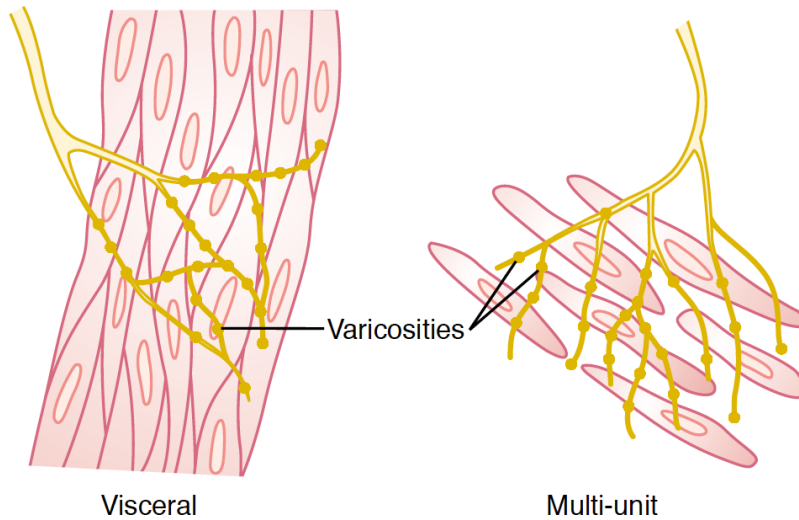


Impulse Propagation

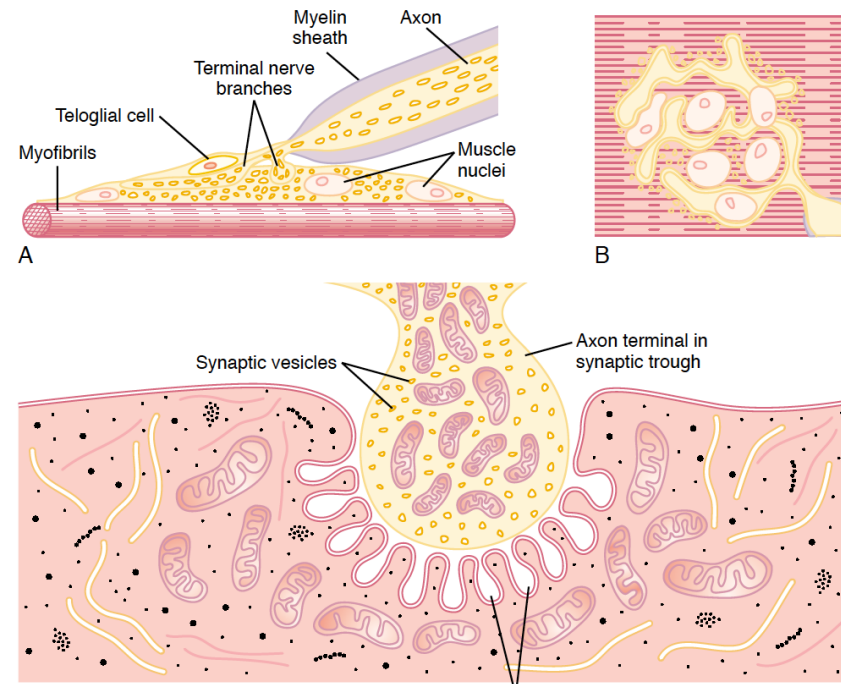
Bioeng 6460
Electrophysiology and Bioelectricity
Derek Dossall
Derek.Dossall@carma.utah.edu

