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MICHAEL FARADAY[1]

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I AM to speak to you to-night of Michael Faraday, of whom we shall hear much during the coming year. For he was one of the greatest experimental philosophers that ever appeared in this country or indeed in all the world; and of his discoveries none has had more consequences than that which he made in 1831, a hundred years ago. It was then that he found the true relation between magnetism and electricity. On this relation and on others, which he discovered in a few following years of intense thought and labor, have been founded all those applications of electricity which form the muscles and nerves of our modern life. How many and great these are we may realize if we think of the consequences of stopping every electric current that is running at this moment, so that we bring to an end all electric distribution of light and power, all transmission of news by telegraph and telephone, and a hundred other uses of electricity on which we have learned to rely. The very means by which I am addressing you to-night, the microphone that stands before me, the machine that transfers its vibrations to the ether, the receiver and the loud speaker which are beside you, are all constructed on principles first enunciated by Faraday; the whole mechanism and conception of broadcasting can be traced back directly to his work. Very few men have changed the face of the world as Faraday has done.

The most striking of his discoveries was made in 1831, and since it has led to the development of the electrical industries of every kind, electrical engineers of all countries are joining in centenary celebrations, of which the principal is to be held in London in September, next. The most public feature will be the fourteen days' exhibition which is to be held in the Albert Hall, beginning on September 23. It is to be arranged conjointly by the Royal Institution, where Faraday lived and worked, and by the Institution of Electrical Engineers, the latter body generously supplying the necessary funds. And since other discoveries of Faraday have been the foundation of some of our greatest chemical industries, English chemists are also taking their share of the enterprise and of the cost.

Our Debt to Faraday

This display will emphasize the great industrial consequences of Faraday's researches. Yet if I am to keep matters in their true proportion, I must at once add other reasons for the general wish to acknowledge our debt to Faraday. Though he described himself as being

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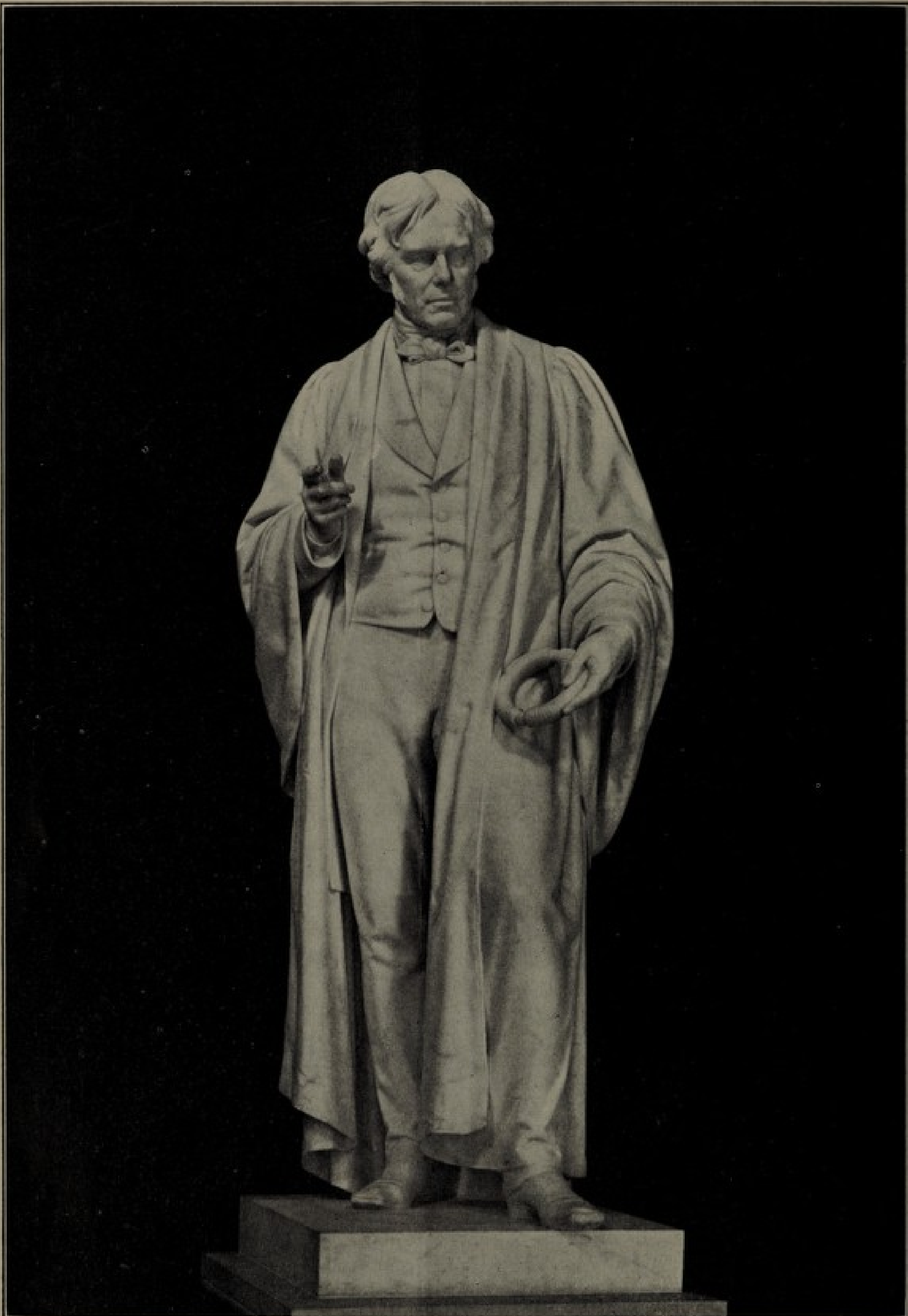

MICHAEL FARADAY

A STATUE BY FOLEY IN THE ENTRANCE HALL OF THE ROYAL INSTITUTION.

nothing else than an experimental philosopher it came about as a necessary consequence of his experiments that he modified profoundly the basic principles of scientific thought. He not only laid the foundation of some of the greatest and most successful of our industries, he also drew from his experiments clear-cut deductions which have made modern science possible and have led towards the strange and fascinating concepts of the physics of to-day. He has modified not only our mode of life but also our ways of thinking.

