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THE PHONOGRAPH: ITS PHYSICS, PHYSIOLOGY, AND CLINICAL IMPORT.[1]

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BEFORE I enter upon a demonstration of the underlying principles and the action of the phonograph, let me occupy a moment of your time by recalling those special characteristics of the human voice, the distinguishing qualities of musical tones, etc., which it is necessary to keep before us in order to thoroughly understand the instrument I intend to dissect, both anatomically and physiologically, before you.

You are all more or less familiar with the phonograph. Five years ago it was a closed book to us. To-day we presume to know it from preface to appendix. I fancy there are many here in this section who casually know me from the few years of work I have done in experimenting with the machine and the fragments that from time to time have gone forth to the profession from my pen and workshop. I can almost hear them say, "Here he is again; what can he have to tell us now?" My answer is simply to let you know the further stage of perfection to which I have been able to carry the recording and reproducing with integrity the sounds and tones which, aside from their general scientific

[1] Communication to the Royal Academy of Medicine and Surgery of Naples, 1894.

importance, must soon become a valuable assistant to us in the positive recognition of disease.

All sound begins in those collisions and attractions among material things by which their parts are thrown into tremors. These are almost as various in quality as the properties of material substances. The sounds we hear are but indices to the vibrations of bodies from which they proceed, and the multitude of such terms as splash, roar, ring, thud, crack, whiz, squeak, crash, illustrate the marvellous diversity of characters which material vibrations may take. In the production of noise, the thrills of matter are transient and irregular, but, when prolonged and regular, they give rise to musical sounds. Vibration depends upon elasticity, and bodies which are capable of the protracted and measured pulsations of music must, of course, be highly elastic. All bodies vibrate differently, and this depends upon the nature, form, and magnitude of the mass in motion. The vibrations of bells differ with their sizes, and the metals and alloys which compose them; while wooden and metallic tubes, strained strings, and stretched membranes illustrate the same thing.

Take a tuning-fork, and set it into vibration by drawing a violoncello string across its prongs; the fork yields its own characteristic note, which will be loud or soft in harmony with the manner in which the fork has been set into vibration. So long as we use one fork only, it is obvious that the only vibration which can be produced in the sounds confines itself to a vibration of their intensity. If the extent of the vibrations be small the sound resulting is feeble, its loudness increasing with the excursion of the prongs. What is true of the tuning-fork is true of any musical instrument, and hence the loudness of musical sounds depends upon the amplitude of the vibratory space of that which produces it. Now take two tuning-forks differing in pitch, and let us presume that one is just an octave above the other. They may be excited in such a way that the notes emitted are of equal loudness, the only point in which they differ being in pitch.

We all know that the pitch of a fork depends upon its rate of vibration, which we can readily measure with suitable apparatus, and thus it is comparatively easy for us to accurately determine the pitch of a tuning-fork, and should we so test the two tuning-forks in question, we should find that the notes of the one of increased pitch would vibrate twice as fast as the other. If the one, say, makes one hundred oscillations per second, the other, an octave higher, would make two hundred in the same interval of time; thus we may be assured that the pitch of any note depends upon its rate of vibration and nothing else.

So having accounted for two characteristics of a musical note, let me come to the third, which is of equal if not greater importance, and by no means so easy of explanation. I refer to what we generally term the *quality*. The French have a more comprehensive term for it—they call it *timbre*, while the Germans have the most exact defining word in the term *Klang-farbe*.

Klang-farbe is that which constitutes the difference between a violin or an organ and a pianoforte, or between two human voices ; indeed, we may say between any sounds, musical or otherwise, which are of the same pitch and loudness, but readily distinguishable from each other.

To explain the physical cause of quality, let us suppose we have a

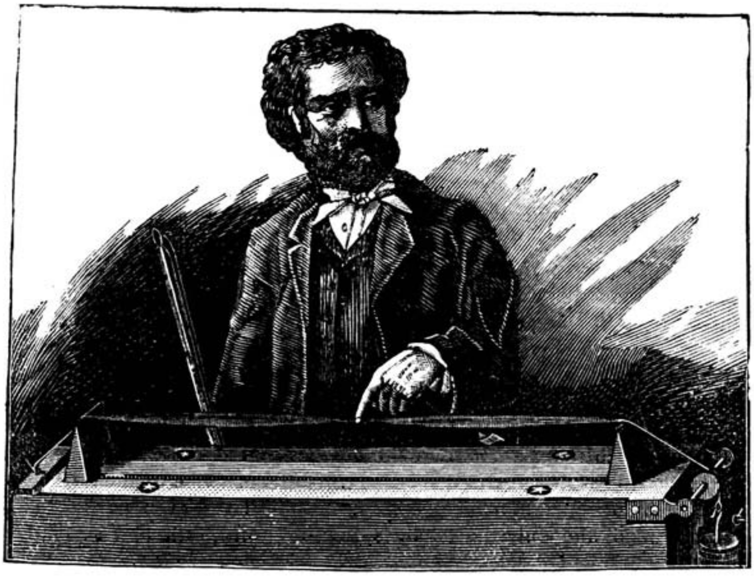


FIG. 1.

thin metallic wire stretched between two points over a sounding board. When plucked at the centre the wire vibrates over its entire length, a loop being formed between the two points. The note emitted by the wire when vibrating in this manner is called the fundamental note. If we should dampen the wire at the centre by laying across it a feather or quill pen, and pluck it at a point midway between the centre and one end, both halves would vibrate in the same manner and independently of each other. That is to say, there will be two vibrating segments at a point of rest or node at the centre. But the rapidity of vibration of each segment will be twice as great as that of the wire when vibrating as a whole, and consequently the note emitted will be the octave of the fundamental.

