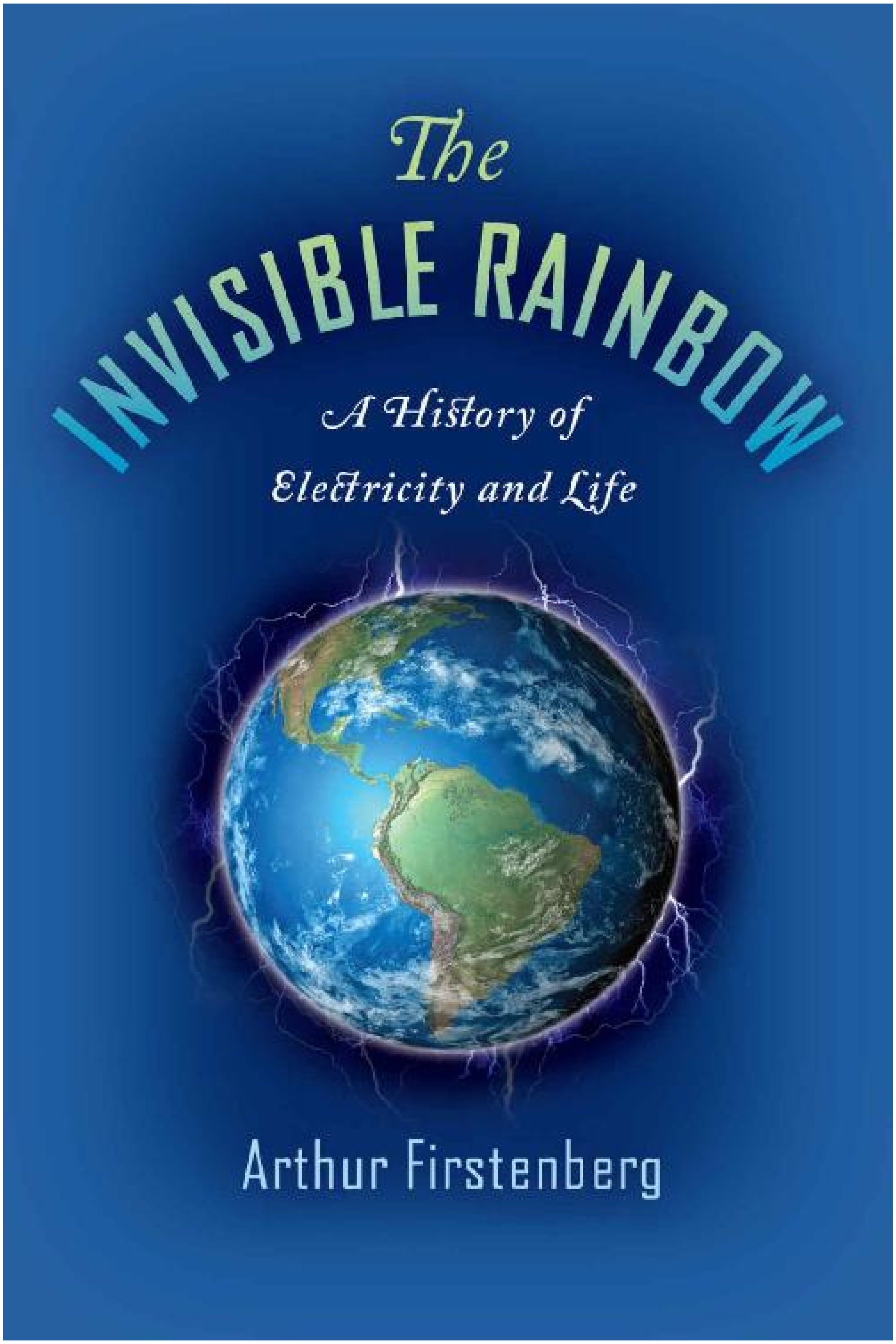

The
INVISIBLE RAINBOW
A History of
Electricity and Life
Arthur Firstenberg

The INVISIBLE RAINBOW

A History of Electricity and Life

Arthur Firstenberg

Chelsea Green Publishing

White River Junction, Vermont

London, UK

Originally published in 2017 by AGB Press, Santa Fe, New Mexico; Sucre, Bolivia.

This paperback edition published by Chelsea Green Publishing, 2020.

Book layout: Jim Bisakowski

Cover design: Ann Lowe

Printed in Canada.

First printing February 2020.

10 9 8 7 6 5 4 3 2 1 20 21 22 23 24

Our Commitment to Green Publishing

Chelsea Green sees publishing as a tool for cultural change and ecological stewardship. We strive to

align our book manufacturing practices with our editorial mission and to reduce the impact of our

business enterprise in the environment. We print our books and catalogs on chlorine-free recycled

paper, using vegetable-based inks whenever possible. This book may cost slightly more because it

was printed on paper that contains recycled fiber, and we hope you'll agree that it's worth it. *The*

Invisible Rainbow was printed on paper supplied by Marquis that is made of recycled materials and

other controlled sources.

Library of Congress Control Number: 2020930536

ISBN 978-1-64502-009-7 (paperback) | 978-1-64502-010-3 (ebook)

Chelsea Green Publishing

85 North Main Street, Suite 120

White River Junction, VT 05001

(802) 295-6300

www.chelseagreen.com

In memory of Pelda Levey—friend, mentor, and fellow traveler.

Author's Note

FOR EASE OF READING I have kept the endnotes to

a minimum. However, all sources referred to in the text

can be found in the bibliography at the back of the

book, together with other principal works I have

consulted. For the convenience of those interested in particular subjects, the literature in the bibliography is organized by chapter, and within some chapters by topic, instead of the usual single alphabetical listing.

A.F.

Contents

Prologue

ONCE UPON A TIME, the rainbow visible in the sky after a storm represented all the colors there were. Our earth was designed that way. We have a blanket of air above us that absorbs the higher ultraviolets, together with all of the X-rays and gamma rays from space. Most of the longer waves, that we use today for radio communication, were once absent as well. Or rather, they were there in infinitesimal amounts. They came to us from the sun and stars but with energies that were a trillion times weaker than the light that also came from the heavens. So weak were the cosmic radio waves that they would have been invisible, and so life never developed organs that could see them.

The even longer waves, the low-frequency pulsations given off by lightning, are also invisible. When lightning flashes, it momentarily fills the air with them, but they are almost gone in an instant; their echo, reverberating around the world, is roughly ten billion times weaker than the light from the sun. We never evolved organs to see this either.

But our bodies know that those colors are there. The energy of our cells whispering in the radio frequency range is infinitesimal but necessary for life. Every thought, every movement that we make surrounds us with low frequency pulsations, whispers that were first detected in 1875 and are also necessary for life. The electricity that we use today, the substance that we send through wires and broadcast through the air without a thought, was identified around 1700 as a property of life. Only later did scientists learn to extract it and make it move inanimate objects, ignoring—because they could not see—its effects on the living world. It surrounds us today, in all of its colors, at intensities that rival the light from the sun, but we still cannot see it because it was not present at life's birth.

We live today with a number of devastating diseases that do not belong here, whose origin we do not know, whose presence we take for granted and no longer question. What it feels like to be without them is a state of vitality that we have completely forgotten.

