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Cover illustration

Carlo Matteucci (1811–1868), the “frogs pile”, and the Risorgimento of electrophysiology

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The invention of the electric battery, communicated to the Royal Society of London by Alessandro Volta (1745–1827) on 20th March 1800, had a tremendous historical impact in putting electricity at the centre stage of nineteenth century science and society. Volta’s invention had been stimulated by previous research on animal electricity performed by Luigi Galvani (1737–1798) in Bologna, in the second half of the eighteenth century. It had been inspired particularly by a reflection on the structure of the electric organ of some fishes, like the torpedo and the eel of Guyana, which accounts for the phrase *organe électrique artificiel* first used by Volta to describe his invention (see Finger and Piccolino, 2011).

An immediate historical consequence of Volta’s success with his device was to cast doubt on Galvani’s hypothesis of intrinsic electricity present in the excitable tissues of ordinary animals, and their involvement in fundamental biological processes such as muscle contraction and nerve conduction. Volta considered that the electrical activity responsible for frog muscle contractions in Galvani’s experiments originated from the metals used to connect muscles and nerves, and that it was not genuinely “animal”. Subsequent research showed that, whenever a metal was put in contact with solutions of similar composition to those of animal tissues (i.e. containing salts, acids or bases) a current was produced as a consequence of electrochemical effects. The “electrophysiological” researcher of the first half of the nineteenth century, wishing to record animal electricity with a galvanometer, was thus confronted with an apparently unsolvable puzzle: how to demonstrate the biological origin of a current measured, given that metal electrodes were needed to connect the animal tissues to the recording instrument. Carlo Matteucci (1811–1868), who would play an important role in the process leading to Italian political unification, the *Risorgimento*, was able to square this circle. He graduated from the University of Bologna and published his first study in the field in 1827 when he was only 16 years old. Less than 10 years later, he obtained an important electrophysiological result, the production of a spark from the shock of a torpedo (Matteucci, 1836). In 1840, soon after his appointment as professor at the University of Pisa, he started the research leading to the measurement of genuine animal electricity from the muscles of frogs and other animal preparations (Matteucci, 1842).

There were some significant steps in Matteucci’s path to this discovery. He first realized that electricity could be measured in a purely muscle preparation (i.e. without nervous tissues) which excluded the possibility that the current was due to a chemical heterogeneity between muscle and nervous tissue (or other physical artefacts). Next he discovered that, in order to detect this muscle electricity, he had to put one electrode of the galvanometer on the intact part of the muscle, and the other on the cut side. He was now ready for the “great step”, somewhat similar to that made by Volta and inspired by a similar mental image. In the case of Volta, it had been the disc assembly of the electric organ of fishes, whereas for Matteucci it was the Voltaic battery itself. Matteucci cut several frogs’ thighs and assembled them serially in a battery fashion (as shown in the cover illustration); the intact part of one preparation was in contact with the cut part of its neighbour. The current recorded by the galvanometer showed a step increase with the addition of each new hemi-thigh, while the number of metal-tissue contacts remained fixed. This was clear evidence of the biological nature of the current recorded. The first image of this landmark experiment was published in a Swiss scientific journal in 1843 (see Fig. 1), and amplified in two chapters of Matteucci’s (1844) important treatise (from which the motif in the cover illustration was

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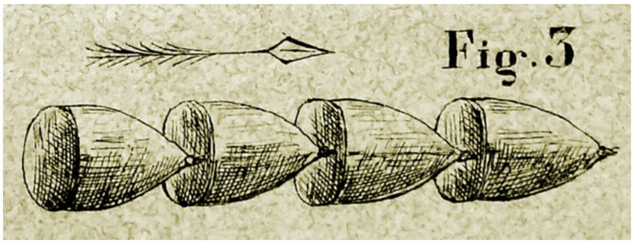

Fig. 1 – The first published image of the "frogs pile" experiment by which Matteucci succeeded in proving the biological origin of the current measured with a galvanometer in muscles. As would appear clearly later, with Bernstein's membrane theory of bioelectric potentials, the current between the cut and intact surface of the muscle is due to the potential difference between the interior and the exterior of the muscle fibres, the injury providing a lower resistance relative to the interior of the fibres. Matteucci correctly found that the cut face is negative with respect to the intact surface. (From Matteucci, 1843.)

derived). This was the year of glory for Matteucci: he gave demonstrations of the experiments of the "frogs pile" or "Voltaic frogs" (as they were called) in France and England (both in London and in York). The same year he received a letter announcing the award of the Copley Medal by the Royal Society of London. It was written by John Frederic Daniell (1790–1845), who had invented the cell that bears his name a few years earlier; it was an improvement on Volta's battery. In his role as Foreign Secretary of the Royal Society, Daniell began the letter with these words: "Dear Sir, I never sat down with greater pleasure to the performance of my official duty, than I do this day to announce to you that the President and Council of the Royal Society of London for the promotion of Natural Knowledge, have unanimously awarded to you the Copley Medal for your Research in Animal Electricity". The letter concluded: "I truly rejoice that I was one of those who had the high gratification of seeing the unambiguous experiments by which you have established one of the most important discoveries of the age." This discovery was a catalyst for the rebirth of electrophysiology, first through the work of German and later British physiologists, and it was also an important step in the emergence of modern neuroscience.

Carlo Matteucci was born two centuries ago but this remarkable anniversary has passed almost without notice. With his "frogs pile" discovery, he provided the platform from which electrophysiology could spring by establishing experimentally the link between Galvani and modern electrophysiology. Matteucci is celebrated in the cover illustration with his portrait in combination with an image of his landmark "frogs pile" experiment which essentially resolved the Galvani-Volta controversy and fostered the emergence of modern electrophysiology. The bicentenary of the birth of this pioneer surely warrants recognition.

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