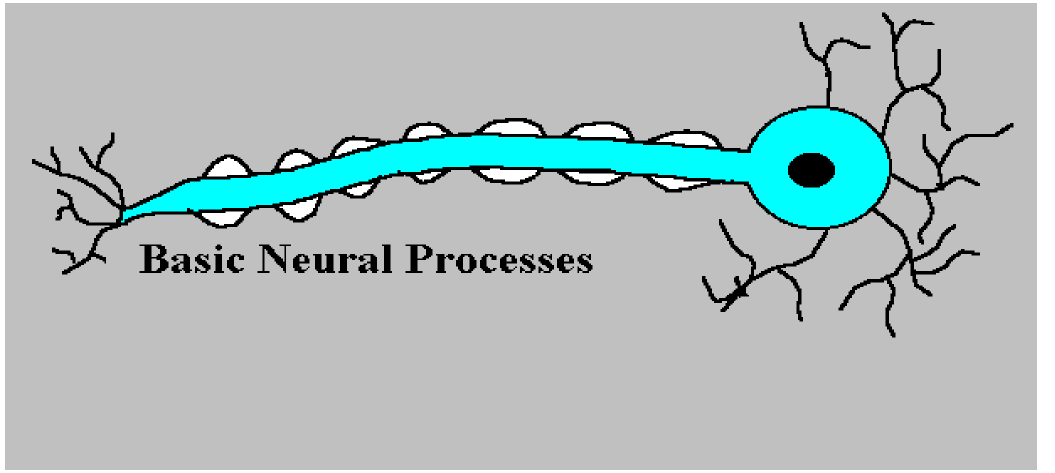
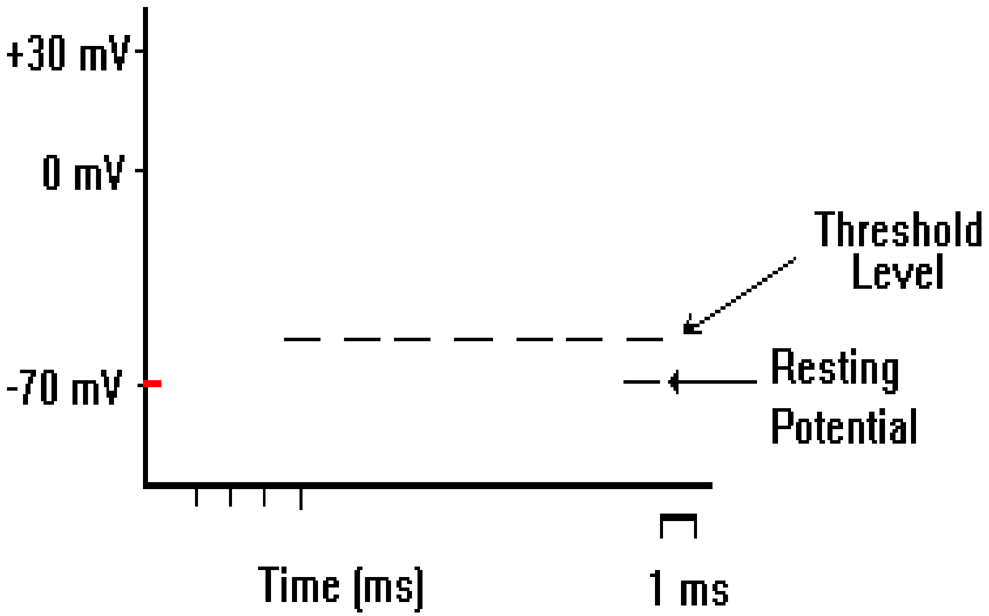
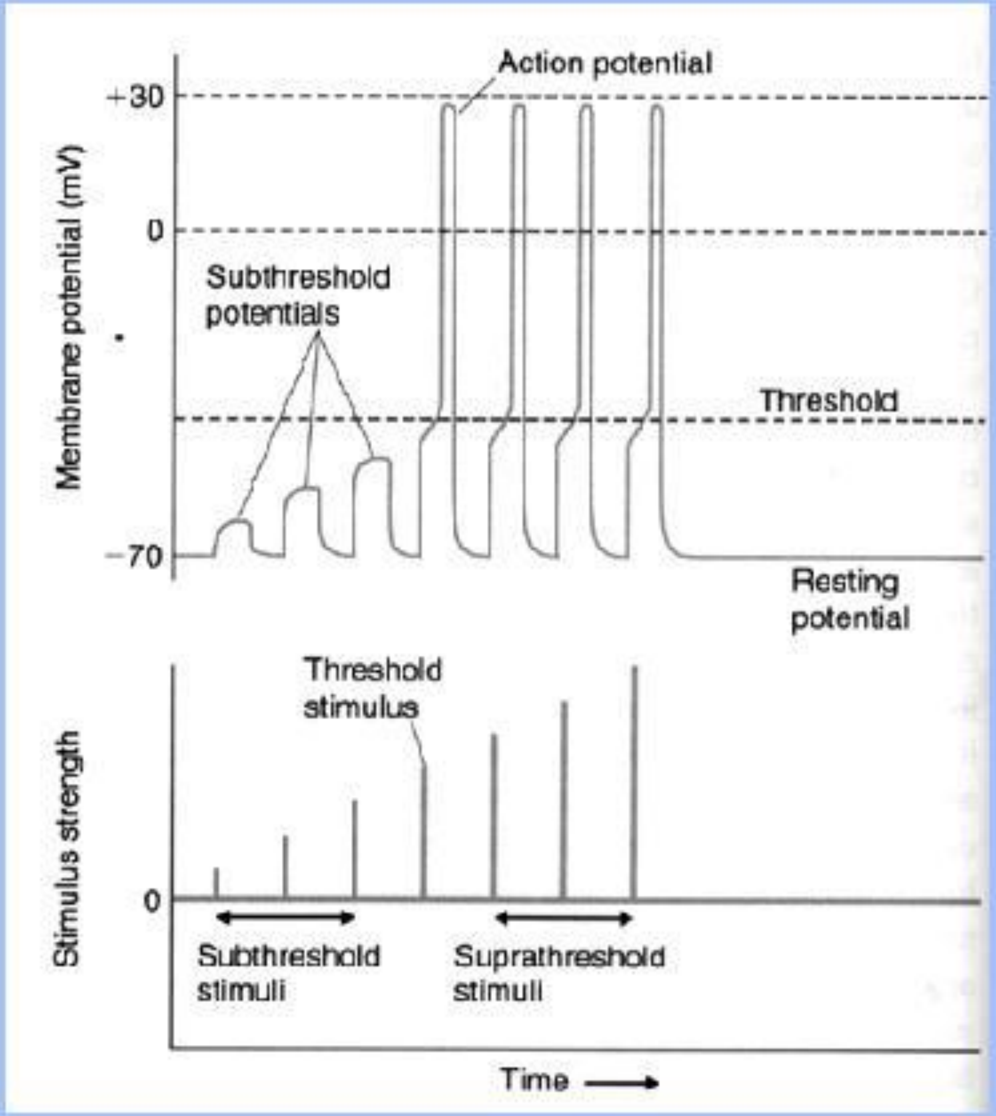
Pasif zar modeli ve kablo teorisi: zarın iletkenlik ve kapasitif özellikleri

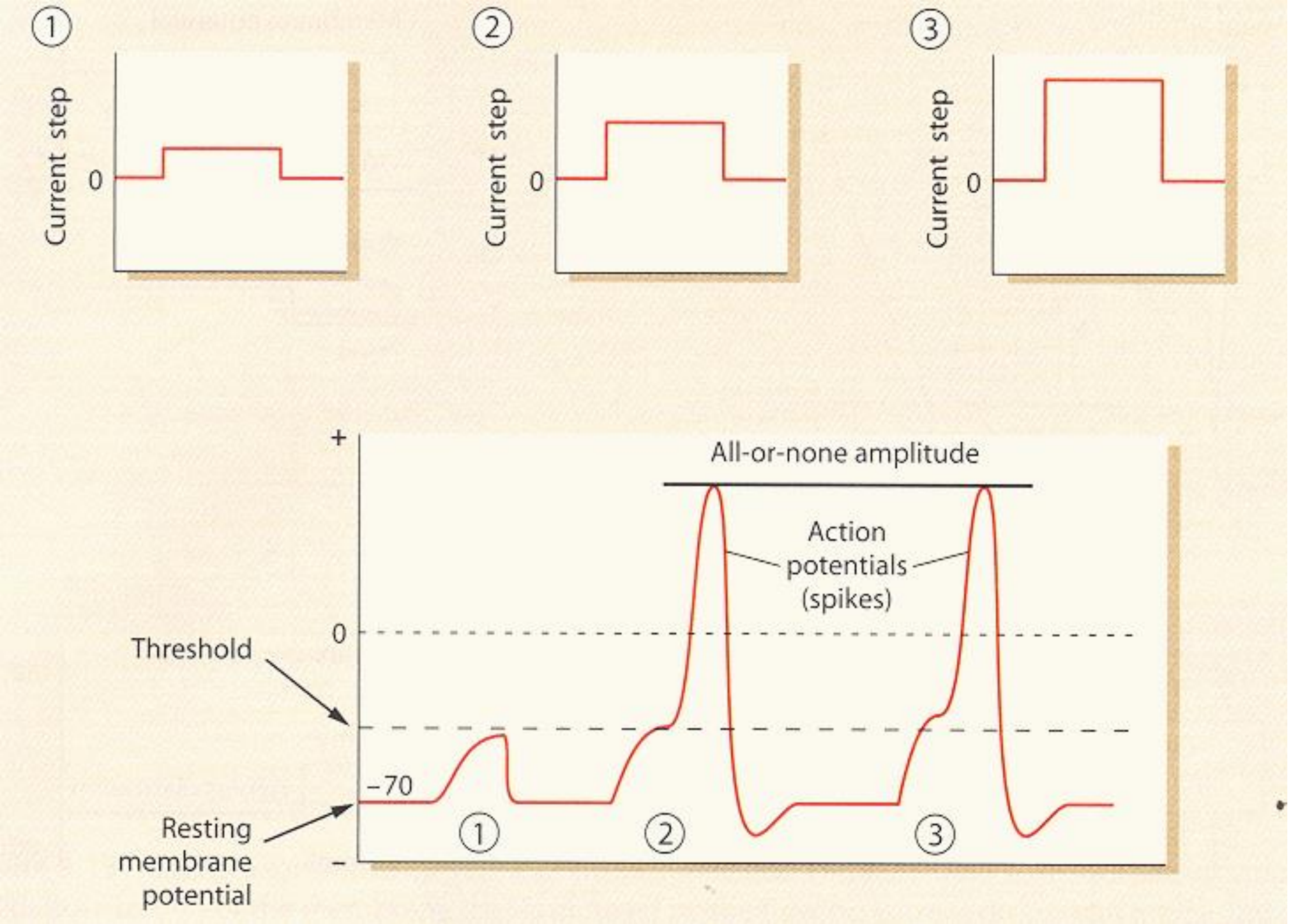


Doç.Dr. Erkan Tuncay

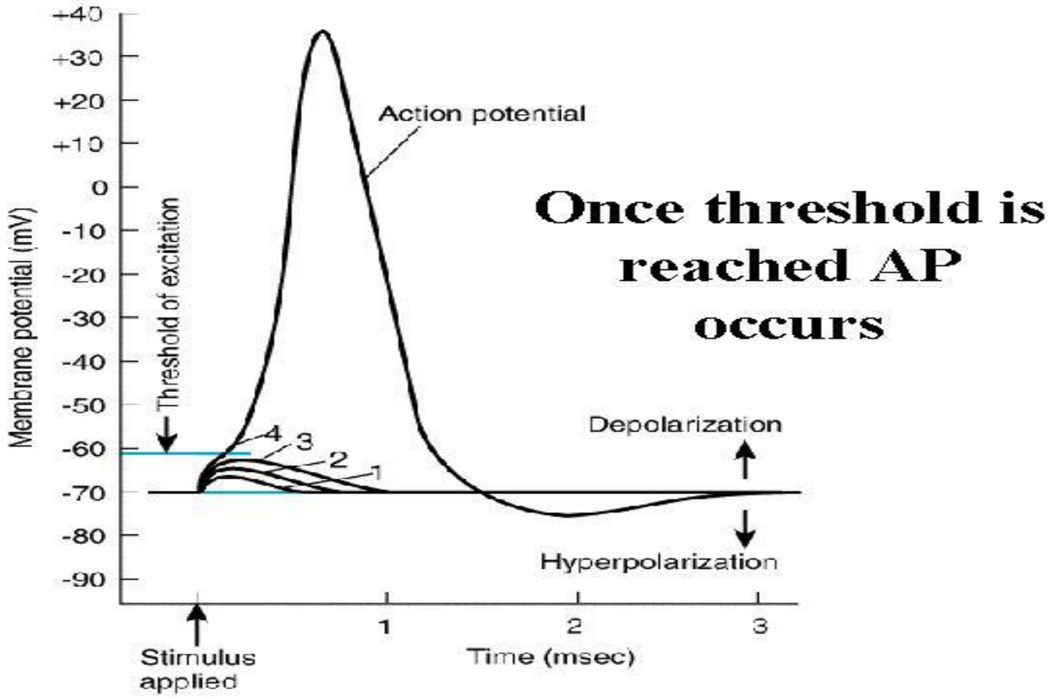


Stimulus-Response: Threshold




①
Current step
0
②
Current step
0
③
Current step
0
+
All-or-none amplitude
Action
potentials
(spikes)
0
Threshold
−70
Resting
membrane
potential
①
②
③
−

