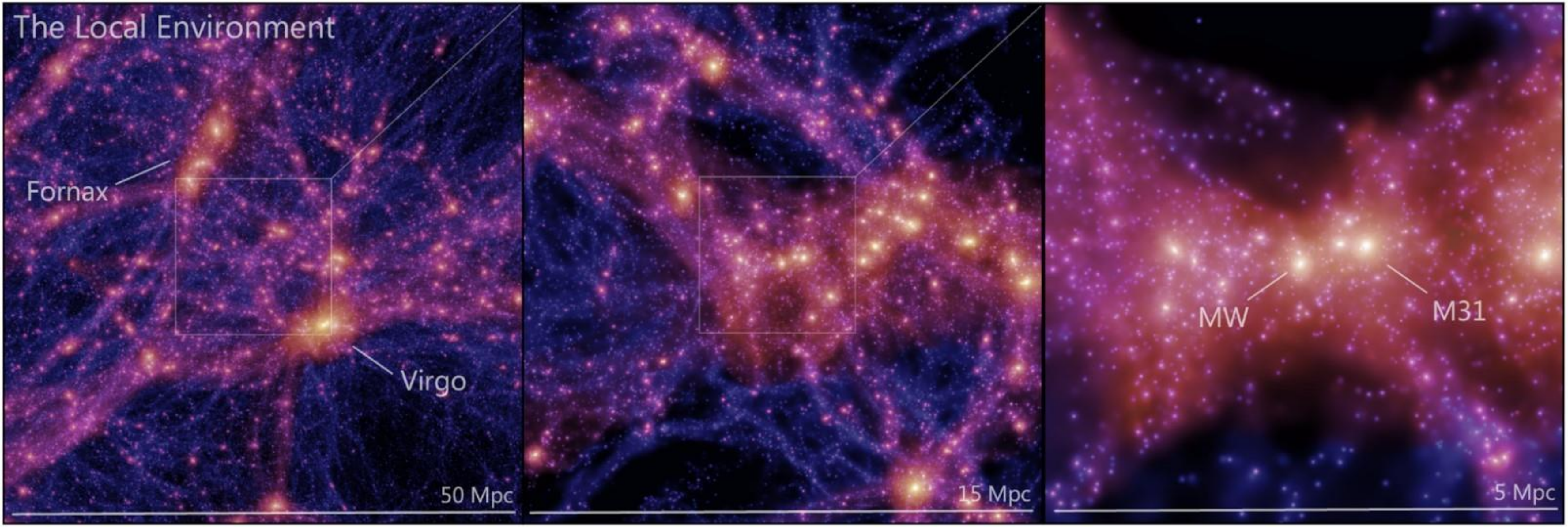
KN8005 Computer Lab #1
VT 2024
Computational Modelling of Neurons

