HUMAN ELECTRICITY:

THE MEANS OF ITS DEVELOPMENT,

ILLUSTRATED BY EXPERIMENTS.

WITH ADDITIONAL NOTES.

BY

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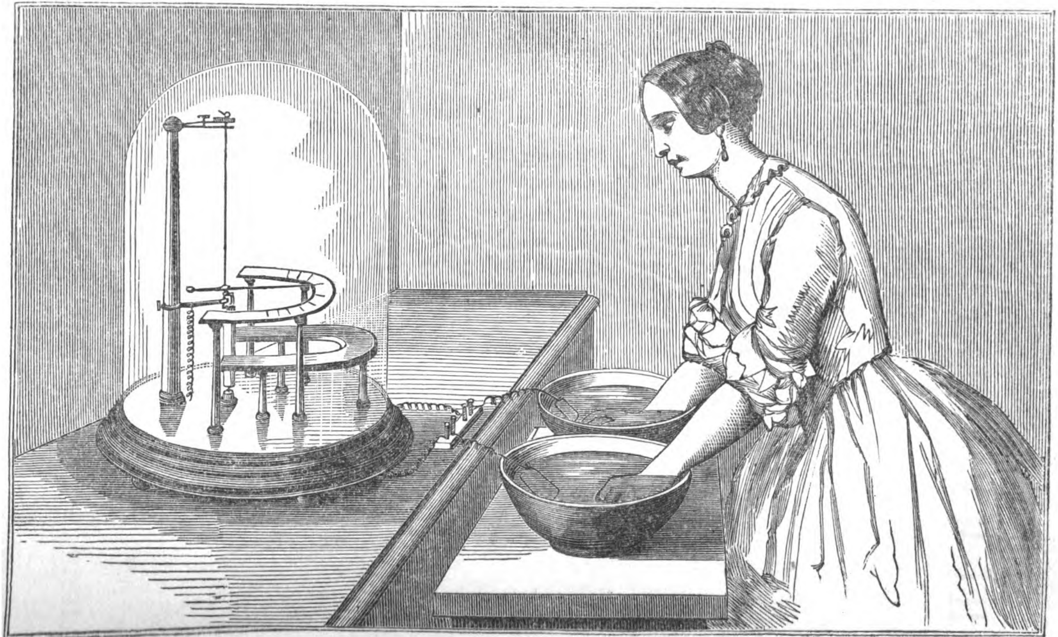

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PREFACE.

The information contained in the following pages is intended only as a means of inciting in the reader a desire for more. The subject treated of is exceedingly interesting, as it is connected with a department of science which not only presents an endless variety of beautiful illustrations, but it is one which is working its way among the utilities of commercial enterprise, and the conveniencies and necessities of social life.

My special object has been to invite attention to Electricity in its various relations with vitality. This is no longer a topic for vague speculations or uncertain conjectures—to be doubted or believed according to the fancy, or the prevailing fashion, in such matters. Animal Electricity in general, and HUMAN ELECTRICITY in particular, are established facts; as easily proved as that air, and food, and water, are necessary to the sustentation of animal life.

That which has been too long concealed underneath the technicalities of scientific phraseology, I have here attempted to put into popular, and, I hope it may prove, intelligible language. If one subject more than another deserves to be classed among the "common things," which ought to be known and understood by us all, I believe it to be Electricity as operating within and around us; and which exercises a powerful influence over our capabilities for enjoying life, if, indeed, it be not one of the principal causes of health and disease.

J. O. N. R.

BLACK ROCK,
BRIGHTON, *Jan.* 23*rd*, 1854.

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HUMAN ELECTRICITY.

CHAPTER I.

SOME NEEDFUL EXPLANATIONS.

THIS book is not intended for scientific readers. It contains very little which is not, or which ought not to be, known and easily understood, by those who make any reasonable pretensions to the study of natural philosophy; especially that interesting, just now increasingly interesting, part of experimental investigation included under the comprehensive term —ELECTRICITY. It is possible that some few things in the following pages may be the means of suggesting an occasional thought, or of giving a different direction to those which already exist; so that by turning old thoughts into new channels, the lines of divergence may be somewhat multiplied and perhaps greatly extended; whilst the common centre remains undisturbed.

A learner for nearly forty years, I know how difficult it is to gather up the tangled threads of successive discoveries, and so to arrange and combine them as to get even an imperfect outline, much less a complete embodiment, of this branch of science. It is not my intention to attempt what is nearly, if not quite, an impossibility. Nor is it necessary. Limiting the illustrations to one department only of electrical phenomena, that is, those immediately connected with, and developed by, the human body, I think there will be less risk of wearying, or, what is perhaps still worse, bewildering the reader. Occasional references to elementary principles, and to simple and well-known conditions, cannot be dispensed with. They will be as few as possible: only such as are really important to the proper understanding of some other experiments.

Nothing new, or extraordinary, is promised. All that is intended, or that will be attempted, is to put together, it is hoped in a readable form, some curious, isolated, and, to some persons, probably unknown, facts relating to a subject which is not now for the first time attracting attention. It deserves all the care, and thought, and examination, the most careful and thoughtful can bestow on it. Experiments which are so easily performed, and which are so closely connected with the laws of our physical organization and mental constitution, cannot fail to be interesting, merely as experiments. When, however, the electricity of the human body is viewed in its relations with external causes—such as temperature, moisture, climate, seasons, the direction of the wind, and other meteorological phenomena; when it is known that locality, occupation, clothing, the structure or situation of the dwelling, or the articles of furniture it contains, are among the conditions which have something to do in determining a state of health, or disease, a joyous life, or an uncomfortable existence; is it too much to hope and expect that, when these things are better known, they will receive proper attention from those who profess to be, and whom we so readily consult as, our guides and helpers? Under various aspects, and by different names, animal electricity has for many years been talked about, written about, and studied; but it seems never to have received that kind and degree of attention which its importance demands.*

* It is not intended here to enumerate even the names by which it has been designated; much less is it part of my plan to occupy

The facts connected with this branch of science are exceedingly numerous, scattered over a wide surface, and only lightly touched upon in popular treatises. They continue to furnish materials and occasions for disputation*—that kind of disputation, however, in which only a very few persons, and the fewer the better, are likely to be interested. To try and separate what can be made agreeable, and, I hope, instructive to ordinary readers, although they may not be acquainted with all the laws and conditions of electricity, from that which only commends itself to those who by education, attendance on lectures,

these pages by anything like a history of the origin and progress of a controversy which, in no one of its phases, has been very creditable to those who have engaged in it. The sciences, and arts, and manufactures, would have made but little progress if every new discovery and invention had been the subject of fierce and undignified contentions. Numerous as have been the mistakes of many of the advocates of Animal Electricity, I believe its opponents have done very little towards correcting those mistakes. Calm and earnest investigation would have been more effective in exposing error, and establishing truth, than volumes of conjecture or dogmatical abuse.—*Additional Note* A.

* The latest example is furnished by a pamphlet (August, 1853) entitled, "On Signor Carlo Matteucci's Letter to H. Bence Jones, M.D., F.R.S. &c., Editor of an Abstract of Dr. Du Bois-Reymond's Researches in Animal Electricity. By Emil Du Bois-Reymond, Member of the Academies of Sciences of Berlin and Vienna, &c. London: Churchill."

or other means of information, may, in these matters, be a-head of their neighbours, is all I have undertaken, or desire to accomplish.

It is too much to expect that everything contained in these pages will receive immediate assent and approval. That which may appear doubtful, because of the difficulties in the way of the kind of demonstration required, forms but a small portion of the subject. It takes its place among other illustrations, because to me the evidences are, and always have been, perfectly conclusive. Moreover, I feel that whatever deserves the name of illustrations of human electricity would be incomplete without some account of the curious manifestations of a power, closely allied to electricity, to say the least of it, which are supplied by the *Magnetoscope*.

During the last two years, no opportunity has been missed of endeavouring to profit by the advice, and many valuable suggestions, which have been offered me on this subject. So also have all kinds of objections, which have come to my knowledge, been carefully and candidly examined; as well as the numerous attempts which have been made to explain, (?) or rather, as it has often appeared to me, to mystify the phenomena. The difficulties, be their nature what it may, are not of my making. What some consider difficult is to me perfectly easy. Without any fanciful theory of my own to establish, my chief concern has been to make sure of the facts. These are plain and intelligible. A great deal more, undoubtedly, remains to be done; but I see no necessity for being in a hurry. Many extraordinary effects are easily produced by the magnetoscope, and with a constancy and uniformity which imply, if they do not prove, the existence of a principle. When the effects are better known, and the conditions understood, there will be less perplexity about the cause. Those who settle everything by a movement of the hand, a shake of the head, or a dash of the pen, are not the most likely persons to make wise counsellors, or impartial judges. There are others who find it easier to object than to reason; for knowing nothing of a subject is certainly not the best preparation for reasoning upon it. Find-fault people never allow themselves time to examine witnesses or hear evidence. More than half their favourite occupation depends on hasty decisions. By some, the experiments with the magnetoscope have been misrepresented, and by others abused. This can do no harm; simply because the experiments themselves are true.

If it had been considered necessary to take shelter behind others, nothing could have been easier. I might have quoted the names of persons, eminent in their respective departments of knowledge, whose good opinion and encouragement, and whose concurrence in the views here ventured to be expressed, would have justified such a course. Truth is strong enough without any such supports. At present, the light it emits may be only like a feeble and far-off glimmering; so feeble, that it is not perceived by unpractised eyes. Wait a little. It will be brighter by-and-by; so much brighter, that it will be seen by all who look for it in the right direction.

Claiming only the same liberty for myself, which I freely admit to be the right of others, I have intentionally abstained from referring, by name, to opponents and objectors to the experiments with the magnetoscope. If they acquire either enviable, or unenviable, notoriety it shall be by their own seeking. Let them not praise or blame the wrong person.

There is one class of objectors so difficult to please that it is waste of time to say anything to them. They speak, and write, and act, as if all the laws and conditions which govern natural processes were known to them by a kind of intuition. So easily do they pronounce an opinion upon the possible and the impossible; so promptly, and with such little effort, do they profess to separate truth from error that, whatever be not in agreement with their stereotyped notions, must, of course, be a mistake, a delusion, or a violation of so-called first principles. With such enlarged views of natural operations, such facilities for appreciating what is true and rejecting what is false, is it not surprising that these extremely clever persons should be always lagging behind the rest of the world? Somehow or other it happens that, in the realities of life, the men who thus profess to know everything are distanced; and not only distanced, but fairly beaten by others who make no pretensions to being instructors, but are always willing to be learners.*

Many real difficulties have attended the subject here proposed for consideration. It would be wrong to understate, or affect to conceal, them. What is there really valuable which can be had without labour, disappointment, and occasional failure? We prize a thing the more highly, just in proportion that the difficulties have been great, and the exertions arduous; and especially, when profiting by the mistakes of others, we have attained what they failed to accomplish. Some who are identified with the most brilliant achievements in science, and whose names will be had in remembrance as long as there are any

* *Additional Note* B.

scientific records, have devoted their time and their skill to animal electricity. The movements in this branch of research have been anything but steady. In some respects they have resembled the celebrated discovery of spasmodic action in the limbs of a dead frog, and in which they originated. At one time there has been more guessing than experimenting; hastily-formed opinions instead of patient efforts at demonstration; and again, just as everything seemed to be settled satisfactorily, the subject, as by common consent, has been laid aside until it was almost forgotten. At every revival of the discussion something has been gained. Step by step, more especially during the last thirty years, new forms of, and important improvements in, apparatus, have led to equally great improvements in manipulatory processes. Various sources of error, not formerly suspected, are now understood and avoided. Everything has been simplified. Experiments which required unusual skill, and care, and caution, and which could be witnessed only by those admissible to privileged circles, are now so easily performed as to be an every-day occurrence.

CHAPTER II.

WHAT IS MEANT BY ANIMAL ELECTRICITY?

WHAT the precise nature of the difficulties, connected with animal electricity, have been, it is unnecessary here to particularize. They can scarcely be understood by those who are not tolerably familiar with the progress of the experiments; extending over a period of more than sixty years. It is especially deserving of notice that what was asserted by Galvani * and his friends, but denied by Volta † and his followers, we now know was incapable of proof by either party. Galvani was partly wrong in assuming that spasmodic contractions in the muscles of a frog, as produced by him, were due to inherent electrical action, and which manifested itself irrespectively of metallic excitation. Volta was also partly wrong in affirming that the whole of

* *Additional Note* C. † *Additional Note* D.

the phenomena,—so new and startling,—were the result of mere contact of dissimilar metals.

Looking back over the long period already mentioned, and with all the advantages now possessed by after-knowledge and experience, the wonder is that Galvani and his contemporaries knew and did so much. By the greatest effort of imagination, it is impossible to place ourselves so near to them as to enter into the feelings of amazement, or rather of awe, with which they witnessed what they believed to be one of the conditions, if not a primary law, of vitality. That which, for want of a better term, we too often call chance, or accident, had done its part; but it had done it so quickly that, like sun-rise within the tropics, there was no preparatory period of twilight. Everything was so strange, so wonderful, so far beyond the range of then existing thought or vision; that one may readily forgive the mistakes which were made, and cease to express surprise at the difficulties which presented themselves.

Much better skilled in anatomy than in electricity, what more natural than that Galvani should turn his thoughts in the direction whither his professional, no less than his favourite, pursuits would first lead them? There is, however, reason to believe that, previous to the discovery which immortalizes his name, he had been engaged in experiments which led him to entertain the idea that the contractions of the muscles of animals were in some way produced by, or dependent on, electricity.* His newly-discovered experiments greatly favoured this theory.

The existence of a "nervous fluid"—something which, if not the principle of life, was considered inseparable from it—was a commonly-received opinion by the learned of that day. Electricity now became the source of vitality: the nervous fluid was hastily dismissed, and both mind and body were supposed to be under the dominion of the more active agent. Pursuing the subject, which, like a new world, had thus been revealed to him, Galvani in the course of his experiments, either by chance, or as a necessary result of some of his manipulations, made the further discovery that an electrical machine was not required to produce convulsions in a frog; exactly the same effects being apparent when the muscle and nerve were made to communicate by contact of dissimilar metals. Here was another new fact; a step greatly in advance of all that had preceded it, and to be speedily followed by still more important disclosures.

* Dr. Roget, Art. "Galvanism," Lib. of Useful Knowledge, 1829.

Wherever these discoveries became known, they excited the most earnest attention. Philosophers of all nations, and others who made no pretensions to the title, were set to work repeating and varying the experiments, and inventing theories for the explanation of the extraordinary phenomena. Accepting the hypothesis which Galvani had himself adopted, there were many who concurred in his views, and Animal Electricity immediately took rank as a new branch of science. But there were some who doubted, and others who openly expressed their dissatisfaction. They contended that Galvani had too readily yielded to first appearances, and, in common with other physiologists, in his eagerness to find what was then so anxiously sought after—the vital principle—he had not sufficiently examined the variable conditions of either of his great experiments.

At this distance in time it is difficult to understand the precise character of the events thus briefly narrated. Let it be remembered that, what is now familiar to the thoughts of children, was then unknown to the greatest philosophers. Most of the laws relating to common, or as it is often termed frictional, electricity had been investigated. That form, or kind, of electricity which is known to us as

Galvanism had not then been discovered.* This may seem a strange statement; but it can very easily be explained.

The experiments with recently-killed frogs had excited great attention, and had been repeated hundreds, perhaps thousands, of times; but the *cause* of spasmodic action still remained a mystery. According to their fortunate discoverer, the convulsions were due to inherent electricity, that is, electricity peculiar to, and constituting a part of, the animal economy. This was supposed to be generated, and, indeed, accumulated in the muscles, transmitted by the nerves, and discharged with the violent agitations witnessed in the former, when these two organs were made to communicate by good (metallic) conductors. This was one view—at the time extensively promulgated, very generally believed, and the more readily because it so exactly harmonized with previously-existing opinions.

If the advocates of the new doctrine reckoned upon a smooth course, and an easy triumph, they were soon undeceived. Opponents multiplied quickly, every inch of ground was disputed, and among the many eminent antagonists of animal electricity, the most resolute, and, it must also be acknowledged,

* *Additional Note* E.

the most successful, was Galvani's own countryman, Volta. Distinguished no less for his amiability in domestic life, than for ability and kindness in the discharge of his professional duties (surgeon and accoucheur), we never can think of Galvani but with feelings of admiration and respect. His fame as a lecturer in anatomy had long been established. In his method of teaching, there was an earnestness —a touch of enthusiasm—which attracted whilst it impressed his hearers. What he believed and knew, or thought he knew, himself, he had no difficulty in imparting to others.

Volta's mind was cast in a different mould. In the practical departments of experimental philosophy he was greatly superior to Galvani. Habitually cautious and thoughtful, the former examined everything as he went along, and, however great the sacrifice, he had sufficient courage to cast away as useless whatever seemed to him unsupported by the test of fair experiment. In him were combined the rare qualities of originality of invention, with patient, or, as it might with equal propriety be called, self-denying investigation. There was the faculty of looking a-head, which enables a man to see a thing more than half finished before it is begun, and yet the movements were not impulsive. Volta reasoned before he acted. A skilful manipulator, but too honest to coax an experiment, he was looking only for truth where others were trying to find materials to support a favourite theory.

If it be asked—why say so much of men long since passed away, and who are identified with that discovery in science which bears their name, chiefly on account of the contentions it occasioned between them? I answer—because it is impossible to obtain an intelligible view of the science itself, without knowing a great deal of those who were the first workers in it. As when shown a specimen of embroidery, we naturally inquire about the head which designed, and the hands which executed, the forms and figures, the lights and shadows; and, scarcely content with this, we even examine the back, that, by contrast, its confusion and entanglements may help to make the picture appear more beautiful—so, whilst searching amongst the motives, the opinions, the discussions, and even the disputes of Galvani and Volta, we must know as much as possible of the men, before we can properly understand the extent, or the value, of their services to the world.

By his own confession, Volta, when he heard of, and had repeated, the famous frog experiment, received at first with his usual caution, but soon afterwards adopted with undisguised approbation, the explanation of the phenomena as given by Galvani. This was of short duration. Doubts were soon succeeded by disbelief; and then commenced a controversy which, outliving the original disputants, has, under various forms, continued to the present day. Animal electricity justly deserves to be designated—a vexed question; much of the vexation so long associated with it having been imported from a totally different subject. It is the bug-bear *animal magnetism*, which, intimidating some and disheartening others, has operated as a serious discouragement to those, in other respects, qualified to decide justly on both subjects. Is it not a strange infatuation in supposing that, by suspending the judgment, refusing to examine phenomena, forming no opinion, shutting the eyes and stopping the ears to all kinds of evidence, and denying what it may not be convenient or agreeable to believe, we thereby increase our knowledge, confer a blessing on the world, and give proofs of our good sense? Is this the way in which we *ought* to try to elicit and establish truth?

Volta went to work in a different way. He never calculated before-hand what the consequences might be to himself or others. Ready to subject his own opinions to the test of experiment, he showed only the same degree of tenderness for the opinions of others. Galvani was over-matched. Gentle in manners, he was unfitted for polemics; least of all on a subject so dear to him, and with an opponent bold in assault and fearless of danger. The controversy lasted long and excited intense interest. Galvani and his friends did their best; but to little purpose.

By successive experiments, as beautifully conceived as they were convincingly executed, Volta showed that in Galvani's experiments with the electrical machine, and with metals alone, spasmodic action in the limbs of a frog was not, as had been supposed, the result of an inherent current, made apparent by conduction between the muscles and nerves. Two dissimilar metals in contact, applied to the muscle, without touching the nerve, produced the convulsions. Here was a proof, as Volta maintained, that the animal electricity theory was wholly untenable. Galvani struggled hard to keep his hold on the ground which was slipping from under him. Varying the original experiment, he replied to his opponent by using only one metal, as the connecting link between muscle and nerve, and which had the same effect as both metals.

At the very commencement of the inquiry, Volta saw, or thought he saw, the true cause of the convulsions. He said it was electricity—not animal nor ordinary electricity; but something, in its effects, very much like the latter, and produced by contact of metals. Galvani seems to have had a somewhat indistinct perception of the same important fact. If he had—by not following up his first impressions, and keeping to the track whither they must have led him, he missed much of the honour due to his own discovery. Advancing again, Volta showed by further experiments that although one metal caused the convulsions, the effects were due to a want of homogeneousness in the metal itself; that when one metal only was used there was less certainty as to the result, and that the organs of the animal required to be in the highest possible state of excitability; whilst with two metals the convulsions always occurred, and could be continued for a longer time.

The disputants were not left to work single-handed. Each had an effective staff of partizans. Some of these did good service to science, although it is to be feared their efforts were not directed to that object alone. But a change was approaching. Sorrow for the death of his wife, a long continuance of ill-health, and the harshness with which he was treated by the Cisalpine Government, incapacitated Galvani for the further prosecution of his researches. Leaving his opponent still occupied by the subject which was becoming every day more interesting, and which eventually was to set its mark on one of the great eras in physical science, the Bolognese philosopher passed away from earth. But his name and his labours will never be forgotten.

The controversy did not end here. Another effort was made to sustain the cause of animal electricity. Once more varying the frog experiment, Valli, a friend of Galvani's, surprised and, for a time, confounded Volta by showing that convulsions could be produced without the aid of metal. This was done by simply placing the nerves in contact with the muscles. Volta was again ready with an answer; which was in effect that, the conditions just mentioned so far from proving anything against his theory, in reality supported and generalized the law he had announced. As in the action, by contact, of dissimilar metals, so was it with the organs of the animal—they required to be heterogeneous; a third substance (moisture of some kind) being interposed.

Other and more important occupations awaited Volta. He was steadily advancing towards that important period in which his great discovery—THE BATTERY—was to be proclaimed to the world. This happened in little more than a year after the death of Galvani. Animal electricity was now comparatively forgotten. The wonders of the Voltaic battery engrossed so much of the time and thoughts of scientific men that everything else was laid aside. Here was GALVANISM in its reality. No longer involved in doubt or mystery, this was the electricity which Volta had been searching after for more than ten years. The frog experiment, after all the contentions about it, proved to be of immense value. If it began in something like accident it ended in an effort of genius—an effort, as we have seen, often prompted and strengthened by the conflicts of opinion, yet guided by such consummate skill that we always hear the voice, and see the hand, of a master.

Turning back to the commencement (page 10) of what by some readers, I fear, will be considered a long story; it will be noticed that I have said Galvani and Volta were both partly wrong in their conclusions about the frog experiment; and yet no means then existed for proving their error, or showing on which side the greatest amount of truth existed. Let me try to explain this. An instrument was required for determining the actual existence of an electrical current, or force, independently of its development by the limbs of a frog. The animal itself was sufficiently sensitive to give indications of the presence of a power which was rightly judged to be electrical; but its source had yet to be discovered. Galvani said it existed in the frog. Volta said it existed in the metals; the convulsions of the frog being nothing more than manifestations of its presence. These were the views with which each party set out. Galvani maintained his opinion to the end of his life. Volta's views were modified by after-experience; although the great principle of metallic electricity, as first announced by him, was finally established. The *galvanometer* was then unknown. Twenty years passed away, and they were eventful years for science. In our own country, as well as on the continent of Europe, the new power, so recently revealed by the voltaic battery, during this period was wielded with wonderful dexterity.

In 1819, Oersted* announced his great discovery. This was ELECTRO-MAGNETISM—the power possessed by a current of galvanic electricity to disturb (deflect) a magnetized needle placed near the wire which connects the poles (extremities) of a voltaic battery. Where each successive step has been so greatly in advance of that immediately preceding it, the most we can do is to mark the epochs, and then try to understand some of the practical benefits.

* *Additional Note* F.

Wearied by their successes, the chief operators in galvanism seemed coming to a stand-still. Electro-magnetism revived them, gave a new direction to their thoughts, and prepared the way for setting electricity to work at the every-day business of life. Vast as was the power already known to be possessed by Volta's battery, Oersted found the means whereby its power would be indefinitely increased. Time and distance have thus had imparted to them a new significance. We used to talk, somewhat poetically, about thoughts being wafted *over* earth and ocean; now they pass *through* them; the telegraph enabling us to speak to each other as easily, and as quickly, when hundreds of miles apart, as if we were face to face.

The galvanometer was invented by Schweiger. It is a type, as simple as it is beautiful, of the fundamental principle of electro-magnetism. By this instrument, as now constructed, exceedingly feeble currents of electricity can be detected, their directions ascertained, and their relative intensities measured. By these means it has been proved, that Galvani was wrong in attributing the *whole* of the effects, as produced by him in the frog experiment, to an inherent and independent electrical current; but that he was perfectly right in believing such a current did exist in the frog, and in other animals; and that no extraneous excitant, metallic or otherwise, was required for its proper manifestation. By the same means it is also proved that Volta was right in affirming that dissimilar metals, subject to certain conditions, were a source of electricity, and that even one metal and various other materials would produce electrical action; but he was wrong in believing that the *whole* of the phenomena exhibited, in operating upon the muscles and nerves of frogs, were the result of separate and extraneous excitation.

What, by way of distinction, is now termed the true "frog current" is easy of proof; and the electrical force, thus exemplified in the frog, is as easily shown to be a law common to the organization of other animals. In the proper place I shall speak of this more in detail. It may here be asked—what has electricity, as manifested by frogs and other animals, to do with human electricity? This is exactly what I have here undertaken, and shall by-and-by try, to explain; venturing, in the meantime, to express a hope that the attentive reader will have no cause for disappointment.

CHAPTER III.

THE HUMAN BODY ELECTRICAL.

An experiment, so simple that a child can perform it, is one of the most instructive illustrations of the principle of what is called common, or frictional, electricity. If a stick of sealing-wax be rubbed briskly for a few seconds, against silk or woollen, it acquires the property of attracting, and temporarily attaching to itself feathers, fibres of cotton, and many other light substances; small pieces of wood, glass, and metal not excepted. A piece of glass rod, or tube, warm and dry, if rubbed in the same manner, exhibits properties similar to those of the sealing-wax. If we were previously unacquainted with this curious phenomenon—the effect of friction only, as we might suppose—on witnessing it for the first time, we should naturally try the same experiment with a great variety of substances; and feel, perhaps, somewhat disappointed at the numerous failures we should meet with. The cause of this must be explained. The attractive property, elicited by rubbing in the manner just described, is not possessed by all substances, nor in an equal degree even by those which are susceptible of it. Sealing-wax will attract sealing-wax, glass will attract glass, and a feather will attract a feather; but in each case there is less attractive energy manifested when the substances are alike, than when they are dissimilar. Hence it must not be inferred, that wood will attract wood, metal attract metal, or stone attract stone. These are conditions which ought to be well understood. They are the very first steps in acquiring a correct view of electrical phenomena.

Without any intention of entering into the details of this part of electrical science, it appears desirable to explain the terms most commonly used, and to describe some of the most remarkable effects produced by certain materials.

Rubbing one substance against another, for the purpose of eliciting its electrical properties, is called *excitation*. We can never proceed far, in this way, in the examination of different substances, without discovering that some are more easily excited than others, that there is a great difference in the same bodies at different times, and that some are not capable of being excited in the same manner as others. A moderately warm and dry atmosphere is a condition most favourable to electrical excitation. It would be useless to try to excite sealing-wax, or glass, by rubbing either of them with a damp silk handkerchief, or piece of flannel. So also if the silk, or flannel be dry, it is equally difficult to produce the desired effect out of doors in cold, damp, weather.

But there are other conditions observable, besides those just mentioned. The inherent properties of substances, as well as their external circumstances, have to be considered, and when we begin to classify, it is needful to be a little more particular. A substance, such as sealing-wax, or glass, which can be excited whilst held in the hand of the operator, is called a *non-conductor*. This means that electricity, excited on its surface by friction, is not immediately dispersed. It will remain long enough to permit us to test some of its properties. Not so with wood, or metal. Each of these is called a *conductor*, and the metal by way of pre-eminence a *good* conductor—meaning thereby, that, if the conditions be the same in both cases, it is impossible to retain the electricity excited in the last-mentioned substance.

Let it be noticed that the terms conductor and non-conductor are relative, and in part arbitrary; used for convenience rather than exactness. Between the extremes, which they seemingly imply, there are many intermediate steps, and these press so closely upon each other, that it is difficult to separate the various kinds of substances into groups. Thus:—the best red sealing-wax is high up the scale as being easily excited, and a non-conductor. But certain conditions must be complied with. The rubber, and the hands of the operator, must be warm and dry. Glass is also a non-conductor, and, in the way just mentioned, can be excited. But it is inferior to wax; less easily excited, and does not retain the electricity so long. This may be shown by slightly altering the conditions. Excite the wax as before, and then breathe on it, when a great part of the electricity will be dissipated. Do the same with the glass, and the whole of the electricity will be discharged. Hence, we learn that wax is a more perfect non-conductor than glass, that dry air is a non-conductor, and moist air, that is, the vapour present in the air, is a conductor. The wax and glass remain in all respects the same in their inherent properties; but, if covered with moisture, or surrounded by damp air, electricity can with difficulty be excited in them, and, if it be, cannot be retained.

These things appear to be very simple and easily understood, and yet, for want of attention, they are not understood, or remembered, so well as they ought. Let us take an example at the other end of the scale,—namely, a good conductor. To do this, we ought to provide a piece of window-glass, clean and dry, about six inches square, on which should be laid a few pieces of feather. Next, we require a silver pencil-case, or, better still, about ten or twelve inches of stout, clean, copper wire, with the ends rounded, and quite smooth. Hold the wire in one hand, and try to excite it by rubbing it against dry woollen cloth, or, what is much better, by a brisk upward movement against the hair of the head, the hair being perfectly dry. On applying the metal to the pieces of feather, to test the presence of electricity, none will be found. Stopping here, we should conclude that sealing-wax and glass could be easily excited, and the electricity made apparent to the senses; whilst metal could not be excited, and that it either did not contain electricity, or required some other treatment to make its effects visible. But let us comply with the required conditions, and then see what will follow. Take a piece of strong glass tube, about eight inches long, the bore of which will fit the copper wire. Fix one end of the wire in the tube with sealing-wax, and having cleaned both the tube and the metal, try to excite the latter, in the manner before directed,—holding it by its (glass) handle. It will soon be seen that metal can be excited; the electricity being retained by the interposition of glass.

Thus we have types of two distinct classes of substances, in relation to their electrical habits or conditions. In general terms, it might be stated, that all substances arrange themselves in one or other of these classes—conductors or non-conductors of electricity. In some substances, electricity is more easily, and, so to speak, more powerfully developed than in others; and it passes more quickly over, or through some substances, than others. For aught we know, the first-mentioned property may be one of appearance rather than reality. Our means of judging are limited and imperfect. We are guided more by the habits of a particular substance, than by our actual knowledge of its properties. In one case, electricity seems to linger, affording us an opportunity of examining and measuring it. In another, as with metals and their congeners, it is difficult to retain a sufficient supply for the purposes of investigation. But in each case we are incapable of determining what it is in the elementary arrangements which is favourable, or unfavourable, to an electrical condition.

Still—it may be instructive to ask—Why cannot metal be excited whilst in contact with the hand of the operator? It can be, and it is, excited; but the electricity cannot be retained. The metal is a conductor, the hand and body of the operator are conductors, the floor of the room, the walls of the house, and the ground upon which the house is built, are conductors. These are the ways by which the electricity escapes. The necessity for affixing a glass handle to the piece of copper wire can now be understood. It is to prevent the electricity from returning to the earth. In reality, the handle is provided to *insulate* (detach or separate) the copper. This is a very expressive word, and implies an important condition in electrical experiments. Glass is not the most perfect insulator (non-conductor); but in practice it is the most useful, especially if it be kept clean, moderately warm, and dry.

