
# PHYSIOLOGY

FACULTY OF PHARMACEUTICAL SCIENCES
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LECTURE 8, PART (1): CONTINUE SENSES (HEARING)

# Objectives

1. Discuss **the nature of sound waves**.
2. Discuss **The auditory function.**
3. Describe **The equilibrium pathway.**

**(Pages 595-607 of the reference).**

# HEARING AND EQUILIBRIUM VIII

- **Hearing** is the ability to perceive sounds.
- The ear has sensory receptors as well as receptors for equilibrium.
- **The ear is divided into three main regions:**

(1) The external ear, which collects sound waves and channels them inward.

(2) The middle ear which conveys sound vibrations to the oval window (to make the sound louder).

(3) The internal ear, which houses the receptors for hearing and equilibrium.

# THE NATURE OF SOUND WAVES

- **Input** occurs in the form of **sound waves.**
- Sound waves (originate from a vibrating object) are alternating high- and low-pressure regions traveling in the same direction through some medium (such as air).
- The larger the intensity (size or amplitude) of the vibration, the louder is the sound. **Sound intensity is measured in units called decibels (dB).**
- An **increase of one decibel** represents a **tenfold increase in sound intensity.**
- The **hearing threshold**—the point at which an **average young adult can just distinguish sound from silence**—is defined as 0 dB at 1000 Hz.

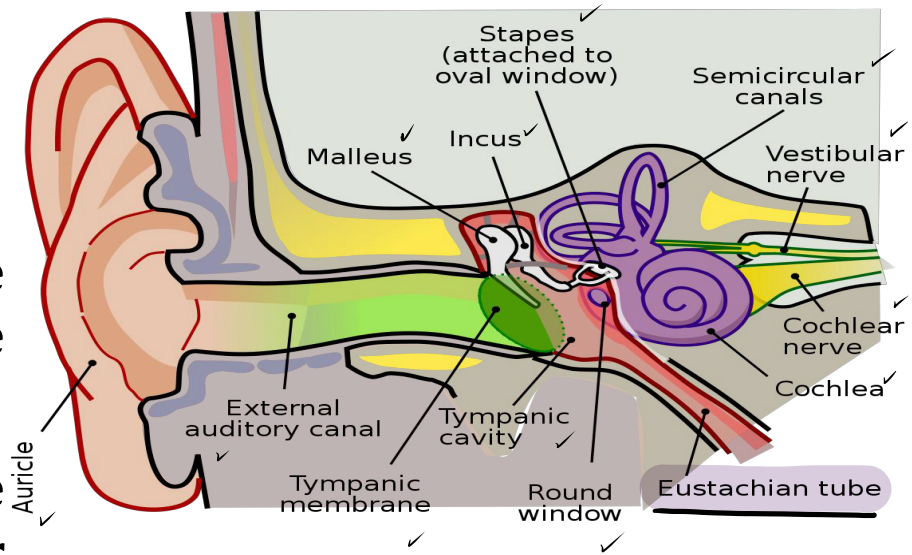
# THE AUDITORY FUNCTION

- **External or outer ear, consisting of:**

**1- Auricle. This is the outside part of the ear.**

**2- External auditory canal or tube. This is the tube that connects the outer ear to the inside or middle ear.**

**3- Tympanic membrane (eardrum). The tympanic membrane divides the external ear from the middle ear.**

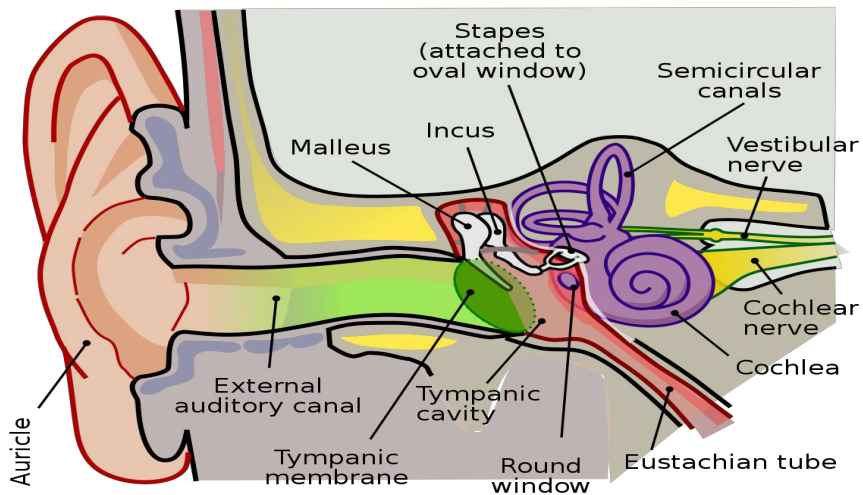


# THE AUDITORY FUNCTION

- **Middle ear (tympanic cavity) , consisting of:**

1- **Ossicles.** Three small bones that are connected and transmit the sound waves to the inner ear. The bones are called: Malleus, Incus and Stapes.

2- **Eustachian tube**. A canal that links the middle ear with the back of the nose. The eustachian tube helps to equalize the pressure in the middle ear. Equalized pressure is needed for the proper transfer of sound waves. The eustachian tube is lined with mucous, just like the inside of the nose and throat.



