ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

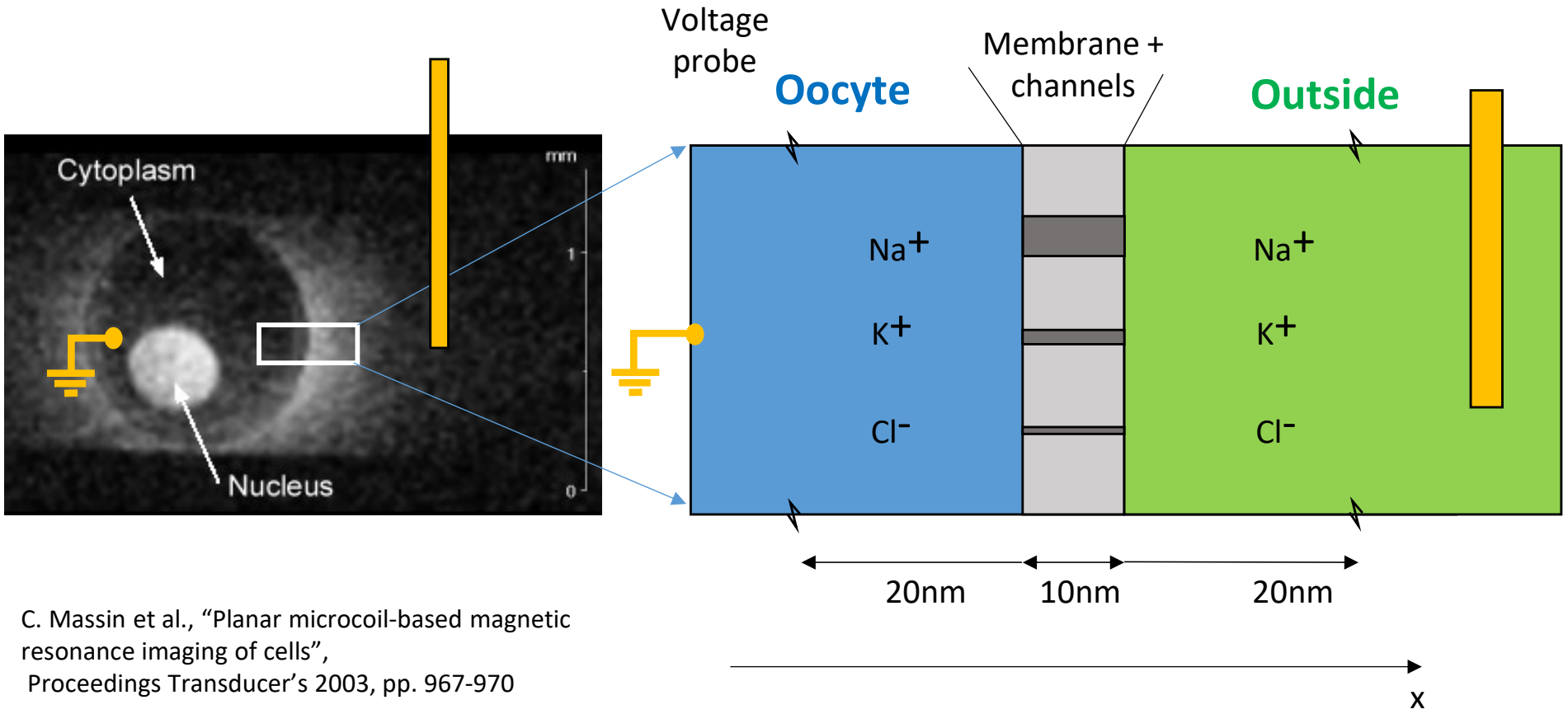
COMPOSANTS SEMI-CONDUCTEURS

IV) Solutions S4

P.A. Besse

EPFL

E 4.2: Frog Oocyte: planar model



C. Massin et al., "Planar microcoil-based magnetic resonance imaging of cells",
Proceedings Transducer's 2003, pp. 967-970

E 4.2: Start situation: all channels closed

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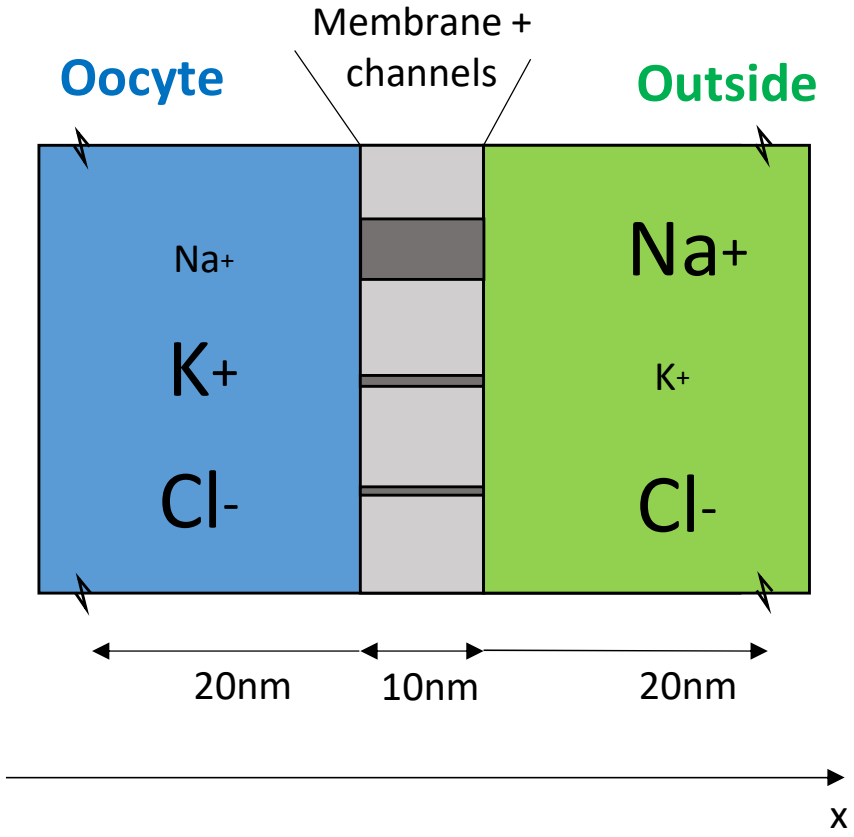
Pompe par ATPase