In describing the experiments with sealing-wax and glass, it has been mentioned that each substance, when electrically excited, acquires the property of attracting light substances, and of temporarily attaching them to itself. A little additional information on this subject is necessary. If a feather, or pith-ball, be suspended (insulated) by a silken thread, and operated upon both by excited wax and excited glass, it will soon be observed that there are, apparently, some strange mistakes made. After the feather has been attracted by the wax, if the latter be again immediately presented to it, the feather will suddenly recede; but if the excited glass be brought near the feather it will be again attracted, and for a short time will adhere to the glass. This phenomenon invariably occurs, whether the wax or the glass be first used. Electricity elicited by the friction of wax first attracts and then repels the substance to which it is imparted, and that from glass does the same. Electricity from wax attracts that communicated by glass, and electricity from glass attracts that communicated by wax. These experiments, and many others having a similar design, are employed to illustrate what have been called two opposite kinds, or states, or qualities of electricity. Perhaps these remarkable properties may, with greater accuracy, be viewed as conditions rather than distinct qualities. It is sufficient to indicate their existence, and also to mention that they are inseparable from electrical phenomena. Call them by whatever name we may, and be the source of electricity the friction of wax, glass, or metal, the opposite kinds, or conditions, always manifest themselves. We have no evidence of the operations of electricity upon any material substance, excepting by what appears to be antagonistic forces.*

At the beginning of this chapter, in giving directions for exciting sealing-wax and glass, the use of silk or woollen is recommended. Keeping in view the subject to which the thoughts of the reader are to be specially directed—human electricity—let us vary these experiments, substituting for a rubber of silk or woollen, the hand of the operator. It is necessary that the hand should be dry and warm; all the other conditions, as respects the warmth of the room and the dryness of the atmosphere, being favourable, as previously mentioned. A little practice will be required to give due effect to the operation. The wax or glass being held in the right hand, must be drawn briskly through the left; the fingers pressing it moderately. This will have to be repeated five or six times, or, until the wax, or glass, shall have become a little warm. It will then be as easily, and as powerfully, excited as by any other kind of rubber. It must be noticed, that the experiment I

* These opposite kinds or conditions have been called *vitreous* and *resinous*, *positive* and *negative*, *plus* and *minus*. It is difficult to give significant names until we know more of the thing signified.

am describing succeeds better with some persons than with others. There seems to be something due to constitutional habits and temperament; so that in one person, electricity is freely elicited, whilst in another, scarcely any evidence of it can be obtained.

For detecting very feeble manifestations of electricity, a safer guide than the attraction or repulsion of light substances, in the various ways I have described, should, if possible, be consulted. The instrument best adapted for this purpose, is a gold-leaf Electrometer—more properly *Electroscope*, and which is represented on the following page.

It consists of a glass vessel, *a a*, fixed to a stand, *b*, and closed at the top by a wooden collar, *c*. In the collar *c*, a glass tube is inserted, through which passes a brass rod, supporting a circular brass plate, *d*. To the lower end of the rod, within the vessel *a a*, two pieces of gold-leaf are attached. On the inner surface of the glass, but on opposite sides, are pasted two narrow slips of tin-foil, which are also continued through the bottom, and in immediate contact with the stand *b*. The brass rod is wrapped round with cocoon silk to insure its more perfect insulation.

When an electrified body is placed in contact with the brass plate *d*, its electricity is conducted by the rod to the gold leaves; which, being thereby similarly electrified, repel each other; assuming the position

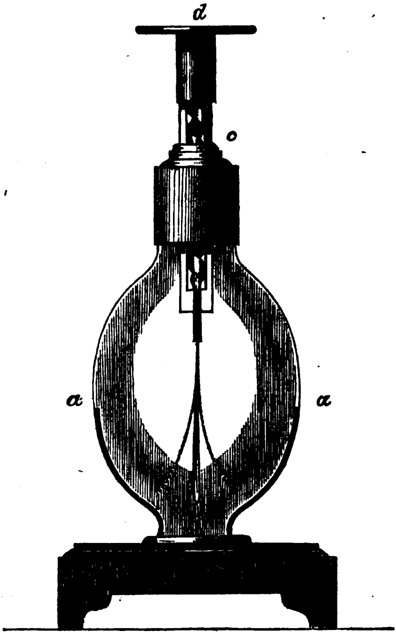

FIG. 1.

shown by the dotted lines. If the electricity thus imparted were permitted to accumulate on the inner surface of the glass, it would soon interfere with the indications of the instrument. The slips of tin-foil are intended to prevent this. The gold leaves must be placed exactly opposite the slips of foil, so that when they open with sufficient force to touch the sides of the glass, the electricity will thus be conveyed to the stand of the apparatus, and thence to the earth. It is necessary to discharge the electricity from the electroscope between each experiment. If this be not done, in the way just mentioned, that is, by the divergence of the leaves, (and a very feeble current is not sufficient for the purpose,) the brass plate *d* must be touched by the finger of the operator.

By means of the electroscope, some very instructive lessons may be obtained, as to the relatively excitable and conducting properties possessed by different substances. So, also, may we learn a great deal about the conditions most favourable to the manifestation of these properties, especially in their relations to atmospherical and other meteorological phenomena. Equally interesting will be the examination of the electrical conditions of different persons, and of the same persons at different times; bearing in mind that such experiments should, as far as practicable, be always conducted in the same room, and under the same circumstances.

Remembering what has been said about the readiness with which wax and glass can be excited, and the different treatment necessary to be pursued towards a piece of metal, in order to produce similar results, let us now try if we can detect any analogous conditions in respect to the electrical properties of the human body.

Among the earliest electrical experiments of the renowned Stephen Gray* (1730)—who evinced just that kind of enthusiasm which is so often an attendant upon the pursuit of knowledge under difficulties, and which the more it is oppressed the more it grows—it is recorded that the conducting properties of the human body engaged his special attention. To prove this, a boy was suspended, in a horizontal position, by horse-hair lines fixed to a beam in the room. By the attraction of leaf-brass, placed upon a stand at the distance of a few inches, electricity, produced by the excitation of a glass rod, was shown to pass through the boy from head to feet, and from feet to head. Enjoying, as we do, the accumulated advantages of the teachings and experiences of those who have thus laboured for us, the foregoing seems a round-about-way of ascertaining a fact, which lies on the very threshold of electrical

* *Additional Note* G.

knowledge. Still, it is right in this place to refer to it, if it were only for the purpose of showing how cautiously the first workers, in this wondrous mine of experimental discovery, examined every particle of ore their investigations brought to the surface.

But the human body is not only a conductor—it is also an *electric*, which means that it can be excited by friction in the same manner as wax, glass, or metal. It has been shown that wax or glass can be excited, by rubbing it against one hand of the operator, whilst held in the other. Not so a piece of metal. That must be insulated; a glass handle being affixed to it to prevent the electricity from returning through the hand and body to the earth. Nor can metal be excited, although it be thus insulated, by friction against the hand. This can very easily be explained. The hand is a good conductor; and, as a general rule it must be observed, in producing electicity by friction, that one of the substances operated with ought to be a non-conductor. It is useless to try to excite a piece of metal, by rubbing it against the hand, because as fast as electricity is produced it escapes to the earth. With a silk handkerchief held in the hand it is difficult to obtain a satisfactory result. Woollen is better, especially when it forms part of the dress; but with that, success is not always certain. The hair is the best, and seldom disappoints, if it be perfectly dry.

Let us go a step further. If a person stand on an electrical stool, that is a stool with glass legs, (which must be clean and dry,) to insure insulation, it can be shown that, if he be rubbed briskly with a piece of silk, or woollen, or fur, he is susceptible of excitation; that is, the living body is proved to be a source of electricity just in the same way that we know electricity can be obtained from wax or glass. But the person so operated upon must be treated like a piece of metal. He must be insulated, or it will be impossible to get the required manifestation of electrical excitability. Hence the use of the stool. By thus separating the person, in electrical language, for a time from the earth, and putting one of his fingers in contact with the brass-plate *d* (fig. 1), the electricity produced by the friction of his body is compelled to pass off to the earth through the electroscope, affording unmistakeable indications of its presence by the divergence of the gold leaves. By merely rubbing the hair of the person insulated with the hand of the operator, the leaves will diverge; and when the surrounding atmosphere, and other circumstances are favourable, if the person be rubbed for a few minutes with a piece of fur (the skin of a cat is best adapted for the purpose), a small Leyden jar, held in contact with his finger, may be sufficiently charged to produce a snap, a spark, and a shock.

These experiments are easily performed, and, I suppose, are well-known to those who have studied the elementary principles of this science. They are not described in the usual treatises on electricity, nor shown in the lecture-room; but, as connected with the electricity of the human body, they deserve to be more frequently explained.

There is reason to believe that many kinds of animals, and birds, and insects,* and probably reptiles, are more powerful electrics, or more susceptible of electrical influences, than mankind. A great deal is due to season, and climate, and temperature. A familiar example of what may be termed not only electrical excitability, but *irritability*, is supplied by the domestic cat. It is pretty evident that excitation with the tips of the fingers, by slowly turning the fur the wrong way, is by no means an agreeable sensation to the animal. The restlessness of cattle, the irritableness of bees and other insects, as well as what we term the sportiveness of fish, when the air is highly charged with electricity, are well known

* *Additional Note* H.

to those who are observers of what is passing around them. If a cat in good (electrical) condition be placed upon an insulating stool, and gently rubbed, not the wrong, but the right way of the fur, the atmosphere around the animal will soon become so highly charged with electricity, that the gold leaves of the electroscope will be made to diverge without actual contact with the instrument. This can also be done by any of the means already mentioned; with wax or glass rubbed against the hand, or metal against the hair. The gold leaves will be affected by the electricity diffused through the air, at a distance of more than a foot.

What has been described, and which I have called electrical experiments, is the same in principle, although so different in degree, as the beautiful illustrations of the presence and power of this wonderful agent, obtained by a machine and suitable apparatus. Familiar as we have become with these things, we shall do well to remember that it is not so very long since they had a beginning. Almost all the laws of electrical phenomena were discovered before the invention of anything, we now should consider, deserving the name of a machine. Cakes of bees-wax, rosin, and sulphur; plates and rods of glass; leaf brass, pack-thread, cork, and silk; horse-hair lines, hazel wands, and the human hand, as an excitant; were the principle articles of electrical apparatus at the commencement of the eighteenth century. What changes have since been effected! Our children, for mere amusement, now perform experiments which so frightened the philosophers who first witnessed and experienced their effects, that it is said they were not only made uncomfortable, but fancied themselves very ill, for several days afterwards.*

Until the seventeenth century, little was known worthy the name of the *science* of electricity. Still, there are numerous facts recorded which show that the human body was believed to be electrical. Setting aside remarkable instances which would occupy too much space, and which it is unnecessary here to describe, we have only to observe and inquire in one's own family, or circle of acquaintance, and we shall not be long in discovering proofs of the existence of human electricity, which in many persons exhibits its effects spontaneously.† There appear to be differences in the electrical habits of individuals, equally great as in their stature, complexion, colour of eyes, hair, and other peculiarities. It has been just now mentioned that, when all the conditions are, as

* *Additional Note* I. † *Additional Note* J.

nearly as possible, alike, there are some persons who can produce scarcely any sensible electrical effects by the friction of wax or glass. Others never experience any difficulty in this way; whilst others, again, are still more highly charged; so that the friction of an article of dress—such as taking off a silk stocking, or a flannel waistcoat, or dressing the hair—is accompanied by attractions and repulsions, and very often by luminous streams or sparks. It would be better if such phenomena were more attentively observed. There would then be reason to hope that they would be better understood. Scattered over society, they remain almost unnoticed, whilst they undoubtedly exercise a powerful influence over the sensations, and most likely the health, of the individuals. The facts are numerous, but they require to be carefully arranged, side by side, before any practical inferences can be deduced from them. If such facts were collected, (but we require a great number of them,) especially in connexion with geological and other local conditions; with the situations of sitting-rooms and bed-rooms, as respects the amount of direct sunlight upon them; with articles of clothing, particularly in protecting the feet; and with occupations, and food, and drink; it is likely we should know more about the means of preserving, or recovering, health than we are likely to do whilst such seemingly trifling, but in reality, important, elements in the constitution of man are unknown, forgotten, or overlooked. The foregoing is one, and only one, of the aspects, or phases, of human electricity. It is difficult to determine, whether electricity excited by rubbing sealing-wax and glass against the hand, possesses exactly the same properties as that excited by rubbing metal against the hair. This much is certain: the latter, namely, that produced by the excitation of metal, all other conditions being alike, affects the leaves of the electroscope differently from either of the others. This subject has never been sufficiently examined; although it would amply reward any one who would make it an object of special and diligent enquiry.

It may be asked, however:—Is the human body a source of electricity? This we know, and can prove, it to be, in the same sense as wax, or glass, or metal. Perhaps the reply is not satisfactory; and it may be asked further:—Can we ascertain if electricity be inherent, that is, part of the elementary structure of wax, glass, and metal? May not the electricity developed in any, or all, of these substances be derived from silk or woollen, the hand or the hair, according as either of these has been used as an excitant? Let it be remembered that electrical excitation can only be manifested by making visible (so to speak) its two opposite states (see page 32), as it is, in reality, only a disturbance of the previously electrical condition of bodies. When two substances are, for this purpose, rubbed against each other, *both*, of necessity, must be equally electrified, although the electricity at the surfaces, at the instant of contact, are dissimilar; one being called positive and the other negative. If there were electricity in wax, or glass, but none in the rubber, be it silk, or woollen, or the hand, and *vice versâ*, it would be useless to try to elicit it by the friction of such substances. Electricity could not be obtained from materials in which it did not previously exist.

In obtaining large supplies of electricity, for experimental purposes, it is necessary that the machine should be in communication with the earth; which means, that there must be a ready passage, by the table, the floor, and the walls of the building for the electricity to pass. In other words, the machine and many parts of the apparatus must be *un*insulated. These things are known to those who are taking their first lessons in the sciences.

But the human body may be insulated, and, whilst in that condition, a great quantity of electricity obtained from it. This can very easily be shown by the electroscope; a person standing on an electrical stool being as well able to excite sealing-wax, glass, or metal, in the way I have described, as if he were in contact with the floor. This favours the opinion that the living organism is a source of electricity; that it is generated within the body, and is, therefore, a condition essential to healthful action among its several parts; its proper development being more closely bound up with our sensations and emotions, than ever we may have suspected, or been willing to believe.

It must be concluded that all substances, animate and inanimate, contain electricity. It is, in the largest sense of the term, an universal agent; occupying all the space in which we are immediately interested, and probably all that we can think about even by the aid of astronomy. It is so subtle that it permeates the hardest substances; so changeable that it seems never to be at rest; so powerful that we know of nothing that will resist its force; and, withal, so tractable that it is as easily managed as the most loving child.

CHAPTER IV.

SOMETHING ABOUT MAGNETISM.

What is Magnetism? A question easily asked, but which it is impossible to answer. Magnetism is only known by its effects. These are truly wonderful; and the more we become acquainted with them, the more does our wonder increase. The cause of magnetism is concealed from us. Perhaps it never will be permitted to man fully to understand it; or it may be that, in this state of existence, it may not be possible for him to do so. Just as ignorant are we of Electricity. Some of the conditions, which we call the *laws* of electricity and of magnetism, are known. These may not improperly be viewed as their habits, or modes of action; the ways in which they manifest themselves to some of our senses. But of what they consist, whether they possess properties peculiar to themselves, and independent of the ponderable substances with which we always find them associated, or, in what respects they differ from light, and heat, and from each other, is beyond the range of our experience, and, probably, of our comprehension.*

The terms employed to describe the effects, and what are also called the properties, of electricity and magnetism are arbitrary and conventional; in reality, they are, perhaps, the most unmeaning and inappropriate which could have been invented. Thus:—we talk about a *fluid*, a *current*, an *aura;* of *poles* and *curves*, *attractions* and *repulsions;* of *molecules* and *vibrations*, *motion* and *rest.* Aiming at greater exactness, other terms have been proposed, such as *electrodes*, instead of poles; and to distinguish one of these from the other, we have a further definition of *anode* and *cathode*, *anion* and *cation.* To the practised manipulator these, and many similar, terms are simple enough, and easily remembered. But, after all, they can be considered only as so many helps in constructing a sort of scientific vocabulary.

* "There was a time when I thought I knew something about the matter; but the longer I live, and the more carefully I study the subject, the more convinced I am of my total ignorance of the nature of electricity."—*Faraday.*

Useful, and, in this respect, indispensable, yet let it not be forgotten that they are definitions and descriptions of what is ideal, mysterious, and unknown.

Unable to answer the question at the beginning of this chapter, let us try another. What is a Magnet? A piece of steel, without reference to size or shape, endowed with magnetic properties. It is either a straight bar, or bent in the form of the letter U, and called a bar, or horse-shoe, magnet accordingly. Every piece of steel is not, in the sense here mentioned, magnetic; and yet all steel is susceptible of magnetism. Iron, that is, common iron, before it is made into steel, can be rendered magnetic; but will not retain the properties imparted to it. This will be explained as we proceed. It is sufficient here to say that, in popular language, a magnet means a piece of steel to which magnetic properties have been communicated.

Magnetic ore, a natural production, called an oxide of iron, and which possesses the power of attracting to itself small pieces of that metal, was known to the ancients. It is often referred to in their writings, and although they knew very little about it, beyond what has just been mentioned, they had so high an opinion of it as to believe that it possessed a soul.*

* *See first part of Additional Note* A.

The name, *Magnet*, is supposed to be derived from *Magnesia*, a country in Lydia, where the ore was probably first discovered, or was most abundant.* It is not easy to determine the precise period when the *directive* properties of magnetism were first observed. That its power of attracting iron was communicable, could not very well be overlooked. By this, I mean the effect produced by rubbing a piece of steel against magnetic ore, which, by this process, imparts its own properties to the steel; and then that piece of steel, in the same manner, can be made to influence a second piece, the second a third, and so on without limit as to numbers. But the directive power is something more than this, and, if it be possible, very much more wonderful. It means the power possessed by a small magnetized bar of steel (commonly called a *needle)*, when poised horizontally by its centre, so to arrange itself in a particular direction, that one of its ends, and always the same end, shall point very nearly towards the north pole of the earth. This it will do however frequently it may be disturbed, and its polarity will continue during a great number of years.

It is stated, on what appears to be respectable authority, that the Chinese were acquainted with the directive properties of the magnet, and availed them-

* *Additional Note* K.

selves of its use, at least 1000 years before the Christian era, in travelling by land in their own country. Like many other statements, connected with Chinese chronology and history, this requires to be received with great caution. Our term *loadstone,* which ought to be written *lode,* is derived from *Leidarstein,* (leading-stone), and evidently had its origin in the application of magnetism to the mariner's compass. This is comparatively a modern invention, known in Europe only about 600 years.

In magnetic ore, (the natural loadstone,) it is difficult to recognise all the phenomena of magnetism. Illustrated by artificial magnets, they are more intelligible, and for practical purposes no others are employed. Specimens of ore are curious rather than useful. Be it understood, therefore, in what is to follow about magnetism, that manifestations of its presence and phenomena are always supposed to be produced by instruments and apparatus, made magnetic by artificial processes. In as few words as possible, I will here enumerate the principal properties of a magnet, how they are communicated and destroyed, the various ways in which magnets are operated upon, how they influence each other, and whether any analogies exist between magnetism and electricity.

At the moment, the connexion between magnetism and human electricity may not be very apparent. Instead of stopping now to explain this, I prefer pushing on towards the object in view. The reader must have some knowledge of the simplest phenomena of magnetism, or he will not be able to understand electro-magnetism. Without a tolerably correct notion of that branch of our subject, the most remarkable developments of electricity, by the human body, will be utterly unintelligible.

The power of magnetic ore to communicate its own properties to a small piece of steel (by friction), and the power of the steel to retain permanently, under certain conditions, the properties thus imparted, may be called the first experiment in making an artificial magnet. Simply as an experiment it is very instructive; but similar effects are more easily, and with greater certainty, produced by rubbing one (steel) magnet against another. To insure success this requires to be done in a particular manner.* First, let it be noticed that, what has been called the attractive force of magnetism must be taken in a limited sense. Thus:—suppose we have two small bar magnets, or, more properly, magnetized needles equal in size, and, as near as they can be made, in magnetic power; each will be endowed with exactly

* *Additional Note* L.

the same properties. Suspend, or poise, these magnets a few feet apart, so that they may move freely on their centres. In a few minutes, after oscillating from side to side, they will arrange themselves parallel to each other and come to rest; their respective ends being directed nearly north and south. The end directed towards the north is called the north, or marked end; a nick being filed in the metal to distinguish it from the south, or unmarked, end. Take one of the magnets in one hand, and place the north end near the south end of that still suspended. The latter will move towards, and adhere to, the former. This is an instance of magnetic attraction. Turn the south end of that in the hand towards the south end of the other, and the latter will recede. Do the same with the north ends, and the effect will be similar, and are examples of repulsion. These attractions and repulsions illustrate a law of magnetism. Similar ends of magnets repel, dissimilar ends attract, each other. This is also called polarity; the properties thus exhibited by the opposite ends of a magnet being termed, but not with strict propriety, opposite polarities. It matters not what the shape of a magnet may be, whether a straight or crooked, a long or short, bar; or a plate either round, square, or oblong; each piece will possess opposite polarities. Hence, what is termed the attractive force of magnetism, always has relation to the special conditions here mentioned. By a little attention to the movements of the suspended magnet, when operated on by that held in the hand, it will be discovered that the forces mutually exercised pass through the interposed air; contact of the two pieces of metal not being a condition necessary to the production of such movements. The greater the magnetic power of one magnet, as compared with that of another in its immediate vicinity, the more extraordinary will be the effects of magnetism operating at a distance. So also on making the trial, it will be found that the force thus exercised by a magnet, be its nature what it may, will pass through solid substances in the same manner as it does through the air. This can easily be proved by operating with magnets on the opposite sides of a door, or a brick, or stone, wall. Magnetism will also pass through glass, and metals; iron being the exception only on certain conditions. The directive force of magnetism must not be misunderstood as implying *motive* force. A magnet has no power to move itself. Allowed to turn freely on its centre, it is endowed with a power of arranging itself, and finally coming to rest, in one particular direction; but it has not the power of locomotion. It can change its position; but will remain in the same place. The directive and attractive forces, unless operated on externally, will not move the magnet the hundredth-millionth of an inch. The magnet makes an effort to point with one of its ends towards the north; but it cannot advance in any direction—north, south, east, or west. Thus much upon the attractive, repulsive, and directive forces of magnetism.

The direction in which a magnet arranges itself has been described as *nearly* north and south. Why is it not *exactly* in that direction? The fact is known—the cause is unknown. Many theories have been invented to try to account for this. We are not sure that any of them are right. It is better to confess our ignorance, than by efforts at concealment to expose it. For many years after the directive properties of the magnet were known, it was supposed to point true north and south. It cannot be determined with certainty who was the first discoverer of what is called the *variation*, or *declination*, of the (magnetic) needle. After it became known, a long period elapsed before the observations were sufficiently accurate or numerous to be depended upon. A subject so little understood might well be supposed to be slow in its progress. Nor has it been without its difficulties. Those unacquainted with such matters can scarcely imagine the amount of labour which has been bestowed on this department of science. Hundreds of thousands of observations have been made and recorded, extending over more than two hundred and fifty years, in every accessible part of the world. The variation from true north, it was soon found, was not alike at different places, nor in the same places at different times. When first observed in this country, the needle pointed to the eastward of geographical north (11° 15′, or exactly $\frac{1}{32}$ of the circle = 360°). This was in 1576. In 1580, it had advanced a little farther eastward, then began to return, and after eighty years pointed true north. From 1657 to 1662, there was no perceptible variation; but in four years more, the needle had taken a westerly direction, which continued until 1815, when it reached its maximum (24° 27′, or nearly $\frac{1}{15}$ of the circle). Slowly returning towards north, the variation at the present time is about 24° west. The value of the magnet (compass) in directing and denoting the course of the mariner is beyond all estimate; yet it will be seen that the familiar expression, "true as the needle to the pole," must be taken with considerable limitations. In a magnetic sense, this is undoubtedly true; but it is not so geographically. Something more than a knowledge of the directive properties of the magnet is required to make a skilful seaman. He must be acquainted with the differences of variation, whether east or west, as well as with the lines of no variation, lying in his track, or he will not be able to conduct his ship, by the shortest route, to the desired port.

The magnet is also subject to other variations. It may be said of magnetism as of electricity, it is never at rest. By the aid of beautifully-constructed instruments, in skilful hands; by self-registering apparatus, in some instances photographic; and by an immense number of observations, reduced to a tabular form; it is known that a magnet is constantly changing its position—first moving in one direction, and then in another—but almost so imperceptibly as to be unobserved by unpractised eyes. These changes are both annual and diurnal; the former varying with the seasons, and the latter with the periods of day-light and darkness. Nor is this all. Other agencies less constant, but by no means less decisive, in their operations are known to be at work. Of these, hurricanes, thunder-storms, and auroræ boreales, are the most remarkable. Sometimes when the eye is wearied by watching, and the ear with listening; when no sights can be seen, nor sounds heard, the nicely-poised magnet seems as if touched by an invisible hand, or breathed upon by a being from an unknown world. These sudden and unlooked-for perturbations are called *magnetic storms*, and, by records of simultaneous observations, have been proved to occur on opposite sides of the globe at the same instant of time.

Another property of the magnet must be briefly noticed. A piece of steel of the proper shape and size for a magnetic needle, must be nicely balanced, so that it may move vertically, instead of horizontally, on its centre. On being magnetized, such a needle no longer retains its horizontal position. Its north end will then incline downwards like a scale-beam with a load at one end. In this country the depression here mentioned, and which is called the *dip* of the needle, is equal to nearly 70°. This is another kind of variation; unlike those just now described but quite as variable. The effect of the dip of the needle is due to the force of terrestrial magnetism, which varies from the poles to the equator. Hence, advancing southward from these latitudes, the dip becomes less and less; until at the equator the needle resumes its horizontal position—the same as it possessed before it was magnetized. This is only to be explained by each end being equally attracted by the polar magnetic forces of the earth. On the south side of the equator the needle is again drawn downwards; the dip of course being at the *south* end. The dip is variable at the same places, at different periods; and influenced too by the same disturbing causes as the horizontal variation.

Now let us speak a little about magnetism in another of its numerous aspects; especially of the way in which it influences iron. The manner in which two steel magnets act upon each other has been noticed, that is, the antagonistic properties, or polarities, they exhibit at opposite ends. It cannot be too forcibly impressed upon the mind that, wherever magnetism manifests itself, there must of necessity be opposite polarities. No matter the shape or size—whether it consist of a particle of steel which can be seen only by a microscope, or a mass of many tons' weight—if it be magnetic, there must also be polarity. Suppose we obtain a magnet so brittle and of such a convenient size that it can easily be broken into two, ten, or twenty separate parts. Be it so. It will be a good experiment. What will be the result? Shall we be able to separate the polarities; the pieces broken off from the north end having only north polarity, and those from the south end south polarity? No: this cannot be done. It is one of the things fairly deserving the name of an *impossibility*. Every part of a magnet, so divided, be it in twenty, or twenty thousand, pieces, will each possess the same properties, in respect to north and south polarity, as the piece of metal did in its entirety. In reality, each piece will be a perfect magnet.

Why is it necessary to use steel for making artificial magnets? Will not iron do equally well? Iron is more easily and powerfully influenced by magnetism, but it does not retain its magnetic properties. Steel is iron combined with carbon (charcoal), whence its hardness, and, in other respects, peculiar texture—conditions favourable to the retention of magnetism among its particles. The magnetism is in the iron, but its escape, so to speak, is prevented by the presence of the carbon. Still, the making of good, that is, powerful, magnets is a delicate and difficult process. Great discrimination is requisite as to the quality of the steel, and its temper, as well as its proportions as to length, breadth, and thickness, and, most of all, its treatment. The magnetizing process requires care, and that kind of skill which can be acquired only by practice. To take a piece of steel, simply because it is steel, and then try to make a powerful magnet of it, would be a loss of time, and a source of disappointment. There is no difficulty in making a piece of steel magnetic. That is not what is meant. To deserve the name of a magnet it must possess an attractive force proportioned to its size and weight, that is, it must be capable of lifting a given number of grains, or ounces, or pounds, according to its own weight. In this sense there is as great a difference between a piece of steel made magnetic, and the same piece of steel made into a magnet, as there is between a wheel-barrow and a locomotive-engine.

The quickness with which magnetism enters and takes possession of iron, and again passes through and out of it, according to the conditions observed, is easily shown. A tolerably strong bar-magnet and a few pieces of stout iron wire, of different lengths, will suffice. After testing each piece of wire separately, to prove that it is not sufficiently magnetic to exercise any attractive force upon the other pieces, apply one of the poles of the magnet near to, but not in actual contact with, one end of a short piece of wire. Place a sewing needle near the other end of the wire and it will be attracted; thus proving that the wire has become magnetic by the proximity of the magnet, and without contact. Here is another instance of magnetism passing through the air, and making a magnet of iron; the force remaining as long as the iron keeps its position. If the magnet be made to touch one end of the wire its opposite end will be more powerfully influenced; and to such a degree, that if brought near the edge of a table it will sustain another piece of wire smaller than itself. In this way also it can be shown that a second piece of wire will attract a third, the third a fourth, and so on until the force of the magnet is no longer visible. The properties thus communicated to the iron, whether with or without contact, are called *induced*, and, with perhaps greater propriety, *coerced* magnetism. The iron, under the circumstances in which it is placed, is *compelled* to become magnetic; and, excepting that its force is less, it possesses directive power and, consequently, polarity just the same as the steel magnet. But this is temporary in its duration; dependent, as I have said, upon its proximity to, or contact with, the magnet. Let it be noticed that the end of a magnet nearest to a piece of iron, induces the opposite kind of polarity, and this order prevails throughout any number of pieces. If the north end of a magnet touch a piece of iron, that end of the iron will be south, and of course the other end will be north. Thus:—beginning with a magnet S.————N., the pieces of iron will follow in the same order S.——N., S.——N., S.——N.

Magnetism manifests itself in other ways than those already described. It is universally diffused, not only among the solid and aqueous materials of our globe, and in the atmosphere which surrounds it, but it probably occupies the immensity of space; and of which that we denominate the solar system is only a very small part.

When speaking of the *dip* of the needle, the effects were attributed to terrestrial magnetism. This means magnetism inherent in, or developed by, the earth; manifesting its presence and power at every part of the earth's surface, at the greatest elevations yet attained, as well as at the bottoms of the deepest mines. Next to magnetic ore, it has been mentioned that, of all substances with which we are acquainted, iron is the most easily influenced by magnetism. Other substances are not indifferent to it; but we must here pass them by. Another opportunity will presently occur for referring to them.

Iron is everywhere, and at all times, influenced by terrestrial magnetism. It is compelled—coerced, is perhaps the best word—to be magnetic, and this must be understood in the widest sense. I mean by it, that all iron, that is, every separate piece, whether large or small, on the earth, or sea, is literally and truly magnetic. Further—the polarity of iron, thus rendered magnetic by the coercive force of terrestrial magnetism, is determined by position. As the strongest directive force is exactly in the line of what is called the magnetic meridian, so does a piece of iron receive its polarity most energetically in that direction; but such polarity always changes by changing the position of the iron.

In pursuing this inquiry, so as to satisfy ourselves that what has been stated can also be demonstrated, we must take care not to be misled or deceived by manufactured articles. The commonest of these, such as pokers, tongs, fenders and fire-shovels; knives, forks, and scissors; nails and needles, and the tools employed in making them, become magnetic by the various processes of forging, hammering, filing, turning, polishing, or grinding. Those articles which are case-hardened, or partly made of steel, not only acquire, but retain and exhibit, magnetic properties independently of position. It requires careful examination to ascertain the magnetic condition of a manufactured article. A case-hardened and highly-polished poker, will often exhibit permanent north and south polarities at different points of the handle, whilst the bit, which is made of malleable iron, will change its polarities as often as we change its position. It has long been known that the poker and tongs are magnetic, and this is often quoted as an example of the effects of the earth's magnetization. Such examples, however, require to be carefully watched, otherwise, by the operation of one or more of the causes just mentioned, the results will not conform to the known laws of terrestrial induction.