Yet another cause of our admiration lies in the extraordinary affection with which he is still regarded. Presumably this is a survival of the feelings of his contemporaries: how strong that must have been is evidenced by its persistence. During the last few months of preliminary preparation for the coming centenary it has been a constant surprise to find that every one interested in science, in other countries as well as in this, entered gladly into the spirit of the proposals, not only because the significance of Faraday's work is well understood, but also because the memory of the man himself still has its charm.

And now I must speak rather more particularly of his life and his work: I must describe the nature of his discoveries in broad outline and I must try to sketch the man himself. I hope I may be able to show you how proud we have the right to be of this countryman of ours and how the spirit in which he set about his work was that before which difficulties always tend to disappear; how he was just the man whose example can be the greatest encouragement in the difficult times through which we are passing.

Early Years

Faraday began his working life in 1804, being then thirteen years old, as an errand boy to a Mr. Riebau, a newspaper agent and bookbinder in Blandford Street, near Manchester Square, London. It was his duty to carry round the news sheet of the day to the various subscribers in turn, giving to each person the time allotted for his reading of it. Faraday is said to have had a tender spot for newspaper boys ever afterwards. A year later he was bound to Mr. Riebau as an apprentice. Professor Tyndall relates that, many years afterwards, Faraday pointed out to him, in the course of a walk which they took together, the spot in the shop where he used to work at his bookbinding. Until quite lately the shop front was still in existence.

The handling of the books gave Faraday opportunities to read which otherwise could never have been his. Until he thus began to teach himself, he had had but the scantiest instruction in arithmetic and grammar. He made his bench his school; and it is very interesting to see what he learned there. Picture the boy, with an acute mind absorbed in the acquirement of knowledge and ill-furnished with it at the outset, gathering all that he could from the volumes that passed through the bookbinder's shop. Some of them were scientific works in which he took the deepest interest. He himself says that he delighted particularly in Marcet's "Conversations in Chemistry"; that Watts' "On the Mind" first made him think, and that his attention was turned to science by the article "Electricity," in an encyclopedia which he was employed to bind.

It is easy to imagine that the beauty of Faraday's style of writing, its clearness, strength and rhythm, were due to the literature which he encountered in this way, and attempted to copy. In all the books that he read he would meet with little that did not conform to the mature style of that day; there was no light literature of the modern kind. It is not surprising to find that the copious

MICHAEL FARADAY AND HIS WIFE

letters which the self-taught young man wrote to his friends seem to emulate the polished and balanced sentences of the *Spectator* or "The Vicar of Wakefield." Take the following from a letter to his friend Abbott, written when he was twenty:

> Let me notice, before I cease from praising and recommending epistolary correspondence, that the great Dr. Isaac Watts (great in all the methods respecting the attainment of learning) recommends it as a very effectual method of improving the mind of the person who writes and the person who receives. Not to forget, too, another strong instance in favour of the practice, I will merely call to your mind the correspondence that passed between Lord Chesterfield and his son. In general, I do not approve of the moral tendency of Lord Chesterfield's letters, but I heartily agree with him respecting the utility of a written correspondence. It, like many other good things, can be made to suffer an abuse, but that is no effectual argument against its good effects.

Finding His Way through

It would not be fair to find fault with the apparent sententiousness of such a passage as this. Faraday was in the absorbent stage and had made great use of his opportunities, drinking in knowledge and ideas from every source available to him. When in later years he had to explain to the world the results of his own experiments, and the deductions which he made from them, the first heaviness disappeared. His writings became models of good and restrained expression, which kept all the qualities he had admired in his youth: every lover of science knows their charm.

Davy's Influence

In 1812 came an opportunity of attending a course of lectures given by Sir Humphry Davy at the Royal Institution. Sir Humphry was then at the height of his fame as a chemist and a lecturer, and his discourses were social events. Faraday took copious notes of a set of lectures on chemistry, one of them on chlorine. This remarkable gas had only recently been isolated and was one of the scientific wonders of the day. Faraday made a fair copy of his notes and bound the beautifully written pages into a volume which he sent to Davy. This book is now one of the greatest treasures in the Royal Institution. Davy was much pleased, but when asked by Faraday if there were any vacant post at the institution he could only say no, for, however he might have liked Faraday as an assistant, the institution was much too poor to find wages for him. It happened, however, not long afterwards that Davy found grave fault with his only laboratory servant and dismissed him on the spot. As the result a carriage and pair invaded Weymouth Street, where Faraday then lodged. A footman descended and took in a note to "Mr. Faraday," which resulted in his engagement next day as assistant to Davy at 25 shillings a week with two rooms in the institution. This was the beginning of Faraday's scientific career. In the quiet laboratories in the basement of the Royal Institution he helped Davy to continue his chemical investigations.

A great experience awaited him in October of the same year, 1813. Sir Humphry and Lady Davy went on the grand tour of Europe, which was to last for a year and a half and to take in some of the greatest sights and the finest scenery on the Continent. Moreover, to the great contentment of Faraday, who went as assistant and amanuensis, visits were to be paid to many of the famous laboratories. In Paris, Davy and Faraday studied with immense interest the new substance, iodine; in Florence they burnt diamonds by means of the concentrated rays of the sun in the laboratory of the Grand Duke; at Rome they were shown experiments on magnetism; at Geneva, on the heat of the sun's invisible rays.

Faraday was a great letter writer, principally to his mother and his young friends, so that the events of the journey are well and fully recorded. So also is the joy of the home-coming in 1815. Once more the pair settled down to steady work at the Royal Institution; but as the years went by Faraday took a greater and greater share of it and, when Davy died in 1829, Faraday was appointed director of the laboratories and all the responsibilities for the work of the Royal Institution devolved upon him.

