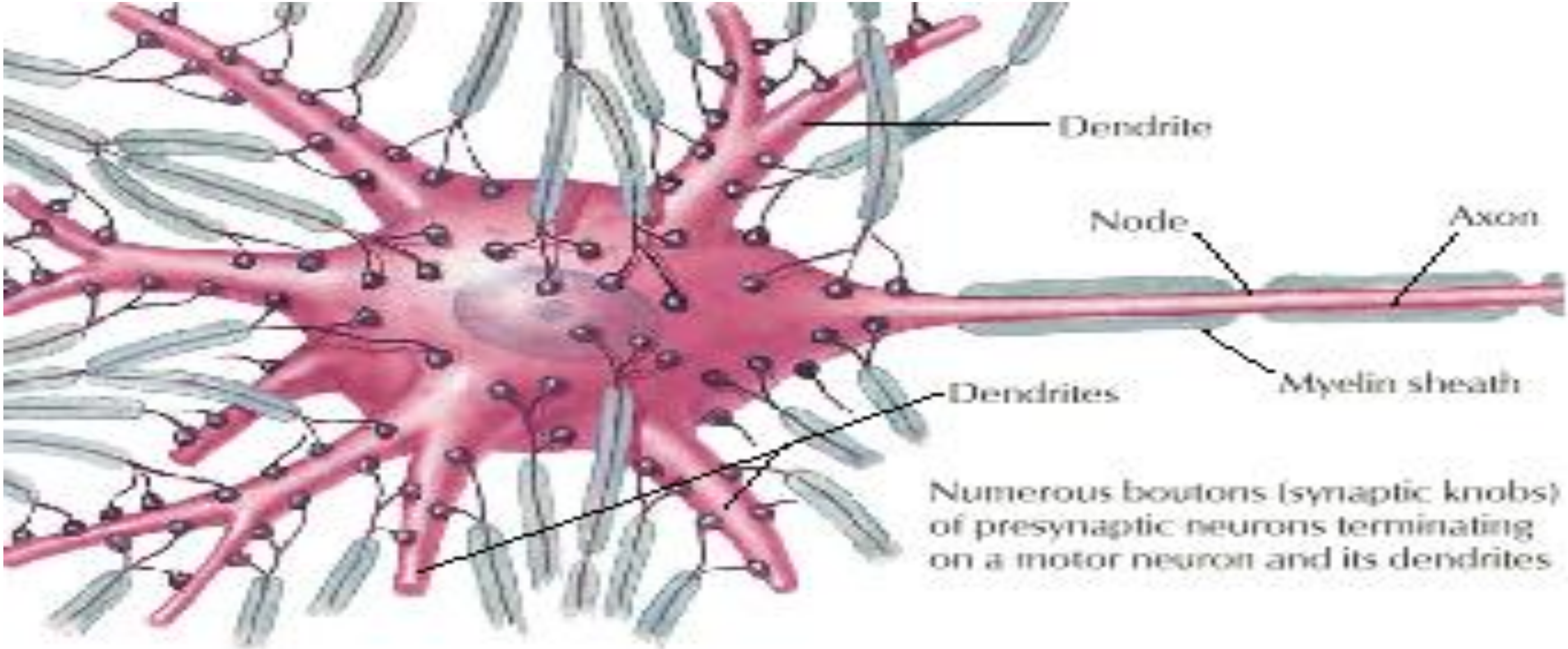
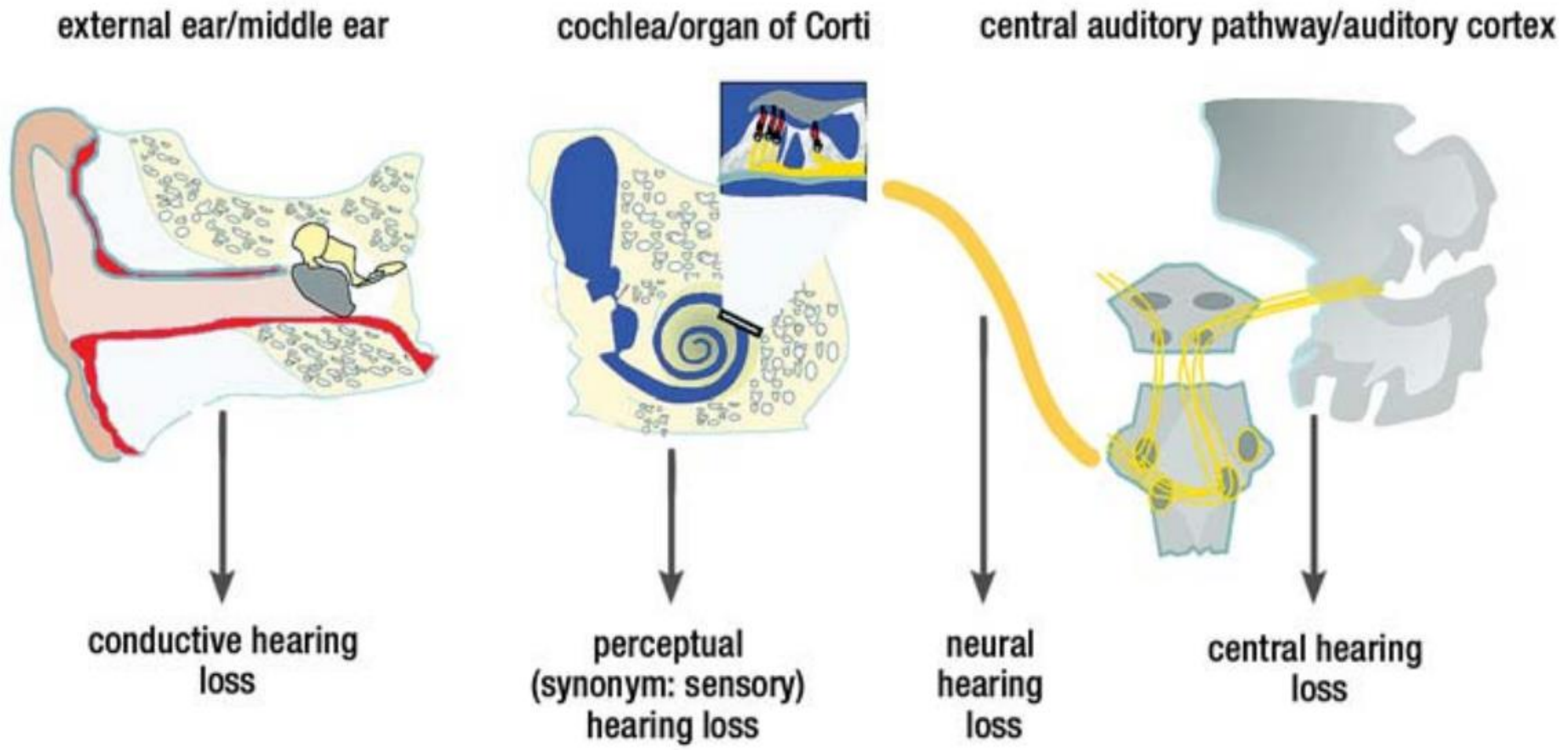


台大新竹分院 神經部 葉伯壽
E-mail: neuron@nctu.edu.tw

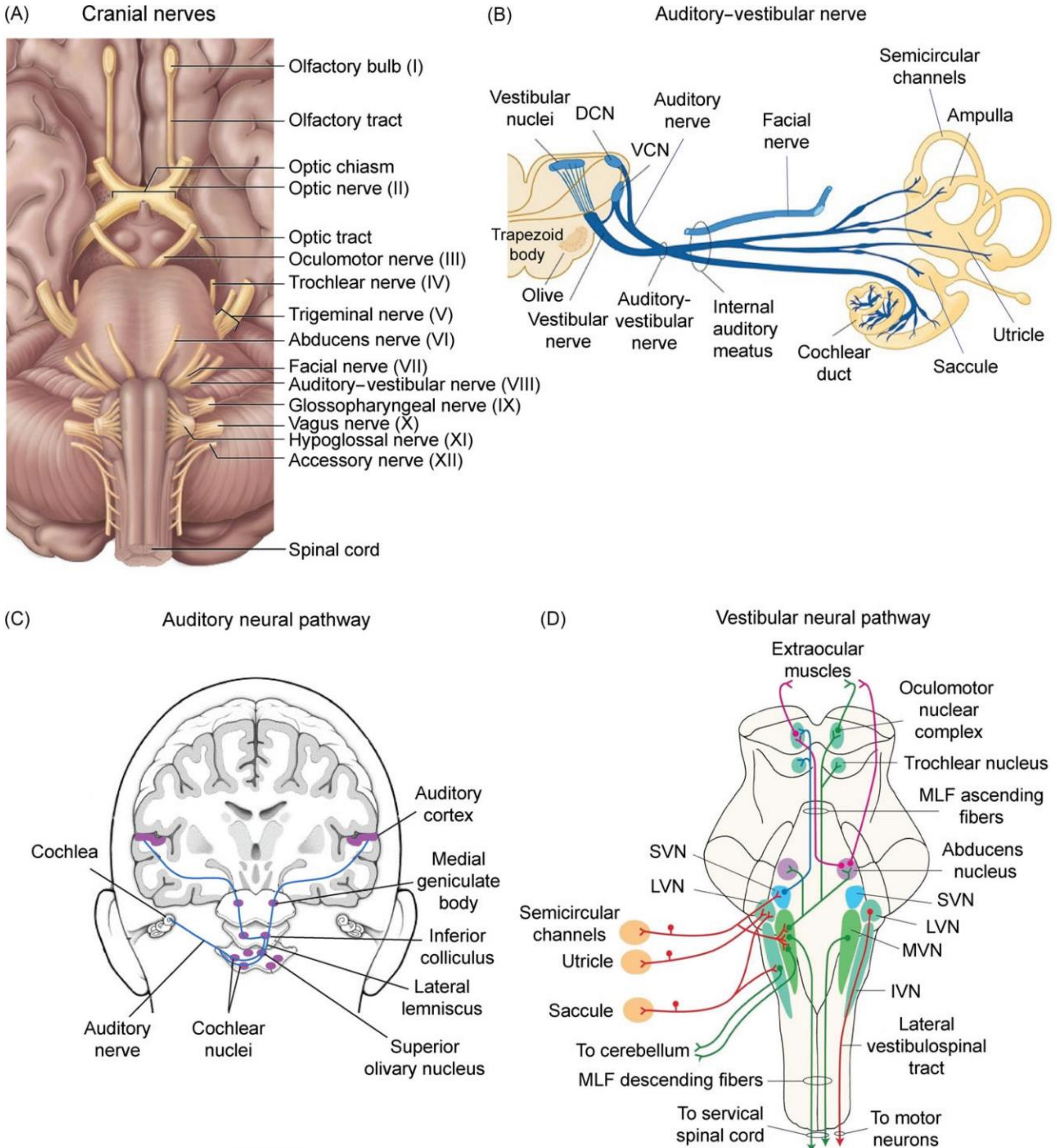
vertigo, nystagmus, tinnitus, and hearing loss

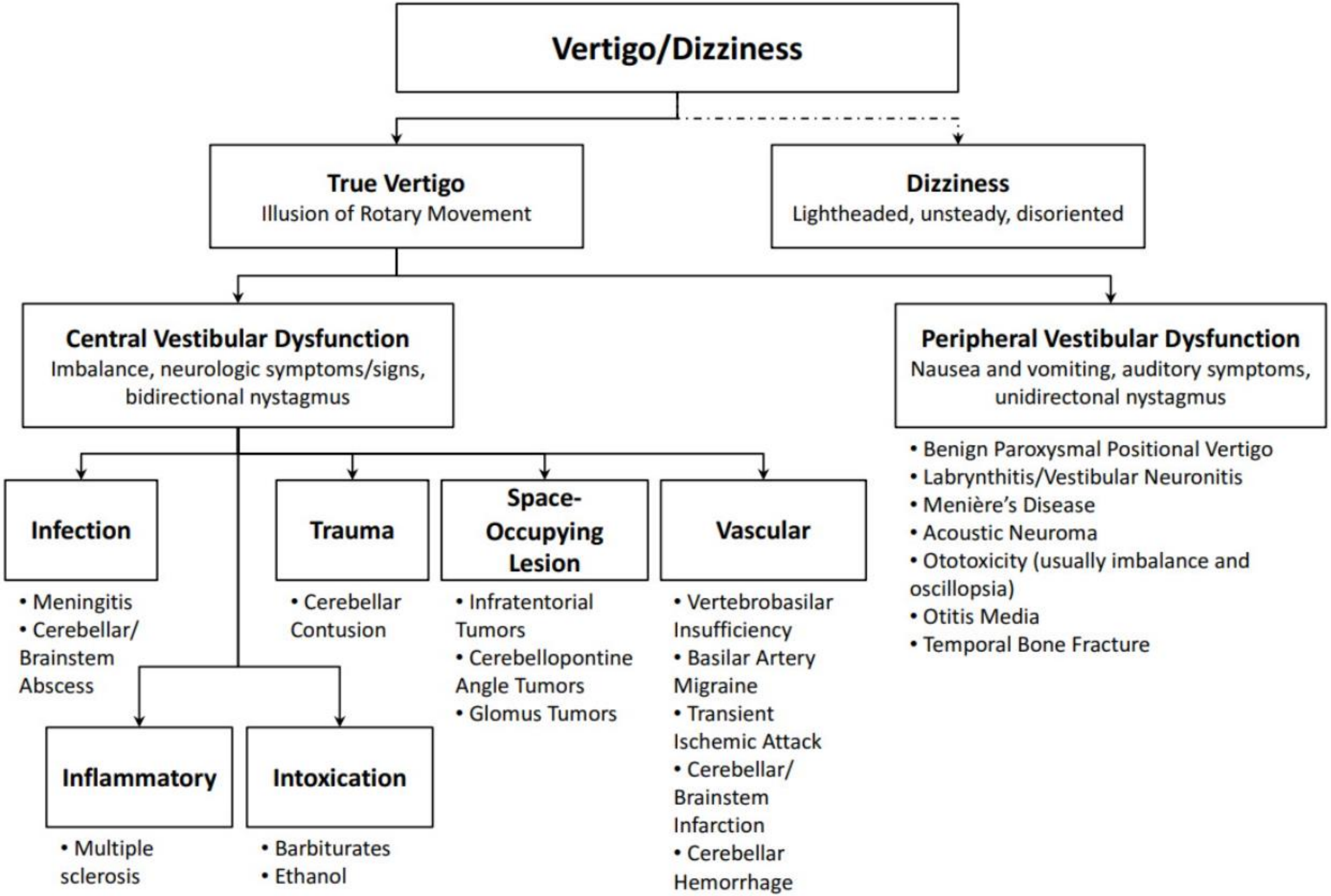


CN VIII

cerebellopontine angle (CPA)
internal auditory canal (IAC)

- superior cerebellar artery
  anterior inferior cerebellar artery
- superior vestibular nucleus → MLF → vestibulo-oculomotor reflex
- medial vestibular nucleus → medial vestibulospinal fascicles→ vestibular-spinal reflex (stability of the head during movements)
- lateral vestibular nucleus→ the lateral vestibulospinal fasciculus → ipsilateral spinal cord→ dedicated to the vestibulospinal reflex (postural correction in response to vestibular stimuli)





Vertigo/Dizziness
True Vertigo
Illusion of Rotary Movement
Dizziness
Lightheaded, unsteady, disoriented
Central Vestibular Dysfunction
Imbalance, neurologic symptoms/signs, bidirectional nystagmus
Peripheral Vestibular Dysfunction
Nausea and vomiting, auditory symptoms, unidirectonal nystagmus
• Benign Paroxysmal Positional Vertigo
• Labrynthitis/Vestibular Neuronitis
• Menière's Disease
• Acoustic Neuroma
• Ototoxicity (usually imbalance and oscillopsia)
• Otitis Media
• Temporal Bone Fracture
Infection
• Meningitis
• Cerebellar/ Brainstem Abscess
Trauma
• Cerebellar Contusion
Space-Occupying Lesion
• Infratentorial Tumors
• Cerebellopontine Angle Tumors
• Glomus Tumors
Vascular
• Vertebrobasilar Insufficiency
• Basilar Artery Migraine
• Transient Ischemic Attack
• Cerebellar/ Brainstem Infarction
• Cerebellar Hemorrhage
Inflammatory
• Multiple sclerosis
Intoxication
• Barbiturates
• Ethanol