Concentrations when all the channels are closed.

Constant concentrations in each region

	Oocyte	Outside	V_{nernst}
Na+	10 mM	90 mM	+ 56 mV
K+	90 mM	10 mM	- 56 mV
Cl- and anions-	100 mM	100 mM	0 mV

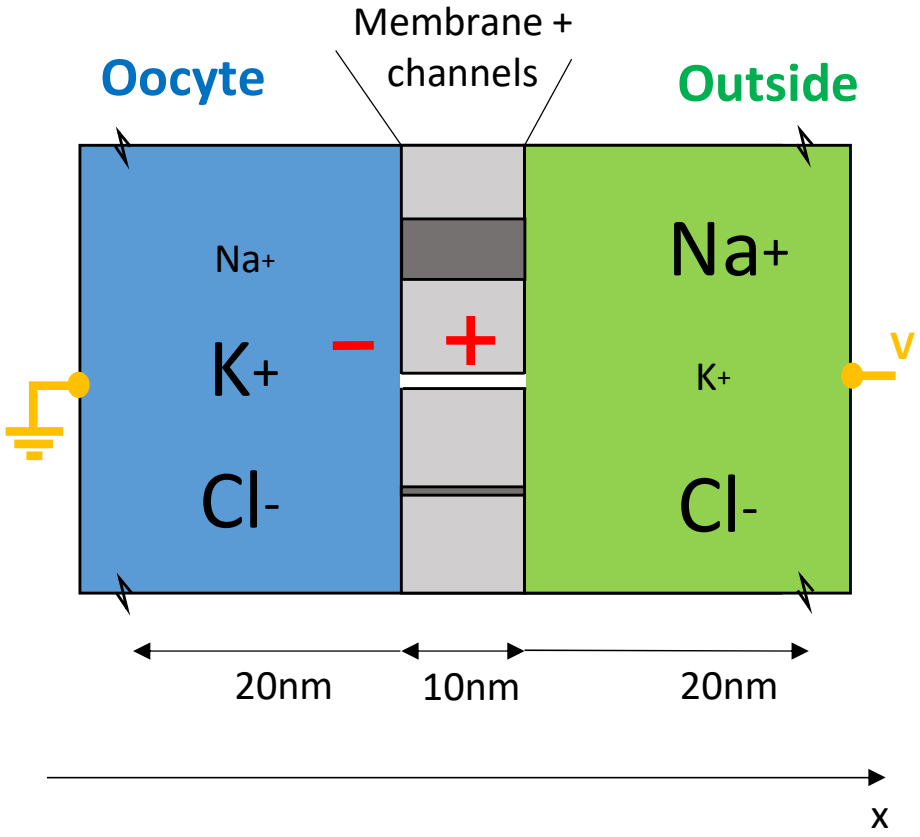
$$1\,mM \equiv 10^{-3}\ mole/liter = 10^{-3}\cdot N_A \cdot \frac{molecule}{1000\ cm^3} = 6\cdot 10^{17}\ molecule/cm^3$$

Nernst voltage: $$V_{nernst} \equiv \frac{RT}{F} Ln\left(\frac{[C_{out}]}{[C_{in}]}\right)$$

$$R \equiv k \cdot N_A$$

$$F \equiv |q_i| \cdot N_A$$

K-channels open



$$V_{bi} = -\frac{kT}{q} Ln\left(\frac{\left[K^+\right]_{out}}{\left[K^+\right]_{in}}\right) = +\,56\,mV$$

- Tension de Nernst

Mathematical model (1)

4 unknown: E, [K+], [Na+] and [Cl-] 4 equations:

Poisson: $\Delta\varphi = -\frac{1}{\varepsilon_0 \varepsilon}\rho = -\frac{1}{\varepsilon_0 \varepsilon} q \cdot \left(\left[Na^+ \right] + \left[K^+ \right] - \left[Cl^- \right] \right)$ $\vec{E} = -\overrightarrow{grad}\varphi$

Continuity:

ATPase

$$\frac{\partial \left[Na^+ \right]}{\partial t} = G_{Na+} - R_{Na+} - \frac{1}{q} div(\vec{j}_{Na+})$$

Drift Diffusion

$$\vec{j}_{Na+} = \left[Na^+ \right] q \, \mu_{Na+} \cdot \vec{E} \; - \; kT \, \mu_{Na+} \, \overrightarrow{grad} \left[Na^+ \right]$$

