

# Brain and behavior, environment of the neuron

# Homeostasis

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

# Homeostasis – nervous system

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

- energetic balance
- volume and osmolarity
- temperature
- performance
- strengthen health
- reproduction
- defense
- .....

# „Function“ is only approximation.

- Nervous system works as a whole, no parts of the NS 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, conductile, output
- generate regenerative electrical potentials
- communication with another neurons

# 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 (ca. 12 cm) what proportionally would be the length of the 1 m axon ?

# Cell membrane

- fosfolipid doublelayer
- ion channels
- transporters
- receptors
- synaptic membrane proteins

# Glial cells

- CNS - oligodendrocytes, astrocytes, microglial cells
- PNS - Schwann cells
- Critical for development of NS

functions: metabolic, immune, homeostatic

# Myelin

Myelin insulate axons – rapid conduction of AP.

Problems: 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 syndrom – peripheral demyelinating disease)

# Internal environment of CNS

- extracellular space: **interstitial fluid**  
(15 % of brain volume)
- ventricles and subarachnoidal space: **cerebrospinal fluid (CSF)** – clear and colorless, up to 4 cells/ $\mu\text{l}$ , relatively little proteins
  - function: homeostatic, protective, mechanical, (information transfer – neuropeptides ?)
  - 450-550 ml/day (70 % is produced in plexus choriodei)
  - circulating volume: 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, dopamin x L-Dopa
- diseases can change barriers function
- circumventricular organs
  - secretory function
    - posterior pituitary (eg. vazopresin)
    - pineal gland (melatonin)
  - physiology parameters monitoring
    - 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 (does not need insulin)
- under starvation and diabetes also ketone bodies
- new-borns also FFA during breastfeeding

# Synaptic transmission

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

# Synapse

- termed by Sir Charles Sherrington (1932 – Nobel Prize in Physiology or Medicine)
- average neuron forms about 1000 (2000) synaptic connections and receives as many as 10.000 connections
- dendritic spines

# Chemical synapse

- **presynaptic cell**
- **synaptic cleft: 20-40 nm**
- **postsynaptic cell**
  
- synaptic delay: 1-5 ms (can be as short as 0.3 ms)
- unidirectional

# Chemical transmission – 4 steps

- 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

- it is synthesized 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 (eg. diffusion, enzymatic breakdown)

# Receptors

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

# Ionotropic receptors

- nAChR, GABA<sub>A,C</sub>, glycin, 5-HT<sub>3</sub>, glutamate
- usually fast
- open ion channels
- motor actions and sensory processing



# Metabotropic receptors

- slow, seconds - minutes
- open and close channels
- modulation of synaptic transmission
- emotional states, mood, arousal, simple forms of learning and memory

# Neurotransmitters

- Neurotransmitters:
  - excitatory - **glutamate**
  - inhibitory - **GABA** in brain, **glycin** in spinal cord
- Neuromodulatores
  - serotonin, dopamin, noradrenalin, acetylcholin, histamin

# Peptide neurotransmitters

- brain/gut peptides – substance P
- opioide peptides – Leu-enkephalin
- pituitary peptides - ACTH
- hypothalamic releasing hormones - ACR
- other peptides