

Общая физиология  
сенсорных систем. Слуховой  
анализатор

## ОБЪЕКТИВНАЯ СЕНСОРНАЯ ФИЗИОЛОГИЯ

явления в  
окружающей  
среде

сенсорные  
стимулы

возбуждение  
сенсорных  
нейронов

интеграция  
в ЦНС

рецепторы,  
подпороговый  
рецепторный  
потенциал

возбуждение  
сенсорных  
центров мозга

взаимодействие  
с сенсорными  
органами

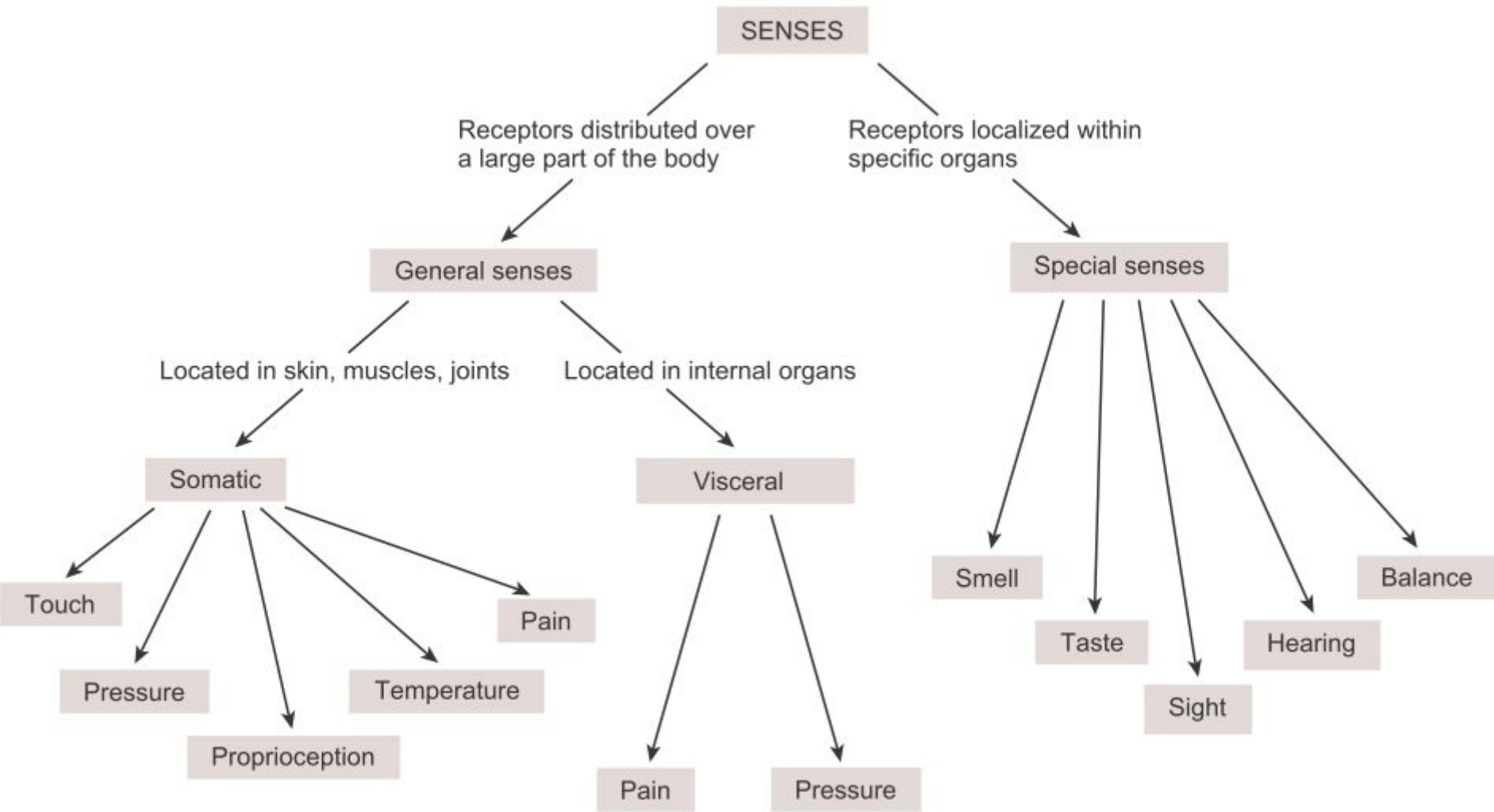
## СУБЪЕКТИВНАЯ СЕНСОРНАЯ ФИЗИОЛОГИЯ

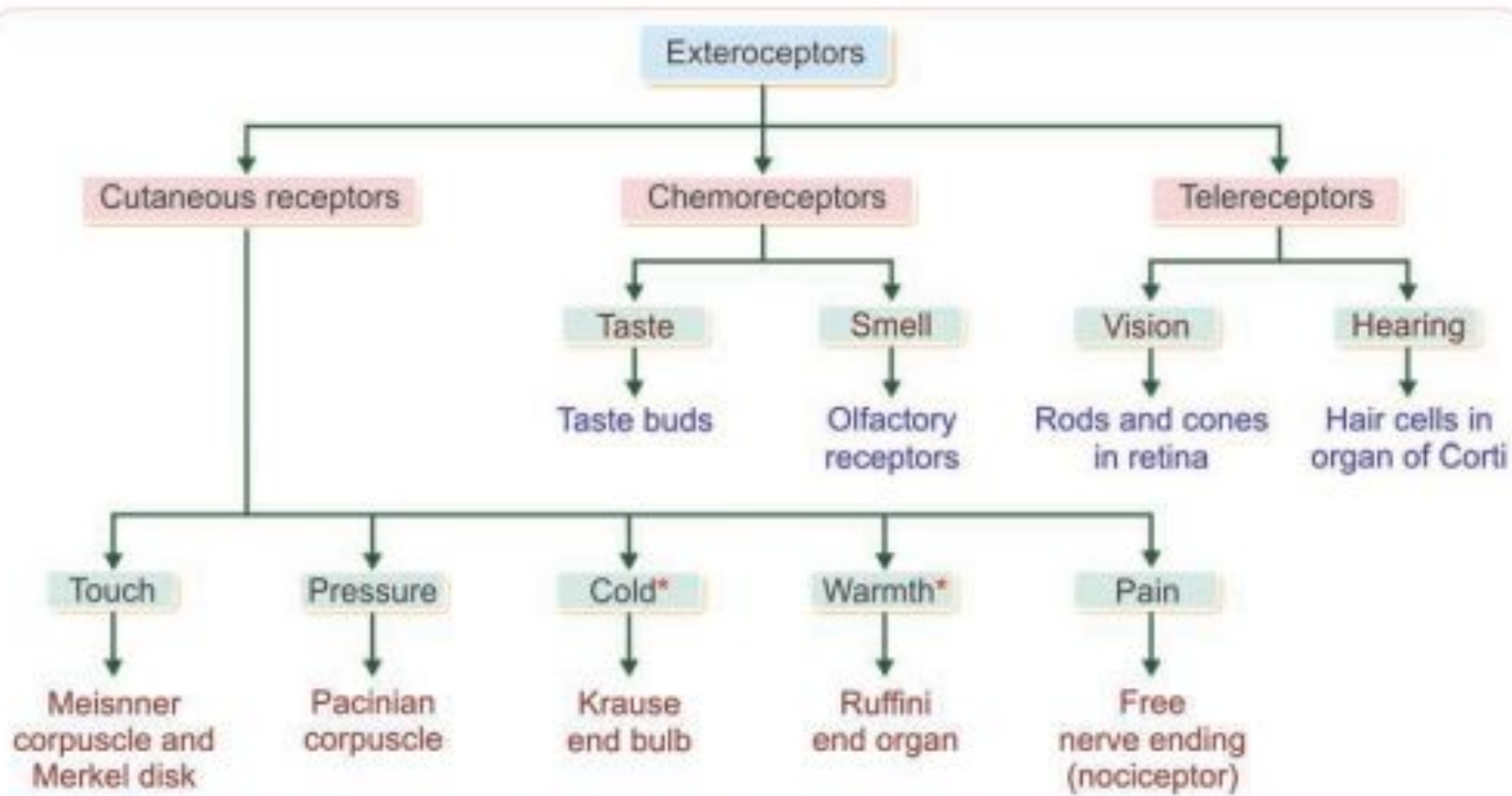
сенсорные  
ощущения

восприятие

испытуемый

испытываемый  
(опыт, мотивация,  
особенности  
личности)





\*Receptors of cold and warmth are together called temperature receptors (thermoreceptors)

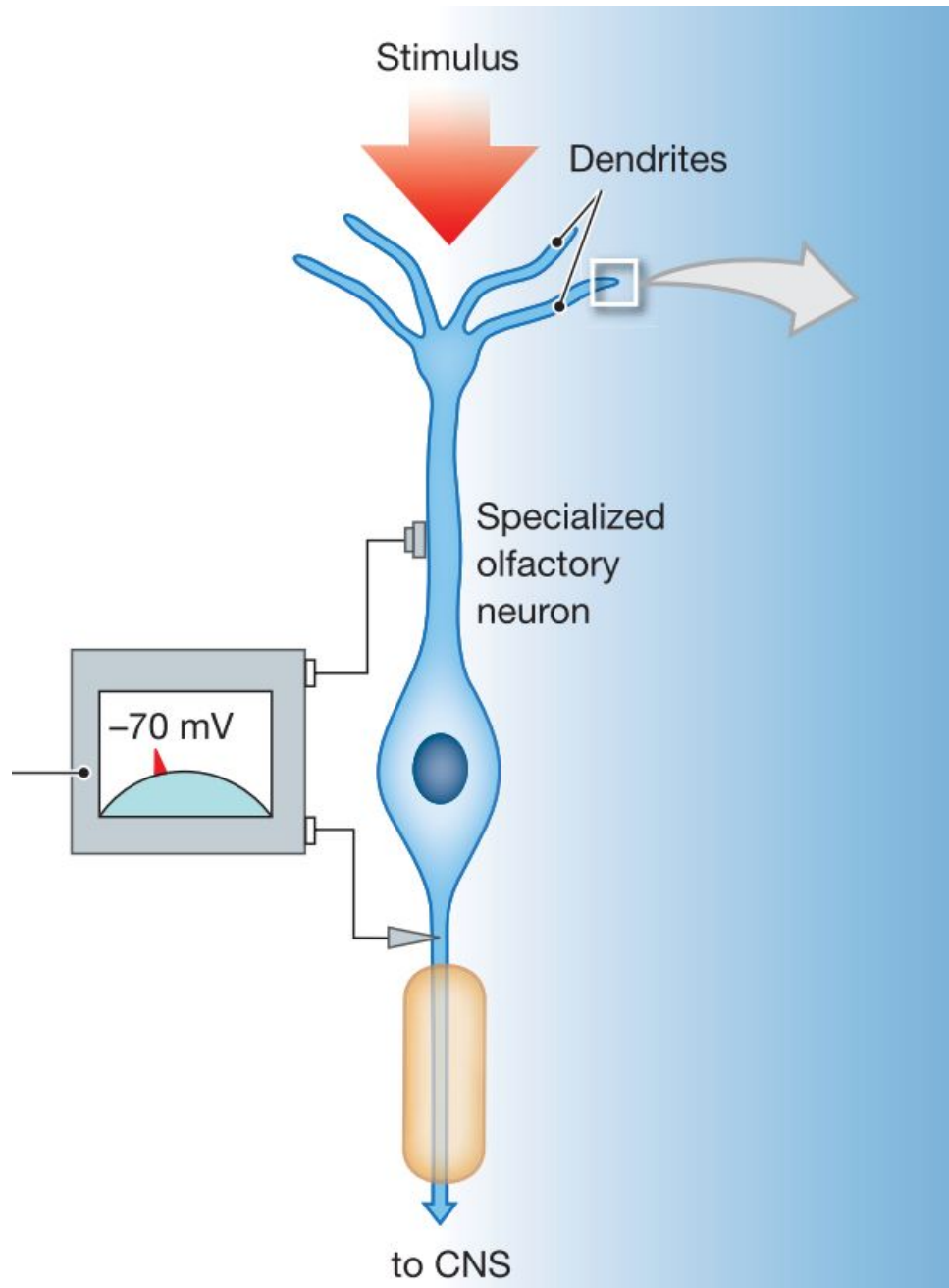
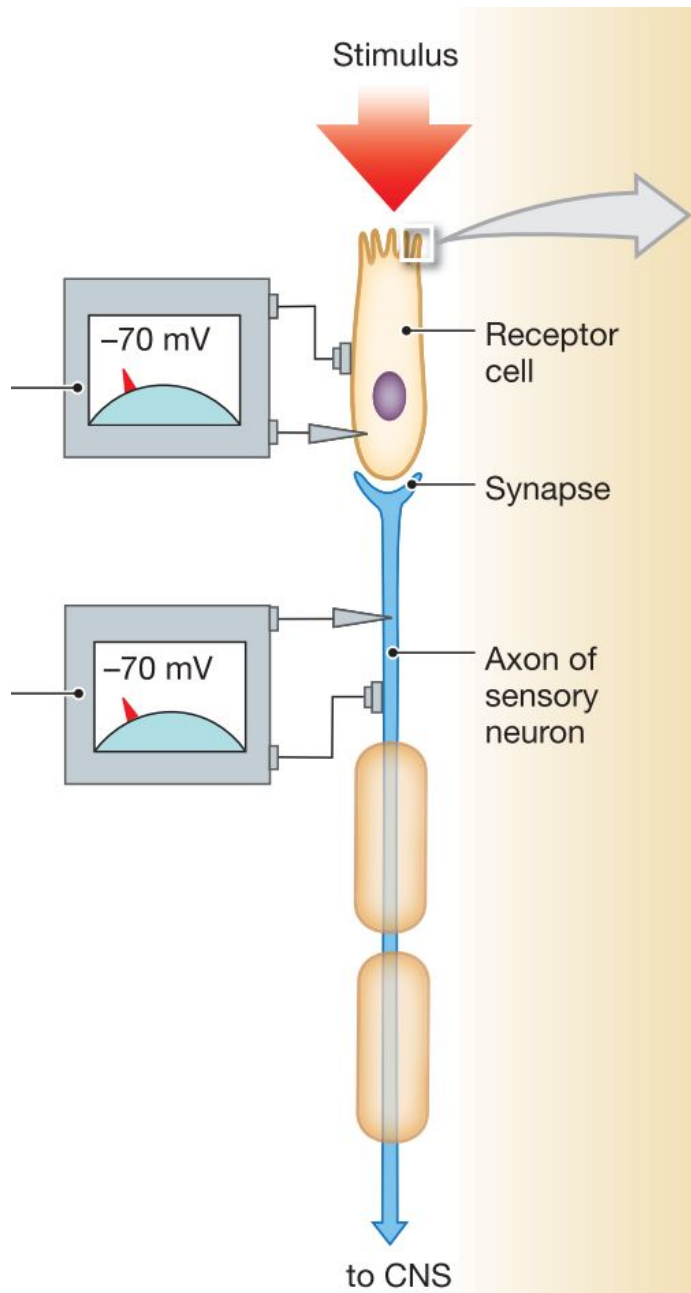
## Interoceptors

### Visceroceptors

Receptors	Situation
1. Stretch receptors	Heart
2. Baroreceptors	Blood vessels
3. Chemoreceptors	GI tract
4. Osmoreceptors	Urinary tract
	Brain

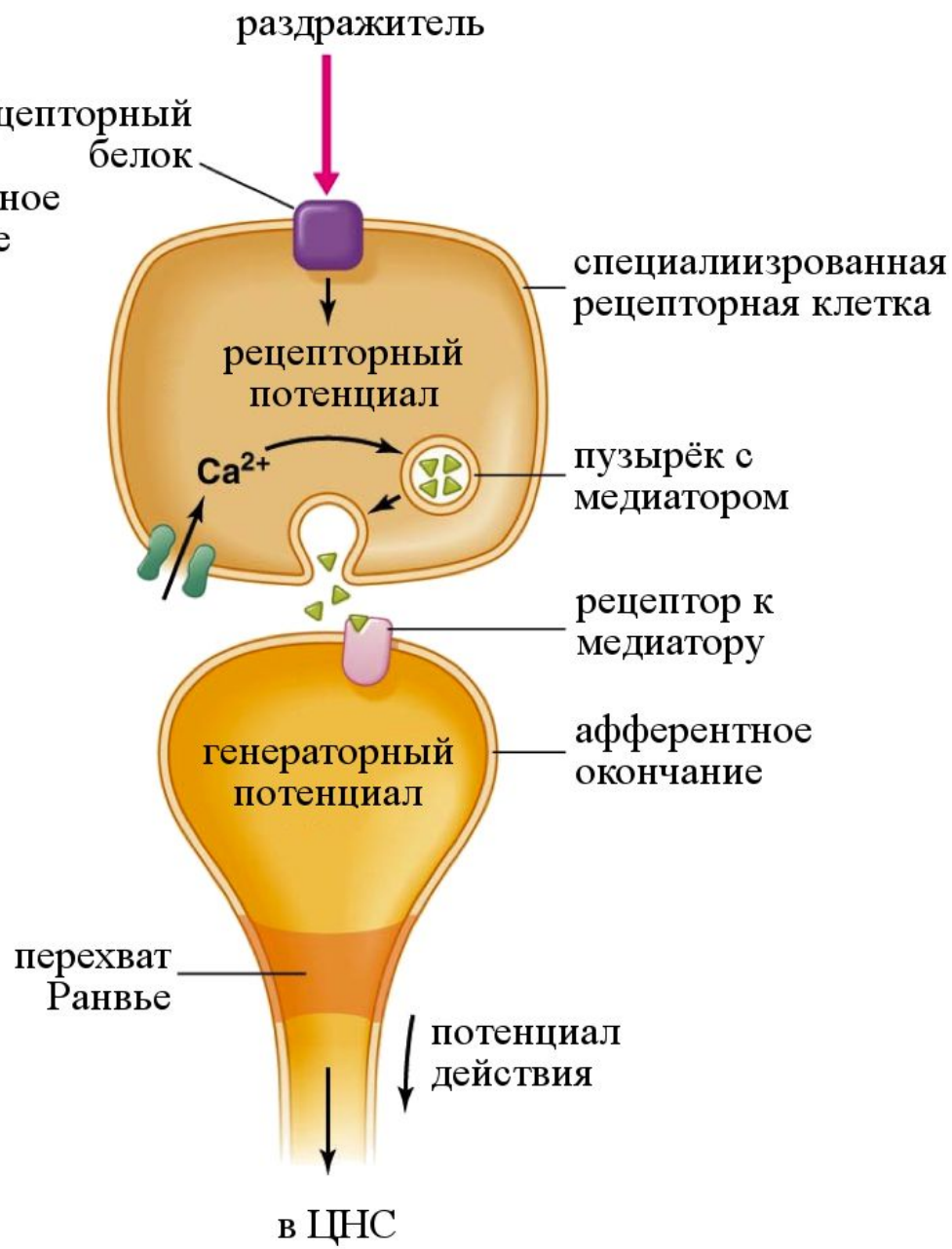
### Proprioceptors

Receptors	Situation
1. Muscle spindle	Muscle
2. Golgi tendon organ	Tendon
3. Pacinian corpuscle	Ligament
4. Free nerve ending	Facia
	Joint
5. Hair cells	Vestibular apparatus

