SCIENCE

Vol. 73 — Friday, April 24, 1931 — No. 1895

SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. McKeen Cattell and published every Friday by

THE SCIENCE PRESS

New York City: Grand Central Terminal

Lancaster, Pa. Garrison, N. Y.

Annual Subscription, $6.00 Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

MICHAEL FARADAY[1]

By Dr. W. F. G. SWANN

BARTOL RESEARCH FOUNDATION

It is a characteristic of the march of progressive in natural philosophy that from time to time we seem to see the end of all that man may hope to learn. There arises before our mental vision a barrier, a barrier in which the horizon of knowledge seems also its boundary. The things that have not already been done seem trivial, or at best so hopelessly complex and involved in relation to our previous fields of thought that nothing but discouragement and waste of time offer themselves as the probable lot of any one who seeks to unravel them.

The tremendous development in electrical science which has taken place in the last hundred and fifty years acts in two diametrically opposite ways in moulding our appreciation of the contributions to science of such a man as Michael Faraday. On the one hand they emphasize to us the fundamentality of his work. They emphasize the fact that it is to investigations made for merely altruistic reasons that the world must look, ultimately, for returns in the form of material progress in the applications of science to everyday life. If we could picture that kindly philosopher who worked in his laboratory a century ago as having a prophetic vision of the results of his labor, we might suppose him well encouraged by the vision of the future in the many discouragements of his present. Wide as was his vision, however, we can hardly imagine that even Faraday could foresee the glorious maturity to which his efforts have grown to-day. To him those strange phenomena concerned with the behavior of light, those effects produced by the mutual motions of magnets and wires, those curious powers possessed by certain fish to give

[1] An address given on February 14, 1931, at the Massachusetts Institute of Technology, under the auspices of the Department of English and History.

electric shocks when touched, and so forth, had every right to appear as a set of more or less heterogeneous phenomena giving little guarantee of anything but much labor and frequent discouragement in their study. It is easy, to-day, to imagine a sort of guardian angel who might have guided the hand of Faraday to do those particular experiments and adopt those particular view-points which most rapidly would have led to a vision of what the future held forth; but even this guardian angel would have required the support of an army of mechanicians and workers of all sorts and kinds if his suggestions were to be of much service. The present-day investigator who would appreciate the greatness of Faraday as an experimenter must put himself in the atmosphere of Faraday's time. He must clear out all the machinery from his workshop, dispense with all his stocks, deprive himself of all electrical supply houses and almost every other kind of a supply house, leaving himself with only his bare hands and a few simple tools. Then he must deny himself all the encouragement to be gleaned from the experiences of successes in the past, and must look only forward into a dark cloud in which are but a few vague glimmers of light. His comforts to be obtained from a picture of the past must be little more than can be obtained from a contemplation of the discovery that if a black ebonite rod be rubbed with the skin of a cat, it will acquire the power to pick up small pieces of paper, and to exhibit a blue glow, visible only in the dark, these powers being hindered by the presence of water. What a suspicious set of phenomena! For black rods, cats and witches have been associated from time immemorial. The effect of the water would provide the cynic with much wherewith to whet his sarcasm when he recalled the oft reiterated appeal to that mythical triumvirate, earth, fire and water. And then, the blue light visible only in the dark adds no great prestige to the phenomena. Nor is such encouragement to be expected from the possible value of the phenomena. For it is perfectly evident that if one should kill all the cats in the world and rub all the black rods in the world with the skins of all the cats the most that one could hope to do would be to pick up a few collar studs. It was in such a setting of the almost immediate past that Faraday commenced his work. He did not have the encouragement which we should have to-day from the fact that the history of the past suggests the probability of success in undertaking the investigation in some unexplored field. To one who contemplates the position of electricity in the economy of our life to-day, it seems a most extraordinary thing that these vast powers could have lain hidden for the whole history of civilization when all the time there existed on this same earth the wherewithal to make a dynamo.

