What is deep brain stimulation and how does it help improve the lives of those with Parkinson's disease?

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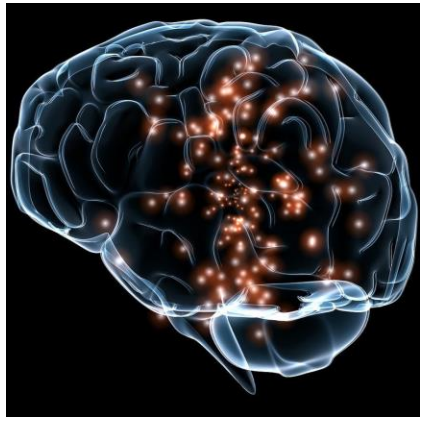

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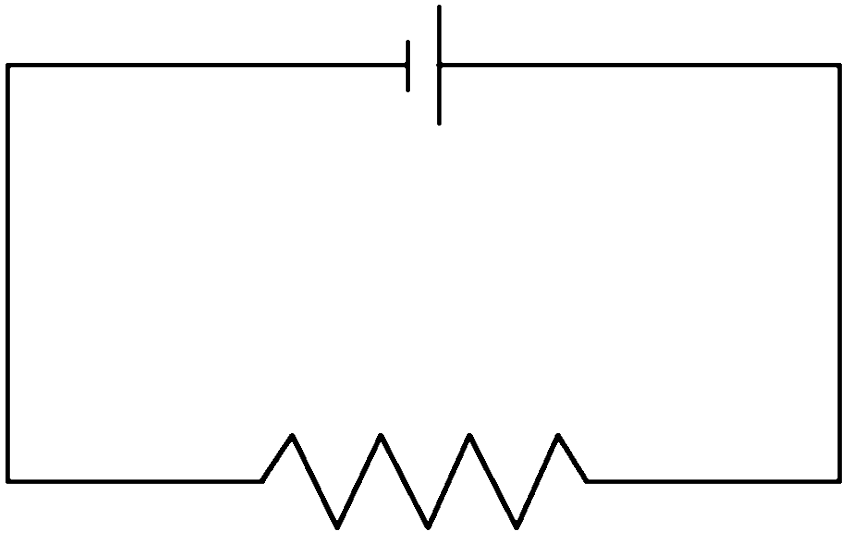
How do neurons behave?

- We have about 86 billion neurons that communicate via electrical and chemical signals
- Neurons transmit electrical signals into their axons and convert them into chemical signals to then communicate with other neurons
- Signal transmission between neurons is continued by junctions called synapses.



*The relationship between neurons can be compared to a circuit. Such that they both rely on some type of electrical component to travel a path.

Parkinson's background

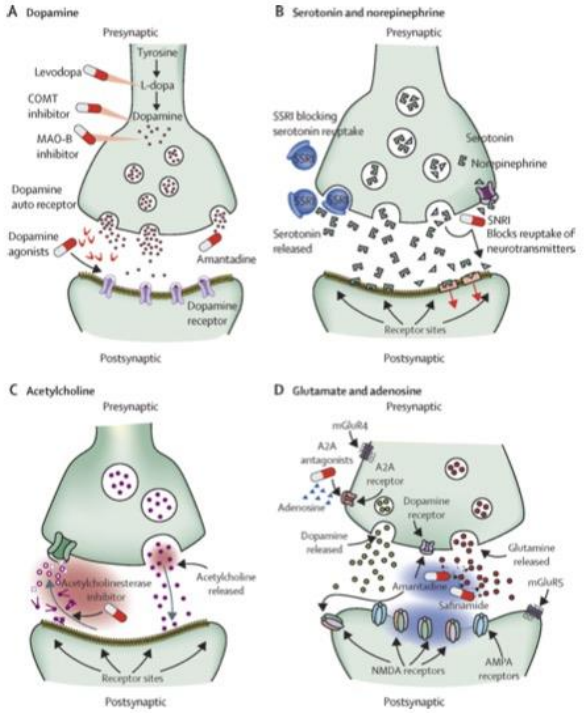


Figure 1

- Parkinson's is a neuro degenerative disorder that affects an individual's motor skills causing tremors and lack of motor control
- Essentially due to poor neural communication as a result of dopamine producing neurons degenerating and dying.
- Parkinson's is tackled in two ways; through chemical methods (figure 1) with antiparkinsonian drugs, or with electrical methods (figure 2) such as deep brain stimulation with electrodes.

