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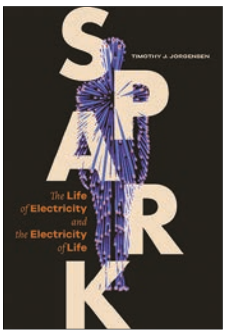
Book

Shocking discoveries and mysteries



Spark: The Life of Electricity and the Electricity of Life
Timothy J Jorgensen
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Despite more than a century of neuroscience since Santiago Ramón y Cajal proposed his neuron theory, "The brain remains largely an electrical black box. We send electrical signals in and we get electrical signals out, but what it all exactly means is open to a lot of interpretation and some intense controversy", remarks health physicist Timothy Jorgensen in his new book. Even so, neuroscience and the application of electricity to medicine have made striking progress, without a profound understanding of how neurons and electricity control brain functioning, behaviour, and consciousness. This reminds Jorgensen of the key electrical applications of the 19th century: the telegraph, motor, generator, transformer, relay, telephone, photoelectric cell, phonograph, light bulb, radio, and power industry. These advances came before physicist J J Thomson's discovery in 1897 of the electron: the basic electrical concept which, even today, despite the 20th-century revelations of quantum theory, remains something of a black box too.

The combination of uncertainty and controversy about neural electricity makes *Spark: The Life of Electricity and the Electricity of Life*, Jorgensen's remarkably diverse story of this crucial subject, full of vitality. In addition to examining the electron and the neuron, the book ranges from sparks around ancient amber (*electrum* in Latin) through lethal lightning strikes (one of which triggered the schoolboy Cajal's interest in science), electrical experiments with frogs' legs by physicist Michael Faraday, and the conception in 1881 of the electric chair for capital punishment by dentist Alfred Southwick to the present-day development of artificial intelligence in computers. Jorgensen even includes invitations to safe self-experimentation by the reader, such as tingling the tongue by touching it to the terminals of an ordinary 9-volt battery. Appealing for both the intended general reader and specialists from the many fields whom the author consults, the book makes no claim, however, to be a history of electricity. Such a history would have to extend far beyond biology, medicine, and physics: the book's primary focus. It would also require the inclusion of mathematics, which Jorgensen deliberately avoids.

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As a professor of radiation medicine, and the author of *Strange Glow: The Story of Radiation*, Jorgensen is acutely aware of controversy surrounding electricity in the history of medicine. Polymath Benjamin Franklin, inventor of the lightning rod in 1752, also had medical interests. Using a Leyden jar to store electrical charge, Franklin administered daily electric shocks to people with paralysed muscles and noted some immediate improvement, but honestly admitted to a physician friend in 1757 that the improvement did not continue after the fifth day and that the patients always relapsed. He eventually abandoned these experiments. Nevertheless, 19th-century physicians promoted electrotherapy and it became fashionable until the end of the century. But electrotherapy finally became taboo in the medical community because of bogus claims and risky procedures, such as the supposed treatment of sexual disorders by application of electricity to the male and female sexual organs—epitomised by a quack, battery-powered belt enclosing the male genitals invented by physicist Isaac Pulvermacher, which claimed to cure impotence and erectile dysfunction, in use until the 1920s.

Then, with the maturing of the electrical and neurological sciences during the 20th century, electrical treatments began to return to the clinic, such as electroconvulsive therapy (ECT) for depression and deep brain stimulation for Parkinson's disease, despite a lack of comprehensive understanding of electricity's neuronal effects. Now the use of electricity has expanded to research that is aiming for the restoration of vision and hearing, and the movement of prosthetic limbs under the mental control of individuals who have had amputations, as discussed in fascinating detail by Jorgensen. After dining in a restaurant with Richard McDonald, who is trialling a camera connected to the visual cortex bypassing the eyes, Jorgensen comments: "I don't think the waiter distributing the menus to each of us even realizes that this man wearing strange headgear is blind". Jorgensen goes on to speculate that in the future "electricity may even replace many drugs as first-line therapies for treating a variety of diseases", potentially avoiding the adverse side-effects of those drugs.

