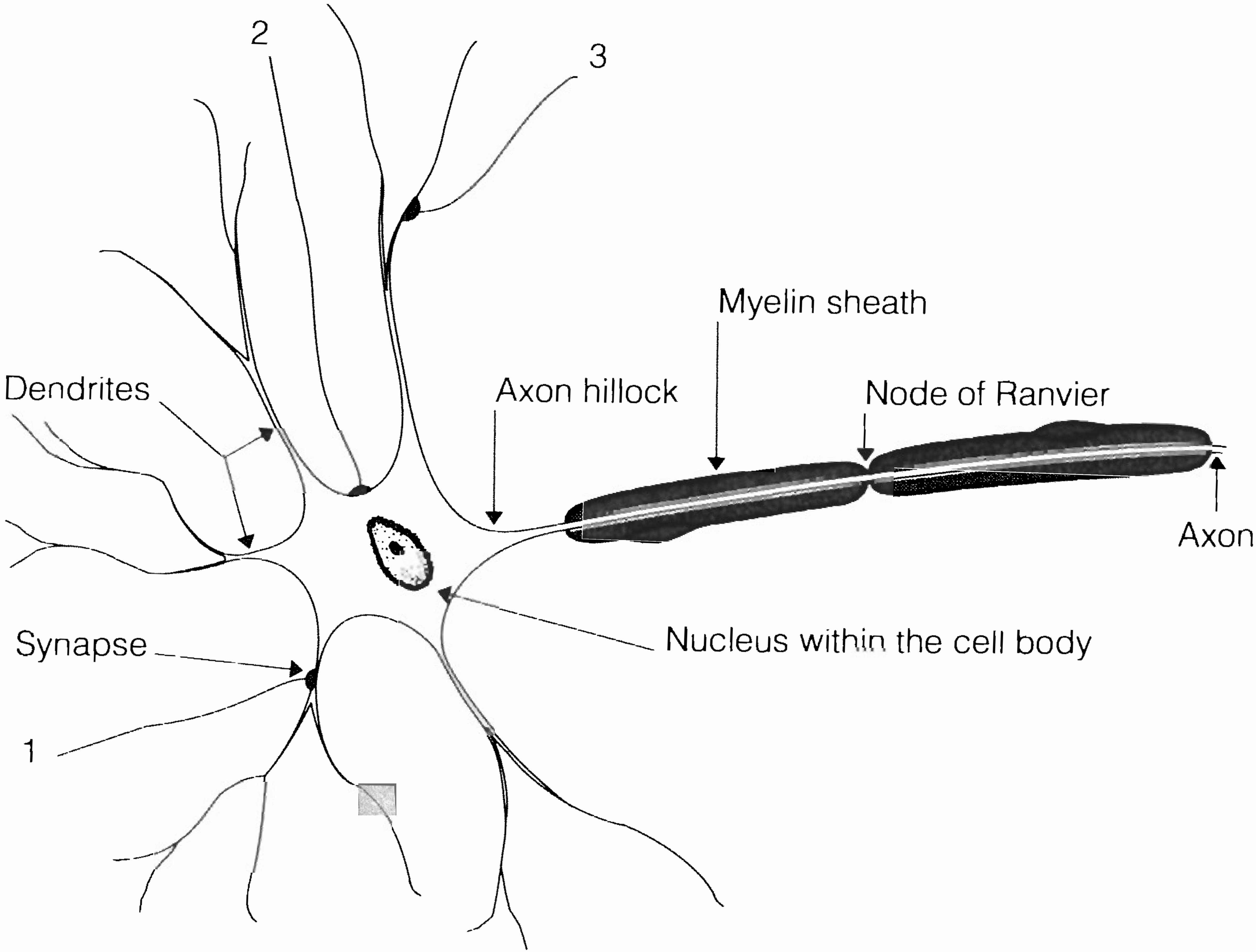
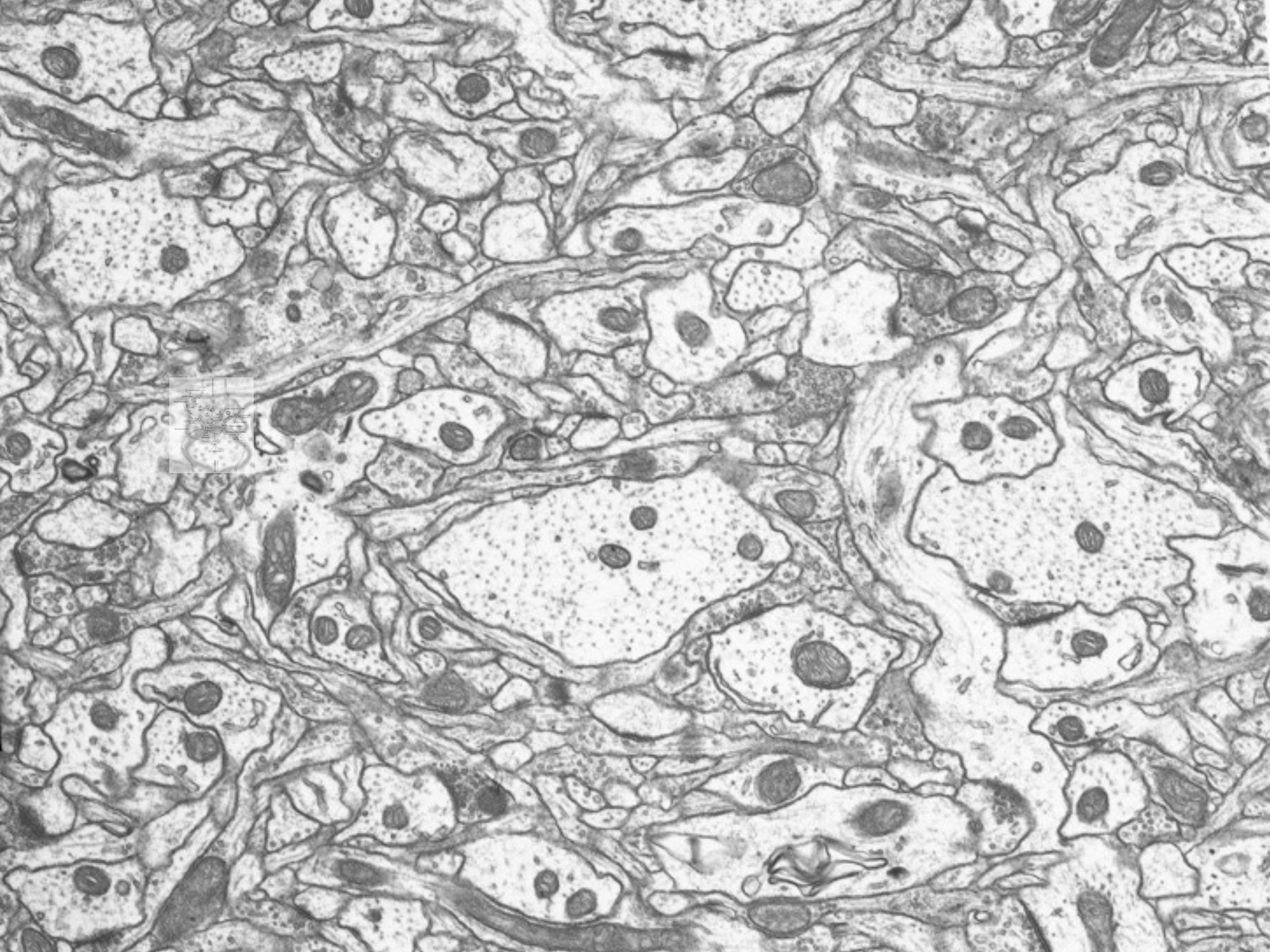
