Return With Us Now

To Those Shocking Days of Yesteryear ...

Ellen R. Kuhfeld, The Bakken Library and Museum

Many of the effects used in modern electromagnetic medicine and studied in modern research are subtle. Elaborate methodologies are needed to prove their existence, let alone their efficacy. It has not always been thus. Touch a doorknob in January, put your finger in the wrong socket, grasp the wrong fish -- and you know electricity has happened to you. Your muscles twitch, your nerves tingle and grow numb.

Your muscles twitch: that's exercise. Your nerves tingle and grow numb: that can be the relief of pain. Throughout history, much of medicine has been the relief of pain, and getting the weak back to strength. Electricity can do things a rational medicine would seize upon and treasure.

The first records of medical electro-stimulation come to us from the Romans. Scribonius Largus[1] wrote in the first century A.D. that

"For any type of gout a live black torpedo should, when the pain begins, be placed under the feet. The patient must stand on a moist shore washed by the sea and he should stay like this until his whole foot and leg up to the knee is numb. This takes away present pain and prevents pain from coming on if it has not already arisen. In this way Anteros, a freeman of Tiberius, was cured...."

Claudius Galen[2] added

"The whole torpedo, I mean the sea-torpedo, is said by some to cure headache and prolapsus ani when applied. I indeed tried both of these things and found neither to be true. Therefore I thought that the torpedo should be applied alive to the person who has the headache, and that it could be that this remedy is anodyne and could free the patient from pain as do other remedies which numb the senses: this I found to be so. And I think that he who first tried this did so for the above-mentioned reason."

Here we have the electric torpedo fish of the Mediterranean -- capable of fifty volts and several amps, moist with salt water for good conductivity -- being used live in medicine. And it is used in familiar ways: relief of pain in gout and headache, muscular stimulation in *prolapsus ani.* (Presumably in the latter, the abdominal muscles would contract and draw the anus back in.)

In China, the electric catfish *parasilurus asota* was recommended for drooping of the eyelid and for facial palsy, as in this prescription from a classic pharmacopoeia (Li, 1596)[3]:

"Cut the tail part from a live catfish and place it directly on the paralyzed spot every morning. The drooping is immediately corrected."

As the centuries wore on, the use of electricity languished. Doctors and pharmacists might be willing to keep a supply of leeches: small, sluggish, available in your friendly local swamp, they are no problem. Live ocean fish are quite another matter. But early in the eighteenth century, Francis Hauksbee the Elder noticed he had accidentally made an electrostatic generator while researching the "mercurial phosphor" in a vacuum. With this technology, the study of electricity spread. In 1743 the students at Halle in Germany asked for their new professor's thoughts. Johann Gottlob Krüger replied[4],

"... all things must have a usefulness; that is certain. Since electricity must have a usefulness, and we have seen that it cannot be looked for either in theology or in jurisprudence, there is obviously

nothing left but medicine."

