



Université Lyon 1

Technologies des Equipements Médicaux

Dispositifs Médicaux de Mesure des signaux physiologiques

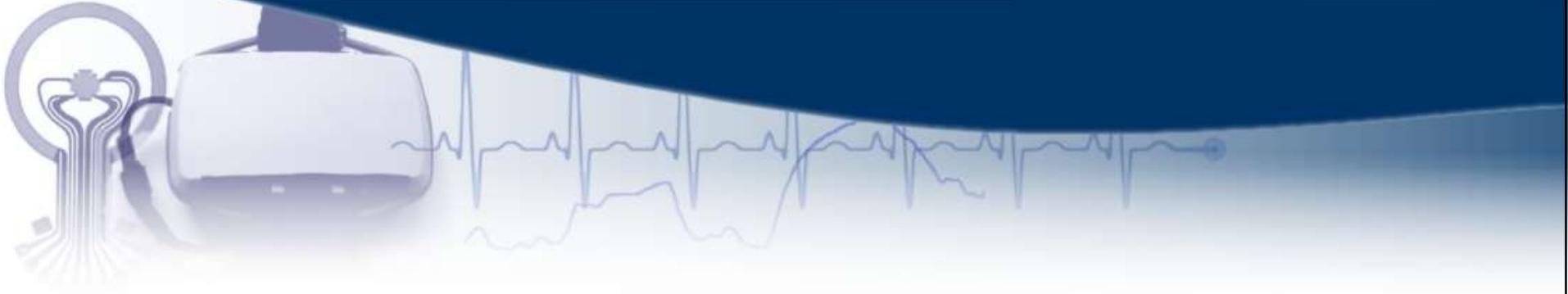


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3

Mesure des biopotentiels

3E- Impédancemétrie

EMG

Electromyograph (EMG) measurement showing a hand holding a device connected to a leg. The top panel shows a VR-style interface with multiple ECG traces. The bottom panel shows a screenshot of EMG Pro software with two waveforms: one blue (EMG) and one red (GSR). The red waveform has a scale from 0 to 40.

ECG

ECG leads attached to a person's chest. A red heart icon with a pulse line is shown above the leads.

EEG

A woman wearing a cap with numerous EEG electrodes. A grey rectangular device is held in front of her torso.

GSR

A hand wearing a grey glove with four blue sensors attached to the fingers. A dashed line indicates the electrode placement on the palm.

EOG

A man wearing yellow EOG electrodes around his eyes. A handheld device with three knobs is shown below his chin.

Impédance

The text "Impédance" is displayed in large black letters.



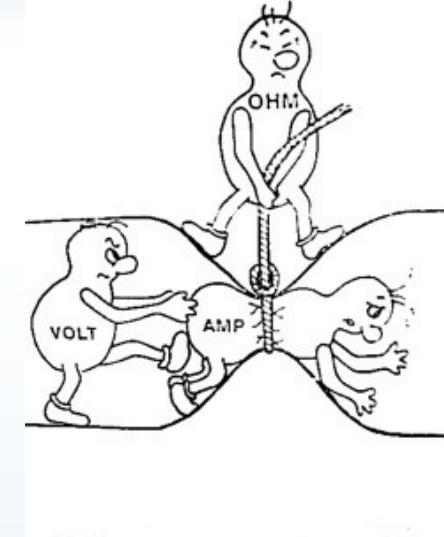
Loi d'Ohm généralisée

$$U = Z * I$$

U en Volts

I en Ampères

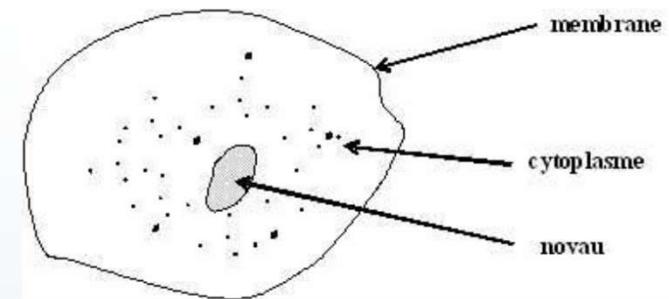
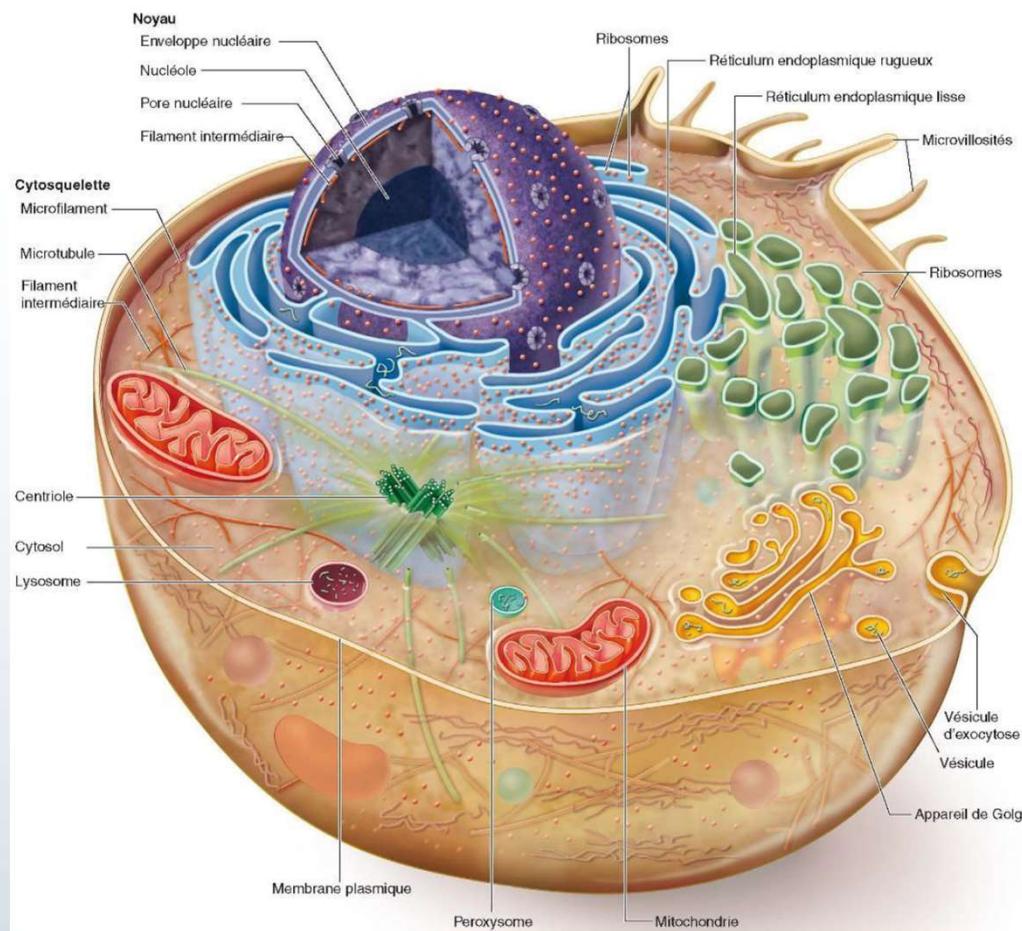
Z en Ohm



