Repairing the Injured Brain with Direct Neural Interfaces

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Neuroprosthetic devices used as interfaces with the nervous system generally can be categorized as open-loop neuromodulation systems, that directly or indirectly excite neural tissue, or brain-computer interfaces, that derive control signals from the brain to operate external devices. Increasingly, neuroscientists, computer scientists and engineers are beginning to envision and develop closed-loop systems that stimulate neuronal populations contingent upon a particular neuronal signal derived from another population of neurons. In the near future, investigations into the feasibility and efficacy of closed-loop systems for treating neurological conditions will likely emerge. Such conditions will include epilepsy, Parkinson's disease, and potentially stroke, traumatic brain injury and spinal cord injury. Thus, Dr. Nudo and his colleagues are focused on understanding how such systems interact with the neural circuitry and how communication may be altered in an adaptive way. Dr. Nudo's current research program focuses on the potential ability for closed-loop systems to regulate synaptic potentiation in long-distance pathways in the nervous system, particularly cortico-cortical pathways between different functional areas. Because the demonstration of long-term potentiation and long-term depression in animal preparations has utilized stimulation timing protocols that are not typically feasible using non-invasive techniques, Dr. Nudo's current pre-clinical model employs recording microelectrodes implanted within the cerebral cortex, and microdevices that discriminate individual action potentials (spikes) in real time, process discriminated spikes from multiple input channels, and then electrically stimulate remote brain regions using implanted microelectrodes. Studies in Dr. Nudo's laboratory have demonstrated the ability of this closed-loop system to modulate synaptic potentiation between the two areas and promote functional recovery after brain injury. Despite the challenges of invasive procedures using implantable technology, such closed-loop systems have the potential to provide new treatment avenues in a host of neurological conditions.