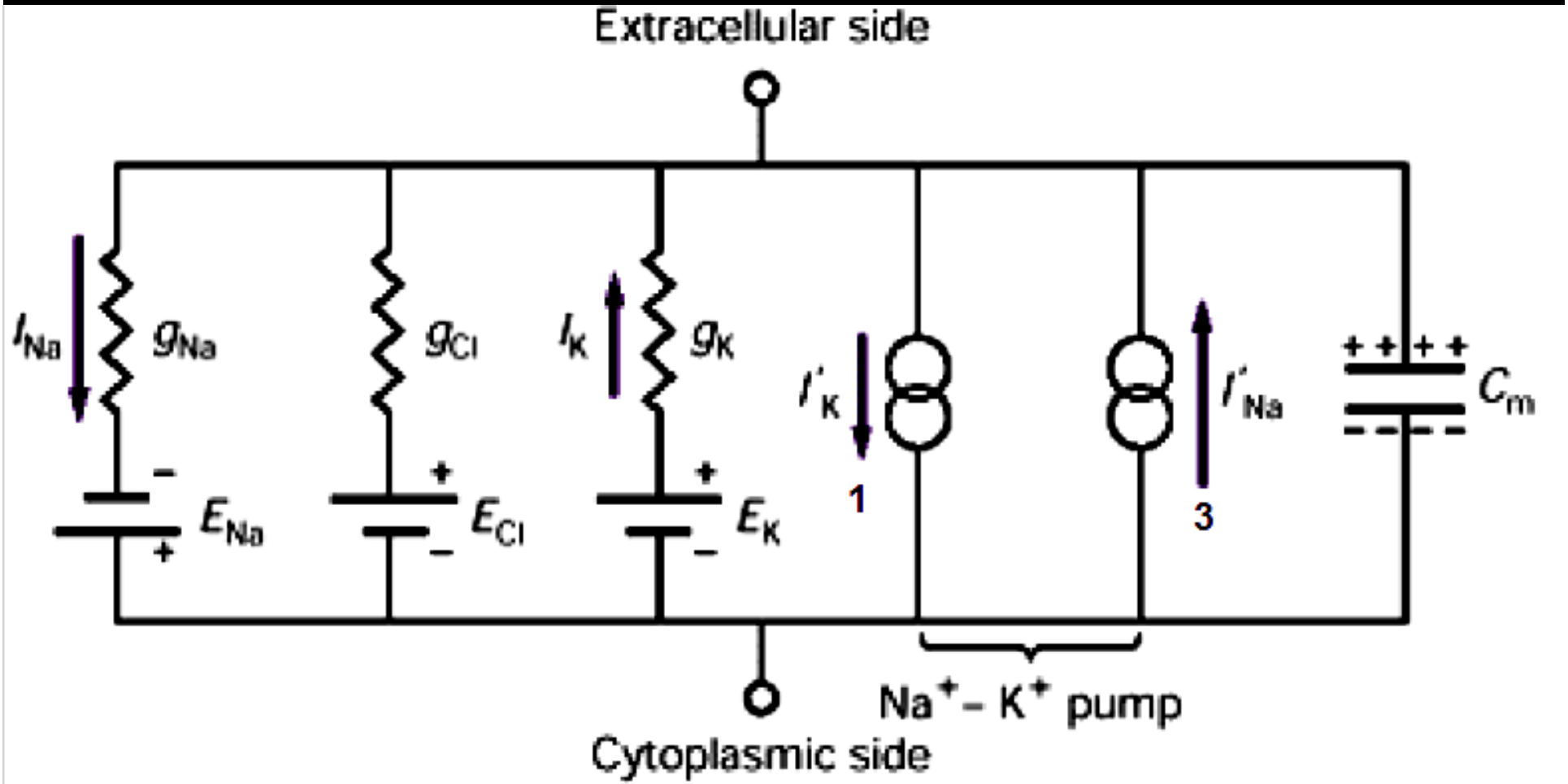
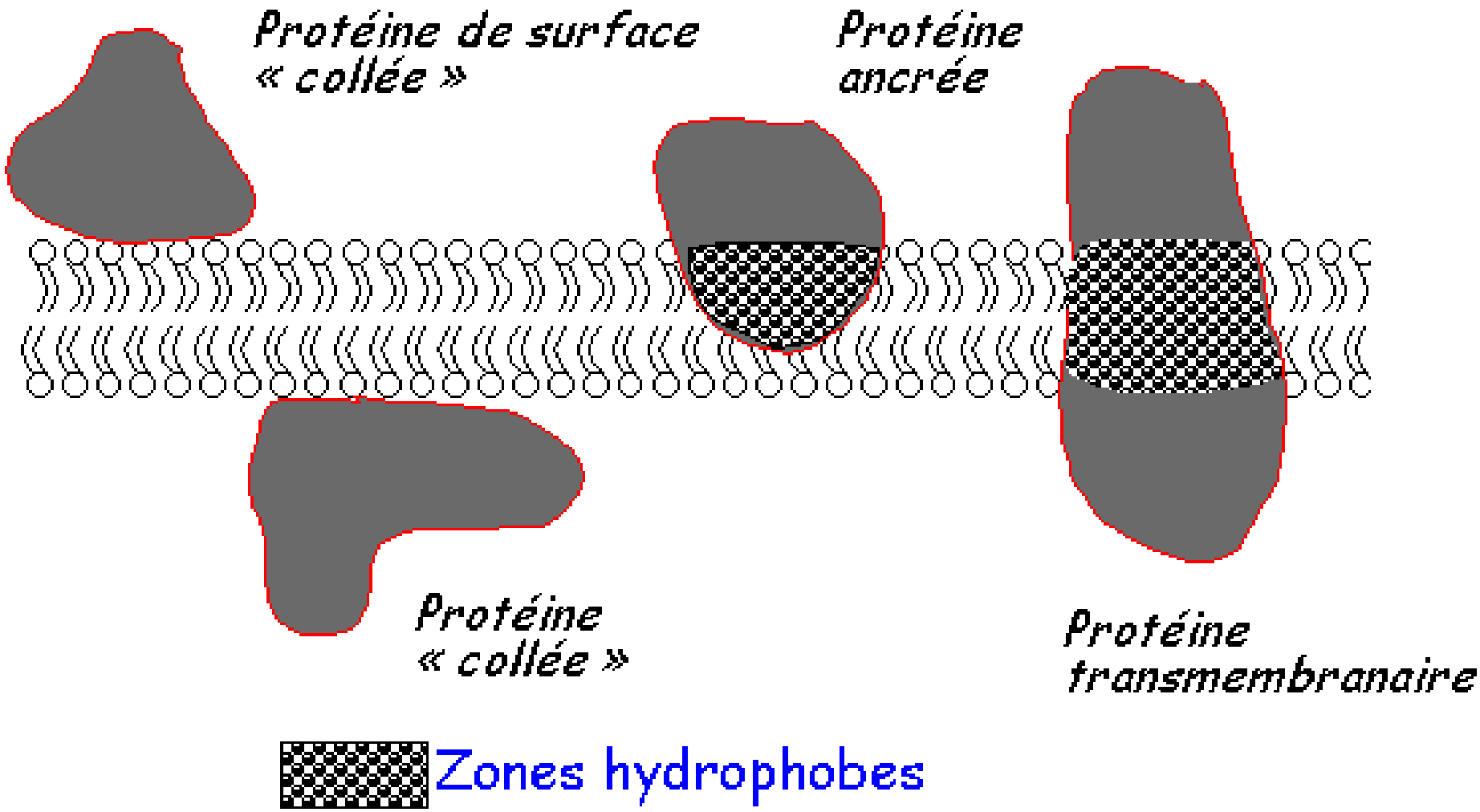
Potentiel d'action

Conduction nerveuse

Potentiels locaux : (électrotonus)

Equivalent électrique de la membrane


Extracellular side
I_{Na}
g_{Na}
g_{Cl}
I_K
g_K
I'_K
I'_{Na}
C_m
E_{Na}
E_{Cl}
E_K
1
3
$Na^+ - K^+$ pump
Cytoplasmic side


Protéine de surface « collée »
Protéine ancrée
Protéine « collée »
Protéine transmembranaire
Zones hydrophobes

Les courants gradués entrants ou sortants dans une cellule provoquent selon le cas une hyperpolarisation ou une dépolarisation graduée de la membrane (Vm).

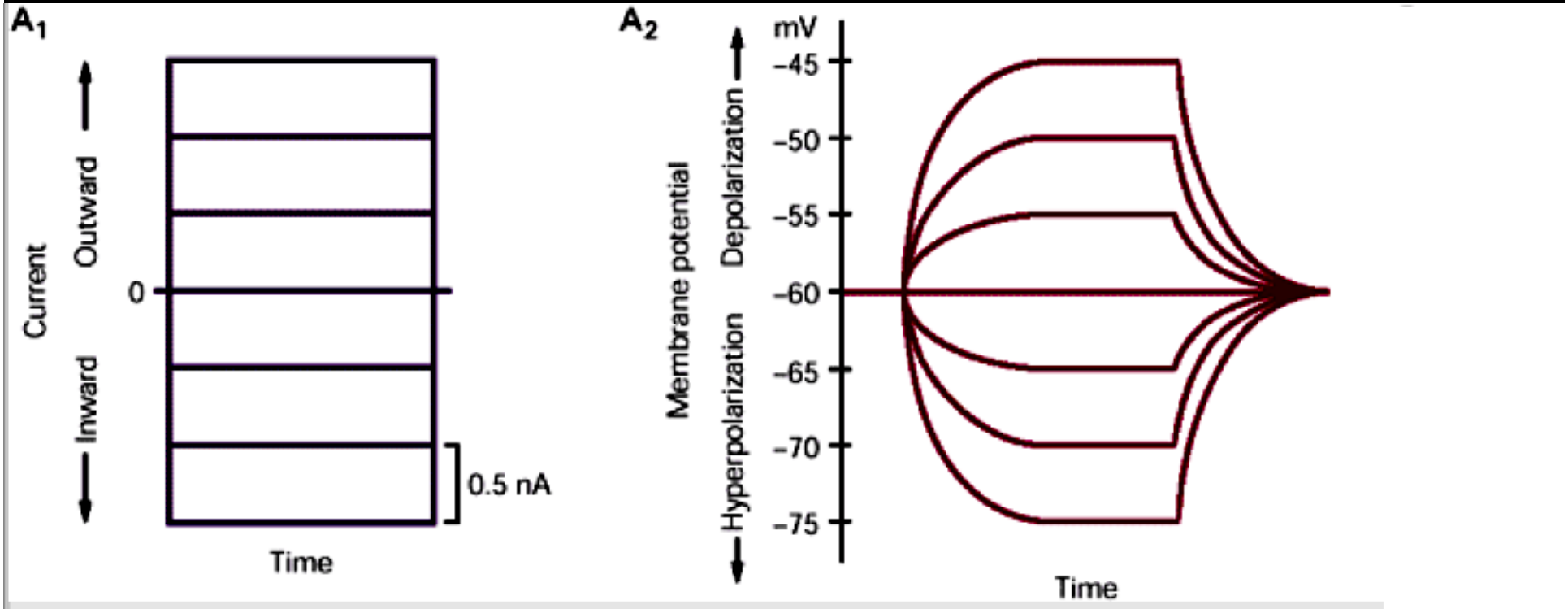
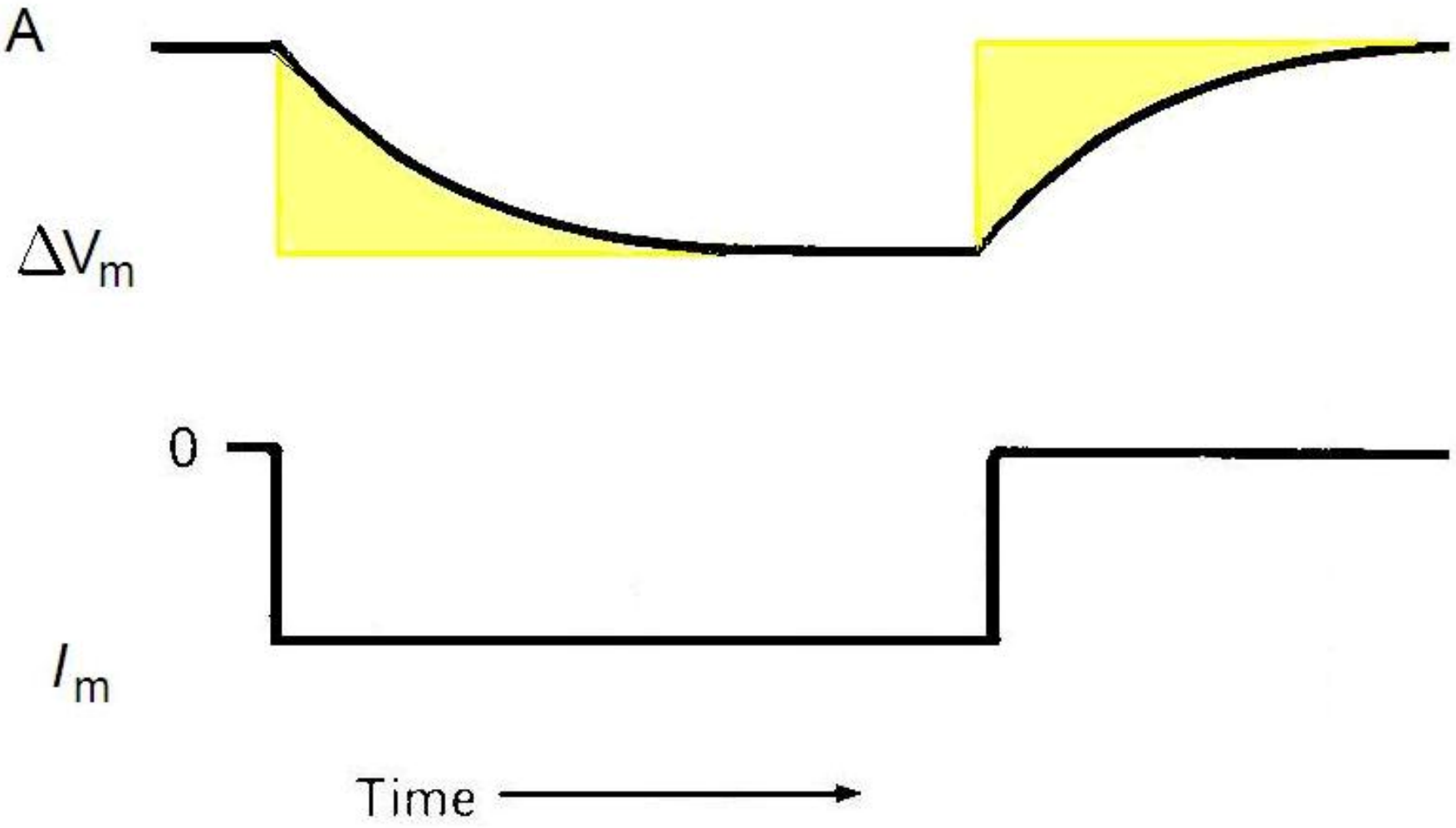


Figure 8-1 Current-voltage relationships. By passing subthreshold, graded, inward and outward current pulses into a cell, one can determine the relationship between current injected into the cell and the resulting changes in membrane potential, V_m.

ANODE

+

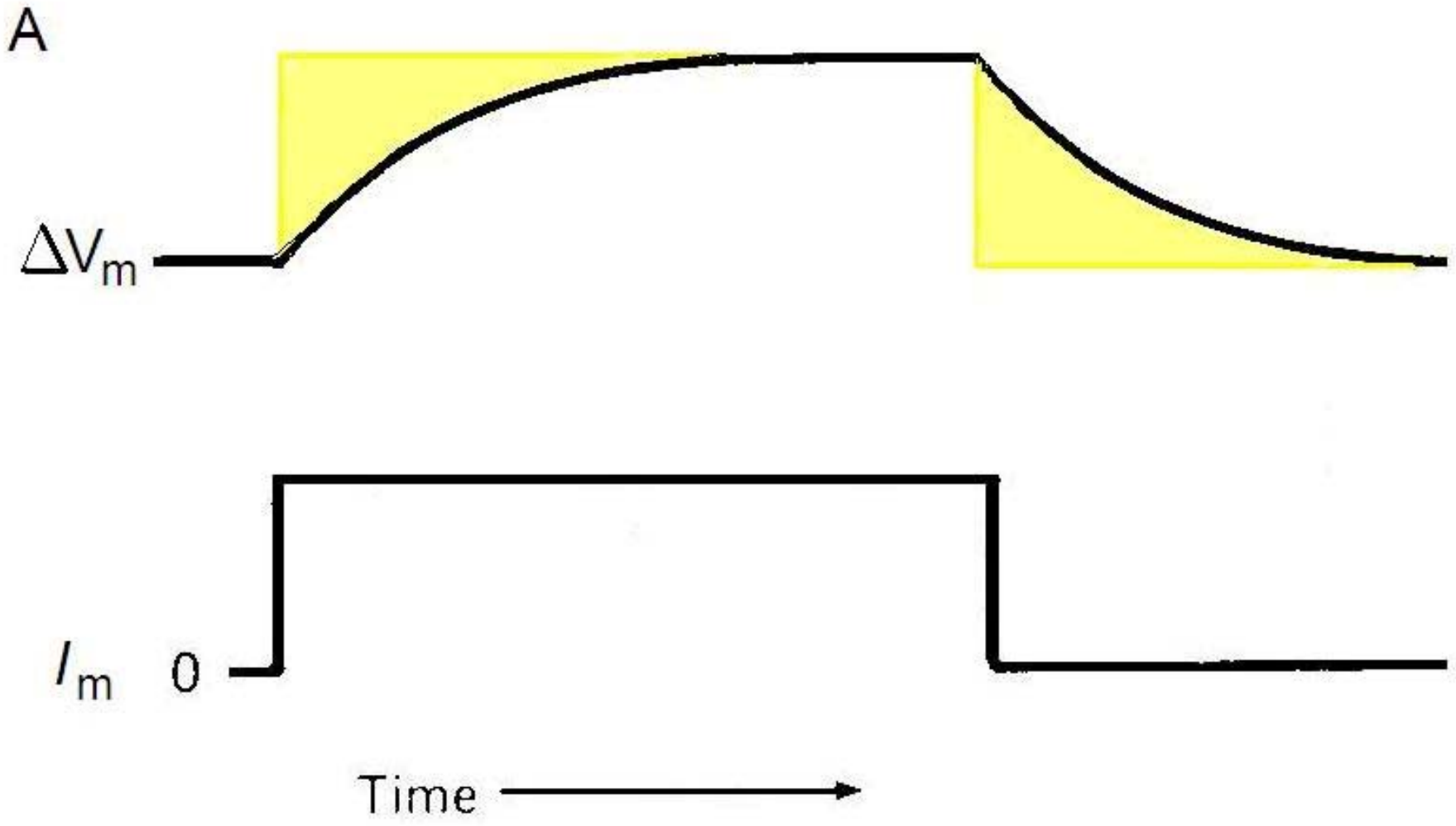
ANELECTROTONUS

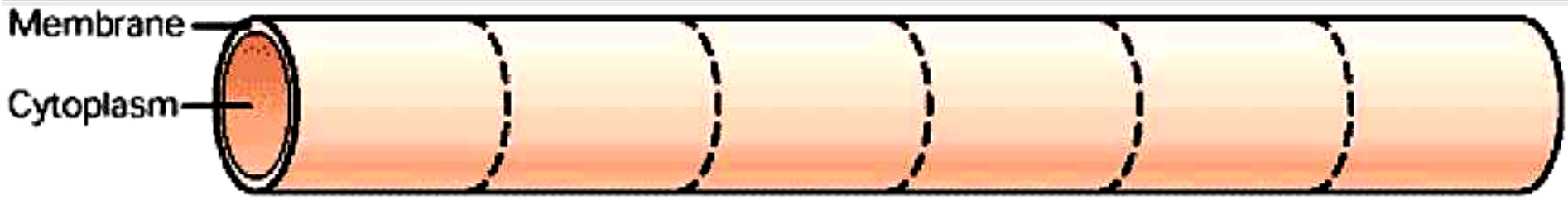


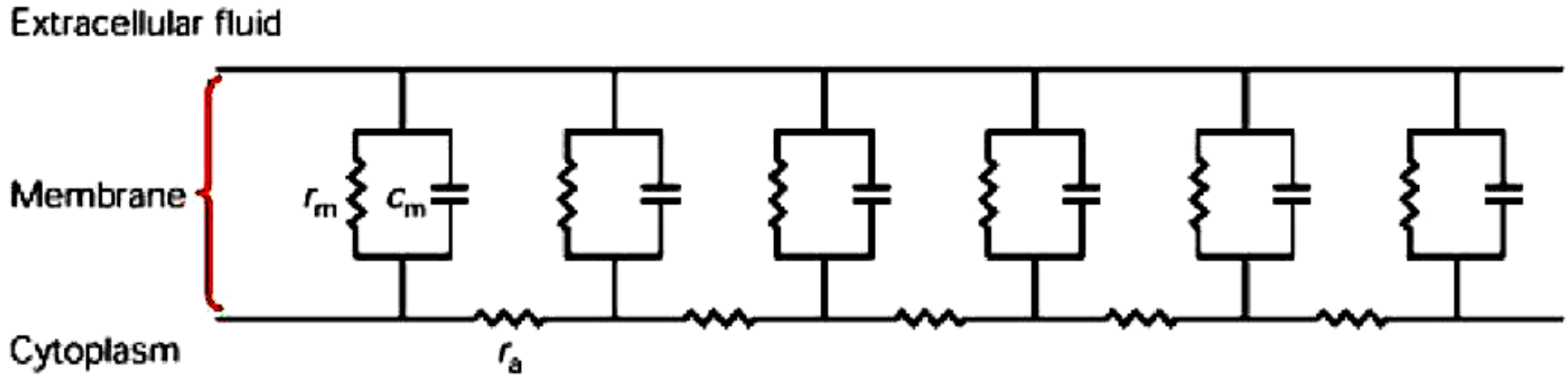
CATHODE

(--)

