AMERICA'S PART IN THE DISCOVERY OF MAGNETO-ELECTRICITY—A STUDY OF THE WORK OF FARADAY AND HENRY.—I.

BY

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THE phenomena of self-induction and of mutual induction are closely connected, and indeed must be treated together as one whole in the modern theories of electricity and magnetism. After the discovery of self-induction by Henry, it seems to me but a step to the discovery of magneto-induction. This step was more easily made easy by the construction by Henry of electromagnets with great numbers of coils of wire. With a suitable galvanometer, also constructed with many turns of wire, there was sufficient residual magnetism in Henry's large electromagnets to give deflections of the galvanometer when the armature of the magnet was moved on or off the poles of the electromagnet, even when the latter was not excited by a battery.

From a careful survey of the evidence presented, I believe that Henry was the first to perceive the fluctuations of the galvanometer due to magneto-induction, and that he had a conception of the relations of magnetism and electricity before Faraday published his first paper on the subject of magneto-induction. Henry has himself stated that he had perceived the phenomena of magneto-induction, and had been intending to study them further; but was prevented from pursuing the subject by unavoidable interruptions, and the desire to construct more powerful apparatus to continue his investigations. When we reflect that he had to insulate his wires with calico cloth, and to wind all his own electromagnets; that he was pursuing his investigations in Albany—then little more than a frontier town—while Faraday was at the Royal Institution, in the intellectual centre of the world, we feel that too much cannot be claimed for our countryman.—John Trowbridge.

In the year 1774, a question of no small significance was presented as a subject for prize essays by the Academy of Bavaria. The subject was one which even at that early day had excited deep interest in the scientific world; it was no less than "the identity of the two great mysterious forces, electricity and magnetism." The essays received in the competition were so numerous as to make 13 large folio volumes of matter, but the report of the Academy nevertheless was to the effect that "although electricity and magnetism are by some experimenters proved to be the same in some respects, in other respects they are dissimilar, so much so that they must of necessity be as yet considered as distinct." In this indeterminate state the matter rested for 56 years, until 1819, when, by the deflection of a needle Oersted became immortal. While the Danish philosopher was one day lecturing to his class in the University of Copenhagen, an experiment occurred to him and he tried it then and there for the first time. It was a simple matter; nothing more than the passing of a galvanic current through a wire parallel to and above a magnetic needle. Oersted found that under these conditions, the needle, swinging upon its pivot, turned eastward, and at length came to rest at right-angles to the wire, its north pole pointing east. When the wire was held below the needle, the north pole turned westward, and settled pointing west. What had happened here? What was there in this mere swaying of a bit of steel through an inch of distance to bring fame to a philosopher like Oersted? The little needle was not a common needle, a mere unresponsible fragment of steel. Endowed with the mysterious principle of magnetism, it had as one might say, a soul, and as human soul answers to human soul, it was quick to respond to another magnetic soul. Had an ordinary magnet been brought to bear upon it, in obedience to the magnetic instinct, it would have excited no surprise, had it responded to its influence. What then, we ask again, had happened in the experiment of Oersted? The little needle was behaving exactly as if the wire traversed by the electric current possessed magnetic prop-
pages on the subject; the fame of his experiment spread with almost unexampled rapidity throughout the civilized world; it was repeated everywhere, and Schweigger seized upon the little needle to make of it the galvanometer, so indispensable in the laboratory of the electrician from that day until this.

Very brilliant were the scientific men in the old world of that day, and about the year 1829 not a few of them were deeply interested in the question of the "identity of electricity and magnetism."

In the same year we find Arago and Sir Humphry Davy passing currents of electricity through wires and noting carefully the attractive power produced. Ampère caused two wires, each traversed by a current, to attract and repel each other, as if they indeed had been two magnets. Arago reached a result of no small importance; it was this: He placed a common steel sewing needle within a glass tube; around the exterior of the tube he wound a helical wire, through which the electric current was made to pass.

The needle under these circumstances was found to become strongly magnetized. Nature here asserted, in most unimpeachable terms, that electricity could produce magnetism. Five years later we find Sturgeon bending a bar of soft iron into a horseshoe and by an obvious adaptation of Arago's method rendering it so strongly magnetic by means of a current of electricity, as to be capable of sustaining a weight of nine pounds.

