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The Impact of Alessandro Volta on German Culture

Thirty years ago, Cesare Cases gave a lecture at the University of Pavia, concerning Volta and his influence on German culture. Cases[1] was inspired by Georg Christoph Lichtenberg (1742-1799), who left an important testimony thanks to his correspondence with the major German scientists of the time. Unfortunately, due to his untimely death, Lichtenberg was not able to witness one of the major turning points of his age: the invention of the battery, which was announced on March 20, 1800.

Volta's famous journey with Antonio Scarpa[2] dates back to 1784, when they travelled to cities such as Vienna, Prague, Dresden, Leipzig, Berlin, Göttingen, Kassel, Gotha, Bamberg, Nuremberg, Augsburg, Munich and Innsbruck. Their journey also included a brief stop in Göttingen from October 15 to October 21, where they stayed with Lichtenberg. There followed a period of ten years during which they communicated less frequently; Lichtenberg wrote his last letter to Volta in 1795, four years before his death.

In a letter sent to the Regio Imperial Consiglio di Governo on April 1, 1788,[3] Volta describes Lichtenberg as "one of the best physicists of our time", thanks to his numerous experiments conducted with the electrometer, with regard to meteorological phenomena, as well as the discovery of electrical figures in the electrophorus. Lichtenberg considered himself a "whole man", which was an expression taken from the English magazine *The Spectator*. It was indeed this consideration he had of himself which guided his aphoristic considerations, defined as "scribbling-books", and entitled *Sudelbücher*: "I lay it down therefore as a rule, that the whole man is to move together".[4] This affirmation, as pointed out by Cases, explains how people from a broad range of disciplines could take "Volta and the

[1] CASES (1973).
[2] See in particular letter n. 608, addressed to Count Johann Joseph Wilzeck of Berlin on behalf of Alessandro Volta, dated September 21, 1784, in *VE*, II, pp. 245-9.
[3] *VE*, II, pp. 429-37, on p. 435.
[4] CASES (1973), pp. 34 and f.

German Culture" to heart.[5] Like Lichtenberg, Alexander von Humboldt (1769-1859) was a "whole man" and he also got to know Alessandro Volta. In this context Lichtenberg risked being struck by lightning in one of his numerous experiments on the subject. Similarly, Humboldt exposed his body to painful effects in order to verify the virtues of his galvanic experiments, in which zinc and silver plates were placed on open wounds in order to study nervous stimulation. All in all, this had nothing to do with the sensational experiments that were being conducted by physicists such as Nollet, Gray and du Fay. "Besides working at the Universities and Academies", these three men "were sought out in aristocratic salons where they had a great following of curious people who enjoyed their 'marvellous' shows".[6] Towards the completion of the final draft of his important study in the field of physiology *Versuche über die gereizte Muskel - und Nervenfaser*,[7] Humboldt realized that Christian Heinrich Pfaff (1773-1852) had anticipated him by publishing *Über thierische Elektricität und Reizbarkeit* in 1795.[8]

In his book Carlo Volpati recounts[9] how Pfaff had completely dedicated himself to the cause of Volta since 1793. In his thesis written in Latin, Pfaff described his experiments on the different degrees of heat at which metals become electrical stimulants. Furthermore, he conducted experiments describing cases in which metals of different nature came into contact with other metals. While Pfaff was conducting these experiments, Humboldt was determined to demonstrate the contractions of frogs when they came into contact with homogeneous metals. In 1798 he demonstrated this same experiment but this time without metals.[10] According to Wilhelm Wundt, if Galvani had not jeopardised the theory at a very crucial point by adding new adjustments to the experiments, they probably could have obtained acceptance for the voltaic theory of contact as early as the publication of *Versuche*. "These experiments consisted of two parts: the first was that contractions were produced by connecting the nerve and the muscle with a metal, the second consisted only of the contact with the nerves and the muscles".[11] Humboldt was driven by a very elementary principle, which was that of reducing the complications as much as possible, by limiting the use of foreign matter. Humboldt's cause was to conduct his experiments and to obtain success in the field of physiology, and he was less interested in discoveries in the electrical field. Furthermore he wanted to study in

