# External and middle ear

By

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# Learning outcomes:

- **At the end of the lecture, you will be able to:**

1. Explain the functions of the ear pinna.
2. Explain the functions of the external auditory meatus.
3. Describe the structure of the middle ear.
4. Describe the tympanic membrane and explain its functions.
5. Explain the functions of the ossicular system.
6. Explain the role of the round window in sound transmission.
7. Explain the functions of the eustachian tube
8. Explain the tympanic reflex

# Hearing

- **The human ear consists of 3 parts:**

a.External ear.

b.Middle ear.

c.Inner ear.

# External ear

- **The external ear consists of:**

a.Ear pinna.

b.External auditory meatus.

# (I) Ear pinna (Auricle)

- **Def:** It is the **cartilaginous external flap**.
- **Functions:**

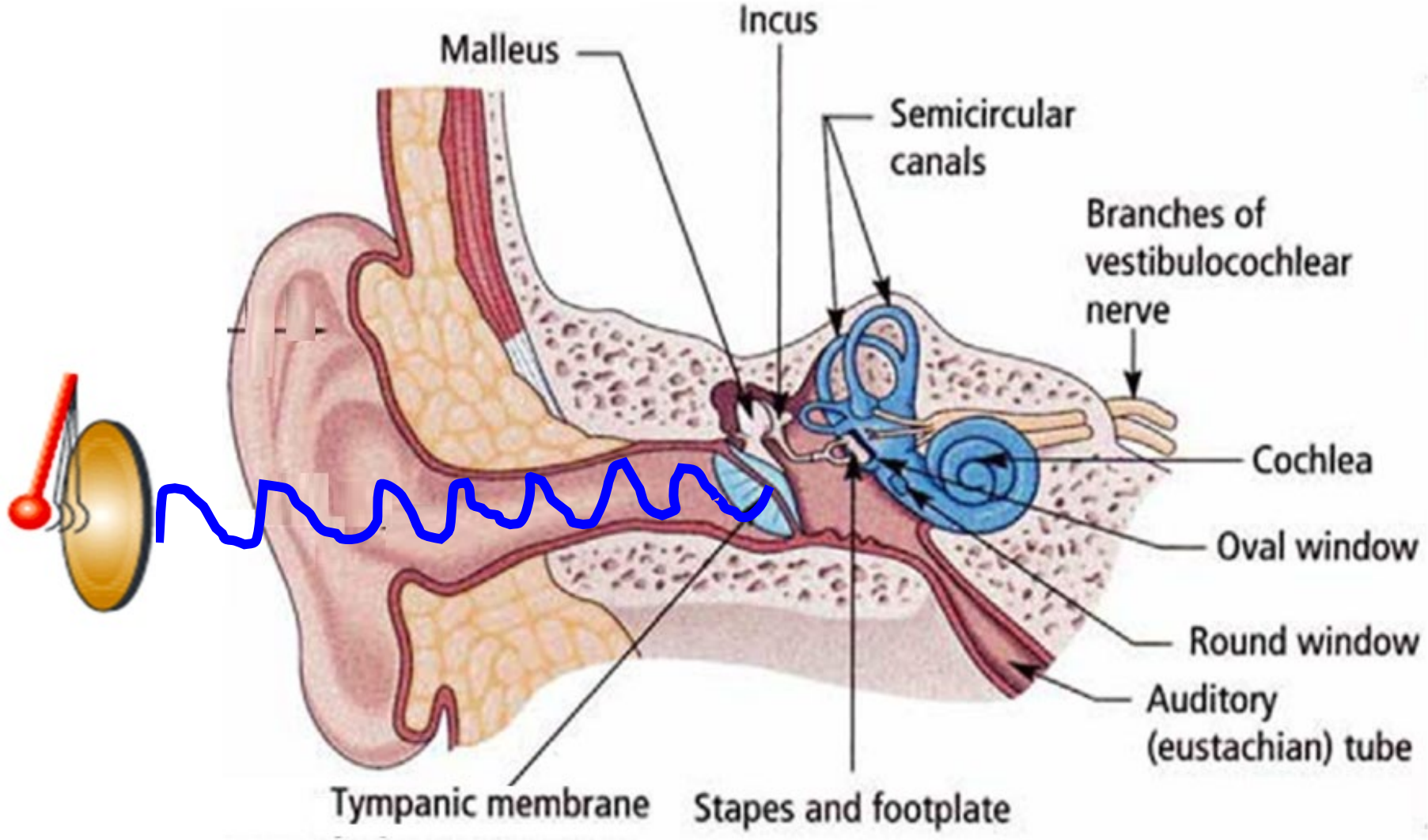
a.It **collects and directs** sound waves into the external auditory meatus.

**b.Sound localization**.

# External auditory meatus

- It is an **oblique tortuous** skin-lined canal of about **2.5cm** length in the **temporal bone**.
- The **tympanic membrane (ear drum)** exists at the end of the canal and completely **separates** the external ear from the middle ear.
- **Functions:**

1. It **conducts and concentrates the sound waves** to the tympanic membrane.
2. It produces **resonance** which **amplifies the sound** and increases its pressure at the ear drum.


Malleus
Incus
Semicircular canals
Branches of vestibulocochlear nerve
Cochlea
Oval window
Round window
Auditory (eustachian) tube
Tympanic membrane
Stapes and footplate

