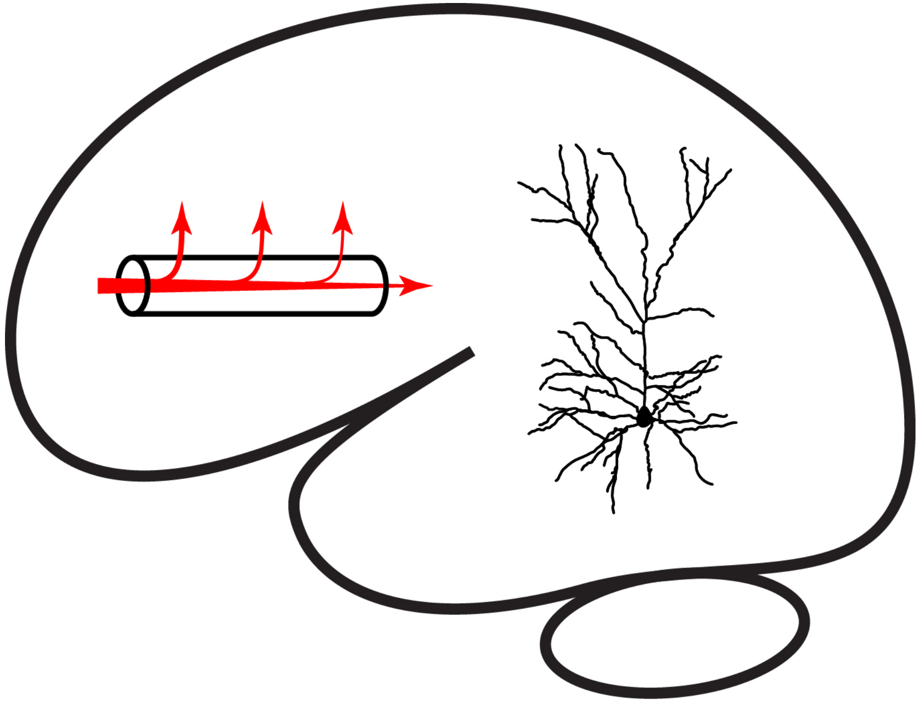
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE



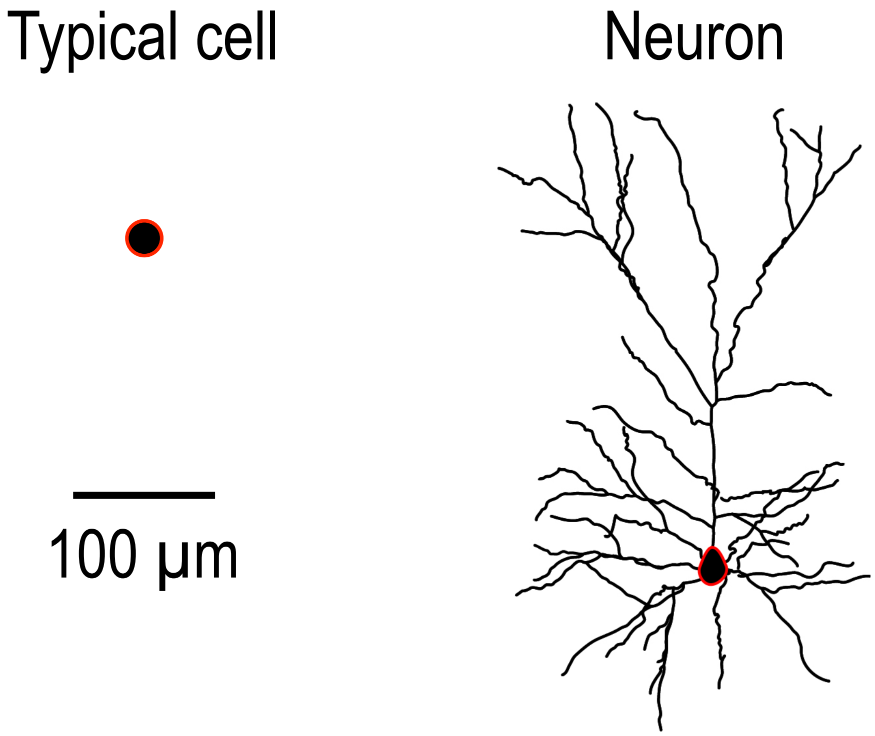
1.5 Cable properties

Cellular Mechanisms of Brain Function

Prof. Carl Petersen

Cable properties of neurons

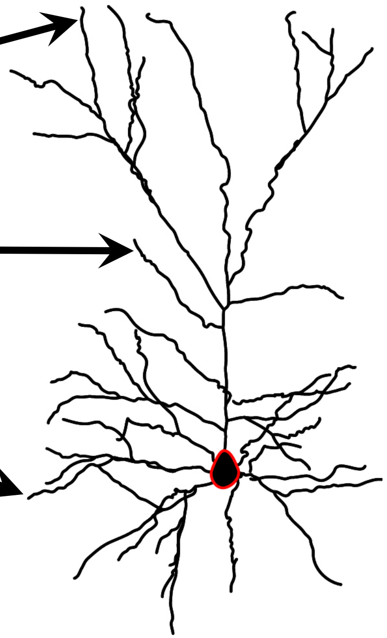
Cable properties of neurons



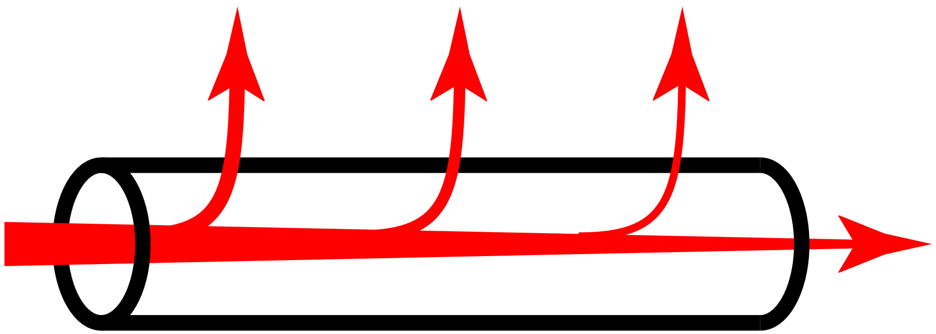
Spatiotemporal V_m dynamics

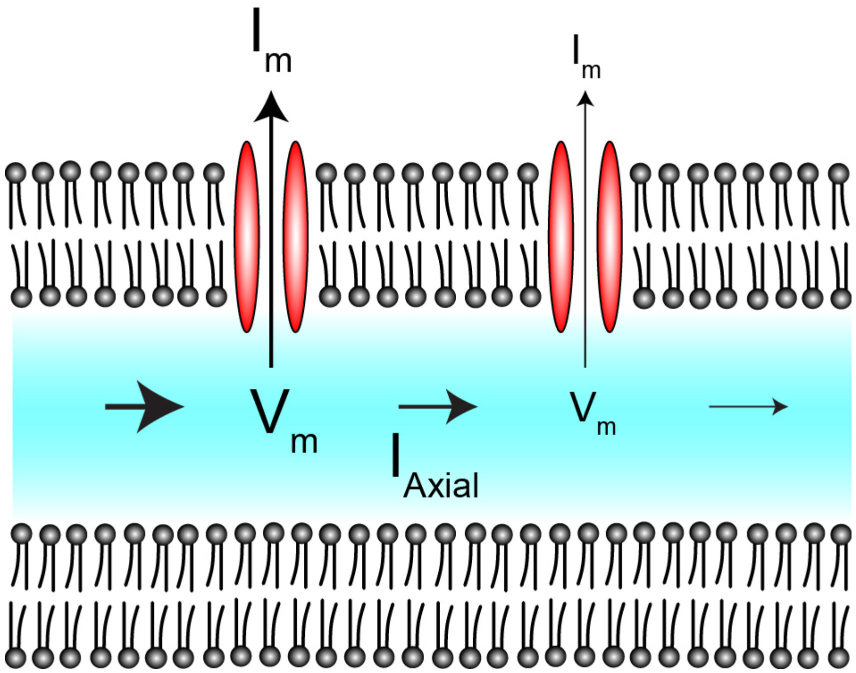
In general, membrane potential (V_m) differs according to location across the neuronal arborisation.