To discover the effects of the earth's magnetism as imparted to, and manifested by, iron—all iron not previously made permanently magnetic by artificial processes—we require only a small magnetized needle, nicely poised by suspending it with 12 or 15 inches of unspun silk. If a bar of malleable (wrought) iron be laid horizontally in the line of the magnetic meridian, that is, true magnetic north and south, and the needle be very slowly and steadily brought near, say, the north end, but in such a way that it shall approach by either side, the *south* end of the needle will be attracted by the north end of the bar. Try the same experiment at the other end, and the *north* end of the needle will be attracted. This is an example of polarity. Quickly change ends with the bar and repeat the experiment. It will be found that the end pointing northward, and which before *attracted* the north end of the needle will *repel* it, and the other end, pointing southward, which before attracted the south end of the needle will also repel that. Change ends with the bar again, and no matter how great the number of times the changes be made, on every occasion precisely the same results will follow; the needle every time showing that the polarity of the bar changes with every change in its position. If the bar be placed in the line of the magnetic dip, that is, inclined southward from the perpendicular at an angle of 70°, the polarizing force will be sensibly greater, and exactly the same changes will occur, by changing ends with the bar, as in the horizontal position. Let the bar now be laid horizontally directly across, that is, at right angles to the magnetic meridian. Testing it in the manner before directed, we shall find each end equally indifferent to the needle, which will be neither attracted nor repelled as it was in the former case. As soon as either end of the bar is moved, so as to form any perceptible angle with the transverse axis of the meridian line, the ends will instantly manifest north or south polarity, according to their position. There is no difficulty about this. In any position, whether in the line of the magnetic meridian, exactly across it, or at any angle with it, the iron is magnetic—compelled to be so;—but the polarizing force diminishes, as the longitudinal axis of the bar approaches the transverse axis of the magnetic meridian. Exactly in that line it is at its minimum; too feeble in its effects visibly to influence the most sensitively-constructed needle.

By the means described, it can be proved that all iron, cast and wrought, old and new, is magnetic. If we examine palisades, or lamp-columns; ships, bridges, or machinery; a common and uniform principle will be found to be operating in all. If the position be vertical, the uppermost end will be a south pole. If lying horizontally, the polarity will be strongest when the longitudinal axis corresponds with the line of the magnetic meridian. When moveable, polarity always changes with the changes of position.

Hereby we may learn something of the perils and responsibilities of those who "go down to the sea in ships, that do business in great waters." It is no wonder that compass-needles should be affected in ships constructed of iron, or containing large masses of machinery, or in which iron is part of their equipment, or the whole of their cargo. Great care, and skill, and watchfulness, are required to detect, and to provide against, magnetic perturbations at sea. It is to be feared that Barlow's beautiful invention for preventing, or compensating for, these disturbances is not sufficiently understood.

Has magnetism anything to do with Human Electricity? We shall presently see.

It is impossible that some of the analogies between magnetism and electricity can escape observation.

Everywhere present, and always operating, these resemblances seem to be but manifestations of the same principle; differing only in some of their habits, rather than in their primary conditions. In electricity, the two opposite states or kinds—negative and positive—are essential to its manifested presence. In magnetism, there must of necessity be the two opposite states or kinds of north and south polarity. Any substance in a state of excitation communicates some of its electricity to surrounding substances, and without contact. A magnet does the same; as we say, because the proof is so easy, to *iron*. There is, however, every reason for believing that the rule is general in its application, and only exceptive to us, in reference to iron, because we do not yet understand, or have not yet made instruments conformable to, the required conditions. Other, and still more remarkable analogies will presently be described; and then I think it will appear that it is far more difficult to detect the differences, than to identify the resemblances, in the varied phenomena of magnetism and electricity.

CHAPTER V.

ELECTRO-MAGNETISM.

THE best things may be used in excess. Even our usual habits of observing and applying—of finding out the uses and commercial values of discoveries and inventions—important as these qualifications may be, can be carried too far. It is so especially in reference to that wonder of the world, and of the age which has produced it,—the Electric Telegraph. The inquiry more frequently is, "What will it cost?" than, "How is it done?" This is one way of perpetuating ignorance; and on a subject, too, which ought to awaken, even in the most practical, feelings of wonder, curiosity, and thankfulness.

Think of the number and length of the wires connected with the central telegraph station in Lothbury; diverging in all directions—north, south, east, and west. These not only communicate with all the principal cities and towns in this country; but some of them trend far away across the ocean; having found for themselves a road far down amongst weeds, and shells, and rocks, out of the reach of waves and storms which agitate the surface. Thus are most of the countries, and principal cities, of Europe brought within speaking distances—held together by sympathies and affinities more powerful than commercial obligations, and, it is to be hoped, more durable than diplomatic treaties. The dream of our own poet, to

"Put a girdle round the earth,"

will soon be realized. In a few years there is every probability that India, China, America, and Australia, by intercommunications in this way, will have become to us like next-door neighbours. The first telegraphic wire which touches any part of the shores of America will immediately have about 15,000 miles of wires attached to it; which is the quantity already at work in that country.

How is this speaking through wires accomplished? By electro-magnetism, which means electricity and magnetism working together—co-operating.

The most interesting objects lose some of their attractions by familiarity; so do the most remarkable phenomena by frequent repetition. It is so with

Oersted's discovery (p. 22). The power possessed by galvanic electricity in passing along a wire, to agitate a magnetized needle, when witnessed for the first time is so astonishing, that the observer needs no prompting to exclaim, "How wonderful! How beautiful!" But such impressions soon wear away. It is natural they should do so. The same person, a few days, or perhaps hours afterwards, will pay a shilling for the transmission of a telegraphic message, without once thinking about the "beautiful" experiment of deflecting the needle. And yet that same experiment, which he thought so "wonderful," in making his wishes known to his distant friend, say, in 20 words, has to be repeated at least 150 times.

A little about electro-magnetism is necessary to be known, before we can understand one of the most remarkable proofs and manifestations of Human Electricity. Let it be remembered that the first line of this book contains a notice of my intentions. In as gentle a manner as possible it is stated, that I have not undertaken to teach those who are already well-instructed. And I will keep to my purpose; trying only so far to engage the attention of *un*scientific readers, as that they may desire to know a great deal more than I can tell them. Thus they will be the more ready to acknowledge that ignorance on any subject is not the most approved qualification for deciding on its merits; whilst the means of obtaining the requisite information upon it is not so very difficult.

The apparatus represented on the following page, and which is now to be described, will perhaps illustrate everything it is necessary to say on electro-magnetism. The experiments are not new; but they differ a little from others usually employed to explain this particular branch of electrical science.

a a' is a circular stand supporting the frame *b b' b''*. From the centre of the cross-beam *b''* depends, by a strand of unspun silk, a helix (flat coil) of copper wire, *c*. It consists of about 4½ feet of No. 6 (⅛ of an inch) wire, formed into a helix with a clear opening of 12 inches by 1 inch, and there are, consequently, only two turns. The wires are held together by being secured, in three or four places, with strong silk, and they are insulated by interposed strips of card-board. The ends of the wire are prolonged by having a few inches of a smaller size soldered to them. The ends of these are bent at right angles to dip into mercury. This is placed in narrow curved troughs, so as to allow the helix to turn freely on its centre, in each direction, without much friction or breaking of contact. A magnetized needle, 11 inches long, supported in such a way that it can be easily removed and replaced; a strong bar magnet the same length, to be supported, when required, by slips of glass so as to occupy the place of the needle; and a small voltaic (Smee's) battery, complete the arrangements.

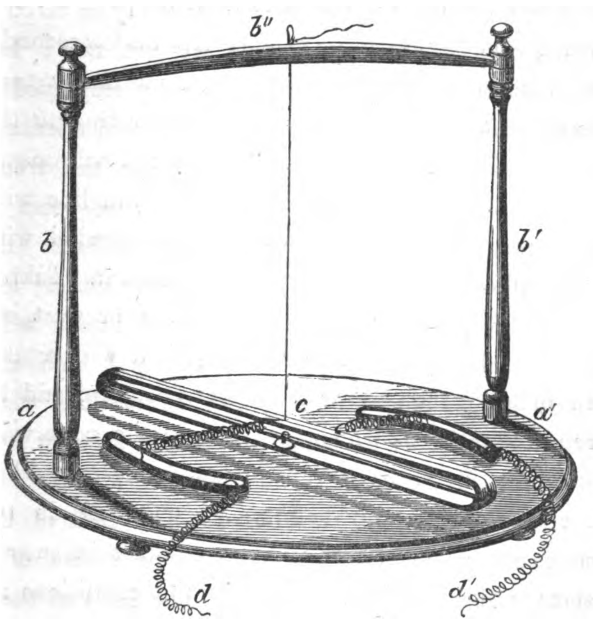

FIG. II.

Experiment I. Place the apparatus in such a position that the cross-beam *b''* shall be exactly at right angles to, and the helix parallel with, the magnetic meridian. The needle being within the helix and the battery in action, on making contact by the poles, *d d'*, with the mercury, the circuit will be closed, and a current of galvanic electricity will then pass through the interposed wires. The instant this happens the needle will start from its position, and swing violently from side to side. After a few seconds, gradually becoming more tranquil, it will finally stop; forming a greater or less angle, according to the power of the battery, with the longitudinal axis of the helix. Instead of being, as before, in line with the magnetic meridian and, therefore, parallel with the copper wire, the needle will be across it. Taking notice in which direction, whether east or west, the north end of the needle has moved, it will return, on breaking contact, to its former position; and by repeating the experiment, exactly in the same way, it will again move (say, for example, *eastward)* in the direction it did before. This it will do ten thousand, or any other number of, times in succession; never varying, as long as the conditions remain the same. On again breaking contact the needle will come to rest in the magnetic meridian. Reversing the poles of the battery, by taking the wire in the left hand which before was held in the right, and *vice versâ*, again close the circuit. The needle will start as before, but, on noting its direction, the north end will be found to turn *westward.* On repeating the experiment, the result will always be the same, whilst all the circumstances remain as thus described.

As was said just now, this is electro-magnetism—an illustration of the process by which electricity and magnetism can be made to co-operate. In this way a telegraphic wire is converted into a conduit for thought. Electricity is a courier, swift as lightning. Magnetism enables us to read its despatches.

The experiment which has here been described is extremely simple, and intended only to illustrate a principle. The apparatus is a galvanometer,* (page 23), but very roughly constructed. Telegraphic instruments, in all their essential arrangements, are galvanoscopes. The wire used in them is, however, as fine as sewing cotton, and there are several hundred feet in each helix. The fineness of the wire, as well as its numerous coils, are necessary to multiply the force; so that a feeble current of electricity may influence the needle at great distances.

Not one half of the mysterious operations of this wonderful agent have yet been told. Familiar as we have become with the use of wires for conveying elec-

* Or rather, *galvanoscope.*

trical currents, it requires no great stretch of mind, or of credulity, to assent to the possibility of its passing over fifty miles, almost as quickly as over fifty yards. This is true. No fact in science is more certain. It is done hundreds and thousands of times every day.

In communicating by telegraph between distant places, a wire is used to convey the electricity in but one direction, or in reality, only half the distance. Let it be understood that a complete circuit must be formed, previously to any deflection of the needle taking place. For example:—If London has to communicate with Birmingham, a current of electricity must pass reciprocally between these two places, that is, from London to Birmingham, and then back to London, before the needle at either end will move. In one direction, for example, from London to Birmingham, the electricity is conveyed by wire; but it returns without wire or guide of any kind. Commencing its journey at Lothbury, it arrives at Birmingham, travelling by the path prepared for it. There is, however, no wire to bring it back. Descending into the earth at Birmingham, it has to find a path for itself, by which to return to London. It does this with unvarying certainty; never missing its way nor loitering on the road. Exactly in the same manner does Birmingham communicate with London.

The electricity goes to London by the wire, and back to Birmingham through the earth.

It is easy to talk and write about these things, yet who can understand them? Watch the process of transmitting a message. The sudden movement of a handle, in opposite directions, makes and breaks contact with the battery. It is done in an instant; and, as far as a looker-on can determine, the needle moves as quickly as the handle. In appearance, these movements are simultaneous. Our senses are not acute enough to detect, or measure, any interval. Yet there must be an interval; for after contact has been made at one end, say, in London, the electricity has to travel to Birmingham by wire, and back again to London by the earth, before the needle will move at either place!

Experiment II. Let us return to the apparatus at page 73, removing the needle from the helix, and putting in its place the bar magnet. This must be supported on slips of glass, or in any other way which will allow the helix to swing freely on its centre from side to side. Let the magnet be laid in the line of the magnetic meridian; its marked end pointing towards the north. On making contact with the battery, as before directed, the helix will be set in motion; swinging round on its centre, just as the needle did;

but not so briskly on account of its greater weight. Whilst endeavouring to arrange itself across the magnet, we must observe in which direction the north end of the helix turns, and we will suppose it to be *westward.* On changing sides with the poles of the battery, and renewing contact, the same end of the helix will move *eastward;* and by restoring the poles to their former position, the helix will again move *westward.* If we vary the experiment by reversing ends with the magnet, the movement will be *eastward;* and by placing the magnet as before, the helix will again move *westward.*

Experiment III. Removing the magnet, and having made contact as before, hold its north end at a short distance (an inch) from the side of the helix. The latter will be attracted, or repelled, according to whether the north or south end of the magnet be directed towards it. It is of no consequence at which end of the helix, the magnet is presented. The same results will follow at either end, because the directive force (polarity) of the helix is at its opposite *sides,* not, as in ordinary magnets, at opposite ends.

What do these experiments teach us? We are taught by them that a current of galvanic electricity whilst passing through, or rather along, a good (metallic ?) conductor, produces without any effort, or contrivance, on the part of the operator, another current, or force, moving with equal velocity, in another direction. This newly-created current operates at right angles to the first, moving tangentially round and round the wire, like a spiral. The secondary, or, as it is called, the electro-magnetic current, is always present, as a necessary attendant upon the first; and this is one of the fundamental laws of electricity, which we can neither make, suspend, nor alter.

In the first of the experiments just described, the needle was set in motion (deflected) in consequence of its being lighter, and, therefore, moved by less force than the copper wire (helix). Its movements were in opposite directions, because the electrical current changed its direction; that proceeding from the zinc end of the battery, by changing the poles, entering the helix at opposite ends. The effect produced by this change is, that the spiral movement of the electro-magnetic force, which, in one case turns from left to right, changes also, and turns the reverse way, that is, from right to left.

In the second experiment the helix was moved. It was, however, just as much inclined to do so in the other; but the needle, by reason of its being lighter, had the first opportunity of moving. Now the conditions are changed; the magnet being heavier, and more powerful than the helix, the latter is set in motion. Wherever these forces are in operation, they act reciprocally; that which moves the needle, re-acting upon the helix; so that they influence each other in opposite directions.

For telegraphic arrangements it has been hitherto found much easier to keep to the fixed helix and moveable needle. Precisely the same results can be produced by reversing this order, that is, by making the helix move whilst the magnet is fixed. I shall have occasion to refer to this again.

The third experiment differed from the others, inasmuch as the helix was set in motion by a magnet being presented externally towards it; supplying us with a proof that the electro-magnetic force, surrounding copper, does, in a certain sense, convert that metal into a magnet. Other kinds of metals are affected in a similar manner. A glass tube, filled with mercury, can be made electro-magnetic by passing a galvanic current through the metal. All the metals, excepting iron, are thus influenced; but they are magnetic only in a limited degree. By virtue of what may be called, with perfect propriety, the atmosphere of electro-magnetism which surrounds it, a piece of copper, or brass, or silver, or, as I have already said, a glass-tube filled with mercury, can be made to obey the attractive and repulsive forces of a magnet; but the metal itself will exhibit no adhesive properties. So to speak, the magnetism is not *in*, but *around* the metal; and although the latter moves towards a magnet held at a short distance, there is no inclination to follow it when in actual contact.

The laws which influence electrical and magnetic forces, are difficult to explain, because we are not yet sufficiently acquainted with all their conditions. More extensive in their application, and more active in all their natural processes, than we may be able to prove, yet we should do wrong to deny this, as there is nothing to fear from our becoming acquainted with further developments of their extraordinary powers. If by Providential arrangement we "live and move," healthfully and comfortably, by the due apportionment, within and without us, of these mysterious forces; if by their presence we learn the special meaning of these words—"the light is sweet;" if, too, they form parts of the air we breathe, the food we eat, the water we drink, and we are thereby refreshed and strengthened; and if, by the disarrangement, or violation, of their spontaneous operations, sickness—either in some of its mildest forms, or as "the pestilence that walketh in darkness,"—spreads itself over the land, is it not better that we should possess a knowledge of these active agencies, than that we should continue ignorant of them? Man, as it would appear, is placed where electricity and magnetism exert, on our planet, their greatest forces. Can we believe this to be without a special purpose and a beneficent design? Is it reasonable to suppose that a being, so "fearfully and wonderfully made"—so sensitive to external impressions, and so powerfully affected by internal emotions—should be able to breathe in an atmosphere of electricity, and to perform every movement within the range of magnetic curves, and yet be indifferent to, and independent of, such influences?

In operating upon iron, electro-magnetism exhibits properties more wonderful, if this were possible, than anything hitherto described. Provide a piece of round iron, about 9 inches long and $\frac{3}{4}$ths of an inch in diameter, and 20 or 30 feet of (covered) copper wire, about the size of small bell-wire. Coil the wire carefully round the iron; and having secured it at one end then proceed, always in the same direction, towards the other end, where it must also be fastened. Test the iron as to its magnetic properties, that is, try if it will attract, or sustain, another piece of iron, or even a small sewing-needle. It is not likely that it will do so. Connect the ends of the wire with the opposite poles of the battery (page 73), and whilst a current of electricity is passing through the copper wire, the iron within it will be made into a magnet. If we try it in various ways, it will attract and sustain, at either end, a piece of iron as heavy, or perhaps much heavier, than itself; it will also attract and repel the opposite ends of a magnetized needle, and in other respects it will appear to possess the properties of a steel magnet. On reversing the wires of the battery, the poles of the newly-made magnet will be instantly reversed; that which at first was north as quickly becoming south. By a mechanical contrivance this may be done either 50 or 500 times in a minute, and is exactly what is effected by the telegraphic instrument; each reversal of the needle, that is, each beat to the right or left indicating a corresponding reversal of polarity in the helix. On breaking contact, the iron will no longer be a magnet. The whole of the magnetism will not be dispersed, *(Note L)*; but practically the electro-magnet will have lost its power.

A piece of iron thus infolded by copper wire, and which is made the medium of communication between the opposite ends of a voltaic battery, *must* become magnetic. It is only another manifestation of the power which agitates the needle and throws it across the wire; and, by the reaction of the same force, agitates the wire and compels it to arrange itself across a magnet. A piece of iron of very moderate dimensions, bent in the form of a horse-shoe (U), with suitable armatures, and a battery properly excited, will sustain a weight equal to a ton (2240 lbs.). Iron seems to be endowed with a special congeniality for electro-magnetism. It can be more *intensely* charged with magnetism, in the way here described, than by any other known process after it has been converted into steel.

Another metal besides iron, namely, nickel, manifests, in a very decided manner, magnetic properties; its directive force being nearly equal to one-third that of steel. Other metals besides these two have been supposed to be magnetic, in the sense in which the term is ordinarily employed; but in many instances the results obtained have been erroneous, owing to the presence of small quantities of iron, either in combination or as accidental impurities, in the specimens examined. This is no more than what happens in chemical analyses, where an unsuspected substance presents itself in the most carefully prepared tests. When every reasonable allowance has been made for accidental contaminations, and when, seemingly, every precaution has been used to detect, or guard against, the presence of iron, there is still enough remaining to baffle the skill, and to try the patience, of the most acute and persevering observer. It was stated just now, when speaking of the source of electricity, that it would be useless to attempt to produce it from materials in which it did not previously exist. The same may be said of magnetism. But it is more difficult, in each case, to prove where they are not, than to find out where they are.

One example, merely for the purpose of illustrating the danger of generalizing, where everything is so completely encompassed by special conditions, is all that I can at present afford.

Plate brass is made magnetic by hammering. Tested in every conceivable way before it is subjected to that treatment, and the hammering, moreover, conducted in such a manner that it is impossible for any iron to come near the brass, yet the experiment invariably succeeds. On heating the brass its magnetism disappears; but this can again be restored by hammering. In a comparative sense, iron can be made powerfully magnetic by being smartly struck with a hammer, and the effects of the blows are most decisive when the iron is held in the direction of the dip of the needle. This is a common experiment; but as we know that iron is always magnetic, it excites no surprise. The manner in which brass is made magnetic, by receiving a certain number of blows, unless it pre viously contained magnetism, or the materials out of which it could be eliminated, seems hard to explain. Speculations and conjectures on these, and many kindred topics, are very enticing, and are becoming more so every day. No wonder that this should be so; for the speculations of one day, frequently turn out to be the realizations of the next; guesses at truth being oftentimes the nearest way of getting at the truth itself.

Returning for a moment to the experiment with plate brass, let it be noticed that the metal is an alloy of copper and zinc, which are commonly used for obtaining chemical (galvanic) electricity. It is known that a very small quantity of alloy alters the habits, as well as the appearances, of various metals; entirely depriving iron of its susceptibility to magnetism. May not violent blows on brass in like manner revive, or set in motion, some of its (latent) electrical conditions, and, by electro-magnetism, induce in it also permanent magnetic properties? Oxygen is magnetic. Brass can be shown, by hammering, to be made sensitive to magnetic influences. May not the many hard blows given to it, force amongst its particles some of the oxygen of the air necessarily in contact, and so communicate magnetic properties?

But I must hasten on. It is probable the reader would be better satisfied than myself, if he had less ground to pass over before reaching, by the beaten track, the end of the book. A little patience, however, is all I solicit; and with that I trust all will be right.

The active manifestations of the presence of electricity, magnetism, and electro-magnetism, have been thus far occupying our thoughts. Let us turn now to a totally different class of phenomena, and in which the difficulties greatly increase; as well by reason of the care which is required in conducting the experiments, as by the numerous sources of error which press in upon every side. Skill, and care, and watchfulness, and the caution acquired by experience, are the best safeguards against error. These are qualities which eminently distinguish the men whose names* are identified with the latest discoveries in this department of an entirely new branch of science;—the science of what may not inappropriately be termed the passive phenomena of magnetism.

More than fifty years ago, by means of extremely delicate experiments, it was ascertained that many substances besides iron, metallic and non-metallic, were affected by magnetism. They evinced a certain degree of sensibility to the presence of a magnet, when properly guarded from currents of air and

* *Additional Note* M.

other disturbing causes, if placed in what we should now call exactly that position, in respect to a powerful magnet, in which the magnetic curves exercise their greatest force. It was a subject on which there were so many differences of opinion, and it was so often taken up and laid aside, that it seemed to be always involved in doubt and dissatisfaction. There was a suspicion, too, that iron, in some way not understood and, certainly, not easily explained, was a constant source of error. But now we know better. It can be proved that almost every substance with which we are acquainted, provided it be not artificially compounded, is just as obedient to magnetic influences as iron itself. Still, it is necessary to make a distinction between the energy displayed by that particular substance, and the apparent indifference (passiveness) which pervades the others. Another distinction has also to be made. That which at one time was supposed to be dependent on the elementary structure of the substances operated upon, is now believed to be due to the arrangement of, and not to the specific properties possessed by, the particles of which a substance is composed.

Let me try to make this more intelligible. With a horse-shoe magnet, the poles of which are, say, four inches apart, and a piece of iron 2½ inches long and

½ an inch in diameter, the latter supported by its centre with unspun silk, it will be easy to do something towards it. Suspend the iron from a fixed support, and, when perfectly at rest, present to it, very slowly and from underneath, the magnet; the poles being at an equal distance from each of its sides. The iron will then begin to move, oscillating from side to side, until at last it arranges itself exactly in line with the poles of the magnet, that is, the *ends* of the iron will point towards its poles. This is very simple; intended only, by contrasting it with an experiment of another kind, to make it the more readily understood.

Instead of a steel magnet and piece of iron, with which we have been supposed to be operating, we must now think of a powerful electro-magnet, the poles of which should be about 2½ inches apart. A thin prism of glass, made with great care, and 2 inches long, must also be provided. The glass being suspended, and at rest between the poles of the electro-magnet, and in the same position as that assumed by the iron, the instant the battery is connected, the glass will begin to oscillate, and in a little time arrange itself lengthwise between the poles, that is, with its *sides* opposite to them.

This last experiment is, in brief, a description of a recent beautiful discovery of Faraday's. Stimulating to further researches, it has been the means of conducting that highly-gifted philosopher a long way beyond the limits of, what once was considered, the outer circle of magnetic influences. Nor can he remain satisfied with what is now known to him. Far-seeing as he is, there is more work for him to do, and greater conquests for him to achieve. Mysteries, darker and deeper than any which have hitherto yielded to the power of his enchantments, yet remain to be solved.

That which has just been described must be considered as only rough illustrations, or rather types, of two distinct classes of phenomena. It is beyond the reach of these pages to enter into particulars. In the first example, we have magnetism in its ordinary mode of operation, and with which those who know anything of the subject, are already familiar. In the second example, a series of new facts present themselves. It is still magnetism, but manifesting itself so differently from what was previously known, that we may well begin to doubt the evidence of our senses; and is what Faraday calls DIA-MAGNETISM, (διὰ, through,) in allusion to the position assumed by the magnetized body. Thus, a substance which is dia-magnetic, arranges itself with its longest dimension passing through, or across, the imaginary line which connects the poles of a magnet; whilst in ordinary magnetism the longest dimension arranges itself upon that line. In other words, all bodies which so arrange themselves as that their *ends* will be attracted by the poles of a magnet, thus:—

are still called magnetic. Those which arrange themselves in a contrary direction, thus:—

and whose *sides* appear to be attracted, and their ends repelled, by the poles of a magnet, are called diamagnetic.

Several substances, besides iron, in the sense here spoken of, are magnetic; being obedient to a magnet, when placed in what is termed that part of the magnetic field in which the force of the curves is strongest. In this way, for example, platinum is magnetic. It is attracted by the opposite poles of a magnet, but does not thus acquire independent polarity. Hence it seems to be endowed with passive, rather than active, magnetism; as it can only be called into action in the presence of a powerful magnet, and appears to be too feeble to show itself in any other way. At present we have no means of proving that one piece of platinum will attract another piece of the same kind of metal. The magnetic property so strong in iron is weak in platinum; and, as in many other substances, is, under ordinary circumstances, unnoticed and unknown. So it is with dia-magnetic bodies; and these are vastly more numerous than the other. From what is already known, it is difficult to believe that *any* substance is altogether indifferent to magnetism. Those which are not in one sense magnetic, are in another dia-magnetic. The latter includes substances of all kinds; solid, liquid, and gaseous; organic and inorganic; and perhaps everything endowed with vitality. It can easily be shown that the blood of a recently-killed animal, and its flesh, both raw and cooked, are dia-magnetic. Water, rock-crystal, a piece of apple, as well as a piece of the tree upon which it grew, may also be mentioned as examples of dia-magnetic bodies.

Even here let us take care not to make mistakes. Definitions are necessary, but we must not rest satisfied with names and distinctions. What are called the magnetic and dia-magnetic properties, or habits, of different substances, is the same force manifesting itself in different directions. This is supposed to be owing to the arrangement of the particles, or crystals, or fibres, of bodies; and by which these subtle, yet sensible forces, develope themselves more powerfully in one direction than in another. It appears that electric and magnetic currents will pass freely one way, but not at all, or with great difficulty, another; and this, probably, as much depends upon the distances they may have to pass, as upon the direction of the fibres. If we cut a narrow slip off either end of a steel magnet, the piece thus separated will be endowed at one of its ends with north, and at the other end with south, polarity. It must be remembered, however, that the ends of the small magnet were just before parts of the sides of the larger one. The same thing will happen with diamagnetic substances. By dividing them, and altering their shapes, the direction of the induced magnetism will be changed; that part which at first was repelled, being afterwards attracted.*

Time would fail in any attempt to describe the various ways by which, if not the identity, most certainly the similarity, between electricity and magnetism might be shown to exist. In some of their simplest forms, both frictional and galvanic electricity produce heat and light, decompose water, and sepa-

* *Additional Note* N.

rate metals from their chemical solutions. So also one kind will make a piece of iron into an electro-magnet, the other communicate permanent magnetism to steel; whilst both cause spasmodic contractions of the muscles (a shock), when passed in a particular manner through the body. Electro-magnetism and magneto-electricity produce similar effects.

Thermo-electricity is another means of manifesting electrical phenomena. This is done by unequal degrees of heat in two dissimilar metals, or in one metal at its opposite ends. The existence of electrical currents can also be shown by the rapid revolution of a plate of copper in front of the poles of a magnet. The inherent electricity of some kinds of fish, the development of which seems to be dependent on their natural instincts, must receive a passing notice in another place.

Now, perhaps, it may be proper to inquire—is any thing known as to the source of magnetism? Where does it come from, and how is the supply kept up? Is it inherent in our planet, and thence communicated to everything in, upon, and around it? These are puzzling questions; especially as it has been so lately observed that we are entirely ignorant of the true nature of magnetism.

The directive force (polarity) of a magnet is always spoken of as under the control of terrestrial magnetism, that is, the magnetism existing in, or around, the earth, and which is supposed to exercise its greatest force at, or near, its poles. This polarity, as we have seen, (page 55), is not constant at all times, or in all places. Hence the phenomena of the variations of the needle; which, in some places points westward of geographical north, in others eastward, and in others again directly north. It must also be remembered that there are diurnal and seasonal variations, which are known to be connected with the alternate periods of day-light and darkness, and with the direction and intensity of the sun's rays, between the summer and winter solstices. We are not left to conjecture on this subject. By a long-continued series of observations, in almost every part of the world, conducted with extraordinary care and involving an incalculable amount of labour, we have been taught that electricity circulates round the earth from east to west, and that the force (intensity) of its currents is controlled by solar radiation. These increase from dawn till noon, as each portion of the globe is exposed to the direct influence of sun-light, diminishing again, as night advances, until sun-rise. The sun, therefore, is the source of electricity, as well as of heat and light;

and as the course of the electrical currents is east and west, there is no difficulty in understanding that the magnetic currents must be across, that is, exactly at right angles to the electrical, or north and south. Whilst we may still talk of terrestrial magnetism, it is necessary to recollect that its origin is celestial; an explanation far more intelligible and satisfactory than the imaginings of former times, about a great magnet situated within the earth. That which we call magnetism, as manifested by the inductive force of the earth, is in reality electro-magnetism; produced by electricity in the sun's rays, and modified, probably, by our attendant satellite, the moon.*

At various times, during the last 250 years, the spots on the sun have engaged the attention of numerous observers. These are supposed to be openings in an atmosphere surrounding that luminary; and through which parts of its opaque body are thus revealed to us. It is now known that the spots appear, disappear, and re-appear in regular periods, that they are more numerous at one time than another, and that they even vary in their forms within a few hours. By observations of many years' duration it has been ascertained that the spots are recurrent in

* *Additional Note* O.

cycles of a little over eleven years, and that the variations in the intensity of terrestrial magnetism in a most remarkable manner coincide with them. Here, then, we have something which seems to point towards a law in actual operation, and which determines the proportions of heat and cold, and of drought and moisture, in a certain number of years; and these conditions are dependent, not on what we call the variableness incident to climate, but on the number, the sizes, and the forms of the spots on the disc of the sun—distant from our earth about 95,000,000 of miles!

In these few words it is impossible to convey a thousandth part of the information, collected by a host of observers during many years past.* This kind of information is not only valuable as being facts in science, and, therefore, the only safe guides in the interpretation of natural processes; but it is of immense importance as connected with human progress. Dispelling ignorance is only another way of letting in additional light. We have need of all that can be obtained; for the more we know, if we make a practical application of our knowledge, the greater the benefits that will accrue to ourselves and others.

Whatever may be the identities, or the diversities,

* *Additional Note* P.

of electricity and magnetism, if they be one in principle whilst various in their manifestations, we have no difficulty in recognizing, amidst their different occupations, the proofs of earnest co-operation. What we can do in imitation of natural phenomena, is very instructive; and thankful ought we to be that we know, and are able to do, so much. Still, we are but as children, who, wearied with their toys, rest awhile, and then return to them again. Natural processes never tire, and they know no rest. He who "neither slumbers nor sleeps," has appointed them their duties. In what various ways these duties are performed is of great importance to us. Our knowledge or ignorance, has much to do with our weal or woe.

CHAPTER VI.

MUSCULAR AND NERVOUS ELECTRICAL CURRENTS.

THE frog has long been a favourite with those engaged in experimenting on animal electricity; and this is because it possesses a remarkable amount of sensibility, which it retains for a longer period after it has been killed, than any other animal with which we are acquainted. The frog is what is called cold-blooded; and, when in good condition, it is endowed, in proportion to its size, with extraordinary muscularity, and is said to be the only animal which has anything deserving the name of a calf to its leg.

Already has it been related, (page 10,) how, in connexion with the science of electricity, the frog first became an object of so much interest. All that I propose further to say, is just so much of what relates to recent experiments with the animal, as, I hope, will convey an intelligible idea of the various ways in which its electrical conditions are demonstrated.