Impédance $Z = \text{Résistance} + j * \text{Réactance}$

Rq: réactance uniquement capacitive sur le corps humain

La cellule vivante



70 à 95% d'eau+ sels

Compositions en Eau des tissus

Water Content Values for Various Tissues and Organs

TISSUE	WATER CONTENT	WEIGHT %	TISSUE	WATER CONTENT	WEIGHT %
Bone	44–45		Lung		80–83
Bone Marrow	8–16		Muscle		73–78
Bowel	60–82		Ocular Tissues		
Brain			Choroid		78
White matter	68–73		Cornea		75
Grey matter	82–85		Iris		77
Fat	5–20		Lens		65
Kidney	78–79		Retina		89
Liver	73–77		Skin		60–76
			Spleen		76–81

Composition ionique des tissus

Concentration of electrolytes in body liquids

	cations (meq/L)		anions (meq/L)	
	extracellular	intracellular	extracellular	intracellular
Na ⁺	142	10	Cl ⁻	103
K ⁺	4	140	HCO ₃ ⁻	24
Ca ²⁺	5	10 ⁻⁴	protein-	16
Mg ²⁺	2	30	HPO ₄ ²⁻ + SO ₄ ²⁻	10
H ⁺	4×10 ⁻⁵	4×10 ⁻⁵	+ organic acids	130
Sum	153	180	Sum	153
				180

mEq = mmol* valence



Impédance du corps humain ?

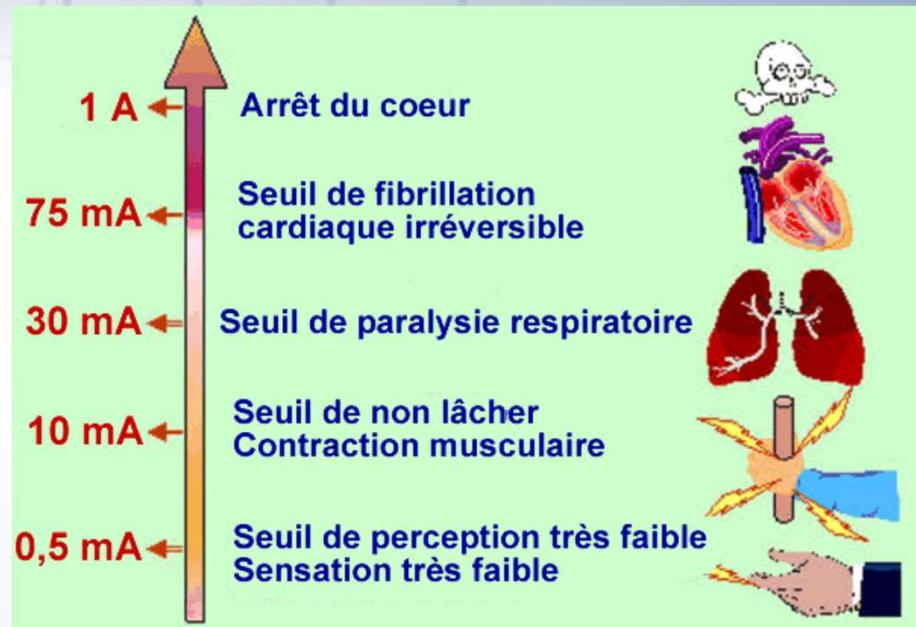
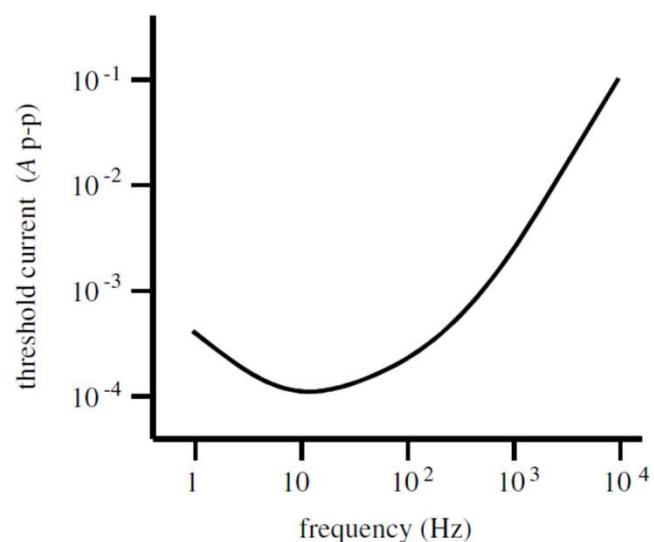
Composition du corps humain :

- Milieux conducteurs (de l'électricité) :
 - Nombreux électrolytes : Na+, K+, Ca+, Cl-...
 - En milieu aqueux : sang, lymphé, milieu interstitiel, milieu intracellulaire...
- Milieux isolants (de l'électricité) :
 - Membranes cellulaires (couches bi-lipidiques)
 - Adipocytes (cellule réservoir de triglycérides)
 - Matière minérale
 - Air
 - Couche cornée (stratum corneum)

Electrisation des tissus biologiques

Effets du passage du courant alternatif (50ou60Hz) sur le corps humain:

- de la simple sensation
- jusqu'à l'électrisation
- puis l'électrocution



Seuil de sensation en fonction de f pour un courant appliqué entre des électrodes anneau de 5mm de large entourant 2 doigts adjacents (sujet sain)

