Sistema AUDITIVO

NEUROCIENCIA

Hayo A. Breinbauer Krebs (Dr.med/PhD).
Universidad de Chile – Departamento Neurociencias

FACULTAD DE MEDICINA
UNIVERSIDAD DE CHILE

LAB - ONCE
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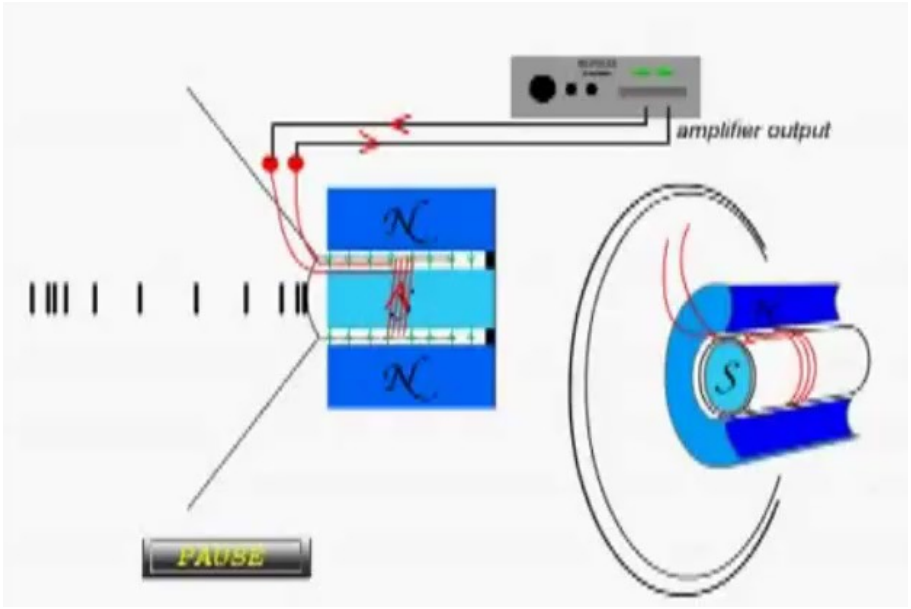
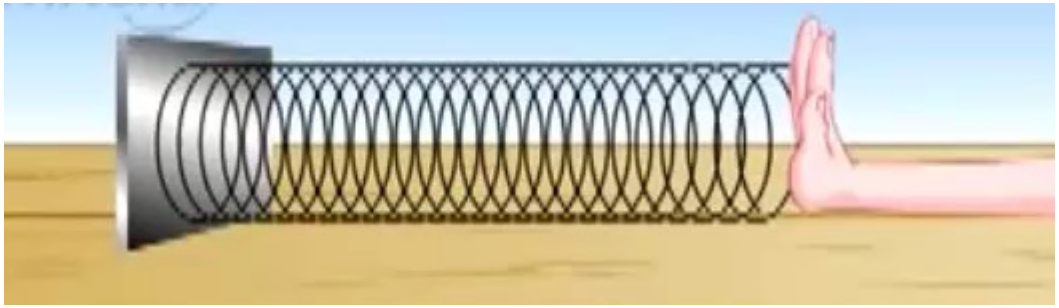
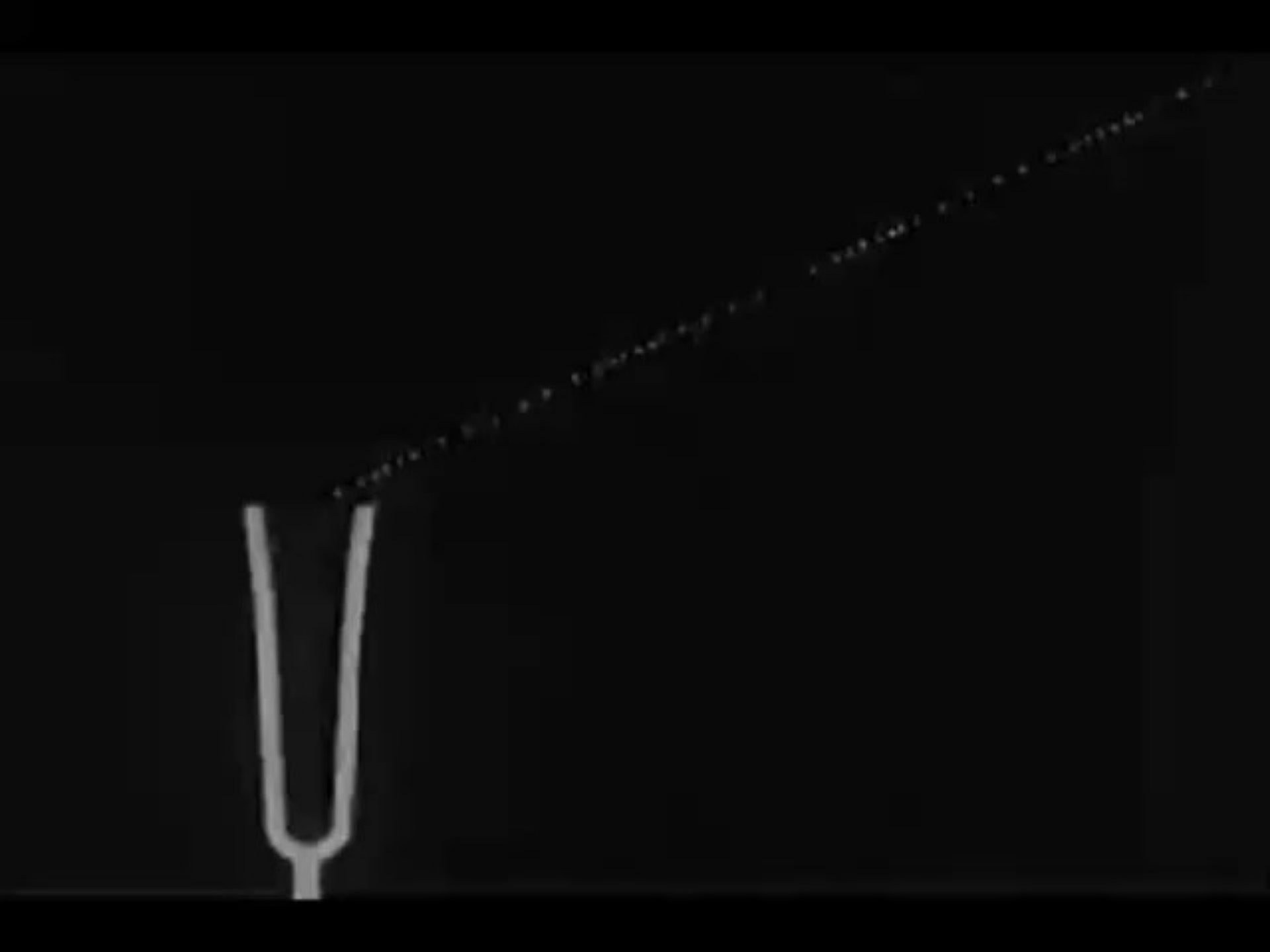
¿Qué es el sonido?

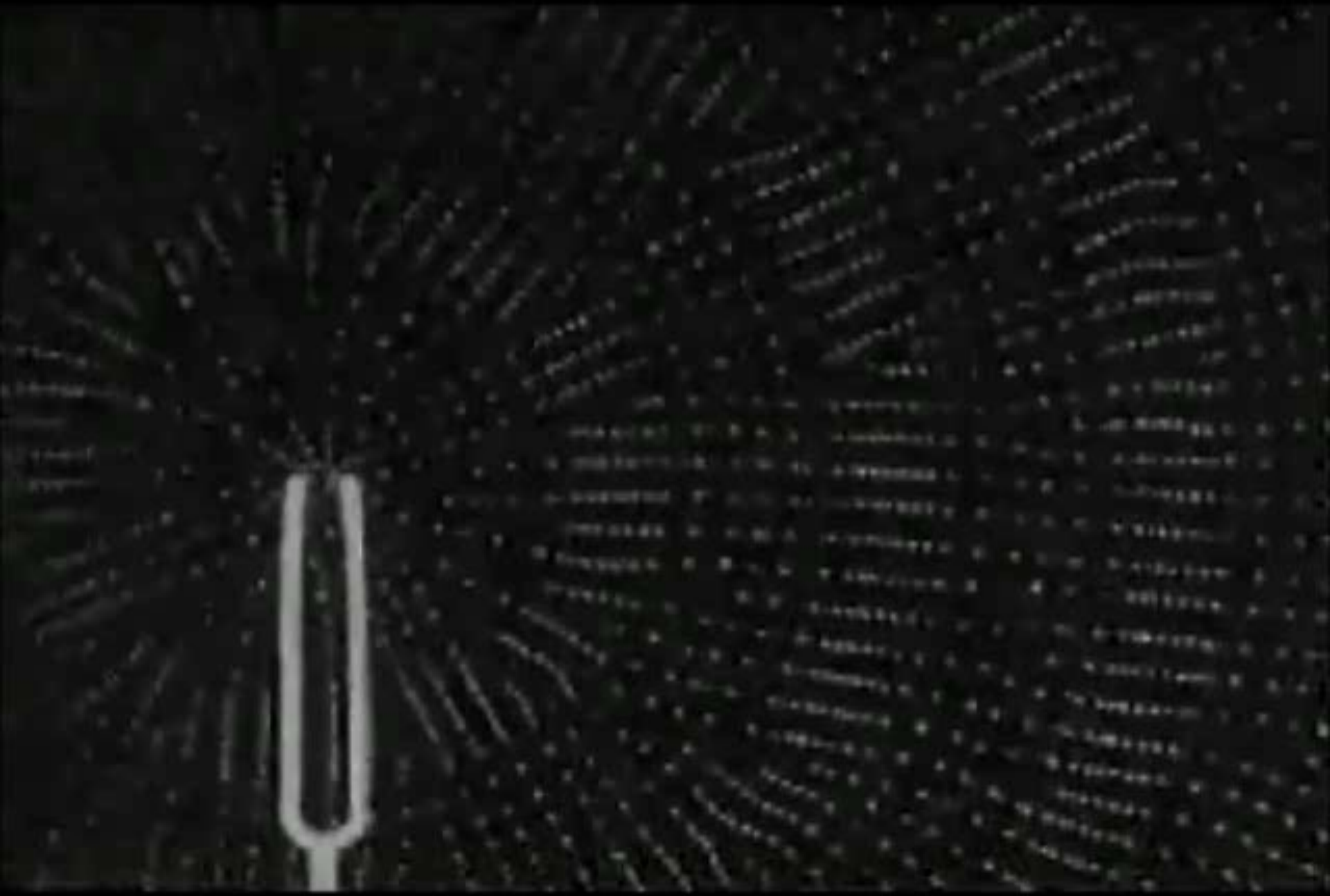
¿QUÉ ES EL SONIDO?

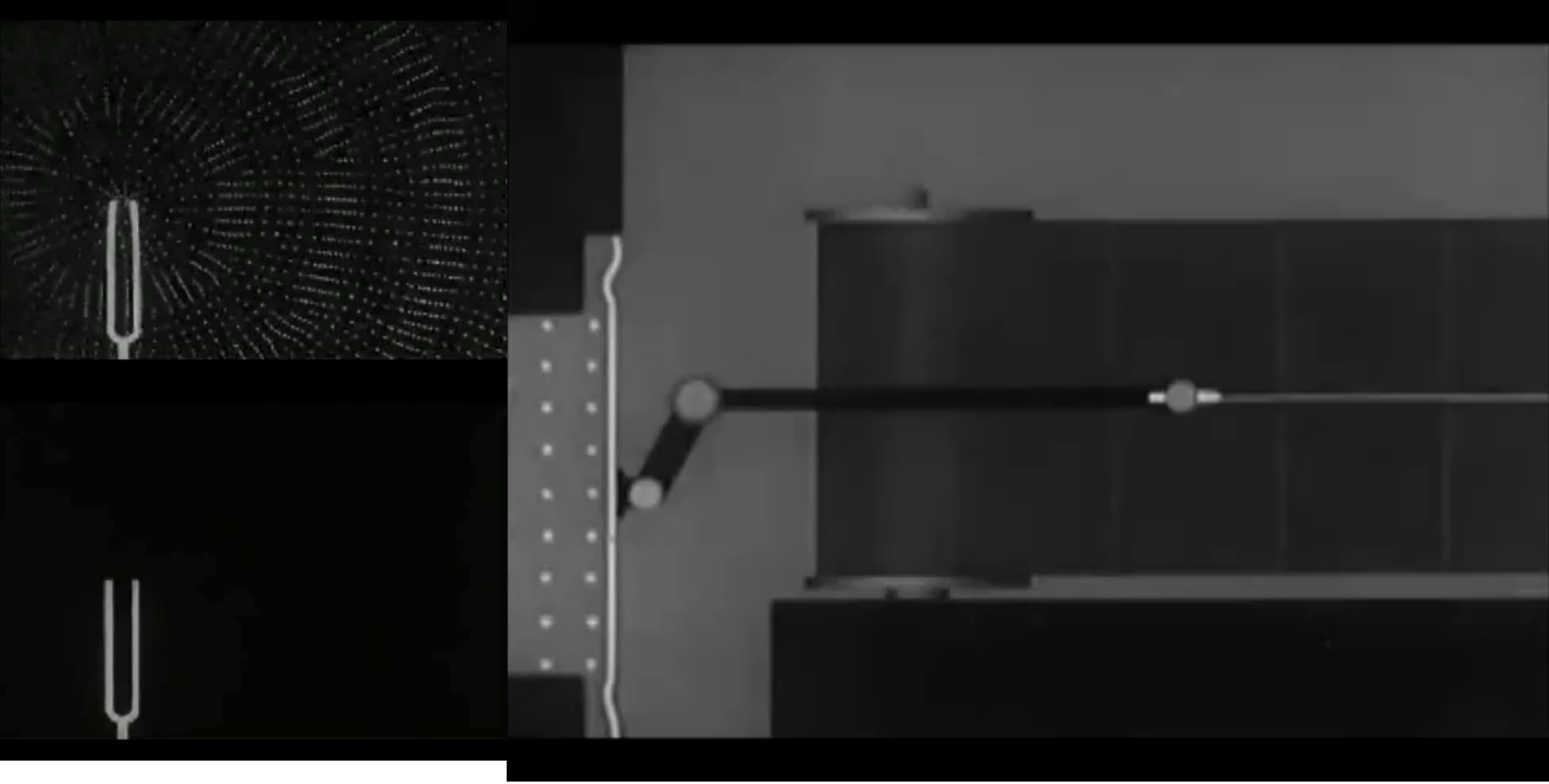
Vibración u **oscilación** de un **medio elástico**, la cual se **propaga** como **onda** a través de dicho medio.

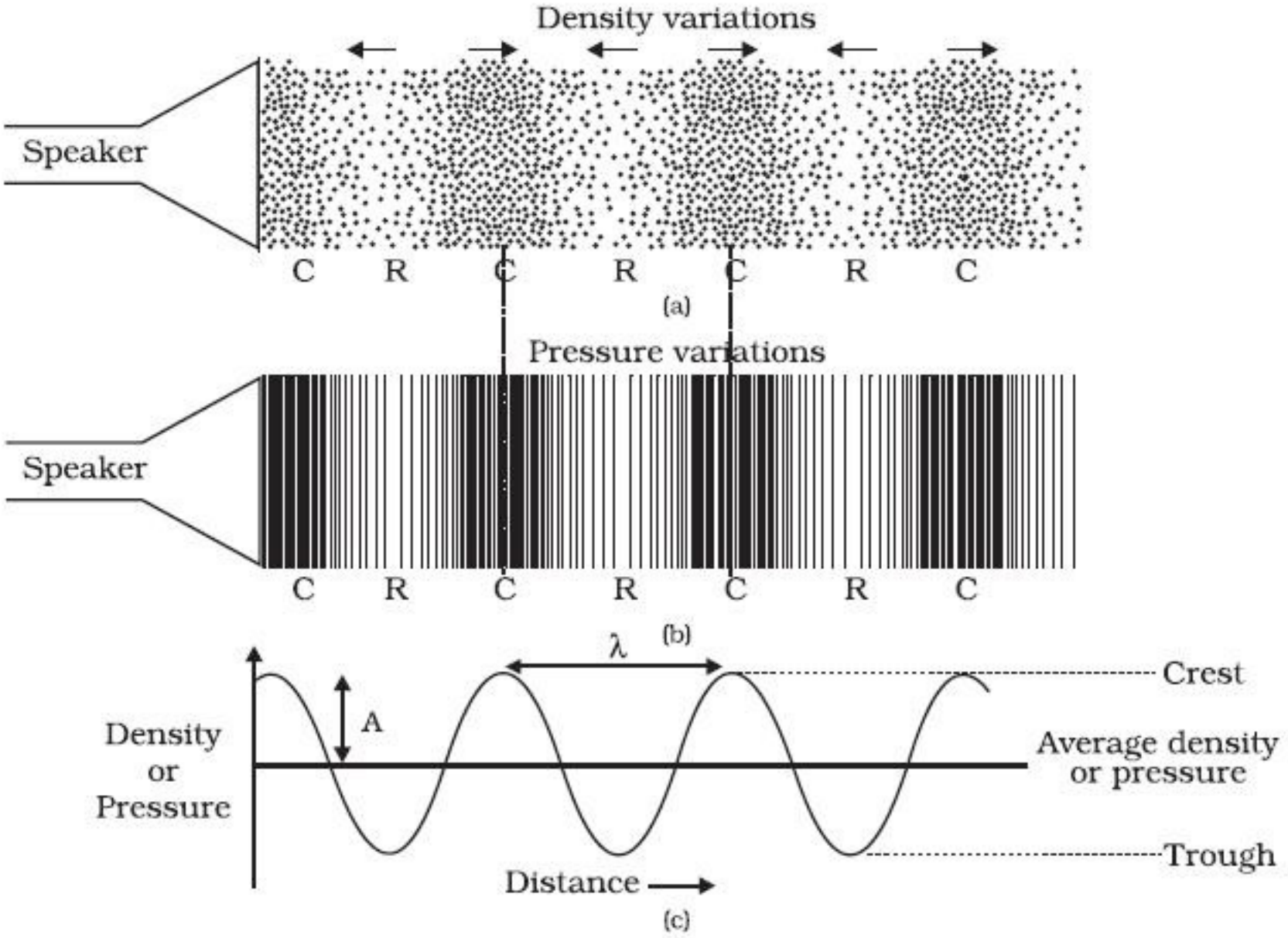




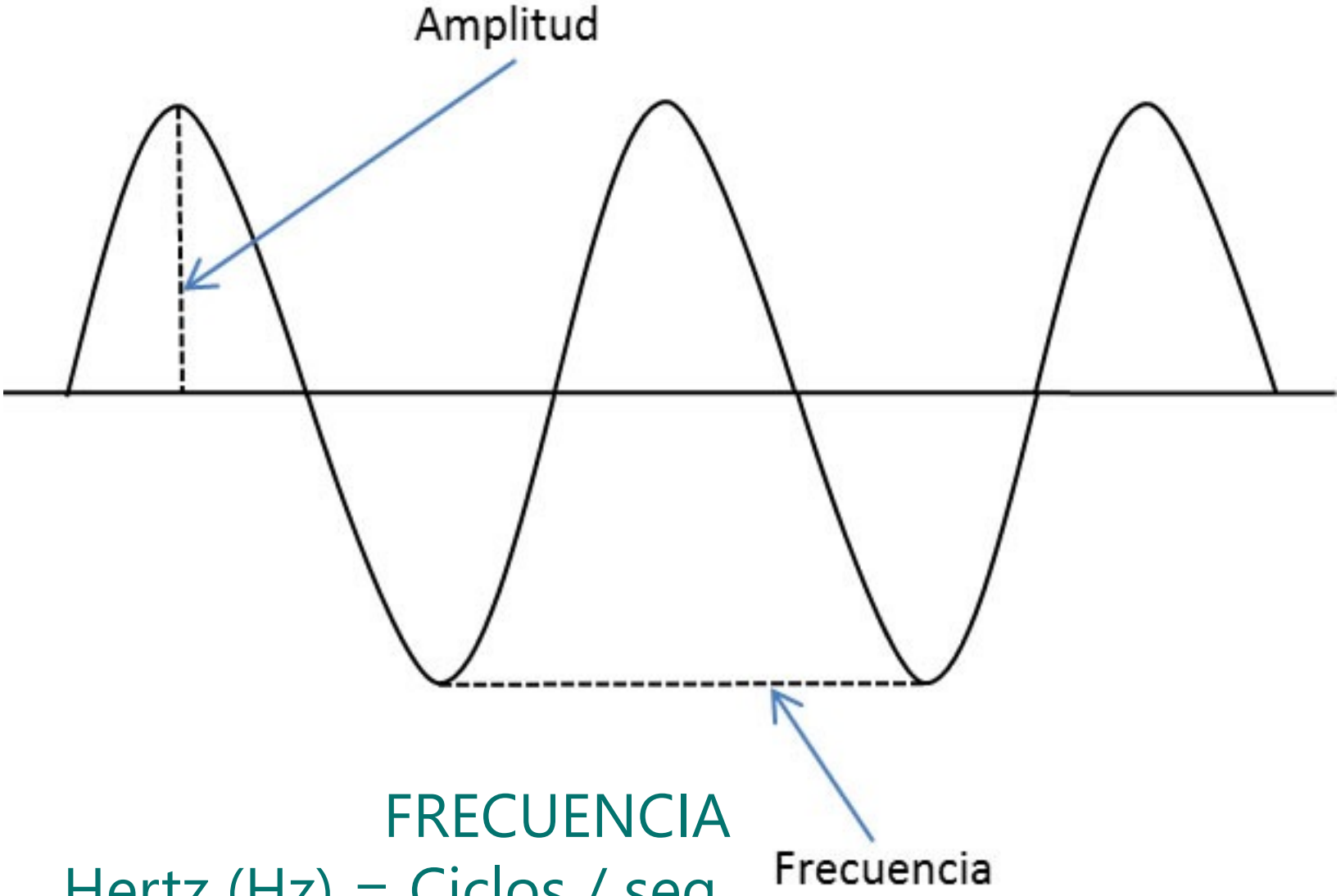






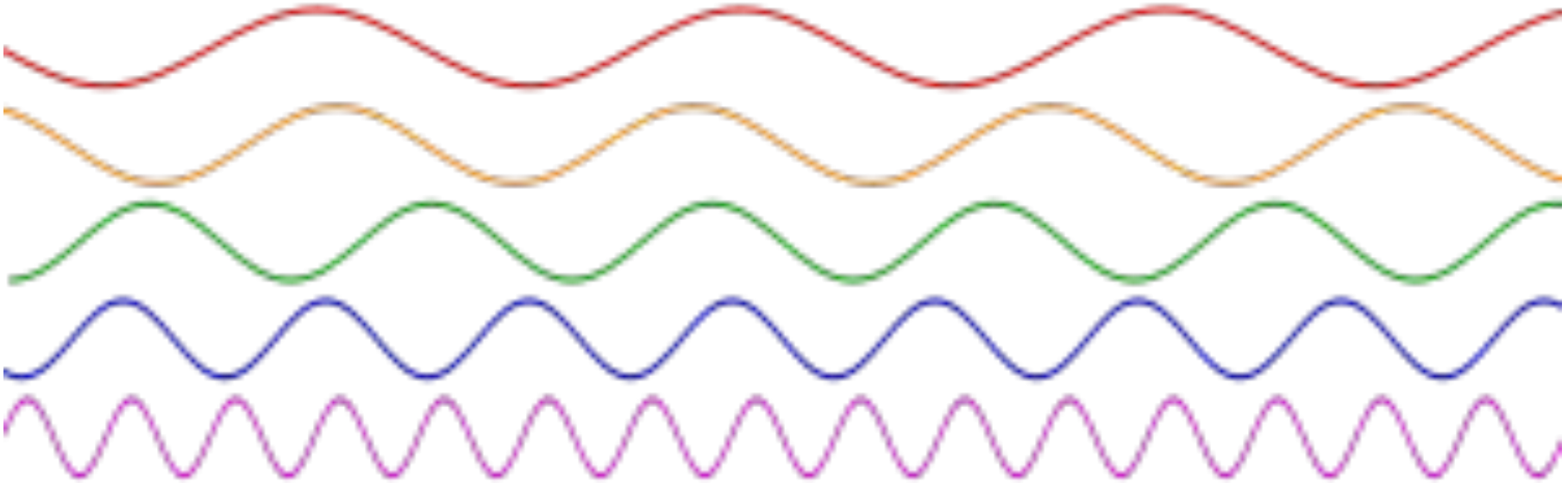

Density variations
Speaker
C R C R C R C
(a)
Pressure variations
Speaker
C R C R C R C
(b)
λ
A
Density or Pressure
Crest
Average density or pressure
Trough
Distance
(c)

INTENSIDAD = DECIBEL (dB)



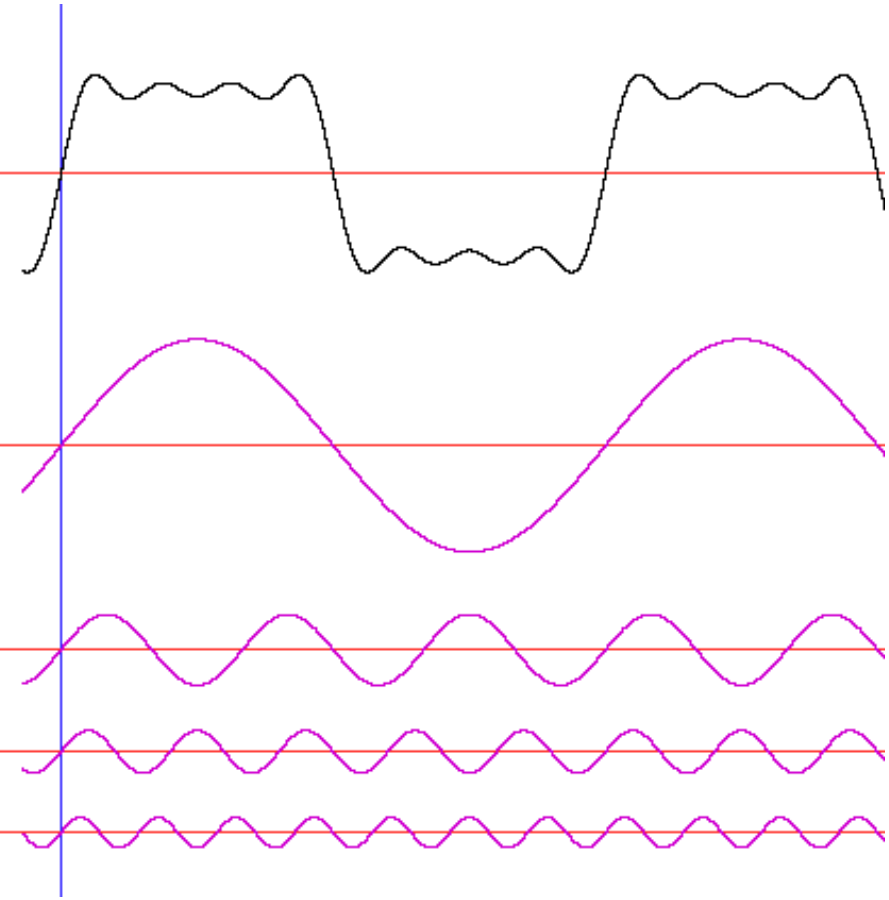
FRECUENCIA

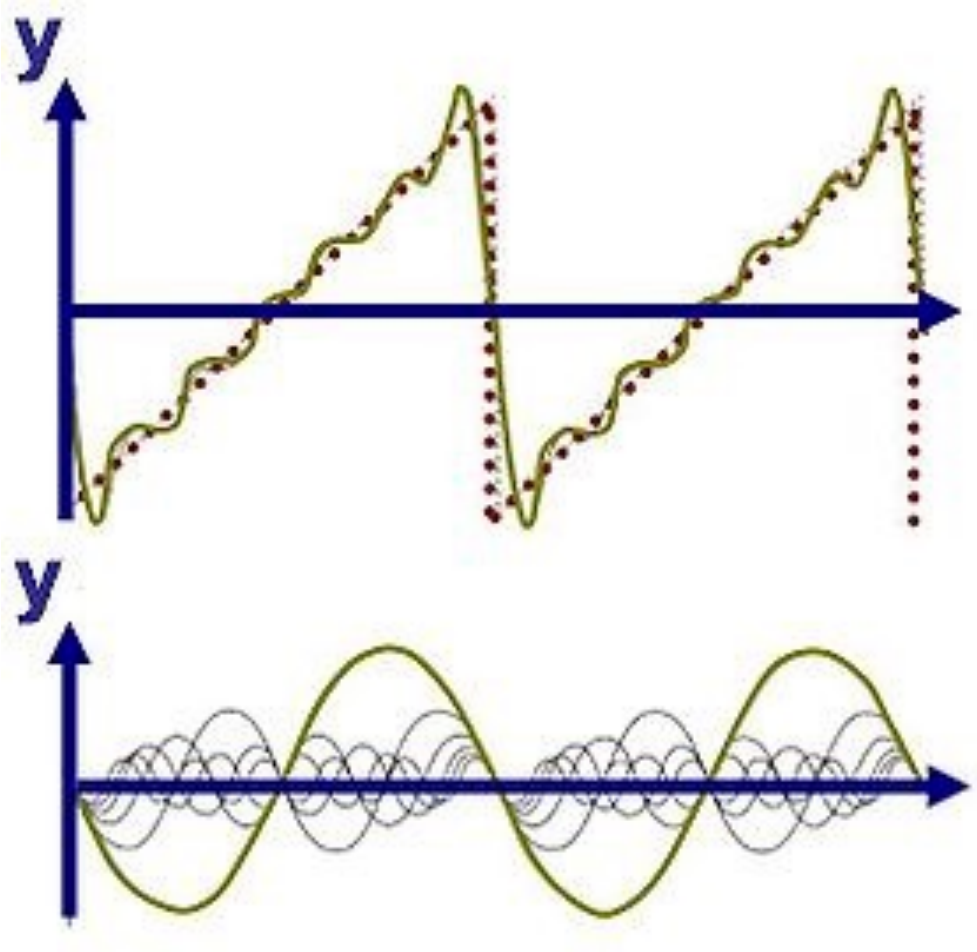
Hertz (Hz) = Ciclos / seg.



