supply a want that has been felt for some time past, and the new society is one that ought to succeed, and, if properly managed, will be sure to be of immense service in the Bombay Presidency.

WE learn from the *Garden* that the directors of the Alexandra Park Company have requested Mr. M'Kenzie to prepare a scheme for establishing a school of horticulture, for which purpose about twenty acres of the grounds attached to the building will be set apart. As we have no school of horticulture in this great gardening country, we hope something more may come of this than of its short-lived and feeble forerunners.

THE Portuguese *Jornal de Horticultura Pratica* announces a forthcoming "Flora" of that country, by Señor Barao de Castello de Piava, who was formerly Professor of Botany in the Academia Polythenica. Great things are expected from the new work, in which the subject will be brought up to the level of the knowledge of the present day, including all the discoveries which have been made since the time of Brotero, whose once celebrated "Flora Lusitanica" is now seldom to be met with for sale.

A NEW *Révue des Sciences Naturelles* has recently been started at Montpellier under the management of MM. Dubreuil and Kecker, to be published every three months.

WE learn that the publication of the *American Journal of Conchology* has closed with the completion of its seventh volume. This quarterly, edited by Mr. George W. Tryon, has appeared under the auspices of the Academy of Natural Sciences in Philadelphia, and has included, from time to time, a great many very important conchological monographs, chiefly presented to the Philadelphia Academy, many of them accompanied by coloured plates. Hereafter, such communications will be published in the Journal of the Proceedings of the Academy itself.

THE Second part of the *Quarterly German Magazine*, just received, contains translations (still into very indifferent English) of only two articles: Dr. J. Rosenthal on Electric Phenomena, and Prof. de Bary on Mildew and Fermentation.

Les Mondes has a long description, with illustrations, of the new "Horloges electriques" of M. C. F. Milde, the principal of which is a commutator for distributing the hours in all directions. It consists of an electro-magnet proportioned to the requirements, whose armature, at the moment of attraction, acts upon the arm of a lever, which governs a sector, whose centre of rotation is upon a pillar.

AN apparatus has been recently devised in Germany for obtaining specimens of water at any desired depth of the ocean. A strong, heavy vessel, entirely closed and empty, has a valve through which water may be admitted, but which is only put in motion by means of powerful electro-magnets connected therewith. These magnets are also connected with a wire which accompanies the rope, by means of which the apparatus is lowered from the ship. When the empty vessel, which is in fact a plummet, has reached the required depth, an electric current is sent from the battery on shipboard to the coils below; the magnetism thus generated opens the valves, and the vessel is filled and ready to be drawn up.

ACCORDING to the correspondence of the *New York Herald*, an ingenious plan has been adopted by Prof. Agassiz's expedition for determining how far the submarine regions are pervious to light. A plate prepared for photographic purposes is inclosed in a case so contrived as to be covered by a revolving lid in the space of forty minutes. The apparatus is sunk to the required depth, and at the expiration of the period stated is drawn up and developed in the ordinary way. It is said that evidence has thus been obtained of the operation of the actinic rays at much greater depths than hitherto supposed possible.

THE BIRTH OF CHEMISTRY

II.

Thales of Miletus—Later beliefs in his doctrine—Anaximenes—Empedokles — Herakleitos—Anaxagoras —Demokritos — The Atomic Theory — Aristotle—The Ethereal Medium—Transmutation of the Elements—The Four-element Theory—Mode of interpreting it—Cause of the absence of Natural Science among the Ancients.

