

streets. I would only so long as the wires were few in number. When they reached twenty I would put the wires underground, and in time, I believe, New York will be comparatively free of telegraph poles."

#### A NEW PHONOGRAPH.

THE Edison phonograph, as shown in 1878, has remained the same up to the present time. This interesting invention, however, was not perfect, for:

1st. Its capacity of registry is limited by the dimensions of the cylinder.

2d. The necessity of raising the impressed sheet destroys the perfection of the embossing.

3d. The tin foil used is incapable, by reason of its malleability, of reproducing the sounds given it, save to a very limited extent.

A young professor of the Polytechnic Association, M. Gustave Gamard, has overcome these objections, and we are pleased (says the *Correspondance Scientifique*) to be the first to give the results to the scientific world. Modifying completely the form of the American phonograph, M. Gamard has substituted rectilinear for curvilinear motion.

His apparatus consists of a platform, upon which may be placed a series of traveling frames, made to traverse horizontally by means of a crank and toothed wheels. In the centers of these frames is fastened, either permanently or temporarily, a thin sheet of silver or copper. Above this sheet of foil is placed the vibrating diaphragm with its needle point. Successive frames are caused to pass under the vibrating plate, until the required speech or conversation is completed.

M. Gamard overcomes the second objection to the Edison phonograph by disengaging the foil without injury from the traveling frames, and replacing this as required; and the substitution of copper or silver for tin gives at the same time a more lasting impression, as well as a clearer registry of the vibrations. The use of rigid foils like those mentioned would be impossible upon a cylinder, while with this new application nothing is more easy.

These happy conceptions of M. Gamard seem to us of a nature to hasten the rise of the phonograph from the idle domain of curiosity to the busy fields of practical life.

#### RECENT WONDERS OF SOUND.

A recent lecture before the Society of Arts, London, by  
W. H. PREECE.

I HAVE not brought you together to astonish you with new inventions, or to excite your wonderment at some of the advances that have been made of recent years. My principal object is to let every boy and girl who has honored me with his or her presence this evening see the advantages to be gained by knowing how to use his or her eyes and hands.

All advances of science are the result of experiment, and experiment is the simple mode by which new facts are brought to our knowledge. A great physician, some hundred years ago or more, lived in the town of Derby, and he was the grandfather of a very great man who lives now, Mr. Charles Darwin. This old doctor said that "a fool is a man who never tried an experiment in his life." I am quite sure that there is scarcely a boy in this room who does not, every day of his life, try an experiment of some kind or the other, and therefore there is no fool among my hearers. Every boy has, at some time or other, taken a paper bag, such as the one in my hand, and after blowing it out has burst it between his hands, with the view of startling his little sister or raising a smile from the cook. When he has done this, he has performed an experiment; but it is one thing to experiment, and another thing to draw a lesson from such experiment; and it is toward the endeavor to exercise your thought, by carrying your minds from the natural effect to its cause, that I am more anxious to lead you than to anything else. For instance, every boy, as I say, has made an experiment; but has any one asked himself why it is that clapping one's hands, blowing a whistle, or making a sound in this way (bursting the bag), produces the effect on the brain that is called sound? When the bag is blown out to its full size, and forcibly compressed, there is a condensation of air in it; and then, by the bursting of the bag, an expansion; and by this sudden expansion, a disturbance of the air about us is produced, which has resulted in something being done between you and me. If I take this popgun and force down the handle rapidly, you hear by the report I have produced a disturbance in the air. Between the popgun and every ear in this room there has been a sudden vibration produced. We all know that, when a clap of thunder is heard, the windows shake; when, in church, the deep notes of the organ are sounded, one can feel the pew vibrate; and those of you who in future years may travel to such places as the Falls of Niagara, will find that in the neighborhood of the enormous roar of this water there is heard an incessant and constant vibration of doors and window sashes. Hence, when we have sound, we must have as a source of production a sudden disturbance of air. There must be a medium to convey these vibrations, and that medium is the air itself. To appreciate sound or know when it is produced, there is something to receive it, and that medium is the organ of the ear. It follows then that sound and vibration are concomitant, or similar things. To convey these vibrations to the ear, they are received by the air in which we live and move and have our being. This air forms an enormous ocean 50 miles deep, and we are nothing but crabs and lobsters crawling at the bottom of it. This air swathes our bodies, and when it is thrown into vibration, it affects our ears, and this effect is what is called sound. What is this air? We cannot see it. We sometimes feel it, especially latterly, during the heavy gales of wind that have prevailed. Birds fly in it. It maintains the lights before us burning, and keeps us alive. We know that this air is composed of atoms and molecules. We will take no notice of the atoms, but will fix our minds on the molecules or clusters of atoms of which the air is composed. This room is the receptacle of more millions upon millions of these molecules than I could count if I were to keep on till tomorrow morning. Every little molecule of air is thrown into motion when sounds are produced, and every motion I make with my lips, and every sound I utter by such motion, strikes your ears, and produces the sound of my voice. To give you an idea how this is done, I have upon this board arranged a series or row of marbles. I have no doubt most of you are acquainted with that highly scientific apparatus, a marble, and have frequently experimented with it in various ways. That row of marbles represents a row of the molecules of air that exist between my mouth and your ears; and when I take a marble from the right hand end of the row, and let it fall back into its position again, you

