THE TONOGRAPH.

BY H. HOLBR'OK CURTIS, M.D.

a' a'♯ b'

PLATE I—TONE PHOTOGRAPHY.

MR. PLUNKETT GREENE SINGING INTO THE TONOGRAPH.

MISS PECK SINGING INTO THE TONOGRAPH.

The illustrations published herewith show the figures which are produced by singing under a tense rubber membrane stretched over an inverted bell jar or curved tube made of metal. The notes of the chromatic scale have been reproduced from photographs taken from a disk of dental rubber dam stretched over a tin horn, the tonograph, curved to roughly represent the external meatus or outer tube leading to the ear drum.

Any one may produce pictures of the octave with its half quarter and fractional tones, for the membrane, when treated properly, becomes far more sensitive to the exact pitch than the human ear. The preparation of the rubber membrane is the only difficult part of making the apparatus, for the membrane must be very homogeneous and of equal tension. The simplest way to construct a disk of equal tension in all directions is to lay a 10 inch square of dental rubber dam on a smooth surface and make a few concentric circles with a pencil around a ten, twenty-five, fifty, and one dollar silver piece respectively. Next we take an 8 inch round embroidery stretcher and press the outside ring over the inner, putting the rubber on the frame as one does a piece of cloth. The membrane is next pulled in all directions to put it on the stretch, care being taken to keep the pencil circles from losing their shape and becoming elliptical. When the membrane is moderately stretched, the frame is overhanded with thread or glued. The diaphragm thus prepared may now be taken and pressed down over the funnel shaped end of the horn, the funnel being 5 or 6 inches in diameter, the horn about 3. By keeping the wooden frame equally distant from the edge of the horn and making forcible downward pressure we get a membrane as nearly homogeneous in tension as possible, and the nearness of the outer pencil circle to the rim will show just how tense it is. When the membrane is quite like a banjo or drum head, we simply tie a cord around the rim of the horn and release the frame, which it is best to leave as part of the machine for future adjustment. The horn then appears as in the picture. If it is intended to take photographs from the membrane, it should then be treated with a fuchsin solution in alcohol and colored a deep red, which appears black in the photograph. The tonograph is then ready for use and only requires sufficient time to ripen for better results, as the longer the rubber is allowed to stand in tension the more homogeneous it becomes and the more perfect will be the geometrical figures which are produced. Rubbing in circular sweeps with the finger and drumming upon it daily increases its delicacy and activity.

For a given instrument the figures are exactly the same for a given tone; but the figures vary for different tensions of the membrane and for different diameters of the disk. The simplest substance to use and best to photograph is a mixture of table salt and fine emery, a few experiments being enough to show how much emery to add to make the cleanest figures. If the salt is damp, it must be placed in the oven and heated to expel the moisture. As much salt as can be put on a ten cent piece is then put in the center or sprinkled over the rubber membrane and a note sung in the open end of the instrument, when at once the beautiful figure appears which is the geometric expression of that pitch. It is more interesting to sing this note through a short tube or horn into the mouth of the instrument, for by this means we can hold the tonograph level, and more readily see the figures produced. In the same tonograph different voices make the same figures, but the overtones which model the nodal lines make more delicate tracery when sung in such a manner that their effect is not marred by bad production. The more beautiful a voice and the more perfectly employed with respect to overtone production or harmonic richness, the more delicate and beau-

