Theoretical & computational Neuroscience:

Programming the Brain

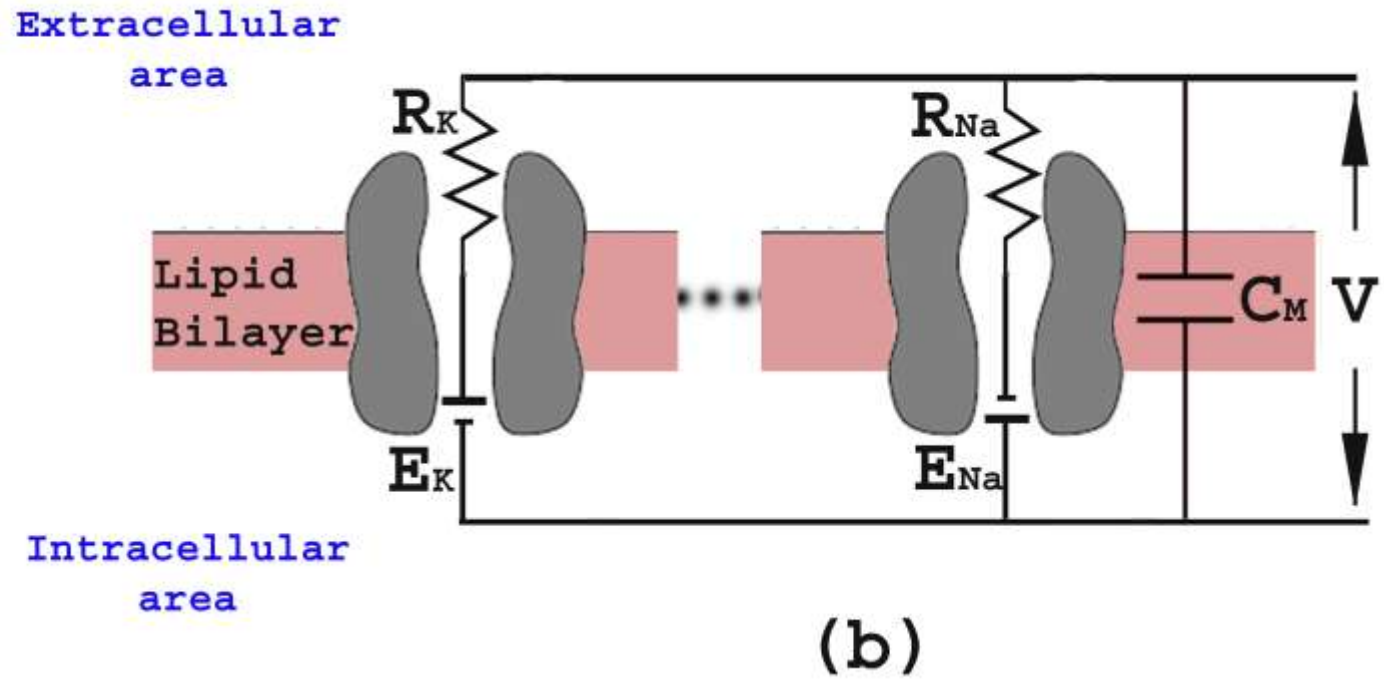
(BM 6140)