ATPase

$$\frac{\partial \left[K^+ \right]}{\partial t} = G_{K+} - R_{K+} - \frac{1}{q} div(\vec{j}_{K+})$$

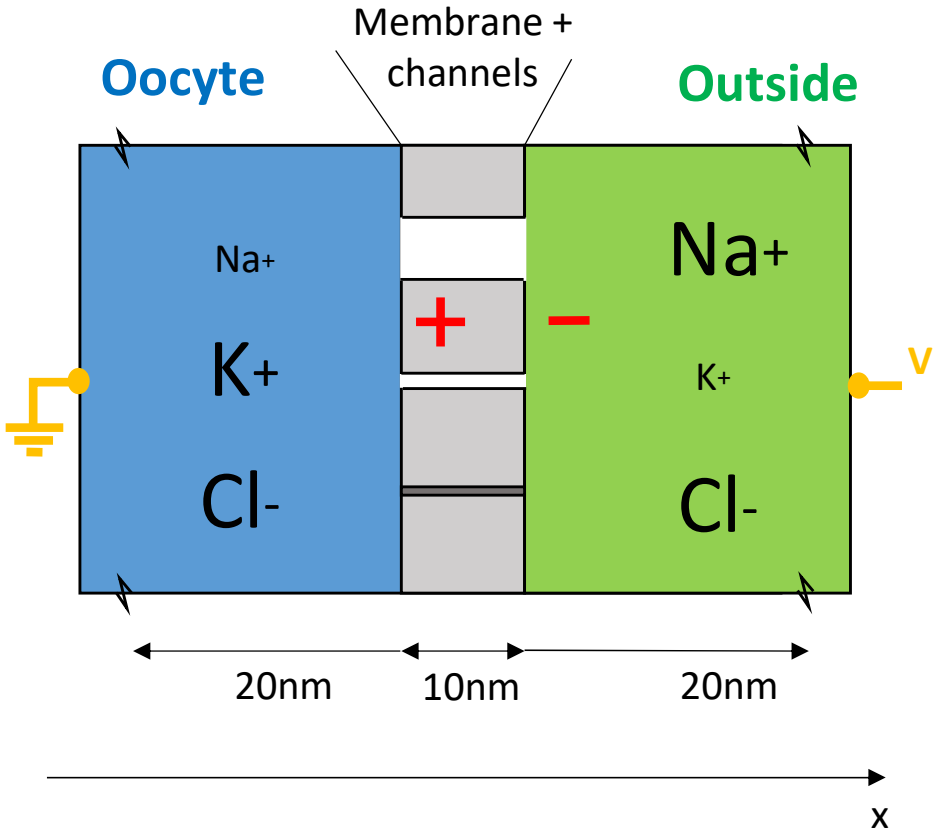
$$\vec{j}_{K+} = \left[K^+ \right] q \, \mu_{K+} \cdot \vec{E} \; - \; kT \, \mu_{K+} \, \overrightarrow{grad} \left[K^+ \right]$$

=0 =0

$$\frac{\partial \left[Cl^- \right]}{\partial t} = G_{Cl-} - R_{Cl-} + \frac{1}{q} div(\vec{j}_{Cl-})$$

$$\vec{j}_{Cl-} = \left[Cl^- \right] q \, \mu_{Cl-} \cdot \vec{E} \; + \; kT \, \mu_{Cl-} \, \overrightarrow{grad} \left[Cl^- \right]$$

