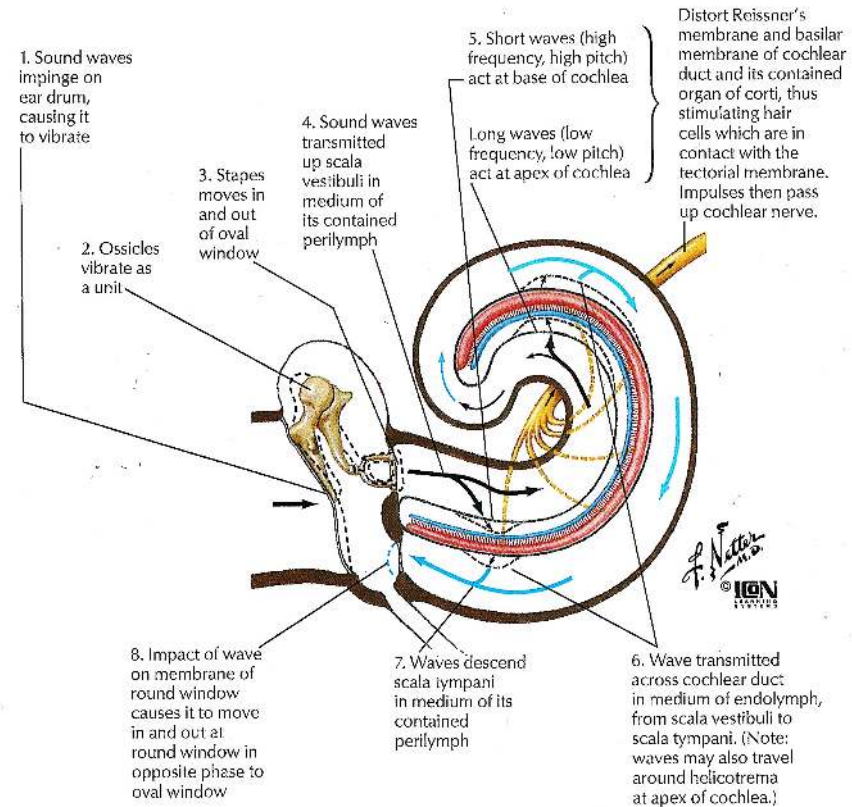


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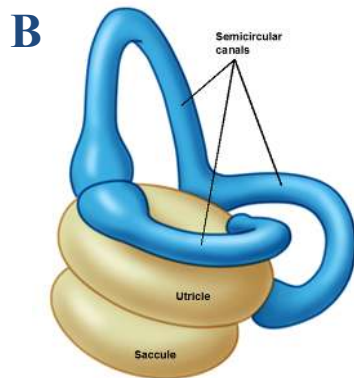
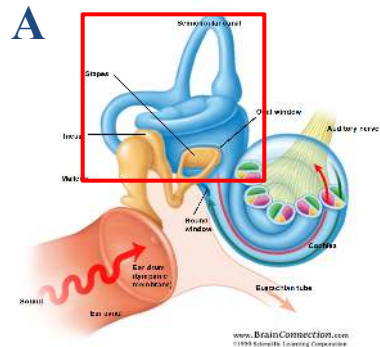
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SUMMARY



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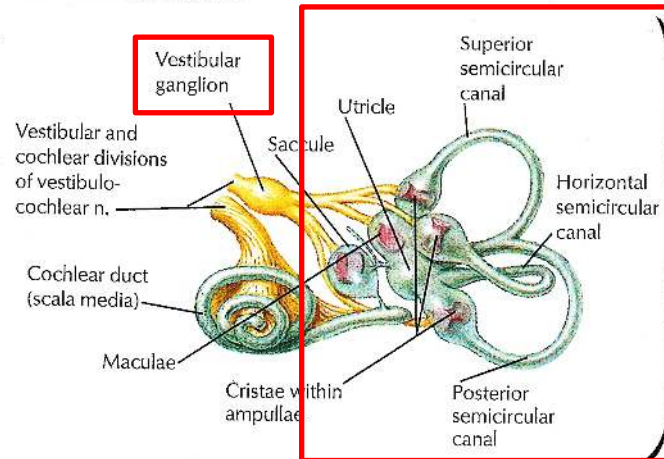
THE VESTIBULAR SYSTEM