# THE AUDITORY FUNCTION

❖ **Inner ear , consisting of:**

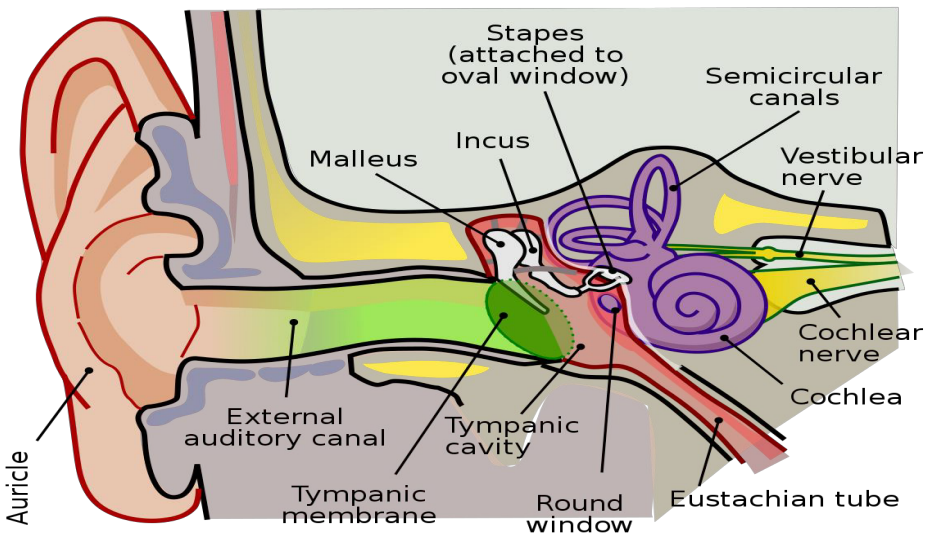
1- **Oval window of cochlear canal.**

2- **Endolymph fluid in the canal. Cochlea. This contains the nerves for hearing.**

3- **Hair cells "auditory receptors".**

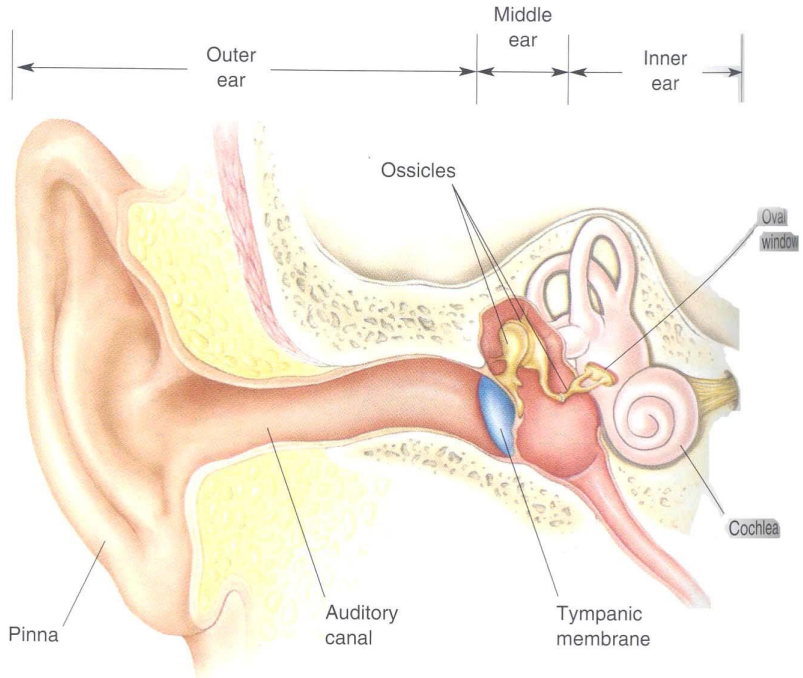
4- **Vestibule. This contains receptors for balance.**

5- **Semicircular canals. This contains receptors for balance.**



# THE AUDITORY FUNCTION

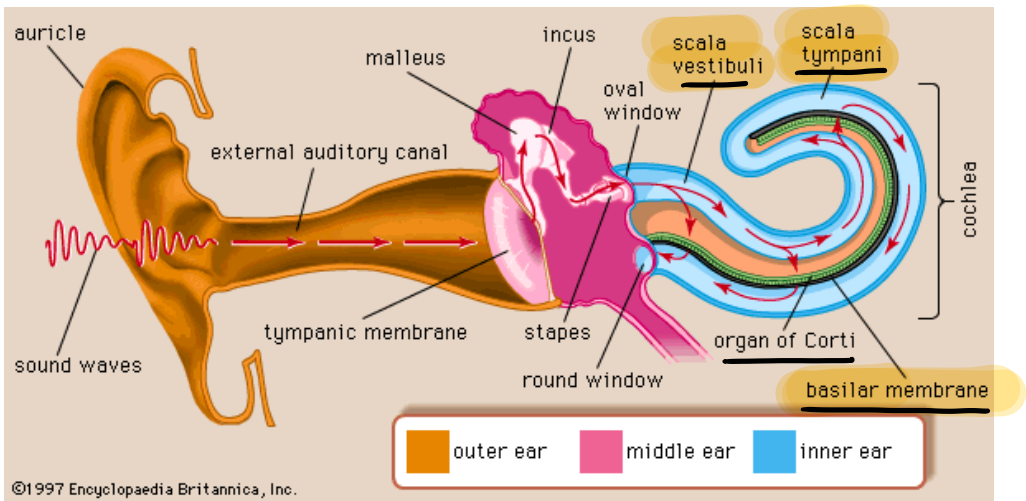
**The outer ear and canal** guide and filter sound. **The tympanic membrane and ossicles** transmit the vibrations to the cochlea itself; the vibrations enter the **cochlea** via the round window and exit via the round window. As they pass through the **endolymph of the scala vestibuli and tympani**, sound waves cause the **basilar membrane to vibrate**. This is the key to auditory function.