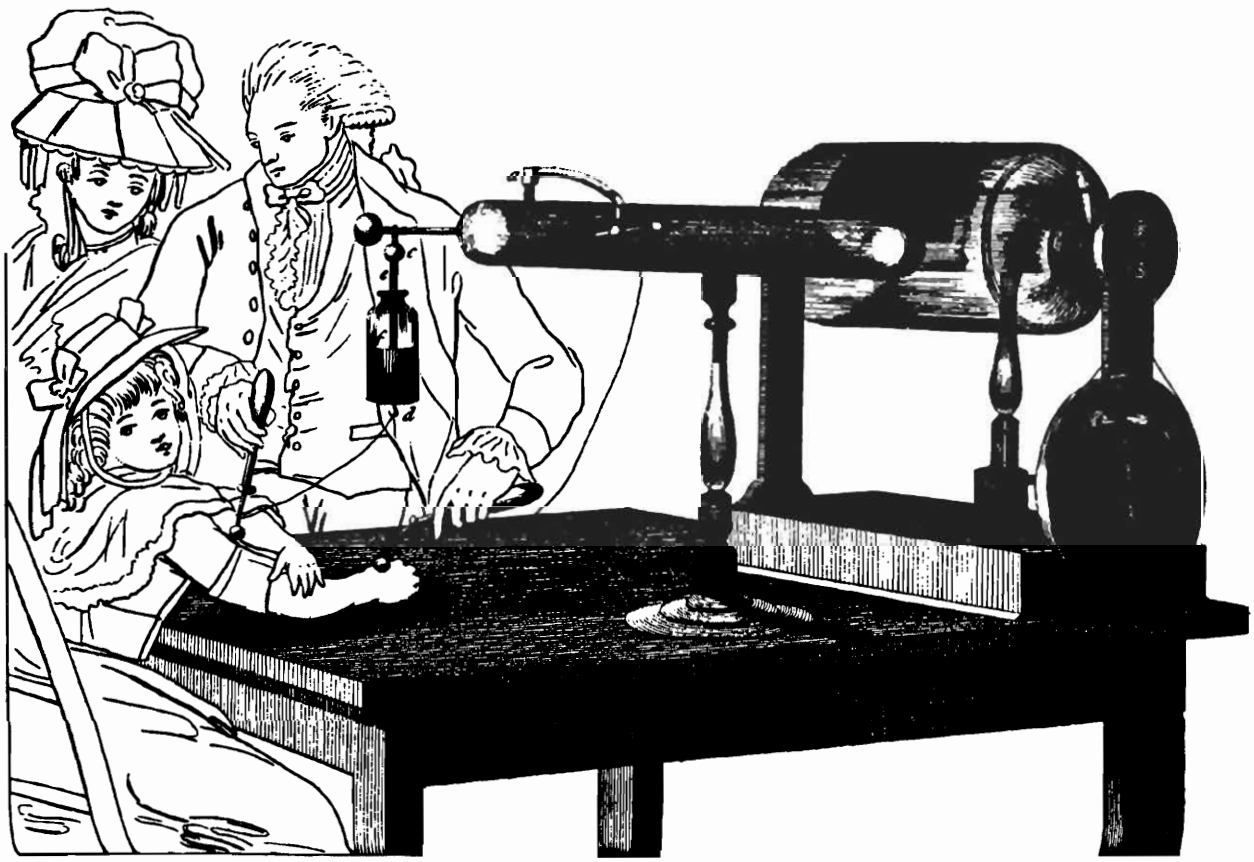
Medical men -- and dilettantes -- tried electricity. Cures were reported, of pain and paralysis and stiffness. But the shocks were mild, your basic shuffle-across-the-carpet-and-touch-the-radiator. An undeniable cure awaited the invention of the Leyden Jar capacitor in the winter of 1745-46. *There* was a shock that could loosen your teeth!

On December 26, 1747, a locksmith named Nogues paid a visit to Jean Jallabert, professor of experimental philosophy and mathematics at Geneva. More than fourteen years earlier, Nogues had suffered an accident while forging a bar of iron. A false blow had thrown him backwards, unconscious. After some days he recovered consciousness but was paralyzed on the right side and unable to speak. After prolonged treatment he was able to walk with a limp, his speech returned, and there was slight movement of the right arm.

Jallabert, together with Daniel Guiot, the leading surgeon of Geneva, examined the patient. All sensation was lost in the right arm, and the wrist was bent towards the forearm. The thumb, index, and little fingers were bent and fixed to the palm. A slight power of movement remained in the middle and ring fingers, and the arm could just be raised or lowered, but no other movements were possible. The arm was emaciated, and the fingers swollen.

With Guiot witnessing the first trial, Jallabert delivered a shock. Nogues' healthy hand held the Leyden Jar, and his paralyzed hand touched it. Jallabert then insulated Nogues on wax, electrified him, and drew sparks from the various muscles of the forearm. He noticed at once that the muscles were "convulsed" and the wrist and fingers agitated. Jallabert immediately had Guiot administer the same treatment to himself, and found similar muscular contractions.