Michael Faraday was born at Newington Surrey, England, on the 22nd of September, 1791. His father was a blacksmith and from such history of him as is recorded we learn that he was a hard working, deeply religious man and a firm adherent to that particular sect of non-conformity to the Episcopal church known as the Sandemanians. Europe was in the throes of Napoleonic war, food was scarce, and Faraday himself records that his bread allowance was limited to one loaf per week. The family moved to London when Faraday was five years of age. Little is known of his schooling, but at the age of thirteen we find him engaged as errand boy to a book seller. At this period, newspapers were only for the wealthy, and even then they were hired and not bought. It was Faraday's duty to convey them from one place to another. In the following year his master, Mr. Riebeau, took him as an apprentice to the trade of bookbinding which he carried on in addition to his profession of book selling. The opportunity thus provided for the young Faraday to come into contact with books seems to have been the first means of firing his interest in science. The "Encyclopaedia Britannica" provided him with his first notions on the subject of electricity and a book, "Conversations of Chemistry," by a Mrs. Marcet, gave him his first introduction into chemistry. Writing later concerning his mental attitude at this time, Faraday says:

> Do not suppose that I was a very deep thinker, or was marked as a precocious person. I was a very lively imaginative person, and could believe in the ''Arabian Nights'' as easily as in the Encyclopaedia. But facts were important to me, and saved me. I could trust a fact, and always cross-examined an assertion. So when I questioned Mrs. Marcet's book by such little experiments as I could find means to perform, and found it true to the facts as I could understand them, I felt that I had got hold of an anchor in chemical knowledge, and clung fast to it. Thence my deep veneration for Mrs. Marcet—first as one who had conferred great personal good and pleasures on me; and then as one able to convey the truth and principle of those boundless fields of knowledge which concern natural things, to the young, untaught, and inquiring mind.

In connection with his activities as a bookbinder's apprentice, young Faraday came into contact with many interesting and prominent people and through the kindness of one of them, a Mr. Nance, who was a member of the Royal Institution, he was provided with the opportunity of hearing four of Sir Humphry Davy's lectures. This was in 1812, when he was twenty-one years of age. In the meantime his enthusiasm for science had grown, and he seems to have been determined by hook or by crook to become a philosopher, the term which, by the way, he always liked to apply to a student of physics. The word physicist was particularly distasteful to him. Having made careful notes of the four lectures, he sent them to Sir Humphry with a letter asking for some kind of employment of a scientific nature, however humble it might be. We learn that Davy seems to have been frankly puzzled by the unusual request. "What am I to do?" he asked one of the managers of the institution. "Do," the other retorted, "Put him to wash bottles; if he is good for anything he will do it directly, if he refuses he is good for nothing." Davy seems to have adopted a kindly and sympathetic attitude toward the young enthusiast. He failed not to point out to him that the life of a philosopher was likely to be no bed of roses, and that he would do well to weigh the advantages in the regular and definite nature of his occupation as a bookbinder, of which he was now a master, as against the uncertain livelihood which he might expect as a devotee of science. However, the young philosopher was not to be dissuaded, and a few months later when a situation became vacant at the Royal Institution it was offered to Faraday and was immediately accepted. The minute of the meeting of the board at which the appointment was confirmed is as follows:

> Sir Humphry Davy has the honor to inform the managers that he has found a person who is desirous of occupying the situation lately filled by William Payne. His name is Michael Faraday. He is a youth of twenty-two years of age. As far as Sir H. Davy has been able to observe or ascertain he appears well fitted for the situation. His habits seem good; his disposition active and cheerful; and his manner intelligent. (March, 1813.)

