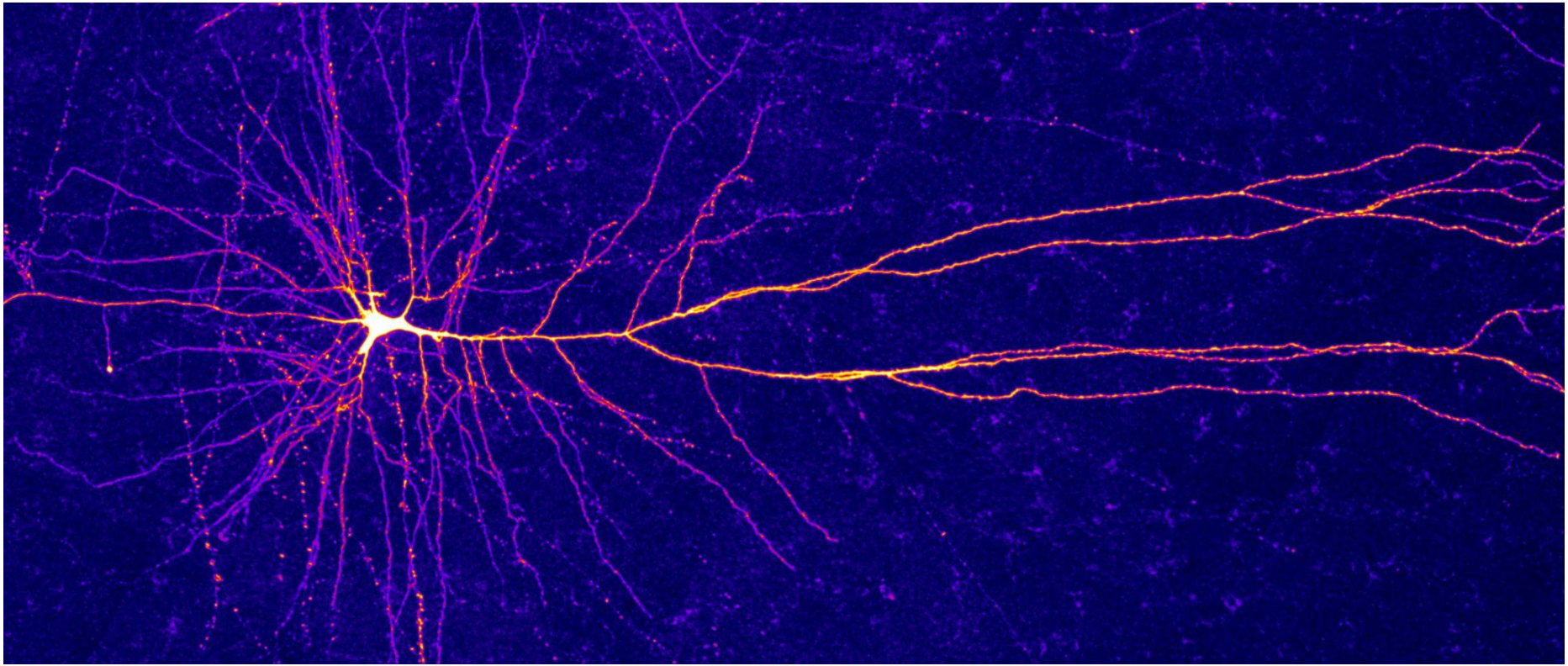
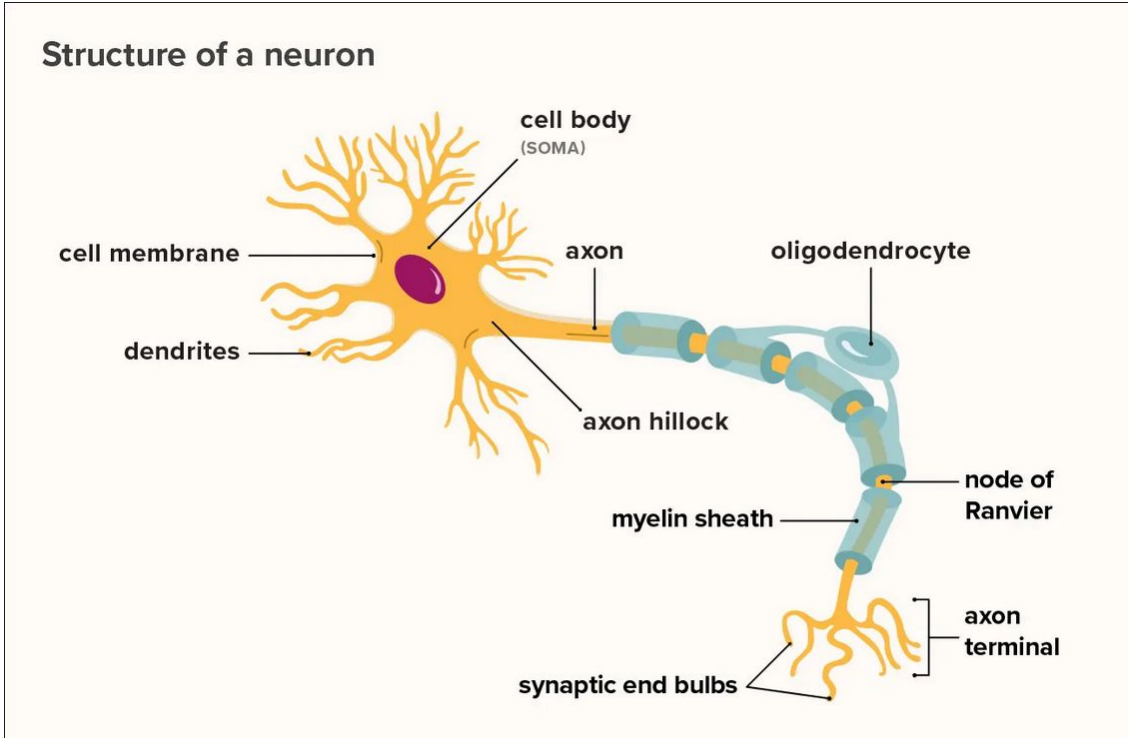
Neurons
Action Potentials
Networks
Epilepsy