CATHELECTROTONUS



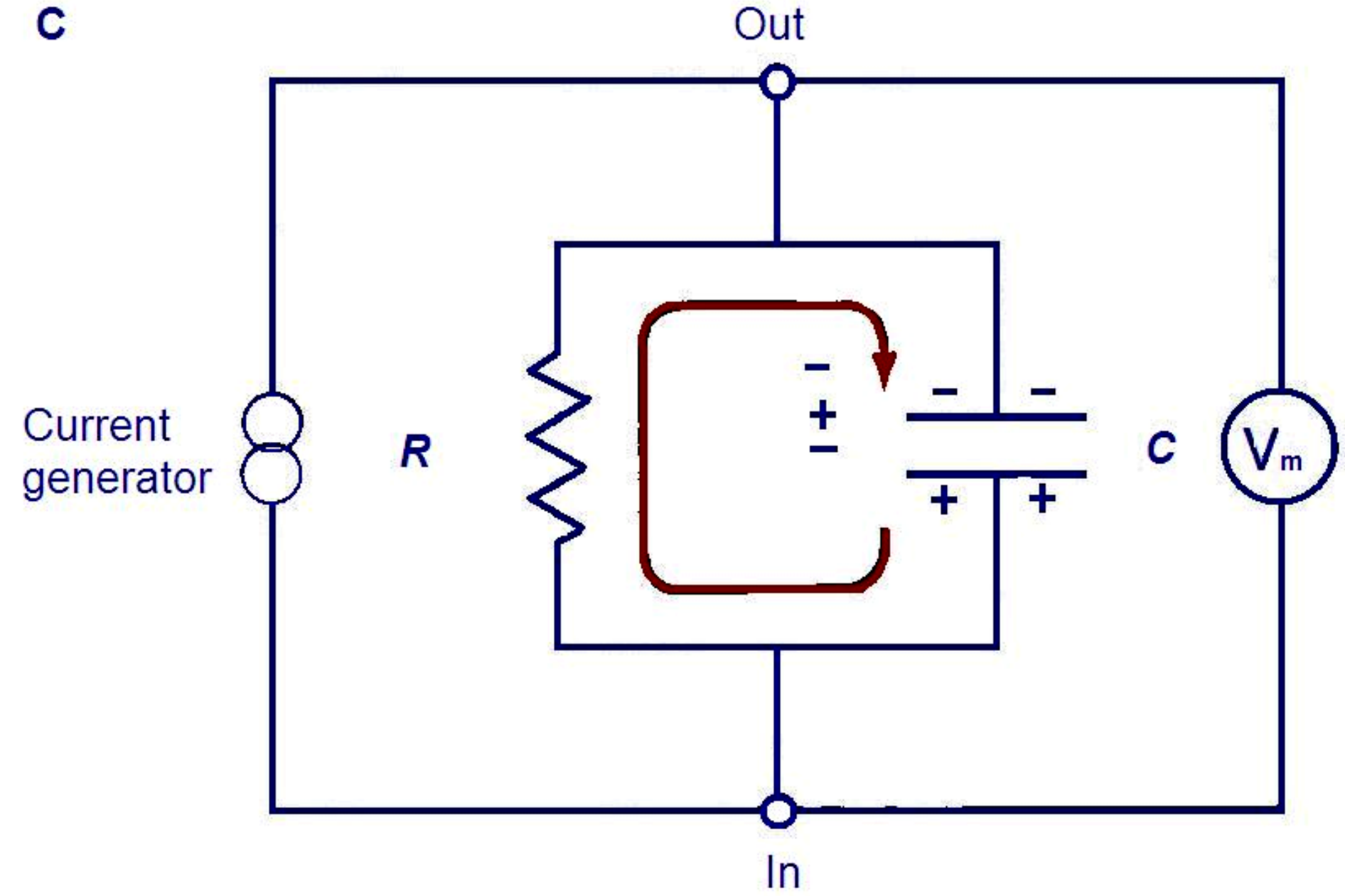

Membrane
Cytoplasm


Extracellular fluid
Membrane
r_m
c_m
Cytoplasm
r_a

DECREMENT TEMPOREL

- **CONSTANTE DE TEMPS :**
- **Tau : $\tau = R_m x C_m$**

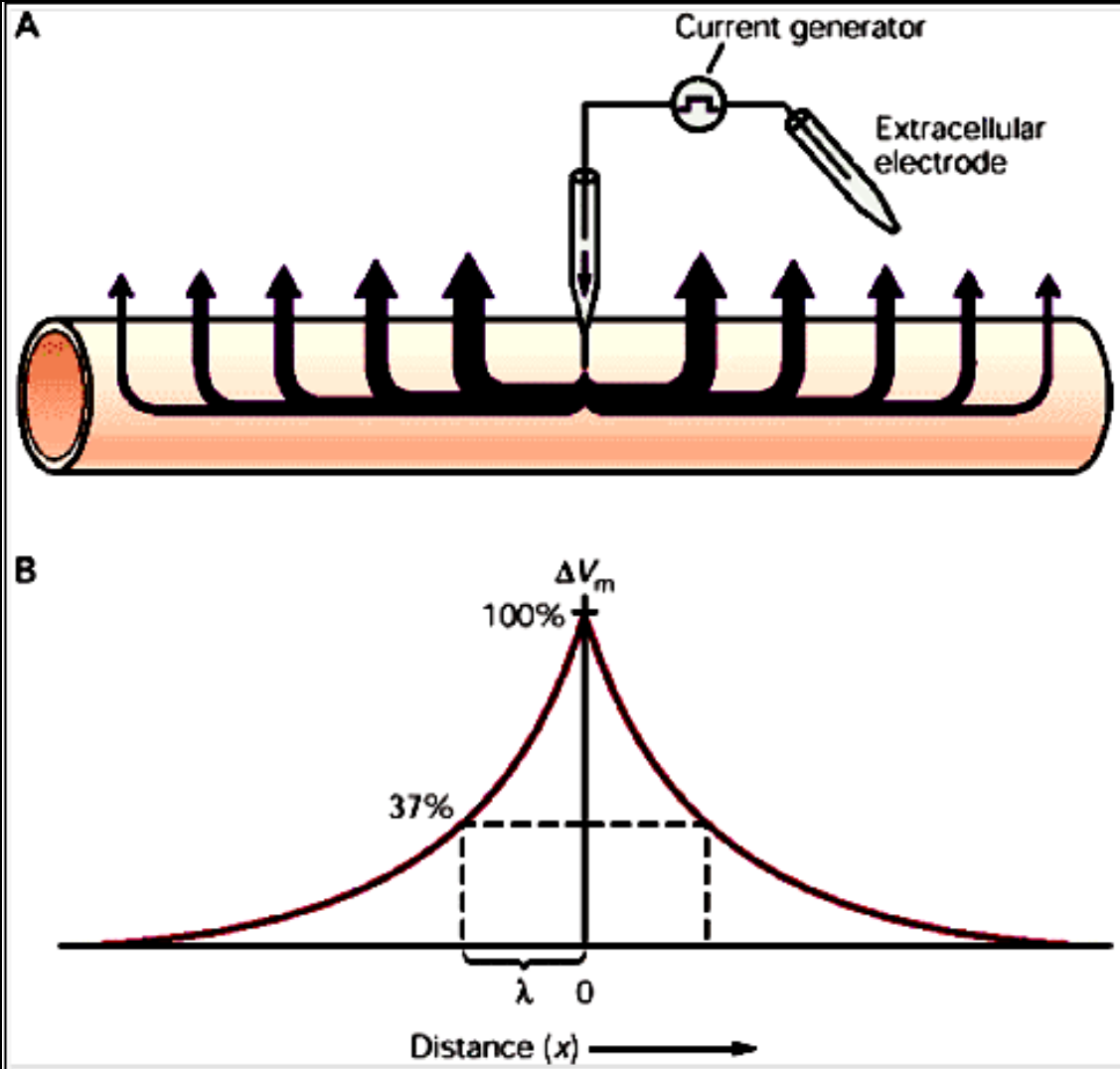
Pour chaque nouvel intervalle de temps Tau (τ), le potentiel de membrane subit une autre décroissance (un décrément) équivalente à 1/e $_x$ Vm (≈ 0,37 Vm), jusqu'à s'annuler en quelques millisecondes (ms).


C
Out
Current
generator
R
C
V_m
In

CONSTANTE D'ESPACE :

Lambda : $\lambda = \sqrt{r_m/r_i}$

Pour chaque distance constante, lambda (λ), le potentiel de membrane diminue jusqu'à $1/e \times Vm$, et diminuer ainsi de proche en proche jusqu'à s'annuler au bout de quelques millimètres .



$$\lambda\left(\frac{1}{e}.V_m\right)=\sqrt{\frac{R_m}{R_i}}$$

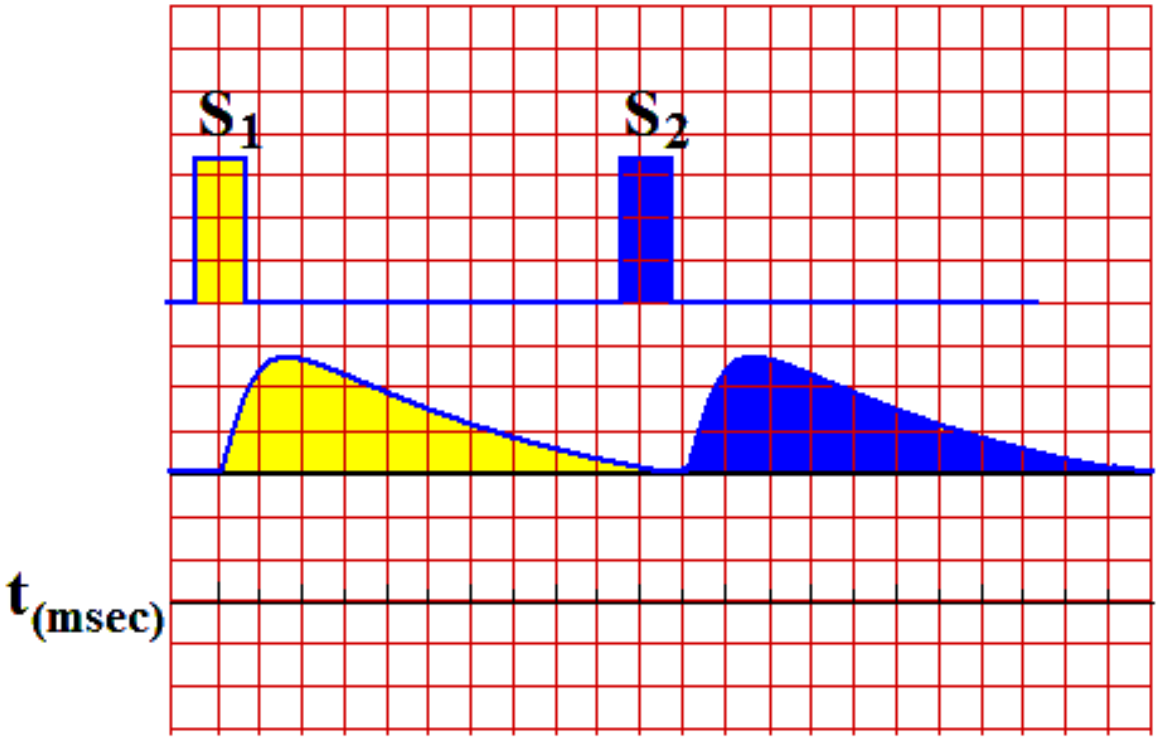
Figure 8-5 The voltage response in a passive neuronal process decays with distance due to electronic conduction.

Sommabilité temporo-spatiale

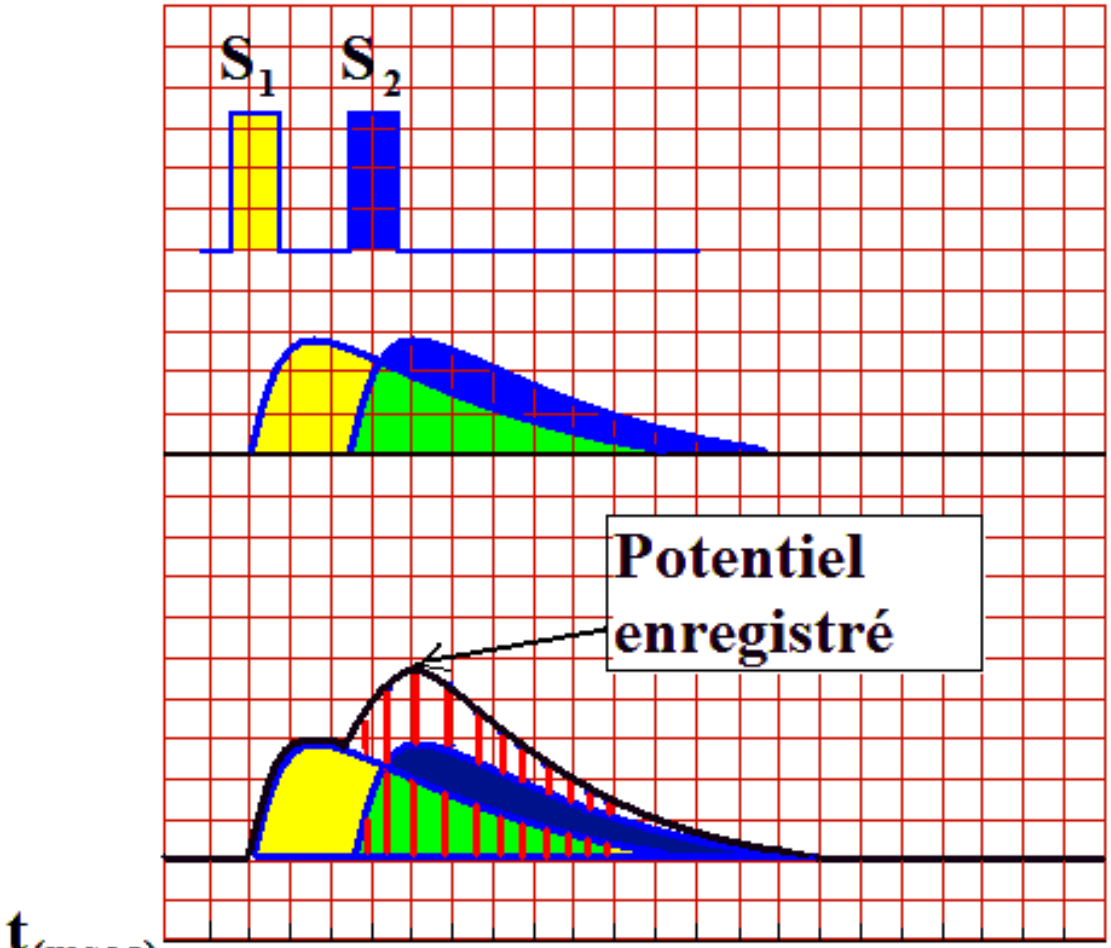
Les courants locaux peuvent subir une sommation algébrique, s'ils sont rapprochés dans le temps et/ou dans l'espace.

SOMMABILITE TEMPORELLE

Stimulus dépolarisants, décalés dans le temps, appliqués au même endroit : pas de sommation des potentiels locaux



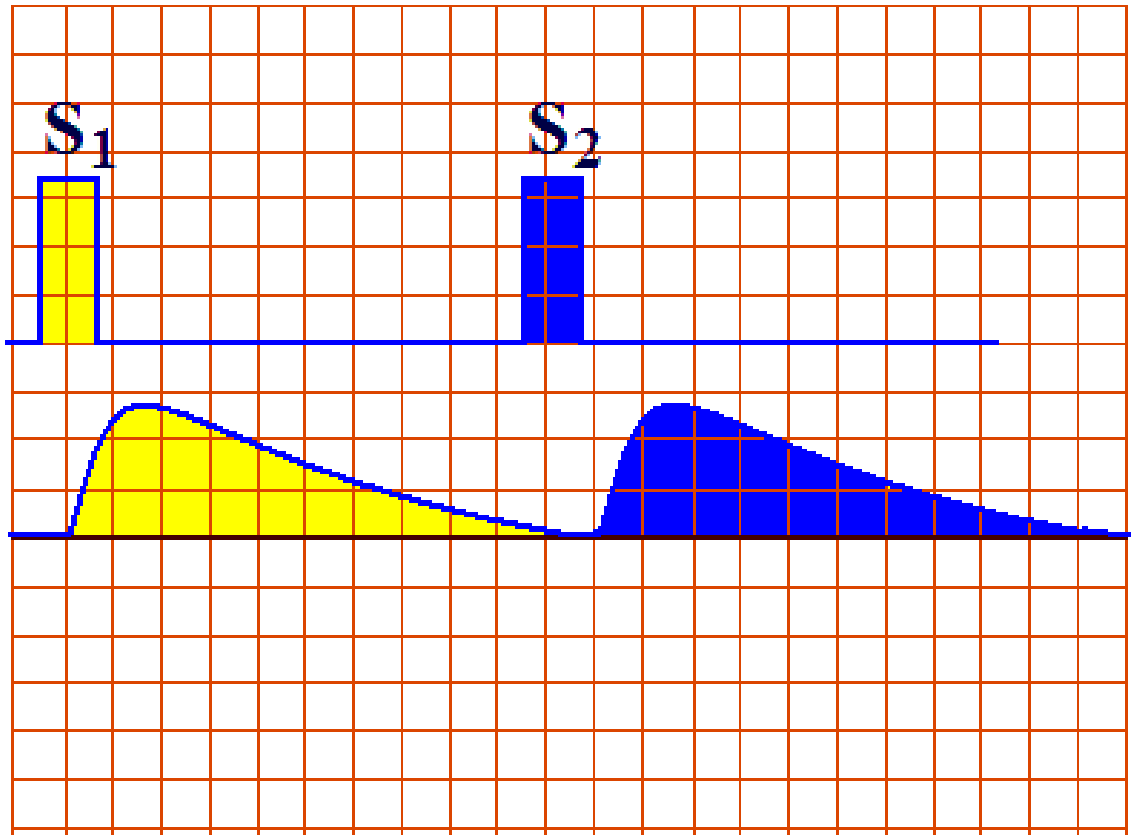
Sommation de deux stimulus dépolarisants rapprochés dans le temps, appliqués au même endroit.



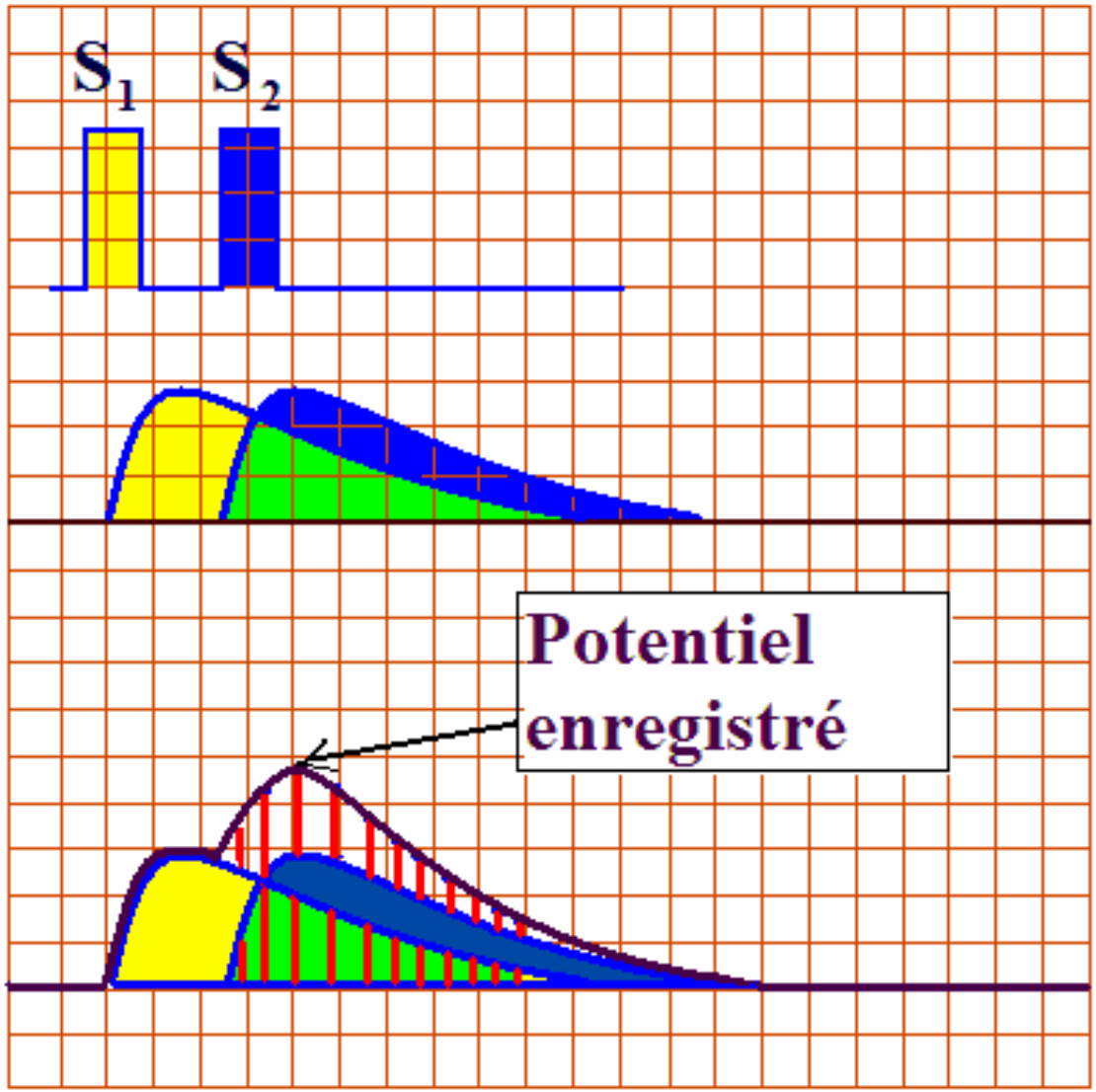
SOMMABILITE SPATIALE

Stimulus dépolarisants

(appliqués en même temps) séparés de quelques millimètres : Pas de sommation des potentiels locaux



