On the frontiers of cyborg science

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No longer just fantastical fodder for sci-fi buffs, cyborg technology is bringing us tangible progress toward real-life electronic skin, prosthetics and ultraflexible circuits. Now taking this human-machine concept to an unprecedented level, pioneering scientists are working on the seamless marriage between electronics and brain signaling with the potential to transform our understanding of how the brain works—and how to treat its most devastating diseases.

Their presentation is taking place at the 248th National Meeting & Exposition of the American Chemical Society (ACS), the world's largest scientific society.

"By focusing on the nanoelectronic connections between cells, we can do things no one has done before," says Charles M. Lieber, Ph.D. "We're really going into a new size regime for not only the device that records or stimulates cellular activity, but also for the whole circuit. We can make it really look and behave like smart, soft biological material, and integrate it with cells and cellular networks at the whole-tissue level. This could get around a lot of serious health problems in neurodegenerative diseases in the future."

These disorders, such as Parkinson's, that involve malfunctioning nerve cells can lead to difficulty with the most mundane and essential movements that most of us take for granted: walking, talking, eating and swallowing.

Scientists are working furiously to get to the bottom of neurological disorders. But they involve the body's most complex organ—the brain—which is largely inaccessible to detailed, real-time scrutiny. This inability to see what's happening in the body's command center hinders the development of effective treatments for diseases that stem from it.

By using nanoelectronics, it could become possible for scientists to peer for the first time inside cells, see what's going wrong in real time and ideally set them on a functional path again.

For the past several years, Lieber has been working to dramatically shrink cyborg science to a level that's thousands of times smaller and more flexible than other bioelectronic research efforts. His team has made ultrathin nanowires that can monitor and influence what goes on inside cells. Using these wires, they have built ultraflexible, 3-D mesh scaffolding with hundreds of addressable electronic units, and they have grown living tissue on it. They have also developed the tiniest electronic probe ever that can record even the fastest signaling between cells.

Rapid-fire cell signaling controls all of the body's movements, including breathing and swallowing, which are affected in some neurodegenerative diseases. And it's at this level where the promise of Lieber's most recent work enters the picture.

In one of the lab's latest directions, Lieber's team is figuring out how to inject their tiny, ultraflexible electronics into the brain and allow them to become fully integrated with the existing biological web of neurons. They're currently in the early stages of the project and are working with rat models.

"It's hard to say where this work will take us," he says. "But in the end, I believe our unique approach will take us on a path to do something really revolutionary."

More information: Title: Nanoelectronics meets biology: From new tools to electronic therapeutics

Abstract
Nanoscale materials enable unique opportunities at the interface between the physical and life sciences, and the interfaces between nanoelectronic devices and cells, cell networks, and tissue makes possible communication between these systems at the length scale relevant to biological function. In this presentation, the development of nanowire nanoelectronic devices and their application as powerful tools for the recording and stimulation from the level of single cells to tissue will be discussed. First, a brief introduction to nanowire nanoelectronic devices as well as comparisons to other tools will be presented to illuminate the unique strengths and opportunities enabled by active electronic devices. Second, opportunities for the creation of powerful new probes capable of intracellular recording and stimulation at scales heretofore not possible with existing electrophysiology techniques will be discussed. Third, we will take an 'out-of-the-box' look and consider merging nanoelectronics with cell networks in three-dimensions (3D). We will introduce general methods and provide examples of synthetic 'cyborg' tissues innervated with nanoelectronic sensor elements that enabling recording and modulating activity in 3D for these engineered tissues. In addition, we will discuss extension of these nanoelectronic scaffold concepts for the development of revolutionary probes for acute and chronic brain mapping as well as their potential as future electronic therapeutics. The prospects for broad-ranging applications in the life sciences as the distinction between electronic and living systems is blurred in the future will be discussed.

References

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3. Q. Qing et al., *Nature Nanotechnol*. 9, 142-147 (2014)

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