Biophysics I (BPHS 3090)

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Website: http://www.yorku.ca/cberge/3090W2015.html

York University
Winter 2015
Lecture 29

Reference/Acknowledgement:
- TF Weiss (Cellular Biophysics)
- D Freeman

Saltatory Conduction

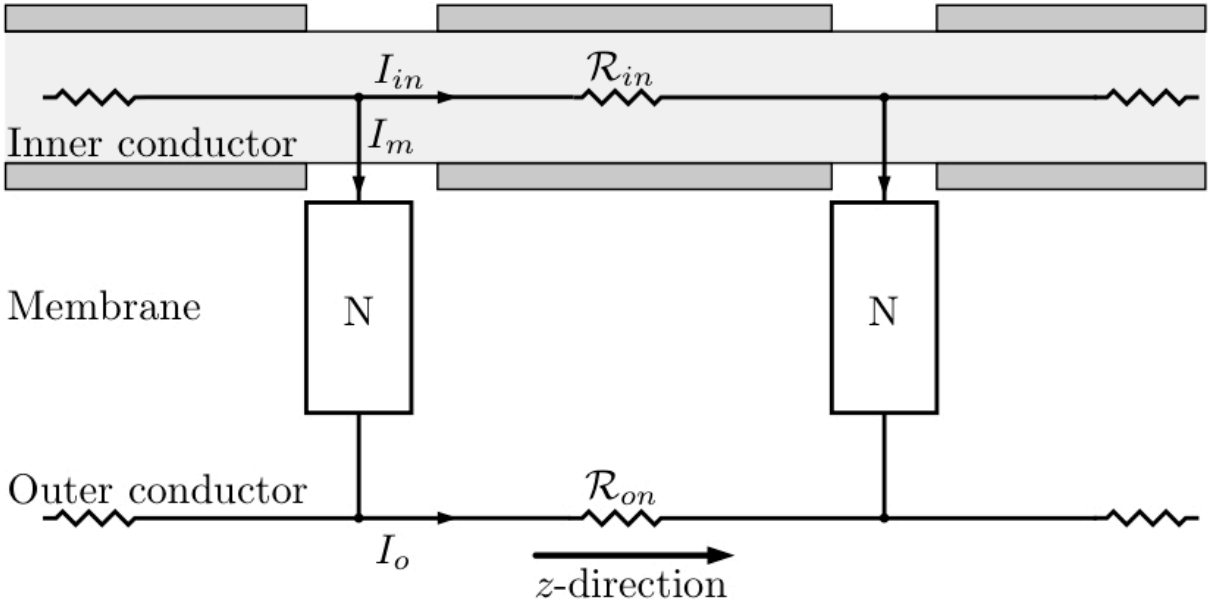
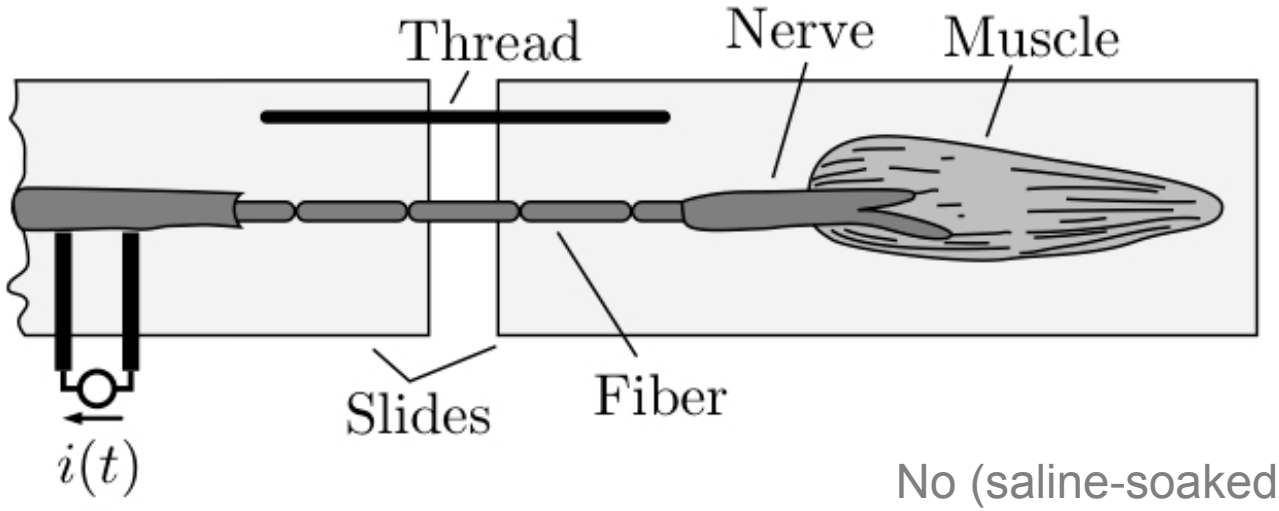