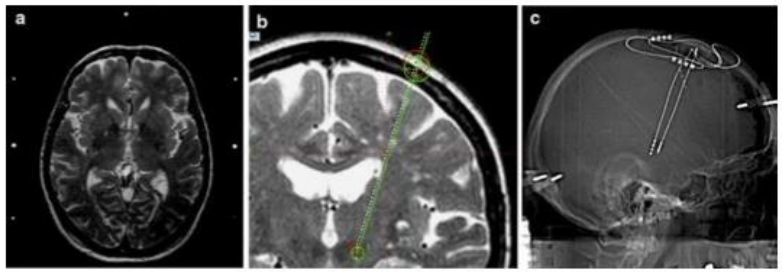


Figure 2

What is Deep Brain Stimulation (DBS)?

DBS is a neurosurgical procedure

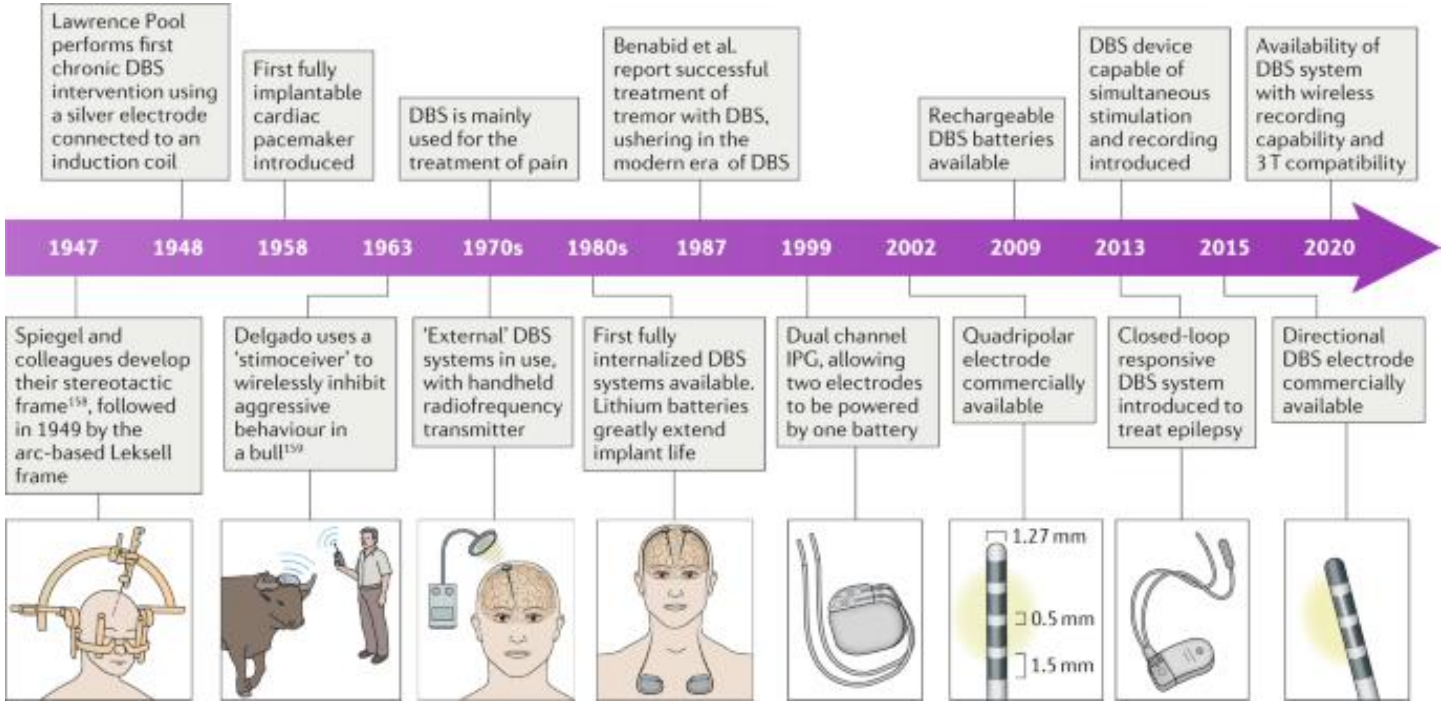
Uses implanted electrodes to and electrical stimulation to treat neurological conditions

Some conditions it is used to treat include Parkinson’s disease (PD), essential tremor, and dystonia.