will see that almost instantaneously the marble at the end of the left hand side of the row leaves its position for a distance and falls back again. If I take two marbles from the right hand and let them fall back, you will notice that two at the left hand are driven off, and so on. So with the molecules of air. Every time I utter a sound the molecules near my mouth are disturbed, and a similar disturbance takes place in your ear. You will see that the action through the row of marbles takes very little time indeed, but with the molecules of air the time taken to produce these movements is perfectly well known, and the movements are easily measured. The velocity or time that a sound takes to travel through the air is about 1,100 feet per second. I say "about," because it varies with the temperature. On those bright, brisk days, a short time ago, when we all enjoyed our skating, sound traveled at the rate of about 1,000 feet per second. On those hot, muggy, uncomfortable days, like yesterday, sound traveled about 1,100 feet per second. In water sound travels very much quicker, being at the rate of 5,000 feet a second. With wood it is quicker still, being about 16,000 feet per second. So that the velocity with which sound passes through different media is simply dependent upon the character of the medium and the ease with which the molecules composing it transmit each other's motion. Bearing in mind the fact that sound travels at the rate of 1,100 feet per second, you can all try an experiment the next time you hear thunder. Lightning travels at a rate which is practically infinite; it is in reality 186,000 miles a second, but it is so fast that you may regard it as instantaneous, and, therefore, the moment you see the flash, you know it has just taken place. Sound, traveling at the rate of 1,100 feet per second, takes about  $4\frac{1}{2}$  seconds to travel a mile. So that, having seen the flash, if you count 1, 2, 3, 4, 5, and so on (representing seconds) till you hear the thunder, then if it occurs on your counting five, you know that the storm is a mile away, and you can put your head beneath the clothes and be perfectly easy. If, on the other hand, you see the lightning, and the crash follows immediately after, it is very near. But there is one thing very certain, that, having heard the crash, you are all right, for the lightning which caused it has passed away. The speed with which sound travels is the cause of having such things as echoes. Echoes are simply due to the reflection of sound. From the far end of the room every sound I utter is reflected back to me, but because the distance is so short, I do not hear any difference between one syllable and another. But if the wall were 1,100 feet away, or rather half that distance, then at the end of each second I should get back the sound that I utter. Hence it happens that in large halls it is extremely difficult to speak, because the echoes are so confusing. In the Albert Hall, for instance, there is a certain spot on the platform where poor unfortunate speakers stand, and, unless they are up to the secret, they get confused in a series of sounds coming from all parts of the building. But when a speaker there knows what to expect, he regulates his voice, and the echo becomes a guide to him how to send his voice right away up to the ceiling. When I had the pleasure of lecturing there, I heard back every word that I uttered, and waited for it before I gave out a second, and the result was that I succeeded in filling the large area with my voice, though it is naturally not a very strong one.