Figure 5.16

- Internodes act as insulators

- APs generated at nodes of Ranvier

- Speeds up propagation without need for larger axon diameter



No (saline-soaked) thread = no AP

Figure 5.15

→ Extracellular path between nodes is critical

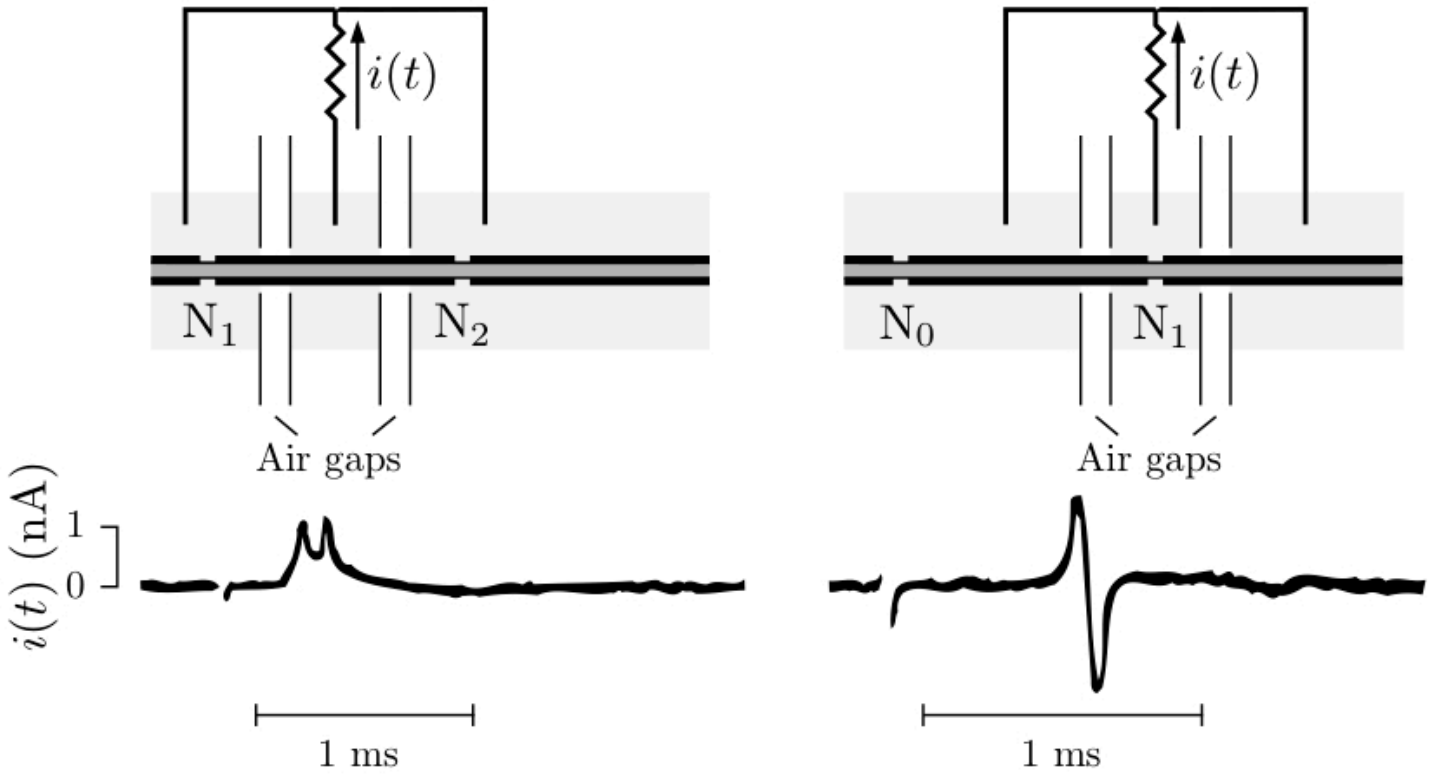


Figure 5.17

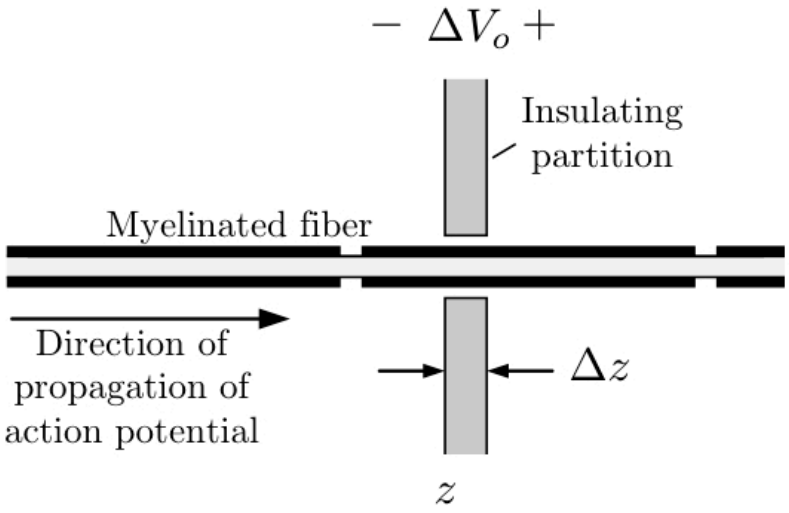


Figure 5.18

→ Current through internodes is non-zero

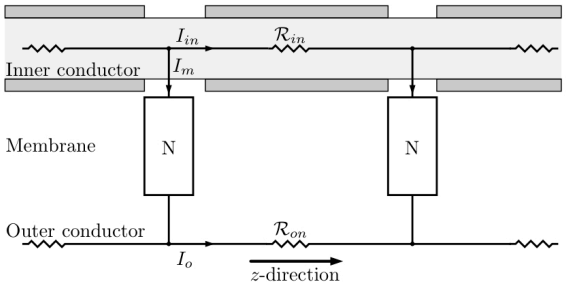


Figure 5.16

This model isn't quite right....