K and Na channels open



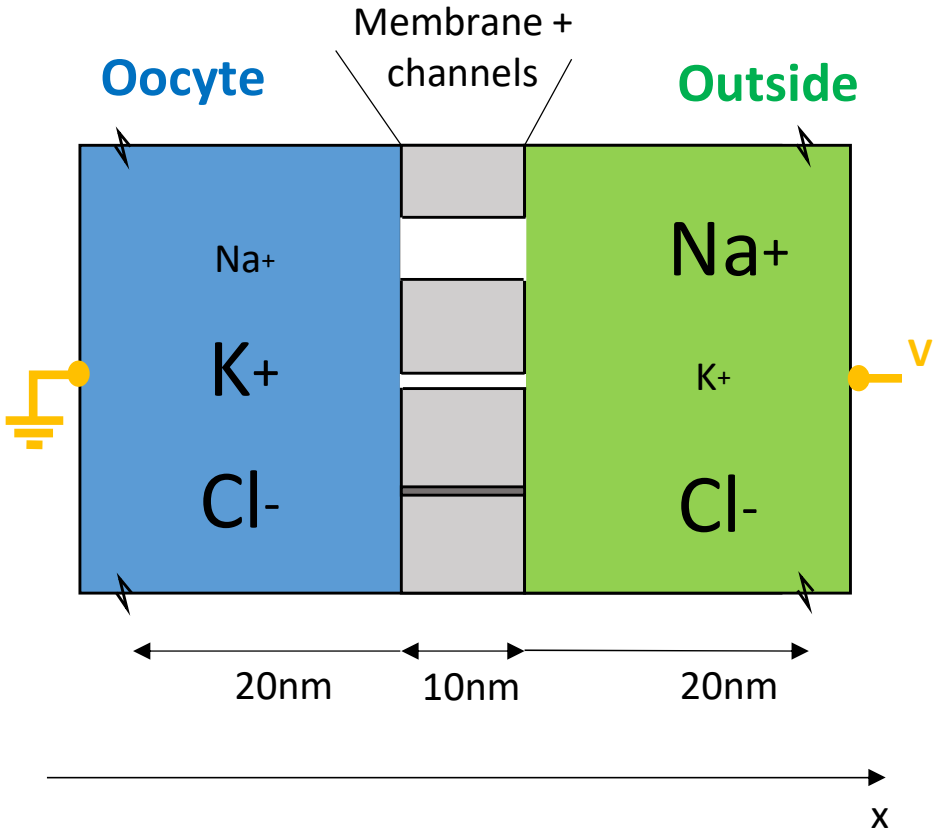
$$\frac{\mu_{Na+}}{\mu_{K+}} = 10$$

$$V_{bi} = -\frac{kT}{q} Ln\left(\frac{\left[K^+\right]_{out} + \frac{\mu_{Na+}}{\mu_{K+}}\left[Na^+\right]_{out}}{\left[K^+\right]_{in} + \frac{\mu_{Na+}}{\mu_{K+}}\left[Na^+\right]_{in}}\right) = -40\ mV$$

