of the vibrations producing it. The more rapid the vibrations, the higher is the pitch.

The slowest vibrations that produce audible musical sounds follow each other at the rate of 8 in a second, and a very low note is the result. As the vibrations become more rapid the pitch rises, till they recur at the rate of 24,000 in a second, when a very high note is produced. Beyond this the vibrations last so short a time that they no longer affect an ordinary ear, and no musical sound is heard.

The Quality of a musical sound depends on the nature of the vibrating body. The human voice, the piano, and the flute, may all produce a note of precisely the same loudness and pitch, and yet we readily distinguish them apart. The difference lies in their Quality.

738. All musical sounds are produced by the regular vibrations either of solids or confined air. This gives rise to a division of musical instruments into two classes:—Stringed Instruments, like the violin; and Wind Instruments, like the flute.

739. Stringed Instruments.—The strings used in musical instruments are made of metal or cat-gut. They are fastened at each end, and are set in vibration with the finger, as in the case of the harp,—or by the stroke of a hammer, as in the piano,—or by drawing across them an instrument made for the purpose, like the bow of a violin.

740. To produce notes of different pitch, two strings must vibrate with different degrees of rapidity. That they may do so, one must be longer than the other, or thicker, or stretched more tightly.

The longer a string is, with a given thickness and tension, the more slowly it vibrates and the graver its tone.—The thicker a string is, with a given length and tension, the more slowly it vibrates and the graver its tone.—The more tightly a string is stretched, with a given length and thickness, the more rapidly it vibrates and the more acute its tone.

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depend? On what, its Pitch? How rapidly do the vibrations that produce the lowest audible musical sounds follow each other? How rapidly, those that produce the highest notes? On what does the Quality of a musical sound depend? Give an example of difference in quality. 738. By what are all musical sounds produced? How are musical instruments, then, divided? 739. Of what are the strings used in musical instruments made? How are they set in vibration? 740. How are two strings made to produce notes of different pitch? State the three laws relating to the length,

Stringed instruments are tuned,—that is, brought to their proper pitch,—by turning pegs to which the strings are attached. Changes in the condition of the atmosphere affect the length and consequently the tone of the strings.

741. The music of the Æolian Harp is produced by the action of currents of air on strings which are stretched between two small uprights two or three feet apart. The most pleasing combinations of sounds sometimes proceed from this simple instrument, commencing with a strain, soft and low, as if wafted to the ear from a distance, then swelling as if it were coming nearer, while other notes break forth, mingling with the first with indescribable sweetness.

742. In the case of the drum, musical sounds are produced by the vibrations of a tense membrane acting on the same principle as strings.

743. Wind Instruments.—In wind instruments, such as the flute, the trumpet, &c., musical sounds are produced by the vibrations of air confined within tubes. In tubes of equal diameter, the pitch of the note differs according to the length of the vibrating column; the shorter the column, the higher or sharper the note.

There are two ways of producing notes of different pitch with the same instrument:—1. By joining tubes of different length and diameter, as in the organ. 2. By having but one tube and providing apertures in it at different intervals, by uncovering which the air is allowed to escape, and the internal vibrations are stopped at any desired point. This is the arrangement in the flute.

A wind and a stringed instrument produce notes of the same pitch when the column of air contained within the former vibrates with the same rapidity as the string which produces the note of the latter.

744. The tubes of wind instruments may be open at both ends, or closed at both ends, or open at one end and closed at the other. In the last case, the note produced is twice as low as in either of the other cases, the length of the tubes being the same.

745. Musical notes are produced with wind instruments by blowing into one end, by causing a current of air to enter an aperture, or by making

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thickness, and tension of strings. How are stringed instruments tuned? What causes them to get out of tune? 741. How are the sounds of the Æolian Harp produced? Describe the music of this instrument. 742. How are musical sounds produced in the case of the drum? 743. How are musical sounds produced in wind instruments? On what does the pitch of the note depend? How many ways are there of producing notes of different pitch with the same wind instrument? Mention them. When do a wind and a stringed instrument produce notes of the same pitch? 744. What is said respecting the openings of the tubes of wind instruments? 745. What three modes of producing musical notes with wind instruments are men-

such a current act on thin plates of metal or wood properly arranged within.

