

convenient attachments. Fig. 4 is a front elevation of the electrostatic multiplier: A is the vulcanite disk on an axis carried by insulating standards. The axis has upon it a pulley which receives a driving cord from a wheel rotated by hand; T, T, are tin foil strips fixed upon the face of the disk, and S, S, are studs in metallic connection with the strips; T, C, C, are the rods to which the metallic collecting combs are attached, and D, D, show the position of the inductors at the back; E, E, are the combs for charging the inductors; they also are insulated, and they are connected by the covered wires, E', with the inductors. S, S, are the springs or wire brushes for making contact with the studs. The contact is made when a finger key (not shown) is depressed. The key acts through silken cords which draw the brushes or springs forward; when the key is liberated they move back out of contact. The magneto-electric machines and the electrostatic multiplier are employed in combination for the production of the electric light. Mr. Varley causes an electric arc to be formed between carbon points by the magneto-electric machine, as is well understood, and in order to render the light constant he applies the electrostatic multiplier, by placing its conductors near the carbon holders, so that a stream of sparks may pass to them constantly so long as the light is being maintained. The high tension electricity which in this manner is caused to pass between the carbon points effectually maintains the magneto-electric discharge.—*English Mechanic*.

THE PHONOGRAPH.

Lecture by Professor J. W. S. ARNOLD.

IN response to an invitation from several prominent citizens, Professor J. W. S. Arnold, of the University of the City of New York, lately delivered a lecture at Chickering Hall upon Mr. Edison's recent invention, the talking machine, known as the phonograph. The lecture, says the *N. Y. Tribune*, from which we take our report, was in great part an exposition of the theory of acoustics; the performance of the phonograph was shown to be in strict accordance with that theory. All the experiments shown were quite successful, the Lissajous curves, shown by the electric light, being especially varied and brilliant in their

mitted in a direct line, and we have very much the same phenomena in sound as we have in waves of water; that is to say, when a stone is thrown into the water you will notice that from the point where the stone impinges upon the water a series of waves starts, spherical in form, and are sent in all directions outward. In order to appreciate the manner in which these waves pass in the atmosphere (because it is necessary we should have some medium to propagate or transmit the waves) we will make use in a moment of a little mechanical contrivance or diagram, which gives us an idea of the propagation of sound. The waves of sound, as they appear in the atmosphere, consist of rarefactions and condensations of the air. Sound can be produced by motion or vibrations in solid bodies as well as in the atmosphere, and we shall see as we study the subject that the ear can appreciate the sensation of sound simply by the vibrations of solid bodies, provided the solid bodies are able to transmit the vibrations directly to the portion of the ear which receives the impressions. But for the general condition of sound we must have air; we must have some substance to carry the waves from one part to the other, and in general, every body, then, that produces a sound on our earth, unless it be the direct transmission of the body, stirs up these waves, and they are carried through the air.

THE MOTION OF SOUND WAVES.

Here we have [illustrating on the screen] what would represent the waves of sound—these light points—and, as I told you, the motion of the particles, which we will study more definitely in a moment, is backward and forward. Now, when a sound is produced, the air is thrown into just the vibrations that we see here. Each one of those waves makes its excursion up and down in all directions. These waves have actually been seen. A physicist of the name of Toepler was enabled, by causing a sound from the electrical discharge, to see the waves of sound, and he found that these waves could be refracted and reflected, and that they obeyed all of the laws which were found in light. In addition to this he found that those waves were spherical, and we have an idea of the propagation of the sound of these waves as spheres overlapping each other, each made up of little particles of air, and these particles vibrating backward and forward. Now we will try an experiment. Here we

can be heard near by, and pretty soon a tone will break forth. [Here the lecturer illustrated his meaning by the apparatus referred to, and was applauded for the success of his experiment.]

SOUND PRODUCED IN TUBES.

The mechanism of the production of sound by this other little instrument is first the generation of hydrogen by decomposing water with the aid of acid. There is a very fine point, from which the hydrogen burns, introduced into a glass tube. The air passing up through the tube becomes heated and is thrown into vibration by the flame, the air being thrown up and down. If we have a very large tube we shall have a very deep tone, and shriller in proportion as the size of the tube diminishes. The vibrations are not so rapid in the large as in the smaller tubes, in the latter case the waves being smaller and consequently lighter in tone. The ordinary effect produced in the organ pipes of course we understand. Here we have simply the puffs of air which pass through tubes of various kinds and we get the various tones, as we shall see. [Illustrating the point by sounding certain stops on the organ.] Here we have the air thrown into vibration simply because the bellows, which is on the inside of the organ, drives the air through the opening into the pipes, and into certain pipes which are known as the diapason pipes, and shocks the air and causes the column to vibrate in the interior of the tube. You see in this tube that I have here, and hold over the flame, the air is thrown into vibrations on account of the heat of the burning hydrogen. [Illustrating it. Applause.] There is another method of producing almost the same general effects which almost every one has heard, and that is the vibration of plates or slips of metal which are met with in the little toy called the metallophone.

