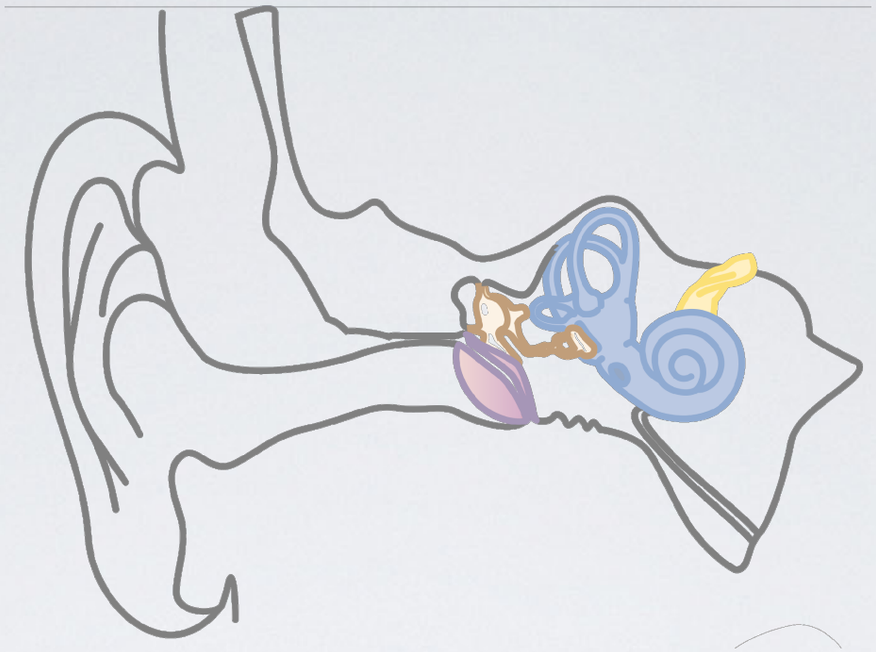


CODING OF ACOUSTIC STIMULI

TONOTOPIC REPRESENTATION

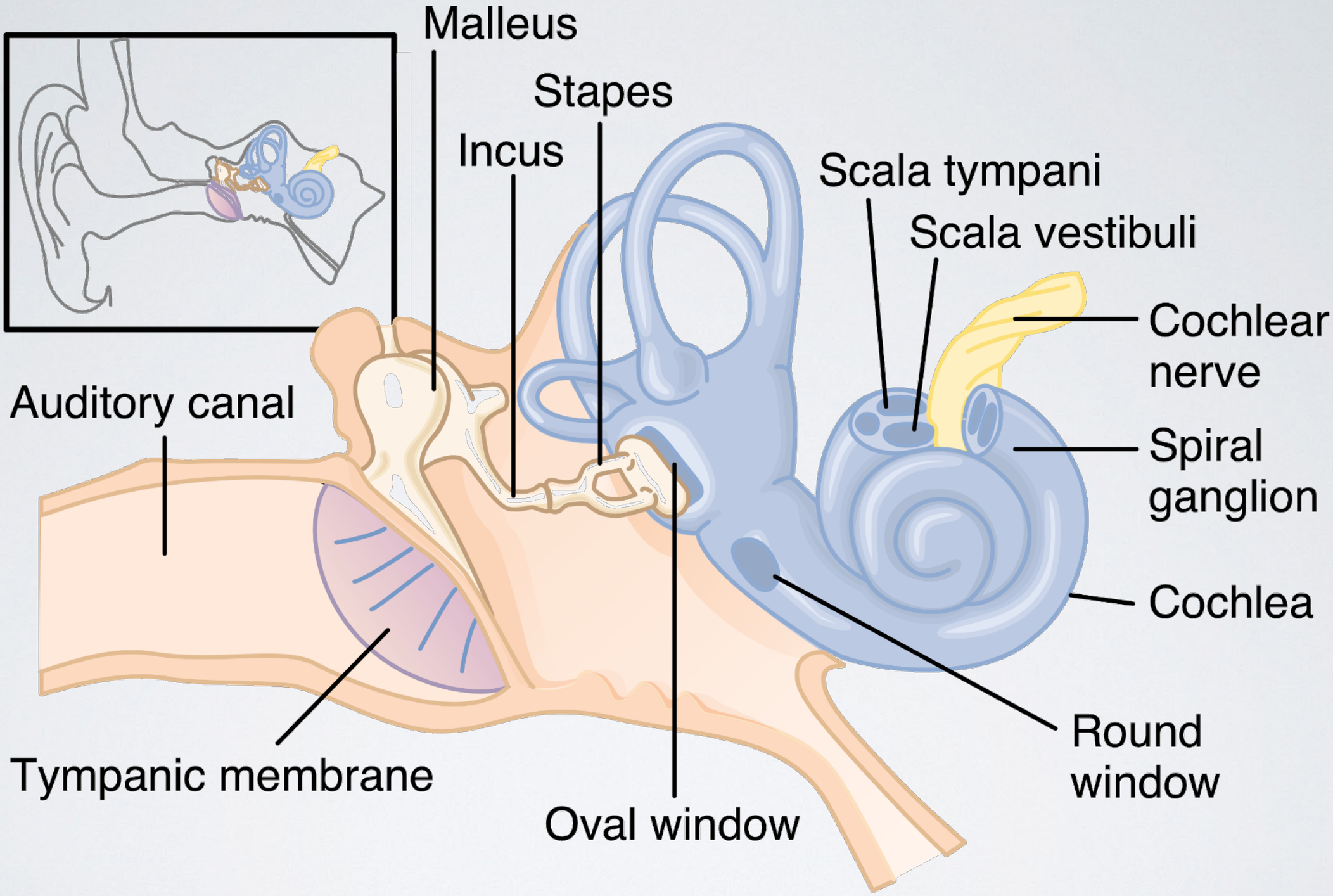
by Florian Scholz

Seminar Physiology

31.03.2016

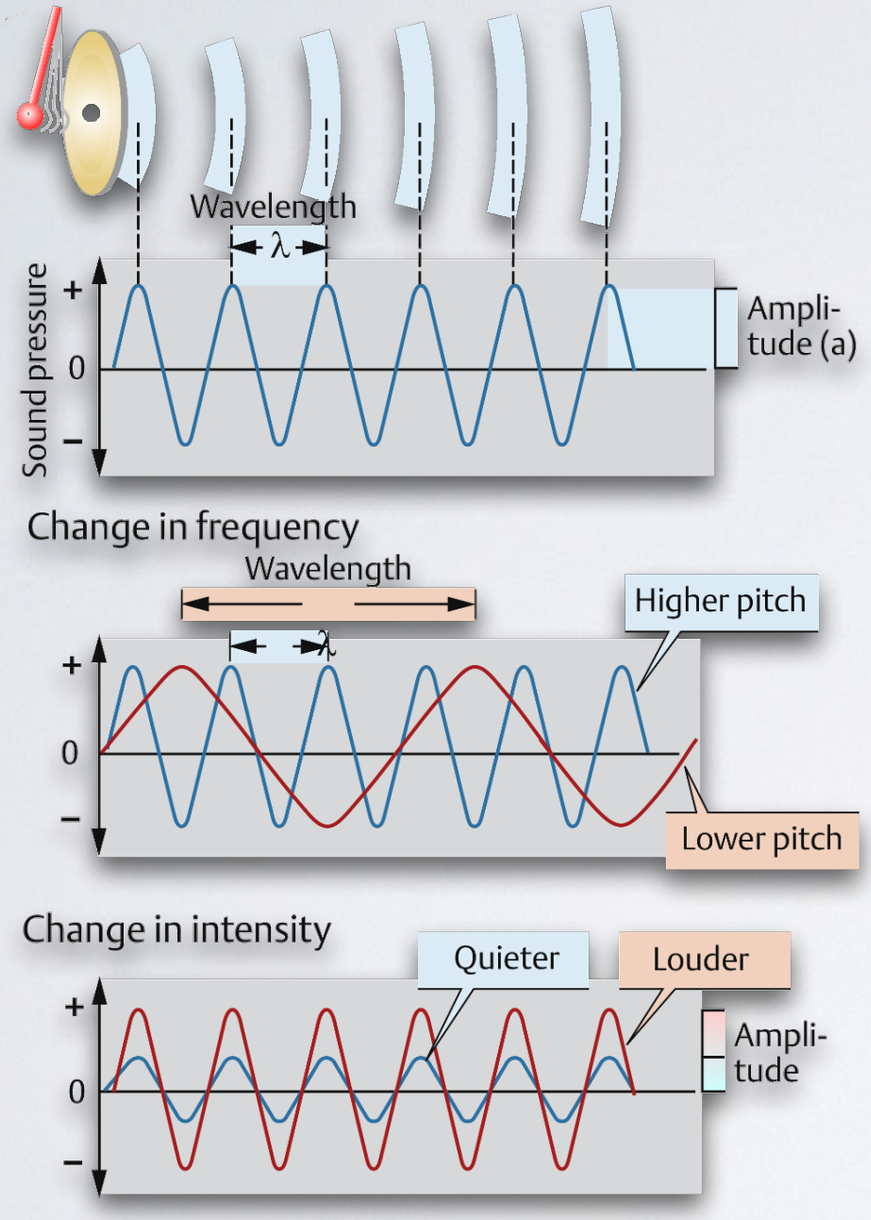
Picture Source: TEXTBOOK OF MEDICAL PHYSIOLOGY, 11th edition, Arthur C. Guyton, John E. Hall, ISBN 0-7216-f-1, Elsevier 2006

