VOICE BUILDING AND TONE PLACING:

BY

H. HOLBROOK CURTIS

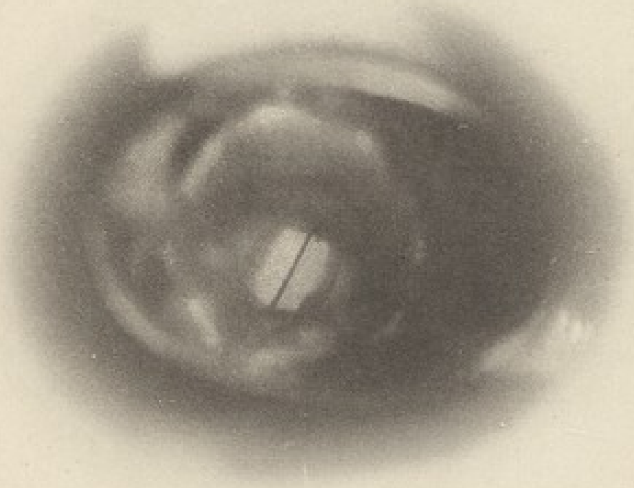
To my best of friends

Madame Nellie Melba,

whose assistance made the existence of this book a possibility. With the affection and esteem of

H Holbrook Curtis

118 Madison Ave
N.Y. 1896.



Facsimile of a photograph of the vocal cords of a distinguished singer, taken by means of the improved apparatus of S. W. Bridgham, Esq.

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SHOWING A NEW METHOD OF RELIEVING INJURED VOCAL CORDS BY TONE EXERCISES

BY

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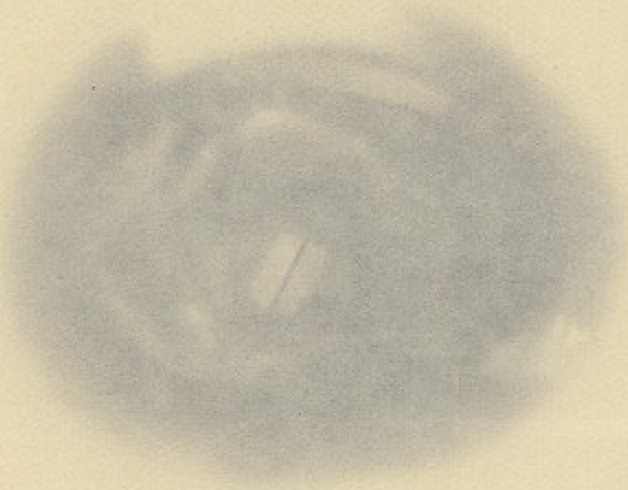

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NEW YORK
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TO MY FRIEND

JEAN DE RESZKE

THIS LITTLE VOLUME IS DEDICATED

IN TOKEN OF

THE AFFECTION AND ESTEEM

OF THE AUTHOR.

PREFACE.

The tangled skein of theories which one must unravel in order to arrive at any simple conclusion in regard to the singing voice, makes our endeavour in the present volume an arduous one. We have tried to cling as closely as possible to facts, and make our subject scientifically satisfactory by the introduction of such of the elementary laws of sound and music, the thorough comprehension of which will enable the student to understand the conclusions deduced in our argument as to the proper production of tone. The chapters on anatomy and respiration are intended to be of value to the physician as well as to the student of singing, and for this reason also, the subject of the vibration of the vocal cords has been entered into in a way not treated of in any other work. The author has for a long time been convinced of the many fallacies which have obtained in the theories as to the so-called "registers" of the human voice, and the absurdities of the deductions as to the manner of vibration of the vocal cords, made from photographs taken during tone production. The writer's theory, that the overtones introduced by the proper method of placing tones in the facial resonators induce a new plan of vibration of the vocal cords, has been verified by the recent investigation with the stroboscope by Professor Oertel, of Munich. We have introduced several of his experiments to explain the true plan of vibration of the cords as seen in the stroboscope, and have tried to elucidate our theory as to the removal of singers' "nodules" by tone exercises, in a scientific way. We would have been unable to do this, except upon theory, had it not been for his experiments. The manner of vibration and the formation of nodes and segments in the cords have been most carefully studied by Oertel as well as by Koschlakoff, Simanowski, and Imbert, but none of these investigators is evidently aware of the practical application of their discoveries. For several years many of our most renowned singers have been convinced of the efficacy of our method of tone exercises in overcoming serious affections of the vocal cords, and we trust that a perusal of this work will amply repay every laryngologist who will take the time and trouble to verify our assertions. We have included some of the simplest exercises for the restitution of cords injured by improper vocal method, which may be employed by the teacher as well as the physician. The general scheme of the building of the voice, on the lines of our theory of tone placing, is appended for the benefit of teachers and students, in the hope that some one may receive aid from a method which, if not elaborate, is certainly beneficial in furnishing a fundamental principle of correct tone placing to the serious student. This book is the result of a vast experience with singers. The ideas have been put together in a concise and simple way, without any attempt at elaboration or style. If it will give assistance to any student or teacher groping amid the dark and dangerous traditions of voice culture, the author will feel that his modest efforts have been crowned with success. To Dr. Frank Donaldson I am indebted for valuable assistance in compilation, and to Madame Melba for her generous aid in the chapter on voice building. To the members of the Metropolitan and German Opera Companies, who have honoured me with their confidence, and given me great assistance in my search for the truth, I am profoundly grateful.

H. Holbrook Curtis.

118 Madison Avenue, New York,
January 1, 1896.

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CHAPTER I.

THE ORIGIN OF MUSIC.

Music did not develop into an independent art among the cultured races of Asia, Africa, and the adjacent peoples of Europe, in either the classical or preclassical epochs. Among the Chinese, Hindoos, Egyptians, and Jews, the Greeks and the Romans, it was closely associated with poetry, the drama, and the dance. The Greek tribes of the Peloponnesus and Hellas, the Egyptians, Phœnicians, the Greeks inhabiting the isles of the Ægean Sea, and more especially those in the Island of Cyprus—all had a primitive "Lament," which came originally from Phœnicia.* This was a funeral chant celebrating the death of the youthful Adonis, who symbolized the beautiful but short-lived spring. The Egyptians

* Neumann, History of Music. Translated by T. Praeger. London, Cassell & Co.

changed the significance of this chant, transforming it into a lament of their own goddess Isis bewailing the death of Osiris. This "Lament" became the "Linos" of the Greeks and the "Maneros" of the Egyptians; but, wherever it was found on the shores of the Mediterranean, it had the character of a plaintive wail at the mortality and frailty of all earthly things. Music, however, lent its voice to the expression of joy as well as of grief, and became the means of expressing a common sentiment, as in the war songs of the people or the emotional appeals to ancient deities and idols. It is a commonly accepted belief that war songs, to the rhythmic beating of drums, were the earliest form of music.

The actual stage of development which music reached among the ancients can only be determined by a study of those specimens of their musical instruments which still remain, the representations of them found upon tombs and monuments, and of certain obscure records. The number of each of these is unhappily limited, but from them we have been able to obtain a fairly satisfactory idea of their musical knowledge. Especially is this the case with the Egyptians, whose monuments show musical hieroglyphs dating back to the fifteenth dynasty.

Among the Chinese, as among all other nations, music owed its origin to religion. The Chinese, however, never made any marked progress in their instruments or vocal art, and their preference to-day for instruments of percussion is an evidence of their low musical organization. As they are the only people who thousands of years ago possessed a system of octaves, a circle of fifths and a normal tone, and once had an elaborate theory of music, we must conclude that the Chinese have retrograded in their musical ideas instead of advancing.

The Japanese took their music from the Chinese, and, curiously enough, it has until very recently remained below the Chinese standard rather than risen above it. Their barbarism in music shows itself, as with the Chinese, in the number of drums, clappers, and bells used by them.

The Hindoos claimed for their music a derivation direct from the gods. Their ideas on the subject were most fanciful and exaggerated, but the art of music under them was carried to a far greater state of development than among other nations. They invented the *Vina*, a seven-stringed instrument of very beautiful tone, sometimes described in ancient writings as the most charming of all musical instruments, but in reality inferior to the Japanese koto.

The ancient Israelites, with their refined sensibility and poetic temperament, naturally possessed exalted ideas about music, connecting it inseparably with religion. They addressed the Almighty in hymns of praise and in penitential psalms, and as their religion was nobler than that of any other people, their music naturally sought higher planes for expression. Moses is believed to have acquired a knowledge of music as practised by Egyptian priests, for he gave directions for the construction of two silver trumpets, used in giving signals to the children of Israel during the forty years' sojourn in the desert. On the Arch of Titus in Rome is a bas-relief of one of these trumpets, and it is claimed that the trumpets themselves were paraded through Rome after the destruction of the Temple of Jerusalem. The shofar, a trumpet of different shape, is found in every Jewish synagogue to-day.

Miriam's song of triumph after the destruction of Pharaoh and his hosts was the first musical outburst of the Israelites, and was probably regarded as of divine inspiration. In the time of David, an immortal poet and musical genius, sacred music attained its highest point, and there can be no doubt that in the reign of Solomon, like all the other arts, it reached a high state of development. The psalms were sung by the Israelites in various ways, antiphonally by the priests and congregations, and by divided choruses, arranged and led by a precentor. Of the tonal system of the Israelites, and the structure of their scales, little is known. Keller,* however, states that in 1890 a number of flutes were found in a grave, dating certainly before 3000 B. C., which, from their construction, give abundant proof that the Egyptians used our diatonic scale. Whether this be true or not, they certainly had harps with as high as twenty strings, and they seemed to have understood the harmony of voices, and of instruments and voices. Moreover, in the accompaniment of penitential songs they employed trumpets, drums, shofars, and timbrels. The "Maneros," or popular songs and general choruses, were sung on occasions of processions and religious festivals.

The Greeks, in their theory of music and in their melody and rhythm, adopted Egyptian, Lydian, and Phœnician traditions. Their innate sense of beauty and proportion saved them from those barbarisms which had marred the work of earlier nations. Music among them assumed a dignity and importance in its relation to the state undreamed of in earlier times. It became a factor in the education of the individual. It grew to be a part of the daily life of the people, though never as a self-sustaining art distinct from that which it accompanied. It was regarded as a strong incen-

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* Keller, Geschichte der Music, Leipsic, 1893.

tive to virtue. It had a place in devotional exercises and in the public games, and was considered an essential accessory to that classical drama of Athens which was always produced with imposing surroundings, and which in its pure intellectuality has never been surpassed. The instrumental accompaniment to it was probably made up of flutes and citharas. The music was sung in unison, careful attention being bestowed upon the rhythm.

Nothing in the theoretical works of the Greek writers indicates that their knowledge of music included that of harmony, although the use of the octave, the fifth, and the fourth were common among them, and, indeed, their tonal art was probably but the handmaid of Poetry. The modern composer manipulates the metres and syllables according to the music, whereas the Greek maestro shaped the melody to the words.

Burney, in his history of music, remarks that, passionately fond as the Greeks were of all kinds of music, there is nothing in their extant treatises on the art, or in the fragments of their melodies which are preserved, to indicate that they had attained such efficiency in composition as would make their performances agreeable to modern ears. How far this statement may be modified, in view of the beautiful choral ode to Apollo, discovered a year ago at Delphi, and performed in Athens and London, to the intense delight of a critical audience, remains to be seen.

That so cultured a people as the Greeks should not have developed the principles of harmony, might excite a certain wonder, until one remembers that the severest simplicity characterized their art, which was preserved in its purity to the end. When singers began to embellish their tunes we find Aristophanes, in his comedy The Clouds, coming down upon them thus:

> "Had any one for sport essayed such shakes and trills to practise,
> Like Phrynis has now introduced, neck-breaking skip and flourish,
> Of stripes he'd had a measure full, for holy art corrupting."

Plato maintained that that music only which ennobled the mind should be tolerated, and that it was the duty of the lawgivers to suppress that which possessed merely sensual qualities. And so as music was, in a sense, a recognised factor in the preservation of public virtue, the jealous care with which its integrity was guarded closed the only avenue to its true and perfect development. That work was left to a later civilization. The Athenian youth in the meantime were instructed in both the art of singing and of playing on instruments, such accomplishments being considered essential for an *entrée* into the cultured society of Athens. Vocal songs called "Orthian," written only on the highest notes, and which had to be sung with great vigour and intensity, were very popular, and therefore much practised.

We have nothing to prove that either oratory or the use of the voice were cultivated among the Egyptians. The political institutions of Greece, however, and the construction of her assemblies, led inevitably to the development of oratorical powers. In the schools of rhetoric young men were systematically trained in the art of speaking. The Sophists, who presided over many of these, were the first to intone, a habit still practised by certain religious sects.

Isocrates was the head of a celebrated school of oratory in Athens. His great aim was to perfect his pupils in the art of speaking and of appropriate gesture, and he may, perhaps, be considered the first model for Delsarte. Aristotle, to be sure, laid little stress on the rules of art, maintaining that the substance of a man's speech was of greater moment than the correctness of the form into which it might be moulded, the truth in an argument being of more importance than any gesture of the speaker.

The purely professional voice trainers were the Phonarci. These Phonarci endeavoured to cultivate the voice both for singing and speaking. They taught enunciation, and proper modulation and inflection of the voice. Most Athenian youths were given a course of training under them, and great rivalry in declamation sprang up in Athens, leading eventually to the establishment of public contests, where prizes were given for elocution. These contests took place in the open air, and from the endeavour to be heard at a distance the speakers and actors were led to such excessive vociferation that Plutarch had to warn his pupils, lest they should bring on rupture and convulsions through undue effort.

The Greeks, however, in addition to their knowledge of how a voice should be cultivated by exercises and training, understood as well how it should be preserved by dieting and hygienic measures. In speaking they were accustomed to use a demulcent liquid containing tragacanth. Onions and garlic were considered beneficial to the vocal organs, as were also leguminous vegetables, fish, and eels. Cubebs, too, seem to have been extensively used. Certain springs were visited as possessing properties beneficial to the voice, especially one near Zama, which seems to have been a sort of Greek Wiesbaden. The Greek physicians used such agents as gum arabic, tragacanth, extract of pine, oil of almonds, thyme oil, etc., for throat and respiratory troubles. Cold drinks were studiously avoided by singers and speakers, who were also careful as to their mode of life, avoiding all excesses in eating and drinking, keeping themselves in every way in the best mental and physical condition.

Turning from Greece to Rome, we find that, notwithstanding the greatness of the Romans in all that relates to government and the constructive arts, the art of music never reached the same development it had attained among the Greeks, from whom they inherited it. Eventually it fell to depths of degradation, which fortunately have never been equalled in subsequent history.

The Etruscans brought the traditions of the Greek school to the Romans, and the instruments used by them—the flute, the cithara, and the lyre; but, while Rome derived from Greece the basis of its musical theory, the life of the people was not one to promote any further development of the art. Rome was without a dignified drama of its own, and the stimulating influence of poetry. The best of her lyric poets, even Horace, lacked the passionate heart expression of the Greek muses, and their verses did not invite musical treatment.

However, certain of the Romans did gain an insight into the true principles of music, for Diodorus, A. D. 50, introduced the major third into their diatonic scale as a consonance, and thus they established a prototype of our diatonic scale. The Greeks used the diatonic, chromatic, and what they called the enharmonic scale. The art of music in Rome at one time received a beneficial impulse from the Dionysic rites, introduced into Rome by the Greek colonists in southern Italy. But the tendency to sensualism soon usurped the place of the pure love of beauty, the dance degenerated into voluptuous costuming, music was at best cultivated to increase the pleasures of life, and the divine art reached such a state of degradation that it fell into the hands of licentious women, and it was expunged, by order of the state, from the curriculum of Roman education. Oratory and the training of the voice, on the other hand, were as carefully practised among the Romans as among the Greeks. Rhetoric and oratory were taught systematically, and indeed The Institutions of Oratory, by Quintilian, is the most complete and systematic treatise of the kind we have inherited from the ancients, and superior to anything produced by the Greeks on the same subject. This work covers the whole question, from the education of the youth to his development into a complete orator. He gives minute and judicious advice on the management and treatment of the voice, and brings out clearly the difference between the aims of the speaker and the singer. He also advised the cultivation of the voice in the middle register, declaring that the deeper tones lacked force, while in the higher the voice is in danger of being cracked. He observes that, in speaking, the breath should not be drawn in too often, or the sentences will be unnecessarily broken and jerky.

He seems, however, to have believed, like so many of our throat specialists to-day, in heroic treatment of the vocal organs. Emulcent applications are advised by him.

As is well known, oratory, as such, reached a very high plane in Rome. The Roman drama, however, though resembling to a certain degree that of the Greeks, was but a poor imitation of it. The Romans never rose to any height in tragedy, and, in their disregard for music, they found it easy to dispense with the chorus. As a consequence, voice culture, as it existed on the Greek stage, was unknown among them. Interesting in this connection is the fact that there is good reason for believing that the Roman actors intoned or chanted their speeches to a musical accompaniment, in a manner somewhat similar, perhaps, to the recitative of a modern opera.

Passing from Rome to the middle ages, we find oratory preserved and eloquence cultivated by the early fathers of the Church. Between the fifth and twelfth centuries, however, oratory with the other arts slept, until in the latter century a revival took place in Italy, which has culminated in the enlightenment of the present age. Throughout the ecclesiastical reign of scholarship the untutored people had a music of their own, which, in its tonal and rhythmical affinities to that of later date, commands present sympathy, and which, having the element of harmony, was the foundation of whatever science and art have together attained.

A great musical resurrection took place in Flanders in the fifteenth century. The Flemings founded schools in Rome, Florence, and Naples, and the rise of art in Germany as well, was directly due to their influence. Adopted by the Church for the people, the principles of harmony were reduced to a system under the name of counterpoint, though counterpoint was developed, according to some authorities, in England during the thirteenth century. It is interesting to note that the first choral service was instituted at Antioch about the time of Constantine, whence St. Ambrose introduced it in the Western churches.

The rise of popular music in Europe is intimately connected with the practice of minstrelsy. The public singer, reciter, and story teller appear, as we know, early in the civilization of almost every country.

The representatives of this class, however, who have perhaps exerted most influence over modern music, are the Provençal poets or Troubadours, who arose in France toward the end of the tenth century.

Finally, the crowning achievement in the musical development of the voice was the invention of the lyric drama, where the power of music to awaken emotions is applied to the systematic illustration of human passions. The first public performance of regular opera took place in Florence in the year 1600, when the Eurydice of Rinuccini and Peri was represented in honour of the wedding of Marie de Medici and Henry IV of France. The further development of opera, up to the time of Mozart, Beethoven, and Weber, to Wagner and Verdi, need not be treated here. It is interesting, however, to recall the fact that Greek tragedy was essentially lyric, and that it fell asleep with other forms of classic art, to be awakened at the end of the tenth century.

CHAPTER II.

THE ANATOMY AND PHYSIOLOGY OF THE LARYNX.

Voice consists of sounds produced by the vibrations of two elastic bands—the true vocal cords—situated in the larynx, an upper modified portion of that passage which leads from the lungs to the pharynx. This apparatus is not, however, in constant activity, but, on the contrary, allows the air to pass without imparting sonant vibrations to it. It is only, in fact, under certain conditions, which are dependent upon our will, that the vocal cords are put in such a position that the air driven past them is set into periodic vibration, causing them to emit a musical note. The lungs and respiratory muscles are therefore accessory parts of the vocal apparatus, the strength of the blast produced by them determining the loudness of the voice. The vocal apparatus of the larynx itself is exceedingly simple, its character being that of a membranous reed instrument, consisting of two elastic plates stretched so as to leave a narrow fissure between. When a current of air passes through this fissure, they are thrown into vibration. The mechanism, however, by which these membranous reeds are adjusted for musical vibration, and the further adaptation of this adjustment for the creation of tones of various pitch, is withal very delicate and complicated. The size of the larynx primarily determines the pitch of the voice, which is lower the longer the vocal cords; hence the shrill voices of children and the usually higher pitch in that of women. Every voice, while its general pitch is dependent upon the length of the vocal cords, has, however, a certain range within limits which determines whether it shall be soprano, mezzo-soprano, alto, tenor, barytone, or bass. This variety is produced by the delicate mechanism above referred to—that is, by the muscles of the larynx—which alter the tension of the vocal cords and the position of the cartilages of the larynx itself. The vocal cords alone would produce but feeble sounds. Those that they do emit are strengthened by the sympathetic resonance of the air in the thorax below and in the pharynx and nose and mouth above, the action of which may be compared to the sounding board of a violin. By the movements of the throat, as of the palate, tongue, cheeks, and lips, the sounds emitted from the larynx are altered or supplemented in various ways and converted into articulate language or speech. The larynx itself consists of a framework of cartilages partly joined by true synovial joints and partly bound together by ligaments and membranes. Muscles are added which move the cartilages with reference to one another and bring about the various adjustments of the vocal bands necessary for the production of vocal sounds.

THE CARTILAGES OF THE LARYNX.—The frame of the larynx is composed of five chief cartilages, namely, the thyroid, the cricoid, the two arytenoids, and the epiglottis. In addition to these, there are two small cartilages on either side, the cartilages of Santorini and of Wrisberg.

THE THYROID.—The thyroid, the largest of the cartilages of the larynx, consists of two large quadrilateral plates, which meet at an angle in front, but separate behind to include the laryngeal space in which most of the remaining cartilages lie. In front the upper junction of the two plates is marked by a notch, more distinct in men than in women. The posterior borders of the two plates are extended above and below into projecting horns. The upper cornua give attachment to the thyro-hyoid ligaments, the lower, however, form a joint with the cricoid cartilage. The cricoid can be rotated on an axis passing through its joints with the lower horns of the thyroid. By the action of the crico-thyroid muscles its front part is brought nearer the thyroid, as will be seen later. Behind and below the thyroid notch is the attachment of the epiglottic ligament, while immediately below this, on either side of the median line, are the attachments of the ventricular bands, and below these, those of the vocal cords. Immediately without the point of attachment of the vocal cords are inserted the thyro-arytenoid muscles.

The Cricoid.—The cricoid cartilage is practically the upper ring of the trachea, only modified and en-

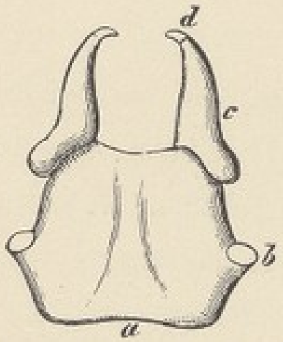

Fig. 1.—Arytenoid cartilages seen from behind: *a*, Cricoid cartilage; *b*, articular facet for articulation with the inferior horn of the thyroid cartilage; *c*, arytenoid cartilage; *d*, cartilage of Santorini. (Meyer.)

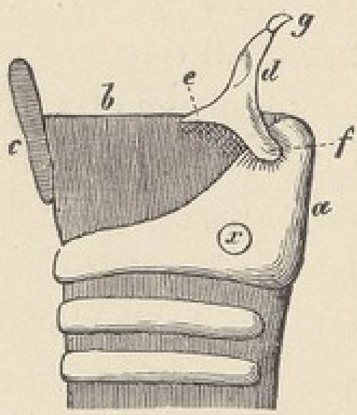

Fig. 2.—Side view of the vocal cords with the arytenoid cartilage: *a*, Cricoid cartilage; *x*, articular surface for inferior horn of thyroid cartilage; *b*, vocal cord; *c*, vertical section of thyroid cartilage; *d*, arytenoid cartilage; *e*, vocal process of *d*; *f*, muscular process of *d*: *g*, cartilage of Santorini. (Meyer.)

larged. Its shape is usually compared to that of a signet ring. The anterior half is rounded, and to it are attached the important crico-thyroid muscles. The posterior half is the broad expanded portion which corresponds to the seal of the ring; upon its upper border are the facets for the articulation of the arytenoid cartilages, and upon the outer, those for the articulations of the inferior cornua of the thyroid cartilage.

The upper border of the cricoid ring gives attachment in front to the crico-thyroid membrane, at the side to those muscles which close the glottis, while posteriorly are inserted the fibres of the posterior crico-arytenoid muscles whose chief function is to open the glottis.

The Arytenoid Cartilages.—The arytenoid cartilages are small, pyramidal bodies, the bases of which are triangular and rest upon the upper edge of the posterior wide portion of the cricoid, forming true joints with it.

The anterior angle of each is prolonged, and to it is attached the vocal cord and the thyro-arytenoid muscle. To the external angle of the base of each is attached the posterior and lateral crico-arytenoid muscles. From the tip of each arytenoid cartilage a fold of mucous membrane, inclosing certain muscles—the ary-epiglottic—extends to the epiglottis. The cartilages of Santorini cause a projection in this fold, just above which there is a similar eminence on each side caused by the remaining pair of cartilages known as the cuneiform, or cartilages of Wrisberg.

Lastly, there is the epiglottis, somewhat like a leaf in shape, and situated between the root of the tongue and the opening of the larynx. It forms a lid which is open to allow the free passage of air in breathing, but protects the larynx in swallowing, so that the food may pass backward safely into the gullet. The constrictor muscles of the larynx, however, are sufficient to exclude food from the air passages, even though the epiglottis has been destroyed by disease. The epiglottis has also an important function in its action upon changing the quality of tones by its inclination backward. The essential organ of the voice is contained within the cavity inclosed by the cartilages above described, and, regarded as an apparatus for producing tone, the most important part of the larynx is formed by the vocal plates which, converging upward in a concave form, terminate in edges which pass from before backward and are called vocal cords. The vocal cords are in reality bands of elastic tissue, lying adjacent and internal to the thyro-arytenoid muscle, and covered by the mucous membrane of the larynx.

The fissure lying between the vocal cords is known as the glottis. From below the glottis is wedge-shaped, but from above it appears as a fissure in a level surface. This description applies only to that portion of the vocal plates which is really employed in the production of tone, that is, to the larger anterior division of the vocal cords; for the smaller or posterior division of the vocal cords into which the arytenoid cartilages are inserted is not free, but

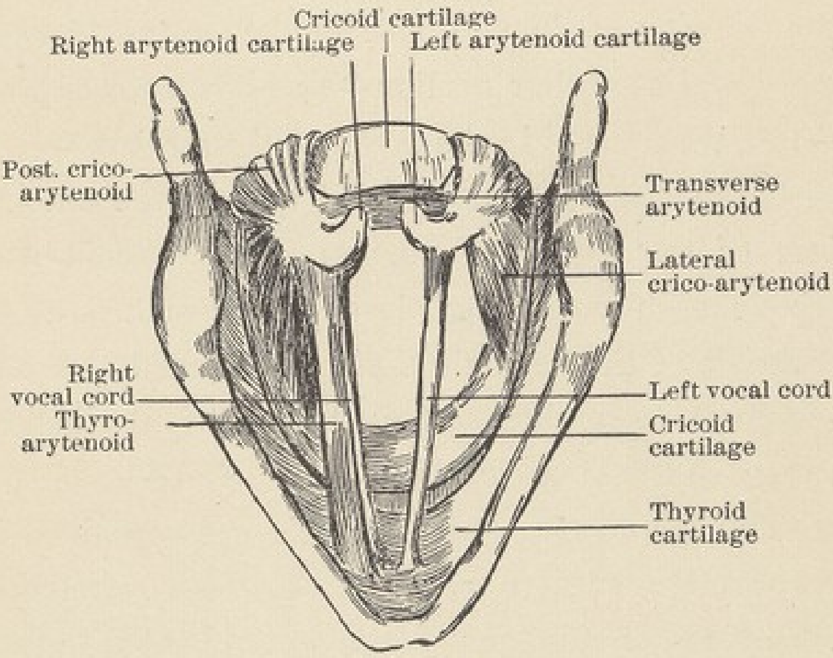

FIG. 3.—Showing the intrinsic muscles of the larynx, seen from above. (Gray.)

attached to the lateral vertical walls of the superior cavity of the larynx, and forms the so-called respiratory part of the glottis, which may be seen as a triangular opening when the vocal cords are in apposition. The elastic vocal cord affords attachment in its whole length to the fibres of the thyro-arytenoid muscle, and is itself practically a ligamentous border of this muscle, which reaches from the inner angle of the base of each arytenoid cartilage to the inner angle of the thyroid cartilage in front where its halves unite. The posterior attachments, however, of the vocal cords follow the distribution of the thyro-arytenoid muscles. One portion is inserted into the anterior angle and face of the arytenoid cartilages, while another portion—that is, the lower fibres—lose themselves in the capsular ligament which invests the crico-arytenoid joint and in the anterior face of the expanded portion of the cricoid ring. Above each vocal cord is a pocket—the so-called ventricle of the larynx. This is bounded above by a somewhat prominent edge—the ventricular band—known as the false vocal cord.

This ventricular band is nothing more than the lower edge of the membranous fold, stretching from the side of the epiglottis in front to the arytenoid cartilage behind, and completing the side wall of the upper part of the larynx. Several writers have assumed that the ventricular bands have an important function in the production of the falsetto voice. This statement is not borne out by observation and experiment. In quiet breathing, and after death, the free inner edges of the vocal cord are thick and rounded, and are also tolerably widely separated behind through their attachment to the arytenoid cartilages. If they are watched with a laryngoscope during phonation, it is seen that the cords approximate behind so as to narrow the glottis. At the same time they become more tense and their inner edges project more sharply and form a better defined margin to the glottis, and their vibrations, especially in the production of *low* notes, can be seen. These various changes are brought about by the delicate co-ordination of the small muscles which move the cartilages to which the cords are fixed.

As we have seen, the glottis is always kept open for the entering and returning currents of air, the posterior edges being separated from each other at their attachments to the arytenoid cartilages. Now, as the utmost width of the glottis must not exceed one twelfth of an inch in vocalizing, some arrangement must be found which can be employed voluntarily to bring the vocal cords in the necessary approximation for the production of tone. This arrangement is to be found in the small arytenoid cartilages, described above, to which the vocal cords are attached.

The movements of these important cartilages are controlled by the intrinsic muscles of the larynx attached to them. In considering the action of these muscles, we must not forget that any given position of the vocal bands is the direct result, not of the action of any given muscle, but of the co-ordinated movement of many muscles and of other forces depending on the nature of the articulation of the arytenoids with the cricoid, and of the cricoid with the thyroid, etc.

THE MUSCLES OF THE LARYNX.—The most important muscles of the larynx, and those which act directly upon the vocal cords, are the crico-thyroid, the posterior crico-arytenoid, the lateral crico-arytenoid, the thyro-arytenoid, and the transverse, or inter-arytenoid. These muscles are in pairs, with the exception of the latter.

THE CRICO-THYROID MUSCLES.—The most important muscles in the production of voice are the crico-thyroid. They are short, thick, triangular muscles, attached in front and below to the cricoid cartilage, and extend from the median line a considerable way backward, the fibres passing upward and outward, diverging slightly, and fixed above to the inferior border of the thyroid cartilage and to the anterior border of its lower cornua. The muscles of the two sides are somewhat separate from one another in the middle line in front. The crico-thyroids are the muscles by which increased tension of the vocal cords is mainly produced.

The explanation of the working of these most important muscles formerly given in the text-books

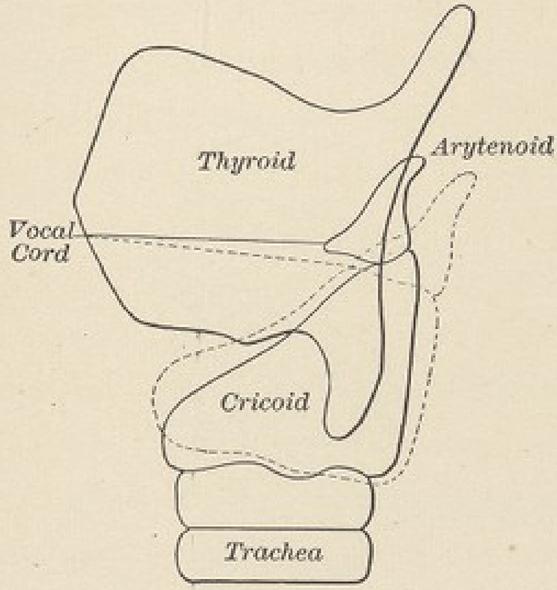

Fig. 4.—Action of crico-thyroid muscles in tensing the vocal cords.

was that on contracting they pulled down the anterior part of the thyroid cartilage, and so increased the tension of the vocal cords, by lengthening the distance from the anterior commissure of the thyroid to the vocal processes of the arytenoid cartilages, the cricoid cartilage remaining fixed and immovable. This explanation, in view of the experiments and observation of many of the best investigators, such as Hooper,* Neuman,† Onodi,‡

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* Trans. Amer. Laryngol. Assn., 1883, p. 118.

† Ann. des Mal. de l'Oreille et du Larynx, vol. xx, Paris, Nov., 1894.

‡ Ungar. Arch. für Med. Wisch, vol. iii, 1894.