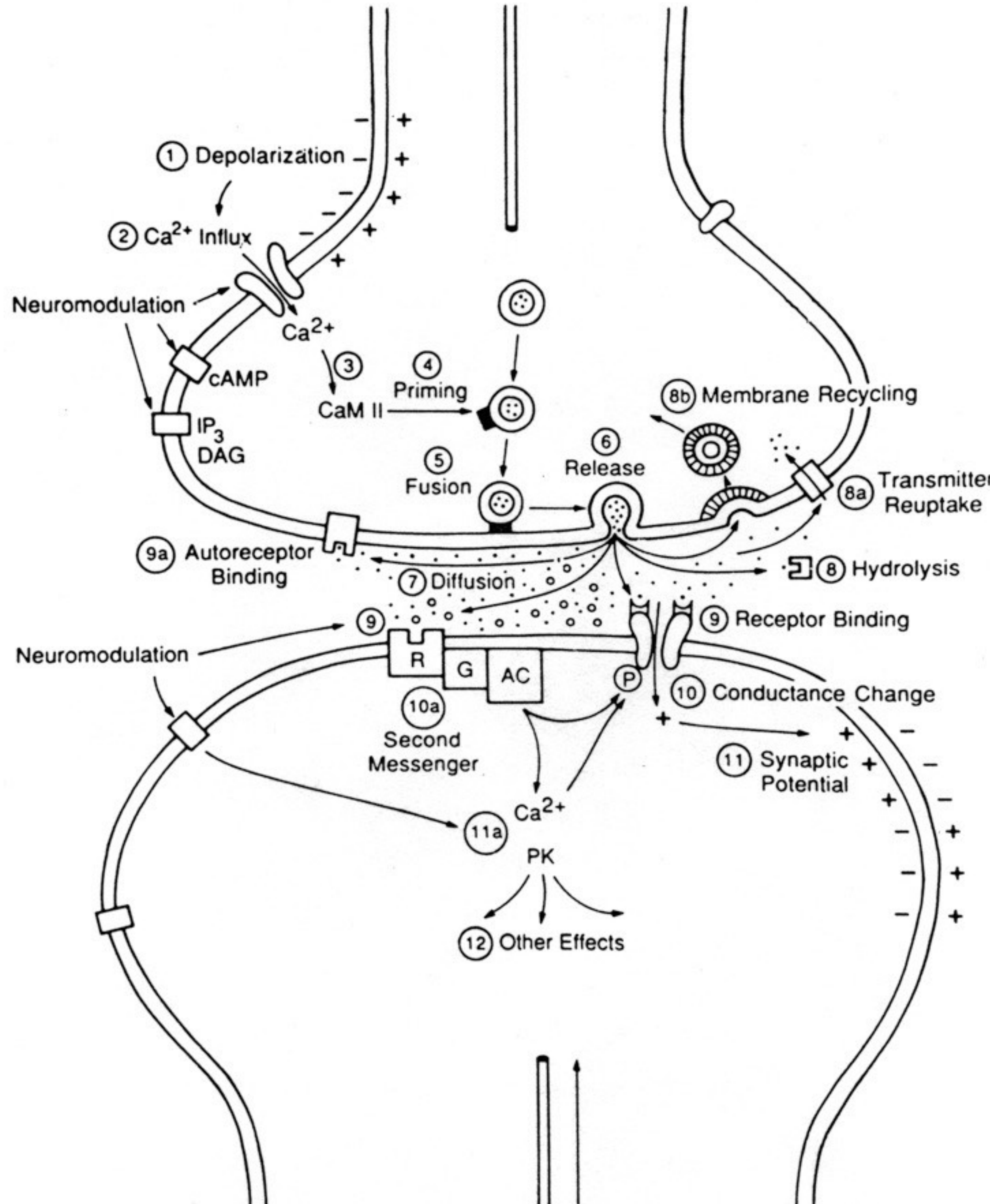
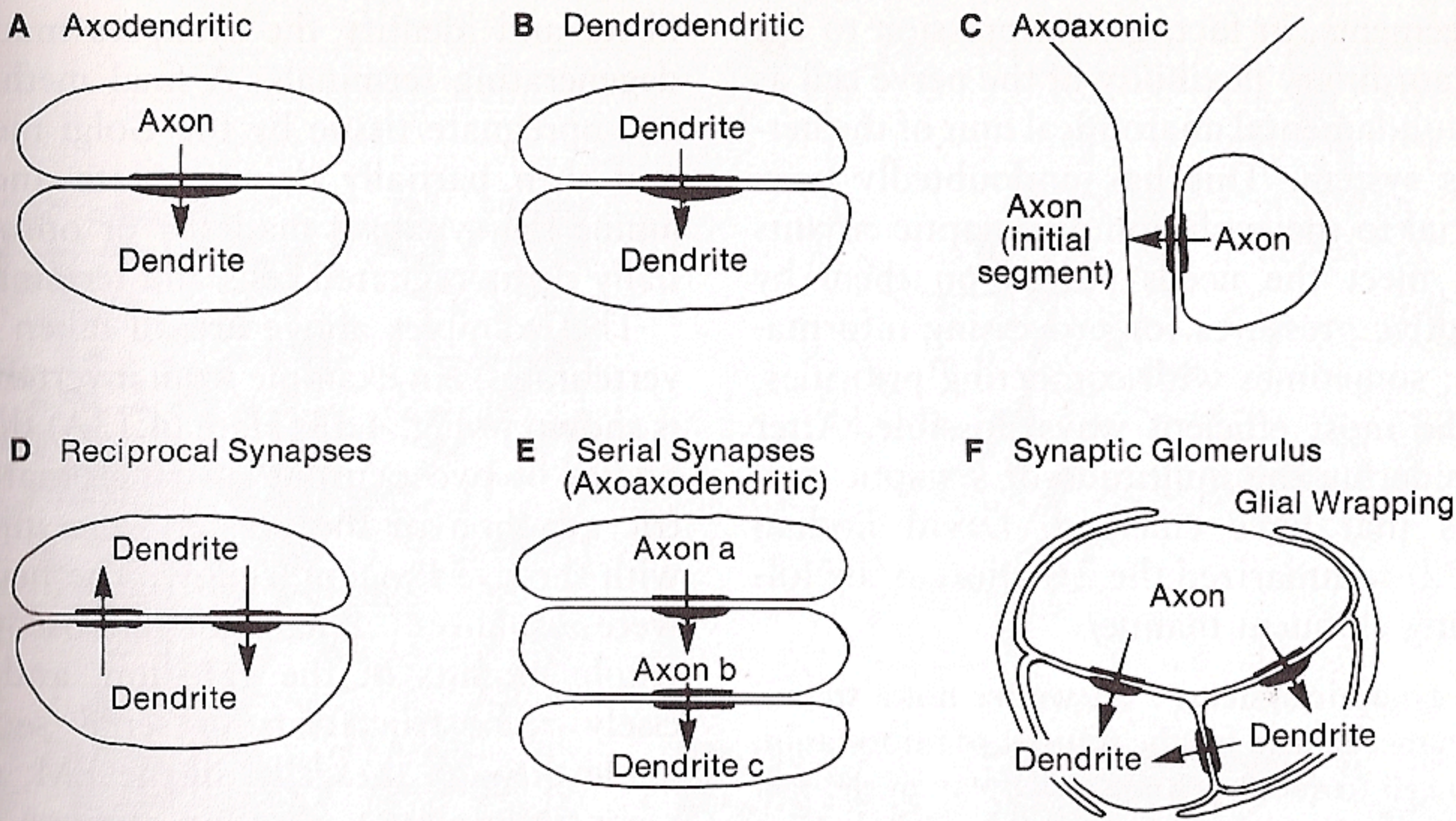