THE elements of the Greek philosophers were, as we shall presently show, rather *principles* than elements in the sense in which we speak of the sixty-five elements now known to chemistry. There was a marked tendency in the earliest period of Greek philosophy to make one element or principle fundamental, and to evolve the other elements and the world from it. Thales, of Miletus, who lived in the sixth century, B.C., and who was called "the first of natural philosophers" by Tertullian, and the "first who inquired after natural causes" by Lactantius, affirmed that water was the first principle of things, perhaps, according to some writers, because Homer had made Okeanos the source of the gods. At least we are reminded of the boundless watery chaos of older cosmogonies. This doctrine of Thales was not without its supporters during the Middle Ages, and, indeed, the convertibility of water into earth and air was not absolutely disproved until about a century ago. One of the ablest supporters of the dogma was Van Helmont (b. 1577, d. 1644), who affirmed that all metals, and even rocks, may be resolved into water; animal substances are produced from it, because fish live upon it; and vegetable substances may be also produced from it. This last assertion he endeavoured to prove by what would appear to be a very conclusive experiment in those days, when neither the composition of the air nor of water was known. He took a willow which weighed five pounds, and planted it in two hundred pounds of earth, which he had previously carefully dried in an oven. The willow was frequently watered, and at the end of five years he pulled it up and found that its weight amounted to one hundred and sixty-nine pounds and three ounces. The earth was again dried, and was found to have lost only two ounces. Thus it appeared that 164lb. of wood, bark, roots, leaves, &c., had been produced from water alone. Hence he inferred that all vegetables are produced from water alone; not knowing, as was afterwards proved by Priestley, that a constituent of the atmosphere called carbonic acid had furnished the solid part of the tree, although, indeed, there was much water with it. Boerhaave devotes a page of his big book to a discussion of "whether water be convertible into earth." He concludes that the small earthy deposit observed when rain-water is distilled, arises from the particles of dust which had settled on the water before its introduction into the distilling vessel. Mr. Boyle had previously affirmed that "a very ingenious person, who had tried various experiments on rain-water, put him beyond all doubt about this transmutation, for he solemnly affirmed, on experience, that rain-water, even after distillation in very clean glasses, near two hundred times, afforded him this white earth." Finally, Lavoisier, in 1770, communicated to the *Académie des Sciences* an elaborate paper, "On the nature of water, and the experiments by which it has been attempted to prove the possibility of changing it into earth." In this he conclusively proved that water cannot be changed into earth, although it be distilled backwards and forwards for many successive days. Here then we find the old Thalesian theory at last disproved, but not before it had endured for twenty-four centuries; and this is by no means a solitary example of the permanence of old ideas. We shall become acquainted with yet older theories, which are still admitted, and which seem to be essential to physical philosophy.

On the other hand, Anaximenes regarded air as the primal element, Herakleitos fire, Pherekides earth, and some philosophers grouped two elements together. Anaximenes held that clouds were caused by the condensation of air, rain by the condensation of clouds; he appears to have clearly connected condensation with cold, rarefaction with heat. Archelaus affirmed that air when rarefied becomes fire, when condensed, water. It was very generally believed during the Middle Ages that water when boiled was converted into air. Empedokles introduced the idea of four distinct elements—earth, air, fire, and water, not capable of passing one into the other, but forming all things by their intermixture. These elements are acted upon by two principles, a uniting force of amity, a separating force of discord, corresponding somewhat to our attraction and repulsion. He endeavoured to prove the four-element theory by the following crude experiment: wood is burnt upon a hearth, fire seems to be evolved from it, the smoke is air, moisture is deposited on the hearthstone, while the ashes are earth, hence wood is made up of earth, air, fire, and water. Empedokles was one of the first to materialise the Homeric gods; he applied his four-element theory even to them, declaring that Zeus was the element of fire, Here the element of air, Nestis the element of water, and Aidoneus the element of earth. Herakleitos (about 460 B.C.) made fire the primal element, and assumed that it condensed itself into the material elements, and that air, water, and earth were respectively formed as the fire became more condensed. He asserted, moreover, that all things are in perpetual motion and change, the moving force being fire; "fire is to him," says Schwegler, "even in individual things, the principle of movement, of physical as of spiritual vitality; the soul itself is a fiery vapour." We find in the fire of Herakleitos to some extent the attributes of what we now call a physical force; thus it is precedent to matter, and is the motive power of the universe, it influences and changes matter, it is perpetually undergoing transformation, but ultimately returns to its own form. Prof. Max Müller speaks of Herakleitos as "one of the boldest thinkers of ancient Greece." We can well understand why fire should, at a very early date, be regarded as chief of the elements, and the motive power of the universe; it had long been worshipped as a symbol of the deity by the Chaldæans; a worship which possibly originated with the Scyths; for Zoroaster, who introduced fire-worship among the Medo-Persic races, is supposed to have been a Scythian. Again, Agni, the god of light and fire, was placed first in the Hindu Trinity.