When damped at a point one-third of the length from either extremity, and plucked half way between that point and the nearer extremity, the wire will vibrate in three equal divisions just as it vibrated before in two divisions, but now the rate of vibration will be three times as great as at first, and the note produced will be a twelfth above the fundamental. Similarly, by dampening and plucking it at suitable points, the wire may be made to vibrate in four parts, five parts, six parts, etc., the rate of vibration increasing to four, five, six, etc., times what it was at first. For example, let us assume that when the wire was swinging as a whole and sounding its fundamental note, the number of oscillations performed in a second was 100. Then we see that, by taking suitable precautions, the wire can be made to break up into two, three, four, five, six, etc., vibrating segments, the rates of vibrations being respectively 200, 300, 400, 500, 600, etc., and the series of notes emitted being the octave above the fundamental, the fifth above the octave, the double octave, the third and fifth above the double octave, and so on. We now come to an important point, which is this : that, the wire being free, it is practically impossible to strike or pluck it in such a way as to make it vibrate according to one of the above systems alone. It will vibrate as a whole, wherever and however it is struck, but this mode has always associated with it or superposed upon it some of the other modes of vibration to which we have just referred. In other words, the fundamental note is never heard alone, but always in combination with a certain number of its overtones, as they are called. Each form of vibration called into existence sings, as it were, its own song, without heeding what is being done by its followers, and the consequence is that the sound which reaches the ears is not simple but highly composite in its character. The word *clang* has been suggested to denote such composite sound, the constituent simple sounds, of which it is the aggregate, being called its first, second, third, etc., partial tones. All the possible partial tones are not necessarily present in a clang, nor of those which are present are the intensities all the same. For instance, if the wire be struck at the centre, that point cannot be a note, but must be a point of maximum disturbance ; hence all the even partial tones are excluded, and only the off ones, the first, third, fifth, and so on, are heard.

That characteristic of a musical note or clang, which is called its quality, depends upon the number and relative intensities of the partial tones which go to form it. The tone of a tuning-fork is approximately simple, so is that of a stopped wooden organ pipe of large aperture blown by only a slight pressure of wind. Such tones sound sweet and mild, but they are tame and spiritless. In the clang of the violin, on the other hand, a large number of partial tones are represented ; hence the vivacious and brilliant character of this instrument. The sounds of the human voice are produced by the vibrations of vocal bands, aided by the resonance of the mouth. The size and shape of the cavity of the mouth may be altered by opening and closing the jaws, and by tightening and loosening the lips. We should expect that these movements would not be without effect on the resonance of the contained air, and such proves upon experiment to be the fact. Hence, when the vocal bands have originated a clang containing numerous well-developed partial tones, the mouth cavity, by successively throwing itself into different postures, can favour by its resonance first one overtone and then another, at one moment *this* group of partial tones, at another *that*. In this manner endless varieties of quality are rendered possible. Anyone may prove it himself, by making the experiments, that when singing on a given note he can only change from one vowel sound to another by altering the shape and size of his mouth cavity.

THE PROPAGATION OF SOUND.

Having thus briefly indicated the physical causes of the various differences in musical notes, and the production of sounds by the organ of voice, I will now devote a few moments to consider how these sounds are propagated through the air and reach the delicate diaphragm of the phonograph, while recording any kind of sounds.

Now, in order that all these multifarious and diversified tremblings of natural objects may be brought into relation with animate creatures, a common medium of communication is necessary. The air around us is such a medium. It possesses the marvellous power of taking up the numberless and ever-varying thrills of material objects, and conveying them through space with all their peculiarities. The sensitiveness of the air (if I may so speak) to the faintest tremors in material objects, and its power of transmitting their individual qualities, are most wonderful. It drinks up the infinitesimal motions of things, and diffuses them swiftly, simultaneously, and in countless myriads, in all directions around.

That air is the medium of sound is proved by the fact that, when vibrations occur in space void of air, the silence is not broken. If a bell suspended by a string in a vacuum be struck, nothing is heard, although if it is in contact with the jar, the vibrations are communicated to the outer air, and sound produced. That air transmits the kind of motion that it receives is also proved by the fact that it will take up vibrations at one point and communicate them to a distant object that is capable of vibrating in the same way.

The velocity of impulses in the air which produces sound has been well established, and all kinds of shocks—the firing of a gun, notes of a musical instrument, or the voice, whether high or low, harsh or soft—all move at the same rate. The velocity is not affected by changes in atmospheric pressure or moisture, or by rain or snow, but it is affected by wind and by temperature. The speed of sound is 1090 feet per second at the freezing-point, and increases about one foot per second for each degree of ascent on the Fahrenheit scale. Sound moves in air with about the speed of a cannon-ball, and at a rate ten times greater than the swiftest motion of air in a hurricane.

The sound produced in the open air tends to move in all directions with equal speed, but this tendency may be disturbed by various conditions. If the whole mass of air is moving in one direction, sound will travel faster with it than against it. In still air the sound of a musket-shot will be heard farthest in the direction of the impulse. Experiments have shown that a person speaking in the open air can be heard about equally well at a distance of one hundred feet in front, seventy-five feet on each side, and thirty feet behind. When an obstacle checks a sound in one direction it can be heard farther in others, because, as a given amount of force produces a given amount of motion, if the motion is arrested in some directions, it is increased in others.

