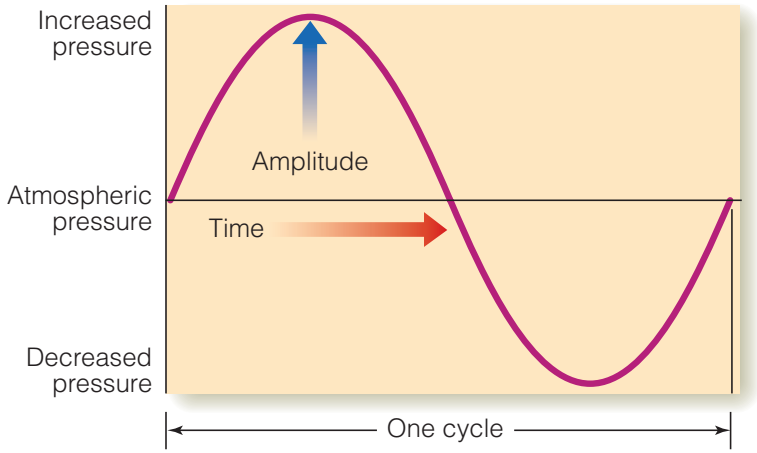
Auditive Wahrnehmung

Physik

Schallwellen:

- Periodische Dichteschwankungen in elastischen Medien
- Parameter:
    - Amplitude / Frequenz / Phase



Physik

Amplitude → Lautheit

- Schalldruck in Pascal (N/m^2)
- Schalldruckpegel als relative Einheit

$$L_p = 20 \log(p/p_0)\ [dB]$$

p_0: Referenzdruck als Hörschwelle für 1kHz-Ton

$2*10^{-5}\ N/m^2$

Physik

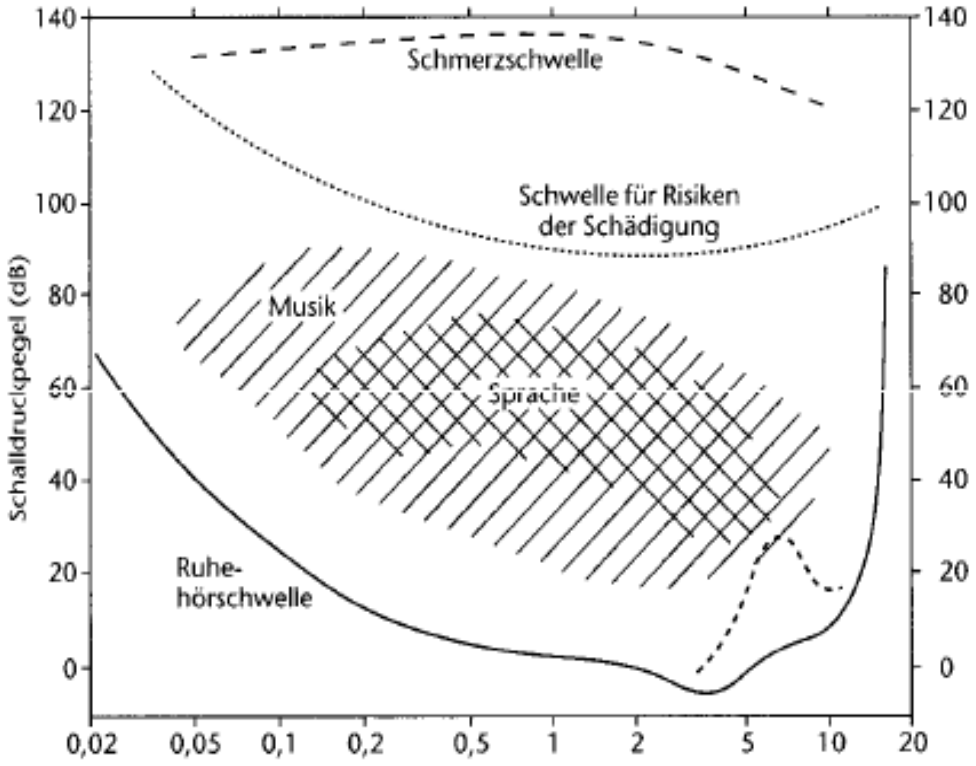
Zusammenhang zwischen Schalldruck und dB Skala

relativer Schalldruck (p/p_0)	Schalldruckpegel (dB)
1	0
10	20
100	40
1 000	60
10 000	80
100 000	100
1 000 000	120
10 000 000	140

Situation und Schallquelle	Schalldruck *p* Pascal
Schmerzschwelle	100 Pa
Gehörschäden bei kurzfristiger Einwirkung	20 Pa
Kampfflugzeug 100 m entfernt	6,3 - 200 Pa
Presslufthammer, 1 m entfernt / Diskothek	2 Pa
Gehörschäden bei langfristiger Einwirkung	$6{,}3 \cdot 10^{-1}$ Pa
Hauptverkehrsstraße, 10 m entfernt	0,2 - 0,63 Pa
Pkw, 10 m entfernt	0,02 - 0,2 Pa
Fernseher in Zimmerlautstärke 1 m entfernt	0,02 Pa
Normale Unterhaltung, 1 m entfernt	$2 \cdot 10^{-3}$ - $6{,}3 \cdot 10^{-3}$ Pa
Sehr ruhiges Zimmer	$2 \cdot 10^{-4}$ - $6{,}3 \cdot 10^{-4}$ Pa
Blätterrauschen, ruhiges Atmen	$6{,}32 \cdot 10^{-5}$ Pa
Hörschwelle bei 2 kHz	$2 \cdot 10^{-5}$ Pa (20 µPa)

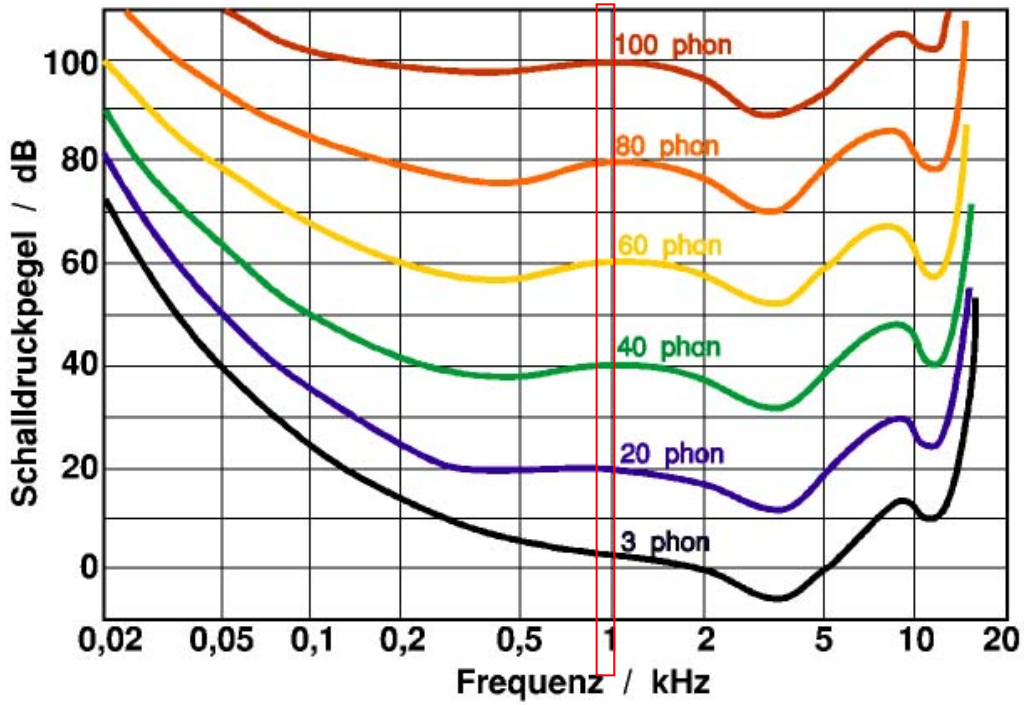
Wahrnehmung

Hörschwelle und Hörfläche



Wahrnehmung

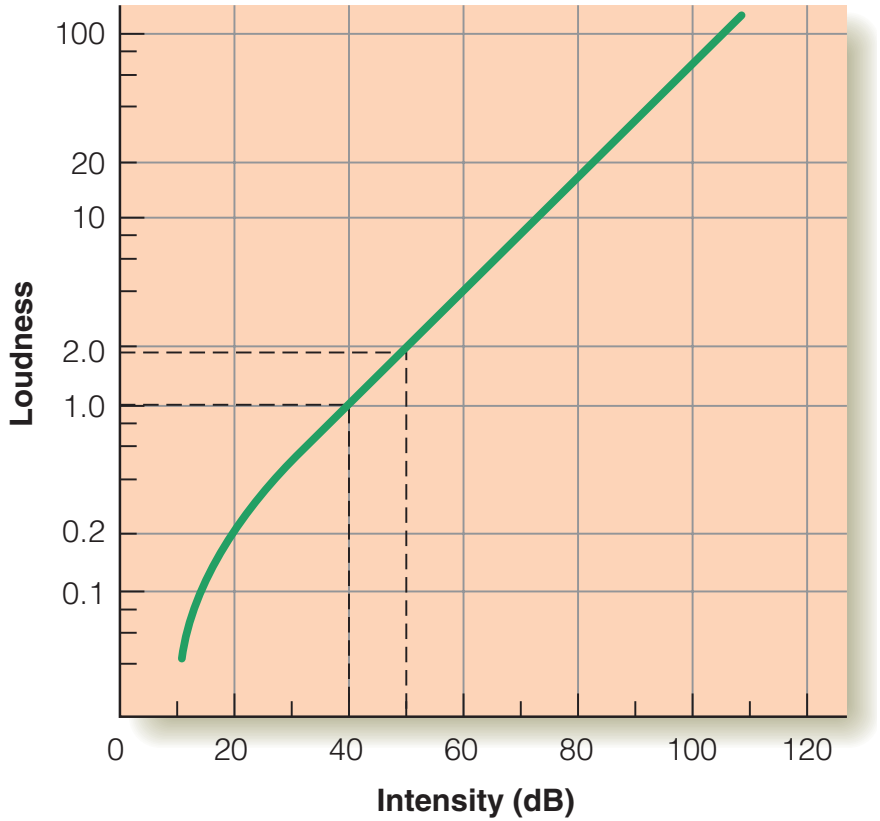
Isophone (Fletscher, 1933): Gleich laut empfundene Töne unterschiedlicher Frequenzen (dB bei 1kHz)