Jelenffy,* Moura,† and Desvernine,‡ can no longer be held as correct; on the contrary, it has been proved beyond any question that the crico-thyroid muscles, on contracting, pull up the anterior border

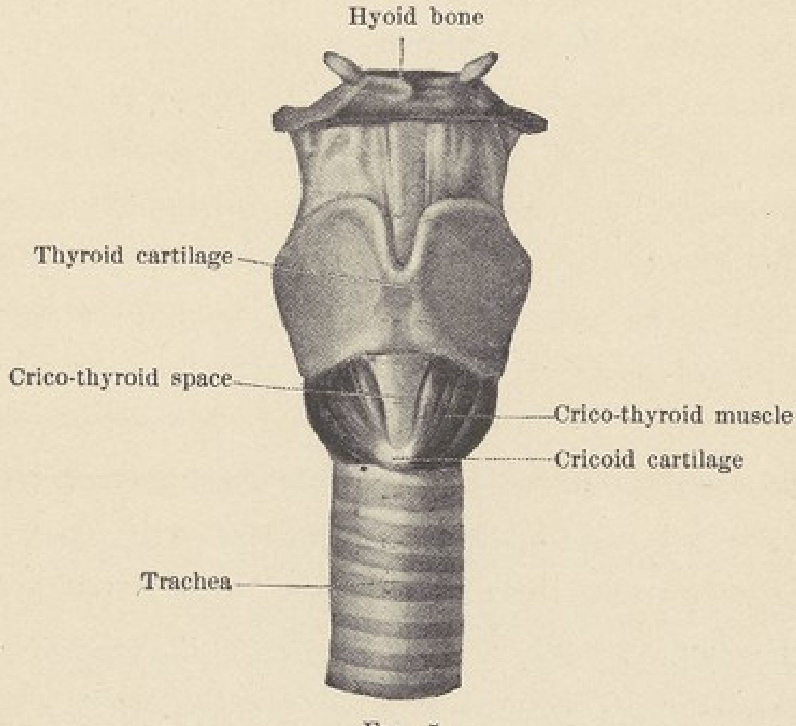

FIG. 5.

of the cricoid cartilage, the thyroid cartilage remaining fixed. This may be made plain by considering, first, the distribution, as given above, of the crico-thyroid muscle, attached as it is to the anterior surface of the cricoid cartilage, and extending

* Arch. für die gesammte Phys., 1873, vol. vii.
† Ann. des Mal. de l'Oreille, 1885, vol. xi.
‡ Jour. of Laryngology, vol. ii., London, 1888.

upward and outward, to be inserted into the inferior border of the thyroid and into the anterior border of its lower cornu. The anterior portion of the muscle on contracting will approximate the cricoid and thyroid cartilages in front. In this action, the thyroid is fixed by the extrinsic muscles; and the anterior part of the cricoid, rotating on the axis which unites the articulations between the cricoid and the lower cornua of the thyroid, is drawn upward. That part of the cricoid behind the crico-thyroid joints is rotated downward, describing an arc, the arytenoid cartilages following the same movement, and consequently the vocal cords are elongated and tensed. The oblique fibres, moreover, assist in the tension of the vocal cords; pulling as they do from the fixed cornua of the thyroid cartilage, they draw the cricoid cartilage slightly backward,* and this action tends to increase the tension of the cords. When we bear in mind that not a single extrinsic muscle is attached to the cricoid cartilage, and reflect upon the mechanical construction of the larynx, it is difficult to comprehend by what mechanism it can possibly be fixed in a sense that will permit the thyroid cartilage to be pulled down upon it, as was formerly

* Quain's Anatomy, p. 532, vol. ii.

stated. On the contrary, its extreme mobility is one of its most striking characteristics. In vocalization, the thyroid cartilage, steadied by the powerful extrinsic muscles inserted into it, may be regarded, as compared to the cricoid, as the passive agent; while the latter, owing to the manner in which it swings upon the short processes of the thyroid behind, and to the mobility of the parts in front, and to a certain extent on its sides, is permitted to play upon the thyroid with every delicacy of adjustment, through the agency of the intrinsic muscles of the larynx attached to it, and to another force presently to be alluded to. Jelenffy has conclusively proved that the thyroid is fixed in vocalization, and the upward movement of the anterior part of the cricoid cartilage on electrical stimulation of the crico-thyroid muscle has been graphically shown by him, as well as by Hooper, Onodi, Merkel,* and Neuman. It is interesting to note here that paralysis of this muscle is accompanied by inability to produce high notes. Onodi has furthermore proved that the crico-thyroids in contracting unquestionably assist in adducting the vocal bands, and increase their tension by bringing the plates of the thyroid cartilage somewhat nearer together.

* Anat. und Phys. d. Mensch, Stimme, Leipsic, 1863.

The Lateral Crico-Arytenoid Muscles.—These muscles arise from the upper margin of the lateral portion of the cricoid cartilage and are inserted into the muscular process of the arytenoid cartilages. They pass upward and backward, and, having their fixed point in the cricoid, they draw the outer angle of the arytenoid cartilage forward, thus throwing its vocal process inward and closing the glottis. The movement they impart to the arytenoid cartilage is in all respects similar to that given to it by the thyro-arytenoid, although their pull has a tendency to place the glottis higher.

The Thyro-Arytenoid Muscles (Fig. 3).—These muscles arise from the posterior and lower portion of the angle of the thyroid. They pass backward along the outer side of the vocal cords, to be inserted into the base and anterior surface of the arytenoid cartilages.

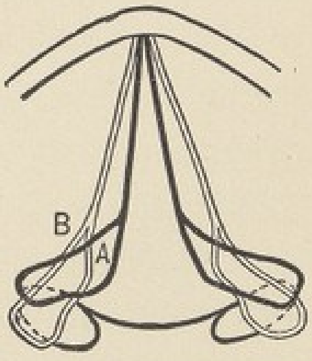

Fig. 6.—Action of thyro-arytenoid muscles in rotating the arytenoid cartilages and approximating the vocal processes and cords, from B to A.

Each muscle is usually described as composed of two portions, an internal and external. The internal is attached to the vocal band in its whole length, and is inserted into the external surface of the vocal process; the external portion spreads out and is inserted into the anterior face of the arytenoid cartilage as far outward as the muscular process.

The action of the internal portion would be to draw forward the arytenoid and posterior portion of the cricoid and antagonize the action of the crico-thyroid, the effect being to relax the vocal cords. If, however, the cords are kept tense and approximated by the action of other muscles, it probably serves only to modify their elasticity and consistence. The action of the external fibers of the thyro-arytenoid is, as we shall see, to rotate the arytenoid in such a manner that its anterior margin and vocal process will be drawn inward and downward. The downward movement, however, is impeded to a certain extent by the elastic counter-tention of the vocal cords. The action of the thyro-arytenoid, as a whole, is, consequently, to adjust the vocal cord, to modify its elasticity, and probably also to increase or diminish its vibrating surfaces in the production of tone. This muscle, it is very evident, must play an important part in voice production, from the lowest to the highest note. The combined action of the thyro-arytenoids and the lateral crico-arytenoids in lowering and raising the vocal cords is interesting as affecting the tone produced in the larynx. The thyro-arytenoid, as we have seen, being attached to the arytenoid cartilage at a higher level than the lateral crico-arytenoid, draws the upper portion of the cartilage more powerfully downward and forward at the same time the vocal process is depressed. The glottis then, when this muscle is acting, is lower than when the vocal cords are in a state of rest.

When, however, the glottis is adjusted by the lateral crico-arytenoid muscles, its plane is higher than when at rest, because these muscles act upon the muscular processes of the arytenoid cartilages and draw them down, and the vocal processes and the principal part of the arytenoid is forced to rise, and consequently the vocal cords are placed on a higher plane. This change does not affect the whole of the glottis, but the posterior portion only, and hence it would be more correct to say that, in adjusting the glottis, the thyro-arytenoid muscles give it such an inclination that the posterior end lies lower than its anterior; the lateral crico-arytenoids, on the contrary, cause a different inclination, raising the posterior part of the glottis higher than the anterior. The changes in the level of the vocal cords brought about by the action of these muscles probably has more or less effect upon the tone produced, for it seems likely that these changes in the position of the glottis must affect the current of air as it strikes against the vocal cords in different ways. The increased height of the glottis caused by the lateral crico-arytenoid muscles must produce a more gradual convergence of the side walls of the lower laryngeal cavity, and consequently the current of air will pass onward with little interruption and strike with full force at the glottis. On the other hand, the lower position of the glottis consequent upon the action of the thyro-arytenoids must produce a more rapid convergence of the side walls of the cavity, and the current of air will be partly expanded upon the walls before reaching the vocal cords.* This change in height of the glottis would mean a change in the angle of incidence of the vocal cords, and, as we shall see, Koschlakoff has found that the angle of incidence effects the type of vibration of the cords and possibly the note produced.

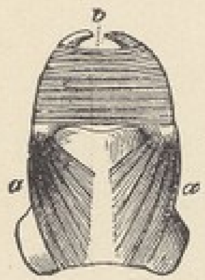

FIG. 7.—View of the transverse arytenoid muscle (*b*) and the posterior crico-arytenoid muscle (*a*) from behind. (Meyer.)

THE TRANSVERSE ARYTENOID MUSCLE.—The transverse arytenoid is a single muscle which passes from the posterior surface and outer border of one arytenoid cartilage to the corresponding portion of the opposite

* Meyer, *op. cit.*

site one. The action of this muscle is to approximate the arytenoid cartilages and to close that portion of the rima glottis which is included between the arytenoid cartilages.

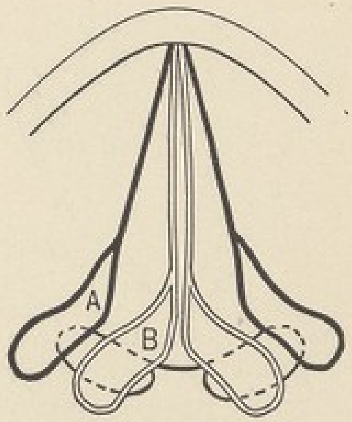

Fig. 8.—Action of transverse arytenoid muscles in pulling cartilages, from A to B.

The muscles above described are the adductor, or closing muscles of the glottis.

The Posterior Crico-Arytenoid Muscles.—The two other muscles of the arytenoid group have the opposite effect, viz., of widening the glottis. The more important muscles producing this effect are the posterior crico-arytenoids, which are essentially the respiratory muscles of the larynx, in contradistinction to all the other muscles of this organ, which are essentially phonatory. The posterior crico-arytenoid muscles arise upon the posterior surface of the plate of the cricoid cartilage, occupying, indeed, each lateral half of the plate; the fibres then converge, and are inserted into the muscular processes of the arytenoids. They draw down these points of the arytenoids backward and inward. The greater part of the arytenoid, which lies within the cricoid cartilage, is consequently drawn outward, that part which is furthest from the fulcrum upon the cricoid, namely, the vocal process, making the largest excursion in that direction. Thus their action is to widen the entire glottis in such a manner that its greatest width lies between the vocal processes.

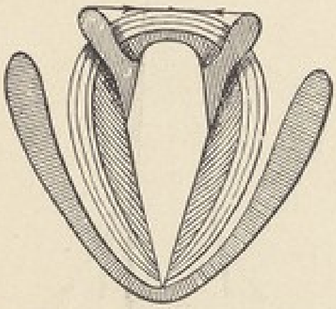

Fig. 9.—Form given to the glottis by the posterior crico-arytenoid muscle. Direction in which the muscle pulls indicated by arrows. (Meyer.)

The above muscles act directly upon the vocal cords. Two other muscles, the thyro-epiglottic and the aryteno-epiglottic, make an almost complete girdle round the cavity of the larynx, and, in contracting, they necessarily constrict the aperture of the larynx, tending to approximate the vocal bands.

The Sterno-Thyroid and Thyro-Hyoid Muscles.—These muscles are of importance, for, as has been shown by Hooper * and others, they perform an important rôle in fixing the thyroid during phonation. The sterno-thyroids arise from the upper edge of the sternum and are inserted in the sides of the thyroid cartilage. The thyro-hyoids arise from the sides of the thyroid, above the insertion of the

* *Op. cit.*

sterno-thyroids, and, passing upward, are inserted into the lower part of the body and great wings of the hyoid bone. The action of the sterno-thyroid would be to lower the larynx; of the thyro-hyoid to raise it; acting together, however, they undoubtedly serve to steady the larynx during phonation and enable the intrinsic muscles of the larynx to perform their functions with a greater degree of nicety.

Let us examine more particularly the action of the larynx and of the parts above and below in voice production. We know that the larynx moves a little downward in the utterance of deep notes and (in certain methods of voice production) rises with the ascending scale. The lowering of the larynx in deep notes, however, is a consequence rather than the cause of low pitch, as a singer instinctively relaxes all the muscles supporting the organ that the cords may be in a position of least tension. The lowering of the chin toward the breast bone is a part of a similar natural adjustment. The reverse of this action may be seen in tenors and sopranos when the head is thrown back in the delivery of notes produced by the method known as the *coup de glotte*. The whole distance, however, which the larynx traverses, from the deepest chest to the highest falsetto note, is so inconsiderable that the mere lengthening or shortening of the vocal tube within so limited a range can have little, if any, effect on the pitch of the sound produced, and it should be remembered that, if the tongue be kept at rest, a great part of the scale can be sounded without any material change whatever in the position of the larynx itself. The elevation of the larynx just spoken of must not be confounded with the approximation of the cricoid upon the thyroid cartilage, and the consequent obliteration of the interval between their borders in front, that is, of the crico-thyroid space (Fig. 4). The contraction of the crico-thyroid muscles can not in any way fix the position of the larynx as a whole, but only the position of the vocal cords in respect to their tension. Approximation of the cricoid upon the thyroid cartilage anteriorly stretches, as we have seen, the vocal cords. Accordingly, we find that in the lowest part of the chest register the interval between the cartilages is greatest, whereas, in the upper notes, the crico-thyroid space is practically obliterated, as can be easily verified by placing the finger in the space above mentioned.

With respect to the parts immediately below the glottis, the trachea rises to a slight extent as the voice goes upward. This fact, however, has probably little or no effect either on the pitch or the quality of the note, but is merely the mechanical result of increased breath power, the larynx, as has been shown by Hooper,* Onodi,† and Neuman,‡ being blown upwards by the breath current and pulling the windpipe with it. In the chest itself there is this notable difference in the two registers, that whereas in the lower the thoracic wall shakes strongly, as can be felt on applying the hand to the singer's chest, the vibration gradually becomes fainter as the high notes are reached, finally ceasing altogether in the falsetto. Speaking broadly, the general act of phonation is as follows: The thyroid cartilage is fixed, as we have seen, by the very strong muscles attached to it, and Meyer says # direct tension of the vocal cords is produced to some extent by the mere adjustment of the glottis, partly through the approximation of the vocal processes of the arytenoid cartilages, and partly through their depression by the thyro-arytenoid or their elevation and adjustment by the lateral crico-arytenoid muscle. Following this preliminary adjustment, there is a fixation of the arytenoid cartilages by the combined action of the posterior with the latero-crico-arytenoids. The rearrangement of the vocal ligaments themselves is due to the action of the internal and external thyro-arytenoid muscles. Tradition says that

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* *Loc. cit.* † *Loc. cit.* ‡ *Loc. cit.*
\# The Organs of Speech, New York, 1884.

the vocal cords rise in phonation because they follow the general rise of the arytenoid cartilages. Unquestionably the arytenoid cartilages obtain their greatest height at the moment of the closing of the glottis, but Neuman * has proved that, through the action probably of the thyro-arytenoid muscles, there is an actual sinking of the vocal cords when they are stretched, and that their posterior insertion is lower than the anterior. This change in the plane of the vocal cords, this dipping of their posterior insertions, has unquestionably been lost sight of in the general rise of the larynx, as seen in the laryngoscope in the production of high notes.

We have seen that, owing to the manner in which the thyro-arytenoid muscles pull upon the arytenoid cartilages, the vocal cords are pulled down and relaxed by that muscle. This may be plainly seen in cases of paralysis of one recurrent nerve, where on phonation the affected cord lies invariably on a higher plane than the healthy one. This descent of the vocal cords on phonation Neuman has shown very prettily as follows: He cut the right recurrent nerve and the right superior laryngeal, thus preventing the crico-thyroid muscle from acting, and the right cord could

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* *Loc. cit.*

be seen distinctly higher than the left, even when the left was in the respiratory position. On stimulation of the cut end of the nerve, the position assumed by the right cord was distinctly lower than before, and yet not quite on the same plane as the tensed normal left cord. Furthermore, the right cord did not assume its normal position until the right crico-thyroid muscle was brought into action by artificial stimulation. We emphasize this sinking of the vocal cords in phonation, for, as we have shown, the shape of the lower laryngeal cavity is unquestionably altered by such movements, and the manner in which the air blast strikes the vibrating cords influenced. It may be readily seen that the extent to which the cords must sink in phonation must vary in different people, and have a distinct effect upon the original pitch of the voice. We have often noted this sinking of the cords in singers—that on the production of a high note the arytenoids and posterior parts of the vocal cords disappear from the fixed mirror, leaving only the anterior commissure visible. This sinking out of sight of the vocal cords under such conditions is easily explained when we remember, first, that, as the crico-thyroid muscles contract, they pull up the anterior surface of the cricoid cartilage, causing the posterior part of the ring to describe an arc backward and downward, and that the arytenoid cartilages follow the downward movement. Second, the position of the cords in the horizontal plane is dependent not upon the arytenoids alone, but upon the actual attachments of the vocal cords to the vocal processes. Third, as Neuman * again has shown, the elasticity of the tense vocal cord itself prevents the rising of the posterior part of the cord, and actually pulls down the vocal process and angle of the arytenoid, instead of raising it.

For the act of phonation, the general adjustment of the glottis, and the approach of the vocal processes having taken place, the larynx having assumed its lowest possible position, and the extrinsic muscles being completely relaxed, the deepest notes are produced by a contraction of the external fibres of the thyro-arytenoid muscles which pull forward the apices of the arytenoid cartilages and approximate the vocal cords, the internal fibres of the thyro-arytenoid probably remaining passive. We say the internal fibres probably remain passive, for while in contracting they may not increase the tension of the vocal cords, they certainly render their free edges more prominent,

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* *Loc. cit.*

and tend to shorten the vibrating plates, which is not to be desired in the production of low notes.

The ascent of the next two or three tones is probably obtained by the gradual relaxation of the external and the gentle contraction of the internal fibres of the thyro-arytenoid muscle. A point is thus reached where the vocal cords are held together by the transverse arytenoid muscle, with some slight assistance, perhaps, from the lateral crico-arytenoid. A new period in the production of the notes now begins, in which the cords are gradually made more tense and brought into closer contact. Now the greatest increase of tension, as we have shown, is caused by the action of the crico-thyroid muscle, but some slight tension is also brought about by the contraction of those fibres of the internal portion of the thyro-arytenoid muscles which are attached in front to the vocal cord and behind to the vocal process of the aryttenoid cartilage, the result being to tighten that division of the cords in front of their attachment to the vocal processes, as Ludwig was the first to demonstrate. At this point the transverse arytenoid comes into full play, and completely shuts the cartilaginous glottis. Now there is a gradually increasing pull of the crico-thyroid muscle until the crico-thyroid space is almost obliterated and the cords are tensed, as far as it is possible for them to be in voice production, with this arrangement of the various muscles concerned. If looked at with the laryngoscope at this time, there is a perceptible change from the horizontal plane of the cords, the posterior ends being distinctly lower, the arytenoids having passed out of the sight in the laryngeal mirror, a point which was emphasized above. Having reached this stage in the production of the lower register, for any other further elevation of pitch a complete rearrangement of the vocal apparatus is necessary. We, perhaps, should have referred before to another element in the tensing of the vocal cords, viz., that furnished by the blast of air. Its effect upon their tension has been experimentally proved by Hooper and Müller, and it is, of course, a factor which is present from the lowest chest to the highest head note. To raise the pitch, the expiratory blast must be increased, for, as we have seen, the pitch of the tone depends upon the strength of the expiratory pressure, whether the increased pressure be produced by pain or intentionally, for the purpose of creating a higher tone. This is Meyer's * opinion, and, though he is contradicted by Morell Mac-

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* *Loc. cit.*

kenzie,* we are inclined to believe that he is right in his statement. In this connection, Meyer calls attention to the fact that the voice of a person speaking in violent anger will often rise suddenly to an exceedingly high pitch. The constant use, moreover, of a very strong blast, as in forcing high notes, causes singers to lose the power of modulation, and turns their notes into a scream. This is the complaint made against so many Wagnerian singers, and, as we know, with many persons the singing of Wagner's music is synonymous with screaming and forcing the voice. *Apropos* of this fact, Morell Mackenzie says: † "It is a mistake to suppose that Wagner's style is more injurious to the voice than that of other masters. To say that Wagner's method of treating the voice is part of a general design, or that his demand for great declamatory emphasis destroys the vocal organs, seems to be absolute nonsense. It is also a mistake to say that Wagner drowns the voice with the orchestra." The truth is, the break-up of the voice of so many Wagnerian singers arises primarily from a bad method of singing, and the consequent overstraining and forcing of the voice.

We have seen that a certain point is reached in

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* Hygiene of the Vocal Organs, London, 1888. † *Loc. cit.*

the production of the chest notes, where to go higher in the scale a rearrangement of the muscles and cartilages of the larynx is necessary; in other words, to go from the highest chest to the head or falsetto notes a change in the mechanism of producing the tones is necessary, and many, or all, of the previously relaxed muscles suddenly contract, as is shown by the closing of the crico-thyroid space as we pass from one register to another. In the production of the falsetto register the centre of vibration is much further forward than in the higher normal register. Many artists by trying a falsetto note are able to determine from the timbre of this single note whether they are in good voice or not. We invariably find that, when it is impossible for them to sing the falsetto, the anterior commissure and that part of the cords immediately connected with it are out of condition. In many text-books it is stated that the falsetto voice is dependent upon the approximation of the false vocal cords, that is, of the ventricular bands. We know that in a close approximation of the glottis there is a narrowing of the ventricular bands, and that they add as resonators some acoustic property to the tone, but that the fundamental tone is produced by the false vocal cords is absurd. In the production of the falsetto voice the cartilaginous glottis is tightly closed and the posterior portion of the cords immediately in front of the arytenoids is brought tightly together, the superior cavity of the larynx being narrowed by the action of the constrictor muscles, and there is an increase in tension, the strings becoming much shorter and tenser, and, with the accompanying tensing of all the tensor-muscles of the larynx, the limit of vocal pitch is reached.

The above would seem to be a plausible explanation of the action of the intrinsic muscles of the larynx. Some anatomists hold that the thyro-arytenoid muscles tense, others that they relax the vocal cords. It is plain, however, that without other resultant forces the action of the muscles, especially of the internal fibres, would be to relax the cord, but we do not doubt that their action is counterbalanced by the downward excursion of the vocal processes. Hence we would consider the function of the thyro-arytenoids to be entirely the production of a suitable enlargement or contraction of the edge of the vibrating plates, and that they have little, if anything, to do with the tension of the vocal cords, but act to render them thicker or thinner as the exigencies of pitch require. The intrinsic movements of the vocal cords will be fully described in the chapter on Registers.

CHAPTER III.

RESPIRATION.

THE motive power, or air blast, which sets the vocal cords in vibration is supplied by the lungs, two large sacs lying in the thoracic cavity. To these sacs the air is conveyed through a series of passages. Entering the pharynx by way of the nostrils or mouth, it passes downward through the larynx, and from this to the trachea, or windpipe, which on reaching the chest cavity divides into a right and left bronchus. Each bronchus is then subdivided into smaller and smaller bronchi, called bronchial tubes, within the lung on its own side, the smallest bronchial tubes ending in sacculated dilatations, the alveoli of the lungs or air cells.

On the walls of the air cells, a delicate network of blood vessels, the capillaries, ramify, and it is here that the vital part of the respiratory process, the purification of the blood, takes place. This consists essentially in an exchange of gases between the blood and the air, the blood yielding up some of the waste matter of the system in the form of carbonic acid, and receiving in return a fresh supply of oxygen.

The air thus taken into the lungs soon becomes laden with carbonic acid gas, and loses much of its oxygen. This interchange takes place for the most part in the deep recesses of the alveoli which are remote from the exterior air, only communicating with it through a long series of narrow tubes. The alveolar air could thus be renewed but slowly were it to depend alone upon gaseous diffusion through these long air passages. That the process is not rapid enough to meet the requirements of the body is readily proved by the feeling of suffocation which follows holding the breath for a short time. Nature, however, provides against this danger by adding a respiratory mechanism to the lungs, by which the air within them is periodically mixed with fresh air taken from the outside, while the air in the air cells is stirred so as to bring fresh layers of it in contact with the walls of the alveoli. The mixing is brought about by the breathing movements, consisting of regularly alternating *inspirations* during which the chest cavity is enlarged and fresh air enters the lungs, and *expirations*, during which the cavity is diminished and air expelled.

The chest, in fact, acts very much as a bellows. When the bellows is opened air enters, in consequence of the rarefaction of that in the interior which is expanding to fill the larger space; and when the bellows is closed again, the air is expelled by contraction. To make the bellows quite like the lungs we must, however, have but one opening in it—that of the nozzle—for both the entry and exit of the air; and this opening should lead, not directly into the bellows cavity, but into an elastic bag, filling it, and tied to the inner end of the nozzle pipe. This bag would represent the lungs, and the space between it and the inside of the bellows the pleural cavities. It is in their capacity as bellows of the vocal apparatus, and also as a resonator in the chest cavity itself, that we are chiefly interested in the lungs.

The chest, or thoracic cavity, has a conical form, its apex being turned upward. In front, behind, and on the sides, it is supported by the rigid framework afforded by the spinal column, the breast bone, and the ribs. Between and over these lie muscles, and the whole is covered on the outside by the skin, and on the inside by the parietal layers of the pleura. Above, the aperture opens into the cavity of the larynx; below, it is bounded by the diaphragm, which forms a movable bottom to the otherwise tolerably rigid box. In inspiration the box is increased in all its diameters, i. e., antero-posterior, lateral, and vertical.

The air taken into the lungs in inspiration distends the air cells, and is driven out again mainly by the contraction of the elastic walls of the cells themselves, and the passive reaction of the diaphragm and chest walls. Inspiration, or, in other words, enlargement of the chest, is a more complex act, and may be brought about in several different ways.

We shall first see how the enlargement of the chest in its different diameters is brought about in what we understand as normal breathing, and how these movements are modified in the act of speaking or singing.

The vertical enlargement of the thorax is caused by the contraction of the diaphragm, a thin, sheet-like muscle, with a fibrous membrane in its centre that serves as a tendon. In rest, the diaphragm is dome-shaped, its convexity being directed upward. From the tendon on the crown of the dome, muscular fibres radiate downward and outward to all sides, and are fixed by their inferior ends to the lower ribs, the breast bone, and the vertebral column.

In inspiration, the muscular fibres of the diaphragm are shortened, flattening the dome, and so enlarging the thoracic cavity. The contraction of the diaphragm thus greatly increases the size of the thorax chamber, by adding to its lowest and widest part. The lungs, always in contact with the walls of the thorax, follow this expansion, and their capacity is increased.

The antero-posterior diameter of the chest box is enlarged in inspiration by the raising of the breast bone, and with it the sternal ends of the ribs attached to it, and so the distance between the sternum and vertebral column is increased. This inspiratory elevation of the ribs is mainly due to the action of the scalene and external intercostal muscles. The former (three on each side) arise from the vertebræ of the upper or neck portion of the spinal column, and are inserted in the upper ribs. The external intercostals lie between the ribs, and extend from the vertebral column to the costal cartilages, their fibres sloping downward and forward. During an inspiration the scalene muscles contract and fix the upper ribs firmly, and thus, when the external intercostal muscles contract, the upper rib being fixed, the lower rib is pulled up and not the upper down. In this way the lower ribs are raised much more than the upper, for the whole external intercostal muscles on one side may be regarded as one great muscle, and when the whole muscular sheet is fixed above, and contracts, it is clear that its lower end will be raised more than any intermediate point. The elevation of the ribs tends to diminish the vertical diameter of the chest; this, however, is more than compensated for by the simultaneous descent of the diaphragm.

Finally, the enlargement of the chest is somewhat due to the diaphragm, which, as we have seen, when it contracts, adds to the lowest and widest part of the chest cavity. A lateral excursion is, however, brought about by the rotation of some of the middle ribs at their articulation with the spine. Rotation at this point has the effect of raising and turning outward the curved part of the rib.

In the inspiratory act the lungs are entirely passive, simply following the dilatation of the chest, brought about in the manner just described; in expiration, on the other hand, the active rôle is taken by the lungs, little, if any, muscular effort being needed. As soon as the muscles which have raised the ribs and the sternum relax, these tend to return to their natural, unconstrained position of rest. By these means the chest cavity is restored to its original capacity, and the air expelled from the lungs, rather by means of the contractility of the parts, which were stretched in inspiration, than by any special expiratory muscles.

When a very deep breath is drawn, or expelled, a great many muscles take part in the respiratory movements, and expiration becomes an actively muscular act. The main expiratory muscles are the internal intercostals, which lie beneath the external intercostals, between each pair of ribs, and have a different direction, their fibres running upward and forward.

Forced expiration is accomplished in this manner: First, the lower ribs are fixed or slightly pulled down, by muscles situated in the abdominal wall, arising from the pubis, and attached to the ribs and sternum; then, the internal intercostals, also contracting, complete the process of pulling down the ribs, and so diminish the chest cavity. At the same time, the contracted abdominal muscles press the walls of the abdominal cavity against the viscera, and pressure upward is transmitted to the diaphragm, assisting to diminish the vertical diameter of the chest.

In violent inspiration, as in expiration, many other muscles are brought into play, and are known as the extraordinary muscles of respiration.

Respiratory Types.—Many authors endeavour to draw distinctions between three methods of what we may call normal breathing. As a matter of fact, the clavicular, the abdominal, and the costal types run imperceptibly into one another, and it is a mistake to attribute one method exclusively to men and one to women. Suffice it here to say that, in both sexes, diaphragmatic breathing is the most important; but, as a rule, men and children use the upper ribs, or superior costal breathing, less than adult women.

That the costal type of breathing as used by women of civilized races is largely the result of the corset and tight lacing, is more than likely. May,* of Philadelphia, took tracings of the respiratory movements of eighty-five women, from ten to twenty-two years of age, six belonging to a non or partially civilized race. Thirty-three were of pure Indian blood, thirty-five of mixed blood. Sixty-nine of the eighty-five showed a so-called abdominal respiration. The remainder, all of whom showed a greater or less tendency to the costal type of breathing, belonged to relatively civilized races.

Proper management of the breath being a fundamental condition of good singing, it is of the utmost importance that the proper method of breathing be taught, and it is our purpose to show

* Journal of Physiology, March, 1890.

how fallacious are many of the methods now used in teaching voice production, and to what extent founded on preconceived or misconceived ideas.

In the first place, the direction so often given the pupil in singing, to breathe "naturally," is, to say the least, misleading; for, to get the best effects in voice production, the normal, natural method of breathing does not suffice.

Ordinary breathing has for its end purely and simply the physiological function of purifying the blood; and it is insufficient for singing, which requires an increased chest capacity, an increased volume of inspired air, as well as a carefully co-ordinated management of the chest muscles and of the diaphragm, that the exit and pressure of the expired air may be regulated. All this requires the cultivation, not of natural, but of artistic breathing; and to this end the pupil should be taught *how* and *when* to take the air into his lungs, and how to control and direct the outflow when emptying them. This, as Mackenzie says, is really one of the most difficult things in the whole art of singing, but it must be mastered, at whatever cost. Wrong breathing must be corrected. It is, of course, more generally found among women than men, owing to the fact that the proper action of a woman's diaphragm is impaired by the pressure of tight stays.

Regular exercises in respiration should be practised. The act should be performed naturally, quietly, and at regular intervals, care being taken that the collar bone does not rise to any perceptible extent while the lungs are being expanded. Both inspiration and expiration should be practised so as to adequately fill and empty the chest with the least visible effort, and to take the breath, in speaking or singing, without noticeable interruption of the phrase. On the other hand, the pupil must strive to gain as much control as possible over the expiratory process, so as to "mould the issuing stream of air to any shape," and regulate its volume and force, that none of it may escape uselessly.

The breathing capacity may be increased by proper exercises, such as walking, running, fencing, swimming, dumb-bells, etc. The "vital capacity" of the lungs—that is, the greatest quantity of air which can be expelled from the lungs by a forced expiration, after the deepest possible inspiration—may be very greatly increased by such regular exercises, and we may finally reach in artistic respiration a point where costal muscles play no secondary rôle in chest enlargement, but contribute equally with the diaphragm to that end. In many cases of observation upon our very best singers, it is interesting to note the changes which take place in the lower abdominal wall, as a result of respiratory method and experience.

The conclusions arrived at from many such investigations go far to prove the fallacy of teaching so-called abdominal respiration to singers. Whereas in normal respiration the pressure exercised by the contracting diaphragm pushes out the entire abdominal wall, the singer who employs all the resources of his art to enlarge the chest nevertheless retracts the lower abdominal wall in taking a deep inspiration, in order to maintain a better control of the expiratory act.

The increase in all the diameters of the chest which follows regular practice and exercise in the many ways Nature indicates for this purpose, and the consequent gain in the vital capacity of the lungs, should of itself prevent the arbitrary order of any instructor to his pupil to breathe by any one muscle or set of muscles alone.

This brings us to the various methods of breathing taught by different masters of singing.

We have already seen that in normal breathing there are three different ways in which the respiratory act may be carried out. The methods of breathing, employed in voice production may be likened in their analogy to them, and so considered.

For our purposes, we have preferred to divide these methods of breathing into—1. The superior costal or clavicular. 2. The abdominal. 3. The inferior costal or diaphragmatic.

The superior costal may be illustrated as the breathing of a woman tightly laced, the respiratory expansion taking place chiefly, if not entirely, in the upper part of the thorax, the upper ribs, collar bone, and sternum rising and falling during the respiratory act.

In the true abdominal type the thorax is supposed to remain completely fixed, the diaphragm taking the ribs as a fixed point, contracting to its greatest extent and pushing down the abdominal viscera and so distending considerably the entire abdominal wall.

