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# STRUCTURES INVOLVED IN THE TRAJECTORY OF THE AUDITORY SYSTEM (PART IV): GENICULATE BODY

Milaine Dominici Sanfins, Piotr Henryk Skarzynski and Adriana Neves de Andrade

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# STRUCTURES INVOLVED IN THE TRAJECTORY OF THE AUDITORY SYSTEM (PART IV): GENICULATE BODY

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Besides the ears, the auditory system is composed of auditory pathways that conduct sound information to the brain. As auditory information makes its way up through different structures and activates increasing numbers of neurons, the system to becomes increasingly complex.

The efficiency of the auditory system is particularly impressive when one considers that the energy in a sound wave, even at high intensity, is extraordinarily small. Moreover, most sounds contain many different frequencies and are usually embedded within competing sounds and noise. The extraordinary perception of a sound is due to a sequence involving detection by the ear, transmission of information along the auditory pathways, and analysis by a sophisticated neural system in the brain (Kandel, Schwartz e Jessel, 1995).

Due to the great complexity of processing auditory information, especially speech, good knowledge of neuroanatomy and neurophysiology of the central auditory nervous system (CANS) can help one better understand what auditory tests mean and offer better guidance for rehabilitation. The present bulletin aims to provide information about the geniculate body (GB) and its role in the central processing of auditory information, but we invite you to read our previous bulletins on the related cochlear nuclei, the superior olivary complex, the lateral lemniscus, the insula, and the corpus callosum.

The geniculate body has three subdivisions, namely:

- **Ventral portion of the dorsal geniculate body** has very homogeneous neurons related to hearing. It exhibits good frequency selectivity and short latency in response to an auditory stimulus.

- **The lateral portion of the lateral geniculate body** is a polysensory area with low frequency selectivity and is related to visual function.

- **The medial portion of the medial geniculate body** is also a polysensory area with low frequency selectivity, but is concerned with responses to auditory stimuli.

# ANATOMICAL LOCATION

In the hierarchy in the auditory system, the geniculate body is located after the inferior colliculus (IC). The IC receives a convergence of auditory inputs originating from ascending and descending fibers which are subsequently sent to the IC, located in the thalamic region. Afferent fibers from the IC are directed to the three areas of the LGN and, simultaneously, the reticular formation sends information to the dorsal and medial portions of the lateral geniculate body. Therefore, the GB needs to process various pieces of information simultaneously with great precision.

The fibers of the auditory nerve are predominantly oriented vertically, whereas in the GB these fibers are longitudinal, transverse, and oblique. The presence of different types of fibers allows for a more refined acoustic analysis.

Anatomically, this area of the auditory pathway needs to send a large amount of information to the brain, and messages will also travel in a reverse path to reach the ears. Given its strategic positioning in the auditory system, there is evidence that the GB may have a predictive role in the outcome of cochlear implants as well as in auditory rehabilitation.

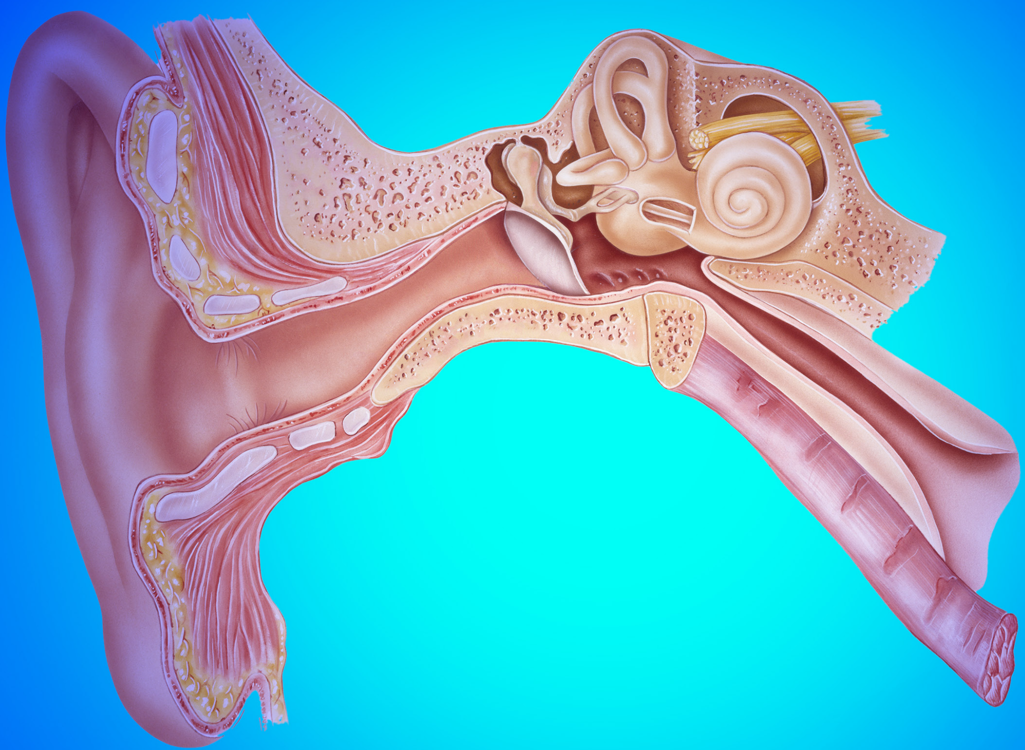
**But what is the role of the geniculate body in auditory processing?**

