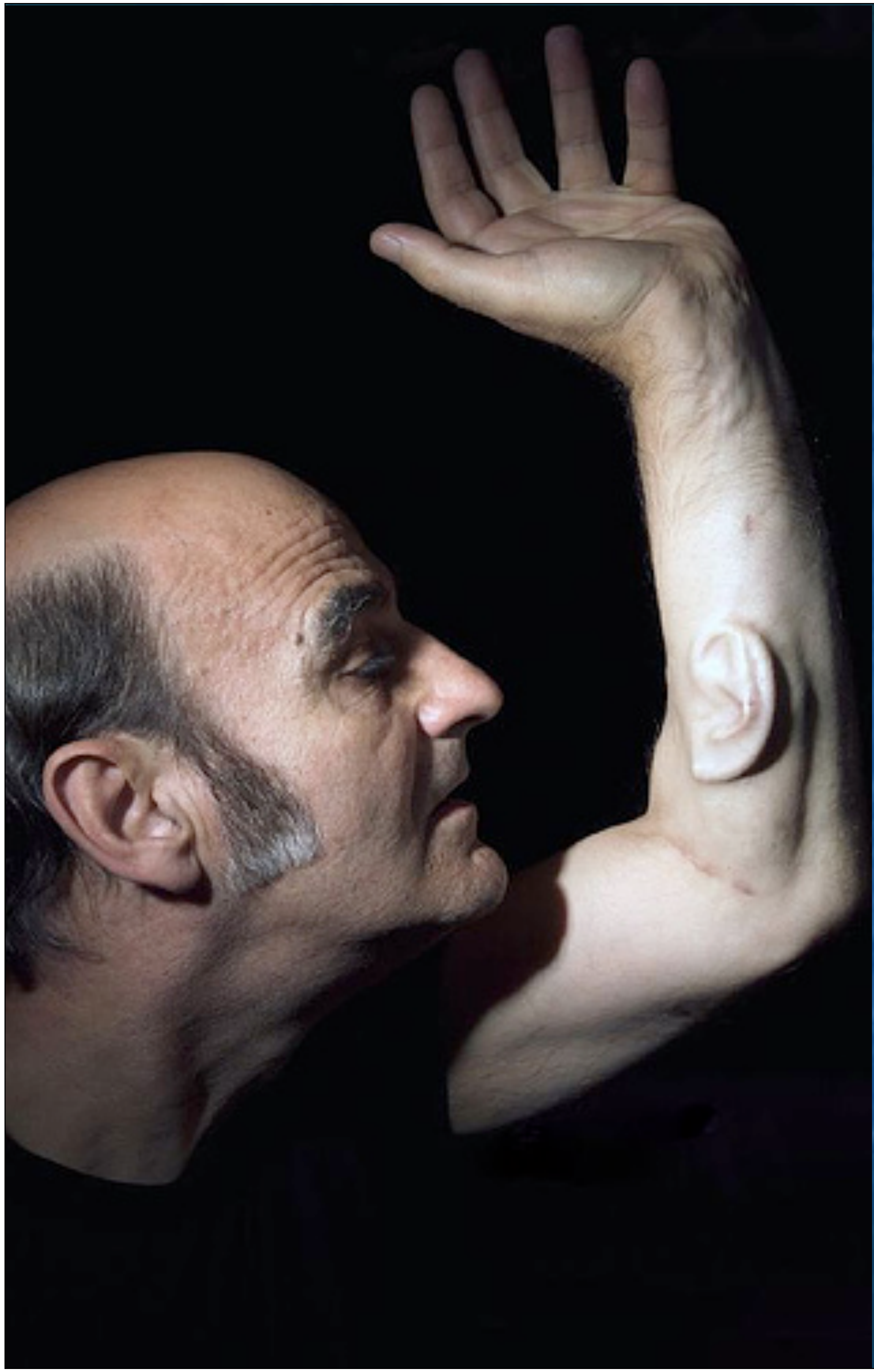
Cognitive Neuroscience of Language: 8: Auditory information processing and the brain

Richard Shillcock



Goals

Look at how the brain represents auditory information

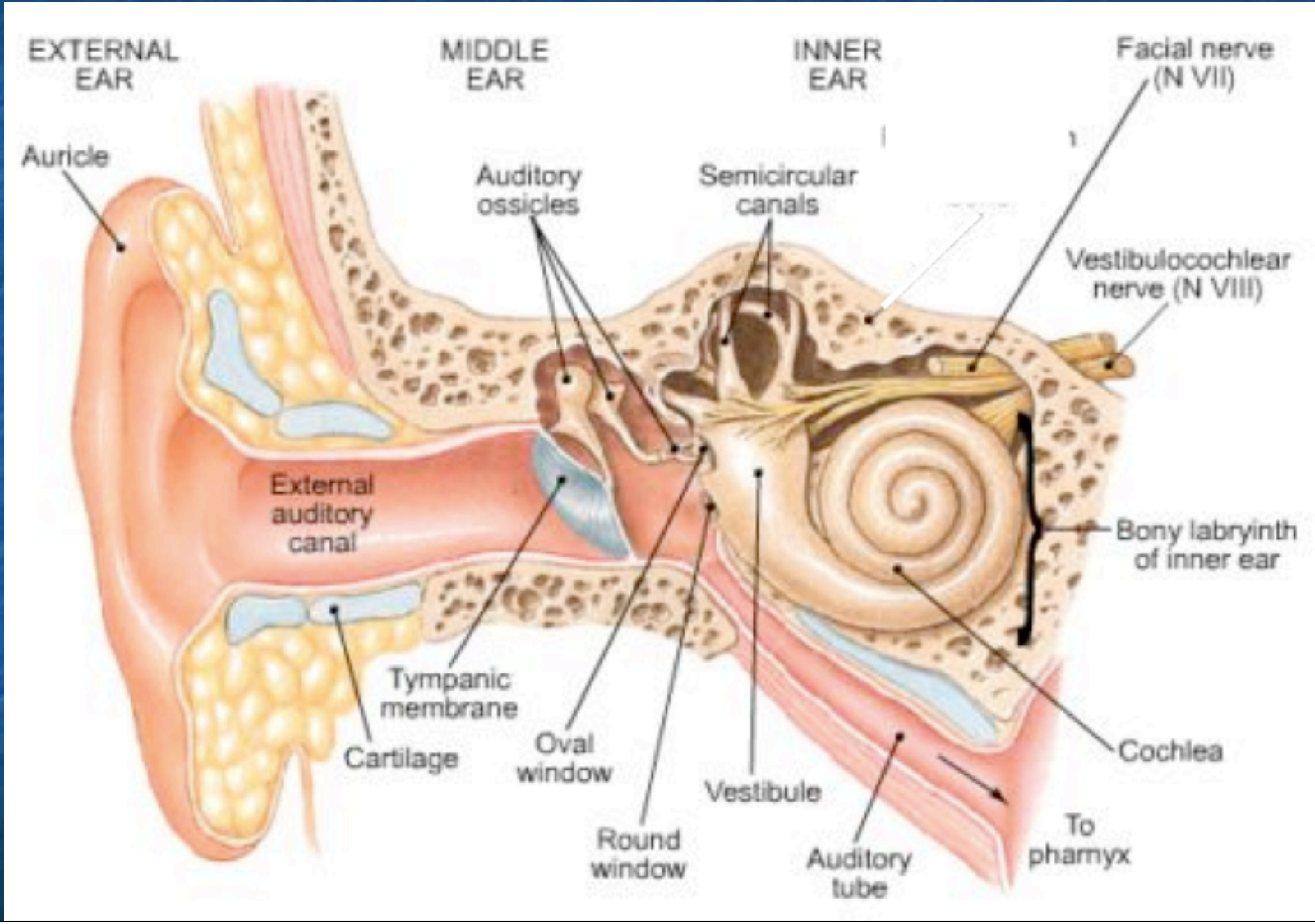
Look at some of the implications for the processing of speech, bearing in mind that phonological activation seems mandatory during reading