- Courant I imposé sinusoïdal
- Tension V mesurée sinusoïdale
- Impédance
- Module Impédance
- Phase Impédance
- Résistance $Z_R = R$ indépendante de la fréquence, $\phi = 0$
- Condensateur $Z_C = 1/jC\omega$, diminue avec la fréquence, $\phi = -90^\circ$

$$I = |I| e^{j(\omega t + \Phi_I)}$$

$$V = |V| e^{j(\omega t + \Phi_V)}$$

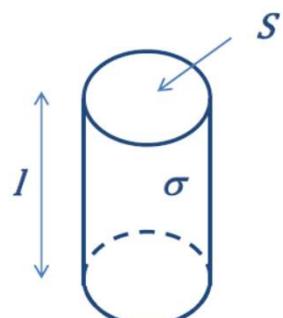
$$Z = \frac{V}{I}$$

$$|Z| = \frac{|V|}{|I|}$$

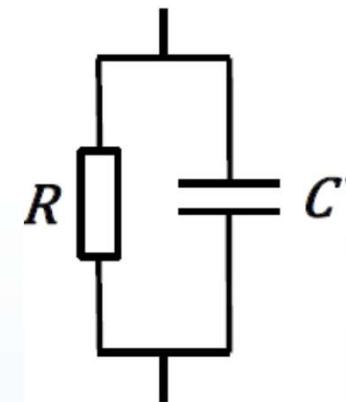
$$\Phi_V = \Phi_I + \theta$$

Propriétés électriques des tissus biologiques

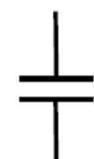
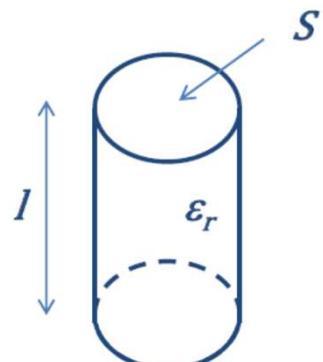
- σ : conductivité ($= 1/\rho$)



$$R = \rho \frac{l}{S} = \frac{l}{\sigma S}$$



- ϵ_r : permittivité diélectrique relative

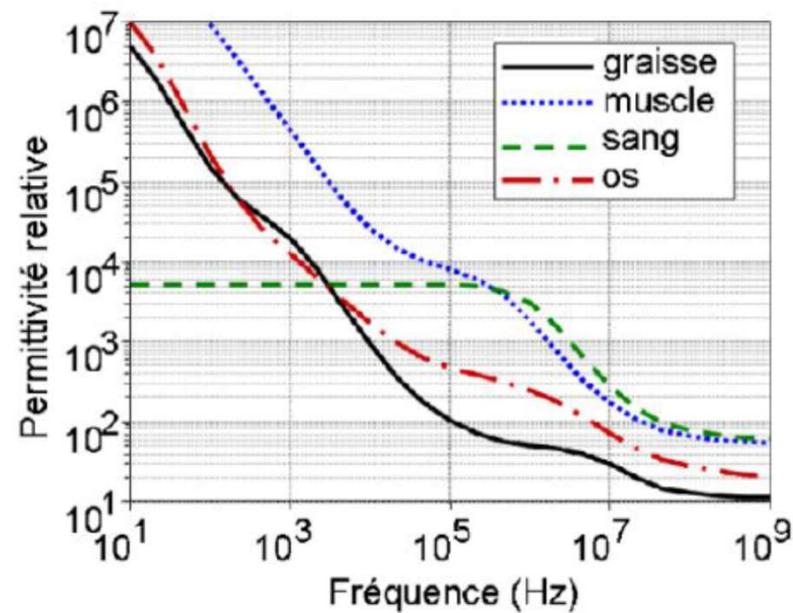
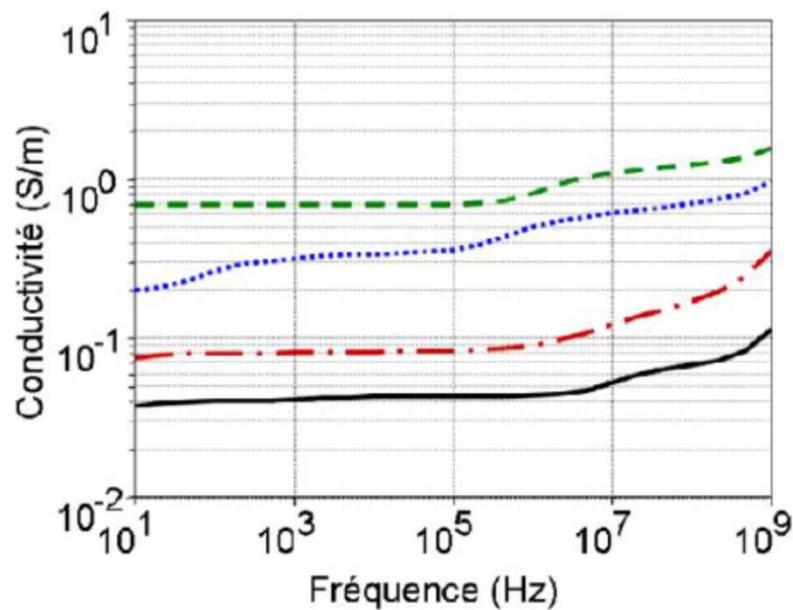


$$C = \frac{S}{l} \epsilon_0 \epsilon_r$$

$$Y = \frac{1}{Z} = \frac{1}{R} + jC\omega$$

$$= \frac{S}{l} (\sigma + j\omega \epsilon_0 \epsilon_r)$$

Propriétés électriques des tissus biologiques



Gabriel et al. 1996

⇒ et lorsqu'un courant électrique va traverser tout cela ?!

- tissus : lieu, géométrie, proportions, orientations relatives (anisotropie)...
- fréquence du courant
- électrodes : matériau, rugosité, surface, écartement, agencement ...

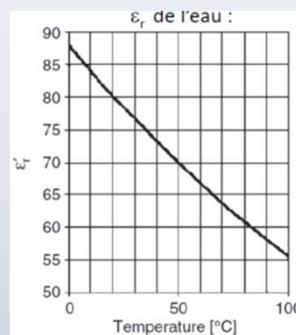


Propriétés électriques des tissus biologiques

Tissue	σ [S/m] 1 Hz to 10 kHz	σ [S/m] ~1 MHz	Φ_{\max} at <10 MHz	Anisotropy
Human skin, dry	10^{-7}	10^{-4}	80°	?
Human skin, wet	10^{-5}	10^{-4}	30°	?
Bone	0.005–0.06		20°	Strong
Fat	0.02–0.05	0.02–0.05	3°	Small
Lung	0.05–0.4	0.1–0.6	15°	Local
Brain (gray matter)	0.03–0.4	0.15	15°	Small
Brain (white matter)	0.03–0.3			Strong
Liver	0.2	0.3	5°	?
Muscle	0.05–0.4	0.6	30°	Strong
Whole blood	0.7	0.7	20°	Flow dependent
Urine	0.5–2.6	0.5–2.6	0°	0
Cerebrospinal fluid (CSF)	1.6	1.6	0°	0
Saline, 0.9%, 20 °C	1.3	1.3	0°	0
Saline, 0.9%, 37 °C	2	2	0°	0
Seawater	5	5	0°	0

Paramètres physiologiques influençant la conductivité et la permittivité:

- État physiologique
- Taux d'hydratation
- Température
- âge



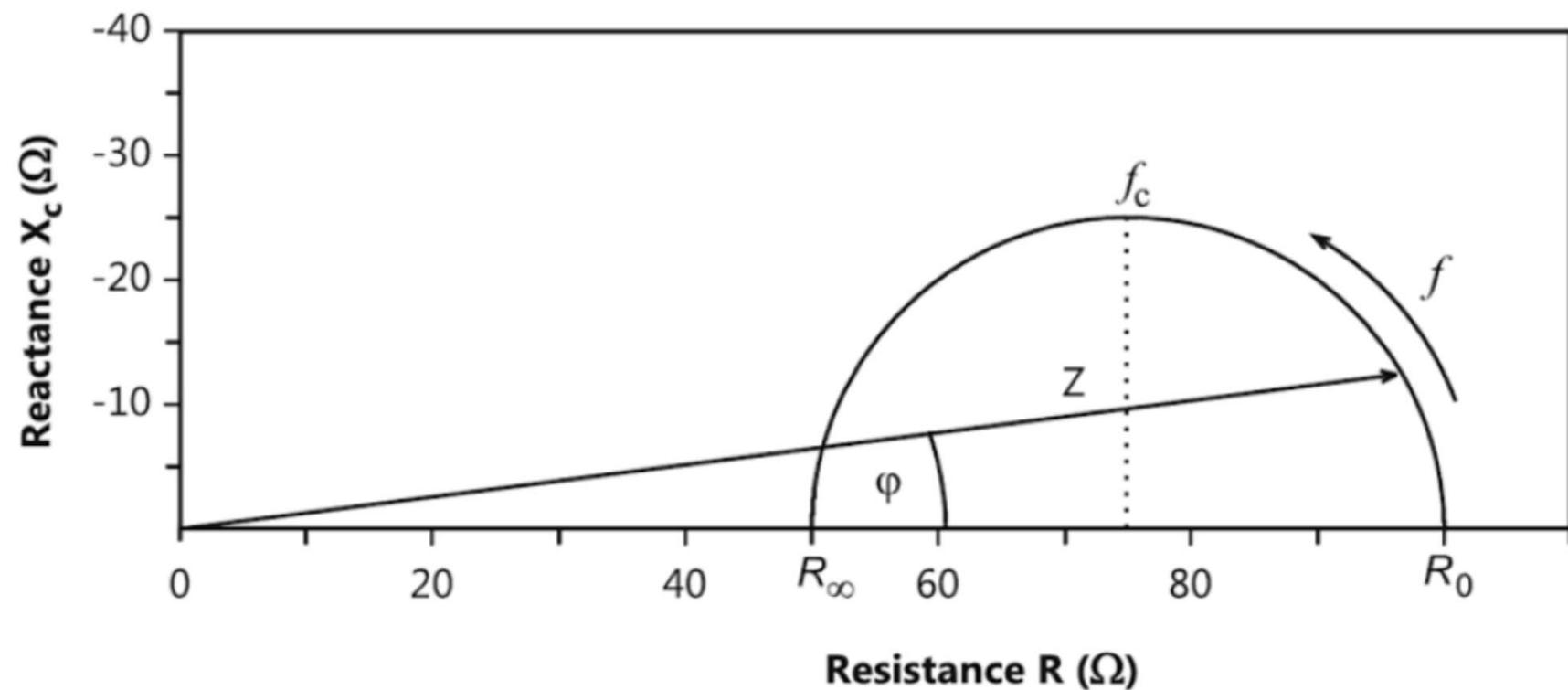
Représentation graphique de l'impédance



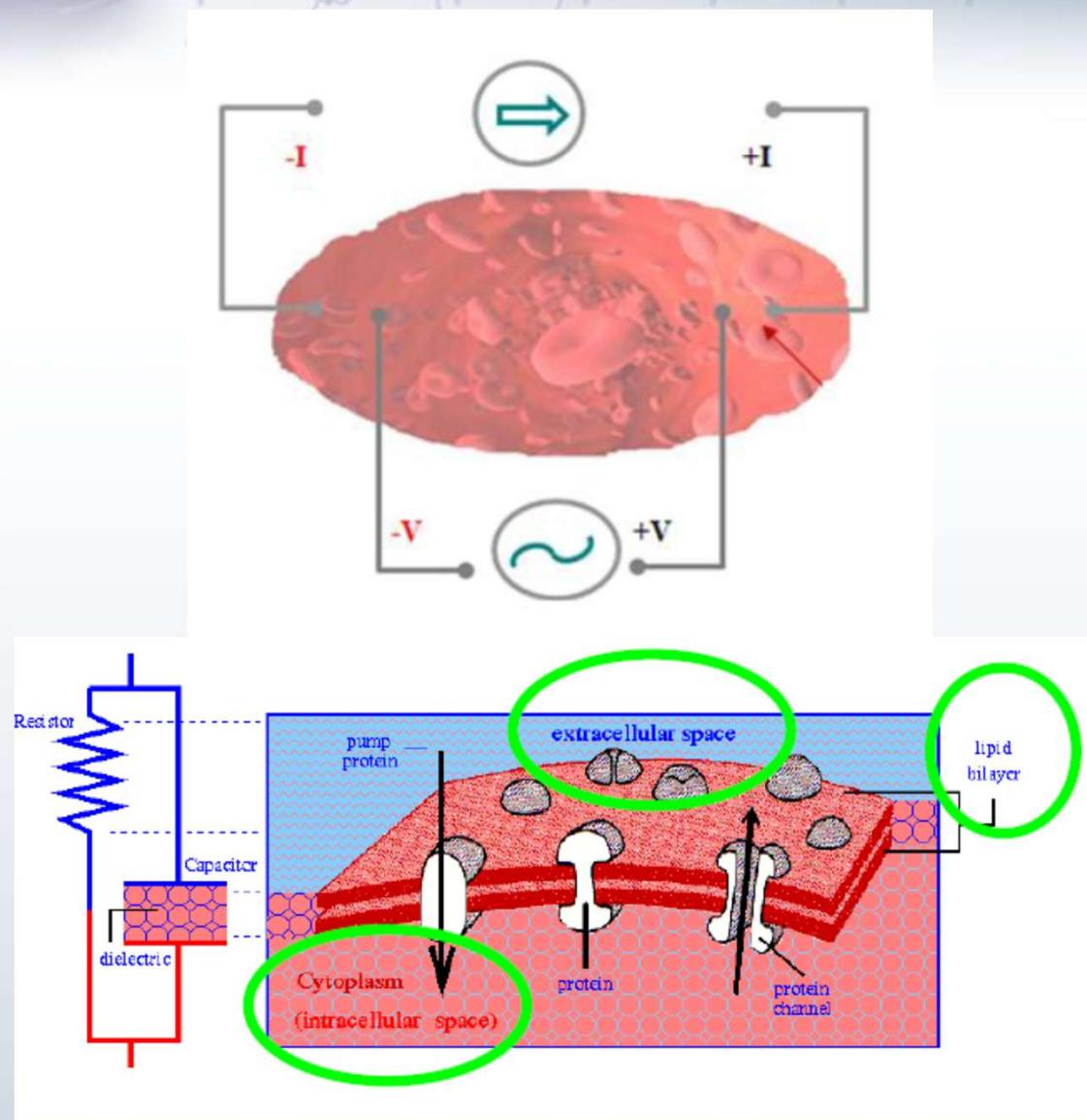
Notation Cartésienne <-> polaire

$$Z = R + jX$$

$$Z = |Z|e^{j\arg(Z)}$$

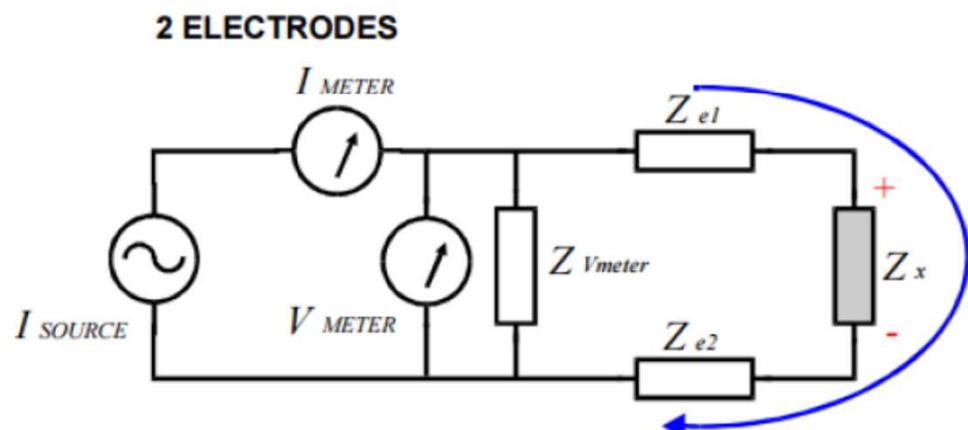
