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Historia medicinae

Evolution of the knowledge of electricity and electrotherapeutics with special reference to X-rays & cancer

Part 1. Ancient Greeks to Luigi Galvani

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We present a chronological review of the growth points in the knowledge of electricity, especially as applied to medicine[§]. Commencing with the ancient Greeks and ending with cancer electrotherapeutics at the turn of the 20th century, our history is arranged in chronological order by the birth years of the investigators. William Gilbert (1540-1603) initiated the era of scientific investigation, followed by advances in later centuries by Otto von Guericke (1602-1686), Abbé Nollet (1700-1770), Luigi Galvani (1737-1798), Alessandro Volta (1745-1827), Michael Faraday (1791-1867) and Nikola Tesla (1856-1943) among others. Although electrotherapy was infrequently used to treat malignancy, it was to make a major contribution to cancer therapy because the experience gained in electrotherapeutics paved the way for the rapid adoption of diagnostic snd therapeutic radiology. Within a year of Röntgen's discovery, more than a thousand books, pamphlets and papers about X-rays were published [1].

Key words: electrotherapeutics, electricity, X-rays, cancer

Introduction with special reference to X-rays

This history, written in three parts, reviews the scientific advances in electricity, beginning with the ancient Greeks and concluding at the end of the 19th century. X-rays had been in use for four years by then. The early publications on radiology attest to the contribution of electrotherapeutics; many of the early papers on X-rays were published in journals which had been previously devoted solely to communications dealing with electricity and electrotherapy. Several early X-ray journals incorporated the words 'electricity', 'electrology' or 'electrotherapeutics' in their titles.

Among them the *American Electro-Therapeutic and X-ray Era* (Figure 1 [2]), the *Archives d'Électricite Médicale*: *électrologie, curiethérapie et physiothérapie du cancer*, and in the United Kingdom [3] the *Archives of*

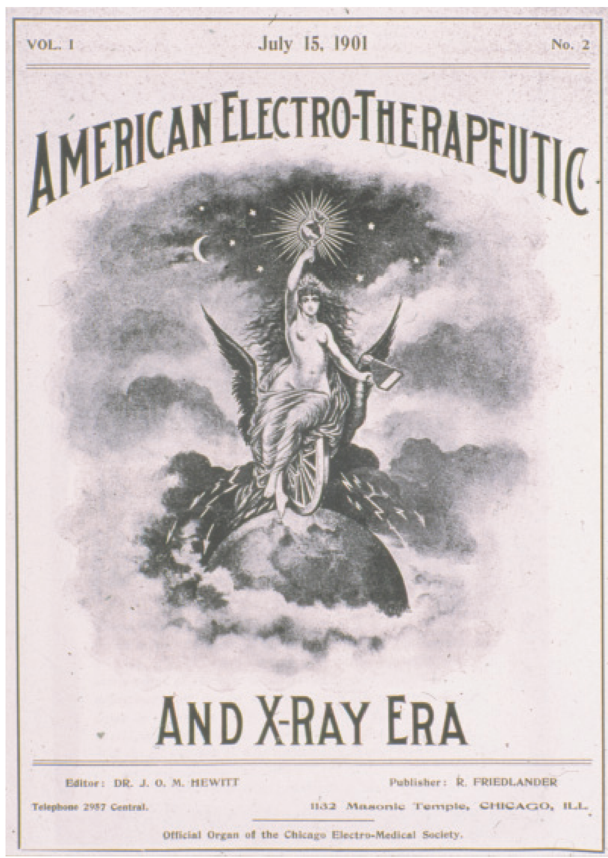

Figure 1. Front cover of the 1901 journal the *American Electro-Therapeutic and X-ray Era* which was described as the Official Organ of the Chicago Electro-Medical Society. This journal was renamed *Archives of Electrology and Radiology* in 1905 and later merged with the *American X-ray Journal* to become the *American Journal of Progressive Therapeutics* [2]

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[§] This paper is the first of three parts. Part 2 continues with Alessandro Volta to James Clerk Maxwell and will be published in *Nowotwory* 1/2007, and Part 3 with Sir William Crookes to 20th century electrotherapists in *Nowotwory* 2/2007.

Radiology and Electrotherapy prior to being incorporated into the *British Journal of Radiology*. The only bibliography of X-ray literature and research for 1896-1897, was published [4] by *The Electrician* (London).

Early textbooks on X-ray therapy and diagnosis often included the words 'medical electricity' or 'electrotherapeutics' in their title [5, 6]. Early radiologists, such as Margaret Cleaves (1848-1917) [7], were officers of electrotherapeutic organizations such as the American Electro-Therapeutic Association and the Société Française d'Électrothérapie.

Most of the section titles in this article refer to the scientists and physicians who were responsible for various growth points in the evolution of the knowledge of electricity and electrotherapeutics.

The illustrations chosen are, wherever possible, related to early designs of equipment (including vacuum pumps and electrostatic machines), which eventually proved essential for X-ray production apparatus. Some rare illustrations showing the use of electrotherapeutics for cancer are also included. Emphasis is given to the electrotherapeutics of cancer, since such treatments were relatively rare and very few illustrations exist.