“Anxiety disorder,” afflicting one-sixth of humanity, did not exist before the 1860s, when telegraph wires first encircled the earth. No hint of it appears in the medical literature before 1866.

Influenza, in its present form, was invented in 1889, along with alternating current. It is with us always, like a familiar guest—so familiar that we have forgotten that it wasn’t always so. Many of the doctors who were flooded with the disease in 1889 had never seen a case before.

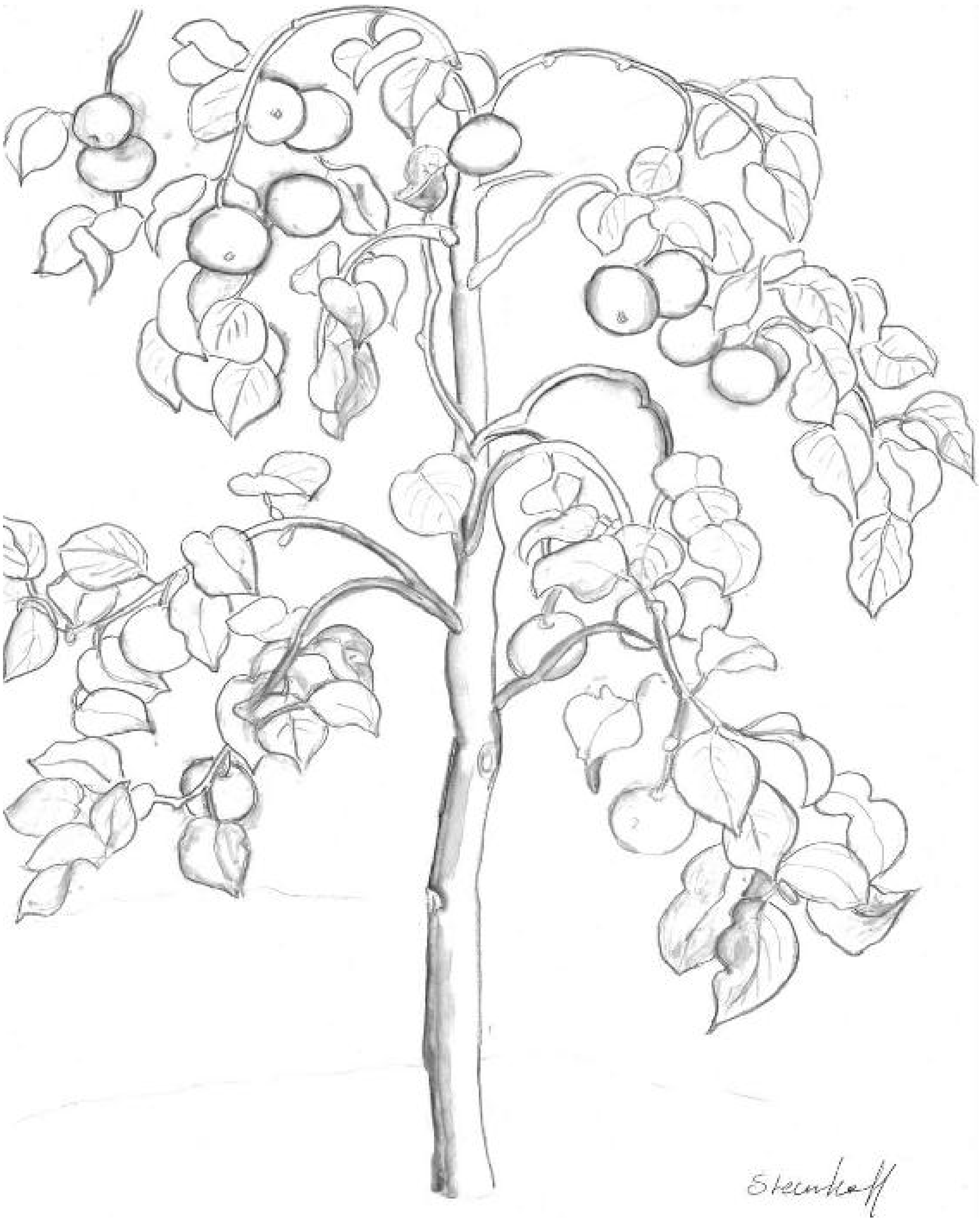
Prior to the 1860s, diabetes was so rare that few doctors saw more than one or two cases during their lifetime. It, too, has changed its character: diabetics were once skeletally thin. Obese people never developed the disease.

Heart disease at that time was the twenty-fifth most common illness, behind accidental drowning. It was an illness of infants and old people. It was extraordinary for anyone else to have a diseased heart.

Cancer was also exceedingly rare. Even tobacco smoking, in non-electrified times, did not cause lung cancer.

These are the diseases of civilization, that we have also inflicted on our animal and plant neighbors, diseases that we live with because of a refusal to recognize the force that we have harnessed for what it is. The 60-cycle current in our house wiring, the ultrasonic frequencies in our computers, the radio waves in our televisions, the microwaves in our cell phones, these are only distortions of the invisible rainbow that runs through our veins and makes us alive. But we have forgotten.

It is time that we remember.