The motion of these particles through the air is in itself an interesting study, but they are very complicated in their action. The nearest approach to the motion that I know of, to give you a mental picture of what takes place in the air, is the swaying of a field of barley. Many of you will remember how the gentle breezes blow the tips of the barley in extremely pretty waves, and the formation which these tips take is almost identically the same form which the molecules of air take when transmitting sounds. In fact, if it were possible to suddenly illuminate this room, and to enable you to see the condition of the molecules of the air, you would see them very much as you see the top of a field of barley, excepting that, as the molecules are so small, you would require an infinitely powerful microscope to see them, whereas in the case of fields of barley you can exercise your own eyes.

Sounds are produced by the sudden expansion of air. Sounds being transmitted by this wonderful material, air, we want something to receive the impacts—the movements—of these little molecules, and that is given to us by the ear. On the wall to my right you will see a diagram representing a section of the human ear. Here is the outside of the ear, the shape of which we all know so well. Then there is the inner tubing, and a little way inside this tubing is what we call the drum of the ear. This drum is, in fact, a membrane or disk (a small-sized drumhead), which is hit by the molecules every time they are disturbed by the utterance of sound. The character or nature of the sound is simply dependent upon the way in which it is struck by these little molecules. There is a wonderful and beautiful system of bones that takes up these sounds again from the drum of the ear, and transmits them to the nervous system, and then to the brain, but we have not to-night to trouble ourselves with what takes place beyond the drum of the ear itself, nor should I attempt to show you, for one very good reason, that I do not know myself, and I do not think that anybody has yet attempted to solve the mystery, how it is that the motion of the molecules of the air is transmitted to the brain.

If anybody is anxious to know what sound is, there is a very simple experiment that you can all try. If I put my watch to my ear I hear the ticking of the watch through those molecules hitting the drum of my ear. If I place the watch in my mouth, so as not to let the teeth touch it, I hear nothing; but if I bite the watch, then the ticking comes out as clearly as when the watch is placed close to the drum of the ear; and in this instance the sound is transmitted to the brain, not through the drum of the ear, but through those complicated bones that support the drum and form part and parcel of the organ of hearing.

We have now to talk about the character of sound. We have seen how it is produced. We have seen how it is transmitted and how received. Here is a box which I will shake, and you hear a sound which, I dare say, many of you will think represents the familiar sound of your money box, but it is caused by nails. Here is a box containing a different arrangement to nails, and you will recognize it as an accordion, from which I can draw forth sound in the shape of music, though I am not player enough to give you a tune. Another sound pleasant to the ear may be produced (as you see I now do) by ringing glasses on your dessert table; you can take your finger-glass and just rub it round the edge, and a very sweet sound is at once heard. I have myself seen a man in the street playing on an arrangement of glasses in this manner with the most beautiful effect. From these illustrations we see, therefore, that sound can be divided into noise and music. But music itself possesses very distinct and separate qualities, and I want particu-

larly to impress upon you these different qualities of sound, because upon them depends your knowledge of the instruments that I am going to bring before you.

First of all, the difference in "pitch" of a note is produced by the number of times that the molecules hit the ear in a given time. Here I have a tuning fork which is so constructed that it wags backward and forward 256 times every second, and consequently it sets the molecules of the air in motion between it and you, and you get a beat on the drum of your ear 256 times every second, and these beats represent the sound known as "do." Here is another tuning fork representing "mi," which beats 320 times every second. Here is "sol," which will disturb the drum of your ear very fiercely 384 times a second. Here is our friend "do" an octave higher, that hits you 512 times a second. In order to show you a little more clearly that these effects are produced, we have here a disk that has a series of holes pierced through it, and I have an India-rubber tube through which I can blow; but blow as I will, you do not hear any sound. If I allow my breath, as it makes its exit through the tube, to pass through the holes in the disk as it revolves, my breath is broken up into a series of pulsations or blows, so that again you get your ears hit with the proper number and rate to produce notes. [The disk is known as the siren, and the "scale" was played once or twice both slowly and rapidly upon it.]

