INTRODUCTION

- Sensory systems
  - Sense of hearing: audition
    - Detect sound
    - Perceive and interpret nuances
  - Sense of balance: vestibular system
    - Head and body location
    - Head and body movements

CONSCIOUS EXPERIENCE

OUTSIDE OF AWARENES

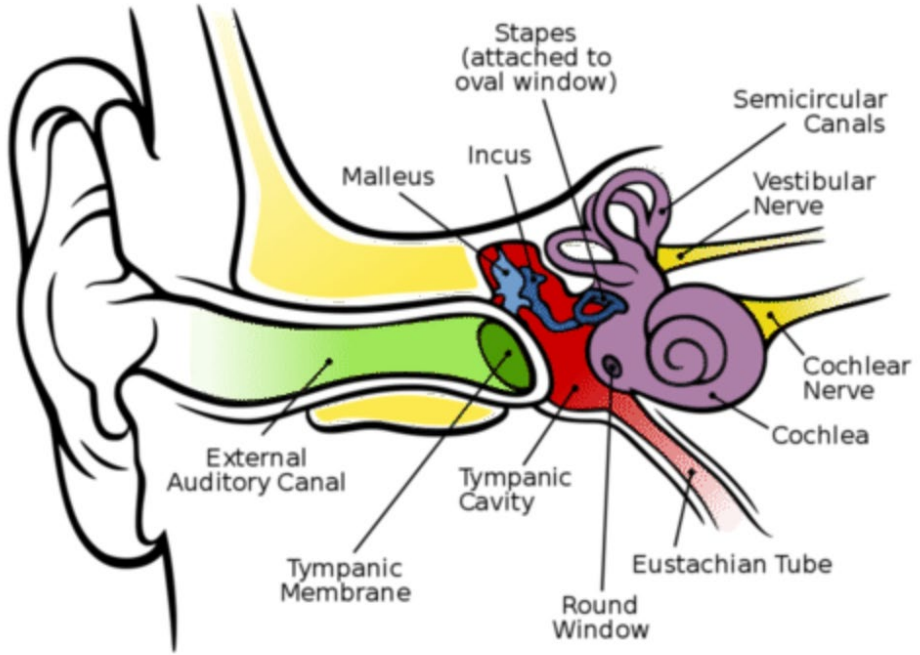
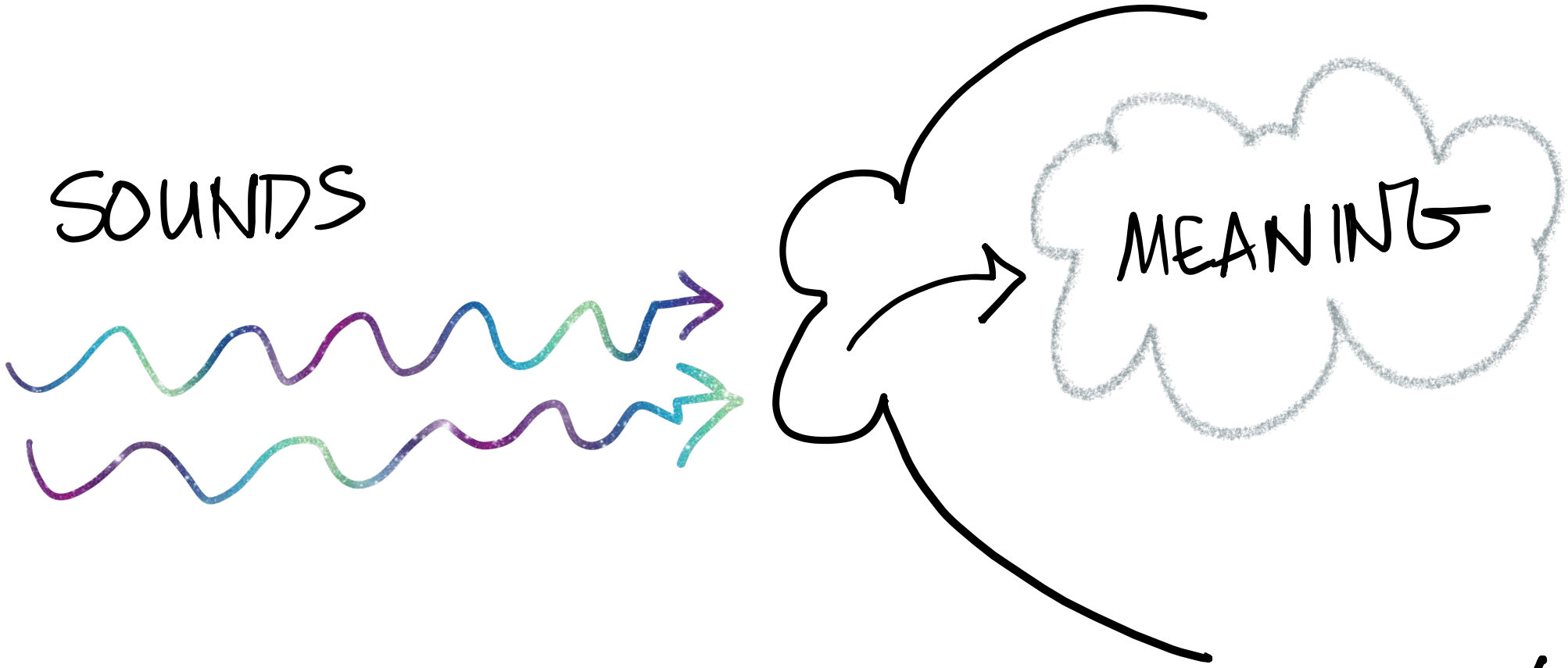


Figure: Chittka L, Brockmann
Source: http://commons.wikimedia.org/wiki/File:Anatomy_of_the_Human_Ear.svg

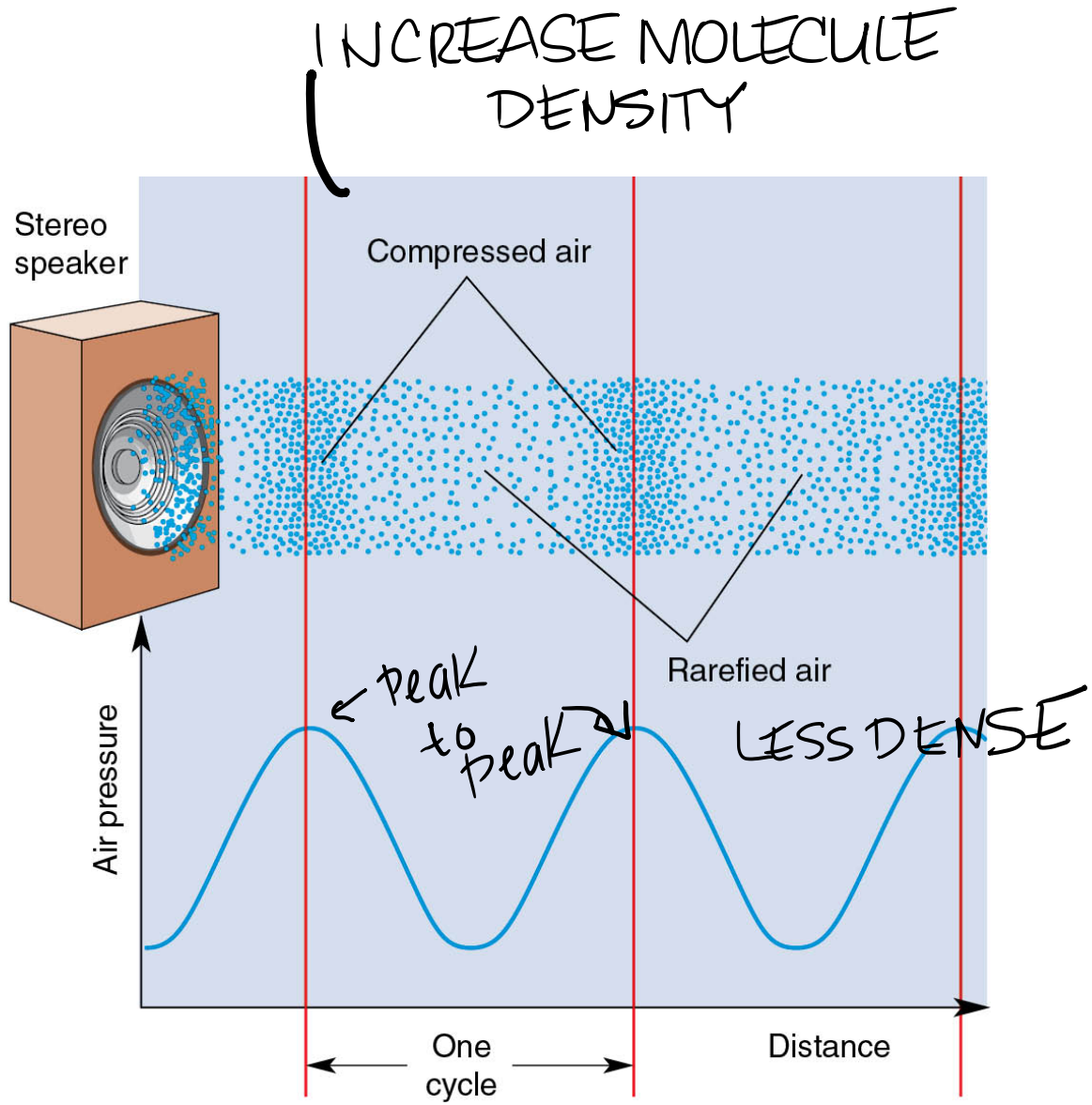
Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.



SPEECH & HEARING ⇒ VITAL FOR COMMUNICATION

THE NATURE OF SOUND

- Audible variations in air pressure
- Cycle: distance between successive compressed patches of air
- Sound frequency: number of cycles per second expressed in hertz (Hz)



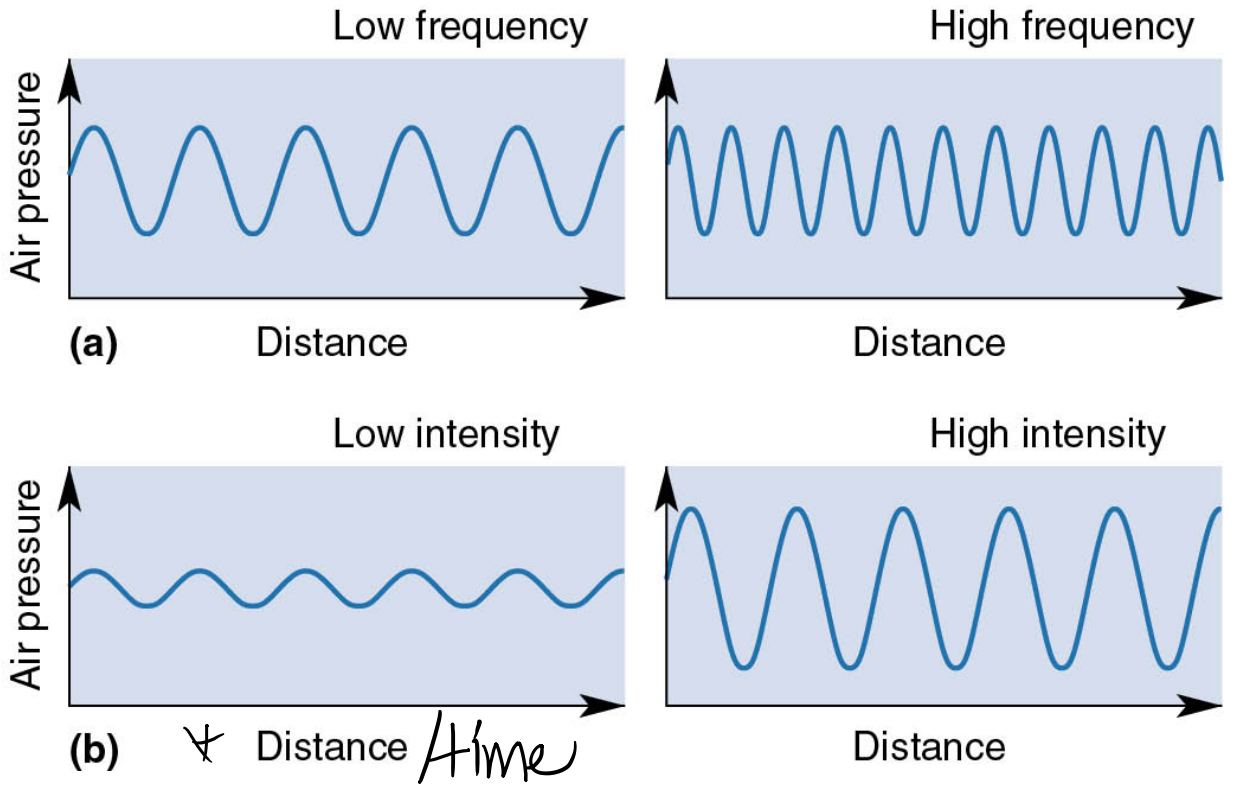
Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.

AUDIBLE SOUND

units:

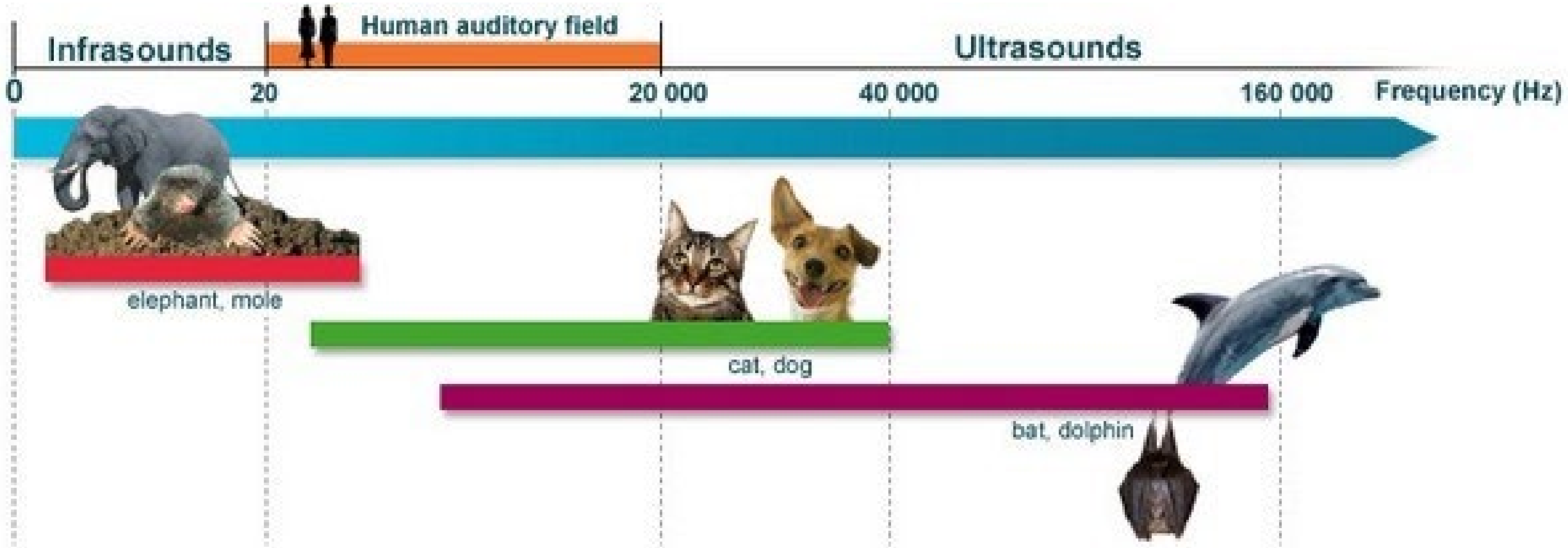
Hertz (Hz) → # cycles per second

- Range: 20 Hz to 20,000 Hz
- Pitch: high pitch = high frequency, low pitch = low frequency
- Intensity (amplitude): high intensity louder than low intensity

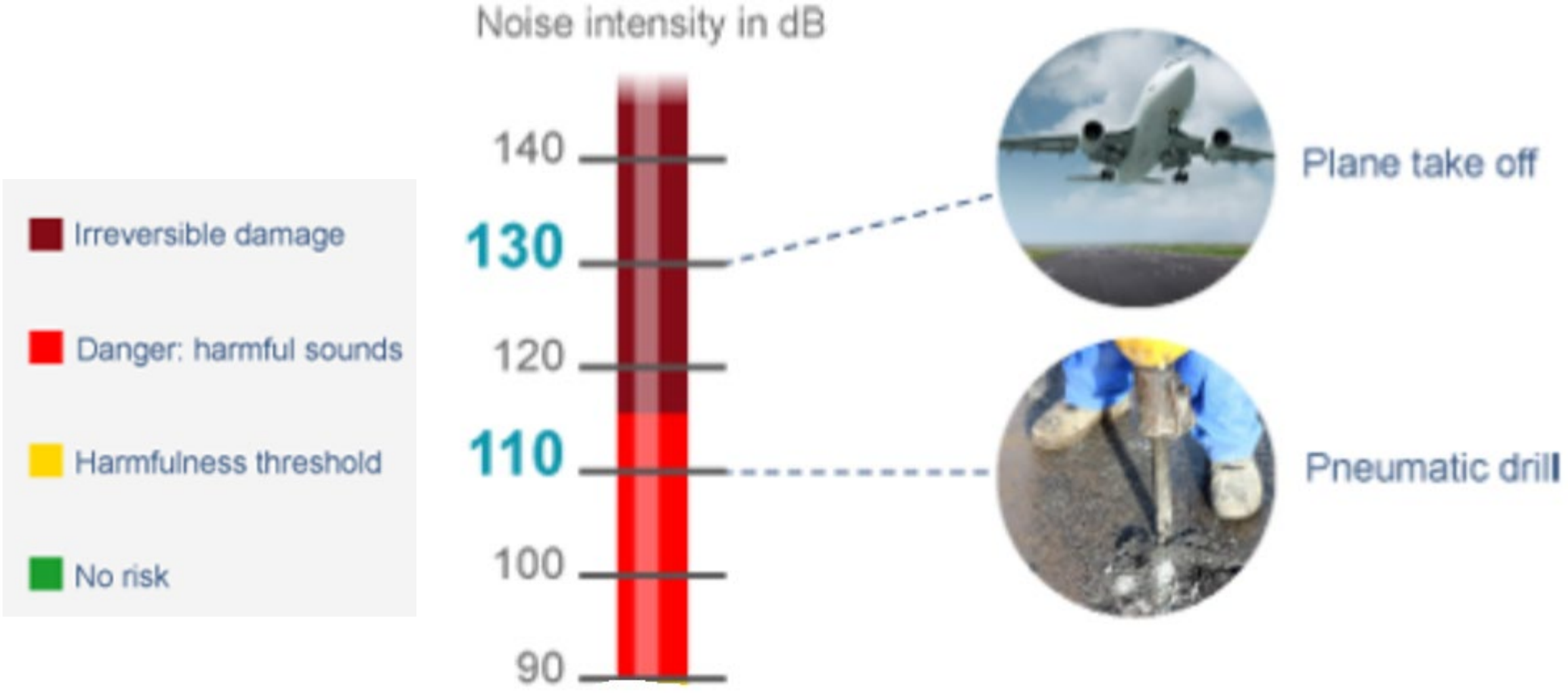


*velocity of sound is constant (767 mph)