# PHYSIOLOGY OF HEARING

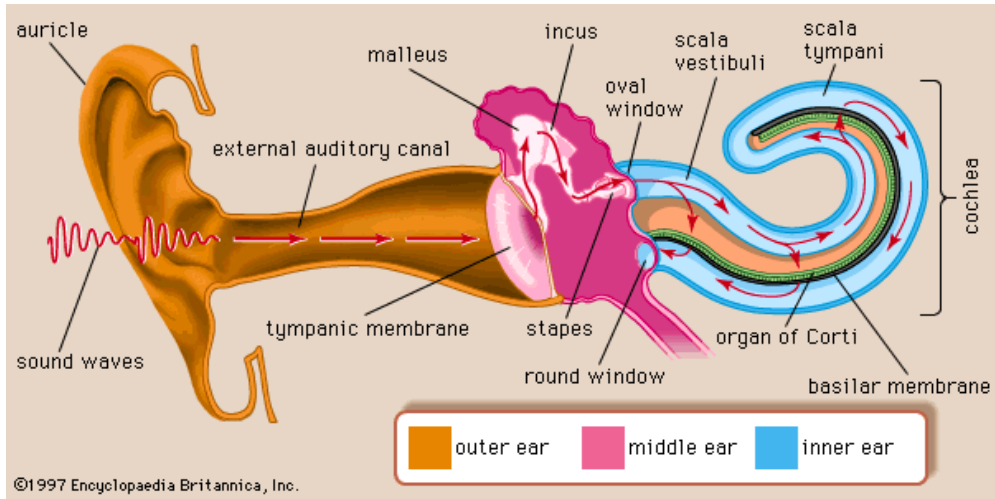
- **The following events are involved in hearing:**

1. The **auricle** directs sound waves into the **external auditory canal**.
2. When **sound waves** strike the **tympanic membrane**, the alternating waves of high and low pressure in the air **cause the tympanic membrane to vibrate back and forth**.



# PHYSIOLOGY OF HEARING

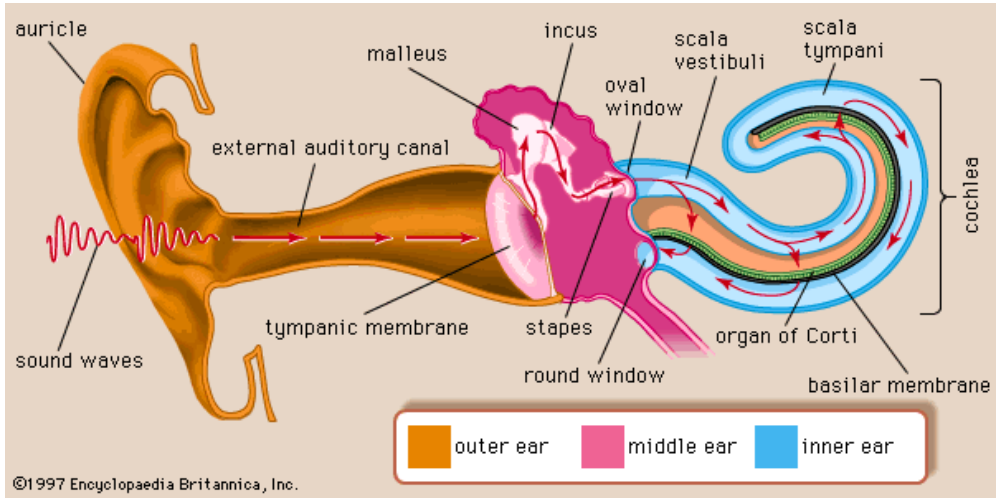
3. The **central area of the tympanic membrane** connects to the **malleus**, which vibrates along with the tympanic membrane. This **vibration is transmitted from the malleus to the incus and then to the stapes**.



# PHYSIOLOGY OF HEARING

4. As the stapes (oval-shaped footplate (**oval window**)) moves back and forth, the vibrations at the **oval window** **are about 20 times more vigorous than those of the tympanic membrane** (efficiently transmit small vibrations spread over a large surface area (the tympanic membrane) into larger vibrations at a smaller surface (the oval window)) .

أنشط



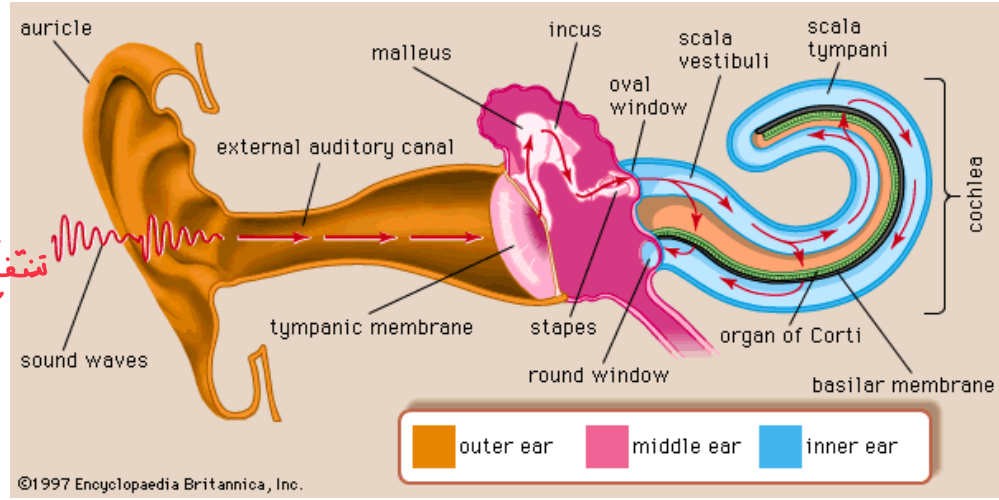

بكفاءة

نقل الاهتزازات الصغيرة المنتشرة على مساحة سطحية كبيرة ( الغشاء الطبلي) إلى أكبر الاهتزازات على سطح أصغر ((نافذة بيضاوية)) .

# PHYSIOLOGY OF HEARING

5. The **movement of the stapes** at the oval window sets up **fluid pressure** waves in the perilymph of the cochlea. As the **oval window bulges inward**, it **pushes on the perilymph of the scala vestibuli**.