Activation Spread by Tissue Type

- Smooth muscle

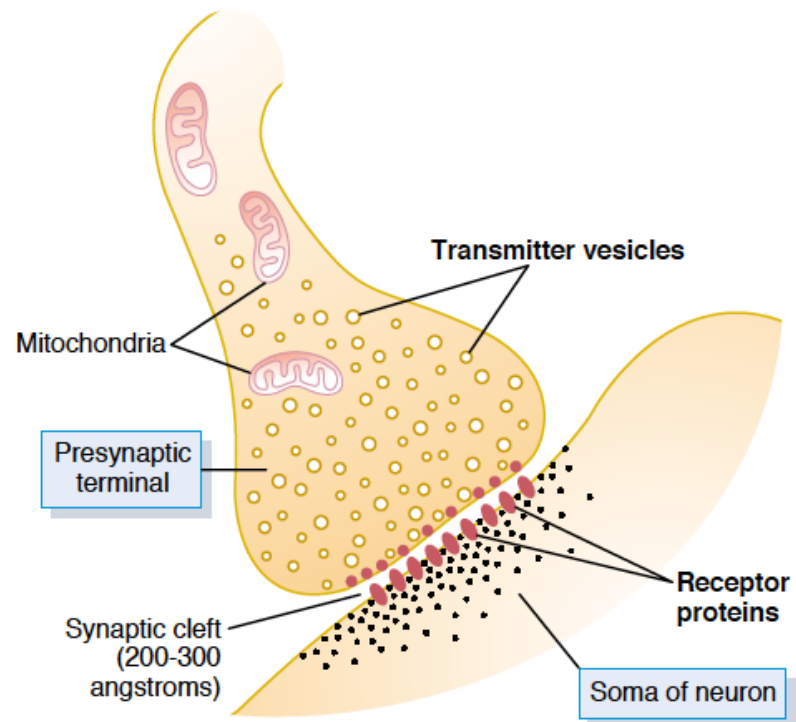
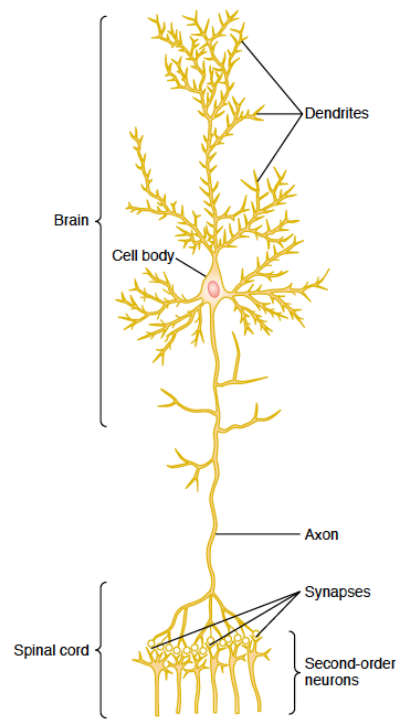