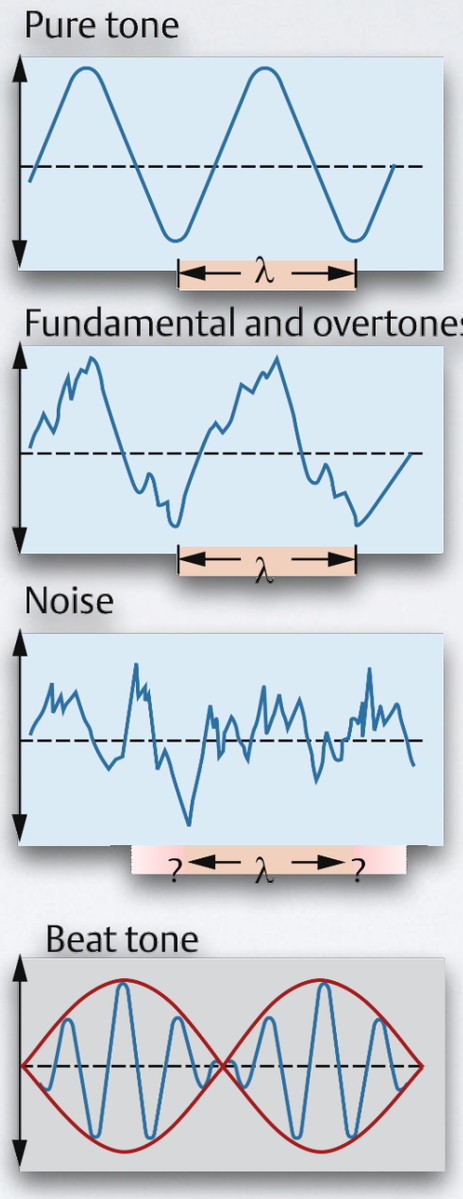
„Tonotopy | Mapping of partial frequencies of a sound event at particular areas of the cochlea + Mapping of frequency perception at particular areas of the cerebral cortex.“



Picture Source: TEXTBOOK OF MEDICAL PHYSIOLOGY, 11th edition, Arthur C. Guyton, John E. Hall, ISBN 0-7216-f-1, Elsevier 2006

SOUND WAVES - STIMULUS FOR HEARING

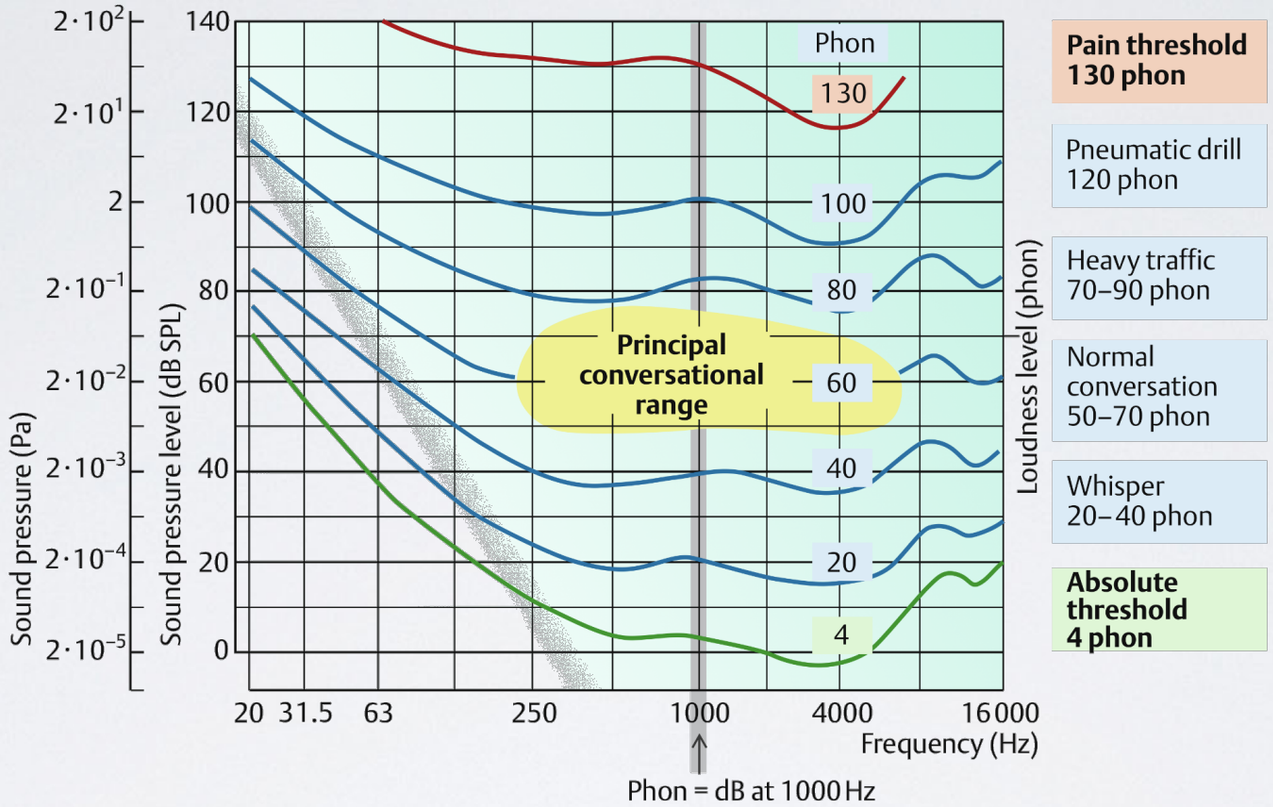




- Sound pressure | local deviation from ambient pressure caused by sound wave (pascal)
- Frequency | number of sound pressure oscillations per unit time | frequency directly related to wavelength | pitch (Hz)
- Wavelength | long - low tone, short - high tone
- Sound intensity | (watt/m2), sound pressure and particle velocity (watt/m^2)| amplitude

Picture source: Color Atlas of Physiology 6th edition, Stefan Silbernagl, MD, Agamemnon Despopoulos, MD, 189 color plates by Ruediger Gay and Astried Rothenburger, Thieme 2003, ISBN 978-3-13-545006-3

HUMAN AUDITORY FIELD



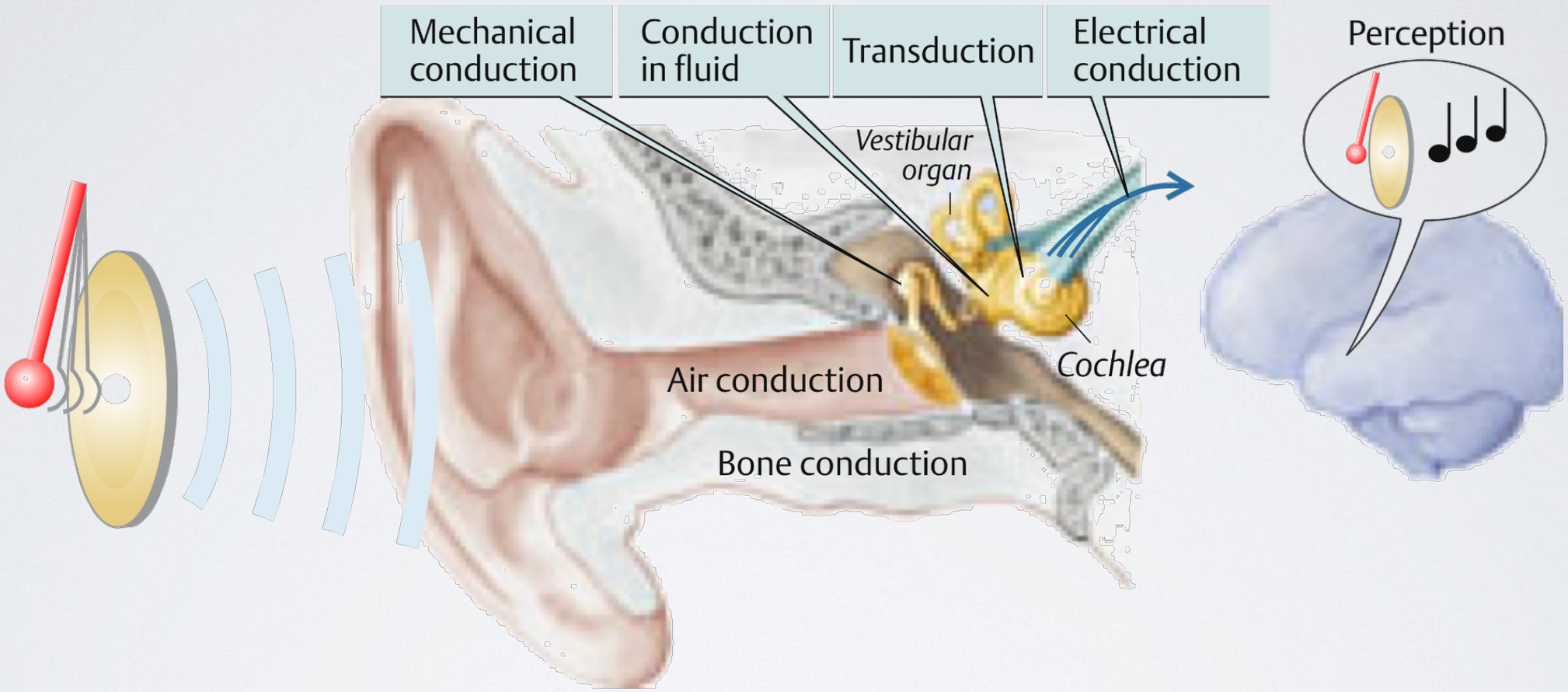
- Sound pressure level (dB)| effective pressure of a sound relative to a reference value, used to simplify deviations in
- 10x Increase in sound pressure = rise in SPL of 20 dB
- 10x difference in SP perceived as twice as loud