Jallabert began systematic treatment, for about an hour and a half each day. He used a short metal rod with a rounded head to direct the



Using electricity to treat paralysis. From George Adams' *Essay on Electricity* (London, 1785)

electricity precisely to the muscle being treated, with three or four shocks being given to each. The arm was massaged before and after treatment as it lay on the warm surface of a stove.

By January 10, on Guiot's third visit to the patient, he was astonished at the improvement. The arm was less emaciated, and all fingers but the little finger and thumb could be extended. By January 28 the patient could pick up a full glass of water. During February Jallabert worked to strengthen the muscles of the upper arm, and Nogues began a course of exercise with weights and movements. Treatment ended in March with complete use of the arm regained. Eventually the locksmith returned to his old trade[5].

What happened here seems obvious. A blow on Nogues' head caused brain damage, the equivalent of a stroke. (Alternatively, a stroke caused the false blow.) Half his body became paralyzed. Muscles atrophied. When the brain learned to route signals around the damaged area, some muscles had atrophied so thoroughly they could not react.

But if you massage and warm those muscles, and discharge a joule or so of electrical energy into them in a microsecond, even an atrophied muscle will snap to attention. Electrostimulation exercised the muscles to a point where conventional physical therapy could complete the job.

John Wesley, founder of Methodism, was concerned with the pain and misery suffered by the poor, and was critical of the medical profession for its use of compounded remedies. These brought profit to doctor and pharmacist alike, and cost too much for many to afford. In 1759 he published *The desideratum: or, Electricity made plain and useful. By a lover of mankind, and of common sense.* By his lights electricity was an excellent medicine. Once you paid for the equipment you could treat suffering humanity all day with no further expenditure save the energy needed to turn the crank.

Electricity was not only good medicine, it was positively lifesaving. In his 1788 *Essay upon the recovery of the Apparently Dead,* Charles Kite recommended electrical shocks from a Leyden jar, applied to the chest to revive a stopped heart. He noted electricity's powerful effect upon the human frame[6]:

"And are we not justified in presuming, that if it is able so powerfully to excite the action of the external muscles, that it will be capable of reproducing the motion of the heart, which is infinitely more irritable, and by that means accomplish our great desideratum, the renewal of the circulation?"

(Kite's *Essay...* was, I might add, a review article. He mentioned several successful resuscitations in earlier years to bolster his arguments.)

