Reviews

Brian Rasnow

Electricity, eels and evolution

Shutterstock/Cuson

Shocking discoveries
Electrogenic animals such as electric eels played key roles in developing our methods and understanding of science.

Spark from the Deep: How Shocking Experiments with Strongly Electric Fish Powered Scientific Discovery
William J Turkel
2013 Johns Hopkins University Press
$34.95hb 304pp

William Turkel's *Spark from the Deep* is a fascinating book that explores a little-known aspect of how we came to understand and control electricity: the role played by electrogenic animals such as electric eels and rays. Such animals, he writes, "inspired [us] to colonize an electric world", and in doing so, they profoundly transformed both our world and ourselves.

The book explores diverse areas of science and history, going well beyond mere descriptions of what happened to provide explanations of how and why biological and cultural evolutionary processes brought us there. A good example concerns Turkel's discussion of vivisection, which makes useful reading for anyone with occasion to defend animal research today. To observers in the ancient and early modern world, strongly electric fish posed quite a mystery because of their ability to inflict pain at a distance. The mechanisms behind this ability could only be found by "opening the box", but the act of doing so was (and still is) morally contentious.

Turkel argues that vivisection played an important role in the development of science because "treating humans and other animals as subjects for experiment or disassembly lowered the conceptual barriers between ourselves and our animal kin". In addition, he writes, vivisection "lowered the barrier between animate and inanimate. If an electric fish could be used as an apparatus, it might also be possible to build an artificial device that could generate a shock like an electric fish". This is exactly what Alessandro Volta did when he presented his first battery to the Royal Society in 1800, calling it his "organe électrique artificiel". What better example of the value of pure versus applied research than the fact that our ubiquitous battery was invented to mimic a part of a fish?

Turkel also points out that many modern medical devices "would not exist if it had not been for the variety of grisly experiments" undertaken in the early days of electricity research. In 1774, for example, a child who arrived "dead" at a hospital was resuscitated by electric shock. But for Turkel, these episodes are more than just interesting anecdotes from the history of medicine and technology; they also contain information about what characterizes us as a species. "We humans," he writes, "are unique in our willingness to treat just about anything as apparatus, including ourselves, one another, human body parts, other animals, animal body parts, inanimate objects, and hybrids of some or all of the above."

The reductionist practices of disassembling animals into functional components naturally led to questions about how they had been initially assembled. For Charles Darwin, electric fish were a "special difficulty" that became chapter 6 of his book *On the Origin of Species*. In it, he wrote: "It is impossible to conceive by what steps these wondrous [electric] organs have been produced…I have to make, in my mind, the violent assumption that some ancient fish was slightly electrical."

Darwin's "violent assumption" was, in fact, a wonderful example of the dynamic evolution of scientific theories. Nearly 100 years later, scientists confirmed his prediction, eventually discovering hundreds of species of weakly electric fish and multiple indisputable evolutionary pathways by which such electricity developed. Darwin actually predicted this multiplicity in a general sense, writing that "I am inclined to believe that in nearly the same way as two men have sometimes independently hit on the very same invention, so natural selection…has sometimes modified in nearly the same manner two parts in two organic beings, which owe but little of their structure in common to inheritance from the same ancestor." What a shame that so many adults today are ignorant of these incredibly powerful (and aesthetically and intellectually beautiful) theories that our ancestors worked so hard to discover and articulate.

Another gem in Turkel's book is his explanation of Darwin's reluctance to publish his *On the Origin of Species* until 1859 – 15 years after a previous work, *Vestiges of the Natural History of Creation*, "brought evolutionary debate to the mainstream". In *Vestiges*, the anonymous author (later revealed to be Robert Chambers, a Scottish journalist and geologist) argued that everything in nature is governed by physical laws, and electricity played a key role in this grand unification scheme. The debate that followed its publication was acrimonious. Turkel argues that *Vestiges* can be interpreted as proposing "a vision of nature appropriate to the industrial age and the middle classes". Consider how dramatically machines and pollution were changing people's relationships with each other and the world. Were these changes an inexorable consequence of natural law? One might see parallels today regarding climate change.