Here is a little contrivance in which, instead of exerting my own lungs, I can bring an artificial pair of bellows into play, the air from which causes a little disk to rotate; and the higher the speed at which this disk rotates (by continuing the pressure of the bellows) the higher the pitch; and by pressing the bellows slower and slower, the note becomes lower. Here is another instrument that shows you the same effect as the one just exhibited; and I want you to thoroughly understand this fact, because it lies at the root of all our microphones and telephones, and therefore it is an essential thing that you should grasp and see for yourselves, with your own eyes, not merely the eyes of your body, but the eyes of your mind, these wonderful things that take place to produce sound. This is simply a little iron disk which I bring into contact with the edge of a toothed wheel. When the wheel is turned, you hear sound produced. As the velocity is increased the pitch of the sound is higher and higher till you hear a perfect shriek; then, on the speed coming down, the pitch becomes lower. You will understand by these illustrations that the pitch of a note depends upon the number of times the drum of your ear is hit by the molecules of air. But I can do more: I can almost make you see the sound. Here is an instrument that is called a phonoscope, and it is the invention of a gentleman named Edmunds. Here we have a glass tube that has been exhausted of air and supplied with gas. We send through that tube currents of electricity, and Mr. Ladd will sing, cough, laugh, etc., and you see a flash of light in the tube for every note. This is an ocular demonstration of the fact that every vibration of the disk produces the effect that leads to sound.

It is worth noticing that the lowest note which can be heard by the human ear is produced by vibrations of 16 to the second—the highest is produced by 38,000 vibrations to the second; so that the human ear has a limit between 16 blows per second and 38,000 blows or vibrations per second. But the human voice itself is only capable of producing vibrations between 65 per second and 1,044 per second; and the highest double C of some of our chief sopranos only means a little more than a thousand vibrations per second. But yet the ear can detect sounds higher than that of the highest voice. There are some ears that can hear the bats cry; there are some that cannot.

There is a very interesting inquiry being carried on just now by Sir John Lubbock, on the habits and manners of ants; and that gentleman has shown beyond question that ants have a mode of communicating their ideas to each other. An ant strolling about may come across a piece of meat, and he will hurry back and say something to the first chap he meets, and they will go together to the meat and will carry it to their nest. The results of Sir John Lubbock's watching of the habits of these little fellows are most wonderful. We are quite sure they talk or have some mode of conveying their ideas; but if it is by sound, the number of vibrations are so excessive that the human ear cannot detect them. The microphone and all kinds of contrivances have been tried to ascertain if they converse, but, so far, it has all been of no use. We have even gone so far as to make a special little instrument that will vibrate nearly 200,000 times a second, but still the little rascals have defied the investigation. There is yet a hope that, by perseverance and observation with special instruments, Sir John may one day find them out, even if not be able to convey their ideas to us.

The first fact that I brought to your notice is that sound varies in pitch. The second quality in which it varies is, that of loudness; and loudness is produced either by the increase of amplitude that is given to the motion of these molecules, or to the quantity of air that we throw in motion. For instance, if I take a small tuning fork and hold it up in the air, you do not hear; but if I take a longer fork, you, perhaps, hear it because its vibrations are greater and it causes a greater amplitude or spreading out of the waves of air. But if I take a little contrivance I have here to increase the quantity of air thrown in motion, you can hear. This is done by placing the tuning fork on a small piece of wood extending from the apex of a paper cone. So if I take a larger surface, a larger paper cone, there is a louder sound, as you can hear. If I take a still larger fork and hit it upon the table, and hold it in the air, you hear the sound without the aid of a magnifier, as I may term it; there is a considerable difference in the loudness of the tone, owing to the greater quantity of the air that is thrown into motion. We can also increase the loudness by taking a conical shaped roll, and speaking into it at the smaller end. It is by taking advantage of this fact that this elegant and scientific apparatus, known as a speaking trumpet, has been utilized for carrying orders to different parts of a ship.