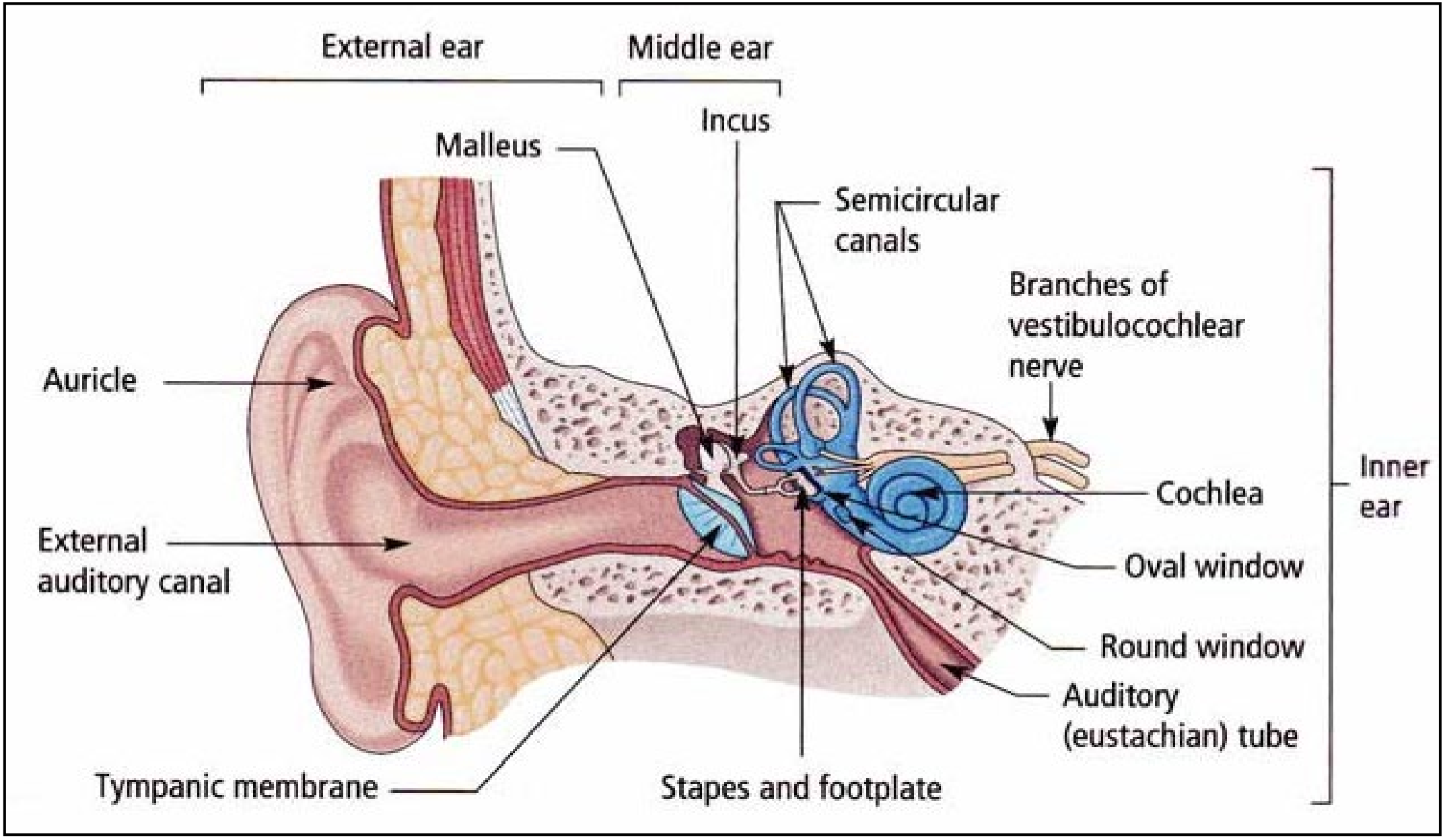
## 3. It protects the tympanic membrane:

a)From external trauma by being ***long and tortuous***.

b)From entrance of foreign bodies or insects by ***hairs & wax***.

c)From growth of microorganisms because the ***wax is of acidic pH and contains lysozymes and immunoglobulins***.

4. It **maintains the proper temperature and humidity of the air inside**, which is essential for the proper function of the ear drum.


External ear
Middle ear
Incus
Malleus
Semicircular canals
Branches of vestibulocochlear nerve
Auricle
Cochlea
Inner ear
External auditory canal
Oval window
Round window
Auditory (eustachian) tube
Tympanic membrane
Stapes and footplate

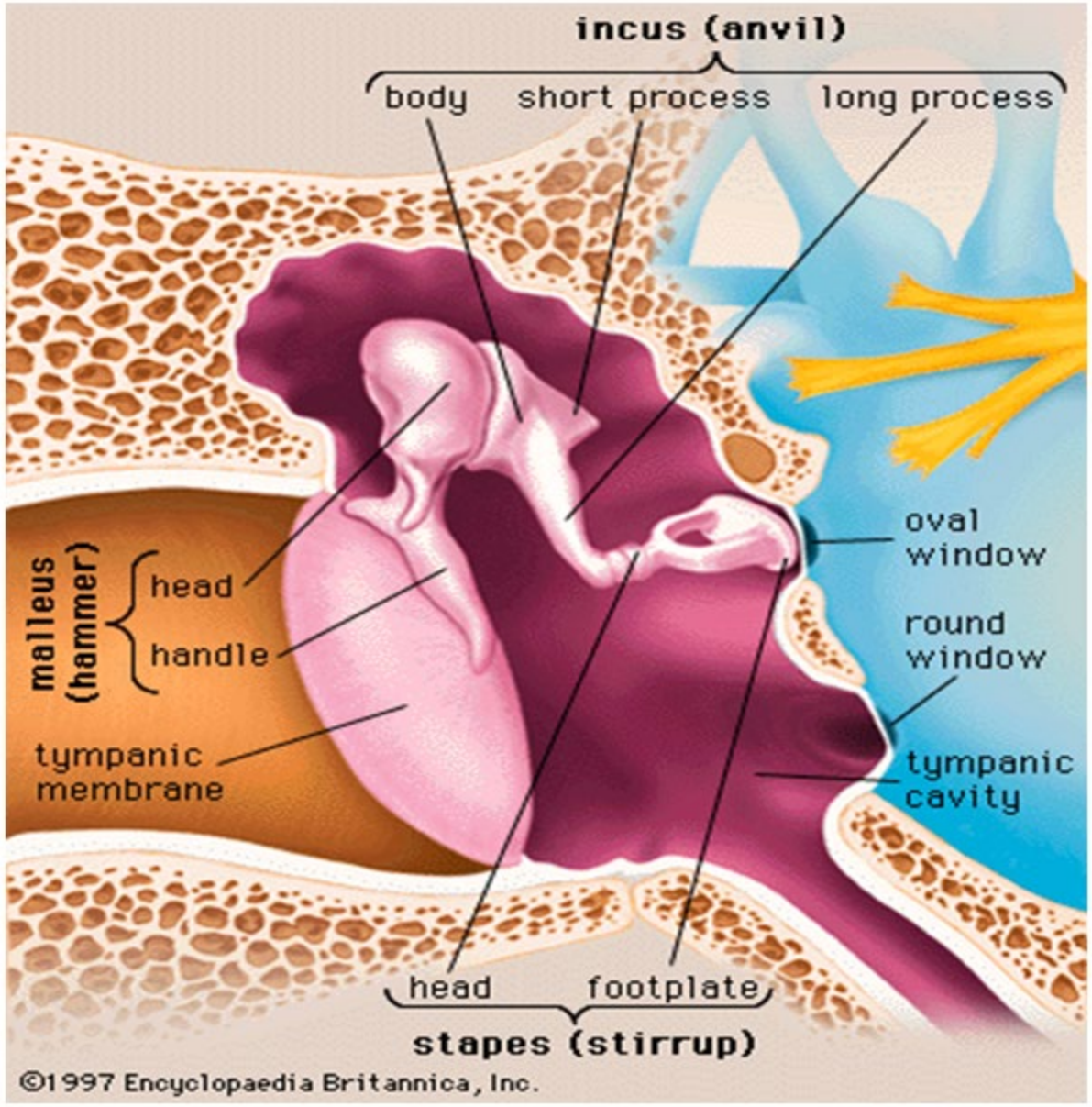
# Middle ear

## *Anatomy of Middle Ear:

- **Def:** It is an **air-filled cavity in the temporal bone**.
- **It contains:**

a) **3 bony ossicles:** the malleus (hammer), incus (anvil), and the stapes (stirrup).