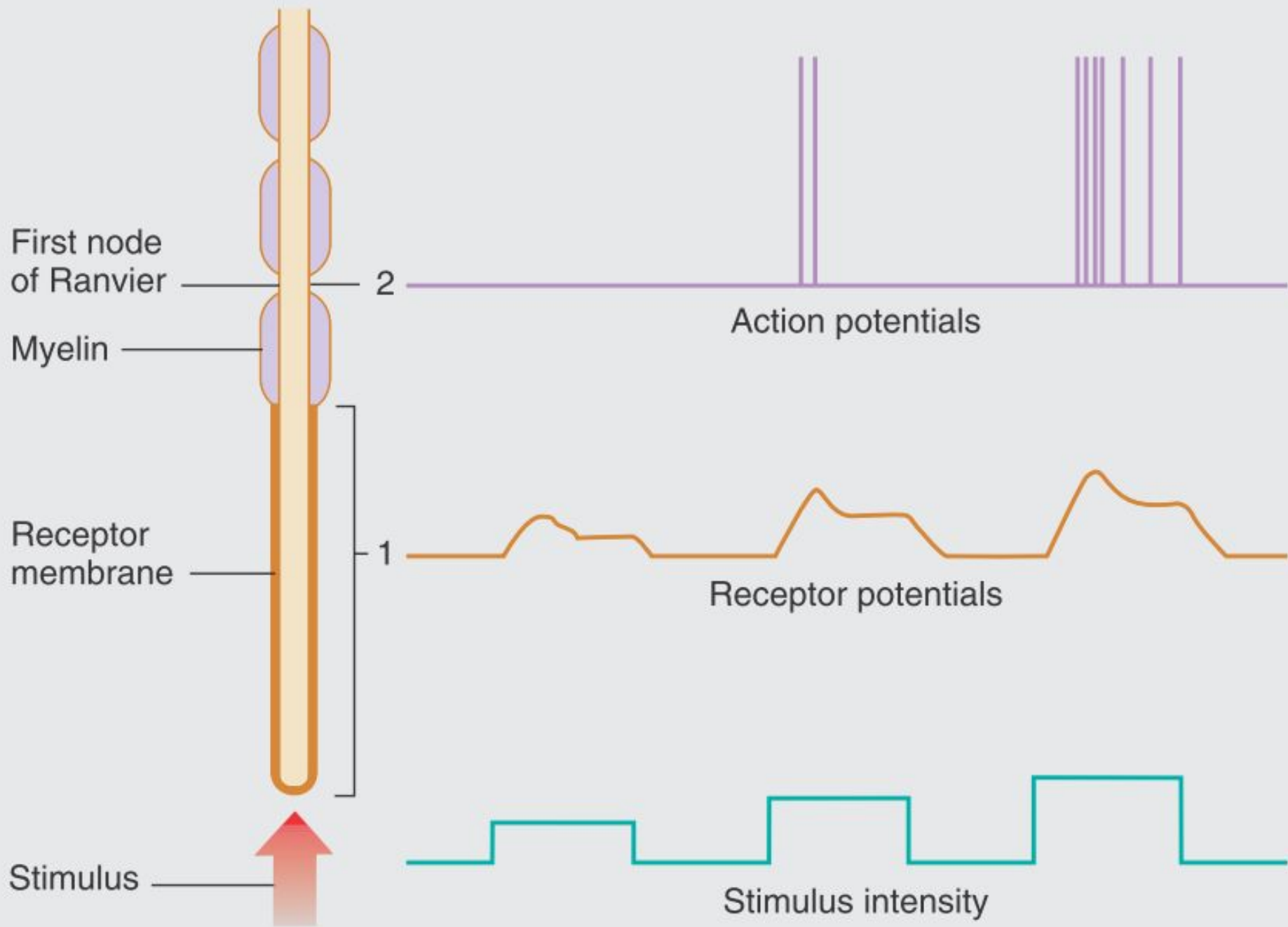




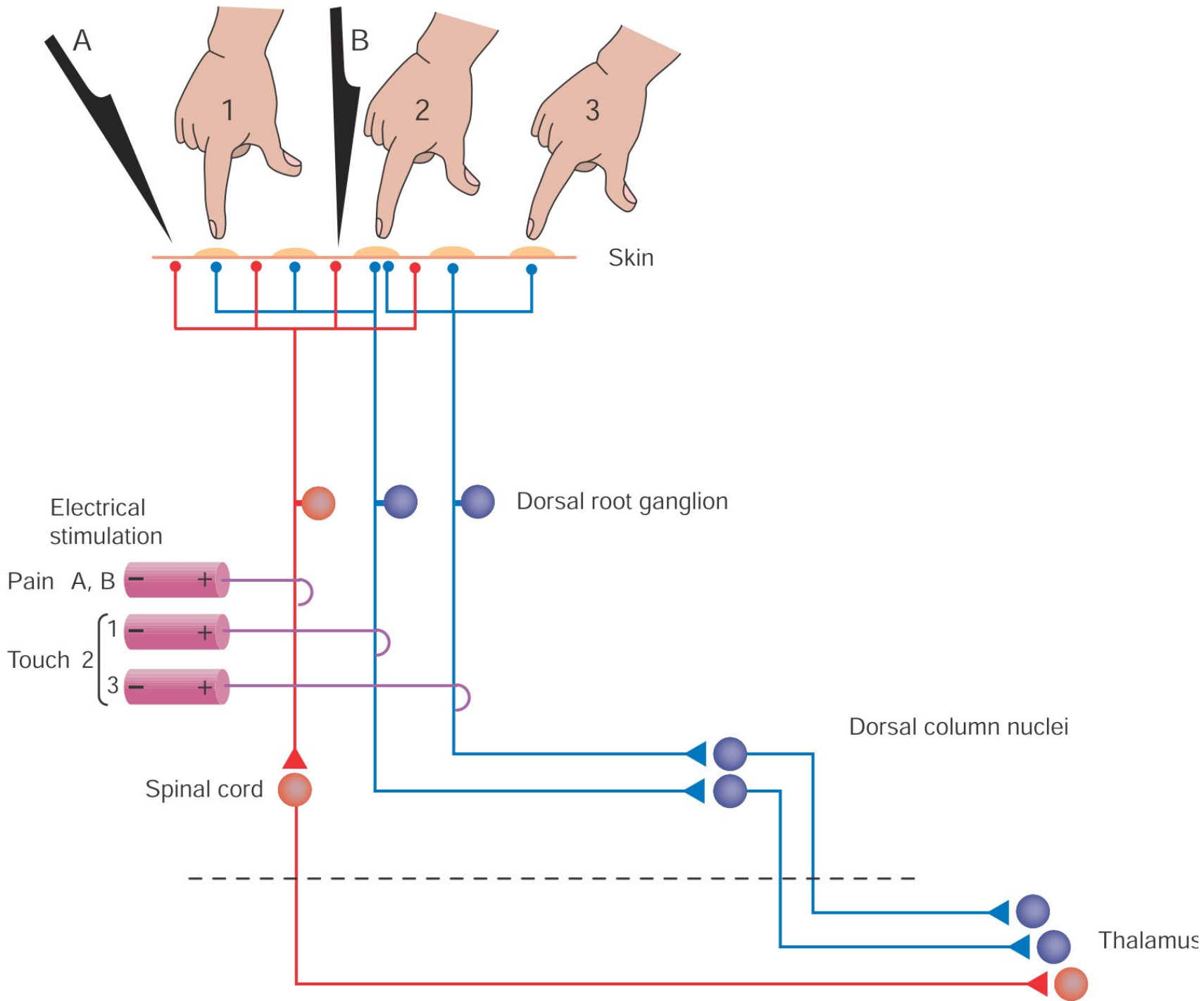
**(a) ПЕРВИЧНЫЙ РЕЦЕПТОР**



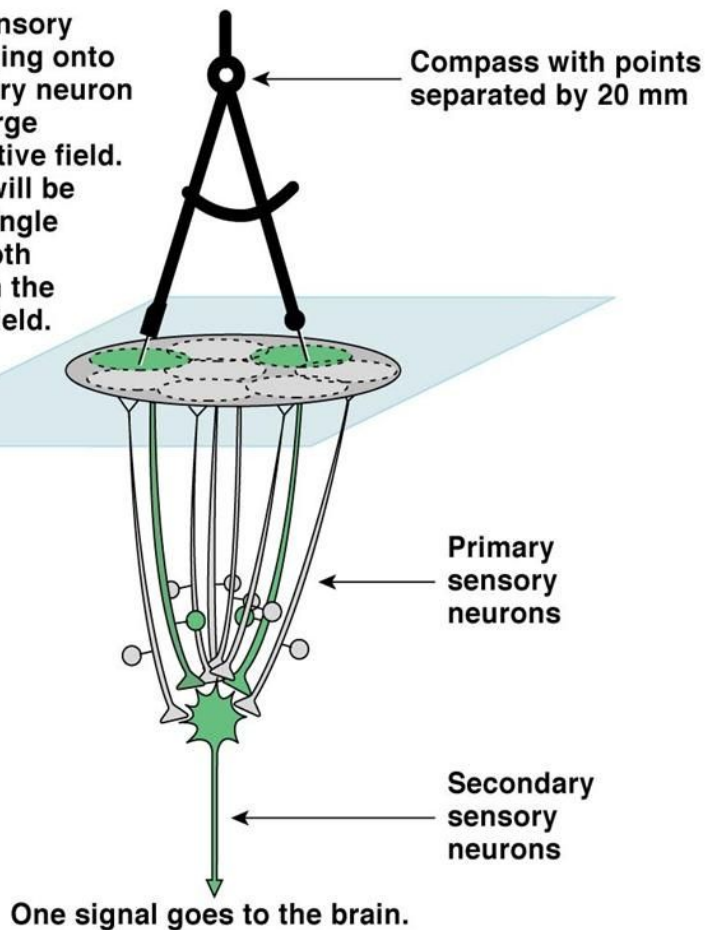
**(b) ВТОРИЧНЫЙ РЕЦЕПТОР**



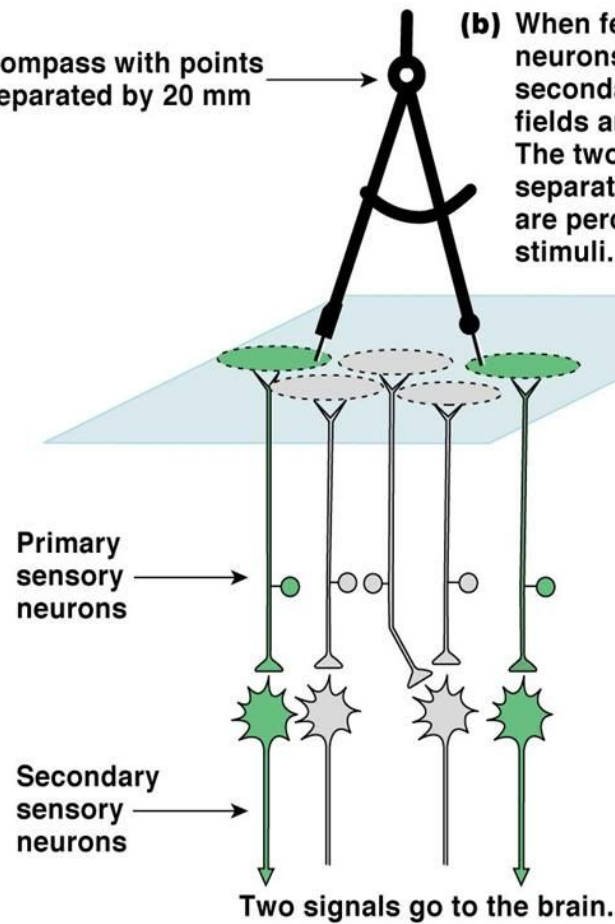




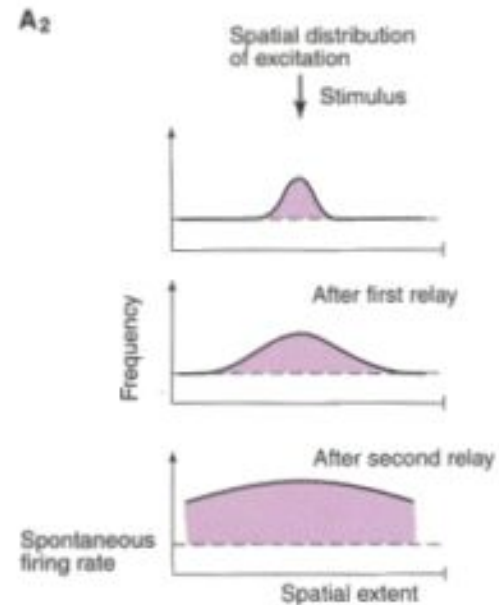
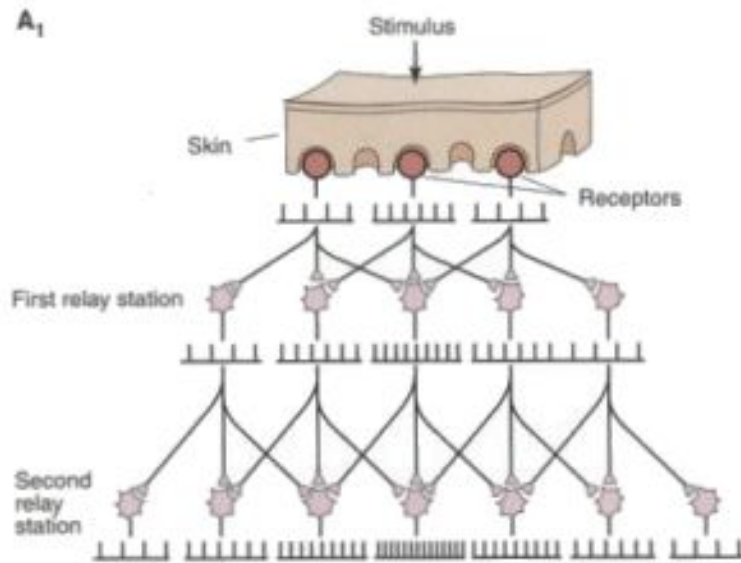
**(a)** Many primary sensory neurons converging onto a single secondary neuron creates a very large secondary receptive field. The two stimuli will be perceived as a single point because both stimuli fall within the same receptive field.



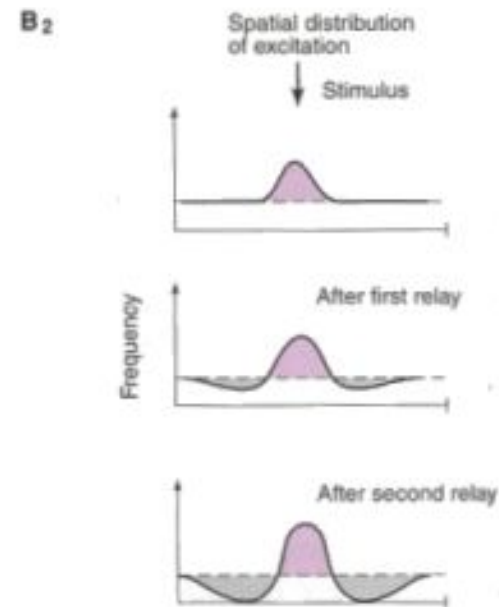
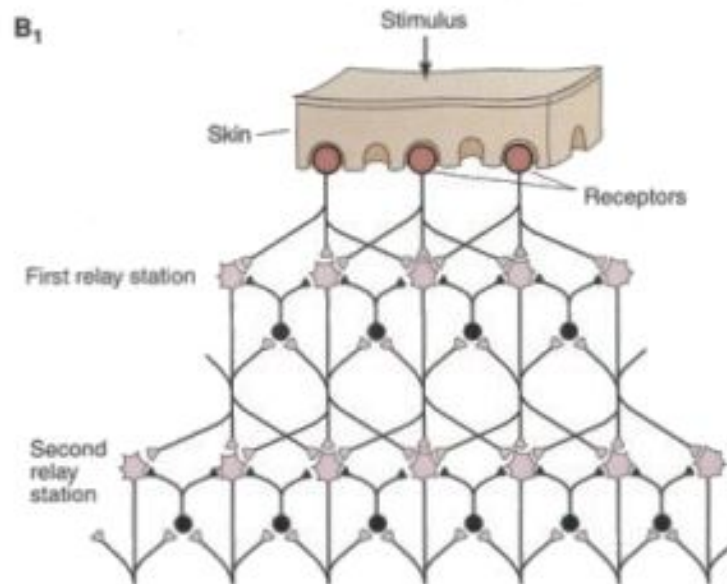
**(b)** When fewer primary neurons converge, secondary receptive fields are much smaller. The two stimuli activate separate pathways and are perceived as distinct stimuli.



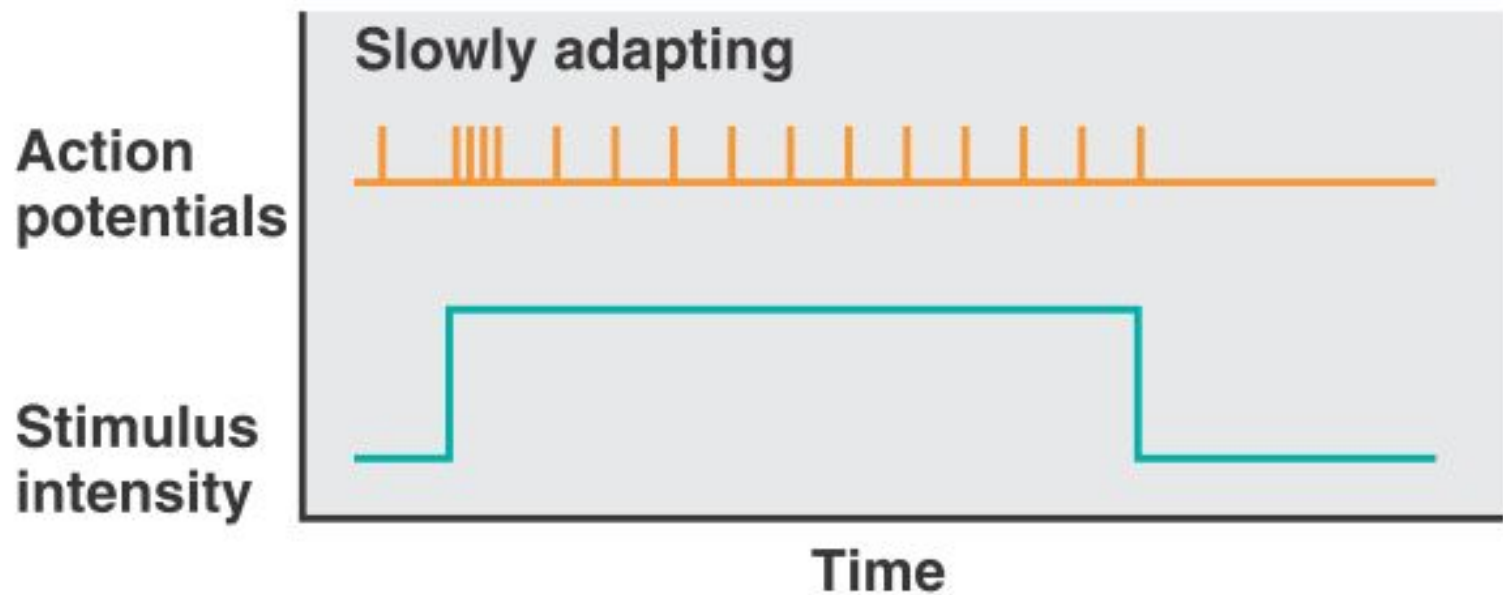
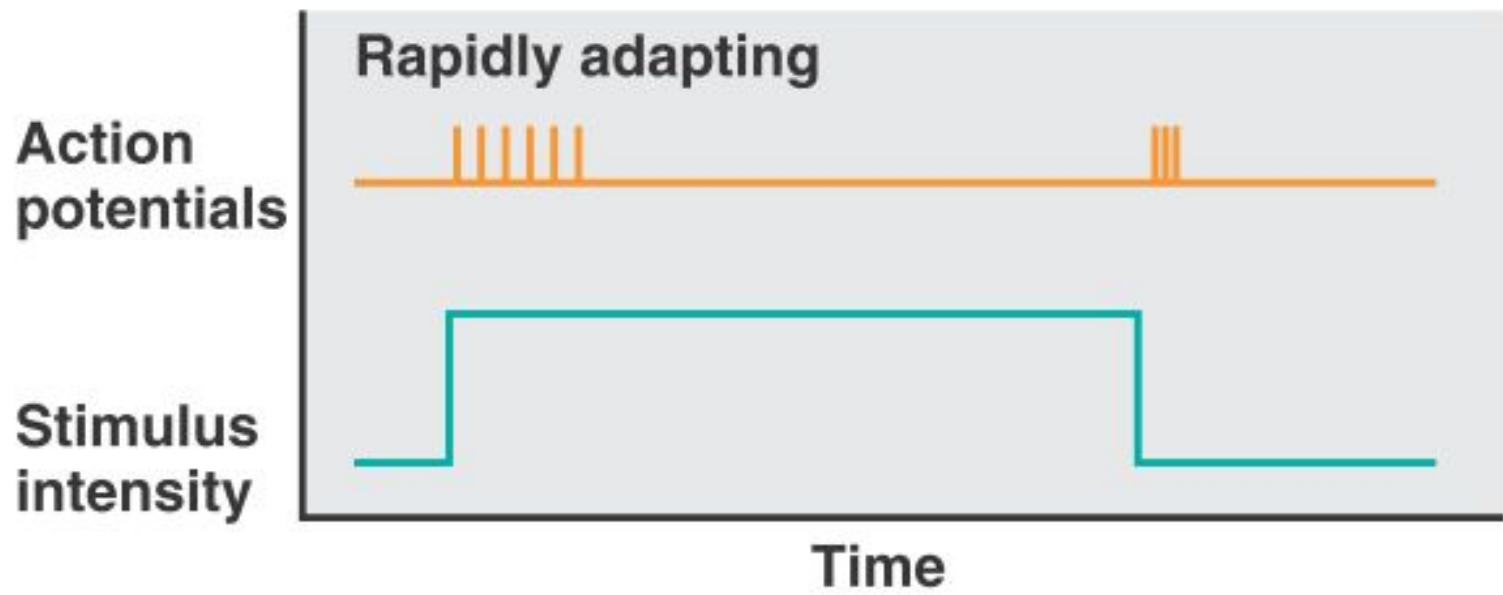
# Without Lateral Inhibition

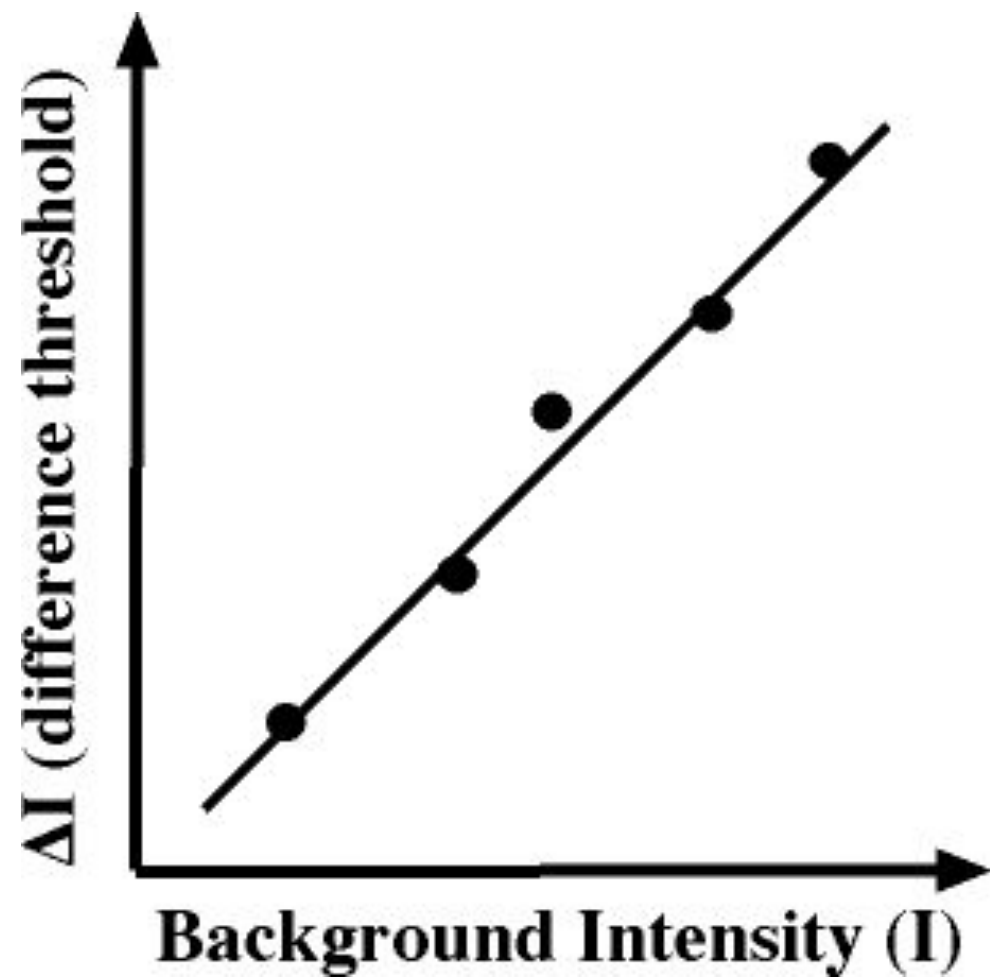


# With Lateral Inhibition



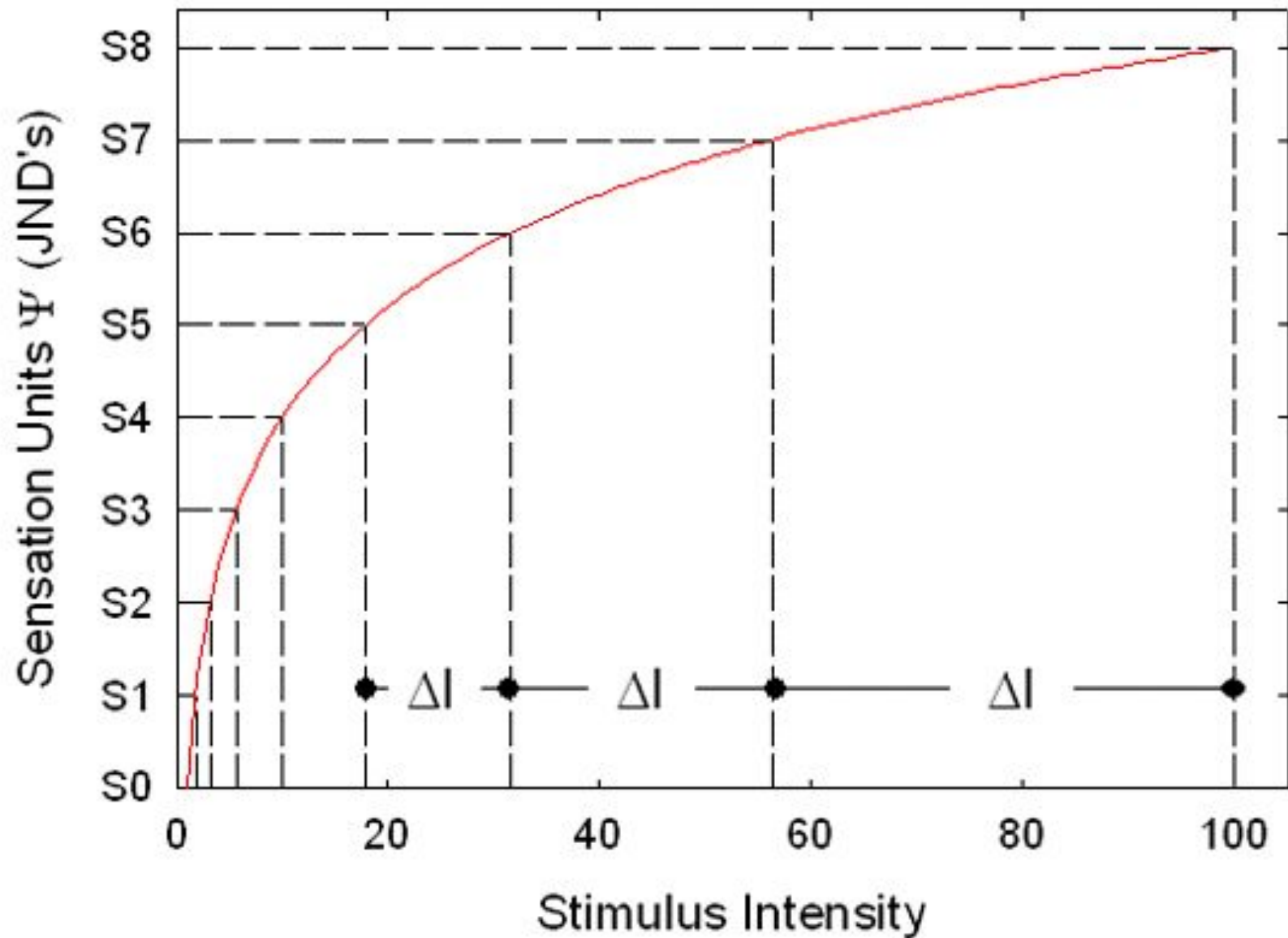
Adapted from Kandel, E. R., Schwartz, J. H., et al. (1995).  
Essentials of neural science and behavior. Stamford, CT, Appleton & Lange.





$$\frac{\Delta I}{I} = \text{const.}$$

# Fechner's Law: $\Psi = k \log I$



# Закон Вебера - Фехнера

$$S = k \cdot \lg(J/J_0)$$

**S** – величина ощущения человека  
(интенсивность ощущения)

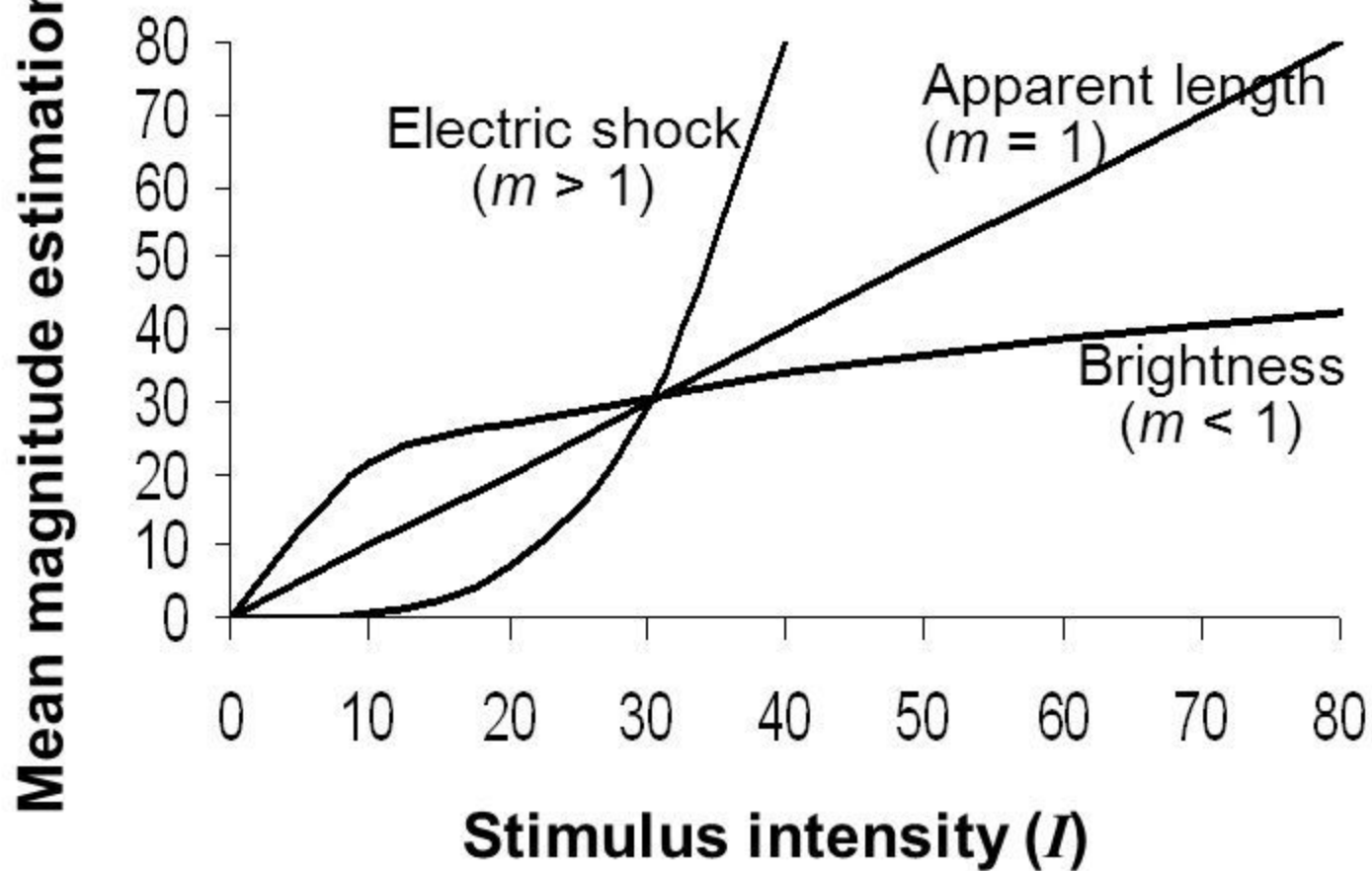
**k** – коэффициент пропорциональности

**J** – уровень (значение) раздражителя

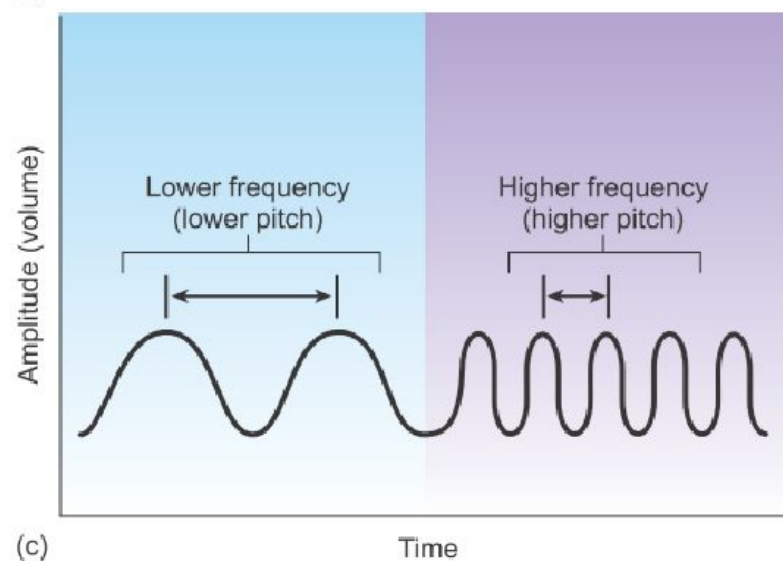
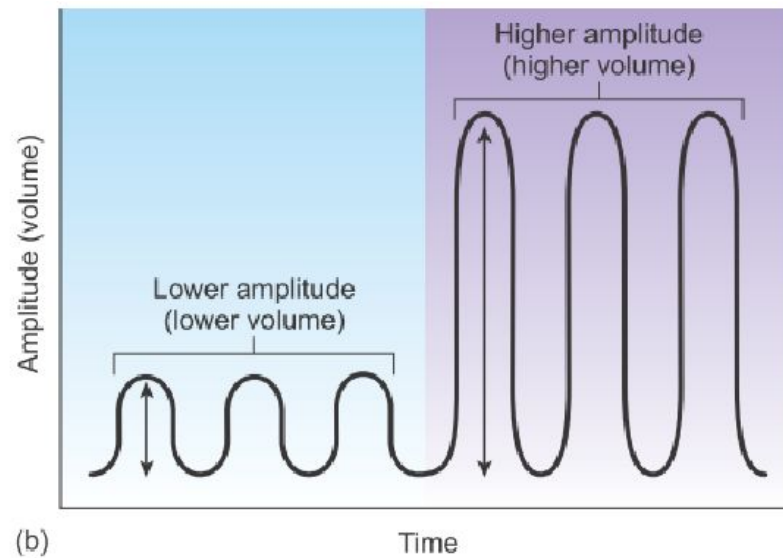
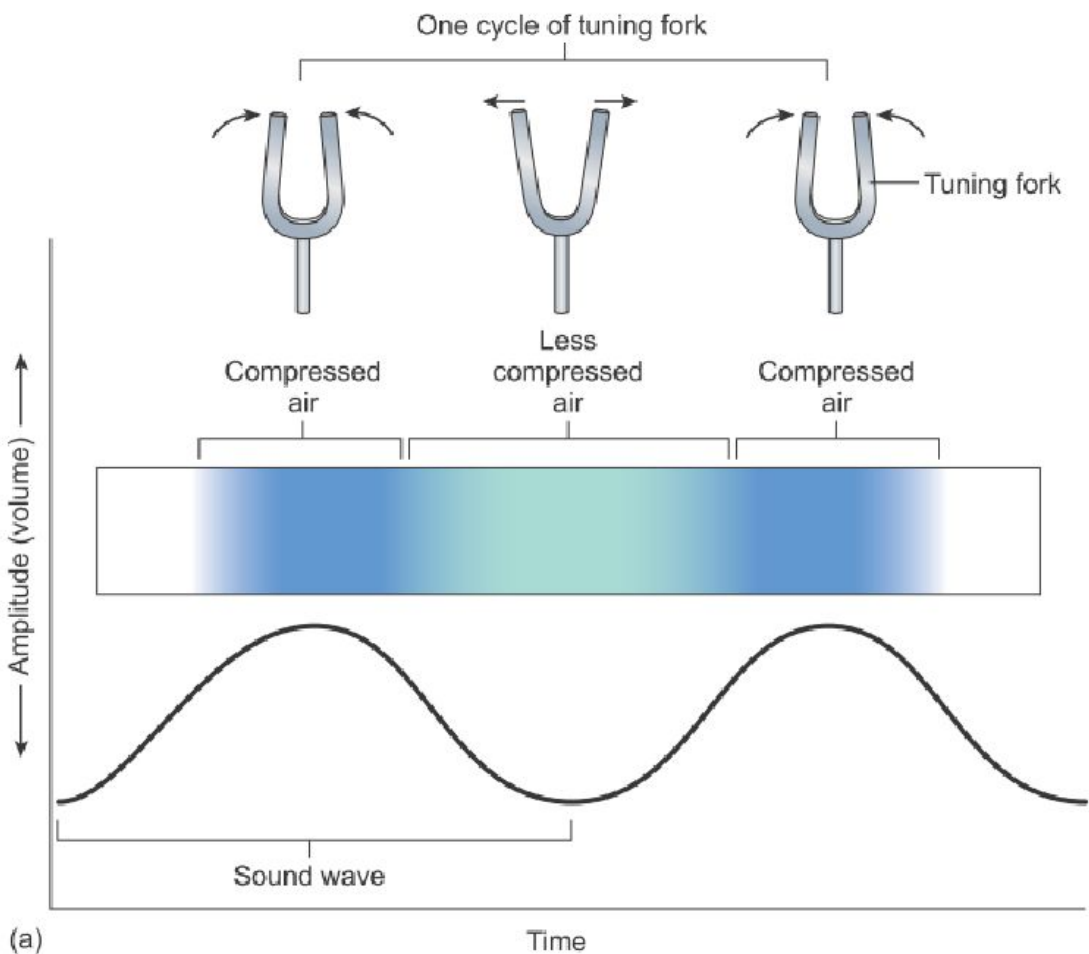
**J<sub>0</sub>** – пороговый осязаемый уровень  
раздражителя