Synopsis of the causes and clinical features of hearing impairment, with differential diagnoses for each hearing impairment syndrome

	Conductive hearing loss	Sensory hearing loss	Neural hearing loss	Central hearing loss
Cause	– acoustic-mechanical disturbance of sound conduction in the external auditory canal, across the tympanic membrane, or in the ossicular chain	– dysfunction of the hair cells or their synaptic connections to the cochlear nerve; if the outer hair cells are affected, loss of cochlear amplification and thus of recruitment of intermediate intensities – blurring of frequency resolution – reduction of temporal resolution	– cochlear nerve dysfunction – delayed impulse conduction – disturbed neural encoding of the acoustic signal	– dysfunction of the audtiory pathway or auditory cortex (processing of bilateral auditory stimuli, synchronization, signal modulation, recognition, noise suppression)
Clinical features	If the cause is in the external auditory canal: – reduced sound intensity (sound is perceived as soft) If the cause is in the tympanic membrane or ossicular chain: – altered sound frequency and intensity (high and low tones may be either softer or louder)	– loss of intensity and dynamics – soft noises or speech may be perceived as either too soft or too loud – often, distorted perception	– similar to sensory hearing loss, but usually unilateral – speech perception worse than tone perception	– there may be no disturbance of tone perception – impaired rapid speech processing – impairment of sound localization, poor understanding of speech with superimposed noise, impairment of auditory memory
Differential diagnosis	Acute: – blockage by cerumen – tubular catarrh – tympanic effusion – traumatic eardrum perforation – acute otitis media or externa Permanent: – canal stenosis/atresia – defect of eardrum or ossicular chain due to chronic purulent infection of the mucosa – cholesteatoma – malformation – otosclerosis – tympanosclerosis	Acute: – idiopathic sudden sensorineural hearing loss – acute noise-induced trauma – blast trauma – explosion trauma – bacterial/viral labyrinthitis Hereditary/permanent:: – hereditary hearing impairment – presbycusis – noise-induced hearing impairment – toxic (incl, drug-induced) hearing impairment – idiopathic chronic progressive hearing impairment – drug side effects – lasting sequelae of infections and sudden hearing loss	– acoustic neuroma (= vestibular schwannoma) – other tumors of the petrous bone or cerebellopontine angle (meningioma, chordoma, chondrosarcoma) – compression syndrome	– infarction – hemorrhage – tumor – multiple sclerosis – auditory processing disorder
Audiological testing	– tuning-fork test – whispering test – test of hearing at a distance – pure-tone audiogram – impedance audiometry	– tuning-fork test – whispering test – test of hearing at a distance – pure-tone audiogram – speech audiogram – otoacoustic emissions	– pure-tone audiogram – speech audiogram – supraliminal tests – auditory fatigue tests – electric response audiometry	– test of hearing at a distance – pure-tone audiogram – speech audiogram – supraliminal tests – auditory fatigue tests – electric response audiometry

Dtsch Arztebl Int 2011; 108(25): 433– 44

NOISE CRITERIA	POSSIBLE FEATURES
Onset	Sudden, gradual
Pattern	Pulsatile, intermittent, constant, fluctuating
Site	Right or left ear, both ears, within head
Loudness	Wide range, varying over time
Quality	Pure tone, noise, polyphonic
Pitch	Very high, high, medium, low

Langguth B, et al. (2013) Lancet Neurol.12:920-930.

Table 1. Selected Causes of Tinnitus

Subjective

Otologic: hearing loss, cholesteatoma, Meniere disease, vestibular schwannoma

Toxicologic: medication or substance use

Somatic: temporomandibular joint dysfunction, head or neck injury

Traumatic: cerumen removal[10]

Neurologic: multiple sclerosis, spontaneous intracranial hypotension,[11] type I Chiari malformation,[12] idiopathic intracranial hypertension,[13] vestibular migraine[14]

Infectious: viral, bacterial, fungal

Metabolic (weak evidence): hyperlipidemia, diabetes mellitus, vitamin B_{12} deficiency

Objective

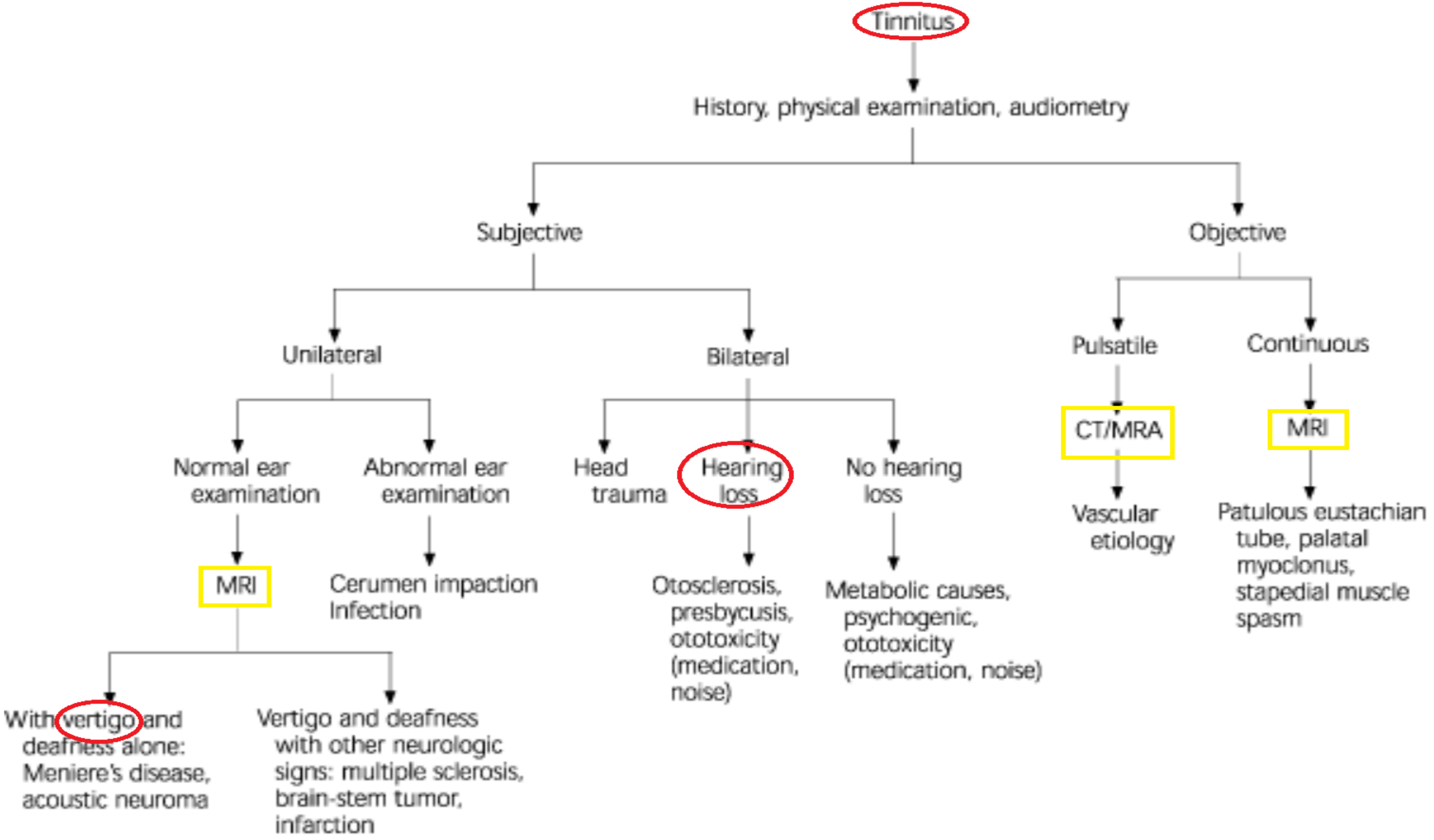
Patulous eustachian tube

Vascular: arterial bruit, venous hum, arteriovenous malformation, vascular tumors, carotid atherosclerosis, dissection, or tortuosity; Paget disease

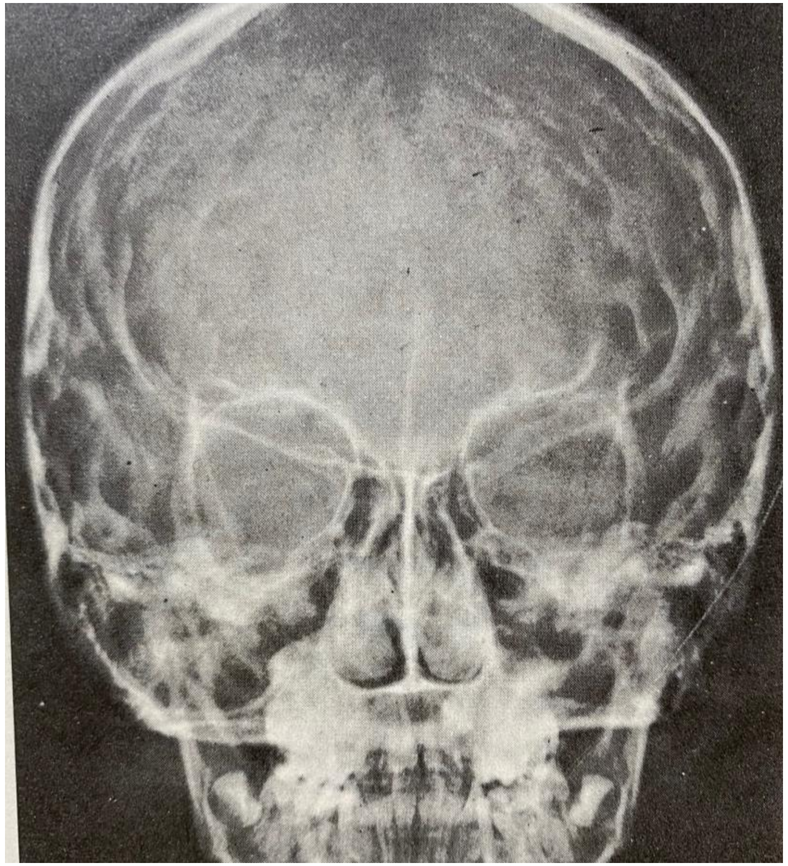
Neurologic: palatal myoclonus, idiopathic stapedial or tensor tympani muscle spasm

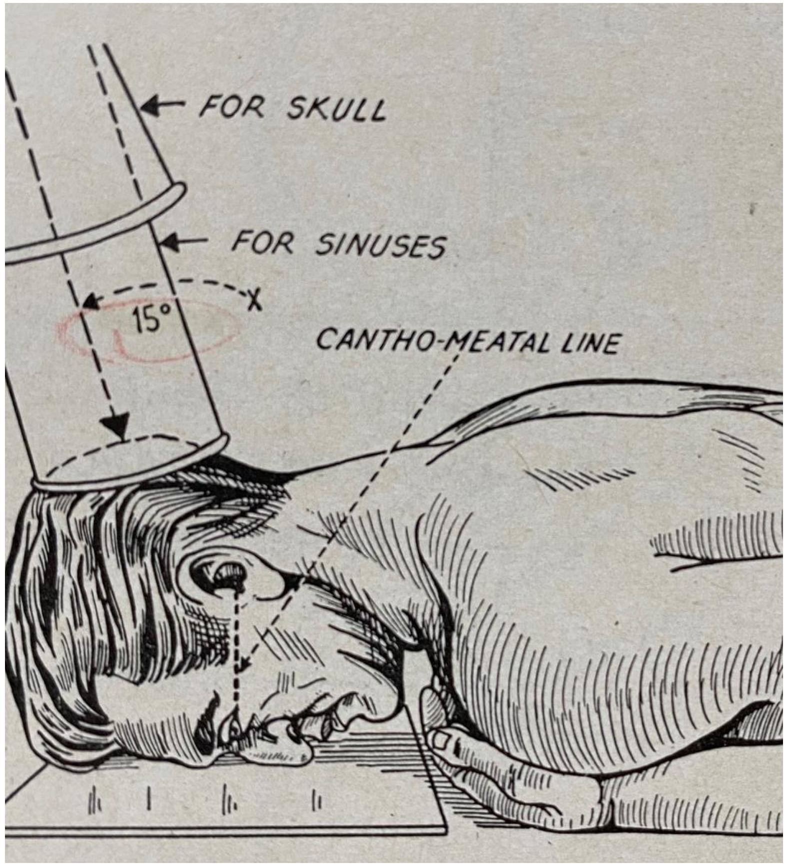
Am FamPhysician. 2014;89(2):106-113.

