Alessandro Volta: Still Fully Charged After 200 Years

by S. Borsacchi, M. Guidotti, A. Sanson, A. Minguzzi, A. Pozzi, A. M. Paci, F. Kerton, M. Peruzzini

In the framework of the International Year of Basic Sciences for Sustainable Development (UNESCO IYBSSD July 2022—2023), the Italian IUPAC NAO organized an open and educational event titled Alessandro Volta's heritage and electrochemistry to respond to the great challenges of the future. Designed to highlight the role of chemistry as a fundamental science to respond to big challenges, the day event was organized in collaboration with two important scientific Italian institutions including the Italian National Research Council (CNR) and the University of Insubria, with the support of IUPAC and its Committee on CHEMical Research Applied to World Needs (CHEMRAWN) (IUPAC project #2022-018-1-021), and in collaboration with the International Science Council.

At the center of the event was the great and creative scientist Alessandro Volta and his extraordinary invention of the voltaic pile, which paved the way to electrochemistry and its applications. This great legacy had an extraordinary impact on innovation and scientific progress over the last two centuries and will, most likely, play an even more important role in the coming years in achieving and maintaining sustainable development.

The event was held on 24 October 2022, in Como, the birthplace of Volta, a splendid Italian town lying on the charming lake of Como, famous for its natural and artistic beauties and for its villas and palaces, as well as a great example of a territory dedicated to innovation, internationalization, and sustainable growth. Furthermore, being close to the Swiss border, Como is ideally located at the crossroads between Mediterranean/Italian cultural area and the Northern European one, as a relevant meeting point between different cultures and traditions. It is worth noting that the University of Insubria, the local academic institution which hosted the event in the beautiful space of the Romanesque Basilica of Sant'Abbondio, is strongly committed to sustainability, environmental protection and ethics, having, since 2018, an UNESCO chair on Gender Equality and Women's Rights in the Multicultural Society.

Students from both the university and secondary schools, researchers and citizens were invited to participate, in person or virtually, through several communication channels, such as the IUPAC and Italian NAO websites, the mailing lists of the CNR and the Italian Chemical Society and social media. Some 70 people attended the meeting in person and 30 joined the event online.

The workshop was opened by two video messages from the presidents of IUPAC, Javier Garcia Martinez, and ISC, Peter Gluckman. In particular, the IUPAC President highlighted the importance of the IYBSSD as a great opportunity for all scientists to work together to

Participants of the workshop in the Sant'Abbondio cloister (Como)

build a better future for all people. Electrochemistry is vital for achieving a sustainable development and in this respect Volta's role and the strong connection between past and future is particularly crucial. In the second video-message, Peter Gluckman, reflecting on Volta's discovery, underlined the importance of basic sciences and their strong impact on our lives and stressed the importance of collaborations between scientists and scientific unions in this critical period.

In keeping with both IUPAC and ISC Presidential messages and auspice, the synergy between the two organizations has been very positive and very effective for the Italian NAO to design and implement this event for the IYBSSD.

Supporting messages from the representatives of the sponsors of the event, the Lombardy section of the Italian Chemical Society (SCI), the Royal Society of Chemistry—Italy Section, the International Society of Electrochemistry and De Nora Foundation concluded this opening part.

Finally, Stefano Serra Capizzano, Prorector of the University of Insubria, pointed out the greatness of Volta as a scientist but also as a humanist, mentioning his commitment for the acquisition of Galileo's manuscripts in the Como Library. These remarks reminded and showed the importance of moving next generations researchers towards a unified knowledge as in the spirit of this celebration.

The event was split into two parts: the first saw the participation of three eminent speakers who gave three stimulating and complementary lectures in Italian, moving from the history of the life and discoveries of Alessandro Volta to the future of electrochemistry, looking to batteries and clean energy.

Luigi Fabbrizzi, emeritus professor of the University of Pavia, where Volta was professor and rector, brought the audience back to the end of the 1700s and the beginning of the 1800s, telling in a lively and fascinating way the history of the life and the scientific career of Alessandro Volta, a multifaceted pioneer of experimental physics and chemistry. Indeed, Volta, observing animal phenomena and learning from other brilliant physicians and biologists, such as Luigi Galvani and Lazzaro Spallanzani, identified the phenomenon of electricity caused by the contact between two metals. He built the first battery, the so-called voltaic pile, which he actually named *artificial electric organ*. Volta was an extraordinary experimentalist, who tested most of his ideas on himself and on the environment around him. He travelled extensively abroad and communicated with many scientists across Europe. His merits were recognized, being awarded the Copley medal in 1794, but he also experienced difficulties and competitiveness in scientific publications, even at that time. Nicholson, inspired by Volta's studies, discovered the electrolysis of water, which directly leads us to one of the most important present and future paths of electrochemistry.