# Psychophysical Function

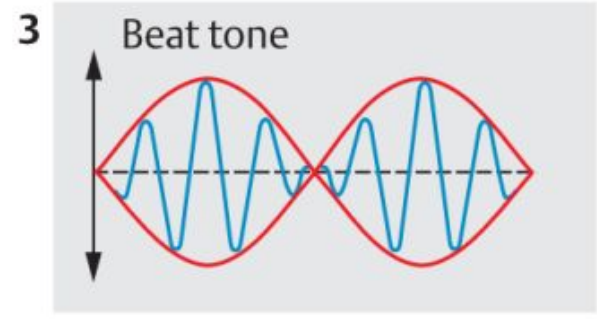
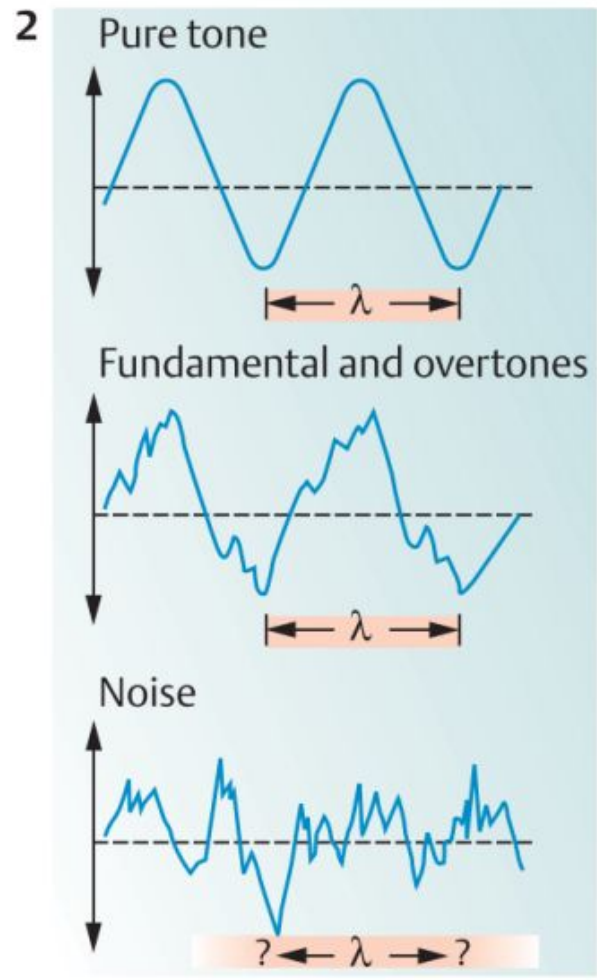
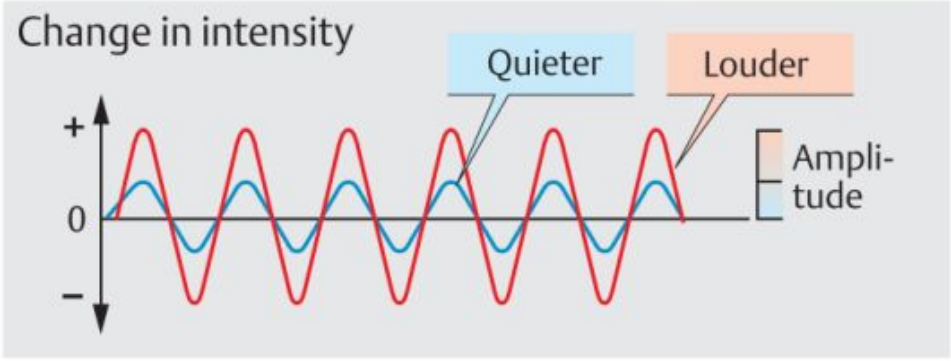
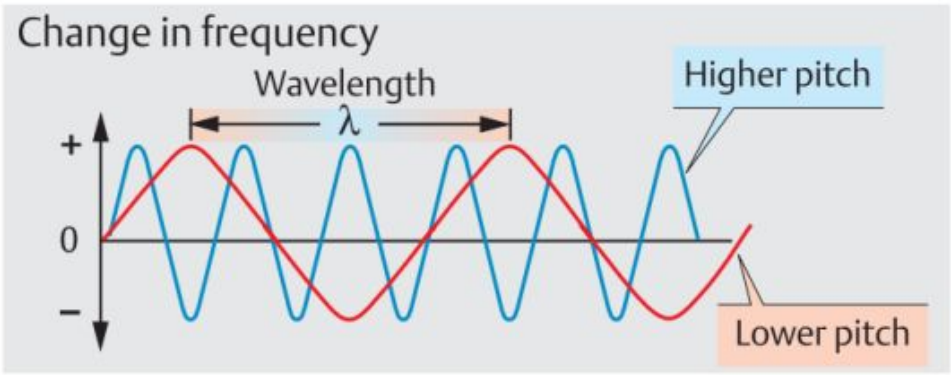
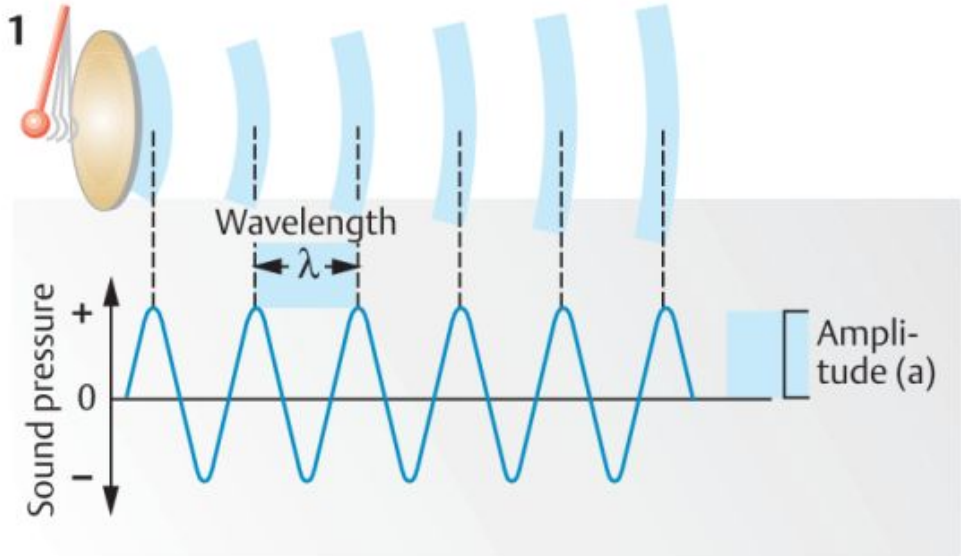
## Stevens' Power Law: $S = aI^m$





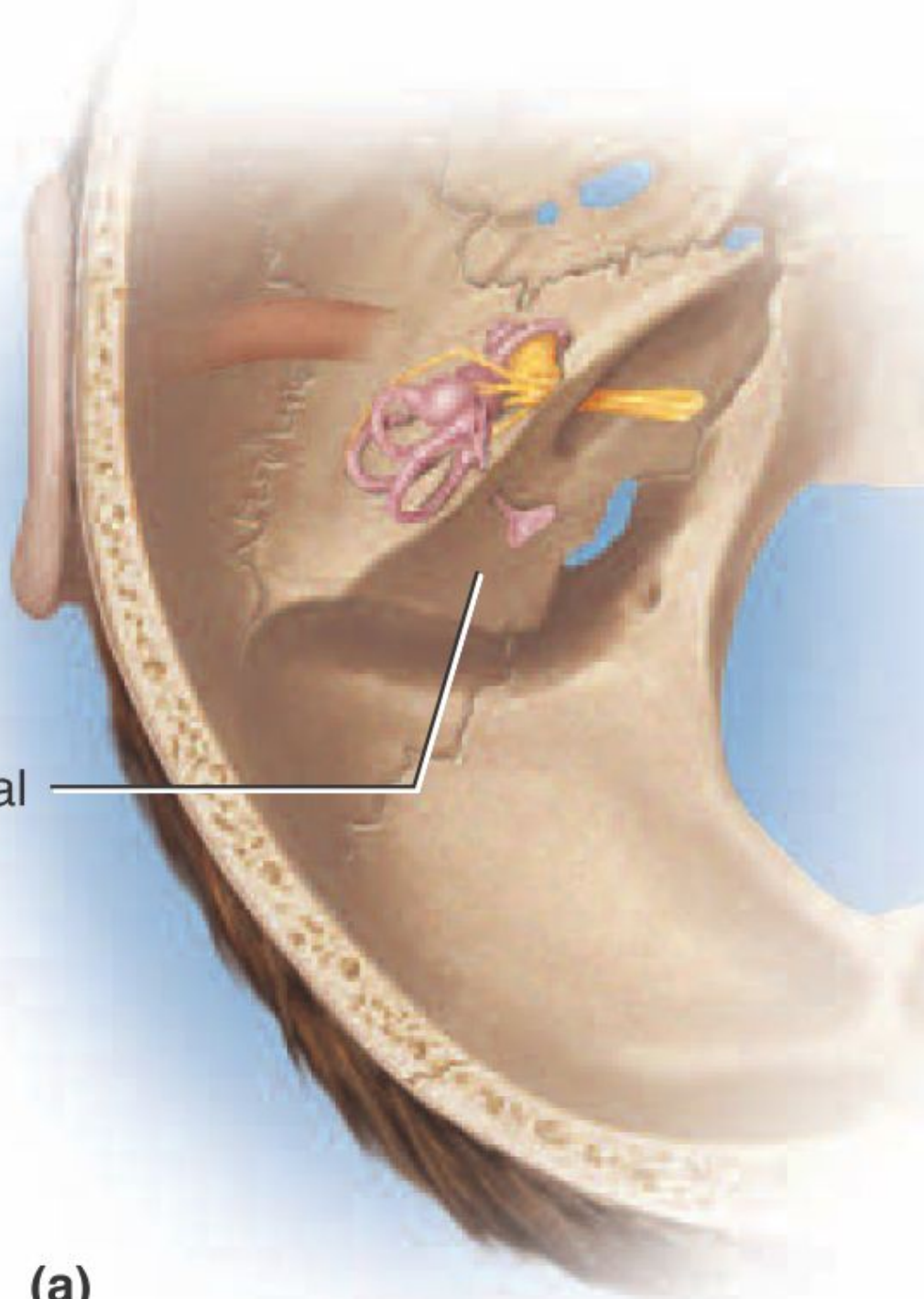


# A. Wavelength, wave amplitude and wave types



Temporal  
bone

(a)



## Outer ear

**Ceruminous glands** secrete **cerumen** (earwax), which protects ear from foreign objects.

**Auricle** collects sound waves and directs them to external auditory canal.

**External auditory canal** directs sound waves to eardrum (tympanic membrane).

**Eardrum (tympanic membrane)** vibrates with incoming sound waves.

Temporal bone

Elastic cartilage

## Middle ear

**Auditory ossicles** transmit vibrations to **oval window** of inner ear (**Malleus, incus, stapes**).

## Inner ear

**Semicircular canals** are also involved in balance.

**Vestibule** contains two sacs involved in balance (**utricle, saccule**).

**Vestibulocochlear (VIII) nerve** transmits nerve impulses to brain:

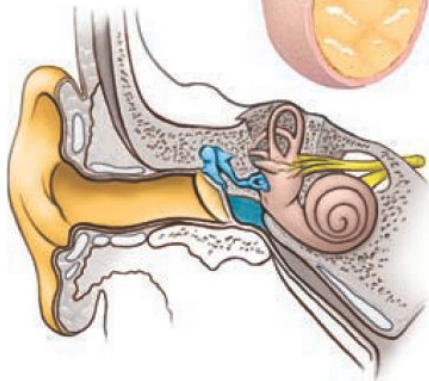
- Vestibular branch
- Cochlear branch

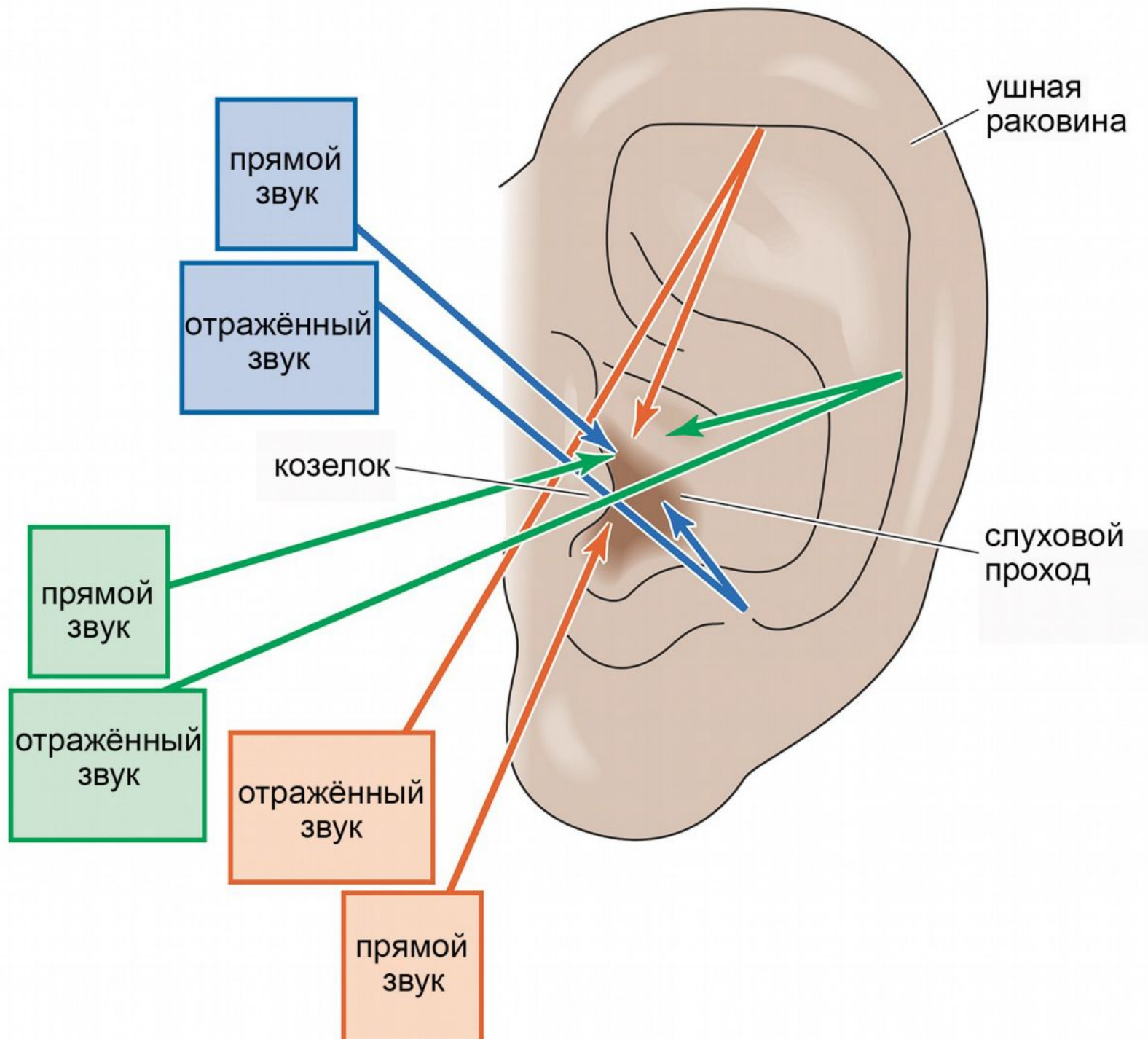
**Cochlea** connects fluid pressure waves into action potentials.