All or Nothing Potential



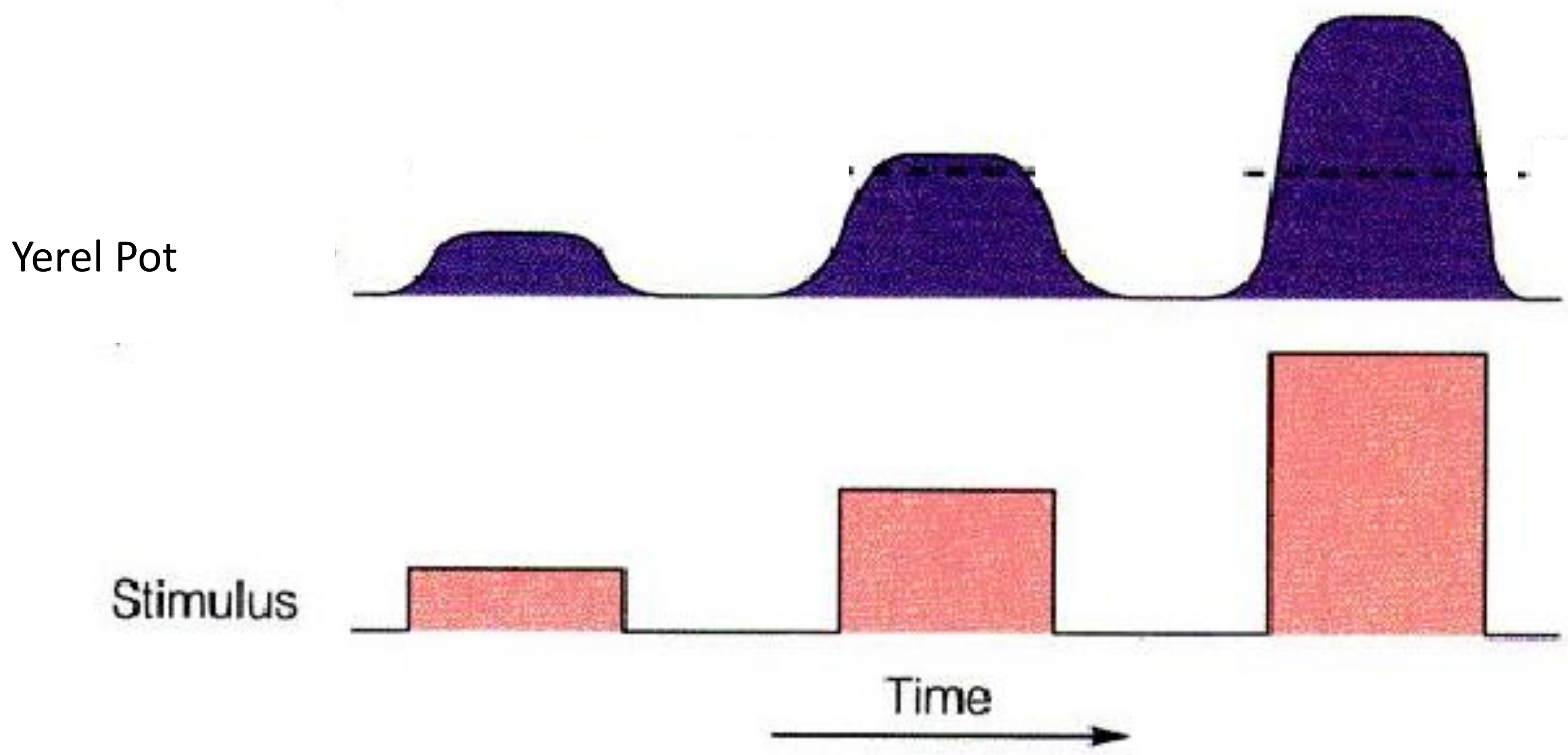
Hep veya hiç yasasına uyar.

Dereceli Potansiyel vs Aksiyon potansiyeli

Depolarize veya hiperpolarize olarak gözlenebilir.	Her zaman depolarizasyon olarak gözlenir.
Genlik uyaranın şiddetiyle orantılıdır.	Genlik ya vardır ya yoktur. Uyaran şiddeti aksiyon potansiyelinin frekansını etkiler.
ligand gated, mechanosensitive, temperature sensitive, cytoplasmic singaling molecules dependent	Voltage gated
Na^+, K^+, Cl^-	Na^+ & K^+
Her hangi bir refraktör periyotla ilişkilendirilmemiştir.	Mutlak ve Bağıl refraktör periyotlar mevcuttur.
Zamansal veya uzaysal toplanabilirler.	Toplanma söz konusu değildir. Ya hep ya hiç kuralı ve refraktör periyotlar!
Sönümlenerek ilerler.	Genliği sönümlenmez.
Prensip olarak hücre plazma membranının her hangi bir bölgesinde meydana gelebilir. (senör uyaranın geldiği bölge)	Voltaj bağımlı Na^+ ve K^+ kanallarının yogunluğunun fazla olduğu membran bölgelerinde meydana gelir.

Yerel pot. Genliği uyarıya bağlıdır.
Uyarı şiddeti arttıkça artar.

Hep veya hiç yasasına uymazlar.


Yerel Pot
Stimulus
Time

KABLO TEORİSİ: ELEKTOTONİK İLETİM

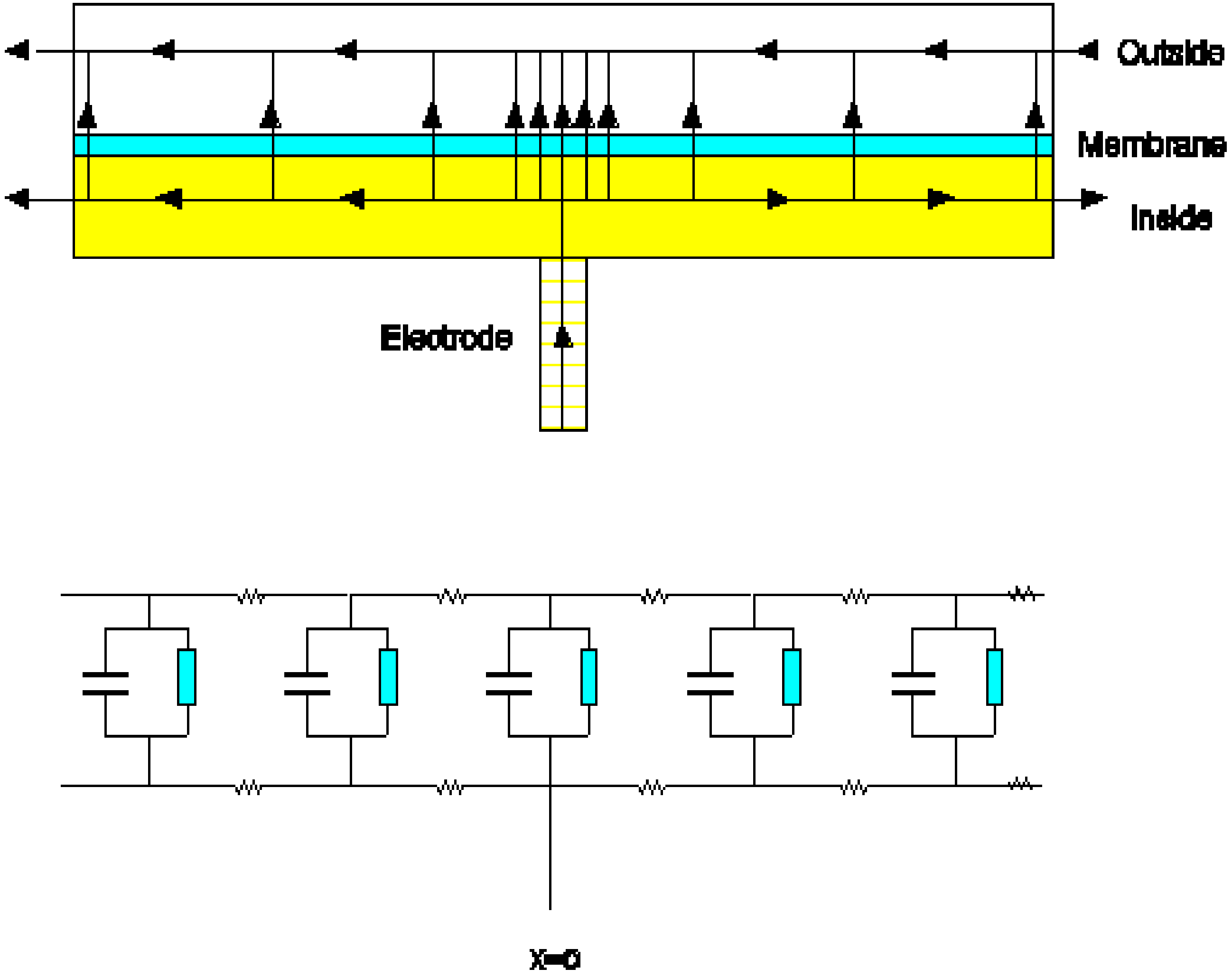
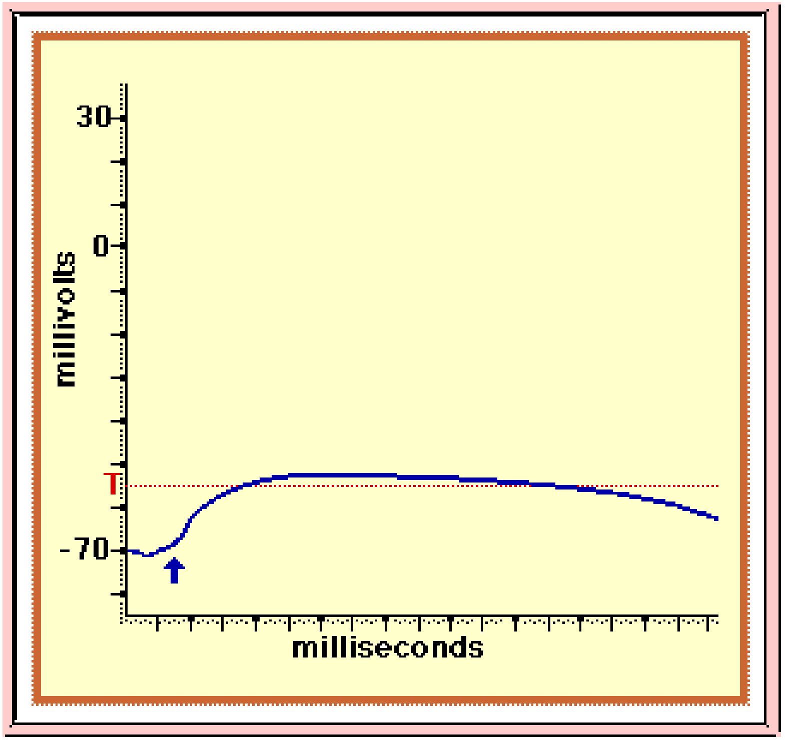
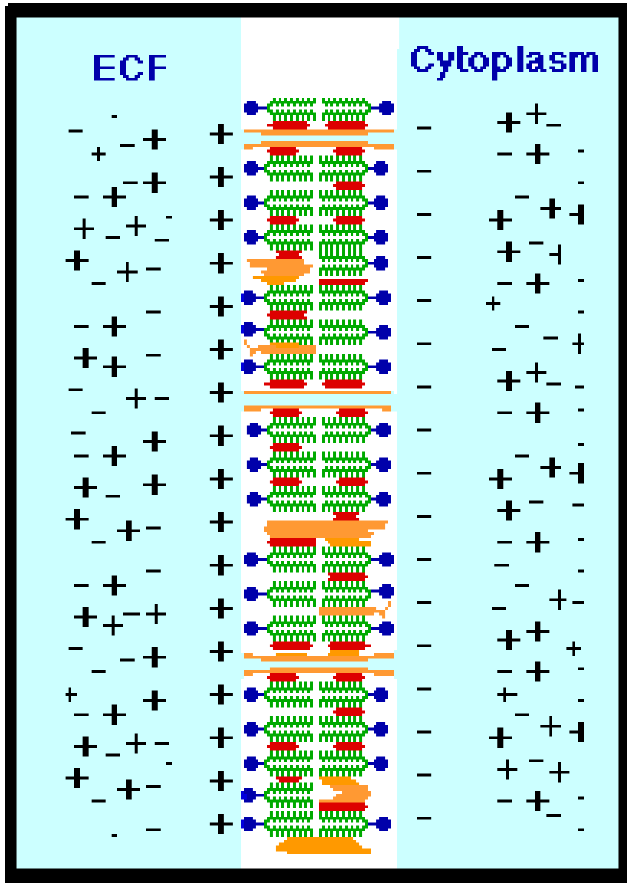


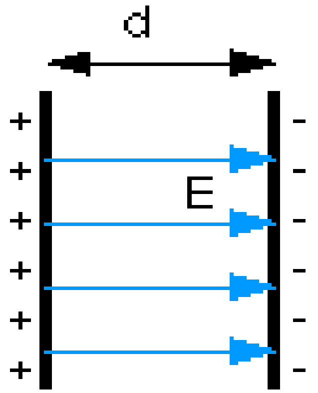
Figure 32. Upper panel: the lines of current flow in the simplified core conductor model. Lower panel: the equivalent circuit of the core conductor model.