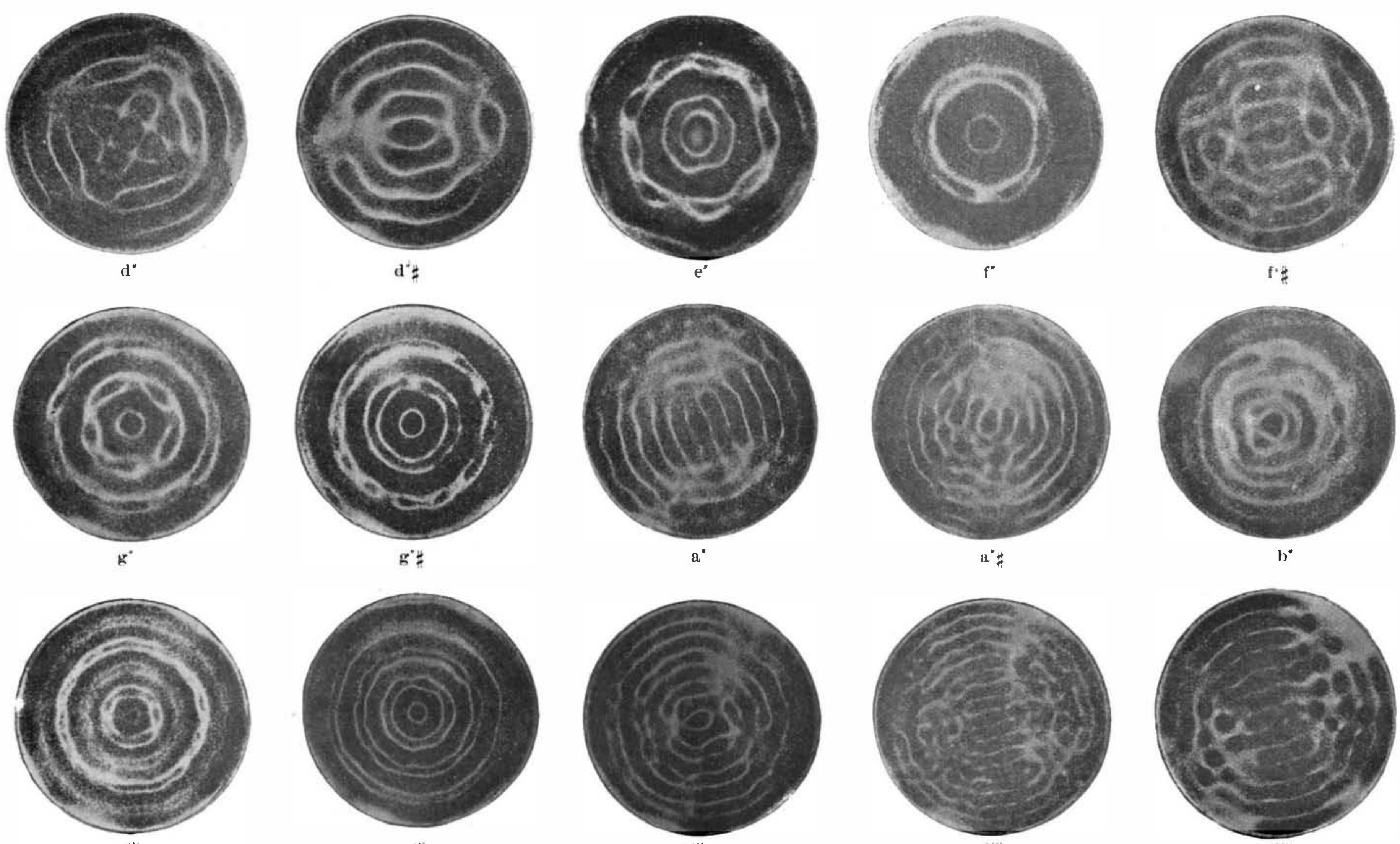


PLATE II—TONE PHOTOGRAPHY—RECORDING THE TONES OF THE VOICES OF CELEBRATED SINGERS TAKEN WITH THE TONOGRAPH BY HOLBROOK CURTIS M.D.

