in which these elements are mixed in their composition. Even the dead body feels cold and darkness.

Zeno, born in the beginning of the 5th century B.C., the fellow-townsman, disciple, and adopted son of Parmenides, is famous for his attempts to prove that the notions of time, space, motion, multiplicity, sight, sound, &c., are self-contradictory and unthinkable. His paradoxes were stated with a subtlety which has forced thinkers even of distinction, who were opposed to his main position, for instance, Sir William Hamilton, to admit some of them to be unanswerable. Against motion Zeno directed several arguments, the most celebrated being that of Achilles and the tortoise, which are founded upon the confusion of that which is infinitely divisible with that which is infinite. Against space Zeno argued that any space, however large, must be in a larger space, this larger space again in a still larger, and so on *ad infinitum*. Against the manifold he argued (1) that the manifold, being divisible into the infinitely small, *i.e.*, into that which has no magnitude, can itself have none, as divisions that have no magnitude must make up a whole without magnitude; and (2) that, being divisible into an infinite number of parts, it must be infinitely large. Against sound he argued—and he applied similar reasoning to sight—that, as you cannot hear a single grain of corn fall, you cannot hear the sound of a number of grains falling, the sound of the falling of the number of grains being made up of the sounds of the falling of each grain. Thus Zeno sought to prove that thought and sense are opposed, and that the latter, contradicting itself, proves itself unworthy of the consideration of the philosopher.

The last of the Eleatic teachers was Melissus of Samos, the friend of Heraclitus, who was probably born somewhat later than Zeno. We only possess fragments of his works, preserved by Simplicius and collected by Brandis. His modifications of the doctrines of his master, Parmenides, are not important, with the exception of his assertion of the infinity, the unlimitedness, of "the One and All," and his distinct insistance upon the doctrine that the "One and All" is immaterial, unextended, without parts.

See the separate articles XENOPHANES, PARMENIDES, and ZENO.

ELECAMPANE (M. Lat., *Enula Campana*), a perennial composite plant, the *Inula Helenium* of Linnæus, which is common in many parts of Britain, and ranges throughout central and southern Europe, and in Asia as far eastwards as the Himalayas. Its stem attains a height of from 3 to 5 feet; the leaves are serrate-dentate, the lower ones stalked, the rest embracing the stem; the flowers are yellow, and 2 inches broad, and have many rays, each three-notched at the extremity. The root, the *radix inulæ* of pharmacy, is thick, branching, and mucilaginous, and has a warm bitter taste and a camphoraceous odour. For medicinal purposes it should be procured from plants not more than two or three years old. Besides *inulin*, $C_{12}H_{20}O_{10}$, a body isomeric with starch, the root contains, according to Kallen, two crystallizable substances—*helenin*, C_6H_8O, and *alantcamphor*, $C_{10}H_{16}O$. By the ancients the root was employed both as a medicine and as a condiment, and in England it was formerly in great repute as an aromatic tonic and stimulant of the secretory organs. "The fresh roots of elecampane preserved with sugar, or made into a syrup or conserve," are recommended by Parkinson in his *Theatrum Botanicum* as "very effectual to warm a cold and windy stomack, and the pricking and stitches therein or in the sides caused by the Spleene, and to helpe the cough, shortnesse of breath, and wheesing in the Lungs." As a drug, however, the root is now seldom resorted to except in veterinary practice. In France and Switzerland it is used in the manufacture of absinthe.

ELECTIONS. The law of parliamentary and municipal elections in England is now governed as to procedure by the 35 and 36 Vict. c. 33 (the Ballot Act, 1872), and as to disputed returns by the 31 and 32 Vict. c. 125 (Parliamentary Elections Act, 1868) and 35 and 36 Vict. c. 60. See BALLOT and BRIBERY.

The inquiry into a disputed parliamentary election was formerly conducted before a committee of the House of Commons, chosen as nearly as possible from both sides of the House for that particular business. The decisions of these tribunals laboured under the suspicion of being prompted by party feeling, and by the above-named Act of 1868 the jurisdiction was finally transferred to Her Majesty's judges, notwithstanding the general unwillingness of the bench to accept a class of business which they feared might bring their integrity into dispute. In future no election shall be questioned except in accordance with the provisions of this Act. Section 11 of the Act orders, *inter alia*, that the trial of every election petition shall be conducted before a *puisne judge* of one of the common law courts at Westminster and Dublin; that the said courts shall each select a judge to be placed on the *rota* for the trial of election petitions; that the said judges shall try petitions standing for trial according to seniority or otherwise, as they may agree; that the trial shall take place in the county or borough to which the petition refers, unless the court should think it desirable to hold it elsewhere. The judge shall determine "whether the member whose return is complained of, or any and what other person, was duly returned and elected, or whether the election was void," and shall certify his determination to the Speaker. When corrupt practices have been charged the judge shall also report (1) whether any such practice has been committed by or with the knowledge or consent of any candidate, and the nature thereof; (2) the names of persons proved to have been guilty of any corrupt practice; and (3) whether corrupt practices have extensively prevailed at the election.

