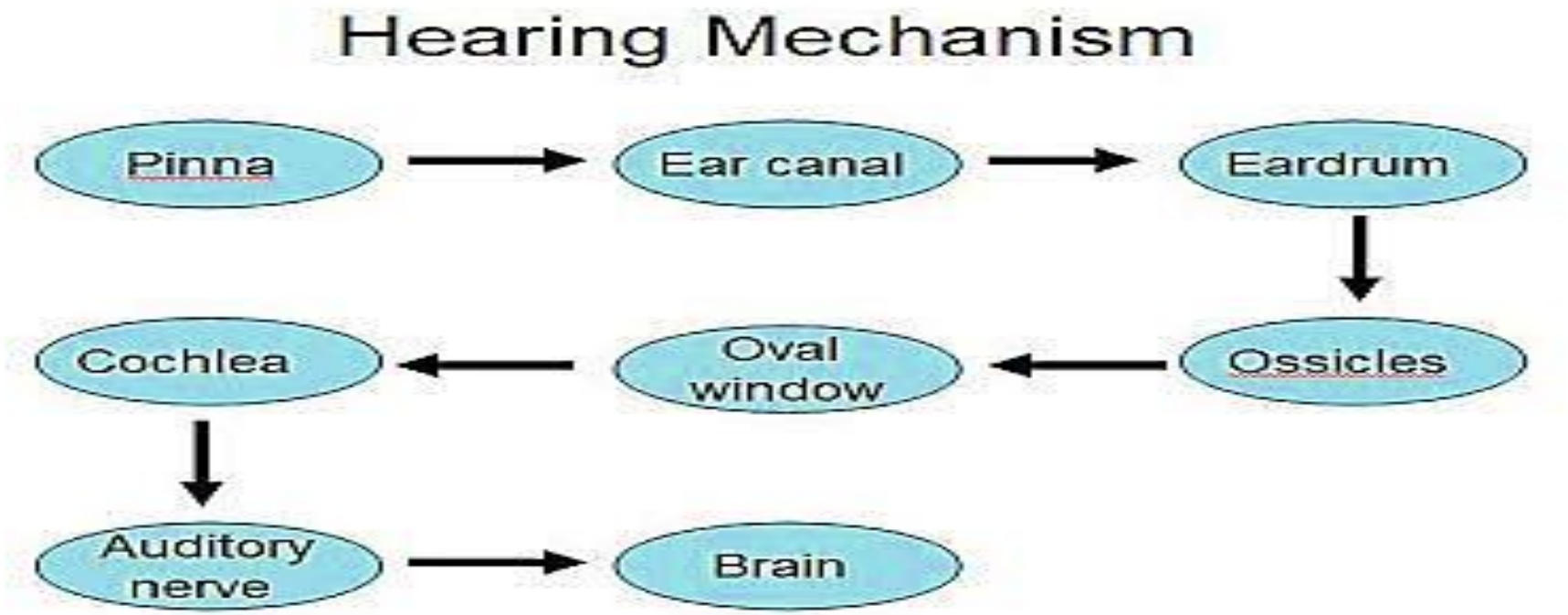
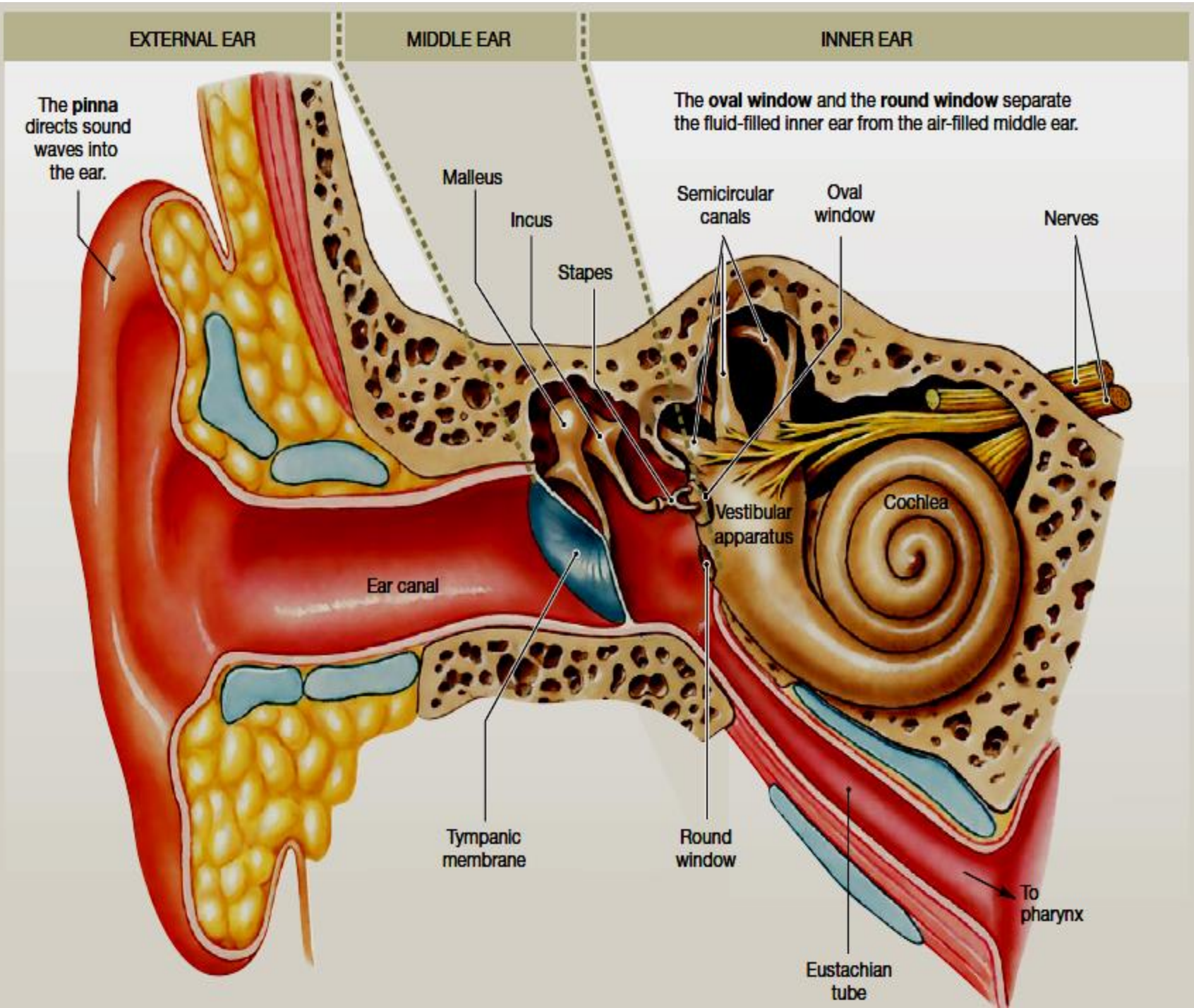
PHYSIOLOGY OF