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



graph S. Blatrix Rémy Pujol http://www.cochlea.org/en/hear/human-auditory-range



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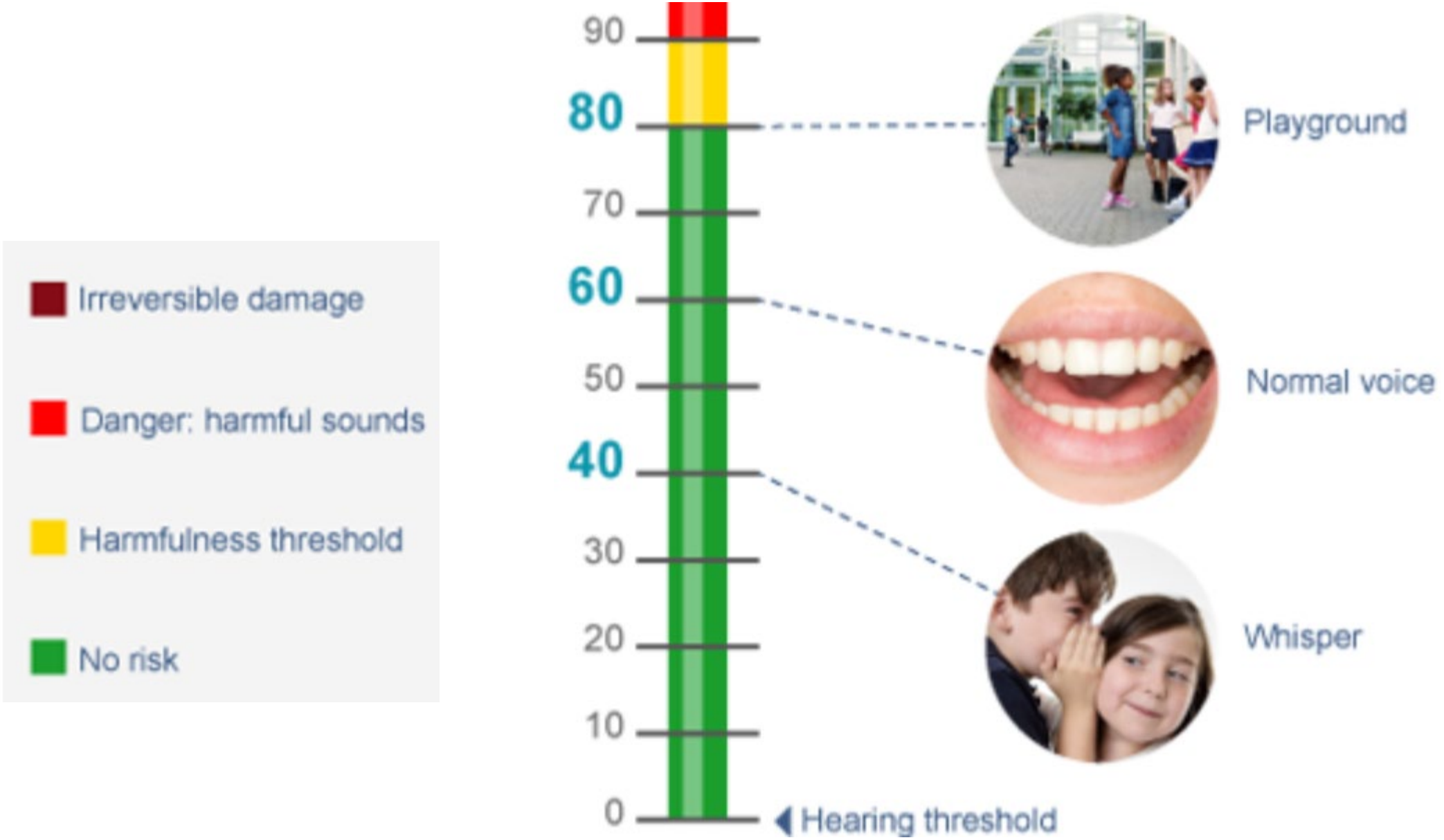
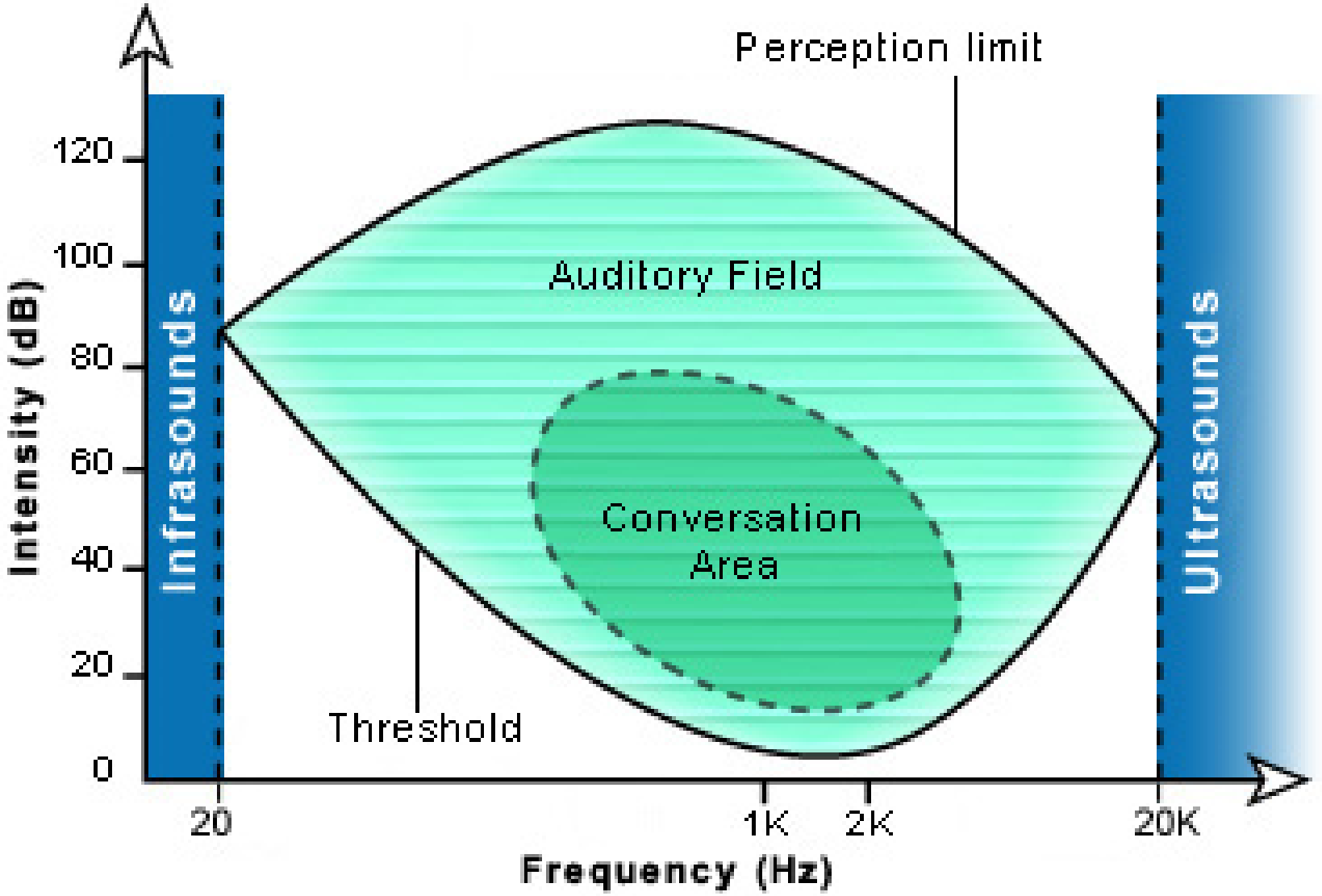
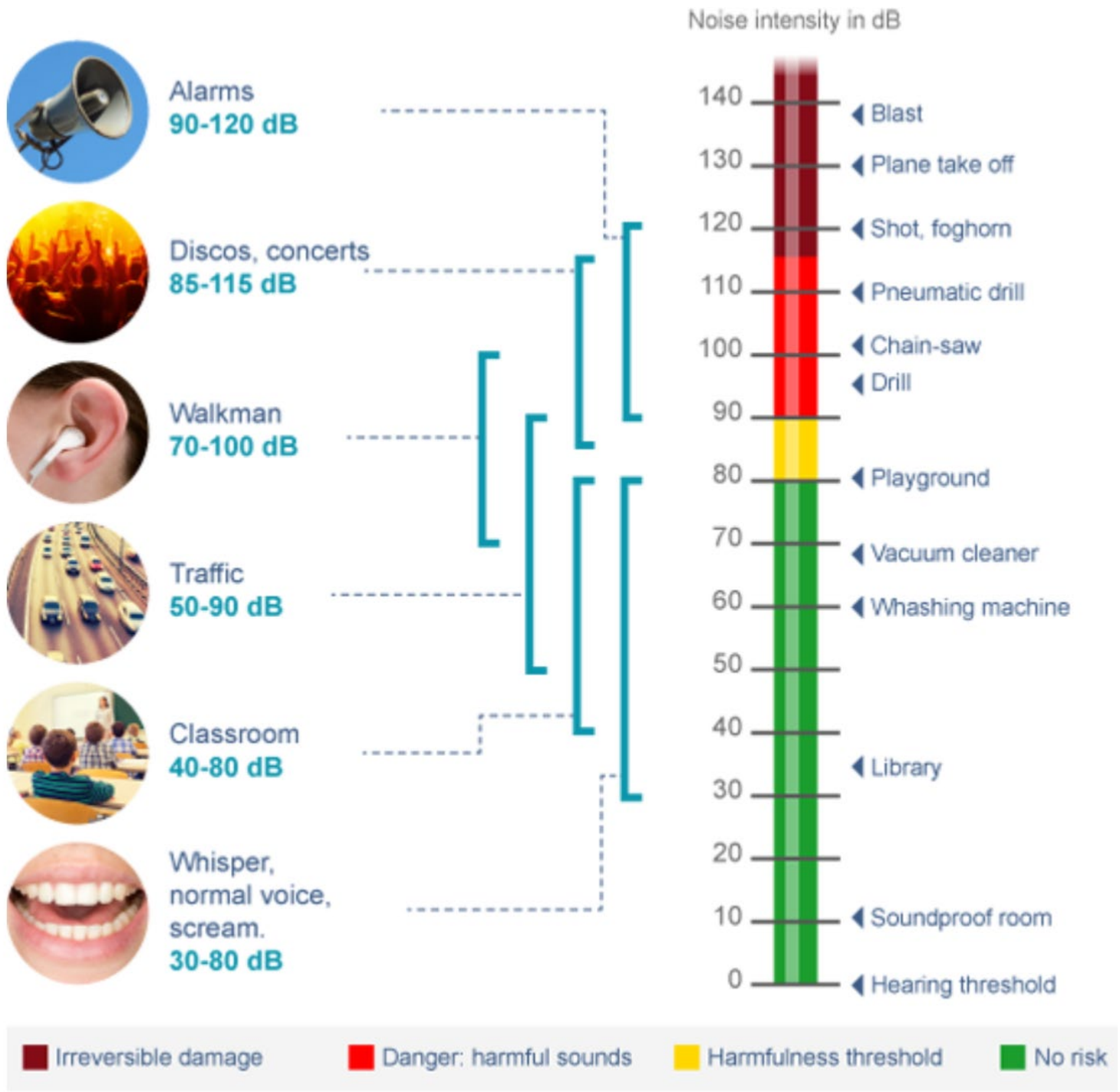


graph S. Blatrix Rémy Pujol http://www.cochlea.org/en/hear/human-auditory-range

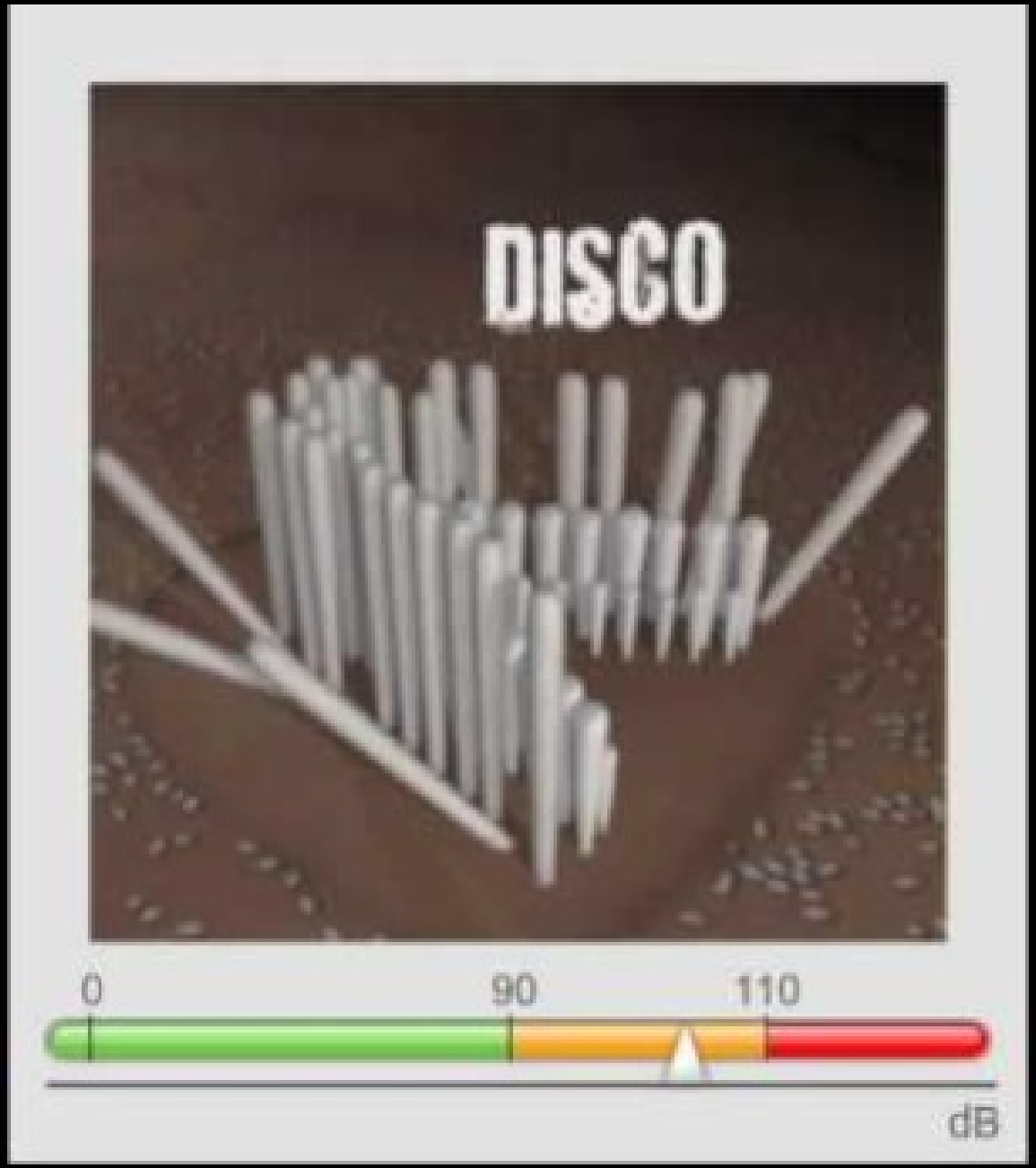
"At each frequency, between 20 Hz and 20 kHz, the threshold of our sensitivity is different."



