Brain and behavior
Environment of the neuron
Synapse

Study materials

- Purves Dale. **Neuroscience**. 6th ed., Oxford University Press, 2018, ISBN10 1605353809
- Purves Dale. **Principles of cognitive neuroscience**. 2nd ed. Sunderland, Mass.: Sinauer Associates, 2013. xxii, 601. ISBN 9780878935734.

- Brain and behavior.
- Hematoencephalic barrier - function. Cerebrospinal fluid - function. Circumventricular organs and their functional effects.
- Neuron – morphology, functional components.
- Glial cells in nervous system and their function.
- Synapses – description and function, mechanism of synaptic transmission.
- Neurotransmitters (excitatory, inhibitory, modulatory) and their receptors.

Homeostasis

- is the process of ensuring that bodily variables stay within a preferred range
- systems: endocrine, **nervous,** immune

Homeostasis – nervous system

- brain is „smart“ – when possible **anticipate** challenges to homeostasis
  → all anticipatory homeostatic adjustments require intact forebrain

Homeostasis – nervous system

- unexpected challenges to homeostasis → are met by largely unconscious reflexes mediated by the spinal cord and/or brainstem

Homeostasis – nervous system

- unconscious – e.g. peristalsis ....

- voluntary – e.g. stable core body temperature

Homeostasis – nervous system

- functions based on interactions with external environment require **behavioral component** and are results of neuronal processing

Behavior

- from simple to complex requires contribution of three main components:

sensory, executive, motivational

Goal directed behavior

- energetic balance
- volume and osmolarity
- temperature
- strengthen health
- reproduction
- defense
- ……

„Function“ is only approximation.

- **Nervous system works as a whole**, no parts of the nervous system operates in isolation.

- A single neural area or pathway may serve integrally in one or a few core functions but also contributes to countless other functions.

→ injury to one region can impact perhaps minutely or perhaps hugely many functions.

Neuron

- approx. 10^{11} of nerve cells (glial cells are 10 times frequent)
- the most consistent neuronal trait is individuality
- neurons differ from one another in location, morphology, connections, physiological characteristics
- cells within localized clusters (nuclei) or layers (laminae) often share many common characteristics

Most neurons share a group of traits:

- four morphological regions – **dendrites, body, axon, synaptic terminals**
- four functional components – **input, integrative, conductive, output**
- communicate with other neurons
- generate regenerative electrical potentials

Neuron – interesting numbers

- an average somatic diameter of 5-25 microns
- axonal diameter varies from 0.5-20 microns
- the longest axons about 1.4 meters

If we represent the soma (25 microns) by a baseball (approx. 12 cm) what proportionally would be the length of the 1 m axon ?

Glial cells

- CNS - oligodendrocytes, astrocytes, microglial cells
- PNS - Schwann cells
- functions: metabolic, immune, homeostatic

Myelin

- insulate axons → rapid conduction of action potentials
- Pathology: the myelin wrapping can loosen, the immune system may attack and break down myelin → **demyelination** – impairment of neuronal communication (multiple sclerosis in CNS, Guillain Barré syndrome – peripheral demyelinating disease)

Internal environment of CNS

- extracellular space represents 15 % of brain volume
  interstitial fluid + extracellular matrix
- ventricles and subarachnoid space:
  cerebrospinal fluid (CSF) – clear and colorless, up to four cells/µl, relatively little amount of proteins
- function: homeostatic, protective, mechanical
- approx. 500 ml/day, 70 % is produced in plexus choriodei
- circulating volume of CSF: 130-150 ml

Brain barriers - notes

- blood-brain and blood-CSF barriers
- barriers keep constant composition of ECF and CSF
- clinical implication: drug penetration – ATB, dopamine x L-Dopa
- diseases can change barriers function
- **circumventricular organs** - are midline brain structures located around the third and fourth ventricles that are characterized by a lack of blood-brain barrier, some of them consists of chemoreceptors to monitor major constituents of body fluids.

  – secretory function: *posterior pituitary* (e.g. vasopressin); *pineal gland* (melatonin)

  – physiology parameters monitoring, e.g.:

  area postrema – chemoreception → vomiting;

  subfornical organ – osmolarity of blood → thirst

Following the nutrients

- The brain (approx. 3 % of body`s mass) requires a steady and considerable supply of oxygen and glucose
- consumption: 25 % of body`s oxygen
- without oxygen: unconsciousness after 10 seconds; irreparable damage after only a few, less than 5 minutes (note: vegetative structures in the brainstem are more resistant to hypoxia)
- arterial blood flow to the brain represents about 15-20 % of cardiac output = cerebral blood flow

Energy sources

- glucose – brain does not need insulin
- under starvation and diabetes also ketone bodies
- newborns also free fatty acids during breastfeeding

Synaptic transmission

- **synapses - communication between neurons and between neurons and target cells**
- chemical x electrical synapses
- **neurotransmitters**

Chemical synapse

presynaptic cell

synaptic cleft: 20-40 nm

postsynaptic cell

- synaptic delay: 1-5 ms
- unidirectional

Synapse

- average neuron forms about 1000 (2000) synaptic connections and receives as many as 10000 connections
- **dendritic spines:** enlarge the surface of dendrites

- termed by Sir Charles Sherrington (1932 – Nobel Prize in Physiology or Medicine)

Chemical transmission

- presynaptic neuron: the synthesis of a transmitter substance, the storage and release of the transmitter
- postsynaptic neuron: transmitter`s interaction with a receptor, removal of the transmitter from the synaptic cleft

Transmitter (neurotransmitter)

- it is synthetized in the neuron, it is present in the presynaptic terminal and released to exert a defined action
- a specific mechanism exists for removing it from its site of action (e.g. diffusion, enzymatic breakdown)

Receptors

- postsynaptic and presynaptic receptors
- ionotropic and metabotropic
- each neurotransmitter: more types of receptors

Ionotropic receptors

– usually fast
– open ion channels
– motor actions and sensory processing

Metabotropic receptors

– slow, seconds - minutes

– modulation of synaptic transmission

– open and close channels

– emotional states, mood, arousal, simple forms of learning and memory

Neurotransmitters

- Neurotransmitters:
  - excitatory - **glutamate**
  - inhibitory - **GABA** in brain, **glycine** in spinal cord

- Neuromodulators
  - serotonin, noradrenalin (norepinephrine), dopamine, acetylcholine, histamine

Peptide neurotransmitters

- brain/gut peptides – e.g. substance P
- opioid peptides – e.g. Leu-enkephalin
- pituitary peptides – e.g. ACTH
- ……