Anaxagoras of Klazomenæ (B.C. 500) asserted that originally all things existed in infinite disorder; before the creation there was a chaos of mingled particles of matter, which were arranged in order by a designing intelligence or mover of matter (νοῦς). The primitive constituents of things are not definite elements, like those of Empedokles, but are *homœomeries* (ὁμοιομέρειαι) that is *like parts*, small particles of matter like the masses they produce when they aggregate. Thus a mass of iron is produced by the aggregation of an infinite number of iron-homœomeries brought out of the chaos by the νοῦς, which latter possesses vortical motion which enables it to separate like parts and bring them together, somewhat on the principle of gold-washing. If a dish containing substances of different relative weight, such as cork, sand, and lead shot, intimately mixed together, be caused to rotate, like particles will come together, the lead in one place the sand in another, and this experiment will help us to realise to some extent the meaning of Anaxagoras when he assumes that the vortical motion of the νοῦς caused homœomeries to aggregate and form the world. Leukippos taught that the world is produced by the falling together of small indivisible particles or *atoms* (from α and τεμνω), which are the principles of things, and which possess rapid circular motion. Demokritos (460 B.C.) extended the atomic theory of Leukippos; he contended that the principles of things are atoms and a vacuum. The atoms are invisible by reason of their smallness, indivisible by reason of their solidity, impenetrable and unalterable. They have no other qualities, neither heat, nor cold, nor colour. Atoms are infinite in number, the vacuum is infinite in magnitude. Atoms differ from each other in size, shape, and weight. They are actuated by necessity or fate (ἀνάγκη), and possess an oblique motion in the vacuum, which causes atoms of like shape to collide and group themselves together, by which means all things are formed. The vacuum is necessary, otherwise motion of the atoms would be impossible, because there would be no place to receive them. Long before the time of Demokritos an atomic theory had been proposed in India by Kanáda, the founder of the Nyaya system of philosophy, of which this theory forms the distinguishing feature. The theory of Leukippos is attributed by Possidonius to Moschus, a Phœnician. During the Middle Ages many writers made the atomic theory a prominent part of their system. Descartes adopted it in a somewhat modified form, and associated with his particles the vortical motion possessed by the homœomeries of Anaxagoras. Finally, almost in our own day, the atomic theory was introduced into chemistry by Dalton, and its introduction marked an important era in the science. At the present time the doctrine of atoms forms a principal feature in chemistry, and other branches of science find the conception most conducive to the philosophical explanation of phenomena. The definition of an atom given by Demokritos is almost as absolute and precise as that which we find in our most modern treatises. Thus the theory has endured for more than twenty-five centuries, and is likely to endure until there shall be no more science. It offers a striking example of the oneness of physical thought; the conception seems to be essential to Natural Philosophy; the most stupendous phenomena may be referred to atomic motions. S. Augustine has well said, "Deus est magnus in magnis, maximus autem in minimis."

The Hindus not only possessed the idea of the atomic constitution of matter, but further associated an attractive force with the atoms. This is well shown in the following extract given by Sir William Jones, from the poem of "Shi'ri'n and Ferhád, or the Divine Spirit, and a human soul disinterestedly pious":—"There is a strong propensity, which dances through every atom, and attracts the minutest particle to some peculiar object; search this Universe from its base to its summit, from fire to air, from water to earth, from all below the moon to all above the celestial spheres, and thou wilt not find a corpuscle destitute of that natural attractibility; the very point of the first thread in this apparently tangled skein; is no other than such a principle of attraction, and all principles beside are void of a real basis; from such a propensity arises every motion perceived in heavenly or in terrestrial bodies; it is a disposition to be attracted, which taught hard steel to rush from its place and rivet itself on the magnet; it is the same disposition which impels the light straw to attach itself firmly to the amber; it is this quality which gives every substance in nature a tendency towards another, and an inclination forcibly directed to a determinate point."