Neurons

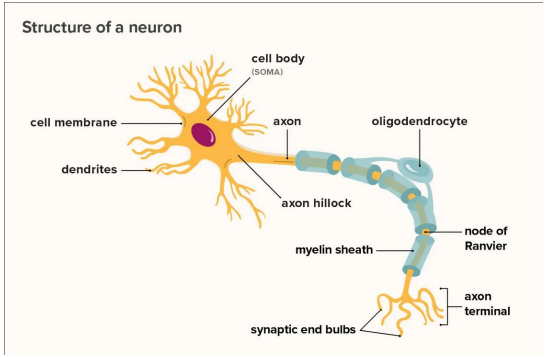


Neurons


Structure of a neuron
cell body
(SOMA)
cell membrane
axon
oligodendrocyte
dendrites
axon hillock
node of
Ranvier
myelin sheath
axon
terminal
synaptic end bulbs

Neurons

- Main computational units of the brain
- Characterized by a voltage difference between inside and outside of their membrane, kept by passive and active ion channels.
- Communicate via Action Potentials, rapid ion exchanges through the membrane that self-propagate via the axon
- They can be excitatory or inhibitory



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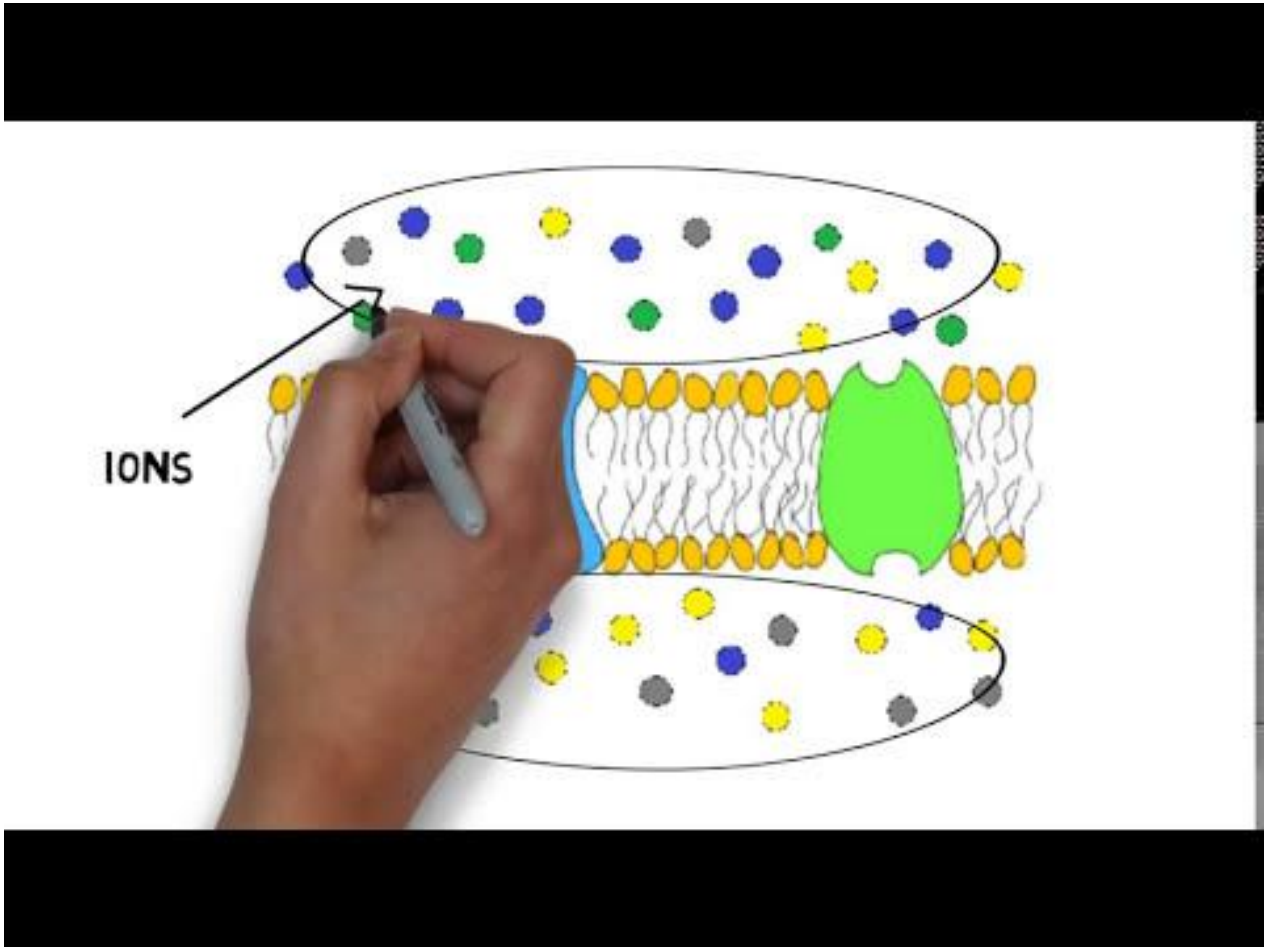
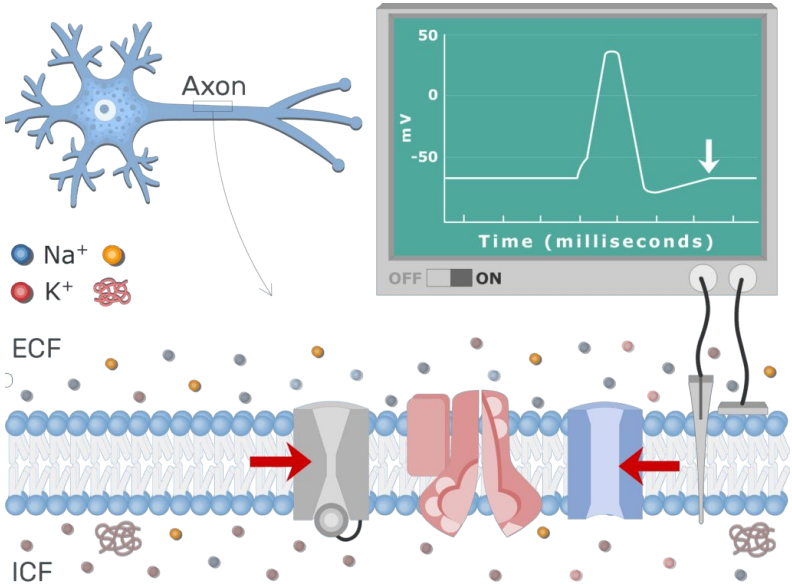