[5] Anacleto Verrecchia pointed out in one of his essays on Lichtenberg "God only knows how one can write a book on Lichtenberg without mentioning Alessandro Volta", see VERRECCHIA (1969), p. 154. In his essay Verrecchia dedicates an entire chapter to the relationship between Lichtenberg and Volta (pp. 153-69). He had already dealt with this relationship in VERRECCHIA (1967).
[6] GIGLI BERZOLARI (1993), pp. 208-9.
[7] HUMBOLDT VON (1797).
[8] PFAFF (1795).
[9] VOLPATI (1927).
[10] On Humboldt's researches on Galvanism, see BECK (1959), pp. 73-4, 98 and ff.
[11] WUNDT (1872), p. 303.

great depth the structure of animal life in order to better dedicate himself to the physiology of plants, which was his greatest interest. He states this fact very clearly in a letter from Bayreuth to Friedrich Albrecht Carl Gren dated June 23, 1795.[12] On August 26, 1795, Humboldt wrote another letter on the subject to Blumenbach, which was later published by Gren in *Neues Journal der Physik*.[13] In this letter, Humboldt wrote: "If Mr. Volta were to interpret his experiments along the lines of the general principles of physics, he could draw some very important conclusions regarding animal economy and in particular the way the nerve reacts upon the muscle. One of Scarpa's pupils, Doctor Presciani of Pavia, discovered nerves in all types of worms […] where this means of Galvanic irritation is particularly evident in shells and which can be very useful in the field of zootonomy. Mr. Mangili was able fully to explain and account for the nerves of the leech and the earthworm (*Diss. de Systemate nerveo hirudinis, lumbrici terrestris aliorumque verminum*, Tic[inum] 1795). Thus did Doctor Fischer, the well-renowned translator of my *Aphor. ex physiol. chem. plantarum*, disagree with my theory that worms lack nerves".[14] That same winter, Humboldt continued his correspondence with Blumenbach in which they discussed galvanism. In these letters, Humboldt precisely defined Volta's thesis regarding the irritability of the nerves by means of dipping them in *oleum tartari per deliquium* rather than in water. He later personally confirmed these experiments, with evident satisfaction, upon his return from his travels in Switzerland and Italy.[15] He concluded with undisguised pleasure that Volta's theory on the impossibility of stimulating muscle contractions in the absence of a conductor was false. In a letter to Pictet, Humboldt wrote:

> I am conducting very strange experiments on frogs. It had been previously ignored that muscular contractions depend on two factors, the force of the stimulus and the excitability of the organs. Since I started this research, to increase this excitability and receptivity, I have noticed phenomena, which others were not able to see. In these experiments not only am I using oxygenated muriatic acid, but a new element which is ten times stronger. I'll send you a record of this element for Mr. Delamétherie. This agent I'm using is *oleum tartari per deliquium* and it is a solution of potash in water. Both arsenic oxide and alkali volatile do not give the same surprising effects as does the potash solution. Organs that were de-sensitised by opium were later revived by this substance. Frog's thighs that gave no response to the galvanic stimulation of zinc and gold, began convulsing when soaked in the *oleum tartari*. This reaction occurred not only with lead and silver but with perfectly homogeneous metals as well. Therefore, this demonstration destroys Volta's theories. By using an alkaline solution, I was able to rouse some muscular contractions without using any sort of muscle conductor.[16]

[12] HUMBOLDT (1787-99), pp. 436-7.
[13] *Ibid.*, pp. 454-6.
[14] *Ibid.*, pp. 455-6.
[15] *Ibid.*, pp. 465-72.
[16] *Ibid.*, pp. 482-6, letter dated January 24, 1796.

