Lecture 8: Biopotential Electrodes

0. Review

1. Basic electrochemistry

2. Electrode-Skin Interface

3. EMG

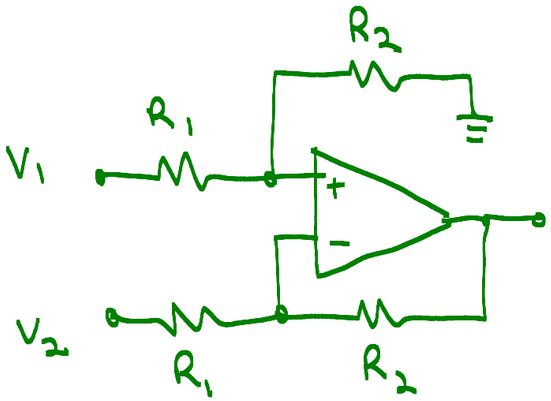
- Today: HW3
- Next Tue: Quiz ← HW3 material
- Fri: Lab 2 report
- Lab 3 report due Feb 14

- Exam #1 (Feb 6)!
  - → HW 1, 2, 3 material
  - → Lectures 1-8
  - → Course website will have sample exam + solutions

0. Review

- **Single Op Amp Differential Amplifier**

  → Mediocre input impedance



$$V_{OUT} = \frac{R_2}{R_1}(V_1 - V_2)$$

- **Instrumentation Amplifier**

  ① High input impedance

  ② High CMRR $= 20\log_{10}\left(\frac{A_d}{A_{CM}}\right)$ ≡ Common Mode Rejection Ratio

- **Inst Amp Output:** $V_{OUT} = V_{REF} + A_d \overbrace{(V_1 - V_2)}^{\Delta V} + A_{CM}\boxed{\frac{V_1+V_2}{2}}$

"Common Mode" Gain

"Common Mode" Input

1. Basic Electrochemistry

- **Electronic vs. Ionic Current**

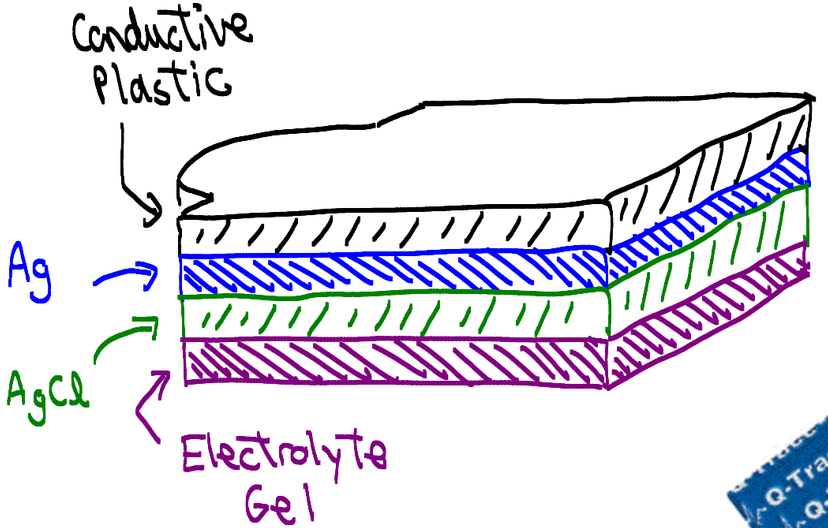
The most commonly used electrode material for measuring biopotentials is **Ag/AgCl**

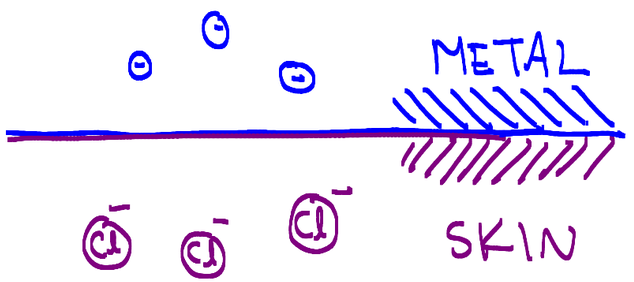
Q: Why not use a thin piece of metal?

A: In order to measure voltage, the measuring device MUST draw some current from the object.

☆ In a metal, electrical signals are carried by electrons

☆ In the body, electrical signals are carried by ions ← e.g. Cl^-





Ions cannot flow into or out of pure metal. ☹

- Electrode - Electrolyte Interface

A. Current flow into body

1. Oxidation of Ag at the Ag / AgCl interface

$\star$ $Ag \rightarrow Ag^+ + e^-$

Ag^+ Enters AgCl ∇!