- Skeletal muscle



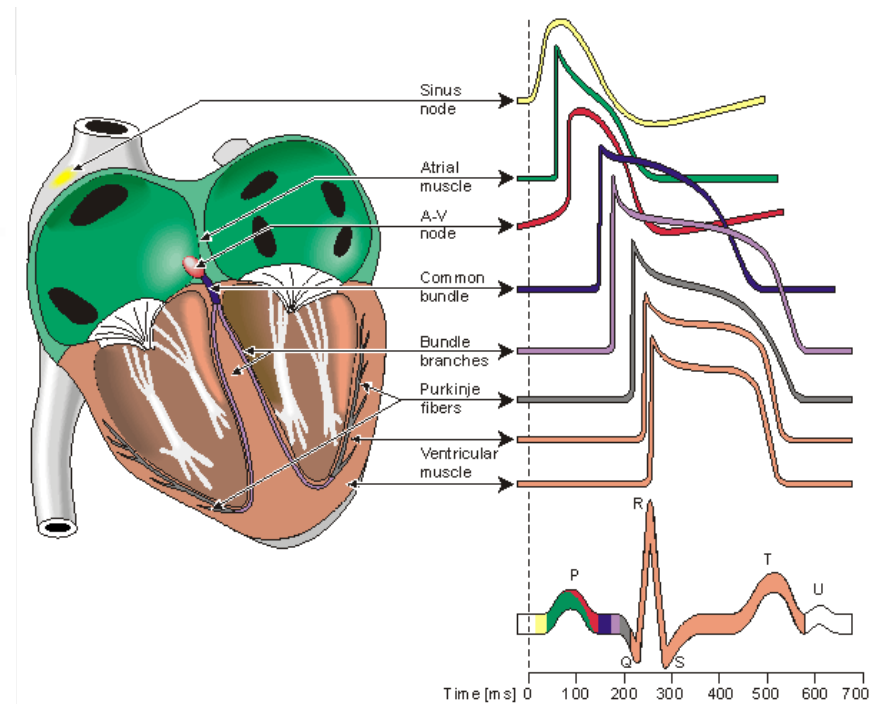
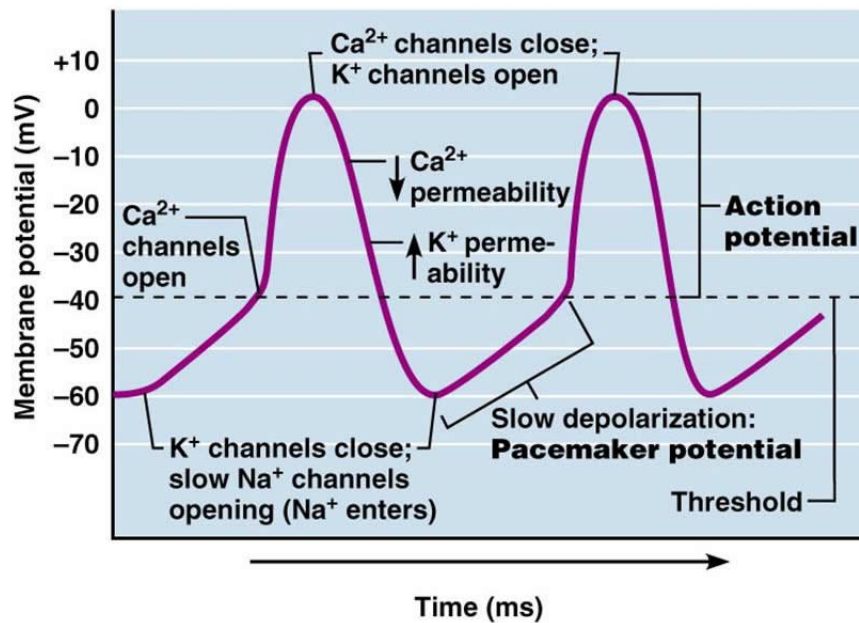
Tissue Types Continued