In the inferior costal type, on the other hand, the inferior ribs (commencing with the seventh) are rotated and elevated, the sternum rising in its inferior portion only, the diaphragm becoming flattened, and the lower abdominal wall being contracted during the inspiratory act.

These three methods of breathing have been the source of much bitter discussion on the part of those advocating one or the other of them as the only proper method of respiration for singers.

The old Italian masters taught that, in inspiration, the anterior abdominal wall should be slightly drawn in—that is, they in reality advocated an inferior costal type of respiration, recognizing, probably, the fact that, when a very great and sudden effort is made, the abdominal wall is drawn in during the respiratory act, this position giving more complete control over the whole act, but especially over expiration, and thus preventing waste of air. Later, Mengozzi,* together with the masters of one of the conservatories, determined upon the following rules, illustrative of breathing, for singers: "The respiratory act in singing differs somewhat from that used in speaking. In speaking, the abdomen is extended in inspiration, and recedes in expiration, while in singing the abdomen must be drawn in during inspiration, returning slowly to its natural state as the chest contracts in expiration, thus retaining as a negative force the air which has been introduced into the lungs."

In 1855, however, Mandl published in the Gazette Medicale his celebrated article, in which he opposed this method of breathing on anatomical grounds, maintaining that the descent of the diaphragm was facilitated by allowing the abdominal walls to be flaccid, and pushed out as far as pos-

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* La Respiration, Dans le Chant, Paris, 1894.

sible in inspiration. Mandl carried his point, and his method was almost universally adopted, and in the Méthode du Conservatoire, published in 1866, Mandl himself was allowed to sing the praises of his theory. Massini, in Italy, adopted and taught the abdominal type, and to such an extent did this fad obtain that, according to Joal,* instruments of torture almost were invented to assist the unfortunate pupils in developing this method. From that time it has been advocated by men of authority and taught by many teachers of the art of singing. Obin and Faure, for example, speak most highly of it. The famous Lamperti is often represented as an advocate of the abdominal method of breathing; but we think wrongly, for, having treated many of the elder Lamperti's pupils, and interrogated them very particularly upon this question, we may unhesitatingly affirm that the elder Lamperti was a strong advocate of the lower costal respiration, always arguing that the abdominal wall should remain quiet, or be slightly drawn in, during inspiration. The evidence of Campanini, Jean de Reszke, and Clara Heyen is in support of the above.

Notwithstanding all that has been written in

* Joal, Revue de Laryngologie, Nos. 8, 9, and 10, Paris, 1892.

favour of this method of breathing, we propose to show that the abdominal as well as the superior costal is wrong, both in conception and practice.

We shall consider these various types of breathing somewhat in detail, for it seems to us of paramount importance that speakers and singers should be better made to understand the enormous influence a correct method of breathing, combined *with a correct position of the vocal cords in singing*, exert not only upon the present production, but upon the future preservation of the voice.

Superior Costal Respiration.—Mandl, in making out his case for abdominal respiration, wrote with great emphasis on the evils which resulted from the superior costal method of breathing. He claimed that all the muscles concerned were greatly fatigued in this respiratory act; that the larynx was pulled down, and the slit of the glottis widened, making the production of a note doubly difficult, and leading first to a great congestion, and, later, to atrophy of the parts, etc.; all of which was founded on false anatomical and physiological data. The truth is, that the superior costal method of breathing does not necessarily lead either to great good or to great harm in voice production. The mere fact, however, that in this method a much smaller amount of air can be inspired, since the movement is limited to the cone of the chest, where all its diameters are smallest, is in itself, we hold, an all-sufficient reason for not using the method, except, of course, as an adjunct to the larger and more profound inspirations produced in the inferior costal type. Finally, Joal says that, if we except Laget and Bonheur, superior costal breathing for men is condemned by all authors. On the other hand, it has been recommended for female singers, notably by Hamonic,* on the ground that the sexual organs in women are likely to be compressed and pushed out of place if they practise abdominal breathing. This observation has been often advanced as an argument against abdominal breathing, and perhaps with some justice.

Abdominal Respiration.—In abdominal respiration a considerably larger amount of air may be drawn into the lungs than in the type we have just been discussing, for the entire chest is enlarged in its vertical diameter. This fact has been proved by both Lennox Browne † and Joal, ‡ by spirometric tracings taken upon a number of people. While a distinctly better type of breathing than the costal, the same objection, though in a lesser

* Manuel du Chanteur, Paris, 1888.

† British Laryngological Society, March, 1892.

‡ *Loc. cit.*

degree, may be urged against it, namely, that it is at best a *partial* respiration only; it is respiration produced by but one of the several means we have at our disposal for enlarging the capacity of the chest on inspiration, and of controlling the outflow of the inspired air.

The inferior ribs, by whose movement, as we have shown, the antero-posterior and lateral dimensions of the chest are so much increased, remain almost immobile, and the relaxed abdominal muscles are in a condition to greatly hinder a co-ordinated, well-controlled expiration. Mandl laid great emphasis on the point that in this method of breathing the movement of the abdominal muscles themselves, to a large extent, brought about the vertical enlargement of the chest, the diaphragmatic movement being to a certain extent passive, and following the downward displacement of the abdominal viscera, and there was consequently little if any fatigue of the diaphragm or of the external intercostal muscles. The assumed prevention of fatigue to these muscles was perhaps the most important factor in the good results which he claimed came from his method.

Why this should be an argument in favour of abdominal breathing we fail to see. The various muscles controlling respiration, like our other muscles, were given us for use, and we know full well that it is only by constant and judicious exercise that any muscle or set of muscles can be made to produce the best results, whether they are used in propelling a boat or in producing vocal tones.

Furthermore, that the chest may take in the largest amount of air possible, and that it may be the sounding board and resonator Nature intended, it must be enlarged in inspiration, in all its diameters, and not in one direction only, which is practically the case in abdominal respiration.

Finally, the pressure brought to bear on the pelvic organs in this method may be, as Joal remarks, the point of departure for pathological changes in these organs, and he gives two instances in comparatively young girls where serious trouble was brought on by the excessive practice of the abdominal method of breathing, and cites that the symptoms were at once relieved by changing the method of respiration. Dr. Wing,* of Boston, has had a like experience of the evil effects of this pernicious method.

Inferior Costal and Diaphragmatic Respiration.—We use this mixed term to describe a more or less general respiration, in which all the

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* Boston Medical and Surgical Journal, 1880.

external intercostal muscles, as well as the diaphragm, are brought into play. We say advisedly, all the external intercostals, for it is our practice in this method to have the subject first raise as far as possible, by muscular effort, the upper chest, which is then kept ostensibly fixed, in inspiration and in expiration. The thoracic cavity is then enlarged in the transverse, antero-posterior, and vertical diameters, the greatest movement, however, taking place at the level of the lower ribs; all but the three or four upper ribs, nevertheless, participate in the excursion, the diaphragm at the same time contracting and curving downward, but to a less extent than in purely abdominal breathing, the lower anterior abdominal wall, being of course drawn in during inspiration, but returning during expiration to its normal position.

It has been proved beyond question that the amount of air taken in, in this modification of the respiratory act, is much greater than by any other method, as evidenced in the experiments of Miss Pollard* and Joal.† Joal found in the case of a number of women, some of whom had received and some who had not received instruction in the art of

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* Journal of Physiology, March, 1890.

† Revue de laryngologie et d'otologie, Bordeaux, April, 1890.

breathing, a very distinct increase in their lung capacity after practising the inferior costal method; they having, in the first instance, used the superior costal type. Again, taking a number of men who breathed naturally—that is, with expansion of the abdominal wall on inspiration—Joal found a considerable increase in the amount of air inspired, on compressing slightly the lower abdominal wall and having them breathe by the inferior costal method.

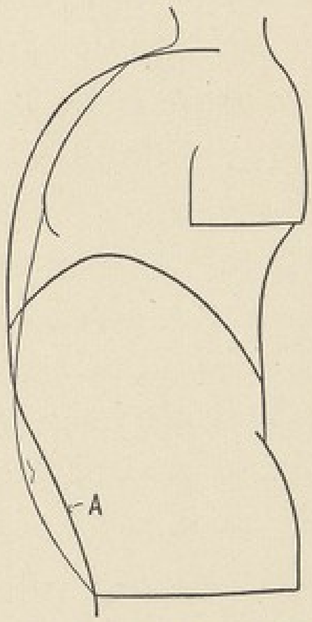

Fig. 10.—Fixed high chest or modified inferior costal respiration.

And again, taking a number of trained singers who could use any of the three methods spoken of above, he found the amount of air inspired, when they used the inferior costal, to be considerably greater than either in the superior costal or abdominal type.

We have not thought it necessary, on our own part, to make any experiments on this point. We were long since convinced that the inferior costal was the proper method of respiration for singers and voice users, but it seemed to us that the act might be made more general, more complete, by adding to it the superior costal elevation, alluded to above; for in this manner, and in this manner alone, are we bringing into play every muscle and every means Nature has given us, not only to fill the lungs, but also to increase the resonating function of the chest. We might express this better by calling it the *fixed high-chest method, or the breathing of singers.*

By thus elevating the chest and keeping it fixed, the apices of the lungs become filled to their greatest possible extent with air, while in the excursion of the lower ribs and diaphragm during respiration the antero-posterior diameter of the upper chest remains a constant factor.

The thoracic cavity then is in a position which permits the lungs to expand to their fullest extent, and a secondary resonance from below is added to the voice, a sort of complementary timbre, the fixed upper thorax allowing the least possible change of colour during tone production. We know that the intensity and timbre of the voice is not only dependent upon the vibrations of the vocal cords, but upon the vibrations of the air in the parts above and below. With a high, fixed chest, we greatly add to the tone vibrations in the chest and accessory cavities of the nose and mouth, and it is this very increase and combination of facial and thoracic tone fortification, or overtone formation, which gives the enormous carrying power to tones produced by this method. It will be seen later how greatly this method of breathing, combined with a properly poised larynx, not only adds to the beauty and the preservation of the voice, but may be the means of restoring voices lost or impaired through hard usage, and improper or faulty methods of voice production.

We have thus far considered the act of inspiration only. But we must remember that it is not alone necessary for a singer to have a larger quantity of air than usual at his disposal, but he must know how to use it to the best advantage in the production of vocal tones. However abundant the supply of air may be, a short, jerky respiration makes it impossible to sustain or colour the phrase; and, as we have said, the control over the expiratory act is, to say the least, much easier of attainment in the method we advocate, where all the muscles concerned are on the alert, as it were, than in either the superior costal or abdominal methods, where the most important muscles concerned in respiration are relaxed and off their guard.

Again, in this method the control of the blast of air in expiration is assisted by the fixation of the upper part of the chest. It must be remembered that these muscles, inspiratory and expiratory, must be kept in a condition of constant abeyance in singing, and await the desired preponderance in the action of one or the other at any instant; that is, their functional independence is, after all, the secret of vocal success. The position of the diaphragm and of the abdominal walls in inferior costal respiration also assists in the control of the breath. On this point Mackenzie* says: "When the abdomen is drawn in in inspiration, one is to a much greater extent master of the expiratory act than when the diaphragm is lowered and the abdominal wall extended, as in abdominal breathing"—a point also emphasized by Gottfried Weber.†

To-day, practically all authorities—for we must consider our greatest singers as authorities—recommend the drawing in of the abdominal wall in inspiration, since it fixes the movable viscera, and so makes a point of vantage for the action of the diaphragm. The *extent* to which the abdominal wall should be retracted, however, is a somewhat debated question. No less an authority than Jean de Reszke declares that the abdominal wall should be retracted in its inferior portion only—i. e., as high as the belt—the pit of the stomach being allowed to follow the

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* Hygiene of the Vocal Organs, London, 1888.

† Caecilia, t. xvii, 1835.

general excursion of the diaphragm and lower ribs; and we are not sure but that his opinion on this point should be considered final. Pol Plançon is a strong advocate of the type of the breathing used by Jean and Edouard de Reszke, his perfectly immobile chest in difficult phrasing being a salient feature of his style. In Melba, Eames, and Nordica we see types of "high-chest" breathing. In Patti we see what a perfect vocal poise and admirable respiratory method will do toward preserving the voice.

CHAPTER IV.

THE VOCAL RESONATORS.

The resonating cavities above the slit of the glottis are numerous and important. Immediately over the vocal cords, on either side are two small pouches whose edges form the ventricular bands. The exact rôle played by these pouches in the production of the human voice has caused some discussion, but they must certainly be included among the resonators.

Extending from the larynx itself is a passage known as the pharynx, which communicates above with the posterior nares and with the cavity of the mouth. The communication between the nose and the pharynx may be entirely cut off by the soft palate, when under certain conditions it is raised and pressed against the posterior wall. This position of the soft palate gives the voice that peculiar and objectionable quality known as *throatiness*, a condition also assisted by the posterior elevation of the tongue. Looking into the open mouth we can see the soft palate, with the uvula hanging down vertically, and in its normal position, meeting the posterior part of the tongue and dividing the cavity of the mouth from that of the pharynx and posterior nares. In swallowing, the uvula and soft palate are drawn backward and upward until they press against the posterior wall of the pharynx. The pharyngeal wall is so modified as to assist this closure, and as the soft palate meets the posterior wall, the back and sides of the pharynx are pressed together by the superior constrictor muscle, whose rôle is to constrict and draw together the walls of this cavity. The prolongations of the soft palate, which are seen on either side of the interior of the throat, are known as the fauces. They are sharply defined folds consisting of two ridges, anterior and posterior. They are known as the pillars of the fauces, and between them on either side lies the tonsil. Each pillar contains a bundle of muscular fibres. The anterior one is known as the palato-glossus muscle, which is connected with the under part of the side of the tongue. The posterior muscle, known as the palato-pharyngeus, runs downward and backward, and is attached partly to the posterior and inner side of the thyroid cartilage and partly to the side of the pharynx. Both these muscles play an important rôle in voice production.

The tonsils vary in size in different people, and are sometimes absent. Their existence in the adult is unnecessary, and as they serve no good purpose, they are best removed if they give the slightest trouble.

We have now to deal with that important resonance chamber, the mouth. It is a large, spacious cavity, the roof being formed by the hard palate. The parts composing its floor are soft, and only partially fixed by their connection with the lower jaw. The anterior border of the mouth is bounded by the lips. A number of muscles, some entirely situated within, and others entering them, enable the lips to assume different shapes and to open and shut in a variety of ways and degrees. The posterior border of the mouth, as we have seen, is bounded by the soft palate and its pillars. The interior of the cavity of the mouth can be enlarged by the depression of the lower jaw, and modified in its form by advancing the latter, and also altered in a great variety of ways, both in form and width, by the activity of the tongue.

The remaining resonating cavities with which we have to do are those of the nose and its accessory sinuses. The nasal space consists of two cavities, separated from each other by a partition known as the septum. Its floor is parallel with the long axis of the mouth, and separated from it by the hard palate. The nasal passages themselves have their extent of surface greatly increased by projections of bone, known as the spongy or turbinate bones, three in each passage. The mucous membrane covering these is very vascular, and the immediate purpose of these convolutions is to present a greater surface over which the air may pass on its way to the chest cavity, and so be tempered, and to some extent filtered and saturated with aqueous vapour, before it passes to the lungs. The heating function of the nose is most important, and it is absolutely necessary that a singer should always breathe easily through the nose, nothing interfering more with the development of the overtones of the voice than a thickened or catarrhal condition of the nasal mucous membrane.

On either side of the nasal passages are hollow spaces known as sinuses, in the bones of the face, which communicate with the nasal cavity. These spaces naturally vary in size in different persons, and they have much to do with vocal resonance. There is also a posterior or sphenoidal, and two anterior or frontal sinuses, which act as resonators, but are not as important as the lateral or maxillary sinuses called the antra.

We shall see in a later chapter the extent to which a tone in any musical instrument may be modified and given a particular quality by the overtones which are developed in the sounding board of the instrument. In a violin, for instance, it is the condition and elasticity of the wood and its sounding board upon which the development of its overtones depend. The condition and shape of the resonance cavities above described give to the human voice a peculiar beauty and timbre. It is therefore plain that the education of these parts must be very thorough, since the bad management of any one of them will mar or even destroy the quality of a voice. It is well known that for every tone there is an air column which most powerfully re-enforces it, and also that the resonator should be exactly tuned to produce the fundamental note of the instrument. In the human voice, the string or reed of the musical instrument is represented by the vocal ligaments, and the sounding board by the cavities above and below the glottis, which are infinitely more complicated in man than in any instrument. The timbre of the voice depends on the shape of the various cavities, and the manner in which they are utilized as resonators.

The size and condition of the cartilages of the larynx unquestionably affect the quality of the tone, and this quality is affected in some degree by every new position of the larynx, which shortens or lengthens the vocal tube. The position and shape of the lips and mouth have also the greatest influence upon the timbre of the voice. The mouth is another important resonator, the pitch of which necessarily varies with the changes which take place in its dimensions. Each vowel sound has a natural pitch of its own, and there is one position of the various parts which we have been considering best fitted for the delivery of any given vowel; but it goes without saying that it is only by a skilful management of these parts that they may be given the fitting position in every case; that not only may purity of tone and volume of sound be obtained, but the timbre of the voice modified and most powerfully re-enforced by overtones. Vowel sounds, therefore, should be assiduously practised before the glass, the position of the lips and the shape of the mouth needing particular attention, that the enunciation may be distinct. Mackenzie says in this connection: "Without an artistic enunciation sound loses one of its greatest charms. To a person of taste, a simple ballad sung with feeling and clearness of utterance gives more delight than the finest music rendered by a voice which sounds the notes but murders and mutilates the words." He thinks English artists the greatest sinners in this respect, and attributes it partly to the prominence of consonants and closed vowels in our language, and partly also to the composer, who, from ignorance of the laws of the pitch of vowels, associates syllables with notes on which they can not be properly sounded. The artist naturally prefers to sacrifice the correctness of the vowel sound rather than the purity of the musical tone. The remedy for this, Mackenzie thinks, is that music should be written with an adequate knowledge of all the phonetic peculiarities of the language in which it is sung, and that composers should make themselves acquainted with the capabilities of the vocal organs as they do with the peculiarities of other instruments.

The tongue is a very important factor in the changes which take place in the shape of the mouth in speaking or singing, and, though difficult to manage, this organ may be brought by judicious training under the direct influence of the will, as far as its position is concerned in the emission of notes. The stiffening of the root of the tongue and the consequent rigidity of the surrounding parts is most destructive to purity of tone, and should be especially guarded against.

Much has been written on the education of the soft palate in singing, and a great deal of it in our opinion is unnecessary. Speaking generally, the soft palate should be kept in a negative state; that is, there should be an absolute lack of tension of the muscles composing and surrounding it, that it may properly perform its real function, that of tuning the resonating cavities of the mouth and nose; in other words, the veil of the palate may be considered a portière which, at the summons of the resonators, may be drawn over the opening of the cavity of the mouth or nose, and so apportion the sound waves to those cavities which are best calculated to re-enforce the fundamental tone and develop and make rich the voice in overtones.

CHAPTER V.

TONE AND OVERTONES.

Any sensation or impression received through our organs of hearing is called sound, and all sound is the result of molecular motion. When there is an explosion, for instance, the air expands suddenly and forces the surrounding air violently away on all sides; the resulting motion of the air close to the exploding body is rapidly imparted to that farther off, the air first set in motion coming to a state of rest. The air at a little distance passes its motion on in its turn to the air at a greater distance, and comes itself to rest. Thus each shell of air takes up the motion of the shell next to it, the motion being propagated as a pulse or wave through the air. The motion of the particles of air is independent of that of the wave; as the wave moves forward, each particle makes its own excursion to and fro. Alternate rarefactions and condensations of the air are thus produced; each condensation, together with its corresponding rarefaction, forming what is known as a sound wave. Sound vibrations thus communicated to the air in the form of waves strike the tympanic membrane which is stretched across the passage leading from the external air to the inner ear, and set this membrane into vibration. Its motion is, in turn, transmitted to the ends of the nerve of hearing, and along that nerve to the brain, where the vibrations are translated into sound.

Sound vibrations, however, may not only be heard, but may also be *seen* and *felt*, as in watching

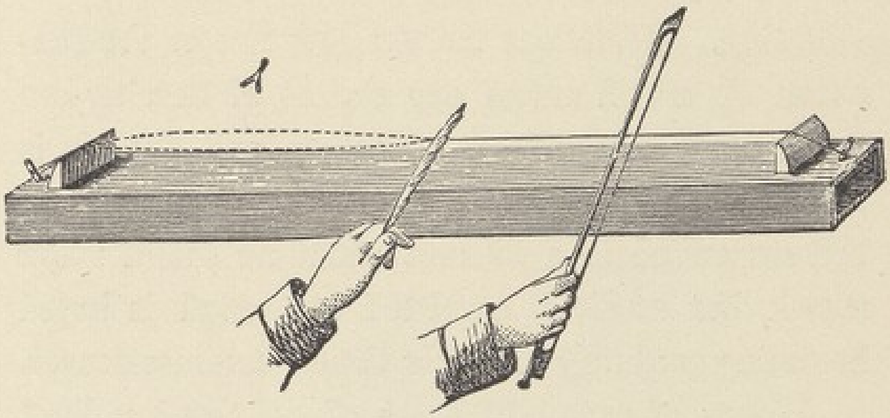

Fig. 11.

a sounding string on which riders have been placed (Figs. 11 and 12), or by drawing a bow over the edge of a plate of metal or glass over which sand has been scattered; the sand is driven from the parts of the plate which vibrate, and collects along certain stationary or nodal lines. On the other hand, vibrations may be *felt* by gently touching a sounding bell or a tuning fork which has been set

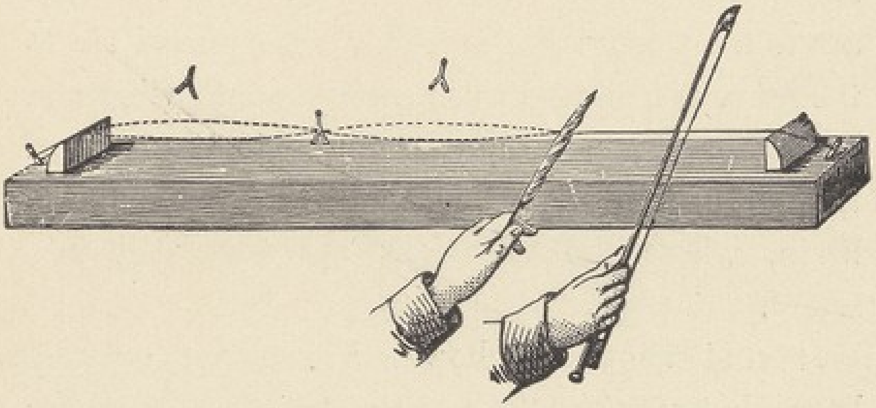

Fig. 12.

vibrating. Vibrations can not give rise to the sensation of sound unless our organs of hearing are thrown into sympathetic vibration, and the air is the medium by which this is accomplished. A bell suspended in a vacuum emits no sound when struck, but as air is admitted the sound is heard becoming gradually louder as the air becomes denser.

Waves of sound, as those of light and radiant heat, may be reflected. The ticks of a watch, held in a given place in front of a concave mirror, will be distinctly heard at the point of focus of the beams of a candle held in the same position as the watch (Fig. 13). This reflection of sound is known as an echo, which, under certain conditions in Nature, can always be heard, provided we are sufficiently far away to distinguish the echo from the original. A sound may be reflected several times in succession, the successive echoes becoming gradually feebler to the ear. In mountain regions, says Tyndall, this repetition and decay of sound produces wonderful and pleasing effects. He instances the fact that the sound of an Alpine horn echoed from the rocks of the Wetterhorn or the Jungfrau is, in the first instance, heard as a harsh sound, but by successive reflections the notes are rendered more soft and flutelike, the gradual diminution of inten-

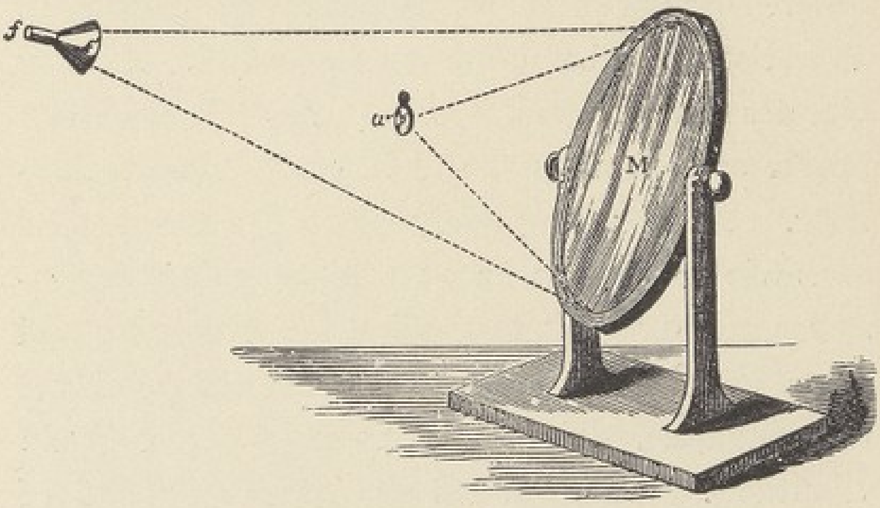

Fig. 13.

sity giving the impression that the source of sound is retreating farther and farther into the solitudes of ice and snow.*

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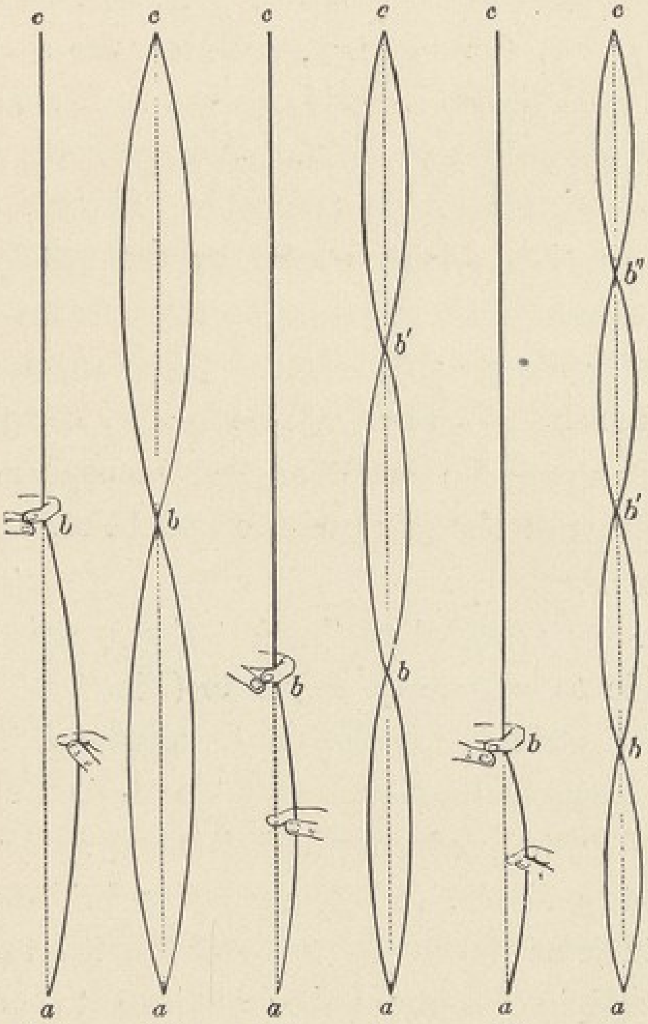
* Sound, p. 41, International Scientific Series.

It is deeply interesting to note that these wonderful little waves of sound may not only rebound from a surface and come back to our ears as an echo, but they can bend around an obstacle, and diffuse themselves at its back. A striking example of this diffraction of a sonorous wave was exhibited at Erith after the tremendous explosion of a powder magazine there in 1864. The village of Erith was some miles from the magazine, but many windows were shattered, and it was noticeable that those turned away from the origin of the explosion suffered almost as much as those which faced it. Vibrations may be simple or compound. A body vibrates simply, when it moves regularly from side to side as a pendulum, and hence pendular vibrations. A vibrating body may execute several eccentric motions at once; a piano string, for instance, when struck, may vibrate not only up and down, but also from side to side and in segments at the same time. The result is a series of compound vibrations. Compound tones are the result of compound vibrations, and are musical if the waves proceed together with perfect regularity. If, on the other hand, the waves of sound interfere with one another, a mere discord is produced. The human ear has the power of resolving compound sounds into their component parts. It should be remembered, however, that it is not the compound vibrations of the string itself, whether of a harp, of a lute, a piano, or a violin, that produce the musical sound; it is the large surfaces, or the sounding boards with which the strings are associated, and the air inclosed by them, that give forth the agreeable musical tones. The excellence of such instruments depends almost wholly on the quality and disposition of their sounding boards, and it can not be too forcibly emphasized that this is also the case with the human voice, whose quality so greatly depends upon the condition and management of the resonance chambers, above and below the slit of the glottis.

We have alluded to the fact that a string may be made to vibrate in segments (Fig. 14). If a stretched string is plucked at its middle point the sound heard is the fundamental or lowest note of the string, to produce which it must swing as a whole to and fro. Place a movable bridge under the middle of the string, thus dividing it into equal parts, and by plucking either of these at its centre a musical note is obtained which is the octave of the fundamental note. Moreover, in all cases, and with all instruments, the octave of the note is produced by doubling the number of its vibrations. It can be proved by the siren that this half string vibrates with exactly twice the rapidity of the whole, one third the string with three times, pro-



(1) (2) (3) (4) (5) (6)

Fig. 14.

ducing a note a fifth above the octave, while one fourth of the string vibrates with four times the rapidity, producing the double octave of the whole string. From this circumstance a law is evolved that the shorter the string the greater its number of vibrations. The vibrations of a string also depend on its tension, thickness, and density; the greater the tension the more rapid will be the vibrations; the thicker the string the lower the note; and the less the density of the string, the other factors remaining equal, the more rapid will

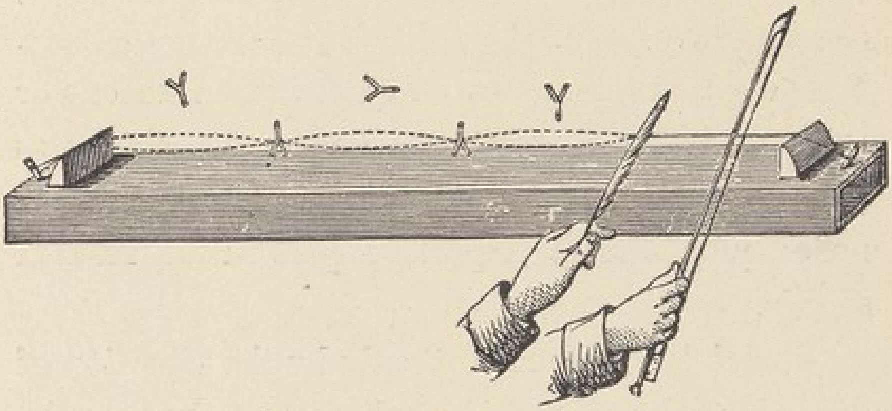


Fig. 15.

be its vibrations. In the violin and other stringed instruments, thickness instead of length is used to obtain the deeper tones. We have shown above that, by placing a bridge at any given point or points of a string, and so dividing it, it may be made to vibrate in segments. Strong pressure, however, is not necessary thus to divide it. Place a feather ever so lightly against the middle of a string and draw a violin bow over one of its segments, the string will yield a note the octave of the fundamental. This light touch is sufficient to cause the string to divide into two vibrating segments. Furthermore, the feather may be removed, and the string will still continue to vibrate and give forth the same note (Fig. 15).

The vibrating parts of the string or wire are called the ventral segments, and the point where the feather touched the wire is known as a *node*, and indicates a point of rest in the vibrating string. When a vibrating string is so divided into one or more ventral segments, it is known technically as *damping*, and, as we shall see, these fixed points, or nodes, play a most important part in all musical sounds.

Sound is produced not only by the vibration of solid, but also of liquid and gaseous bodies, the vibration of the air in an organ pipe being the best example of the latter. Sounding pipes are of two kinds, flue, or mouth pipes, and reed pipes, and the sound is produced either by breaking up the air blown into them or by causing it to enter in puffs. Fig. 16 shows the most common form of a flue pipe. The pipe is hollow, and is either open or closed at the top, and has its embouchure at *m*. Fig. 17, shows the same in section. The air enters by the tube *a* into the box *b*, and breaks through the narrow fissure against the thin edge of l, and as a result a musical sound is obtained. Fig. 18 shows the reed pipe. The air entering at r

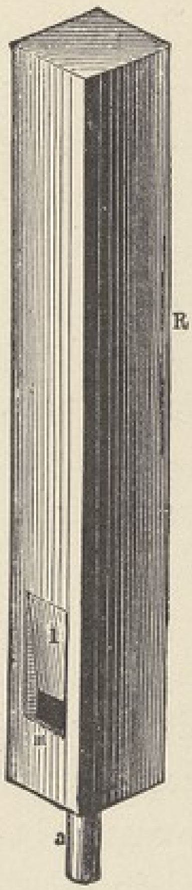


Fig. 16.

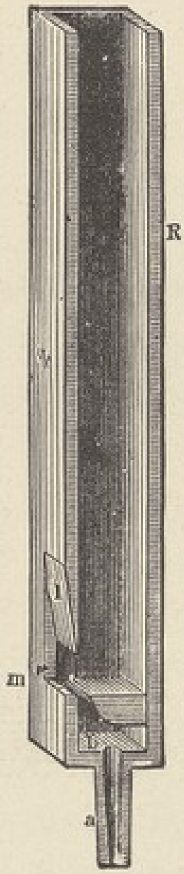


Fig. 17.