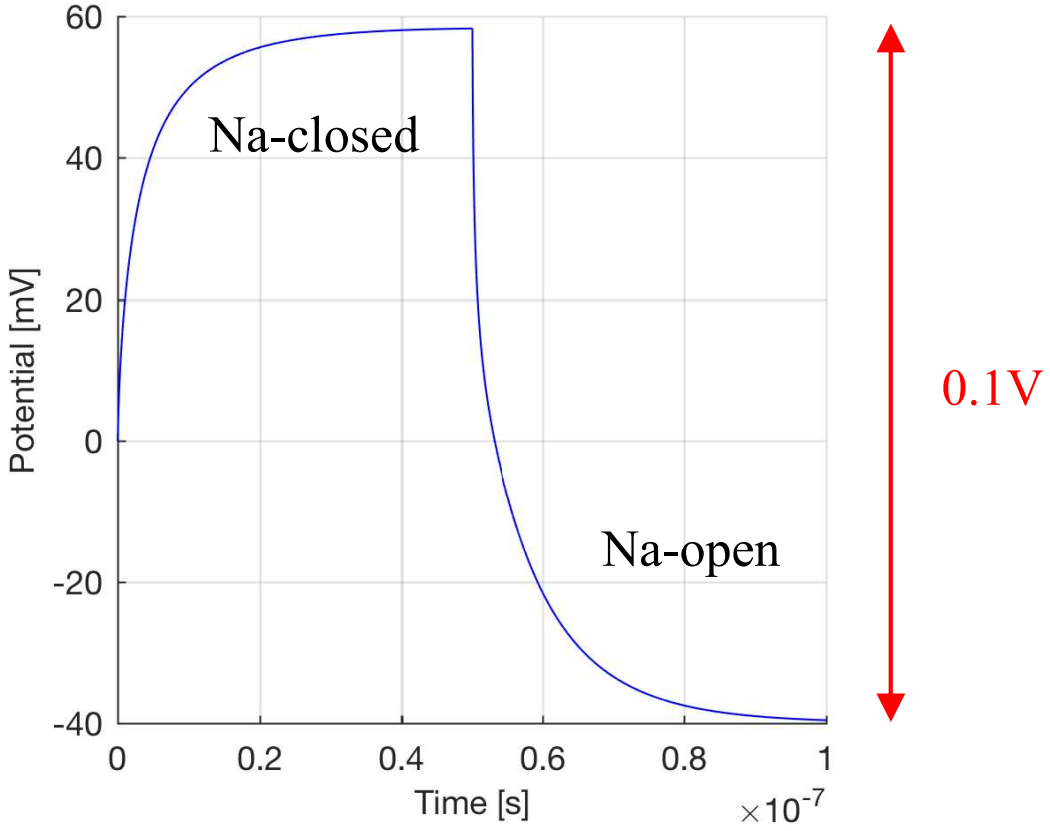
- Tension de Nernst

Na channels opening and closing

$$\frac{\mu_{Na+}}{\mu_{K+}} = 10$$

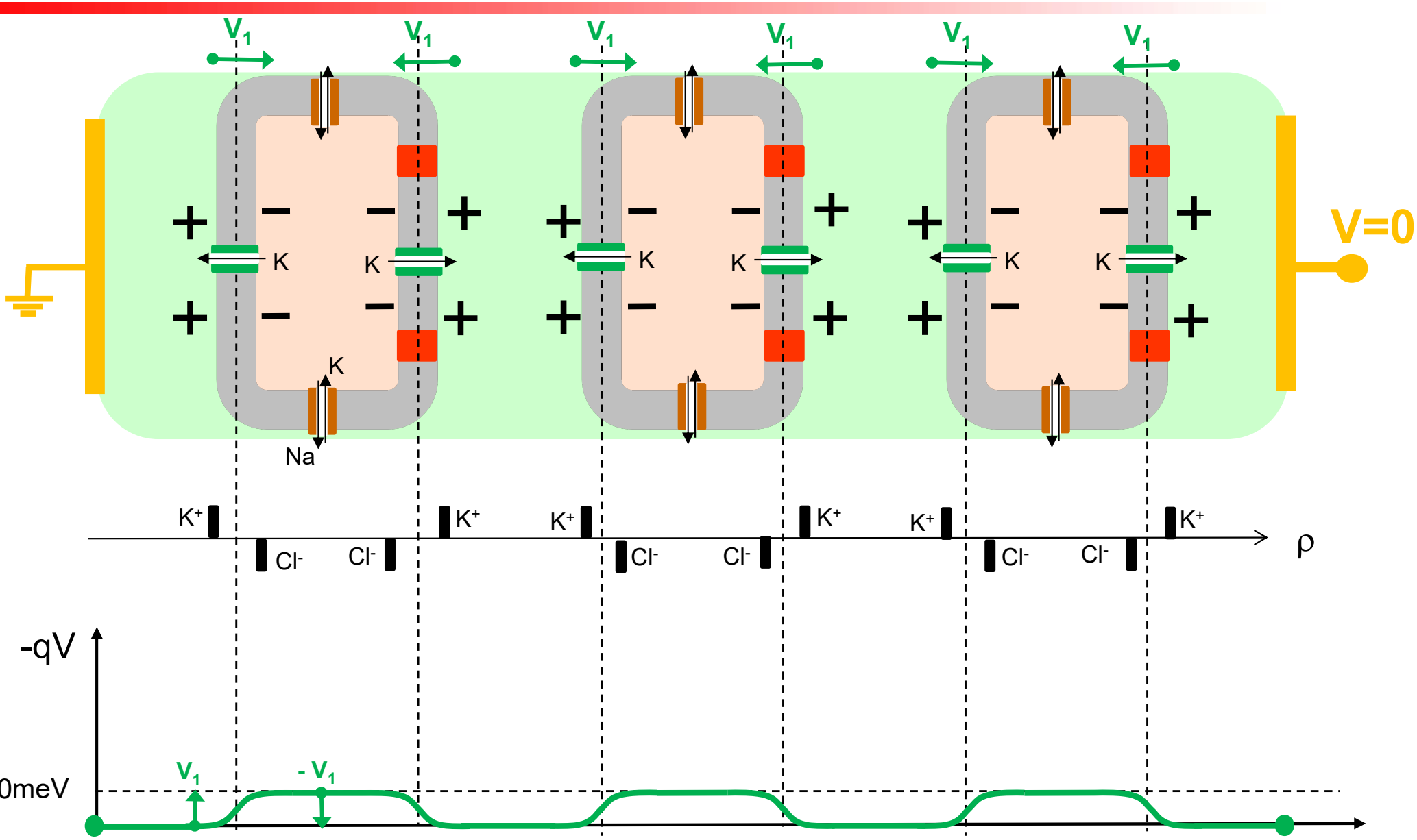


$$V_{bi} = -\frac{kT}{q} Ln\left(\frac{\left[K^+\right]_{out}}{\left[K^+\right]_{in}}\right) = 56\ mV$$