Electricity and magnetism in ancient times

Electricity

The ancients noted that when rubbed, amber (the fossil resin of a pine tree) attracted light bodies such as hair, straw or feathers. Thales of Miletus (c. 634-546 BC) who is considered to be the father of Greek philosophy, science and mathematics, explained this curious effect by the presence of a 'soul' in the amber. Theophrastus (c. 372-287 BC) and the Venerable Bede (673-735 AD) observed similar effects with lynthuricum (probably tourmaline) and jet (compressed coal) [8], respectively.

As early as 400 BC, torpedo fish were used to treat a variety of ills, including gout, arthritis, headache and haemorrhoids. The treatment consisted of applying the live fish to the afflicted body part, and hence administer a series of localised electric shocks. These were of some 100-150 volts and gave transient pain relief. Plato (428-348 BC) in one of his *Dialogues* tells Socrates (c. 469-399 BC) 'you seem both in appearance and in your power over others to be like a torpedo fish, who torpifies those who come near him, as you have now torpified me, I think. For my soul and my tongue are really torpid and I do not know how to answer you'. Aristotle (384-322 BC) said that the torpedo fish 'narcotises' its prey.

Torpedo fish were studied more than 2,000 years later, in 1903 by the electrical engineer and radium pioneer, William J. Hammer (1858-1934), in his book *Radium and Other Radio-active Substances* [9]. He reported an experiment which took place in the Aquarium of Naples when six radium tubes were placed for 20 minutes on the back of the fish to see if the radium would cause paralysis. The fish were only paralysed for 15 minutes after irradiation but it may have simply been exhausted by the shocks it had applied to the experimenters before the experiment commenced!

Magnetism

In the times of the ancient Greeks, magnetism was confused with static electricity, and lodestone which is a magnetic oxide of iron Fe_3O_4 was known not only to Thales but also in much earlier times in ancient China. Lodestone is found in various parts of China, especially at T'szchou which was formerly known as the City of the Magnet. According to Munro [10] it is related in Père du Halde's *Description de la Chine* that, in the year 2635 BC, the Emperor Hoang-ti having lost his way in the fog, constructed a chariot which showed the cardinal points. It is also known that a 'magnetic carriage' preceded the Emperors of China in state ceremonies during the 4th century. The magnetic part of the carriage would have been either a magnet floating on water or on a pivot: the earliest compass. A servant in a feathered dress always pointed to the south. The name magnet is said to derive from the city of Magnesia in Asia Minor or from the mythical shepherd who was said to have discovered lodestone by the attraction of his iron crook.

William Gilbert 1540-1603

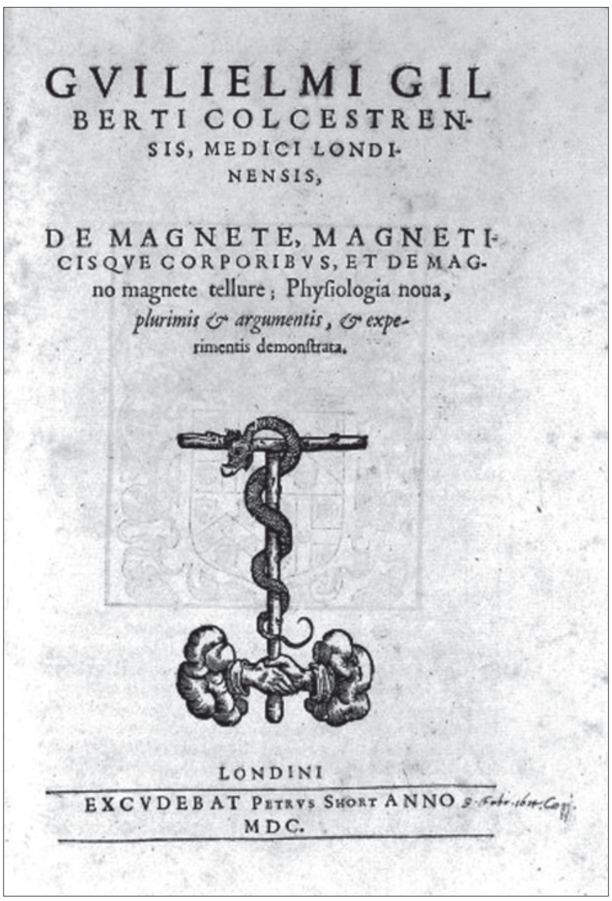
William Gilbert (Figure 2), physician to Queen Elizabeth I and also a President of the Royal College of Physicians, experimented with the production of fractional electricity. He called the phenomenon *electrics* after the Greek word for amber, *elektron* (ηλεκτρου), but observed that the property was not limited to amber, but rather shared by a large class of bodies, including sulphur, wax and precious stones. He published these observations in 1600 in his famous work *De Magnete* (Figure 3). About half a century later, the philosopher Sir Thomas Browne (1605-1682) in his book *Pseudodoxia Epidemica* (which was published in London in 1646) introduced the word *electricity* [8].

The knowledge handed down from Hippocrates (c. 460-377 BC) and the Greek physician Galen (c. 130-200 AD) was dominated by the humoural theory which held that there were four bodily fluids (humours) of blood, phlegm, yellow bile and black bile. Cancer was attributed to an excess of black bile. Within this theory William Gilbert proposed that the electrics phenomenon was caused by some sort of material humour or fluid, which he termed *effluvia*.