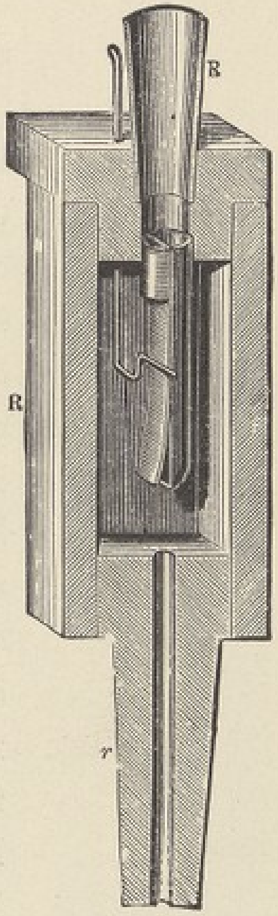


Fig. 18.

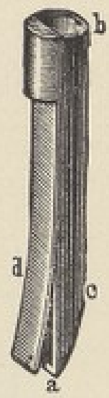


Fig. 19.

in order to reach the sounding pipe has to pass through the lower opening a (Fig. 19), and this opening is closed by the elasticity of the metallic tongue of the reed d. The vibration of this tongue causes a rapid opening and closing of the box so that the air penetrates at regular intervals in puffs, and produces a musical sound. In all pipes the loudness of the sound depends upon the strength of the blast, the note depending upon the dimensions and upon the length of the pipe *R*. We can construct a pipe which will give either a fundamental note or a series of higher ones. In an organ, each pipe is constructed so as to give only its fundamental note. Many wind instruments, however, such as the flute, trumpet, trombone, etc., are, in reality, pipes constructed to give a series of notes. This is done by giving the instrument greater length; in some cases it being straight and in others twisted, the air being set into vibrating columns by stops of different kinds, as the pistons in a cornet or the keys in a flute. In other words, by these means we may develop nodes in the column of air. The

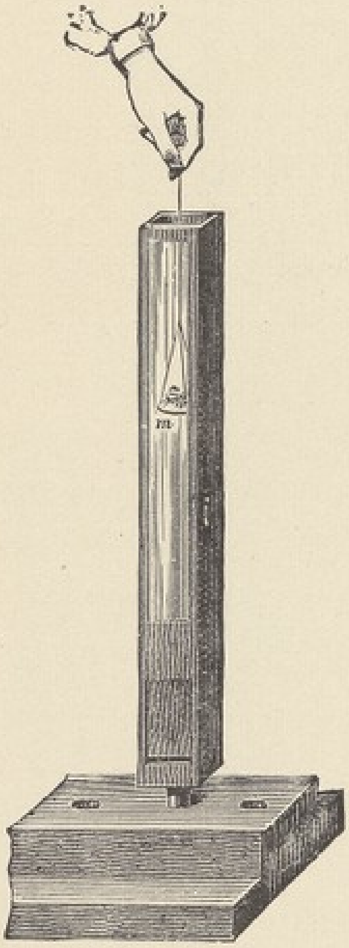


FIG. 20.

vibration of air in a pipe and the presence of nodes is prettily shown in Fig. 20. A membrane, *m*, upon which some sand is sprinkled is introduced into the upper end of an open sounding pipe, one wall of which is made of glass. The sand will be seen jumping about upon the membrane, and this is plainly caused by the vibrations of the air in the pipe being imparted to the membrane. It will be observed that at the middle of the pipe the movement of the sand ceases. In other words, we have at this point a true node; as the membrane sinks beyond the middle point, the sand is again set in motion by the vibrating air.

We have now to deal with musical sound. The difference between noise and a musical sound lies in the manner with which the vibrations strike the ear drum. Noise affects us as an irregular succession of shocks; we are conscious of a jarring of the auditory nerves. A musical sound, on the other hand, flows smoothly and without harshness or irregularity. This smoothness, which is the characteristic of musical sound, is secured by *rendering the impulses received by the tympanum perfectly periodic.* To produce a musical tone we must have, then, a body which vibrates with unerring regularity, and which imparts sufficiently rapid impulses to the air.

"Imagine the first of a series of pulses following each other at regular intervals. The tympanum is shaken by the shock and can not come immediately to rest, though the human ear is so constructed that sonorous motion vanishes with extreme rapidity; still, its disappearance is not instantaneous. If the motion imparted to the auditory nerve by each separate pulse continues until its successor arrives, the sound will be continuous. The effect of each shock will be renewed before it vanishes, and the recurrent impulses will link themselves together as a continuous musical sound. If these pulses, on the contrary, are of irregular strength and recurrence, they produce merely noise; and so we see that the one condition necessary to the production of musical sound is that the *pulses shall succeed each other in the same interval of time.* If we could cause a watch to tick with sufficient rapidity, say, a hundred times a second, the ticks would lose their individuality and blend to a musical tone. If the strokes of a pigeon's wing were as rapid, the progress of the bird through the air would be accompanied by music. In the case of the humming bird, the necessary rapidity of wing movement is attained, and hence we have the note which is characteristic of the bird and gives it its name." *

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* Tyndall, *loc. cit.*, pp. 78 and 79.

Loudness of tone depends upon the amplitude or width of swing of the vibration of the air particles, upon the distance it has travelled before reaching the ear, and upon the density of the air in which it is generated. Indeed, every sonorous impression of which we are conscious has a dependent relationship to the condition of the atmosphere. This is prettily emphasized by Tyndall, who says: "Were our organs sharp enough to see the motions of the air through which a voice is passing, we might see stamped upon the air the conditions of motion on which the sweetness of the voice depends." Higher or lower numbers of vibrations which go to make a tone are called pitch. The pitch of a tone depends solely upon the rate of vibration; the greater the number of vibrations in a given time the higher the pitch. Fewer than sixteen vibrations a second are not perceived by the ear as tone, but merely as separate shocks, and over forty thousand per second produce, as a rule, no sensation of sound. Any tone of a given pitch may be varied from a very soft to a very strong sound by increasing the amplitude of the vibrations, and soft or strong tones of the same pitch may vary in quality, or, as is commonly said, in timbre, or *Klangfarbe*—that is, in tone tint. These facts may be readily demonstrated by an instrument known as the siren. The siren, in its simplest form, is shown in Fig. 21, and consists of the revolving disk *A*, twenty inches in diameter, with a series of thirty-two round perforations at equal distances from each other on a sixteen-inch circle. Over this disk is placed a bent tube, *m*, connected with a pair of bellows, by means of which the air may be

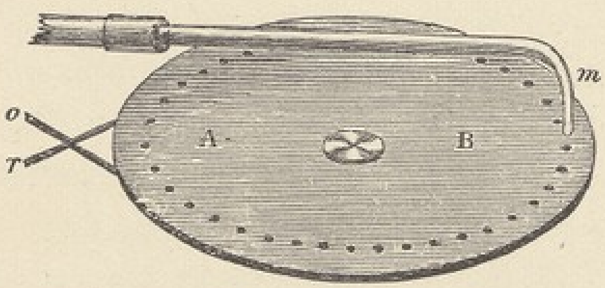

FIG. 21.

driven through the tube and against the disk. If the disk be set rotating, the air passes through the holes in a series of puffs, and as they succeed one another they will produce pulses in the air which will blend into a continuous musical note. The more rapidly the disk rotates, the higher will be the note. If, for instance, the disk revolves eight times a second, the air would pass through 256 holes, and would thus be rarefied and condensed 256 times a second, the tone produced corresponding to the c' of our scale. Doubling the speed of the disk, we produce the note the exact octave of the first, or $c'' = 512$. Decrease the speed to four revolutions per second, and a tone one octave below c' is produced, or $c = 128$. The greater the number of revolutions per second the higher the note, and *vice versa*.

If against the holes in the above disk two currents of air are directed instead of one, it is plain we should, on turning the disk, get a puff through two holes at the same time, and the result would be a considerable increase in the *intensity* of the sound, the pitch, however, remaining the same. The tones produced by blowing against either round or square holes in a revolving disk do not vary in pitch at the same speed, but they do vary slightly in quality. In both cases the number of vibrations produced is the same, but the way in which the air is rarefied and condensed is in each case different, and there is to the trained ear a perceptible difference in quality. With a siren properly constructed we can ascertain exactly the number of vibrations corresponding to a musical note.

Operating delicately, says Tyndall, we might even determine from the hum of an insect the number of times it flaps its wings in a second.*

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* *Loc. cit.*, p. 95.

We have seen that if a stretched string is stopped at half its length, the number of its vibrations is doubled; if at one third, it will be trebled, and so on. A vibrating string giving the note c' stopped at its central point will give c''; at one third of its length, g''; at one fourth or three quarters, c'''; at one fifth, two fifths, three fifths, and four fifths, e'''; at one sixth and five sixths, g''', each segment vibrating as a new and independent string. Now it is not possible to sound the string as a whole without at the same time exciting to a greater or less extent its subdivisions. The higher notes produced by the vibrations of the subdivisions are called the harmonics of the string, and these overtones mingling with the fundamental tone determine the *quality* or *timbre* of the string or instrument which produces the sound.

The subdivisions of the string being constantly in vibration, the fundamental tone is accompanied and augmented by the tones of these subdivisions. A vibrating string which produces the fundamental tone, $c'=256$ vibrations, the tones of its nodes, c'', g'', c''', e''', g''', etc., will augment in a small degree the tone c'. Furthermore, the character of the tone c' is affected by the readiness with which the tones of its nodes develop and synchronize with it, and the quality of c' will be the result of the mingling of the fundamental tone and the tones of its harmonics in the string. The fundamental tone is distinct, but the tones of the segments will be scarcely perceptible to the unaided ear. The fundamental tone gives the substantial impulse, while the tones of the segments give to the fundamental tone a special character and an increased delicacy. These additional tones, which are ever present, are called *partials* or *overtones*, and are known as second, third, fourth, and fifth upper partials. A simple fundamental tone is not known in music. All tones are compound, consisting, as we have seen, of the fundamental and its overtones.

There are also lower partials or undertones in combination with fundamental tones, but they are, generally speaking, of little importance. The presence and importance of overtones in sound was discovered forty-five years ago by Helmholtz. The presence of thirty-three to thirty-four overtones to given fundamentals has been shown, but exact data as to the influence of overtones on instruments and the voice have been calculated scientifically for the first fifteen to seventeen only. Tones from *different* sources, however, fundamental and compound, moving through air, will always form a compound wave, which may be readily divided into the original waves. Thus, from an approaching band, at first we hear but few of the instruments, and then more and more, until finally the sound of all the instruments is combined in one compound wave, and we have, as a result, a harmony produced by all the instruments. The fact that all sound waves travel at the same speed makes it possible for us to hear the different instruments of high and low pitch simultaneously. Compound waves of different fundamental tones form some tones which are agreeable to the ear, and others which are intolerable. The first are called consonant or harmonic, the latter dissonant or disharmonic tones. The vibrations imparted to the air by a fundamental tone are known as sympathetic vibrations, and the fact that the fundamental tone sets the air into secondary vibrations, producing overtones, may be shown very beautifully by Helmholtz resonators. These are little hollow metal spheres, as shown in Fig. 22. The small projection *b*, which has an orifice, is placed in the ear; the sound waves entering the hollow spheres through the aperture *a* throw the contained air into sympa-

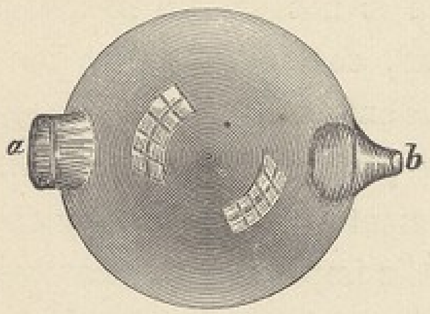

FIG. 22.

thetic vibrations. These resonators are of different sizes, and are made so that the air within the cavity is thrown into vibration by a note of a given pitch, *a*, *b*, *c*, *d*, etc. A resonator tuned to *c* will not resound to *b* when placed to the ear and the tone sounded, but will become at once excited by *c*. By means of these resonators a note re-enforced by its particular sphere, and thereby rendered more powerful than its companions, may be in a measure isolated from a composite clang. Sympathetic vibrations are only set up in a secondary string, or pipe, when they are capable by themselves of producing the fundamental note. If we take a sonometer on which two strings are stretched, tuned to give the same note, and place paper riders on the strings, as shown in Fig. 15, and one of the strings is rubbed so that it will give forth its fundamental note, all the riders on this string will be thrown into the air, and the second string, which has not been touched, will exhibit the same phenomena, although more feebly. This means that the second string, of course, vibrates in the same way as the first; but it will not take place if the second string is stretched more than the first. In this instance the vibrations of the first string are transmitted to the bridge on which it rests and thence to the second string. Vibrations are also transmitted by the air; if a tuning fork, for instance, is placed beside an organ pipe having the same fundamental pitch, and the latter is made to sound, the tuning fork will at once reproduce the note. If, however, a pipe is used which gives a different note, there is no secondary vibration of the fork. This again may be proved by means of Savart's bell,

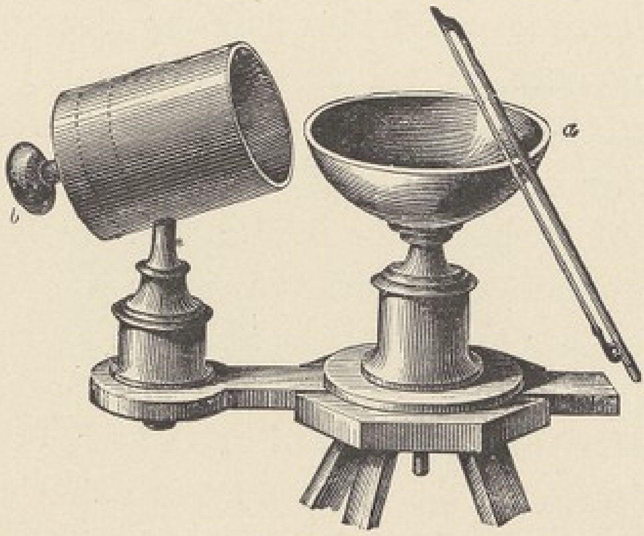

FIG. 23.

Fig. 23. A large bell, *a*, when caused to vibrate, produces a powerful note. The hollow cylinder *b* with a movable bottom is brought near it; by altering the position of the bottom, and thus modifying the depth of the cylinder, the point at which the re-enforcement of the sound is greatest is easily found. The effect is very remarkable if

the sound of the bell is allowed to diminish until it is scarcely audible, when, on bringing the cylinder nearer, the sound will again become very perceptible. In a well-tuned piano we can produce the overtones of any fundamental tone by the sympathetic vibrations of the air. The demonstration is easiest in the bass. If we take, for example, the tone $C = 64$ vibrations per second, its overtones are $C = 64$, $c = 128$, $g = 192$, $c' = 256$, $e' = 320$, $g' = 384$, $b\flat' = 448$, $c'' = 512$, $d'' = 576$, $e'' = 640$, $f'' = 704$, $g'' = 768$, etc. This gives a total of 4,992 vibrations a second to the fundamental and its existing first twelve overtones. For the higher overtones the number of vibrations increases rapidly, so that $C = 64$ with sixteen overtones will give nearly twice as many, or 9,984 vibrations a second. The multiples of sound waves for each fundamental tone in an orchestra, and the possible thirty-four overtones for each instrument, can be conceived, but are not to be heard with the unaided ear.

To show the overtones of $C = 64$ vibrations a second on a well-tuned piano, press down singly or together with the right hand the keys c, g, c', etc., so gently that the hammer of the key does not strike the piano string. Then strike the key $C = 64$ with the left hand hard and rapidly. The damper will quickly stop the vibrating string $C = 64$, and, on listening attentively, the higher tones of the keys held down by the right hand are heard vibrating, the result being a most melodious harmony. Of the tones produced by sympathetic vibrations, those which correspond to the lower overtones will be most easily distinguishable, while the higher will grow fainter and less audible, being much more difficult to produce. Reversing this experiment, press down lightly the key $C = 64$ vibrations and hold it; then, with the pedal down, strike alternately two chords with the right hand—that is, seven overtones —first, c, g, c'; second, e', g', bb', c''. On releasing the pedal this $C = 64$ will become quite audible, and, through the sympathetic vibrations of its overtones, of a highly melodious quality. If, however, we try the last two experiments with any other notes than the overtones, neither the fundamental nor the overtones will be forthcoming in a well-tuned piano.

Examining the overtones of $C = 64$, we find Nos. 2, 3, 4, 5, 6, 8, 10, 12, 16, etc., to be consonant or harmonic, Nos. 7, 9, 11, 13, 15, etc., dissonant or disharmonic, and that the former increase, while the latter mar, the pure melodious quality of the sound. This is the reason why a piano string is struck on one seventh or one ninth its length in order to eliminate these discordant harmonics, and also the reason that in large organs the so-called third and fifth octaves, and even the twelfth stops, are coupled that they may sound simultaneously with the fundamental tone and strengthen its sonorous quality. It is evident that a different intensity, as well as the presence or absence of one or more overtones, though inaudible in itself, would change the quality of a tone. Violins have all the overtones to the seventh prominent; clarinets the third, fifth, and seventh; flutes the first and second; reed organs up to the twentieth; and in pianos the third, seventh, twelfth, and thirteenth can often be heard by the unaided ear. To what extent the conditions influencing the timbre in any instrument may vary will be easily seen, for in pianos alone the presence of the first six overtones in different degrees of intensity may produce many thousand changes in timbre—all slight, but audible to our ear. The same conditions for the production of overtones exist in reed as in string instruments. In flutes we find that in the lowest octave the air vibrates as a whole. In the second octave the air column vibrates in halves through the air space, the player changing slightly the manner of tone production and the air blast; while in the third octave the air inside the flute quarters. In cornets and other wind instruments the tones are produced in a similar way. The character and timbre of all wind instruments, however, is dependent upon the presence of certain overtones in different intensity and strength; and the form also of the hollow spaces in which the tone is produced has

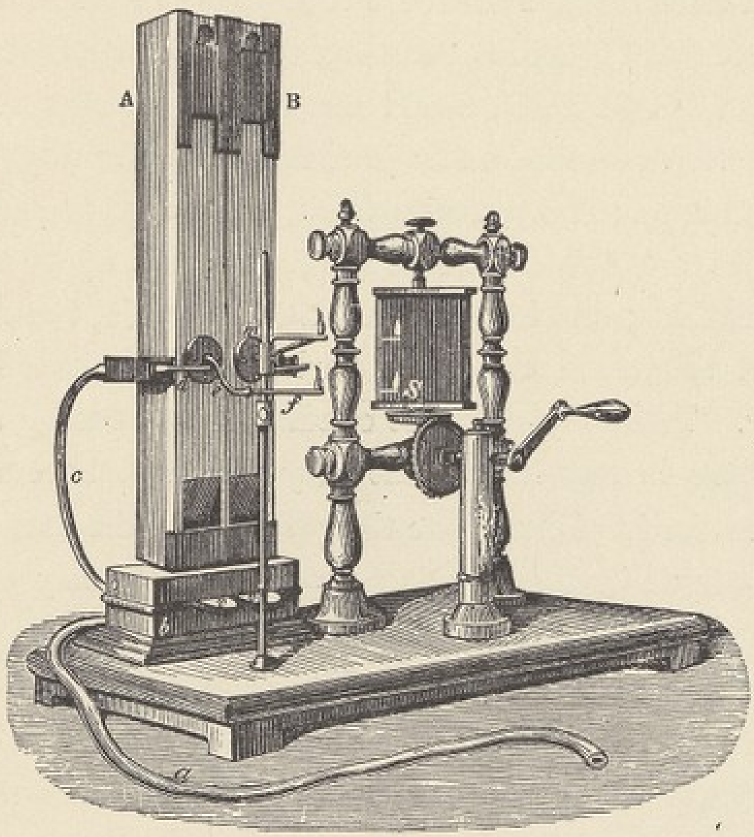

FIG. 24.

naturally much to do with the formation and production of the fundamental and its overtones. The difference between a clarinet with the nasal twangy-tone quality and one of exactly the same size and make with a full, sonorous timbre, lies in the minute differences in the various borings and air spaces. The elasticity also of the material from which the clarinet is constructed has much to do with the formation of the fundamental and overtones.

The vibrations of air in sounding pipes and the existence of overtones is beautifully shown by a mechanism invented by Prof. König, for producing his so-called manometric flames. The instrument is shown in Fig. 24. One or more pipes of the same size are mounted on a small box which acts as an air chest, the tube *a* connecting it with the bellows. The valves *v* enable us to use one or both the pipes. *e* represents an opening under which there is an elastic membrane which serves to separate the interior of the pipe from the interior of the capsule. This capsule is in communication on one side with the glass tube *c*, and on the other with the small tube *f*, which ends in a gas burner. The gas enters the capsule and passes through it to the burner, and a small lean flame is produced. If the pipe is not sounded the gas passes through the capsule, and the flame burns quietly. If, however, the pipe sounds, the movement of the vibrating air is communicated to the membrane of the capsule, and from it to the gas, and the flame will be seen rising and falling rapidly as it is affected by the vibrations of the air in the pipe. If a four-sided mirror, S, is placed in front of it, which can be turned rapidly round its vertical axis while the pipe is sounding, the positions of the flame in rising and falling will be seen succeeding one another with perfect regularity, as in Fig. 25. If no note is sounded a continuous ribbon of flame, without teeth, is reflected in the mirror. If a smaller pipe be used, which gives a note an octave higher than the first, the vibrating flames will be seen to be of double the number of teeth in the mirror; in other words, the higher the note with an equal speed of the mirror, the nearer together are the flames, and, conversely, the more rapid the vibrations of the air in the pipes. Indeed, the reflected flame is seen in the revolving mirror, ever varying its shape with the different tones. By changing the apparatus so that a speaking tube takes the place of the pipe, and playing a fundamental tone and its octave into it, the mirror will show a number of bat's wings in flame. If, however, we add a tone corresponding to the next overtone, the mirror will show several tongued flames of different lengths.

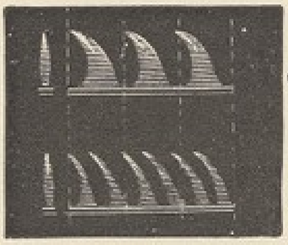

Fig. 25.

We have seen that each vowel sound has a natural pitch of its own, and this may be distinctly seen by speaking the vowels into the funnel con-

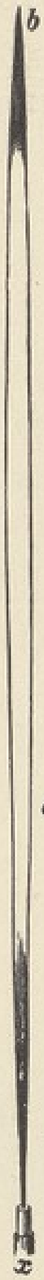

Fig. 26.

nected with the above instrument, where each will be found to give its distinctive ribbon of light. Tones of the same pitch played on different instruments or sung by different persons will give a slightly different picture in the mirror. The vowel flame, Figs. 26 and 27, is one of astonishing sensitiveness. The mere dropping of a coin into the hand already containing a piece of metal yards away will cause the flame to drop. It is startled by the patter of a raindrop, and the tick of a watch causes it to fall and roar. A loud U does not move the flame, but when O is spoken it quivers. By E it is strongly moved, and by the sound Ah it is thrown into very great commotion, showing how beautifully this flame illustrates the theory of vowel sounds. It is plainly most sensitive to sounds of high pitch, and from its action there is but one conclusion to be drawn—viz., that the sound Ah contains higher notes than E, E than O, and O possesses a naturally higher pitch than U. For this reason the same fundamental note sung with different vowels will give a different

Fig. 27.

image of its overtones in the revolving mirror (Fig. 29).

Tones of the same pitch produced by different voices show some overtones stronger and more prom-

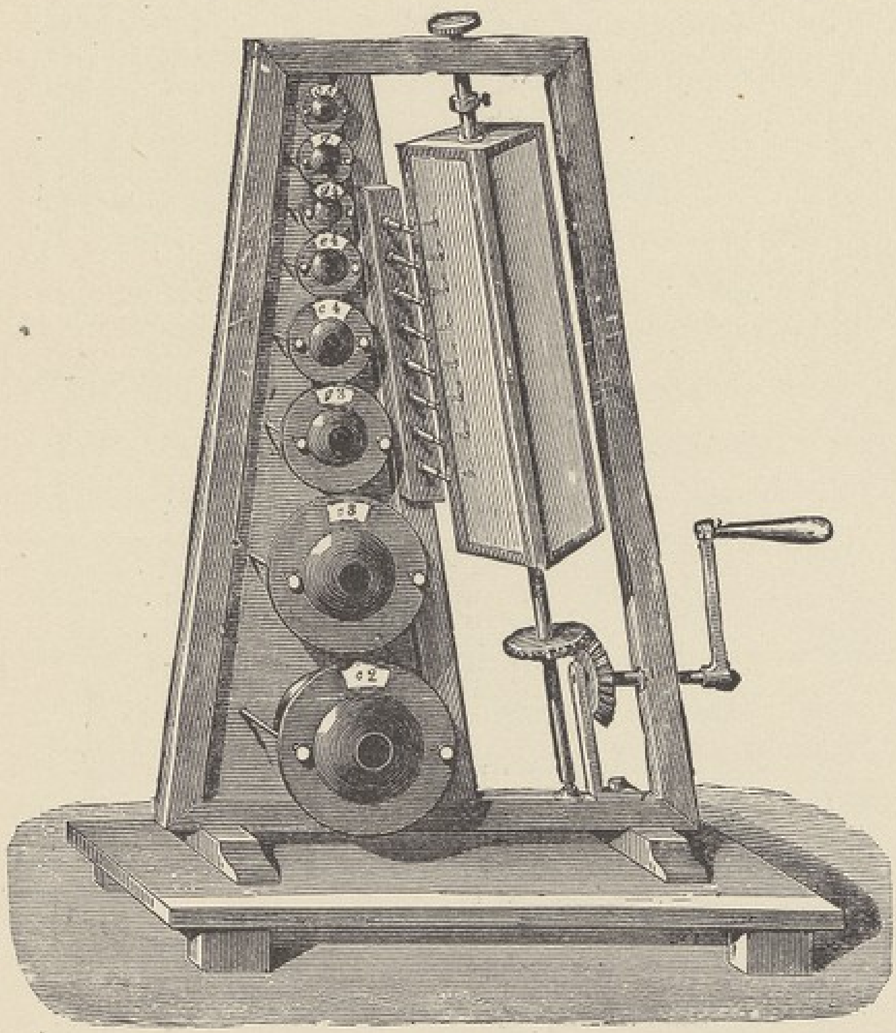

FIG. 28.

inent, some weaker, while some may be missing from one or the other voice altogether. The slightest change in the manner of producing a fundamental tone and its overtones will give a different quality to the musical sound, the quality of a musical tone being in fact dependent upon the relative intensity and strength of its overtones. A very interesting apparatus for analyzing overtones is shown in the accompanying figure (Fig. 28). König has taken eight resonators tuned to the overtones of the fundamental note *c*, each with their delicate flames placed one above the other, so that the reflected image of the ribbons of light in the revolving mirror corresponds to the fundamental and the first seven overtones. A note corresponding in pitch to the largest or fundamental resonator should be sung close to the apparatus, and if overtones be present, they will set the resonators in action, and in turn the corresponding flames. These will be pictured in the revolving mirror (Fig. 29). The first overtone will be seen to have double the number of serrations, or teeth, as the fundamental, the second three times as many, the third four times as many, etc., provided they be present. If they are not present, the mathematical ratio will not be constant, showing the absence or interruption of that overtone not in series. In this manner the presence and strength of the lower overtones of the human voice, or any instrument, may be determined, and a photograph will record the image of the timbre of different voices, so that we can mathematically write an equation of any given voice on a fundamental tone. With this instrument the influence of the vowels may be

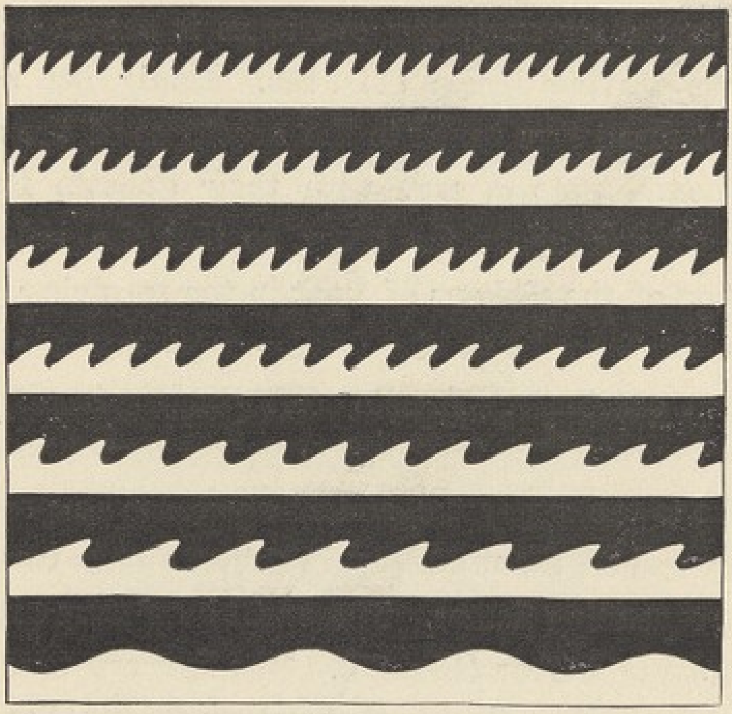

FIG. 29.

shown on the ribbons of light, and the different overtones which each accentuate be demonstrated. Fig. 29 shows the reflected image of the fundamental *c* and its first six overtones.

CHAPTER VI.

THE REGISTERS OF THE HUMAN VOICE.

In singing an ascending scale, there is a point beyond which it is difficult to go without changing the method of producing the tone. The places in the musical scale at which this change occurs vary in different persons, and divide the scale into the so-called registers of the human voice. By register we mean the tones which are produced by a particular arrangement of the vocal cords. Mancini,* writing as far back as 1774, says that in certain rare instances there is only one register—the chest—used throughout the whole compass of the voice; and Dr. Wesley Mills † also states that in rare cases he found that the chest register, i. e., the

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* Mancini, Pensieri è riflessioni practiche sopra il canto figurato, Vienna, 1774, p. 43.

† An Examination of Some of the Controverted Points of the Physiology of the Voice, especially the Registers of the Singing Voice and the Falsetto (American Association for the Advancement of Science, August, 1882).

chest mechanism, was the only one used, and he attributes this peculiarity either to special endowment or to a special method of teaching.*

Mackenzie † found, after a special investigation of some four hundred trained singers, that the chest register was generally used throughout by pure sopranos, and he shows the vocal picture to be such in the cases of Nilsson, Albani, and Valeria —certainly a most remarkable observation. On the other hand, he found that contraltos sang their high notes almost invariably in the head register, mezzo-sopranos generally making use of both. Tenors also used both registers, though five-sixths of their notes were sung with the chest mechanism. A few, however, confined themselves entirely to the latter. Barytones, when they sang within their compass, used the chest register, as of course bass singers always do. As we shall presently see, nearly all scientific observers describe two registers in the human voice. Musicians, on the other hand, invariably give five, while singing teachers generally divide the registers into chest, middle or

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* This corresponds with our own observation. It is the result of a special method of producing the voice, however, as we shall show, and not of a special endowment.

† Mackenzie, Hygiene of the Vocal Organs, London, 1888, p. 35.

medium, head, and falsetto. The term falsetto is used ambiguously by many writers. It is frequently used to indicate the medium register, between the chest and head. We prefer to use the term as describing the false voice in man simulating the upper tone of a soprano, and as descriptive of an extreme birdlike register sometimes found in the altissimo of women's voices.

Garcia,* writing in 1861, divided the voice into three registers, chest, falsetto, and head—all three of them common to both sexes, the female having a greater range in head and men in the chest notes. He further divided the chest into an upper and lower, and the head into an upper and lower register, thus making five distinct mechanisms. Madame Seiler † followed Garcia in his division of the registers. Émile Behnke ‡ divided the voice into a thick (chest), a thin (falsetto), and a small (head) register. The thick and thin he again subdivided into an upper and lower, and this is the division made in his work in collaboration with Mr. Lennox Browne.# Dr. Wesley Mills,‖ in his excellent

* Observations. Physilogiques sur la Voix Humaine, Paris, 1861, p. 25.

† Seiler, The Voice in Singing. Philadelphia, 1881, p. 52.

‡ Behnke, Mechanism of the Human Voice, London, 1880, p. 71.

Voice, Song, and Speech, London, 1886, p. 171.

‖ *Op. cit.*

paper, seemed to agree with the divisions of Garcia and Madame Seiler; but in a private letter to Mackenzie * said he did not care to be set down as a hard and fast advocate of any of the divisions of the registers now adopted. Mandl † advocated two registers only, and he applied the term lower to the chest and the term upper to the head division. Bataille, ‡ Koch,# Vacher, ‖ Gouguenheim and Lermoyez,^ and Martels ◊ also declare for two registers. Mackenzie ↕ says that there are essentially two registers—one *the chest*, in which the pitch is raised by means of increasing tension of the vocal cords, the other *the head*, in which a similar result is brought about by shortening of the vibrating reed. He thinks that the terms long reed and short reed would serve well enough to express the fundamental differences in the mechanism of voice production. If we read him aright, he uses the head or short reed as synonymous with the falsetto. ↧

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* Quoted by Mackenzie, *op. cit.*, p. 196.