And so at the age of twenty-two, and at a weekly wage of 25 shillings, Faraday began that career whose fruits were a revolution in civilization greater than has ever been made by any king, conqueror or empire. It is not without interest to contemplate the state of mind of the great investigator at this early period in his career. He seems to have pondered upon many things, and to have formed concerning them opinions which are very surprising for their maturity when one meditates upon the limited opportunities for coming into contact with a world, which he must have had at this time. An apparently little known comment of his upon the art of scientific lecturing, written in the form of a letter, at the early age of twenty-one, might well serve as a guidance to many of us to-day. I wish I could read the whole letter to you, but I must content myself with a few extracts. After commencing with a statement of how he came to put down his thoughts upon the subject he goes on to dilate upon the matter of arriving at a lecture late which he considered "an impropriety of no small magnitude and indeed bordering on an insult to the lecturer." He goes on to discuss the ventilation of the lecture-room. He writes:

> There is another circumstance to be considered with respect to a lecture-room of as much importance almost as light itself, and that is ventilation. How often I have felt oppressive in the highest degree when surrounded by a number of others and confined in one portion of air! How have I wished the lecture finished, the lights extinguished, and myself away, merely to obtain a fresh supply of that element! The want of it caused the want of attention, of pleasure, and even of comfort, which were not to be regained without its previous admission. Attention to this is more particularly necessary in a lecture-room intended for night delivery, as the lights burning add considerably to the oppression produced on the body.

Then later we read:

> The fitness of subjects, however, is connected in an inseparable manner with the kind of audience that is to be present, since excellent lectures in themselves would appear absurd if delivered before an audience that did not understand them. Anatomy would not do for the generality of audiences as the Royal Institution, neither would metaphysics engage the attention of a company of schoolboys. Let the subject fit the audience, or otherwise success may be despaired of.

Even at this early age he had evidently sensed out several well-known groups of people among whom were to be found the superficially learned, when he writes, "A lecturer may consider his audience as being polite or vulgar (terms I wish you to understand according to Shuffleton's new dictionary), learned or unlearned (with respect to the subject), listeners or gazers." And when at the end of the paragraph he writes, "Lastly, listeners expect reason and sense, whilst gazers only require a succession of words."

An example of his rather caustic wit is found when he remarks:

> With respect to the action of the lecturer it is requisite that he should have some, though it does not here bear the importance that it does in other branches of oratory; for though I know of no species of delivery (divinity excepted) that requires less motion, yet I would by no means have a lecturer glued to the table or screwed on the floor. He must by all means appear as a body distinct and separate from the things around him, and must have some motion apart from that which they possess.

Nevertheless, he has little sympathy with theatricalism, as when he writes,

> Let your experiments apply to the subject you elucidate, do not introduce those which are not to the point. Though this last part of my letter may appear superfluous, seeing that the principle is so evident to every capacity, yet I assure you, dear Abbot, I have seen it broken through in the most violent manner—a mere ale-

house trick has more than once been introduced in a lecture, delivered not far from Pall Mall, as an elucidation of the laws of motion.

During the period of his apprenticeship we find him already engaged upon scientific experiments. The language in which he writes of them shows an interesting mixture of humility and confidence. In the case of a young man feeling his wings in the fields of science we frequently find either a superficial arrogance or a timidity of judgment which seems to call for the comfort of approval of some older head to give it confidence. In Faraday, at this time, we find the most perfect equanimity of judgment combined with a boyish enthusiasm of irresistible freshness. To most people natural philosophy is a mysterious sort of thing which is accommodated in a special part of the brain kept clean for study and unhampered by the phenomena of every-day life. But to young Faraday, the phenomena of science are just like everything else. He describes his discoveries as one would tell the story of a human episode. The byways of knowledge are to him like the lanes through a beautiful wood. There is to him a real beauty in the things which he sees, and to seek a utilitarian purpose, at least in the line of his own benefit, is as far out of mind as it is for one who walks through a beautiful forest and enjoys the scent of the trees and beauty of the flowers to seek a reason to cut the trees for lumber or pluck the herbs for the market. Writing to his friend Abbot, he says, "I have lately been thinking a few simple galvanic experiments." He describes his purchase of materials and goes on to describe the conception of a voltaic pile:

> The first I completed contained the immense number of seven pairs of plates!!! And of the immense size of halfpence each!!!! I, Sir, I my own self, cut out seven discs of the size of halfpennies each. I, Sir, covered them with seven halfpence, and I interposed between seven, or rather six, pieces of paper soaked in a solution of muriate of soda! But laugh no longer, dear Abbot; rather wonder at the effects this trivial power produced. It was sufficient to produce the decomposition of sulphate of magnesia—an effect which extremely surprised me; for I did not, could not, have any idea that the agent was competent to the purpose. A thought here struck me, I will tell you. I made the communication between the top and bottom of the pile and the solution with copper wire. Do you conceive that it was the copper that decomposed the earthy sulphate—that part, I mean, immersed in the solution? That a galvanic effect took place I am sure; for both wires became covered in a short time with bubbles of some gas, and a continued stream of very minute bubbles appearing like small particles ran through the solution from the negative wire. My proof that the sulphate was decomposed was, that in about two hours, the clear solution became turbid; magnesia was suspended in it.

And so he goes on still with his enthusiasm to describe several other experiments of similar character. Then mixed up with his thoughts on philosophy, we find, at this time, a mature consideration of other things. Writing his friend Abbot, he exlaims:

> What a singular compound is man! what strange contradictory ingredients enter into his composition, and how completely each one predominates for a time, according as it is favoured by a tone of the mind and senses, and other exciting circumstances! At one time grave, circumspect, and cautious; at another, silly, headstrong, and careless;—now conscious of his dignity, he considers himself a lord of creation, yet in a few hours will conduct himself in a way that places him beneath the level of beasts; at times free, frivolous, and open, his tongue is an unobstructed conveyer of his thoughts—thoughts which, on after-consideration, make him ashamed of his former behaviour; indeed, the numerous paradoxes, anomalies, and contradictions in man exceed in number all that can be found in nature elsewhere, and separate and distinguish him, if nothing else did, from every other created object, organized or not.

Almost immediately after Faraday's appointment to the Royal Institution, Sir Humphry Davy planned an extensive European trip for the purpose of conferring with the learned scientific men of the continent. He took Faraday with him in the capacity of a sort of combination of valet and scientific assistant, in which complex situation he was not at all times as happy as he might have been. Writing his friend he remarks:

> I am quite ashamed of dwelling so often on my own affairs, but as I know you wish it, I shall briefly inform you of my situation. I do not mean to employ much of this sheet of paper on the subject, but refer you to the before mentioned long letter for clear information. It happened, a few days ago before we left England, that Sir H's valet declined going with him, and in the short space of time allowed by circumstances another could not be got. Sir H told me he was very sorry, but that, if I would do such things as were absolutely necessary for him until he got to Paris, he should there get another. I murmured, but agreed. At Paris he could not get one. No Englishmen were there, and no Frenchmen fit for the place could talk English to me. At Lyons he could not get one; at Montpellier he could not get one nor at Genoa, nor at Florence, nor at Rome, nor in all Italy; and I believe at last he did not wish to get one: and we are just the same now as we were when we left England. This, of course, throws things into my duty which it was not agreement, and is not my wish, to perform, but which are, if I remain with Sir H, unavoidable. These, it is true, are very few; for having been accustomed in early years to do for himself, he continues to do so at present and he leaves very little for a valet to perform; and as he knows that it is not pleasing to me, and that I do not consider myself obliged to do them, he is always as careful as possible

to keep those things from me which he knows would be disagreeable. But Lady Davy is of another humor. She likes to show her authority, and at first I found her extremely earnest in mortifying me. This occasioned quarrels between us, at each of which I gained ground, and she lost it; for the frequency made me care nothing about them, and weakened her authority, and after each she behaved in a milder manner. Sir H has also taken care to get servants of the country, ycleped *lacquais de place*, to do everything she can want, and now I am somewhat comfortable; indeed, at this moment I am perfectly at liberty, for Sir H has gone to Naples to search for a house or lodging to which we may follow him, and I have nothing to do but see Rome, write my journal and learn Italian.