The chapter about ECT, entitled "Inner sanctum", is particularly revealing. This therapy began in 1938 when neurologist Ugo Cerletti, assisted by psychiatrist Lucio Bini, experimented on a man with severe schizophrenia in Rome, Italy, who had been referred to Cerletti by the police. This painful, and potentially lethal, treatment was based on Cerletti's observations of pigs stunned by electrical shocks in a slaughterhouse, followed by his experiments with escalating voltages applied across electrodes attached to dogs' temples—120 volts for a few seconds to induce a seizure, 400 volts for over 60 seconds to kill a dog—ignoring the fact that it is not voltage, but amperage, that causes death. (A Taser electroshock weapon stuns, but does not kill, with 50 000 volts but only a few milliamps.) After several attempts to determine the patient's voltage threshold for seizures, he was given electroshocks that induced seizures at least 10 times over a few weeks and, according to Cerletti, made a remarkable recovery. Further trials by Cerletti on other people with schizophrenia produced similar results. Later, the treatment was applied to patients with depression, also with reported success. Soon, Cerletti's clinic was deluged with requests for ECT.

Today, ECT is administered under general anaesthesia and with muscle relaxants used to minimise muscle contractions during the convulsions, so that patients feel no pain. ECT is known to be effective in severe depression, because it has been subjected to "a string of randomised clinical trials", notes Jorgensen. Indeed, ECT is "among the more effective and safe treatments in medicine", he suggests. Yet, "No one is sure exactly how ECT works", he comments, rather disturbingly. One explanation, he writes, is the so-called anticonvulsive theory, which is based on the observation that most patients require the electrical dose to be steadily increased with each subsequent treatment. "The thought is that the mechanism causing seizure resistance is somehow linked to the treatment effect. But, of course, this 'hypothesis' just kicks the can down the road because we don't know the mechanism of the acquired seizure resistance," writes Jorgensen. No wonder ECT is also "one of the most controversial of psychiatric treatments", partly, no doubt, because of an understandable public fear of electrocution, infringements of patients' rights in the way ECT was used historically in psychiatry, and also ECT's cultural depiction as a means of patient torture, most notably in Miloš Forman's film about a psychiatric institution, *One Flew Over the Cuckoo's Nest* (1975), based on Ken Kesey's novel.

Another controversial area that Jorgensen explores is artificial intelligence (AI), the subject of the book's final chapter, "Future shock", following his discussion of the inner mysteries of the brain. He tags it, memorably, to a detailed presentation of the Californian launch in 2019 of Neuralink, a company co-founded in 2016 by business magnate Elon Musk, which aims to "link" the brain to computers. As Musk announced: "It is important for us to address brain-related diseases...Whether it's an accidental, congenital or brain-related disorder, or a spinal disorder... we can solve that with a chip. And this is something that most people don't understand yet." As Jorgensen describes, Musk wants to create computers as intelligent as HAL, the artificial general intelligence (AGI) computer in the film *2001: A Space Odyssey* (1968), which its director, Stanley Kubrick, mistakenly predicted would become a reality by 2001. But is AGI, as opposed to AI, really feasible in the coming decades, as predicted by Musk—given our ignorance about the functioning of the brain?

Musk's ambitious goal, of course, raises the long-debated issue of whether the brain really is like a computer—a comparison strongly disliked by some neuroscientists. They maintain that the most intriguing aspects of the brain, such as consciousness and sleep, emerge from its functioning, rather than being programmed into its component parts. Thus, a true understanding of the brain requires studying its control of behaviour, not only its internal circuitry. Neuralink proposes to place circular computer chips in a human brain, each of which would be connected to 3072 electrodes spread over 96 threads about one-tenth the diameter of a human hair (that is, 32 electrodes entwined in a single thread). This procedure would supposedly be achieved using a small cookie cutter-like device to make a hole in the skull so as to access the cortex, through which a neurosurgeon would then insert the threads into the cortex with the assistance of a robotic "sewing machine" at the rate of up to six threads per minute. Then the hole will be plugged with a chip. According to Jorgensen, "This sewing machine approach for brain implantation may seem futuristic, but Musk claims a human clinical trial is imminent". Jorgensen thinks it is likely to take longer to happen, but supports the idea in principle as a "worthwhile and laudable endeavour" in the amazing history of technology.

Yet Jorgensen thinks that Neuralink's plan "may very well fail in its ultimate goal of curing brain diseases", after discussing the concept with various specialists, whom he quotes at some length. Computer scientist Stuart Russell, an expert on AI, points out that "we understand almost nothing about the neural implementation of higher levels of cognition in the brain, so we don't know where to connect the device and what processing it should do". Thus, "we may hit upon ways to provide the brain with additional memory, with communication channels to computers, and perhaps even with computer channels to other brains—all without ever really understanding how any of it works". After all, Jorgensen reminds the absorbed reader once again, the human brain inexplicably invented the electric power industry without any awareness of the electron.

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