2
3
Myelin sheath
Dendrites
Axon hillock
Node of Ranvier
Axon
Synapse
Nucleus within the cell body
1

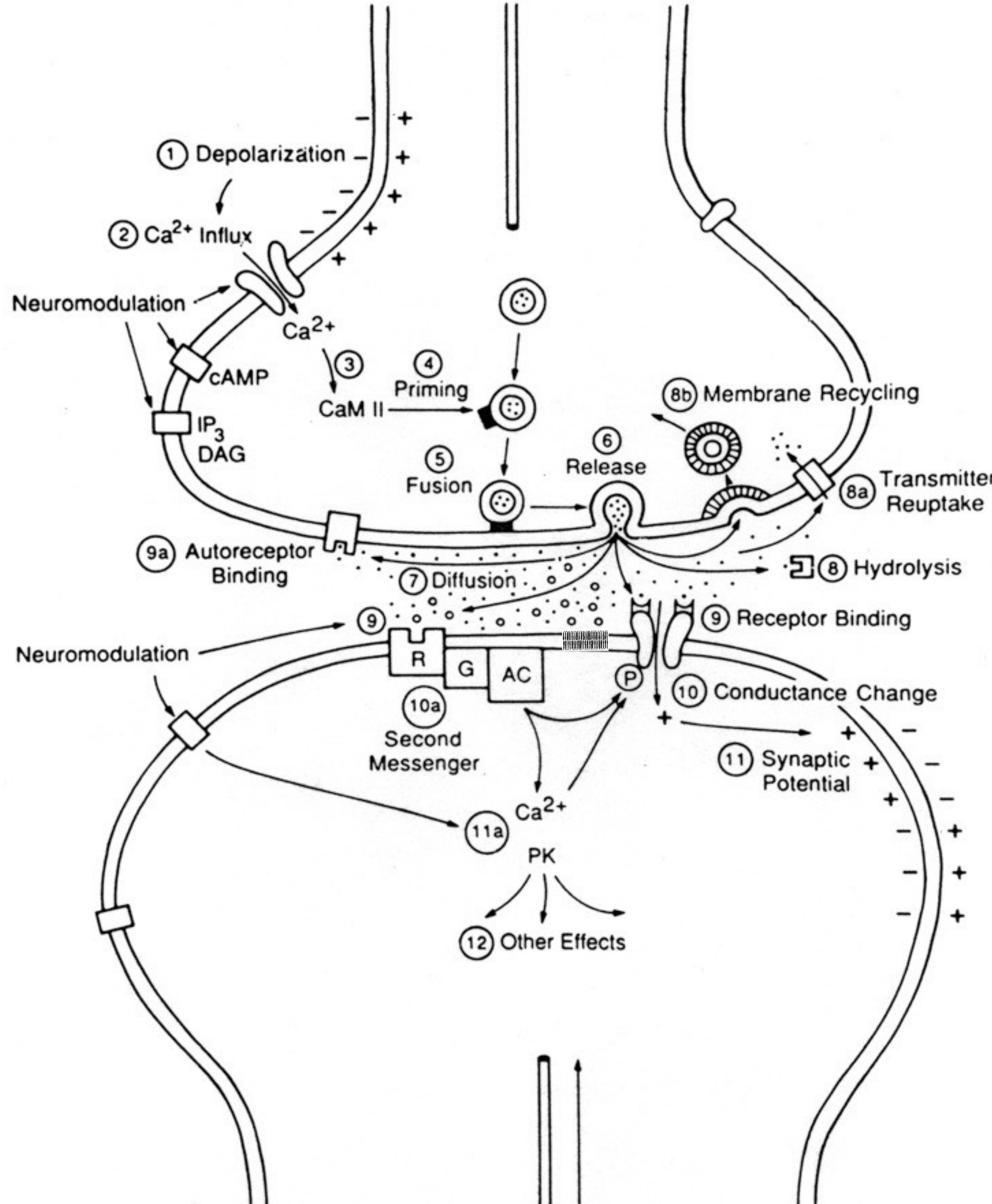


Anatomy of a synapse

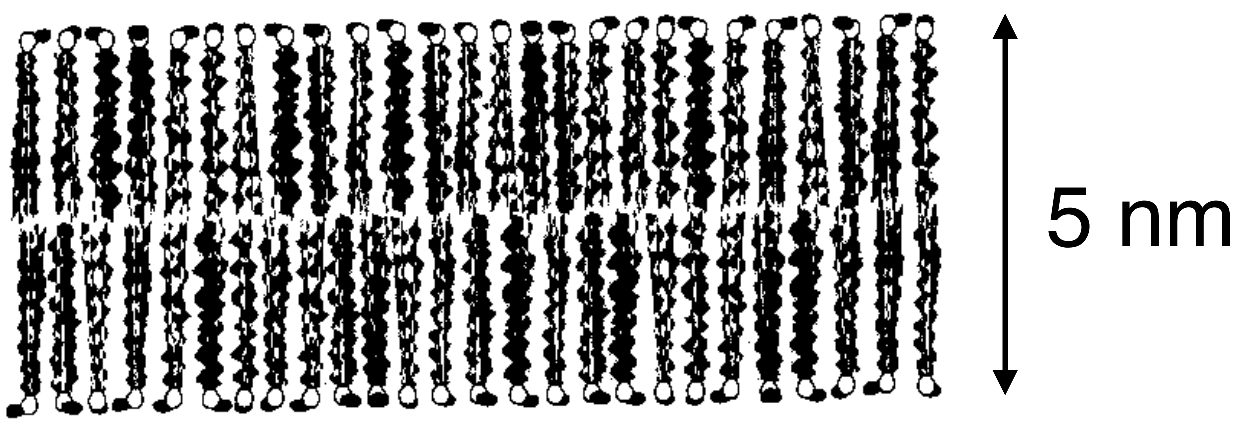



A Axodendritic
Axon
Dendrite
B Dendrodendritic
Dendrite
Dendrite
C Axoaxonic
Axon
(initial
segment)
Axon
D Reciprocal Synapses
Dendrite
Dendrite
E Serial Synapses
(Axoaxodendritic)
Axon a
Axon b
Dendrite c
F Synaptic Glomerulus
Glial Wrapping
Axon
Dendrite
Dendrite