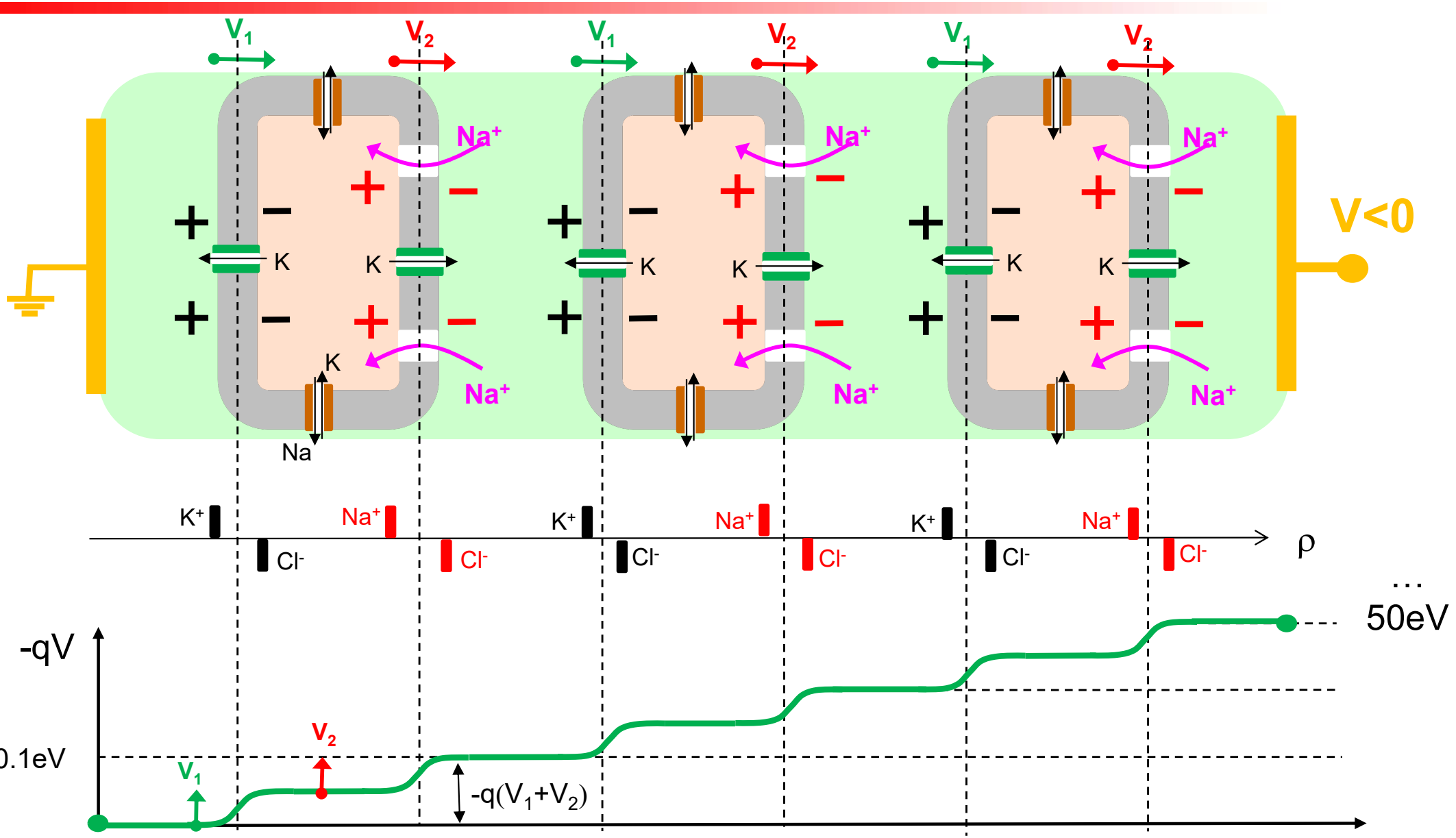


$$V_{bi} = -\frac{kT}{q} Ln\left(\frac{\mu_{K+}\left[K^+\right]_{out} + \mu_{Na+}\left[Na^+\right]_{out}}{\mu_{K+}\left[K^+\right]_{in} + \mu_{Na+}\left[Na^+\right]_{in}}\right) = -40\ mV$$