After having cancelled several experiments which Pfaff had already made public, Humboldt then presented his work in two parts. The first part dealt with the influence of galvanism on dissected animal bodies, which was attributed to the preliminary step of electrophysiology. The second part was dedicated to the influence of chemical substances on irritable fibres, which constituted the basis of vital chemistry. It was Du Bois-Reymond who noticed that Humboldt took an intermediate position between Galvani and Volta by constructing his thesis of irritability on two unknown factors: "The first was physical galvanism which was later to be confirmed by the discovery of the electrical battery. The second factor was the electricity of animal parts".[17] The fact remains that Volta continued to maintain his pre-eminent position in a time of great discoveries on electrical conductors. This observation was made by Francesco Mocchetti in a letter to Volta dated June 23, 1795, where he writes about how presumptuous the Germans were to believe that they were always the first to find scientific solutions. On June 5, 1795, Volta reported to Mocchetti that pyrites are not only good conductors but can also be good electromotors of the electrical fluid. Mocchetti replied:

> I don't know how to express the pleasure I felt in reading these observations, especially because I am convinced that most times the Germans claim for themselves the difficult title of discoverers in those same matters in which the Italians have previously distinguished themselves. In Dr. Pfaff's dissertation I have found nothing but the results of the experiments you have tried on different minerals and pyrites, or metallic sulphides. Being the time in which your sensible observations were published in Italy definitely prior to that of Pfaff, am I not right to call them pretended and not real inventors?[18]

We know for a fact that Pfaff proceeded step by step along the lines of Volta's work. He had always been a devoted follower of Volta and he continued to publicise Volta's discoveries in Germany, especially after the battery demonstrations which Volta performed in Paris in 1801. In 1837, Pfaff finally decided to publish a revised version of one of Volta's demonstrations despite his unhappiness at how much criticism it received in Germany, "the results of Faraday's research was that the chemical theory was approaching a successful conclusion".[19]

Therefore at that period in Germany, it was necessary to maintain a complete balance between voltaism and galvanism. Given their interference with the progress of knowledge, one had above all to work to disprove commonly held false theories about magnetism. Such theories were nevertheless to contribute to German culture in the Romantic age.

Lichtenberg gave a brief account of this, after Volta's departure from Göttingen:

> There is definitely a sort of incredulity regarding physics which is just as harmful as credulity. Incredulity however, is the same as credulity in famous men who have been

[17] WUNDT (1872), pp. 305-6.
[18] *VE*, III, pp. 260-1.
[19] VOLPATI (1927), p. 546.

teaching in the course of the years. The more I deal with these matters, the more I believe that everything that is learnt in physics should then be re-examined from the beginning with the maximum precision and with the help of the latest and the most complete instruments. This revision should allow us to find ways of rendering visible what up till now has been invisible, then new revisions will become indispensable. An example of this is Mr. Volta's condenser, an instrument thanks to which we are able to obtain sparks which are three fourths of an inch long, from bodies normally considered of medium electricity. If everything is then re-examined in an accurate manner, taking into account all the theories of mesmerism, one out of 100 is precise and if we contribute only a hundredth of these to the truth, then our work will not have been in vain. Magnetic force can be transmitted to other materials besides iron. Even the garnet acquires a polarity; in fact, there are very few materials in the world that cannot be attracted by a magnet. Mr. Brugmans, who was for the magnet what Franklin was for electricity, was even able to attract the lightest form of diamonds with the magnet, though it was the metal content of the diamond which was attracted.

Another physicist, Erxleben, said that iron solutions are not attracted: this is completely wrong. Even the weakest iron solutions such as iron vitriol are attracted by the magnet. I believe that everything that is attracted by the magnet and is polarised obtains this result from the iron components present and the effect that this material has on the human body should and could be explained by the imaginative force of the individual.[20]

Lichtenberg was probably the last of the generation of German Enlightenment scholars and thinkers with whom Volta collaborated and he enjoyed the Italian's highest esteem. Lichtenberg primarily dealt with electrical phenomena, which were verified by the use of the electrometer and the electrophorus, further distinguishing himself for numerous observations on electrical meteorology. Lichtenberg was not as involved in galvanism as other scientists were, so he did not run the risk of falling into what Volta called the "precipice" of dynamical physics.