Questions of law may be referred to the decision of the Court of Common Pleas. The report of the judge is equivalent to the report of an election committee under the old system. Petitions may be presented by the following persons:—(1) some person who has voted or had the right to vote at the election; (2) some person claiming to have a right to be returned or elected; (3) some person alleging himself to have been a candidate. The trial of a petition shall be proceeded with notwithstanding the acceptance by the respondent of an office of profit under the Crown, and notwithstanding the prorogation of Parliament; though it would appear that the dissolution of Parliament abates a petition. The judge appointed to try a petition shall be received with the same state as a judge of assize in an assize town. The costs and expenses of the petition shall be paid by the parties in such manner and such proportions as the court or judge may determine, regard being had to the discouragement of needless expense by throwing the burden thereof on the parties by whom it has been caused, whether they are on the whole successful or not. When a returning officer has wilfully neglected to return a person found on petition to have been entitled to be returned, such person may sue the officer (within one year of the act complained of, or six months of the trial of the petition), and shall recover double the damage he has actually sustained, together with full costs of suit.

To meet the additional work imposed on the English courts of common law by this Act, power was given to appoint an additional judge to each of them. Section 58 applies the provisions of the Act, with certain modifications, to Scotland.

This, like the Ballot Act, is a continuing Act.

Petitions against municipal elections are dealt with in 35

and 36 Vict. c. 60. The election judges under the last described Act appoint a number of barristers, not exceeding five, to try such petitions. No barrister can be appointed who is of less than fifteen years standing, or a member of Parliament, or holder of any office of profit (other than that of recorder) under the Crown; nor can any barrister try a petition in any borough in which he is recorder or in which he resides, or which is included in his circuit. The barrister sits without a jury. The provisions are generally similar to those relating to parliamentary elections in the former Act. The petition may allege that the election was avoided as to the borough or ward on the ground of general bribery, &c., or that the election of the person petitioned against was avoided by corrupt practices, or by personal disqualification, or that he had not the majority of lawful votes. And no election shall be questioned by any other process whatsoever for a matter for which it might have been questioned under this Act.

ELECTRICITY

THE word *Electricity* is derived from the Greek word ἤλεκτρον, meaning *amber*. The term was invented by Gilbert,[1] who used it with reference to the attractions and repulsions excited by friction in certain bodies of which amber may be taken as the type. To the cause of these forces was given the name Electricity; and out of the study of these and kindred phenomena arose the science of electricity, of which it is the purpose of the present article to give a brief outline.

The science has been divided into three branches—*Electrostatics*, which deals with electricity at rest; *Electrokinetics*, which considers the passage of electricity from place to place; and *Electromagnetism*, which treats of the relation of electricity to magnetism. We shall, however, make no attempt to adhere to this division, but shall exhibit the different parts of the subject in such order and connection as seems most clear and natural in the present state of the science. For the sake of the non-scientific reader we prefix a brief history[2] of the science of electricity, wherein mention is made of some of the more striking electrical discoveries and of the steps by which our knowledge of the subject has advanced to its present condition.

HISTORICAL SKETCH.

Thales, 600 B.C. The name of the philosopher who first observed that amber when rubbed possesses the property of attracting and repelling light bodies has not been handed down to our times. Thales of Miletus is said to have described this remarkable property, and both Theophrastus (321 B.C.) and Pliny (70 A.D.) mention the power of amber to attract straws and dry leaves. The same authors speak of the *lapis lyncurius*, which is supposed to be a mineral called *tourmaline*, as possessing the same property. The electricity of the torpedo was also known to the ancients.
Animal electricity. Pliny informs us, that when touched by a spear it paralyzes the muscles and arrests the feet, however swift; and Aristotle adds that it possesses the power of benumbing men, as well as the fishes which serve for its prey. The influence of electricity on the human body, and the electricity of the human body itself, were also known in ancient times. Anthero, a freedman of Tiberius, was cured of the gout by the shocks of the torpedo; and Wolimer, the king of the Goths, was able to emit sparks from his own body. Eustathius, who records this fact, also states that a certain philosopher, while dressing and undressing, emitted occasionally sudden crackling sparks, while at other times flames blazed from him without burning his clothes. Such are the scanty gleanings of electrical knowledge which we derive from the ancient philosophy; and though several writers of the Middle Ages have made occasional references to these facts, and even attempted to speculate upon them, yet they added nothing to the science, and left an open field for the researches of modern philosophers.

