his telephone is evidently correct, still you can transmit sounds by making the magnet or coil vibrate relatively to each other, if you take off the iron vibrating-plate of a telephone and connect it in circuit with another telephone; if you tap any portion of the telephone which has no disc, the wood, cane, coil, magnet, with anything you like, you can hear that tap transmitted to the other telephone. I suppose the tapping disturbs the relative positions of coil and magnet, and so the lines of force of magnet are cut by the coil, hence a current which is transmitted to the other telephone. So why cannot one make a telephone on this principle also—a vibrating magnet—and a permanent fixed coil, or *vice versâ*, and no iron disc?

The President: I call upon you, Gentlemen, to return a vote of thanks to Lieut. Savage for his very interesting communication.

This was unanimously agreed to.

The President: I have now the pleasure to call upon Mr. William Preece to favour us with his lecture on "The Connection between Sound and Electricity."

Mr. W. H. Preece: Mr. President, a late member of the present Ministry, at a dinner given by the Institution whose hospitality we experience in this hall, implied on the authority of one of the leading members of the engineering profession that invention, like cocktails and Colorado beetles, had taken root in America and had deserted old England. It is therefore to me, as I am sure it is to you, a great gratification to have brought before us an invention which is the offspring of British soil. During the last few months the science of acoustics has made marvellous and rapid strides. First of all we had the telephone, which enabled us to transmit human speech to distances far beyond the reach of the ear and the eye. Then we had the phonograph, which enabled us to reproduce sounds uttered at any place and at any time; and now we have that still more wonderful instrument which not only enables us to hear sounds that would otherwise be inaudible but also enables us to magnify sounds that are audible; in other words, the instrument which I shall have the pleasure of bringing before you to night is one that acts towards the ear in the same capacity that the microscope acts towards the eye.

I may point out in the first instance that the telephone and the phonograph depend essentially upon the fact—and a great fact it is—that the mere vibration of a diaphragm can reproduce all the tones of the human voice. In the telephone the voice is also made to vibrate a diaphgram, which by completing an electric circuit, or by varying a magnetic field, or by altering the resistance or electromotive force of the circuit, produces effects at a distance which result in the reproduction of the motion of the diaphragm; but in this new instrument diaphragms are cast aside, and we have the direct conversation of sonorous vibrations or sound waves into forms of electrical action.

Now if it had been the habit or custom of this Society to give to the papers and discourses delivered here sensational titles, I should have been inclined to call the few remarks I am going to make to-night "A philosopher unearthed." Professor Hughes is well known to us all. He has been more or less associated with this Society since its first inception. Whenever he is in London he is always amongst us. His instrument is well known to us as one of the most exquisite pieces of mechanism ever invented, and his works, though few, are known because they are sound. The chief characteristic of this philosopher whom I have succeded in unearthing is his extreme modesty. If he had been left to himself I do not think we should even have had the microphone here, but by a lucky chance he recently admitted me into his secret, and I am enabled to-night to bring before you the results of his labours, and they have been labours indeed. For months and months he has been working and striving at the ideas which at last he has elaborated into the microphone.

Now, the chief characteristic of the apparatus I am going to introduce to you to-night is its great homeliness, its uncouth roughness, and its absurd simplicity. With common nails, with small pieces of wood, with halfpenny money-boxes, with plain sealing-wax, with the ordinary apparatus which every child has at its command, he has been able to attack Nature in her stronghold, to ask her questions, and receive back answers, and lay bare to us, facts and thoughts which, though they have existed from time immemorial, are brought to light now for the first time.

Now let us, in the first place, ask ourselves this question.

What is sound? It is a very difficult question to answer in the short time at my disposal; but it is necessary I should first say something to you about the nature of sound, and then say something about the nature of electricity, and show you how the one can be converted into the other.

Now, what is sound? While I am speaking to you I am setting the air in this room into vibration. The air of this room is composed of an infinite number of infinitely small molecules: every molecule is set in motion and vibrates to and fro, backwards and forwards, like the bob of a pendulum, and between my mouth and every one of the ears in this hall there is a rapid but short excursion to and fro of every single molecule that composes the atmosphere of this room, and it is the impinging of these molecules against the drum of the ear that produces that sensation called *sound*. But more than that, not only is the air of this room in this marvellous state of motion, but every piece of wood, every wall, every picture—everything in this hall at this moment—is almost I may say alive, trembling away, moving backwards and forwards, forming what are called sonorous vibrations. If the sound be loud enough and the note deep enough we can distinctly feel these vibrations. Sound is therefore the vibration, in particular periods and particular phases, of matter.