Lichtenberg's scientific adventure began in 1770 in England, when George III assigned him the duty of taking the measurements of the cities of Hanover, Osnabrück and Stade for political and territorial reasons. Lichtenberg's results obtained the praise of Johann Bernoulli, who helped him in his feat. However Lichtenberg's true passion was experimenting with atmospheric electricity. When Lichtenberg began working seriously on the phenomena of electrification, he, like many others, was fascinated by the Leyden jar. He built himself an electrophorus in order to study the different kinds of electrical charges. He realised that it was possible to apply electrical charges on non-conductors, and these charges cause particles of electrified fine dust to assume a different shape depending on whether the charge is negative or positive. This discovery seems to suit perfectly a man of culture as, though of modest usefulness, it had considerable aesthetic effects. "The figures produced from positive electricity are as different from the forms created by negative electricity as the sun is from the moon".[21] Even the more orthodox

[20] LICHTENBERG (1780-84), pp. 925-7, on p. 926.
[21] LICHTENBERG (1956), p. 29.

physicists, Volta and de Luc, took note of this phenomenon which inspired Lichtenberg to write an amused letter to the philosopher Wolf: “De Luc and Volta have been discussing my ‘figures’ at such great length, that one might have expected a ponderous work from the former. De Luc wrote me some time ago, in a flippant tone: your stars will shine again, one day in the night of electricity”.[22] In fact, de Luc believed that the means of proving the nature of electricity and of the electrical fluid had been discovered thanks to this experiment. In the meantime, Lichtenberg was looking for a more pragmatic way of taking advantage of his discovery, in order to study the illumination created by rarefied gas.

In a letter to Reimarus, dated May 2, 1782, Lichtenberg expressed a negative opinion on Volta’s invention of the condenser. In his view it could not be considered a real new invention, being only a modified version of the electrophorus previously invented by Volta himself.[23]

The first signs of real enthusiasm arrived on September 30, 1784 prior to Volta and Scarpa’s visit to Göttingen.[24] Lichtenberg was making plans to go to Italy with Jöns Matthias Ljungberg, but the aim of the trip was quite different from what the professors of Pavia University had in mind. He desired to visit Florence, Rome, Naples, Calabria and Messina (which was the victim of a massive earthquake on February 5, 1788) to further his studies of ancient architecture and geo-seismic phenomena. To Lichtenberg’s enduring regret, the trip was never to take place. Much has been written on what followed,[25] so it is appropriate to conclude the chapter on Lichtenberg’s life at this point.

Teichmann wrote about eighteenth-century eclecticism and therefore of the often too hasty scientific hypotheses of men such as Albrecht von Haller, Lichtenberg and Goethe, cultured men who are hybrids between natural science and exact science. “All three were poets and naturalists of the German language, a combination incomprehensible to us now, especially to the modern German who is conditioned by the scientific disputes of the nineteenth century. Lichtenberg came between these two periods, as reflected in his attitude to nature, in his relationship with the interpretative subject, in his elaboration of this interpretation not as a synthesis of the opposite parts but as a quick evaluation of fine distinctions, felt as urgent and sometimes supported by a visionary outlook”.[26]

This visionary view, of which Teichmann speaks, can also be seen as intuition, an intuition which should not be confused with the real visionary view which early

[22] LICHTENBERG (1780-84), p. 655, letter dated July 13, 1783.
[23] Here is what he wrote about the analogies between the two devices: “The semi-electric body [the condenser] turns out to be a semi-electrophorus and the thing is thus very easily explained”, in LICHTENBERG (1780-84), p. 318.
[24] LICHTENBERG (1780-84), p. 909, letter dated September 30, 1784, in Schernhagen.
[25] See the ample section dedicated to Lichtenberg in VOLPATI (1927), pp. 551 and ff.
[26] TEICHMANN (1975), p. 24.

Romantics such as Ritter, Humboldt, Steffens, von Baader used to proceed in their scientific experiments.

Lichtenberg was one of the most enthusiastic interpreters of the principles of Kantian philosophy[27] and he was convinced that all we know is nothing but our own representation, and that to assert that external objects exist is inevitably a contradiction. The individual cannot emerge from himself but can replace the Cartesian formula "cogito ergo sum" with "sentio ergo sum": "Does the entire history of physics not teach us that all these hypotheses have yielded nothing, that we do not possess the necessary means of explanation and that these manifestations of nature are nothing but our own inventions?".[28]

The years 1795 to 1805, which mark fundamental steps in the relationship between Volta and Humboldt, also mark the decline of an era and the beginning of the great period of electrical chemistry. On July 17, 1798, Ritter sent Volta an important letter repeating his scepticism regarding galvanism and expressing what one can describe as "romantic demonstrations of physics".