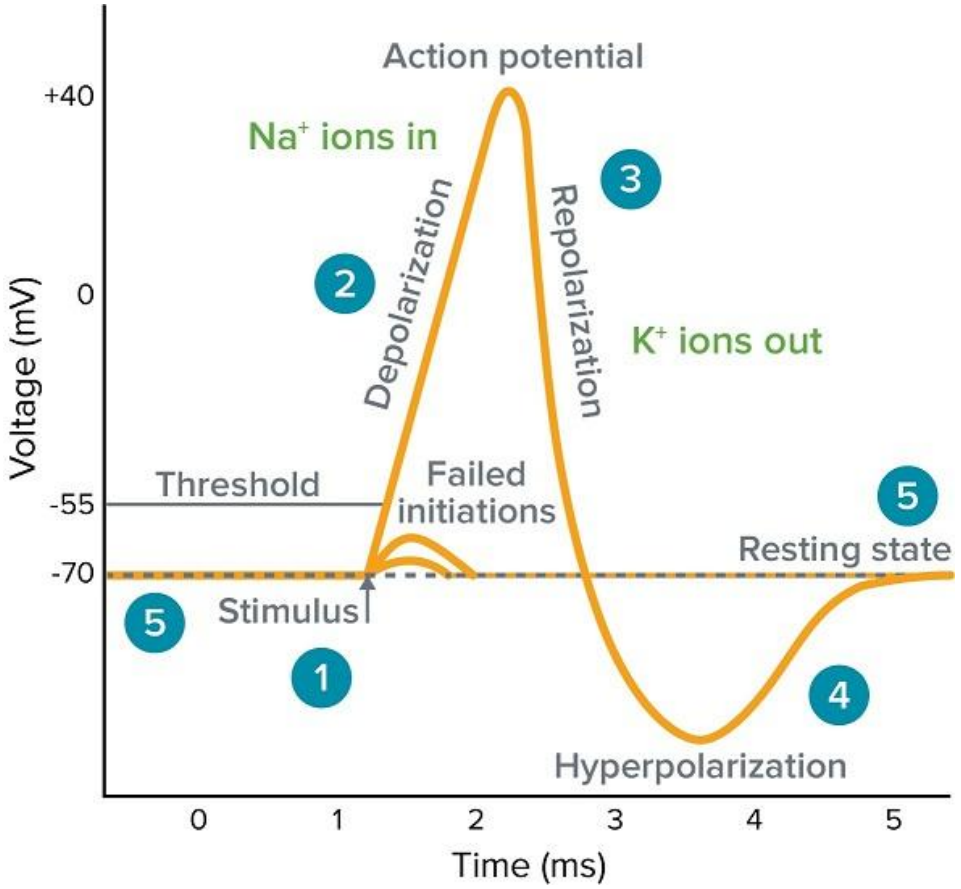
Action Potential - Ion exchange

A neuronal cell membrane is both a passive, and an active element, that regulates the trafficking of several species of ions between the intra- and extra-cellular environments. Among these ions, the most notable are Na+, K+, Ca+, Mg+, and Cl-

The activation of large enough number of channels in a short period of time, might lead to a cascade event called ‘action potential’ (also referred as ‘spike’)

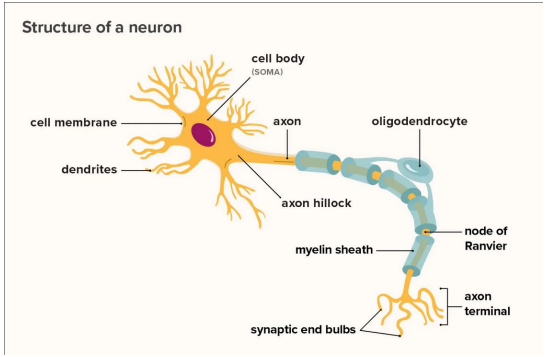


Action Potential



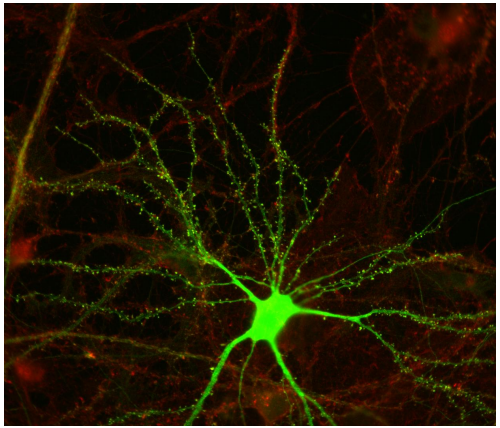
Action Potential

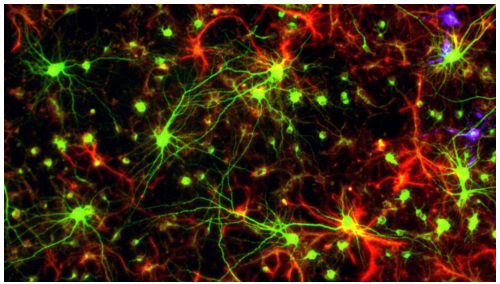
- Triggered when the membrane potential of a neuron is depolarized over a certain threshold
- Approximated sometimes as an ‘all or nothing’ or binary signal
- Can only be generated up to a certain number of times per second (depending on neuron type, maximally between 40-300Hz)
- They are essentially very fast (~ms) exchanges of ions through the membrane