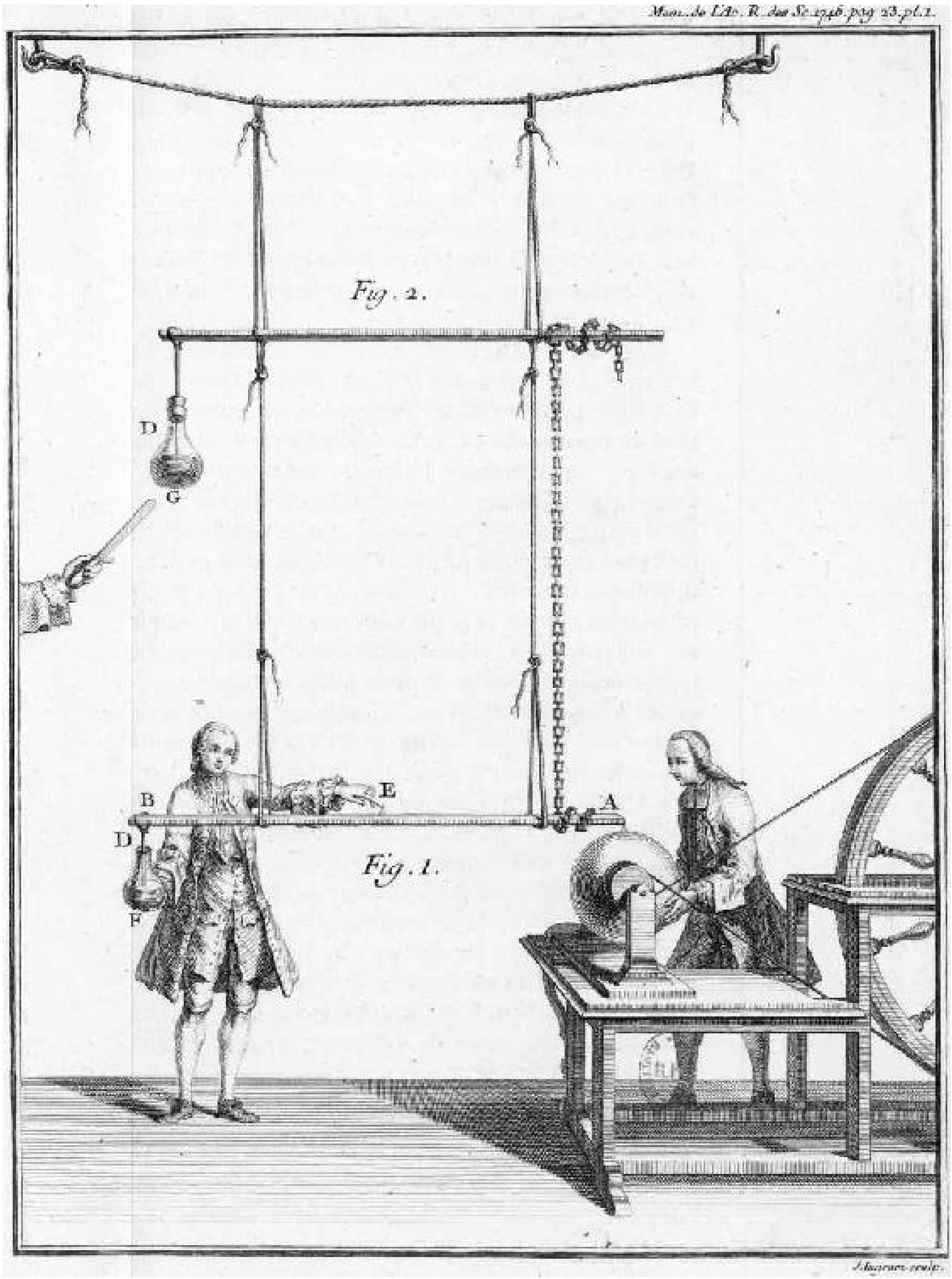
PART ONE

1. Captured in a Bottle

THE EXPERIMENT OF LEYDEN was a craze that was immense, universal: everywhere you went people would ask you if you had experienced its effects. The year was 1746. The place, any city in England, France, Germany, Holland, Italy. A few years later, America. Like a child prodigy making his debut, electricity had arrived, and the whole Western world turned out to hear his performance.

His midwives—Kleist, Cunaeus, Allamand, and Musschenbroek—warned that they had helped give birth to an *enfant terrible*, whose shocks could take away your breath, boil your blood, paralyze you. The public should have listened, been more cautious. But of course the colorful reports of those scientists only encouraged the crowds.

Pieter van Musschenbroek, professor of physics at the University of Leyden, had been using his usual friction machine. It was a glass globe that he spun rapidly on its axis while he rubbed it with his hands to produce the "electric fluid"—what we know today as static electricity. Hanging from the ceiling by silk cords was an iron gun barrel, almost touching the globe. It was called the "prime conductor," and was normally used to draw sparks of static electricity from the rubbed, rotating glass sphere.



Line engraving from *Mémoires de l'Académie Royale des Sciences* Plate 1, p. 23, 1746

But electricity, in those early days, was of limited use, because it always had to be produced on the spot and there was no way to store it. So Musschenbroek and his associates designed an ingenious experiment—an experiment that changed the world forever: they attached a wire to the other end of the prime conductor and inserted it in a small glass bottle partly filled with water. They wanted to see if the electric fluid could be stored in a jar. And the attempt succeeded beyond their wildest expectations.

"I am going to tell you about a new but terrible experiment," Musschenbroek wrote to a friend in Paris, "which I advise you never to try yourself, nor would I, who have experienced it and survived by the grace of God, do it again for all the Kingdom of France." He held the bottle in his right hand, and with the other hand he tried to draw sparks from the gun barrel. "Suddenly my right hand was hit with such force, that my whole body shook as though struck by lightning. The glass, although thin, did not break, and my hand was not knocked away, but my arm and whole body were affected more terribly than I can express. In a word, I thought I was done for." [1] His companion in invention, biologist Jean Nicolas Sébastien Allamand, when he tried the experiment, felt a "prodigious blow." "I was so stunned," he said, "that I could not breathe for some moments." The pain along his right arm was so intense that he feared permanent injury. [2]

But only half the message registered with the public. The fact that people could be temporarily or, as we will see, permanently injured or even killed by these experiments became lost in the general excitement that followed. Not only lost, but soon ridiculed, disbelieved, and forgotten. Then as now, it was not socially acceptable to say that electricity was dangerous. Just two decades later, Joseph Priestley, the English scientist who is famous for his discovery of oxygen, wrote his *History and Present State of Electricity*, in which he mocked the "cowardly professor" Musschenbroek, and the "exaggerated accounts" of the first experimenters. [3]

Its inventors were not the only ones who tried to warn the public. Johann Heinrich Winkler, professor of Greek and Latin at Leipzig, Germany, tried the experiment as soon as he heard about it. "I found great convulsions in my body," he wrote to a friend in London. "It put my blood into great agitation; so that I was afraid of an ardent fever; and was obliged to use refrigerating medicines. I felt a heaviness in my head, as if I had a stone lying upon it. It gave me twice a bleeding at my nose, to which I am not inclined. My wife, who had only received the electrical flash twice, found herself so weak after it, that she could hardly walk. A week after, she received only once the electrical flash; a few minutes after it she bled at the nose."

From their experiences Winkler took away the lesson that electricity was not to be inflicted upon the living. And so he converted his machine into a great beacon of warning. “I read in the newspapers from Berlin,” he wrote, “that they had tried these electrical flashes upon a bird, and had made it suffer great pain thereby. I did not repeat this experiment; for I think it wrong to give such pain to living creatures.” He therefore wrapped an iron chain around the bottle, leading to a piece of metal underneath the gun barrel. “When then the electrification is made,” he continued, “the sparks that fly from the pipe upon the metal are so large and so strong, that they can be seen (even in the day time) and heard at the distance of fifty yards. They represent a beam of lightning, of a clear and compact line of fire; and they give a sound that frightens the people that hear it.”

The general public did not react as he planned, however. After reading reports like Musschenbroek’s in the proceedings of France’s Royal Academy of Sciences, and his own in the *Philosophical Transactions* of the Royal Society of London, eager men and women by the thousands, all over Europe, lined up to give themselves the pleasure of electricity.

Abbé Jean Antoine Nollet, a theologian turned physicist, introduced the magic of the Leyden jar into France. He tried to satisfy the insatiable demands of the public by electrifying tens, hundreds of people at once, having them take each other by the hand so as to form a human chain, arranged in a large circle with the two ends close together. He would place himself at one of the ends, while the person who represented the last link took hold of the bottle. Suddenly the learned abbot, touching with his hand the metal wire inserted in the flask, would complete the circuit and immediately the shock would be felt simultaneously by the whole line. Electricity had become a social affair; the world was possessed, as some observers called it, by "electromania."

The fact that Nollet had electrocuted several fish and a sparrow with the same equipment did not deter the crowds in the least. At Versailles, in the presence of the king, he electrified a company of 240 soldiers of the French Guard holding each other by the hands. He electrified a community of monks at the Carthusian monastery in Paris, stretched out in a circle more than a mile around, each connected to his neighbors by iron wires.