Hearing



Prof. Khaled Abdel-Sater, MD


EXTERNAL EAR
MIDDLE EAR
INNER EAR
The pinna directs sound waves into the ear.
The oval window and the round window separate the fluid-filled inner ear from the air-filled middle ear.
Malleus
Incus
Stapes
Semicircular canals
Oval window
Nerves
Vestibular apparatus
Cochlea
Ear canal
Tympanic membrane
Round window
To pharynx
Eustachian tube

I-The External (Outer) Ear

A- The Auricle (= Ear Pinna):

-Functions: Collection and conduction of sound and acts as a funnel.

B- The External Auditory Canal

-Functions: 1- It acts as a resonator.

2-It conducts sound to the ear drum.

3- It protects the ear drum. *Because*:

a. Its wax: for lubrication and antiseptic.

b. Its hair: prevents entrance of large particles

c. its temperature is nearly constant 37° C and cannot be exposed to dryness.

C-The Tympanic Membrane (= Ear Drum):

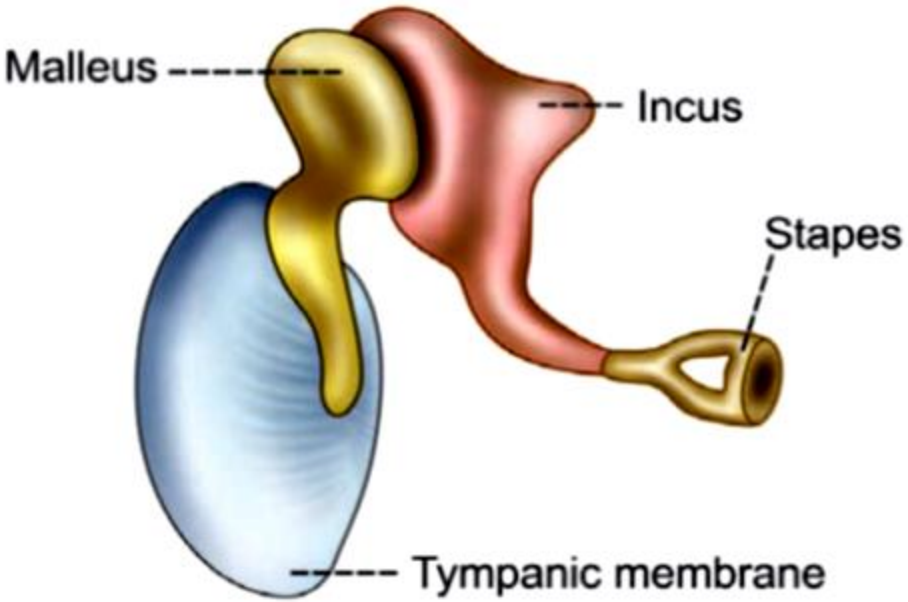
-Functions:

