Lecture: 11

Physiology of Hearing

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Physiology Team

OBJECTIVES

Not given

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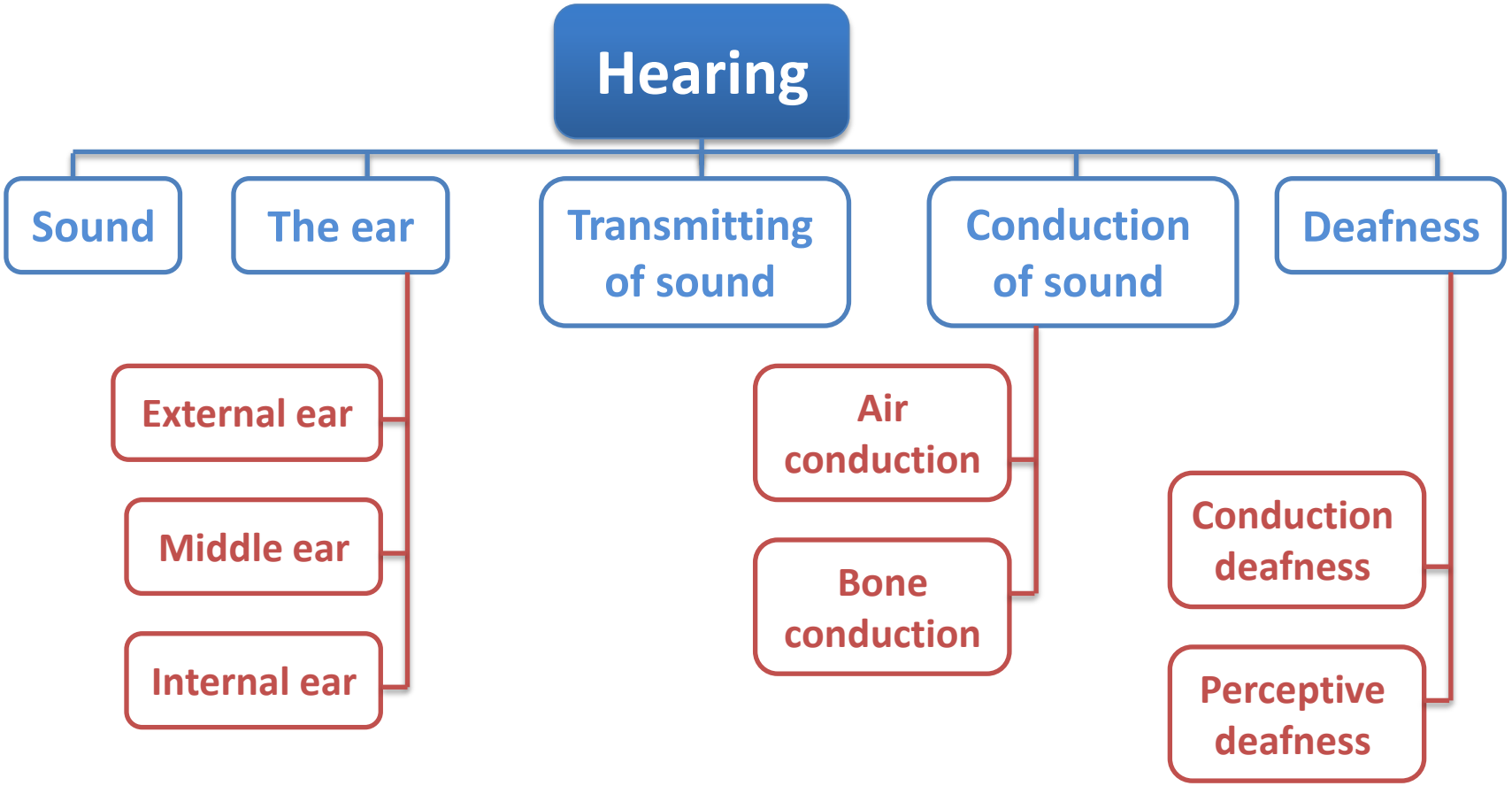
MIND MAP



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Sounds

- **Nature of sound :**
  Sound is produced from alternate compression and rarefaction of air molecules by **vibrating** body.

- **Characteristic (parameters) of sound :**
  1. **Pitch (Tone)** (1)**:** depend on No. of cycles\sec. Human ear can detect sound waves with frequency between 20-20.000 cycle\sec.
  2. **Intensity (Loudness):** depend on amplitude.
  3. **Quality:** depend on the over tone or interference.

1. Unit of sound decibel (dB)
   - 15 dB whispering.
   - 40 – 45 dB is normal conversation.
   - More than 70-80 dB is dangerous.