- Loudness (phon)| subjective measure, SPL + duration
- 16-20000 Hz audible frequency | lowest sound pressure at 1000 Hz 3x10^-5
- 120-140 dB threshold for painful sound intensity, dependant on frequency

Picture source: Color Atlas of Physiology 6th edition, Stefan Silbernagl, MD, Agamemnon Despopoulos, MD, 189 color plates by Ruediger Gay and Astried Rothenburger, Thieme 2003, ISBN 978-3-13-545006-3

HEARING

mechanoelectric transduction of sound signal

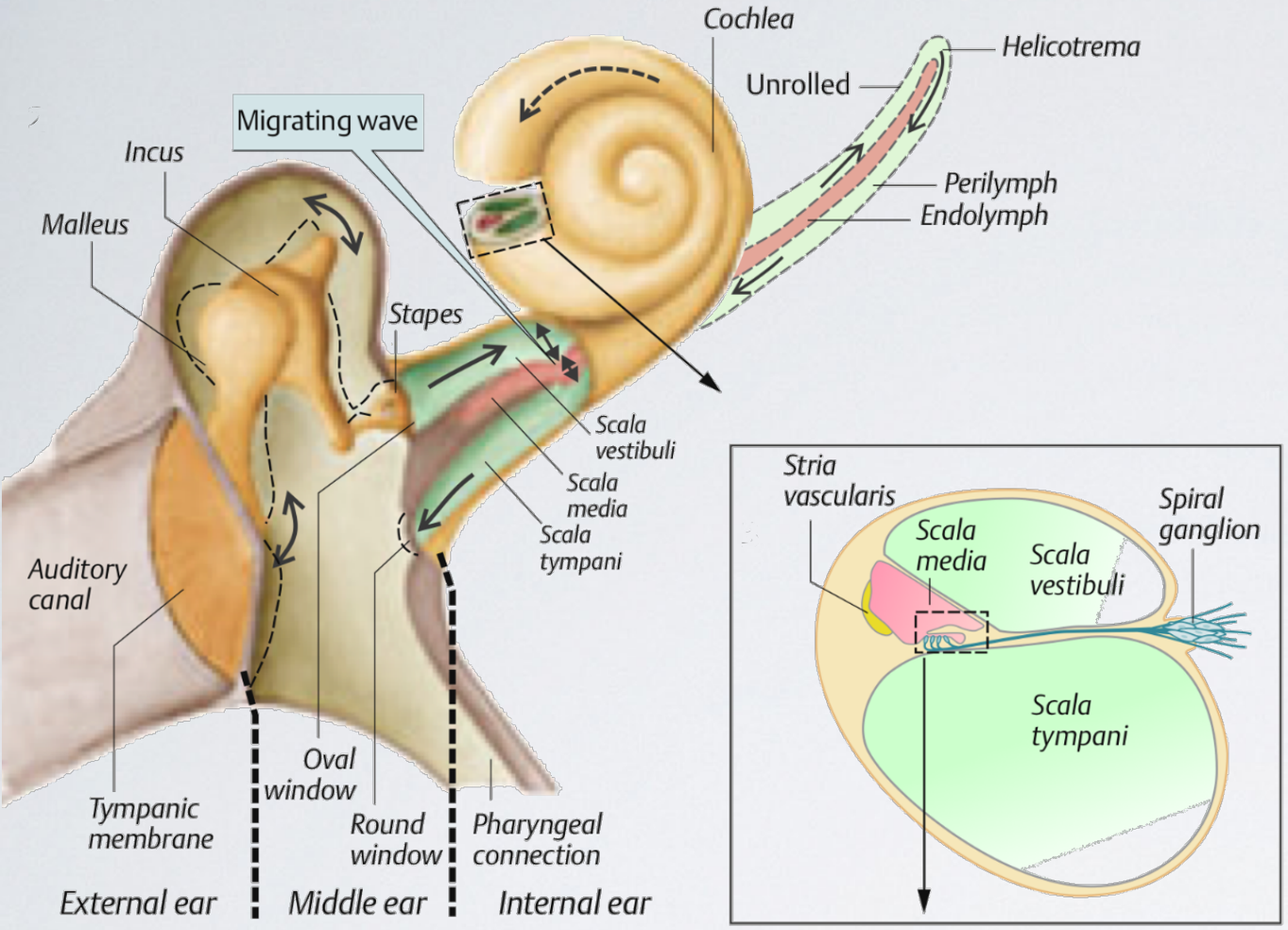


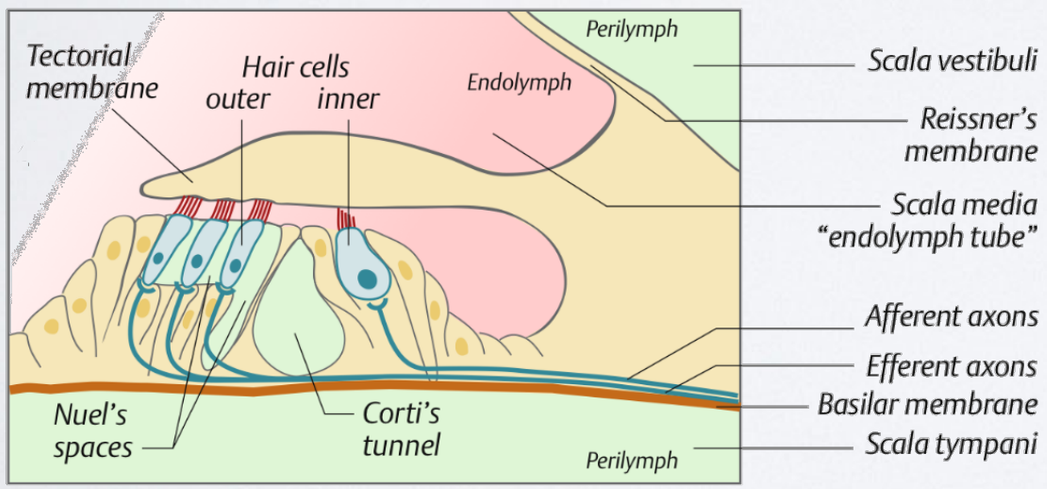
Impedance Matching | 22x pressure amplification

Attenuation | decreased intensity, protection, masking, sensitivity

Picture source: Color Atlas of Physiology 6th edition, Stefan Silbernagl, MD, Agamemnon Despopoulos, MD, 189 color plates by Ruediger Gay and Astried Rothenburger, Thieme 2003, ISBN 978-3-13-545006-3

CONDUCTION OF SOUND WAVE





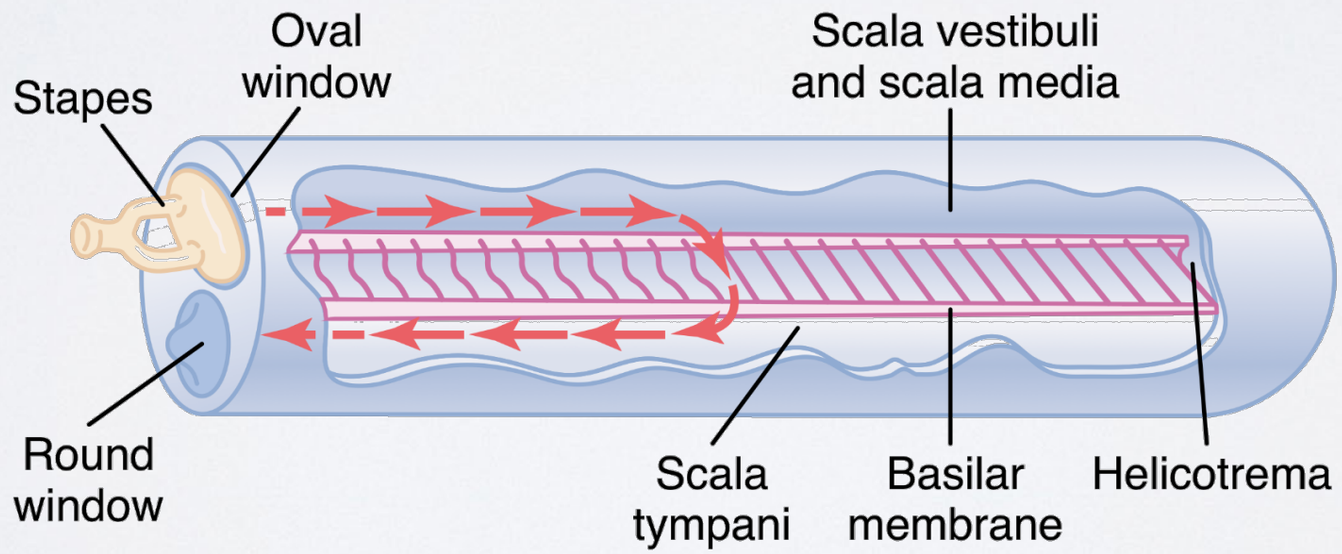
- Perilymph + Endolymph
- Movement of perilymph
  forward: stapes in

  backward: stapes out
- Basilar membrane
- Organ of Corti
- Decrease intensity of travelling wave