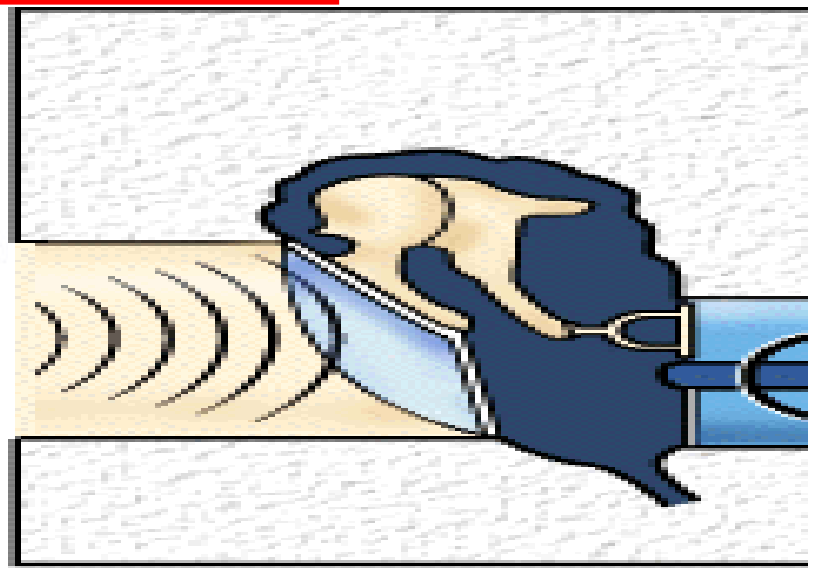
1- It acts as a resonator.

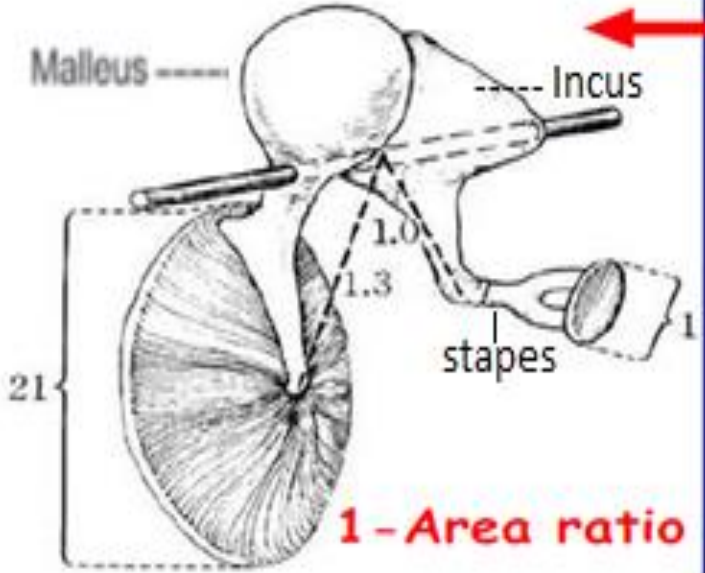
2- It acts as a barrier, so protects the delicate structures of middle ear.