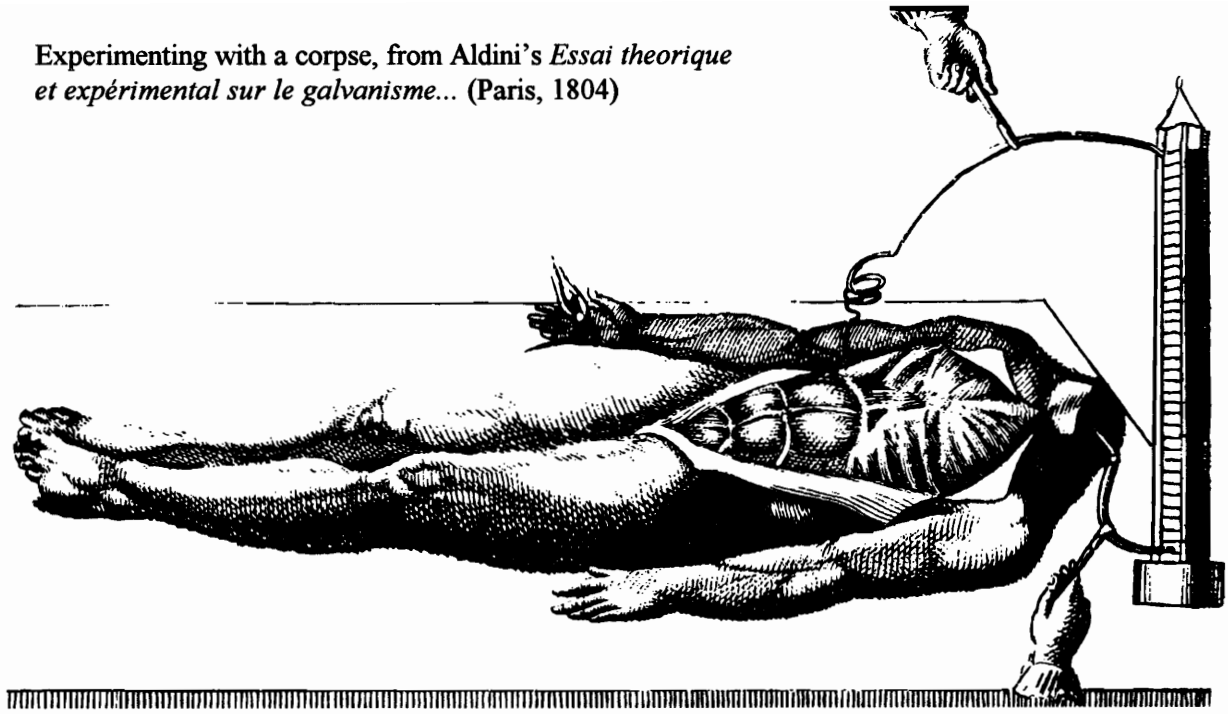
Electricity was becoming associated with the life force -- so much so that when Luigi Galvani discovered "animal electricity" upon the martyred bodies of a thousand frogs, his announcement[7] sent scientists across Europe into their laboratories. Truly unexpected discoveries are not received so enthusiastically. The general reaction seems to have been, "At last! He's found where the Vital Principle is hiding!"

One of the scientists was Alessandro Volta. He initially accepted Galvani's theory of an animal origin for the electricity. As his experiments continued, he began to think of bimetallic electricity. In 1800 he announced what immediately was called the Voltaic Pile[8].

Controversy raged. Was Galvani right, or Volta? Both were right, and both were wrong. Galvani thought he had obtained electricity from animal tissues. He had actually discovered the bimetallic arc -- a crude form of electrochemical cell. Volta thought his electricity was created by the contact of two dissimilar metals. It actually came from an electrolyte in contact with those two metals. Each man and his supporters devised ingenious demonstrations. Huge amounts of science were done in a very short time. All was eventually proven: what they thought they had discovered -- and what they really *had* discovered.

Jean Aldini, Galvani's nephew and collaborator, was a noted student of the new animal electricity. Using a voltaic pile, he performed a series of terrible public experiments upon the bodies of executed murderers. He found

Experimenting with a corpse, from Aldini's *Essai theorique et expérimental sur le galvanisme...* (Paris, 1804)



they retained muscular irritability for two hours after death, and that he could excite many of the motions of life.

Some feared Aldini and the other Galvanists would indeed return a murderer to life. The legal questions were daunting, let alone the moral questions. Aldini stirred the mixture by suffocating a dog to the point of cardiac standstill, then resuscitating it with thoracic shocks from a Voltaic pile.

Mary Shelley was thinking of these experiments when she wrote *Frankenstein*[9]. "*Perhaps a corpse would be re-animated; galvanism had given token of such things....*"

Frankenstein was first published in 1818. Richard Reece, MD, published a family medical guide at roughly the same time[10]. In one of his chapters we meet the "Re-Animation Chair of Doctor De Sanctis". In a vision echoing the researches of Aldini and Frankenstein, De Sanctis had devised a sort of "Code Blue" apparatus. It was a reclining chair whose resuscitation equipment included a bellows with laryngeal tube to inflate the lungs, a heated globe to create inhalant vapors -- and a Voltaic pile.

" The brain and the heart should be stimulated by passing through them the Galvanic fluid. [...] one of the wires is to be applied to the

The Re-Animation Chair of Doctor De Sanctis[10]

[silver] tube passed down the gullet, whilst the other is to be successively made to touch different parts of the external surface of the body, particularly about the regions of the heart, the diaphragm, and the stomach during the inflation of the lungs...."

