in bare theory.” They compared its performance with that of the object-glass of 123-ft. focal length presented to the Royal Society by Huygens, and found that Hadley’s reflector “ will bear such a charge as to make it magnify the object as many times as the latter with its due charge, and that it represents objects as distinct, though not altogether so clear and bright. . .. Notwithstanding this difference in the brightness of the objects, we were able with this reflecting telescope to see whatever we have hitherto discovered with the Huygenian, particularly the transits of Jupiter’s satellites and their shadows over his disk, the black list in Saturn’s ring, and the edge of his shadow cast on his ring. We have also seen with it several times the five satellites of Saturn, in viewing of which this telescope had the advantage of the Huygenian at the time when we compared them; for, being in summer, and the Huygenian telescope being managed without a tube, the twilight prevented us from seeing in this some of these small objects which at the same time we could discern with the reflecting telescope.”

Bradley and Molyneux, having been instructed by Hadley in his methods of polishing specula, succeeded in producing some telescopes of considerable power, one of which had a focal length of 8 ft.; and, Molyneux having communicated these methods to Scarlet and Hearn, two London opticians, the manufacture of telescopes as a matter of business was com­menced by them (Smith’s *Opticks,* bk. iii. ch. 1). But it was reserved for James Short of Edinburgh to give practical effect to Gregory’s original idea. Born at Edinburgh in 1710 and originally educated for the church, Short attracted the atten­tion of Maclaurin, professor of mathematics at the university, who permitted him about 1732 to make use of his rooms in the college buildings for experiments in the construction of telescopes. In Short’s first telescopes the specula were of glass, as suggested by Gregory, but he afterwards used metallic specula only, and succeeded in giving to them true parabolic and elliptic figures. Short then adopted telescope-making as his profession, which he practised first in Edinburgh and after­wards in London. All Short’s telescopes were of the Gregorian form, and some of them retain even to the present day their original high polish and sharp definition. Short died in London in 1768, having realized a considerable fortune by the exercise of his profession.

*Achromatic Telescope.—*The historical sequence of events now brings us to the discovery of the achromatic telescope. The first person who succeeded in making achromatic refracting telescopes seems to have been Chester Moor Hall, a gentleman of Essex. He argued that the different humours of the human eye so refract rays of light as to produce an image on the retina which is free from colour, and he reasonably argued that it might be possible to produce a like result by combining lenses composed of different refracting media.@@1 After devoting some time to the inquiry he found that by combining lenses formed of different kinds of glass the effect of the unequal refrangibility of light was corrected, and in 1733 he succeeded in con­structing telescopes which exhibited objects free from colour. One of these instruments of only 20-in. focal length had an aperture of 2½ in. Hall was a man of independent means, and seems to have been careless of fame; at least he took no trouble to communicate his invention to the world. At a trial in Westminster Hall about the patent rights granted to John Dollond (Watkin *v.* Dollond),@@2 Hall was admitted to be

the first inventor of the achromatic telescope; but it was ruled by Lord Mansfield that “ it was not the person who locked his invention in his scrutoire that ought to profit for such invention, but he who brought it forth for the benefit of mankind.”@@3 In 1747 Leonhard Euler communicated to the Berlin Academy of Sciences a memoir in which he endeavoured to prove the possibility of correcting both the chromatic and the spherical aberration of an object-glass. Like Gregory and Hall, he argued that, since the various humours of the human eye were so combined as to produce a perfect image, it should be possible by suitable combinations of lenses of different refracting media to construct a perfect object-glass. Adopting a hypothetical law of the dispersion of differently coloured rays of light, he proved analytically the possibility of con­structing an achromatic object-glass composed of lenses of glass and water. But all his efforts to produce an actual object­glass of this construction were fruitless—a failure which he attributed solely to the difficulty of procuring lenses worked precisely to the requisite curves (*Mem. Acad. Berlin,* 1753). Dollond admitted the accuracy of Euler’s analysis, but dis­puted his hypothesis on the grounds that it was purely a theo­retical assumption, that the theory was opposed to the results of Newton’s experiments on the refrangibility of light, and that it was impossible to determine a physical law from analytical reasoning alone *{Phil. Trans.,* 1753, p. 289). In 1754 Euler communicated to the Berlin Academy a further memoir, in which, starting from the hypothesis that light consists of vibrations excited in an elastic fluid by luminous bodies, and that the difference of colour of light is due to the greater or less frequency of these vibrations in a given time, he deduced his previous results. He did not doubt the accuracy of Newton’s experiments quoted by Dollond, because he asserted that the difference between the law deduced by Newton and that which he assumed would not be rendered sensible by such an experi­ment.@@4 Dollond did not reply to this memoir, but soon after­wards he received an abstract of a memoir by Samuel Klingenstierna, the Swedish mathematician and astronomer, which led him to doubt the accuracy of the results deduced by Newton on the dispersion of refracted light. Klingenstierna showed from purely geometrical considerations, fully appreciated by Dollond, that the results of Newton’s experiments could not be brought into harmony with other universally accepted facts of refraction. Like a practical man, Dollond at once put his doubts to the test of experiment, confirmed the conclusions of Klingenstierna, discovered “a difference far beyond his hopes in the refractive qualities of different kinds of glass with respect to their divergency of colours,” and was thus rapidly led to the construction of object-glasses in which first the chromatic and afterwards the spherical aberration were corrected *{Phil. Trans.,* 1758, p. 733).

We have thus followed somewhat minutely the history of the gradual process by which Dollond arrived independently at his invention of the refracting telescope, because it has been asserted that he borrowed the idea from others. Montucla, given for his invention, was the dead, and his son brought an action for infringing the patent against Champness. There is no report of the case, but the facts are referred to in the reports of subsequent cases. It appears that workmen who had been employed by Mr Moor Hall were examined, and proved that they had made achromatic object-glasses as early as 1733. Dollond’s patent was not set aside, though the evidence with regard to the prior manu­facture was accepted by Lord Mansfield, who tried the case, as having been satisfactorily proved . . . Mr Hall was a bencher of

the Inner Temple, and was alive at the time of the action. He was a man of some property, and is spoken of on his tombstone as an excellent lawyer and mathematician. He was not a fellow of the Royal Society, but must certainly have known of the gift of the Copley medal to Dollond. It is very curious the conflicting evi­dence we have to reconcile, but I think the balance of evidence is in favour of there having been a prior invention of achromatic object-glasses before the date of Dollond’s patent” (*Astron. Register,* May 1886; see also the *Observatory* for same date).

@@@1 The same argument was employed by Gregory more than fifty years previously, but had been followed by no practical result. The lens of the human eye is not achromatic.

@@@2 At a meeting of the Royal Astronomical Society held on 9th May 1886 a legal document, signed by Chester Moor Hall, was presented by R. B. Prosser of the Patent Office to the society. On the same occasion A. C. Ranyard made the following interesting statement respecting Hall :—

“ Some years ago very little was known about Moor Hall. It was known that, about seven years after the patent for making achromatic object-glasses was granted to Dollond, his claim to the invention was disputed by other instrument-makers, amongst them by a Mr Champness, an instrument-maker of Cornhill, who began to infringe the patent, alleging that John Dollond was not the real inventor, and that such telescopes had been made twenty- five years before the granting of his patent by Mr Moor Hall. John Dollond, to whom the Copley medal of the Royal Society had been

*@@@3 Gentleman’s Magazine,* 1790, part ii. p. 890.

@@@4 For a good account of this controversy, see Dr H. Servus, *Geschichte des Fernrohrs,* p. 77 seq. (Berlin, 1886).