† Hygiène de la Voix Parlée ou Chantée, 2d ed., Paris, 1879, p. 37.

‡ Nouvelles récherches sur la Phonation, Paris, 1861, p. 67.

De la Voix Humaine, Luxembourg, 1874, p. 20.

‖ De la Voix chez l'Homme, Paris, 1877, p. 29.

^ Physiologie de la Voix et du Chant, Paris, 1885, p. 145.

◊ Physiologie de la Phonation, Revue bibl. Univ. des Sciences Médicales, t. ii, xiii, and l. 1885.

↕ *Op. cit.*, p. 32. ↧ *Op. cit.*, p. 42.

As to the mechanism of the registers, most observers agree that in the lower notes of the chest register the whole of the glottis is thrown into full loose vibration, but as the pitch rises and the cartilaginous glottis comes into closer apposition, there is a considerable increase of tension and decrease in breadth of the vocal cords themselves, and the glottic aperture becomes much narrowed. In the falsetto, most writers hold that the vocal cords are relaxed, and that their margins, or their mucous coverings, only vibrate at the free border.

The theory of purely marginal vibrations in the falsetto was first advanced by Lehfeldt,* and though resting upon a single experiment, it was taken up by Müller,† and since that time has been accepted by almost every writer on the subject. They have disagreed as to the way in which the mucous membrane was thrown into vibration, as to the extent of surface involved, as to the tension of the cords, and the appearance and extent of the glottic aperture; but, generally speaking, they have agreed that tone in this register is produced by the

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* Lehfeldt, Nonnulla de vocis formatione, Dissert. Inaug., Berlin, 1835, p. 58.

† J. Müller, Ueber die Compensation der physischen Kräfte am menschlichen Stimmapparat, Berlin, 1839.

vibrations either of the thin edges of the vocal cords or of their mucous covering only.

We have contented ourselves with this general statement since the revelations of the laryngo-stroboscope, which we shall presently describe, have disproved the various theories as to the action of the vocal cords advanced by different writers. A suggestion, however, of Martels,* in discussing the formation of the registers, is worthy of attention. Martels considered that the difference between the chest and the falsetto registers was that, while the notes in the former are produced by the cords themselves acting as reeds, in the falsetto they are in reality *flute* sounds, and that they are not the result of the vibrations of the cords proper, but of the air in the cavities above. This is also the opinion of Chater,† who from a long and careful study of the falsetto says: "In the production of this voice the vocal mechanism becomes an instrument of the clarinet or oboe class—that is, the vocal cords become reeds of the flexible variety and cease to influence the pitch of the tone produced, but act as do the reeds of those instruments, merely for the purpose of setting the air in the tube in vibration,

* *Op. cit.*

† Scientific Voice, Artistic Singing, etc., London, 1890, p. 53.

the pitch being governed by the alterations in the length of the tube.

For convenience, we assume that there are three registers, *chest*, *medium*, and *head*, which need be considered in training the human voice; but we believe that there are but two distinct mechanisms, and even the transition from one register to the other in singing the scale may be made practically imperceptible, if the proper method be employed. As to the shape of the glottis, we admit that the whole glottis is open in all voices in the lowest or chest register, and that this condition is maintained up to a certain pitch, which varies in different individuals. Beyond this point the cartilaginous glottis is closed and the head mechanism begins. We are, however, convinced that one mechanism may be cultivated throughout the entire compass of the voice; that the vocal cords may be made to assume a position in which they are to all intents and purposes parallel throughout their whole extent; and, furthermore, that this relation of the cords is not necessarily disturbed in passing from the chest to the head register. In this method of voice production the vocal cords, as we pass from one register to another, divide themselves into vibrating segments by the formation of one or more nodes in the length and breadth of the cords. Again, we hold that the separate notes in the chest register are the result of varying changes of tension brought about by the intrinsic muscles of the larynx and of the vocal cords themselves; but that in the head register the vocal cords are divided into two or more vibrating segments, and become to a certain extent flexible reeds, sometimes commanding and sometimes commanded by the vibrations of the columns of air in the resonating cavities above. The tones are not always the result of the vibrations of the cords themselves imparted to the air, but of the vibrations of the air column in the vocal tube and resonating cavities. And so we find that the more perfect the management of the resonating cavities in the vocal apparatus, the more readily the air column is subdivided and the richer the voice becomes in overtones.

The production of tone in the human larynx is similar to a combination of tone production in reed instruments and tongue flutes, the vocal cords of the larynx taking the place of the tongue in flutes and of the reed in reed instruments. The throat, mouth, and the cavities above assist in the formation of tone in the same way as do the hollow spaces in these instruments. There can hardly be a doubt that, as in flutes, the air in the cavities of the human organs of speech vibrates in some persons for the lower or first notes as a whole, for the medium notes in two air columns, and for the upper in three. In very highly trained voices, moreover, a fourth register or falsetto may be developed which has always a beautifully clear, birdlike quality. This has been observed mostly in soprano and alto voices, and in such cases the column of air is probably quartered.

The position of the larynx varies in the head register, but we have observed that it does not necessarily rise as the scale ascends, as is so commonly supposed, and certainly not in the method employed by many of our best singers. This fact was also noted by Chater, who found that, in passing from the chest to the head register, there occurred frequently a fall of the larynx to a slightly lower position, and where this was the case there was encountered an entire absence of muscular contraction and facial contortion which often accompanies the singing of the head register.

The position and movements of the vocal cords in the production of tone have been the source of much acrimonious discussion. Photographs galore of the cords emitting different notes have been made and, we fear, touched up to meet preconceived requirements, and much ink has been wasted in describing what different observers saw or did not see. This can not be wondered at when we reflect that the ordinary laryngoscopic mirror was used and conclusions drawn as to the delicate intrinsic movements of the vocal cords from this fleeting picture.

Oertel, of Munich, was the first to apply more delicate and scientific methods to the examination of the vocal cords. As far back as 1878, in the Centralblatt for Scientific Medicine, he published an article describing an instrument called the laryngo-stroboscope, used for the examination of the vocal cords in phonation. In a very important article in the Archives für Laryngologie for 1895, Oertel returns to the subject, and, with the aid of a much improved instrument, he has established some new and very important facts, both as to the vibration of membranes and of the vocal cords.

Briefly, the stroboscope is an instrument which enables us to see the intrinsic movements of any vibrating object, such as a string, a membrane, or the vocal cords of the human larynx. The instrument, as perfected by Oertel, is shown in Figs. 30 and 31. Behind the large reflector M is a rotating disk S, in the periphery of which there are rows of holes, *a b c*, respectively 32, 16, and 8 in number, covering three octaves. By the handle B the reflector can be placed over one or the other row of holes. The disk is made to rotate by the motor D, whose rate can be regulated by the rheostat R. On the other hand, the rate of the

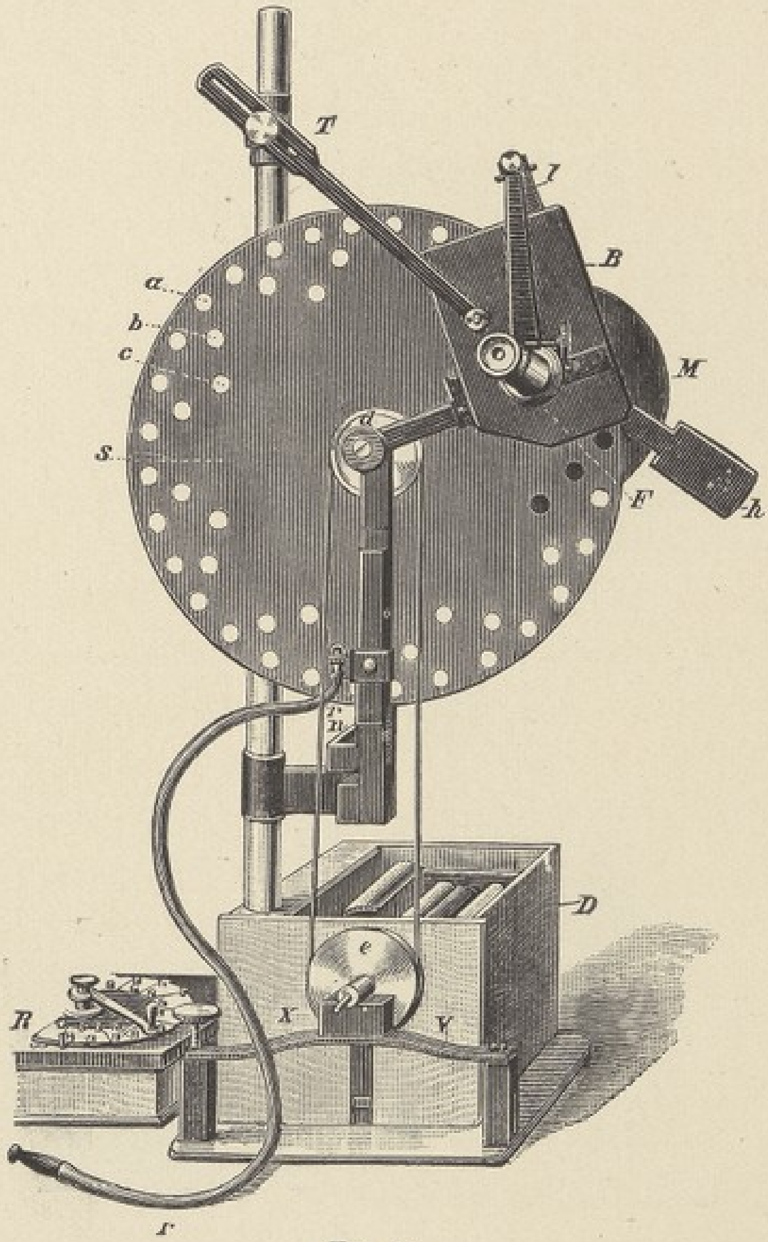

FIG. 30.

disk itself may be further controlled by a brake, V. In order to find the exact rate of interrup-

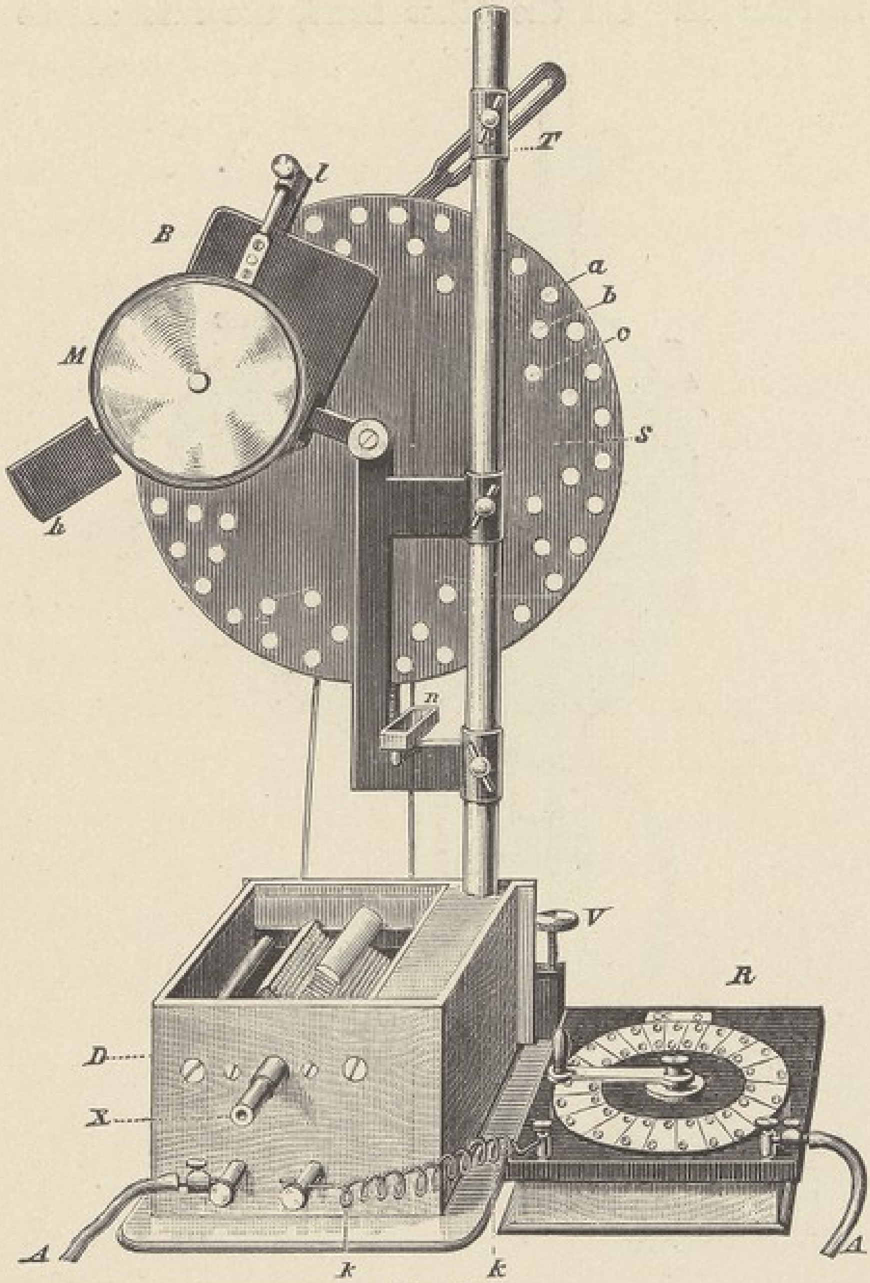

FIG. 31.

tion of the disk, and its relation to the rate of vibration of the membrane, which is an absolute necessity in the examination of the vocal cords, the disk is arranged so that it acts as a siren, and we can get an exact correspondence between the note of the cords and of the disk. In other words, we can get synchronism between the vibrations of the two. When the tone of the vocal cords is the same as that of the disk, we see the vocal cords apparently at rest, but by varying the rapidity of the rotating disk the intrinsic movements of the vocal cords become very distinct. This may be readily understood when we remember, that when there is unison between the tone of the disk and that of the vocal cords, in the time which elapses between the appearance of the vocal cords through one hole and their appearance through the next, the cords will have completed one vibration, and consequently will be seen as if at rest. If, however, the rate of the disk is slower than the oscillations of the vocal cords, the vocal cords will have finished one excursion to and fro, and begun a second, before a second hole comes to give us a glimpse of them. Thus, with a difference of $\frac{1}{n}$, for example, between the rate of the disk and that of the vibration of the cords, the cords between each opening will have described

$n+1$ movement in time, but we see only the movement represented by n, and so in a given series we see the membranes moving as slowly as we please, and we may observe any portion of their surfaces. By magnifying the size of the vocal cords we are enabled to see very plainly under the stroboscope their intrinsic movements. In order to get such a magnified image of the cords, a telescope, F, Fig. 30, is fixed to the instrument. Any method of illumination of the throat may be used, and the hand mirror is introduced and manipulated as in an ordinary laryngoscopic examination.

In the article above referred to, Oertel begins by saying, and we entirely agree with him, that the theoretical assumption that in the upper register the free border only of the vocal cord vibrates, lacks any anatomical, physiological, or physical basis. To produce this condition, where only a thin edge of the cords is presented to the outgoing air, the internal fibres of the thyro-arytenoid muscle would have to be strongly contracted, and the elastic fibres of the cords themselves considerably narrowed, and the result of any such contraction of the muscle would be to very greatly narrow the glottic slit, which is exactly the condition we do not find in the head tones. On the contrary, we know that, in this register there is a comparatively wide glottis, which fact excludes the possibility of any such active participation of the thyroid-arytenoid muscle in the formation and shape of the vocal cords in this register. Furthermore, observation and experiment convinced Oertel that this muscle is, in the head register, only passive in its action, simply giving tone and elasticity to the vocal ligament. That the edge only of an elastic membrane should be set into vibration by the air blowing against it is impossible, and a further argument against this theory. We must therefore look for another explanation of the action of the cords in the upper register than the one so generally held, that in this register, the vibrations are limited either to the free edge only, or to the mucous covering of the cords.

That it is, however, that segment of the cords near the free border that is thrown into most active vibration in the high register, can be seen even with the ordinary laryngoscope. In mild cases of catarrh, says Oertel, and we have often noticed the same phenomenon, tiny pearls of mucus may be seen to move from the ventricles of Morgagni out toward the edge of the vocal cords and run toward apparently fixed points, where they remain till expectorated. Observers have always spoken of these spots as nodal points on the cords. Oertel says that this is not the case; that, as a matter of fact, the tiny pearls of mucus are driven by the centrifugal force of the vibrating vocal cords to the middle point of the vibrating segment, and from thence are thrown outward. They mark, then, if anything, points of greatest movement in the vibrating segments, and not points of rest.* This fact Oertel proved conclusively with rubber membranes stretched over a tube through which air might be blown, and over funnels of different sizes connected with the tube. On the membranes were placed little drops of a mucus-like jelly, and when the membrane was set vibrating the drops were thrown toward the free edge, from which points they would be expelled, or they sometimes moved along the free edge to the point of greatest vibration in the middle of the segment, and from there would be carried out by the blast of air. The points at which the pearls of mucus would come to rest were not fixed, but varied very much from

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* This observation confirms the theory advanced several years ago by the author as to the formation of nodules of attrition in singers' cords, and explains the removal of the same by exercises in vocalization, which exercises were theoretically supposed to make the cords vibrate in a way which prevented their ventral segments from touching; the method employed being a change of the plan of vibration of the cords, by bringing into use the overtones which were always found lacking in singers subject to this affection. See, The Effects on the Vocal Cords of Improper Methods of Voice Production, and their Remedy, read before the Pan-American Medical Congress, 1893.

time to time in each membrane, so that there could be no doubt that they were not nodal points. These facts most conclusively prove that the vibrating membrane in the upper register is not limited to the free border of the cords, and least of all to its mucous covering. Oertel found, too, the interesting fact that the greater the difference between the diameter of the tube and that of the mouth of the funnel, the smaller relatively became the transverse diameter of the vibrating portion of the membrane. And so in the case of the human larynx in its relation to the trachea; that portion of the vocal cords lying against the thyroid cartilage would be set into greater or less vibration by the air, according to the relative diameter of the larynx as compared with that of the upper trachea. We shall see that the above statements are confirmed by stroboscopic examination of the vocal cords in the chest and head registers, to which experiments we shall presently refer. The vibration of membranes as seen by the stroboscope is interesting, and has a direct bearing upon the vibrations of the vocal cords as seen in the same manner. Oertel found that membranes set in motion by an air blast vibrate in their entire length and breadth, and at the same time they subdivide into segments, longitudinally and transversely, the segments being divided

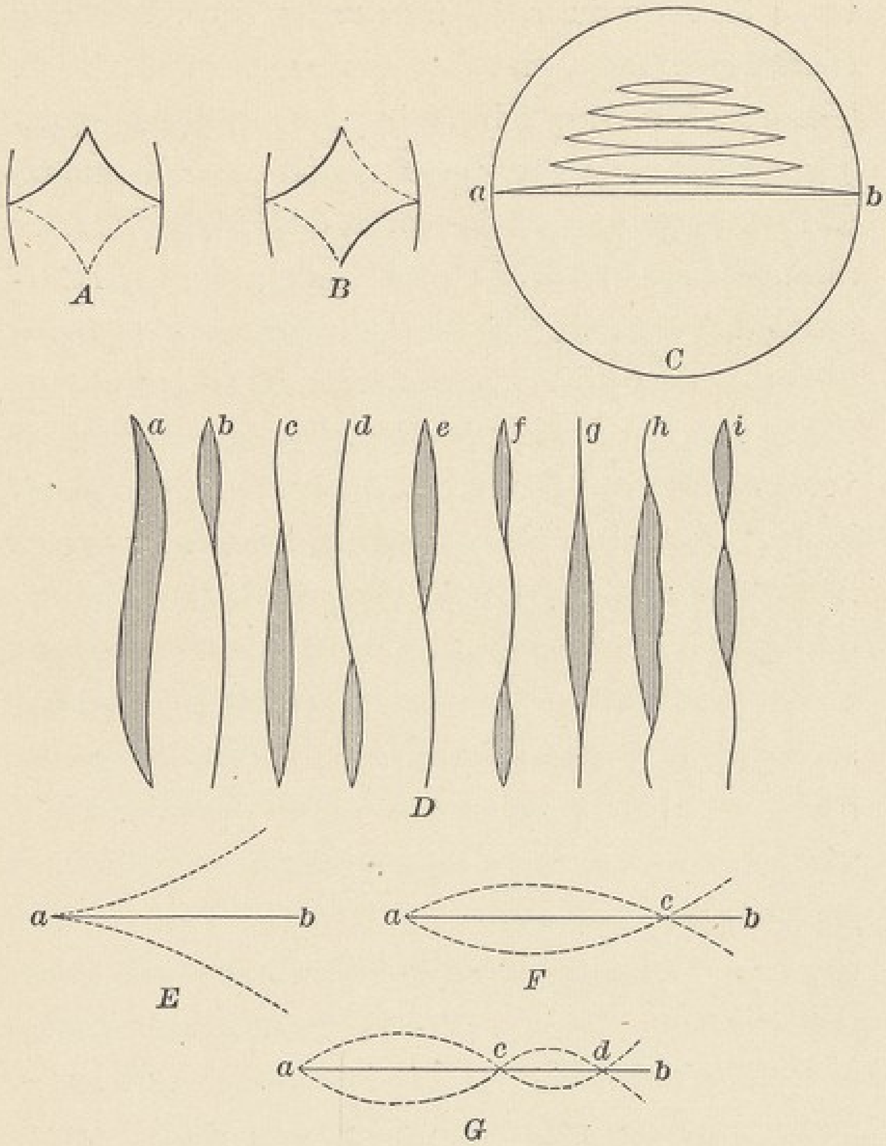

FIG. 32.

by nodal lines. Under these conditions the membrane vibrates longitudinally, like a stretched string (Fig. 32, D, *g*), transversely, as a rod fixed at one end (Fig. 32, E, F, G). Two membranes under the same tension vibrate synchronously (Fig. 32, A). If, however—and this is important in view of its application to the vocal cords—they are subjected to a different tension, the vibrations become alternate (Fig. 32, B). Oertel was the first to discover this fact, and it has been confirmed by Koschlakoff * and Simanowski.†

In its transverse diameter the membrane is divided by nodal lines, between which are well-marked waves of vibration, Fig. 32, C, *a b* being the slit of the glottis. The first nodal line is close to the free border of the membrane, and divides it into a wave whose width is about one quarter that of the latter. The waves increase in length very greatly as they near the free border of the membrane, and vibrate in opposite directions, that is while the crest of one is above, the crest of the next is below the level. A cross section of the membrane under these conditions gives an exact picture of a vibrating rod fixed at one end and divided by nodal points (Fig. 32, G). Longitudinally, nodal points are formed on the free edge, and the membrane is divided into separate vibrating

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* Wratsch, St. Petersburg, 1884, No. 38; Pflügers Archives für Physiologie, 1885, Band 34; Pflügers Archives für Physiologie, 1886, Band 38, p. 428.

† Russkaja Medicina, 1885, No. 24.

segments. Oertel most often saw a nodal point establish itself at about one quarter the length of the membrane (Fig. 32, D *b*); they established themselves, however, at other points under certain conditions, as in *c d e f g*, Fig. 32 D. The vibration of the segments of the free border are best seen when the membranes are not vibrating synchronously. Longitudinal vibrations extend but a very little distance transversely over the membrane, and a longitudinal section of the free edge gives a picture like that of a string set into segmental vibration. Imbert,* using Oertel's stroboscope, found that rubber membranes set into vibration divided themselves into segments separated by nodal lines, as shown in Fig. 33, in which the membrane is seen in

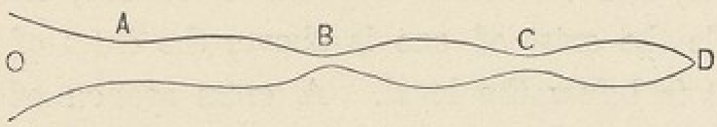

Fig. 33.

transverse section, D being the fixed and O the free border of the same. B is a true nodal point, and is formed both when the membrane is set in motion by the air or when it is pulled up by its free border. It is plainly the result of the interference of the direct waves and those reflected from the fixed end D.

* Nouv. Montpellier Médicale, 1892, Supplement, p. 149.

A and C are nodes of inflection, A being caused by the alternate rarefaction and condensation of the air in the box over which the membrane is stretched, by the vibration of the free edge of the membrane.

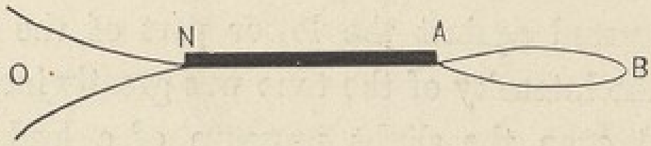

Fig. 34.

This node, he thinks, corresponds to Oertel's nodal line seen in the vocal cords. The nodal line C is formed by the posterior section B D spontaneously dividing itself into segments which can vibrate synchronously with the segments O A and A B. If the transverse tension of the membrane is increased the pitch of the note will gradually rise until it becomes bi-tonal. Increasing the tension still further, the nodes A and C will disappear, and there will be a sudden fall of pitch. Imbert found that when he damped the membrane in the middle with a solid plate, N A (Fig. 34), on its being moved toward O the pitch fell; if moved toward B it became higher. If the part A B is covered by a second plate, there is a remarkable increase in the intensity of the tone, the reason being that in this case a part of the membrane is damped, which could with difficulty vibrate in unison with the anterior segment. He proved this by damping the lower part of a rubber tube, which was fixed on the end of a rigid one, through which air was blown. If, under these conditions, the free end of the tube was drawn into a glottislike opening, and a solid plate was pressed against the lower part of the rubber tube, the intensity of the tone was greatly increased. Indeed, even the slight pressure of a lead pencil against certain points had the same effect. In both these cases the augmentation of the tone was due to the subdivision of the tube into segments which readily vibrated in unison. Imbert applies the results of these experiments on membranes to the larynx, as follows:

He thinks that the internal thyro-arytenoid muscle acts as the plate did when applied to the membrane. It increases or decreases the vibrating surface of the vocal cords, and so raises or lowers the pitch. We should liken the action of the internal thyro-arytenoid muscle in limiting the vibrating surface of the vocal cords, to that of the wire which is used in some organ pipes to press against the reed to lengthen or shorten it, and thus to vary its rate of vibration.

Imbert thinks that the increase and decrease of pitch observed by varying the transverse tension of a membrane may have its counterpart in the stretching of the mucous covering of the larynx and cords, which may result from the rise or fall of the thyroid cartilage.

Koschlakoff, examining the vibrations of membranes with the stroboscope in an artificial larynx, as shown in Fig. 35, confirmed in every detail the experiments of Oertel. In a former chapter we suggested that the angle of incidence of the vocal cords must have a considerable effect on the formation of the tone. In this connection Koschlakoff makes the interesting statement that the angle of incidence of the cords affects the type of their vibration, alternate vibrations being generally found where the angle of incidence is small, and that as the angle increased the more distinctly synchronous the vibrations became. He found, too, that where the vibrations were alternate the cord vibrated as a whole, but as they became synchronous the vocal cords were divided into segments. We have thus seen that membranes do divide themselves into segments, and that under all conditions the entire membrane is set into vibration; that in certain conditions, however, it is the outer edge and the more superficial

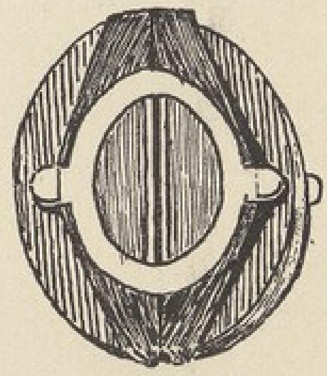

Fig. 35.—Artificial larynx with rubber membranes.

parts which participate most violently in the vibrations. We shall see that these phenomena are to a considerable extent reproduced in the vibrations of the vocal cords when seen with the stroboscope.

To pass now to the movements of the vocal cords as seen in the stroboscope.

The Chest Register.—If the disk of the stroboscope and the vocal cords are vibrating in unison, and the lowest note is sounded, the vocal cords will be seen *at rest*, with a transverse concavity extending along their entire length, and their free border forming a convex line which extends from their posterior to their anterior insertion. If the relation between the rate of the disk of the stroboscope and the oscillation of the vocal cords is changed—that is,

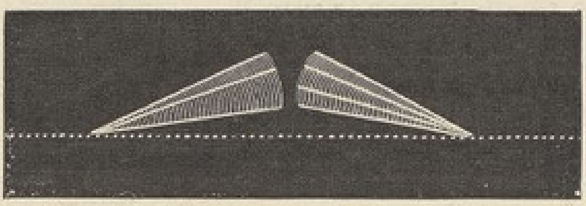

Fig. 36.—Vibration of the vocal cords in the chest register in transverse section.

if the disk is made to revolve more slowly—the vocal cords will be seen throughout their entire length and breadth in oscillation, and in such a way that the extent of the excursion of individual points increases with their distance from the fixed border of the cords (Fig. 36).

The vibrations of the cords are synchronous, and the extent of oscillation considerable. When a higher tone is sounded an increase in length and a decrease in the breadth of the vocal cords is distinctly visible, but at this point the intrinsic movements of the cords are lost, not to appear again until the disk is set rotating at or about the rate of vibration of the vocal cords (Fig. 37).

THE UPPER REGISTER.—Here again the vocal cords are seen vibrating throughout their entire

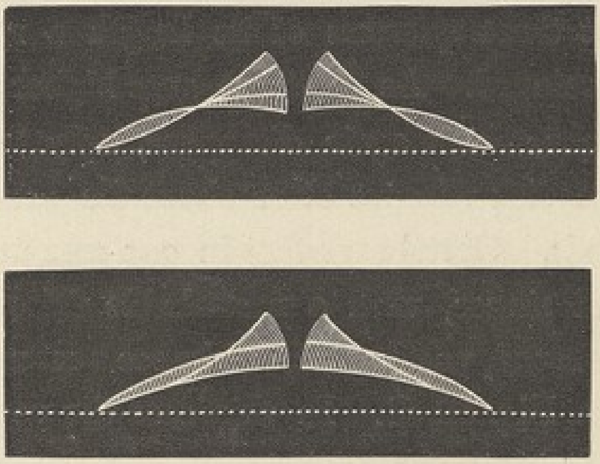

FIG. 37.—Vibration of the vocal cords in the upper register in transverse section.

length and breadth, but the character of the movements is entirely altered. First, the vocal cords are flatter and their edges thinner, and they are divided into segments which have their own rate of vibration. This division is characterized by a faint oval line, marking off a narrow zone comparatively close to the free border.

This oval line is a *nodal* line which divides the cord into two unequal segments (Fig. 32 F). In this case a node has been developed at *c*, and we have a wave which takes up in cross section three quarters of the width of the cord. The extent of the movement of the peripheral segment is small.

The vocal cord is thus divided into two unequal segments, and its movement may again be likened to the transverse vibration of a rod fixed at one end, where at three quarters of its length a node has been developed. As the tone goes higher the intrinsic movements again disappear, only to return when the disk vibrates at or about the rate of the vocal cords. Oertel says that in one case only, in a cultivated singer, with a remarkable falsetto, who had very broad, vocal cords, did he see a second nodal line, as in Fig. 32, G. In this case the vocal cord was divided into three segments. As the result of these observations, we are justified in saying that tone in the chest register is produced by the vibrations of the vocal cords themselves through their entire length and breadth; in the upper register by their subdivision into vibrating segments, separated by nodal lines. Oertel's observations on the living larynx have been confirmed in every particular by

Koschlakoff, except that he saw a second nodal line but once, and that was in an exsected larynx with which he was experimenting. Curiously, it was in a larynx the mucous membrane of which was much infiltrated and loosened, and the whole cord considerably broadened, which partially fulfilled the condition present, i. e., of a broad vocal cord, where Oertel saw two nodal lines. Koschlakoff is of the opinion that the formation of more than one nodal line in the cords is found under pathological conditions only. Under normal conditions he saw but one nodal line in the cords, in the artificial, the living, and the exsected larynx. In his experience, both in the head and in the chest register, the tension of the vocal cords increased as the note was raised. The movement in the upper register of the outer segment of the cords was very small, that of the inner segment—that is, the free border of the cord—much greater, but nothing like so extensive as the movement of the cords in the chest register. Koschlakoff also confirmed the alternate oscillation of membranes under different tension. In order to see if this were true for the vocal cords, Simanowski cut the crico-thyroid muscle on one side, in one experiment, and exsected the superior laryngeal nerve in another. In both cases he found that the alteration of tension thus produced caused alternate oscillations of the vocal cords. Alternate oscillations of the vocal cords were found to take place, according to Oertel, where in acute or chronic laryngitis the thickness of the cord had been increased, and there was a corresponding loss of tension. He mentions the case of an old man where there was very great relaxation and sagging of the superficial layer of the cords, and where the elastic parts could be plainly differentiated from the internal fibres of the thyro-arytenoid muscle. Here, too, he found the same alternate vibrations, and distinct segmental vibrations of the vocal cords through the building of nodal lines. It may be remembered that Oertel stated that nodal lines were always more plainly to be seen in those membranes which were unequally tensed, and in which there were consequently alternate vibrations, conditions which were satisfied in this latter case.

CHAPTER VII.

TONE PLACING.—THE APPLICATION OF THE CORRECT FOCUS OF TONE IN REMOVING PATHOLOGICAL CONDITIONS, CAUSED BY THE USE OF IMPROPER METHODS OF VOICE PRODUCTION.

A MAJORITY of singers lose their voices not from overwork, but as a result of improper emission and respiration.

