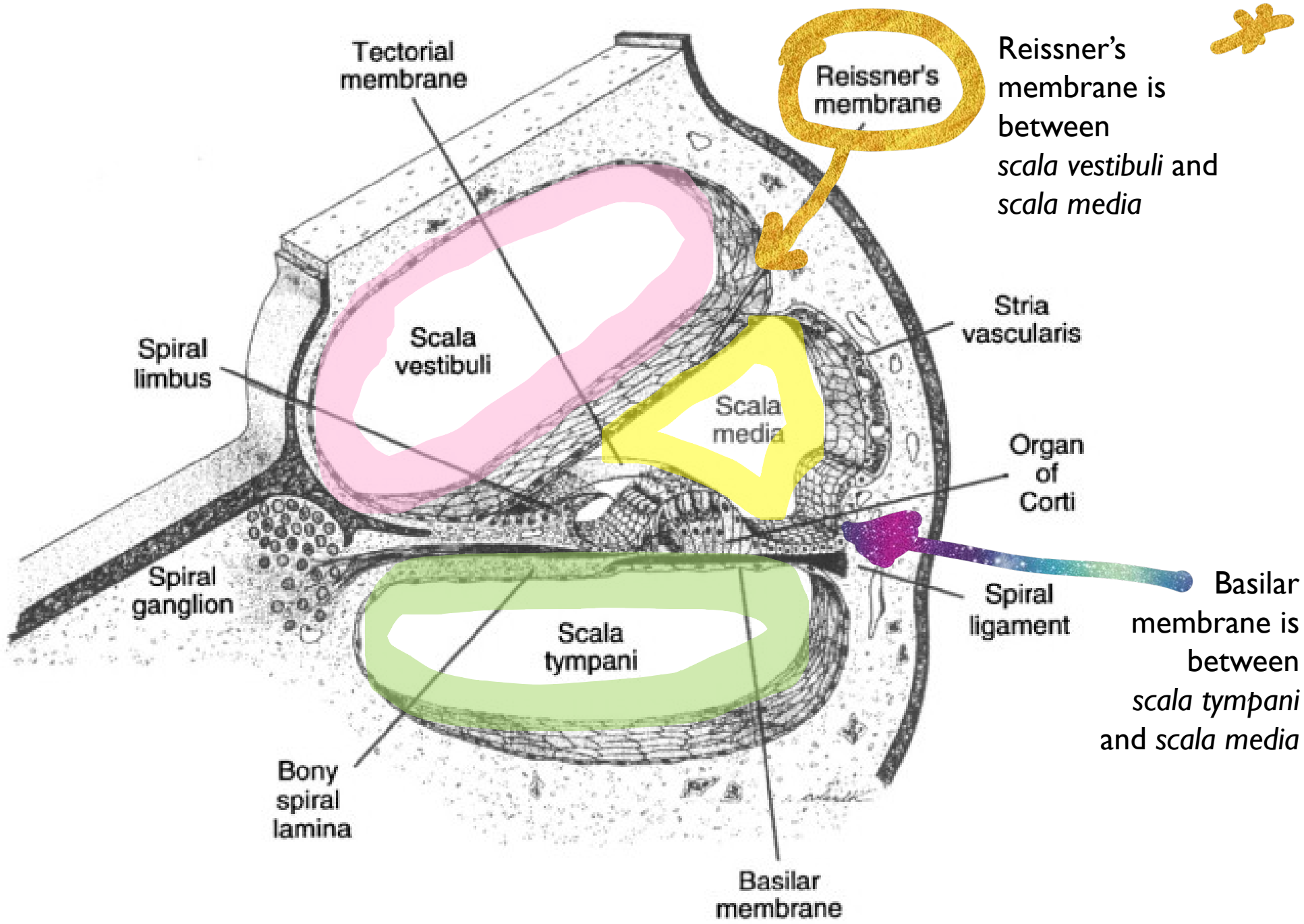


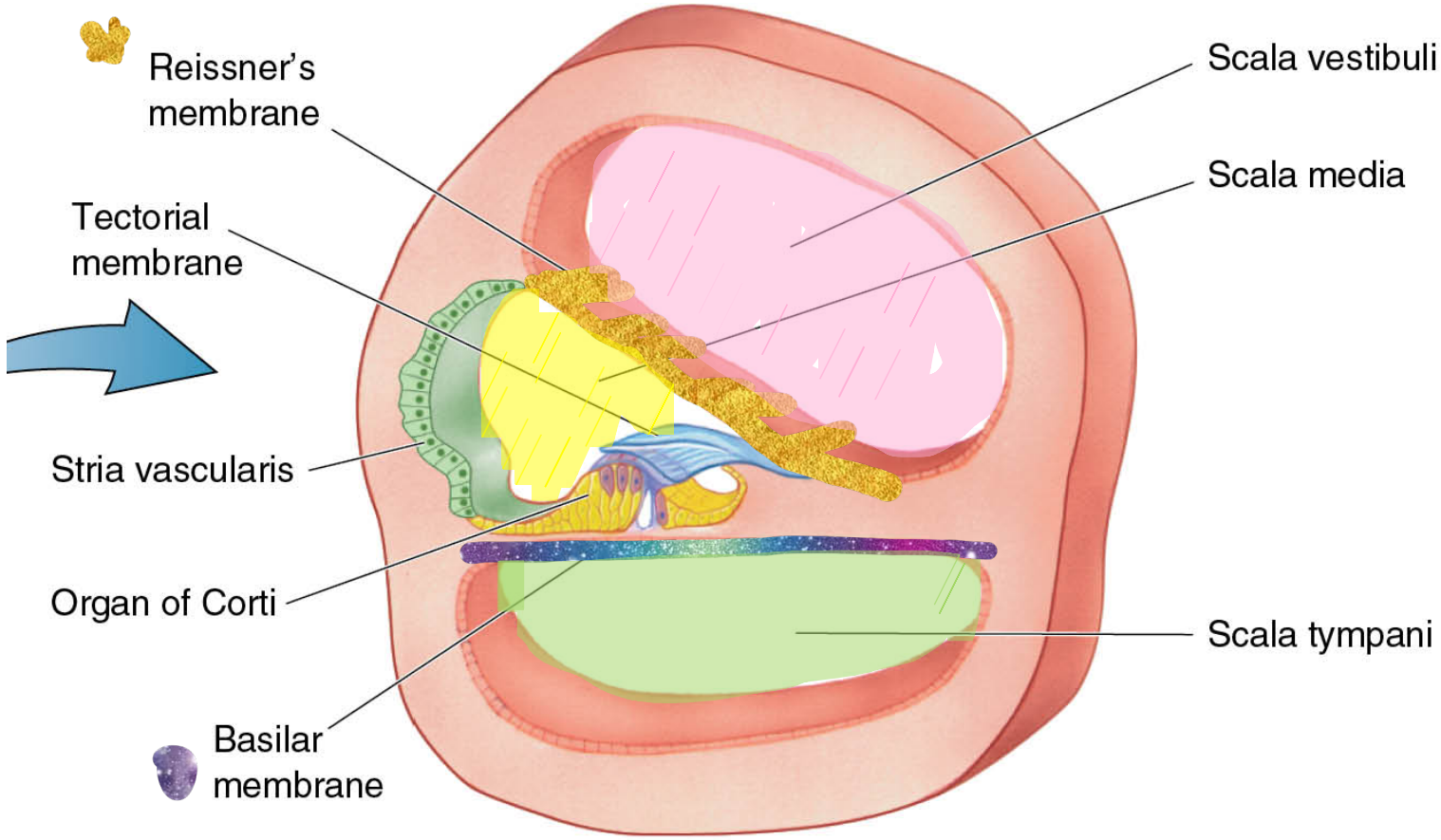
Reissner's membrane is between *scala vestibuli* and *scala media*

Basilar membrane is between *scala tympani* and *scala media*

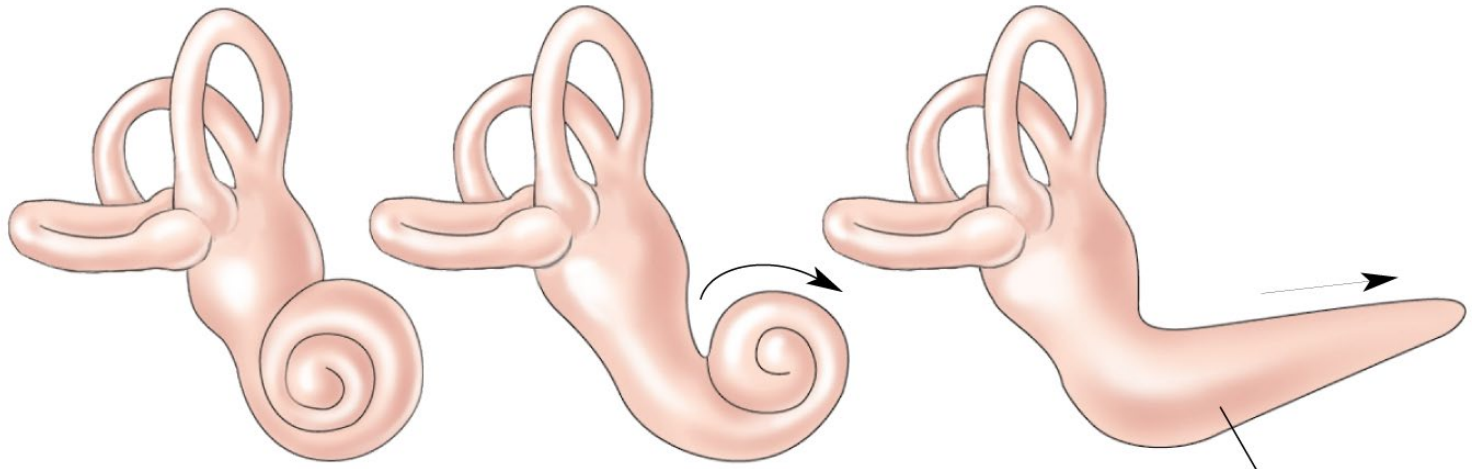
Felten, David L., Anil Narsinha Shetty, and David L. Felten. *Netter's Atlas of Neuroscience*. 2nd ed. Philadelphia, PA: Saunders/Elsevier, 2010. Print.

THE INNER EAR → SOUND TO NEURAL SIGNALS

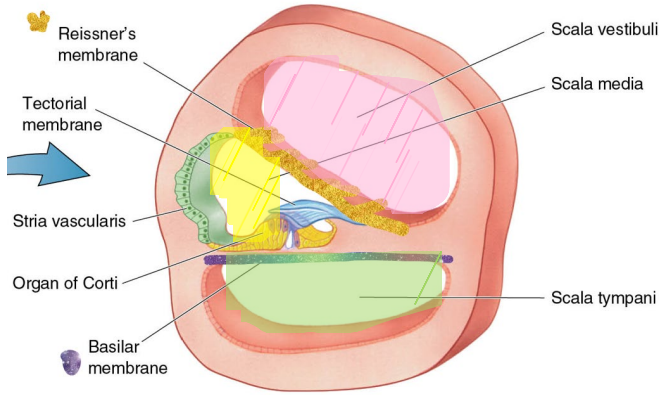
- Anatomy of the cochlea
- Perilymph: fluid in scala vestibuli and scala tympani
- Endolymph: fluid in scala media
- Endocochlear potential: endolymph electrical potential 80 mV more positive than perilymph

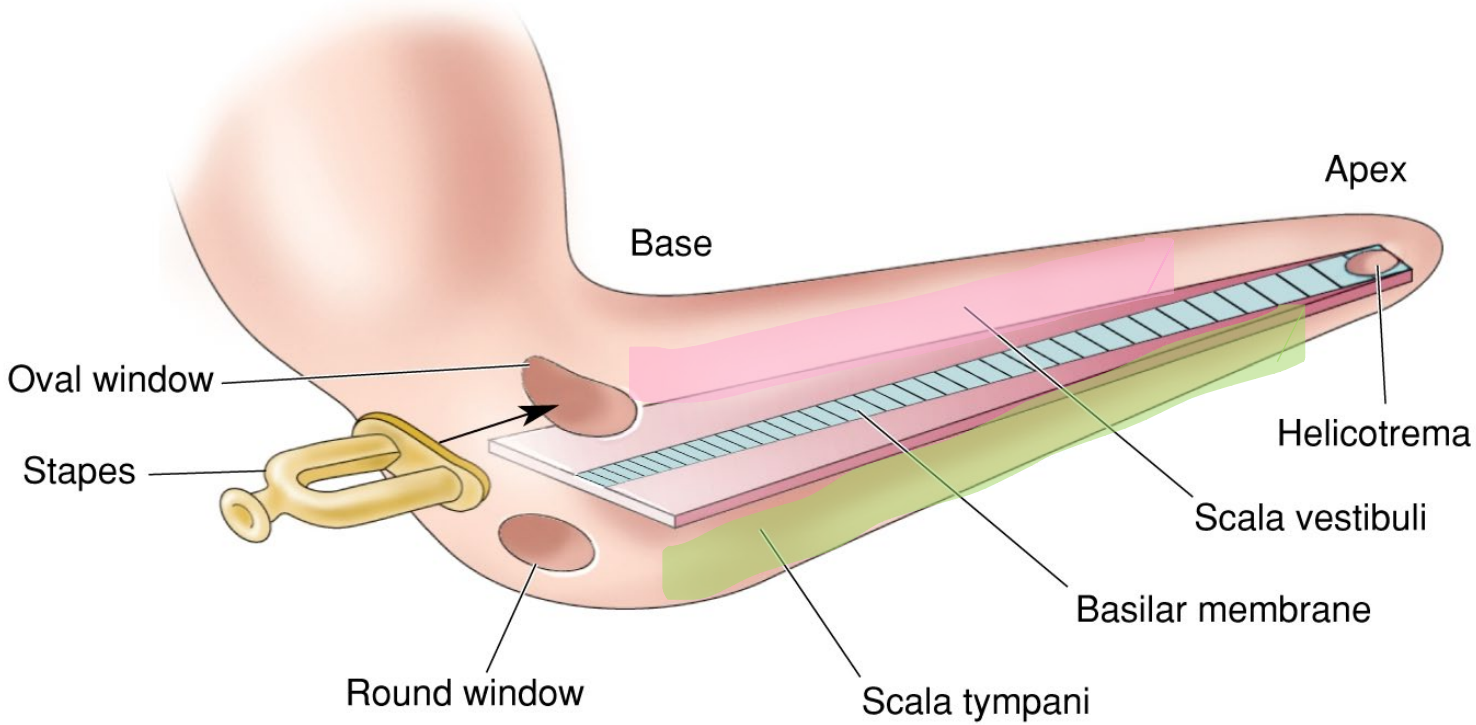


Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.



The cochlea narrows from base to apex

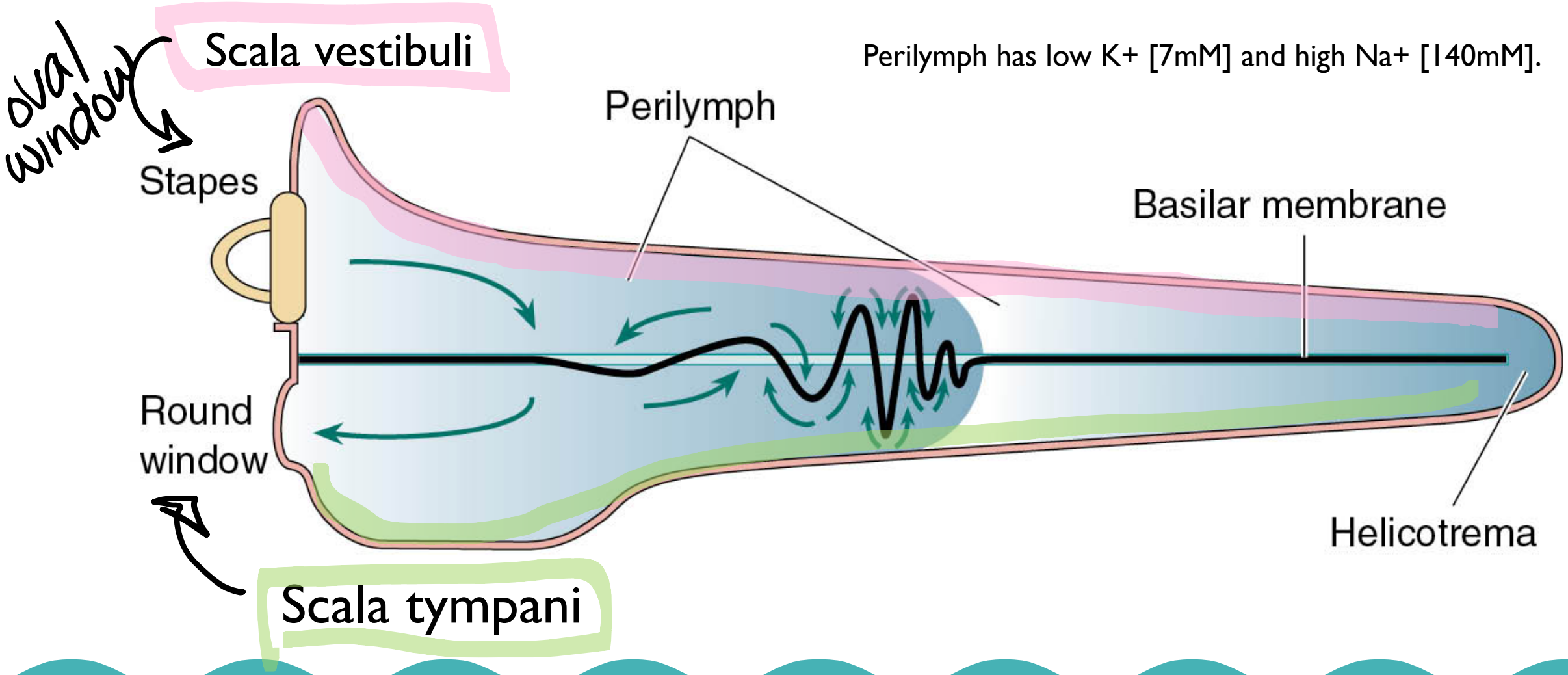




The basilar membrane WIDENS towards the apex.

Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.

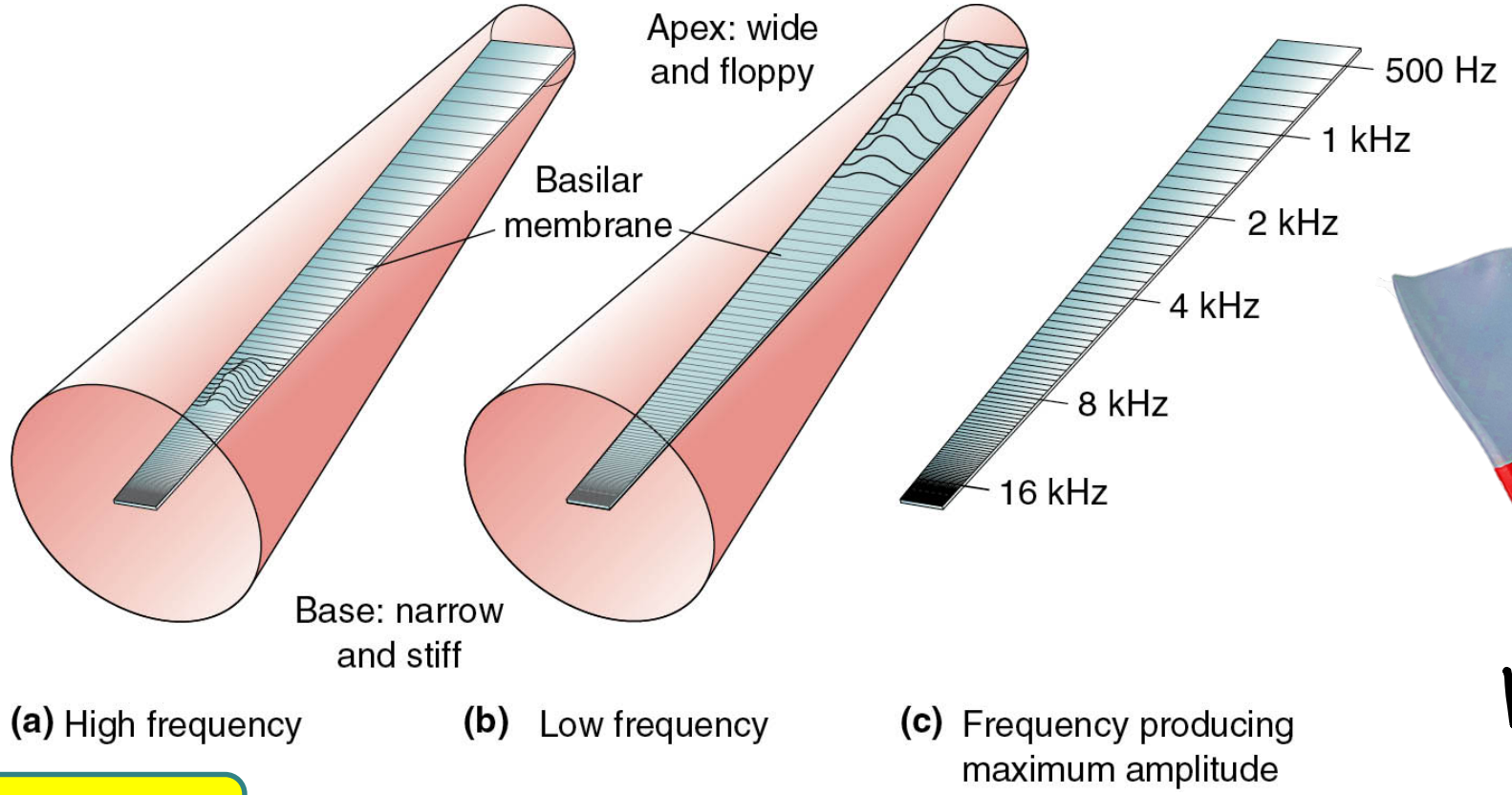
Perilymph has low K+ [7mM] and high Na+ [140mM].