**Round window** eliminates the sound waves that have been heard.

**Auditory (eustachian) tube** connects middle ear with nasopharynx and equalizes air pressure behind eardrum.

- Outer ear
- Middle ear
- Internal ear



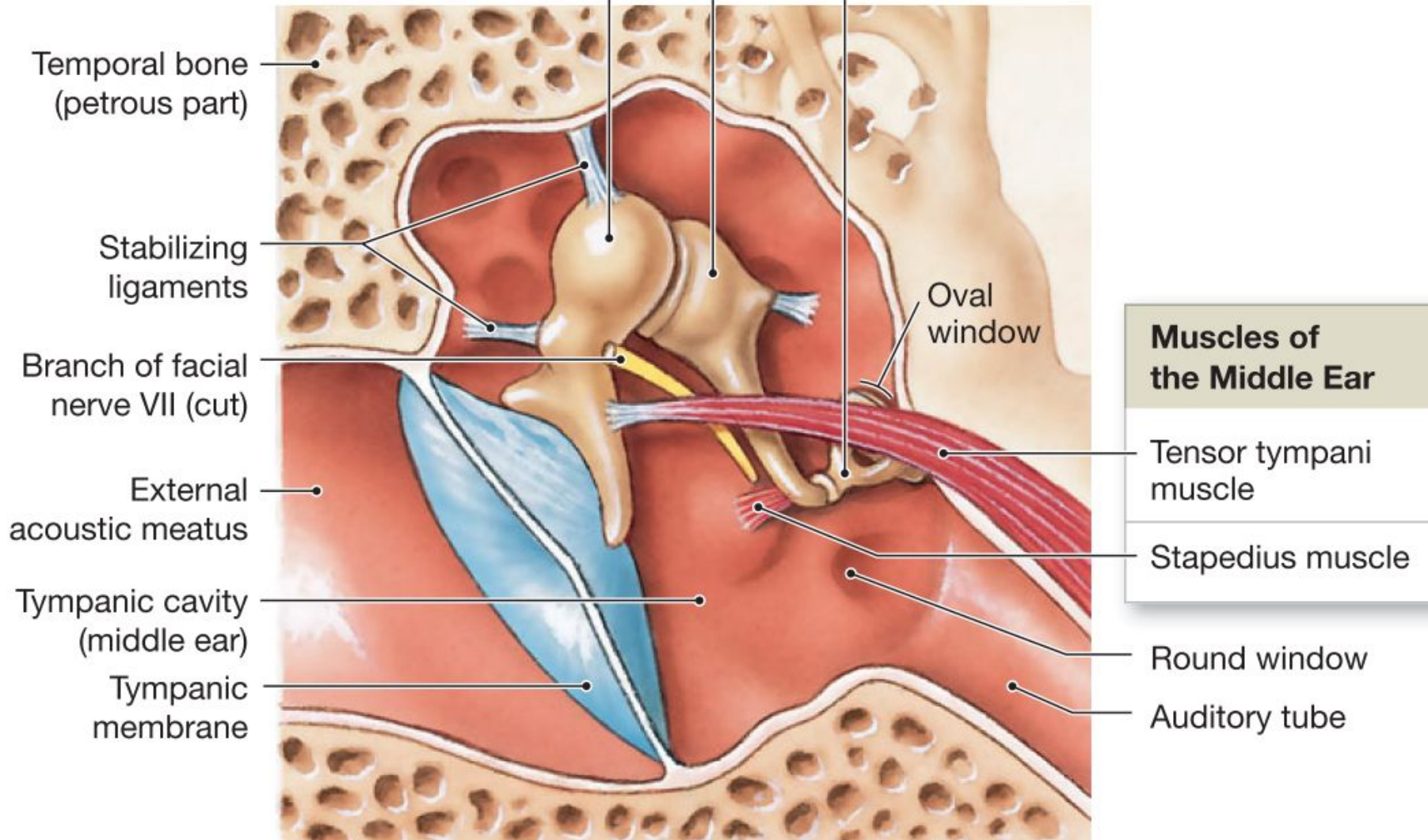


## Auditory Ossicles

Malleus

Incus

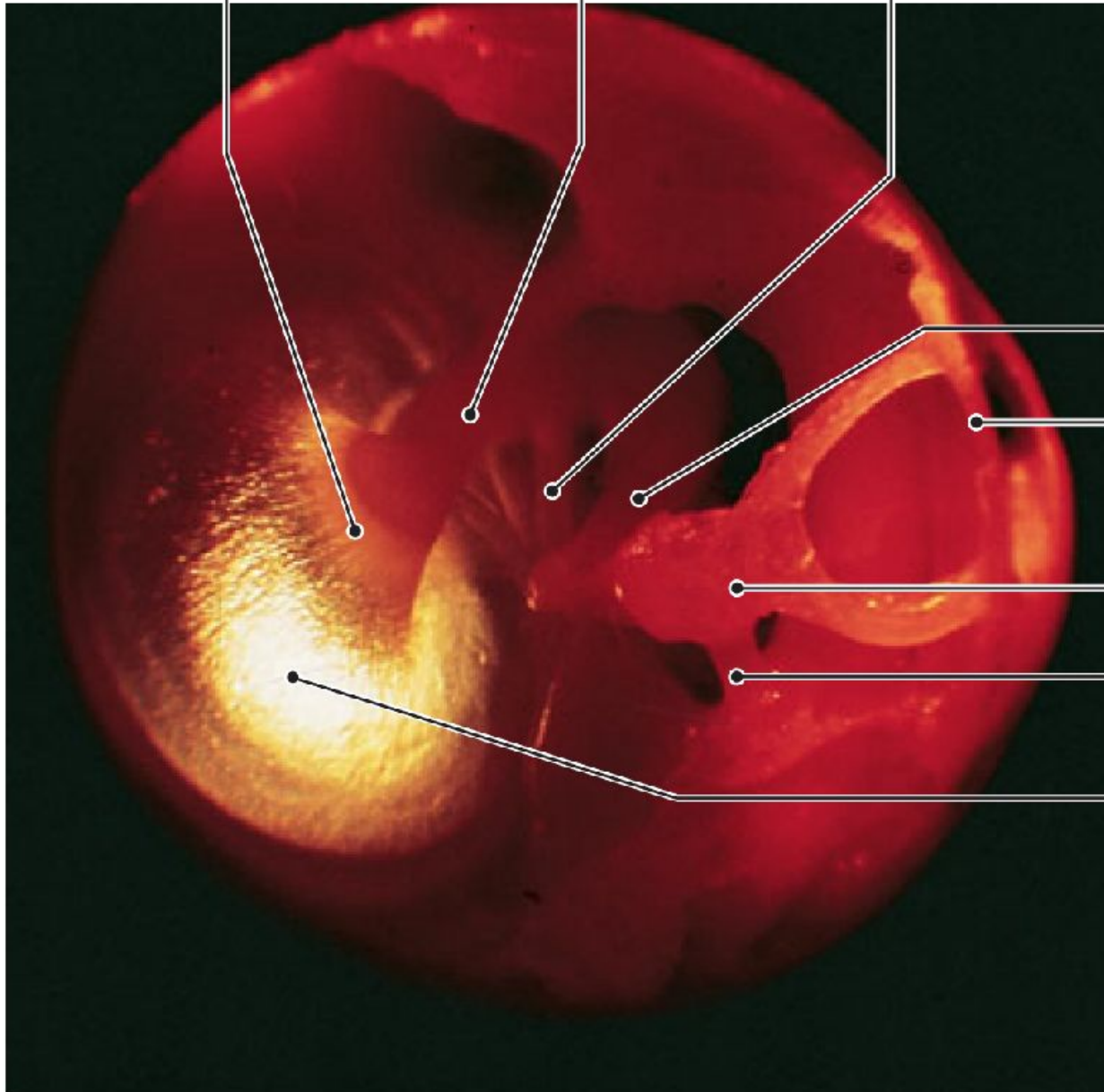
Stapes



Malleus attached to  
tympanic membrane

Malleus

Tendon of tensor  
tympani muscle



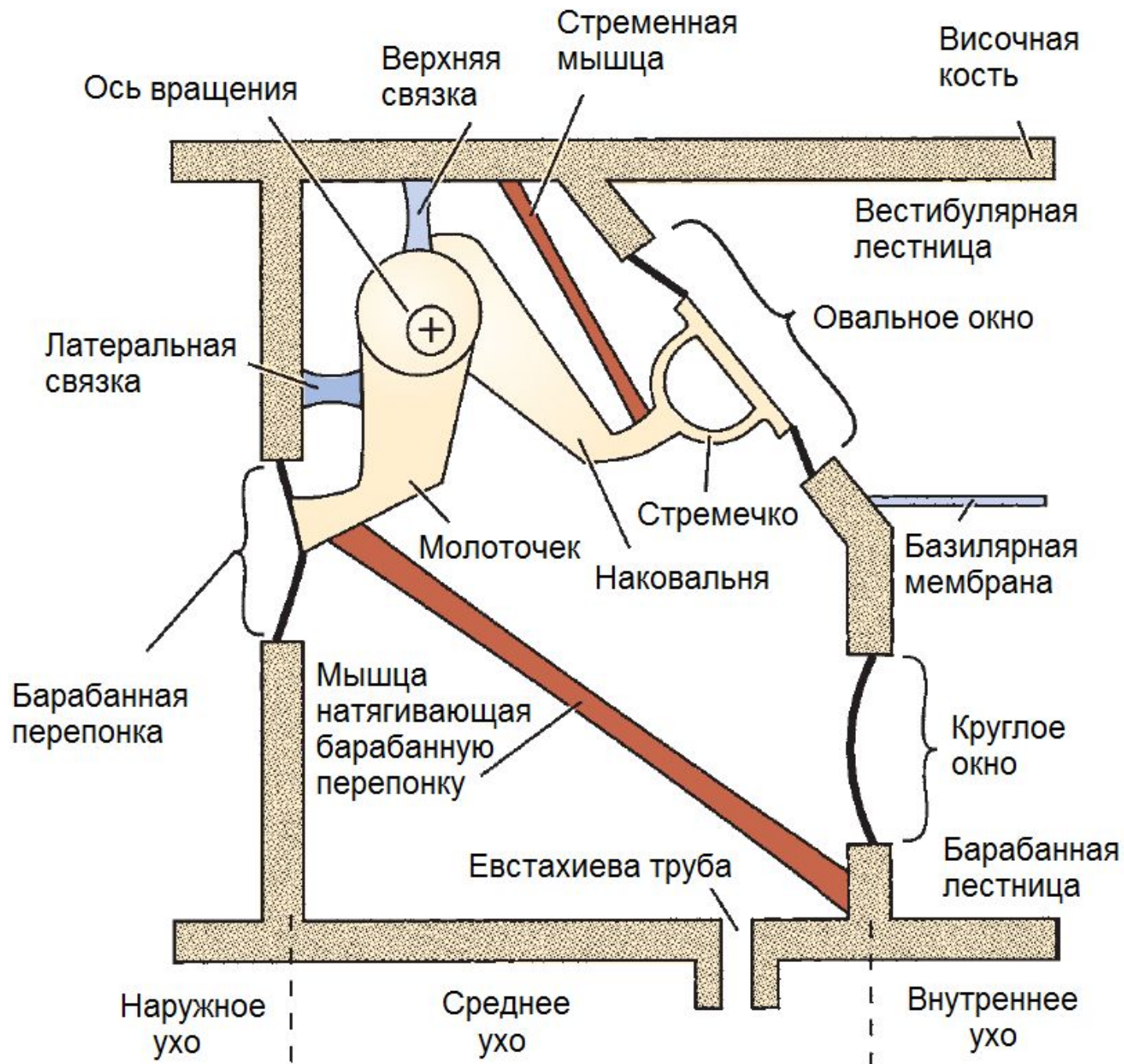
Incus

Base of stapes  
at oval window

Stapes

Stapedius muscle

Inner surface of  
tympanic membrane





Outer ear

Middle ear

Inner ear

Stapes

Incus

Malleus

Sound wave

Tympanic membrane

Auditory tube

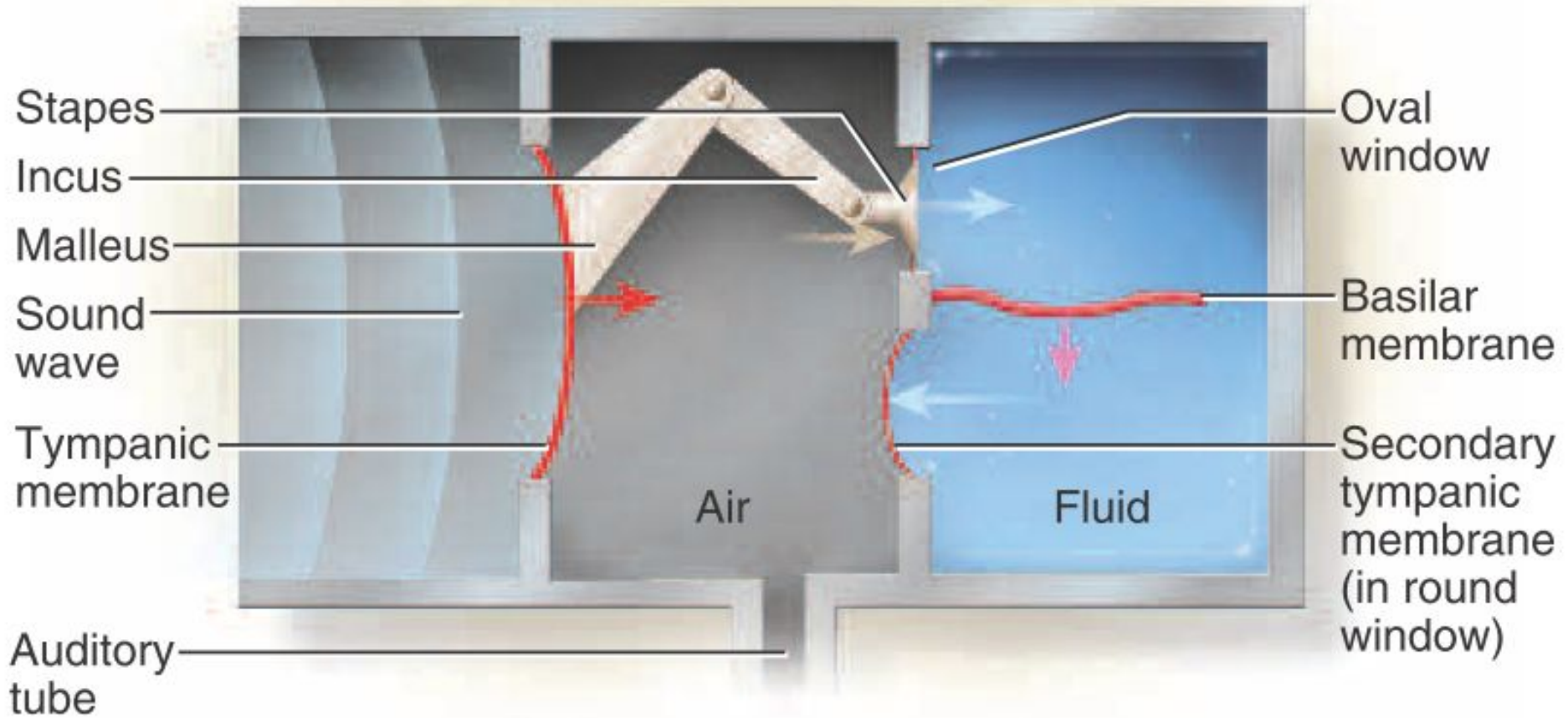
Oval window

Basilar membrane

Secondary tympanic membrane (in round window)

Air

Fluid



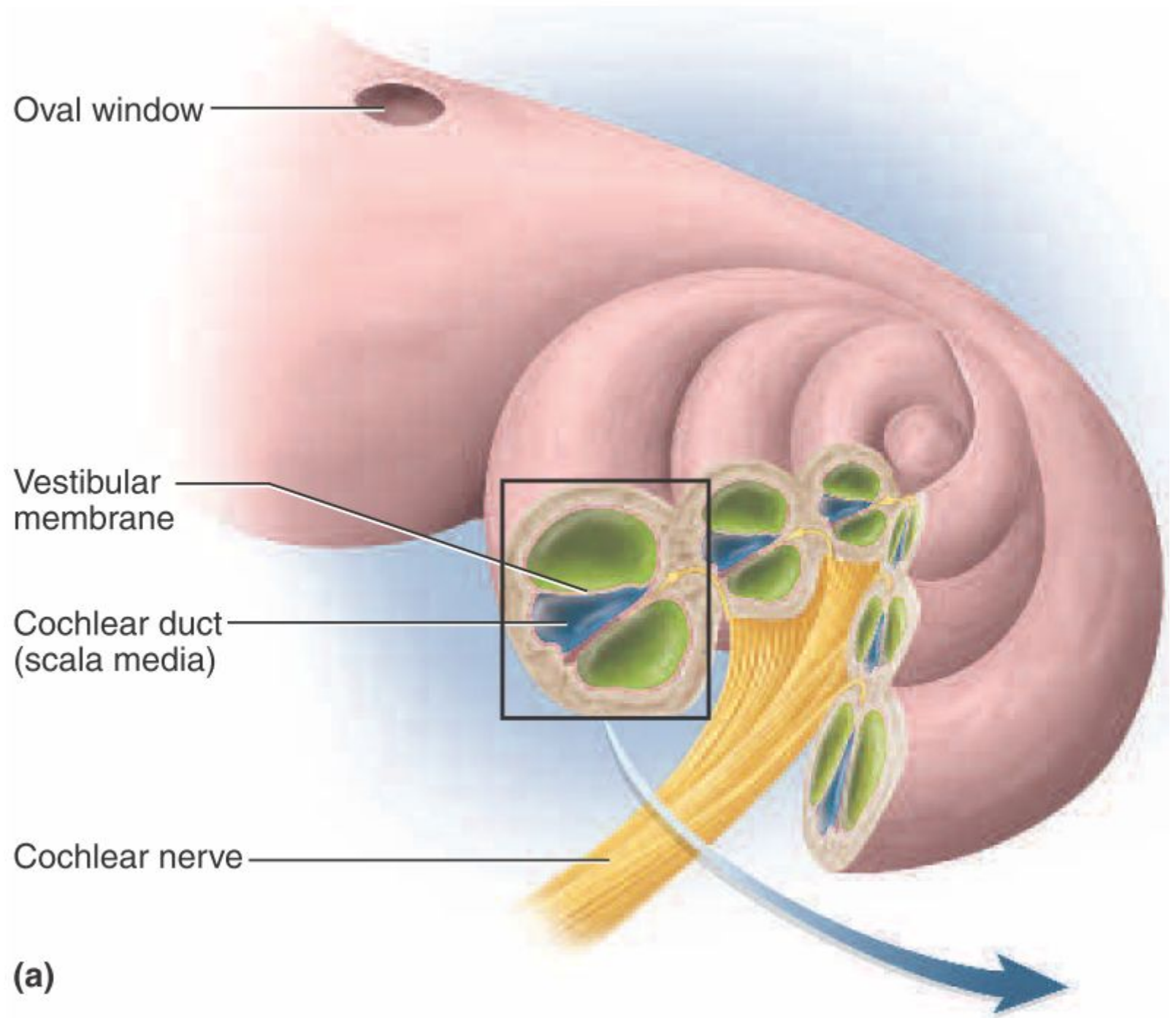
Oval window

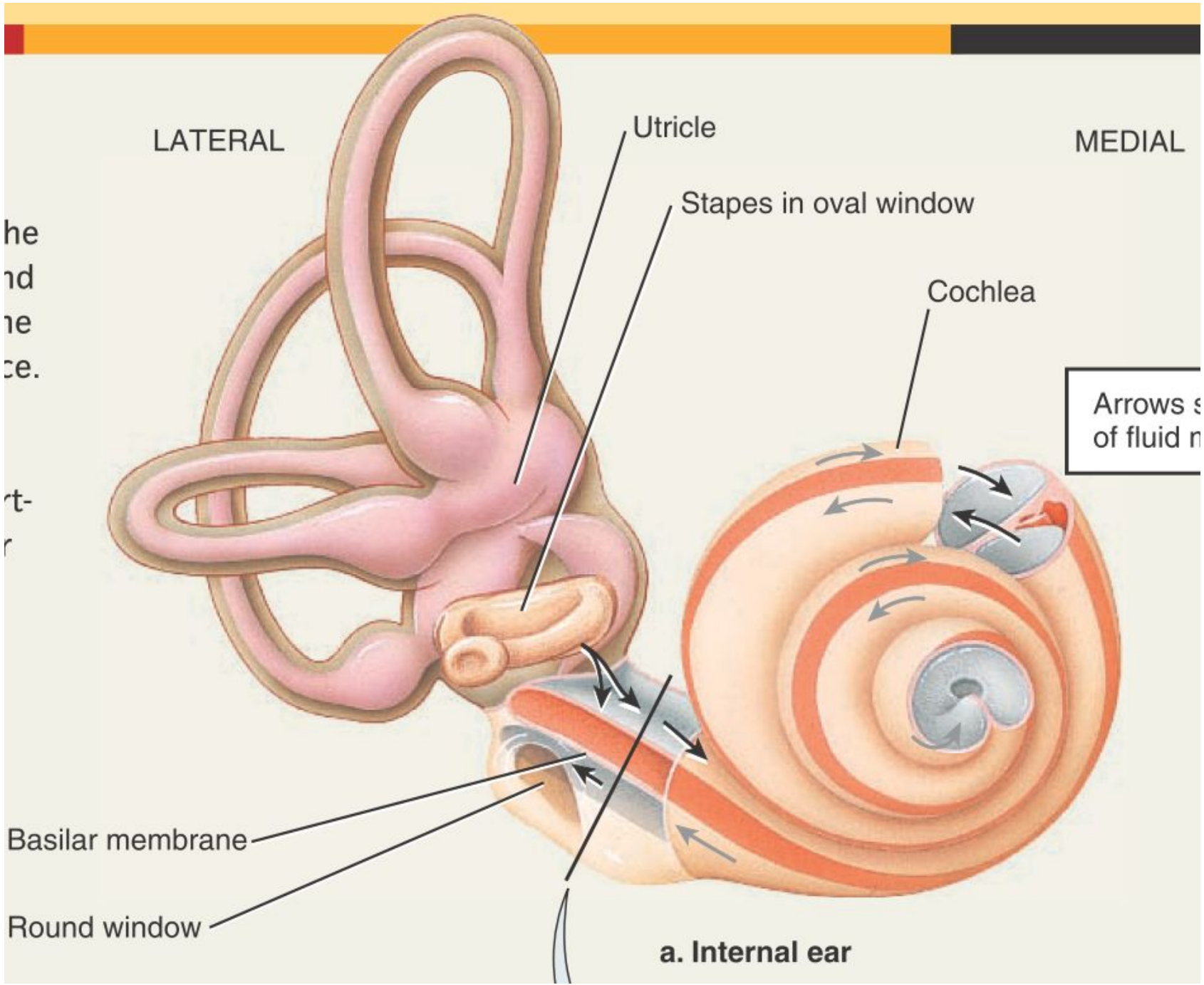
Vestibular membrane

Cochlear duct (scala media)

Cochlear nerve

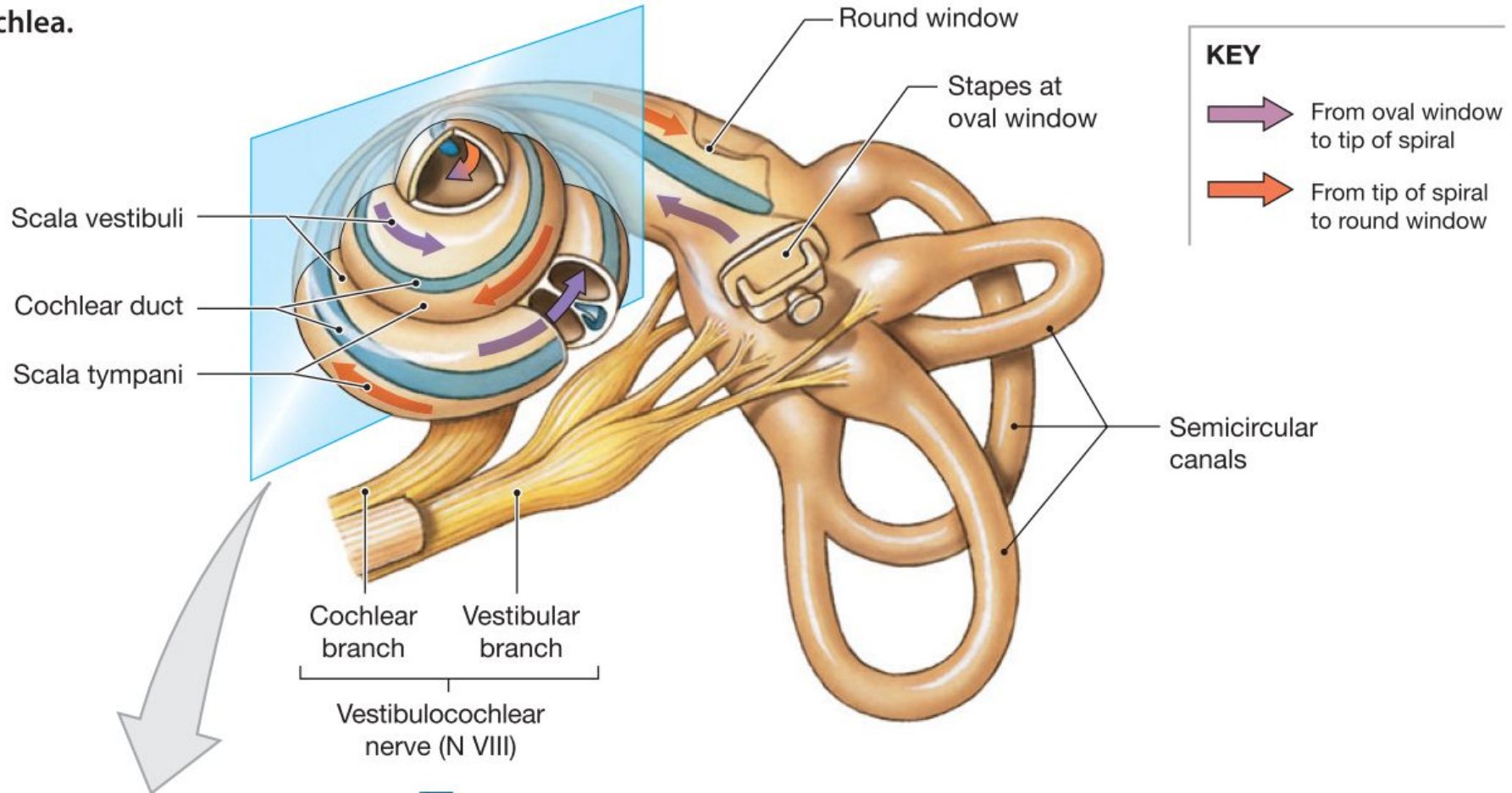
(a)





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# The Cochlea.



Spiral ganglion

Scala vestibuli  
(with perilymph)

Vestibular  
membrane

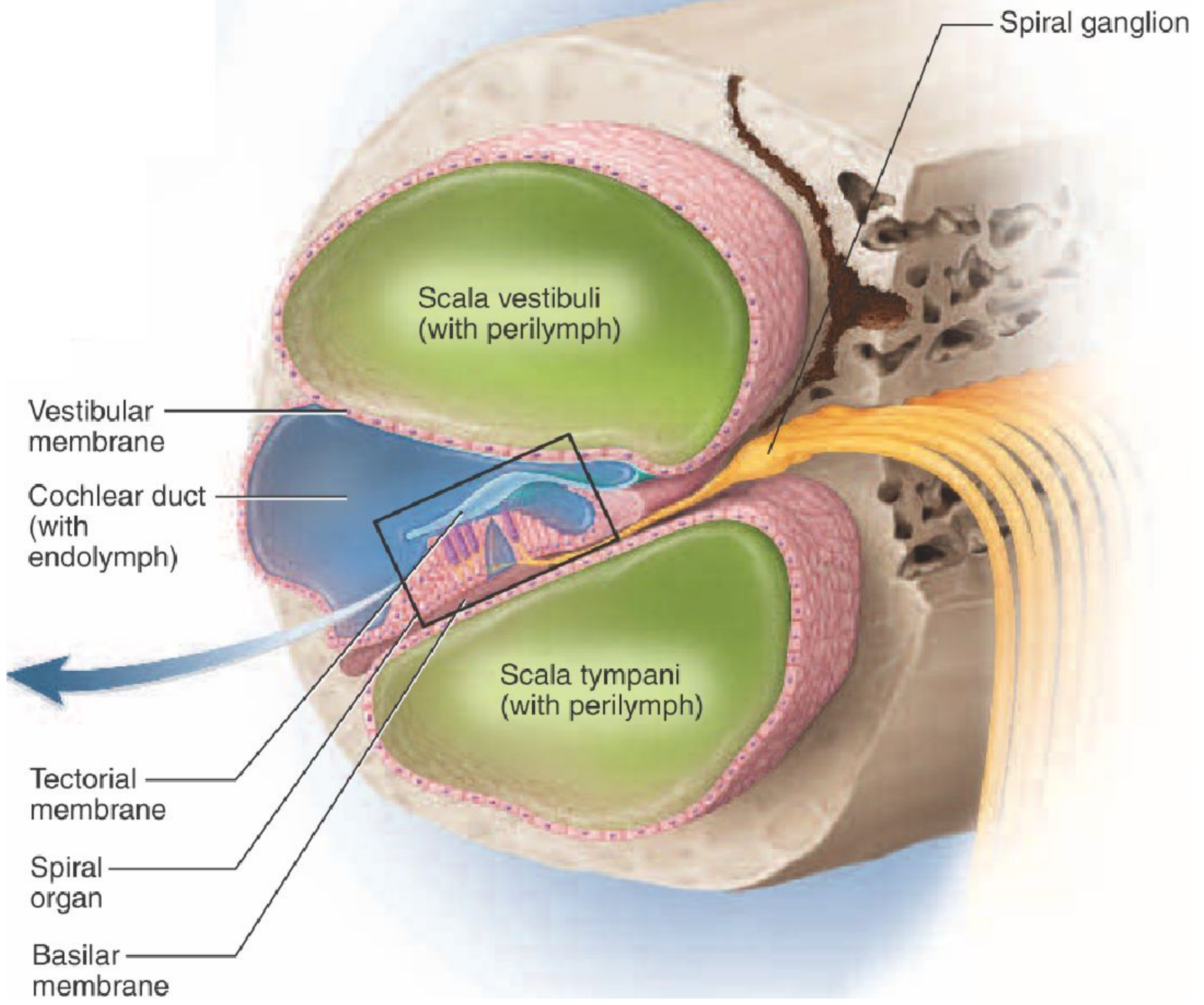
Cochlear duct  
(with  
endolymph)

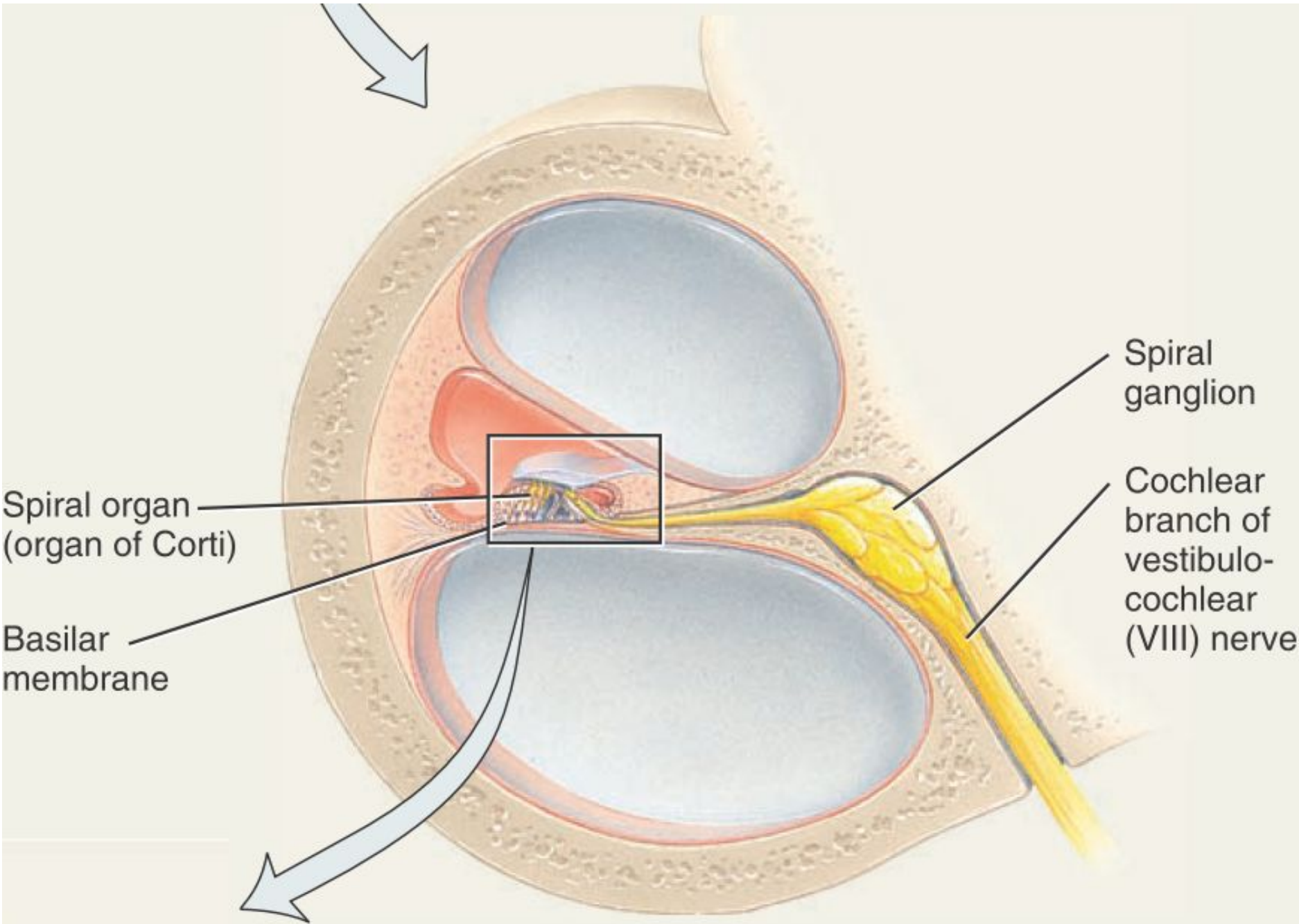
Scala tympani  
(with perilymph)

Tectorial  
membrane

Spiral  
organ

Basilar  
membrane



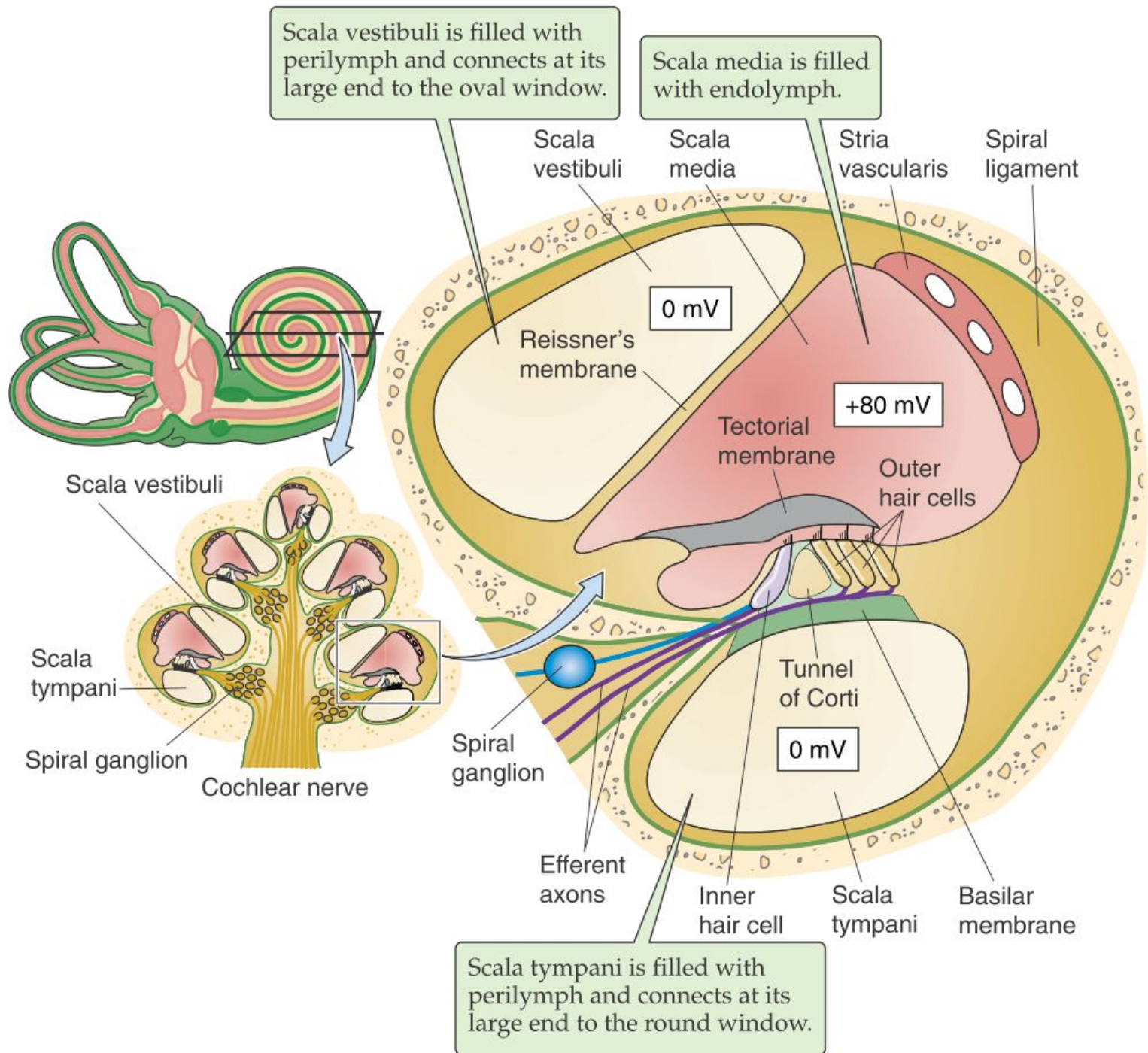


Spiral organ  
(organ of Corti)

Basilar  
membrane

Spiral  
ganglion

Cochlear  
branch of  
vestibulo-  
cochlear  
(VIII) nerve



Scala vestibuli is filled with perilymph and connects at its large end to the oval window.