Yerel pot zamana bağlı değişimi Üsteldir.



Membran Kapasitansı



$$C = k\varepsilon_0 A/d$$

k= 2-3 :membranın dielektrik sabiti

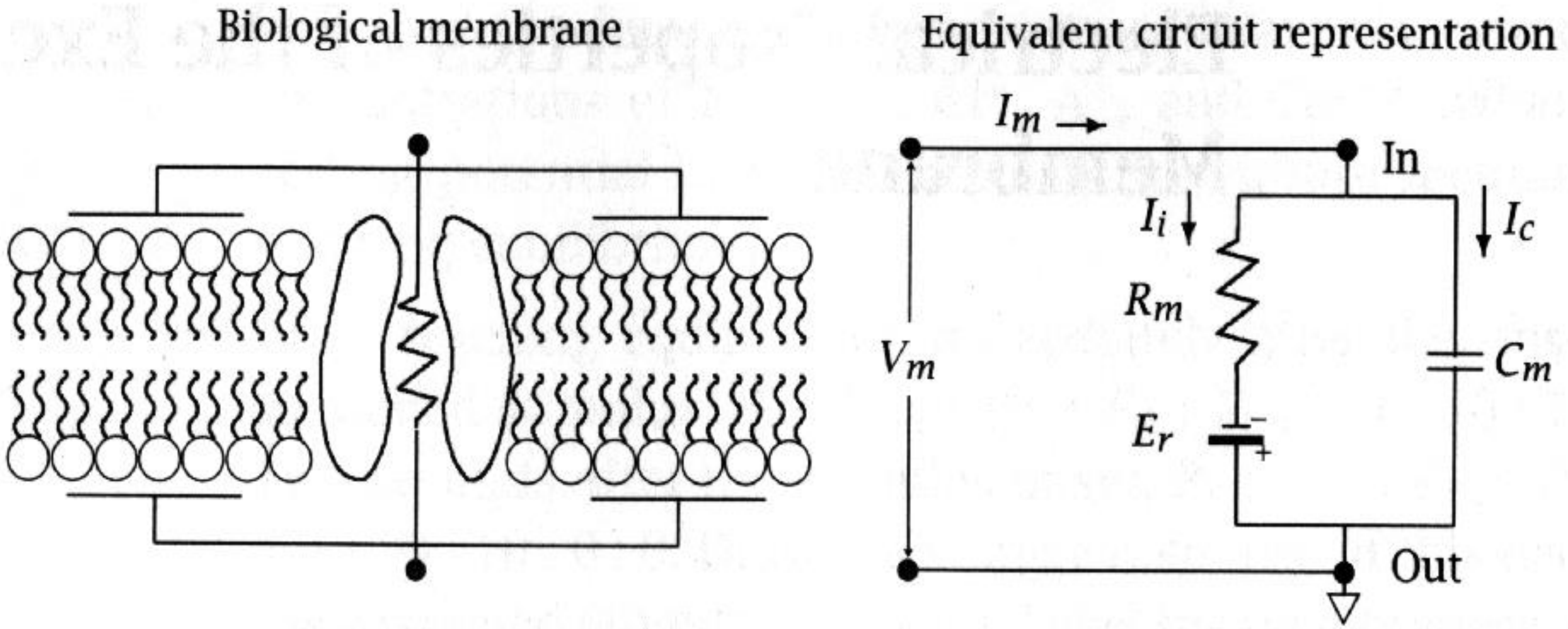
$\varepsilon_0 = 8.854 \times 10^{-12}$:boşluğun geçirgenliği

Birimi $\mu f / cm^2$

$C_m = 10\ \mu f / cm^2$ kas

$C_m = 1\ \mu f / cm^2$ sinir

Ohmic model



iyonik akım   Kapasitif akım

$I_m = I_i + I_c$

Kapasitör üzerinde ki yüklerin miktarında bir değişiklik olması için

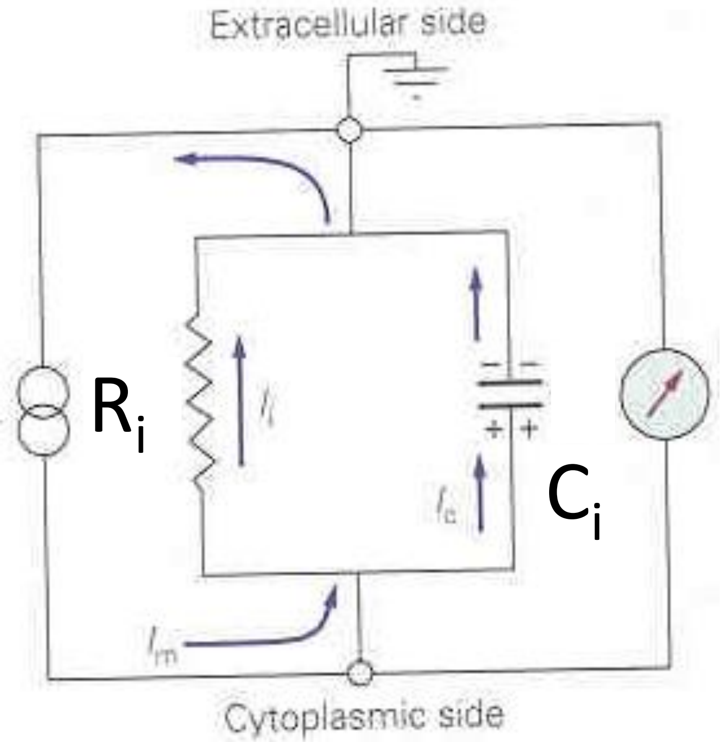
Akan akım I_c

$I_c = \Delta Q / \Delta t$

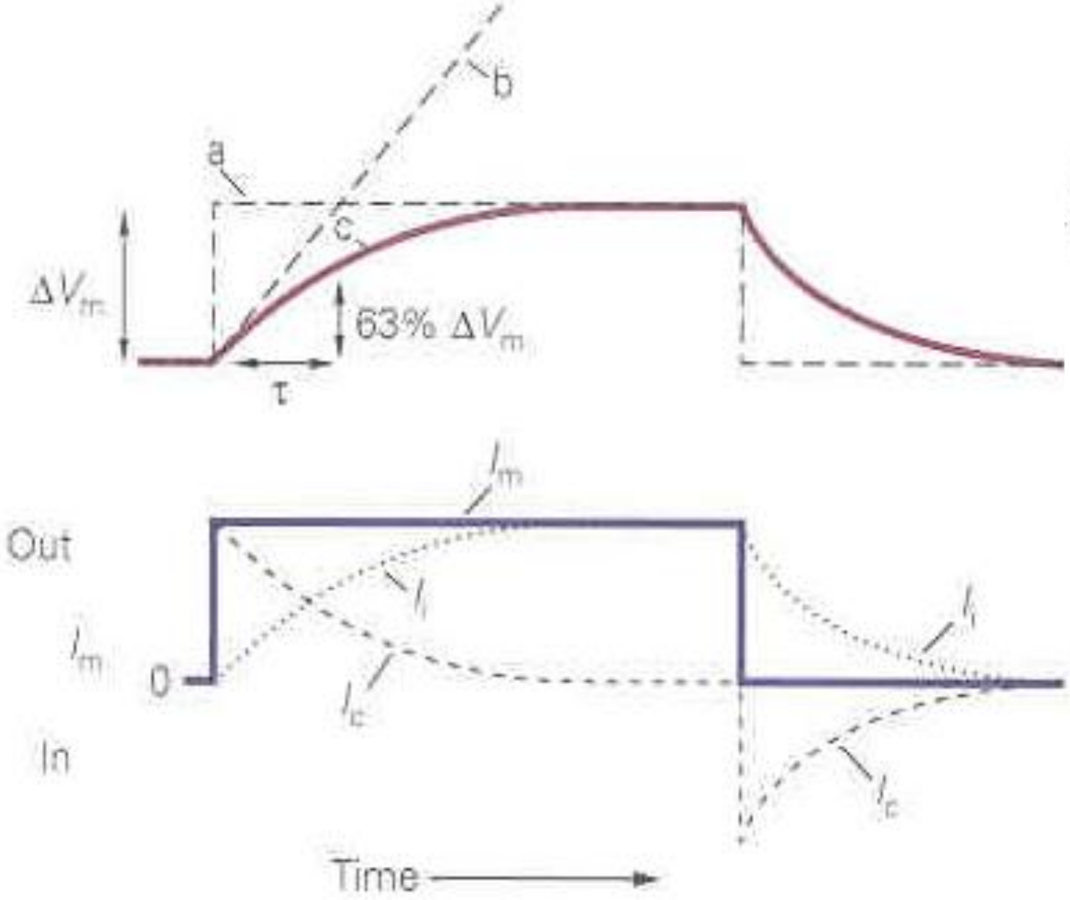
Δt : kapasitif akımın süresi

Kapasitif akım membranda depolanmış yükü değiştiren akımdır.

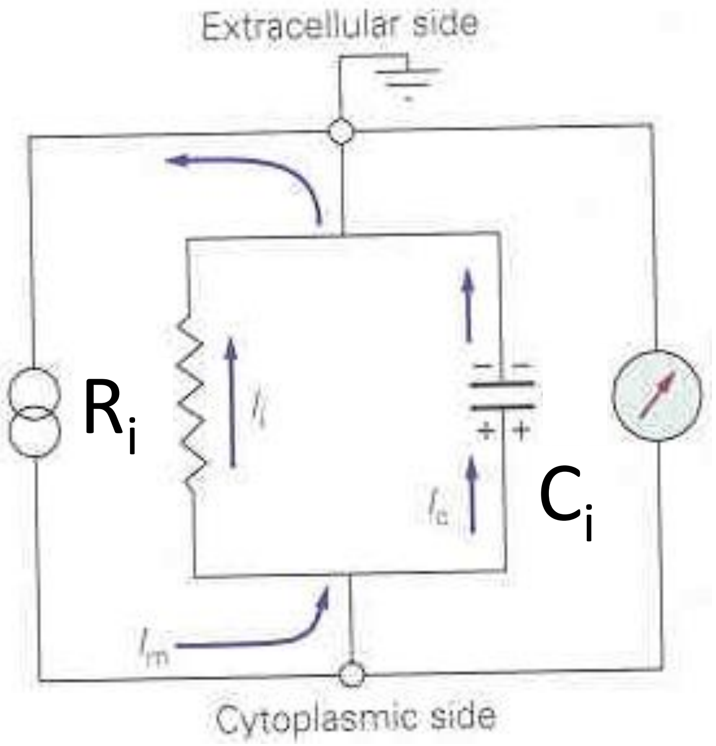
$I_c = \Delta Q / \Delta t$



$I_m = I_i + I_c$



a
b
c
ΔV_m
63% ΔV_m
τ
I_m
Out
I_m
0
I_i
I_c
In
I_i
I_c
Time



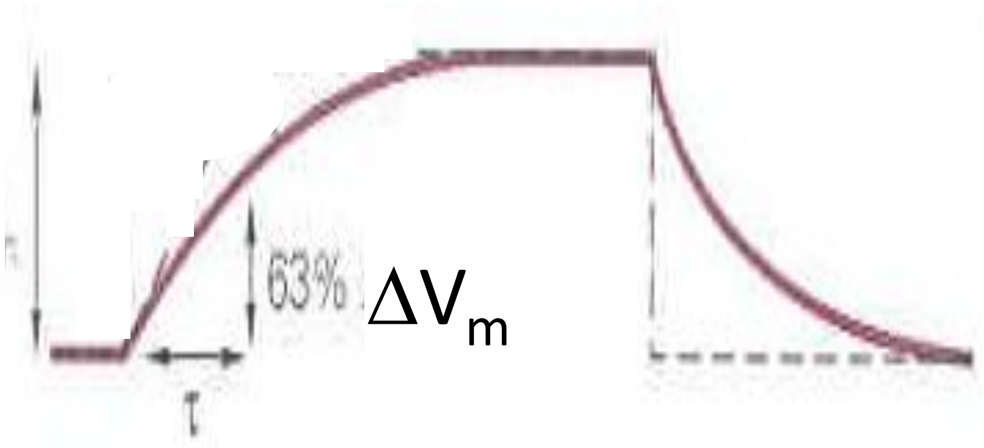
Extracellular side
R_i
I_i
C_i
I_c
I_m
Cytoplasmic side