I must refer to two famous pieces of work which belong to these years. The first, in 1823, was the condensation of chlorine into a liquid, one of the early events in the story of the liquefaction of gases now so great a matter both in pure science and in industry. The story goes that Faraday was experimenting with chlorine and had sealed up a portion of the substance in its usual gaseous state, confining it in a closed glass tube. It happened that a very high pressure had been reached in the process. A little of the gas condensed and formed a patch of oily liquid within the tube. An interested visitor to the laboratory remarked that the tube must be dirty, a friendly insult which had to be washed out by a thorough examination of the circumstances. Next day Faraday was able to say that the oily liquid was condensed chlorine. Several other gases were similarly liquefied, but the more difficult gases—oxygen, nitrogen, hydrogen—were beyond the means available at that time. Though Faraday subsequently discovered that chlorine had already been liquefied by Northsmore in 1805, a fact which he hastened to acknowledge, yet his own researches on this subject were of great importance. The work was a notable contribution to the knowledge of a subject which is of high theoretical value and is the main principle of the refrigerating industries.

The other discovery of this period was that of benzene. It was then the custom to supply illuminating gas under compression in iron cylinders. Faraday's brother was actually one of the men engaged in the house-to-house delivery and collection. The cylinders returned as empty contained a small quantity of a fluid which Faraday examined. From it he isolated a substance of which he determined the constitution to be, by weight, twelve parts of carbon to one of hydrogen. He named it bicarburet of hydrogen: we now call it benzene. A little of the first liquid which he thus obtained is still preserved in the Royal Institution. Now, as is well known to many, this substance is the basis of half organic chemistry, and in particular of modern dyes. Faraday did not, it is true, make these dyes, nor did he come to a knowledge of those further developments and processes, due to the great organic chemists of the nineteenth century, which finally led to the establishment of the dye industry. But Faraday's part of the work is gratefully recognized by chemists as that of their pioneer. On the centenary of the discovery of benzene six years ago, a large meeting was held in order to record their debt. Perhaps the most striking way by which to draw general attention to the greatness of this work is to point to the recent excited discussion over the renewal of the dyestuffs act, of which it may justly be said that the point at issue was whether or no it was for the good of the country that our people should be given favored opportunities for the manufacture of the products derived from Faraday's bicarburet of hydrogen.

Experiments with Electricity

Now we come to the famous electrical discoveries made in the half dozen years of which 1831 was the first. Let me try to explain their significance.

The first of these discoveries gave us the means by which, in these days, we produce electric currents. There is no need to enlarge on the extent to which the electric current is used in modern life. But in those days electricity was a philosopher's toy. Even the curious experimenter who wished to generate electricity must employ the cumbersome old machines in which charges were developed by rubbing plates or cylinders of glass, or he must make use of the expensive primary batteries consisting of metals acted upon by acids. There was no such thing as insulated wire to be bought: it had to be made in rough and ready ways in the laboratory.

Now there had for some time been prevalent an idea that it might be possible to generate electric currents, by means of what men called induction. The principle was simple enough. A magnet, as was well known, transformed any neighboring piece of iron into at least a temporary magnet, though the iron had previously shown no traces of being magnetic until the primary magnet "induced" it to become one. The induced magnetism persisted in the iron as long as the proximity was maintained. So also an electrified metal sphere "induced" charges upon any neighboring metal sphere, though the latter might be previously uncharged. Again the induced charge persisted so long as the spheres were neighbors. Then, it was asked, might it not be expected by analogy that if a wire along which a current ran steadily in one direction lay alongside another wire which was capable of carrying a current, induction would cause a current to run in the second wire so long as it ran in the first? We may be sure the effect was often looked for. It is easy to say now that, of course, nothing of the sort should happen. Faraday himself made many electromagnetic experiments without hitting on the truth. But on August 29, 1831, he made the great discovery, which is so simple that it does not seem possible to make the telling of it dramatic. The same difficulty stands before us in the matter of the Centenary Exhibition at the Albert Hall. We are to have a statue of Faraday in the center with his first apparatus about his feet while the fruits of his experiments line the walls and the connecting links run between like the spokes of a wheel. But when we make up the old experiments or take down the original pieces of apparatus, if we have them, from the cases where they are carefully preserved, the few pieces of wire and tape and string and iron look so insignificant that we might become afraid. Surely, however, those who see these little things will ponder on their meaning and give us that imagination without which any effort to kindle enthusiasm is like putting a match to an empty grate.

A Simple Experiment—

When Faraday, on August 29, 1831, tried the experiment of electric current induction as others besides himself had tried before, but now by a new and most aptly devised method, he found that the expected induction was there but not quite in the expected form. A current ran in the second wire, while the current was being started in the first: as soon as the current in the first wire reached its full strength and became steady there was no further current in the second. But when the current of the first wire was being stopped there was again a current in the second which ran until the stopping was over. In other words, a steady current has not the power to induce. It is only a changing current that can do it, and that is the whole story. By subsequent experiments Faraday widened and clarified his first ideas. He soon made it clear that it was equally effective if the position of the first wire was undergoing change while its current remained steady, or if again a magnet were brought near the second

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AT THIRTY-NINE YEARS OF AGE. A PORTRAIT PAINTED BY H. W. PICKERSGILL.

wire; because all these different actions were but variants of one, namely, an alteration of the magnetic conditions in the space near the second wire. In Faraday's mind the space about a magnet, whether a permanent steel magnet or an electromagnet such as he wound in numbers for himself, using his home-prepared wire, was in some way affected, so that it was abnormal: and he imagined that this state varied in intensity from point to point. He was very curious about this condition: he scattered iron filings over a sheet of paper lying over the magnet and watched them as they arranged themselves in elegant lines, thinking so to come to some ideas about that condition, just as the marks on the sand may show which way the tide has run. These material lines were to him the visible signs of "lines of force" in space, as he called them, and as electricians have called them ever since. So we may make the great statement in yet another simple and comprehensive way. As long as there is change proceeding in the magnetic conditions of any space there will be a tendency for currents to run in a conductor embedded in that space. It is necessary to say tendency, for, of course, the conducting circuit might not be complete, so that no current could get round it, however great the tendency might be.