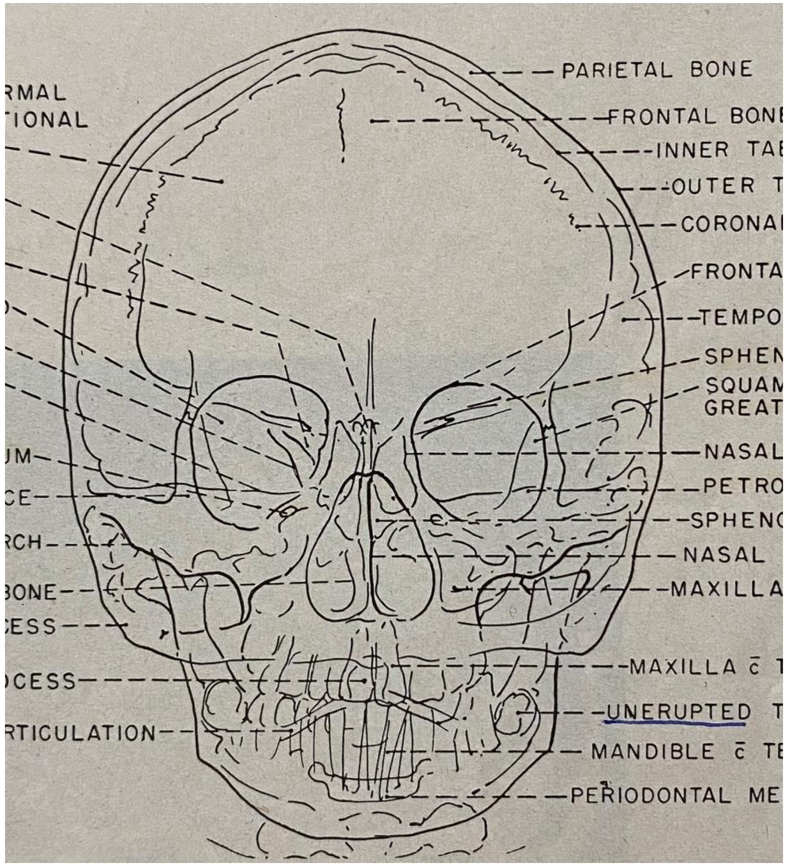
Diagnostic Approach to Tinnitus



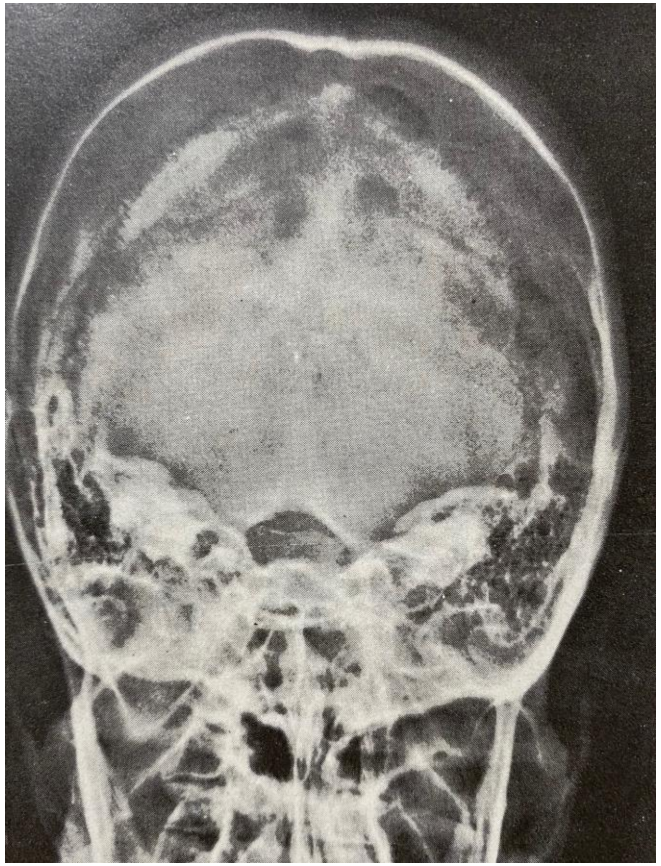
Caldwell's projection

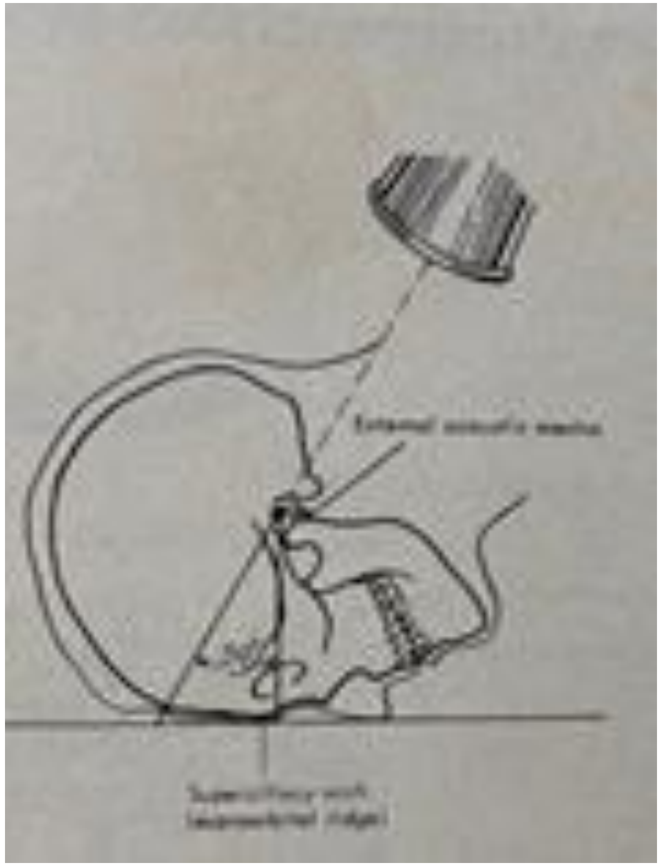


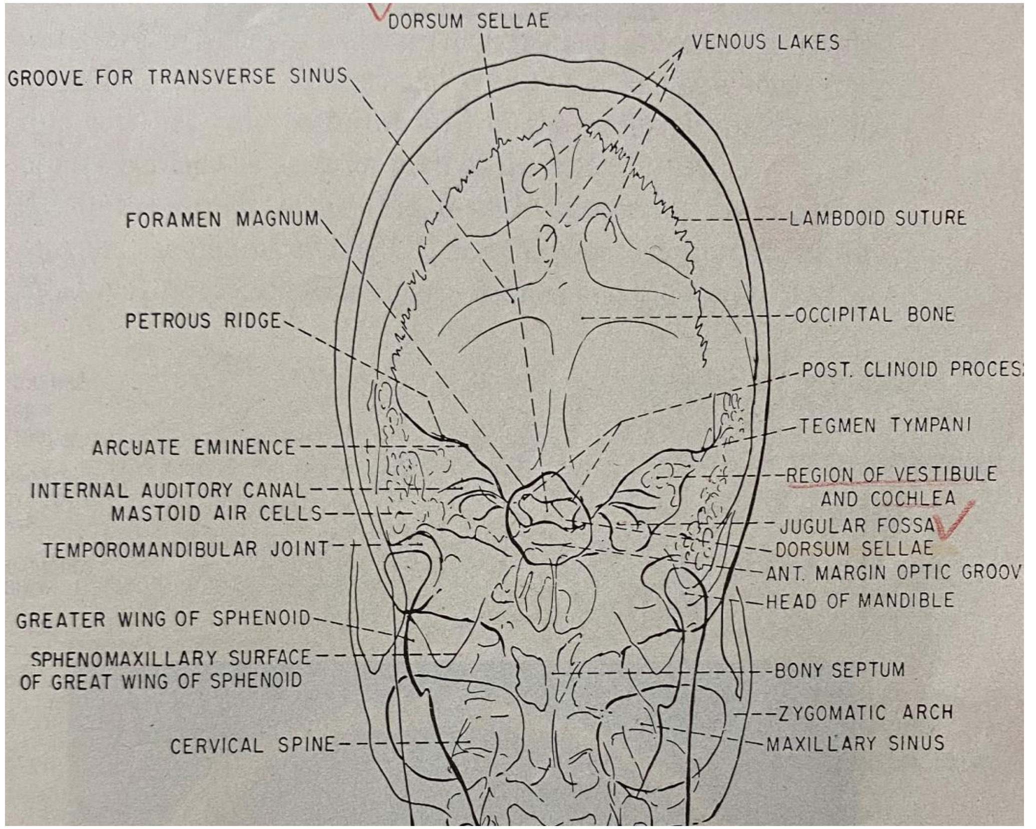




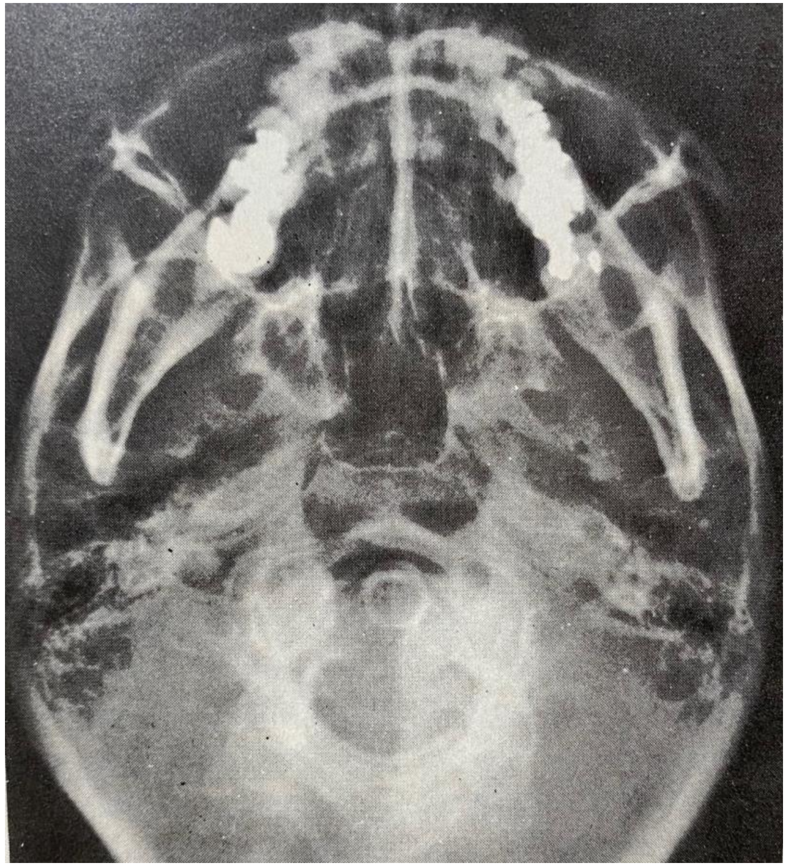
Towne's projection

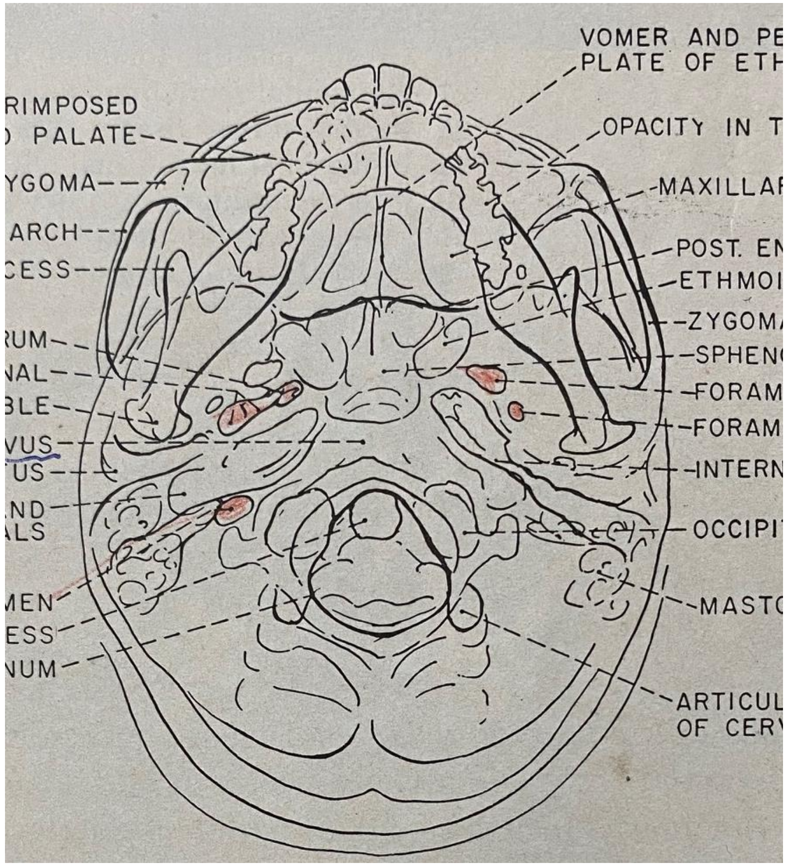




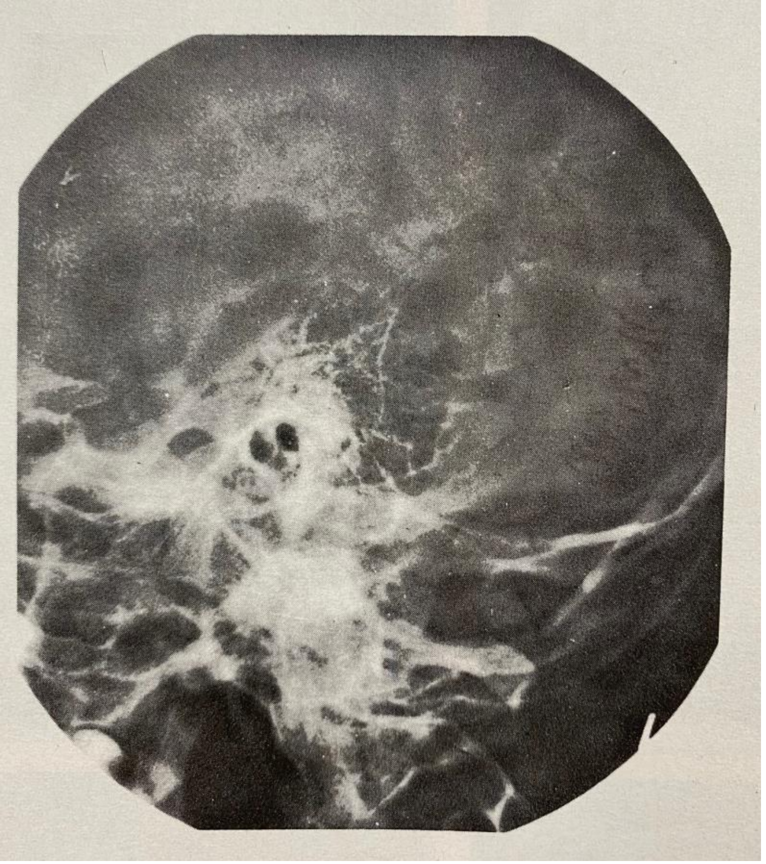


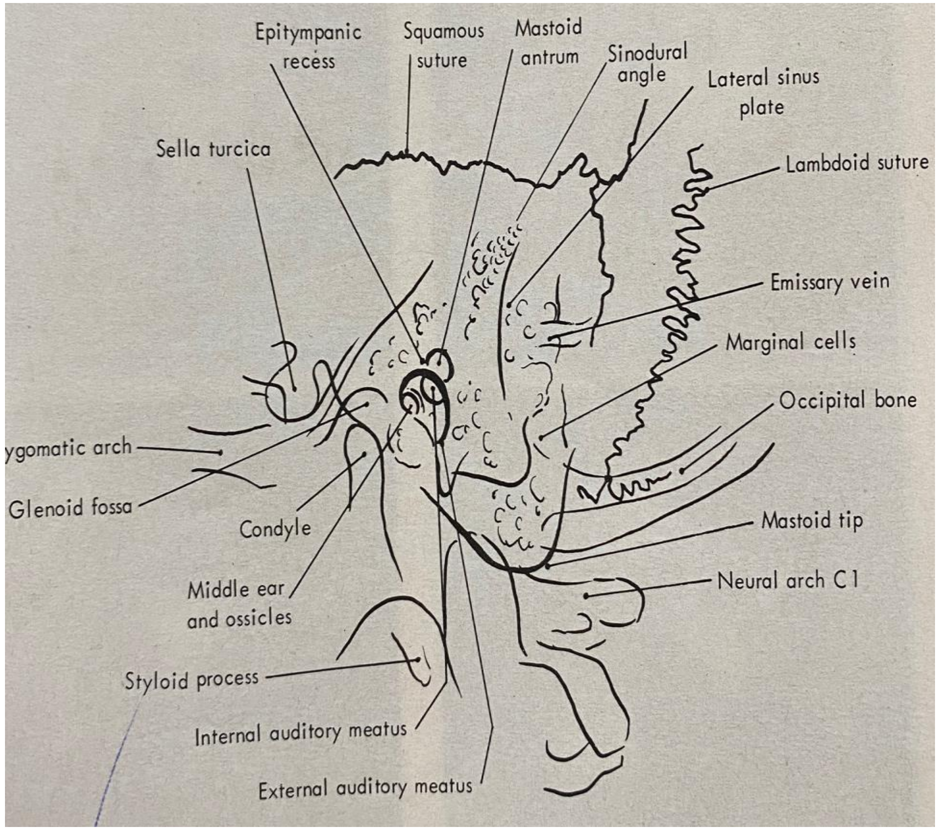
Verticosubmental view

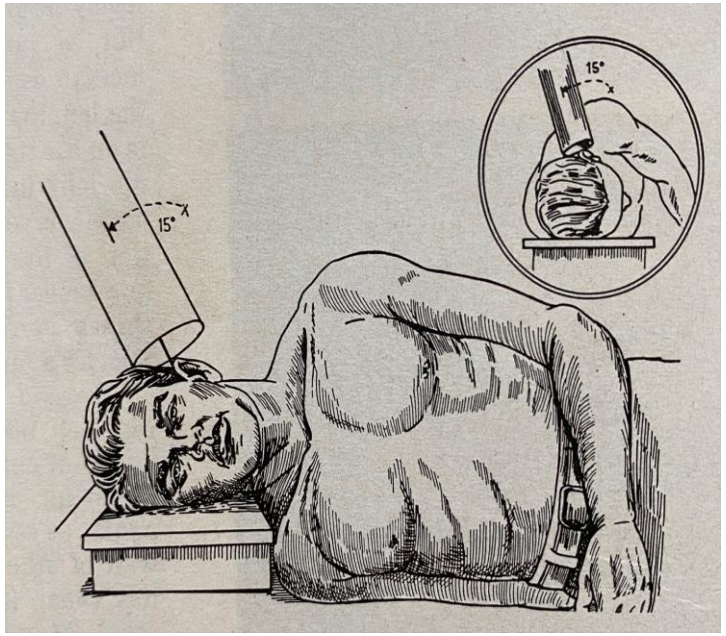




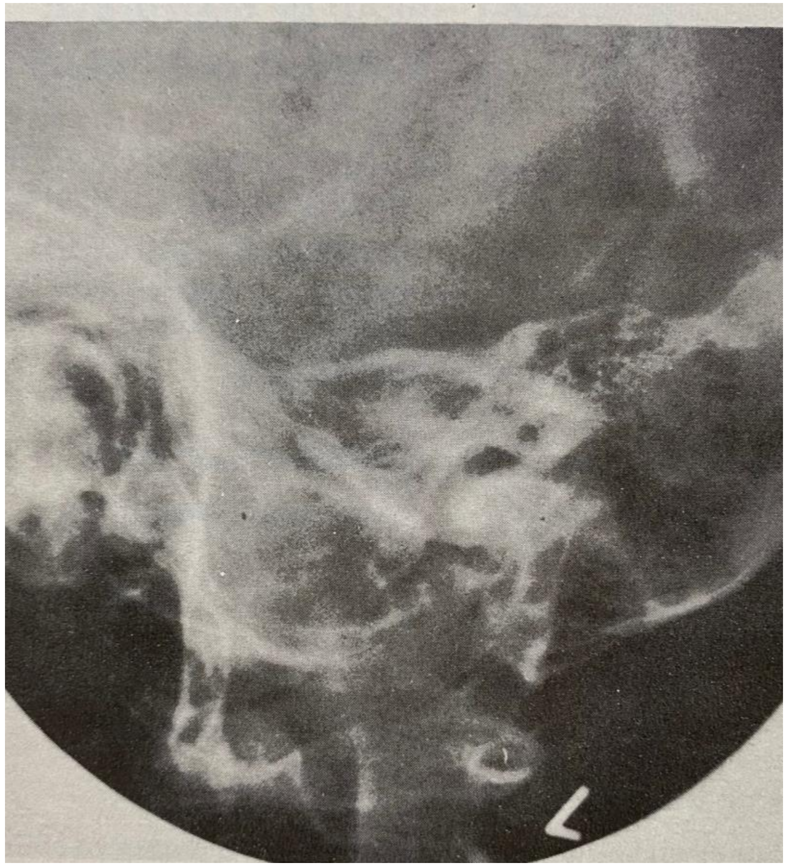
Law's Position

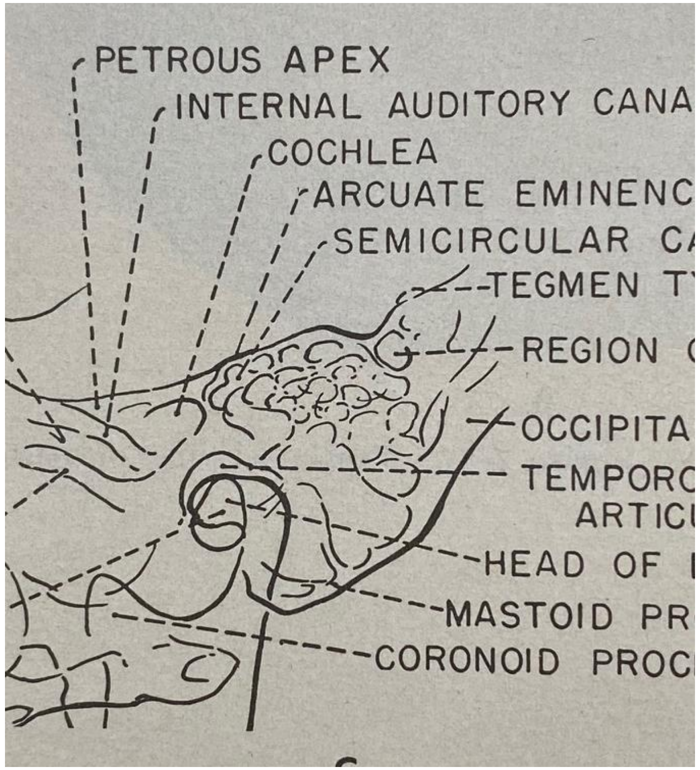


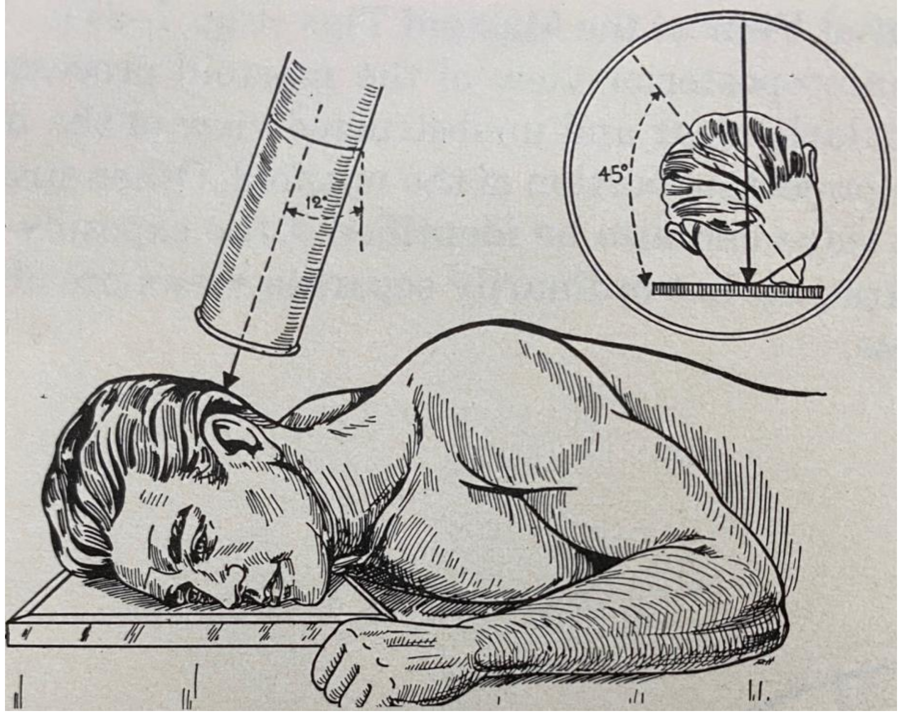




Stenver's Position