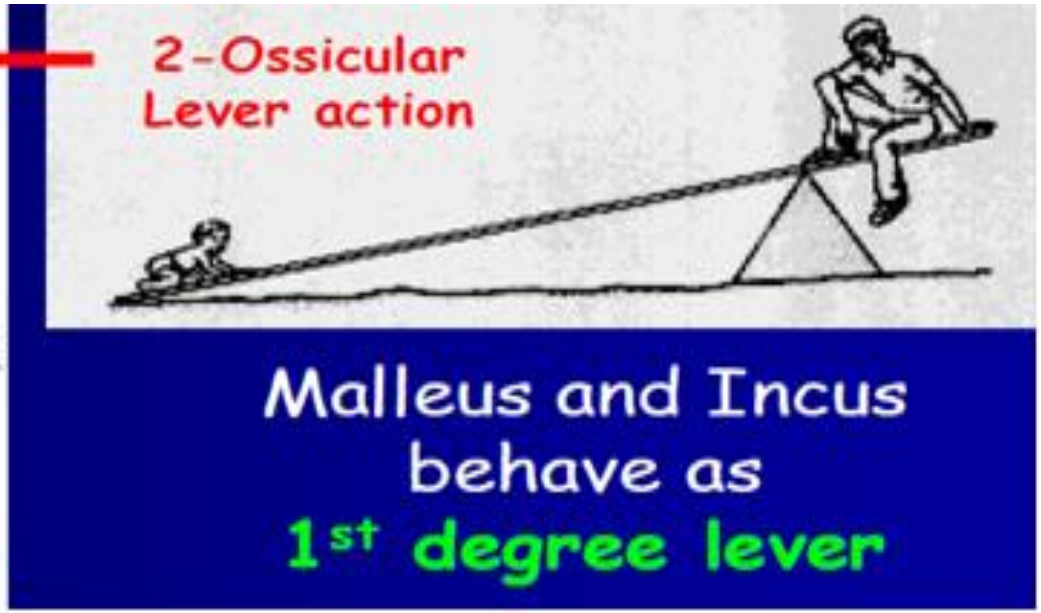
3- It changes the sound wave to mechanical vibrations.

II- The Middle Ear









A- The Middle Ear Ossicles

-Functions: **Impedance Matching** معادلة الإعاقة

(impedance = resistance, matching = over coming).

-The sound conduction properties of air (external ear) and of water (inner ear) are different. So, most of sound energy will be reflected and little would enter to the inner ear.

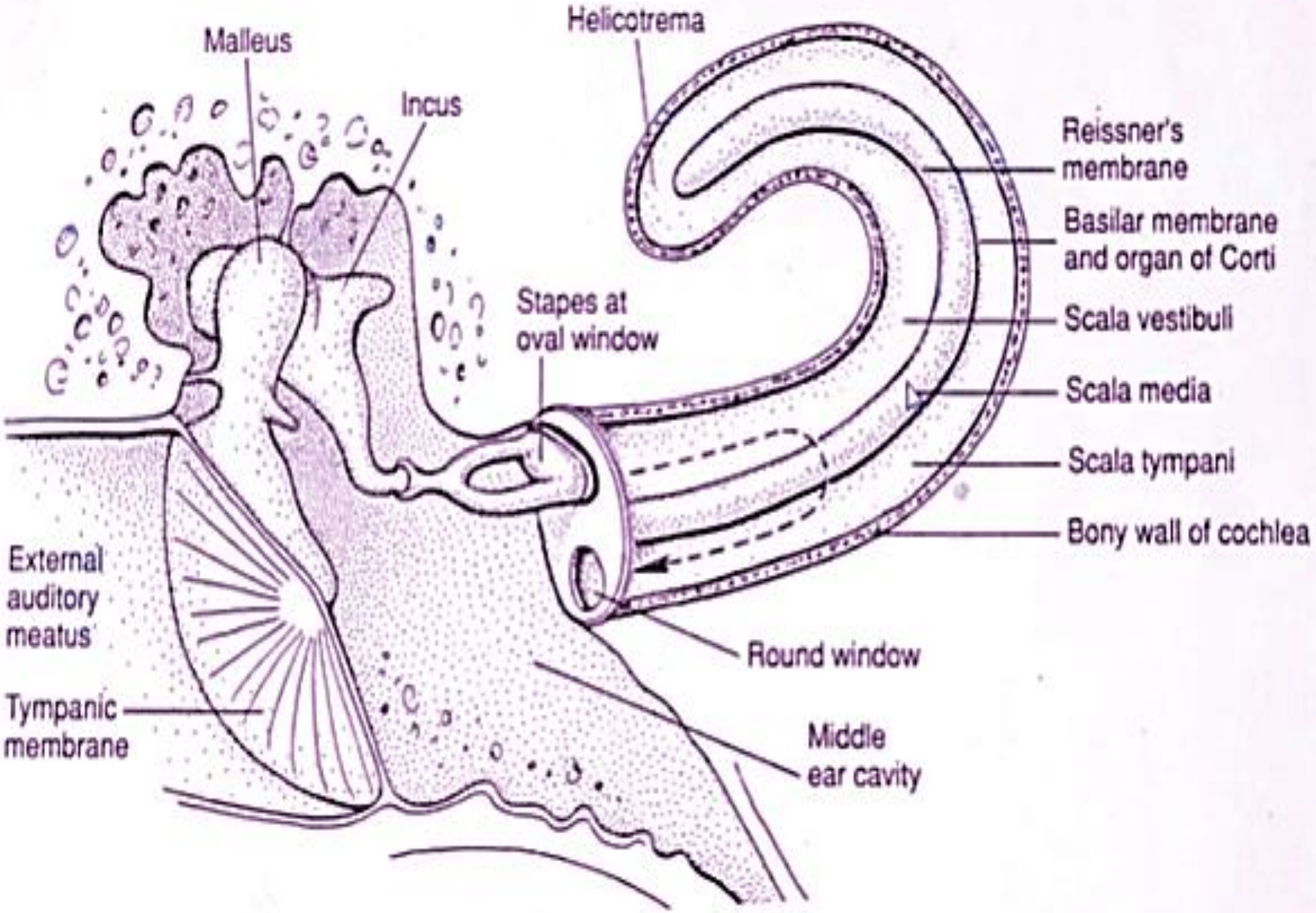
-However when the sound waves are conducted through the middle ear ossicles the sound impedance is only 40% and 60% of sound is transmitted to the inner ear.