تنتفخ

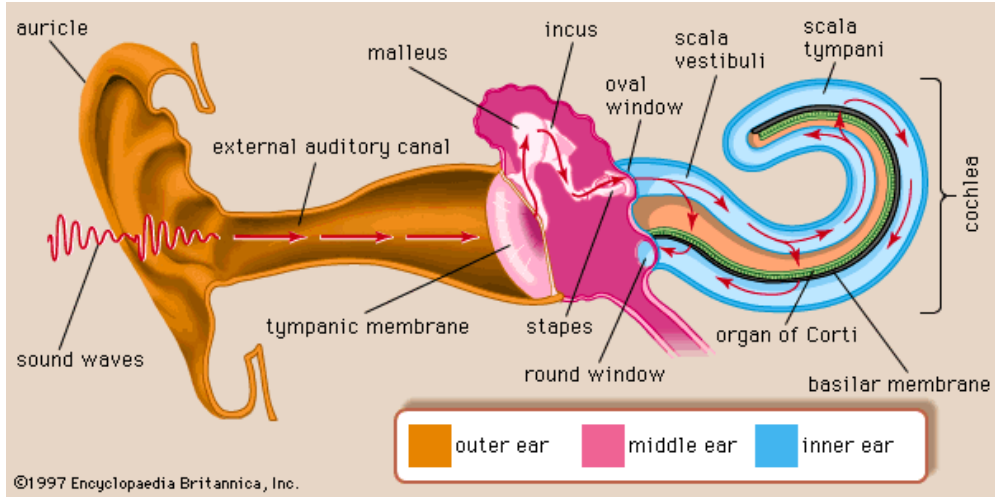


# PHYSIOLOGY OF HEARING

ينقل

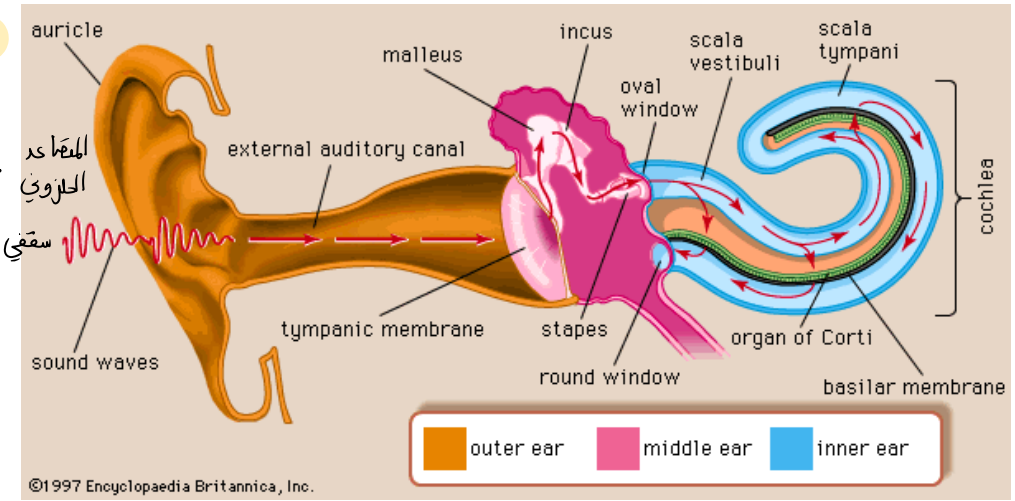
6. **Pressure waves** are transmitted from the scala vestibuli to the scala tympani and eventually to the round window, causing it to bulge outward into the middle ear.

7. The pressure waves travel through the perilymph of the scala vestibuli, then the vestibular membrane, and then move into the endolymph inside the cochlear duct.



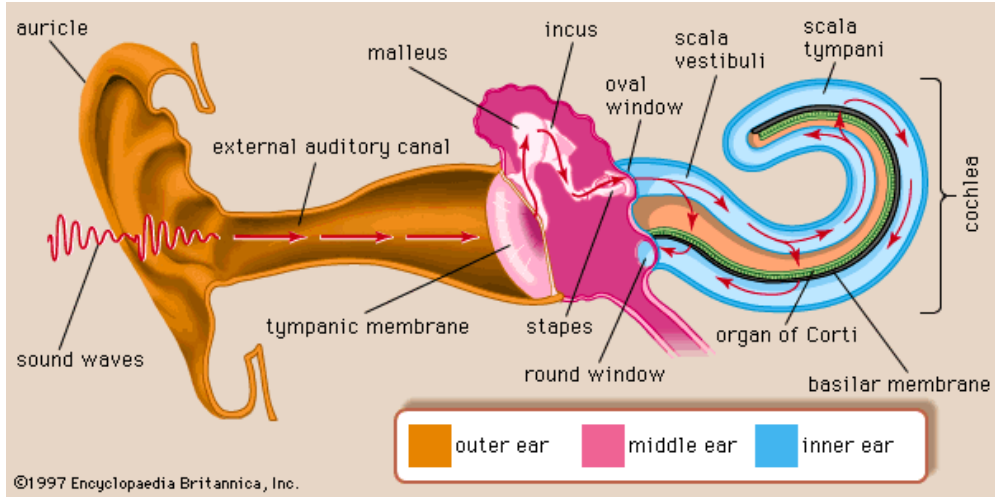
# PHYSIOLOGY OF HEARING

8. The **pressure waves** in the endolymph cause the basilar membrane to vibrate, which moves the hair cells of the spiral organ against the tectorial membrane. This leads to bending of the stereocilia and ultimately to the generation of nerve impulses in first-order neurons in cochlear nerve fibers.



