Chapter 2
Astrocytes and the Developing Brain

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ABSTRACT

Astrocytes are the most proliferate glial cells in the central nervous system (CNS); they are considered as the supporting cells in the CNS, and play a big role in behavioral, circuit, and synaptic functions. Astrocytes are also important for neuronal repair, neurogenesis, and survival. Astrocytes play a main role in brain protection, by maintaining a regulated ion balance and blood flow, and preserving an antioxidant functions in brain. In this chapter, the authors elaborated an overview of the role of astrocytes on the developing brain.

INTRODUCTION

The nervous system is made up of two main cell types, neurons and glial cells. Glial cells are more numerous than neurons; representing 90% of the human brain (He and Sun, 2007), and the two types of cell cover a similar proportion of the area within the nervous tissue. The principal types of glial cells found in the central nervous system include astrocytes and oligodendrocytes, while in the peripheral nervous system they include Schwann cells, enteric glial cells and satellite cells (Jessen, 2004). In this chapter, we concentrate on the astrocyte, which has numerous clearly defined functions; astrocytes regulate ion

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homeostasis, absorb glutamate at synapses and give metabolic support to nearby neurons (Ullian et al., 2004; He and Sun, 2007), and most importantly synapse formation. Protoplasmic astrocytes in grey matter develop widely branched stalks that terminate in delicately ramified leaf-like formations called perisynaptic astrocytic processes (PAPs), enabling single astrocytes to establish connections with hundreds or even millions of synapses, according to the species (Zhou et al., 2019; Torres-Ceja and Olsen, 2022). The development of astrocyte morphological complexity in the mouse cortex is timed to coincide precisely with a phase of explosive synaptogenesis, indicating that the two processes are linked (Stogsdill et al., 2017). Astrocytes have a key role in the development of synapses via the production of synaptogenic factors. This chapter will focus on some of these factors and how they mediate synapse formation during brain development, after highlighting the role of astrocytes in the adult brain.

Astrocytes Functions in The Brain

Astrocytes are the most proliferate cells in the Central Nervous System (CNS) (Markiewicz and Lukomska, 2006), in mammalian brains, astrocytes account for around 20-40% of the overall number of neuronal cells (Herculano-Houzel, 2014).Following the initial finding that astroglial functions go way deeper than passive structural support, they have established their position as critical contributors to neuronal functioning. Also they are the key for neural repair and neurogenesis. By now, astrocytes exhibit a wide range of cellular-level functions, like synapse maturation, formation and elimination, neurotransmitter clearance, ion homeostasis, extracellular space volume regulation and modulation of both synaptic plasticity and activity (Araque et al., 2014; Dallérac and Rouach, 2016). Furthermore, they have been shown to be implicated in rhythm production as well as neural networks (Fellin, 2009; Lee et al., 2014; Poskanzer and Yuste, 2016).

By studying post-mortem human tissues, Oberheim and colleagues subsequently presented a more detailed study of human astrocyte categories. Four types of astrocytes, characterised by a high expression of the glial fibrillary acidic protein (GFAP), that rises with aging (Nichols et al., 1993); have been found in the human brain: interlaminar, located in layers I and II of the cortex; protoplasmic in layers III and IV of the cortex; varicose projections in layers V and VI of the cortex; and fibrous astroglia in the white matter (Figure 1).

Interlaminar Astroglia

Typical interlaminar astrocytes in human cortex are resident in layer I and extend in long threads through several laminae, ending in layer III/IV (Colombo and Reisin, 2004; Falcone et al., 2019).Interlaminar astrocytes in human brains are different to those in primate. In contrast to the oblong somata found in primates, interlaminar astrocytes in humans are more abundant and display smaller, rounder cell bodies. Yet a further noticeable distinction is the presence, in humans, of shorter processes that spread out in all directions and contribute to the boundaries of the pial glia via a network of GFAP fibers. While the functional importance of interlaminarastroglia remains to be defined, it has been suggested by Oberheim and associates that its properties point to a potential role in long-distance intra-cortical coordination and communication (Vasile et al., 2017).

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