$$V_m(x_1, y_1, z_1, t) \neq V_m(x_2, y_2, z_2, t) \neq V_m(x_3, y_3, z_3, t)$$

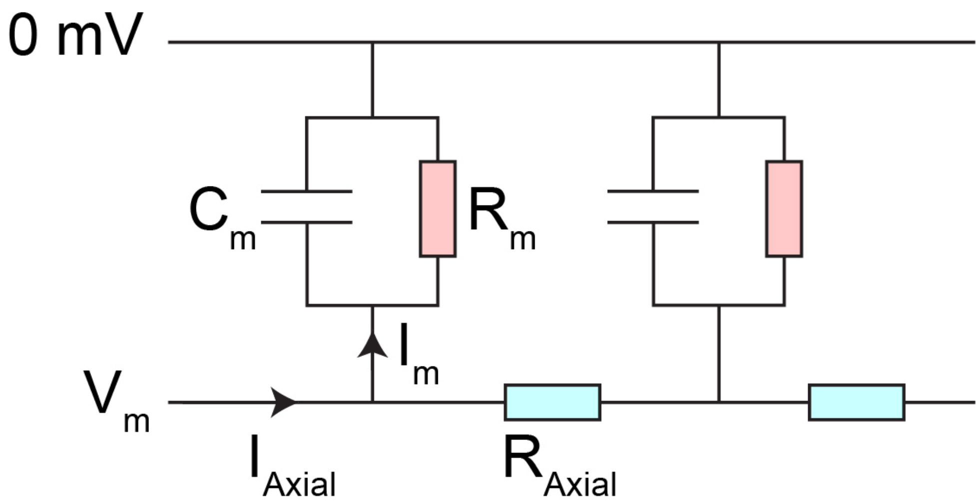


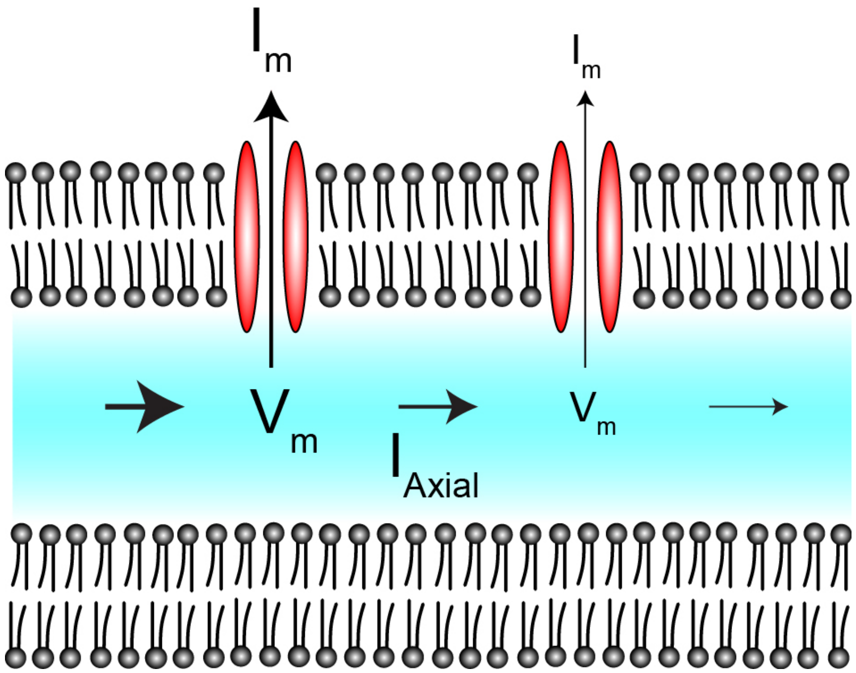
Leaky cables



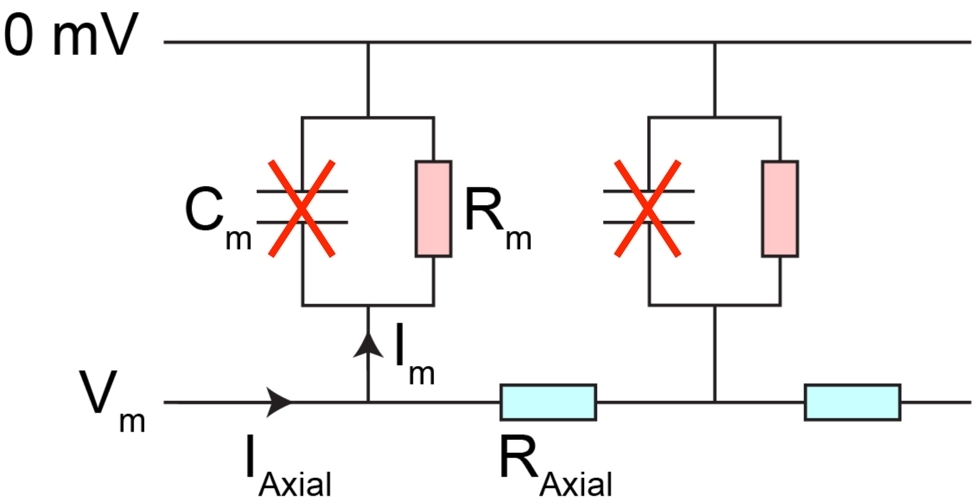


Leaky cables with capacitance





Cable equation at steady state



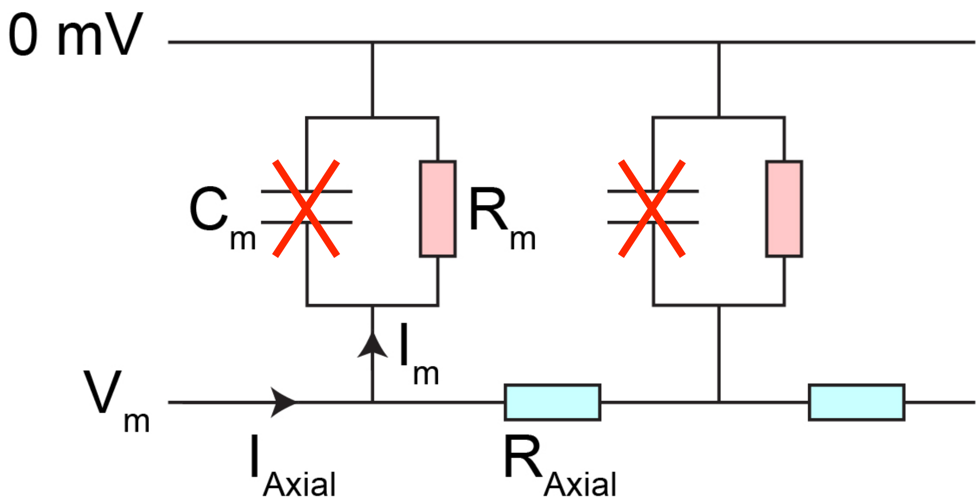
