The limits of sounds employed in music are much narrower, especially in singing. SAVART gives for the gravest sounds of the male voice, 190 vibrations per second, and for the female voice, 572. For the most acute sounds of the male voice he gives 678 vibrations per second, and for the female voice, 1606.

Two sounds, corresponding to the same number of vibrations per second, are in *unison*.

Musical Scale.—Gamut.

164. The ear not only distinguishes between given sounds—which is most grave, and which is most acute—but it also appreciates the relations between the number of vibrations corresponding to each. We can not recognize whether for one sound the number of vibrations is precisely two, three, or four times as great as for another, but when the number of vibrations corresponding to two successive or simultaneous sounds have to each other a simple ratio, these sounds excite an agreeable impression, which varies with the relation between the two sounds.

From this principle there results a series of sounds characterized by relations which have their origin in the nature of our mental organization, and which constitute what is called a *Musical Scale.*

In this scale sounds recur in the same order in groups of seven. Each group constitutes what is called a *Gamut* of seven notes, known by the names, *ut, re, mi, fa, sol, la, si.* The first six of these names are the first syllables of the first six verses of the hymn that is chanted at Rome at the feast of St. John. The name, *si*, has been given more recently to the seventh note. The notes are more generally called by the first letters of the alphabet, A, B, C, &c.

The word gamut comes from the name *gamma*, the third letter of the Greek alphabet, because GUIDO D'AREZZO, who first represented

What are the limits in singing? When are sounds in unison? (**164.**) What is a Musical Scale? *What is a Gamut? Why so called? Name the notes of the gamut.*

the notes by points placed upon parallel lines, designated these lines by letters, choosing the letter *gamma* to designate the first line.

Intervals.—Accords.

165. An INTERVAL is the relation between two sounds, that is, between the number of vibrations corresponding to those sounds.

The interval between two successive notes is called a *second;* thus, the interval between *ut* and *re* is a second, as is the interval between *re* and *mi*, *mi* and *fa*, and so on.

If the interval between two notes comprises one, two, three, four, five, or six notes, this interval is called *a third, fourth, fifth, sixth, seventh, eighth*, or *octave*. For example, the interval between *ut* and *mi*, is a *third*, that between *ut* and *fa*, a *fourth*, or *quarter*, and so on. Finally, the interval between the *ut* of one gamut, and the *ut* of the next succeeding gamut, is an *octave*.

The coexistence of several sounds is called an *accord*. When the ear can distinguish, without fatigue, the relation between two sounds, which is the case when this relation is simple, the coexistence of these sounds is called a *consonance;* when the ear is painfully affected by the coexistence, it is called a *dissonance*.

The most simple accord is *the unison*, in which the number of vibrations are equal; then comes *the octave*, in which the number of vibrations, corresponding to one sound, is double that corresponding to the other; then *the fifth*, in which the numbers are as 3 to 2; then *the fourth*, in which the numbers are as 4 to 3; and finally *the third*, in which the ratio is that of 5 to 4.

When the numbers of vibrations corresponding to three simultaneous sounds, are as 4, 5, and 6, the combination is called a *perfect accord*. For example, the notes *ut, mi, sol*, form a perfect accord, as

(**165.**) What is an Interval? *What is a third, fourth, fifth, sixth, seventh, octave?* What is an Accord? A Consonance? A Dissonance? *What is the simplest accord? The next simplest? Next three in order? What is a perfect accord? Example.*

do the notes *sol, si, re.* These accords produce upon the ear the most agreeable sensation.

The Tuning Fork.

166. A TUNING FORK is an instrument used in tuning musical instruments of fixed sounds, like the piano.

It consists of a plate of steel, bent into the shape of the letter U, mounted upon a wooden box, as shown in Fig. 114. The wooden box is open at one extremity, and serves to