746. A jet of hydrogen gas, ignited and made to pass through a glass tube about an inch in diameter, produces sweet musical sounds, which may be made soft or loud at pleasure by raising or lowering the tube. These sounds are caused by vibrations excited in the confined air by the burning hydrogen.

747. *The Organ.*—The grandest and most complicated of wind instruments is the organ. It combines the tones of almost every other wind instrument, in such a way that they may be used singly or together at the pleasure of the performer. An organ in Switzerland has tones so closely resembling those of the human voice, that visitors who hear it imagine they are listening to a full choir of singers. The great organ at Haarlem, in Holland, which is the most celebrated one in the world, has no less than 5,000 *pipes*, as the tubes of the organ are technically called.

The water-organ, or *hydraulicon*, was known more than two hundred years before the Christian era. Its invention is attributed to Ctesibius, the barber of Alexandria, already mentioned as the inventor of the lifting-pump. Wind-organs appear to have been little known until the eighth century after Christ, though perhaps invented some time before. We read that an instrument of this kind was sent to King Pepin, of France, in the year 757, by the Greek Emperor, Constantine.

748. The Gamut.—Notes are said to be *in unison* when the vibrations that produce them are performed in equal times.

Two notes, one of which is produced by twice as many vibrations as the other, are called Octaves. In passing from a note to its octave, there are several intermediate sounds, produced by intermediate numbers of vibrations, each of which the ear recognizes as a distinct note. These notes are distinguished by different names, as shown below. Assuming the number of vibrations producing the first to be 1, the relative number of vibrations producing

tioned? 746. How may musical notes be produced with a jet of hydrogen gas? 747. What is the grandest of wind instruments? What are combined in the organ? What is said of an organ in Switzerland? How many pipes has the great Haarlem organ? How long ago was the water-organ known? By whom was it invented? When do wind-organs appear to have first become known? 748. When are notes said to be *in unison*? What is meant by Octaves? Between a note and its octave,

the other notes will be expressed by the fractions respectively placed below them, the number of the eighth note being, as already stated, double that of its octave.

Names of the notes,	C	D	E	F	G	A	B	C
or,	do	re	mi	fa	sol	la	si	do
Pronounced,	*do*	*ra*	*me*	*fah*	*sole*	*lah*	*se*	*do*
No. of vibrations,	1	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{15}{8}$	2

These eight notes constitute the Gamut, or Diatonic Scale. The notes of the next higher octave bear the same relations to each other, but are produced by vibrations performed in half the time, and therefore twice as numerous in each case. The notes of the next lower octave again bear the same relations to each other, but their vibrations take twice the time, and are therefore only half as numerous. In other words, a given note of any octave is produced by vibrations twice as rapid as the same note of the next octave below, and only half as rapid as the same note of the next octave above.

749. Harmony.—Some notes, reaching the ear simultaneously, produce an agreeable impression in consequence of their vibrations' frequently coinciding, and constitute what is called *concord*. Other notes, whose vibrations rarely coincide, impress the ear unpleasantly and produce *discord*. A combination of concordant musical sounds is called a Chord. An agreeable succession of musical sounds constitutes Melody. A succession of chords constitutes Harmony.

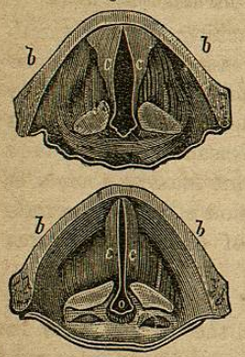
The most agreeable concord is that of the octave; next, the fifth; then, the fourth; and then, the third. Thus, in the scale given above, concord is produced when C is sounded with its octave C, and with the notes G, F, and E.