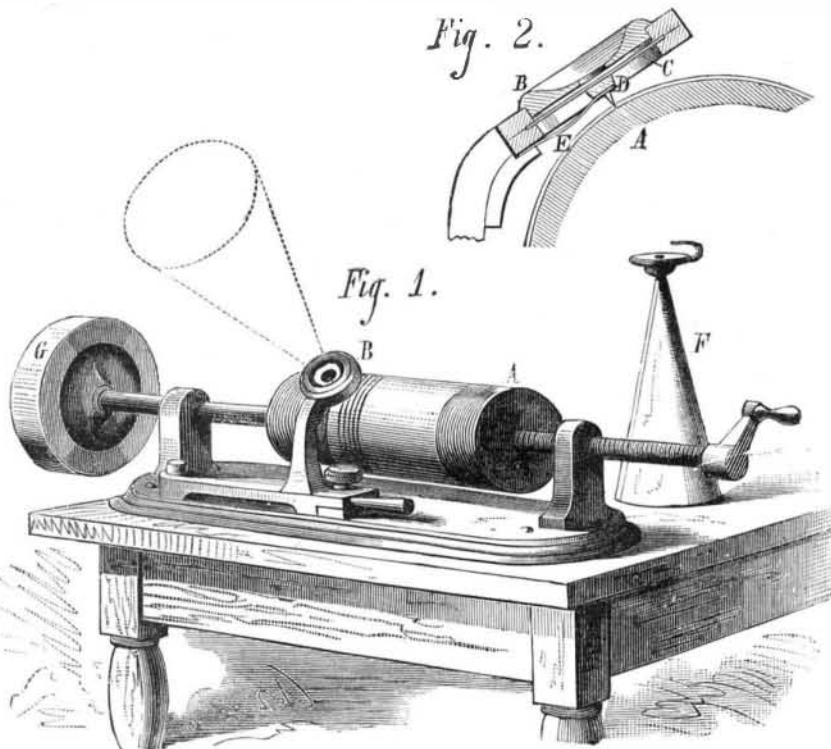
Now, then, about the manner of measuring the wavelength of sound. How do we know how long a wave-length is? In measuring it we must have some standard of measurement. First, we must know exactly how rapidly sound travels; secondly, how rapidly the body vibrates. Here is a tuning-fork which vibrates exactly 512 times in one second, and at about the temperature of the atmosphere of this room the sound will travel about 1,120 feet. If I sound this fork we will have wave-lengths which measure exactly two feet two inches, and the manner in which we arrive at that conclusion is by dividing the rate at which sound travels by the number of vibrations in one second. There are instruments, of course, by which we can measure very accurately the number of vibrations any body produces. Among other instruments we have the siren, which I have shown you; and if we produce a tone by this fork, which corresponds exactly in pitch to the tone produced in the siren, we can read off in the index to the siren the number of vibrations produced in a second.

MUSIC COMPARED WITH NOISE.

Now, we come to the question of the difference between noises and musical tones. A noise is the result, of course, of vibrations, but the vibrations are irregular. They do not follow each other at regular intervals, whereas in every musical tone we have the vibrations following each other at perfectly regular rates. The result is that the ear is pleased with a succession of regular intervals of vibration and displeased with those which are irregular. A tone and a noise, then, differ simply in this respect, and, as I have already told you, the pitch or the height of the note depends upon the number of vibrations produced in a given time. If I start the siren once more and allow it to run for a certain length of time, you will notice that as the speed increases the tone becomes higher and higher, until finally we can get quite a shrill tone from what was at first quite a low tone. [The Professor at this point performed the experiment satisfactorily amid applause.] Now, what is the difference between the timbre, or quality, of the note produced by the siren, that produced by the violin, by a canon, and finally by the human voice? What is the mechanism of production? It can be answered in this way: Every time a musical sound is produced, such as we would have in the plucking of a string or by the sounding of a pipe, we hear not only one sound, but a great many sounds, and these other sounds are known as over-tones or harmonics. There is the fundamental tone, which is the principal one, and which we can distinguish by sounding the tuning-fork carefully—thus. Now, see if I can produce another tone from the tuning-fork. [Doing so.] There is a different one, and here [producing still another tone] is still a different tone. Both of these are sounded when the fundamental tone is produced, but they are not nearly so loud as when we make them especially. These over-tones, then, give the peculiar quality to the various kinds of instruments and to the human voice, and we find these over-tones are produced in the same mathematical ratio. For example, if we take the note "C" as the starting point, we find its first over-tone is its octave, which has twice as many vibrations as the original note. Then the next over-tone or harmonic is the fifth above this octave. Then we have "C," and then "E flat," and so on. We have then a succession of tones which overlap or are mixed with the fundamental tone, and these tones have the ratio of vibration of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. That is to say, the first over-tone or octave of the fundamental tone has twice as many as the second, the second three times as many, the third four times as many, and so on. Now, it depends upon the number and loudness of these as they mix with the fundamental note whether there is produced either the sound of the violin, or that of the trumpet, or of the flute. If we take, for example, on the organ a hautboy or a clarinet stop, we have a peculiar tone. Now we will take the trumpet stop, and now the piccolo. See how different they are. The human voice has its peculiarities in the same way, and, as we see, the vowel sound must be analyzed very carefully, so that the number of over-tones and the peculiar pitch of them are all recognized, and in this manner we can appreciate the various qualities of sound or its timbre.

THE MECHANISM OF HEARING.