# THE GENICULATE BODY AND AUDITORY SKILLS

**Given the complexity and nuances of the structures located in the thalamus, small lesions in these structures can affect the processing of auditory information, according to studies conducted on animals.**

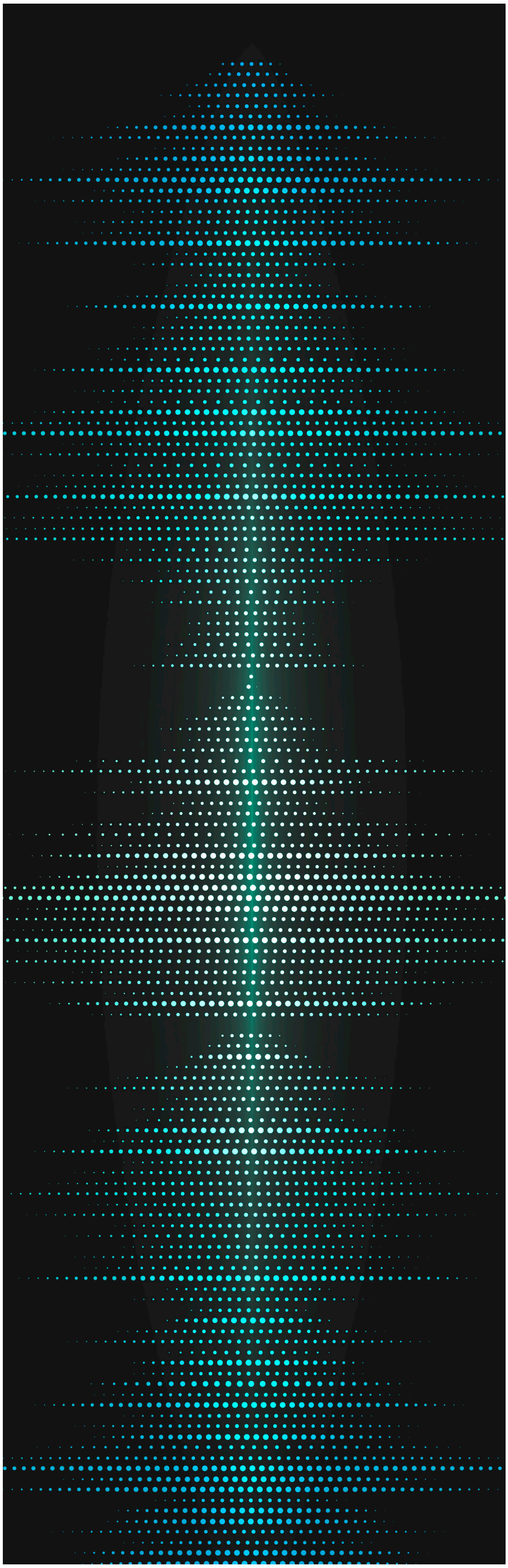
# TEMPORAL PROCESSING FOR SHORT-DURATION STIMULI

**The frequency-specific response, known as tonotopy, observed in the cochlea, also occurs at all levels of the ascending auditory pathways in the CNS.**



In the GB, the representation of low frequencies is located in the ventral component and high frequencies in the medial component, according to studies conducted on cats. A large number of cells located in this portion of the CANS are responsible for the detection and perception of sound stimuli that start and end quickly, called transient stimuli, highlighting the GB's ability to process short-duration stimuli.

Short-duration auditory stimuli are important for speech comprehension, as the perception of subtle timing differences allows for the distinction of different phonemes that convey important meaning and can define the correct meaning of a word. A recent study by Meng and Schneider (2022) found that the magnocellular division of the medial geniculate nucleus is responsible for the selective encoding of transient auditory stimuli, while other divisions of this structure respond similarly to both transient and sustained sounds.



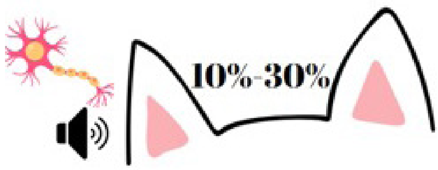
# SOUND LOCATION AND LATERALIZATION

The abilities to locate and lateralize a sound stimulus depend on the active participation of the GB, the integrity of the peripheral auditory system, and the development and maturation of the entire CANS.

Regarding the neuronal activation of the GB, a study conducted on cats demonstrated that 60% of the neurons located in the GB can be activated by auditory stimuli presented to either ear. About 20–30% can be excited solely through contralateral stimulation. And finally, around 10–20% ipsilateral inhibition may occur (Calford, 1983).