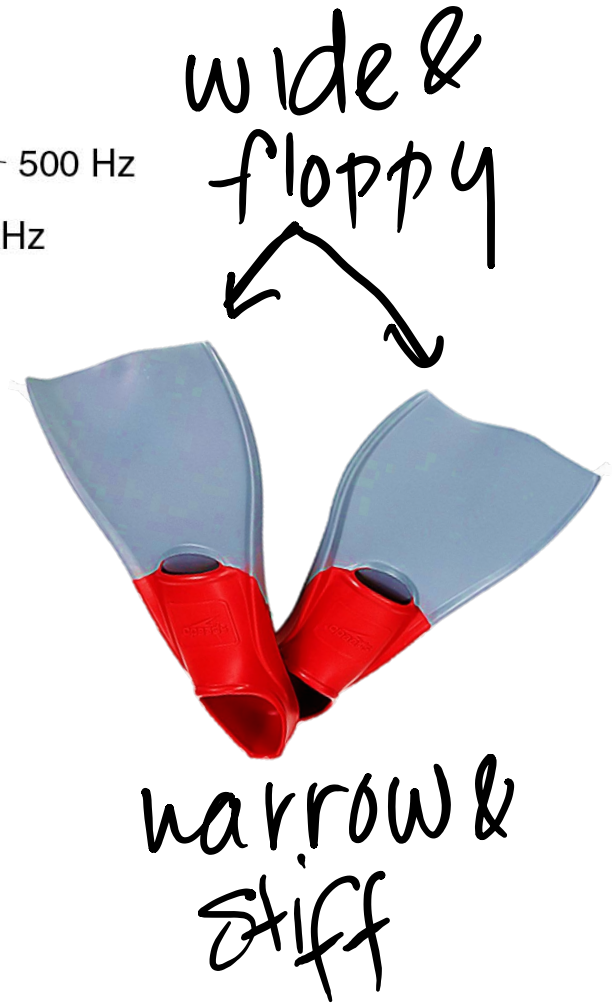


TRAVELING WAVE IN THE BASILAR MEMBRANE

Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.

Recall: Basilar membrane is flexible and bends in response to sound.



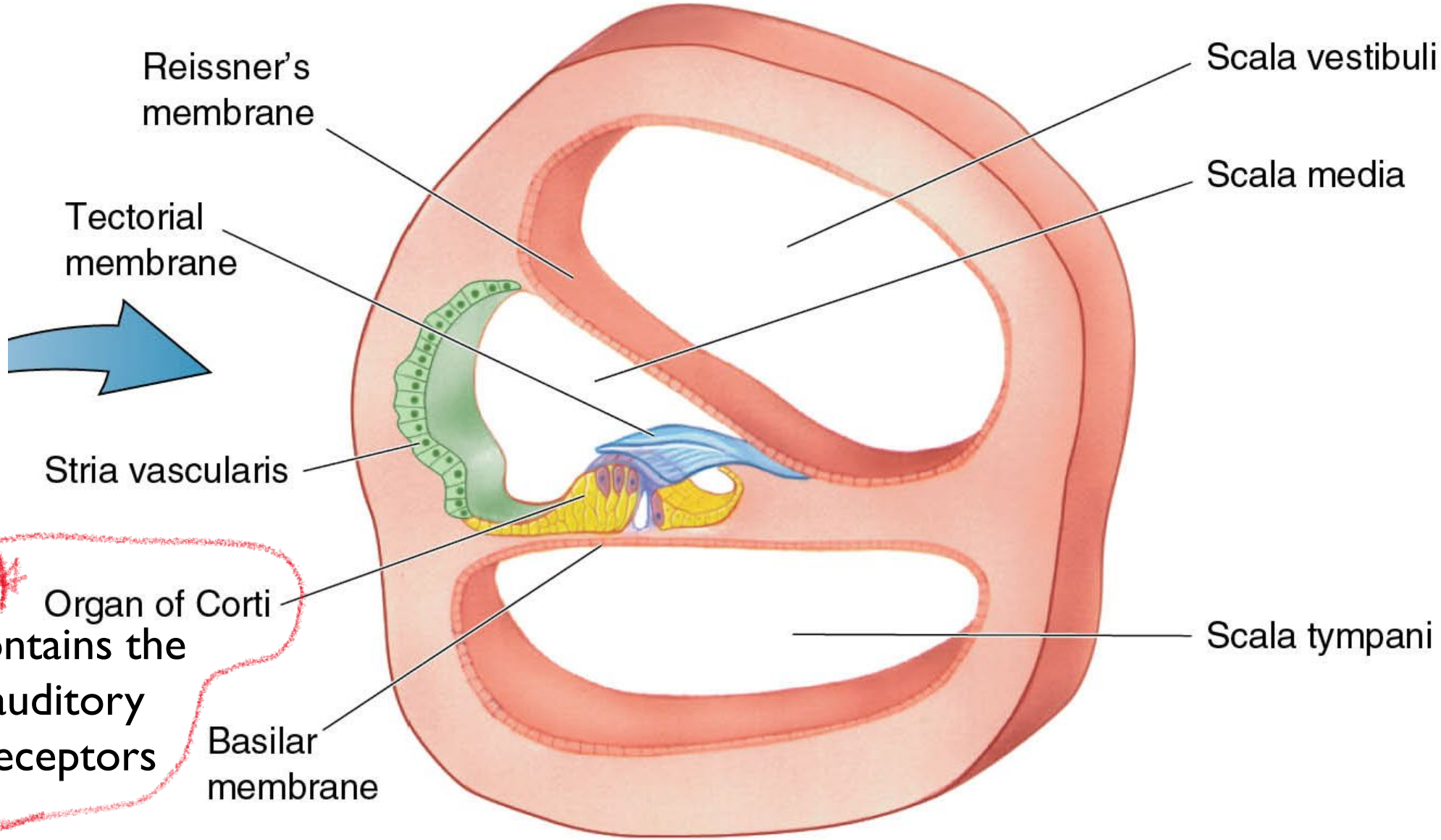


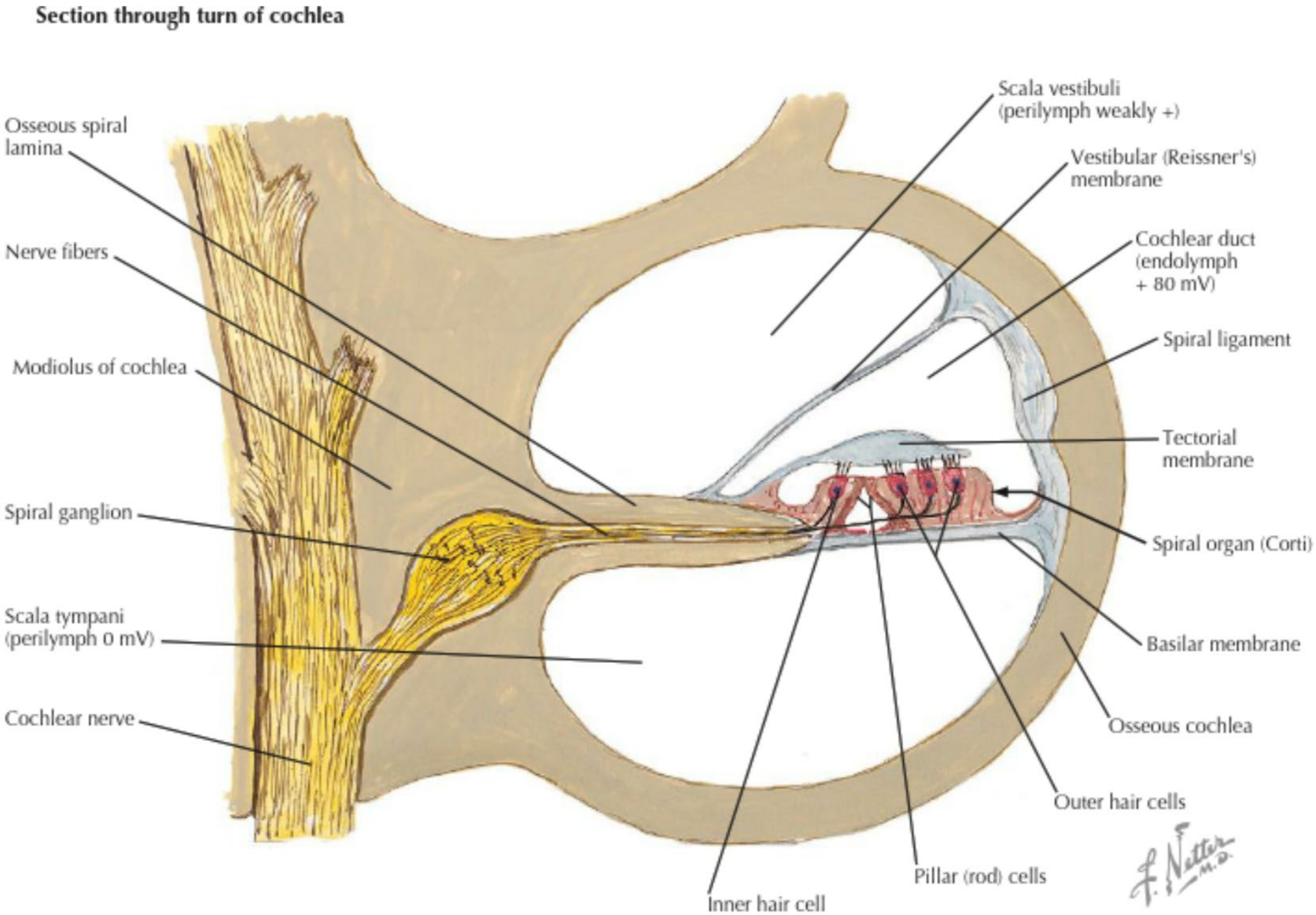
PLACE CODING

RESPONSE OF BASILAR MEMBRANE TO SOUND

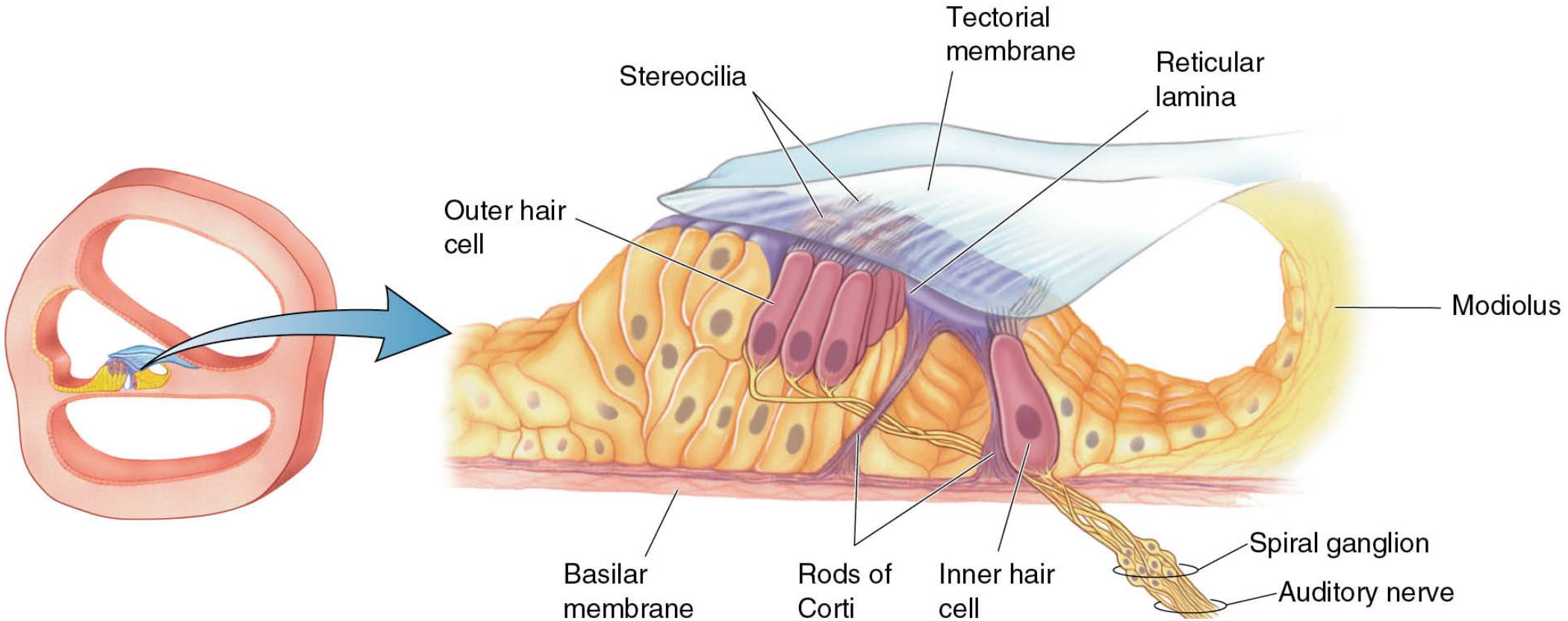
Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.

The organ of Corti – auditory receptors



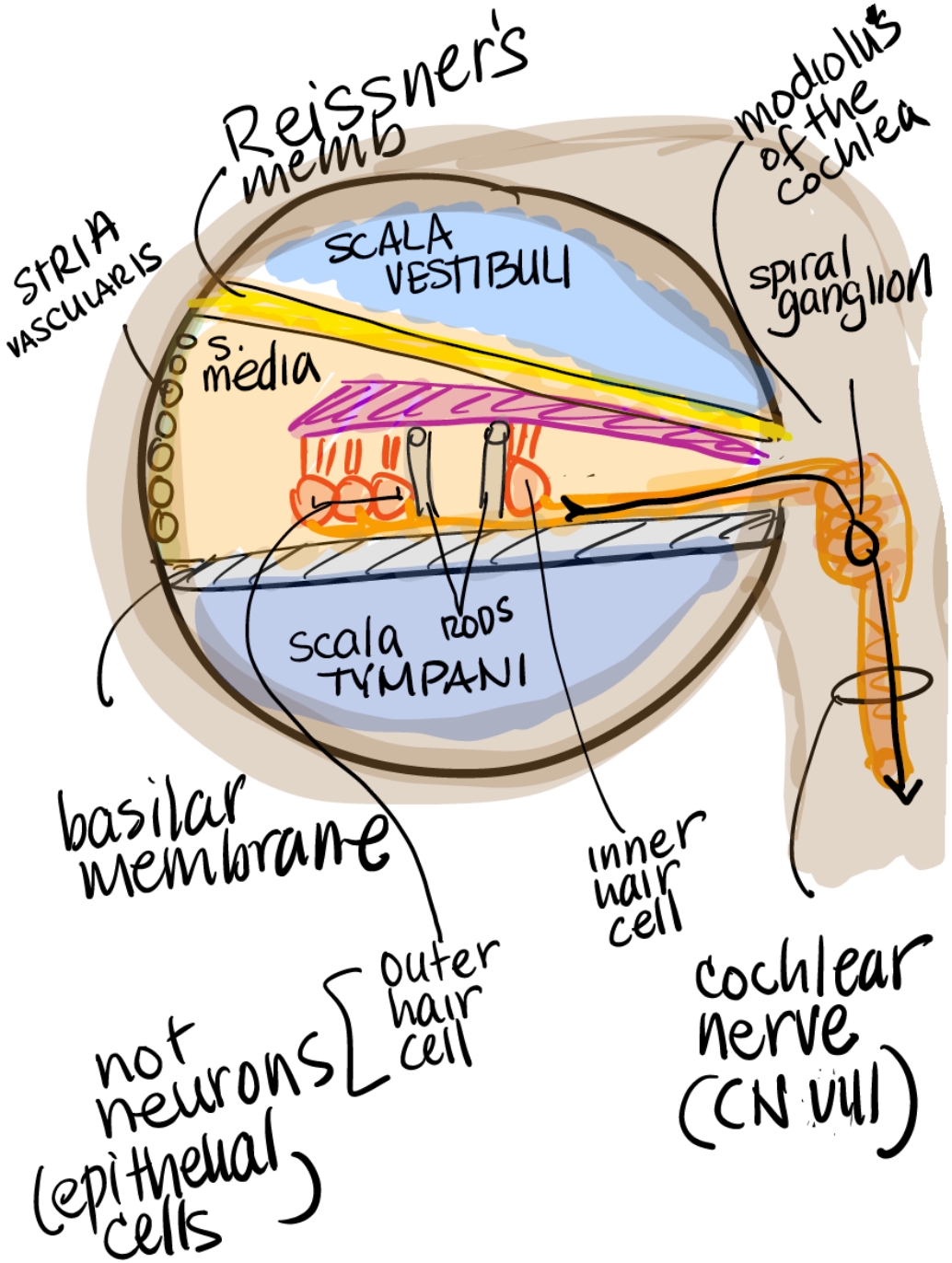


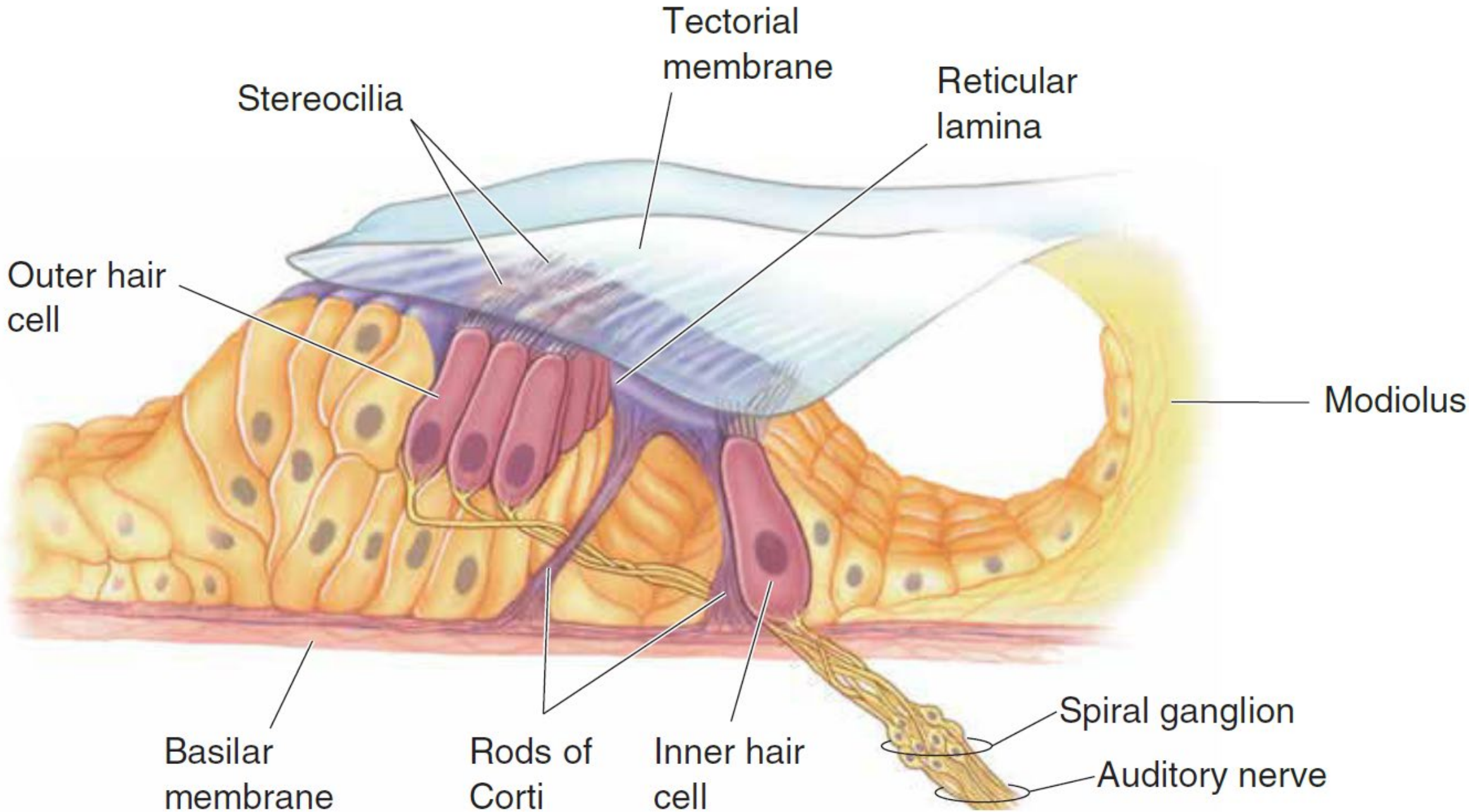
Felten, David L., Anil Narsinha Shetty, and David L. Felten. *Netter's Atlas of Neuroscience*. 2nd ed. Philadelphia, PA: Saunders/Elsevier, 2010. Print.