graph P. Minary *Rémy Pujol* http://www.cochlea.org/en/hear/human-auditory-range

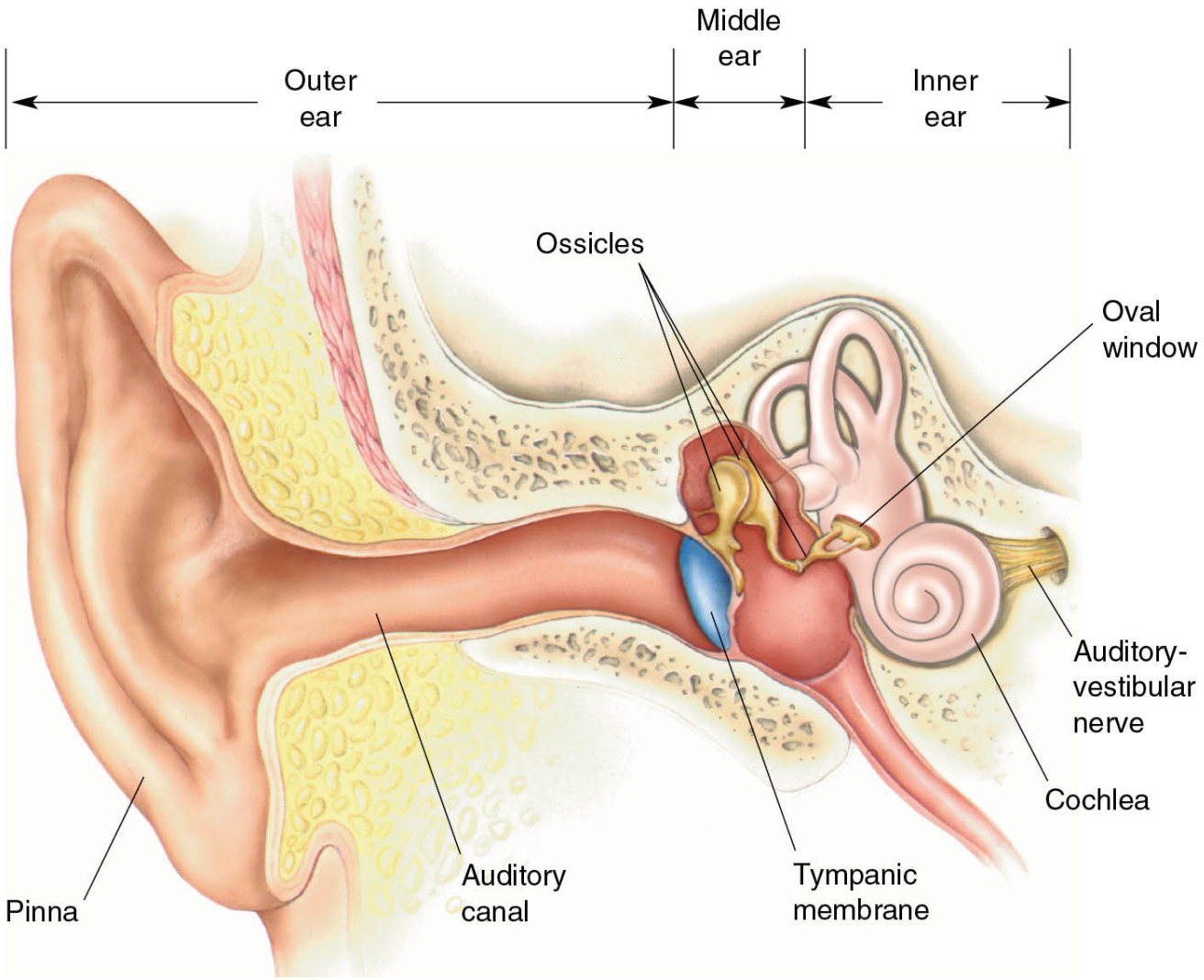


graph S. Blatrix Rémy Pujol
http://www.cochlea.org/en/hear/human-auditory-range

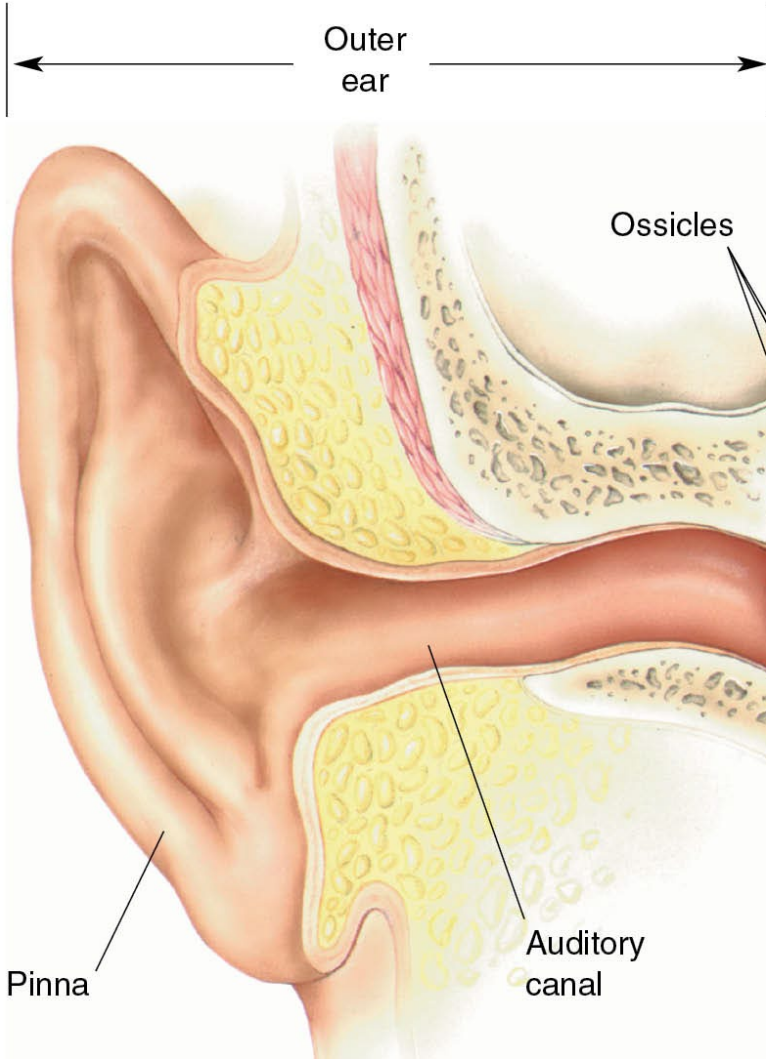


https://youtu.be/3MBUv4NQxbE

STRUCTURE OF THE AUDITORY SYSTEM



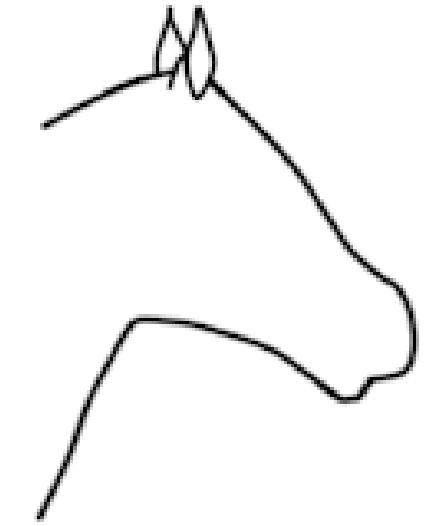
Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.



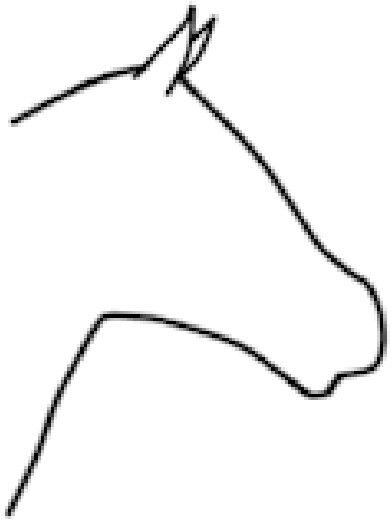
OUTER EAR

- Collect sounds
- Orientation
- Localization

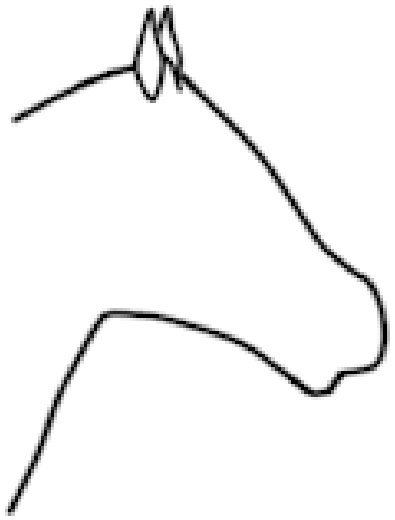
- Auditory canal is 2.5cm



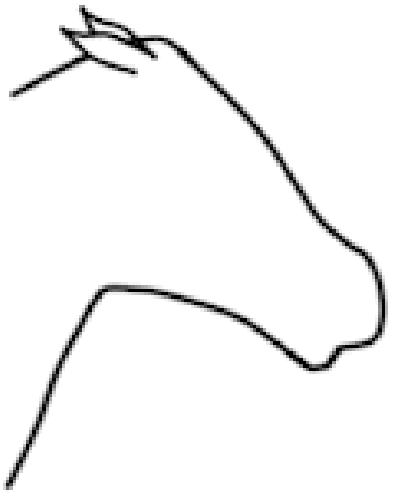
Alertness interest
& curiosity



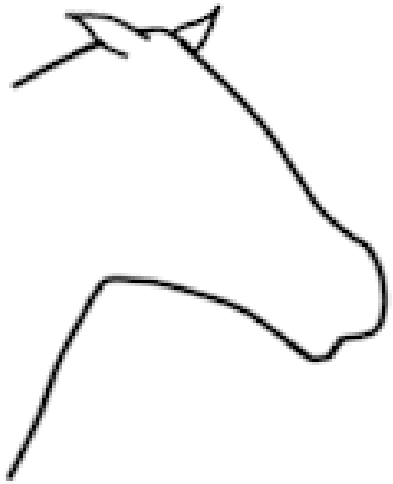
Intense interest
& curiosity



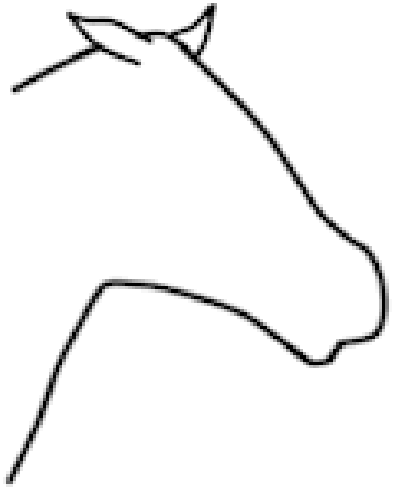
Submission,
slight concern



Anger, aggression,
irritation, warning

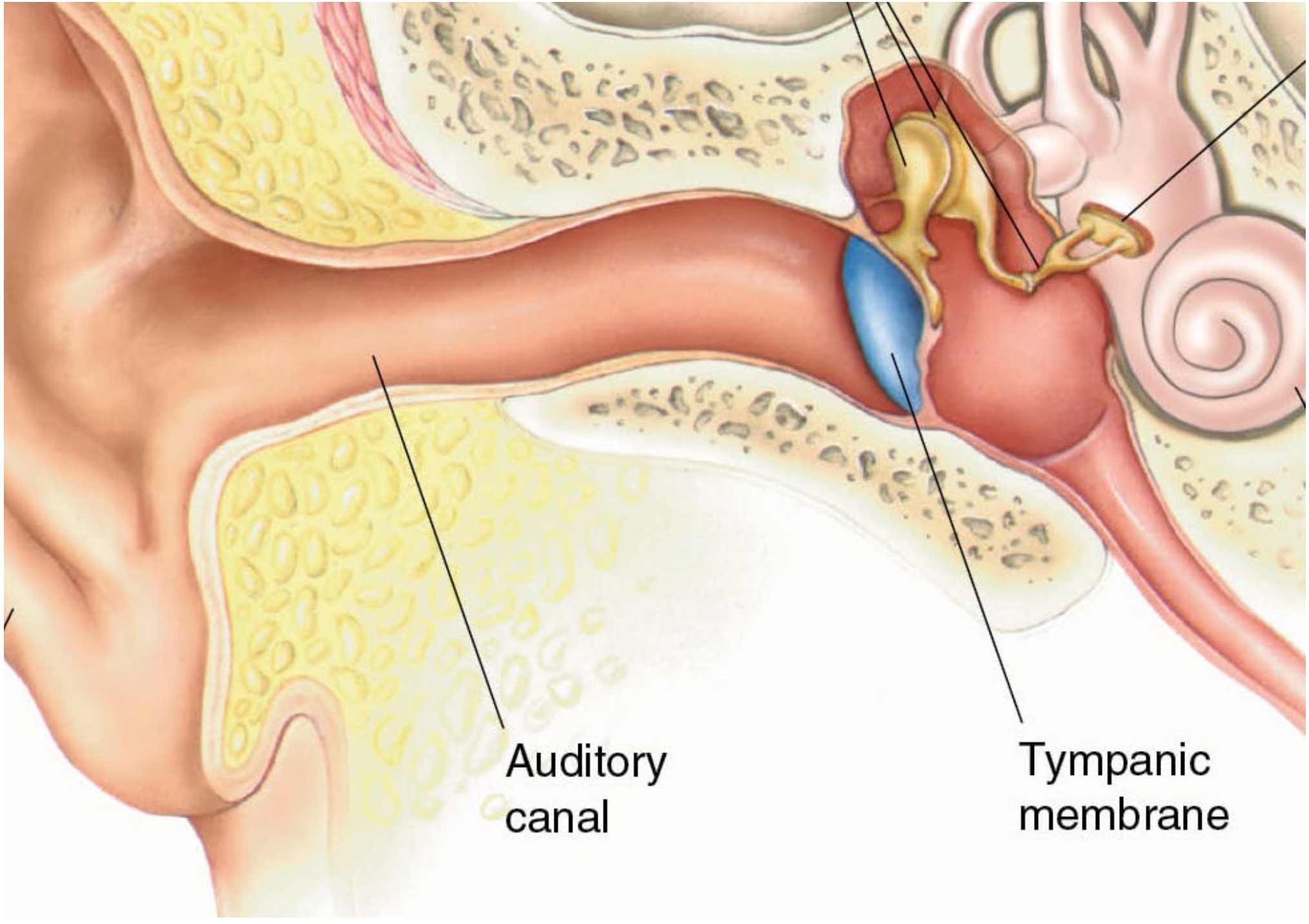


Terror

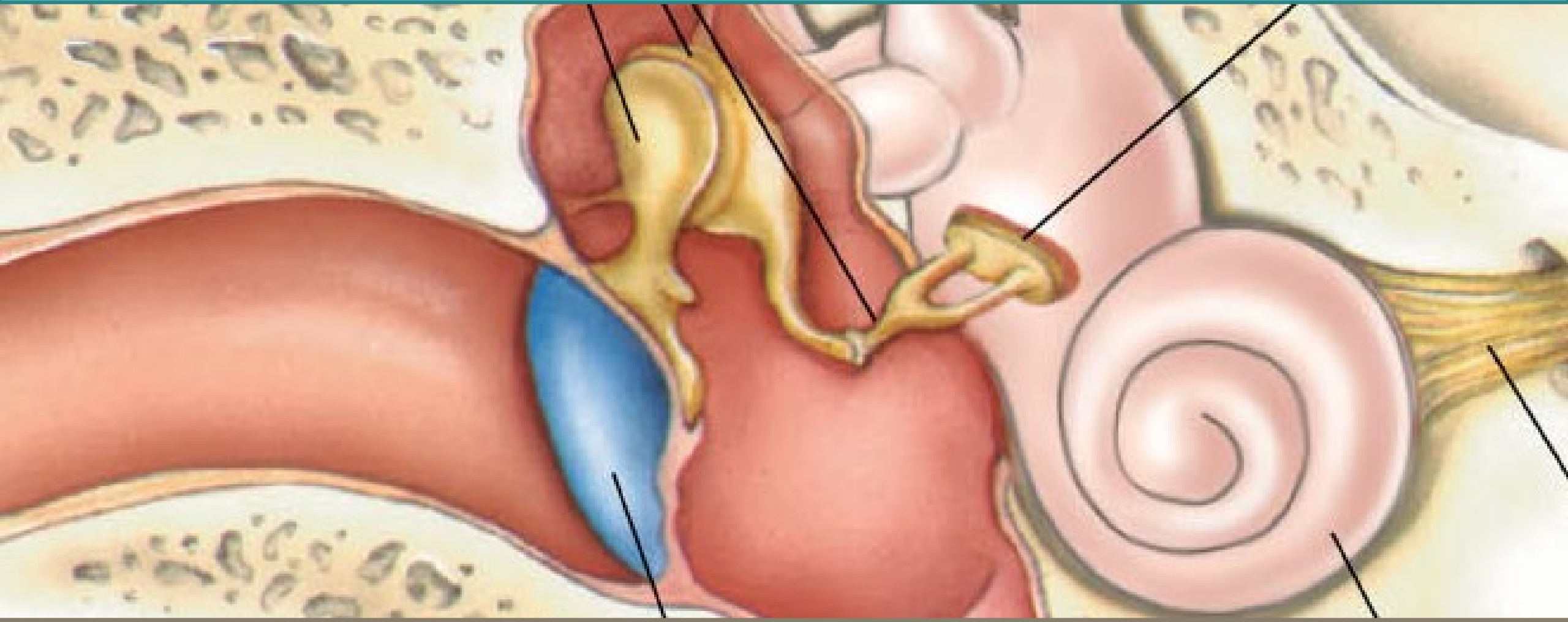


Divided attention

https://sielearning.tafensw.edu.au/MPR/8131G/equine/Behaviour/Normal/Images/Ears.gif