There is not the shadow of a doubt, after the year 1829, that electricity can produce magnetism; but the reverse, can magnetism produce electricity? With ever-deepening interest year after year goes by, the scientific world asks this question, but with all the most eminent men of Europe at work upon it, nature vouchsafes no reply, and so we come down to the last days of August, 1831, and to two men, one in the old world, the other in the new, at work upon the problem, each unconscious of the other, an ocean between them. One of these men is Michael Faraday, professor of chemistry in the Royal Institution of Great Britain; the other is Joseph Henry, professor in the Albany Academy in the State of New York. These two were destined to find the key to the problem; the answer to the question which had baffled the world of science for half a century.

We say the last days of August, 1831, because at that date, the work of the two men nearly touched in point of time; but the actual discovery of magneto-electricity, the reader will see, if with kind patience he will follow our story, had been made by the one, that is, Henry, at least a year earlier, namely, in August, 1830, while it was not fully accomplished by the other until some thirteen months later, namely, the 24th of September, 1831; for this we shall find to be the date at which Faraday first fully recognized the phenomenon, and the principle by which it is controlled.

To understand properly the work of these two men, in reference to the discovery of magneto-electricity, it is necessary to know something of the circumstances in which they were placed. When Sir Humphry Davy was asked, which he considered his greatest discovery, he answered, "Michael Faraday." Entering the Royal Institution in an humble capacity in 1813, the flower of his genius growing and expanding under the fostering care of Sir Humphry, Faraday had attained a high position, and an enviable scientific reputation, in the great London institution. Director of the laboratory, he was surrounded by every possible facility for the prosecution of his investigations; and what was perhaps even more important, had unlimited time at his command in London, the great centre of scientific light. He was now forty years of age. Henry was nine years younger. When Faraday first entered the Royal Institution as an assistant, Henry was but thirteen. Counting the years of his age with those of the century, he had entered upon a course of original investigation as early as 1827, but amid such arduous duties as an instructor in the Albany Academy, that of all the twelve states of the year, he could only claim the month of August, the vacation time of the institution, as really his own. During four years he had been able to secure hardly more than as many months for regular scientific research. Could we look into his laboratory at this time, we would find, instead of the well-filled cabinets of the Royal Institution, only a few rude instruments made at great expense of time and labor by his own hands. Even the material for these rude tools was often difficult to obtain. Experiments, for instance sometimes stopped merely for the want of a scrap of zinc. We say "could we look into his laboratory," but we would seek in vain for a room which could properly be so called. Each series of experiments was necessarily carried on in the large hall of the Academy, which was available for Henry's use at no other time than during the summer vacation. Invariably all investigations came to a stop with the first of September, the beginning of the autumn session of the Academy, and were rarely resumed.
until the month of August came again. The invaluable stimulus of scientific intercourse and appreciation too, was wanting. Very different was the dull commercial town of Albany, from London, the intellectual metropolis of the world. A wide expanse of waters, not yet crossed by the swift ocean steamer, lay between Henry and all the culture of the old world, and in provincial America, little could be found to make good its place. Moreover, it must not be forgotten that Henry was the first who had undertaken a series of electrical experiments in America since the time of the immortal philosopher who first drew lightning from the cloud; "the mantle of Franklin"--said Dr. David Brewster--"has fallen upon his young shoulders." Excepting Dr. Hare of Philadelphia, who was making notable improvements in galvanic apparatus, almost alone in the electric field, he stood to face the army of the old world.

Recalling the wide difference in condition surrounding the two, it is of no small interest now to see what eminence each had at this time attained, the one during his eighteen years of culture and unimpeded work; the other in his few months of intermittent study, snatched at long intervals from the crowded days of four years of indispensable professional labor. Constantly pursuing similar investigations, making many identical discoveries, Faraday and Henry seem like two competitors in a closely contested race, upon whose course we have suddenly come in these August days of 1831, and with curious eyes we scan the field to see how they are running. Bence Jones says: "If Faraday's life had ended at this time, when he finished his higher education, it might have well been called a noble success, but when we turn to the eight volumes of manuscripts of his Experimental Researches which he bequeathed to the Institution, we find that his great work was just going to begin."

Henry had begun his course with a series of original discoveries which might well weigh in the balance with anything Faraday had as yet accomplished, while in the particular field in which the "great work" of Faraday, which he was now "just going to begin," he had not only entered, but was already far ahead. The mysterious phenomena of the induction of electric currents, the reciprocal production of the magnetic and electric forces, were to him already old stories, intimately familiar, singularly well understood by him at this early date. And he in turn but amplifying the results which Faraday has just begun to seek, in these waning days of the summer of 1831. The younger man, as it were, had struck almost immediately into this particular path, and is now almost lost to sight in it, while the elder has only just come to the spot where his entering footsteps began.

