
Charge carriers:

\[ \text{METAL} \quad \text{SOLUTION (brain)} \]

Double layer: separates the two systems.

Definitions:

- IPE → ideally polarizable electrode
- INPE → non-polarizable electrode

Reversibility = desirable for in vivo & in vitro tests.

Irreversible = electrode damaged after use.

- CSO = charge storage capacity
- CPP = charge per period \( \text{max}(\text{CPP}) = \text{CSO} \)

\( J, I, \varphi \rightarrow \) traditional definition.

Charge balance:

\[ t_e A_e = t_a A_a \]
Cyclic Voltammetry (CV)

**IMPOSE**: \( \uparrow \) \( V \)

**MEASURE**: \( \downarrow \) \( I \)

**SYSTEM**: electrode under investigation (working)

reference and counter electrodes

"Conductive, simple, media"

CV: scan rate defines your target molecule or process. Molecules have to be "electroactive".

Ex. - dopamine detection: fast CV (>100V/s).
- \( O_2 \) (molecular Oxygen) <100mV/s
- capacitive effects: usually <100mV/s.

* dopamine: neurotransmitter. Synthesized in the body (by neurons + adrenal glands). It's a precursor to epinephrine + norepinephrine.
EXAMPLE OF FCV:

for (DOPAMINE)

* background current
* carbon fiber electrode

difference:

\[ f(T_2) - f(T_1) \]
SLOW CV: trying to get the most charge out of the electrode in the brain.

(Derive -)
Electrode model:

- In solution:

\[
\begin{align*}
C_d & \quad \text{Cd} \\
\text{Rs} & \quad \text{Rs} \\
C_0 & \quad \text{C_0}
\end{align*}
\]

System response to:

- Voltage ramp:

\[
E = v t, \quad \text{where } E \in [V], \quad v \in \left[\frac{V}{s}\right] \quad \text{(sweep rate)}
\]

\[
\begin{align*}
\nu t & = E_s + E_d \\
v t & = R_s i + \frac{q}{C_d} \\
v t & = \frac{1}{R_s C_d} \int_{q_0}^{q} \frac{dt}{t}
\end{align*}
\]

\[
\frac{dq}{dt} = \frac{v t - q}{t} \\
q(0) = 0
\]

Initial condition: \( t=0, \quad q=0 \)

\[
i = C_d v \left[1 - e^{-\frac{t}{R_s C_d}}\right]
\]

For \( t \to \infty \), \( i = \nu C_d \)
COCHLEAR IMPLANT.

First test: 1800, Volta - electrodes in each ear, prob. 50V discharge - he describes he heard a huge noise/bang. Never tried it again.

1957 - Djourno + Eyries: 1 patient, identifies rhythm of speech.

Major advancement: 80's → from one electrode to MULTIELECTRODES - better results.

Block diagram:

→ AMP

Microphone

signal processor

... → internal processor

transcutaneous link

current drivers

BATTERY

→ MEA.

Websites:

[bionics](http://www.bionics.com)

[cochlear](http://www.cochlear.com)

[medel](http://www.medel.com)
1999: 900,000 Americans could not function without the use of a hearing aid.

How does it start?

Conductive: may be temporary. Outer or middle ear prevent signal from being transmitted.

* Usually mild hearing loss - surgery, medication, or hearing aids can help

Sensory/neural: missing hair cells. Usually permanent.

No surgery! Hearing aids can help, as well as the cochlear implant.

Neural: absence or damage to auditory nerve.

* Cochlear implant won't help.

Maybe brainstem implant (100 people implanted in the U.S.A., versus 20K in 1999).
RETINA IMPLANT

* EYE - how it works.

* Blindness:
  - birth retinitis pigmentosa
  - macular degeneration

* Strategies:
  - Subretinal: 1
  - Epiretinal: 2
  - Optic nerve: 3
  - LGN/cortical: 4

Advantages / disadvantages of each:
- surgery / placement / infection
- processing
- repeatability from patient to patient
Homework → due 09/11 - 7pm:

Nature Vol 442 | 07/13/06 - p 164 - 171
Neuronal ensemble control of prosthetic devices by a human with tetraplegia.
Leigh R Hochberg et al.

1. It's easy to suggest improvements on this BrainGate. What do you think would be a straightforward, feasible next step?

2. a. Two points that surprised you or:
   b. Two things that you can't understand.

3. What was in your point-of-view - the bottleneck for this technology to take off?

4. Give at least one failure mode with this project (why wouldn't it work for a long in a long-term situation?)