Networks

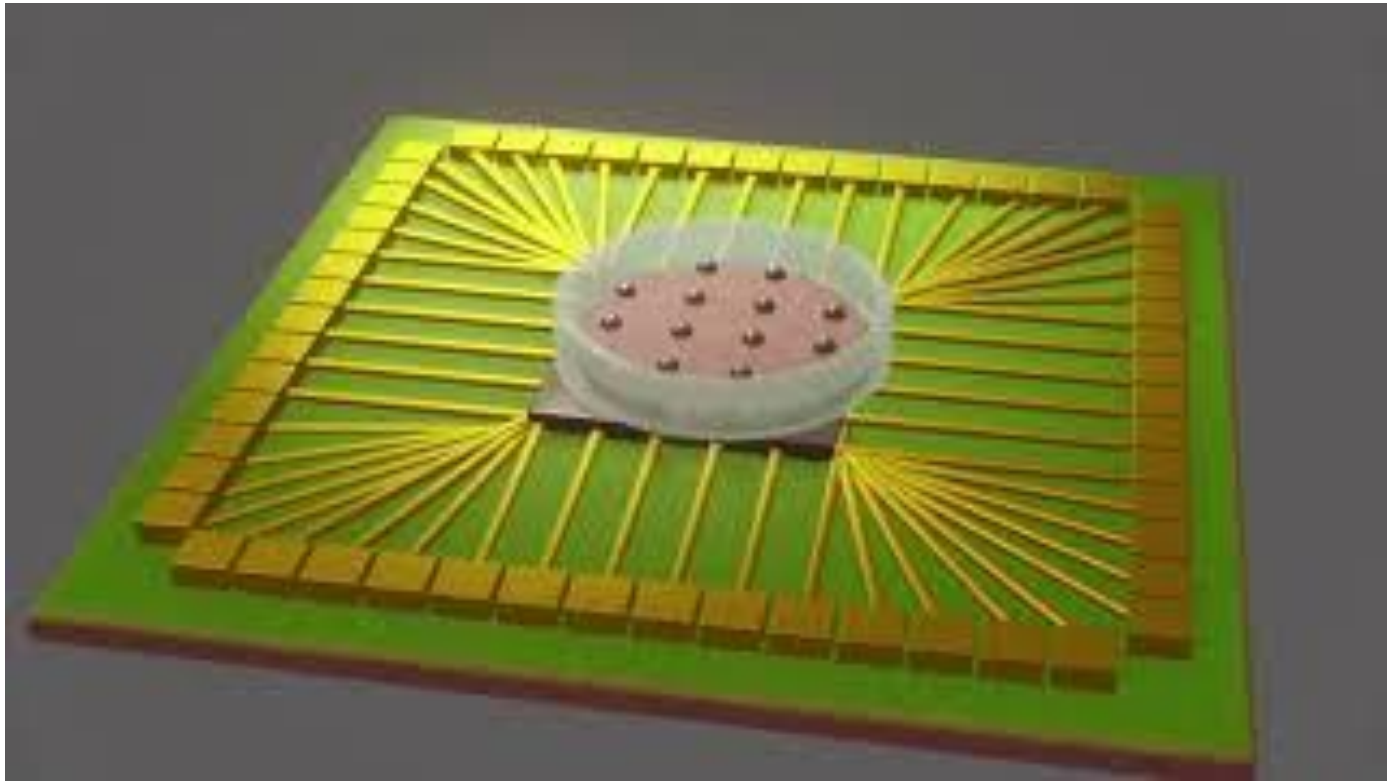
- Each neuron can have thousands of synapses (connections with other neurons)
- There are between 60k and 250k neurons in 1mm^3 of the human cortex, about 80% of them being excitatory, 20% inhibitory
- Inhibitory neurons *tend to* form synapses at a limited distance
- Without inhibitory neurons, a strong enough stimulus might drive the network in a self-sustained activity loop..





Epilepsy

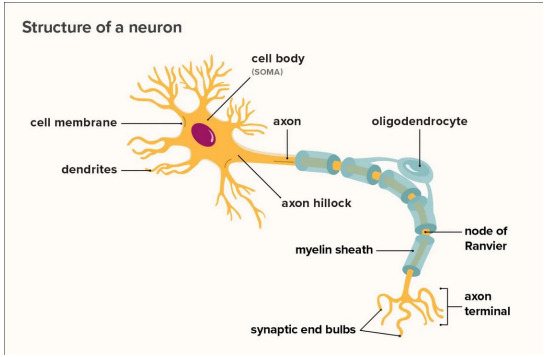
Epilepsy



Epilepsy

Epilepsy is a neurological disorder characterized by recurrent, unprovoked seizures, due to abnormal neuronal activity, affecting ~1% of the global population.

Epilepsy can be due to a number of factors, mostly involving brain injury, cell death, or imbalance in neurotransmitters. The main effect is thought to be an alteration of the excitation-inhibition balance.