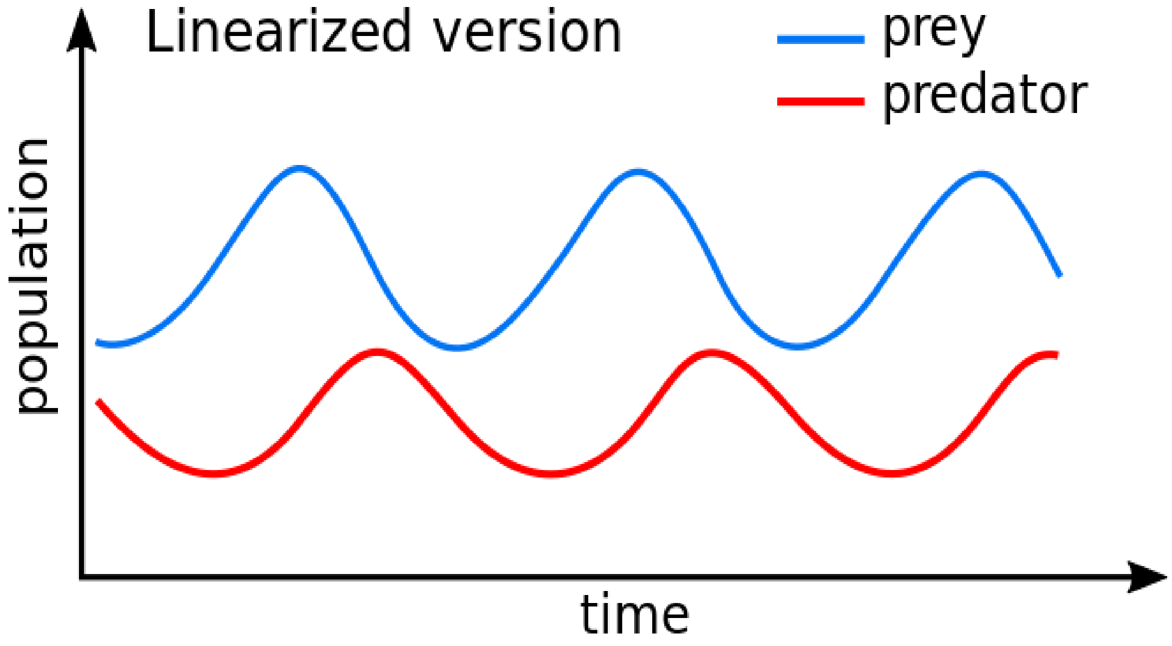


McAlpine et al., 2022

Model Foundation	Model Construction and Refinement	Model Validation and Use
Experimental Data Prior Knowledge Hypotheses formation	Model specification Model ⇆ Simulation ⇆ Data	Tests on New Data Model Predictions Hypothesis Testing

A Simpler Model

VS



The Lotka-Volterra Model

The Lotka-Volterra Equations (And Assumptions)