Reading for this lecture

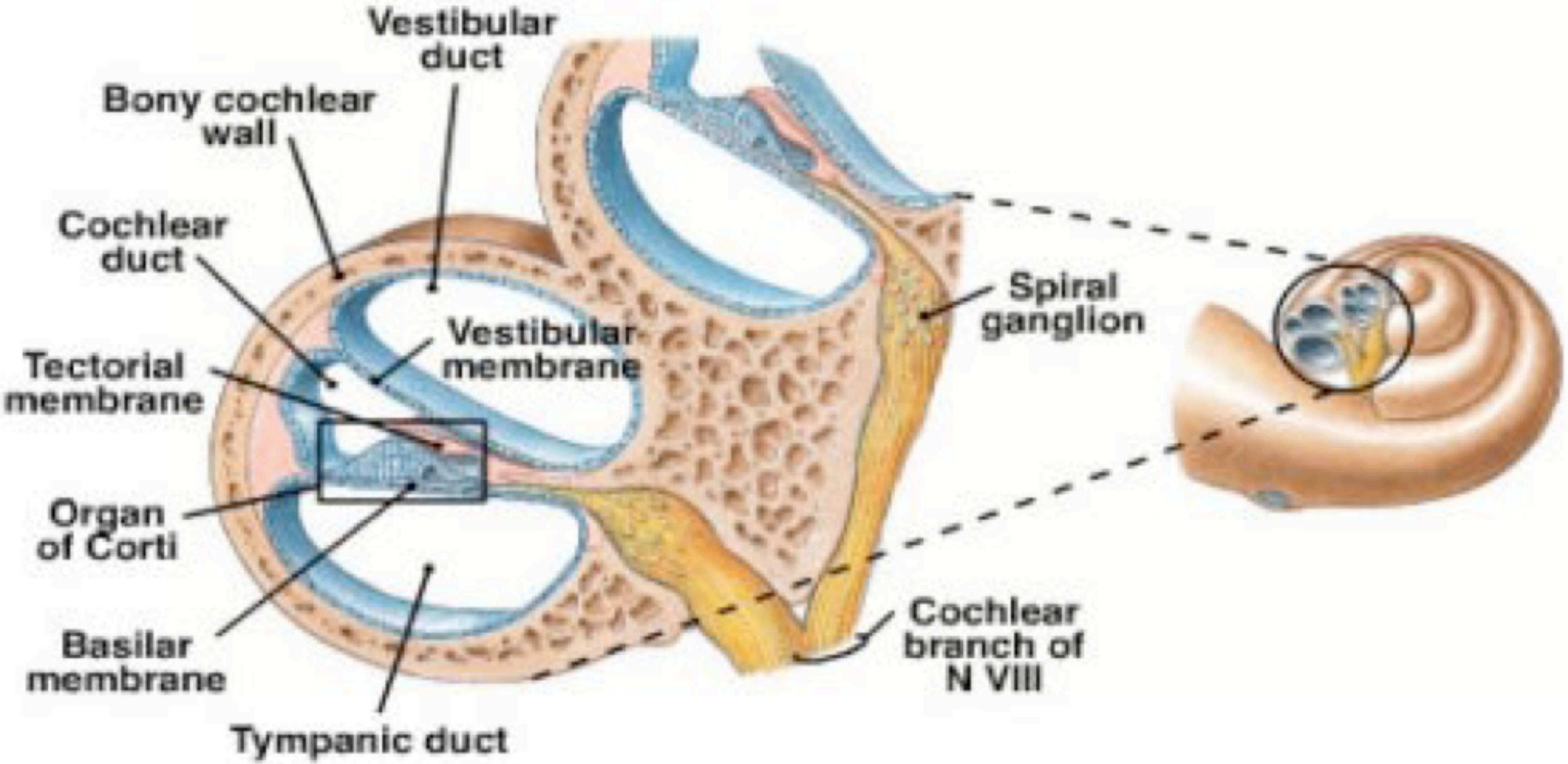
Zatorre, R.J., Belin, P. & Penhune, V.B. (2002). Structure and function of auditory cortex: music and speech. *TICS*, *5*, 37–46.

Cutler, A. (1997). The comparative perspective on spoken-language processing. *Speech Communication, 21*, 3-15.