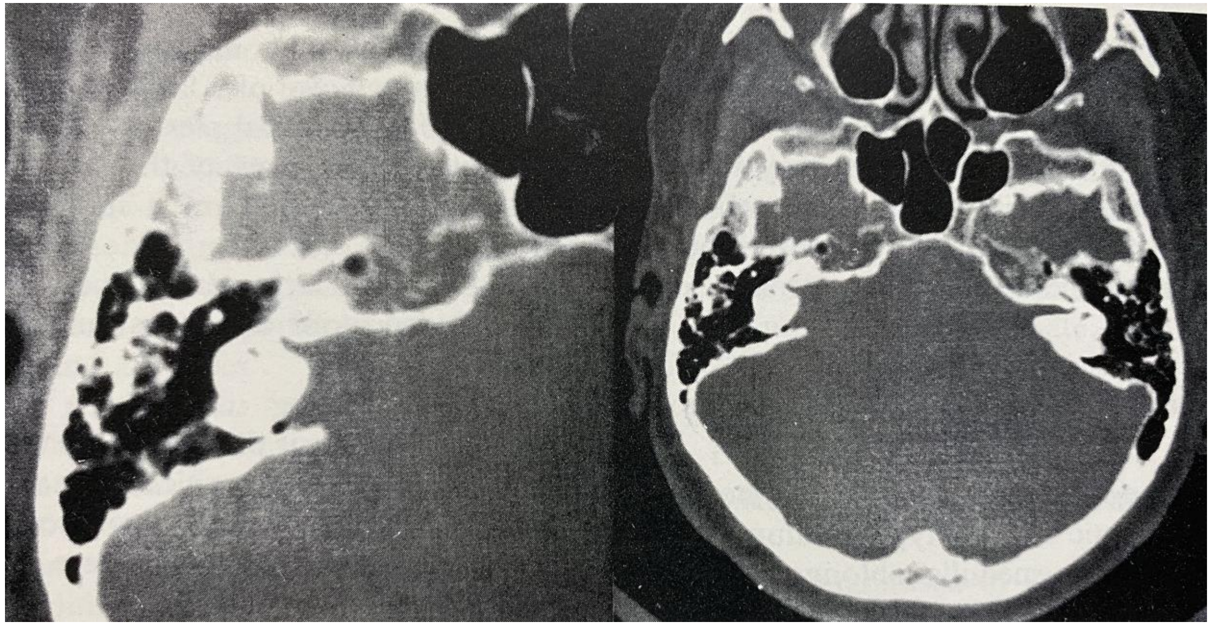




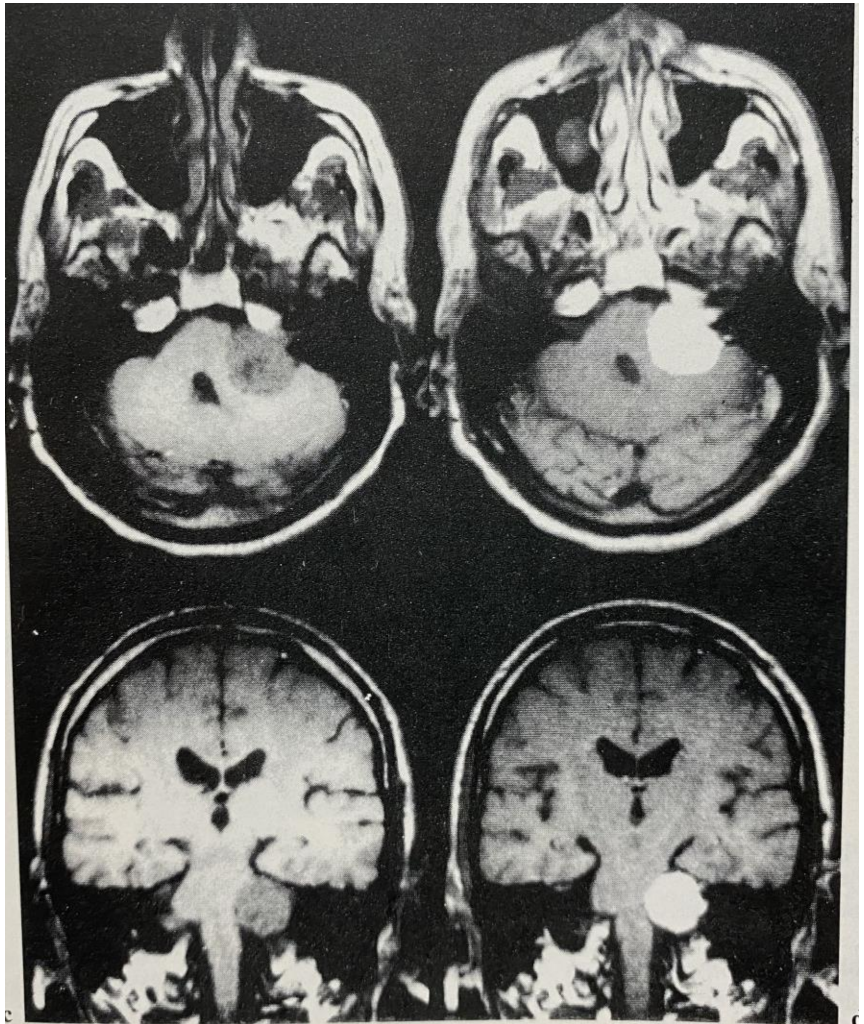


CT Acoustic neurinoma

Fig. D3.2. Acoustic neurinoma of the right side in a 50-year-old man with a [redacted]



MRI



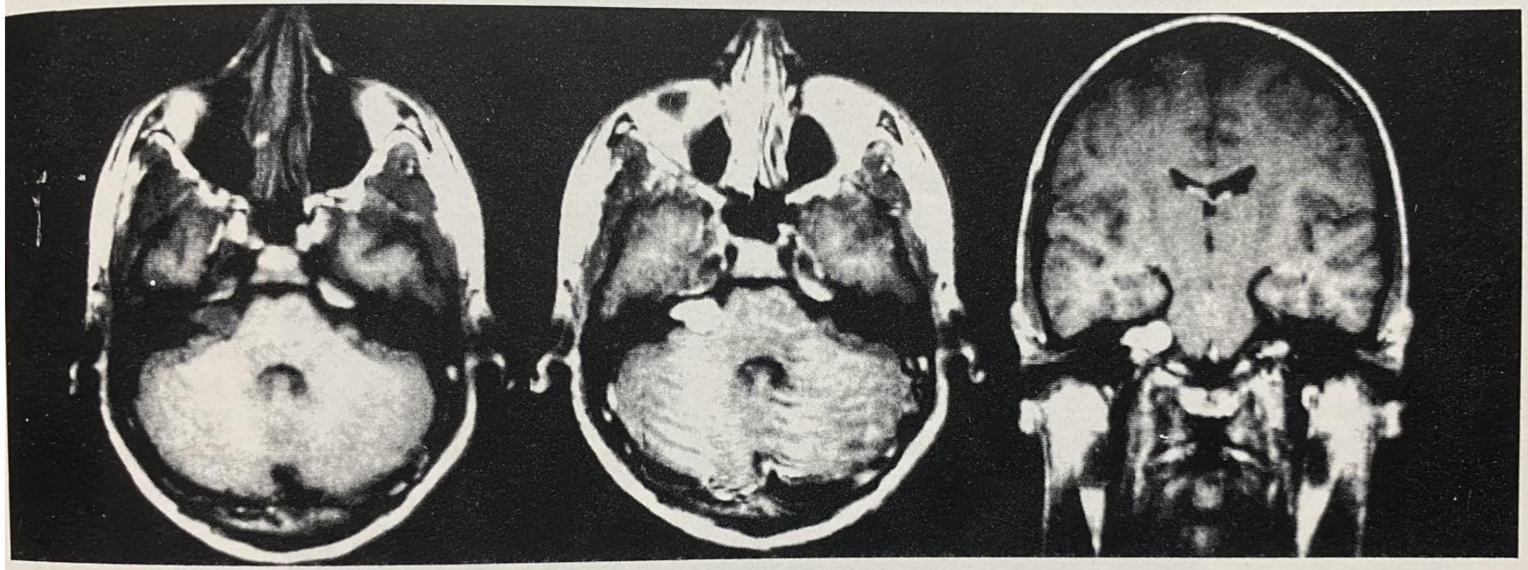
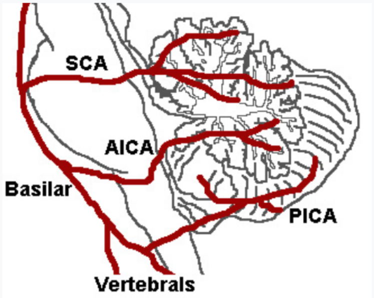


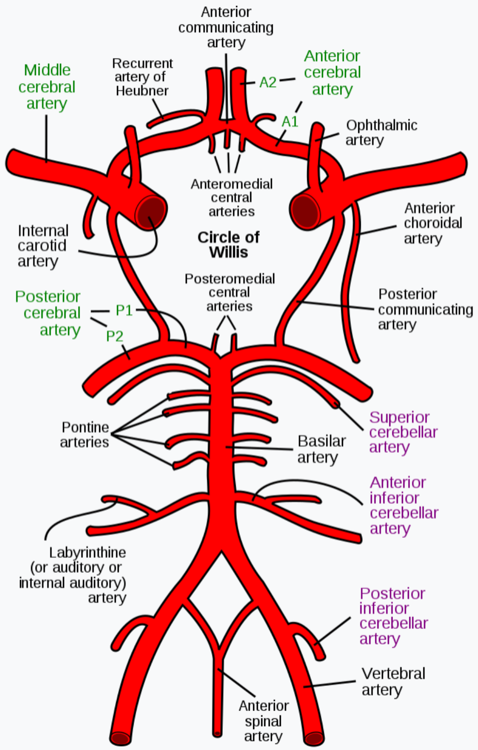
Fig. D3.11. Acoustic neurinoma of the left side in a 20-year-old man with decreased hearing and tinnitus in the left ear and vestibular hypoexcitability. MR: *left* SE 400/30, *center* SE 400/30 post Gd-DTPA, *right* SE 400/30 post Gd-DTPA coronal. Scans demonstrate a hyperintense tumor projecting into the pontocerebellar cistern on the left side