2-credit

Parallel conductance model

$$I_{inj} = i_c + i_{Na} + i_K$$

$$I_{inj} = C_m \frac{dV}{dt} + (V - E_K)g_K + (V - E_{Na})g_{Na}$$

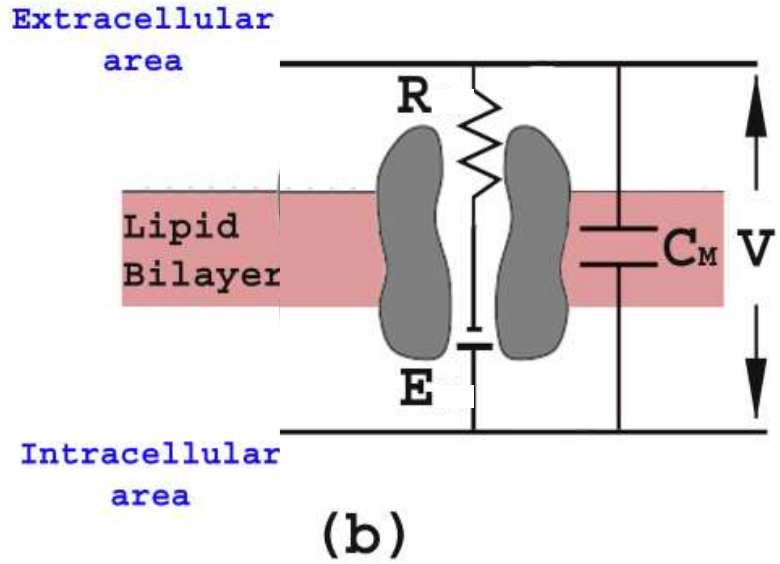


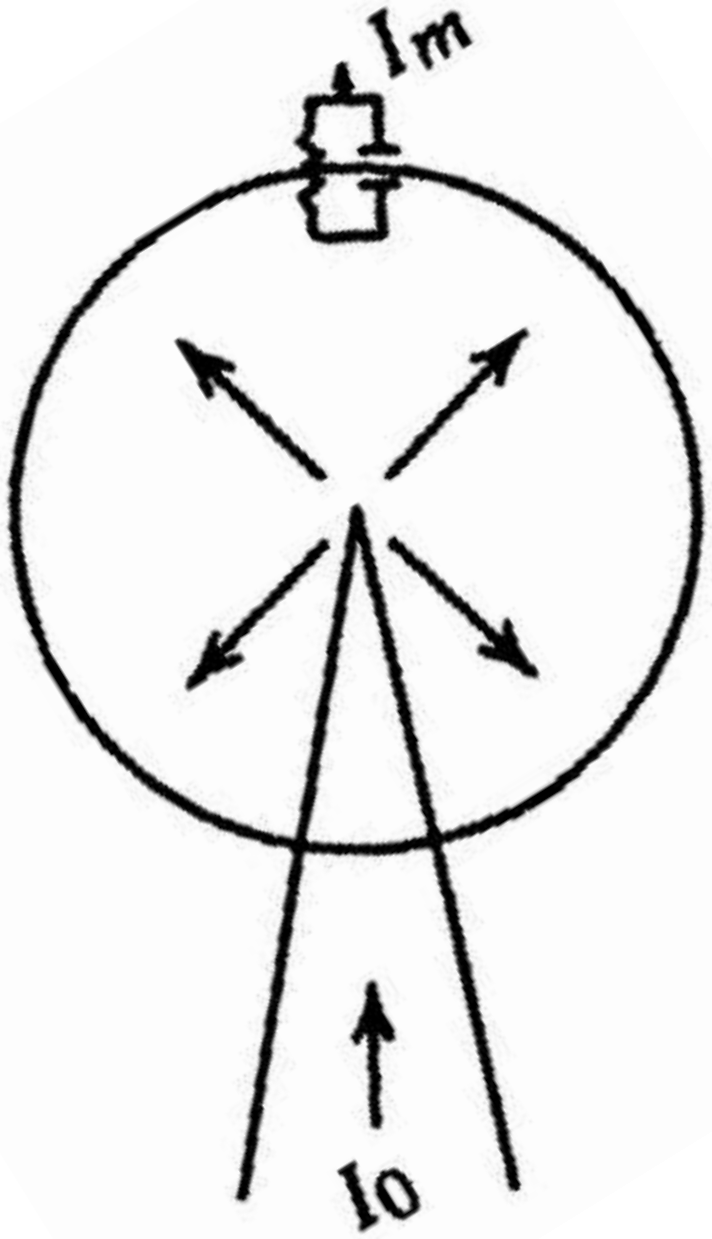
Current injection