Sommation de deux stimulus dépolarisants rapprochés sur la membrane excitable

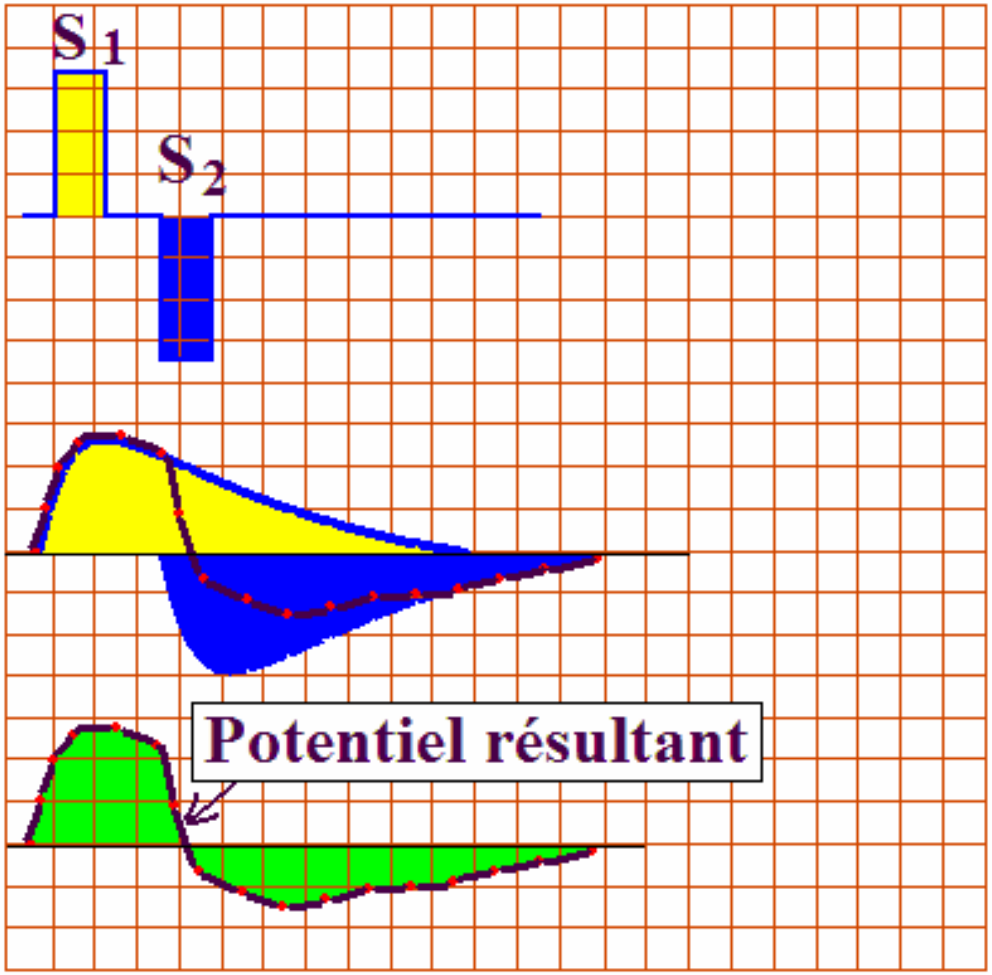


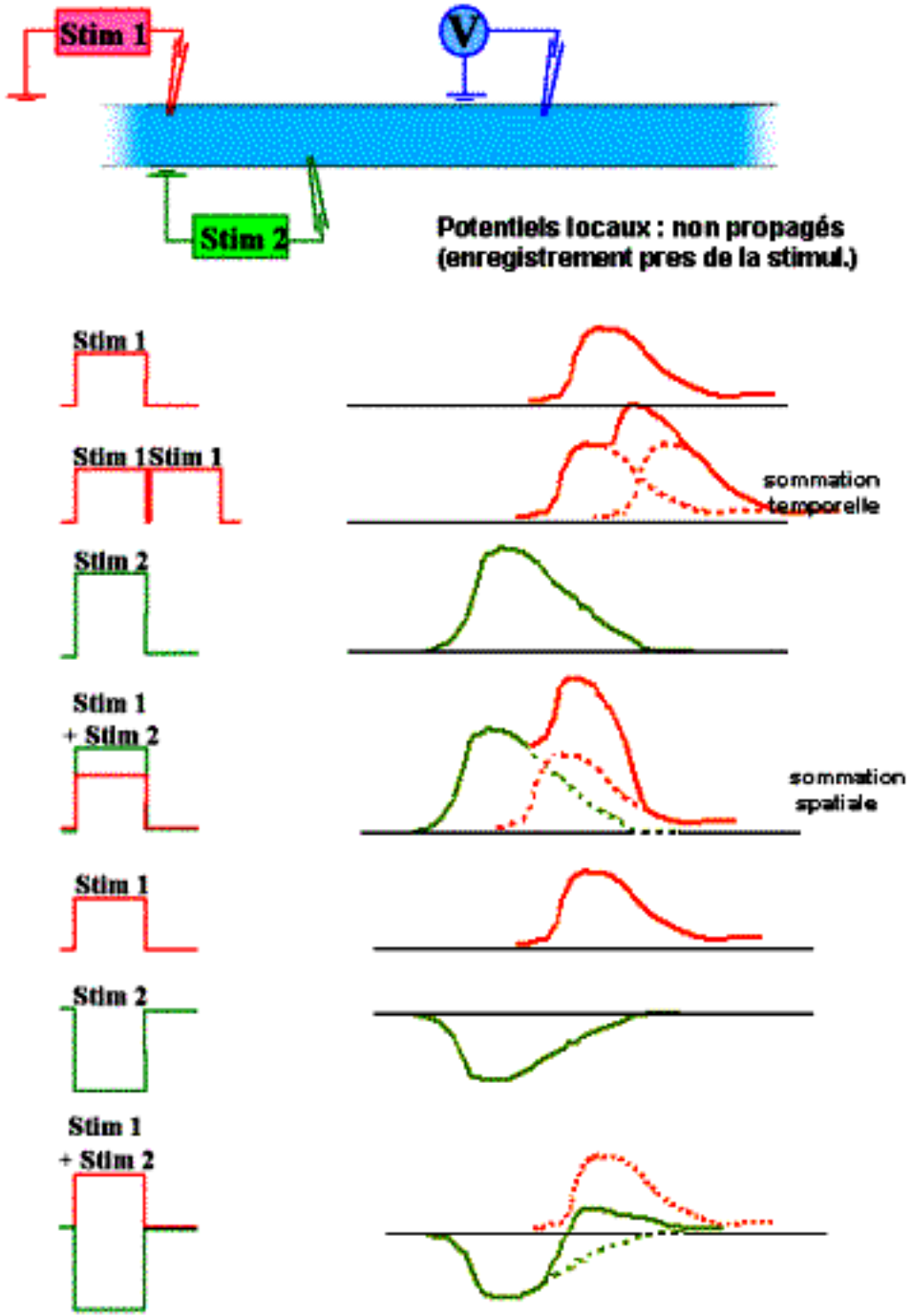
SOMMABILITE ALGEBRIQUE

(en fonction du signe + ou -)

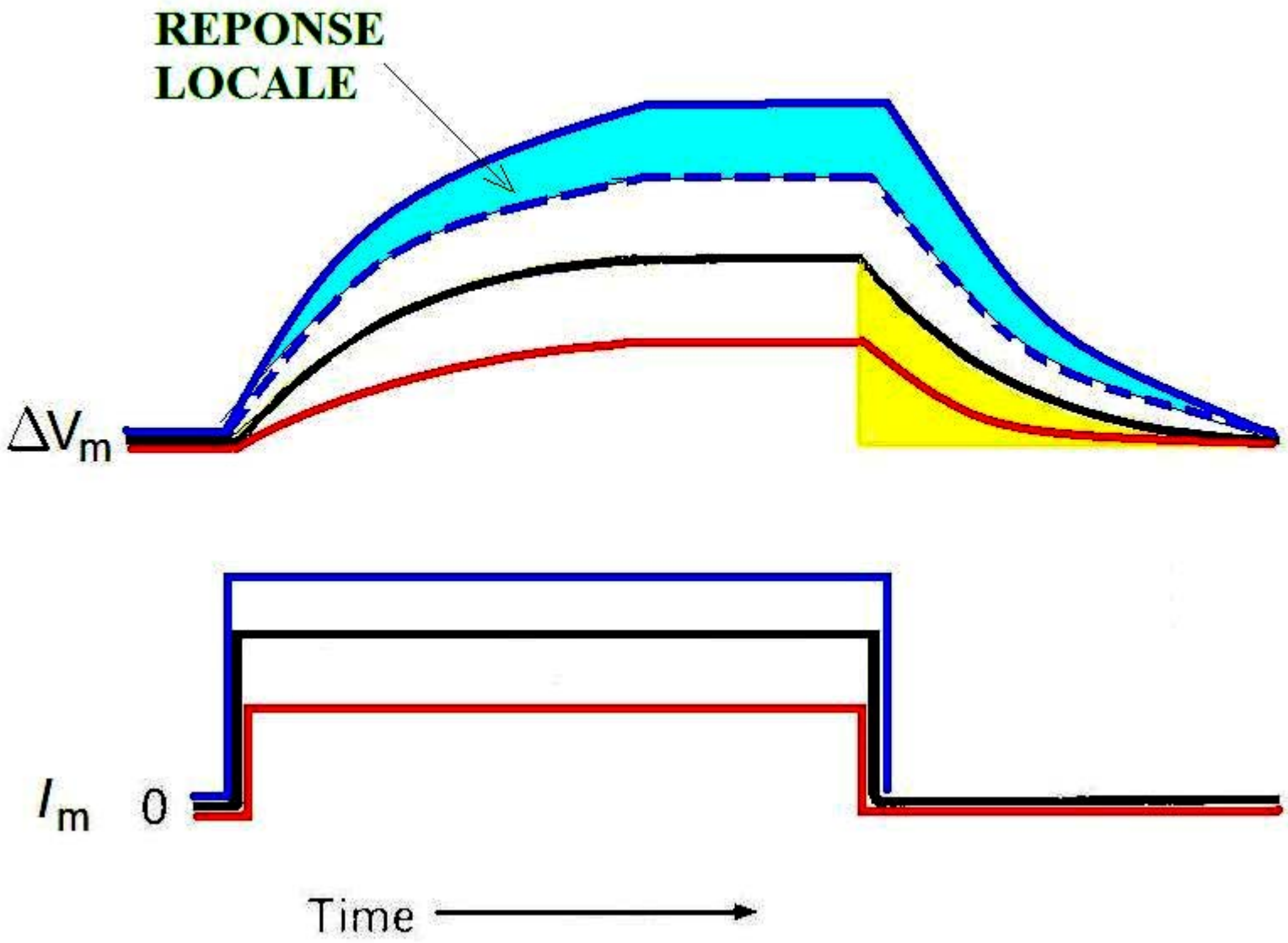
Stimulations de polarités inverses, appliquées en 2 points rapprochés

(au même moment)




Stim 1
V
Stim 2
Potentiels locaux : non propagés
(enregistrement pres de la stimul.)
Stim 1
Stim 1Stim 1
sommation
temporelle
Stim 2
Stim 1
+ Stim 2
sommation
spatiale
Stim 1
Stim 2
Stim 1
+ Stim 2

REPONSE LOCALE

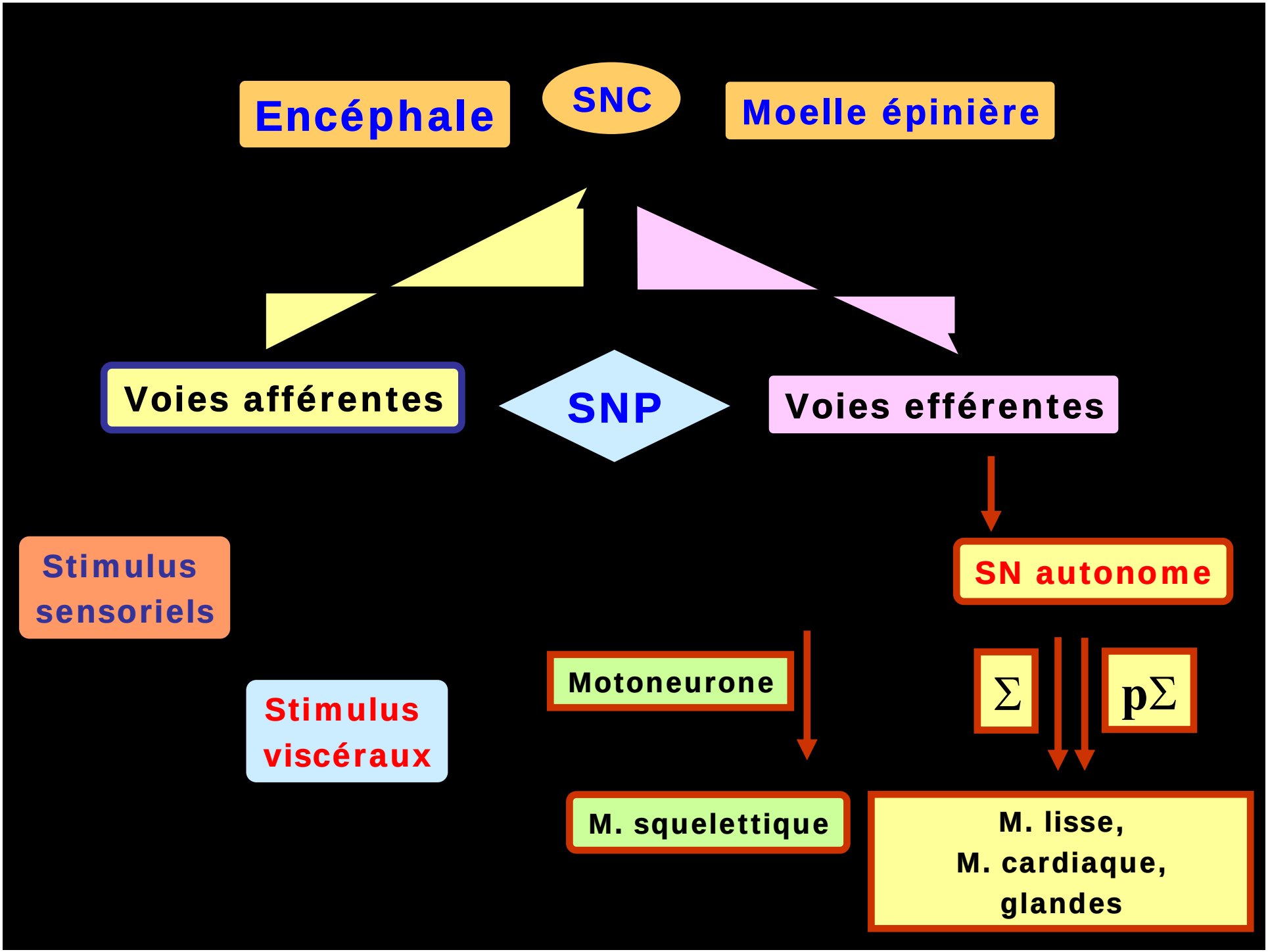


REPONSE LOCALE

- Pour des dépolarisations proches du seuil de production de potentiel d'action, la membrane se dépolarise à une valeur supérieure à celle qui serait liée à un phénomène passif.
- C'est la « réponse locale », qui se surajoute au phénomène membranaire passif. (ce dernier n'est pas lié à des mouvements d'ions, alors que la réponse locale, est liée à une faible entrée de Na…)

Organisation du système nerveux

- Système nerveux central
- Système nerveux périphérique

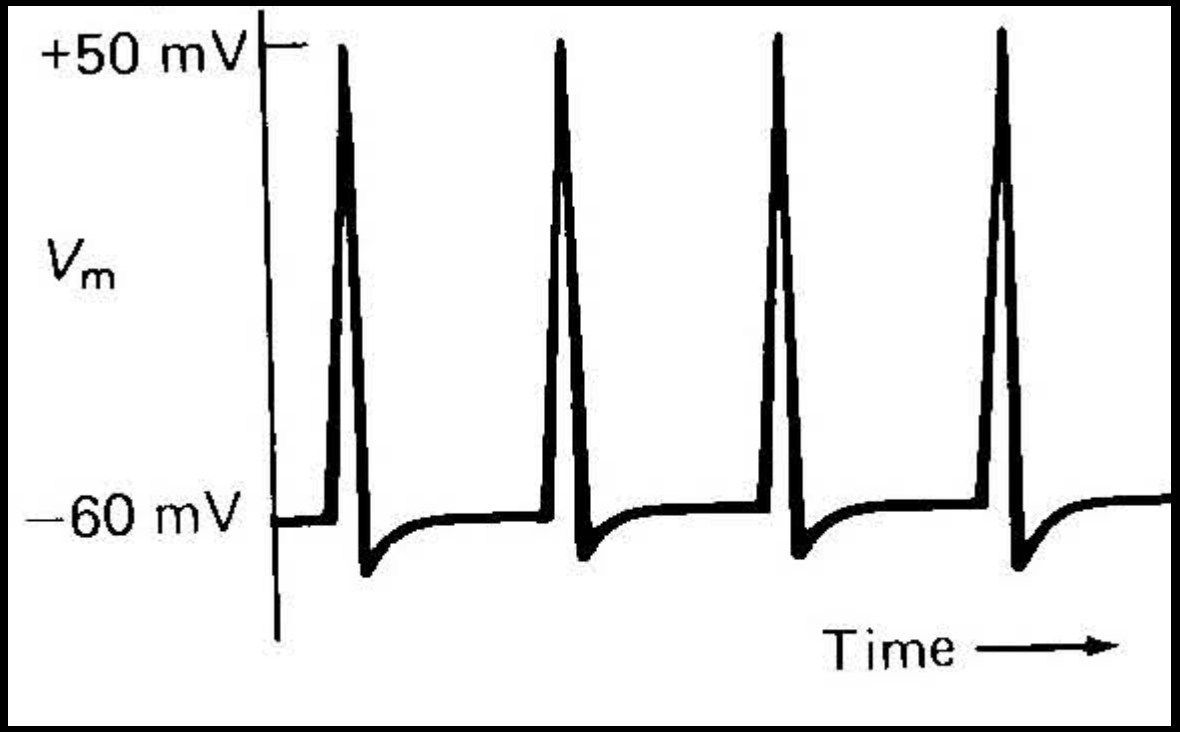

Encéphale
SNC
Moelle épinière
Voies afférentes
SNP
Voies efférentes
Stimulus sensoriels
SN autonome
Stimulus viscéraux
Motoneurone
Σ
pΣ
M. squelettique
M. lisse,
M. cardiaque,
glandes

PA : unité de message nerveux.

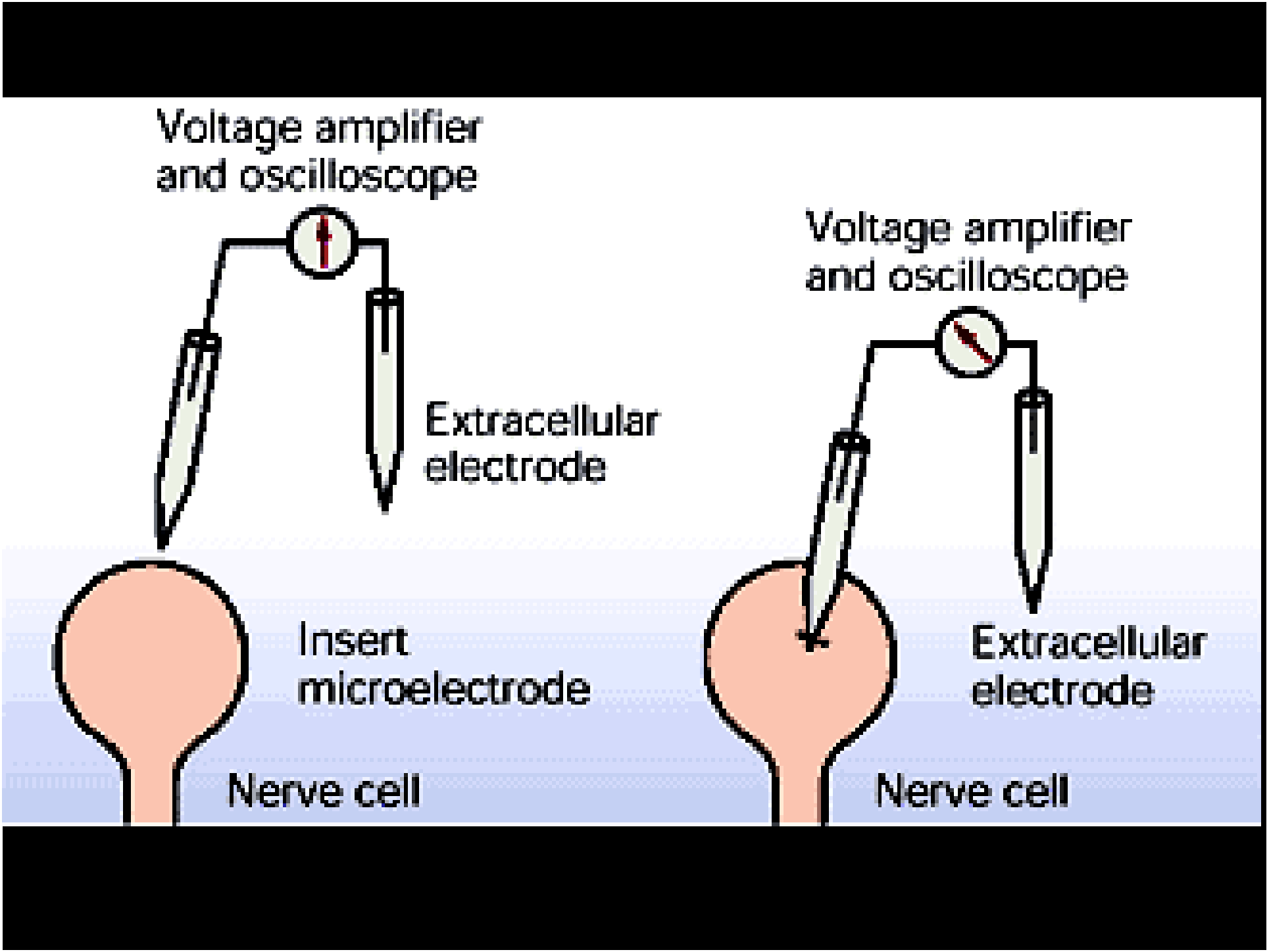
Codage binaire :