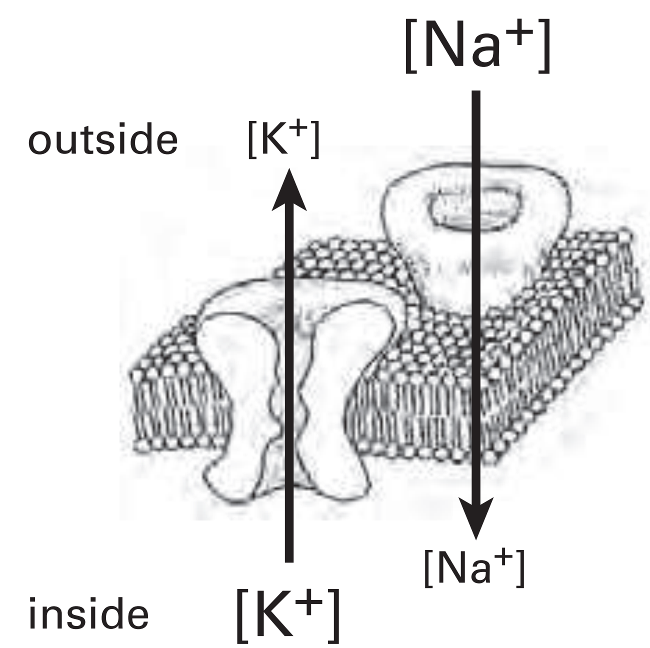
Anatomy of a synapse

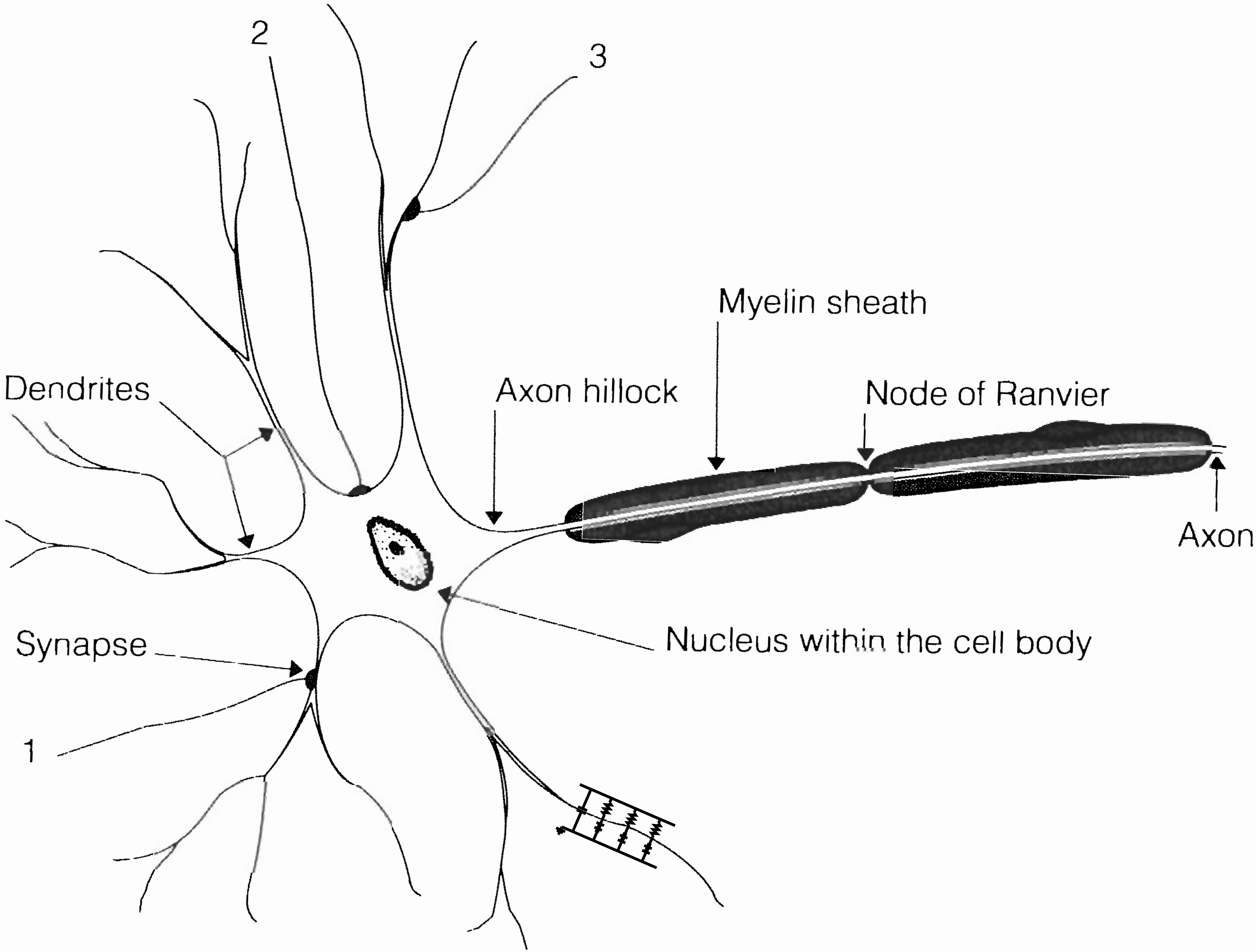


neuron membrane



ion channels

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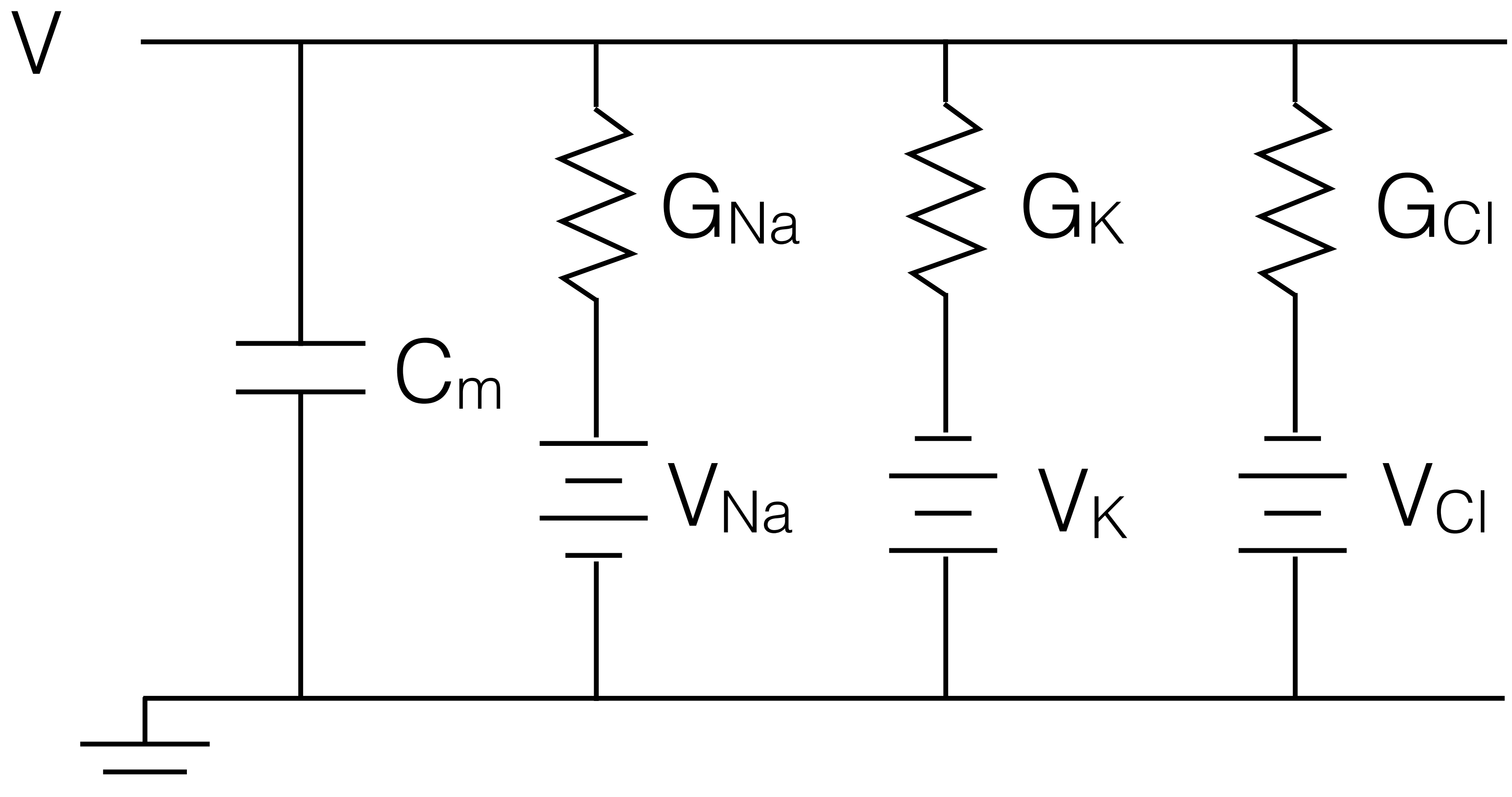
1

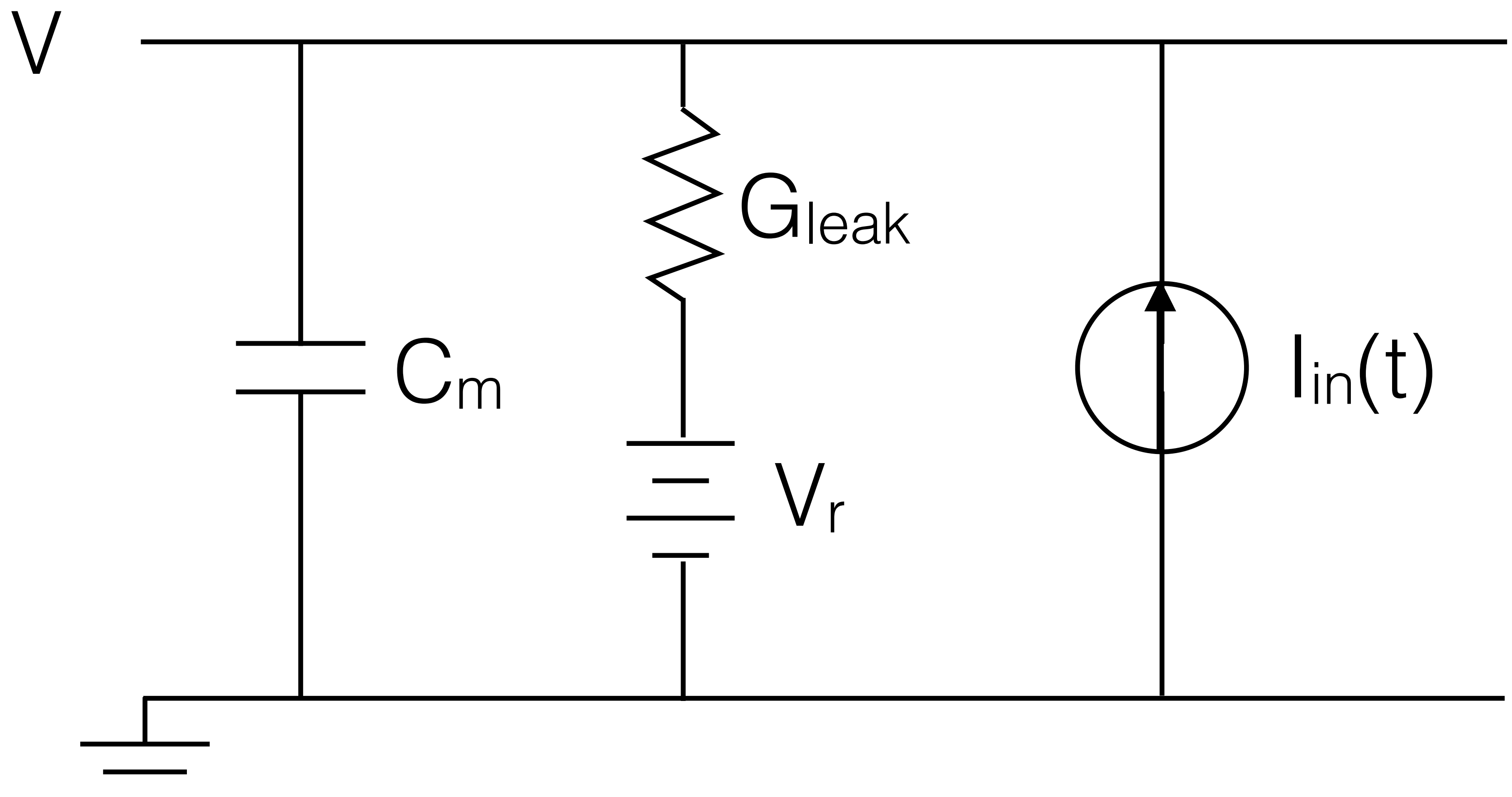
Membrane equation



$$\tau \frac{dV}{dt} + V = \frac{V_{Na}\, G_{Na} + V_K\, G_K + V_{Cl}\, G_{Cl}}{G_{\text{total}}}$$

$$G_{\text{total}} = G_{Na} + G_K + G_{Cl} \qquad \tau = \frac{C_m}{G_{\text{total}}}$$

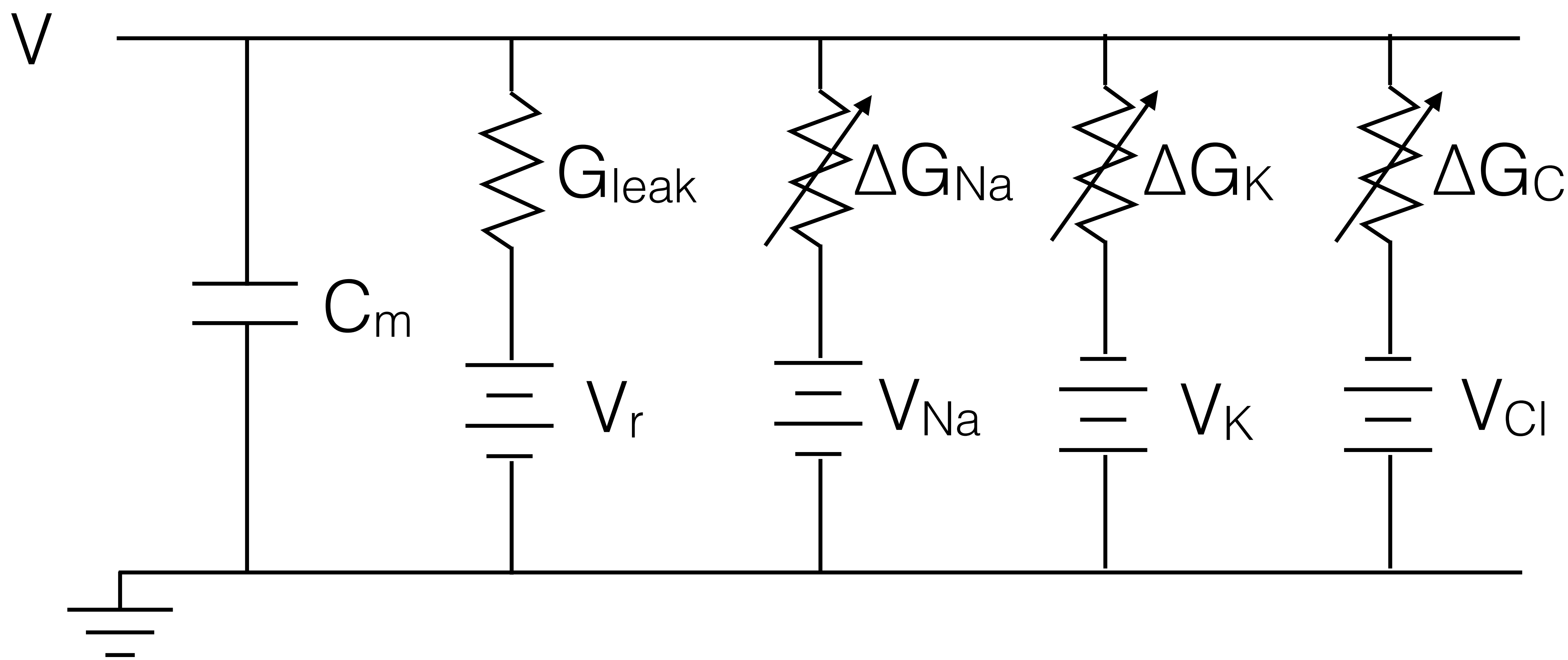
Membrane with input current



$$\tau \frac{dV}{dt} + V = V_r + \frac{1}{G_{\text{leak}}} I_{\text{in}}(t)$$

$$G_{\text{leak}} = G_{Na} + G_K + G_{Cl} \qquad \tau = \frac{C_m}{G_{\text{leak}}}$$

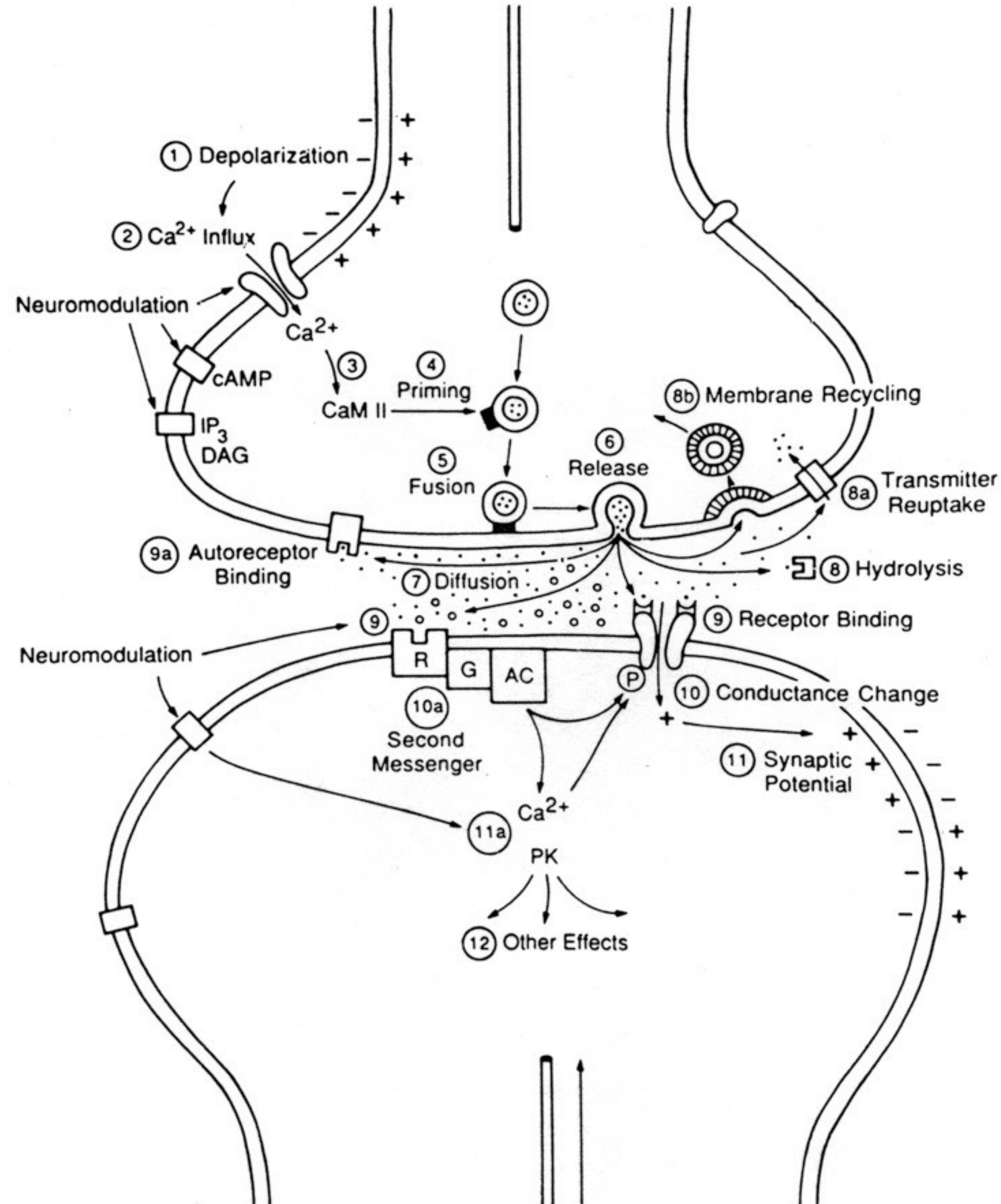
Membrane with synaptic inputs



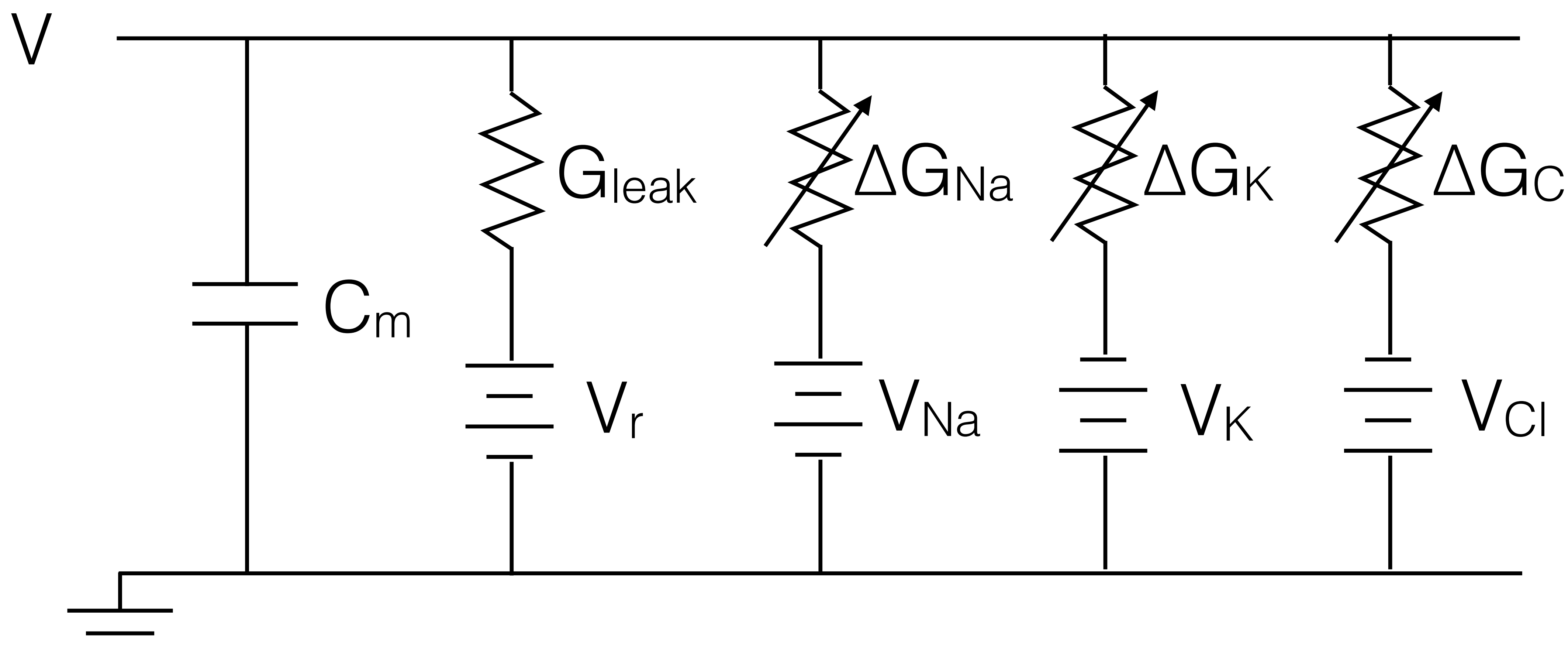
$$\tau \frac{dV}{dt} + V = \frac{V_r\, G_{\text{leak}} + V_{Na}\, \Delta G_{Na} + V_K\, \Delta G_K + V_{Cl}\, \Delta G_{Cl}}{G_{\text{total}}}$$

$$G_{\text{total}} = G_{\text{leak}} + \Delta G_{Na} + \Delta G_K + \Delta G_{Cl} \qquad \tau = \frac{C_m}{G_{\text{total}}}$$