b) **2 skeletal muscles:** the tensor tympani muscle (supplied by the 5$^{th}$ cranial nerve) and the stapedius muscle (supplied by the 7$^{th}$ cranial nerve).


incus (anvil)
body
short process
long process
malleus (hammer)
head
handle
tympanic membrane
oval window
round window
tympanic cavity
head
footplate
stapes (stirrup)
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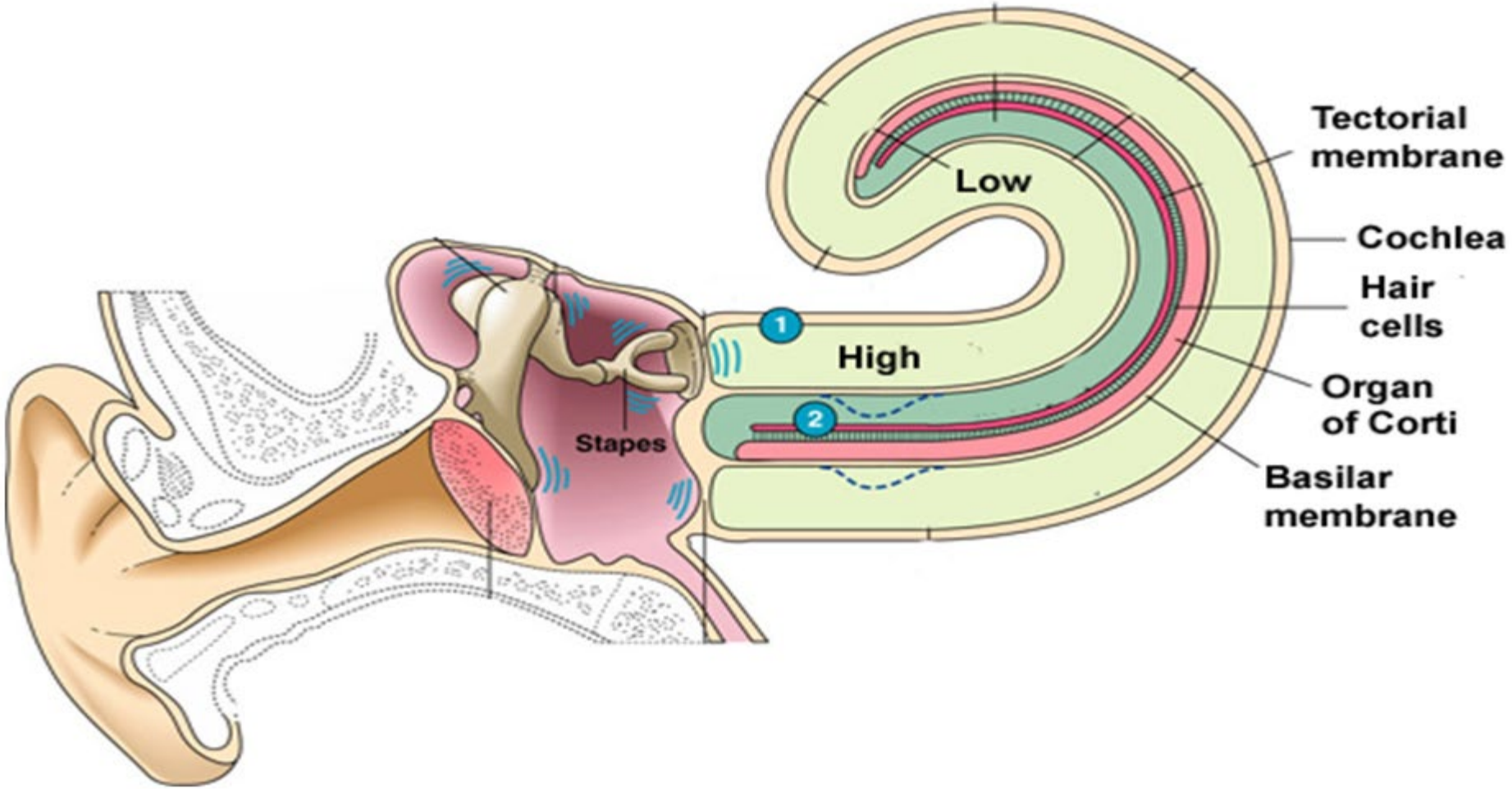
- It is **bounded by:**

➢**Tympanic membrane** on **lateral side** and

➢**Oval and round windows** on the **medial side**.