DBS does not resolve conditions, but it can improve quality of life and decrease need for medication

Overview of How DBS Works:

- Implant 1+ small wires (electrodes) in brain during surgery
- Leads receive mild electrical stimulation from small pulse generator implanted in chest
- Proper patient selection, precise placement of electrodes and adjustment of pulse generator are essential for successful DBS surgery



Physics Behind DBS

Movement related systems of neurological conditions are caused by disorganized electrical signals in the brain

Successful DBS interrupts these irregular signals that cause tremors and other movement symptoms

Leads inside the brain are connected through an insulated wire to a small electrical generator (neurostimulator) around the collarbone

Neurostimulator is programed to deliver an electrical signal

Neurostimulator runs on a battery that generally lasts 3-5 years, others need regular charging

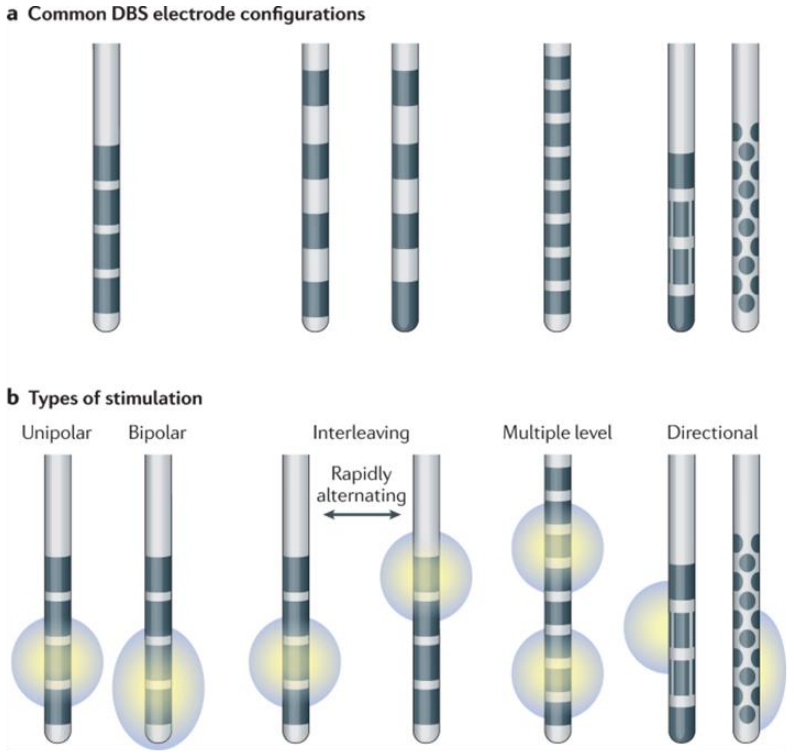
DBS Electrodes

Electrode Configurations:

- Electrode spacing affects the reach and precision of the electrical signals.
  - ➢ Wider spacing increases the target area, while closer spacing allows for more controlled stimulation.

Stimulation Types:

- Unipolar: current flows from battery to a contact
- Bipolar: current flows between two contacts (at lease one anode, one cathode present)
- Interleaving: alternates between different settings
- Multiple-level stimulation targets different brain area
- Directional stimulation focuses the current based on local anatomy or symptoms