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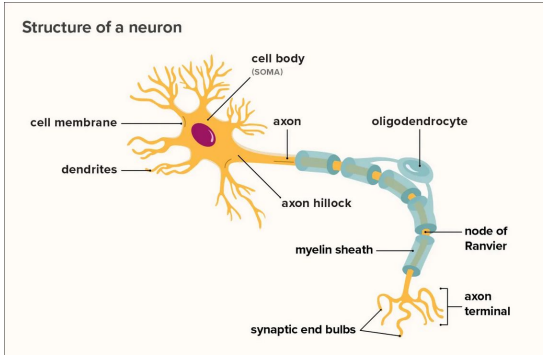
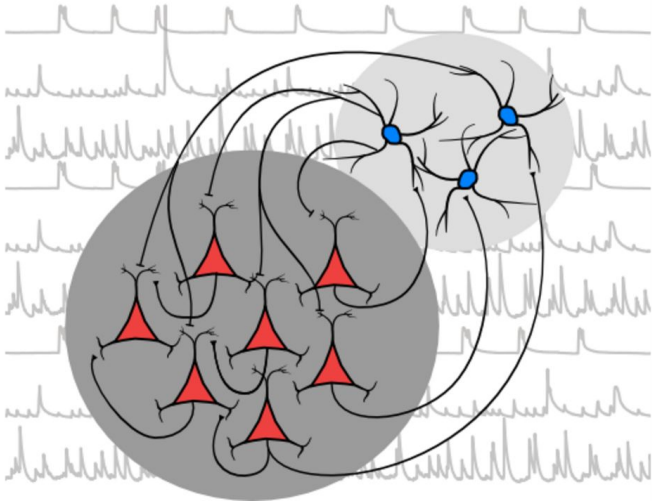
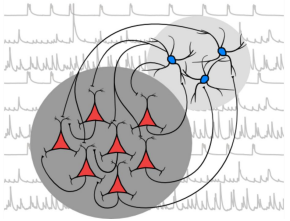




Simulated epilepsy



Base simulation

- Based on ‘point neurons’ (without a geometry), including excitatory and inhibitory cell types.
- $0.6mm^3$
- Neurons are assigned a random connectivity based on physiological parameters
- Every neuron is activated by a small electrical current ‘noise’ stimulus, mimicking externally incoming activity

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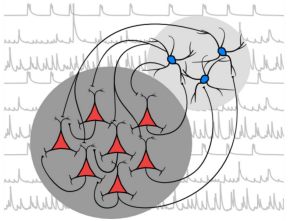
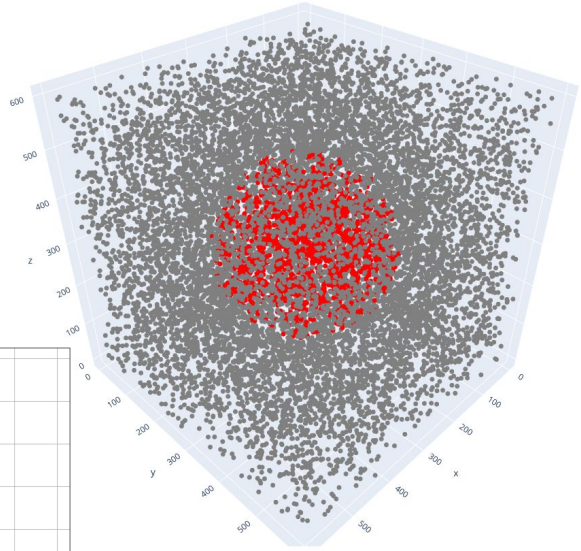
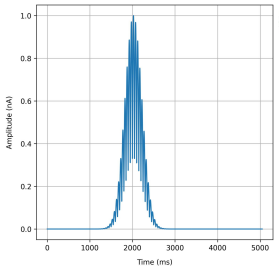


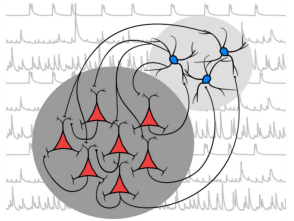
Epilepsy

- Ionic imbalance, causing a difference in the equilibrium potential of potassium ions
- Sprouting: damaged neurons regrow their axons, but randomly so, causing higher excitatory-excitatory connectivity
- External epileptic stimulus, driving only a subset of neurons





Simulated epilepsy + ionic modulation



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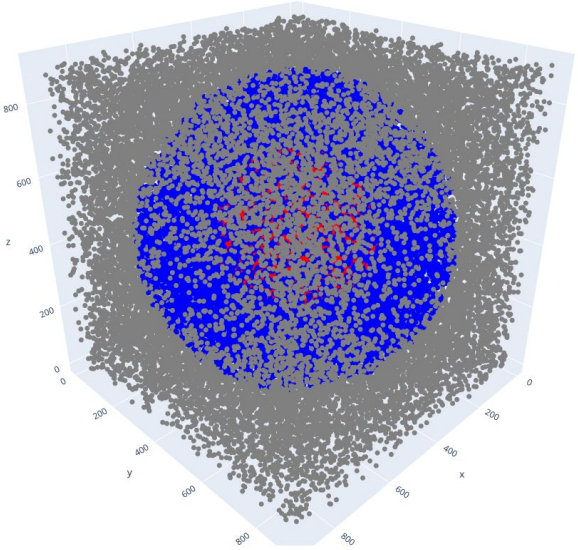