We have now seen that air is the common vehicle of sound, and that the sound impulses move in all directions at a high speed. But what is it that actually moves? The particles of air are certainly not shot from the vibrating body to the ear, for then we should live in the midst of storms ten times more violent than tropical cyclones. The wonderful elastic properties of gases here come into play. The vibrations of bodies produce waves or pulses in the air. When a disturbance is produced at any point in an aerial at rest, sonorous undulations spread out from that point in all directions. These undulations are the effect of the rapid vibratory motion of the air particles. The analogy of water waves will help us to understand what is taking place under these circumstances. If a stone be dropped into the still surface of a pond, a series of concentric circular waves are produced, each wave consisting of a crest and a hollow. The waves travel from the centre of disturbance, while the drops of water which constitute them have an oscillatory motion in a vertical direction—that is to say, following any radical line, the water particles vibrate in a direction at right angles to that in which the wave is propagated. The distance between two successive crests or two successive hollows is called the length of the wave; the amplitude of vibration is the vertical distance through which an individual drop moves. In a similar manner sonorous undulations are propagated through air by the oscillatory motion of the air particles. But there is this important difference between the two cases—in the latter, the vibrating particles move in the *same* direction in which the sound is being propagated. Consequently such waves are not distinguished by alternate crests and hollows, but by alternate condensations and rarefactions of the air, the transmission of which constitutes the transmission of sound. The wavelength is the distance between two consecutive condensations or rarefactions. It depends upon the pitch of the transmitted sound being shortened as the sound is more acute, while the extent of vibration of the air particles increases with the loudness. Such are the peculiarities of the vibratory motion in air corresponding to the pitch and loudness of the transmitted sound. But what is there in the character of the motion to account for the difference in quality? A little reflection will show that there is only one thing left to account for these, and that is the form of the vibration. Let us mentally isolate a particle of air, and follow its movements as the sound passes.

If the disturbance is a simple one, produced, say, by the vibration of a tuning-fork, the motion of the air particle will be simple also—that is, it will vibrate to and fro like the bob of a pendulum, coming to rest at each end of its excursion, and from these points increasing in velocity until it passes its neutral point. Such, however, is clearly not the only mode of vibration possible. If the disturbance be produced by a clang comprising a number of partial tones of various intensities, all excited simultaneously, it is obvious that the air particle must vibrate in obedience to every one of these tones. Its motion will be the resultant of all the motions due to the separate partial tones. We may imagine it starting from its position of rest to move forward, then stop short, and turn back for an instant, then on again until it reaches the end of its excursion. In returning it may perform the same series of to and fro motions in the opposite direction, or it may move in a totally different way. Nevertheless, however complex its motion may be—and, as a rule it will be exceedingly complex—its periodic character will be maintained. All the tremors and perturbations in one wave will recur in all the others.

Could we see what takes place in a room when a tuning-fork is in vibration, giving out a "single note," we should behold all the particles of the air agitated in tremulous sympathy, and filling the space with swiftly expanding spheres of spectral beauty. Or, were the effect produced by several instruments played, we should see forms in countless variety, carving the air into ever-changing figures of geometrical harmony, and creating the perfect music of geometrical forms. Such a revelation is impossible from the swiftness of movement, which would baffle the eye; but it would be also impossible, because the complications of movement would confuse it. But where the optical sense fails, the auditory sense succeeds. The membrane of the ear receives the torrent of motion, and transmits it with all its harmonies. In an orchestra, where scores of instruments are playing through the whole compass of the scale, the air is cut into waves or pulses by every complexity of vibration—grave tones mingle with shrill, soft with harsh, fundamentals are merged in overtones, and the storm of impulses is shot with the speed of rifle-bullets against the diaphragm of the phonograph as against the tympanum, and yet there is no confusion. In all their infinite diversity of qualities the waves are graven upon the little membranes.

In order to complete the physics in this paper, I cannot pass over it without paying some attention to visible sound.

The idea of getting a visual expression for musical vibrations occurred to Chladini, a physician of the last century. He fastened a plate of glass by its centre, and then, having scattered some sand over the surface, threw it into sonorous vibration bv means of a violin bow. The plate, being thus

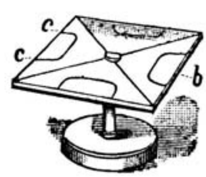


FIG. 2. Vibrations of a Clamped Plate.

set in vibration, the sand was tossed away from certain parts of the surface and collected in other parts, forming regular geometrical figures. The plate, like a string, has one rate of vibrations which belongs to it, but again, like a string, by *dampening* it with a touch of the finger or fingers in different points along the edge, the note changes, and with it the figure made by the sand. The lines on the plate where the sand settles are nodes, the lines of comparative rest. The violent agitation in the parts left bare can be shown by mixing a little lycopodium powder with the sand. This is excessively light, and is caught in the little whirlwinds of air generated about the vibrating segments.

The marvellous intricacy of the vibrations of these plates may be seen from a few figures given below, which indicate the lines taken by the sand when certain notes were sounded on the plate. A little instrument

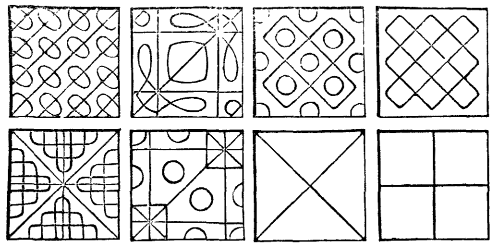


FIG. 3. Chladini's Figures of Vibrating Plates.

invented by Prof. Sedley Taylor, and called the phoneidoscope, gives a most exquisite illustration of music made visible. He says that by this contrivance it is possible by means of a soap film to get different figures for different pitches, for different intensities, and for different qualities of tone. I did not, however, find this instrument to answer in practice.