(١) تعطينا اختلافات مخارج الاصوات

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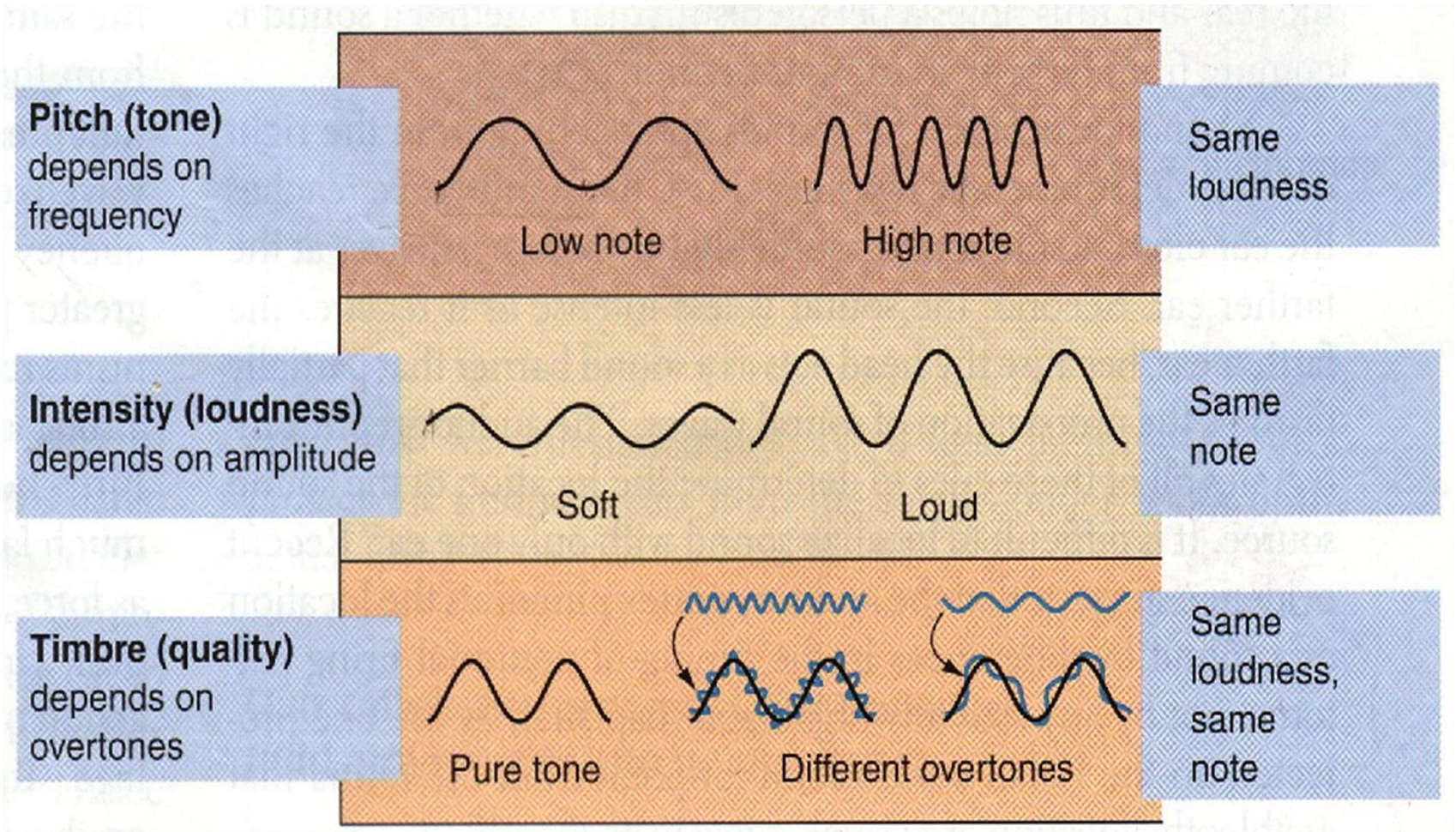