Wahrnehmung

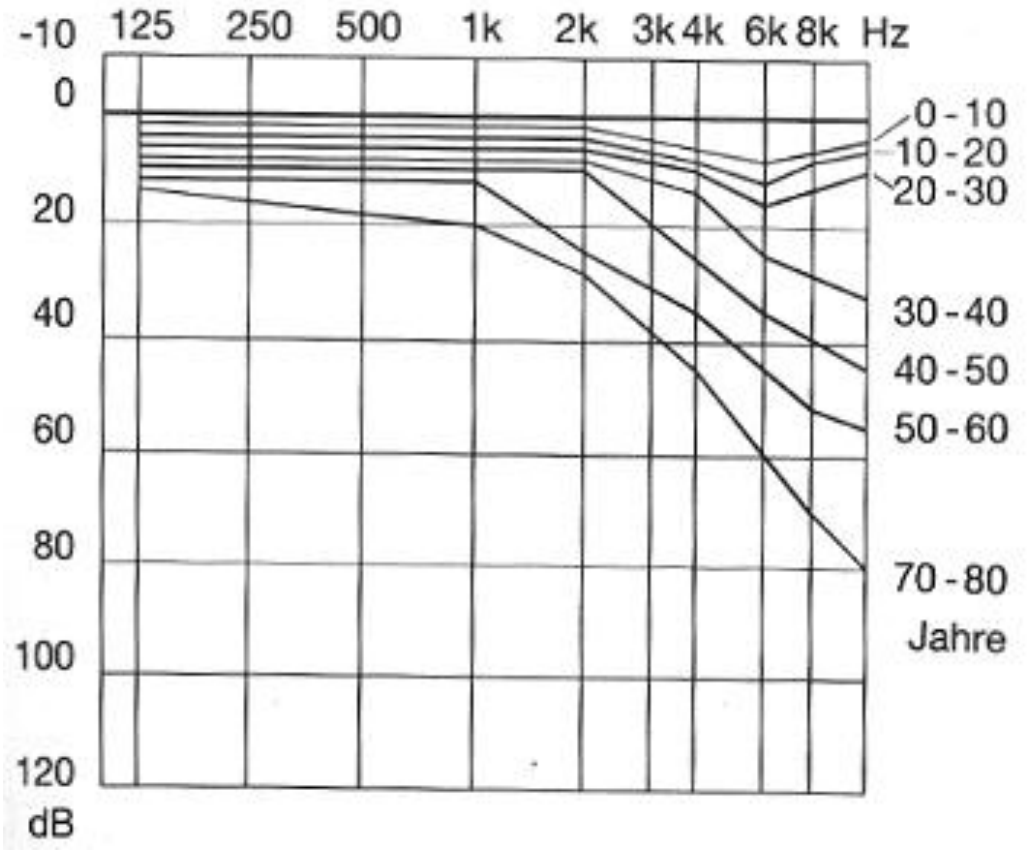
Sone (Stevens, 1956): 1 Sone = 40dB (1kHz)

$$N = k * L_p^{0.6}$$



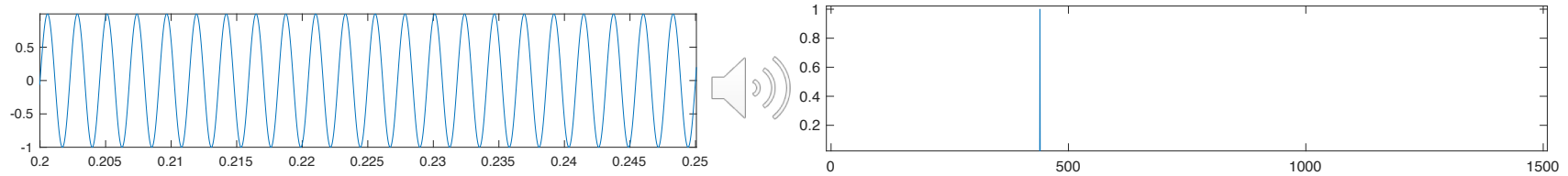
Wahrnehmung

Hörschwellenveränderung im Alter

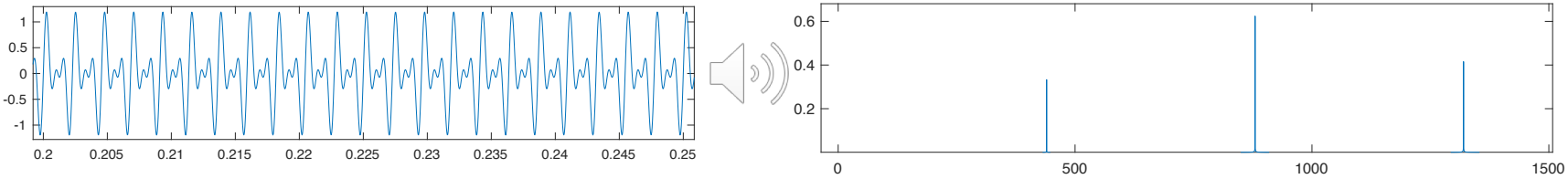


Wahrnehmung

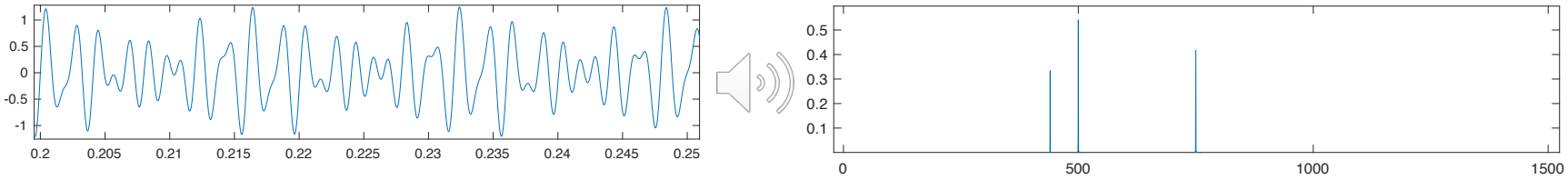
Ton:



Klang:

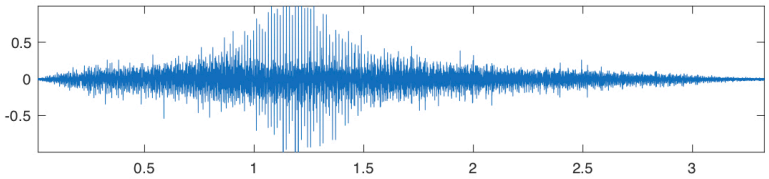


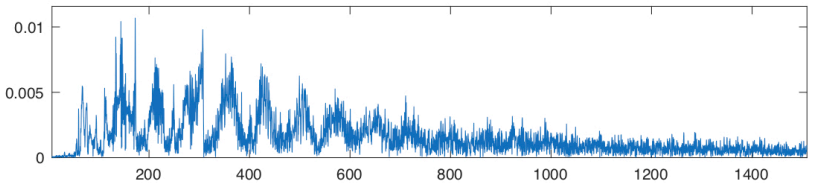
Tongemisch:



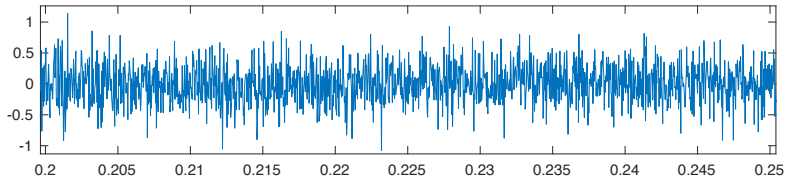
Wahrnehmung

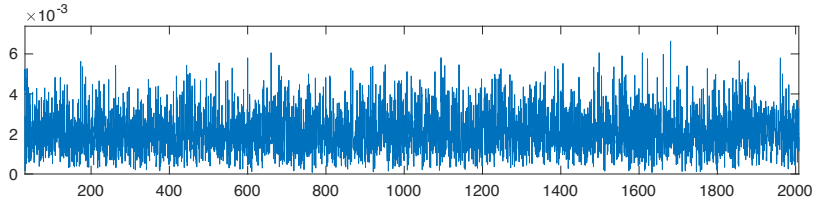
Geräusch:

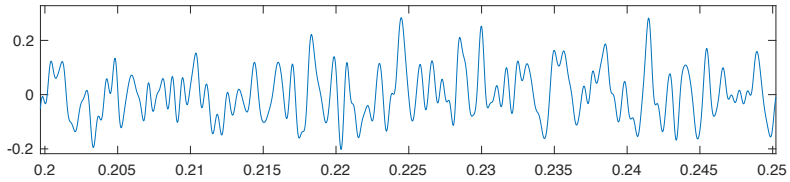


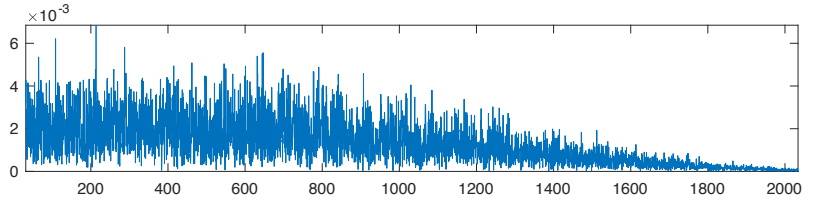


Rauschen:



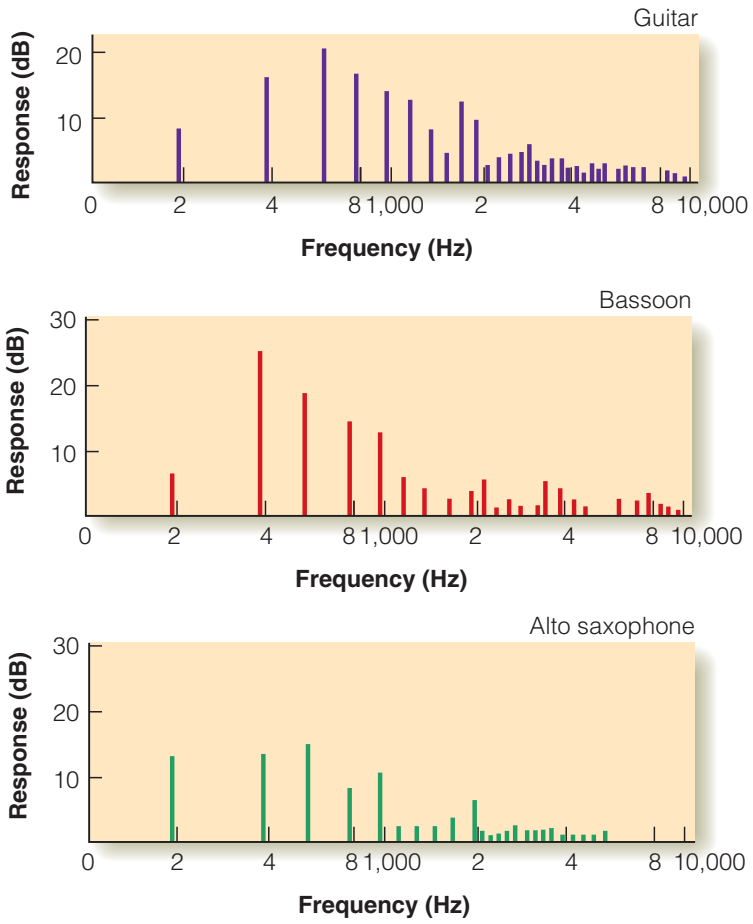






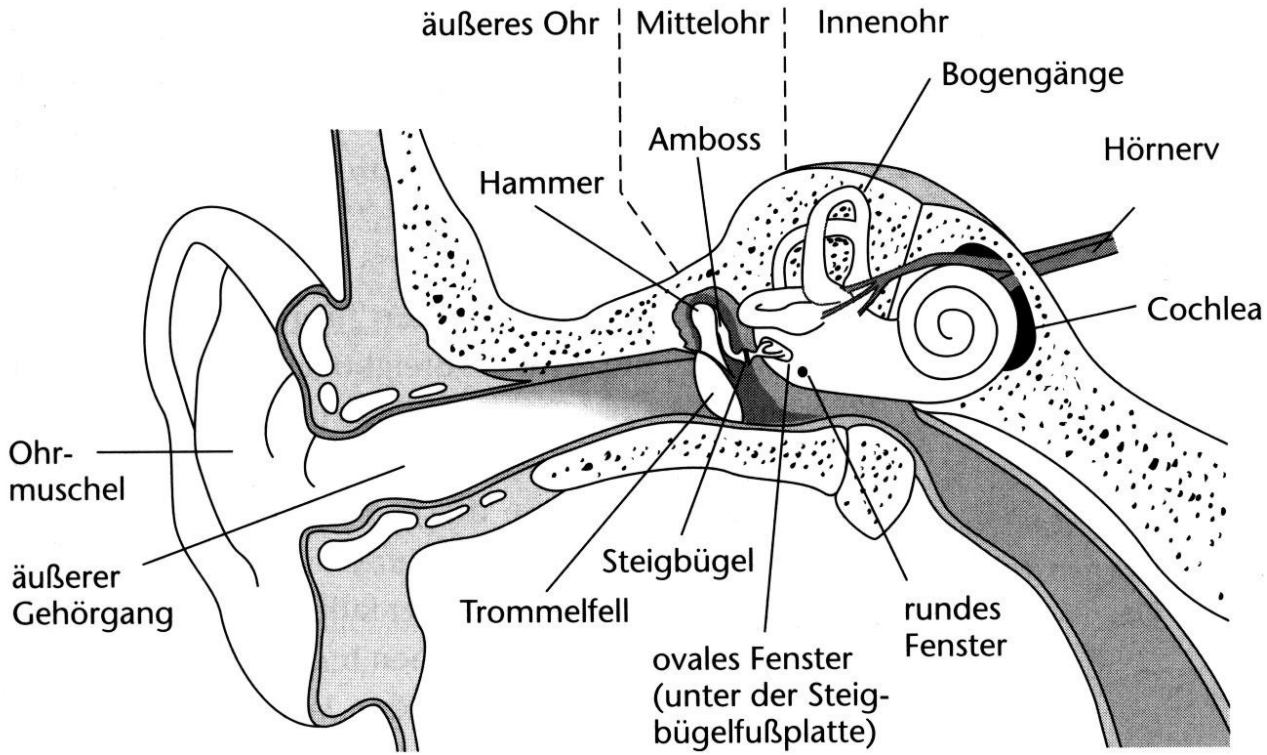
Wahrnehmung

Klangfarbe:



Sinnesphysiologie

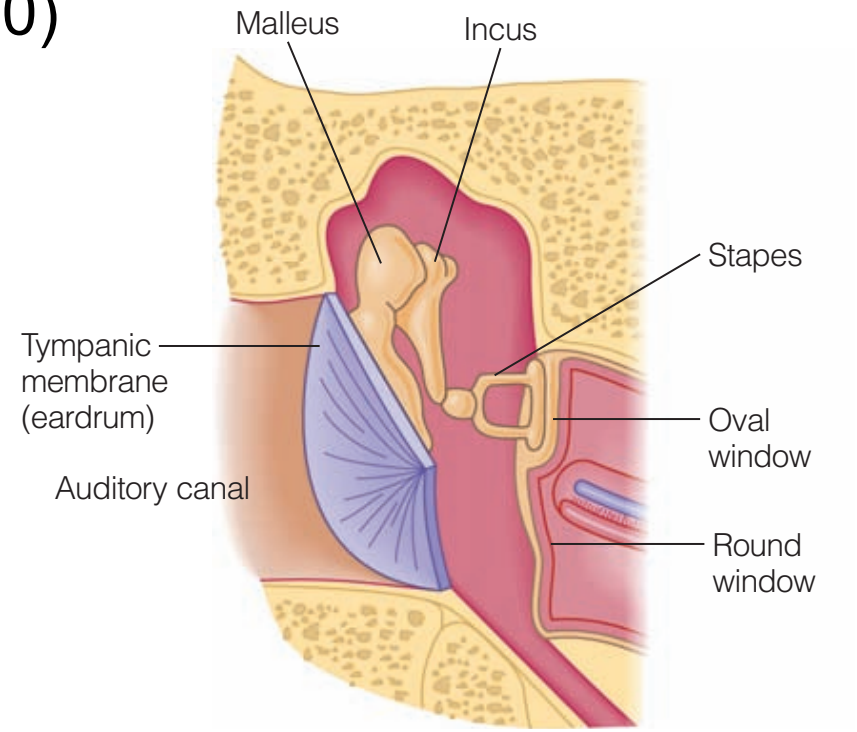
Das Ohr



Sinnesphysiologie

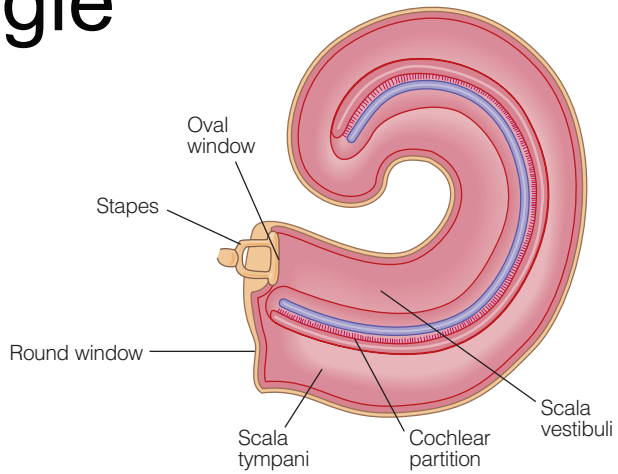
Das Mittelohr

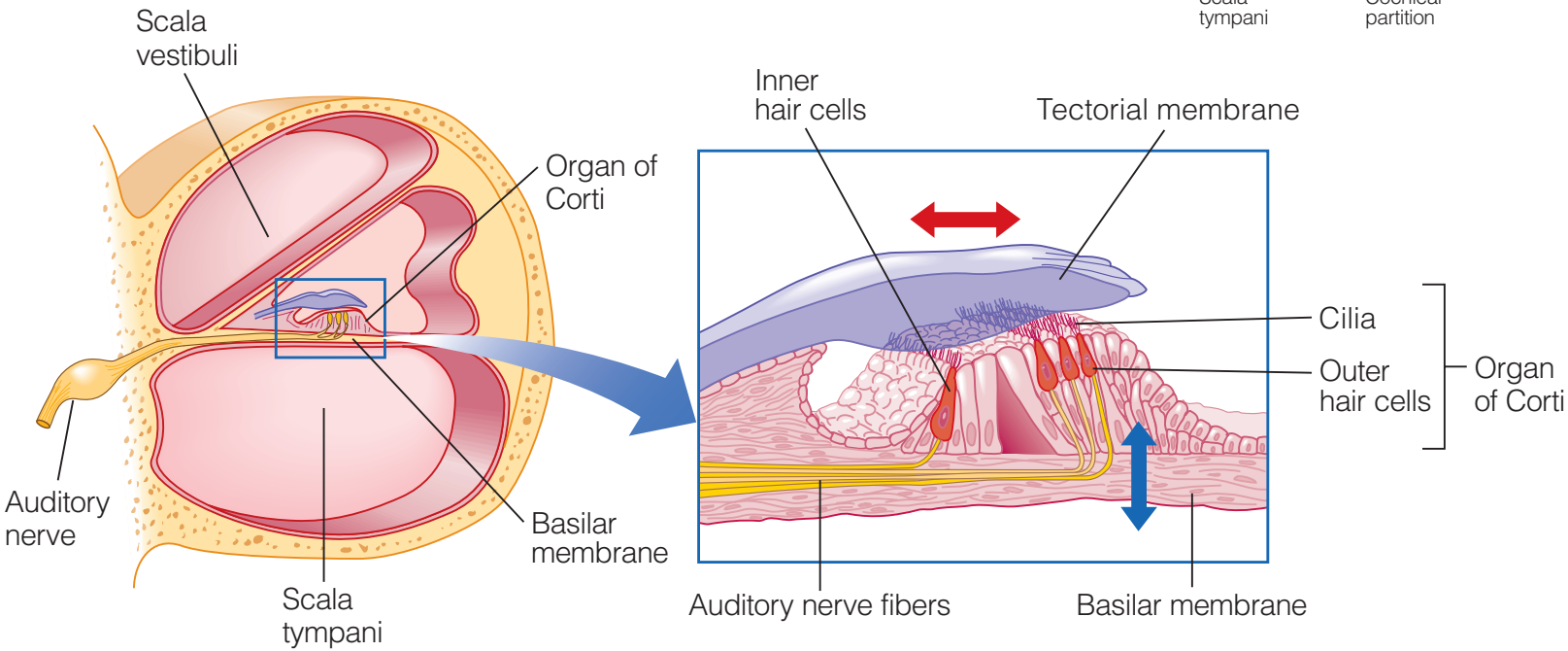
Mechanische Signalverstärkung durch Mittelohr (bis zu x100 – Schubert, 1980)



Sinnesphysiologie

Die Choclea



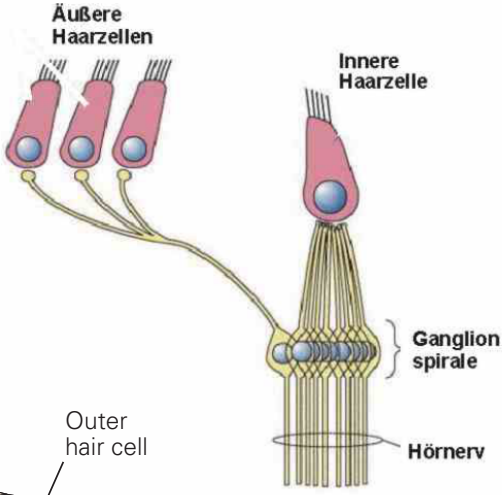


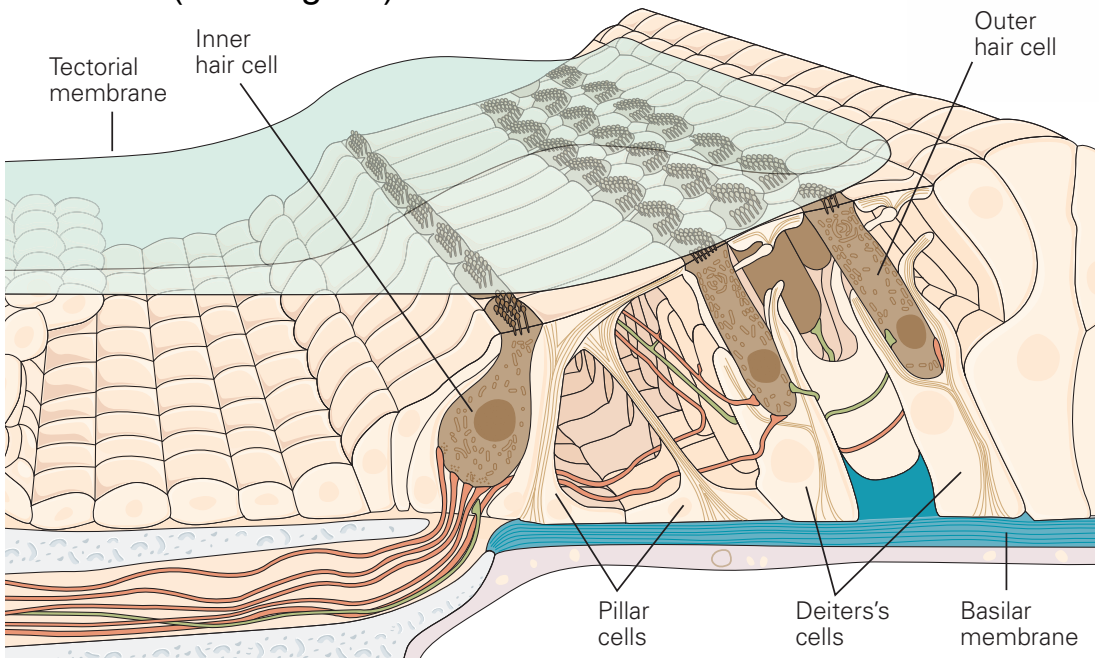
Sinnesphysiologie

Das Cortische Organ

3500 innere Haarzellen (Divergenz)

12000 äußere Haarzellen (Konvergenz)



