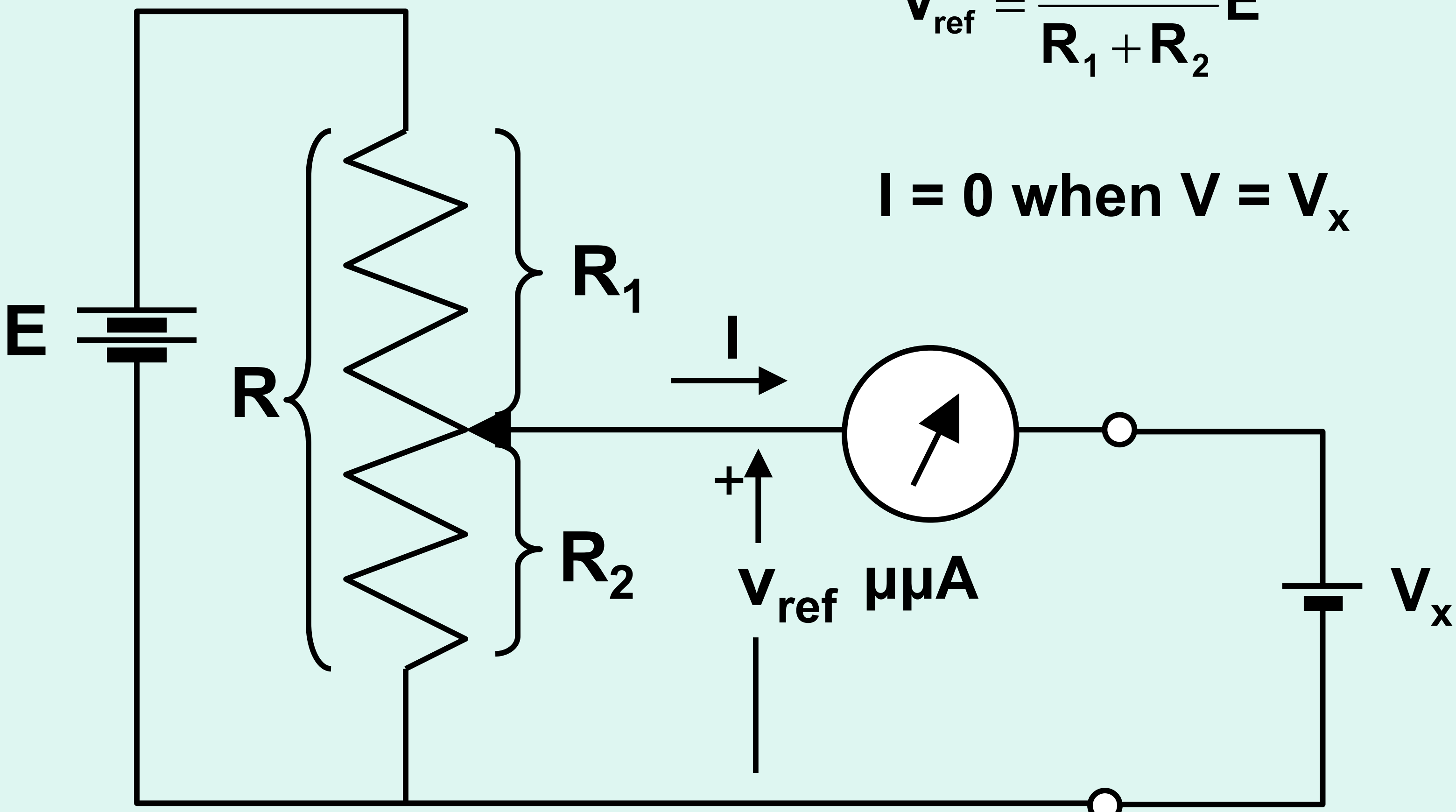
Potentiometer

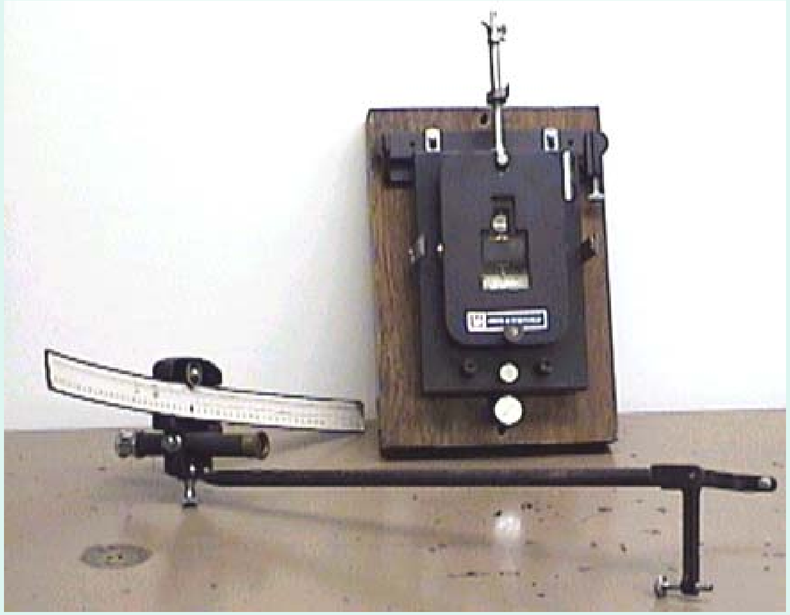
$$V_{ref} = \frac{R_2}{R_1 + R_2} E$$

$$I = 0 \text{ when } V = V_x$$



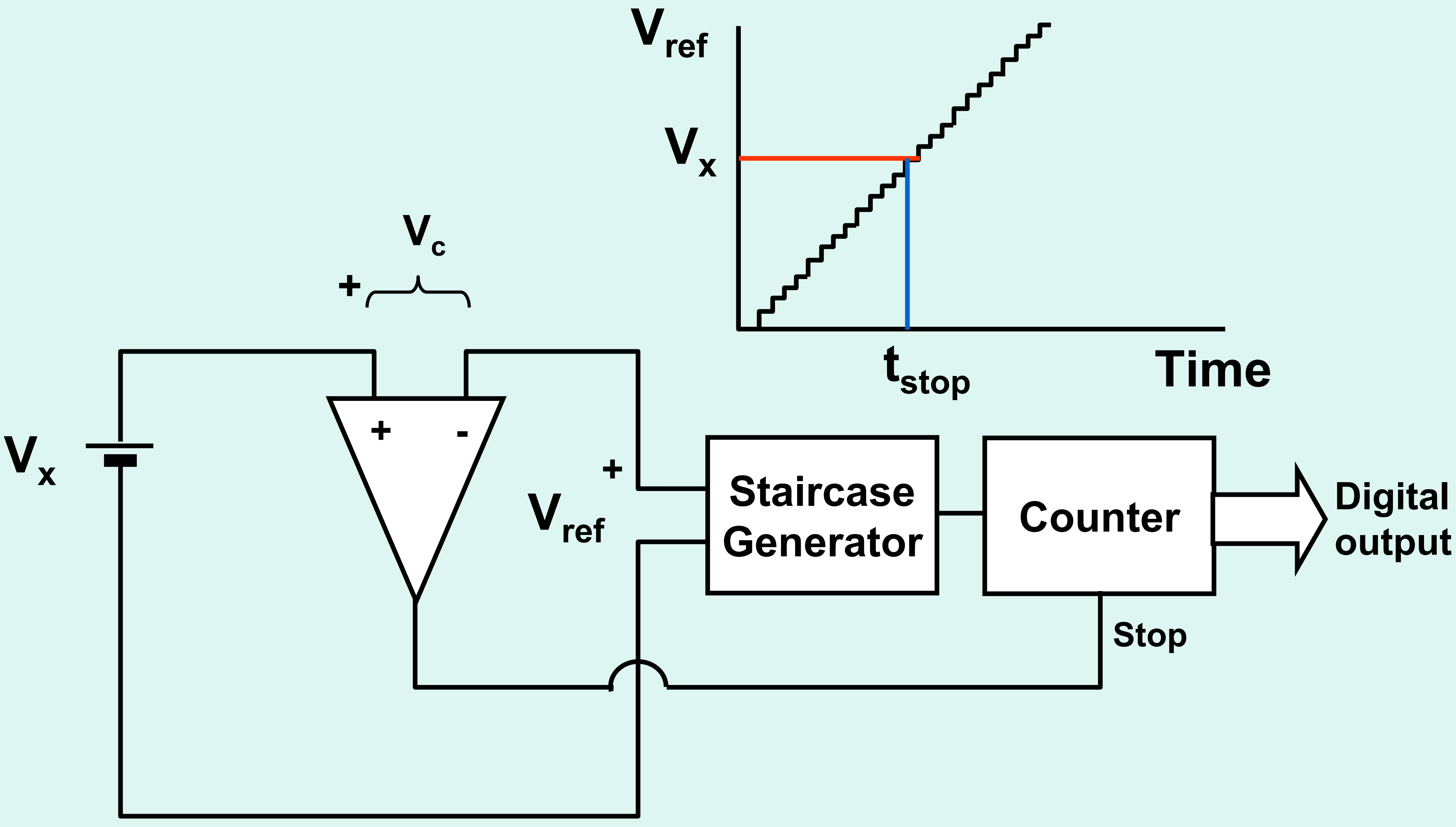
Historical Potentiometer

Leeds and Northrup
K-2 Potentiometer



Galvanometer

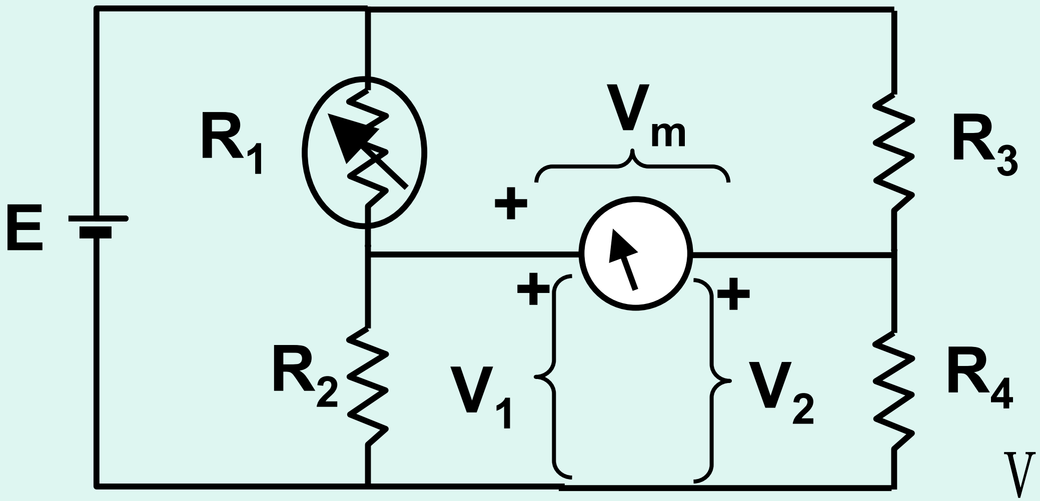
Modern Potentiometers: Analog to Digital Converters



Application: Electronic Thermometer

- Easy to read digital display
- Rapid response
- Equilibrium indication
- Disposable protective sheath
- Inexpensive enough for home use

Wheatstone Bridge



$$V_1 = \frac{R_2}{R_1 + R_2} E$$

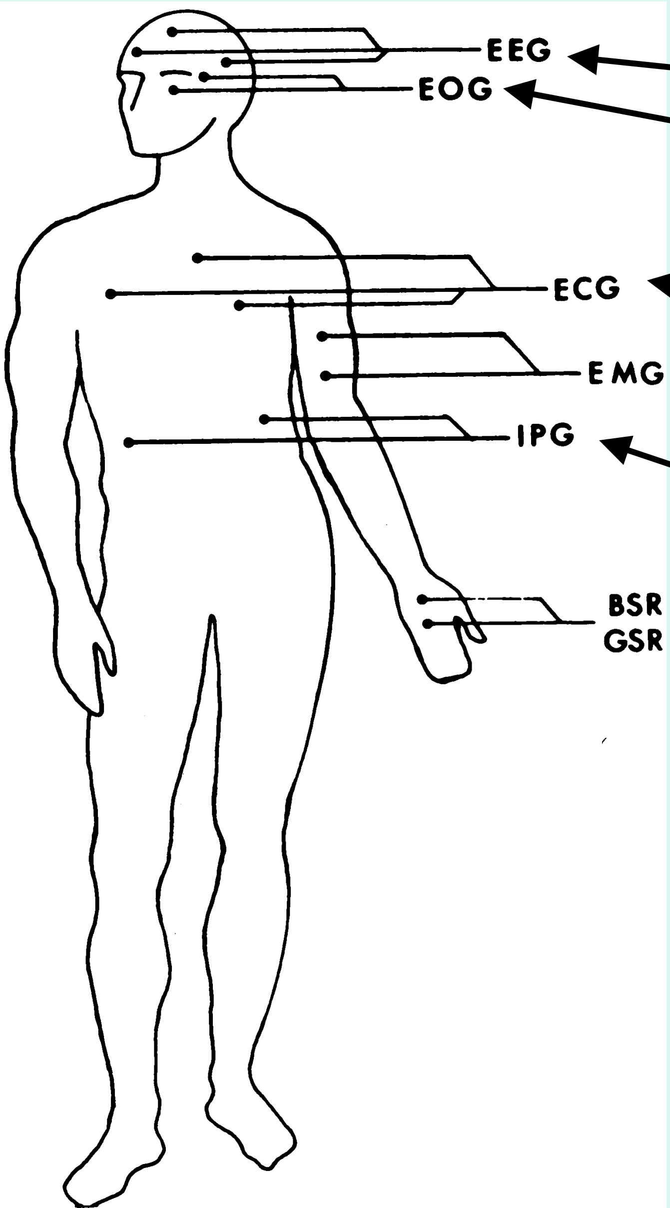
$$V_2 = \frac{R_4}{R_3 + R_4} E$$

Meter voltage

$$V_m = V_1 - V_2$$

$$\mathbf{V_m} = \frac{R_2}{R_1 + R_2} E - \frac{R_4}{R_3 + R_4} E$$

Biopotentials



Electroencephalogram

Electro-oculogram
Electroretinogram (ERG)