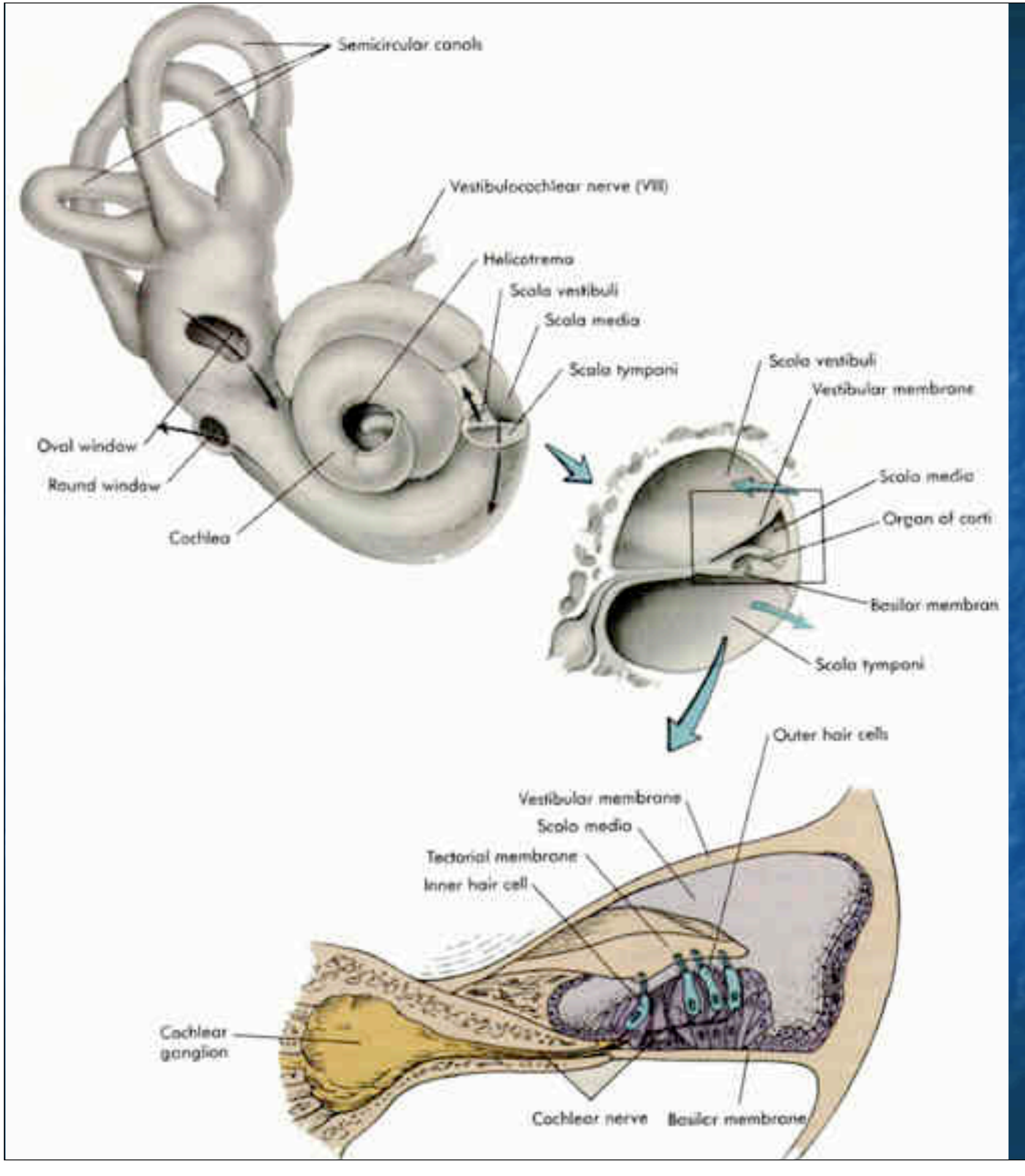
From sound to neurons



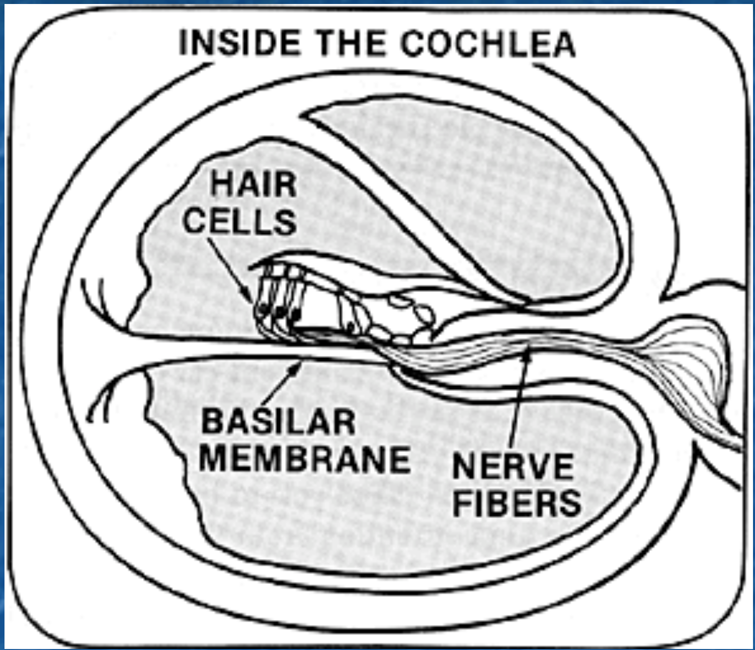
From sound to neurons



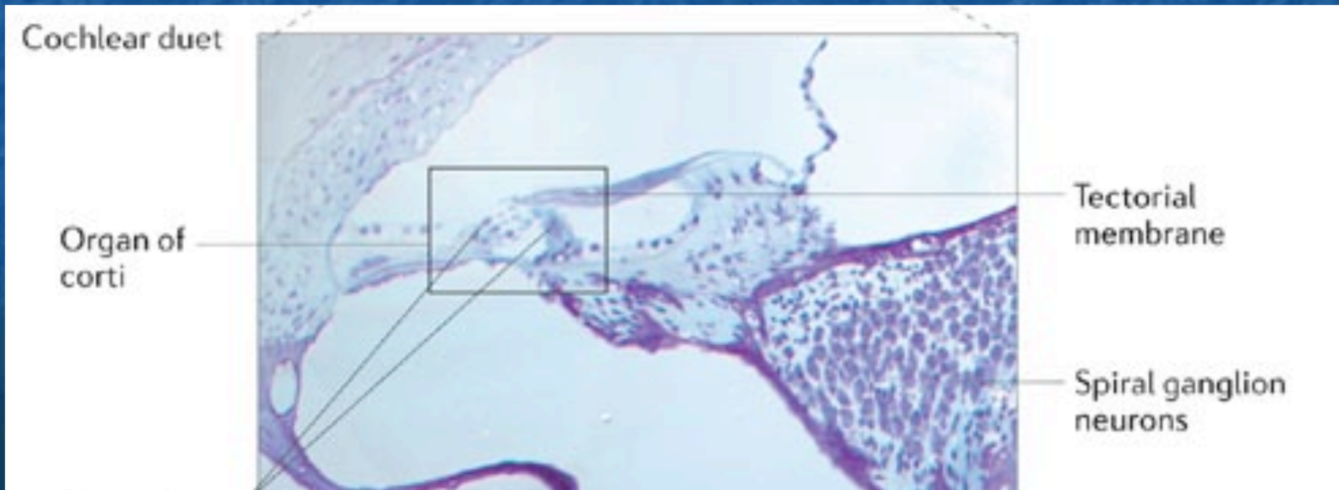
From sound to neurons

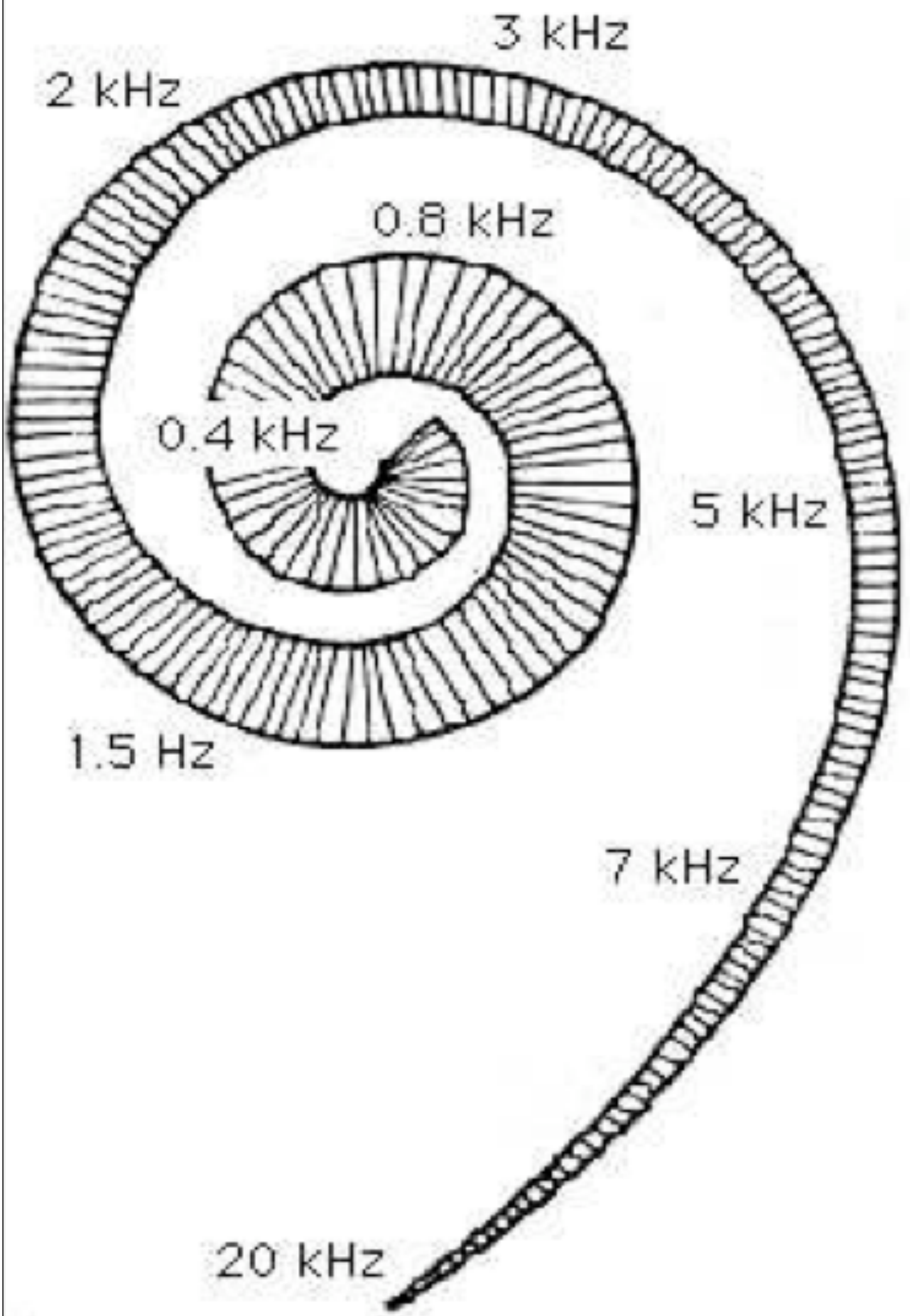


From pressure change to neural firing



Different hair cells have different thresholds to respond to intensity differences





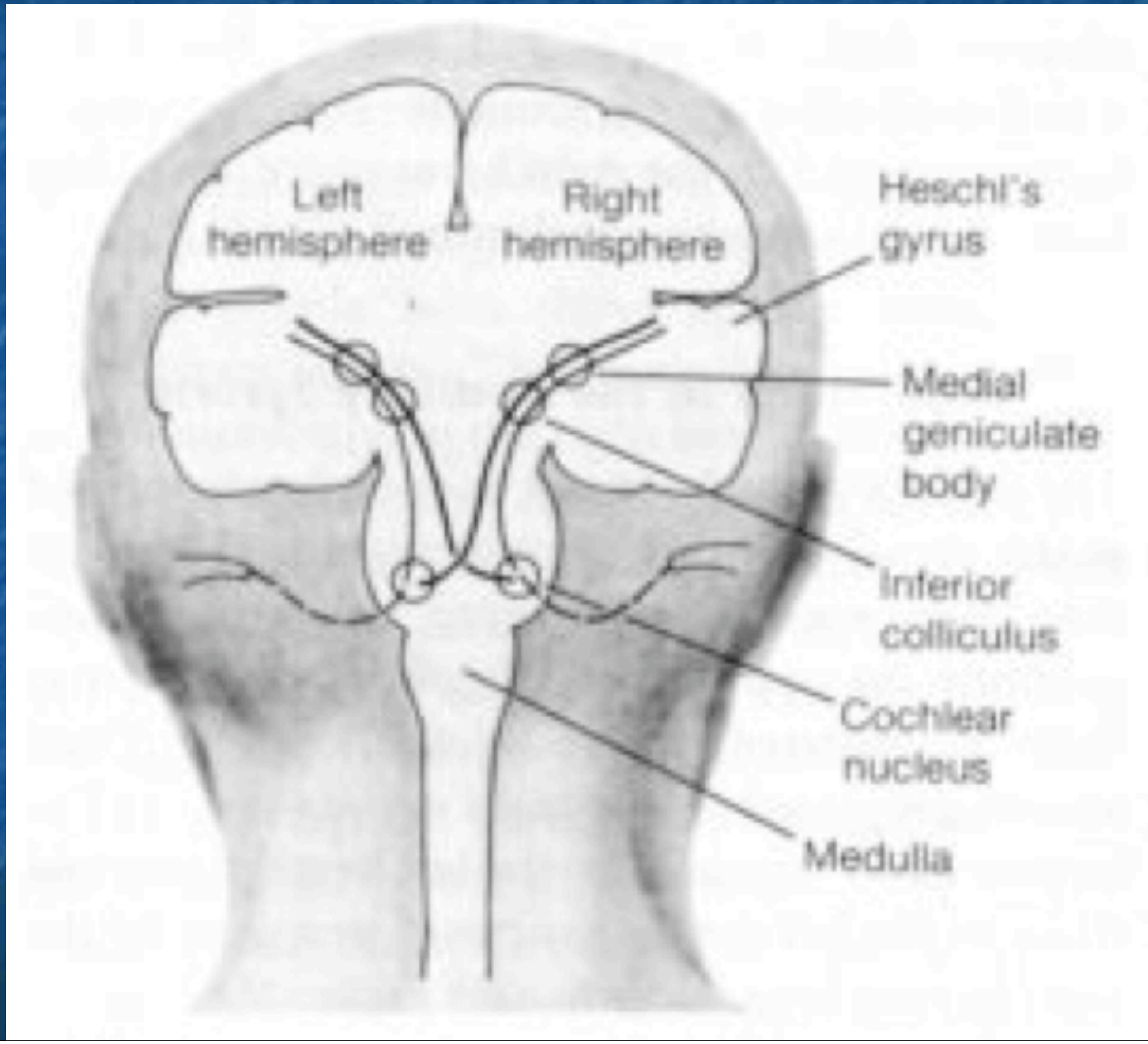
Tonotopic mapping

but see ...