Now let us consider some of the points in connection with the reception of sound by the ear. The ear is a very curious piece of apparatus—the most complicated probably of any that exists in the body. The ear is capable of appreciating about eleven octaves of sound. The eye is capable of appreciating but one octave in color, so that the ear has a far greater range of appreciation than the eye. There are certain peculiarities about the ear by which we are enabled to appreciate these sounds; and we must not forget that our appreciation of sound—the subjective condition of sound—is, as we already see, very different from the actual condition of things or of matter which produces the sound. Sound consists of vibrations, and the ear takes these vibra-



THE PHONOGRAPH.

changes of combination. Professor Arnold introduced a singing telephone, which afforded much amusement; it reproduced, in the musical sounds of a guitar, the notes of songs sung in another room by his assistant, Dr. Miller. An exceedingly interesting experiment showed on the screen the vibrations which are caused by the voice in enunciating different syllables; the figures thus obtained flashed only for an instant into view, but they were evidently geometrical forms. The phonograph machine repeated the words spoken to it loudly and clearly, so that it was heard in every part of the hall and gallery. The tone is slightly metallic and has a strained effect, very much like the voice of a ventriloquist; it is evidently in need of further improvement in quality and distinctness.

THE LECTURE.

I suppose that most of those who have come on this occasion have gathered themselves here for the simple purpose of hearing the celebrated machine of Mr. Edison talk. After a while we shall see, I think, that the speaking phonograph, or talking machine, is probably the greatest invention in acoustics or the greatest acoustical phenomenon of this century. In order, however, to appreciate the mechanism by means of which the human voice is reproduced in such an extraordinary manner, we must first take a rapid glance at the physics and physiology of hearing.

The physics and physiology of hearing—like that of sight—must be studied in two ways: first of all, the actual conditions which are necessary to produce sound, and then the manner in which sound is appreciated by the individual; in other words, we must become fully acquainted with the objective and subjective phenomena, and then bring these two together. In the first place, both light and sound are phases of motion. Light consists, as we know, of undulations or waves, and sound consists of undulations or waves also; but the undulations or waves of light differ in the manner in which they travel, in which they make their journeyings. The light waves are propagated from a luminous body, and take their direction in straight lines from the luminous body, but the direction or motion of the particles of luminous ether are at right angles to the direction of the propagation. On the other hand, sound waves are trans-

have a slit-like formation on the screen, and in this we will be enabled to see the vibration of the particles. Each leaves its position only for a short distance. The intensity or the loudness of the sound depends upon the distances each of these particles moves. By the generation of the sound it moves from the position it has at rest to a certain position and back again in an opposite direction, as you see represented on the screen. So far, then, for the generality of the sound waves. There are a great many other points which we have to hurry over to-night in order to get a general and, unfortunately, somewhat superficial idea of the whole subject.

Now, take into consideration the manner in which these waves can be thrown into action. Thunder is produced, as we know, by an electrical discharge in the atmosphere. The electricity being driven through the atmosphere with tremendous rapidity, causes the air to be thrown into vibrations, which cause the sound we recognize as thunder. The electricity is the lightning, the sound is the thunder. If we agitate any body which is solid, we then produce a certain number of vibrations in the atmosphere, and these correspond to the vibrations of the body. If we cause a column of air to vibrate in a tube, we produce a musical tone, which is simply due to vibrations of the air in the confined space of the tube. A tuning-fork in sounding is simply a mechanical disturbance of the air, and, when in vibration, it produces what is known as a musical tone. We shall see that the musical tone depends upon certain peculiar conditions of vibration, and we shall see also that noises differ from musical tones simply as they can be referred to other peculiarities of vibration. In sounding a fork we have a pleasant tone to the ear. This is a mechanical vibration of the air by the vibration of an elastic body, viz., the steel of which the fork is composed. In a moment we will try another experiment where we throw into vibration a column of air confined in a tube. We can also produce vibrations by a succession of puffs. Here is a little instrument called a "siren." It has a disk which is perforated, and an air-chamber. There is now compressed air in the cylinder, and, as it is turned on, the puffs of air escape, causing it to come opposite the opening in this air-chamber very rapidly and evenly, and there is a succession of puffs which

tions by a peculiar sympathetic process, which we will understand later on, and the brain then has generated in it a peculiar condition which we understand as sound. If we irritate the nerves which go to the ear we feel no pain, but have a rumbling sound. If the irritation be even, so that the vibrations or taps of the nerve follow each other at regular rotations and equal intervals, music is the result; if irregular, noise is the result; but the acoustic nerve can transmit no other sensation to the brain but that of sound. In like manner the optic nerve can transmit no other sensation but that of sight. If it be wounded, a flash of light follows; if the acoustic nerve be touched, a sound follows. And you know there are some nerve diseases, the result of disturbances occurring in the ear, where there is a continuous sound or humming kept up, and this gives us an idea of the peculiarities of these nerves. We can appreciate, then, the subjective conditions, and we wish to study now the manner in which the sound is carried to the ear. There are two distinct sets of apparatus in the ear, one for the reception of the sound and transmission of it externally, and then the internal arrangement by means of which the sound is received and transmitted to the brain.

CONSTRUCTION OF THE EAR.