The muscles of the larynx, like those of the arms and legs, get similarly tired and exhausted after excessive work. The baseball player and the golfer lack proper co-ordination after a long game, and their delivery or stroke, as the case may be, becomes uncertain. So with the singer after overwork; as the muscles of the larynx tire there ensues a lack of perfect equilibrium, and the tones are produced by forcing, in an attempt to overcome the uncertainty which one always feels as the result of loss of tension from muscular fatigue. We often observe in the laryngoscopic mirror, after the singer has overstrained them, a dusky congestion of the cords and a slight bulging of their middle third. If one looks closely and asks the person to sing a note in the medium, it is remarked that the cords touch one another in the bellied portion. We say often, for, unfortunately, the stroke of the glottis is so generally taught even to-day that this picture is constantly presented.

It is very important for the laryngologist and the scientific teacher to accurately observe the middle portion of singers' cords, for by this means one is able to determine whether the so-called method of production is correct or otherwise. Long before the nodules of attrition appear on the cords, we are enabled to observe that there is a tendency toward these dreaded growths, the *bête noire* of artists.

First we should investigate the tendency to touch in the middle, or, more properly speaking, the junction of the anterior and middle third, in singing the medium register. This condition should be looked for in this register, for it can not be observed when the cords are put in greatest tension until much later.

The subjective symptoms are these: Pupils complain that they are losing their piano notes, and it is difficult to sing *mezzo-voce.*

At the commencement of this condition the high notes are as good as ever, for the reason that in greater tension the cords do not touch in the centre. The next complaint we hear is that the singer is beginning to sing a trifle off the pitch, and they complain that for the first time, they are hoarse after singing.

Absolute rest will cure this stage of the malady, and the books all are agreed as to the advice that should be given in these cases—to wit, three months to a year of absolute rest.

This is a very easy thing to say in one's office, but how many times it means to the patient the cessation of income and a condition of absolute want staring him in the face. For the benefit of this class of patients it is our purpose to introduce some exercises, which oftentimes will restore an absolutely wornout voice in the short space of a few days. These exercises have been employed by scores of artists at our suggestion, and as we have yet to hear a dissenting voice as to their efficacy, it is with a certain degree of confidence that we advance the theory upon which this chapter is founded.

With the following axioms we presuppose the pupil to have become familiar:

1. Singing should be done with the least possible effort.

2. No excessive external muscular contraction should interfere with the natural play of the thyroid

and cricoid cartilages (the larynx) during tone production.

3. In exit the tone should be allowed to resonate in all the natural acoustic cavities and attain its greatest complement of overtones or harmonics.

4. The respiration should be so regulated that the greatest amplitude of vibration of the cords be produced with the least possible air blast.

5. The intrinsic muscles of the larynx should be so trained that attrition of the cords becomes an impossibility.

6. The health of the body should be kept at the best, that the mucous membranes of the throat and nose do not thicken and affect the timbre or quality of the voice.

7. The facial muscles and the muscles of the neck should not involuntarily contract during tone production.

8. The tongue and soft palate should be relaxed, except in the employment of the necessary muscular action required in articulation and tone modification.

If we study the formation of the consonants we perceive that M, P, and B are essentially produced, both in speaking and singing, upon the lips; hence they are called labials.

The letters T, D, and often N are formed on a plane passing vertically through the front teeth, and are consequently known as dentals.

A combination of labial and dental is discovered in pronouncing F and V.

If we now go backward, imagining a succession of vertical planes through the mouth, we find in pronouncing the consonants that the sides of the tongue approximate to the teeth instead of the point which forms the dentals T and D, and produce in succession going toward the soft palate C, Z, S, K, W, and Y.

These consonants may be classified as linguals for our purposes.

The vowel sounds A, E, I, O, and U originate in the larynx.

Now let us leave for a moment the consideration of the vertical plane and assume a succession of horizontal planes from the glottis or vocal cords to the level of the root of the nose. We will try in succession several consonants and combinations and seek to determine the relative origin of tone.

First, place the tip of the finger upon the larynx or Adam's apple and sing the words Mama, Papa, Baba, May, Pay, and Bay, and then sing the vowel E, pronounced as in ear. We observe that there is more commotion under the finger when E is sung than when Ma or Pa is attempted, and the origin of the vowel is in the larynx.

The same will be found true of Ah, the attack being felt in the larynx proper. In singing the labials P and B we can feel the air compressed behind the lips before the tone breaks through. So in singing Ah and E we can feel the pressure of the air column below the cords before the tone issues.

This production in the larynx is known as the *coup de glotte*, or stroke of the glottis. We find by prefixing a labial consonant, M, P, or B, that the shock is reduced to a minimum, and the vocal cords do not necessarily touch each other in the initial attack; hence, Ma or Maw should be the word to use in practice, and almost never Ah, and never E.*

The vowel E is responsible for the ruin of many a young singer's voice. It exists in our language and we must sing it, but that does not prove that we must ruin our throats to attain it, nor employ it in practising if it is harmful.

That the vowels A, pronounced as in ah, and E, as in me, are injurious when given with the

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* Madam Melba has repeatedly told me that she never practises her highest notes. She simply "feels" that they are present by the general condition of her throat and voice, and she does not attempt them except when she uses them on the stage. Her exercises for warming the voice always commence with Ma, sung *dans le masque* in the medium register.

shock or stroke of the glottis, is evidenced in numerous pupils of singing who present themselves to have their throats treated, thinking that their laryngitis is due to causes other than their pernicious method of practising their vocal exercises.

The exercises which have proved beneficial to the singer with bulged cords and to those who present nodules of attrition are based upon the foregoing considerations.

If a person in riding has been pulled for a long time by a gay horse the arms and hands become numb and stiff with fatigue and overstrain. To cure this condition we might tell the horseman to rest and he would recover in a few hours. To employ dumb-bells in mild exercises would facilitate the restitution of a normal condition in less time than if rest alone were employed; while if passive massage were combined with the dumb-bells the recovery would take place in even a shorter space of time.

It is upon a similar theory that we have developed the means which we consider very important factors in the care and development of the human voice. By studying the laws of vibration of strings and pipes in physics, we find that there are sections of the vibrating string and portions of the air in the organ pipes, which do not vibrate with the string or pipe as a whole, but which as nodes and segments subdivide the string and pipe into active and passive portions. By careful observation we are enabled to see whether the vocal cord is making a segment in the centre, or whether the vocal cords are vibrating longitudinally without making a segment that touches the opposite one in vibration.

If there happens to be a little mucus on the cord it will facilitate the observation. The eye must be especially educated in order to appreciate what it observes; for with students it is very difficult to make them see even the premonitory pearl which is the first indication of the development of singer's nodules. Even before the appearance of

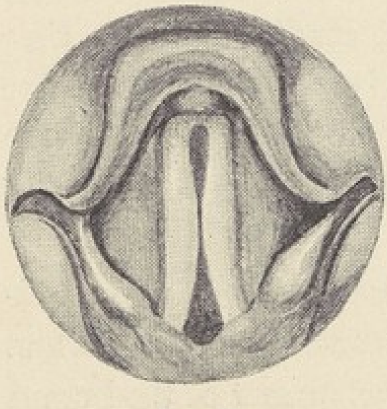


Fig. 38.

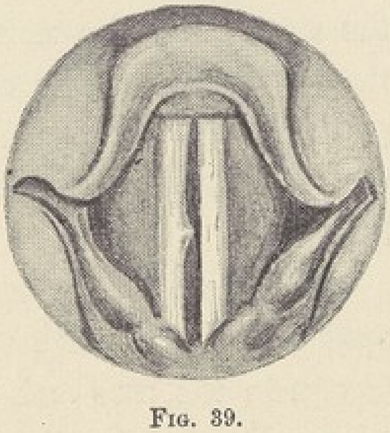


Fig. 39.

the pearl, which is simply a glistening point, we are able to observe the convex contour of the margins, as shown in the plate (Fig. 38), the cords tending to converge in the middle. Another phase is shown in Figs. 39 and 40, which shows the develop-

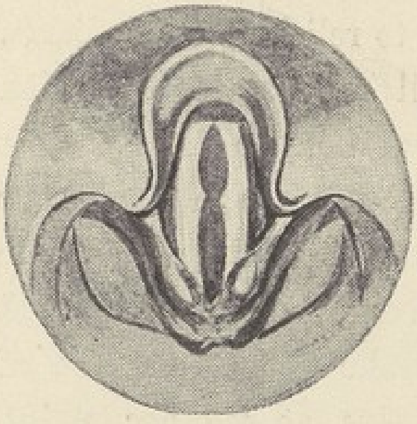


FIG. 40.

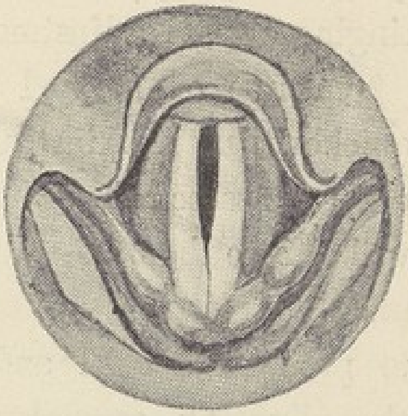


FIG. 41.

ment of the so-called double glottis. Here it would look as though the nodule of attrition had become a true node, but this is not so, as undoubtedly there is not a double segmentation of the cords in vibration, but the nodule is only more pronounced from inflammatory changes. Two deductions may be drawn from this picture, either the cords are being used in singing with insufficient tension, or their internal adjustment by the thyro-arytenoid muscle is faulty, for the latter

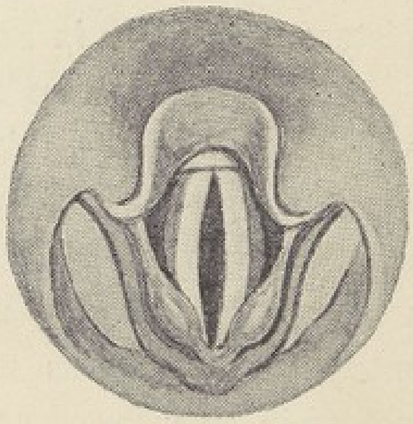


FIG. 42.

condition would cause an improper plan of vibration.

The cords are being injured, and the method of singing needs readjustment to relieve this condition.

Change of method will relieve this condition quicker than rest, instrumentation, or drugs. It is upon the same principle that a change to dumb-bells will relieve the overstrained arms of the rider. We must seek to bring other resultant forces to work to produce tension and make the convexities of the vibrating segments focus at another point. This may be brought about by a change in the method of voice production.

We once observed that all the pupils of a certain singing master had what is known as a breathy tone, and on examination their cords presented the picture as is shown in Figs. 41 and 42.

In questioning we found that in the method which had produced this bowing, or elliptical opening of the glottis, the vowel O had been almost constantly employed in daily practice, and no attention whatever given to the respiration, nearly twice as many respirations as were necessary being employed in ordinary phrasing.

In another class of pupils from a well-known conservatory where the stroke of the glottis was daily taught and practised, we observed the opposite of this condition; instead of the ellipse we found the cords bulged, presenting a convexity one toward the other (Figs. 38 and 40), the centre showing the result of attrition.

Here upon investigation we ascertained that the vowel A, as in ah, and E, pronounced as in ear, were the vowels used in the daily routine work with the explosive attack. Having by repeated observation verified the truth of the hypothesis, we undertook an interesting experiment to observe the effect of a change of method upon the condition of the cords.

One pupil, ruined by the false theory of the conservatory, we advised to apply to the teacher whose product was elliptical, and whose horror of the *coup de glotte* had carried him to the extreme of breathiness of tone; while another pupil of the elliptical school was sent to the advocate of the "French attack."

To our utter surprise we found both pupils absolutely cured of the condition of which they complained at the end of a very few lessons, and each roundly denounced the method and the teacher who had led them into such error.

It was the appreciation of how much lay in the realm of theory in teaching, that led us to investigate in how far the troubles of singers were due to their faulty emission and habits of tone production.

The subject has proved so vast, yet so highly important, that even with the hearty co-operation of many of the very best artists of to-day, we must admit we are but on the threshold of truth, and write our convictions with a certain degree of precaution, fully conscious that the strictly scientific treatment of the subject will like all other innovations, find plenty of adverse criticism.

We can only say that our demonstrations have been so successful that some of our greatest artists have discarded the stroke of the glottis, after looking at the picture of their own cords and the cords of others in more or less advanced stages of singers' nodules, appreciating after a week of exercises with the proper attack that it was a new method of voice production they needed instead of drugs.

When a voice is getting worn, losing its carrying power and warmth of tone, when a little too much effort causes hoarseness and vocal fatigue, look for two things—explosive attack, which causes a bulging of the cords and the nodules of attrition, or breathiness of tone, causing an elliptical condition of the vocal ligaments.

The laryngoscopic mirror will in every case confirm the diagnosis, and we will generally find one of the above pictures presented.

We can in no fewer words illustrate the method of relieving this condition than to quote from a monograph read by the author before the State Music Teachers' Convention in Rochester two years ago, which will review somewhat the rules laid down in the chapter on respiration, and the proper focus of tone.

"If we take a good-sized laryngoscopic mirror—No. 4, for example—and ask a patient to sing E or Ah, the cords come into view for two reasons: First, the epiglottis becomes more perpendicular, allowing a better view of the bands; and, secondly, the cords themselves are on a more elevated plane, owing to a slight elevation of the larynx and relaxation of the intrinsic tensors of the cords. In this position we remark that the free borders of the cords come together in the anterior and central portions, and we are able to study the initial tone attack, the membrane separating as the tone bursts through the closed chink. This picture may be said to be an imitation on a small scale of the so-called stroke of the glottis. In this method of producing a tone, the initial attack being upon the cords themselves, the central portions of the cords necessarily touch. The peculiar muscular equilibrium which is employed in this mode of attack invites a reflex elevation of the soft palate, cutting off the oral from the nasal cavities. As we look at this picture our minds revert to the singing teacher who commands her pupils to keep their palates up, sing in the back of their heads, and strike the glottis. Could ever villainy be more compounded! Let us take the same patient and require him to sing the same note, but in an entirely different way. We will first ask him to expand his upper chest, not necessarily by respiration, but by elevation of the superior ribs by a muscular effort, at the same time slightly drawing in the abdominal wall. We now introduce the smallest mirror and ask our patient to sing A, pronounced as in law or maw. With this position of the larynx and muscular poise we observe two things: First, the epiglottis does not assume its most vertical aspect, not inclining as near the perpendicular, and the soft palate and uvula do not spring upward and backward to make the partition between the mouth and naso-pharynx. Different in every respect is the tone produced by the cords which may be assumed to vibrate longitudinally, but never touching each other in the middle portion, even in making the initial attack. The cords appear narrower, tenser, lower in the voice tube, equidistant from each other, more homogeneous, and whiter in colour.

"These two pictures should be well considered, as they become the basis of criticism in distinguishing the correct and eliminating incorrect methods on the one hand in singers' voices, and of the greatest assistance to the laryngologist in correcting pathological conditions, the result of bad training.

"Within the past three years the entire theory of musical education has changed in France, the explanation of this change being that there is at present a better appreciation of the influences bearing upon the production of tone and a better understanding of the physiology of the larynx by reason of the advances made in laryngoscopy.

"Modern teaching tends to cultivate tone harmonies and sympathy in the voice at the expense of brilliancy of execution. The same judgment should be exercised in the training of an individual who proposes to make singing his or her art as should be employed in advising the painter that his special forte lies in landscapes, rich in colour, to which he may give expression to his imaginative genius, rather than the sterner facsimile of portraiture.

"How many singers we hear whose technicque and brilliant staccato in the Bell Song of Lakme calls forth our admiration and amazement, but who are absolutely unable to put any sympathy whatsoever into the simplest ballad. We should study colour harmonies in music in the same way that they must be studied in painting. There is no rule for the palpitating sunlight effects and prismatic play of colours in the school of Claude Monet; it is certainly a subtile feeling which is given by an ingenious mingling of pure spectrum colours. In the human voice that added colouring of tone, which appeals to the heart as well as to the ear of the listener, must be brought about by the employment of those harmonics, which are added to the original tone by intervibrations within the accessory cavities of the nasal passages. To sing *dans le masque*, as the French say, is to give this added richness to the initial tone; but to sing in this manner requires the soft palate and uvula to be lowered in the production of tone. Likewise, to make the purest initial tone from the cords we must get the utmost possible tension. Several elements enter into the question of the greatest possible tension, one of the most important of which is that the trachea be drawn down to assume the position that it takes when the apices of the lungs are filled to their greatest extent with air. One of the greatest singers that the world has ever known told me that the reason he adopted a fixed high chest was that he had found, after an operation performed on one of his cords, that the only way in which he could be at all sure of his voice while singing was in the maintenance of the so-called high-chest respiration. This is easily explained by the fact that in this position—

the upper ribs remaining fixed—the apices of the lungs, always remaining in contact with the thoracic wall, are expanded to their fullest extent, the cords reflexively tending to keep in their state of greatest possible tension. In this position the breathing becomes entirely inferior costal and diaphragmatic. The position of the thoracic cavity, as indicated above, permits the lungs to expand to their fullest extent, thus adding a secondary resonance to the voice from below—a sort of complementary timbre —the fixed upper thorax allowing of the least possible change of colour during tone production.

"It is this combination of facial and thoracic tone fortification which gives the enormous carrying power to tones produced by this method. For a number of years, before I made a special study and estimated the great significance of these factors in singing, I deluged the throats of singers with sedative and astringent sprays when their cords appeared congested and swollen, ofttimes presenting nodules in their centre which I had never previously recognised as being due entirely to singing with an improperly poised larynx."

Let us imagine we have a voice presented, suffering from either of the above-mentioned conditions. Since we have found *Ma* or *Maw* to be the combination of most anterior origin, we will ask our pupil to pose a tone as follows. (If a soprano, take c'', or a note thereabouts, for example.)

1. Hum a tone with the mouth closed, preceded by a slight puff of air through the nose, as one would imitate the hum of a bee.

2. After making this tone as pure and musical as possible (by musical is meant resonant or full of overtones), fix the mind upon the word *Maw* and mentally bring forward the tone, almost saying it, until we feel conscious of the vibration upon the lips; at the same time the position of the initial tone should not be changed. To ascertain if the mouth focus is correct, simply pluck the lower lip with the finger as you would pluck the string of a musical instrument, and if the mouth tone is sufficiently far forward an explosive sound like *Mum* will answer. If this tone is not of almost equal purity to the head tone, which all the time must be sounding, the equilibrium of tone—i. e., the division into the mouth and facial—is not satisfied, and we must experiment until we get the mouth tone as pure as the facial.

3. Having gotten the purest tone possible, let us now direct the pupil to drop the lower jaw and open the mouth by simply allowing the weight of the jaw to accomplish this without the slightest muscular effort. Our mental *Maw* now breaks on

the lips into tone, and we have the pure vowel with its prefixed consonant without being aware of the effort that has produced it—it comes so spontaneously and beautifully, and seems to originate on the lips. The mouth is now closed, and if we have not interfered with our focus of attack we hear the initial *Hum* still vibrating pure and beautiful in the facial resonators.

4. After this exercise with the correct focus of tone has become thoroughly familiar, the next step is to take a phrase and sing the notes with *Maw* or *Ma* instead of the words of the song, always commencing in that portion of the scale which will allow of the easiest initial tone for the focus.

These are the exercises so much appreciated by singers that we employ for the reduction of nodules of attrition on the cords, which exercises, strange to say, have been the object of ridicule by certain laryngologists who have undoubtedly not given the subject of physics a proper amount of consideration. We are indebted to the stroboscope for the scientific vindication of our theory and treatment of singers' nodules. The word *Ma* should be sung in this manner for several minutes at a time and every hour in the day. It makes no difference on what note it is sung, provided the resonators add new overtones to the voice and thus produce a rearrangement of the vocal cords in their manner of vibration. These exercises must be accompanied by the high-chest method of breathing, as described in the chapter on respiration. As we have so often stated, an additional resonance and consequent augmentation of overtones is derived from this source, and constructively assists in the rearrangement of the manner of vibration of the cords, at the same time increasing their tension. After all, the correct focus of attack or the proper placing of tone is the most important thing to be studied in singing. Without it our voices do not possess charm and the vitality is jeopardized. By the steady employment of them for an hour the above exercises have pulled many a weary voice together, and enabled many a distracted artist to go with confidence upon the stage or platform. Their daily use gives new overtones to the voice, prevents attrition and allied affections of the cords, and enables the singer to use his voice through many a cold with comparative immunity. We have given but two examples of affections encountered in singers, but these two will cover almost every condition brought about by bad methods. In the treatment of relaxed cords and of congested cords a good piece of advice to give a pupil is this: Until you can do a pure *Hum* with the mouth closed and without effort, do not attempt to talk, simply whisper and make the attack upon the lips even while doing this. By observing this rule many a prolonged hoarseness may be prevented. In either of the above conditions the *Maw* exercises may be commenced with benefit to the cords as soon as the head *Hum* is easily produced. The above terms are not expressed in elegant English, but we have attempted to make the explanation in the simplest possible manner that our meaning be not misunderstood. The pupil who has been struggling with various teachers for years to educate his or her voice will ofttimes produce a tone so satisfactory to himself by this simple means, after a few minutes' work, that he will immediately assert that his entire study has been in vain. Not so; for even if the tone has not been previously properly placed and overtones have been disregarded, he has learned his music and at the same time has strengthened the intrinsic muscles of his larynx. A word as to the male voice, for the above relates more particularly to the female registers. Whether a pathological condition has commenced on the cords or a voice has simply become throaty, with stiff base of tongue and raised uvula, the same principles may be demonstrated. Our treatment in either case will be identical. We ask the pupil to commence with the note *c*, for example, in the bass clef, and hum through the nose, pinching it together with the thumb and forefinger and letting go suddenly to make an explosive sound on the attack. See that the soft palate is entirely relaxed, and that it keeps so absolutely during the *arpeggio* which we sing, commencing with *Maw*, and *Awe*, *Awe*, *Awe*, with the mouth open to observe the soft palate and base of tongue. Carry these *arpeggios* up until the voice reaches its limit. The soft palate should not be felt in the slightest degree, and every muscle of the pharynx must be in relaxation. These *arpeggios* are now to be sung with a sound as if made by the word *Hawng*, and *Awng*, *Awng*, *Awng*, and the French sound of *En*. After any of these notes is sung, if the sound be prolonged and the mouth closed, the tone must continue in the facial resonators, or *dans le masque*, as the French say. The question asked by the pupil will be, Will not this practice make the tones nasal? No, it will only enrich them and take the attack from the cords, for the moment you add words and consonants the nasal quality we have heard in the exercises disappears. These exercises are identical in their effect with the first examples we gave for the female voice. The soprano, however, would commence at c'' in the treble clef or thereabouts on whatever note was found to be easiest to focus exactly in this method.

Tradition says that Madame Rudersdorf taught exercises similar to these. If she did she never ruined a voice, a fact which many teachers can not boast. If the beginner were taught first the proper respiration, and then had the separate notes of his voice so built up that he might obtain the best quality of overtones, and afterward was educated to sing with absolute relaxation of the extrinsic muscles and freedom from forcing, we might expect a perfect voice. The shock, or *coup de glotte*, is death to the voice; it is born of ignorance, and to teach or allow its continuance is a crime. We have no words strong enough to properly condemn it. Having seen the dire effects upon many pupils of those who advise it, are we not justified in considering its advocates parties to either gross ignorance or atrocious malpractice? We have arrived at the solution of the question of voice placing after many years of study assisted by some very celebrated artists. We have attempted to explain in a few words, and without an unnecessary phrase, the results we have attained. We do not say it boastingly, but we think we have found the truth, at any rate we have started the investigation of many teachers in the right direction. By the methods just described, which appear so simple, to some almost childish at first glance, we have restored seemingly worn-out voices in an incredibly short space of time; we have rendered easy what seemed to many a thing of terror. Our case books are full of letters of unbounded gratitude from sufferers, but our means have been so simple that we almost feel that an apology is due to the great musical public on account of this very simplicity of our methods. On welcoming my dear friend Jean de Reszke to my house after his fourth return to our shores I said to him: "Jean, have you any new facts for my poor book? Have your studies during the past year taught you anything which may be of use to me?" "Yes," he responded, "I find that the great question of the singer's art becomes narrower and narrower all the time, until I can truly say that the great question of singing becomes a question of the nose—*la grande question du chant devient une question du nez.*"

There are many other considerations which enter into the medical treatment of singers, which are, however, without the province of this book, such as medication, electricity, hygiene, gymnastics, massage, hydrotherapy, diet, etc., which we hope to treat of at another time. As to the use of astringents and local applications to the larynx of singers, perhaps the least said the better. We find the natural secretions quite sufficient to lubricate and moisten the mucous membrane of the vocal cords without recourse to drugs, provided, however, that the nose is properly performing its functions of filtering, warming, and moistening the inspired air. So here also, as in tone production, we may say it becomes a question of the nose.

CHAPTER VIII.

VOICE BUILDING.

We have discussed the physical laws by which a tone is produced, and find that the inherent quality of a tone depends upon the number of its harmonics, upon their relative position and strength, and also upon the way in which the tone is attacked and released.

In the voice the harmonics of the tone depend upon the resonating cavities of the larynx, pharynx, nose, and mouth.

A good quality of tone can only be attained by peculiar co-ordination and adjustment of these cavities.

To secure this a vowel should be used which is most conducive to this condition, one which contains the richest overtones, and at the same time induces increased tension of the vocal cords.

The nature of the initial attack is altered by every consonant employed. Therefore a consonant should be prefixed to the vowel which least disturbs the muscular poise and insures the least injurious attack.

The first point in teaching is to secure the relaxed condition of the jaw, tongue, soft palate, and lips.

The vowel A, as pronounced in awe, should be used, as in this tone the harmonics have the best relative position, and the most agreeable quality is produced.

A labial consonant, in preference M, should preceed the sound of the vowel to bring the attack upon the lips. Reasons for this have been stated in another chapter.

The M concentrates the energy in the front of the face, makes the attack incisive, and prevents the initial attack from injuring the vocal cords by originating in the larynx.

The breath must not be forced in the attack, but must be regulated by the muscles of expiration, and not modified by muscular contraction above the glottis. The tone should be produced without any appreciable respiratory effort.

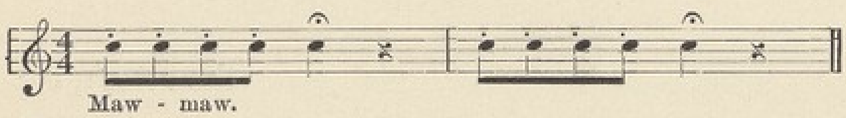
The tone should be light and free, and directed toward the front of the face at the base of the nostrils. If it is directed only toward the teeth it will lack that extra re-enforcement given by the resonators of the nose.

The word "direct" is used unadvisedly. All vocal teaching is done by giving mental impressions. Never give the pupil the idea of singing or pushing the note out from the throat toward any given place. If this is done the breath will be forced out violently, and muscles involuntarily contracted which should remain at rest.

The attack of the tone must be upon the lips, and at the same time resound in the facial resonators.

In learning to make a free attack a note should be taken which lies in the middle of the compass of the voice.

The pupil should attack this tone several times in succession with the combination *Maw.*



The tone should not be sustained any length of time, as the respiratory muscles are not yet strong, and the effort of sustaining will fatigue the intrinsic muscles of the larynx, and give a tremulous, forced tone.

The attack has been so thoroughly explained in the chapter on *tone placing* that further remarks on the subject are unnecessary.

The first exercises for attack must be modified according to the need of the pupil. In some cases, where the initial tone will not come forward, and is restricted by contraction of the soft palate and muscles of the pharynx, it is necessary for the pupil to practise entirely by humming until the tone is correctly focused.

Having considered the poise of the initial tone we may now discuss the subject of voice compass.

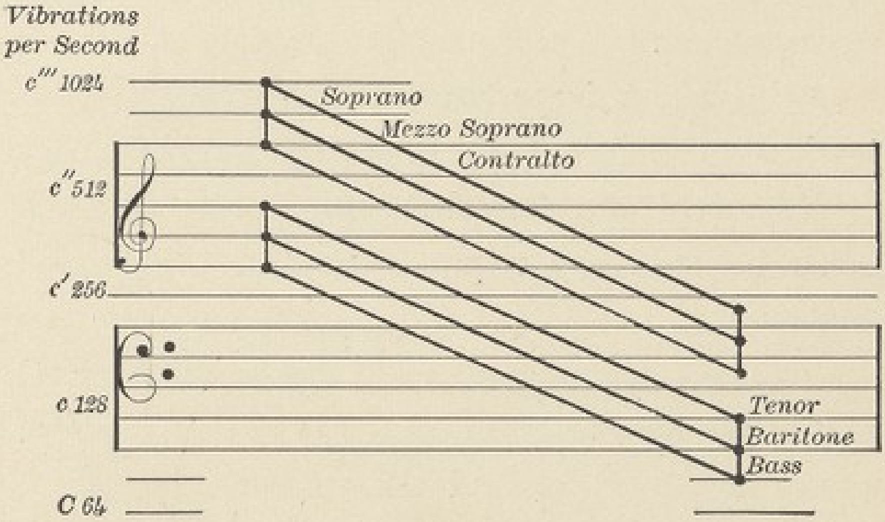


Fig. 43.—The compass of the human voice.

Three distinct qualities of tone are usually found in the natural, untrained voice, which for convenience in explaining the vocal scale will be called chest, medium, and head. The so-called medium register should be disregarded, for it is produced later by the same mechanism as the head register, and is in reality the head tone incomplete from the absence of its proper resonance or overtones, the mouth quality being present at the expense of the facial. The chest and medium qualities are usually very distinct in the untrained voice. The covered head tone is less often present, the thin, white, medium quality being carried up to take its place. Yet it is just this so-called covered head timbre which is needed to give to the tones their best re-enforcement, and with which the voice should be built and strengthened.

Of highest importance is the ability of the teacher to differentiate between the high, shrill medium and the true head tone; also to distinguish between the upper chest and the medium quality.

The lack of a proper acoustic perception on the part of the teacher often results in permitting registers to be forced beyond their natural limits, thus injuring and overstraining the voice.

The existence and position of registers in the more advanced training of the voice should not be considered.

If each register is considered an entity and trained in its own special quality, the difference between the registers will become more pronounced, and the act of passing from one to the other will be accompanied by more effort. If the voice is trained from the low to the high tones there is danger of overlapping and forcing the chest register beyond its limit, and of advancing the medium, sometimes to the entire exclusion of the head quality. Such treatment impairs the timbre and is the cause of the so-called "hole" in the voice.

The voice should be trained from the *head register down*—that is, the timbre of the head tone should predominate the scale, and should be brought as low in pitch as possible.

In a woman's voice the vocal poise of this register should be maintained throughout the descending scale, until the later development of the proper chest quality makes its involuntary impress upon the lower tones. The vocal attitude in the production of these head tones reflexively tenses the vocal cords.

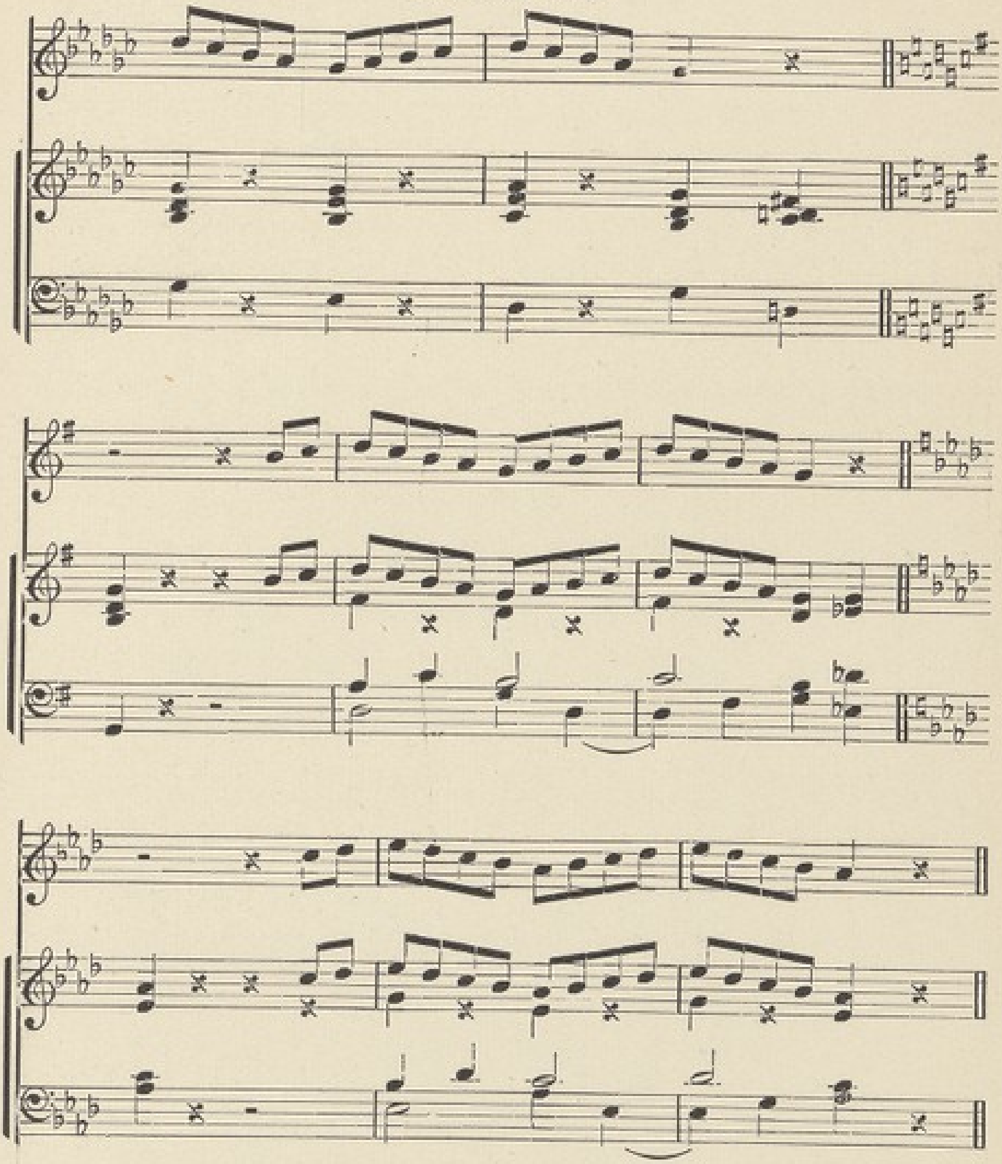
The natural head tones of the untrained voice lie ordinarily just above the middle of the vocal scale; in the soprano voice c'' or $c''\sharp$ is usually the lowest; therefore the exercises for training the voice should begin on, or in the vicinity of, these notes (c'', $c''\sharp$), for, by so doing, the cords become correctly approximated and homogeneous, and allow the production of a pure tone, which can be carried throughout the descending scale. Let the teacher then test the voice until the lowest tone which is produced by the mechanism of the head register is discovered. On this let the pupil sing *Maw*, as described in a previous chapter, until the tension is sufficient to allow the production of a pure resonant tone, without breathiness and without contraction. It will now be found that this covered, forward vowel, with the labial consonant, will help the pupil place the tone in its proper focus.

