Medical Neuroscience | Tutorial Notes

Non-Neuronal Cells of the CNS

MAP TO NEUROSCIENCE CORE CONCEPTS[1]

NCC2. The brain is the body's most complex organ.

LEARNING OBJECTIVES

After study of the assigned learning materials, the student will:

1. Describe the basic classes of cells found in the central nervous system (CNS).
2. Describe the basic functions of the three types of glial cells found in the CNS.
3. Characterize the blood-brain barrier.

TUTORIAL OUTLINE

I. Neuroglia (or just "Glia" for short)
   - A. general functions of neuroglia in the CNS
     1. support the metabolic and signaling functions of neurons
     2. participates in neuron circuit formation and synaptic plasticity
     3. make myelin (axonal insulation)
     4. contribute to formation of blood-brain barrier
     5. participate in inflammatory response in injured neural tissue, including phagocytosis of cellular debris
     6. contribute to the formation of scar tissue in damaged neural tissue
   - B. major types of neuroglia (see **Figure 1.5**[2])
     1. **astrocytes**
        - a. found primarily in gray matter, because they are closely associated with neuronal cell bodies, dendrites and synapses
        - b. help maintain ionic balance of extracellular fluids
        - c. remove and process neurotransmitters from synaptic clefts
        - d. assist in the formation of new synapses ("synaptogenesis")

[1] Visit **BrainFacts.org** for *Neuroscience Core Concepts* (©2012 Society for Neuroscience) that offer fundamental principles about the brain and nervous system, the most complex living structure known in the universe.
[2] Figure references to Purves et al., *Neuroscience, 5th Ed.*, Sinauer Assoc., Inc., 2012. [click here]

e. contribute to formation of blood-brain barrier and brain-ependymal (ventricular) barrier (see below)

f. contribute to the formation of scars that fill-in small spaces that have been cleared of necrotic neural tissue following injury

2. **oligodendrocytes**

a. form myelin in the CNS and are found, therefore, primarily in white matter (a different cell type, the Schwann cell, makes myelin in peripheral nerves)

b. myelin aids in the propagation of neural signals along myelinated axons (see **Figure 3.11**)

i. insulate by generating layers of membrane that wrap around a segment of an axon; this decreases the ionic (electrical) "leakiness" of the axonal membrane

ii. gaps between myelin segments, called "nodes of Ranvier", allow for the economical concentration of ion channels and ion pumps that are necessary for electrical signaling in axons (fewer channels are needed to propagate electrical signals than would be needed without myelin)

c. oligodendrocytes present antigens that influence the outgrowth of axons in developing and recovering brain

d. unfortunately, subject to immunological attack in certain diseases of the CNS (e.g., multiple sclerosis)

3. **microglia**

a. special type of mononuclear phagocyte that resides in the CNS

b. derived primarily from hematopoietic precursor cells that migrate into the brain during development

c. exists in one of two forms: amoeboid and ramified

i. the ramified form is the dormant state

ii. the amoeboid form is the activated, mobile state when microglia cells are engaged in phagocytic activity

iii. activated microglia secrete signaling molecules (cytokines) that modulate local inflammatory responses in injured tissue

4. **glial stem cells**

a. subset of astrocytes located near the ventricles, often adjacent to blood vessels

i. may give rise to more stem cells, mature astrocytes or oligodendrocytes, or mature neurons

ii. exhibit key properties of somatic stem cells: proliferation, self-renewal, and the potency to make all the cells of a given tissue (CNS, in this case)

b. oligodendroglial precursors scattered throughout the white matter

i. mainly give rise to mature olgiodendrocytes, but may also generate astrocytes and neurons under certain conditions

c. although the discovery of these intrinsic stem cells in the CNS has garnered an intense amount of current research activity, the functional and clinical significance of these populations of stem cells remains unclear

C. more on the blood-brain barrier (see **Figure A20**)

1. specialized permeability barrier between the capillary endothelium and the extracellular space in neural tissue

a. formed by tight junctions between capillary endothelial cells, which are surrounded by "end-feet" processes of astrocytes (forming a "glia limitans", or limiting glial border)

b. exclude large, water soluble molecules from freely diffusing into CNS, as well as pathogenic microbes and certain toxins

c. some molecules, such as glucose and certain amino acids, are transported passive or actively across the capillary endothelium

d unfortunately, this barrier also prevents the administration of many potentially useful pharmaceutical agents (e.g., dopamine)

e. across the lifespan, the blood-brain barrier remains porous in certain regions of the CNS that are involved in hormone secretion (e.g., median eminence of the hypothalamus; pineal gland)

STUDY QUESTION

Consider a patient with a stroke that caused a small region of brain damage. Which happened first?

A. Microglia were stimulated to convert from ramified to amoeboid states.
B. Astrocytes formed scar tissue to fill-in space vacated by damaged tissue.
C. Microglia phagocytosed cellular debris.
D. Glial stem cells repopulated region of damage neural tissue.