$$V = I_m R_m$$

$$\frac{dV}{dx} = - I_{Axial} R_{Axial}$$

$$\frac{dI_{Axial}}{dx} = - I_m$$

Cable equation at steady state

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE



$$V = I_m R_m$$

$$\frac{dI_{Axial}}{dx} = - I_m$$

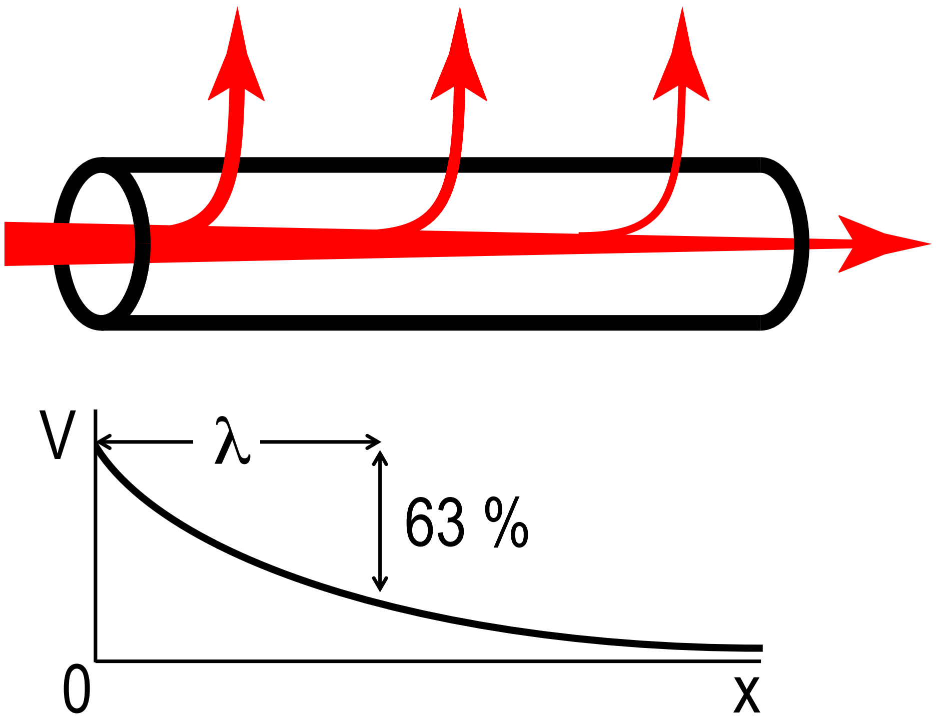
$$\frac{dV}{dx} = - I_{Axial} R_{Axial}$$