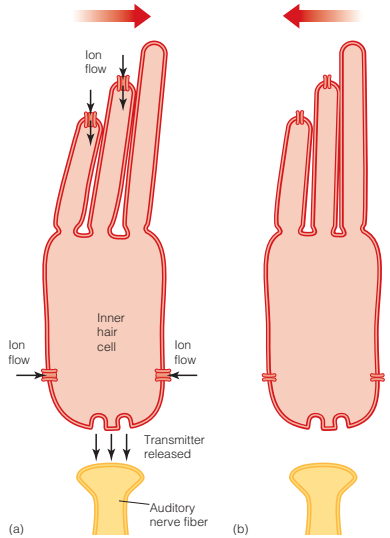


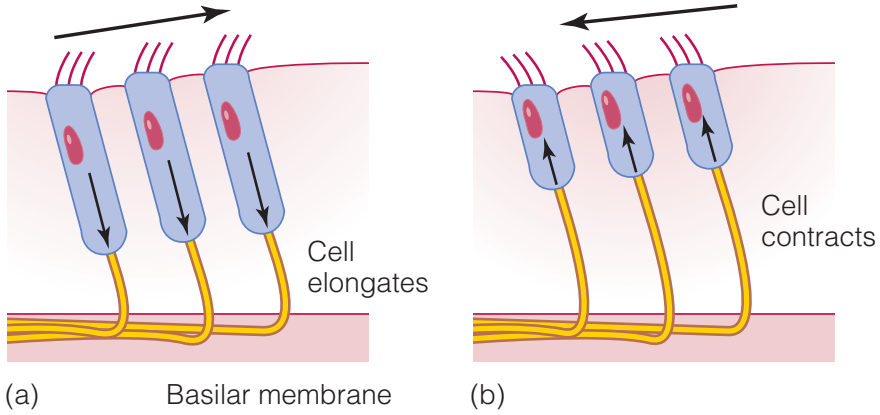
Sinnesphysiologie

Das Cortische Organ

Innere Haarzellen nehmen Bewegung der Endolymphe auf

Äußere Haarzellen verstärken Bewegung der Basilarmembran





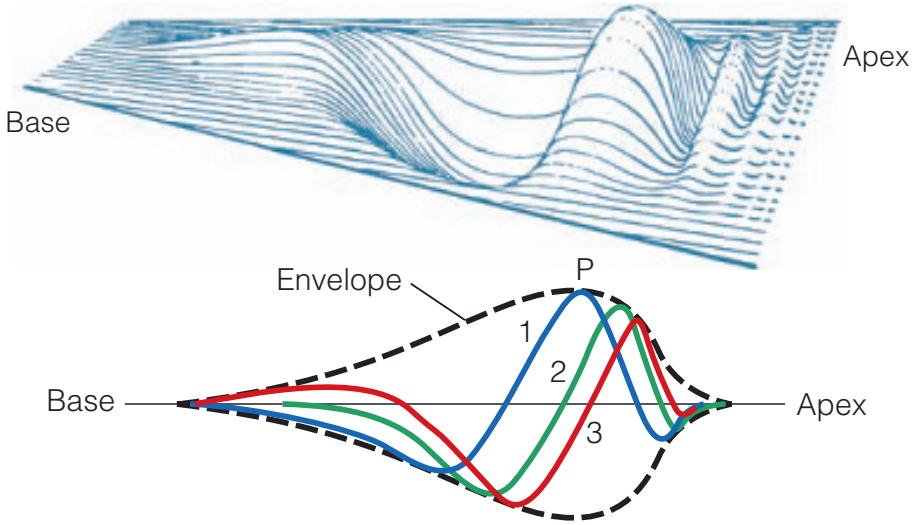
Sinnesphysiologie

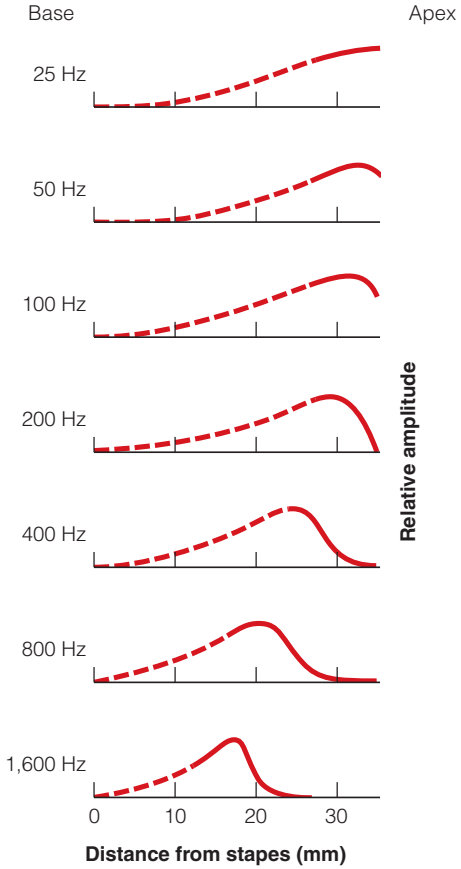
Äußere Haarzellen sind efferent innerviert

Sinnesphysiologie

Ortstheorie der Frequenzkodierung (Bekesy, 1961)

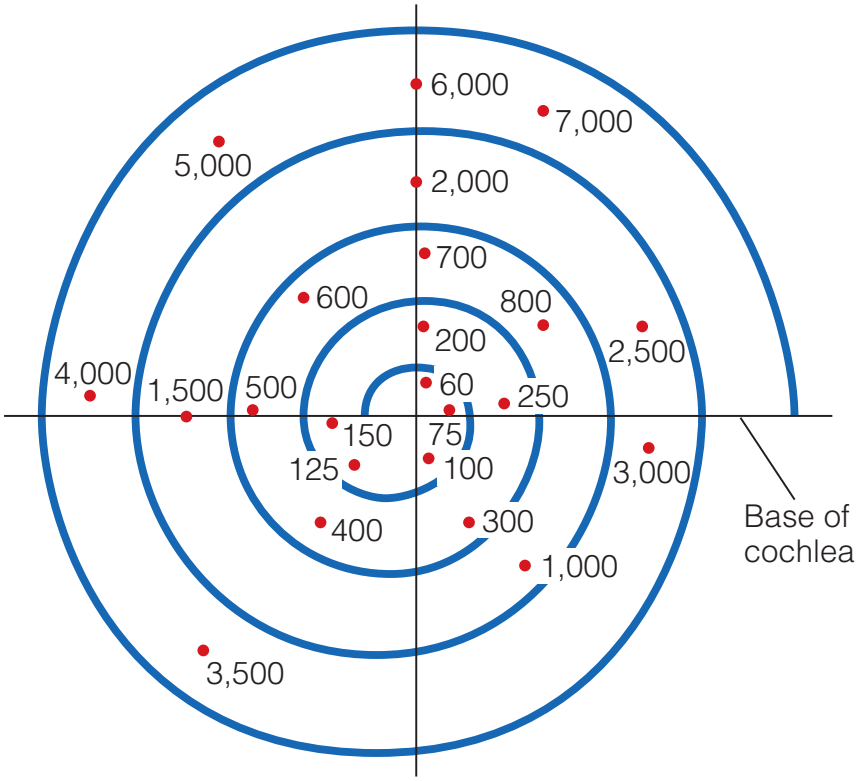
Ton erzeugt Wanderwelle mit Hüllkurve auf Basilarmembran

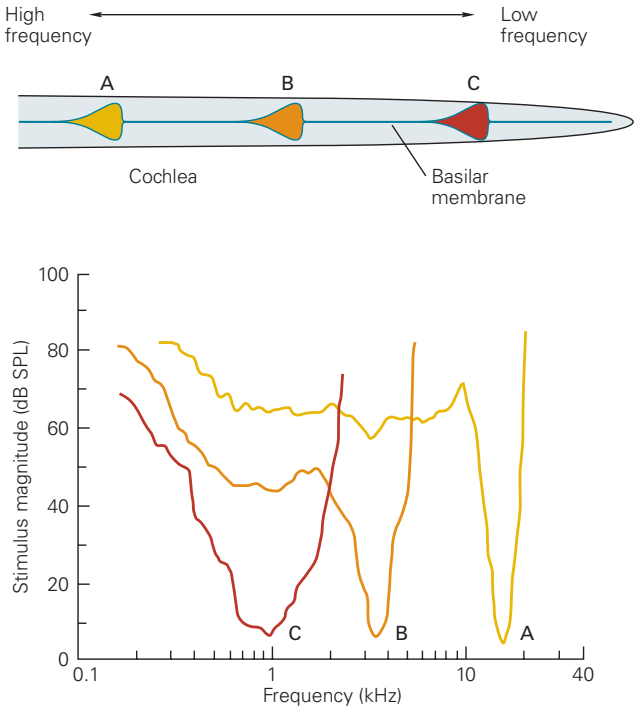




Sinnesphysiologie

Passive Tonotopie (Culler, 1943)

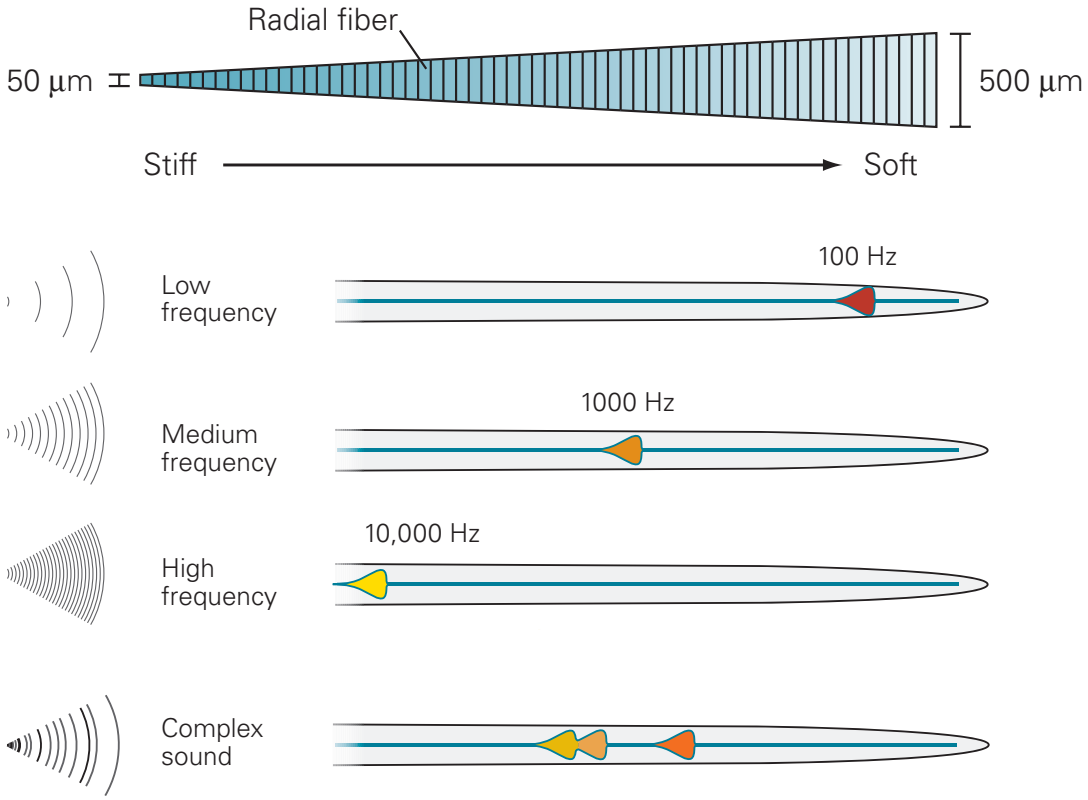




Frequenztuning einzelner Zellen (Kiang, 1980)