We are now upon the very threshold of Mrs. Hughes' voice-figures, of which I have spoken *in extenso* in a previous communication ; but for the sake of completeness, I will recapitulate some of the important points set forth therein. She has reached the path which brought her to them by the phoneidoscope. Her eidophone is constructed on the same principle as the phoneidoscope : instead of the frail lamina of soapsuds she has a stretched membrane of india-rubber to receive the vibrations, and on this is spread a thin layer of some pasty substance which will retain the record made by the vibrations of the membrane. These voice-flowers are not the simple visual forms corresponding with the vibrations of the air set in motion by the voice. The waves generated in the closed bowl of the eidophone are reflected again and again from the sides of the vessel. The volume of air enclosed has its own rate of vibration ; the stretched membrane has also its own rate, which in turn is modified by the character and thickness of the paste spread upon it. Added to these are molecular forces of cohesion and adhesion between the particles of paste, and again between the paste and the membrane. The form which grows into shape is the resultant of all these complicated forces, and, in some instances, new elements of change have been added. A glass plate is placed on top of the vibrating membrane and moved over it. We have a new body introduced with its proper rate of vibration, besides a mechanical motion further to complicate the problem.

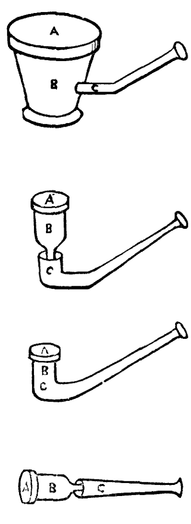
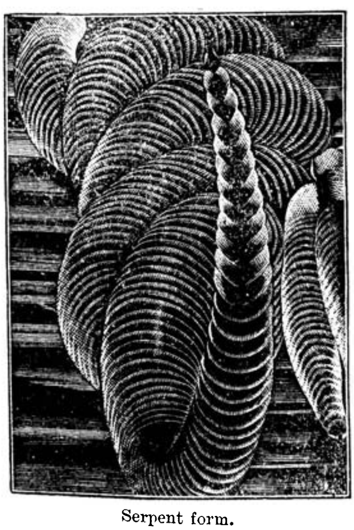
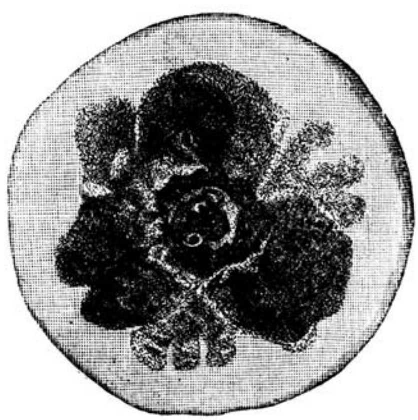


FIG. 4.
The Eidophone.

I IG. 5. Seaweed or landscape form.

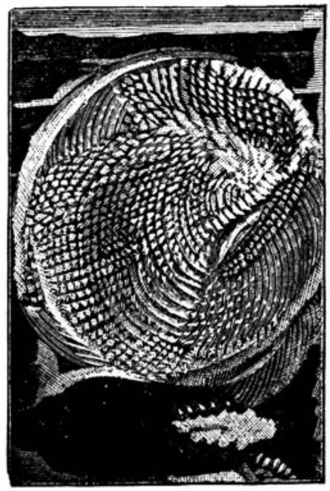


Serpent form.



Pansy form.

FIG. 6. Mrs. Hughes' Voice Figures.



Tree form. **Cross vibration figure.**

FIG. 6 *continued.* **Mrs. Hughes' Voice Figures.**

The results are very wonderful and beautiful, and open up a field for investigation which is most interesting; but so far we have the resultant of many forces, not one of which has been weighed and measured. In a letter Mrs. Hughes, replying to some questions asked in the hope of greater accuracy, says: "The notes producing the figures vary necessarily with the weight of material used and the tension of the membrane, so that any one note may, under different circumstances, produce different figures, and conversely, different notes may, under different circumstances, produce similar figures."

The daisy forms were sung into shape, she says, by extremely low notes very softly sounded, some of them by A in the first space of the bass clef—a wonderful note to be reached by a woman's voice, whose highest note is the B-flat above the treble clef, a compass of over three octaves. Sometimes geometrical forms not given in the illustrations were produced by the highest notes of her voice, while the serpent, fern, and tree forms were made by singing her middle notes with great intensity.

Among some of the first experimenters of hearing with the eyes were Messrs. Lissajous and Duhamel, whose researches in that line are known to all of us. The more recent men who worked in this field are Leon Scott and Dr. Koenig. The first is the inventor of the phonautograph, whose instrument gave a more comprehensive sound-writing. The latter's gave an impressive means for making sound visible by a compound series of flames produced by a single burning jet connected with two or more tubes, and combined with a series of resonators; this has been exceedingly serviceable in the elucidation of those obscure qualities of sounds by which he was enabled to distinguish different voices and instruments, even when the pitch and intensity of the notes were the same.

It is useless to dive into the minute description of these apparatuses, etc., as they may be found in all works on modern physics.

Early last April I had occasion to apply the principles demonstrated by the work of Chladini and Mrs. Hughes to another and a highly important branch of our science. The results of these experiments will probably be made known to the members of this congress by my colleague, the distinguished American physician, Dr. George Engleman, of St. Louis, with whom I was engaged in the task of bridling the faradic current, and accurately measuring and calculating the number of interruptions of the faradic machines used by our electro-therapeutists, and observing the physiological action at the various rates of interruptions. Dr. Engleman, as I understand, will detail the exhaustive research he has made in this direction in the section of electro-therapeutics.