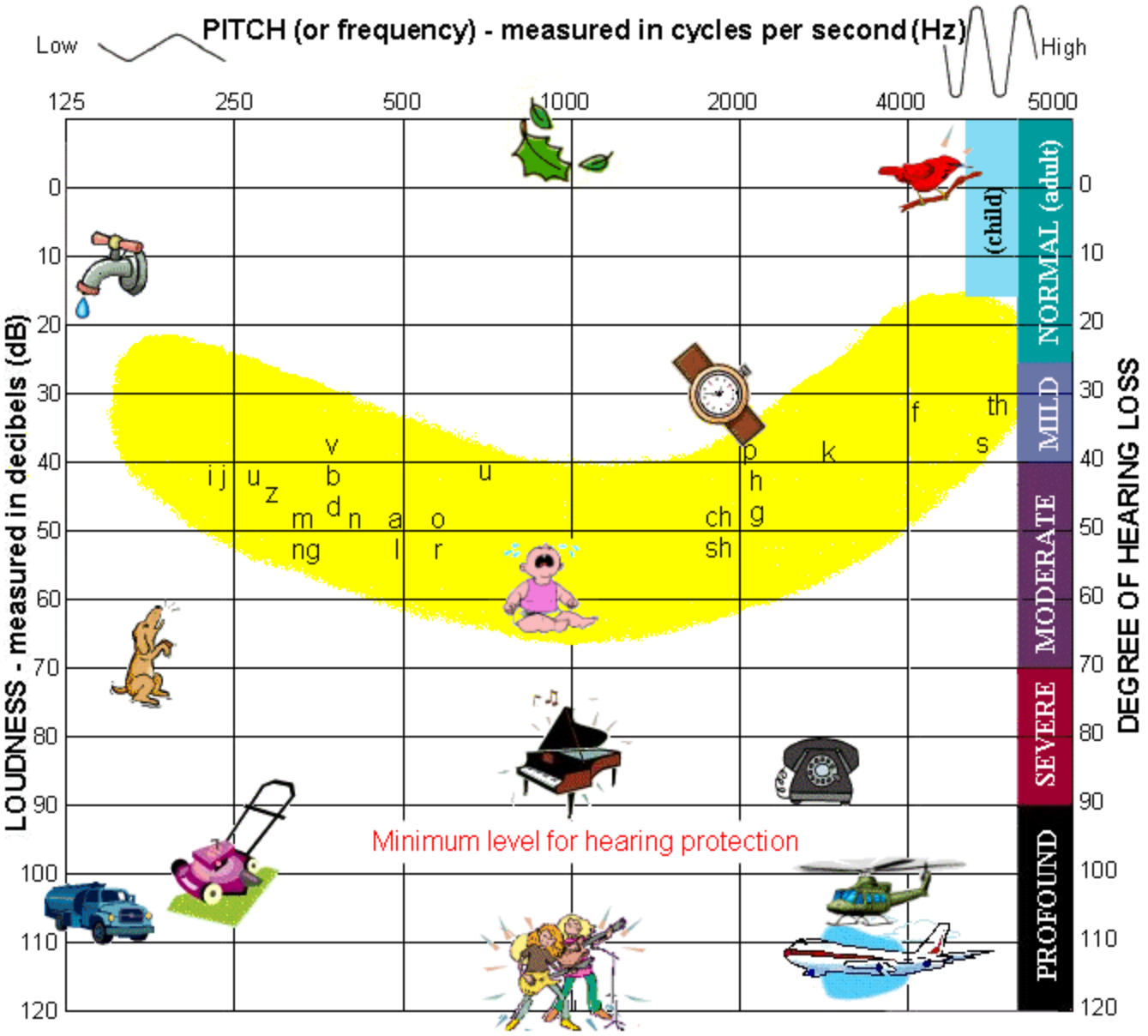
Low frequency

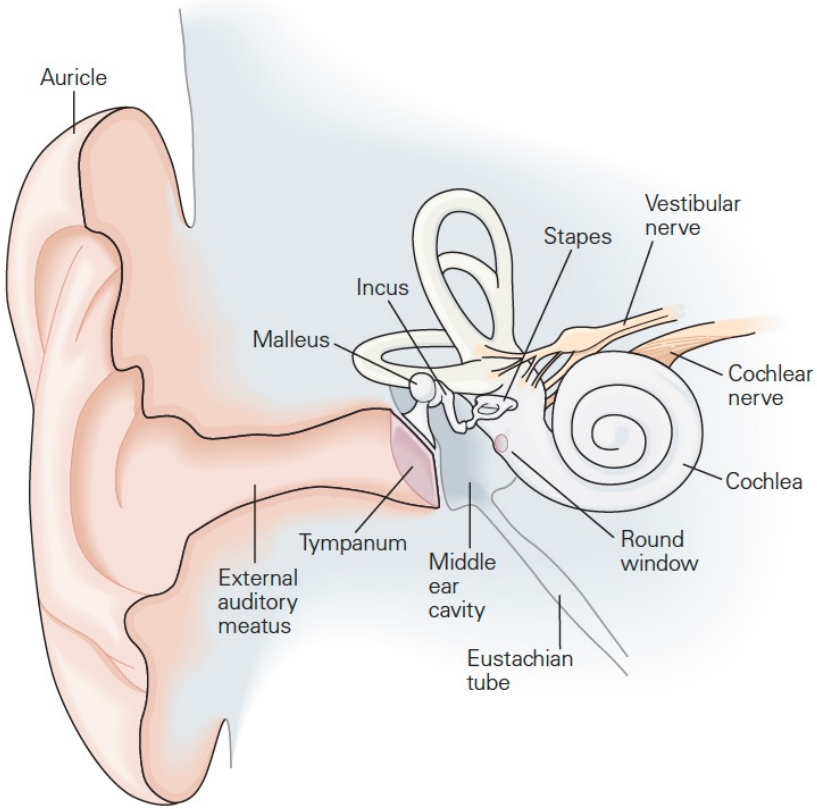
High frequency



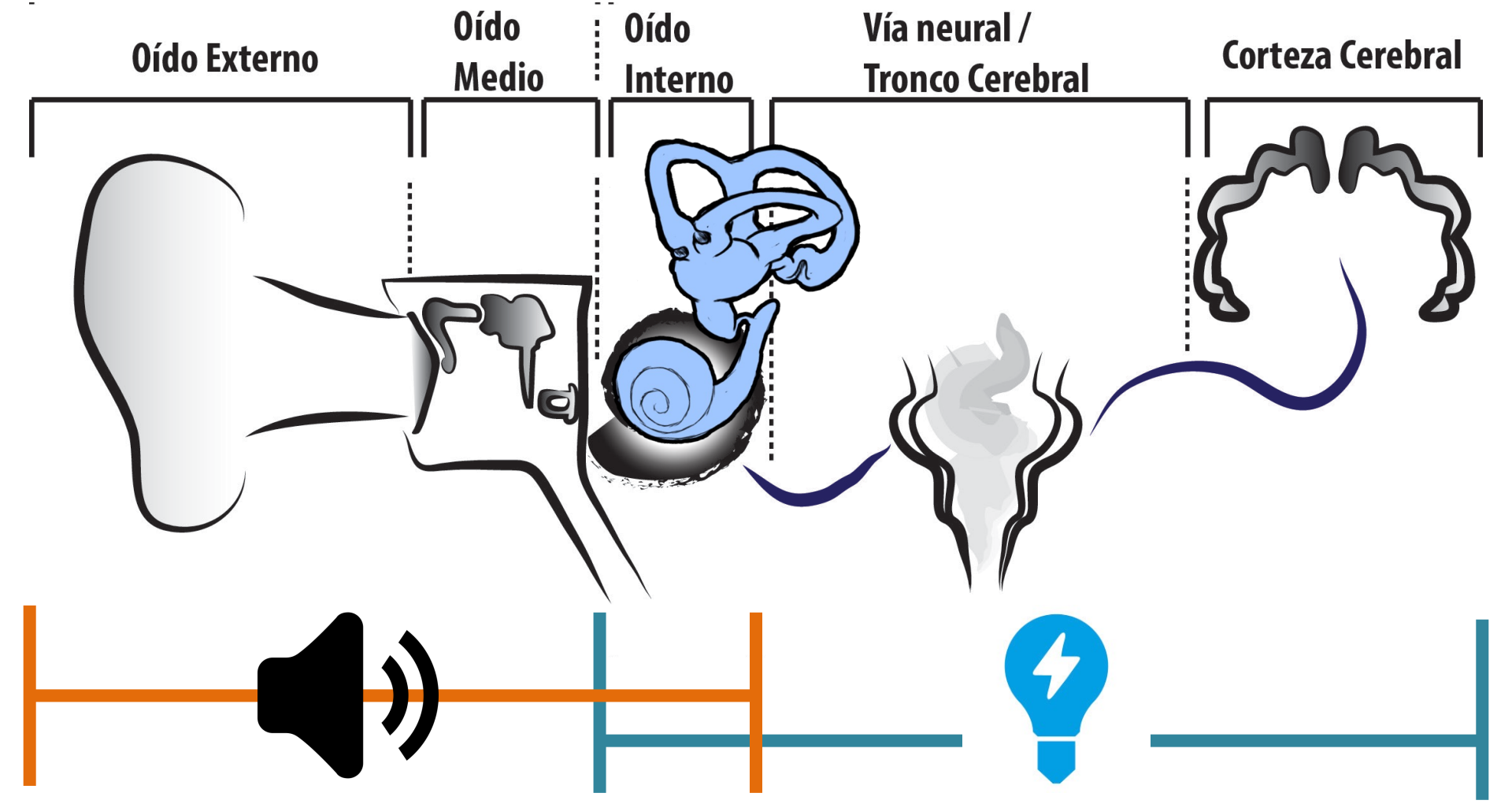


DESCOMPOSICIÓN FRECUENCIAL FOURIER


PITCH (or frequency) - measured in cycles per second (Hz)
Low
High
125
250
500
1000
2000
4000
5000
LOUDNESS - measured in decibels (dB)
0
10
20
30
40
50
60
70
80
90
100
110
120
DEGREE OF HEARING LOSS
(child)
NORMAL (adult)
MILD
MODERATE
SEVERE
PROFOUND
i j u z v b d m n ng a l o r u ch sh p h g k f th s
Minimum level for hearing protection

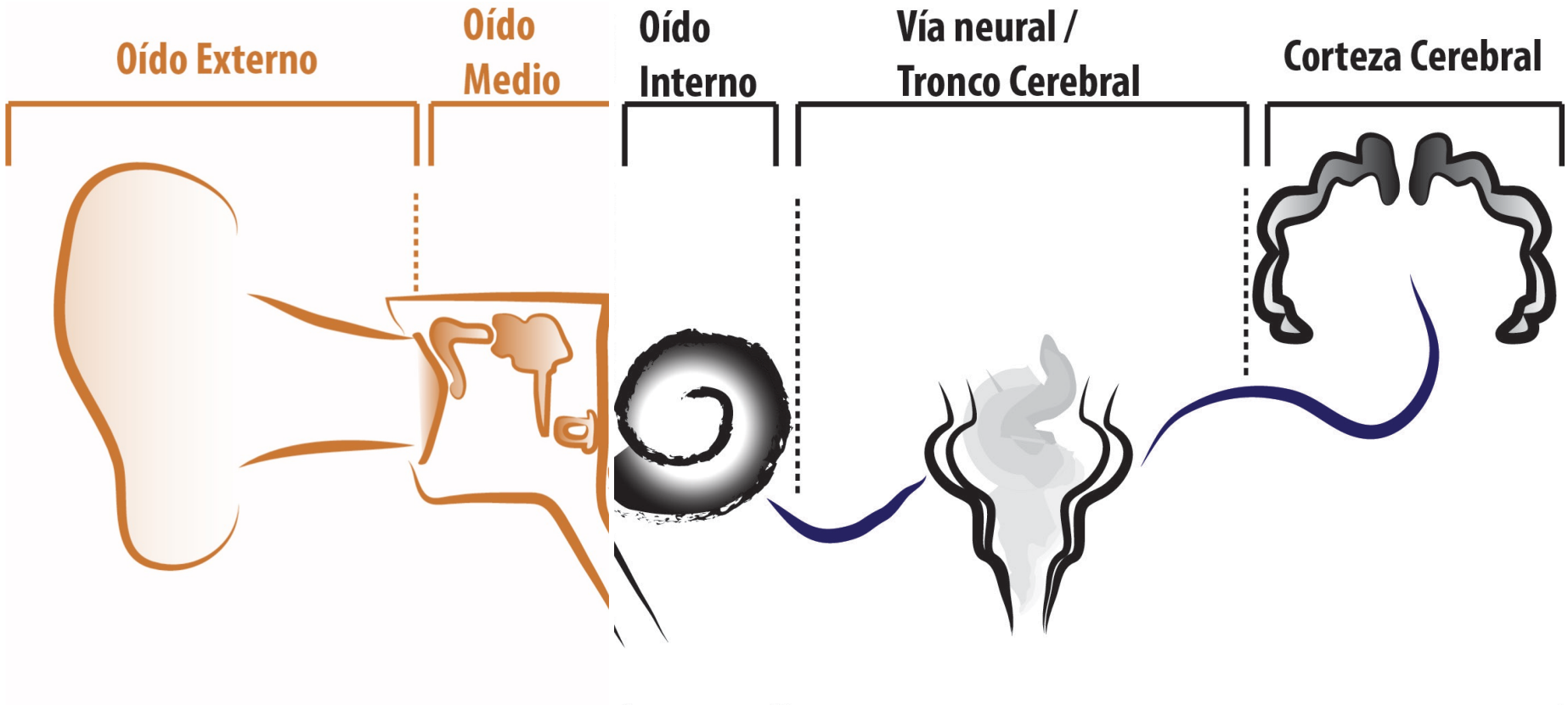

Auricle
Vestibular nerve
Stapes
Incus
Malleus
Cochlear nerve
Cochlea
Round window
Tympanum
Middle ear cavity
External auditory meatus
Eustachian tube

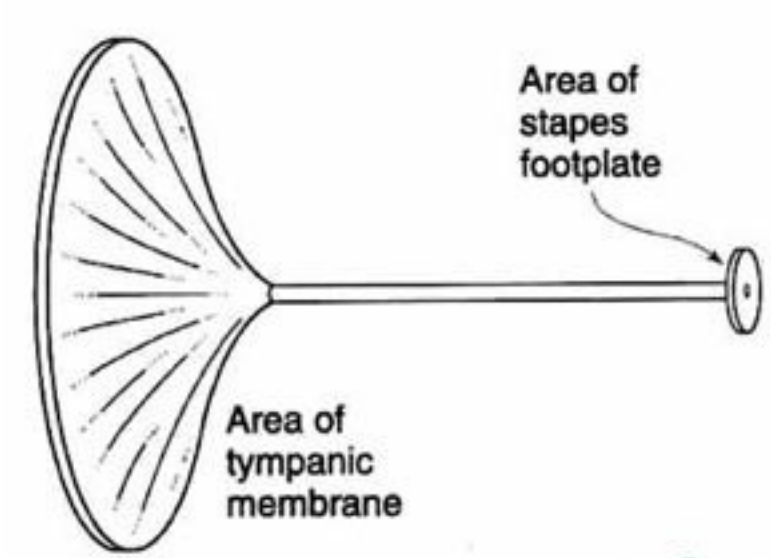
La audición en un minuto

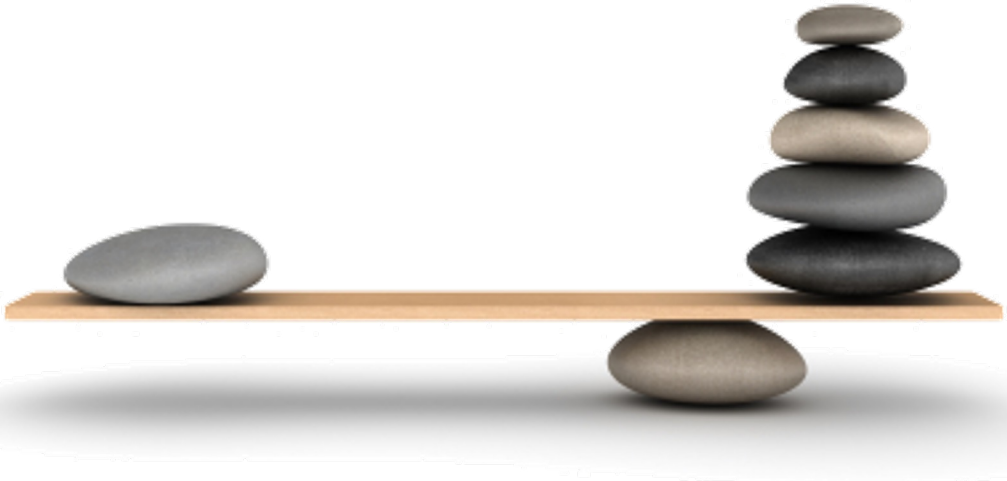


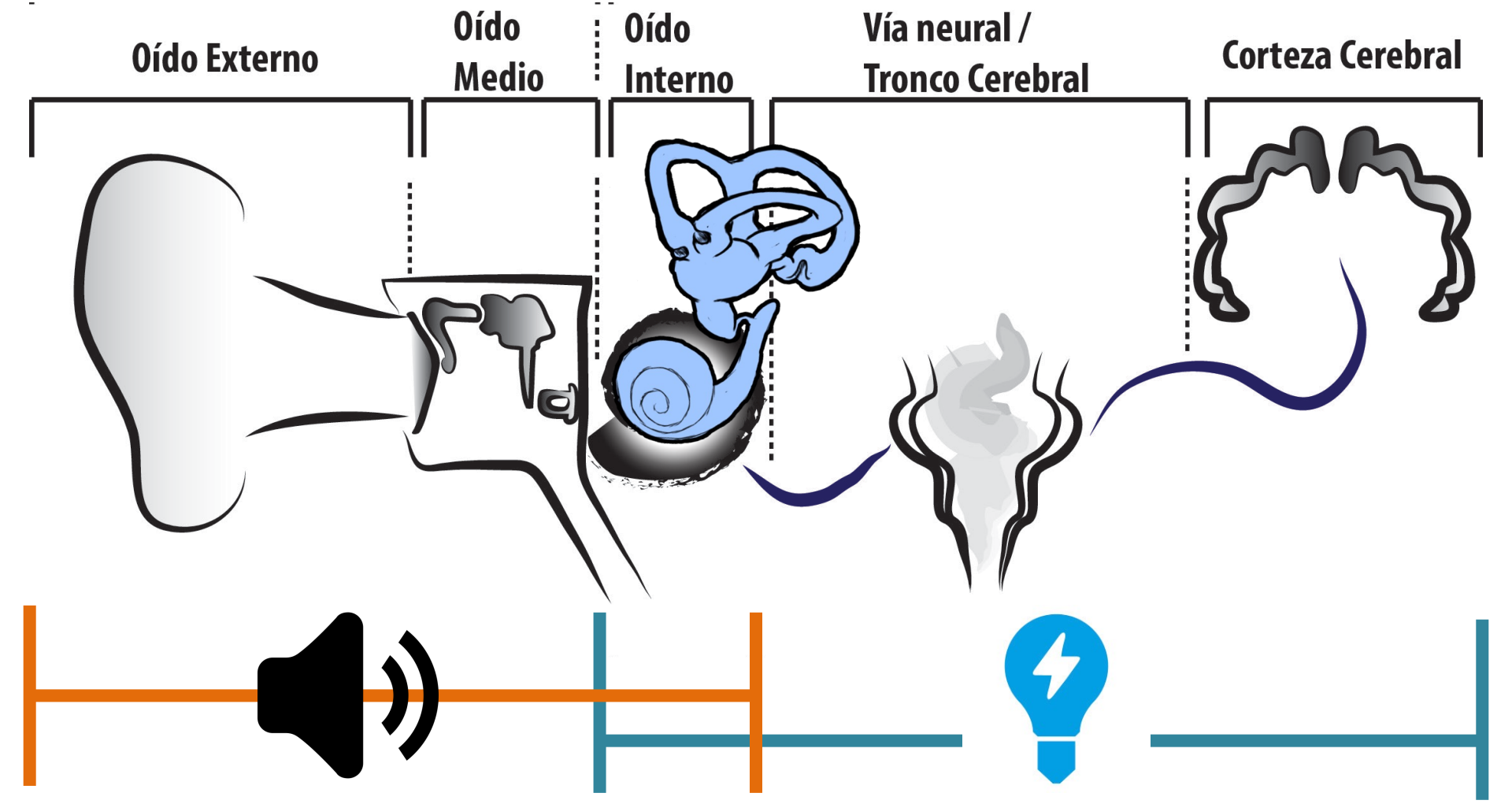
Onda Mecánica

Señal bio-eléctrica


Oído Externo
Oído Medio
Oído Interno
Vía neural / Tronco Cerebral
Corteza Cerebral