Cerebellopontine angle lesions and incidence

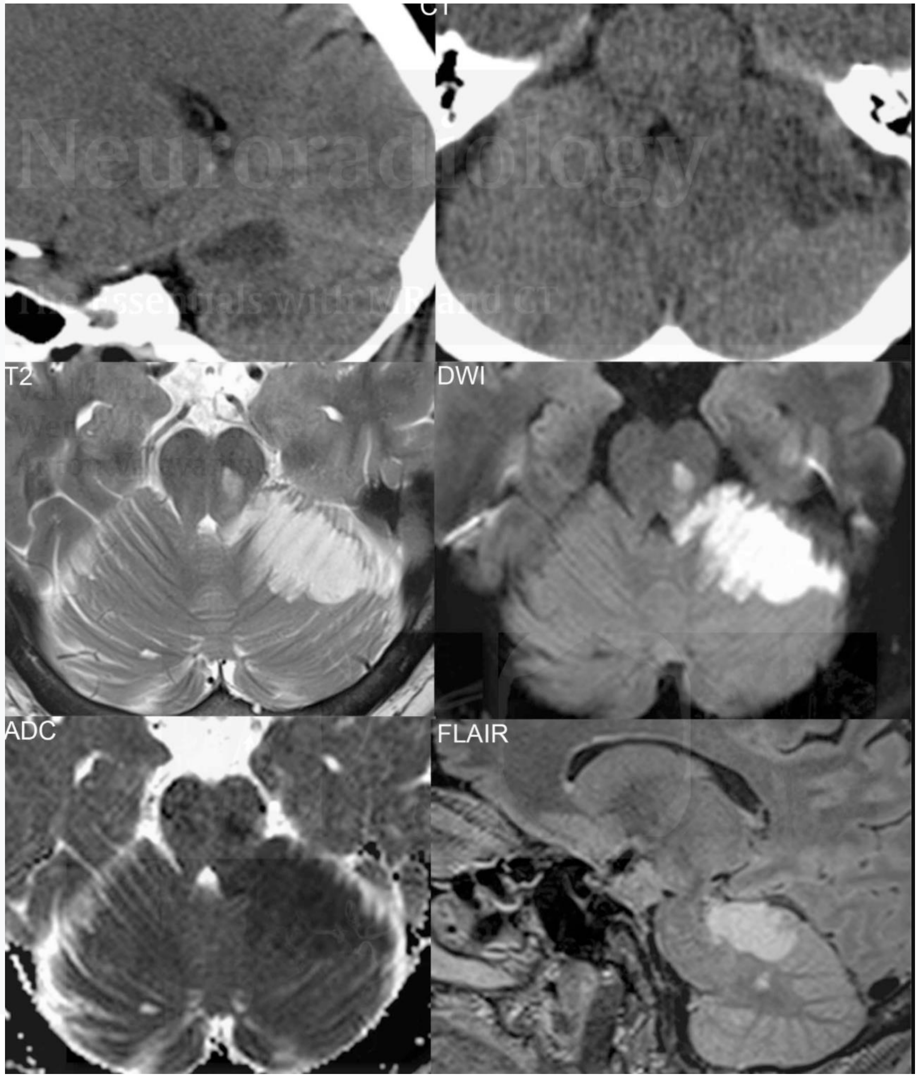
Acoustic schwannoma	60% to 75%
Meningioma	10%
Epidermoid	5%
Schwannomas of other cranial nerves	5%
Paraganglioma	2% to 10%
Vertebrobasilar dolichoectasia	3% to 5%
Aneurysm, arteriovenous malformation	1% each
Brainstem or cerebellar astrocytoma	1% to 2%
Metastases	1% to 2%
Hemangioma, lipoma, chordoma	< 1% each
Arachnoid cyst	< 1%



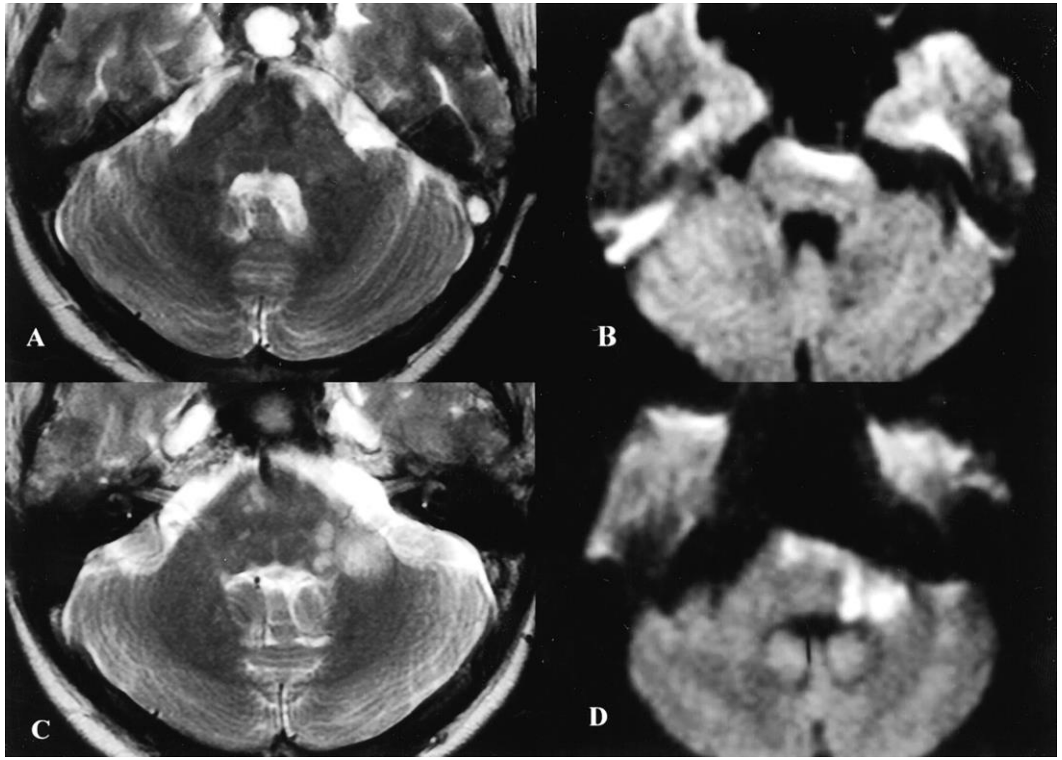
The three major arteries of the cerebellum: the SCA, AICA, and PICA.



superior cerebellar artery



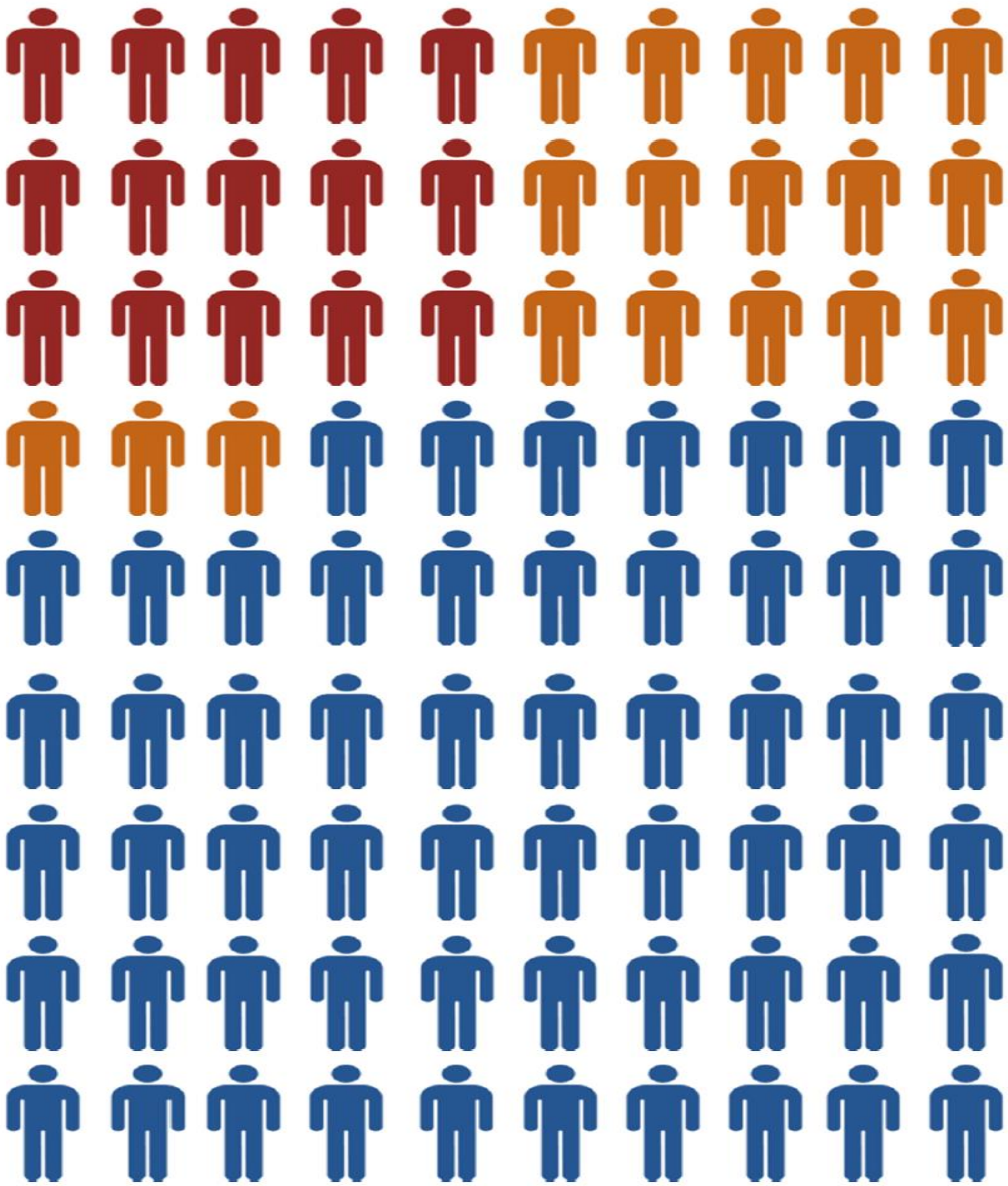
anterior inferior cerebellar artery



1st day (A)axial T2-weighted brain MR showed a hyperintense spot in the left ventrolateral pons. (B)Diffusion-weighted images showed a possible hyperintense focus in the middle cerebellar peduncle and dorsolateral pons were spared.
6th day (C) axial T2-weighted and (D) diffusion-weighted MRI of the brain demonstrated hyperintense foci in the left middle cerebellar peduncle, left dorsolateral pons, and ventral pons.

Tinnitus

- Tinnitus is characterized by the perception of sound in the absence of an external auditory stimulus. The network
- connectivity of auditory and non-auditory brain structures associated with emotion, memory and attention are functionally
- altered in debilitating tinnitus.



Tinnitus

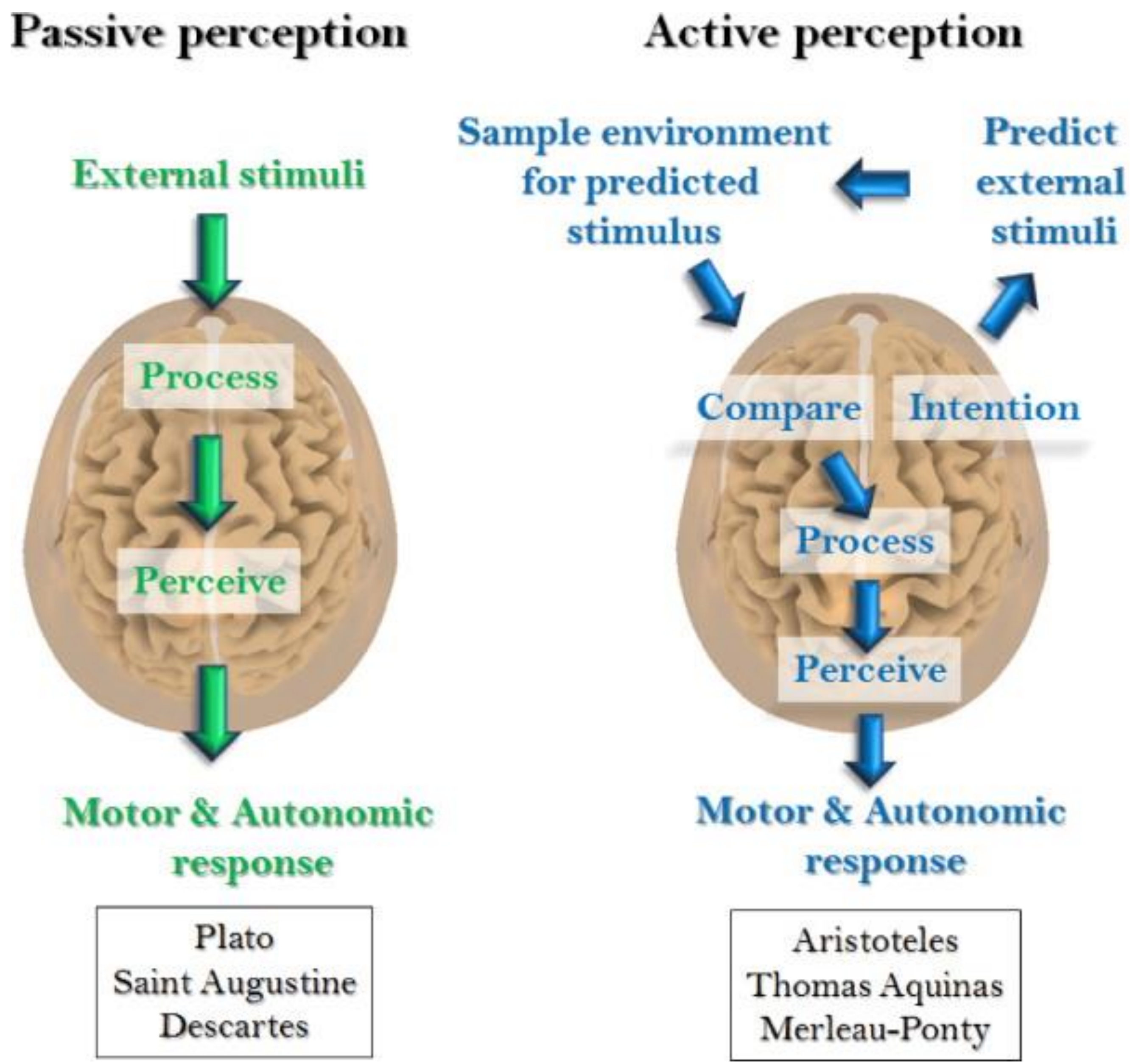
- In an adult population 10 to 15% perceives tinnitus continuously
- Increasing up to 33% in the elderly population

Neural correlate of tinnitus – auditory cortex

- Is there hyperactivity in auditory cortices due to tinnitus? --Hyperactivity may be due to reduced inhibition and/or increased excitation

Bayesian brain:

conceptualized as a probability machine that constantly makes predictions about the world and then updates them based on what it senses (Friston, 2010)