So if we move magnets past coils of wire we have the dynamo: and if we send electric currents alternately in opposite ways round one coil of wire we may generate alternating currents in neighboring coils and we have the transformer; and so the whole family of electromagnetic devices. That is all. It is a very simple conception on which to build so greatly.

—And Its Consequences

But there is even more in this than the foundation of industries employing millions of men. For here begins one of those great sweeps of thought that form the winding road by which research makes its way into the unknown. Faraday had conceived the idea that the space about the magnet was the seat of the working of those laws whose effects his experiments revealed to him. The iron and the copper wire were to him no longer the repositories of the powers whose actions he observed. These lay in the invisible tenuous space of which the materials in use might be considered to be the boundaries. He drew away from the older idea that magnets acted on one another across a space which was not concerned in the action. He began to think that on the contrary this space or a medium which filled it was the real seat of power. It was a breakaway from the material to the immaterial. The idea has been extraordinarily fruitful, first in Faraday's hands and then in the hands of Clerk Maxwell and other great men who followed him. It is true that the road has turned other corners since then. But what Faraday did has still its immense consequences, not only on the practice but also on the thought of our own times.

The wish to make these things clearer to himself was one of the reasons that prompted him to undertake a second set of experiments of fundamental importance. These related to the mutual attractions and repulsions of electrified bodies. He wanted to know whether in this case also the medium played a principal part. A conductor could be charged with electricity. What did charging mean, and where was the electricity? Was it on the surface, or was it distributed through the interior or was it partly outside and partly inside? There were appearances that suggested the importance of surfaces generally. Would it be good, therefore, to pack a hollow globe with a quantity of tin foil, which certainly had plenty of surface? Such a globe might more readily receive

a charge of electricity when the tin foil was there than when it was not. Comparison might be made with the effect of filling the globe with water. But he found no such differences. He tried a great number of experiments of this kind. In some of them he used a large boiler which he had obtained from the coppersmith's. He mounted it on insulating supports and charged it with electricity. He then tried to find what proportion of the charge was to be found within. His final experiment, made on January 15, 1836, was the construction of a great cube with an edge of 12 feet, made of a light framework, over which he stretched a covering lined with conducting material. It was set up in the theater of the Royal Institution and blocked up the center to the level of the gallery. It rested on insulating supports so that when connected with an electrostatic machine it could be charged with electricity until sparks flew from it and brushes glowed at every outside corner and projection. Faraday was inside the cube while this was going on and was in perfect electrical peace: his most delicate detectors of electricity showed no sign of disturbance.

This was the climax of a series of experiments which answered for him his question. The power that is displayed in the attractions and repulsions of electrified bodies or in the electric spark does not lie in those bodies. It is seated in the surrounding space, of which the bodies may be regarded as boundaries: he had held a similar belief as regards magnetic effects. That is why nothing electrical happens inside an electrified conductor. That is why Faraday could sit peacefully inside his cube while electrical storms raged outside. His case was a perfect lightning conductor or rather protector from lightning. His experiment showed that energy could be stored in the space between two conductors differently charged with electricity. This is the principle of the so-called (and very badly called) condenser. How important this discovery has been every electrical engineer knows well, whether he deals with the distribution of alternating currents or with submarine cables, or wireless, or, indeed, with the majority of the applications of electricity.

Now it may be argued that Faraday's experiments can nowadays be interpreted in different terms. That is not of the least consequence. Faraday's interpretations were a new presentation of the whole matter, illuminating and fruitful in the highest degree. What he saw and put into his own language is there still, and will be there for all time. Faraday's mode of thought supposed the existence of a space-filling medium which could be the seat of his magnetic and electric forces. We speak of this medium as the "ether." Clerk Maxwell, whose centenary is to be celebrated at Cambridge this year, showed that the ether which Faraday described so as to satisfy his experiments must be able to carry waves, and he framed the famous hypothesis that light itself was simply an electromagnetic disturbance traveling through the ether as a wave travels over the surface of the sea; or a sound wave through the air. We are using such ether waves at this moment. The ether of Faraday and Maxwell is as useful as ever, even though there are newer and bolder flights of thought which express themselves without it.