Area of
stapes
footplate
Area of
tympanic
membrane



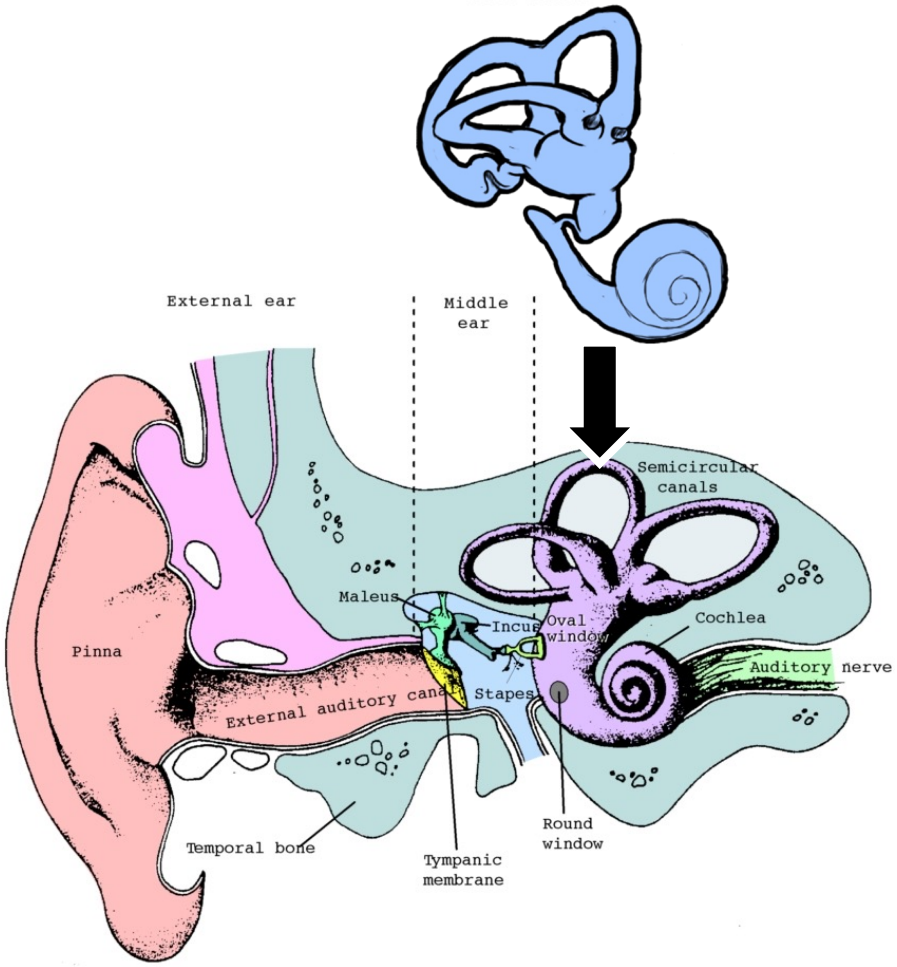


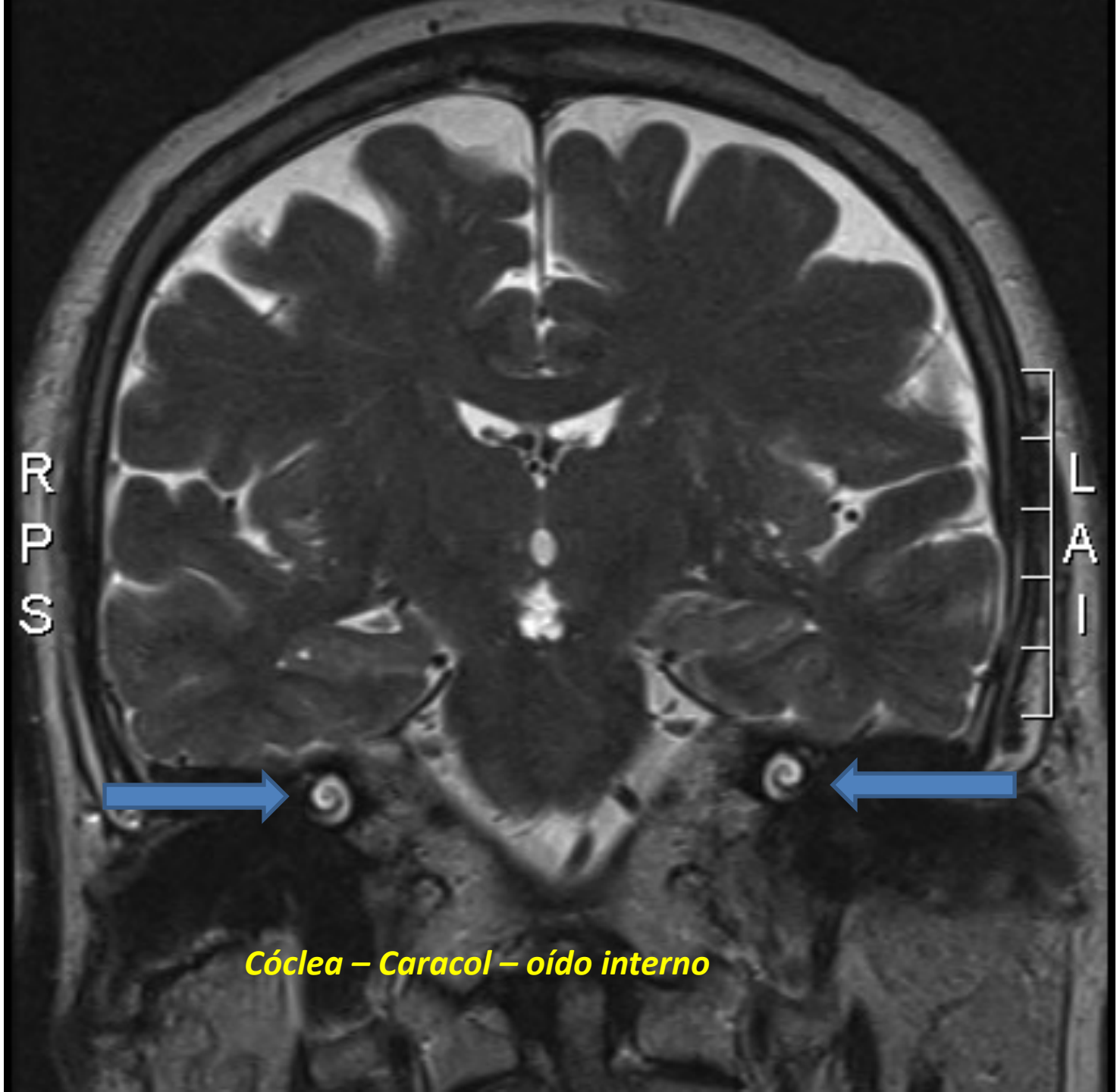
Onda Mecánica

Señal bio-eléctrica

OIDO INTERNO

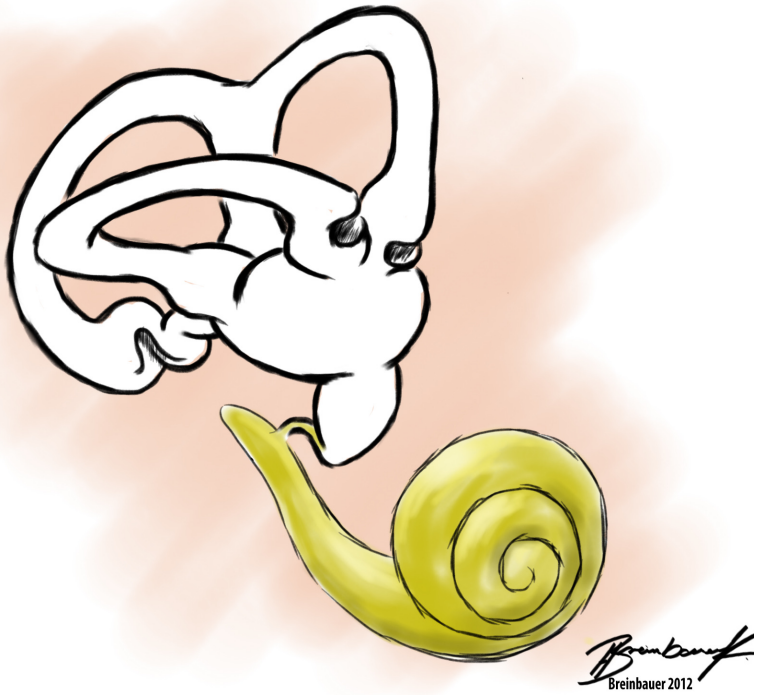
FIG 27.2



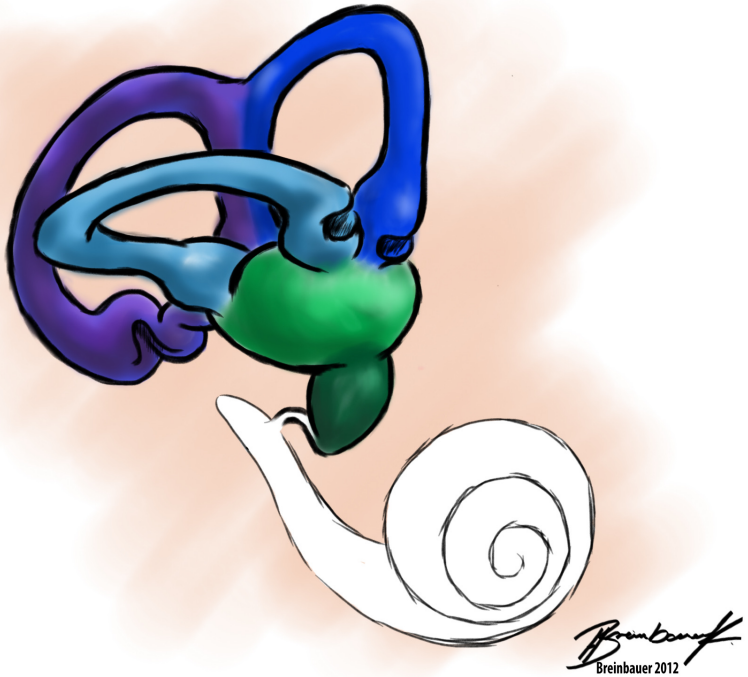


Cóclea – Caracol – oído interno

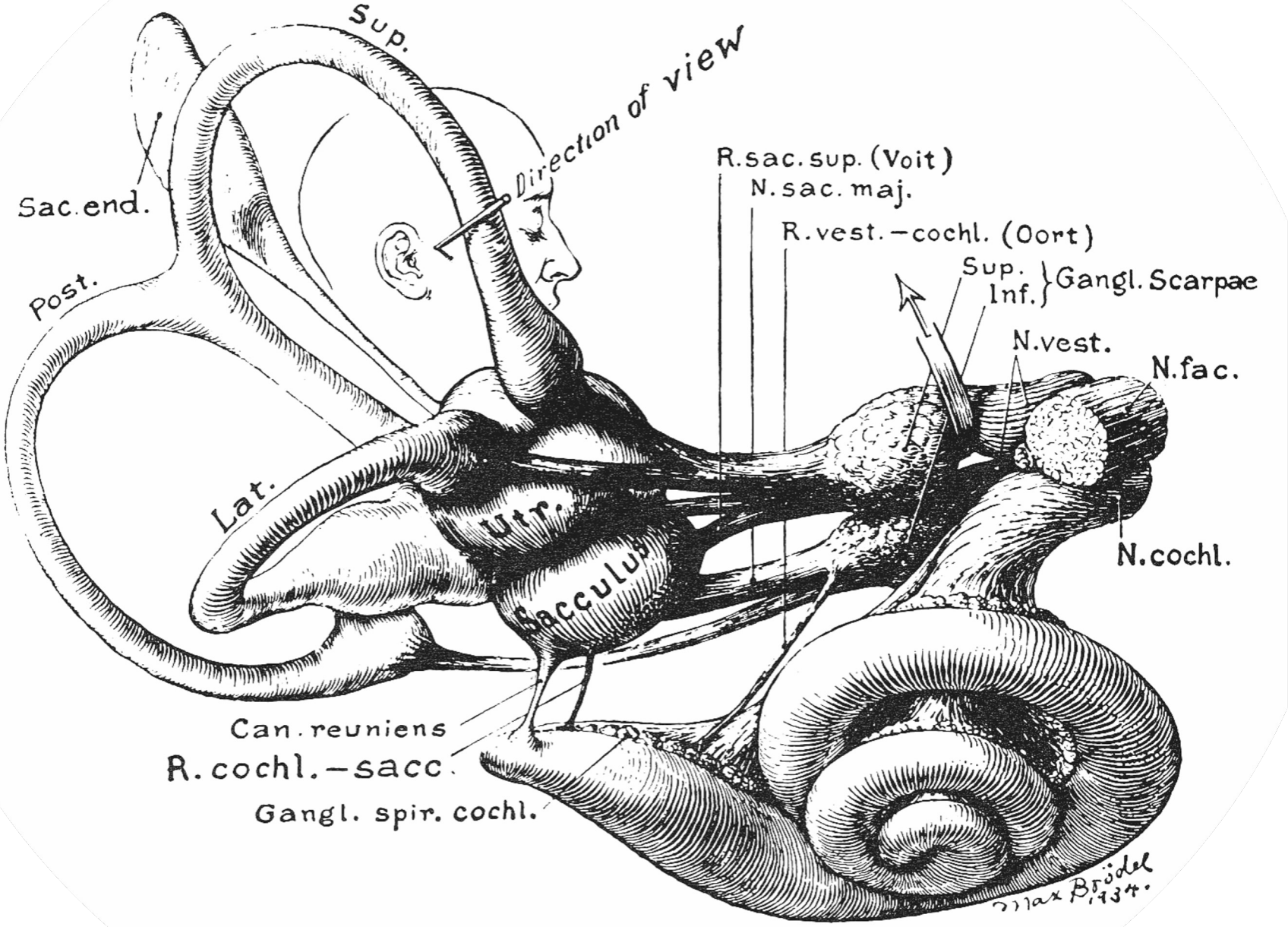

Breinbauer 2012

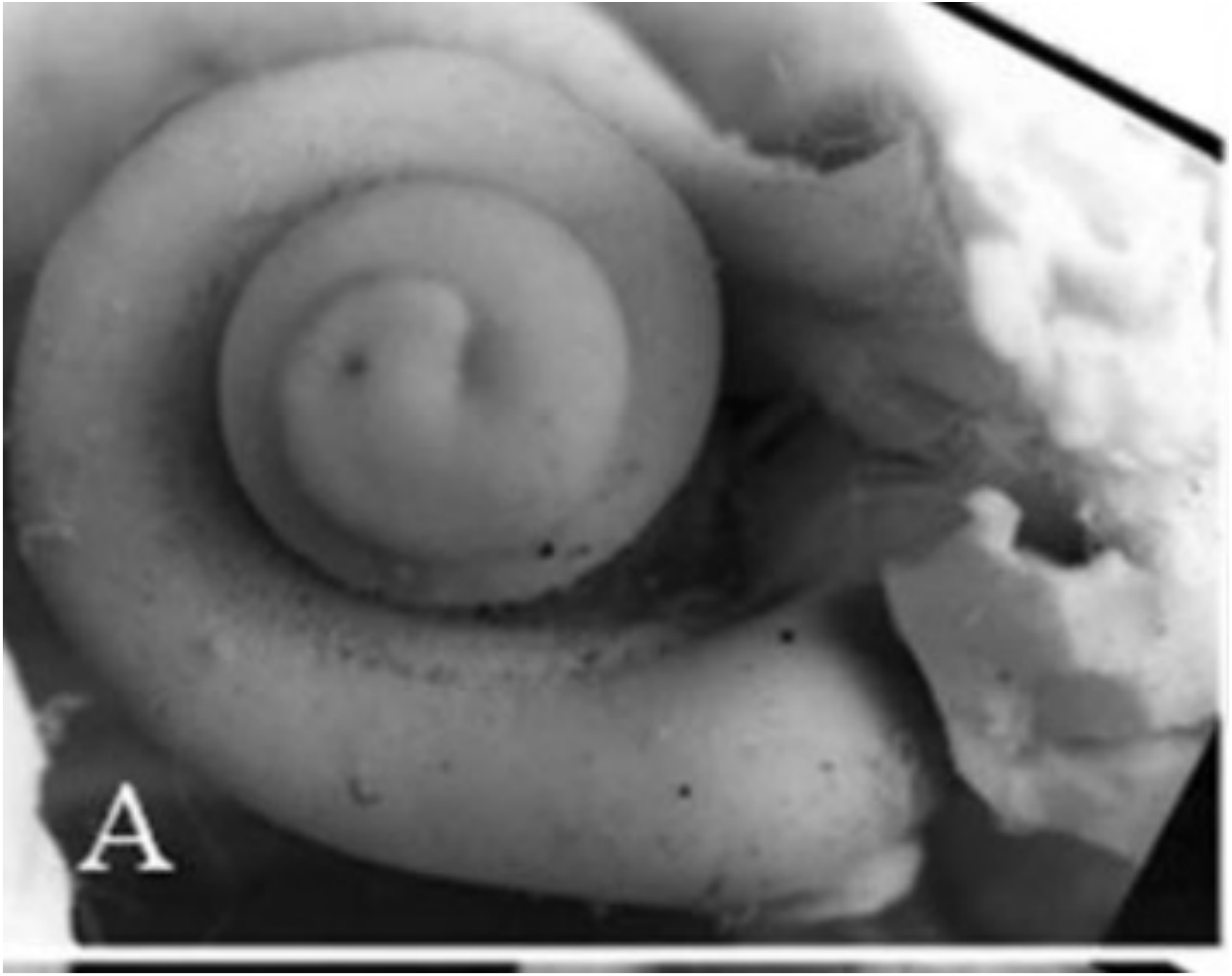


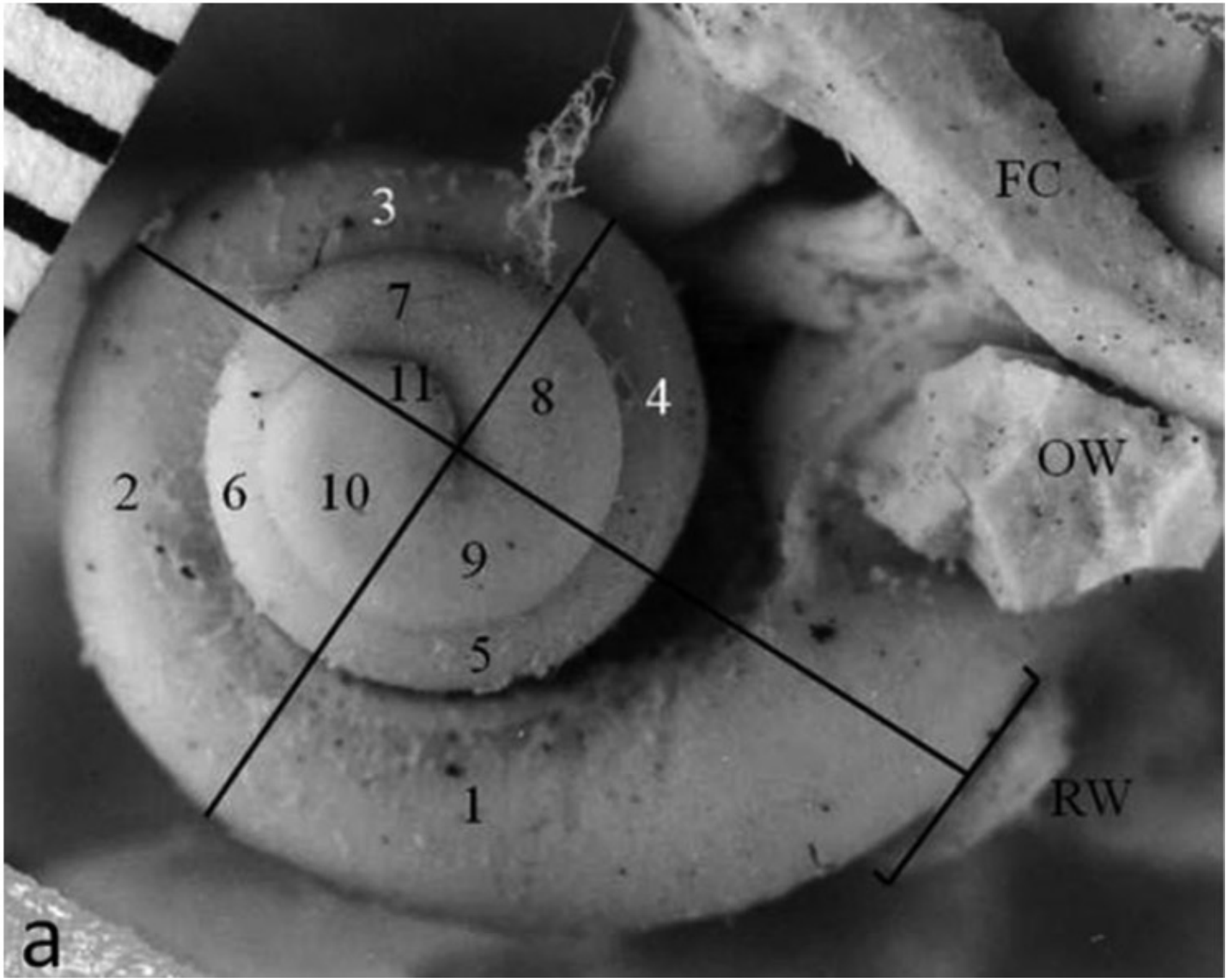
AUDITIVO

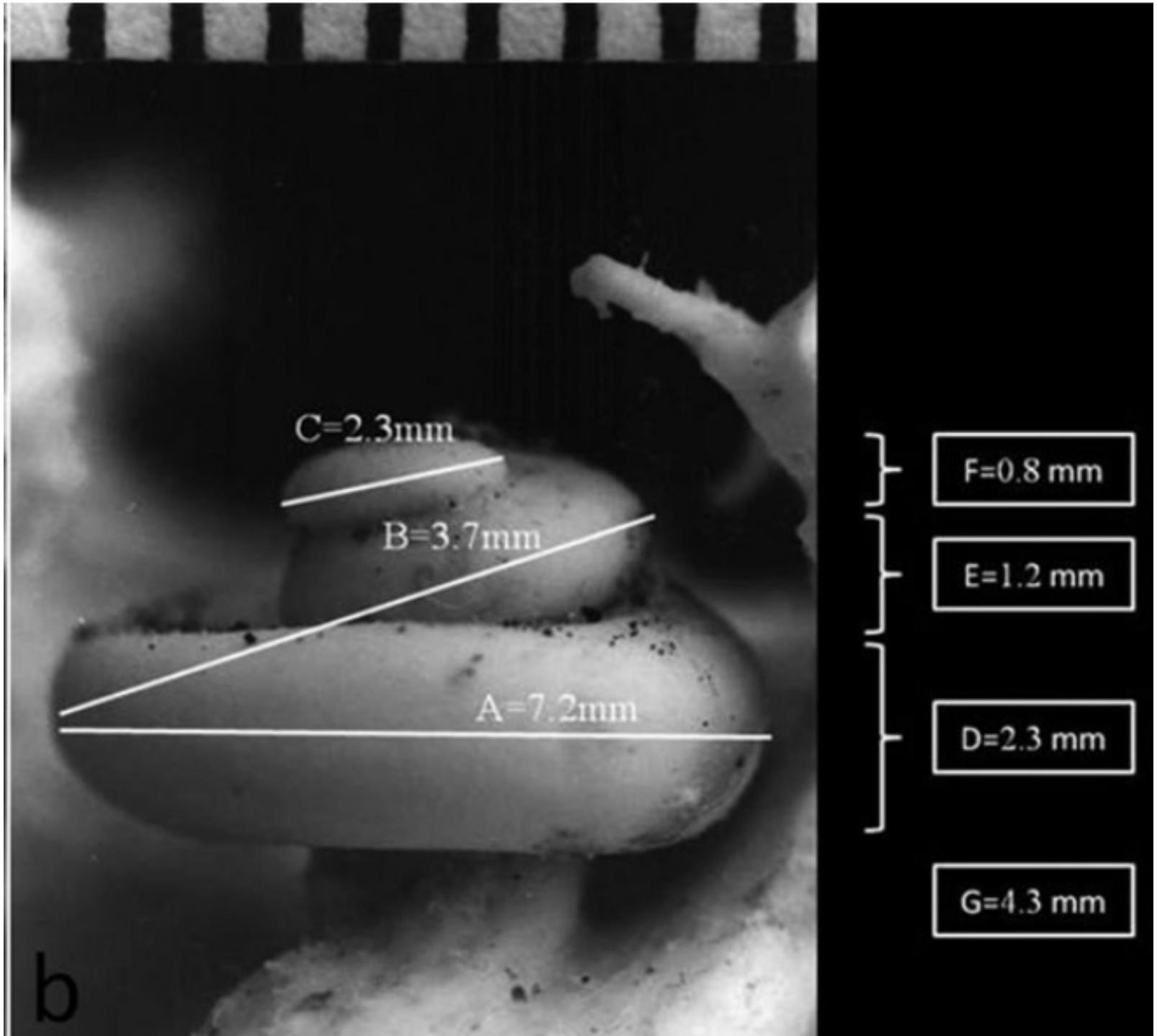


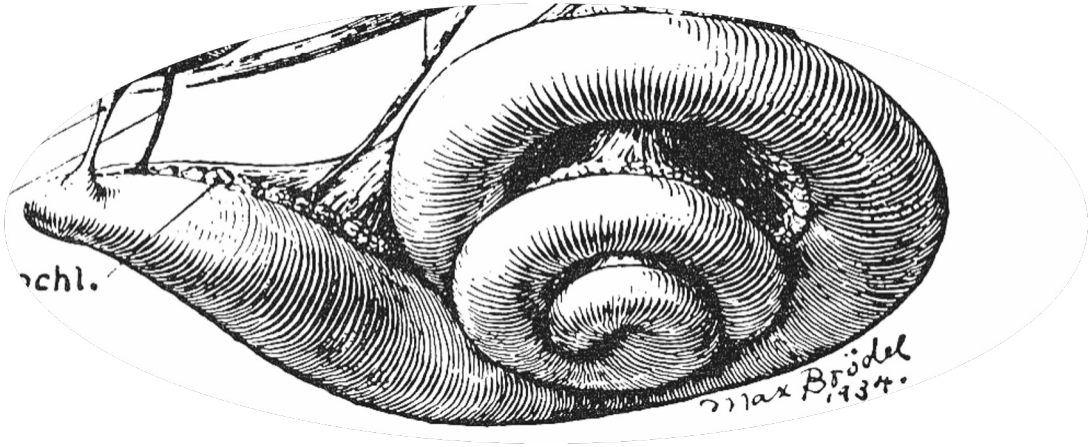
VESTIBULAR

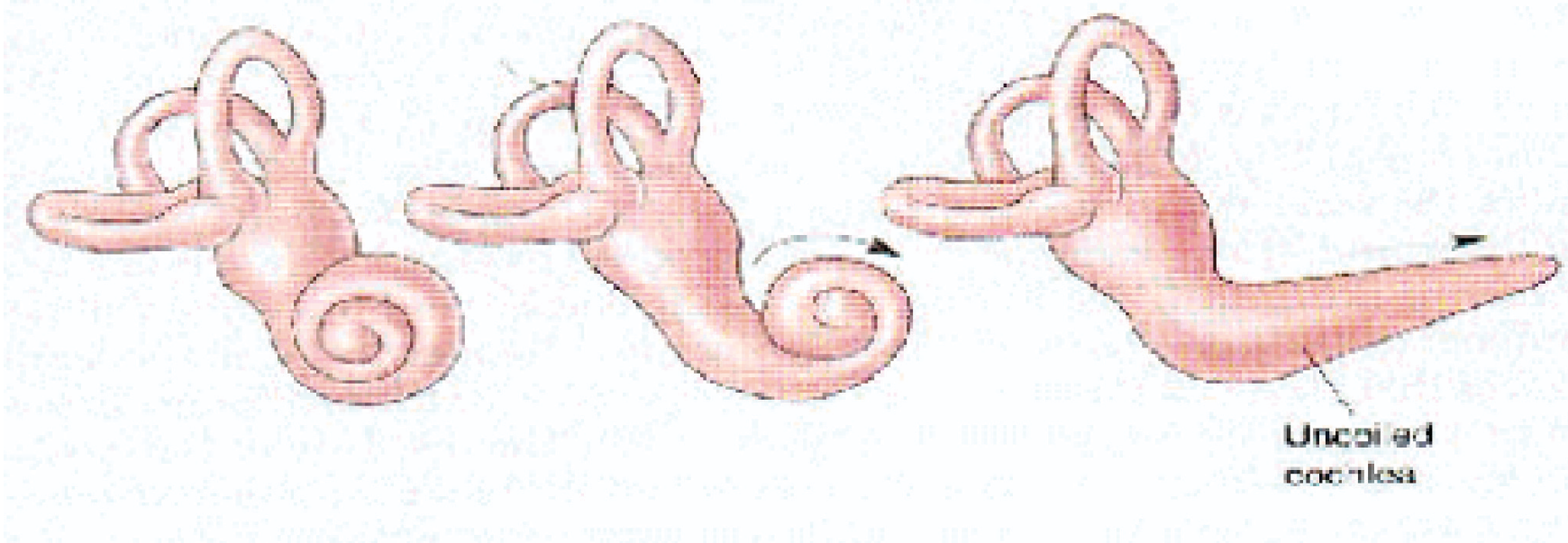

Sup.
Direction of view
Sac. end.
Post.
R. sac. sup. (Voit)
N. sac. maj.
R. vest. – cochl. (Oort)
Sup.
Inf.
Gangl. Scarpae
N. vest.
N. fac.
Lat.
Utr.
Sacculus
N. cochl.
Can. reuniens
R. cochl. – sacc.
Gangl. spir. cochl.
Max Brödel 1934.

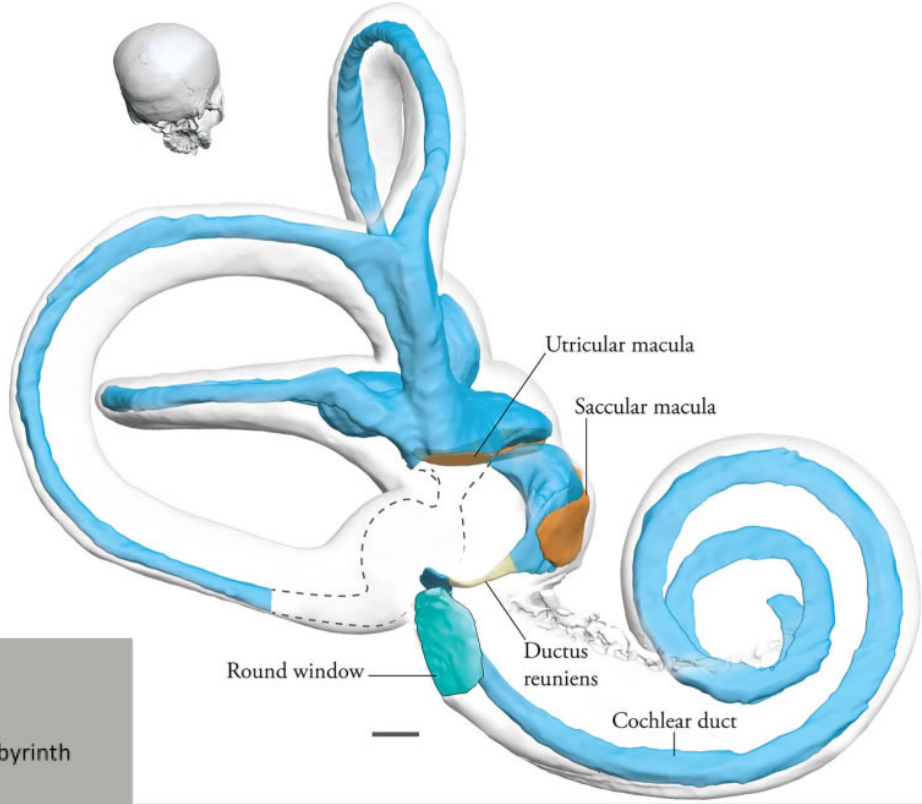

A

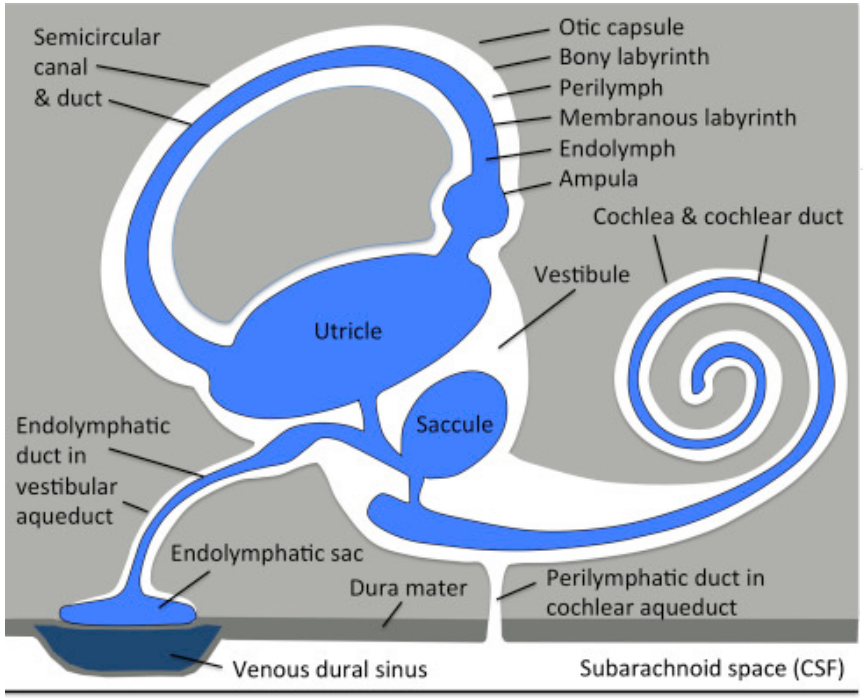

3
7
11
8
4
2
6
10
9
5
1
FC
OW
RW
a

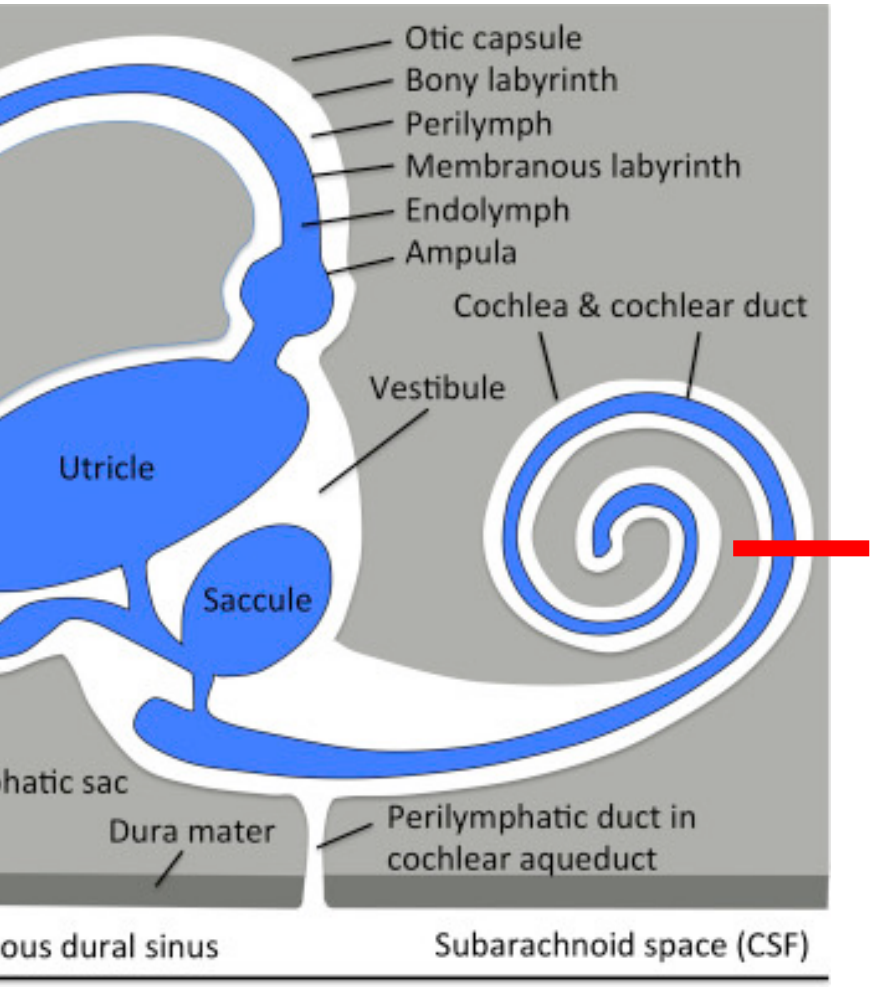

C=2.3mm
B=3.7mm
A=7.2mm
F=0.8 mm
E=1.2 mm
D=2.3 mm
G=4.3 mm
b

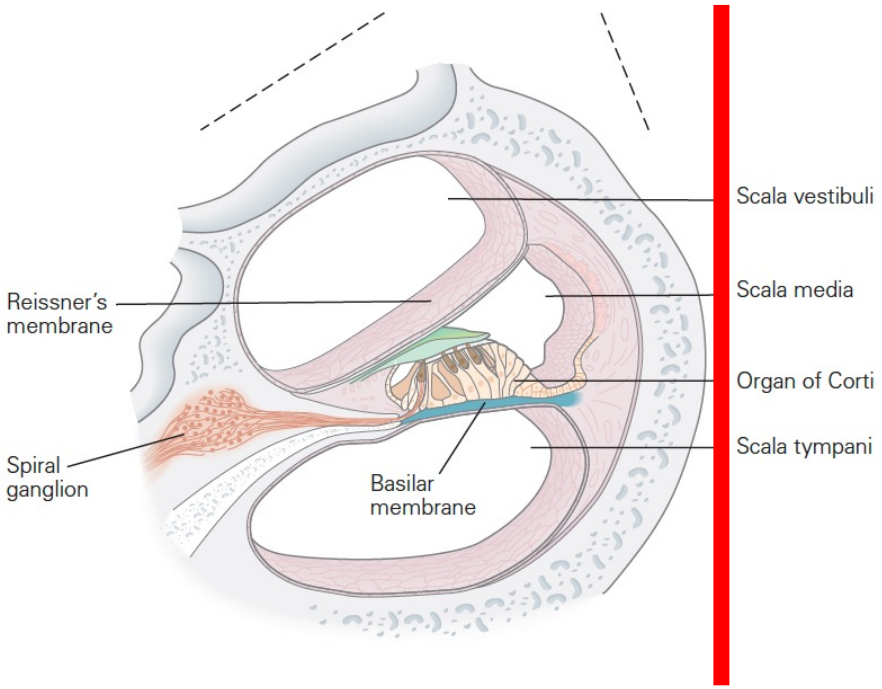

chl.
Max Brödel, 1934.