# PHYSIOLOGY OF HEARING

9. **Sound waves** of various frequencies cause **certain regions of the basilar membrane** to **vibrate more intensely than other regions**.



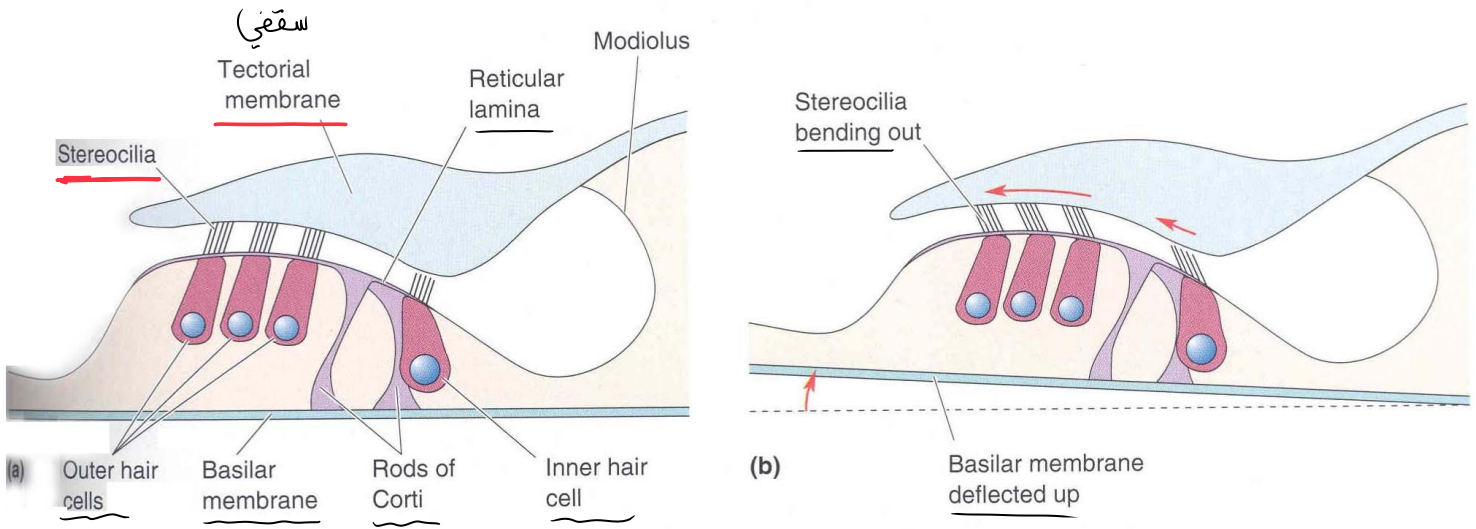
# THE AUDITORY PATHWAY

receptors

- Hair cells **transduce vibrations into depolarization**. This in turn leads to **vesicular release that excites auditory afferent fibers and causes them to discharge.**

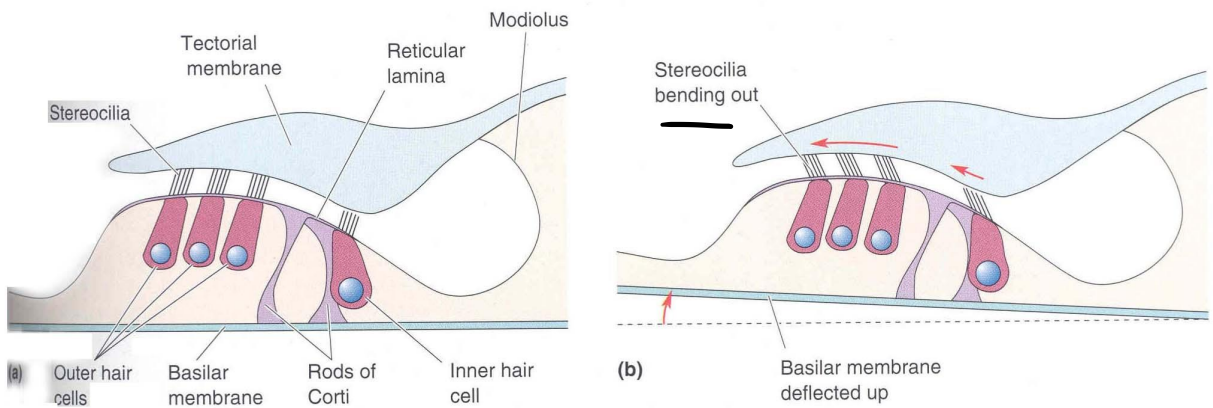
sensory

حوسلي



# THE AUDITORY PATHWAY

- **Hair cells are firmly attached to the basilar membrane** and therefore **move up and down with it as it vibrates**. **The "hairs" or cilia of these cells are attached to a tectorial membrane; this membrane is fixed- it does not vibrate in response to sound.** So, as you can imagine, when the basilar membrane moves upward, the cilia will be bent. **This is the first step in the transduction process.**