Dr Gilbert of Colchester may be considered as the founder of the science, as he appears to have been the first philosopher who carefully repeated the observations of the ancients, and applied to them the principles of philosophical investigation. **Gilbert (1540–1603).** In order to determine if other bodies possessed the same property as amber, he balanced a light metallic needle on a pivot, and observed whether or not it was affected by causing the excited or rubbed body to approach to it. In this way he discovered that the following bodies possess the property of attracting light substances:—amber, gagates or jet, diamond, sapphire, carbuncle, rock-crystal, opal, amethyst, vincentina or Bristol stone, beryl, glass, paste for false gems, glass of antimony, slags, belemnites, sulphur, gum-mastic, sealing-wax of lac, hard resin, arsenic, rock salt, mica, and alum. These various bodies attracted, with different degrees of force, not only straws and light films, but likewise metals, stones, earths, wood, leaves, thick smoke, and all solid and fluid bodies. Among the substances which are not excited by friction Gilbert enumerated emerald, agate, carnelian, pearls, jasper, calcedony, alabaster, porphyry, coral, marble, Lydian stone, flints, hematites, smyris (emery or corundum), bones, ivory, hard woods, such as cedar, ebony, juniper, and cypress, metals, and natural magnets. Gilbert also discovered that the state of the atmosphere affects the production of electricity; dryness with north or east wind being a favourable condition, while moisture with south wind is unfavourable. An account of Gilbert's experiments will be found in his book *De Magnete*, lib. ii. cap. 2.

Robert Boyle added many new facts to the science of electricity, and he has given a full account of them in his *Experiments on the Origin of Electricity*. By means of a suspended needle, he discovered that amber retained its attractive virtue after the friction which excited it had ceased; and though smoothness of surface had been regarded as advantageous for excitation, yet he found a diamond which in its rough state exceeded all the polished ones and all the electrics which he had tried, having been able to move a needle three minutes after he had ceased to rub it. He found also that heat and *tersion* (or the cleaning or wiping of any body) increased its susceptibility of excitation; and that if the attracted body were fixed, and the attracting body movable, their mutual approach would still take place. To Gilbert's list of "electrics" Boyle added the resinous cake which remained after evaporating one-fourth part of good oil of turpentine, the dry mass which remains after distilling a mixture of petroleum and

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[1] *De Magnete Magneticisque Corporibus.*

[2] A portion of this historical sketch was written by Sir David Brewster, and formed the introduction to his article "Electricity" in last edition of the *Encyclopædia*. It has been modified by suppressions and alterations here and there, and by large additions at the end which were thought necessary to make it suit the present state of science. For the sake of the student in search of original sources of information, pretty copious reference to such has been added throughout. Valuable for information of this kind the student will find Riess's *Reibungselectricität*, Young's *Natural Philosophy*, Wiedemann's *Galvanismus*, and the recent work on electricity by Prof. Mascart, of the Collége de France.

strong spirit of nitre, glass of lead, caput mortuum of amber, white sapphire, white amethyst, diaphanous ore of lead, carnelian, and a green stone supposed to be a sapphire.

To these discoveries of Boyle his contemporary Otto von Guericke added the highly important one of *electric light* (*Experimenta Nova Magdeburgica*, lib. iv. cap. 15). Having cast a globe of sulphur in a glass sphere, and broken off the glass, he mounted the sulphur ball upon a revolving axis, and excited it by the friction of the hand. By this means he discovered that light and sound accompanied strong electrical excitation, and he compares the light to that which is exhibited by breaking lump sugar in the dark. With this powerful apparatus Guericke verified on a greater scale the results obtained by his predecessors, and obtained several new ones of very considerable importance. He found that a light body, when once attracted by an excited electric, was repelled by it, and was incapable of a second attraction until it had been touched by some other body; and that light bodies suspended within the sphere of influence of an excited electric possessed the same properties as if they had been excited.

Newton (1643–1727).

To our illustrious countryman Sir Isaac Newton the science of electricity owes some important observations. He used in his electrical experiments a globe of glass rubbed by the hand instead of the sulphur globe of Von Guericke. It would appear that Newton was the first to use *glass* in this way (*Optics*, query 8th). We owe also to Sir Isaac a beautiful experiment on the excitation of electricity which has since become very popular. Having fixed a round disc of glass in a short brass cylinder, he placed small pieces of thin paper within the cylinder and upon a table, so that the lower surface of the glass was one-eighth of an inch distant from the table. He then rubbed the upper surface of the glass, and he observed the pieces of paper "leap from one part of the glass to the other, and twirl about in the air." This experiment, after a previous unsuccessful trial, was repeated by the Royal Society in 1676 (Brewster's *Life of Newton*, p. 307).