Let us dwell for a moment upon the importance of the answer to the great question we have been considering, the value to the world of the discovery made by these two men. It is not too much to say that it constitutes a veritable epoch in electrical science; upon it depend many of the most important applications of electricity to the uses of man, and new applications are developing day by day. Tyndall, the successor of Faraday in the Royal Institution, does not attempt to restrain his enthusiasm in the contemplation of it:

5. The Albany Academy, in which Joseph Henry occupied the chair of Mathematics and Natural Philosophy from 1826 to 1846, is an institution which for three quarters of a century has been held in deservedly high esteem, not alone in the community in which it is situated, but throughout the United States. Among the oldest foundations of its kind in the country, its venerable walls seem imbued with that subtle spirit of the past, that favors study, and that nothing but time can give. The Academy building, beautifully situated on the public square made by the intersection of the principal streets of the city, is a dignified and stately architectural example of the classical or "colossal" type. In the words of a writer of the period, as the Academy was in its centennial anniversary of Academy in 1841: "Time has not rendered it in any degree unfitted for its purposes. Its beautiful situation in the midst of the public buildings of Albany, and the imposing aspect which it presents, have always a charm of dignity upon it. The building is the result of the labors of the best architects, and has contributed to give the city its present dignified aspect." The room in which Henry presented his memorable experiments in electricity and magnetism, during the vacations of the Academy, has remained almost unchanged, with its fine high windows, well lighted and spacious hall of red brick, adorned with the proportions, and chase and classical decoration, and is in no respect unworthy of the interesting associations that cluster about its venerable walls. [Editor.]


7. Faraday as a Discoverer.


9. S. S. Cox, Memorial Speech in the House of Representatives Jan. 16, 1870.
former endowed with the subtle capacity which enabled it to respond to the electric influence at long distances; the magnet, in fact, which made the telegraph a commercial possibility instead of a philosopher's plaything. He had discovered and made the law governing the relation between the electric flow and the electric resistances in battery and magnet, and by this discovery had married, as it were, his magnets to their respective batteries; the "intensity" magnet of a long wire to the "intensity" battery of many pairs of plates; the "quantity" magnet of many short wires to the "quantity" battery of a single large pair of plates; and had sent forth these children of his brain, through the pages of Silliman's Journal, to take their places as willing servitors in all the physical laboratories of the world; all this in the early days of this very year, in January, 1831.

Prof. William B. Taylor says:

"The importance of this discovery can hardly be over-estimated. The magnetic 'spool' of fine wire, a length—ten and even hundreds of times as great that ever before employed for this purpose was in itself a gift to science which really forms an epoch in the history of electric magnetism. It is not too much to say that almost every advancement which has been made in this, to what branch of physics since the time of Sturgeon's happy improvement; from the earliest researches of Faraday downward has been directly indebted to Henry's magnets. By means of a Henry 'spool' the magnet almost at a bound was developed from a feeble childhood to a vigorous manhood. And so rapidly and so generally was the new form introduced abroad amicably by experimenters, few of whom had ever seen the papers of Henry, that probably very few indeed have been aware to whom they were directly indebted for this familiar and powerful instrumentality. But the historic fact remains that prior to Henry's experiments, in 1829, no one on either hemisphere had ever thought of winding the limits of an electromagnet on the principle of the 'bobbin,' and not till after the publication of Henry's method in January, 1831, was it ever employed by any European physicist."

"But in addition to this large gift to science, Henry has the pre-eminent claim to popular gratitude of having practically worked out the differing functions of two entirely different kinds of electromagnets, the one surrounded with numerous coils of no great length, designated by him the 'quantity'; the other surrounded with a continuous coil of very great length designated by him the 'intensity' magnet. The latter and feeble system (requiring for its action a battery of numerous elements shown to have the singular capability, never before suspected or imagined, of giving a very distinct source. Here for the first time is experimentally established the important principle that there must be a proportion between the aggregate resistance of the battery and the whole external resistance of the conjunctive wire or conducting circuit. This was a very important, though unconscious, experimental confirmation of the mathematical theorem of Ohm, embodied in his formula expressing the relation between electric flow and electric resistance, which, although propounded two or three years previously, failed for a long time to attract any attention from the scientific world."

