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

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

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
      - granullar 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 Pukrinje 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 → axon hillock → the initial segment → axon
  - axolemma
  - axoplasm: no GER
  - collateral branches
  - transport
    - anterograde: cell body → 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
  - → 3Na+ out of the cytoplasm/2K+ into the cell
  - → potential difference (voltage) across the axolemma
  - approx. -70 mV = **resting membrane potential**
    - inside negative
    - outside positive
- stimulus → opening ion channels → Na+ influx → +30mV 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 or 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.