REVIBRATIONS

All of us at one time or another have shouted down into a well or empty barrel and you know the confused rumbling sounds that you hear as a result. This peculiar sound you hear is due to the sound waves which strike the walls of the well or barrel

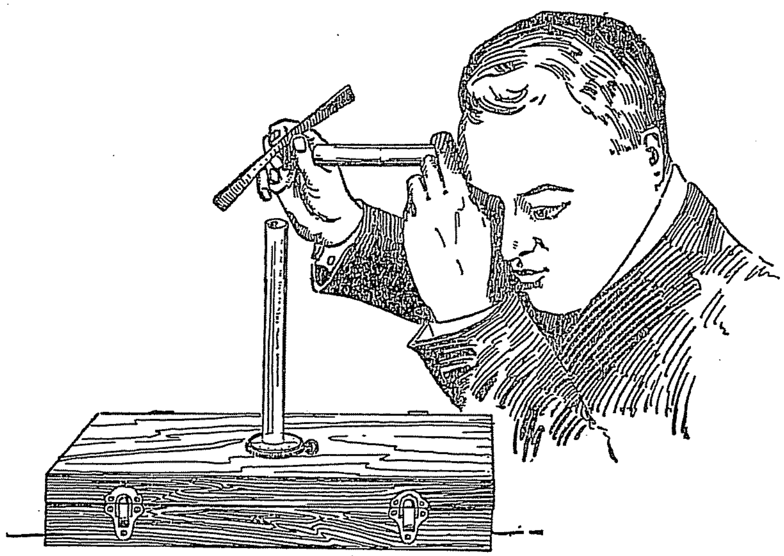

FIG. 46

and are bounced back and forth between them. The walls are so close together that the sound waves follow one another very closely and make a confusion of sounds.

Experiment No. 35. Make two paper tubes about 3 feet long and 3 or 4 inches each in diameter, or use two glass tubes about 6 inches long and 5/8 of an inch in diameter. Arrange them as in Figure 46. Under No. 1 tube place a watch. In

position No. 2 place a piece of glass; at position No. 3 place the other tube and at the end of this tube put your ear where you may listen. With your ear away from the tube the ticking of the watch cannot be heard, but if the ear is placed at the tube, as per illustration, the ticking of the watch will be distinctly heard. In other words the sound waves are passing up tube No. 1, hitting the glass at No. 2 and reflected through tube No. 3 to the drum of the ear where, in turn, they are recorded by relays to the brain.

ACOUSTIC PROPERTIES OF BUILDINGS

You often hear people speak of the acoustic properties of buildings. By this they refer to the science of arranging a building so that sounds made in any part of it may be heard all over the building. Some of these buildings are called "whispering galleries." Probably one of the best illustrations in the United States is the Tabernacle in Salt Lake City.

This tabernacle was built without a single metal nail. The whole structure being of wood the shape of a bowl. Although it is some 200 feet long, the acoustic properties are so fine that a pin dropped in one end of the building can be heard 200 feet away. The sounds in a building of this kind are repeatedly reflected from point to point, which causes them to travel around the walls and be heard in any part of the building.

REFLECTION AND REFRACTION OF SOUND WAVES

Whenever sound waves meet the surface between two media, both reflection and refraction take place.

Experiment No. 36. Fill a toy balloon with carbon dioxide, which will have to be done for you in a laboratory. If you take the balloon that has been filled with carbon dioxide and place it between your ear and a watch, then move it back and forth you will find a position where it will amplify the sound. (See Figure 47.) The cause of this is almost identical with the action of the convex lens on light waves. (See the Gilbert book on "Light.") The sound waves are converged to a focus just as light waves are with a convex lens.

Now exactly the opposite results can be obtained by a repetion of the experiment only with hydrogen gas. Instead of the sound waves being converged to a focus, the hydrogen gas diffuses them in exactly the same way as light waves are diffused in passing through a concave lens. This refraction of

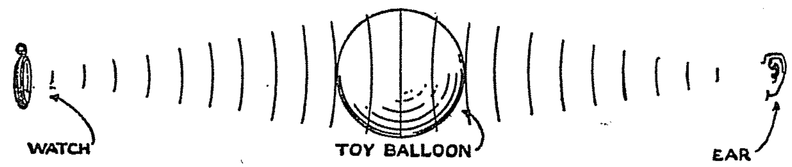

FIG. 47

sound is due to change in velocity and has been caused by that part of the sound waves that passes through the balloon. Sound travels through air faster than through carbon dioxide gas but slower than through hydrogen gas.