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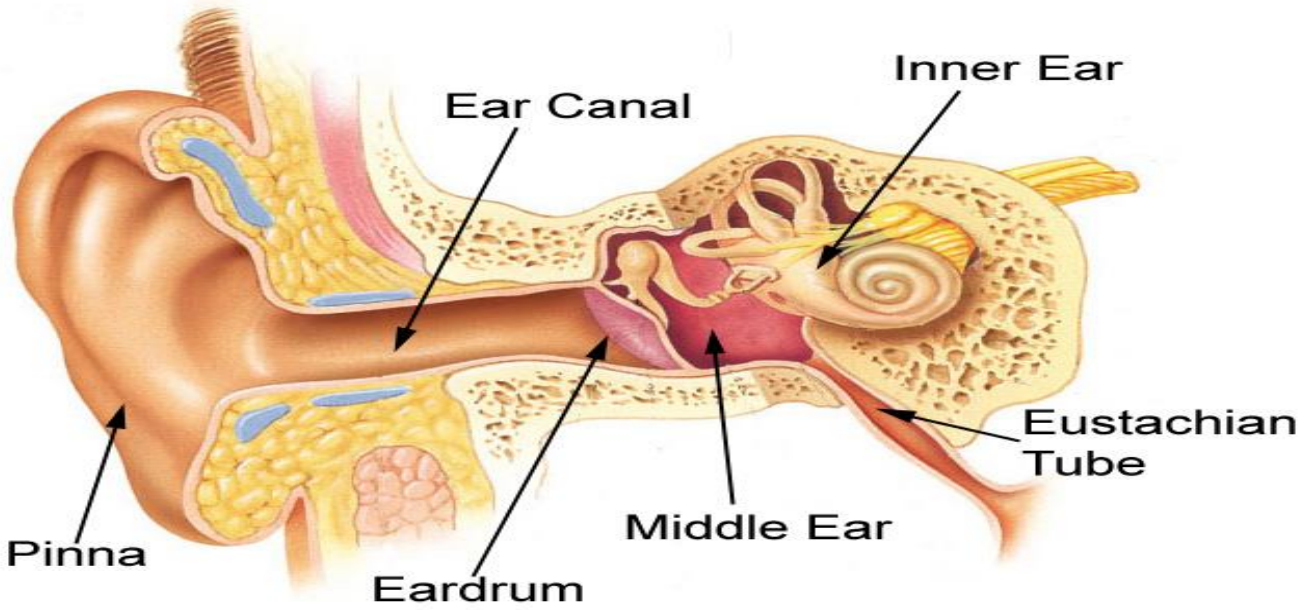
The Ear

- **Function of the ear:**

1. **Hearing.**
   - Involved parts : (**External Ear - Middle Ear - Internal Ear**)
2. **Equilibrium.**
   - Involved parts : **Internal Ear** (Semicircular canals, Utricle, and Saccule)



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Functional Anatomy of The ear

- **External Ear.**
  1. Pinna
  2. External canal
  3. Tympanic membrane (Funnel shaped , pointing inward)

- **Function of External Ear :**
  1. Act as funnel to **collect sound.**
  2. Sound localization (front , back , high , low).
  3. **Protection**. **Ex : wax.**
  4. Alter amplitude **(Pinna)**.

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Functional Anatomy of The ear

- **Middle Ear** : its an **air filled** cavity**.**
  - Contain **three bones (ossicles)**:
    1- Malleus.
    2- Incus.
    3- Stapes (it's foot sitting of the oval window of the inner ear)
  - and **two Muscles** :
    1- Tensor tympani.
    2- Stepedius.

- **Function of Middle Ear :**
  1. Act as space between the tympanic membrane and inner ear **(Wave transmission).**
  2. **Protection** from high sound (over 70dB).
  3. **Magnification** of sound wave.

Note: Middle ear opens via Eustachian (auditory) tube into nasopharynx

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#1-Transmission of sound through the middle ear

1. sound waves vibrate the **tympanic membrane**.
2. Tympanic membrane moves the **handle of malleus**

2. Tympanic membrane moves the handle of malleus
3. Then **Incus** will moves.

3. **Stapes** move **in & out** of the oval window.
4. The pressure transmitted through **cochlea** cause stimulation **of hair cells** in the **organ of corti**, which will stimulate the auditory nerve.

#2- Protection from high sound

➢ Mechanism :

1-OSSICLES:

Manubrium of the **malleus** attached to the back of the tympanic membrane and its short process attached to the incus.

The **incus** then articulates with the head of the **stapes**, and its foot plate attached to the **oval window.**

2-MUSCLES:

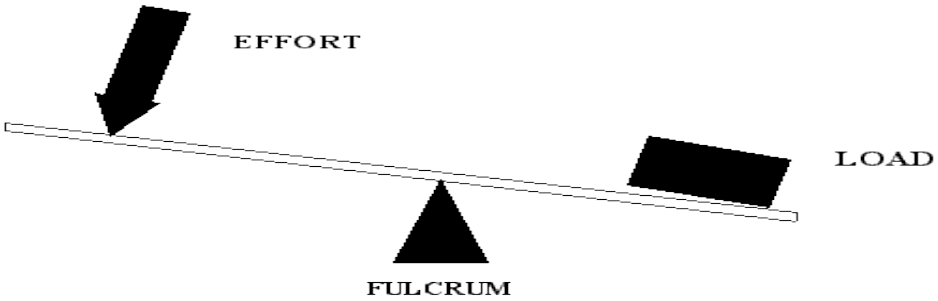
1. When muscles contract reflexly in response to loud sound (over 70dB), Contraction of **the tensor tympani** pulls the **manubruim** & makes the tympanic membrane tens. Thus **decreasing the vibration.**
2. Contraction of the **stapeduis** pull the foot plate outward so that vibration are reduced.