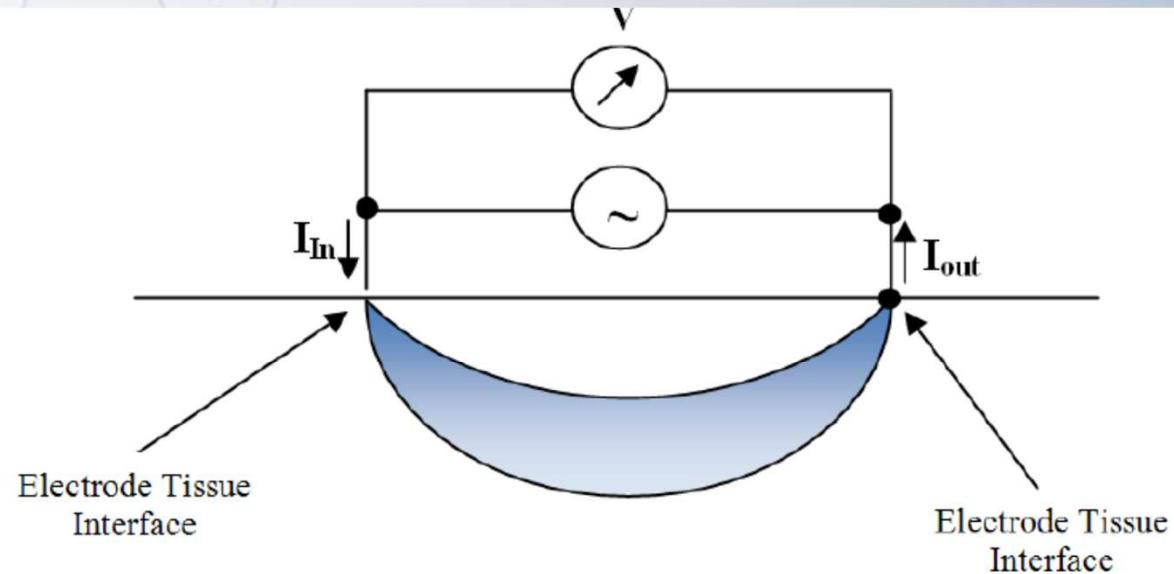


Mesure de la Bioimpédance



Mesure à 2 électrodes

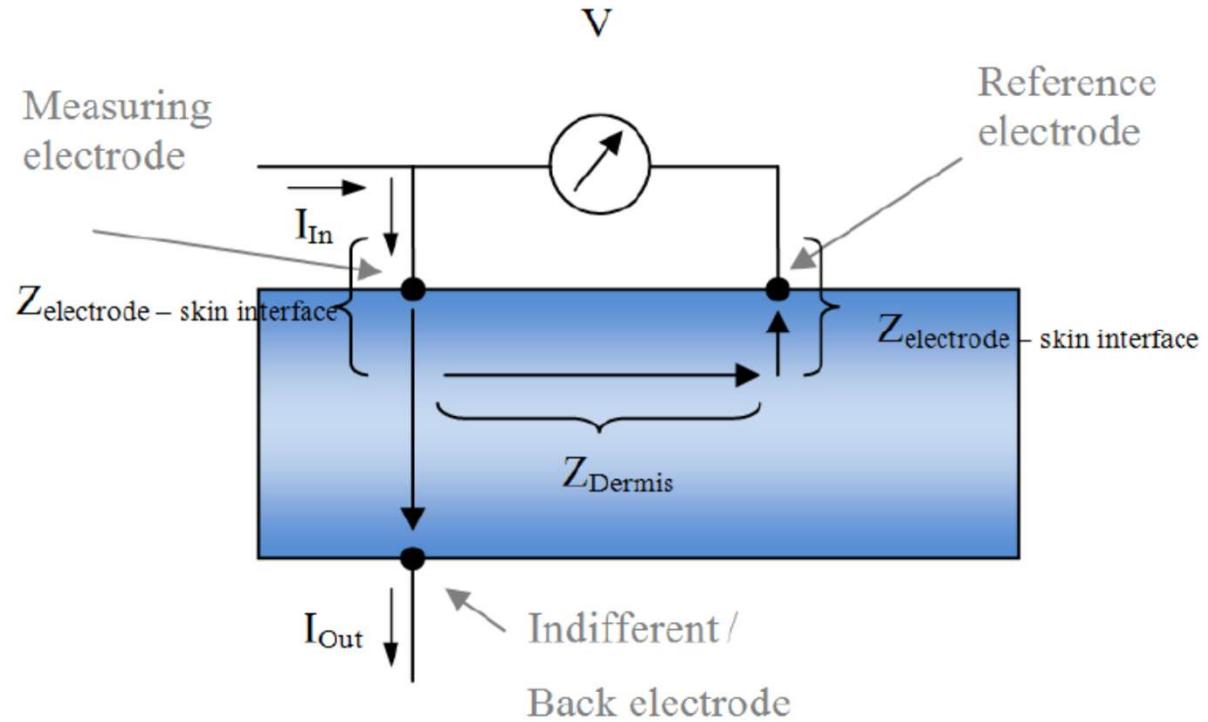
- À 2 électrodes :
 - I appliqué
 - V mesuré



$$Z_{MEAS} = \frac{V_{MEAS}}{I_{MEAS}} = Z_x + Z_{e1} + Z_{e2} \approx \begin{cases} Z_{e1} + Z_{e2} \\ Z_e \gg Z_x \\ Z_{VMETER} \gg 2 \cdot Z_e \end{cases}$$