Hawksbee, 1705.

Francis Hawksbee, one of the most active experimental philosophers of his age, added many new facts to the science. In 1705 he communicated to the Royal Society several curious experiments on what he calls "the mercurial phosphorus." He showed that light could be produced by passing common air through mercury placed in a well-exhausted receiver. The air rushing through the mercury, blew it up against the sides of the glass that held it, "appearing all around like a body of fire, consisting of abundance of glowing globules." The phenomenon continued till the receiver was half full of air. These phenomena had been observed in the Torricellian vacuum before Hawksbee's time, and various explanations suggested. He suspected that they were due to electricity, and remarked their resemblance to lightning. Like Newton he used a revolving glass globe rubbed by the hand to generate electricity. Besides the experiment above alluded to he made many others on the electric light and on the attractions of electrified bodies. Descriptions of these will be found in his *Physico-Mechanical Experiments*, 1709, and in several memoirs in the *Philosophical Transactions* about 1707.

About the same time Dr Wall (*Phil. Trans.*, 1708) observed the spark and crackling sound accompanying the electrical excitation of amber, and compared them to thunder and lightning.

Stephen Gray (1696–1736).

One of the most ardent experimentalists of his time was Stephen Gray, a Fellow of the Royal Society. In his first paper, published in 1720, he showed that electricity could be excited by the friction of feathers, hair, silk, linen, woollen, paper, leather, wood, parchment, and gold-beaters' skin. Several of these bodies exhibited light in the dark, especially after they had been warmed; but all of them attracted light bodies, and sometimes at the distance of eight or ten inches. An epoch was made in the history of electricity by the discovery of Gray in 1729, that certain bodies had, while others had not, the power of conveying electricity from one body to another, *i.e.*, in modern phrase, *conducting* it. Gray experimented with a glass tube, into the ends of which were fastened two corks; into one of these he fastened a fir rod, and to the end of the rod an ivory ball. On rubbing the glass he found that the ball attracted the light bodies as vigorously as the glass itself. He made a variety of experiments with rods of different length, and with a packthread, by which he suspended his ball from the balcony of an upper story of his house, all with the same result. He then attempted to carry the electricity horizontally on a packthread which he suspended with hempen strings; but the experiment failed. On the occasion of a repetition of the experiments at the house of his friend Wheeler, silk strings were suggested as a support, and found to answer, while metal wires failed. Gray and Wheeler were thus led to the conclusion that it was the material of the supports that was in question, and that whereas packthread had, silk had not the power of transmitting electricity to a distance. Gray and Wheeler managed, by supporting a packthread by silk loops, to convey electricity from a piece of rubbed glass to a distance of 886 feet. The conducting power of fluids, and of the human body, was established by Gray. He also made many curious experiments on the electrical properties of resinous cakes, which he allowed to cool and harden in the ladles in which they had been melted. For an account of these and others the student is referred to memoirs in the *Philosophical Transactions* for 1731, 1735, &c.

Desaguliers.

Desaguliers made many experiments confirming Gray's conclusions, and found that bodies that have the property of being electrically excitable by friction, or *electrics per se*, have not the power of *conduction;* whereas *conductors* are not *electrics per se*. These terms, introduced by him, were useful in bringing into concise and scientific language the discoveries of Gray.

Dufay (1699–1739).

While Gray was pursuing his career of discovery in England, M. Dufay, of the Academy of Sciences, and superintendent of the Royal Botanic Gardens, was actively employed in the same researches. He found that all bodies, whether solid or fluid, could be electrified by an excited tube, by setting them on a glass stand slightly warmed, or only dried; and that those bodies which are in themselves least electrical received the greatest degree of electricity from the approach of the glass tube. He repeated the experiments of Gray, confirming his results, and found that electricity was transmitted more easily along packthread when it was wetted, and that it might be supported upon glass tubes in place of silk lines. In this way he conveyed it along a string 1256 feet long. He suspended by silken strings and electrified a child as Gray had done; and having suspended himself in a similar manner, he discovered that an electrical spark, accompanied with a crackling noise, took place when any other person touched him, and he has described the prickling sensation like the burning from a spark of fire, which is at the same time felt either through the clothes or on the skin. The great discovery of Dufay, however, was that of two different kinds of electricity. He fully recognized the importance of this fundamental fact, and gave the name of *vitreous* electricity to that which is produced by exciting glass, rock-crystal, precious stones, hair of animals, wool, and many other bodies; and the name of *resinous* to that which is produced by exciting resinous

bodies, such as amber, copal, gum-lac, silk, paper, thread, and a number of other substances. The characteristic of those two electricities was, that a body with vitreous electricity attracted all bodies with resinous electricity, and repelled all bodies with vitreous electricity; while a body with resinous electricity attracted all bodies with vitreous electricity, and repelled all bodies with resinous electricity. Two electrified silk threads, for example, repel each other, and also two electrified woollen threads, but an electrified silk thread will attract an electrified woollen thread. Hence it is easy to determine whether any body possesses vitreous or resinous electricity. If it *attracts* an electrified silk thread, its electricity will be vitreous; if it *repels* it, it will be resinous.