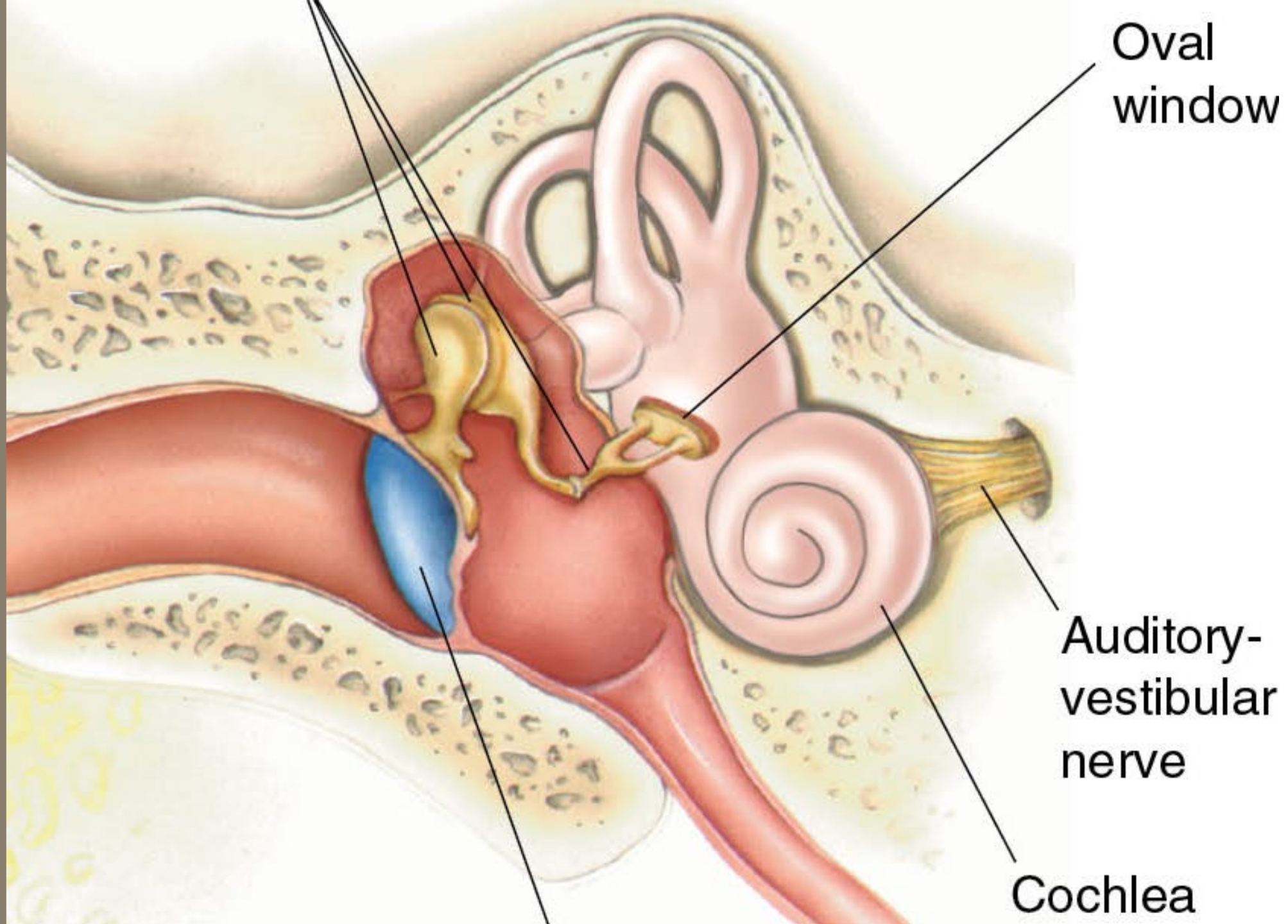

Auditory
canal
Tympanic
membrane

Ossicles – transfer movement of the tympanic membrane to the oval window

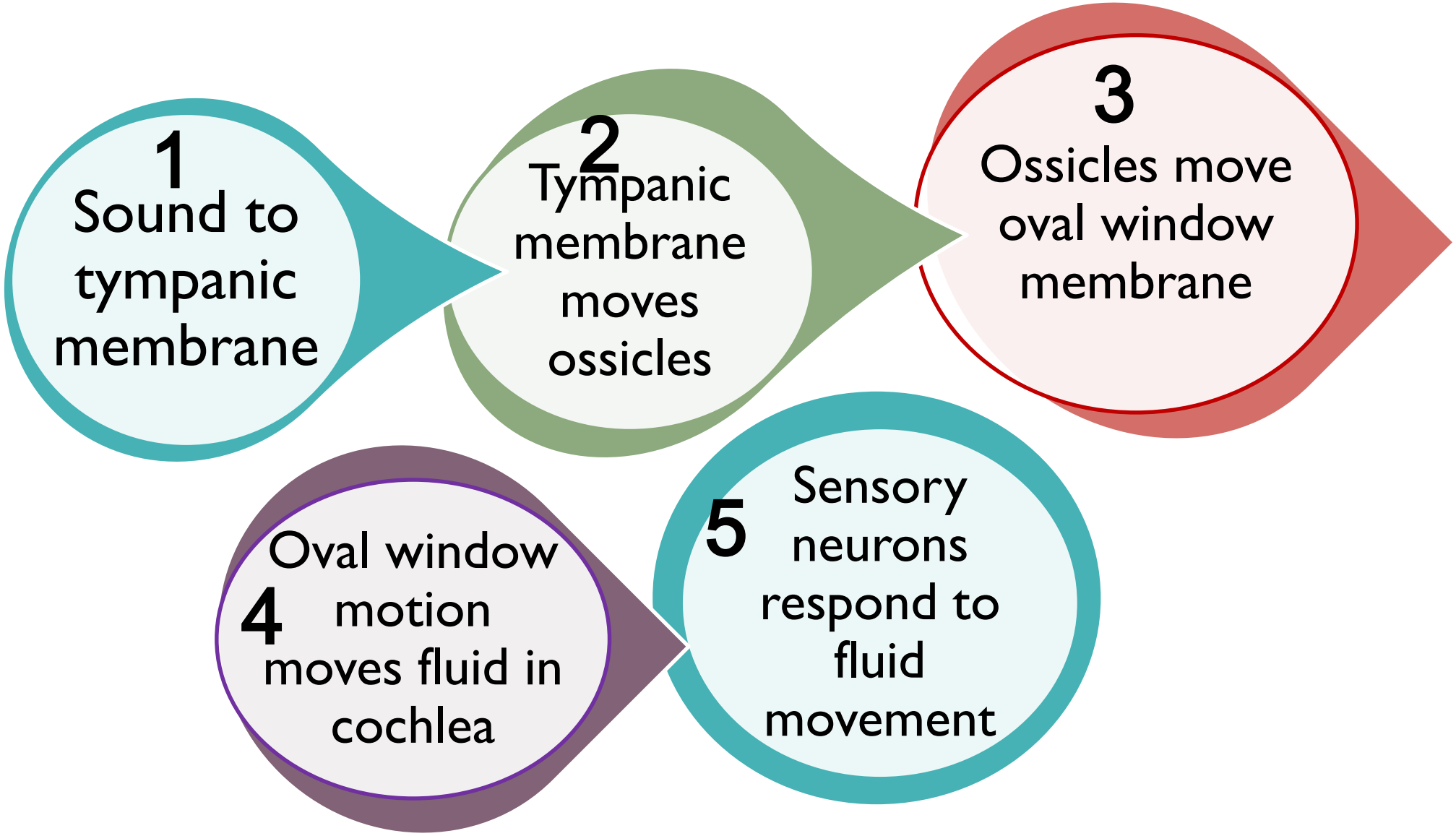


Middle Ear: Tympanic membrane and ossicles

Everything medial to the oval window is considered the inner ear

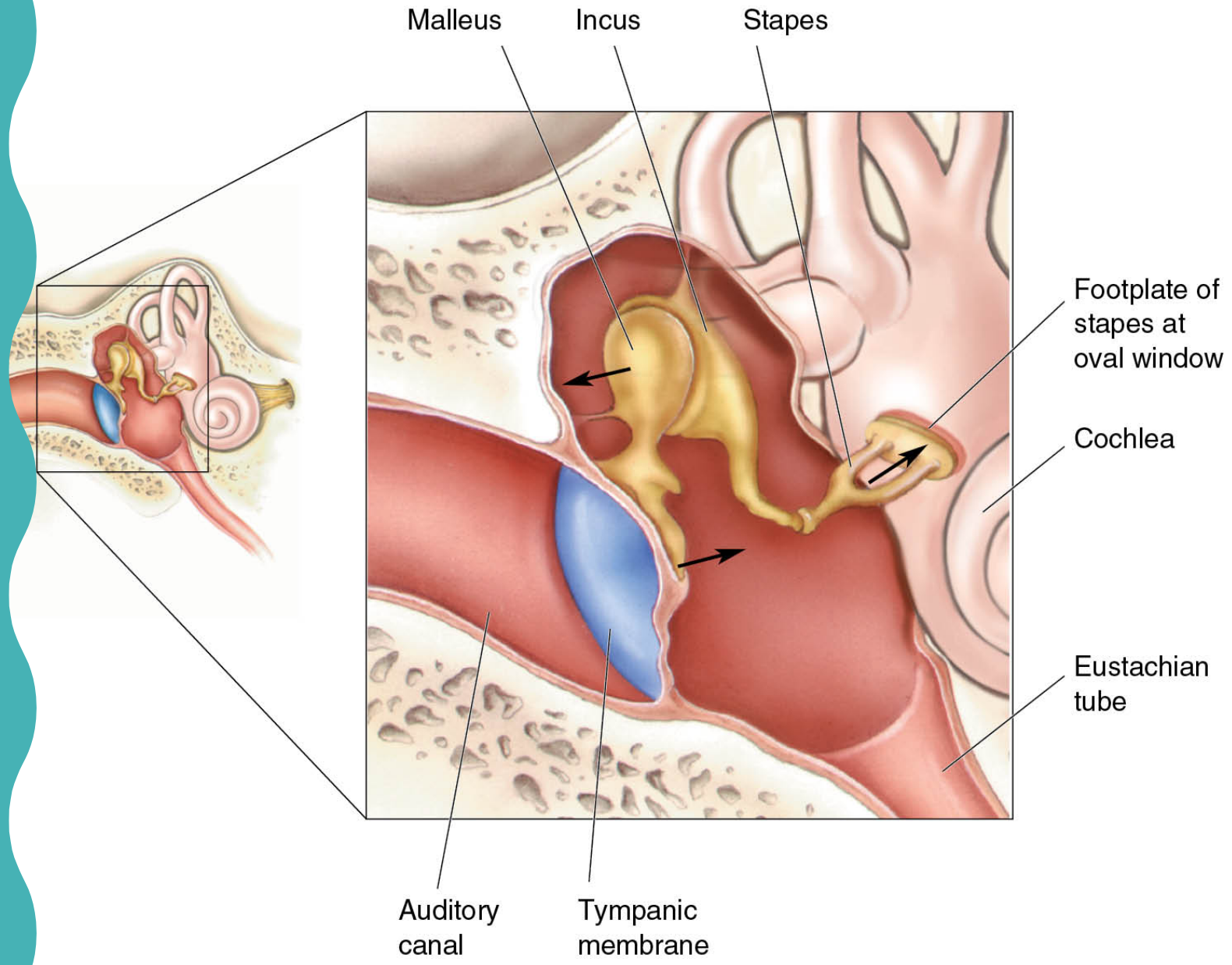


1ST STAGES AUDITORY PATHWAY:

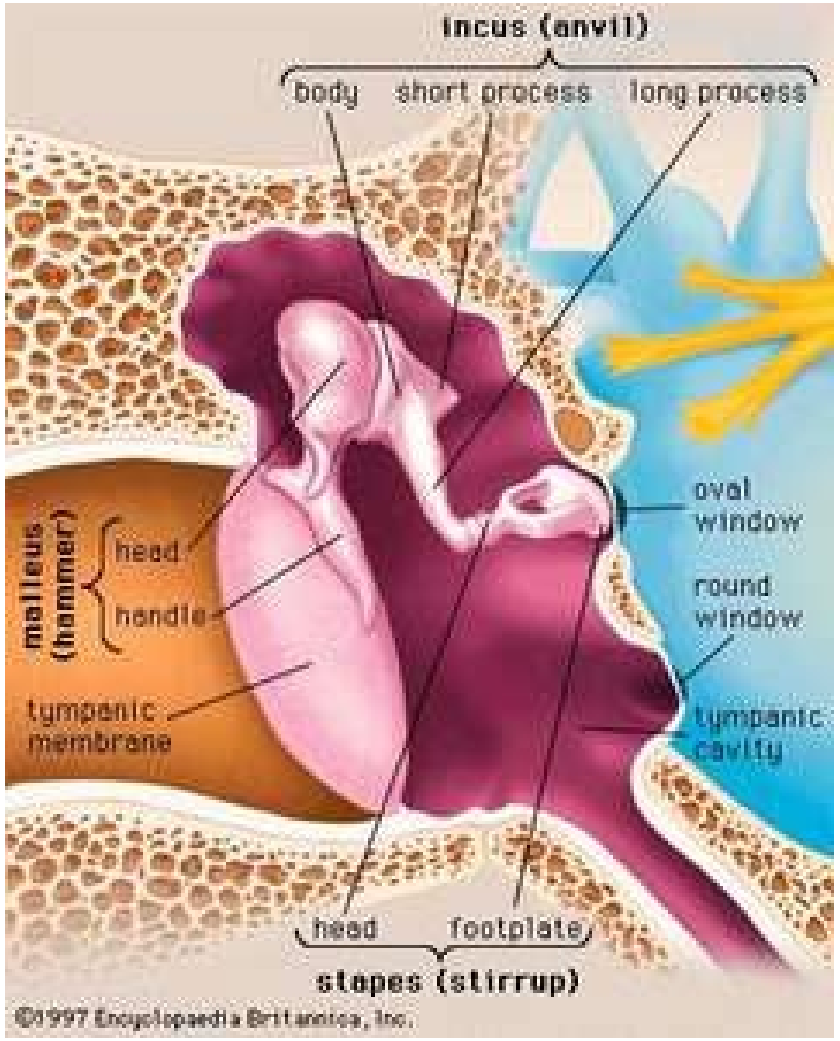


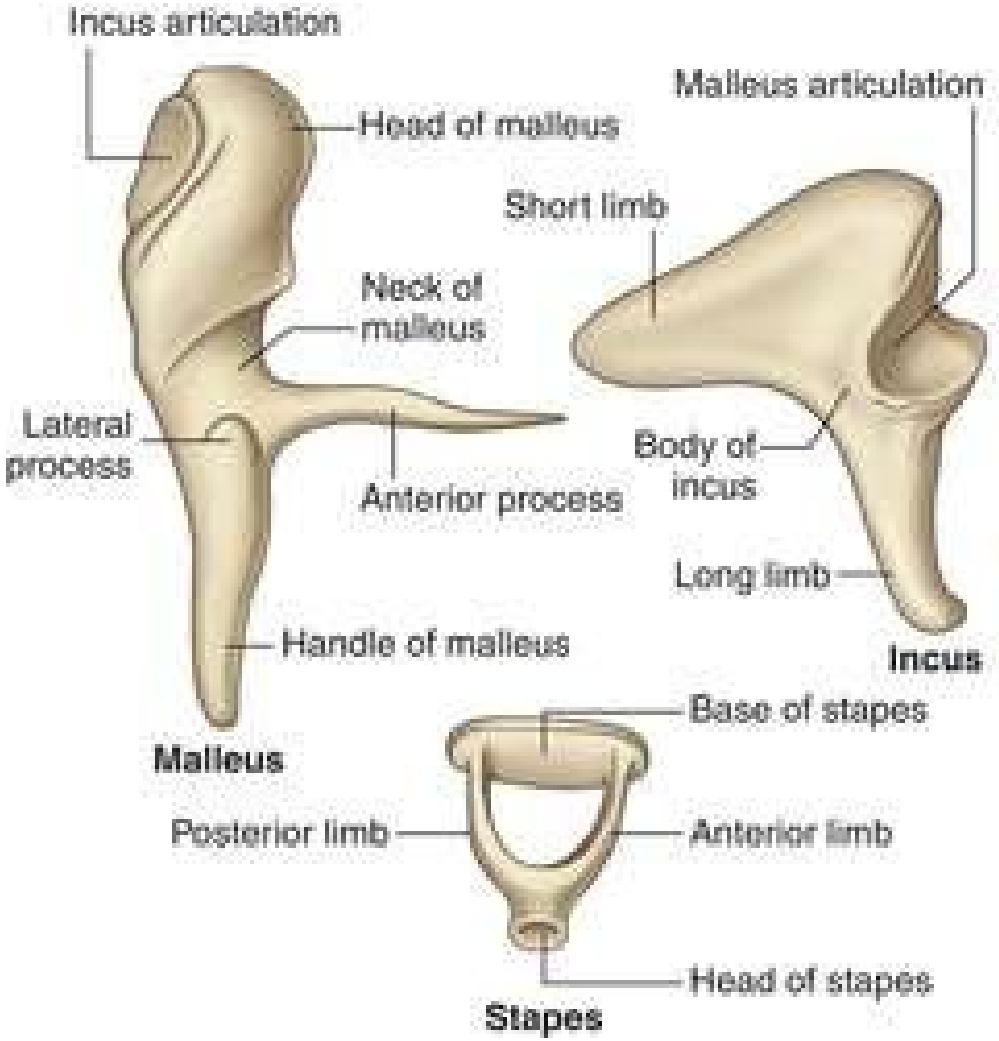
COMPONENTS OF THE MIDDLE EAR

Tympanic membrane, the ossicles and the two muscles that are attached to the ossicles.



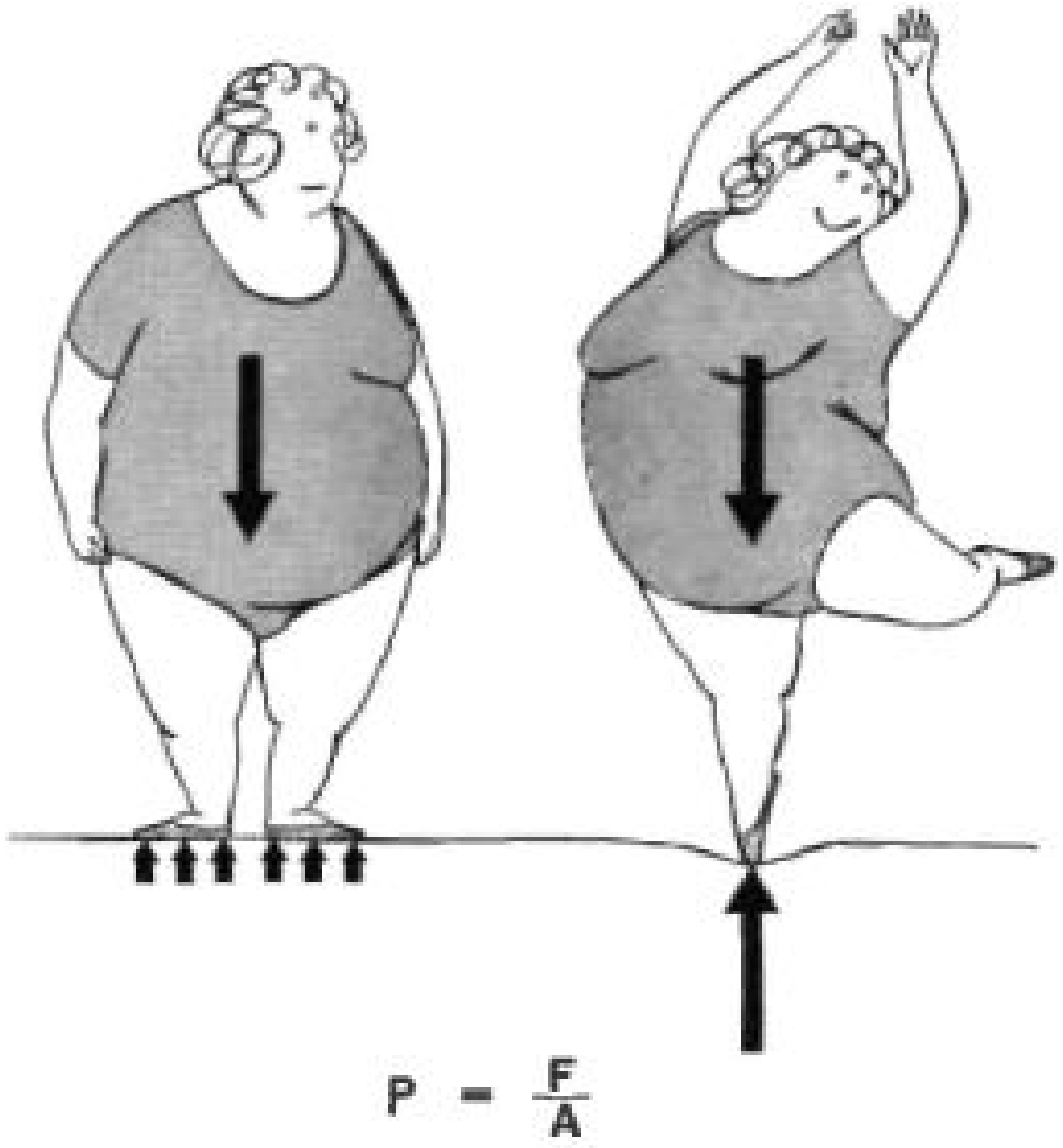
Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.





https://www.britannica.com/science/ear-bone

https://medical-dictionary.thefreedictionary.com/auditory+ossicles



Recall:
"Pressure" is force supported per unit area.

A broad area of support results in lower values of average pressure.

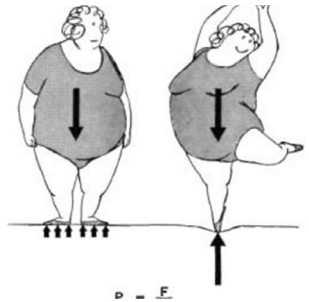
http://www.oandplibrary.org/popup.asp?frmItemId=AF49DC28-7031-4956-BBFF-CA4E486A6995&frmType=image&frmId=3

https://medlineplus.gov/ency/anatomyvideos/000063.htm

THE MIDDLE EAR

1. OSSICLES ACT AS LEVERS

2. OVAL WINDOW IS SMALLER THAN T.M.



Sound force amplification by the ossicles

Pressure: force per surface area

Greater pressure at oval window than tympanic membrane, moves fluids.