When the pupil has learned the production of this tone, and one or two higher tones, and is able to recognise the timbre of a pure head tone, let an easy exercise be used which, in practice, will extend this quality over a greater range of the voice.

A simple musical figure should be used, not exceeding the range of five notes.

MOORE.

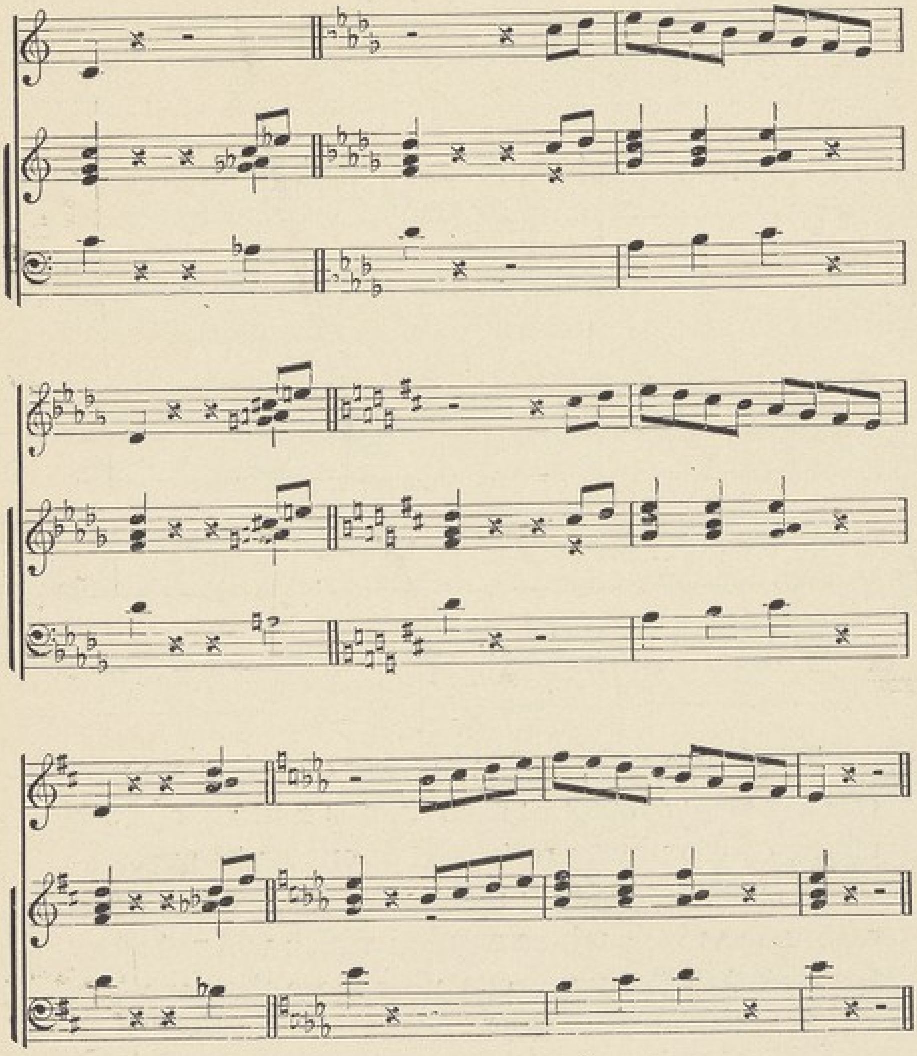
KEY OF F♯.



The figure and rhythm in these exercises are necessarily very simple, as the range is limited, and the attack of the phrase restricted to one or two notes.

A short descending scale may follow, one of an octave or a ninth, with a rhythm which will not allow the accent to fall upon one note more than another.

KEY OF C♯.



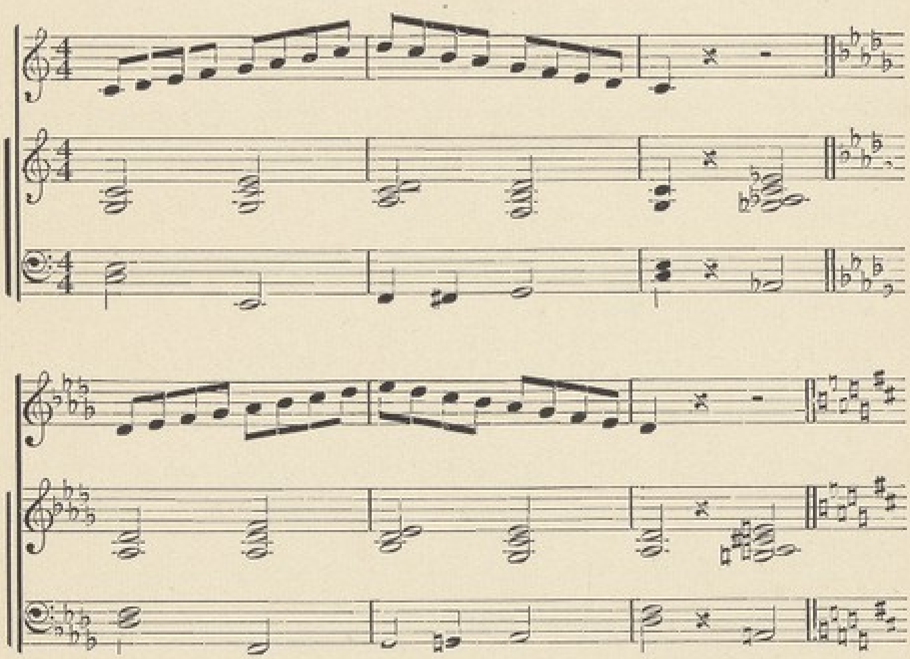
In these exercises the pupil, by passing quickly from the high to the low tone in one breath, will be able to compare constantly each tone, and in this way will learn to use the mechanism of the head register for all the tones in the descending scale, and thus eliminate the so-called medium register at once.

The scales should be sung *piano* and *leggiero*, with as little effort as possible. There should be, as yet, no attempt to produce intensity of tone. The great masters of all instruments (with the exception of a few Germans) now insist upon the soft, light touch to begin with. This touch lies between the *staccato* and *legato*; it is free and delicate; it lacks strength at first, but is resonant and the best foundation for purity and richness of tone. So with the voice, the first exercises should be gentle, and should be sung *mezzo-voce*.

No loud, sustained tones, *crescendo-diminuendo*,  should be used by beginners. Such exercises invariably force and strain the voice.

When the pupil, by practising the above scales, has learned to carry the timbre of the head register through the descending scale without disruption of breath, and has learned to attack *c′* in the same manner as *c″*, then a series of ascending scales may be used.

All exercises may be transposed to suit the compass of each voice.



When the voice has become comparatively smooth and even by the use of these scales, exercises should be practised to strengthen particular sections. The short five-note figure should be used, with more variety in the musical form, and with the *tempo* slightly slower than in the scales.

First measurement of Intervals. ASHFORTH.

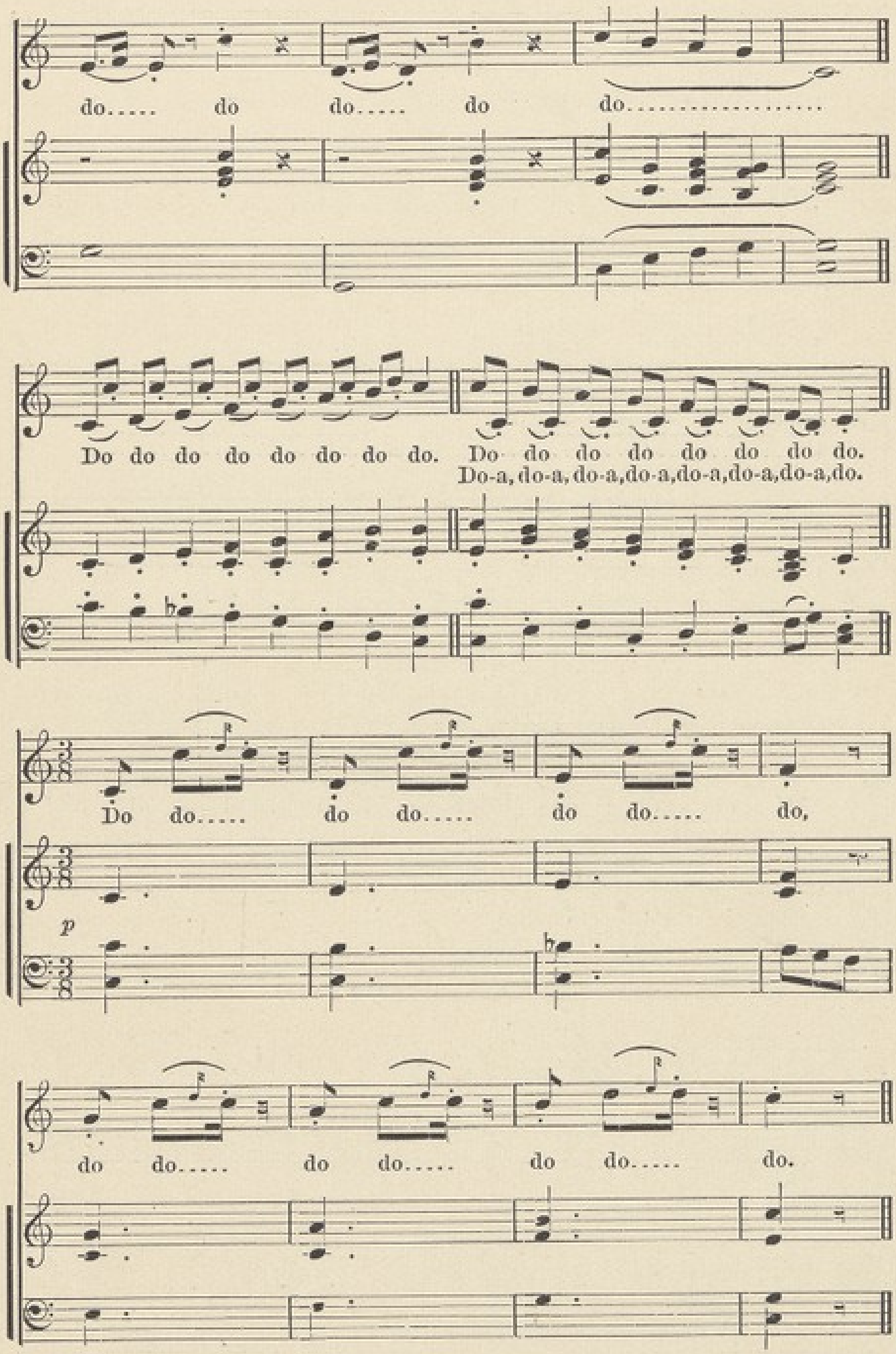
Extension of Intervals.

Exercises to produce flexibility of the muscles of the cheeks, lips, tongue, and throat may now be studied. A dental consonant should be used, though the vowel may be changed to suit the condition of the voice. The attack of the first note must be incisive, while the second note is *staccato* and soft.

LANKOW.

The jaw, soft palate and tongue must be relaxed. The tongue, especially, must be loose and kept in the front of the mouth.

LANKOW.

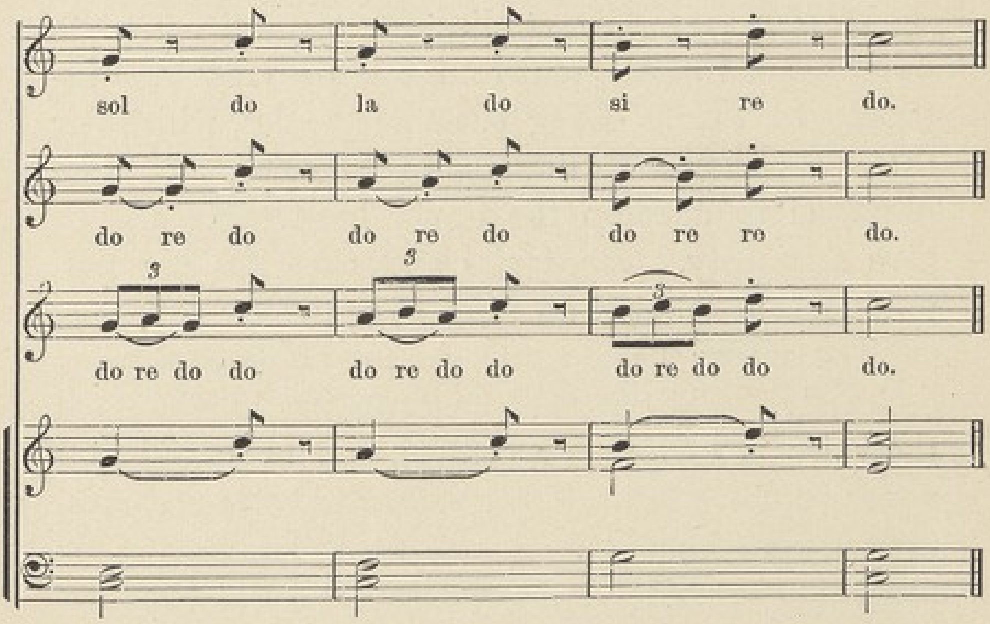


The consonant must be more accentuated as intensity of tone increases.

SPEECH-EXERCISES.

Exercises for enunciation should accompany the above studies. These quick staccato speech-exercises make the tongue and lips supple and aid greatly in learning to enunciate clearly and distinctly. At first they may be practiced in a whisper, and afterwards sung *mezzo voce.*

LANKOW.



All the exercises to be modulated chromatically, according to the range of voice.

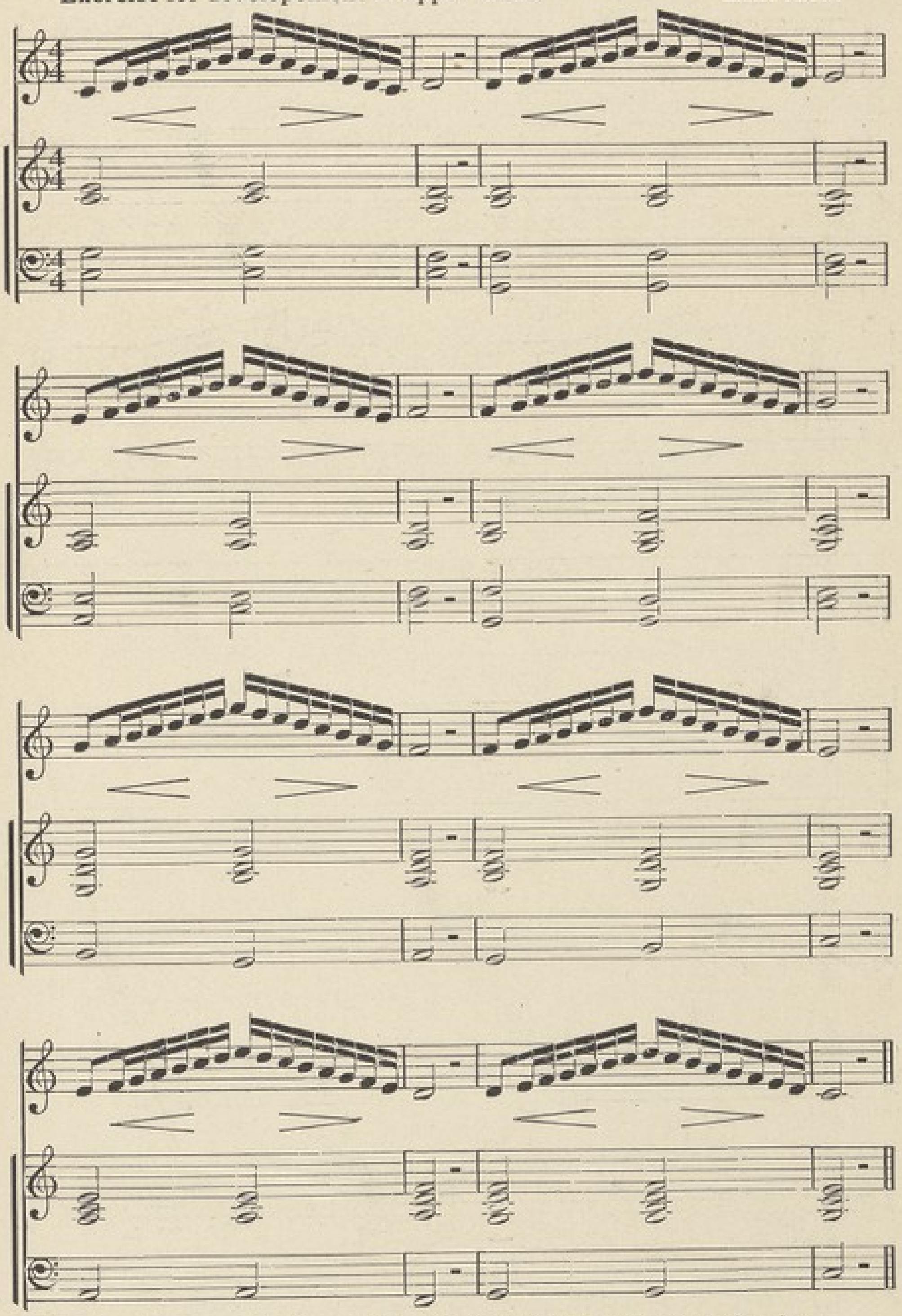
Exercise for learning the quick breathing in "demi respiration." Breath to be taken after the staccato note and on the sixteenth rest *only*.

Now may follow studies for a more complete development of the entire range of voice and intensity of tone. Long sustained scales, which, by their character, give impetus to the voice, should be practised to develop the upper head tones and to give flexibility. *Arpeggios* and exercises for sustaining tones should be used as the voice develops.

The upper head tones should be treated very delicately. They should be sung *mezzo-voce* until the voice is well under control, and at first should never be sustained. Even after the voice has been placed, care should be taken to avoid fatigue by practising them too loud or sustaining them for too long a time.

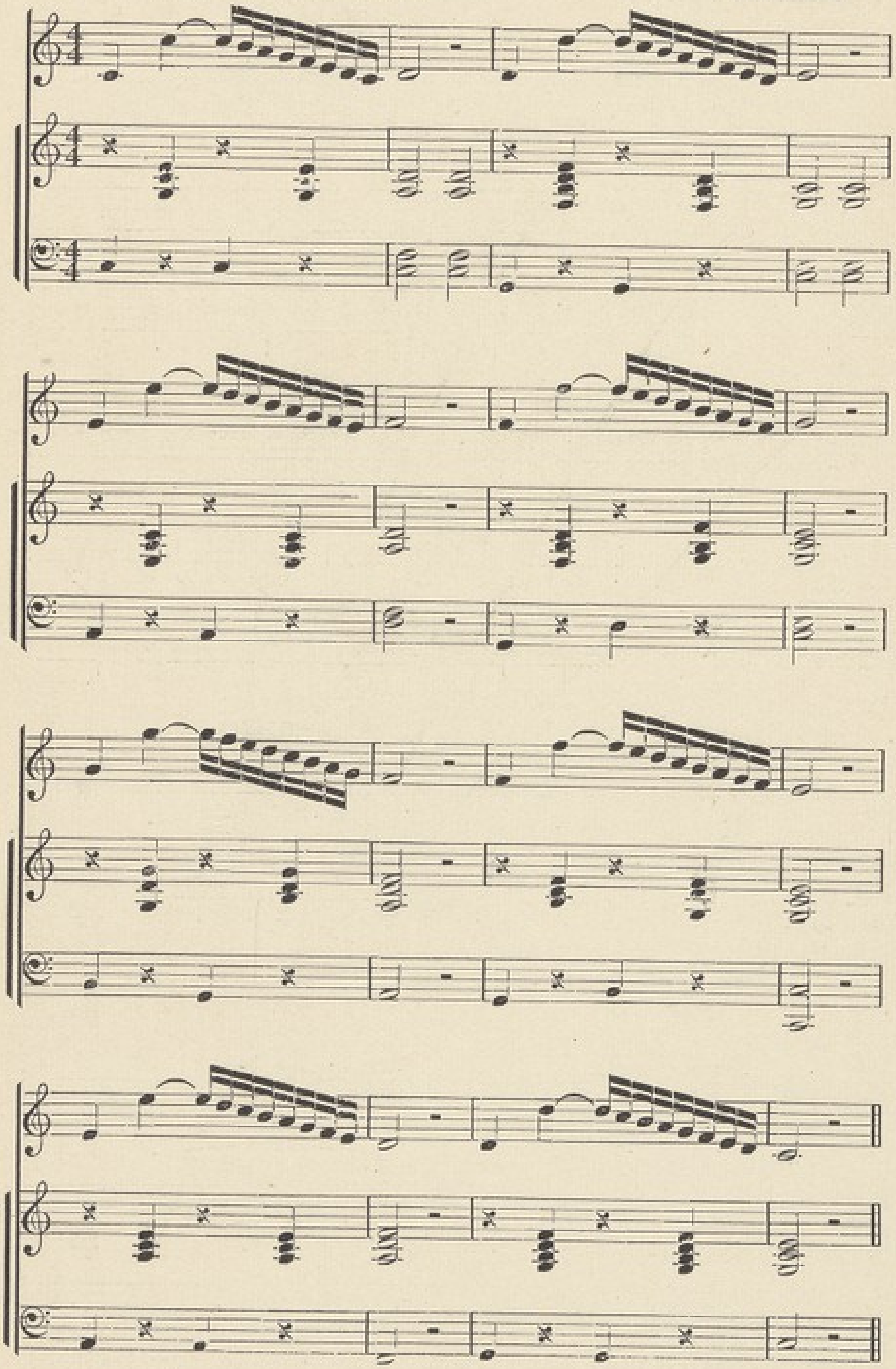
EXERCISES FOR THE LATER DEVELOPEMENT OF THE VOICE.

Exercise for developement of upper tones. ASHFORTH.



To be transposed chromatically according to range of voice.

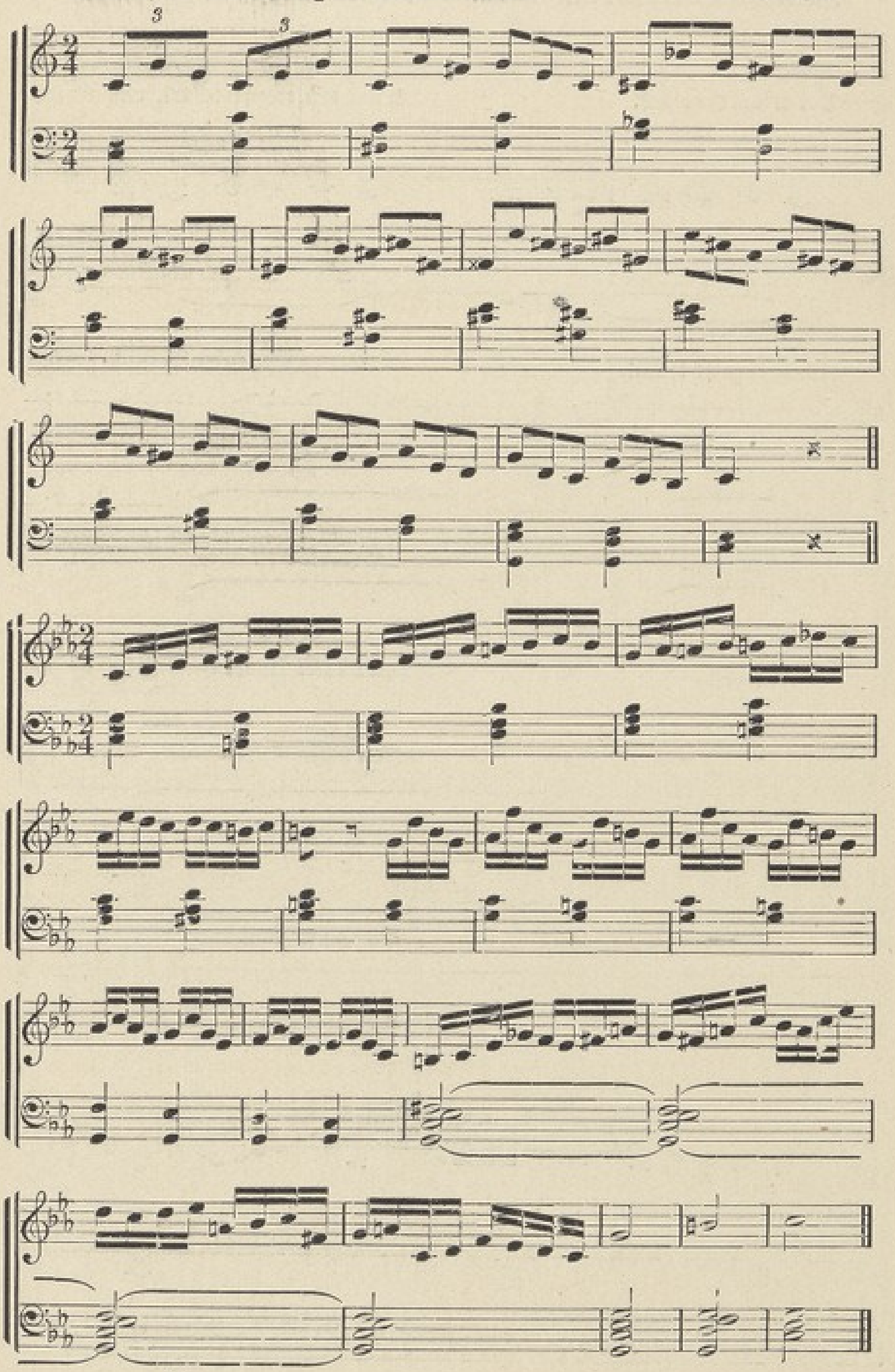
Exercise for full octave attack. ASHFORTH.



Exercises in sustained tones. ASHFORTH.

Studies in Minor Scales. GARCIA.

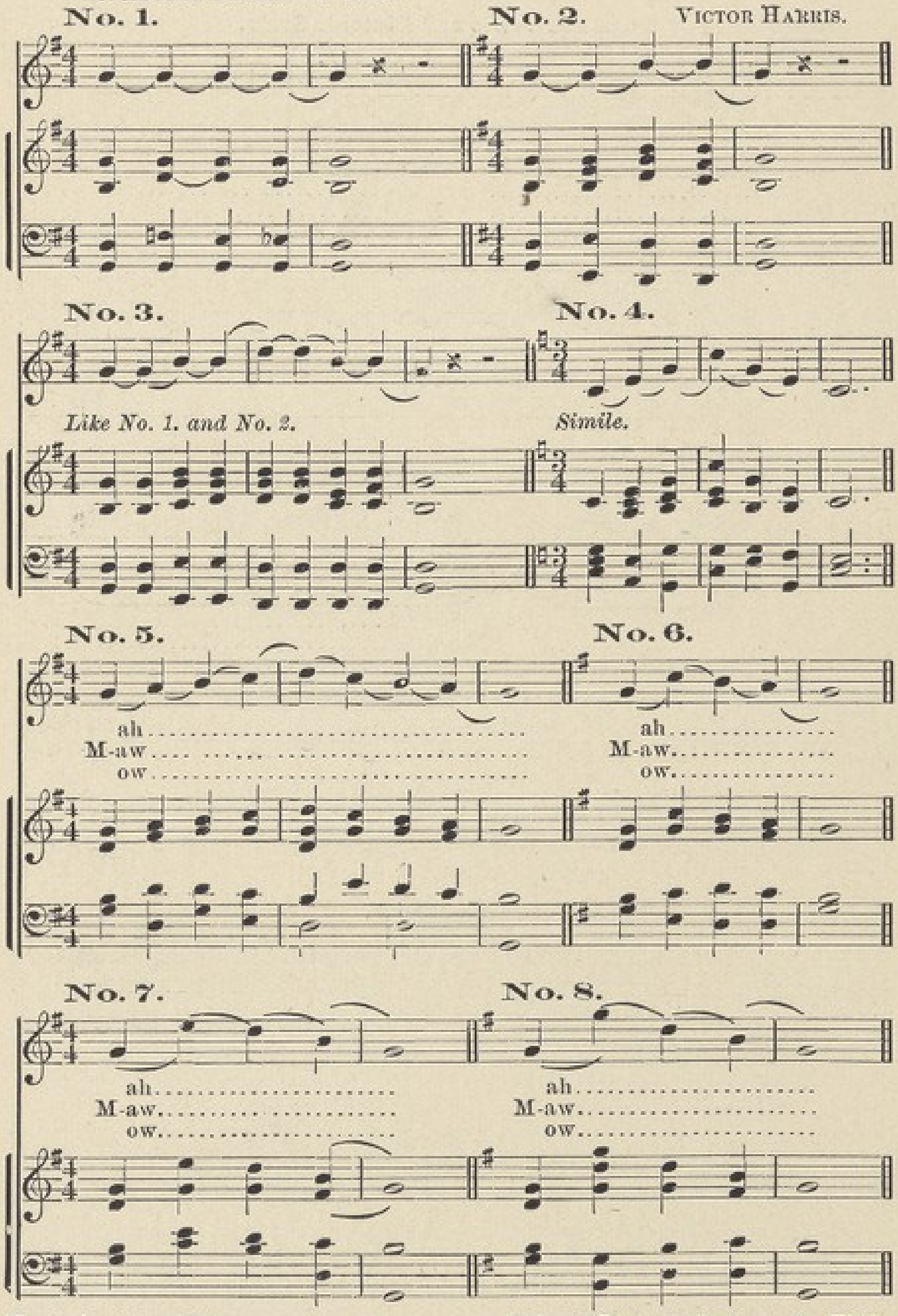
Studies for facilitating correct intonation. GARCIA.



Exercises for correct intonation. MADAM EAMES.

Examples of Randegger Scales.

Exercises in sustained tones.



No. 1. Sustained Tone.
No. 2. Sustained tone and Third.
No. 3. Sustained tone, Third and Fifth.
No. 4. Sustained tone, Third, Fifth and Octave.
No. 5. Diatonic Scale to the Fifth.
No. 6. Interval of the Fourth.
No. 7. Interval of the Sixth.
No. 8. Interval of the Octave.

SCALE EXERCISES.

Combination of Sustained Tones and Diatonic Scale.

No. 9. **No. 10.** VICTOR HARRIS.