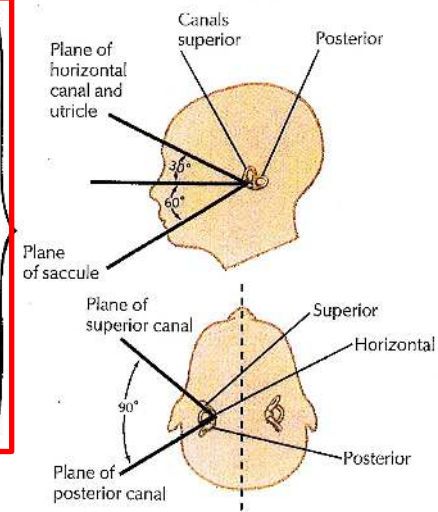
THE RECEPTOR STRUCTURES OF THE VESTIBULAR SYSTEM ARE LOCATED IN THE BONY VESTIBULE AND SEMICIRCULAR CANALS OF THE INNER EAR (A, ENFRAMED REGION). THE LINEAR ACCELERATION AND DECELERATION ARE SENSED BY RECEPTORS BUILT INTO THE ENDOLYMPH-FILLED SACCULE AND UTRICLE (B). THE ANGULAR ROTATION IS MONITORED BY HAIR CELLS OF THE CRISTA AMPULLARIS, A RECEPTOR STRUCTURE PRESENT IN EACH OF THE MEMBRANOUS SEMICIRCULAR CANALS. THE SPATIAL ARRANGEMENT OF THE SEMICIRCULAR CANALS ENABLES THE DETECTION OF ANGULAR ROTATION OF THE HEAD IN ALL DIRECTIONS. THE HAIR CELLS OF THE UTRICLE AND SACCULE POSSESS HAIRS EMBEDDED IN THE OTOLITH MEMBRANE. THE CALCIUM CONCRETIONS GIVE THE OTOLITH MEMBRANE A HIGHER SPECIFIC GRAVITY THAN THE ENDOLYMPH AND BY BENDING THE HAIRS IT CAN STIMULATE THE HAIR CELLS. IN THE SEMICIRCULAR CANALS, THE MOVEMENT OF ENDOLYMPH TRIGGERS THE HAIR CELLS AND CHANGES THEIR ACTIVITY DEPENDING ON THE DIRECTION OF THE FLOW. THE ALTERED RECEPTOR STATUS IS REPORTED BY THE VESTIBULAR NERVE

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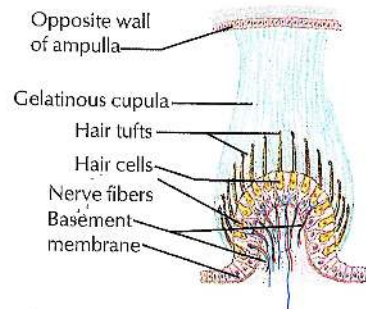
A. Membranous labyrinth