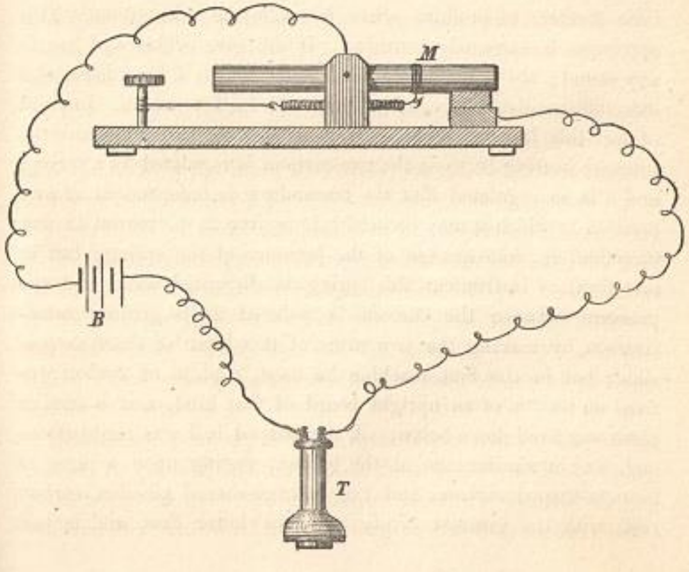
Now, what is electricity? Faraday, the greatest electrician perhaps that ever lived, was asked that question, and he said the more he studied electricity the more he unravelled its mysteries, the more mystified he became as to its source and its origin; therefore it seems an act of impudence on the part of myself or anybody else to attempt to answer the question—what is electricity? But great strides have occurred since the days of Faraday; we know a great deal more now of the internal molecular action of bodies: we know that light and heat and sound are the mere action of those molecules of which matter is composed: and we feel sure from the facts brought to our notice by the delicate apparatus of the present day that electricity is simply a mode of motion, nothing more nor less than the simple play of the molecules of matter. The truth of this will be made evident to-night by the wonderful connection which exists between sound which we know to be a mere mode of vibration, and electricity, which will reproduce to us the effects of sound.

To make this evident to us, we must have two instruments—the one a detector, which will render apparent to us any electrical action that shall result in sound, and it fortunately happens that this marvellous telephone is an instrument of such extreme delicacy that it has made us acquainted with *currents* of electricity hitherto unknown, though their presence has been suspected. The telephone which Professor Hughes has used in his researches is as simple in its construction as are all his other apparatus. It consists of two rough pieces of board clamped together. There is half the end of an electro-magnet that probably has been in his possession since his early experiments, to judge from its appearance. The magnet is a piece of steel rod that has been magnetized. The wire used, and which he has found extremely useful to him, is wire that was originally made for very different purposes—for ladies' bonnets—and in front of this is placed a piece of ferrotype iron, well known by those who have experimented with the telephone.

But what is the source of sound? It was necessary in making these experiments that he should have a source of sound—something which would generate those sonorous vibrations of which I have spoken. This source of sound was a small mantelpiece clock of French manufacture, which cost originally three or four francs. It has been in use many years, and has been in many parts of the world. It is repaired with great lumps of sealing wax, but nevertheless it has, or ought to have, a pendulum, which gives a succession of beats, and those beats form a source of sound. Now, with this source of sound, and this beautiful scientific apparatus, the telephone, as a detector, he started upon one of Sir William Thomson's discoveries, viz.: that wires alter their electrical condition when they are placed under strain. He took a piece of wire, applied weights to it, connected the clock with it, and heard nothing. He was not disconcerted: he applied weight after weight till he reached the breaking strain of the wire, and at the moment when the wire broke he heard a rush or sound which he thought was an indication of what he was searching for: so he took the two ends of his wire and laid them together, placed his sources of sound above them, and to his intense delight heard—what imagination perhaps assisted him in believing to be—a tick. He thought he was on the right track, and he then manufactured, with a flat piece of brass for a lever, a pin for an anxle, sealing wax for cement, black wax for solder, and the uncovered bonnet wire for binding, a little apparatus which enabled him to apply constant pressure to the thing he was experimenting upon: in fact, by this means he was enabled to produce what we electricians call a "bad joint."

To his intense delight he found with this bad joint and rough application of pressure, by putting various things, pieces of metal, chain, &c., underneath this little contrivance, he was able to obtain sonorous effects. But this contrivance, simple as it appears, was a great deal too elaborate and complicated for his purpose, so he took two French nails—little bright nails, so much used in France—laid them side by side, not touching each other, and bringing the ends of the wire in contact with them, and laying between or across them a third and similar nail, he was able to reproduce almost perfectly the sound of the clock, and, more than that, he began to get indications of the sound or tone of the voice. He then used chains; he took a gold chain and put it beneath his little compressor, and with that he was able to speak with great ease; from that he tried filings, and found with matter in a finely divided state he was able to reproduce all the effects of sound. At last he made little glass tubes, about two inches long, filling them with white bronze powder which artists use, which is a mixture of zinc and tin, and he was able to reproduce exactly the tones of the voice. But in his experiments with carbon he was able to make what may be called quite an independent and another discovery. The carbon he experimented with was the common carbon used by artists in sketching their drawings, and this carbon he found to be a non-conductor of electricity. The idea struck him that this non-conductor of electricity might be made a conductor, and by various processes he at last arrived at a plan of boiling or heating this carbon in quicksilver. Carbon so heated in an atmosphere of quicksilver itself becomes permeated through and through with quicksilver, and by that means we get the mercury subdivided into an almost infinitely pure state. Probably mercury

in this state as closely approaches the molecular as anything can do; there is no apparent indication of mercury under the microscope, and yet we know that the carbon has been mercurised, because it is converted from a complete insulator into a conductor, and it has a metallic ring when it falls. Now, then, having by these processes arrived at a substance which is remarkably sensitive to all the variations of the sound of the human voice, his next task was to construct these things into such a form as to make them telephonic transmitters. For that purpose he brought to his aid a very cheap kind of apparatus, a halfpenny money-box; inside this he placed his carbon transmitter, and as this discovery is not fenced in by fear of the patent or any other law, I am quite sure you will be glad to know how to make a Hughes' transmitter. First, he takes a piece of ½-inch board about 2 inches long and 1 inch broad, and he raises upon that two thin brass bearings with a hole worked through by means of a pin for the support of his axis; he then takes a piece of carbon about 2 inches long, which has been mercurised, which has a pin cemented to it, near its centre, which



acts as an axis, and makes it into a lever. On the board he places another smaller piece of carbon similarly treated, and upon this rests another similar sized piece of carbon, the two being connected by a piece of paper. (See Fig., in which M represents the transmitter, B the battery, and T the telephone.)

