mouthpiece. The vibrations of the diaphragm cause the needle point to make indentations more or less deep, according to the intensity of the sound, in the surface of the tinfoil. If the mouth­piece is then raised, the drum turned back to its original position, the

mouthpiece lowered so that the point rests on the groove which it previously made, and the drum again turned, the diaphragm, acted on by the needle point passing over the indentation, will give out the same words which were spoken to it. (T. GR. )

TELESCOPE

THE telescope is an optical instrument employed to view or discover distant objects.@@1 The fundamental optical principles involved in its construction have already been dealt with in the articles Light and Optics, and these should be first perused by the reader.

History.

The credit of the discovery of the telescope has been a fruitful subject of discussion. Thus, because Democritus announced that the milky way is composed of vast mul­titudes of stars, it has been maintained that he could only have been led to form such an opinion from actual examination of the heavens with a telescope. Other passages from the Greek and Latin authors have similarly been cited to prove that the telescope was known to the ancients. But, as has been remarked by Dr Robert Grant (*History of Physical Astronomy,* p. 515), we are no more warranted in drawing so important a conclusion from casual remarks, however sagacious, than we should be justified in stating that Seneca was in possession of the discoveries of Newton because he predicted that comets would one day be found to revolve in periodic orbits. Molyneux, in his *Dioptrica Nova,* p. 256, declares his opinion that Roger Bacon (who died *c.* 1294) “did per­fectly well understand all kinds of optic glasses, and knew likewise the method of combining them so as to compose some such instrument as our telescope.” He cites a passage from Bacon’s *Opus Majus,* p. 377 of Jebb’s edition, 1733, translated as follows :—

“ Greater things than these may be performed by refracted vision. For it is easy to understand by the canons above mentioned that the greatest objects may appear exceedingly small, and the contrary, also that the most remote objects may appear just at hand, and the converse ; for we can give such figures to transparent bodies, and dispose them in such order with respect to the eye and the objects, that the rays shall be refracted and bent towards any place we please, so that we shall see the object near at hand or at any dis­tance under any angle we please. And thus from an incredible distance we may read the smallest letters, and may number the smallest particles of dust and sand, by reason of the greatness of the angle under which we see them. . . . Thus also the sun, moon, and stars may be made to descend hither in appearance, and to be visible over the heads of our enemies, and many things of the like sort, which persons unacquainted with such things would refuse to believe. ”

Molyneux also cites from Bacon’s *Epistola ad Parisiensem,* “ Of the Secrets of Art and Nature,” chap. 5 :—

" Glasses or diaphanous bodies may be so formed that the most remote objects may appear just at hand, and the contrary, so that we may read the smallest letters at an incredible distance, and may number things, though never so small, and may make the stars also appear as near as we please. ”

These passages certainly prove that Bacon had very nearly, if not perfectly, arrived at theoretical proof of the possibility of constructing a telescope and a microscope ; but his writings give no account of the trial of an actual telescope, nor any detailed results of the application of a telescope to an examination of the heavens. It has been pointed out by Dr Smith, in his *Complete System of Optics,* that Bacon imagines some effects of telescopes which cannot be performed by them, and his conclusion is that Bacon never actually looked through a telescope.

Giambattista della Porta, in his *Magia Naturalis,* printed in 1558, makes the following remarkable statement :—

“ If you do but know how to join the two (viz., the concave and the convex glasses) rightly together, you will see both remote and near objects larger than they otherwise appear, and withal very distinct. ”

Wolfius infers from this passage that its author was the first actual constructor of a telescope, and it appears not improbable that by happy accident Porta really did make some primitive form of telescope which excited the wonder of his friends. Here, however, his interest in the matter appears to have ceased, and he was unable either to ap­preciate the importance of his discovery or to describe the means by which the object was attained. Kepler, who exa­mined Porta’s account of his concave and convex lenses by desire of his patron the emperor Rudolph, declared that it was perfectly unintelligible. Poggendorff (*Gesch. der Physik,* p. 134) throws considerable doubt on the origin­ality of Porta’s statement.

Thomas Digges, in his *Stratioticus,* p. 359, published in 1579, states that his father, Leonard Digges,

“among other curious practices had a method of discovering by perspective glasses set at due angles all objects pretty far distant that the sun shone upon, which lay in the country round about,” and that this was by the help of a manuscript book of Roger Bacon of Oxford, who he conceived was the only man besides his father who knew it. There is also the following passage in the *Pantometria* (bk. i. chap. 21) of Leonard Digges @@2 (originally published by his son Thomas in 1571, and again in 1591):—

“Marvellous are the conclusions that may be performed by glasses concave and convex, of circular and parabolic forms, using for multiplication of beams sometime the aid of glasses transparent, which, by fraction, should unite or dissipate the images or figures presented by the reflection of other.”

He then describes the effects of magnification from a com­bination of lenses or mirrors, adding :—

“ But of these conclusions I minde not here to intreate, having at large in a volume@@3 by itselfe opened the miraculous effects of perspective glasses.”

It is impossible to discredit the significance of these quotations, for the works in which they occur were pub­lished more than twenty years before the original date claimed for the discovery of the telescope in Holland.

That Roger Bacon had tolerably clear ideas as to the practical possibility of constructing telescopes, and that Leonard Digges had access to some unpublished MSS. of Bacon, and by their aid constructed some form of tele­scope, seem to be obvious inferences from the preceding evidence. But it is quite certain that previous to 1600 the telescope was unknown, except possibly to individuals who failed to see its practical importance, and who confined its use to “ curious practices ” or to demonstrations of “ natural magic.” The practical discovery of the instru­ment was certainly made in Holland about 1608, but the credit of the original invention has been claimed on behalf of three individuals, Hans Lippershey and Zacharias Jansen, spectacle-makers in Middelburg, and James Metius of Alkmaar (brother of Adrian Metius the mathematician).

Descartes, in his treatise on *Dioptrics* (1637), attributes the dis­covery to Metius “about thirty years ago,” whilst Schyrælus de Rheita, a Capuchin friar, in his *Oculus Enoch et Elise* (Antwerp, 1645), gives the credit to Lippershey about 1609. Peter Borel, physician to the king of France, published at The Hague, in 1655, a work *De Eero Telescopii Inventore.* He was assisted in its pre­paration by William Borel, Dutch envoy at the court of France, and the latter declares, as the result of patient investigation, that

@@@1 In recent years the term “photographic telescope” has been applied to instruments employed to record the appearance of celestial objects by photography.

@@@2 He died about 1570. His son alludes to his untimely death in the preface to the *Pantometria.*

@@@3 There is no further trace of this volume.