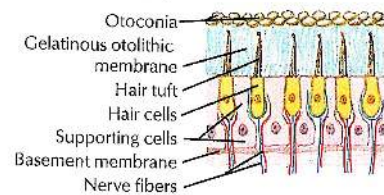
B. Position within base of skull



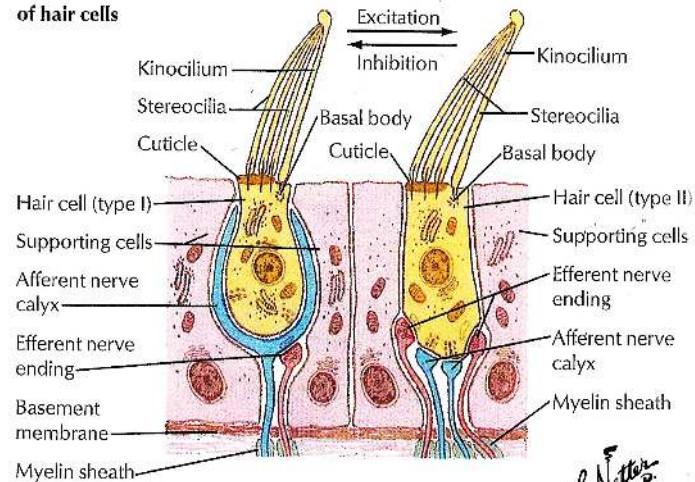
C. Section of crista



D. Section of macula



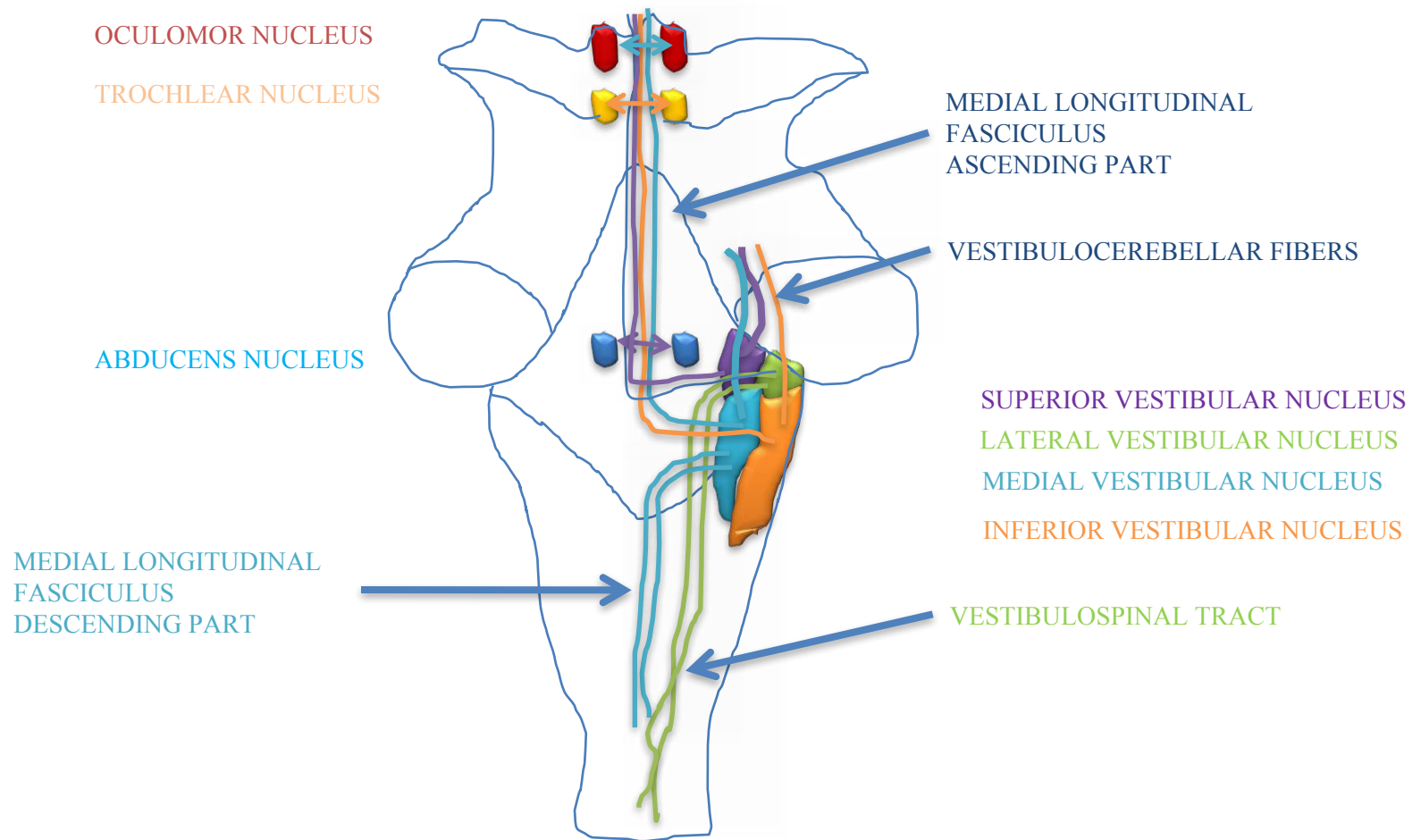
E. Structure and innervation of hair cells