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- Sprouting: damaged neurons regrow their axons, but randomly so, causing higher excitatory-excitatory connectivity
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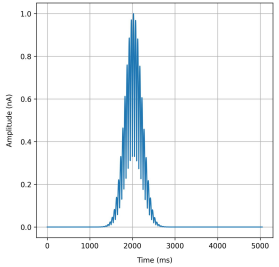
Ionic modulation

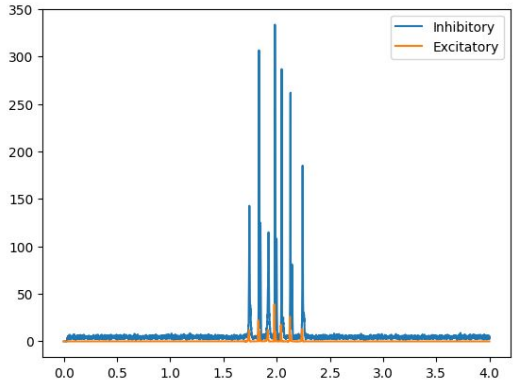
- A subset of neurons has their potassium (K+) concentration altered
- This corresponds to a different equilibrium potential for K+ (Nernst Equation), decreasing excitability

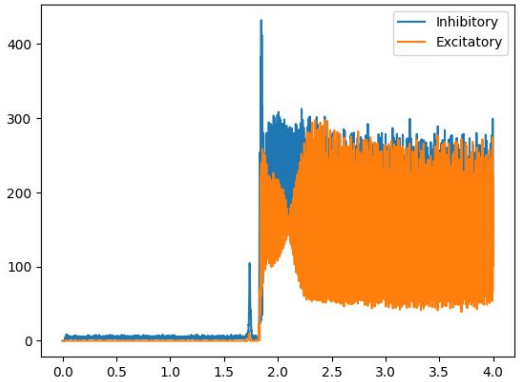
Simulated epilepsy + ionic modulation

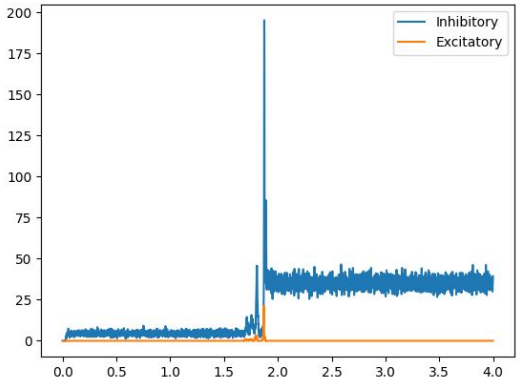
Results

- A decrease in potassium might block the onset of an epileptic-like activation of the neuronal network, but will fail at blocking it if the activity is already too sustained.