Note : This mechanism give protection from constant loud noise, but not sudden noise, latency of 40-80 m.sec.

#3- Middle ear magnifying effect

1. The force from a large surface area (Tympanic membrane.) is **concentrated** to a small (oval window) with ratio about 17:1
2. Lever action* of ossicles increase the force of movement 1.3 times (size differences between these 3 bones) .

1. ▲ the total increase 17 X 1.3 = 22 times



* حركة العتلة\المقبض

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Functional Anatomy of The ear

- **Inner Ear.**
  - **Bony** and **membranous** labyrinth:
  1. **Cochlea** (snail like, coiled tubular system laying deep in the temporal bone)
  2. Vestibule
  3. Semicircular canals.

- **Cochlea:**

  Is a system of **three coiled tubes** through it length **filled with fluid**.
  The basilar membrane and vestibular membrane (reissners) divide it into three canals :

  1. **Scale** (1) **vestibule**
  2. **Scale media** (which contains **organ of corti**).
  3. **Scale tympani**

Responsible for change the mechanical movements into action potential

(1) Scale means small

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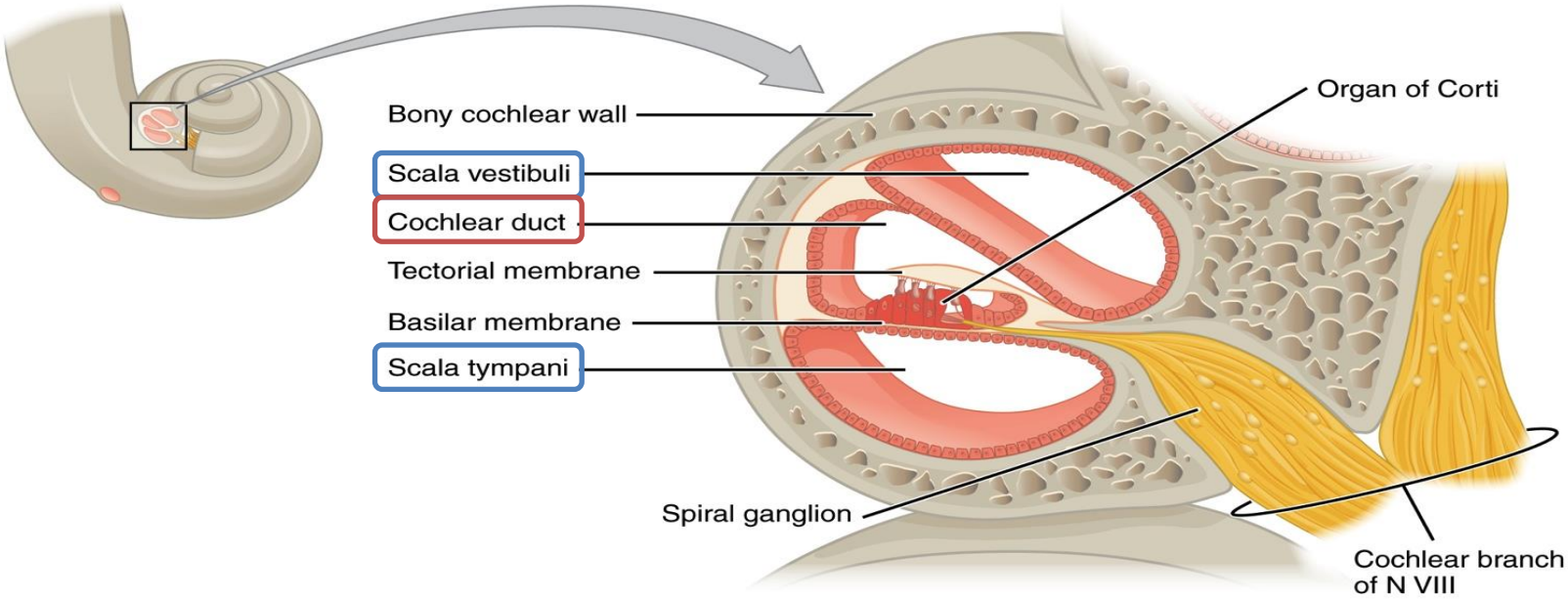
Composition of cochlea fluid

Scale Vestibule	NA+ high	K+ low
Scale Tympani	NA+ high	K+ low
Scale Media	**NA+ Low**	**K+ High**