Na+ channels closed

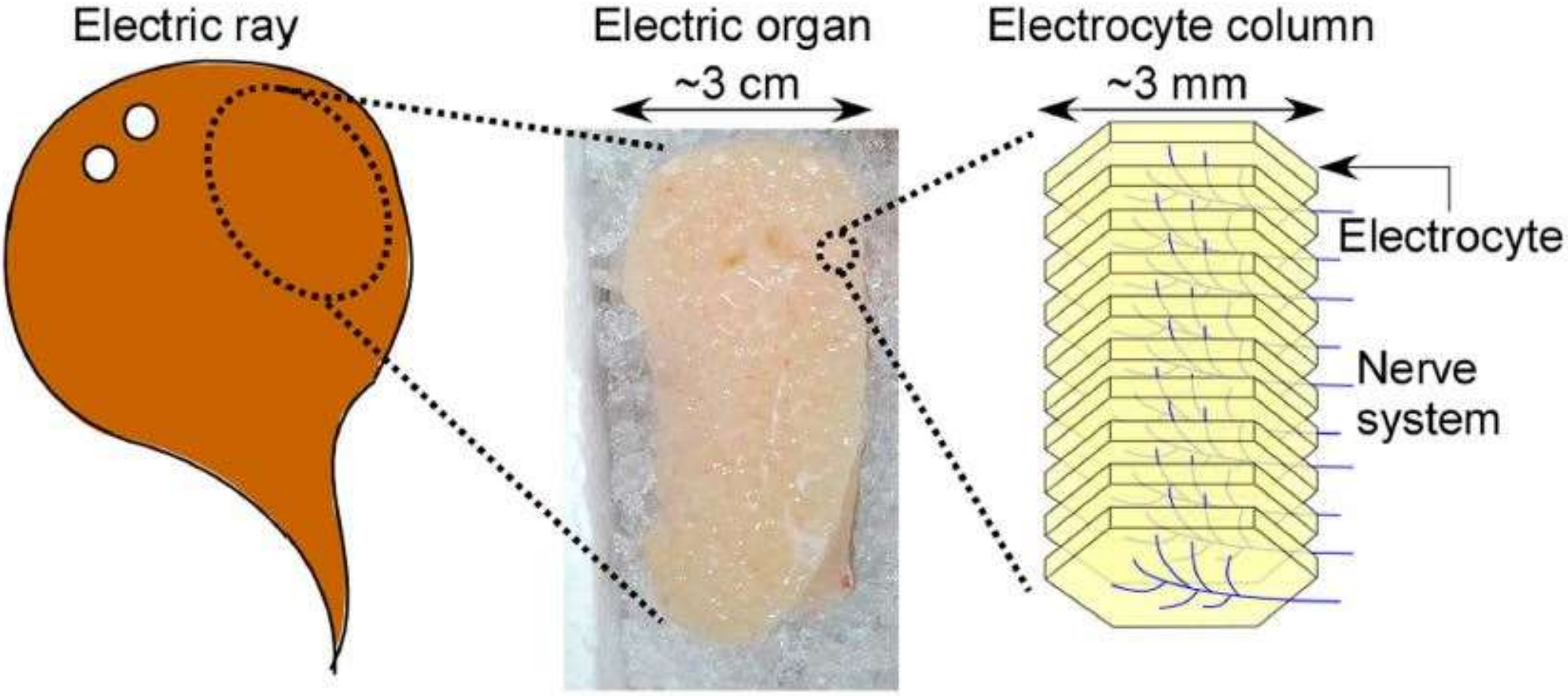


Na+ channels open



Electric rays

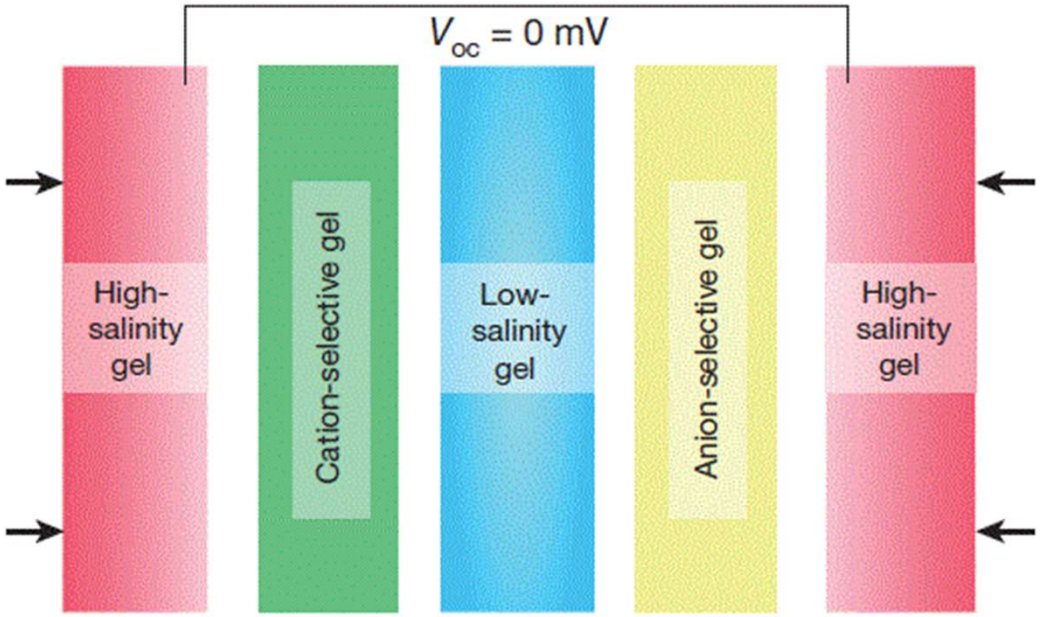
about 500 cells in series in electric rays (*Torpedinidae)*



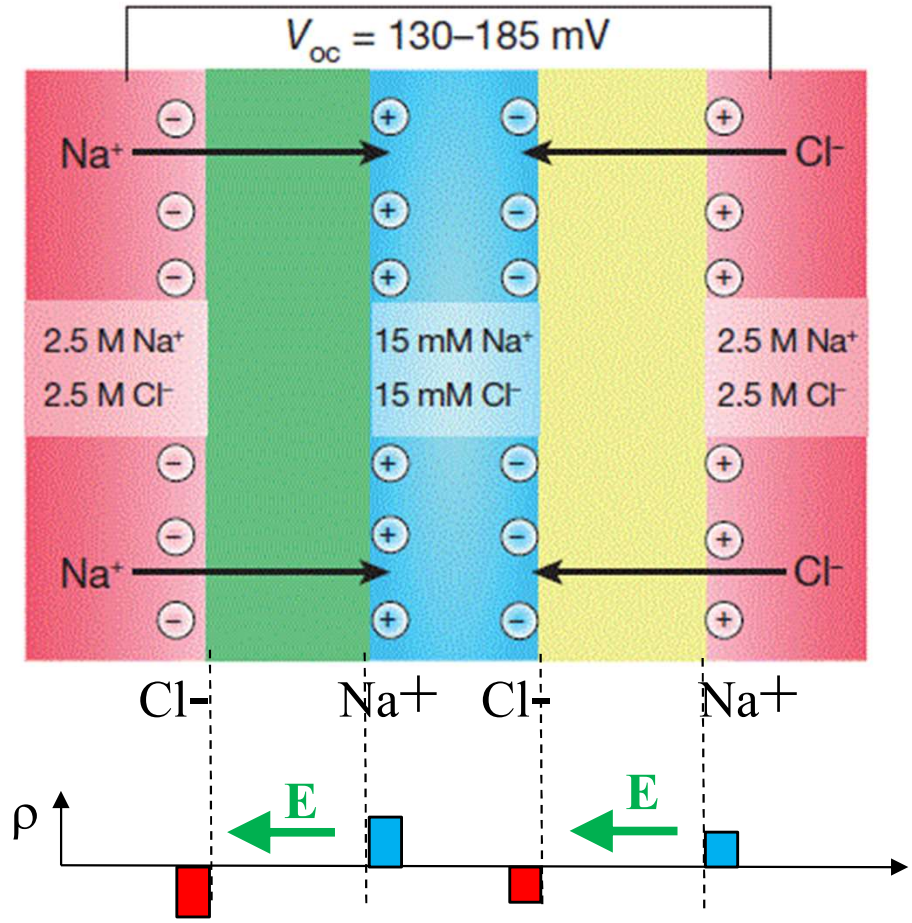
Y. Tanaka et al. «An electric generator using living Torpedo electric organs Controlled by fluid pressure-based alternative nervous systems"
www.nature.com/scientificreports , May 2016

Source de tension «gels ioniques»