Now the battery is another remarkable specimen of scientific manufacture. Three little glass tumblers are taken; at the bottom of each a piece of copper wire is coiled spirally. The copper wire is covered with a little sulphate of copper. The tumbler is then filled with moistened clay, and upon the top of this clay is placed a piece of scrap zinc. The three cells are placed in a cigar box. The tube-transmitter consists of a glass tube about 2 inches long and ¼-in. diameter, inside which several pieces of mercurized carbon are inserted, touching each other with a pressure regulated by a screw fixed to each end. The size of the carbon appears to be of little consequence. He has produced effects with carbon not larger than the head of a pin. We shall show this by-and-bye; but rather than disturb the order of these researches I think it advisable in the next place to show you how this principle has been carried a little farther, to produce what he calls the microphone. This apparatus is extremely sensitive. It will give evidence of nearly any sound; but in the microphone itself, which I have here, this extreme sensitiveness is carried to a still further extent. In point of fact this is a microphone; but in this particular instance the pressure bearing between the two carbons is regulated by a spring, and it is so regulated that the transmitter is independent of any position in which it may be held. It is free to be moved in any direction, in consequence of the pressure of the spring; but in one form of instrument this spring is dispensed with, and the pressure between the carbons is reduced to its greatest sensitiveness by making the two arms of this lever as short as possible; but in the first machine he used, a piece of carbon was fixed on the top of an upright board of that kind, and a smaller piece was fixed down below. A cup-shaped ball was made at one end, and a similar one at the bottom, resting upon a piece of lozenge-shaped carbon; and this lozenge-shaped piece of carbon rests with the greatest nicety upon its lower disc, and is just

in that position of equilibrium that the slightest atmospheric disturbance produces the effects which we are now about to show you.

I think it desirable to tell you that you must not expect to-night distinct articulations. We have made a violent effort to make these experiments evident to you all. [*Illustrations were here given of speaking, singing, &c., and were heard all over the hall.*]

Now, the effects you have just heard have been produced by a microphone similar to that drawn on the board. We will now repeat the effects with the machine on the table, and in order that you may judge of the effect—for Professor Hughes desires you should see there is no deception—we will connect this up, and use his old friend the clock to make its ticks, if it will, evident over the whole room. One of the greatest effects which this instrument produces is to render evident the tramp of a fly, and we have some nice little captives with which we will demonstrate that effect at the close of the meeting. [*Illustration with clock.*]

To show that the sounds come from the clock itself Professor Hughes will lift up the clock, when all traces of sound will have disappeared, and on putting it down again the sounds will be produced; so that the sound you hear is the sound of that clock which has been magnified.

Now, we have here a common quill pen, and Professor Hughes will do as they do on the stage, pretend to write a letter, and I have no doubt if you listen attentively you will hear the scratching of his pen. [*Illustrated.*]

Now, there are some peculiarities in this apparatus that are very striking. In the first place, though the sounds produced are very great, they do not interfere with each other. If you have a friend at the other end speaking to you, you can hear his voice distinctly working through your voice, and the result is you get a duplex action. Two or three persons can talk to each other without impediment or confusion.

Yet another point is, that the articulation is absolutely perfect. One of the great difficulties both in the telephone and the phonograph is getting the noises and sibilant sounds reproduced, such as "s" and "c" and "sh," &c., which are produced by such extremely minute variations in the sonorous vibrations that they are lost in those instruments. Thus, if through the telephone you ask a person to waltz, it will come out "walk," and names like my own with the sound of "s" in it, though it is spelt with a "c," would come out "Pree"—not Preece. In this transmitter one of its chief peculiarities is the fact that all sounds are faithfully reproduced, and it tends very much to upset the notion—Helmholtz' theory—that vowel sounds and other sounds are due to the superposition of waves upon waves of tones and overtones. This apparatus shows almost unquestionably that all these different properties, all these effects of intonation, are due to differences in the form of the wave sent. Another peculiarity is this: I have told you that all in this room, every one's body while I am speaking, is alive with sound. If you take this transmitter and place it in front of your mouth, or put it on your forehead, or on the top of your head, or put it in your pocket, or upon your breast, it will still transmit sounds to distant places. Put it in a room, it does not matter where, it will reproduce the sounds. Put it anywhere in a drawing-room where there is a piano, you will hear the sounds of the piano faithfully reproduced. It is, as you see, a marvellously rough affair; you may throw it up, kick it about, and do what you like with it; it will always act. Here is the identical box that Professor Hughes made two or three months ago; it has never been touched; it has been always at work, and never needs repair.