The next point connected with sound that I want to call your attention to is its quality. You are all acquainted with this extremely beautiful musical instrument in my hand. Perhaps some of you may think it is an expensive flute, but, between ourselves, I am bound to tell you that I paid a penny for it; and, though modest in price, good music may be got out of it. Here is another musical instrument—a fiddle; and if I were Paganini or one of those three fellows who played before "Old King Cole," I could give you some good music, but as it is the first time I have handled a fiddle, I will only just touch it that you may hear the kind of sound it produces. I am playing the note C on this fiddle. I now take the whistle and blow the note C, and so on I may go through all the musical instruments—cornet, clarinet, accordion, jewsharp, etc., and sound C;

and although each instrument will strike your ears exactly the same number of times per second to produce the note C, nevertheless the notes differ very much in the particular form that distinguishes one instrument from the other. This quality is due, not to the number of times that your ear is struck—not to the strength of the blow, but to the form in which it is struck. Here is a little instrument by which I hope to show you what I mean. It is a spring with a silver bead on the top. The silver bead reflects, as you see, a spot of light. You will see that when I move the bead straight up and down, or to and fro sideways, a line of light only is reflected; but when I vibrate it, and move it toward you, the most beautiful waves are reflected. The human voice is one of the finest musical voices ever constructed; in it you have all the beautiful tones of music. But you never find two voices sound alike; you never hear a man speak twice in exactly the same way; and the result is that the human voice differs very much more than any other form of apparatus, but it does so simply because of the construction of the mouth, the size of the tongue, the formation of the teeth, and the way in which one breathes at the time air is taken into the lungs. Any slight difference in these things varies the form of the air when it passes from the mouth of the speaker to the ear of the listener. I will illustrate this by my jewsharp. If I place the harp in my mouth, and shape my mouth for the sound "O" to be given out, on striking the harp you hear that sound given; if I alter the shape of my mouth, "A" is given, and so on.

We have spoken of sound varying in pitch, loudness, and quality. We have now to speak of the impression of sound. We want to impress the sound on something. If any of you, when at home, will take the trouble to open the top of the piano, particularly if a grand piano, and press down the soft pedal, and sound on the middle note the vowels *a o e*, you will find these vowels come back to you perfectly distinct. You all must have noticed that when any one sings to a piano there are certain notes that always vibrate in sympathy to the human voice, and sounds are heard back again. It has been said that Lablache, one of the greatest deep bass singers we ever had, was able to sing a note so loud that he could crack a tumbler, and did actually break one before his audience.

To illustrate this impression of sound I must borrow a hat. Here is a hat, to the crown of which I will fix a little apparatus, consisting of a spring, which when it vibrates makes contact in a telegraphic circuit, in which two telephones are fixed at the far end of the room. The spring vibrates when the crown of the hat vibrates, and if I speak into the hat the sounds are given off by the telephones. [The audience near the telephones recognized the sounds.] The crown of a hat is not essentially necessary to show you this. A disk of thin iron, ebonite, or parchment, about three inches in diameter, will, under the influence of my voice, vibrate in the same way; and I want to show you that they not only vibrate in this manner, but they do so just the number of times required to make the note spoken, just the amplitude required to produce loudness, and just in the form required to produce quality. My friend Mr. Stroh (to whom I am so much indebted each time I have had the pleasure of being here) has made one of the most beautiful apparatus that I know of to illustrate this point, and he has kindly brought it to illustrate my lecture. It is a phonoscope. We have a magic-lantern, in front of which is a thin disk, upon which there is a mirror which reflects a spot of light on the screen on the wall, and it is to the movements of that reflected spot of light that I want to call your attention.

[The gas was then turned down, and Mr. Stroh caused the spot of light to rotate rapidly, forming an unbroken ring of light on the screen. He then spoke the vowels to the disk, and each vowel caused its representative variation in the edge of the circle of light. Coughs, laughing, etc., also were shown to break up the rim into greater or less zigzag projections.]