Gray repeated and varied the experiments of Dufay, and made many new ones. Like Hawksbee and Dr Wall, he recognized the similarity between the phenomena of electricity and those of thunder and lightning; and he expresses a hope "that there may be found out a way to collect a greater quantity of electric fire, and consequently to increase the force of that power, which, by several of these experiments, *si licet magnis componere parva*, seems to be *of the same nature with thunder and lightning*."

Boze, Winkler, &c.

The discoveries which we have now recounted began to rouse the activity of the German and Dutch philosophers. To the electrical machine used by Newton and Hawksbee, Professor Boze of Wittenberg added the *prime* conductor, which at first consisted of an iron or tin tube supported by a man standing upon cakes of rosin; but it was afterwards suspended by silken strings. Professor Winkler of Leipsic substituted a *cushion* in place of the hand for exciting the revolving globe; and Professor Gordon of Erfurt, a Scotch Benedictine monk, first used a glass cylinder, eight inches long and four broad, which he caused to revolve by means of a bow and string. By these means electrical sparks of great size and intensity were produced, and by their aid various combustible substances, both fluid and solid, were inflamed. In 1744 M. Ludolph of Berlin succeeded in firing, by the electrical spark, the ethereal spirit of Frobenius. Winkler did the same by a spark from his finger; and he succeeded in inflaming French brandy and other weaker spirits after they had been heated. Gordon kindled spirits by a jet of electrified water. Dr Miles inflamed phosphorus by the electric spark; and oil, pitch, and sealing-wax, when strongly heated, were set on fire by similar means. We refer the student for lists of the works of the philosophers just mentioned to the admirable bibliography given by Young, *Natural Philosophy*, p. 515.

Leyden phial 1745

These striking effects were all produced by the electricity obtained immediately from an excited electric; but a great step was now made in the science by the discovery of a method of accumulating and preserving electricity in large quantities. The author of this great invention is not distinctly known; but there is reason to believe that a monk of the name of Kleist, a person of the name of Cuneus, and Professor Muschenbroeck of Leyden had each the merit of an independent inventor. The invention by which this accumulation was effected was called the *Leyden Jar* or *Phial*, because it was principally in Leyden that it was either invented or tried. Having observed that excited electrics soon lost their electricity in the open air, and that their loss was accelerated when the atmosphere was charged with moisture or other conducting materials, Muschenbroeck conceived that the electricity of bodies might be retained by surrounding them with bodies which did not conduct it. In putting this idea to the test of experiment, he electrified some water in a glass bottle, and a communication having been made between the water and the prime conductor, the assistant, who was holding the bottle, on trying to disengage the communicating wire, received a sudden shock in his arms and breast, and thus established the efficacy of the Leyden jar.

Sir Wm. Watson (1715–1807).

Sir William Watson made some important experiments at this period of our history (Memoirs in *Phil. Trans.* about 1747). He succeeded in firing gunpowder by the electric spark; and by mixing the gunpowder with a little camphor he discharged a musket by the same power. He also fired hydrogen by the electric spark; and he kindled both spirits of wine and hydrogen by means of a drop of cold water, and even with ice. In the German experiments the fluid or solid to be inflamed was set on fire by an electrified body; but Sir William Watson placed the fluid in the hands of an electrified person, and set it on fire by causing a person not electrified to touch it with his finger. Sir William Watson first observed the flash of light which attends the discharge of the Leyden phial, and it is to him that we owe the present improved form of the Leyden phial, in which it is coated both without and within with tinfoil. Dr Bevis indeed had suggested the outside coating, and at Smeaton's recommendation, he coated a pane of glass on both sides, and within an inch of the edge, with tinfoil; but still the idea of coating the jar doubly belongs to Sir William Watson.

Experiments of the Royal Society.