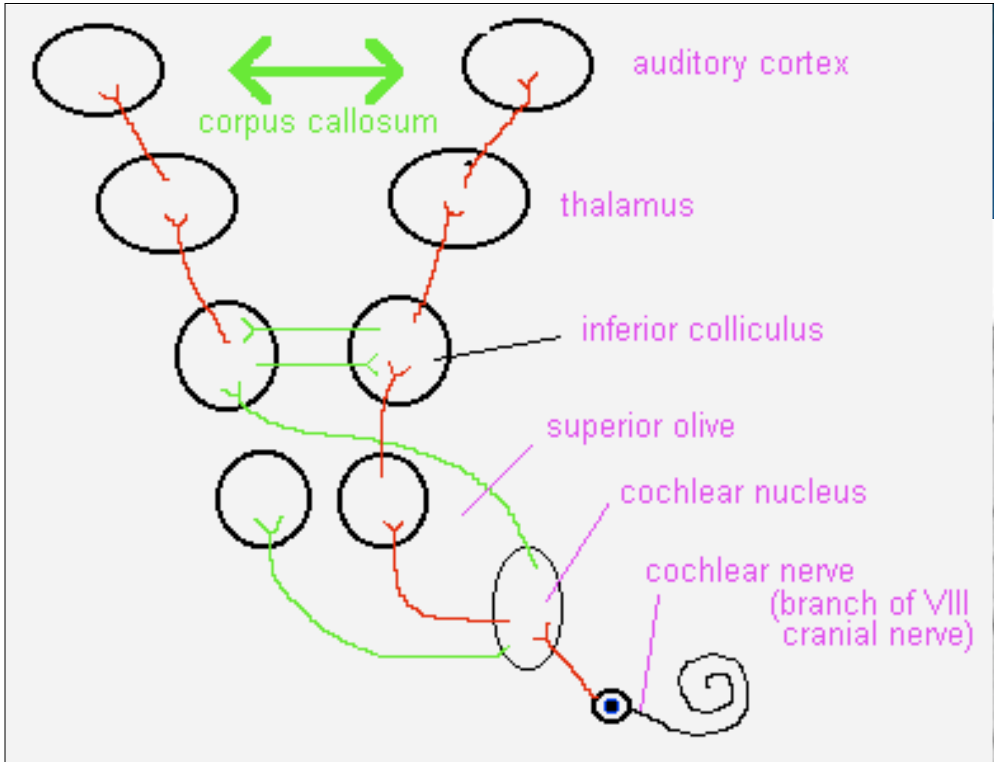
http://www.blackwellpublishing.com/matthews/ear.html

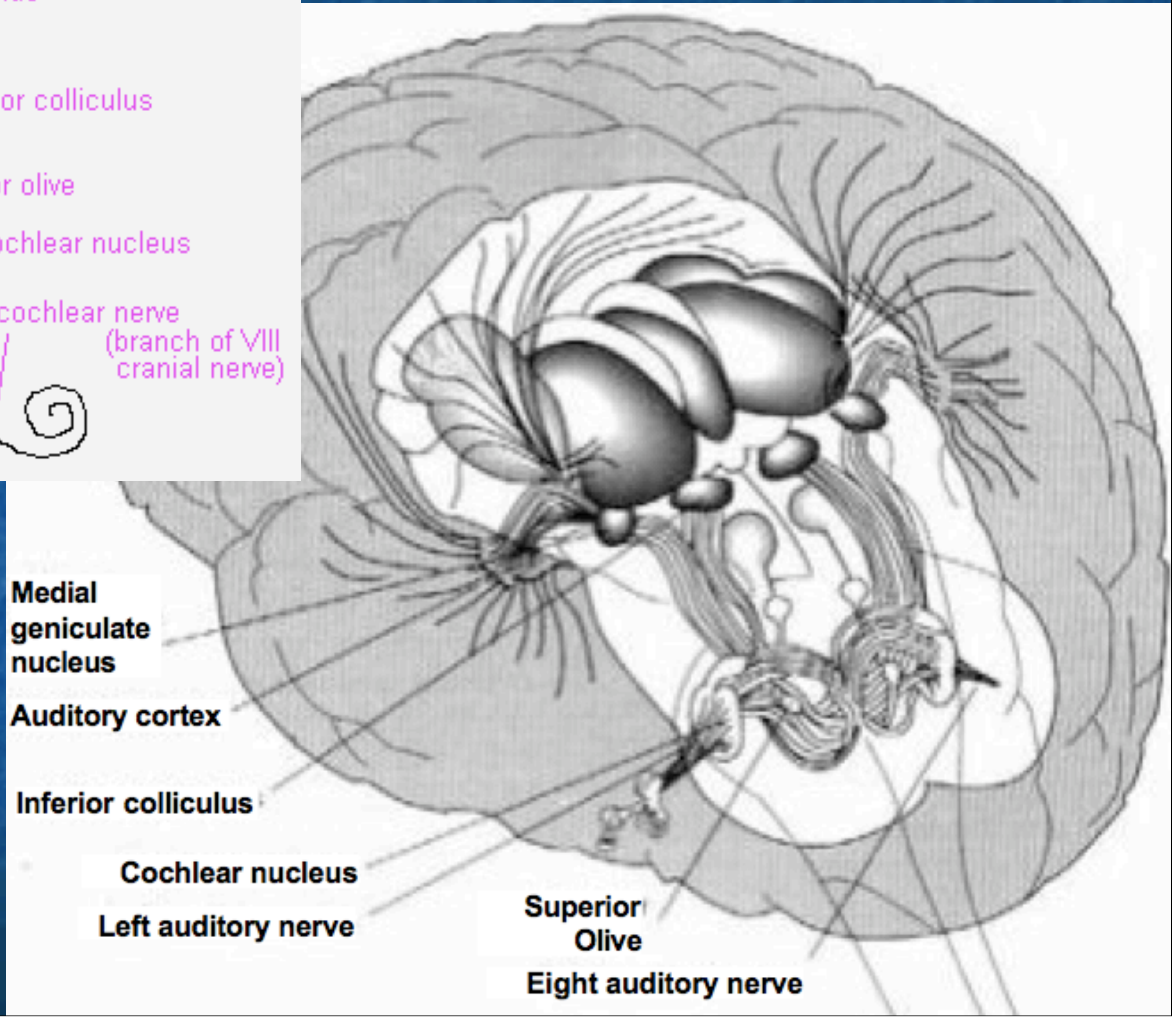
... for the correct relation between frequency and the cochlea

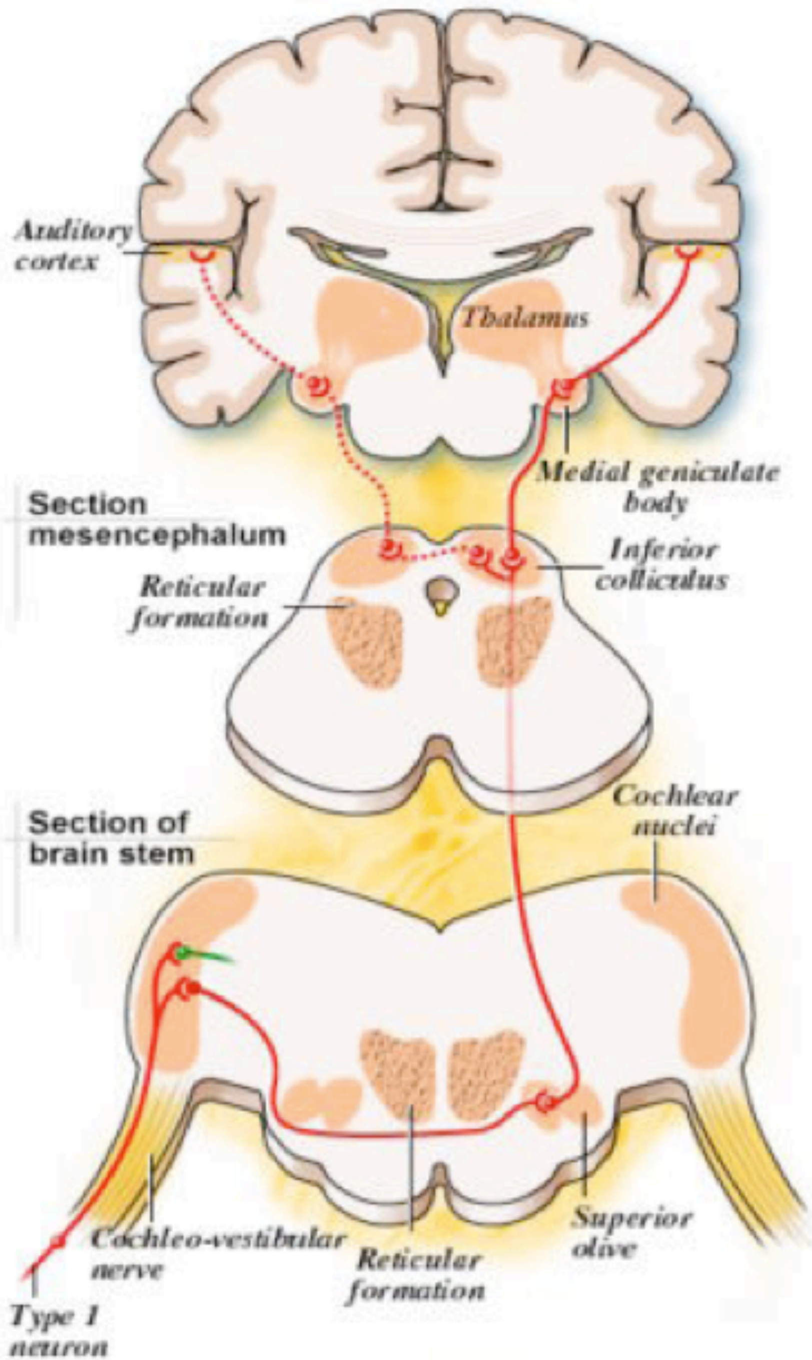
Auditory pathways



Auditory pathways







The final neuron of the **primary auditory pathway** links the thalamus to the **auditory cortex**, where the message, already largely decoded during its passage through the previous neurons in the pathway, is recognised, memorised and perhaps integrated into a voluntary response.

