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STRUCTURES INVOLVED IN THE TRAJECTORY OF THE AUDITORY SYSTEM (PART III): CORPUS CALLOSUM

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STRUCTURES INVOLVED IN THE TRAJECTORY OF THE AUDITORY SYSTEM (PART III): CORPUS CALLOSUM

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This text discusses auditory structures that are key to the central processing of auditory information. Knowledge of the neuroanatomy and neurophysiology of the central auditory nervous system (CANS) is important for health professionals and allows them to provide better guidance in patient interventions. Here we focus on one essential structure within the auditory system, the corpus callosum (CC). We recommend that the reader refer back to previous bulletins with information about other structures in the auditory system, which will allow a greater understanding of the functioning of the system as a whole.

The CC is a brain structure that provides integration between the right and left cerebral hemispheres. It is considered the largest of the cerebral commissures and is made up of white matter, i.e. myelinated axons (approximately 200 million), which connect and transmit neuronal information in the cortex.

The shape of this structure resembles an inverted letter 'C' (Figure 1) in sagittal section. The anterior part is made up of the knee and rostrum, the medial part is the trunk, and the posterior part is the splenium. Development takes place in an anterior–posterior direction, so the posterior portions are susceptible to damage between the 3rd trimester and birth.

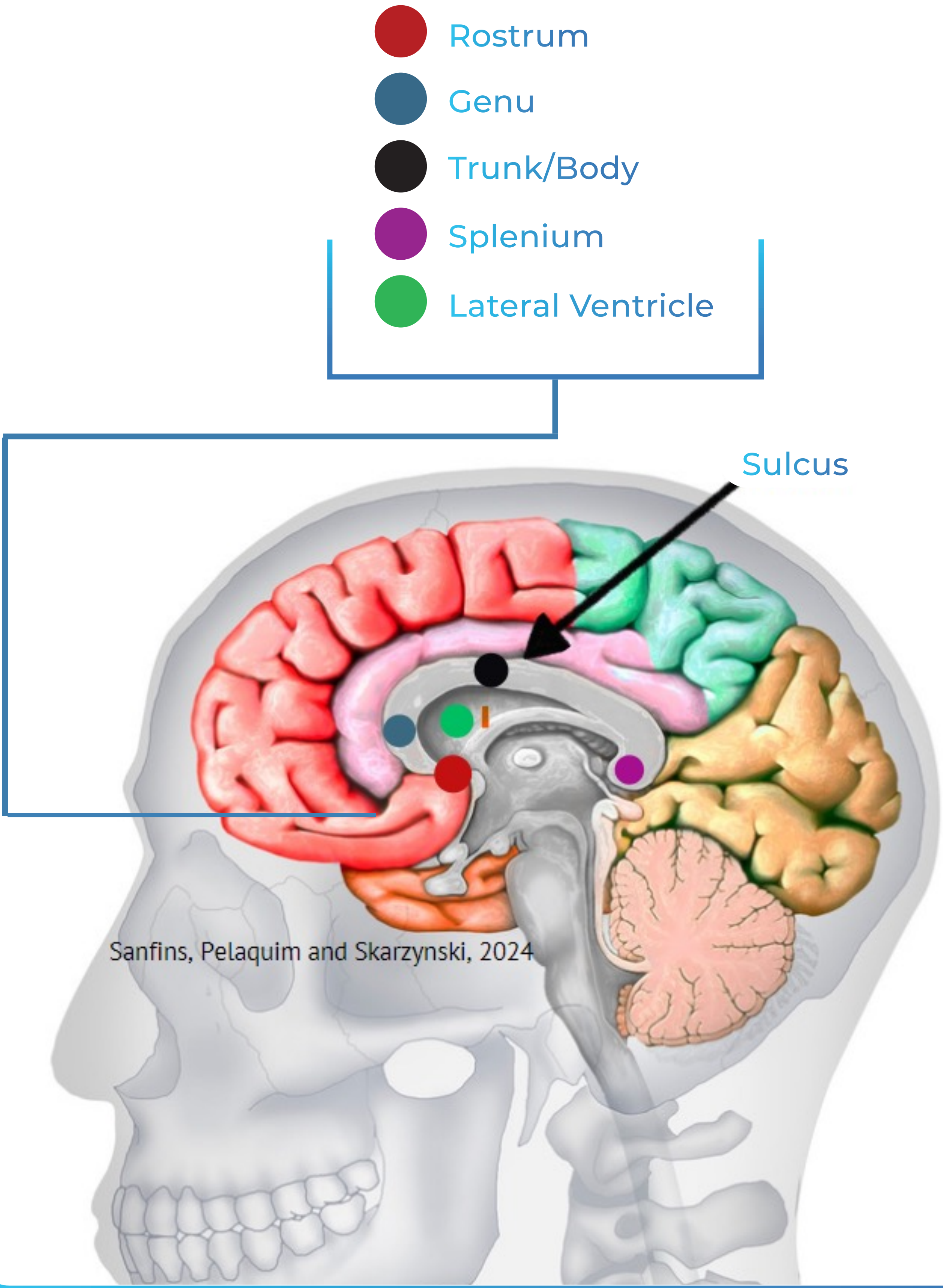
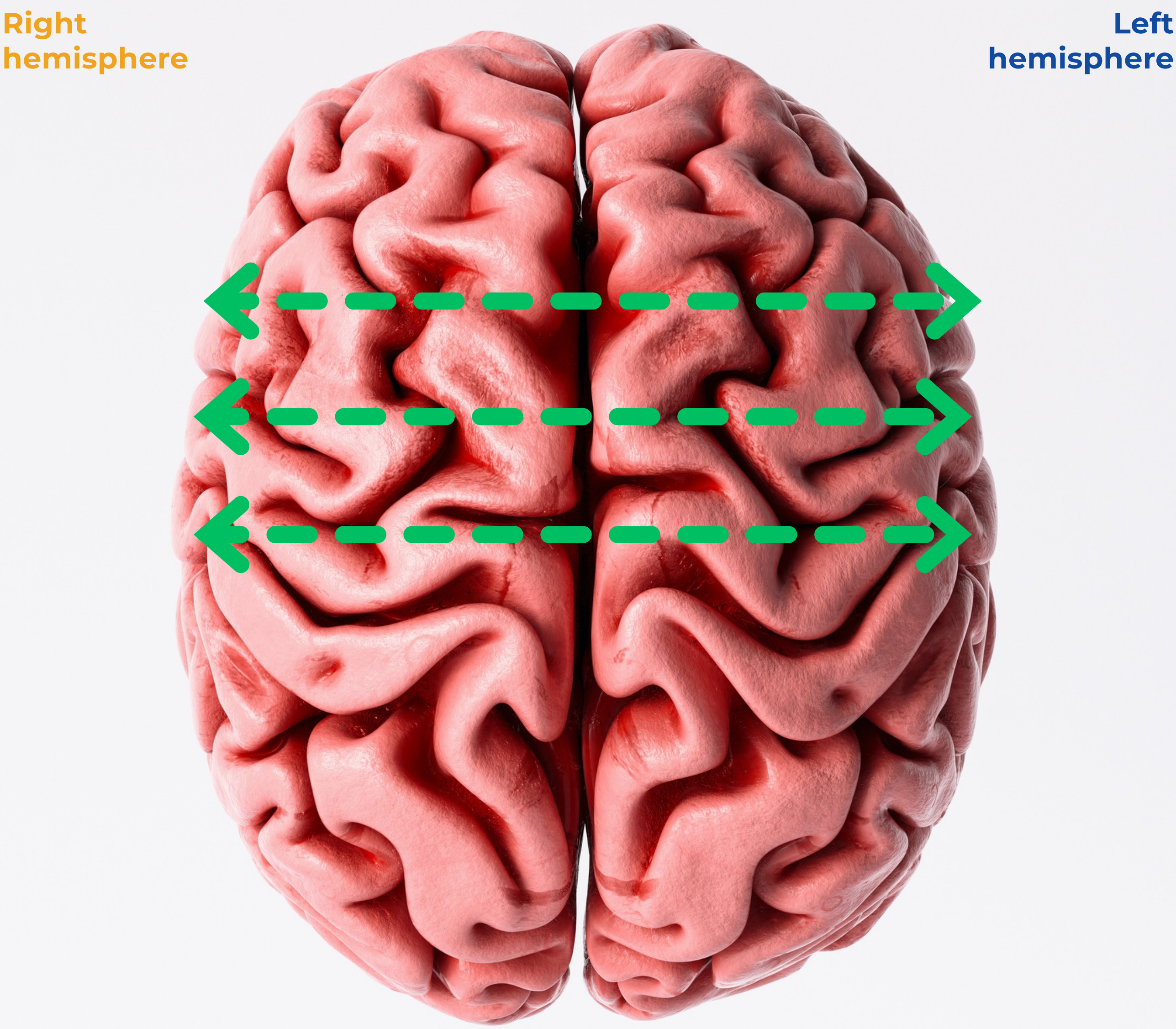


Figure 1: Diagram of the corpus callosum and its components (sagittal section). Image developed by the authors.