These are some of the peculiarities of this instrument, and I dare say some of you would like to know a little about its theory. We have here two points in contact, and those two points in contact complete an electrical circuit. The electric current that flows through that circuit depends for its strength entirely upon the obstacles or resistances in that circuit to the flow of the current. Any alteration in any shape or form in the resistance of that circuit will result in the increase or decrease of the strength of the current flowing, and upon this board I will make a rough attempt to endeavour to give you an idea of what occurs. You must not conceive that these round balls are molecules themselves; they are merely meant to represent the sphere of action of each molecule at each point of contact. In a normal state the molecules rest against each other as shown by the upper line. When from any cause pressure is increased, they are contracted, as shown in the second line; when from any cause the pressure is decreased they expand in the form shown on the other line. While I speak at you, the air of this room is thrown into vibration, the mass of air being subdivided into molecules in compression and molecules in extension. In a long wire these successions of compressions and extensions compensate each other; but when we break up a body into infinitely small parts, when we make contact between two bodies as shown there, we isolate the portion of the sonorous wave in compression from that in extension, the result is that we have a variation in the resistance of the line. Now this variation in resistance depends upon the compression and dilatation of the molecules. It depends upon the tone of the voice, and the result is the resistance of the current varies with its variation of pressure, and at the distant end we have currents varying exactly as the voice varies, and reproducing on the telephone all the effects which we have seen. Hence follows the action of the microphone, which depends upon the variation produced in the contact of bodies by the sonorous vibrations of the voice. As I am now speaking at that microphone all the molecules of that transmitter are thrown into this elaborate series of compressions and dilatations. The current is varied; the current goes to the room below and is reproduced upon the telephone as we have heard. Hence the effect is due to the difference of pressure at the points of contact, as is proved by using atmospheric pressure, applying heat, making noises, and any large variation of pressure results in sound being reproduced.

No one has ever been nearer a great discovery than Mr. Edison. His telephone is based on the variation of resistance in carbon due to pressure. He used carbon and finely divided matter, but he worked on the idea that the difference in pressure was produced by the vibration of a diaphragm. Had he thrown away his diaphragm he would have forestalled Professor Hughes in this respect, and found that the sonorous vibrations themselves produced this difference of pressure.* The great secret of Professor Hughes's discovery

* It appears that Mr. Edison actually did this, but he was anticipated by Professor Hughes.

is,—that sonorous vibrations and electrical waves are to a certain extent synonymous.

Now, as to the uses to which this instrument is capable of being applied. It has been applied to surgical purposes in the form of the stethescope. Though it does not show very markedly the beats of the heart, because they are more mechanical thumps than sonorous vibrations, yet it will show the injection and ejection of air in the lungs, and for many other surgical purposes it must become a valuable instrument. It admits us to some of the mysteries of insect life, and by its means we can hear sounds emitted by insects which have never been heard before. Going further, it has enabled the deaf to hear; deaf persons who never heard a telephone before have been able to hear distinctly. It has enabled us to hear the physical operation which goes on in the process of crystallization of bodies and other things which before were wholly inaudible, and in fact it is impossible to say to what uses it may not be put.

It is rather remarkable that in an excellent paper read before the American Electrical Society the author, Mr. Pope, makes these curious remarks:—

"The most striking results are to be looked for in the direction first pointed out by Mr. Gray, for the reason that if an effectual method of controlling the resistance of the circuit by means of atmospheric vibrations can be discovered, the source of power, which in this case is the battery, may be augmented to any required extent. It is not to be denied that the problem thus presented is one of exceeding mechanical difficulty, but there is no reason to suppose that it may not be successfully solved. It is to the development of this variety of speaking telephone rather than to that of the magneto instrument that inventors will find it most advantageous to turn their attention, for I hazard little in saying that the latter has already reached such a surprising degree of efficiency as to leave comparatively little more to be done within the necessary limitations which have been pointed out."

Mr. Pope throws out as a suggestion what has now been done with the exception of the supposed mechanical difficulty, and that has been got over by a halfpenny money-box.

Now, one very pleasing and gratifying circumstance attaches to this discovery of Professor Hughes: he has thrown it open to the world, and by that means he has no doubt checked that species of immorality—I don't know what else to call it—connected with the infringement of the patent law as regards the telephone. He allows us all to manufacture microphones for ourselves; but even he has been subject to a rather peculiar incident. One impulsive and active gentleman, who was present at the Royal Society the other night when Professor Hughes first described his invention, went home and made himself a microphone, wrote a description of it, and sent it off post haste to Paris. A short time afterwards, Professor Hughes himself, with great care, prepared a paper to be read before the French Academy, but to his great surprise he found that he had been forestalled—a description of his instrument had already appeared in the Paris prints from the gentleman in question.

There are lessons to be learnt from this discovery; and the principal lesson is—we can all of us, with the means at our disposal, cross-question Nature and find out her secrets; and there are many secrets which yet remain to be divulged. We learn the wonderful connection which exists between all the physical forces: heat and light, and electricity and magnetism, are all co-related; and it has come to this, that what boys have said in joke has come to pass in earnest. We have been able to convert electricity into light and light into electricity. We are now able to convert electricity into sound and sound into electricity, and thus we are enabled to see the thunder and to hear the lightning.

The President: We have listened to a very interesting and instructive address, and I hope it will be followed by an equally interesting discussion. I see many here who are fully able to take part in it, and, with your permission, I will call upon His Grace the Duke of Argyll to open the discussion.