By means of sensitive diaphragms, and a dry powder, like lycopodium, I obtained visual pictures of regular geometric shape, corresponding accurately to the number of breaks in the current. In this instance I employed a hollow cylinder about three inches in diameter and about six inches long, over which I stretched an elastic membrane.

Upon the centre of this membrane a small part of dry lycopodium was dropped, and the cylinder was placed upon the diaphragm of a telephone receiver, the open end next the diaphragm. With each change in the number of interruptions in the faradic current the powder assumed a different geometric form, and we were thus enabled to calculate the number of interruptions with absolute accuracy, as they ranged from 3000 to 50,000, and, as I have since learned, up to 102,000 per minute, some of the figures resembling those of Hughes and Chladini.

When sonorous undulations impinge upon the delicate diaphragm of a phonograph the latter is set in vibration. Its particles move to and fro in some way or other. The complexity of their motion will depend upon that of the air from which it was derived. This brings me to what I have to say of the phonograph itself.

In the annals of modern inventions the phonograph, and its inventor, Thomas A. Edison, will always occupy a foremost place. Years ago, had a scientist had the temerity to proclaim that he could record and reproduce human speech, the sounds of music and other living tones, and preserve them for ages just as the pathologist guards his specimens from the ravages of time, he would have been proclaimed a sorcerer, and perhaps burned at the stake as were the so-called witches in my own country only two centuries ago. How times have changed! I need not rehearse the early trials and tribulations of the illustrious gentleman whose ideas, crystallized in tangible form, are before you. It would simply be a repetition of the fortunes of all the great observers whose work has become historic. He fought against almost insurmountable obstacles and overcame them. Let me briefly recount the story of the discovery of the phonograph.

Edison's early phonograph was founded upon the discovery that if a delicate diaphragm or sounding-board is provided with a sharp point of steel, its vibrations under the sound of the human voice will cause the sharp point or stylus to make a series of impressions or indentations upon a sheet of wax or other analogous material passed beneath it. Such indentations, though microscopic, are sufficiently defined to cause similar vibrations in the diaphragm, if the stylus is again passed over the furrow of indentations, and this reproduction is loud enough to be distinctly heard. Thus, the phonograph, in its primitive form, consists of a little sounding-board carrying on its under surface a needle point, and a sheet of wax so held as just to touch the needle. The sound-waves of the voice cause the sounding-board or diaphragm to vibrate with a rapidity varying with the pitch of the note.

If the wax sheet was made to move slowly along while the sound-waves of music, talking or singing were allowed to impinge upon the sounding-board, the result was found to be a continuous line of minute indentations, corresponding in depth and geometric form with the outline of the original sound-waves.

These lines were continued side by side until the smooth surface of the sheet was covered over with indentations.

This done, on raising the stylus and the diaphragm, and again placing it in the first furrow of indentations, the stylus as it travelled through the series of lines caused the sound-board again to vibrate, sending out an exact repetition of the sounds as they were originally impressed in the wax. Although somewhat changed in pitch, intensity and quality, they were yet of sufficient accuracy to demonstrate the possibility of recording and reproducing living sounds.

Photographs and measurements of these tracings of the sound-waves on the wax cylinders, etc., were recently made by Hermann, of the Königsberg Physiological Institute, and are of great interest in the study of the physics of sound.

The defects of the first phonograph were so great that Edison found it impossible to interest capitalists in perfecting it. At the same time eminent men in Europe were not wanting, who predicted great things for the phonograph of the future. What it accomplished was so wonderful that inventors were tempted to work over it.

But the phonograph of to-day, the novel and remarkable instrument, has passed much of its experimental stage. It is now practically successful in every respect, and must be regarded as instrumental in opening up a new field for scientific research, and making one more application of science to industry. Its aim is to record and reproduce speech ; to make a permanent record of vocal or other sonorous vibrations ; to recreate these vibrations in such a manner that the original vibrations may be again imparted to the air as sounds.

Notwithstanding all that has been said against the properties of the sounds reproduced by the phonograph, there is no doubt but that they are reflected in absolute integrity, but somewhat decreased in volume. In other words, I mean to say that the record of a sound as it is given out, or as we hear it coming from the phonograph, is an exact miniature of the original.

And this is easily explained if we bear in mind the fact that the diaphragm can only record those wave pulses which are caught up and encompassed by the recording trumpet. The others lose themselves in space, yet the pitch and quality remain unchanged.

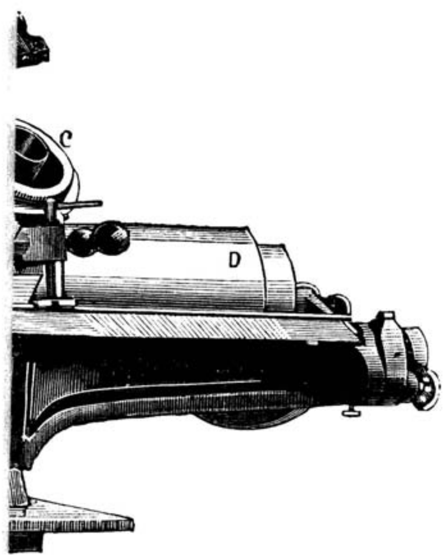


Fig. 7.