Picture source: Color Atlas of Physiology 6th edition, Stefan Silbernagl, MD, Agamemnon Despopoulos, MD, 189 color plates by Ruediger Gay and Astried Rothenburger, Thieme 2003, ISBN 978-3-13-545006-3

BASILAR MEMBRANE + RESONANCE

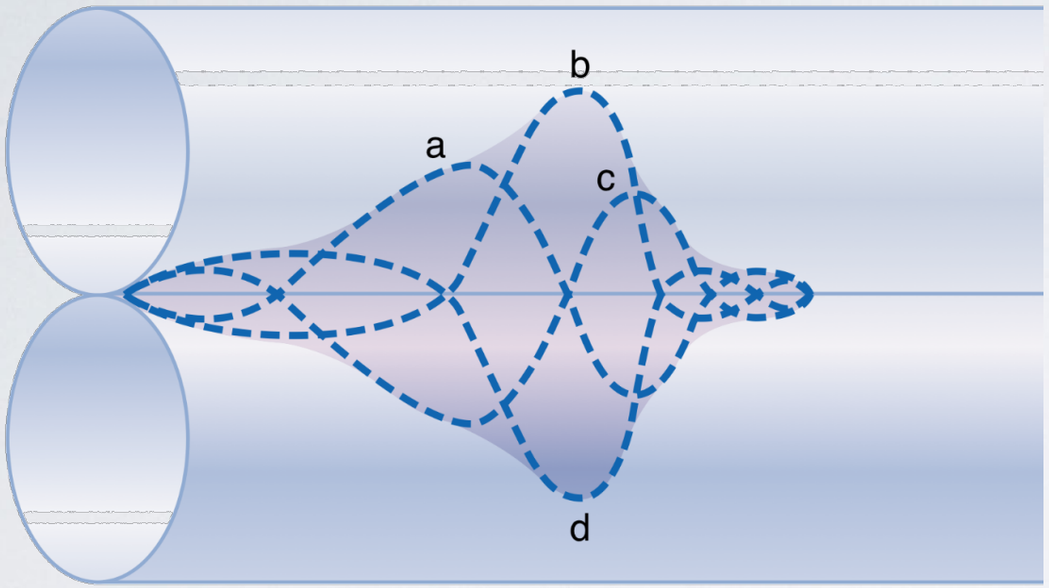
- Basilar Fibers | 20-30000, stiff, elastic, fixed to modiolus, other end free
- Length | increase from oval window to helicotrema
- Diameters | decrease from oval window to helicotrema
- high frequency resonance | at base
- Low frequency resonance | near helicotrema

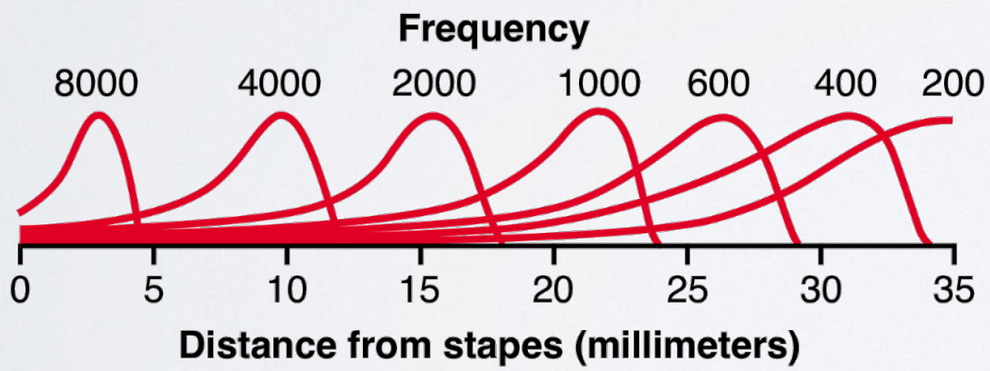


- Sound wave enters | basilar membrane bends towards helicotrema

Picture Source: TEXTBOOK OF MEDICAL PHYSIOLOGY, 11th edition, Arthur C. Guyton, John E. Hall, ISBN 0-7216-f-1, Elsevier 2006

RESONANT POINT





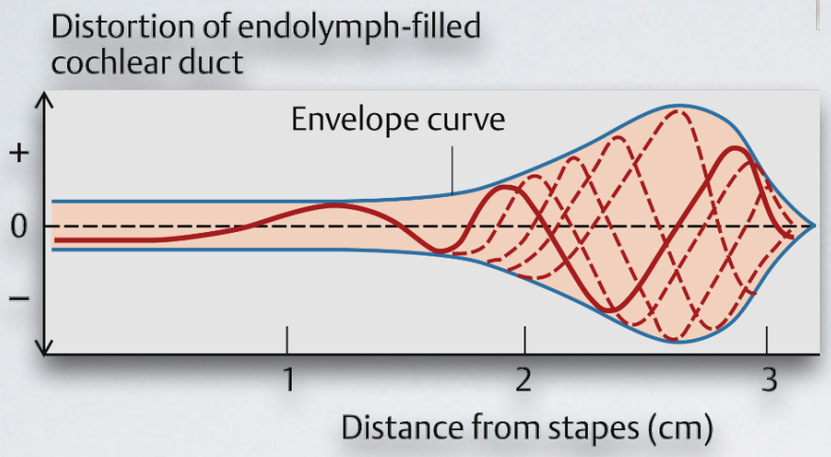
- Amplitude pattern of basilar Membrane | extend of Vibration of basilar Membrane During whole Vibration cycle for a certain frequency

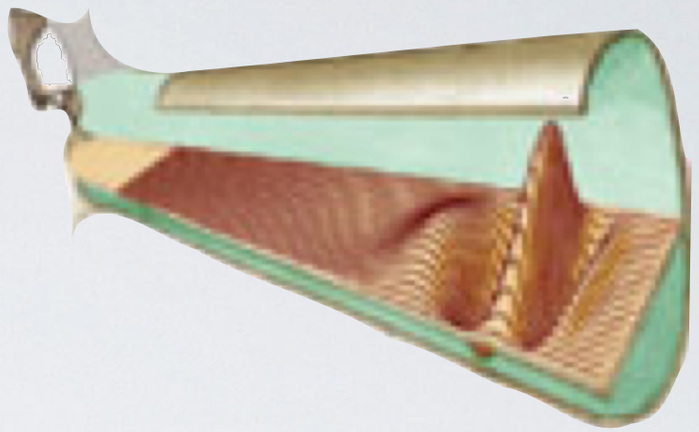
- Initial fast wave | high frequencies can separate

- Initial weak wave | becomes strong at portion with natural resonance frequency equal to respective sound frequency

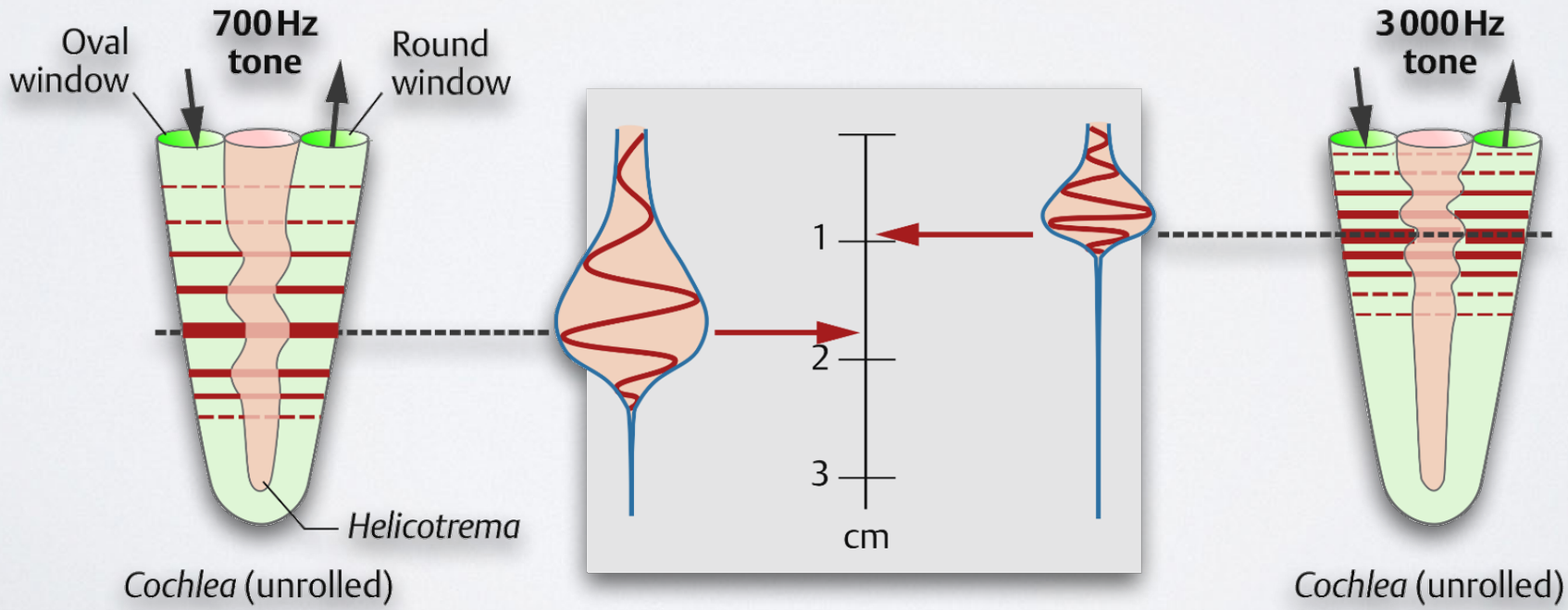
- After Resonant Point | wave Quickly dies - easy vibration takes up energy