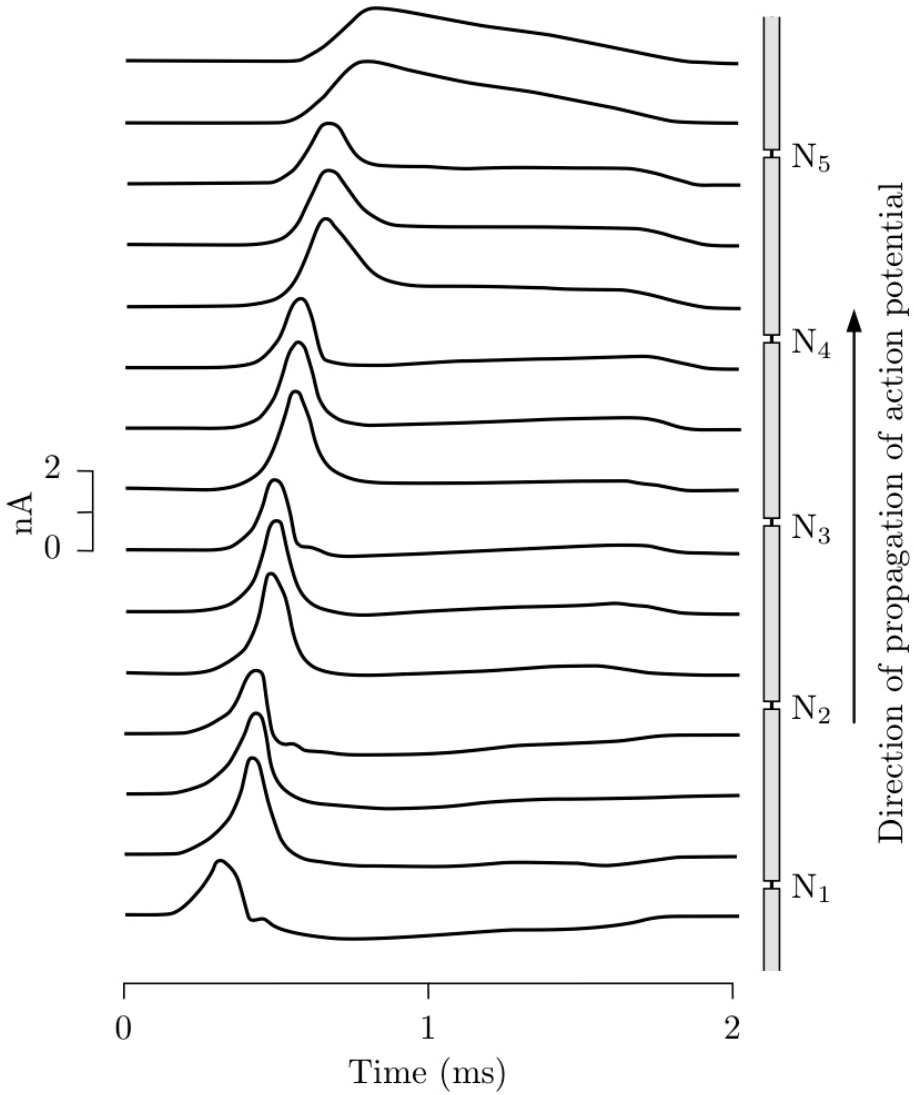
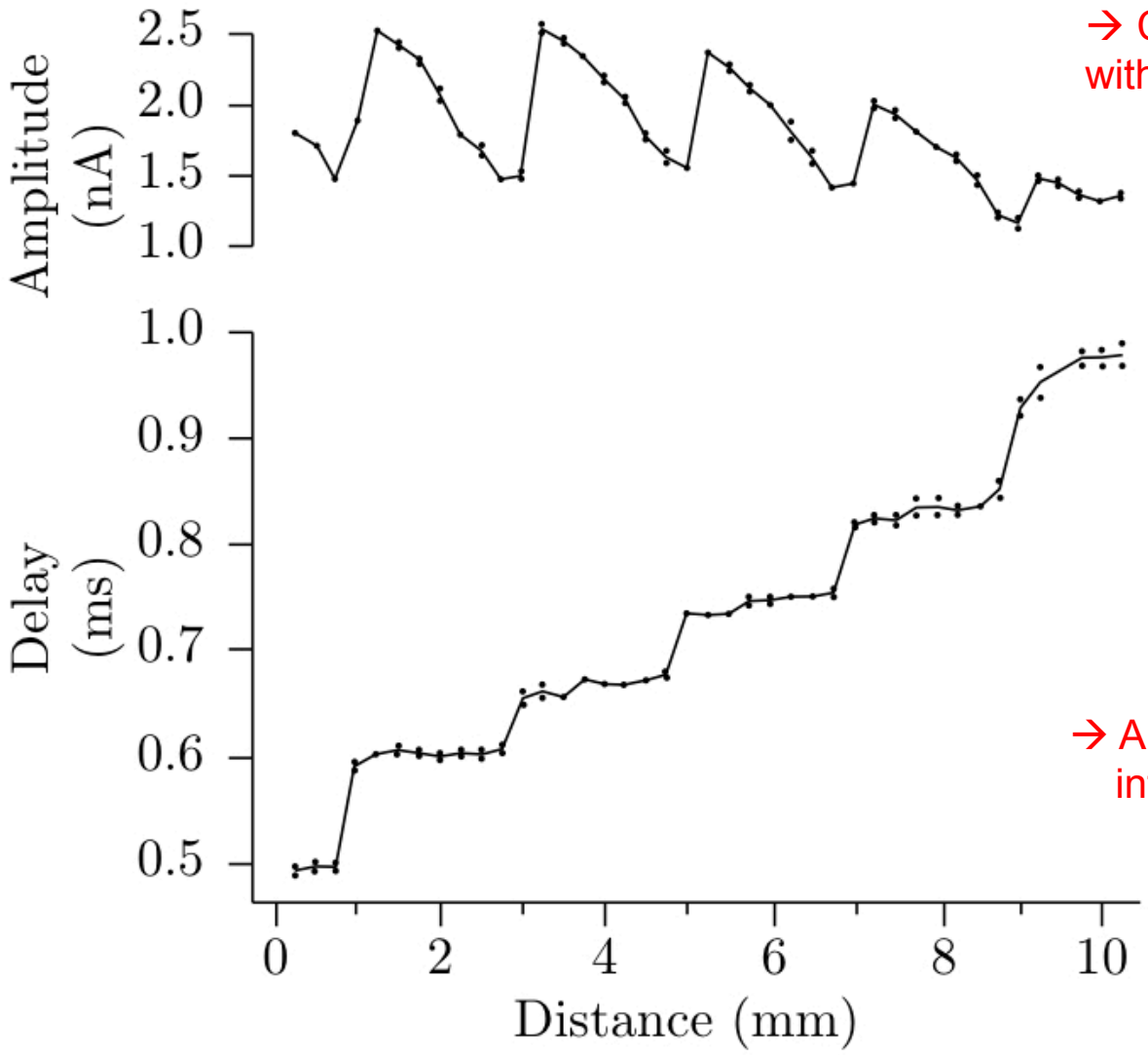


Figure 5.19



→ Current amplitude decreases with distance from node

→ APs move much faster along internodes than at nodes

Figure 5.20

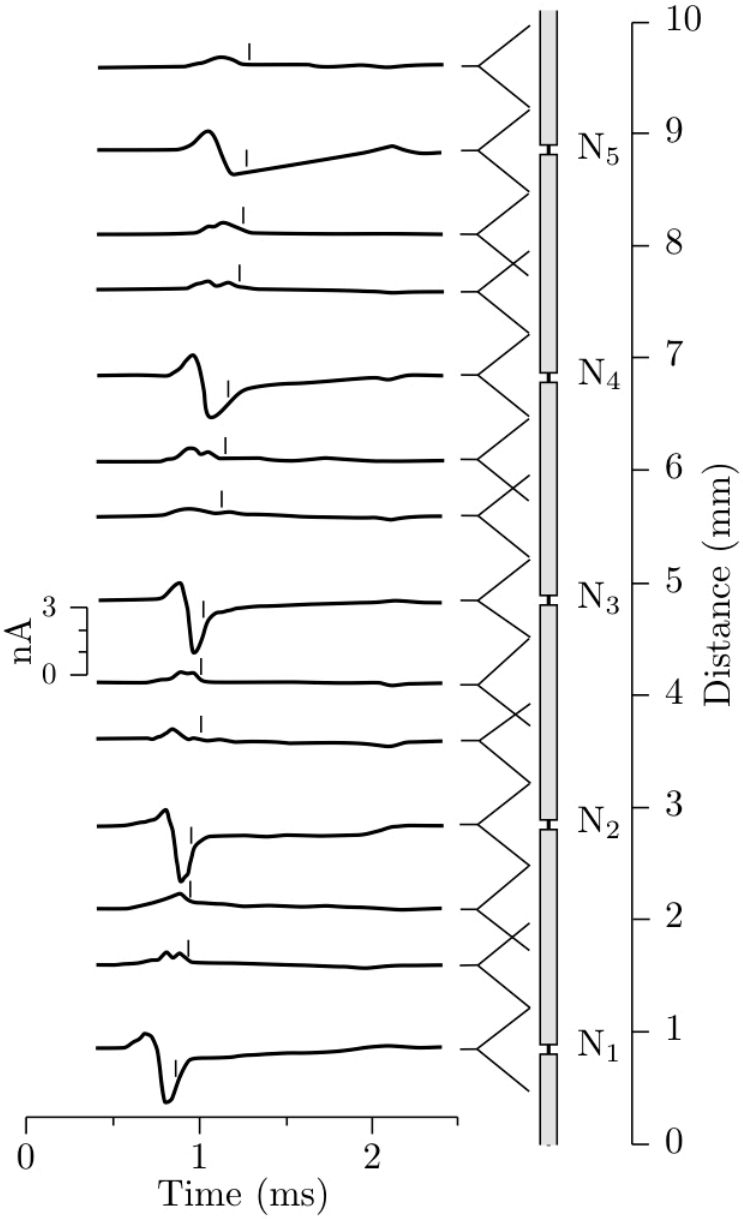


Figure 5.21

→ Internodes behave like cable model
(i.e., leaky submarine cable)