The experience became so popular that the public began to complain of not being able to give themselves the pleasure of an electric shock without having to wait in line or consult a physician. A demand was created for a portable apparatus that everyone could purchase for a reasonable price and enjoy at their leisure. And so the "Ingenhousz bottle" was invented. Enclosed in an elegant-looking case, it was a small Leyden jar joined to a varnished silk ribbon and a rabbit skin with which to rub the varnish and charge the jar. [4]

Electric canes were sold, "priced for all pocketbooks." [5] These were Leyden jars cleverly disguised as walking canes, which you could charge surreptitiously and trick unsuspecting friends and acquaintances into touching.

Then there was the "electric kiss," a form of recreation that even preceded the invention of the Leyden jar but became much more exciting afterwards. Physiologist Albrecht von Haller, at the University of Göttingen, declared incredulously that such parlor games had "taken the place of quadrille." "Could one believe," he wrote, "that a lady's finger, that her whale-bone petticoat, should send forth flashes of true lightning, and that such charming lips could set on fire a house?"

Line engraving c. 1750, reproduced in Jürgen Teichmann, *Vom Bernstein zum Elektron*, Deutsches

Museum 1982

She was an “angel,” wrote German physicist Georg Matthias Bose, with “white-swan neck” and “blood-crowned breasts,” who “steals your heart with a single glance” but whom you approach at your peril. He called her “Venus Electrificata” in a poem, published in Latin, French, and German, that became famous throughout Europe:

If a mortal only touches her hand

Of such a god-child even only her dress,

The sparks burn the same, through all of one’s limbs,

As painful as it is, he seeks it again.

Even Benjamin Franklin felt compelled to give instructions: “Let A and B stand on wax; or A on wax and B on the floor; give one of them the electrised phial in hand; let the other take hold of the wire; there will be a small spark; but when their lips approach, they will be struck and shock’d.”6

Wealthy ladies hosted such entertainment in their homes. They hired instrument makers to craft large, ornate electrical machines that they displayed like pianos. People of more moderate means bought off-the-shelf models that were available in an assortment of sizes, styles, and prices. Aside from entertainment, electricity, assumed to be related to or identical with the life force, was used primarily for its medical effects. Both electrical machines and Leyden jars found their way into hospitals, and into the offices of doctors wanting to keep up with the times. An even greater number of "electricians" who were not medically trained set up office and began treating patients. One reads of medical electricity being used during the 1740s and 1750s by practitioners in Paris, Montpellier, Geneva, Venice, Turin, Bologna, Leipzig, London, Dorchester, Edinburgh, Shrewsbury, Worcester, Newcastle-Upon-Tyne, Uppsala, Stockholm, Riga, Vienna, Bohemia, and The Hague.

The famous French revolutionary and doctor Jean-Paul Marat, also a practitioner of electricity, wrote a book about it titled *Mémoire sur l'électricité médicale* ("Memoir on Medical Electricity").

Franklin treated patients with electricity in Philadelphia—so many of them that static electric treatments later became known, in the nineteenth century, as "franklinization."

John Wesley, the founder of the Methodist Church, published a 72-page tract in 1759 titled *Desideratum; or, Electricity Made Plain and Useful*. He called electricity "the noblest Medicine yet known in the World," to be used in diseases of the nervous system, skin, blood, respiratory system, and kidneys. "A person standing on the ground," he felt obliged to add, "cannot easily kiss an electrified person standing on the rosin."[7] Wesley himself electrified thousands of people at the headquarters of the Methodist movement and at other locations around London.

And it wasn't just prominent individuals who were setting up shop. So many non-medical people were buying and renting machines for medical use that London physician James Graham wrote, in 1779: "I tremble with apprehension for my fellow creatures, when I see in almost every street in this great metropolis a barber – a surgeon – a tooth-drawer – an apothecary, or a common mechanic turned electrical operator." 8

Since electricity could initiate contractions of the uterus, it became a tacitly understood method of obtaining abortions. Francis Lowndes, for example, was a London electrician with an extensive practice who advertised that he treated poor women gratis "for amenorrhea." 9

Even farmers began testing electricity on their crops and proposing it as a means of improving agricultural production, as we will see in chapter 6.

The use of electricity on living beings in the eighteenth century was so widespread in Europe and America that a wealth of valuable knowledge was collected about its effects on people, plants, and animals, knowledge that has been entirely forgotten, that is far more extensive and detailed than what today's doctors are aware of, who see daily, but without recognition, its effects on their patients, and who do not even know such knowledge ever existed. This information is both formal and informal—letters from individuals describing their experiences; accounts written up in newspapers and magazines; medical books and treatises; papers read at meetings of scientific societies; and articles published in newly founded scientific journals.

As early as the 1740s, ten percent of all articles published in the *Philosophical Transactions* were related to electricity. And during the last decade of that century, fully seventy percent of all articles on electricity in the prestigious Latin journal, *Commentarii de rebus in scientis naturali et medicina gestis*, had to do with its medical uses and its effects on animals and people.10

But the floodgates were wide open, and the torrent of enthusiasm about electricity rushed on unhindered, and would continue to do so during the coming centuries, sweeping caution against the rocks, crushing hints of danger like so many bits of driftwood, obliterating whole tracts of knowledge and reducing them to mere footnotes in the history of invention.

2. The Deaf to Hear, and the Lame to Walk

A BURMESE ELEPHANT has the same set of genes whether it toils in a logging camp or runs free in the forest. But its DNA will not tell you the details of its life. In the same way, electrons cannot tell us what is most interesting about electricity. Like elephants, electricity has been forced to bear our burdens and move great loads, and we have worked out more or less precisely its behavior while in captivity. But we must not be fooled into believing we know everything important about the lives of its wild cousins.

What is the source of thunder and lightning, that causes clouds to become electrified and discharge their fury upon the earth? Science still does not know. Why does the earth have a magnetic field? What makes combed hair frizzy, nylon cling, and party balloons stick to walls? This most common of all electrical phenomena is still not well understood. How does our brain work, our nerves function, our cells communicate? How is our body's growth choreographed? We are still fundamentally ignorant.

And the question raised in this book—"What is the effect of electricity on life?"—is one that modern science doesn't even ask. Science's only concern today is to keep human exposure be-low a level that will cook your cells.

The effect of nonlethal electricity is something mainstream science no longer wants to know. But in the eighteenth century, scientists not only asked the question, but began to supply answers.

Early friction machines were capable of being charged to about ten thousand volts—enough to deliver a stinging shock, but not enough, then or now, to be thought dangerous. By way of comparison, a person can accumulate thirty thousand volts on their body in walking across a synthetic carpet. Discharging it stings, but won't kill you.

A one-pint Leyden jar could deliver a more powerful shock, containing about 0.1 joules of energy, but still about a hundred times less than what is thought to be hazardous, and thousands of times less than shocks that are routinely delivered by defibrillators to revive people who are in cardiac arrest. According to mainstream science today, the sparks, shocks, and tiny currents used in the eighteenth century should have had no effects on health. But they did.

Imagine you were a patient in 1750 suffering from arthritis. Your electrician would seat you in a chair that had glass legs so that it was well insulated from the ground. This was done so that when you were connected to the friction machine, you would accumulate the "electric fluid" in your body instead of draining it into the earth. Depending on the philosophy of your electrician, the severity of your disease, and your own tolerance for electricity, there were a number of ways to "electrize" you. In the "electric bath," which was the most gentle, you would simply hold in your hand a rod connected to the prime conductor, and the machine would be cranked continuously for minutes or hours, communicating its charge throughout your body and creating an electrical “aura” around you. If this was done gently enough, you would feel nothing—just as a person who shuffles their feet on a carpet can accumulate a charge on their body without being aware of it.