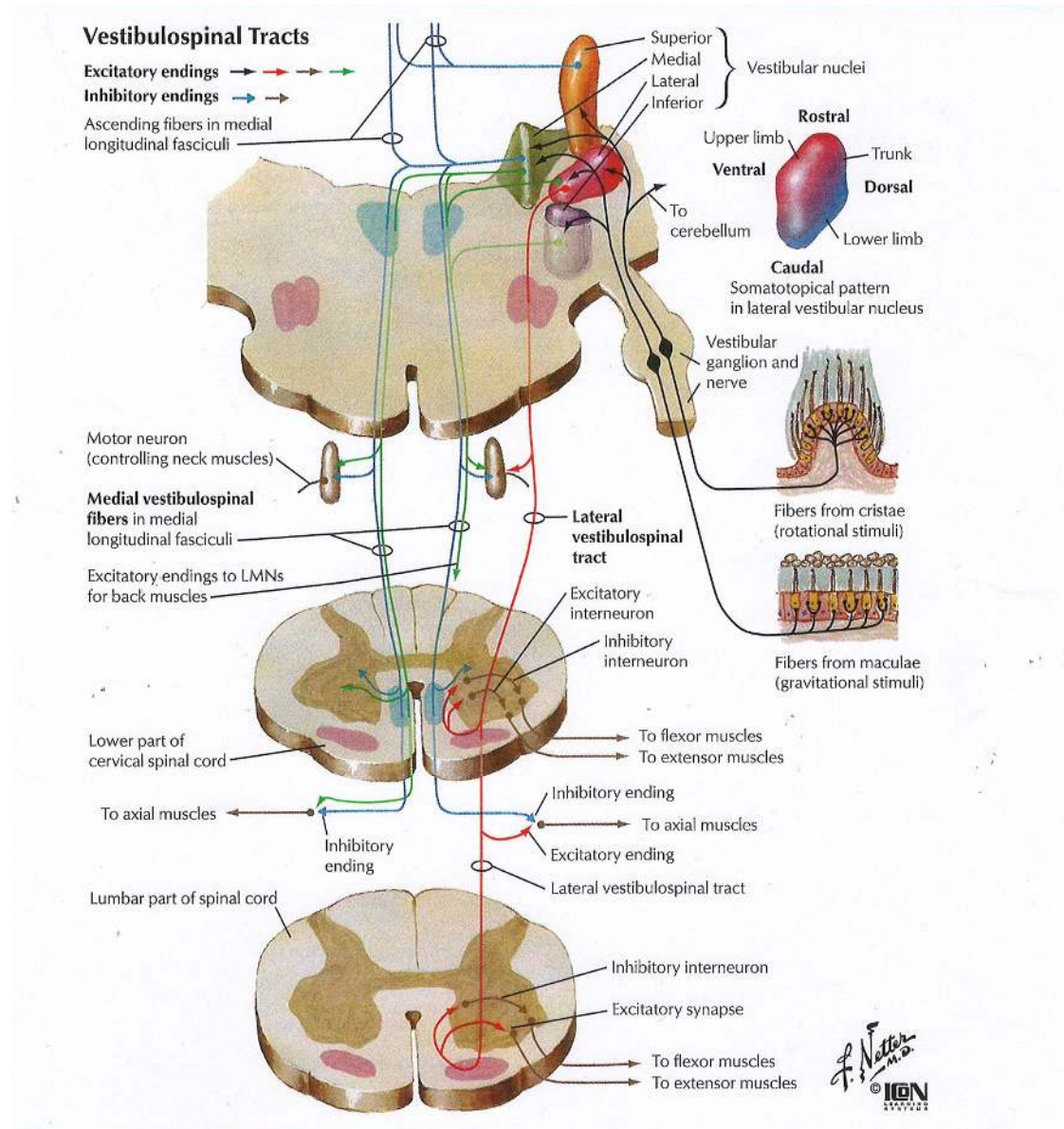
F. Netter M.D.
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ILLUSTRATIONS