tiful will be the picture. The picture made on this instrument is as exact as the tuning fork in determining pitch, and the pitch of any note may be at once ascertained by reference to the chart. It was my wish to reproduce the intricate picture of d''' in altissimo on the tonograph, at the demonstration of the invention at the Academy of Medicine, in April, but for a moment it seemed impossible to get the pitch, as there was no fork or piano at hand. I however stated that, possessing natural pitch, I could strike c'' an octave below, and verify it by the picture produced on the chart, and then by taking the note above give the pitch to the boy soprano, Master Witter Peabody, who had kindly consented to sing the high notes for me. I did this, at once making the beautiful figure c'', when taking the next note and singing the octave above, Master Peabody immediately duplicated the most intricate d''' in altissimo on the chart in its minutest detail. The plates of the chromatic scale are reproduced from the photographs without any retouching or disturbance of the salt. Two of these plates will be seen to be duplicates, c''' and d''', which are inserted to show the differences of the figures as sung by widely differing voices. Thus the second plate of c''' was sung by a very celebrated light soprano, while the heavier lines in the first plate of c''' (1,024 vibrations of the vocal cords per second) was sung by an equally celebrated prima donna, whose voice is of a more dramatic quality. The differences in timbre of the two voices are shown in such a way that we can see the strength of the overtones and the preponderance of certain harmonics which go to make up the quality of the respective tones—a truly visible musical analysis. The plates of d''' were sung by a very high soprano and by the boy soprano mentioned above. In the second plate we see the quality of the male voice in the heavier lines and a wider plan of segmentation.

Plate III shows b' and c" on the staff, sung by a male voice, a well known tenor. There occur two or three figures between b' and c", as also between many of the notes, showing that there are notes in the geometric scale not taken into consideration by our musical notation on the piano, but which undoubtedly we recognize on the violin and cello. This subdivision of intervals undoubtedly lends the peculiar charm to these instruments.

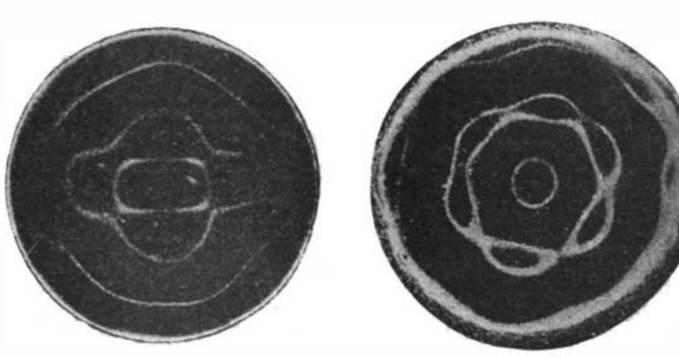
Plate IV shows the intermediates between c" and d". As we descend lower in the scale, the figures become simpler, Plate I showing a', a'♯ and b', as sung by a basso.

The above figures were sung by Madam Calvé, Jean de Reszke, Ben Davies, Plancon, Plunkett Greene, Ed. de Reszke, Miss Marie Donavin and Miss S. K. Peck. From a careful study of the results with such distinguished co-operation, I have arrived at the following conclusions:

A tone, to make a perfect geometric figure, must be sung well forward, with no forcing or tension, and with absence of shock or breathiness of tone. In other words, perfect production must be employed to make a harmonious figure, in the same way that it must be studied to make an agreeable impression upon our ear; and, from the same analogy, may we not reason that the little membrane of our ear drum may be divided up in the same exquisite arrangement of nodal lines by audible tones, and thus communicate to the brain, by means of the auditory nerve, the impression of agreeable quality in tone.

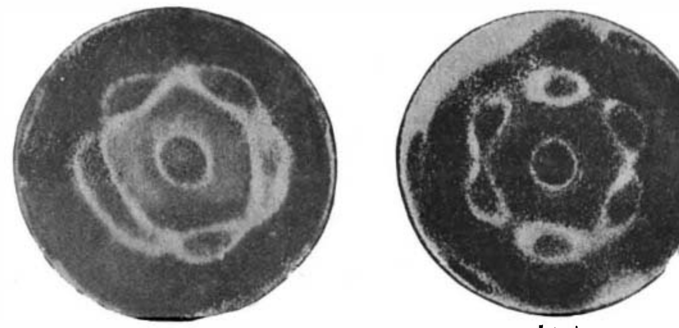
The pioneer in the study of shapes made by the voice in sand and pigments was Mrs. Watts Hughes, of London, and it was in attempting to imitate the shell and flower forms which she so beautifully described in the Century Magazine for May, 1891—pictures I have reproduced in my book on "Voice Building and Tone Placing," Appleton, 1896—that I conceived the idea of making a geometric musical scale, and the above mentioned figures have been the result of over a year's experiments with a vast amount of apparatus and many kinds of membrane. The simplest in the end has given the best results, and I describe my instrument in its easiest construction. The beautiful figures are of endless variety, and are as complicated as the sand forms on a Chladni plate or the scrolls made by the reflection of a ray of light from Wheatstone's luminous bead on a vibrating rod. My only claim to originality lies in the fact that I have utilized mixtures on a vibrating membrane to construct a geometric musical scale in figures, which are the same for equal tensions and diameters of membrane; and have further studied the relative specific gravities of the mixtures of salts and emery I employ to produce the best results for given thicknesses and tensions of the vibrating membrane—a subject I shall elaborate at another time.