After you were thus “bathed,” the machine would be stopped and you might be treated with the “electric wind.” Electricity discharges most easily from pointed conductors. Therefore a grounded, pointed metal or wooden wand would be brought toward your painful knee and you would again feel very little—perhaps the sensation of a small breeze as the charge that had built up in your body slowly dissipated through your knee into the grounded wand.

For a stronger effect, your electrician might use a wand with a rounded end, and instead of a continuous current draw actual sparks from your ailing knee. And if your condition were severe—say your leg was paralyzed—he could charge up a small Leyden jar and give your leg a series of strong shocks.

Electricity was available in two flavors: positive, or “vitreous” electricity, obtained by rubbing glass, and negative, or “resinous” electricity, originally obtained by rubbing sulfur or various resins. Your electrician would most likely treat you with positive electricity, as it was the variety normally found on the surface of the body in a state of health.

The goal of electrotherapy was to stimulate health by restoring the electrical equilibrium of the body where it was out of balance. The idea was certainly not new. In another part of the world, the use of natural electricity had been developed to a fine art over thousands of years. Acupuncture needles, as we will see in chapter 9, conduct atmospheric electricity into the body, where it travels along precisely mapped pathways, returning to the atmosphere through other needles that complete the circuit. By comparison electrotherapy in Europe and America, although similar in concept, was an infant science, using instruments that were like sledgehammers.

European medicine in the eighteenth century was full of sledgehammers. If you went to a conventional doctor for your rheumatism, you might expect to be bled, purged, vomited, blistered, and even dosed with mercury. It's easy to understand that going to an electrician instead might seem a very attractive alternative. And it remained attractive until the beginning of the twentieth century.

After more than half a century of unceasing popularity, electrotherapy fell temporarily out of favor during the early 1800s in reaction to certain cults, one of which had grown up in Europe around Anton Mesmer and his so-called "magnetic" healing, and another in America around Elisha

Perkins and his “electric” tractors—three-inch-long metallic pencils with which one made passes over a diseased part of the body. Neither man used actual magnets or electricity at all, but they gave both those methods, for a while, a bad name. By mid-century electricity was again mainstream, and in the 1880s ten thousand American physicians were administering it to their patients.

Electrotherapy finally fell permanently out of favor in the early twentieth century, perhaps, one suspects, because it was incompatible with what was then going on in the world. Electricity was no longer a subtle force that had anything to do with living things. It was a dynamo, capable of propelling locomotives and executing prisoners, not curing patients. But sparks delivered by a friction machine, a century and a half before the world was wired, carried quite different associations.

There is no doubt that electricity sometimes cured diseases, both major and minor. The reports of success, over almost two centuries, were sometimes exaggerated, but they are too numerous and often too detailed and well-attested to dismiss them all. Even in the early 1800s, when electricity was not in good repute, reports continued to emerge that cannot be ignored. For example, the London Electrical Dispensary, between September 29, 1793, and June 4, 1819, admitted 8,686 patients for electrical treatment. Of these, 3,962 were listed as “cured,” and another 3,308 as “relieved” when they were discharged—an 84 percent success rate.[1] Although the main focus of this chapter will be on effects that are not necessarily beneficial, it is important to remember why eighteenth century society was enthralled with electricity, just as we are today. For almost three hundred years the tendency has been to chase its benefits and dismiss its harms. But in the 1700s and 1800s, the daily use of electricity in medicine was a constant reminder, at least, that electricity was intimately connected with biology. Here in the West, electricity as a biological science remains in its infancy today, and even its cures have been long forgotten. I will recall just one of them.

Making the Deaf Hear

In 1851, the great neurologist Guillaume Benjamin Duchenne de Boulogne achieved renown for something for which he is least remembered today. A well-known figure in the history of medicine, he was certainly no quack. He introduced modern methods of physical examination that are still in use. He was the first physician ever to take a biopsy from a living person for the purpose of diagnosis. He published the first accurate clinical description of polio. A number of diseases that he identified are named for him, most notably Duchenne muscular dystrophy. He is remembered for all those things. But in his own time he was the somewhat unwilling center of attention for his work with the deaf.

Duchenne knew the anatomy of the ear in great detail, in fact it was for the purpose of elucidating the function of the nerve called the chorda tympani, which passes through the middle ear, that he asked a few deaf people to volunteer to be the subjects of electrical experiments. The incidental and unexpected improvement in their hearing caused Duchenne to be inundated with requests from within the deaf community to come to Paris for treatments. And so he began to minister to large numbers of people with nerve deafness, using the same apparatus that he had designed for his research, which fit snugly into the ear canal and contained a stimulating electrode.

His procedure, to a modern reader, might seem unlikely to have had any effect at all: he exposed his patients to pulses of the feeblest possible current, spaced half a second apart, for five seconds at a time. Then he gradually increased the current strength, but never to a painful level, and never for more than five seconds at a time. And yet by this means he restored good hearing, in a matter of days or weeks, to a 26-year-old man who had been deaf since age ten, a 21-year-old man who had been deaf since he had measles at age nine, a young woman recently made deaf by an overdose of quinine, given for malaria, and numerous others with partial or complete hearing loss.2

Fifty years earlier, in Jever, Germany, an apothecary named Johann Sprenger became famous throughout Europe for a similar reason. Though he was denounced by the director of the Institute for the Deaf and Dumb in Berlin, he was besieged by the deaf themselves with requests for treatment. His results were attested in court documents, and his methods were adopted by contemporary physicians. He himself was reported to have fully or partially restored hearing to no less than forty deaf and hard of hearing individuals, including some deaf from birth. His methods, like Duchenne's, were disarmingly simple and gentle. He made the current weaker or stronger according to the sensitivity of his patient, and each treatment consisted of brief pulses of electricity spaced one second apart for a total of four minutes per ear. The electrode was placed on the tragus (the flap of cartilage in front of the ear) for one minute, inside the ear canal for two minutes, and on the mastoid process behind the ear for one minute.

And fifty years before Sprenger, Swedish physician Johann Lindhult, writing from Stockholm, reported the full or partial restoration of hearing, during a two-month period, to a 57-year-old man who had been deaf for thirty-two years; a youth of twenty-two, whose hearing loss was recent; a seven-year-old girl, born deaf; a youth of twenty-nine, hard of hearing since age eleven; and a man with hearing loss and tinnitus of the left ear. “All patients,” wrote Lindhult, “were treated with gentle electricity, either the simple current or the electric wind.”

Lindhult, in 1752, was using a friction machine. Half a century later, Sprenger used galvanic currents from an electric pile, forerunner of today’s batteries. Half a century after that, Duchenne used alternating current from an induction coil. British surgeon Michael La Beaume, similarly successful, used a friction machine in the 1810s and galvanic currents later on. What they all had in common was their insistence on keeping their treatments brief, simple, and painless.

Seeing and Tasting Electricity

Aside from attempting to cure deafness, blindness, and other diseases, early electricians were intensely interested in whether electricity could be directly perceived by the five senses—another question about which modern engineers have no interest, and modern doctors have no knowledge, but whose answer is relevant to every modern person who suffers from electrical sensitivity.