A party of the Royal Society, with the president at their head, and Sir William Watson as their chief operator, entered upon a series of magnificent experiments, for the purpose of determining the velocity of the electric fluid, and the distance to which it could be conveyed. The French savans had conveyed the influence of the Leyden jar through a circuit of 12,000 feet; and in one case the basin at the Tuileries, containing about an acre of water, formed part of the circuit; but the English philosophers made a more complete series of experiments, of which the following were the results:—

1. That in all their operations, when the wires have been properly conducted, the electrical commotions from the charged phial have been very considerable only when the observers at the extremities of the wire have touched some substance readily conducting electricity with some part of their bodies.
2. That the electrical commotion is always felt most sensibly in those parts of the bodies of the observers which are between the conducting wires and the nearest and the most non-electric substance, or, in other words, so much of their bodies as comes within the electrical circuit.
3. That on these considerations we infer that the electrical power is conducted between these observers by any non-electric substances which happen to be situated between them, and contribute to form the electrical circuit.
4. That the electrical commotion has been perceptible to two or more observers at considerable distances from each other, even as far as two miles.
5. That when the observers have been shocked at the end of two miles of wire, we infer that the electrical circuit is four miles, viz. two miles of wire, and the space of two miles of the non-electric matter between the observers, whether it be water, earth, or both.
6. That the electrical commotion is equally strong, whether it is conducted by water or dry ground.
7. That if the wires between the electrifying machine and the observers are conducted on dry sticks, or other substances non-electric in a slight degree only, the effects of the electrical power are much greater than when the wires in their progress touch the ground, or moist vegetables, or other substances in a great degree non-electric.
8. That by comparing the respective velocities of electricity and sound, that of electricity, in any of the distances yet experienced, is nearly instantaneous.

In the following year these experiments were resumed with the view of ascertaining the absolute velocity of electricity at a certain distance, and it was found "that through the whole length of a wire 12,276 feet the velocity of electricity was instantaneous."

The theory of positive and negative electricity which was afterwards elaborated by Franklin, was distinctly announced by Sir W. Watson. He lays it down as a law that in electrical operations there is an afflux of "electric fluid" to the globe and the conductor. and also an efflux of the same matter from them. In the case of two insulated persons, the one in contact with the rubber and the other with the conductor, he observed that either of them would communicate a much stronger spark to the other than to any bystander. The electricity of the one, he says, became more rarê than it is naturally, and that of the other more dense, so that the density of the electricity in the two insulated persons differed more than that between either of them and a bystander.

A variety of interesting experiments were made about this time by Le Monnier, Nollet, Winckler, Ellicott, Jallabert, Boze, Menon, Smeaton, and Miles. In 1746 Le Monnier confirmed the result previously obtained by Gray, that electricity is communicated to homogeneous bodies in proportion to their surfaces only. Boze discovered that capillary tubes which discharged water by drops afforded a continuous stream when electrified. The Abbé Nollet (*Essai sur l'Electricité*, 1746; *Recherches*, 1749; *Lettres*, 1753), the friend and coadjutor of Dufay, ascertained that electricity increases the natural evaporation of fluids, and that the evaporation is hastened by placing them in non-electric vessels. Jallabert confirmed the result previously obtained by Watson, that electricity passes through the substance of a conducting wire, and not along its surface. Smeaton found that the red hot part of an iron bar could be as strongly electrified as the cold parts on each side of it. Dr Miles kindled common spirits by a stick of black sealing-wax excited by dry flannel. Ellicott conceived that the particles of the electric fluid repel each other, while they attract those of all other bodies. Mowbray concluded that the vegetation of two myrtles was hastened by electrifying them,—a result which Nollet confirmed in the case of vegetating seeds. The Abbé Menon found that cats, pigeons, sparrows, and chaffinches lost weight by being electrified for five or six hours, and that the same result was true of the human body; and hence it was concluded that electricity augments the insensible perspiration of animals.

Franklin (1706–90).

A high place in the history of electricity must be allotted to the name of Dr Benjamin Franklin of Philadelphia. His researches did much to extend our theoretical and practical knowledge of electricity, and the clearness and vigour of his style made his writings popular, and spread the study of the subject.