Moving from the past to the future, Catia Arbizzani, professor at the University of Bologna, gave an overarching lecture on batteries and their crucial role in the decarbonization. To electrify more and more our lives, we need efficient and sustainable batteries, capable of storing and accumulating energy. Even if, at present, the most widespread batteries are based on lithium ions, it is absolutely necessary that research moves toward more sustainable and efficient systems,

The organizers and the speakers of the event. From left to right: A. Minguzzi, M. Guidotti, F. Bella, A. Pozzi, A.M. Paci, M. Peruzzini, L. Fabbrizzi, C. Arbizzani, and S. Borsacchi.

improving materials and processes, with particular attention to recycling and reuse. The lecturer pointed at the importance of combining photovoltaics and batteries and exhorted all the young people present to a better and responsible use of energy and devices.

The last lecture was given by Federico Bella, professor at the Turin Polytechnic, who outlined an interesting picture of the synergies to be adopted to effectively approach the energy transition and decarbonization. The different tools and methods that chemistry can provide must complement, rather than compete, with each other. In this sense combining photovoltaics with electrolysis, making solar fuels, producing energy vectors, such as hydrogen or, better, ammonia via electrochemical reduction of nitrogen, are key topics on which multidisciplinary efforts must be devoted.

These last ideas introduced the second part of the event, a hybrid round table, in presence and online. This session, held in English and chaired by Alessandra Sanson, acting director of CNR-ISSMC (Institute of Science, Technology and Sustainability for Ceramics), saw the participation of the three lecturers together with Francesca Kerton, Chair of IUPAC CHEMRAWN Committee and Lidia Armelao, President of the Inorganic Chemistry Division of IUPAC (Division II) and current Director of CNR-DSCTM (Department of Chemical Sciences and Materials Technology). The panellists discussed the role of chemistry, electrochemistry, and partnerships in building sustainable development. It clearly emerged the involvement of chemistry and the need for chemists to work towards the many different UN SDGs, from energy, to environment to zero hunger, as well as the importance of collaborating with other scientists to address the current challenges. In the specific fields of electrochemistry, the partnership with scientists, engineers, and industries is mandatory for optimizing both materials and processes, which are still the core of all electrochemical processes and are

Video messages of the IUPAC president, J. Garcia Martinez and of the ISC President, P. Gluckman.

crucial for future advances. Reflecting on the future of electrochemistry, the panellists also highlighted the importance of focusing on recyclable and reusable devices, with a careful choice of non-critical chemical elements.

A common message, strongly raised by the speakers, concerned the need of setting up specific multidisciplinary university curricula aimed at training specialists in electrochemistry and batteries, who are and will be increasingly needed.

This event, full of history, concepts, ideas, and perspectives, clearly demonstrated the importance of chemistry for our present and future and their great potential for building a diffuse well-being for all. It has been a very instructive and inspiring moment for all participants, and in particular, for the younger ones. We hope that chemists and electrochemists will significantly contribute to build a better future.

The video recording of the event is available on the Italian NAO website (www.iupac.cnr.it).

Starting from this event, the three lecturers kindly agreed to prepare in the coming months a feature article to be submitted for publication on *Pure and Applied Chemistry*.

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Alessandro Volta: Man or Myth?

Biography prepared by Luigi Fabbrizzi

Alessandro Volta was born in Como on 18 February 1745 into a family of minor nobility, the sixth of seven children. The older brothers and sisters all devoted themselves to religious life (friars, priests, and nuns). Alessandro chose a different life: from the age of thirteen he attended the Jesuit school, then entered the seminary, but at eighteen he left to devote himself to the study of physics, in particular electricity. As an autodidact, Volta began doing experiments at home and corresponding with important Italian and foreign physicists. At the age of twenty he began to frequent the laboratory of his friend Giulio Cesare Gattoni, a canon and amateur physicist. At the age of twenty-four Volta published his first work on electricity ("De vi attractiva ignis electric ac phaenomenis inde pendentibus"), a treatise that he sent to the most illustrious Italian scientists. In 1774, he was appointed Superintendent and Regent of the Royal Schools of Como. In 1775 he communicated to Joseph Priestley the invention of a surprising instrument, which he called the "perpetual electrophorus." This apparatus was able to produce electricity not by friction, as in the electrostatic machines of that time, but by induction and was immediately applied to the systematic production of abundant and lasting supply of electricity in all European laboratories. Volta so achieved considerable notoriety in the scientific world: in 1775 he was appointed professor of Physics at the 'Real Ginnasio' in Como and in 1778 he was called to the University of Pavia, where the chair of physics, formerly held by Carlo Barletti, a piarist father, was split into that of Experimental Physics—with a pronounced phenomenological character—which was assigned to Volta, and that of General Physics—based on solid mathematical foundations—which remained with Barletti. In contrast to the provincialism of the Italian scientists of the time, who travelled very little, thus avoiding comparison with other cultures, Volta between 1781 and 1782 travelled in Europe through Savoy, Switzerland, Germany, Belgium, Holland, France and England, with the aim of finding new instrumentation for his laboratory and to exchange ideas and build relationships with the leading scientists of the time.