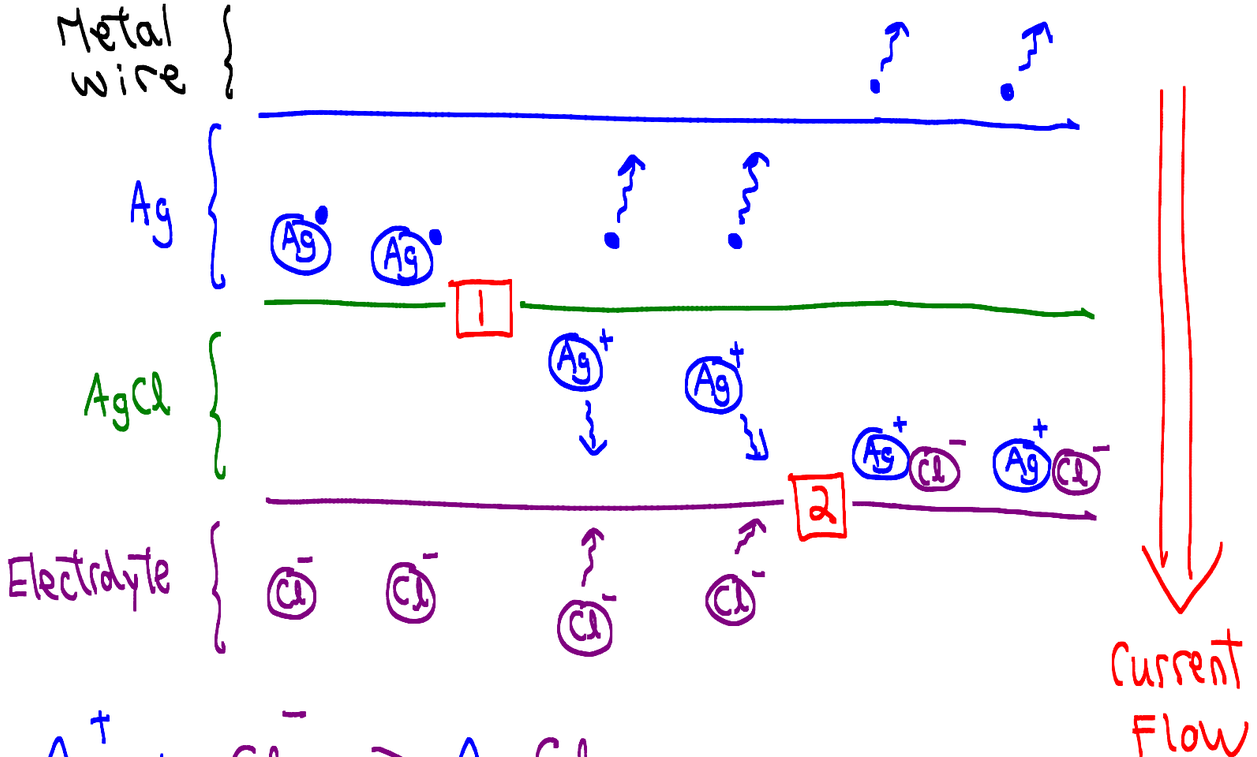
Leaves silver

2. Association of AgCl at the AgCl / Electrolyte interface

$\star$ $Ag^+ + Cl^- \rightarrow AgCl$

Cl^- Enters AgCl ∇!

