Reverse and Forward Engineering of the Brain

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Abstract

The US National Academy of Engineering identified "Reverse-engineer the brain" as one of 14 grand challenges for engineers in the 21st century, and an online poll ranked this as the 4th most important. A strict definition is the discovery of the principles underlying the functioning of the brain, much the way reverse engineering implies taking a device apart to discover its components and design. By analogy "forward engineering" implies using that knowledge to build a new device that incorporates those components and design concepts to accomplish a similar function. Neuroscience has made tremendous strides in reverse engineering the brain, learning the anatomy, chemistry, and functional properties from molecular to cellular to systems to behavior. Neural engineering, building off this base knowledge, has made tremendous strides in both directions. Many engineering technologies, from early electrical recording to advanced magnetic resonance imaging to computational models, have contributed spectacularly to our understanding of brain function. However, forward engineering has also been spectacular, with cochlear implants being perhaps the best example, but complemented by a number of neuroprosthetic devices in various stages of development. Also included are the wealth of brain machine interfaces that extend brain functioning to control the outside environment. Finally, this talk discusses the author's own contributions to the field of neural cell culture, with approaches that allow the design of neural circuits in a dish with consequent manipulation of the functional properties of neural tissue.