Zaman sabiti

$\tau = R_m C_m$ 1-20 ms

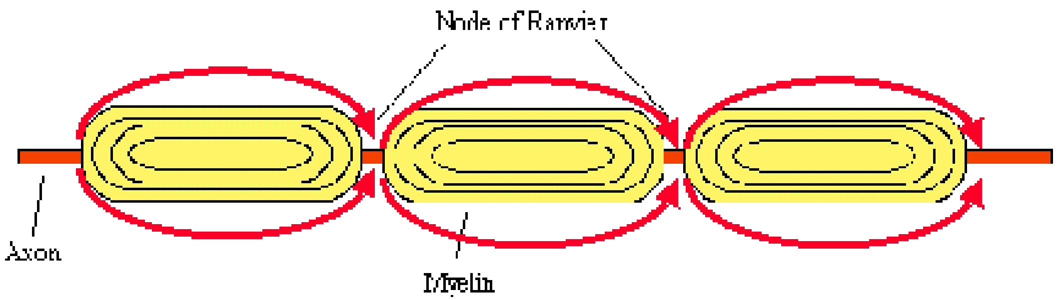
Zaman sabiti akson boyutlarına bağlı değil

ΔV_m



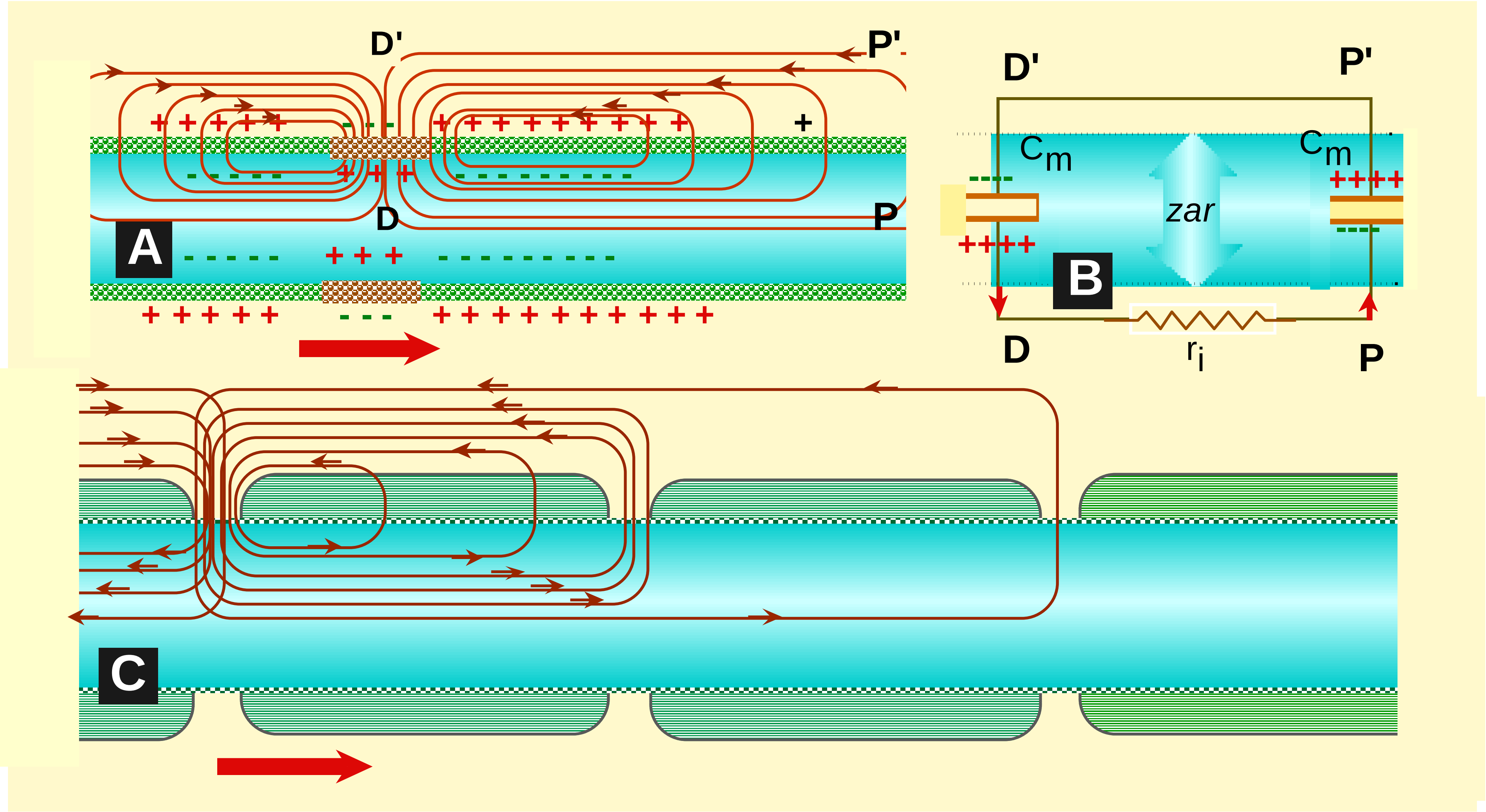
ΔV_m

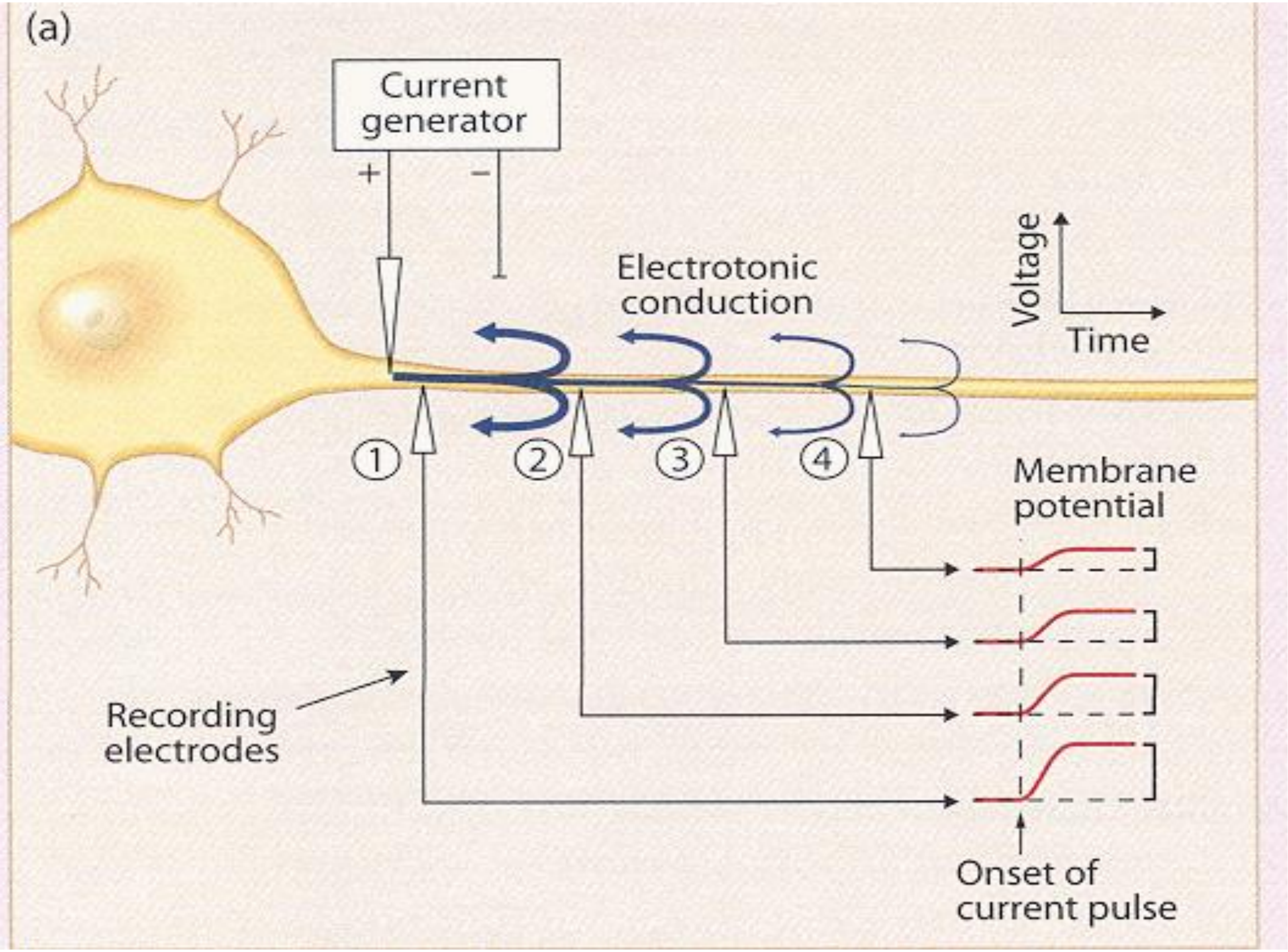
$C = k\varepsilon_0 A/d$

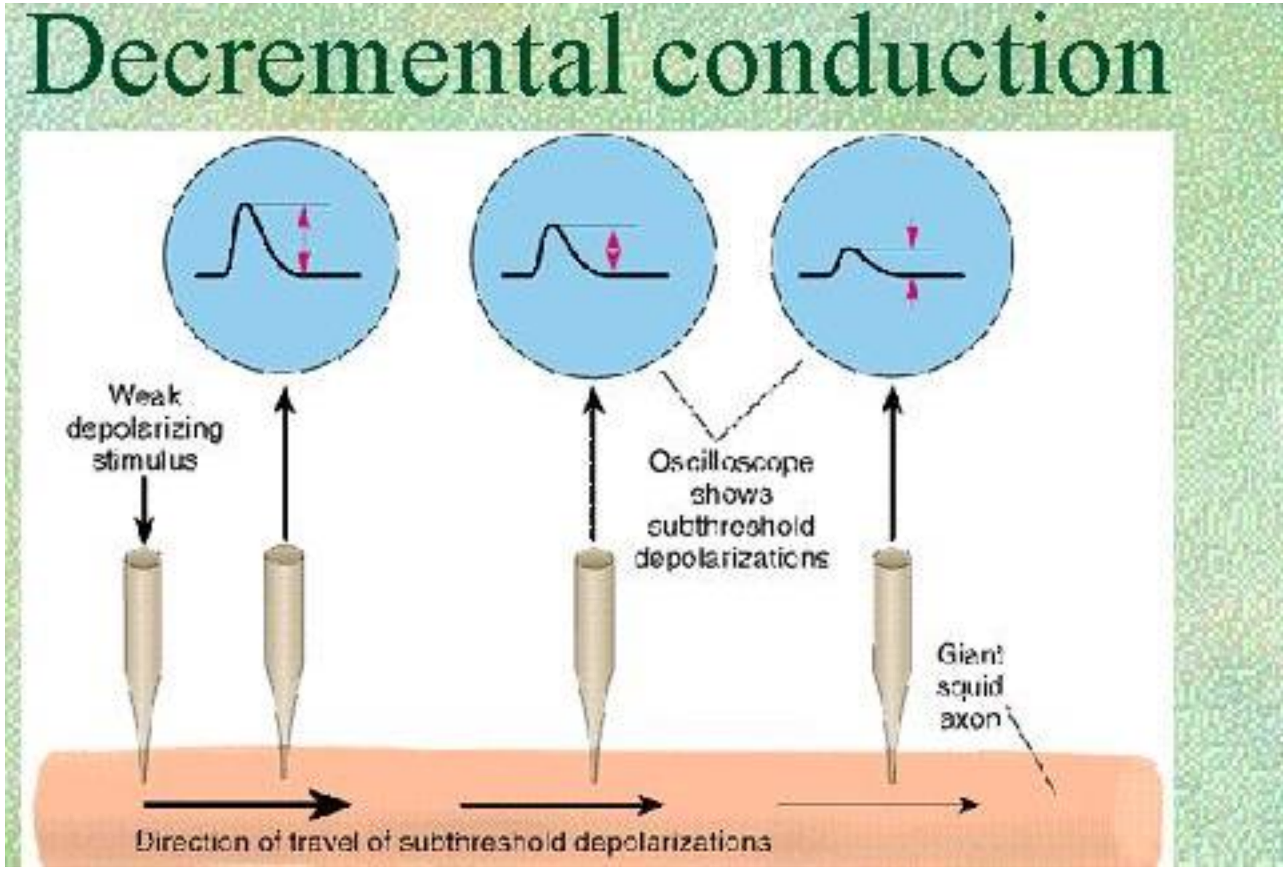


Zaman sabiti küçük olan zarlar kolay ve çabuk depolarize olurlar ve bu nedenle hızlı iletirler