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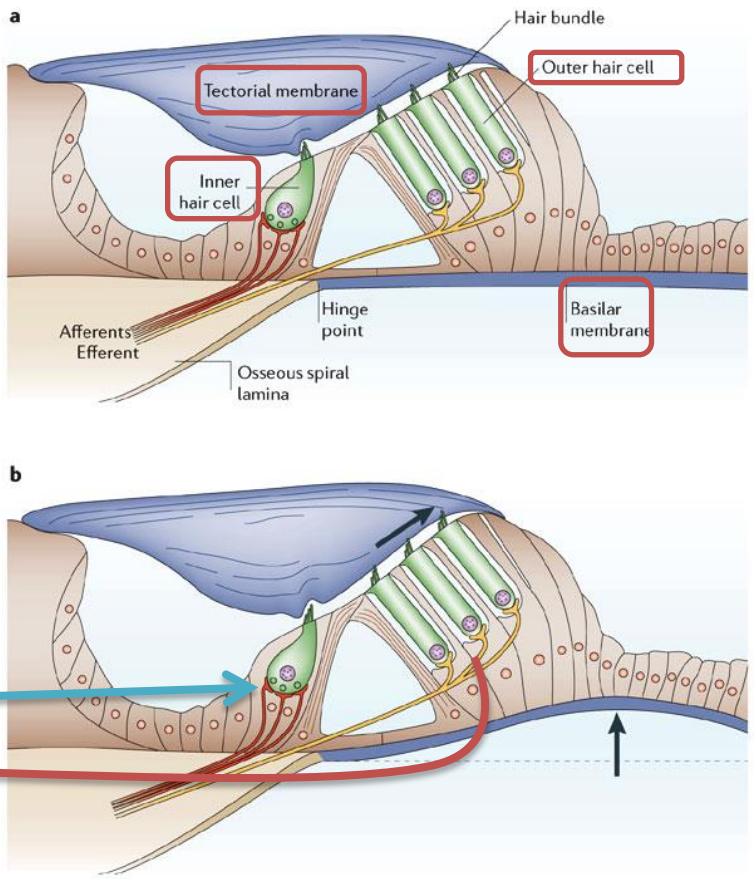
Organ of Corti

- Resting on the **basilar membrane.**
- Extend from base to apex of cochlea.
- Contain inner & outer **hair cells** (Hearing Receptors).
- **The tectorial membrane cover the hair cells**
- The apical (top) surface of the hair cells give raise to projections **(cilia)** :
  - Called **Stereocilia**



The arrangement of the hair cells:

- **One** row of **Inner** hair cell (not attached to tectorial membrane).
- **Three** rows of **Outer** hair cells. (attached to the reticular lamina or tectorial m.)

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Hair Cells

inner hair cells	outer hair cells
Stereocilia **not embedded** in tectorial membrane. but **bent** by fluid movement under the tectorial membrane.	**Large number**, but stimulate only **small** fraction of nerve fibres in the cochlear nerve.
- **primary receptors for sound** - transducing fluid movement in cochlea into action potential in the auditory nerve.	If damaged, significant **loss of hearing** (they control the sensitivity of inner hair cells to particular sound frequency by making the basilar membrane dense or loss)

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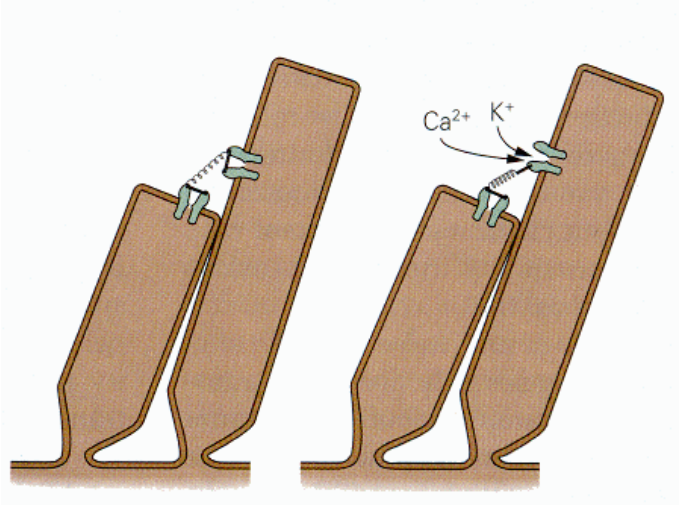
Receptors & Endo-cochlear potentials

Boys Slide

- When sound wave transmission into the inner ear cause upper & lower movements of the reticular membrane (tectorial membrane.) –"although in guyton it's says that the basilar membrane is the one which move".
- Produce bending of steriocillia of the other hair cells alternatively open & close **cation** channels at the tip of the steriocillia.

- *Inward current **(inward movement)**: Depolarization.
- Outward current **(outward movement)**: Hyperpolarisation.
  The net results is depolarization
- The depolarization produce receptors potentials to Release of neurotransmitter → production of **action potentials.**



* د.سلطان قال ان الحركة مالها اتجاه محدد! ولكن اي اتجاه يسوي Depolarization عكسه يسوي Hyperpolarization. فهي تعتمد على وضعية الـ Receptor

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So How Action potential Develop ?