PA =1 ;

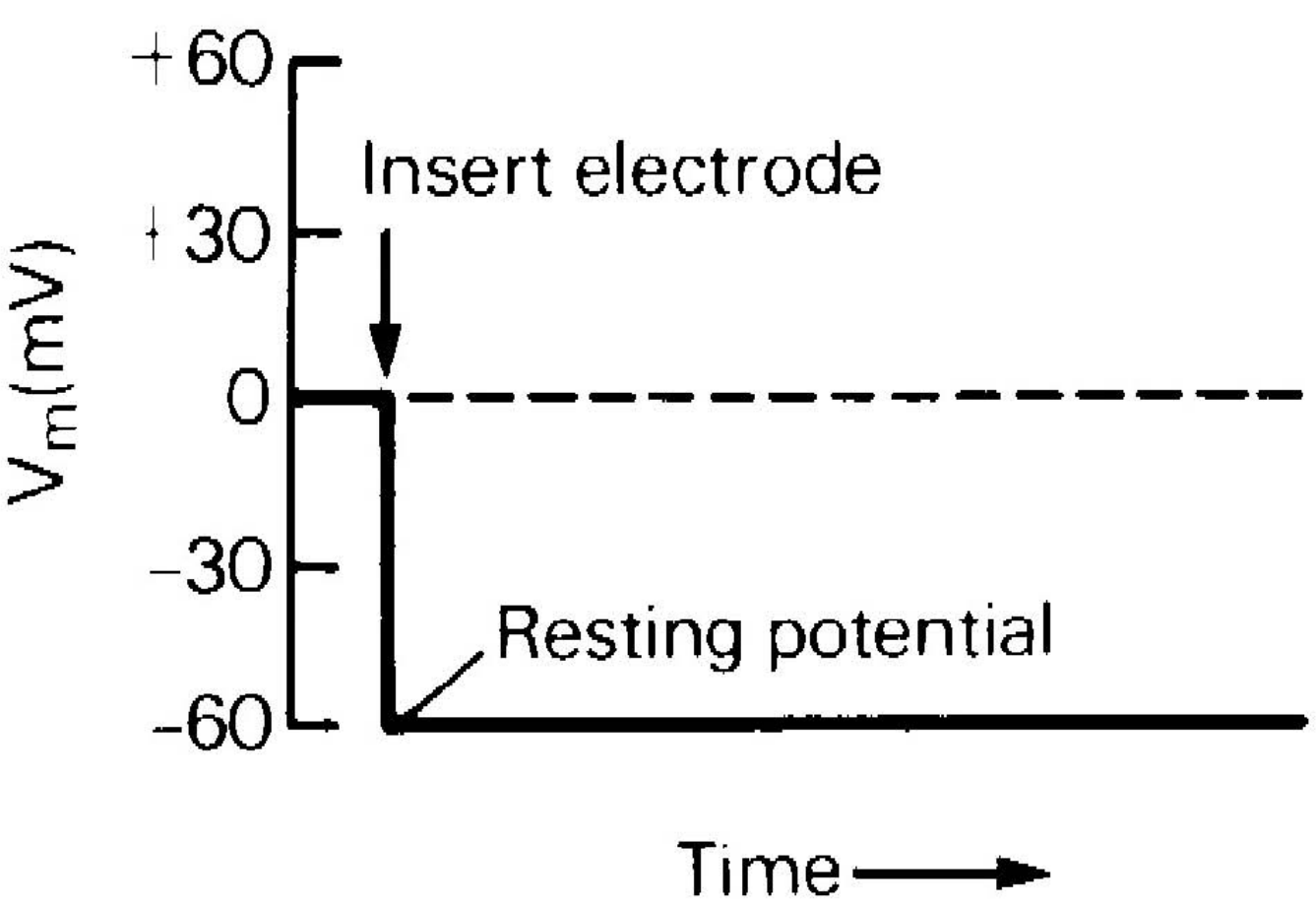
Pas de PA = 0

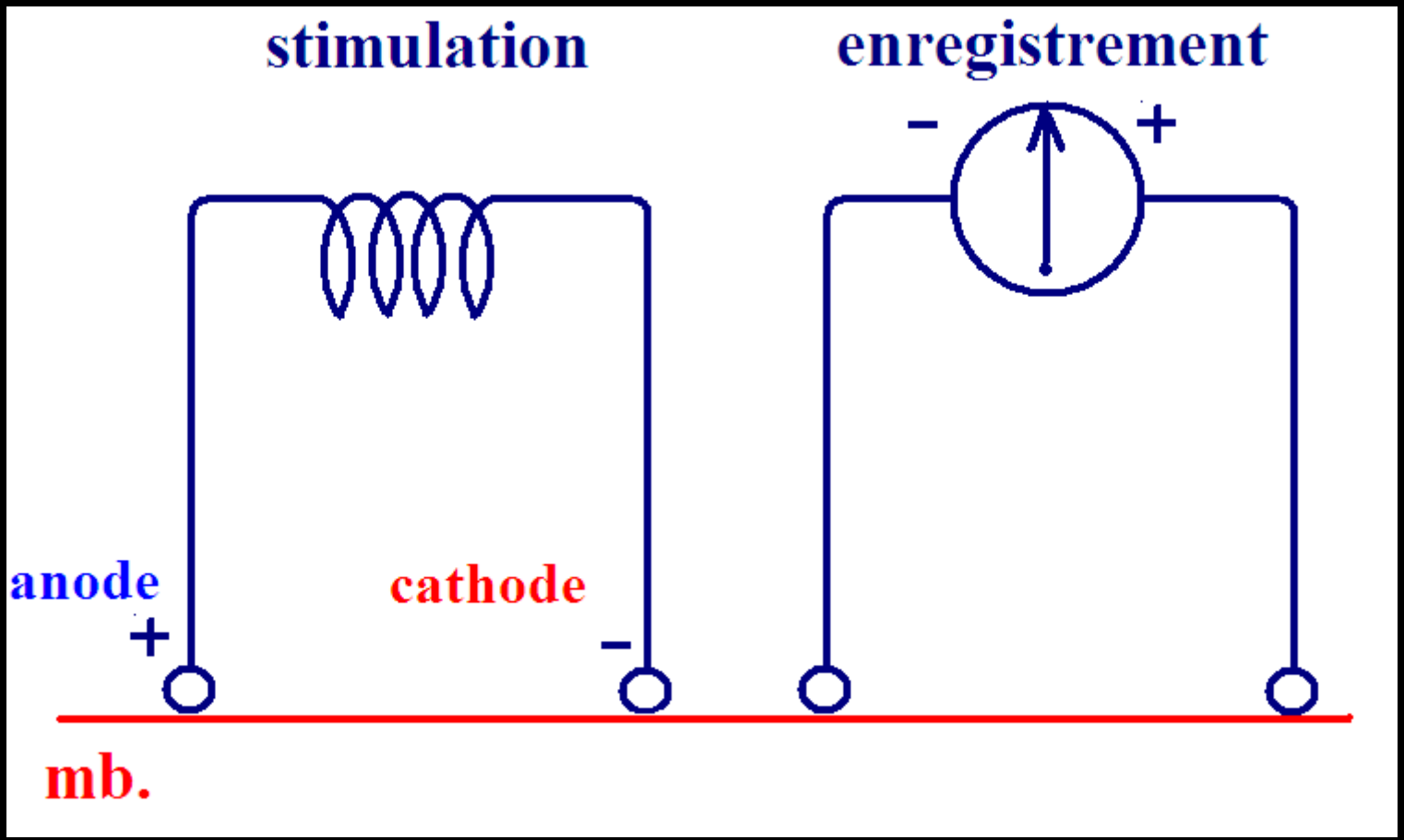


Mesure


Voltage amplifier
and oscilloscope
Extracellular
electrode
Insert
microelectrode
Nerve cell
Voltage amplifier
and oscilloscope
Extracellular
electrode
Nerve cell

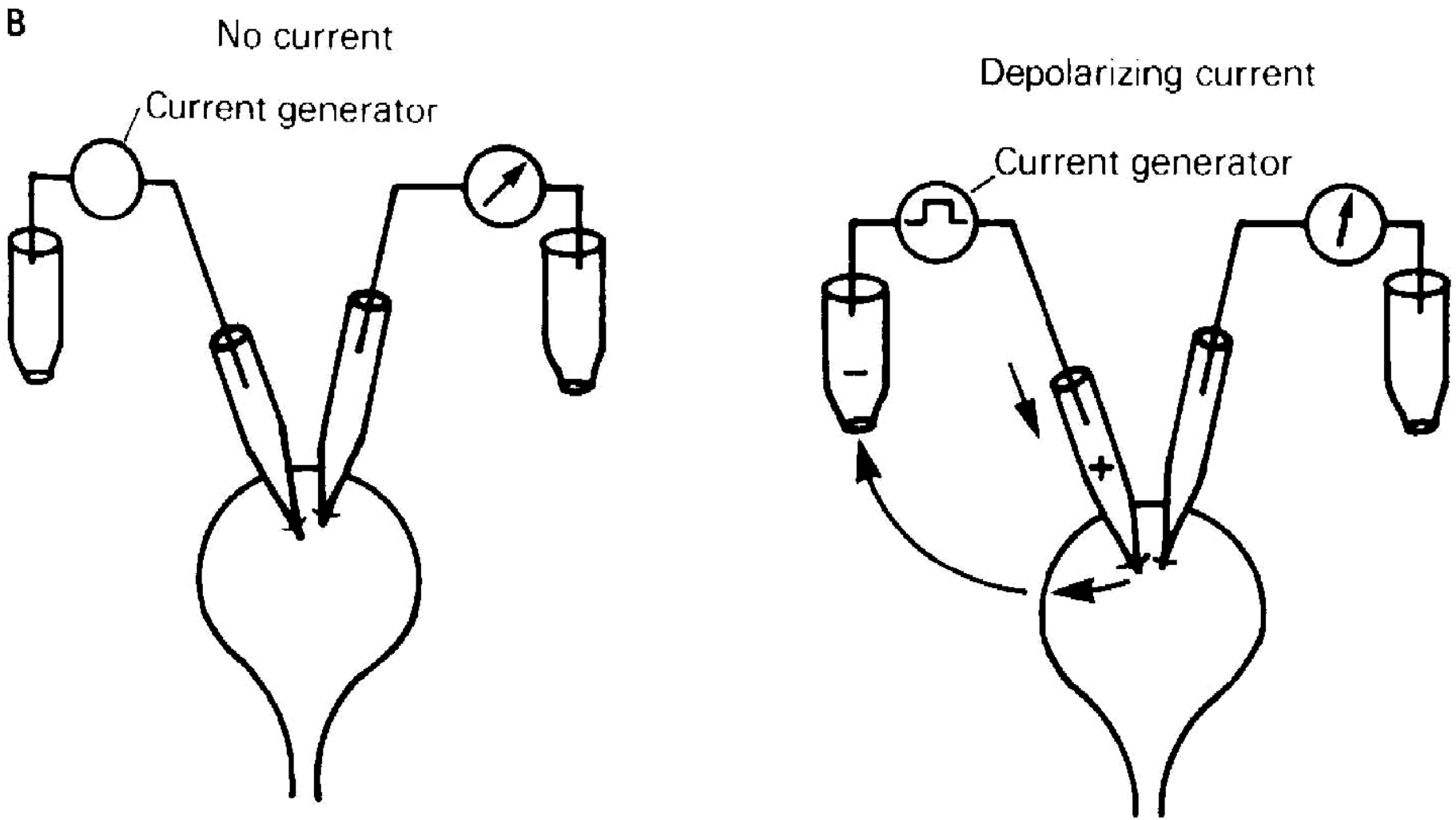
Insertion de la microélectrode


Oscilloscope display
+60
+30
0
−30
−60
V_m(mV)
Insert electrode
Resting potential
Time


stimulation
enregistrement
–
+
anode
+
cathode
–
mb.

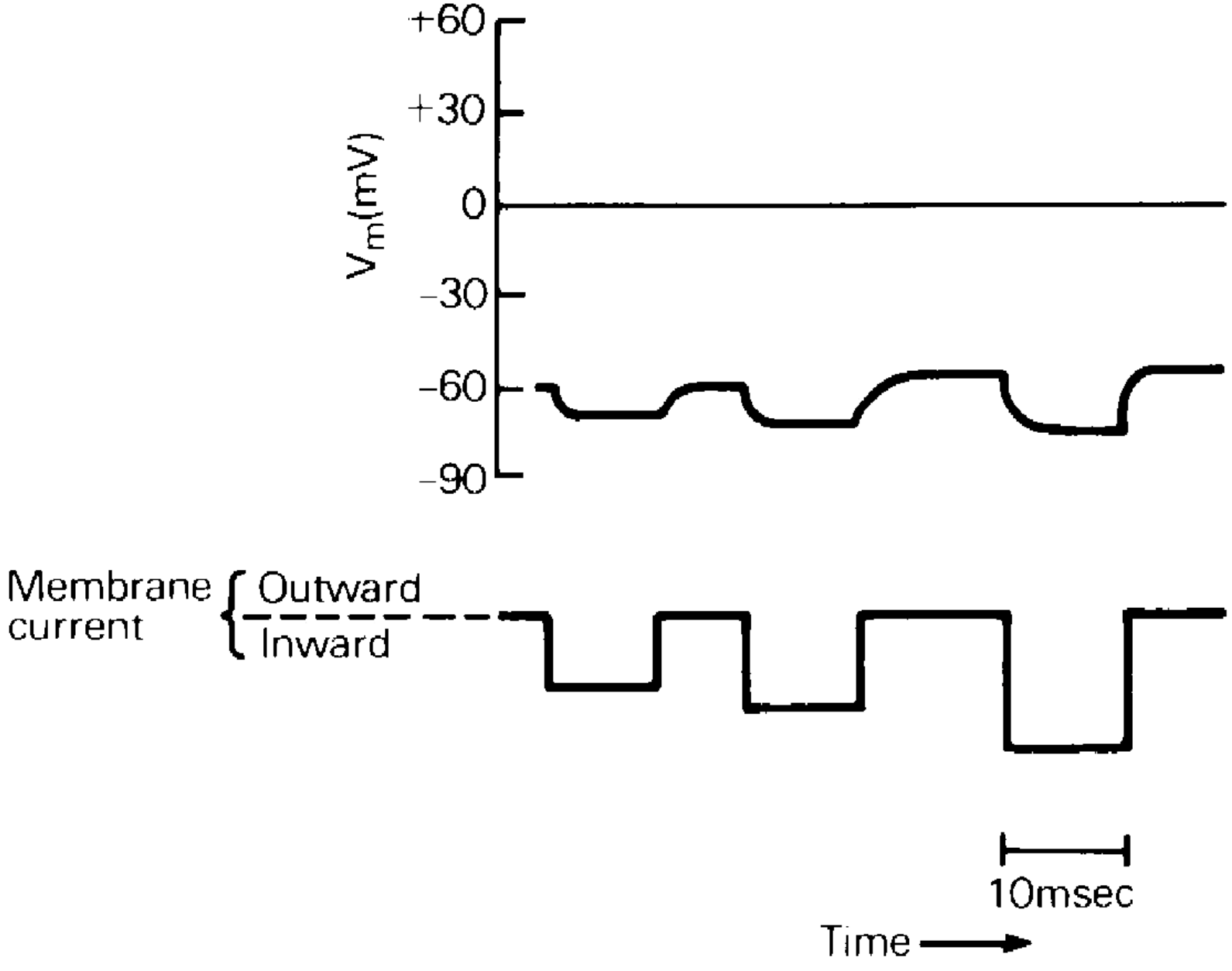
Courant dépolarisant

- Microélectrodes de stimulation et d’enregistrement


B
No current
Current generator
Depolarizing current
Current generator
−
+

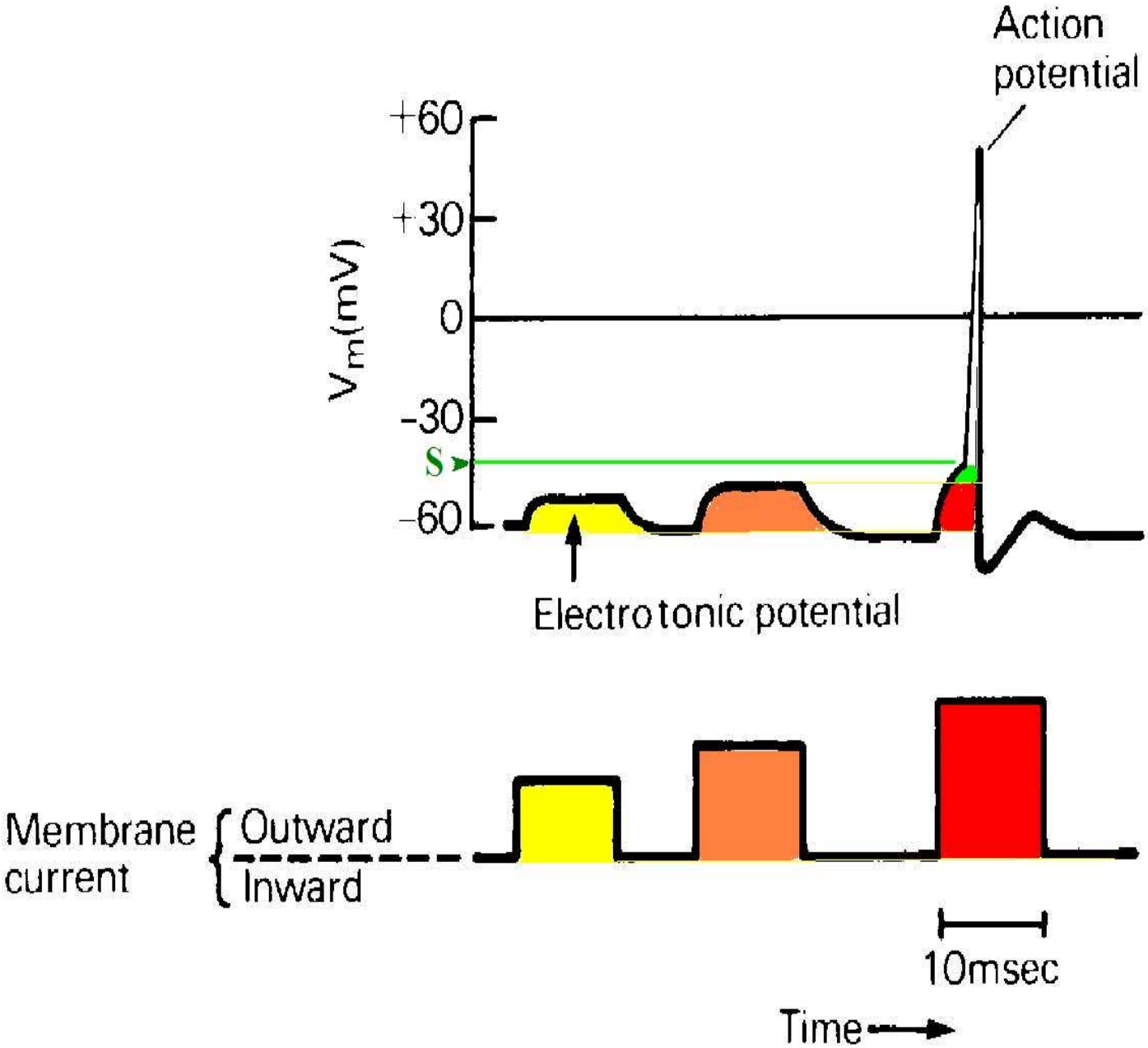
Stimulus hyperpolarisant

- Courant anodique


+60
+30
0
-30
-60
-90
V_m(mV)
Membrane current
Outward
Inward
10msec
Time

Stimulus dépolarisant

- Courant cathodique


Action potential
+60
+30
0
-30
-60
V_m(mV)
S
Electrotonic potential
Membrane current
Outward
Inward
10msec
Time

Le potentiel d'action (P.A.)

Définition : dépolarisation automatique d'une membrane excitable en réponse à une stimulation supraliminaire.

Valeur « liminaire » = valeur seuil

Membrane excitable : capable de produire des potentiels d’action.