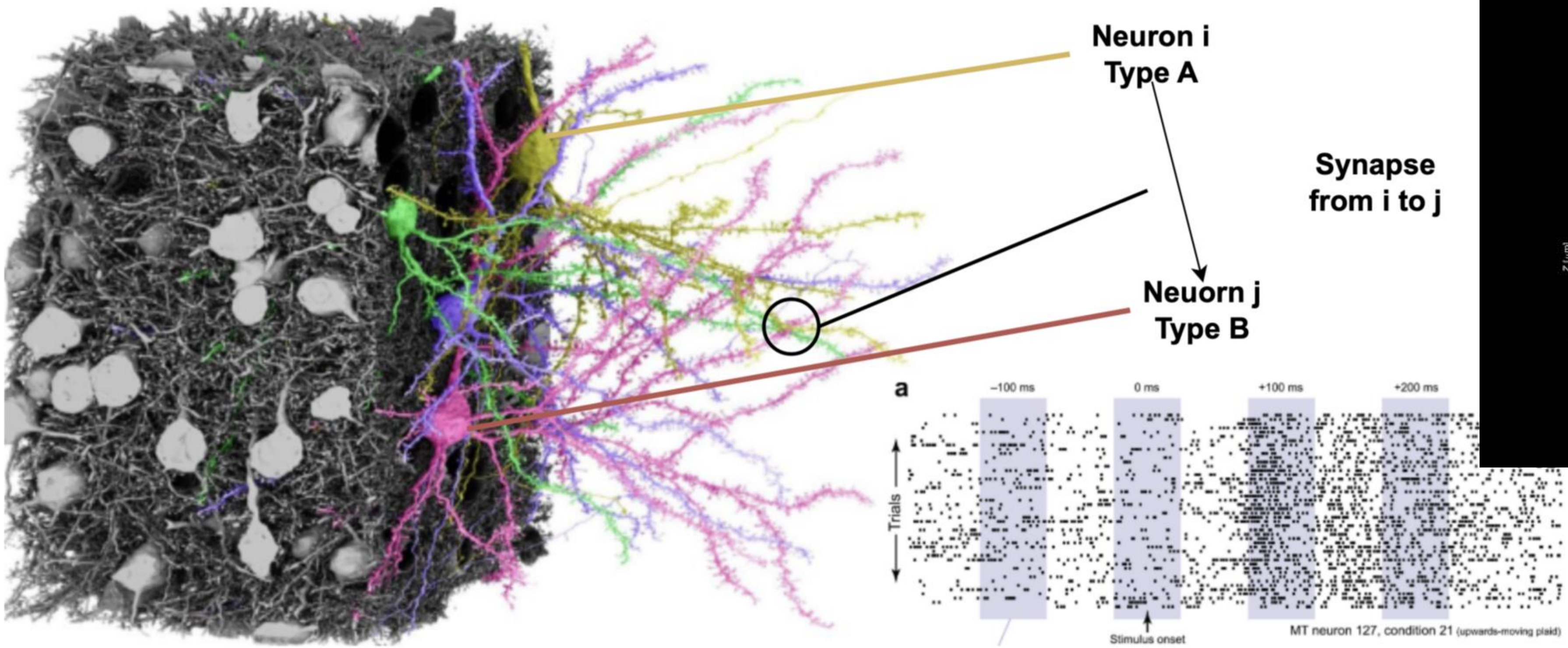
$$\frac{dP}{dt} = -Pm + bHP$$

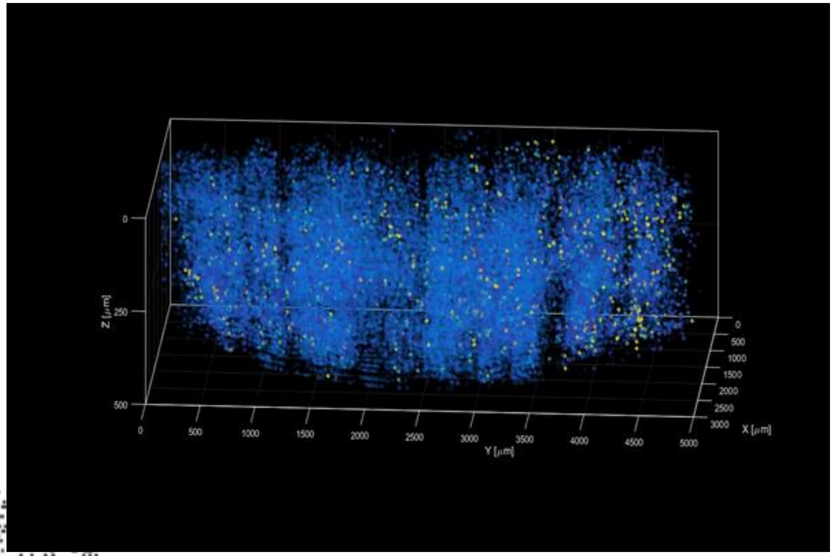
$$\frac{dH}{dt} = Hr - aHP$$

$$\begin{cases} P = P(t) & \text{Number of Predators} \\ H = H(t) & \text{Number of Prey} \end{cases}$$

$$\begin{cases} r > 0 & \text{Birth Rate of Prey} \\ m > 0 & \text{Death Rate of Predators} \\ a > 0 & \text{Death Rate of Prey/Predator} \\ b > 0 & \text{Birth Rate of Predators/Prey} \end{cases}$$

Modelling Neuronal Activity





250 x 140 x 90 μm, layer 2/3, mouse visual cortex [Dorkenwald et al. 2019]

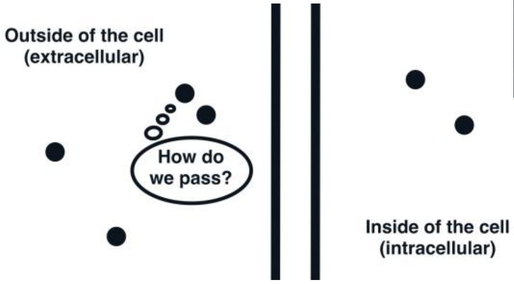
Designing Our Model

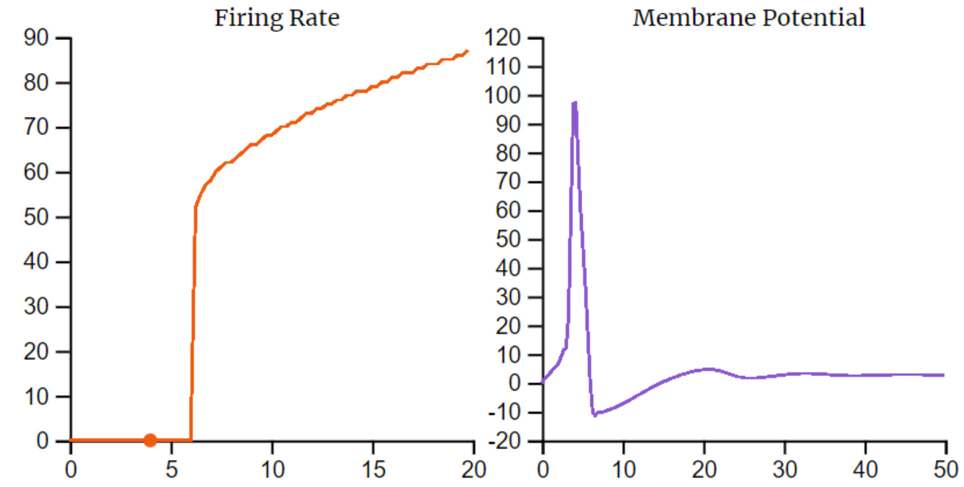
Identity *(What does the neuron look like?)*