Otto von Guericke 1602-1686

In 1646 Otto von Guericke, the burgomaster of Magdeburg, devised the first air pump for the purpose of producing a vacuum with which to study celestial conditions. A follower of Nikolaus Copernicus (the Polish astronomer and mathematician 1473-1543), he reasoned that the earth, moon and other heavenly bodies observed through the telescope of Gallileo (1564-1642) must be

Figure 2. Although he studied electricity, the major focus of William Gilbert's work was magnetism. This early 20th century painting by Ernest Board depicts Gilbert demonstrating a magnet to Queen Elizabeth I in 1598 (Courtesy The Wellcome Library, London). Gilbert invented a lightweight device called a *versorium* that looked like a compass but didn't use a magnetised needle. The pointer was balanced and would spin in reaction to magnetic attraction, even if there was not enough force to lift a light object. A 19th century modification of the versorium is the electroscope, such as was used by Pierre and Marie Curie to detect the ionisation in air by the radioactive substances polonium and radium



GVILIELMI GIL
BERTI COLCESTREN-
SIS, MEDICI LONDI-
NENSIS,

DE MAGNETE, MAGNETI-
CISQVE CORPORIBVS, ET DE MAG-
no magnete tellure; Physiologia noua,
plurimis & argumentis, & expe-
rimentis demonstrata.

LONDINI
EXCVDEBAT PETRVS SHORT ANNO
MDC.

Figure 3. Title page of William Gilbert's *De Magnete*, published in 1600 (London: P Short). This book laid the foundations for both magnetism and electricity (Courtesy The Wellcome Trust, London)

moving in empty space, (otherwise the air resistance would have long since brought all to a standstill).

He later improved his vacuum pump by using a vertical cylinder in which a piston could be moved up and down with a lever and an automatic leather valve replaced the stopcock he had used in his original design. In the world's first textbook on X-rays (1896) contained an advertisement for an air pump called the 'Geryk', likely after von Guericke (Figure 4) [11].

Von Guericke also invented the first electrical generator: consisting of a moulded sulphur sphere. When a dry hand was brushed against the rotating sphere, an electrical potential developed. The excited sphere attracted all types of light objects: such as paper, particles of gold, and silver leaf. This attractive property could be communicated over a distance of 90 cm through a linen thread. This was the first transmission of an electrical impulse over a conductor.

He fancifully speculated that the earth was a great electrical machine 'rotated by the hand of the Almighty and excited by the friction of the solar rays' [12], (Figure 5).

Jean Picard 1620-1682 & Jakob Bernouilli 1654-1705

Jean Picard, a French priest and astronomer, in 1678 was the first to describe a luminous glow within a vacuum chamber. The glow appeared in the vacuum of a Torricelli barometer. (Evangelista Torricelli (1608-

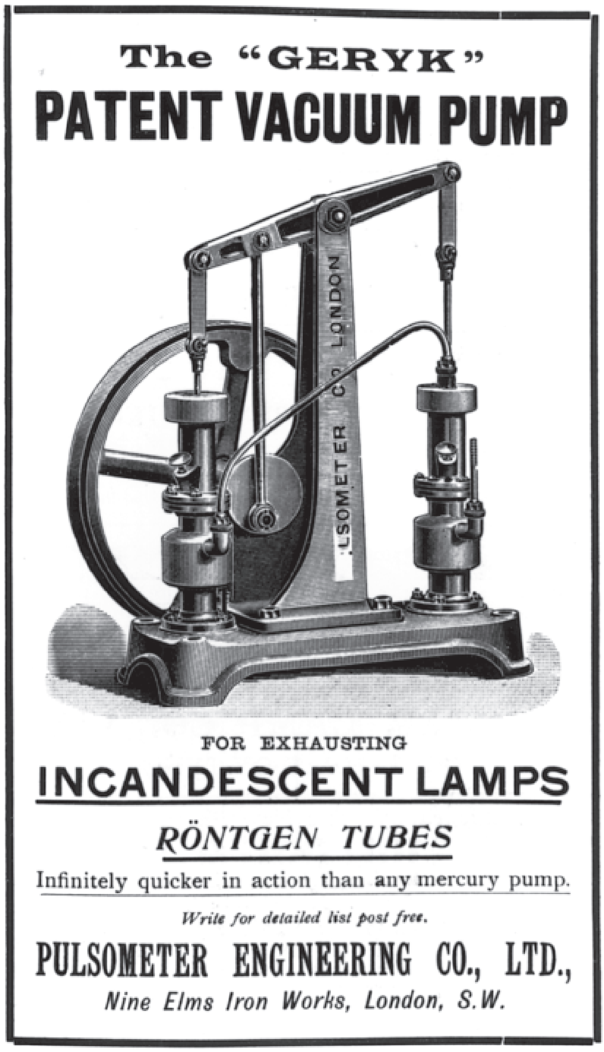


Figure 4. Advertisement from 1896 [10]