Elle possède **un seuil d’excitabilité**

Seuil de dépolarisation :

valeur de la dépolarisation membranaire qui provoque un P.A. pour 50% des stimulations

Loi du « tout ou rien »

- En dessous du seuil de dépolarisation : **pas de PA**
- Pour une stimulation liminaire (seuil) :

  50 % (**P= 0,5**) : pour 100 stimulations liminaires, on observe un potentiel d'action en moyenne une fois sur deux (donc en théorie 50 PA environ)

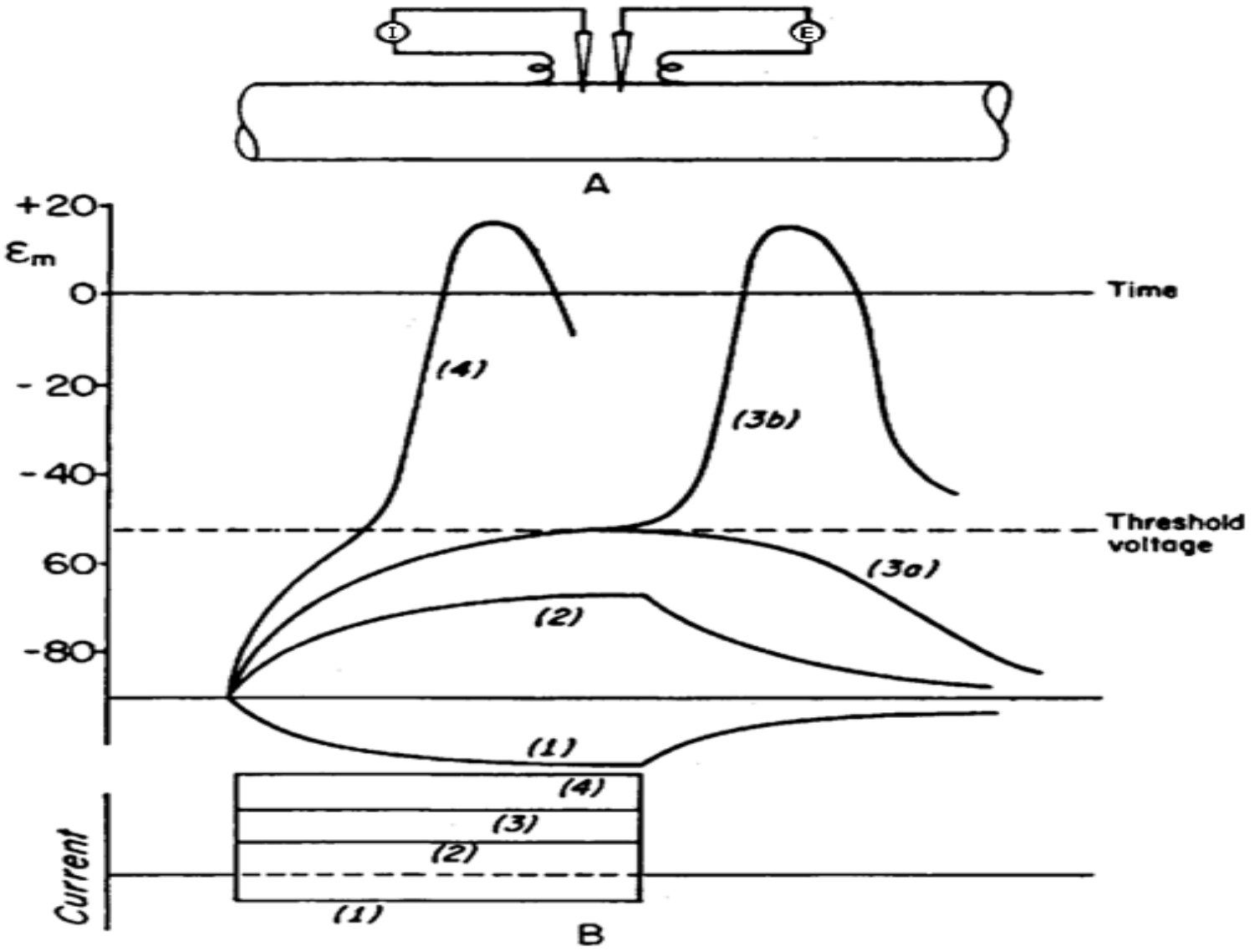
- **Stimulation supraliminaire :**

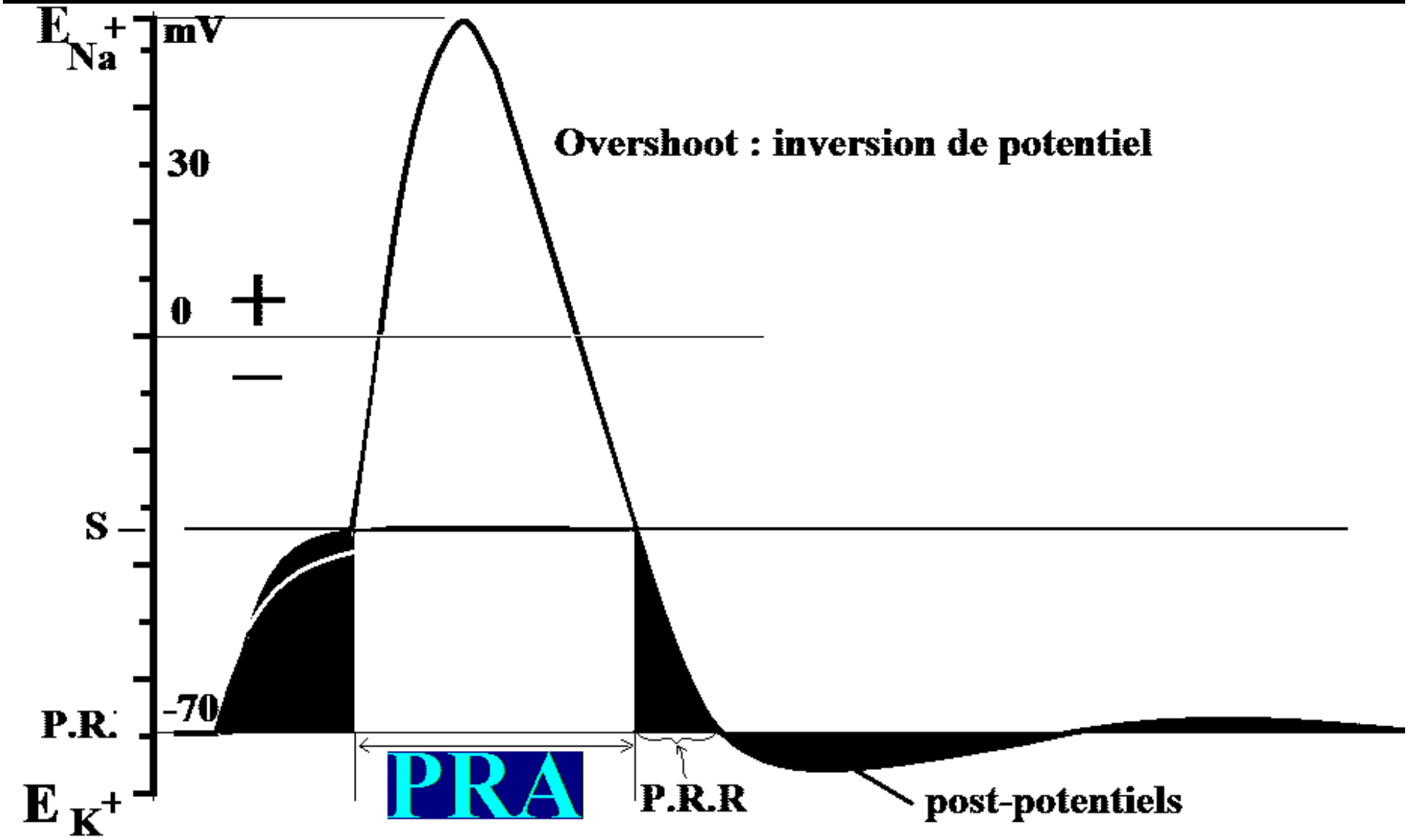
  → **P.A. (Automatique)**

Périodes réfractaires :

- → **PRA : Absolue (excitabilité = 0)**
- → **PRR : Relative (excitabilité < 100%)**

Stimulations 1234




E Na+
mV
30
0
+
—
S
P.R.
-70
E K+
Overshoot : inversion de potentiel
PRA
P.R.R
post-potentiels

Premier P.A. (Hodgkin & Huxley)

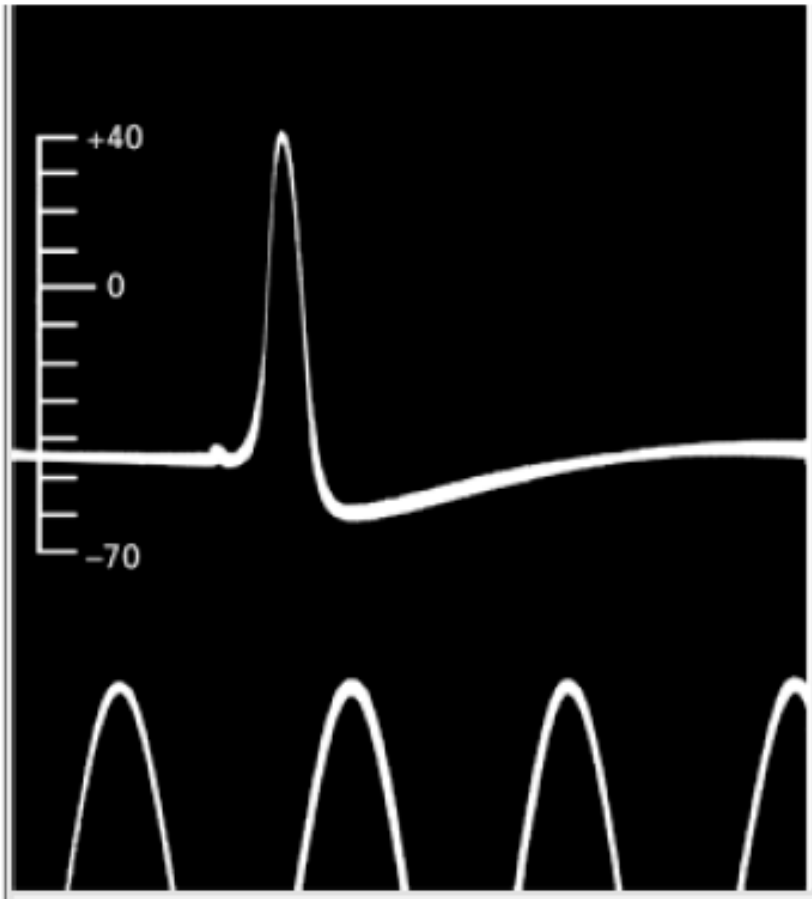
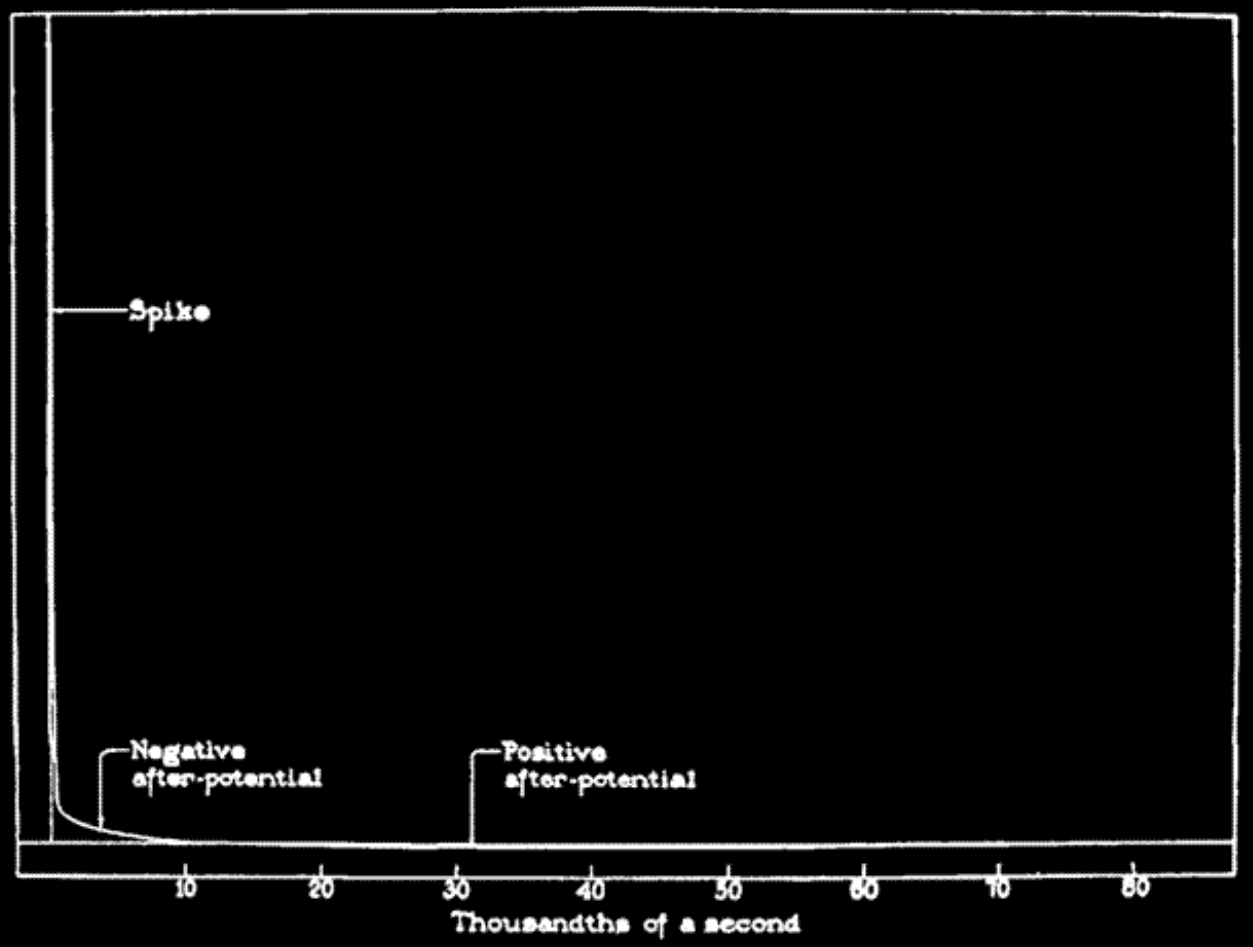


Figure 2-3 This historic tracing is the first published intracellular recording of an action potential. It was obtained in 1939 by Hodgkin and Huxley from the squid giant axon, using glass capillary electrodes filled with sea water. Time marker is 500 Hz. The vertical scale indicates the potential of the internal electrode in millivolts, the sea water outside being taken as zero potential. (From Hodgkin and Huxley 1939.)

P.A. (Gasser)

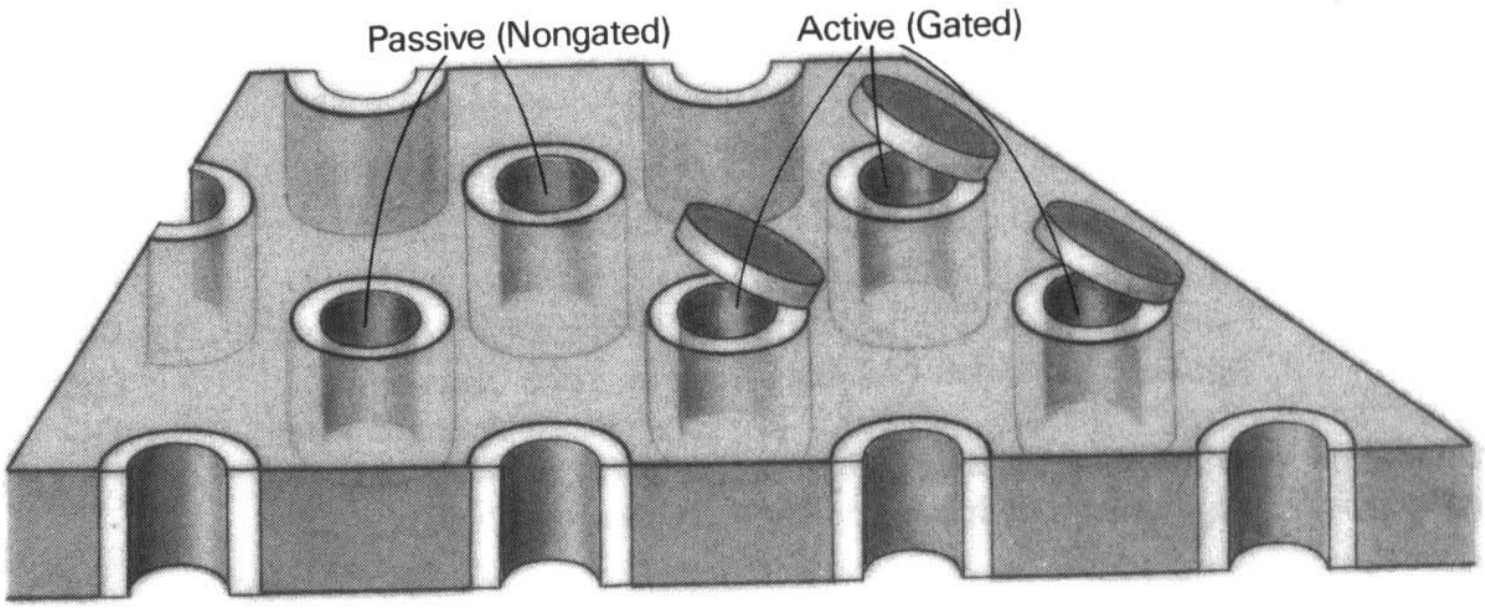


Diagrammatic representation of an action potential in A fibers of the cat, with the spike and negative and positive afterpotentials drawn in their correct relative size and true relationships. [From Gasser, with permission.]

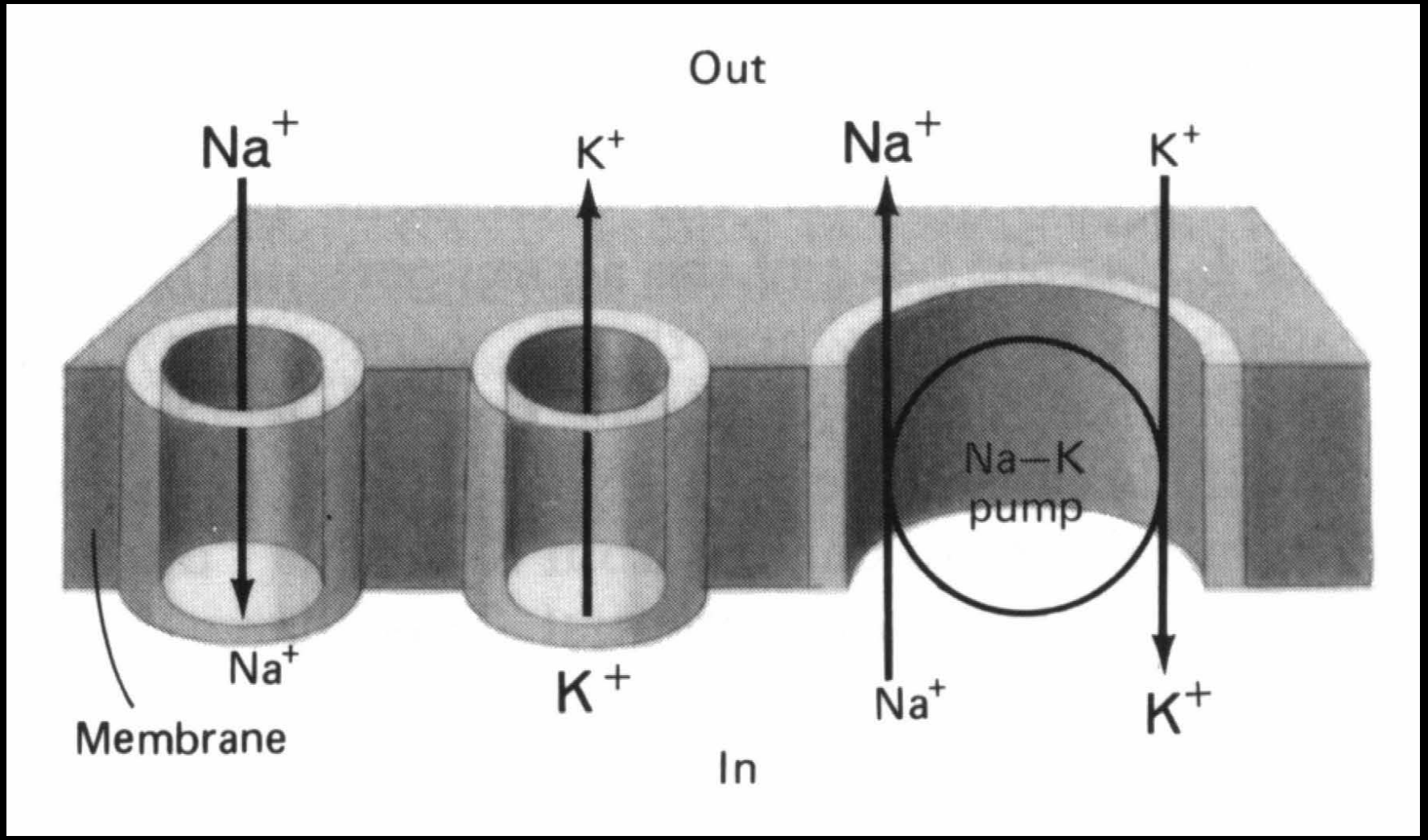
Mécanismes ioniques

- Canaux ioniques voltage dépendants
- Technique du voltage imposé
- Utilisation de toxines spécifiques :
  - –TTX, STX
  - –TEA