Leaves electrolyte



B. Current Flow Out of body

1. Reduction of Ag at the Ag / AgCl interface

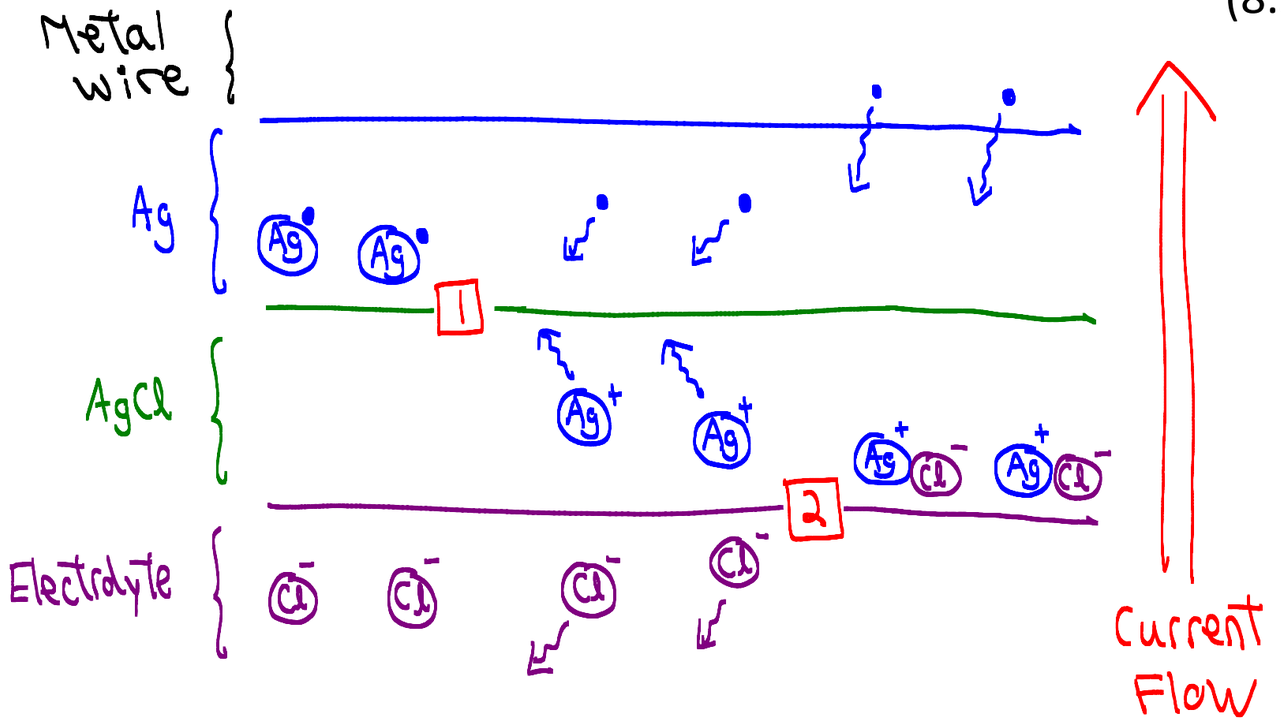
★ $Ag \leftarrow Ag^{+} + e^{-}$

Leaves AgCl ∇!
Returns to silver

2. Dissociation of AgCl at the AgCl / Electrolyte interface

★ $Ag^{+} + Cl^{-} \leftarrow AgCl$

Leaves AgCl ∇!
Returns to electrolyte



- Polarizable and Non-polarizable Electrodes

For Ag/AgCl electrode,
charge flows freely
across interfaces.

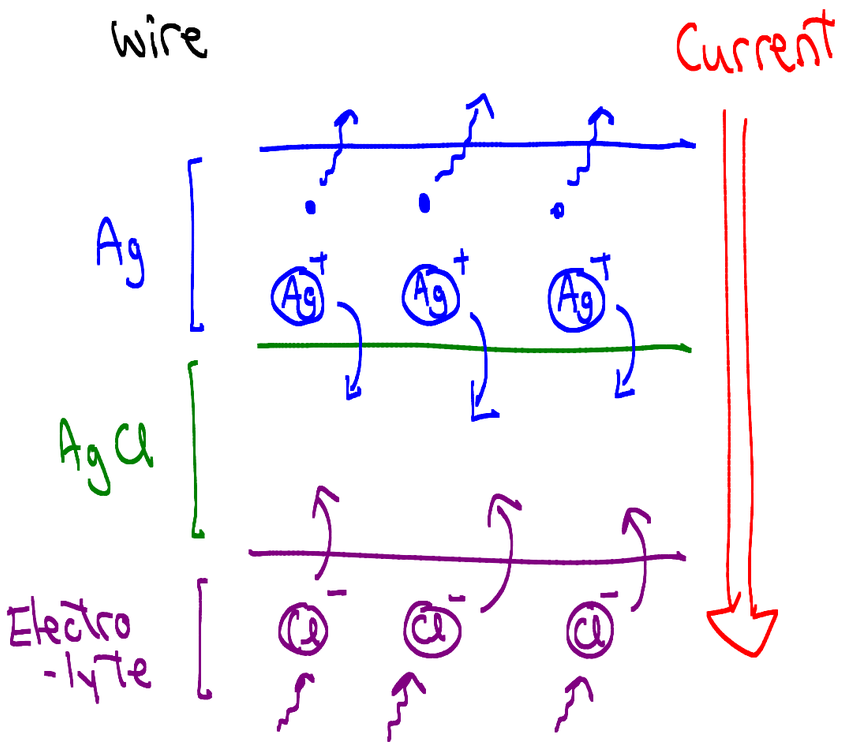
⇒ e^- flow in wire + Ag

⇒ Ag^+ actually leave the metal

⇒ Cl^- actually leave the electrolyte.

✡ Charges do not accumulate at interfaces

⇒ This is called a non-polarizable electrode ← best for biopotentials!