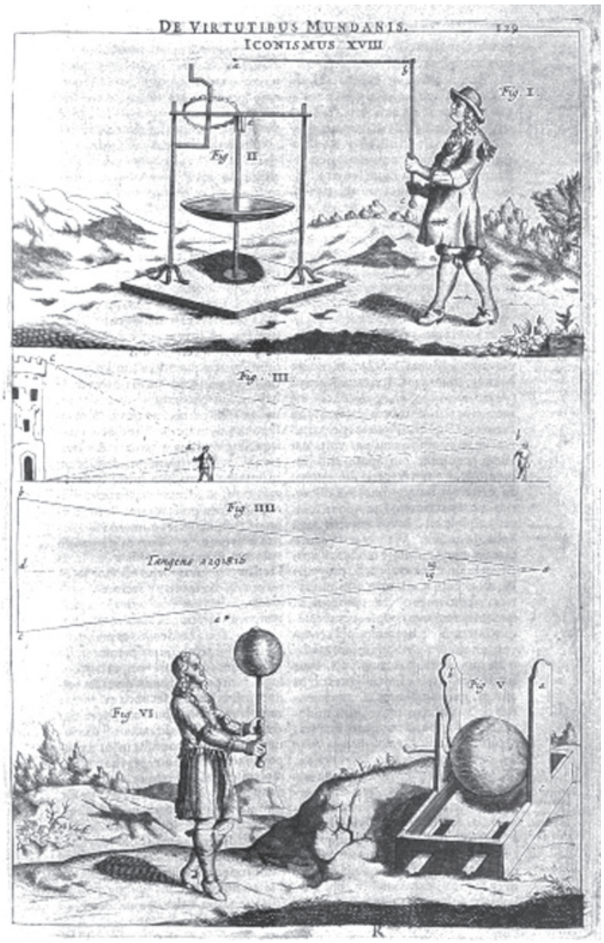


Figure 5. Otto von Guericke's electrical machine incorporating a sulphur sphere (Figs. V and VI) and other electrical experiments. The title description is 'Experimenta nova (ut vocantur) Magdeburgica de vacuo spatio'. These drawings were published in Amsterdam in 1672 by J. Jansson-Waesberge (Courtesy The Wellcome Trust, London)

1647) had, independent of Guericke, created a sustained vacuum) after it was carried up stairs in his darkened observatory. Picard found that the glow was generated by shaking the mercury.

The German mathematician Jakob Bernoulli came across Picard's notes in 1698, and performed his own experiments by agitating mercury with and without a vacuum. He produced considerable light which he termed 'mercurial phosphorus' and believed that he had invented a mechanical substitute for candles [12].

Robert Boyle 1627-1691 & Sir Isaac Newton 1643-1727

Robert Boyle and Sir Isaac Newton improved on the design of the von Guericke pump and undertook various experiments. For example Boyle studied the behaviour of gases when enclosed in glass tubes and in 1676 observed that the electrostatic effects of rubbed amber and the effects of magnetism also occur in a vacuum. Newton in 1675 built an electrical machine with a rotating glass sphere and observed that it was possible to electrically charge one side of a glass plate by rubbing the other side with a cloth [12].

Francis Hauksbee 1660-1713

Francis Hauksbee, a student of Robert Boyle, was the curator of experiments and instrument maker to the Royal Society of London. He demonstrated the underlying mechanism for Bernouilli's observation that electricity generated by the friction of mercury on the glass produced the 'mercurial phosphorus'. He built machines for the rapid rotation of vacuum bulbs 15 cm or 20 cm in diameter and found that the friction of his dry hand on the outside of these globes gave a purple glow, (Figure 6).

Hauksbee also observed that a quiescent vacuum tube lying near one that was excited would glow without being touched. When finger tips held near the excited tubes they would emit a brush-like radiance. He had discovered the phenomenon of *electrostatic induction*: but offered no name or explanation.

He also obtained sparks which were larger than had ever been seen in a laboratory. Hauksbee wrote 'I have observed the light to break from the agitated glass like lightening, and if the hand is held near the fricated glass a light will be seen to dart from it with the noise like that of a green leaf in a fire, but not so loud' [12].

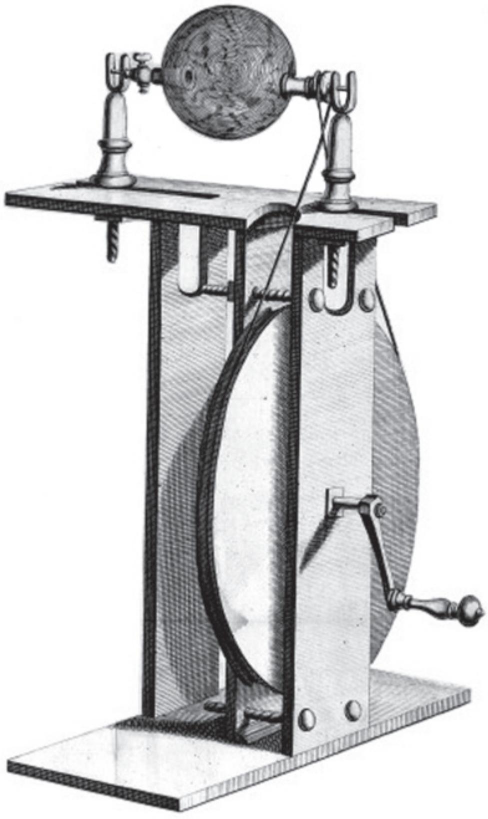


Figure 6. Francis Hauksbee's electrostatic machine,1709, the 'electric egg' is seen at the top (Courtesy The Wellcome Trust, London)