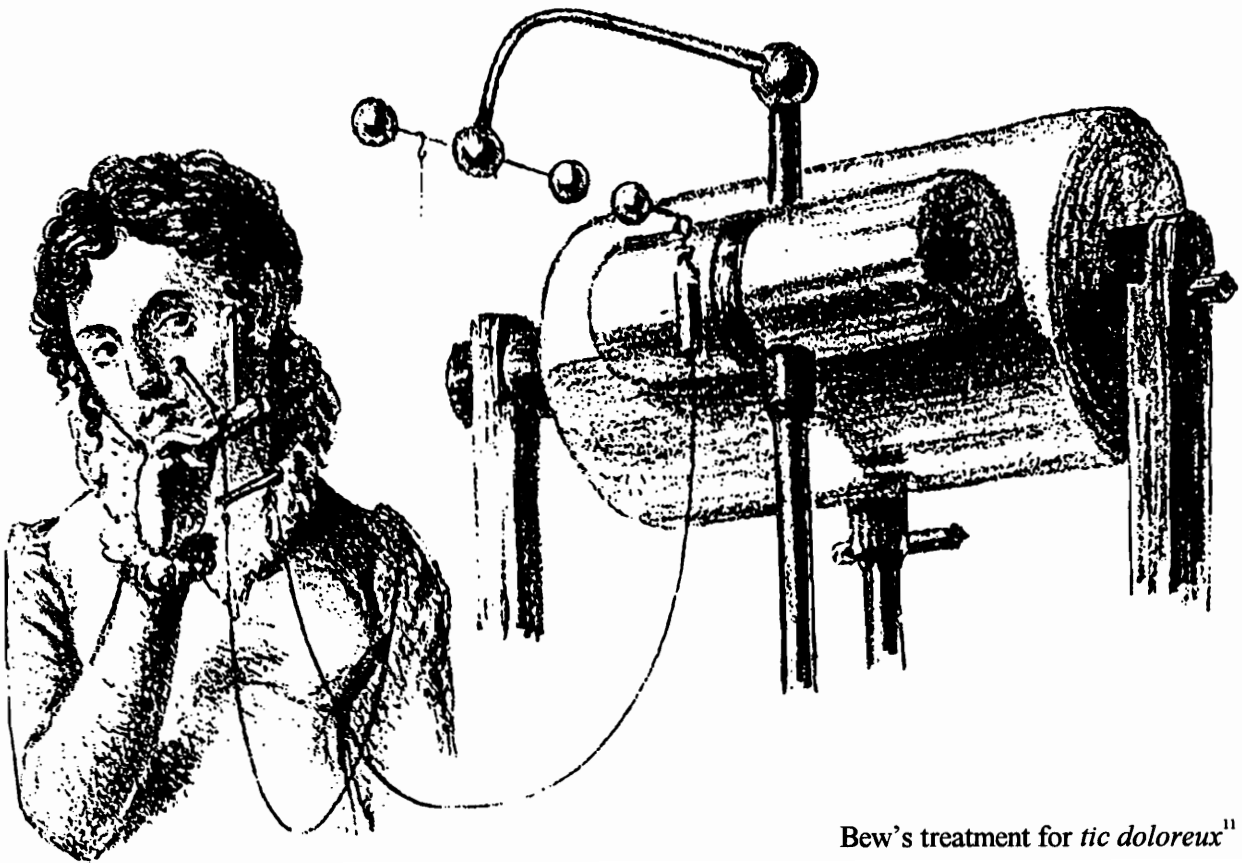
In short, De Sanctis recommended cardiac electrostimulation via esophageal and precordial electrodes, in an attempt to get a stopped heart beating again. This is little different in concept from defibrillation and external pacing as they are practiced in modern medicine.