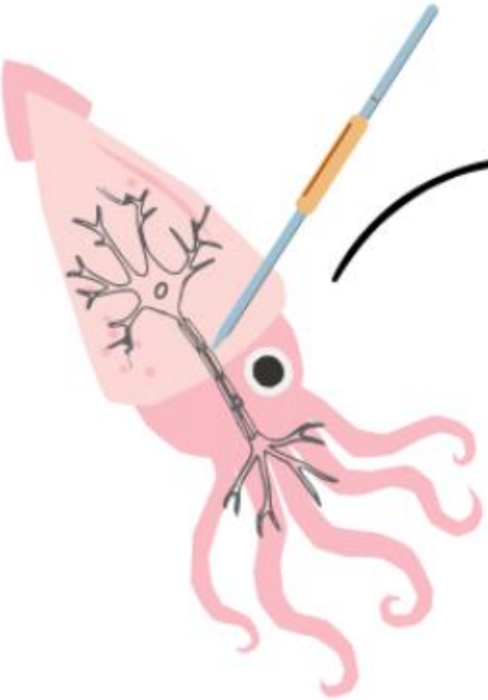
Connectivity *(What type of synapses does the neuron have?)*

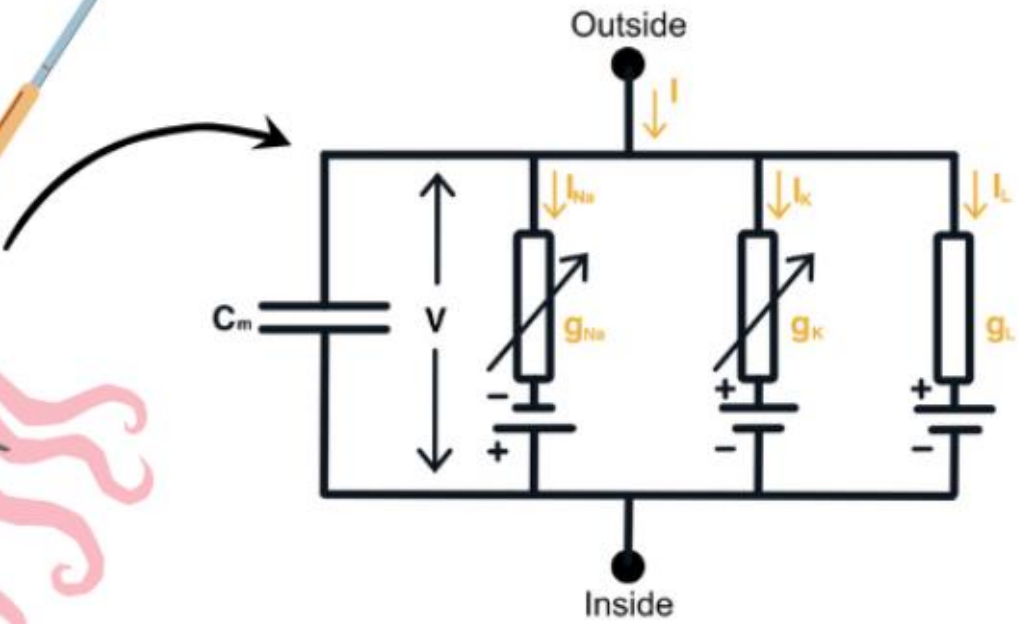
Activity *(What type of input does the neuron receive?)*

Modelling Neuronal Identity
The Hodgkin-Huxley Model







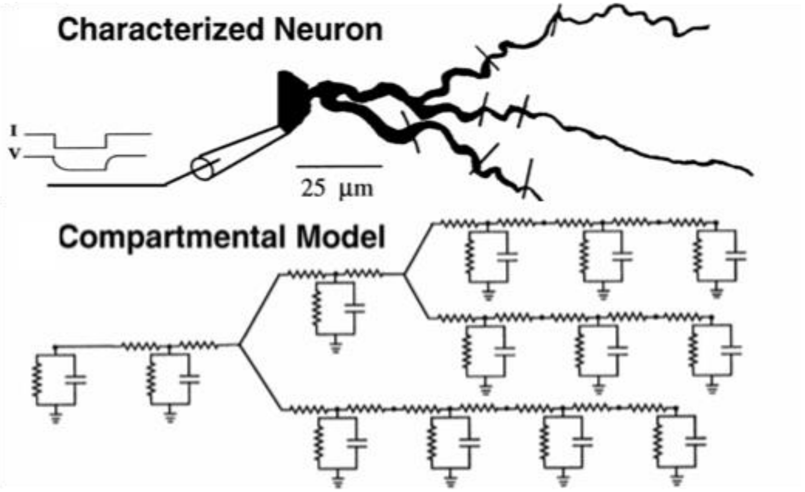


Pierzchlewicz, Paweł A. (2022)