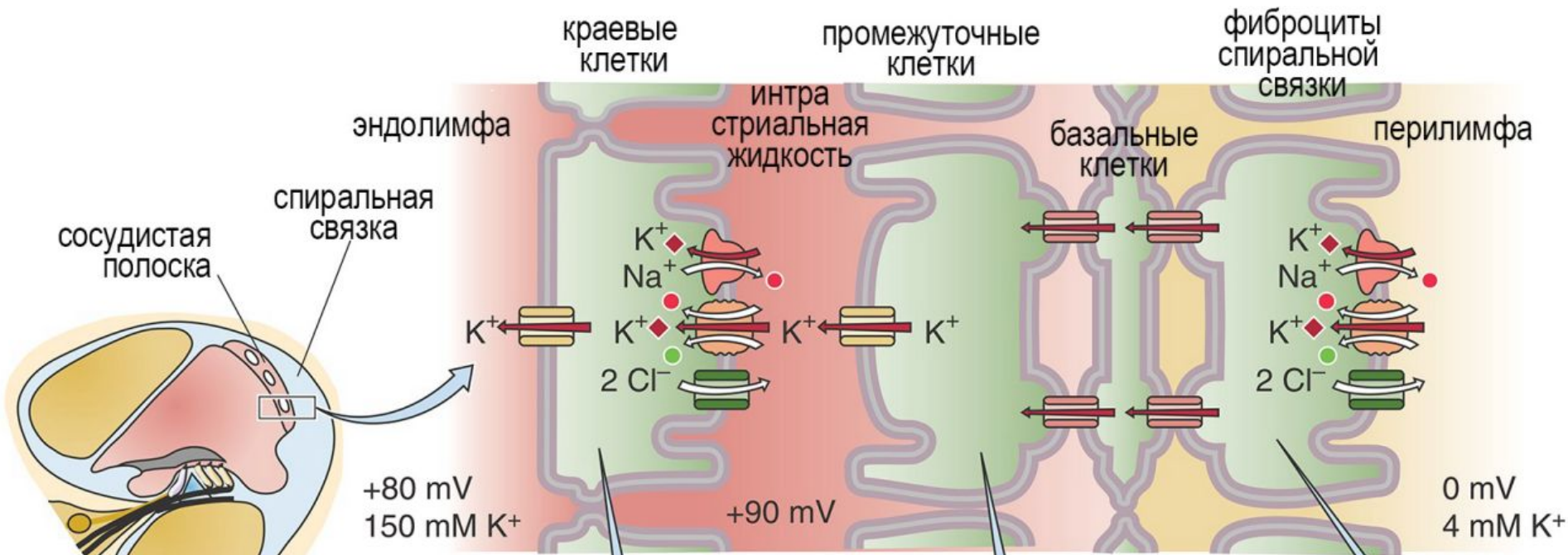
Scala media is filled with endolymph.

Scala tympani is filled with perilymph and connects at its large end to the round window.

0 mV

+80 mV

0 mV

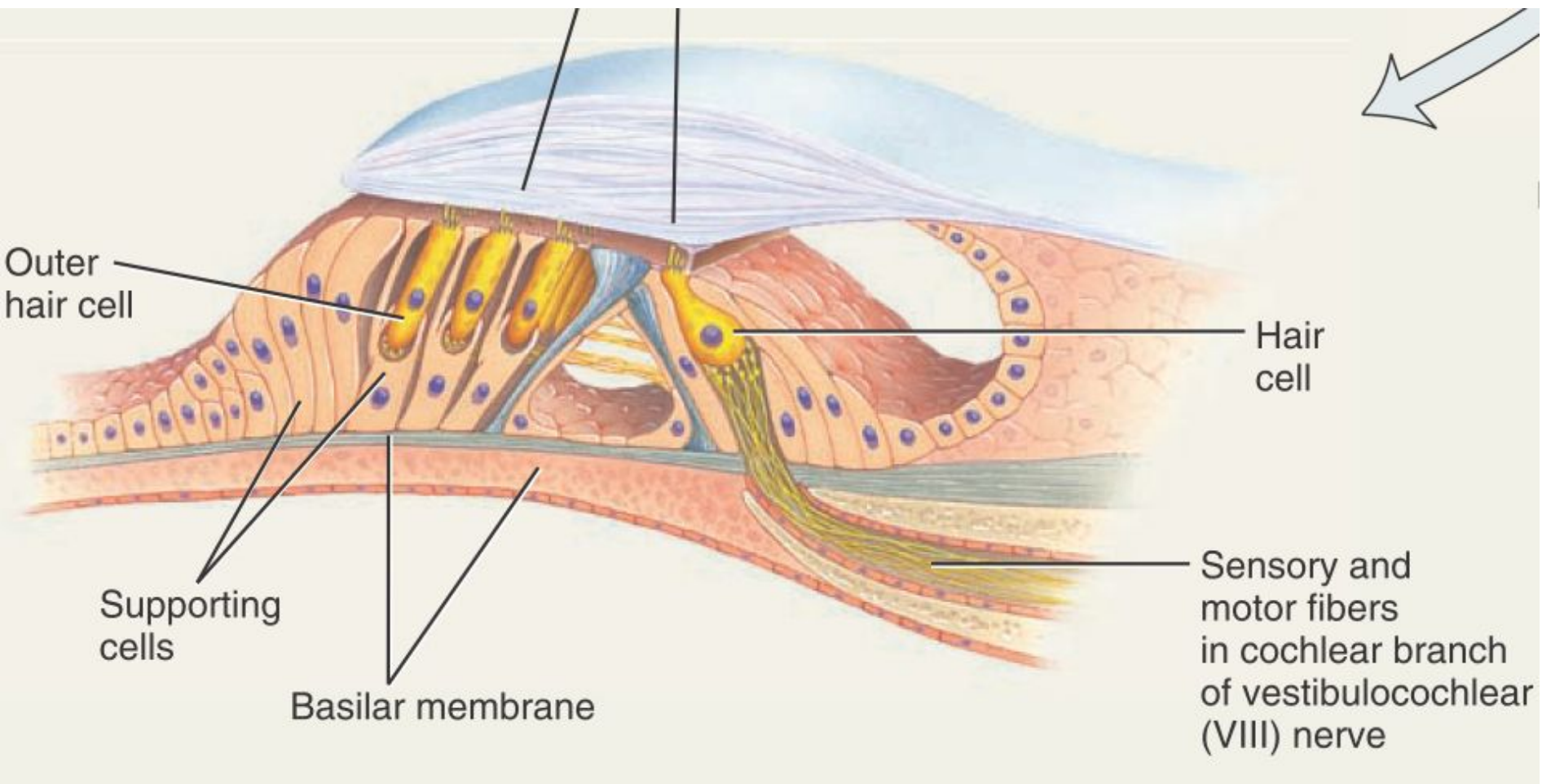


**3**  
 Краевые клетки переносят K<sup>+</sup> из интрастриальной жидкости в эндолимфу.

**2**  
 Эндокохлеарный потенциал создаётся за счёт калиевых каналов промежуточных клеток.

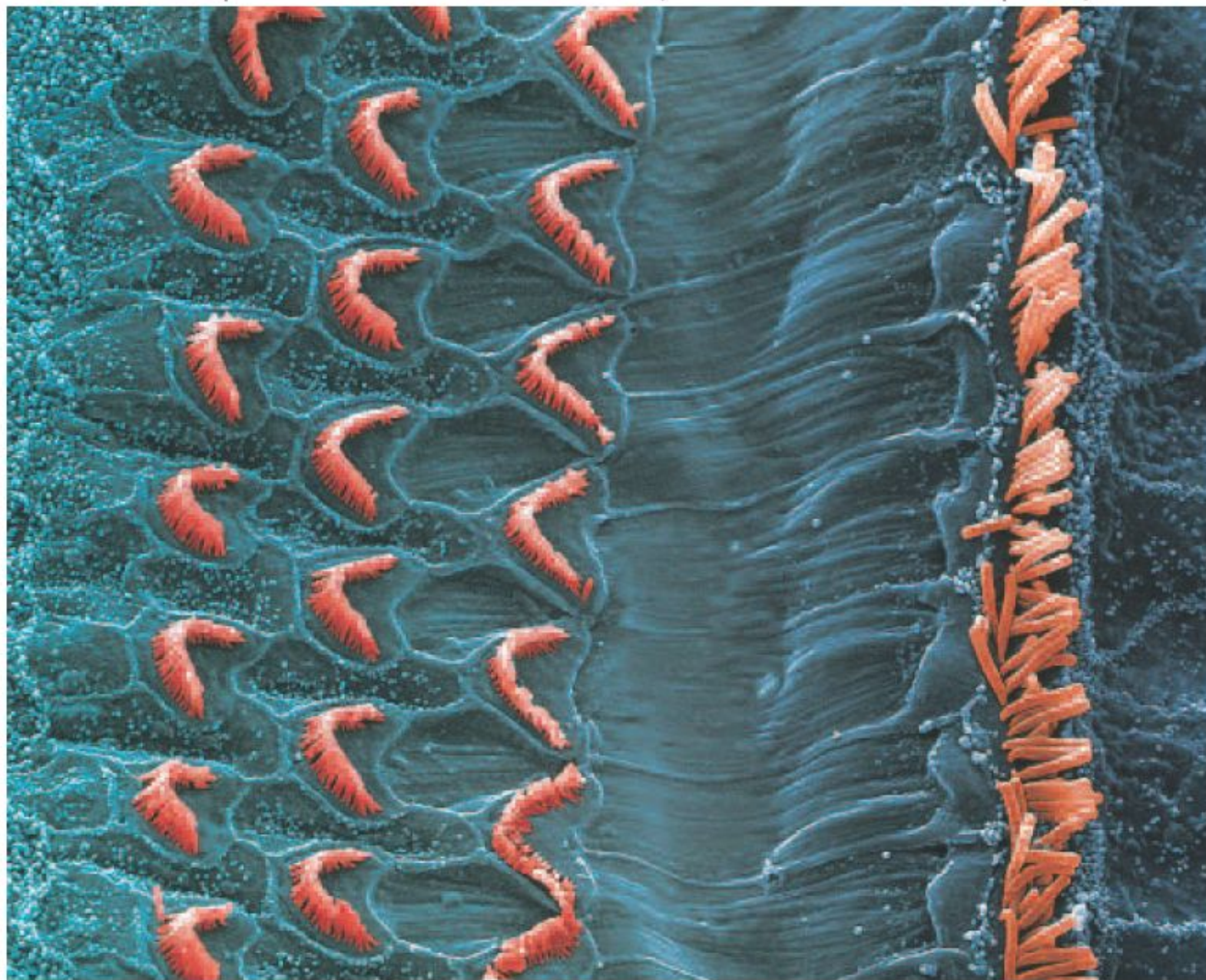
**1**  
 Фиброциты накапливают K<sup>+</sup>, и ионы калия перемещаются в промежуточные клетки.



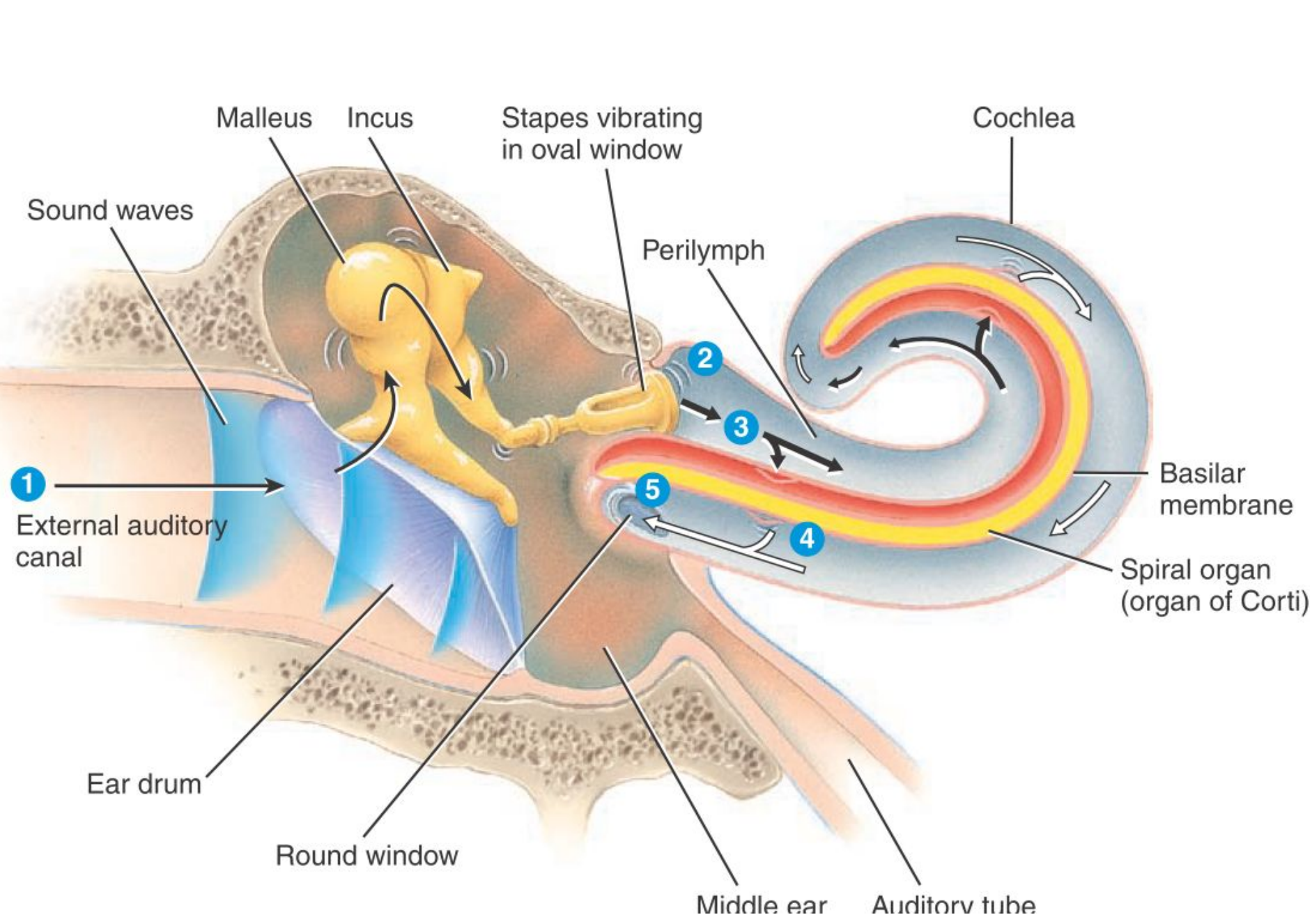


Outer hair cells

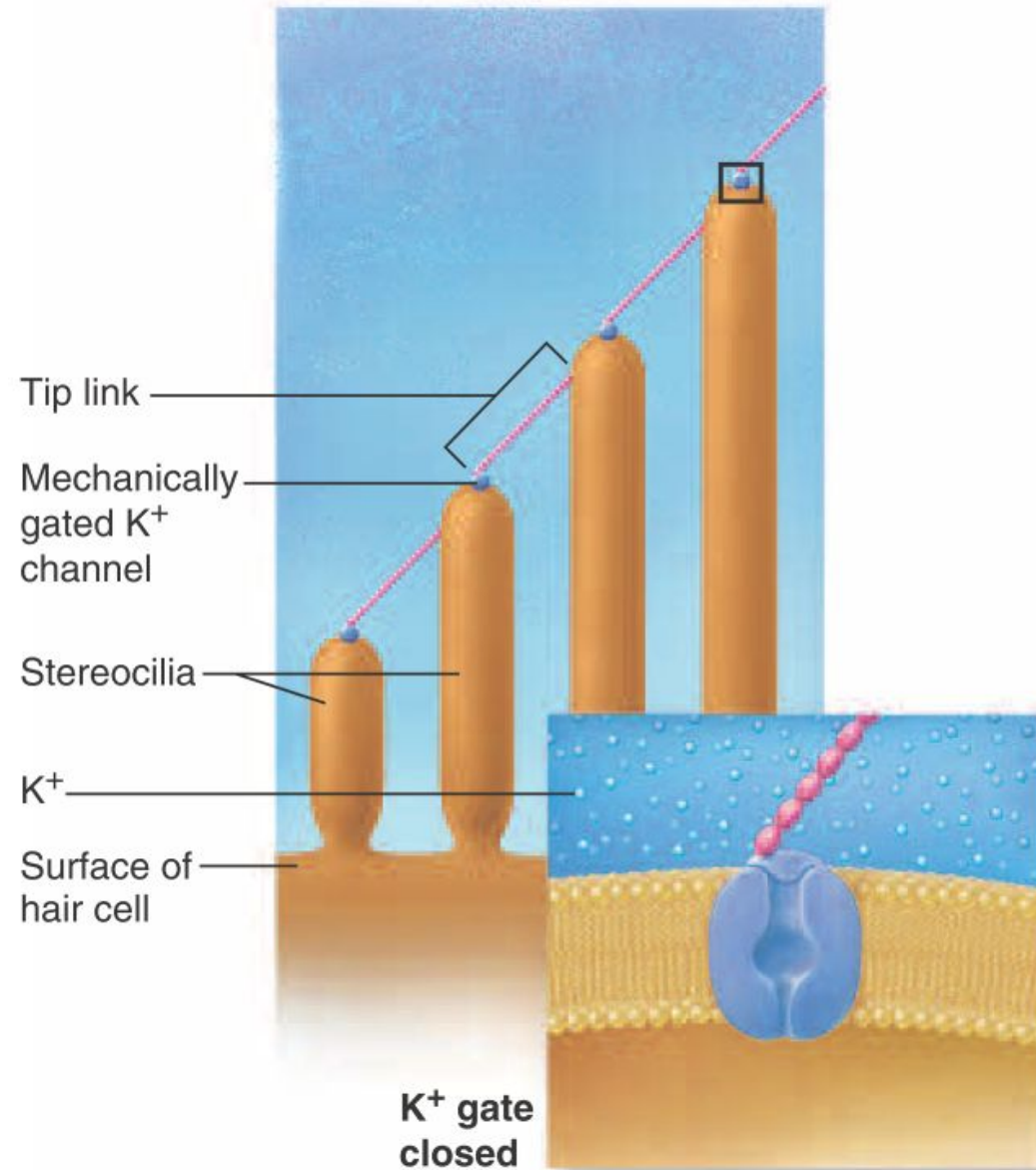
Inner hair cells



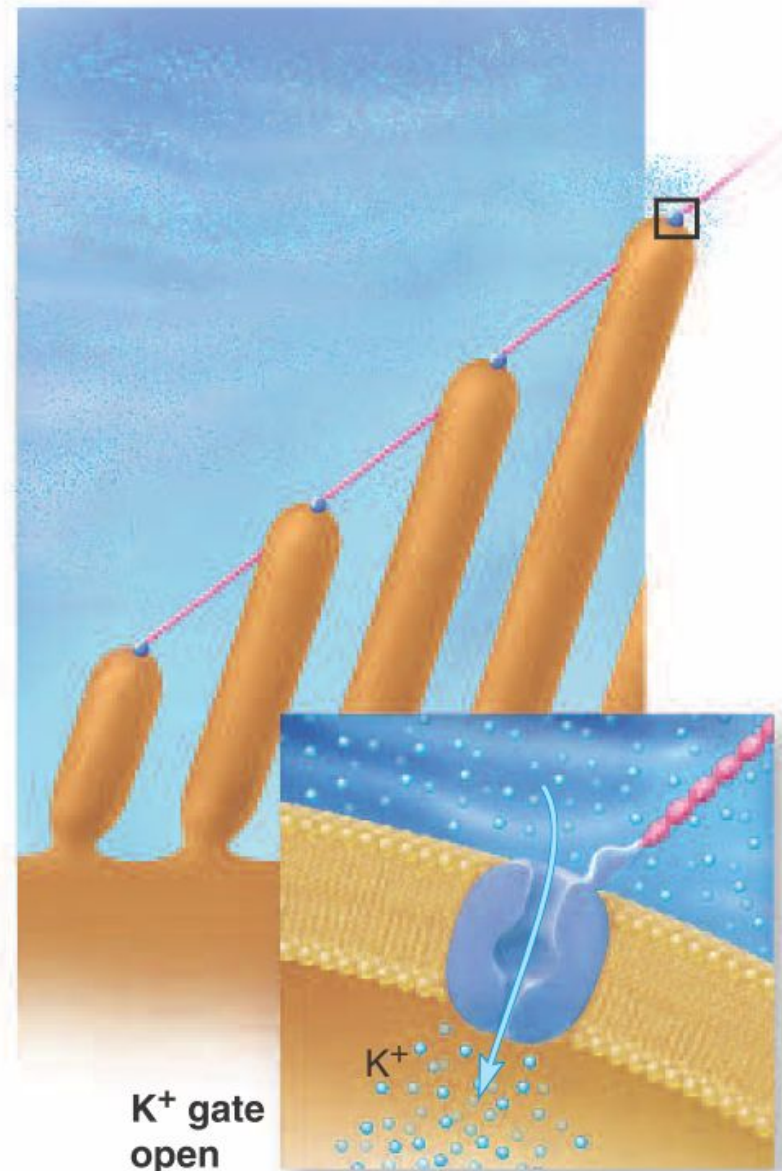
10  $\mu\text{m}$

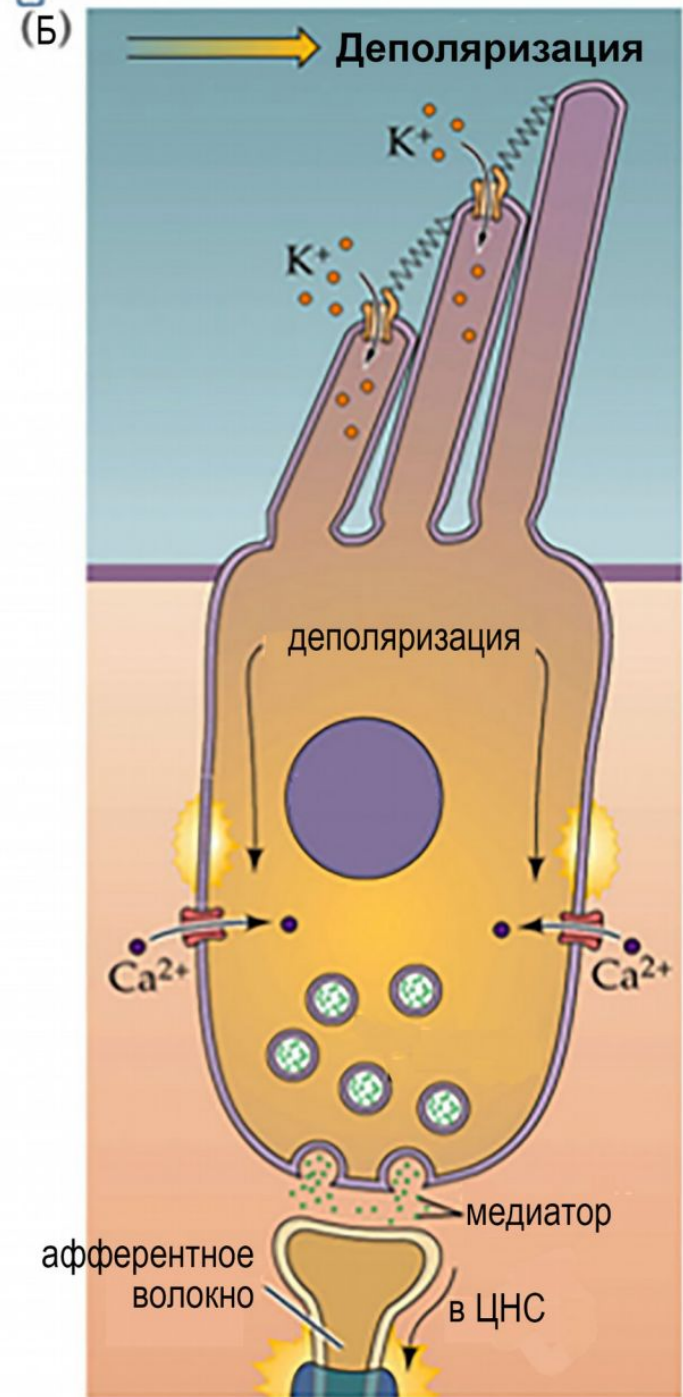
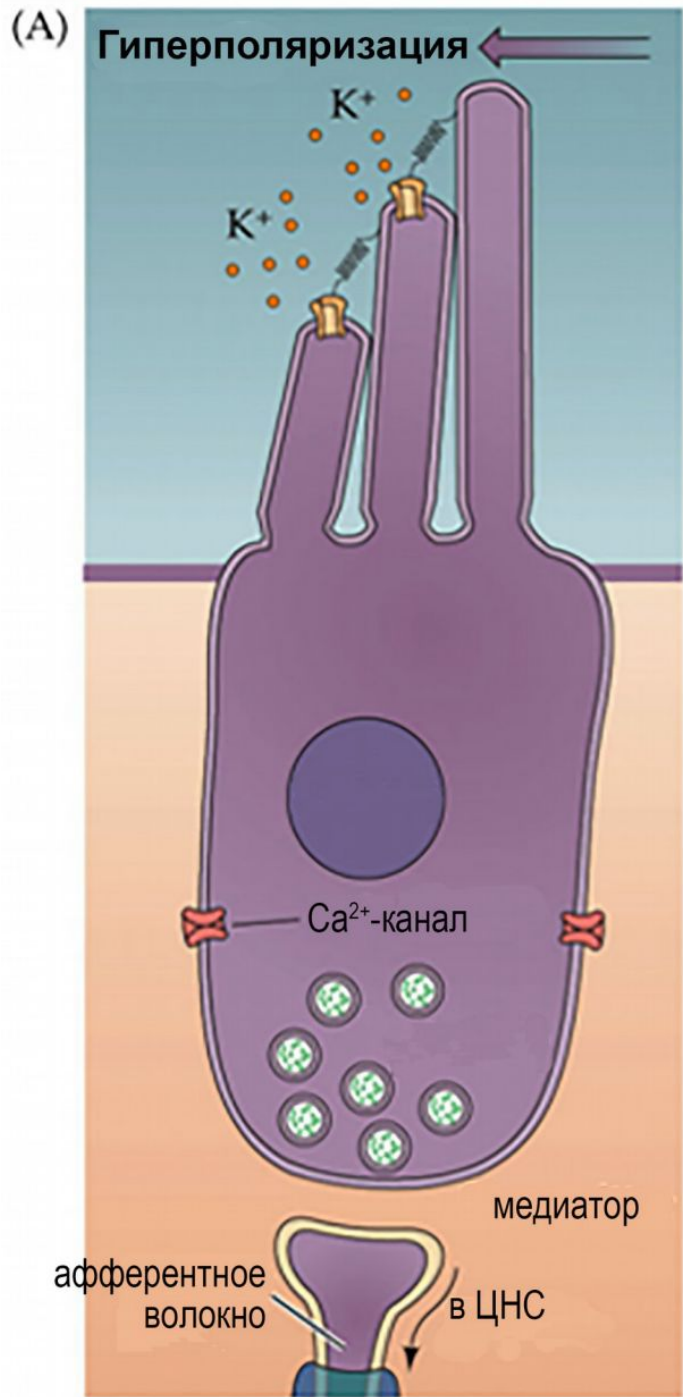