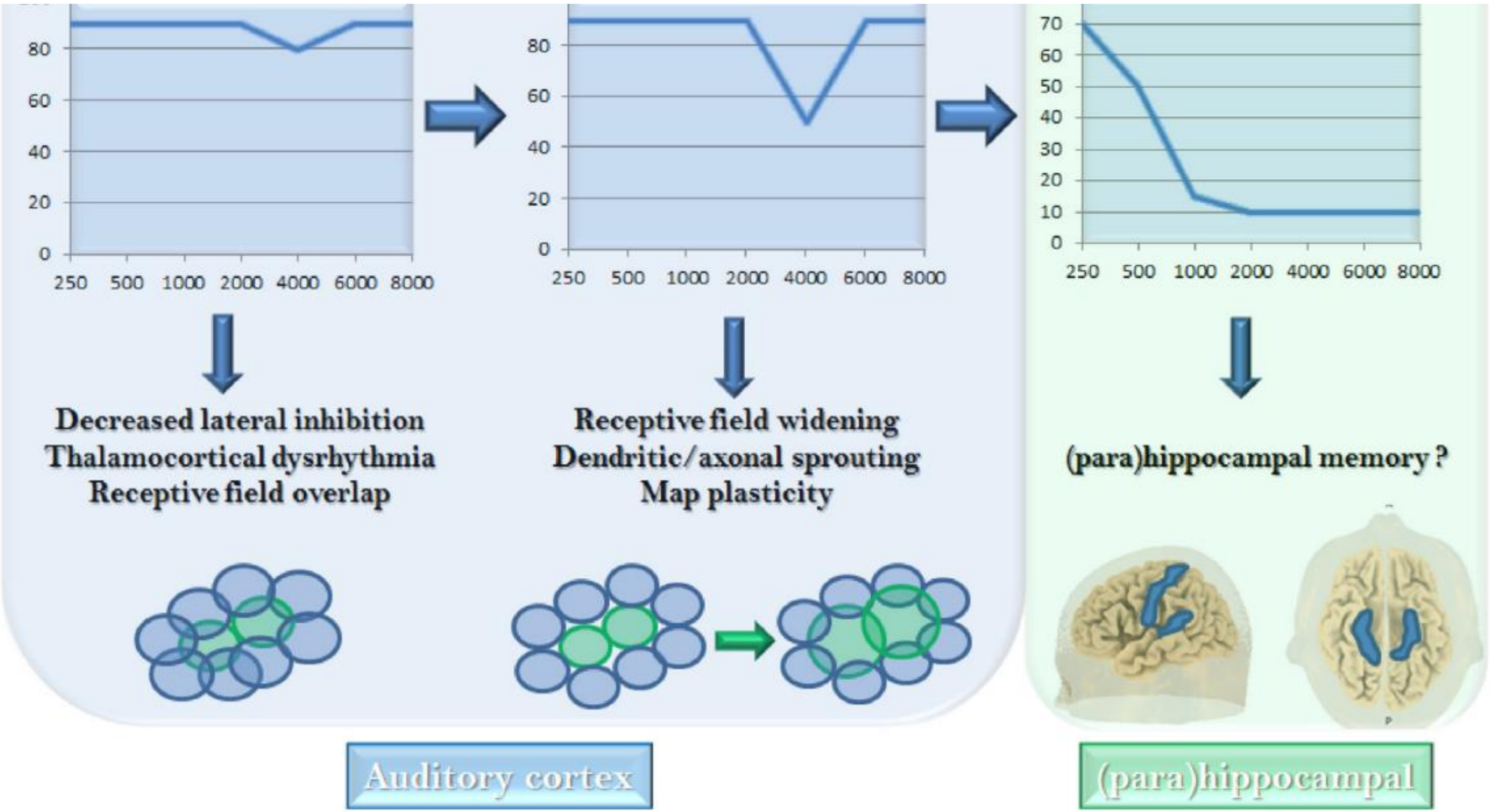
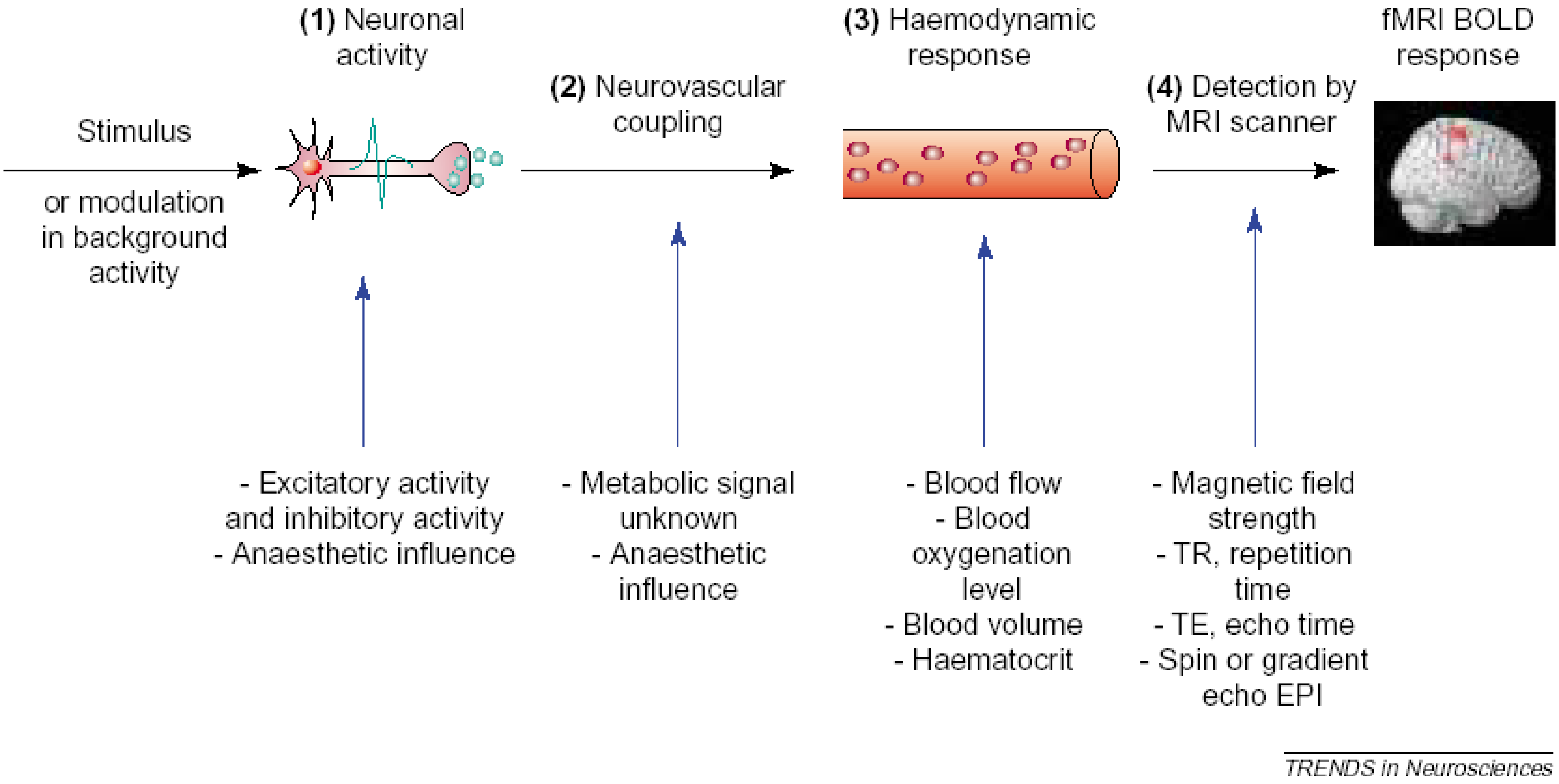


Fig. 3. Staged free-energy reduction. It is proposed that reduction of Shannonian free energy, i.e. uncertainty involves different stages, depending on the lack of information. When the missing information is topographically restricted, the overlap of receptive fields might suffice to obtain the information. If this is insufficient the receptive fields

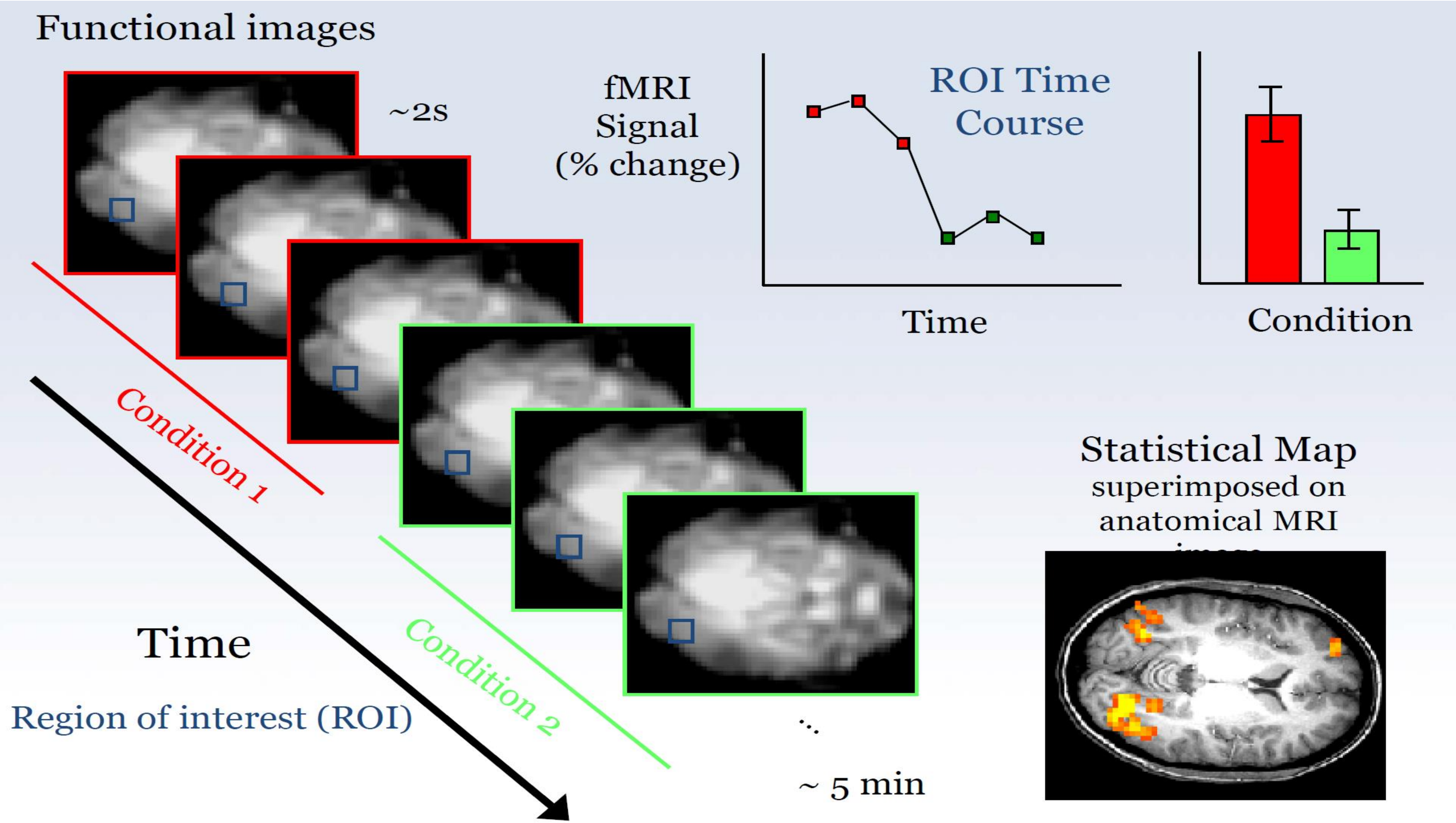
D. De Ridder et al. / Neuroscience and Biobehavioral Reviews 44 (2014) 4–15

BOLD = Blood oxygen-level dependent

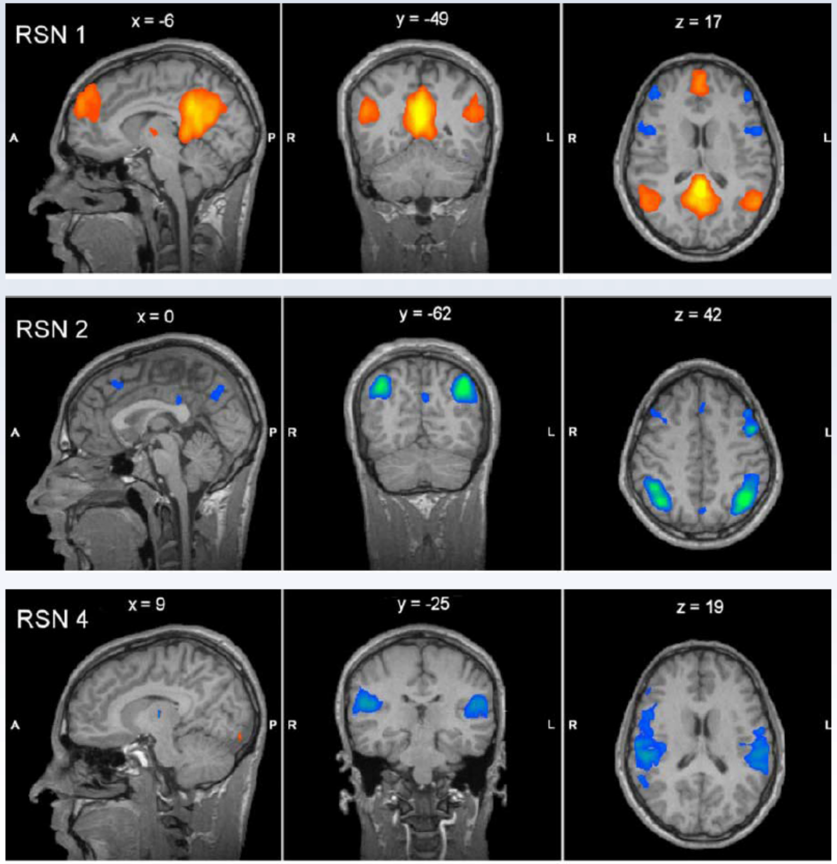


Arthurs & Boniface, 2002, *Trends in Neurosciences*

Activation Statistics



Resting State Functional Connectivity (RS-FC)



Default mode network

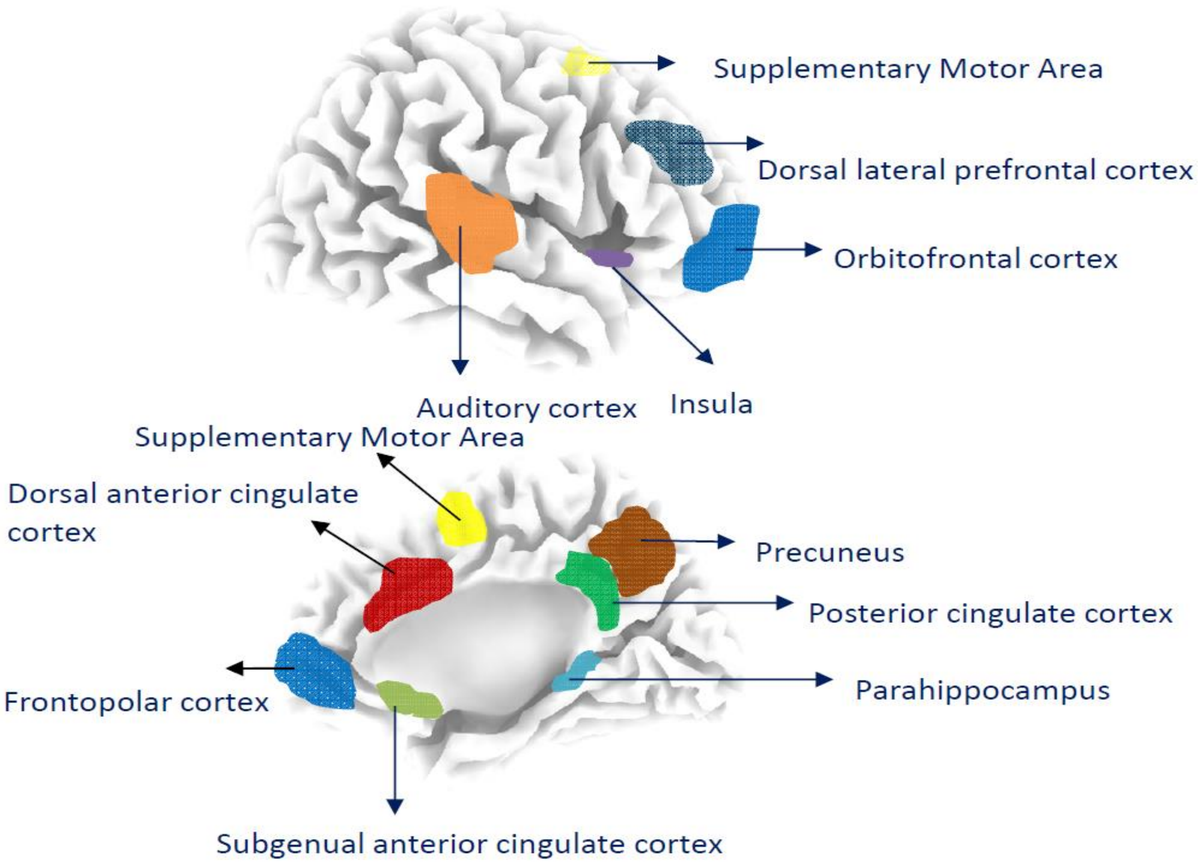
Dorsal attention network

Auditory network

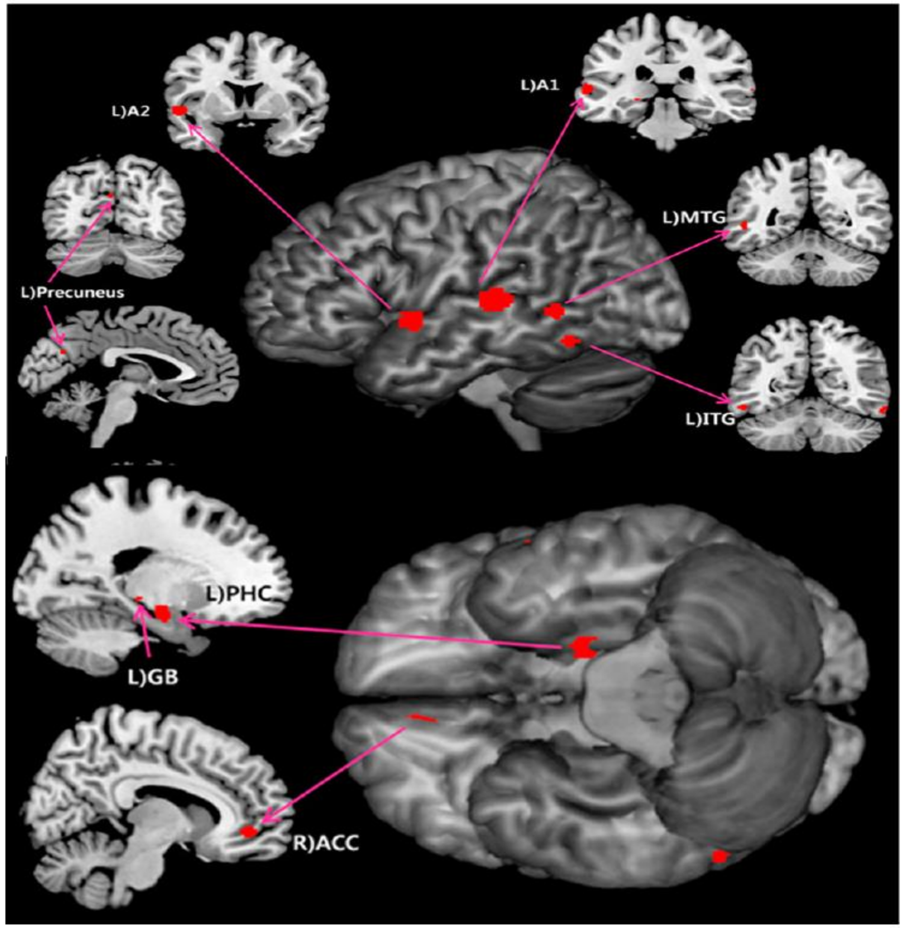
Spontaneous fluctuations in the BOLD response that can be organized into coherent, spatially-correlated networks