FOG SIGNALS

A good example of reflection and refraction may be gotten in a boat out in a fog. It is almost impossible for anyone who has not had experience to locate where a sound comes from in a fog. For instance, a fog horn may not be heard at all by a vessel near the shore and even in danger. Even experienced mariners cannot be absolutely sure of themselves, because the sound is reflected and refracted on account of the different

temperatures of the air during these times. We have already learned that sound travels at different velocities in different temperatures of air. If the lower portion of a horizontally moving sound wave is in warmer air than the upper part, it will travel faster and cause the wave front to change its direction

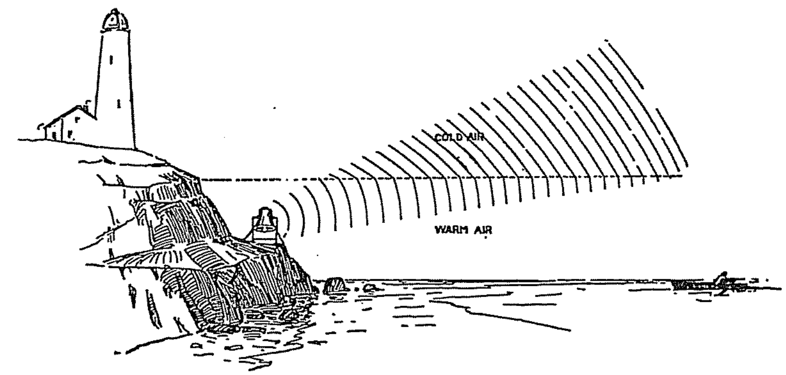

FIG. 48

and may even cause it to curve upward, as here illustrated (Figure 48).

WIND WILL FACILITATE THE HEARING OF SOUND WAVES

If you live back of a hill, there will be times when you can not hear sounds at all from the other side of a hill and at other times they will be quite audible. The reason for this is that the wind will carry the sound waves over the hill when it blows, and when the air is still the sound waves will not be carried in this way.

Experiment No. 37. Take a tumbler or glass jar and fill it with water and into this insert a glass tube. Over the glass tube put a tuning fork, as in Figure 49. Now set the tuning fork in vibration and move the glass tube up and down until it reaches a position where the air in the tube responds to the tune of the fork and you will find that the sound will be increased and stimulated. In physics they call this glass tube a resonator.

The prongs, in vibrating, push the particles of air down, forming a condensation, which goes to the bottom of the tube or to the surface of the water. Here it is reflected back to the prongs

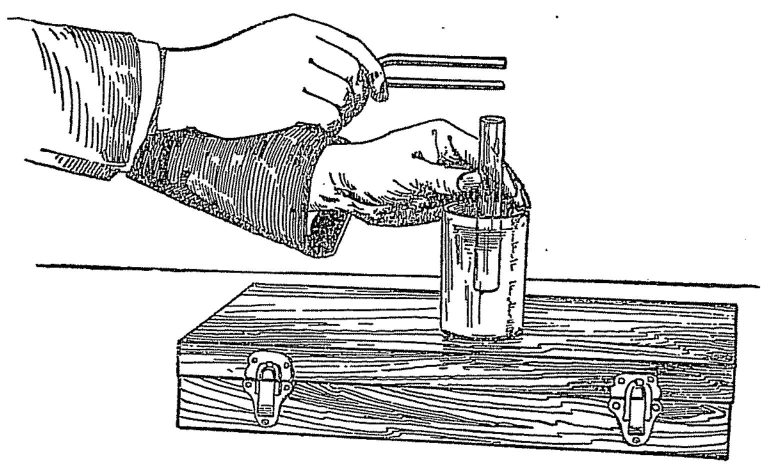

FIG. 49

just in the nick of time to join the next condensation produced by the fork vibrating upward, and this strengthens the sound.