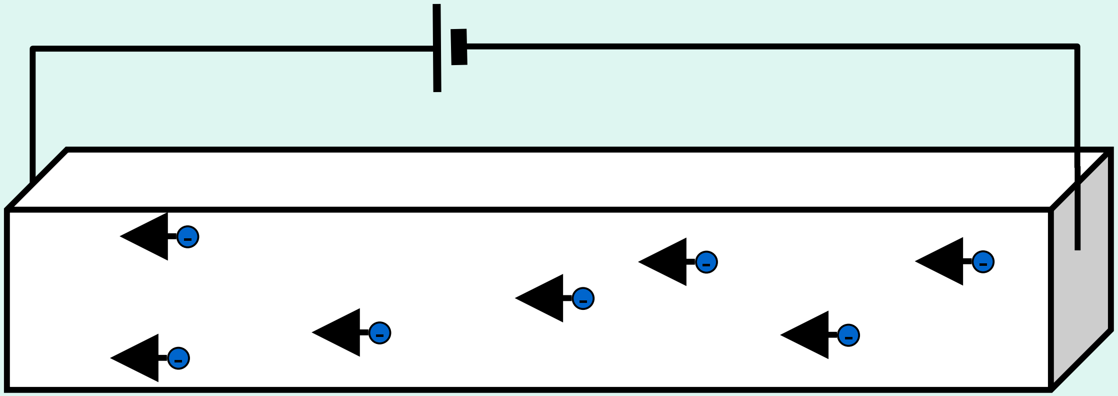
Electrocardiogram

Electromyogram

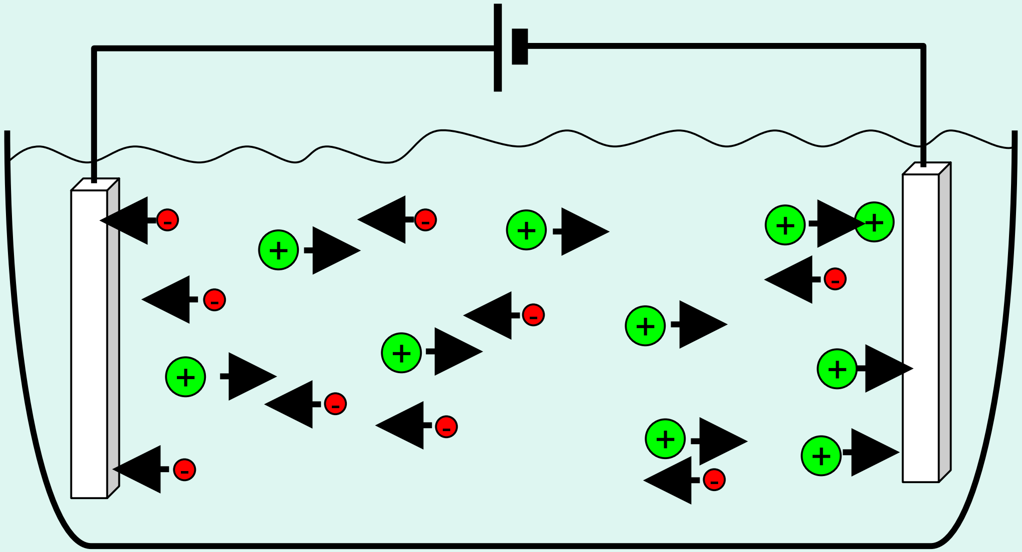
Impedance Pneumogram

Galvanic Skin Response

Electrical Conduction

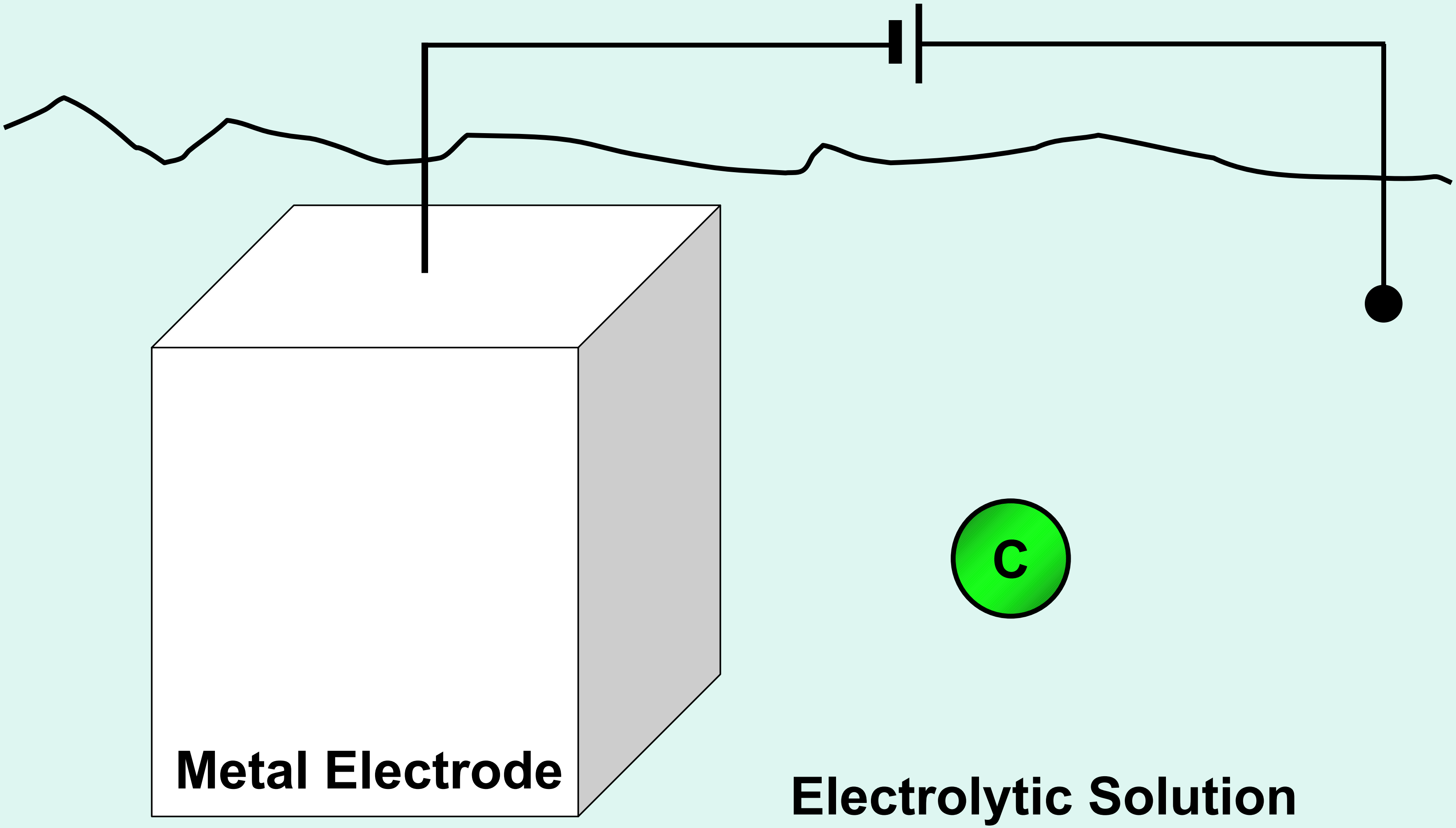


Electronic Conduction

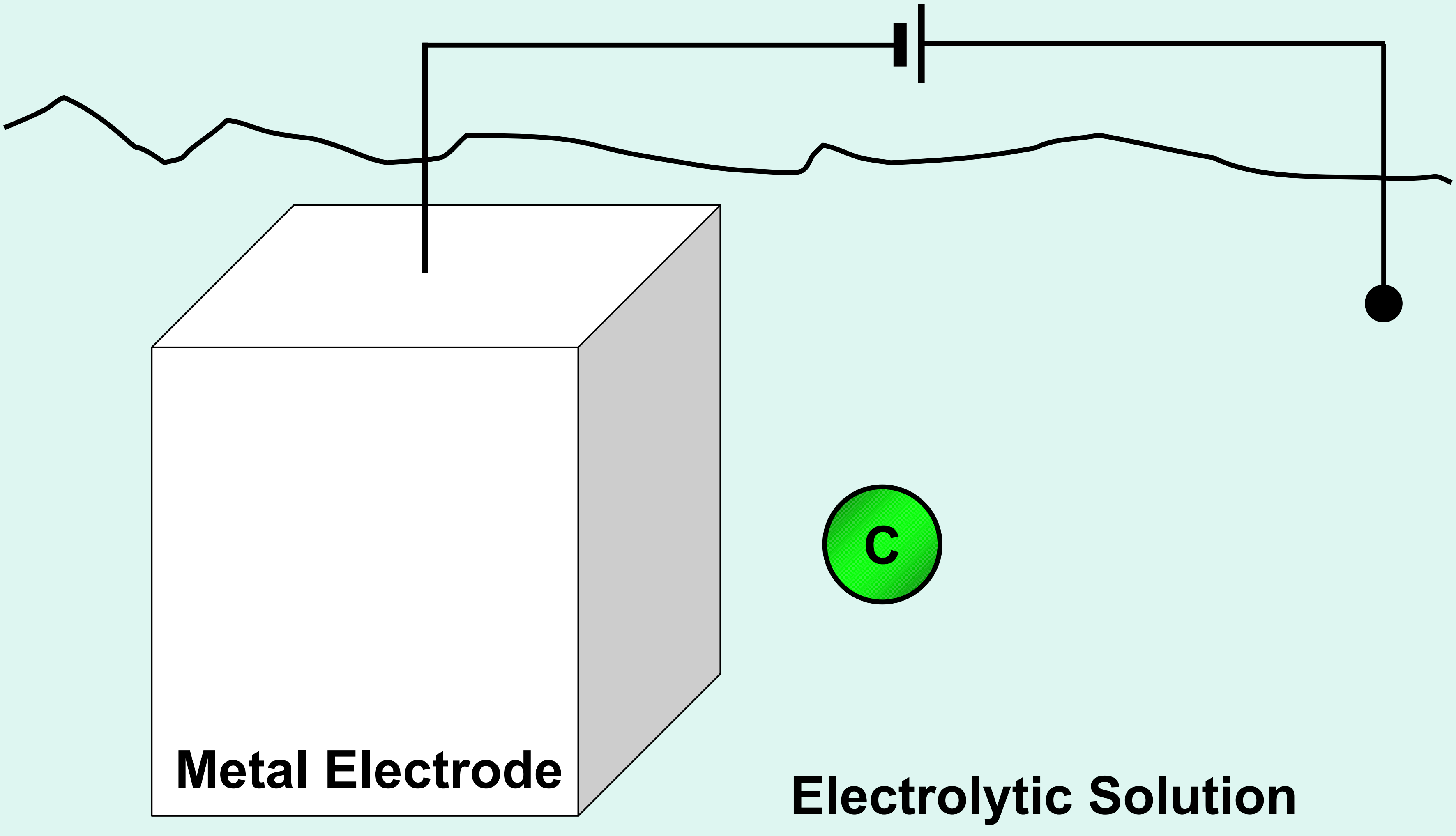


Ionic Conduction

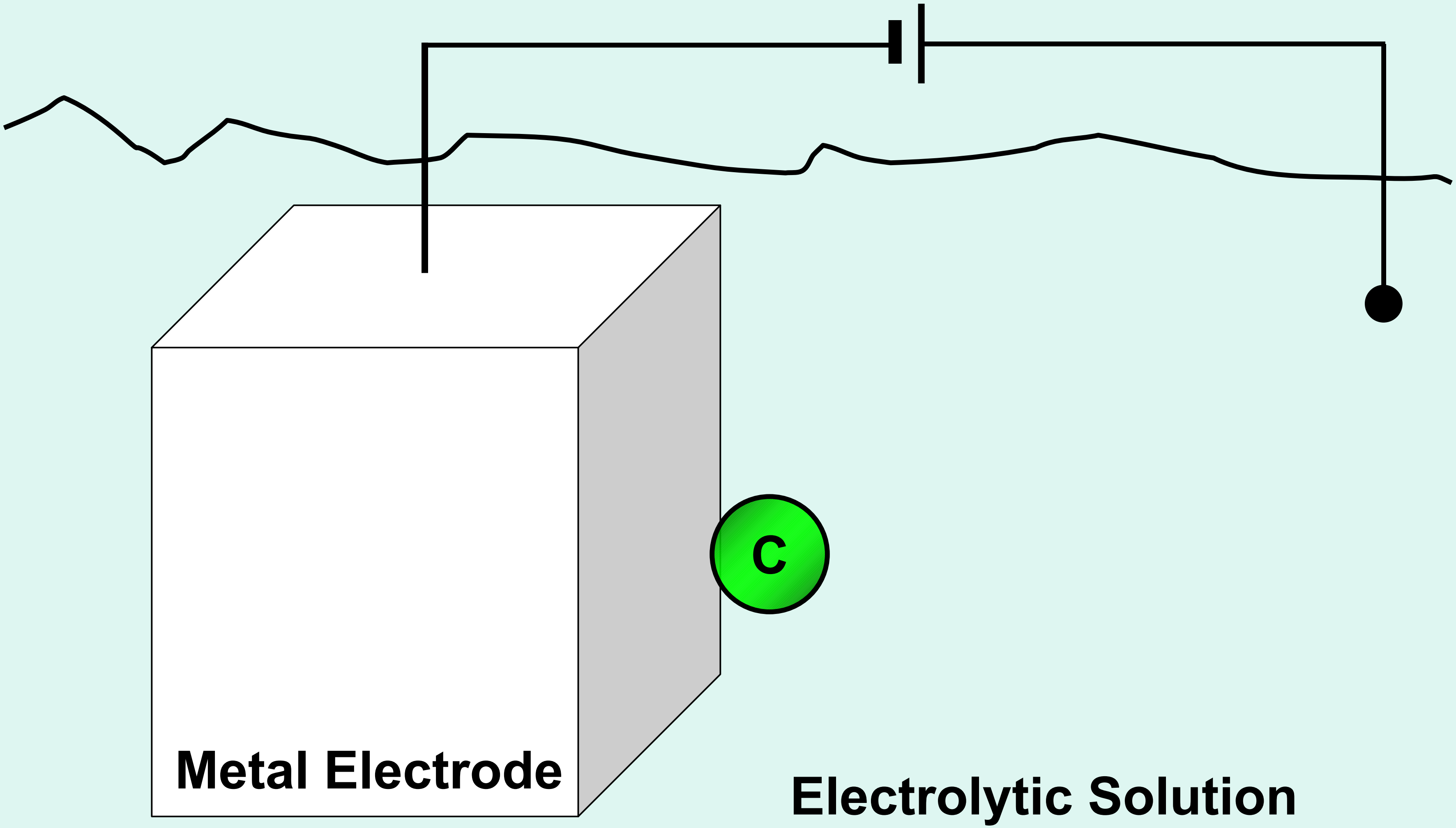
Electrode/Electrolytic Solution Interface



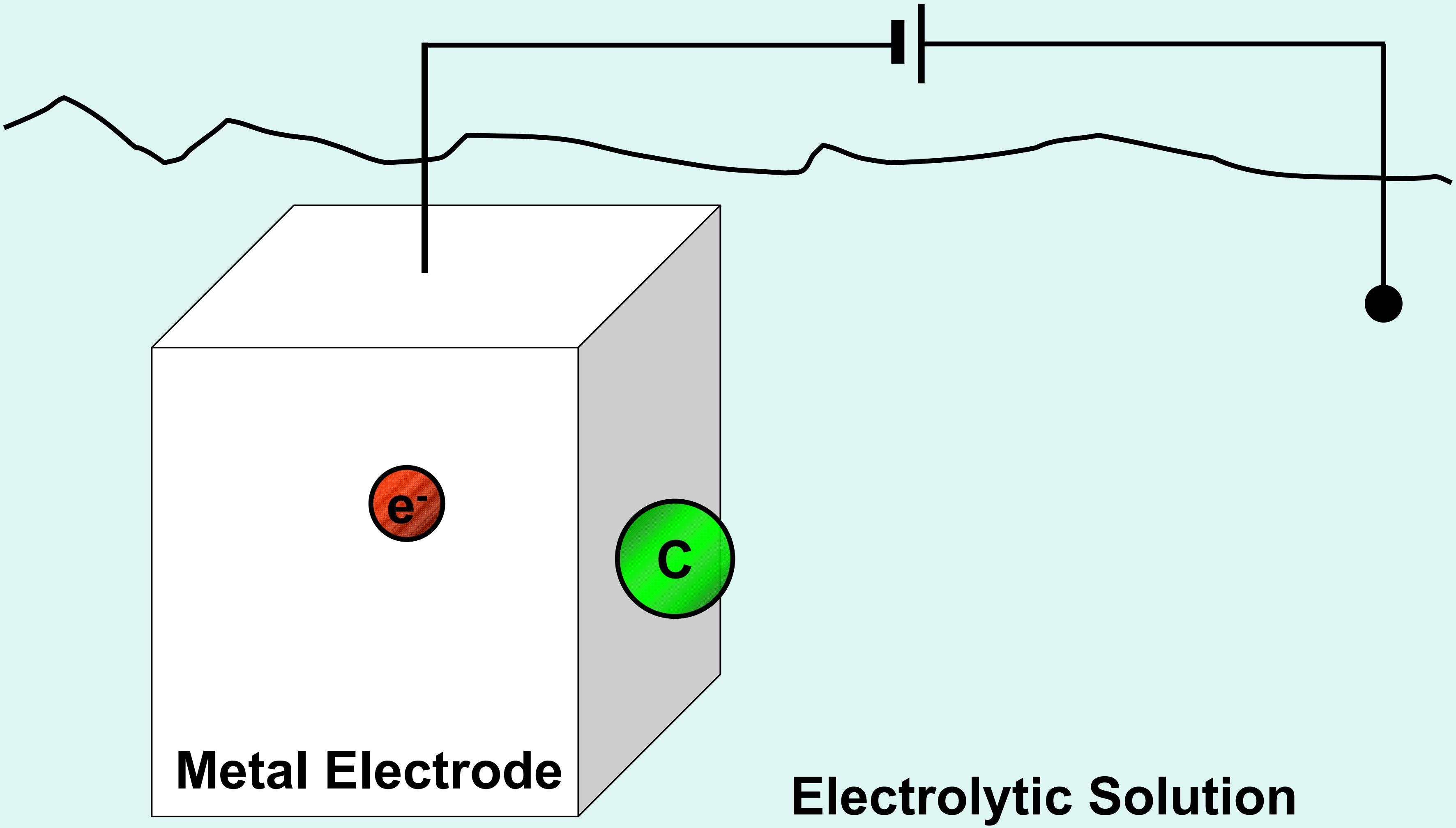
Electrode/Electrolytic Solution Interface



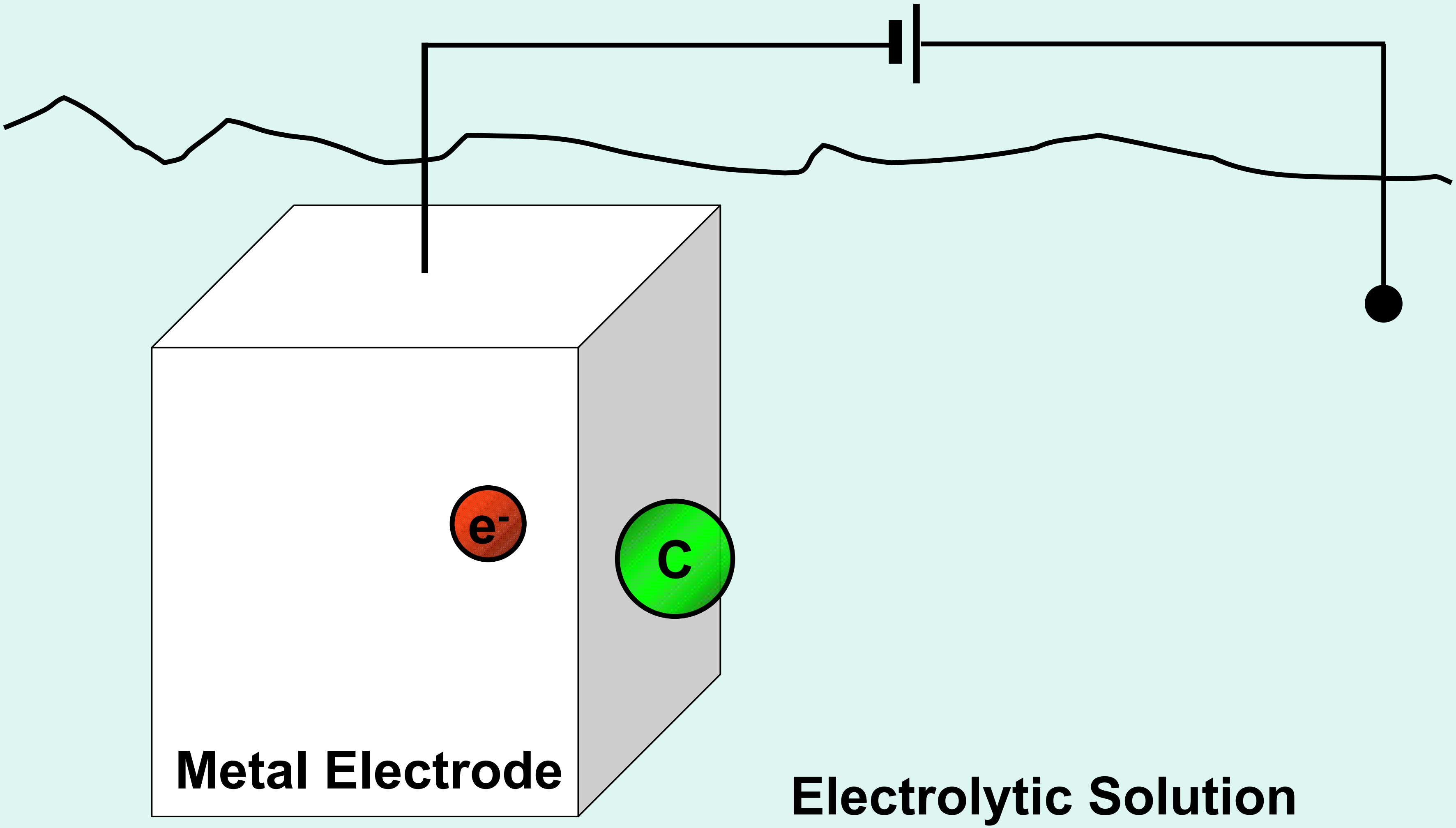
Electrode/Electrolytic Solution Interface