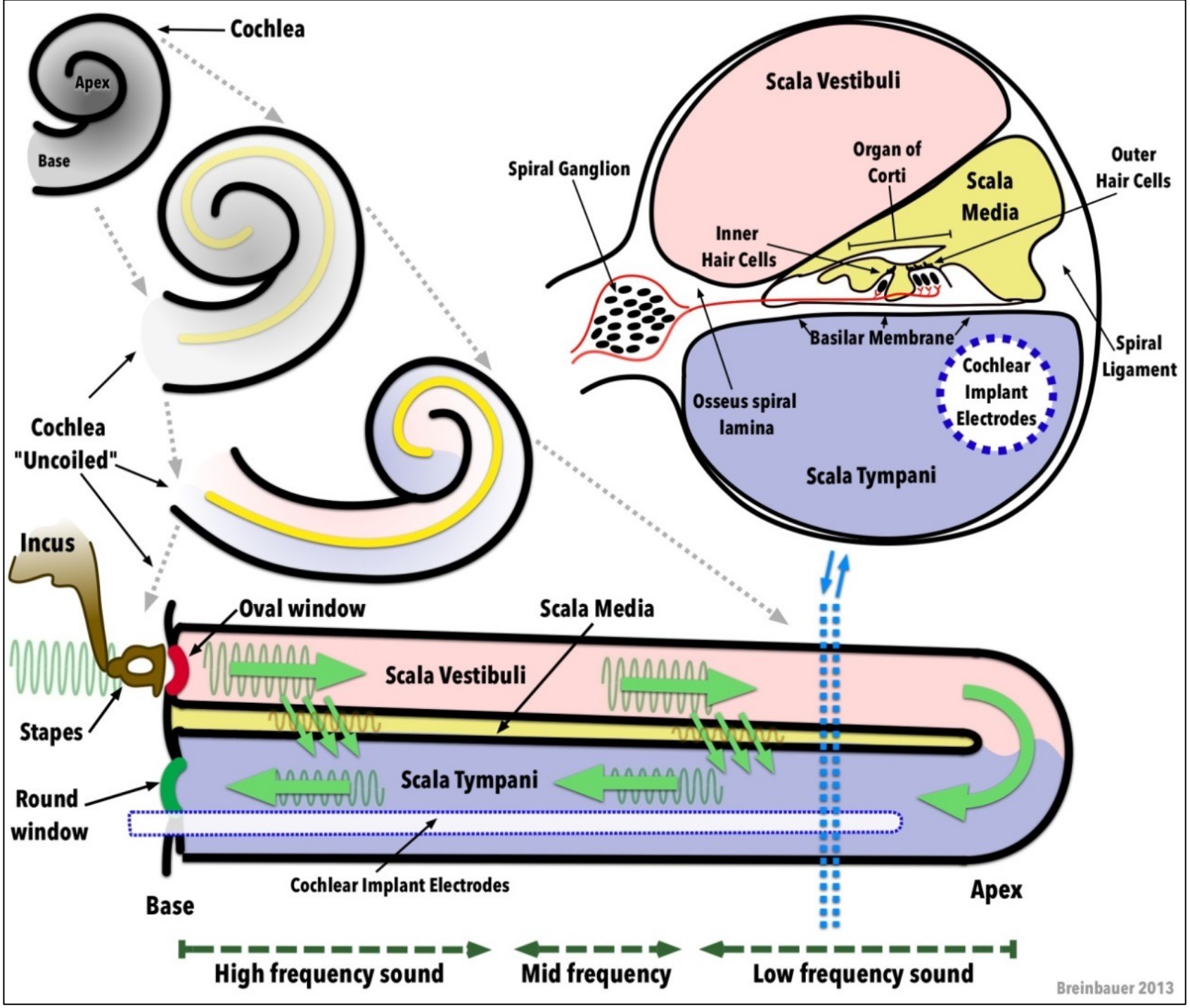

Uncoiled
cochlea

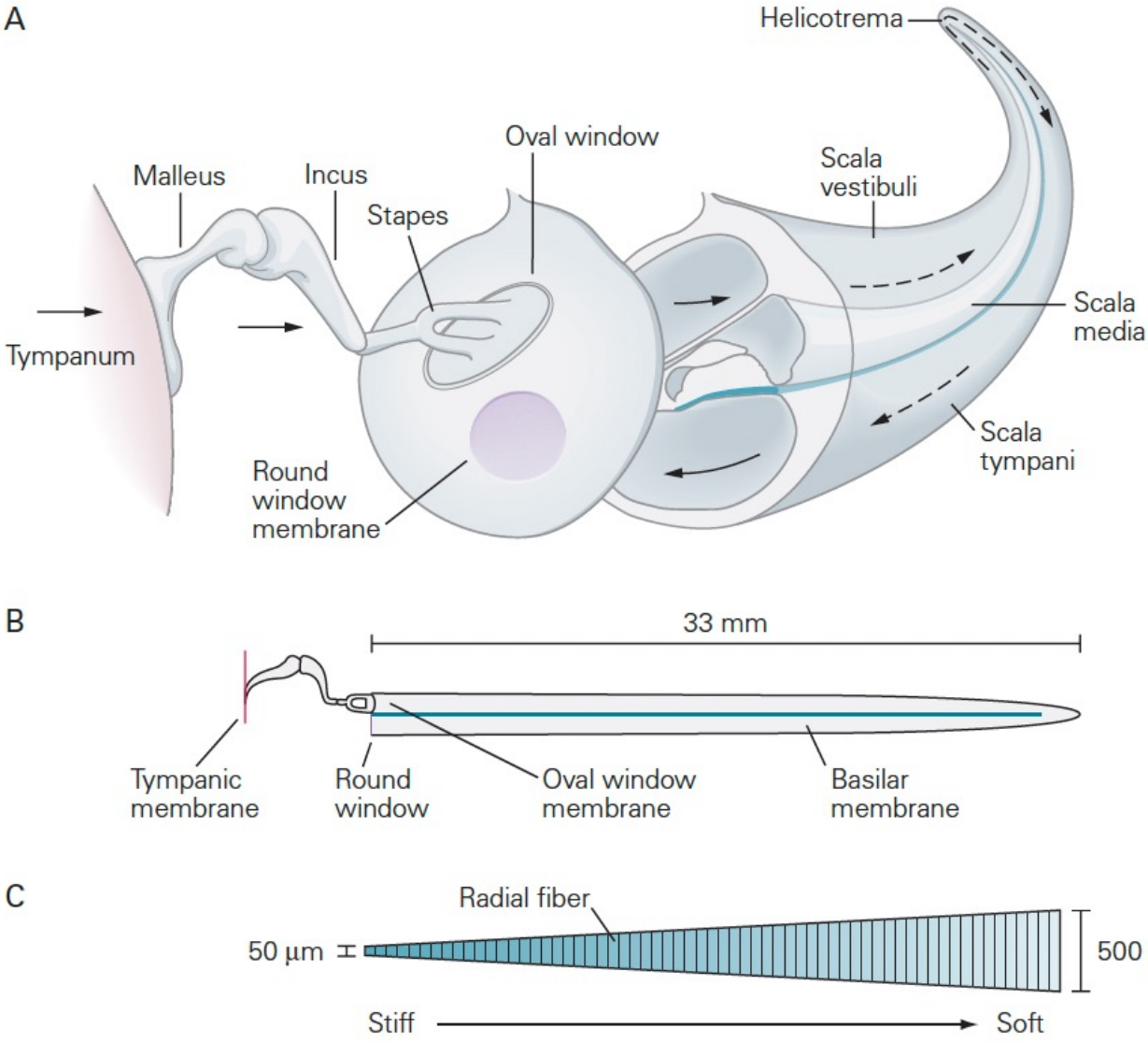

Utricular macula
Saccular macula
Ductus reuniens
Round window
Cochlear duct

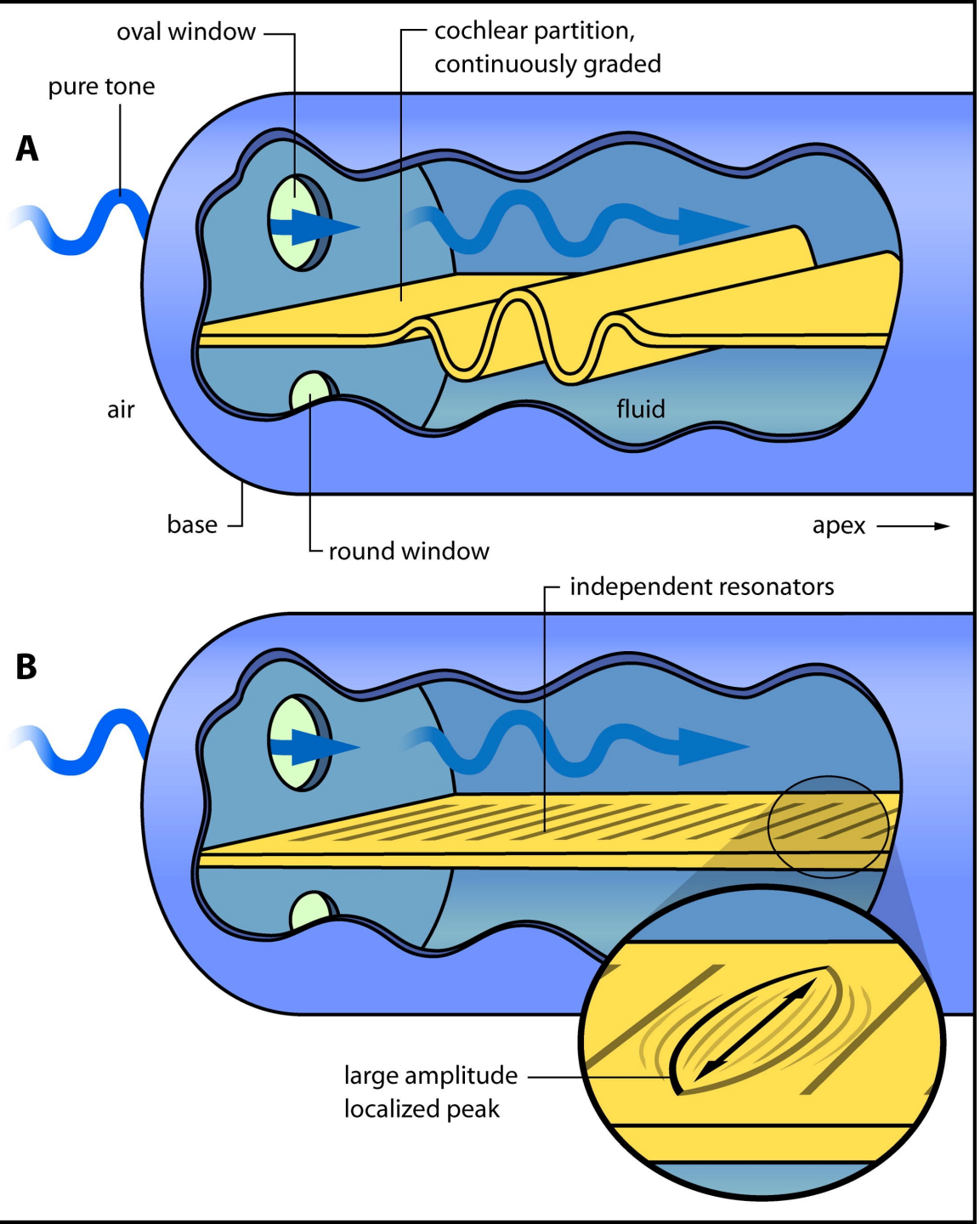

Semicircular canal & duct
Otic capsule
Bony labyrinth
Perilymph
Membranous labyrinth
Endolymph
Ampula
Cochlea & cochlear duct
Vestibule
Utricle
Saccule
Endolymphatic duct in vestibular aqueduct
Endolymphatic sac
Dura mater
Perilymphatic duct in cochlear aqueduct
Venous dural sinus
Subarachnoid space (CSF)


Otic capsule
Bony labyrinth
Perilymph
Membranous labyrinth
Endolymph
Ampula
Cochlea & cochlear duct
Vestibule
Utricle
Saccule
hatic sac
Dura mater
Perilymphatic duct in
cochlear aqueduct
ous dural sinus
Subarachnoid space (CSF)


Scala vestibuli
Scala media
Reissner's
membrane
Organ of Corti
Scala tympani
Spiral
ganglion
Basilar
membrane


Cochlea
Apex
Base
Cochlea "Uncoiled"
Scala Vestibuli
Organ of Corti
Scala Media
Spiral Ganglion
Outer Hair Cells
Inner Hair Cells
Basilar Membrane
Spiral Ligament
Cochlear Implant Electrodes
Osseus spiral lamina
Scala Tympani
Incus
Oval window
Scala Media
Scala Vestibuli
Stapes
Scala Tympani
Round window
Cochlear Implant Electrodes
Base
Apex
High frequency sound
Mid frequency
Low frequency sound
Breinbauer 2013


A
Helicotrema
Oval window
Malleus
Incus
Stapes
Scala vestibuli
Scala media
Tympanum
Scala tympani
Round window membrane
B
33 mm
Tympanic membrane
Round window
Oval window membrane
Basilar membrane
C
Radial fiber
50 µm
500 µm
Stiff
Soft


oval window
cochlear partition,
continuously graded
pure tone
A
air
fluid
base
round window
apex
independent resonators
B
large amplitude
localized peak

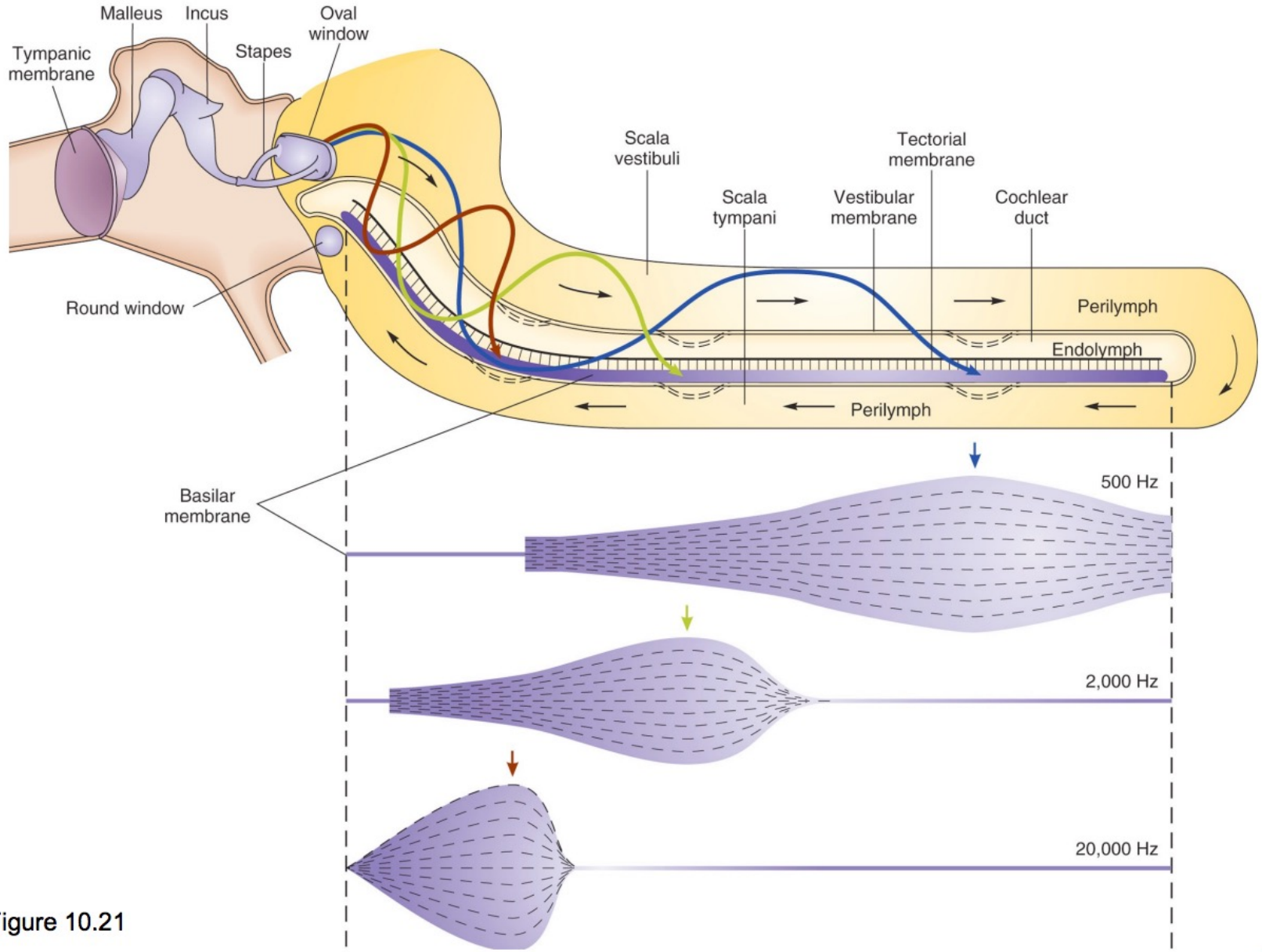
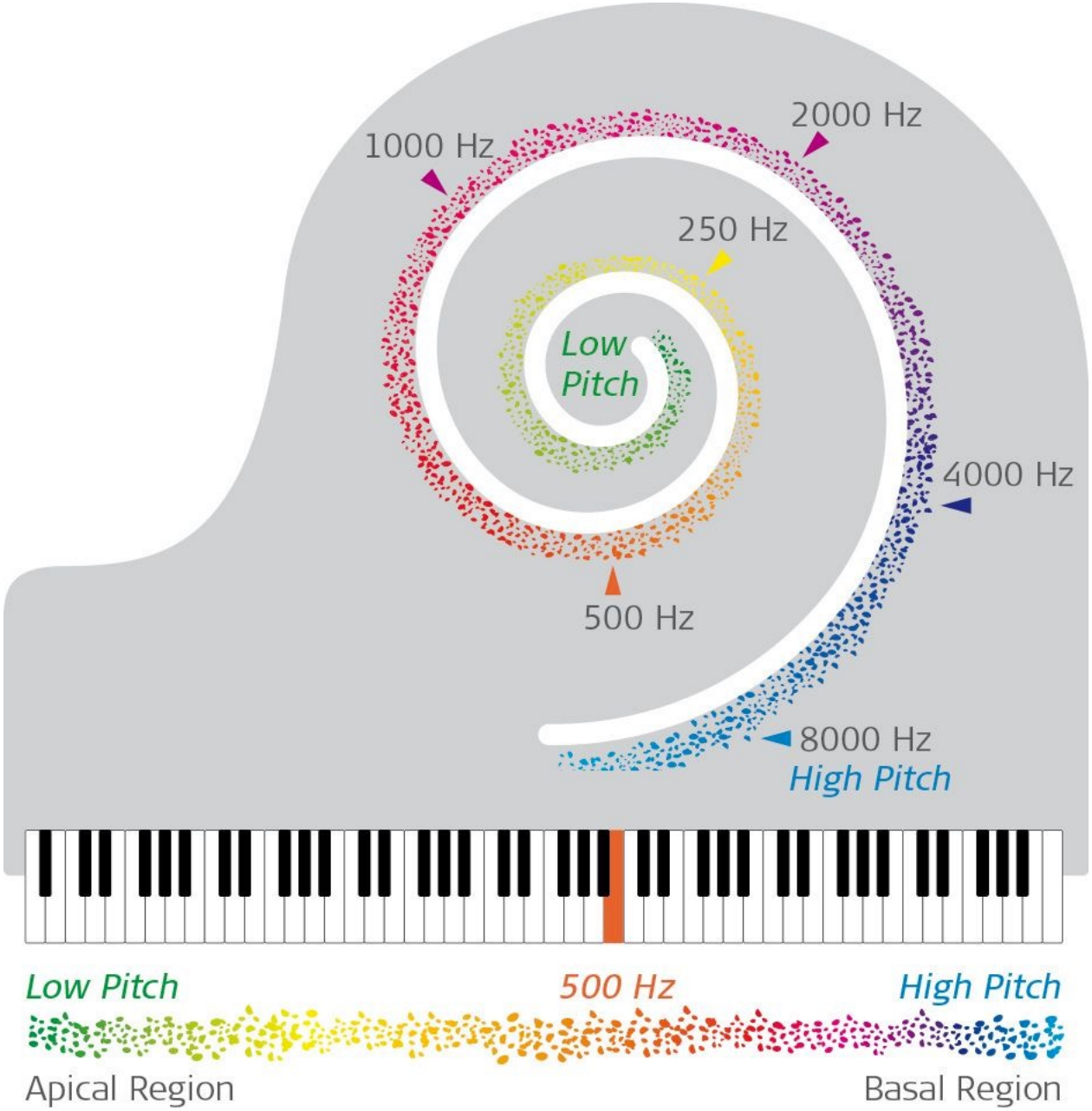
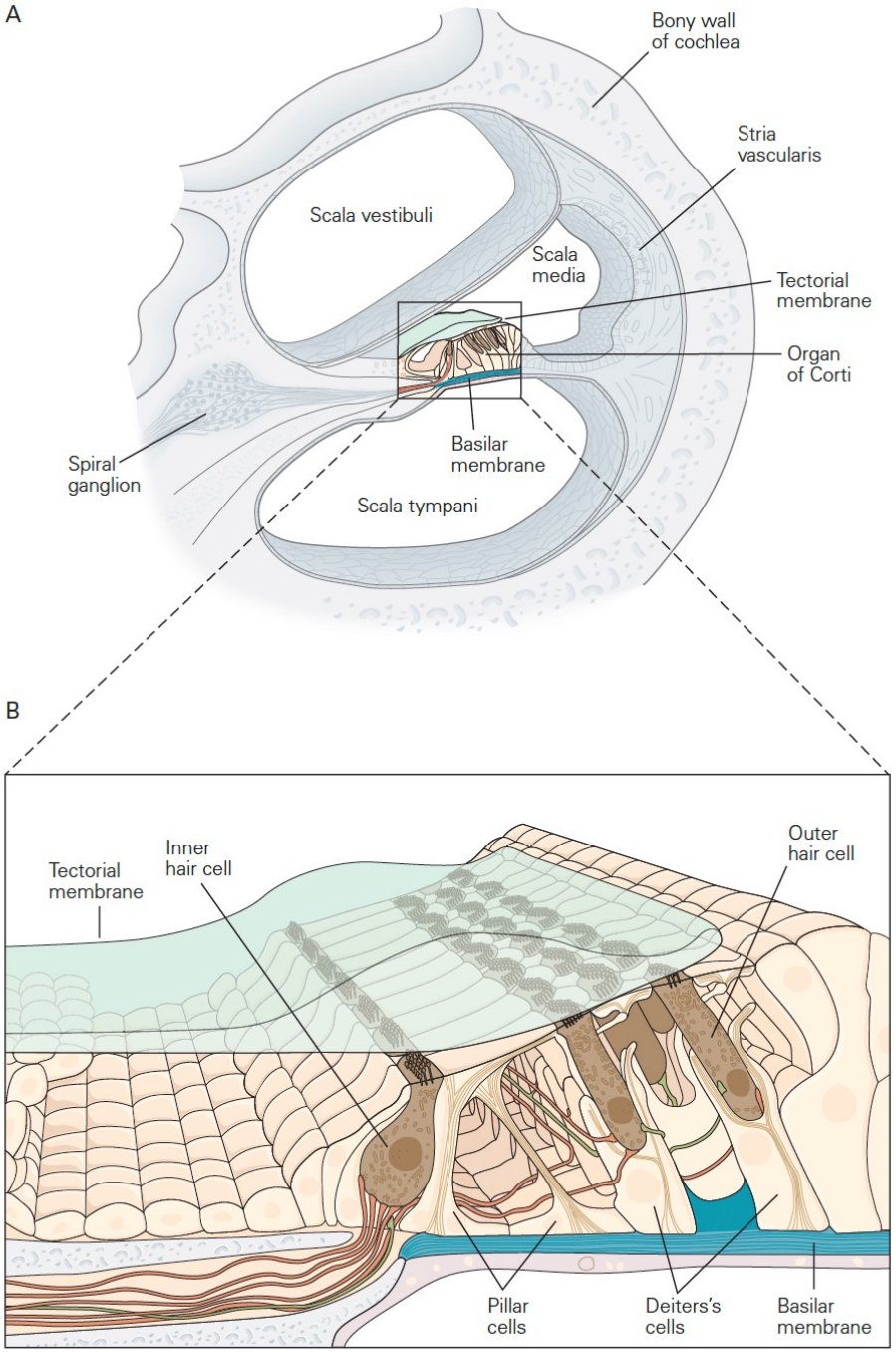
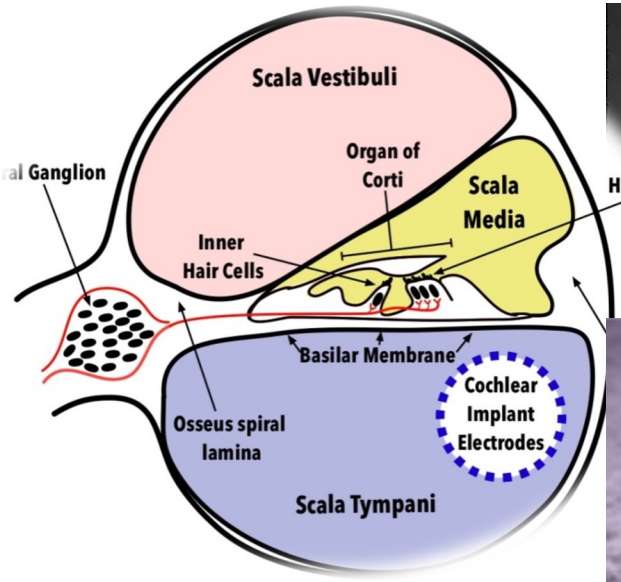

Malleus
Incus
Oval window
Tympanic membrane
Stapes
Scala vestibuli
Tectorial membrane
Scala tympani
Vestibular membrane
Cochlear duct
Round window
Perilymph
Endolymph
Perilymph
Basilar membrane
500 Hz
2,000 Hz
20,000 Hz

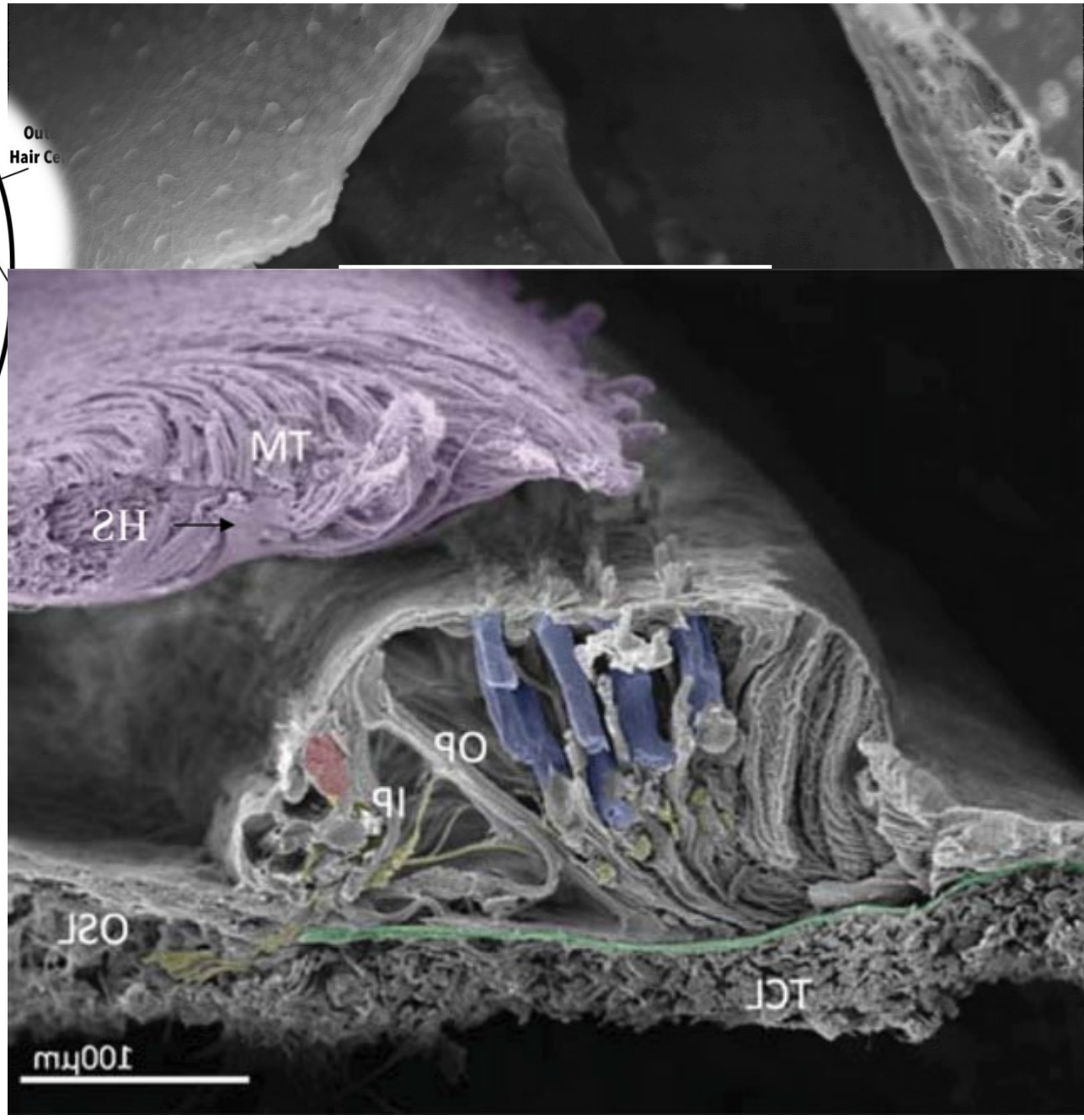
Figure 10.21

Tonotopía

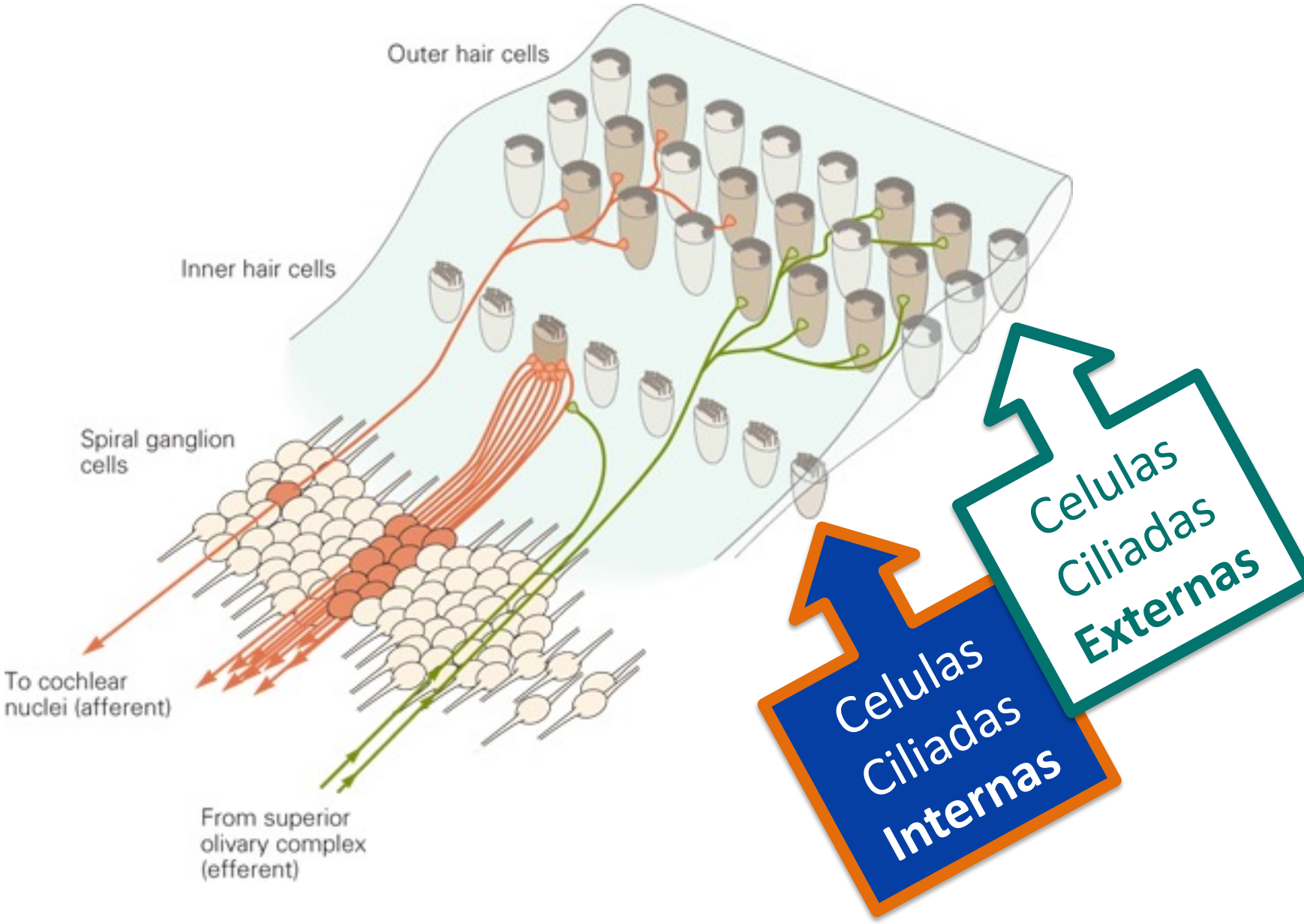

1000 Hz
2000 Hz
250 Hz
Low
Pitch
4000 Hz
500 Hz
8000 Hz
High Pitch
Low Pitch
500 Hz
High Pitch
Apical Region
Basal Region

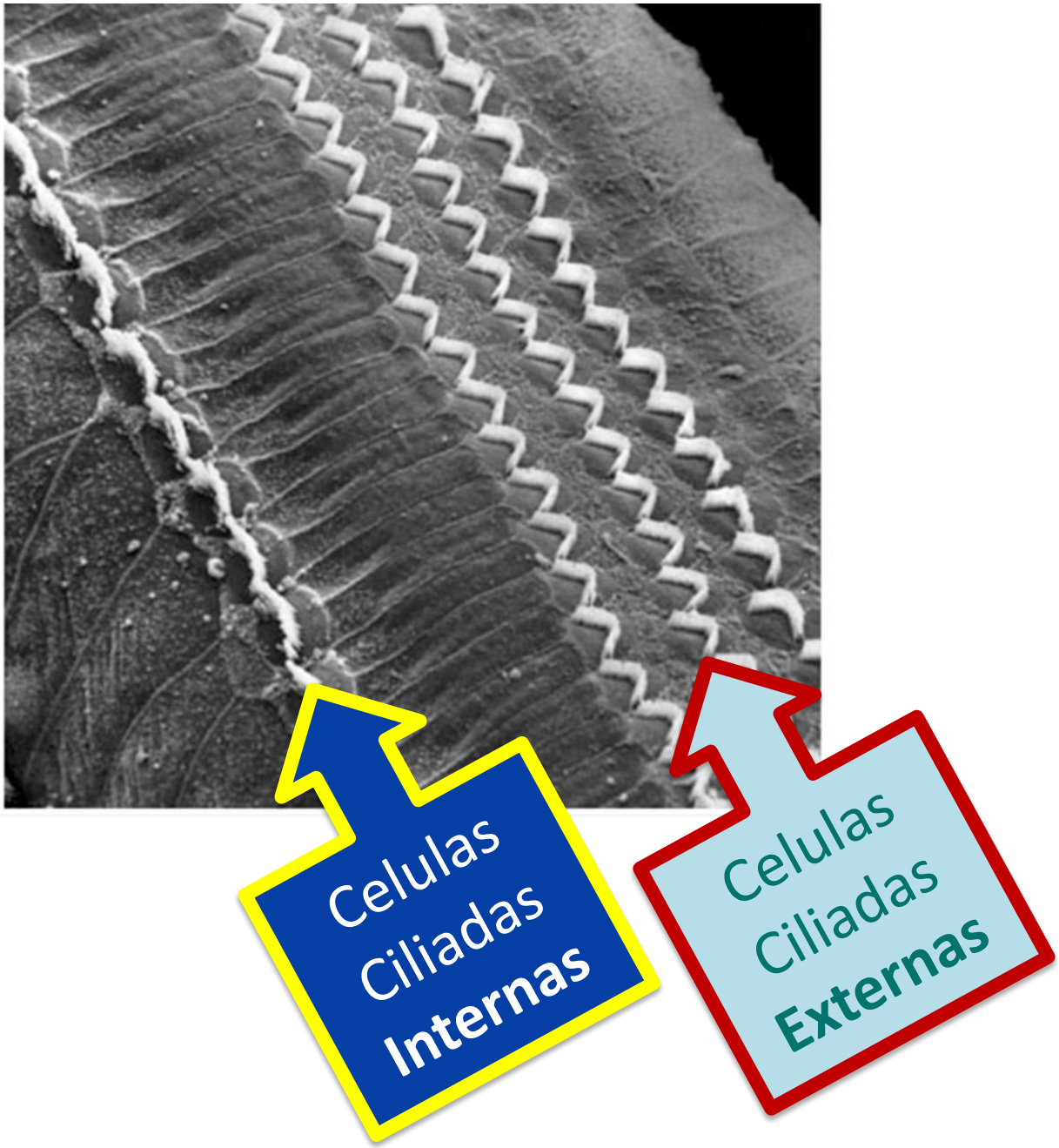

A
Bony wall of cochlea
Stria vascularis
Scala vestibuli
Scala media
Tectorial membrane
Organ of Corti
Spiral ganglion
Basilar membrane
Scala tympani
B
Tectorial membrane
Inner hair cell
Outer hair cell
Pillar cells
Deiters's cells
Basilar membrane