1. We said before that when **Stapes** moves in and out of the **oval window,** The pressure of vibration transmitted through **cochlea** of inner ear.
2. Sound pressure transmuted into the cochlea move the fluid inside (perilymph) and that will **cause upper & lower movements of the basilar membrane.**
3. So when the basilar membrane vibrate the hair cell get **bent** in one direction and then to the other.
4. When the **Stereocilia** get bent toward the others, **(K+ channels)** are opened and that cause the **depolarization** of hair cells and **action potential develop.**
5. when the opposite thing happen , **(K+ channels)** close and hyperpolarization occur**.**
6. Action potential get carried by nerve fibres to the **primary auditory cortex and processing happen there.**

SEE THIS VIDEO FOR BETTER UNDERSTANDING

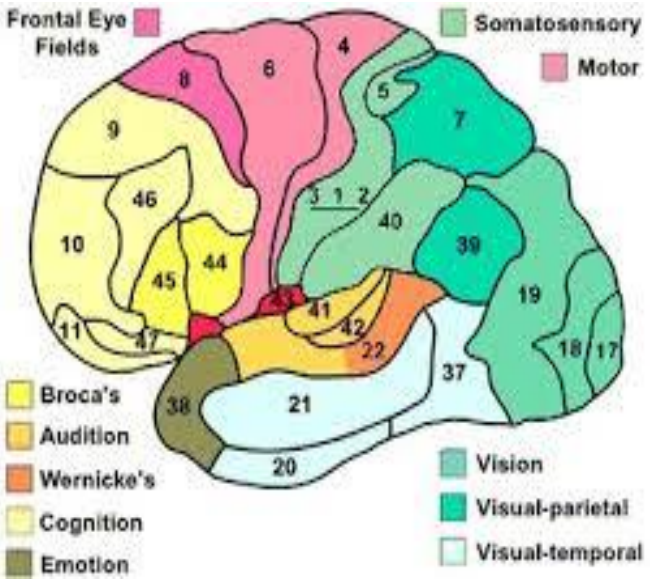
http://www.youtube.com/watch?v=dCyz8-eAs1I

The central Auditory Pathway

- **Begins:** in the organ of corti.
- **End**: in the primary auditory cortex

  (area 41 & 42, superior temporal gyrus in the temporal lobe of the brain)

- Fibres **end** in the primary auditory area, where it is heard, then interpretation occurs in the **auditory association areas** (Wernicke's area 22)



Note: There is a **bilateral cortical connection** of auditory area thus damage to one side only **slightly reduces hearing**.

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Sounds Localization

Mechanism of sounds localization:

1. By detecting the **differences** in the **time arrival** of the sound wave at the ears (time-lag).
2. By detecting the differences in **the loudness (intensity).**

Masking effect:

- Presence of background noise affect the ability to hear another sound, due to some receptors are in **refractory period**.(1) **.** This phenomenon is known as **masking.**
- (the new wave unable to stimulate the hair cells because it is occupied by previous wave)
- Masking is **more clear** if two sound are having the same **frequencies.**
- Noise pollution is an environmental hazard
- Exposure to sound intensity above 80dB may damage outer hair cells

Note

The wave inter cochlea through oval window but the **Releasing (ending)** occurs in the round window of inner ear.

(1) **Refractory period:** The period immediately following the transmission of an impulse in nerve in which a neuron still regains its ability to transmit another impulse.

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Conduction of sound wave

There is two type of conduction:

1- Air conduction:

- Cause: Travel of sound in the air causes vibration of tympanic membrane, the wave get transmited by the ossicles to oval window.
- Example : **Normal situation of hearing.**

2- Bone conduction:

- Cause: the sound will cause vibration of the skull bone directly transmitting the sound vibration to the cochlea .
- Example : Placing tuning fork on the head or mastoid bone.

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Deafness

	1- Conductive deafness	2-Perceptive deafness
Definition	Impairment of sound transmission through **external** or **middle** ear.	Due to congenital or damage to **cochlea** or **auditory nerve pathway**
Causes	1. Wax. 2. Repeated infection. 3. Perforated drum. 4. Destruction of Ossicles. 5. Osteosclerosis (pathological fixation of stapes on the oval window)	1. Toxins (antibiotic : gentamycin). 2. Inflammation. 3. Tumor 4. vascular
Sound effected	All sound frequencies are equally affected	_____
Extra	**Bone conduction** is better than air conduction	Both air and bone conduction are affected (complete deafness)

Note: in old people with low Ca+ that will cause osteoporosis in ossicles which reduce hearing

Test of Hearing

- **Audiometer.**
- **Weber test.**
- **Rinnes test.**

Steps of Rinnes test :

1. The base of the tuning fork placed on mastoid process until the sound is not heard.
2. Then the prongs of the fork held in air near the ear

- Normal subject continue to hear near ear **(positive test)**
- If not reveres the test (if heard near the mastoid process, **negative test**)

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Test of Hearing

Boys Slide

Table 9–1. Common Tests with a Tuning Fork to Distinguish between Nerve and Conduction Deafness.