The Duke of Argyll, K.G., rose and said: Mr. President and Gentlemen—Though I am a stranger here, I am very glad of the opportunity which the kind invitation of your President gives me to say a few words as to the extreme interest with which I am sure we have all heard the admirable lecture just delivered by Mr. Preece —one which, for interest of matter and for clearness of exposition, I have never heard excelled in the course of my experience of scientific lectures. It is quite obvious that we are here in the presence of one of the most remarkable discoveries of an age which is full of discoveries—discoveries which are sure to be utilised in a thousand ways which at present we cannot foresee. Mr. Preece has said at the beginning of his lecture that he rejoices on this occasion at least that the progress of this discovery has taken place on English soil. On further inquiry, however, I am not sorry to find that the distinguished man whose discovery has just been explained is, although a resident in this country, a citizen of America, because, though I have as strong a patriotic feeling as any gentleman present in this assembly, I am one of those who, in matters of science, are thoroughly cosmopolitan in the triumphs of human intellect by whatever nation they may be made—and further, I am one of those who feel that the citizens of America are, after all, our fellow-countrymen. Now, with regard to the uses to which this discovery may be put, there are many which immediately suggest themselves to one's imagination.

I am sorry to hear, from Mr. Preece, that the immediate application of it, in so far as it has yet been tried, to the sounds of the human heart, does not throw much additional light on that most curious matter, the circulation of the blood, because probably the sounds are of a very muffled nature, and do not give rise to sonorous waves such as those which have been explained to us; but I cannot doubt for a moment that one of the most immediate applications of this very valuable discovery will be a surgical application, and that through it our medical men will be able to pronounce upon a series of diseases with which we are at present wholly unacquainted. Now, being myself accustomed to think a good deal about political affairs, I confess I was struck with some of the inconveniences which might occur through the agency of this discovery. We are now very close, you know, to Downing Street, and it occurred to me if you placed one of these little halfpenny boxes in the room where the Cabinet sits we should have the whole of the secrets of the Cabinet revealed in this hall of the Civil Engineers (laughter); or

if by any extraordinary ingenuity, such as many conjurors can command, one of these little boxes could be inserted in the pocket of my distinguished friend Count Schouvaloff or Lord Salisbury, I have no doubt we should be at this moment in possession of all those secrets which the whole of this country and of Europe are desirous to know. I should like to know from Professor Hughes that there is some means of preventing this. I remember a lady friend who was very fond of attending sermons, and she was laid up by a complaint which prevented her going to church; but she contrived to take a lodging almost under the roof of the church where a celebrated minister preached, and she had a speaking trumpet fixed near the pulpit, and by that means she was able to enjoy the sermons she so much desired to hear. But with this instrument of Professor Hughes we shall be able to poach on every one's manor and know every one's secrets; and I should much like to know from Professor Hughes whether—since one of these little boxes set anywhere in a room is capable of transmitting to a distance all the conversation which takes place in that room—he is able to provide an antidote for it.

Dr. Lyon Playfair, M.P.: I can only sympathise with the remarks which my noble friend the Duke of Argyll has just made to us. In fact one sees no end to the application of this discovery. I have no doubt before long Professor Hughes will connect his instrument with the aerophone which magnifies sounds so that one can hear it over four or five square miles. Only conceive what might happen in a debate in which such orators as the Noble Duke who has just sat down or Mr. Gladstone made one of their magnificent speeches: supposing one of these instruments were connected with the aerophone, and instead of those speeches being confined to the area of St. Stephen's they were sent over four square miles of London, and allowed millions of the public to enjoy the beneficial effects of that eloquence! It is not only possible but probable. Only conceive to what large influences such a discovery as this may lead. Or supposing you connect this instrument with the Opera house, where one of our great contraltos or sopranos are singing, it would be possible by means of the aerophone to communicate it to a whole town. The development of this instrument in connection with others already in existence may be productive of prodigious effects. I think in the hands of the physician it will prove to be a discovery of the greatest importance and value. It occurred to me that though the muffled sounds of the heart might not be adapted for repetition it might be possible in acute diseases, such as inflammation, or other acute diseases which proceed from too energetic action in particular parts of the body, it occurred to me that these might be detected by this agency. In the beginning of a discovery of this kind it is impossible for the most lively imagination to see the results that may flow from it; and in the hands of Professor Hughes, or in the hands of others, it is impossible to place a limit to the development which may result from the description we have heard to-night. I consider it one of the most remarkable discoveries of modern times, and I congratulate Professor Hughes upon it. He is a citizen of a country to which I am dearly attached by many acts of kindness shown to me; at the same time he has been so long connected with this country that we may fairly claim this as the joint discovery of two great nations.

