Introduction to Neuroglia: Definition, Classification, Evolution

1

Definition of neuroglia

There is no clear definition for neuroglia: most of the existing ones depict neuroglia as a supportive element of the nervous system. For example:

“The supportive tissue of the nervous system”
http://www.thefreedictionary.com/

“sustentacular tissue that surrounds and supports neurons in the central nervous system”
Web definitions from google.com

“supporting structure of nervous tissue”
www.aimsusa.org/UsefulDefinitions.htm

Neuroglia (always plural) represent all cells in the brain which are not neurones and which are electrically non-excitable.

We may define neuroglia as a heterogeneous population of cells of neural and non-neural origin responsible for brain homeostasis (all neuroglia), myelination (oligodendrocytes) and defence (astrocytes and microglia).

2

Diversity of Neuroglia


3

Neuronal-glial network

Glia to neurone ratio

Neurones/Non-neuronal cell numbers were determined by isotopic fractionation, which calculates total number of nuclei and total number of NeuN-positive cells that are considered to be neurones.


Evolution of neuroglia

Evolution of glia

Glia-neuronal ratio in various structures of the human brain:

- Cortical grey matter 1.65 : 1
- White matter: ~ infinity: 0
- Thalamus 17 : 1
- Brainstem ~ 10 : 1
- Cerebellum 0.1 – 0.25 : 1

Verkhratsky & Butt (2013): *Physiology and Pathophysiology of Neuroglia*, Wiley
Evolution of glial function

Functions of invertebrate glia: Ancestral astrocytes

- Metabolic support of neurones (*Nematodes*)
- Regulation of development (*Nematodes*)
- Control of extracellular ion homeostasis (*Nematodes*)
- Isolation/separation of nervous circuits
- Compartmentalisation of the nervous system (*Annelida*)
- Increase of axonal conduction velocity through formation of multilayered glial sheath around axons (*Annelida* and some *Arthropoda* – prawns)
- Formation of blood-brain barrier (*Arthropoda*)
Neuroglia in *Caenorhabditis elegans*

C. elegans has 302 neurons and 56 glial cells.

**Glial cell types:**
- 50 cells cover dendrites of sensory neurons; 4 of these 50 (CEP sheath glia) envelop the nerve ring and send processes to some synaptic sites in the brain.
- 6 cells (GLR glia) form gap junctions to both muscle cells and motor neurons.

**Artificial ablation of glia in C. elegans does not kill neurones** but greatly affects their development (neuronal assembly and neurite morphogenesis) and function.


C. elegans glia may also have sensory functions (from Shai Shaham laboratory webpage http://shahamlab.rockefeller.edu/research.php)

Calcium signalling in *C.elegans* glia is controlled mainly by voltage-gated Ca channels (Vlad Parpura, personal communication).

The ancestral glia retains some neuronal features


**Neuroglia in leech** (*Annelida*)

**Glial cell types:**
- Packet glial cells (ensheath neuronal somatas)
- Connective glial cells (ensheath axons)
- Giant glial cells (form neuropil and provide for ion and neurotransmitter homeostasis)

All glial cells are coupled through gap junctions and form a panglial syncytium

**Functions:**

Metabolic support
Control over ion and neurotransmitter homeostasis


**Neuroglia in insects** (*Arthropoda*)

**Glial cell types:**
- Surface glia
- Cortex glia
- Neuropile glia
- Tract glia

Further diversity:
- Optic lobe glia
- Fenestrated glia
- Pseudocartridge glia
- Satellite glia
- Epithelial glia
- Marginal glia
- Glia of the deeper optic lobe regions
- Glia of the olfactory system
- Glia of the antenna
- Mushroom body glia

**Main functions:**

Formation of blood-brain barrier
Transport of substances from haemolymph to neurones
Compartmentalisation of the nervous system
Neurotransmitter homeostasis (histamine and glutamate)
Ion homeostasis
Trophic support
Neuroprotection (especially of dopaminergic neurones)
Circadian rhythms
Development of the CNS
Reactive gliosis
Phagocytosis

**Evolutionary advances:**

1) Great increase in morphological/functional diversity
2) New function (BBB; compartmentalisation)
3) Removal of glia kills neurones
Neuroglia in vertebrates

**Main Glial cell types:**
- Astrocytes
- Oligodendrocytes
- Radial glia
- NG2 cells
- Microlgia
- Peripheral glia (Schwann cells)

**Great morphological and functional diversity**
Profound morpho-functional heterogeneity of neuroglia between various brain regions and within regions

**Main functions:**
- Development of CNS/PNS
- Control over blood-brain barrier
- Main homeostatic elements of the brain (metabolic, transport, control over ions and neurotransmitters etc.)
- Myelination
- Brain defence
- Higher brain functions

**Evolutionary advances:**
Neuroglia becomes main homeostatic/defensive system of the brain

**Evolution of myelination**

Early evolutionary roots of myelination and fast action potential propagation

- The giant prawns, the *Anomalocaris*, where the largest and the most ferocious predators of the Cambrian period (500 - 540 millions years ago) oceans; they were > 1 meter long and had exceedingly complex composite external eyes with composed from tens of thousands of hexagonal ommatidial lenses.


Myelin sheath increases the speed of action potential propagation.

Oligodendroglia – myelinating cells of the CNS

Without myelination each human optic nerve would have a diameter of 0.75 m.

The NG2 Glia – the cells of oligodendroglial lineage with an unknown function.
NG2 glia – enigmatic “fifth” glial element

NG2 glia are present throughout the brain

NG2 glial cells receive proper glutamatergic synapses

Peripheral glia
Types of Schwann cells

Satellite glia: homeostatic cells of sensory and sympathetic ganglia

Morphology of Schwann cell

Enteric nervous system
Enteric glia integrates cellular elements of the gut

Olfactory system

Olfactory encheathing glial cells