Modelling Neuronal Identity

Compartmental Models and LIFs

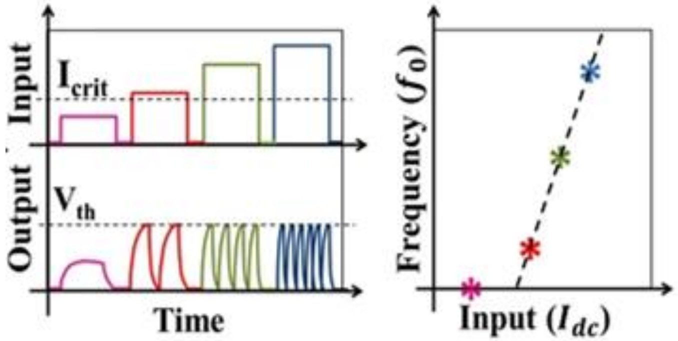
Compartmental models simulate parts of the neuron with separate properties, usually based on experimental observations

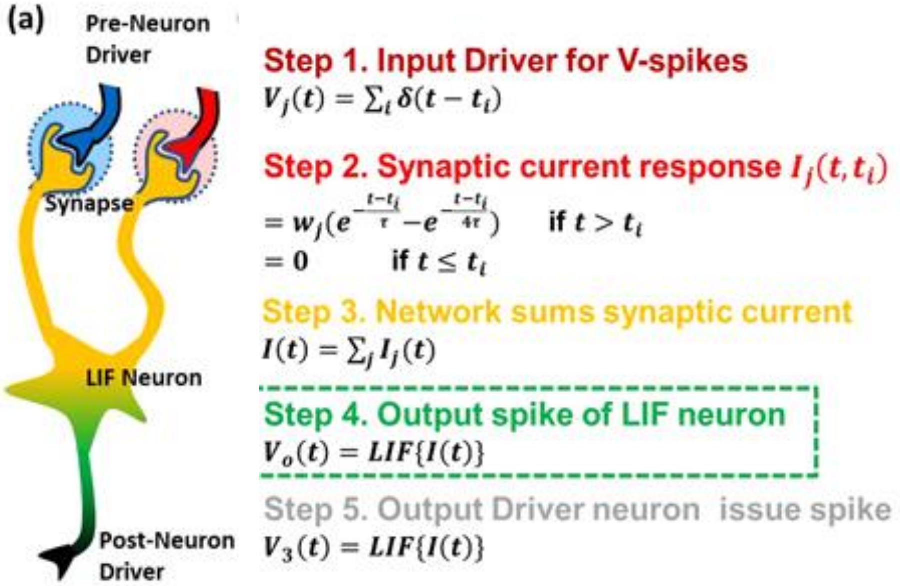


Point Neuron Models

Leaky Integrate and Fire (LIF) Neurons

- Spatiotemporal integration of synaptic inputs that will produce a spike at a certain threshold
- The ‘leakiness’ creates spontaneous change in potential (as in H-H)
- Only two states:
    - Subthreshold
    - Spike and reset



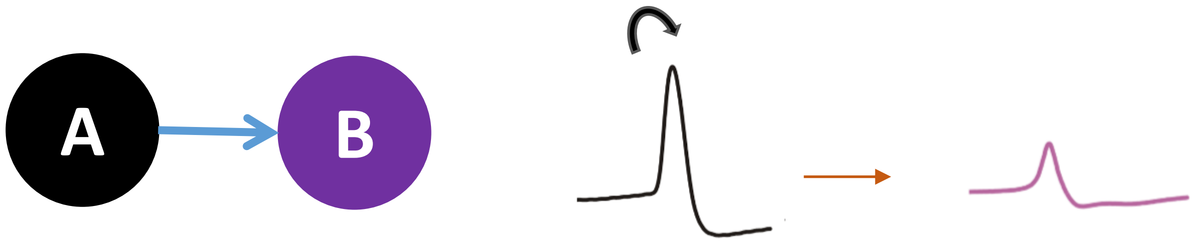


Dutta et al., (2017)