Mr. Willoughby Smith: Marvellous discoveries have been brought before us lately in such quick succession that I am pleased we have at length an opportunity to pause and reflect on what we have already seen and heard. I cannot agree with Mr. Preece in his molecular and sound-wave theory of the "Microphone." I believe the phenomena to be solely due to what is known as a varying contact, and that the "microphone" is nothing more than a sensitive commutator. Mr. Preece has told us that by the aid of the microphone the tramp of a fly can be heard, resembling that of a horse walking over a wooden bridge; but I can tell you something which, to my mind, is still more wonderful, that by the aid of the telephone, I have heard a ray of light fall on a bar of metal; this may appear a startling statement, but with the whole facts before you it will become extremely simple. I have on a previous occasion shown that the electrical resistance of selenium is very much reduced immediately it is exposed, either to solar or artificial light, consequently if a bar of selenium, excluded from the light, form part of a circuit in which are included a battery, a telephone, an electrical bell, and a galvanometer, nothing will be heard until the light be allowed to fall on the selenium, which is done simply by raising the lid of the box in which the selenium is placed, when immediately sound is heard in the telephone, the bell rings, and the needle of the galvanometer moves, simply because the resistance of the circuit is reduced, and consequently the electromotive force increased. Now, when I read that Professor Hughes had discovered that bodies were susceptible to sound as selenium to light, I removed the selenium from the circuit, and substituted every substance I could think of in its place, and used every conceivable means to produce sound, but without effect. But if, in a metallic circuit, be placed either a loose contact or a sensitive commutator, then one can produce all the phenomena claimed for the microphone. I have obtained very satisfactory results from three very fine "rat-tail" files placed in the circuit, similar to the letter H, one end of each of the side files being fixed, and the other file simply lying across them; the longer the side files, and the nearer the cross one is placed to the unsupported ends of the other two, the better; if the cross file be replaced by loose threads of metalized silk, and a spirit lamp be placed beneath the same, so as to create a draught, then is heard in the telephone a noise similar to the sound of the burning wick of the lamp, especially when first lighted. What Professor Hughes has discovered is that, by allowing the breath or other motive power to effect a sensitive loose contact or commutator, contacts of varying duration are made, which are reproduced in corresponding sounds on that marvellous instrument the telephone; this is an important discovery, and Professor Hughes has my hearty congratulations.

Mr. Latimer Clark: I did not intend to make any observations, and I feel almost out of place, after the eloquent addresses we have heard, in going back to the ordinary technical view of the subject; but I would just remark that Mr. Preece, has, I think, omitted to mention one of the experiments of Professor Hughes. The little glass cylinder you see here [*exhibiting*], with small segments of willow wood carbon dipped in mercury, is extremely sensitive to heat, so much so that the approach of the hand or other warm body causes very great variation in the resistance of the circuit, and also causes a noise in the telephone. So does a slight alteration of the pressure on the end: if you press on the end of the tube you cause a noise in the telephone, and produce great deflection of the needle of the galvanometer. You might make a sensitive relay by causing a needle or an electro-magnet to slightly compress the segments in this tube which would doubtless be more sensitive to delicate currents than any relay we have at present. I therefore throw out the suggestion in order to make it public. I also think a very excellent Morse sounder may be made from the microphone by causing a continual sound to be produced in the telephone, and it is obvious that one source of movement would cause any number of instruments in an office to produce continuous sounds, the signals would be received on a relay and would come out, not as dots, but as dots and prolonged dashes which could be more accurately and easily read than the ordinary sound signals.

Lord Lindsay, M.P., F.R.S.: I will only mention one experiment which struck me as being interesting. I constructed one of Professor Hughes's little instruments from a description which I read of it, and having stretched a piece of parchment over a circular frame so as to form a vibrating membrane, I attached to its centre a piece of carbon which was connected in circuit with a battery by means of a fine copper wire. Against this piece of carbon I placed a second similar piece, so arranged that I could increase or diminish its pressure upon the first piece by means of an adjusting screw, and to this piece was also attached a copper wire by which it could be placed in circuit with a battery and telephone and with the other piece of carbon. Under the influence of sonorous vibrations the membrane vibrated, and in doing so produced a variation in the pressure, and consequently in the electrical contact between the pieces of carbon, reproducing the original sounds in the distant telephone. On one occasion I placed the apparatus on the sounding-board of a pianoforte, upon which my little girl was practising, she was playing scales, and I noticed a very remarkable effect. Whenever one particular note was struck, a harsh loud sound was heard in the distant telephone, although all other notes were clearly transmitted and reproduced. On examination I found that the note which produced this curious effect

was that whose period of vibration corresponded with that of the membrane, and in the sound produced could be heard the fundamental note and overtones, as well as the octaves and other sympathetic notes sounded by the strings of the pianoforte.