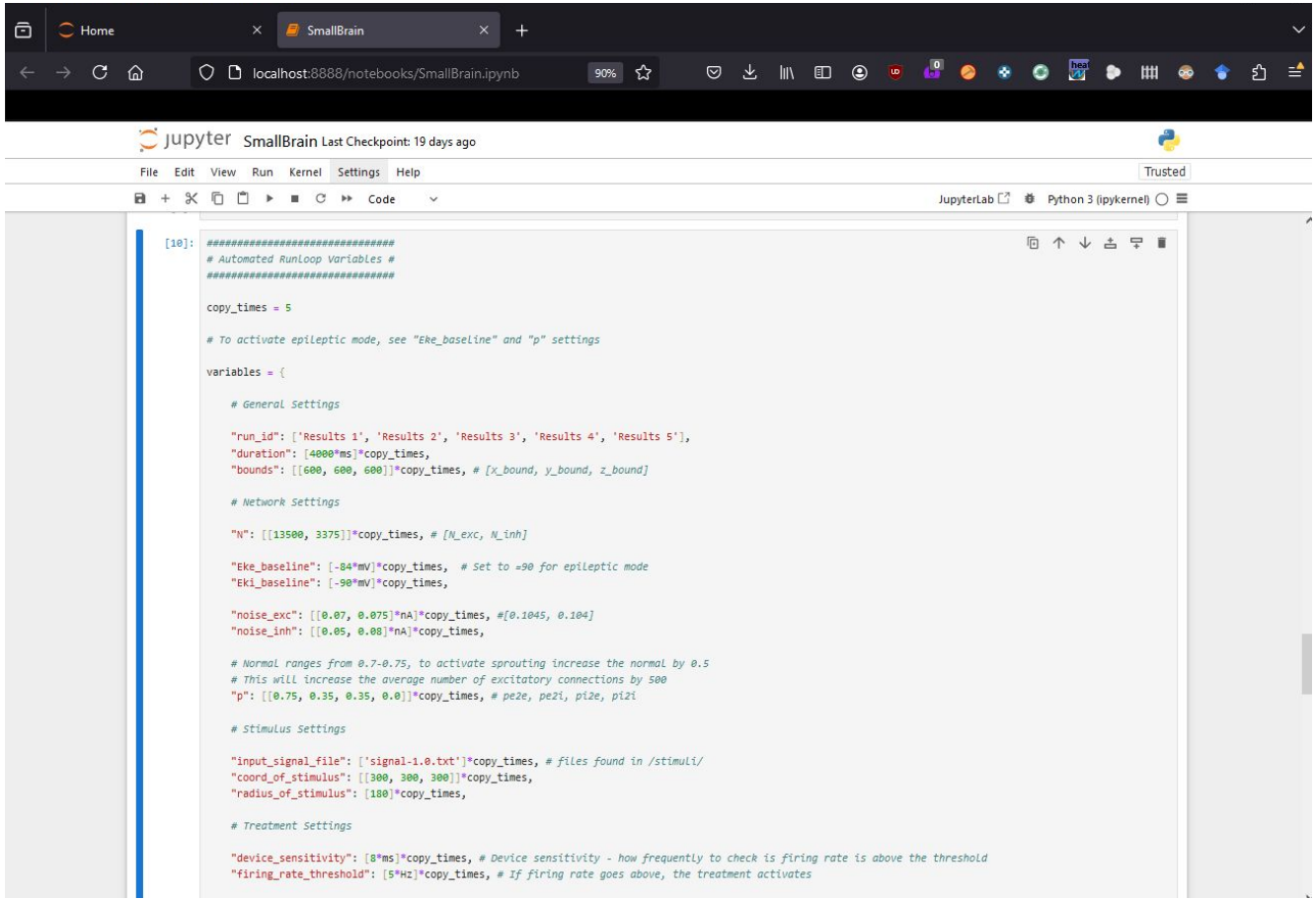






What you need

- **Download the simulation**
- **Download and install Anaconda (or Miniconda)**
- **Install Jupyter Notebook**
- **Unzip the simulation**
- **Follow the instructions in the README file**
- **Use the following commands to activate the environment, in Anaconda's command prompt:**
  - **cd <path of the simulation folder>**
  - **conda activate <NAME of the environment>**
  - **Jupyter notebook**
- **Now double click (in your browser's Jupyer's notebook) on SmallBrain.ipynb**
- **Run the whole simulation by pressing the little arrows at the top. Note that the simulation might need 5-30m to run.**
- **The main parameters are in the "Automated Runloop Variables" section**


Home
SmallBrain
localhost:8888/notebooks/SmallBrain.ipynb
90%
jupyter SmallBrain Last Checkpoint: 19 days ago
File Edit View Run Kernel Settings Help
Trusted
Code
JupyterLab
Python 3 (ipykernel)
[10]:
##############################
Automated RunLoop Variables
##############################
copy_times = 5
# To activate epileptic mode, see "Eke_baseline" and "p" settings
variables = {
# General Settings
"run_id": ['Results 1', 'Results 2', 'Results 3', 'Results 4', 'Results 5'],
"duration": [4000*ms]*copy_times,
"bounds": [[600, 600, 600]]*copy_times, # [x_bound, y_bound, z_bound]
Network Settings
"N": [[13500, 3375]]*copy_times, # [N_exc, N_inh]
"Eke_baseline": [-84*mV]*copy_times, # Set to -90 for epileptic mode
"Eki_baseline": [-90*mV]*copy_times,
"noise_exc": [[0.07, 0.075]*nA]*copy_times, #[0.1045, 0.104]
"noise_inh": [[0.05, 0.08]*nA]*copy_times,
Normal ranges from 0.7-0.75, to activate sprouting increase the normal by 0.5
This will increase the average number of excitatory connections by 500
"p": [[0.75, 0.35, 0.35, 0.0]]*copy_times, # pe2e, pe2i, pi2e, pi2i
Stimulus Settings
"input_signal_file": ['signal-1.0.txt']*copy_times, # files found in /stimuli/
"coord_of_stimulus": [[300, 300, 300]]*copy_times,
"radius_of_stimulus": [180]*copy_times,
Treatment Settings
"device_sensitivity": [8*ms]*copy_times, # Device sensitivity - how frequently to check is firing rate is above the threshold
"firing_rate_threshold": [5*Hz]*copy_times, # If firing rate goes above, the treatment activates

Resources

- Simulation download link https://drive.google.com/file/d/1QjmyHN26P0Fns4EvDJDUVQJmkgoc-DhW/view?usp=sharing

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