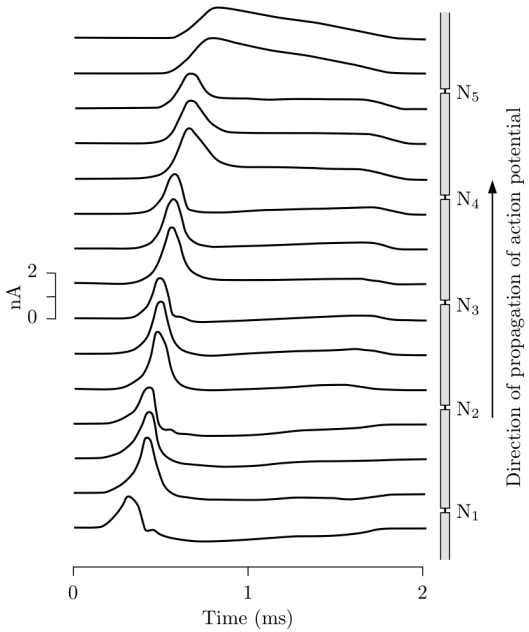


Figure 5.19

By means of the core-conductor model, we can determine the membrane potential

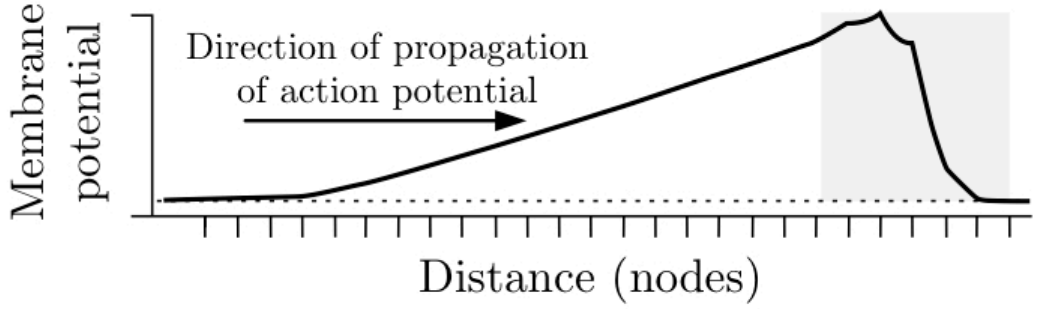


Figure 5.22

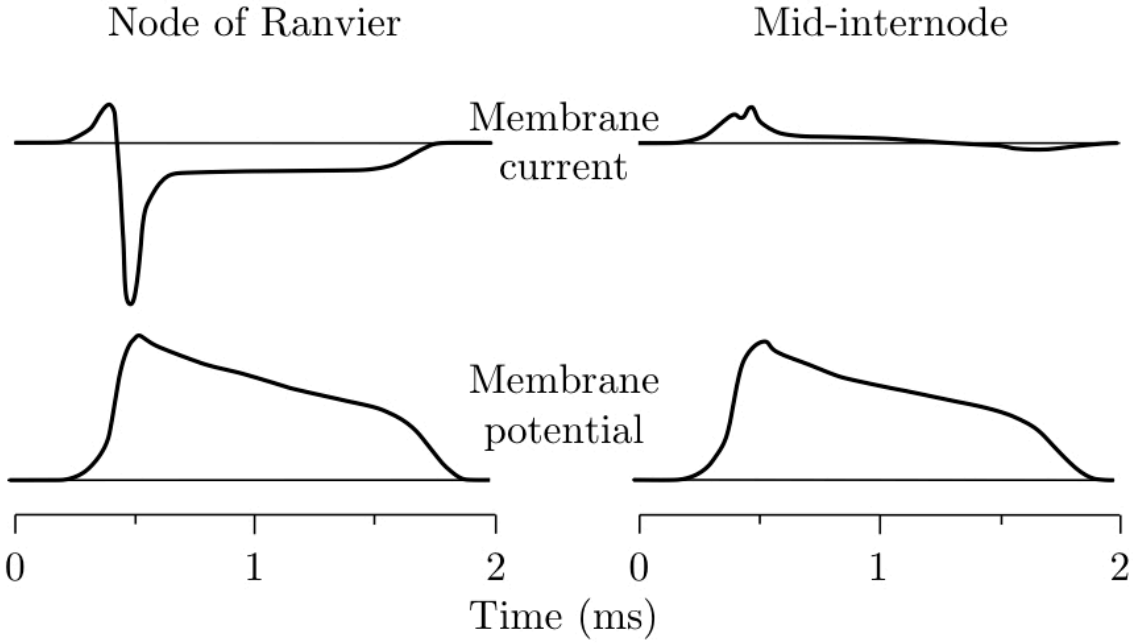
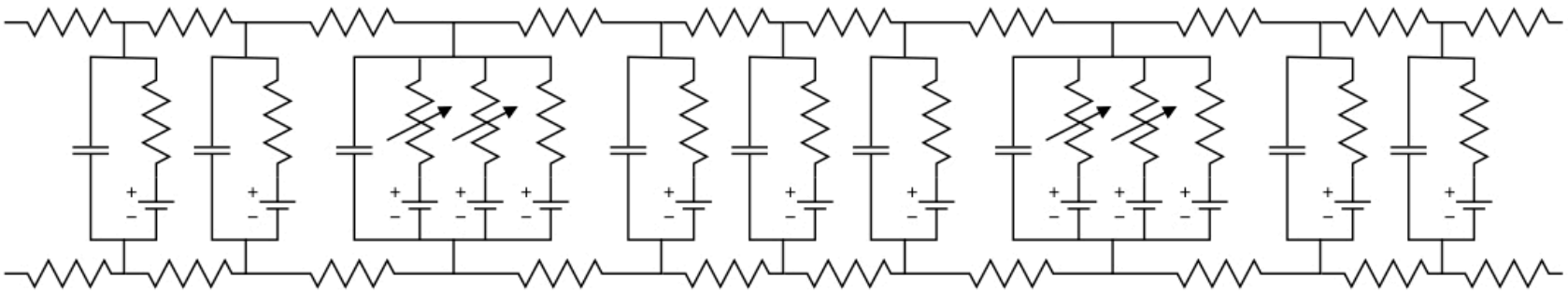
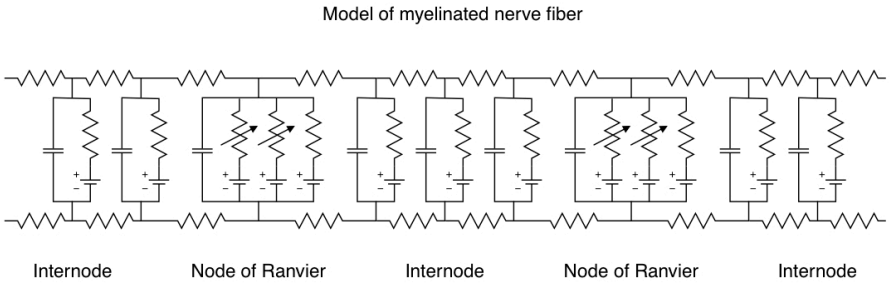