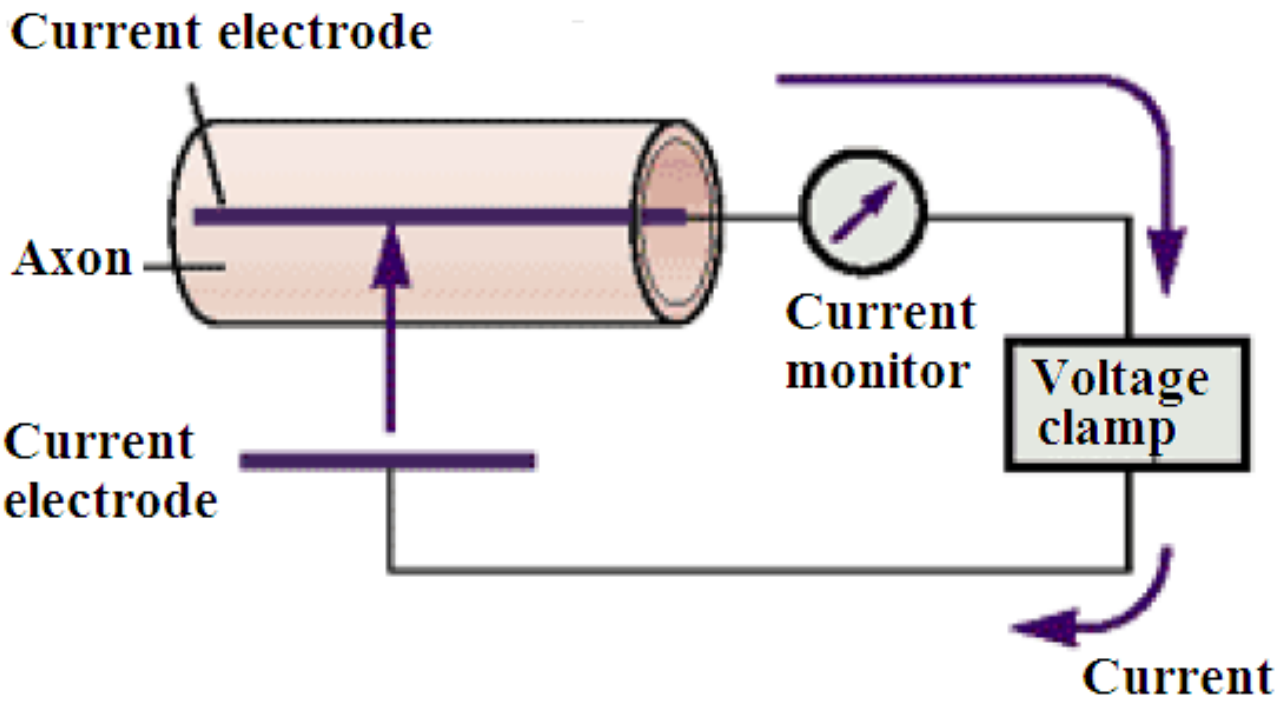
Canaux ioniques voltage dépendants



Canaux ioniques voltage dépendants

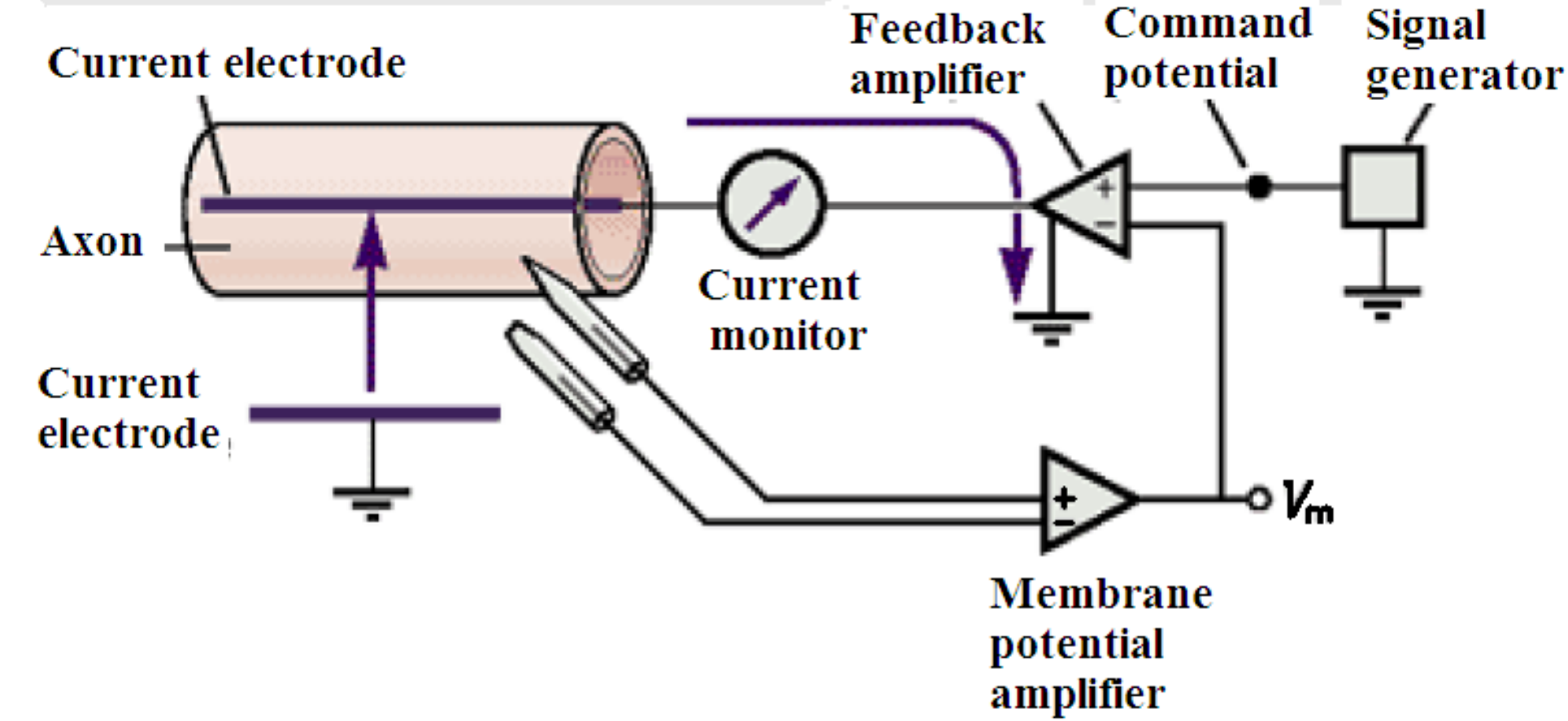


Voltage imposé (1)



The voltage clamp is a current generator that is connected to a pair of electrodes. It is used to change the charge separation, and thus the electrical potential difference, across the membrane. Monitoring the additional current that is passed to clamp the membrane potential at its new value then provides a measure of the membrane current passing through the ion channels in the membrane.

Voltage imposé (2)

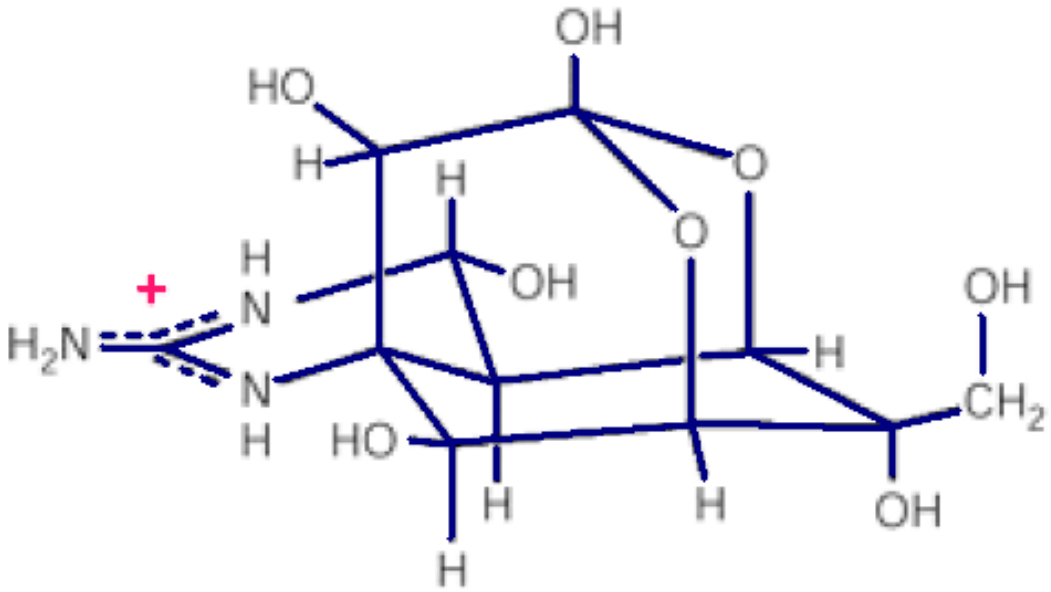

Current electrode
Feedback amplifier
Command potential
Signal generator
Axon
Current monitor
Current electrode
V_m
Membrane potential amplifier

Drugs that block voltage-gated Na+ channels.

Drugs that block voltage-gated Na+ and K+ channels.

TETRODOTOXINE

Tetrodotoxin (TTX)

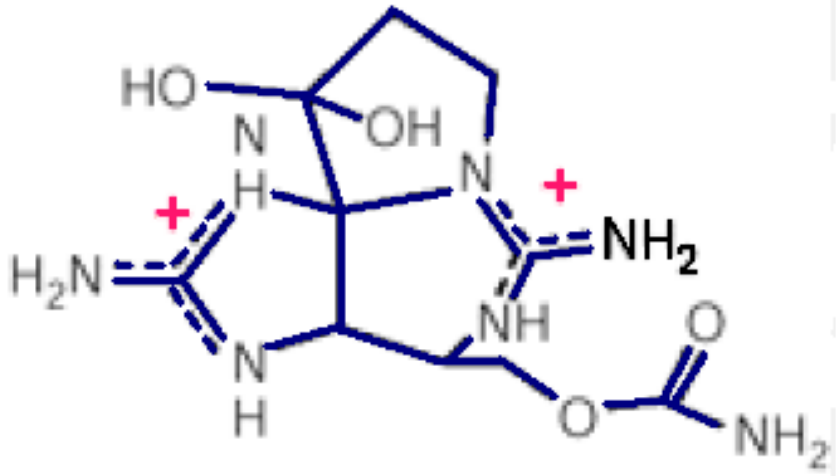


Tetrodotoxin and saxitoxin both bind to Na+ channels with a very high affinity.

- **Tetrodotoxin is produced by certain puffer fish, newts, and frogs.**

Drugs that block voltage-gated Na+ and K+ channels.

SAXITOXINE (STX)

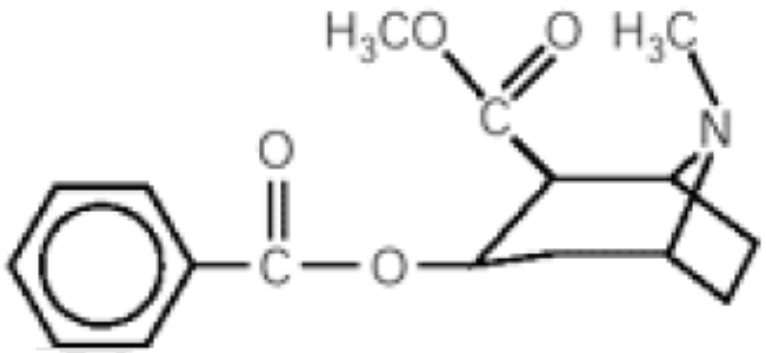


- Saxitoxin is synthesized by the dinoflagellates Gonyaulax that are responsible for red tides.

Consumption of clams or other shellfish that have fed on the dinoflagellates during a red tide causes paralytic shellfish poisoning.

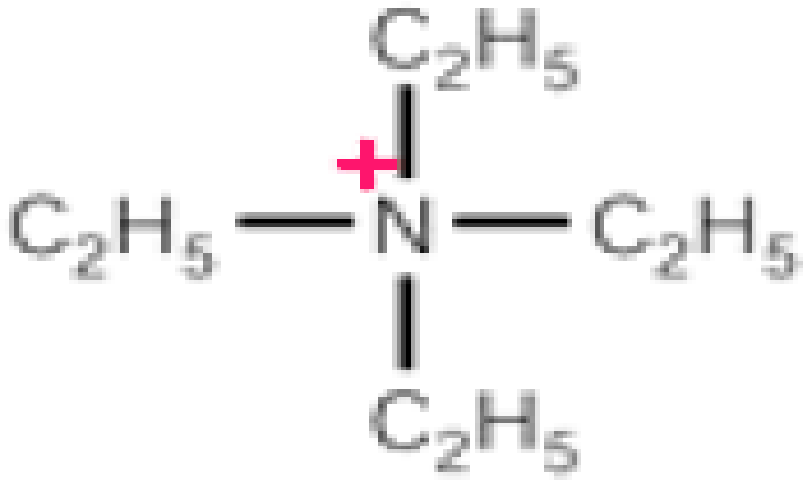
Cocaïne

Cocaine

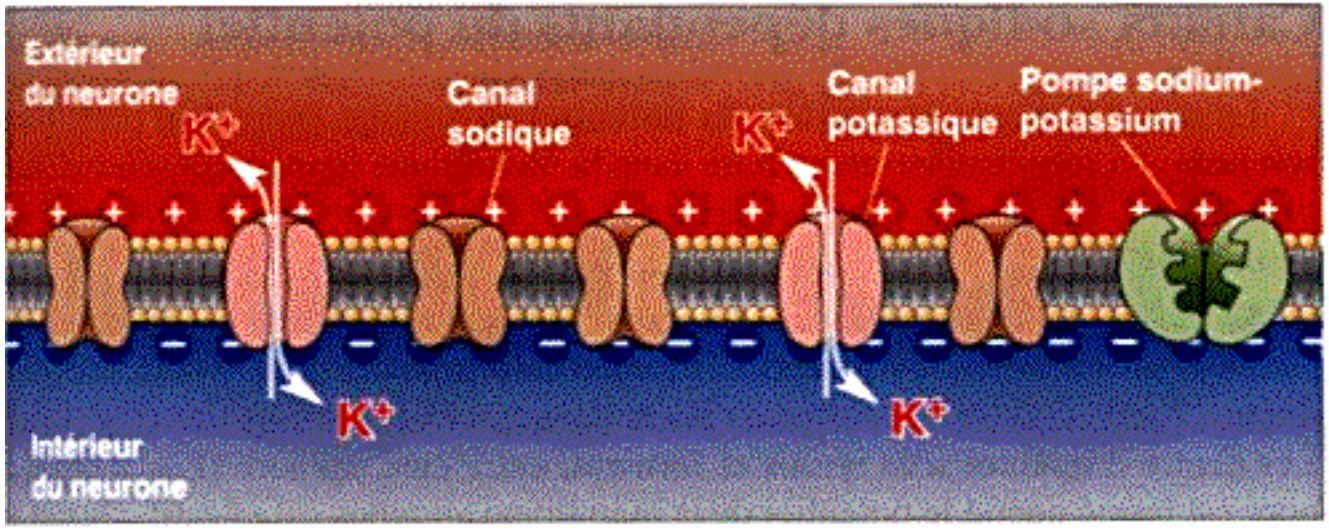


Cocaine, the active substance isolated from coca leaves, was the first substance to be used as a local anesthetic. It also blocks Na+ channels but with a lower affinity and specificity than tetrodotoxin

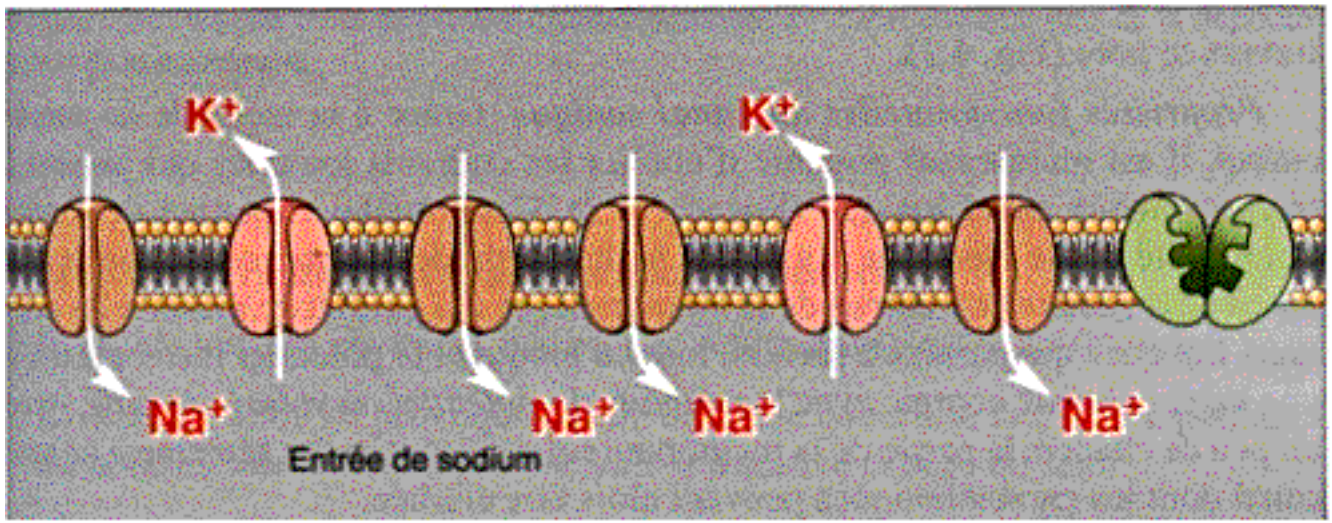
Tetraethylammonium (TEA)

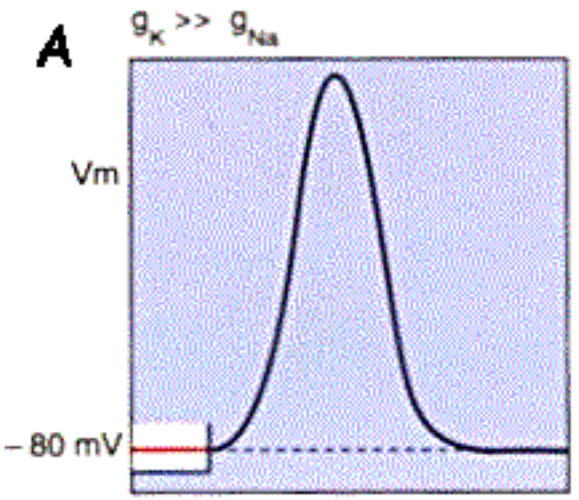


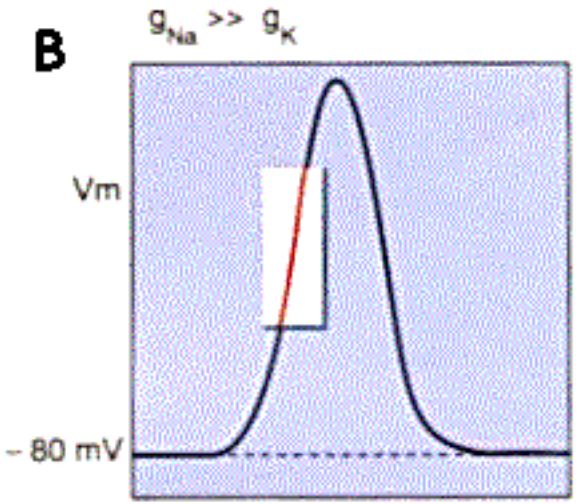
Tetraethylammonium is a cation that blocks certain voltage-gated K+ channels with a relatively low affinity.

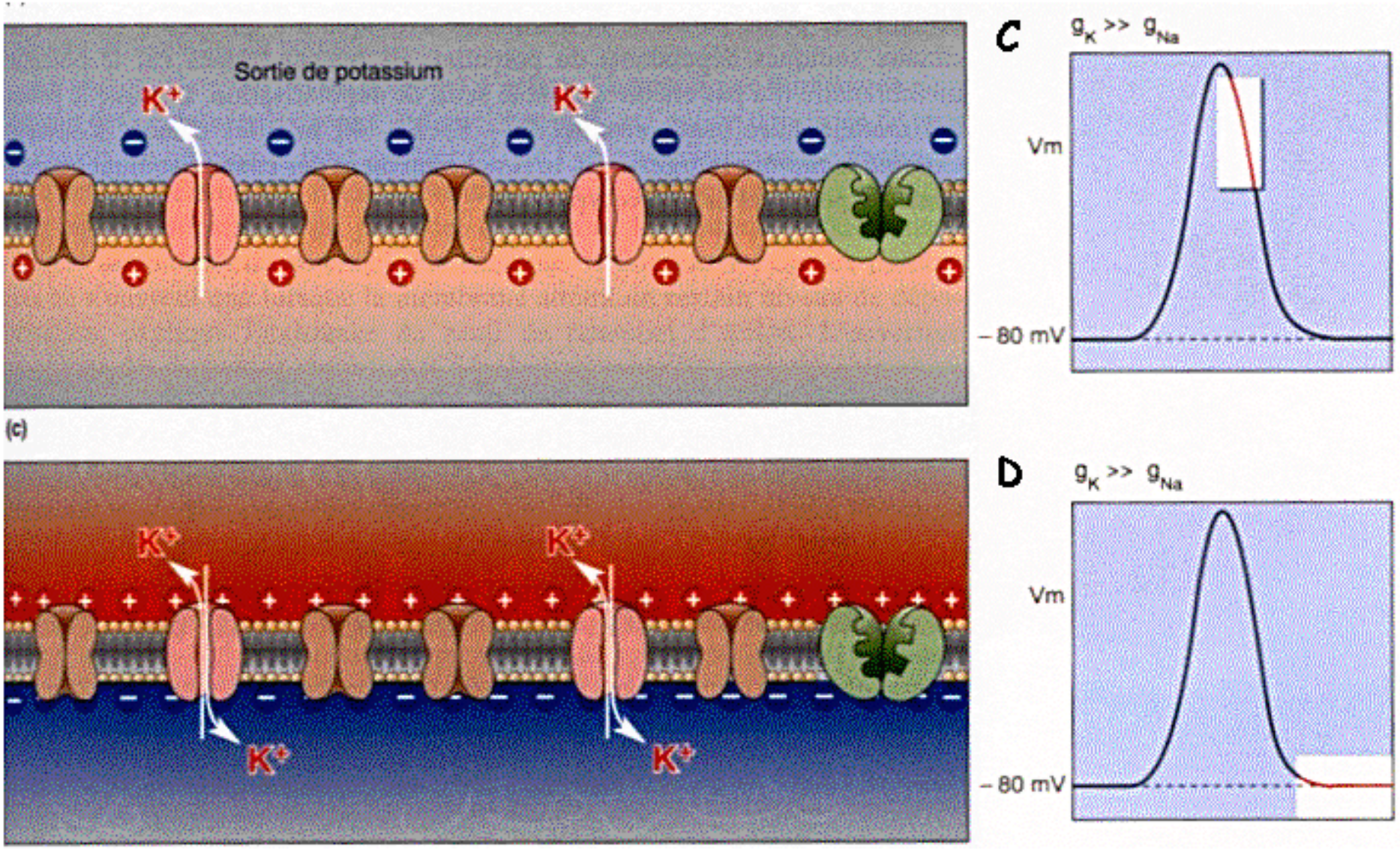

Extérieur
du neurone
Canal
sodique
Canal
potassique
Pompe sodium-
potassium
K+
K+
K+
K+
Intérieur
du neurone

(a)