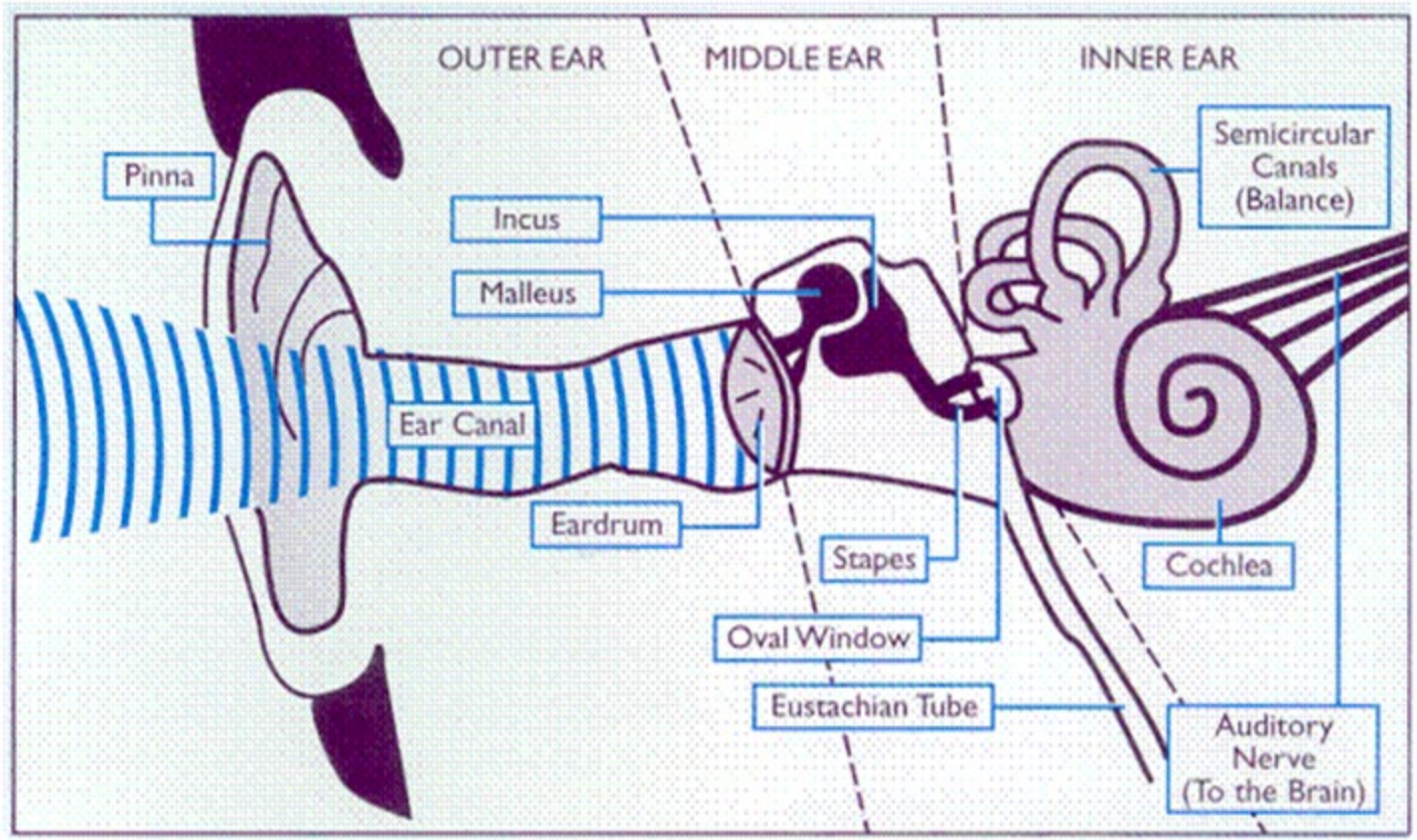
- It is **connected with** the naso-pharynx by the **Eustachian tube**.

***Functions of Middle Ear:** Transfer sound from the external ear to inner ear.


Tectorial membrane
Low
Cochlea
Hair cells
1
High
Organ of Corti
2
Stapes
Basilar membrane

# (I) Tympanic membrane

- **Def:** It is a **thin semi-translucent** membrane.
- **Shape:** **Conical** with its **concavity** directed **laterally**.
- **Surface area:** **55 $mm^2$**
- **Thickness:** **0.1 mm**.


OUTER EAR
MIDDLE EAR
INNER EAR
Pinna
Incus
Malleus
Ear Canal
Eardrum
Stapes
Oval Window
Eustachian Tube
Semicircular Canals (Balance)
Cochlea
Auditory Nerve (To the Brain)

- **Functions:**

1. It **acts as a resonator** that reproduces the vibrations of the sound source **i.e.** vibrates in and out according to the frequency and intensity of the sound introduced.
2. It is **highly damped** **i.e.** its vibration stops when the applied sounds stop, this prevents the unnecessary sound prolongation.
3. It is **aperiodic** **i.e.** it has no natural frequency, but takes up the characteristics of the vibrations applied on it.

# (II) Functions of ossicular system (Amplification and impedance matching)

- The **transmission** of sound waves from **air** in the external ear to **endolymph** in the inner ear results in a **great loss of energy**.
- **More than 97% of a sound's energy** would be reflected at the surface of water (**i.e.** sound of loud speaker would be lowered to just whisper).

- **This impedance sound transmission can be matched by 2 mechanisms:**

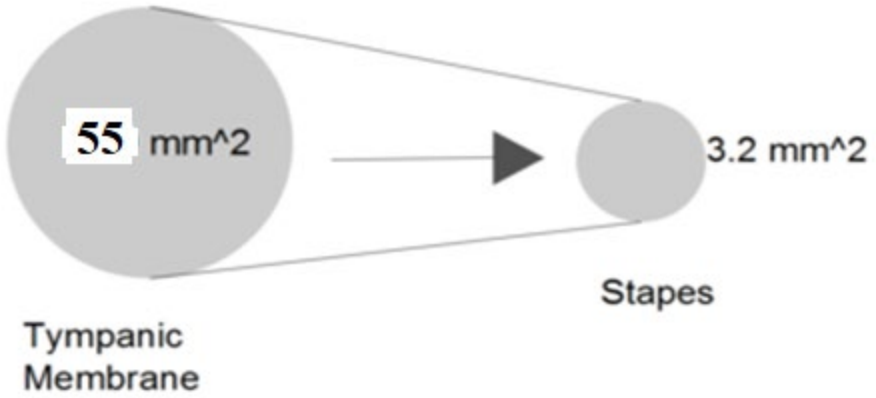
***1) The areal ratio of the tympanic membrane and the oval window:***

- The surface area of the **drum (55 $mm^2$)** is about **17 times** greater than that of the **foot plate of the stapes (3.2 $mm^2$)**.

- This areal ratio produces an amplification of sound waves about **20 folds** at the oval window.

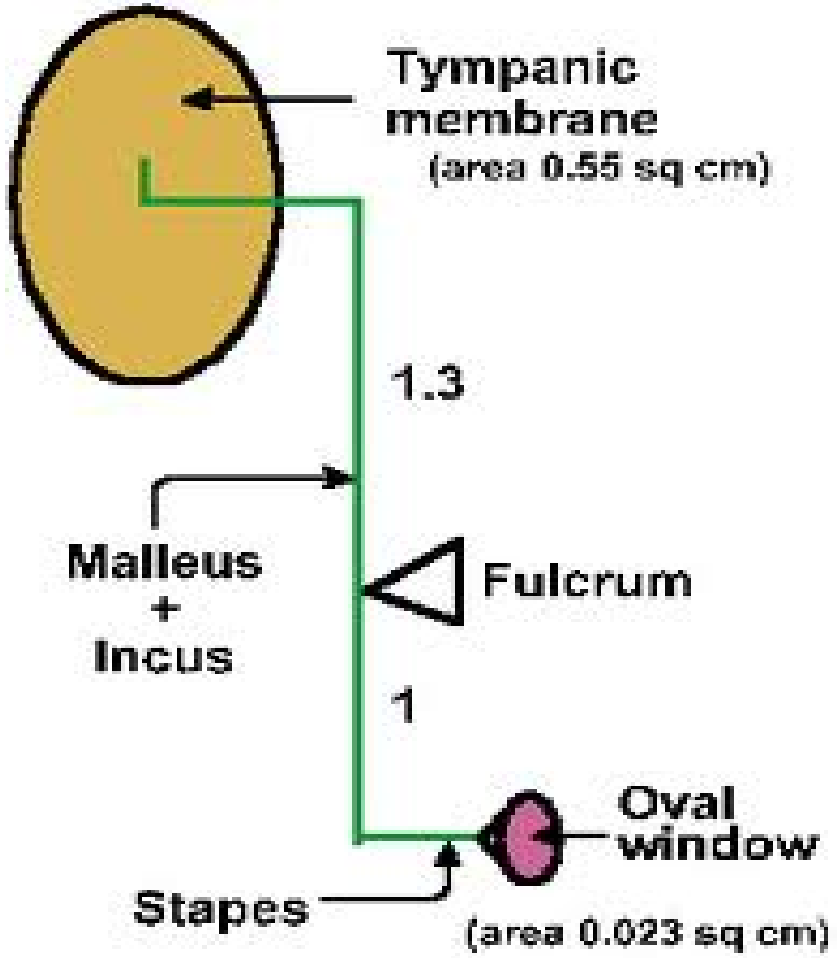
## Areal Ratio of Tympanic Membrane to Stapes