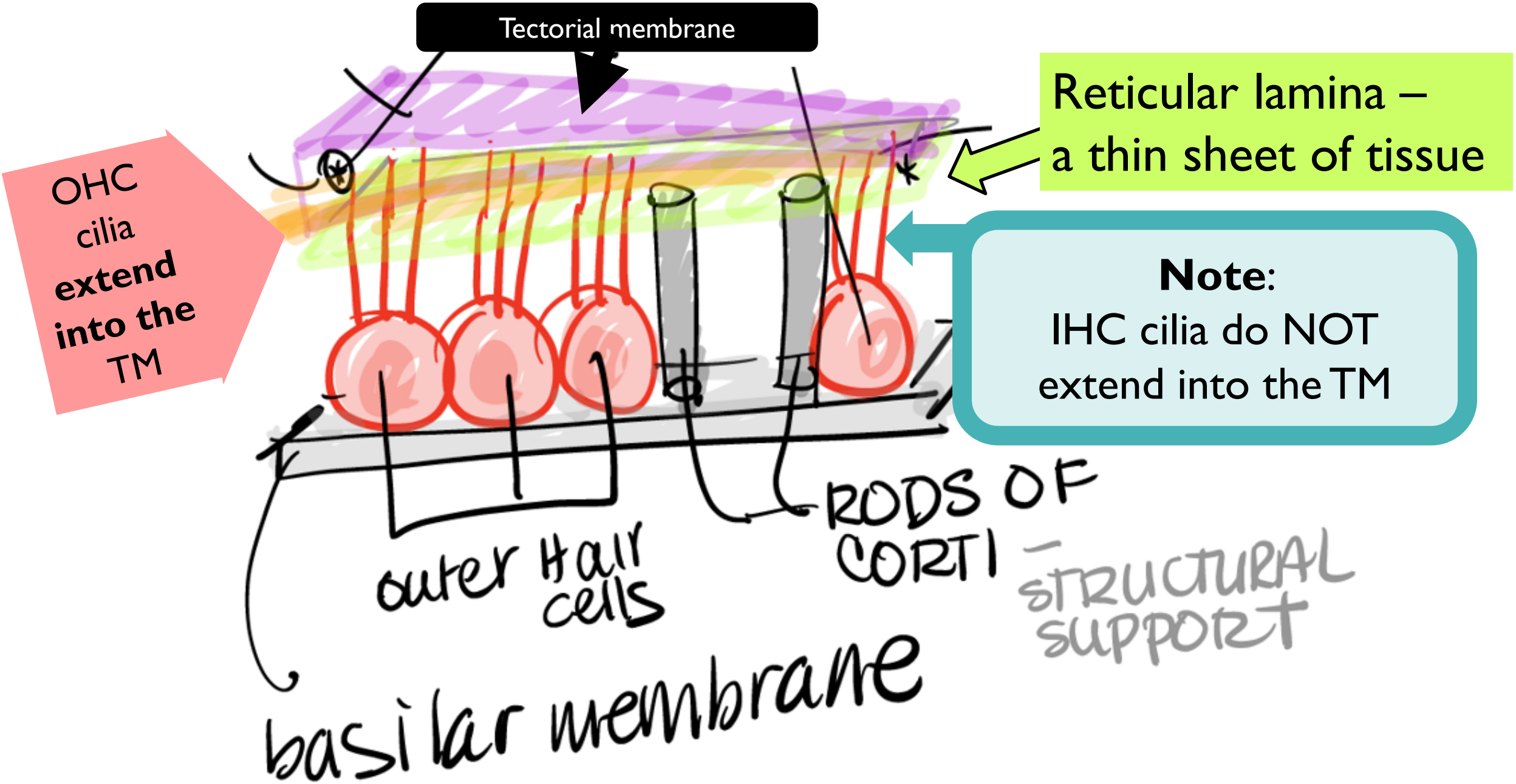


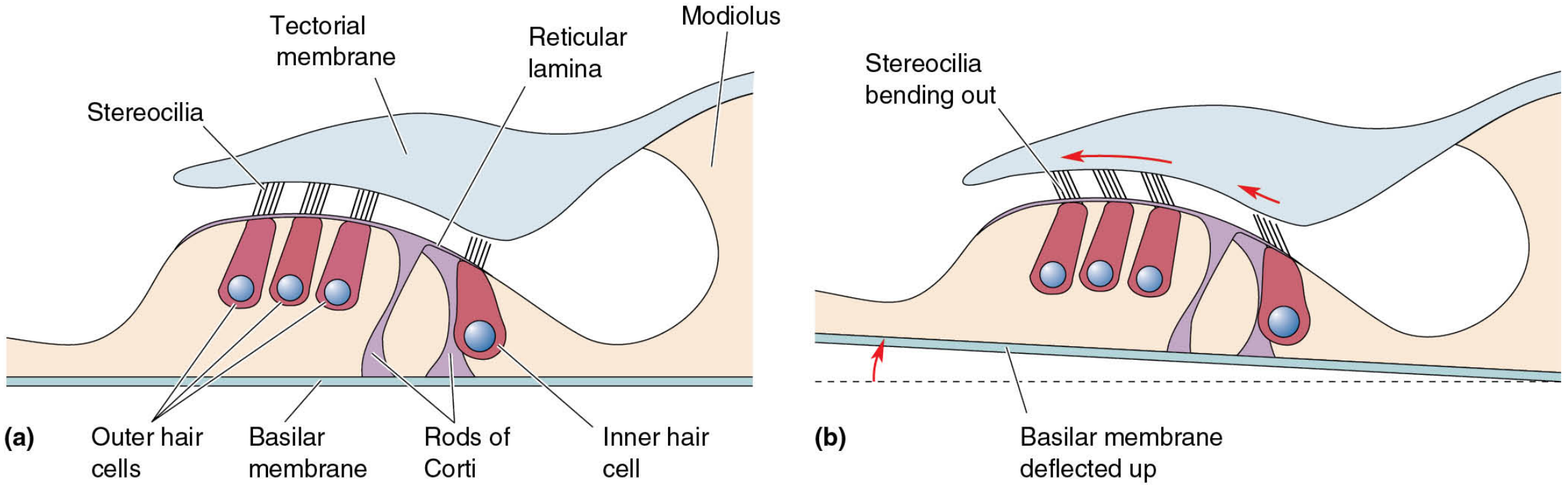
THE ORGAN OF CORTI AND ASSOCIATED STRUCTURES

Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.


Reissner's memb
modiolus of the cochlea
STRIA VASCULARIS
SCALA VESTIBULI
spiral ganglion
s. media
scala TYMPANI
RODS
basilar membrane
inner hair cell
outer hair cell
not neurons (epithelial cells)
cochlear nerve (CN VIII)

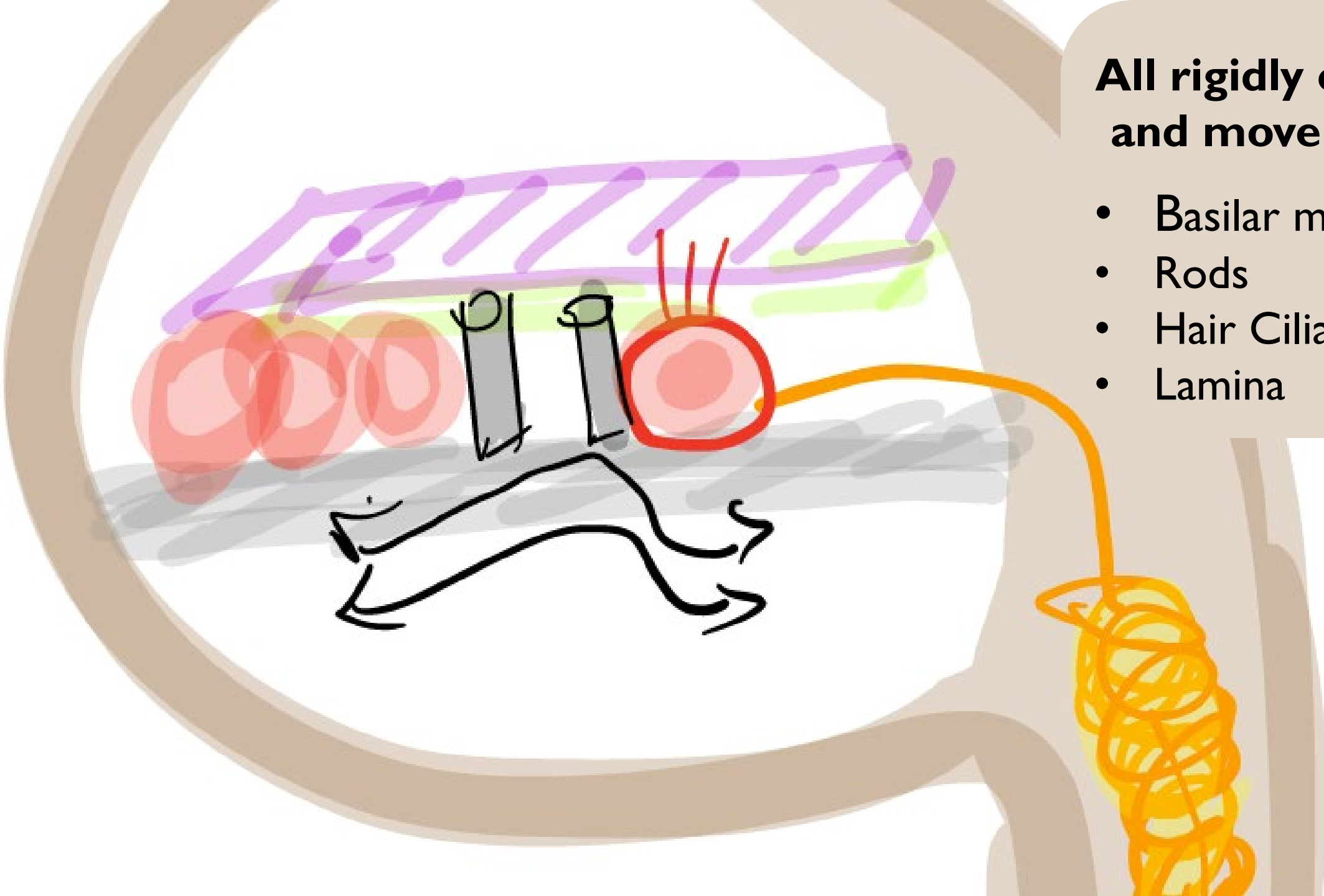

Tectorial membrane
Stereocilia
Reticular lamina
Outer hair cell
Modiolus
Basilar membrane
Rods of Corti
Inner hair cell
Spiral ganglion
Auditory nerve


Tectorial membrane
Reticular lamina – a thin sheet of tissue
OHC cilia **extend into the** TM
Note: IHC cilia do NOT extend into the TM
outer Hair cells
RODS OF CORTI – STRUCTURAL SUPPORT
basilar membrane



THE BENDING OF STEREOCILIA

Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.

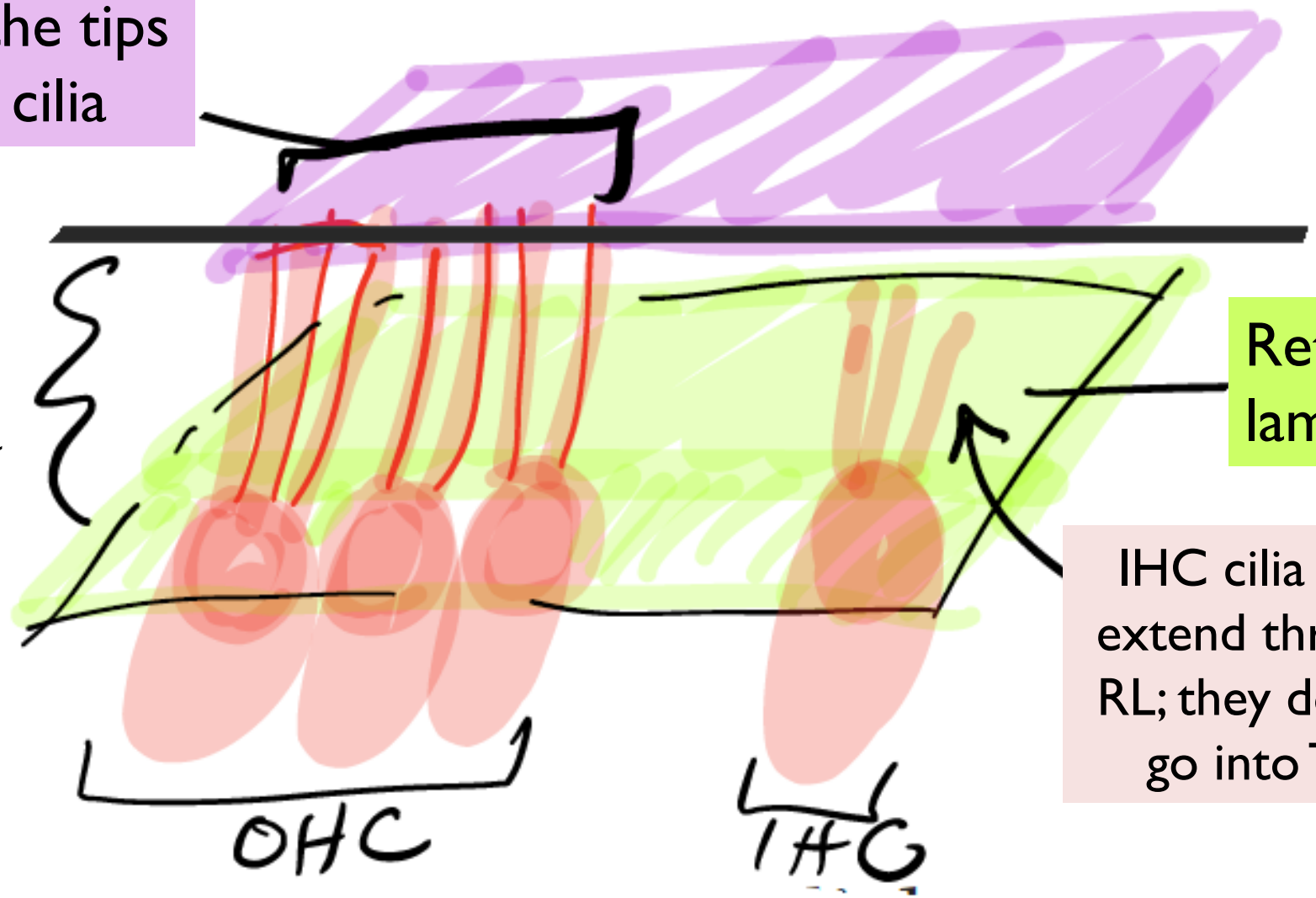


All rigidly connected and move as a unit:

- Basilar membrane
- Rods
- Hair Cilia
- Lamina

TM holds the tips of OHC cilia

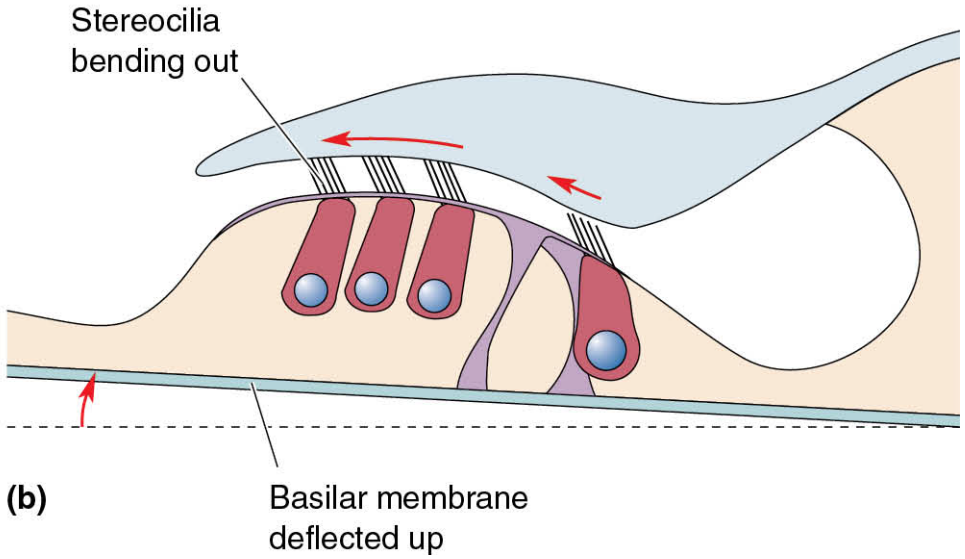
OHC cilia extend through the lamina into the TM