There you have a perfect representation of all the different qualities and properties of sound. I want now to speak of the transmission of sound, and I must claim your indulgence, for the time is going very fast, and I cannot dwell on the experiments. You are all familiar with speaking tubes as used at the present day, for conveying orders from room to room in the house, hotel, or office. The ancients employed speaking tubes in connection with their idols, and used sometimes to make their oracles tell the most wonderful stories. The gentleman whom I mentioned in the opening of my lecture, Dr. Erasmus Darwin, was one of the first in England to construct a speaking tube. He fixed it between his dining-room and his kitchen—very near the fireplace in the latter. A patient sent his servant one night to the doctor for assistance, and while the man was sitting by the fire in the kitchen waiting for his message, he heard a sepulchral voice, coming apparently from the fire, say, "I want some coals," and he jumped up and ran away, and told all the neighborhood that Dr. Darwin was a magician. We have a mode of producing and transmitting sound that is due to the late Sir Charles Wheatstone. Between a room down-stairs and here is this deal rod, which is resting upon a musical box. As it is, you hear nothing at all; but if I take this butler's tray and place it on the deal rod, you hear the musical-box playing, which disappears on my taking off the tray, and reappears on my again placing it on the rod. It is a good experiment; but I must pass on, as it is difficult to keep pace with time, which, as you know, waits for nobody. This is one of the first forms of telephone, invented as far back as 1819. The sound is reproduced in that case only from the room below. We are now going a little further, and will transmit and reproduce sound from the city. Between this room and the city there is a telegraph wire, and on that wire telephones have been fixed. There are numerous forms of telephones. The diagrams on the wall will give you some idea of what they are. I have shown you Wheatstone's mechanical telephone. There is a form of string telephone that you are all, I have no doubt, acquainted with, and a very beautiful scientific apparatus it is, and one through which conversation can be carried on for a considerable distance. But Professor Bell, in 1876, formed an instrument by which sound could be reproduced at a much greater distance than by any means previously known. Reiss, a German schoolmaster, in the year 1860, had done precisely what I showed you with the hat; and in fact I ought to have told you that the hat arrangement was nothing but a Reiss telephone. But Bell went very much further than Reiss. He was able to reproduce speech, and the electric signals coming through the wire coming into this room from the city are transmitted with just the amplitude and form that I showed you on the disk, and they reproduce all the qualities of sound, either of musical instruments or the human voice.

Still further improving on what had been done before, Professor Hughes invented the microphone, an instrument by which the motions of the air, the sonorous vibrations as

they are called, act directly on a portion of the electric circuit, and vary the electric currents in all their beautiful waves. The instrument which I have before me is one of Mr. Louis Crossley's (of Halifax). It is a form of transmitter, based on Professor Hughes' discovery, and the arrangement between this room and the city is just what you see on this diagram. We now ask the man in the city to say a few words—and there you hear what he says. His voice in the city is setting electric currents flowing which produce vibrations in the air. The sonorous vibrations in the city impinge on a disk, just as those of my voice did on the hat; that disk produces currents of electricity, which vary in number, form, and quality. These currents of electricity traverse the telegraph wire between the two rooms, and are received on the instrument here by a little magnet, and this magnet causes the disk at this end to vibrate just in the same way as the disk vibrates in the city. I repeat, then, that what a telephone does is this: A disk is thrown into vibration by your voice, just as you saw Mr. Stroh's phonoscope thrown into vibration. These vibrations are transformed into currents of electricity, which come to this distant station and here cause another disk to vibrate in exactly the same way, and throw the air of this room into similar vibrations, as the air is vibrated in the room in the city, and the effect is that we hear apparently the voice of the man at the sending place. If wires were clear, that is, free from what is called induction, distance would be practically of no consequence. I have spoken between Holyhead and Dublin in the same way that I am speaking to you. I was in Holyhead, my friend in Dublin, and I talked so nicely that he actually told me that he could smell my cigar. In America they have talked through a greater distance. There was an account in the paper the other day of a conversation being held at a distance of 2,000 miles. In fact, Professor Bell and myself spoke through "resistance," as it is called, that represented 10,000 miles, and the wire through which we talked was within itself really a telegraph 10,000 miles long. There is no doubt whatever that, if we had a telephone or a wire from here to the moon, and if any of you were to follow Jules Verne's hero and go to the moon, we should be sure to talk comfortably, and without the slightest difficulty.