Constant current I_{inj} injected for time t' and then turned off

Assume only a single leak conductance

Calculate V(t) ? $V = V_{in} - V_{out}$



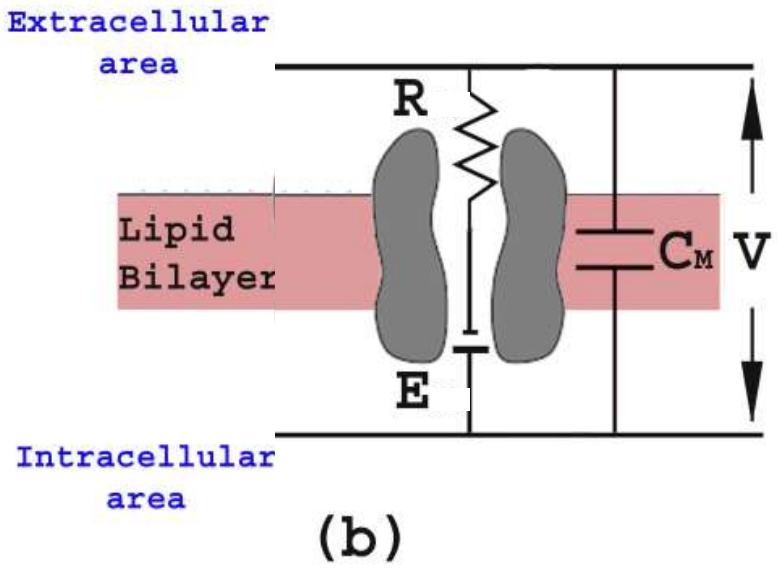


Johnston & Wu, Foundations of Cellular Neurophysiology

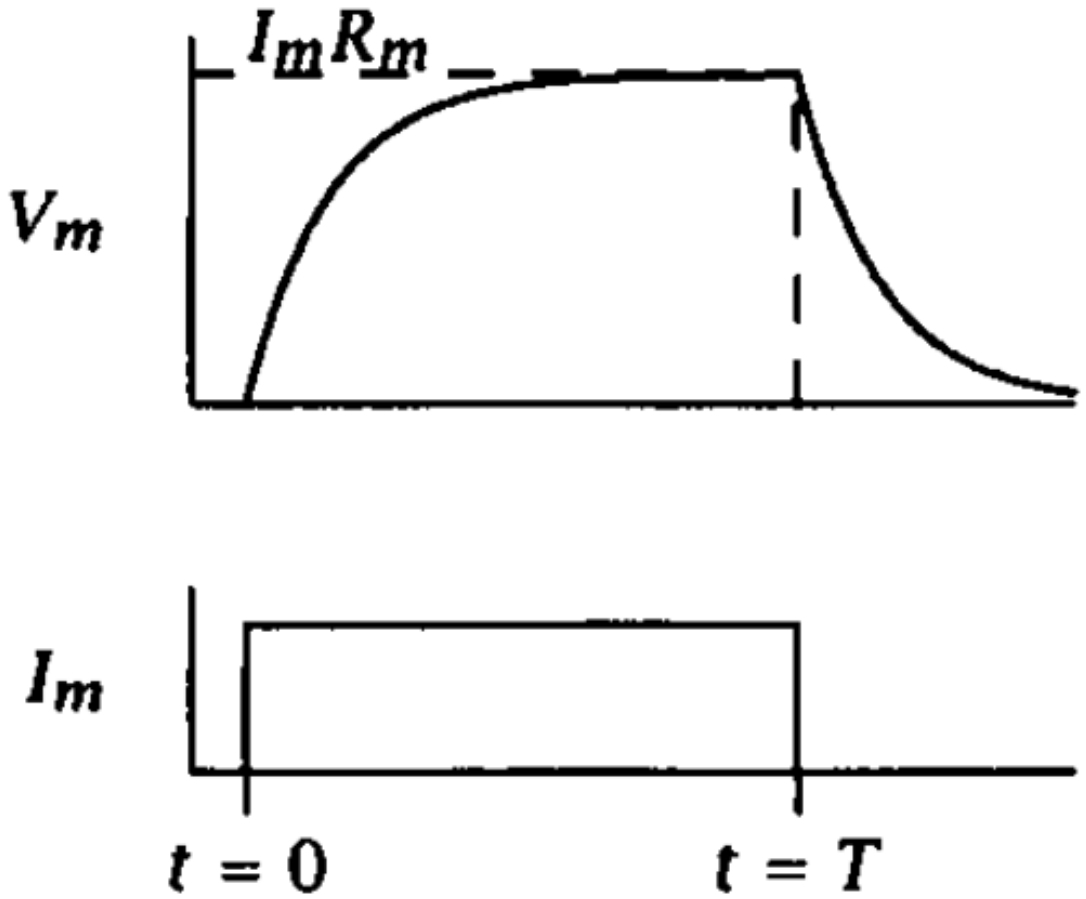
Applying Kirchoff….