750. The Human Voice.—The sounds of the human voice, whether used in speaking or singing, are produced by the vibrations of two membranes stretched across a tube, which connects the mouth with the lungs. This tube is the wind-pipe; and the upper part of it, which consists

what occur? Name the notes by letters. Give their other names. Assuming the number of vibrations that produce C to be 1, mention the relative numbers that produce the other notes. What do these eight notes constitute? What relation do the notes of the next higher octave bear to these? The notes of the next lower octave? 749. What is meant by Concord? By Discord? What is a Chord? What is Melody? What is Harmony? Which is the most agreeable concord? Which next? Which next? 750. How are the sounds of the human voice produced? Describe

of cartilage, is called the Larynx. The larynx is flattened at the top, and terminates in two membranes, which nearly close the passage, leaving between them a narrow opening, known as the Glottis. These two membranes are called the Vocal Chords, and it is by their vibration, caused by the passage of the air breathed out from the lungs, that the sounds of the voice are produced. Small muscles enable us to stretch the vocal chords more or less tightly at pleasure, and also to enlarge or diminish the opening between them. By these means we produce notes of different pitch. To produce a change of note, we have only to make a difference of $\frac{1}{1200}$ of an inch in the length of the vocal chords.

Fig. 264.



THE GLOTTIS AND VOCAL CHORDS.

Fig. 264 represents the glottis under different circumstances. The upper plate shows it at rest: *b*, *b*, represents the top of the larynx, and *c*, *c*, the vocal chords, relaxed so that the breath passing through the opening makes no sound. The lower plate shows the glottis in the act of emitting a musical sound, the chords being now tightly stretched, and made to vibrate by the air breathed out between them. *o* is a passage leading into the wind-pipe, which remains open, however close to each other the chords may be brought.

751. The vocal chords are shorter in boys and women than in men; hence the voices of the former are sharper or higher than those of the latter. When boys reach the age of 14 or 15, the vocal chords rapidly enlarge, and the voice is said *to change*.—The more forcibly the air is expelled from the lungs through the wind-pipe and larynx, the louder is the voice.

752. His surprising flexibility of voice enables man to imitate almost exactly, not only the cries of birds and beasts, but also the sounds of various musical instruments. This was shown by the performances of a band of twelve Germans a short time since in the principal cities. Each imitated a different instrument with his voice, and so accurately, that those who heard

the Larynx and the Glottis. What are the membranes stretched across the top of the larynx called? How do we produce notes of different pitch? How great a difference in the length of the vocal chords produces a change of note? Point out the different parts in Fig. 264. 751. Why are the voices of men deeper than those of boys and women? What causes the voices of boys *to change*? On what does the loudness of the voice depend? 752. What is said of the flexibility of the human

them could hardly believe they were not listening to an instrumental concert.

753. *Ventriloquism.*—Some persons have the faculty of uttering sounds and words without moving their lips. When, besides this, they can throw their voice into any object (as the expression is), or make it seem to come from a distance, they are called Ventriloquists. By practice ventriloquists attain to wonderful power over their voices.

Amusing exhibitions of ventriloquism are often given, in which the performer imitates to perfection the buzzing of bees, the grunting of pigs, the spitting of cats, the chirping of crickets, the drawing of corks, the gurgling of liquids, the moaning of the wind, the puffing of a locomotive, the cry of a young infant, conversation between different parties represented as approaching or receding, in different parts of the room, under tables, &c.—It is supposed that the priests of the ancient oracles practised ventriloquism, and thus made their responses appear to come from shrines, statues, &c.

754. *Stammering.*—Stammering is a defect in speech caused by the organs' not performing their respective parts in regular succession. A convulsive nervous action interferes with their operation.

755. The difficulty in the case of deaf mutes does not lie in any imperfection of the organs, but proceeds simply from their deafness. Having never heard their own voices or those of others, they are utterly unable to appreciate sounds or adjust the organs properly for their articulation.

756. Voices of the Inferior Animals.—Man alone has the power of articulation. The inferior animals utter cries of different kinds, according to the conformation of the larynx and the nasal cavities connected with it. Some of the cat's tones very closely resemble those of the human voice.

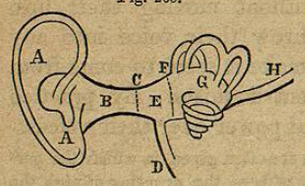
The sounds of insects are produced in various ways,—by the rapid vibration of their wings, the rubbing of their minute horns against each other, the striking of their organs on the bodies around them, &c.