Figure 5.23

Model of myelinated nerve fiber



Internode Node of Ranvier Internode Node of Ranvier Internode



→ AP potential spans multiple nodes

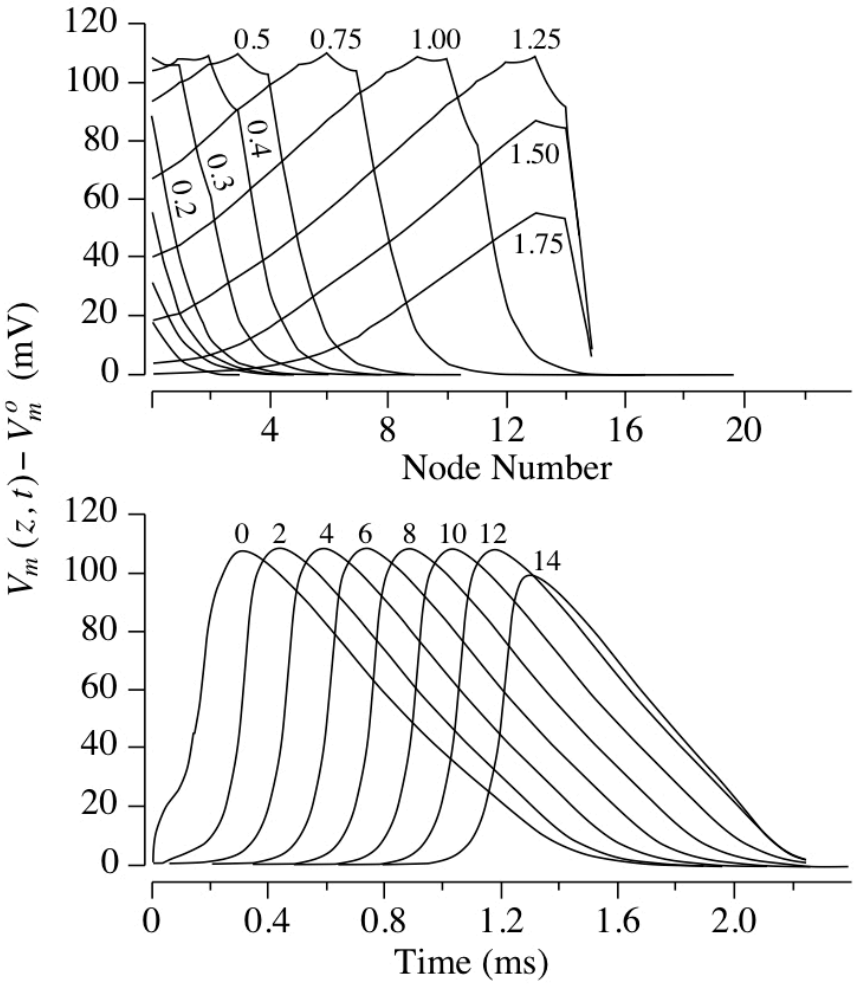
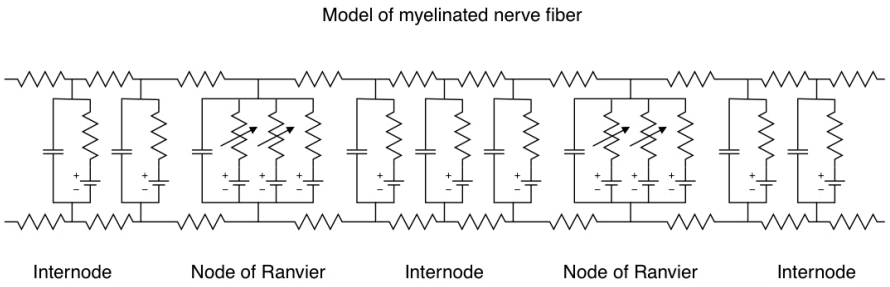


