Primate astrocyte

Primate Astrocytes: Unique Features and Roles in Brain Function

Astrocytes are a type of glial cell in the central nervous system (CNS) that play crucial roles in maintaining brain homeostasis, synaptic function, and neuroprotection. Primate astrocytes, including those in humans, exhibit unique structural and functional characteristics that distinguish them from those found in rodents and other non-primate species.

Key Characteristics of Primate Astrocytes 1. **Larger Size and Complexity**

1. Primate astrocytes, especially human astrocytes, are significantly larger than those in rodents.
2. They exhibit a more complex morphology with extensive branching and a greater number of processes that interact with neurons and blood vessels.
3. Their spatial domains are larger, meaning that a single primate astrocyte can interact with thousands of synapses, whereas rodent astrocytes influence fewer connections.

2. **Increased Functional Diversity**

1. Primate astrocytes show enhanced calcium signaling, which is critical for regulating synaptic activity and neurotransmitter release.
2. They have a greater ability to modulate neuronal excitability and participate in higher-order brain functions, such as cognition and memory.
3. Human astrocytes support faster synaptic transmission compared to their rodent counterparts.

3. **Enhanced Neuroprotective Properties**

1. Human and non-human primate astrocytes produce higher levels of antioxidant molecules, such as glutathione, which protect neurons from oxidative stress.
2. They contribute more effectively to the blood-brain barrier (BBB) and regulate cerebral blood flow with greater precision.

4. **Species-Specific Gene Expression**

1. Transcriptomic studies have identified genes that are uniquely expressed in primate astrocytes and absent in rodents.
2. These genes contribute to the enhanced synaptic regulation, metabolism, and neuroinflammatory responses observed in primates.

5. **Differences in Reactive Astrocytosis**

1. In response to brain injury or neurodegenerative diseases, primate astrocytes exhibit a distinct pattern of reactive changes.
2. They tend to form a more complex glial scar, which may have implications for conditions like stroke, Alzheimer's disease, and traumatic brain injury.

Implications for Neuroscience and Medicine - **Neurodegenerative Diseases**: Understanding the unique properties of primate astrocytes is critical for developing treatments for diseases such as Alzheimer's, Parkinson's, and Huntington's, where glial dysfunction plays a key role. - **Brain Evolution**: The structural and functional complexity of primate astrocytes suggests they have contributed significantly to the evolution of advanced cognitive functions in humans. - **Regenerative**

Medicine: Insights into primate astrocyte function may aid in designing astrocyte-based therapies for brain repair following injury or disease.

Conclusion Primate astrocytes differ significantly from those in rodents, with larger size, increased synaptic regulation, and enhanced neuroprotective abilities. These differences likely play a role in the advanced cognitive capacities of primates, making them a crucial focus of neuroscience research.

How astrocytes evolve in primates is unsettled. Ciuba et al. obtained human, chimpanzee, and macaque induced pluripotent stem cell-derived astrocytes (iAstrocytes). Human iAstrocytes are bigger and more complex than the non-human primate iAstrocytes. They identified new loci contributing to the increased human astrocyte. They showed that genes and pathways implicated in long-range intercellular signalling are activated in the human iAstrocytes and partake in controlling iAstrocyte complexity. Genes downregulated in human iAstrocytes frequently relate to neurological disorders and were decreased in adult brain samples. Through regulome analysis and machine learning, they uncover that functional activation of enhancers coincides with a previously unappreciated, pervasive gain of “stripe” transcription factor binding sites. Altogether, they revealed the transcriptomic signature of primate astrocyte evolution and a mechanism driving the acquisition of the regulatory potential of enhancers [1)]

1)

Ciuba K, Piotrowska A, Chaudhury D, Dehingia B, Duński E, Behr R, Soroczyńska K, Czystowska-Kuźmicz M, Abbas M, Bulanda E, Gawlik-Zawiślak S, Pietrzak S, Figiel I, Włodarczyk J, Verkhratsky A, Niedbała M, Kaspera W, Wypych T, Wilczyński B, Pękowska A. Molecular signature of primate astrocytes reveals pathways and regulatory changes contributing to human brain evolution. Cell Stem Cell. 2025 Jan 29:S1934-5909(24)00458-2. doi: 10.1016/j.stem.2024.12.011. Epub ahead of print. PMID: 39909043.

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