The practical result I hope to attain is, to construct a tonograph which shall be so delicate that the pictures will record not only a mathematical expression for pitch, but for an analysis of tone quality as well.

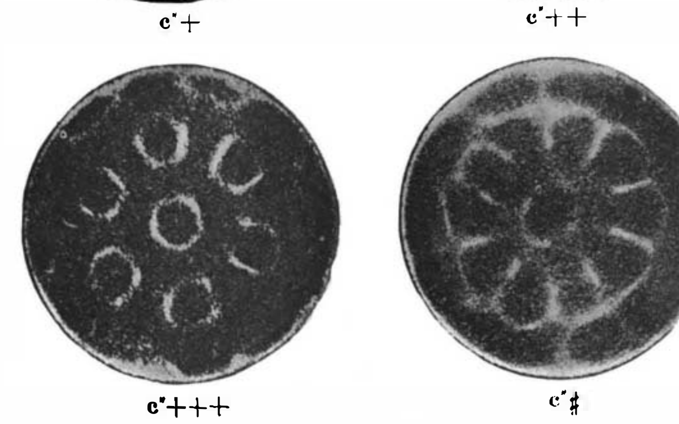


b' c"

PLATE III.



c"+ c"++



c"+++ c"♯

PLATE IV—TONE PHOTOGRAPHY.

Odd Causes of Electrical Fires.

The quarterly report of the Electrical Bureau of the National Board of Fire Underwriters makes mention of the following odd causes of fire:

A plush curtain in a theater, on being hoisted, came in contact with a 32 candle power incandescent lamp. The common size is 16 candle power. The heat from the lamp ignited the curtain, but the fire was discovered, with no loss, except the curtain.

A stage hand was ordered to turn out an incandescent lamp, and not knowing how to do it, instead of turning the switch, he wrapped a damp towel around the bulb. Some time afterward the towel was discovered smouldering.

A portable incandescent lamp was allowed to remain lighted lying on a mattress. The heat from the lamp ignited the cloth and the excelsior of the mattress, and the fire spread through the basement and store.

An electric pressing iron was allowed to stand with the current turned on. The heated iron after a time set fire to the table, and the flames communicated to the surrounding combustible material.

A wagon loaded with gasoline collided with an electric car. The wagon was demolished and the oil flooded the street. The accident attracted the attention of the motorman of another car, who ran his car up to the scene. Seeing the oil running under his car, he turned on the current to get away. A spark from the wheel immediately ignited the gasoline fumes, and instantly the street was ablaze. Four people were injured, one seriously, and one horse was burned to death.

Fire occurred in a basement, owing to dripping water falling on an electrical measuring instrument, thereby short-circuiting it.

Sparks from arc lamps in a department store ignited cloaks on a table underneath.

An elevator motor was burned out, having been left running when the employes left the store, the motor brushes being badly adjusted.

A carpenter dropped a nut on the coils of a rheostat, short-circuiting them with an iron frame resting against a gas pipe. An arc was formed between the frame and the pipe; the latter was melted and the escaping gas ignited.

Rats gnawed the insulation from a wire which lay on a gas pipe; an arc was established between the wire and the gas pipe, setting fire to the gas.

ACCORDING to recent experiments of Prof. Trowbridge, says the Electrical World, with a 20,000 volt storage battery, it appears that the lowest voltage which will produce satisfactory Roentgen rays is about 100,000. He also found that electrostatic polarization is largely instrumental in the generation of X rays.