Professor Graham Bell: No one can more heartily congratulate Professor Hughes upon his great discovery than I do: I think all those who investigate telephonic effects will realise that we have touched upon the threshold of a new science, and that we have discoveries yet in store for us. I must confess that the explanations of the action of the microphone afforded by Mr. Preece and Mr. Willoughby Smith are to my mind not perfectly satisfactory. There are certain points in the telephone itself that may lead us to the true solution of this problem. If you fix your attention upon the first diagram shown by Mr. Preece you have a constant source of electricity (the battery), a telephone, and this curious instrument. Now, the laws of audibility of the electric current by the telephone are analogous to the laws of induction. No sound is audible so long as your current is of uniform intensity. But the moment you change its intensity you have a sound from the telephone. Conversely when you have a sound from a telephone the intensity of the current passing through it has been changed; and the loudness of the sound is an index of the amount of change. Now, unless the microphone were itself a source of electricity, it is evident that the only way in which it can change the current is by varying the resistance of the circuit. So far, we may be perfectly certain that the action of this instrument depends upon the variation of the resistance; and the only question is as to how this variation of resistance can be accomplished by the influence of such feeble sounds as those produced by the escapement of a watch or the footsteps of a fly. As the sounds produced from the telephone are quite loud, the current must change very greatly in intensity, and the resistance of the microphone must vary in a most extraordinary manner, probably being at its maximum many times the resistance of the rest of the circuit, and at its minimum, but a fraction of it. Mr. Preece seems to consider that the molecules of the substance composing the microphone change their shapes when subjected to compression by a variable force; and he has figured to us his conception of the alternate contraction and expansion of a chain of molecules under the influence of sound. Mr. Willoughby Smith, on the other hand, attributes the effects produced by the microphone to imperfect contact. He supposes the carbon points to rattle against one another under the influence of a sound, and he seems thus to regard the microphone as a delicate form of interrupter. I am more inclined to accept Mr. Willoughby Smith's explanation than that given us by Mr. Preece, but the reproduction of articulate speech negatives the assumption that the microphone acts as an interrupter. The possibility of producing electrically any given quality of sound depends upon the possibility of producing a current of electricity the intensity of which varies in a manner proportional to the varying velocity of a particle of air during the production of that sound. Hence, however much the points in contact may rattle together, the circuit must not be broken or the effect of quality will be lost and a mere noise be produced instead. If I might offer a suggestion I think it probable that there is a variation in the *amount* of contact. Let us suppose an enormous number of particles to be in contact (each singly offering a high resistance to the passage of a current, but conjointly offering very slight resistance), then when the microphone rattles under the influence of a sound, a larger or smaller number of particles come into contact and the resistance of the microphone changes without absolute break of circuit. Still, we must not forget that at each increase of resistance heat must be produced at the points of contact, and it is probable, nay, extremely likely, that heat has a great deal to do with the results obtained. I was experimenting with a microphone the other day, and it kept on vibrating on its own account for nearly two minutes. A clear musical tone was emitted by the telephone in circuit with it. The microphone always exhibits a tendency towards vibration on its own account when it is adjusted most delicately. The instrument, as I constructed it, consisted of a rod of charcoal placed horizontally with its ends resting upon two other rods of charcoal. This arrangement, when shown to Professor Dewar, at once suggested to his mind Trevelyan's bars. I think it not at all unlikely that the microphone is in reality a species of Trevelyan's rocker, and

that it may thus be in a condition to be affected by feeble sounds. It is quite conceivable that sounds too weak by themselves to throw the mass of the microphone into sensible vibration may yet be sufficiently strong to start and control the vibrations due to heat, or at least it is conceivable that heat may assist the action of the sound. For instance, suppose the charcoals rattling together under the influence of a sound. Now, as the charcoals separate, the resistance of the microphone increases, the points of contact become heated, and the expansion due to this cause occasions a greater separation than would otherwise take place. Thus, heat may co-operate with a feeble sound to produce a greater amplitude of vibration at the points of contact than would be produced by the sound alone. Those who are interested in this subject would do well to read Professor Page's paper upon "The Vibration of Trevelyan's Bars by the Galvanic Current."* The microphone recalls vividly to my mind some of the illustrations in this paper. Whatever may be the true explanation of the effects produced by the microphone, there is evidently a vast field opened before us for inquiry. I will not take up your time with any further remarks, but will merely again offer my congratulations to Professor Hughes upon his discovery.

Professor HUGHES: It seems that the description of the microphone is not well understood. I can excuse that because it is as much as I can do to understand it myself; but, as far as my experiments have gone, they show that the effects produced are the result of the increase and diminution of the resistance. Mr. Willoughby Smith designated it a commutator, and attributes the effects to contact. That is quite right, only it is not from the point from which I view it, and that is the way in which the effects differ.

If we take a board like this [*illustrating*], and give it a blow here, that nail will jump up from the transmission of force. The same thing takes place in acoustic properties. A blow is simply rapid pressure, as distinguished from hydraulic pressure: the difference between a blow and hydraulic pressure is one of rapidity. If you take a piece of glass and put sand on it, and strike the glass, the sand will jump away and form figures. So it is here. [Professor

* Silliman's Journal, 1850, ix., pp. 105-108.

Hughes illustrated his views by means of diagrams on the board, showing the curves of articulated sounds, both in speaking and singing, &c.]

The PRESIDENT: As time is advancing, and as Mr. Preece, I believe, has some further experiments to exhibit at the close of the meeting, I will make a few observations only on the very interesting matter which has been brought before us. The discussion that has taken place is remarkable for the excellent temper which has been shown between two great rival discoverers. I think all of us must have been pleased to have seen how these two gentlemen, Professor Bell and Professor Hughes, have described and brought before us their particular views regarding certain actions in the two instruments, the telephone and microphone, which, when we come to compare them, will be found to have many points of analogy, and though essentially different in detail tend towards the accomplishment of the same important end. Mr. Preece and Professor Bell differ with regard to the action which takes place in the microphone, and Professor Hughes favours naturally the views which Mr. Preece has expressed; but I think there is probably not so much difference between those two views. It is quite evident that the action of the microphone is due to variation in electrical resistance produced by vibrations in an imperfect conductor, such as carbon, or an aggregate of divided pieces of metal, and the question for consideration is how this variation in resistance is effected. When two pieces of carbon are pressing one upon the other, and vibration is imparted to one of them, it is easily conceived that in consequence of this vibration the pressure between the adjoining points of the carbon will be modified, and in consequence of such variation in pressure, the electric conductivity of the carbon is also influenced, whilst according to Professor Hughes' explanation, the cause of variations in the electrical resistance must be looked for in the lateral increase of points of contact.