But I must first try to explain, a little more accurately, the Galvanometer. It has often been mentioned, and in the apparatus at page 73 its principle is practically embodied. If we are desirous of knowing what is meant by a delicate, or more appropriately a *sensitive,* apparatus of this kind, we must think of some arrangements differing greatly from those which were just now described. A galvanometer which is intended to indicate the presence of extremely feeble currents of electricity, requires to be made, and afterwards managed, with more than ordinary skill and care. Its name implies that it is a measurer of galvanic currents, but in many cases it is only a means of making visible their comparative forces, and in the latter sense it is a *galvanoscope.*

Oersted's famous discovery of electro-magnetism, was no sooner announced than it was seized upon as precisely what was then most needed. Without it galvanism and the voltaic battery were incomplete. There is no example on record of any discovery being at once so quickly understood, and its principles so satisfactorily explained, as that of electro-magnetism.

According to the different uses to which a galvanometer is intended to be applied it must necessarily be made more or less sensitive. For ordinary purposes, where the object in view is simply to discover the presence and the direction of an electrical current, 20 or 50 feet of tolerably fine (covered) copper wire, formed into a helix, and enclosing a nicely-poised magnetised needle, is all that is required. The way in which the indications are obtained will be evident by referring to page 74. Something different from this, however, will be required in searching for the manifestations of electricity where they can scarcely be suspected, or believed, to exist. For this purpose a differently-constructed instrument will have to be provided, and which must consist of several thousands of feet of wire almost as fine as a hair. The wire must be continuous, very closely compacted, and coiled in one direction only; yet in this arrangement no part of the wire must be in metallic contact with another. The needle, which must be accurately balanced, must be double; consisting of two needles so united, that the north pole of one shall be at a little distance above, and pointing in the direction of, the south pole of the other. This is called an *astatic* arrangement, and is so constructed that the influence of terrestial magnetism may, as much as possible, be counteracted.

A remarkably sensitive galvanometer, of the kind just described, has been lately used by Du Bois-Reymond, of Berlin, in his experiments on animal electricity. Its operations were witnessed by a few persons, specially invited, at the Royal Institution, in May, 1852. The wire employed is described as .0055 of an inch in diameter. It is 16,752 feet long, equal to 3⅓ miles, and makes 24,160 turns on the frame upon which it is coiled. The astatic needles are a little more than 1½ inch long, and their weight is only 4 grains. The whole of the arrangements in the construction of, and for the proper mode of using, this instrument, are so exceedingly delicate and beautiful, that they can be understood only by those who are already familiar with the manipulatory processes. It must further be noticed that the ends (terminals) of the helix consist of platinum plates, kept perfectly clean; and, in other respects, every possible precaution must be observed for insuring their homogeneousness.

Now for something more about frogs.* Those

* With the exception of some experiments undertaken many years ago in this country, for the purpose of illustrating the effects of galvanic electricity upon the human body, and the bodies of animals, after death, almost everything we know relating to animal

who have never witnessed experiments with these harmless and interesting little animals, can scarcely believe in their strength and activity. When in good health, and only recently removed from their favourite haunts, they seem to be literally overflowing with life; and, as I have before mentioned, they hold it tenaciously. Many hours after a frog is, what we call, dead—its head having been cut off, and both the sensation and capability of suffering, as we might naturally suppose, having ceased—irritability of the nerves, and a great degree of muscular force still remain; not only in the body as a whole, but even in its divided parts. Several minutes after the head of a frog has been separated from the body, I have caused the latter to leap off a table. This was done by touching (irritating) the cerebral end of the spinal cord *(medulla oblongata)* with the point of a glass rod.

At one time it was supposed that the leg of a frog was more sensitive to galvanic electricity than any instrument the ingenuity of man could devise. By improvements in the galvanometer, copper wire and a magnetic needle, are now made a more delicate test than the nerves and muscles of this animal.

Let it not, however, for an instant be supposed

electricity, has been the results of the labours of continental philosophers.

that electricity is LIFE. Of electricity we know a little—of vitality we know nothing. By care and watchfulness we may learn how electricity comports itself. At our command, suddenly appearing and just as suddenly disappearing—sometimes we give it one name and sometimes another. One minute we say it is electricity, the next it is electro-magnetism. Almost before we have done speaking it is magnetism, and then, by a touch, more powerful than that of a magician's wand, all is changed, the magnetism has disappeared, and electricity has come back to us again. But in these changes, with all the evidences of activity, there are no proofs of vitality. We may safely say that electricity is an appendage to life in its innumerable forms, and that wherever there is life, so far as it is at present cognizable by us, there is also electricity. But, after all we may do or say, "LIFE is beyond the search of the most exalted human intelligence. VITAL FORCE in its lowest development is infinitely superior to electricity in its highest manifestations, and it requires no great penetration to perceive subtle powers, which are not yet 'dreamed of in *our* philosophy,' beyond these physical forces with which we are, as yet, so imperfectly acquainted, and these still inferior to that approach to spiritualization which we call *life*."*

* *British Quarterly Review*, No. xxxv., p. 108.

Wonderful as have been the revelations of chemistry, in its efforts to unveil the mysteries of organized substances, we must ever remember that *life* is not one of the chemical elements. *That* makes its escape before the chemist even commences his work. He may be ready with his ordeal of fire, or of water, his tests may be pure, and skilfully applied; but he must be content with an analysis of what was, not is, endowed with vitality; and in which the changes, the instant after death, may have been as great, as any which occur in the same substances between death and decomposition. Still, it is both interesting and instructive to witness this lingering—a sort of unwillingness to depart—evinced by one of the attendants upon vitality. This is electricity; whose companionship has, probably, been as close and constant, as a physical agent, as it is possible for the material to be associated with the immaterial. Many other animals, besides frogs, afford the same manifestations of electrical sensibility. Two examples are all I may here mention, namely, the convulsive twitchings of the flesh of a recently-slaughtered ox, and the spasmodic contortions of an eel after it has been skinned.

Galvani was a skilful anatomist. In his numerous experiments upon frogs, he discovered a means of dissecting them, which has been very generally adopted by those who have since studied this department of electro-physiology. Prepared in the usual manner, the legs of a recently-killed frog, adhering to part of the pelvis, must be skinned and the crural nerves gently separated from the muscles of the thigh in which they are embedded. The legs are then ready for use; their sensitiveness to an electrical current being easily shown by placing a piece of zinc in contact with the muscle, and on touching the nerve with one end of a piece of silver wire and the zinc with the other end, the limb will be convulsed—starting suddenly, somewhat in the same manner as it did when the animal was alive. A live fish, a worm, or a snail, will evince its dislike of copper and zinc, or any two dissimilar metals, if they are placed in contact with different parts of its body, and more decidedly if the metals are brought into electrical communication by means of an interposed wire. In the frog, let it be observed, that the spasmodic contortions, of which I am speaking, are those occurring after its death. During its life, a frog is sensitive to electricity in a more exalted degree than a fish, a worm, or a snail. Many hours after death has ensued, a frog will exhibit a greater degree of electrical sensibility than many animals and insects during life;

and this is undoubtedly due to differences in their organization.

Excellent as were the plans pursued by Galvani they have since been improved upon. Never forgetting his own labours, nor those of his immediate disciples; those of Humboldt, more than fifty years ago, and of Nobili, about thirty years later; I must now refer to what has more recently been accomplished by Matteucci,* and Du Bois-Reymond.† Most truly has it been said by the latter, "Galvani really discovered not only the fundamental physiological experiment of galvanism, properly so called (the contractions of the frog when touched with dissimilar metals), but also that of the electricity inherent in the nerves and muscles. Both of these discoveries were, however, hidden in such confusion of circumstances, that the result in both cases appeared equally to depend upon the limbs or tissues of the animals employed."

How can it be shown that electricity *is* inherent in the nerves and muscles? Listen awhile:—

Notwithstanding all that had been done by others, it must be admitted that to Nobili (1827) belongs the honour of first demonstrating, by means which were independent of the animal itself, that a true

* *Additional Note* Q. † *Additional Note* R.

electrical current existed (circulated) in the body of a frog. This he accomplished by improvements in the galvanometer. It is true Nobili misunderstood the import of his own experiment, erroneously ascribing the current to thermo-electricity. That was of little consequence, excepting that it probably put off, for some years, the further examination of the phenomena. The fact was established, the experiment can be easily repeated, and it is as conclusive as the original experiments of Galvani with dissimilar metals. The following will convey an idea of what is here intended. Thus—Let two small glass vessels, containing water, or brine, be provided. If the feet of a properly prepared frog be dipped into one vessel, and the spinal column into the other, at the instant of making a communication, by means of a good conductor (a few fibres of moistened cotton will do) between the vessels, the limbs of the animal will be convulsed. Here, it must be observed, is the same phenomenon which presents itself in the common experiment of developing electricity in the frog by contact of metals. But in the case now described no metal is used. We have thus the means of showing that Galvani and Humboldt, and many others, were right in some of their experiments without metals, although, at that time, the truth of such experiments could not be proved. Why was this? Because the galvanometer was then unknown.

Nobili's first attempt was a failure. He constructed an instrument and made it part of the circuit, connecting by it the two vessels, instead of using the fibres of cotton. The current passed through the wire of the galvanometer, for the frog was convulsed; but the needle remained stationary. In this case the frog was more sensitive than the galvanometer. Another instrument was made. With that the experiment succeeded; the needle being deflected more than 20°; whilst the direction of the current was noticed to be from the muscles to the nerves, that is, upwards from the feet to the head. It was thus demonstrated that the current in the frog was truly electrical; the same in its properties as that produced by the contact of metals. In other words, it was *galvanism*, generated in the muscles, and transmitted along the nerves of the animal, in the same manner that a similar, although more powerful, current is generated by copper and zinc, and conducted by the connecting wires of a voltaic battery. At the risk of being thought tedious, let me repeat that, a frog, both living and dead, is extremely sensitive to electrical influences, as when brought near a machine, or touched with the opposite poles of a battery; but this is only something like the sensitiveness of a delicately-formed instrument, by which we detect the presence of electrical currents. There is a great deal more than mere sensitiveness to electricity; for the living frog possesses within itself the power of producing supplies of electricity, and which are, so to speak, a part of its nature, and necessary to its existence. The apparatus (muscles and nerves) by which the electricity, during the life of the animal, is produced, retains its power, though in a less degree, many hours after it is dead. The body, and even a dissected limb of a frog, is therefore what we may call an exquisitely beautiful voltaic apparatus; the structural arrangements of nerves and muscles producing an animal galvanic current, somewhat in the same manner that metals produce a chemical galvanic current. That it is galvanism, is taught us by its effects upon the galvanometer. By deflecting the needle it declares itself to have evolved electro-magnetism.

Guarding almost every expression, whilst trying to fix the thoughts upon the process I have been describing, let it not be supposed, because I have compared animal with chemical electricity, that we know the source of either. They may be exactly alike or totally different. This is not revealed to us. We judge of them, speak of them, examine them, only through their effects—their manifestations. How muscles and nerves act upon each other, to produce such wonderful results even in a dead body, is far beyond our comprehension. Futile is the effort to place ourselves so near to the living organization as to be able to understand its mysteries.

When Nobili had proved the existence of what he called the "proper frog current," scarcely anything more was done during the next ten years. It was about 1837 that Matteucci directed his attention to the subject, repeating and varying Nobili's experiments with frogs, as he himself says, "in a thousand different ways." Matteucci extended his researches to warm-blooded animals, both living and dead; recording and, from time to time, making public the results of his investigations. For some years he seems to have held the opinion that what, by way of distinction, was called the "frog current," was peculiar to that animal alone. It is not so. Afterwards it was found that electrical currents exist in all animals. May we not fairly suppose that electricity is a necessary condition of vitality?

The galvanometer supplies us with the means of observing, if not, in the strictest sense, of measuring, the force of an electrical current. If the bodies of five or six frogs be so arranged, that the legs of the first shall touch the nerves of the second, and the legs of the second the nerves of the third, and so on, in the same order, throughout the series, the current which passes through the galvanometer, from the legs at one extremity to the nerves at the other, will be much stronger than from one frog only. So also, if instead of whole bodies, the legs, or better still, the muscular parts of the thighs, of several frogs be arranged in the order above mentioned, that is, muscle to nerve, muscle to nerve, and so on with all the thighs, there will be most decisive proofs that the force of the current is greater from a number of thighs than from one only. This may be called a frog-battery, in the same sense that a series of plates of dissimilar metals is termed a voltaic battery.

Du Bois-Reymond commenced his labours on animal electricity in 1841. To him we are indebted for many new experiments, as well as improved methods of performing old ones; by which he has cleared up some of the difficulties seen, but not satisfactorily explained, by Matteucci. The beautiful galvanometer used by Du Bois-Reymond has been already mentioned (page 102). The delicacy (sensitiveness) of that instrument, as well as the skill with which it has been applied, have given the operator advantages which he has turned to good account.

What was so long called the "frog current" is common to all animals, and is produced by the muscles. It manifests itself in different directions in the limbs of different animals, and with greater intensity in some animals than in others. The electro-motive forces, thus operating in the muscles, are stated by Du Bois-Reymond to depend upon the opposite electrical conditions existing between their longitudinal and transverse sections. So also, with respect to the nervous system, he states that the nerves are subject, in their sectional arrangement, to the same law as the muscles. This must be understood, however, with reference only to the exercise of their inherent electro-motive forces. In transmitting the muscular current, the nerves perform the part of inactive conductors.

It is interesting to notice how conclusively the doctrine, that electrical excitation was due to the heterogeneousness of nerves and muscles, has been refuted. Volta made the most of this in his disputes with Galvani. Matteucci has shown that Volta was wrong. Still, it is remarkable that Galvani and Volta, their friends and followers on both sides, and many others at subsequent periods, have been so near to the true cause of the muscular current, that they may be said to have touched, and actually worked with, it, and yet it was not recognised.

According to Du Bois-Reymond it is not in the whole, or a large part of a muscle, that an electrical current can alone be shown to exist; but that every particle, the merest shred or fragment, even what may be considered microscopic, is equally obedient to electrical influences.

In these brief references it is impossible to do justice to Du Bois-Reymond's experiments, which, there is reason to fear, are not so well known as they ought to be in this country. Until they are more attentively studied, can it be said that the medical profession have availed themselves of all the sources of information thus laid open to them? Will they have performed all that might have been fairly expected from them in acquiring some additional knowledge of electro-physiology?

CHAPTER VII.

THE HUMAN ELECTRICAL CURRENT.

Pursuing the subject only very briefly described in the last chapter, and assisted by his delicate galvanometer, Du Bois-Reymond was the first who developed the muscular (electrical) current in the human body. Imitating, as nearly as possible, the conditions he had observed succeeded best in some experiments with the legs of a frog, he found that by forcibly contracting the muscles of one of his arms, whilst those of the other arm were relaxed and at rest, he was thereby enabled to cause a deflection of the needle, first in one direction and then in another, according to which arm was thrown into a state of tension (tetanized). In this experiment Du Bois-Reymond firmly grasps a bar of wood, at the same time dipping his fore-fingers into glasses, containing salt and water (brine), and in which are also placed the platinum ends of the wire of the galvanometer. The circuit is completed through the operator's body, which, for the occasion, may be said to represent a (human) battery, the fore-fingers being its electrodes.

On first hearing of this experiment (1851), I began to contrive an instrument for the purpose of verifying it; part of which was completed, but was perfectly useless, just about the time that Du Bois-Reymond's galvanometer was first seen in this country. When the experiment was shown at the Royal Institution (May, 1852), some friends, who were present, kindly sent me an account of what they had witnessed. More anxious than ever to examine the subject myself, my attention was again directed towards the most likely means of obtaining a properly-constructed apparatus. Here was a difficulty, which increased with the efforts I made to overcome it. Wire of the proper size could not be obtained in England; and, if that had been possible, the quantity required would have made its cost a matter for serious consideration. After many inquiries a supply of wire was at last obtained—not so fine as could have been wished, but finer than had been expected.

In these renewed efforts I was kindly aided by a gentleman skilled in electrical and electro-magnetic science, whose attention had been recently directed to the testing of exceedingly feeble currents, and who, in the most friendly manner, offered me the advantages of his instruments, and his experience. With one of his sensitive galvanometers, although in its roughest form, the first successful experiment was made. This was sufficiently encouraging to show that the human current could, in this way, be detected. Fertile in contriving, as he is ingenious in constructing, it was not long before Mr. Whitehouse placed at my disposal a finished instrument. With so good a model to guide me, there was no difficulty in making a similar apparatus; a few details for convenience, and greater durability, being all that were required. With this instrument, as represented opposite the title-page, during the last twelve months, many hundreds of experiments have been made.

To a circular stand a pillar is fixed, on the top of which is a moveable bracket, with a collar and adjusting-screws. From the bracket, by unspun silk, is suspended an oval-shaped compact coil of (covered) copper wire. The ends of the wire are soldered to small binding-screws at each extremity of the coil, by which contact is made with cups containing mercury. The helix moves with scarcely any friction; only that caused by terminals of very fine silver wire dipping into the mercury. A powerful Haarlem magnet* is supported horizontally, in such a position as that its poles are as close as possible to the sides of the helix, but without touching them; the latter being placed in that part of the magnetic field where the curves exert their greatest force. Connected with the mercury cups, and passing underneath the stand, are wires terminating, at a convenient distance from the apparatus, in platinum plates. When out of use, to preserve their homogeneousness, these plates are kept together in a vessel of distilled water. On a square, at the top of the helix, is fixed a nicely-balanced brass index, to which is adapted an engraved semi-circle. A glass shade, fitting into a groove in the stand, protects the whole from dust, moisture, and currents of air. The apparatus is placed on a strong and firmly-fixed bench, in a room which is not only on the ground-floor, but, for greater steadiness, has its floor on the ground. On a separate bench are two basins, each containing about three quarts of the purest spring, or distilled, water. When the apparatus is used, the platinum ends of the helix are placed in these basins.

* *See Additional Note* L.

Turning back to pages 72, 78, and referring to the apparatus and experiments there described, the reader will have no difficulty in recognizing both the principle, and the operation, of the galvanoscope now under consideration. In the second experiment, (p. 77,) it is shown that, when the magnet is placed within the helix, on passing an electrical current through the latter, it will begin to move; making an effort to arrange itself across the magnet. It is also noticed that the helix will move in either direction—east or west—according to the way in which the conducting wires of the battery are applied. The difference in the sizes and quantities of the wires of which the helices are made, one being as large as a quill, and there being but little more than four feet of it, and the other almost as fine as a hair, and consisting of several hundred feet; the position of the helices, which in one case is horizontal, and the other vertical; the difference in the shapes of the magnets, one being a bar, and the other a horse-shoe; are simply matters of detail and convenience. The objects to be attained are different—so wide apart in their modes of operation that they seem to be at opposite extremes—and yet, in their results, they are exactly alike. By what may be called the rough and cumbrous arrangements, all that is intended is to illustrate the principle of electro-magnetism, and without regard to the force of the electrical current. By the more delicate contrivances, the purpose is to make a practical application of the principle, and in such a way that a current, so weak as by other means to be imperceptible, shall be made to manifest itself; producing mechanical effects by which it can be easily identified, and, as we hope, in process of time become as well, or better, understood than any of the other forms of electrical phenomena.

There can, I think, be now no difficulty in perceiving wherein the newly-invented galvanoscope (or galvanometer) differs from one of the ordinary kind. In the latter the smallness of size and extraordinary length of the wire act as an electro-magnetic multiplier; so increasing the force of an otherwise feeble current, that it manifests itself by influencing a delicately-poised needle. This is the mode of action in Du Bois-Reymond's galvanometer. In the galvanoscope the action is reversed. A comparatively small quantity of wire is made electro-magnetic by a current of low intensity, and, placed within the range of the curves of a powerful magnet, the wire disposes itself accordingly. In one case the helix is stationary, and by the force of the electro-magnetic current the magnet (needle) is moved; in the other the magnet is a fixture and the helix is set in motion.

Thus have I endeavoured to explain how the galvanoscope is made. Let me next describe what it will do.

In experimenting with the before-mentioned instrument, a very important condition is—quietness. To prevent vibration, the operator, as well as the observers, should move about as gently as possible. Everything being properly arranged, and the index pointing steadily at 0°, the hands of the operator are to be placed in the basins, so as to be well covered with water, but not to touch the platinum plates. As it almost always happens that the index is slightly disturbed, at the instant the hands are immersed, it is necessary to wait a few seconds for it again to come to rest. Beginning, say, with the right hand, it must be clenched firmly; forcibly contracting the muscles of that hand and arm to the shoulder, but keeping those of the left hand and arm perfectly relaxed. On doing this, the index will probably move 4° or 6°. The current is reversed by contracting, in the same manner, the muscles of the left hand and arm, and relaxing those of the right; when the index will most likely move, say, to 4° or 6° beyond 0° in the other direction. Repeating these alternate contractions and relaxations six or eight times, taking care to watch the index, and making the tension of the arms to synchronize with its movements, the maximum range will be, probably, 14° or 16°. It will then decline; more quickly with some persons than others, showing that the power of the operator is nearly exhausted. After resting a few minutes the experiment can be repeated; but in most cases with very decided proofs of diminished energy.

What has just been described can be done by all persons who attempt it, provided, of course, the required conditions be complied with. In its principle it is the same as the experiment on the human muscular current by Du Bois-Reymond; differing, however, in some of its details. Instead of using salt and water (brine), as a conducting medium (p. 115), in which the fore-fingers alone are placed, I use pure water in which the hands are immersed. Few persons, as I am informed, are able to develop the muscular current by Du Bois-Reymond's galvanometer. By the galvanoscope it is easily done; children of both sexes being able to deflect the helix equally well, and with as much force, as adults.

What may be the amount, or rate, of deflection, and which may be supposed to indicate the relative force of the current, is of less importance than the fact it establishes. Here is galvanic electricity eliminated by the muscles and nerves of the living body. Call it chemical, or animal, or vital electricity, or by any other name we may choose, and all we do is to make distinctions where it is very difficult to detect any differences. A piece of silver and zinc, so small as to be scarcely recognizable by the unassisted eye, and excited by a single drop of water, will produce a current of electricity, which, tested by the galvanoscope, possesses incalculably greater force than that which can be developed, as I believe, by the efforts of any human being.

But it is not the quantity, or force, of the current in the living organism which is the chief object of our search. We want to know if there be in the human body any electricity, and if so, how it manifests itself, and whether its properties, so far as our instruments will enable us to examine them, are like, or similar to, those exhibited by the electricity of inorganic substances. Here is the proof; for which we are bound to express our acknowledgments to the phenomenon of electro-magnetism.

The experiment with the galvanoscope, proving the existence of an electrical current, which manifests itself by the forcible contraction of the muscles of the hands and arms, has been repeated a great number of times by myself, and other members of my family, and, in my presence, by more than a hundred and sixty other persons. It would take up too much space, and, until we know more about the conditions, would, probably, be of little practical value, to enumerate all the various phenomena which have been noticed. A few only of, what I consider, the most important will be here mentioned.

There is no evidence, in anything I have witnessed, that the difference in the force* of the current, as shown by different persons, is any test of strength or muscular power. On the contrary, it has been found that persons possessing the greatest amount of muscle, both men and women, provided they be in good health, almost always manifest less electrical power, as shown in this way, than do others who have weaker bodies, but who seem to have a larger share of nervous sensibility. It must, however, be mentioned that, although in muscular persons the force of the current is, apparently, not so great as in weaker individuals, there is a difference in respect to its continuance. Here the strongest bodies have the advantage. The maximum range of the index may

* This term is used throughout in its most popular sense, as implying the relative amount of disturbance of the helix, and the consequent deflection of the index.

be only 6° or 8°; but by some persons this can be maintained for several minutes, say, during 16 or 20 deflections. With the other class the case is different. By the very first impulse the index will start 6° or 8°, taking a range of 15° or 16° in, perhaps, three oscillations. It will then as suddenly decline to 4° or even 2°; the operator, in less than half a minute, experiencing sensations of fatigue which are unknown to him in ordinary processes.

The state of health has an evident influence on the force of the current.* When in good health,—that desirable condition in which there is nothing to remind us we have a head, a brain, or a stomach—all the organs, and their several functions, seem to be in a state of equilibrium; their powers being so well-adjusted and accurately balanced, as to produce the greatest quantity of vital energy, with the least amount of waste by wear and tear of material.

From a great number of observations, on myself and others, I am led to believe that a healthy and vigorous person is unable to develop the (muscular) electrical current as freely and forcibly as another

* It must be specially observed that it is not only difficult, but impossible, to make some persons understand what they have to do in making this experiment. Hence the necessity for rejecting a number of observations as useless.

with some accidental or constitutional defect, even when it may not be sufficient to occasion pain, or other symptoms of ill-health. Quite as much appears to depend upon the nerves as the muscles. It is considered (using electrical phraseology) that the current is generated in, or by, the muscles, and that the nerves, co-operating with them, only perform the part of inactive conductors. It may be so; but I still think that the nerves are more sensitive, or more perfect, conductors in some persons than in others, and in the same person, according to the state of health, at one time than another. Nervous sensibility, or irritability, is, therefore, a condition which must not be omitted. Many remarkable examples have been noticed; some, in which an overworked brain has disabled an apparently strong and healthy body; others, in which bodily infirmities have produced an unusual degree of excitability in the nervous system. In all such cases, the electrical current is very easily, perhaps I ought rather to say, suddenly, developed; its force being greater, but, as already mentioned, less durable than in strong and healthy persons.

Opportunities have occurred of testing the force of the current, in the same individuals, at intervals of several months. In many instances there has been a degree of uniformity which was wholly unexpected. Exceptive cases have not hitherto been numerous; but those which have occurred have appeared to illustrate the law, as respects the health of the operator, to which I have before referred.

A difference is frequently observed between the left and right hand of the same person. This may either be normal, habitual, or accidental. In many cases the left hand developes the strongest current, although it may be least used. A temporary difference can be produced in either hand by violent muscular exertion, as lifting heavy weights, striking smart blows with a hammer, or holding one hand in a restrained position, for some minutes, above the head.

It was noticed by Du Bois-Reymond that abrasion of the skin, or a slight wound, on either hand, caused a difference in the force of the current; that proceeding from the wounded hand being the most powerful. This I have frequently verified; a scratch, or chap, on the hand, and forgotten by the operator, having in this way been detected. In one case, during the cold of last winter, a person, whose hands were severely chapped, and, therefore, unusually tender, caused a deflection = 38°. As soon as a small, but painful, wound on one of his hands was covered with water, without putting forth any muscular effort, the index moved 7°.

In cold weather it is not only more agreeable to the operator, but greatly aids the experiment, to warm the water; which is easily done by standing a jug of hot water, for a few minutes, in each of the basins. Just that degree of temperature which is most agreeable is what is required. If the water be too warm it is relaxing, if too cold it is paralyzing, to the hands; and is, consequently, unfavourable to the success of the experiment.

The muscular current can be passed through a second person, included in the circuit, by the following arrangements, namely, the right hand of one person, and the left hand of the other, must be immersed in the usual way in the basins (p. 121), and the other hands dipped into another basin containing a strong solution of common salt. On each person alternately contracting and relaxing the muscles of the hands in the basins, as before directed, but keeping the hands in the salt and water perfectly relaxed, the deflection will be nearly equal to that produced by either of the persons when operating separately.

It now becomes necessary to say a few words on the quality of the human muscular current, by which I mean, its resemblance to the ordinary galvanic current produced by metals. Referring to the experiments described in Chapter V. it will be noticed, at page 74, that as long as the conditions remain the same, it is stated the needle will always move in the direction indicated; and that its direction is changed by changing places with the wires of the battery. In using the galvanoscope the conditions should always be alike; that is, the wires should be connected in the same order with the basins, and the position of the magnet on all occasions be the same. This is necessary, if we are desirous of insuring uniformity and consistency in the experiments. In its action on the galvanoscope, the muscular current agrees with that evolved from the zinc end of a simple voltaic circle.

For testing the apparatus I employ a wire, well protected by varnish, to one of the ends of which is soldered a piece of zinc, and to the other platinum; but only the merest point of each metal is exposed. On closing the circuit between the basins, by dipping the ends of the wire into the water, the direction of the current is ascertained. This (test-battery) wire is also useful as proving, in an instant, if the galvanoscope be in proper order.

In their electrical relations, muscles and metals are not in all respects alike, nor, in a similar sense, are nerves as insensible as conducting wires, although they are said to perform their duties in the same manner. There are variations in the direction of the current, both in man and animals, which can easily be shown to exist, although they are not so easily understood. It is only reasonable to expect this kind of adaptability to every possible exigency; but we seek in vain for its analogies in ordinary electrical phenomena.

One of the variations, now to be described, I believe I have been the first to notice. Following the directions already given, instead of clenching the hands, the fingers must be forcibly extended, and, whilst in that state, the muscles of the hand and arm contracted, when the helix will be deflected in the direction opposite to that when the hand is clenched. By alternately stiffening and relaxing the muscles of each arm the current will be reversed. Its force is not so great as in the other experiment, but, whilst the proper conditions are complied with, its direction is invariable.

Another variation in the direction of the current has occasionally occurred, which appears to depend on the state of health, or sudden exhaustion of the operator; or it may, probably, proceed from both these causes acting together. Instances have not been sufficiently numerous to require anything more than a passing notice.

The galvanoscope is an exceedingly sensitive electrical apparatus. Taking into account the quickness with which it can be used, and the little risk there is of putting it out of order, it is perhaps more sensitive than any instrument previously made. With 8 miles of copper wire, included in the circuit, the muscular current produces a deflection. There is nothing remarkable in the fact that an electrical current of low intensity will pass through 8, or even 80, miles of wire. When the conditions are favourable, I believe it to be difficult to assign a limit as to distance. The more feeble the current, the more easily does it pass; because we then approach nearer to, what appears to be, the law in natural processes. The greater the disturbance of the electrical equilibrium, the greater are the difficulties of insulation. It is one thing to pass a feeble current through many miles of wire, and, by a sensitive instrument, recognize its presence; and a totally different affair to transmit a powerful current through the same wire, so as to make it (as in telegraphing) perform some kind of mechanical operation.

In any voltaic arrangement with metals, however small the quantity (in a metallic form), it is impossible to obtain a current sufficiently weak as to resemble, in that respect, the muscular current in man.

That, however, I have accomplished in another way. The dissimilar elements consist of two equal quantities (500 grains) of distilled water, in glass vessels; one of which, having its bottom formed of a piece of thoroughly-cleansed bladder, is placed in the other. The water in the first-mentioned vessel holds in solution the $\frac{1}{1000}$th of a grain of potassa. The necessary precautions, for insuring homogeneousness in the platinum ends of the helix, and for guarding against errors from other causes, are carefully observed. At the moment of closing the circuit the deflection is usually = 2°, increasing to 4°, and then, slowly declining until the index becomes steady at 0°.

The sensitiveness of the galvanoscope will, of course, within certain limits, depend on the power of the magnet. Taking advantage of this, I have adapted to the apparatus an electro-magnet, which is more convenient, and, in some other respects, more useful than a steel magnet.

Although by this instrument, it is so easy to recognise the presence, and determine the direction, of electrical currents, which, until lately, had been only supposed, but were not proved, to exist; let it not be concluded that, we hereby are brought much nearer to the ultimate limit of electrical forces. If, by the little we know, we may judge of what remains to be known, it is probable that the feeblest muscular current, which reveals itself by the galvanoscope, is as powerful, in comparison with the gentler currents circulating in the brain and nervous system, as a 100-horse steam-engine when contrasted with the strength of one man.

CHAPTER VIII.

MAGNETOID CURRENTS.

An old device*—so old, indeed, that its origin is lost in the mist of accumulated years,—and one which, from the period of their earliest recollection, was known to some, but never seen or heard of by others, has lately become a subject of frequent conversation, and been repeated in almost every conceivable way, many thousands of times, in various parts of the world. In its simplest form, this experiment, if it may be dignified by the name, consists in suspending either a gold-ring, or shilling, by a piece of thread about eight inches long, and held between the thumb and fore-finger of the right hand, within a glass tumbler. In many cases, if held steadily, the ring, in a few seconds, will begin to oscillate like a pendulum, and in a direction to and from the operator. By exercising a little skill, it can be made to strike

* *Additional Note* S.

the sides of the glass any given number of times which may agree with the particular hour of the day, or night, at which the experiment is performed. In this way, children have been frequently amused, and sometimes gravely admonished that it was "quite bed-time." The oscillation of the ring is a true physical phenomenon; very difficult to explain—if, indeed, its proper explanation be not at present altogether unknown. Whatever, then, may be the cause of motion in the ring, that must not be mixed up with the dexterity required to produce a certain number of strokes upon the glass.