No. 11. **No. 12.**

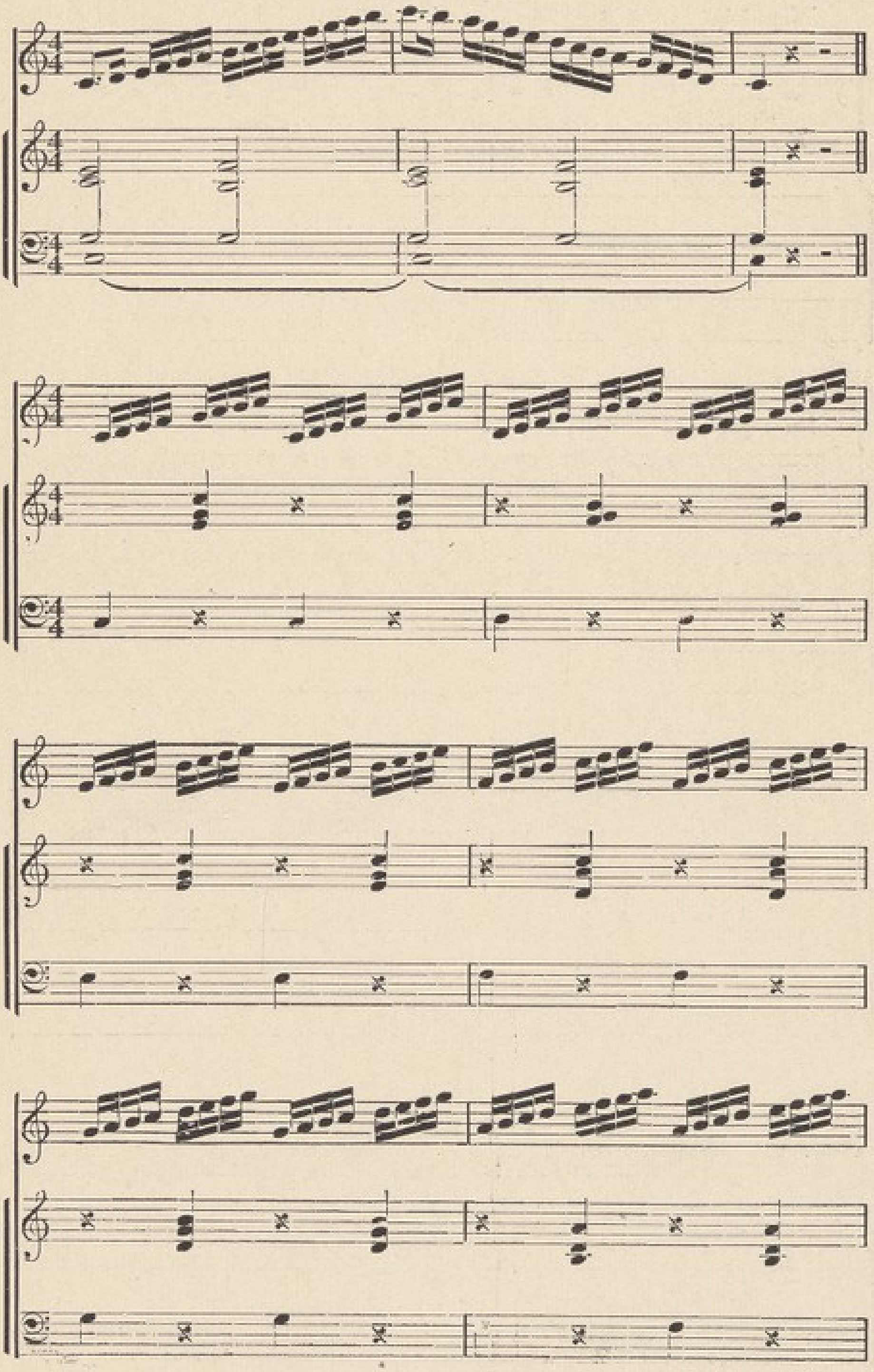
No. 13. **No. 14.**

No. 9. Scale of the Octave.
No. 10. Scale of the Ninth.
No. 11. Scale of the Eleventh.
No. 12. Arpeggio of the Twelfth.

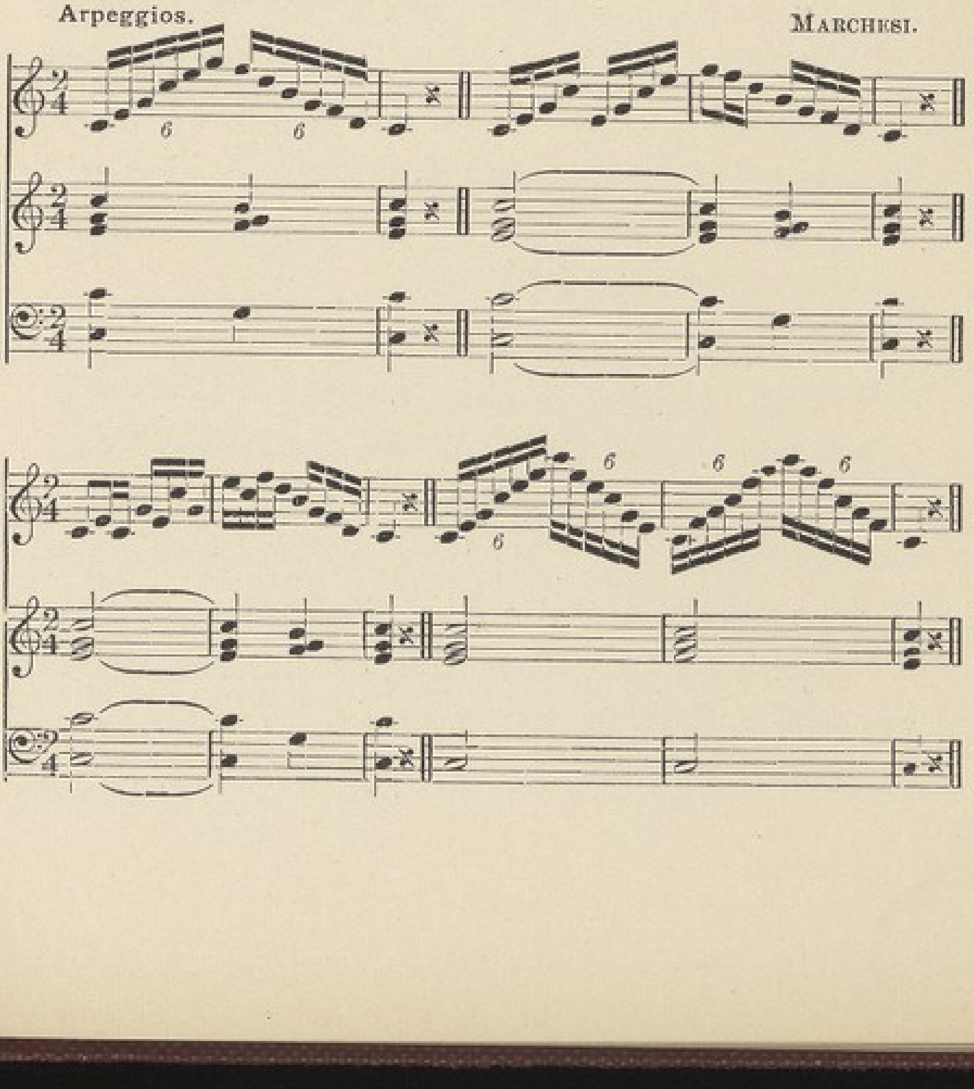
No. 13. Tenth.
No. 14. Twelfth.
No. 15. Octave.
No. 16. Tenth.

No. 15. **No. 16.**

Examples of Marchesi Scales.



Arpeggios. MARCHESI.



The length of time a singer should practise depends much upon the character and condition of the voice. Specific rules can not be given. Madam Melba, when asked how many hours of practice a day she would advise for a pupil, said, "No hours for a beginner, but minutes. I myself never practise more than an hour a day, and usually much less."

Forty minutes or an hour of actual voice practice is quite sufficient to develop most voices. This time should be divided into periods of ten or fifteen minutes each.

Long hours of practice will not hasten the work of voice building. They only fatigue the voice and wear it out. Regularity in practice is the greatest aid to advancement.

The voice develops gradually, and nothing will be gained in trying to force its natural growth by continuous hours of work.

All the work of learning and memorizing music should be mental. When the mind is concentrated upon learning the melody, rhythm, and construction of a composition the voice should not be used.

The attention can not be given successfully to the learning of vocalizes, songs, arias, etc., and at the same time to the proper use of the voice.

There should be a thorough knowledge of the music before any attempt is made to sing it.

The student, in usual daily practice, should not sing in full voice. The secret of fresh notes is the *mezzo-voce* practice. The high tones in the voice, especially, should be practised *piano*.

Songs should be sung quietly, and more attention given to purely musical phrasing than dramatic expression.

It might be well in this connection to again refer to the subject of respiration, treated in another chapter.

As proper breathing is of utmost importance in phrasing, the pupil must constantly practise advancing the chest and drawing in the abdomen. It should be impressed upon the pupil that this attitude must be assumed before a full inspiration is taken.

At first this exercise is accomplished with difficulty, but after a time the high chest may be maintained indefinitely without the slightest fatigue. The practice of high-chest breathing may be begun in this manner:

1. The chest must be raised, but not the shoulders.

2. A deep inspiration must be taken.

3. The alphabet should be said slowly and dis-

tinctly, with the hands on the upper chest, until the chest is felt to fall; then the chest must be elevated again entirely by the muscles, not breathing until it is raised and fixed. At first only a few letters can be spoken before the chest is felt to give way, but after a time the alphabet can be repeated several times without another inspiration. In like manner the chest should be raised and kept in that position while walking a block, until, finally, this mode of breathing with a fixed high chest becomes so natural that for miles one can continue it without fatigue.

It must not be understood that this method of respiration is a *sine qua non* for all singers, and that it must be used upon all occasions; but we must insist that these exercises develop the chest in a truly wonderful degree, and their employment gives to the voice a charm and quality which is especially necessary in preliminary voice building. Any one who may take pains to observe will see to what an extent the De Reszkes, Maurel, and Plançon make use of this method, as well as Nordica, Melba, Eames, Calvé, and many others. Not a few of our male singers wear an abdominal belt, which they strap tightly during a performance; this is of particular service to one who is trying to cure himself of the bad habit of so-called abdominal respiration. These breathing exercises should antedate vocal training, as it is much easier to acquire a good habit than rid one's self of a bad one. Their use should also be accompanied by light gymnastics, much outdoor exercise, and, above all things, by plenty of bathing. In speaking of bathing, it is of the utmost importance that the skin should be kept very active, and this is best accomplished by taking a warm bath on rising in the morning, and, after a thorough scrubbing of the skin, one should dash cold water over the chest and neck with a sponge, while the feet remain in warm water. This manner of bathing avoids all disagreeable shock and imparts the greatest vigour to the skin. To pour a pitcher of cold water down the spinal column after a warm bath is of great value where an additional stimulus to the nervous system is necessary.

These hygienic suggestions, as well as the importance of the above-mentioned respiratory exercises, should not be undervalued, as the bodily health of the singer is a great element of success in a life of necessary hardship and nervous strain.

As this book does not pretend to discuss any theory of advanced musical training, but only to touch upon the elements of *tone placing* and the rudimentary principles of *voice building*, the later development of the voice must be accomplished under the guidance of a teacher who will give attention to technic, phrasing, style, etc. It is in the preliminary work that many voices are injured. If, however, the proper attack and tone focus is employed, it will be found difficult to do but temporary injury to a voice, even by overwork. We trust that a careful study of the simple principles laid down in this little volume will at least have been an indication to the student that his path lies in the right direction, or otherwise.

CHAPTER IX.

VOICE FIGURES.

A ROD, fixed at one end, vibrating either as a whole or divided into segments and producing a musical note, may be beautifully demonstrated and its sonorous vibrations made visible by a simple and ingenious optical method designed by Sir Charles Wheatstone. We shall presently see that the vibrations of the vocal cords, or rather the tones produced by the cords, may be also pictured for our delight and edification. Chladni was the first to render sonorous vibrations visible. If fine sand is scattered over a square metallic plate and the middle point of one of its edges is damped by touching it with the finger nail, and a bow is drawn across the edge of the plate near one of its corners, the sand is tossed away from certain parts of the surface and collects along two nodal lines which divide the large square into four smaller ones, as in Fig. 44. This division of the plate corresponds to its lowest tone. Scattering sand once more over its surface and damping one of the corners of the plate, if we draw a bow across the middle of one of its sides the sand again dances over its surface, and finally arranges itself in two sharply defined ridges over its diagonals (Fig. 45). The note here produced is the fifth above the last. By damping it in different places we can produce a series of notes, each of which will give its own particular picture,

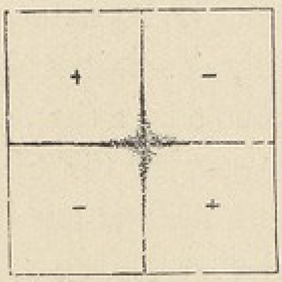


Fig. 44.

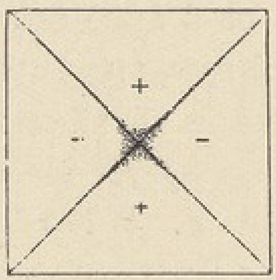


Fig. 45.

as may be seen from the beautiful series of patterns shown below (Fig. 46). If the shadow of a vibrating rod is thrown upon the screen and it is damped at the point *a* (Fig. 47), and struck sharply between *a* and *o*, the rod divides into two vibrating parts separated by a node, and we see upon the screen a shadowy spindle between *a* and its fixed point below, and a shadowy fan above *a* with a black node between them. This is the simplest method of making visible the vibrations of such a rod. To show those vibrations of this rod which are rapid

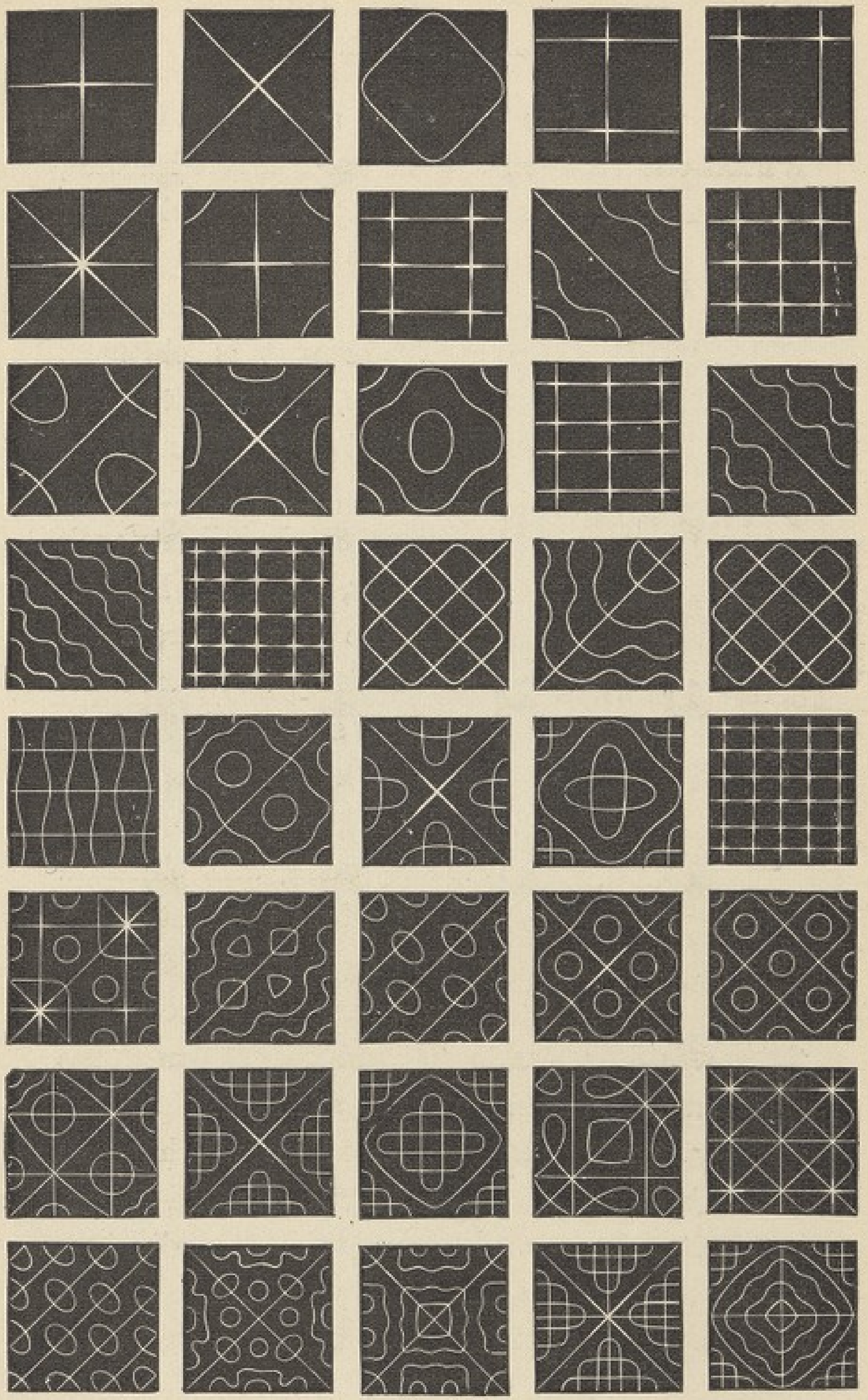


Fig. 46.

enough to produce a musical sound, Sir Charles Wheatstone attached a glass bead, silvered within, to the end of a metal rod, and by allowing the light of a lamp or candle to fall upon the bead a small, intensely illuminated spot is obtained. When the rod vibrates, this spot describes a brilliant line, which shows the character of the vibration. In Wheatstone's instrument, called the kaleidophone, the vibrating rods are screwed firmly into a massive stand and a condensed light is permitted to fall upon the silvered bead, a spot of sunlike brilliancy being thus obtained. Placing a lens in front of the bead a bright image of the spot is thrown upon the screen. If the rod is drawn aside and suddenly liberated, the spot describes a ribbon of light, at first straight, but speedily opening out into an ellipse which passes into a circle, and this back again to a second ellipse, into a straight line. If we now draw a violin bow across the rod, or, in other words, cause it to vibrate in segments, a musical note will be heard, and an

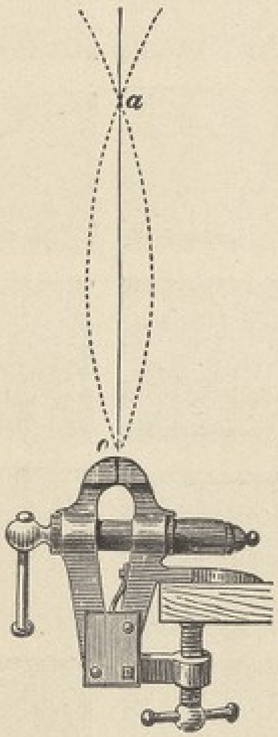


Fig. 47.

almost infinite variety of luminous scrolls can be produced, the beauty of which may be inferred from the subjoined figures, first obtained by Wheatstone (Fig. 48).

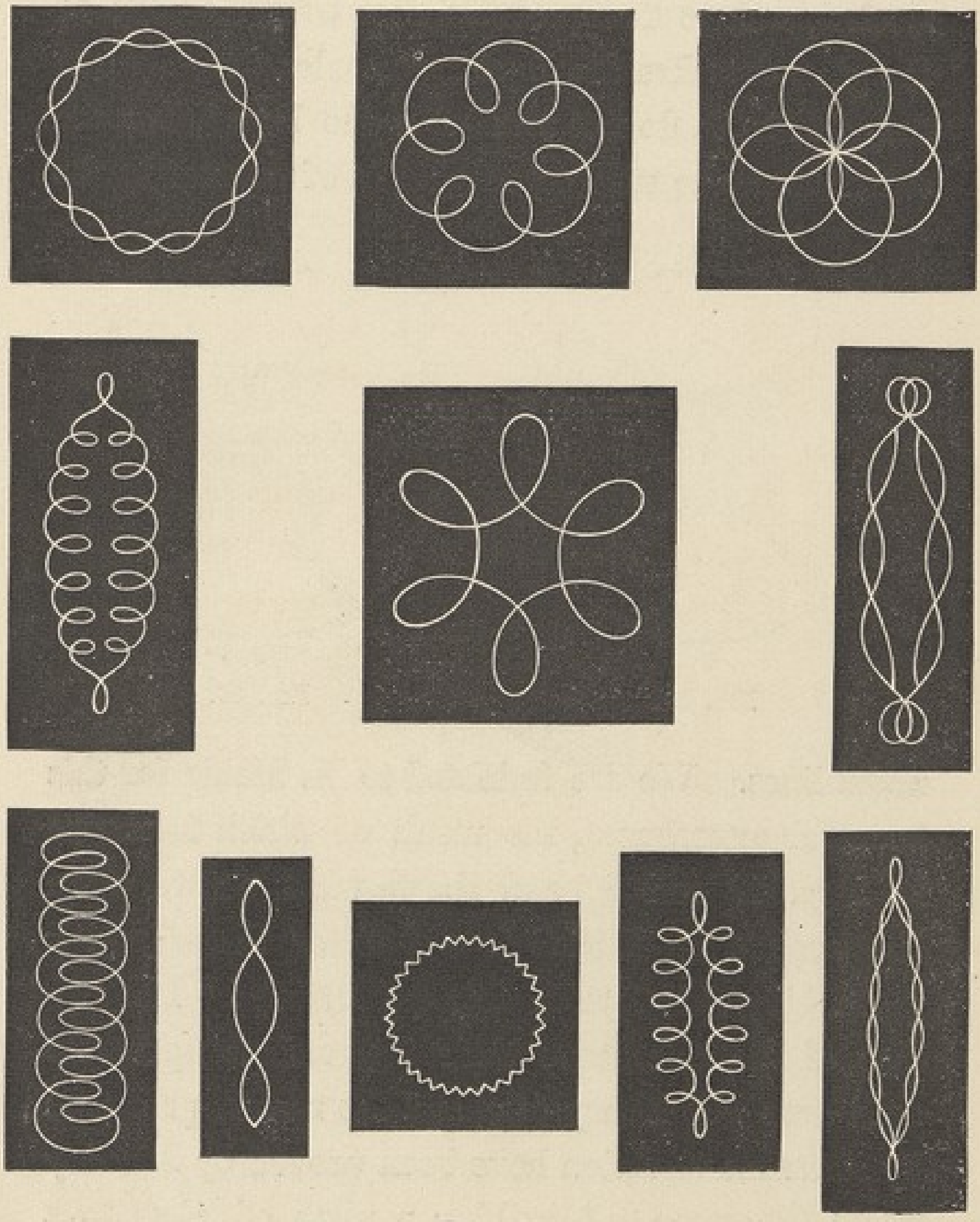


Fig. 48.

Sound waves in a bell, as well as in a rod or a vibrating plate, may be made visible; we can get in beautiful ripples an expression of its sonorous tones. If a bell glass is filled with ether or with alcohol, a short sweep of the bow over the edge of the glass detaches the liquid spherules which, when they fall back, do not mix with the liquid, but are driven over the surface on wheels of vapour to the

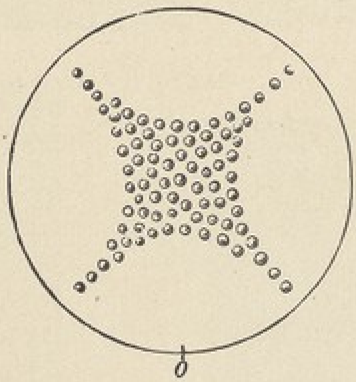


Fig. 49.

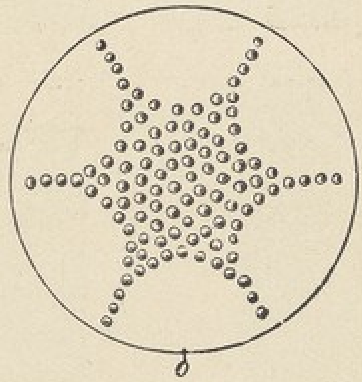


Fig. 50.

nodal lines. We are indebted to M. Melde for this beautful experiment, the result of which is shown in Figs. 49 and 50, and shows what occurs when the surface is divided into four or six vibrating parts. Tyndall says in this connection: "The ripples of the tide leave their impressions upon the sand over which they pass, and the ripples produced by sonorous vibration have been proved by Faraday to do the same. Attaching a plate of glass to a long flexible board and pouring a thin layer of water over the surface of the glass, on causing the board to vibrate its tremors cause the water to chase into a beautiful mosaic of ripples." A thin stratum of sand strewed upon the plate

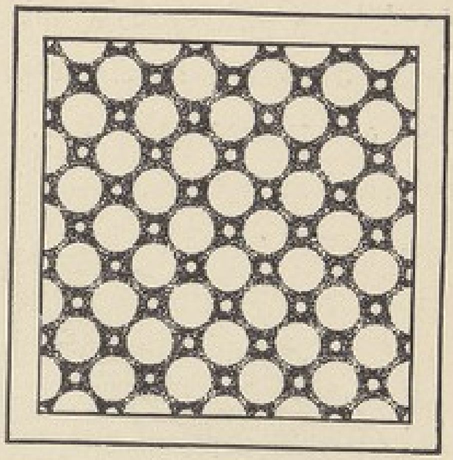


FIG 51.

is acted upon by the water and carved into patterns, of which Fig. 51 is a reduced specimen.

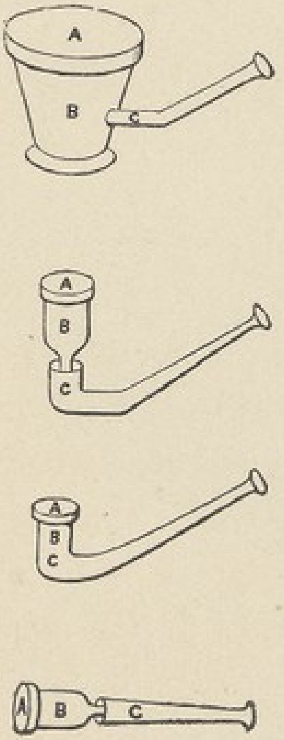


FIG. 52.—The eidophone.

However beautiful and interesting these visible results of sonorous vibrations, they do not compare in beauty and delicacy to the pictures which may be, under certain conditions, produced by the tones of the human voice. It remained for Mrs. Watts-Hughes, of London, to take the first pictures, if we may use the term, of the tones of the human voice. The voice figures were first shown in London in 1885, and are described by her in The Century Magazine for May, 1891. They were obtained by singing into an instrument called the eidophone (Fig. 52). It is a simple tube bent upward at one end, over which a membrane of india

Fig. 53.—Seaweed or landscape form.

rubber is stretched. A film of water is poured over this, and on it is smoothed a layer of very light powder, which has been made into a paste. The notes are sung into the other end of the tube and the paste on the membrane forms itself into a variety of ex-

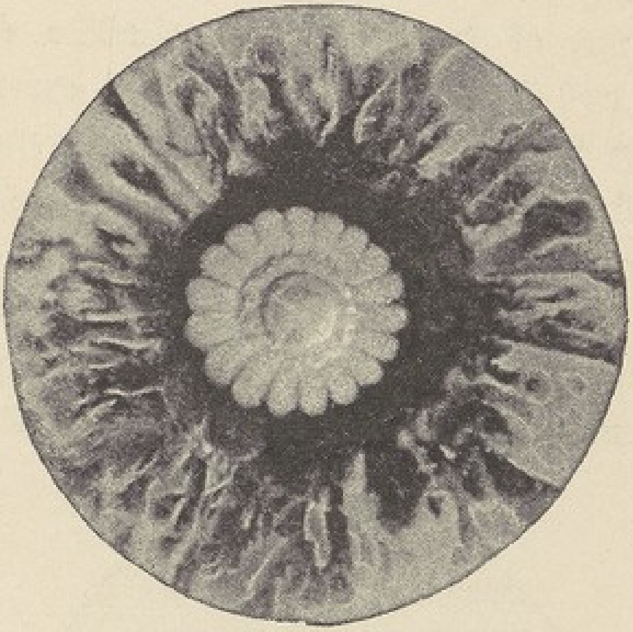


Fig. 54.—Daisy form.

quisite figures corresponding to the different notes sung. These forms may be taken on a piece of glass as well as on the membrane by letting the glass rest lightly over it as the notes are produced. Writing of Mrs. Watts-Hughes's voice pictures in the London Spectator for October 26, 1889, Miss Isabelle Barrington speaks of a visit she made to Mrs. Hughes's Home for Poor Little Boys at Islington, and she says: "Instead of blinds or curtains drawn across the lower panes of the windows, there are wonderful designs in colour, strange, beautiful things suggesting objects in Nature, but which are certainly neither exact repetitions or imitations of anything in it. Perfectly drawn designs of shell-like forms, of trumpet and snake-like designs, twisted and involved in complicated curves, impelled on to the glass seemingly by the force of a power like that which impels and weaves into varying shapes the steam from the funnel of an engine. Thus pictured on the glass they are rendered into the most elaborate and perfectly drawn perspective, each curve coloured and toned with gradations as

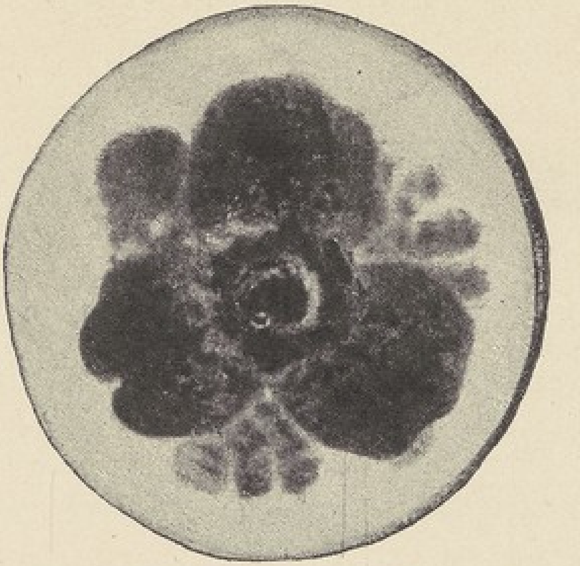


Fig. 55.—Pansy form.

subtile as those of the most beautiful shell or the most delicate petal of a flower. Strange and suggestive indeed are these window panes which the little boys at Islington have to look through. They see weird caverns at the bottom of the sea, full of beautiful coloured sea anemones and mussel shells,

Fig. 56.—Fern form.

headless snakes, entanglements of flower and leaf-like forms, all seemingly vital with the same laws of growth as those which inspired the creation of the designs in Nature which they suggest."

The daisylike shapes shown in Fig. 54 were produced by very low notes, some of them by an *A* in the first space of the bass clef, sung firmly and sharply. The globules of paste when this note is struck will be seen leaping and spluttering all over the membrane, and end by forming in a heap in the centre of the same. The character of the note is then altered, but not the pitch. It is simply sung much more gently. From the heaps in the centre the paste flies out in starlike shapes to unequal distances. Sometimes two such furtive attempts will be made to form a definite figure, when suddenly a perfect and symmetrical row of petals will

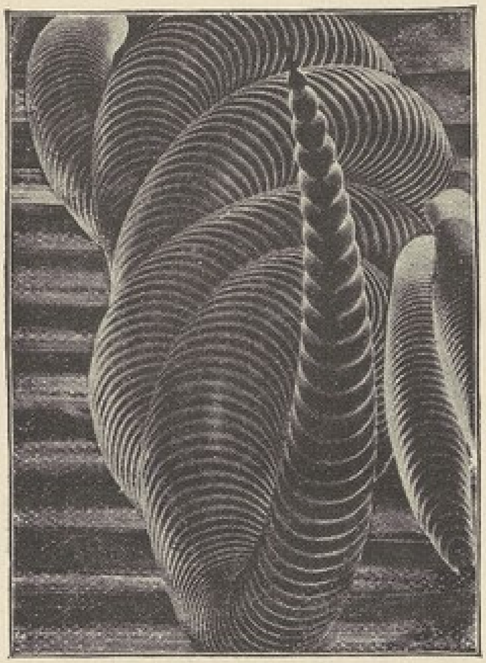


Fig. 57.—Serpent form.

start out and create with the centre heap an exquisitely finished, daisylike form (Fig. 54). Sometimes even three rows of petals will be the answer to the note sung, whereas at others one row will be imperfect and will require the note to be produced again and again before the figure will become perfect. Mrs. Hughes says that under certain conditions other varieties of figures are formed, which she describes as resembling the pansy (Fig. 55), the marigold, the chrysanthemum, and the sunflower, and she goes on to say that the special feature of this daisy class is a ring or rings of petals, generally pretty even in size, surrounding the raised centre. The number of petals may be from six to thirty or more, the number increasing with every rise of the pitch of the note sung. They usually appear as a single layer, but Mrs. Hughes has noticed two, three, or four layers of petals partly overlapping one another, showing the same difference which we see between our double and treble garden flowers and their simple wild progenitors. Other forms of voice flowers which Mrs. Hughes describes as the pansy class included forms like the violet, primrose, and geranium. The great care and delicacy in singing which are demanded for the production of these floral forms will afford ample training for any vocalist in sustaining notes varying from the softest *pianissimo* to a very loud *forte*, since every grade of intensity is required in its turn in order to evoke these forms in their various sizes, ranging from that of a pinhead to a large-sized daisy. She goes on to say that when these notes have been sung with special force she has observed that along with the figure usually appearing, certain additional curves and forms present themselves, and she is convinced that these latter are produced by overtones which are

FIG. 58.—Cross-vibration figure.

usually inaudible, even to a well-trained ear. Carrying out the suggestion given us by the way these flowers are formed, may it not be that a perfect picture—that is, a flower perfect in its details—can only be produced by a particular note perfectly sung? Indeed it would seem that the infinite delicacy, intricacies, and differences of the human voice may find their counterpart in the variations of these flowery forms, and dramatic expression and emotion have also their effect in varying the exquisite tracery. In singing the shell- and trumpet-like figures (Figs. 57 and 58) Mrs. Hughes sings the middle notes of her voice with great intensity. In these forms, however, she uses a paste made not with a white powder, but with Prussian blue, madder lake, or, indeed, any colour which she finds will respond readily to her voice and will work easily on to the glass or mem-

FIG. 59.—Tree form.

brane. At the Arts and Crafts Exposition in 1889, Mrs. Hughes exhibited a number of these beautiful pictures, and Miss Barrington says of them that in these voice pictures the old saying that "Colour is quality" is amply exemplified. "Most of the voice figures have been sung into the most ordinary colours, but the exquisite perfection and finish of the designs, and the subtile toning, shading, and gradation which the tones of the voice give to this ordinary paste and water produce an exquisite quality and beauty of colour which might be a lesson to any painter." The variations in colour and perfection in detail of these voice pictures it seems to us are but the pictorial expression of the richness of any given voice in overtones. The more perfect the production of the notes and the richer the voice in overtones, the more beautiful and delicate the picture. We are under a great debt of gratitude to Mrs. Hughes for having shown us that the human voice may be a source of delight even to those whom we know as tone deaf, not to mention the scientific interest which these beautiful pictures possess.

THE END.

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THE END.

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