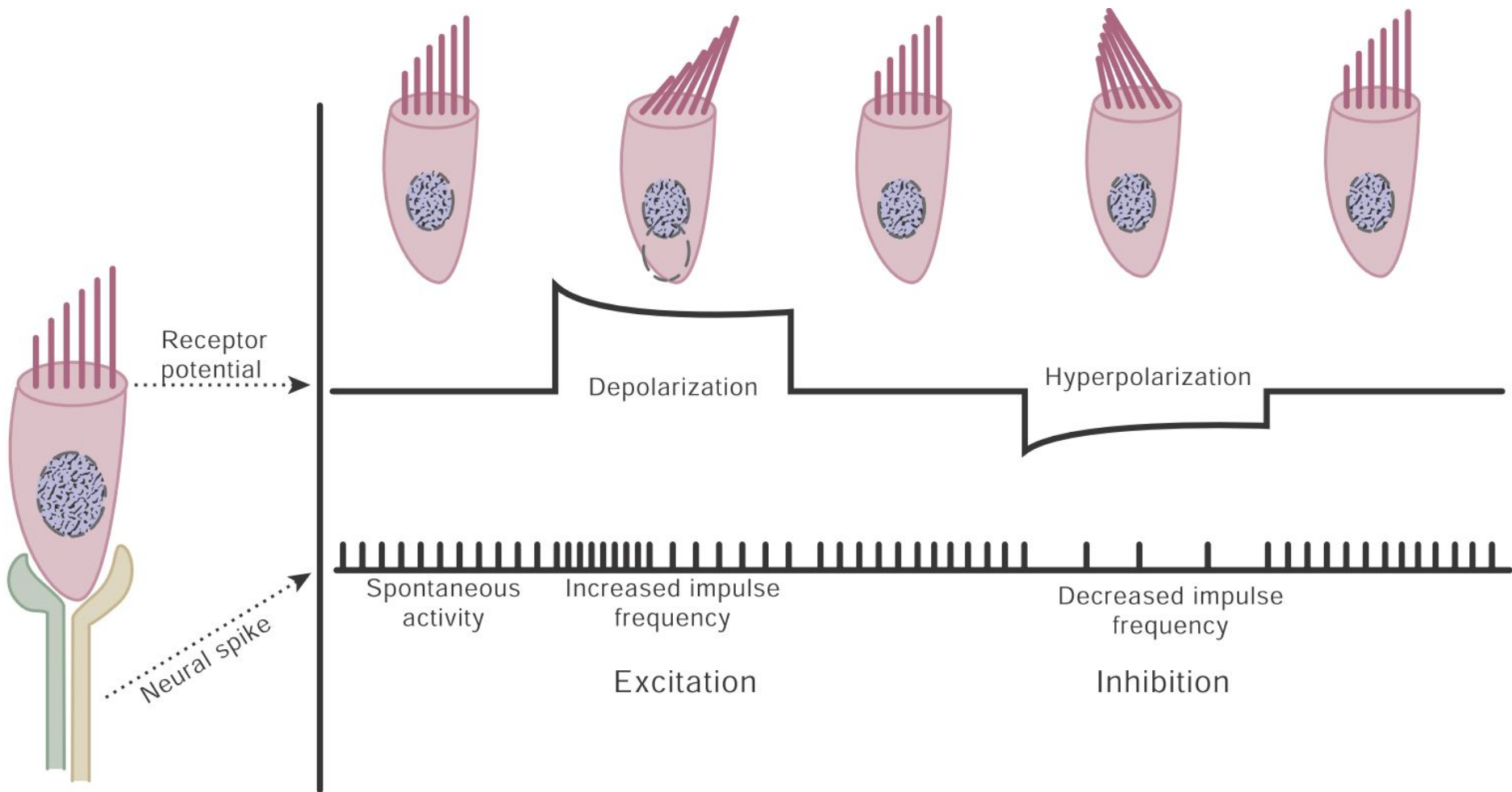
### Unstimulated



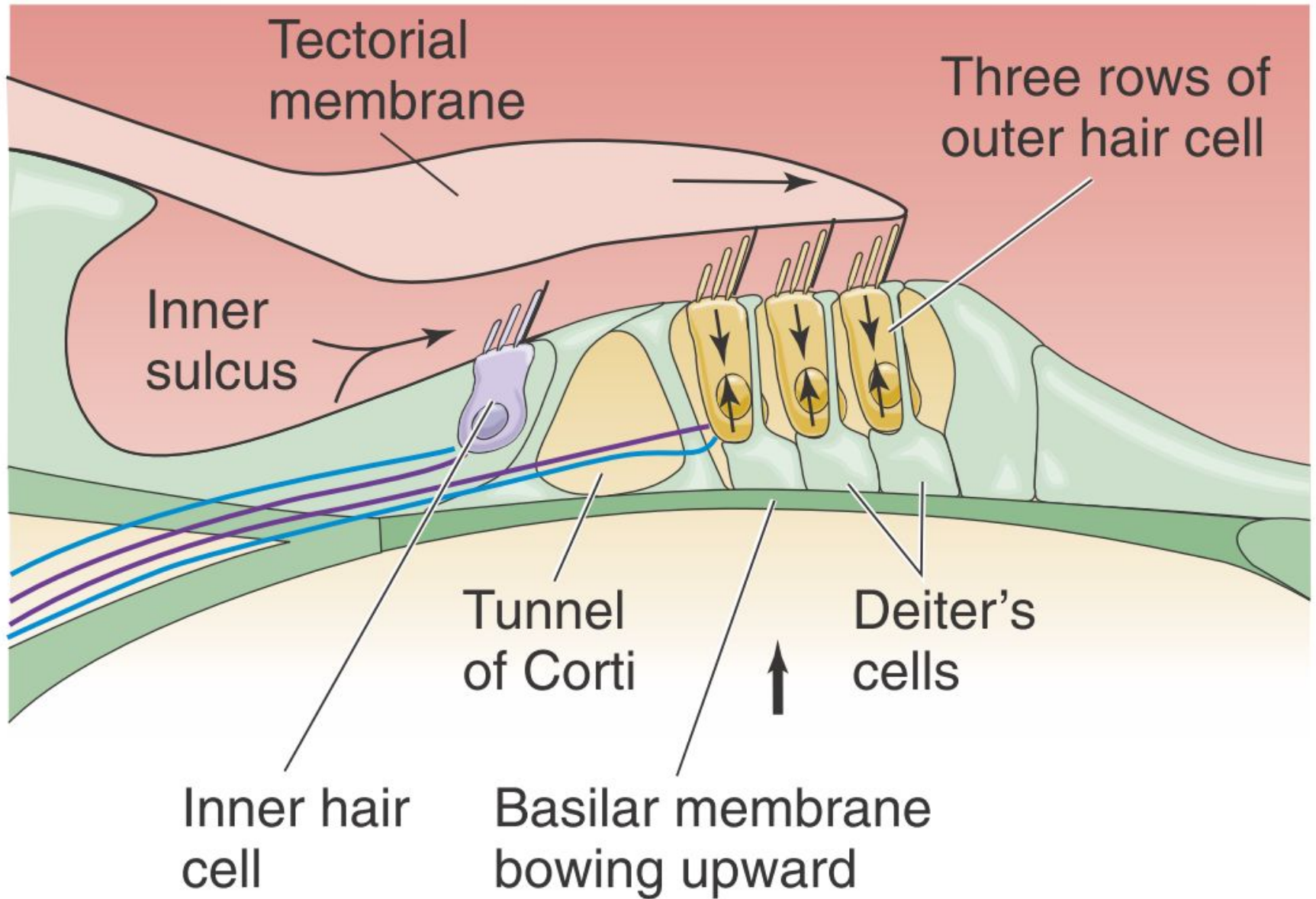
### Stimulated



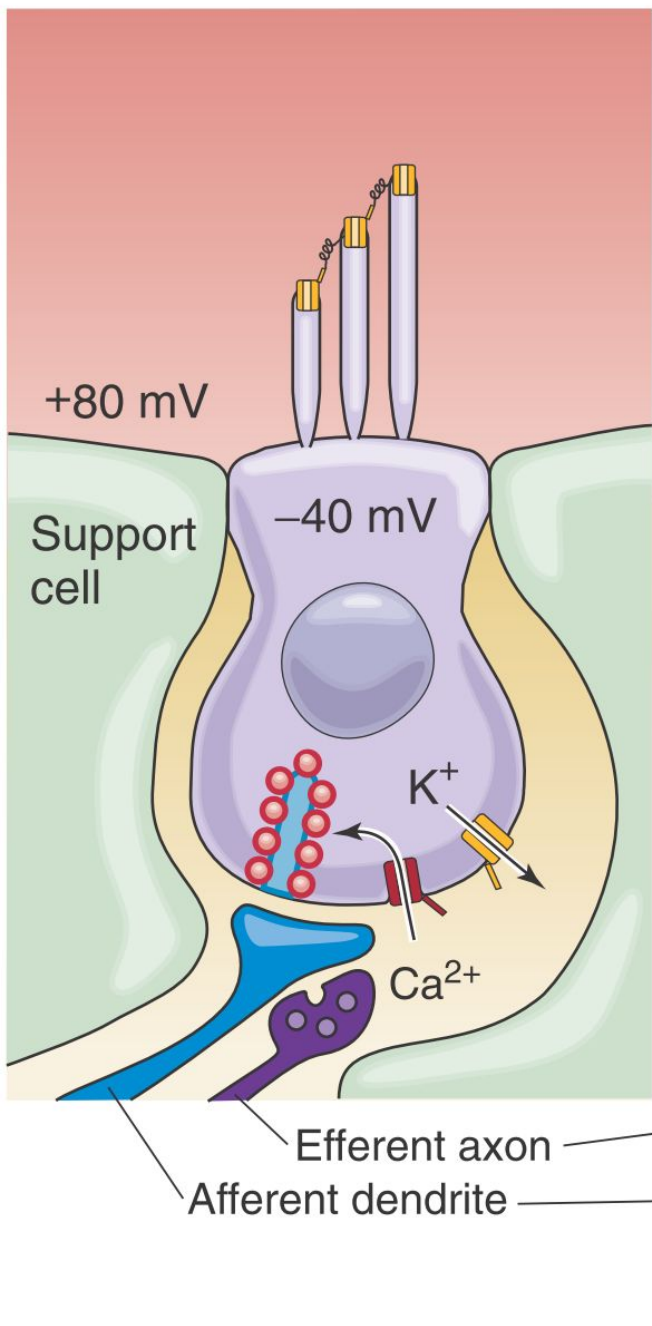




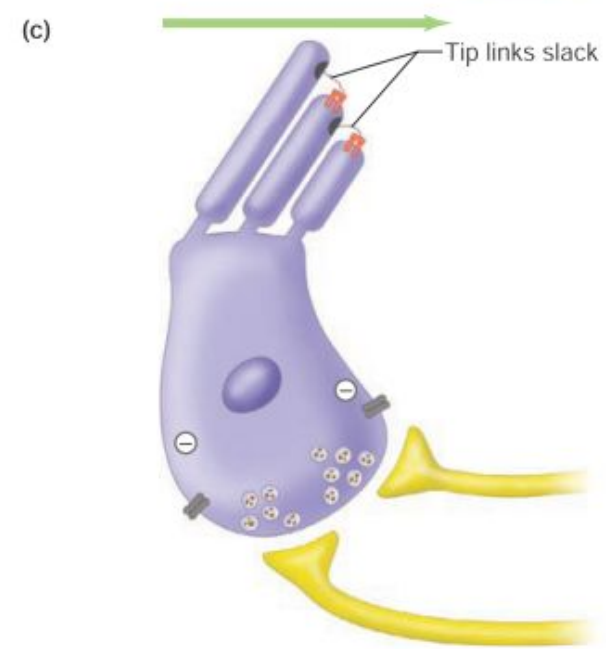
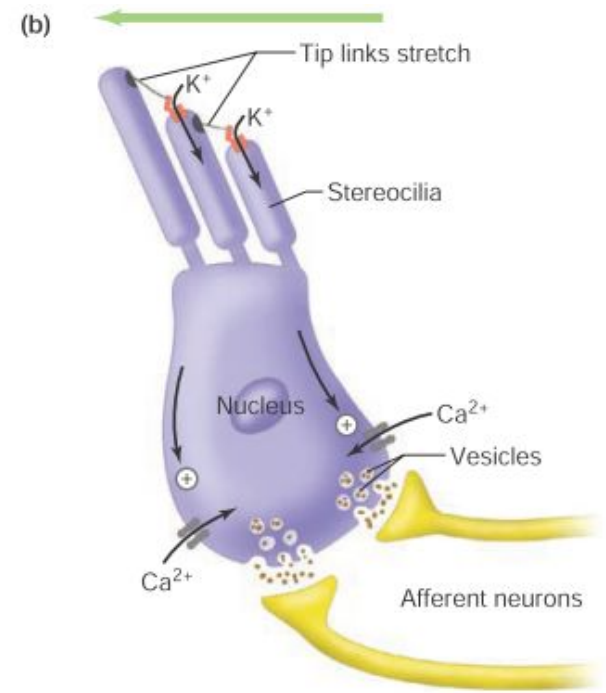
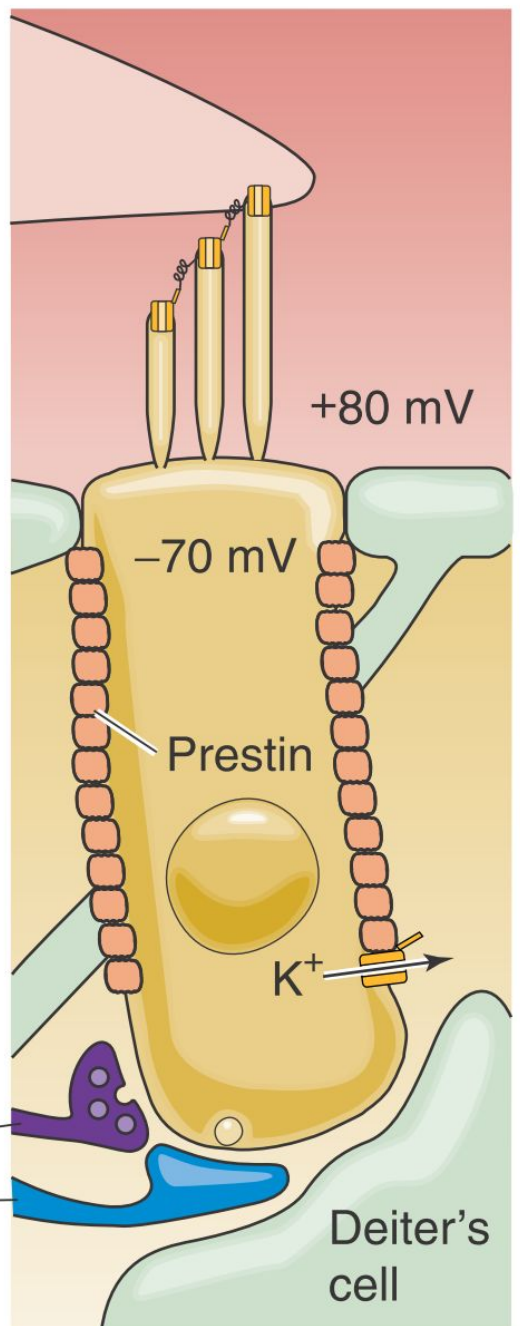
# A UPWARD BOWING OF BASILAR MEMBRANE



## B INNER HAIR CELL

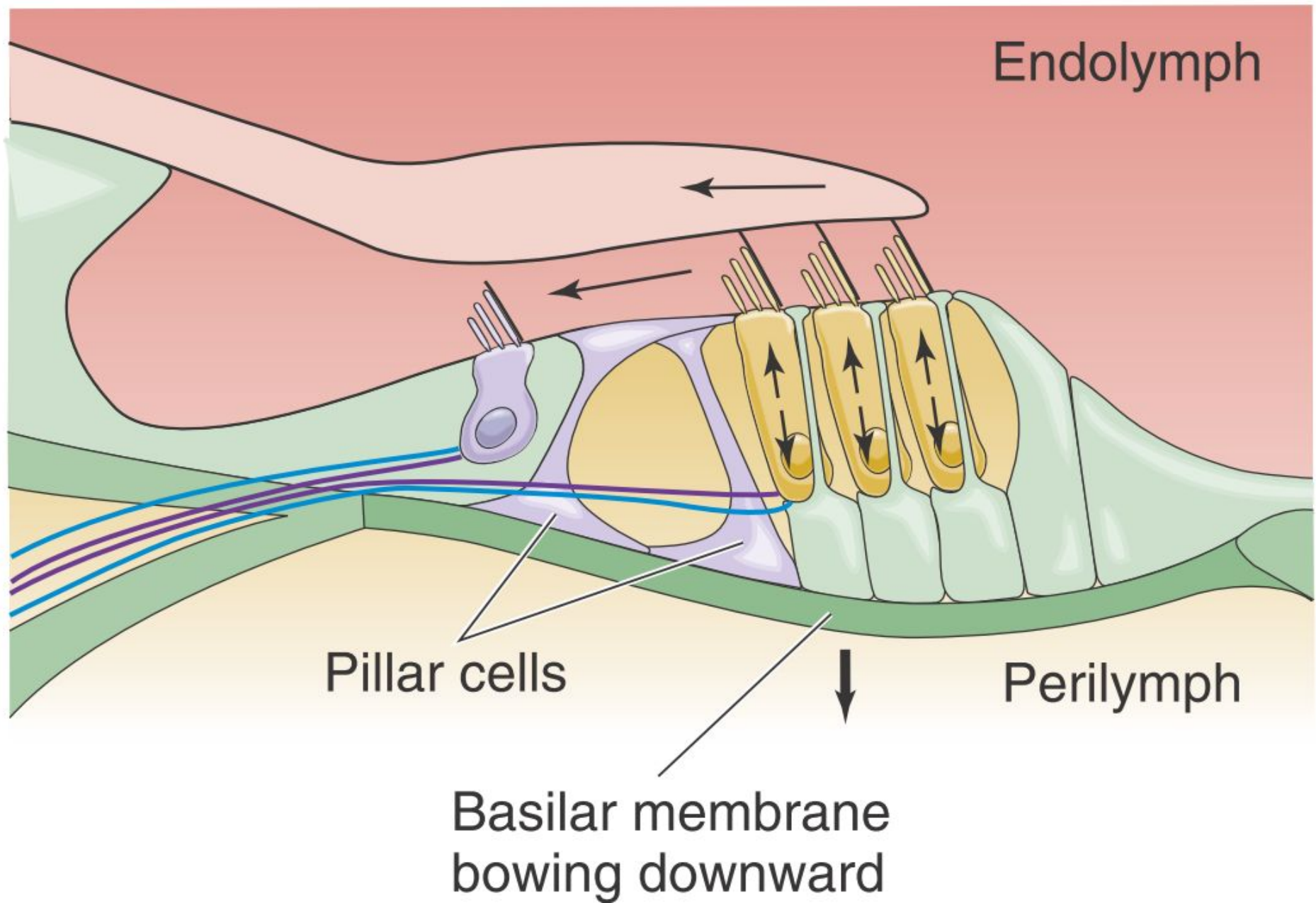


## C OUTER HAIR CELL

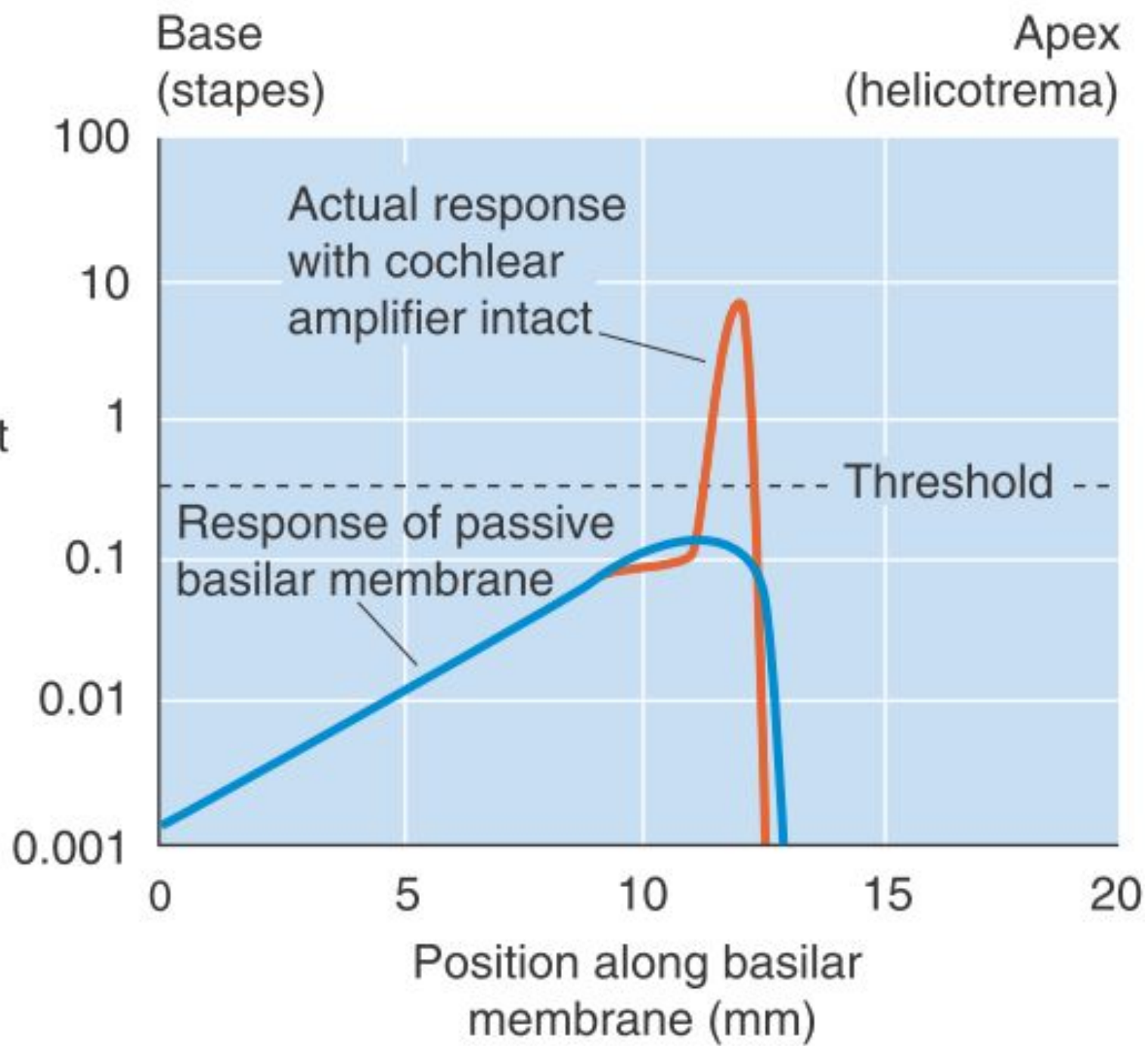




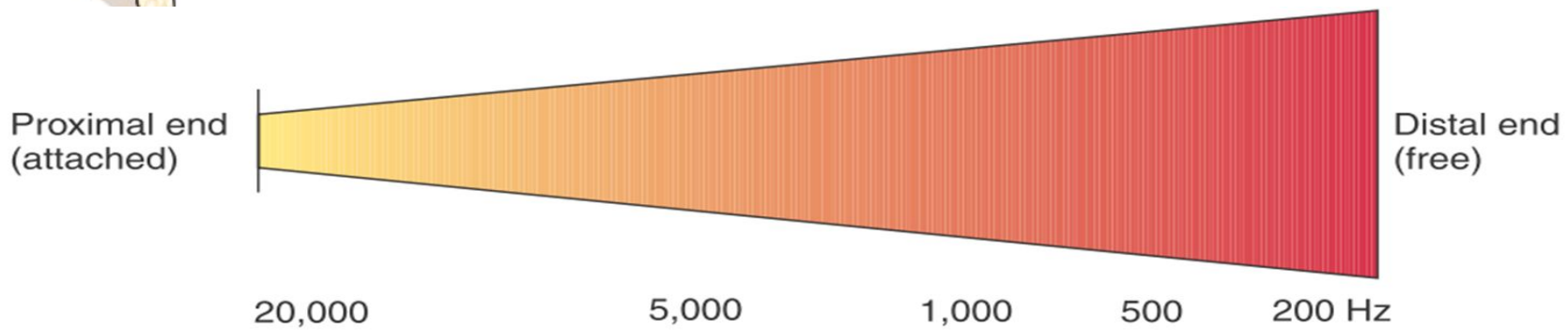
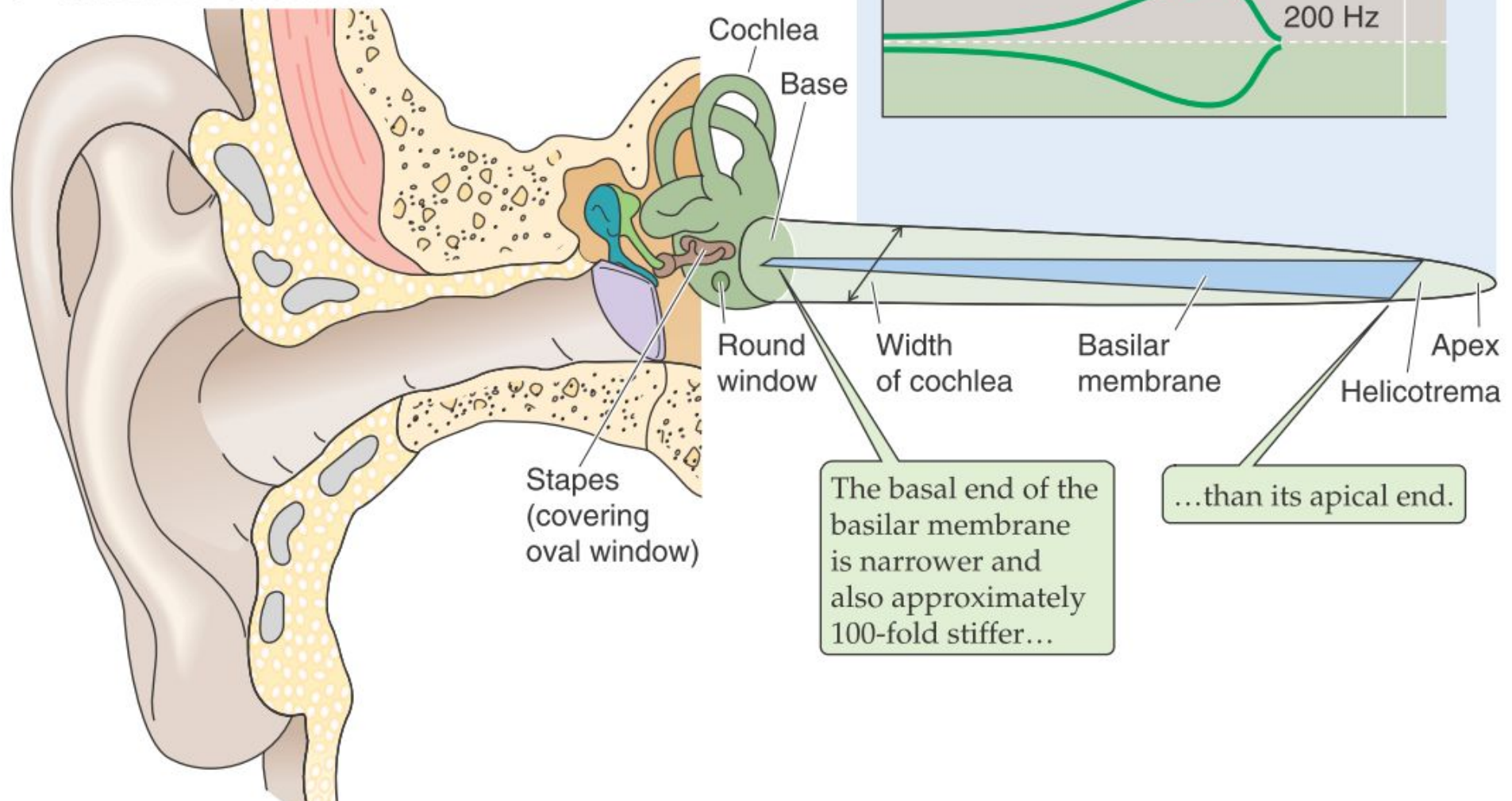
# D DOWNWARD BOWING OF BASILAR MEMBRANE

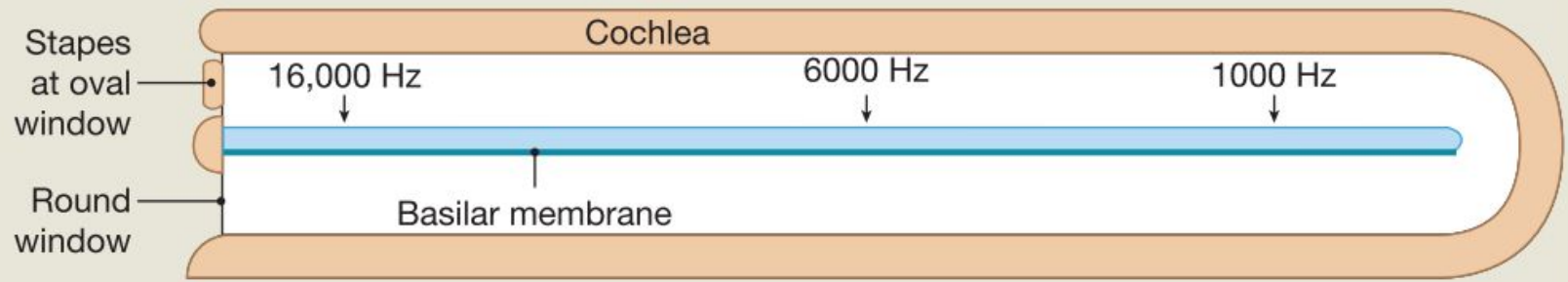


Peak displacement of basilar membrane (nm)