**Sanfins et al, 2024**


**Sanfins et al, 2024**




**Sanfins et al, 2024**

**Figure 1:** Representative figure of neuronal activation after sound stimulation in the GB region. Sanfins et al, 2024

When analyzing the azimuthal location of a sound source, the medial portion of the IC has the ability to localise sounds based on differences in time and intensity. Azimuthal localization is related to the ability to identify the horizontal direction from which a sound is coming. The azimuth is the angle measured in a horizontal plane from a reference point. See the figures which show the sound source at the 0° azimuth (figure 2) and 45° azimuth (figure 3).

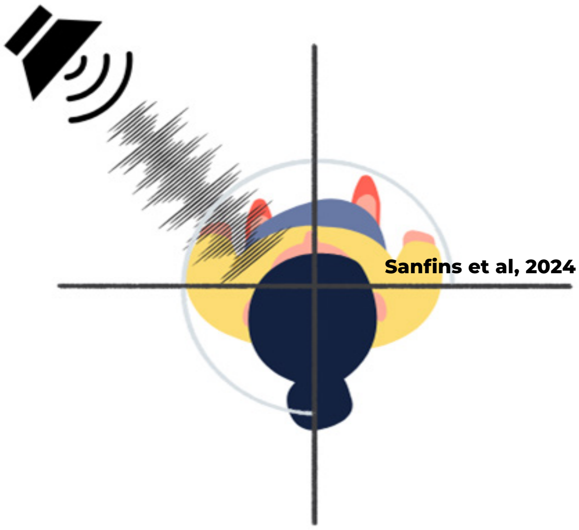



**Figure 3:** Representative figure of the sound source positioning at a 45° azimuth angle. Sanfins et al, 2024

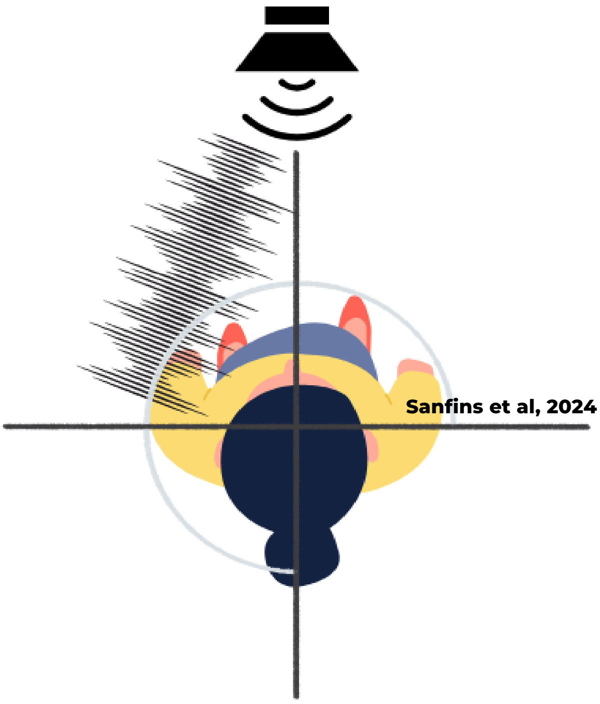



**Figure 2:** Representative figure of the sound source positioning at the 0° azimuth position. Sanfins et al, 2024

The analysis of the sound that reaches the ears allows for the identification of some important information such as the difference in the time of arrival of the sound at the ears and the difference in sound intensity in each ear.

Humans locate the direction of the sound source in the horizontal plane using two different strategies depending on the frequency of the sound stimulus (Kandel et al., 2014). For frequencies below 2000 Hz, the time cue is more relevant, and for sounds with frequencies above 2000 Hz, the analysis of the intensity difference between the two ears is used. The analysis and integration of this information, which occurs in the IC of the midbrain, allows for precise localization of the sound source across a wide range of frequencies (Kandel et al., 2014).