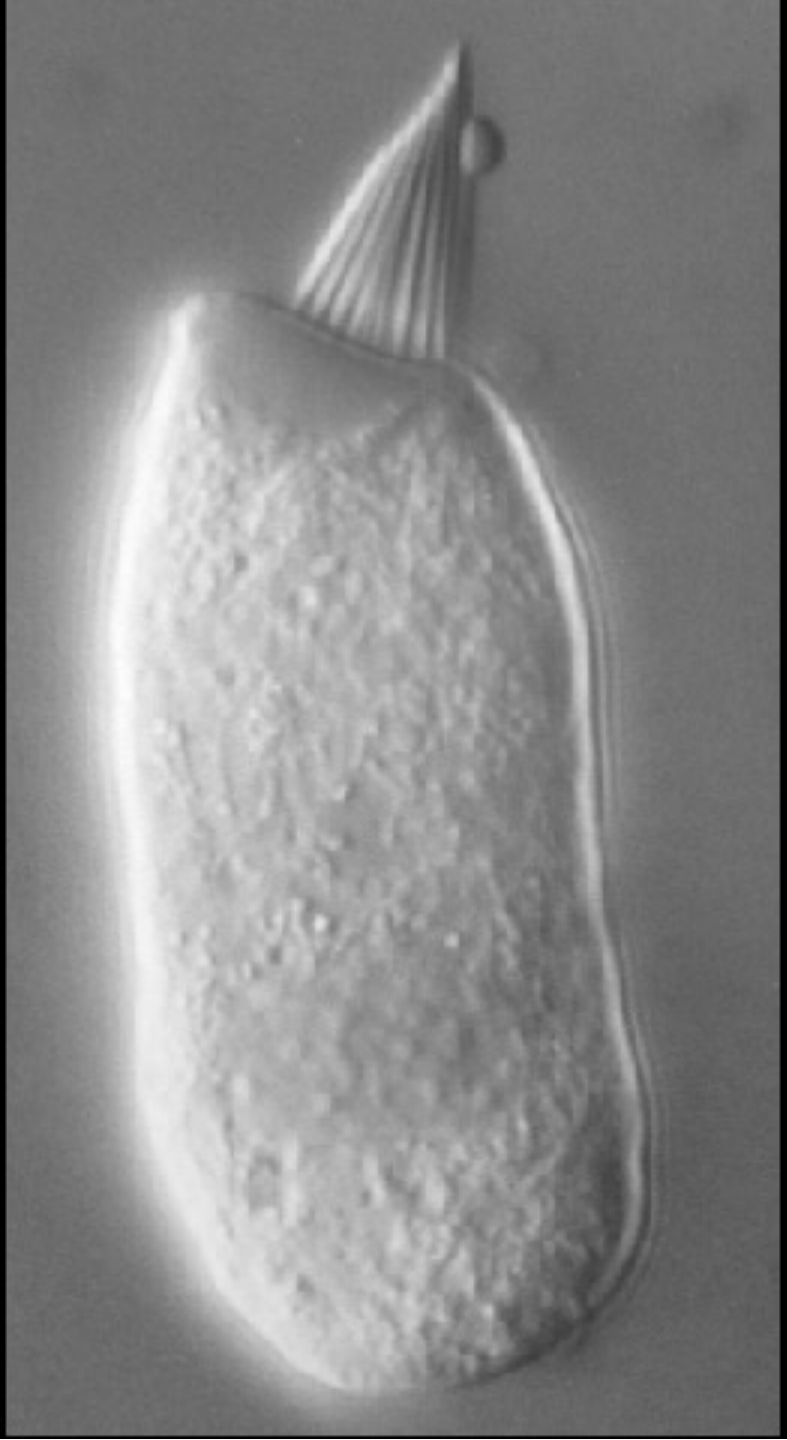


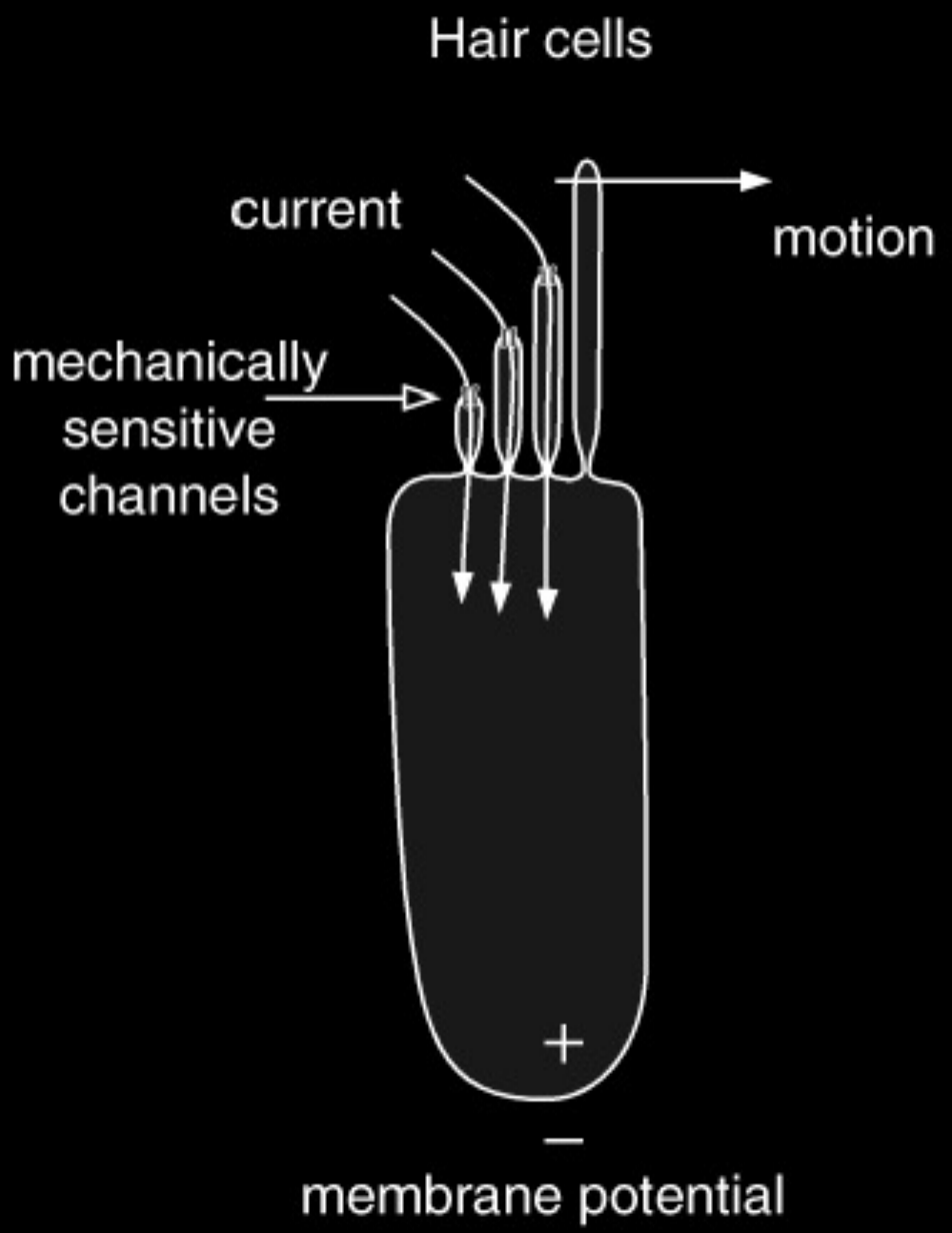


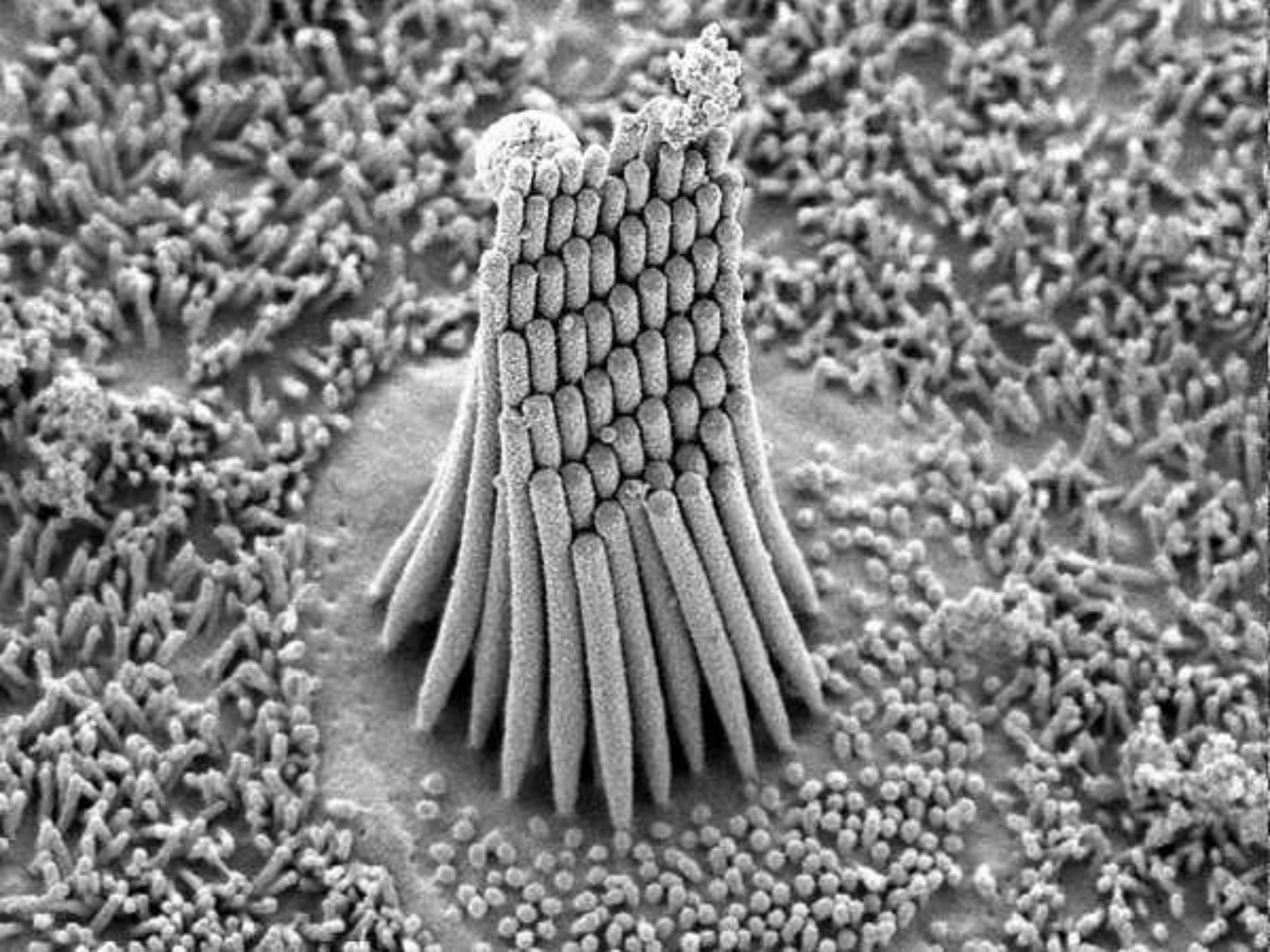
Rask-Andersen 2012

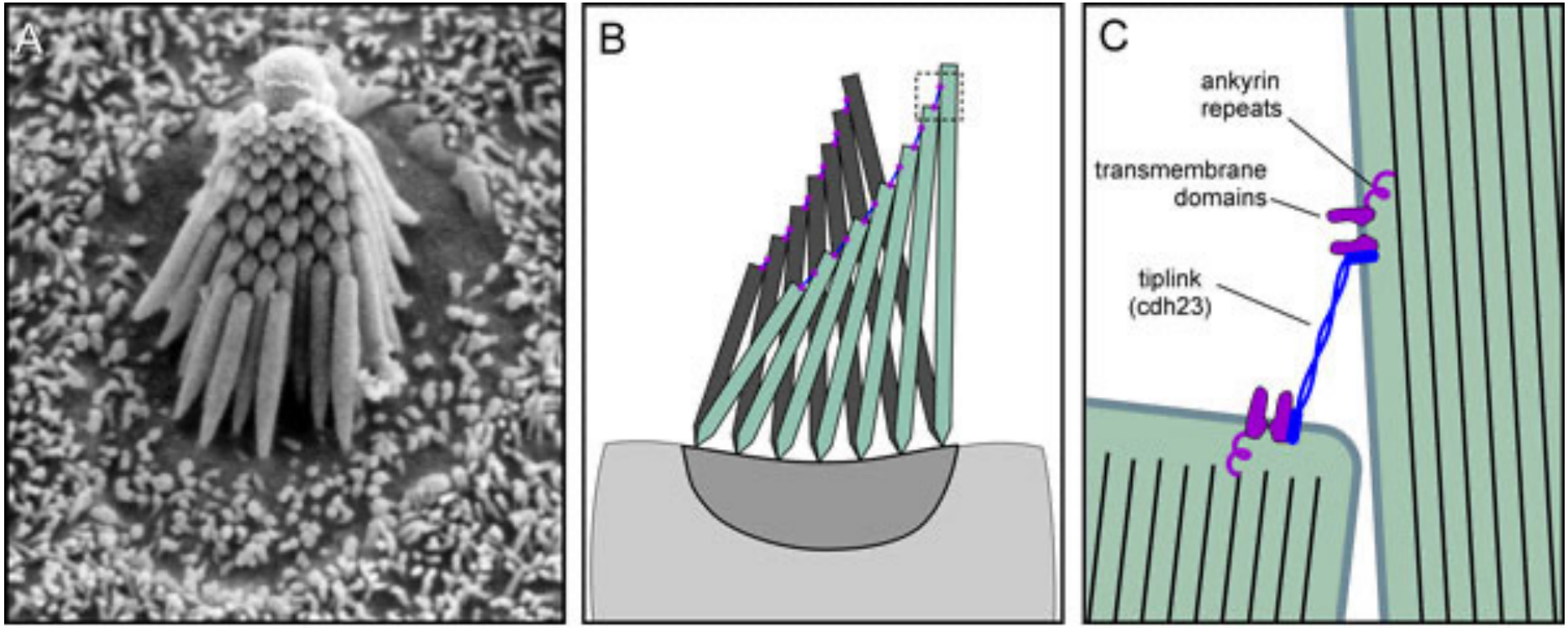

Outer hair cells
Inner hair cells
Spiral ganglion cells
To cochlear nuclei (afferent)
From superior olivary complex (efferent)
Celulas Ciliadas Externas
Celulas Ciliadas Internas


Celulas
Ciliadas
Internas
Celulas
Ciliadas
Externas

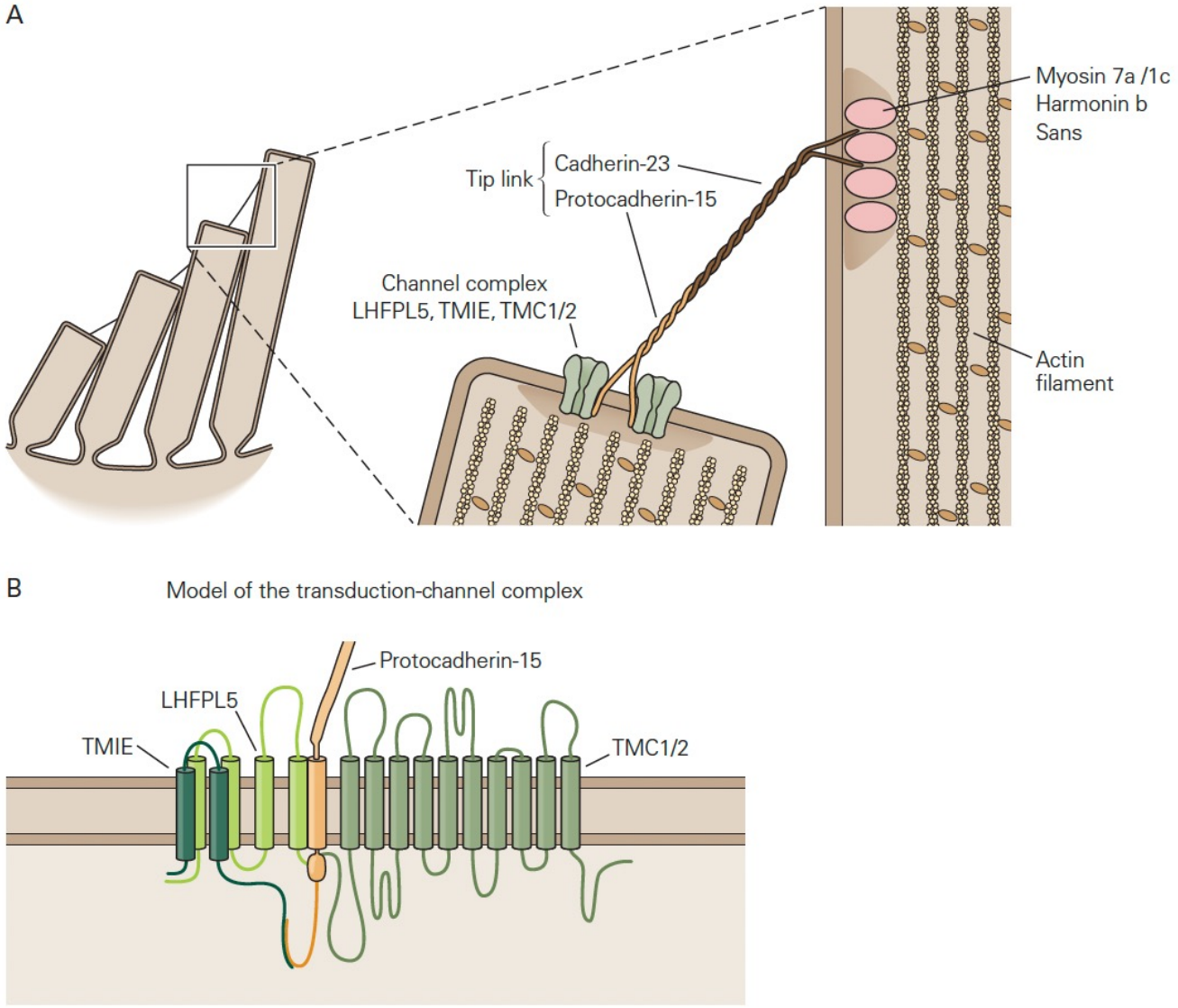



Hair cells
current
motion
mechanically
sensitive
channels
+
–
membrane potential

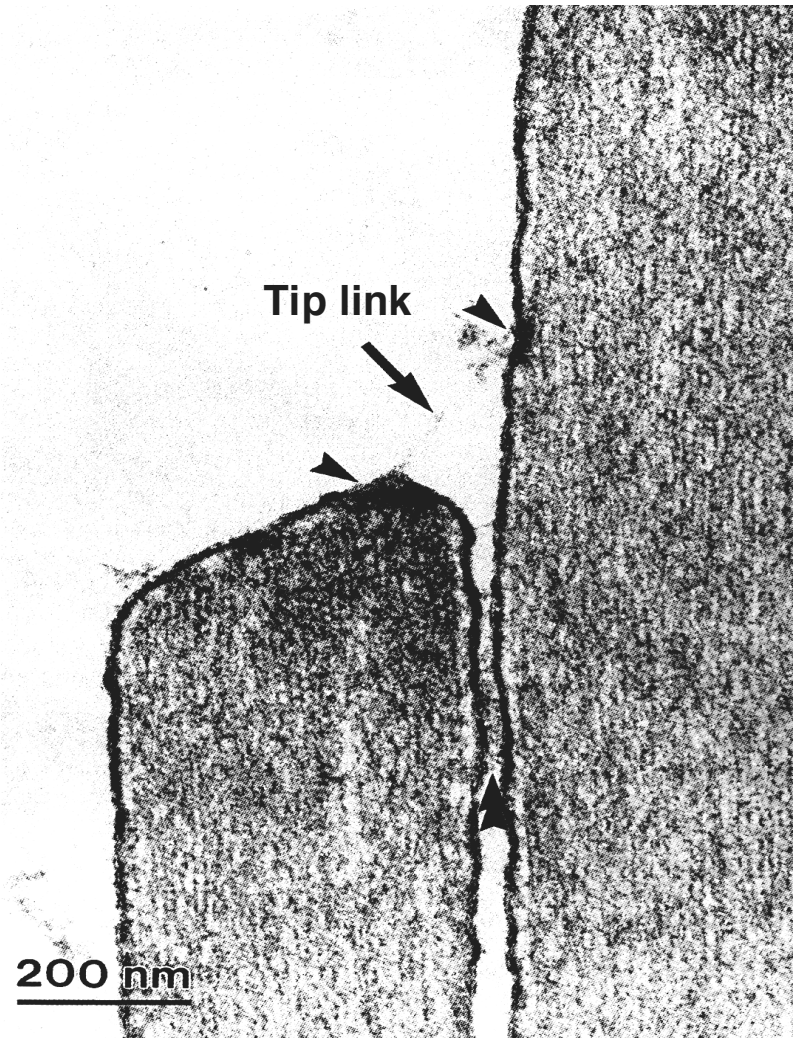


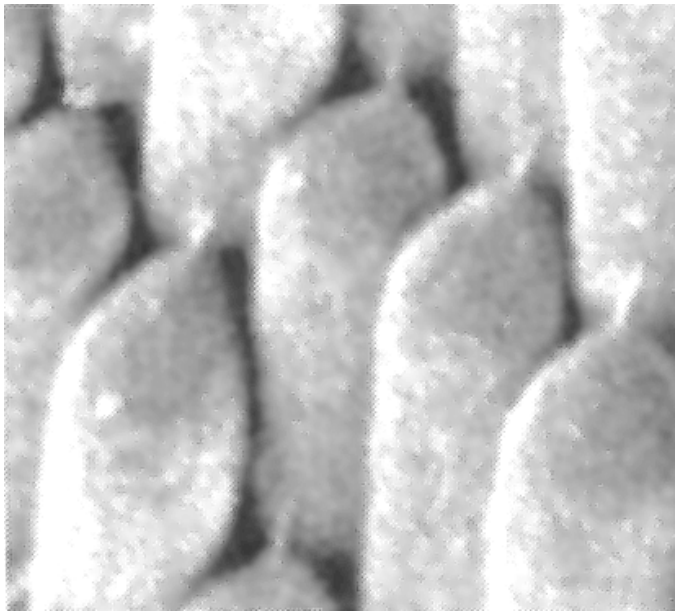


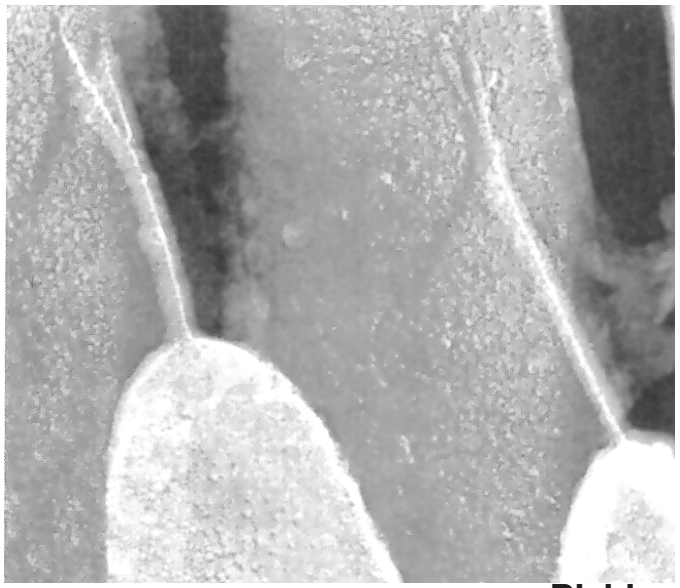
Theoretical and Computational Biophysics Group
Beckman Institute
University of Illinois at Urbana-Champaign


A
Myosin 7a /1c
Harmonin b
Sans
Tip link
Cadherin-23
Protocadherin-15
Channel complex
LHFPL5, TMIE, TMC1/2
Actin
filament
B
Model of the transduction-channel complex
Protocadherin-15
LHFPL5
TMIE
TMC1/2