In an adult, the CC is about 6.5 cm long and varies in width from 0.5 to 1.0 cm.

The fibers of the CC take two main forms (Figure 2):



HOMOLATERAL

(which connect the same site in opposite hemispheres)

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(01) Homolateral fibers, which connect the same site in opposite hemispheres.
(02) Heterolateral fibers, which connect different sites in opposite hemispheres.

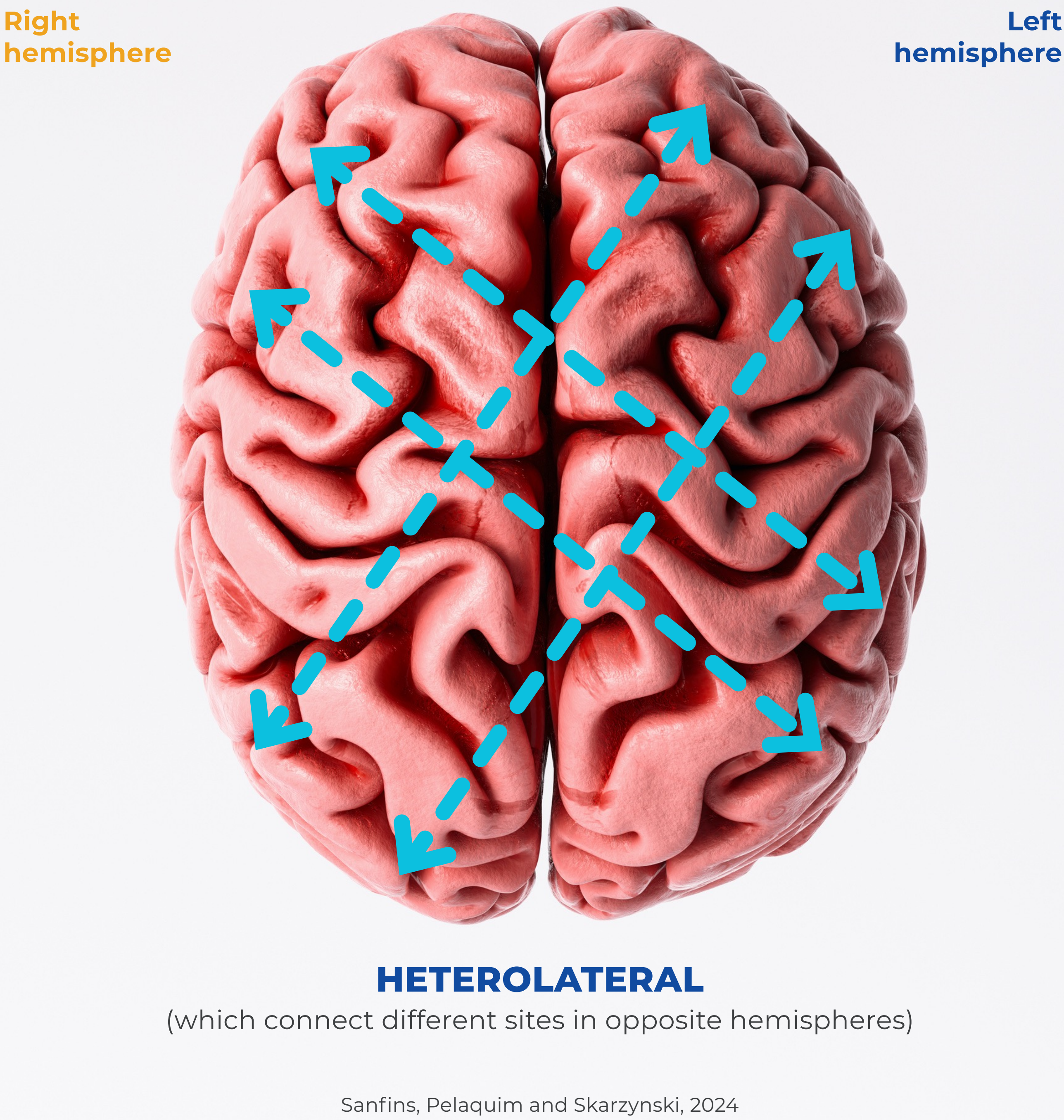

Figure 2: Representative image of the projection of the fibers of the corpus callosum. Image developed by the authors.