In Pavia Volta continued his research in the field of electrostatics inventing new devices such as the condenser electrometer and perfecting known apparatuses. The turning point was 1791, when Luigi Galvani, professor of anatomy and obstetrics at the University of Bologna, published a pamphlet in Latin entitled "De viribus electricitatis in motu musculari," which he sent to leading Italian scientists, including Volta. Galvani had observed that when an arc made of two different metals is touched to a muscle and a nerve of a treated frog (i.e. killed and skinned), the legs of the frog contract as in the grip of toxic convulsions. Galvani formulated the idea that there exists an animal electricity, an

electric fluid secreted by the brain which, conducted by the nerves, reaches and activates the muscles. Volta repeated Galvani's experiments and extended them to a variety of animals (mammals, reptiles, birds, insects, worms) each time observing contraction induced by contact with a dimetallic arc and formulated a new theory on the electrical nature of the phenomenon: electricity is generated by the contact of two different metals (metallic electricity) and the muscular or nervous tissue of the frog behaves as a 2nd species conductor (today we say electrolyte). The frog (or the animal in question) closes the circuit. Volta published these results in the periodical of the Royal Society of London, Philosophical Transactions, the most prestigious scientific journal of the time (A. Volta, Account of Some Discoveries Made by Mr. Galvani of Bologna, With Experiments and Observations on Them. Phil. Trans R. Soc. Lond. 1793, 83, 10-44, in French). The article aroused great interest and Volta was awarded the Copley Medal (the equivalent of the Nobel Prize at the time) by the Royal Society for this. A scientific controversy on the nature of electricity, whether animal or metallic, then arose between Galvani and Volta, a controversy that was also bitter, but always conducted within the limits of mutual respect and esteem. Volta settled the matter in 1800 when he published the work: A. Volta, On the Electricity Excited by the Mere Contact of Conducting Substances of Different Kinds, Phil. Trans. R. Soc. London 1800, 90, 403-431, in French). The article described a device consisting of a column of contiguous pairs of silver and zinc discs, interfaced by cardboard discs soaked in salt water (a device later defined as pile in English literature). For the design of the pile Volta was inspired by the columnar and discoidal structure of the electric organs of the torpedo raia (electric fish already known in Roman times) Volta's pile generated an electric shock in anyone who touched the two ends with their hands and the shock was revealed the stronger the greater was the number of pairs of metal discs of which it was made. During the months of construction of the pile, in the midst of the war between Austria and Napoleon, the University of Pavia had been closed by the Austrians and the professors fired (some, like Father Barletti, imprisoned for "democracy and Jacobinism"). Volta built the pile in his country house in Lazzate (Como) and this explains why he limited himself to experimenting the effects of the electric current on his sense organs and not on the variety of animals that his biologist colleagues at the

Alessandro Volta (1745 – 1827)

University of Pavia from Institute directed by Lazzaro Spallanzani had treated and made available in 1793. Volta's article was a resounding success and hundreds of professional or amateur scientists throughout Europe built piles, tried to improve their efficiency and explored their applications.

Volta returned to his university, reopened by the victorious Napoleon and was invited by Napoleon himself to Paris to illustrate his research in front of the Académie des Sciences. Napoleon rewarded Volta with a medal, the title of Senator of the Kingdom of Italy and the title of Count (with attached generous salaries). Volta gradually reduced his didactic and scientific activities in Pavia, partly due to family commitments (he had married at the age of fifty, had three children and wanted to take care of their education), partly because he was satisfied with the enormous success and perhaps aware of not being able to compete in the development of the pile with much more aggressive European research centers, operating in countries with a more consolidated and widespread scientific and technological tradition than Italy in the 19th century. In 1819 he retired from the University, in 1827 he died in Como at the age of 82.