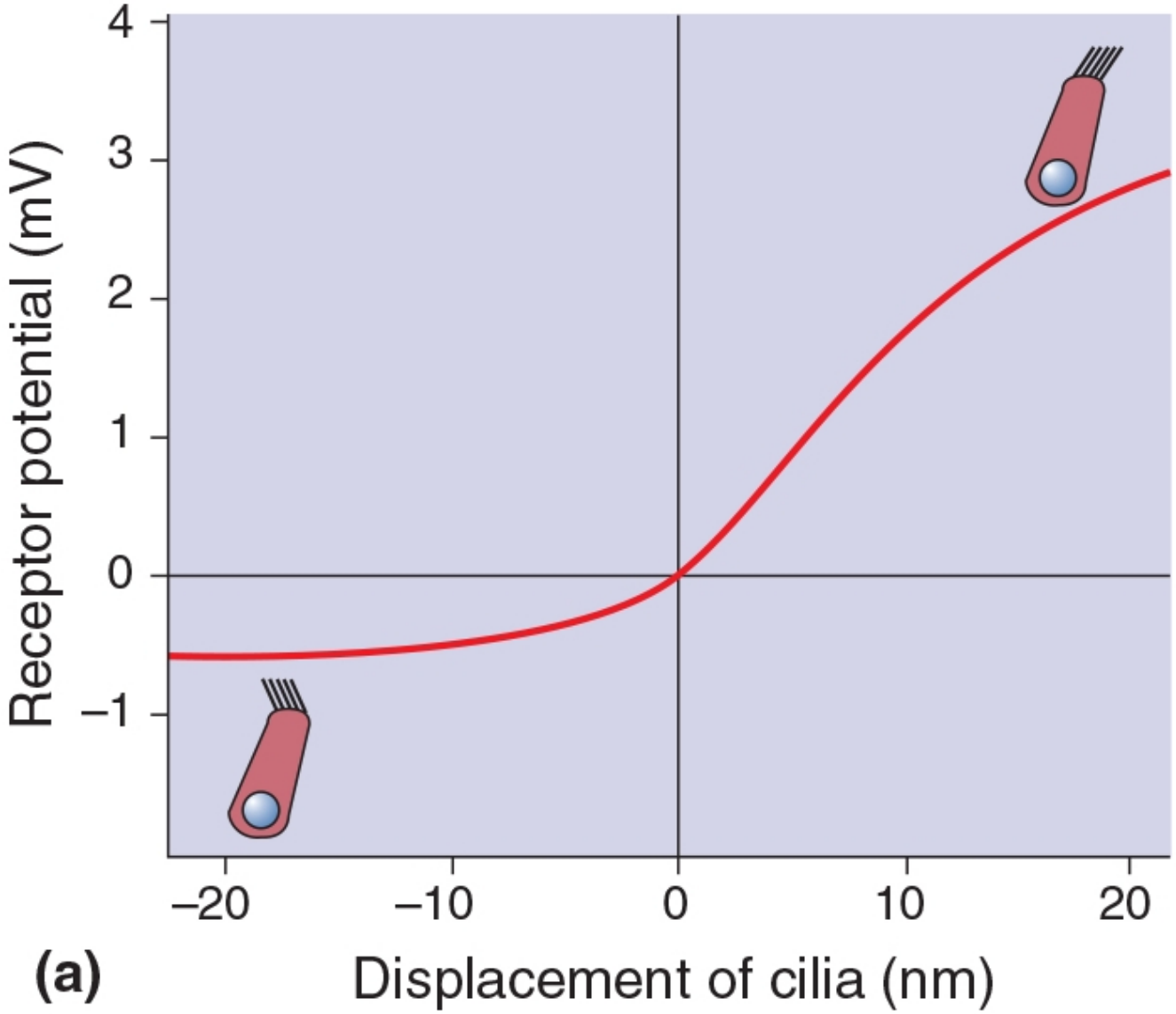


Reticular lamina

IHC cilia only extend through RL; they do not go into TM

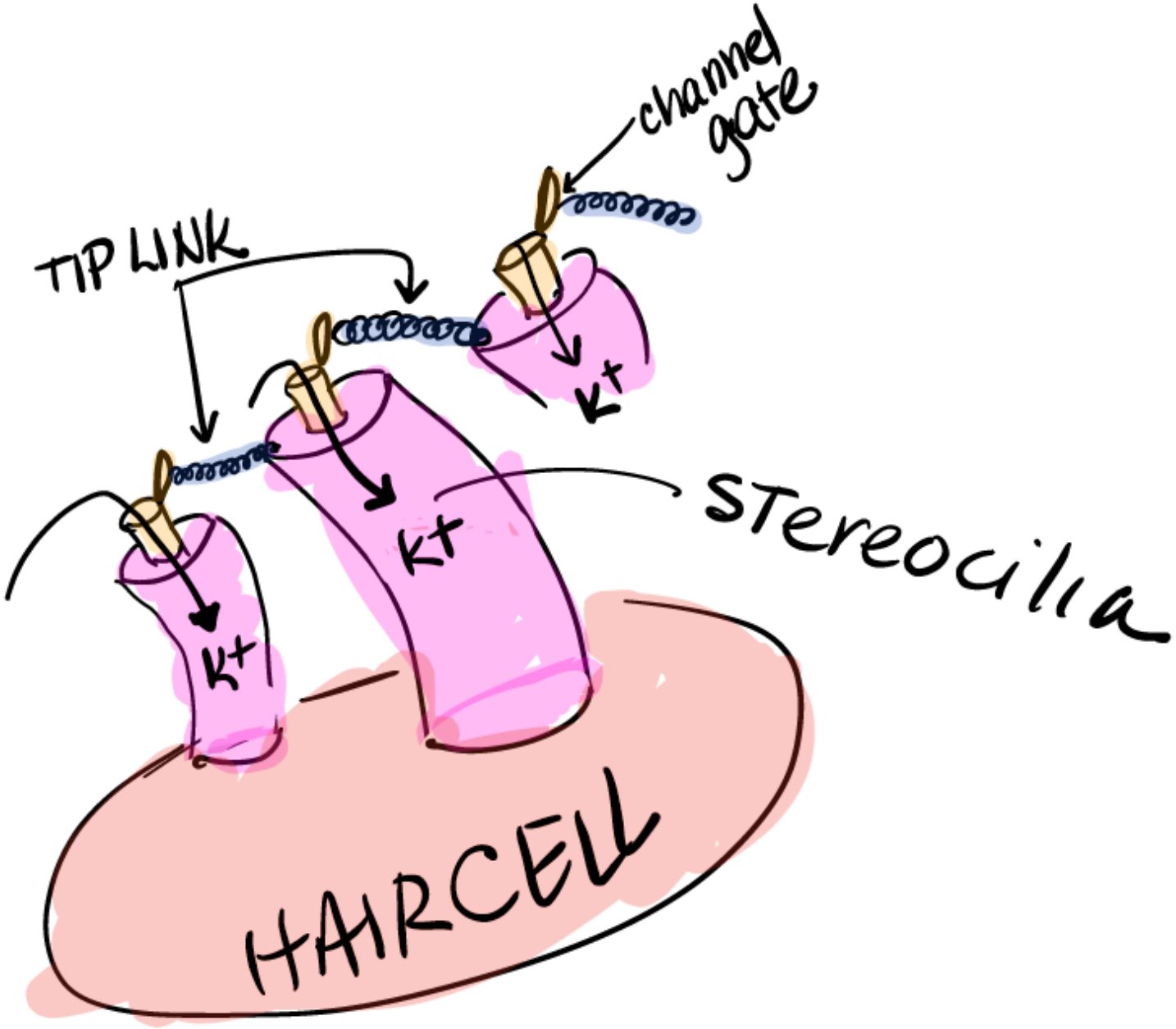
The hair cell depolarizes or hyperpolarizes depending on the direction in which the sterocilia bend.



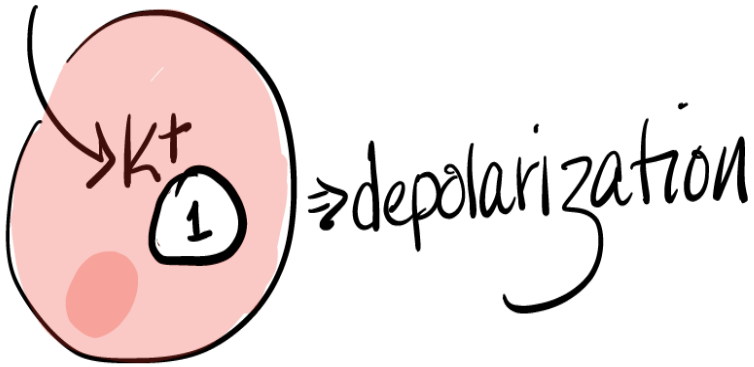


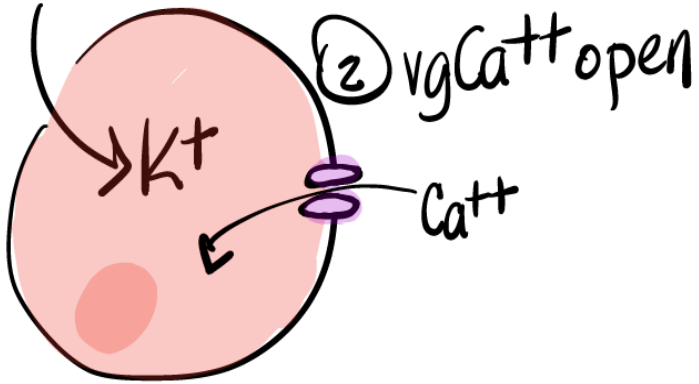
Mechanosensitive transduction

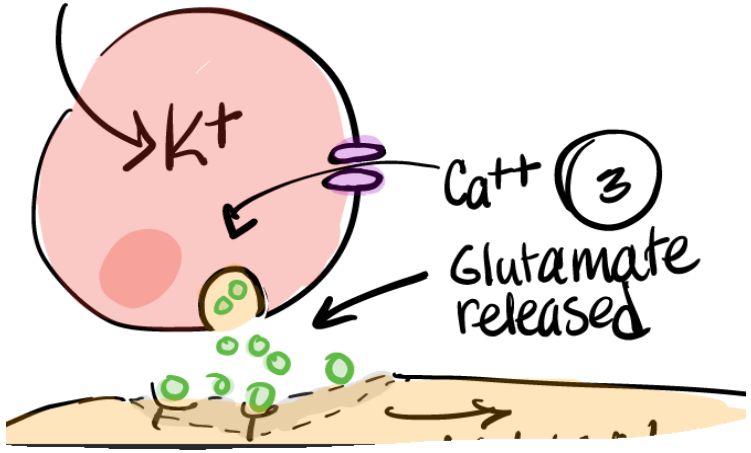
Tip links mechanically open ion channel on the tip of the cilia.



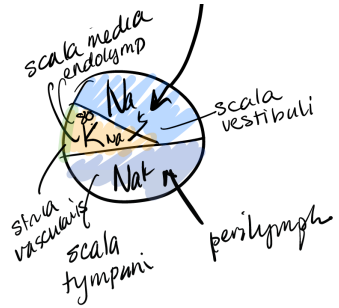
Hair Cell Receptor Potential





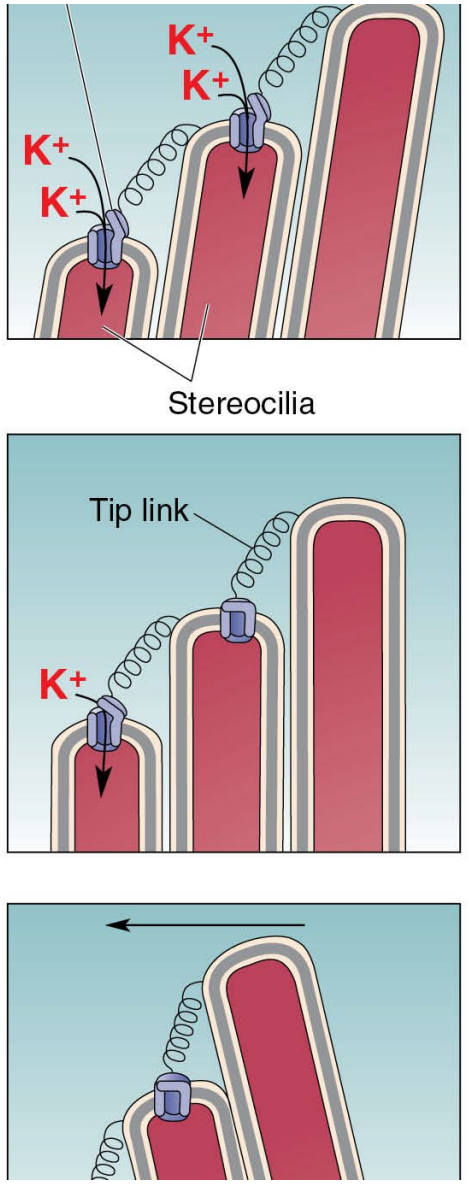


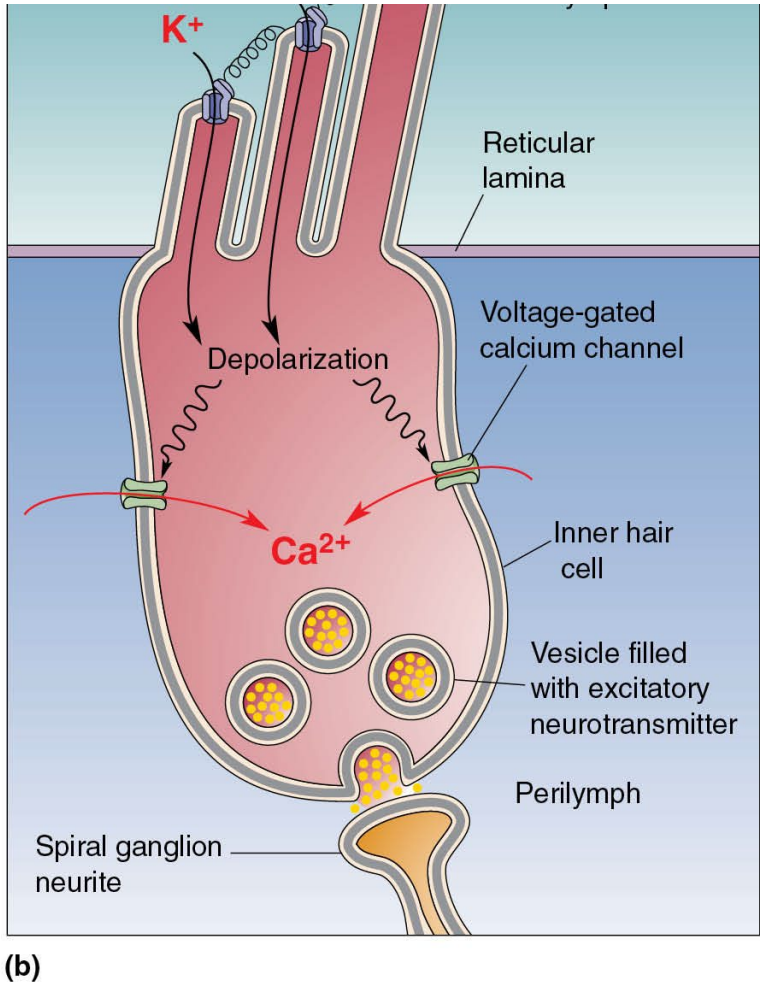
Recall: Endolymph has very high K+



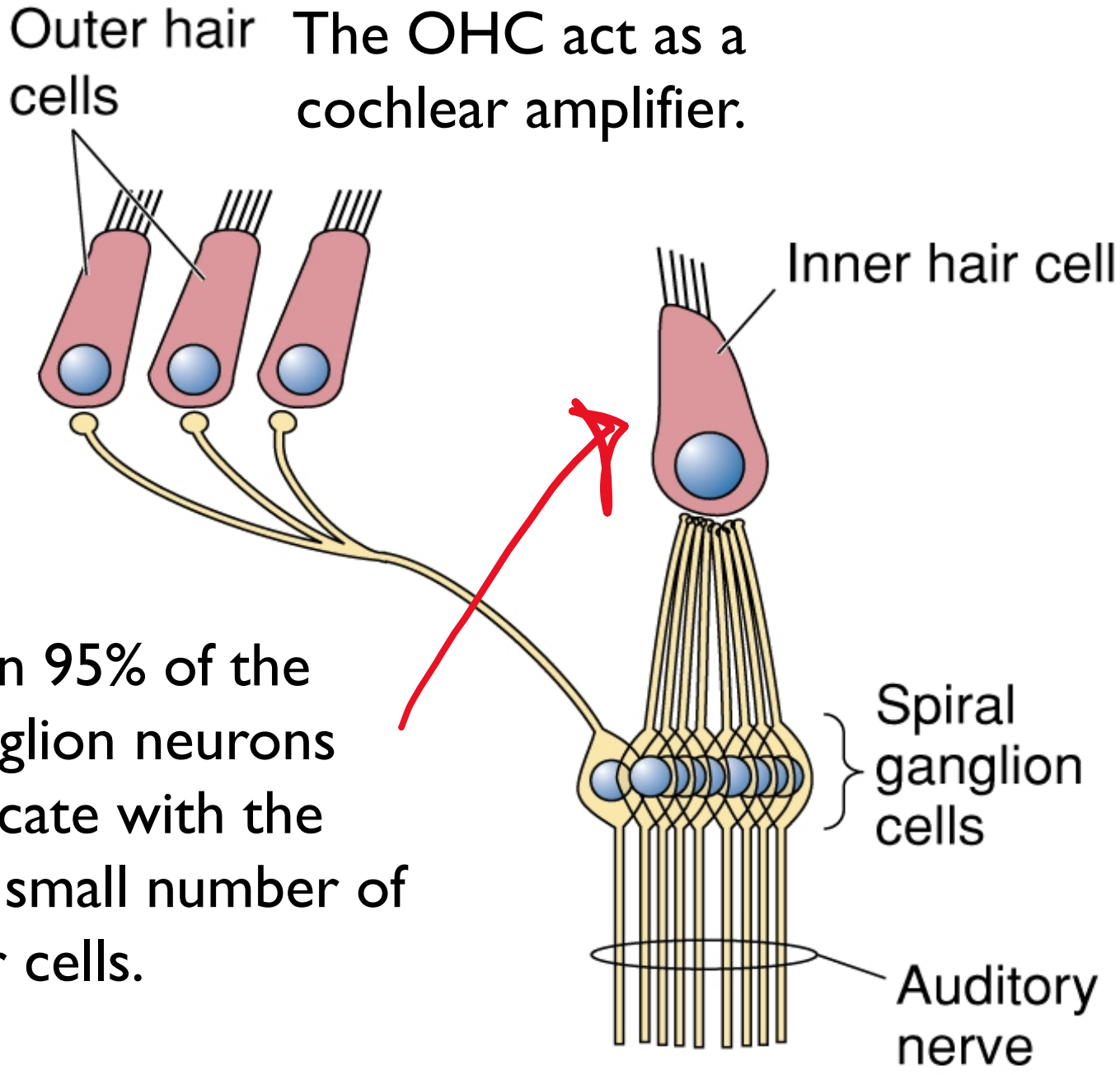
TRANSDUCTION BY HAIR CELLS

- When the tip-links are stretched the hair cell is depolarized – by K+ entering the cell.
- Once depolarized by K+, VGCa++ opens and glutamate is released into the synaptic cleft.
- Ek = 0mV
- Receptors on the spiral ganglion neurites receive the signal.





Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.



The OHC act as a cochlear amplifier.

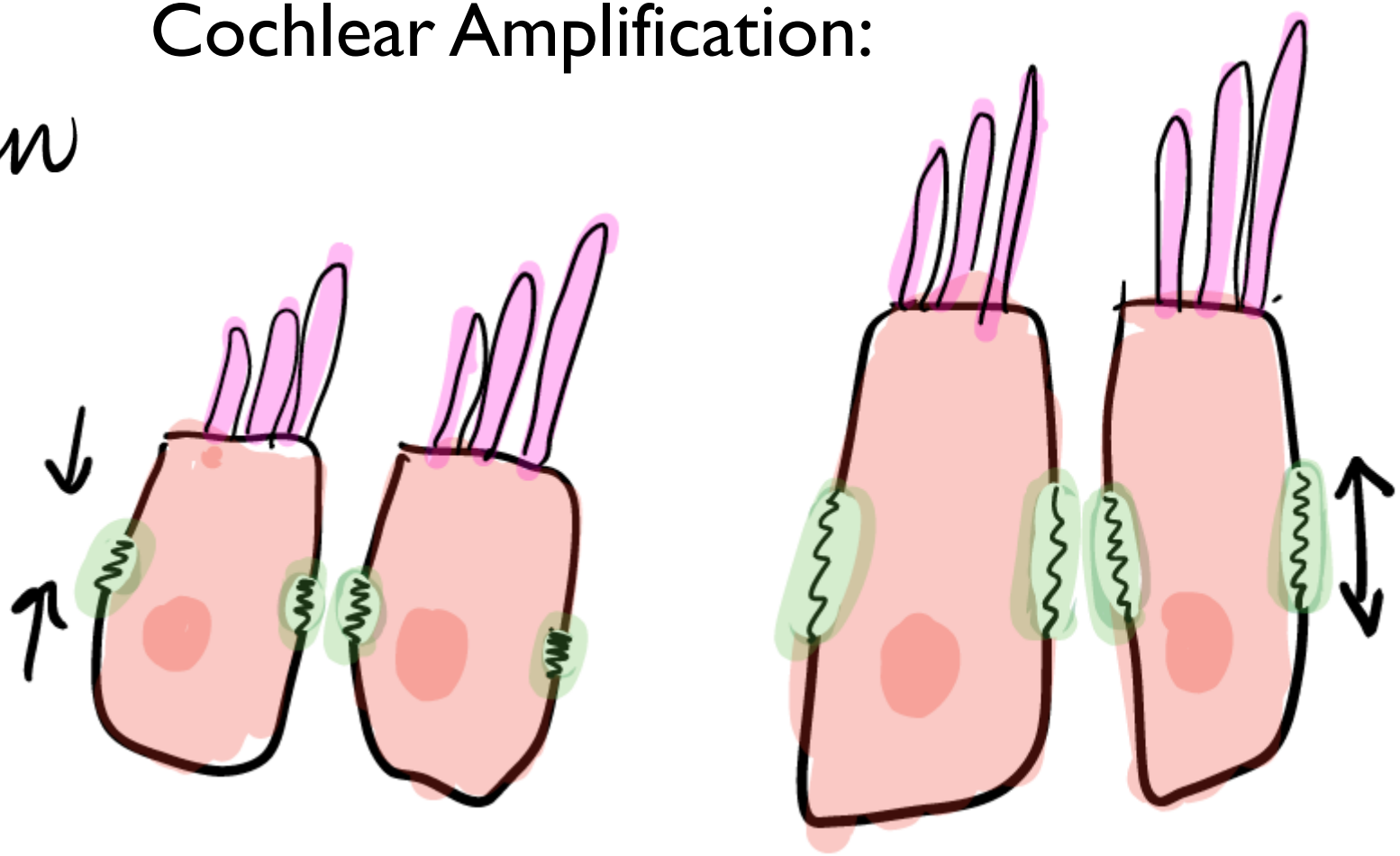
More than 95% of the spiral ganglion neurons communicate with the relatively small number of inner hair cells.