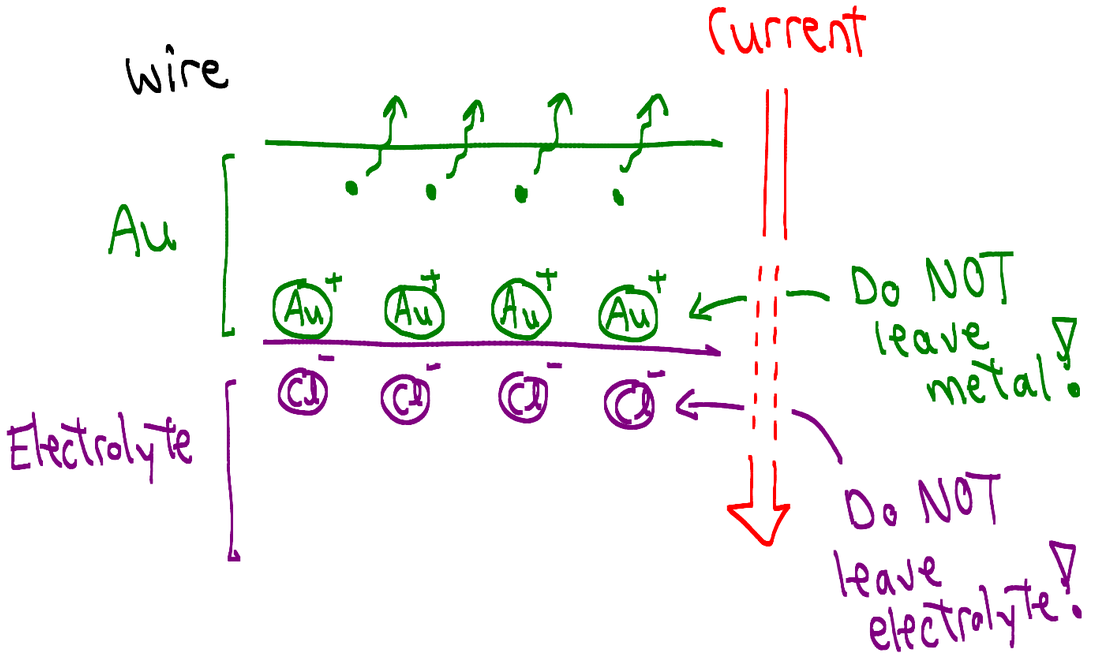


For gold electrode ← common for EEG

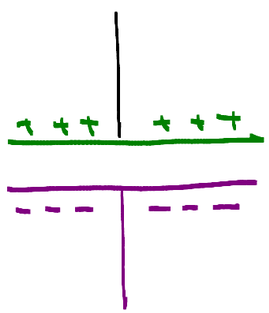
⇒ Au is relatively inert metal

Current causes build up of charge at interface

⇒ Acts like a capacitor



✱ This is called a polarizable electrode

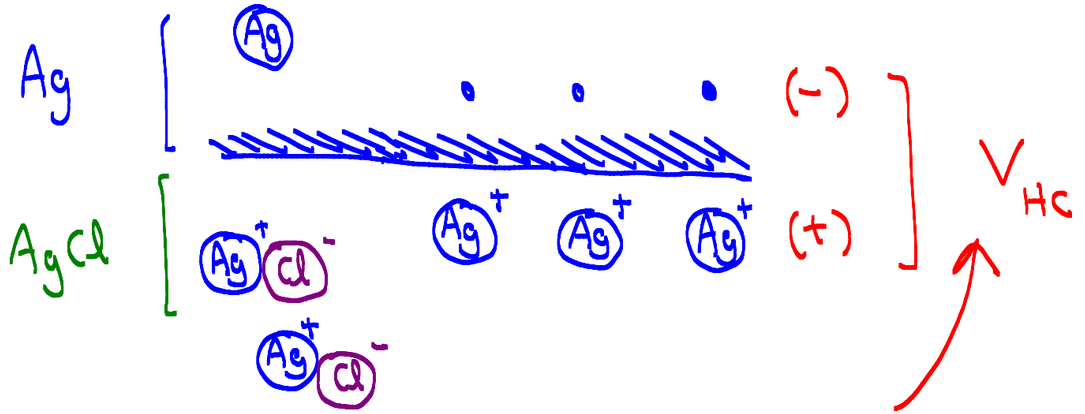


☹ ← not the best for measuring biopotentials

✱ Current between electrode and electrolyte is achieved by displacement currents!

- **Half-Cell Potential**

Even when no current exists, there is a small voltage that develops across the electrode/electrolyte interface.

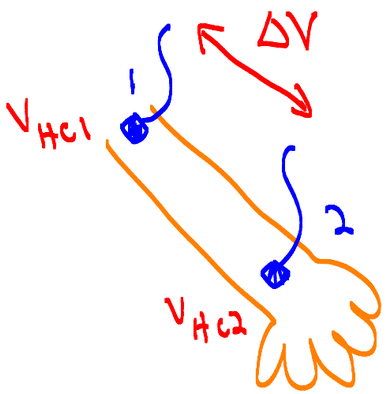


✡ The half-cell potential can vary between Ag/AgCl electrodes

$$\Delta V = V_{HC1} - V_{HC2}$$

↑ Differential

Offset voltage can be tens of mV! (even ~300 mV) ☺ ☹



- Depends on many factors (metal type, ion concentration, etc.)