Arguing from Unity

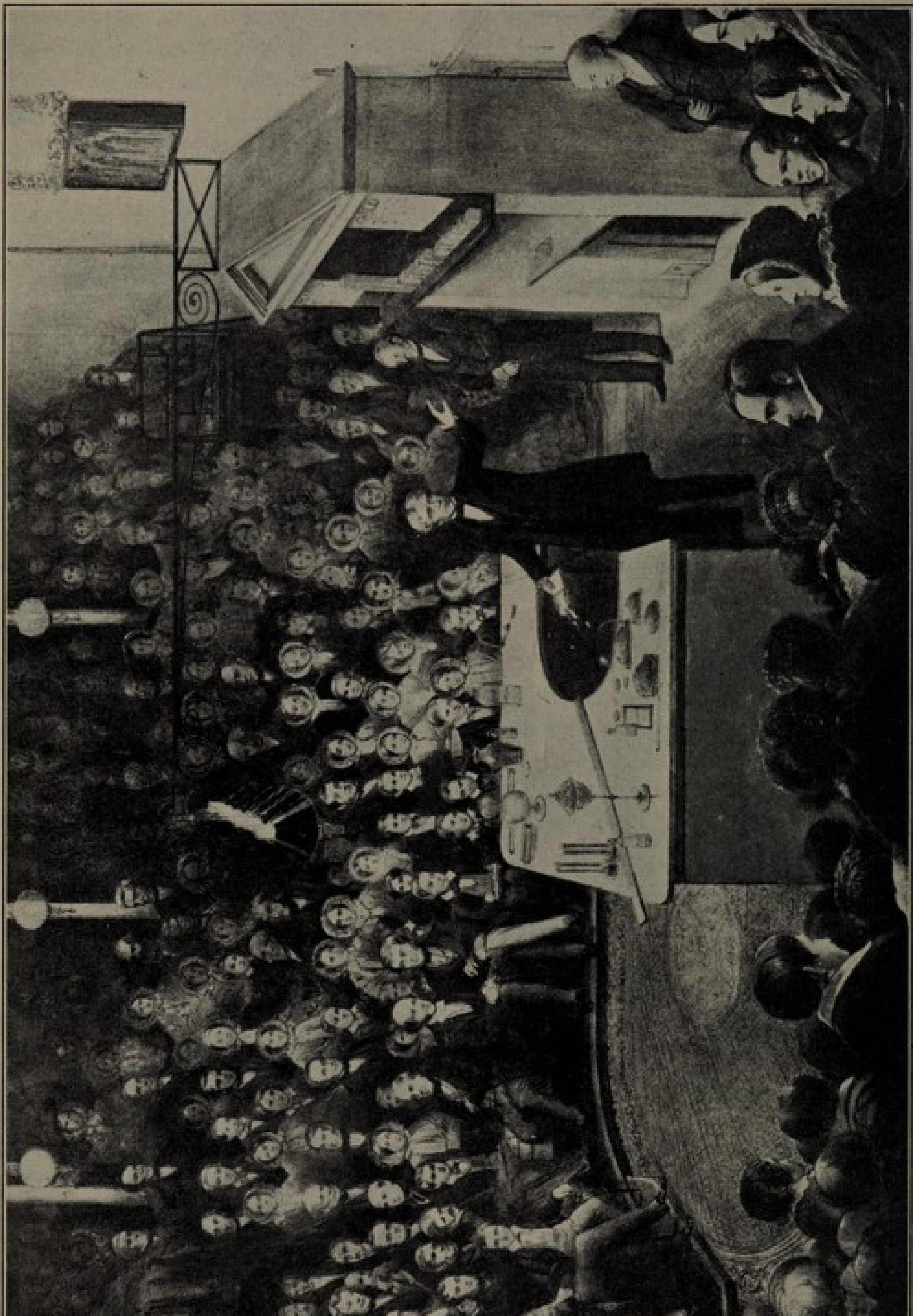
Thus Faraday threw all magnetic and electric actions into his medium. It would not appear to him that confusion might be introduced by doing so, and Maxwell's development of his ideas was their justification. We shall better understand his thought in this respect, and, indeed, the whole movement of his mind, if we consider the vision that urged him forward. He had a fundamental belief in the unity of nature's

manifestations. Light, heat, magnetism, electricity, chemical action, gravity, cohesion and so on, must somehow, he thought, be interconnected. Many such mutual relations were, of course, known in Faraday's day: heat, for example, could influence chemical action. But Faraday had more in his mind than the existence of a limited series of separate links. In pagan days men raised up a little god to rule independently over every separate manifestation of nature —sunshine and wind and rain, lightning and thunder. As thought broadened the little powers became aspects of a greater majesty. The world became one kingdom. To Faraday it seemed that the laws of such a kingdom must bear a common impress and be interwoven in their effects. Whatever electricity was, or sunshine, or chemical action, surely their operations could not be independent; electricity, for example, must be connected with magnetism, with chemistry, with gravity and so on. To look for the connections must be a fundamental inquiry. Indeed, it would not be wrong to sum up the greater part of Faraday's scientific activities as an endeavor to join all nature's manifestations together, to bind the parts into one great whole. It was in this spirit that he hacked his way through endless labors and dull details so often to emerge triumphant at last. Sometimes he failed where others have succeeded in later years.

These two great experiments that I have described, the first on the generation of current by magnetic induction, the second on the seat of electrostatic force, were the important members of a long series by which Faraday worked out the laws that govern the construction of electric devices. They may be said to be represented by the two quantities, inductance and capacity, which are the chief immaterial contents of the wireless set. Their relative adjustment constitutes "tuning in." And that which is thus made capable of reception is the "wave" which Maxwell described in precise detail as following necessarily on Faraday's work. But, of course, the wireless set is very far indeed from being the solitary example of the application of Faraday's principles.

In the Scientist's Laboratory

I should like to tell you very briefly of another research. I have said that Faraday put before himself as a main purpose the discovery of the connection, which he believed to exist, between every pair of the manifest forces of nature. He tried in 1845 to find some connection between magnetism and light, to find whether a light-ray could be affected in any way by his lines of electric or magnetic force. Imagine him standing in his quiet laboratory on the morning of September 13, 1845. He has already been at work for several days searching for any effect of electricity on light. He has filled many pages of his diary, but always at the end of the short description of each experiment he has been obliged to write "No effect." To-day he will try whether magnetism will serve him better. For magnetism he has magnets at his disposal, and for light there is daylight coming in through the windows and he can produce artificial light if he requires it. What shall he do first? Shall he allow a strong beam of light to fall on a piece of iron and then magnetize the iron in the hope that some change will appear in the light or the iron? He may try, but his means of observation are not powerful enough to give him a result. He goes about the matter in a more sensible way. If there is an effect which nobody in the world has ever seen before, it surely requires favorable circumstances and delicate observation. He will therefore use his great electromagnet, the strongest that he has. If light is to be affected, the quality or condition of the light which



FARADAY IN THE LECTURE THEATER OF THE ROYAL INSTITUTION

DELIVERING ONE OF THE CHRISTMAS JUVENILE LECTURES ON METALS.

he is most likely to watch with success must surely be one in which it is easy to detect change. Now there is one in which such detection is extremely easy. He must use polarized light: that is to say, light in which the ether vibrations are not taking place in every possible direction perpendicular to the ray, as they are usually, but are confined to one such direction indicated by what is known as the plane of polarization. The early years of the nineteenth century had been full of investigations of light in its polarized form. At the Royal Institution itself, Thomas Young, one of the foremost thinkers in the subject, had taught and worked. Polarized light is common enough in nature, as, for example, the light from the sky; and the physicist can produce it in various ways at will. Faraday produces such a ray of polarized light and adjusts his instruments to the determination of the plane of polarization, an observation which can be made with great accuracy. He makes his ray skim the surfaces of his magnet poles and turns on the current that makes the poles active. There is no result. He enters the fact carefully in the diary. He rearranges his poles, alters his ray, makes it traverse various transparent substances while near the poles, and in many ways he looks for an arrangement which will show him what he seeks. For some time the day is no more successful than the days that have gone before. What could have kept him to his patient search but conviction that it was reasonable to hope for a result? And if one should appear he would see for the first time a vision of one of the great laws of the universe. He was well aware of the significance of his search.