The majority of the auditory information to the CNS if from the inner hair cells.

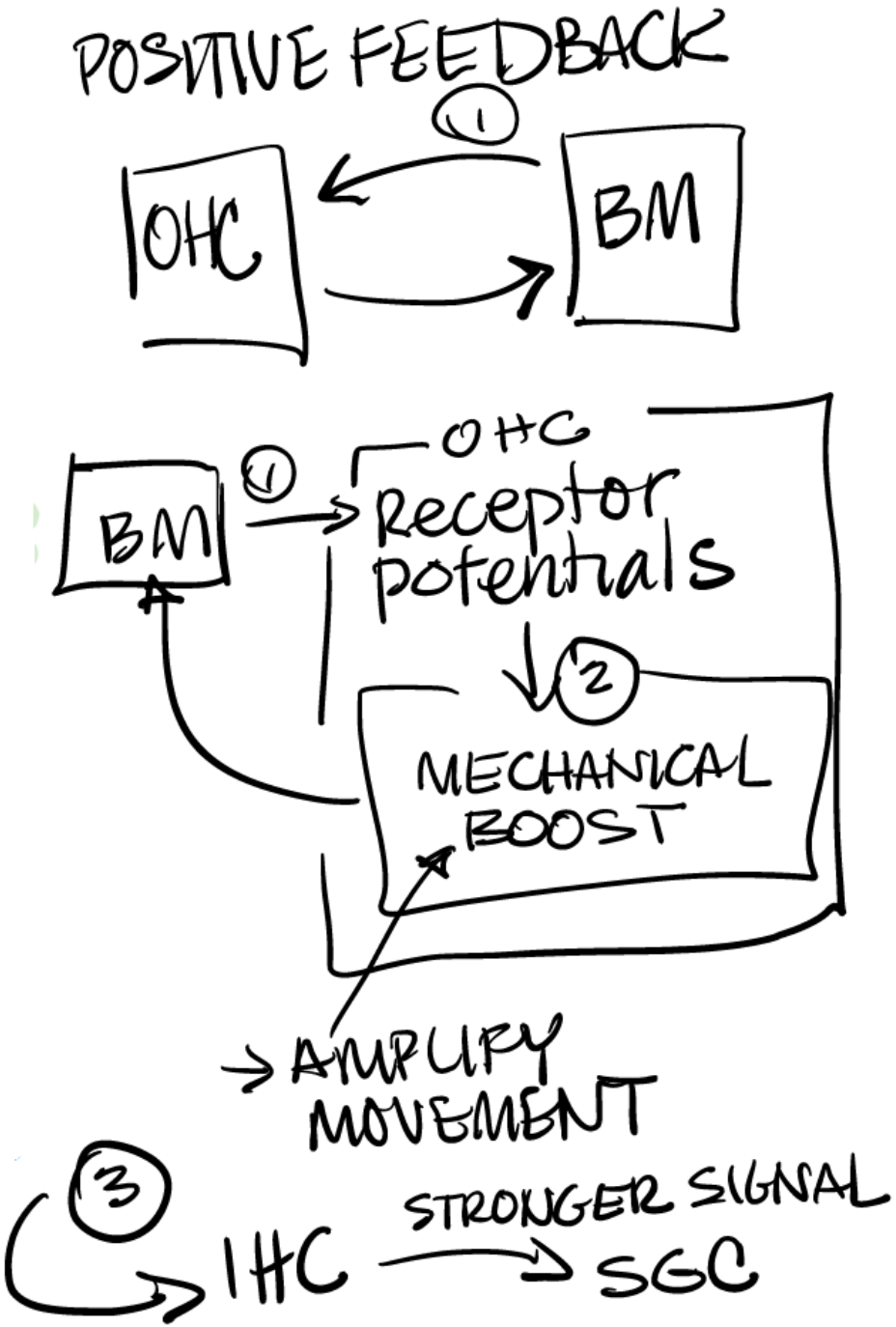
Cochlear Amplification:

prestin
↑ - muscle protein

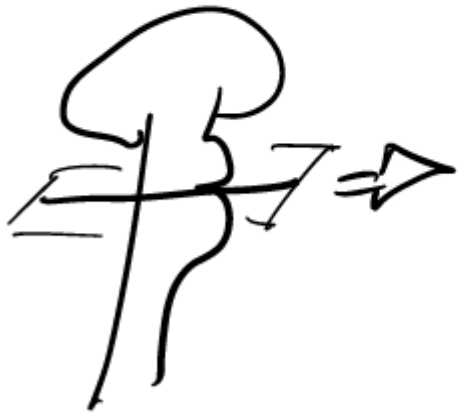
-very fast "presto"
-driven by receptor potential
-moves in response to sound (feedback)

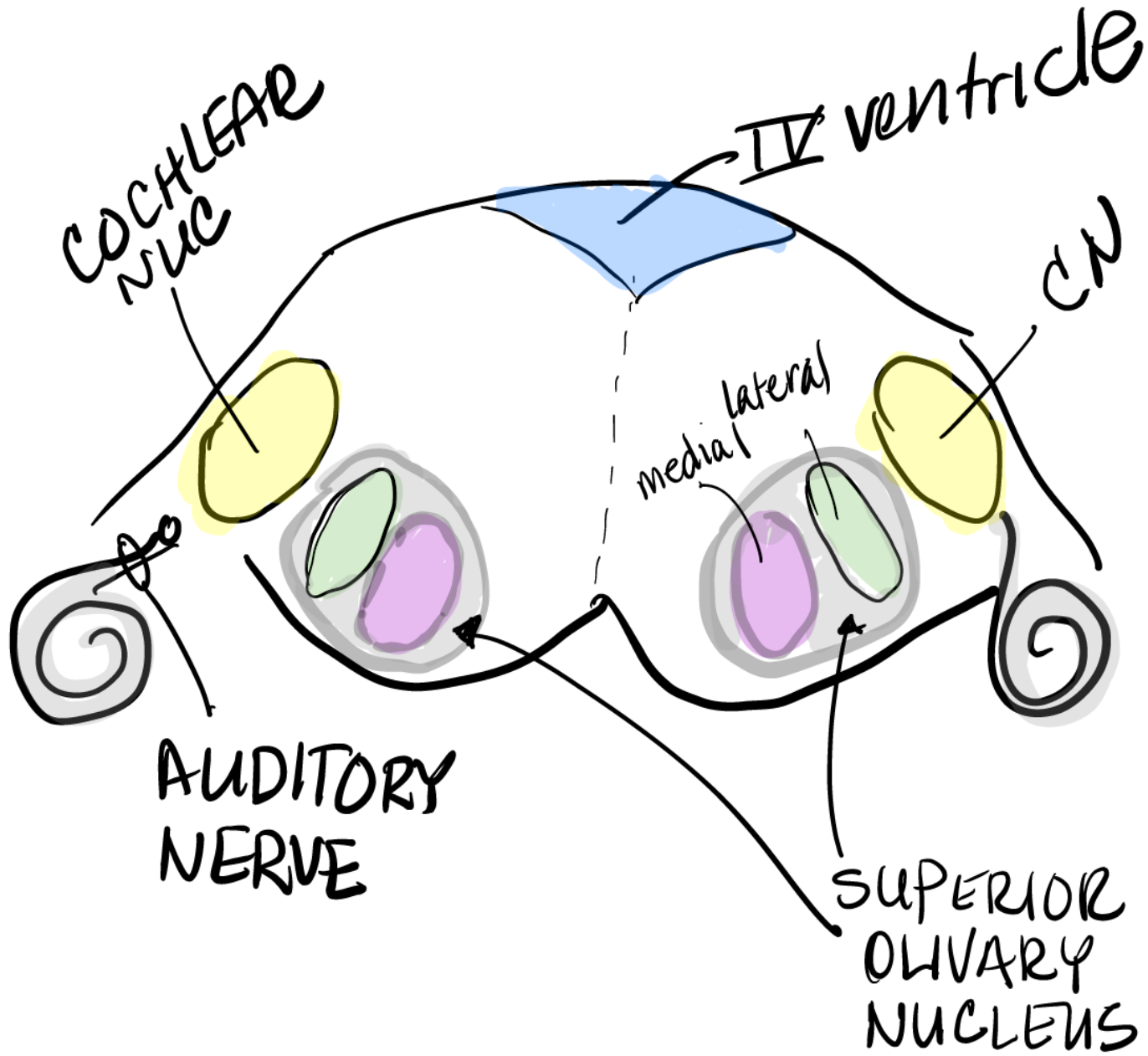


Changes the length of the OHC

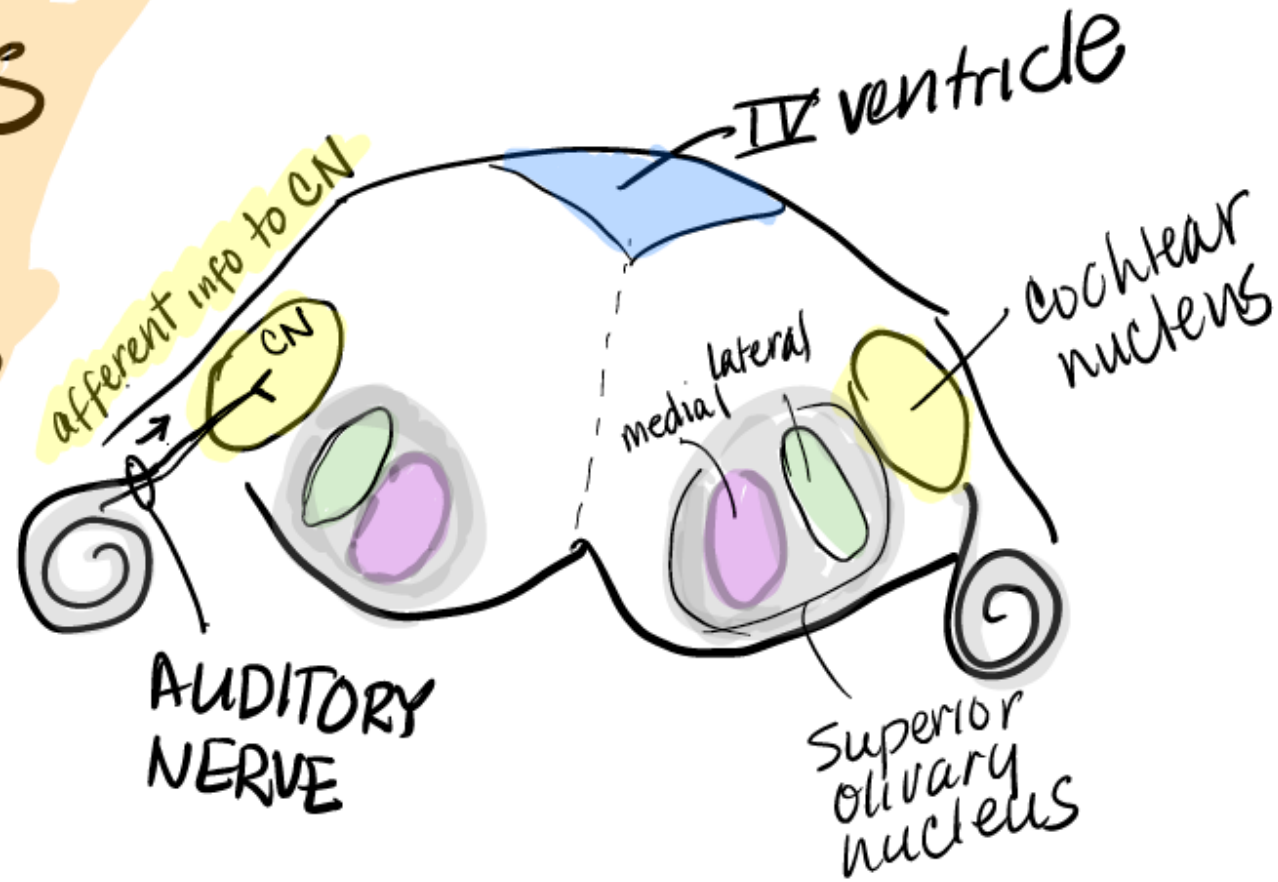

POSITIVE FEEDBACK
1
OHC
BM
BM
1
OHC
Receptor potentials
2
MECHANICAL BOOST
AMPLIFY MOVEMENT
3
IHC
STRONGER SIGNAL
SGC

BRAINSTEM




COCHLEAR NUC
IV ventricle
CN
lateral
medial
AUDITORY NERVE
SUPERIOR OLIVARY NUCLEUS

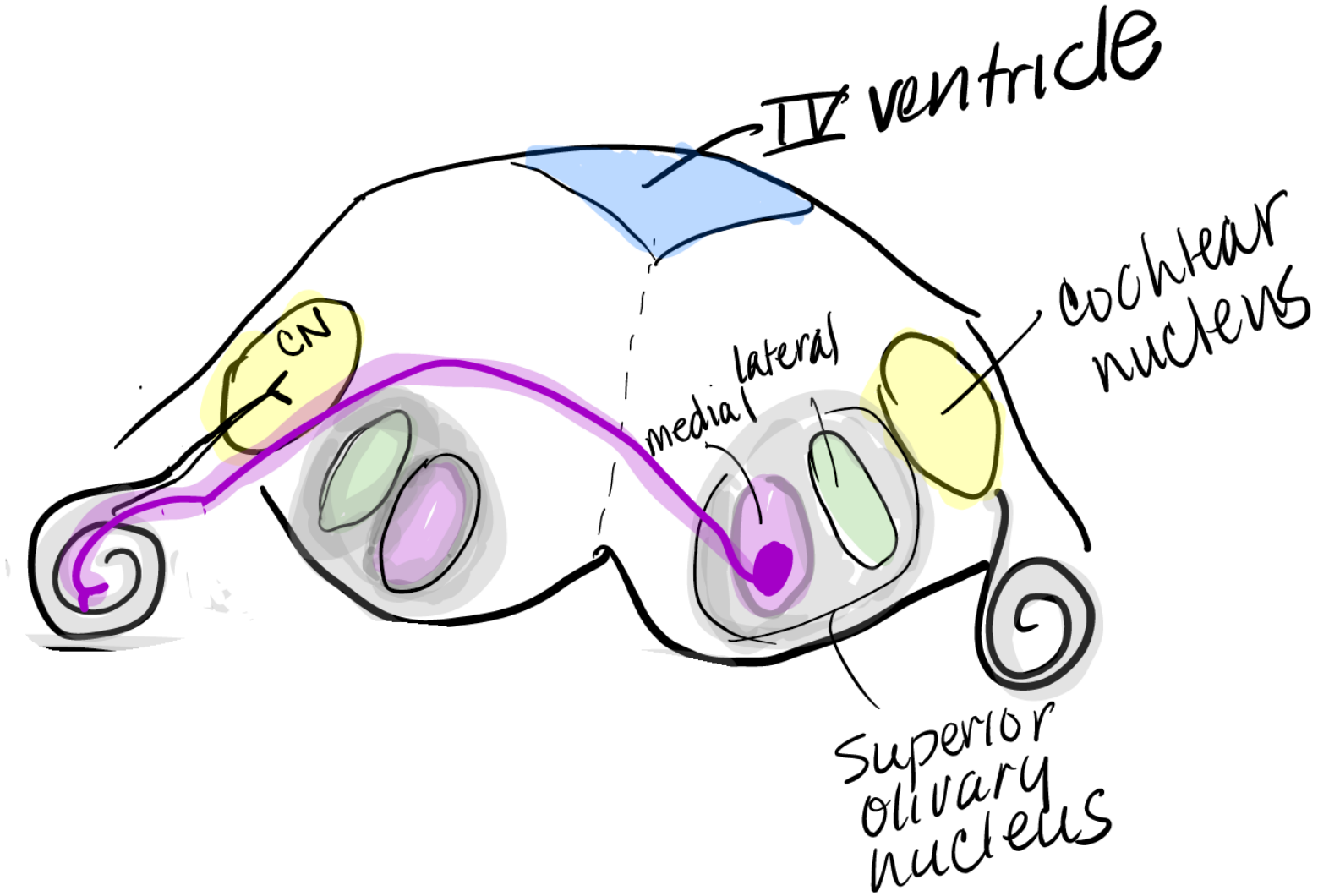
Auditory system has both ascending & descending pathways

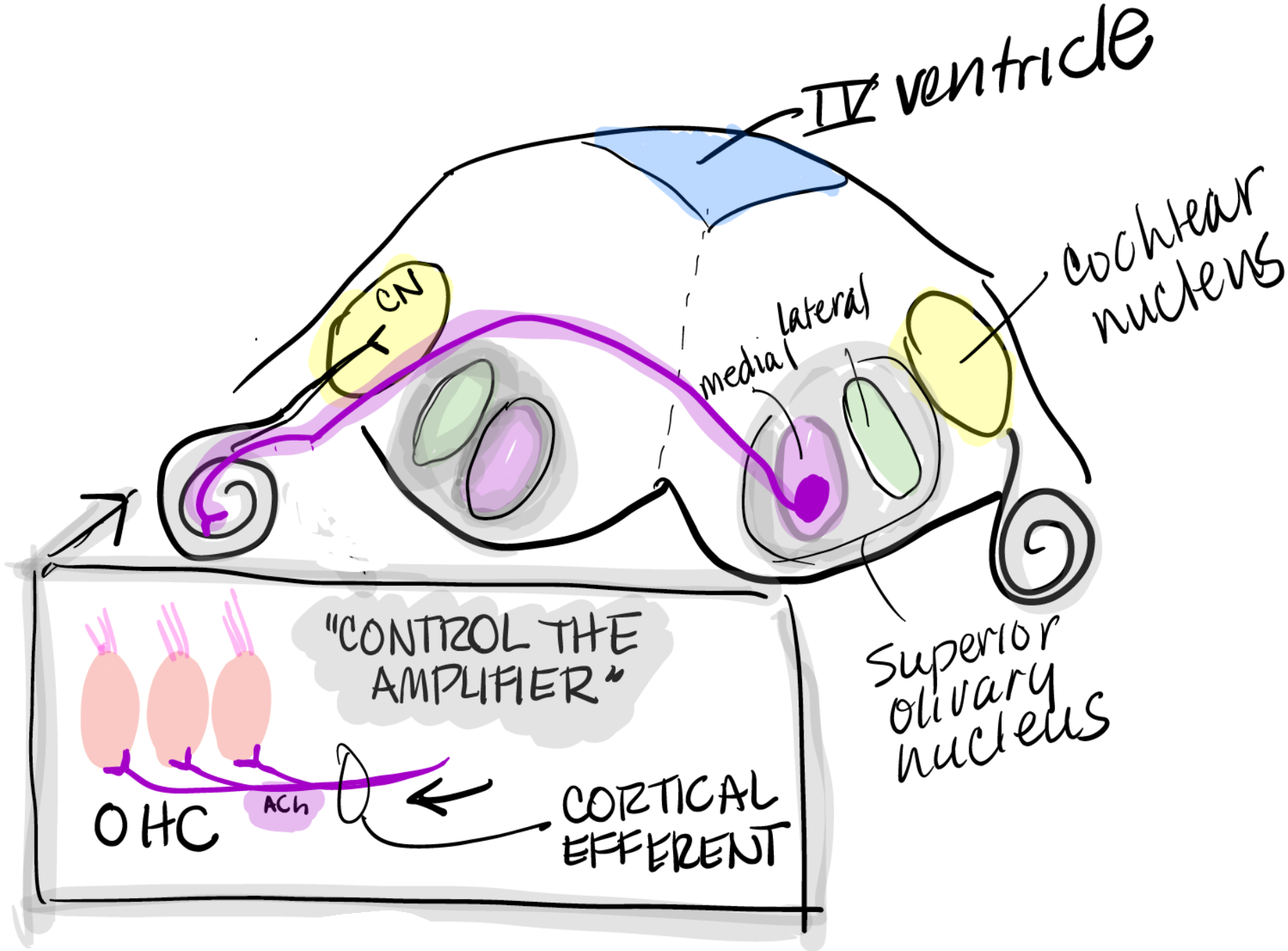


CORTICAL INPUT TO COCHLEA

↳ MODULATE INPUT!