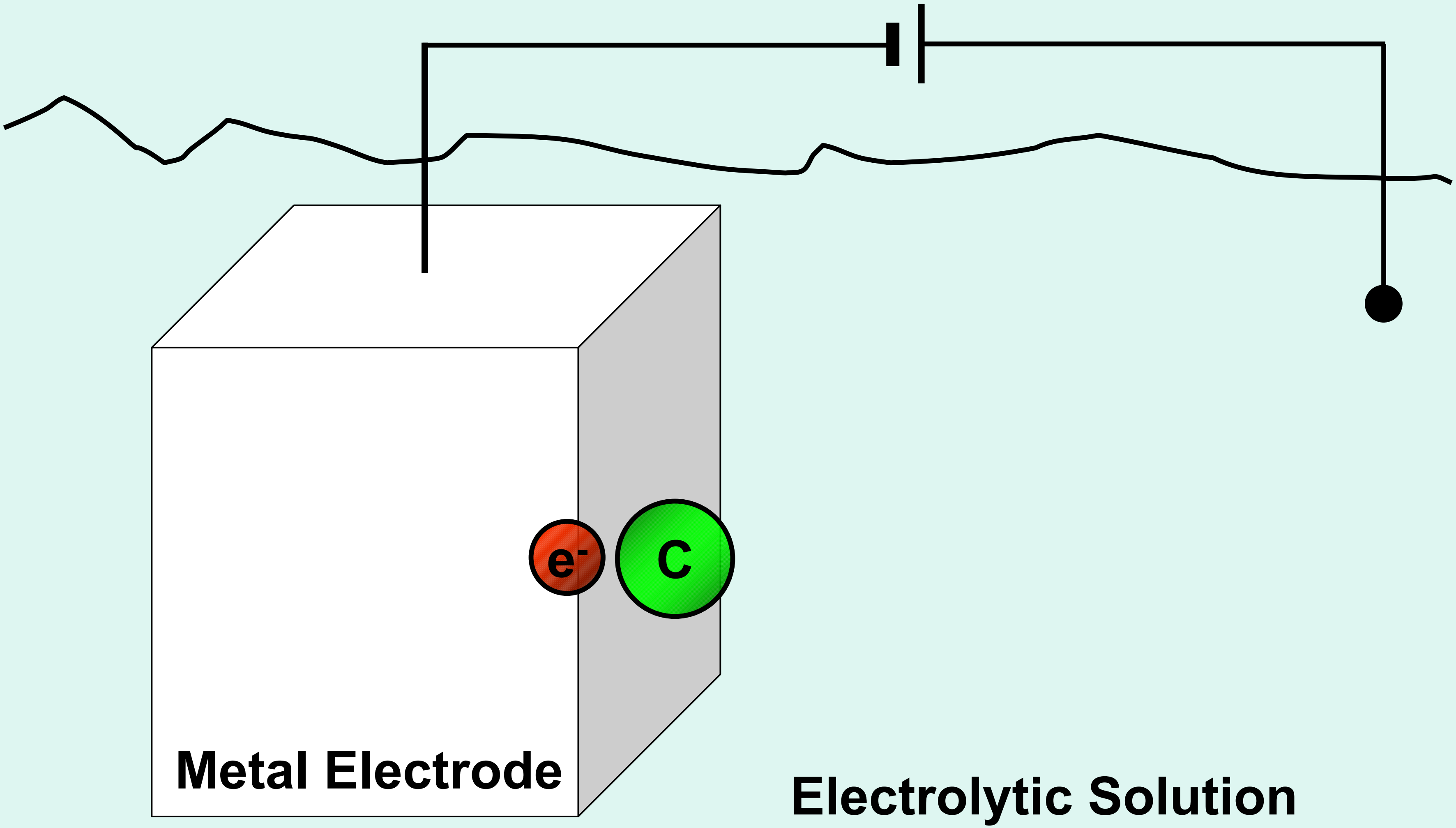
Electrode/Electrolytic Solution Interface



Electrode/Electrolytic Solution Interface



Electrode/Electrolytic Solution Interface



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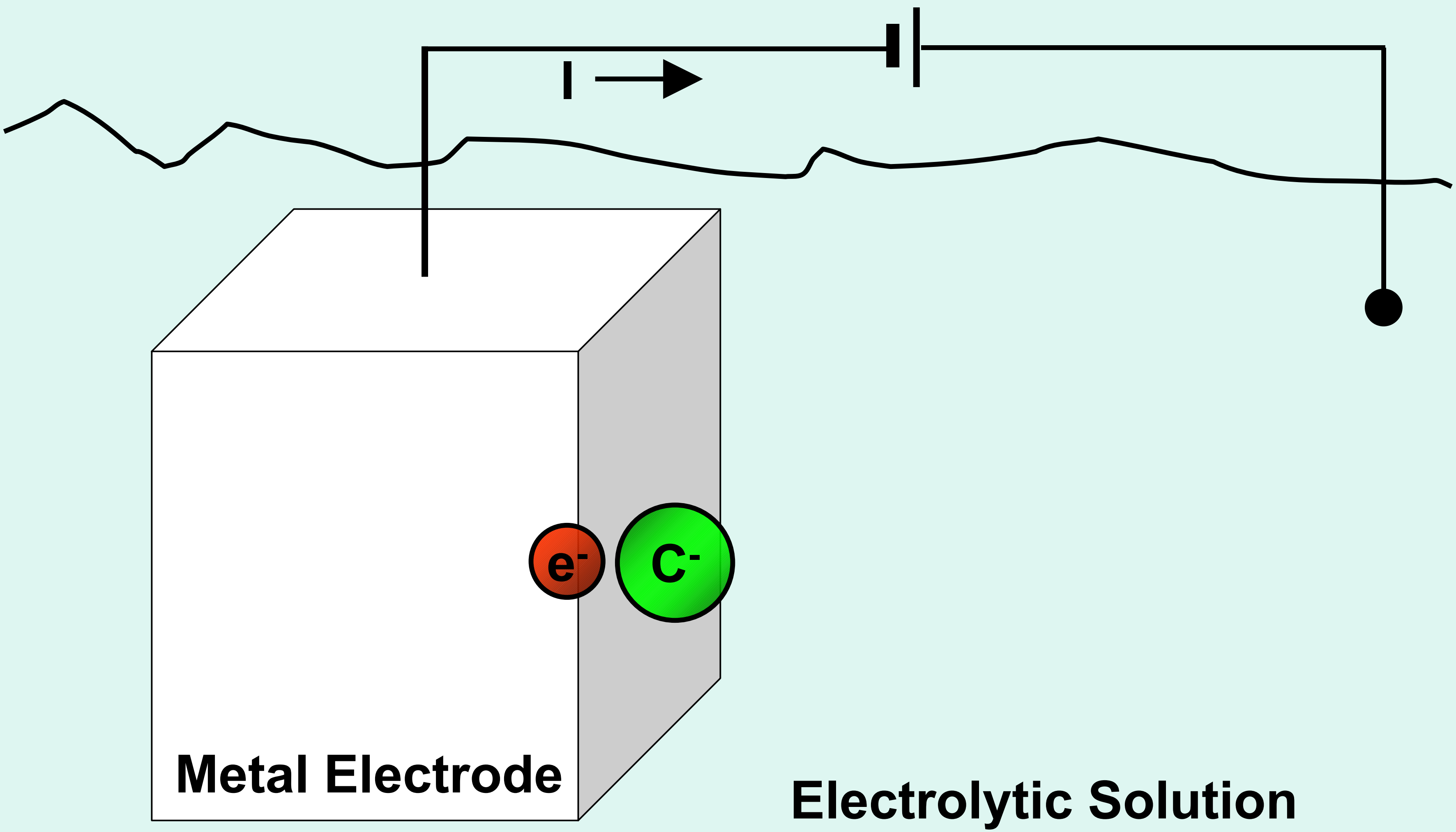

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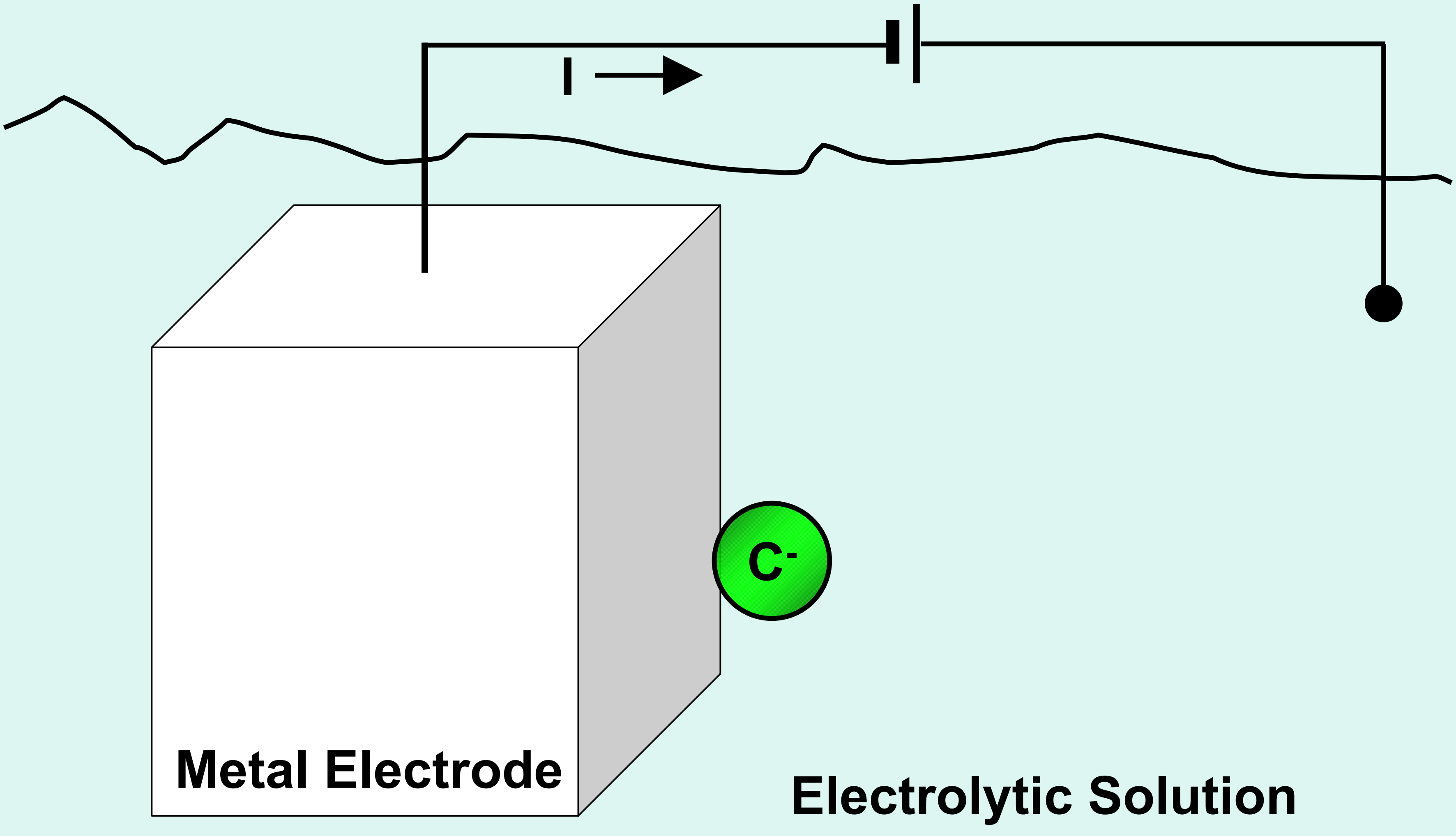