Picture Source: TEXTBOOK OF MEDICAL PHYSIOLOGY, 11th edition, Arthur C. Guyton, John E. Hall, ISBN 0-7216-f-1, Elsevier 2006





- Place of Max. Amplitude of Stimulation | discrimination of frequencies
- Tonotopic Organisation
- Volley frequency principle | distal end stimulation by all frequencies below 100Hz, distinguished in cochlear nuclei



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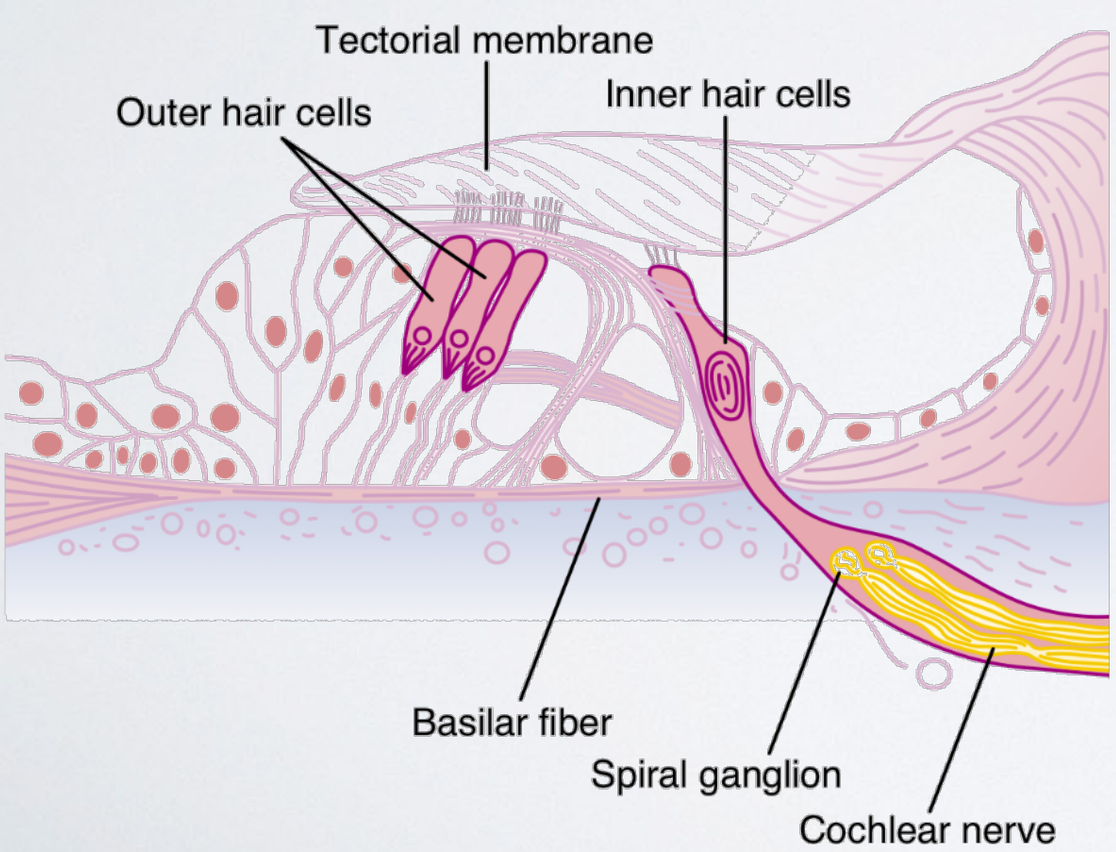
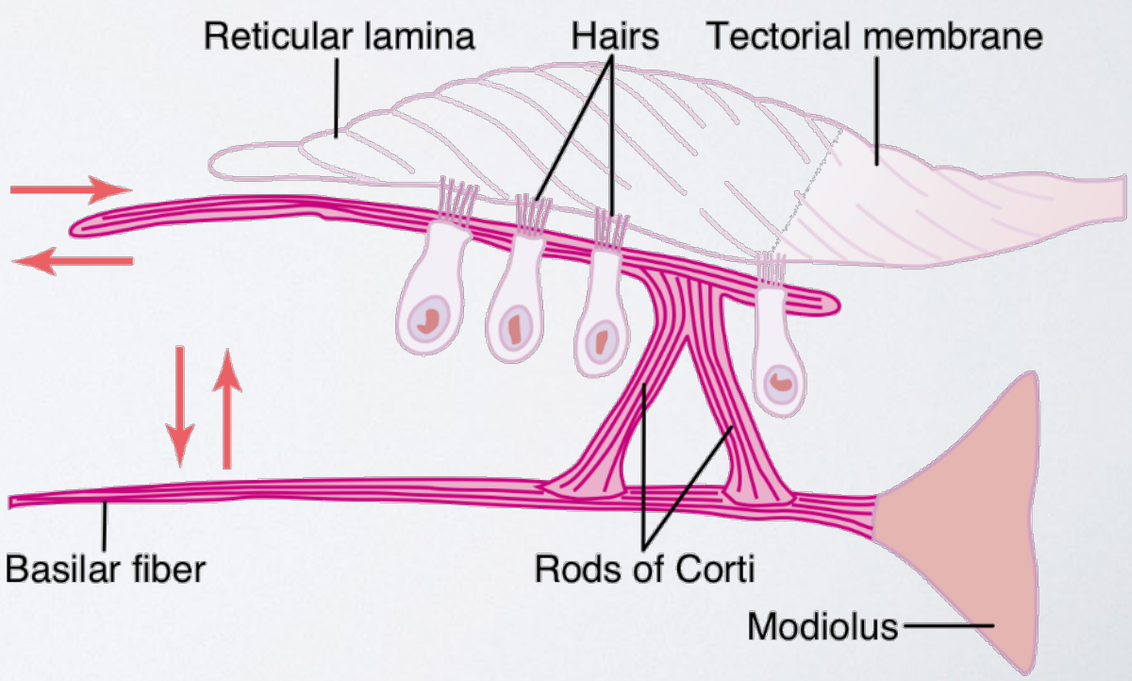
ORGAN OF CORTI FUNCTION

- Generation of nerve Impulses | in response to basilar Membrane Vibration
- Inner hair Cells | 90-95% of nerve endings | Type I fibers | Sound perception
- Outer hair Cells | 3x as many | Type 2 fibers | "tuning" function