2. Electrode-Skin Interface

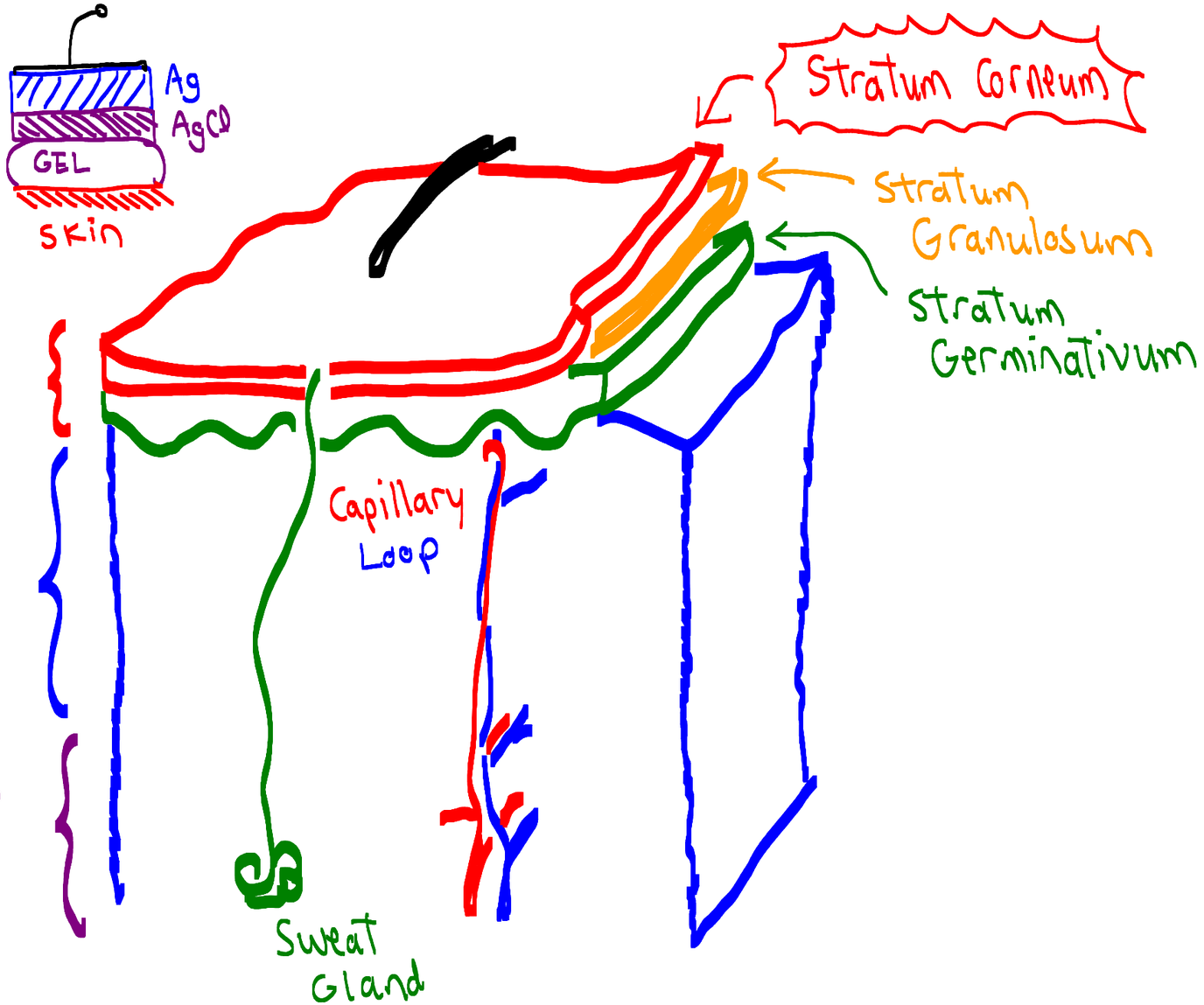
↑ Can have big effect on ECG signal

Epidermis has lots of dead cells → Epidermis

↑

Stratum Corneum is bad for ECG ∴

Deeper layers have similar electrical properties as body → Dermis, Subcutaneous Layer