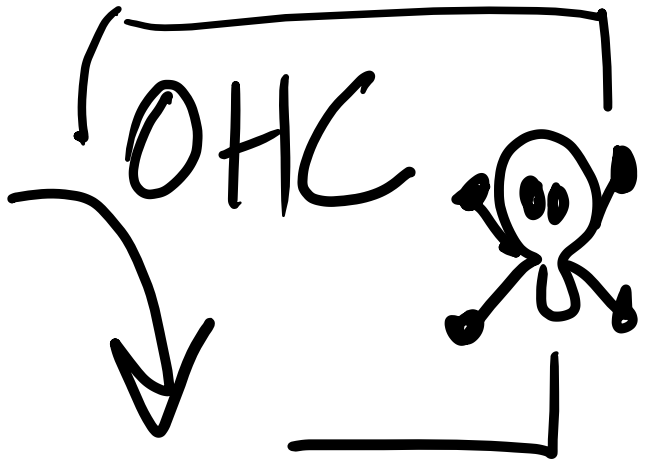
WOW!

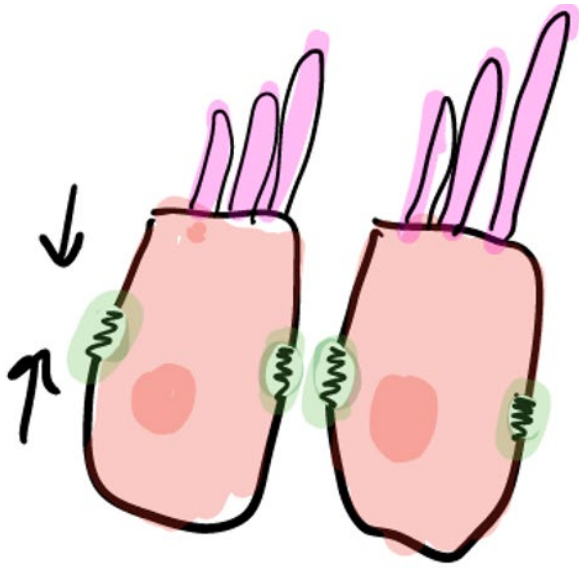


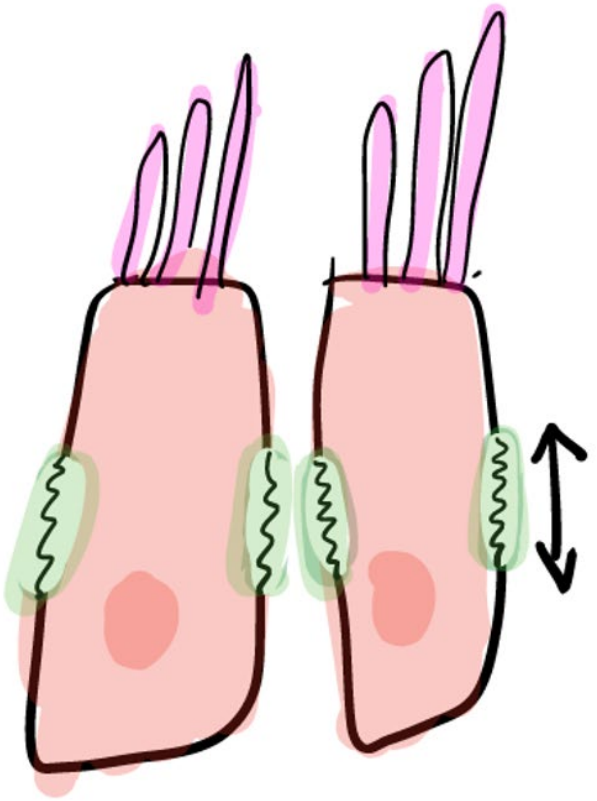

IV ventricle
CN
cochlear nucleus
medial
lateral
Superior olivary nucleus
"CONTROL THE AMPLIFIER"
ACh
OHC
CORTICAL EFFERENT

KANAMYCIN +
FUROSEMIDE
(loop diuretic)

} OTOTOXIC







THE INNER EAR– SUMMARY

The innervation of hair cells

One spiral ganglion fiber synapses with one inner hair cell, numerous outer hair cells

Amplification by outer hair cells—cochlear amplifier

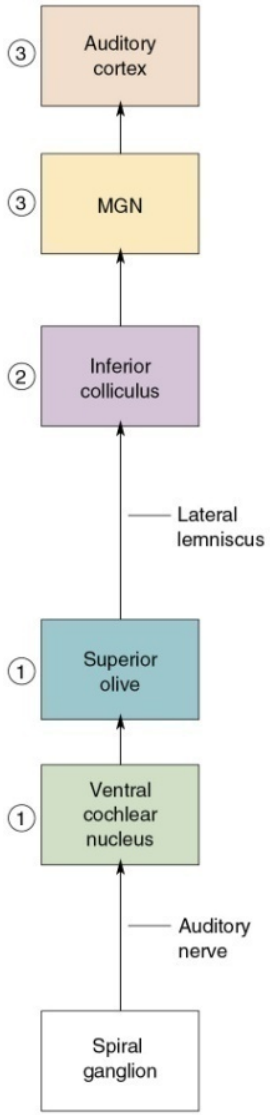
Function: sound transduction

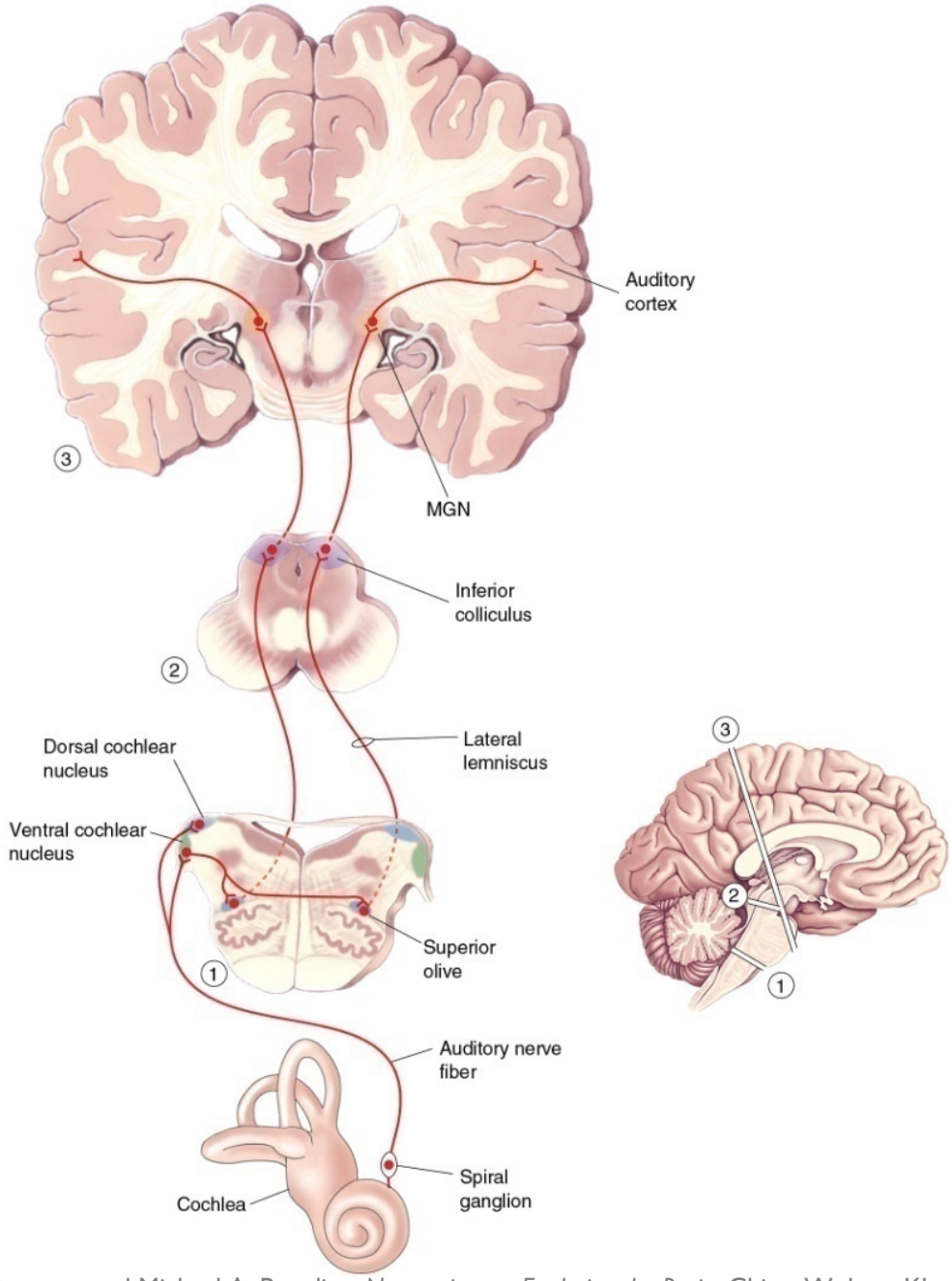
Motor proteins: change length of outer hair cells

Prestin: protein required for outer hair cell movements

Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.

AUDITORY PATHWAYS





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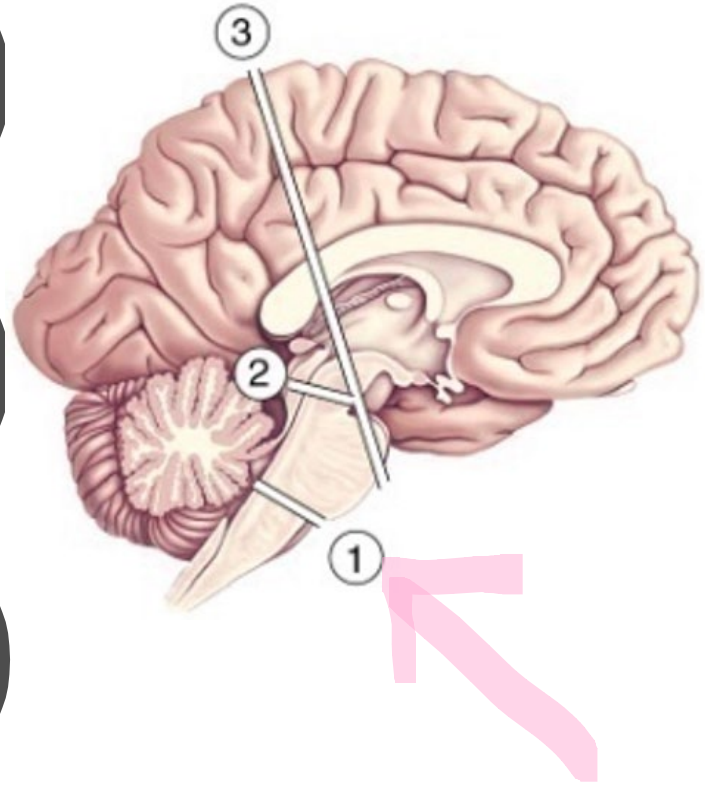
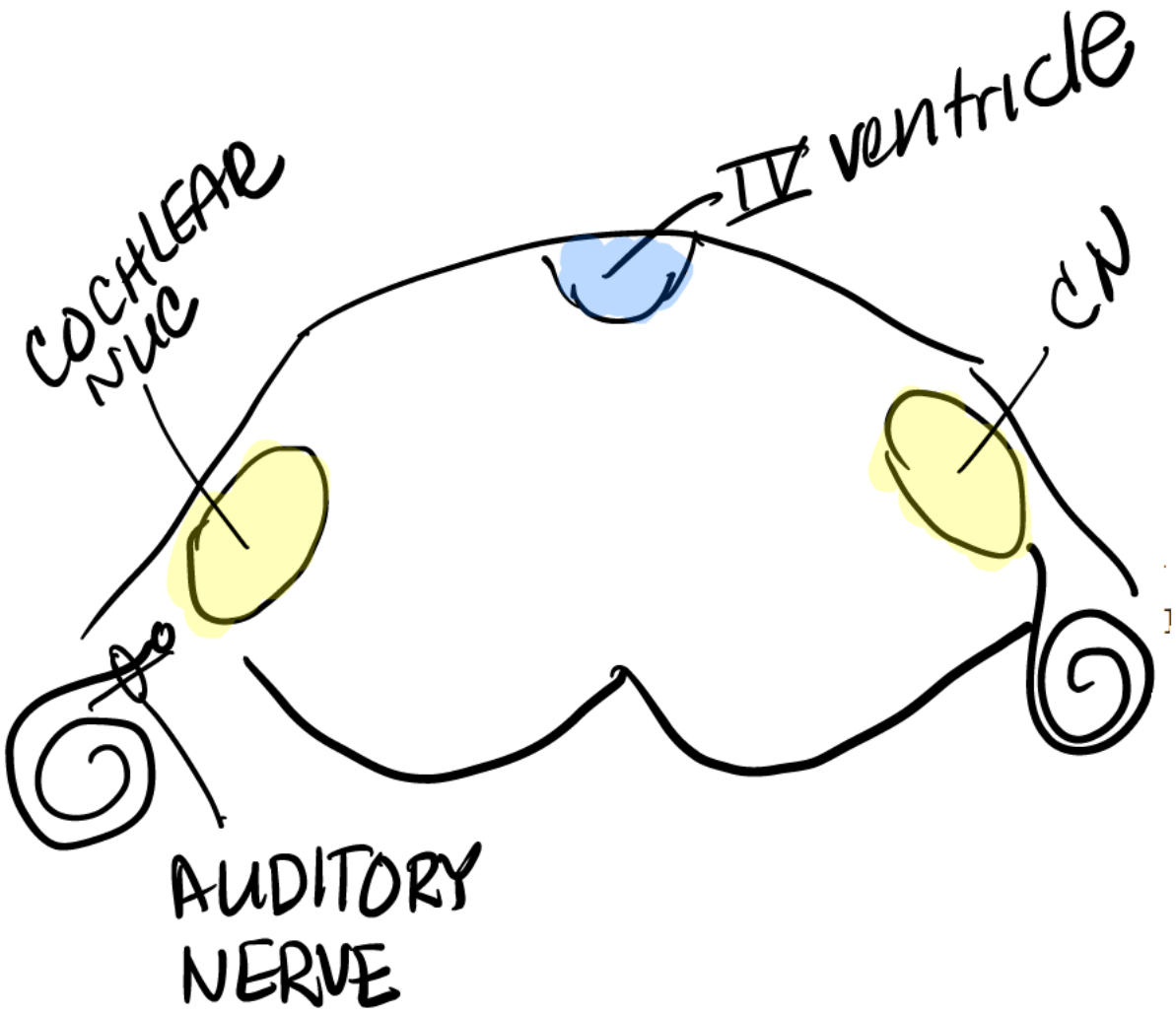
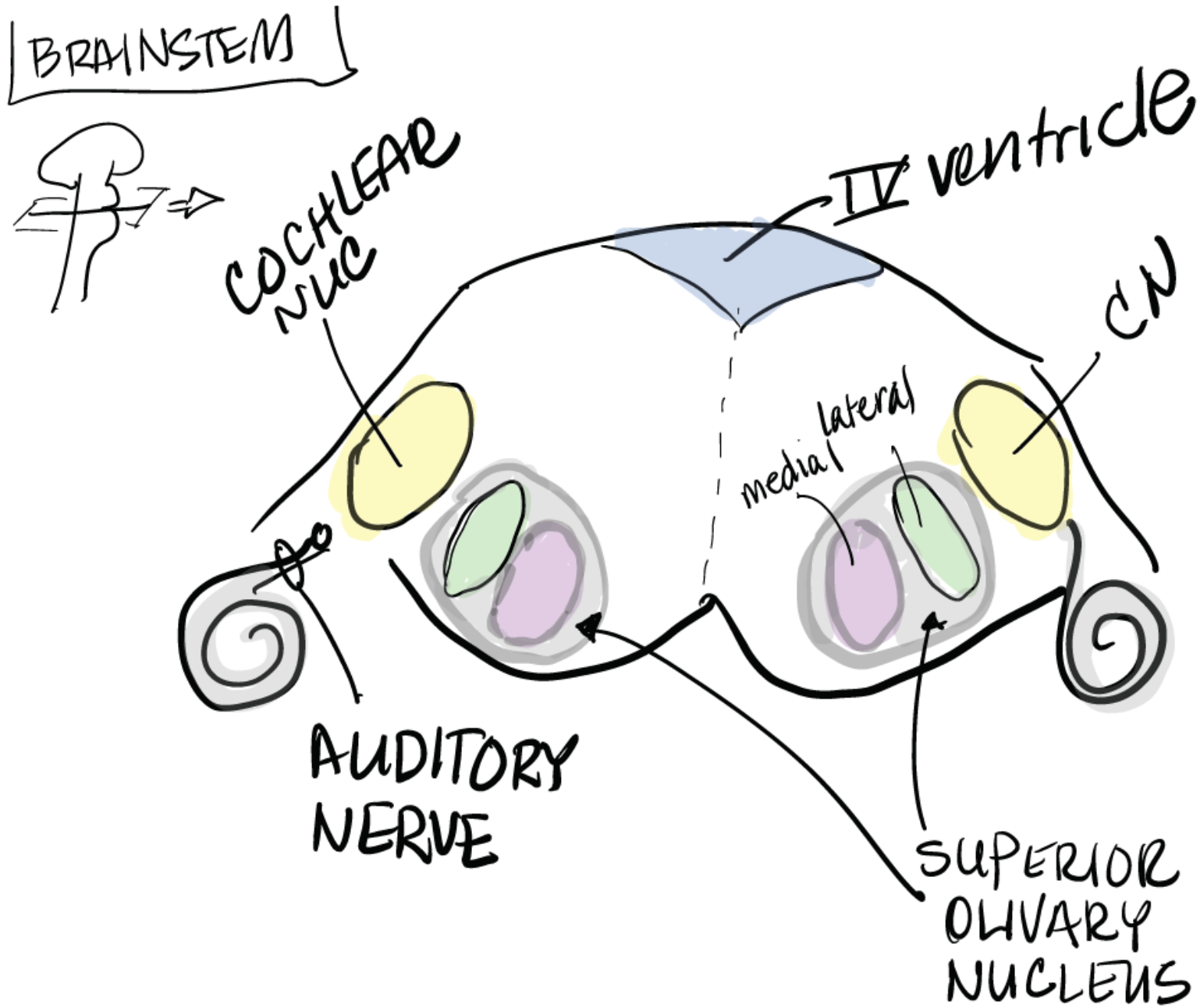
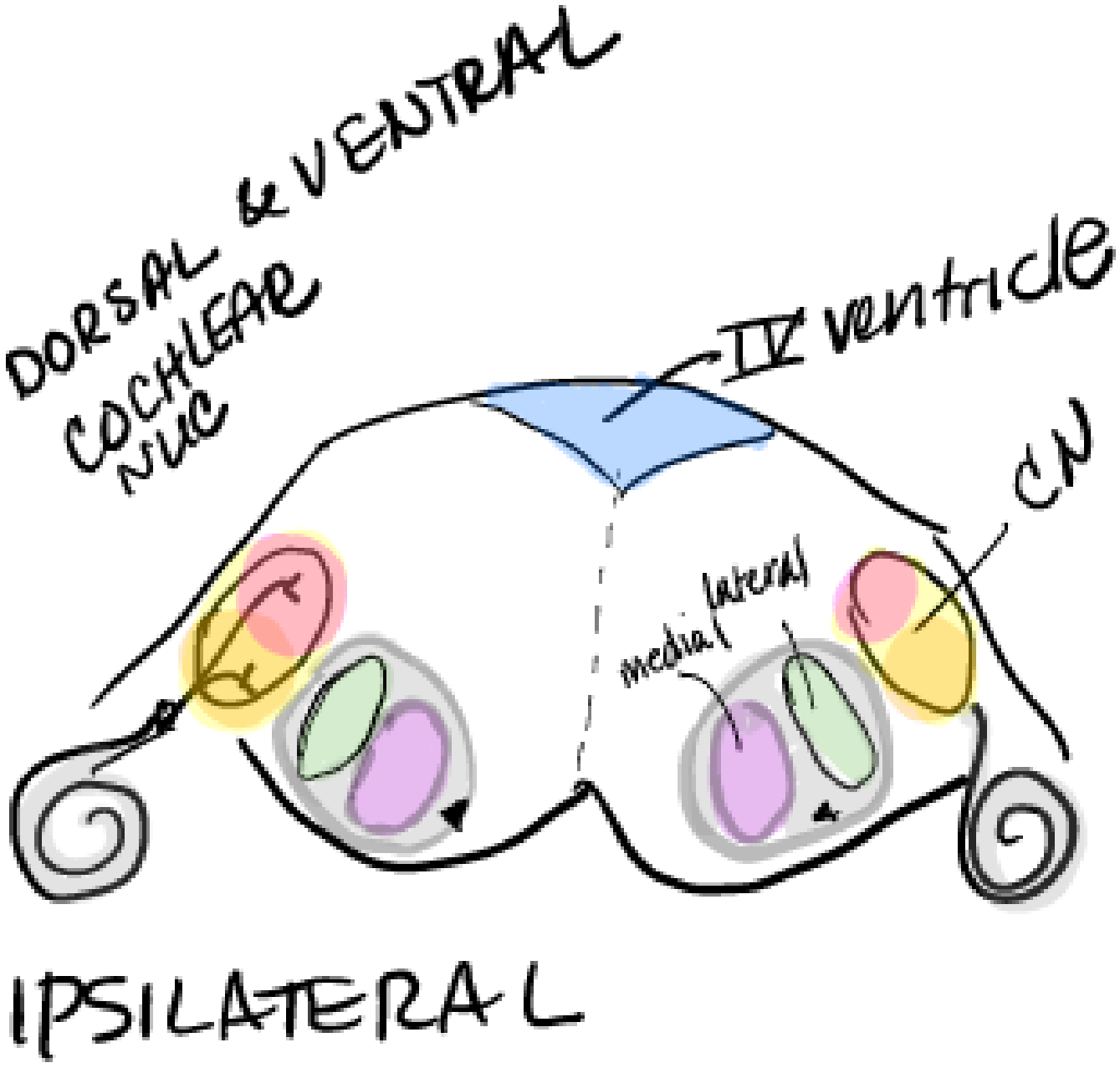