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THE VESTIBULAR PATHWAYS

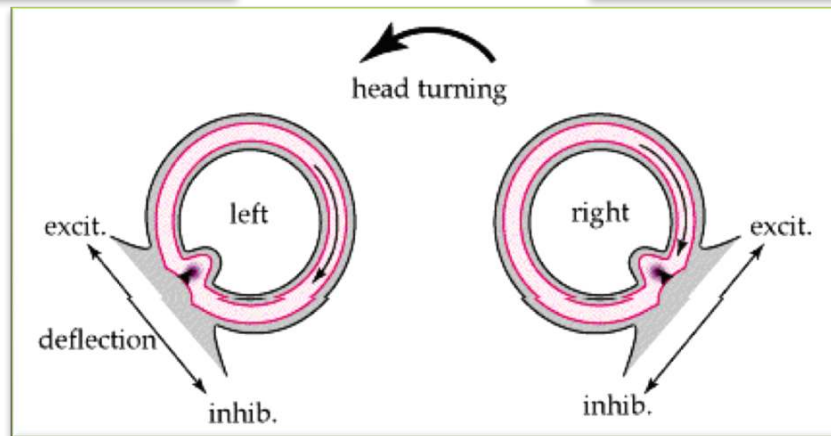
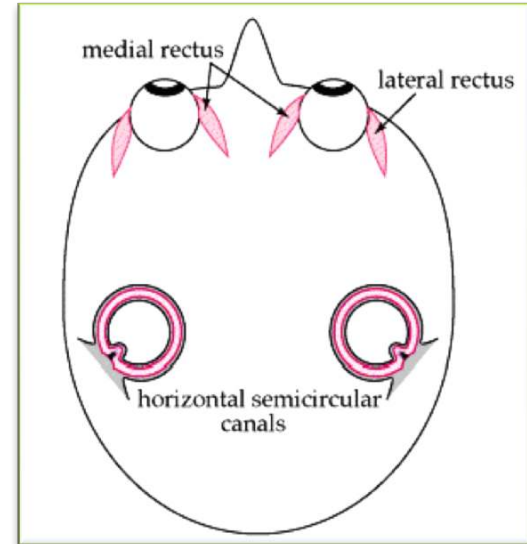
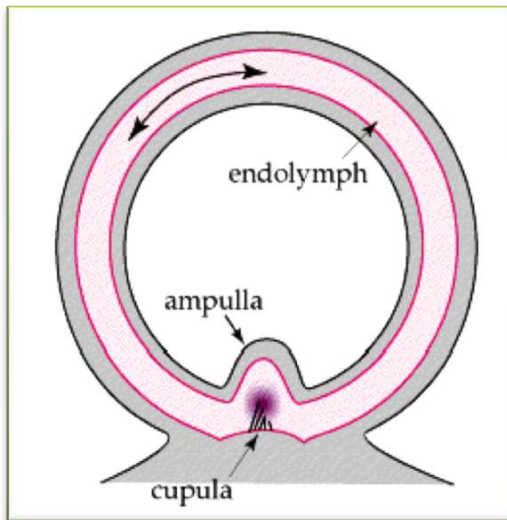