In 1795 Humboldt wrote to Blumenbach, telling him of his meeting with Volta in Como and how he showed Volta that, even though zinc is connected to the nerve and the muscle by means of an arc of dry gold, this does not produce contractions. However, when one blows on the gold, a spasmodic contraction is observed. He goes on, adding that he and Volta had arrived at the same conclusions, that the contractions occur even when they are stimulated by the same kind of nerve and muscle. After stating his conviction that water is a stimulant and not just a conductor, Humboldt relayed to Blumenbach the experiments conducted by Volta and repeated by himself.

There were no important exchanges between the two scientists for two years. However, in August 1797, after Volta came into possession of the first part of Humboldt's study *Versuche über die gereizte Muskel - und Nervenfaser*, he wrote the following to Luigi Valentino Brugnatelli:

> Humboldt has recently published an octavo volume of over 400 pages on animal electricity, which he still interprets in his manner, that is by having much recourse to chemistry and by attributing most of the phenomena in question not only to oxygen, but also to nitrogen and hydrogen as well. […] From what I have already seen, he is not satisfied with my theory, which reduces everything to an extrinsic electricity moved by the contacts between different conductors. However, he still does not know all my experiments which decide the matter: at least I think I can explain all his experiments in a

[27] "The methodological prescriptions of achieving the delicate mixture of teleological and mechanistic explanatory frameworks were set forth by Immanuel Kant. Kant had been following the work of Buffon, Haller, Blumenbach, Wolff and others for several years […] Basically Kant concluded that while the goal of science must always be to press as far as possible in providing a mechanical explanation, mechanical explanations in biology must always stand under the higher guidance of a teleological framework", in LENOIR (1990), p. 120.

[28] LICHTENBERG (1804), p. 154.

> much simpler way by using my principles only, rather than his chemico-physiological theories or by mixing these theories with my principles. I do not deny that some of his experiments show new and surprising aspects which have truly struck me. His work is after all very nice and contains subtle research and some very ingenious views.[29]

The point of disagreement was that Humboldt, maintained that, when placing different metals on the tongue, each metal gave a different taste. He believed that this was due to the chemical decomposition of the products which occurs on the tongue due to the passage of electricity. Volta, on the other hand, believed that electricity had a direct effect on the taste glands. Humboldt also accused Volta of considering animal organs as just inanimate masses, like a piece of sponge or wet rope. Humboldt also announced his intention of demonstrating that galvanism presents phenomena which are produced by vitality, concluding that his theory demonstrated how the will can produce muscular movements by means of galvanism.

For most of the Germans engaged in electrical enquiries, the main concern was to maintain a condition of equilibrium in the experiments on electrical conduction and to avoid exasperating the stimulations to the point of reaching a condition of uncontrolled *Steigerung* (increase). Rather, the energy produced should harmoniously connect the internal and the external agents. This also explains the negative reaction of Goethe against the methods of the Newtonians in their experiments on colours, as shown in the *Farbenlehre*, on which he began to work in 1790.

At Easter, 1798, Johann Wilhelm Ritter (1776-1810) had published his most famous work: *Beweis, daß ein beständiger Galvanismus den Lebensproceß in dem Thierreich begleite*[30] [Demonstration that constant galvanism accompanies the vital process in the animal kingdom].

On October 29, 1799, Ritter gave a presentation to the Academy of Naturalists of Jena on a problem which, in his view, would give a new approach to the study of galvanism. The question had a philosophical ring to it: “Does the vital process consist of a form of galvanism that could perhaps be more stable than the one made up of infinite chains linked to one another in a disorganised way?” A year later, Ritter answered that these systems of the vital process are parts of more complex chains which in turn are parts of yet more complex chains, until they reach the main chain, which contains all the previous ones.