It has been stated, that "in many cases" the ring will oscillate in the manner described; thus implying that in *some* it will not do so. This is perfectly correct. There are numerous exceptions, and the causes of failure are as little understood as those of success. Let it be observed, however, that close attention and a steady hand are necessary conditions. There is a great difference between holding the hand steady, without mechanically influencing the ring, and in the latter way setting it in motion by design.

In the early part of 1851, I was reminded of the "ring and tumbler" by an article in *Chambers's Edinburgh Journal,** giving an account of some curious

* No. 375, March 8th, 1851, p. 155.

experiments described by Herbert Mayo, M.D., in a new edition of his work "On the Truths Contained in Popular Superstitions." *

To convey some idea of the information thus communicated, the following may be taken as examples :—

If a gold ring, suspended from a piece of silk or cotton thread,† about eight or ten inches long, be held between the thumb and fore-finger of the right hand, say, half-an-inch above the bowl of a silver (table) spoon, with most persons the ring will soon show signs of motion, and begin to rotate from left to right, that is, in the direction of the hands of a clock.

If the operator be a male, and his left hand be touched by the hand of a female, the ring will immediately become unsteady in its movements, and, after a little time, rotate in the contrary direction, that is, from right to left.

If a loop be tied at the end of the thread, and the ring suspended on the first (nail) joint of the thumb, it will oscillate backwards and forwards like a pendulum, and in the direction towards which the thumb points.

* Blackwood & Sons, Edinburgh. This was the second edition. A third was soon afterwards published. The author has since died.

† *Additional Note* T.

Holding the hand in the same direction as before, and suspending the ring on the first (nail) joint of the fore-finger, it will again oscillate, but its plane of oscillation will be at right angles to that caused by the thumb, that is, across the line of direction in which the finger points.

Trifling as the foregoing appears, I considered it a subject worthy of further investigation. The result has been such, as to furnish the fullest conviction that the motions here described are, in some remote way, connected with a law, at present only very imperfectly understood. Whatever it may be, and although so little can with certainty be said about it, it is not the less interesting, nor the less important, as it is, undoubtedly, connected with some of the conditions which influence life, and health, and physical energy. On pursuing the inquiry, and testing the experiments in every way I could think of myself, or which was suggested by others, and after using, instead of a ring or coin, a variety of substances, comprising the common metals, sealing-wax, glass, amber, wood, gems, and charcoal, it was found that a fixed instrument would be preferable to the continued use of the hand. A good operator has no difficulty in satisfying himself that neither muscular nor mechanical force is applied to the pendulum. There is a consciousness that its motions are perfectly independent of his hand, as far as

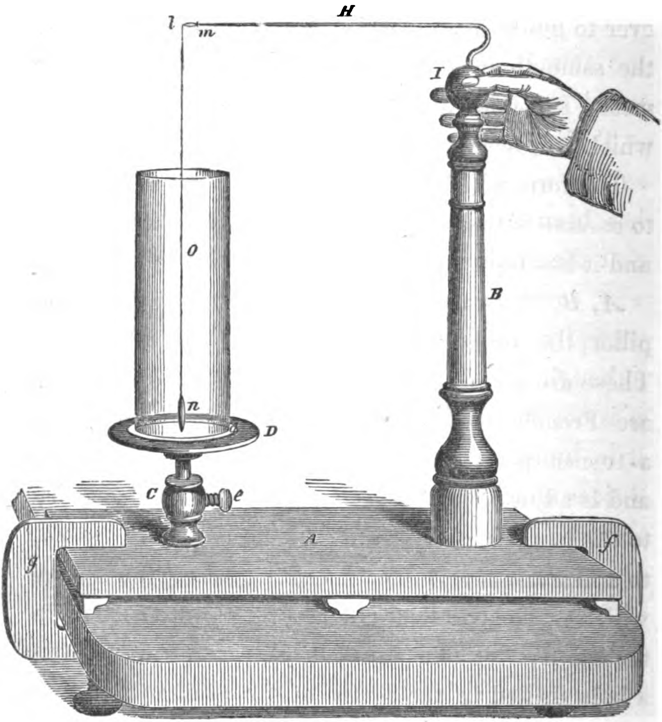

FIG. III.

regards their directions. It is not so easy, however, to satisfy an observer, especially if the individual should happen to be himself unable to produce any similar motions, without resorting to such a degree of mechanical force as can instantly be detected.

In contriving an instrument I had nothing whatever to guide me. Failures were numerous, but, at the same time, not without their uses. By their means I accidentally discovered the effect of ivory, which will hereafter be mentioned.

The form which the apparatus was at length made to assume is that represented on the opposite page, and it has been called a Magnetoscope.*

A, B, C, D, respectively refer to the platform, the pillar, the support for the disc, and the disc itself. These are all made of well-seasoned mahogany, and are French-polished. The disc, *D,* is supported on a turned pivot, working through the centre of *C,* and is adjusted by the set-screw, *e.* To give stability to the instrument, it should be secured by clamps, *fg,* to a firm and level table, placed in a room, the floor of which is, comparatively, free from vibration. *H* is a brass arm passing through the (brass) cap, *I,* and fitting a hole drilled in the centre of the pillar. The arm tapers towards its extremity, *l,* which is formed into

* Very lately I have discovered that it is difficult to invent even a new name. In "*Mosaicall Philosophy, by Robert Fludd,* 1659," in referring to sympathy and antipathy, the author describes them as connected with, and their influence shown by, a *Magnetick Scope.*

forceps, the tension of which is assisted by a sliding ring, *m*. The pendulum, *n*, is made of ebony, and is suspended from the points of the forceps, *l*, by a single thread of unspun silk. On the disc, *D*, is placed a piece of plate-glass, *d*, say, about 4½ inches in diameter, with its centre immediately under, and about a quarter of an inch below, the point of the pendulum, *n*. To protect the latter from currents of air, and from the breath of observers, it is advisable to surround it by a glass, *O*, say, 3½ inches in diameter, and 10 or 12 inches in height.

In using the magnetoscope, the principal conditions are that, the operator should stand at the side of it, placing the thumb and finger of the right hand (one on each side) in contact with the brass cap, as shown in the figure, his attention, at the same time, being directed towards the pendulum, *n*. The instrument must be held loosely, otherwise the circulation in the finger and thumb will be impeded, and no current will then pass. The hand should be kept open; that is, the unoccupied fingers should not be closed in the palm of it.

The directions of the pendulum will be better understood, and more easily remembered, by referring to the following diagram; a copy of which, without the arrows and letters of reference, should be drawn in pencil on a piece of paper about the size of the glass, *d*, and placed underneath it.

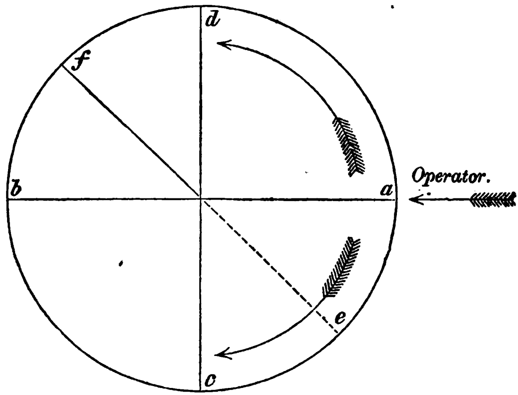

FIG. IV.

This is sufficient, as far as the construction and method of using the magnetoscope are concerned; and I shall next endeavour to explain the meaning of the terms which I have adopted, to describe the motions which are most readily produced by the instrument.

Direct rotation.—Circular motion from left to right; that is, in the direction *a* to *c*.

Reverse rotation.—Circular motion from right to left; that is, in the direction *a* to *d*.

Direct oscillation.—Pendulum motion, in the line of direction towards which the thumb and finger point, *a b*.

Transverse oscillation.—Pendulum motion at right angles to the last-mentioned, *c d*.

Diagonal oscillation.—*e f*.

Solely as a matter of convenience, and until a more appropriate name can be applied, I have designated these phenomena, *Magnetoid Currents*, (ειδος, form, that is, resembling magnetic currents.) They are not new, for they must, of course, have existed as long as electricity has been associated with vitality; but perhaps they have never before been sufficiently observed, so as to be recognised as a law of our physical constitution.

It has been already mentioned, that many persons do not possess the power of producing the motions of the pendulum, which are hereafter to be described. If they are incapable of producing them with an apparatus of the simplest kind, such as a ring and silver-spoon, for example, it will be utterly useless for them to attempt to influence the magnetoscope. This observation is made by way of warning, and to prevent disappointment.

A person who sees, and takes hold of, an ordinary tool for the first time, is not likely to use it with the facility acquired by long practice. In this case, however, the exercise of skill is not at all necessary, as the operator in reality is required to do nothing. Other conditions being similar, either hand of both sexes is capable of producing the motions in the same directions. But even among those who possess the power, there are differences in degree. The left hand is greatly inferior in power to the right. There are differences in the same person at different periods, even of the same day, and which seem to be connected with the state of health, and the use of certain kinds of food. The effects of medicine, of anxiety, and of fatigue, are also discoverable in a difference in the results produced in performing the experiments.

By the frequent transmission of electric and magnetic currents through copper wire, always in one direction, a molecular arrangement is, in a little time, produced among the particles of the metal, which makes it more susceptible than it was at the commencement. When working with constant batteries of low intensities, and with the means of measuring with extreme accuracy the amount of duty performed, I have invariably found that the current, when passed in one direction only through a definite quantity of wire, would do a great deal more work, with a given battery power, than when the current was occasionally reversed. Magnetoid currents are subject to a similar law. At first they pass feebly through the body and hand of the operator; the motions produced being remarkably slow, the directions indistinct, and the various changes with difficulty effected. These are conditions and analogies which must not be overlooked; for if they are, the experiments will be things only to be wondered at, instead of being understood and turned to good account. That which is worth doing at all, ought to be done well. Let no one be dissatisfied, or consider his own an exceptive instance, until he has given the process a fair trial.* In some cases, although the motions are readily distinguished, and are perfectly correct in their respective directions, they are so feeble as to form circles of not more than one-eighth of an inch in diameter; whilst in other cases they will be from an inch to two inches in diameter. Every person, without exception as to sex or age, has the power of

* A fair trial. This expression will be differently interpreted by different persons. Take my explanation. No one need give up the experiments as impracticable, because the motions may not be produced in a few minutes, or even a few hours. Have patience. Try but for a few minutes at a time, three or four times a day, and that during several weeks in succession. This is what I mean by a fair trial.

changing the direction of the currents by contact with the operator.

EXPERIMENTS WITH THE MAGNETOSCOPE.

1. Touch the instrument with the thumb and finger, as already directed (p. 140). The motion produced will be direct rotation.*

2. Thumb and finger, as in 1, the left hand of the operator being touched by the thumb of a male.—Direct oscillation.

3. Continue 2, touched by the forefinger of a male.—Transverse oscillation.

4. Continue 3, touched by the hand of a male.—Diagonal oscillation, *e f.* (fig. 4.)

5. Continue 4, touched by the thumb of a female. Transverse oscillation.

6. Continue 5, touched by the forefinger of a female.—Direct oscillation.

7. Continue 6, touched by the hand of a female.—Reverse rotation.

8. Conditions as 1, with direct rotation of the pendulum being fully established; if gold, platinum, silver, copper, or iron (unmagnetized) be held in the

* To avoid the necessity for repeating, or varying, the instructions, it must be understood that the operator is supposed to be a male.

left hand of the operator, the results will be as follow, namely, gold, silver, and copper,—reverse rotation; platinum—direct oscillation; iron—reverse rotation, but elliptical instead of circular, in the direction, *g h.*, (fig. 5, p. 150.)

9. Conditions as 1, with direct rotation.—If the marked end of a bar magnet, a piece of ivory,* a feather, or a dead fly, be held in the left hand of the operator, the motion of the pendulum will cease.

These experiments will be more interesting, and the conditions better understood, if, at the conclusion of each, the pendulum be brought to rest. This will occupy considerable time; but the time will be well employed in examining the force and direction of the currents.

It is desirable that the operator, as soon as possible, should familiarize himself with the effects of different substances, as a means of enabling him to stop the pendulum. There is a difference, in this respect, with different persons. Susceptibility to one substance, as contrasted with another, is sometimes immediate, whilst in other cases it comes on slowly. Let it be remembered that, what may be termed the

* The effect of ivory, in stopping the motions of the pendulum, was discovered whilst endeavouring to construct an apparatus with that material.

negative effects upon the pendulum, that is, preventing its movements, are just as much dependent on the polarizing influence of magnetoid currents, as inducing, or altering, their forces or directions by other means, influence its movements. Bringing the pendulum to a dead stop, in a few seconds, is a great convenience, as well as a remarkable phenomenon; and supplies a tolerably fair test of the relative force of the current in different operators, and the facility with which they use the magnetoscope. This I can best illustrate by an example. When the pendulum has acquired a certain momentum, either rotatory or oscillatory, as the case may be, if left to itself it will occupy seven or ten minutes in coming to, what might be considered, even an approach to, a state of rest. If the same experiment be performed, observing precisely the same conditions, and if the operator be readily influenced by ivory, or bone, a dead fly, or some other kind of dead animal matter, or by certain vegetable or mineral substances (the effects of which had been previously ascertained), he will be able to bring the pendulum to a state of absolute rest, say, in from five to twenty seconds.

10. Conditions the same as 1.—If any number of persons, male and female, arrange themselves in such a manner as that one of each sex shall alternately

join hands (one by one, and left hand to right throughout the series) beginning at the left hand of the operator, the motion of the pendulum will change to diagonal oscillation, *ef* (fig. 4), with each male, and to reverse rotation with each female. The sex of the person last in the series, that is, most remote from the operator, will always determine the motion, and without regard to the number of persons of each sex.

11. Conditions as 1.—Vary the preceding experiment by a number of persons joining hands, one by one, at intervals of about five or ten seconds, say, females first, when the pendulum will acquire additional force as each individual adds her influence; constituting what may be termed a magnetoid battery. Similar results will, of course, follow when persons of the male sex in like manner join hands. When the pendulum has acquired its greatest force, by a number of persons thus joining hands, if the last person in the series touch the right hand of the operator, the circuit will be closed, and the pendulum will stop. In performing these, and many similar, experiments the practised operator will easily distinguish the persons most sensitive to the influence of these phenomena.

12. Conditions as 1, the operator standing on an electrical (insulating) stool. The pendulum will

remain stationary. If one end of a piece of cotton thread be held in the left hand of the operator, and the other end placed upon the floor, the motion of the pendulum will be immediately resumed, and will be—direct rotation.

13. Place a bar magnet, in the direction of the meridian, near the left hand of the operator. Conditions as 1. If the left hand be held within the range of the magnetic curves, say, two or three inches beyond the south pole—direct rotation; at the same distance from the centre, on the east side—direct rotation; at the same distance on the west side—reverse rotation; and at the same distance from the north pole the pendulum will stop.

14. The motions just described are also produced by the hand being held in different positions near the head of a person of either sex. Thus:—about three or four inches from the back of the head—direct rotation; at the right side—direct rotation; at the left side—reverse rotation; and at the same distance immediately in front of the head the pendulum will stop.

15. If a specimen of rock crystal (quartz) be laid on the left hand of the operator, its longitudinal axis being in a line with, and its apex pointing towards, his fingers—oscillation in the direction *e f* (fig. 5.)

16. Changing the position of the crystal, its base being directed towards the fingers—oscillation, *g h*. If the crystal be laid across the hand, with its base directed towards the operator—reverse rotation; and on changing its position again, so that its apex shall be towards him—direct rotation.

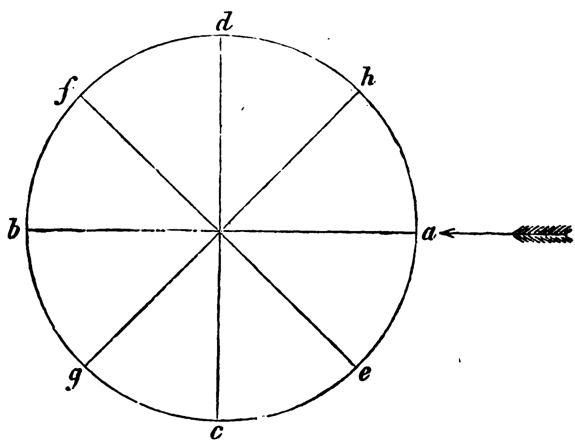

FIG. V.

17. If the crystal, held steadily between the thumb and finger of the right hand of the operator, be placed against the brass cap, *I*, of the magnetoscope, the various motions of the pendulum, as described in the last experiment, will be produced by contact, in this way, of the ends and sides of the crystal.

18. The power of a crystal is further shown by

placing it on a stand, entirely detached from the table which supports the magnetoscope, and in such a manner that it shall only be very near to, but not in actual contact with, the brass cap, *I*, of the instrument. In this position, if the right hand of the operator be laid upon the crystal, whilst the pendulum is perfectly at rest, it will soon begin to move in one of the directions already indicated, according to which part of the crystal is directed towards the instrument. On changing the position of the crystal the motion of the pendulum will also change.

The last-mentioned experiments are exceedingly interesting; but require great care, quietness, and attention. They admit of many variations with perfect crystals, as well as with native crystalline formations of metalliferous ores.

Passing from these to the metals themselves, I soon perceived that, tested by the magnetoscope, the motion of the pendulum produced by each metal, was irrespective of its quantity; the smallest particle which could be identified, causing its characteristic motion with unvarying constancy. At an early period in these investigations, the effects of very small quantities of salt, sulphur, and several other substances, had also been noticed.

These few hints must suffice. There may be a substratum of truth where there is much that an ordinary observer may consider fanciful, or mysterious. A great deal of what appears to be mysterious, is made so by habitual neglect. Careful investigation would clear up many difficulties. But who will undertake to investigate, in the hope of satisfying those who make up their minds before they hear any evidence? If all persons, on first touching the magnetoscope, could influence it alike, we might have less confidence in its sensitiveness, and the accuracy of its indications. When it is found that those most anxious to set the pendulum in motion, after frequent trials, have no power over it; whilst others impart to it the proper motions, although feebly, in a few minutes, it is evident that wishing is one thing and realizing another? The conditions are exceedingly simple. There is no special virtue in any particular piece of wood, or brass; but if, in total defiance of every reasonable condition, attempts be made to elicit magnetoid phenomena, and such attempts fail, the failures ought neither to occasion regret, nor excite surprise.

Many illustrations which are not described, have presented themselves, most unexpectedly, as incidents in other experiments, and they are, therefore, in a certain sense, entirely accidental. For that reason, however, they are immeasurably the more valuable. In this way I have been taught a great deal, unknown to me before, about the different effects of sun-light, and of moon-light, on metals, crystals, plants, wood, meat, fish, and the human body. The polarizing influence of the earth, whether produced by electricity or magnetism, is also a subject intensely interesting; the proofs of which are much nearer to us, and much more abundant, than may be generally expected.

Whatever be the cause of the various motions of the pendulum, it is sufficient, for my present purpose, to have described some of the results of my own experience. Although it is more than two years since my attention was first directed to this subject, I am now as unwilling, if not as unable, as I was then to undertake any explanation of it. We believe many things we cannot understand; and there are occasions when it is of greater importance to investigate phenomena, and record facts, than invent theories.

Those who are most familiar with electricity, magnetism, and electro-magnetism, and those especially who know anything about dia-magnetism, will have but little difficulty in linking together, in what very much resembles an endless chain of cause and effect, phenomena which, whether viewed separately or in combination, present, even to the most practised observers, a succession of wonders. Guided by what is already known, of electricity inherent to the human body, of its relations with inorganic substances, as well as its susceptibility to vital influences; there is no great effort required in believing that, such influences extend very far beyond the range of any instruments hitherto constructed for detecting their existence. The galvanoscope, sensitive as it is to muscular and nervous currents, set in motion by voluntary efforts, is wholly incapable of indicating the presence of others, which in a certain sense, may be termed involuntary. Every movement, look, or gesture; every sensation of pain or pleasure; every emotion, however transient; and, perhaps, every thought unexpressed or word uttered, is, most assuredly, accompanied by the disturbance of electromotive forces. These, however, are so much more feeble than any with which we have hitherto become acquainted that, in the healthiest and most active, during a week, or perhaps a month, their cumulative effects may not be equal to those evolved by one smart blow of the hand upon a table.

Whether the motions of a pendulum, produced in the manner I have been describing, be truly and entirely electrical, or whether they be of a mixed character partly dependent on vitality, and partly on electricity, and which cannot be disassociated, is more than I will undertake to decide.* There is enough in these experiments to encourage and reward further inquiry; the most likely means which I can think of for arriving at the truth.

Let it not be supposed that I am ignorant, or regardless, of the numerous objections which have been made to the experiments with the magnetoscope. These have at all times received the attention which I have considered due to them. Those most frequently repeated will be referred to in another place.† The chief part of the objections have originated with persons who have never witnessed my experiments, and who have had no other means of judging of them than from the unauthorized and, frequently, incorrect statements of others.

* *Additional Note*, U. † *Additional Note*, V.

CHAPTER IX.

ARE HEALTH AND DISEASE AFFECTED BY ELECTRICITY?

Is it likely that a knowledge of human electricity will be productive of any practical benefit to man? This is an important question—so important that no one is more impressed with the necessity, and, at the same time, the difficulty, of answering it than the writer himself.

It has been shown (page 38), that the human body is electrical—capable of being electrically excited in the same sense that a piece of sealing-wax, or glass, can be said to be so operated upon. It has also been stated that the body requires to be treated in a manner different from wax or glass, to make it develop its electrical properties. This is because the human body is a conductor, whilst wax and glass are non-conductors. A piece of metal is as easily excited as wax, but to enable us to obtain proofs of its excitability it must be insulated, that is, a glass handle must be affixed to it. By causing a person to stand upon a stool with glass legs, and then rubbing him briskly with a piece of dry fur, a sufficient quantity of electricity may be soon collected from him to charge a Leyden jar; and, by its means, to explode gunpowder, inflame spirits of wine, or produce the ordinary phenomena of a snap, a spark, and a shock. A person, thus insulated, can excite electricity by the friction of wax, or glass, or metal, against his own hand, or head, exactly in the same manner as when he is standing on the floor.

It must be remembered that electricity always evinces a sort of antagonism, very difficult to call by its right name, because we are ignorant of what constitutes these opposite states or conditions.* The

* Whatever may be the real cause of this, and whether or no it it will ever be known and satisfactorily explained, or remain as great a mystery as it is at present, the following effects are easily proved, namely,—that bodies in similar states of electrical excitation *repel*, while those in opposite states *attract*, each other. It ought to be mentioned further that, in every case of repulsion and attraction, the action between the bodies operated upon is strictly mutual. A feather is not attracted by a piece of glass with greater force, in proportion to its weight and the quantity of electricity it may contain, than the glass will be attracted by the feather. But in practice the feather is moved simply because it is the lightest body of the two.

fact is sufficiently plain, that one kind, or state, or condition, of electricity never exists alone. Where-ever there is any manifestation of electricity there also will be found to exist the two opposite kinds, waiting, as it appears to us, for the first convenient opportunity to liberate themselves from the state of antagonism which had been excited in them. Taking this view of what is, confessedly, involved in great obscurity, we may imagine that, whilst all electrical forces are resultants of these mutual interchanges, the energy exhibited is proportionate to the amount or rate of disturbance. Hence it is reasonable to believe that *ordinary* electrical phenomena are unknown to us, not because they are intentionally unnoticed, but because we have not yet learned the way, and do not yet possess the means, of recognizing them; and that all we really know about electricity is from observing some of its *extraordinary* manifestations as occurring in natural processes, or as produced by some special arrangements, as a means of instruction or amusement.

The foregoing illustrations refer to what is called common or frictional electricity, because, both in their appearances and effects, they resemble the electricity elicited by the ordinary machine. Here, therefore, we experience no difficulty in recognizing in the living organism of man, the same electrical properties which appertain to inorganized substances. Any one who wishes to obtain the necessary proofs may do so by a few simple experiments.

The same kind of electricity which presents itself to our notice the instant we rub a piece of wax or glass, or, by the special arrangements before described, a piece of metal, is always the attendant upon our planet, as constituting a part of the atmosphere. In a literal sense, we may be said to be immersed in an ocean of electricity; for we cannot suppose it to be ever absent from the earth, more especially near to the surface. The quantities in the air are variable; changing from day to day, and hour by hour. These changes, we are accustomed to say, are influenced by heat and cold, drought and moisture, the force and direction of the wind, and cloudiness and sunshine; but it seems more probable that the variableness in the quantities of electricity is the cause, and not the effect, of such changes (p. 97).

The phenomena of magnetism have been hurriedly glanced at, and whilst some of the special influences of magnetism upon iron and steel have been noticed, we must try to realise the fact that it is as constant an attendant on our world as electricity. At page 65

I have described a method by which it can be proved that iron is always magnetic, that is, endowed with what is called magnetic polarity. This aptitude of iron, a congeniality in the arrangement, or the quality, of its molecules, for the reception and retention of magnetism is very wonderful; but is it more so than the aptitude of sealing-wax, or glass, when rubbed against the hand, or a piece of metal, when rubbed against the hair, to exhibit electrical properties?

That which is so easily elicited by the friction of one substance, and which we call electricity, may, for aught we know, be what is called magnetism in another substance. There is nothing fanciful in this, nor is it opposed to analogy. By rubbing, in a particular manner, a piece of iron, or copper, or silver, it will manifest electrical properties; by moistening the surfaces of any two of the same metals and placing them in contact, electricity will be again elicited; and by passing a current of (galvanic) electricity through, or along, (for we are not sure it goes through,) either of the same pieces of metal it will become (electro-) magnetic. It is true, a great difference is observed between, what we call, the habits of common and chemical (galvanic) electricity; but this is most likely owing to our being, as yet, unable to find out other manifestations of the pre sence and power of this wonderful agent. We see its operations only in detached parts, widely separated from each other. In one place it is diffused; a small quantity spreading itself out and covering a county or a kingdom. In another it concentrates its energies; striking so suddenly and with such irresistible force, that "men's hearts fail them for fear." Seeking it again, in some other direction, it presents itself still more closely compacted; a quantity, perhaps, greatly exceeding that which in the thunder-storm fills us with dismay, quietly reposing in a few drops of water.*

These variations, together with the different names we have applied to them, and the instrumentalities

* "It is wonderful to observe how small a quantity of a compound body is decomposed by a certain portion of electricity. Let us, for instance, consider this . . in relation to water. *One grain* of water, acidulated to facilitate conduction, will require an electric current to be continued for three minutes and three quarters of time to effect its decomposition, which current must be powerful enough to retain a platinum wire, $\frac{1}{104}$th of an inch in thickness, red-hot in the air during the whole time; and if interrupted anywhere by charcoal points, will produce a very brilliant and constant star of light. If attention be paid to the instantaneous discharge of electricity of tension, . . it will not be too much to say that this necessary quantity of electricity is equal to a *very powerful flash of lightning*."—*Faraday.*

we employ to elicit their effects, are but so many concurrent proofs that we have to do, under different aspects, with one mighty and universally diffused agent. We are able to follow electrical phenomena through many of their changes; but there is "a path which the vulture's eye hath not seen," and at the entrance of which we can only stand still, and wonder, and admire. Still, however, let us not be discouraged. Casting a look backwards at the mixtures of fable and folly—the unintelligible jargon—which passed for learning and philosophy about 200 years ago, there is enough to inspire thankfulness for what we now know, still leaving a wide margin on which to exercise hope for the future.

The illustrations of electro-magnetism must not be forgotten (page 73); especially the fundamental principle that a current of electricity, when moving in a particular direction through, or along, a conductor, creates another current (the electro-magnetic), at right angles to itself. Dia-magnetism, and some of its marvellous revelations, have had a few passing words bestowed upon them (page 88); and so has a still more difficult subject—the sun as the source of electricity in all its varied aspects (95).

The conducting properties of the earth are exemplified in the telegraphing process (page 76). The different materials of which the crust of the earth consists, and the occurrence of local disturbances, whether natural or artificial, appear to offer no impediment to the transmission of an electrical current. Whatever be the distance a current is conveyed, in one direction, by a wire, whether hundreds or thousands of miles, the same current will return, in the other direction, through the earth. This is not a newly discovered fact; although its practical application is of a recent date. More than 100 years ago it was proved by experiment that the earth was a good conductor; an ordinary Leyden jar having been discharged through a circuit several miles long, and which consisted of both earth and water.

The existence of a true galvanic current in the muscles and nerves of all animals when living, and in some after they are dead, has also occupied our thoughts; after which, in their natural order, followed experiments with the galvanoscope, proving the existence of a similar current in the human body.

The curious illustrations of what, I have called, magnetoid currents occupy the next chapter. By those who wish it, these experiments may be kept by themselves until they are better understood.

From the several branches of the subject which have thus passed, very briefly, under review, I think the following deductions may fairly be made; premising, for the convenience of the reader, that a difference in the arrangement of type is made to distinguish those which can be demonstrated by experiment from those which, at present, can only be inferred.

a.—That the atmosphere surrounding the earth always contains, what is known as, common electricity; but in variable quantities, in different places, and at different times.

b.—That magnetism is always present in the earth and the atmosphere, and that its intensity and polarity are variable.

c.—That the earth is a good conductor of both kinds of electricity—common and galvanic.

d.—That (in scientific phraseology) the atmosphere is a non-conductor of galvanic, and a slow, or very imperfect, conductor of common, electricity; but that its conducting properties are increased by moisture.

e.—That all animals possess inherent electricity, which is generated—not derived; and in some it manifests itself only as galvanic, but in others in both forms—common and galvanic.

aa. Is it not reasonable to believe that all animals, reptiles and insects—everything endowed with vitality on the earth, in the air, and in the sea—are subject to a common law of electralization?

f.—That man possesses inherent electricity, which is generated—not derived; and that it manifests itself in both forms—common and galvanic.

bb. The only way, at present known, for detecting the existence of a galvanic current in the human body, is by its electro-magnetic effects, as shown by the galvanoscope; but it must not hence be supposed that there are not galvanic currents, evolved by the ordinary processes of life, which are of inconceivably lower intensity than any which have been hitherto discovered.

cc. If the presence of a galvanic current can only be detected by its electro-magnetic effects, such currents, however feeble, are electro-magnetic. May we not also conclude that *all* electrical force is accompanied by a corresponding electro-magnetic force?

dd. If electro-magnetism be a constant attendant upon electricity, are there not magnetic, as well as electric, currents always circulating in the human body? And, if so, were some of the old writers very far wrong in their curious guesses about animal magnetism? Instead of some, and only a comparatively small number of, persons being sensitive to magnetism, is it not more wonderful that the number so affected is not greater?

ee. It is a mistake to suppose that because persons of certain temperaments, or in some particular states of health (electro-sensitives), are susceptible to magnetic influences, that they ought, therefore, to be able, by the force of their own electro-magnetic (?) currents to influence a magnet. This is just as reasonable as it would be to say, because an elephant can carry a man, a man ought, therefore, to be able to carry an elephant. A very little electrical knowledge will teach any ingenuous inquirer, that the conditions are widely different. The force of the human current, in its ordinary state, is so feeble that it is absorbed (neutralized) by that of terrestrial magnetism; and, unless the former be greatly increased (multiplied, as by a galvanometer), no proof can be obtained that electricity, and, its attendant, electro-magnetism, are evolved at all. By the force of the *ordinary* human current we are no more able to influence a magnetized-needle, however delicately it may be constructed, than we are to project a shadow upon the disc of the sun, by the aid of a wax-taper.

ff. Electricity being so closely associated with vitality, is it not probable that it exercises a powerful influence over the operations of mind? May not the brain be like a central telegraph-station—a medium of communication between the mental and the corporeal?