Images from Mantini et al, 2007

The brain involved in tinnitus



Vanneste & De Ridder, Frontiers in System Neuroscience, 2012



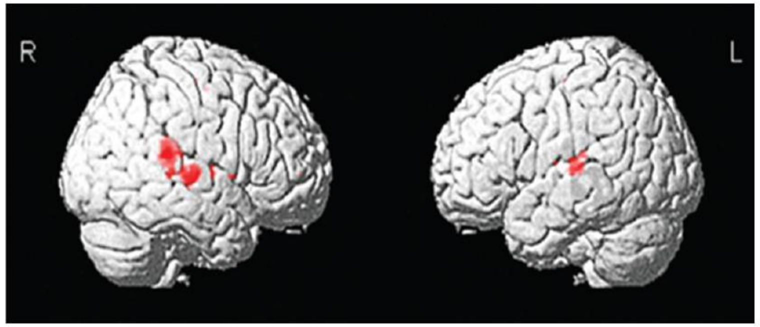
Song, De Ridder & Vanneste, Journal Nuclear Medicine, 2012

1. Hyperactivity within the auditory cortex

a. fMRI

Increased BOLD activity within the **auditory cortex**

De Ridder& Vanneste, JNS, 2011



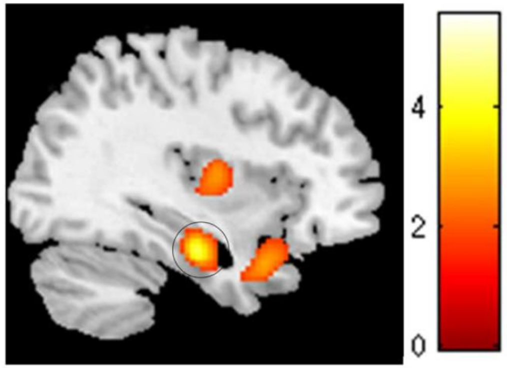
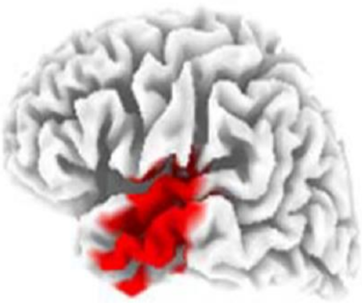


Figure 1. rCBF increase (pFWE <0.05 after SVC) in the left parahippocampal gyrus in tinnitus patients compared with control subjects.
doi:10.1371/journal.pone.0087839.g001

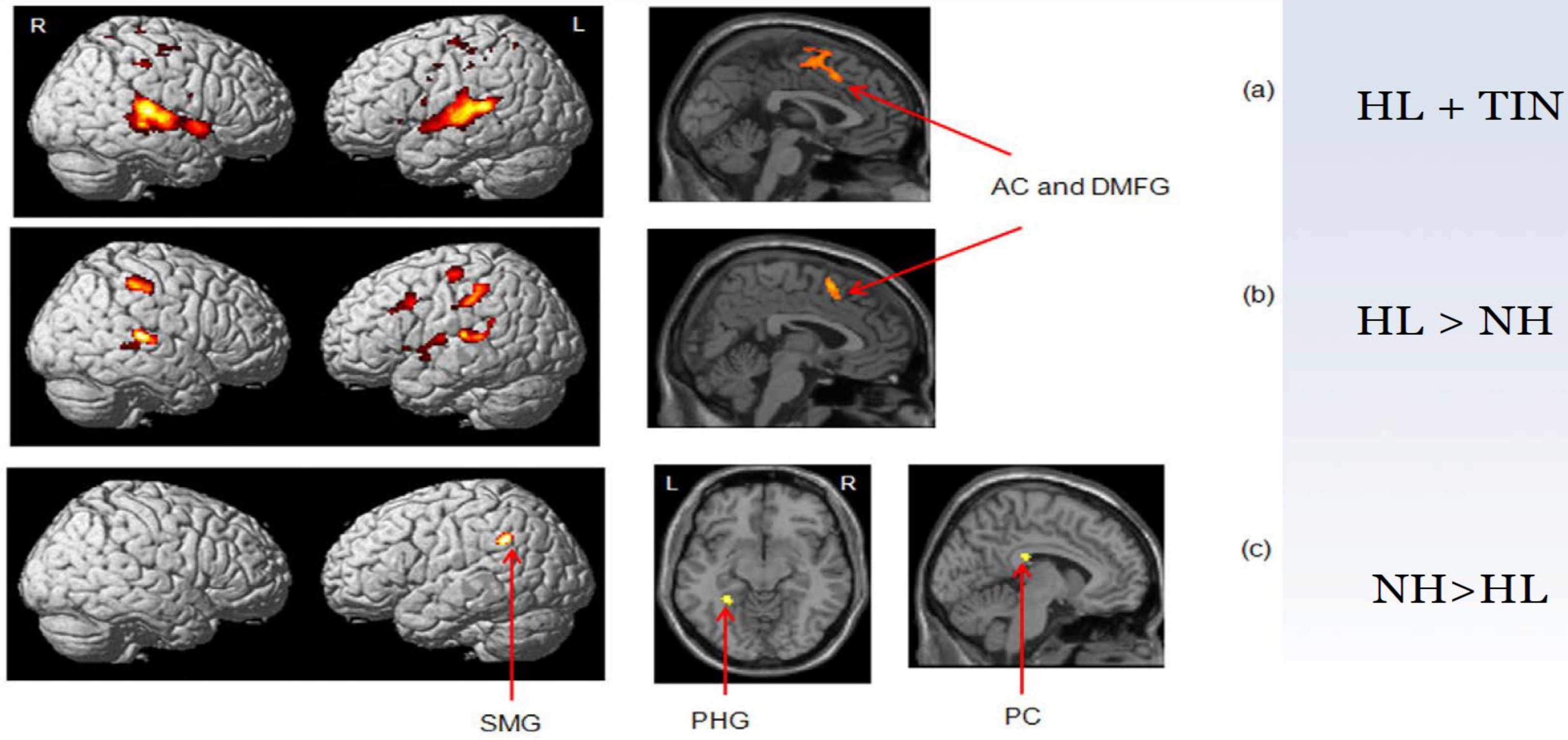
b. Source localized EEG



A **positive correlation** between **the tinnitus loudness** and the current density within the **auditory cortex** at the **gamma frequency band** (r = .65)

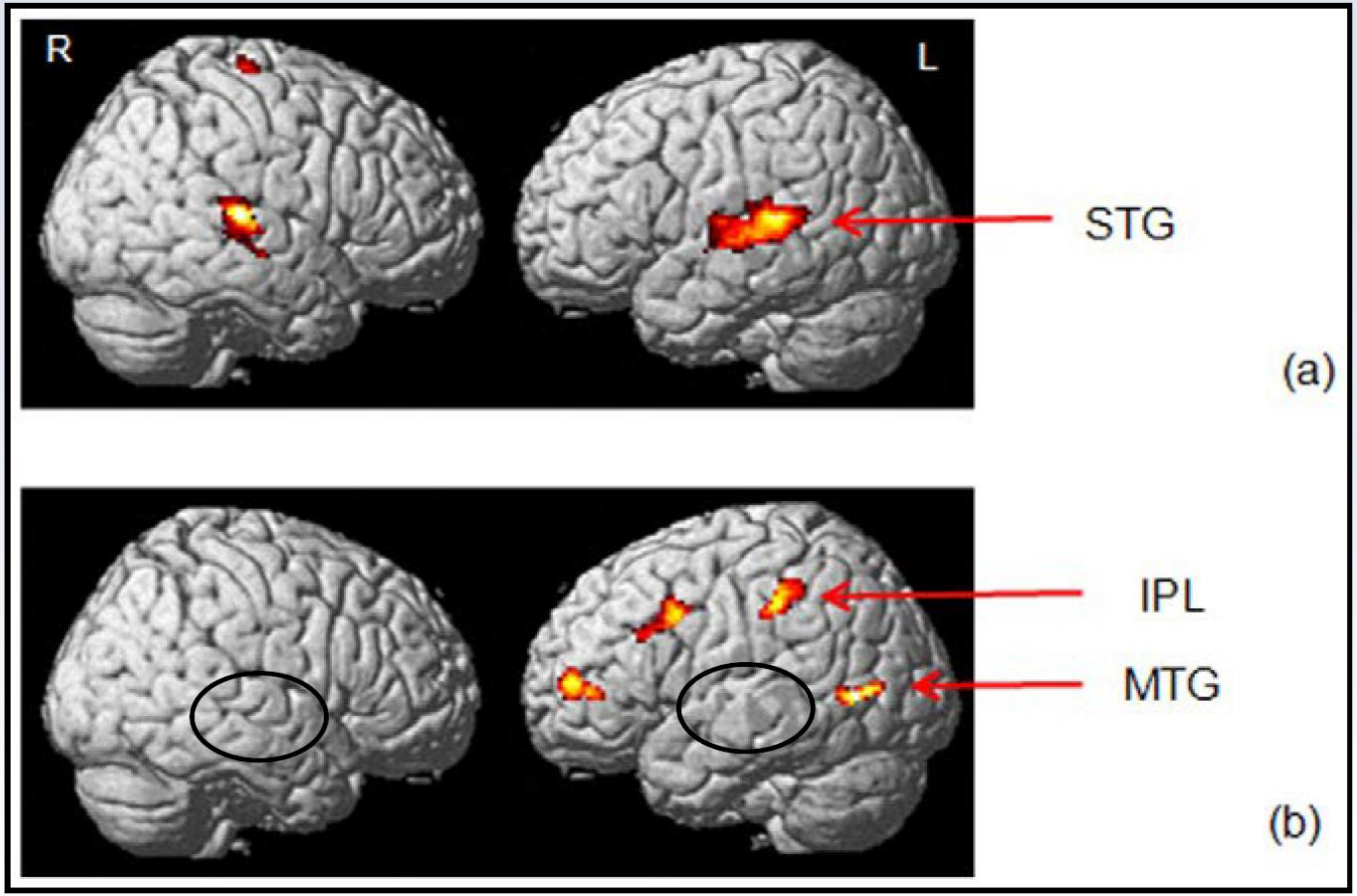
Van der Loo, Vanneste et al., Plos one, 2009

Effect of Hearing Loss



Husain et al., PLoS ONE, 2011

Effect of Tinnitus

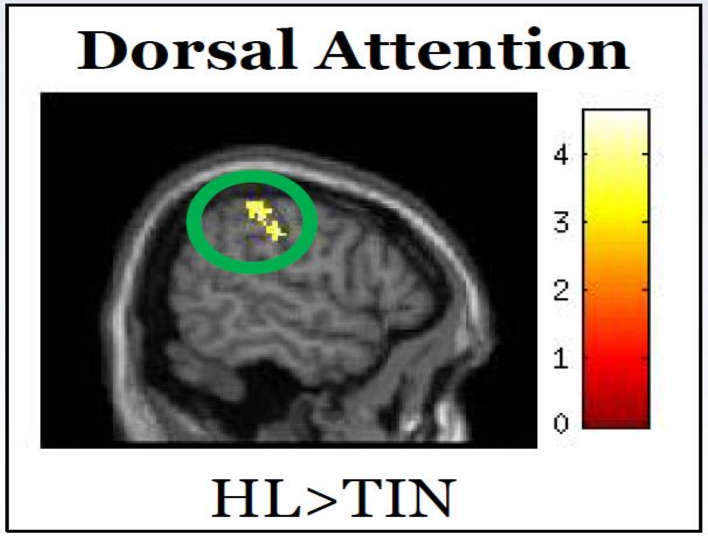


TIN > NH
(no NH>TIN)

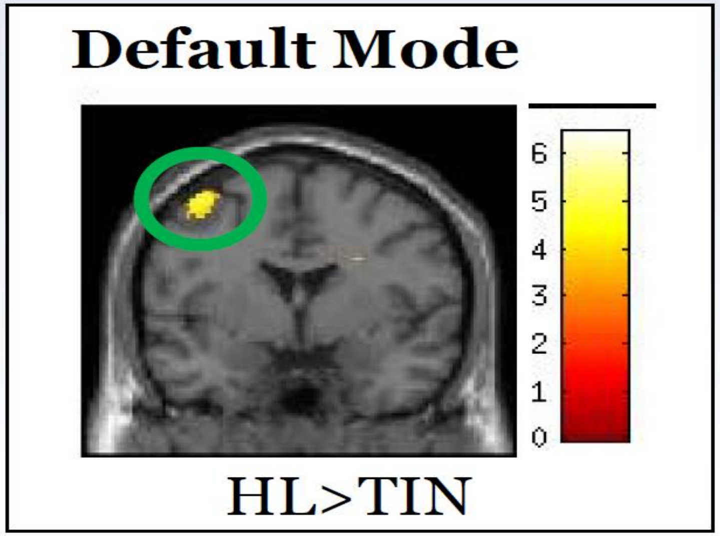
HL > TIN
(no TIN>HL)

Attention

- Decreased connectivity between seeds in Dorsal Attention and Default mode networks and attention-related regions in mild tinnitus



Right supramarginal gyrus (ips seeds)