"Never should it be forgotten that he who exalted the 'quantity' magnet of Sturgeon from a power of twenty pounds to a power of two hundred pounds, and who declared creator of the 'intensity' magnet; and that the principles involved in this creation constitute the indispensable basis of every form of magnetic telegraph since invented."

It detracts nothing from Henry's independent and original discovery of the law of relation between the "electric flow" and the "electric resistance," that Ohm, in far-distant Munich, had a theoretical dream of such a law, which, with a sagacity little short of marvelous, he reduced to a concrete mathematical formula. It is only a moment the distinction between the man who propounds a theory and the man who makes a veritable discovery; for precisely in these two attitudes stand Ohm and Henry in relation to the principles in the discovery of the electromagnet.

INTENSITY MAGNET MADE BY HENRY in 1829, NOW IN THE CABINET OF THE COLLEGE OF NEW JERSEY. A theory may, it is true, be of inestimable value; but however ingenious, however founded upon intimate knowledge of the subject, it at the most can only suggest what may be; can only point out an intelligent mode of making Nature a question. The theory may, or may not, prove to be true. A discovery, on the contrary, tells us what is; it tells us that a certain fact or a certain relation in nature actually exists. Of the theory of Ohm, now at the tongue's end of every schoolboy, but for a long time ridiculed, or at least unnoticed by the scientific world, Henry, in far-distant America, knew absolutely nothing. Five years later, in a letter written from Princeton, dated December 17, 1835, we find him asking Dr. Bach: "Can you give me any information about the theory of Ohm? Where is it to be found?" In another letter of about the same period: "Who is Ohm? What is his theory?" It was not until 1836, during his visit to London, that he sees at last Ohm's theory, and finds that, after all, it is in substance nothing more nor less than his own discovery, interpreted in the language of mathematical prophecy.

ASBESTOS PORCELAIN.

In a recent communication to the Académie des Sciences, M. F. Garros called attention to a new form of porcelain brought out by him. He takes asbestos fibre and reduces it to a fine powder. If pure, it exhibits an exceedingly white appearance, but if traces of iron oxide are present there is a slightly yellow tint. In the latter case the oxide is removed by sulphurous or hydrochloric acid. The powder is then made into a paste, moulded into shape, dried slowly and baked at 1200° C. from 17 to 18 hours. If placed in a very high-temperature furnace, a remarkably transparent species of porcelain is obtained. This "asbestos porcelain" has already been used for filtration and sterilization purposes, experiments showing that it is a more rapid and effective filter than ordinary porcelain, and that the pores are less liable to become clogged up.

11. "It is evident"—says Mr. Fable—"that it was not until after the interview with Henry (on April 11, 1831) that Whistome recognized the importance of Ohm's laws to telegraphic circuits, the study of which would likewise have enabled him to ascertain the relation between the length, thickness, etc., of the cells, as compared with the other resistances in the circuit, and to determine the number and size of the elements of the battery necessary to produce the maximum effect. [History of Electric Telegraphy, P. 51]. Yet Whistome—characteristically, it must be said—has not hesitated to claim Henry's discovery for himself; in a statement written by him in 1841, to be presented to the arbiters in a dissertation which had arisen between himself and Mr. Fabel. "I believe," he says, "that various methods of completing the secondary circuits have lost nearly all their importance, and are scarcely worth confounding about."—"Wherefrom, from Ohm, Gauss, or Henry himself, any other person, I have, and shall always be ready to acknowledge it." Yet Henry, in Silliman's Journal, had then and had before published that Whistome was the first to bring out the subject, and Henry himself had explained to Whistome in King's College, on April 11, 1831, the construction of an "intensity" magnet of his late invention. Furthermore, Whistome became somewhat more guarded in his assertions, for we find him stating in his "History of Electric Telegraphy," p. 51, that "it is remarkable that even Whistome became somewhat more guarded in his assertions, for we find him stating in his "History of Electric Telegraphy," p. 51, that "it is remarkable that Whistome became somewhat more guarded in his assertions, for we find him stating that Whistome was the first to bring out the subject, and Whistome himself had explained to Whistome in King's College, on April 11, 1831, the construction of an "intensity" magnet of his latest invention. Furthermore, Whistome became somewhat more guarded in his assertions, for we find him stating in his "History of Electric Telegraphy," p. 51, that "it is remarkable that