Sinnesphysiologie

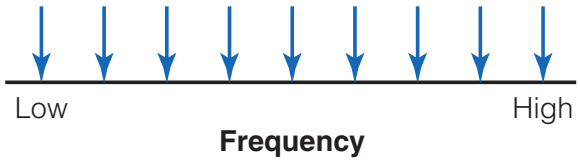
Fourieranalyse auf der Basilarmembran



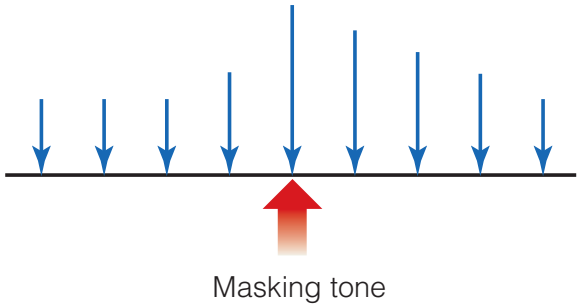
Sinnesphysiologie

Auditive Maskierung

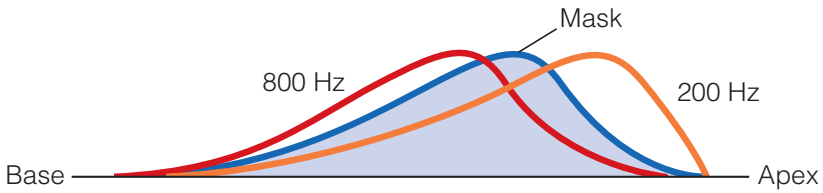
Bessere Wahrnehmung unterhalb des Maskierungstons



(a) Measure thresholds at different frequencies (blue arrows)



(b) Remeasure thresholds with the masking tone present

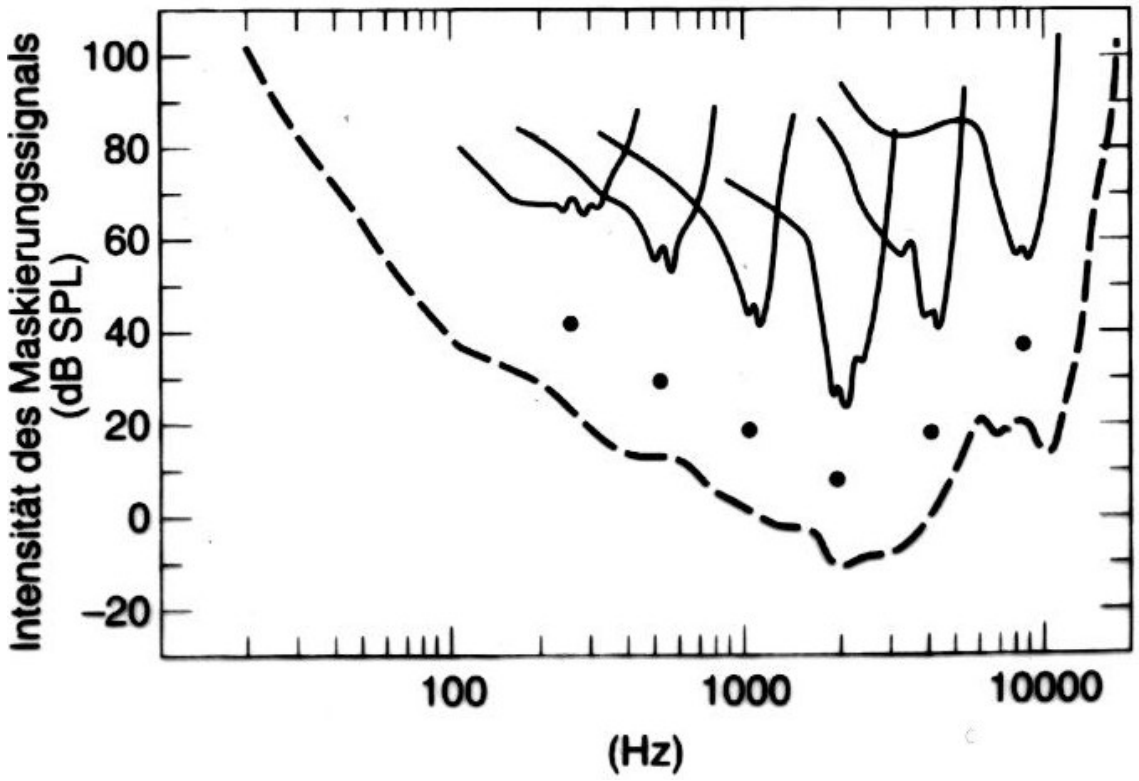


Unterschiedlichere Hüllkurven bei niedrigeren Frequenzen

Sinnesphysiologie

Auditive Maskierung

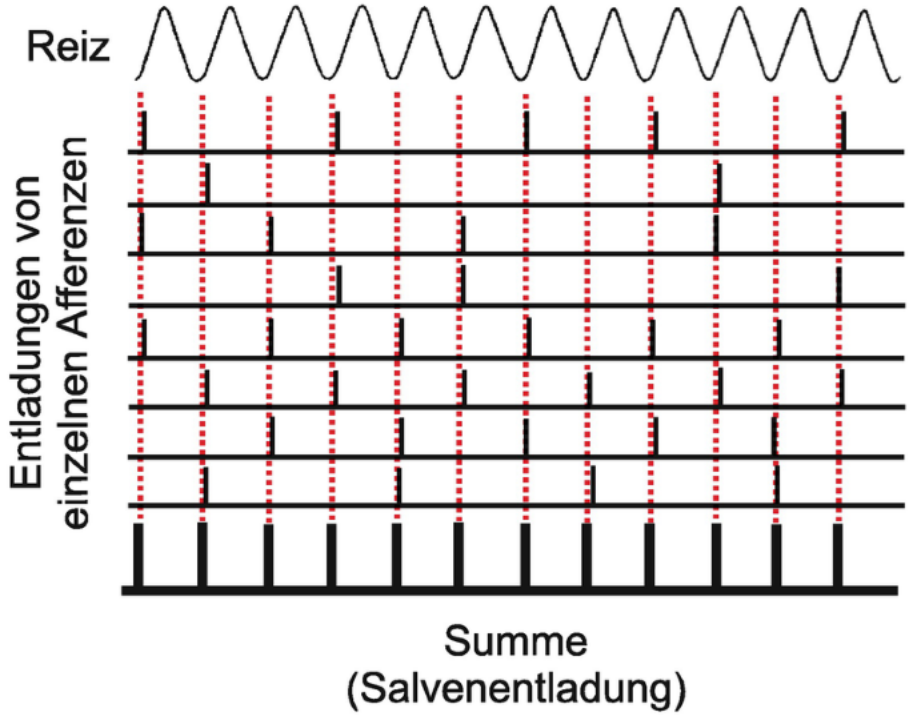
Maskierungsschwelle parallel zur Hörschwelle



Sinnesphysiologie

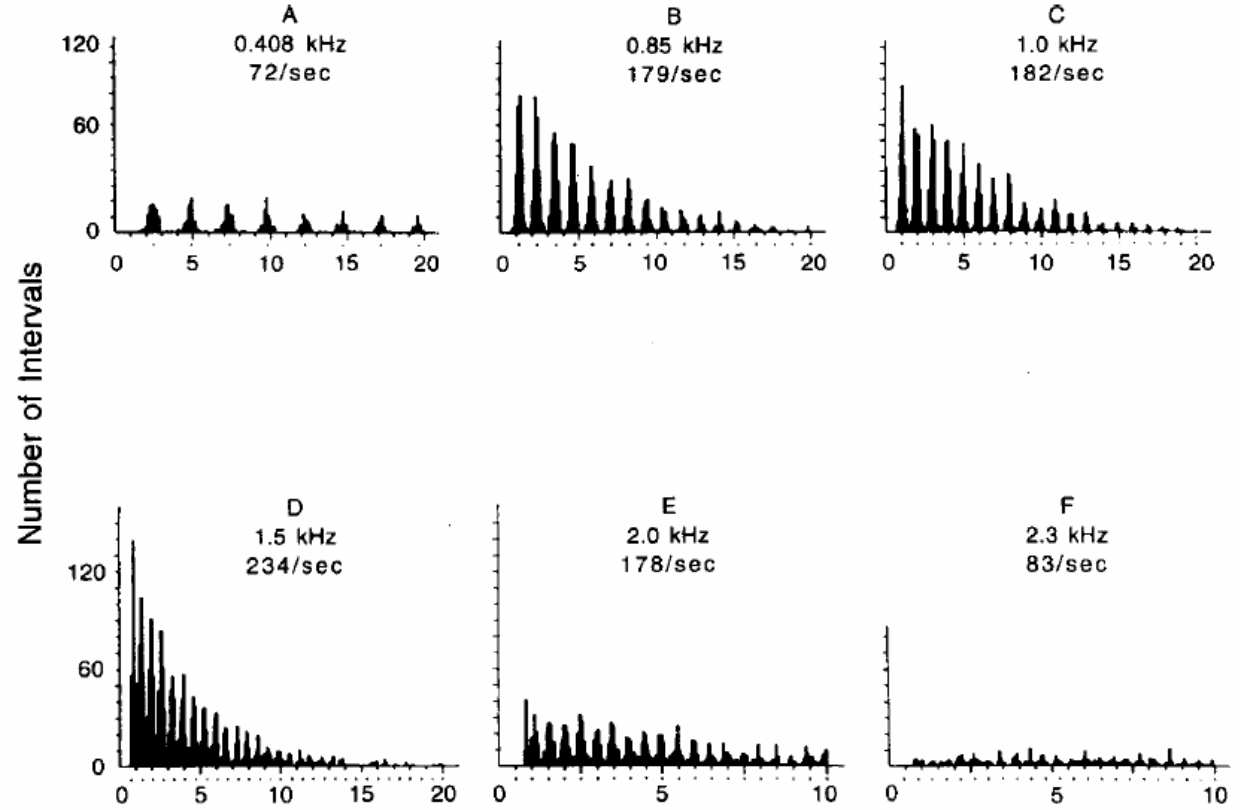
Zeittheorie der Frequenzkodierung (Rose, 1967)