We have on the external portion of the head what is called, ordinarily, the ear. Now, this is supposed, in a human being, to be of little account so far as collecting sound is concerned, because from records we have of practices in savage countries, where the ear has been cut off, we have found that the hearing is scarcely impaired; but in the lower animals, undoubtedly, by putting the ear in various positions, they can collect the sound, and cause it to enter the interior portion of the ear. In the interior of the ear, as we pass in from this exterior portion, there is a little piece of membranous tissue, which is known as the drumhead or membrana tympani, and the waves of sound impinging against this cause it to vibrate, and the vibrations are transmitted inward, and they set in vibration, by means of a peculiar chain of little bones, another membrane, and this covers a cavity filled with fluid, and within this cavity are the filaments of the acoustic nerves. These filaments are attached to little strings, and by sympathetic vibrations these pick up the tones—not only the fundamental tones, but all the overtones which we have seen to exist in every musical sound—and there vibrate according to the intensity of the original tone produced.

This particular part of the mechanism of the ear is inclosed in a bony box, and the complicated arrangement which is here met with is enough for a life-long study. The general conditions which I have mentioned are that we have these carefully protected, that we have waves produced in a fluid, and that the undulations or waves in this fluid are the direct means by which the terminations of the acoustic nerves are set in motion, and these produce a sensation of sound. Now, a question would naturally arise as to whether or not these little membranes do not possess a fundamental tone. If this membrane were simply free, if it was simply attached around an opening with nothing else in connection with it, we would hear constantly, when a fundamental tone was sounded, this ringing in our ears; but nature has provided a peculiar arrangement which we find holds good in physics, and which you will see to be beautifully represented in the talking-machine here, namely, that it has damped, that it has checked this fundamental tone. About the center there is a little bone which is attached to this membrane, and this is in connection with several others and acts as a damper or weight. Now, if we apply this to the central portion of the membrane, it will not then respond to the fundamental tone; but by forced vibrations other tones will be transmitted, and we will not have a confusion of the fundamental tone continually drummed in our ears. And this membrane, instead of being flat, is stretched backward, and this kills, more than anything else, the fundamental tone. The result is that we have a perfect arrangement for transmitting sound.

VIBRATIONS OF SPEECH SHOWN ON THE SCREEN.

Here is a little piece of India-rubber with a little mirror in the center, and when certain tones are spoken in this tube, which is the carrying portion of the ear, we shall see that this is thrown into vibration. I will generate here an intense beam of light from the electric lamp. Now you see the light upon the screen, and if we sing a note in the tube, you will see the membrane is thrown into vibration. If those vibrations could be photographed we could analyze the number and character of the harmonics. Now we will say the words "one," "two," "three" [singing the action to the words]; and now when we sound the vowel "u" we see also the peculiar effect produced on the screen. [Applause.] This then is one method of analysis of tone.

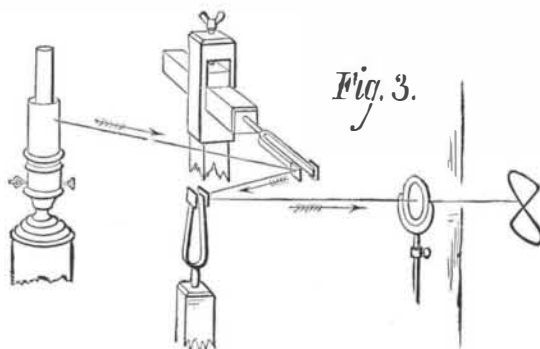
Now then let us follow out completely the mechanism of the production of the sensation of sound. The wave is generated, and it throws into agitation the membrana tympani, and that membrane carries it into the interior of the ear by means of a chain of bones. One of these bones comes in contact with another membrane situated deeper in, which closes over a cavity containing fluid. This fluid receives the wave impression, and as these are received the undulations are transmitted deeper into the structure of the ear, and the structures here take up the waves or vibrations and throw into agitation certain little cords, of which there are about 3,000 in the ear, and these little cords vibrate in unison or sympathy to the peculiar tone that has been produced by the sound. As they vibrate they agitate the internal filaments of the acoustic nerve, and thus the sound is transmitted to the brain. This curious part of the ear is very complicated in structure, but we shall be enabled in a moment to see the principal part where the sound is supposed to be received. [Illustrating on the screen.] There is the drum membrane of the ear, seen from its exterior surface. It is a little membrane attached to a bony structure and projecting out toward the center, where it is attached to the hammer bone. We can hear a tone which consists of sixteen vibrations in a second; we can hear a tone which consists of about 40,000 vibrations; but when we get below about forty vibrations there is produced what would be called an unpleasant sensation, which is more a noise than a musical tone. On the other hand, when we get above 4,000 vibrations there is a shrill scream. Music then consists of from 40 to 4,000, but the complete compass of the ear is from about 16 to 40,000. These little strings arranged in the ear are capable then of giving us this long variation, and not only this, but an appreciation of the $\frac{1}{4}$ part of an interval between two tones. Take for example what is called a full tone or a whole tone [touching a key on the organ]. Now the next interval of a whole tone is this [striking it]; and a half tone is very different, you see. The ear, however, can detect the difference between the $\frac{1}{4}$ part of one of these whole tones or $\frac{1}{8}$ of a half tone. In the ear these fibers are

so tuned that the fiber which is next in order just vibrates with this difference of intensity. Now, in order to appreciate the manner in which these fibers vibrate—how it is that the sound is conducted from the membrane into the ear—we will make a little experiment.

PROOF THAT VIBRATIONS ARE TRANSMITTED.