Nor was pain neglected in the nineteenth century. Charles Bew recommended facial electrostimulation to relieve the pain of *tic douloureux*[11] Bew used an electrostatic discharge similar to that of Kite's defibrillator, though with a smaller Leyden jar.

Electrostatic machines gave powerful single pulses. Many people felt that getting their electrotherapy in one instantaneous blast was little better than the pain it drove away. When the induction coil was invented, medicine had a gentler source which gave a rapid, continuous train of pulses quite like the output of a modern TENS stimulator. Tripier[12] said:

"M. Francis (of Philadelphia) has announced that Faradization of teeth renders their extraction infinitely less painful, after assessing the results of a large number of trials of this method of anesthesia. A dentist of Geneva recommends attaching the dental key or forceps to the negative lead of a medical induction coil, while the patient holds the positive electrode in his hand. The tooth should be extracted immediately after the application of the electrified forceps."

Perhaps the most prescient early use of the induction coil was that of Henry Hall Sherwood[13], as described in his 1845 *Manual for Magnetizing* ... Despite the title, Sherwood used pulsed electricity. The induction coil was still young, and



Bew's treatment for *tic doloreux*[11]

terminology had not settled down. His coil made its pulses of electricity through electro**magnetic** induction.

Sherwood treated curvature of the spine. The *Manual* says he *"had 67 cases of lateral curvatures of the spine from the 1st of April to the 8th of Oct. 1844 ..."* He found *"The muscles are always swelled, thickened, or tuberculated on the posterior side of the curve ... and emaciated or atrophied and paralyzed on the other."* To exercise and strengthen the weakened muscles, he and a therapist stimulated them with his machine. Eventually he developed a specialized chair to hold the patient in proper position for the treatment.

Sherwood treating curvature of the spine

Guillaume Benjamin Amand Duchenne began to study the interaction of electricity and the human body. In 1835, attending a patient suffering from neuralgia, he tested the effects of electropuncture. This had been introduced to Europe, ten years earlier, by Sarlandière[14]. Duchenne noticed that on closing the circuit a single muscular contraction occurred, limited to the site of the puncture. Repeated trials convinced him it was possible to confine the effects of electricity to individual nerves and muscles.

And so, Duchenne used electrical stimulation to map out nerves and muscles, with increasing sophistication[15]. The use of electricity in physical therapy and diagnosis was becoming very nearly respectable. In America, George Beard and Alphonse D. Rockwell published *Medical and Surgical Electricity*, which was to go through ten American editions[16]. Shortly thereafter, Rockwell was refused permission to read a paper on the subject before the New York Medical Society. They felt electrotherapy was advocated only by quacks. It was not until 1877, when S. Weir Mitchell endorsed exercise of muscles by faradic current, that Beard and Rockwell were accepted as equals by their fellow physicians[17].

By the twentieth century, electrical stimulation of muscles in physical therapy was an accepted treatment. But one muscle was still off-limits: the heart. It made sense. One false move with the heart -- and there goes the patient. That sort of thing tends to discourage experimentation.

You can't be killed if you're already dead. Thus, electricity was applied to the heart only in the most desperate cases. That was Kite; that was De Sanctis; and in the 1930s, that was Albert Hyman. Hyman had graduated from the Harvard

Medical School in 1918, and was very interested in cardiac resuscitation[18].

His first experience with a human patient came in 1918, with a 44-year-old man whose heart stopped in the Emergency Room. Hyman noted, *"It had long been known that in certain instances of sudden death, for example, on the operating room table, active massage of the heart or injections of cardio-stimulating drugs like adrenaline might restore automatic activity to the heart."* This patient died, as did all but thirteen of the eighty-one cases he observed during the next six years of hospital duty.