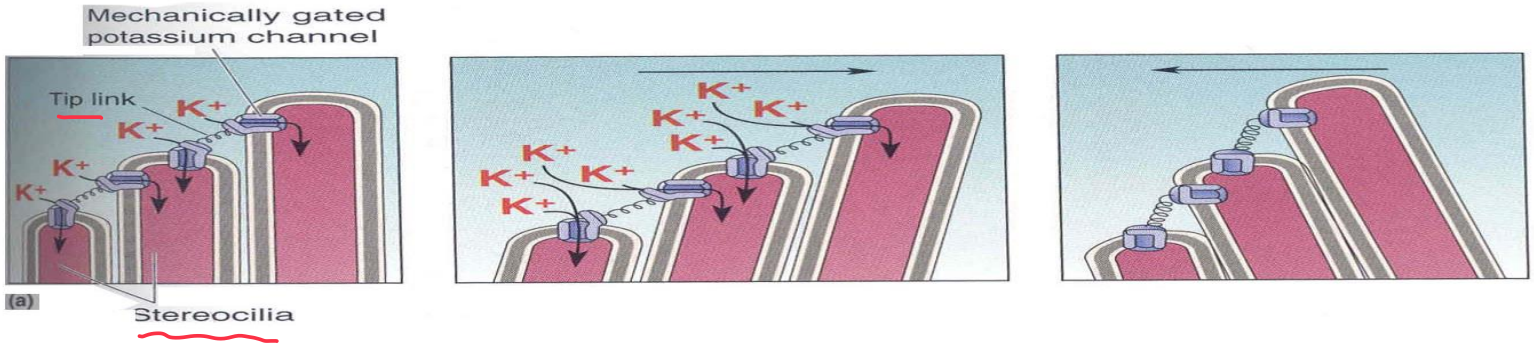


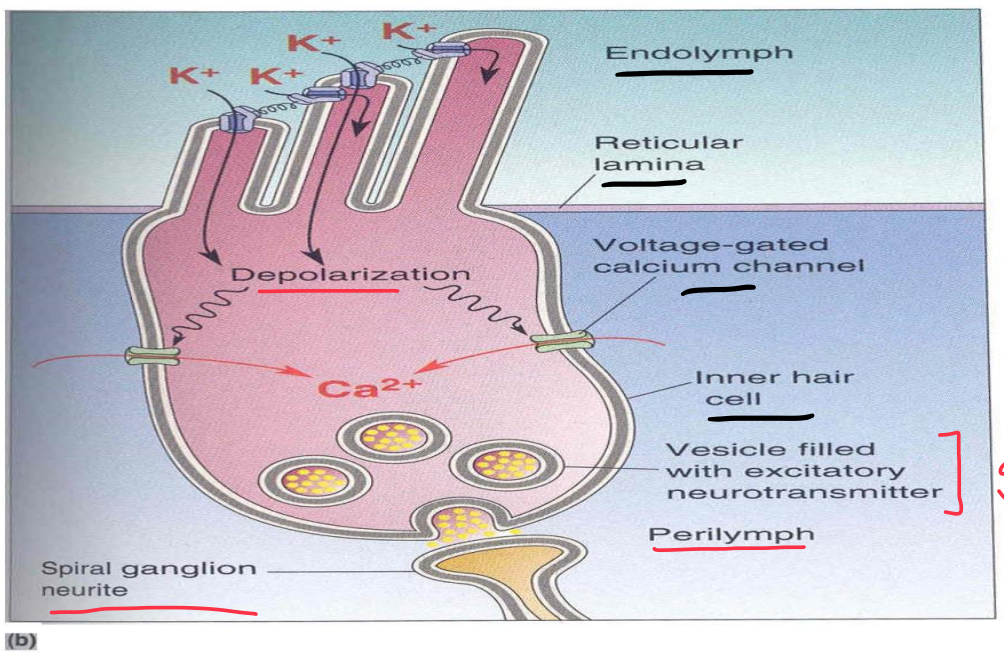
# THE AUDITORY PATHWAY

- **When the cilia bend in one direction it causes the hair cell to hyperpolarize; bending in the opposite direction causes depolarization.**

- This effect is due to the **mechanical coupling of the cilia to K+ channels at their tips**. The depolarization ($K^+$ enter the hair cell cytosol and produce a **depolarizing receptor potential**) causes **$Ca^{2+}$ entry** and the fusion of vesicles and **release of glutamate from hair cells.** This cause **excitation and spiking of the auditory afferent fibers**.

sensory


Mechanically gated potassium channel
Tip link
K+
Stereocilia
(a)


K+
Endolymph
Reticular lamina
Depolarization
Voltage-gated calcium channel
Ca2+
Inner hair cell
Vesicle filled with excitatory neurotransmitter
Perilymph
Spiral ganglion neurite
(b)

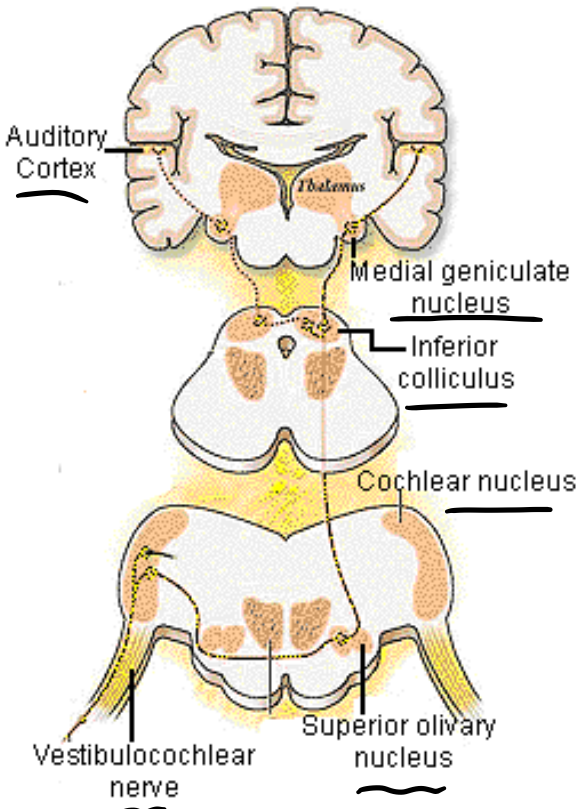
glutamate

# THE AUDITORY PATHWAY

From **hair cells of the cochlea**, **auditory information** is conveyed along the **cochlear branch of the vestibulocochlear (VIII) nerve** and then to **the brain stem (cochlear nucleus is in the medulla oblongata)**, **thalamus**, and **cerebral cortex (primary auditory area).**

- Note that this pathway is **bilateral** unlike the contralateral (body sensations) somatosensory pathway. This makes sense since sound always reaches both ears.