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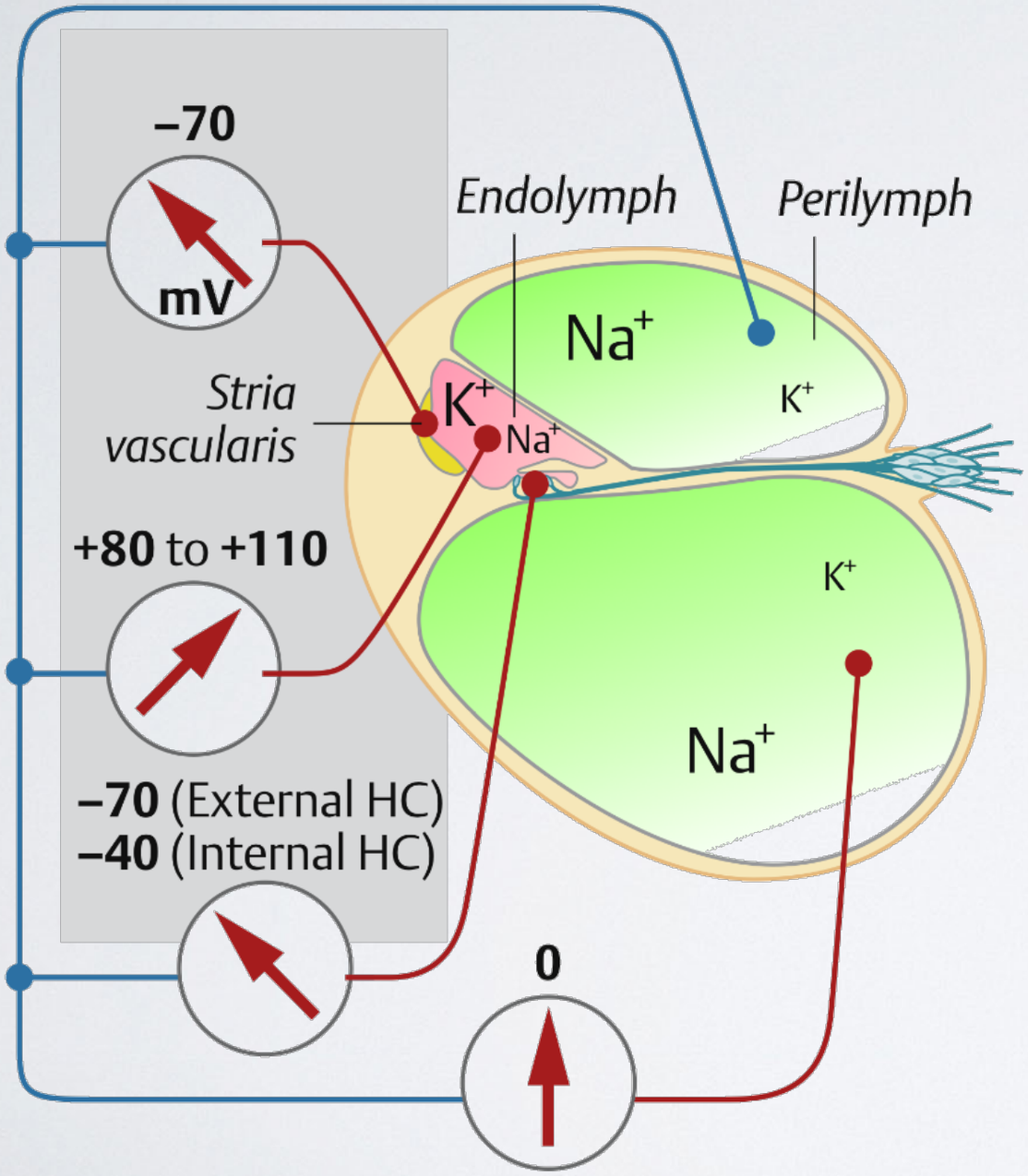
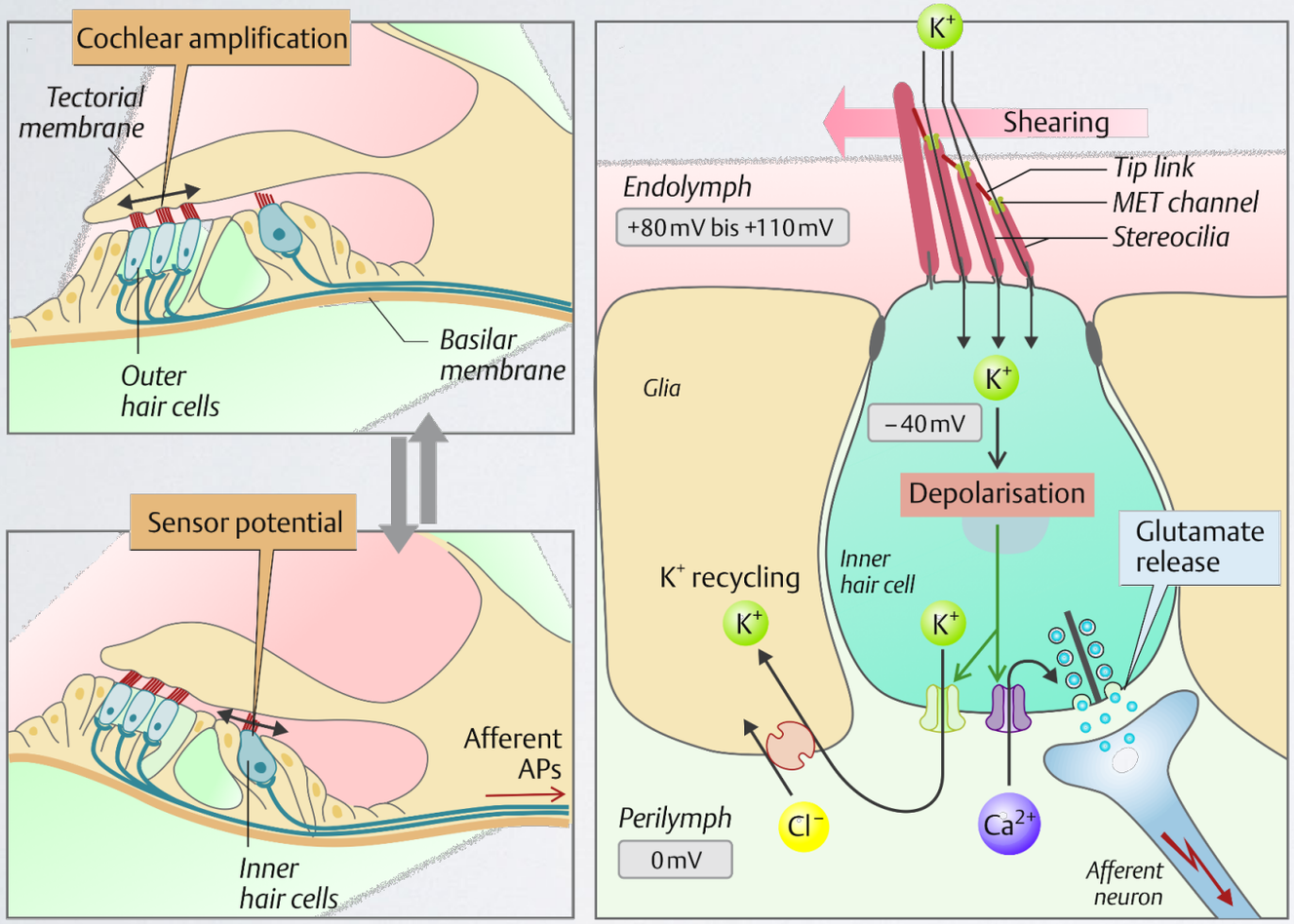
ENDOCOCHLEAR POTENTIALS



- Stereocilia in Endolymph | high K+, low Na+
- Cellbodies in Perilymph
- Electric potential
- Intracellular negative potential
- -70mV to perilymph
- -150mV to endolymph | higher sensitivity
- K+ constantly secreted by stria vascularis

Picture source: Color Atlas of Physiology 6th edition, Stefan Silbernagl, MD, Agamemnon Despopoulos, MD, 189 color plates by Ruediger Gay and Astried Rothenburger, Thieme 2003, ISBN 978-3-13-545006-3

HAIR RECEPTOR POTENTIAL + EXCITATION OF AUDITORY NERVE FIBERS



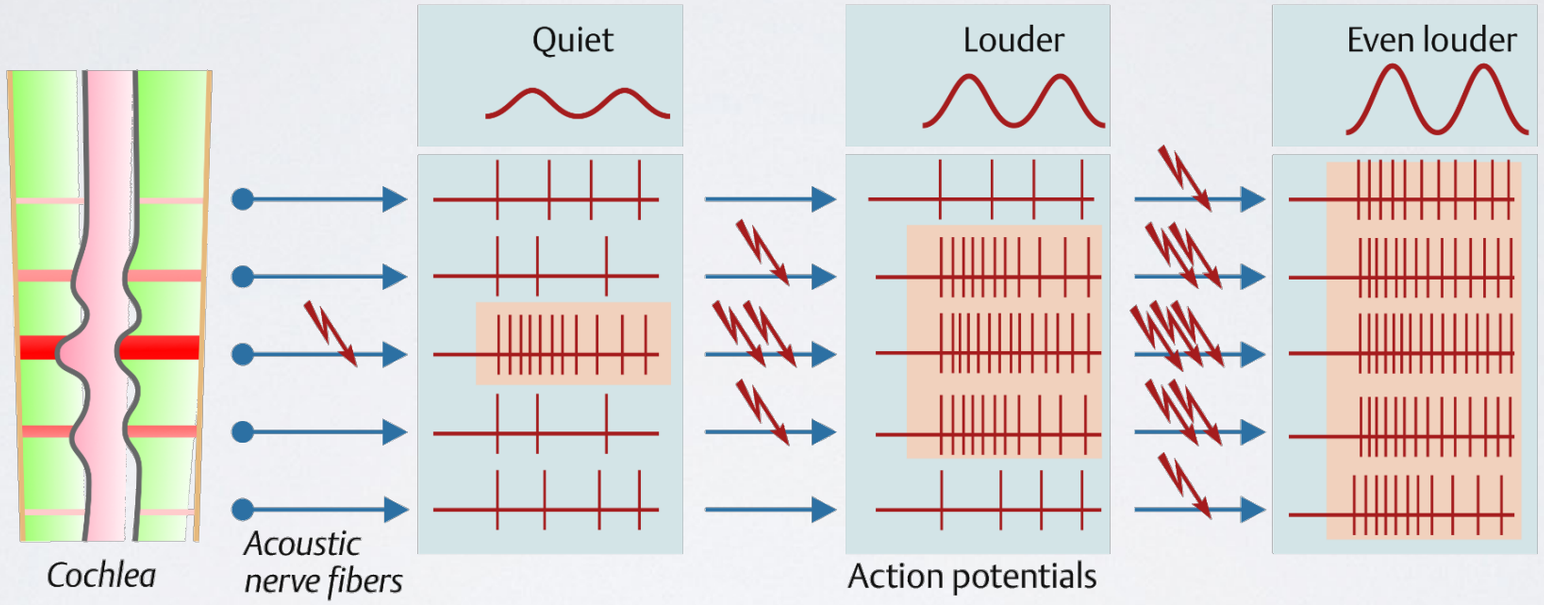
- Ca. 100 stereocila per hair cell
- Tip links to subsequent stereocilia
- Disposition of Stereocilia | Opening 200-300 cation channels
- Potassium influx from scala media
- Depolarization | opening Ca2+ channels
- Excitation of auditory nerve fiber via Glutamate
- Mechanoelectric transduction