One of the first labours of the American philosopher was to present, in a more distinct form, the theory of positive and negative electricity, which Sir W. Watson had been the first to suggest. He showed that electricity is not created by friction, but merely collected from its state of diffusion through other matter by which it is attracted. He asserted that the glass globe, when rubbed, attracted the electrical fire, and took it from the rubber, the same globe being disposed, when the friction ceases, to give out its electricity to any body which has less. In the case of the charged Leyden jar, the inner coating of tinfoil had received more than its ordinary quantity of electricity, and was therefore electrified *positively* or *plus*, while the outer coating of tinfoil having had its ordinary quantity of electricity diminished, was electrified *negatively* or *minus*. Hence the cause of the shock and spark when the jar is discharged, or when the superabundant plus electricity of the inside is transferred by a conducting body to the defective or minus electricity of the outside. This theory of the Leyden phial Franklin established in the clearest manner, by showing that the outside and the inside coating possessed opposite electricities, and that, in charging it, exactly as much electricity is added on one side as is subtracted from the other. The abundant discharge of electricity by points was observed by Franklin in his earliest experiments, and also the power of points to conduct it copiously from an electrified body. Hence he was furnished with a simple method of collecting electricity from other bodies; and he was thus enabled to perform those remarkable experiments which we shall now proceed to explain. Hawksbee, Wall, and Nollet had successively suggested the similarity between lightning and the electric spark, and between the artificial snap and the natural thunder. Previous to the year 1750 Franklin drew up a statement, in which he showed that all the general phenomena and effects which were produced by electricity had their counterpart in lightning. After waiting some time for the erection of a spire at Philadelphia, by means of which he thought to bring down the electricity of a thunder-storm, he conceived the idea of sending up a kite among the clouds themselves. With this view he made a small cross of two small light strips of cedar, the arms being sufficiently long to reach to the four corners of a large thin silk handkerchief when extended. The corners of the handkerchief were tied to the extremities of the cross, and when the body of the kite was thus formed, a tail, loop, and string were added to it. The body was made of silk to enable it to bear the violence and wet of a thunder-storm. A very sharp pointed wire was fixed at the top of the upright stick of the cross, so as to rise a foot or more above the wood. A silk ribbon was tied to the end of the twine next the hand, and a key suspended at the junction of the twine and silk. In company with his son, Franklin raised the kite like a common one, in the first thunder-storm, which happened in the month of June 1752. To keep the silk ribbon dry, he stood within a door, taking care that the twine did not touch the frame of the door; and when the thunder-clouds came over the kite he watched the state of the string. A cloud passed without any electrical indications, and he began to despair of success. He saw, however, the loose filaments of the twine standing out every way, and he found them to be attracted by the approach of his finger. The suspended key gave a spark on the application of his knuckle, and when the string had become wet with the rain, the electricity became abundant; a Leyden jar was charged at the key, and by the electric fire thus obtained spirits were inflamed, and all the other electrical experiments performed which had been formerly made by excited electrics. In subsequent trials with another apparatus, he found that the clouds were sometimes positively and sometimes negatively electrified, and so demonstrated the perfect identity of lightning and electricity. Having thus succeeded in drawing the electric fire from the clouds, Franklin conceived the idea of protecting buildings from lightning by erecting on their highest parts pointed iron wire or conductors communicating with the ground. The electricity of a hovering or a passing cloud would thus be carried off slowly and silently; and if the cloud was highly charged, the lightning would strike in preference the elevated conductors.

The most important of Franklin's electrical writings are his *Experiments and Observations on Electricity made at Philadelphia*, 1751–54; his *Letters on Electricity*, and various memoirs and letters, *Phil. Trans.*, 1756, 1760, &c.

About the same time that Franklin was making his kite experiment in America, D'Alibard and others in France had erected a long iron rod at Marli, and obtained results agreeing with those of Franklin. Similar investigations were pursued by many others, among whom Father Beccaria deserves especial mention.

Death of Richman, 1753

These experiments were often dangerous, and in one case a fatal accident occurred. Professor Richman of St Petersburg had erected on his house an iron rod to collect the electricity of thunder-clouds. On the 6th August 1753, during a thunder-storm, he was observing, along with his friend Sokolow, the indications of an electrometer which

formed part of his apparatus, when a tremendous thunder-clap burst over the neighbourhood. Richman bent to observe the electrometer; while in this position, his head being a foot from the iron rod, Sokolow saw a globe of bluish fire about the size of the fist shoot from the iron rod to the professor's head, with a report like that of a pistol. The shock was fatal; Richman fell back upon a chest and instantly expired. Sokolow was stupified and benumbed, and the red hot fragments of a metallic wire struck his clothes, and covered them with burnt marks.

Canton (1715–72).

One of the most diligent labourers in the field of electrical science was an Englishman, John Canton (*Phil. Trans.*, 1753–54). Before his time it had been assumed as indisputable that the same kind of electricity was invariably produced by the friction of the same electric,—that glass, for example, yielded always *vitreous*, and amber always *resinous* electricity. Having roughened a glass tube by grinding its surface with emery and sheet lead, he found that it possessed vitreous or positive electricity when excited with oiled silk, but resinous electricity when excited with new flannel. He found, in short, that vitreous or resinous electricity might, in certain cases, be developed at will in the same tube, by altering the surfaces of the tube and the exciting rubber. Removing the polish from one half of the tube, he excited the different electricities with the same rubber at a single stroke, and, curiously enough, the rubber was found to move much more easily over the rough than over the polished half. Canton likewise discovered that glass, amber, sealing-wax, and calcareous spar were all electrified positively when taken out of mercury; and hence he was led to the important practical discovery that an amalgam of mercury and tin was most efficacious in exciting glass when applied to the surface of the rubber. Canton discovered, and to a certain extent explained by the then prevalent theory of "electrical atmospheres," the fundamental fact of *electrification by induction*. He also found that the air in a room could be electrified positively or negatively, and might remain thus electrified for a considerable time.