Figure 5.31



→ Current is more discontinuous (i.e. “saltatory”) than the potential

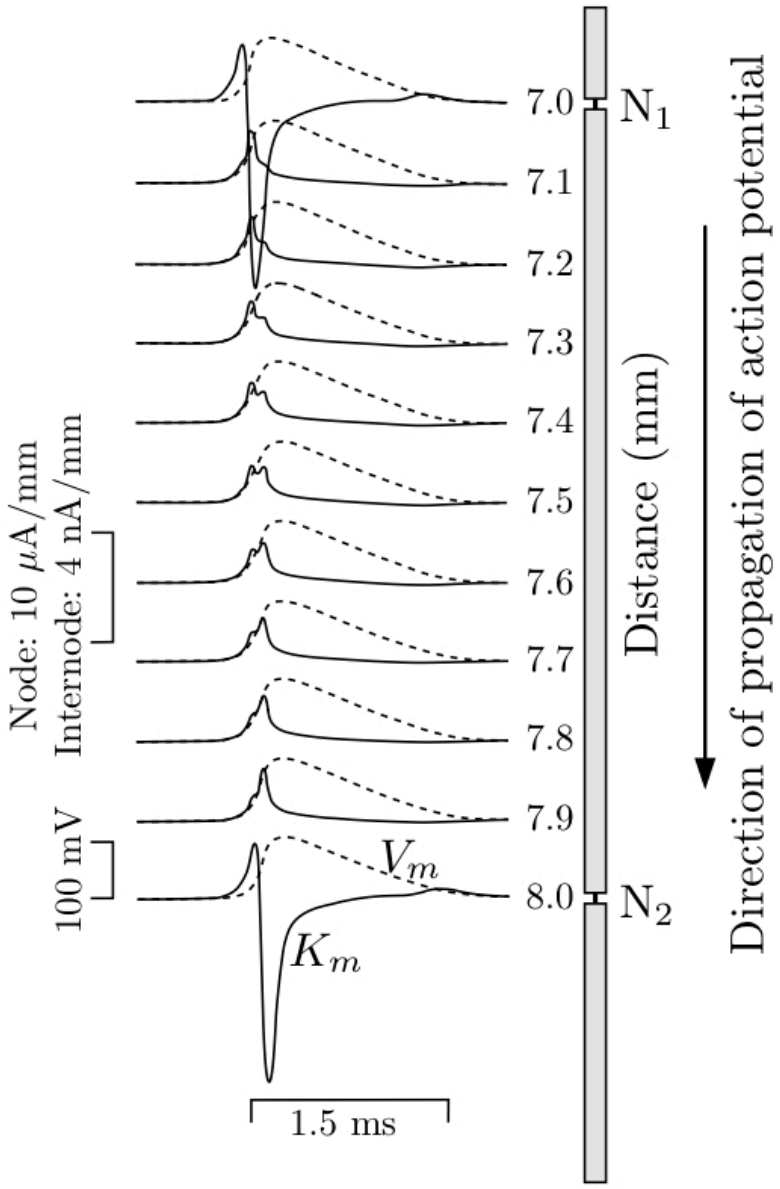


Figure 5.32

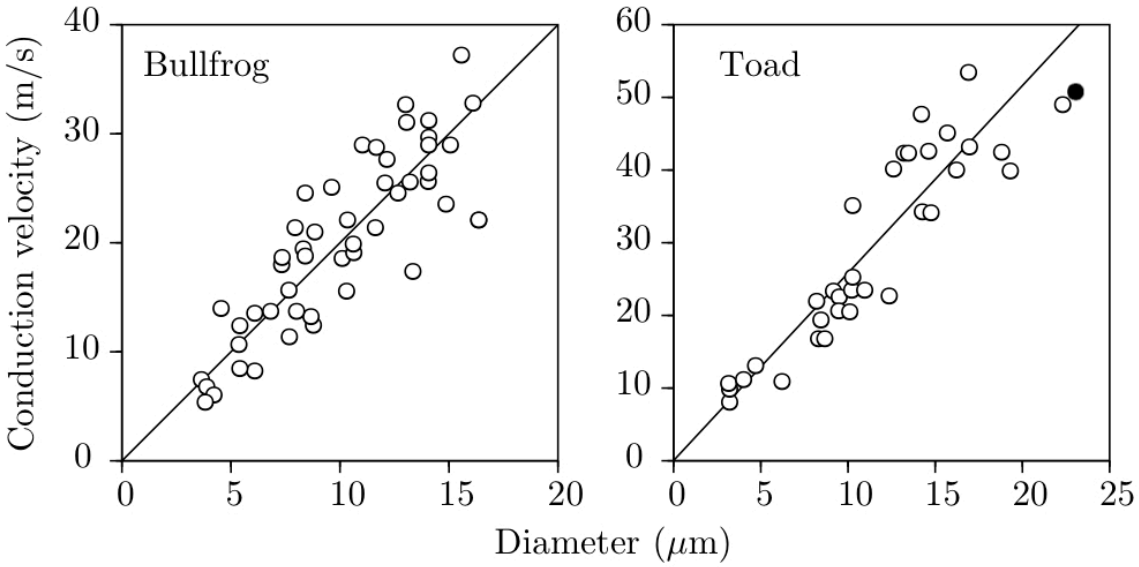


Figure 5.33

Myelinated fibers
conduction velocity ~ fiber diameter

Unmyelinated fibers
conduction velocity ~ square root of fiber diameter

→ Myelin speeds things up, which has numerous functional/evolutionary implications

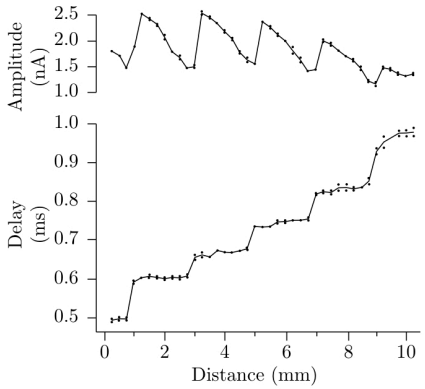


Figure 5.20

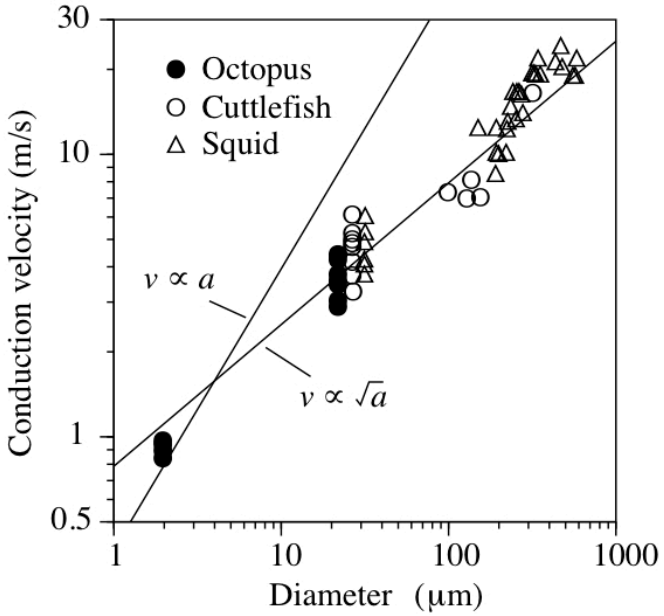
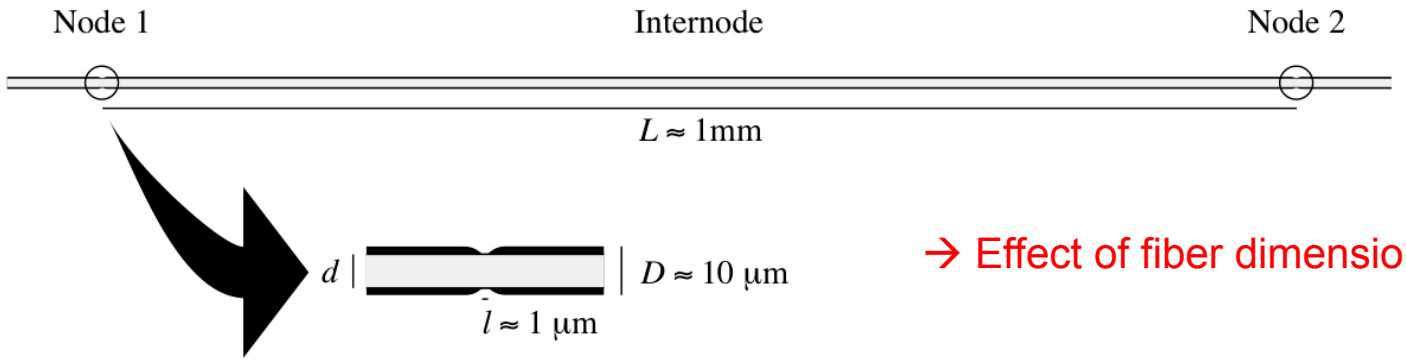


Figure 2.16



→ Effect of fiber dimensions?