ثنائي الجانب



# PHYSIOLOGY OF EQUILIBRIUM

- **There are two types of equilibrium or balance:**

اتزان ثابت

- **Static equilibrium** refers to the maintenance of the position of the body (mainly the head) relative to the force of gravity.

اتزان ديناميكي

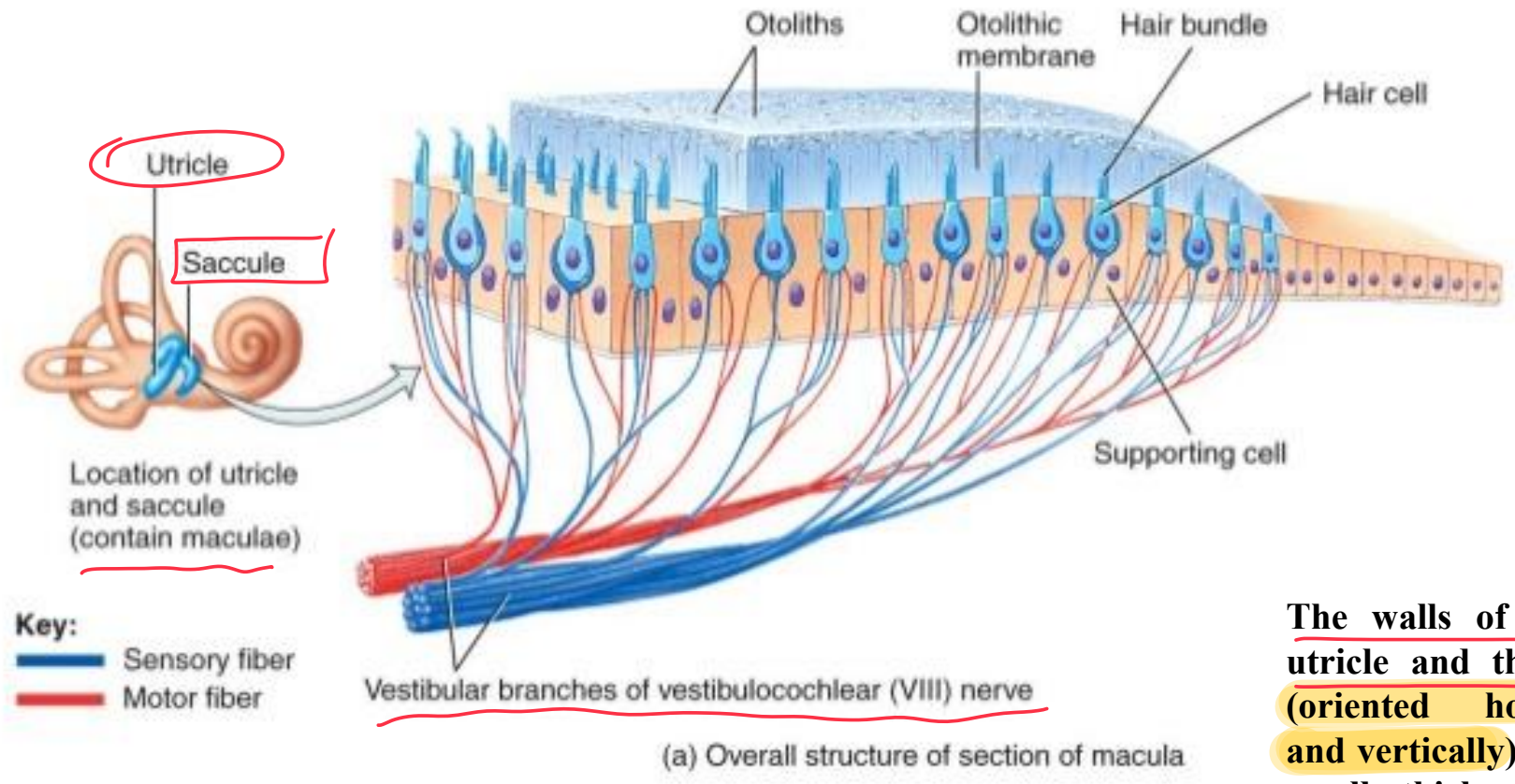
- **Dynamic equilibrium** is the maintenance of body position (mainly the head) in response to sudden movements such as rotational acceleration or deacceleration.

تسارع دوراني

تباطؤ

- **The receptor organs for equilibrium** are called the vestibular apparatus; these include the saccule, utricle, and semicircular ducts (oriented in three different dimensions ,containing endolymph fluid, which its moving leads to bend the hairs and thus produce AP and send it to the brain).

# Hearing and Equilibrium




**The walls of both the utricle and the saccule (oriented horizontally and vertically) contain a small, thickened region called a macula.**

البقعة

# PHYSIOLOGY OF EQUILIBRIUM

- **The two maculae (plural), which are perpendicular to one another, are the receptors for static equilibrium.**

متعامد

- The **maculae** consist of two kinds of cells: **hair cells (containing stereocilia)** , which are the sensory receptors, and **supporting cells.**

1

2

- afferent -

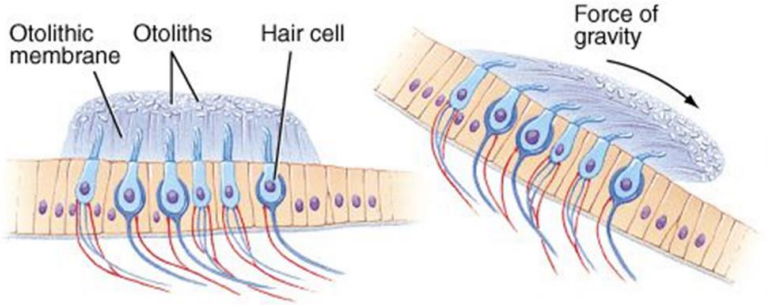
- The **movement of stereocilia** (bending in one direction) initiates **depolarizing receptor potentials**. However, bending in the opposite direction closes the transduction channels and produces **hyperpolarization**.