When he was still in his early twenties, the future explorer Alexander von Humboldt lent his own body to the elucidation of this mystery. It would be several years before he left Europe on the long voyage that was to propel him far up the Orinoco River and to the top of Mount Chimborazo, collecting plants as he went, making systematic observations of the stars and the earth and the cultures of Amazonian peoples. Half a century would pass before he would begin work on his five-volume *Kosmos*, an attempt to unify all existing scientific knowledge. But as a young man supervising mining operations in the Bayreuth district of Bavaria, the central question of his day occupied his spare time.

Is electricity really the life force, people were asking? This question, gnawing gently at the soul of Europe since the days of Isaac Newton, had suddenly become insistent, forcing itself out of the lofty realms of philosophy and into dinnertime discussions around the tables of ordinary people whose children would have to live with the chosen answer. The electric battery, which produced a current from the contact of dissimilar metals, had just been invented in Italy. Its implications were huge: friction machines—bulky, expensive, unreliable, subject to atmospheric conditions—might no longer be necessary. Telegraph systems, already designed by a few visionaries, might now be practical. And questions about the nature of the electric fluid might come closer to being answered.

In the early 1790s, Humboldt threw himself into this research with enthusiasm. He wished, among other things, to determine whether he could perceive this new form of electricity with his own eyes, ears, nose, and taste buds. Others were doing similar experiments—Alessandro Volta in Italy, George Hunter and Richard Fowler in England, Christoph Pfaff in Germany, Peter Abilgaard in Denmark—but none more thoroughly or diligently than Humboldt.

Consider that today we are accustomed to handling nine-volt batteries with our hands without a thought. Consider that millions of us are walking around with silver and zinc, as well as gold, copper, and other metals in the fillings in our mouths. Then consider the following experiment of Humboldt's, using a single piece of zinc, and one of silver, that produced an electric tension of about a volt:

"A large hunting dog, naturally lazy, very patiently let a piece of zinc be applied against his palate, and remained perfectly tranquil while another piece of zinc was placed in contact with the first piece and with his tongue. But scarcely one touched his tongue with the silver, than he showed his aversion in a humorous manner: he contracted his upper lip convulsively, and licked himself for a very long time; it sufficed afterwards to show him the piece of zinc to remind him of the impression he had experienced and to make him angry."

The ease with which electricity can be perceived, and the variety of the sensations, would be a revelation to most doctors today. When Humboldt touched the top of his own tongue with the piece of zinc, and its point with the piece of silver, the taste was strong and bitter. When he moved the piece of silver underneath, his tongue burned. Moving the zinc further back and the silver forward made his tongue feel cold. And when the zinc was moved even further back he became nauseated and sometimes vomited—which never happened if the two metals were the same. The sensations always occurred as soon as the zinc and silver pieces were placed in metallic contact with each other. [3]

A sensation of sight was just as easily elicited, by four different methods, using the same one-volt battery: by applying the silver "armature" on one moistened eyelid and the zinc on the other; or one in a nostril and the other on an eye; or one on the tongue and one on an eye; or even one on the tongue and one against the upper gums. In each case, at the moment the two metals touched each other, Humboldt saw a flash of light. If he repeated the experiment too many times, his eyes became inflamed.

In Italy, Volta, the inventor of the electric battery, succeeded in eliciting a sensation of sound, not with one pair of metals, but with thirty, attached to electrodes in each ear. With the metals he originally used in his "pile," using water as an electrolyte, this may have been about a twenty-volt battery. Volta heard only a crackling sound which could have been a mechanical effect on the bones of his middle ears, and he did not repeat the experiment, fearing that the shock to his brain might be dangerous.4 It remained for German physician Rudolf Brenner, seventy years later, using more refined equipment and smaller currents, to demonstrate actual effects on the auditory nerve, as we will see in chapter 15.

Speeding up the Heart and Slowing it Down

Back in Germany, Humboldt, armed with the same single pieces of zinc and silver, turned his attention next to the heart. Together with his older brother Wilhelm, and supervised by well-known physiologists, Humboldt removed the heart of a fox and prepared one of its nerve fibers so that the armatures could be applied to it without touching the heart itself. “At each contact with the metals the pulsations of the heart were clearly changed; their speed, but especially their force and their elevation were augmented,” he recorded.

The brothers next experimented on frogs, lizards, and toads. If the dissected heart beat 21 times in a minute, after being galvanized it beat 38 to 42 times in a minute. If the heart had stopped beating for five minutes, it restarted immediately upon contact with the two metals.

Together with a friend in Leipzig, Humboldt stimulated the heart of a carp that had almost stopped beating, pulsing only once every four minutes. After massaging the heart proved to have no effect, galvanization restored the rate to 35 beats per minute. The two friends kept the heart beating for almost a quarter of an hour by repeated stimulation with a single pair of dissimilar metals.

On another occasion, Humboldt even managed to revive a dying linnet that was lying feet up, eyes closed on its back, unresponsive to the prick of a pin. "I hastened to place a small plate of zinc in its beak and a small piece of silver in its rectum," he wrote, "and I immediately established a communication between the two metals with an iron rod. What was my astonishment, when at the moment of contact the bird opened its eyes, raised itself on its feet and beat its wings. It breathed again for six or eight minutes and then calmly died."[5]

Nobody proved that a one-volt battery could restart a human heart, but scores of observers before Humboldt had reported that electricity increased the human pulse rate—knowledge that is not possessed by doctors today. German physicians Christian Gottlieb Kratzenstein[6] and Carl Abraham Gerhard, [7] German physicist Celestin Steiglehner,[8] Swiss physicist Jean Jallabert,[9] French physicians François Boissier de Sauvages de la Croix, [10] Pierre Mauduyt de la Varenne,[11] and Jean-Baptiste Bonnefoy,[12] French physicist Joseph Sigaud de la Fond,[13] and Italian physicians Eusebio Sguario[14] and Giovan Giuseppi Veratti[15] were just a few of the observers who reported that the electric bath increased the pulse rate by anywhere from five to thirty beats per minute, when positive electricity was used. Negative electricity had the opposite effect. In 1785, Dutch pharmacist Willem van Barneveld conducted 169 trials on 43 of his patients—men, women, and children aged nine to sixty—finding an average five percent increase in the pulse rate when the person was bathed with positive electricity, and a three percent *decrease* in the pulse rate when the person was bathed with negative electricity.[16] When positive sparks were drawn the pulse increased by twenty percent.