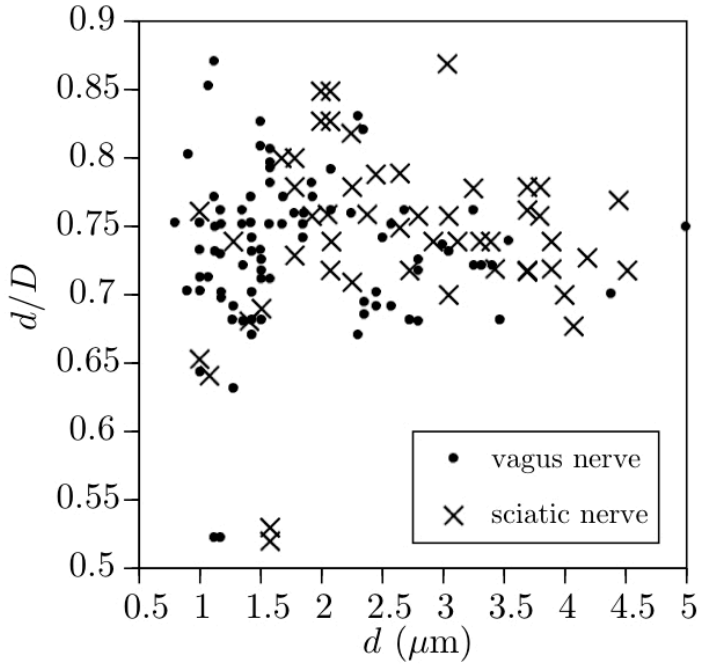


Figure 5.9

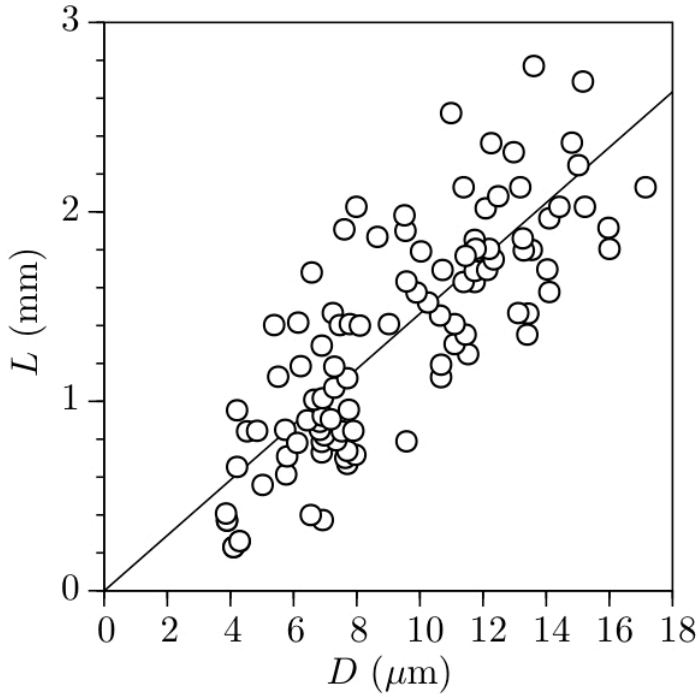
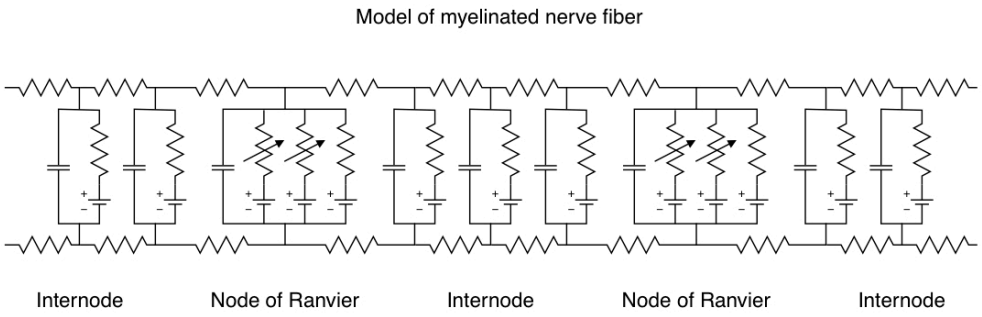


Figure 5.10



Model:

- Predicts relationship between v and D (not $\sqrt{D}$)
- Allows for constraining different interrelationships to see effects

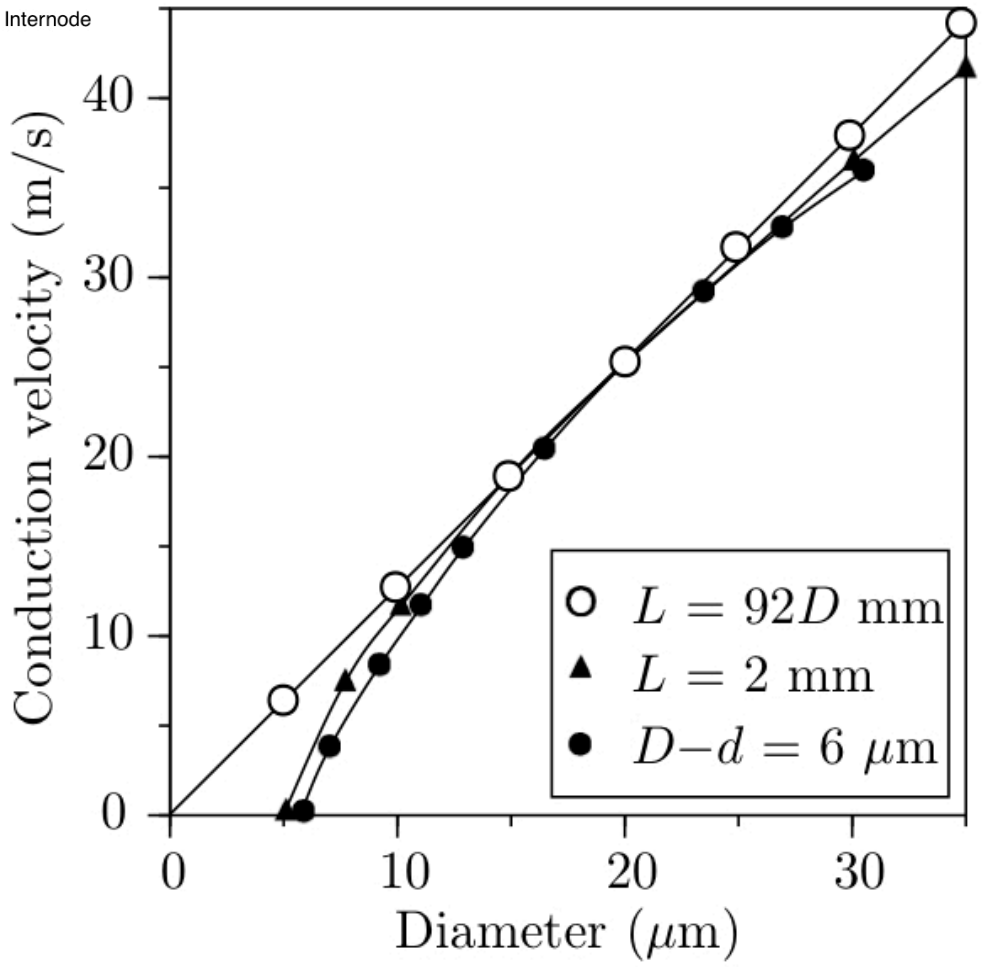
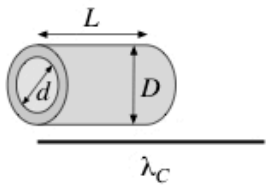
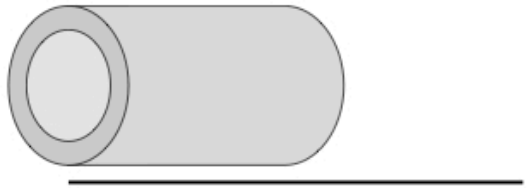
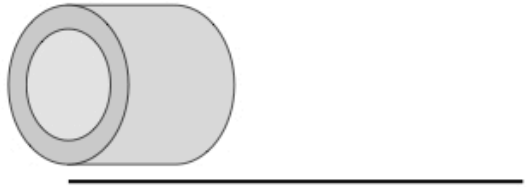
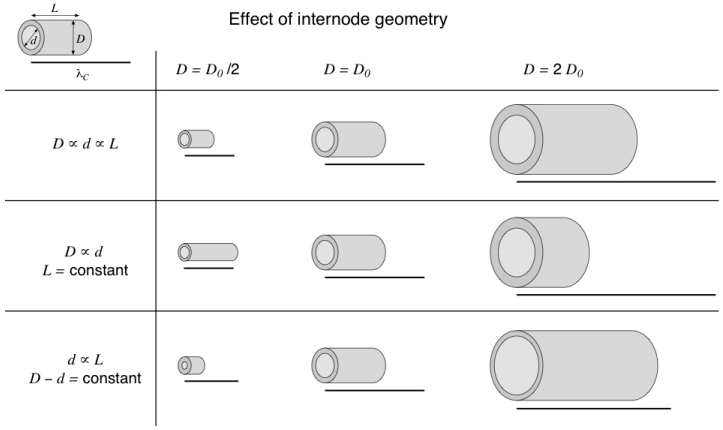