Picture source: Color Atlas of Physiology 6th edition, Stefan Silbernagl, MD, Agamemnon Despopoulos, MD, 189 color plates by Ruediger Gay and Astried Rothenburger, Thieme 2003, ISBN 978-3-13-545006-3

CODING OF SOUND STIMULI

Determine frequency and therefore pitch we here, also wavelength so high or low ton

Determining frequency (quality)| "place principal", neural pathway starts at frequency specific part of cochlea and ends in frequency specific region in cortex | tonotopic organization,



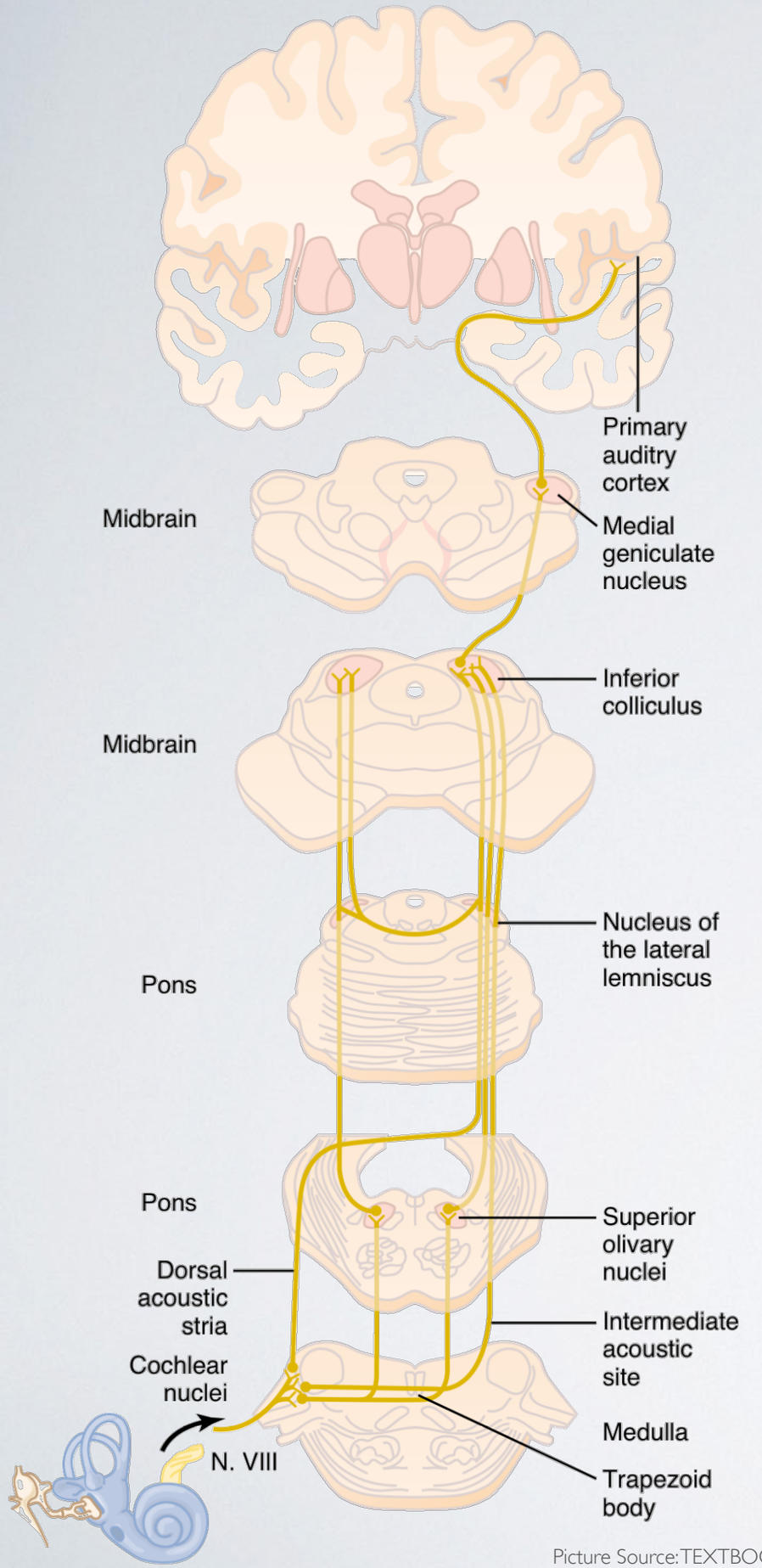
Determining Loudness (quantity)| higher amplitude - higher excitation rate, Spatial Summation, Outer hair cells stimulated

Direction of Sound | lag time + difference in Intensity, medial and superior Olivary nucleus

Distance| High frequencies attenuated faster, lower proportions of high frequencies, the longer the sound travels

Picture source: Color Atlas of Physiology 6th edition, Stefan Silbernagl, MD, Agamemnon Despopoulos, MD, 189 color plates by Ruediger Gay and Astried Rothenburger, Thieme 2003, ISBN 978-3-13-545006-3

