

Nerve tissue

Development and
function of the
nervous system

Neuron

Membrane potentials

Synaptic
communication

Development

- neuroectoderm
 - neural plate → neural tube:
 - brain vesicles
 - spinal cord
 - neural crest
 - sensory ganglia
 - ganglia of cranial nerves, spinal ganglia
 - adrenal medulla
 - melanocytes
 - meningeal layers

Function

- highly specialized
- processing and transmission of cellular signals
- excitable and irritable: propagation of the action potential
- divisions
 - sensory
 - somatic sensory: skin, skeletal muscles, joints
 - visceral sensory: intestines and other visceral organs
 - motor
 - somatic: voluntary control of skeletal muscles
 - visceral motor: involuntary smooth muscle, cardiac muscle, glands
 - memory
 - cognitive
 - homeostasis and neuroendocrine function
 - ...

Nerve tissue

- cells

- neurons = nerve cells
 - cell body (soma) = perikaryon
 - neurite = axon
 - dendrites
- glia cells (neuroglia)
 - oligodendrocyte
 - astrocyte
 - ependyma
 - Schwann cell = neurolemmocyte
 - microglia

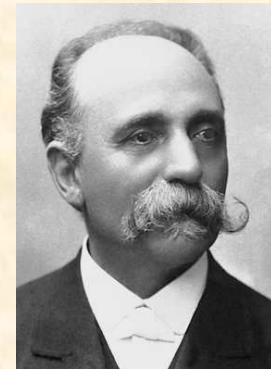
***neuropil** = dense network of processes of neurons and glia*

- matter

- grey matter: accumulated neuronal cell bodies, glia, capillaries
- white matter: mainly processes and glia cells

Neurons

- classified according to the processes
 - apolar: embryonic neuroblasts
 - unipolar: retinal amacrine and horizontal cells
 - pseudounipolar: sensory neurons of the spinal ganglia
 - bipolar: retinal bipolar neurons
 - multipolar: single axon, more dendrites cells
 - Golgi I: long-projecting axonal processes
 - pyramidal cells
 - Purkinje cells
 - anterior horn motor neurons
 - Golgi II: axonal process projects locally
 - granular cells of the cerebellum



Camillo Golgi
1906 Nobel Laureate

Purkinje cells

- large inhibitory projection neurons of the cerebellar cortex
- up to 120 x 60 x 30 μm
- up to 150-200 000 dendritic spines with synapses
- Czech anatomist Jan Evangelista Purkyně

- 1837 Purkinje cells
- 1839 Purkinje fibres
- Purkinje images
- Purkinje color shift
- cell theory + M. Schleiden, T. Schwann

Neurons

- classified according to their function
 - **sensory = afferent neurons** - convey information from tissues and organs into the CNS
 - **motor = efferent neurons** - transmit signals from the CNS to the effector cells
 - muscle
 - glands
 - **interneurons** - connect neurons with other neurons

Morphology of neuron

- **cell body** = perikaryon
 - 4-100 μm
 - trophic center of the cell
 - nucleus with euchromatin
 - prominent nucleolus
 - GER = Nissl bodies
 - neurofilaments (intermediate f.) and microtubules
 - pigments
 - neuromelanin: related to catecholamines
 - lipofuscin: residual from lysosomal digestion
- **dendrites**
 - tree-like branching = arborization
 - receive synapses on dendritic spines
- **axon** = neurite
 - perikaryon \rightarrow axon hillock \rightarrow the initial segment \rightarrow axon
 - axolemma
 - axoplasm: no GER
 - collateral branches
 - transport
 - anterograde: cell body \rightarrow synaptic terminals; kinesin (ATP-ase)
 - retrograde: towards the perikaryon: dynein (ATP-ase)
 - fast: 50-400 mm/day
 - slow: 0.3-3 mm/day

Axon

- carries the membrane potentials from the soma to the periphery
- axonal transport
- length up to 100 cm
- single axons, but branched → a number of target cells
- axon hillock = arising from the perikaryon
 - followed by the initial segment
 - the greatest density of voltage-dependent Na⁺ channels
 - the most easily-excited part of the neuron
 - receives inputs from other neurons
- the axon terminal
 - contains synapses
 - neurotransmitters are released in order to communicate with target neurons
 - the membrane of the vesicle fuses with the presynaptic membrane at the synapse
 - the vesicle membrane is recycled

Membrane potentials

- Na^+/K^+ ATP-ase
 - $\rightarrow 3\text{Na}^+$ out of the cytoplasm/ 2K^+ into the cell
 - \rightarrow potential difference (voltage) across the axolemma
 - approx. -70 mV = **resting membrane potential**
 - inside negative
 - outside positive
- stimulus \rightarrow opening ion channels $\rightarrow \text{Na}^+$ influx $\rightarrow +30\text{mV}$ depolarization = **action potential**
 - approx. 5 ms
 - recovery

Synaptic communication

- transmission of nerve impulses
 - between neurons
 - between neurons and other cells (muscle, glands)
- presynaptic cell membrane → synaptic cleft → postsynaptic cell membrane
- **chemical synapse**
 - converting electrical signal into a chemical signal
 - using neurotransmitters and cell adhesion proteins
 - synaptic cleft 20-30 nm
 - approx. 10^{14} within the brain
- electrical synapse
 - transmit ionic signals through gap junctions
 - direct electrical coupling, 3-4 nm
 - neurons, cardiac and smooth muscle

Types of synapses

- according to morphology
 - axo-dendritic
 - axo-somatic
 - axo-axonic
- neuromuscular and neuro-glandular junctions act as chemical synapses
 - motor end plate
 - varicosities of autonomic nerve system
- the effect of the neurotransmitters on the postsynaptic membrane
 - excitatory → depolarization; e.g., glutamate
 - inhibitory → hyperpolarization; e.g., GABA
 - neuromodulation = modulating sensitivity

Synapses and drugs

- organophosphates (insecticides, nerve agents/weapons) – inactivate acetylcholinesterase
- succinylcholine – inhibits the action of acetylcholine, myorelaxation in anaesthesia
- botulinum toxin – blocking the release of acetylcholine – muscle paralysis
- nicotine – stimulates nicotinic acetylcholine receptors (autonomic ganglia and CNS)
- SSRI – selective serotonin re-uptake inhibitors – antidepressants
- etc.