$$\frac{d^2V}{dx^2} = \frac{R_{Axial}}{R_m} V$$

$$V = V_0 \, e^{-(x/\lambda)}$$

$$\lambda = \sqrt{(R_m / R_{Axial})}$$

Spatial distribution of V_m at steady state



$$\frac{d^2V}{dx^2} = \frac{R_{Axial}}{R_m} V$$

$$V = V_0 \, e^{-(x/\lambda)}$$

$$\lambda = \sqrt{(R_m / R_{Axial})}$$

Spatiotemporal dynamics of V_m

One-dimensional time-dependent cable equation:

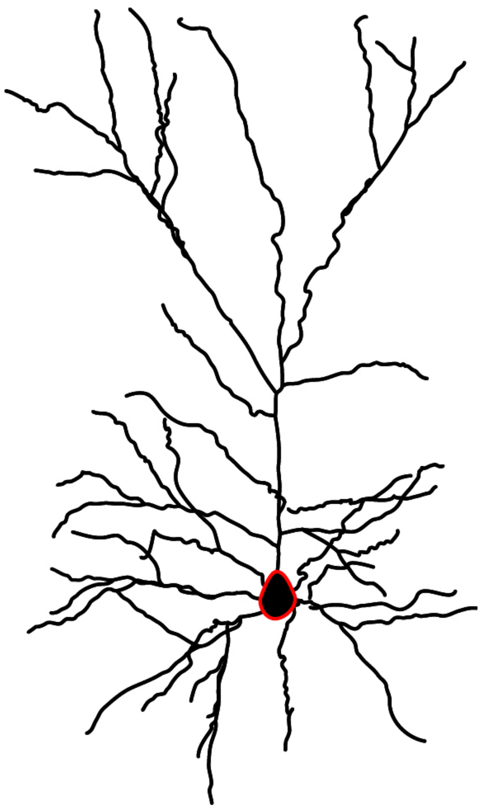
$$\frac{R_m}{R_{Axial}} \frac{\partial^2 V(x,t)}{\partial x^2} - R_m C_m \frac{\partial V(x,t)}{\partial t} - V(x,t) = 0$$

Length constant:
$\lambda = \sqrt{(R_m / R_{Axial})}$

Time constant:
$\tau = R_m C_m$

Note that these ‘constants’ may vary in time and space.