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

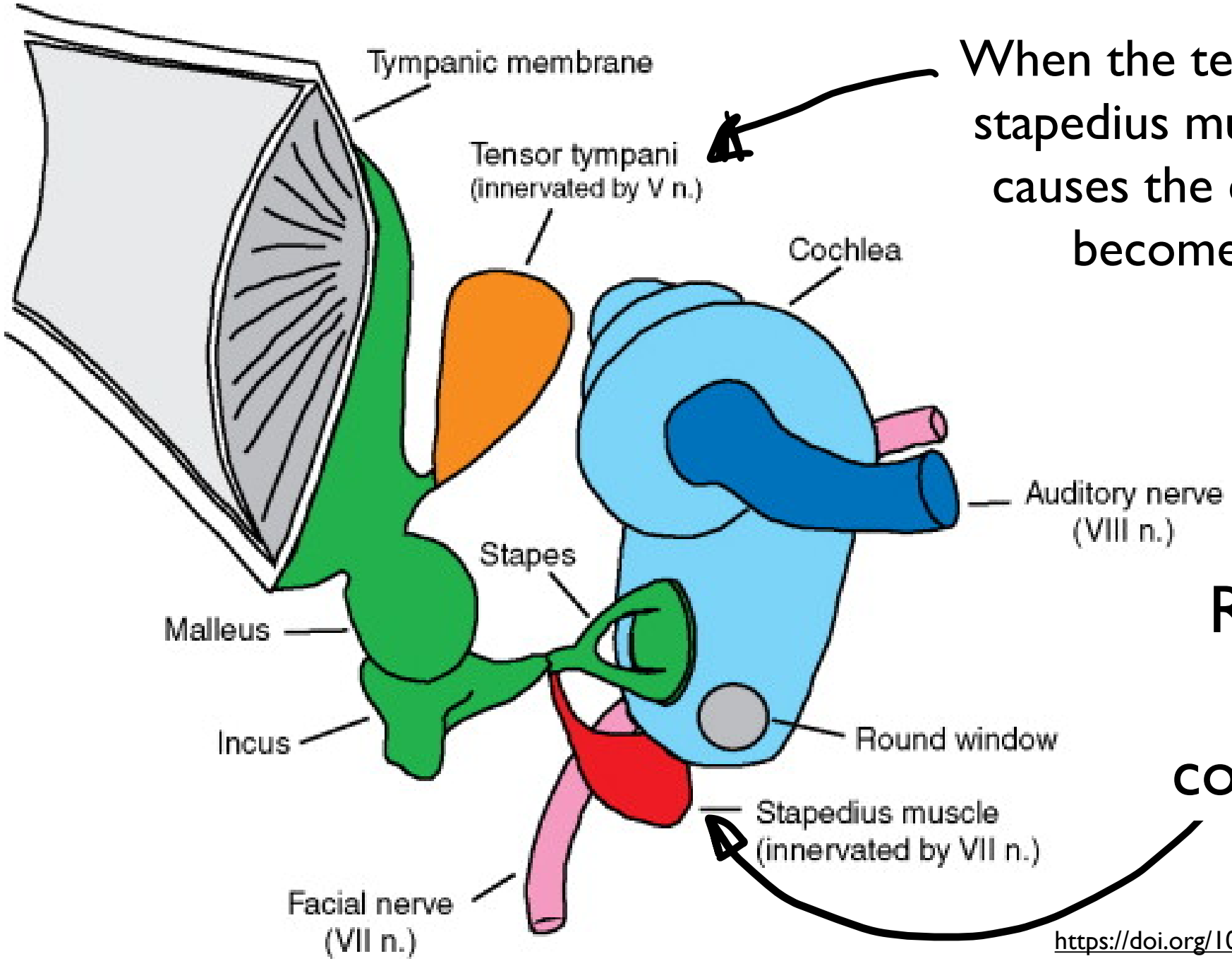
THE MIDDLE EAR

The attenuation reflex

Response when onset of loud sound causes tensor tympani and stapedius muscle contraction

Function: adapts ear to loud sounds, protects inner ear, enables us to understand speech better

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



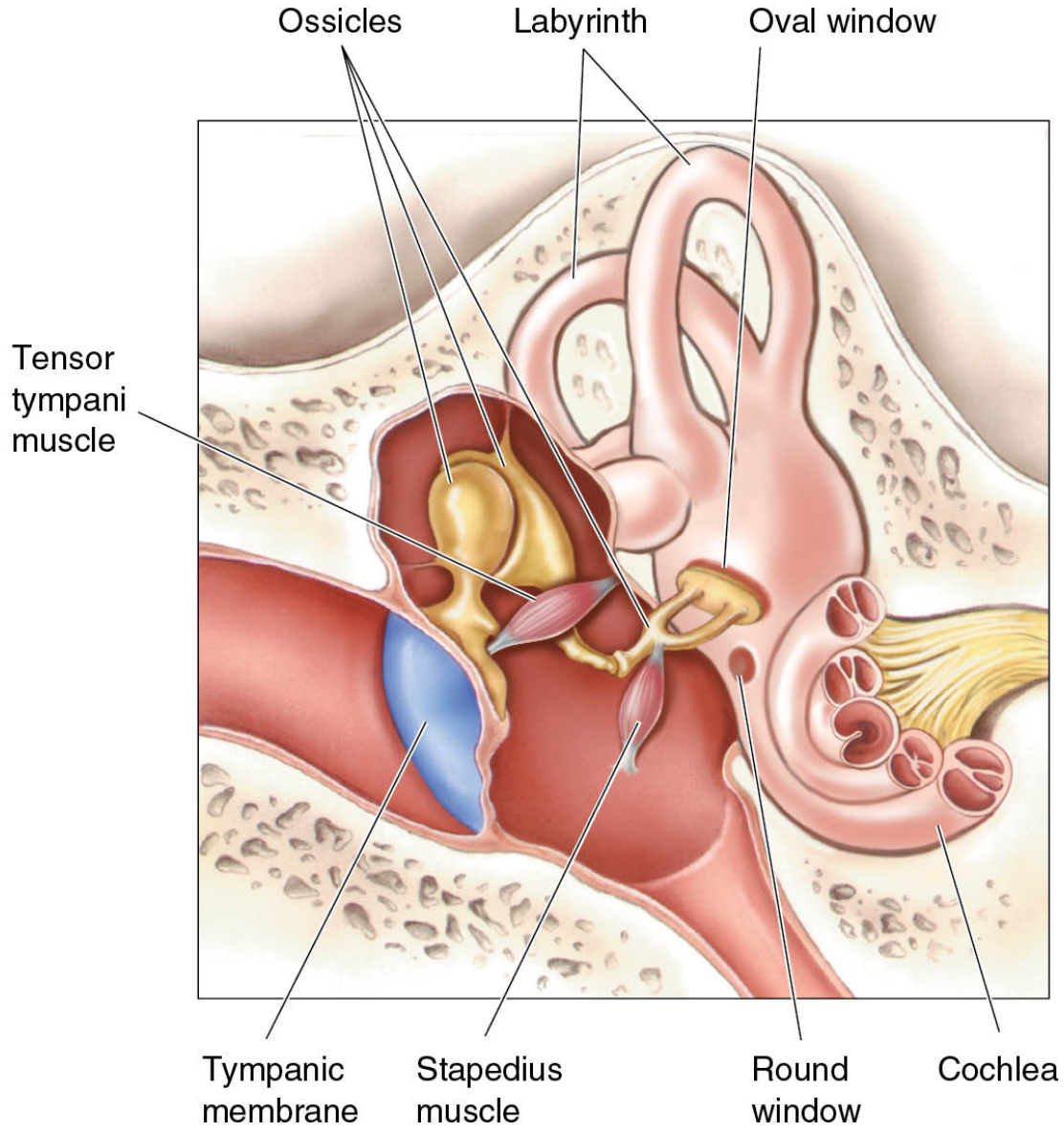
When the tensor tympani and stapedius muscles contract it causes the chain of ossicles become more rigid.

Reducing sound conduction.

https://doi.org/10.1016/B978-008045046-9.00248-5

Brown, M. C. "Auditory System: Efferent Systems to the Auditory Periphery." *Encyclopedia of Neuroscience*. Ed. Squire, Larry R. Oxford: Academic Press, 2009. 753-57. Print.

THE MIDDLE AND INNER EAR

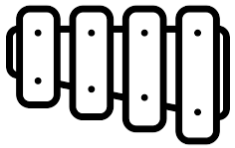


Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.

THE INNER EAR

Physiology of the cochlea

Motion at oval window pushes perilymph into scala vestibuli, makes round window membrane bulge.



The response of basilar membrane to sound

Structural properties: wider at apex, stiffness decreases from base to apex

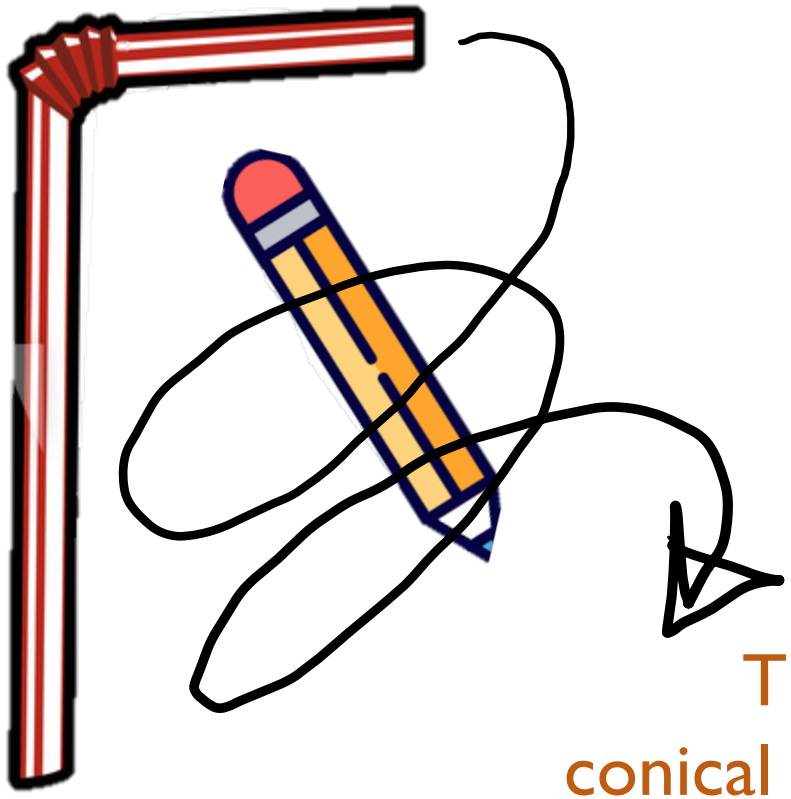
Research: Georg von Békésy

Endolymph movement bends basilar membrane near base, wave moves toward apex.

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

"The cochlea is similar to a drinking straw wrapped two and a half to three times around the sharpened tip of a pencil."

Straw is the hollow tube made out of bone



The pencil is the conical bony structure called the central pillar

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

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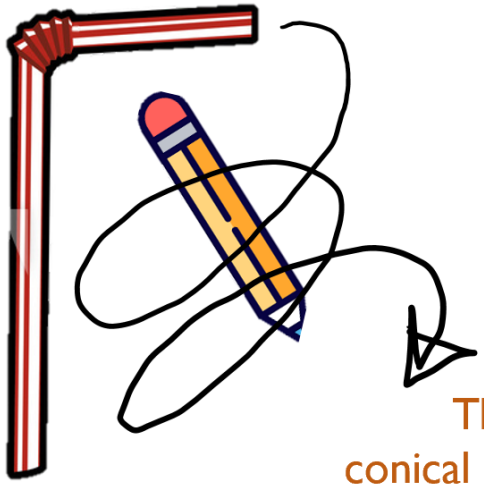


The pencil is the conical bony structure called the central pillar

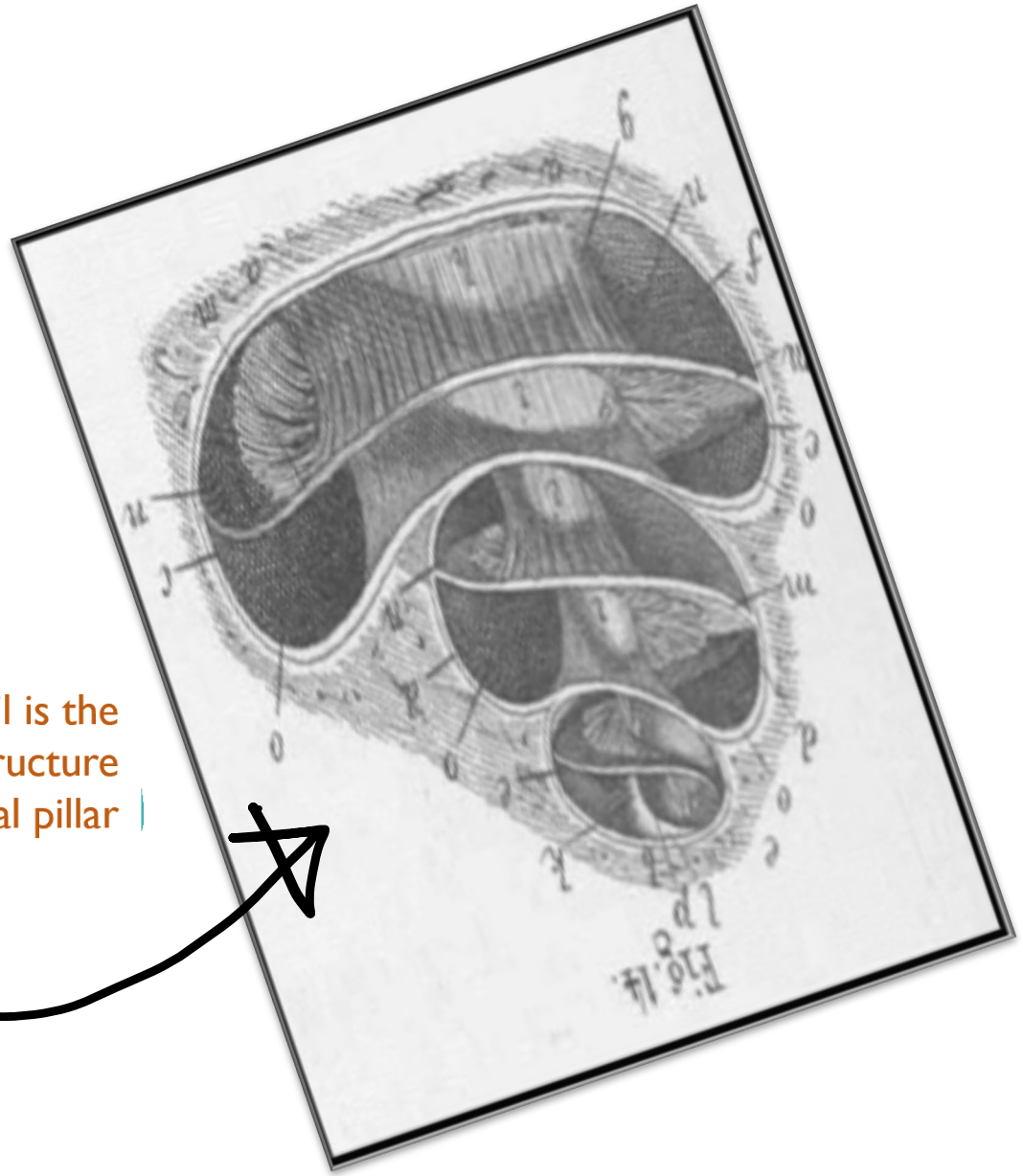
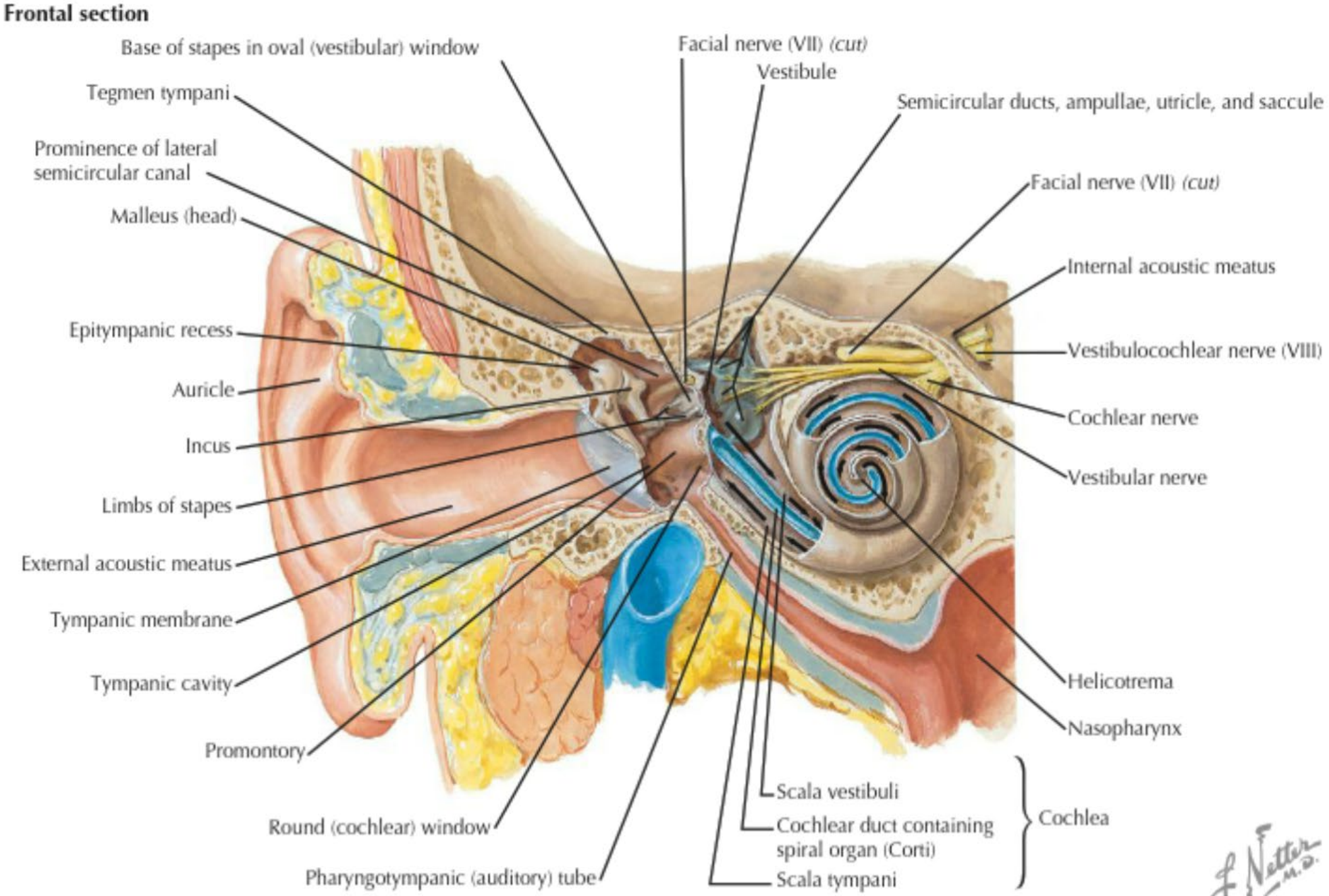
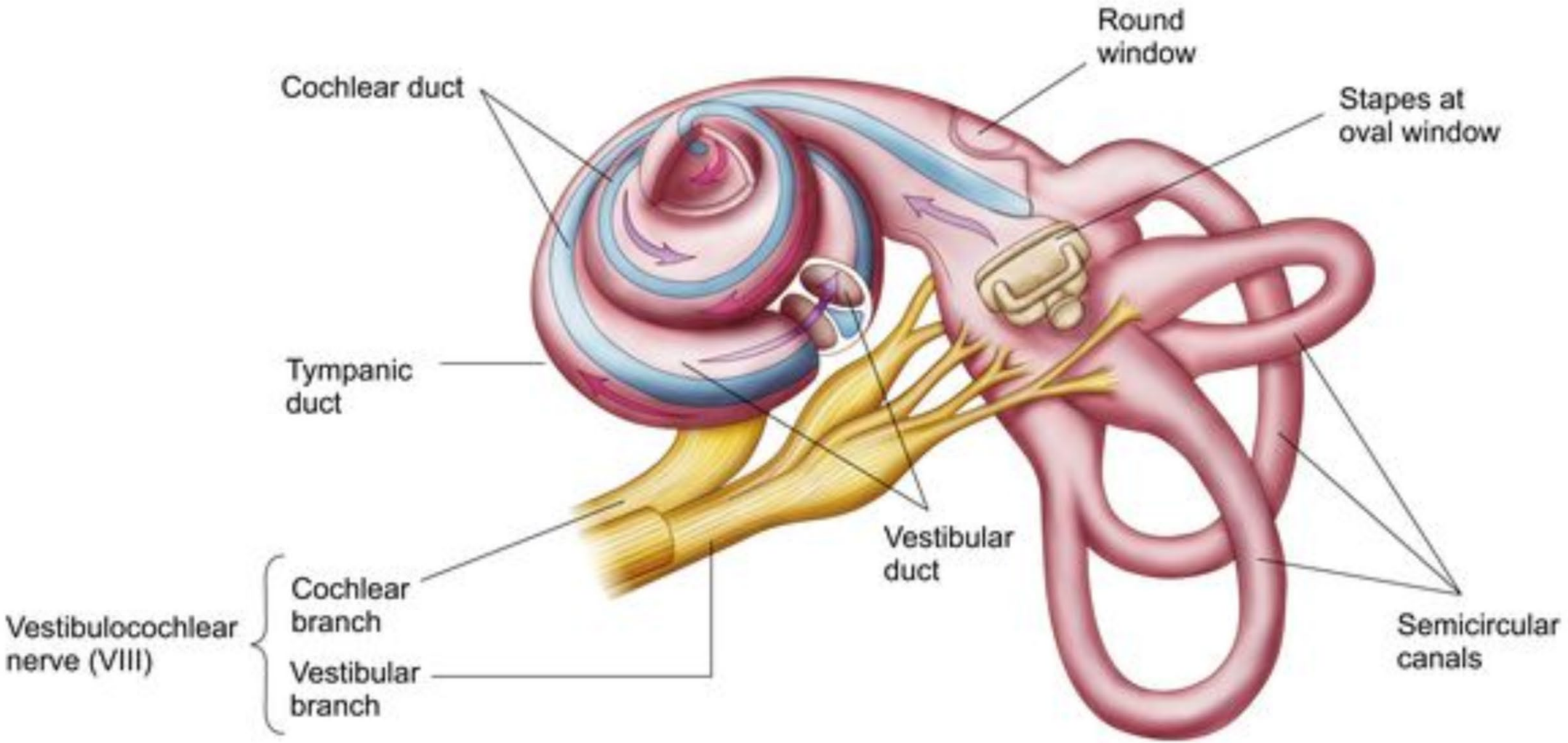