In subsequent research he found *"...that the most important factor in all of the intracardial injection procedures was the actual puncture of the heart wall. As a result of the puncture wound an action current of injury ... developed ... of much greater difference of electric potential than the intrinsic sinus nodal pacemaker stimulus ..."* And he concluded, *"If, instead of waiting for an uncontrolled ectopic stimulus to be generated from the needle injury, an artificial electric stimulus, more or less identical with the normal sinus pacemaker stimulus, could be delivered to the atrial area near the sinus node ... the artificial pacemaker would take over the functions of the normal sinus pacemaker until such time as the latter could assume its normal activity.*

He developed and assembled such an apparatus, and said, *"By March 1, 1932, the artificial pacemaker had been used about 43 times, with a successful outcome in 14 cases."* Hyman was beset with abusive correspondence, and even lawsuits, from irascible people who regarded his resuscitation endeavors as sacrilegious tampering with Divine Providence. Despite this he persisted; and even used his pacemaker in Adams-Stokes disease.

With the development of open-heart surgery in the 1950s, the need grew for some means to keep a stalled heart beating. Repair of a septal defect could traumatize the normal conduction system of the heart; it would not re-start after surgery. C. Walton Lillehei at the University of Minnesota began suturing insulated stainless-steel wires to the heart before closing the chest. Pacing impulses could be delivered through this wire for a week or so until the heart healed. Then the wire could be withdrawn with a simple pull[19].

Use of this pacemaker for a week edged closer to long-term use. And it exposed the patient to more than the simple hazards of an experimental treatment. Pacemakers were line-powered in these days, and when a power failure took the life of one young patient, Lillehei called in Earl Bakken to "make something that runs on batteries"[20]. The rest is history -- **industrial** history as well as medical, for this was the foundation of Medtronic's fortune.

Today, with many thousands of people alive only through use of pacemakers, it is impossible to ignore or scorn medical electricity. The question is no longer "can electricity be good medicine?" *That* question has been answered. The questions a given treatment must answer are "What are the benefits? What are the hazards?"

The first undoubted electrical cure was in the middle of the eighteenth century. Medical electricity did not gain widespread professional respect until the twentieth century. During all those intervening years, there were intelligent scientists and doctors doing intelligent things with electricity. Why did medical electricity take so long to become respectable?

This article has been a list of high points. There were some very low points, too. There were any number of charlatans and fools putting electricity (of which they knew little) into bodies (of which they knew less). Charlatans were drawn by the same aspects of electricity that drew the intelligent.

When you get a shock, you **know** electricity has happened to you. Electricity is impressive. At the same time it is relatively safe, compared to the drugs and knives of the competition. This is fertile ground for the quack, and for the placebo effect. Both the quack and the placebo can sow confusion.

Then too, there is the state of medical knowledge of the day. Bleedings and purges were common. Germs were unknown. The details of paralysis and sudden death were a mystery.

Jallabert cured one paralyzed hand, but as Marragues later pointed out,

"Jallabert wrote of only one case of paralysis, his first, twenty-five years ago. Certainly he must have tried electricity on others since and having had no further success has maintained a profound silence[21]"

Benjamin Franklin was more forthcoming.

"Some years since, when the newspaper made mention of great cures performed in Italy or Germany, by means of electricity, a number of paralytics were brought to me from different parts of Pennsylvania and the neighboring provinces to be electrified; which I did at their request ... I do not remember that I ever saw any amendment after the fifth day; which the patients perceiving, and finding the shocks pretty severe, they became discouraged, went home, and in a short time relapsed.[22]"

Some paralytics can be treated successfully; many cannot. If the physician treats all comers, the incurable cases make the cure statistics for even the most valid treatments look pretty grim. Until medicine understands paralysis, *all* treatments will be judged failures.

Likewise with cardiac resuscitation. There's only a short time when re-starting the heart does any good. How likely are you to be there, with the apparatus ready? And even if you re-start it -- why did it stop in the first place? What's to say it won't stop again?

Reviving victims of sudden death is a marginal therapy at best. Even with modern medical knowledge, defibrillation doesn't have a very good record. Few of the re-animated emerge from the hospital to take up a normal life again.