Salvenprinzip/Phasenkopplung

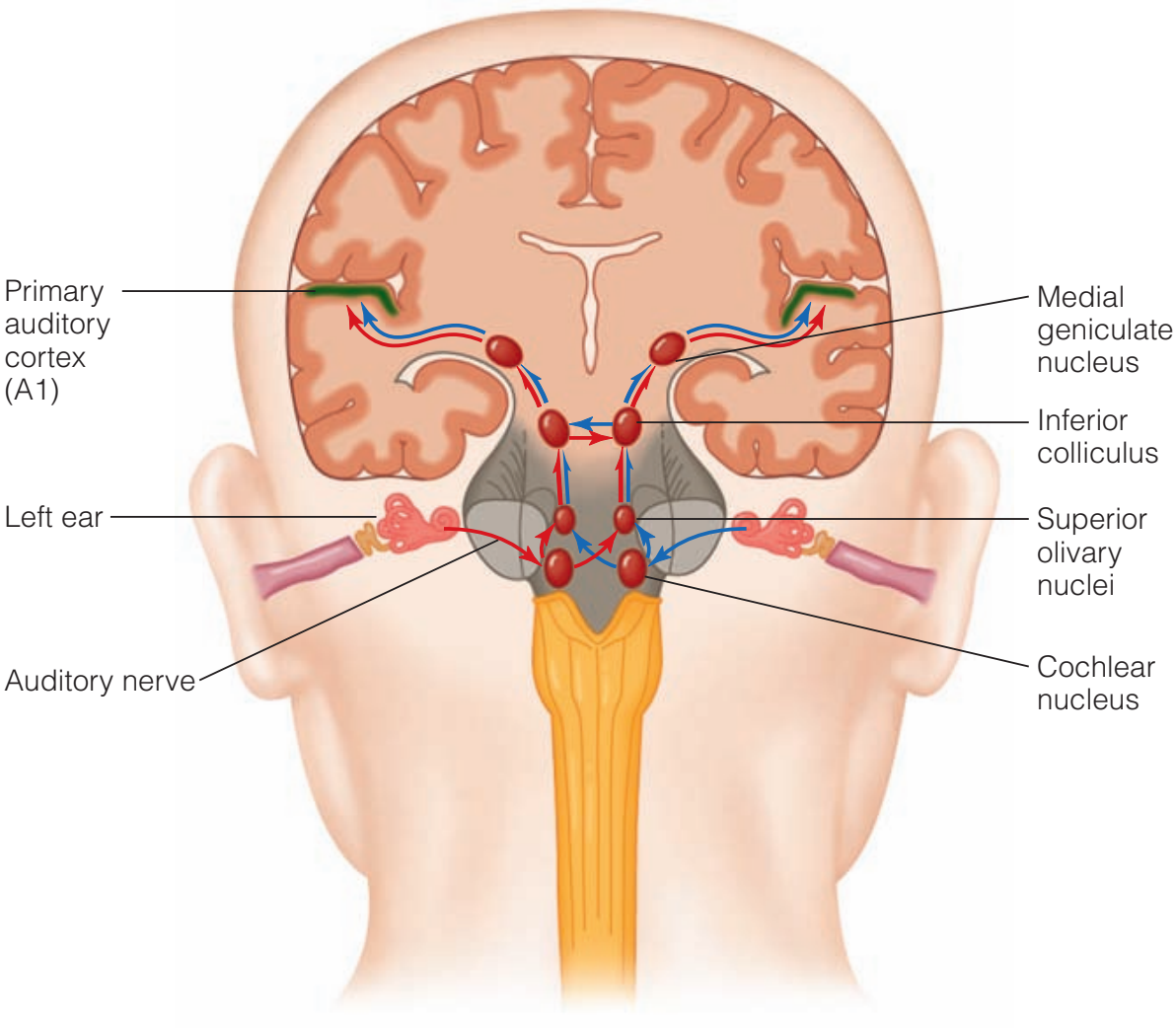


Sinnesphysiologie

Entladungsrate der Nervenzellen als Vielfaches der Stimulationsfrequenz

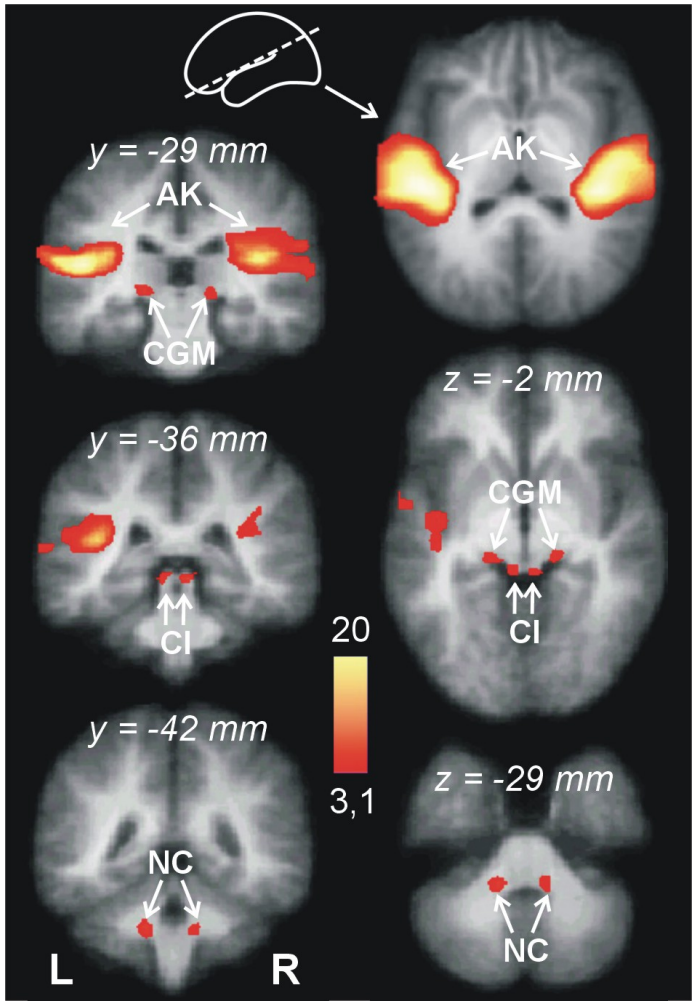


Hörbahn


Primary auditory cortex (A1)
Medial geniculate nucleus
Inferior colliculus
Left ear
Superior olivary nuclei
Auditory nerve
Cochlear nucleus

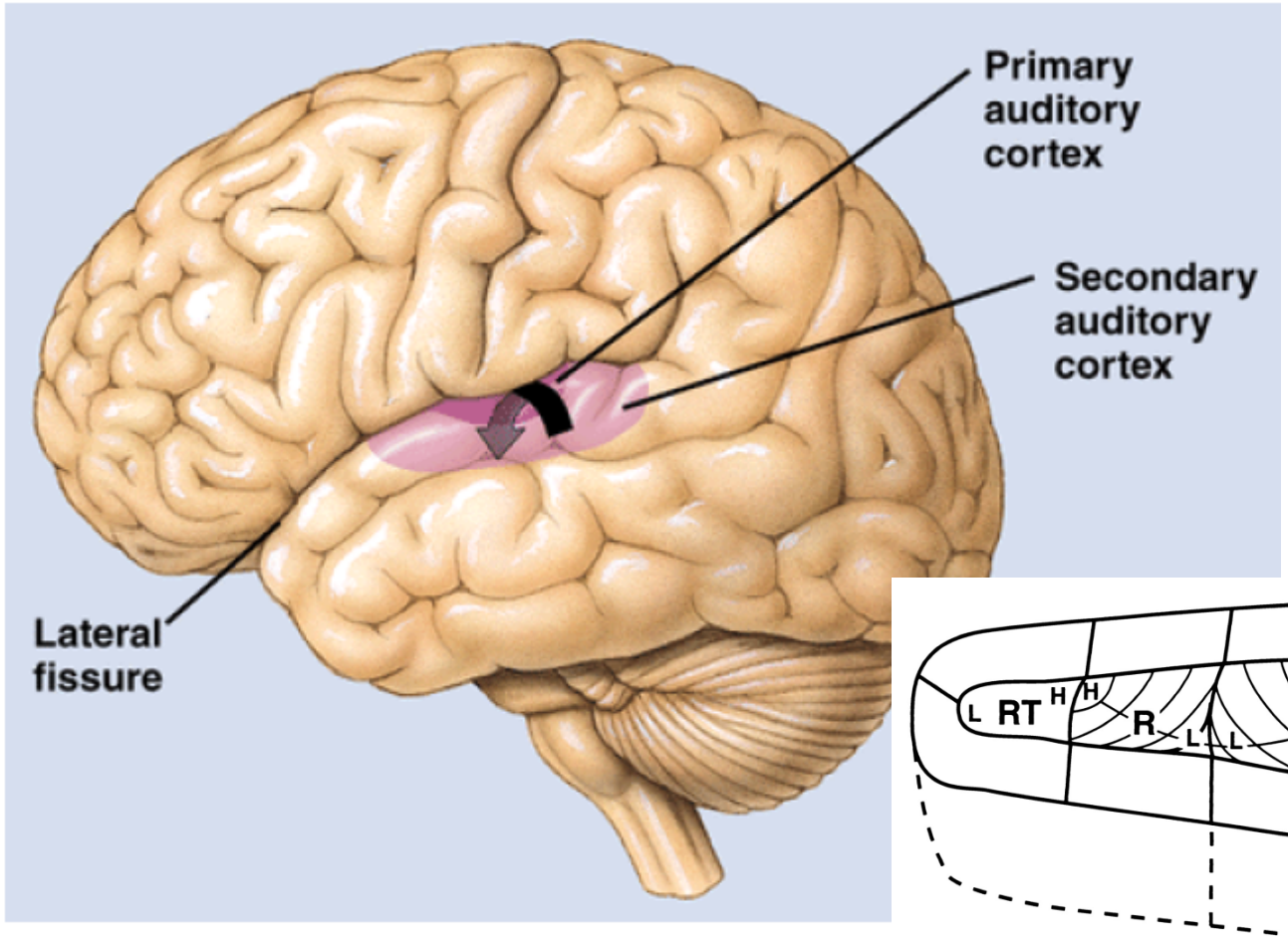
Hörbahn

Dichotisches Hören



Krumbholz et al, EJN, 2005

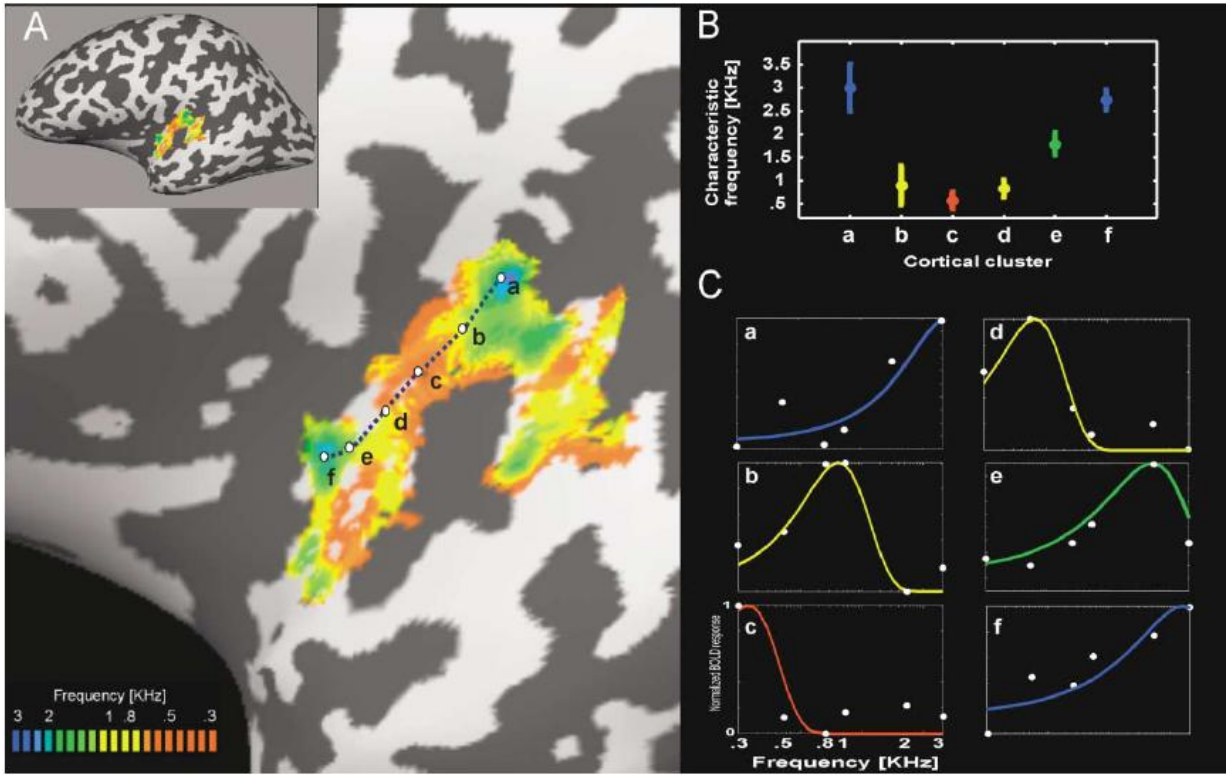
Auditorischer Kortex



Kaas and Hackett, PNAS 2000

Auditorischer Kortex

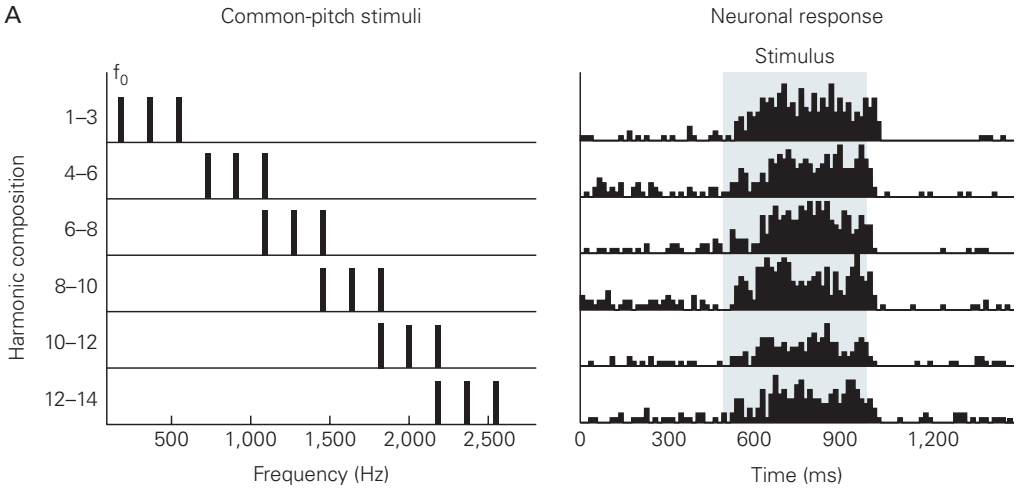
Tonotopie im menschlichen auditorischen Kortex