A Triumphant Entry

And then there *is* a result. A particular arrangement of the magnet, a particular adjustment of the light, a special piece of glass through which the light has to go: it is a heavy glass taken from a batch prepared while working at glass under a government commission. And when he turns the current on to the magnet the plane of polarization moves, a glimmer of light appears in the optical arrangement which has been adjusted to darkness when the electric current was off. It is delightful to see in the diary the expression of his joy. "But," in capital letters underlined, "when . . . such and such arrangements were made . . . there was an effect produced on the polarized ray and thus magnetic force and light were proved to have relations to each other." There is in this case no outstanding industrial development of his new discovery, but it was to him, and is to us, another of the links that bind nature's forces into one.

His attempts to connect gravitation with electricity or heat are of the same character: their interest is none the less because they failed completely. Faraday leaves us a record of his feelings as he entered the empty lecture theater from the high roof of which he intended to drop coils of wire which might possibly be found to be carrying currents on their way down. "It was almost with a feeling of awe . . ." he writes at the beginning of the note in his diary. It happened, curiously enough, that for many days he believed he had found what he looked for: but his effect was spurious. Indeed, it was impossible that he should be successful. It was not until Einstein had developed his theory of relativity and the astronomers had carefully measured up their observations of the eclipse in Brazil that a true effect was found. Then it was clear that the ray from a star had been *bent* by going close to the sun. Electromagnetic waves had been turned aside by the gravitational forces of the sun's mass. Gravity and light were linked together.

THE ROYAL INSTITUTION IN LONDON

WHERE FARADAY DISCOVERED THE RELATION BETWEEN MAGNETISM AND ELECTRICITY.

Faraday could never have found any such effect, though he was sure that something was there to be found and returned often to the search for it.

I have now said enough, I believe, to give an idea of the nature of the problems which Faraday attacked, and of his reasonings and methods, though I have referred only to a very few of the things which he did. I have said nothing, for example, of his tremendously important work on the connection between electricity and chemistry. This work may be described as having established the atomic theory of electricity and, indeed, as having foreshadowed the electron. It laid down the laws of electrolytic action and made a notable addition to the chemical knowledge of the atom and the molecule. It is the basis of some of the most important electrochemical industries of modern time.

The Lecturer and Man

When the knowledge of Faraday's work became general in the scientific circles of Europe, principally through his publications in the journals of the Royal Society, and when its value came to be perceived, he became a notable figure. But at home he had yet another mode of entry into men's regard. He lectured in the theater of the Royal Institution with such clearness and power, such simplicity and charm, that tradition, now speaking but rarely at first hand, still passes on the most reverent and affectionate memories. The courses of lectures which he gave so often at Christmas, nineteen times in all, to "Members of a juvenile auditory," as the old phrase has it, would alone have made him and the Royal Institution famous. Sir Alfred Yarrow, the famous shipbuilder, one of the few now living who went to his lectures, has told me how he and his boy friends so loved a word with the old man that they used to waylay him on Sunday on his way to church. And having benefited by one lot of kindly greetings they would let him walk on, but themselves run by back streets to intercept him again.

He took a great and helpful interest in the scientific affairs of the nation. Even in his earlier days his reputation as an experimenter and thinker brought to him many who wanted his help and advice. He could indeed have built up a lucrative consulting practice, but refrained because he wanted his time and energies for his researches. His decision was marked by a drop in his income from fees, from over £1,100 in one year to £160 in the next. But he responded generously to suggestions that he should place his scientific abilities at the service of the state. There was in the eighteen-twenties no little anxiety as to the state of the glass industry, particularly in respect to glass of high quality. Faraday formed one of a small working committee set up to make experiments. They worked first in Camberwell, but subsequently a glass furnace was built for Faraday in the Royal Institution. Very interesting work was done, though nothing emerged of immediate practical application. Some remarkable glasses were made and the whole labor and cost were indeed covered by the striking use which Faraday was able to make of some of the glasses in his subsequent researches. I have already spoken of one of them.

Service to the State

Faraday was consulted by the government in respect to mining dangers, and was indeed one of the first to point out the explosive character of suspensions of coal dust in the air. But his most extensive and continuous service to the state was rendered as scientific adviser to the Trinity House, which post he occupied during the greater part of his life. This body takes charge of the lighthouses. It is interesting to observe

FARADAY AT WORK

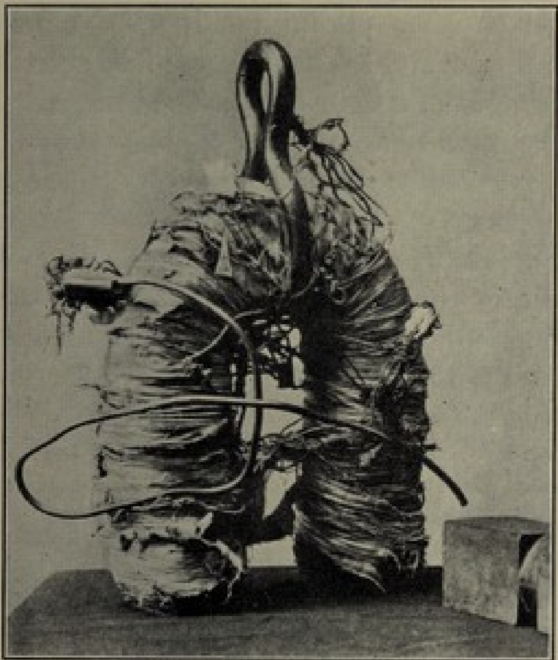
IN HIS OLD LABORATORY AT THE ROYAL INSTITUTION. FROM A CONTEMPORARY WATER COLOR.