	Weber	Rinne	Schwabach
Method	Base of vibrating tuning fork placed on vertex of skull.	Base of vibrating tuning fork placed on mastoid process until subject no longer hears it, then held in air next to ear.	Bone conduction of patient compared with that of normal subject.
Normal	Hears equally on both sides.	Hears vibration in air after bone conduction is over.	
Conduction deafness (one ear)	Sound louder in diseased ear because masking effect of environmental noise is absent on diseased side.	Vibrations in air not heard after bone conduction is over.	Bone conduction better than normal (conduction defect excludes masking noise).
Nerve deafness (one ear)	Sound louder in normal ear.	Vibration heard in air after bone conduction is over, as long as nerve deafness is partial.	Bone conduction worse than normal.

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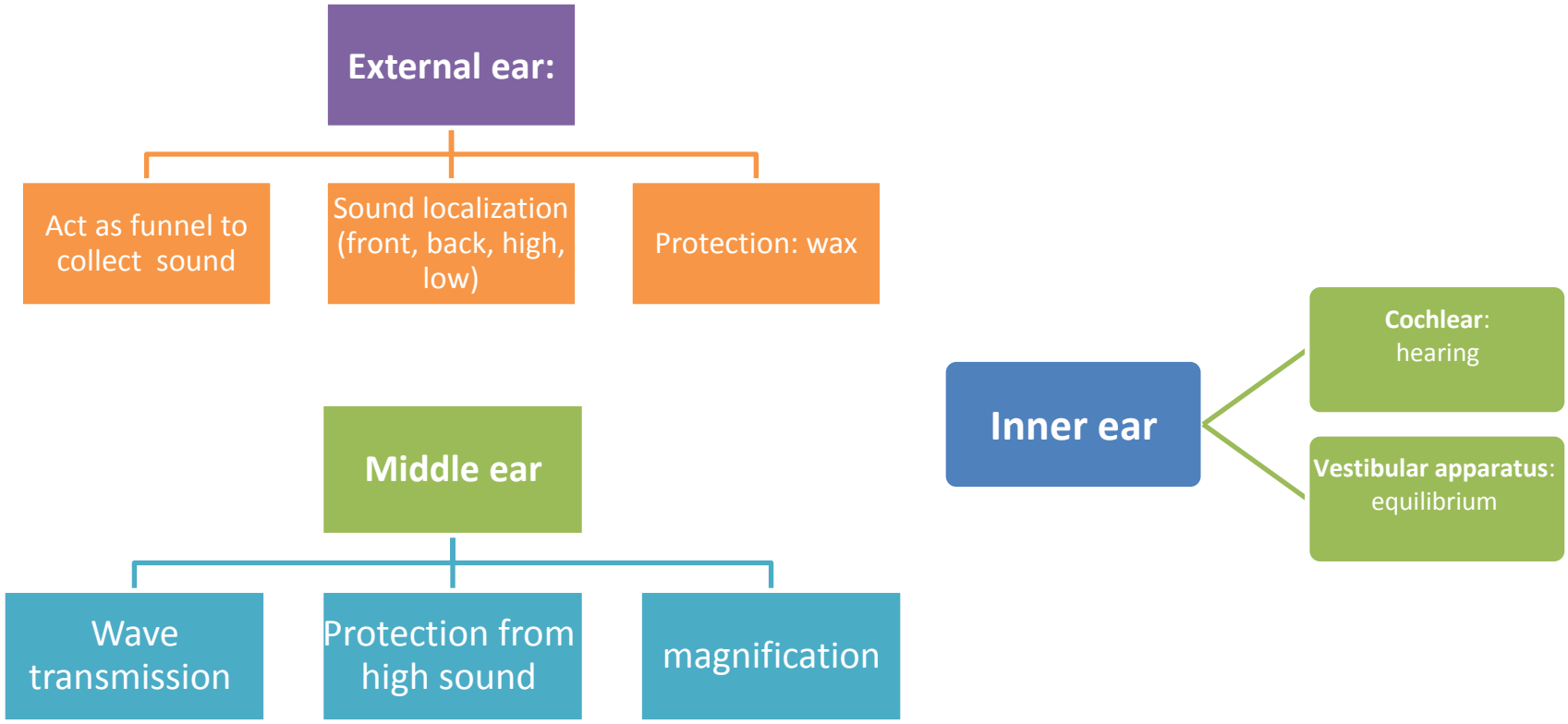
SUMMARY