$$I_{inj} = i_c + i_R$$

$$I_{inj} = C_m \frac{dV}{dt} + \frac{(V-E)}{R}$$



Membrane charging and discharging



Johnston & Wu, Foundations of Cellular Neurophysiology

Typical values of model parameters

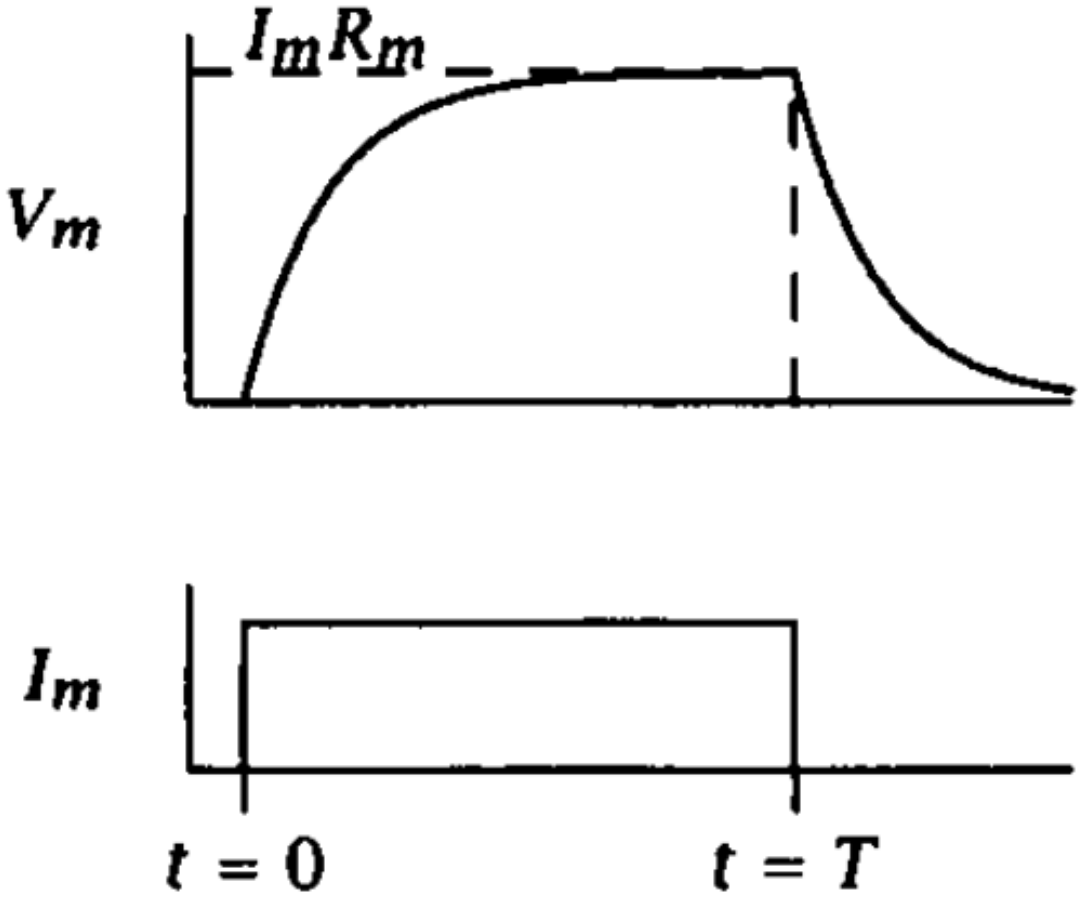
Specific membrane Capacitance = 1uF/cm^2

Specific membrane resistance due to pure lipid bilayer = 10^8 ohm.cm^2

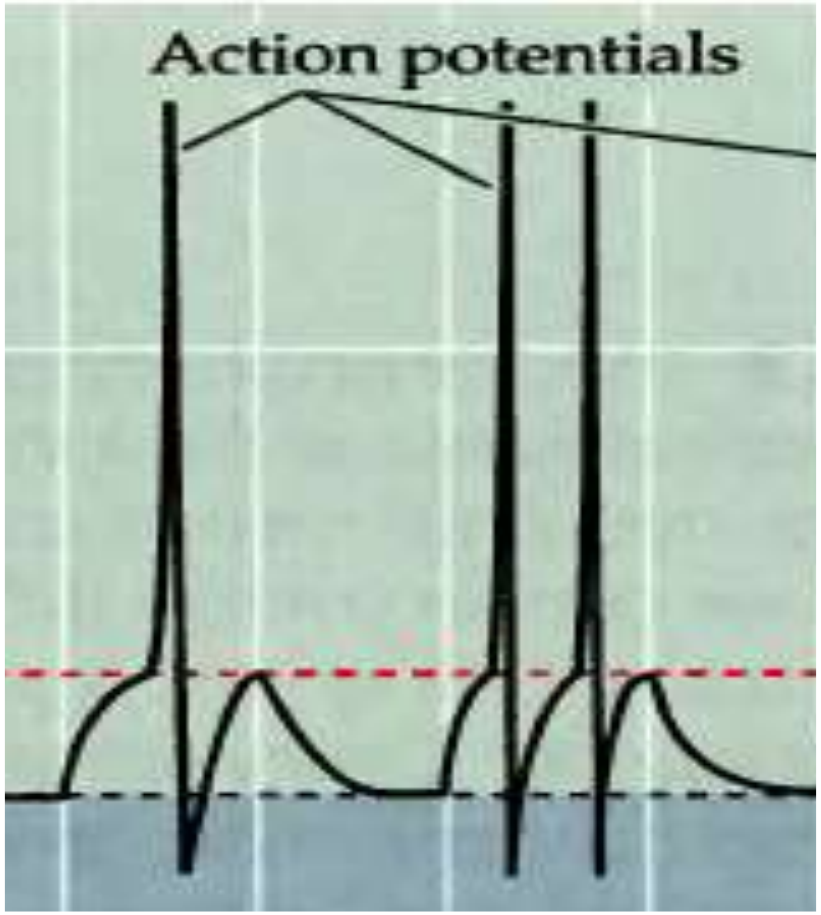
Specific Membrane R = 10^3 – 10^5 ohm.cm^2 (due to leak ion channels)