Figure 5.35

Effect of internode geometry



	$D = D_0/2$	$D = D_0$	$D = 2\,D_0$
$D \propto d \propto L$			
$D \propto d$ L = constant			
$d \propto L$ $D - d$ = constant			



Effect of Internode Geometry

Solutions to the cable equations depend on only two constants.

$$\tau_M = \text{membrane time constant} = \frac{c_{IN}}{g_{IN}}$$

$$\lambda_C = \text{cell space constant} = \sqrt{\frac{1}{g_{IN}(r_o + r_i)}}$$

We can express the parameters of the cable model in terms of material properties (ρ_i, ρ_m, ϵ_m) and geometrical parameters of the cable (d, D, L).

$$c_{IN} \approx \frac{\epsilon_m \pi d}{(D-d)/2} \qquad g_{IN} \approx \frac{\pi d}{\rho_m (D-d)/2}$$

$$r_i = \frac{\rho_i}{\pi d^2/4} \qquad r_o << r_i$$

Substitution of these expressions into the definitions of the cable constants shows how the cable constants depend on cable geometry.

$$\tau_M = \frac{c_{IN}}{g_{IN}} \approx \epsilon_m \rho_m \text{ (independent of geometry)}$$

$$\lambda_C^2 = \frac{1}{g_{IN}(r_0 + r_i)} \approx \frac{\rho_m (D-d)/2}{\pi d} \times \frac{\pi d^2/4}{\rho_i} = \frac{\rho_m}{8\rho_i}(D-d)d$$

Chicken or Egg: Does myelin cause saltatory conduction, or is such a mechanism inherent?

→ Demyelinated fibers (e.g., multiple sclerosis)

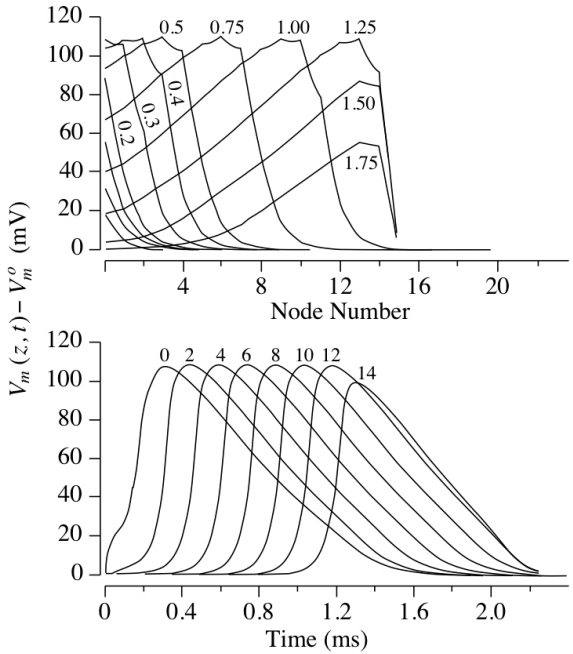


Figure 5.31

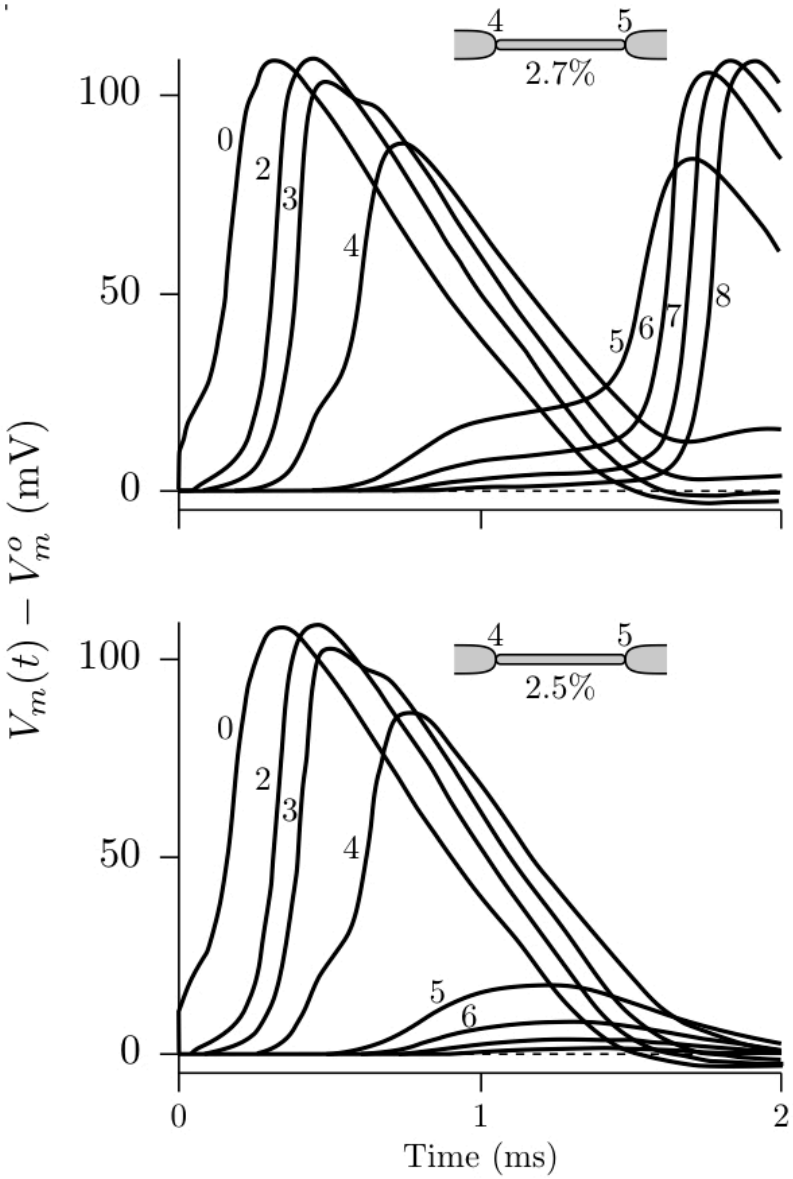


Figure 5.38