757. The Human Ear.—The human ear consists of three distinct parts; the outer ear, the drum, and the in-

voice? What instance of its remarkable flexibility is given? 753. What is Ventriloquism? Describe some of the feats of ventriloquists. What use is supposed to have been made of ventriloquism in ancient times? 754. What is the cause of Stammering? 755. Why are deaf mutes unable to use their voices? 756. What is said of the tones of the inferior animals? How are the sounds of insects produced?

ner ear. These parts and their connections are represented in Fig. 265.

Fig. 265.



THE HUMAN EAR.

A A is the *outer ear*, which acts on the principle of the ear-trumpet, collecting the sound-waves and reflecting them along the pipe B to the membrane C, called the *membrane of the tympanum*. E is the *tympanum* or *drum*, bounded by the membrane C on the one side, and the membrane F on the other, and filled with air, which it receives from the tube D, communicating with the mouth. G, the *inner ear*, contains a number of ducts, and is filled with a liquid in which the acoustic nerve floats.

The sound-waves transmitted from the outer air cause the membrane C to vibrate. C excites vibrations in the air confined in the drum, and this in turn causes F to vibrate. The liquid in the inner ear receives the vibrations from the membrane F, and transmits them to the acoustic nerve, by which they are conveyed to the brain, and the sensation of hearing is produced. When a person takes cold, the tube which connects the drum with the mouth is apt to be obstructed, and temporary deafness is the consequence.

EXAMPLES FOR PRACTICE.

1. (*See* § 724.) If the air were perfectly still and uniform in density, how would the report of a musket heard by a person 50 feet off compare in loudness with the same report heard at a distance of 250 feet?
2. A cannon is heard a quarter of a mile off with a certain degree of loudness. How far must a person be removed, to hear it with only $^1/_{100}$ of its former distinctness?
3. (*See* § 725.) How far does sound travel through air in 10 seconds? In 20 seconds? In one minute?
4. How much faster does the sound produced by the discharge of a cannon travel, than that produced by the snapping of a whip?
5. (*See* § 726.) I see the flash of a cannon two seconds before I hear its report. How far is it off?
6. A clap of thunder does not reach the ear till four seconds after the accompanying flash is visible. How far off is the thunder-cloud?
7. A thunder-cloud is distant about one mile. How many seconds will elapse between the flash and the clap?
8. (*See* § 727.) About how many feet will sound travel through water in 10 seconds? Through iron? Through wood?

757. Name the parts of which the human ear consists. With the aid of Fig. 265, point out the different parts, and show the operation of the organ. Why is temporary deafness produced by a cold?

CHAPTER XVI.

ELECTRICITY.

758. If a dry glass tube or a stick of sealing-wax be rubbed with a piece of flannel, and then held a short distance above some shreds of cotton, they will be instantly attracted to it, and after adhering to its surface for an instant again thrown off. A peculiar odor is perceived; and the face, when brought near the glass or wax, feels as if a cobweb were in contact with it. If the tube or sealing-wax be presented to a metallic body in a dark room, a spark, accompanied by a sharp cracking sound, will be seen darting from it to the metal.

The property thus developed by friction is called Electricity. The body in which it is developed is called an Electric, and is said to be *excited* or *electrified*. The attraction exerted by the excited electric over light bodies is called Electrical Attraction. The substance by whose friction the electric is excited is known as the Rubber.

759. Electricity as known to the Ancients.—The term *electricity* is derived from the Greek word *electron*, amber, the property in question having been first observed in that substance.

Thales, one of the seven wise men of Greece, who flourished 600 years B. C., is said to have discovered electricity in amber; Theophrastus and Pliny, at a later date, speak of the attraction of amber for leaves and straws. Both Pliny and Aristotle were acquainted with the electrical properties of the torpedo; and we are informed that a freedman of the Emperor Tiberius cured himself of gout by the use of its shocks. Yet the ancients appear to have known nothing more than a few isolated facts connected with the subject; and as a science Electricity had no existence till the commencement of the seventeenth century.

758. If a glass tube or a stick of sealing-wax be rubbed with flannel, what phenomena will be observed? Name and define the terms used in connection with this experiment. 759. What is the derivation of the term *electricity*? What allusions are made to this property by ancient authors? When did electricity originate as a sci-