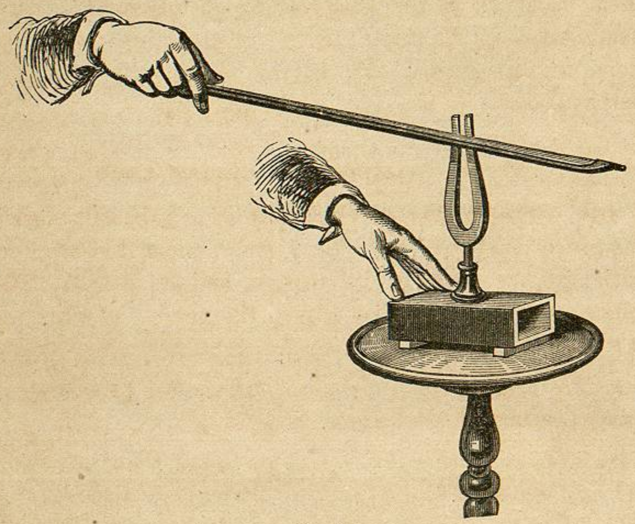

Fig. 114.

reinforce the sound, which would otherwise be feeble. The fork is made to sound by drawing across one of its branches a violin bow, or by straining the branches apart by a wedge of wood or metal, and then suddenly withdrawing it, or finally, by striking one of the branches with a solid body. The tuning fork is usually constructed so as to sound the *la*, which corresponds to 856 vibrations per second.

(**166.**) What is a Tuning Fork? Describe it. How is it made to sound?

Transverse Vibrations of Cords.

167. We have already seen (Art. 146), that when a stretched cord is drawn from its position of equilibrium and abandoned, it returns to its position of rest by a succession of continually decreasing vibrations.

Cords used in musical instruments are generally made of catgut, or of twisted wires. They are made to vibrate by drawing a bow across them, as in the violin; by drawing them aside, as in the harp; or by percussion with little hammers, as in the piano. In all of these cases, the vibrations are *transversal*, that is, the movements take place perpendicularly to the direction of the cord.

aws of Transversal Vibrations of Cords.

168. The number of vibrations of a stretched cord in any given time, as in one second, for example, depends upon its length, its thickness, its tension, and its density. The following are the laws that govern the number of vibrations in a fixed time:

1. *The tension being the same, the number of vibrations varies inversely as its length.*

If a given cord makes 18 vibrations per second, it will make 36 if its length be reduced to one half, 54 if its length be reduced to one third, and so on. This property is utilized in the violin. By applying the finger, we virtually reduce the length of the vibrating portion at pleasure.

2. *The tension and length being the same, the number of vibrations varies inversely as its size.*

Small cords vibrate more rapidly than large ones, and consequently render more acute sounds. A cord of any given size

(**167.**) Of what are musical cords made? How set in vibration in different instruments? (**168.**) Upon what does the number of vibrations of a cord depend? What is the first law? *Illustrate.* The second law? *Illustrate.*

makes twice as many vibrations as one of double the size. Other things being equal, the notes rendered differ by an octave.

3. *The length and size being the same, the number of vibrations varies as the square root of the tension.*

If a cord renders a given note, it will, if its tension be quadrupled, render a note an octave higher, and so on. This property is utilized in stringed instruments by means of an apparatus for increasing or diminishing the tension at pleasure.

4. *Other things being equal, the number of vibrations varies inversely as the square root of the density.*

Dense cords render graver notes than those of less density. Small, light, and short cords, strongly stretched, yield acute notes. Large, dense, and long cords, not strongly stretched, yield grave notes.

Verification of the Laws of Vibration.

169. The laws enunciated in the preceding article may be verified by means of an instrument called a *Sonometer*, shown in Fig. 115.

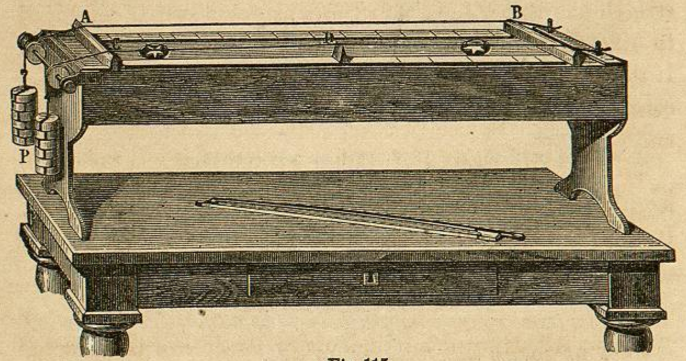

Fig. 115.