We have another discoverer who has already thrown light upon this subject, viz., Mr. Edison, of New York, the well-known discoverer of the phonograph, who, in constructing a form of telephone of his own, introduced carbon contact, which gave him resistances variable with the amount of physical pressure he brought to bear

upon the carbon; and I must say that this question of varied resistance due to vibration will probably resolve itself simply into a question of pressure between particles of matter which are conducting in themselves, but which are held so lightly in contact that pressure is needed in order to establish conductive continuity.

I should have liked that something more had been said of this discovery of the microphone, with reference to its two elder sisters, the telephone and the phonograph, being of opinion that the three are only separate steps in the achievement of an advance in physical science which bids fair to be considered hereafter as one of great moment, not only as regards telegraphy, but as a means also of affording a more perfect insight into the nature of molecular action. We have heard from Mr. Willoughby Smith that in substituting crystalline selenium for carbon in the microphone, a ray of light produces an effect analogous to mechanical vibration, and announces itself in a report comparable to a clap of thunder, and I can quite follow him in his arguments with respect to the matter. His Grace the Duke of Argyll alluded to the application of this discovery to physiological research, and I could have wished that some of our learned physicians had taken up this point in the discussion, because I believe myself that the influence of these discoveries upon physiological research will be very great indeed. One thing has occurred to me in considering these matters, which I will take the liberty of mentioning. We have the remarkable effect of the phonograph producing a record of sounds simply from the indents given to a slip of tin foil, which record can be reproduced at any time. This strikes me as being an exceedingly analogous case to the impress produced upon the brain by what we hear and see. An impress is produced, which, for the moment seems lost, but which, in a vigorous mind can be reproduced at any time. Now, the faculty of memory is not conceivable on any other hypothesis but that of a mechanical record being left on the brain and stored up for perhaps half a century to be restored in the succession in which it has been laid down; otherwise how could the human mind reproduce impressions imparted years ago at will, or how could they be involuntarily revealed in our dreams? The discoveries which are now brought before us will undoubtedly serve to increase our stock of knowledge on physiological and metaphysical, as well as physical subjects, regarding molecular action, of which we have hitherto had but very imperfect indications, and I think we cannot be too thankful to those gentlemen who have enabled us to discuss them as we have done, and I will therefore move that a hearty vote of thanks be given to Mr. William Preece for his communication. I think our thanks are also due to the two discoverers who are here to-night, and have given us the benefit of their views. I therefore propose that we also return our thanks to Professor Hughes and Professor Graham Bell.

The votes of thanks were unanimously accorded.

Mr. W. H. Preece: My remarks will be very few. As I said, when I spoke on the theory of the thing, I had not time to enter into it. In point of fact there is no real difference between the views of Mr. Willoughby Smith, Professor Graham Bell, and my own. The only difference is difference of language. Most differences in scientific controversies are attributable to difference of language. Whether variation of current is due to difference of contact or difference of pressure, matters very little, provided we use contact and pressure to imply the same thing. That which I call pressure others call contact, and that which Mr. Willoughby Smith calls contact I call pressure. It has afforded great pleasure to me to bring this matter before you. I have had, during the last twelve months, the pleasure of introducing before you the Telephone, the Phonograph, and now the Microphone, and I hope next year when we meet again it will still be my pleasure to bring forward other new inventions and discoveries. I was anxious that Professor Hughes should have brought this subject before you himself, but if I had not undertaken to do so you would not have had it. Beyond assisting Professor Bell, Mr. Edison, and Professor Hughes in any way I could, I can claim no merit of my own either in respect of the Telephone, the Phonograph, or the Microphone.

The Meeting then adjourned to the 13th November.

ORIGINAL COMMUNICATIONS.

NOTE ON ELECTROLYTIC POLARISATION.

By Professors John Perry and W. E. Ayrton,

of the Imperial College of Engineering, Tokio, Japan.

The following experiments made in connection with the general subject of electrolytic polarisation (which we are now and have been for some time investigating) have so obvious a bearing on the tests suitable for determining whether the leakage from a faulty telegraph cable is at only *one* or at *many* points, that we have thought it desirable to communicate them to the Society before the completion of our second paper on electrolytic polarisation, designed to follow the one that has already appeared in their Journal.

The plan of the following experiments consists in sending a current with one or more Daniell's cells through a voltameter and measuring the current after a certain number of minutes, then suddenly reversing and observing the current a fixed time after reversal. A comparison is then made between the two currents so observed as one or both of the voltameter plates is altered in size, material, &c.

The results given in the following table are to be explained if we remember first, that, since the surface of the wire in the voltameter is extremely small compared with that of the plate, the gases deposited on the wire will have far more effect than those deposited on the plate in the polarisation of the voltameter; secondly, that oxygen deposited on copper will, on account of its forming an oxide, be less operative in producing a reverse current than hydrogen; while on the other hand, on account of the great absorption of hydrogen by platinum and of the difficulty of forming an oxide of platinum, it will be the deposited oxygen that will produce the chief polarisation in the platinum voltameter. When, therefore, the anode in the second set of experiments was a