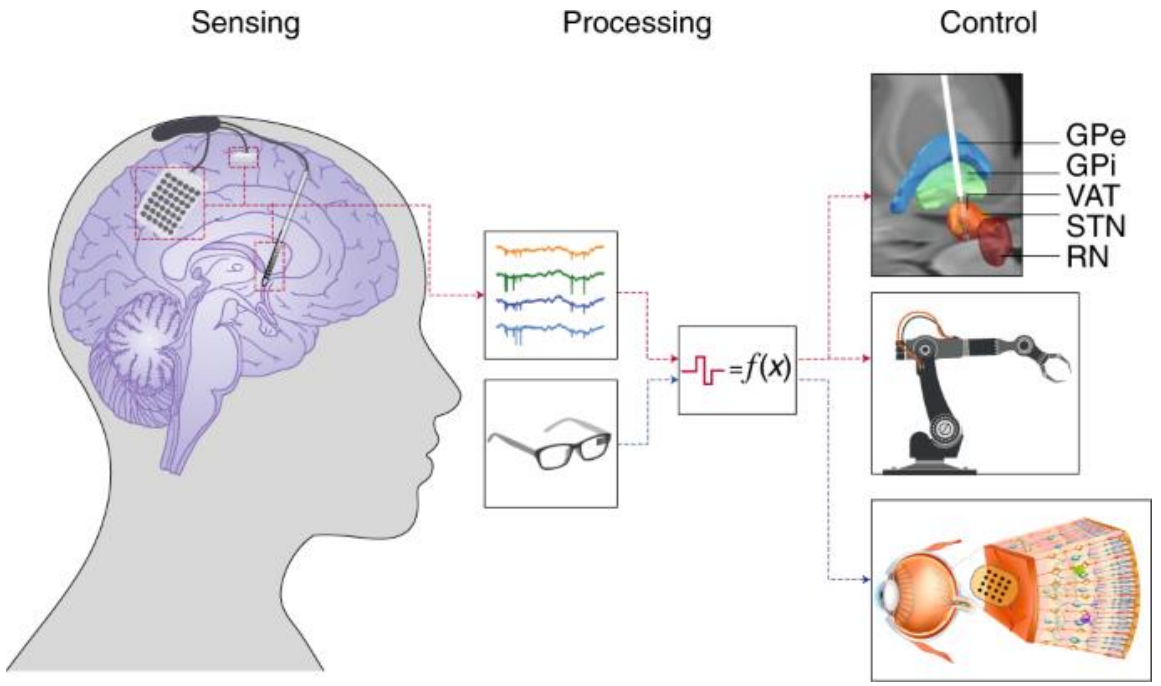


a | Common electrode configurations for deep brain stimulation (DBS). Dark grey regions illustrate electrode contacts, which can be activated to deliver current. **b** | Modes of stimulation, depending on the type of DBS system in use.

Sensing and Feedback

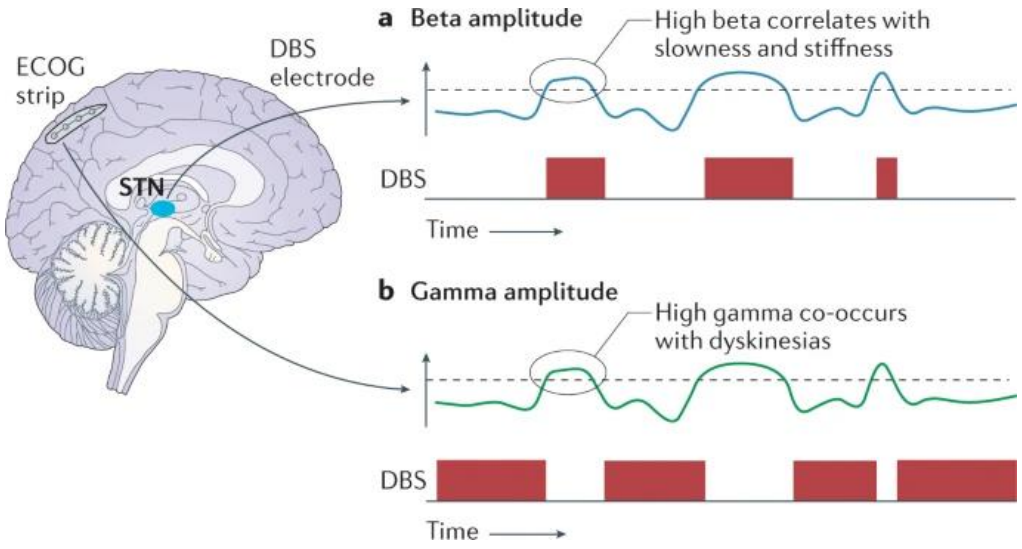
- To date, most neural devices are unidirectional—capable of recording or stimulating neural activity, but not both.

- Bidirectional neurostimulation devices are capable of both sensing and stimulating in a real-time and adaptive manner, thus creating new opportunities leveraging closed-loop approaches.



Adaptive and Closed-Loop System

Local field potentials (LFPs) recorded from contacts of implanted electrodes revealed differences in power spectra in various disorders



Neural biomarker	Recording site	Disease	Main uses	Refs
Gamma (~70 Hz) activity	Cortex	Parkinson disease	Feedback signal related to dyskinesia for adaptive DBS	85
Beta (~20 Hz) activity	Cortex	Essential tremor	Triggering stimulation in response to movement in adaptive DBS	86
Beta (~20 Hz) activity	Subthalamic nucleus or globus pallidus internus	Parkinson disease	Feedback signal related to bradykinesia–rigidity for adaptive DBS; localizing signal for contact selection in programming	87,88, 89
Theta (~7 Hz) activity	Subthalamic nucleus or globus pallidus internus	Dystonia	Feedback signal related to muscle spasms for adaptive DBS	90
Event-related resonance activity (~260 Hz)	Evoked potentials from subthalamic nucleus stimulation	Parkinson disease	Localizing signal for contact selection in programming	91

Current Research and Future Directions

- **DBS** treats movement disorders like Parkinson's by modulating brain circuits.
- **Technological advances** have led to smaller, rechargeable, implantable devices.
- **Directional leads** personalize stimulation by shaping current based on anatomy.
- **Closed-loop systems** adjust stimulation in real-time using neural biomarkers.
- **Open-access software** helps localize electrodes and model tissue activation.
- As DBS becomes **wireless**, remote programming is possible, but privacy concerns, like "brainjacking," need addressing.