Anatomy of a synapse

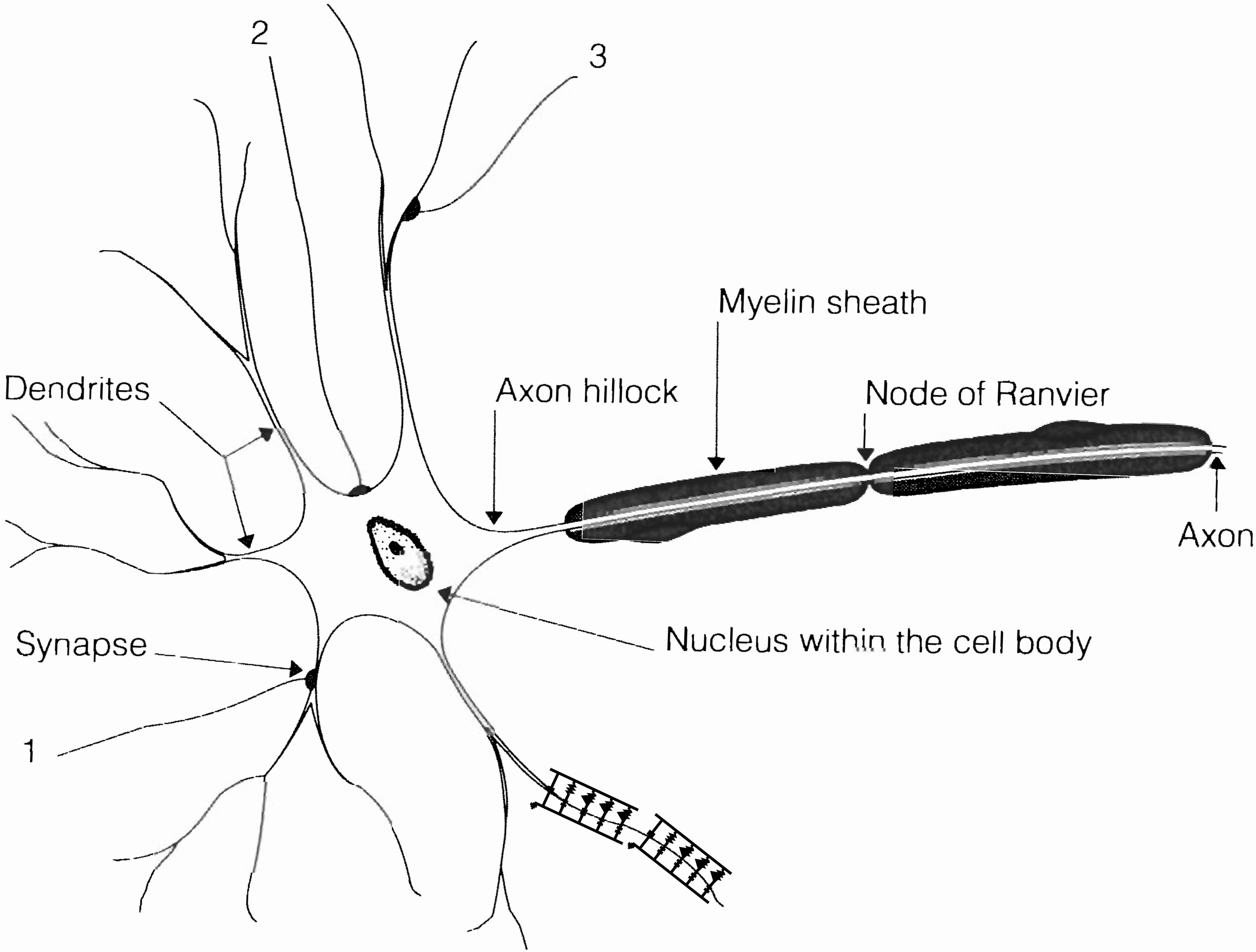


Membrane with synaptic inputs



$$\tau \frac{dV}{dt} + V = \frac{V_r \, G_{\text{leak}} + V_{Na} \, \Delta G_{Na} + V_K \, \Delta G_K + V_{Cl} \, \Delta G_{Cl}}{G_{\text{total}}}$$

$$G_{\text{total}} = G_{\text{leak}} + \Delta G_{Na} + \Delta G_K + \Delta G_{Cl} \qquad \tau = \frac{C_m}{G_{\text{total}}}$$



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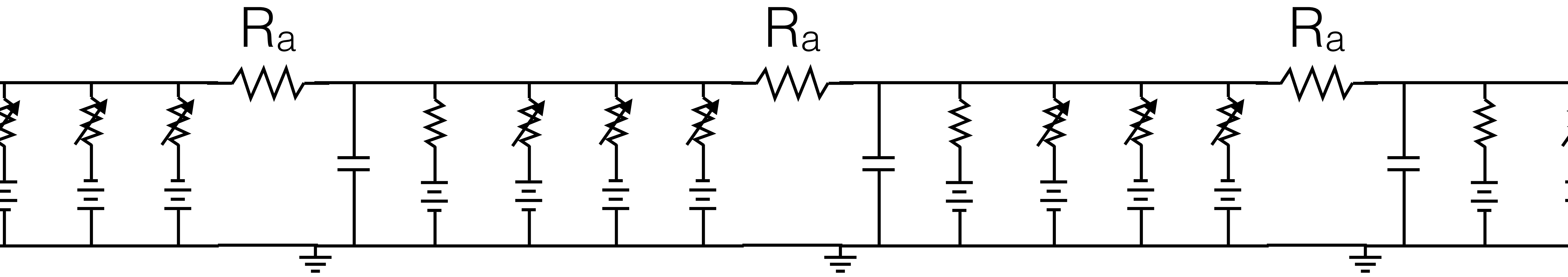
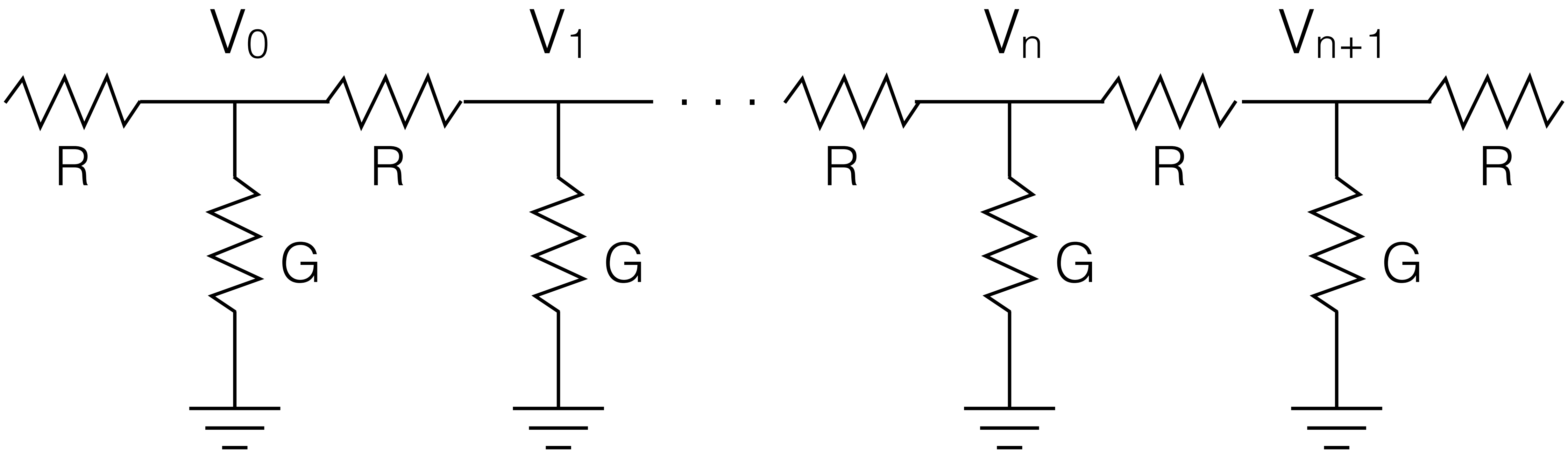

Ra
Ra
Ra

Resistive network

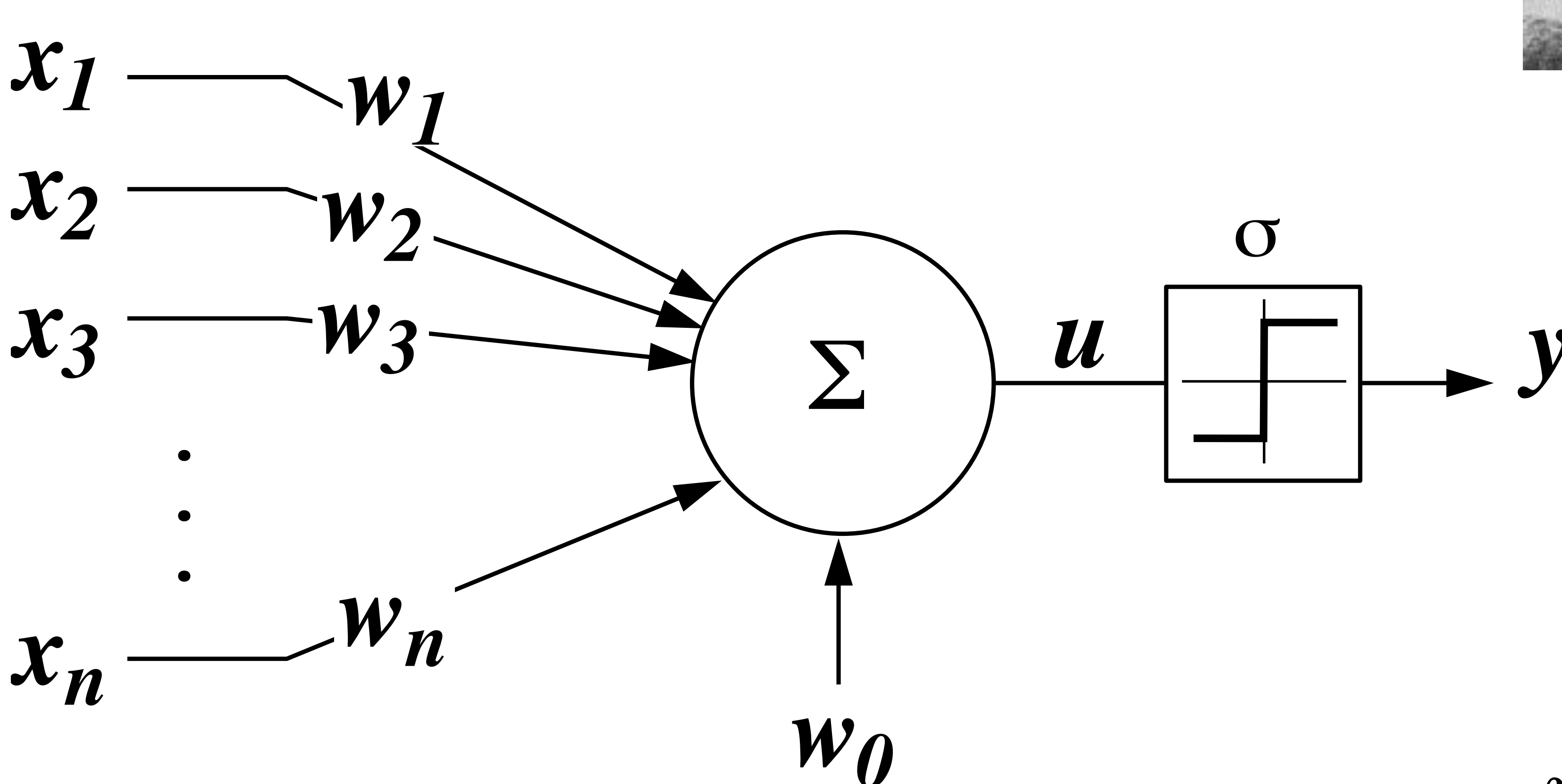


$$\left.\begin{aligned}\frac{dV}{dx} &= -I\,R \\ \frac{dI}{dx} &= -V\,G\end{aligned}\right\}$$

