National Institutes of Health
Office of Science Policy

NEUROSTIMULATION TECHNOLOGIES

HARNESSING ELECTRICITY TO TREAT LOST NEURAL FUNCTION

The human nervous system serves as a command center, allowing us to perceive and respond to the world around us, and it was long thought that any damage to it was irreversible. Paralyzing spinal cord injuries or profound hearing loss were permanent, and there was little to relieve the effects of neurodegenerative diseases like Parkinson's Disease. Now, with NIH support and years of research, we understand the nervous system enough to help compensate for lost function using electrical stimulation to enhance neural activity. NIH, along with many other contributors, has guided and supported this research, helping to take neurostimulation technologies from initial discoveries in the lab and animal models to innovative treatments for patients.

AN ELECTRICAL NERVOUS SYSTEM

The nervous system is made up of many types of cells, including neurons which link together like living wires, conducting electrical signals throughout the body. This principle was first described in the 19th century when scientists used electrical stimulation to contract muscles.[12] Decades later, surgeons seeking to identify and remove seizure-inducing brain tissue electrically stimulated different brain areas, unlocking a wealth of knowledge about how the brain is organized.[13] When the pacemaker was introduced in the 1950s, researchers demonstrated for the first time that electrodes and batteries could be implanted in the body to simulate the action of healthy nerves.[14]

NEUROSTIMULATION: THEN AND NOW

THEN (pre-1980s)

The only electrical device that could be safely implanted into humans was the cardiac pacemaker, first used in the 1950s.[3]

- The electrical properties of the nervous system, though discovered more than a hundred years ago, had not been harnessed for treatments.[1]
- Early prototypes of neurotechnologies were very limited. The first cochlear implants in the 1970s could only enhance patients' awareness of their environment and aid with lip-reading.[7]
- Most advances in care for spinal cord injury were focused on limiting further damage shortly after injury, rather than improving function over the longer term.[9]

NOW

FDA has approved cochlear implants for hearing loss[4], deep brain stimulators for Parkinson's[5], and a device that can restore some vision.[6]

- Technologies for electrically stimulating the nervous system allow patients to compensate for many types of nerve damage.[2]
- Cochlear implants have enabled people with hearing loss to hear and understand speech. Over 324,000 devices have been implanted worldwide, including 100,000 in the US and 38,000 in American children.[8]
- Emerging technologies have the promise of restoring vision[10] and movement after paralysis and traumatic injury.[11]

RESEARCH-TO-PRACTICE MILESTONES IN NEUROTECHNOLOGY

For more information on the supporting evidence and research sponsors for these milestones, see the Web appendix.

1950s-60s: STIMULATING NERVES WITH ELECTRICITY

1957 — Scientists first realized that electrical stimulation might simulate hearing. Attempting to repair a facial nerve injury, surgeons electrically stimulated the auditory nerve, causing the patient to perceive sounds.[15]

1960 — Researchers first tested the long-term safety and effectiveness of implanting electrodes in the human brain.[16]

1960s — Scientists, including many supported by the NIH, began experimenting with implanted electrodes as a means of restoring hearing loss.[17,18] NIH

1968 — The first commercial spinal cord stimulation system was introduced as a treatment for chronic pain.[19]

1970s-80s: UNLOCKING THE POTENTIAL OF NEUROTECHNOLOGY

1971-1973 — NIH researchers characterized the normal electrical function of deep brain areas involved in movement, which are affected in Parkinson's.[20,21,22] NIH

1972 — The first functional cochlear implant prototype, using a single electrode, was implanted into a patient.[23]

1973 — Using technology from spinal cord stimulation, investigators developed the first long-term, implanted device to stimulate the brain.[24] NIH

1979-1983 — Researchers used a new animal model for Parkinson's disease to identify brain regions responsible for movement and motor symptoms.[28,29,30] NIH

1980s — Academic researchers, alone and in partnership with technology companies, worked to upgrade cochlear implants using multiple electrodes.[25,26,27] NIH

1984-1985 — The FDA approved the first two cochlear implant devices, which were the first neural prostheses approved to treat hearing loss in adults.[31]