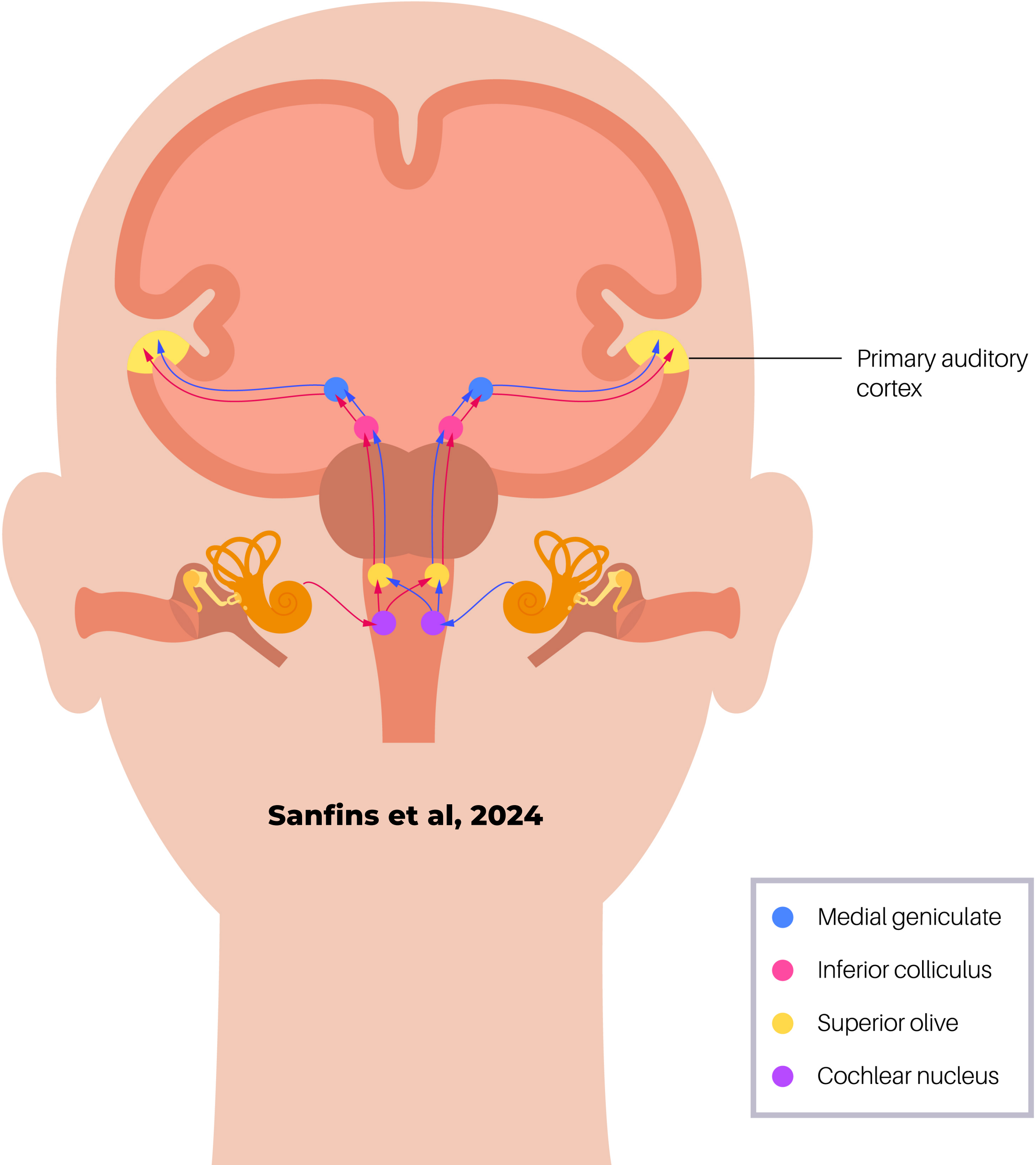



**Figure 3.1:** Figure developed by authors.

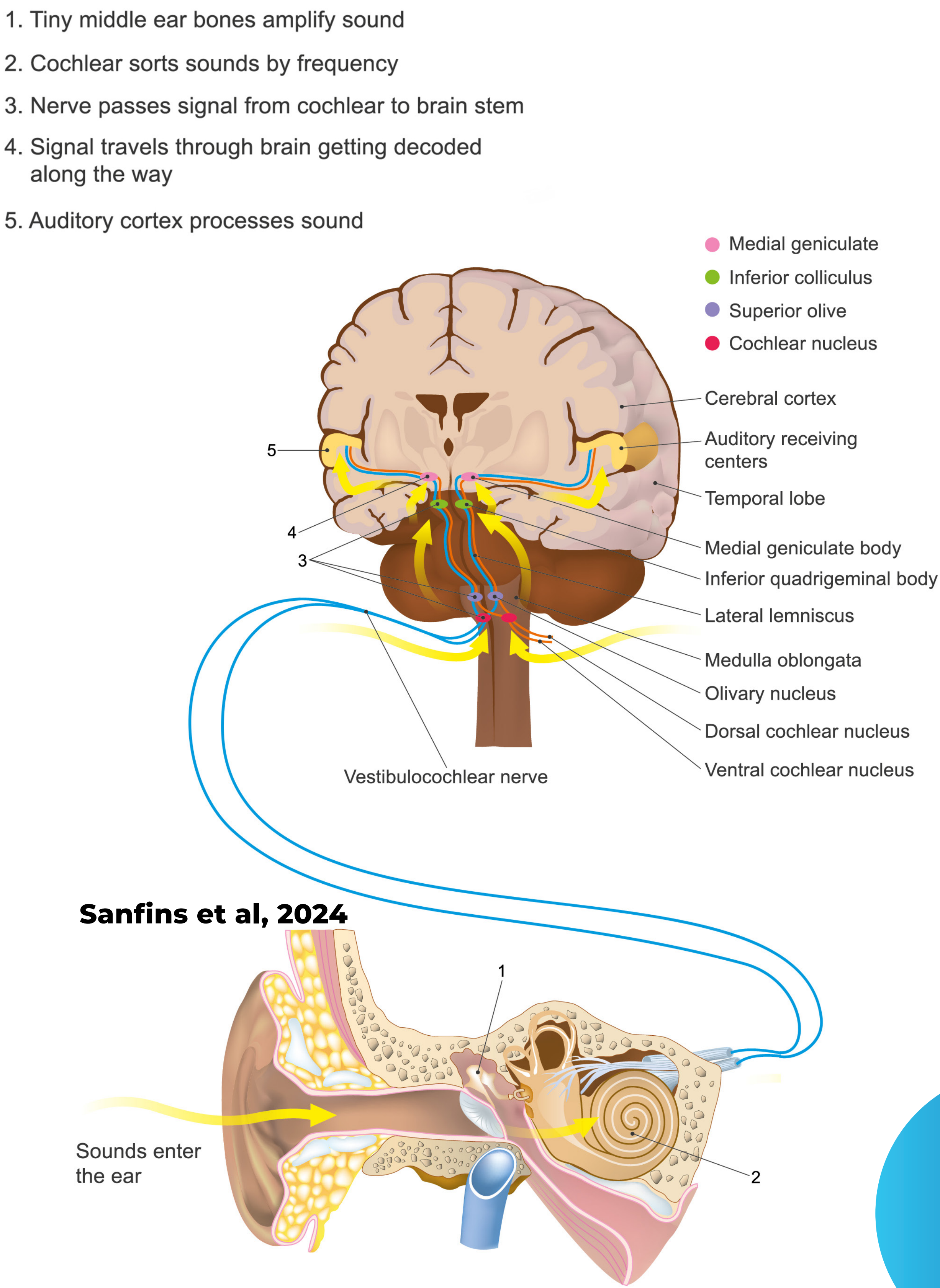



**Figure 3.2:** Figure developed by authors.

The medial GB plays an important role in analyzing the difference in time and intensity between sound stimuli, facilitating the localization of a sound, as evidenced by studies with imaging exams.

The need to process different acoustic stimuli of low and high complexity causes the IC and the GB to have some kinds of functions similar to those developed by the primary cortex. Subcortical structures are part of a hierarchically organized CANS which depends on a continuous and efficient flow of auditory information.

# NEUROPLASTICITY AND LEARNING

The ability to perceive and process stimuli over time depends on the interaction of exogenous and endogenous factors. Among the endogenous factors, one can consider brain maturation, which depends on the passage of years and the development of the human being. Exogenous factors, on the other hand, depend on the characteristics of a specific sound stimulus and, therefore, the more access we have to a specific sound, the greater the chances of adapting our auditory system to process this particular sound.

Thus, with growth and maturation, there is a development of auditory structures, with a greater network of neurons being activated over the years. Given the analysis of information from a large neural network, the GB plays an important role in neuroplasticity and learning. Thus, it can be said that this important structure participates in both the classical and non-classical auditory pathways.

Studies in animals have shown that cells of both the IC and the GB cells appear to be more active when an auditory task is demanded, whereas in passive listening there is reduced activation. Thus, learning to identify a sound stimulus is more attractive and beneficial to animals and individuals when there is interest in performing the activity. All of this confirms various studies in the field of education that emphasize the importance of activities, whether playful or non-playful, which provide an emotional engagement to the listener.