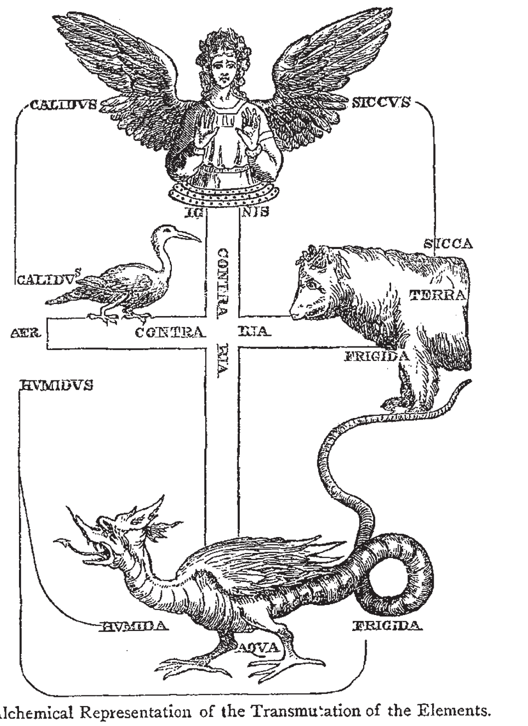
The most prolific writer on Science amongst the ancients was Aristotle (b. 385 B.C., d. 322). He was the author of various treatises, on the Heavens, on Generation and Corruption, on Physics, on Respiration, on Audibles, &c., and his views as well on metaphysics and ethics, as on science, were nearly universally accepted during the Middle Ages. Indeed, the scientific writings of Aristotle influenced science for nearly twenty centuries. Few, however, of his opinions concern us here. He was the first to introduce into Greek philosophy the *ether*, which he regarded as a fifth element (hence afterwards called *quinta essentia*) more subtle and divine than the other elements. The word quintessence is frequently used by the alchemists and early chemists, and is found in our most recent English dictionaries. The idea of an infinitely rarified and all-penetrating matter had long existed in physical philosophy, notably in the Hindu systems; it was probably recognised as a fifth element prior to the ninth century B.C. Aristotle is said to have called it αἰθὴρ from ἀεὶ and θέω, because he conceived it to be always in motion, and to be the moving agency of the other elements; but we cannot admit this derivation now, and prefer to trace it to αἴθω and *indh*. In the present day we find it impossible to explain various phenomena, notably those connected with radiant heat and the polarisation of light, without assuming the existence of some rare ethereal medium, cubic miles of which would not weigh a milligramme, and we still call it the ether. Few physical systems have avoided this supposition; we make less use of it in chemistry than in physics; but it would be difficult to account for such actions as the combination of chlorine and hydrogen under the influence of light, without it. Aristotle held that the four elements are mutually convertible, and he assigned two qualities to each, one of which was common to some other element. Thus he said:—

Fire is hot and dry.
Air is hot and moist.
Water is cold and moist.
Earth is cold and dry.

In each of these one quality is dominant. Thus fire is more hot than dry, air more moist than hot, water more cold than moist, and earth more dry than cold. If the dry of fire be vanquished by the moist of water, air will result; if the hot of air be vanquished by the cold of earth, water will result; if the moist of water be vanquished by the dry of fire, earth will result. This idea of the transmutation of the elements was adopted generally in works on alchemy; the following figure which embodies it is from a work entitled "Preciosa Margarita Novella," published in Venice in 1546.

Aristotle's method of expressing the transmutation of the elements does not seem to differ much from that of earlier philosophers; it would appear that he means to imply that if water be heated air is produced, while if it be heated more strongly so as to evaporate it to dryness, earth is left. His account of the generation of fire from air and earth is based on the most shallow and meagre observation, and shows to what results the most astute mind may be led if unaided by experiment. The generation of fire, he says, is made evident by the senses, for flame is notably fire, but flame is burning smoke, and smoke is from air and earth.

It is not here that we may tell how the philosophy of Aristotle was introduced into Europe by the Arabians, how from it arose that stupendous mass of false philosophy and perverted Aristotelianism called Scholasticism, and how for centuries the blind acceptance of the Peripatetic dogmas retarded the progress of science. Worse than all, Averroës, who has been called "l'âme d'Aristote," and who scattered Aristotelianism broadcast over Europe, did not know Greek, and the Latin versions of Averroës were "Latin translations from an Hebrew version of an Arabic commentary on an Arabic translation of a Syriac version of a Greek text." We may not, therefore, blame Aristotle for the results which followed from the too general and literal acceptance of his philosophy. Mr. Lewes has well said, "However he may have been impelled to systematise on imperfect bases, and to reason where he should have observed, it is not too much to say that had he reappeared among later generations, he would have been the first to repudiate the servility of his followers, the first to point out the inanity of Scholasticism. His mighty and eminently inquiring intellect would have been



Alchemical Representation of the Transmutation of the Elements.

the first to welcome and to extend the new discoveries. He would have sided with Galileo and Bacon against the Aristotelians."