The sonometer is said to have been invented by PYTHAGORAS, about 600 years before our era. In its present form,

The third law? *Illustrate.* The fourth law? *Illustrate.* (**169.**) How may the preceding laws be verified? What is a Sonometer?

it consists of a wooden box about four feet in length, upon which are mounted two fixed bridges, *A* and *B*, and a movable one, *D*. On these bridges, two cords, *CD* and *AB*, fastened firmly at one end and passing over pulleys at the other end, are stretched by means of weights, *P*.

Let the cords be exactly alike and stretched by equal weights. If the bridge *D*, be moved so as to render *CD* equal to one half of *AB*, the notes of the two cords will differ by an octave; that is, *CD* will vibrate twice as fast as *AB*. If *CD* be made equal to one third of *AB*, by moving the bridge *D*, the former will vibrate three times as fast as the latter, and so on. This verifies the *first* law.

To verify the *second* law, we remove the bridge *D*, and use two cords, one of which is twice as large as the other. It will be found that the notes yielded will differ by an octave. If one cord be taken three times as large as the other, the latter will be found to vibrate three times as fast as the former.

To verify the *third* law, let the two cords be alike, and stretch one by a weight four times as great as that employed to stretch the other. The notes will differ by an octave. If the stretching force in one, is nine times that in the other case, the former will vibrate three times as fast as the latter, and so on.

To verify the *fourth* law, we make use of cords equal in length, size, and equally stretched, but of different densities. It will be found that the law is verified in each case

Stringed Instruments.

170. All stringed instruments of music are constructed in accordance with the preceding laws. They are divided into instruments with *fixed sounds*, and instruments with *variable sounds*.

Describe it. How is the first law verified? The second? The third? The fourth? (**170.**) How are stringed instruments classed?

To the former class belong the piano, the harp, &c. They have a cord for each note, or else an arrangement is made so that by placing the finger at certain points, as in the guitar, the same cord may be made to render several notes in succession.

To the latter class belong the violin, the violoncello, &c. They are provided with cords of catgut, or sometimes of metal, put in vibration by a bow. Various arrangements are made for regulating the notes, such as increasing the tension, placing the finger upon the cords, and the like. These instruments are difficult to play upon, and require great nicety of ear, but in the hands of skillful players they possess great power. They are the soul of the orchestra, and it is for them that the finest pieces of music have been composed.

Sound from Pipes.

171. When the air in a *pipe*, or hollow tube, is put into vibration, it yields a sound. In this case, it is the air which is the sonorous body, the nature of the sound depending upon the form of the pipe and the manner in which the vibrations of its contained air are produced.

To produce a sound from a pipe, the contained air must be thrown into a succession of rapid condensations and rarefactions, which is effected by introducing a current of air through a suitable *mouth-piece.* Two principal forms are given to the mouth-piece, in one of which the parts remain fixed, and in the other there is a movable tongue, called a *reed.*

Pipes with fixed Mouth-pieces.

172. Pipes with fixed mouth-pieces are of wood or metal, rectangular or cylindrical, and always of considerable

Examples of each class. Which are most difficult to play upon? (**171.**) What is the sonorous body in the case of a pipe? How thrown into vibration? What is a mouth-piece? How many forms? (**172.**) What are the characteristics of pipes with fixed mouth-pieces?

length compared with their cross section. To this class belong the flute, the organ pipe, and the like. Some of the forms given to pipes of this class are shown in Figs. 116, 117, 118, 119, and 120.

Fig. 116 represents a rectangular pipe of wood, and Fig. 117 shows the form of its longitudinal section. *P* represents the tube

