the end of the strip *p* is similarly in connexion with the terminal *a.* The receiver consists of an electromagnet made up of a magnetiz­ing coil H, with a stout knitting needle for a core. When in use these two instruments are joined in circuit with a battery B, so that under ordinary circumstances a continuous current is flowing through the line. Suppose a sound is then produced in front of the mouthpiece M, the successive variations in the pressure of the air are communicated to the inside of the box, and cause the mem­brane to vibrate in unison with the sound. Reis’s theory of the action of the instrument was that at each outward impulse of the membrane the point *g* would be thrown out of contact with the plate underneath it and would thus break the circuit. There would con­sequently result as many breaks in the circuit as there were vibra­tions in the sound, and, in conformity with Page’s discovery, the electromagnetic receiver would give out a rapid succession of beats, which would together form a continuous sound of the same pitch as that to which the transmitter was subjected.

Fig. 2 shows the first telephone made by Bell for transmitting speech. It consisted of a wooden frame F, to one side of which a tube T was fixed ; over the end of the tube a membrane M was stretched taut by a stretching ring R. To the opposite side of the frame and with its axis in line with that of the tube T was fixed an electromagnet H, and between the membrane M and the end of the electromagnet a hinged arma­ture A was arranged in such a way that its motions would be con­trolled by the membrane. The instrument was joined in circuit with a battery and another simi­lar instrument placed at a dis­tance. A continuous current was made to flow through the circuit, which kept the electromagnet magnetized. Bell reasoned thus : when words are spoken in front of the tube T the membrane will be set in vibration and with it the armature A, and the vibration of the armature in front of the electro­magnet will induce variations in the line current ; their magnitude will be proportional to the amplitude, and their frequency to the frequency, of the vibrations of the armature ; in fact, the difference between the actual and the average current in the circuit will be at each instant proportional to the rate of motion of the armature. It follows from this that the armature and membrane of the distant instrument should have induced in them a motion precisely similar to that of the membrane of the transmitter. This telephone was made in June 1875, but was put aside after trial as unsatisfactory on account of the feebleness of the sounds it produced ; since then, however, a successful telephone has been made on precisely the same plan as that here indicated.

The next form tried is shown in fig. 3. It is very similar except in constructive details to the first ; the hinged armature, however, is omitted, its place being taken by a small iron disk A fixed to the centre of the diaphragm D. The electro­magnet H is, as before, placed so as to have the centre of the soft iron core C opposite to the centre of the disk, and the theory ac­cording to which it was expected to act is the same. The results obtained with this instrument were much more satisfactory ; indeed it was with one precisely like that shown in the figure that the remarkable results of the Philadelphia exhibition in 1876 were obtained. A perspec­tive and a sectional view of the receiving instrument used along with that shown in fig.

1. are illustrated in figs.
2. and 5. It consisted of an iron cylindrical box B, through the axis of which a rod of soft iron C was passed to form the core of an electromagnet, having the magnetizing helix H wound on the upper half of its length. Across the top of the box a thin disk D of soft iron was fixed, the core C being just clear of the disk when the strongest current is flowing through the helix. In the per­spective view the disk is removed, showing the end of the core. These instruments are interesting, not only because they may be considered the first really successful speaking telephones, but be­cause they are of the same form as those brought to Great Britain in 1876 by Sir W. Thomson, and exhibited before the British Asso­ciation at Glasgow in that year.

Fig. 6 shows one of the earliest forms brought into commercial use. On each pole of a somewhat large horse-shoe permanent magnet

M a short coil E with a soft iron core was fixed. This is one of the early forms of permanent magnet telephones, of which there were at that time several, including a hand telephone very similar to that shown in fig. 7. In another form, introduced about the end of 1877, the small magnetizing coils and soft iron cores were fixed on the side and opposite the poles of the horse-shoe magnet, and the diaphragm was placed with its plane parallel to that of the magnet. The diaphragm in these telephones was of thin sheet iron and a little over *4* inches in diameter.

The form of telephone now almost universally in use is shown in fig. 7. It was introduced in December 1877 and consists of a com­pound permanent magnet M, fitted into the centre of a tube of vulcanite or “hard rubber” and carrying at one end a short electro­magnet, the coil of which through its terminals *t, t* is in­cluded in the cir­cuit when the instrument is in use. In front of the electromagnet, with its plane normal to the axis of the magnet, is fixed a thin soft iron disk about 1¾ inches in diameter, which has its cover cut to a convenient shape to form a mouthpiece. This telephone acts well either as a transmitter or as a receiver ; but for the former purpose it is now seldom used on account of the great advances which have been made in “ microphone ” transmitters.

It has been stated that Bell and Elisha Gray almost simultane­ously suggested the use of a column of liquid to vary the resistance in the circuit. The form of instrument proposed by the former and said to have been exhibited at the Philadelphia exhibition is shown in fig. 8. It con­sists of a speaking tube or mouthpiece M, across the lower end of which a membrane D is stretched. To the centre of the mem­brane a light rod R, made of metal or of carbon, is fixed with its length at right angles to the plane of the membrane. Under the lower end of R a small metallic vessel C is sup­ported on a threaded rod, working in a nut fixed to the sole F, so that its height may be readily adjusted. Suppose C to be filled with water or any other con­ducting liquid, and the rod R to be of metal. C is raised until the liquid just touches the point of the rod, when advantage is taken of the change of contact resistance with the greater or less immer­sion of R during the vibration of D. Good results were obtained with mercury as the liquid and with a rod of carbon.

The arrangement proposed by Elisha Gray is almost identical in form with Bell’s. The only difference seems to be that Gray in­tended the rod R (fig. 9) to reach near to the bottom of the vessel B or to the end of another rod, a prolongation of *b,* projecting up from the bottom. The variation of the current was produced by the variation of the distance between the ends of the rod caused by the vibrations of the diaphragm. This plan was not tried until after the success of Bell’s experiments was known, and when it was