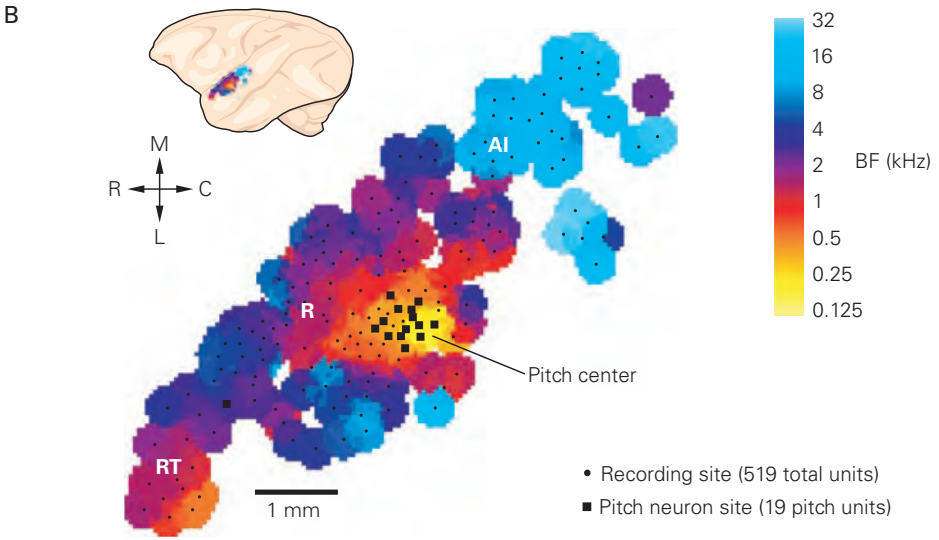


Formisano et al., Neuron, 2003

Auditorischer Kortex

Klangneurone

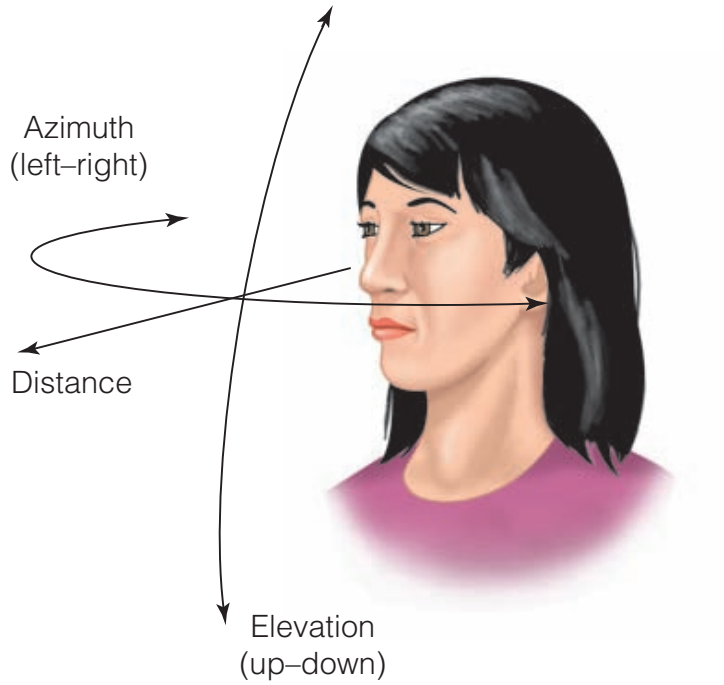




Bendor, 2005

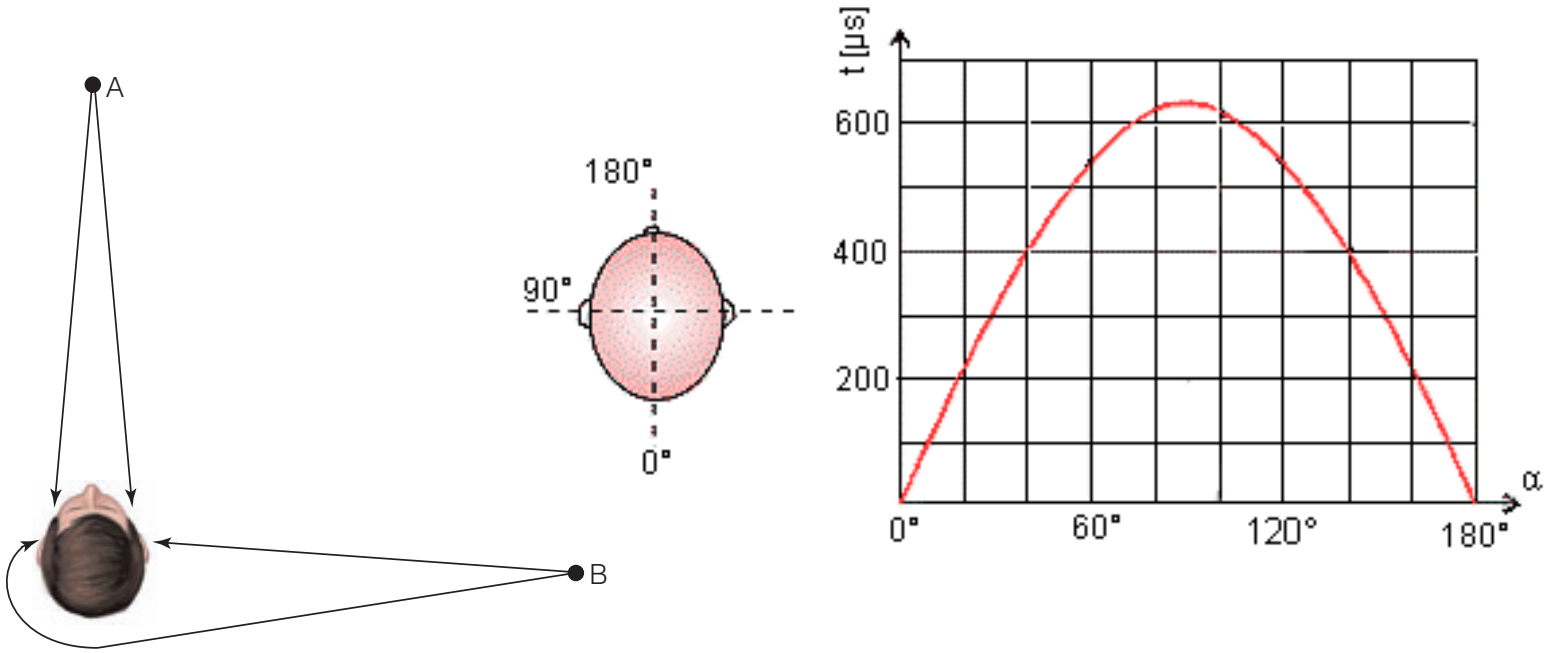
Raumwahrnehmung

Azimut/ Elevation



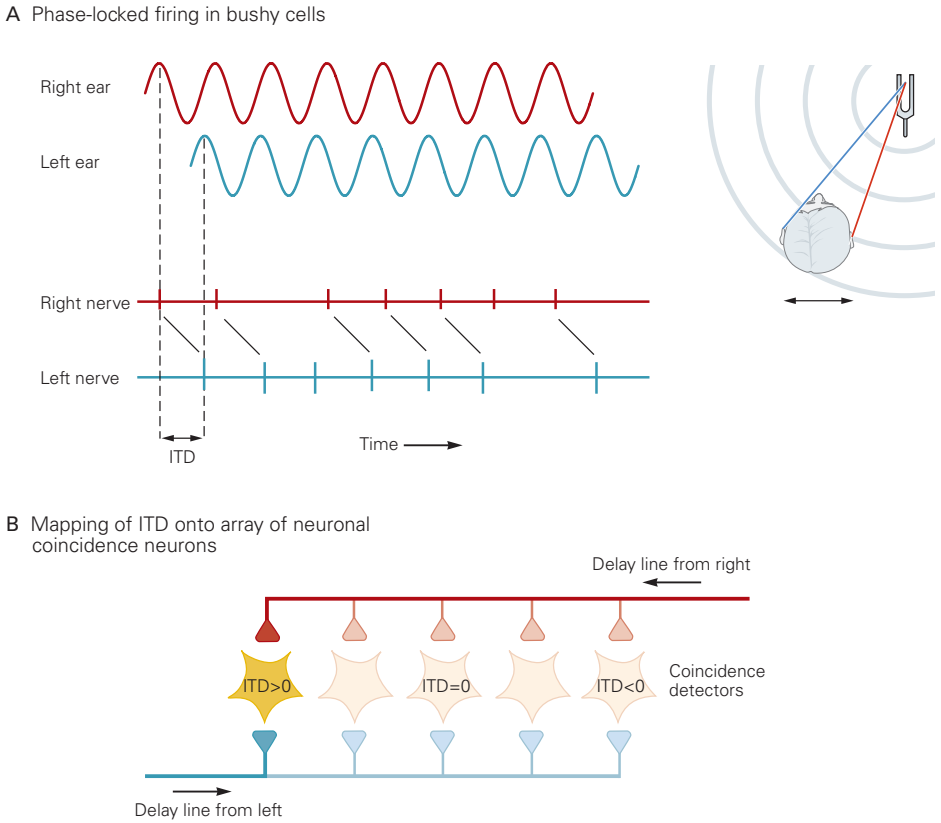
Raumwahrnehmung

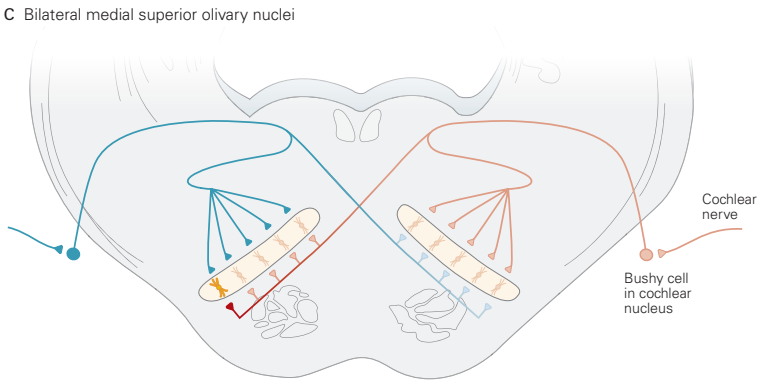
Interaurale Zeitdifferenz



Raumwahrnehmung

Interaurale Zeitdifferenz

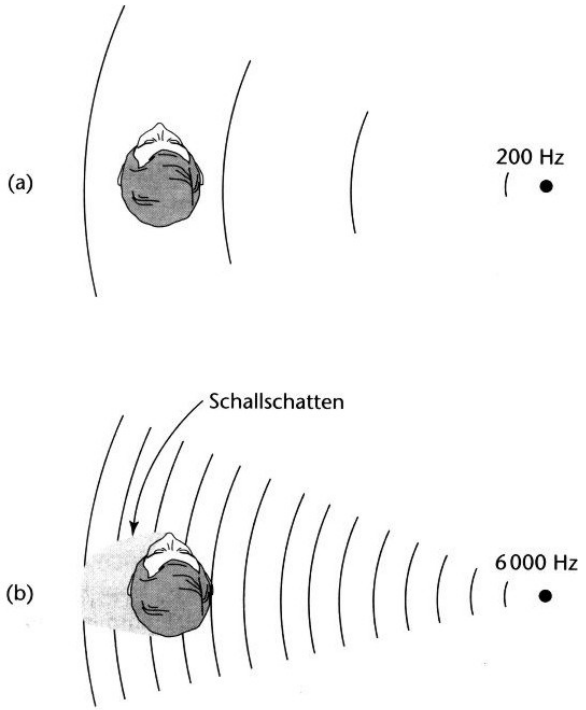


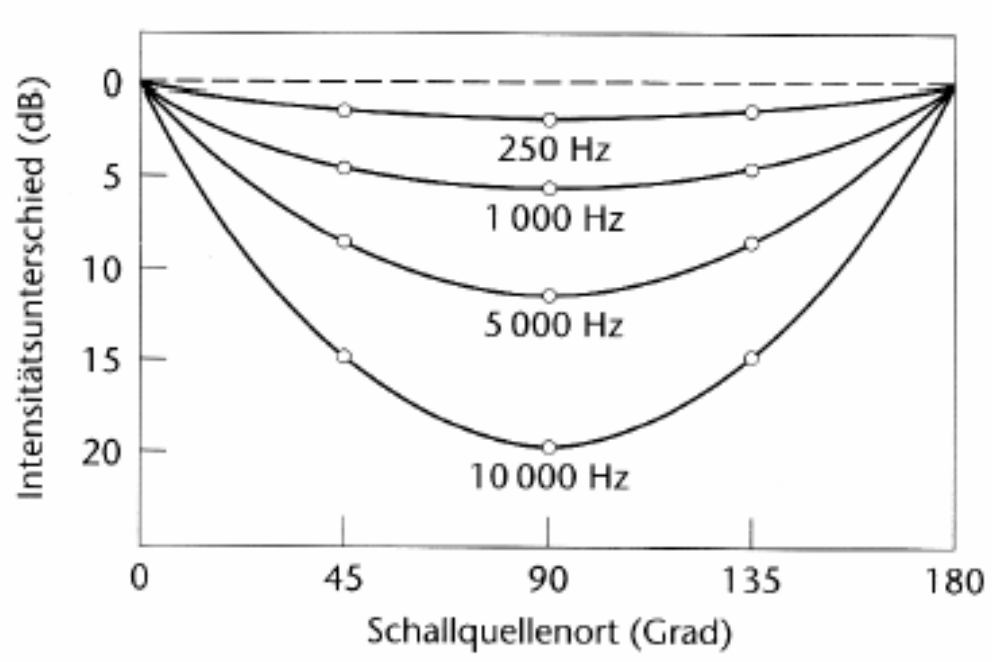


Kodierung in den oberen Oliven

Raumwahrnehmung

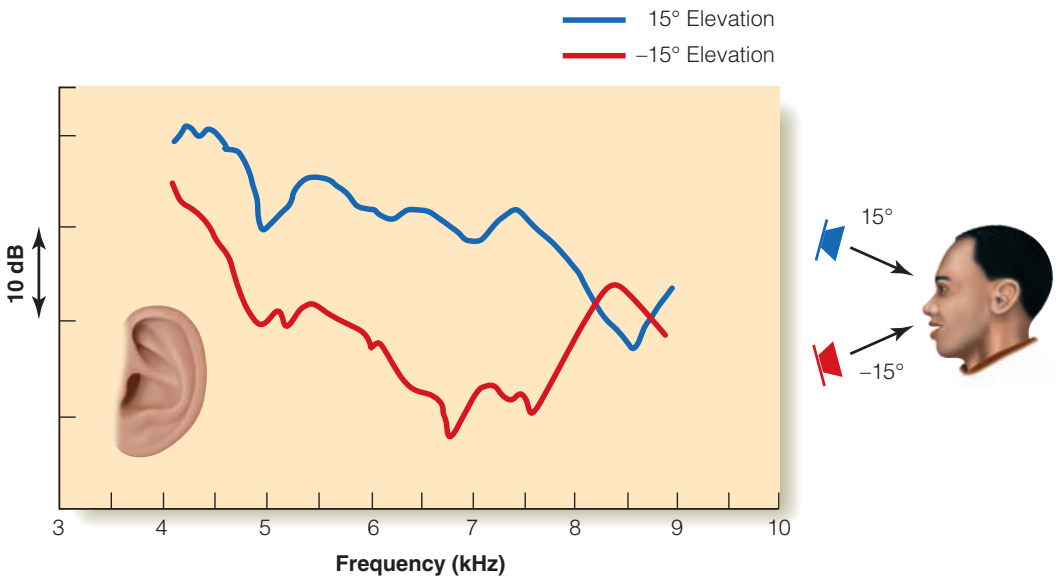
Interaurale Pegeldifferenz

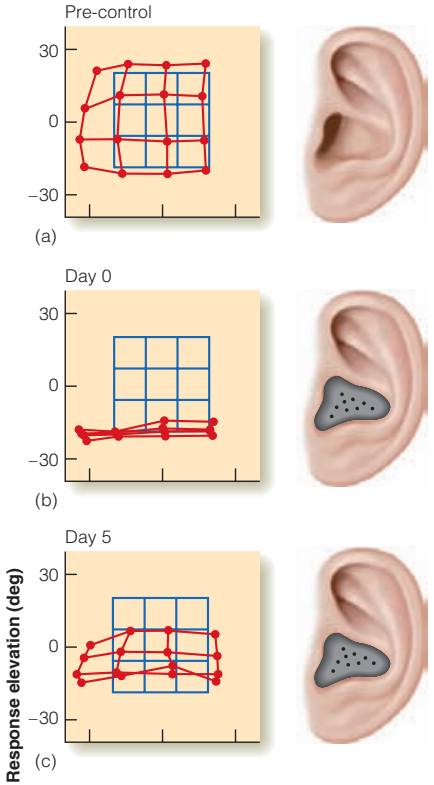