- **Motion Artifacts** ← Bad

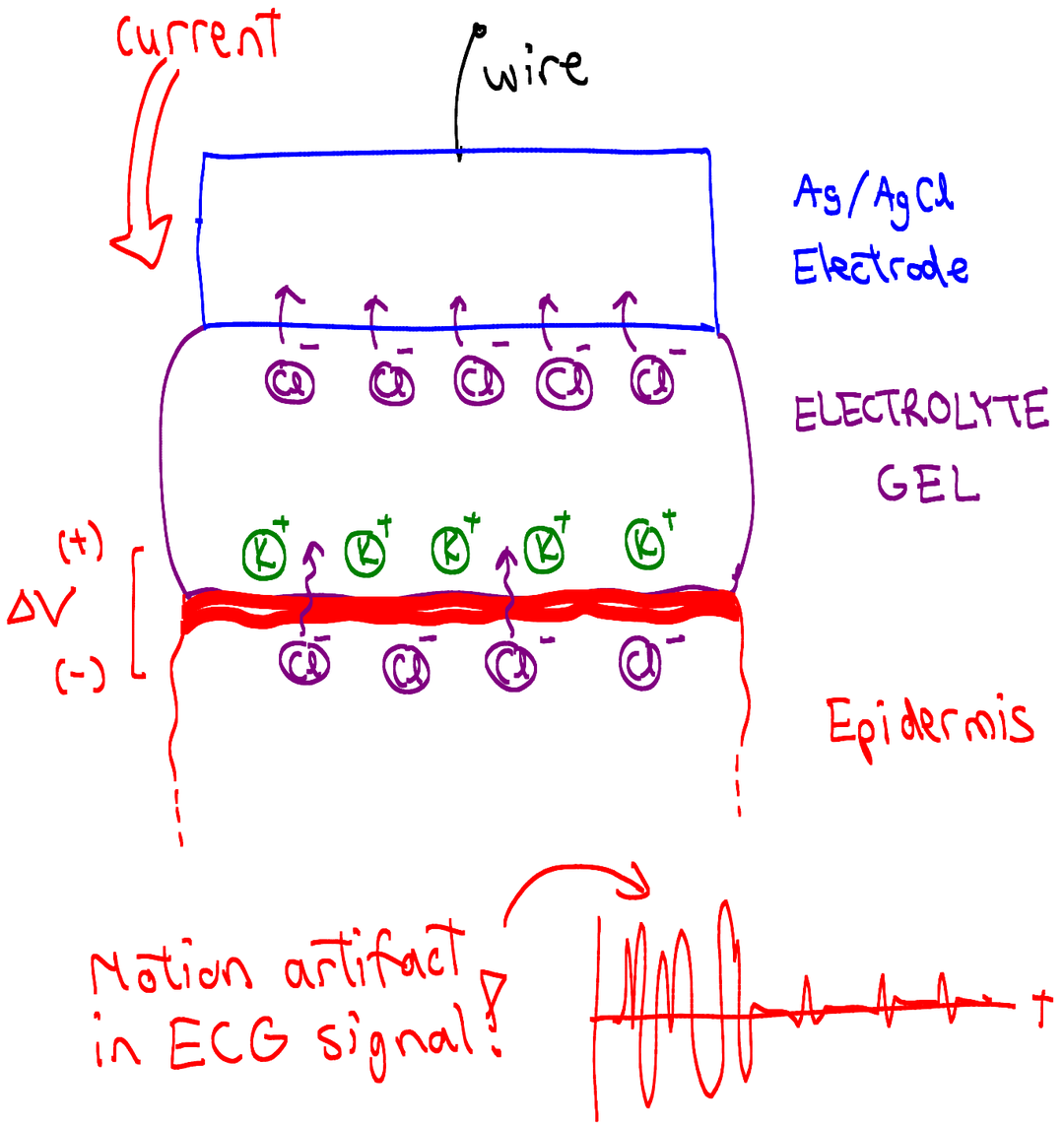
Ag/AgCl Electrode

Stratum corneum acts like a membrane that is semipermeable to ions

⇒ Differences in ion concentration across the membrane

⇒ Electric potential difference can be up to ~200 mV!

✡ Movement of electrolyte-skin interface causes charge layers to move ⇒ changes ΔV