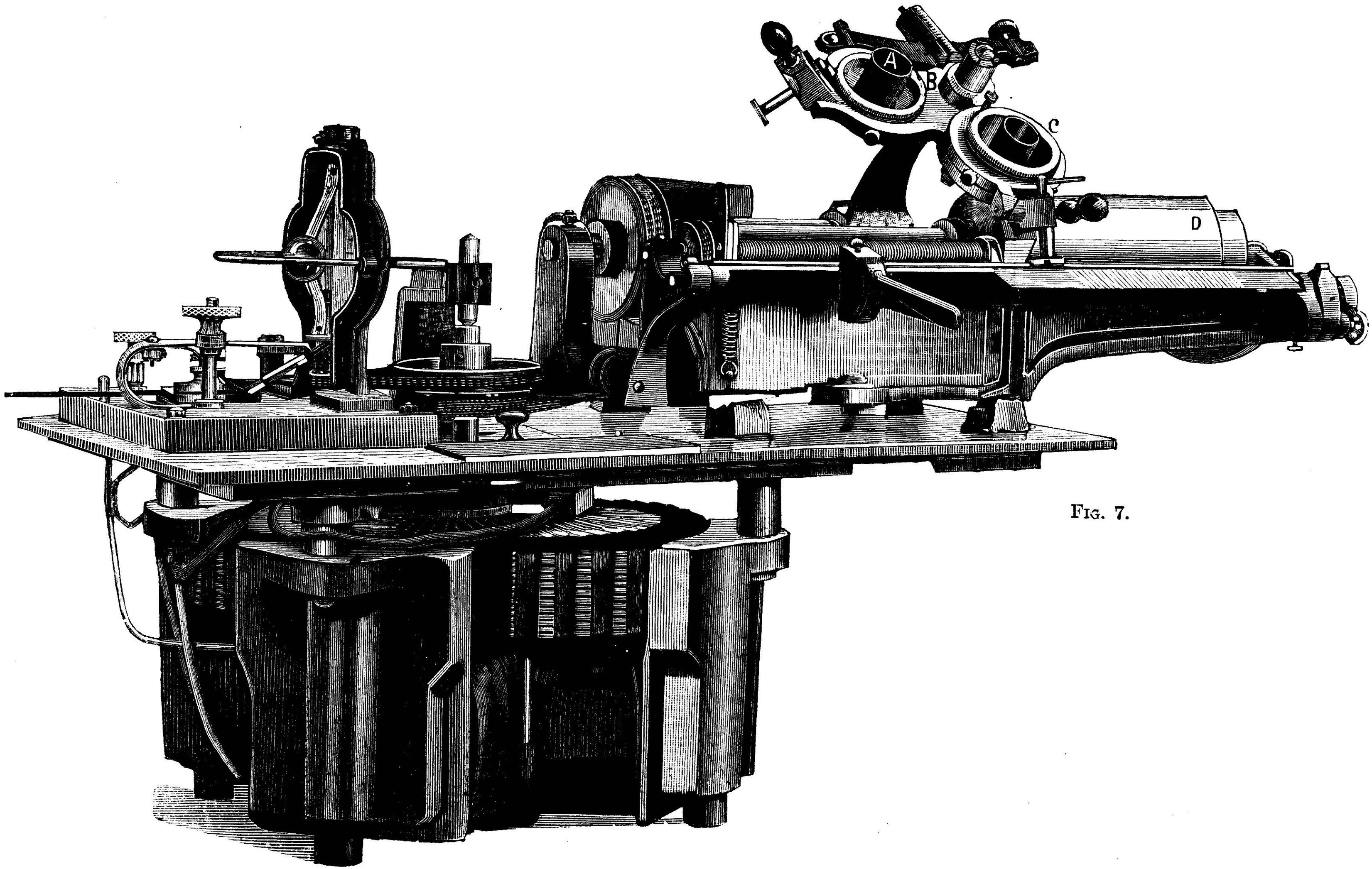


Fig. 7.

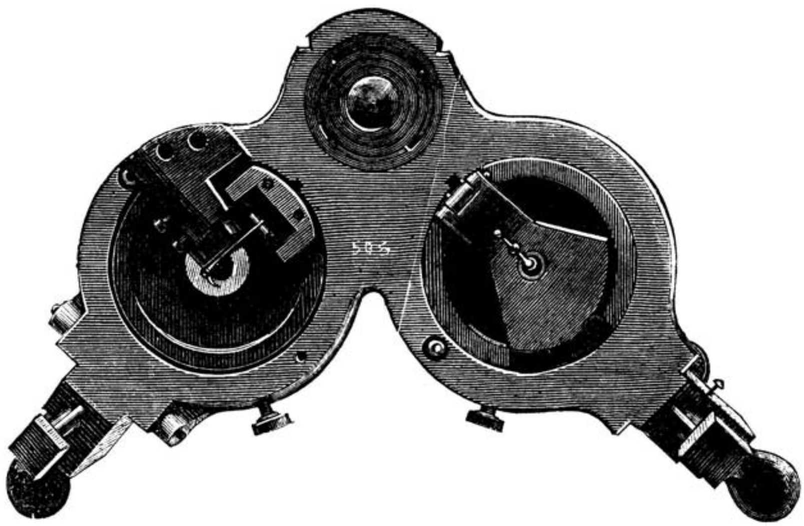


Fig. 8.