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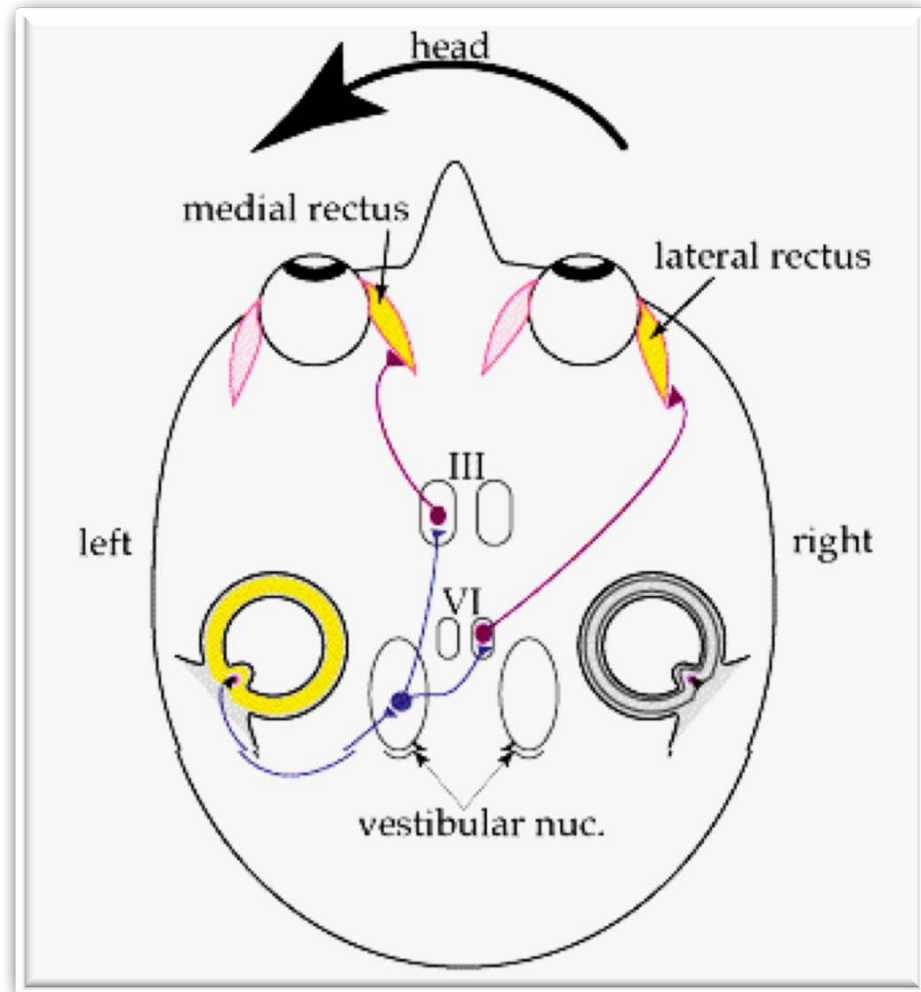
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Vestibulo-ocular reflex Vestibulo-ocular reflex