-The middle ear ossicles perform the impedance matching by:

1. Lever action of the ossicles (ratio between handle of malleus and long process of incu is 1.3: 1) → increasing the force of movement of sound 1.3 times.

$$\text{الفائدة الالية للرافعه} = \frac{\text{المقاومه}}{\text{القوه}} = \frac{\text{ذراع القوة}}{\text{ذراع المقاومة}}$$

2. Concentration of sound waves from large tympanic membrane (55 mm^2) onto smaller oval window (3.2 mm^2) → increasing the force of movement of sound 17 times. so, this will increase the force of sound 22 times more than obtained from ear drum (1.3 X17= 22).


Malleus
Incus
Helicotrema
Reissner's membrane
Basilar membrane and organ of Corti
Stapes at oval window
Scala vestibuli
Scala media
Scala tympani
Bony wall of cochlea
External auditory meatus
Round window
Tympanic membrane
Middle ear cavity

The Basilar Membrane

-It is composed of 2000 to 30000 fibers.

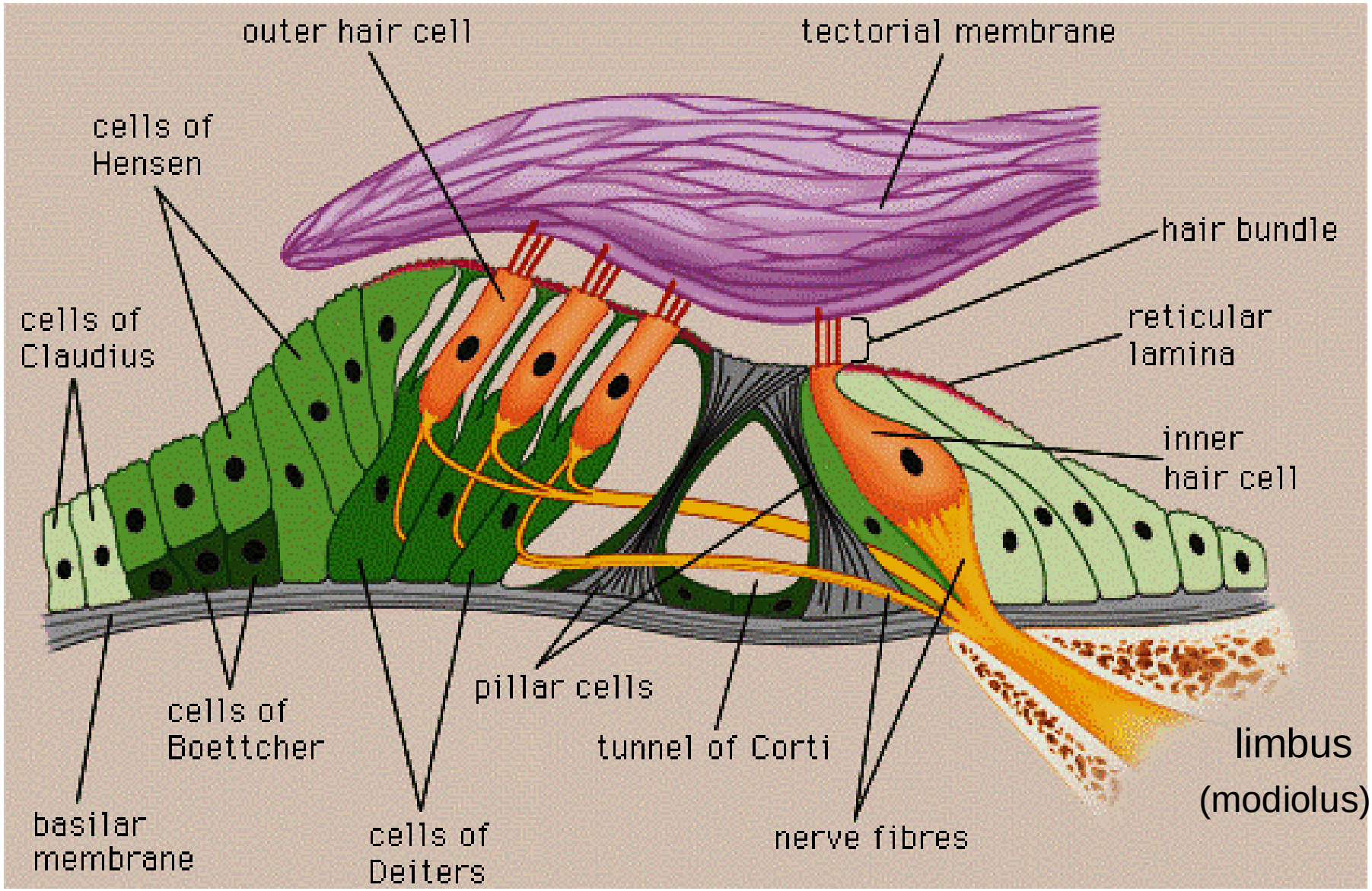
- It is like reeds of harmonica.