Typical time constant ?

Our models

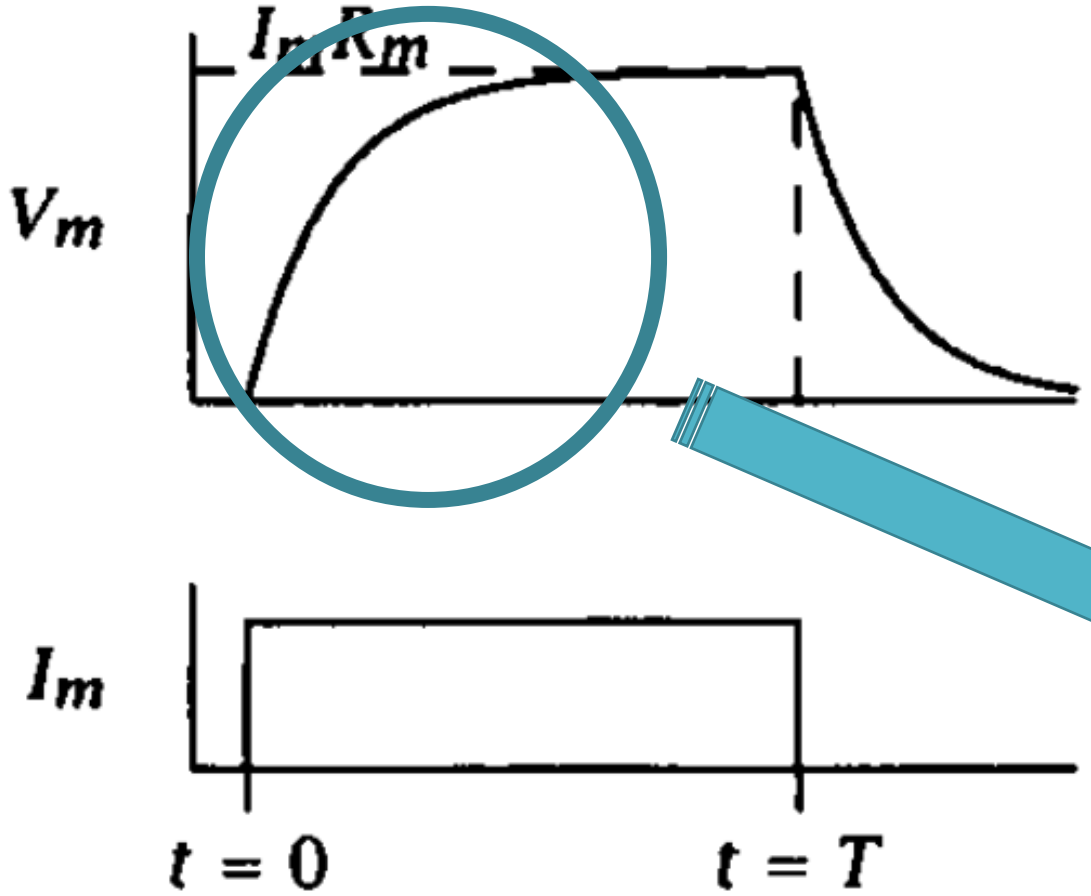


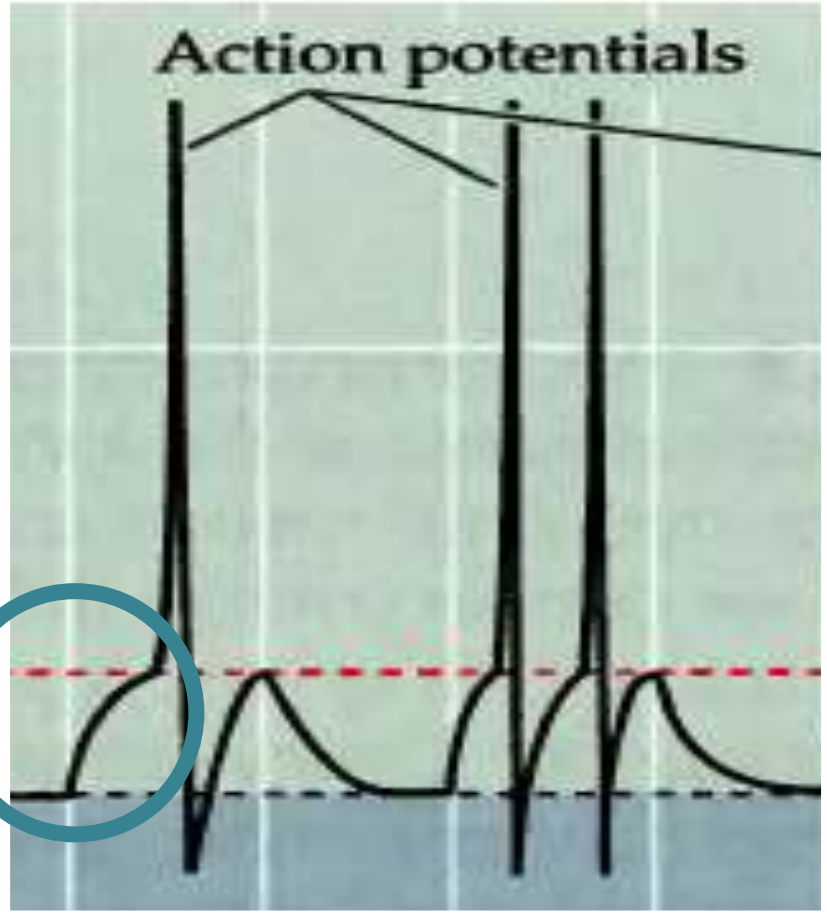
Real neurons



Where is the similarity between