Education in a pleasant and stimulating context is an important tool in auditory training programs that aim to improve or rebalance the CANS. And the ascending auditory pathways, which include the GB, seem to play a relevant role in learning that later involves the auditory cortex.

As a consequence, the GB has a role in neuroplasticity. The plasticity resulting from learning can promote modifications in behavior patterns, create synapses, recruit new neurons, and enhance neural connections. These pieces of evidence highlight the prominence of GB cells in activities considered highly complex. The GB therefore takes on an even more significant role in the CANS and its functioning can have serious repercussions (including benefits) in higher areas.

ADDITIONAL INFORMATION

# NEUROLOGICAL ALTERATIONS

The functions of the GB are truly surprising. The vast majority of studies have been conducted on animals, but studies on humans have already confirmed the complexity of this structure.

The connections of the GB with the cerebral cortex provide a wide variety of analyses of sound stimuli. A change or interruption in the connection between the CG and the cortex due to neurological alterations can cause serious consequences in how sound is processed. Thus, auditory, speech, and language skills are affected by functioning of the GB. Damage in an afferent pathway of the auditory system can affect the quality of responses and temporal cues may be compromised. However, if the damage is more extensive and affects both ipsilateral and contralateral afferent pathways, more information may be lost and the information sent to the cortex will be seriously impaired.