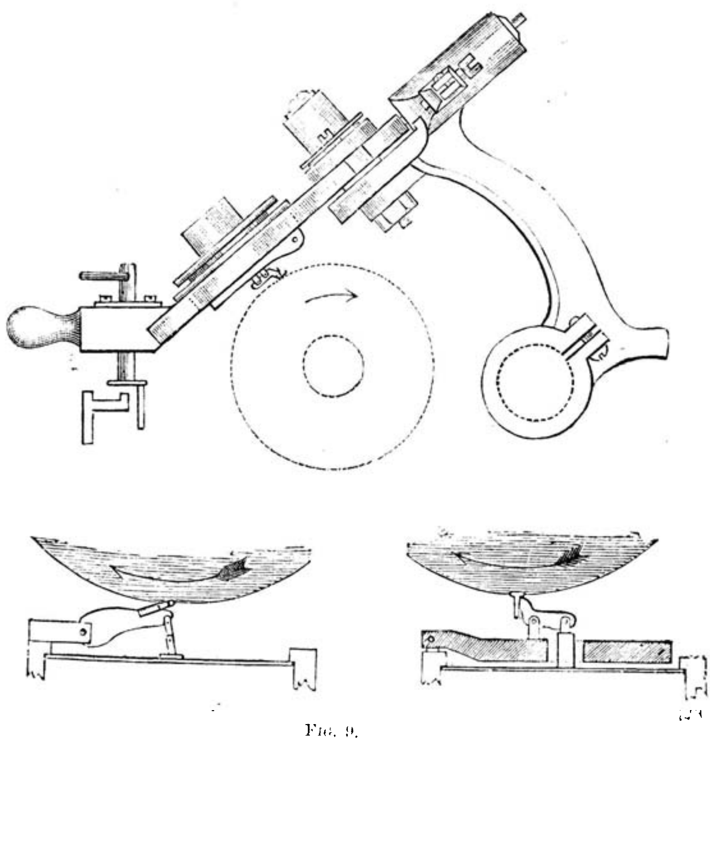


Fig. 9.

The phonograph is really a natural outcome of the telephone, but, unlike any form of telephone, it is mechanical and not electrical in its action.

The following anecdote is told by M. Paskos, Mr. Edison's agent, who presented the first phonograph for exhibition before the academicians of Paris. It was a curious spectacle to witness the expression of the faces of these academicians when M. Paskos caused the wonderful instrument to speak. A murmur of admiration was heard from all parts of the hall, a murmur succeeded by repeated applause. The learned Academy, generally so cold, had never before abandoned itself to such enthusiasm, yet some members of a sceptical turn of mind, instead of examining the physical fact, ascribed it to moral causes, and a report soon ran through the room which seemed to accuse the Academy of having been mystified by a clever ventriloquist. Certainly the spirit of ancient Gaul is still to be found among the French, even in the Academy. One said that the sounds emitted by the instrument were precisely those of a ventriloquist. Another asked if M. Paskos' face and lips, as he termed the instrument, did not resemble the grimaces of a ventriloquist. A third admitted that the phonograph might emit sounds, but believed it was much helped by the manipulator. Finally, the Academy requested M. du Moncel to try the experiment, and, as he was not accustomed to speak into the instrument, it was unsuccessful, to the great joy of the incredulous. Some members of the Academy, however, desirous of ascertaining the real nature of the effects, begged M. Paskos to repeat the experiment before them again under such conditions as they laid down for him. M. Paskos complied with this request, and they were absolutely satisfied with the result. Others still remained incredulous, and it was necessary, before they accepted the fact that speech could be reproduced in so simple a way, to give further demonstration.

The anecdote I have just related cannot be interpreted to the discredit of the Académie des Sciences, since the Academy is bound to preserve the true principles of science intact, and to accept startling facts only after careful examination. Owing to this attitude, all that emanates from the Academy can be received with complete confidence, and we cannot approve too highly of reserve which does not give way to the first impulse of enthusiasm and admiration.

Its present achievements in recording music are wonderful. The phonograph will reproduce any kind of music—singing, the piano, violin, cornet, oboe, etc.—with a beauty of tone and accuracy astonishing to the musician. It is possible also to magnify musical sounds without distorting them, as often happens where speech is concerned. Thus, when a *musicale* is arranged, the phonograph is put up so as to be heard one hundred feet away. Even should the phonograph never reach greater perfection than its present stage, which is hardly possible in this age, it is and will continue to be of the greatest use to musicians, elocutionists, authors, editors and physicians. To this last-named profession, of which I am a member, I have been the means of directing their attention to the practical use of the phonograph in medicine.

For several years past I have devoted considerable time to studying the uses to which it may be put as a recorder of the sounds of disease and organs in health, upon which the physician depends so much for the accuracy of his diagnosis. Already I can say, notwithstanding its many imperfections, the phonograph is made to record many of the characteristic sounds of disease of the respiratory apparatus. For example, when in good voice the vocal expression of singers may be recorded and kept for comparison with the sound produced in case the vocal bands are affected. Time and again have I realized great benefit from the phonograph of tenors, baritones and bassos among my patients, and not only have thus been able to recognize the difference in shade of tone and quality, and thus direct my attention to remedying the defect, but patients have also been able to recognize the deterioration of their voices from the normal standard themselves. This is one of the reasons why I desire to forcibly place before you the possible advantage the phonograph possesses in the perfection of elocution and singing, and to laryngologists in particular.

As a specialist in the department of medicine involving diseases of the throat, nose, and chest, I owe much of what little success I have had to the phonograph. Naturally my practice brings me into direct contact with celebrated people of high vocal culture, many with already fully trained voices, and so from the outset the phonographs which I made a standard of singing, speaking, etc., represented a condition very near the standard of perfection, which both teachers of singing and elocution are striving to attain. The excellent artists whose records I have taken, and treasure very much, were those educated in singing in the various methods of the German, Italian, and French schools, and representing over and over again these phonographs I have been able to detect readily any change or oncoming change in the normal action of the vocal bands. It is astonishing to hear the difference in the methods that the special training of one of these schools gives to singers, to actors and elocutionists ; and more astonishing is it to compare singers of a mixed school with those whose singing is simply a natural exponent of fine vocal organs *plus* the training. The music that is in the well-trained artist rings forth its melody in pure musical sound from out of the indented pulse waves imprinted on the cylinder of wax. By utilizing these for a comparative study with the lesser natural and other voices, I have reached much profit from the study of the different shading of tones and quality possessed by their vocal organs.