A straight-sided tube is a poor resonator in that it responds to a limited number of tones. Resonators have been made in various shapes, usually with curved bottoms, the object being to obtain resonance with as many different tones as possible.

WHAT MAKES THE SOUND LIKE WAVES WE HEAR IN THE SEA SHELL?

You are probably familiar with the sounds that are emitted from a sea shell. They are generally known as sea waves, because some people imagine that because the shell is found in the sea the noises in them are waves. These sounds are really air waves, and the reason we can hear them so well in a sea shell is because the shell is a wonderful sounding box. There is nothing better constructed than the shell as a resonator. The sounding box of the violin or guitar can be likened to the sea shell, but it is not nearly as perfect a resonator as the sea shell. A perfect resonator such as the sea shell will pick up sounds which are not possible to detect with the naked ear. Although to you everything about you may be absolutely quiet, the little sea shell will pick up sound waves and magnify them. It has been demonstrated that the sea shell will not emit sounds in places that are absolutely sound proof and where there are no sounds.

TABLE RAPPING

Through the Science of Sound you will be able to understand the various manifestations which have been given the name of "rapping" and which are practiced by so-called Spiritualists.

There are many mechanical inventions for producing this phenomenon, electrically and otherwise, but the most interesting method and the one that was the origin of all Spiritualism was produced by a physical action of certain elements in the body. These sounds were produced in a way that could not be reasonably understood by people who attended the Spiritualistic seances.

In March, 1848, there began in a little rustic cottage in Mydesville, Arcadia, near Newark, Wayne County, N. Y., manifestations by two children, known as the Fox Sisters, in the form of noises that were attributed to the spirits. This was the beginning of Spiritualism and the news of the phenomenon produced by these two girls traveled around the world. We will not attempt to describe the interesting child play that took place and led up to this discovery, but the facts in the matter are that these two girls discovered that by disjointing certain bones in their feet they were able to produce noises and when their feet were placed in contact with a resonant body such as a vibrating floor or wooden table, mysterious noises or rappings were produced, the origin of which could not be detected by anyone. These girls became very expert and absolutely mystified the entire world with these phenomenal manifestations. They were nothing more than sound waves produced by articulations of joints and ligaments which produced sympathetic vibrations when in contact with resonant bodies that magnified the sound.

THE HUMAN VOICE

There is no musical instrument—not even the violin—which is capable of producing sounds that are so marvelously rich in overtones as those produced by the vocal cords. This fact is yet more wonderful when you consider that the vocal cords of a bass singer, for example, are only about an inch long. Of course, however, we must remember that they act under forced vibration, which always results in a greater variety of overtones than free or natural vibration. It must also be remembered that the length and tension of the vocal cords may be changed at will by the singer.

Perhaps the most important feature in vocal tones, however, is the resonating system which Nature has provided. The chest and the cavities of the mouth and nose serve as resonators and the beauty of them is that they can be changed appropriately from moment to moment. The overtones of the lower notes

are reinforced by the chest as a resonator, which does best when well expanded. This is why a singer has plenty of air in his lungs, especially when singing the low notes.

It is not only in singing that the effect of our natural resonators is felt, but in talking as well. The qualities of sound which enter into the sounding of vowels and which determine the kind of voice a person has are controlled by the upper resonators—the mouth and nose. These can be quickly varied within a wide range by members of the higher races of mankind. The lower races, however, such as the South Sea Islanders, do not have this control over the upper resonators and hence their language consists almost entirely of consonants, giving one the impression of nothing but a series of clicks, coughs and sneezes, or even grunts.

INTERFERENCE IN WAVE MOTIONS

I will ask you to repeat the first experiment with the coil springs, by which we demonstrated a wave set up by a blow struck on a wire. Now just as this wave, which was started by striking the spring, reaches the other end of the spring strike another blow and produce a second wave. These two waves will meet in the middle of the spring and, being of the same amplitude, will counteract each other; this is called interference. You will notice, though, that this does not stop vibration of the spring except at the point where the two waves meet. On the contrary, each wave continues on in its original direction.

Isn't this just what happens when two sets of swells meet in the water? Watch the swells from two steamers as they pass one another. Where the two sets of swells meet, the water is choppy and you cannot distinguish either set of waves. After a few seconds, however, you can see one set traveling off in one direction and the other in another direction, neither of them any the worse for their encounter.