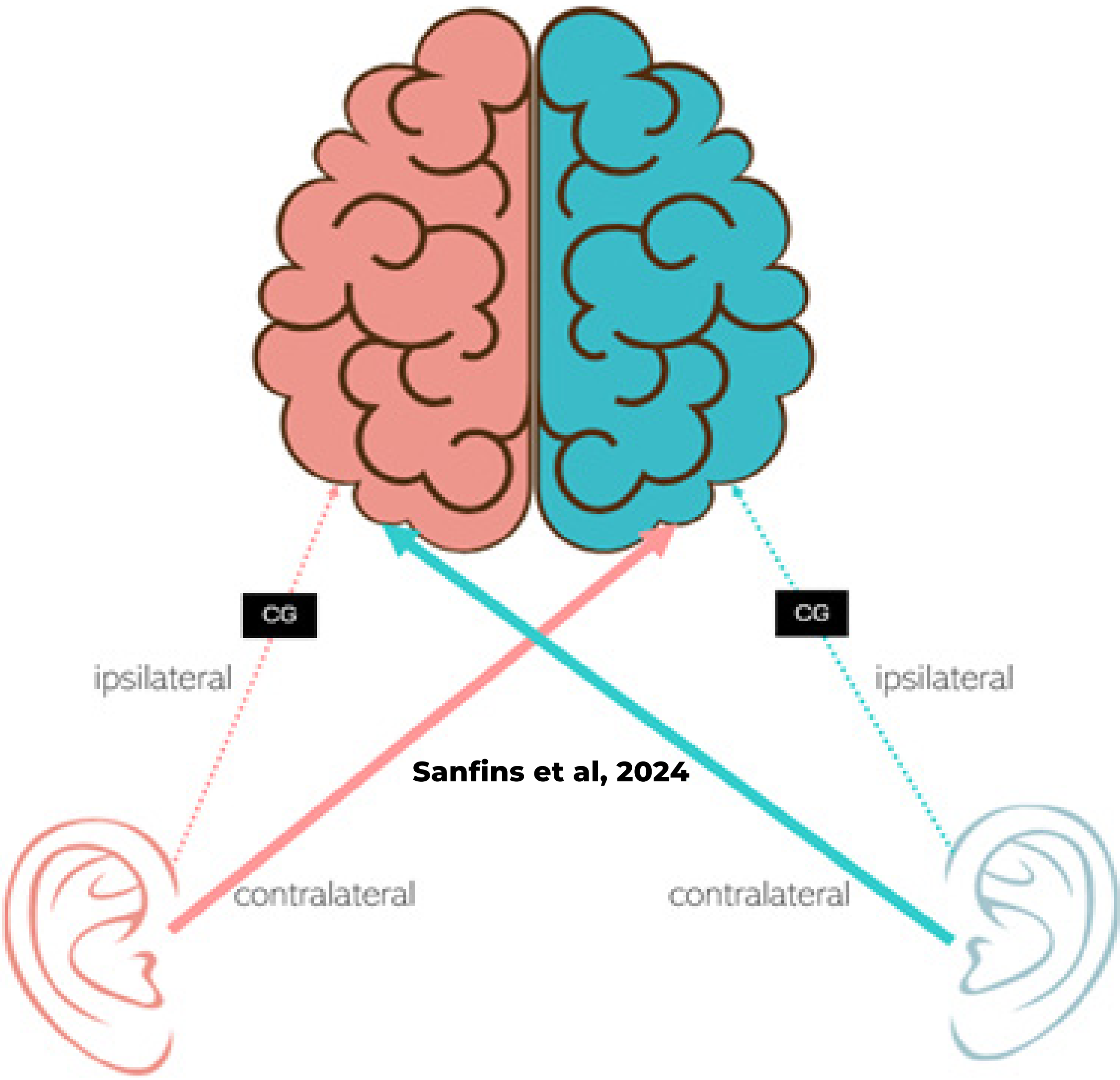



**Figure 4a:** Representative figure of an intact auditory system.

Sanfins et al, 2024

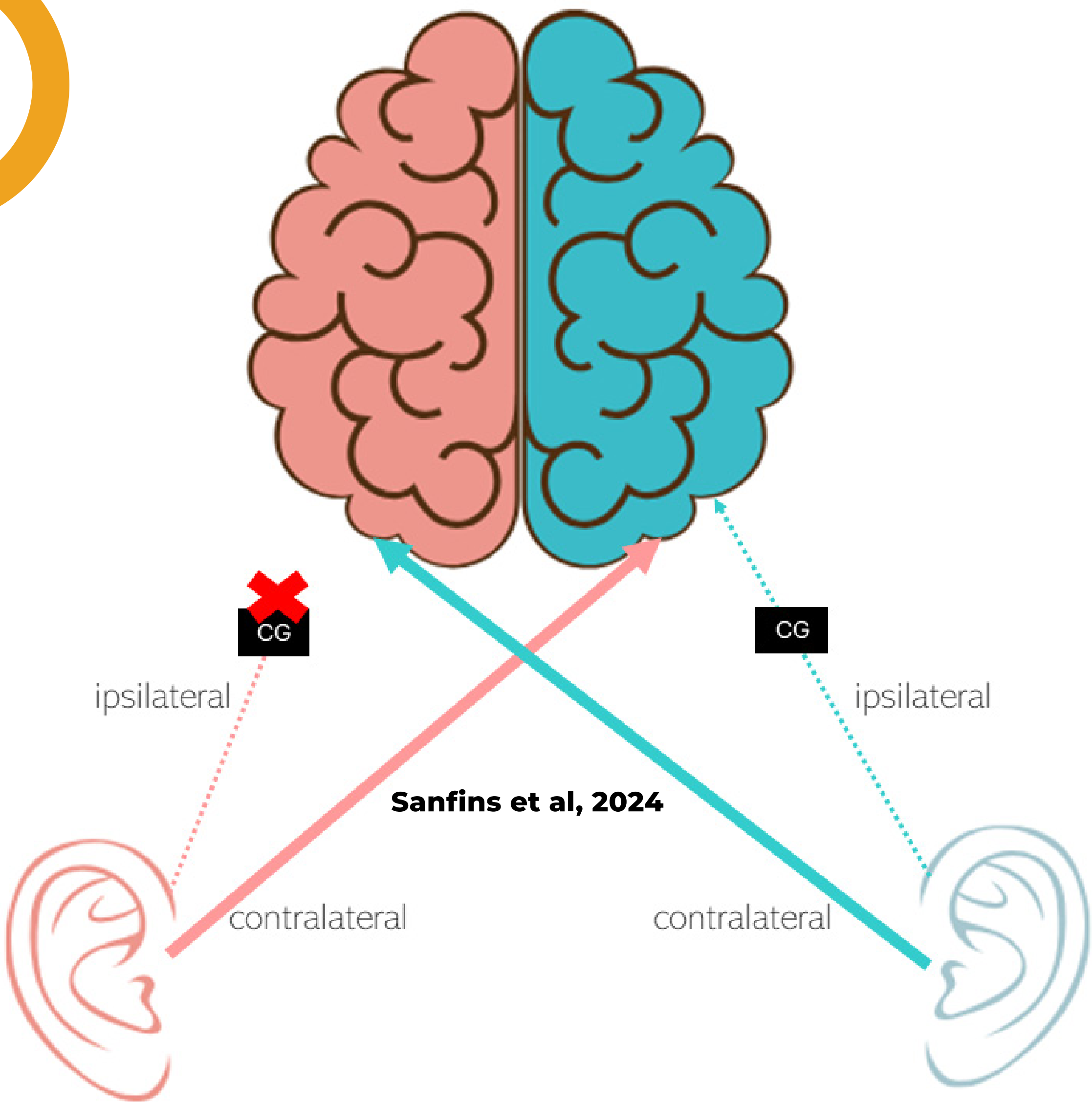