Tip links

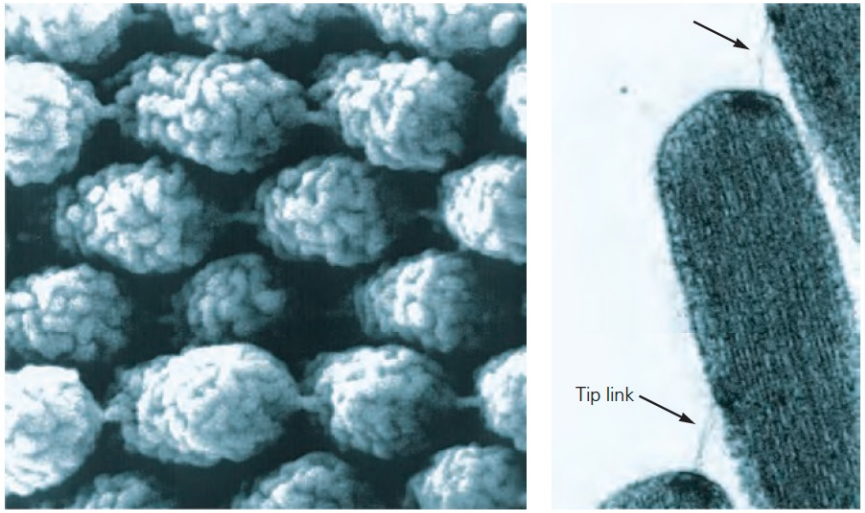




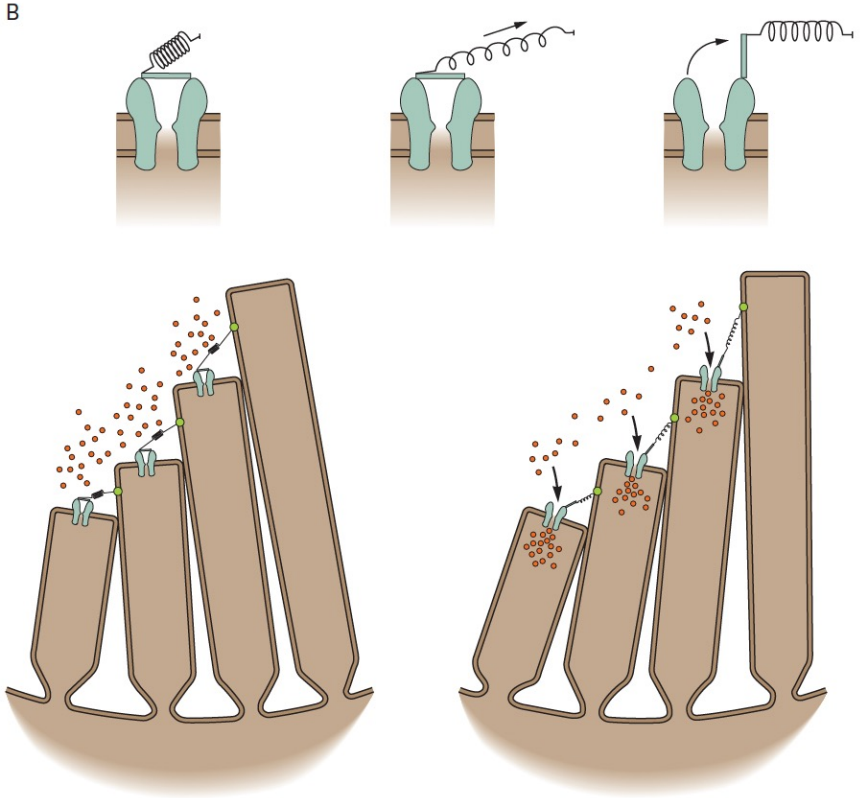


Pickles, 1984

A

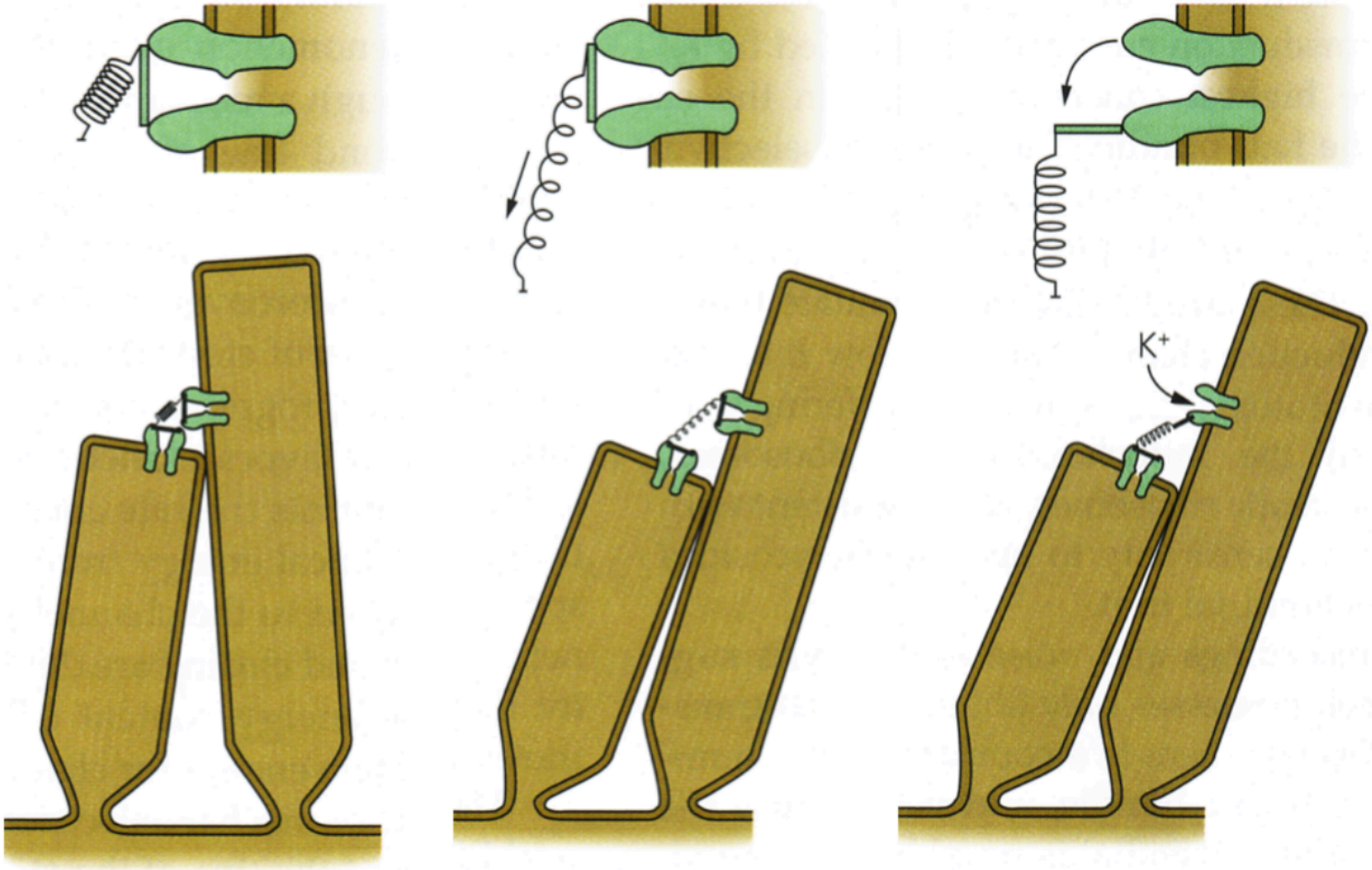


B



Deflection of stereocilia opens K+ channels

K+ rushes into hair cell, causing depolarization



Deflexión Cilios

Apertura Canales por tensión

Tip-links

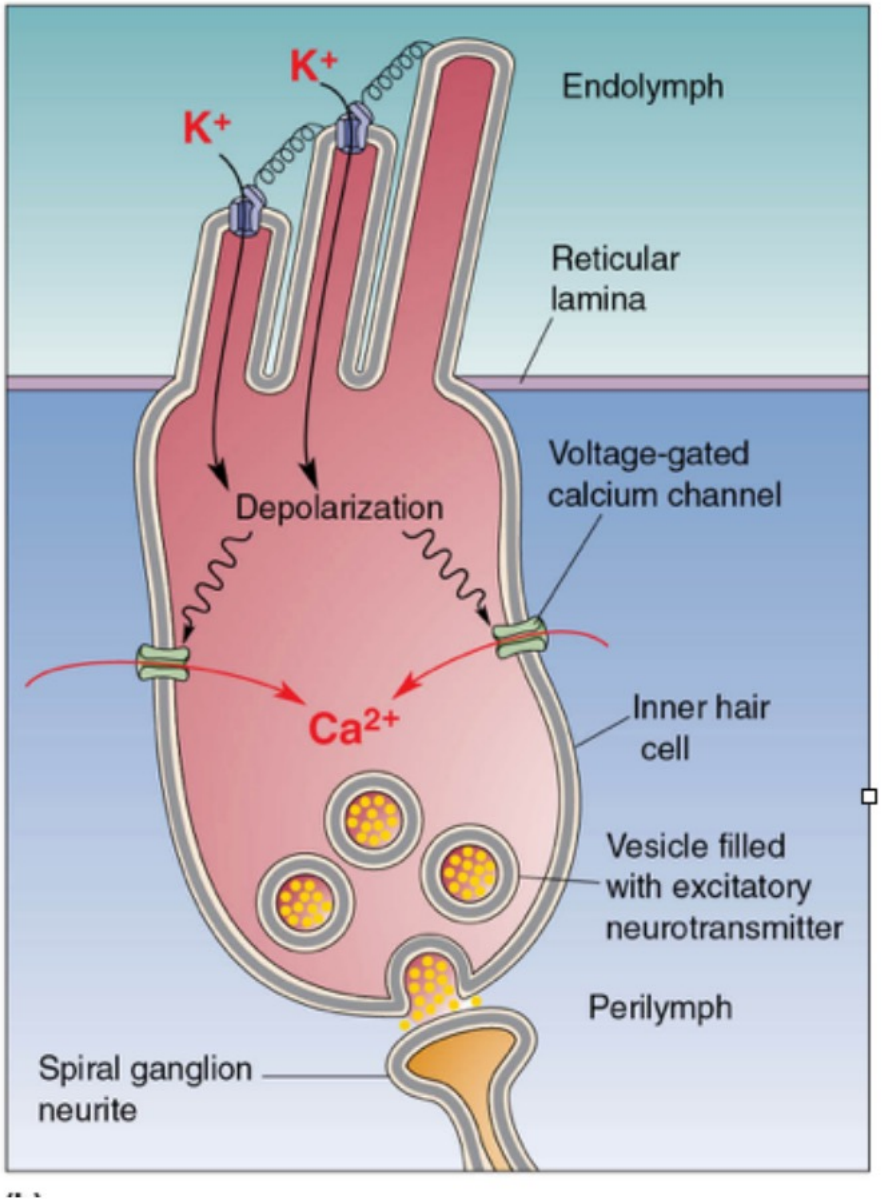
Ingreso K^+

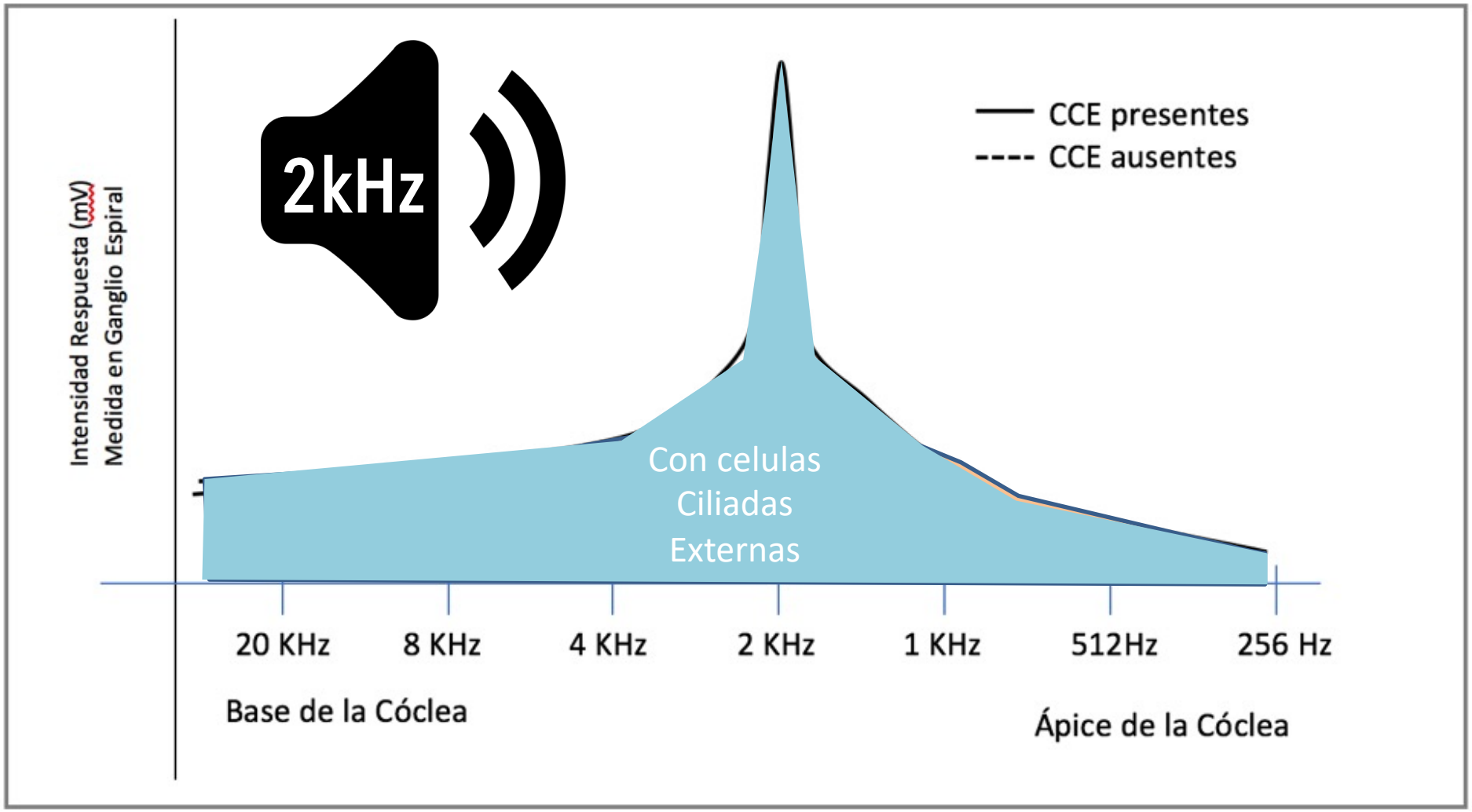
Depolarización

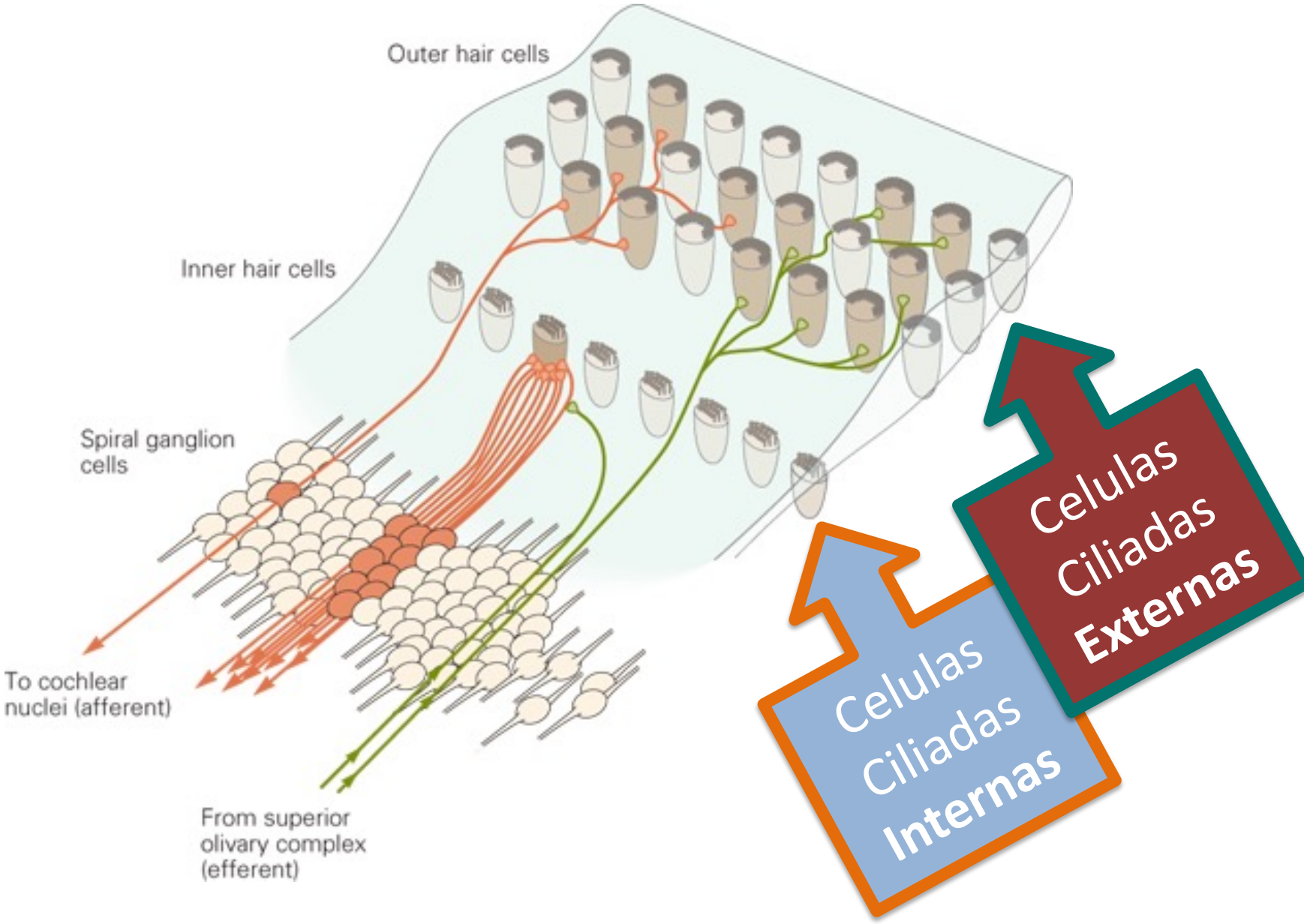
Apertura Canales de Ca^+

Excositosis Vesiculas con Neurotransmisores (Glutamato)

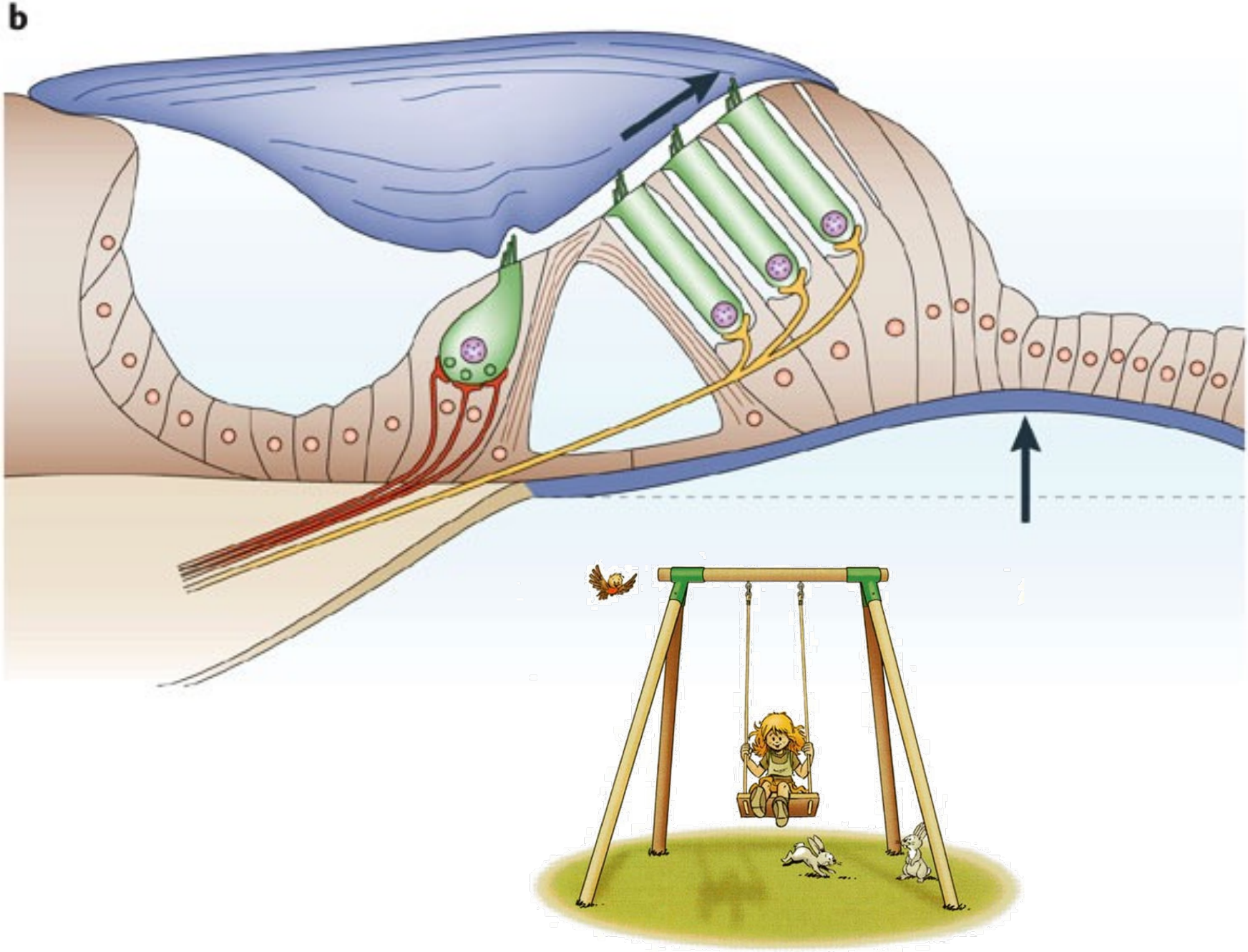
Dentrita Aferente → Potencial de Acción en Ganglio de Scarpa

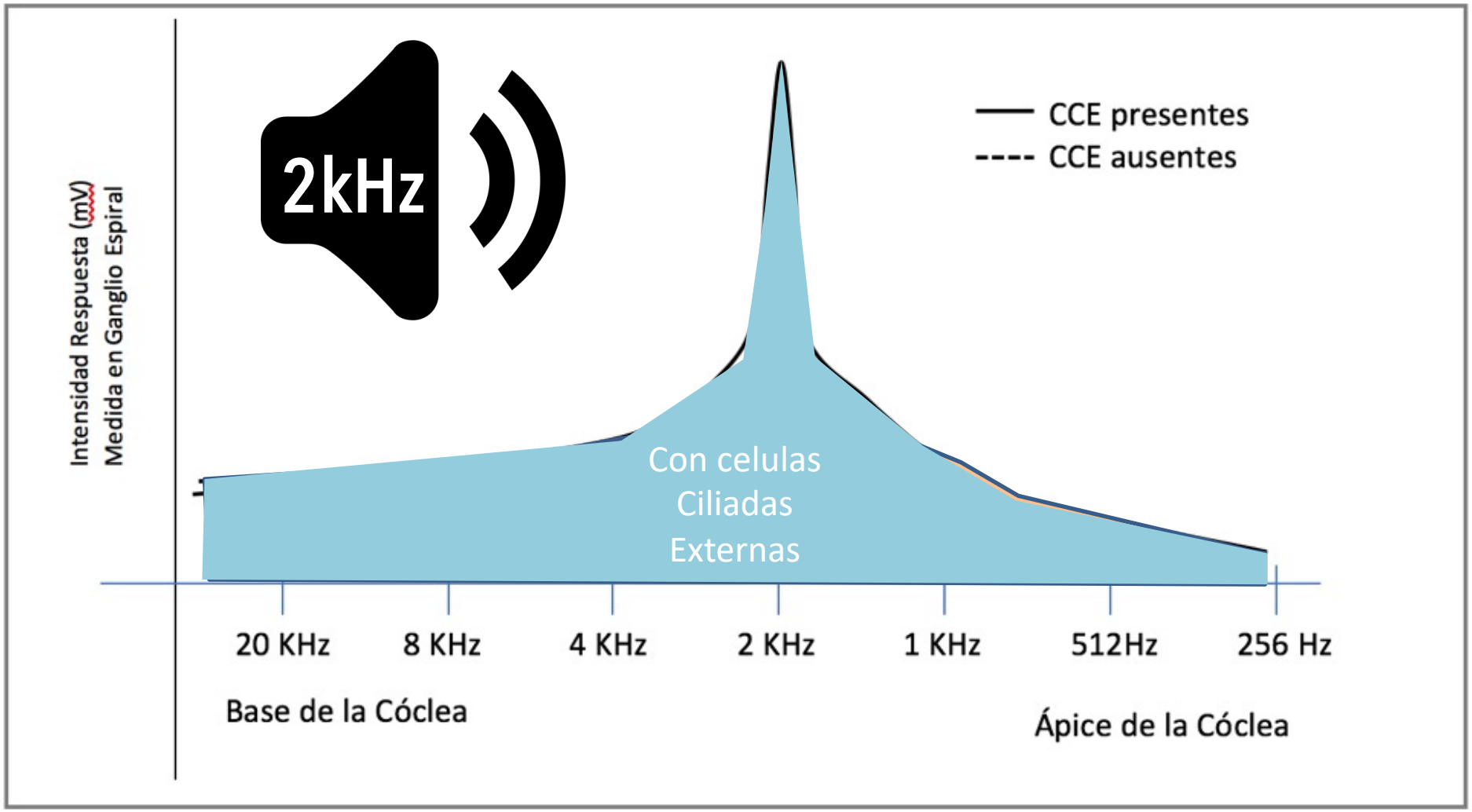



2kHz
CCE presentes
CCE ausentes
Intensidad Respuesta (mV)
Medida en Ganglio Espiral
Con celulas
Ciliadas
Externas
20 KHz
8 KHz
4 KHz
2 KHz
1 KHz
512Hz
256 Hz
Base de la Cóclea
Ápice de la Cóclea

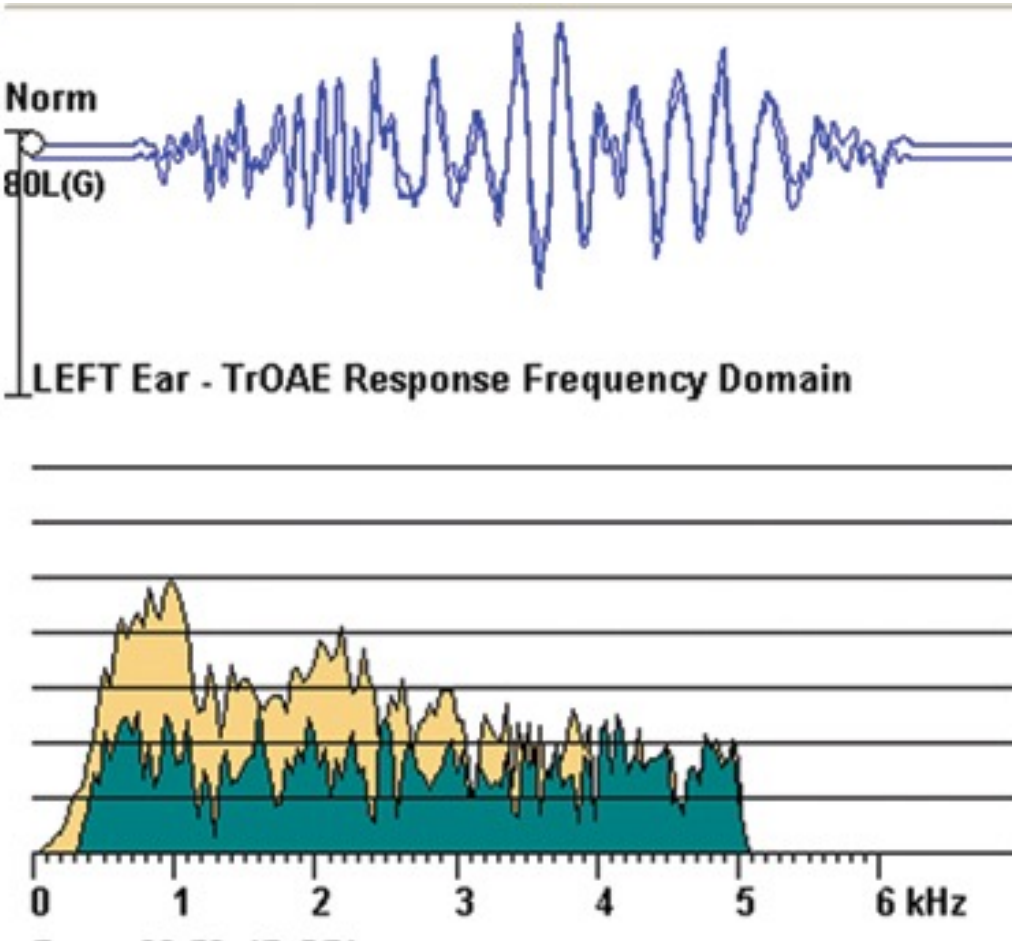

Outer hair cells
Inner hair cells
Spiral ganglion cells
To cochlear nuclei (afferent)
From superior olivary complex (efferent)
Celulas Ciliadas Externas
Celulas Ciliadas Internas

Célula Ciliada Externa


b

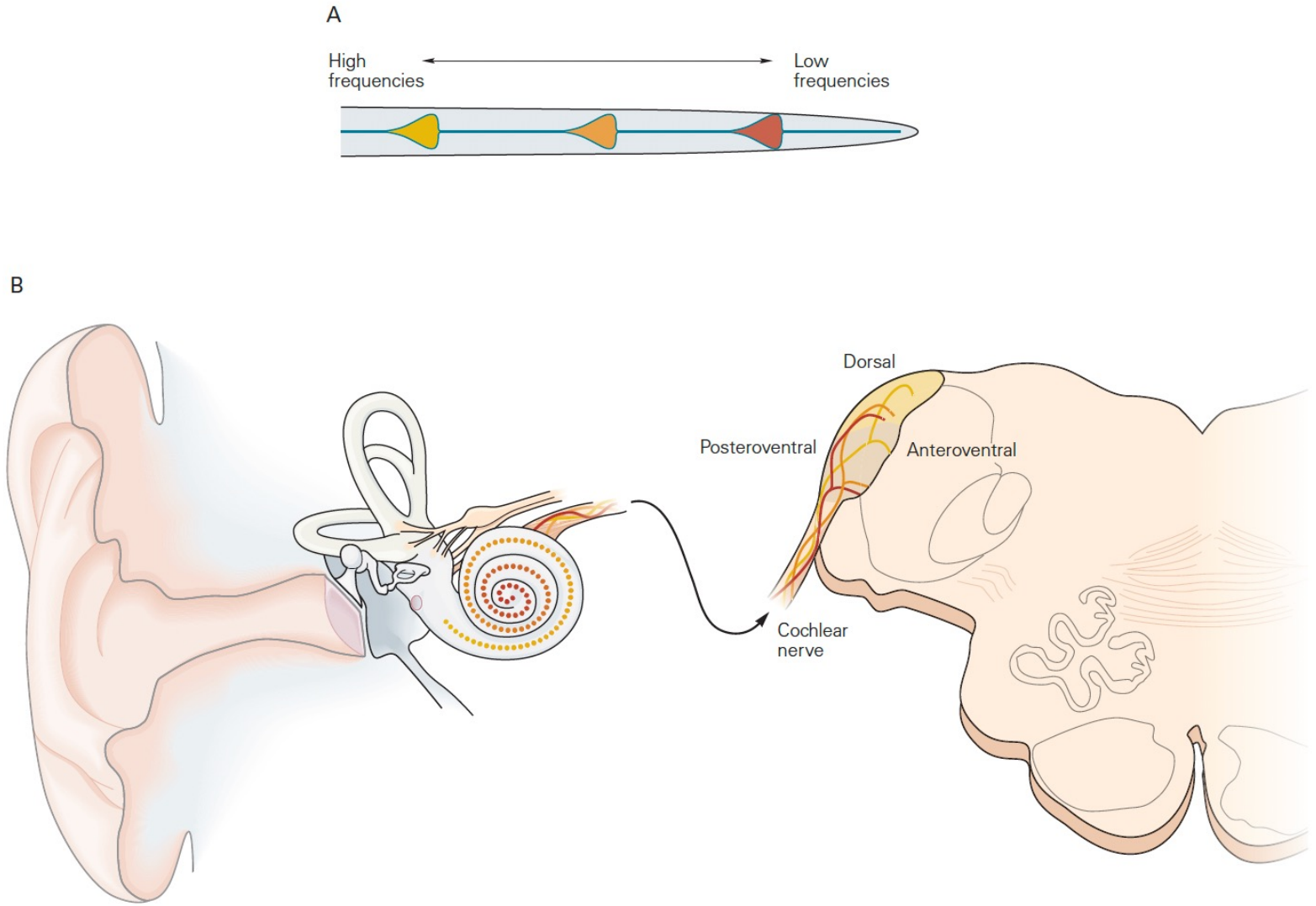

2kHz
CCE presentes
CCE ausentes
Intensidad Respuesta (mV)
Medida en Ganglio Espiral
Con celulas
Ciliadas
Externas
20 KHz
8 KHz
4 KHz
2 KHz
1 KHz
512Hz
256 Hz
Base de la Cóclea
Ápice de la Cóclea