Experiment No. 38. Take your tuning fork and set it in vi-

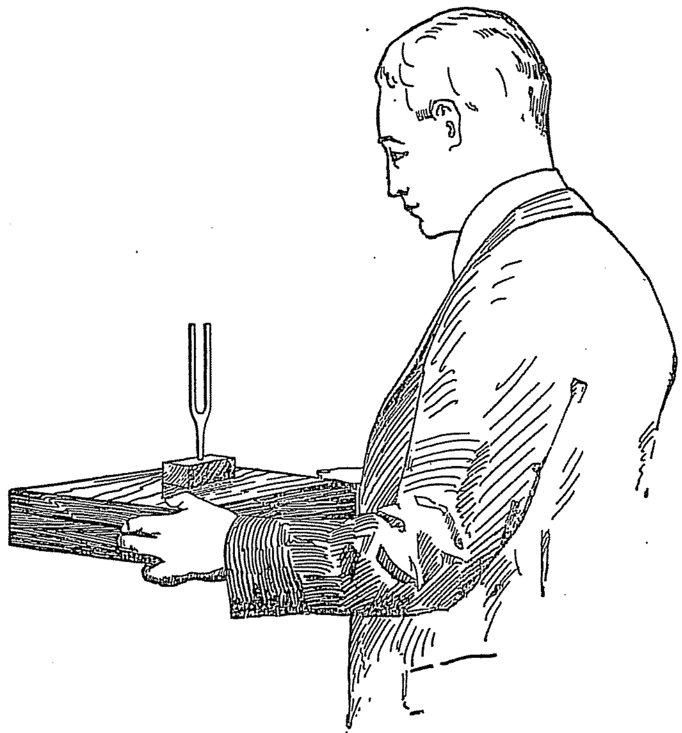

FIG. 50

bration, preferably on a sounding box, and move it toward a smooth wall. (See Figure 50.) Here you will observe the phenomenon of interference of wave motion the same as in the spring. You will find a position of the fork in which the sound

will be faint. In this position, the condensations as reflected back from the wall just match up with rarefactions at the fork, and interference takes place at that point. You can move the fork and find a position in which the sound is loudest. This

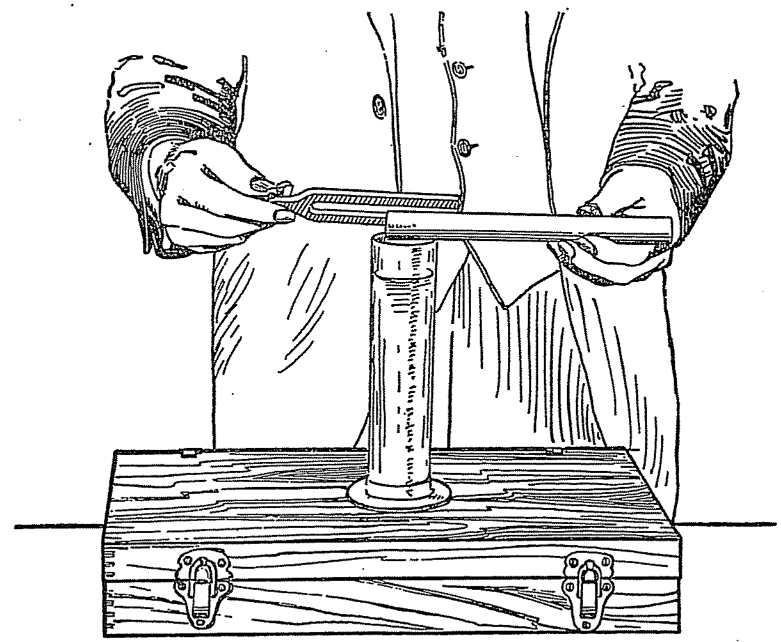

FIG. 51

you should recognize as the same principle which was at work in the case of the resonating tube. The condensations are reflected back from the wall just in time to join other condensations produced by the vibration of the fork.