Like Humboldt, Ritter tried to establish analogies between the muscular and nervous systems and organic fluids like blood and lymph in order to produce a completely new physiology. They both saw chemical reactions as part of the total dynamic process in which electricity is manifested as part of the whole. In view of

[29] *VE*, III, pp. 362-3, letter dated August 4, 1797.
[30] RITTER (1798).

the close analogies Ritter established between electricity and chemistry, he can be considered one of the founders of modern electrochemistry.[31]

From his early publications in 1792 Volta attributed his results on galvanism to the contact of the heterogeneous conductors of the first class (metals) with a conductor of the second class (electrolytic solution). The frog's thighs and the tongue carry out the simple role of transmission. On the contrary, Ritter believed that it was impossible for the galvanic chain to exist only in the presence of inorganic bodies. Starting from an analogical principle based on galvanism, Ritter stressed that electricity and the chemical system can throw light on each other. In particular, he considered Volta's experiments on water decomposition with the battery and demonstrated that it is possible to collect hydrogen and oxygen either together or separately, thereby obtaining similar results to those obtained one year earlier by Nicholson and Carlisle. After Herschel's discovery of infrared rays in 1800, the postulation of similar analogical links between the prismatic spectrum and magnetic or electric polarity guided Ritter to the discovery of ultraviolet rays in 1801.

In 1802, Ritter was able to produce what can probably be considered the first dry pile. In 1803 he realised a crude prototype of the modern accumulator (secondary charging battery or storage pile). In 1805 he made progress in the study of the principles of electrical current distribution, which Kirchhoff was later to perfect. These historical and scientific data help us to understand where Ritter's theories arrived in the field of physics, but they also show Ritter's adhesion to Galvani's position, from a philosophical and literary point of view. The disregard he held of Volta, produced a spread of ideas which penetrated every corner of Idealism and, thanks to Novalis' (1772-1801) tireless work on uniting the sciences, every branch of the discourse concerning man and nature. The following is what Desideri wrote about the collaboration between Novalis and Ritter:

> Several of Novalis' reflections seem to take a 'Ritterian' direction (especially in the *Physics Fragments*) in their search for unity among the forces of nature. In the sense that the instrument for such a unification seems to be shaped more upon electro-chemistry (or better still electro-galvanism) rather than upon physics. In this context we should consider both his interest in Van Marum's experiments on the presence of caloric in electrical phenomena […] and an observation like the following: "The flame unites what is separated and separates what is united. It composes and decomposes water. It oxidises and deoxidises, magnetises and demagnetises, electrifies and de-electrifies. The universal means of separation is also the universal means of union". […] What Novalis seems to have in mind here is the circularity of the self-regeneration of nature: "The genuine products must anew produce the producer. The generator comes up again from what was generated".[32]

[31] As pointed out by Schipperges in RITTER (1969), I, p. 12.
[32] DESIDERI (1993), p. 13.

Thanks to Ritter, Novalis was firm in his idea that it is possible to find a "general analogical formula" which guides the "individual model" which in this case constitutes the relationship between "rigid" (heat) and "fluid" (light). We can see how this analogy is spaced out in the various fields of knowledge in a fragment of his "Allgemeines Brouillon":

> Galvanism of antique works of art, their subject: the re-vivification of antiquity. Marvellous religion which stirs around itself – its history – the philosophy of sculpture – gems – human petrifaction – painting – portraits – landscape – man has always expressed a symbolic philosophy of his essence in his work and in doing and in omitting – he announces himself as well as his Gospel to nature. He is the Messiah of nature – antiquities are at the same time products of future and former times.[33]

If, from everything that has been stated so far, it is clear that if in Germany Volta's theories met initially with many difficulties, the cultural climate in which they were presented was characterised by the principles of enlightened rationalism; on the other hand, the scientific tradition represented by Galvani, Humboldt and Ritter in Germany was to emerge in parallel to the strong scientific impact which Volta generated in France and England, in a rather uncontrolled form of mysticism.

[33] NOVALIS (1968), p. 248; It. transl. in NOVALIS (1993), II, pp. 273-4.

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