His description of the various incidents of the journey are rich with interest and detail, and betray that sense of humor which must have served him in good stead on many an occasion in the uphill path of his earlier years. He describes his arrival in France:

I was in hope of going on shore, but understood that no one could leave the ship until the arrival of an officer to examine us. Late in the afternoon the mighty men of office came, attended by several understrappers and a barge full of Frenchmen, apparently beggars and porters. A formal examination then ensued. One of the officers came to me, taking my hat off, he first searched it, and then laid it on the deck; he then felt my pockets, my breast, my sides, my clothes, and lastly desired to look into my shoes; after which I was permitted to pass. A similar ceremony was performed on all the strangers; and though I felt surprised at such a singular reception, I could hardly help laughing at the ridiculous nature of their precautions.

Then later he goes on to say:

The various parts of the carriage, the boxes, packages, etc., being placed on deck, word was given and immediately the crew of Frenchmen poured on them, and conveyed them in every direction, and by the most awkward and irregular means, into the barge alongside, and this with such an appearance of hurry and bustle, such an air of business and importance, and yet so ineffectually, that sometimes nine or ten men would be around a thing of a hundred pounds' weight, each most importantly employed; and yet the thing would remain immovable until the crew were urged by their officer or pushed by the cabin boy.

On November the second he writes, "The streets of Paris are paved with equality—that is to say, no difference is made in them between men and beasts, and no part of the street is appropriated to either; add to this that the stones of which the pavement consists are very small and sharp to the foot, and I think much more need not be said in praise of it"—and so on. On the ninth he describes his difficulties concerning passports. On the 13th, he visits the church and ends with the remark, "A theatrical air spread through the whole, and I found it impossible to attach a serious or important feeling to what was going on." On the 23rd he starts off "MM. Ampère, Clement, and Desormes came this morning to show Sir H. Davy a new substance, discovered about two years ago, by M. Courtois, saltpetre manufacturer." Then he goes on to speak of the properties of this new substance, iodine. On the 24th, he dilates upon the domestic economy of the English as compared with the French houses and ends with the remark, "French apartments are magnificent, English apartments are comfortable; French apartments are highly ornamented, English apartments are clean; French apartments are to be seen, English apartments enjoyed; and the style of each kind best suits the people of the respective countries." And so, describing everything in detail, he goes on to talk of philosophy, travel, art, politics and everything that comes under his enthusiastic vision.

On his return to the Royal Institution, Faraday took up his duties as Davy's assistant. Davy was at the height of his activity, and his researches at this period included those on fire damp in coal mines which resulted in the invention of the celebrated Davy safety lamp. With the limited facilities at the disposal of the investigator at this time, the labor of carrying out experiments was enormous and most of the burden must have fallen upon Faraday. In addition he was soon called upon to act as assistant for the various lectures at the Institution, and his duties involved a preparation of lecturing experiments. He was evidently exceptionally skilful in this capacity for we read that "He who has the good fortune to have Faraday for his assistant is lecturing on velvet." At the same time he labored to extend his own knowledge in all directions, through his own reading, through attendance at the lectures and through contact with Davy and the men of learning who visited his laboratory. But it was through his own experiments that he seems to have learned most. He had, in an outstanding degree, that characteristic so frequently found in the born experimenter, the desire to repeat experiments which have been done before, as a preliminary to proceeding to extend them further. It is said that he never felt satisfied that he had obtained all that could be obtained from a recorded observation unless he himself had repeated it; and that it seems that he would hardly trust himself to reason from an experiment unless he himself had performed it with his own hands. When in 1821 he wrote an account of all that was then known of electro-magnetism, he was not satisfied with the mere quotation of the experimental results obtained by others, but repeated with his own hands the great majority of experiments upon which the subject rested at that time. As his knowledge and experience grew, he found time to carry out original work on his own account, and his first paper, "An Analysis of Naturally Occurring Caustic Lime," appeared in the *Quarterly Journal of Science* in 1816, when he was about twenty-five years old. He speaks of having published this paper "With my fear greater than my confidence and both far greater than my knowledge; at a time also when I had no thought of ever writing an original paper on science." The paper was well received and was followed by others on chemical subjects. Two years later he wrote a paper on sounding flames in which he demonstrated an error in the theory of the great Professor De la Rive.