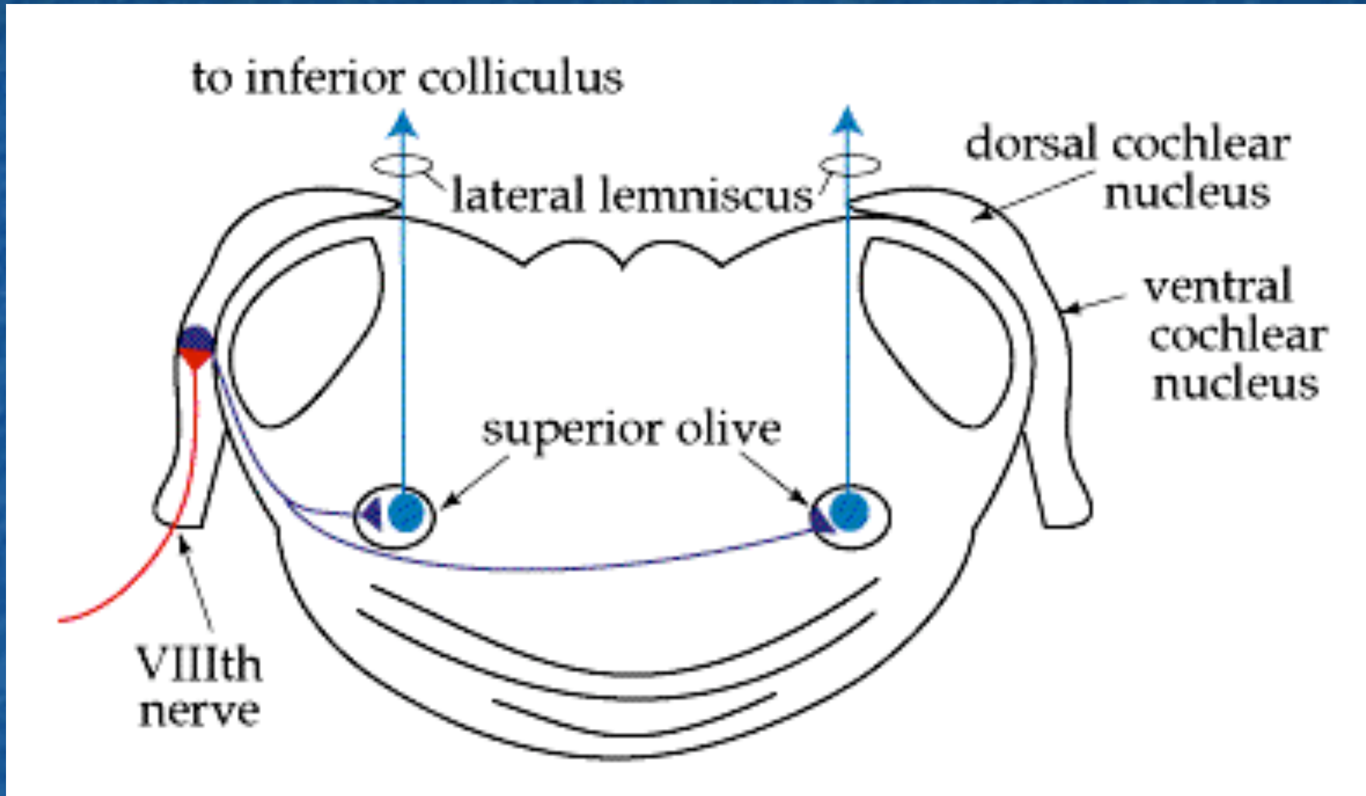
A final relay, before the cortex, occurs in the thalamus (**medial geniculate body**) it's here that an important integration occurs: preparation of a motor response (eg vocal response).

A third neuron carries the mesage up to the level of the **Inferior colliculus** (in the mesencephalon), which is an auditory reflex center. Frequency information is combined with location information.

The second major relay in the brain stem is in the **superior olivary complex**: the majority of the auditory fibres synapse there **having already crossed the midline**. First point at which information from both ears is integrated

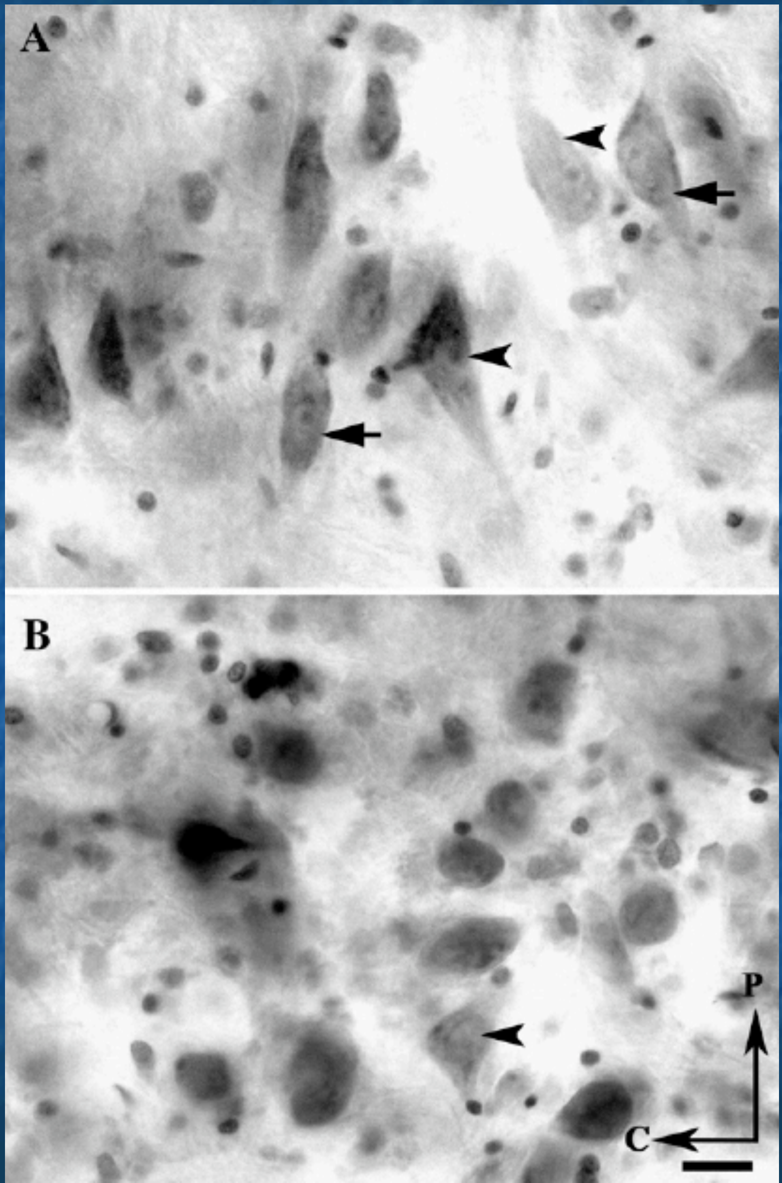
The first relay of the primary auditory pathway occurs in the cochlear nuclei in the brain stem, which receive Type I **spiral ganglion axons** (auditory nerve); at this level an important **decoding of the basic signal** occurs: duration, intensity and frequency.

Direction of sound



In the medial and lateral superior olive, minute timing and intensity differences are compared, allowing sound direction to be computed.