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Vestibulo-ocular reflex



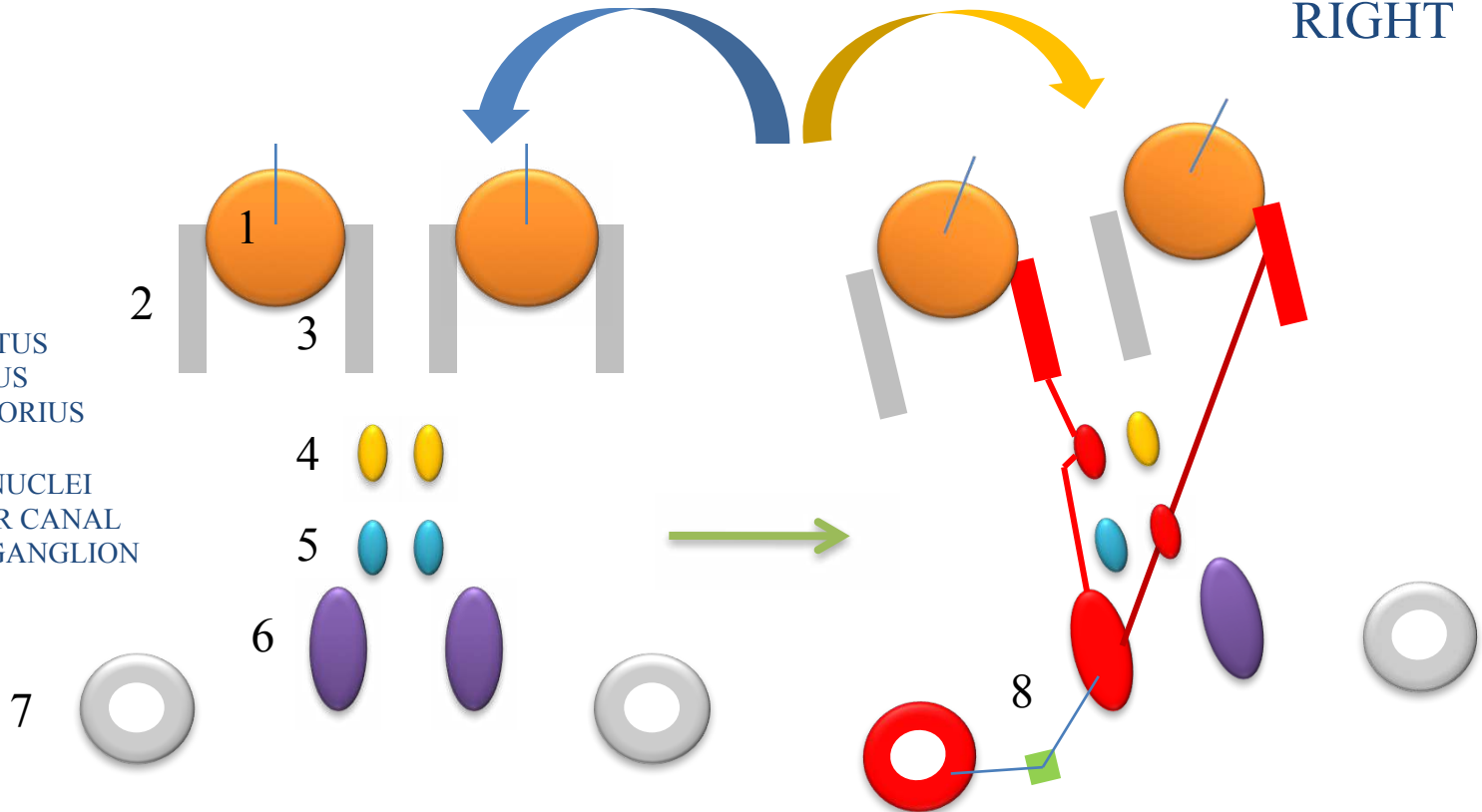
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THE VESTIBULO-OCULAR REFLEX

LEFT

RIGHT

1. EYE BALL
2. LATERAL RECTUS
3. MEDIAL RECTUS
4. N. OCULOMOTORIUS
5. N. ABDUCENS
6. VESTIBULAR NUCLEI
7. SEMICIRCULAR CANAL
8. VESTIBULAR GANGLION



MOVING THE HEAD TO THE LEFT SIDE IN THE HORIZONTAL PLANE EVOKES THE CONJUGATED MOVEMENT OF THE EYE BALLS TOWARD THE RIGHT SIDE