We have spoken above of the endurance of the Thalesian theory, that all things are formed from water, and of the yet older theories of the existence of an ethereal medium, and of atoms; but the theory which affirms that the world is composed of the four elements—earth, air, fire, and water, is yet older, and is, indeed, the oldest physical theory of which we have any knowledge. It certainly existed before the fifteenth century B.C., it was adopted in India, Egypt, and as we have seen, in Greece at a very early date. Then in the case of those philosophers who made water, air, fire, &c., primal elements, this element was first transmuted into the three other elements, and the world was formed from the four. We must be careful, however, to remember that these four elements are not to be understood too literally, they were rather principles or types of qualities than actual elements. Several philosophers divided fire into a purer and grosser part. Seneca tells us that the Egyptians extended the theory by assigning to each element an active and a passive form: thus fire was divided into light which shines, and into fire; air into passive atmosphere and active wind; water into fresh and salt water; and earth into cultivable land on the one hand, and rocks on the other. These elements were extended yet more. In later times *Fire* would come to signify everything appertaining to ignition; thus light, whether accompanied by heat or otherwise, flame, the heat inherent in all bodies, incandescent bodies, stars, fiery meteors, lightning, and all visible manifestations of electricity, would be included under the term. *Air* would include smoke, steam, all vapours, and whatsoever approached to the nature of a gas. When gases were first discovered a hundred years ago, they were called *Airs;* thus we read of *fixed air*, *nitrous air*, *dephlogisticated air*, &c. *Water* would include all liquids, of which, no doubt, blood, milk, wine, and oil, were in early times the most familiar; the words *aqua fortis*, *aqua regia*, *aguardiente*, *eau-de-vie*, &c., are vestiges of the old practice. *Earth* included all rocks, however dissimilar they might be, all kinds of cultivable land, metals, and whatever appertained to solidity. Every solid was regarded as a kind of earth at first. A century ago many substances were called earths. At the present time out of the sixty-five elements known to the chemist, eight are classed as "earths" and three as "alkaline earths." The fact is, the four ancient elements were types of great classes of which the whole world was constituted. In their most general sense, *earth*, *water*, *air*, signified *solidity*, *liquidity*, *gaseity*, while *fire* was the force exercising itself upon matter. We have seen that the elemental fire of Herakleitos is the mover of matter, the principle of movement, that which produces perpetual changes around us. Fire was the ψυχή, the anima, the soul, the vivifying spirit. The mythological side of the belief is seen in the story of Prometheus, who is fabled to have stolen fire from Heaven and therewith vivified mankind. The philosophical side of the belief is seen in the dogmas of Herakleitos. The four-element theory evolved itself from the crude ideas about ether and chaos, mind and matter, before discussed; it is one of those crude physical theories which is enunciated and accepted by races the most diverse in character, country, faith, destiny. There is great oneness in the human mind in the matter of broad principles in crude cosmical ideas. And let us not forget that the four-element theory was universally accepted during the Middle Ages, and was only disproved a century ago, when air was proved to be a mixture of two gases, water a combination of two gases, fire the result of intense chemical action, and earth a mixture of some dozens of elementary bodies, some combined, some single. We do not deny that during the continuance of the four-element theory it may often have been taken in its strictly literal sense; but we do venture to assert that the richer and more cultured intellects regarded it in the light we have above described.