Figure from: https://www.slideshare.net/ravindradaggupati/anatomy-of-inner-ear-by-dr-ravindra-daggupati

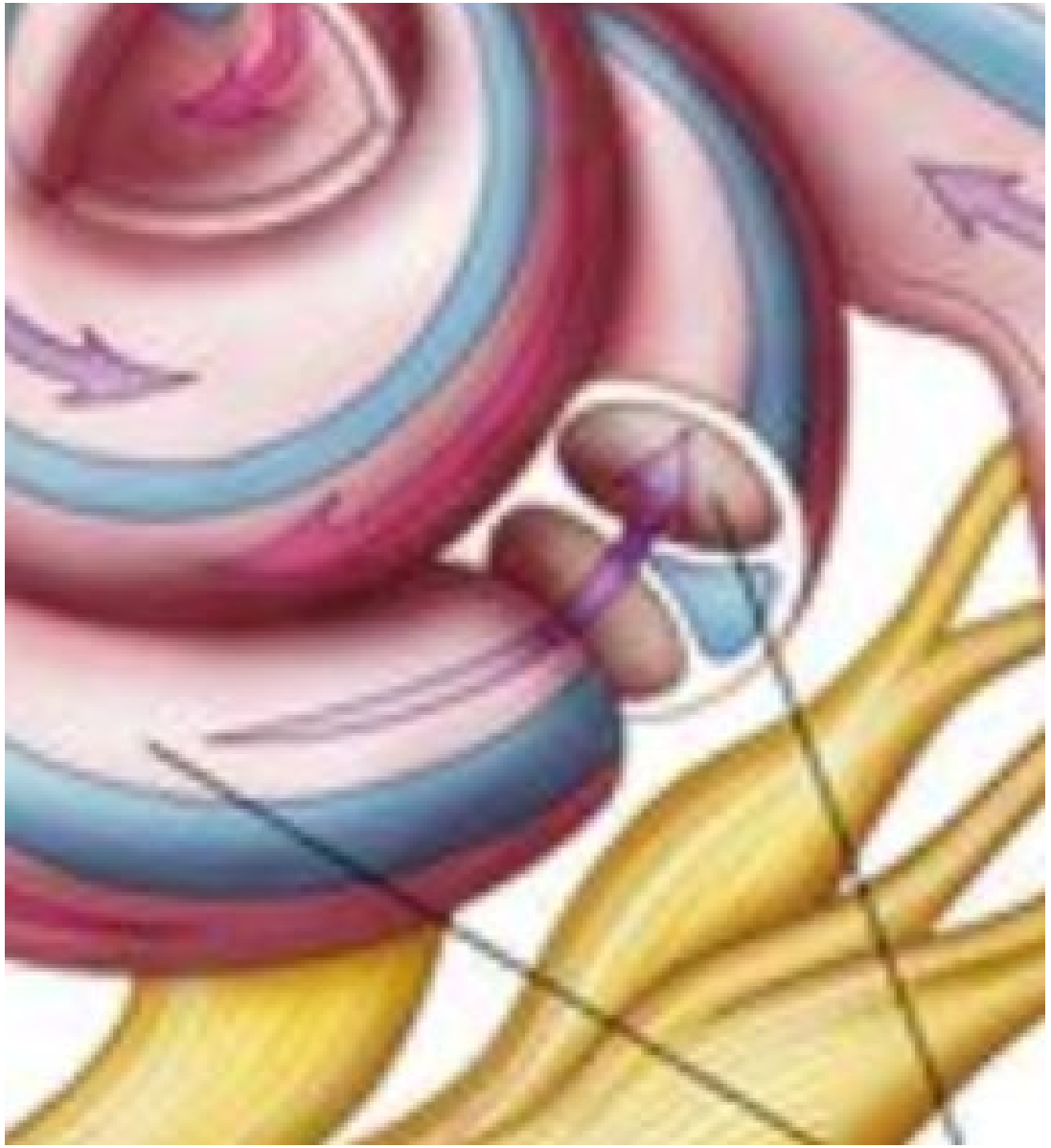


Felten, David L., Anil Narsinha Shetty, and David L. Felten. *Netter's Atlas of Neuroscience*. 2nd ed. Philadelphia, PA: Saunders/Elsevier, 2010. Print p336.



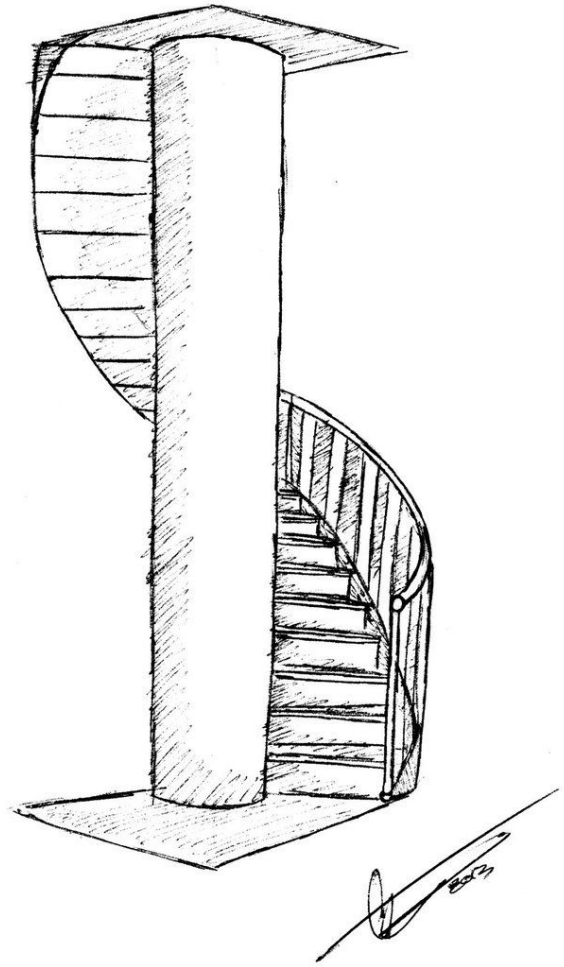
https://www.verywellhealth.com/what-is-a-perilymph-fistula-1191964

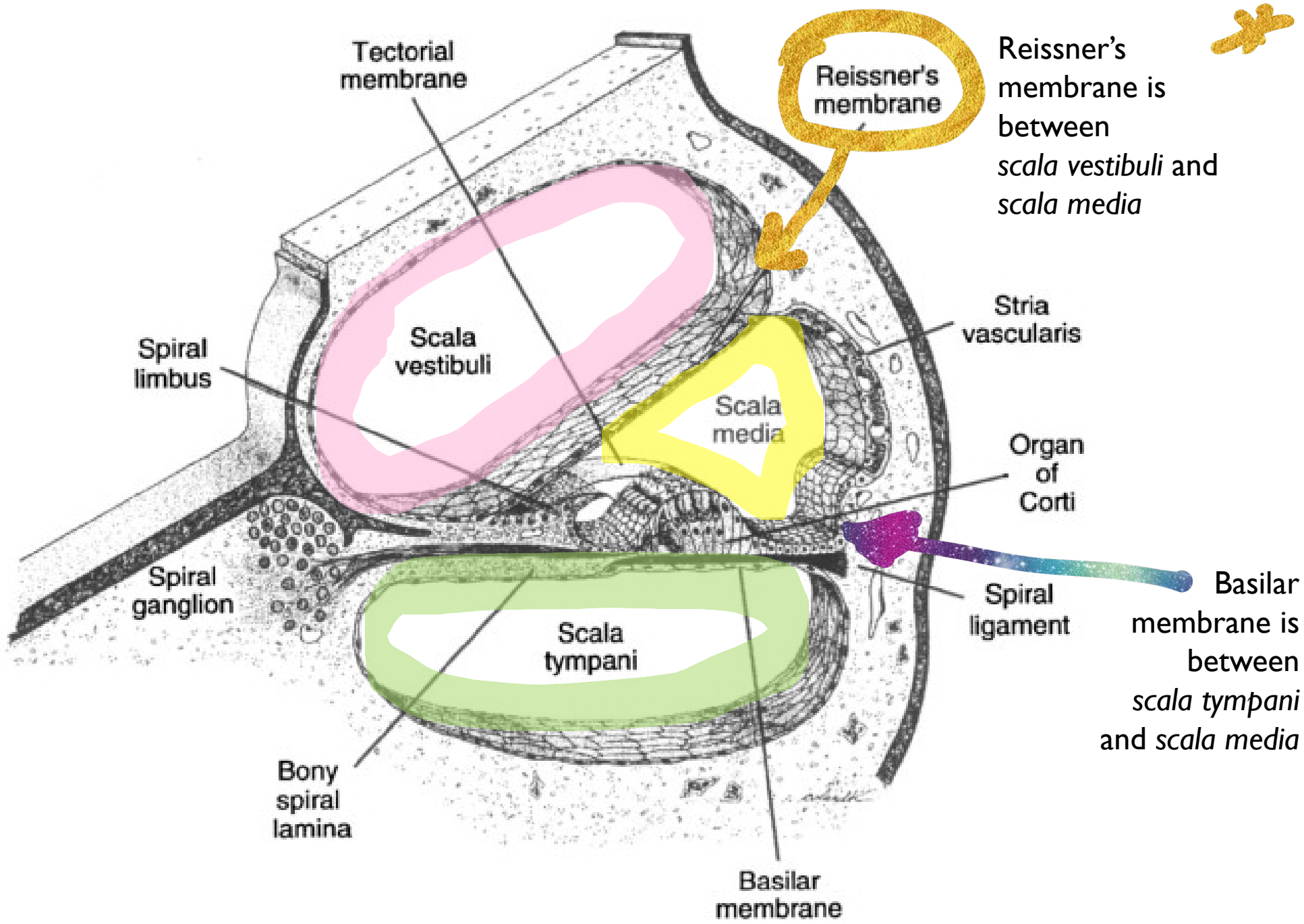
3 FLUID FILLED CHAMBERS



https://www.verywellhealth.com/what-is-a-perilymph-fistula-1191964

"scala" =
staircase
in Latin





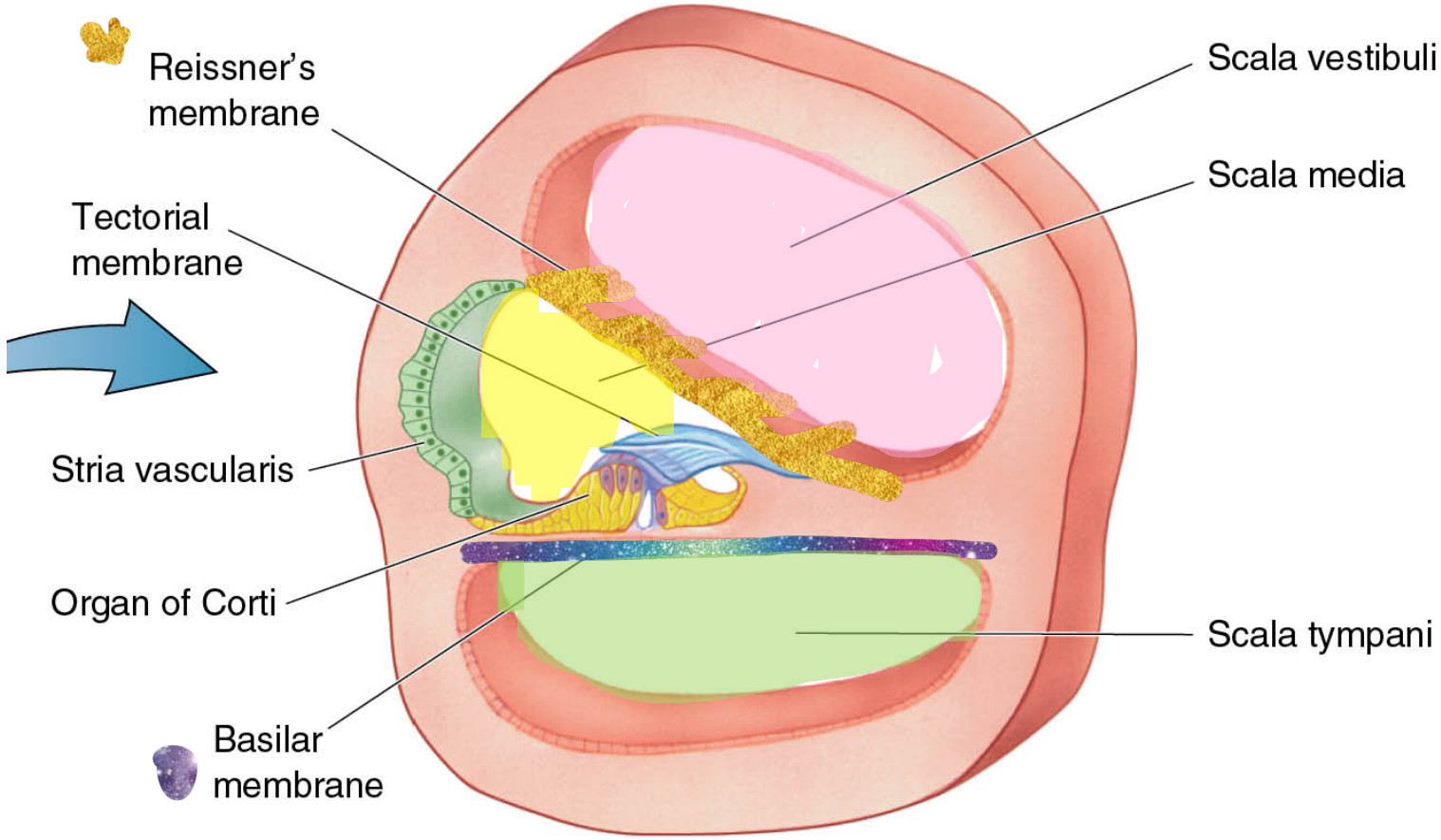
Reissner's membrane is between *scala vestibuli* and *scala media*

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

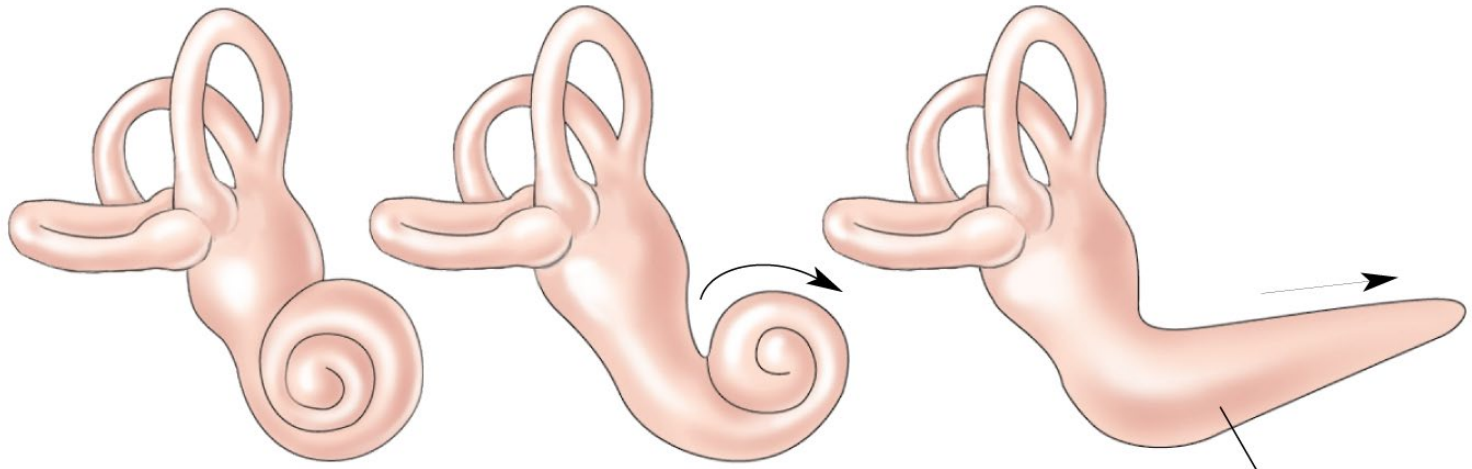
Felten, David L., Anil Narsinha Shetty, and David L. Felten. *Netter's Atlas of Neuroscience*. 2nd ed. Philadelphia, PA: Saunders/Elsevier, 2010. Print.

THE INNER EAR → SOUND TO NEURAL SIGNALS

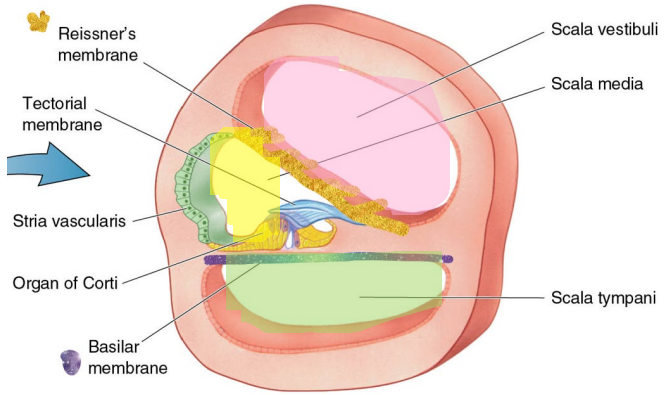
- Anatomy of the cochlea
- Perilymph: fluid in scala vestibuli and scala tympani
- Endolymph: fluid in scala media
- Endocochlear potential: endolymph electrical potential 80 mV more positive than perilymph

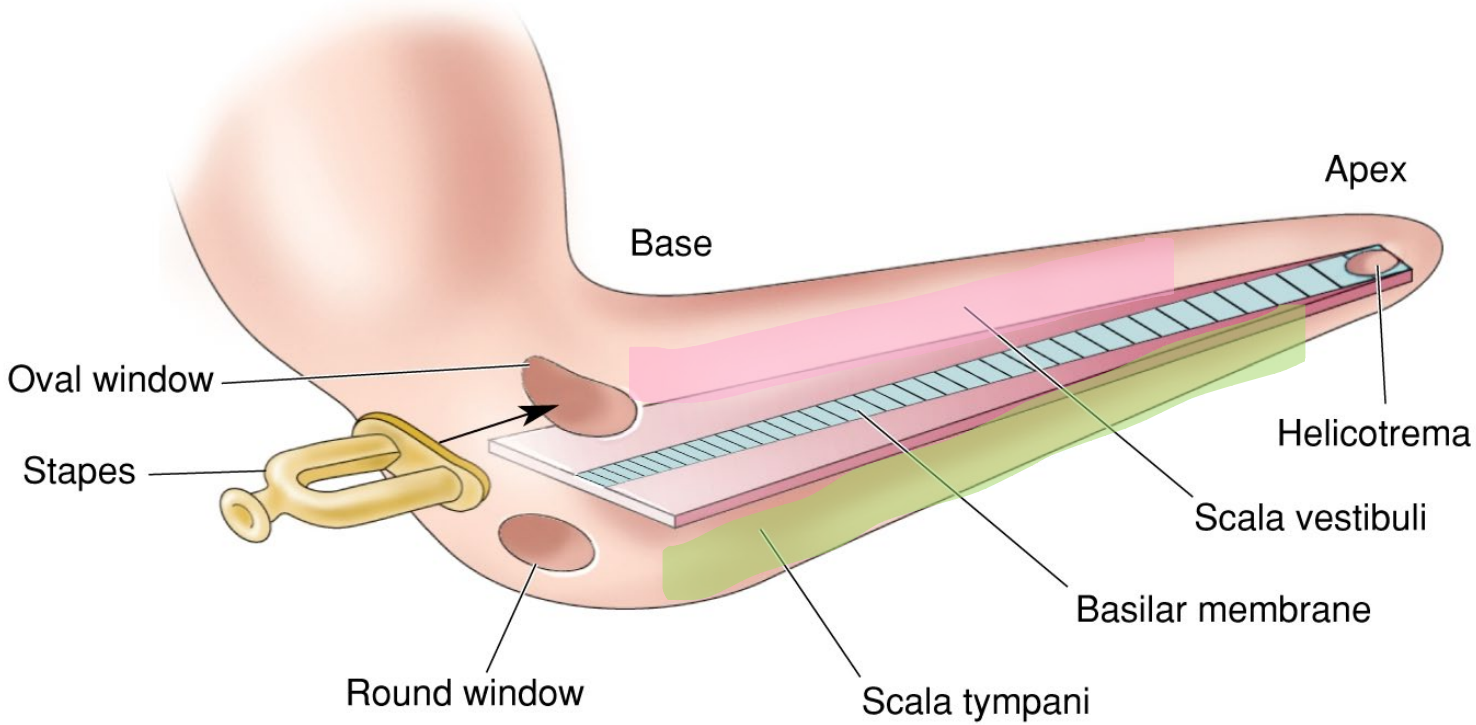


Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.