THE PRODUCTION OF GRAND OPERA.*

Grand opera, to be given adequately, requires a permanent home, and the Metropolitan Opera House, New York City, may be regarded as the home of grand opera in America, for here is given the longest season and here the great artistic triumphs are made. The Metropolitan Opera House has many interesting features; therefore we have selected it for the subject of the present article.

The building is built of yellow brick and occupies the entire block bounded by Broadway and Seventh Avenue, Thirty-ninth and Fortieth Streets. The auditorium is handsomely decorated and is capable of seating an enormous audience. We shall, however, confine our attention to that most interesting of places—the stage.

The stage of the Metropolitan Opera House is 101 feet wide and the depth is 84 feet. The height from the stage to the "gridiron" overhead, from which hang the scenes, is 90 feet. The first "fly gallery" is 36 feet above the stage, and the depth of the cellar is 28 feet. A reference to the plan will show that the stage is divided laterally into four sections, called "bridges," which run entirely across the stage. Each bridge is in turn divided into four parts, so that there are really sixteen working bridges. When it is desired to raise any part of the stage above the level, to represent broken ground or for any other purpose, a narrow trap door is lifted and a man at each end of the bridge raises it up to the desired height, as shown in our engraving. The bridges are counterweighted, so that it requires very little effort to raise them. It is possible to lift them to a height of 22 feet. The plan also shows the wing posts at the sides; these also slide up and down freely. They secure the "wings," or side scenes. No use is made of the cellar for raising the scenes, as it is found more satisfactory to operate the scene from above. The cellar is used for storage purposes and is divided into two mezzanine stories. When not in use the large drop scenes and the borders are rolled up and placed in racks. A section of the stage floor is arranged to lift up so as to permit of the long rolls of canvas being lowered into the racks. In the cellar is also machinery for working the various traps which will be noticed in the plan. These traps are very useful for suddenly elevating persons or properties to the level of the stage.

Going up several flights of stone stairs, the visitor arrives at the first "fly gallery." The "fly galleries" are narrow galleries which extend across each side of the stage. From the "fly galleries," which are most massive, the curtains, the "drop scenes" and the "borders" which form the sky are lowered. As the "drops" at the Metropolitan measure 45 × 70 feet, it will be seen it would be no small task to raise and lower them. From the "fly galleries" a very large number of these "drop scenes" are hung; more are hung up than are to be used for the opera. The canvas is hemmed so as to permit of a wooden pole or batten being thrust through it. This bar is secured to the ropes which raise the scenes or "drops" by means of clamps. At the very top of the building, underneath the roof, is what is called the "gridiron." It is an iron framework covering the entire top of the stage. It supports the pulleys over which the ropes run to raise the "drops," "borders" and "border lights." Each scene drop is supported by five ropes and most of the "borders" are also supported by an equal number. These ropes are attached at equal intervals along the length of the scene or border, and each rope passes over a pulley on the "gridiron" directly above the clamp which secures the wooden bar. The ropes are then assembled and pass down on the left of the stage to the first fly gallery. It will be noticed by reference to our engraving that all of the ropes are brought over to one side. This is called the working fly gallery. In raising or lowering a scene the five ropes are pulled at the same time and are secured to the "fly rail" by means of the belaying pins. The fly men climb up to the second and third fly galleries when heavy scenes are to be raised, and, catching hold of the ropes, descend to the first fly gallery on them. The curtain is raised and lowered by hand power by means of a winch, wire rope being used. An asbestos curtain is provided which may be instantly dropped to the level of the stage in case of fire.

We present an engraving of a corner of the stage showing the great switchboard and the prompter's desk, though, of course, in grand opera the prompter takes up a position under a hood directly in front of the conductor, just beyond the footlights. Just before the conclusion of the act the conductor rings an electric bell in the fly galleries as a warning and later gives the signal to drop it. The curtain calls from the audience

* Abridged from "Magic, Stage Illusions and Scientific Diversions," a new work which will be published in the autumn. Copyrighted, 1897, by Munn & Co.