The length of these fibers increase from base of cochlea to apex but the diameter of fibers are decrease from base to apex

-The high frequency sounds vibrate the base (short & stiff fibers).

- **L**ow frequency sounds vibrate the apex (**l**ong & flexible fibers).

The Organ of Corti



The Organ of Corti

-It lies on the basilar membrane.

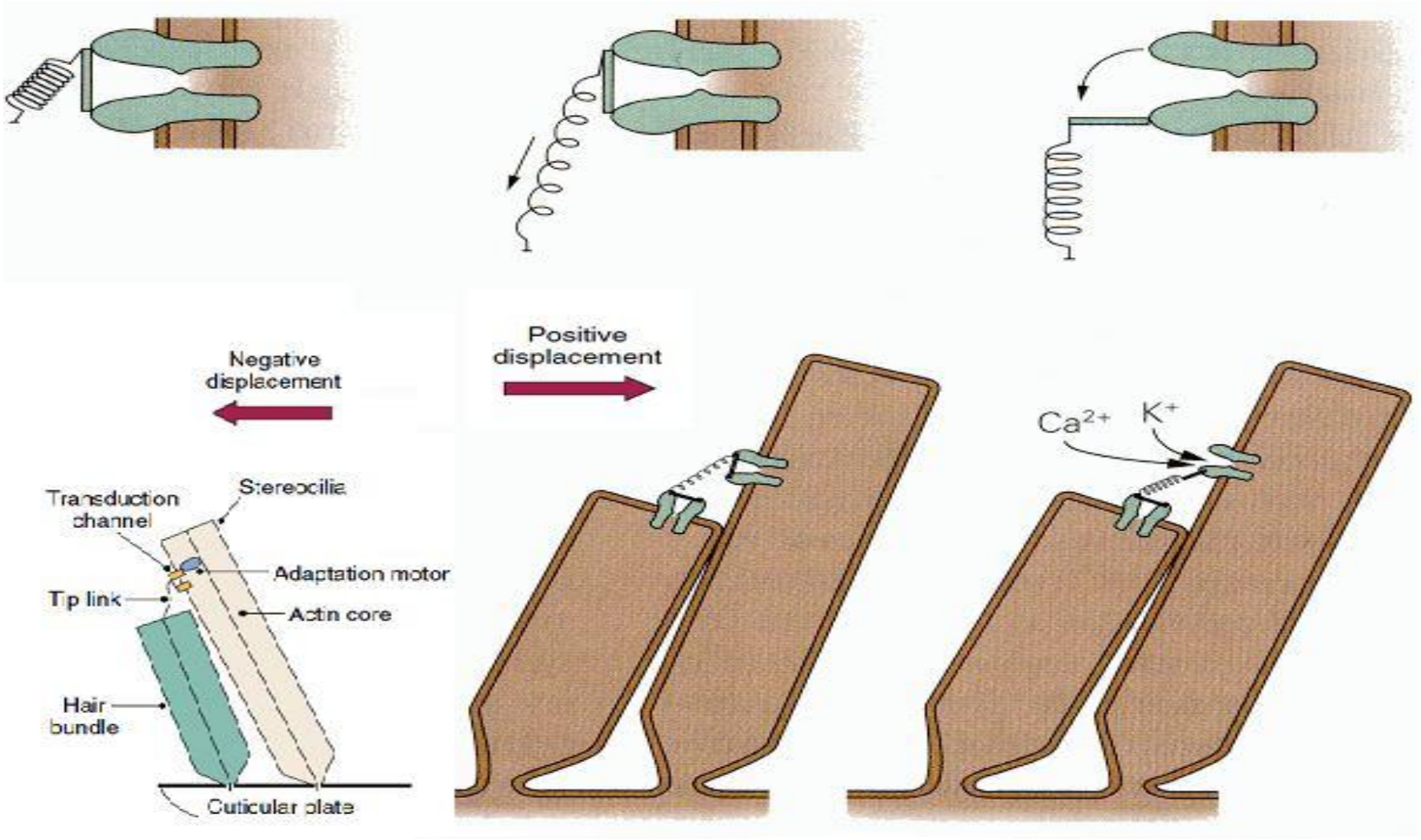
-It is composed of hair cells.