Mesure à 3 électrodes

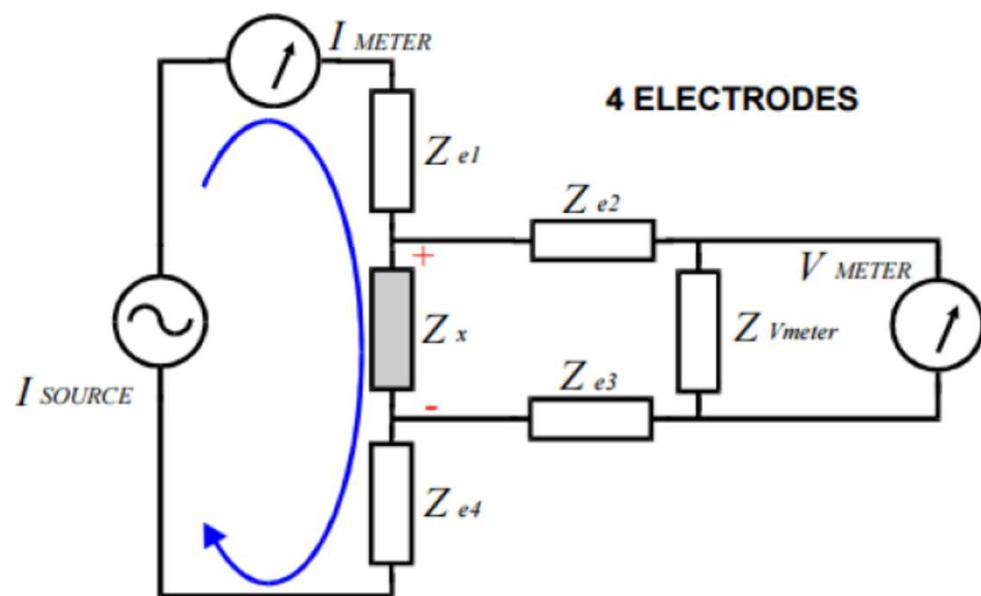
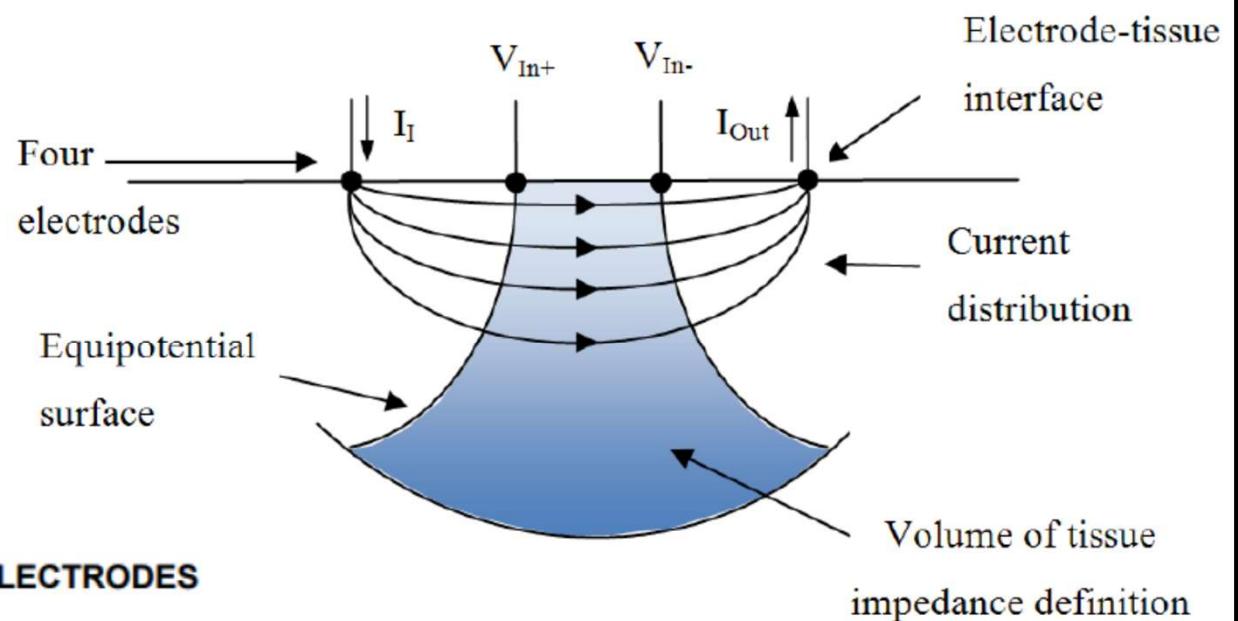
- À 3 électrodes :



- Courant appliqu   par 2  lectrodes (measuring et back electrode)
- Une 3  me  lectrode est utilis   pour mesurer la tension r  sultante (ref)
- L'imp  diance mesur  e est celle de l' lectrode de mesure seule (et ses proches alentours) : mesure localis  e.