the two graphs ?? What is the difference ??

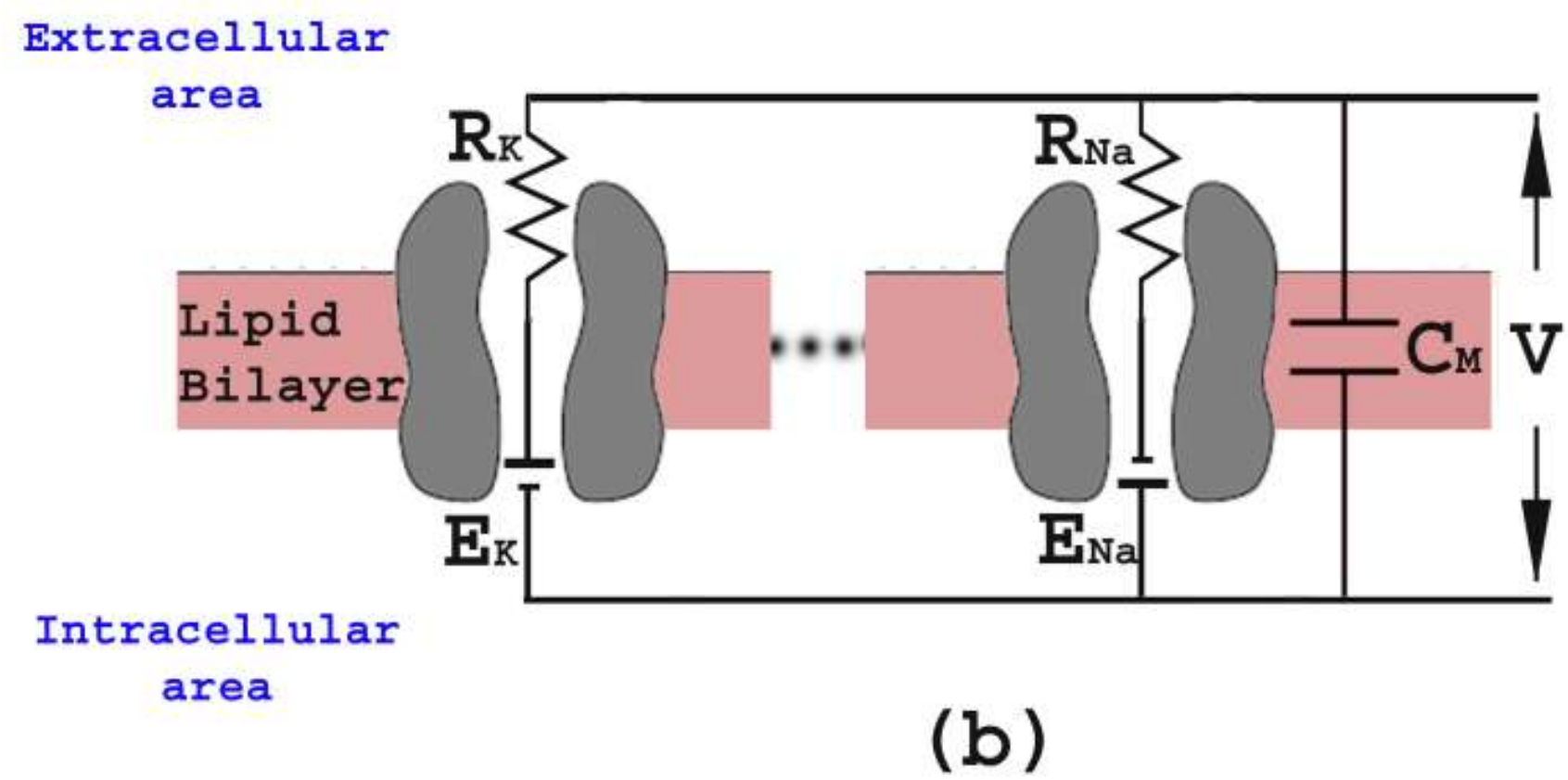
Why is our model unable to spike ?
Should we increase current injected ?