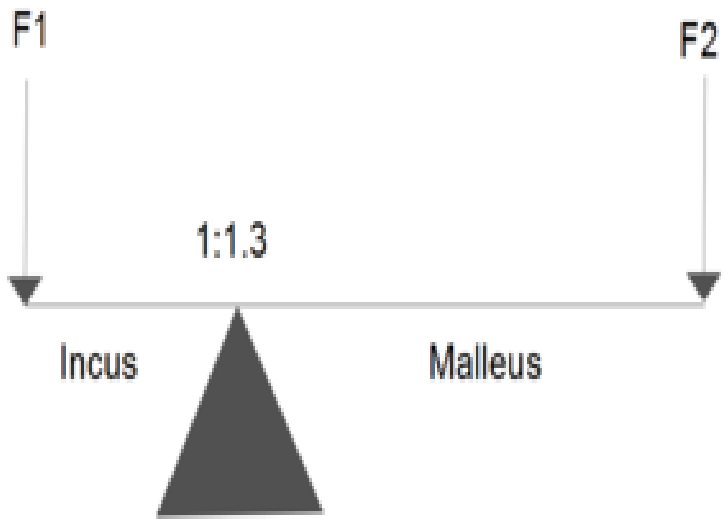
Areal Ratio = 13.4



# 2) The lever system of the bony ossicles:

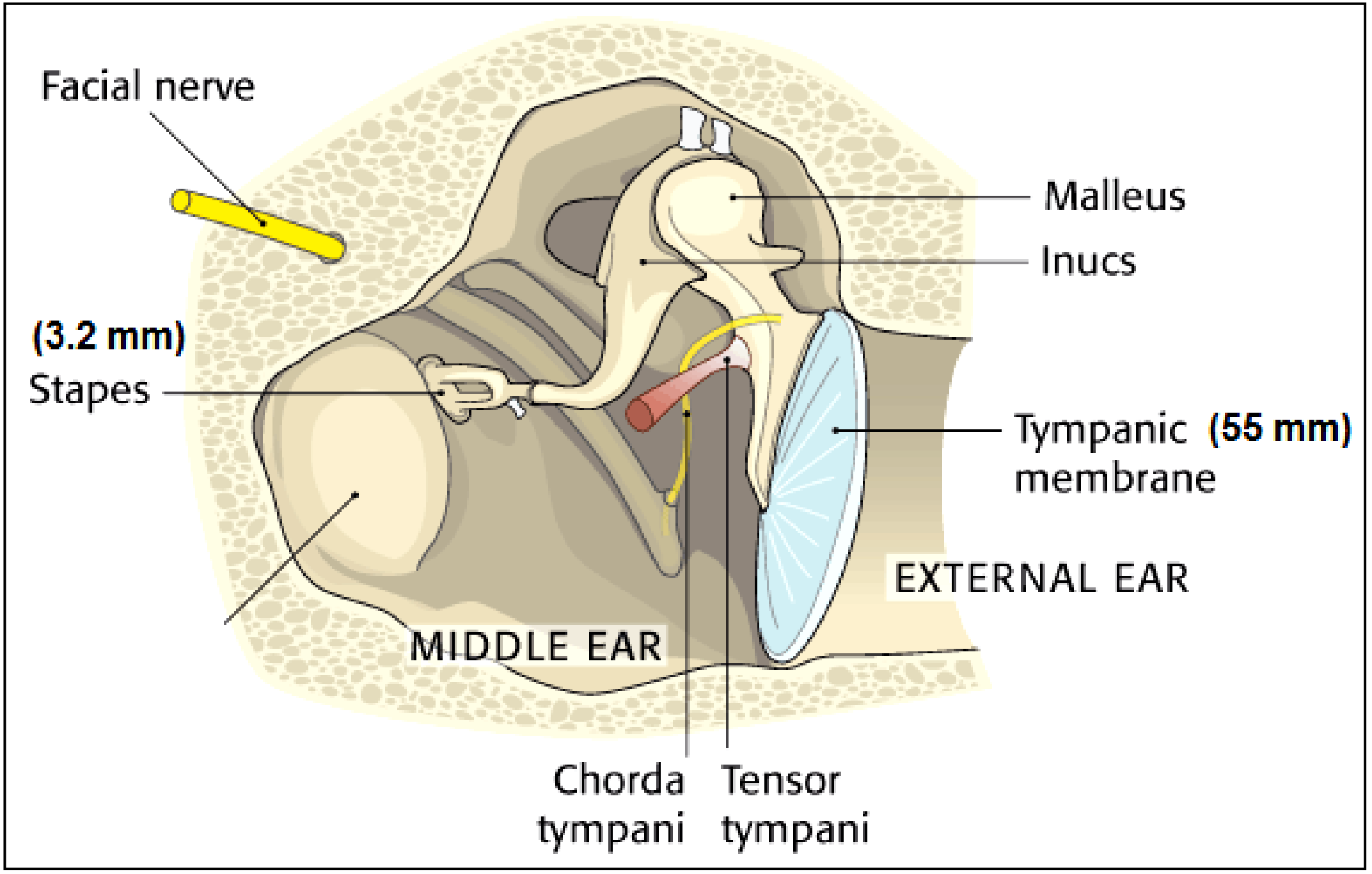
- The bony ossicles are arranged in such a manner that they function as a **series of levers**. The **handle of the malleus is about 1.3 times that of long process of the incus**. This lever action of the malleus and incus increases the force of movement of the stapes about **1.3 times**.