Emisiones Otoacústicas

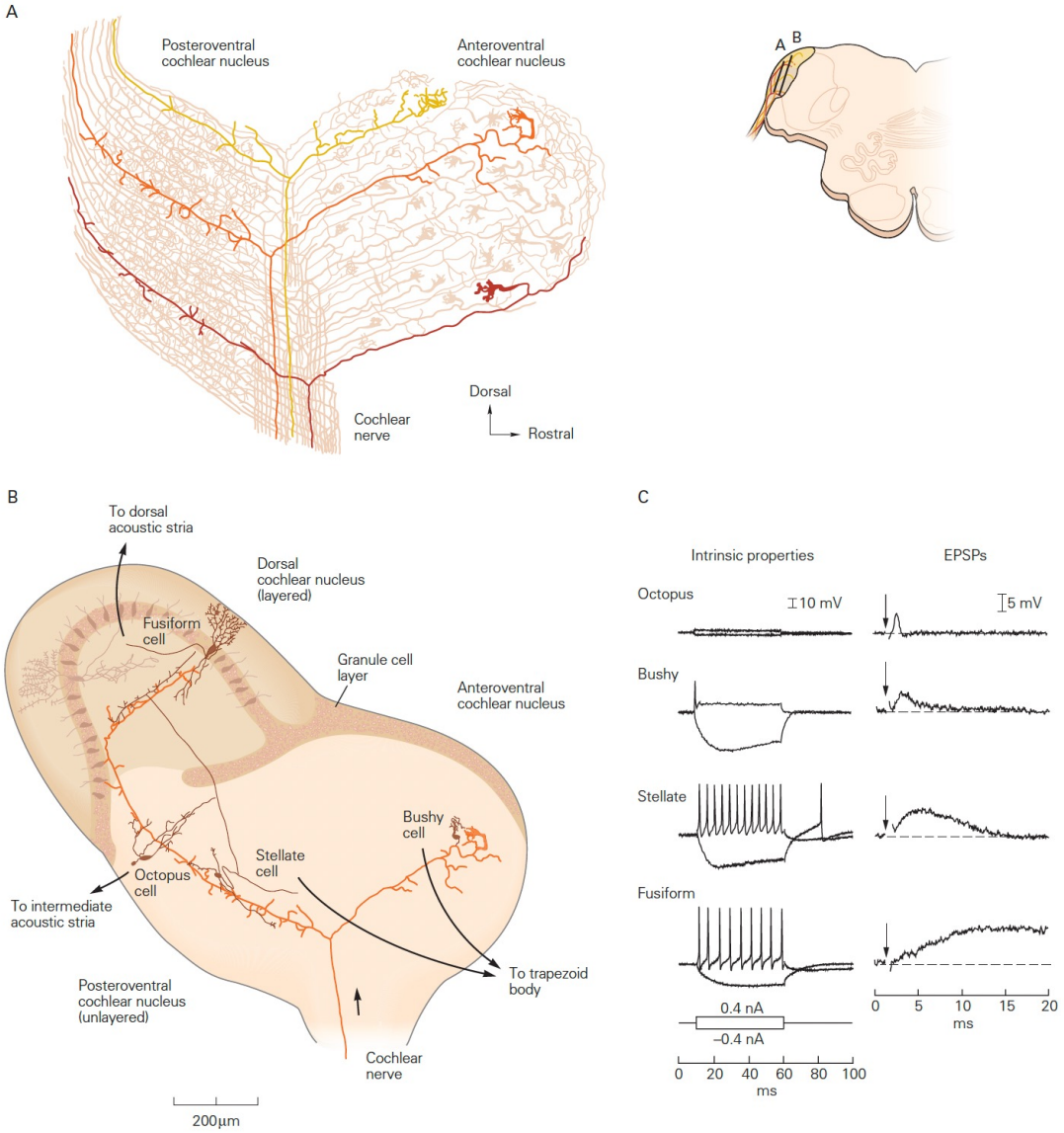


Transientes

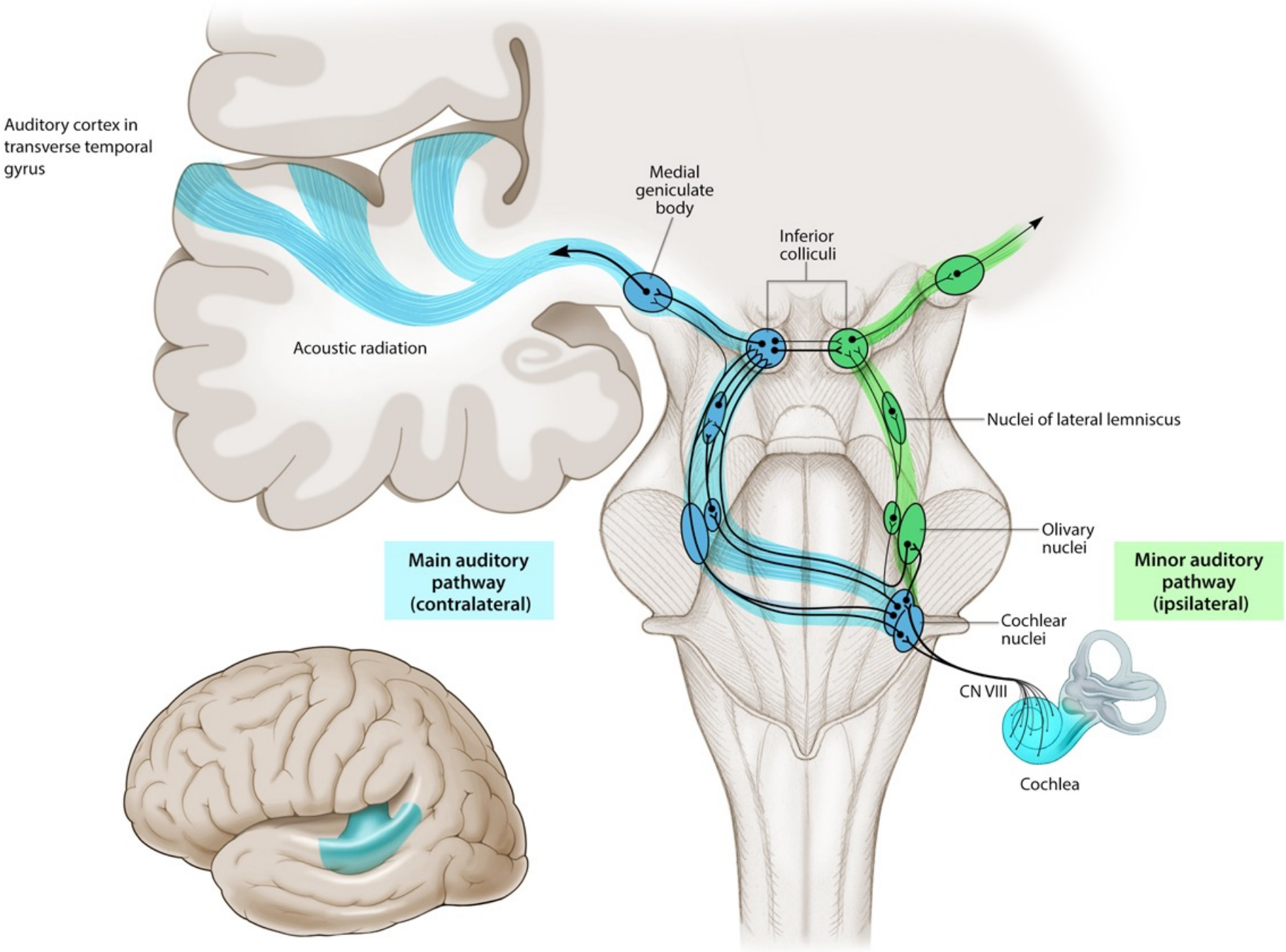

CANCEL
SAVE



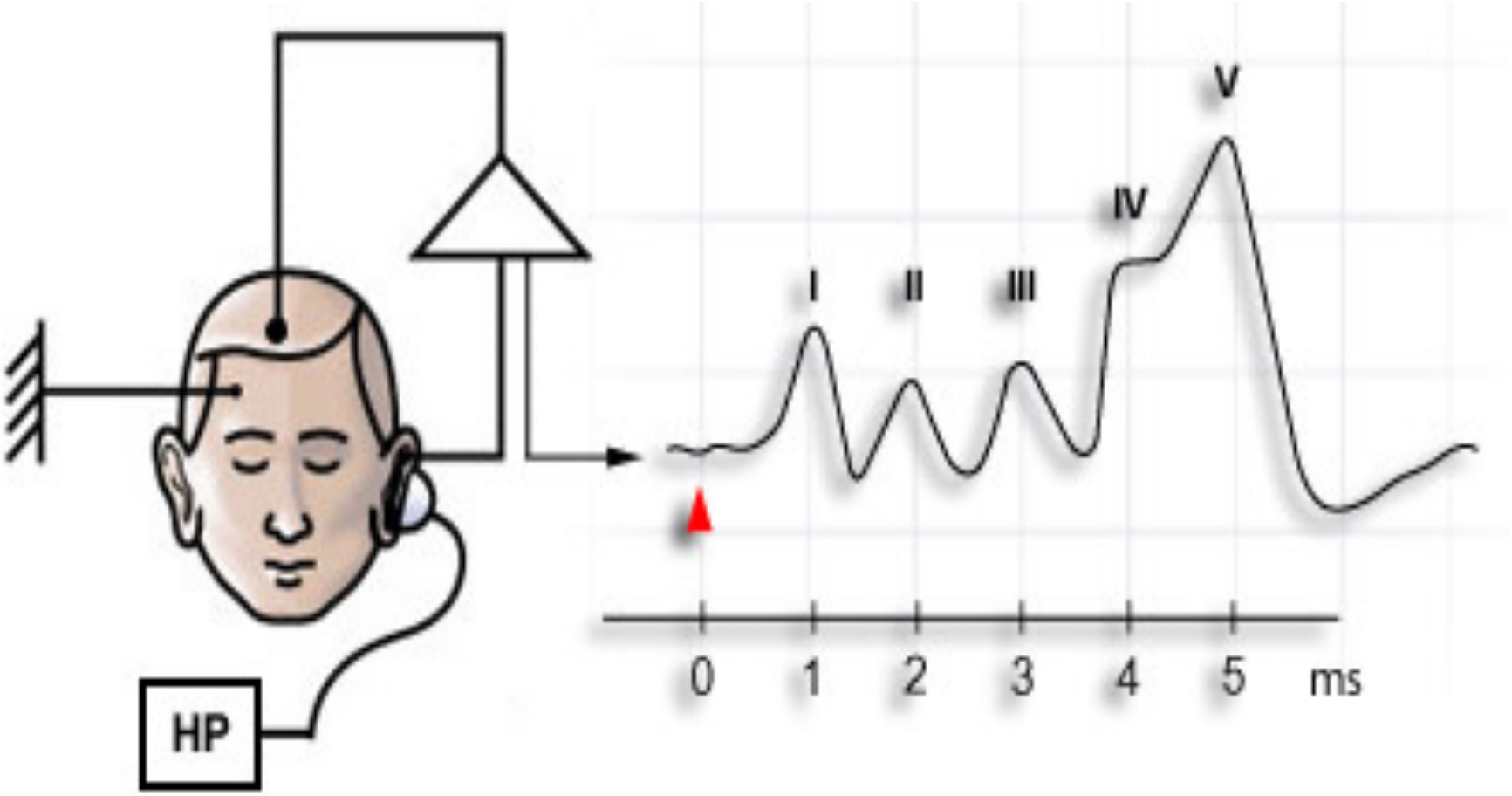
Núcleo Coclear



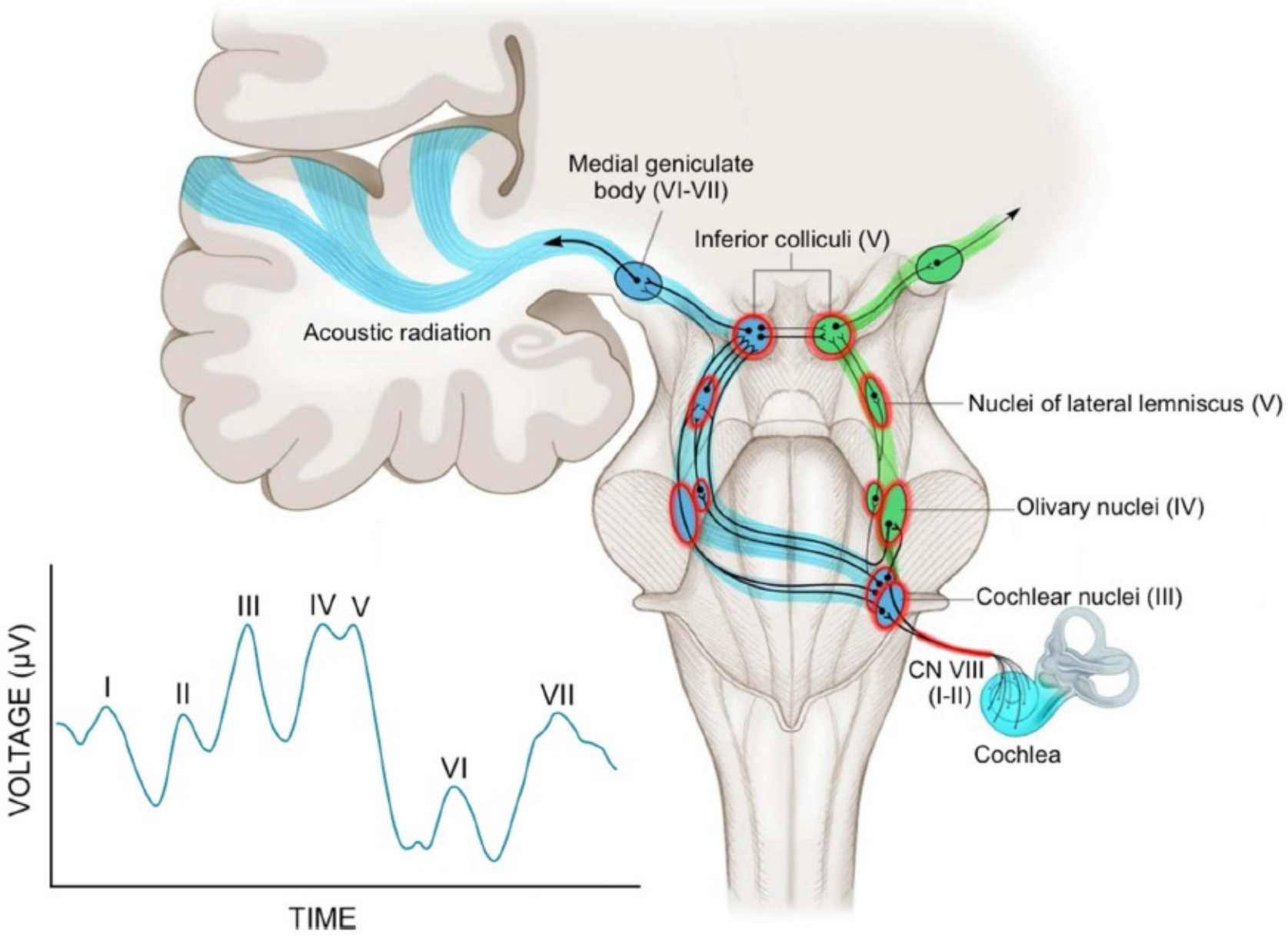
Núcleo Coclear


Auditory cortex in transverse temporal gyrus
Medial geniculate body
Inferior colliculi
Acoustic radiation
Nuclei of lateral lemniscus
Olivary nuclei
Main auditory pathway (contralateral)
Minor auditory pathway (ipsilateral)
Cochlear nuclei
CN VIII
Cochlea

Potenciales Auditivos de Tronco Encefálico




ABR
ABR


Medial geniculate body (VI-VII)
Inferior colliculi (V)
Acoustic radiation
Nuclei of lateral lemniscus (V)
Olivary nuclei (IV)
Cochlear nuclei (III)
CN VIII (I-II)
Cochlea
VOLTAGE (μV)
I
II
III
IV
V
VI
VII
TIME

Corteza Auditiva

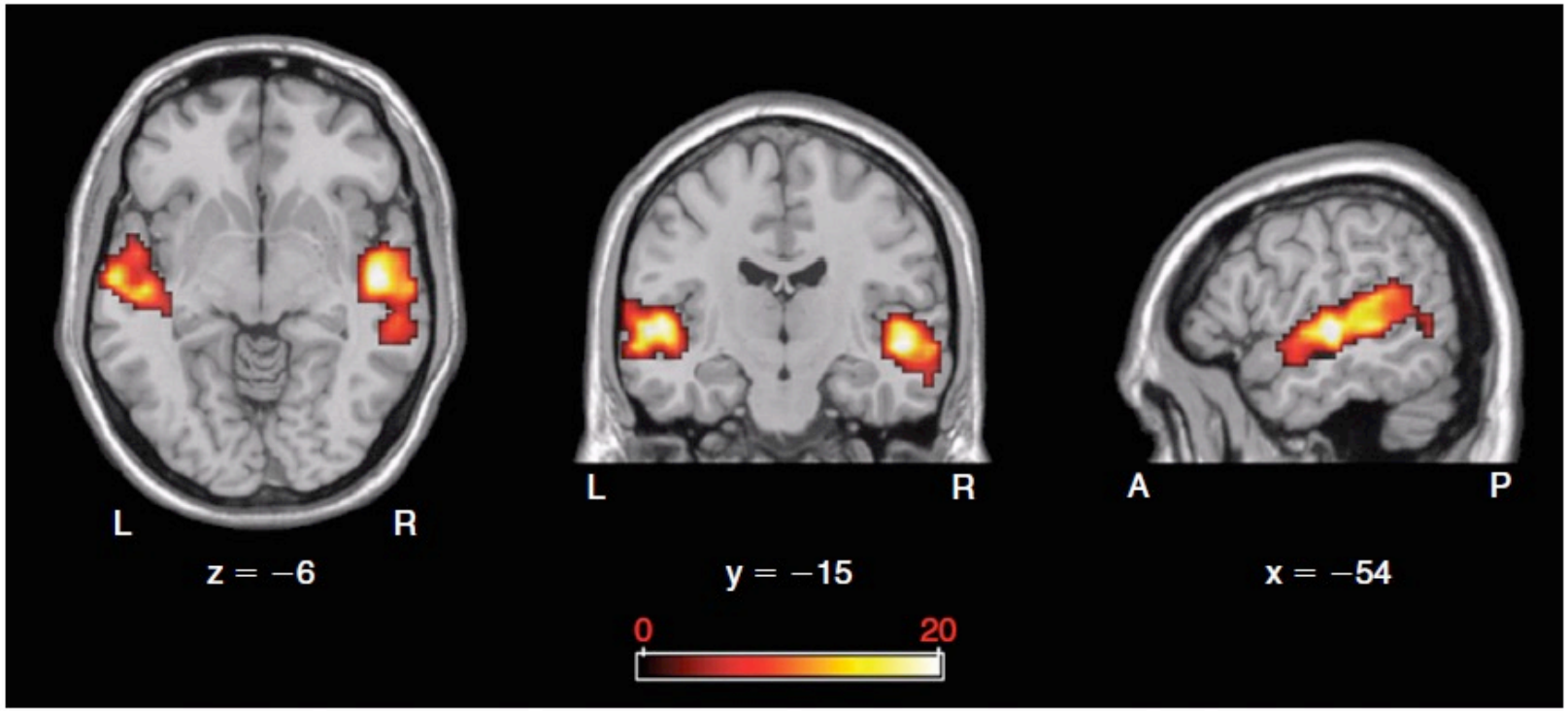
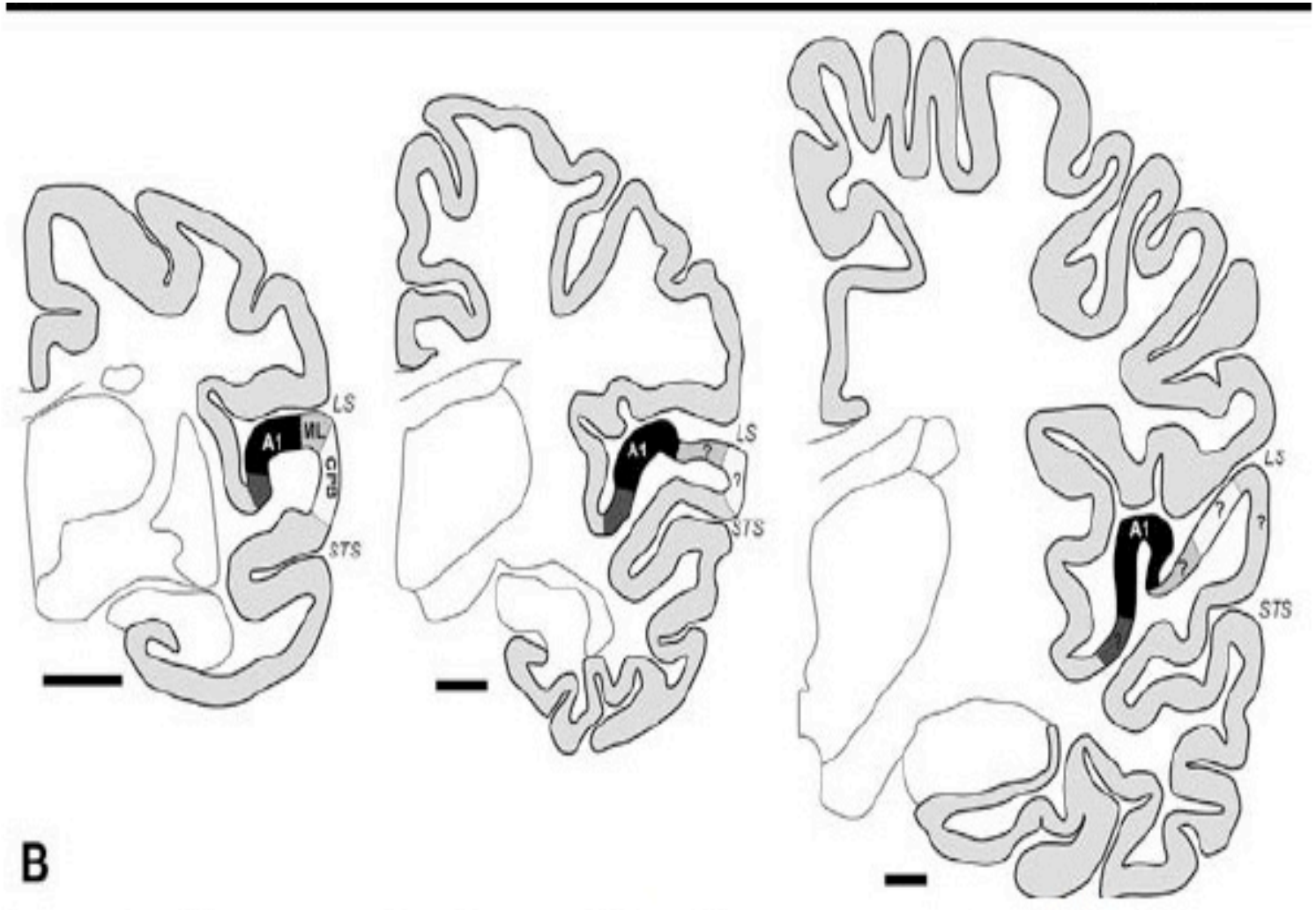
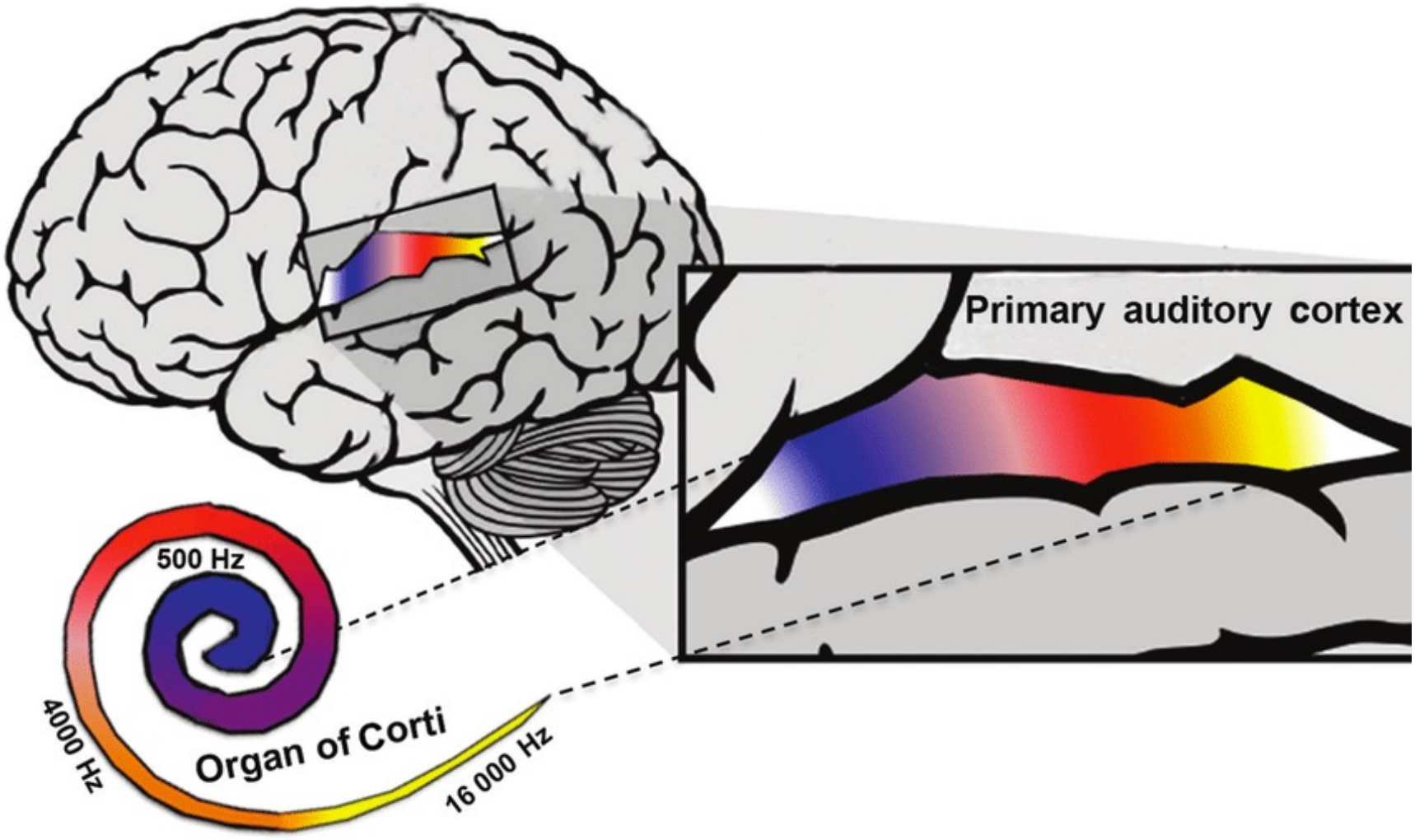


Fig. 127.7 Functional magnetic resonance imaging of the brain of a musician listening to music. The primary and secondary auditory cortex in both hemispheres shows strong activation. The brighter colors indicate more intense cortical activation. *A*, Anterior; *L*, left; *P*, posterior; *R*, right. (Courtesy C. Limb, MD.)

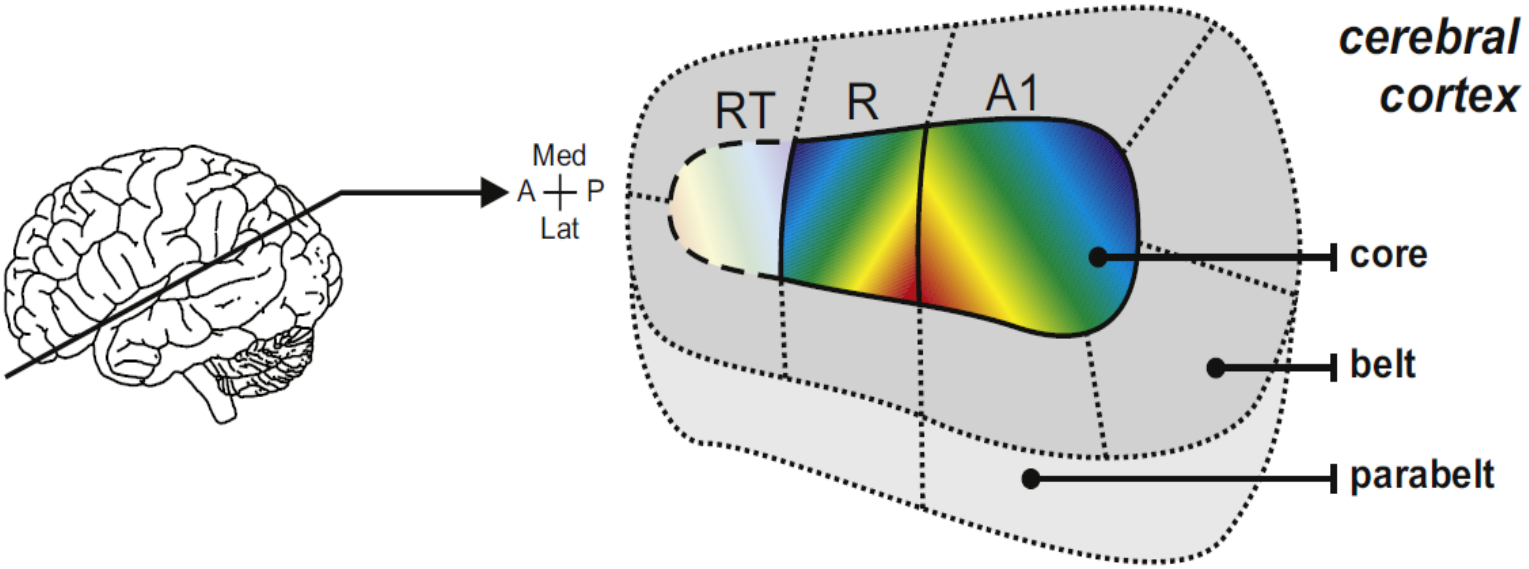
Corteza Auditiva



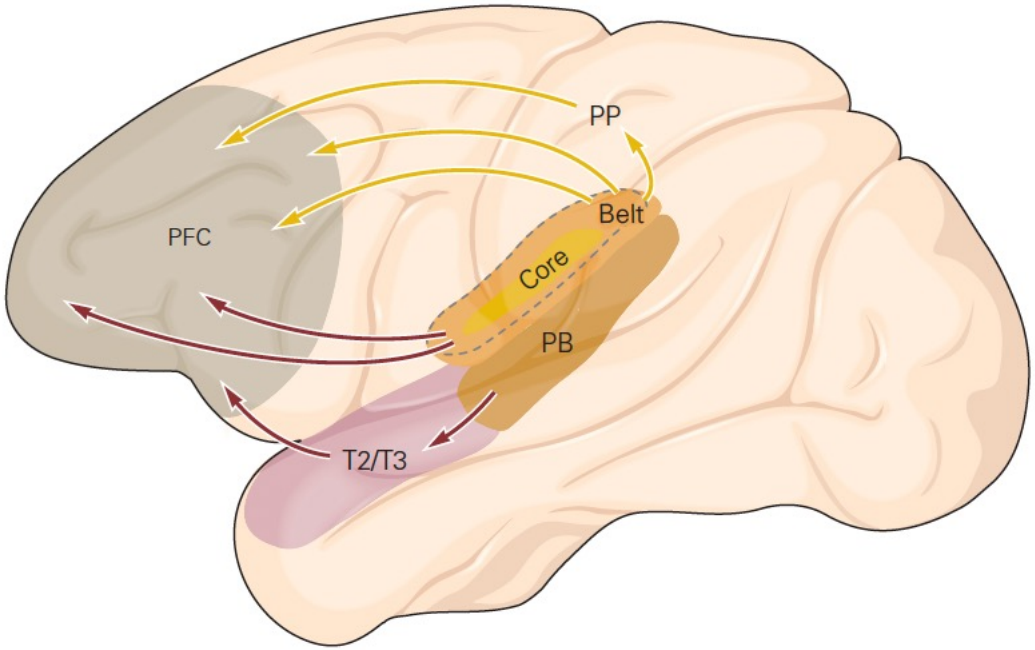
Macaco Chimpancé Humano

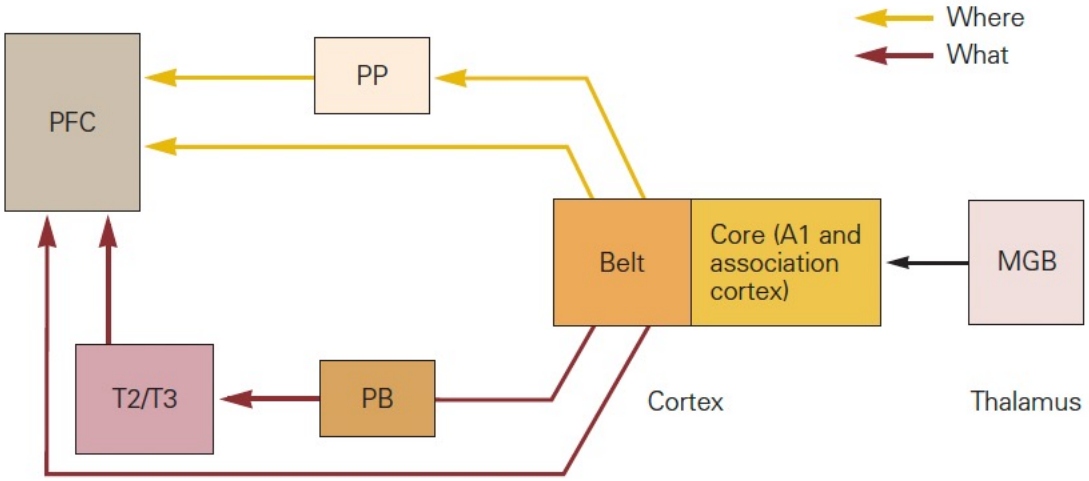

Primary auditory cortex
500 Hz
4000 Hz
Organ of Corti
16 000 Hz

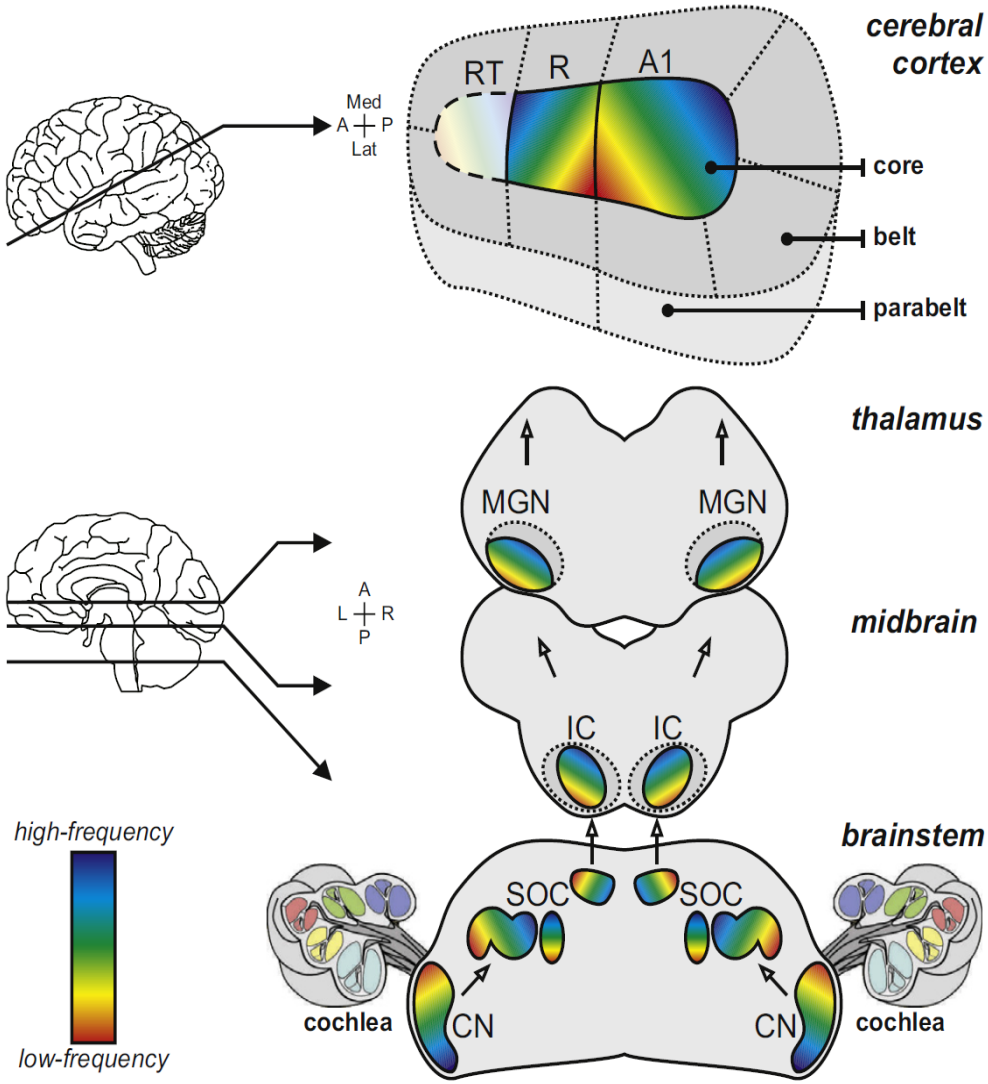
A1



Saenz & Langers, Hear Res 2014

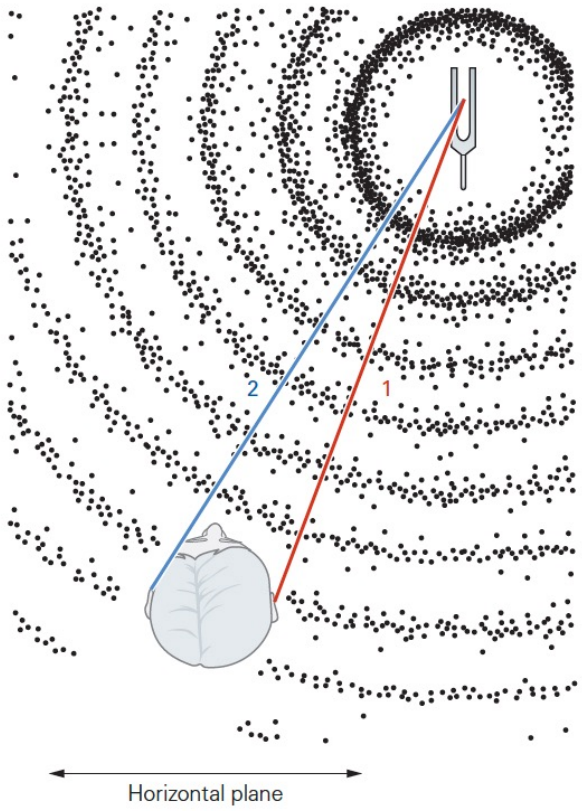

PP
Belt
PFC
Core
PB
T2/T3


Where
What
PFC
PP
Belt
Core (A1 and association cortex)
MGB
T2/T3
PB
Cortex
Thalamus

