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Anniversary of Faraday's Satisfying Tour

Two hundred and ten years ago, 22-year-old Michael Faraday accompanied a leading chemist of the early 1800s, Sir Humphry Davy, on a tour of France and Italy. This epiphanous trip transformed an otherwise talented and conscientious person with a deep religious faith built on the Sandemanian religious sect into a scientific genius who any school or university would be envious of producing. This article discusses this tour and its consequences for Faraday.

FARADAY'S GRAND TOUR

March 2023 marked 210 years since Faraday set off with Davy on his first trip outside of London to Europe. Faraday had grown up in humble circumstances in a village named *Newington Butts*, now in the London Borough of Southwark and near the Elephant and Castle. He was born on 22 September 1791 to a blacksmith and his wife who were members of the Sandemanian Christian Church [1]. This was an austere and fundamentalist faith that had its origins in a schism from the Church of Scotland. It spread around Scotland, England, and America. Sandemanians equated faith with intellectual assent to the facts of the Bible. The church had no clerical hierarchy or organization except for a system of elders and deacons. It taught that the accumulation of wealth was improper. Defined as a "simple faith" or "bare faith," the sect required no emotion or even an act of will for salvation. It was an extreme version of "easy believism."

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Faraday's parents moved to London from the small settlement of Outhgill in the bleak winter of 1790–1791. Due to his father's meager income, Faraday and his family faced many hardships. These difficult circumstances deprived Faraday of much formal education, although he learned to read and write, and eventually, he finished school aged 13. He delivered newspapers and books for a bookbinder, George Riebau, who apprenticed him in 1805. It was then that Faraday found his passion for reading and grew confident in working with his hands. He had a chance to read many books, and this broadened his knowledge. Riebau encouraged Faraday's learning and provided space for his books and equipment. One favorite book was on chemistry. This pricked Faraday's curiosity, and through Riebau's contacts he received tickets to attend lectures at the Royal Institution.

The Royal Institution had been established in 1799 by Benjamin Thompson, Count Rumford, FRS, who purchased a property for it on Albemarle St. in London. It is still there to this day. This Institution became central to conveying the latest science to the general public. Humphry Davy was employed by the Institution in 1801 as an assistant lecturer in chemistry, the director of the chemical laboratory, and an assistant editor of the journals of the Institution. He was also given a furnished room in the building. Davy gave lectures and demonstrations in chemistry that were sometimes spectacular and dangerous. This, and his physical presence, made him a popular speaker. Davy was an early researcher in the field of electrolysis [2], using a voltaic pile obtained from Alessandro Volta to split common compounds, and identified new elements such as chlorine (named for its color by Davy), sodium, and potassium. Faraday, who was interested in chemistry, attended the lectures given by Davy. He wrote up the notes from Davy's lectures, bound them into a volume, and presented them to him. Davy was so extremely impressed with this gift that he ultimately employed Faraday to assist with his experiments in 1813.

Davy was knighted in 1812 by the Prince Regent, who was acting on behalf of his father, King George III, for his new discoveries, and soon after, he gave up his position at the Royal Institution. He had also recently married a wealthy

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heiress, Jane Apreece [3]. A grand tour was planned to Europe to visit scientists in Paris, Florence, Milan, and Rome, commencing the following year. At the time, England was still at war with France and it was before the Battle of Waterloo. Davy had received dispensation from Napoleon Bonaparte to enter France for scientific exchange with French scientists. Some thought this visit to France was treasonous, but the thick-skinned Davy shrugged off these criticisms. The Davys took their maid to assist Lady Davy although Faraday functioned as Sir Humphrey's valet as his normal servant had resigned just before departing London [4].

The overseas trip was to be the making of Faraday, who at the time was just 22 years old. On the trip he had become conversant in French and Italian, which he used in later correspondence. He would experience the company and mentorship of a leading international scientist, Davy, undertake experiments under Davy's direction, and, through Davy, meet some of the leading scientists of his day. He would meet André-Marie Ampère, and even be present at a formal meeting between Volta and Davy in Milan in June 1814. Davy had been using Volta's voltaic cell for experiments since the 1800s to develop the first coherent theory of electrochemical action. At this meeting, Volta was suitably dressed for the occasion, but Davy was dressed more casually. As a gift, Volta gave Faraday his latest voltaic battery, now in the collection of the Royal Institution (see Figure 1), which is worth a visit when in London. There are several detailed descriptions of the tour [1], [4], [5]. During the trip, Davy received a medal from Bonaparte, and Davy and Faraday proved that diamonds were flammable.

It was not all work. Faraday ascended the cone of Vesuvius [4, pp. 180–184], and he participated in Roman new year revelries in 1815 when he paired up with a lady to play pranks on their acquaintances [4, p. 170]. In April, Davy and Faraday returned to England after Napoleon escaped from Elba, and before the Battle of Waterloo.

What this article seeks to concentrate on is the opportunity, mentorship, and environment that transformed an otherwise talented and conscientious person into an educated man and a scientific genius who any leading university would be envious of producing. All these quantities, an underlying curiosity, self-learning, his deep faith, basic talent, a supporting collaborator, and the environment that travel provides combined within Faraday as did rubbing shoulders with great scientists. He would hear about the latest work and discuss this with them as well as having his senses opened to new sights, food, and smells. The constant companionship with Davy and his mentorship contributed to Faraday's maturation as a scientist. His accounts of Davy's experiments on and observations of iodine, hot springs, rocks, and diamonds are described dispassionately in his diary [4]. Travel broadened Faraday's ideas about his way of thinking, but not always the ideas in his mind. He found the food and some customs strange. Some have commented that he was like a typical Englishman abroad.

His investigation of heating and illuminating oils led to the discovery of benzene and other hydrocarbons.

Faraday's chief scientific gains from the tour were stronger support from Davy and his foreign contacts, and particularly their effect on the empirical challenges that had impacted his approach. This was rooted in real science, which required him to see and do firsthand the science that was to become a hallmark of his career. Faraday wrote that, "I was never able to make a fact my own without seeing it, and the descriptions of the best works altogether failed to convey to my mind such a knowledge of things as to allow myself to form a judgement upon them."

To fill in the rest of the story of Faraday, once back in Britain in 1814, Faraday, supported by Davy, commenced work on electrolysis as he developed skills as an analytical and practical chemist. He also commenced separate work on electrical conduction. As his chemistry knowledge increased, he was given more responsibility. Among his achievements, Faraday liquified various gases, including chlorine and carbon dioxide. His investigation of heating and illuminating oils led to the discovery of benzene and other hydrocarbons. The discovery that the flow of an electric current through a wire produced a magnetic field around the wire by Hans Christian Oersted quickened Faraday's interest, and he became determined to construct an apparatus that confirmed this result. This device, in September 1821, demonstrated electromechanical motion. Faraday hung a rigid wire from a flexible joint and into a glass dish, which had a bar magnet secured at the bottom. The glass dish was partly filled with mercury. When Faraday connected this apparatus to a battery, a current went through the wire, creating a magnetic field around it. This field interacted with the field from the magnet, which caused the wire to rotate clockwise. With this experiment, Faraday was able to show how a magnetic field and a current could produce continuous mechanical motion. He had invented the basis for the electric motor.

Earlier, on 12 June 1821, Faraday married 21-year-old Sarah Barnard. They belonged to the London chapter of the Sandemanian church [1], through which he received mentoring from an elder. The couple had rooms in the

FIGURE 1. The voltaic pile presented to Michael Faraday by Alessandro Volta in 1814 (Source: Photo courtesy of the Royal Institution [6].)

Royal Institution for more than 30 years. They remained married until Faraday's passing in 1867. Faraday became a member of the Sandemanian church on 21 July 1821, advanced to deacon in 1832, and became an elder in 1840.

Soon after his marriage, friction developed between Faraday and Davy. The latter claimed that Faraday failed to cite the contributions of other scientists, including Davy, in papers that he had published. Faraday, on the other hand, was convinced that his work was independent of the prior accomplishments of others to the extent that they did not need to be cited. Another cause of friction between the two men came in 1823 after Faraday managed to liquify chlorine. Upon hearing of the method, Davy used the same approach to liquify another gas. Some commentators have suggested that Davy was professionally jealous, and others have proposed that living in the same building caused friction between the two families. Faraday's friend and fellow scientist John Tyndall said that jealousy played no part in the controversy [7]; rather, it was over Davy's objection to Faraday's nomination for membership to the Royal Society without his knowledge. Davy was president of the Royal Society at the time, and he opposed the nomination. Faraday was elected a fellow of the Royal Society, nonetheless. The relationship appears to have improved soon after, for Davy supported Faraday's appointment as director of the Laboratory of the Royal Institution in 1825. Davy died shortly after in May 1829, just past the age of 50.

FIGURE 2. Michael Faraday FRS in circa 1830. A portrait by Henry Pickersgill, R.A. Reprinted with permission from The Board of Trustees of the Science Museum.

Although he was usually well prepared, there were days when he worked things out as he went along, which was a fascinating experience for the audience.

As a new fellow of the Royal Society, Faraday had his portrait painted in circa 1829 or 1830 by Henry Pickersgill, R.A. (see Figure 2). This painting has been used as the basis for an engraving by J. Cochran in 1846 and by more recent artists. In 1831, Faraday announced to the world the generation of magnetic induction (see Figure 3). When a current flows in coil A, Faraday observed an induced current flowing in the opposite direction in coil B [7], [8]. Both Earth-shattering results of mechanical motion producing a current and magnetic induction were due to excellent preparation and an experimental technique due to "keeping his mind alert, so that results different from those which he expected should not escape him through preoccupation" [7, p. 20]. These were qualities Faraday had honed during his lectures at the Royal Institution. He continued giving lectures on a weekly basis until only shortly before his death. His lectures always attracted a large following. Although he was usually well prepared, there were days when he worked things out as he went along, which was a fascinating experience for the audience. He continued experimenting too. One area that proved fruitless was his search for a possible gravelectric effect, which was the interaction between gravity and electromagnetic fields [1]. When he retired from the Royal Institution, he was offered a knighthood by Queen Victoria, which he declined to remain Mr. Faraday, although he accepted a cottage at Hampton Court from her. Faraday was sometimes mistakenly assumed to have been knighted. In [7, p. 8], Tyndall recalls visiting his old bookbinder's shop on Baker St. in London one evening while walking with Faraday. The new proprietor referred to the previous owner, Mr. Riebau, as the master of Sir Charles Faraday (sic). "Nonsense," Faraday replied. "There is no such person." She was delighted to then be introduced to Faraday.

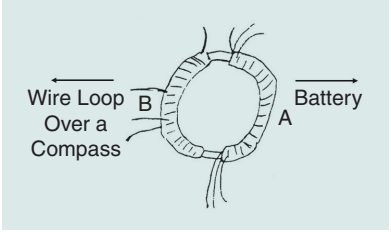

FIGURE 3. Faraday's first successful induction experiment in August 1831. Two coils of wire were wound on a welded iron ring [7]. A battery was connected to coil A. Coil B was connected to a long wire, which passed over a compass needle. When the battery was connected or disconnected, the compass needle went to the right or left in response to induction (after [8]).

Through all this time, Faraday's faith sustained him and his wife. They continued to live modestly and worship regularly. He traveled to several other places in England and Scotland with Sandemanian churches to meet with their elders or to settle disputes [1]. Clearly, his faith sustained him as he saw it to be greater than his science. He thought that by using his mind and body in science, he was following his faith to the fullest. One of his quotations include "mathematics offers only a limited training for the mind since it deals with logical relationships and not with the behavior of physical objects in the world." In this article, I do not go deeper into his faith, however, the interested reader is referred to [1] and [9].

CONCLUSION

Finally, Faraday's travels in Europe from 1813 to 1814 were an important beginning and epiphany for a young man.

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to the development of our community is immeasurable. I very much would like to continue to impart knowledge and inspire young minds, knowing that through their achievements, my impact as an educator will extend far beyond the boundaries of the classroom.

SUMMARY

In part I of this series we have featured the contributions of five academics. A common aspect of these reflections is enthusiasm. Enthusiasm for the discipline and for helping students learn is part of the foundation for a reflective approach to teaching. As has been noted in [6], "teacher enthusiasm is central to providing an effective educational experience to students. While techniques can add value, it is enthusiasm that infuses life into our classes." An enthusiastic approach may lead to one asking "Why do I teach?" As a practical tip, the other way round may work too!

In part II of this series we will hear from five more colleagues, and discuss some additional important common themes that emerge from the accounts of academic colleagues on why they teach.

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They set him on a quest for continuous improvement of his mind and his science. This he did with utmost devotion to science and his faith. He was fortunate to receive mentoring during his early life from several people, although his greatest mentor was Davy. Faith and science were interwoven in Faraday the scientist. Through this, he became one of the most admired and famous people of all time while remaining humble and modest, although he could be forthright when required. Two hundred and ten years on, Faraday is one of the most recognized people the learned world has produced, comparable to Archimedes, Leonardo Da Vinci, and Albert Einstein. This article leaves Faraday to have the last word: "Nothing is too wonderful to be true if it be consistent with the laws of nature" [10].

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