$$\frac{d^2V}{dx^2} = R\,G\,V$$

$$V = V_0\,e^{-\frac{|x|}{L}} \qquad L = 1/\sqrt{R\,G}$$

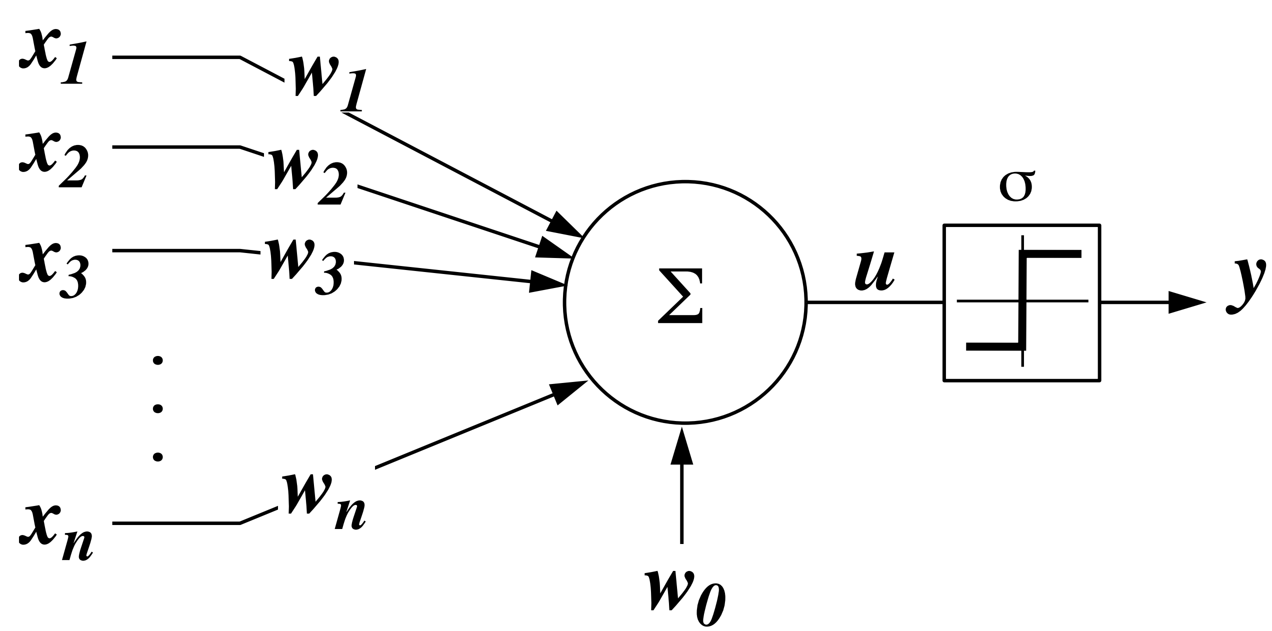
Perceptron model
(Rosenblatt, ca. 1960)



$$u = w_0 + \sum_{i=1}^{n} w_i \, x_i$$

$$y = \sigma(u)$$

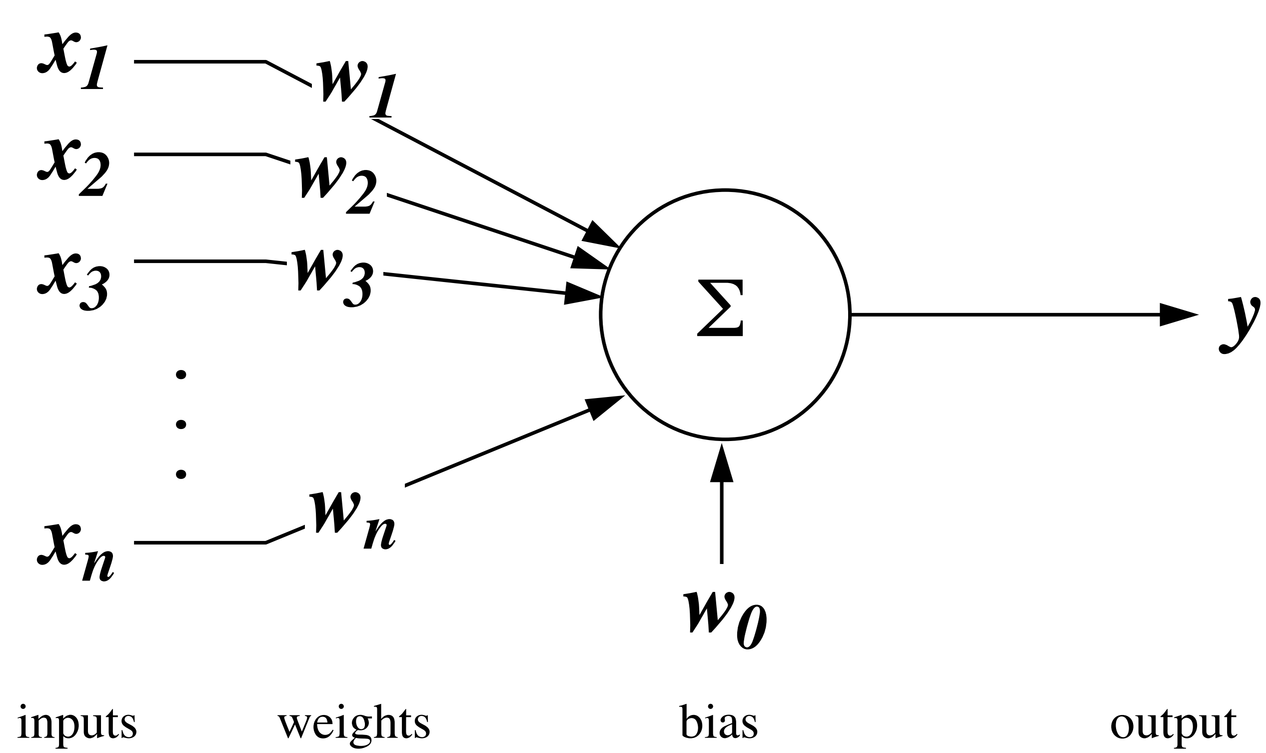
Perceptron learning rule
(Rosenblatt 1962)



$$\Delta w_k = \begin{cases} 2\eta\, T^{(\alpha)}\, x_k^{(\alpha)} & y^{(\alpha)} \neq T^{(\alpha)} \\ 0 & \text{otherwise} \end{cases}$$

$$= \eta\left(T^{(\alpha)} - y^{(\alpha)}\right) x_k$$

Linear neuron learning rule
(Widrow & Hoff 1960)



Objective function ⟶ Learning rule

$$E = \frac{1}{2} \sum_{\alpha} \left[T^{(\alpha)} - y^{(\alpha)} \right]^2$$

$$\begin{aligned} \Delta w_k &= -\eta \frac{\partial E}{\partial w_k} \\ &= \eta \sum_{\alpha} \delta^{(\alpha)} \, x_k^{(\alpha)} \\ \delta^{(\alpha)} &= T^{(\alpha)} - y^{(\alpha)} \end{aligned}$$