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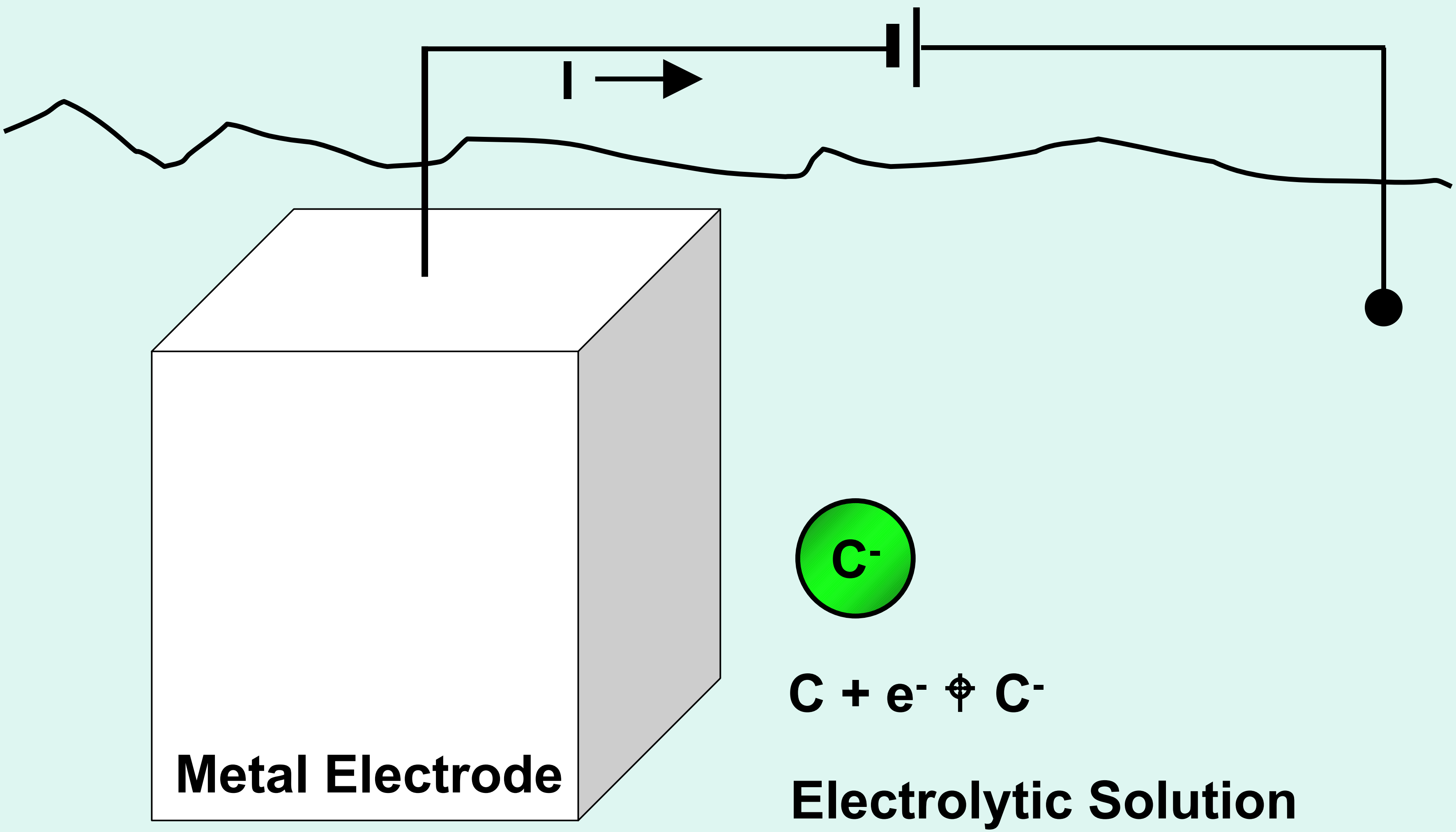

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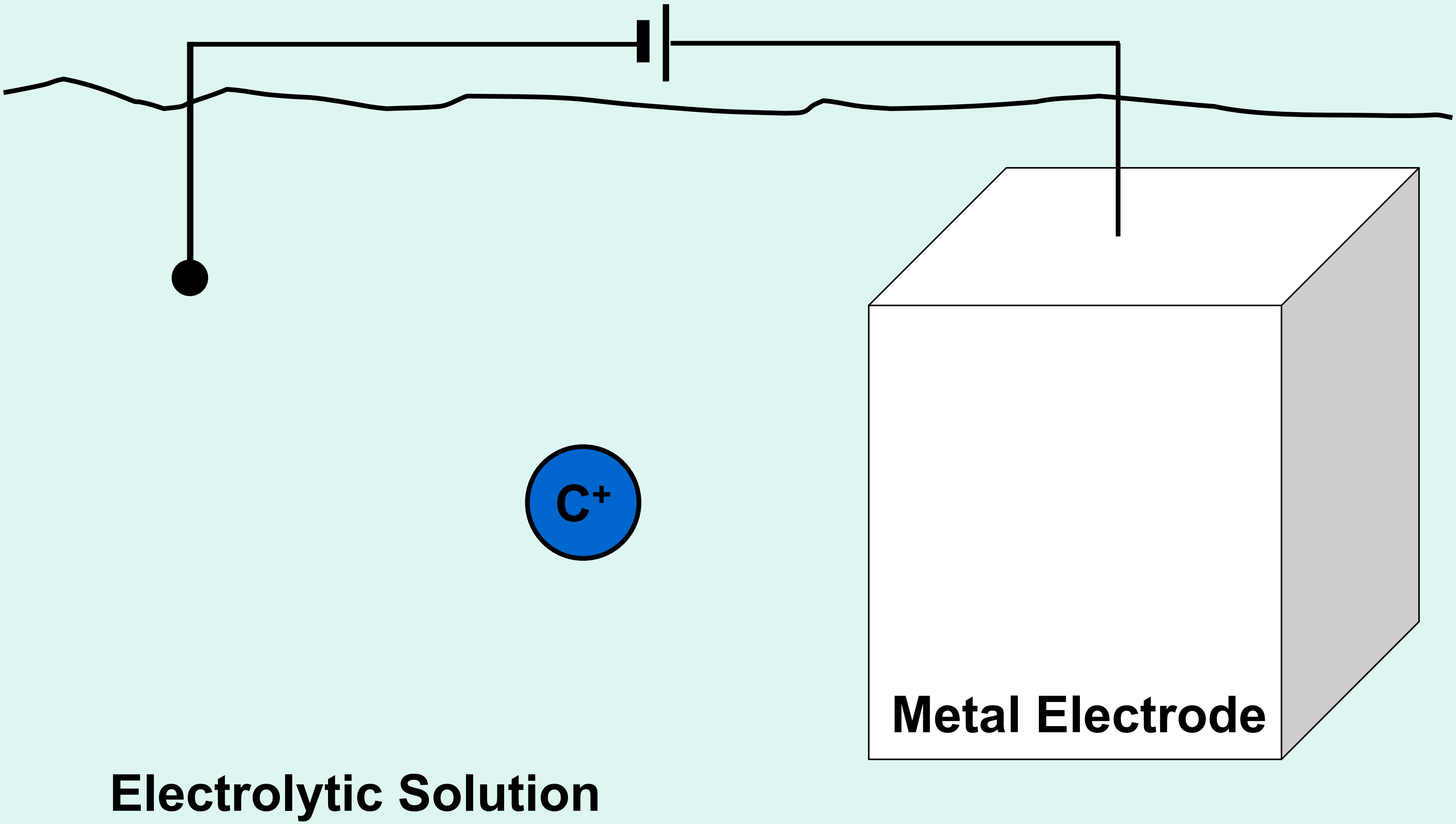

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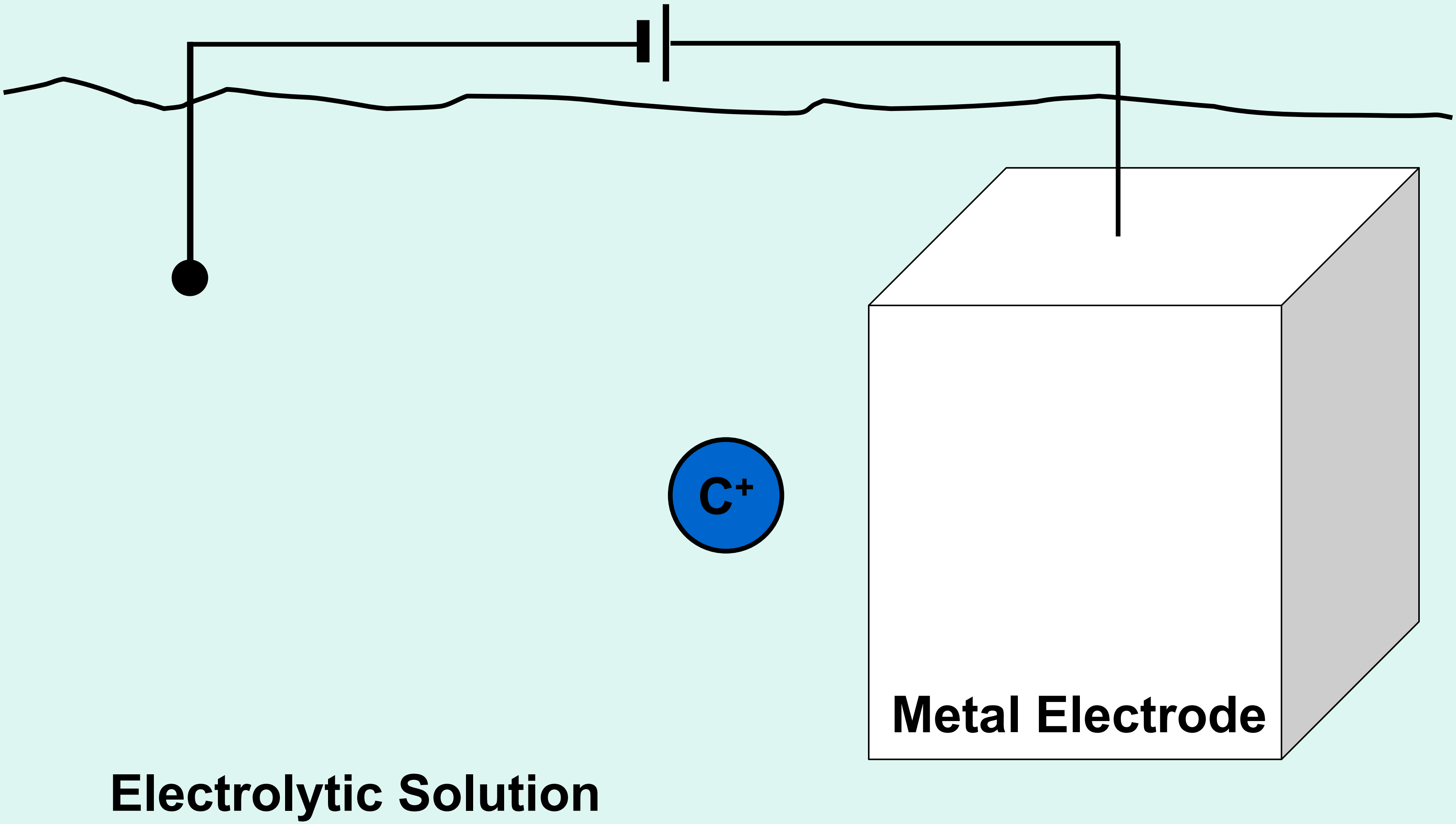

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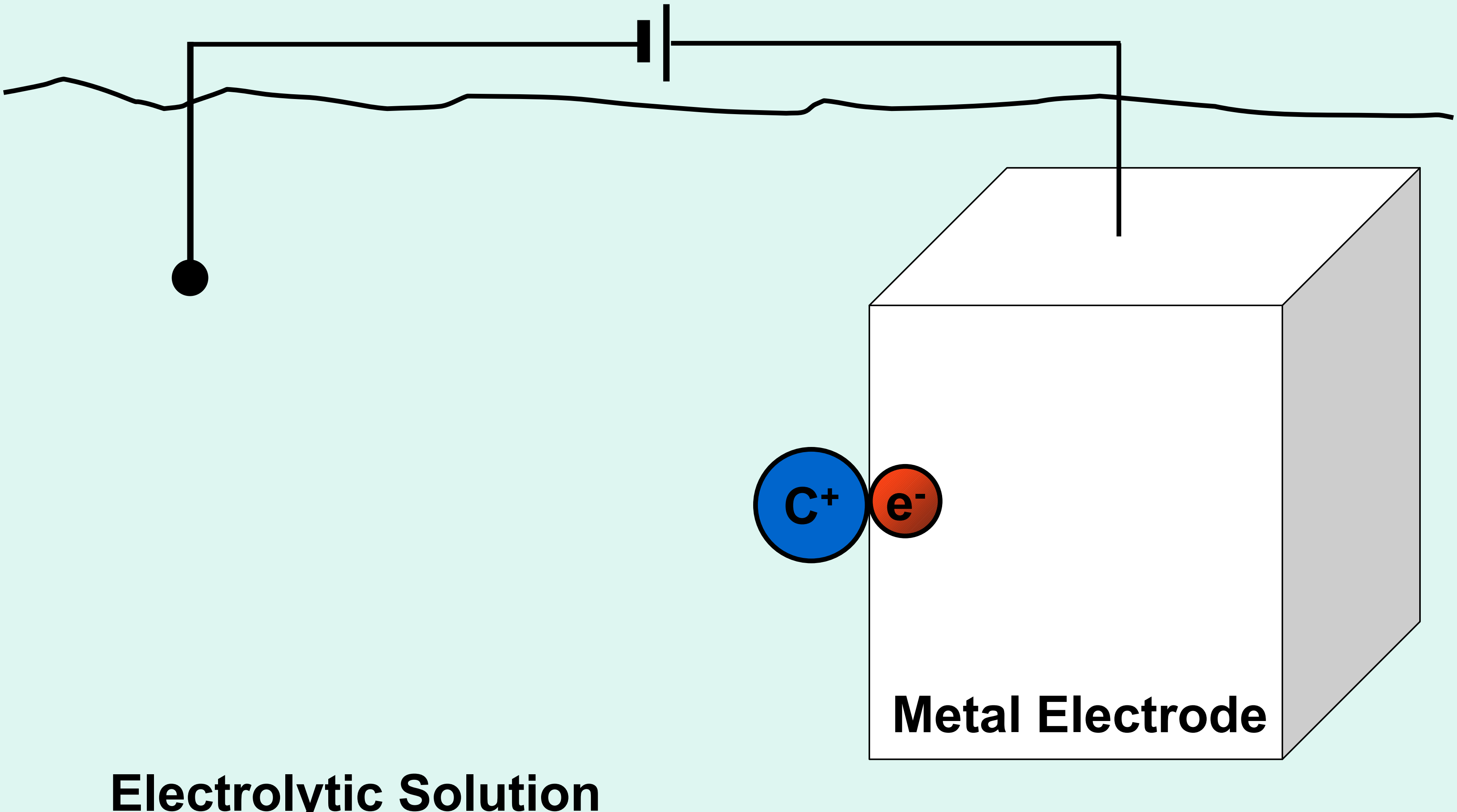