- Neuron to neuron conduction

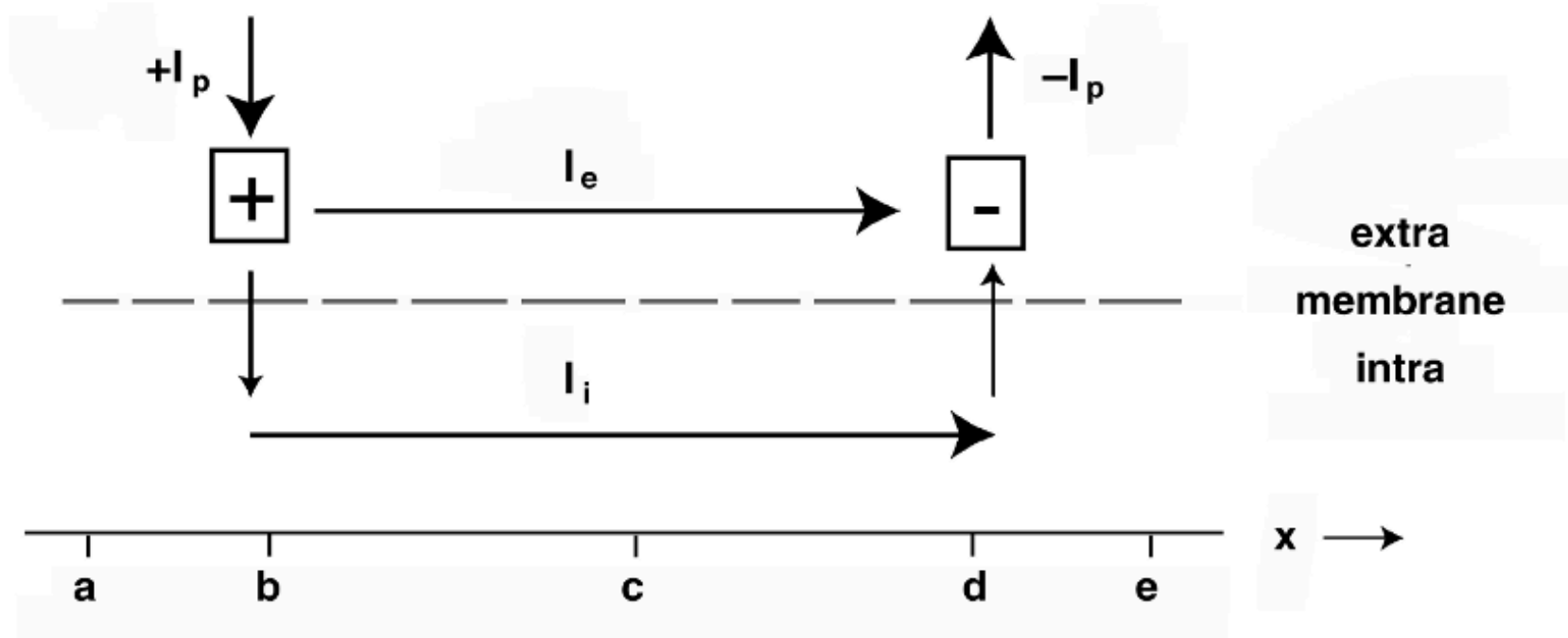


Tissue Types Continued

- Cardiac



Electrical Stimulation

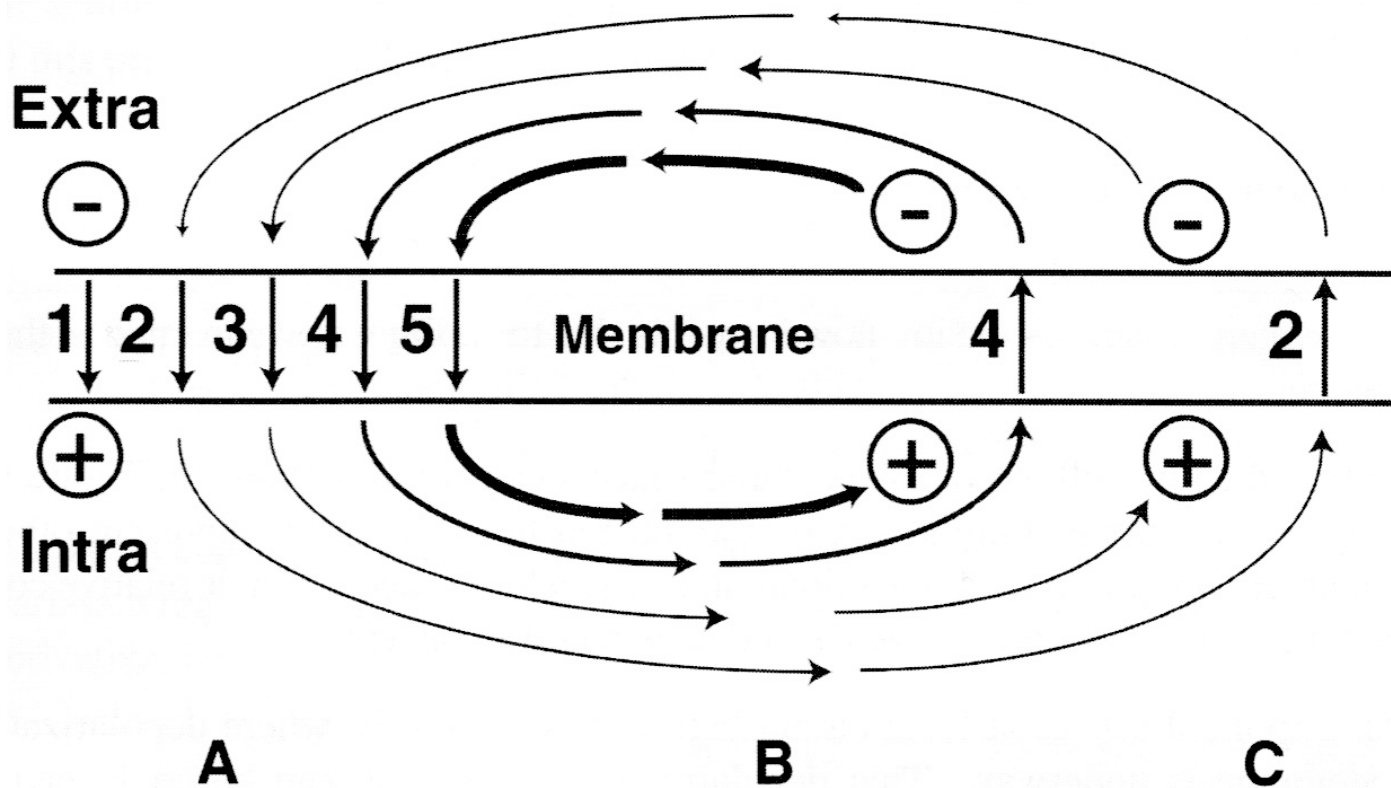


I at a and $e = 0$

I_m at $b = -I_m$ at d

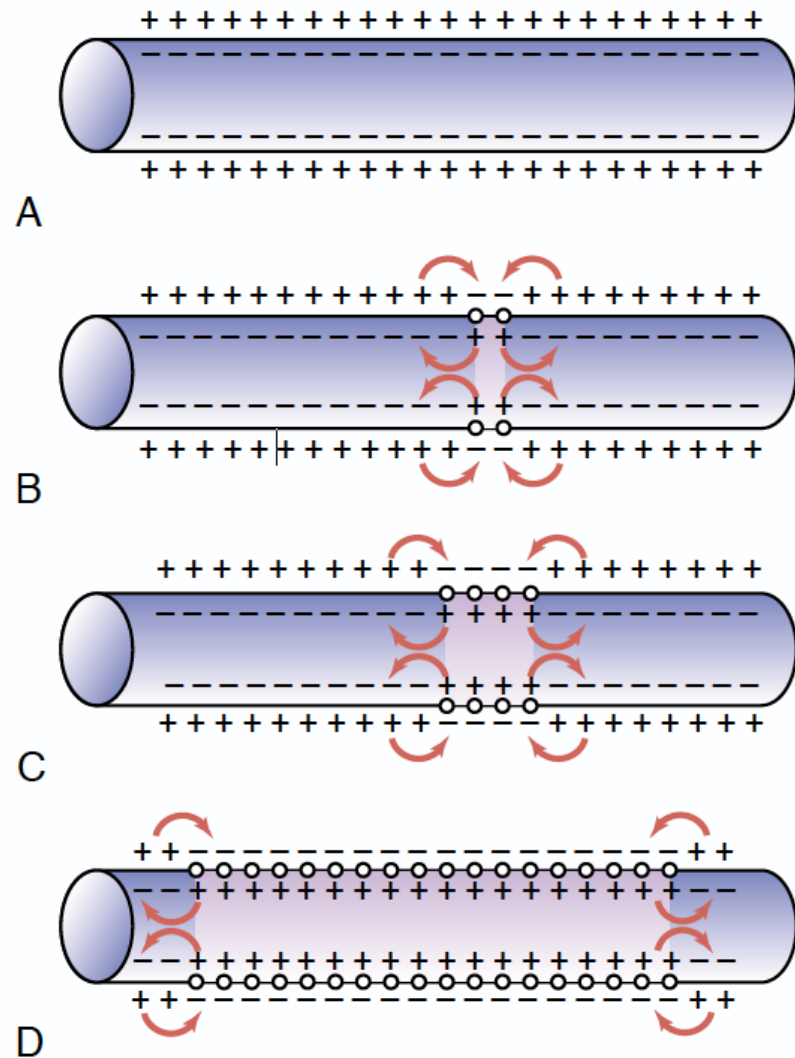
I_m at $c = 0$

After activation starts...



I_i causes propagation

- One area of I_m causes adjacent Na channels to open
- Activation can spread in both directions



Propagation Models

Thevirtualheart.org

Java scripts, modify ion conductance

The screenshot shows a web browser window with the URL <http://thevirtualheart.org/>. The page features a navigation menu on the left with buttons for Home, Cardiac Rhythms, Cardiac Anatomy, Java Applets, 3D Museum, Movies, Who We Are, Publications, Awards & News, Links, and Contact. The main content area is titled "Java Applets" and includes a sub-menu with options: Introduction, Ions, Cardiac Models, Cell dynamics, 1D dynamics, Alternans, 2D dynamics, 3D, Other various, and Info. The selected option is "Cell dynamics", which leads to "The Hodgkin-Huxley Model" for "one cell".