Medial superior olive in autism

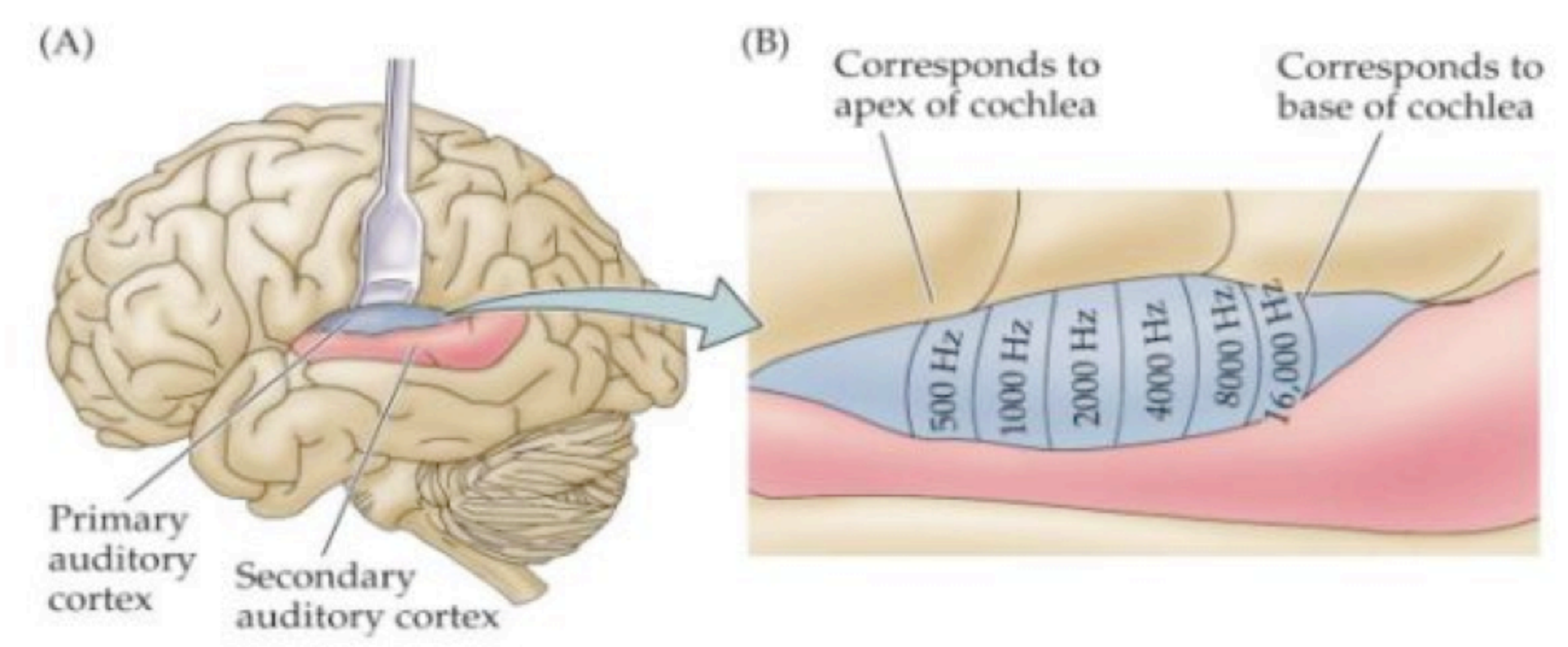


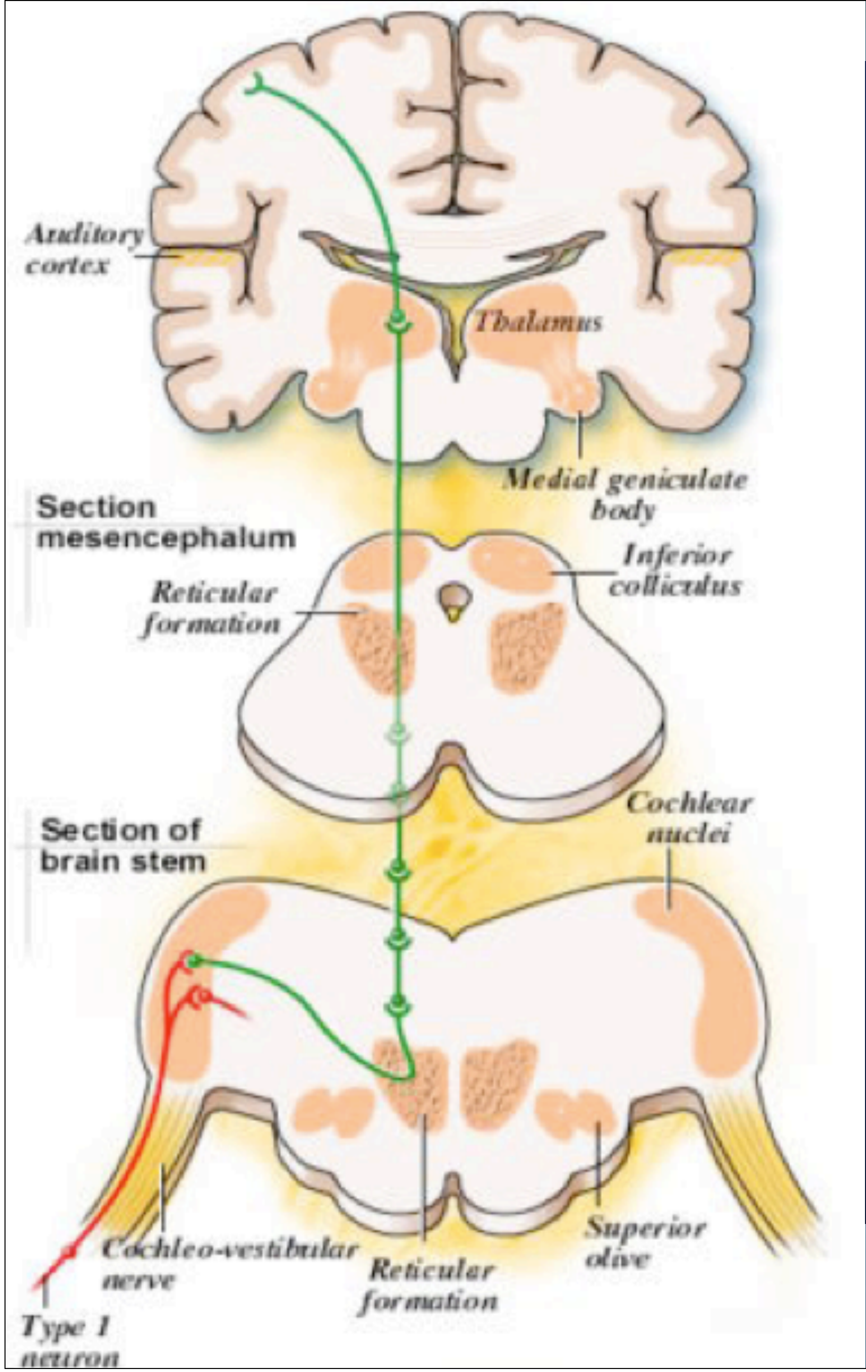
Normal

Autistic

Kulesza & Mangunay (2008)

In the cortex



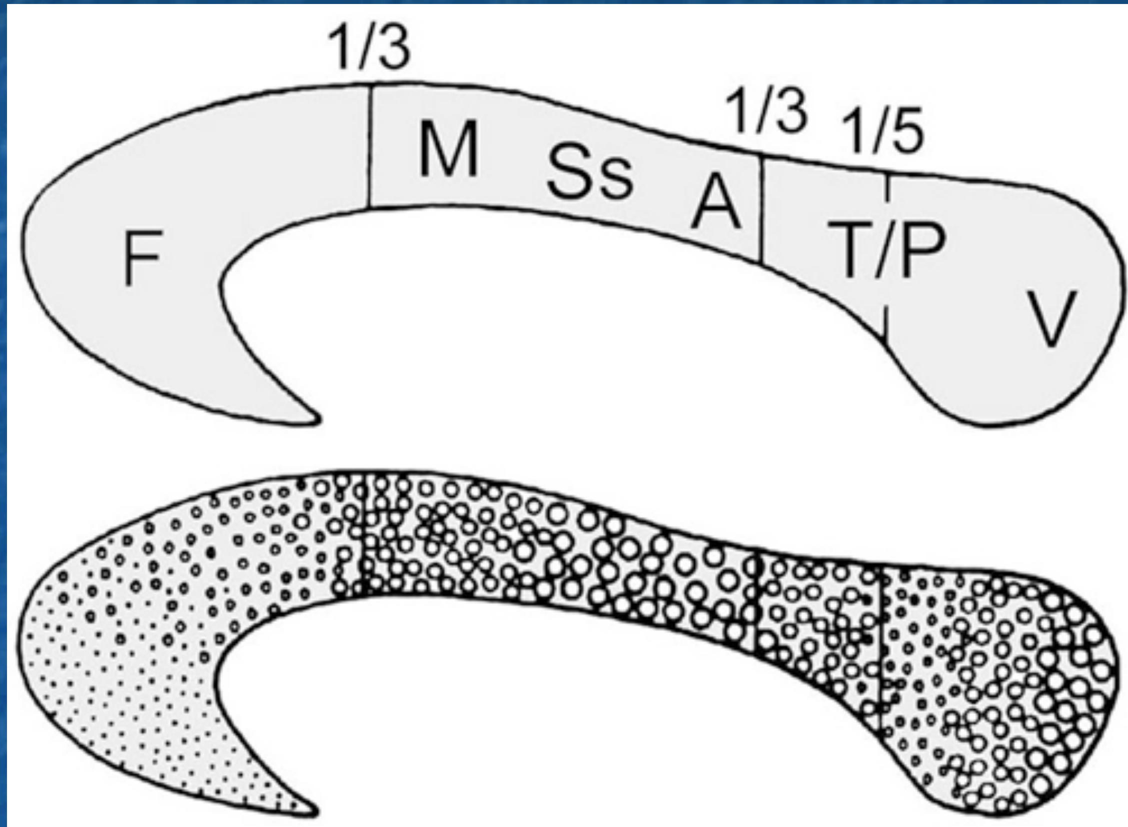


After the reticular formation, the non-primary pathway leads to the thalamus, then to the polysensory cortex. NB : connections are also made with the hypothalamus and the vegetative centres (not shown on the diagram)

In the reticular pathway of the brainstem and the mesencephalus, several synapses occur. It's here that the auditory **information is integrated with all the other sensory modalities** to select the information that should be treated as priority by the brain. (mesencephalon -> motivation centres)