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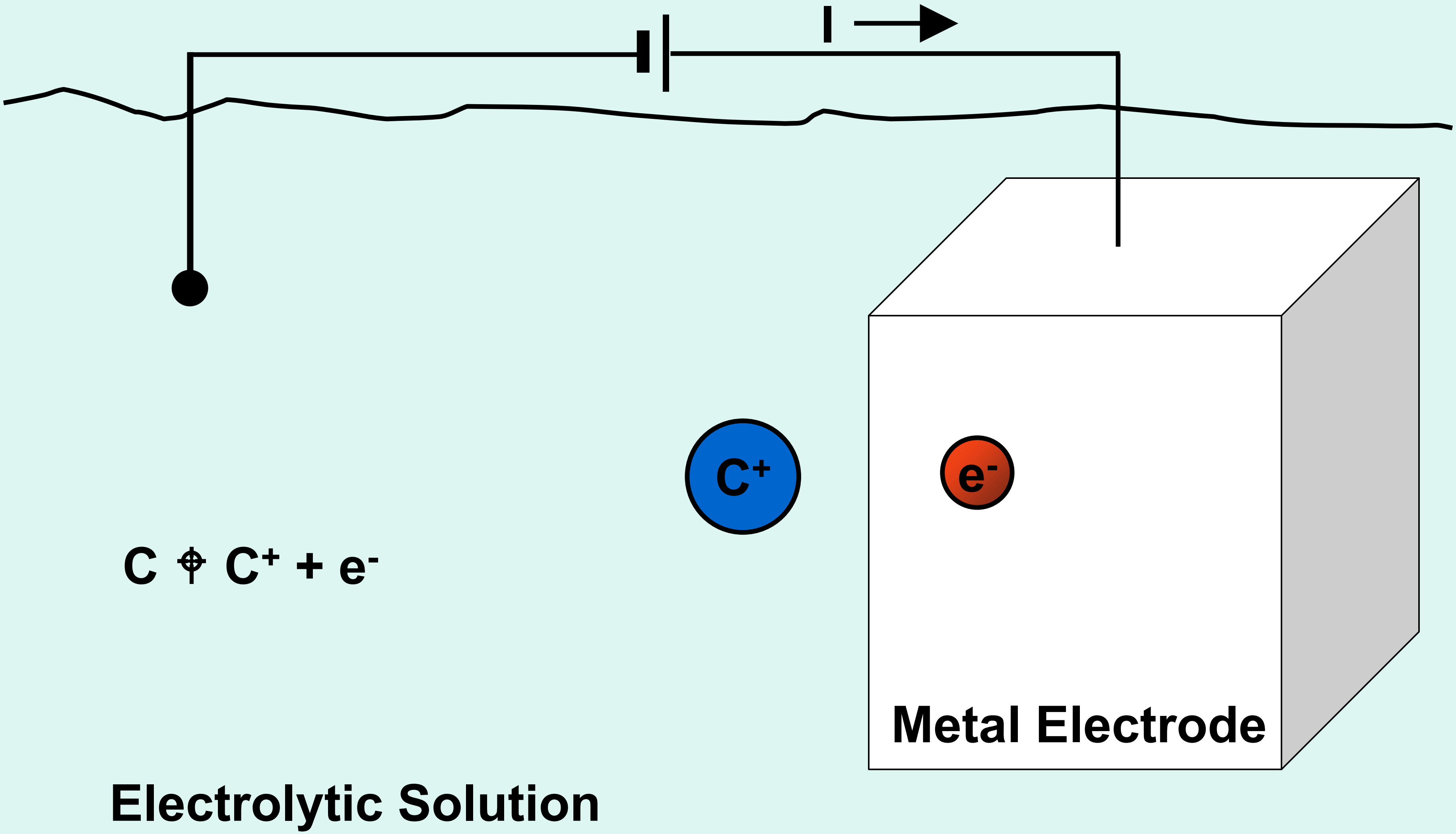
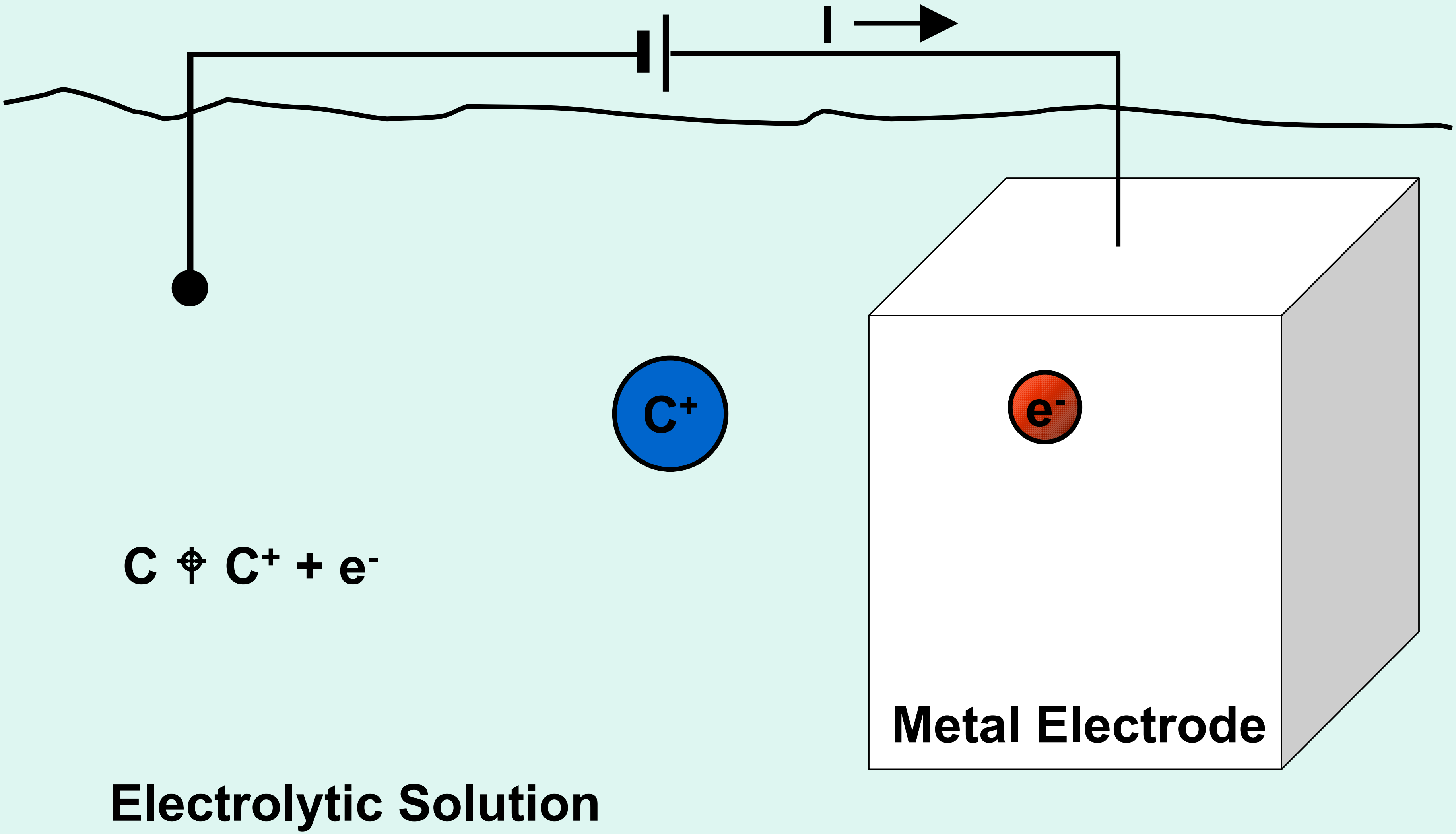
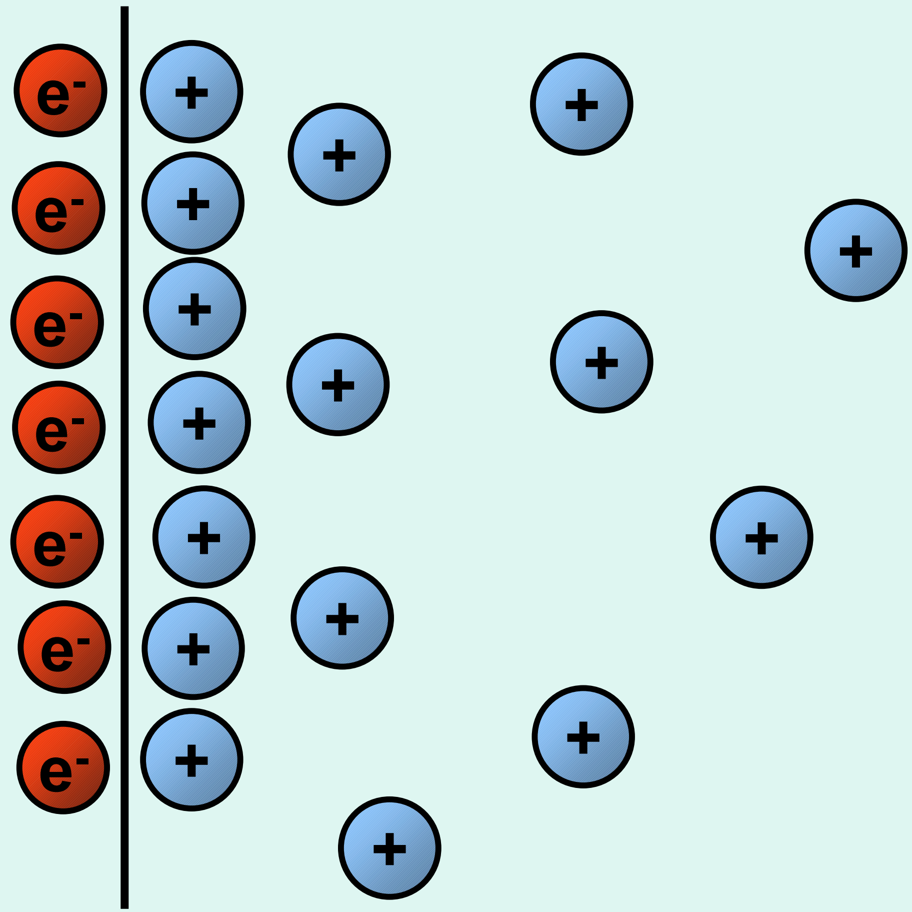