But the knowledge gained from re-starting stopped hearts is applicable. When the physician knows a heart is in danger, the equipment can be prepared and at hand. When a septal-defect repair leads to heart block in a youngster, a pacemaker can tide the heart over until it's in shape to start beating again on its own. Next thing you know, an elderly patient with Stokes-Adams is in the next room from the kid. "Gee," thinks the doctor. "A pacemaker works on *kids* with heart block ..." And therapy is revolutionized.

Science is a solution of facts, dissolved in a vast ocean of ignorance. Toss something useful into the solution, and in the early days, it will seem to melt away. But the ocean will have just a bit more fact in it, and be just a bit closer to saturation. As more facts are tossed into the ocean, parts of it reach saturation.

And at that moment, a wee bit of fact tossed in will start facts crystallizing into a solid piece of knowledge.

Few scientists ever throw a completely original fact into the ocean. Most spend their lives finding and shoveling data to increase the saturation of the sea. The lucky ones start a crystal growing.

It took over a century for dense, readily-observed facts such as the twitch of a person receiving a shock to reach saturation and begin to crystallize. The effects of atmospheric electrification (which Nollet was studying back in the 1750s[23]) are more subtle. A solid datum is harder to find. Argument is still more common than consensus. But some unexpected day, everything will come together.

Look at it this way. The Babylonians began the study of astronomy, but it took millennia for Galileo and Tycho and Copernicus to start the crystallization. Medical uses of electricity are well ahead of astronomy in rate of progress.

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1. Quoted in Schechter, Charles, *Electrical Cardiac Stimulation* (Medtronic, Minneapolis, 1983) pg. 19

2. Quoted in Schechter, *op cit* pg. 20

3. Wu, Chau H., "Electric Fish and the Discovery of Animal Electricity", *American Scientist* November-December 1984

4. Quoted in Licht, Sidney, *Therapeutic Electricity and Ultraviolet Radiation* (Second Edition, Baltimore, 1967) pp. 3-7

5. This account chiefly taken from Rowbottom, Margaret and Susskind, Charles, *Electricity and Medicine: History of Their Interaction* (San Francisco, 1984) pp. 15-17, supplemented by Licht, *op cit* pg. 7.

6. Kite, Charles, *Essay upon the Recovery of the Apparently Dead* (London, 1788)

7. Galvani, Luigi, *De viribus electricitatis in motu musculari* (Bononiae, Ex Typographia Instituti Scientiarum,

1791)

8. Volta, Alessandro, "On the electricity excited by the mere contact of conducting substances of different kinds" (in French), *Philosophical Transactions* 90, 403-431, 1800

9. Shelley, Mary, in the introduction to: *Frankenstein, or the Modern Prometheus* (Third Edition, London, 1831)

10. Reece, Richard, *The Medical Guide...* (13th Edition, London, 1820)

11. Bew, Charles, *Opinions on ... tic douloureux* (London, 1824)

12. Tripier, Auguste, *Manuel d'Electrothérapie* (Paris, 1861, passage translated by E. Kuhfeld)

13. Sherwood, Henry Hall, *Manual for magnetizing, with the rotary and vibrating magnetic machine, in the duodynamic treatment of diseases* (New York, 1845)

14. Sarlandière, Jean Baptiste, *Mémoires sur l'électropuncture* ... (Paris, 1825)

15. Duchenne, Guillaume Benjamin Amand, *De l'électrisation localisée et de son application a la physiologie, a la pathologie et a la thérapeutique* (Paris, 1855)

16. Beard, George and Rockwell, A.D., *A practical treatise on the medical and surgical uses of electricity...* (New York, 1871)

17. Licht, *op cit* pg. 20

18. Schechter, *op cit* pp. 88-93

19. C. Walton Lillehei, speech at The Bakken Library and Museum, June 18, 1996

20. Earl Bakken and C. Walton Lillehei, personal discussions

21. Licht, *op cit* pg. 11

22. *ibid.*

Nollet studying the effects of atmospheric electrification upon plants and animals[23].

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