I have here a tuning-fork and in front of the lantern is another. These are tuned so that the tones are in perfect unison. Near the top of one of the tuning-forks is a little ball suspended by a filament. Now if we project a shadow of this latter one upon the screen and sound the other tuning-fork—which is some fifteen feet distant—you will be enabled to see that the vibrations of that tuning-fork [the one shown on the screen] will throw the ball away from it. There is the physiology of it. [Illustrating it by the actual experiment, in which the screen showed the ball violently agitated, and repelled from the distant fork.] Now those little strings which are tuned in unison must vibrate when a sound is produced of exactly the same fundamental note.

There is just one more point before we go to the mechanism of the voice, and that is the combination of sounds pleasant to the ear and those unpleasant. I sound, for example, two tuning-forks. [Doing so.] Those tones are pleasant, but if we have the intervals too close [sounding the forks again] there is something which we don't like to hear; and we can illustrate that very readily again by taking a low tone where the vibrations are deep. [Striking low notes on the organ.] Those, you see, are not pleasant, and if you listen you will see there is an interval of silence which occurs when those two are sounded. Now, let us explain. [Turning to the blackboard.] Here we have from this point on the blackboard to this point a wave of sound. Suppose that this wave starts at the same time [drawing another] as that one does, but moves a little faster, it will make an excursion to this point [illustrating it], and then one wave will be going in one direction and the other wave will be going in an opposite direction, and when they are just in an opposite position they neutralize each other and no sound results. However, as they pass along they get into the same phase, as it is called, and the apices of each meet and then we have an intensification of the tone; and we find by bringing these two tones out of unison and sounding them together, we have a beating motion which is unpleasant to the ear, and this is known as dissonance or discord. Where there is no chance, however, for one wave to go over another, we have the sound called consonance or accord. There is no reason why this should be, except that it is a physiological fact. We can study the manner in which various combinations of tone are produced by combining the reflected images of the vibrations of the forks with each other.



THE LISSAJOUS CURVES.

I will show you the experiments of Lissajous, where we have tuning-forks tuned to each other at different intervals, and they are each caused to vibrate so as to produce reflected images on screens. There are certain laws which these follow which can be worked out by mathematics, so that we can understand the relation of vibrations to each other. The vibrations caused by Lissajous' forks are simply conditions of the pendulum vibrations. It will simply show you the manner in which the vibrations appear when one fork is vibrated perpendicularly to the other. I will throw a beam of light from the lantern so that it strikes a mirror. The beam of light is reflected from the mirror of the first fork, which is vertical, to the second, which is horizontal. The forks are kept in perfectly even vibrations by means of electro-magnets. The forks are slightly out of tune so that we can see the manner in which these waves are following each other all the time when the intervals are not exactly tuned, and you will see a perfect figure which represents the interval, and there will be backward and forward phases in this figure known as the waves. When their crests agree with each other we have a perfect figure. When there is any difference the figure changes backward and forward in the negative and positive phase, as it is termed. Here [referring to the screen] we have a circle which is the perfect phase. Now you see that circle turned so as to form an ellipse, then the lines cross and go back again to a circle. It will take a moment or two to put in another fork, and the next one will be an octave with just double the number of vibrations. These are also slightly out of tune so as to show all the phases of this figure. Now the figure produced by the octave is very different from the other. Here we have an octave which resolves itself on the screen into the figure 8. We will try another combination, where the figure will be changed. We will take one that is somewhat complicated—that is, one fourth above the fundamental note. The nearer the notes are the more complicated is the figure. There are other intervals which can be shown, but that is not necessary.

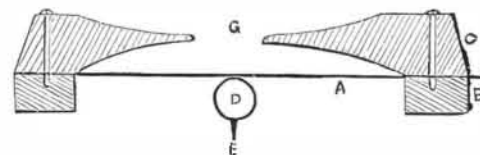
RELATION OF VOICE TO SOUND.

Voice is produced by vibrations of what are known as the vocal cords. The vocal cords are little membranes situated in the throat, which, by the action of certain muscles, can become tense and lax, and the air which is driven out by a respiratory effort throws these little cords into vibrations, and they transmit the vibrations to the column of air. Now we have the cavity of the mouth, which contains the teeth and the tongue, the hard palate and the soft palate, and the roof of the mouth, and when we enunciate certain words we produce the vowel sounds and the consonants. We make use of the lips in producing what are called the labials. We use certain powers back in the throat for producing the gutturals, and the tongue for producing what are called the lingual sounds. All of these combinations of sounds are the result of changed forms of the oral cavity. The vibrations are set up by throwing into agitation the vocal cords, which are struck on the same principle as the reed pipe in the melodeon, the reed pipe being simply a tongue of metal over

an aperture, and this throws into agitation a column of air contained in an apartment where the reed is situated. So, then, we can have in the mechanism of the voice the vowel sounds and the consonants and the guttural tones, and all of those which are not pure musical tones which are generated in ordinary conversation. By combining the two we have spoken language. If we cause the voice to throw a membrane into agitation which has any electrical connection with a battery, and if we have magnets which will represent the agitation, we will then produce what is called the singing telephone. Now I have a conversational and a singing telephone upon the table, and I shall ask my assistant, Dr. Miller, to tell me when he is ready, and when he sings in the mouth-piece of the telephone it will be heard here, not the words but the quality, which is represented by this guitar body. In the place where the strings are fastened on the guitar is a piece of wood glued firmly to the top of the guitar. Secure upon that is a soft iron plate, and the ends of this magnet are brought opposite this iron plate. Upon the other end, where Dr. Miller is, there is a membrane made of paper, and in the center is a little piece of metal, which is in the center of the circuit, and the pin which makes or breaks the circuit as the vibrations of his voice are brought against the membrane. [The tuning by Dr. Miller were distinctly heard, but with the quality of guitar music.]