Tympanic membrane
(area 0.55 sq cm)
1.3
Malleus + Incus
Fulcrum
1
Oval window
Stapes
(area 0.023 sq cm)




Lever Principle For Malleus and Incus

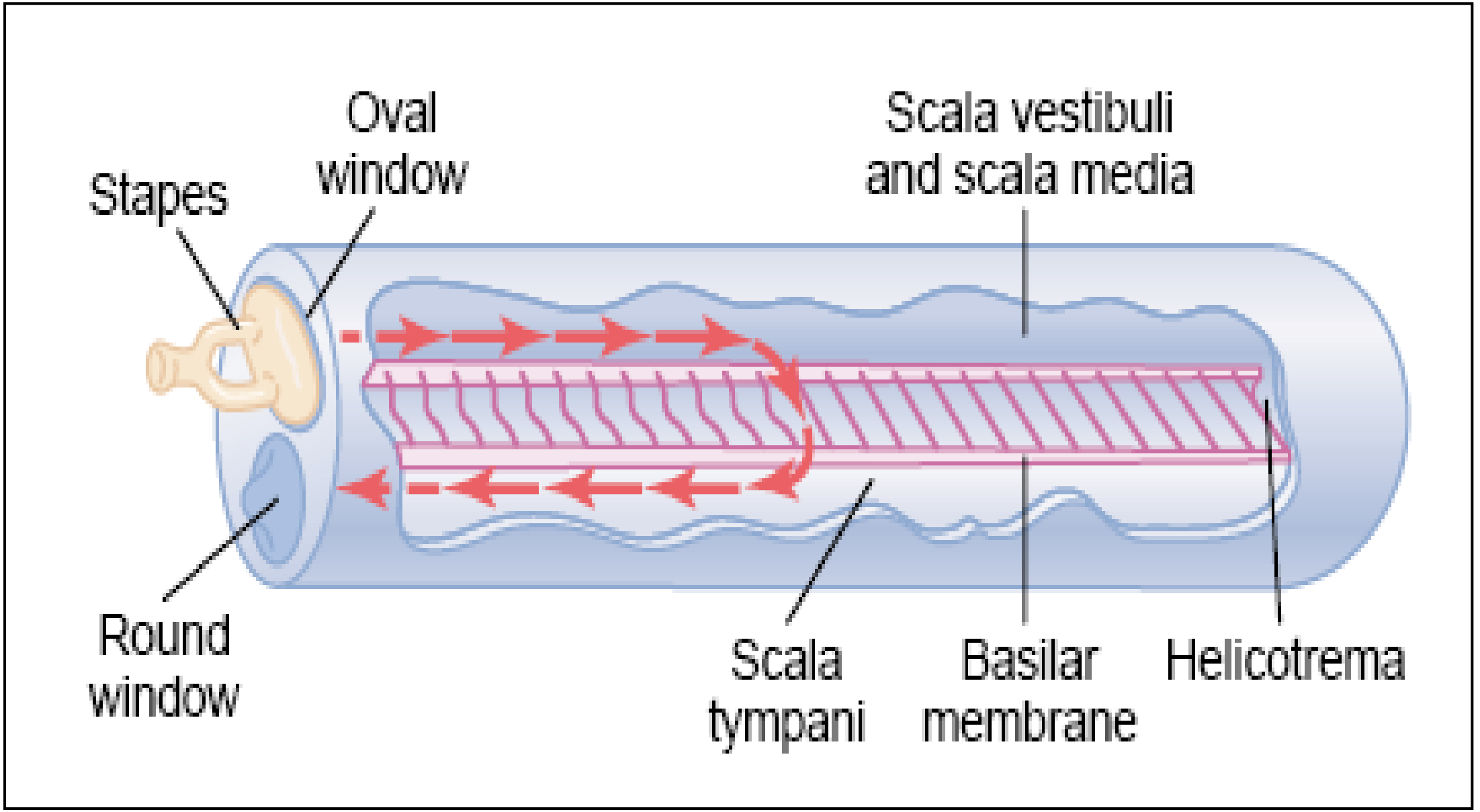
- ***The lever action of ossicles and areal ratio of the tympanic membrane and oval window*** amplify the sound pressure at the oval window about ***22 times***.
- The **efficiency the impedance matching device** is not 100%, but it is about **50 to 75%** for sound frequencies between 300 and 3000Hz