-The upper end of hair cell is ciliated and the cilia are embedded in the tectorial membrane.

-The tips of these cilia are connected by filamentous structures known as tip links.

-Each hair cell has small freely-movable cilia called stereocilia & one large stiff cilium called the kinocilium.

Hair Cells

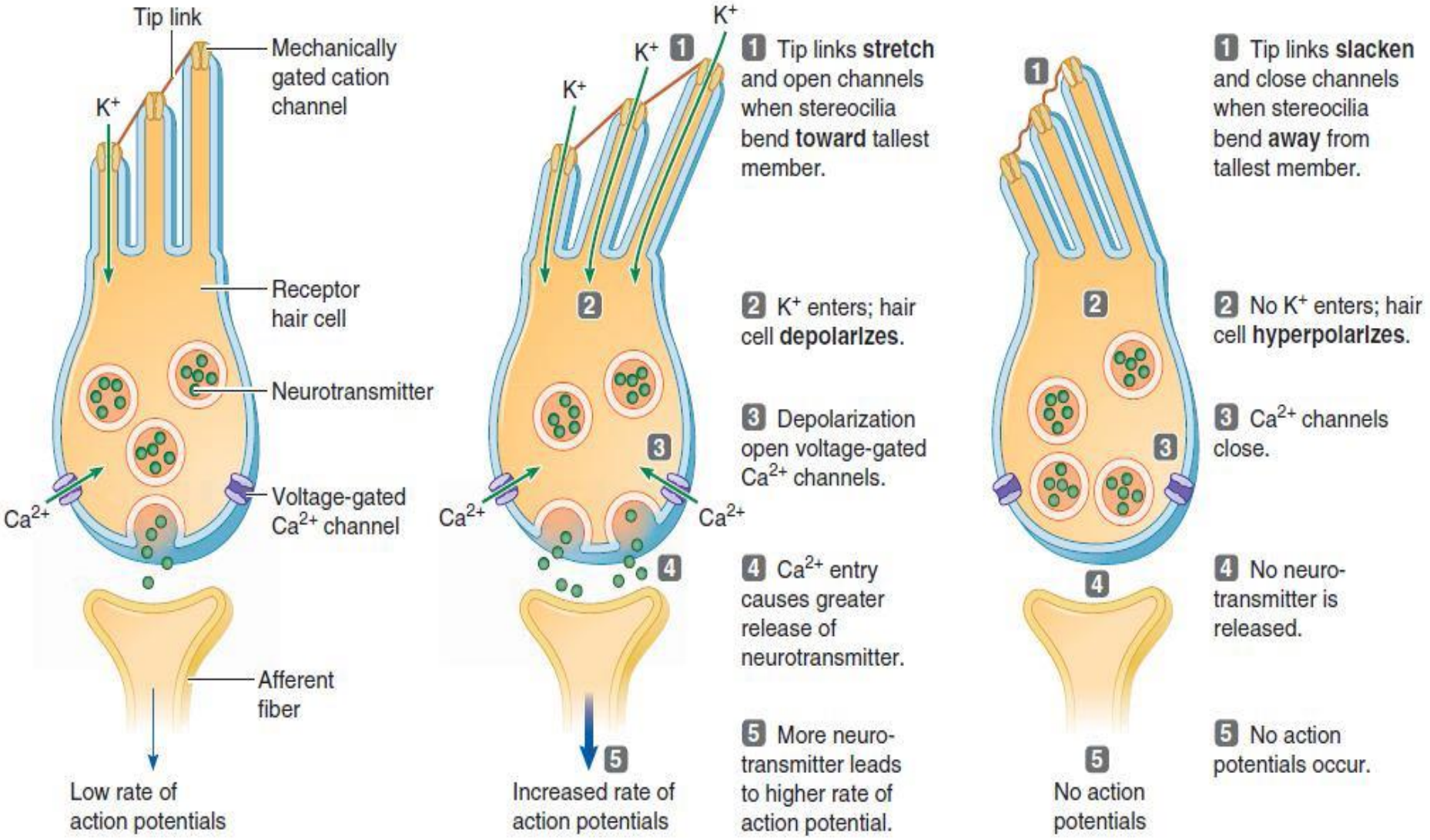

Negative displacement
Positive displacement
Transduction channel
Stereocilia
Adaptation motor
Tip link
Actin core
Hair bundle
Cuticular plate
Ca^{2+}
K^{+}