Beccaria (1716–81).

Beccaria, a celebrated Italian physicist, kept up the spirit of electrical discovery in Italy. He showed that water is a very imperfect conductor of electricity, that its conducting power is proportional to its quantity, and that a small quantity of water opposes a powerful resistance to the passage of electricity. He succeeded in making the electric spark visible in water, by discharging shocks through wires that nearly met in tubes filled with water. In this experiment the tubes, though sometimes eight or ten lines thick, were burst in pieces. Beccaria likewise demonstrated that air adjacent to an electrified body gradually acquired the same electricity, that the electricity of the body is diminished by that of the air, and that the air parts with its electricity very slowly. He considered that there was a mutual repulsion between the particles of the electric fluid and those of air, and that in the passage of the former through the latter a temporary vacuum was formed. Beccaria's experiments on atmospherical electricity are of the greatest interest to the meteorologist. For farther account of his work, see his *Lettere dell' Elettr.*, 1758; *Experimenta*, 1772; and letters. &c. in *Phil. Trans.* about 1770.

The science of electricity owes several practical as well as theoretical observations to Robert Symmer (*Phil. Trans.*, about 1759). In pulling off his stockings in the evening, he had often remarked that they not only gave a crackling noise, but even emitted sparks in the dark. The electricity was most powerful when a silk and a worsted stocking had been worn on the same leg, and it was best exhibited by putting the hand between the leg and the stockings, and pulling them off together. The one stocking being then drawn out of the other, they appeared more or less inflated, and exhibited the attractions and repulsions of electrified bodies. Two white silk stockings, or two black ones, when put on the same leg and taken off, gave no electrical indications. When a black and a white stocking were put on the same leg, and after ten minutes taken off, they were so much inflated when pulled asunder, that each showed the entire shape of the leg, and at the distance of a foot and a half they rushed to meet each other.

"But what appears most extraordinary is, that when they are separated, and removed at a certain distance from each other, their electricity does not appear to have been in the least impaired by the shock they had in meeting. They are again inflated, again attract and repel, and are as ready to rush together as before. When this experiment is performed with two black stockings in one hand, and two white in the other, it exhibits a very curious spectacle; the repulsion of those of the same colour, and the attraction of those of different colours, throws them into an agitation that is not unentertaining, and makes them catch each at that of its opposite colour, at a greater distance than one would expect. When allowed to come together, they all unite in one mass. When separated, they resume their former appearance, and admit of the repetition of the experiment as often as you please, till their electricity, gradually wasting, stands in need of being recruited.

Symmer likewise found that a Leyden jar could be charged by the stockings either positively or negatively, according as the wire from the neck of the jar was presented to the black or the white stocking. When the electricity of the white stocking was thrown into the jar, and then the electricity of the black one, or *vice versa*, the jar was not electrified at all. With the electricity of two stockings he charged the jar to such a degree that the shock from it reached both his elbows; and by means of the electricity of four silk stockings he kindled spirits of wine in a tea-spoon which he held in his hand, and the shock was at the same time felt from the elbows to the breast. Symmer has the merit of having first maintained the theory of two distinct fluids, not independent of each other, as Dufay supposed them to be, but co-existent, and, by counteracting each other, producing all the phenomena of electricity. He conceived that when a body is said to be positively electrified, it is not simply that it is possessed of a larger share of electric matter than in a natural state, nor, when it is said to be negatively electrified, of a less; but that, in the former case, it is possessed of a larger portion of one kind of electricity, and in the latter, of a larger portion of the other; while a body, in its natural state, remains unelectrified, because there is an equal amount of the two everywhere within it.

Contemporary with Symmer were Delaval, Wilson, Cigna, Kinnersley, Wilcke, and Priestley (for the works of these electricians consult Young). Delaval found that the sides of vessels that were perfect conductors were non-conductors, and that animal and vegetable bodies lost their conducting power when reduced to ashes. Wilson concluded that when two electrics are rubbed together, the harder of the two is generally electrified positively and the other negatively, the electricities always being opposite. Cigna made many curious experiments by using silk ribbands in place of the silk stockings of Symmer. Kinnersley, the friend of Franklin, made some important experiments on the elongation and fusion of iron wires, when a strong charge was passed through them in a state of tension (*Phil. Trans.*, 1763); he also experimented on the disruptive discharge in air. Wilcke brought to light many phenomena respecting the electrification produced by the melting of electric substances.

The pyro-electricity of minerals, or the faculty possessed by some minerals of becoming electric by heat, and of exhibiting negative and positive poles, now began to attract the notice of philosophers. There is reason to believe that the *lyncurium* of the ancients, which, according to