Experiment No. 39. Use the apparatus described in Experiment No. 37. When you have adjusted the length of the air column so that it is in resonance with your tuning fork, hold the fork horizontally over the glass tube and revolve it slowly about its axis—that is, with a rolling motion. You will find a point where the sound is practically inaudible, it is so faint. With the fork in this position, slip a cardboard tube over one prong of the fork, being careful not to touch the fork. (See Figure 51.) The sound will now be heard very plainly again.

This experiment shows interference of air waves. Each prong sends a set of waves down the jar; but, when one prong is higher than the other, the two sets of waves do not reach the bottom of the jar in the same manner. In other words, a condensation and a rarefaction reach the bottom at the same time, neutralizing each other. When the cardboard tube is put over one prong, one set of waves is cut out and you are able to hear the sound from the other prong of the fork.

BEATS

The hands of a clock move at different speeds. There are times when both hands are together, but most of the time they are more or less separated. In the same manner, two tuning forks may be vibrating at different rates, yet there will be times when the prongs of both forks will be in the same relative position. The result of such a condition may be nicely shown in the following manner:

Experiment No. 40. If a little wax is placed upon one of the prongs of one tuning fork, it will not vibrate as fast as the other fork. (Refer to Figure 34.) When both forks are vibrated at the same time, you will hear a sound whose intensity increases and diminishes at regular intervals. These are called beats and their cause should be clear to you now. When the prongs of both forks are vibrating together, the sound waves from the two forks reinforce each other; but when the prongs

are going in opposite directions, interference takes place and the sound becomes faint.

You may now press a piece of shot into the wax and thereby increase the load that fork will have to carry. This will still further cut down the rate of vibration. When the two forks are now set in vibration, the beats will be more frequent and less pleasing to the ear. If you reason it out, you will see that the

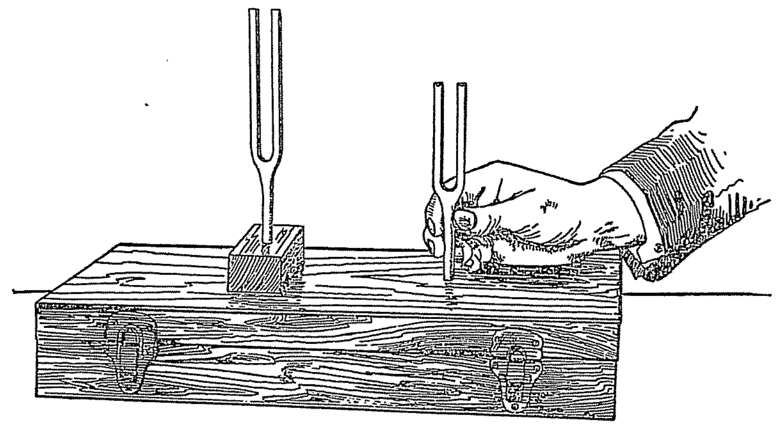

FIG. 52

greater the difference in the rates of vibration the more frequently the two forks will be in and out of unison.

This feature of musical tones is the cause of harmony and discord in music which are so often spoken of. It has been found that when the beats are about thirty-two per second the greatest discord results. When the beats are fewer than ten or more than seventy per second, they are somewhat unpleasant, but do not produce discord.

Take two tuning forks, a long one and a short one. Set one in vibration and place it firmly on a box cover. Do the same with the other fork, placing it near the first one, as in Figure 52. The tone you will now hear will be a pleasing sound instead of series of beats. The phenomenon of beats takes place in this