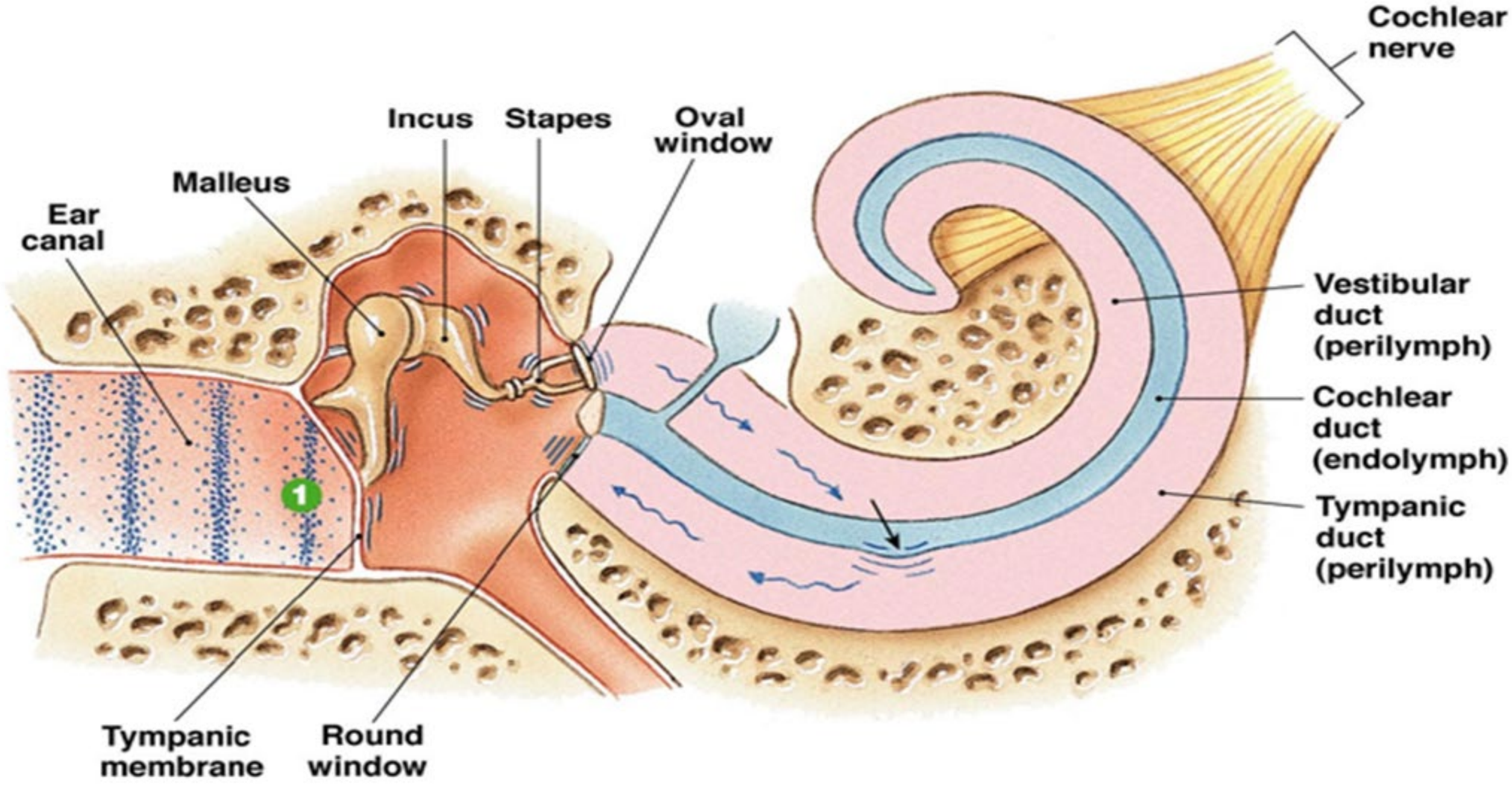

Facial nerve
Malleus
Inucs
(3.2 mm)
Stapes
Tympanic (55 mm)
membrane
EXTERNAL EAR
MIDDLE EAR
Chorda
tympani
Tensor
tympani

# (III) Role of round window in sound transmission

- The **oval window** opens into the **scala vestibuli** and the **round window** opens into the **scala tympani.**
- **If sound waves strike the two windows simultaneously** (as that occur when the transformer action of the middle ear is not present) ➔ the effect could be the same as that produced by making equal pressure on the two ends of an open U tube filled with water **i.e**. there would be no displacement of fluid, this is called **cancellation effect**.

- In **intact ear**, sound is applied to the **ear drum** → vibrations are transmitted to the **ossicular bones** → to the **oval window** → then through the **scala vestibuli** and **scala tympani** to the **round window**.
- Therefore, when there is **condensation phase**, at the **oval window** there will be **rarefaction phase** at the **round window i.e.** the two windows vibrate reciprocally in response to sound energy.
- So the round window serves as **a relief hole** in the bony cochlea.


Oval window
Scala vestibuli and scala media
Stapes
Round window
Scala tympani
Basilar membrane
Helicotrema


Cochlear nerve
Incus
Stapes
Oval window
Malleus
Ear canal
Vestibular duct (perilymph)
Cochlear duct (endolymph)
Tympanic duct (perilymph)
1
Tympanic membrane
Round window

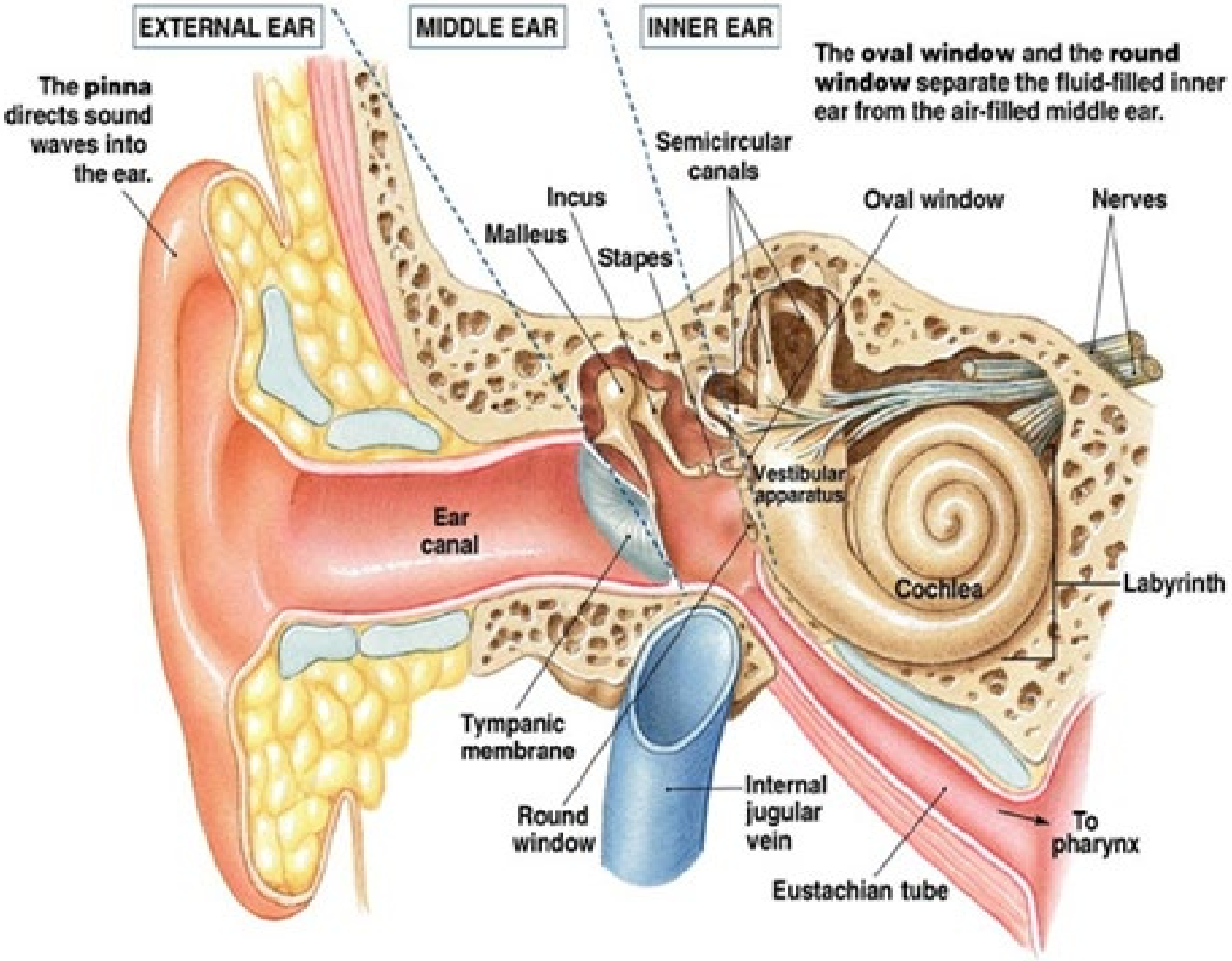
# (IV) Eustachian tube

- It connects the **middle ear** with the **nasopharynx**.
- **Functions:**

1. It **equalizes pressure on both sides of tympanic membrane:**

➢ **Normally** the tube is **closed** but it opens during swallowing, chewing, yawing, blowing the nose, and sneezing.