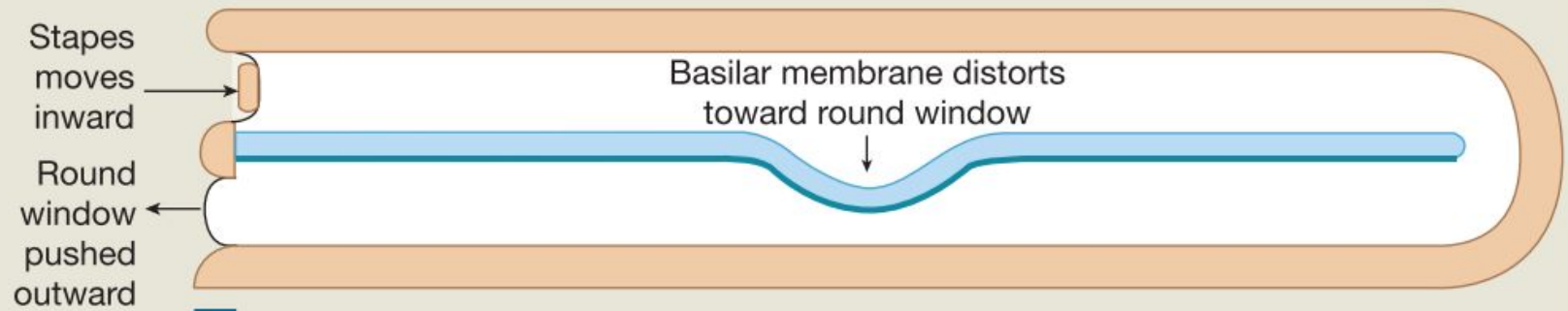


# C UNCOILED COCHLEA

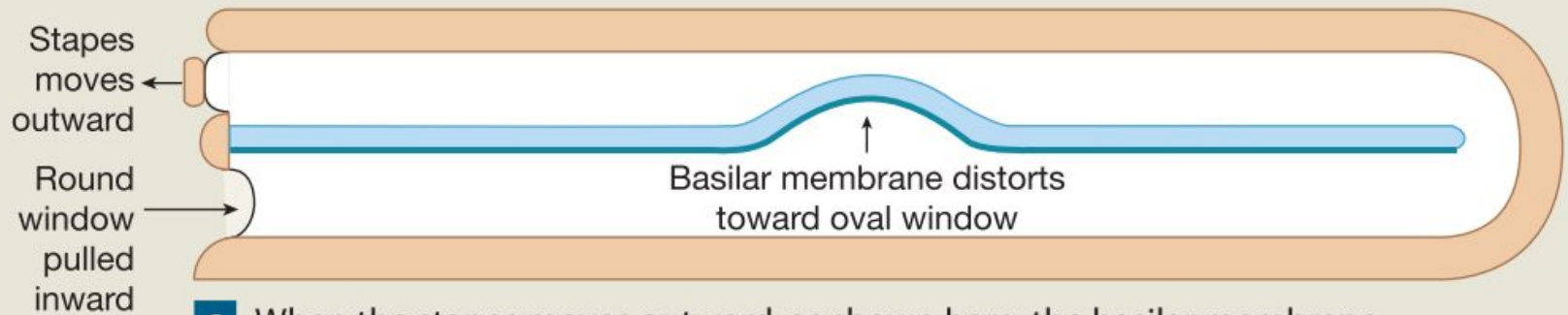




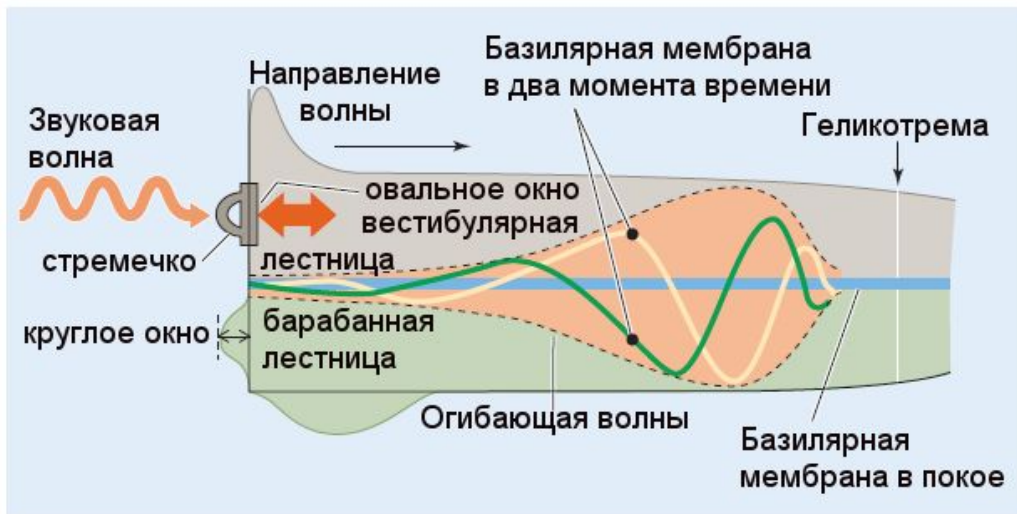
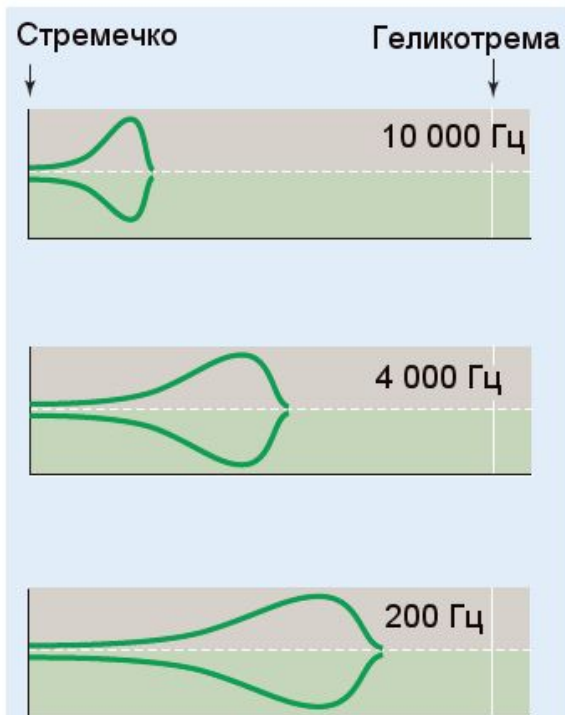
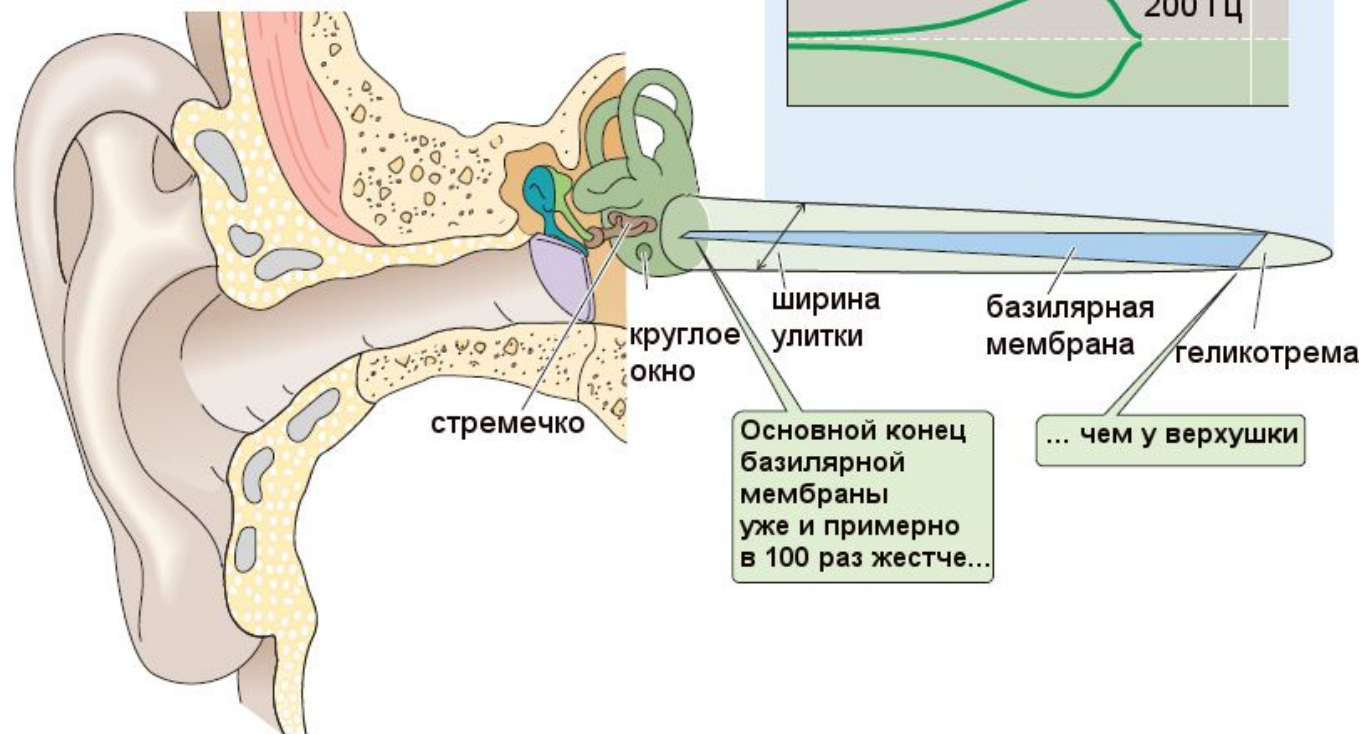
**a** The flexibility of the basilar membrane varies along its length, so pressure waves of different frequencies affect different parts of the membrane.

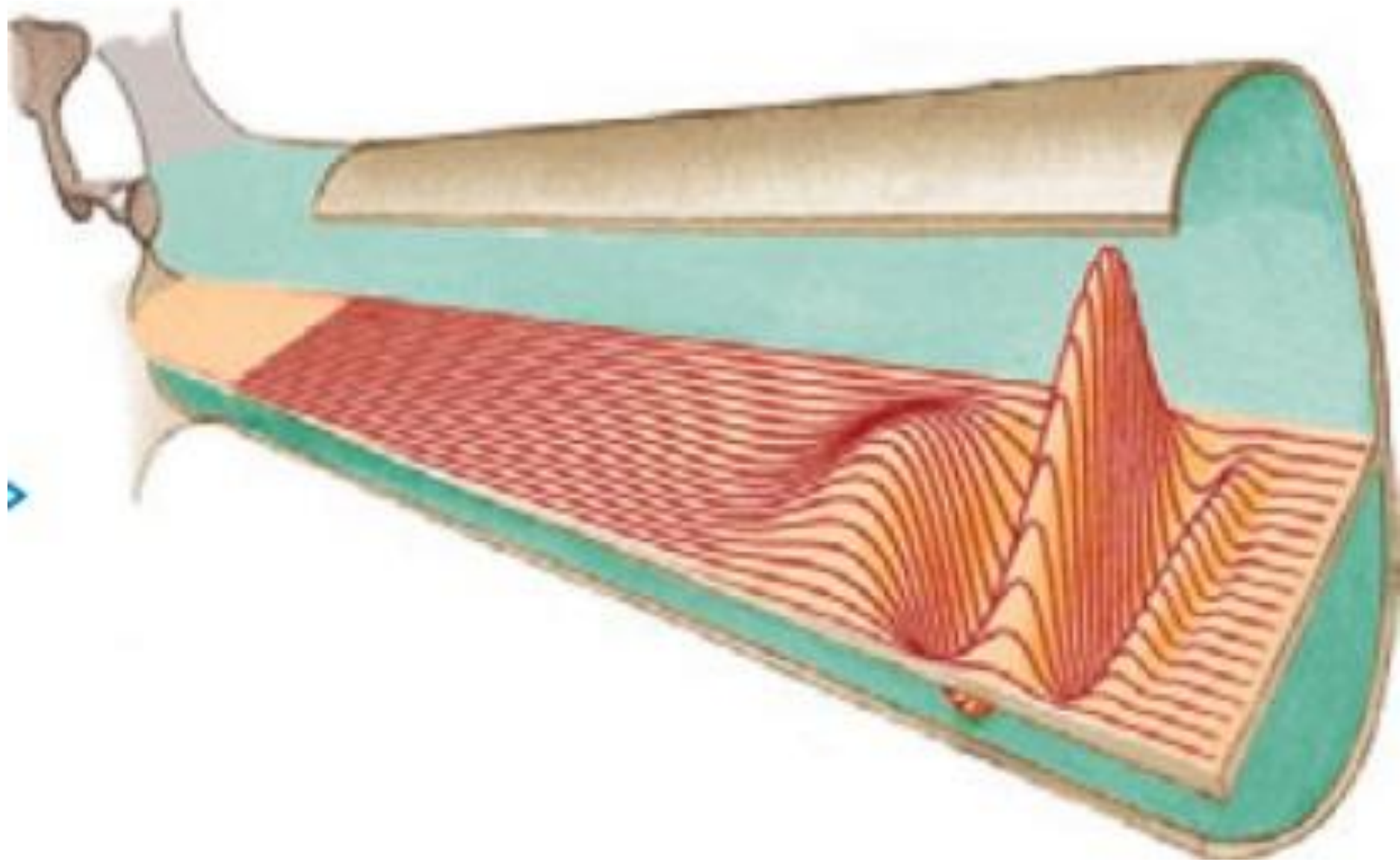


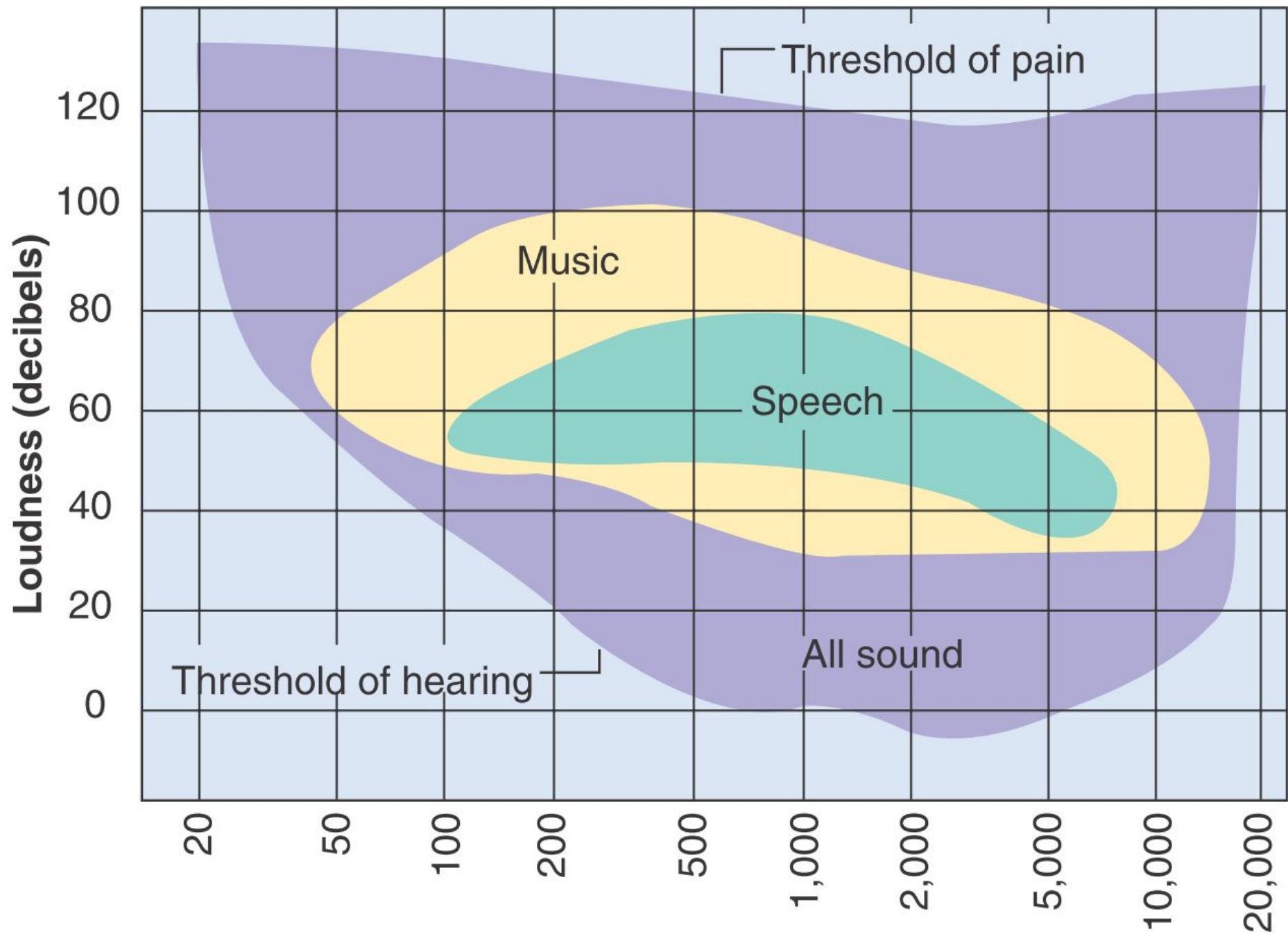
**b** The effects of a vibration of the stapes at a frequency of 6000 Hz. When the stapes moves inward, as shown here, the basilar membrane distorts toward the round window, which bulges into the middle-ear cavity.

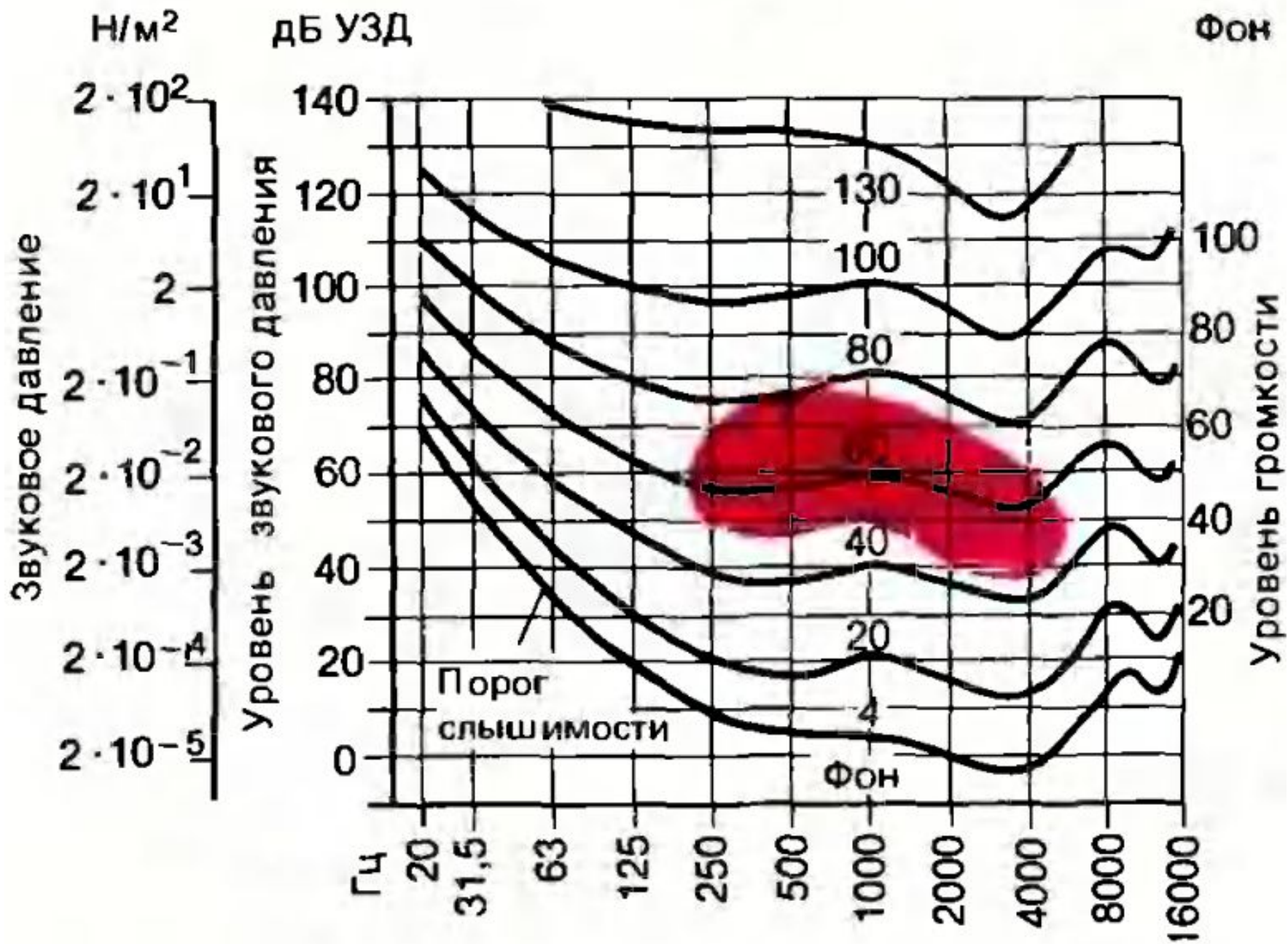


**c** When the stapes moves outward, as shown here, the basilar membrane rebounds and distorts toward the oval window.

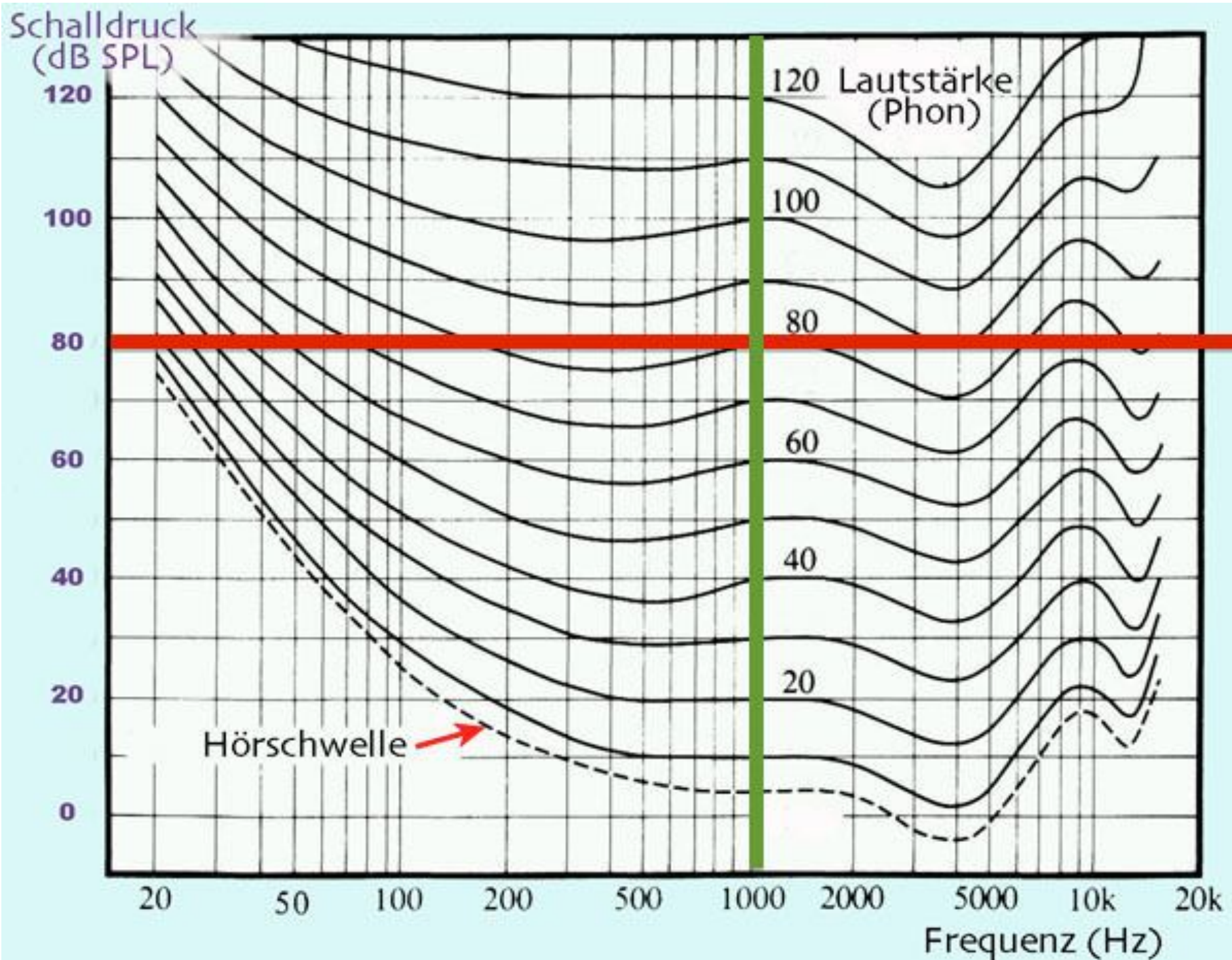
**А****Б****В**







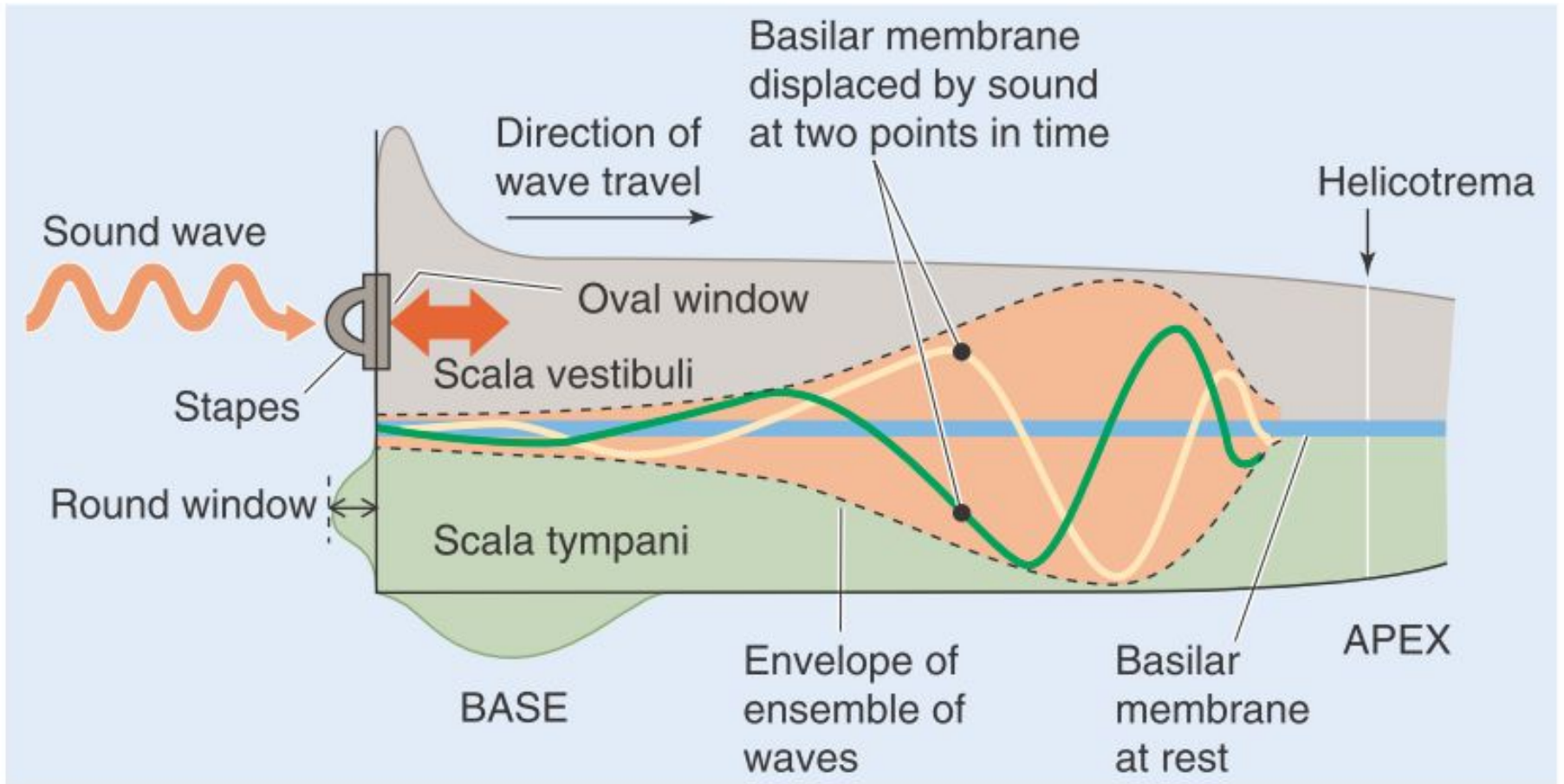




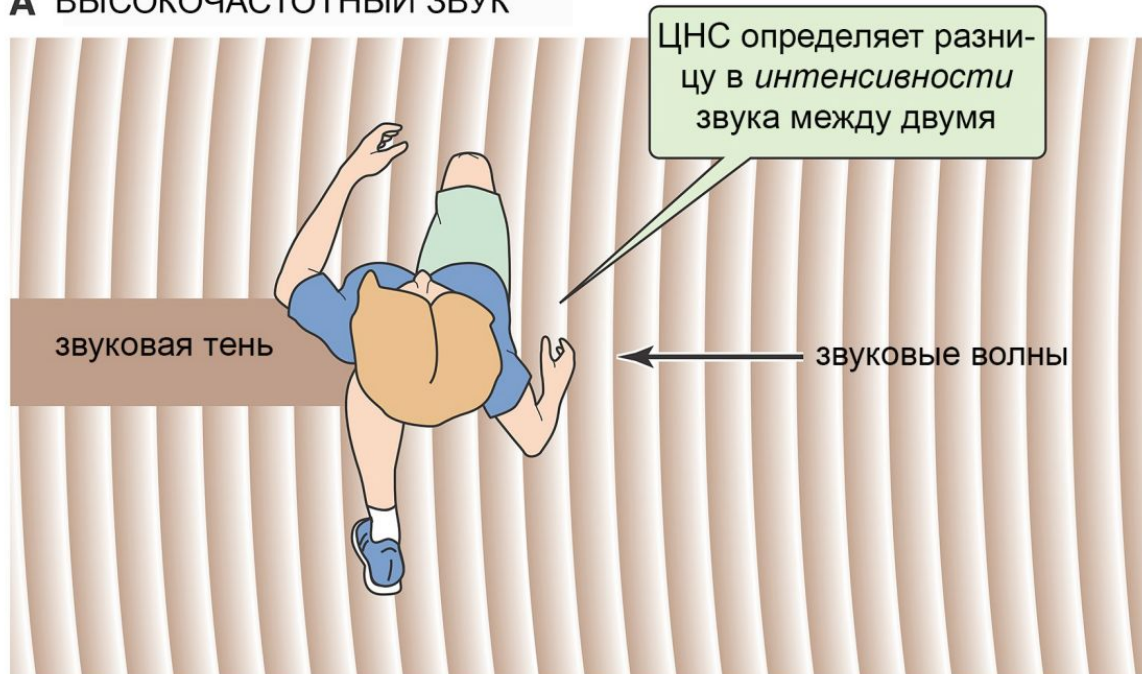
$$\text{УЗД} = 20 \cdot \lg \frac{P_x}{P_o} [\text{дБ}].$$

$$\frac{P_x}{P_o} = \frac{2 \cdot 10^{-1}}{2 \cdot 10^{-5}} = 10^4, \quad \text{УЗД} = 20 \lg 10^4 = 20 \cdot 4 = 80.$$