The cochlea narrows from base to apex





The basilar membrane WIDENS towards the apex.

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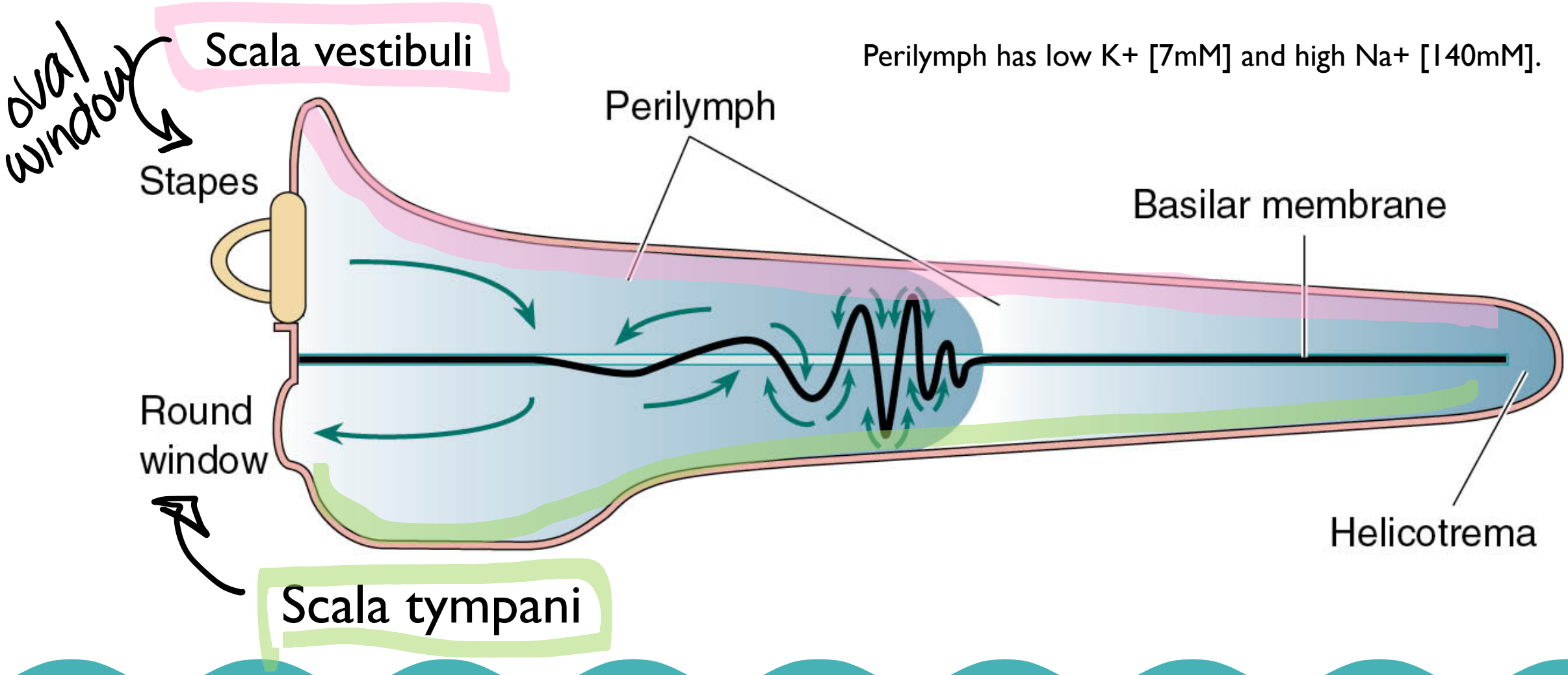
Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.

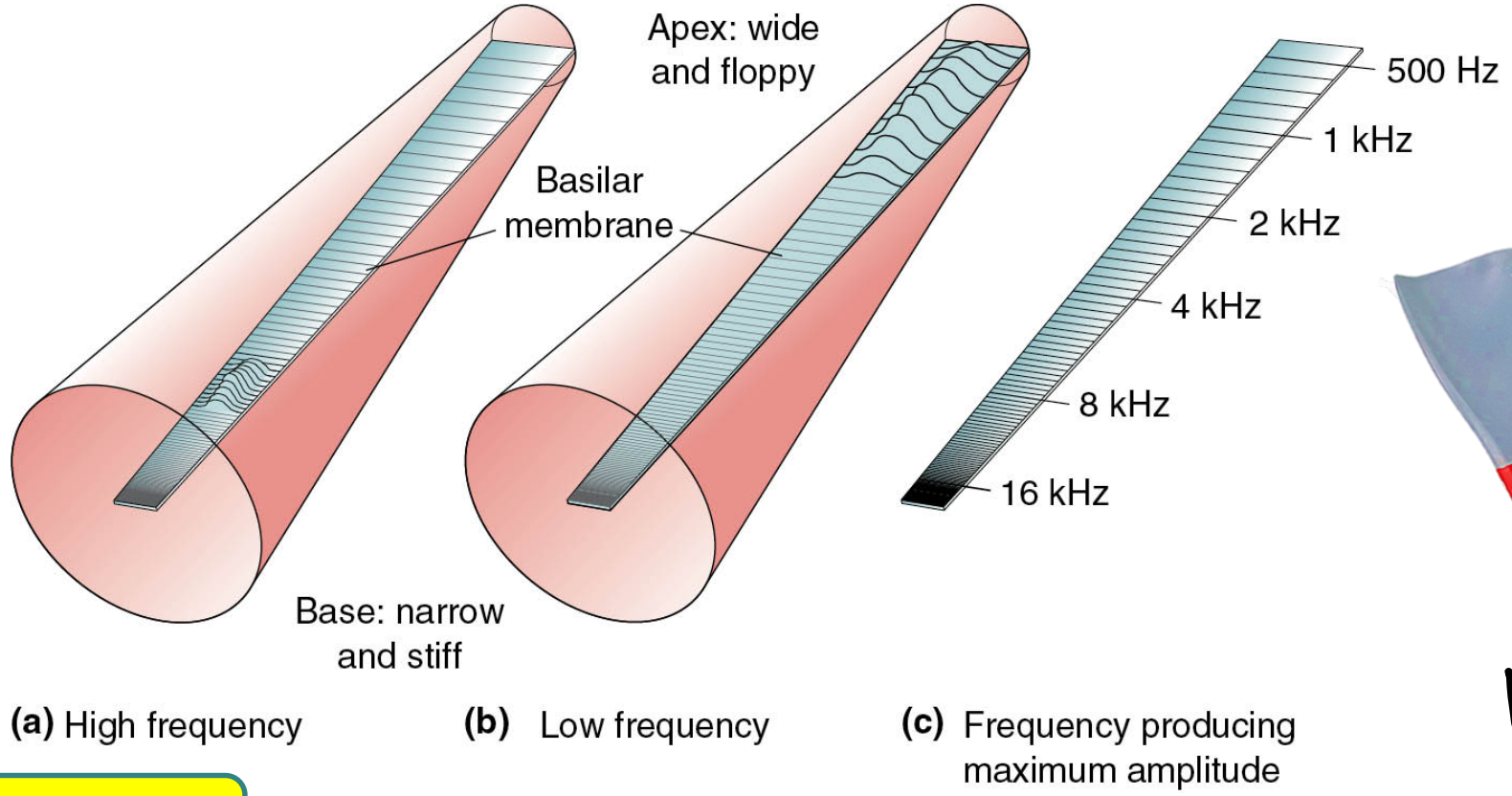
Perilymph has low K+ [7mM] and high Na+ [140mM].

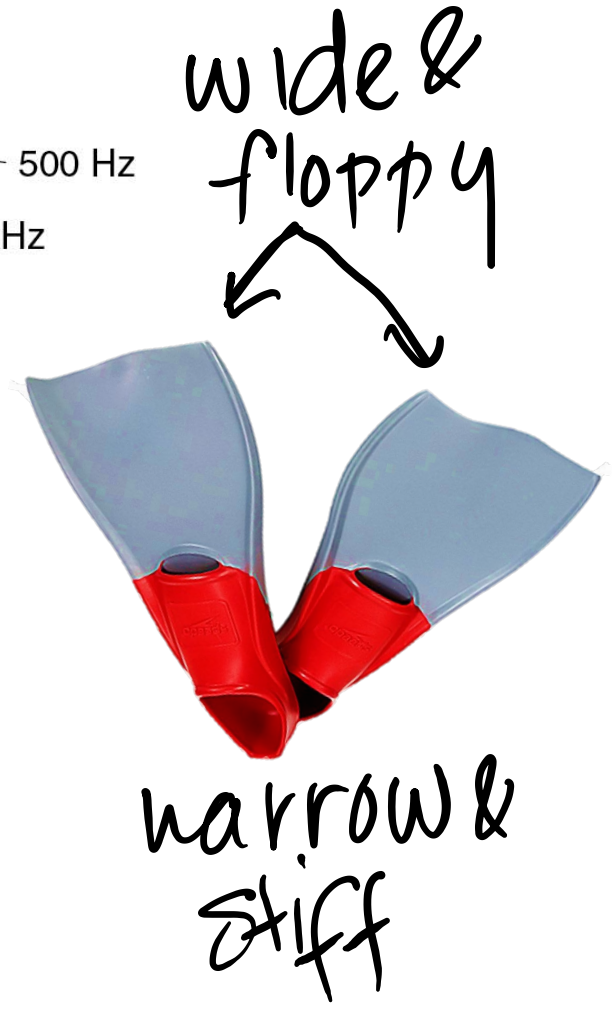


TRAVELING WAVE IN THE BASILAR MEMBRANE

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.