We can quite understand why there was so little natural science among the ancients, when we remember the absence of all experimental method and means, and the obstacle presented by the habit of mind which induced them to apply reasoning in place of experiment in the study of nature, to reason upon an immature or ill-observed fact, and to generalise upon altogether insufficient data. A simple sophistry applied to observation could lead to the most monstrous results. Take, for example, the argument of Diodorus, as given by Sextus Empiricus to prove that nothing is moved:—"If a thing be moved, it is either moved in the place where it is, or in the place where it is not. But not in that wherein it is, because it rests in the place wherein it is; neither in that wherein it is not, for where a thing is not, there it can neither act nor suffer. Therefore nothing is moved." Again, Sokrates and many of his followers taught that it was unwise to leave those affairs which directly concern man, to study those which are beyond his control and external to him. Thus, to inquire into the nature and distance of the stars seems an useless speculation, because even if we could ascertain these things, we could neither alter the course of the stars nor apply them to any benefit of mankind.

We have, however, seen above that many of the Greek philosophers had more or less definite notions concerning matter and force, and that they frequently insist upon the transmutation of matter from one form into another; so far and so far only are we concerned with their dogmas in our inquiry into the Birth of Chemistry. But we must not fail to notice the existence at a very early date of the four-element theory, of an atomic theory, of the idea of an ethereal medium, of the idea of transforming one kind of matter into another by the agency of some motive principle. Neither let us forget to note the similarity of principles in diverse philosophies; thus the homœomeries of Anaxagoras and the atoms of Leukippos are clearly related, so, too, are the νοῦς of Anaxagoras, the ἀνάγκη of Demokritos, the actuating form of fire of Herakleitos, the moving ether of Aristotle. The links which bind together ancient and modern physical thought are strong and enduring, and since they have lasted during the rise and fall of many nations, and during the most profound changes in the mode and tone of thought, it is not unlikely that they will endure as long as the chain itself.

G. F. RODWELL

THE DIATHERMACY OF FLAME

I HAVE just read Mr. Ericsson's paper on "The Sun's Radiant Heat" in NATURE, October 3, p. 458, and find that he has made some experiments on the diathermacy of flame closely resembling those which I made in 1869, and described in chap. viii. of "The Fuel of the Sun" published January 1870. Although the object of our investigations was identical and the method of proceeding very similar, the results obtained are so contradictory that one of us must be quite wrong, and therefore I think the subject demands discussion.

Referring the reader to the engraving illustrating Mr. Ericsson's paper, I may easily describe my apparatus. Like Mr. Ericsson's, there was a gas-pipe from the side of which projected a row of burners, each provided with a separate stop-cock. My burners, however, differed from his in being perpendicular to the main pipe which was always used in a horizontal position. My blackened bulb thermometer was similarly fixed at one end of a chamber or vessel, the other end of which was open to receive the radiations from the flames. This, however, was much simpler than Mr. Ericsson's. It had not the double chamber with intervening wall, nor was it surrounded by water, but was simply a thin tube of tin plate *polished inside* to prevent absorption of radiant heat. The thermometer was insulated from metallic contact with this tube, and thus could only receive heat from it by radiation, which the polishing reduced to a minimum. The sectional form and opening of the tube was made to correspond nearly with that of the presented side of the gas flames, but was somewhat larger.

At first I used Bunsen-burner flames, then flat flames like those figured by Mr. Ericsson, afterwards simple jets formed by the gas issuing from a small pin-hole, the jets being far enough apart to be quite independent; finally a row of such jets so near to each other that they came in contact, coalesced fully, and formed one sheet of flame, the edge of which was presented to the mouth of the polished tube containing the thermometer.

Guided by results obtained in a previous series of photometric experiments on the transparency of flames to their own special radiations, and by the first experiments I made on diathermacy, I relied on the arrangement last described, viz. the coalescing jets. The reason for this will presently appear.

My mode of proceeding differed in another respect from Mr. Ericsson's. Instead of lighting one jet at one end and then another and another in succession towards the thermometer, I always worked with an odd number of flames, and began with the middle jet, then lighted one on each side, next one on each side of those three, then one on each side of those five, and so on. My flames were thus maintained at a constant mean distance from the thermometer.