Modelling Neuronal Connections

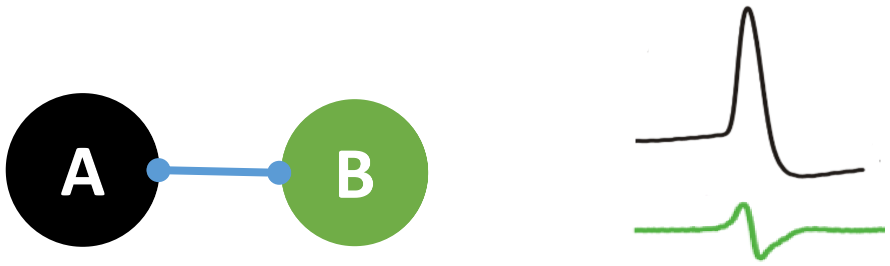
Types of Synapses

1. Static



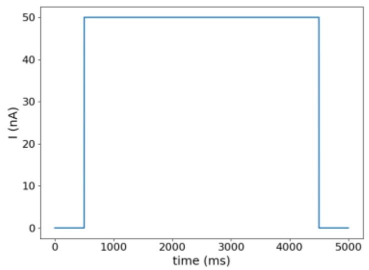
2. Facilitating or Depressing
- Synapse strength changes with consecutive spikes

3. Electrical Synapses
- Neurons are coupled with gap junctions

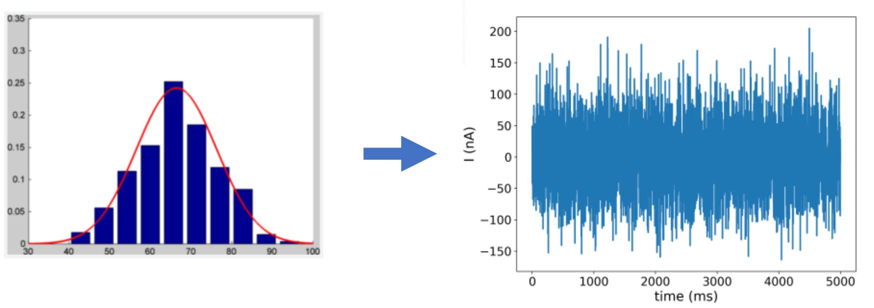


Modelling Neuronal Connections
Types of Input

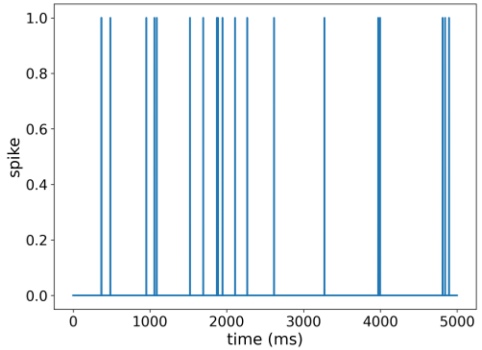
1. Current Injection
- Current of fixed amplitude is applied



2. Gaussian
- Variable current. Captures the **randomness** of brain activity by introducing **noise** to the input

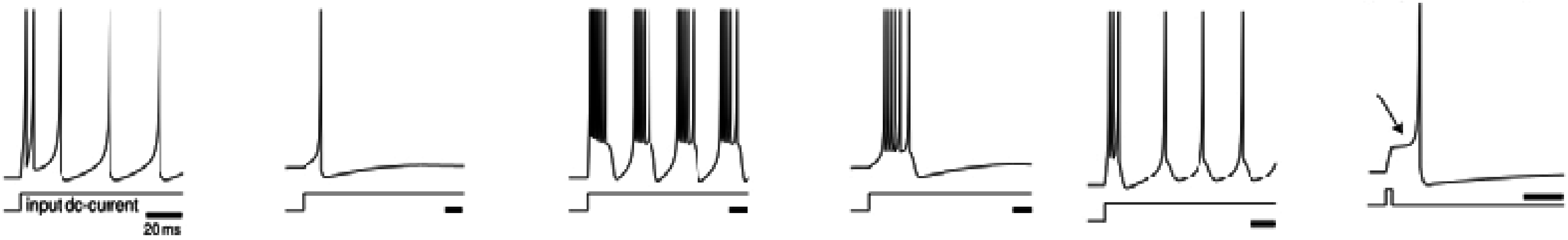


3. Poisson Process
- Events (spikes, arrivals, etc.) occur randomly and independently.
- The time between consecutive events follows an **exponential distribution**.



Your Task

To Model Different Firing Patterns using LIF model



Neuronal Circuits > Resources> Labs> Simulation Labs> link to lab 1 in the manual