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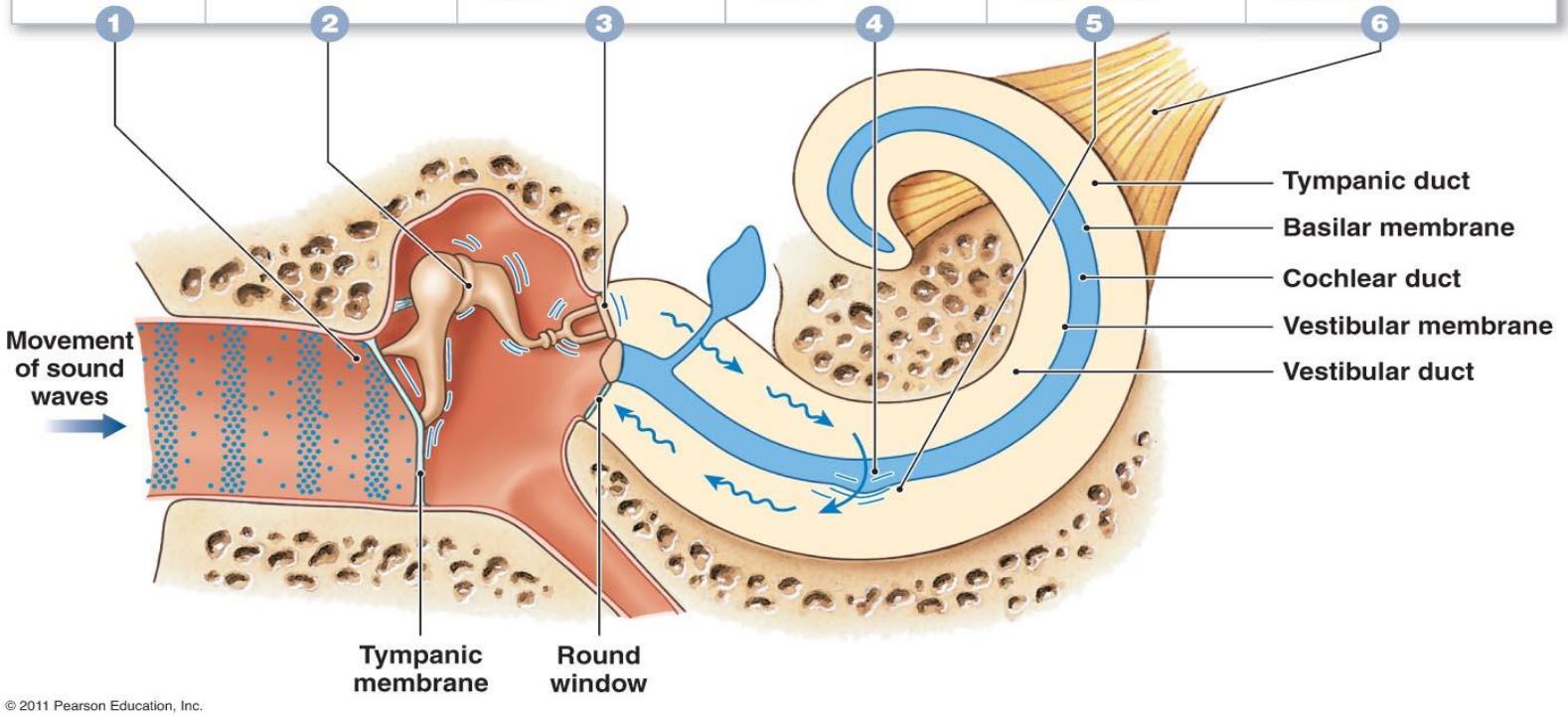
SUMMARY

Events Involved in Hearing					
Sound waves arrive at the tympanic membrane.	Movement of the tympanic membrane causes displacement of the auditory ossicles.	Movement of the stapes at the oval window establishes pressure waves in the perilymph of the vestibular duct.	The pressure waves distort the basilar membrane on their way to the round window of the tympanic duct.	Vibration of the basilar membrane causes vibration of hair cells against the tectorial membrane.	Information about the region and the intensity of stimulation is relayed to the CNS over the cochlear branch of cranial nerve VIII.



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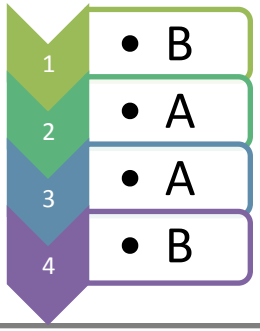
QUESTIONS

- **Q1: Which one is the primary receptor of hearing?**
  A. Outer hair cells
  B. Inner hair cells

- **Q2: How many time the sound waves magnified by the middle ear?**
  A. 22
  B. 17

- **Q3: The primary auditory cortex?**
  A. area 41 & 42
  B. wernicke's area 22

- **Q4: Complete defness due to?**
  A. Osteosclerosis
  B. Congenital



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THE END

If there are any Problems or Suggestions,
Feel free to contact:

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THANK YOU