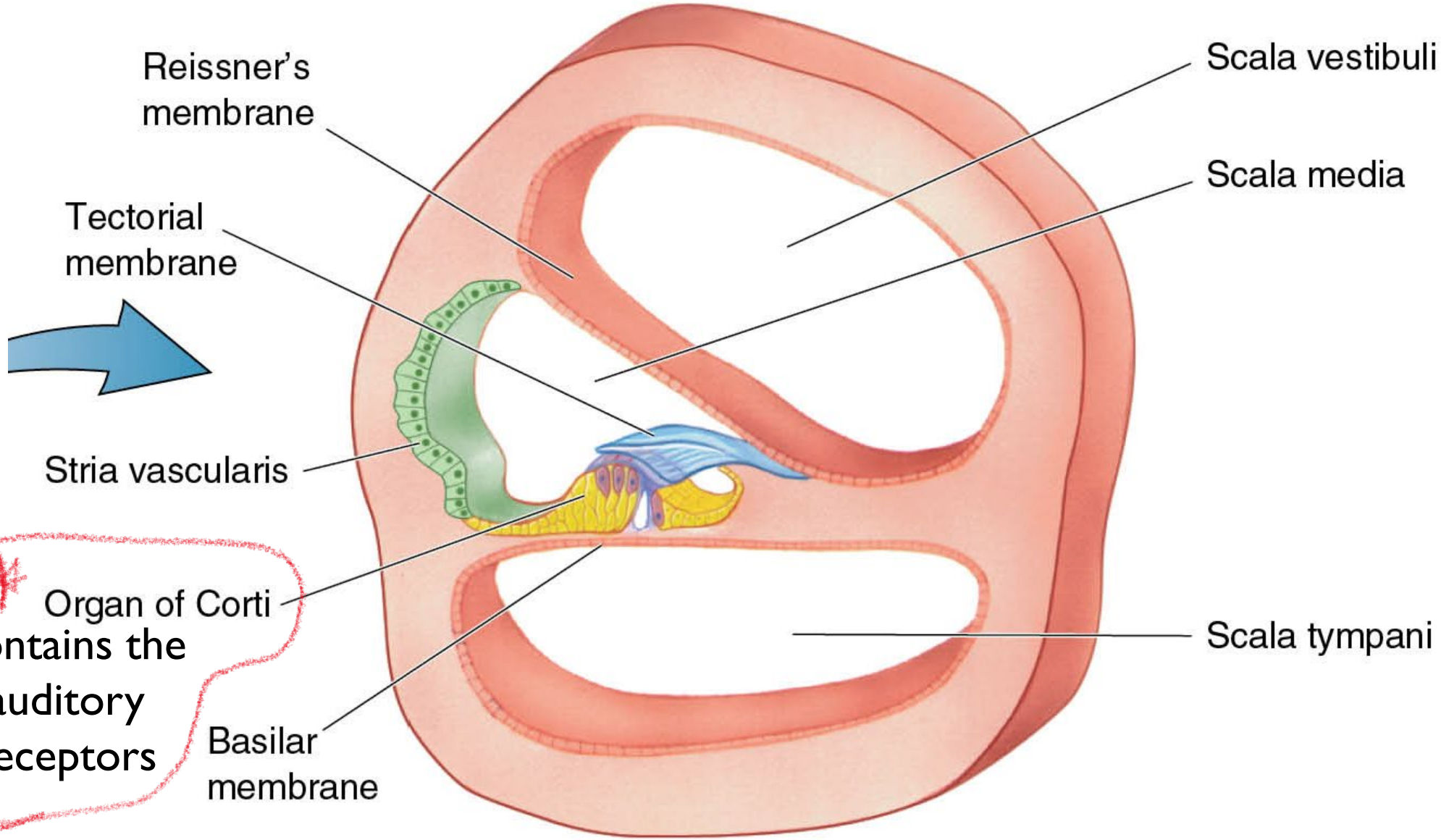


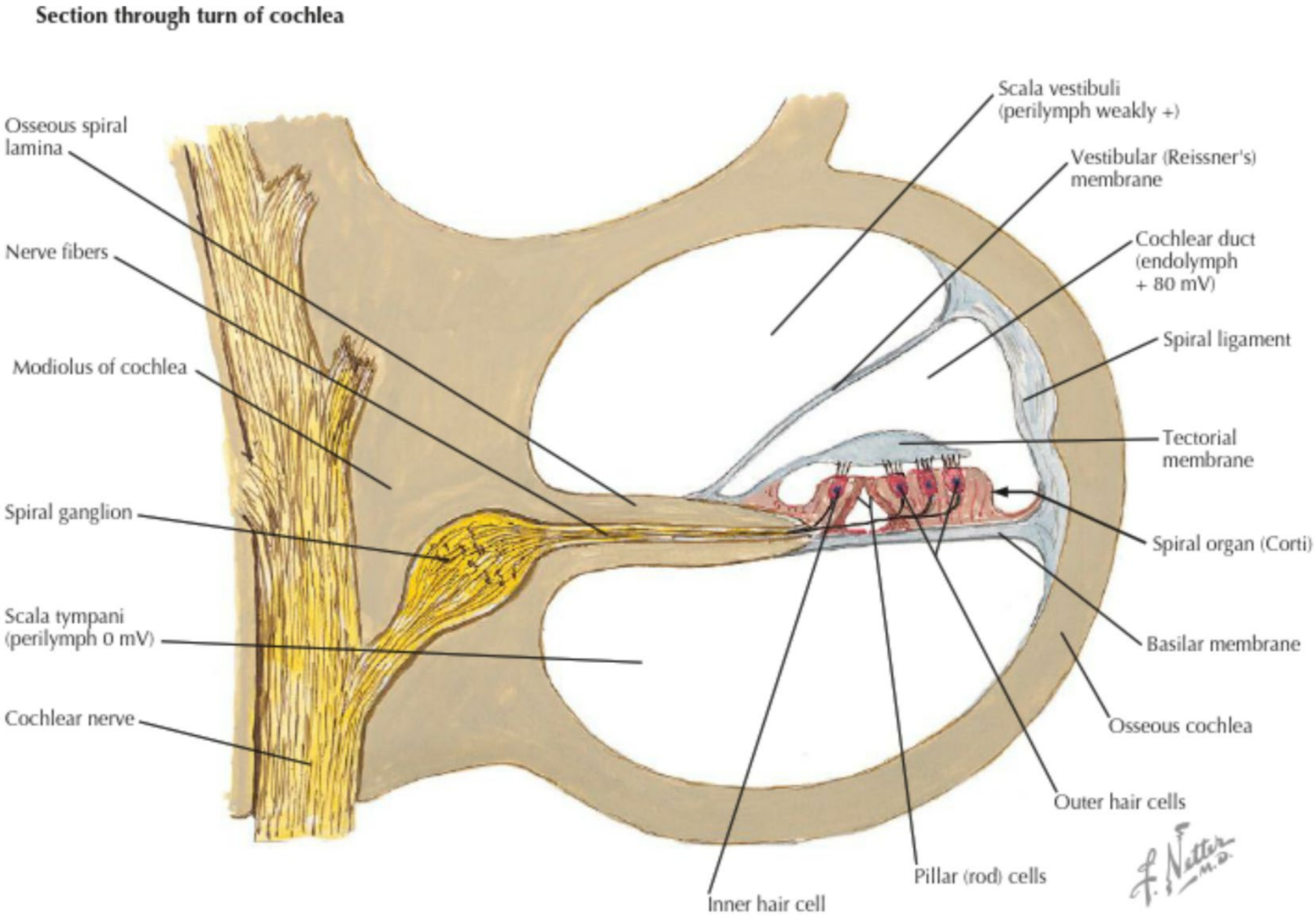
PLACE CODING

RESPONSE OF BASILAR MEMBRANE TO SOUND

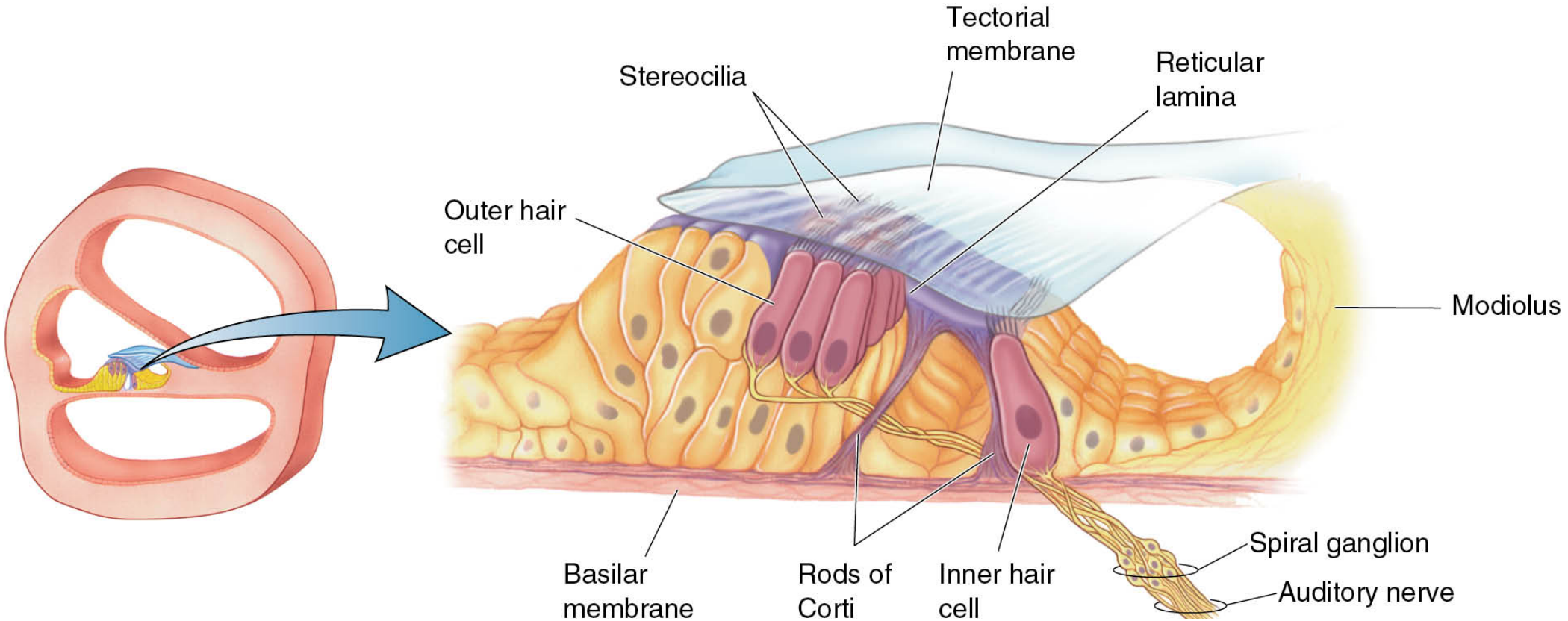
Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.

The organ of Corti – auditory receptors



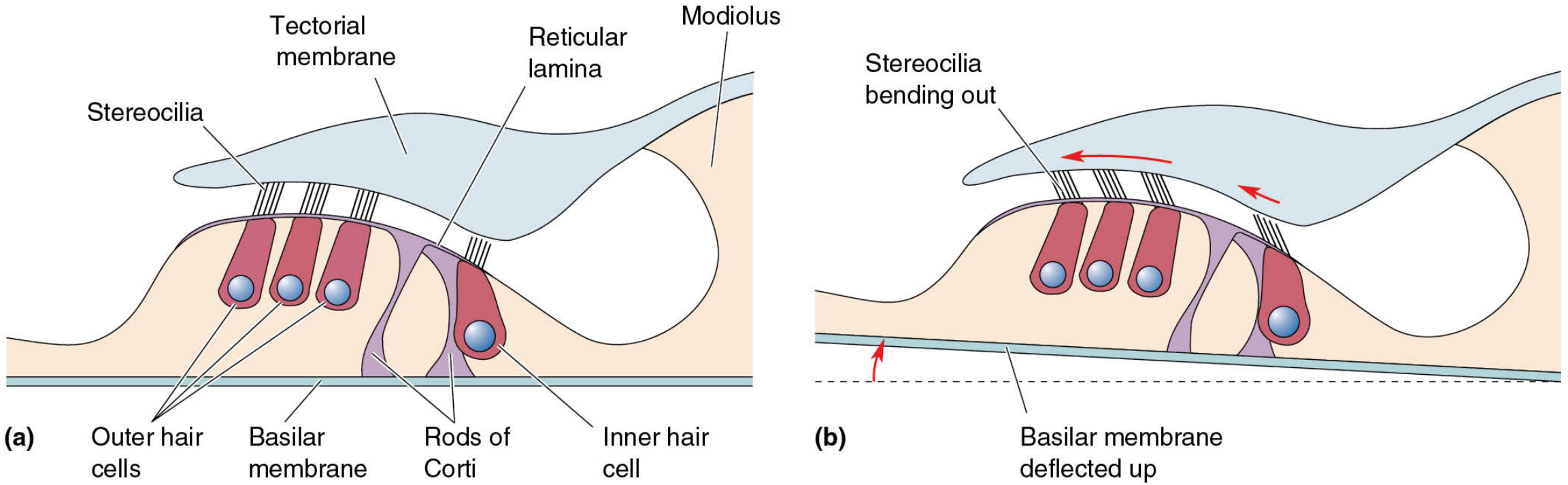


Felten, David L., Anil Narsinha Shetty, and David L. Felten. *Netter's Atlas of Neuroscience*. 2nd ed. Philadelphia, PA: Saunders/Elsevier, 2010. Print.



THE ORGAN OF CORTI AND ASSOCIATED STRUCTURES

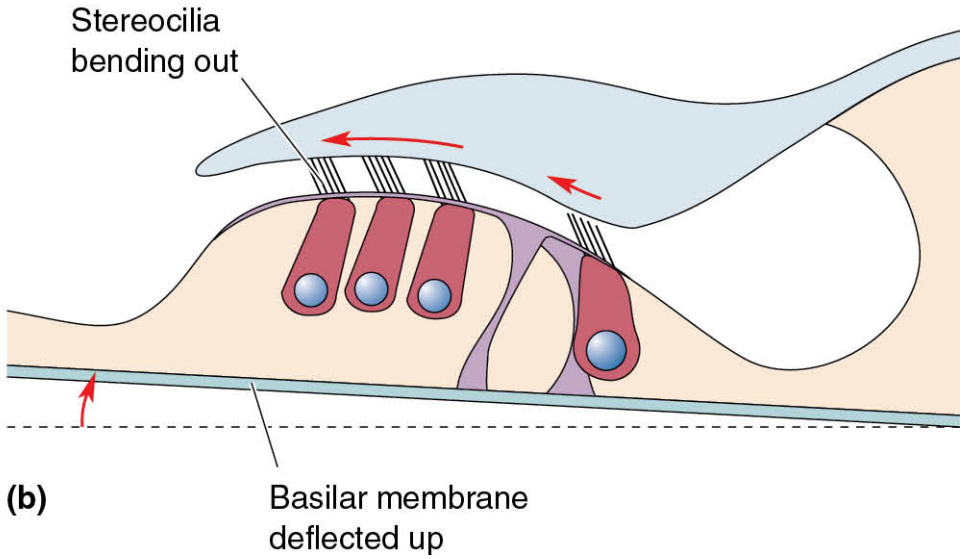
Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience : Exploring the Brain*. China: Wolters Kluwer, 2016. Print.

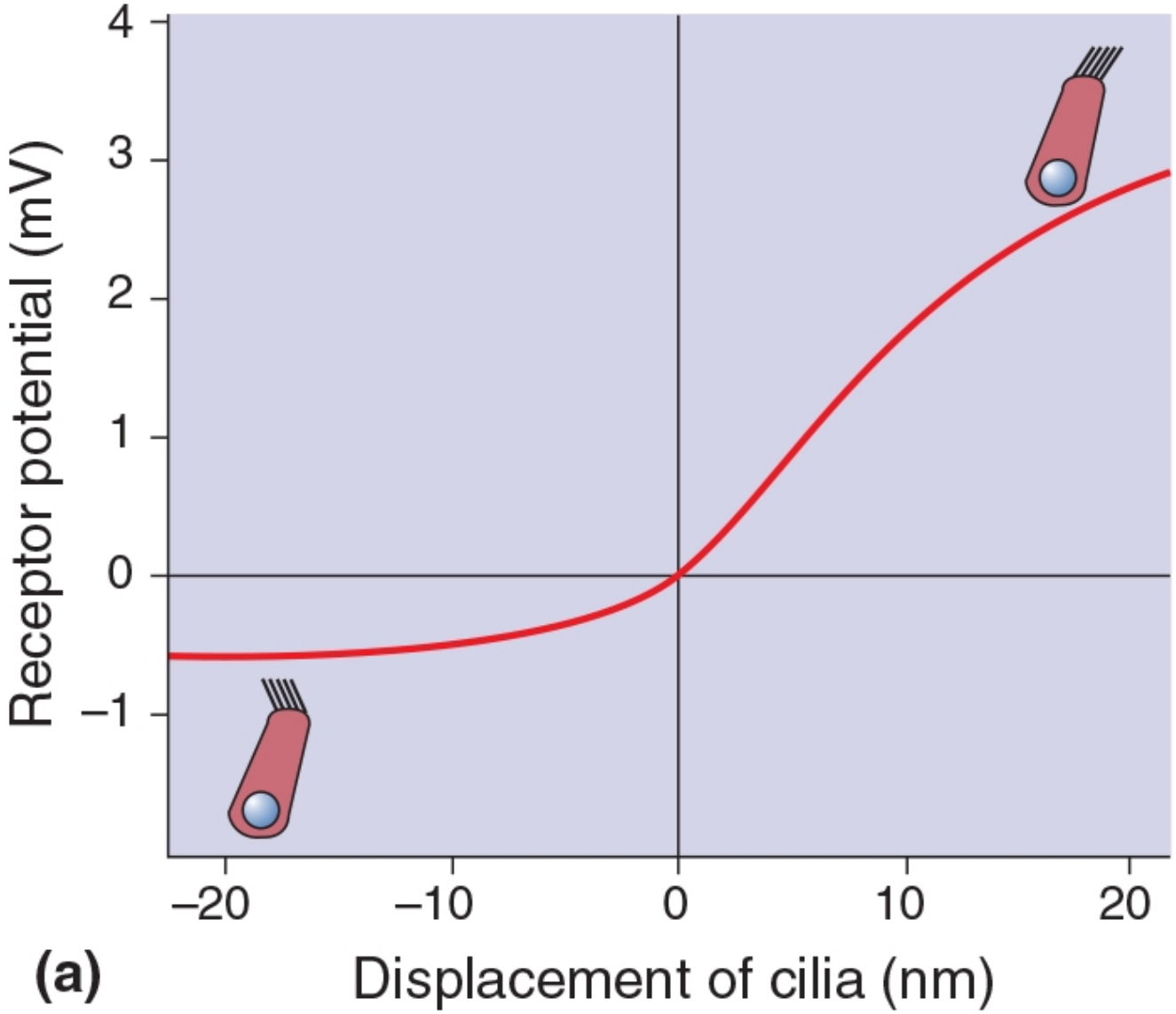


THE BENDING OF STEREOCILIA

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

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





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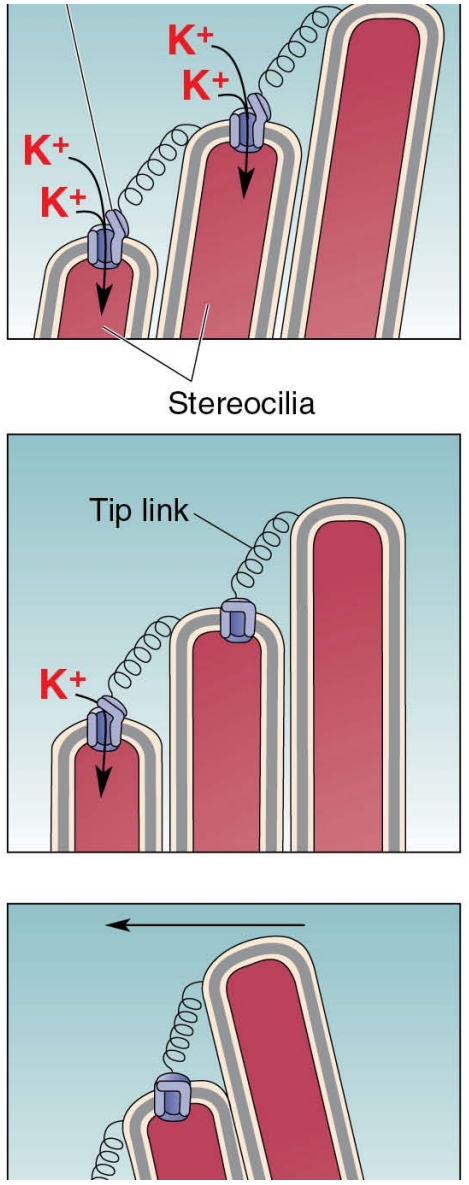
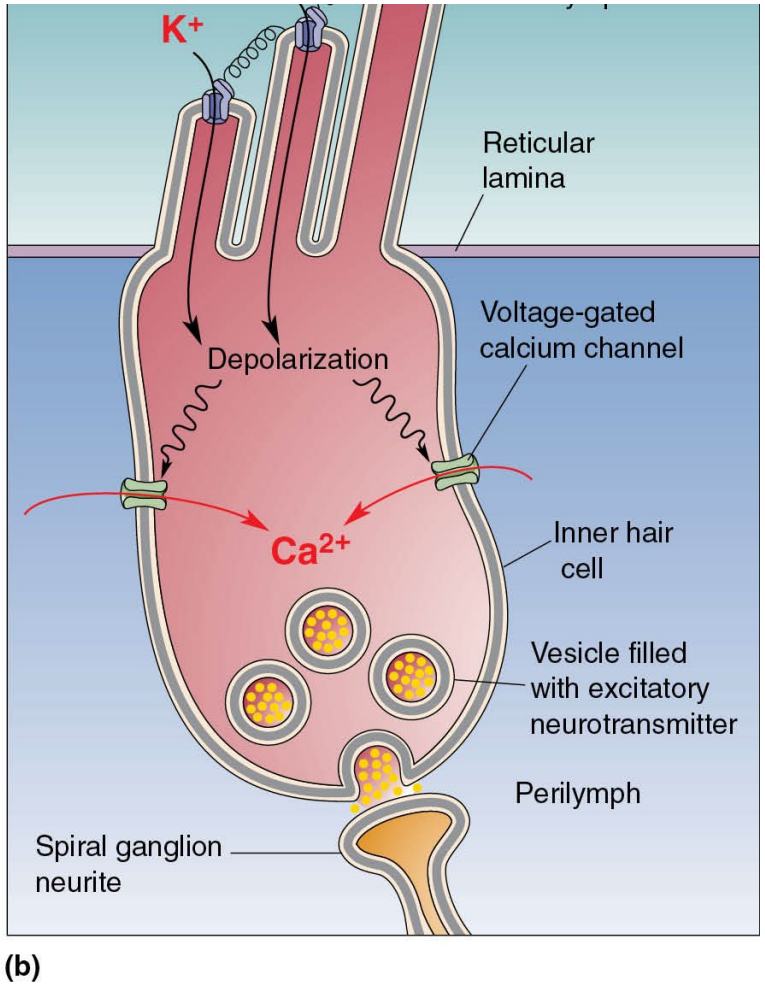
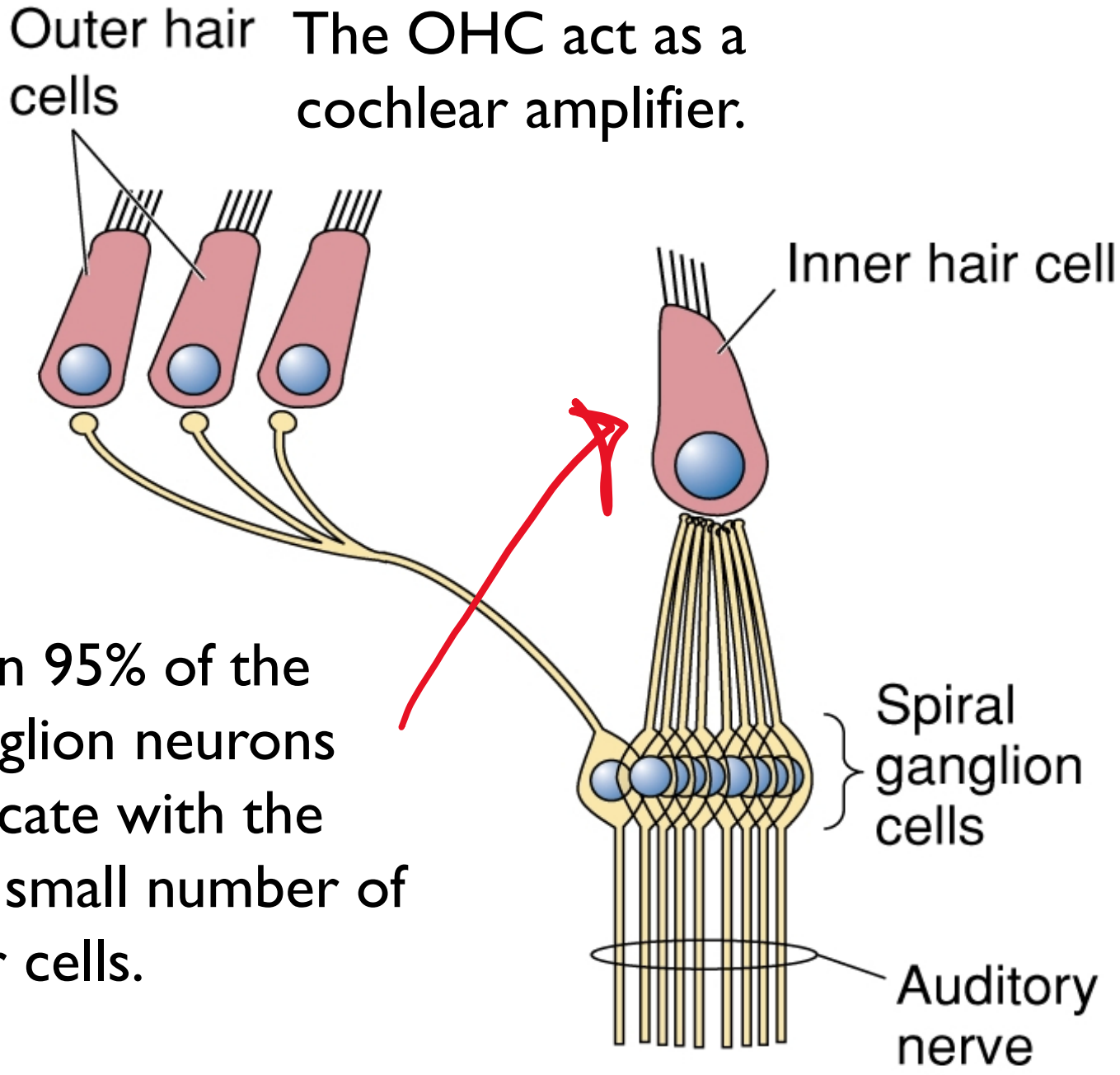
TRANSDUCTION BY HAIR CELLS

- 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.

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

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

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