I want now to say one word about talking machines. There are many such. There is Faber's, which was introduced in England in 1843, and is now in England, but not on public show. We can all make talking machines for ourselves if we like. Here is a penny trumpet. If I close the end with my hand, and, on blowing through the tube, imitate the motion of the lips with my hand, I can make it sound "ma-ma." Not a very good one perhaps, but, nevertheless, it shows you that, by the proper manipulation of India-rubber tongues and lips, or things of that kind, it is possible to construct a machine to emit sounds representing speech; but Mr. Edison has far transcended anybody else, and by taking advantage of this power that we have of making disks represent in pitch, in loudness, and in quality, the sonorous vibrations, he has been able to reproduce the human voice with wonderful exactitude by the phonograph. Here is a phonograph or talking machine. Its construction is illustrated by the diagram on the wall. The diagram is not exactly a representation of the particular one before you, which is regulated by clockwork. You will notice the disk into which words are spoken. Here is a cylinder upon which lead foil is fixed, and when I speak into that disk I cause it to vibrate. The vibrations cause a little point to impinge on the lead. On this lead dots, and ruts, and waves, and curious marks are made; and when these marks are caused to go a second time over the same ground with the disk in contact with or again pressing on them, they reproduce the sounds first spoken. [Several sentences were spoken into the phonograph, and the sounds of coughing and laughing were sent into it, and came out again clearly.]

We have the pleasure this evening of having among us a gentleman who has recently returned from the Cape, and whose name in that part of the world is a household word. I mean Sir Theophilus Shepstone. He can speak Zulu; and I have no doubt that many of you will be glad to hear the sound of the Zulu language. But we are also anxious to know if the phonograph itself will reproduce the Zulu tongue, because in the Zulu and Kaffir languages there are sounds we do not know on this side of the globe—curious clicks. [Sir Theophilus Shepstone spoke a few sentences in Zulu to the phonograph, which he said repeated the words very faithfully.] I am indebted to you all for your very kind attention to-night to what I have said. I have led you up from the mere elements of sound, from sonorous vibrations to the way in which you may "waft a sigh from Indus to the Pole;" and to the mode by which we can even reproduce voices that are still. But although there are wonders, and recent wonders of sound, I do not want you to forget that they are the outcome of experience, and the wish that I have in giving this short course of lectures is simply to induce boys and girls to use their eyes and hands in observation and experiment.

#### MAGNETIC REACTIONS.

By TH. DU MONCEL.

THE effects of magnetism, as they are usually pointed out, are far from agreeing with those which practice is revealing at every moment; and, owing to the often inexact data that are possessed, it sometimes happens that we meet with deception only in the results expected. The reason is that two magnetic actions which are essentially different are confounded with each other—static action, that is, the action revealed by magnetic attraction, and dynamic action, which gives rise to the reciprocal mechanical reactions of magnets and currents. These two actions are not mutually dependent on each other, although they may have a reciprocal influence, and consequently may be independent. Dynamic action is induced by those magnetic currents which Ampère supposed to envelop the magnet throughout its whole extent and perpendicular to its axis, and may be considered as dependent upon a resultant applied to the center of the magnetized bar. This resultant, then, represents all the individual actions of the currents constituting the magnetic helix. From this point of view the magnetic action is found to be most energetic, exactly according to the neutral line, where, however, no action of attraction takes place. In fact, it is at this point that the effects of induction are most energetic, and this is why MM. Poggenдорff, Muller, Fabre, and others have advised the rolling of the helices of the induction coil like a spindle. It is for this reason, too, that when a small induction coil is caused to revolve on a magnetized bar, the resulting induced currents are direct when the coil moves from the neutral line, and inverse when they approach it. Static action, on the contrary, closely approximates to that of the electricity by induction, which is in play in electrical condensers. Without in any way entering into the theory

of the molecular effects which may then be produced, it may be said that, under the influence of the polarities that are developed at the two extremities of a magnetized bar, there is determined, in the presence of a magnetic body such as iron, a peculiar arrangement of the magnetic atoms, which, without altering the motion of the peculiar currents of Ampère, has the effect of exercising at a distance an action by induction, analogous to that of static electricity, and of constituting around the magnet what is known as a *magnetic field*, and in which all magnetic substances become polarized according to the known laws of electric attraction and repulsion; and from this result the effects of attraction with which we are acquainted. In a magnet these static effects have two centers of action which form what are called the *poles of the magnet*; and these poles are, as we know, situated near its extremities. It is the middle portion which is found to be in a neutral state, and consequently without action, regarded from the standpoint of the actions which we are now studying. If the two actions which we have just analyzed can act independently of each other to attract iron, and can produce induction currents, they can nevertheless reciprocally influence one another. So a magnet surrounded by an induction coil, which will furnish currents of opposite natures, will, whenever it is magnetized and demagnetized, give rise to currents which are infinitely more energetic if a static reaction intervenes; i. e., if its two extremities be provided with two iron armatures; and this proves that, in this case, static reaction has strengthened the magnetic power of the magnet. This action then is effected after the manner of that which is developed in a condenser, and we shall soon see how the phenomenon may be produced.