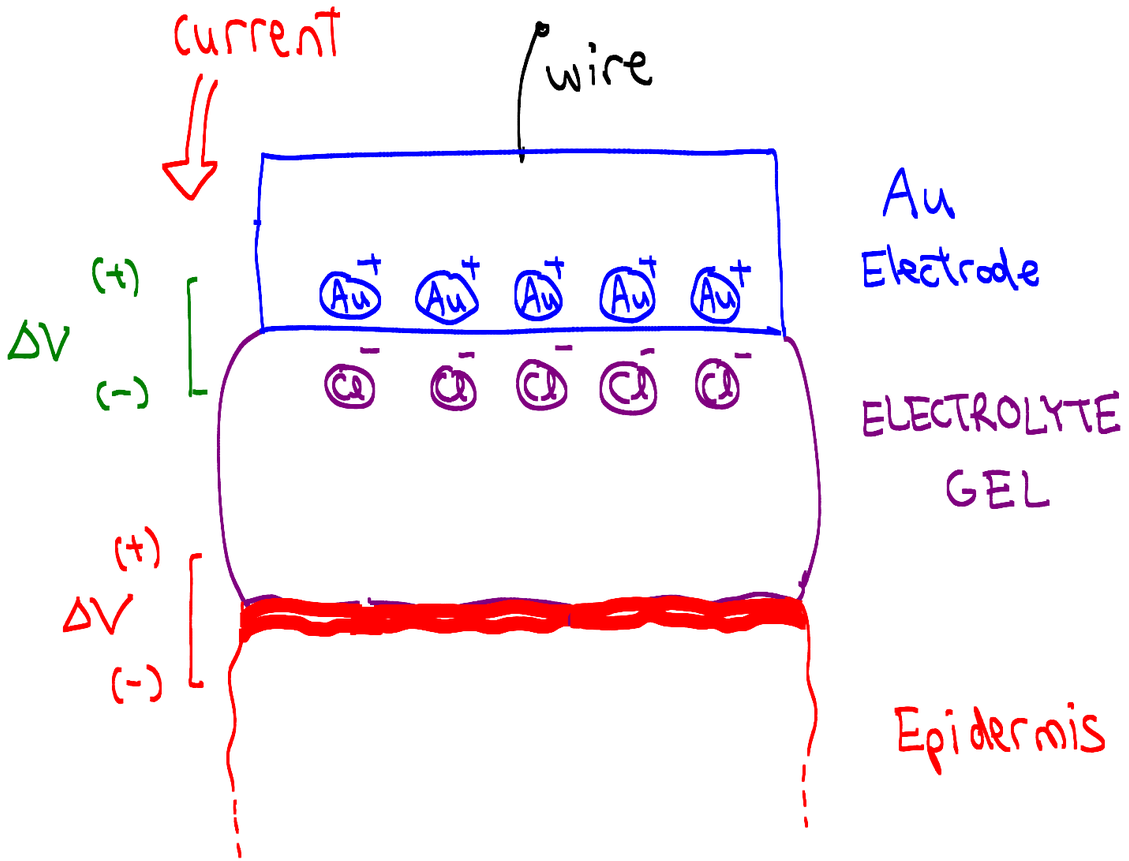


- Polarizable electrodes (e.g. Au) also have a double layer of charge at electrode-electrolyte interface

⇒ Electrode movement can disturb this charge layer (e.g. breathing motion)