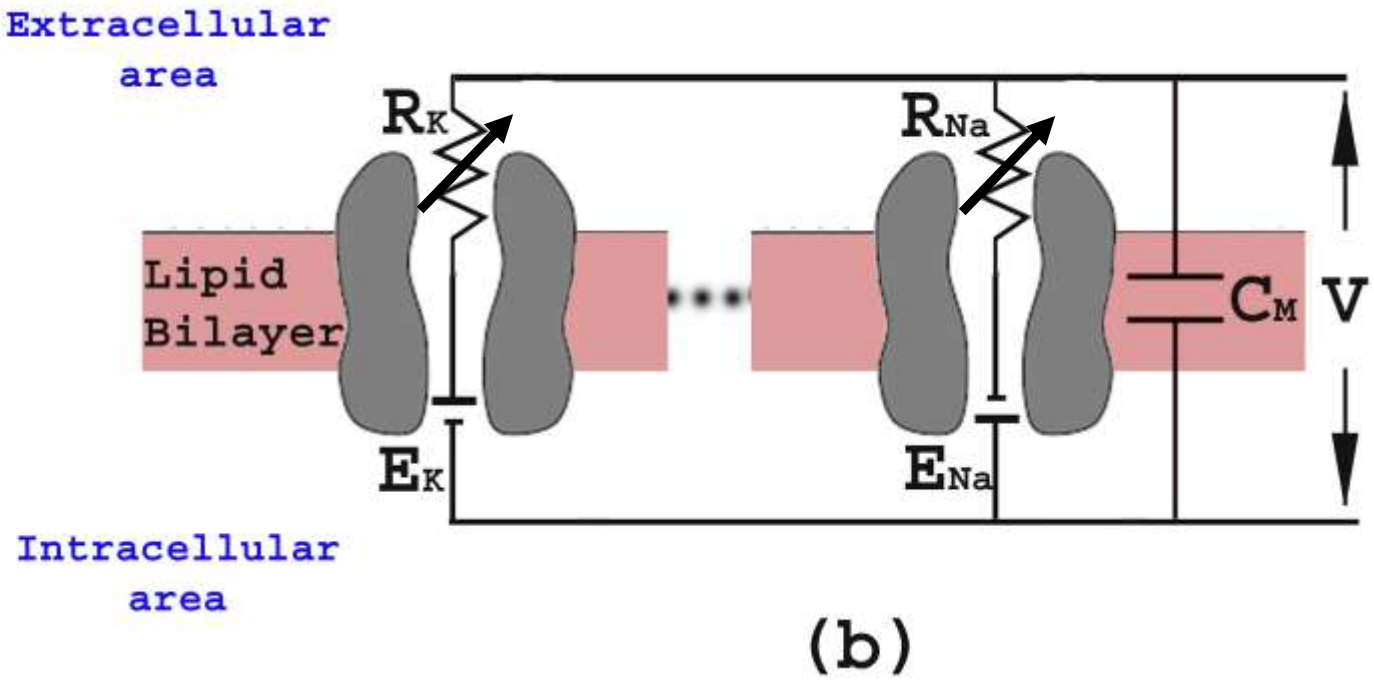


Beyond passive properties

We have till now hardly encountered the power of neurons !! Why ???