The interface includes a control panel with the following parameters:

- Res:
- g_{Na}:
- g_K:
- S1 at:
- S2 at:
- time:

A "Replot" button is located to the right of the plot. Below the plot, there are checkboxes for "Voltage" (checked), "m gate", "h gate", and "n gate".

The plot shows the membrane potential V over time (ms). The x-axis ranges from 0 to 40 ms, with markers at S1 (5 ms) and S2 (18 ms). The y-axis represents voltage. The plot displays two action potential spikes, one at S1 and one at S2, with a small step increase in voltage between S1 and S2.

Relationship between V_m and I_i

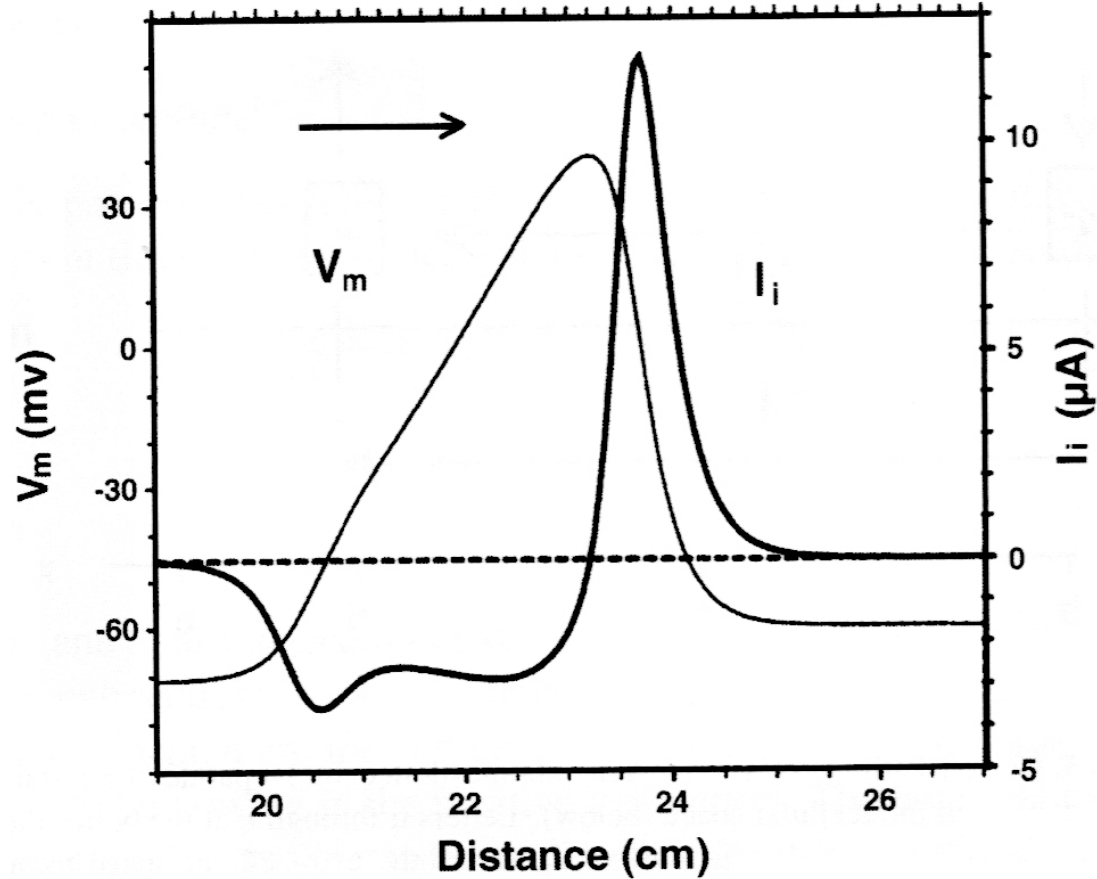
$V_m \equiv \phi_i + \phi_e$ Taking the first spatial derivative...