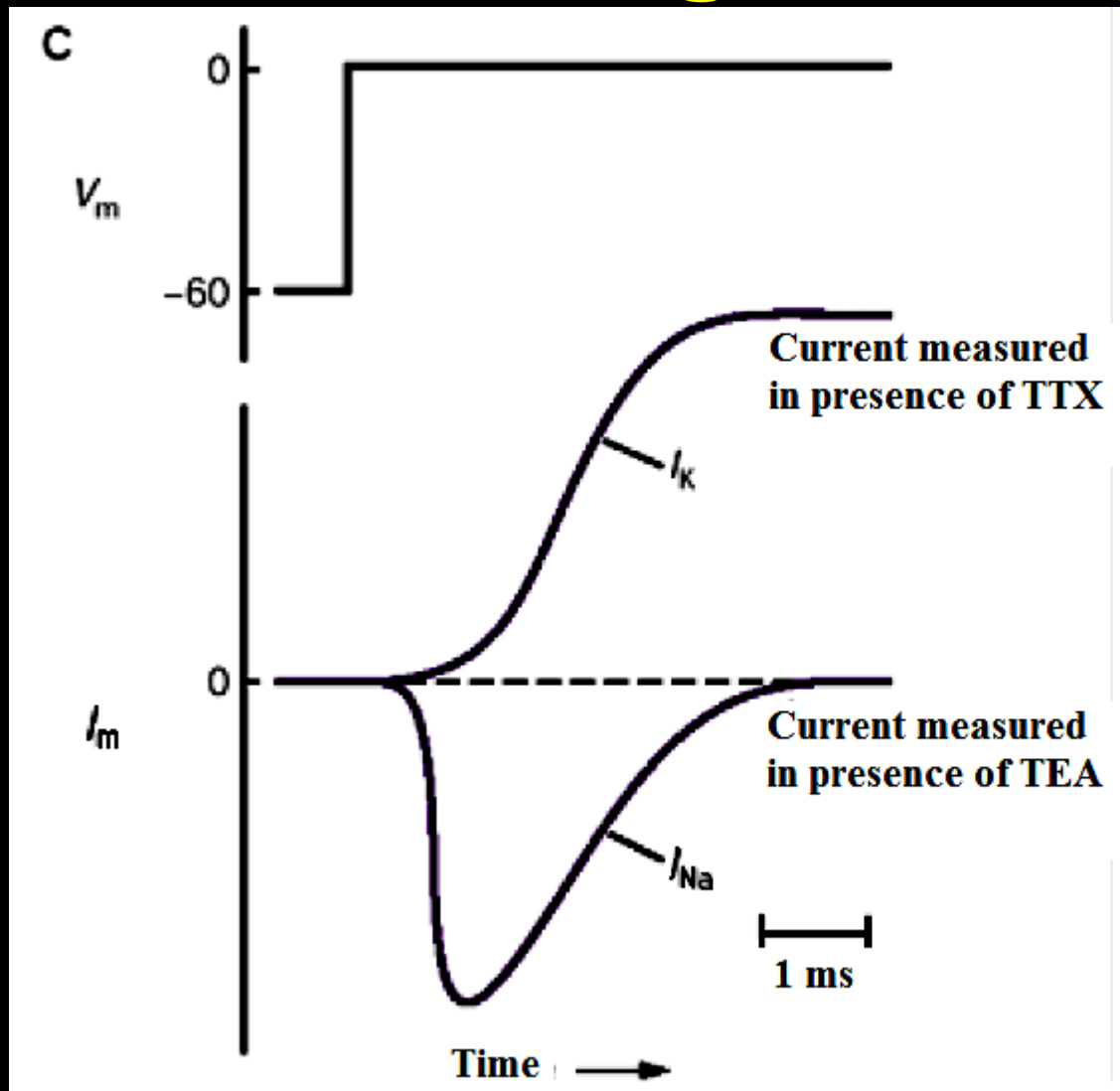

K+
K+
Na+
Na+
Na+
Na+
Entrée de sodium


A
$g_K >> g_{Na}$
Vm
– 80 mV


B
$g_{Na} >> g_K$
Vm
– 80 mV


Sortie de potassium
K+
K+
(c)
K+
K+
K+
K+
C
$g_K >> g_{Na}$
Vm
– 80 mV
D
$g_K >> g_{Na}$
Vm
– 80 mV

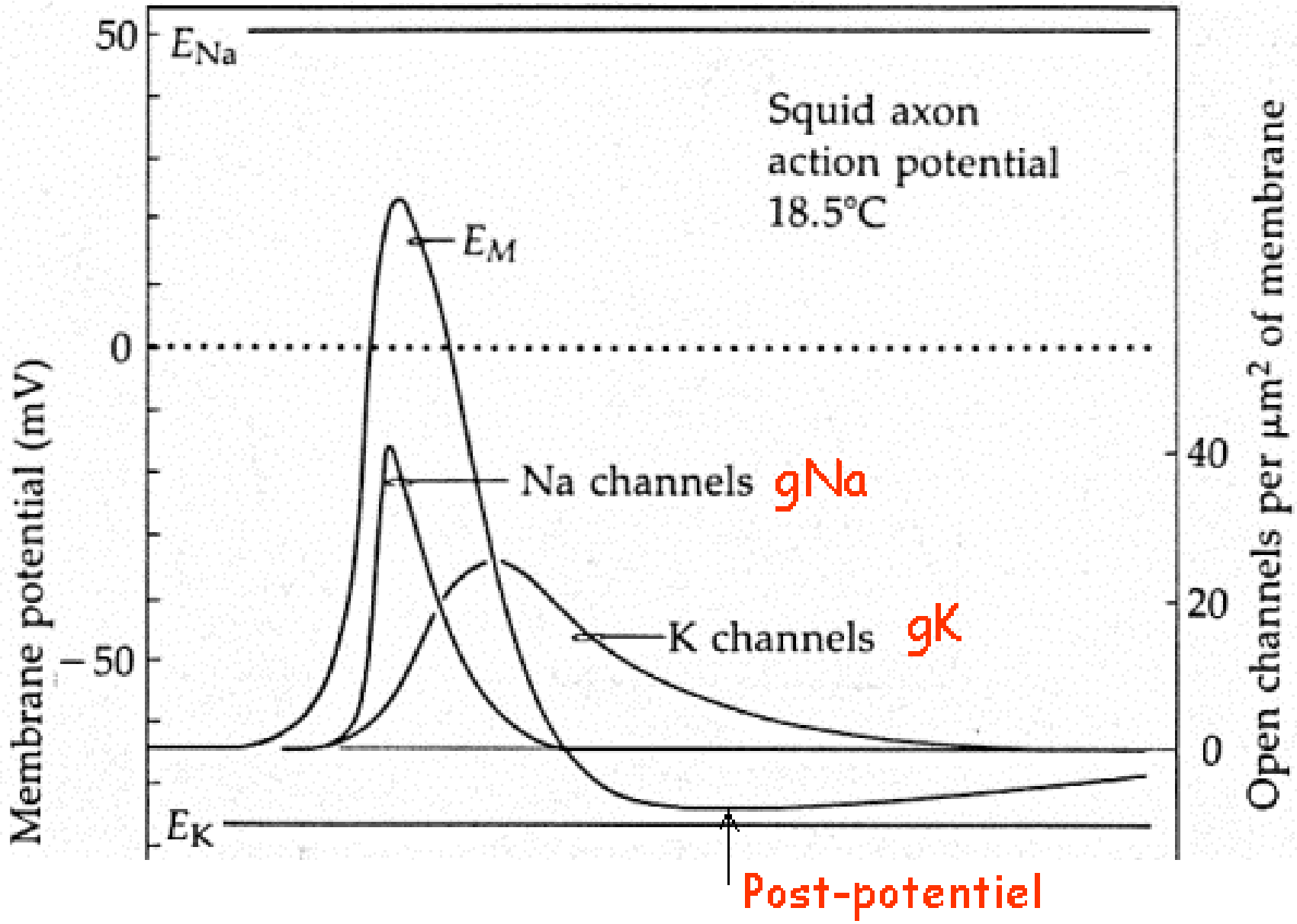
PA : gNa^+ et gK^+

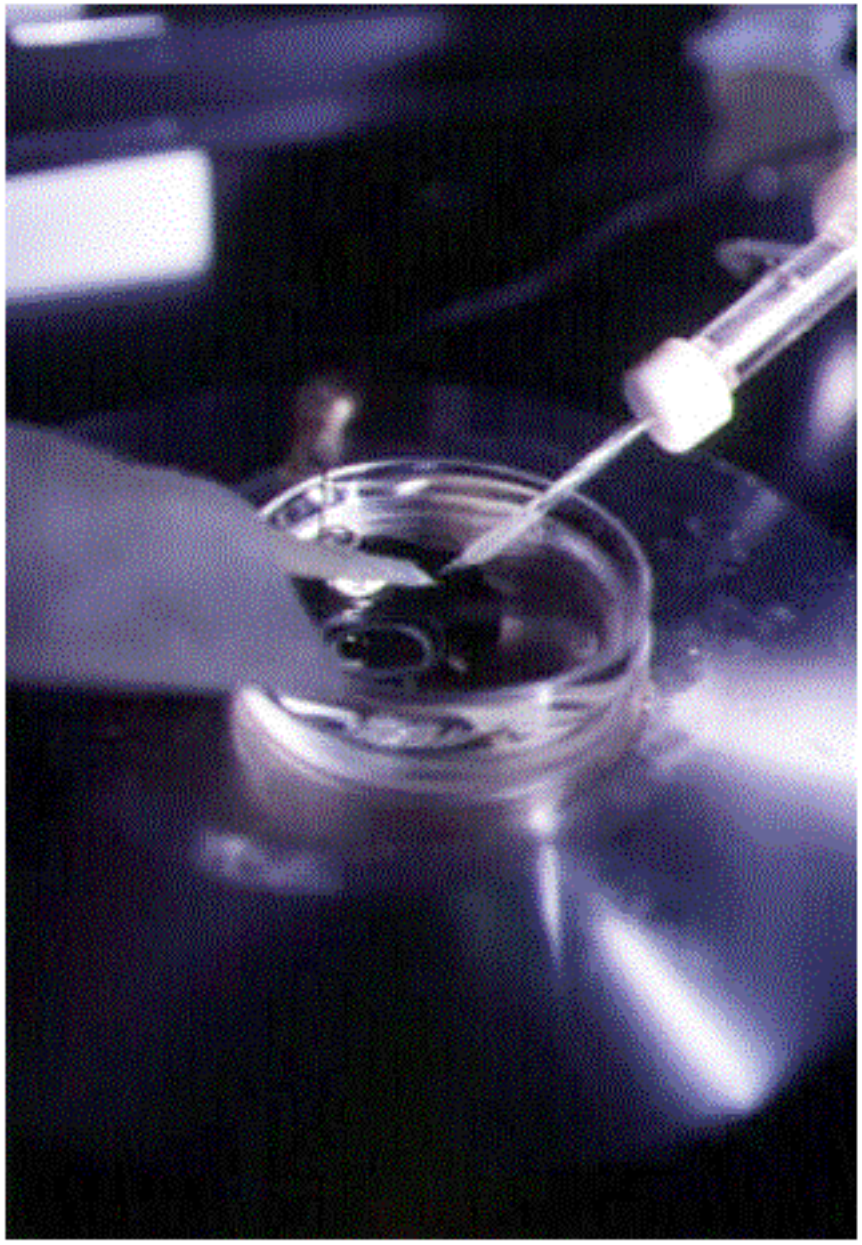


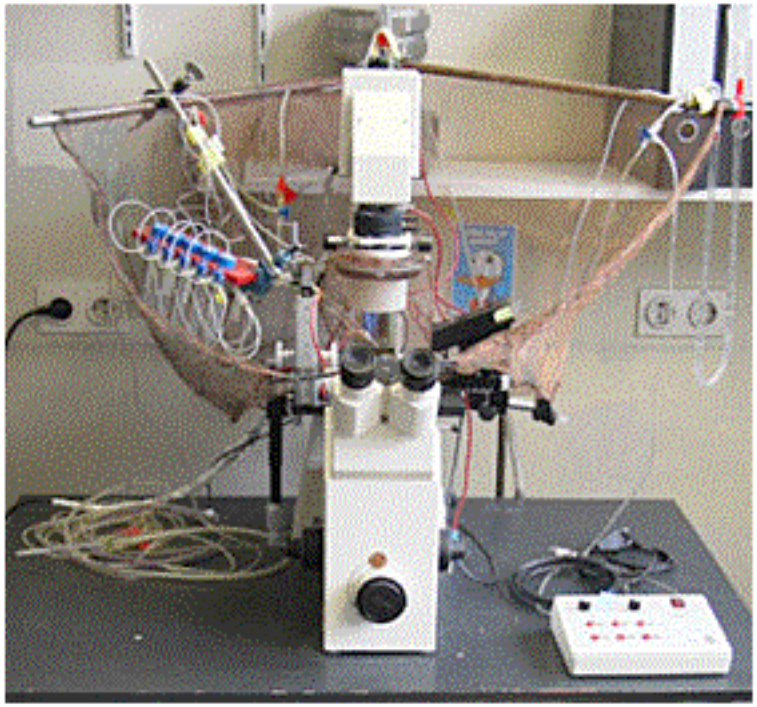
C. Depolarizing the cell in the presence of tetrodotoxin (which blocks the Na+ current) and again

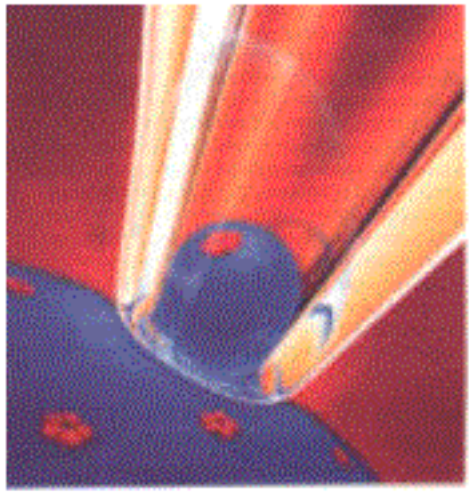
in the presence of tetraethylammonium (which blocks the K+ current), reveals the pure K+ and Na + currents

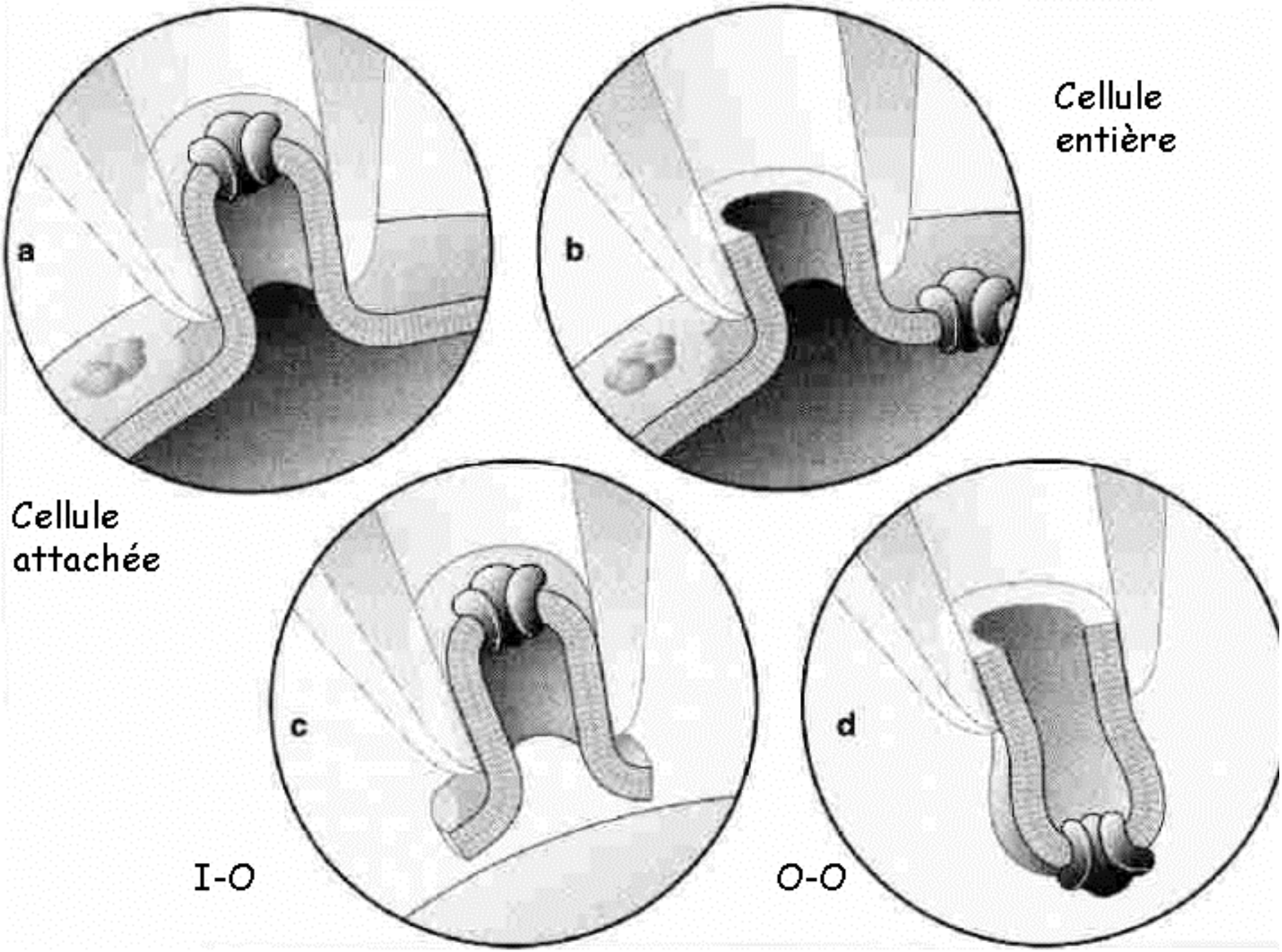
(IK and INa, respectively) after subtracting Ic and Il.


50
E_{Na}
Squid axon
action potential
18.5°C
E_M
0
Na channels gNa
K channels gK
−50
E_K
Post-potentiel
Membrane potential (mV)
40
20
0
Open channels per μm² of membrane