It has been stated that electricity is generated within the human body—not derived from external sources. We know nothing of the processes in operation, or of the materials employed, for its production. For the present we must be satisfied with a knowledge of the fact. Its existence can be proved, and we can also prove that, when all the conditions appear to be alike, electricity is evolved more readily (with greater force, or greater quantities in a given time) by one person than another. It is also certain that some persons are more susceptible to external electrical influences than others. For example, some are affected by sudden changes in the weather, or the direction, or force, of the wind; by an unusual quantity of electricity in the atmosphere, or the contrary; by the proximity of an electrical machine in action, or the occurrence of a thunder-storm. Others are still more susceptible—for they know by their sensations, whilst in bed, if the direction of the wind has changed during the night; they can foretell coming changes of weather which are not expected by the proverbially "weather-wise;" they can indicate the approach of an electrical cloud, when it is too far off to be recognized by an ordinary observer; and they can direct attention to the *aurora-borealis* when unseen by themselves.

Antipathies with respect to certain animals, birds, insects, and reptiles, and which in some instances are mutual, and in others only on one side, are most likely allied to this class of phenomena. The proofs are sufficient that the sensations, said to be experienced are neither fancied nor feigned. Nor is it undeserving of notice, that the command which some persons exercise over animals, and even venomous reptiles and insects, is more easily accounted for, by reference to their electrical relations, than on any other principle.

Man cannot, even if he were to desire it, be an isolated being. He may shut himself up, or wander far away, out of the reach of human society; but he must still communicate with the living world. If all other connecting links are broken or destroyed, in "the electric chain," there is yet one which cannot be separated until life has departed. We know scarcely anything about the processes by which constant supplies of electricity are, by the mechanism of the body, provided for our use; nor are we able to estimate its quantity, the rate at which it is diffused, or the arrangements by which galvanic electricity circulates in the muscles, and nerves, whilst common electricity is evolved from the hair, the hands, and other parts of the body. Still, sufficient is known to satisfy any attentive observer that electricity is involuntarily, yet necessarily, in this way diffused; and with a greater, or less, force dependent upon sex, age, and temperament; the state of the health, and condition of the atmosphere, and, perhaps, upon a number of other circumstances which are far beyond the range of our capacities to understand. In this way, in a special sense, we are connected with the external world, and to none of us is this a matter of mere choice, but one of stern necessity. In this way, too, we become identified with particular localities, and participate, in common with those around us, in whatever special influences, whether for good or ill, that may appertain to a house, a street, or a village; or even to a town or country.

The operation of the agencies which produce and propagate diseases, whether endemic or epidemic, are, at the present time, enveloped in much obscurity. The sudden occurrence, and frequently as sudden disappearance, of these visitations are commonly attributed to atmospherical influences. At one time, commencing in special localities and radiating as from a centre, they gradually expand in volume and increase in power, whilst their progress is unchecked either by rivers, mountains, continents, or seas. At another time, they appear simultaneously over large geographical surfaces, and without regard to differences of climate or temperature, or the habits of the people, all classes and conditions of men, whether in the crowded city, or the open country, are alike subject to the prevailing disease. Sometimes, following isothermal lines with remarkable exactness, to the unscientific observer, a disease appears to go out of its way in search of materials; whilst at others, a practised eye can recognise the most arbitrary deviations with respect to temperature, but a steady advance upon the track of the thickly-populated districts. In all this, there is enough to make the most enlightened person feel, how difficult is any attempt to determine where such calamities come from, and in what places they again conceal themselves.

Whilst acknowledging, in the broadest sense, the ceaseless operations of a general and special Providence, it is equally our duty to believe that the "pestilence," whatever be its form, is as much the result of the operations of natural processes, acting in conformity with fixed laws, as those which produce sunshine and clouds, cold and heat, wind and rain. The prevalent opinion that certain diseases originate in, and are propagated by, the atmosphere, has too readily, and for too long a period, drawn off our attention from other and more active agencies; and whose operations are carried on not only above, but beneath, us. Instead of examining the air which comes to us from the hills, or from the sea, we might be better occupied in searching for *miasma* in, and around, our dwellings. It is there, whether we believe it or not; and, like vapour from a foaming caldron, is emitted from drains, sewers, cess-pools, and closets. More concealed, but not less dangerous, it is always ready to rush out from vaults and burial-grounds, and the polluted waters of rivers, wells, and water-butts; and, although a little more diluted, and on that account likely to be less dreaded, it has its lurking-places in damp cellars, gardens, and court-yards; and in cold, damp, imperfectly lighted, and still more imperfectly ventilated, sitting-rooms and bed-rooms. These are as truly manufactories of influenza, fever, rheumatism, diarrhœa, and cholera, as large buildings, with tall chimneys, and filled with workmen and machinery, are of candles or calicoes.

That the atmosphere is one of the media through which the conditions necessary to preserve health, or produce sickness, are readily attained cannot, I think, be denied; but is there any evidence that the atmosphere, in large quantities, ever contains anything injurious to animal or vegetable life, excepting the impurities which, so to speak, are accidentally mingled with it near the surface of the earth? In this sense, and in no other, perhaps, it may be said that the atmosphere generates and propagates diseases. Is it not, however, equally true that the evils man has thus to endure, are, either through ignorance or habitual negligence, self-inflicted?

When we become better acquainted with the habits and properties of the newly-discovered element in the atmosphere, *ozone*,* it is probable we shall know a great deal more about the important offices assigned

* *Additional Note* W.

to electricity. One of these offices, undoubtedly, is restorative — revivifying that which is hastening to decay. Quickening the varied processes of decomposition, it also neutralizes the separated elements, and then, endowing them with life-sustaining properties, they are diffused hither and thither—passing through their innumerable transformations without either waste or weariness.

That life and health are not dependent upon any ordinary degree of temperature, we have abundant proofs from the testimony of residents within the tropics, the physical condition of the people inhabiting the north of Europe and America, as well as in the experience of the arctic navigators. An extraordinarily dry, or damp, atmosphere is not, in itself, unfavourable to health. In Australia the atmosphere is occasionally so hot and dry that it resembles the air issuing from a heated oven, but even there, persons who have been accustomed to the more temperate climate of England experience no ill effects. Those who pass the greater part of their lives at sea, and who are exposed to every conceivable variation of heat, and cold, and moisture, are not more liable to disease than others.

Pure air, pure water, cleanliness of the person, cleanliness in and around the dwelling, effective drainage, the hasty removal of everything in a state of putrefaction and pollution, are conditions absolutely necessary to the preservation of health. Something more than these is also necessary, according to climate, and the changes in the weather. We require warmer clothing, at one time than another; and at all times, next to a warm, and well-ventilated, dwelling what is so essential as wholesome and nutritious food?

A humid atmosphere, that which is so well known in this country because the moisture can be seen as well as felt, is usually the fore-runner of colds, coughs, and rheumatism.* At the time when these prevail the air is a good conductor of electricity, and, following the well-known law of its diffusion, a greater quantity of it than usual is then abstracted from the body. This may, in part, be prevented by extra and suitable clothing; and it is especially necessary that the feet be kept dry and warm. The loss of animal heat is probably accompanied by that of electricity. Inflammation is often the result of sudden exposure to cold. Is it not possible to account for this by the rapid abstraction of electricity, either locally or generally, the disease affecting particular organs, according to the kind, or degree, of exposure, or their

* *Additional Note* X.

special susceptibilities? Many diseases peculiar to particular countries, and which are sometimes widely prevalent at the same time, although not classed as epidemics, are, probably, occasioned by sudden changes in the electrical relations of the body, and of the surrounding atmosphere. Does it not frequently happen that either a gale of wind, a severe thunder-storm, or a shower of rain, is the harbinger of health and comfort to thousands of persons?

Concerning the disease which has so lately re-visited this country, and which fell with such terrible force upon one particular district, very little is yet known. Many years ago it was considered remarkable that, in its progress from city to city, and country to country, the cholera advanced against the wind; and it was also considered equally remarkable, that it frequently appeared at almost the same instant of time in places many miles apart, having passed by, or over, others lying directly, as we should imagine, in its route. On these grounds, the disease was viewed as connected with something altogether beyond the range of ordinary epidemics, and thus terror helped to increase the number of its victims. If rightly interpreted, some recent experiences are, seemingly, calculated to inspire hope and a greater degree of confidence. Whilst lamenting the dead, renewed energies are still required on behalf of the living. Cholera is controllable; although, at present, in some of its worst forms, it may, perhaps, be incurable.

Impurities, operated upon by a specific temperature, appear to be precisely the conditions required to produce this much-dreaded disease. It is impossible to classify the impurities, to state their exact quantities, or to fix upon the particular degree of temperature. There may be other processes at work, along with these primary elements, which are at present unknown to us. Still, electricity cannot be excluded. As a restorative, it will be found to be busiest where the amount of impurity is greatest. But supposing the impurities in any given locality to exceed, what we may call, the mean averages, how are we then likely to get on? If either through ignorance, or negligence, or design, more work has been allotted to electricity, in that particular locality, than it could possibly perform, should we, therefore, expect it to deviate from its ordinary course, in order to protect man from the consequences of his own misconduct?

No fact is more easily proved than that electricity exists in variable quantities in the atmosphere, and which, according to temperature and the relative proportions of moisture present, is at one time a slow, and at another time an exceedingly quick, conductor. I believe, therefore, that inherent electricity—that electricity which is generated in the bodies of men and animals, is more rapidly diffused at one time than another. In an impure atmosphere, I consider that the demand upon the electrical mechanism (?) of the human body may be so great, and so suddenly made, as to produce such a degree of exhaustion of the vital energies, as will result in disease and death. In addition to a polluted atmosphere, requiring electrization to deprive it of its noxious properties, if the demand upon the electricity of the body be further increased by impurities in the earth, the house, the clothing, the food, and, perhaps, worst of all, in the water, can we wonder that, in such a locality, "man goeth to his long home and the mourners go about the streets?"*

We have a great deal yet to learn, and to put in practice, with regard to the preservation of health. The beneficial effects of sun-light are not sufficiently considered. Apart from the cheering influence of light, as contrasted with darkness, there is a specific power in the direct rays of the sun, which must be experienced to be fully appreciated. By the con-

* *Additional Note* Y.

valescent and the habitual invalid (electro-sensitives?) this is much better understood than by persons in good health.

In the management of our houses there is room for improvements, and especially in that of large houses with a corresponding number of occupants. In this proverbially variable and humid climate, sufficient attention is not bestowed upon the necessity for keeping the interior of a house thoroughly dry. The opening of windows, and the letting-in of fresh air, should not be neglected; but even here, in what appears to be so very simple a matter, the exercise of a little discrimination is still required. Exceptive cases should be attentively studied; and, when the atmosphere is charged to excess with moisture, some other means of ventilating should be adopted. At such times no air should be admitted direct from without, but only through the entrance-hall or passages. By having fires occasionally in the different apartments, not excepting the bed-rooms, the walls and furniture would be kept dry and warm, and the spontaneous circulation of pure air promoted. There should also be an exercise of judgment, even in violation of otherwise good rules, in reference to the washing of floors, more especially those of bedrooms, during the winter months. Without precautionary measures of this kind, too much washing will occasion more mischief than too little. In schools, the foregoing hints are particularly deserving of consideration; because that kind of miasma should be most guarded against which makes its attacks insidiously. There may be, what is considered, the extremes of care and cleanliness; and yet, by overdoing the scrubbing and washing, and under-doing the drying and warming, the conditions best calculated to preserve health will be unintentionally inverted. Above all, let it be remembered that, if there be one thing more likely than another to generate disease it is the air which, having once passed into the lungs, is breathed over again by the same, or another, person.

Our notions of ventilation are very much too limited. Instead of thinking only of ventilating a room, or a house, we should endeavour to devise the best means for extending the process to a street, a district, or a town. Nor must we be content with one form of ventilation only. It is as much required beneath, as it is above the surface of, the ground; and unless a perfect system of drainage be combined with effective ventilation, the inhabitants of crowded cities will never realize the blessing of a sufficient supply of pure air.

Why are the cold and damp walls and furniture of a house unfavourable to the health of its occupants? I believe the reason is that, being good conductors, they abstract the electricity too rapidly from the body; and for precisely the same reason all descriptions of cold, damp, and ill-ventilated rooms, whether public or private, are the most certain places for passing through the preparatory stages of an attack of disease; and which is more likely to assume the character of a prevailing epidemic than any other.

The unanimity which sometimes subsists between persons who are, apparently, as opposite as they can well be in their dispositions and tempers; the influence which, not unfrequently, one person acquires almost instantly over another, or many others; the sensations, both pleasant and disagreeable, which some persons produce on others; the dislike to particular kinds of meat, vegetables, fruits, and odours,* are all very well known and readily acknowledged. These, I believe, are referable to electrical susceptibilities, and to that cause alone. The excitement and healthfulness of horse exercise, are by no means likely to be entirely due to an elevation of a few feet from the ground; but are probably occasioned, in part at least, by electrical communication with the animal;

* *Additional Note Z.*

and, if so, may not the health and soundness of the horse be of importance to its rider?

Whilst man is thus placed in circumstances in which he appears to be surrounded by so many dangers and difficulties, it should never be forgotten that many of them are of his own making. Good and evil are at present closely allied. They exist amidst the highest attainments of civilization, as well as in the lowest depths of barbarism. To know how to recognise good, and make it the object of our choice, and, at the same time, to be enabled to reject the evil—this is, or at least ought to be, the putting into practice some of the first lessons taught us by philosophy.

It should also be mentioned that external, and what we may call physical, influences are not exclusively the cause of electrical disturbances in the human body. I have referred (p. 113) to a current in the nerves, proper to themselves, and independent of muscular action. Here we approach so near the operations of thought, and the extraordinary power which it exercises over the functions, the motions, and the sensations, of the body, that it is safer only to hint at such facts than attempt to explain them. How it happens that a look, a word, a scream, the sight of blood, the description of an accident, the receipt of a letter, or a hundred other circumstances which occur in the every-day scenes of life—blanches the cheeks, takes the strength out of the limbs, makes food distasteful, or prostrates man on a bed of sickness, surpasses our comprehension. With such phenomena we are but too familiar, and we know and often feel them to be true; but, making this admission, it is best here to leave them.

In all that has been stated my principal object has been, to try to direct the thoughts of others to that which I know to be an important subject. It is only by the practical application of a knowledge of human electricity, and of our electrical relations with the outer world, that we can expect to be benefited ourselves, or hope to confer benefits on others. It is easy to say, "these things have long been known," and then to pass by on the other side. If they have been known, why have they been so often denied? And why have so few efforts been made, to apply such knowledge to the relief of suffering, and the prevention and cure of diseases? The more numerous our privileges the greater are our responsibilities. Let us not neglect the warning, "Whatsoever thy hand findeth to do, do it with thy might."

ADDITIONAL NOTES.

ADDITIONAL NOTES.

A.

Animal Magnetism.—*Note A, page 4.*

It is necessary to make a distinction between Animal Electricity and Animal Magnetism. The latter, now more commonly called Mesmerism, stands first in order of time, and had caused a vast deal of contention many years before Animal Electricity was known, or even suspected, to exist. The natural loadstone (magnetic iron ore) as well as artificial (steel) magnets, have long been supposed to exercise a peculiar influence over the human body. In ancient times the mineral (loadstone) was used in a variety of forms, either alone, or mixed with other materials, as a medicine for the cure or relief of certain diseases. It was applied both internally and externally, and its effects were considered to operate beneficially upon the mind as well as the body. In process of time the invisible magnetic "fluid," that is, the magnetic curves, or emanations, existing around a magnetized body was supposed to be equally efficacious, in preserving or restoring health, as the loadstone or magnet in its grosser and palpable form.

In an age when a belief in the magical and the supernatural, in connexion with the commonest affairs of life, was all but universal; when everything was attributed to occult and mysterious influences, and the causes of the most ordinary of natural processes were neglected and unknown; when charms, and amulets, and exorcisms were the constant resource of those who professed to practise the healing-art; when surgical operations, judged by our present knowledge and experience, were cruel and dangerous; when medicines were compounded of materials revolting to the feelings, and administered in a way that was disagreeable and often indecent;—we need not be surprised if an agency, so truly marvellous in its physical manifestations as the magnet, should have arrested the attention and won the sympathies of all classes.

It is easy to express our wonder at the ignorance which prevailed, even at a period comparatively near to our own times, say, within the last hundred years; but it is not so easy mentally to realize the disadvantages under which the (so-called) learned men of that day thought, and reasoned, and acted. There was the desire for knowledge then, as now, and it was as highly prized as by ourselves. But the labour of searching for it was immense. A little truth was buried under heaps of rubbish—the whole of which had to be turned over and carefully examined. This was the work of years—often of a whole life. Many natural phenomena known to us, were as well known at very remote periods; and not the facts only, but the conditions. For want of the same methods of preserving and diffusing knowledge which we enjoy, these things were lost; then found again; and again lost, for longer or shorter periods, according to the age, the country, or the habits of the people.

Pain, and sickness, and sorrow are the conditions inseparable from the present life. This is the law—a rule to which uninterrupted health, and a long, happy, and prosperous life are the rare exceptions. No wonder, therefore, that deliverance from pain, the cure of disease, and comfort to the mind, should be earnestly and anxiously sought after; and that the means of their attainment should be a secondary consideration. It is not so very difficult to understand why there are longings after the mysterious, and why the desire to get a little light reflected on the future, is an irrepressible instinct of our nature. On this principle we may expect that, amidst the varied forms of superstition and belief in the supernatural, there would always be a leaning towards any special agencies by which the physical, the vital, and the mental, in the constitution of man could be most easily operated upon. Such influences, whether real or imaginary, would always be directed towards the mitigation of suffering, and the prolongation of life.

The loadstone, in the form in which it was first known, as a metalliferous ore, and afterwards, when its properties were imparted to artificial magnets, was admirably adapted to foster the belief that its wonderful powers were analogous to those of vitality. Influencing other bodies without actual contact, possessing dissimilar properties at opposite ends, and exercising a directive force with unerring constancy—it might well be supposed to be endowed with something very much like life, if not in reality a living principle.

But in former times, as in the present day, there were differences of opinion. Some attributed to the magnet the power of relieving pain, of preventing and curing diseases, of exciting pleasurable emotions, and even of revealing secrets. Others, however, contended that its influences were of a malignant character; and they went so far as to include it amongst the most active poisons.

Of magnetism, as a science, very little was known until near the end of the sixteenth century, when Gilbert* collected and arranged the facts then known; adding many which were entirely new. He paid great attention to induced and terrestrial magnetism, and appears to have been the first to promulgate the theory, afterwards adopted by Halley, that the earth contained a central magnet. This was supposed to operate on all bodies, animate and inanimate, influencing other planets, and being in like manner influenced by them, according to their relative sizes, distances, and positions.

Apart from what are now considered his erroneous theoretical views of magnetism, Gilbert deserves to be remembered as an able experimentalist, and for having carefully recorded what he knew. Very few of his contemporaries, or of his successors during the next hundred-and-fifty years, did anything worthy to be compared with him in the examination of the laws of magnetic phenomena. Profiting by Gilbert's discoveries, but delighting more in fancies than in realities, many of the learned men of that period indulged in the most absurd speculations; wasting their time, and exhausting their energies, in pursuits, which, viewed in the light of modern science, seem scarcely fit to occupy the attention of children. Passing these over, it is still proper to mention that, an influence which was supposed to be diffused throughout the planetary system, could not very easily be separated from minerals, plants, and animals. It is about the middle of the seventeenth century that we first notice the use of the terms mineral, vegetable, and animal magnetism.

To a superficial observer nothing seems easier than, by a blow of the hand, to demolish a whole mountain of errors. Not so easy.

* William Gilbert, born at Colchester, in 1540. He was educated at Cambridge, and a Fellow of the College of Physicians. Died, 1603.

These old errors have spread themselves out, and taken a firm hold of the ground. They are not to be dealt with summarily and in masses. Examine them singly—and the more carefully they are examined, the sooner will it appear that the work is one of great difficulty. Taking any one of what are called popular errors, or popular superstitions, and on looking at it thoroughly, we shall be sure to discover in it a firm underlaying stratum of truth. There may be more than we suspected of folly and of fancy; but, when these are stripped off, there remains quite enough of that stiff, unyielding, material which belongs not to persons, or periods, but is common to all ages, to puzzle the learned and silence the scoffer. So is it with many popular (old women's?) remedies. Underneath a great deal of absurdity something really valuable is often concealed. It is much easier to prove that, than to explain how it came there. Such remedies are founded on experience—of itself no trifling recommendation—and if the most which can be said of them is that they sometimes succeed, and at other times fail, can more be affirmed of some of the remedies which are prepared according to the most exact rules of art?

This is not intended as an apology for folly, or quackery, or imposture. These are the natural offspring of ignorance, credulity, and superstition—the stock-in-trade of the charlatan, whatever be his profession. It well deserves the attention of the philosopher, the physician, and the divine, each in his department, to separate the true from the false in matters of popular belief. People are not insensible to the claims, and the importance, of truth; but they require to know where they may be sure to find it.

The properties of the loadstone in its natural state, but more frequently as exhibited in artificial magnets, occupied the attention of medical men for many years subsequent to the period to which I just now referred. In France, magnets were manufactured in a variety of forms, worn as ornaments on the person, and adapted to different parts of the dress, in such a way that their medicinal virtues should be communicated, exactly where it was supposed they were most needed.

That a considerable number of persons are, in various ways, affected by magnetism, that some are more easily operated on than others, whilst probably a great proportion of the people we meet with every day are insensible to any such impressions or influences; are conclusions which it is easier, and safer, and wiser to admit, than to attempt to deny. Attaching no greater value to the records of experiments and observations on this subject, than on any other, I know not why they are to be received with less favour, or less confidence, than similar reports on totally different matters, by the same men, or, by others, at least, in no respect superior to them in ability or general repute.

After making more than, what in any other case would be considered, reasonable deductions for the difficulties which confessedly attach to experiments in which the sensations and the imagination are partly concerned, enough remains to place it beyond doubt that, under particular circumstances, (which may be either organic and permanent, or induced by disease and, therefore, occasional,) there is, in certain individuals, a sensitiveness to magnetism, accompanied by results which cannot be produced by any other known (physical) influence, and which cannot be prevented by personal efforts either bodily or mental.

The animal magnetism of our own times next requires to be briefly noticed. In 1775, Mesmer* first made public his peculiar opinions upon magnetism as a remedial agent. Some

* Frederick Anthony Mesmer, a German physician, born in 1734, at Mersburg, in Suabia. Died at the same place in 1815.

years earlier (in 1766) he had avowed his belief in astrology (not at all extraordinary at that period), and especially that part of it which treated of planetary influences as affecting the nervous systems of animated beings.

The personal history of Mesmer, the controversies in which he was constantly engaged, the opposition he met with, and the official investigations of his system, undertaken by some of the most renowned men of that day, constitute in reality the history of animal magnetism (mesmerism) during a period of nearly forty years. This is not the place, nor the occasion, for entering upon the details of so difficult a subject. All that is intended by the foregoing remarks, and by those which follow, is to show the difference between animal magnetism and animal electricity. It is not improbable that a principle common to both is the acting, influencing, operating, agent in each. This has to be proved. It is no part of my business here to indicate analogies and try to find the right clue. This is, most likely, nearer to us than is generally suspected, and when known will not excite much surprise.

Whatever may have been the motives or the mistakes of Mesmer, whether he was the author of any new discovery, or only presented in a more imposing and attractive form certain phenomena which had been known before, but not by the public generally; this much is tolerably certain, namely, that like most other men who have believed they have made some wonderful discovery, Mesmer was anxious to acquire by his own both fame and fortune. He was not, however, prepared for the opposition, jealousy, detraction, and vexations and disappointments in a thousand other forms, which on all sides awaited him. Hence he evinced very little of the calmness and self-possession so necessary to a man towards whom so many eyes were directed. It is even doubtful whether Mesmer knew much about magnetism as a science. He certainly was deficient in some kinds of knowledge common to the philosophers of his day.

That which we are chiefly interested in knowing is this:—Did Mesmer invent, or was he the means of originating, the manipulatory process which has since been called by his name?* This, I think, cannot be disproved. Was he the first who, by such manipulations, showed the power which one person could exercise over another, and who associated the force, or power, or influence, or whatever it might be, which was thus emitted by the hands of the operator, with the force, or power, or influence, which some persons experienced when operated on by magnets? Of this there appears to be no reasonable doubt. Were the effects produced by Mesmer and his followers the same as those now so commonly known as mesmeric phenomena? And, can such phenomena be produced (admitting that it is done more quickly with some persons than with others) under circumstances, and with a constancy, which entitle them to the confidence of any honest, ingenuous, and intelligent observer? To each of these questions the reply must be in the affirmative.

Many persons affect to disbelieve the phenomena of animal magnetism (mesmerism). They contend that the results attributed to it are simulated, imaginative, or, at any rate, if they exist at all, that they are produced by other agencies. Others, finding it impossible to deny the facts, have tried in a variety of ways, to account for them on different principles, or to describe the phenomena by different names. The most notable example of recent date is the so-called Hypnotism, promulgated by Mr. Braid, a surgeon, at Manchester. There seems to be a world of meaning in the inquiry, "What's in a name?" This new name, it is said, has commended itself to members of the medical

* "The system originated in 1774, from a German philosopher, named Father Hehl, who greatly recommended the use of the magnet in medicine. M. Mesmer, a physician of the same country, by adopting the principles of Hehl, became the direct founder of the system."—*Sibly.*

profession who scarcely ever venture to utter the other—mesmerism. What is Hypnotism? Mesmerism, with a veil thrown over it, trying to pass itself off as something else. Ultra-mesmerism is its most appropriate designation. It is difficult to reason with some people, and, indeed, reasoning is of very little use. A class, more numerous than is generally supposed, will never acknowledge they are convinced of anything they are unwilling to believe.

Let it be observed that I here purposely refer only to mesmeric phenomena in their simplest forms. These may be witnessed, in some of their most interesting aspects, in almost every family. Wherever there is a sincere desire to verify them, by actual experiment, there are abundant opportunities for doing so; and without being dependent on the operations, or the testimony, of others, whether friends or strangers.

The term *magnetism*, in connexion with this subject, is liable to mislead those who are not acquainted with its origin. The influence of magnetism, as already mentioned, was generally supposed to pervade all substances, and every form of animated being. Its effects on persons of peculiar temperaments had been noticed, long before the discovery of the more numerous and remarkable phenomena produced by the agency of vitality, that is, the influence which, under certain conditions, one living being exercises over another. The first-mentioned phenomena were attributed to magnetism as operating upon animated beings, and was hence called *animal* magnetism, to distinguish it from mineral and vegetable magnetism. The name has been retained (even where that of mesmerism has been adopted), although magnets are now only very rarely employed; and because it was believed that the effects of ordinary magnetism on sensitive persons, were identical with those produced by the manipulatory processes invented by Mesmer.

The most that with certainty can be said, on a subject so imperfectly understood, is this:—In mesmeric phenomena there are undoubtedly some remarkable analogies and resemblances to magnetism, or, perhaps, more strictly speaking, to electro-magnetism. These, however, are too feeble in their action, too quick in their movements, too delicate in their indications, to be examined by ordinary rules, or measured by any known instruments. Judged by their effects, they are not deficient in energy or activity; but it is the energy of a ray of light in painting a portrait, and the activity of a galvanic current in a telegraphic-wire. In photography and in telegraphy we know that some unseen and powerful agent has been present with us, and has made itself intelligible to some of our senses; but this we know only by reason of its having done the work we had assigned to it. So is it in the phenomena of animal magnetism. They manifest themselves by their effects. We must be content, for the present, to confess that very little is known about their cause.

B

Pooh-pooh.—*Note* B, *page* 8.

There is not one of the important inventions and extensions of power of the last wonderful age, which has not had to struggle against the chilling philosophy of Mister Pooh-pooh. History is full of the instances in which he has condemned, as impracticable and absurd, proposals which have ultimately, in spite of him, borne the fairest fruit. Gas-lighting was referred to Sir Humphry Davy and Wollaston, as the two men best qualified to judge of its feasibility; but Mister Pooh-pooh was at their elbow, to insinuate all sorts of objections and difficulties, and they pronounced against an article of domestic utility which is now used, more or less, in nearly every house, in every town and village in the kingdom. It was all that steam-navigation could do to get over Pooh-pooh's opposition. Even James Watt, who had in a manner made the steam-engine, gave way to the whispers of Pooh-pooh regarding its use in vessels. Sir Joseph Banks was applied to by some enthusiastic advocate of this application; when, under the inspiration of Pooh-pooh, who stood beside him, he said: 'It is a pretty plan, sir; but there is just one little point overlooked—that the steam-engine requires a firm basis on which to work.' He sent away the man under the disgrace of his pity, and, we suppose, thought no more of the matter till he heard of steamers plying regularly on the Hudson and the Clyde, with or without the firm basis to work upon.

When Pooh-pooh first heard that some persons were so mad as to think of carriages being drawn by steam, on rails, at the rate of twenty-five miles an hour, he was indignant, and set himself to prove, which he did entirely to his own satisfaction, that the carriages would not go at anything like that speed. If driven to it, the wheels would merely spin on their axles, and the carriages would stand stock-still. He was sincerely anxious that this should prove to be the case, and we may imagine his feelings when the plan was realized with the effect contemplated by its projectors. The same unsanguine gentleman gave a lecture at Newcastle, in 1838, to prove to the British Association that steamers could never cross the Atlantic. Some people wished, hoped, prayed that they might cross the Atlantic; he indulged in a calm but happy belief that they never would. Here, too, he underwent the mortification of defeat. . . .

Pooh-pooh has generally some tolerable degree of scientific reputation; it is hard to say how acquired—sometimes, it is to be feared, only by looking wise and holding his tongue. There he is, however, a kind of authority in such matters. Wo it is for any new project in mechanics, or any new idea in science, to be referred to him, and all the more so if it be a thing 'in his line,' for no mercy will it meet! . . .

The external aspect of Mister Pooh-pooh is hard and repelling. He has a firm, well-set, self-satisfied air, as much as to say: 'Don't speak to me about that, sir.' He has a number of phrases, which he uses so often that they come to his tongue without any effort of his will; such as, 'It will never do'—'All that has been thought of before, but we know there is nothing in it'—'People are always meddling with things they know nothing about,' and so forth.—*Chambers's Edinburgh Journal, No.* 494, *June*, 1853.

C.

Galvani.—*Note* C, *page* 10.

Louis Galvani was born in 1737, at Bologna, in Italy, and died in 1798. Educated amidst the austerities of Romanism, he wished to have become a monk. Dissuaded from his purpose, by a brother of the convent to which he had attached himself, he turned his attention to medicine, became celebrated as a philosopher, a physiologist, a lecturer on anatomy, and a practical surgeon and accoucheur. He married the daughter of Galleazzi, one of the professors under whom he studied. By the death of this lady, in 1790, her husband was so greatly affected that he never regained either health or cheerfulness. Galvani appears to have been of a remarkably amiable, gentle, and affectionate disposition; very exemplary in his conduct, and so thoroughly conscientious that he was not only prepared to suffer, but actually did suffer, the loss of his public appointments and other means of subsistence, rather than do what he considered to be socially, or politically, wrong.

The great discovery which renders the name of Galvani so famous, and by which it will be known to the latest posterity, had its origin in the preparation of some frogs for making soup; a work in which his wife, who was in delicate health (1786), was engaged—the soup being for her own use. This was going on near to an electrical machine which one of Galvani's assistants had in action. He seems, quite unintentionally, to have touched part of one of the dead frogs with the point of a scalpel (knife) when, to his surprise, the muscles of the animal were powerfully convulsed. Signora Galvani witnessed the experiment. She was a lover of science, and was not likely to permit so remarkable a phenomenon to pass unnoticed. The Professor himself was soon informed of what had occurred; by whom the experiment was successfully repeated and varied in every conceivable way. Thence commenced the most important era in electrical science.

In the experiment with an electrical machine, Galvani observed that the convulsions occurred at the instant a spark was emitted from the conductor, provided some metallic substance was in contact with the nerve of a frog. Pursuing these investigations he soon found that a machine was not required; precisely the same effects being produced by contact of dissimilar metals. Here was the starting-point for the development of a new kind of electricity—better known, and more appropriately, by its popular name, GALVANISM.