While electromagnetic phenomena were radically transforming industrial society, physiologists began exploring how to measure feeble bioelectricity in more typical animals. In the 1820s, the most sensitive current-measuring instrument available to scientists was a freshly pithed frog leg. Within a year of Alexander Graham Bell's 1876 invention of the telephone, Emil du Bois-Reymond and his students were listening to bioelectric signals from muscles and nerves. Their instruments opened up completely new kinds of perception – a prerequisite to manipulating and controlling those newly discovered domains. In more recent times, electric organs have been the source for purified ion-channel proteins and DNA, and weakly electric fish remain some of the best model systems for a more holistic "neuroethological" approach to understanding brain function. Unfortunately, funding for such "exotic" research has virtually dried up, in spite of its history of important discoveries.

Turkel demonstrates throughout his book how evolution is an incredibly powerful key, one that can unlock and explain disparate questions about how and why we came to be who and where we are in this world. His concluding chapter contains a concise summary of chemical evolution that was a prerequisite to biological evolution, and also the pre-prerequisite of cosmological evolution. Evolution does for history what calculus does for mathematics. Our pursuits of pure science starting with electric fish led us on an unpredictable path to the most important and transformative discoveries in human history. But although the path was unpredictable, the fact that humanity would embark on such a journey is deeply encoded in our genes.

Brian Rasnow is an applied physicist at California State University Channel Islands, US, e-mail brian.rasnow@csuci.edu

Web life: *Lunar Reconnaissance Orbiter Camera*

NASA/GSFC/Arizona State University

URL: http://lroc.sese.asu.edu

So what is the site about?

Launched in June 2009, NASA's Lunar Reconnaissance Orbiter has spent the past five-and-a-bit years mapping the surface of our Moon, with the initial goal of identifying safe landing sites for future manned missions. Its camera, the LROC, is one of seven instruments on board the spacecraft; together, these instruments transmit about 155 GB of data back to their Earth-bound controllers every day. This steady stream of data has, naturally, created some challenges for the LROC's science team. As they stated on the camera's website, "When you have over a million individual images of the Moon, what do you do with them?" Part of the team's response has been to develop this website, which contains several impressive visualizations and tools to help scientists (and curious onlookers) explore some of the fascinating and beautiful images in the LROC's archive.

What can I do on the site?

Amateur lunar enthusiasts will have fun with the site's Gigapan tool, which makes it possible for casual visitors to explore the LROC Northern Polar Mosaic. This composite image contains 680 gigapixels of valid image data and covers a patch of the Moon that, at 2.54 million km^2, is slightly smaller than the combined areas of France, Spain, Germany and Scandinavia – all at a resolution of 2 m per pixel. The result is, according to the site, "likely one of the world's largest image mosaics in existence, or at least publicly available on the Web", and one can easily pass a pleasant half-hour simply marvelling at the profusion of craters and other features in it. But the LROC site isn't just about pretty pictures. There are also links to a range of professional tools, such as the Lunaserv lunar-mapping service, that help both team members and external scientists extract data from the camera's huge, information-rich archive.

Who is it aimed at?

In addition to the pages for armchair explorers and members of the professional lunar-science community, the site also features areas that cater to teachers and students. The "Learn" section, for example, contains short answers to a handful of commonly asked questions about lunar science, including "Does the Moon have volcanoes?" (Answer: yes, several, but they're not active anymore) and "What is the largest impact feature on the Moon?" (Answer: the South Pole-Aitken Basin, which is 2500 km in diameter). The "Teach" section is more detailed, with a range of lesson plans, fact sheets and posters tailored towards students of all ages. One of the most complex projects, for example, asks older secondary-school students to design a chamber for growing terrestrial plants on the lunar surface, but there is also a junior version called "Moon Munchies" that should get the creative juices flowing for the youngest scientists.

Anything else?

If you only have a few minutes to spare, check out the "Images" tab, which showcases some of the LROC archive's "most exciting" shots of the lunar surface. At the time of writing, the top image in the list showed the eroding walls of the Maskelyne B crater – a reminder that the Moon has not always been static in geologic (lunalogic?) terms. Another image shows a track made by the Russian rover Lunokhod 2 as it trundled along the lunar surface in early 1973. At around 42 km, Lunokhod's journey is still the longest made by any rover on the surface of another celestial body. Thanks to the LROC, we can see where its travels ended: in another image, the 1.6 m-wide defunct rover shows up as an irregularly shaped black blob on the grey lunar surface.