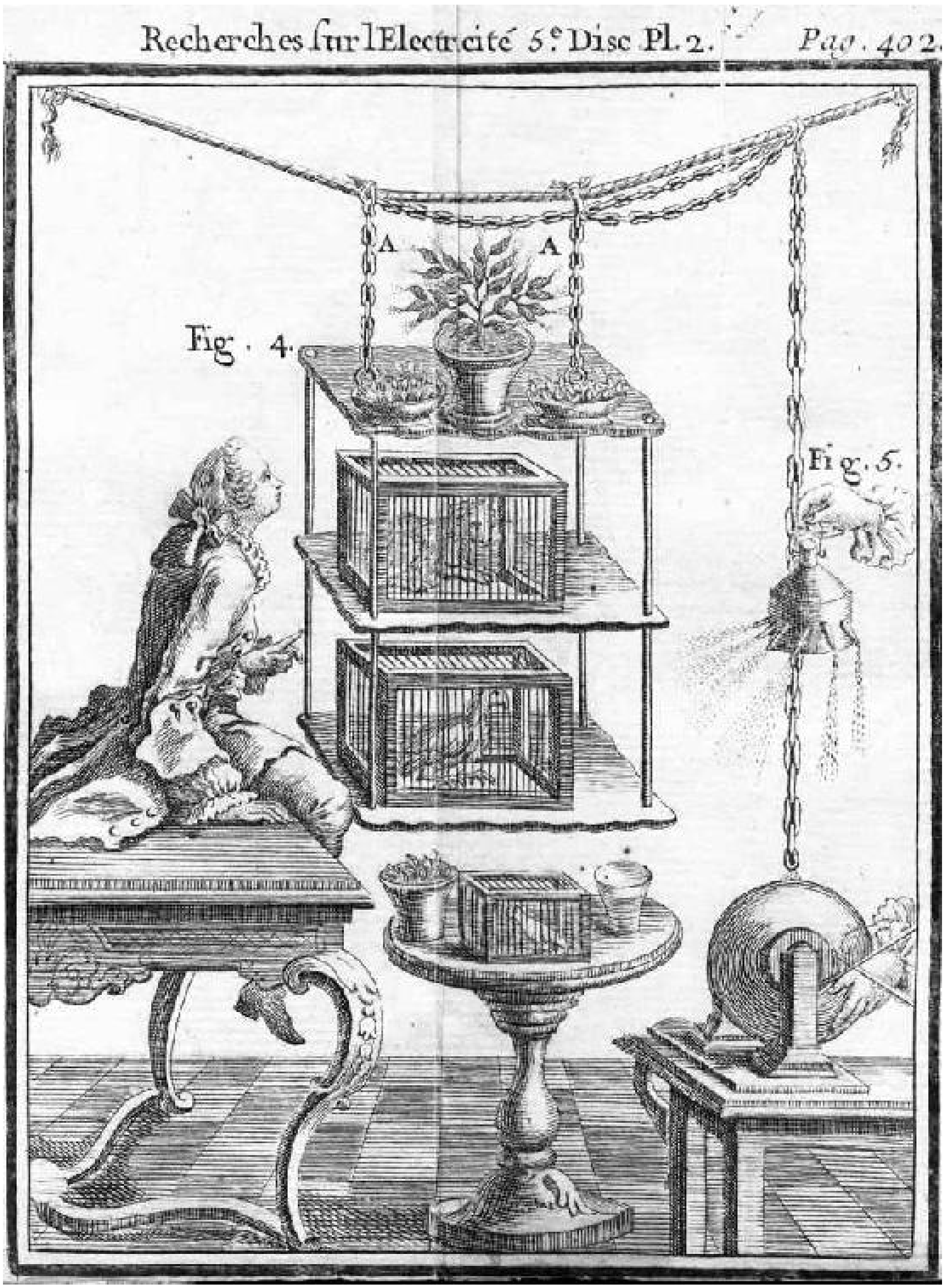
But these were only averages: no two individuals reacted the same to electricity. One person's pulse always increased from sixty to ninety beats per minute; another's always doubled; another's pulse became much slower; another reacted not at all. Some of van Barneveld's subjects reacted in a manner opposite to the majority: a negative charge always accelerated their pulse, while a positive charge slowed it down.

"Istupidimento"

Observations of these kinds came quickly and abundantly, so that by the end of the eighteenth century a basic body of knowledge had been built up about the effects of the electric fluid—usually the positive variety—on the human body. It increased both the pulse rate, as we have seen, and the strength of the pulse. It augmented all of the secretions of the body. Electricity caused salivation, and made tears to flow, and sweat to run. It caused the secretion of ear wax, and nasal mucus. It made gastric juice flow, stimulating the appetite. It made milk to be let down, and menstrual blood to issue. It made people urinate copiously and move their bowels.

Most of these actions were useful in electrotherapy, and would continue to be so until the early twentieth century. Other effects were purely unwanted. Electrification almost always caused dizziness, and sometimes a sort of mental confusion, or "istupidimento," as the Italians called it. [17] It commonly produced headaches, nausea, weakness, fatigue, and heart palpitations. Sometimes it caused shortness of breath, coughing, or asthma-like wheezing. It often caused muscle and joint pains, and sometimes mental depression. Although electricity usually caused the bowels to move, often with diarrhea, repeated electrification could result in constipation. Electricity caused both drowsiness and insomnia.

Humboldt, in experiments on himself, found that electricity increased blood flow from wounds, and caused serum to flow copiously out of blisters.[18] Gerhard divided one pound of freshly drawn blood into two equal parts, placed them next to each other, and electrified one of them. The electrified blood took longer to clot.[19] Antoine Thillaye-Platel, pharmacist at the Hôtel-Dieu, the famous hospital in Paris, agreeing, said that electricity is contraindicated in cases of hemorrhage. [20] Consistent with this are numerous reports of nosebleeds from electrification. Winkler and his wife, as already mentioned, got nosebleeds from the shock of a Leyden jar. In the 1790s, Scottish physician and anatomist Alexander Monro, who is remembered for discovering the function of the lymphatic system, got nosebleeds from just a one-volt battery, whenever he tried to elicit the sensation of light in his eyes. "Dr. Monro was so excitable by galvanism that he bled from the nose when, having the zinc very gently inserted in his nasal fossae, he put it in contact with an armature applied to his tongue. The hemorrhage always took place at the moment when the lights appeared." This was reported by Humboldt.[21] In the early 1800s, Conrad Quensel, in Stockholm, reported that galvanism "frequently" caused nosebleeds.[22]



Line engraving from Abbé Nollet, *Recherches sur les Causes Particulières des Phénomènes*

Électriques, Paris: Frères Guérin, 1753

Abbé Nollet proved that at least one of these effects—perspiration—occurred merely from being in an electric field. Actual contact with the friction machine wasn't even necessary. He had electrified cats, pigeons, several kinds of songbirds, and finally human beings. In carefully controlled repeatable experiments, accompanied by modern-looking data tables, he had demonstrated measurable weight loss in all of his electrified subjects, due to an increase in evaporation from their skin. He had even electrified five hundred houseflies in a gauze-covered jar for four hours and found that they too had lost extra weight—4 grains more than their non-electrified counterparts in the same amount of time.

Then Nollet had the idea to place his subjects on the floor underneath the electrified metal cage instead of in it, and they still lost as much, and even a bit more weight than when they were electrified themselves. Nollet had also observed an acceleration in the growth of seedlings sprouted in electrified pots; this too occurred when the pots were only placed on the floor beneath. "Finally," wrote Nollet, "I made a person sit for five hours on a table near the electrified metal cage." The young woman lost 4½ drams more weight than when she had actually been electrified herself.23

Nollet was thus the first person, back in 1753, to report significant biological effects from exposure to a DC electric field—the kind of field that according to mainstream science today has no effect whatsoever. His experiment was later replicated, using a bird, by Steiglehner, professor of physics at the University of Ingolstadt, Bavaria, with similar results.24

Table 1 lists the effects on humans, reported by most early electricians, of an electric charge or small currents of DC electricity. Electrically sensitive people today will recognize most if not all of them.

