currents, and sounds were given out corresponding in pitch, and also to some extent in quality, with the sounds produced at the transmitting station. A cylinder of chalk was used in some of Edison’s later experiments with this receiver.

The transmitter (fig. 4), in an early form, consisted of a cell of insulating material having at its bottom a flat-headed platinum screw G ; on the top of G was a layer of carbon powder C, on the top of that a platinum disk D, and above that again, forming the cover of the cell, a disk of ivory B, held in position by a ring E. Resting on the centre of the ivory disk was a small piece of rubber tubing, and this was lightly pressed by the diaphragm A, which was held in place by the mouthpiece Μ. The varying pressure on A, when a sound was produced near it, caused corresponding variations in the pressure on the carbon powder, and this produced similar variations in its electric resistance.

Experiments very similar to these of Edison were made by Elisha Gray of Boston, Mass., and described by him in papers communicated to the American Electrical Society in 1875 and 1878. In these experiments the electric current passed through the fingers of the operator’s hand, which thus took the place of the spring in Edison’s apparatus. The diaphragm was itself used as the rubbing surface, and it was either mounted and rotated or the fingers were moved over it. When the current passed, the friction was felt to increase, and the effect of sending a rapidly undulating current through the arrangement was to produce a sound. The application of this apparatus to the transmission of music was described by Gray.@@1

In another form of telephone, brought prominently forward by Professor A. E. Dolbear,@@2 the effects were produced by electrostatic instead of electromagnetic forces, as in the Bell telephone. Sir W. Thomson (Lord Kelvin) observed in 1863@@3 that when a condenser is charged or discharged, a sharp click is heard, and a similar observation was made by Cromwell F. Varley, who proposed to make use of it in a telegraphic receiving instrument.@@4 In Dolbear’s instrument one plate of a condenser was a flexible diaphragm, connected with the telephone line in such a way that the varying electric potential produced by the action of the transmitting telephone caused an increased or diminished charge in the condenser. This alteration of charge caused a corresponding change in the mutual attraction of the plates of the condenser; hence the flexible plate was made to copy the vibrations of the diaphragm of the transmitter. It is obvious that this apparatus might be used either as a transmitter or as a receiver, but that the effects must under ordinary circumstances be in either case extremely feeble.

It was very early recognized—and, indeed, is mentioned in the first patents of Bell, and in a caveat filed by Elisha Gray in the United States patent office only some two hours after Bell’s application for a patent—that sounds and spoken words might be transmitted to a distance by causing the vibrations of a diaphragm to vary the resistance in the circuit. Both Bell and Gray proposed to do this by introducing a column of liquid into the circuit, the length or the resistance of which could be varied by causing the vibrations of the diaphragm to vary the depth of immersion of a light rod fixed to it and dipping into the liquid.

On the 4th of April 1877 Émile Berliner filed a caveat in the United States patent office, in which he stated that, on the principle of the variation with pressure of the resist­ance at the contact of two conductors, he had made an instrument which could be used as a telephone transmitter, and that, in consequence of the mutual forces between the two parts of the current on the two sides of the point of contact, the instrument was capable of acting as a receiver. The caveat was illustrated by a sketch showing a diaphragm with a metal patch in the

centre, against which a metal knob was lightly pressed by an adjusting screw. This seems to have been the first transmitter in which it was proposed to use the resistance at the contact of two conductors.

Almost simultaneously with Berliner, Edison conceived the idea of using a variable resistance transmitter@@5 He proposed to introduce into the circuit a cell containing carbon powder, the pressure on which could be varied by the vibrations of a diaphragm. He sometimes held the carbon powder against the diaphragm in a small shallow cell (from a quarter to half an inch in diameter and about an eighth of an inch deep), and sometimes he used what he describes as a *fluff,* that is, a little brush of silk fibre with plumbago rubbed into it. In another form the plumbago powder was worked into a button cemented together with syrup and other substances. In the specification of the patent applied for on the 21st of July 1877 he showed a sketch of an instrument which consisted of a diaphragm, with a small platinum patch in the centre for an electrode, against which a hard point, made of plumbago powder cemented together with india-rubber and vulcanized, was pressed by a long spring, the pressure of the carbon against the platinum disk being adjusted by a straining screw near the base of the spring. Subsequently he filed an application for a patent in which various forms of springs and weights assisted in maintaining the contacts and otherwise improved the instrument.

In the early part of 1878 Professor D. E. Hughes, while en­gaged in experiments upon a Bell telephone in an electric circuit, discovered that a peculiar noise was produced when­ever two hard electrodes, such as two wires, were drawn across each other, or were made to touch each other with a variable degree of firmness. Acting upon this discovery, he constructed an instrument which he called a “microphone,”@@6 and which consisted essentially of two hard carbon electrodes placed in contact, with a current passing through the point of contact and a telephone included in the same circuit. One of the electrodes was attached to a sounding board capable of being vibrated by sound-waves and the other was held either by springs or weights in delicate contact with it. When the sounding board was spoken to or subjected to sound-waves, the mechanical resistance of the loose electrode, due to its weight, or the spring, or both, served to vary the pressure at the contact, and this gave to the current a *form* corresponding to the sound-waves, and it was therefore capable of being used as a speaking-telephone transmitter.@@7

The next transmitter of note was that introduced by Francis Blake, which came into wide use in the United States of America and other countries. In it the electrodes were of platinum and carbon.

To a frame F (fig. 5) was attached a diaphragm D of thin sheet iron; in front of this was a cover Μ, M provided with a suitable cavity for directing the sound-waves against the diaphragm. The microphonic arrangement consisted of a spring S, about the hundredth of an inch thick and the eighth of an inch broad, fixed at one end to a lever L, and carrying at its free extremity a brass block W. In one side of W a small disk C of gas carbon was in. serted, resting on the hemispherical end of a small platinum pin K, about the twentieth of an inch in diameter, held in position by a thin spring A. The pressure of the carbon on the platinum point could be adjusted by the screw N, which turned the lever about the flexible joint G. The electrical connexions of the instrument as arranged for actual use are also illustrated in the figure. The current circuit went through S, W, C, K, A, and the primary circuit of the induction coil I to the battery B, and thence to S again. This formed a local circuit at the transmitting station. The line of circuit passed through the secondary of the induction coil I to the line, from that to the telephone T at the receiving station,

@@@1 See George B. Prescott, *The Speaking Telephone* (London, 1879), pp. 151-205.

@@@2 *Scientific American,* 18th June 1881.

*@@@3 Electrostatics and Magnetism,* p. 236.

@@@4 See *Tel. Journ.,* 1st August 1877, p. 178; also Adams, *Journ. Soc. Tel. Eng.,* 1877, p. 476.

@@@5 See *Journal of the Telegraph,* New York, April 1877; *Phila­delphia Times,* 9th July 1877; and *Scientific American,* August 1877.

@@@6 This term was used by Wheatstone in 1827 for an acoustic apparatus intended to convert very feeble into audible sounds; sec his *Scientific Papers,* p. 32.

@@@7 See *Proc. Roy. Soc.,* xxvii. 362; *Proc. Phys. Soc.,* ii. 255; *Phil. Mag.,* 5th scr., vol. vi. p. 44; W. H. Preece, *Journ. Soc. Tel. Eng.,* vii. 270.