that he saw the gradual replacement of the old oil-burning lanterns by the electric machinery which he himself had made possible. He appears, however, to have been very cautious in the matter, and to have asked for exhaustive trials rather than to have pressed impatiently for progress. Even when he was over seventy he was still making trips by sea in order that he might have the material for his reports. For this work he received a certain pay, but it was extremely moderate in amount, perhaps because he himself did not ask for more. He writes to the deputy master of Trinity House:

In consequence of the goodwill and confidence of all around me, I can at any moment convert my time into money, but I do not require more of the latter than is sufficient for necessary purposes. The sum, therefore, of £200 is quite enough in itself, but not if it is to be the indicator of the character of the appointment; but I think you do not view it so, and that you and I understand each other in that respect.

He certainly received at no time a worthy pay from the managers of the Royal Institution. On July 4, 1853, when he had been at the Royal Institution for forty years, the managers report to the general meeting that

They have advanced the salary of Dr. Faraday from £100 to £300 per annum. . . . The financial condition to which the Institution was long reduced by these various disasters restrained former Committees of Managers from offering to Dr. Faraday that consistent remu-



FARADAY'S "GREAT" ELECTROMAGNET

neration which, as they were well aware, his intimate acquaintance with the state of the Institution would have then withheld him from accepting. But the effects of these disasters have now passed away, and the prosperity of the Institution is as permanently secured as is compatible with the condition of a society depending on public estimation. The Managers therefore now feel themselves fully justified in awarding to Dr. Faraday the only remuneration which it is in their power to bestow.

Thus Faraday grew not only to be a great figure in scientific circles but also to be a valued public servant. He may even be said to have been a figure in society life of the day. He was the first secretary of the Athenaeum Club. But his relations to society were one-sided. His discourses at the Royal Institution drew hearers of every class: the Prince Consort himself was a frequent attendant. He certainly admired Faraday himself, and we may well believe that he considered Faraday's work and influence to be of high value to the nation. But though society came to Faraday, Faraday did not go into society. This was not because he was unsociable. On the contrary, he was full of fun. I wonder what the staid managers of the Royal Institution thought of the parties when velocipedes were ridden round the corridors of the theater. His abstention from all society engagements except the meetings with a few intimate friends was due simply to the decision that he must concentrate on his principal work.

It would be absurd to think of these renunciations of money and social pleasures as marks of a foolish quixotism or an unhappy nature. From all such perversions Faraday was poles apart. He knew perfectly well what he was about. He was thoroughly happy in his work, which filled his mind with great visions. And he was just as happy in his private life, of which it is necessary that I should say something. If he had not been so content he could not have given his hearers so much delight and encouragement. *Punch* may have rallied him for his lack of a certain ambition:

Oh, Mr. Faraday, simple Mr. Faraday!
Did you of enlightenment consider this an age?

THE HISTORIC RING OF SOFT IRON

WOUND WITH SEPARATE COILS OF COPPER WIRE CONNECTED TO BATTERY AND GALVANOMETER, RESPECTIVELY, USED BY FARADAY IN HIS FIRST SUCCESSFUL EXPERIMENT IN ELECTRO-MAGNETIC INDUCTION.

Bless your simplicity, deep in electricity,
But in social matters, unsophisticated sage!

—but the lines were surely written with a very kind smile and very deep respect. Of all the words in the English language the word "simplicity" has variations of meaning which differ most from one another: the simplicity of Faraday was of the kind which brings the other virtues in its train.

A chief contributor to the happiness of his private life was the wife whom he married as Sarah Bernard in 1821, when he was thirty. He was devoted to her. She does not appear to have demanded more than he gave her, or was able to give her in the mode of life which he chose. She must have satisfied him completely, because whenever he was away from her he wrote in terms that show how he turned to her; and when he passed through the long periods of overstrain which his eagerness brought upon him, she was his constant and beloved companion. There were no children.

The only recurrent complaints that appear in Faraday's letters to his friends are in respect to his loss of memory and oppression by headaches. No doubt the burning excitement of his researches made him too little aware of bodily exhaustion. After the period of the first great electrical researches in 1831 to 1840 a long rest was necessary: and when in 1845 he tried to begin again he found he was hampered by inability to concentrate. Nevertheless, there were still great times before him. Only, as he grew older the bursts of activity became shorter and the necessary resting time longer. Wilhelm Ostwald, who has recently written a most interesting psychological study of Faraday, believes that it was his inability to trust his memory that led him to write his well-known diary, his day-by-day record of his work and deliberations and proposals for the future, interspersed with occasionally delightful little touches of jubilation or resigned disappointment. He began, however, to write his diary in his early days, when there was no evidence of distress, and the careful style changes very little as the years go by. Although his letters show that the loss of memory was severely felt as a hindrance to his work, it does not appear, according to his own account, to have affected his spirits.