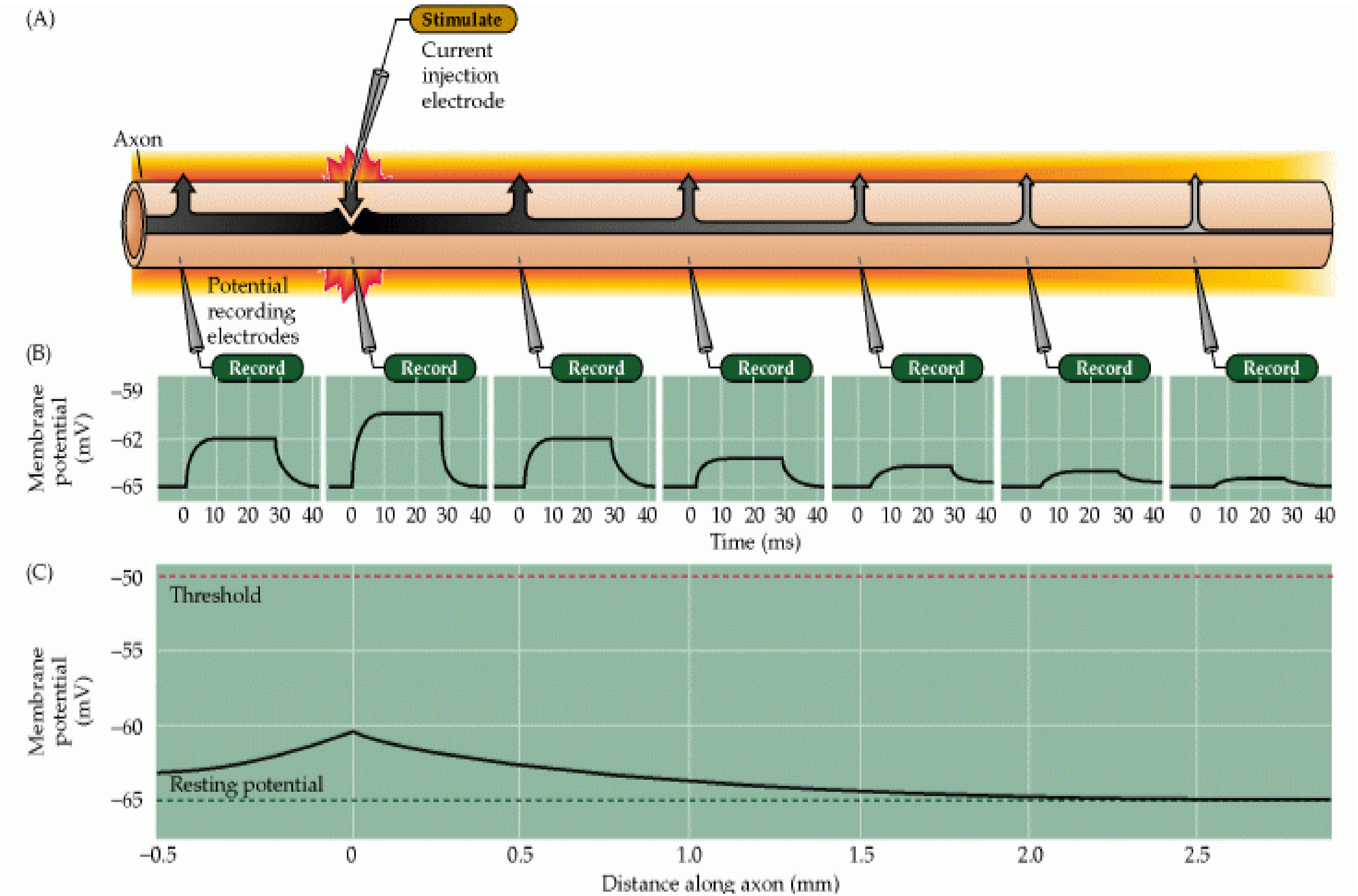
Miyelinsiz ve Miyelinli Aksonlarda Yöresel Akımlar



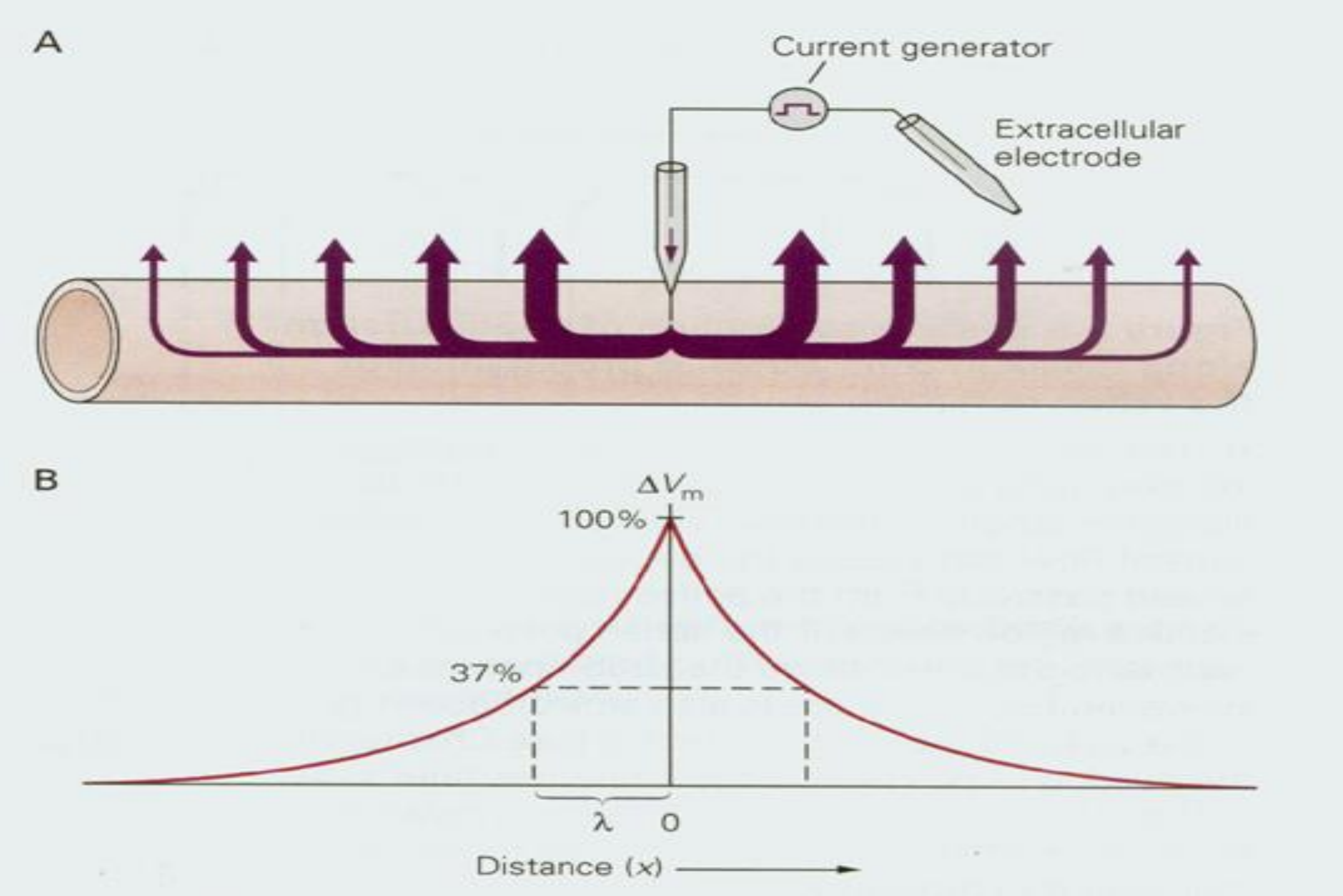

(a)
Current generator
+
−
Electrotonic conduction
Voltage
Time
1
2
3
4
Membrane potential
Recording electrodes
Onset of current pulse



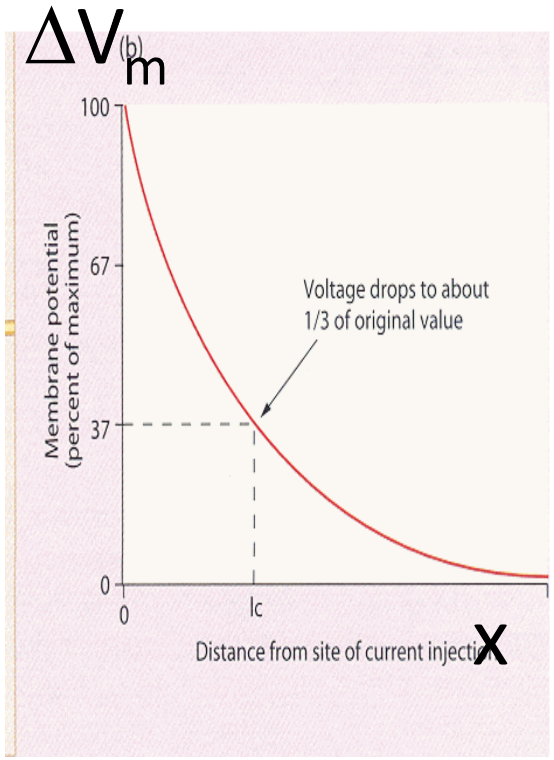
Yerel pot genliği uzaklığa bağlı olarak azalır.



(A)
Stimulate
Current injection electrode
Axon
Potential recording electrodes
(B)
Record
Membrane potential (mV)
−59
−62
−65
0 10 20 30 40
Time (ms)
(C)
Membrane potential (mV)
−50
−55
−60
−65
Threshold
Resting potential
−0.5
0
0.5
1.0
1.5
2.0
2.5
Distance along axon (mm)



A
Current generator
Extracellular
electrode
B
ΔVm
100%
37%
λ
0
Distance (x)