Raumwahrnehmung

Ohrenspezifische richtungsabhängige Übertragungsfunktion



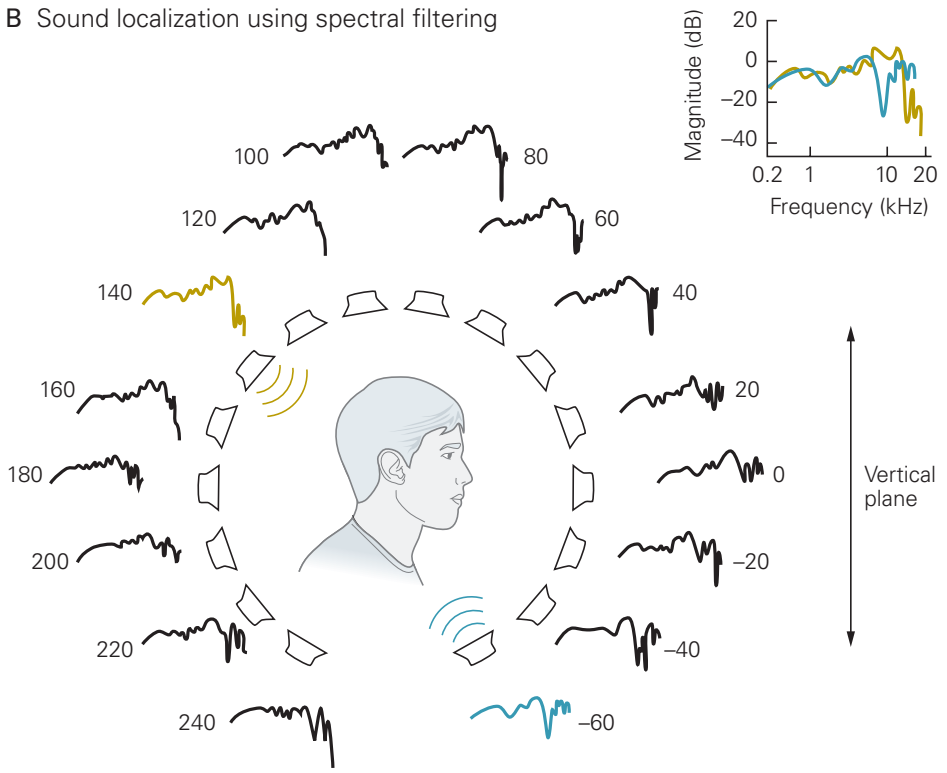


Hofman, 1998

Raumwahrnehmung

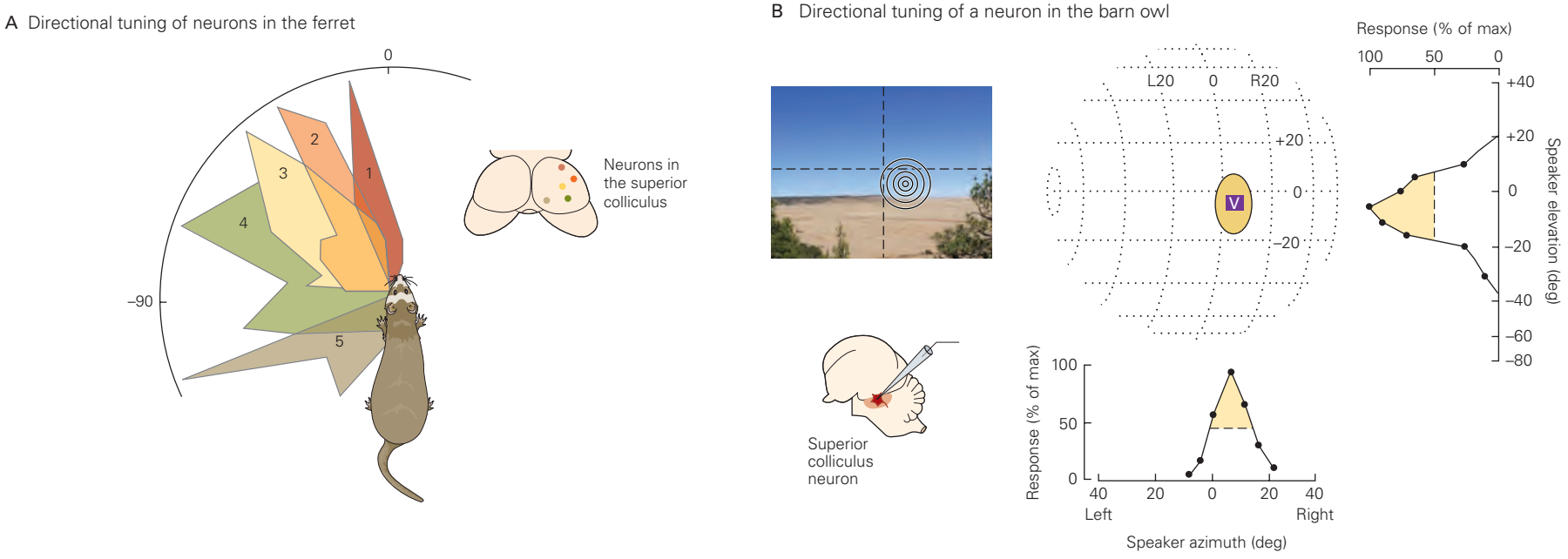
Körpereigenschaften (Schultern, Kopf, Ohrmuschel) bilden spektralen Filter

Modulation weißen Rauschens im Abhängigkeit vom Ort



Raumwahrnehmung

Räumliche rezeptive Felder der auditiven Wahrnehmung in den inferioren/superioren culliculi



Tinnitus

- Entstehung durch Affarenzverlust der Cochlea – Aufrechterhaltung wsl subkortikal/kortikal?
- Zusammenhang mit Primären auditorischen Kortex?
- Maladaptive kortikale plastische Prozesse?

→ bis jetzt: unklare Pathogenese!!!