$C \rightleftharpoons C^+ + e^-$

Electrode/Electrolytic Solution Interface



Charge Build-up at Interface



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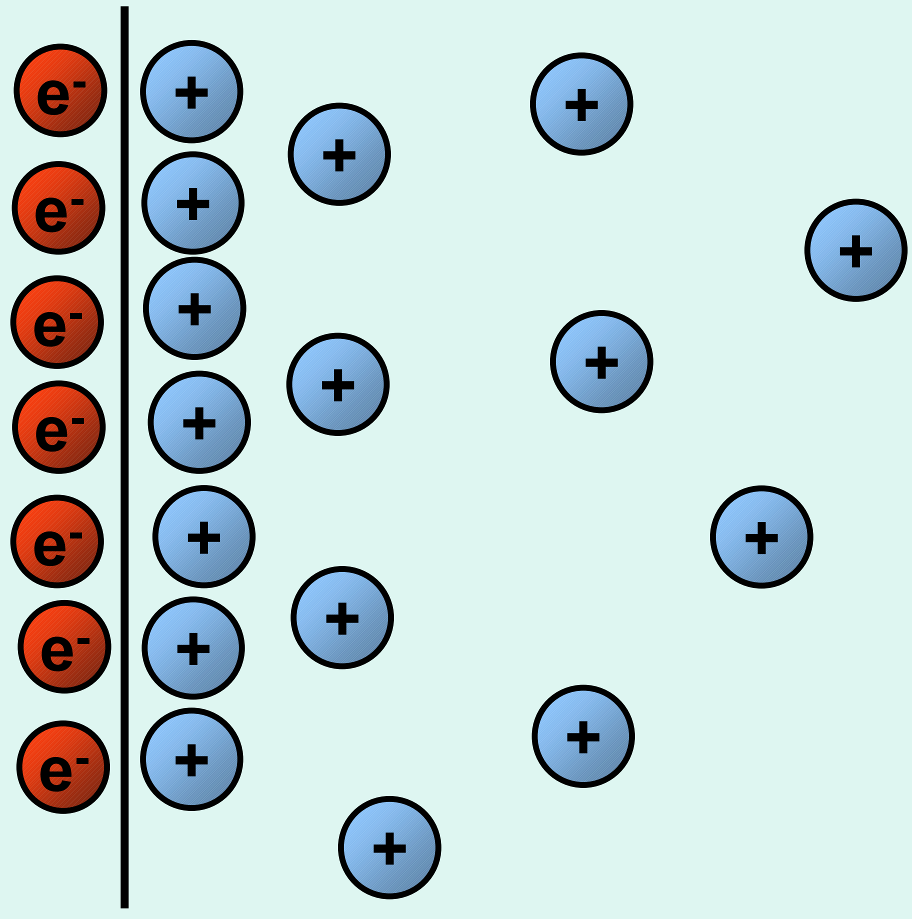
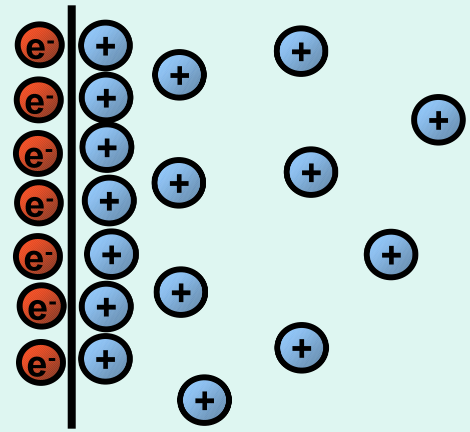
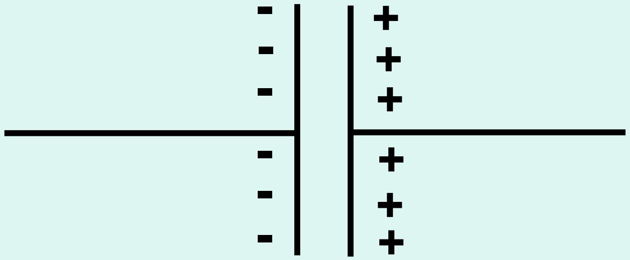