By a combination of pipes in this organ [the large organ in the hall] there is what is called the *vox humana*, which gives a very curious effect [illustrating it on the organ]. It is simply the reed pipe, as it is called, which is shortened, according to the description given to me by one of the gentlemen who manufactured the organ. It is boxed up or confined and carried off to a great distance from the organ, and opens, in this case, in the ventilator.

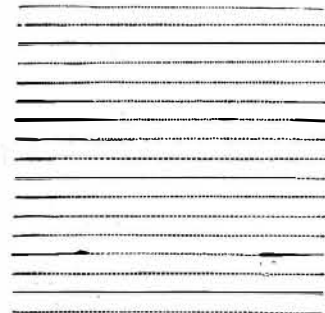
Now, if you are perfectly quiet, we will see if it is possible to have this speaking machine of Mr. Edison's recite to you something about Mary and a little lamb. [Laughter.] Now this is nothing but a mechanical contrivance. Professor A. M. Mayer has recently written an elaborate description of it, and he speaks of a celebrated talking machine constructed by Professor Faber, of Vienna. This consisted of a machine that represented all the parts of the vocal apparatus. There was a reed to take the part of the vocal cords, an oral cavity which could have its shape changed by depressing keys on a key-board, a rubber tongue and lips to make the consonants, and a little windmill rolling in the throat to make the R's. This was simply the reproduction of nature as far as possible. But there had to be a special combination in order to produce each of the different sounds. When certain sounds had to be produced, lips had to be changed in order to produce them. In the machine, however, which has been invented by Mr. Edison there is simply a piece of ferrotype plate, about 0.01 of an inch thick and $1\frac{1}{2}$ inch in diameter, and it is damped and clamped between two rings. There are pieces of India-rubber pressed in between these two rings so that the ferrotype cannot sound its fundamental note, but will only respond to what are called forced vibrations. Now, upon the under surface of this plate there is a little steel point, which is attached to the plate by means of a rubber ring intervening between the plate and the steel point. [Here the Professor drew a section of it on the blackboard.]



PHONOGRAPH MOUTHPIECE—IN SECTION.

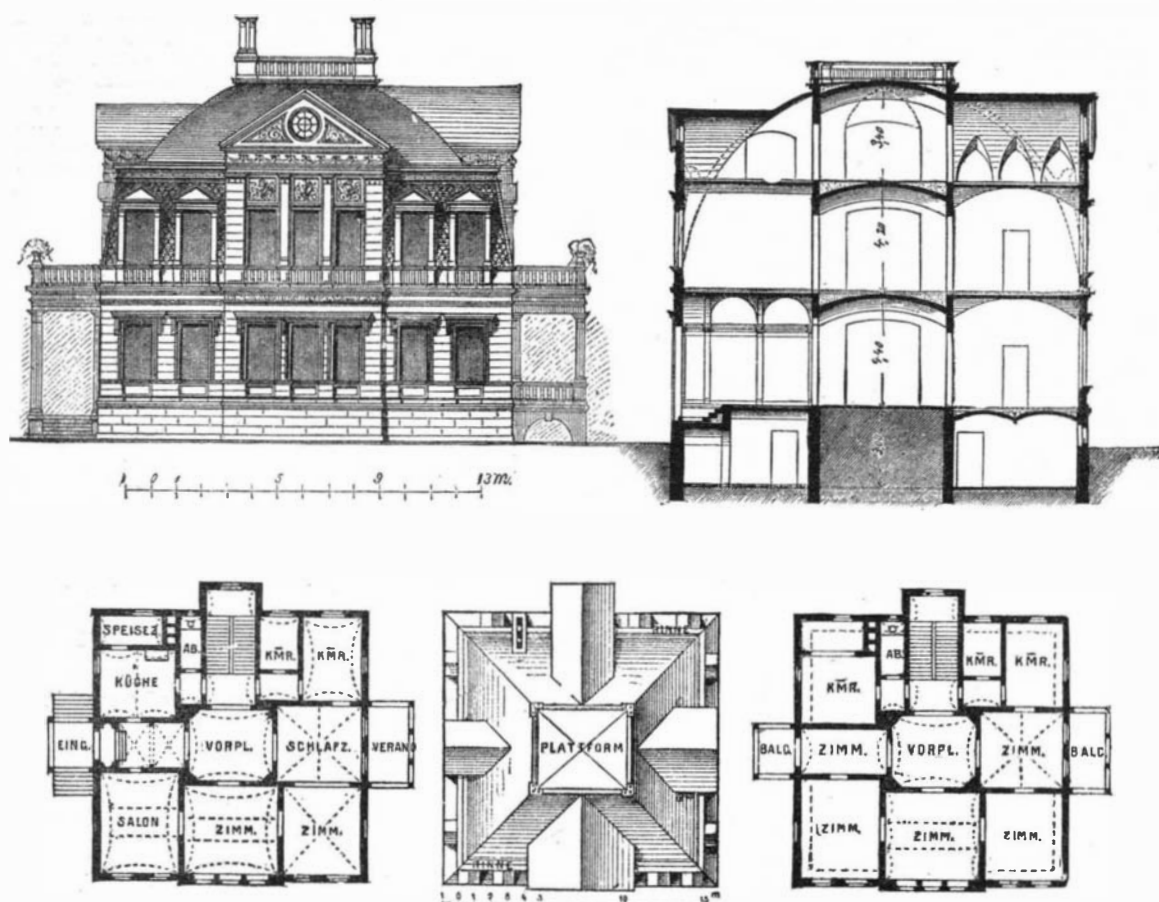
The above represents a sectional view of the mouthpiece of the speaking phonograph. A is a thin plate of iron, circular in form, about $2\frac{1}{2}$ inches in diameter. This plate is placed between two brass rings, B, C, the latter being hollowed out above and below, so as to touch the iron plate at the edges only, thus leaving the latter to vibrate freely at its center. To this plate is attached, on the under surface, a small piece of rubber, D, and a fine steel point, E, is affixed to the rubber. It will be readily understood from the above that when the lips are placed at the opening, G, in the ring, C, the vibrations of sound produced in speaking will be communicated to the iron plate, A, thus causing the steel point to be depressed and raised, these motions succeeding each other with a rapidity depending upon the rate of vibrations in a given tone of the voice.