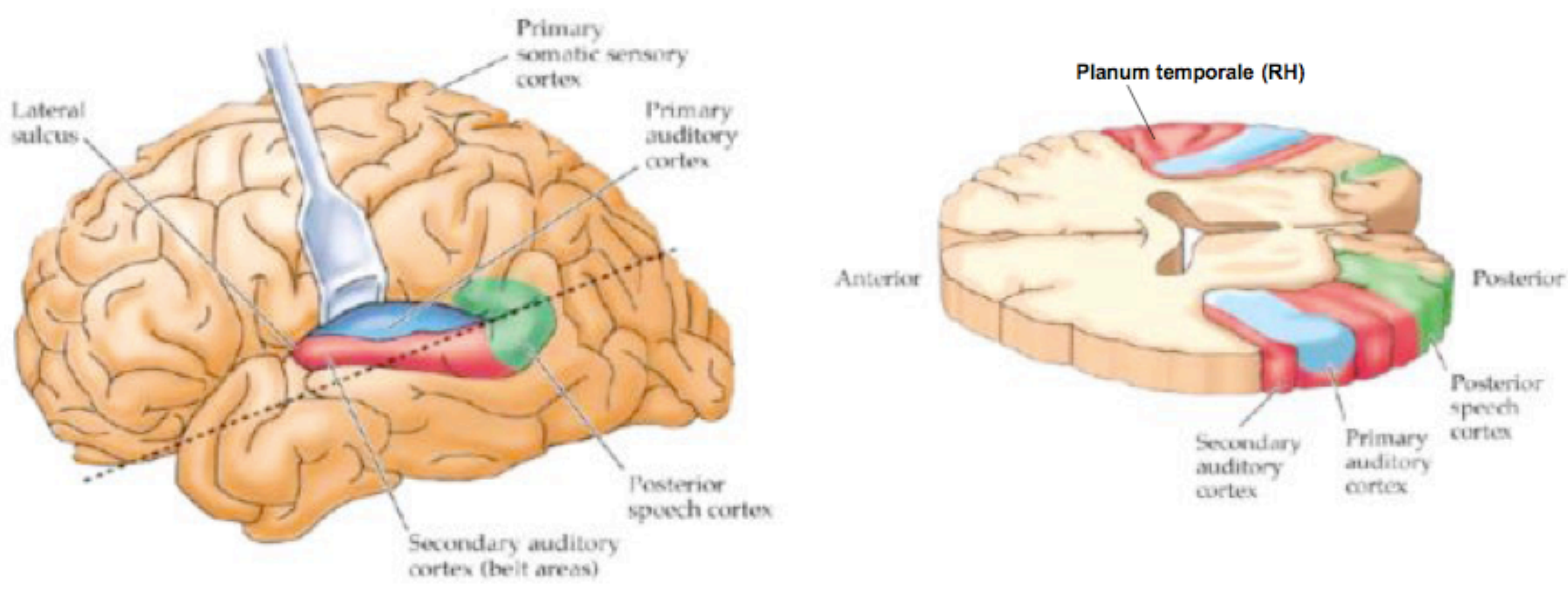
The primary relay, in common with the primary auditory pathway formed in the cochlear nuclei (brainstem).

Auditory callosal coordination.

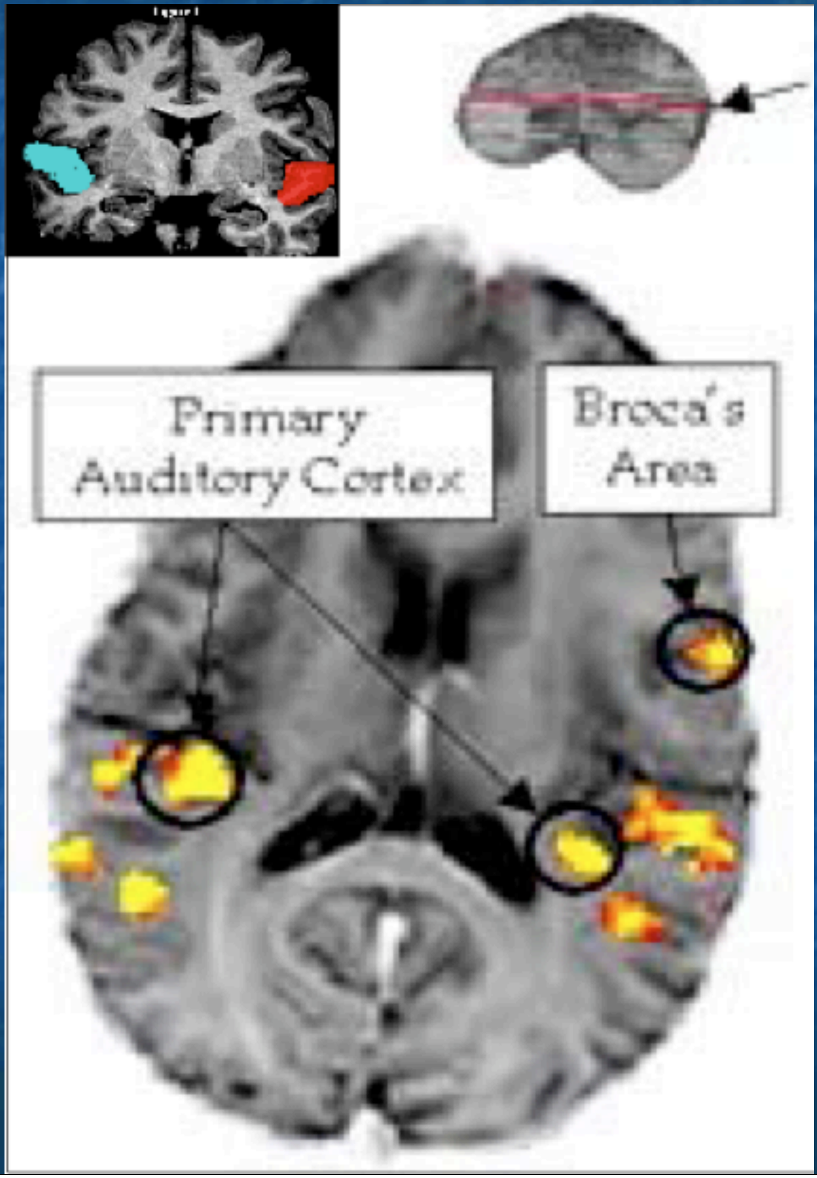


"A" shows the placement of auditory connections in the corpus callosum (Aboitiz *et al.*, 2003)

Auditory cortical areas

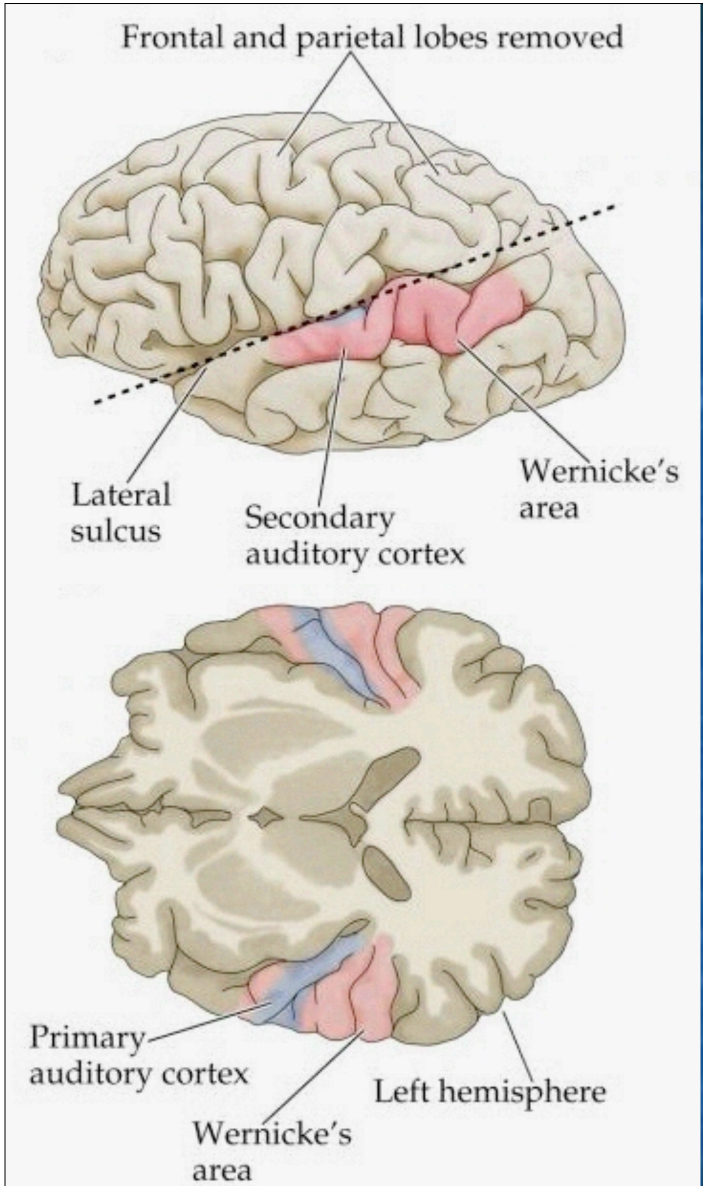


Primary auditory cortex

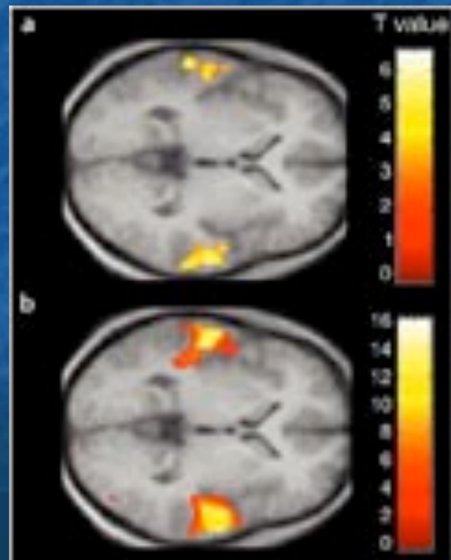


Cells in A1 respond well to pure sounds, and damage to A1 results in cortical deafness