➢ **If the tube is continuously opened** ➔ the sounds of breathing and talking will produce noise and interfere with normal hearing.


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.
Semicircular canals
Incus
Malleus
Stapes
Oval window
Nerves
Vestibular apparatus
Ear canal
Cochlea
Labyrinth
Tympanic membrane
Round window
Internal jugular vein
To pharynx
Eustachian tube

- **If the tube is continuously closed** (as in common cold)→ the air in the middle ear will be absorbed → a negative pressure in the middle ear → sucking of the tympanic membrane inwards → limitation of its movement and ↓ hearing.

2. **Continual renewal of air in the middle ear**.

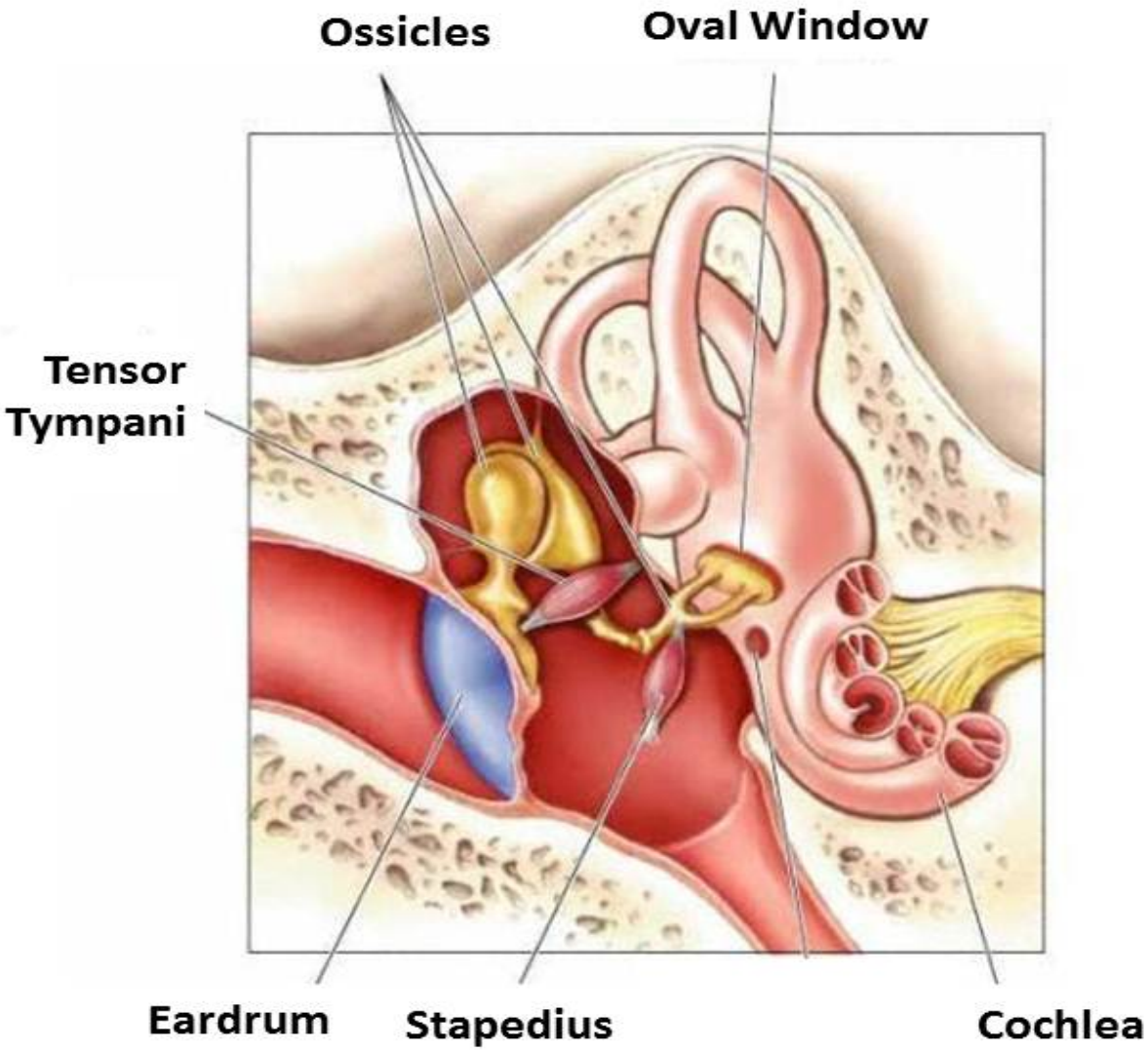
- ***Otitic Barotrauma:***

❑ ***During ascent of an airplane***, *the external pressure ↓ & the Eustachian tube is closed to equalize the pressure on both sides of the drum.*

❑ ***During rapid descent of an airplane***, *the external pressure ↑ and pushes the drum inwards and may rupture it unless the person swallows*

# (V) Tympanic (attenuation) reflex (Functions of middle ear muscles)

- **Def:** This is a reflex contraction of both **tensor tympani** and **stapedius** muscles in response to sounds of **high intensity** and **low frequency** (above **80 dB** and below **1000 Hz**).


Ossicles
Oval Window
Tensor Tympani
Eardrum
Stapedius
Cochlea

- **Mechanism:**

➢ The **tensor tympani** muscle pulls the **handle of the malleus inward** while the **stapedius muscle** pulls the **stapes outward**.

➢ These two forces cause the entire ossicular system to develop a **high degree of rigidity** and **greatly reduce the transmission of loud sound**.

➢ This reflex has a **long latent period** (about **40 m.sec**).

- **Importance:**

1. It **protects the cochlea from the damaging vibrations caused by very loud sound** which is usually of low frequency. The effect of the reflex is **not complete** because of its **long latent period**.

2. It **masks low frequency sounds in loud environments** **i.e**. it provides selective attenuation of low frequency sounds so ***removes a major part of the background noise*** and allows a person to ***concentrate on sounds above 1000 Hz***.
3. It **decreases the person's hearing sensitivity to his own speech**, (this effect is activated by collateral signals transmitted to these muscles during speech).

# References


1. Costanzo, Linda S. "BRS Physiology (Board Review Series)." (2018).

2. Ganong, William F. "Review of medical physiology." (2020).