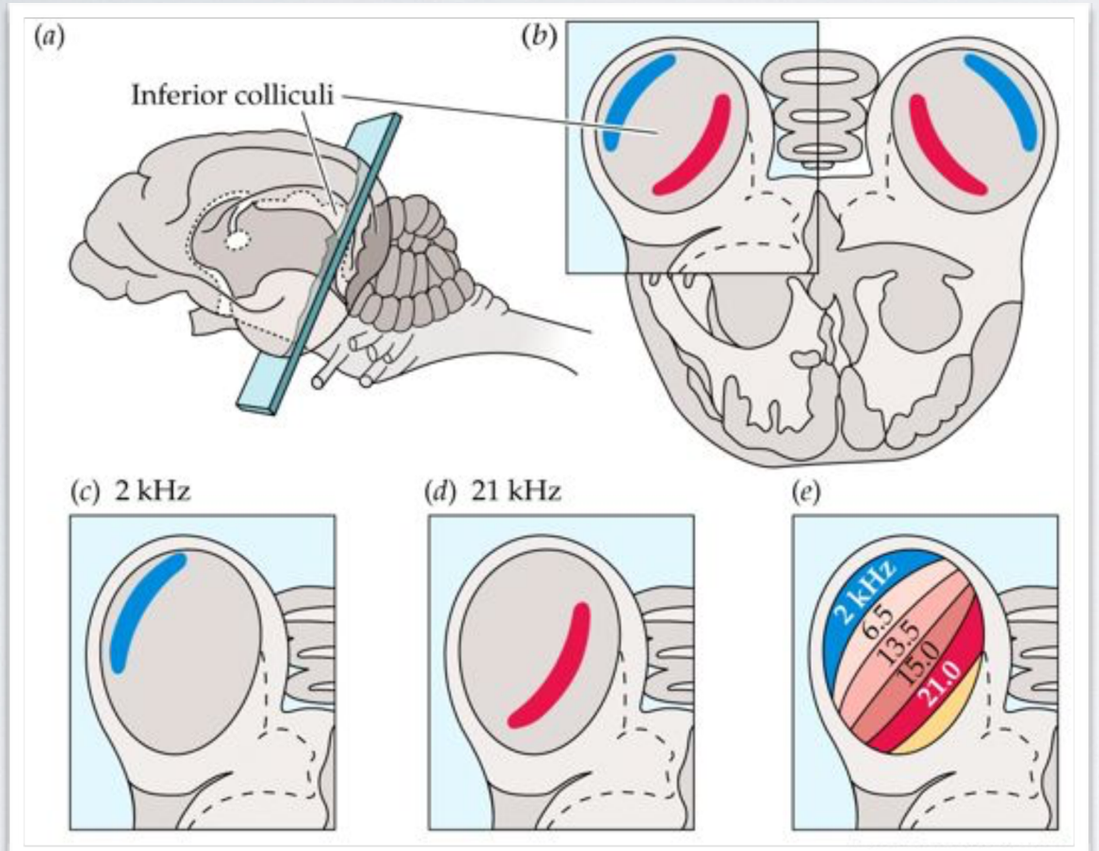
CENTRAL AUDITORY MECHANISM



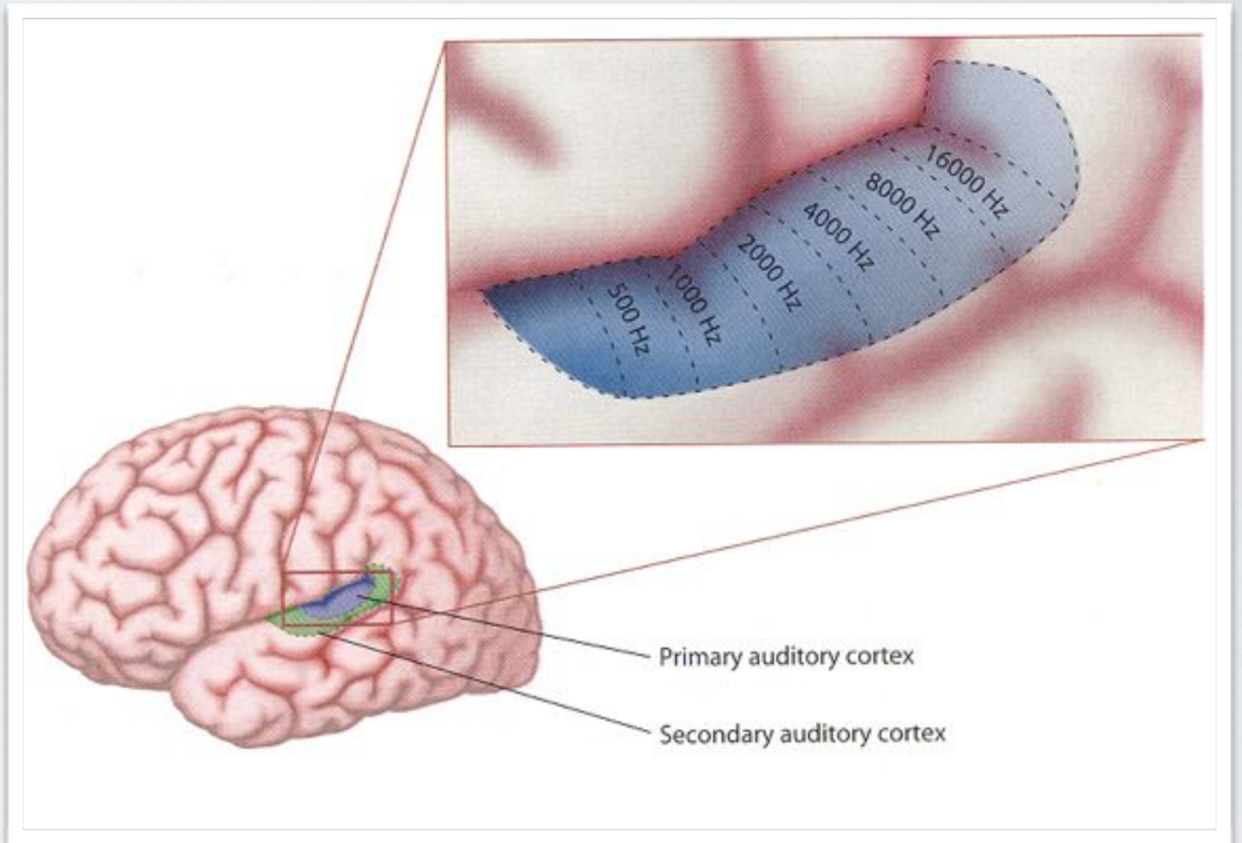
- Signal from one ear travels bilateral
- 3 crossing over sites
- Spatial orientation of fiber tracts | Cochlear nuclei, inferior colliculi, cortex
- Sup. Olivary nucleus | detection of direction of sound
- No direct transmission of sound from ear - dissection on impulse level
- Cortical neutrons respond only to small range
- Lateral inhibition
- Firing Rate

Picture Source: TEXTBOOK OF MEDICAL PHYSIOLOGY, 11th edition, Arthur C. Guyton, John E. Hall, ISBN 0-7216-f-1, Elsevier 2006

TONOTOPIC ORGANISATION



Inferior Colliculus



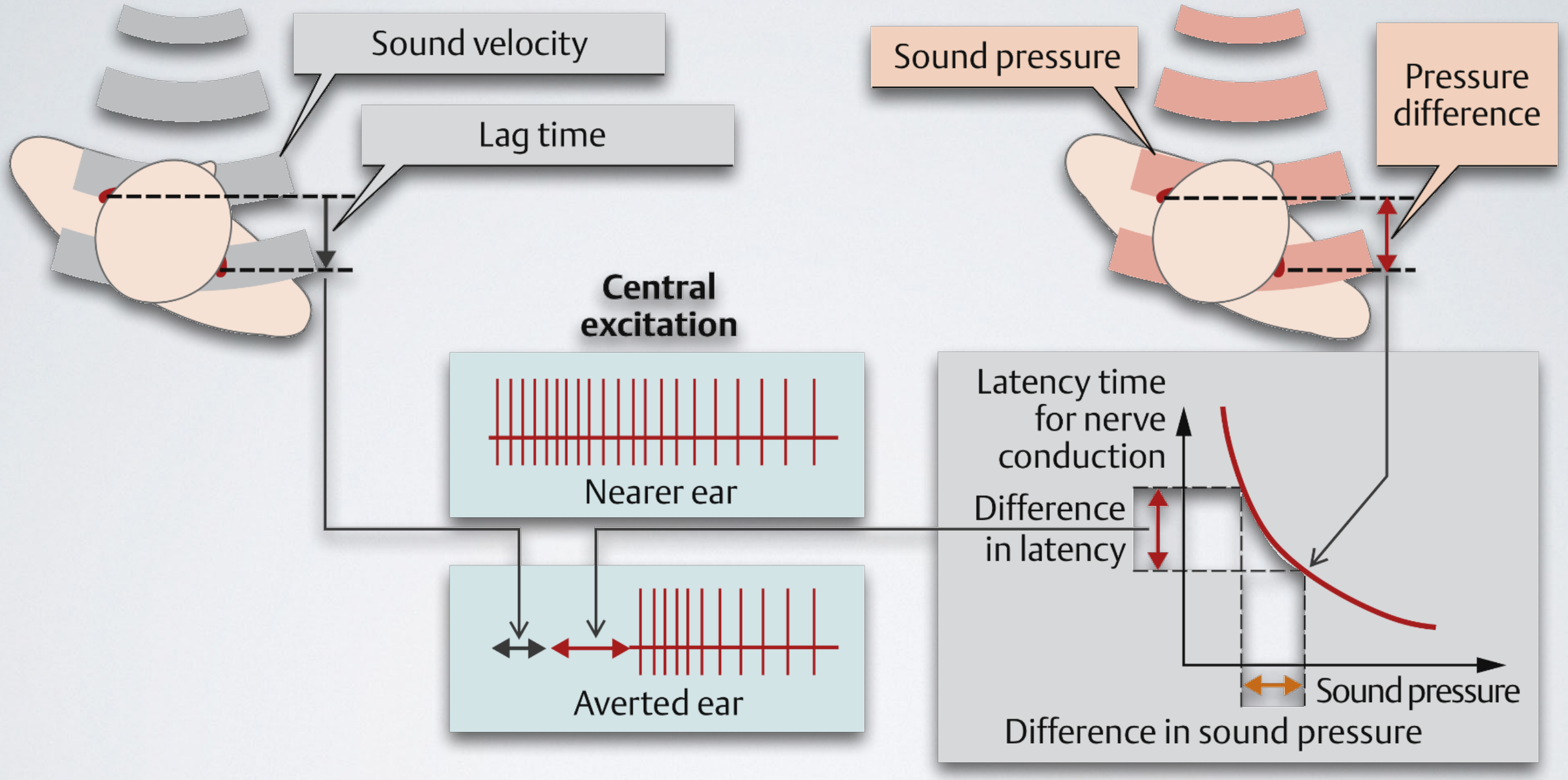
Cortex

Inf. Colliculus divided to subregions/ sub-nuclei | response to high and low frequencies

Picture source: http://www.cns.nyu.edu/~david/courses/perception/lecturenotes/localization/localization-slides/Slide3.jpg

Picture source: http://www.cns.nyu.edu/~david/courses/perception/lecturenotes/localization/localization-slides/Slide5.jpg

DETECTION OF DIRECTION OF SOUND



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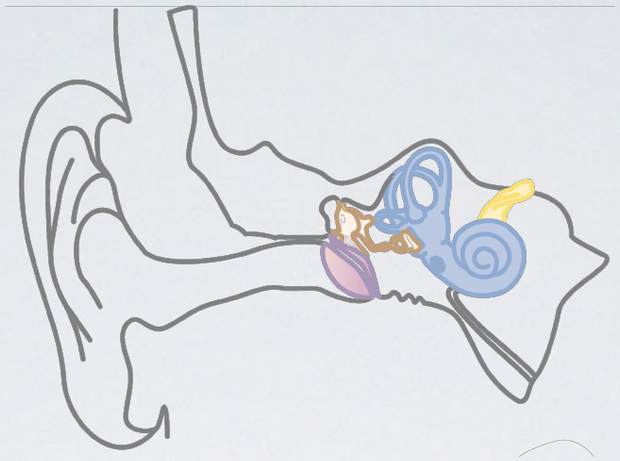

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"Color Atlas of Physiology" 6th edition, Stefan Silbernagel, Thieme 2009

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