$$\frac{\partial V_m}{\partial x} = \frac{\partial \phi_i}{\partial x} + \frac{\partial \phi_e}{\partial x} = -r_i I_i + r_e I_e$$

$$\frac{\partial V_m}{\partial x} = -r_i I_i + r_e (I - I_i) = -(r_i + r_e) I_i + I r_e$$

$$I_i = \frac{-1}{(r_i + r_e)} \left[\frac{\partial V_m}{\partial x} - I r_e \right]$$

V_m and I_i (Fig 6.6)



$$I_i = \frac{-1}{(r_i + r_e)} \left[\frac{\partial V_m}{\partial x} - I r_e \right] \text{ When } I=0 \text{ (no stimulation) } I_i \propto \frac{\partial V_m}{\partial x}$$

Relationship between V_m and i_m

$$\frac{\partial V_m}{\partial x} = -(r_i + r_e)I_i + Ir_e \quad \text{Take 2nd derivative}$$

$$\frac{\partial^2 V_m}{\partial x^2} = -(r_i + r_e) \frac{\partial I_i}{\partial x} + r_e \frac{\partial I}{\partial x}$$

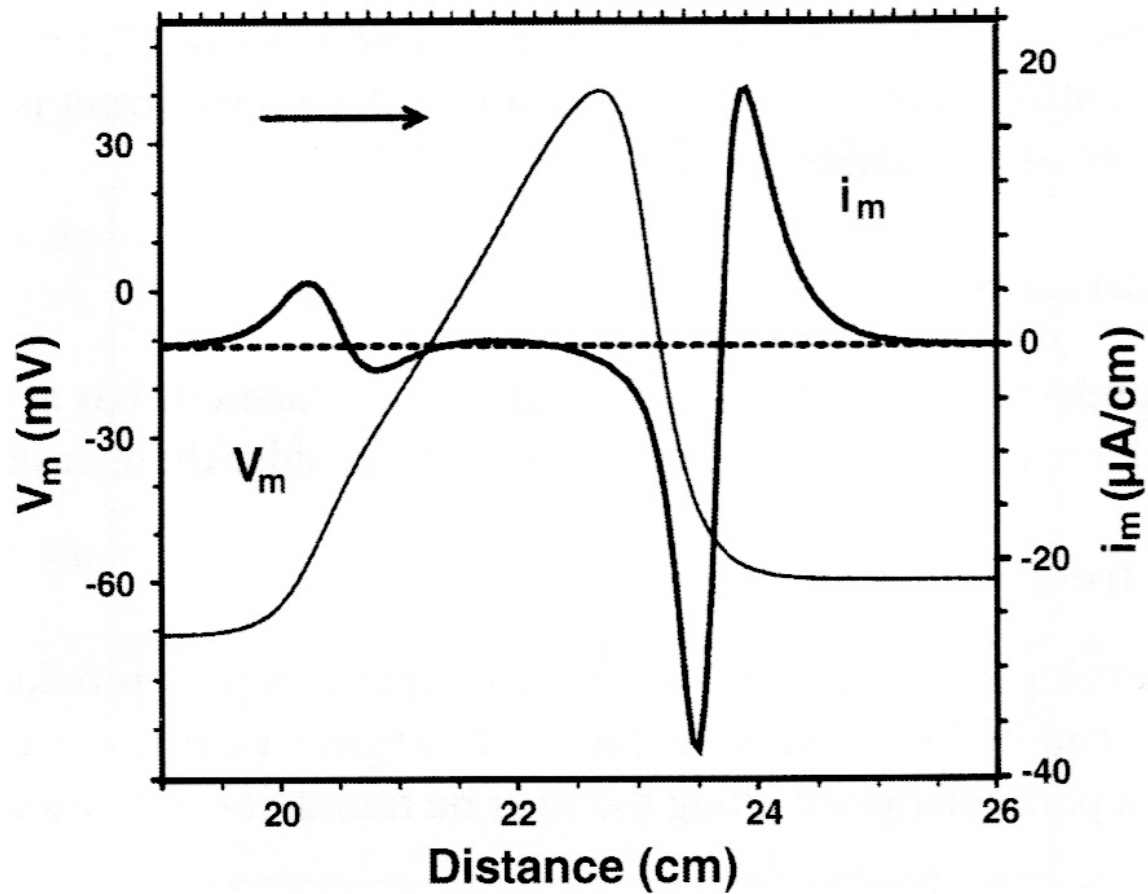
Remember that:

$$\frac{\partial I_i}{\partial x} = -i_m \quad \text{and} \quad \frac{\partial I}{\partial x} = i_p \quad \text{So...}$$

$$\frac{\partial^2 V_m}{\partial x^2} = (r_i + r_e)i_m + r_e i_p$$

$$i_m = \frac{1}{(r_i + r_e)} \left(\frac{\partial^2 V_m}{\partial x^2} - r_e i_p \right)$$

V_m and i_m



$$i_m = \frac{1}{(r_i + r_e)} \left[\frac{\partial^2 V_m}{\partial x^2} - r_e i_p \right] \quad \text{If } i_p = 0 \text{ (no stimulation)} \quad i_m \propto \frac{\partial^2 V_m}{\partial x^2}$$

Conduction Velocity

Hodgkin and Huxley found that:

$$\theta \propto \sqrt{a}$$

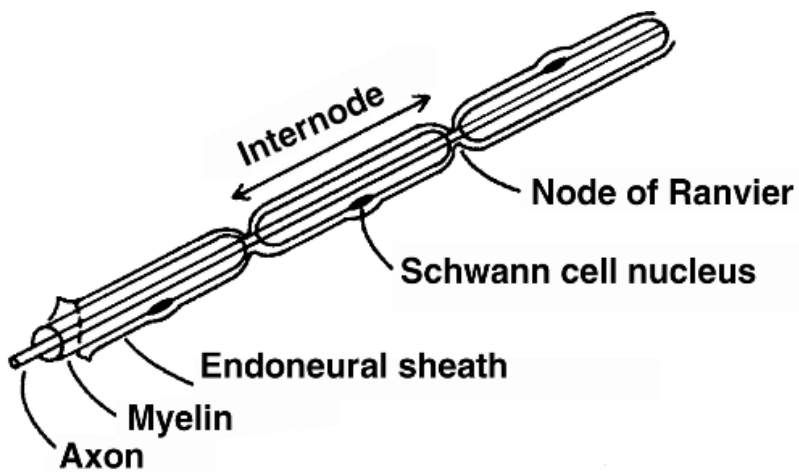
And

$$\theta \approx \sqrt{d}$$

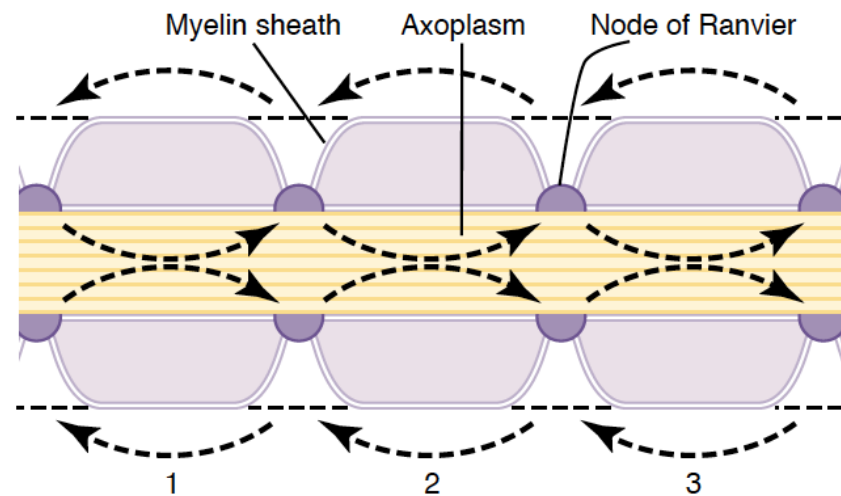
Where d is fiber diameter in μm and θ is m/s

Myelination

- Myelinated axon



- Saltatory conduction



$$\theta \approx 6 \times D$$