Nor was this, properly speaking, an accidental discovery; a description of work of which there is less in the world than some people imagine. It is easy to talk about such things happening by chance or accident, and there is a sort of morbid desire to make it appear that all great discoveries are accidental—mere chance-work—unattended by preparatory thought, or effort, of any kind. No such thing. A discovery, or an invention, be it what it may, implies, on the part of the discoverer or inventor, a well-disciplined mind. The capability for observing phenomena, of recognizing what is new, and especially of reasoning correctly upon conditions and consequences, are necessary qualifications for seizing upon, holding fast, and following out to their first principles, what some are thus pleased to call chance, or accident. Without some such qualifications as these the most wonderful phenomena are passed by unheeded. A man may have the use of his eyes; but still lack the right sort of capacity for seeing with them. In reality he sees; but with his eyes only: he does not perceive. Hence there is no exercise of the understanding. How many of the most valuable natural products, both vegetable and mineral not even omitting the localities of gold itself, have been overlooked, or unknown, until mind, and thought, and intelligence—the teachings of science manifesting themselves in what is termed "a scientific habit"—have been brought to bear upon them?

The necessity for sonething more than simply seeing what is remarkable may be illustrated in a variety of ways. Here is one example, which I think is singularly instructive.

Extract from a Communication to the Royal Society, published in the Philosophical Transactions, Vol. xxxvii. No. 424, p. 327, July and August, 1732, entitled, Experiments to prove the Existence of a Fluid in the Nerves. By Alexander Stuart, M.D., Med. Regin. R. S. S. &c.:—

"The Existence of a *Fluid* in the *Nerves* (commonly called the *Animal Spirits*) has been doubted of by many; and notwithstanding Experiments made by Ligatures upon the *Nerves*, &c., continues to be controverted by some. This induced me to make the following Experiments, which I hope may help to set that Doctrine, which is of so much consequence in the Animal Æconomy and Practice of Physick, in a clearer Light than I think it has hitherto appeared in.

"Experiment I.

"I suspended a Frog by the Fore Legs in a Frame leaving the inferiour Parts loose; then the Head being cut off with a Pair of Scissars, I made a slight Push perpendicularly downwards, upon the uppermost extremity of the *Medulla Spinalis*, in the upper Vertebra, with the Button-end of the Probe, filed flat and smooth for that Purpose; by which all the inferiour Parts were instantaneously brought into the fullest and strongest Contraction; and this I repeated several times, on the same Frog, with equal Success; intermitting a few seconds of Time between the Pushes, which, if repeated too quick made the Contractions much slighter.

"Experiment II.

"With the same flat Button-end of the Probe, I pushed slightly towards the Brain in the Head, upon that End of the *Medulla Oblongata* appearing in the Occipital Hole of the Skull; upon which the Eyes were convulsed. This also I repeated several times, on the same Head with the same effect.

"These two Experiments shew that the Brain and Nerves contribute to muscular Motion, and that to a very high Degree."

These experiments were recorded before Galvani was born. To entitle them to the place they occupy it must be presumed that the convulsions produced, in the manner described by Stuart in the limbs of a dead frog, was a newly-discovered fact. In their results they were precisely the same as those with which the name of Galvani is associated. Nor was the mode of operating very different; even in the application of only one kind of metal. In Galvani's experiments, excitation was produced by contact, or communication, of nerves and muscles. In Stuart's experiments, convulsions were produced by exciting the spinal marrow, and the results were due to what is termed "irritability." The use of metal is not necessary. Similar effects are produced by a probe made of glass. But what is the cause of nervous and muscular irritability? Are they occasioned by the disturbance of the electrical conditions, normally subsisting between the several parts of the medullary substance of the brain and spinal cord?

It deserves notice that our countryman, Stuart, went to work for the purpose of proving the existence of what he called, "a fluid in the nerves;"—moved thereto, no doubt, by the same ardent longings after the "vital principle" which engaged the thoughts of many others at that time. Contrasting the proceedings of the two men, what more strongly marks their respective habits of thought and action, than the course which each pursued? Stuart's experiments were probably as new and original as those of Galvani; and containing also the additional elements of forethought, intention, and contrivance. Stuart was successful; and in realizing his expectations was perfectly satisfied. There is no evidence that the inquiry was conducted any further. It is difficult to conceive that any man could be so near to Galvani's discovery, as Stuart was, without touching it and making it his own.

Not so with Galvani. An incident which, happening in the presence of persons less sagacious and well-instructed, or, in other words, possessing less of "the scientific habit," might have passed unnoticed, was reported to him. He immediately tried it, and found it to be true; and then set to work with an earnestness and a constancy which entitled him to greater honour, and kinder treatment, than it was his lot to receive. In the conduct of these two men, we learn that seeing is not sufficient: there should also be the habit of observing.

D.

VOLTA.—*Note* D, *page* 10.

ALEXANDER VOLTA, a native of Como, in Italy, born in 1745, died in 1826. He entered public life as an ecclesiastic, but soon became so eminent in the pursuit of science that he was appointed Professor of Natural Philosophy in his native town, and, afterwards, at Pavia. In the midst of his brilliant career as an electrician (1801), and especially as the inventor of the *battery* now called by his name, Volta was invited by Napoleon to visit Paris, where he exhibited and explained his discovery before the Academy of Sciences. About this period he laid aside his clerical habit and married. Later in life his religious impressions were revived, and, grieving on account of having violated his vow of celibacy, his health was thereby greatly impaired.

Of the many distinguished men whose attention was attracted towards Galvani's discovery, not one of them was more remarkable for his ability, or better qualified by his experience, than Volta. Entering most heartily at first into the views of his countryman, he was delighted with his own success in repeating the frog experiments; but, altering his opinions as to the source of the electricity, he quickly passed through the successive stages of doubt and unbelief to openly-avowed antagonism. Ever regretting the bitterness infused into the controversy between Galvani and Volta, and their respective adherents, it is useless to deny that, by their disputes, science has gained more than it was ever likely to have done by their agreement. This is one of the instances of bringing good out of evil which is beyond our control. We must admit the fact, be thankful for such an issue, but we had better not attempt an explanation. Each party was put upon his mettle. The controversy lasted long, the contest was severe, and was only brought to an end by the illness and death of Galvani. He left his opponent occupying the largest portion of the debateable ground, and within view of a nobler achievement than ever was effected by the strategies of war.

In the proper places, I have shown that each of the men of whom we are speaking was in part right, and in part wrong; but they were not in possession of the means we now enjoy of correcting their own errors or of having them corrected by others. A few words only are required in explanation of the processes by which Volta arrived at the invention of the *pile*—the first putting together of materials which eventually expanded into the more effectual apparatus—the *battery*. It would be pleasant to tell of believing and doubting, of successes and failures, of discouragements and ultimate triumph; but this would occupy too much space. Volta was thus engaged during more than ten years.

One fact deserves to be mentioned. Sulzer, a German writer,* had many years previously noticed the effects upon the organs of taste when two dissimilar metals (lead and silver) were so placed in contact that their edges, making an even surface, were applied to the tongue. This had heen recorded with the observation, that "it was not improbable that, by a combination of the two metals, a solution of either of them may have taken place, in consequence of which the dissolved particles penetrate the tongue; or we may conjecture that the combination of these metals occasions a trembling motion in

* Theory of Agreeable and Disagreeable Sensations. Berlin, 1762.

their respective particles, which, exciting the nerves of the tongue, causes that peculiar sensation." Here was the first germ of a voltaic battery. It was, at the time, considered curious, and nothing more.

On finding that muscular contractions in a frog could be produced only under favourable circumstances, unless by contact of dissimilar metals, Volta dissented from Galvani's theory of animal electricity. Trying by the same means to produce muscular contractions in the human body, he failed; but when he (most likely unconscious of what Sulzer had done) repeated the old experiment, only varying it, by placing a metal above and below the tongue, he detected a peculiar taste at the instant of contact and guessed its cause. That which by Sulzer had been laid aside as curious, became, in the hands of Volta, the ground-work of the science of chemical electricity. At first Volta thought that contact of heterogeneous metals, and contact only without any interposed excitant, was the source of Galvani's newly-discovered form of electricity. This theory out-lived its author, although Volta himself admitted it was untenable.

To describe a Voltaic battery, its various forms, the materials of which it is made, the uses to which it has been applied, and the wonders which have been wrought by it, especially in our own country, is altogether unnecessary. Only would I add that, whilst the misunderstanding which existed between Volta and Galvani, is but one amongst many similar instances in which the wise and the learned have fallen out by the way, such conduct is not to be justified. Still it behoves us to think of them kindly; being ourselves also "compassed with infirmity."

Let it not be supposed that Volta's battery, in anything but its principle, resembled those of the present day. A long list of names would have to be quoted, in any attempt to do justice to the eminent men, even of our own country, who have taken part in the improvement of this wonderful apparatus. Whilst remembering what has been done by Daniell, and Grove, and Smee, during the last few years, we ought not to forget that Cruikshank, in 1800, a few months after Volta's discovery became known, invented what was then called the *galvanic trough*. This facilitated the use of the apparatus, and so greatly increased its power that, comparing it with Volta's, it was like the spring of a tiger to the spasm of a dead frog. The trough, with all its inconveniences, will ever be memorable in the annals of electrical science as associated with Davy and his brilliant discoveries. He did so much in galvanism, and did it so well, that he left scarcely anything worth attempting by others.

E.

Galvanism.—*Note* E, *page* 14.

Galvanism is one of the various forms, or kinds, of electricity, or more properly, it is one of the ways in which it can be made manifest to the senses. It is always at work in ways and in places unseen and unknown by us, and not only around but within us. The merit of its discovery is due to Galvani (see p. xiv) and thence its name is derived. He elicited the principle —the electric action produced at the points of contact of two dissimilar metals when chemically excited by a suitable material. This is galvanic electricity as generated by what is called a simple circle, and can be shown by a $\frac{1}{1000}$th of a grain of zinc and silver, immersed for an instant in a drop of water. But in the popular sense, in which galvanism is now understood, something more than this is intended. It was Volta who devised the means of converting a simple into a compound circle. To him we are indebted for the development of the powers of the wonderful agent which Galvani first saw at work amongst the nerves and muscles of a dead frog;—an agent the most wonderful, and the most powerful, ever yet wielded by the hands of man.

In speaking of Galvanism it is right to observe the distinction between the discoverer of the principle, and the inventor of the apparatus. It is Galvanic, not Voltaic, electricity—a Voltaic, not a Galvanic, battery.

F.

OERSTED.—*Note* F, *page* 22.

HANS CHRISTIAN OERSTED was born in 1777, at Rudkiöving, in Langeland, an island of Denmark. He died in 1851.

Possessing a richly-endowed mind, this excellent man contemplated the works of God with the eye of a philosopher and the imagination of a poet. Valuable as were the labours of Galvani and Volta, the progress of discovery was soon to be marked by another epoch, with which OERSTED and ELECTRO-MAGNETISM will for ever be associated. By the brilliant discovery of the accomplished Dane, Galvanism and the Voltaic battery were not thrust into the shade. On the contrary, their real value was never before made known, whilst that which they possessed was immeasurably increased. Their sphere of operations had hitherto been the laboratory and the lecture-table. Now they were to take their places amongst the utilities of commerce and the necessities of every-day life; and, following the divergent lines of enterprise and international communication, they will soon encircle the globe.

In 1807, Oersted announced some opinions on the relations of electricity and magnetism, from which their identity might be inferred. His views were not, however, supported or illustrated by any new experiments, and they, therefore, attracted but little attention. It was only a question of time, and he could well afford to wait. Years passed on. In 1820 his expectations were realized. An experiment so simple that it never could be forgotten, and so decisive that it never could be misunderstood, rewarded the patience and immortalized the name of its fortunate observer. This was electro-magnetism;—which means, that whenever a current of galvanic electricity passes along a metallic conductor, no matter of what kind of metal it may be, a second current is thereby produced at right angles to the first; that is, it circulates around and across the conductor, and possesses the properties of a true magnet.

G.

STEPHEN GRAY.—*Note* G, *page* 37.

OF this remarkable man very little is known. The date and place of his birth I have not been able to discover; nor can I find any record of what was his occupation, or profession, previous to his becoming a resident in the Charter House. There he greatly distinguished himself by his experiments on electricity, and from 1720 to 1736 contributed largely to the Philosophical Transactions of the Royal Society. His last communication was dictated to the Secretary, Dr. Mortimer, the evening before his death, which happened February 15th, 1736. To this communication I shall have occasion to refer in another place.

H.

Chirrup of the Cicada.—*Note* H, *page* 40.

There is one species of the Cicada which utters a very characteristic note. It is named by the people "cay-de-deet," from the resemblance of these syllables to its peculiar call. It utters them by repetition, nearly in seconds of time, and so loud that on a quiet night it may be heard at least half-a-mile off.

I am acquainted with a strange truth in relation to this little creature. I know not whether I have the merit of being the first to discover it, but I have never heard of it elsewhere. I cannot explain its "philosophy," and I offer the fact to some more accomplished naturalist. Thus then:—When the Cicada is busy with his "chirrup," if you place your hand or your finger only, against the tree on which it is perched, it will abruptly cease its song and remain silent. No matter how tall the tree, or how high the little animal may be; no matter how dark the night, or how silently you may have stolen to the tree and performed the manipulation; the song will be interrupted all the same. What is the explanation? The animal has not been affrighted by any noise you have made. You may utter what sound you please *under* the tree, provided always you do not touch the bark, and it will not heed you, but continue its chirrup. What then? Can it be electricity?—*The Scalp Hunters, by Capt. Mayne Reid.—Explanatory Note.*

I.

Gilbert.—*Note* I, *page* 42.

Our countryman, Dr. Gilbert, of Colchester, in 1600, (Appendix, p. vi.,) was the first to collect and arrange the scanty fragments of electrical phenomena, as recorded by the ancients;

and which, during 2000 years, had excited the wonder, but not the serious investigation, of numerous observers. Repeating the well-known experiment with amber, Gilbert found many other substances equally susceptible of excitation. Reasoning on facts, as well as verifying them, he gradually extended his observations; discovering that dry air was favourable, but moist air unfavourable, to his experiments. Thus was laid the foundation of a new science. It is impossible to understand, or properly to value, the services of Gilbert. In electricity and magnetism he was so truly a pioneer—working alone and with almost nothing to guide him—that if any man's discoveries deserve to be called original, here is one of the most, if not *the* most, notable of such examples.

The first electrical machine (of glass) is stated to have been made by Newton (1675). It consisted of a globe, about 8 or 10 inches in diameter, mounted in a frame to admit of its being turned quickly on its axis, and was excited by the friction of the hand.

The electrical machine, with the improvements made in it by Hawksbee and others (1705), was not much used in Gray's time (1730); for, in his experiments, mentioned at page 37, continual reference is made to a glass rod excited by rubbing it against the hand.

The maker of the first *cylindrical* machine was Professor Gordon, a Scotch Benedictine monk at Erfurt (1744). It was 8 inches long by 4 inches in diameter—almost exactly the form of the cylinder-machine at the present day. The spark obtained from the prime conductor of this machine ignited various kinds of inflammable substances. It caused great terror in those who first witnessed its effects, and was described as being sufficiently powerful to burst the skin of the finger and occasion a wound!

Next followed, in 1746, the discovery of the Leyden phial—at first simply a glass bottle partly filled with water. If a spark from the conductor frightened the operators, what must have been the effects of a shock? When first witnessed, it occurred by what perhaps might be fairly called accident. The narrator states that, "he felt himself struck in his arms, shoulders, and breast, so that he lost his breath, and was two days before he recovered from the effects of the blow and the terror." Another, who made the experiment with a common drinking-glass, describes the shock as so powerful as to have deprived him of breath for some moments, and that he felt so intense a pain along his right arm that he feared permanent injury from it. A lady who took a shock twice, was so disabled by it that she could hardly walk. But she was not deficient in curiosity or in courage; for a week afterwards she took a third shock, which produced bleeding at the nose!

These shocks, so frightful in their effects to those who first witnessed and felt them, are not likely to have been half so powerful as are now commonly taken at public lectures, or for amusement in the family. But the early experimentalists were deficient in that kind of knowledge which imparts confidence. They had to learn what *would* happen; and, therefore, fear and uncertainty, operating through the mind, helped to increase the force of disagreeable and painful sensations in the body.

J.

Electricity of the Human Body.—*Note* J, *page* 42.

Many instances are recorded of persons being so highly electrical as to emit sparks from the body, and from the various articles of apparel worn by them. The following case is not more remarkable than others, but I select it as occupying less space, and also because it shows that the phenomenon was observed when electrical experiments first began to occupy the attention of the learned. It is extracted from a communication, read before the Royal Society, on 13th June, 1745,* and addressed to the President, by the Rev. Henry Miles, D.D. and F.R.S., of Tooting, Surrey, entitled, "Observations of Luminous Emanations from Human Bodies and from Brutes; with some Remarks on Electricity."

. . . . "In the late edition of the works of the Honourable Mr. *Boyle*, vol. 5, page 646, is a letter from Mr. *Clayton*, dated *June* 23, 1684, at St. James City in *Virginia;* in which he gives Mr. *Boyle* an account of a strange accident (as he calls it); and adds that he had inclosed the very paper Colonel *Digges* gave him of it, under his own hand and name, to attest the Truth; and that the same was also asserted to him by Madam *Digges*, his Lady, sister to the wife of Major *Sewall*, and Daughter of the Lord *Baltimore*, to whom this accident happened.

"This paper, very unhappily, came not to hand till after Mr. *Boyle's* works were printed; and therefore could not be inserted with Mr. *Clayton's* letter; but having since met with it, I present the exact copy of it to you, and, if you judge fit, by your hands to the *Royal Society*:—

'MARYLAND, *Anno.* 1683.

'There happened about the month of *November*, to one Mrs. *Susanna Sewall*, Wife of Major *Nic. Sewall*, of the Province abovesaid, a strange flashing of sparks (seem'd to be of fire) in all the wearing apparel she put on, and so continued till *Candlemas;* And in the company of several, viz., Captain *John Harris*, Mr. *Edward Braines*, Captain *Edward Poulson*, &c., the said *Susanna* did send several of her wearing apparel, and when they were shaken, it would fly out in sparks and make a noise much

* Philosophical Transactions, vol. xliii, 1744–5, p. 441.

like unto Bay-leaves when flung into the fire; and one spark litt upon Major *Sewall's* thumb-nail, and there continued at least a minute before it went out, without any heat: All which happened in the company of

'Wm. DIGGES.

'They caused Mrs. *Susanna Sewall* one Day to put on her Sister *Digges's* Petticoat, which they had tried before-hand, and would not sparkle; but at night, when Madam *Sewall* put it off, it would sparkle as the rest of her own Garments did.'" *

Omitting all about the spark which "litt upon Major Sewall's thumb-nail," (?) there is nothing in this account at variance with "modern instances" of a similar character. There are many well-authenticated cases in which sparks were emitted from the hands and feet of the persons thus affected, when brought near good conductors. It is admitted that such instances are rare; but only one such case among ten thousand, or even a hundred thousand, persons is sufficient to establish the fact. The explanation, that is, the cause of it, is quite another matter. All that can be said is, that it indicates an abnormal condition of the body, either organic or functional, which is favourable to *spontaneous* manifestations of electrical phenomena; and to a degree which it is difficult, and perhaps impossible, to produce by special excitation.

K.

A Loadstone Mountain.—*Note* K, *page* 50.

Magnetic ore is found in most of the iron districts, but the finest specimens abound in Sweden, Norway, Russia, and India. From the latter the celebrated "wootz" steel is manufactured.

* "The additional lines are not in Colonel *Digges's* Hand, but appear to be Mr. Clayton's."

An interesting account of a "Loadstone Mountain," in the Island of St. Domingo, was recently published in the Athenæum (No. 1338, June 18, 1853). It was communicated to that journal by Mr. Robert H. Schomburgk, the gentleman who had visited the locality.

The following is an extract:—

"Naturally, this hill with magnetic iron was to me of the greatest interest. It rose above the savanna to a height of about 60 feet, crowned at the summit with a majestic palm-tree, of the species called Palma real. The hill extends from north to south about 600 feet, and is bathed on its western foot by the river Yuna. Its northern part is covered with rugged black rocks, of all sizes, from that of a pigeon's egg to masses of a ton in weight,—every one of which, great or small, is more or less magnetic.

"I ascertained, in the first instance, the true north point upon the adjacent savanna, far from all influence of the magnetic ironstone, and marked it by stakes. I then ascended the Loadstone hill with our host. The blocks, as already observed, are of different sizes; some are very black in appearance, with metallic lustre,—others are more or less coloured red by oxidation. A magnifying glass shows that the forms of the crystals are those of the octohedron,—others are rhomboid.

"The influence which these rocks exercise upon the needle is scarcely credible. I used for my observations one of Cary's prismatic, and one of Troughton and Simms' pocket compasses. The needles were placed in violent gyrations when approaching the ground,—in some instances they whirled round with great rapidity before ultimately settling with the north point to the south. When placed on other blocks, the motion was less rapid, but the poles were invariably reversed. Raising the compasses gradually above the rocks, the magnetic influence lessened; and when from three to four feet above the rocks, it ceased altogether. Nevertheless, I found that the deviation was not fixed: Cary's compass differed $1\frac{1}{2}°$ to 4° east from the true north point.

"The ore attracts, with the greatest ease, sewing-needles; and a piece which I possess, only two inches in size, and five inches in its largest circumference, weighing 2,294 grains (apothecaries' weight), raises up a small key of iron weighing 32 grains.

"The German mineralogist, G. A. Netto, as Señor Vasquez informed me, dug for about six feet into the ground,—where he found that the quantity of the magnetic iron-ore diminished. I am inclined to think, therefore, that they are erratic or travelled fragments. A trace of the ore occurs again near Cotuy, traversing the high road;—but the blocks have much less magnetic power than at the Hattillo.

"With regard to its value, I will observe that Netto considered the ore equal to the best iron-ore of Danamora in Sweden, and Arendahl in Norway. If it be considered that the Yuna waters the foot of the hill, and that the surrounding heights are clothed with pinewood,—what advantages would accrue to the persons who should work this mine! Here tropical lassitude has tied the arms of Industry."

L

Making Magnets.—*Note* L, *page* 52.

Nothing is easier than to communicate magnetism to iron or steel. For illustrating the principle iron is preferable, because what we do with it can, if required, be instantly undone. It is scarcely possible to bring a magnet near to, or in contact with, a piece of iron without making it, for the moment, magnetic.

Provide a small magnetized needle, nicely poised, or suspended; a tolerably good bar, or horse-shoe magnet; and three or four pieces of $\frac{1}{4}$th of an inch iron rod, about half the length of the magnet, cut from the same rod, and with smoothly-filed ends. This will be all the apparatus required. Holding a piece of iron in the left hand, and the magnet in the right, if the *north* end of the latter be placed on the centre of the rod, and drawn quickly along it to the end, on presenting the end thus rubbed to the needle it will show that it possesses *south* polarity. Rub the same end of the rod in a similar manner with the *south* end of the magnet, and it will indicate *north* polarity. In this way the polarity of the rod can be changed as often as may be desired, and by at last touching it with the magnet still more gently, the iron may be deprived of very nearly all the magnetism it contained. By magnetizing all the rods, and trying in succession the relative attractive (lifting) force of each, their power will be fonnd very much to depend on the number of strokes received from the magnet. There is a sensible limit to this. Iron receives magnetism more promptly than steel, but it parts with it more quickly. By the method described it is impossible, in the proper sense of the word, to make a *magnet* of a piece of iron. There is also a limit to the capacity of steel for receiving and retaining magnetism; owing, as we believe, to differences in the quality and temper of the metal. Both substances, by exactly similar processes, can be made magnetic; but it is impossible to force more than a certain quantity into iron or steel. So also is it impossible by any of the ordinary processes to get all the magnetism out of these metals. Some of it will linger there for many years, and, for aught we know to the contrary, will remain in alliance with them as long as the metals themselves exist, and that may be, what we commonly call "for ever." Soft, malleable, iron cannot be made into a permanent magnet. Pure iron, if we knew how to prepare it, would most likely be more susceptible of the influences of magnetism than any other substance; and it would, doubtless, give up the whole of that which had been communicated to it. The impurities mixed with it, but especially the carbon, give to this metal such extraordinary retentive properties.

The making of steel magnets, possessing great attractive force, that is, the power of sustaining the greatest load, in comparison with their own initial weight, is a difficult and, in a certain sense, a secret process. In the Great Exhibition, 1851, there were many remarkable specimens of magnets. But of these the most conspicuous for their constant sustaining power were those manufactured by Mr. W. M. Logeman, of Haarlem. One of his (horse-shoe) magnets, now in my possession, obtained direct from the maker, and which weighs 2lbs. 5oz., has a sustaining power equal to 28lbs. (more than 12 times its own weight), and with a beveled armature only one-tenth of an inch thick. The inventor of the process by which these magnets are prepared is Mr. Elias, of Haarlem. I have seen and used a Haarlem magnet more powerful than my own. Its size and initial weight were about the same; but it had a sustaining power equal to 36lbs.

The greater the power of a magnet, in relation to its own weight, the more sensitive will it be to external influences, and the more quickly will it part with some of its magnetism. Good magnets must be handled carefully. They must be kept in certain positions, and the poles protected by armatures (keepers) of soft iron. They must not be struck, thrown down, or, in any other way, put into a state of vibration; nor should they be exposed to the influence of other magnets.

Some very delicate experiments have shown that a bar of steel is slightly enlarged, but in one direction only, by being made magnetic. In these experiments change of temperature was carefully guarded against.

The force of a magnet is increased by its constant use; regard being had to careful treatment. By whatever name it may be known, the magnetic atmosphere, or aura, which envelopes a magnetized body is always in motion. This force is not emitted in straight lines, or divergent rays, losing or expending its influence by mixing with the air or other surrounding bodies. The force, or power, emanating from a magnet is believed to consist of closed curves, extending on all sides to great distances; every point of emission at one pole having a corresponding point of immission at the opposite pole. We know nothing about the actual force of a magnet, in relation to distance. The more sensitive the instrument by which we try to measure that force, the more readily is it brought under the control of terrestrial magnetism. Whatever be the power of a magnet, our ordinary magnetic instruments will be affected by it only at such distances where its force is greater than that of terrestrial magnetism. When the force of the artificial magnet is absorbed in, or neutralized by, that of the earth, the former no longer appears to exercise any power in that particular locality. It is so only *in appearance;* for we have been able to ascertain nothing with certainty about the matter. The influence of a magnet is as likely to extend a hundred yards as a hundred inches. To understand what is really meant by magnetic forces, how they operate, and how far those induced in artificial magnets extend into space, we require to get beyond the reach of terrestrial influences; and to pursue our experiments in a place, if there be one, where magnetism is not, as it is here, an universally-diffused agent.

M.

DIFFICULTIES IN OBTAINING INFORMATION.—*Note* M, *page* 87.

DISCLAIMING everything like an attempt to give a connected history of electricity, I purposely omit the names of very many of the great men who have done good service in this department of science. To enumerate names and dates would be equivalent to occupying all the space I have prescribed to myself. I make no pretensions to the possession of exclusive sources of information, and as I have but little time, and few opportunities, for pursuing experiments on any subject, it is impossible for me to know all I could wish on subjects which are accessible to others, and who have far better means for seeing and knowing what is new. My only desire is to give such a connected view of the various branches of electricity, magnetism, and electro-magnetism, as shall enable the reader to understand their relations; and, especially, that he may be able to judge correctly of some of the electrical phenomena of the human body.

N.

IDENTITY OF MAGNETISM AND DIA-MAGNETISM. (?)—*Note* N, *page* 93.

IN a paper read at the meeting of the "British Association for the Advancement of Science," held at Hull, in September, 1853, Professor Plücker, of Bonn, stated, "That for every substance there is a limit of magnetization, to which it approaches more or less rapidly by increasing the power of the electro-magnet," . . . and that "he does not know what magnetism and dia-magnetism are; but the curves for dia-magnetic bodies being included on both sides by curves for magnetic substances, he thinks there is no difference at all between the magnetic and dia-magnetic state of bodies."

O.

Solar and Lunar Magnetism.—*Note* O, *page* 96.

"No one has contributed more to the progress of Terrestrial Magnetism, during the last few years, than my distinguished predecessor in this chair. Formerly, we owed theories on this subject much more to the boldness of ignorance than to the just confidence of knowledge; but from the commencement of the systematic observations which Colonel Sabine has been so active in promoting, this vague and useless theorizing ceased, to be succeeded, probably ere long, by the sound speculative researches of those who may be capable of grappling with the real difficulties of the subject, when the true laws of the phenomena shall have been determined. Those laws are coming forth with beautiful precision from the reductions which Colonel Sabine is now making of the numerous observations taken at the different magnetic stations. In his address of last year he stated to us that the secular change of the magnetic forces was confirmed by these recent observations, and also that periodical variations depending on the solar day, and on the time of the year, had been distinctly made out, indicating the sun as the cause of these variations. During the present year the results of the reduction of the observations made at Toronto have brought out with equal perspicuity, a variation in the direction of the magnetic needle going through all its changes exactly in each lunar day. These results with reference to the sun prove, as Colonel Sabine has remarked, the immediate and direct exercise of a magnetic influence emanating from that luminary; and the additional results now obtained establish the same conclusion with regard to the influence of the moon. It would seem, therefore, that some of the curious phenomena of magnetism which have hitherto been regarded as strictly terrestrial, are really due to solar and lunar, as much as to terrestrial magnetism. It is beautiful to trace with such precision these delicate influences of bodies so distant, producing phenomena scarcely less striking either to the imagination or to the philosophic mind, than more obvious phenomena which originate in the great luminary of our system."—*From the Inaugural Address of W. Hopkins, Esq., President of the British Association for the Advancement of Science, at the Meeting at Hull, Sep.*, 1853.

P.

MUCH VALUABLE INFORMATION LOST.—*Note* P, *page* 97.

A GREAT deal of valuable information is unavailable, and the labour of collecting it, in a certain sense, thrown away, for want of an uniform system of registering, and reducing to common formulæ, or standards of comparison, the works of different observers—professional as well as amateur. There is also a want of that species of co-operation by which well-conducted experiments and observations could be examined, tabulated, and made public. If this could be done, much time and toil would be saved. The advantages of possessing such records, for comparison and reference, would be incalculable. In meteorology this is especially true. Thousands of observations are annually lost; which, if preserved and put into proper forms, would be great helps in explaining the laws which influence the weather, and particularly storms. In no country in the world is this kind of knowledge more needful than on the different parts of the British coasts; where the wrecks are more numerous, in any given period, than on all the coasts of Europe, and, probably, of America, put together.

It is not many months since a gentleman called on me, whose name I have forgotten; and I never knew whence he came, or whither he was going. Telescope in hand—that instrument was his constant companion. He showed me, on a small card, a diagram of the sun's disc, with the number, shapes, relative sizes, and situations of the spots depicted thereon, as they appeared that day. This gentleman informed me that he had been observing the spots, and making drawings of them, every day, (on which the sun was visible) during, I think he said, the preceding five years. He mentioned, further, that the re-appearance of particular spots, at stated periods, could almost as certainly be predicted as that of the sun itself. Should not such information, collected with so much zeal and perseverance, be, in some way or other, made public?

Q.

MATTEUCCI.—*Note Q, page* 107.

CARLO MATTEUCCI, Professor in the University of Pisa. See his "Lectures on the Physical Phenomena of Living Beings," translated under the superintendence of (the late) Jonathan Pereira, M.D., F.R.S. Longman and Co., London, 1847. This work contains only a small part of what has been written and, in other forms, published by its Author. It is, however, accessible to English readers and well deserves an attentive perusal.

R.

Du-Bois Reymond.—*Note* R, *page* 107.

Emil Du-Bois Reymond, Member of the Academy of Sciences of Berlin, &c., &c. See a work "On Animal Electricity; being an Abstract of the Discoveries of Emil Du-Bois Reymond," edited by H. Bence Jones, M.D., A.M. Cantab., F.R.S., &c. Churchill, London, 1852. See also a pamphlet, the title of which is quoted at page 4, which, apart from its controversial character, contains a great deal of valuable information on Animal Electricity. These are only small portions of the Author's writings, but I believe they are all which have been published in this country.

S.

"An Old Device."—*Note* S, *page* 134.

"By this art, practice, or experience, you shall know what it is a-clock, if you hold between your finger and thumb a thread of six or seven inches long, unto the other end whereof is tyed a gold ring, or some such like thing; in such sort as upon the beating of your pulse, and the moving of the ring, the same may strike upon either side of a goblet or glass. These things are (I confess) witch-craft because the effect or event proceedeth not of that cause which such coseners say, and others believe they do."—*Reginald Scot, Discovery of Witchcraft*, 1665.

FROM THE PHILOSOPHICAL TRANSACTIONS, VOL. 39, No. 441, 1735-6.