3
2
1

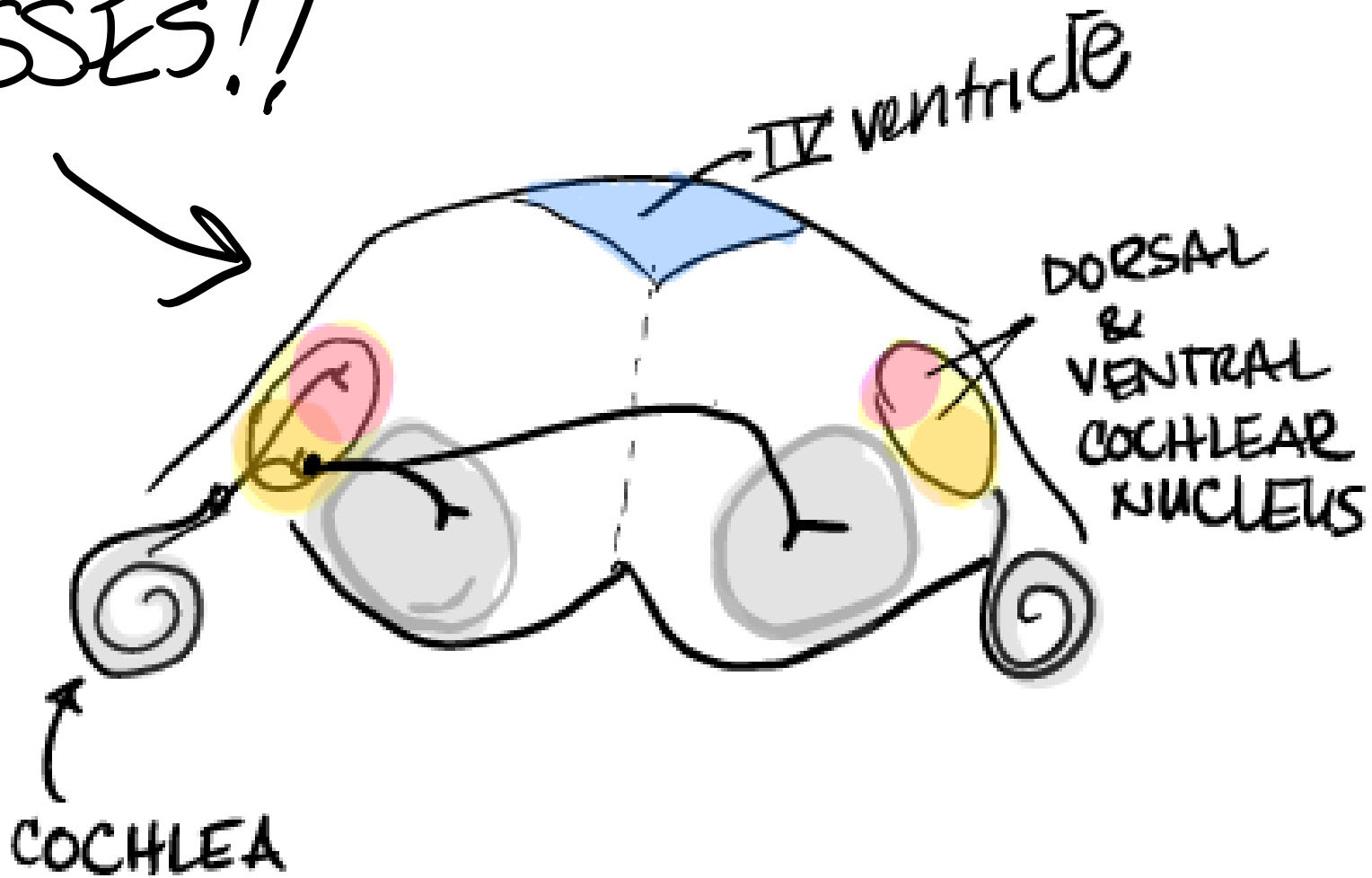

COCHLEAR NUC
IV ventricle
CN
AUDITORY NERVE

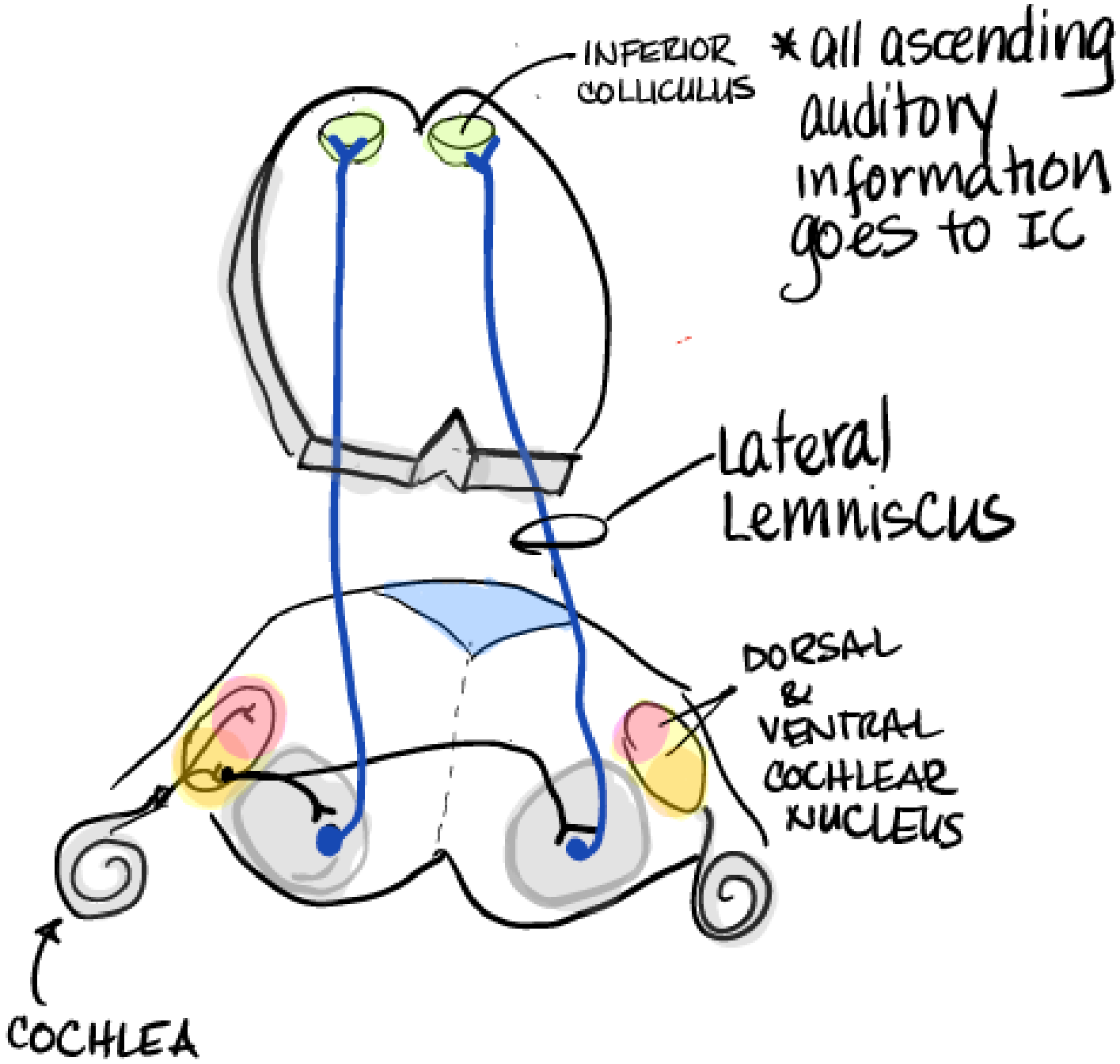

BRAINSTEM
COCHLEAR NUC
IV ventricle
CN
media
lateral
AUDITORY NERVE
SUPERIOR OLIVARY NUCLEUS

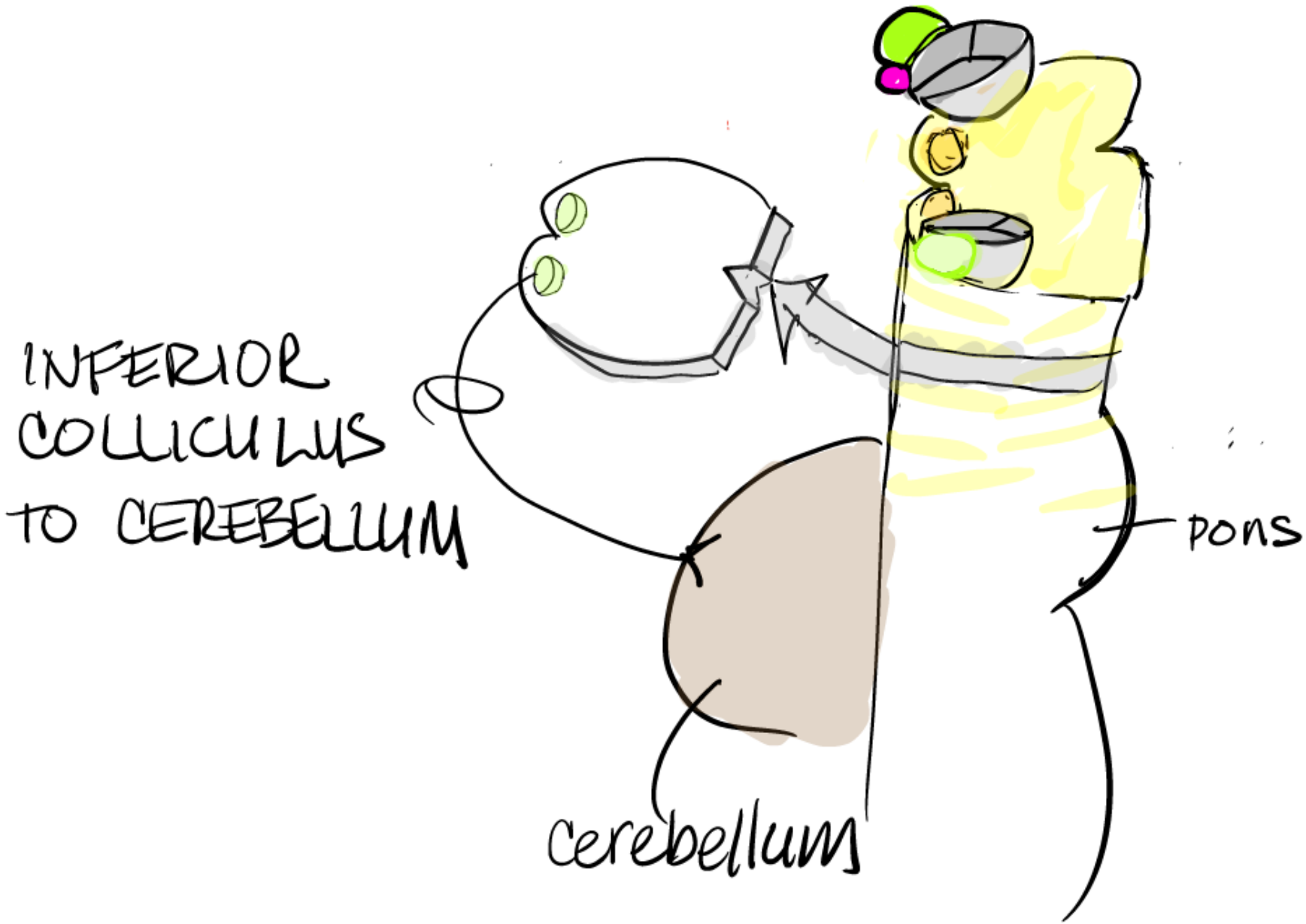


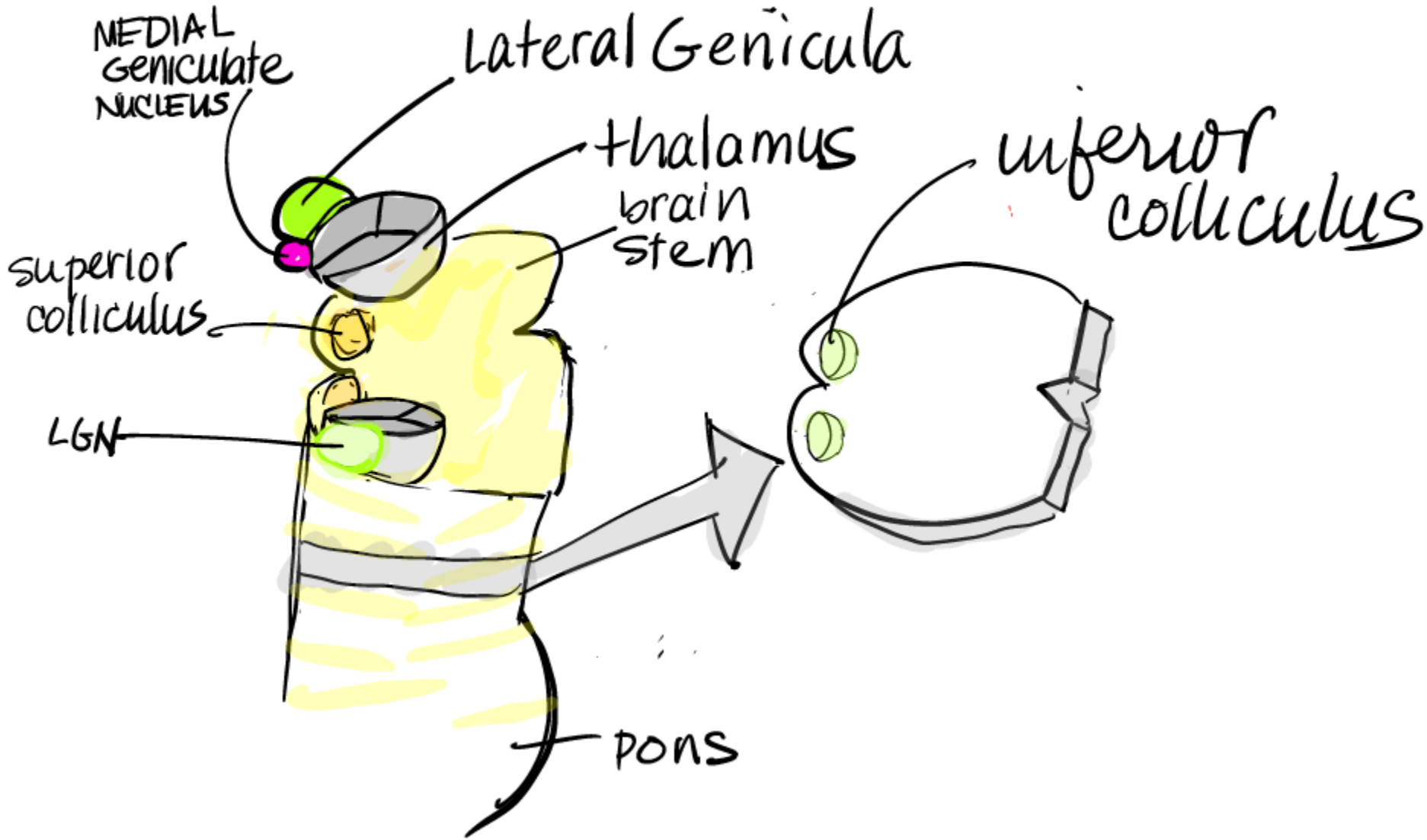
IPSILATERAL

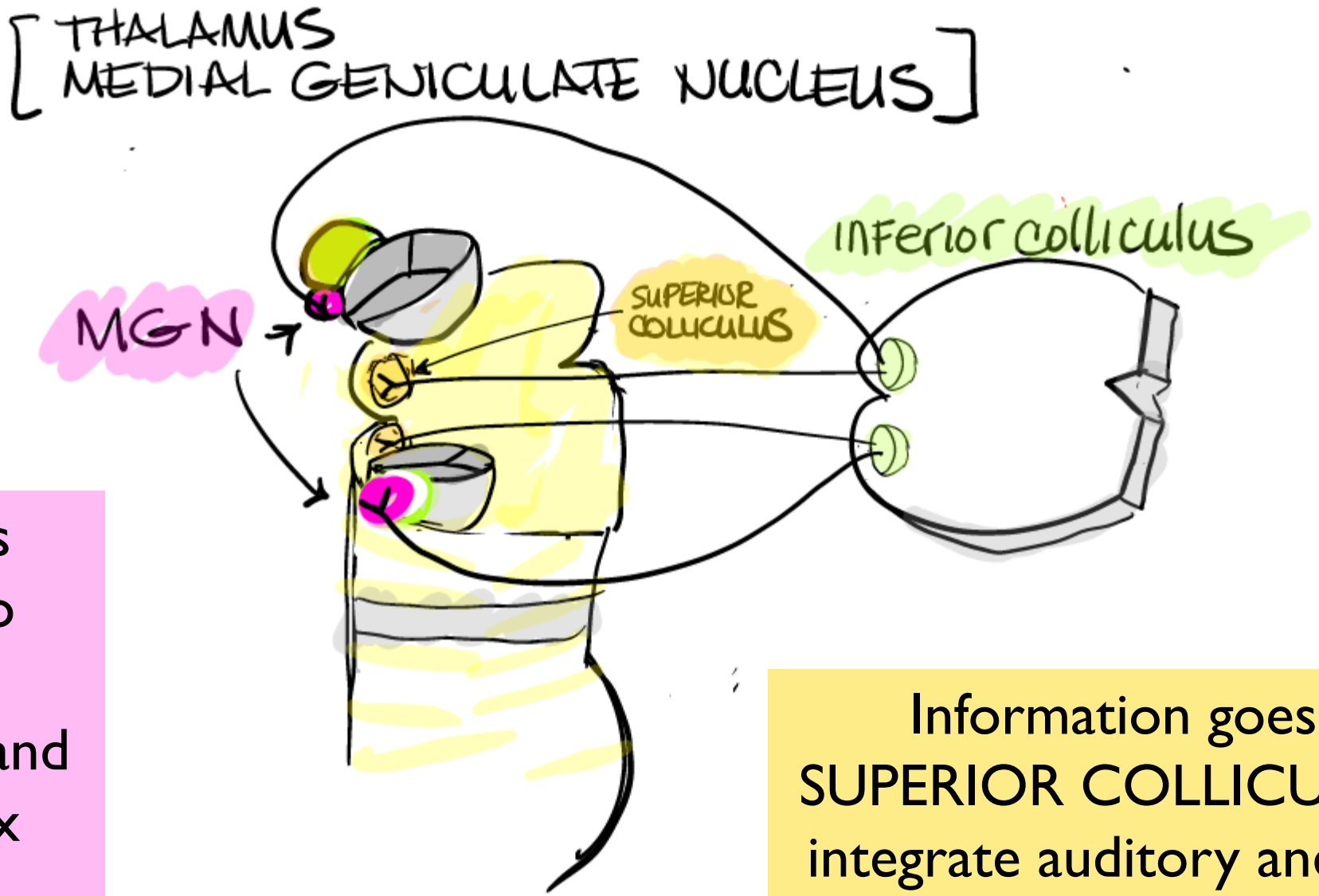
IT CROSSES!!