IT SHOULD BE NOTED THAT THE CC IS ABLE TO PERFORM ITS FUNCTIONS FROM BIRTH. FORMATION OF THE CC BEGINS AROUND THE 10TH AND 11TH WEEKS OF GESTATION AND IS FULLY DEVELOPED BETWEEN THE 18TH AND 20TH WEEKS OF INTRAUTERINE LIFE. AROUND THE 16TH WEEK OF GESTATION, THE TYPICAL ADULT SHAPE IS SEEN.

The transmission time of information from one side of the brain to the other is an extremely important role of the CC and, for this reason, it relies on the participation of two types of neural fibers:

1. Excitatory fibers (information transmission time of 3 to 6 milliseconds)
2. Inhibitory fibers (information transmission time over 100 milliseconds).

However, the myelination of neural fibers is a continuous process that is completed during puberty. Consequently, adolescents have the shortest information transmission time, i.e. neural fiber firing is faster due to the high amount of myelin which improves neural conduction speed. However, morphological changes can occur throughout life. Aging can also influence the functioning of the CC, which can lead to impaired information processing as a result of low myelin levels in the neural fibers or as a result of atrophy.

Regarding the relationship between sex and neural maturation of CC, there is still some controversy, but it is believed that females have a later maturation than males, which could be explained by the more pronounced hormonal changes in women.

Much of the knowledge about CC comes from studies on animals or patients with brain damage. Researchers have reported that after sectioning the CC in animals (cats and monkeys) there was an inhibition of transfer of somatosensory information between the cerebral hemispheres. In addition, other researchers have evaluated and compared the responses of animals (monkeys) with and without sectioning of the CC and concluded that even with sectioning there may be no changes in learning ability.

The CC of epileptic patients has been sectioned in order to prevent epileptic activity in one hemisphere, and through these studies it has been possible to observe that each hemisphere can function independently. Clearly, there are abilities that only one hemisphere can exercise; however, some types of processes can be carried out by either hemisphere, such as sensory analysis, memory, learning, and calculation. The right hemisphere has a limited capacity when it involves analytical tasks or complex reasoning. Despite this, the right hemisphere can be considered superior to the left when spatial–perceptual problems are involved.

But is there any relationship between functioning of the CC and the auditory system? Before discussing this aspect, it is important to understand that the auditory system contains structures and nerve fibers along its path which have synapses responsible for detection, discrimination, recognition, and understanding of sound stimuli. However, the processing of auditory information can only be complete with the effective functioning and integrity of the CC.

Each part of the CC is responsible for specific functions. In terms of hearing, the anterior portion of the splenium, a thin portion of the CC called the sulcus, is involved. The sulcus has fibers from the superior temporal gyrus and the posterior insula. The anterior commissure also has fibers responsible for auditory processing. Alterations in the integrity of the CC can result in significant impairments in the development of auditory skills and, consequently, in speech, oral language, written language, and learning skills.

Hearing skills that require the interaction of both hemispheres – such as dichotic listening – depend on the integrity of the CC. In dichotic listening, verbal sounds presented in the right ear are sent directly for processing in the left hemisphere (dominant for language), whereas a verbal message presented to the left ear is initially processed in the right hemisphere (non-dominant for language) and then sent to the left hemisphere via the CC so that it can be effectively decoded.

Recently, there has been discussion about the differences in the morphologies of the CC. It is believed that the size of the CC is related to the number of fibers that carry information between the two hemispheres. In this way, individuals with a more robust CC are able to process auditory information faster and more accurately.

On the other hand, when the CC has some kind of problem, such as agenesis, there are signs of language disorders and autism spectrum. Agenesis of the CC can be total (absence of all parts) or partial (absence of one or more parts). In children with developmental disorders, it is estimated that between 2% and 3% have alterations in the CC. This condition can arise from somatic and genetic diseases, such as malformation, attention deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD), sensorineural hearing impairment, and syndromes associated with CC agenesis (Donnai-Barrow Syndrome, Chudley-McCullough Syndrome, and Aicardi and Kabuki Syndrome).

In addition to agenesis, a larger anterior CC is associated with reduced right-ear performance in right-handed individuals, which can lead to greater recruitment of the left ear or even inhibition of the right hemisphere. In these cases, there is a delay in language development, as well as significant impairments in speech production and comprehension.

At the same time, there are studies that relate the CC to the role of modulating attentional processes, ensuring a role in dichotic listening, and modulating the function of each hemisphere. If we were to characterize in one word the function of the CC within the central nervous system, it could be considered the «conductor» of a large orchestra, someone who organizes a large number of «neuronal cells» to transmit sensory information in an orderly, organized, and precise way.

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