1 Biological-neurons

1.1 Neurons

- **Dendrite(s)**: Input(s)
- **Axion**: Output
- **Soma**: Cell body
- **Nucleus**: Cell core

Neurons collect electrical signals to process and transmit to other *neurons*. *Axon* terminals of one connect to *dendrites* of other *neurons*. *Synapses* are structures to connect those electrically/chemically (however no physical connetion is made).

1.2 Synapse

Electrical signal trasnission through Ion-filled Substrate.

- **Pre***synamptic neuron*: Sending Signals from Axiom
- **Post***synamptic neuron*: Receiving Signals at the Dendrite

Voltage changes open Voltage gates from the neural-fluid into the *presynaptic neuron*. This pulls in Ions from the neuralfluid maing *vesicles* release realese *neurotransmitteres* into the *synaptic cleft* to move between the *neurons*. The *postsynaptic neuron* receives these trasmitteres into receivers and converts the chemical information to an electrical signal.

1.3 Signals

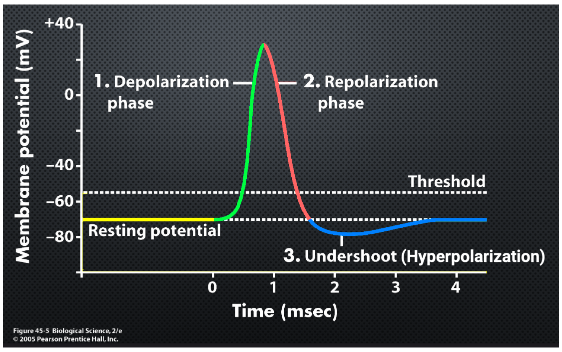

Abbildung 1: Neuron Spike

- *Resting* at -70mV
- *Depolarization phase*: Excitation from input signal reaching an artificial threshold resulting in a voltage jump (up to $+40\text{mV}$)

- *Repolarization phase*: Return to resting potential
- *Undershoot (Hyperpolarization)* return to resting.

All voltages with respect to outside brainfluid.

This process thakes around $3\text{ms}\ \ (333.33\text{Hz})$. The *Myelin Sheaths* decreases performance and throughput aswell. This is faster due to thight packing and parallel processing.

The spike is seemingly identical between different neurons (same Amplitude and timeframe).

1.3.1 Resting membrane potential (default state)

Different ion concentration: more negative inside the neuron than outside. Measurement in reference to outside. Outside: Mostly $Na+$ and $Cl-$. Inside: $K+$ and $A-$. Resting voltage sits at around -65mV to -70mV.

1.3.2 De-polarization

Ions flow through the neuron. Signal excites gates. Gates are ion-specific and only allow certain kinds of ions. These are *voltage-gates channels*.

Ions like Sodium ($Na+$) enter the neuron resulting in a positive voltage swing up to $+40\text{mV}$. Once all Sodium gates are open the threshold is reached. The gates open with very little voltage.

1.3.3 Hyper-polarization

Once the voltage between neuron and outside fluid is positive, the Sodium gates close (as they're voltage controlled). Respectively the Potassium ($K+$) gates open. Positive charge leaves the neuron making the voltage drop to below the threshold. At resting potential the Potassium gates close. Due to the delay in closure undershoot occurs.

1.3.4 Encoding Information

Information is seemingly encoded in timeing between pulses. Amplitudes and Durations of spikes are too simmilar between spikes.

1.4 Artifical Neruons

1.4.1 Perceptrons

A simple neural model.

All dendrites u_i get weighted w_i and summed resulting in the activation z. The summation simulates the *soma* core.

$$z = \sum_{i=1}^{n} \omega_i \cdot u_i$$

The threshold and axiom are simulated by an activation function ϕ resulting in the *perceptrons*' output v.

$$v = \phi(z)$$

Activation functions tend to clamp the output in the range of -1 to 1.

An activation function dictates the output space. A heaviside function can only output a binary result. Functions with infinite range may diverge. Sigmoid functions can't overflow however the may saturate. The computataional cost is quite prohibitive.

1.4.2 Hodgkin-Huxley Model

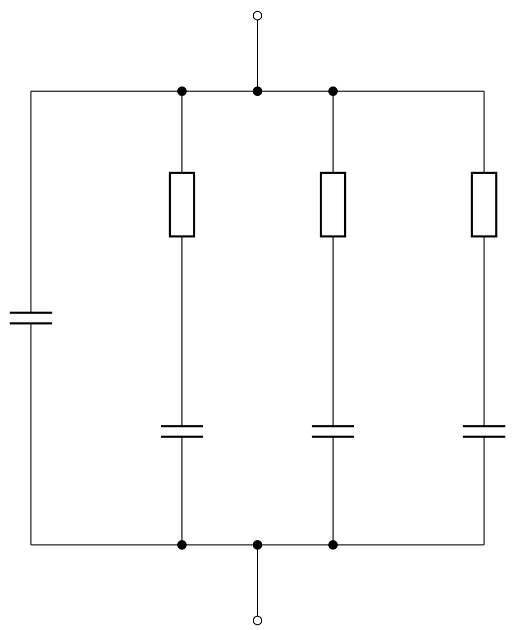

Abbildung 2: