How Wonderfully We Stand Upon This World

By Dr. Alan Hirshfeld

Step through the front door of George Riebau's bookbindery at 2 Blandford Street near Manchester Square in London and feel the present dissolve into centuries past. The pungent aroma of leather, glue, and varnish invades the nostrils. A murmurous drumbeat—the binder's mallet tamping gathered pages—sounds an insistent rhythm: *work, work, work*. Books are everywhere, on shelves, on tables, even wedged into the cubby-like window frames, where they eclipse the light that struggles to enter. In this dim paper-and-leather universe of long ago, French émigré George Riebau and his three apprentices stand at their posts, plying the bookbinder's craft. Before them lie the accoutrements of their trade: needles, thread, Jaconette cloth, engraving tools, standing press, cutting boards. The room buzzes with conversation, for Riebau is a genial man who likes to keep his workers and his customers happy. Yet for all the chatter, the binding and selling of books appear to be the sole order of business here. In short, George Riebau's modest establishment is the last place one would conceive as an incubator for an aspiring scientist. Especially in 1812 England.

But move beyond the benches to the fireplace that keeps the workers' fingers supple through the frigid London winters. There on the mantelpiece, arrayed in no particular order, is a curious assortment of devices that bear no connection to the binding of books: Voltaic piles—batteries, in today's parlance; copper and zinc electrodes; coils of wire; bottled acids; glass cylinders for generating and storing electricity. Nearby, meticulous pencil sketches of electrical machines. And alongside these, jottings about electrical phenomena. Here is the after-hours "laboratory" of young Michael Faraday, one of George Riebau's apprentices, who is at present probably counting the minutes until he can set aside his tools and resume his homespun experiments. Faraday's teachers, such as they are, do not wear silken robes or roam ivy-covered buildings; they speak to Faraday silently from the printed pages that pass through his hands on the way to more advantaged customers. To Faraday, Riebau's shop is truly library, classroom, and laboratory. The mantelpiece curios are manifestations of a dream by a young man whose ambitions press ever more despairingly against the harsh realities of British society. This is an age when the term "upward mobility" holds no practical meaning for the mass of humanity—when, for the most part, scientists are born, not made.

In a few short months, Michael Faraday's apprenticeship will end and, for his family's sake, he must dutifully take up the career for which he trained: bookbinding. And therein lies the source of the searing realization that his life might be spent in the mindless packaging of countless words on countless subjects, and not one of his own devising. For Faraday longs to uncover nature's secrets, not as a hobbyist in some dusty shop corner, but as a professional man of science in a real laboratory. Only then might he fulfill his deep-seated goal: to discern God's invisible qualities through the very design of the world. That this modest apprentice would surmount the many obstacles in his path and lay the foundations of our modern technological society is the true essence of the power of purpose.

Born in a London slum in 1791, Michael Faraday came to George Riebau's bookbindery in 1805. The shop proved a fertile environment for the inquisitive, but virtually unschooled, Faraday. Books came in, books went out, a steady stream of treacle and treasure that Faraday sampled haphazardly in his off-hours. This week's "lesson" might be *Arabian Nights*, next week's a collection of Hogarth illustrations, and after that, Fanny Burney's edgy take on English society, *Evelina*. But it was books on science that excited him most.

At the dawn of the 19th century, science and its institutions were in flux, spurred as much by new discoveries as by the growing belief that scientific research might enhance a nation's agricultural and industrial development. The fundamental building blocks of matter—atoms—were as yet unknown. Electricity, magnetism, heat, and light were variously "explained," none convincingly. Through careful measurement, the mathematical character of nature's forces could be determined, but their underlying mechanisms, interrelationships, and means of conveyance through space were subject to dispute. Faraday plunged headlong into this melange of ideas, trying with his meager knowledge to sort out fact from fancy. His scientific musings tumbled joyfully, almost uncontrollably, in his head. Riebau described his young charge as perpetually scouring the countryside, "searching for some Mineral or Vegitable curiosity ... his mind ever engaged." All around was God's handiwork, in plain sight, yet inextricably bound up in mystery. Faraday saw no higher purpose than to study, comprehend, and share with others the subtle plan of nature.

Inspired by his literalist reading of the New Testament, Faraday eschewed pride and wealth in favor of piety, humility, and community within his small Protestant congregation. Much of his overt serenity in later life owed itself to the affirmative aspects of his religion. "He drinks from a fount on Sunday which refreshes his soul for a week," noted a friend. Faraday's spiritual framework informed his science without compromising his objective consideration of facts. He believed that God's signature would appear in a fundamental unity of the universe, a philosophy that shaped his scientific outlook. And he took human fallibility as a given, so never staked his ego on the correctness or acceptance of his ideas. He was a scientific pilgrim, inching his way toward the heart of a complex universe. Whether his chosen path proved mistaken was of little consequence; there was always another path. The joy was in the journey.

Although the young Faraday might have fancied himself a proto-scientist, he was too grounded not to see who stared back at him from the mirror: a rough-edged, ill-educated son of a blacksmith. Characterizing his own language as "that of the most illiterate," he took elocution lessons two hours every week for seven years. He ordered his friends to mercilessly correct his speech, spelling, and grammar. For ready reference, he carried in his pocket the popular self-help volume *Improvement of the Mind*. He attended evening lectures on science and began a commonplace book, whose pages he filled with miscellanea about the natural world.

When the new edition of the *Encyclopedia Britannica* arrived in the shop, Faraday devoured the 127-page entry on electricity. He followed up with Jane Marcet's *Conversations on Chemistry*, which detailed the electrochemical discoveries of England's celebrated scientist, Humphry Davy. Faraday was the consummate skeptic: he trusted his eyes and senses to be the sole arbiters of what was true and what was not. In Riebau's back room, he validated Davy's experimental claims as best he could. "I was a very lively, imaginative person, and could believe in the 'Arabian Nights' as easily as in the 'Encyclopedia'; but facts were important to me and saved me." Faraday had further reason to admire Davy: the now-famous chemist had risen from humble circumstances like his own; Davy had become what Faraday longed to be.

In early 1812, a customer learned of Faraday's scientific interests and invited him to hear Humphry Davy speak at London's Royal Institution. Davy's evening lectures had become social events for the well-heeled, turning normally sedate Albemarle Street into a frenzy of carriages and pedestrians. Faraday's pulse was surely pounding as he ascended the broad, stone staircase to the Royal Institution's auditorium. Hearing Davy describe his recent work only strengthened his resolve. "The desire to be engaged in scientific occupation, even though of the lowest kind, induced me, whilst an apprentice, to write, in my ignorance of the world and simplicity of my mind, to Joseph Banks, then President of the Royal Society." England's venerable Royal Society, established in 1645, was England's premier scientific organization and boasted in its lineage the likes of Christopher Wren, Isaac Newton, and Edmund Halley. Faraday went to the Society's offices only to be told that his letter "required no answer"; in the eyes of the scientific establishment, Michael Faraday did not exist. Undeterred, he wrote and illustrated a 386-page synopsis of Davy's theory of acids and sent the leather-bound volume to Davy, along with a letter pleading his case. This time there was a reply, delivered to his door by a footman in a grand carriage. On March 1, 1813, Faraday took up his new post as Humphry Davy's laboratory assistant: salary one guinea per week; lodging in the attic with fuel and candles; and, most critically, access to the Royal Institution's apparatus.

Faraday reveled in his day to day interactions with Davy, who tutored him in all manner of laboratory techniques. In October 1813, the pair embarked on a prolonged tour of Europe's scientific facilities. To Faraday, who had never strayed more than three miles beyond London, the trip was a living tutorial in science, geography, art, history, politics, and manners. Imagine the impact of the snow-capped Alps on a young man who had earlier marveled at the "mountains" of

Devonshire. Every day presented a sight or event worthy of entry into his journal: glimpsing Napoleon in a procession; describing the anatomy of French pigs; inspecting Galileo's celebrated telescope; incinerating a diamond in Florence; climbing the slopes of Vesuvius. By the time he returned a year and a half later, Faraday could maneuver with confidence through the social thicket as well as the laboratory. He worked incessantly, both for Davy and for others in need of his analytical skills. In 1816, Faraday published his first scientific paper, on the chemical properties of caustic lime. Other papers followed in quick succession. Faraday delivered his own series of lectures at the City Philosophical Society, and was increasingly sought out as a technical advisor. To Davy's consternation, the standing of his acolyte from the slums began to rival his own.

In 1820 came news of a remarkable discovery: Danish physicist Hans Christian Oersted had found that an electrical current flowing in a wire deflects a magnetic compass needle: electricity generates magnetism. Repeating Oersted's experiment, Faraday realized that such electrically induced magnetism might be harnessed for rotary motion. In 1821, he assembled the first electric motor, in which a suspended, electrified wire circled the pole of a magnet. Announcement of the curious contraption brought Faraday immediate notoriety—and near ruin. Rumors circulated – rumors, Faraday learned, stoked by Davy—that he had stolen his idea from unpublished work by William Hyde Wollaston, one of England's foremost scientists. Only after two agonizing years, and repeated entreaties from Faraday, did Wollaston grudgingly break his silence and speak in Faraday's defense: the discovery of the electric motor was Faraday's own. Davy subsequently opposed his protégé's nomination to the Royal Society, to no effect; Faraday was elected – the lone dissenting vote presumably Davy's own. Even so, Faraday never spoke ill of his mentor; his spiritual imperative was to reveal the workings of nature, not the shortcomings of man. To do so would have merely detracted from the nobility of his cause.

Faraday's most far-reaching contributions came in 1831, when he succeeded in generating electricity from magnetism. First, he showed that the magnetism of an electrified wire coil creates an electric current in an adjacent coil; here lay the foundation of the modern electrical transformer. He found, too, that he could induce spurts of current in a coil by simply thrusting a magnet into the coil's interior. And by spinning a copper disk between the poles of a magnet, Faraday produced a steady stream of electricity—the world's first dynamo. Here was the generation of electrical power by machine. The societal implications were enormous.

Pondering next the interconnectedness of electricity and magnetism, Faraday entered the laboratory of the mind and modeled electrical and magnetic forces in a completely new way: as tensioned lines of force surrounding electric charges, magnets, circuits—invisible motive tentacles that impel material objects that stray among them. In Faraday's conception, force arises, not when some impulse shoots instantaneously from a seat of power to a remote object, but when the object encounters the "force field" that surrounds every seat of power. In keeping with his unified view of nature, he wondered whether light might be a related phenomenon, perhaps a vibratory disturbance of intertwined electrical and magnetic fields. He envisioned waves of light—ripples of "electromagnetic" energy—fanning out through the field like waves on a pond.

Here Faraday's quest to elucidate reality encountered its severest challenges: his own intellectual limitations and the prejudices of his contemporaries. Faraday's particular gift was to make visible in the laboratory that which had been invisible, to magnify nature's subtle effects to the point of sensibility. He was a powerful thinker whose speculations (by choice) were anchored solely in what was rendered plain by experiment. Only now he had entered a realm of study in which experimental verification was difficult, if not impossible—the realm of the mathematician, who solves equations to find plausible explanations of physical phenomena. And Faraday, facile as he was in the laboratory, was a grade-school mathematician. At a time when mathematics was fast becoming the key analytical tool of theoretical physics, Faraday put forth his revolutionary ideas in the only way he could, through the skilled use of intuition, logic, and language.

So taxing was his mental effort to explain nature's underlying architecture (heaped high atop other work) that by late 1839 Faraday was felled by nervous exhaustion, and for five years remained silent on the subjects of electricity and magnetism. He returned with an exquisite experiment proving that light can be altered by magnetism; as he had predicted, light possesses a magnetic character. Then came a speculative paper summarizing his thoughts on “ray vibrations,” a remarkably prescient forerunner of the modern electromagnetic theory of light. The scientific establishment viewed these “ramblings” with bemusement, if not scorn, for the new language of science was mathematical. Faraday’s response: “Nothing is too wonderful to be true, if it be consistent with the laws of nature.” It would not be until the 1870s that the gifted mathematician James Clerk Maxwell fully translated Faraday’s complex ideas into the hard dialect of equations. Only then did scientists concede the essential correctness of Faraday’s views on force and light, which Einstein characterized as the “greatest alteration … in our conception of the structure of reality since the foundation of theoretical physics by Newton.”

Beyond the motor, generator, and other electromagnetic advances, the list of Faraday’s contributions to humanity runs long, touching areas as diverse as chemistry, geology, metallurgy, optics, cryogenics, and education. He sought no personal gain from his discoveries and routinely refused honors and lucrative consultantships as immaterial to his committed purpose.

For nearly forty years, Faraday invited the public to the Royal Institution to share his enduring sense of wonder: “Let us now consider, for a little while, how wonderfully we stand upon this world.” Complete with sparks, flames, and all manner of devices, Faraday’s Friday Evening Discourses and annual Christmas lectures for children established him as England’s scientific ambassador to its citizenry. One attendee recalled how Faraday’s “enthusiasm sometimes carried him to the point of ecstasy when he expatiated on the beauty of nature.” Transcriptions of his children’s lectures reveal his gentle, avuncular style, and also how addressing young audiences provided a source of renewal: “I will return to second childhood, and become as it were, young again among the young.”

There is a serenity in knowing that nature is explicable and beckons generation after generation to know it better. Michael Faraday sought to understand the natural world on behalf of us all, in the belief that the revealed knowledge would nourish the collective soul of humanity. He was one of those rare scientists in the mold of Galileo, Newton and Einstein, free of blinding preconceptions about nature and thus endowed with a vision denied his contemporaries. Faraday's legacy is nothing less than our own technological society. Through his unrelenting power of purpose, the onetime binder of books appropriately invited nature to pen another chapter in the story that is our universe.

Quotation sources:

“searching for some Mineral or Vegitable curiosity,” Williams (1965), p. 11.

“He drinks from a fount on Sunday,” John Tyndall, in Williams (1965), p. 6, from Tyndall’s Journals at the Royal Institution.

“that of the most illiterate,” Faraday Memoir, p. 81.

“I was a very lively, imaginative person,” Faraday to A. de la Rive, October 2, 1858; Williams (Isis, 1960), p. 522.

“The desire to be engaged in scientific occupation,” and “required no answer,” Faraday Memoir, p. 82.

“Nothing is too wonderful to be true,” Gooding website article.

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“Let us now consider,.” Faraday, Forces of Matter lecture, 1859.

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