The only portion of that plate that can vibrate is about half an inch across. That is the portion which we have here [indicating it]. Underneath the plate there is a piece of rubber ring cemented to the plate. The cylinder which we turn by hand is grooved into a spiral thread, and this little point impinges in the depression so that it does not touch the plate. As we turn it around, we would trace the spiral on the whole of this surface, which is covered over with tin-foil, and there is a screw-thread cut in the axle, so that when we turn this machine it simply describes a spiral on the surface of the cylinder. All that is necessary to do to make the machine talk is to put on a piece of tin-foil.



SPEECH TRANSCRIBED ON TIN-FOIL.

The needle simply is to make a very light groove, and then you talk against this plate or through a paper cone of this construction [exhibiting it]. Now we have simply to reverse the motion and turn the crank again in the same way as it was at first, and we have repeated what was said. The loudness is not very great yet, as the invention is not yet perfected. When the plate is thrown into vibration the point dips down and makes indentations in this tin-foil. Now those indentations correspond to the peculiar form of wave-sounds which have been uttered by the mouth. The consequence is that the plate is made to vibrate in this direction, as you see.



A CONCRETE DWELLING HOUSE.

an attempt has been made to render them essentially architectural. The entire theater is being decorated, and will be ready for dedication in a short time. The cost of the two buildings, exclusive of the land, will be \$125,000.—*Am. Architect and Build. News.*

A CONCRETE DWELLING HOUSE.