LATE 1980s/1990s: NEXT GENERATION DEVICES AND APPLICATIONS

1987-1998 — Studies, some funded by the NIH, revealed that electrical stimulation of deep brain regions could reduce tremors associated with Parkinson's disease.[33,34,35,36] NIH

1990 — The FDA approved cochlear implant use in children, enabling hearing to be restored during key developmental years.[32]

Mid-1990s — Industry scientists performed clinical trials of deep brain stimulation for tremor and Parkinson's disease.[37,38]

2000s-2010s: A RAPIDLY GROWING FIELD SEEKING NEW TARGETS

2002-2003 — A deep brain stimulation device was approved by the FDA to treat symptoms of Parkinson's disease.[39]

2009 — FDA approves a humanitarian exemption for deep brain stimulation as a treatment for Obsessive-Compulsive Disorder.[40]

2011-2015 — Researchers used electrical stimulation to help patients with spinal cord injury regain control of bodily functions, make small voluntary lower body movements, and briefly stand unaided.[41,42] Ongoing studies have begun stimulating the spinal cord through the skin.[43] NIH

2014 — The FDA approved the first visual prosthesis,[44] developed with NIH support, which allows patients with certain types of vision loss to perceive a small, low-resolution visual field. NIH

Cochlear implants are devices that translate sounds into electrical stimulation of the nerves in the inner ear, allowing many people with hearing loss to hear sounds and understand speech.

NIH *indicates NIH-funded milestones*

IMPACTS OF NEURAL STIMULATION TECHNOLOGIES

The use of neural stimulation technologies can compensate for lost nerve function, improve quality of life, and lower the cost of education and treatment. The two examples below illustrate the value of neurotechnology and its potential application to diverse diseases and conditions.

COCHLEAR IMPLANTS

Over 80% of children who received an implant by 18 months of age were able to join and participate in classes with their hearing peers.[47]

- As of December 2012, **approximately 324,200 implants have been fitted worldwide,** a nearly 30-fold increase from 1995.[45] In the United States, roughly 58,000 were implanted in adults and 38,000 in children.[46]
- The vast majority of cochlear implant users **continue to use their implant 10 years** after implantation.[48]
- Implantation saves society **$30,000-50,000** per person over a lifetime.[49,50]

DEEP BRAIN STIMULATION

DBS patients experience about **5 hours of additional easy moving time** per day.[53]

- Over **100,000 people with Parkinson's disease worldwide** have received implants.[51]
- DBS reduces disease symptoms, and can be more effective than drug therapy, which involves unpleasant side effects.[52]
- Patients continue to experience positive effects for **10 or more years.**[54]
- DBS can lessen Parkinson's patients' reliance on drugs for symptom relief, **reducing drug side effects by 44%.**[55]
- The two main pioneers of DBS as a Parkinson's treatment shared the 2013 Lasker Prize, often called America's Nobel.[56]
- DBS has an FDA Humanitarian Device Exemption to treat obsessive compulsive disorder, and is being tested in other conditions, such as treatment-resistant depression and dementia.[57]

SUPPORTING A FUTURE WHERE NEUROLOGICAL DAMAGE IS TREATABLE

- Our understanding of the nervous system will continue to grow, thanks in part to major research efforts like the **Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative**[58] and the **NIH Common Fund's Stimulating Peripheral Activity to Relieve Conditions (SPARC) program**.[59] These programs aim to develop and apply new tools to map the nervous system, read its activity, and alter that activity to improve function for an ever-growing number of conditions.
- These initiatives support research that could one day allow implanted neurotechnologies to automatically detect and prevent epileptic seizures,[60] restore bladder function and reduce bladder pain,[61] relieve treatment-resistant depression[62], and make everyday activities easier for patients with traumatic brain injuries[63], to name just a few possibilities.
- Advances in neural stimulation technology, in combination with a deeper understanding of the nervous system, offer a path to an incredible goal: a future in which the effects of neural diseases and injuries can be reversed.

For references, supplementary information, and more on the impact of NIH, please visit **http://www.nih.gov/impact**