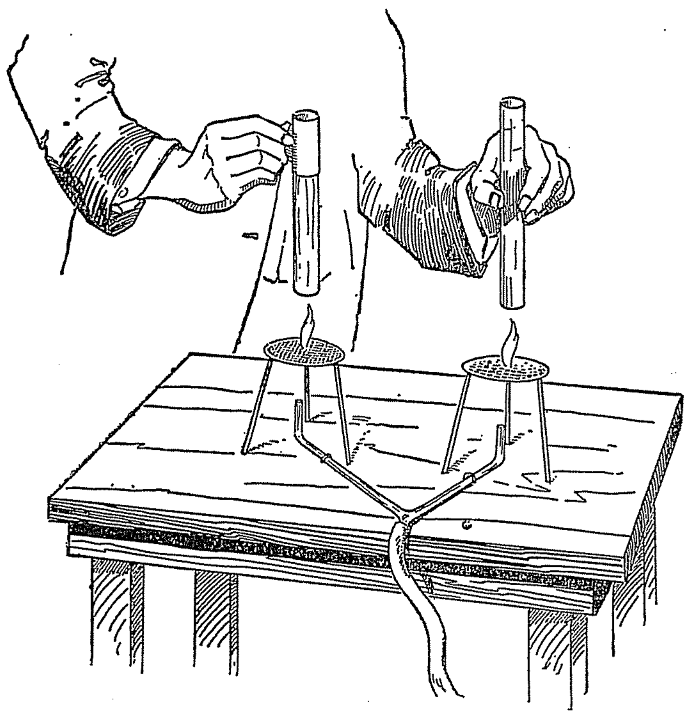

FIG. 53

case, but the ear does not detect them as such, as in the case of notes that are nearly the same.

Experiment No. 41. Set up the apparatus described in Musical Flames in duplicate. In other words set up two metal

tripods covered with wire gauze and place a gas jet under each. After lighting the gas above the wire gauze, hold a glass tube over each flame. If these two tubes are of the same size, you should hear a uniform loud tone. By slipping a cardboard cylinder over one of these tubes (see Figure 53) and thus varying its length, you can cause it to give a sound of a different pitch. If the pitch of the sound made by this tube is only slightly higher or lower than that of the other tube, you should hear distinct beats. By sliding the cardboard cylinder up or down and thus causing the pitch of the tone from that tube to be changed, the frequency of the beats will also be changed. You will find that a point is found where the beats are so rapid that you cannot detect them, and the result will be a sound similar to that produced when you vibrated two tuning forks of decidedly different lengths.

Chapter VII

HOW WE HEAR SOUND

In introducing the Science of Sound I aroused your curiosity by saying that the ear was the important factor in sound. You may hardly conceive of such a thing, but it is true, nevertheless, that if we had no ears, there would be no sound. Noises like

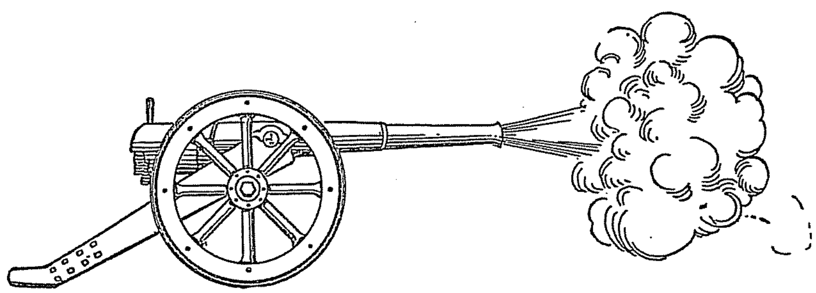

FIG. 54

the report of a gun and music from the piano do not travel through the air as sound, as we are apt to think they do. It is just Nature's swinging pendulum—the "to and fro" motion of air particles. The ear does, however, interpret them as sounds.

Sometime, if you are around where a cannon is being shot off, put your fingers in your ears so tightly that you cannot hear. You will see the flash of the cannon and you will feel the air disturbance, if you are standing anywhere near it, but you will not hear the report of the explosion. You will hear no sound.

When your fingers are in your ears, the report of the cannon is just what it seems to be—a disturbance of the air. (See Figure 54.)

You can very beautifully visualize by comparison the mechanism which Nature has provided for hearing and its similarity to the telephone transmitter. (See Figures 55 and 56.)