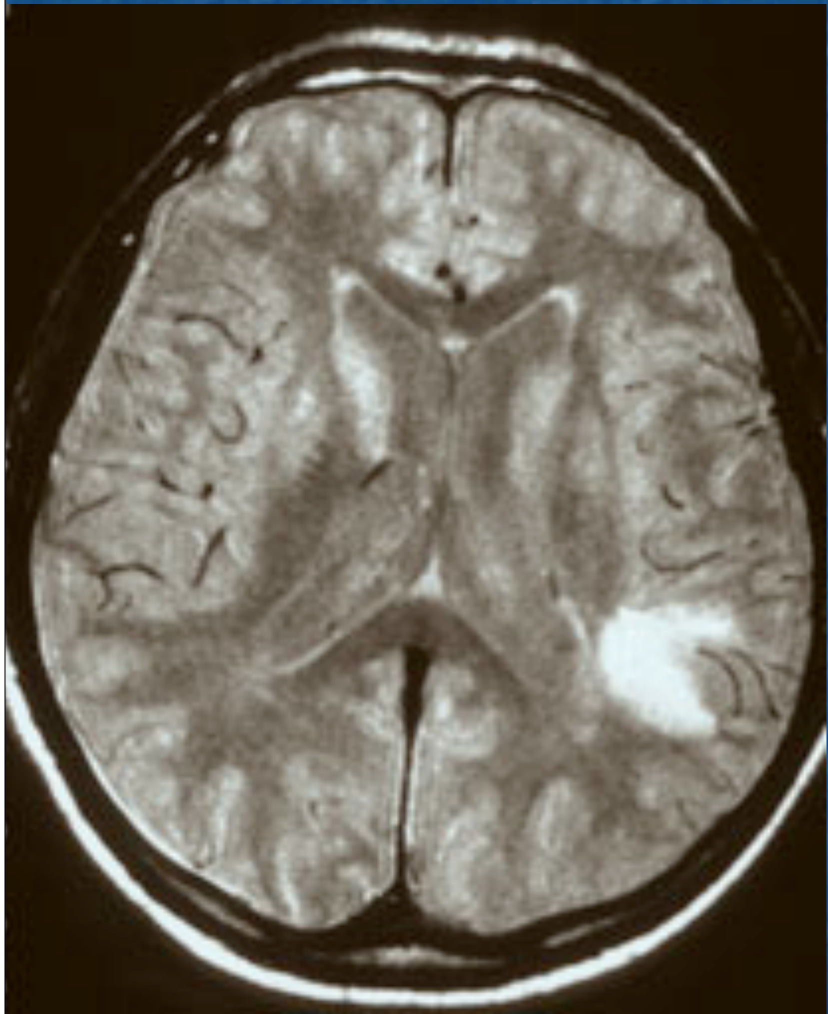
Secondary auditory cortex



Cells in A2 respond weakly to pure sounds (*cf.* spots of light in V1), but strongly to band-passed noise (*cf.* bars in V2)



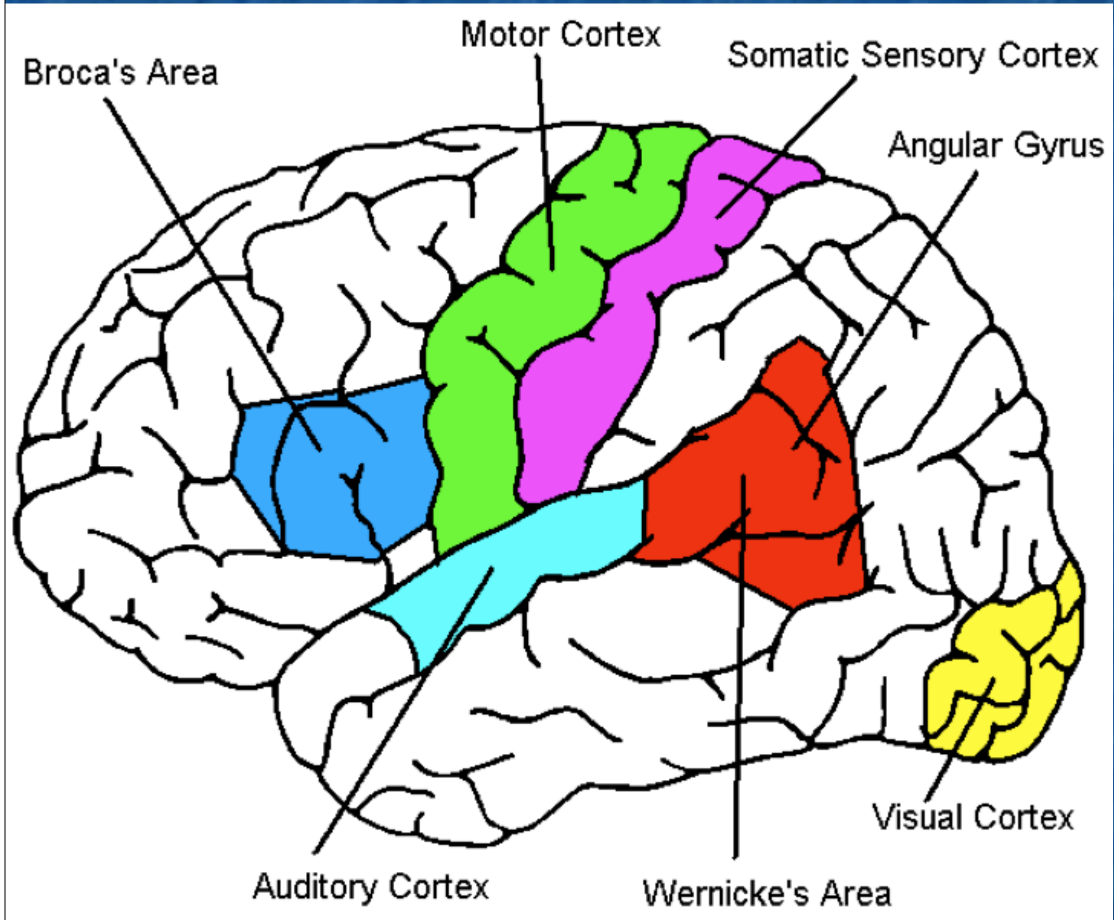
Auditory hallucinations and A1



Auditory hallucinations in schizophrenia can cause activation in Heschl's gyrus (primary auditory cortex)

They can also be the result of lesions (see left)

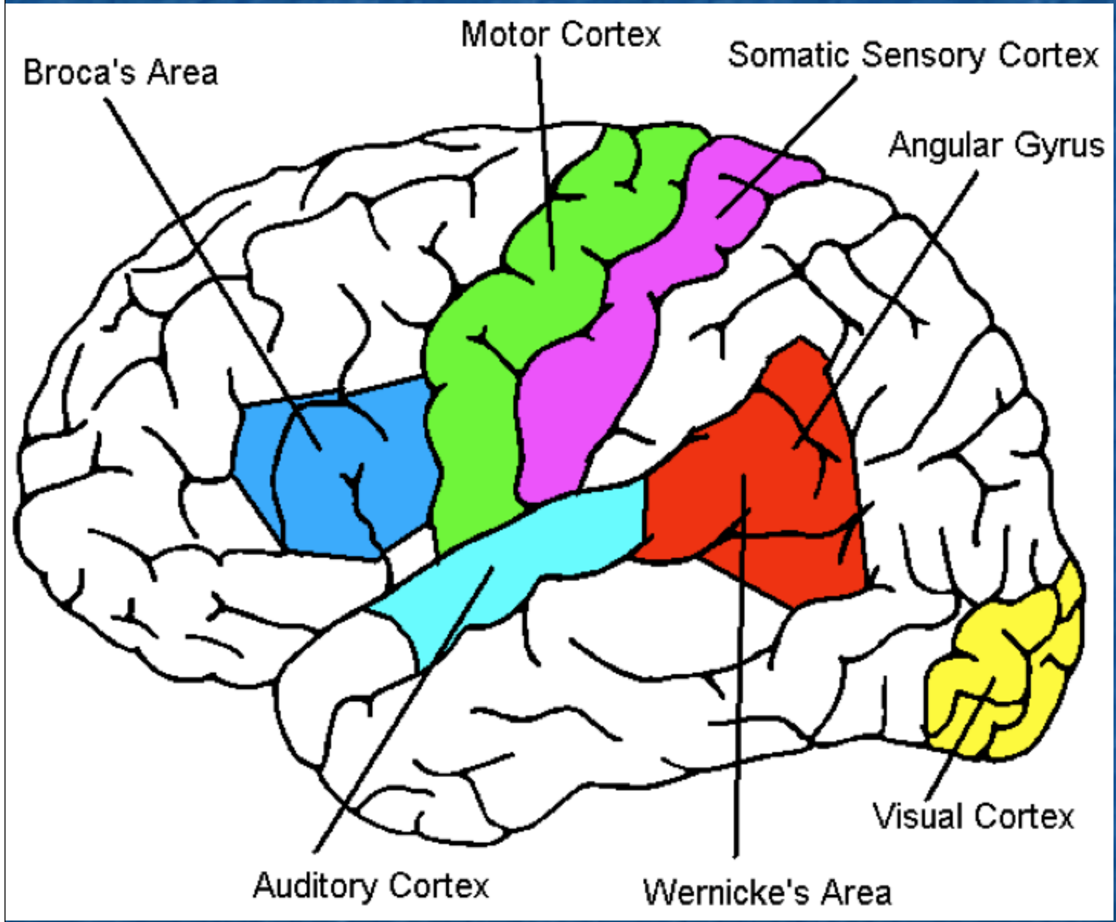
Speech comprehension



Pure word deafness (central hearing loss) can result from disconnections involving Heschl's gyrus and Wernicke's area, and other central impairments

Non-speech hearing is retained

Non-speech comprehension



Central hearing loss can also involve normal speech perception, but impaired perception of non-speech sounds (auditory agnosia), or music (amusia), typically involving the RH

Summary

Early binaural projection (compared with vision)

Tonotopic mapping and very precise temporal processing

Speech/non-speech dissociation