Stephen Gray 1666-1736

Stephen Gray, a pensioner at the Charterhouse in London (which is near St. Bartholomew's Hospital) described Hauksbee's production of sparks as 'light and crackling noises' which could be produced by rubbing various materials (hair, silk, linen and leather) together. Gray was the first to discover that electricity is a current and will flow over conductors, as well as remain a charge on the surface of glass or sulphur. He also showed that conductors must be insulated and that insulators are not conductors [12]. Gray also transmitted a charge of electricity along a pack-thread insulated with silk, to a distance of several hundred metres, thus presaging the eventual invention of the electric telegraph [10].

Gray reported to the Royal Society that 'the Electrick Vertue of a Glass Tube may be conveyed to any other Bodies so as to give them the same Property of attracting and repelling light Bodies as the Tube does, when excited by rubbing' [13].

Charles du Fay 1678-1739

Charles-François de Cisternay du Fay was Director of the Royal Gardens in Paris, as well as a chemist at the Académie des Sciences. He observed that rubbing paper with wool, and glass with silk, yielded two different types of electricity [12]. He termed one type of electricity 'vitreous' and the other type 'resinous' [8].

Pieter van Musschenbroeck 1692-1761
Georg von Kleist 1700-1748

Pieter van Musschenbroeck came from a family of instrument makers (air pumps, microscopes and telescopes). He studied at the university of Leyden, earning a degree in medicine and a doctorate of philosophy in natural philosophy (physics). He held professorships in the universities of Duisberg, Utrecht and finally Leyden, from 1740-1761. He visited Newton in 1717, and introduced his ideas in The Netherlands..

In 1746 Pieter van Musschenbroeck and his pupil Andreas Cunaeus (1712-1788) unexpectedly encountered the *capacity* of an electrified jar of water, because of the sudden shock which accompanied its discharge. Cunaeus was the first to experience the phenomenon when he removed an iron rod connected to an electrostatic machine from a bottle containing water.

Musschenbroeck repeated Cuneus' experiment and received a shock so staggering that he lost consciousness. It was two days before he recovered from the effects of the blow, but not the terror it had induced. Writing to René-Antoine Réaumer (1683-1757) soon afterwards he averred that 'he would not take a second shock for the kingdom of France' [10, 14, 15].

Ewald Georg von Kleist, Dean of Camin Cathedral in Pomerania, independently invented the *Leyden jar* in 1745. Although von Kleist's finding predated that of van Musschenbroeck (November 1745 versus January 1746), the site of the later's discovery became eponymous with the apparatus.

Leyden jars can be connected together in 'batteries', either in series or in parallel. The first radiological journal, the *Archives of Clinical Skiagraphy* (the forerunner of the *British Journal of Radiology*) illustrates in its first issue (May 1896) a pear-shaped X-ray tube, an induction coil and three Leyden jars (Figure 7).

Jean Antoine (Abbé) Nollet 1700-1770

The spectacular effects that could be generated from the Kleist/Leyden electricity storage jars were demonstrated to the King of France by Abbé Nollet. He killed many small birds and animals by electric shock, and discharged a jar through a 160 metre chain of Carthusian monks holding hands, making them jump all together.

Whereas Hauksbee had placed the source of high tension electricity within an evacuated tube, Nollet placed it outside and led the high tension to the glass vessel by means of an iron chain sealed into the vessel wall (it was called an 'electric egg' because its shape, Figure 8). It was essentially an X-ray generator (a vacuum tube attached to an outside source of high tension electricity, although the vacuum was inadequate and the photographic plates/ fluorescent screens were not yet available [2, 12].

Charles Phillips noted in 1897 [2] 'that in one of Nollet's little books entitled *Recherches sur les causes particulières des Phenomenes Electrique*, there is an illustration depicting the operation of electrically exciting

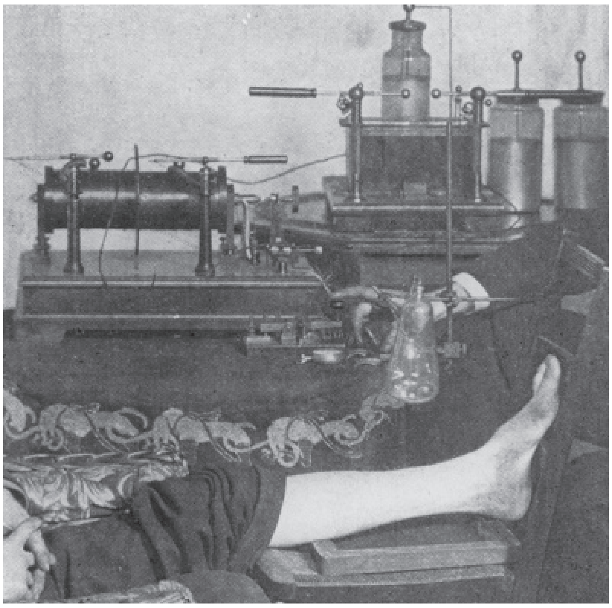


Figure 7. Leyden jars can be seen top right in this May 1896 illustration in the *Archives of Clinical Skiagraphy*. The caption stated 'Photograph of apparatus and method employed for obtaining a skiagram. In this case the leg'

an exhausted set of glass vessels, and we see pictured there some of the effects so well known to physicists of the present day'.