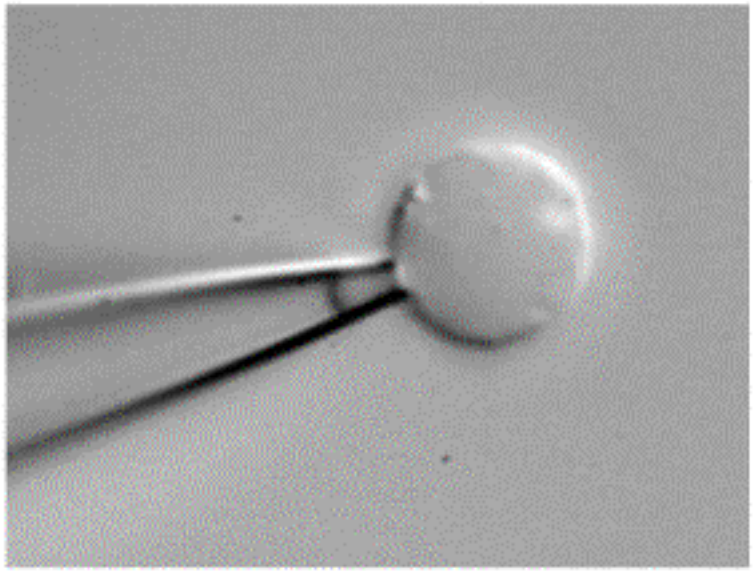




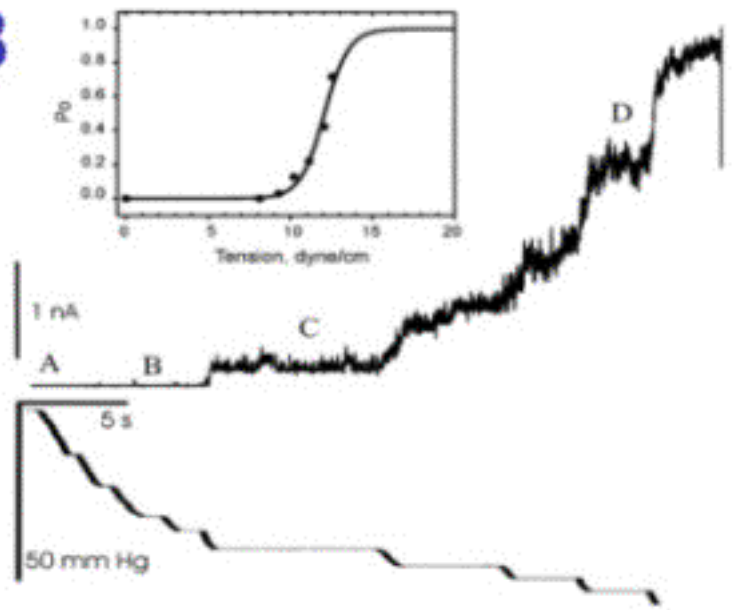



a
b
Cellule entière
Cellule attachée
c
d
I-O
O-O

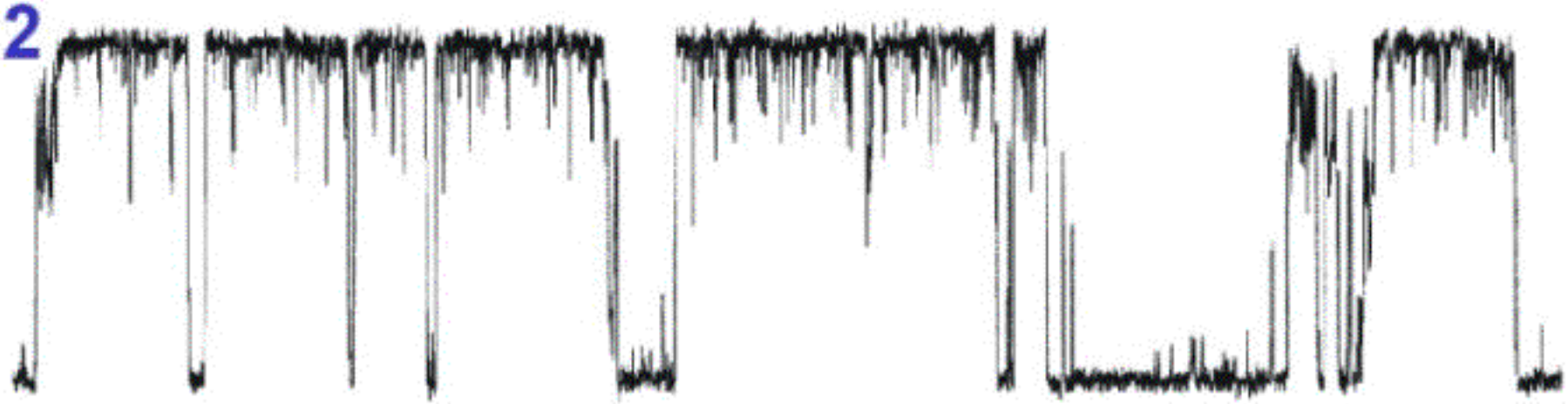
1

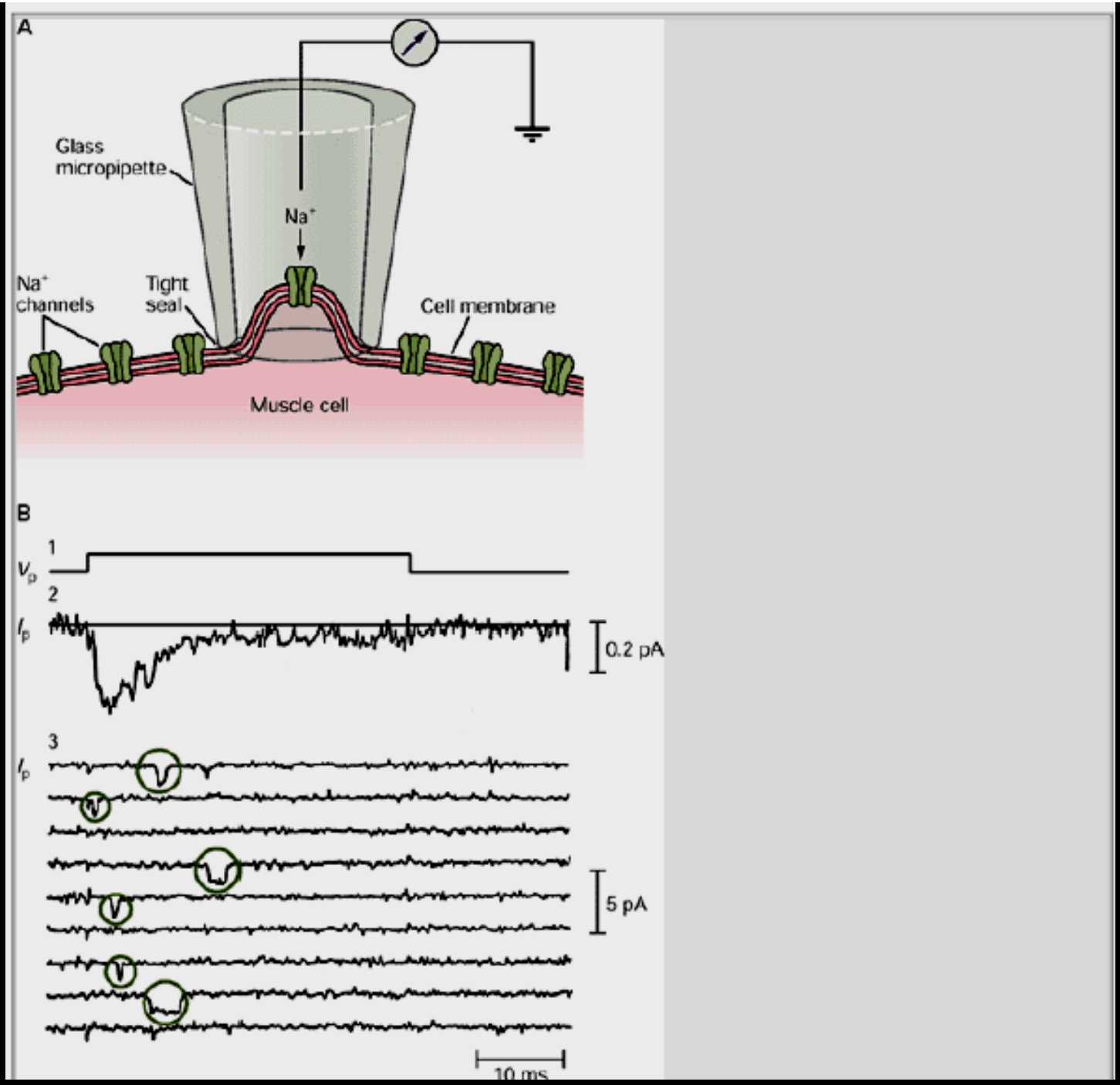


3


1.0
0.8
0.6
0.4
0.2
0.0
Po
0
5
10
15
20
Tension, dyne/cm
1 nA
A
B
C
D
5 s
50 mm Hg

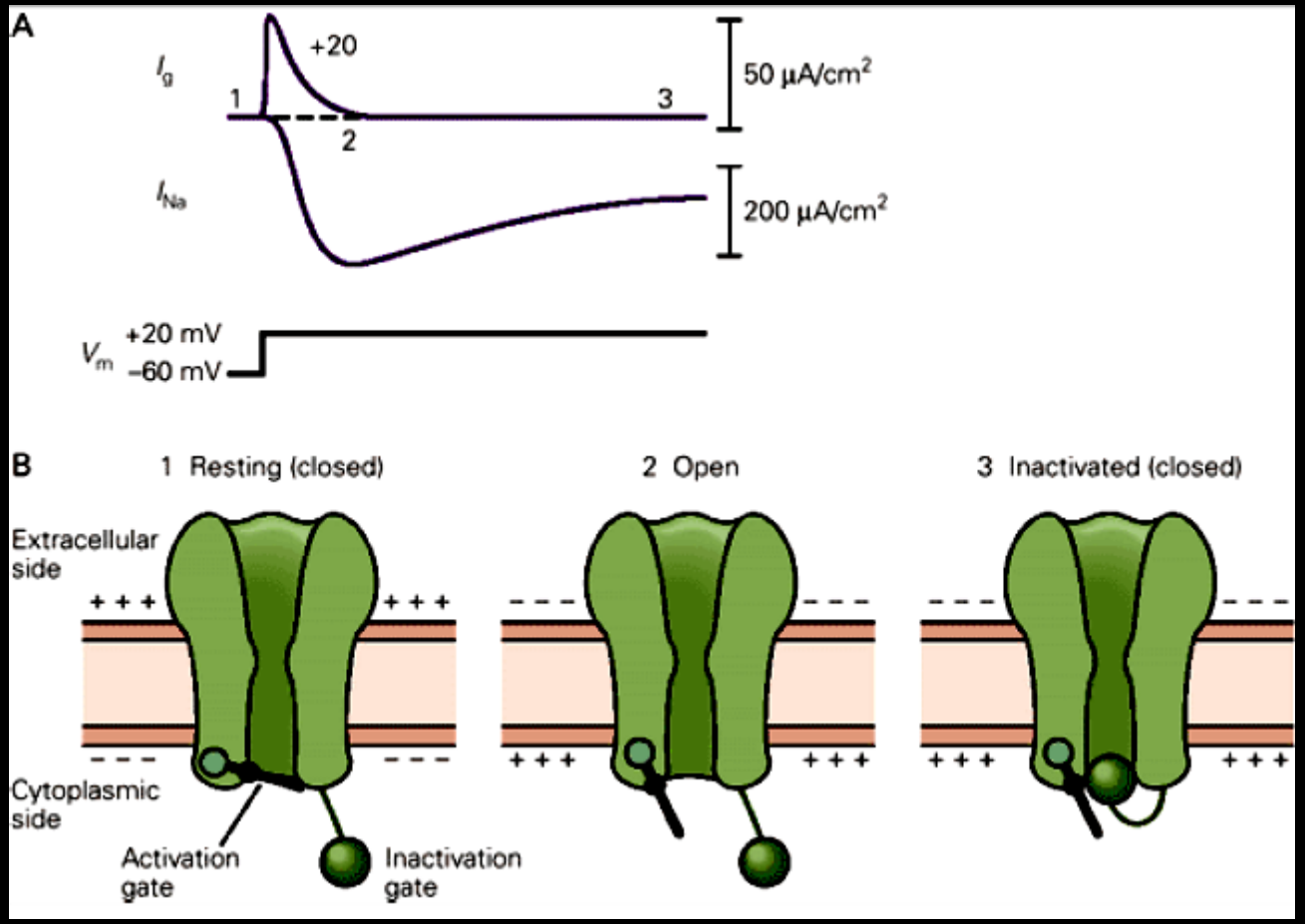
2



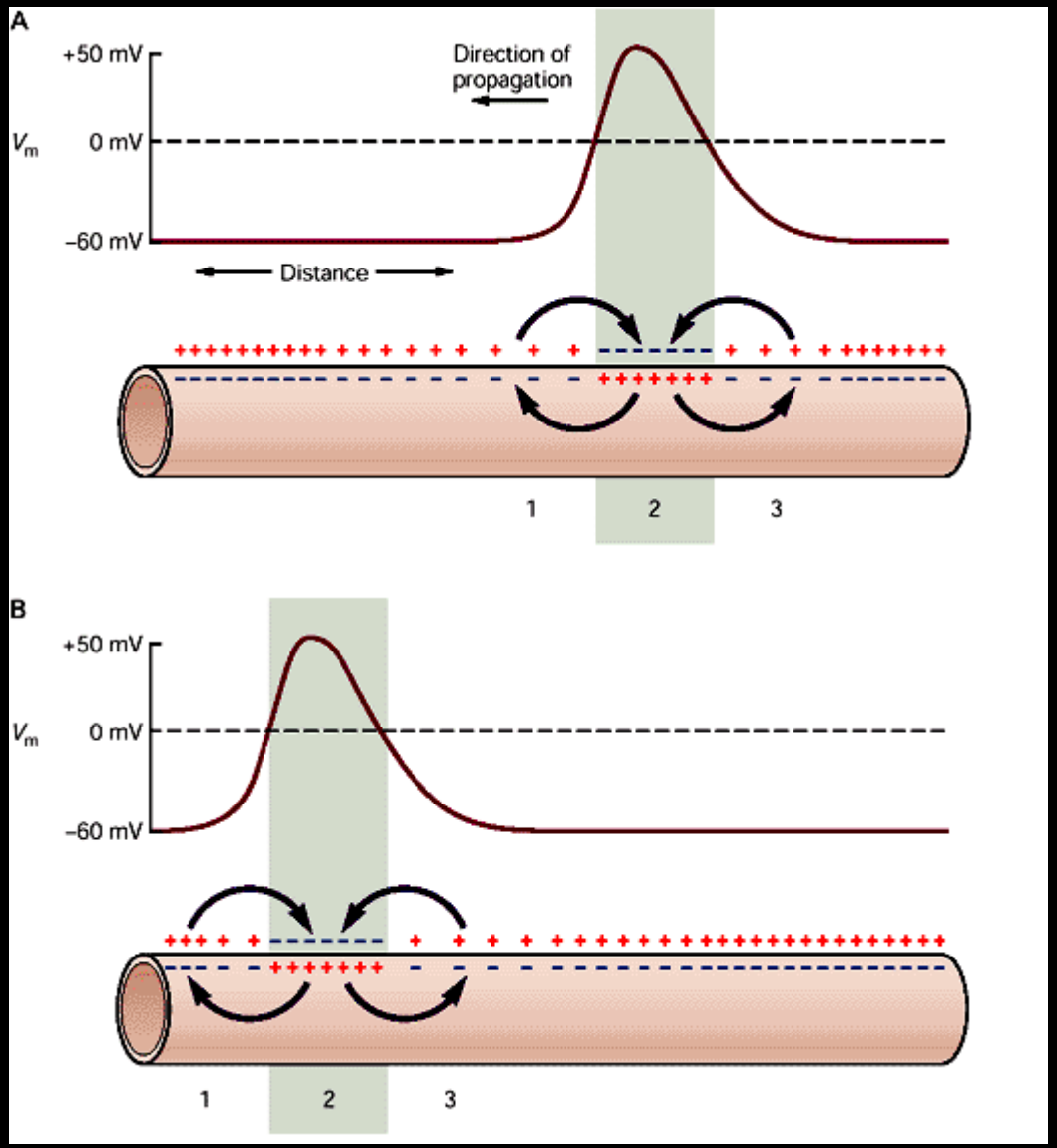

A
Glass micropipette
Na+
Na+ channels
Tight seal
Cell membrane
Muscle cell
B
1
Vp
2
Ip
0.2 pA
3
Ip
5 pA
10 ms

La dépolarisation /PA: entrée Na^+

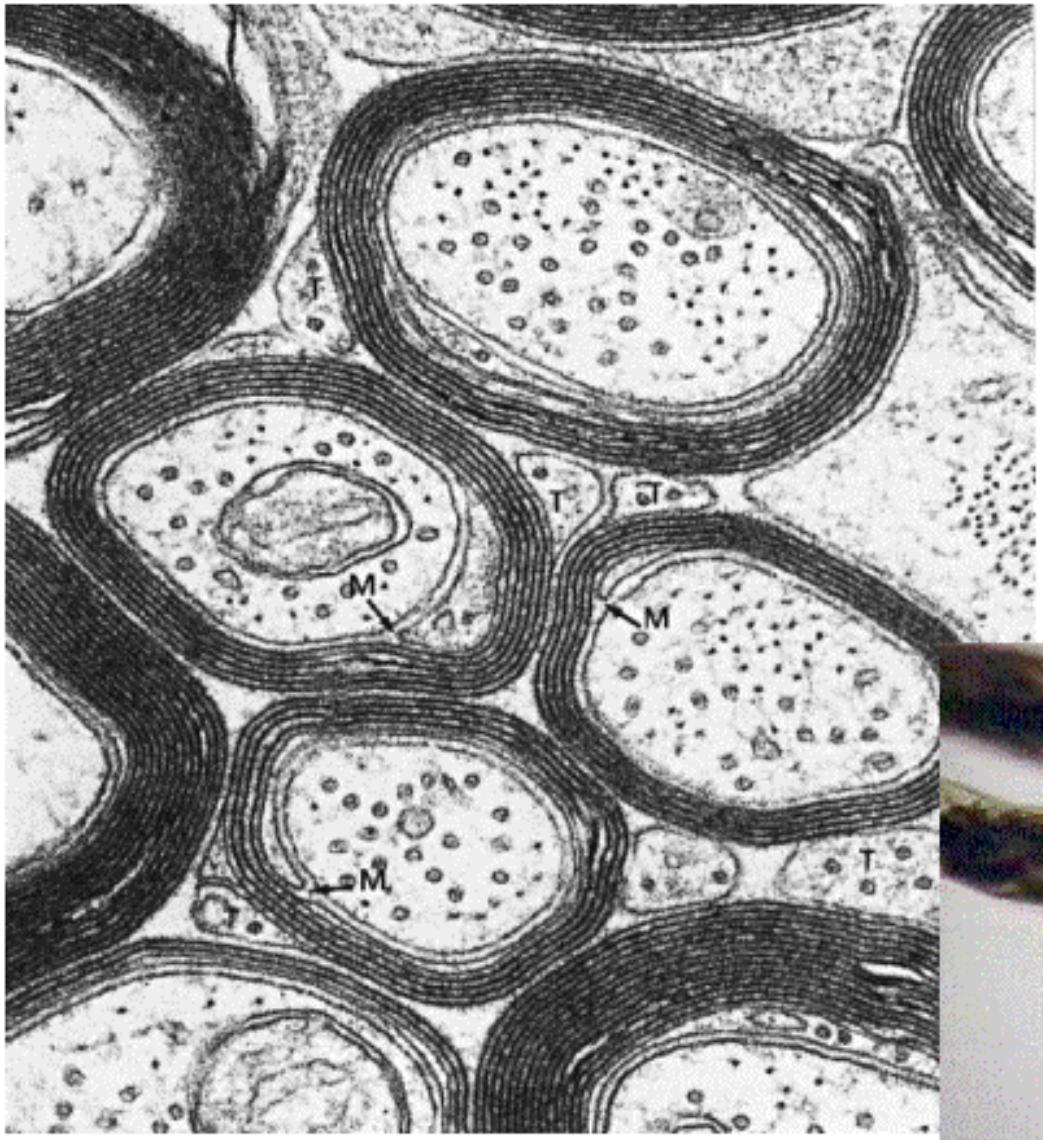
Activation inactivation canaux Na+ voltage-dépendants

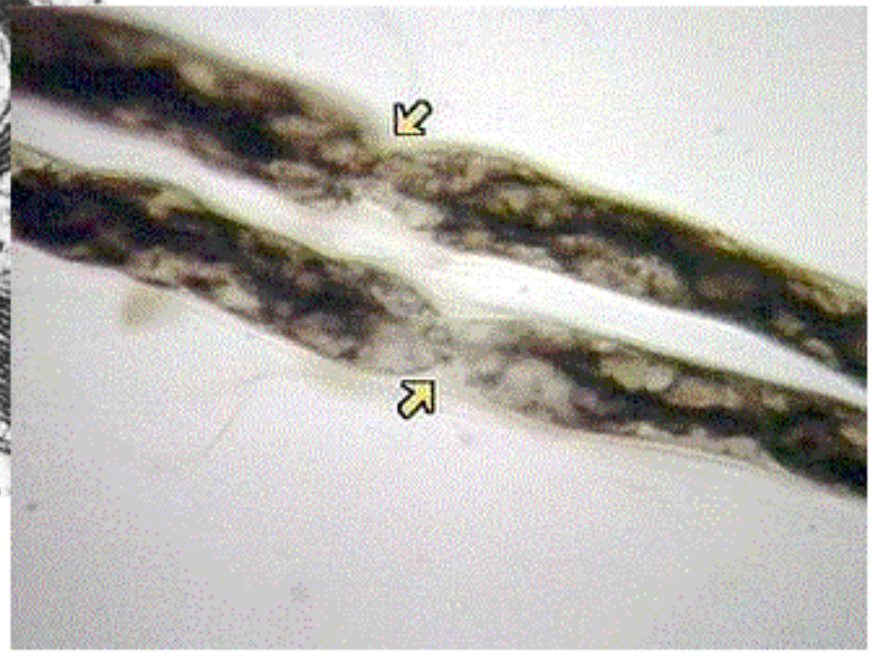


Conduction : fibre amyélinique



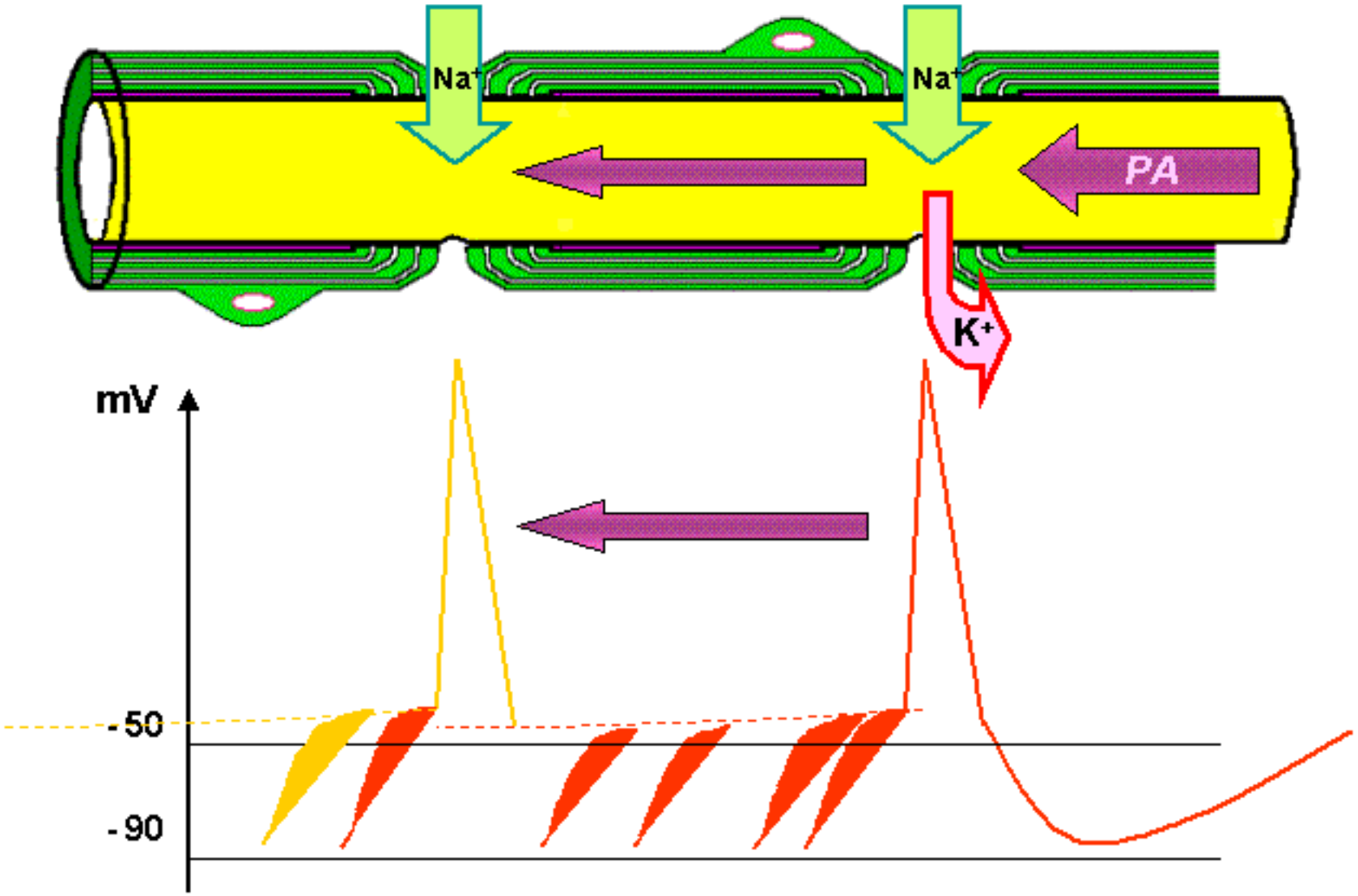
Conduction : fibre myélinisée (1)





Nœuds de Ranvier

Propagation sur un axone myélinisé : conduction "saltatoire"



Vitesse de conduction
Classification

Types de fibres	Fonction	Diamètre (µm)	Vitesse de propagation de l'influx (en m/s)
Aα	afférences fuseau musculaire et afférences visuelles ; efférences du muscle squelettique	15	70 - 120
Aβ	afférences cutanées (tactiles)	8	30 - 70
Aγ	efférences du fuseau musculaire	5	15 - 30
Aδ	afférences cutanées (thermiques et douleur "rapide")	3	12 - 30
B	fibres sympathiques préganglionnaires	3	3 - 15
C	afférences cutanées (douleur "tardive") ; fibres sympathiques postganglionnaires	1 (amyélinique)	0,5 - 2

Classification des fibres nerveuses

Classification des fibres nerveuses

Erlanger-Gasser (1925) **:** ***fibres Aα, Aβ, Aγ, Aδ, B, C,***
Lloyd (1943) **:** ***fibres I, II, III, IV***