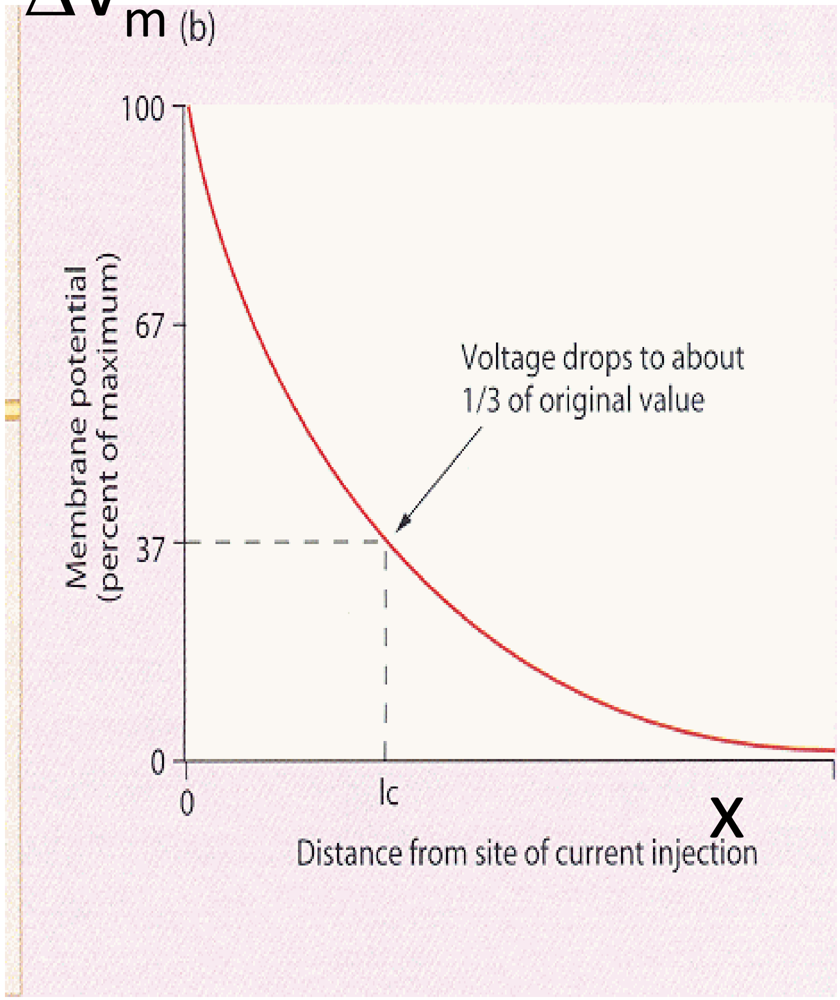


$$\Delta V_m = \Delta V_o \, e^{-x/\lambda}$$

Uzunluk(kablo) sabiti : λ

Uzunluk(kablo) sabiti : λ

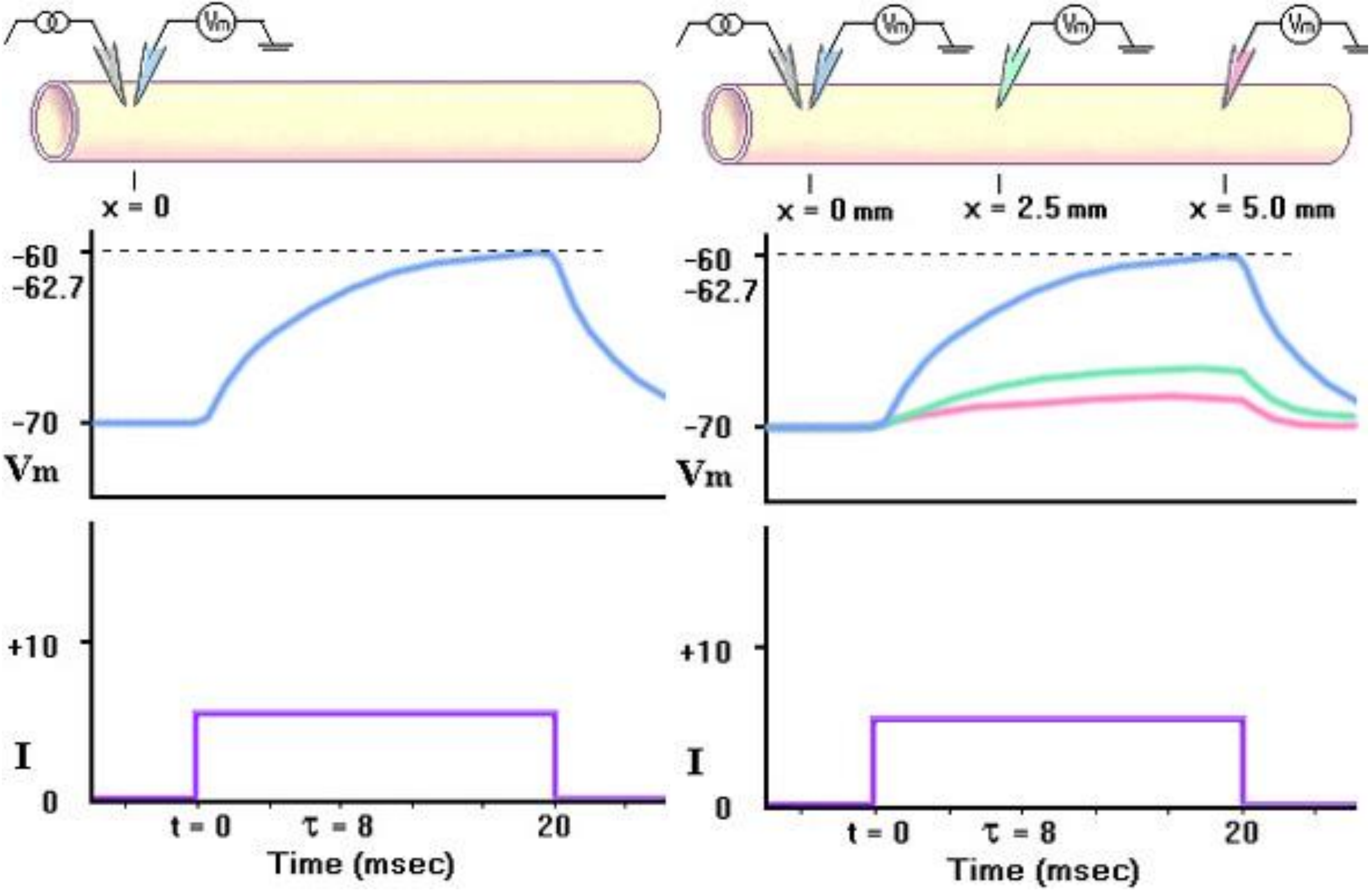
ΔV_m

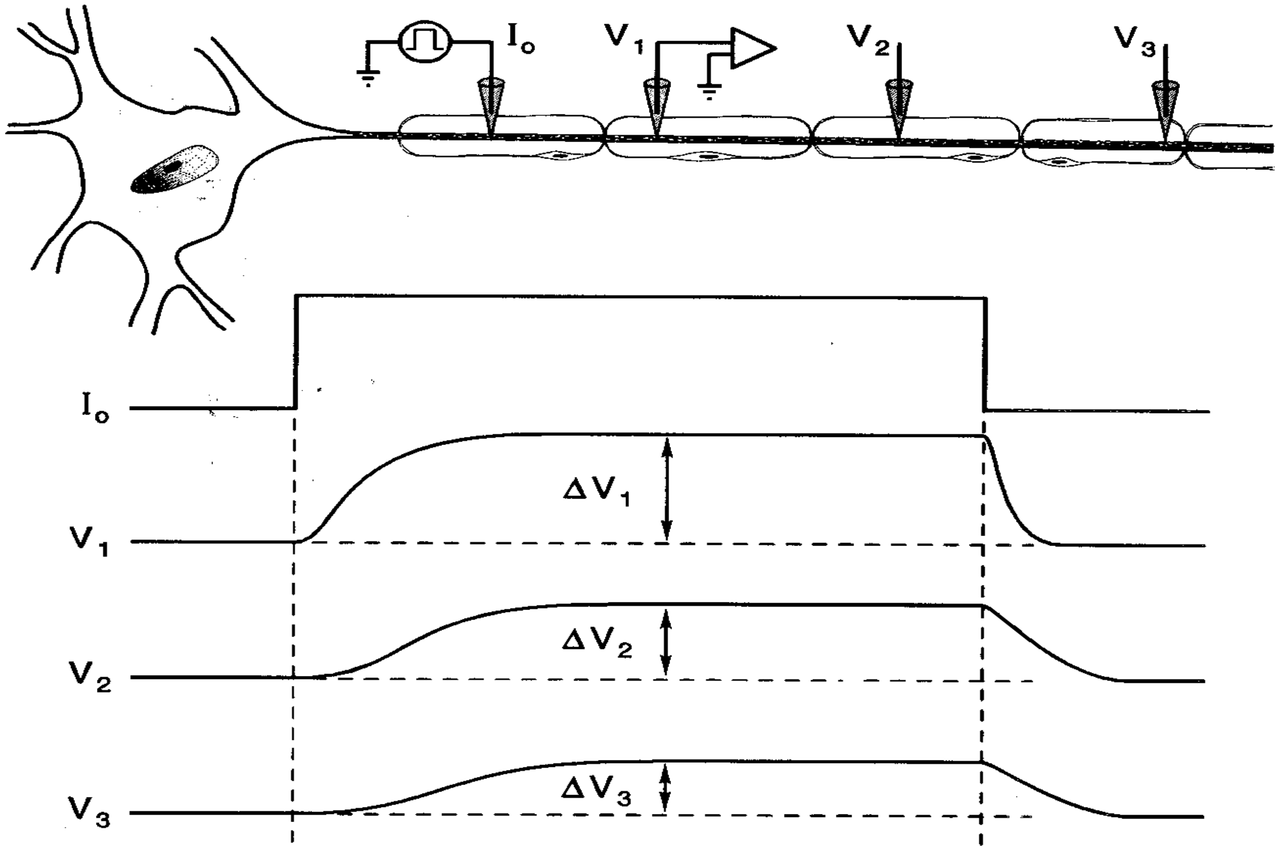


ΔV_o in 1/e ‘sine Düşmesi için gerekli uzunluk

$$\lambda = \sqrt{r_m / r_a}$$

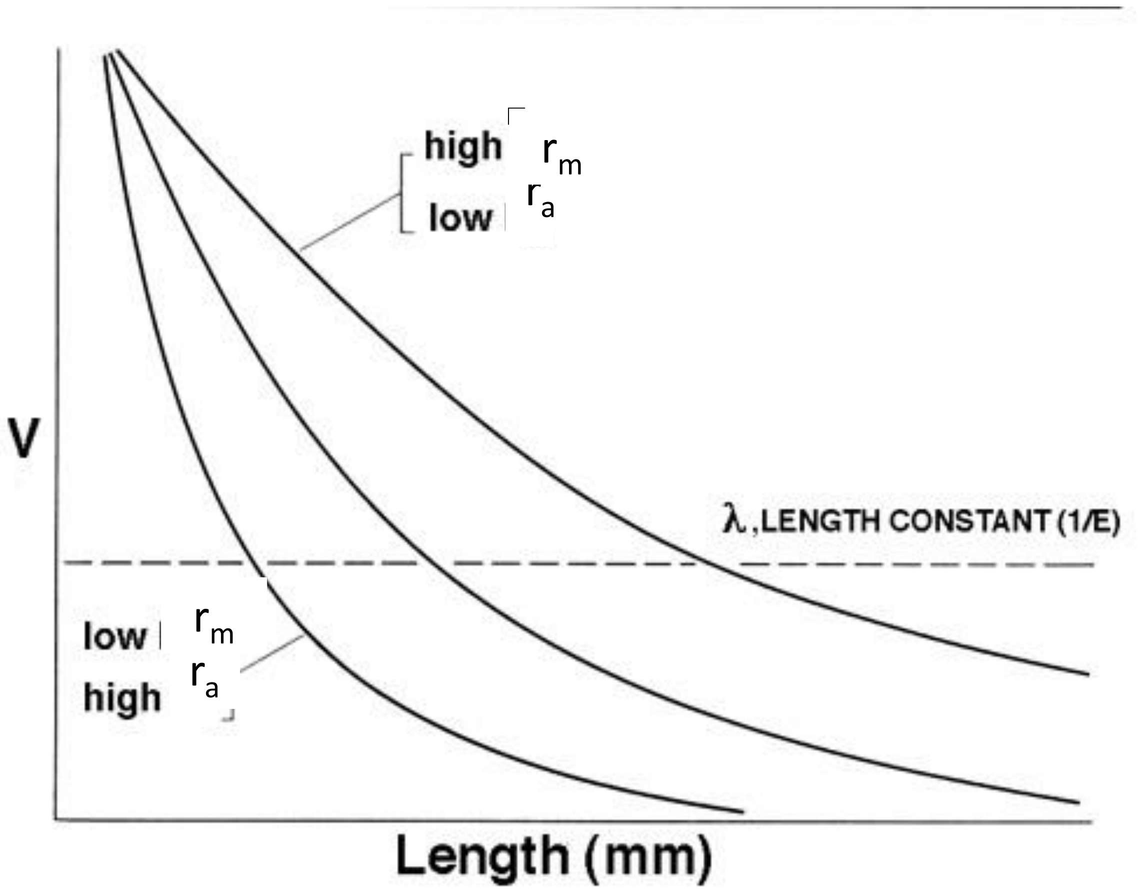
r_m → 1 cm uzunluğun direnci Ohm cm


Vm
x = 0
-60
-62.7
-70
Vm
+10
I
0
t = 0
τ = 8
20
Time (msec)
Vm
Vm
Vm
x = 0 mm
x = 2.5 mm
x = 5.0 mm
-60
-62.7
-70
Vm
+10
I
0
t = 0
τ = 8
20
Time (msec)



$\tau_m = r_m c_m$ zar zaman sabiti (s), $\lambda m = \sqrt{r_m / r_i}$ zar uzay sabiti