John Wesley 1703-1791

The Reverend John Wesley, concerned that medical care and pharmaceuticals were inaccessible to the poor [16], proposed electricity as 'the noblest medicine yet known in the world', a remedy that spared the expense of both physician and apothecary [17].

Wesley experimented with electricity and designed a machine for the treatment of various ailments, including melancholia (Figure 9). He also organised dispensaries for the treatment with this 'this unparalleled remedy' as one of their principal therapeutic agents.

Benjamin Franklin 1706-1790

Du Fay's observations led Franklin to postulate his single-fluid theory of positive and negative electricity. Franklin is though, best remembered for his experiments and theories relating to atmospheric electrical discharges during thunderstorms, especially for demonstrating that lightening is an electrical discharge, and for devising the lightening conductor (rod). He also established that pointed rods conduct electricity better than balls [18].

He reported his famous kite and key experiment (Figure 10) to Peter Collinson FRS in a single page letter dated Oct. 19 1752. The text is reproduced below [19, 20] using the original line breaks: in the 18th century many scientific communications were in the form of letters.

'As frequent mention is made in the news papers
from *Europe* of the success of the *Philadelphia*
experiment for drawing the electric fire from

Figure 8. Abbé Nollet, professor of physics at the University of Paris, installed this electrostatic generator in the Hôtel des Invalides in 1746 (probably representing the first hospital-based electrotherapy unit). This engraving, the frontispiece of Nollet's *Essai sur l'électricité des corps* (1746) depicts an experiment on the physiological effects of electricity, repeating Gray's experiments 'on the electrified boy'. Top left on the third shelf of the wall cabinet can be seen one of Nollet's 'electric eggs' (Courtesy The Wellcome Trust, London)

clouds by means of pointed rods of iron erected on high
buildings, &c. it may be agreeable to inform the curious
that the same experiment has succeeded in *Philadelphia*
though made in a different and more easy manner, which
is as follows:

Make a small cross of two light strips of cedar, the
arms so long as to reach to the four corners of a large
thin silk handkerchief when extended; tie the corners of
the handkerchief to the extremities of the cross, so you
have the body of a kite; which being properly accom-
modated with a tail, loop, and string, will rise in the air,
like those made of paper; but this being made of silk is fitter
to bear the wind and wet of a thunder gust without tear-
ing. To the top of the upright stick of the cross is to
be fixed to a very sharp pointed wire, rising to a foot or more
above the wood. To the end of the twine, next the
hand, is to be ty'd a silk ribbon, and where the silk and
twine join, a key may be fastened. This kite is to be
raised when a thunder gust appears to be coming on, and
the person who holds the string must stand within a door
or window, or under some cover, so that the silk ribbon
may not be wet; and care must be taken that the twine

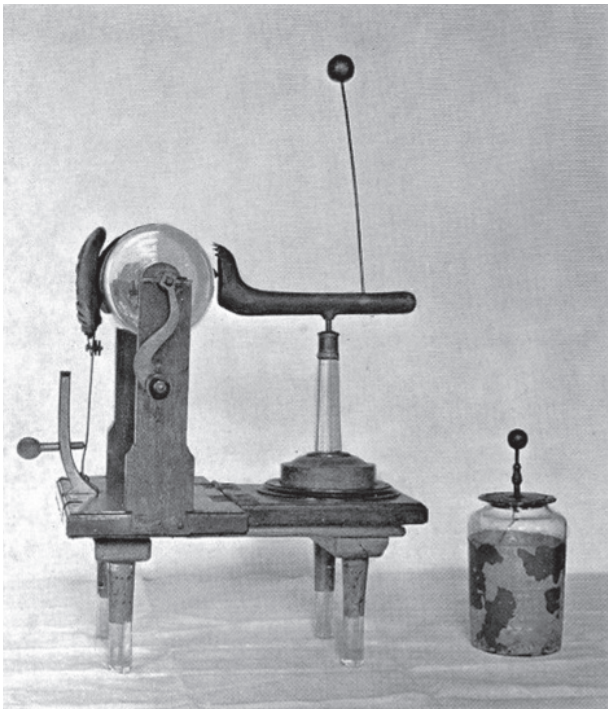


Figure 9. John Wesley's electrical machine (Courtesy The Wellcome Trust, London)