**Figure 4b:** Representative figure of an auditory system with exclusive ipsilateral damage.

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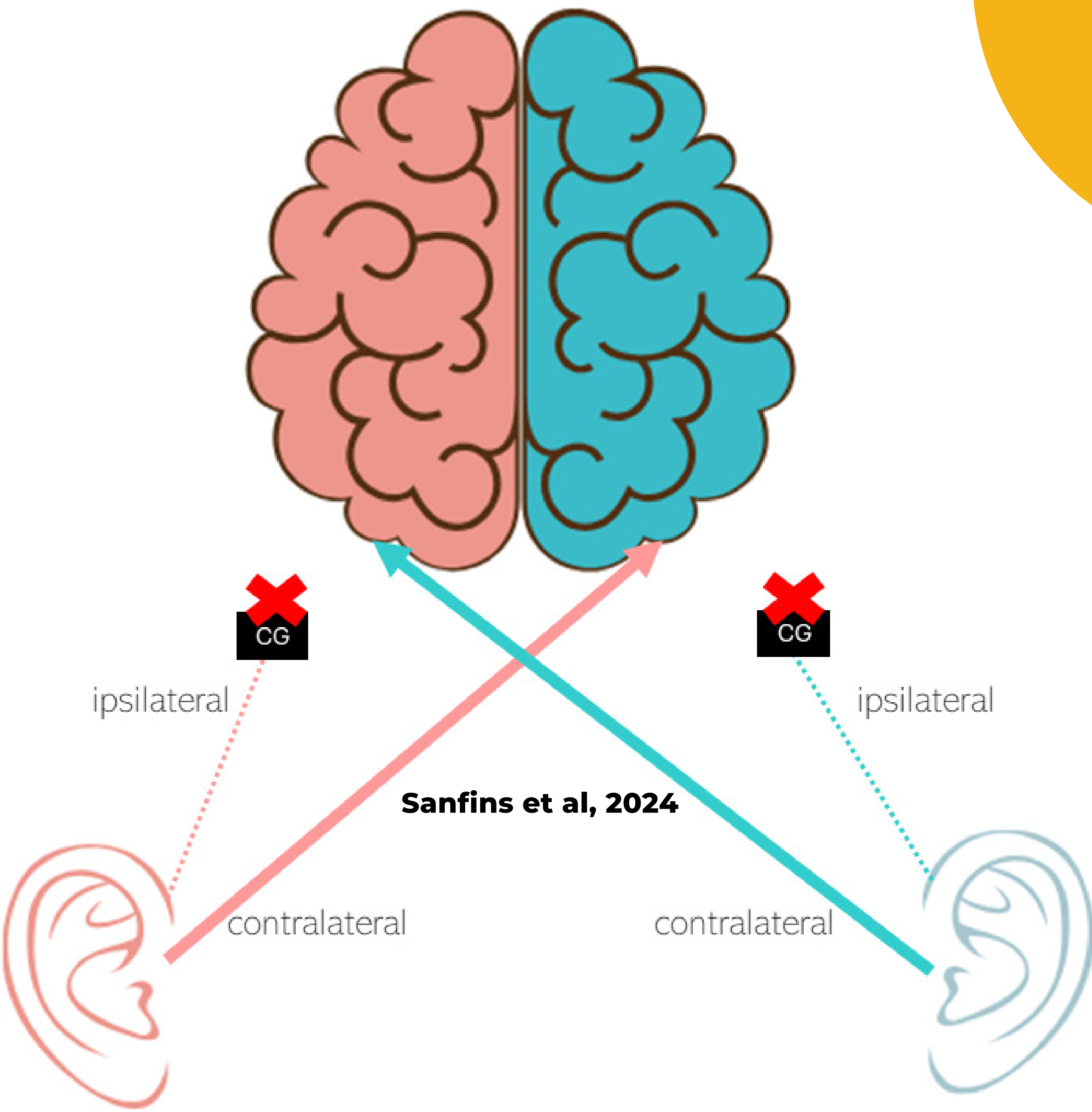