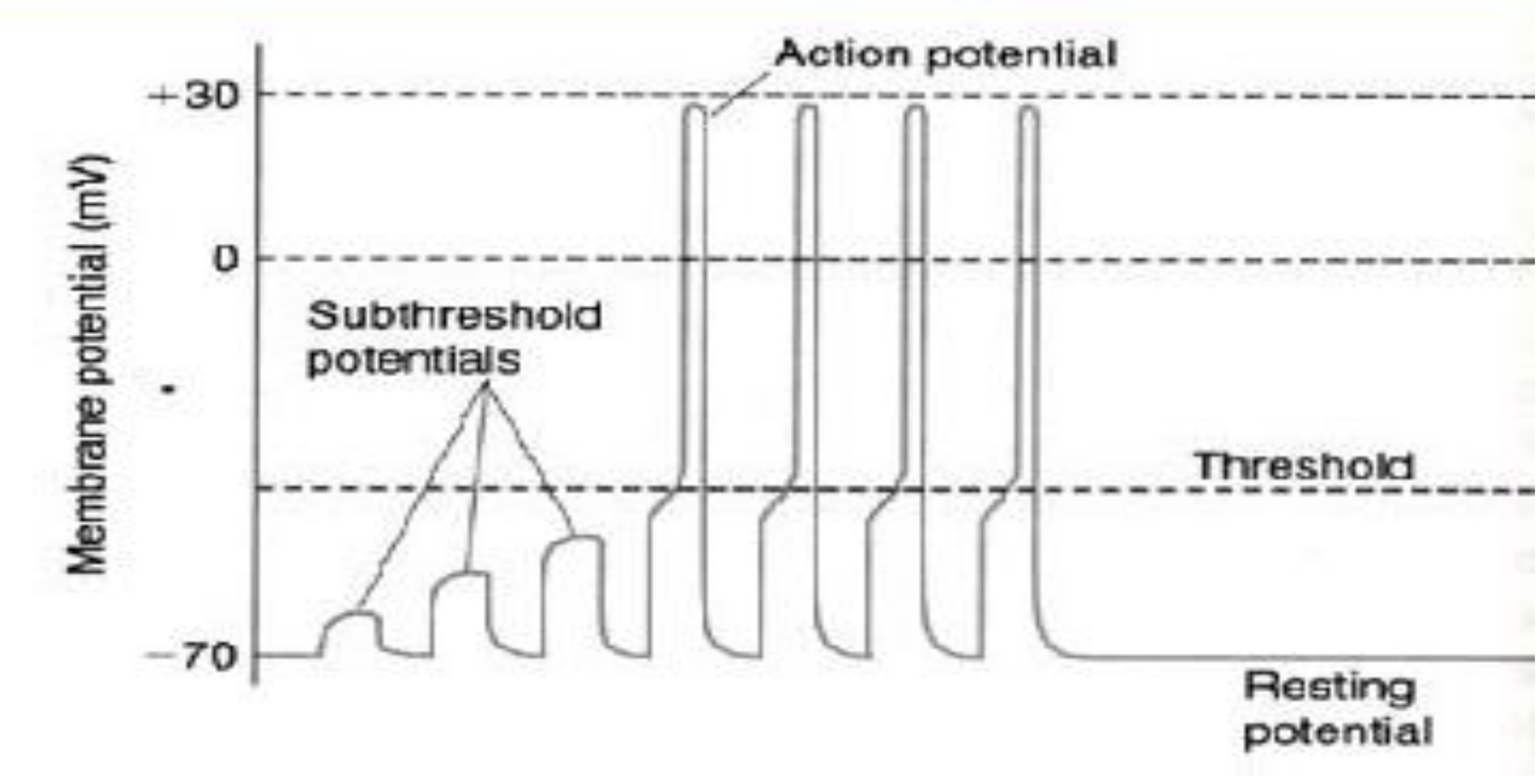
potansiyel farkının akson boyunca pasif iletilmesine elektrotonik iletim adı verilir



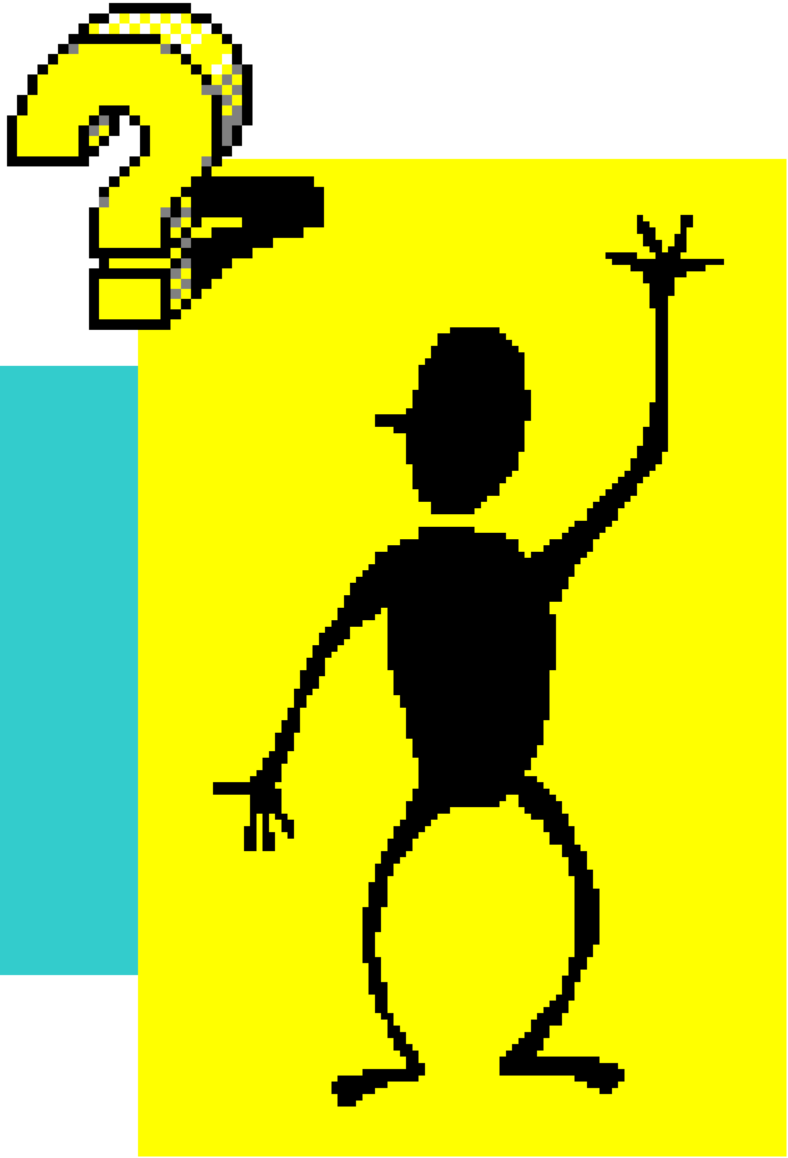
high
low
r_m
r_a
V
λ, LENGTH CONSTANT (1/E)
low
high
r_m
r_a
Length (mm)

Stimulus-Response: Threshold

Yerel potansiyelin belirli bir eşiği geçmesi durumunda A.P oluşur.



$\lambda \rightarrow$ Büyük olan sinirlerde?????



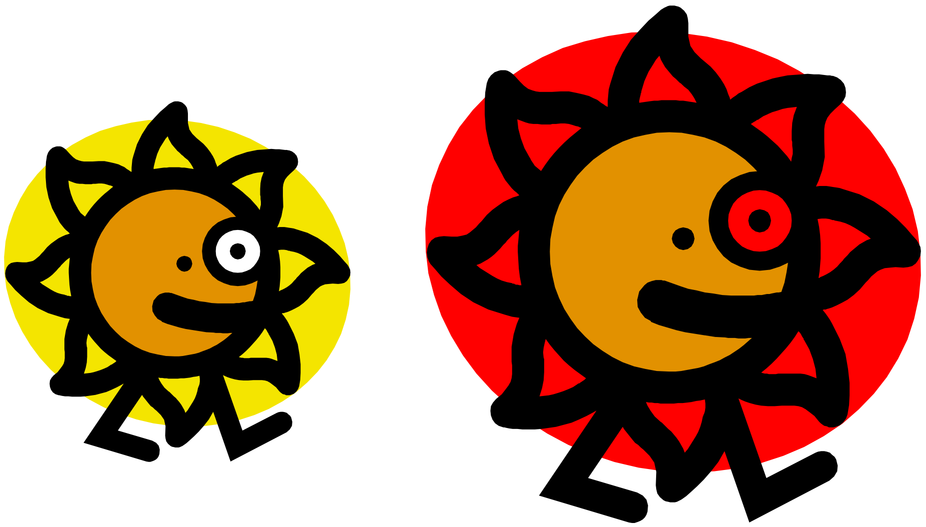
Ohm's Law

$$I = V / R$$

Voltaj büyürse akım artar

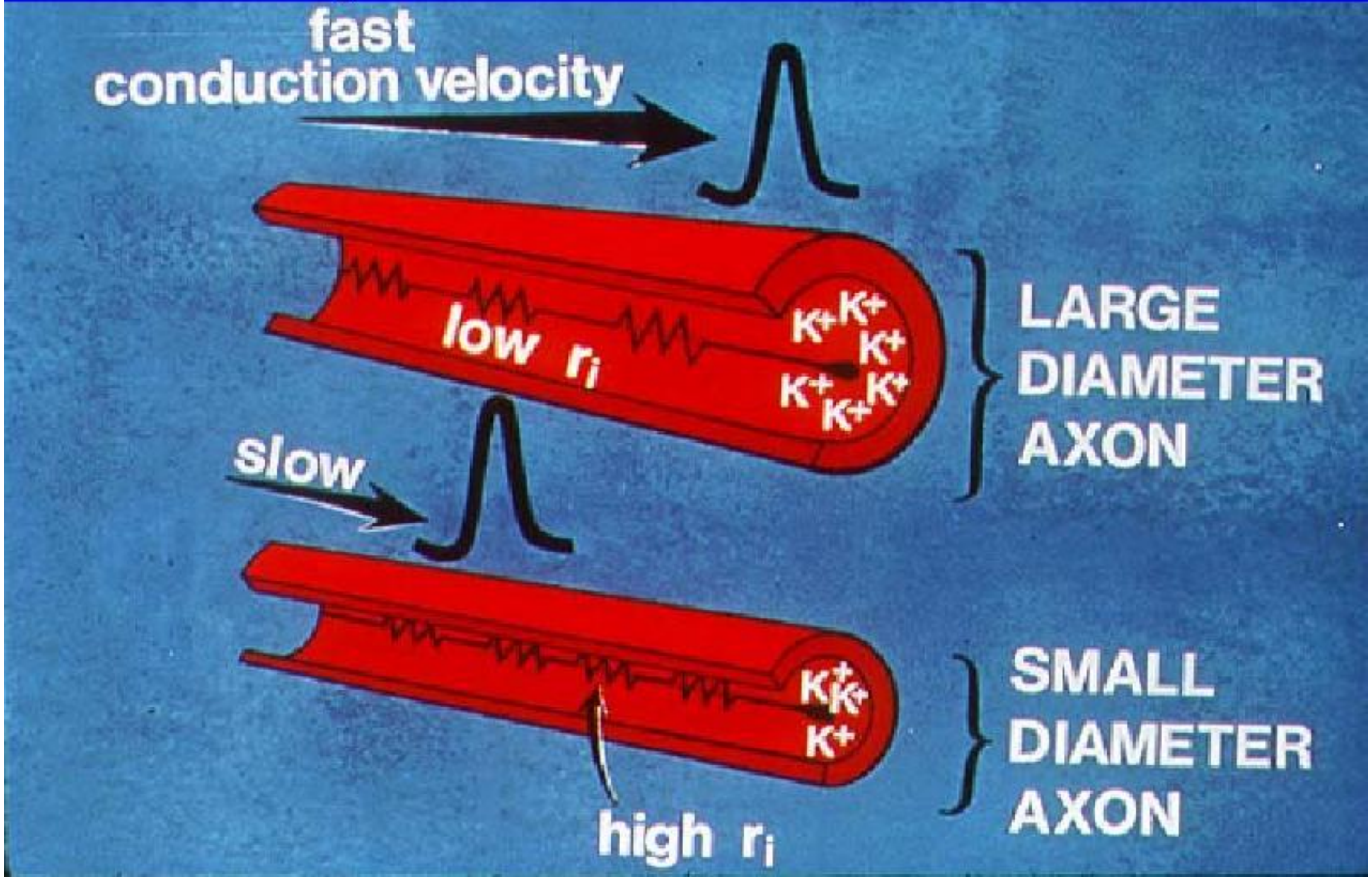
Direnç büyürse akım küçülür.

Büyük Nöronlarda yüzey alanı
Büyür.