Transduction in the Cochlea

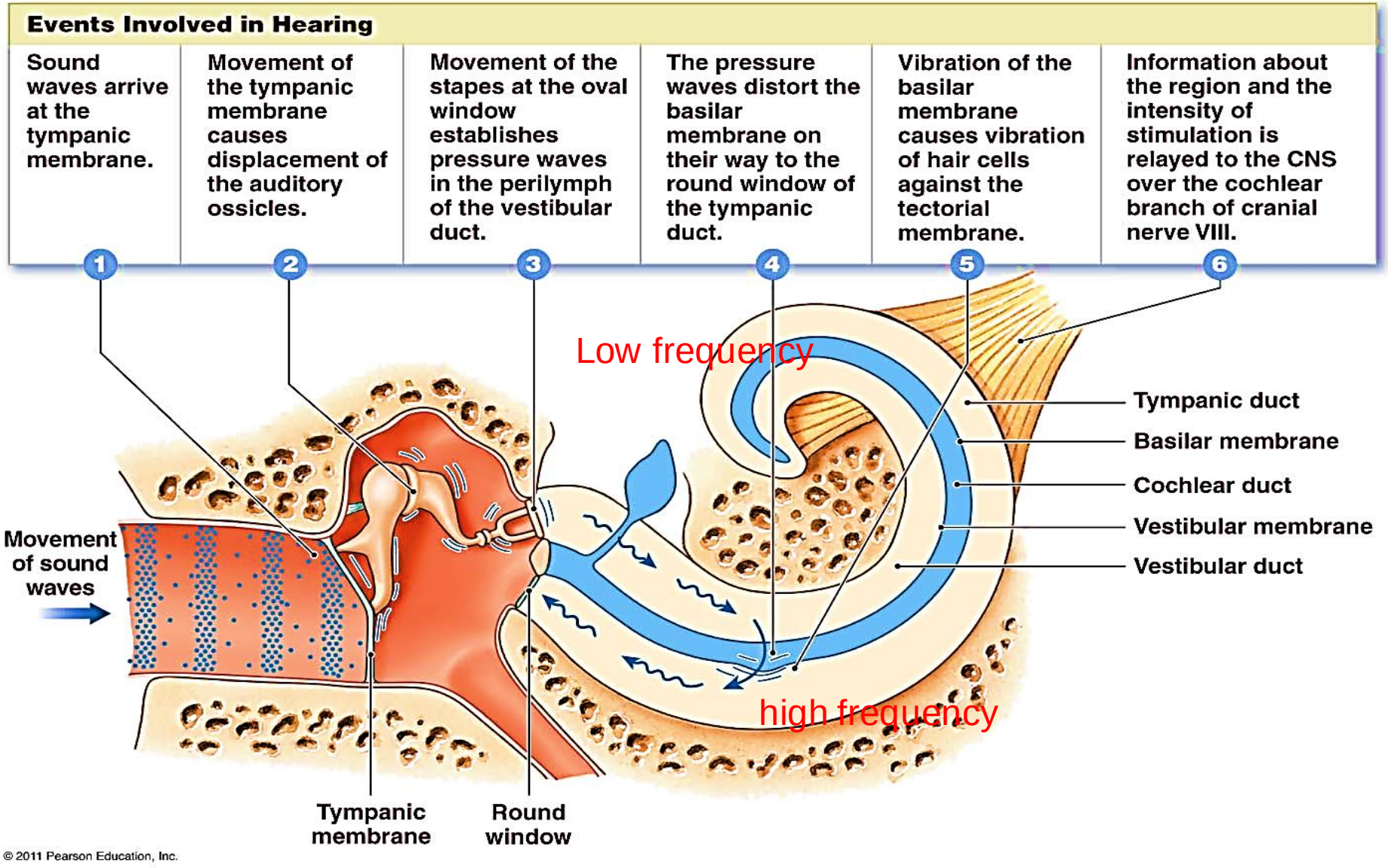
-Bending of the stereocilia towards the kinocilium (away from the limbus) → depolarization (stimulation); bending away from kinocilium (toward the limbus) → hyperpolarization (inhibition).

-From the lower end of hair cells afferent axons pass to cochlear nerve which enter the medulla.

Transduction in the Cochlea



Mechanism of Hearing



Thank You