On another hand, if the static reaction is such that it modifies the magnetic polarities of the magnet, or of a system composed of a magnet and an iron armature, dynamic action is not for that reason disturbed; and, although at the point where a neutral line should be found, we discover a perfectly characterized magnetic polarity. The induced currents which are then produced demonstrate that, from a dynamic point of view, the system is regularly constituted. But in order that we may be able to understand all these effects, it is essential that we should first study the manner in which static magnetism is distributed in a simple magnetic system or in one combined with an armature. Figure 1 represents the *magnetic phantom* of a regularly constructed

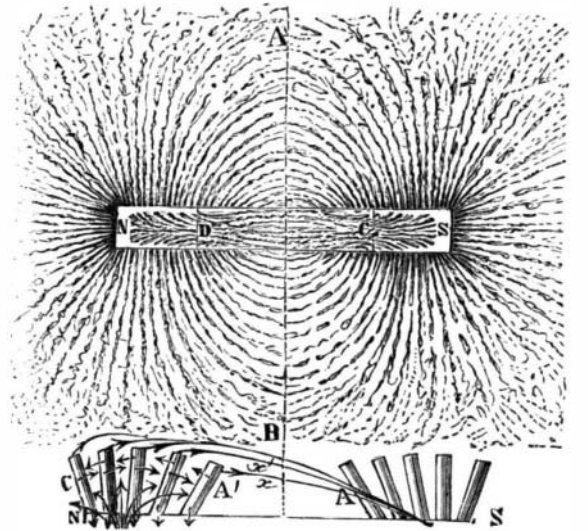
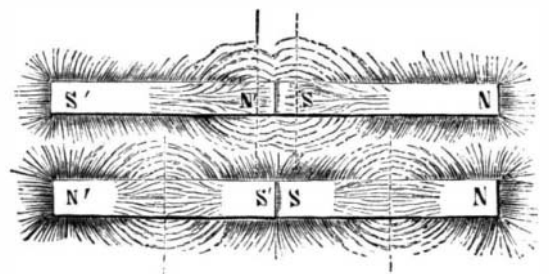


FIG. 1.

magnet, N S, the neutral line of which is at A B. The figure is so styled which is formed by iron filings strewn over a sheet of paper placed beneath a magnet. The filings collect together according to certain so-called lines of magnetic force, which radiate around the poles and unite toward the neutral line to form more or less pronounced curves that indicate the neutral region of the magnet. The small figure seen beneath the larger one shows how, in consequence of magnetic attractions and repulsions, these aggregations of particles of iron produce these lines of magnetic force. I have spoken of this at some length in my work "On Magnetism," and without attaching as much importance to it as the English do, I will make use of it here merely as a means of easily recognizing magnetic distribution in magnetic systems of greater or less complexity. Consequently, when we see curves of iron filings in a magnetic phantom, we may be assured that the normal line in the middle of such curves will represent the neutral line of the system. This granted, let us now examine the phantoms of two equal magnets united by their like and unlike poles. These phantoms are represented in Figs. 2 and 3. The one in Fig. 2 belongs to



FIGS. 2 AND 3.

the two magnets united by their opposite poles. It is seen that the curves of filings no longer remain at the middle of the bars; they seem to have become fused into a single system, which ought to furnish but a single neutral line were the adhesion of the two magnets perfect, but which, by reason of their imperfect contact, gives rise to two distinct neutral lines. The phantom of Fig. 3, on the contrary, shows that the distribution of magnetism has been little altered on each of the two magnets, since the two systems of curves are found to nearly correspond in the middle of each. When these magnets are separated by a slight space, the phantoms exhibit themselves in the form seen in Figs. 4 and 5, and which show that the magnetic field, in cases where opposite poles are in presence, behaves like a true magnet—conditions which do not exist when like poles are opposed