INFERIOR COLLICULUS
* all ascending auditory information goes to IC
lateral Lemniscus
DORSAL & VENTRAL COCHLEAR NUCLEUS
COCHLEA


INFERIOR
COLLICULUS
TO CEREBELLUM
pons
cerebellum


MEDIAL
Geniculate
NUCLEUS
Lateral Genicula
thalamus
brain
stem
inferior
colliculus
superior
colliculus
LGN
pons

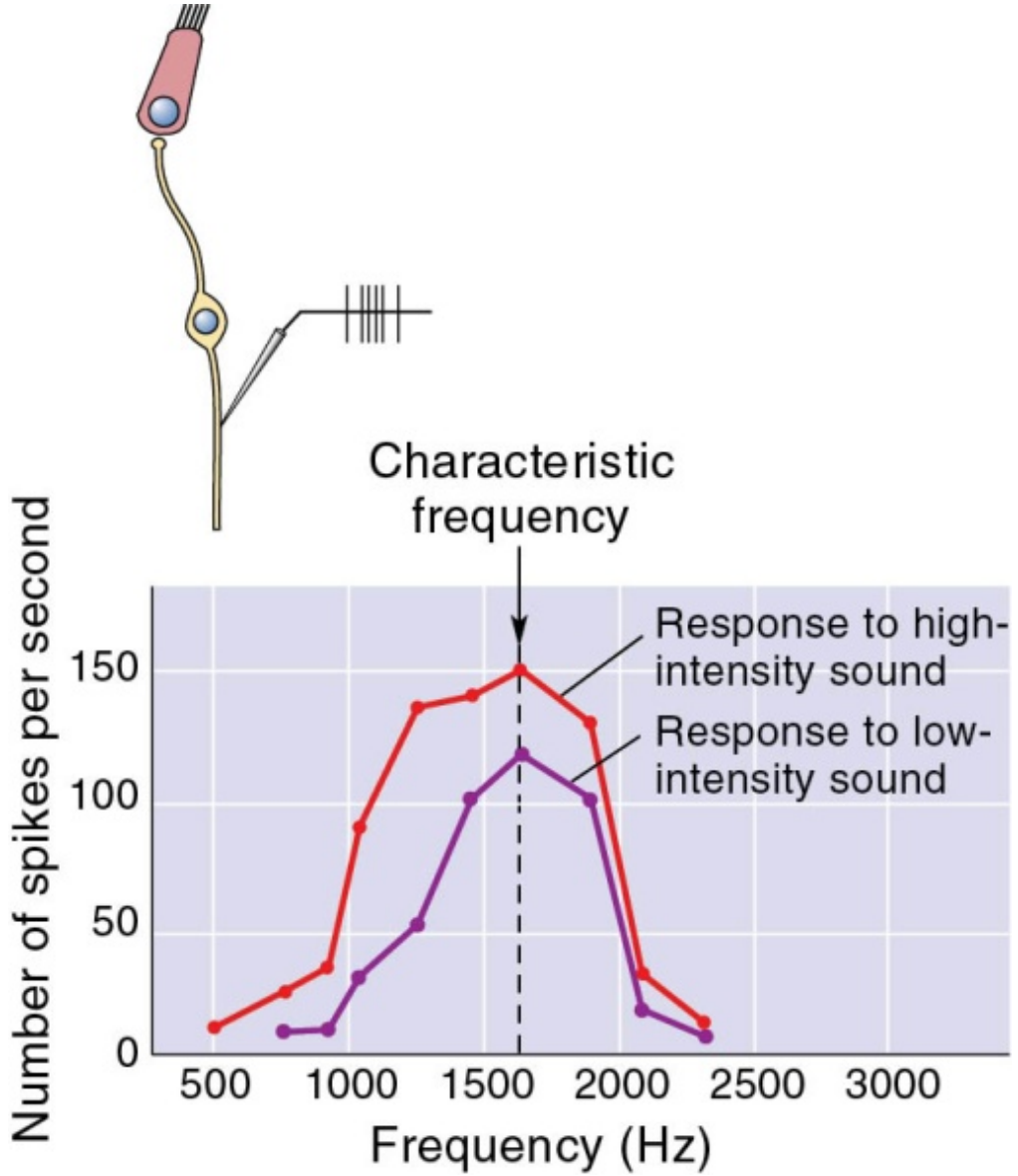


MGN cells respond to specific frequencies and to complex sounds

Information goes to SUPERIOR COLLICULUS to integrate auditory and visual information.

RESPONSE PROPERTIES OF NEURONS IN AUDITORY PATHWAY

- Characteristic frequency: frequency at which a neuron is most responsive—from cochlea to cortex
- Response properties more complex and diverse beyond the brain stem
- Binaural neurons are present in the superior olive.



Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.

ENCODING SOUND INTENSITY

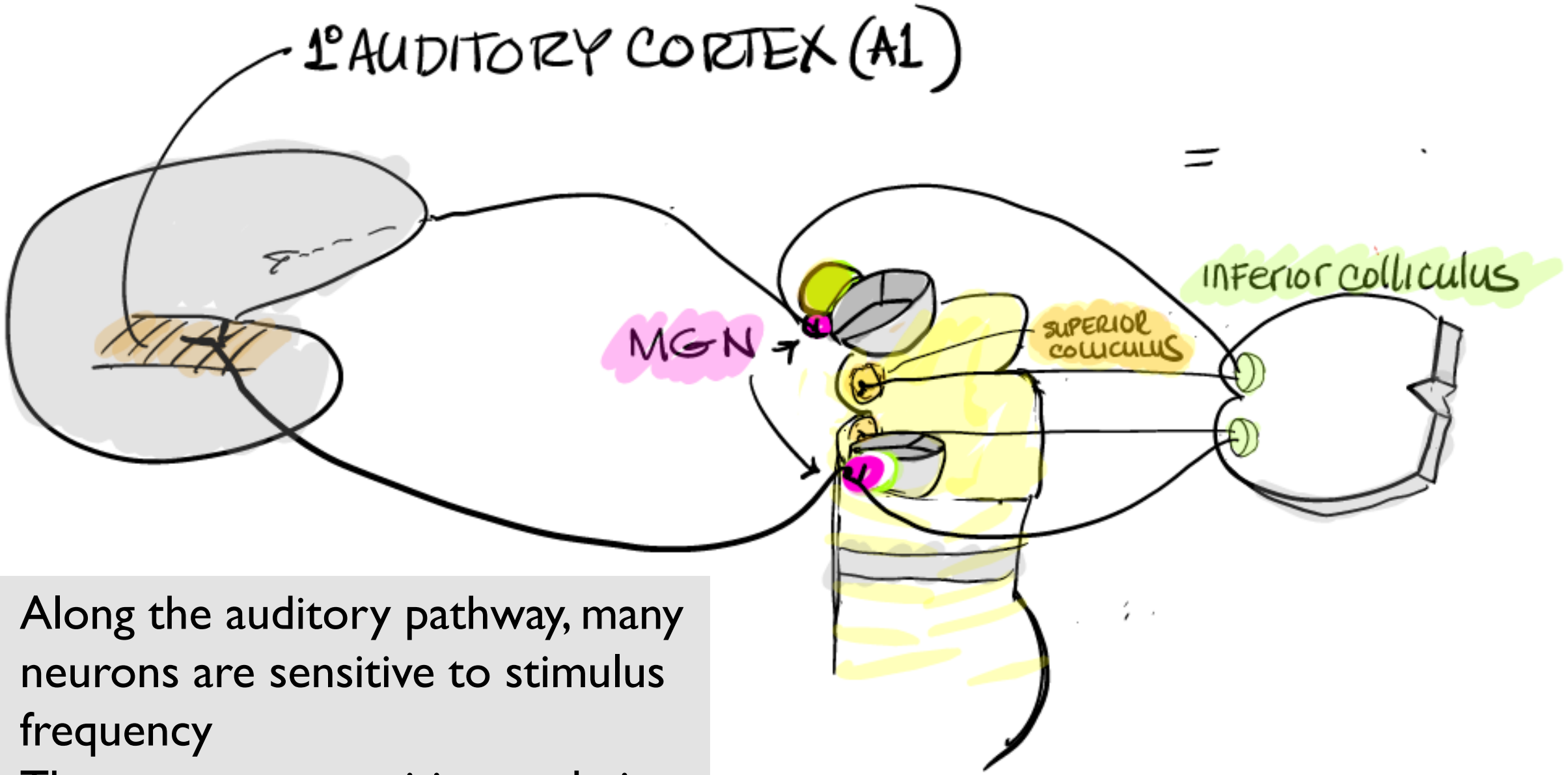
Encoding information about stimulus intensity

- Firing rates of neurons
- Number of active neurons

Membrane potential of activated hair cells more depolarized or hyperpolarized

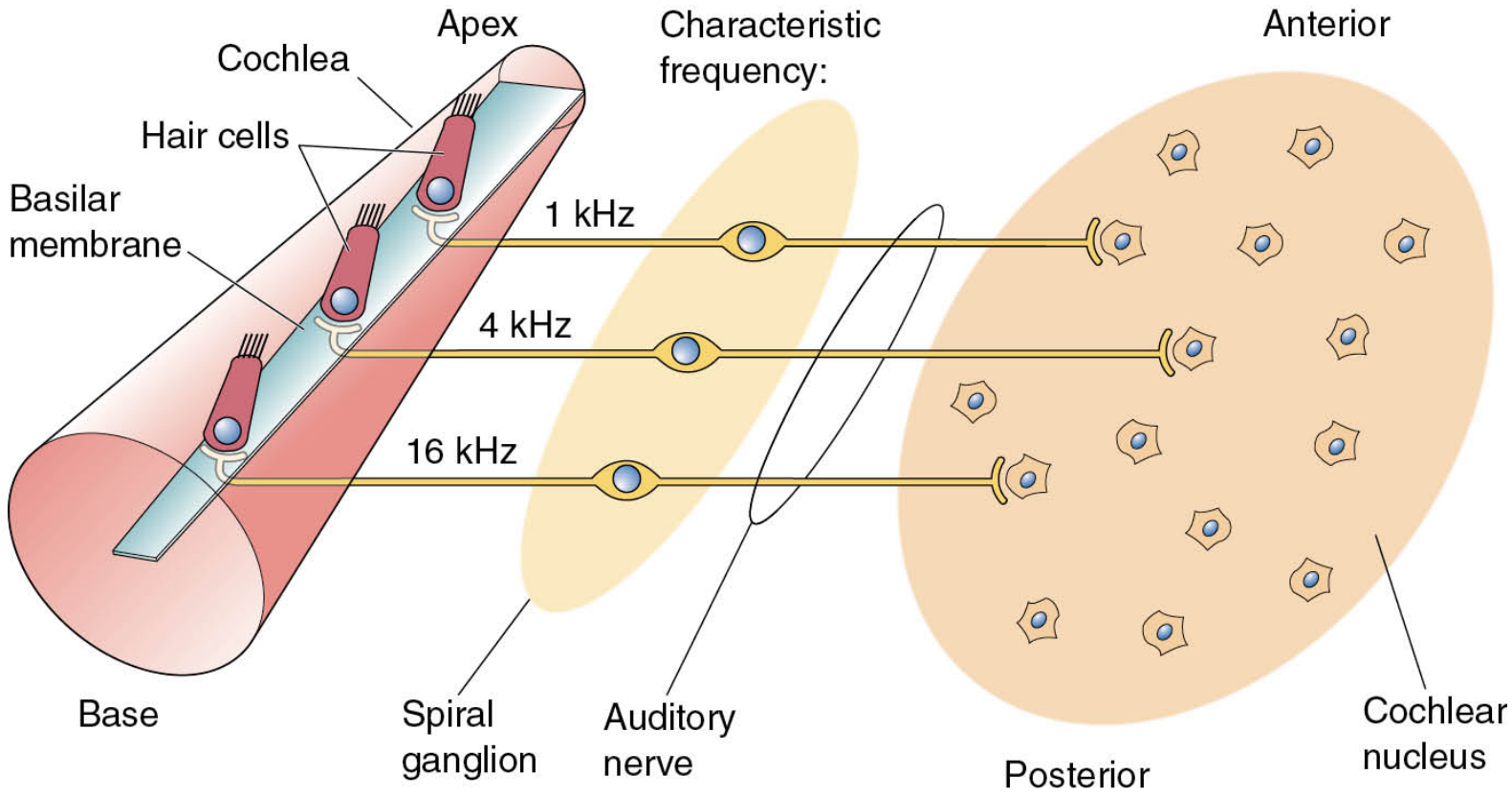
Loudness perceived is correlated with number of active neurons.

Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.



- Along the auditory pathway, many neurons are sensitive to stimulus frequency
- They are most sensitive to their characteristic frequency.

Frequency sensitivity is a result of the basilar membrane mechanics.



Corresponding representation in the auditory nerve and on to the Cochlear nucleus.

ENCODING SOUND FREQUENCY

TONOTOPIC MAPS ON THE BASILAR MEMBRANE AND COCHLEAR NUCLEUS

Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.

TONOTOPY

- Tonotopic maps on the basilar membrane, spiral ganglion, and cochlear nucleus
  - From the base to apex, basilar membrane resonates with increasingly lower frequencies.
  - Tonotopy is preserved in the auditory nerve and cochlear nucleus.
    - In cochlear nucleus, bands of cells with similar characteristic frequencies increase from anterior to posterior.

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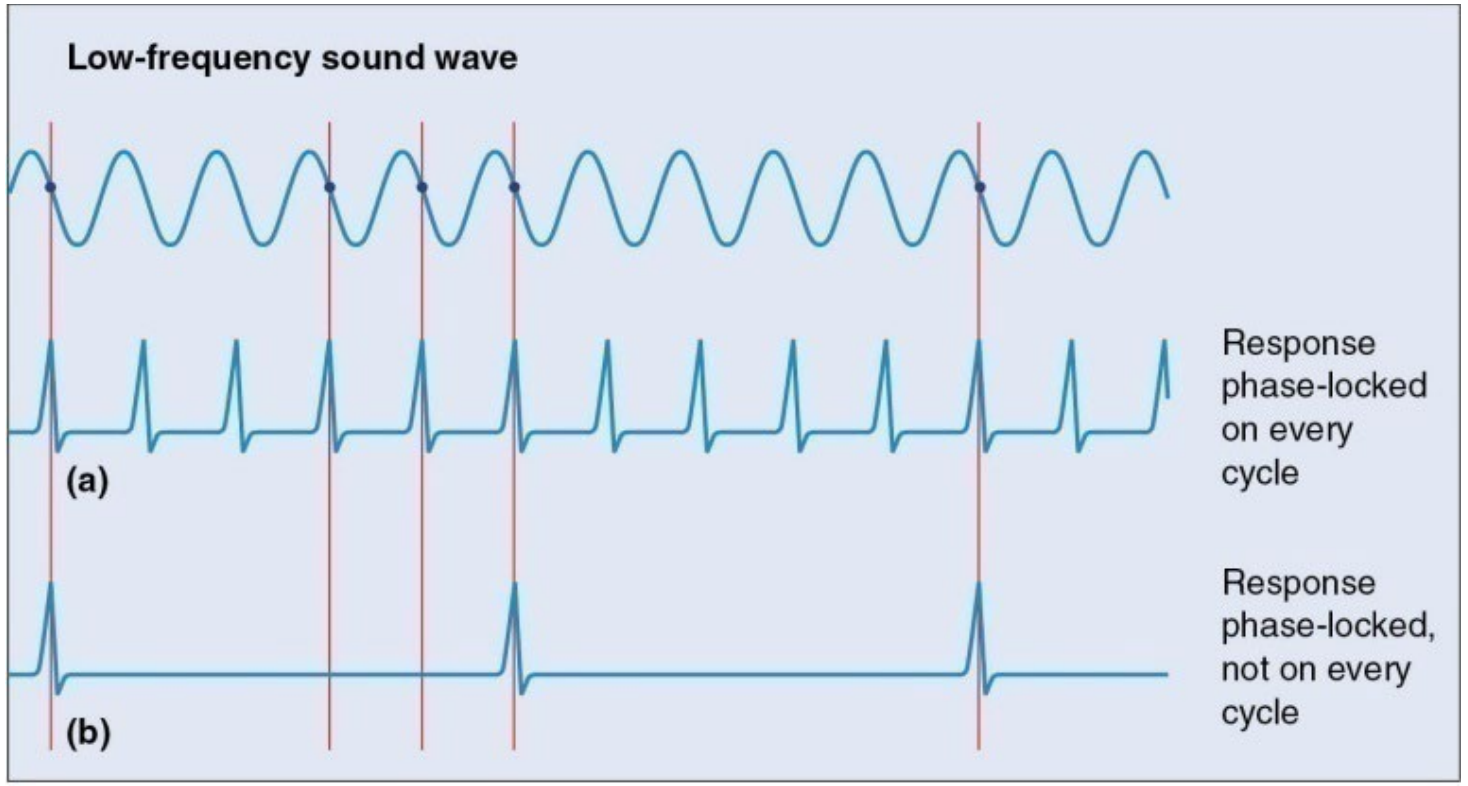
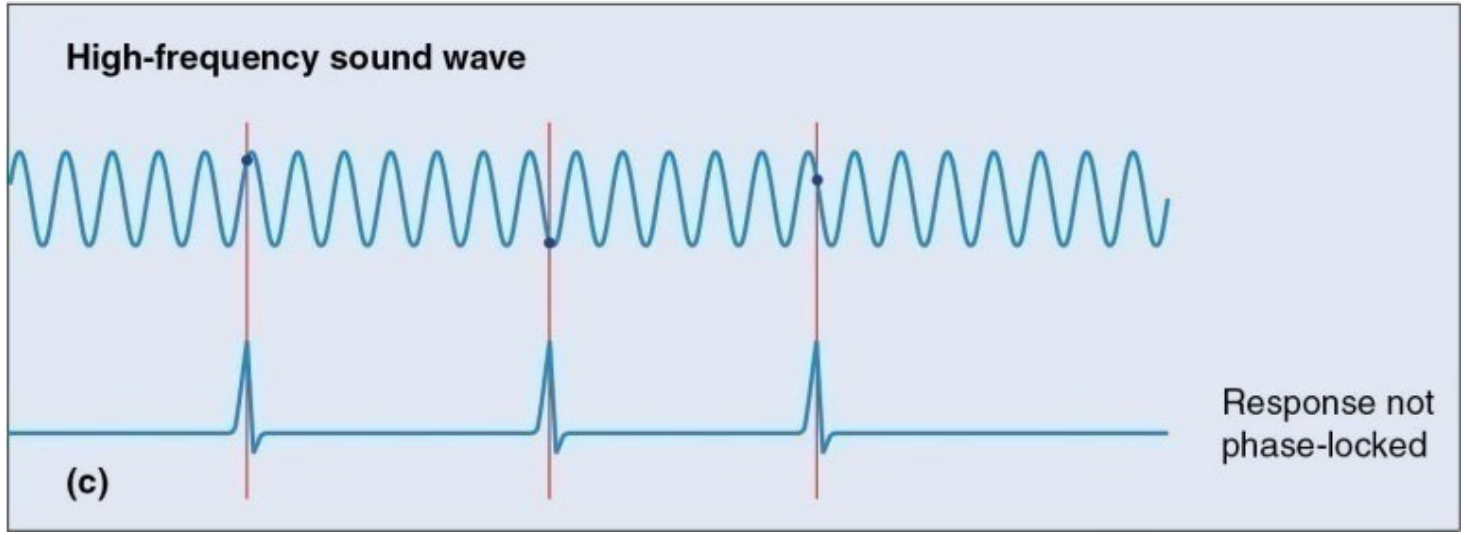
PHASE LOCKING

- Low frequencies: phase locking on every cycle or some fraction of cycles (up to 5kHz)
- High frequencies: not fixed – because frequency is too fast for a single neuron to fire action potentials.





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SOUND FREQUENCY REPRESENTATION

low frequencies → phase locking

intermediate frequencies → both phase locking and tonotopy

high frequencies → tonotopy