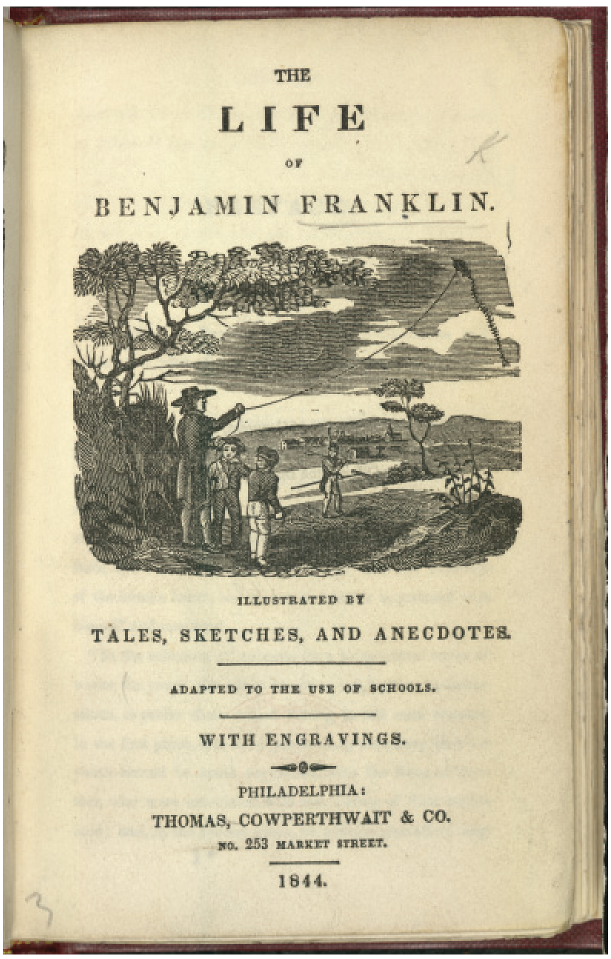


Figure 10. The kite experiment, illustrated on the frontispiece of *The Life of Benjamin Franklin*, published in Philadelphia in 1844 (Courtesy The British Library, London)

does not touch the frame of the door or window. As soon as any of the thunder clouds come over the kite, the pointed wire will draw the electric fire from them, and the kite, with all the twine will be electrified, and the loose filaments of the twine will stand out every way, and be attracted by an approaching finger. And when the rain has wet the kite and twine, so that it can conduct the electric fire freely, you will find it stream out plentifully from the key on the approach of your knuckles. At this key the phial may be charged; and from the electric fire thus obtained, spirits may be kindled, and all the other electric experiments performed, which are usually done by the help of a rubbed glass globe or tube; and thereby the sameness of the electric mater with that of lightening completely demonstrated'.

Comroe [20] in his *Retrospectroscope* on medical discoveries was using Franklin's one-page letter in a chapter illustrating how some important discoveries or concepts were presented briefly. Other examples of brevity included the announcement of the discovery of radium in 1898 by Pierre & Marie Curie and Gustave Bémont [21] (only two and one-half journal pages); and by Frédéric & Irène Joliot-Curie reporting in 1934 their discovery of the phenomenon artificial radioactivity [22].

Franklin's renown as an investigator of static electricity led to the use of his name to identify static electrotherapeutics (franklinism), but Franklin was disappointed in his own attempts at treating disease. He wrote, "… 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 first day … I never knew any advantage from electricity in palsies that was permanent. And how far the temporary advantage might arise from the exercise in the patient's journey, and coming daily to my house, or from the spirits given by the hope of success, enabling them to exert more strength in moving their limbs, I will not pretend to say" [23].

Christian Kratzenstein 1723-1795

Kratzenstein is considered to be the first to successfully apply electrotherapy, curing a young woman's paralysed finger [24]. In 1744 he published the first medical electricity text [25] and predicted that electricity would be useful 'not only in physical, but also in mental patients whose wealth worries, and anxieties prevent them from sleeping'. He also predicted its efficacy as a remedy for 'hypochondriasis and women with hysterical conditions'.

It has also been claimed that Kratzenstein was the basis for Dr Victor Frankenstein [26,27] in Mary Shelley's famous novel of 1818 [28]. Mary was Percy Shelley's second wife: his first, Harriet drowned in London in 1816 and rescuers took her lifeless body to a receiving station of the London Society. There, smelling salts, vigorous