In the year 1820, Oersted discovered that a wire carrying a current possessed the power to influence the magnet in a curious way. The discovery appears to have been more or less of an accident, and the nature of the force between the wire and current was quite a mystery, since the force did not act in a line joining the wire to the magnet. Following upon this discovery Ampère had shown, in the most brilliant way, that, as regards its power to produce a magnetic field, a wire carrying a current was the equivalent of a magnetic shell whose boundary was the current, and he traced out in great detail the system of forces between the current elements which would be the equivalent of the forces between the circuits carrying the currents. In Maxwell's eulogy of this masterly achievement of Ampère he writes:

> The experimental investigation by which Ampère established the laws of the mechanical action between electric currents is one of the most brilliant achievements in science. The whole, theory and experiment, seems as if it had leaped, full grown and full armed, from the brain of the "Newton of electricity." It is perfect in form, and unassailable in accuracy, and it is summed up in a formula from which all the phenomena may be deduced, and which must always remain the cardinal formula of electro-dynamics.

I can not here resist continuing Maxwell's statement a little further, in his comparisons of the methods of attack of Ampère and Faraday. He writes:

> The method of Ampère, however, though cast into an inductive form, does not allow us to trace the formation of the ideas which guided it. We can scarcely believe that Ampère really discovered the law of action by means of the experiments which he describes. We are led to suspect, what, indeed, he tells us himself, that he discovered the law by some process which he has not shown us, and that when he had afterwards built up a perfect demonstration he removed all traces of the scaffolding by which he had raised it. Faraday, on the other hand, shows us his unsuccessful as well as his successful experiments, and his crude ideas as well as his developed ones, and the reader, however inferior to him in inductive power, feels sympathy even more than admiration, and is tempted to believe that, if he had the opportunity, he too would be a discoverer. Every student should therefore read Ampère's research as a splendid example of scientific style in the statement of a discovery, but he should also study Faraday for the cultivation of a scientific spirit, by means of the action and reaction which will take place between the newly discovered facts as introduced to him by Faraday and the nascent ideas in his own mind.

These discoveries were of overwhelming interest to Faraday. He collected and repeated all the experiments which had been performed bearing upon the effect and published his account of the progress of electro-magnetism in the *Annals of Philosophy*. The force between the current and the magnetic pole was like no force that had ever been discussed before. Instead of being in the line adjoining the pole to the current it was perpendicular to that line. Dr. Wollaston thought that he could convert the deflection of the needle by the current into a continuous rotation of needle around the current, and he also hoped to devise means by which the current could be made to rotate around the magnet. With these objects in view he carried out tests in the presence of Sir Humphry Davy, at the Royal Institution, but without success. The difficulty in the case of the rotation of the magnet arises of course from the existence of the two poles. If one passes the current through a wire which goes through the center of the magnet in the direction perpendicular to the axis, there is as much tendency to rotate the North pole in one sense as there is to rotate the South pole in the opposite sense, and consequently no rotation takes place. On the other hand, if one places the magnet again with its axis perpendicular to the wire carrying the current, but at some distance from the current, one might suppose that the greater proximity of one pole to the wire would result in the tendency to turn that particular pole in one direction overbalancing the tendency to turn the other pole in the opposite direction. However, the differences in the two forces on the pole is just compensated as regards the rotational effect by the greater moment per unit of force when the force is applied at a greater distance from the axis of the rotation, and again no rotation takes place. By the adoption of an ingenious device by which the current is caused to divide into two channels in such a way that during the revolution of the magnet the current is transferred from the channel in front to the channel in the rear so that the middle of the magnet can pass through the current without stopping it, Faraday succeeded in realizing to his great delight the extremely interesting achievement of causing a magnet to rotate about a current. He also succeeded in devising an apparatus by which a current was caused to rotate around the pole of the magnet and in principle therefore the germ of the modern motor was conceived.