"MR. STEPHEN GRAY, F.R.S., his last Letter to Granville Wheler, Esq., F.R.S., concerning the Revolutions which small pendulous Bodies will, by Electricity, make round larger ones from West to East as the Planets do round the Sun.

'I have lately made several new Experiments upon the projectile and pendulous Motion of small Bodies by Electricity, by which small Bodies may be made to move about larger ones, either in Circles or Ellipses, and that either concentrical or excentrical to the Centre of the larger Bodies about which they move, so as to make many Revolutions about them; and this Motion will be constantly the same way that the Planets move about the sun, viz., from the Right to the Left, or from West to East.

'I have not yet communicated these Experiments to the Royal Society, being in hopes of making some farther Discovery, or at least of shewing them after somewhat more elegant a manner than I make them at present, when you may expect to hear a farther Account of them from,

'Sir,
'Your most obedient
'Humble Servant,
'STEPHEN GRAY.'

'*London*, *Feb.* 6*th*, 1735-6.'

Vol. 39, No. 441, p. 400.

"An Account of some Electrical Experiments intended to be communicated to the Royal Society by Mr. Stephen Gray, F.R.S., taken from his mouth by Cromwell Mortimer, M.D., R.S. Secr., on Feb. 14, 1735-6, being the Day before he died.

"EXPERIMENT I.

"TAKE a small Iron Globe of an Inch or Inch-and-half Diameter, which set on the Middle of a Cake of Rosin of about seven or eight Inches Diameter, having first excited the Cake by gently rubbing it, clapping it three or four times with the Hands, or warming it a little before the Fire; then fasten a light Body, as a small Piece of Cork, or Pith of Elder, to an exceeding fine Thread, five or six Inches long, which hold between your Finger and Thumb, exactly over the Globe, at such an Height that the Cork or other light Body, may hang down about the middle of the Globe: This light Body will of itself begin to move round the Iron Globe, and that constantly from West to East, being the same Direction which the Planets have in their orbits round the Sun. If the Cake of Rosin be circular, and the Iron Globe placed exactly in the centre of it, then the light Body will describe an Orbit round the Iron Globe, which will be a Circle; but if the Iron Globe be placed at any Distance from the Centre of the circular Cake, then the light Body will describe an (Elliptical) Orbit, which will have the same Excentricity as the Distance of the Globe from the Centre of the Cake.

"If the Cake of Rosin be of an elliptic Form, and the Iron Globe be placed in the Centre of it, the light Body will describe an Elliptical Orbit of the same Excentricity as the Form of the Cake.

"If the Iron Globe be placed in or near one of the Focus's of the Elliptic Cake, the light Body will move much swifter in the Apogeé Part of the Orbit, than in the Perigeé Part, contrary to what is observed of the Planets.

"Experiment II.

"Take the same or such another Iron Globe, and having fasten'd it on an iron Pedestal about one inch high, set it on a Table, then set round it a Glass Hoop or Portion of an hollow Glass Cylinder of seven or eight Inches Diameter, and two or three Inches high: This Hoop must be first excited by warming and gently rubbing it, then hold the light Body suspended as in the first Experiment, and it will of itself move round the Iron Globe from West to East in a circular orbit, if the Hoop be circular and the Globe stand over the Centre of it, but in an Elliptic Orbit with the same Excentricity, if the Globe does not stand in the Centre of the Hoop, as in the first Experiment, when the Globe does not stand on the Centre of the Cake.

"(What will happen if the Hoop be Elliptic, he did not mention; I suppose he had not an oval Glass Hoop by him.)

"Experiment III.

"This same Iron Globe being set on the bare Table, without either the Cake of Rosin or Glass Hoop, the small light Body being suspended as in Experiments 1 and 2, will make Revolutions round it, but slower and nearer to it than when it is placed on a Cake of Rosin or within a Glass Hoop.

Remarks.

"He had not yet found that these Experiments would succeed, if the thread, by which the light Body was suspended, was supported by any other thing than an Human Hand; but he imagin'd it might happen the same if the thread should be supported or fasten'd to any animal substance whatever; and he intended to have tried the Foot of a Chicken, a Piece of raw Flesh, or the like.

"He imagin'd, to explain the foregoing, particularly by the following odd Phænomenon, of which he assured me, he was very certain, having often observed it, viz.,—If a man resting his Elbows on his Knees, places his Hands at some small distance from each other, they will gradually accede to each other, without any will or intention of the man to bring them together; and they will again recede of themselves. In the like manner the Hand will be attracted by the Body; or the Face of a Man, if he stand near a Wall, will be attracted to the Wall, and be again repelled by it.

"He told me he had thought of these Experiments only a very short time before his falling sick, that he had not yet tried them with a variety of Bodies, but that from what he had already seen of them, which, struck him with new surprize every time he repeated them; he hoped, if God would spare his life but a little longer, he should, from what these phænomena point out, bring his Electrical Experiments to the greatest perfection; and he did not doubt but in a short time to be able to astonish the World with a new sort of *Planetarium*, never before thought of, and that from these Experiments might be established a certain Theory for accounting for the motions of the Grand *Planetarium* of the Universe.

"In trying these Experiments since his Death, I have found that the small light Body will make revolutions round a Body of various Shapes and Substances, as well as round the Iron Globe, if set on the Cake of Rosin; thus—I tried with a Globe of Black Marble, a Silver Sand-dish, a small Chip-box, and a large Cork, I observed that the Cake, if nothing stood upon it, would, in any part, strongly attract the light Body, as held suspended by the Thread; but when the Globe, or other Body, was set upon it, the Edges of the Cake attracted the strongest, and so gradually the attraction seem'd, as it approached the Centre, to grow less, till, at a certain distance, it was changed into a repulsion, which proceeded from the Globe, or other Body placed upon the Cake, which very strongly repels the light Body, unless it be held very near it, and then it attracts it strongly. While the light Body is suspended, as in the foregoing Experiments, if you approach the Fingers of the other

Hand near it, it will fly from the Finger, or be repelled by it with great vigour."

For the foregoing extracts I am indebted to a kind correspondent (a lady), and for many others, on similar subjects, collected from scarce books and manuscripts in the British Museum. It is impossible, on the present occasion, to use a hundredth part of the information, relating to animal electricity and magnetism, which has been thus most generously supplied, and for which I here express my grateful acknowledgments.

T.

OD.—*Note* T, *page* 136.

THE suspended ring was called by Dr. Mayo an "Odometer," as he said, "on the conviction that the influence in question was neither more nor less than Von Reichenbach's Od force."

The "Researches"* of the Baron Von Reichenbach exhibit a very remarkable example of patience and perseverance, under circumstances which, to many persons, would have been considered wearisome and full of discouragements. I allude particularly to the numerous experiments with both sickly and healthy "sensitives."

As a fact in philosophy, the emission of luminous rays by a magnet, is just as reasonable as the emission of dynamical curves. Luminosity is, probably, one of the conditions of all magnetic,

* Physico-Physiological Researches on the Dynamics of Magnetism, Electricity, Light, Crystallization, and Chemism, in their relations to Vital Force, by Baron Charles Von Reichenbach. The complete work from the German second edition. With the addition of a Preface and Critical Notes, by John Ashburner, M.D. Baillière, London, 1851.

electric, and electro-magnetic phenomena. That persons, who may very properly be termed electro-sensitives, are capable of seeing this luminousness, and of feeling its effects; whilst to others it is never visible, nor by any other means recognizable, is perfectly consistent with the conducting (sensitive) properties of some substances, and the non-conducting (insensitive) properties of others. We may even go further, without violating any canon of analogy. The differences which Von Reichenbach has stated to exist in different individuals, as to their relative degrees of sensitiveness to electrical and magnetical influences (currents), are not greater than those which are well known to exist in the habits of different kinds of inorganic substances, and which are included under the general term of conductors.

Is not the introduction of the terms *od*, *odic*, *odyle*, and *odylic*, into electro-physiological nomenclature unnecessary if not objectionable? I ask this not because we are already over-done with significant names, but because these are made the exponents of a new force, or power, or influence—another imponderable element introduced to us as part of the material universe. Throughout the "Researches," I can recognize only some of the *old* forces manifesting themselves, not in new, but in newly-observed, relationships. The luminousness of a magnet — seen and felt by some—felt but not seen by others—and, by a far more numerous class, neither seen nor felt at all; the aura diffused by a crystal, or a piece of gold or iron, or an electricized copper wire; the direct, or reflected rays of the sun, or moon, or stars producing sensations of coldness in one person, and of warmth in another, or different sensations at different parts of the body, of the same person, are very wonderful, if viewed as isolated phenomena; but, when examined more closely, and under the guidance of previously-ascertained facts, the wonder ceases. Placed side by side with what is known in electricity, and if judged only by its ordinary laws and operations, it is unintelligible. Among the many curious illustrations recorded by Von Reichenbach, there is nothing which, as I can perceive, requires a new force to produce, or a new principle to explain. Granting, most readily, that we are quickly approaching the development of subtleties, or if the word will suit better, *sublimities*, in electricity, which were not "dreamed of" a few years ago, I yet see in this no necessity for summoning to our aid any new powers. If we will but be willing to learn, where so much has yet to be acquired, we shall every day be made to feel that enough is left of the old forces to serve us for years to come. Had we not better study their habits more attentively, before we begin to cast about us for others?

It is curious that Reichenbach has made choice of a word *(Od)** which, in some of its inflexions, reminds us of another *(Odible)*† used 200 years ago, in connection with, what were then considered, (vital) magnetic phenomena. In the work by Fludd, the title of which is quoted at page 139, we meet with the expression "odible passion," and "odible property."

* "*Vâ*," in Sanscrit, signifies to blow (as the wind). In Latin, "*Vado*," and in the ancient Norse, "*Vada*," means "I go, I go fast, I hasten on, I flew on." Hence, in the old German dialect, "*Wodan*" signifies the idea of the *all-penetrating*, which in various old idioms passes into "*Wuodan, Odan, Odin*," meaning the *all-pervading power*, which was ultimately personified in a Germanic deity. "OD" is, therefore, the sound appropriate to a dynamide or imponderable force, which rapidly penetrates, and constantly flows through all objects in collective nature, with irresistible and unrestrainable power."—*Reichenbach.—Popular Letters, &c., translated by William Gregory, M.D., F.R.S.E., &c. Zoist, No* xliv., *Jan.* 1854, *page* 349.

In Welsh, *Od* means *notable, singular.—Webster's Dict.*

† Odible, from Latin—hateful. In this sense it was used by Fludd, as descriptive of "magneticall antipathy or expulsion," the opposite of "sympathy or attraction."

U.

Table-Moving.—*Note* U, *page* 155.

Is table-moving a delusion, or is it true? By this is meant—are the effects produced, either intentionally or unconsciously, by mechanical or muscular force alone; or do they constitute a physical phenomenon, dependent on a few simple conditions, the cause of which is at present unknown? Judging what has of late been so frequently witnessed, by the ordinary principles of mechanical forces—those in constant requisition in the every-day business of life—it is extremely difficult to understand how a table, which requires the united strength of two persons to move it only a few inches, can, by a different process, that is, if the same persons touch it gently with the tips of their fingers, be moved several feet at a time, in various directions, and without visible, or conscious, application of force of any kind.

That tables, and various other articles, may be set in motion by the manipulatory processes which have of late been so often described, and that the motion communicated is of that kind best expressed by the word *gyratory*, I consider it impossible to disprove. Rejecting, as undeserving a moment's consideration, very many of the so-called experiments, and recording, in the most emphatic manner, my disapproval of the exhibitions of levity and impiety of which they have been made the occasion, I believe there yet remain enough of the simple elements of a genuine phenomenon to justify the conclusion that table-moving, by means at present undiscovered, is a fact. Most readily do I admit that it is impossible to give anything like a satisfactory explanation of the cause; but in this I see no greater reason for denouncing the results as impostures, or delusions, or as dependent on direct supernatural operations, than there is to say the same of many other things with whose effects, both by habit and experience, we are daily familiar, whilst their cause is wholly inexplicable.

Those who talk oracularly about the course of nature, and the laws of nature, and who try to make it appear that everything which cannot be explained by an immediate reference to their own exposition of such laws, is not entitled to belief, have a great deal yet to learn. Such persons ought to become pupils before they set themselves up for teachers. In another place (p. 161), it has been mentioned that in the one branch of science (electricity) which is there the special subject of consideration, it is probable we are acquainted with only detached and widely-separated parts of its phenomena. The laws which control its combined and ceaseless operations, and by which the greater part of its work is performed, are, perhaps, so remote from our view, and so far beyond the reach of our perceptions, that we may never with certainty know anything even of their existence.

Ascribing to Satanic influence whatever is at variance with ordinary experience is not new, and, therefore, not remarkable. It has in all ages been a common practice; but because of its antiquity it is not the less reprehensible. By some persons, such things are not merely considered supernatural, but, whatever may be their probable design, whether as extending our knowledge of other worlds, or only of our own planet and the beings which inhabit it; or whether they be for the prevention of diseases, and the relief of pain and suffering, they are all set down as devices of the enemy of man. How much more rational and christian-like would it be, first of all, to manifest an anxiety to recognize the hand of Him who is "good to all, and whose tender mercies are over all His works!" Whatever be the difficulties in understanding and explaining many things which are constantly occurring around us, if it were not for the teachings of history, it would be vastly more difficult to discover a satisfactory solution for these constant leanings towards Satanic interference;

and where the presence, and power, and goodness of God ought only to be seen and gratefully acknowledged. There is no more proof that spiritual agencies, and least of all any which are under the dominion of Satan, are concerned in moving a table, by the means so recently made public, than in moving a telegraphic-needle at a distance of two or three hundred miles from the operator, or in keeping a clock going for several years, with the accuracy of a chronometer, without weight, or spring, or winding-up.

Do we ever call in question the energy, the activity, or, so to speak, the docility of the various phenomena of electricity as associated with inorganic substances? Can we, then, with any show of reason, deny that they possess less energy, less activity, and that they are less obedient when united with animated beings, made the inseparable companions of vitality, and placed under the control of instinct, intelligence, and reason? No opinion is hereby intended to be expressed that table-moving is effected, either wholly or in part, by the agency of electricity. If it be the acting, and operating, principle, and which is extremely probable, it is so changed in its habits, and so modified or concealed in its influences that we have, at present, no apparatus for detecting it. But in this, is there anything more wonderful than in the difference observed between a piece of sealing-wax and a piece of metal? By gently rubbing the first, a few times against the hand, its electricity is excited and can be tested by a suitable instrument. Treat the metal and test it precisely in the same manner, and if the rubbing were continued until the hand of the operator were worn to the bone, there would be no development of electricity. Whilst saying thus much on, what has become in more than one sense of the word, a *vexed* question, let it not be supposed that I am ignorant of the extreme liability to mistake of persons who have a fondness for the marvellous. Such persons are not only incapable of judging correctly of what they see, or believe they see, others perform; but they are just as incapable of reporting, or judging, accurately of many things they do themselves. Still, it requires more forcible arguments than any I have yet heard, and better evidence than I have yet seen, to make me believe in the wonder-working powers of "suggestion," "expectant attention," "involuntary muscular force," and "dominant ideas." If any one of these will enable us to do only a fractional part of what some persons have lately attributed to them, there must, certainly, be great waste of "voluntary" muscular force in performing the commonest duties of life. I am willing to make liberal deductions from any of the experiments on table-moving, whether of a simple, or more complicated kind; but the deductions on the other side must be quite as great, or we ought soon to hear of "dominant ideas" wheeling wheel-barrows, and carrying hods of mortar.

A recent attempt to prove that table-moving is the result of involuntary muscular force, by one whose opinion on many other subjects is entitled to the utmost respect, is very generally acknowledged to have been unsuccessful.* Neither the arguments nor the apparatus appear to me as calculated to settle the question. It is still open to discussion—deserving of further examination—and certain to yield instruction to those who set about it in a proper spirit, and in the right way. But it were better that the subject should never be thought, or spoken, or written, about again than that it should be made a vehicle for promulgating folly, and slander, and blasphemy. Rightly used, but not abused, table-moving is neither likely to injure the health, nor unsettle the mind. If it be made a means of reviving painful recollections, or of casting a shadow over the future, the operators have themselves only to blame—not tables, nor supernatural agents.

* Athenæum, No. 1340, July 2, 1853, p. 801.

V.

THE QUARTERLY REVIEW.—"DOMINANT IDEAS."—*Note* V, *p.* 155.

THE usual objections against the experiments with the Magnetoscope, having very recently been repeated by a writer in the *Quarterly Review*, it would be mere affectation, or something worse, to suppose that, in so popular a work, an article with such a tempting title* has not been very extensively read. Some of its readers are not likely ever before to have known, even heard, anything of "Mr. Rutter's Brighton Magnetometer" (p. 542); and they must, therefore, have been somewhat puzzled that, notwithstanding a "fallacy" so easily "demonstrated," and "avowed with a candour (?) very creditable" to him who was one of the earliest objectors to these experiments, Mr. Rutter "still draws after him a train of admiring disciples."

It never has been my practice, and it is not my purpose, to enter into controversy with any one about what I have designated Magnetoid Currents. So many curious phenomena have, unexpectedly, presented themselves, which I am unable to explain on any known principle of electrical or magnetical science, and which are still more inexplicable on any of the numerous theories hitherto suggested by others, that I am anxious those who take any interest in such matters should investigate and judge for themselves, instead of yielding assent without previous inquiry and examination.

Listening attentively to all classes of objectors, and watching them, with the same degree of attention, when they have professed to "demonstrate" that the motions of the pendulum were produced by "pulsation," by "mechanical force," by "ex-

* *Electro-Biology and Mesmerism.* Quarterly Review, No. 186, Oct. 1853, p. 501.

pectant attention," by "ideo-motor force," or by the "will;" I long ago came to the conclusion that it was a subject the least likely of any to be settled by disputation. By the statements of the *Quarterly Reviewer* I am more than ever convinced that, in this respect, I have chosen the right course, and I mean, therefore, to keep to it. Some people are always in such a hurry that they prefer cutting a knot to untying it. I see no necessity for this. Those who have preceded us have had their patience tried; and it is very much like presumption on our part to suppose that everything is to come at our bidding, whilst others have had both to work and wait, and have never lived to see and enjoy the fruits of their labours. The world has gone on for ages past, and is likely to do so for ages yet to come, although so great a portion of its phenomena are known to us only by their effects. Many things which we call common, because of their constant recurrence, we are unable to explain, and perhaps shall never be able to find out their true cause.

According to the extent of his knowledge, I dare say the *Reviewer* has fairly stated his own opinions. But his knowledge of the subject, with which he has associated my name, is extremely limited; and, if it be possible, he seems to know still less of "Mesmerism and Electro-Biology." Having never witnessed my experiments, the *Reviewer* refers to them as they have been represented by others. Such accounts are not always to be relied upon as safe guides. If he had wished it, he might have availed himself of my own published statements. Let me here mention that the objections to these experiments are, as nearly as possible, the same as were made, more than 100 years ago, to those communicated by Stephen Gray to the Royal Society;* excepting that they are now called by more imposing names. Similar objections have, at various times, been made

* Philosophical Transactions, Vol. xli., Part 1, 1739-40, p. 118.

in France to the same class of phenomena.* This does no harm, for truth is always put upon its trial, and, in many instances, at the first examination, fares worse than falsehood. Almost everything, a little beyond the range of common observation, has to run the gauntlet of doubt and unbelief. Still, in such cases, disputation never does much good. It is better to examine than to dispute, for a great deal of the latter is like

"Ocean
Into tempest wrought,
To waft a feather
Or to drown a fly."

Following as closely as I can upon the track of the *Reviewer*, I shall now refer to those of his objections which are most deserving of notice.

The *Reviewer* speaks of the "magnetometer." I have never given the apparatus any such designation. The "immobility" of the magnetoscope has never been insisted upon, or even hinted at, by me as a necessary condition; and I have never attempted to make it *immoveable*, because it is impossible to do so. That the "pendulum" can be moved *intentionally* in various directions, either rotatory or oscillatory, no one, I suppose, would ever think of denying. But although this is said to be so easy, it has never been done in my presence, by the most skilful and practised manipulators, without being instantly detected; as it has also by other observers as quickly as by myself. In my own case I *know* the motions of the pendulum are not produced by mechanical or muscular force of any kind. If

* It is only during the last few months I have known that anything had ever been written about the "ring" experiment excepting by Dr. Mayo. How refreshing it would be to fall in with something *really new!*

there be any who think it clever, or meritorious, to practise deception either upon themselves, or others, they are perfectly welcome to all such "honours."

In the construction of a magnetoscope there is no necessity for a projecting arm "to admit of the greatest sensible effect being produced by the smallest amount of imparted motion." Other forms of apparatus have been made by myself and others; but the results are precisely the same. In one of these the pendulum is suspended from a central pillar, immediately underneath the hand of the operator, and enclosed in a glass vessel. The *Reviewer* says the pendulum must "be watched." He is quite right; for I have always maintained that to be a special condition. I am no more able to explain the necessity for it, than I am why we look at the eyes of a person whom we address, not only as being in conformity with good manners, but as also the readiest, if not the only, means of ascertaining if what we say is understood or approved. The power of the eye is undisputed. What would be thought of a preacher, an advocate, or a senator, if he were to shut his eyes, or direct them away from his auditors? In the most ordinary affairs, when we have ascertained that certain conditions are essential to the success of any particular operation, we naturally do our utmost to comply with them. We know, for example, that a current of electricity, conducted hundreds of miles by a wire, will return, without guide or director, through the earth to the place whence it set out; but we also know that, to accomplish this feat, the wire at each end must be in good communication with the earth. Supposing the terminal wires were pointed upwards into the air, what would happen? The telegraph-needle would come to a stand-still, even more quickly than when the eyes of the operator are directed away from the pendulum of the magnetoscope, "no definite vibrations take place."

If "definite movements" are so easily produced, either intentionally or involuntarily, that is, by "the influence exercised by ideas over muscles," by "expectant attention," or by the operation of the still more powerful agent, recently discovered by the *Reviewer*, namely, "DOMINANT IDEAS;" how is it that all who try to produce these "definite movements" do not succeed? It is found, in actual practice, that, comparatively, a very small number only are able to produce the movements; and that others, many of whom are particularly anxious to do so, invariably fail.

The *Reviewer* is a better tactician than he is a reasoner; and which is apparent throughout the whole of his curious article. Hence, whilst talking so much about the "movements" or "vibrations" of the pendulum—why does he ignore the power of bringing it, almost instantly, *to a dead stop?* Do "dominant ideas" introduce us to a new law in mechanical forces, or is the motor-force of mind greater than, as well as independent of, that of the body?

Why does the pendulum move only in such a small number of directions, and, the conditions being the same, always in the same directions?

Why am I able (and I have never failed) to influence the magnetoscope, through the hand of another person, and to produce precisely the same results as when my own thumb and finger are in contact with the instrument?

How does a (quartz) crystal produce specific motions of the pendulum when the hand of the operator touches the crystal only, and not the instrument? And how is it that precisely the same motions are produced when neither the crystal, nor the hand of the operator, is in contact with the magnetoscope? Will "dominant ideas" pass through a piece of flint? Is seeing through a nine-inch wall a figure of speech, or a reality?

Trusting to the statements of objectors, the *Reviewer* concludes that specific motions of the pendulum are produced only when the operator knows the nature of the substances held in his hand. This is a mistake. Such knowledge is not necessary. In numerous instances, precautions have been adopted by which it was impossible that I could know, or even guess, the qualities of the substances, until they were indicated by the magnetoscope. In other instances, similar results have followed when a particular substance has been held by another person; but who was, of course, in communication with myself. On one occasion a deception was purposely (but very improperly) practised, by describing a substance by a wrong name. The cheat was, however, immediately detected by the motion of the pendulum.

That the mind influences the body, and in a thousand ways controls and directs its movements—as often, perhaps, by what we call unconscious and involuntary processes, as by those which are intentional and, therefore, observed by us,—is only, in other terms, affirming that man is a living and sentient being. But, I believe, the differences are as great in the manifestation of this force or power (apart from that which is usually understood by the term mental or intellectual), as in the properties of different inorganic substances for conducting heat, transmitting light, exhibiting electrical excitability, or obeying the dynamical forces of magnetism.

To attempt to measure, or even estimate, the susceptibility of other persons to electric, or magnetic forces, or, it may be, a conjunction of such forces, by our own feelings and experiences, is as unreasonable as to make the mental qualifications of any particular individual a standard of comparison for all others. It matters not by what name it may be called (for there is no fear of getting appropriate names for what is good, and, therefore, useful), nor is it important that its precise nature should all at once be known; but I believe there is in every human being a force which is very much under the control of the mind, and associated with the action of the brain, which in some respects, resembles electric and electro-magnetic forces, by operating at a distance and passing through all kinds of interposed media. In the manifestations of this force the diversities are as numerous, and the different degrees of susceptibility as great in different persons, and in the same person at different times, as have ever been noticed in the habits and properties of inorganic bodies, whether as excitants, or conductors, of electricity, or as susceptible of magnetic or dia-magnetic influences. Most readily do I admit that, of the true nature of the force, which is thus so intimately bound up with vitality, very little is known; and that, in its operations between man and man, as well as between man and the physical world around him, there is much which, at present, we can neither explain nor understand; but, whilst making this admission, I am not prepared to assent to the absurdities which have lately been set down to the potencies of "suggestion," "expectant attention," and "DOMINANT IDEAS."

W.

OZONE.—*Note* W, *page* 172.

WHAT is Ozone? Its true nature is at present unknown. A great deal has lately been told us about the means of recognizing it, how it may be artificially produced, and what are some of its peculiar qualities; but it is, notwithstanding, impossible to say of what it consists. By watching certain conditions, and carefully noting their effects, we soon discover that ozone is endowed with wonderful properties. It is, therefore, only reasonable to conclude that, in natural processes it is the attendant upon man, and, in some way, connected with the preservation of health and the means of enjoying life.

Ozone* was discovered by Professor Schönbein, of Bâle. Everyone who has used an electrical machine must have noticed the peculiar odour which is diffused as soon as sparks begin to be emitted through the air. This is due to the presence of ozone (electricized oxygen?), and, although many attempts had previously been made to explain the cause of that odour, it was reserved for Schönbein to reveal its *true* cause, and, accordingly, to give the right explanation.

Ozone exists in the atmosphere, but in variable quantities, and its presence there can be detected by a chemical test.† The quantity at any given period seems to depend, chiefly, upon the relative proportions of moisture in the air, and on the direction of the wind. It is influenced by temperature, but not in so great a degree as by moisture (vapour.) This curious material possesses bleaching, oxidating, and deodorizing qualities; and, as far as we can yet understand the matter, it is probably oxygen, or perhaps oxygen and hydrogen in combination, dissolved (?) in aqueous vapour by the agency of electricity.

For many months past I have been making observations on ozone, as it has presented itself in the atmosphere at Brighton.‡ During the prevalence of easterly or northerly winds it can rarely be detected, and, if at all, only in extremely small quan-

* From ὄζω, I smell.

† Pure iodide of potassium, 1 part—starch, 10 parts—water, 200 parts, to be boiled together for a few moments. A little of this preparation, spread on writing-paper and exposed to the air, is changed blue in a shorter or longer period, according to the quantity of ozone present.

‡ About 70 yards from the edge of the cliff—a little eastward of Kemp Town.

tities. Many instances have occurred in which a test, exposed during eight or ten hours without indicating the slightest traces of its presence, has changed colour in *twelve minutes* after the wind had suddenly veered round from a northerly to an opposite direction. After a little experience of the conditions attendant upon the manifestation of ozone, an attentive observer will, very frequently, be able to detect it by his own sensations. When present in its greatest proportions, the atmosphere is what we are accustomed to call *balmy;* that is, mild, soft, and of a genial temperature. Perhaps it may be wrong to conclude that when we are unable to detect ozone it is not present in the air. It may still be there, but in a slightly altered condition and, consequently, not recognizable by the usual test. There may be too little, or too much, aqueous vapour; too little or too much electricity; or the temperature may be too high or too low. These are precisely the things we wish to ascertain, and which can only be known by carefully-conducted observations.* As far as my own investigations have gone, the conditions most favourable to the development of ozone, on that part of the coast already mentioned, are with the wind blowing from some southerly point between south-east and west, and without any special reference to temperature. Other circumstances being the same, there appears to be more ozone in the air in summer and autumn, than in winter and spring. I have also noticed that it is most abundant in that state of the atmosphere which diffuses odours (both good and bad) the most readily; and which, probably, is most active in promoting the fermentation of vegetable, and the putrefaction of animal, substances. May we not hope to recognize a special adaptation in this newly-discovered deodorizer for neutralizing miasmata when they are most numerous and most noxious?

* Upwards of sixty gentlemen are at work, in this country, recording observations.

X.

Metallic Respirators.—*Note X, page* 174.

Perhaps it may be deserving a thought, whether the comfort experienced by some persons who wear metallic respirators, may not be temporary relief only, obtained at the risk of permanent injury. It is scarcely possible to believe that air can be inhaled through one of these respirators without altering its electrical conditions. Warming the air may, and, undoubtedly, does deprive it of some of its irritating properties; but is not electrization likely to render it, in other respects, too exciting to the bronchial membranes and cells of the lungs? Is it not possible to make a respirator of some material which is a non-conductor of heat, and not so powerfully electrical as metal?

The quantity of moisture present in the atmosphere is dependent upon temperature, and is greater in summer than in winter. When the temperature is low, and the atmosphere humid, it is because the *dew-point* assimilates very nearly to the temperature of the air;—which means, that if the air were suddenly cooled, perhaps only 1° or 2°, the vapour present in it would become visible, as fog or rain. It is not the actual quantity of vapour inhaled, which causes uncomfortable sensations in those whose air-passages are sensitive; but the relative quantity, as compared with the temperature of the air with which it is mixed. Many persons can breathe comfortably in a dry, frosty, atmosphere, who dare not venture out of doors in a November fog.

Y.

MIASMA NOT GAS.—*Note* Y, *page* 177.

As the result of my own experience and observations, during more than twenty years, I can testify that amidst, what are always considered to be, the disagreeable odours and deleterious gases which are diffused in the manufacture of coal-gas, the men employed on the works are as healthy and as vigorous as any of their class. A distinction not sufficiently noticed, and certainly not very well understood by sanitary officers, is that miasma is not *gas*, but *vapour*, (vaporized vegetable and animal substances.) It is mechanically mixed with the gases evolved by the contents of sewers, drains, cess-pools, and other receptacles, or sources, of pollution; but it is no more entitled to the name of gas, than the *vapour*, always present in variable proportions in the atmosphere, can with propriety be called *air*. The specific effects of certain gases on the respiratory organs, or on the brain, ought not to be confounded with the effects of miasma. In the processes of coal-gas manufacture some of the workmen inhale in an hour, a greater quantity of *sulphuretted hydrogen* (hydro-sulphuric acid—the gas commonly emitted by drains, sewers, and closets) than any one of the inhabitants of the filthiest district in the kingdom is likely to do in a week or, perhaps, a month. In the former case the gas is comparatively innoxious, because it is a purely chemical product; but in the latter, although more diluted, it is deleterious because it has mixed with it the miasma of decomposing vegetable and animal matter.

Let it also be noticed that in chemical works, and other manufactories, those for the melting and working of metals not excepted, the existence of large fires produces spontaneous ventilation within and around the premises; and the workmen, by this means, enjoy special immunities from vapours and gases which might otherwise affect their health and comfort.

Z.

GENERAL ———. *Note Z, page* 180.

GENERAL ——— fainted at the smell of honey, and could detect its proximity when unperceived and unknown by others. He was a strong man, 6ft. 2in. in height. On one occasion this gentleman was tested by placing, without his knowledge, a pot of honey in a cupboard of the sideboard in the breakfast-room. A few minutes after he had sat down he turned pale and fainted. It had been his infirmity from childhood.—*Communicated by an Eye-witness.*

A. A.

ELECTRICAL FISH.—*Note* A. A., *page* 94.

THE electrical power of some kinds of fish, the *Torpedo* and *Gymnotus*, for example, is a special provision enabling them to defend themselves, and also to attack their prey. On dissection they exhibit a peculiarity of structure in, what is called, their electrical organs; showing an adaptation of the nervous system to the work to be performed. It has often been proved that the electricity developed by these animals is precisely the same as galvanism. The shocks they communicate are voluntary; the force and direction of which can be so regulated that there seems to be a certain degree of intelligence manifested which excels our ordinary notions about instinct.

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