Polarization

Equivalent Circuit

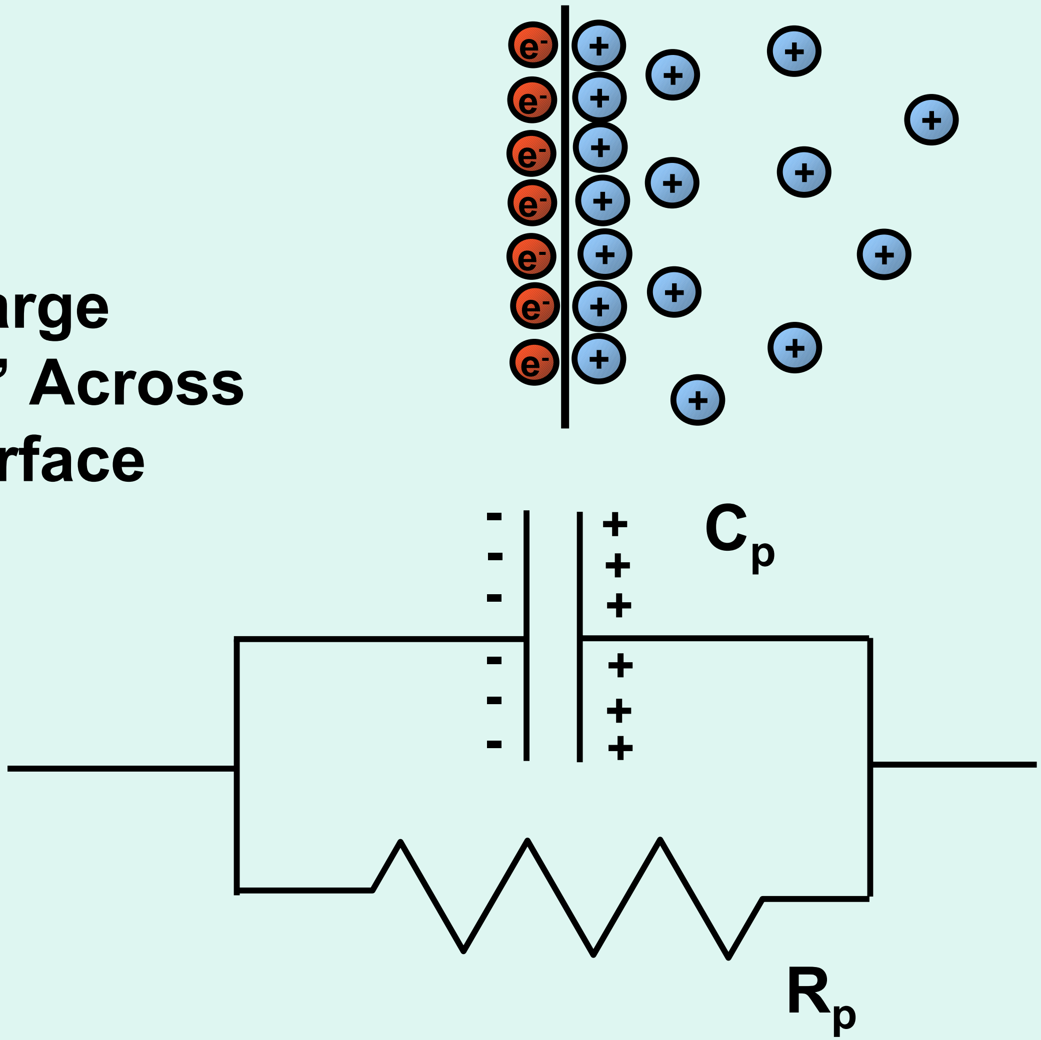
Looks like a capacitor



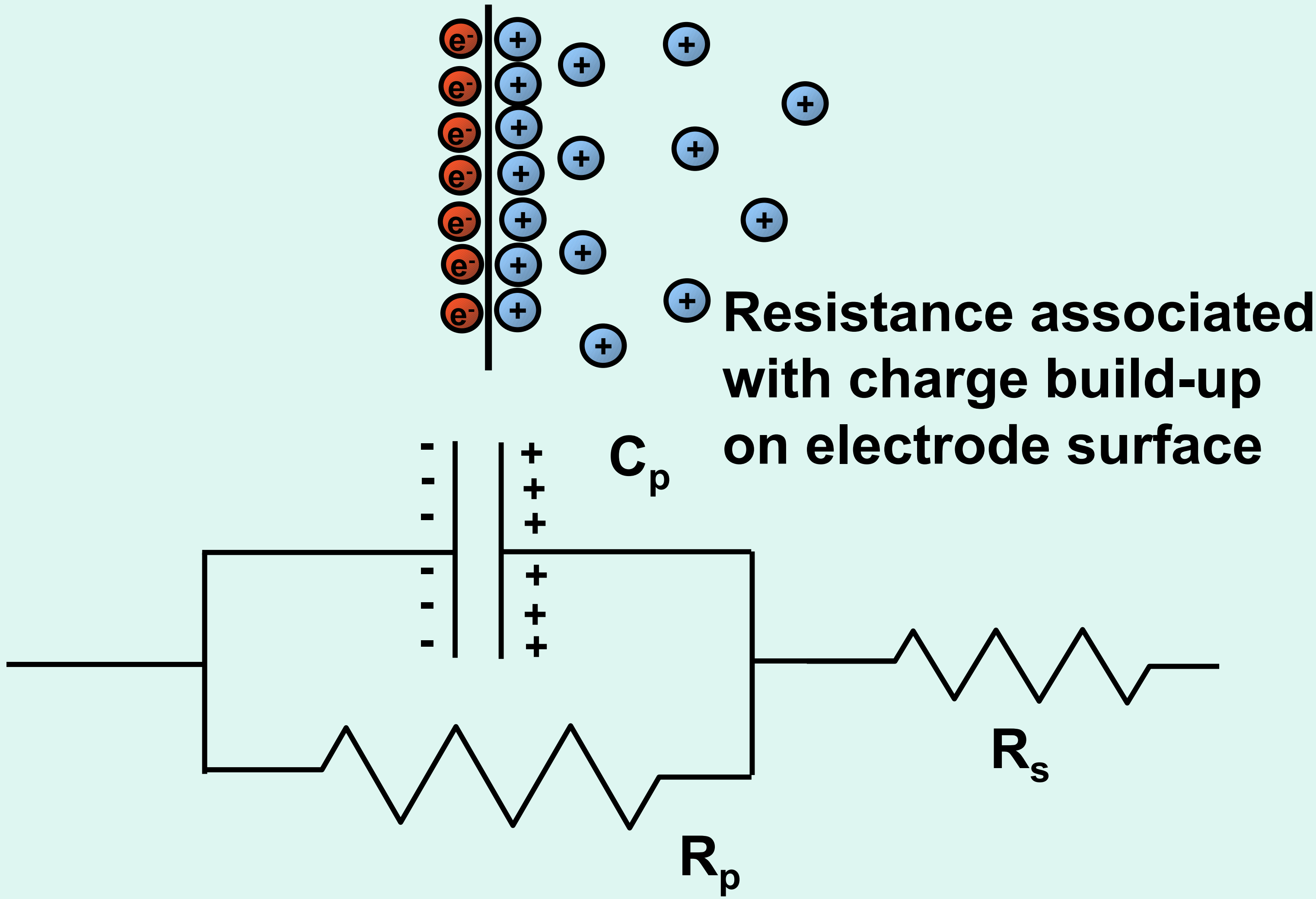


Equivalent Circuit

But Charge "Leaks" Across the Interface

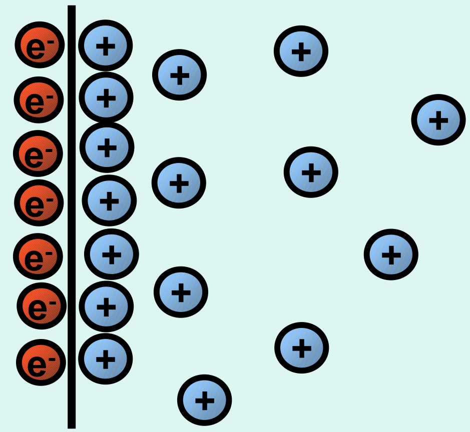


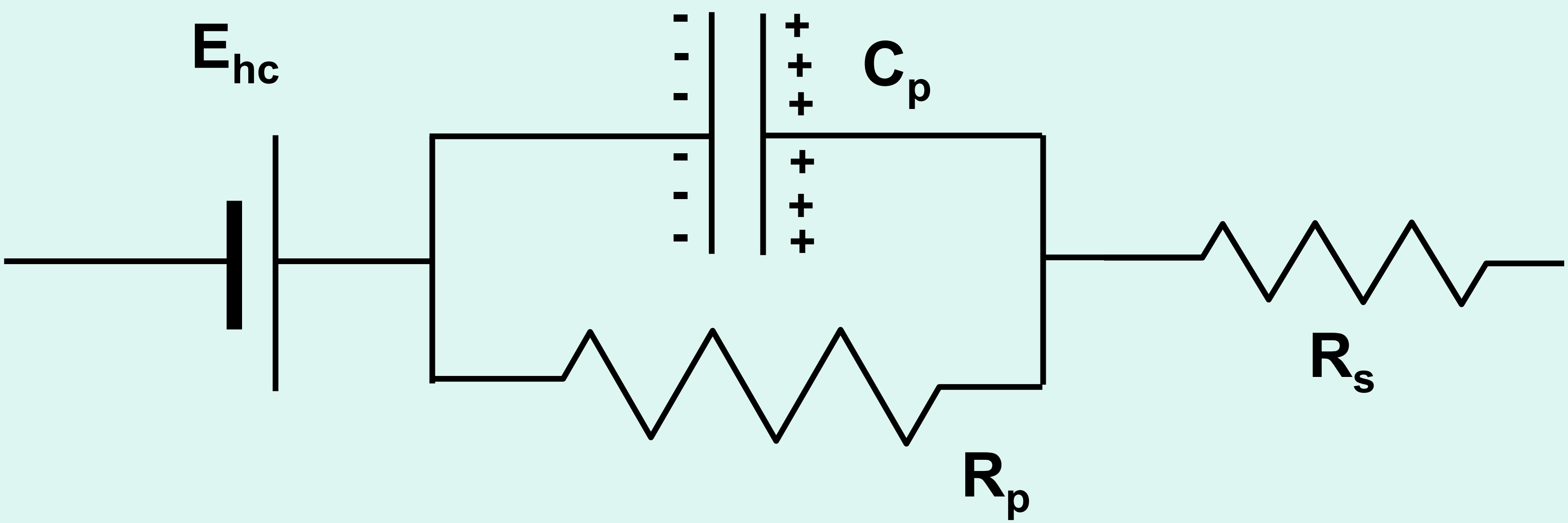
Equivalent Circuit



Equivalent Circuit

Charge distribution results in a potential across the interface, the *half cell* potential





Half-Cell Potentials

$Al \rightarrow Al^{3+} + 3e^-$	- 1.662 V
$Zn \rightarrow Zn^{2+} + 2e^-$	- 0.962 V
$Ni \rightarrow Ni^{2+} + 2e^-$	- 0.250 V
$Pb \rightarrow Pb^{2+} + 2e^-$	- 0.126 V
$H_2 \rightarrow 2\ H^+ + 2e^-$ (Pt)	- 0.0 By definition
$Ag + Cl^- \rightarrow AgCl + e^-$	+ 0.223 V
$Cu \rightarrow Cu^+ + e^-$	+ 0.521 V
$2\ Hg \rightarrow Hg_2^{2+} + 2e^-$	+ 0.788 V
$Ag \rightarrow Ag^+ + e^-$	+ 0.799 V

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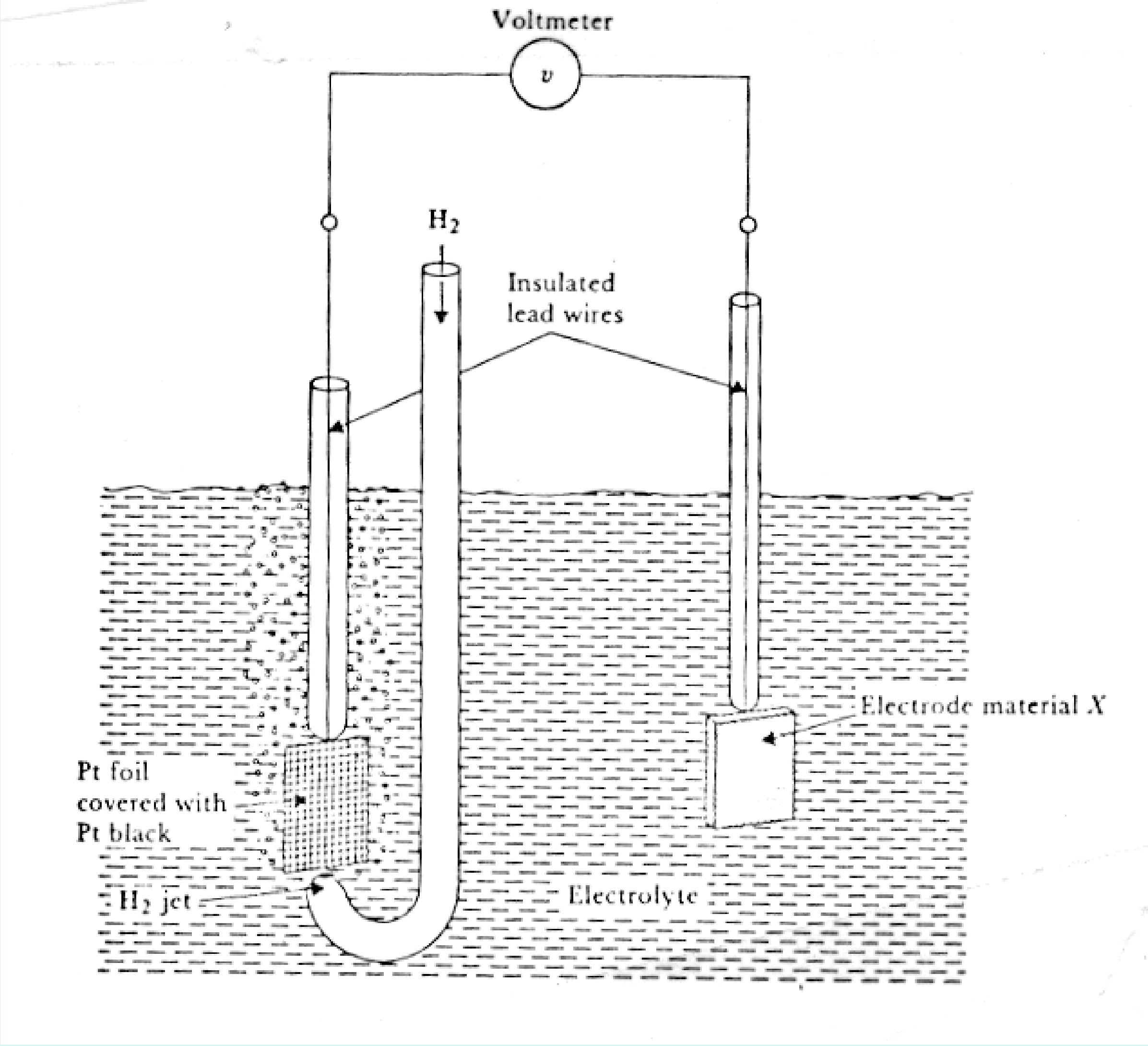
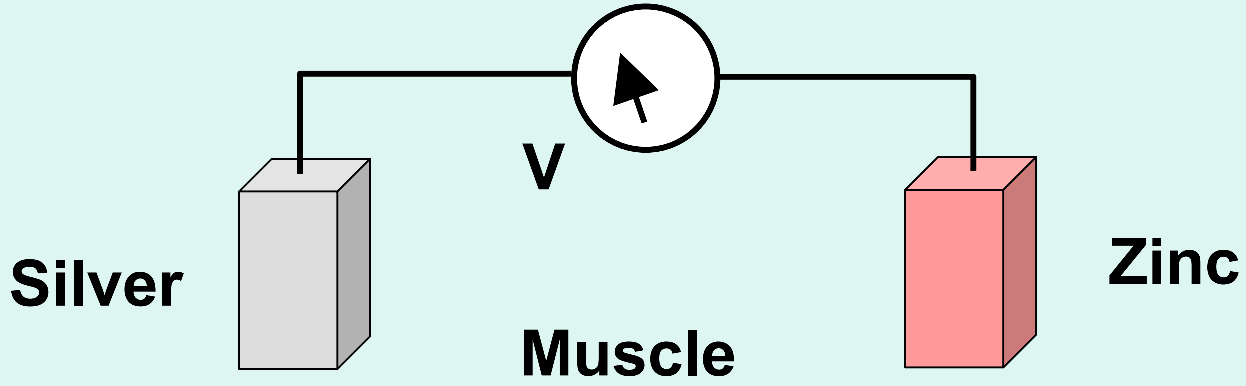
Hydrogen Electrode



Sample Problem

A biological battery is proposed that consists of a zinc and a silver wire placed in the extracellular fluid of a biologic tissue such as muscle. What will be its output voltage. (By the way, don't try this. Silver is toxic!) Which metal will be positive?



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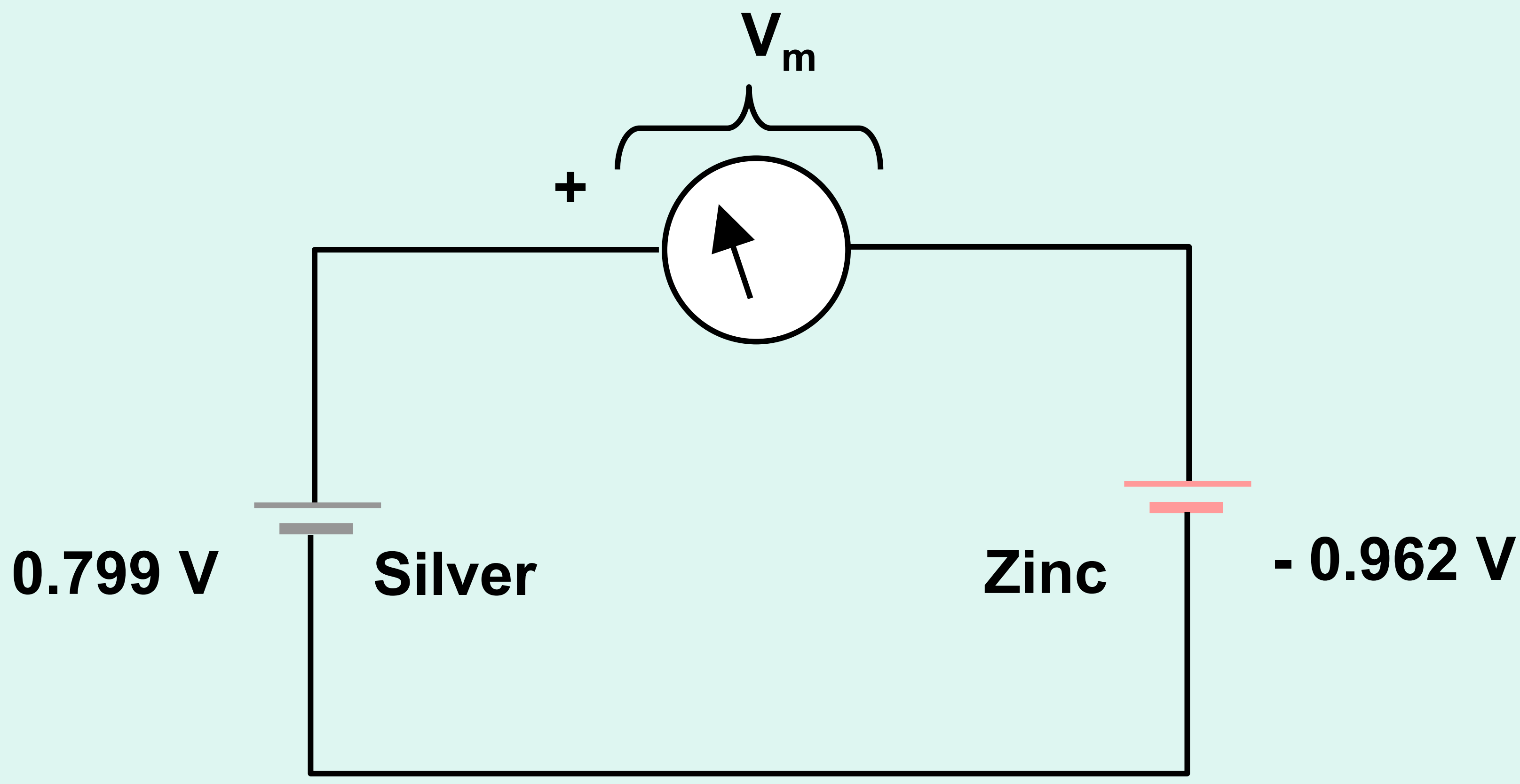
Equivalent Circuit



V_m = 0.799 V – (- 0.962 V) = 1.761 V

The silver will be positive with respect to the zinc

Reference Electrodes