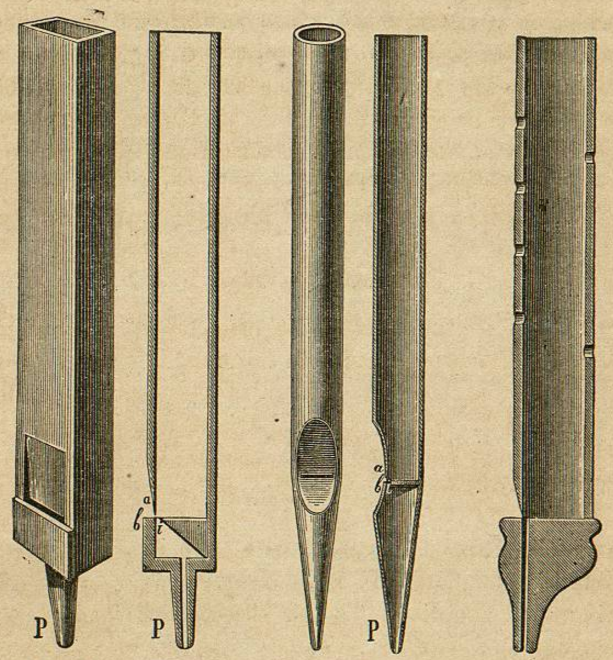

Fig. 116. Fig. 117. Fig. 118. Fig. 119. Fig. 120.

through which air is forced into it. The air passes through a narrow opening, *i*, called the *vent.* Opposite the vent is an opening in the side of the pipe, called the *mouth.* The upper border, *a*, of the mouth, is bevelled, and is called the *upper lip*, the lower border is not bevelled, and is called the *lower lip.*

Describe the mouth-piece. The vent. The mouth. The lips.

The current of air forced through the vent strikes against the upper lip, is compressed, and by its elasticity, reacts upon the entering current, and for an instant arrests it. This stoppage is only for an instant, for the compressed air finds an outlet through the mouth, again permitting the flow. No sooner has the flow commenced than it is a second time arrested as before, again to be resumed, and so on.

This continued arrest and release of the current gives rise to a succession of vibrations, which are propagated through the tube, causing alternate and rapid condensations and rarefactions, which result in a continuous sound. The vibrations are the more rapid as the current introduced is stronger, and as the upper lip approaches nearer the vent. Such is the nature of the organ pipe.

Fig. 118 represents a second form of organ pipe, which is shown in section in Fig. 119. This is but a modification of the pipe already explained. The letters indicate the same parts as in the preceding figures.

Fig. 120 represents the form of the mouth-piece of the flageolet, and it will be seen that it bears a close resemblance to the pipes already explained.

In the flute, an opening is made in the sides of the pipe, and the arrest and flow of the current is effected by the arrangement of the lips of the player.

Reed Pipes.

173. In Reed Pipes the mouth-piece is provided with a vibrating tongue, called a *Reed*, by means of which the air is put in vibration. To this class belong the clarionet, the hautboy, and the like. The reed may be so arranged as to beat against the sides of the opening, or it may play freely through the opening in the tube.

Figs. 121 and 122 show the arrangement of a reed of the first kind. A piece of metal, *a*, shaped like a spoon, is fitted with an elastic tongue, *l*, which can completely close the opening. A piece of

Explain the action in detail. How is the mouth-piece in the flute? (**173.**) What is a reed? What are some of the reed instruments? *Explain the arrangement of a reed of the first kind.*

metal, *r*, which may be elevated or depressed by a a rod, *b*, serves to lengthen or shorten the vibrating part of the reed. This arrangement enables us to diminish or increase the rapidity of vibration at pleasure.

The mouth-piece, as described, connects with the tube *T*, and is set in a rectangular box, *KN*, which is in communication with a bellows, from which the wind is supplied. For the purpose of class demonstration, the upper part of the tube *KN*, has glass windows on three sides to show the motion of the reed.

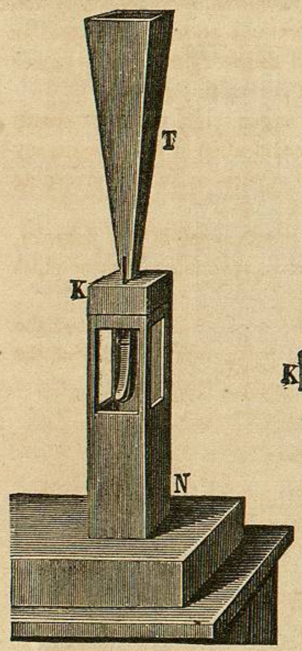

Fig. 121.

