Goal:

- To understand the gross organization of the brain.
- To understand the basic computational units of the brain.
Spinal cord (Rückenmark)  Gathers info from sensors (e.g., skin, muscles, joints). Distributes motor commands. Processes motor reflexes.

Brain stem (Hirnstamm)  Controls autonomous functions, e.g., digestion, respiration, heart rhythm. Visual and auditory reflexes.

Cerebellum (Kleinhirn)  Fine motor skills, motor learning.

Diencephalon (Zwischenhirn)

  Thalamus  Relay for all sensory input to the cortex

  Hypo-Thalamus  Autonomous and hormonal functions, metabolic functions.

Prosencephalon (Vorderhirn)

  Hippocampus  Memory consolidation

  Amygdala  Emotions

  Cortex (Kortex)  Higher cognitive capabilities
A  Looking at words

B  Listening to words

C  Speaking words

D  Thinking of words
Two Types of Cell Types in the Nervous System

Nerve cells aka neurons

Glial cells

Information processing

supporting cells
Neurons

Dendrites
Cell body
Nucleus
Axon hillock
Axon
Presynaptic cell
Myelin sheath
Synaptic terminals
Signal direction
Synapse
Postsynaptic cell
**Soma (Zellkörper)**  Contains the nucleus; metabolism

**Dendrites (Dentriten)**  Input area of the cell. Gathers signals of *presynaptic* cells.

**Axon**  Output area of the cell. The axon conducts the signals of the cell to the *postsynaptic* cells (length: 0.1mm to 2m; thickness: 0.0002mm to 0.02mm).

**Axonhilloc**  Where the axon meets the soma.

**Synapses (Synapsen)**  Signal transfer from the presynaptic cell to the postsynaptic cell.
**Membrane**  The cell membrane is the border between the inside of the cell (intracellular) and the outside of the cell (extracellular).

**Ions**  Both, the intracellular as well as the extracellular fluid consist of water with dissolved ions (K, Na, Ca, Cl).

**Membrane potential**  Because the concentrations of ions inside the cell are different than the concentrations outside, the cell is electrically charged. The Membrane potential is the potential of the intracellular fluid w.r.t the extracellular fluid. It is usually around -65 mV.
The cell membrane itself is not permeable to ions, however, in the membrane there are

**Ion pumps** which pump ions into and out of the cell, thereby keeping the membrane potential.

**Ion channels**

- They open under certain conditions.
- When open, they let certain ions traverse the membrane.
- Opening of channels therefore leads to local changes in the membrane potential.
Electrical signals which are transmitted via the axons are called *action potentials*.

Action potentials are fast (1ms width) and stereotypical voltage pulses of about 100mV amplitude.

The information content of a spike is not given by its shape but by its occurrence and probably the time of occurrence.

First measurement of an action potential by Hodgkin and Huxley, 1939.
General Function of Nerve Cells

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March 2008
Legenstein Robert
1. Analog signals (voltage changes) are produced at the input region.

2. As those voltages are conducted towards the soma, they are integrated (nonlinearly summed up).

3. It is decided at the Axon hillock whether an action potential is generated.

4. The action potential is conducted to the synaptic terminals via the axon.

5. The synaptic terminals release neurotransmitters.

6. Those neurotransmitters cause a local voltage change in the postsynaptic neuron.
A Simple Neuron Model

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Long-range axonal connections are myelinated for the sake of faster signal propagation. A newer hypothesis is that myelination *controls* signal propagation speed.
Two Types of Neurons

A neuron is either excitatory or inhibitory.

**Excitatory cells**

- They excite their postsynaptic targets (i.e., bring them closer to firing).
- Defined by the neurotransmitter which is used for synaptic transmission: e.g. Glutamate, Ach.
- A potential evoked is called “excitatory postsynaptic potential”, EPSP.

**Inhibitory cells**

- They inhibit their postsynaptic targets (i.e., tend to keep them from firing).
- Defined by the neurotransmitter which is used for synaptic transmission: e.g. GABA (gamma amino butre acid).
- A potential evoked is called “inhibitory postsynaptic potential”, IPSP.
Neurons are strongly interconnected, each receiving input from approx. 10000 other neurons (in cortex). Neuronal connectivity shows highly structured randomness.
In the human brain, there are

- \( \approx 10^{12} \) neurons
- \( \approx 10^{15} \) synapses
- \( \approx 10^5 \) neurons per 1 mm\(^3\)
- \( \approx 10^9 \) synapses pro 1 mm\(^3\)
- \( \approx 4 \) km axons per 1 mm\(^3\)
- \( \approx 500 \) m dendrites per 1 mm\(^3\)
- \( \approx 10^4 \) inputsynapses per neuron (in cortex)
- \( \approx 10^{13} \) glial cells.