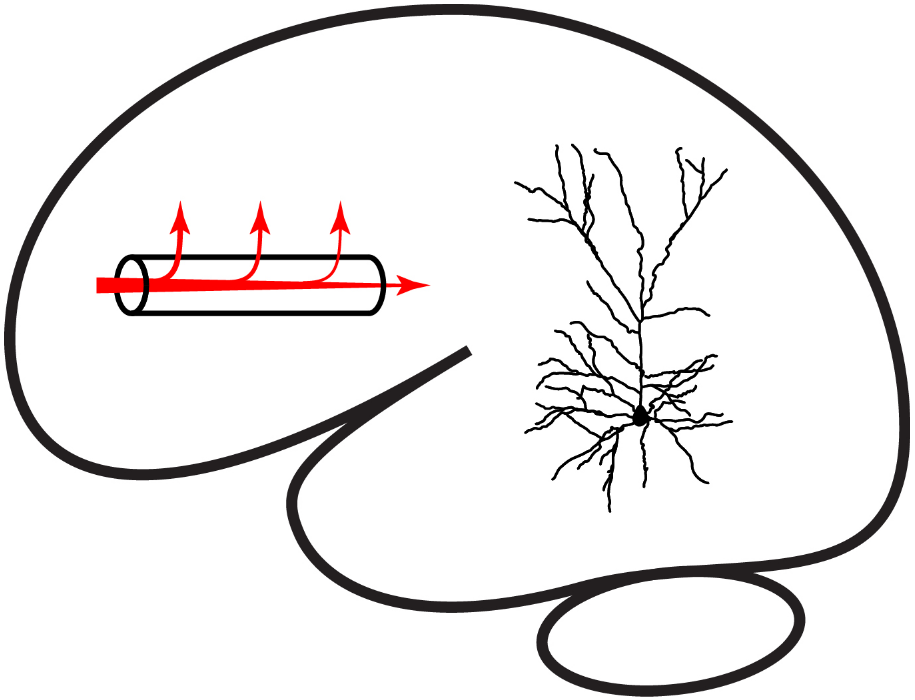
Spatiotemporal dynamics of V_m



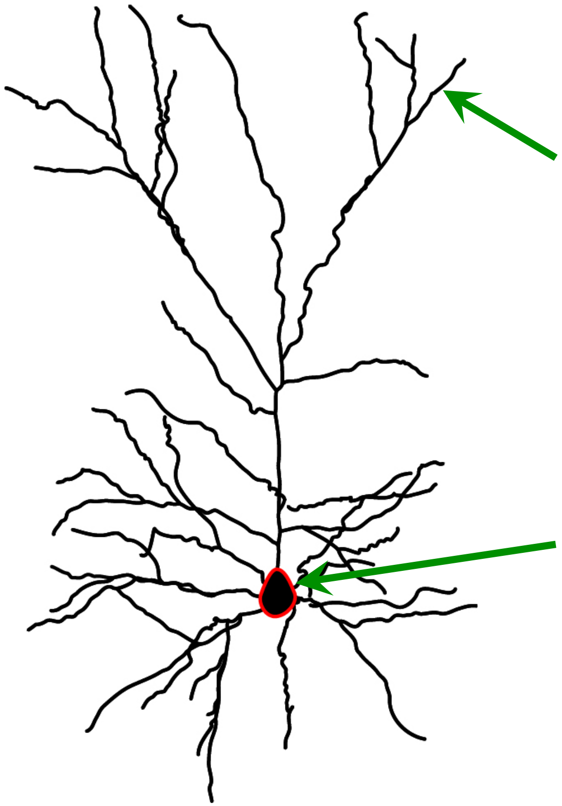
In general, there are no analytical solutions to the cable equations for real neuronal structures and numerical computer simulations are therefore typically used.

For example NEURON
www.neuron.yale.edu

Cable properties of neurons



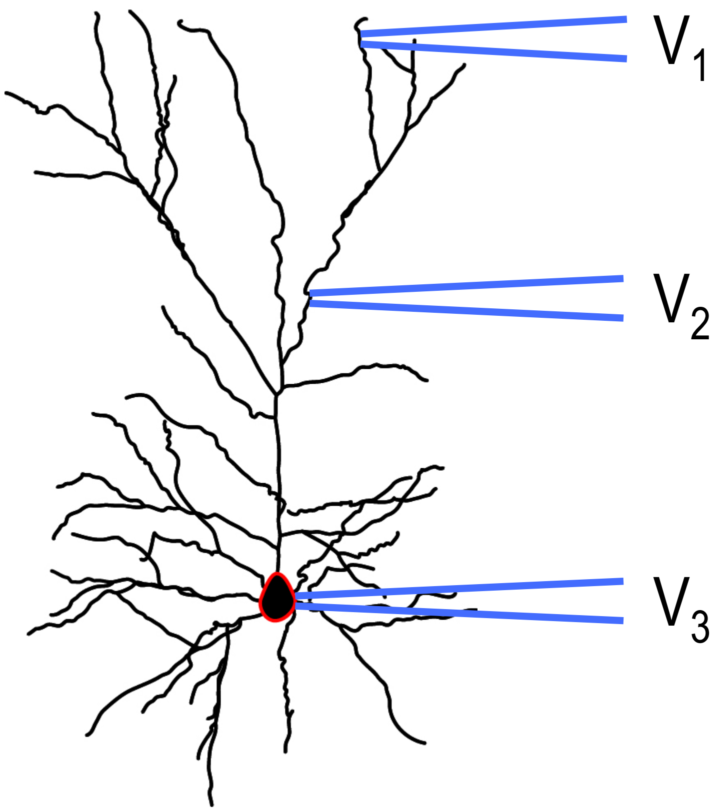
Some numbers – Membrane area



Dendrite diameter ~1 µm

Cell body diameter ~10 µm

Some numbers - Spatiotemporal dynamics of V_m



Cable properties of neurons

- Neurons have extensive arborisations that electrically can be considered as leaky cables with significant capacitance.
- V_m has complex spatiotemporal dynamics within single neurons with significant attenuation and filtering of signals across arbors.