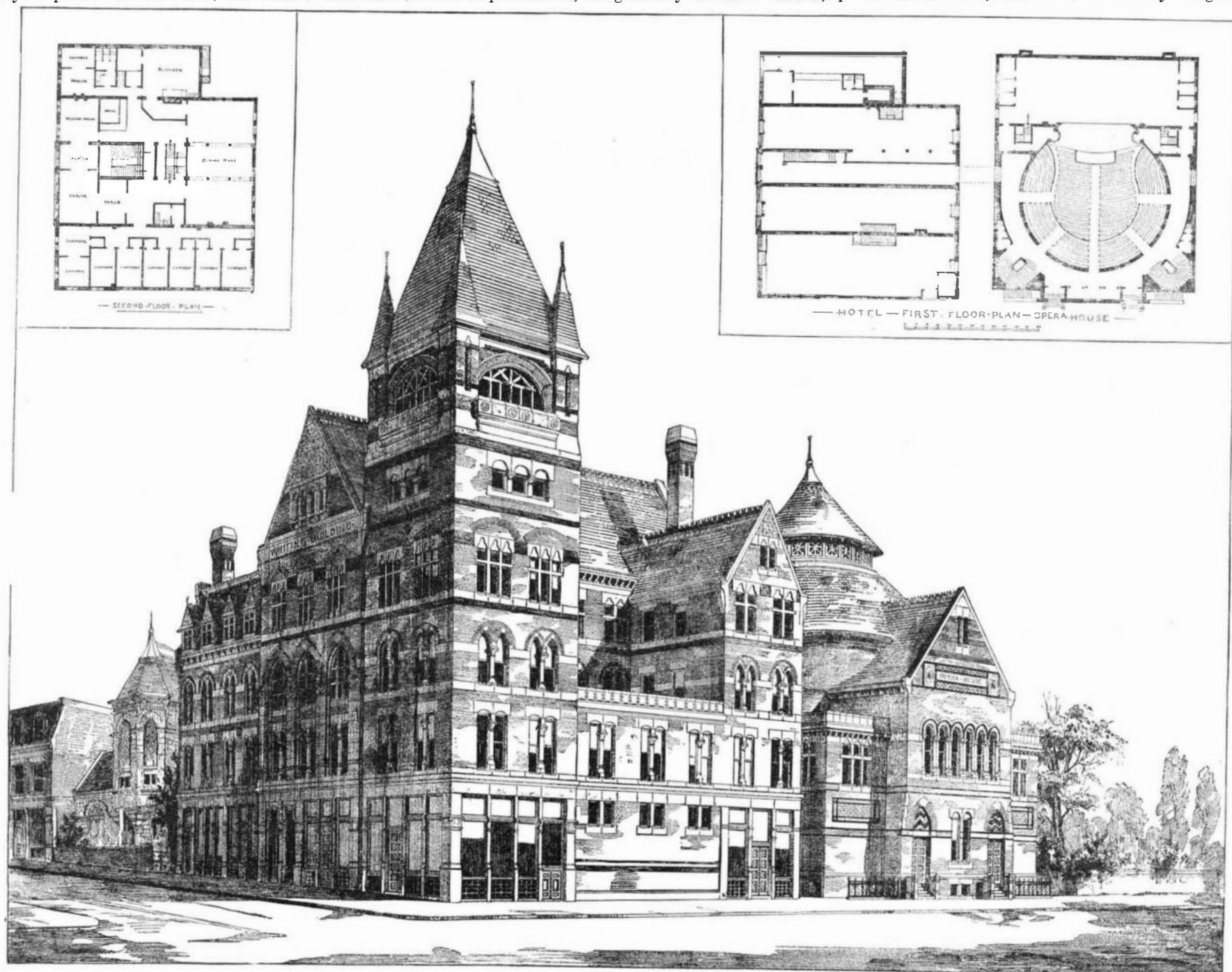
MR. LIEBOLD, an architect of Holzminden, has published in the *Deutsche Bauzeitung* an account of a dwelling house of concrete, lately built by him in Vorwohle for a gentleman engaged in the manufacture of Portland cement. Although the house (see illustration) was quickly built, it yet seems to contain a *tour-de-force* of almost every constructive form for which concrete can be employed. The rooms are covered with various kinds of vaults, many of which have a very considerable span. Over the vestibules of the different stories—spaces thirteen by seventeen feet—three vaults are superimposed without the use of iron, and depend solely upon the vaults of the adjoining rooms for a counteraction of their side thrust. The original and striking feature of the building is the great cloister-vaulted roof, which, resting on the four principal corners of the structure, rises through a story and a half. At its base the concrete of which it is formed is one foot in thickness; at its summit only from four to five inches. It is to be regretted that it has received no architectural expression on the exterior; the objectionable mansard is excused by Mr. Liebold on the ground that it was desired by his client. The outer walls of the house are one foot thick; division walls and partitions being from eight to ten inches thick. In the cellar these dimensions are increased by four inches. The walls are anchored at suitable points, and were built above ground by means of adjustable wooden boxes, into which the cement is poured. Below ground the cellar and foundation walls were cast in trenches, the cellar itself not being excavated until after their hardening. The trenches, consequently, were dug to the depth of the cellar below the level of the earth, plus that necessary for the foundation below its floor. This total depth must have been between seven and eight feet, and can only have been obtained in firm soil.

The concrete employed was composed of one part cement to seven and four parts respectively of gravel and sand. The stairs have treads of slate, and are cast so as to measure on the string four inches at the re-entrant and seven inches at the outer angle of each step. In them a coal-slag was substituted with good effect for the gravel; the weight of the concrete thus prepared being but one-half to one-third that of the concrete made with stone. The cornices, window-casings, steps, etc., were formed of three parts of sand to one of cement, and were ready to be walled, or rather cast, into the walls, as the building advanced. The entire cost of the house, says the *Amer. Arch. and Build. News*, which is in effect a cube with a side of between fifty and fifty-five feet, was \$4,300 gold. From the itemized account it appears that all the interior vaulting cost \$420; the stairs, \$82; and the roofs and the platform, \$438, all in gold. The cost of concrete walls, including the wooden forms, etc., was 13½ cents per cubic foot. The building was completed in four months, and its construction may be regarded

THE WHITING BUILDING AND OPERA HOUSE,
HOLYOKE, MASS., MR. C. S. LUCE, ARCHITECT.

THESE buildings were erected for William Whiting, Esq., the present Mayor of Holyoke, and are now rapidly approaching completion. The hotel building is constructed of Philadelphia pressed brick, with finish of light Nova Scotia sandstone, and comprises stores on the ground floor, dining hall, kitchen, parlors and chambers on the second and third stories and a public hall on the fourth story. The tower is about one hundred and fifty feet in height. On the exterior of the opera house, light Philadelphia and dark Holyoke pressed brick are used; and bands of black brick

and panels of majolica tiles are introduced. The central gable is further ornamented by two circular panels containing heads of Comedy and Tragedy. The auditorium includes an orchestra, parquet circle, and one gallery, and has a seating capacity of about eleven hundred. It is finished throughout in the Neo-Grec style. The plan is circular. The ceiling consists of a large covered cornice, pierced by eight semicircular lunettes (forming a series of furred vaults), surmounted by a flat dome, and is ornamented at the center with a *rosace*, which serves as a ventilator to the auditorium, and from which depends a large brass chandelier. All the ornamental work is executed in papier-mâché. In the two prosceniums, though merely decorative features,



WHITING BUILDING AND OPERA HOUSE, HOLYOKE, MASS.
MR O.S. LUCE, ARCHITECT.