in his *Histoire des Mathématiques* (pp. 448-449), gives the following footnote, communicated to him by Lalande:—

"Ce fut Chestermonhall" (an obvious misprint for Chester Moor Hall) “ qui, vers 1750, eut l’idée des lunettes achromatiques. 11 s’adressoit à Ayscough @@1 qui faisoit travaillir Bass. Dollond ayant eu besoin de Bass pour un verre que demandoit le duc d’Yorck, Bass lui fît voir du crown-glass et du flint-glass. Hall donna une lunette à Ayscough, qui la montra à plusieurs personnes; il en donna la construction à Bird, qui n’en tint pas compte. Dollond en profita. Dans le procès qu’il y eut entre Dollond et Watkin, au banc du roi, cela fut prouvé; mais Dollond gagna, parce qu’il étoit le premier qui eût fait connoître les lunettes achromatiques.”

It is clearly established that Hall was the first inventor of the achromatic telescope; but Dollond did not borrow the inven­tion from Hall without acknowledgment in the manner sug­gested by Lalande. His discovery was beyond question an independent one. The whole history of his researches proves how fully he was aware of the conditions necessary for the attainment of achromatism in refracting telescopes, and he may be well excused if he so long placed implicit reliance on the accuracy of experiments made by so illustrious a philosopher as Newton. His writings sufficiently show that but for this confidence he would have arrived sooner at a discovery for which his mind was fully prepared. It is, besides, impossible to read Dollond’s memoir *(Phil. Trans.,* 1758, p. 733) without being impressed with the fact that it is a truthful account, not only of the successive steps by which he independently arrived at his discovery, but also of the logical processes by which these steps were successively suggested to his mind.

The triple object-glass, consisting of a combination of two convex lenses of crown glass with a concave flint lens between them, was introduced in 1765 by Peter, son of John Dollond, and many excellent telescopes of this kind were made by him.

The limits of this article do not permit a further detailed historical statement of the various steps by which the powers of the telescope were developed. Indeed, in its practical form the principle of the instrument has remained unchanged from the time of the Dollonds to the present day; and the history of its development may be summed up as consisting not in new optical discoveries but in utilizing new appliances for figuring and polishing, improved material for specula and lenses, more refined means of testing, and more perfect and convenient methods of mounting.

About the year 1774 William Herschel, then a teacher of music in Bath, began to occupy his leisure hours with the construction of specula, and finally devoted himself entirely to their construction and use. In 1778 he had selected the *chef-d'oeuvre* of some 4∞ specula which he made for the cele­brated instrument of 7-ft. focal length with which his early brilliant astronomical discoveries were made. In 1783 he com­pleted his reflector of 18 7/10 in. aperture and 20-ft. focus, and in 1789 his great reflector of 4-ft. aperture and 40-ft. focal length. The fame of these instruments was rapidly spread by the brilliant discoveries which their maker’s genius and per­severance accomplished by their aid. The reflecting telescope became the only available tool of the astronomer when great light grasp was requisite, as the difficulty of procuring disks of glass (especially of flint glass) of suitable purity and homo­geneity limited the dimensions of the achromatic telescope. It was in vain that the French Academy of Sciences offered prizes for perfect disks of optical flint glass. Some of the best chemists and most enterprising glass-manufacturers exerted their utmost efforts without succeeding in producing perfect disks of more than 3⅛ in. in diameter. All the large disks were crossed by striae, or were otherwise deficient in the neces­sary homogeneity and purity. The subsequent history of the development of the art of manufacturing glass disks for telescopic objectives will be found in the article Glass; *§ Optical.*

Instruments, &c.

We proceed to give an account of the methods and prin­ciples of construction of the various kinds of telescopes, and

to describe in detail special typical instruments, which, owing to the work accomplished by their aid or the practical advances exemplified in their construction, appear most worthy of record or study.

*Refracting Telescope*

In its simplest form the telescope consists of a convex objective capable of forming an image of a distant object and of an eye-lens, concave or convex, by which the image so formed is magnified. When the axis of the eye-lens coincides with that of the object-glass, and the focal point of the eye-lens is coin­cident with the principal focus of the object-lens, parallel rays incident upon the ohject-glass will emerge from the eye-piece as parallel rays. These, falling in turn on the lens of the human eye, are converged by it and form an image on the retina.

Fig. I shows the course of the rays when the eye-lens is convex (or positive), fig. 2 when the eye-lens is concave (or negative). The former represents Kepler’s, the latter Lippershey’s or the Galilean telescope. The magnifying power obviously depends on the proportion of the focal length of the object-lens to that of the eye-lens, that is,

magnifying power=F∕e, where F is the focal length of the object-lens and *e* that of the eye-lens. Also the diameter of the pencil or parallel rays emerging from the eye-lens is to the diameter of the object-lens inversely as the magnifying power of the telescope. Hence one of the best methods of determining the magnifying power of a telescope is to measure the diameter of the emergent pencil of rays, after the telescope has been adjusted to focus upon a star, and to divide the diameter of the object­glass by the diameter of the emergent pencil. If we desire to utilize all the parallel rays which fall upon an object-glass it is necessary that the full pencil of emerging rays should enter the observer’s eye. Assuming with Sir William Herschel that the normal pupil of the eye distends to one-fifth of an inch in diameter when viewing faint objects, we obtain the rule that the minimum magnifying power which can be efficiently employed is five times the diameter of the object-glass expressed in inches.@@2 The defects of the Galilean and Kepler telescopes are due to the chromatic and spherical aberration of the simple lenses of which they are composed. The substi­tution of a positive or negative eye-piece for the simple convex or concave eye-lens, and of an achromatic object-glass for the simple object-lens, transforms these early forms into the modern achromatic telescope. The Galilean telescope with a concave eye-lens instead of an eye-piece still sur­vives as the modern opera-glass, on account of its shorter length, but the object-glass and eye-lens are achromatic combinations.

(D. GI.)

*Telescope Objectives.@@*3—In spite of the improvements in the manufacture of optical glass (see Glass) practically the same crown and flint glasses as used by John Dollond in 1758 for achromatic objectives are still used for all the largest of the modem refracting telescopes.

It has long been known that the spectra of white or solar light yielded by ordinary crown and flint glasses arc different: that while two prisms of such glasses may be arranged to give exactly the same angular dispersion between two Fraunhofer

@@@1 Ayscough was an optician in Ludgate Hill, London.

@@@2 In the case of short-sighted persons the image for very distant objects (that is, for parallel rays) is formed in front of the retina; therefore, to enable such persons to see distinctly, the rays emerging from the eye-piece must be slightly divergent; that is, they must enter the eye as if they proceeded from a comparatively near object. For normal eyes the natural adaptation is not to focus for quite parallel rays, but on objects at a moderate distance, and practi­cally, therefore, most persons do adjust the focus of a telescope, for most distinct and easy vision, so that the rays emerge from the eye-piece very slightly divergent. Abnormally short-sighted per­sons require to push in the eye-lens nearer to the object-glass, and long-sighted persons to withdraw it from the adjustment employed by those of normal sight. It is usual, however, in computations of the magnifying power of telescopes, for the rays emerging from the eye-piece when adjusted for distinct vision to be parallel.

@@@3 For the methods of grinding, polishing and testing lenses, see Objective.