Mesure à 4 électrodes

- À 4 électrodes :
 - 1 paire injecte I
 - 1 paire mesure V

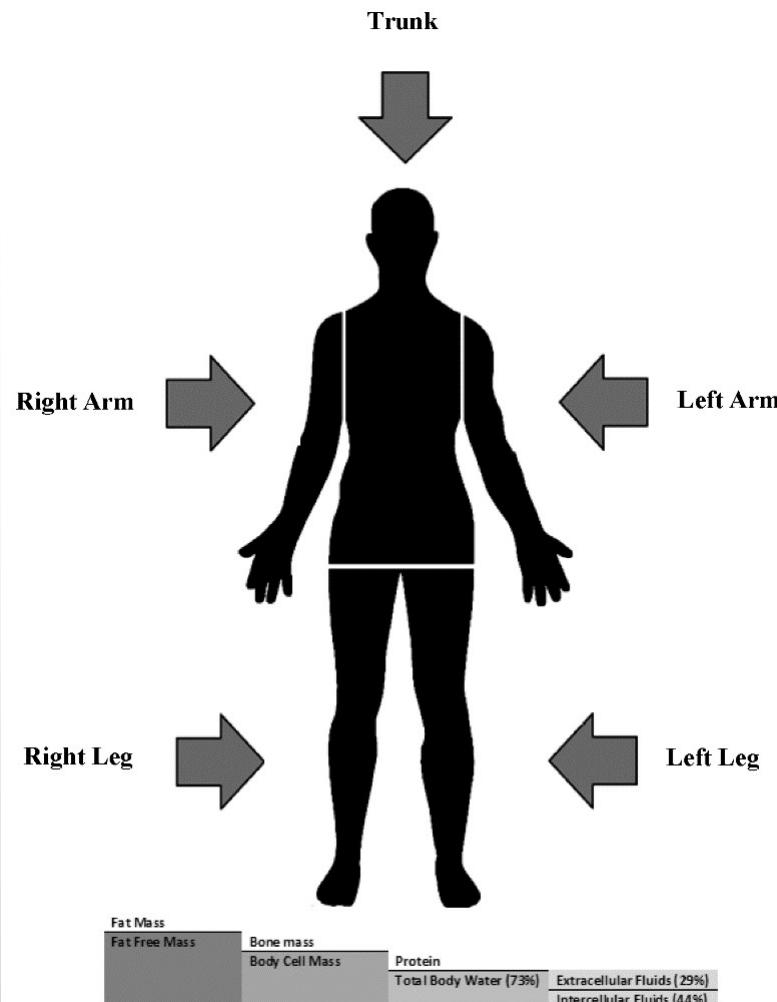


$$Z_{MEAS} = \frac{V_{MEAS}}{I_{MEAS}} = \boxed{\frac{Z_x}{Z_{VMETER} \gg Z_e}}$$

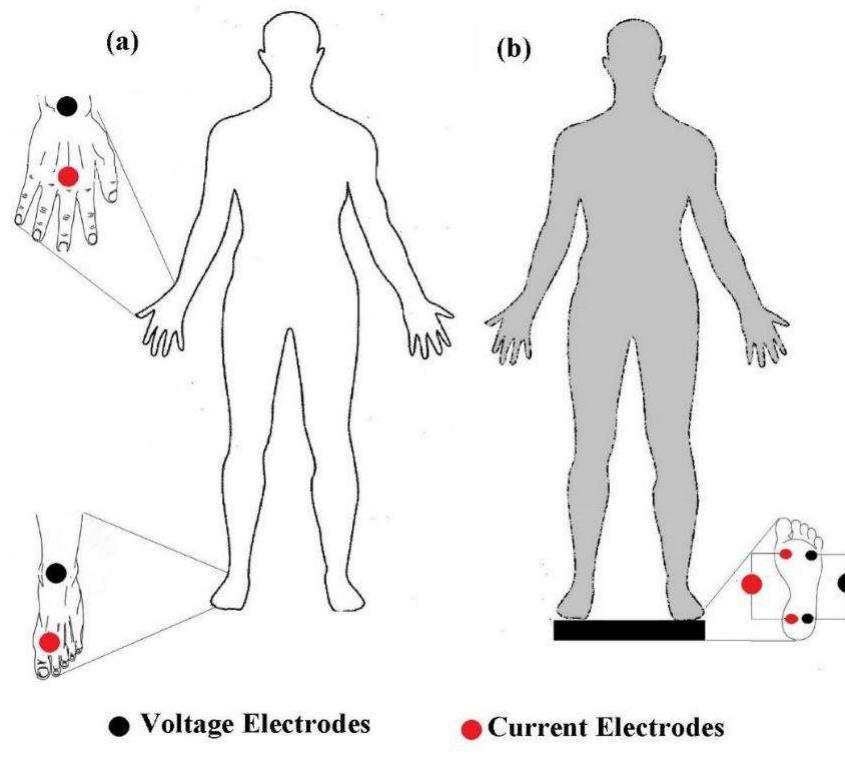
- **Bioimpédance Fréquence unique (SFBIA)**
 - Analysis of bioimpedance information obtained at 50 KHz electric current is known as single-frequency bioimpedance analysis.
 - SFBIA is the most used and is one of the earliest proposed methods for the estimation of body compartments, it is based on the inverse proportion between assessed impedance and TBW, that represents the conductive path of the electric current
 - SFBIA predicts the volume of TBW that is composed of fluctuating percentages of ECF which is almost equal to 75% of TBW, and ICF that represent the rest
- **Bioimpédance Fréquence Multiple (MFBIA)**
 - Analysis of bioimpedance that is obtained at more than two frequencies is known as multiple-frequency bioimpedance analysis.
 - MFBIA is based on the finding that the ECF and TBW can be assessed by exposing it to low and high frequency electric currents, respectively
- **Spectrométrie de Bioimpédance (BIS)**