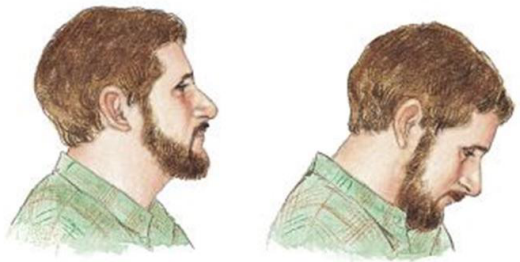
# PHYSIOLOGY OF EQUILIBRIUM

- The **three semicircular ducts (containing a group of hair cells and supporting cells)** function in **dynamic equilibrium**.

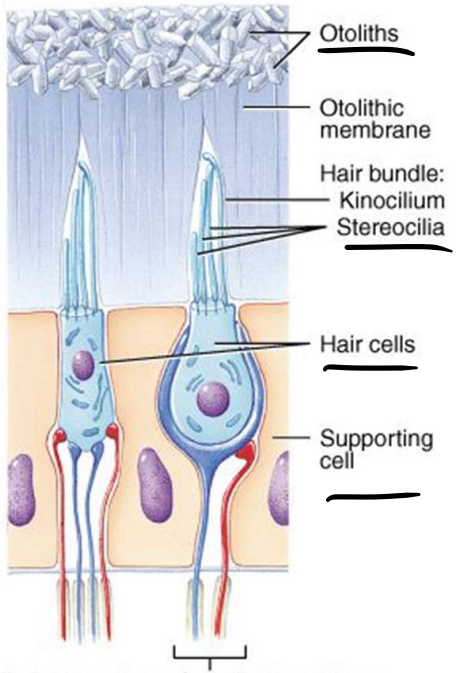
- **When you move your head**, the attached **semicircular ducts and hair cells move with it**. As the **moving hair cells** drag along the stationary endolymph, **the hair bundles bend.** Bending of the hair bundles produces **receptor potentials**. In turn, the receptor potentials lead to **nerve impulses that pass along the vestibular branch of the vestibulocochlear (VIII) nerve**.

# How the macula functions in relation to gravity



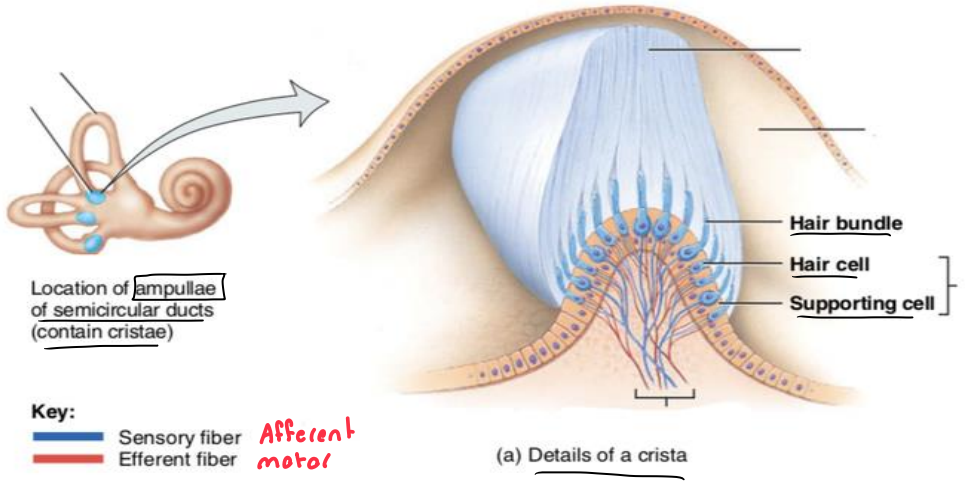

(c) Position of macula with head upright (left) and tilted forward (right)




(b) Details of two hair cells

**FIGURE 17.26 Location and structure of the semicircular ducts of the right ear.** Both first-order sensory neurons (blue) and efferent neurons (red) synapse with the hair cells. The ampullary nerves are branches of the vestibular division of the vestibulocochlear (VIII) nerve.

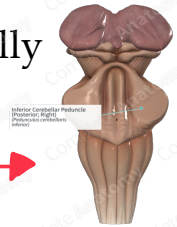
The of each semicircular duct contains a crista that is covered by a



# THE EQUILIBRIUM PATHWAY

- From **hair cells of the semicircular ducts, utricle, and saccule**, **vestibular information is conveyed along the vestibular branch of the vestibulocochlear (VIII) nerve** and **then to the brain stem, cerebellum, thalamus, and cerebral cortex**.

1. **Bending of hair bundles of the hair cells in the semicircular ducts, utricle, or saccule** causes the **release of a neurotransmitter (probably glutamate)**, which generates **nerve impulses** in the sensory neurons that innervate the hair cells.
2. The **cell bodies of sensory neurons are located in the vestibular ganglia**. **Nerve impulses** pass along the axons of these neurons, which **form the vestibular branch of the vestibulocochlear (VIII) nerve**.
3. Most of **these axons synapse with sensory neurons in vestibular nuclei**, the major integrating centers for equilibrium, in the medulla oblongata and pons.
4. **The vestibular nuclei also receive input from the eyes and proprioceptors**, especially proprioceptors in the neck and limb muscles that indicate the position of the head and limbs.
5. The **remaining axons enter the cerebellum** through the inferior cerebellar peduncles.



# Vestibular pathways