**Figure 4c:** Representative figure of an auditory system with ipsilateral and contralateral damage.

**Sanfins et al, 2024**

## BIOMARKERS AND PREDICTORS

Given the special place of the GB within the auditory system, it is understandable how it plays an important role in auditory rehabilitation, and this structure can be considered a valuable predictive biomarker for the outcome of a cochlear implant. If there is greater integrity in the ipsilateral auditory pathways compared to the contralateral fibers, this may indicate better conditions for nerve impulse transmission and, therefore, the chances of a good prognosis might be improved.

There is also the possibility of future interventions directly on the GB. Perhaps neurosurgical intervention could involve application of drugs or even stem cells, thus enabling a therapy that might rescue or at least improve functioning of the central auditory nervous system.

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# Authors

**PROF. DR. MILAINE DOMINICI SANFINS**

- Professor of the Audiology da Universidade Federal de São Paulo (UNIFESP);
- Research group member, Institute of Physiology and Pathology of Hearing, Kajetany, Poland.
- Professor of the post-graduate program in Clinical Audiology at the Albert Einstein Israelite Institute of research and teaching;
- Postdoc at the World Hearing Center, Warsaw, Poland;
- Sandwich Doctorate by School of Medical Sciences, Universidade Estadual de Campinas (FCM-UNICAMP) and by Università degli Studi di Ferrara/Italy;
- Expertise in Audiology by Federal Council of Speech Therapy and Audiology;
- Speech Therapist and Audiologist, Master by Medical School of University of São Paulo (FMUSP);
- Member of the Teaching and Research Commission of the Brazilian Academy of Audiology (2024-2026);
- Reviewer of scientific articles in the area of Neuroaudiology, Neuroscience, Electrophysiology and Audiology;
- Instagram @misanfins / email: msanfins@uol.com.br and msanfins@unifesp.br

**PROF. DR. PIOTR HENRYK SKARZYNSKI**

- Professor, ENT, Master and Doctorate by Medical University of Warsaw;
- Research, didactic, clinical, and organizational work in World Hearing Center of Institute of Physiology and Pathology of Hearing, Institute of Sensory Organs and Medical University of Warsaw;
- Specialist in ENT, pediatric ENT, audiology and phoniatrics, and public health. Participated in the 3rd Stakeholders Consultation meeting during which the World Hearing Forum of WHO was announced;
- Member of the Roster of Experts on Digital Health of WHO, Vice-President and Institutional Representative of ISfTeH;
- President-elect of International Advisory Board of AAOHNS, member of Congress and Meeting Department of EAONO, Regional Representative of Europe of ISA, VicePresident of HearRing Group, Auditor of EFAS, member of the Facial Nerve Stimulation Steering Committee;
- Board Secretary of the Polish Society of Otorhinolaryngologists, Phoniatrists and Audiologists. Member of Hearing Committee (2018–19);
- Goodwill Ambassador representing Poland at the AAOHNSF 2021 Annual Meeting & OTO Experience, and since 2021 a member of Implantable Hearing Devices Committee and Otology & Neurotology Education Committee of AAOHNS;
- Consultant Committee of International Experts of CPAM-VBMS (by special invitation), honorary member of ORL Danube Society, and honorary member of Société Française d'Oto-Rhino-Laryngologie;
- Member of the Council of National Science Center;
- Expert and member of numerous national organizations.

**PROF. DR. ADRIANA NEVES DE ANDRADE**

- Graduated in Speech Therapy from the Federal University of São Paulo (2005);
- Specialization in Clinical Audiology from the University of São Paulo (2006) Master's (2009) and Doctorate (2014) in Sciences from the Human Communication Disorders program of the Department of Speech-Language Pathology at the Federal University of São Paulo;
- Assistant Professor of Audiology at the Department of Speech-Language Pathology at the Federal University of São Paulo;
- Board Member of the Brazilian Academy of Audiology- ABA (2023-2025);
- Reviewer of scientific articles in the field of Audiology and Neuroaudiology;
- Teaches classes and gives lectures on the topics of expertise, in addition to supervision and mentoring.