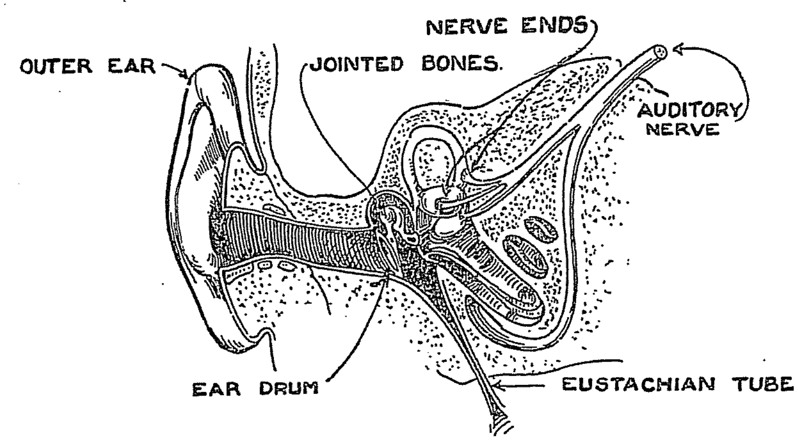

FIG. 55

Our ear is divided into three parts: the external, middle and internal ear.

The external ear, like the telephone transmitter, is shell-like in form. Both the ear and the telephone transmitter serve for collecting the sound waves, directing them toward the internal parts. When air waves tap on the ear drum—that is, when waves of air strike it—they set up a "to and fro" motion, vibrating and oscillating, and this impulse serves to transmit these vibrations received on the drum to the internal parts.

Right here it is interesting to remark that this "to and fro" motion will only be perfect on the drum of the ear when the air on both sides is of the same degree of density. Nature has well provided for this by putting a hole which leads from inside of the throat to just back of the drum which allows the free passage of air in and out. This short tube which connects the middle ear and the throat is called the Eustachian tube. This tube is about 1½ inches long, and if your hearing apparatus is

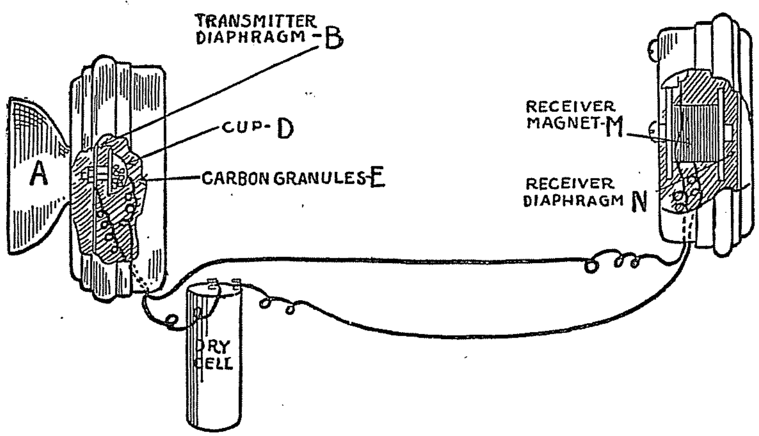

FIG. 56

working as it should there is a free and ready passage of air at all times in and out.

Some of us, when we have a cold—that is, a cold that affects this tube—allow inflammation to be set up and clog it up, which does not permit the free passage of air. Then we have difficulty in hearing. Sometimes the tube becomes so affected that we practically lose our hearing temporarily at least. Therefore it is important to be very careful with colds and particularly in the case of throat colds, and you will find that our good friend the

Doctor will always advise our spraying or gargling the throat to prevent infection spreading into these tubes.

Now just a word about

THE MIDDLE EAR

The middle ear is made up of three very fine and minute bones, one of which is attached to the drum; and the last in the series which are connected together extends to the opposite side where there is another membrane, and the two membranes are united together by means of these bones.

Just one other reference to these bones and that is that there are some very small muscles that connect and control them. It is assumed that these little muscles are controlled by the nervous system and that when we strain our ears in an endeavor to detect faint sounds they act in some way or other to tighten these membranes, so that we can detect the faintest sounds.

THE INTERNAL EAR

The membrane at the base of the middle ear that we have just referred to closes the middle ear from the internal ear. Very little is known about the internal ear except that it is a very complicated mechanism. We do know that it is made up of many filaments and spiral tubes and that these tubes and filaments are filled with watery fluid. Into these fluids there extend fine hair-like nerve ends which are the terminals of the nerves of the ear, and they unite to form the auditory nerves which go to the brain to relay the messages that are received.

If you have followed our description you know that sound waves tap on the ear drum and that the little bones that are attached to it communicate these vibrations through the chain of bones to the internal membrane, thereby producing a corresponding vibration into the watery fluid by pressure and sen-