Impédancemétrie Corps entier

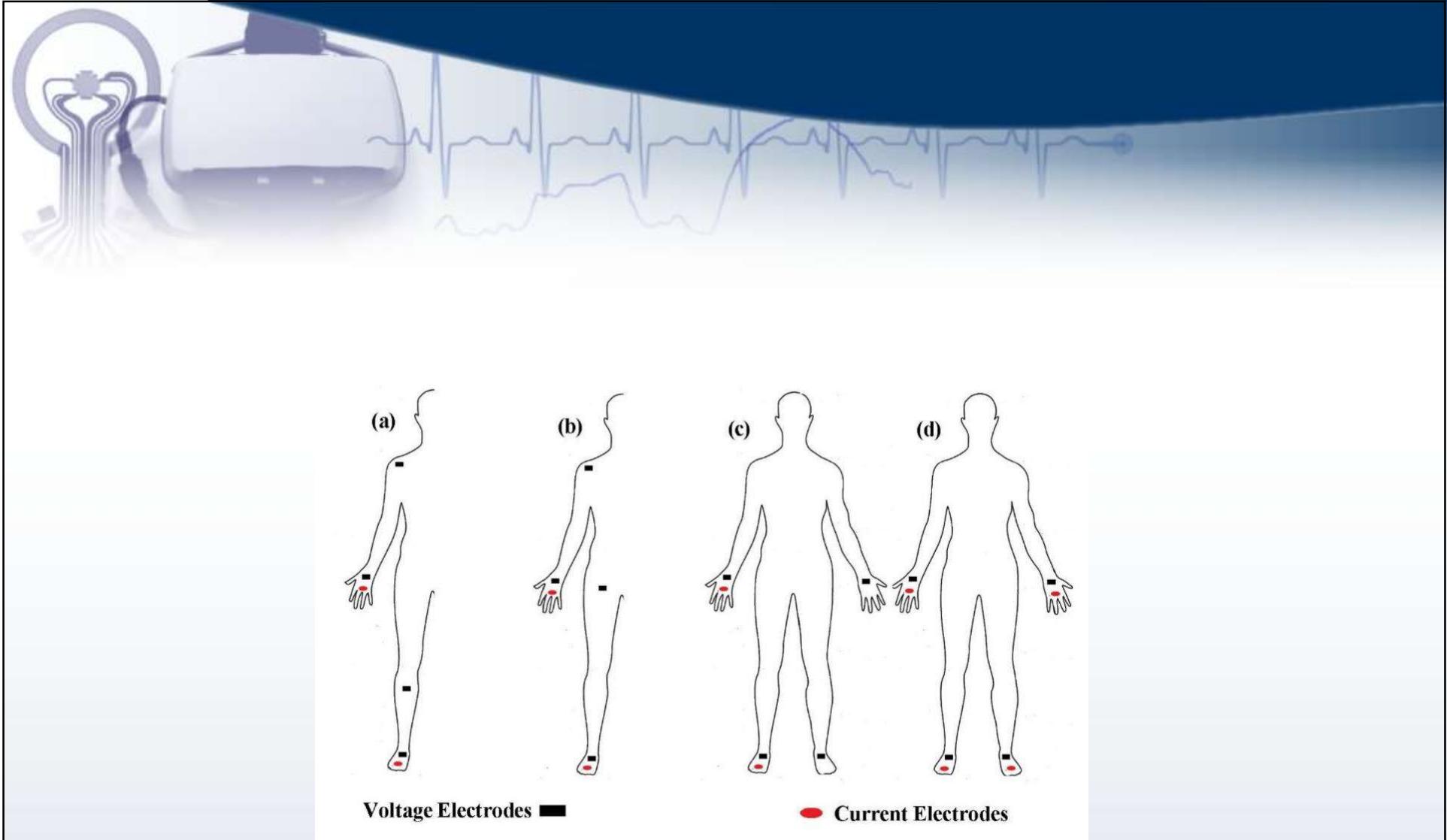
Principaux segments corporels



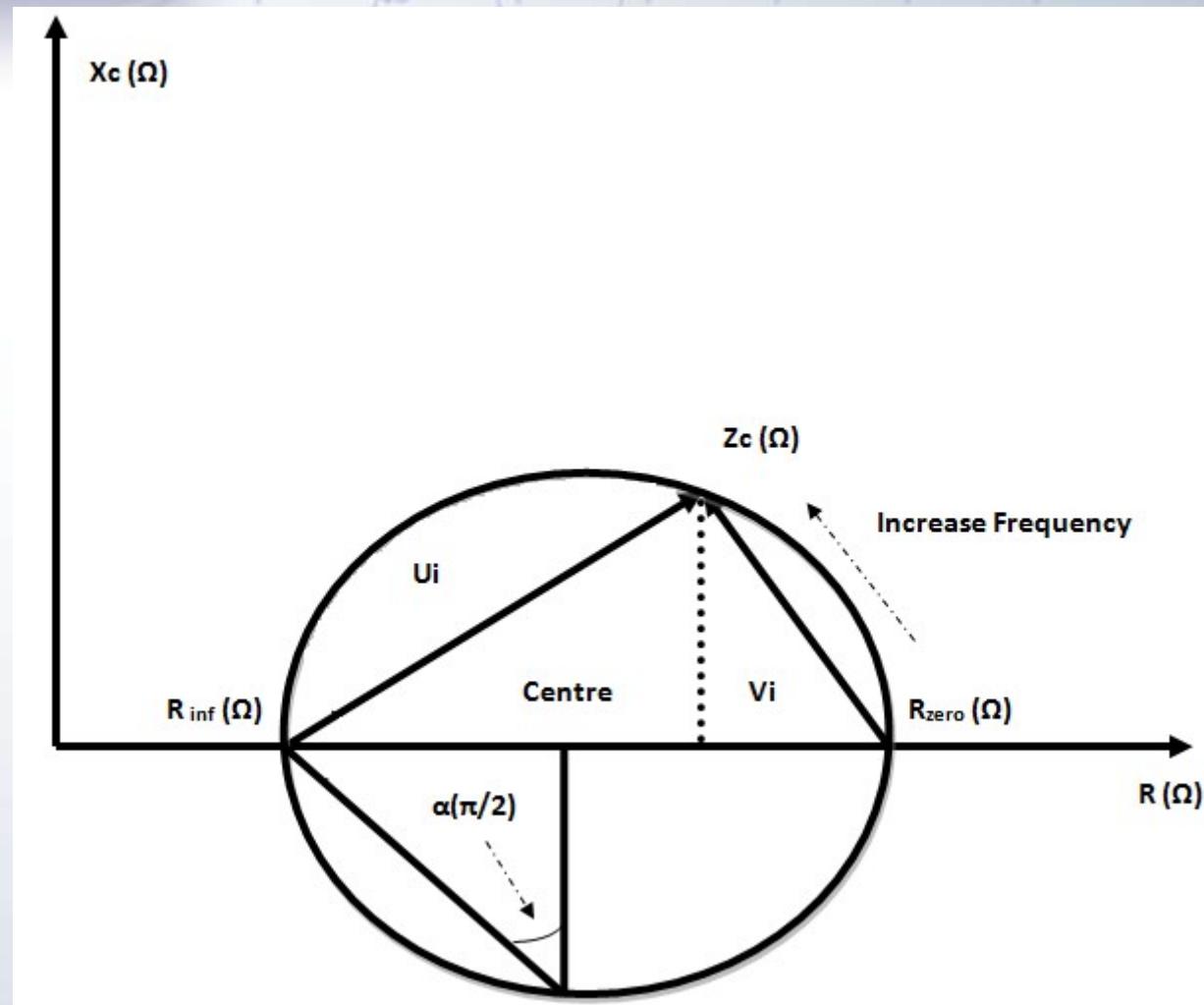
Impédancemétrie corps entier



(a): Hand to Foot. (b): Foot to Foot



Sectrométrie de Bioimpédance (BIS)





MFIA_front_0.png.webp

Analyseur d'impédance pour la recherche



Caractéristiques principales

- 1 mHz à 500 kHz, 1 mΩ à 1 TΩ
- 0,05% de précision de base
- Compensation des parasites et indicateur de confiance
- API de LabOne pour Python, C, MATLAB® et LabVIEW™
- analyse de l'impédance des tissus,
- croissance cellulaire,
- recherche sur les aliments