! Non-linearity !
Conductance varies with time, voltage and temperature



Why is non-linearity important for a neuron ?

Non-linear neurons

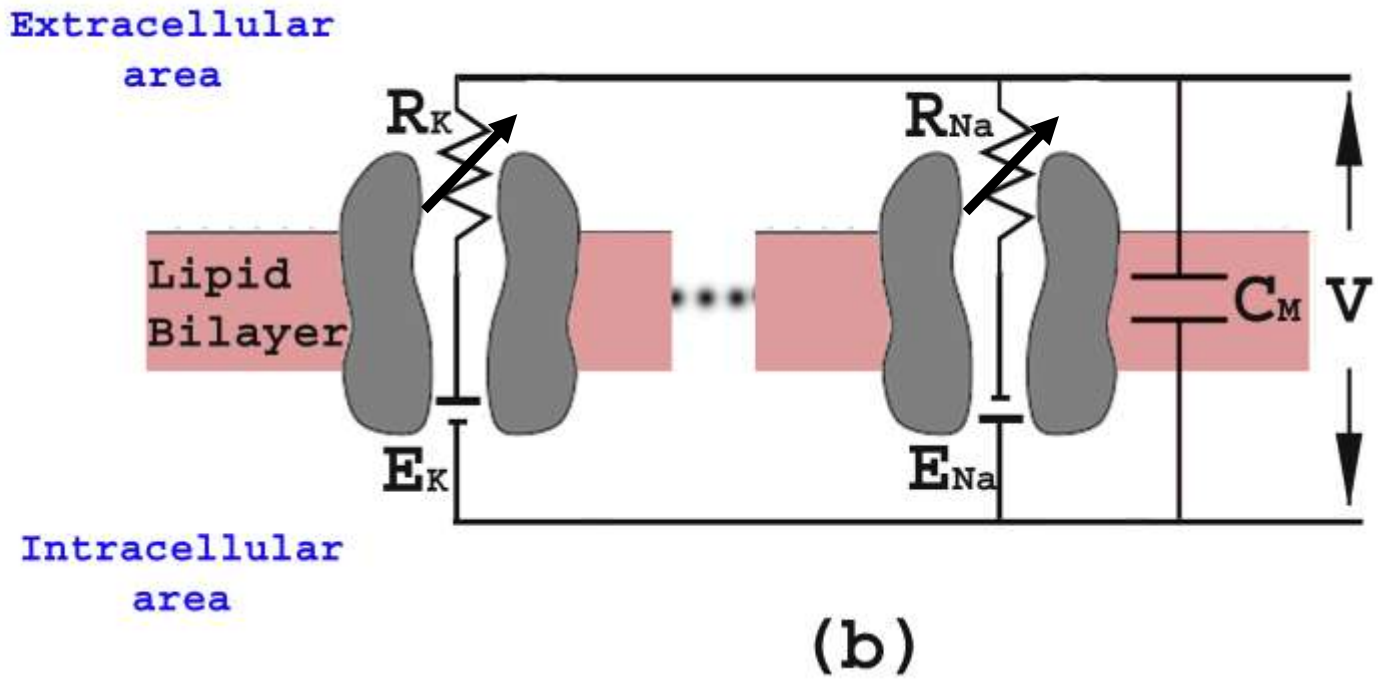
- Due to these non-linearities, small synaptic potentials sum up to cause a large action potential !
- Regenerate signal(AP) during propagation
- When I-V relation is non-linear membrane is said to be rectified. When conduction is better inwards, membrane is inward rectified. Similarly outward rectification may be defined

Modeling non linearity

$$I_{inj} = i_c + i_{Na} + i_K$$

$$I_{inj} = C_m \frac{dV}{dt} + (V - E_K)g_K + (V - E_{Na})g_{Na}$$

Now g_K and g_{Na} are functions of voltage, time and temperature !!



Quantitative analysis of AP : Hodgkin-Huxley

- Hodgin, Huxley 1952, series of papers
- Nobel prize (1963) in physiology or medicine