⇒ Produces change in ΔV that interferes with signal :(

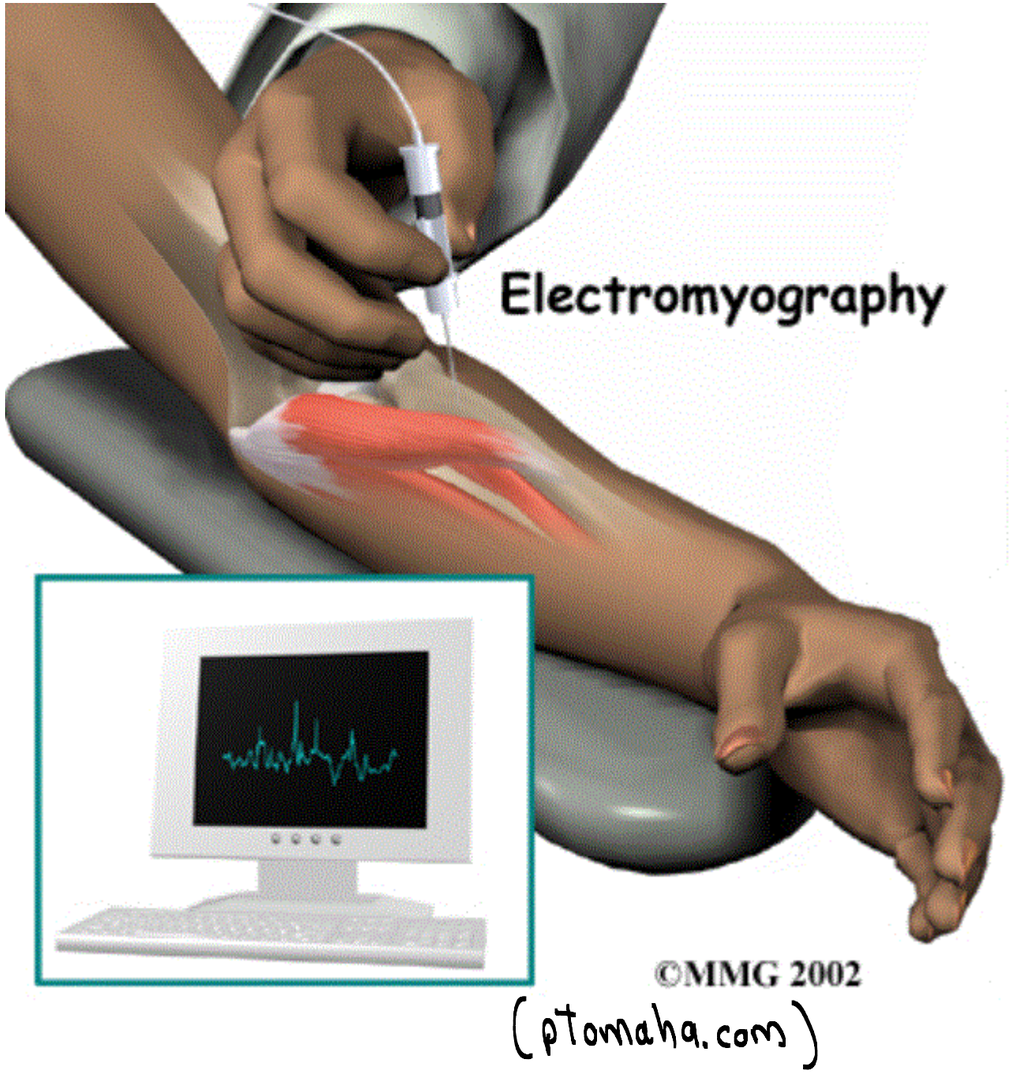
✱ Patient needs to be VERY still



3. Electromyography (EMG)

A. Intro

- Record the electrical activity associated with skeletal muscle
- Diagnostic tool for identifying:
  - → neuromuscular diseases
  - → lower back pain, motor disorders
- Produce control signals (prosthetic devices)
- Two electrode types:
  1. Surface (surface EMG)
  2. Needle (Intramuscular EMG)



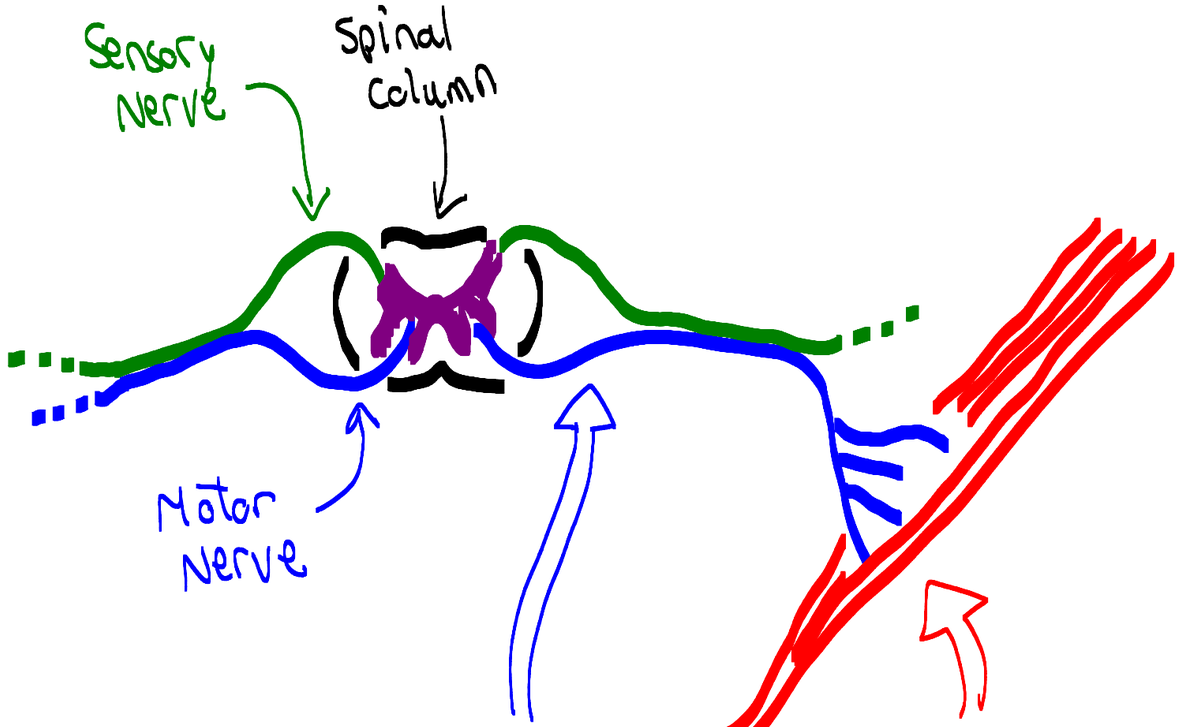
(ptomaha.com)

B. Single Motor Unit (SMU)

- Smallest neuromuscular unit that can be activated
- Muscle = Interspersed fibers from multiple SMUs
- Evoked field potential:
  - 3-15 ms
  - .02-2 mV
  - → 6-30 firings/sec
- High muscle activity

→ Active SMU fires more often

→ New SMU's are recruited



SMU = [Single motor neuron] + [bundle of muscle fibers]

C. EMG Processing

→ Raw EMG signal is not that useful

→ Integrated EMG leads to an activity index