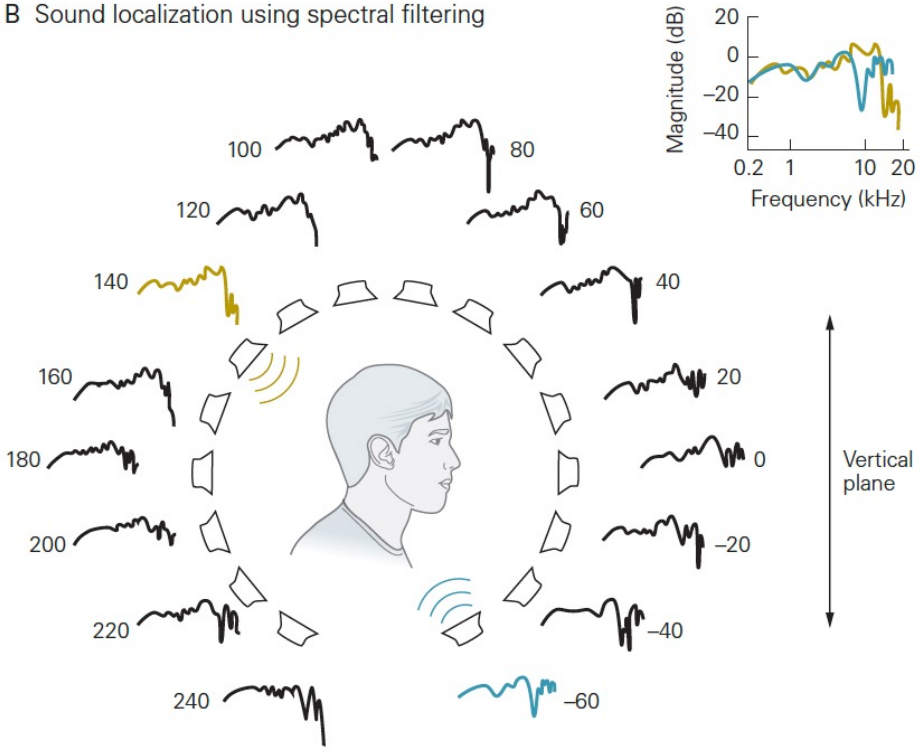


Saenz & Langers, Hear Res 2014

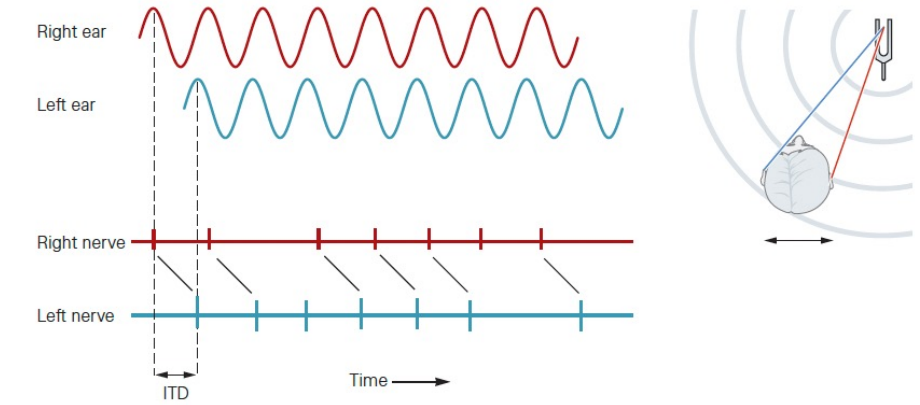
A Sound localization using interaural difference



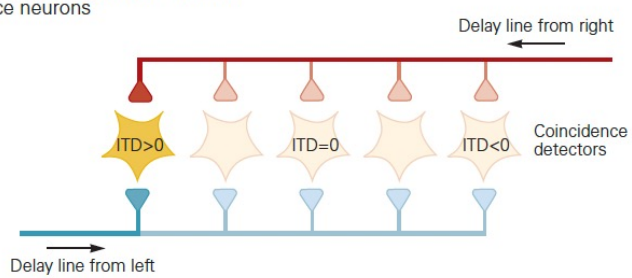
B Sound localization using spectral filtering



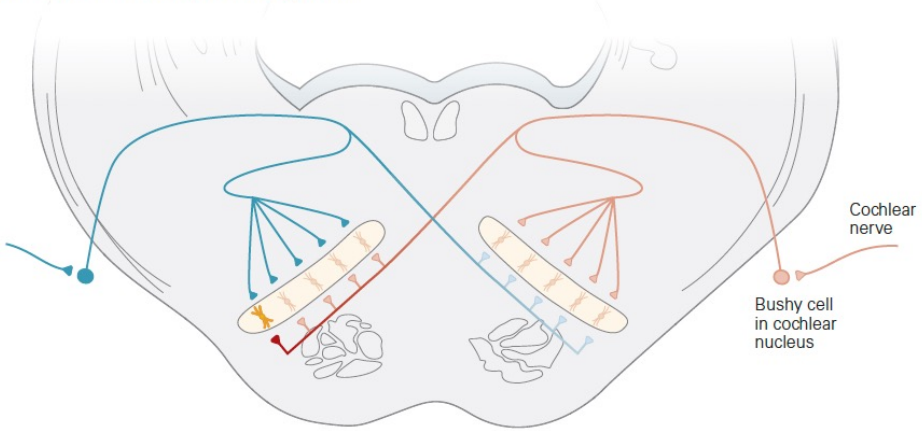
A Phase-locked firing in bushy cells



B Mapping of ITD onto array of neuronal coincidence neurons

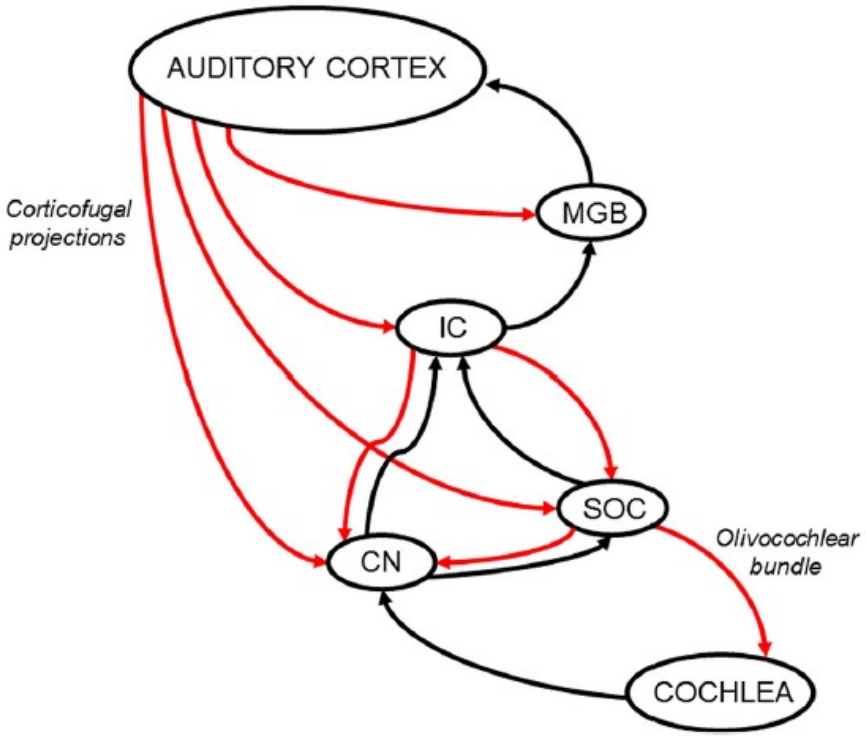


C Bilateral medial superior olivary nuclei



Vía auditiva central

eferente



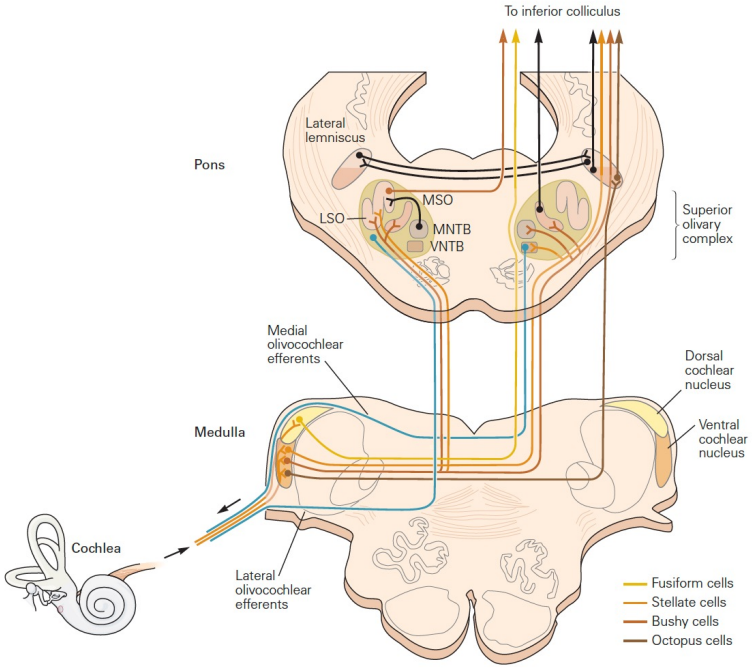
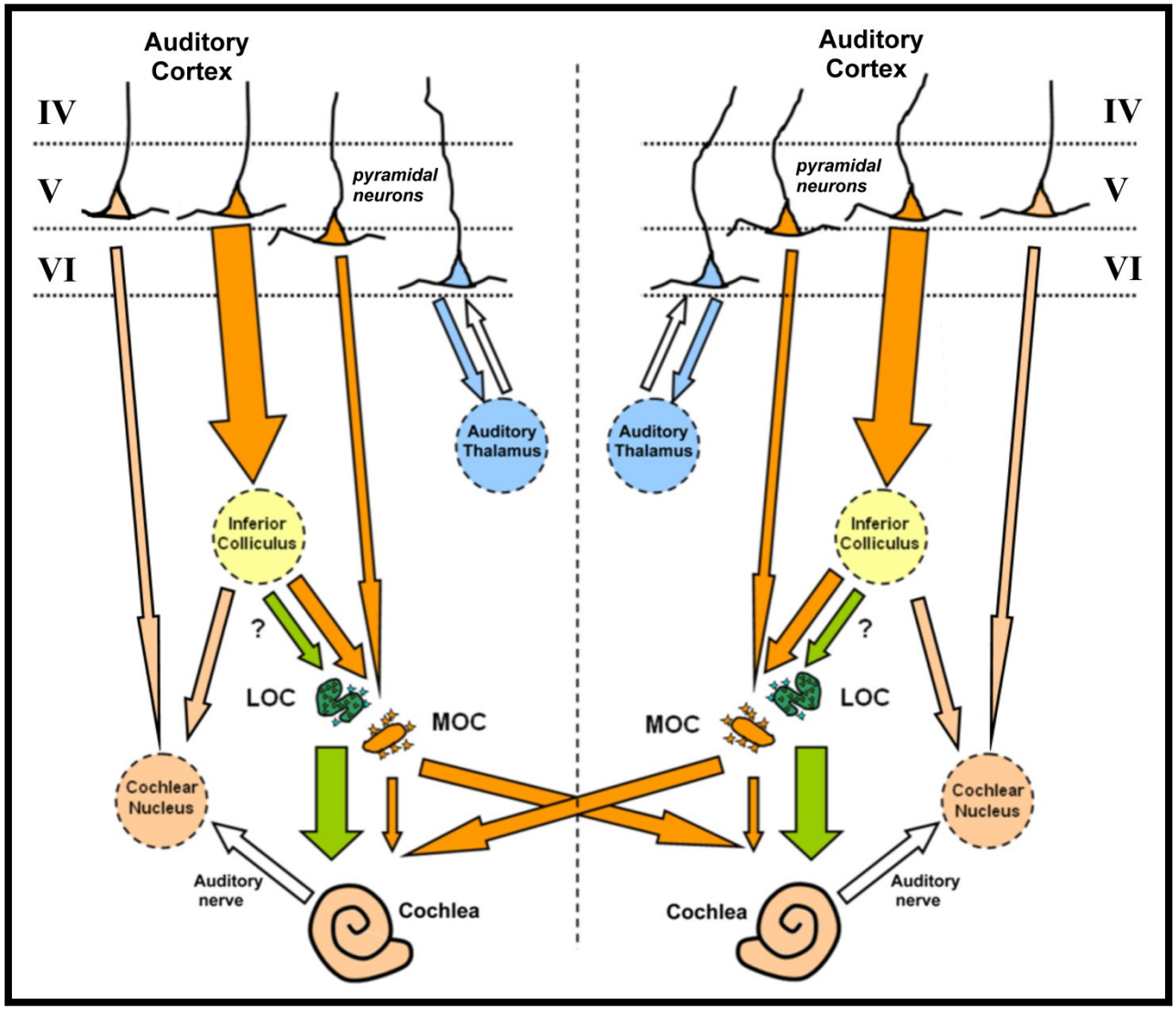
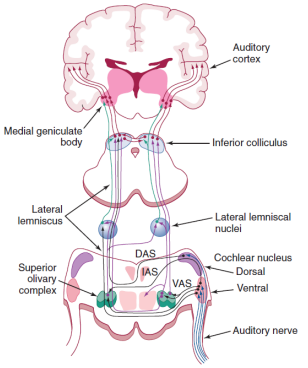


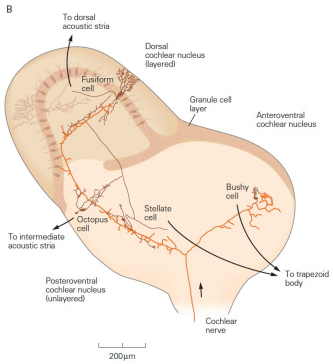
FIGURE 1 | Schematic diagram of the auditory efferent network.
Ascending and descending pathways are depicted in black and red arrows

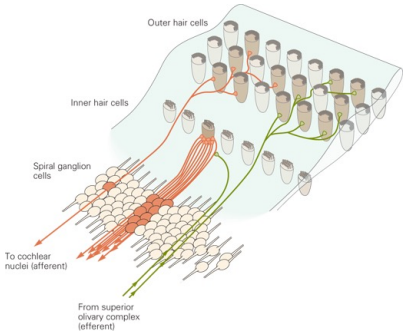
Terreros and Delano, 2015

Sistema eferente córtico-coclear

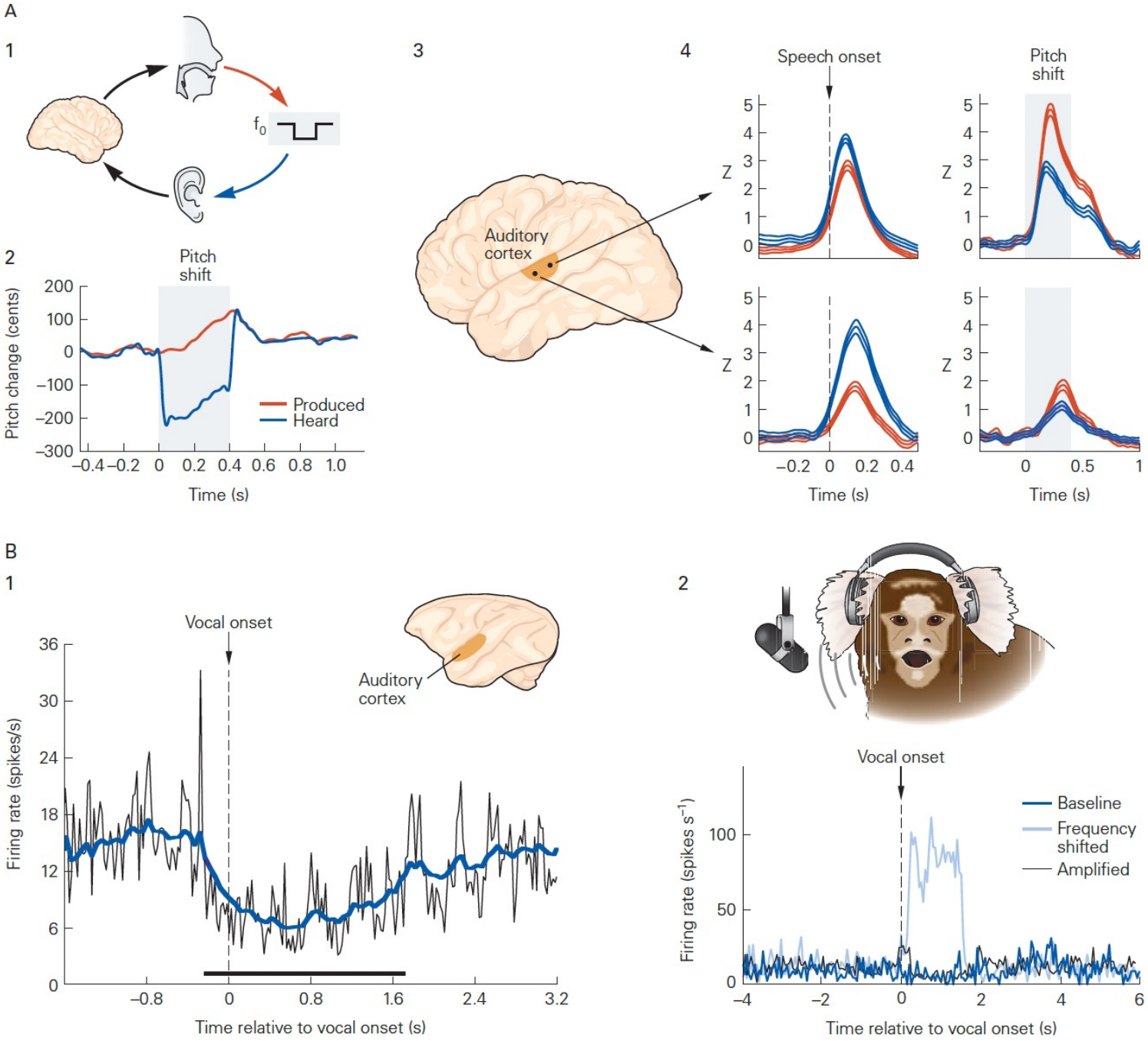






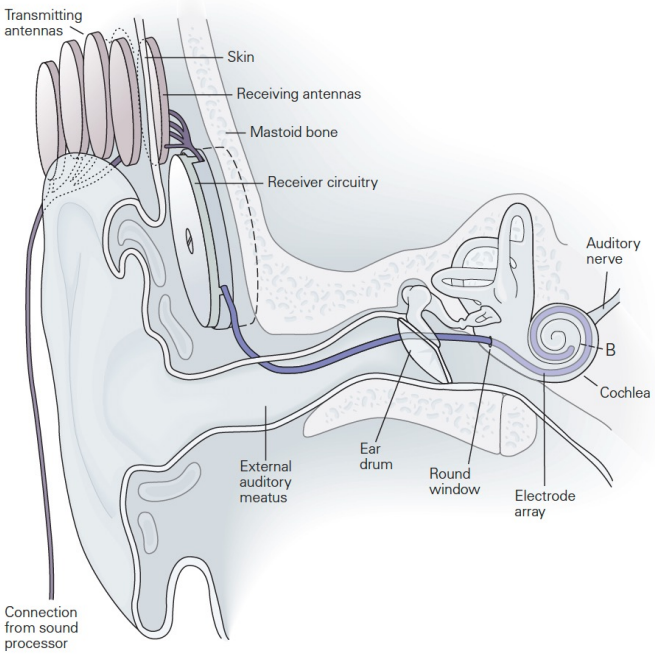


Robles and Delano, 2008.

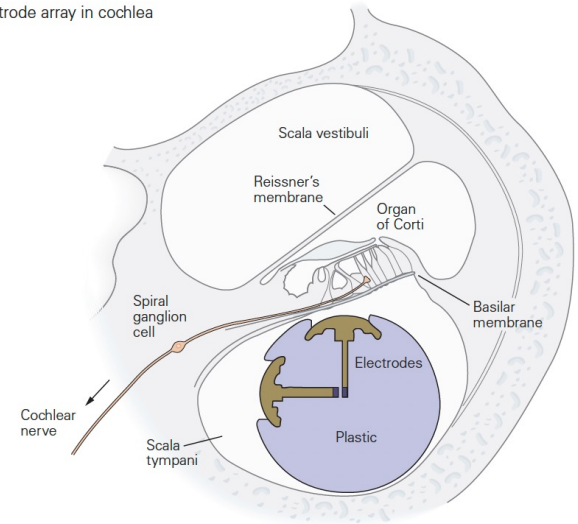

A
1
f_0
2
Pitch shift
Pitch change (cents)
200
100
0
−100
−200
−300
−0.4 −0.2 0 0.2 0.4 0.6 0.8 1.0
Time (s)
Produced
Heard
3
Auditory cortex
4
Speech onset
Pitch shift
Z
5
4
3
2
1
0
−0.2 0 0.2 0.4
0 0.5 1
Time (s)
B
1
Vocal onset
Auditory cortex
Firing rate (spikes/s)
36
30
24
18
12
6
0
−0.8 0 0.8 1.6 2.4 3.2
Time relative to vocal onset (s)
2
Vocal onset
Baseline
Frequency shifted
Amplified
Firing rate (spikes s^{-1})
100
50
0
−4 −2 0 2 4 6
Time relative to vocal onset (s)

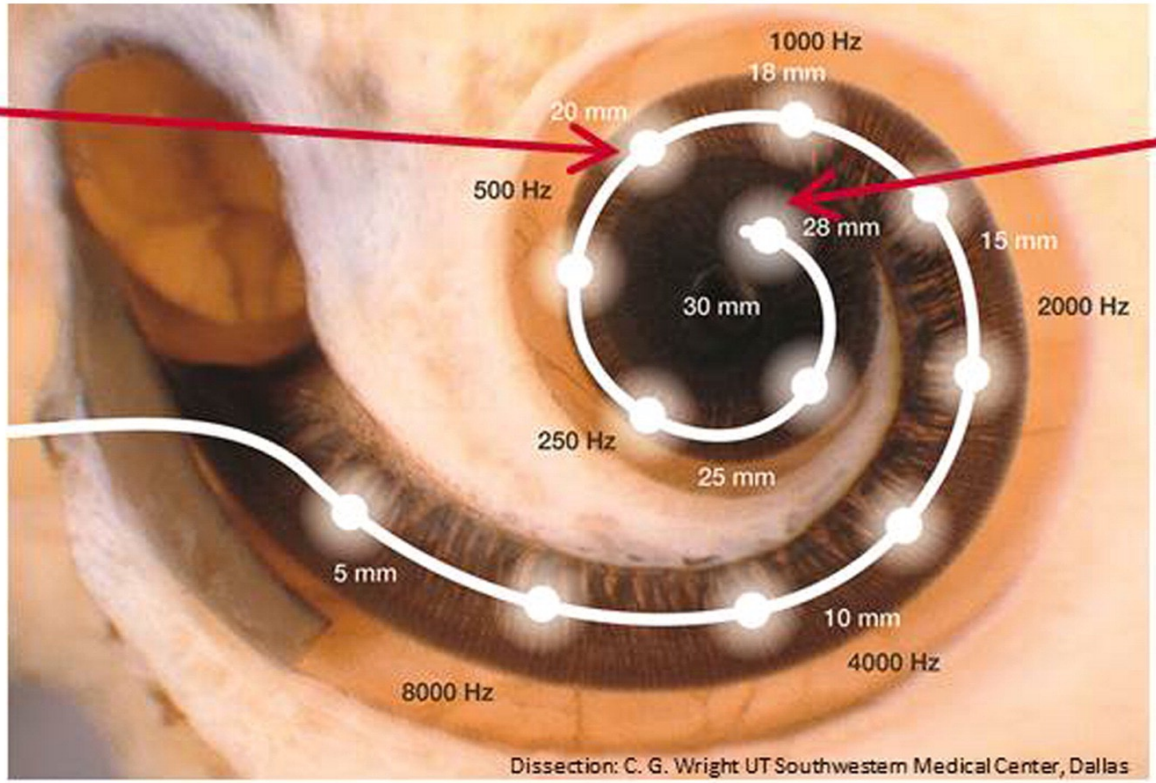
Cochlear Implants

A Sound transmission to cochlea

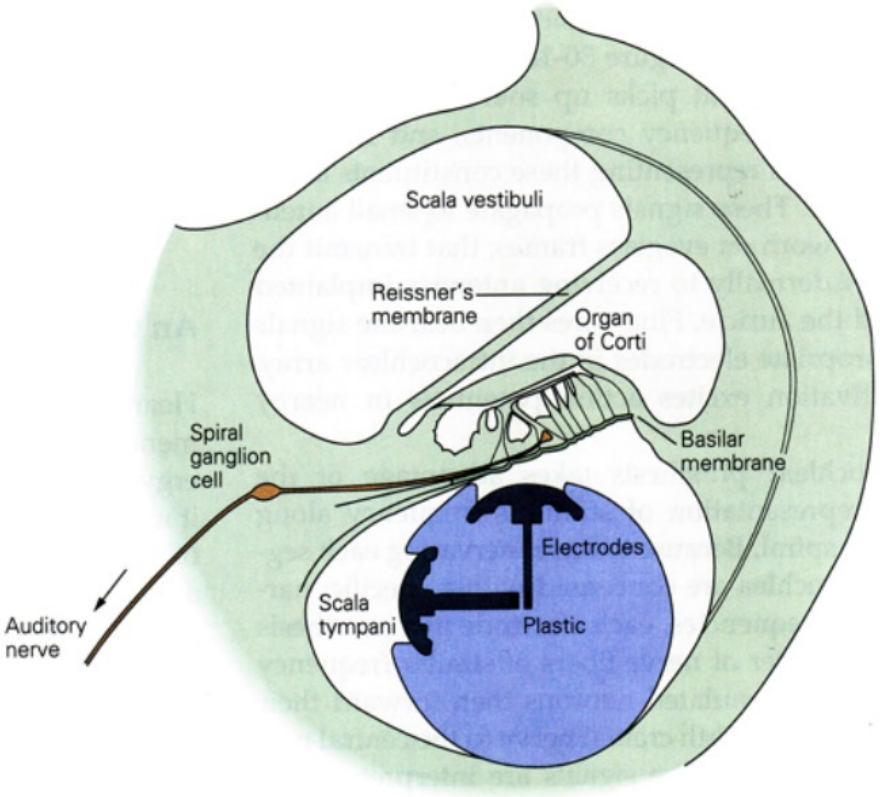


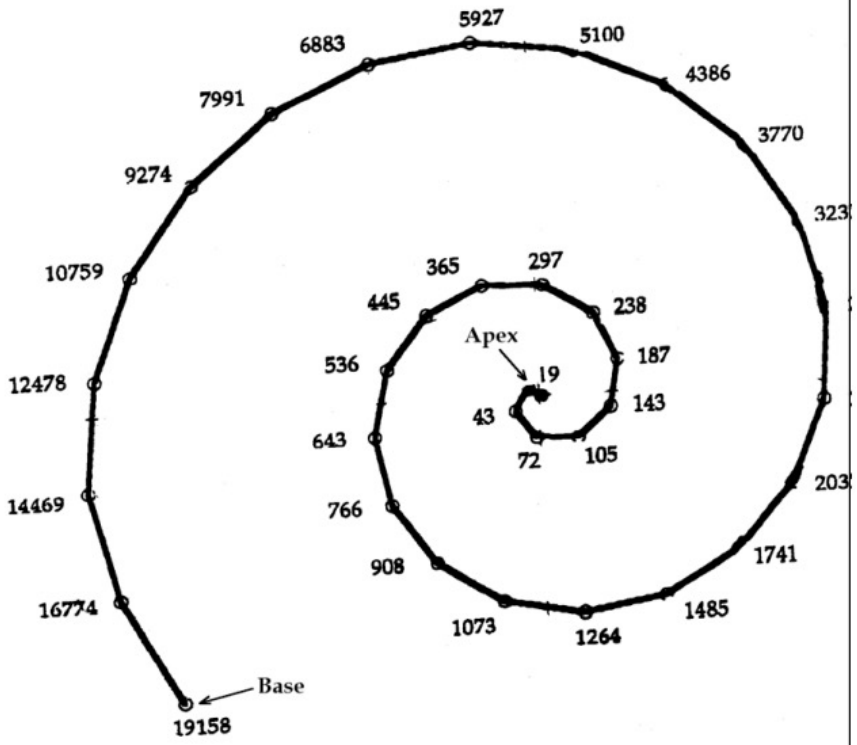
B Electrode array in cochlea




100Hz
Most Apical
~ 20mm
1000 Hz
18 mm
20 mm
500 Hz
28 mm
15 mm
30 mm
2000 Hz
250 Hz
25 mm
5 mm
10 mm
4000 Hz
8000 Hz
Dissection: C. G. Wright UT Southwestern Medical Center, Dallas
100Hz
Most Apical
~ 30mm

Cochlear implant to cure deafness by directly stimulating auditory nerves





cochlear implant -> 32 different frequencies
(normal inner ear -> 300+ different frequencies

http://graemeclarkfoundation.org/bionic_ear/CI%20Function.htm

Sistema AUDITIVO

NEUROCIENCIA

Hayo A. Breinbauer Krebs (Dr.med/PhD).
Universidad de Chile – Departamento Neurociencias

FACULTAD DE MEDICINA
UNIVERSIDAD DE CHILE

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