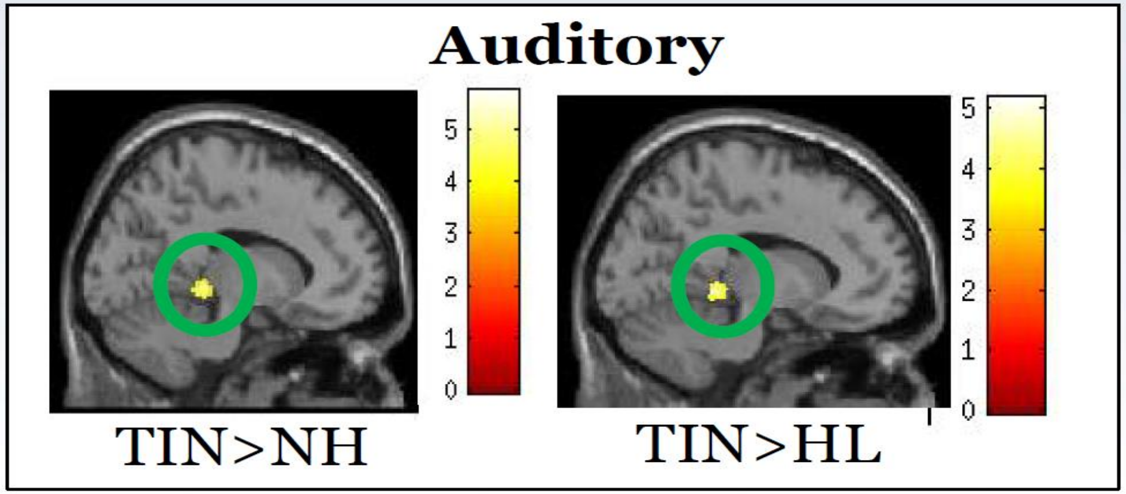


Left precentral gyrus

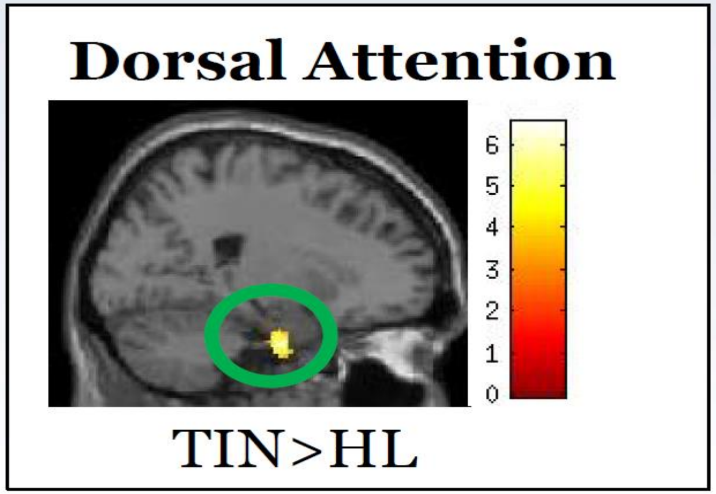
Images from Schmidt et al., PLoS One, 2013

Interaction with Emotion

- Increased connection to limbic/emotion regions was seen in both auditory and attention networks in tinnitus



Left parahippocampus
(only a trend vs HL)

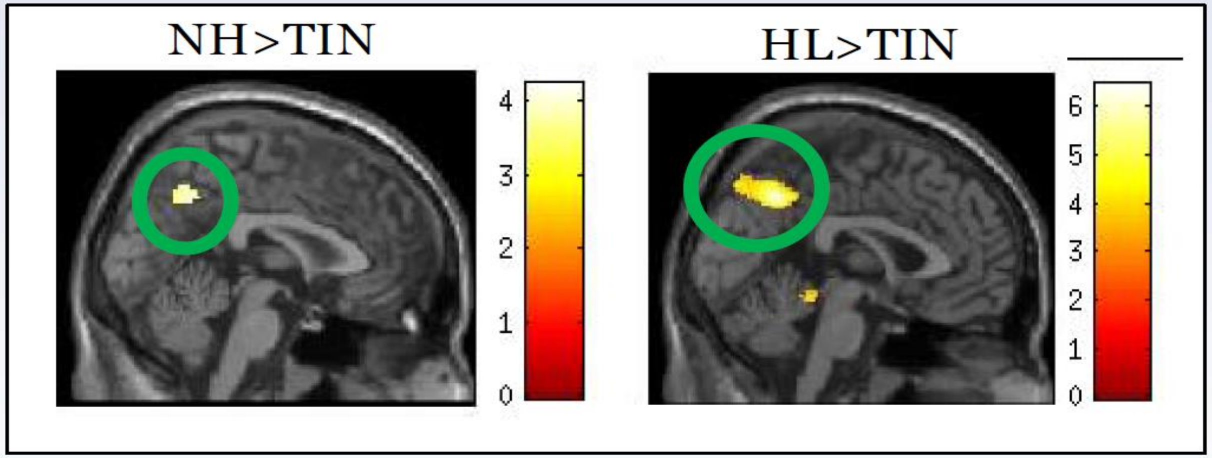


Right parahippocampus
(fef seeds)

Images from Schmidt et al., PLoS One, 2013

Default Mode Network

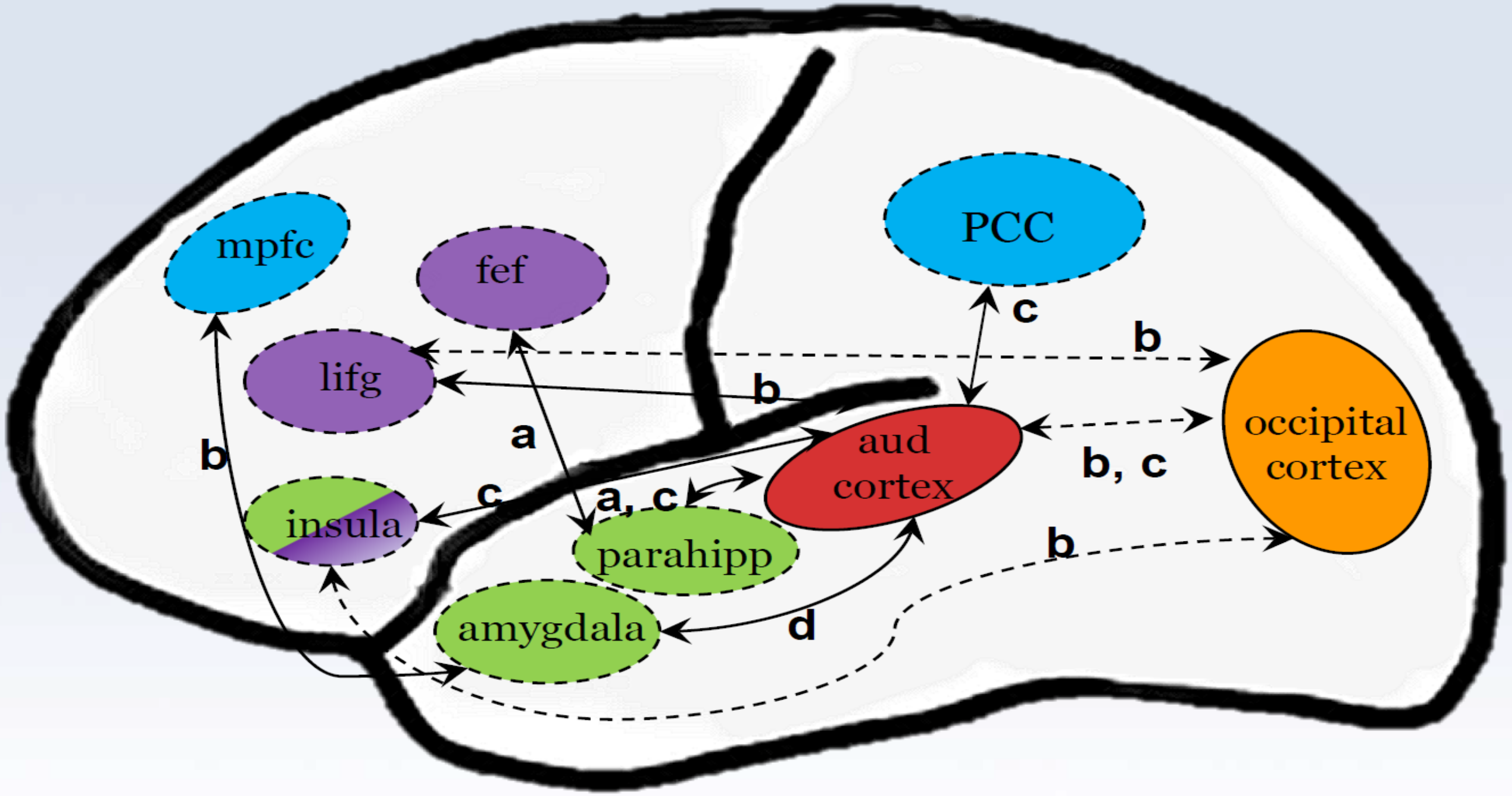
- The default mode network is disrupted in tinnitus



Precuneus

Images from Schmidt et al., PLoS One, 2013

RS-FC findings in tinnitus



Blue: default mode network

Green: limbic

Red: auditory network

Orange: visual network

Purple: attention

a: Schmidt et al, 2013
b: Burton et al., 2012
c: Maudoux et al, 2012a
d: Kim et al, 2012

From Husain and Schmidt, 2014

Brain response to auditory deprivation

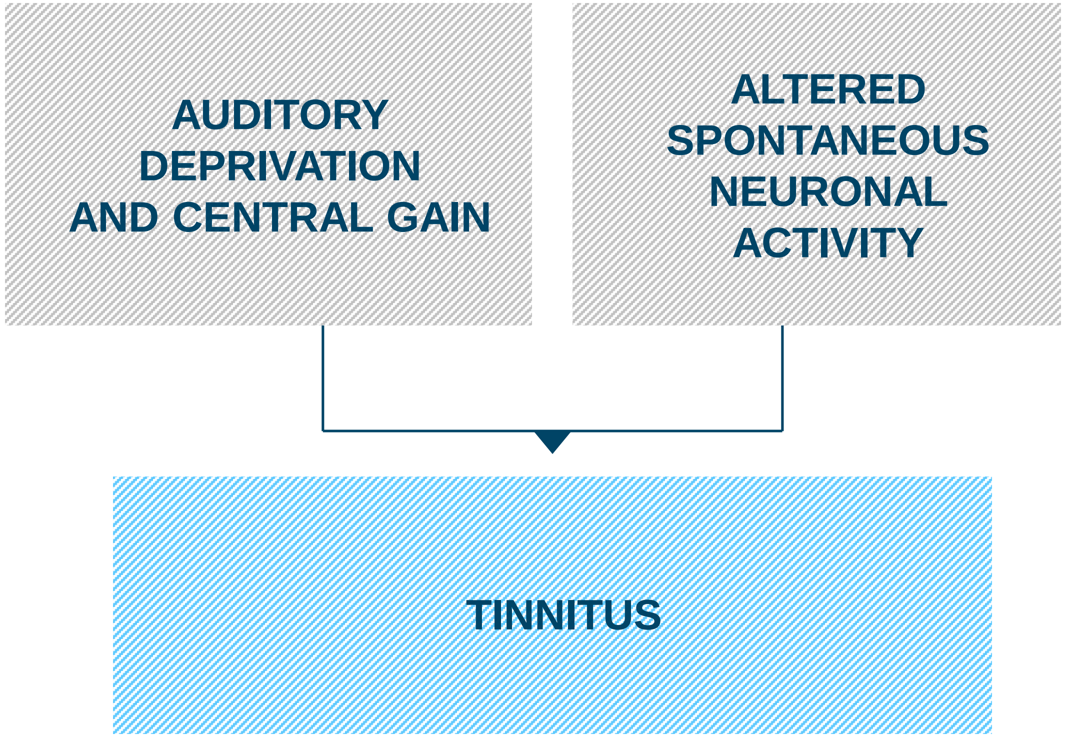
- Patients with tinnitus exhibit enhanced auditory sensitivity

- This is caused by hyperactivity of the auditory central nervous system
  – Homeostatic pathways cause increased central ‘gain’ (i.e. sensitivity) in response to auditory deprivation to:
  1. Maintain central nervous system activity during low sensory input
  2. Ensure nerve activity is modulated to respond to changes in sensory input
- In patients with tinnitus and hearing loss, the tinnitus pitch and the hearing loss frequency spectrum are usually matched

Hebert S, et al. (2013) J Neurosci 33:2356-2364; Langguth B, et al. (2013) Lancet Neurol.12:920-930; Norena AJ, Farley BJ. (2013) Hearing Res 295:161-171.

Tinnitus is a balance of sensory input and spontaneous activity

The decreased input from the cochlea, due to outer hair cell damage, results in readjustments in the central auditory system resulting in abnormal neural activity including hyperactivity, bursting discharges and increases in neural synchrony.



Norena AJ, Farley BJ. (2013) Hearing Res 295:161-171.
Kaltenbach JA. (2011) „Tinnitus: models and mechanisms“. Hear Res. June; 276 (1-2) : 52 – 60.

Tinnitus and hearing loss

Most patients with tinnitus have some degree of hearing loss

75%–90%
OF PATIENTS WITH OTOSCLEROSIS HAVE TINNITUS

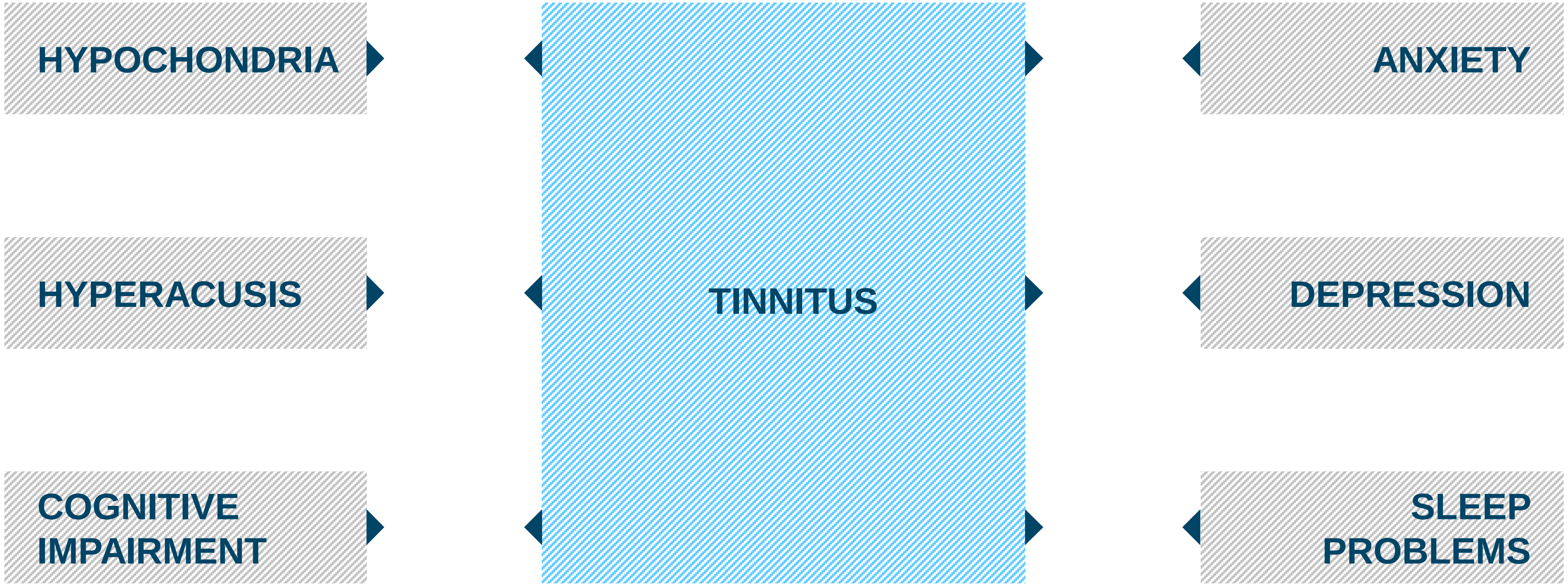
ABOUT 80%
OF PATIENTS WITH IDIOPATHIC SENSORINEURAL HEARING LOSS HAVE TINNITUS

> **“Hearing loss is a hidden disability and to have tinnitus is sort of like a double whammy”**
>
> Family physician with moderate tinnitus, Canada

Axelsson A, Ringdahl A (1989) Br J Audiol 23:53-62; Ayache D, et al (2003) Otol Neurotol 24:48-51; Nosrati-Zarenoe R et al (2007) Acta Otolaryngol 127:1168-1175; Sobrinho PG et al. (2004) Int Tinnitus J 10:197-201; Schaette R et al. (2012) PLoS One 10.1371/journal. pone.0035238.

Other psychological associations with tinnitus

- Tinnitus is associated with increased levels of psychological problems
  - 24/90 (26.7%) versus 5/90 (5.6%) for age-matched controls without tinnitus



Andersson G, McKenna L. (2006) Acta Otolaryngol Suppl. 556:39-43; Belli H, et al. (2012) Gen Hosp Psychiatry. 34:282-9; Jackson J, et al. (2013) Int J Audiol. E-pub ahead of print; Langguth B, et al. (2013) Lancet Neurol.12:920-930.

Summary

- Resting state functional connectivity appears to be replicable for both controls and participants reporting tinnitus
- In those with mild tinnitus, greater activity in the auditory cortex when responding to affective sounds compared to neutral sounds (relative to severe tinnitus).
- Change in functional connectivity from auditory cortex to right parahippocampal gyrus
- Reliable and useful tool to objectively measure impact of tinnitus in the brain