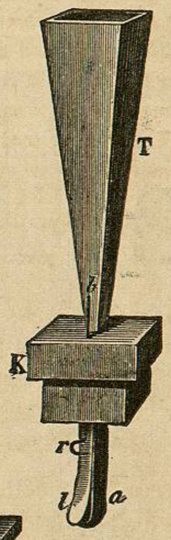

Fig. 122.

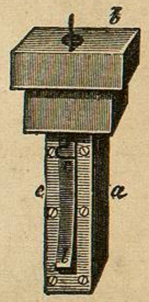

Fig. 123.

When a current of air is forced into the tube *KN*, the reed is set in rapid vibration, causing a succession of rarefactions and condensations in the air of the pipe *T*, and causing it to emit a sound. The air entering the tube *KN*, first closes the opening by pressing the

Explain its action.

reed against it; the reed then recoils by virtue of its elasticity, permitting a portion of condensed air to enter the pipe, when the reed is again pressed against the opening, and so on as long as the current of air is kept up. It is evident, that the rapidity of vibration will be increased by increasing the tension of the air from the bellows, and also by shortening the vibrating part of the reed.

Fig. 123 shows the arrangement of the free reed. The vibrating plate, *l*, is placed so as to pass backwards through an opening in the side of the tube *ca*, alternately closing and opening a communication between the tube and the air from the bellows. The regulator, *r*, is entirely similar to that shown in Figs. 121 and 122, as are the remaining parts of the arrangement. The explanation of the action of this species of reed is entirely similar to that already described.

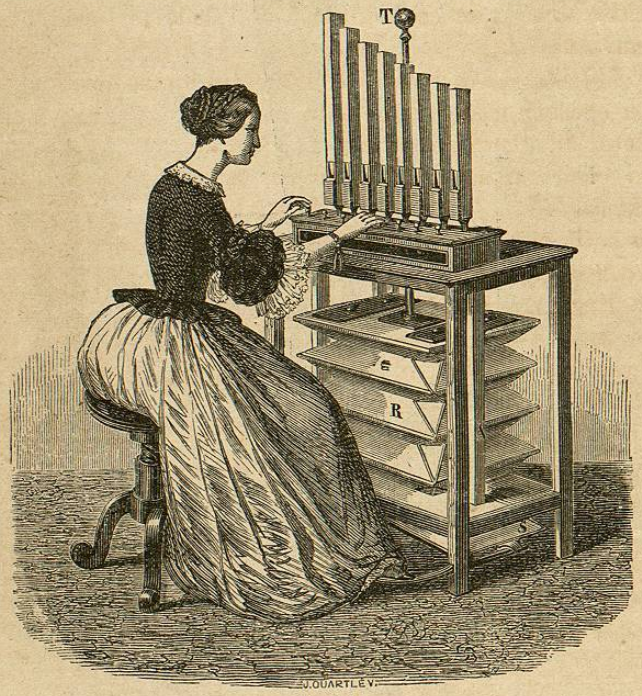

Fig. 124.

Explain the arrangement of the Free Reed. What is its mode of action?

The Bellows.

174. Fig. 124 represents one form of the *Bellows*, used in causing pipes to sound. It is worked by a pedal. The air enters a valve, *S*, through which it passes to a leathern reservoir, *R*. The top of the reservoir is weighted so as to force the air into a box, from which it is admitted to the pipes by means of valves, which are opened and shut at the will of the player.

Wind Instruments.

175. WIND INSTRUMENTS of music consist of pipes, either straight or curved, which are made to sound by a current of air properly directed.

In some, the current of air is directed by the mouth upon on opening made in the side, as in the flute. In others, the current of air is made to enter through a mouth-piece, as in the flageolet. In others, the reed is used, as in the clarionet. In the organ, there is a collection of tubes, similar to those shown in Figs. 116 and 118. In some instruments, like the trumpet and the horn, a conical mouth-piece is used, of the form shown in Fig. 125, within which the lips of the musician vibrate in place of the reed. The rapidity of vibration can be regulated at will.

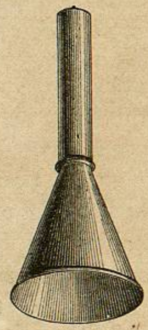

Fig. 125.

(**174.**) Describe the Bellows used with wind instruments. (**175.**) What are Wind Instruments? Explain their different varieties.