In 1821 Faraday married, and was accorded permission to bring his young wife to live at the Royal Institution. The Royal Institution of Great Britain was founded by Count Rumford, in 1799. Its stated purpose was "The promotion, diffusion, and extension of science and of useful knowledge." In the early period of its history it was financially in rather low water, and there was probably a feeling to the effect that its activity should be devoted as far as possible to the discovery and development of phenomena which promised an early return for the benefit of mankind. In 1821, Faraday commenced a series of experiments to improve the quality of steel used in surgical instruments; and, in 1825, the Royal Society called upon his services in the matter of improving the manufacture of glass. Much labor was spent in this type of work until 1829 when in a dignified letter to the Royal Society he begs to go free to follow the light within him and to work out his own thought upon other subjects. Of these semi-commercial activities, the most notable was his invention of a certain type of heavy glass. It was not so much for the purpose for which it was intended that it became famous, as in the fact that it later constituted the material in which he discovered the rotation of the plane of polarized light under the influence of a magnetic field. During this period Faraday acquired a fame such that his value was particularly recognized in the commercial field; and, presumably he would have had no difficulty in making himself a comparatively rich man had he been willing to sacrifice his time to such purposes. We learn that in the year 1830 he earned, by chemical analysis, an addition to his income of more than a thousand pounds and in 1831 a still greater addition. His friend, the great physicist, Professor John Tyndall, who was in a position to know the circumstances, estimates that by 1832 he had only to will it to raise his professional income to five thousand pounds. His decision to concentrate his efforts on pure science, however, resulted in his income falling from about a thousand pounds in 1831 to a hundred and fifty-five pounds in 1832, from which it fell with slight oscillations to ninety-two pounds in 1837 and to zero in 1838. Between 1839 and 1845 Tyndall informs us that, except in one instance, it never exceeded twenty-two pounds. However, during this period of his commercial activity, he managed to make worthy contributions to the field of pure science; and, in 1823 he succeeded in liquefying chlorine. The phenomenon occurred while heating, at the suggestion of Sir Humphry Davy, a certain solid hydrate of chlorine in a steel tube. The hydrate had been recently discovered, and the nature of its constitution was a question of interest at the time. The solid fused at blood-red heat and the tube became filled with a yellow gas. A certain Dr. Paris who happened to enter the laboratory while Faraday was performing the experiment jokingly accused him of working with a tube contaminated with oil. The next morning he received from Faraday a letter, "Dear Sir: The oil you noticed yesterday turned out to be liquid chlorine." In subsequent years there seems to have been some jealousy on the part of Sir Humphry Davy in the matter of this particular experiment. It is true that Davy suggested heating the substance, but there is no great evidence to show that he expected the result which was obtained. That the oily liquid was chlorine was a matter figured out by Faraday for himself, however much it may have been in the mind of Davy as a possibility. Following this discovery Faraday succeeded in liquefying several of the other so-called permanent gases and removed that distinction which had so far existed between gases and vapors, a distinction founded upon the belief that the latter were the only ones which were capable of liquefaction. These experiments were not without danger, and we learn on one occasion that no less than thirteen pieces of glass found their way into Faraday's eye, luckily without permanent injury.

In 1823, Faraday was elected a fellow of the Royal Society. At that time Sir Humphry Davy was president, and it is a regrettable fact that he actively opposed Faraday's election, presumably as a result of the matter concerning the credit for the liquefaction of chlorine. In 1825 Faraday was elected director of the laboratory. His first act showed a desire to promote the welfare of the members. He invited them to come to evening meetings in the laboratory, and it was from these evenings that the first Friday evening discourses of the Royal Institution had their origin.

In 1832 the managers of the Royal Institution, still in financial difficulties, after mature consideration came to the conclusion that they could not recommend a reduction in Faraday's stipend which, amounting as it did to one hundred pounds per annum with house, coals and candles, was already at what seemed to be an irreducible minimum. In the following year, however, a Mr. Fuller founded at the institution the professorship of chemistry, which is known by his name, and the institution, which was fully alive to Faraday's value, hastened to show its appreciation by electing him to the first Fullerian professorship for life, at the same time relieving him from the necessity of having to give any lectures unless he so desired.

(To be concluded)