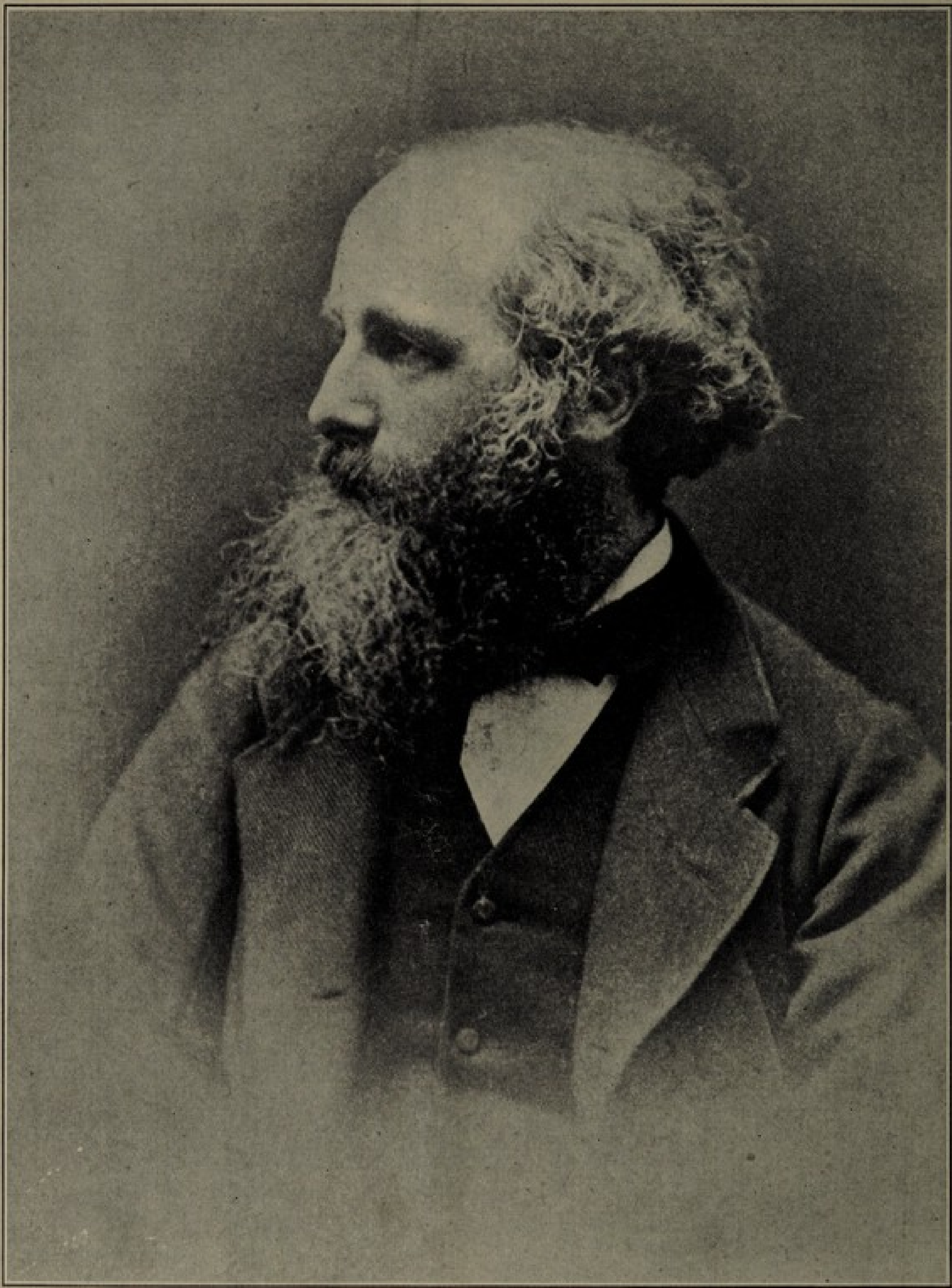
Religious Beliefs

Lastly, I come to one of the most interesting aspects of Faraday's life: his religion. It would not be right to pass it by, as we may shrewdly believe that Faraday would have done had he been charged with the task of giving an account of himself. His attitude is clearly characteristic, and our chances of understanding him would be less if we paid no regard to it. Faraday was a member of a small and isolated sect known as Sandemanians, after their founder. Their beliefs implied a very simple form of worship: they demanded spiritual reverence, a close adherence to the teaching of the Scriptures, mutual help in matters of religion, and general charity. With this little body Faraday associated himself at the appointed times, cutting himself adrift, to outward appearance, from all his science. He did not even inform his wife of the moment when he made his profession of faith and was formally received into fellowship. He took his part in the worship, though, it is said, with a hesitation and difficulty that were totally absent in the lecture theater. The injunctions to charity were certainly fulfilled: it is known that he gave large sums away, though he kept no account whatever of his gifts as he kept careful records of his scientific work.

If this complete separation of his religion from his science seems strange, we must remember that it would not seem so strange to any of us if we could put

ourselves back into his days: and I think it may be added that to some of us it would not seem strange even now, if we consider what Faraday may have meant by it. Remember that he himself was filled with a vision: he had actually been himself the first to see the workings of some of the great laws of the universe, and the unity of it all possessed him. Here were facts in natural accordance with the universal presence and power of the One God he had been taught to believe in. But his experiments could tell him nothing more of the qualities of that God. They fitted perfectly into their place, but they were trifles in comparison with the wider vision which he believed that his own spirit could ponder on and hope to see. This he sought in the quiet of his fellowship. We do not know, of course, to what extent he was satisfied. He was intensely reserved in religious matters: in answer to one correspondent he even deprecated religious discussion as generally unprofitable, but this was certainly a statement for a special occasion, and as a general expression of his attitude would go much too far. His attachment to a simple communion can cause us no surprise. He would, in the first place, be guided by his family tradition, and in the second place his own tastes were against any display. We ought not to go further in the attempt to see into Faraday's mind in religious matters: all that I may do legitimately is to give possible reasons for his very interesting attitude. For the rest Faraday was a very happy man, who was also a center of happiness, and we must judge by that.

It is Faraday's public life that belongs to us: it is one of the possessions of the nation, one of the great treasures. It is not only that his work has had such far-reaching consequences that all the world is affected by what he did, not only that he made plain the intricate connection between electricity and magnetism so that we are in daily dependence upon these forces of nature for the transfer of power and intelligence; it is not only that on his discoveries are now resting great British industries which are alive and are helping us through these difficult times. All these things are marvels so that we are proud of our famous countryman. But we all love the man himself for his simplicity of faith and purpose, for the breadth of his vision, and the humility of his thought, for his kindly generosity and for the light which he shed around him. He thought first of the quality of that which he gave, and only in the second place of that which he received in return. Could there be a nobler leading? Could there be any following more certain to bring us through times of depression and doubt to a triumphant ending?



JAMES CLERK MAXWELL