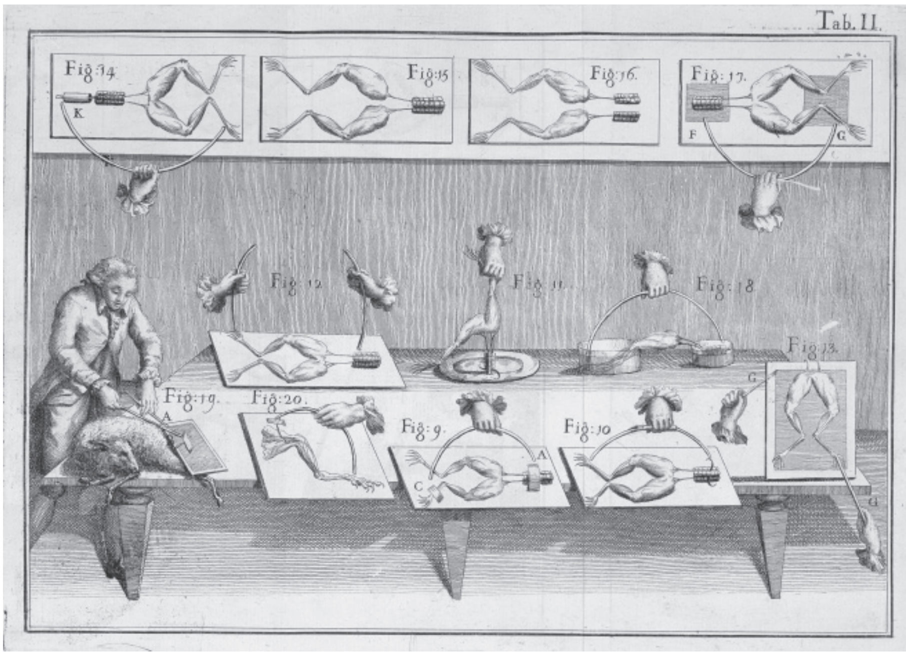


Figure 11. Galvani conducting electrical experiments with frogs' legs. The diagrams demonstrate various stages in the experiment. On the left, Galvani holds down a sheep. This figure was published in 1792 (Courtesy The British Library, London). Galvani's nephew, Giovanni Aldini (1762-1834), grotesquely extended his uncle's experiments by electrically contorting the faces of slaughtered oxen and executed criminals in public demonstrations

shaking, artificial respiration and electricity were tried, but to no avail.

An alternative basis for Dr Frankenstein was James Lind (1736-1812) of Windsor [26]. His son described his father's study as containing, 'telescopes, galvanic batteries, daggers, electrical machines, and all the divers apparatus which a philosopher is supposed to possess' [29]. Lind and Percy Shelley were friends and in the latter's rooms in Oxford there were 'an electrical machine, an air pump, the galvanic trough, a solar microscope' [30].

Charles Augustin Coulomb 1736-1806

Coulomb began his professional life as a military engineer, serving the first three years in Martinique. Beginning in 1781 he was stationed in Paris but upon the outbreak of the revolution in 1789 he retired to a small estate in Blois. He was recalled to Paris to take part in the new determination of weights and measures which had been decreed by the Revolutionary government. He is most famous for his work in 1785 on torsion balances and his verification that electric force obeys an inverse square law, and became one of the first members of France's National Institute.

The instrument known as the torsion balance (more properly called an electrometer) measures the force of repulsion between two similarly electrified bodies, by balancing the repelling force against the force exerted by a fine wire untwisting itself after it has been twisted. Coulomb found that the force exerted between two small electrified bodies varies inversely as the square of the distance between them when the distance is varied. In 1779 he published an investigation into the laws of friction and in 1799 a treatise on viscosity. However, it is the three reports he published in 1785 in the *Histoire de l'Académie Royale des Sciences* which contained his most important results. These were entitled *Premier*, *Sécond* and *Troisième Mèmoire sur l'Electricité et le Magnétism*.

Luigi Galvani 1737-1798

It had long been assumed that a 'very subtle humour' transmitted sensation and muscular stimulation through nerves; by the mid 18th century, physiologists were speculating that the humour was electricity. Luigi Galvani*, professor of anatomy and obstetrics at the University of Bologna was one of many who tested this hypothesis [31, 32] and was the one who made the crucial experiment which resulted in the discovery (1780-1783) that nerves and muscles in animals function by tiny electrical currents, which can be stimulated by the application of electricity from external sources. He demonstrated the twitching of frog's legs suspended by a copper hook to an iron rail (Figure 11), incorrectly deducing that the tissues had generated the 'animal electricity'. There were several books on 'animal electricity' of which Richard Fowler's is just one example [33].

Galvani's discovery was important as it was to lead to new methods in the study of neurology and to providing a detector of electric currents which was far better

* The histories of Luigi Galvani and Alessandro Volta are intertwined. Part 2 in *Nowotwory* issue 1/2007 commences with Volta (1745-1827) and includes the application of Voltaic cells.

Figure 12. 'The Golden Remedy or Electrical Panacea', an 1818 cartoon by George Cruickshank (1792-1878) showing a doctor administering the new electric shock treatment, thought to cure hysteria and other nervous conditions (Courtesy The Science Museum, South Kensington, London)

than tactile sensation. It also led to his 1789 discovery of chemically generated electric current [34].

Galvanism, as it was called, caused a furor among the general population in the late 18th early 19th centuries. Cartoons (Figure 12) depicted a galvanised corpse rising from the dead, and a London gentleman successfully reviving his libido. Self-styled professors of medical galvanism demonstrated 'portable galvanic apparatus' using a direct electric current.

Pierre Bertholon 1742-1800

The Abbé Bertholon contended that disease was caused by an excess or deficiency of nervous fluid [35]. He was perhaps the earliest to recommend electrotherapy for the treatment of cancer. He also recommended the modality for consumption, hydropsy, dysentery, plague, small pox, venereal diseases, cirrhosis and paralysis [24].

Jean-Paul Marat 1743-1793

It is usually forgotten that, prior to his ill-fated career as a revolutionary, Marat was a physician, having received a mail-order degree from Scotland's oldest university, St. Andrews [36]. A researcher in electrotherapy, he separated his subjects from the apparatus because he was concerned that their responses might be influenced by the crackling sparks and ozone odour. He concluded from his studies that electricity was effective for the treatment of skin eruptions, stupor, paralysis and rheumatism; but ineffective for many of its other purported indications. He specified the treatment duration because he believed that electricity, like drugs, should have a prescribed dosage [37]. His treatise on electrotherapy [36] was widely respected, and won the Prix de Rouen.

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