Table 1 - Effects of Electricity as Reported in the Eighteenth Century

Therapeutic and neutral effects

Non-therapeutic effects

Change in pulse rate

Dizziness

Sensations of taste, light,

Nausea

and sound

Headaches

Increase of body temperature

Nervousness

Pain relief

Irritability

Restoration of muscle tone

Mental confusion

Stimulation of appetite

Depression

Mental exhilaration

Insomnia

Sedation

Drowsiness

Perspiration

Fatigue

Salivation

Weakness

Secretion of ear wax

Numbness and tingling

Secretion of mucus

Muscle and joint pains

Menstruation, uterine

Muscle spasms and cramps

contraction

Backache

Lactation

Heart palpitations

Lacrimation

Chest pain

Urination

Colic

Defecation

Diarrhea

Constipation

Nosebleeds, hemorrhage

Itching

Tremors

Seizures

Paralysis

Fever

Respiratory infections

Shortness of breath

Coughing

Wheezing and asthma attacks

Eye pain, weakness, and fatigue

Ringing in the ears

Metallic taste

3. Electrical Sensitivity

"I HAVE ALMOST ENTIRELY given up the electrical experiments." The author of these words, in referring to his own inability to tolerate electricity, wrote them not in the modern era of alternating currents and radio waves, but in the mid-eighteenth century when all there was was static electricity. French botanist Thomas-François Dalibard confided his reasons to Benjamin Franklin in a letter dated February 1762. "First, the different electrical shocks have so strongly attacked my nervous system that I am left with a convulsive tremor in my arm so that I can scarcely bring a glass to my mouth; and if I now were to touch one electrical spark I would be unable to sign my name for 24 hours. Another thing that I notice is that it is almost impossible for me to seal a letter because the electricity of the Spanish wax, communicating itself to my arm, increases my tremor." Dalibard was not the only one. Benjamin Wilson's 1752 book, *A Treatise on Electricity*, helped promote the popularity of electricity in England, but he himself did not fare so well by it. "Upon repeating those shocks often for several weeks together," he wrote, "I at last was weakened so much that a very small quantity of electric matter in the vial would shock me to a great degree, and cause an uncommon pain. So that I was obliged to desist from trying any more." Even rubbing a glass globe with his hand—the basic electrical machine of his day—gave him "a very violent headache." 1

The man who authored the first book in German devoted solely to electricity, *Neu-Entdeckte Phænomena von Bewunderns-würdigen Würckungen der Natur* ("Newly Discovered Phenomena of the Wonderful Workings of Nature," 1744), became gradually paralyzed on one side of his body. Called the first electrical martyr, Johann Doppelmayer, professor of mathematics at Nuremberg, stubbornly persisted in his researches and died of a stroke in 1750 after one of his electrical experiments. 2

These were just three of the earliest casualties—three scientists who helped birth an electrical revolution in which they themselves could not participate.

Even Franklin developed a chronic neurological illness that began during the period of his electrical researches and that recurred periodically for the rest of his life. Although he also suffered from gout, this other problem worried him more. Writing on March 15, 1753, of a pain in his head, he said, "I wish it were in my foot, I think I could bear it better." One recurrence lasted for the better part of five months while he was in London in 1757. He wrote to his doctor about “a giddiness and a swimming in my head,” “a humming noise,” and “little faint twinkling lights” that disturbed his vision. The phrase “violent cold,” appearing often in his correspondence, was usually accompanied by mention of that same pain, dizziness, and problems with his eyesight. [3] Franklin, unlike his friend Dalibard, never recognized a connection to electricity.

Jean Morin, professor of physics at the Collège Royale de Chartres, and author, in 1748, of *Nouvelle Dissertation sur l’Électricité* (“New Dissertation on Electricity”), thought that it was never healthy to expose oneself to electricity in any form, and to illustrate his point he described an experiment conducted not with a friction machine but with his pet cat. “I stretched out a large cat on the cover of my bed,” he recounted. “I rubbed it, and in the darkness I saw sparks fly.” He continued this for more than half an hour. “A thousand tiny fires flew here and there, and continuing the friction, the sparks grew until they seemed like spheres or balls of fire the size of a hazelnut… I brought my eyes near one ball, and I immediately felt a lively and painful stinging in my eyes; there was no shock in the rest of my body; but the pain was followed by a faintness that made me fall to the side, my strength failed me, and I battled, so to speak, against passing out, I fought against my own weakness from which I did not recover for several minutes.” 4

Such reactions were by no means confined to scientists. What is known to few doctors today was known universally to all eighteenth-century electricians, and to the nineteenth-century electrotherapists who followed them: electricity had side effects and some individuals were enormously and unaccountably more sensitive to it than others. “There are persons,” wrote Pierre Bertholon, a physicist from Languedoc, in 1780, “on whom artificial electricity made the greatest impression; a small shock, a simple spark, even the electric bath, feeble as it is, produced profound and lasting effects. I found others in whom strong electrical operations seemed not to cause any sensation at all… Between these two extremes are many nuances that correspond to the diverse individuals of the human species.” 5

Sigaud de la Fond’s numerous experiments with the human chain never produced the same results twice. “There are people for whom electricity can be unfortunate and very harmful,” he declared. “This impression being relative to the disposition of the organs of those who experience it and of the sensitivity or irritability of their nerves, there are probably not two persons in a chain composed of many, who experience strictly the same degree of shock.”6

Mauduyt, a physician, proposed in 1776 that “the face of the constitution depends in great part on the communication between the brain, the spinal cord and the different parts by means of the nerves. Those in whom this communication is less free, or who experience the nervous illness, are then more affected than others."7

Few other scientists made any attempt to explain the differences. They simply reported them as fact—a fact as ordinary as that some people are fat and some thin, some tall and some short—but a fact that one had to take into account if one were going to offer electricity as a treatment, or otherwise expose people to it.

Even Abbé Nollet, popularizer of the human chain and electricity's leading missionary, reported this variability in the human condition from the very beginning of his campaign. "Pregnant women especially, and delicate persons," he wrote in 1746, "should not be exposed to it." And later: "Not all persons are equally appropriate to the experiments of electricity, be it for exciting that virtue, be it for receiving it, be it finally for feeling its effects." 8

British physician William Stukeley, in 1749, was already so familiar with the side effects of electricity that he observed, after an earthquake at London on March 8 of that year, that some felt "pains in their joints, rheumatism, sickness, headach, pain in their back, hysteric and nervous disorders… *exactly as upon electrification*; and to some it has proved fatal."9 He concluded that electrical phenomena must play an important role in earthquakes.

And Humboldt was so amazed by the extraordinary human variability that he wrote, in 1797: "It is observed that susceptibility to electrical irritation, and electrical conductivity, differ as much from one individual to another, as the phenomena of living matter differ from those of dead material." 10

The term "electrical sensitivity," in use again today, reveals a truth but conceals a reality. The truth is that not everyone feels or conducts electricity to the same degree. In fact if most people were aware of how vast the spectrum of sensitivity really is, they would have reason to be as astonished as Humboldt was, and as I still am. But the hidden reality is that however great the apparent differences between us, electricity is still part and parcel of our selves, as necessary to life as air and water. It is as absurd to imagine that electricity doesn't affect someone because he or she is not aware of it, as to pretend that blood doesn't circulate in our veins when we are not thirsty.

Today, people who are electrically sensitive complain about power lines, computers, and cell phones. The amount of electrical energy being