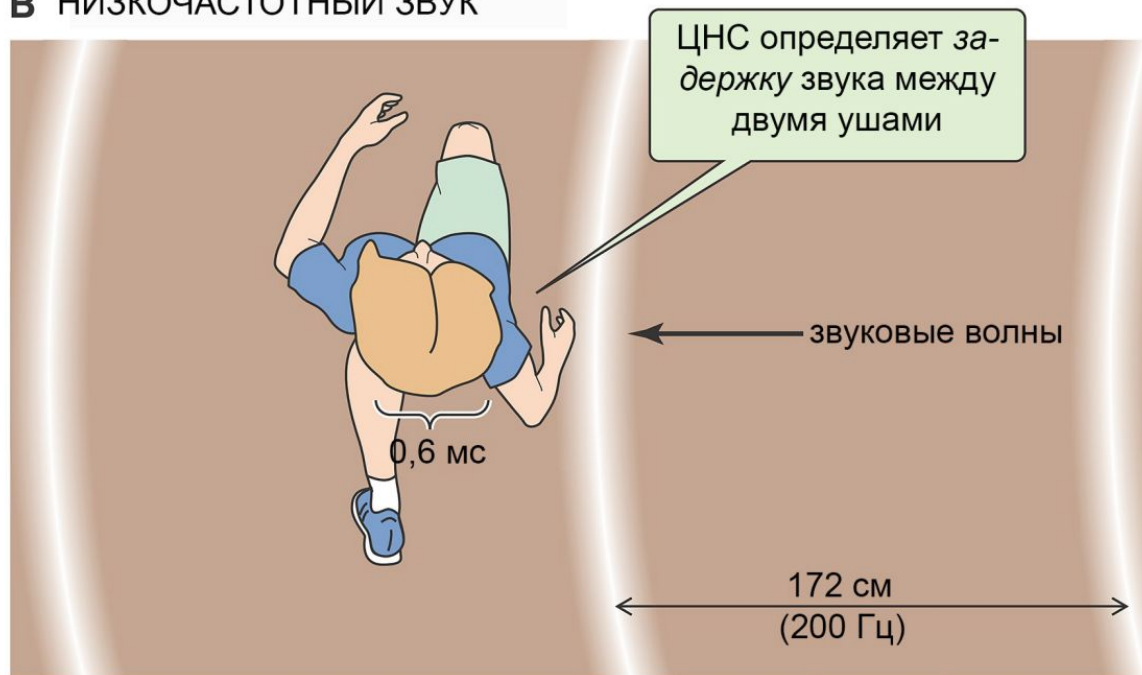
# A ENVELOPE OF MAXIMUM WAVE AMPLITUDES



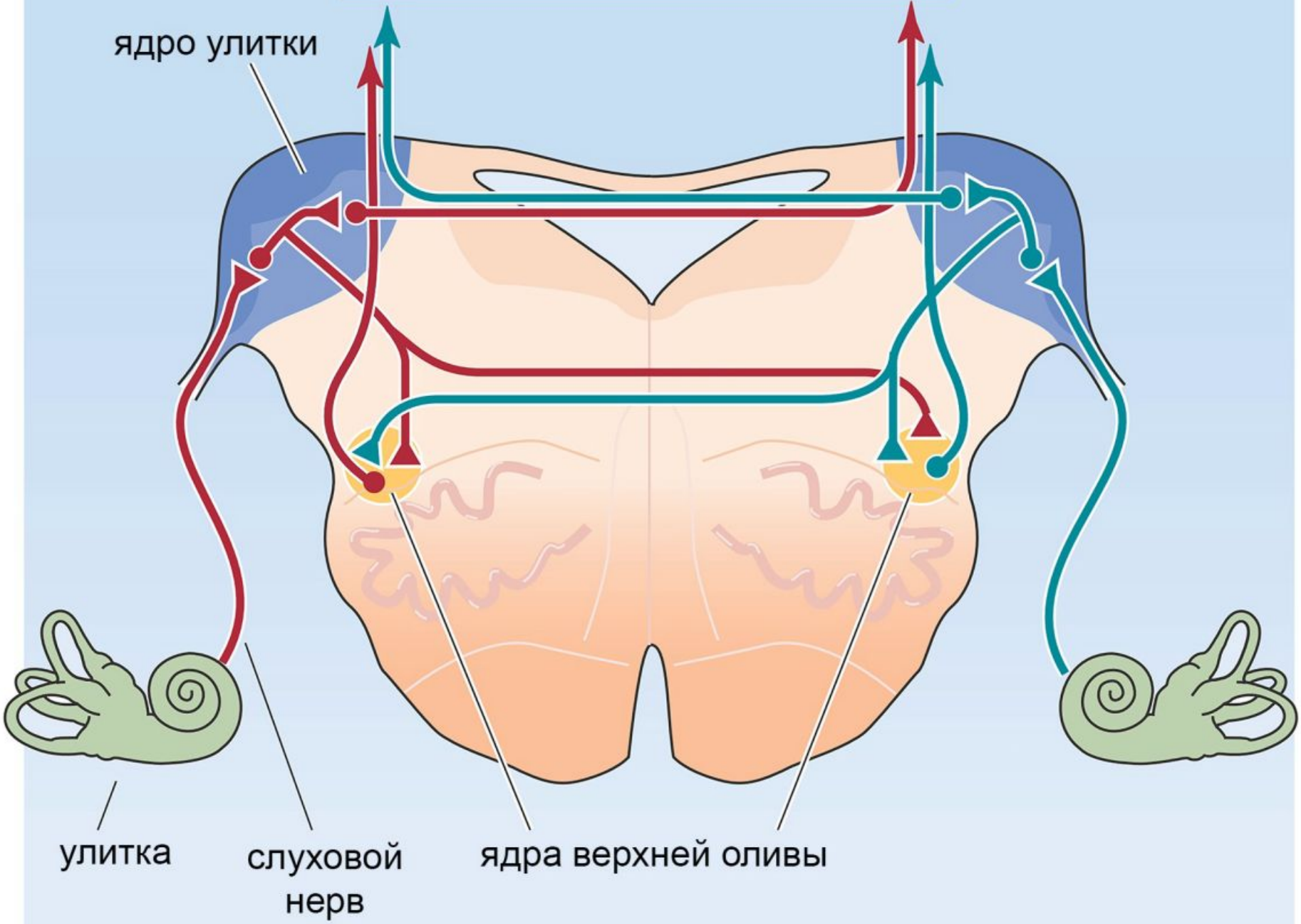
## А ВЫСОКОЧАСТОТНЫЙ ЗВУК



## Б НИЗКОЧАСТОТНЫЙ ЗВУК



В ВЫШЕЛЕЖАЩИЕ ЦЕНТРЫ

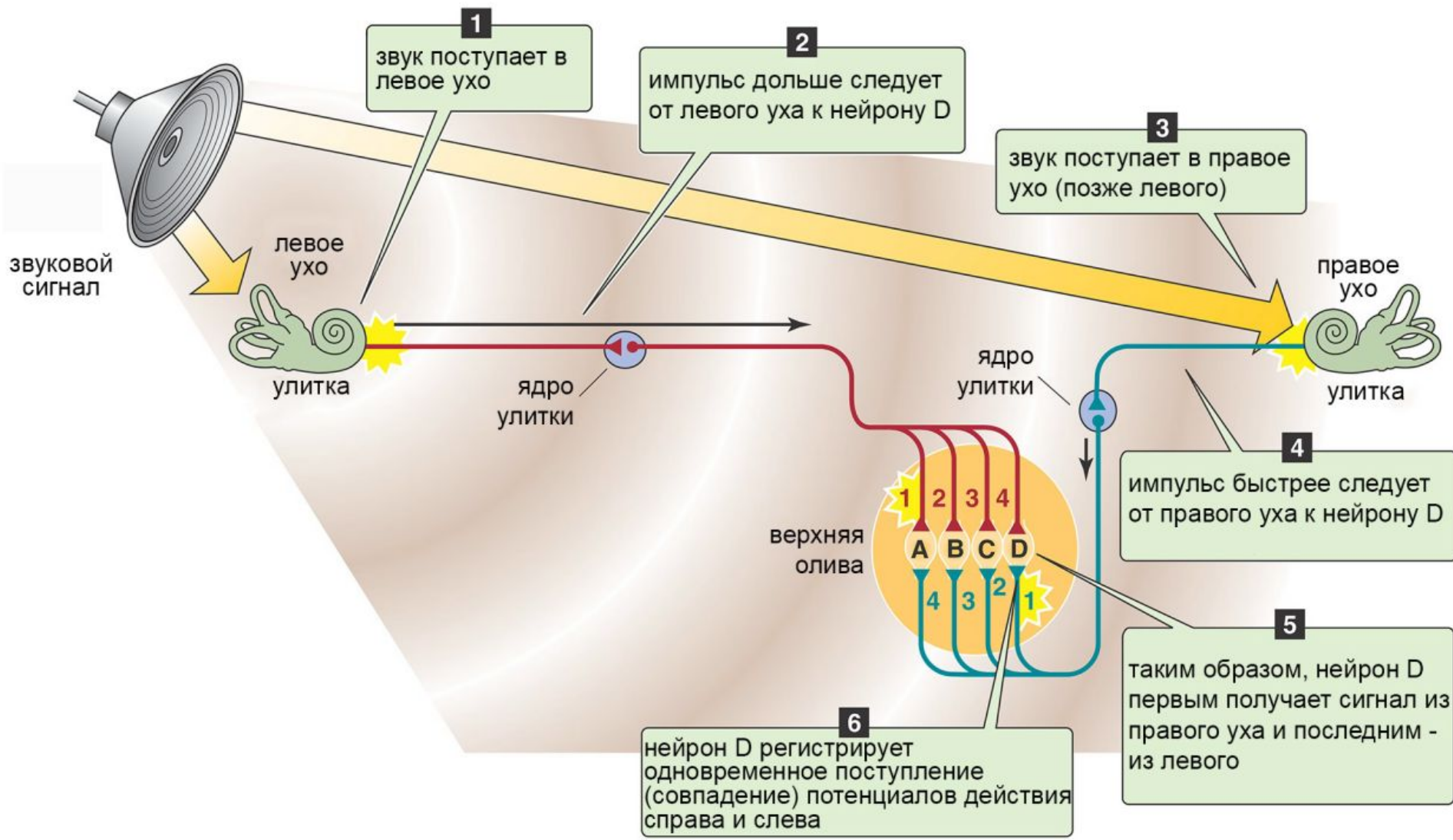


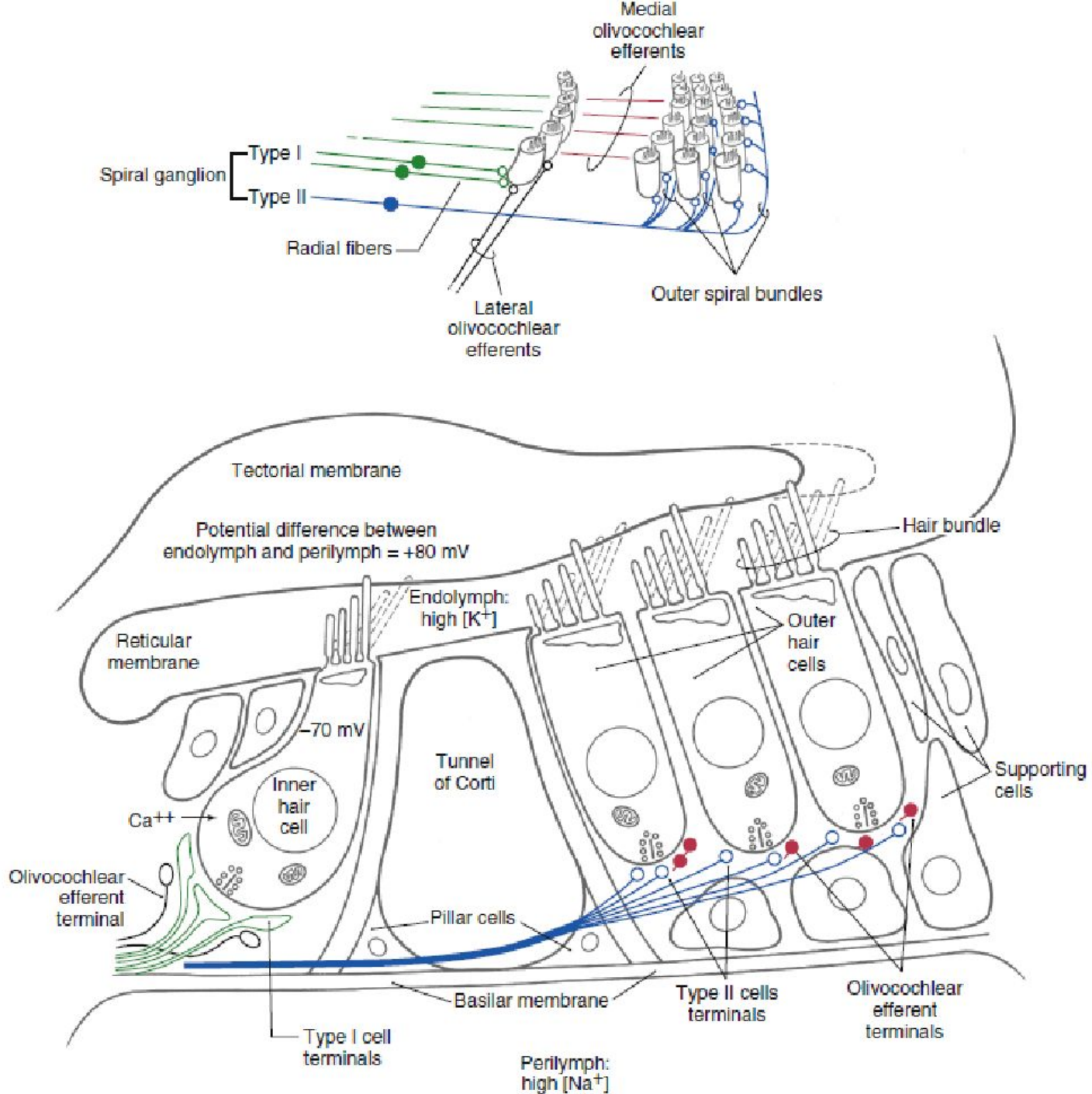
ядро улитки

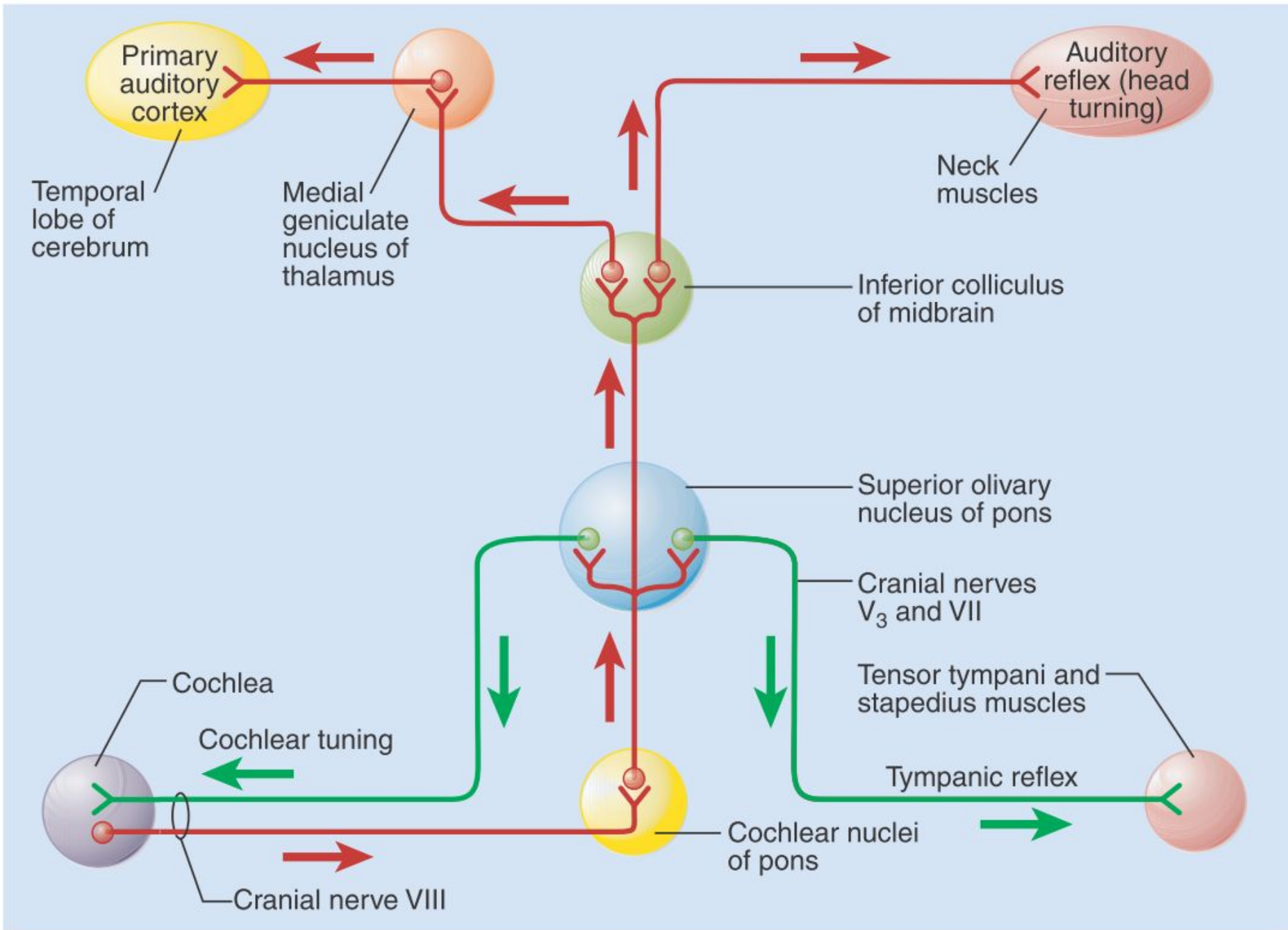
улитка

слуховой  
нерв

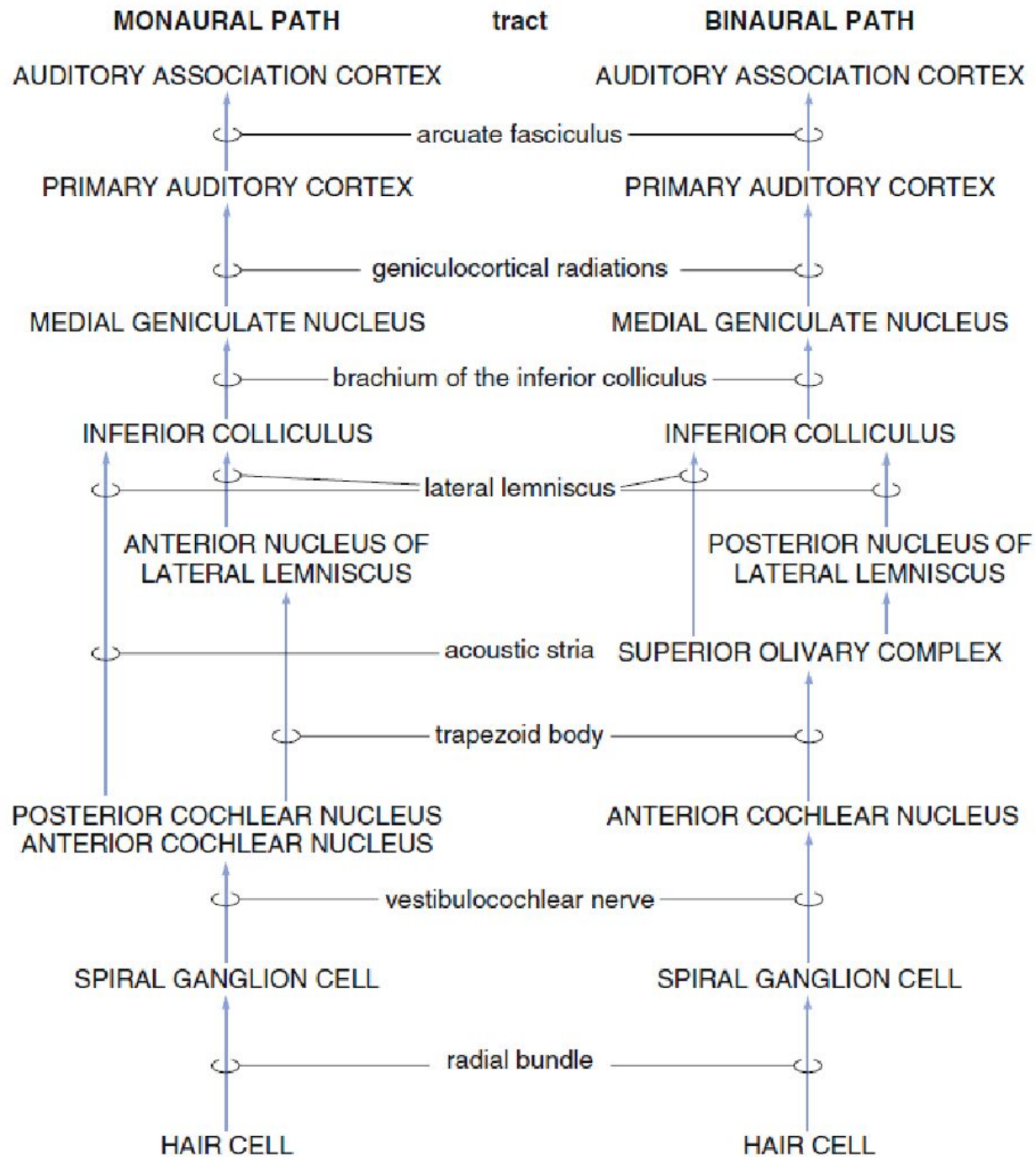
ядра верхней оливы

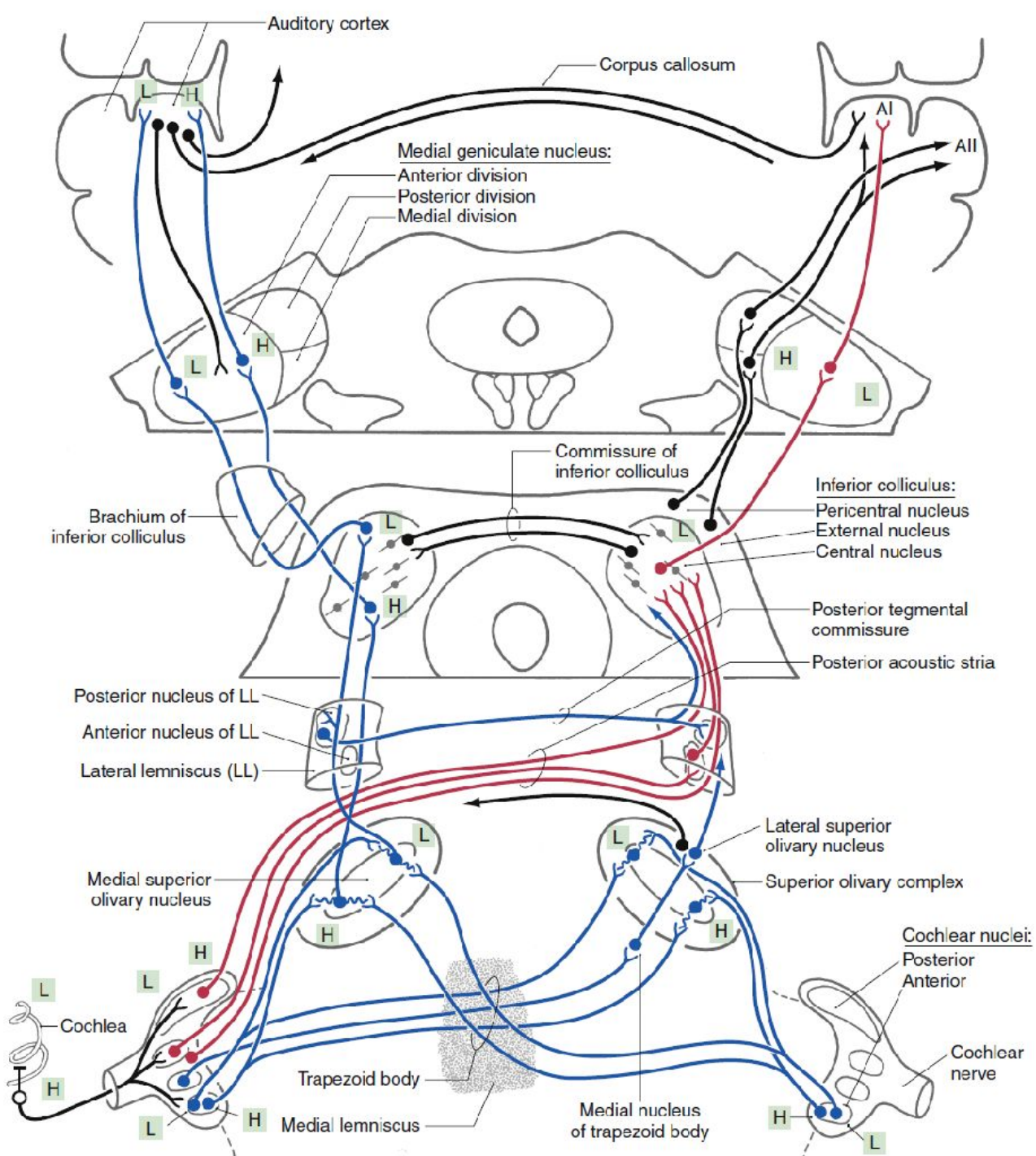












**Figure 17-32** Pathways for Auditory Sensations.