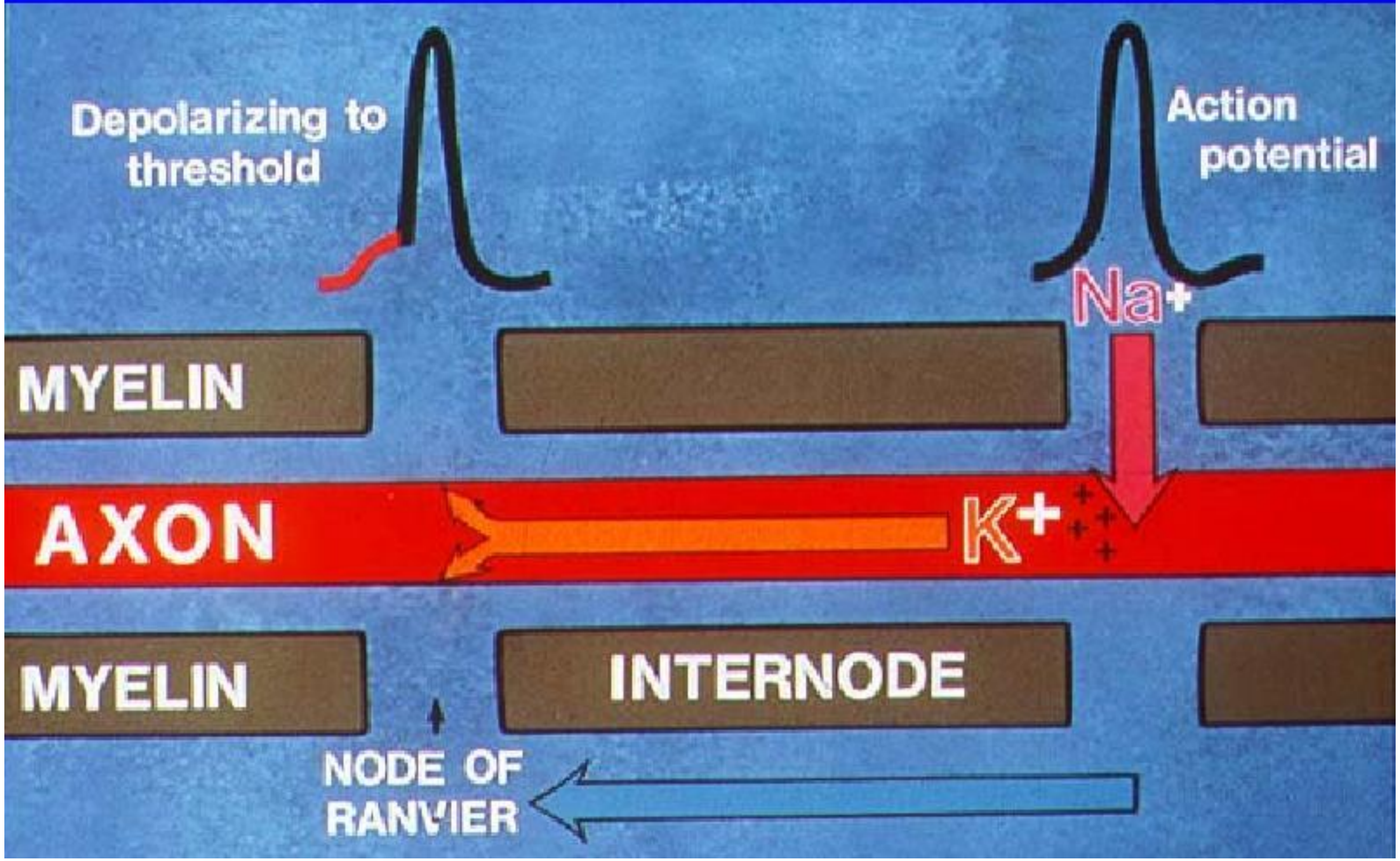


R_a

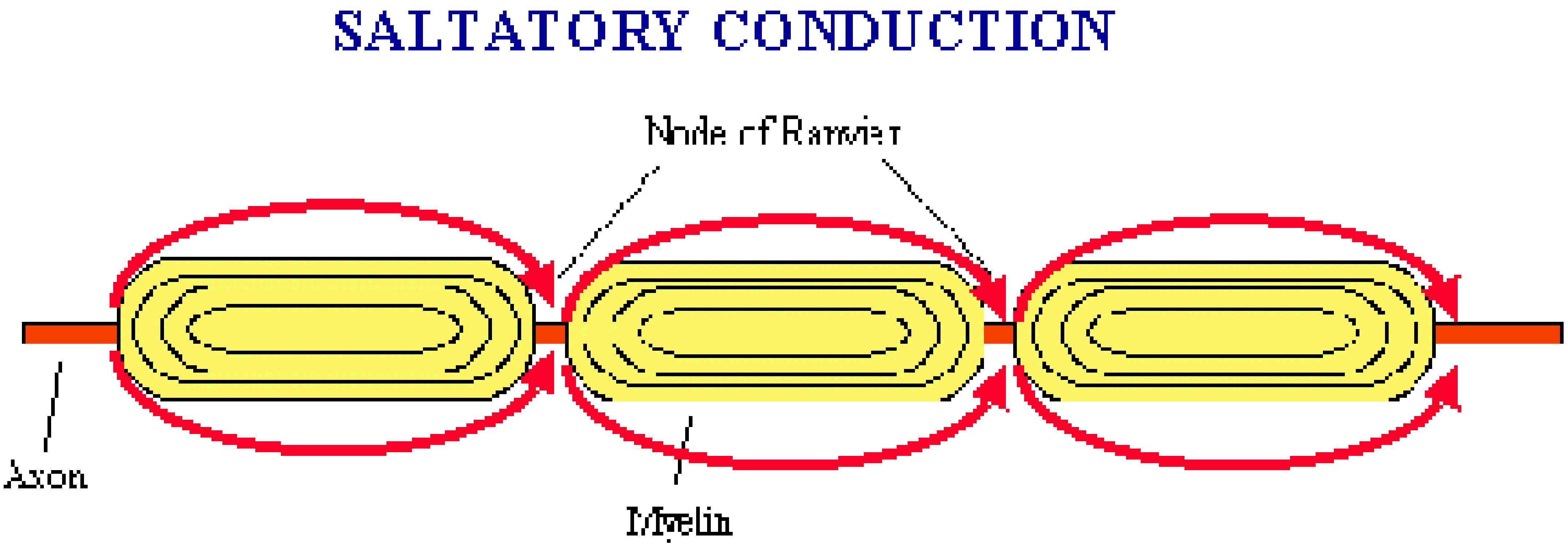
Impact of Axon Diameter



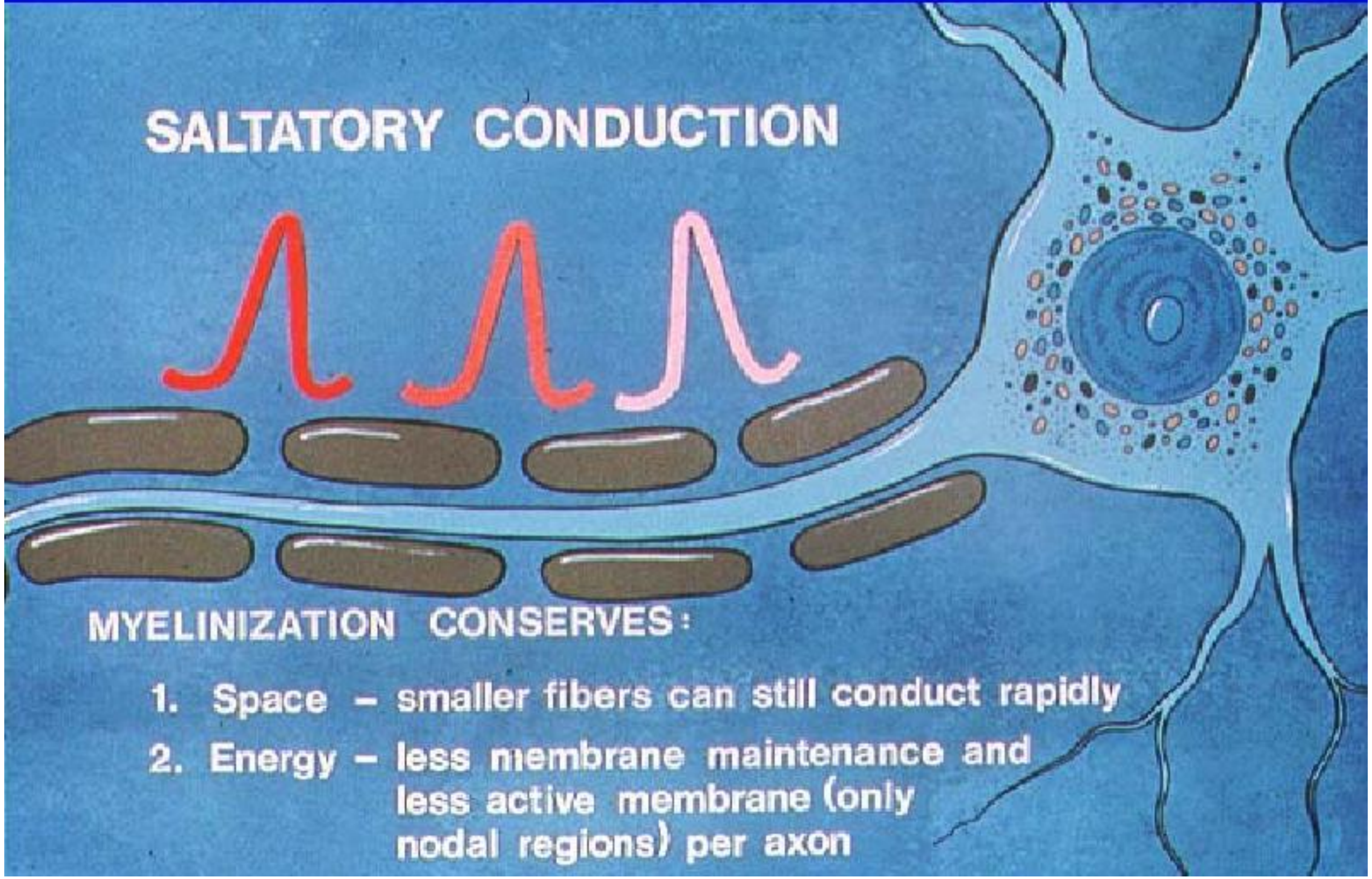
Nodes of Ranvier

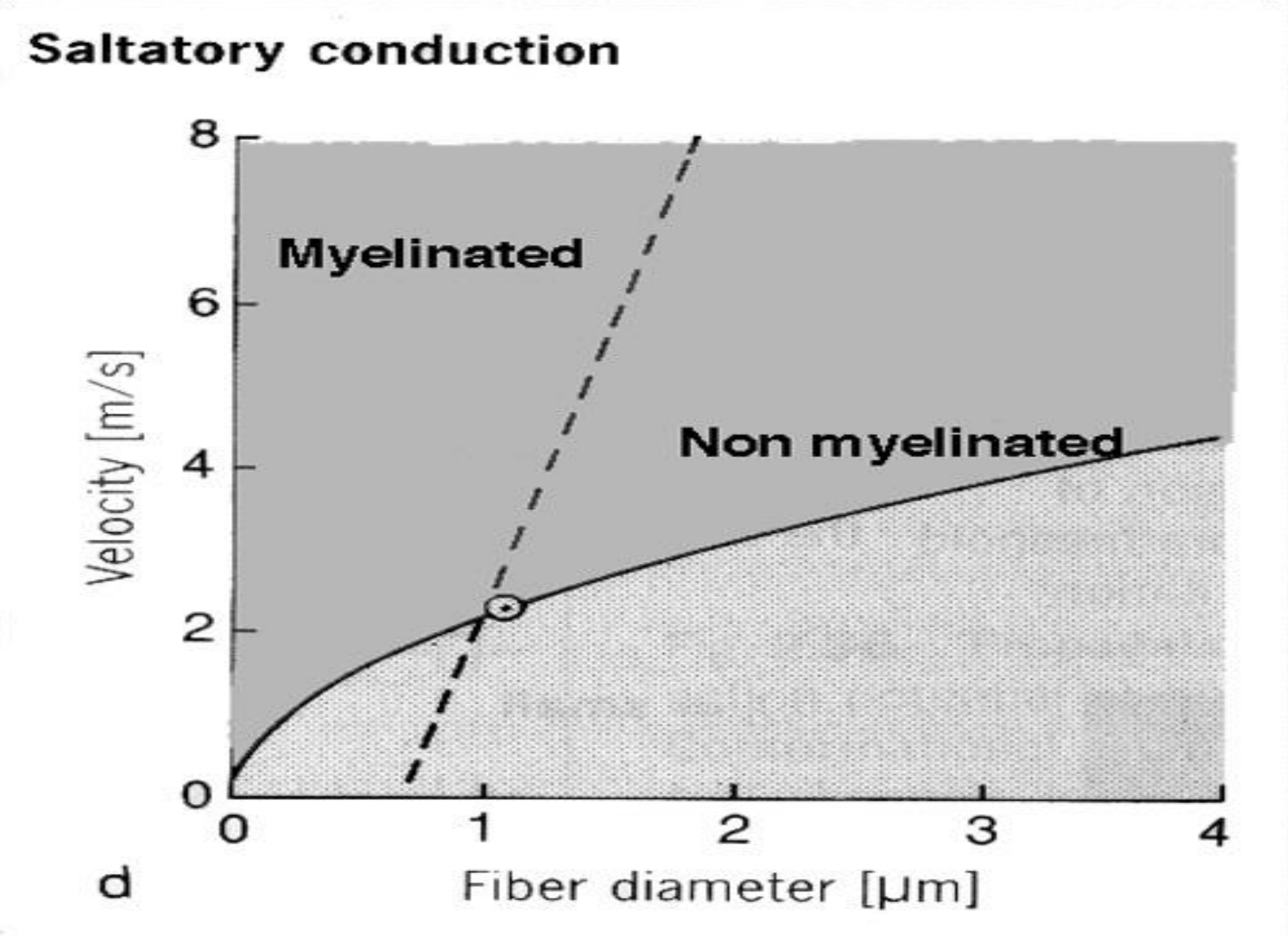


SALTATORİK İLETİM



Benefits


SALTATORY CONDUCTION
MYELINIZATION CONSERVES:
1. Space - smaller fibers can still conduct rapidly
2. Energy - less membrane maintenance and less active membrane (only nodal regions) per axon


Saltatory conduction
Myelinated
Non myelinated
Velocity [m/s]
8
6
4
2
0
0
1
2
3
4
d
Fiber diameter [µm]