Mr. Edison's intention is now nearly fulfilled in his being able to manufacture a quantity of instruments as perfect as the best of the present experimental machines, and to make them so automatic in action and so easily adjusted that everyone who uses a sewing-machine, or typewriter, or a telephone, can use the phonograph. We concede at once that a wonderful field is before it.

The price of phonographs is nominal, and the new wax cylinders upon them cost scarcely more than writing-paper. Once a cylinder has been engraved or has had a message recorded upon it, it can be passed through the phonograph any number of times, apparently without deterioration. I possess some valuable phonograms which have been read, sung, and played thousands of times by the phonograph, and no special indication of wear is observable. Finally, bear in mind that having once obtained a good phonogram it can be multiplied and duplicated at small cost. What a wonderful prospect opens before us! This duplication of phonograms is not known to us as yet, but no doubt experiment will give it to the public, and duplication will be as common as in photography.

Imagine what the phonograph will do for the man on the borders of civilization. It will supply him with books in a far more welcome shape than print, for phonographs will read themselves. The mail will bring him the latest play from London or opera from Vienna. If he cares for political speeches, he can have the *Congressional Record* in the shape of phonograms. It is possible even to imagine that many books and stories may not see print at all; they will go into the hands of their readers or hearers rather as phonograms. But think what a musical critic can do for his public. He can give whole arias from an opera, or entire movements from a symphony, by way of proof or illustration. The very tones of an actor's or singer's voice might be reproduced in the morning notice of last night's important dramatic or musical event.

In music, as already hinted, the value of the phonograph in its present stage is indisputable. Musicians are divided, probably always will be, as to the manner in which certain famous symphonies ought to be conducted. The metronome marks used by Beethoven are, at best, but uncertain guides, while no written directions as to dynamic values, expression, etc., are worth much. The phonograph will make it possible for the musician of the future to know exactly how our composers wished their music given, for it will repeat that music as played to-day with every shade of expression, with all its infinite changes of time. Moreover, the phonograph offers to the composer that long-sought instrument—an automatic recorder of improvization upon the piano or other instrument. In the far-off future, when our descendants wish to compare our simple little Wagner operas with the complex productions of their own times, requiring perhaps a dozen orchestras, playing in half a dozen different keys at once, they will have an accurate phonographic record of our harmonic simplicity. In logic we say that where a premise is established the deduction is evident. So what can be done in one instance can be done in all other similar instances. Those persons who smile incredulously when it is said that the perfected phonograph will do away with letter-writing, will read to us, sing to us, teach us foreign languages with their proper accents, teach us different methods of singing, elocution, give us books, music, plays, speeches, at almost no cost—become a constant source of instruction and amusement—must have forgotten the ridicule they heaped upon the rumour that an American inventor proposed to talk from New York to Chicago. The achievements of the phonograph will be no less wonderful than those of the telephone.

Marvellous as this instrument is, it is still quite new, and it is impossible to say to what degree of perfection it may yet be carried. It has already opened the door to an entirely new and untried field in the realm of sound. It is a new instrument in the hands of science, wherewith to search out laws in Nature still unknown. Already it has suggested many valuable uses. Undoubtedly it is the most remarkable invention of this century.

If time permitted I should talk more in detail regarding the use of the phonograph as a teacher of singing, elocution, etc., but from the demonstration of phonograms one must be satisfied of the truth and of the value of the phonograph.

I am still in hopes, notwithstanding the fact that at present the microphone is very unsatisfactory in its workings in many respects, to be able to record the sounds of the heart and the respiratory tract both in health and disease. The value of such record, I need not tell you, would go a great way towards the practical education of our medical students in the groundwork of physical diagnosis.

I have already made several records of pathognomonic sounds, but my work, owing to the pressure of time and the responsibilities of a large practice, is still so incomplete that I hesitate to present it to such an august body of distinguished medical men.

At the next congress I may be able to show you the cabinet of records, which will demonstrate aurally these special sounds of disease of the deeper air-passages and heart, just as we hear them in the hospital ward and recognize them from the descriptions in our books of lessened or intensified pitch and changed quality.

In my own specialty the phonograph has been of much service. In all diseases affecting the vocal bands we are apt to have a change in the character of the vocal sounds. These sounds in not a few instances are pathognomonic, but as we go on in our experience and observation they will become extensive enough to have an accepted classification, without which phonographic records would signify little. Nevertheless, for the expert, I can say safely that to him the phonograph must prove of great value in this branch. With a complete microphone, as I hope and feel it can be perfected, both the classification and recording of the more inaudible sounds will be made so that all of us, even the general practitioner, will be able to make his diagnosis of these internal pathogonomic sounds of heart and lungs more positive.

As for the more audible sounds, like coughs, nasal obstructions, laryngeal growths, laryngeal obstructions — like stenosis, hoarseness, defection in speech, and many of an allied kind—the phonograph is, beyond a doubt, the instrument for recording them to perfection.

To my American colleagues and to those of other countries who may chance to come to my city I extend a cordial invitation to visit my workshop, which, unfortunately, I could not transport, and see the work as it has progressed up to this time.

I shall ever be ready to demonstrate and show you how far I have succeeded, and so give you the ocular proof of what I have laid claim to in this paper.