Gels séparés

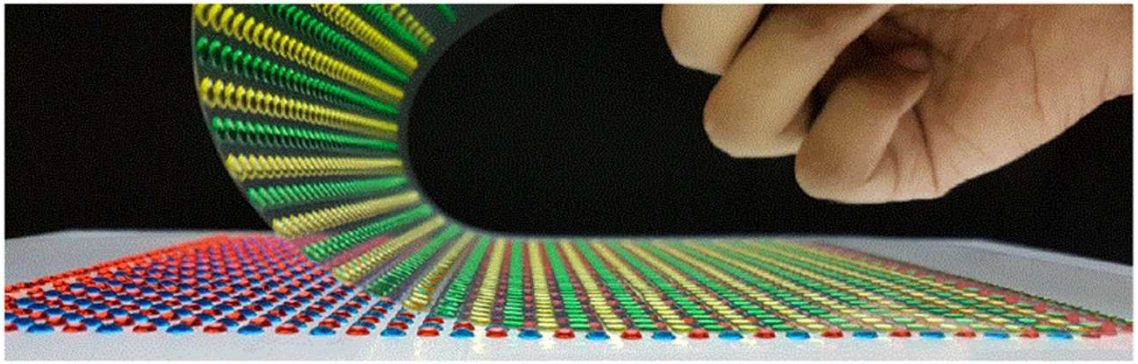


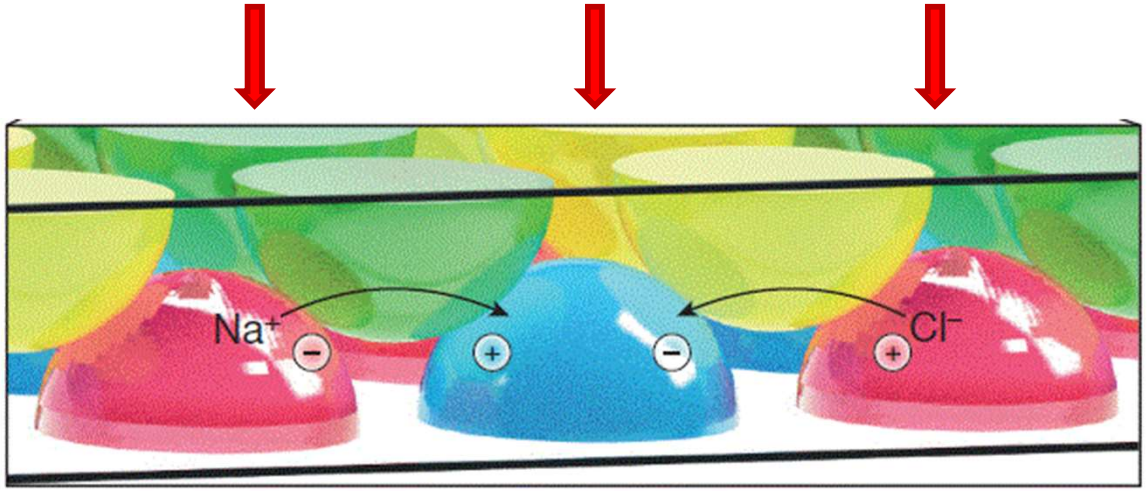
Gels en contact
(pression mécanique)



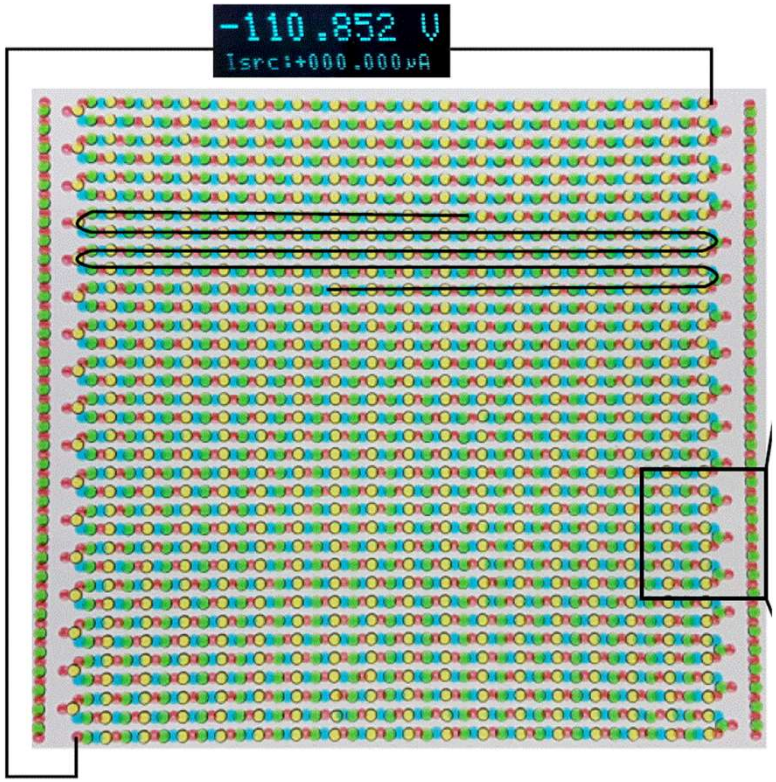
T. B. H. Schroeder, et al., «An electric-eel-inspired soft power source from stacked hydrogels»,
Nature, Vol. 552, p. 214-218, 14 dec. 2017

Source de tension «gels ioniques»





2449 gels (612 cells de 180 mV)
→ 110 V



T. B. H. Schroeder, et al., «An electric-eel-inspired soft power source from stacked hydrogels», Nature, Vol. 552, p. 214-218, 14 dec. 2017