By means of a well-constructed experimental gas meter, with micrometic regulator, and a minute alarum clock, the supply of gas was accurately adjusted, so that each additional jet, or pair of jets, should consume an exactly equal differential increase of gas. The results obtained were as follows:—

Number of Jets	Consumption of gas in cubic feet per hour	Highest reading of Thermometer
1	1·0	19°·0 Cent.
3	1·5	23°·0 ,,
5	2·0	27°·0 ,,
7	2·5	31°·0 ,,
9	3·0	35°·5 ,,
11	3·5	39°·0 ,,
13	4·0	43°·5 ,,
15	4·5	48°·0 ,,
17	5·0	53°·0 ,,

Here, then, is a serious discrepancy. I get an increase of 4° by the first addition of two flames, and by eight of such additional pairs obtain an increase of 34°, instead of the 32° due to theoretical diathermacy. These 2° of excess (being due to the latter end of the series) I attributed to the increased temperature of my apparatus.

Mr. Ericsson obtained an increase of only 7°·9 instead of 17°·6, the theoretical requirement.

Without any disposition to underrate the value and importance of Mr. Ericsson's researches, I think that in this matter he has been deceived by overlooking some important sources of fallacy.

1. He tells us nothing about the quantity of gas consumed. His jets all issue from the same main pipe, which he describes as supplied with "gas at ordinary pressure." Now with such a supply the quantity of gas burning from each jet would steadily diminish as he turned on the additional jets. On turning the second jet the first would diminish; when the third was turned the supply to both first and second would be reduced; and so on, to an extent depending upon rates of sectional area of the supply pipe to that of the jet holes. If Mr. Ericsson's drawing is made to scale, the error due to this was of great magnitude.

A second source of error is described in Mr. Ericsson's own words; he says, "It will be observed that the prolongation of the axis of the conical vessel upwards passes through the central portion of the flames at the point of maximum thickness and intensity." Now the point of maximum thickness of a flame is just that part which is hollow, and consists of a central core of unburnt gas with an outer coating of true flame, and the central portion of such a flat flame as Mr. Ericsson represents includes much of the blue portion of the flame, consisting of hydrocarbon not yet in full combustion. Mr. Ericsson, therefore, was not experimenting upon the diathermacy of ten flames, but upon the diathermacy of ten discs consisting of a mixture of flame proper and unburnt hydrocarbon. Now Tyndall has demonstrated the remarkably high resisting or absorbing power of such hydrocarbon in reference to the radiations from a flame produced by hydrocarbon combustion. The flame itself might therefore be perfectly diathermous, and yet, when examined in this manner, exhibit a considerable degree of athermacy.

There is still a third source of error in Mr. Ericsson's mode of proceeding, the magnitude of which I am not yet able to estimate, though some experiments made since publishing my first results lead me to suspect that it is sufficiently important to demand very careful elimination. I allude to the arrangement of a series of separated flat flames, with the broad surfaces presented to the thermometer.

What must we have between each of these separated flat flames? Obviously each flame is coated with a film of vapour, the product of the combustion of those portions of flame lying below it; these vapours, though rapidly rising, must form a layer of sensible thickness equal to an important fraction of the whole thickness of such thin flames. When operating with the whole eleven flames, there were twenty-one such films between the first flame and the thermometer. Now, we know from the experiments of Tyndall, that a large proportion of the rays of heat emitted from a hydrocarbon flame will be absorbed by such intervening strata of aqueous vapour, carbonic acid, and carbonic oxide. It is true that the middle or blue part of the flame, having less combustion going on below it, must have a thinner coating of such vapours than the upper part; and thus in Mr. Ericsson's arrangement this third source of error is diminished in the same proportion as the second is increased. It was these theoretical considerations, confirmed by results of preliminary experiments, that induced me to abandon the flat flames in favour of the simple round jets, and finally to adopt the continuous flame formed by the coalescent jets.

As I stated on the first publication of the results of these experiments on the diathermacy of flame, I do not regard them as sufficiently delicate to be finally and quantitatively conclusive; the means at my disposal rendered them less satisfactory than those I made on the transparency of flame. Still, I think they are not open to any such serious sources of error as those I have here pointed out.

I hope that Mr. Ericsson will not be offended by the candour of my criticism, nor by the egotism which is inevitable in an unaffected defence of one's own philosophical bairns.

My experiments, like those of Mr. Ericsson, were made with the direct object of throwing some light upon the great mystery of solar radiation; and the fact that we have arrived at such pposing conclusions will, I hope, lead to further investigation,