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A POSSIBLE INFLUENCE, IN THE FIELD OF  
PHYSIOLOGICAL OPTICS, OF IBN SÎNÂ ON  
IBN AL-HAYTHAM\*

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Ibn al-Haytham was widely known in late medieval Europe where he was called Alhazen, the Latinized form of his first name Al-Ḥasan. Concerning him David C. Lindberg writes:

“Alhazen was a prolific writer on all aspects of science and natural philosophy. More than two hundred works are attributed to him by Ibn abî Usaybi‘a, including ninety of which Alhazen himself acknowledged authorship. . . .

“Alhazen’s extant works on the subject of optics are the following: (1) *Kitab al-Manazir (Book of Optics)*, translated into Latin as *De aspectibus* or *Perspectiva*, (2) *On the Paraboloidal Burning Mirror*, translated into Latin as *De speculis comburentibus*, (3) *On the Spherical Burning Mirror*, (4) *On the Burning Sphere*, (5) *On Light*, (6) *On the Rainbow and Halo*, (7) *On the Nature of Shadows*, (8) *On the Form of the Eclipse*, which deals with the theory of radiation through apertures, (9) *On the Light of the Moon*, and (10) *On the Light of the Stars*. Finally a section on optics appears in Alhazen’s (11) *Doubts Concerning Ptolemy*. Another work frequently attributed to Alhazen, *On the Twilight* (translated

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into Latin as *De crepusculis*) was actually written by Abu 'Abd Allah Muhammad ibn Mu'adh. Among those works of Alhazen that are, so far as is known, no longer extant, we find the following that bear on optics or on the visual process: (12) an analysis of the optical knowledge of Euclid and Ptolemy, (13) *On the Nature of Sight and the Manner in Which Sight Occurs*, (14) *On Optics According to the Method of Ptolemy*, (15) an analysis of Aristotle's *De anima*, (16) an analysis of Aristotle's *Meteorologica*, and (17) *On the Perfection of the Art of Medicine*, containing chapters on diseases of the eye, on the usefulness of the parts of the body (probably based on Galen's *Usefulness of Parts*), and on the opinions of Hippocrates and Plato (probably based on Galen's *De Placitis Hippocratis et Platonis*). What must impress one about this list of works is Alhazen's remarkable scope. . . .

"Besides the works thus far mentioned, what others did Alhazen have at his disposal? . . . As for optical sources, the wide circulation of al-Kindi's *De aspectibus* and Hunain's *Ten Treatises* makes it probable that Alhazen was familiar with them. Moreover, the former contains theoretical contributions that were essential to Alhazen's new intromission theory, and I regard it as most unlikely that Alhazen arrived at these independently. It is ironic that Avicenna and Alhazen, two of the greatest Islamic writers on optics, should make their contributions contemporaneously. Few of their works can be dated precisely enough to allow us to determine the possible pattern of influence, though it appears that Avicenna wrote (or at least began) his principal work, the *Shifa*, some fifteen or twenty years before Alhazen wrote his great synthetic work, the *Kitab al-Manazir*. However, we know nothing about the immediate circulation of Avicenna's works, and I can find no parallels between the works of Avicenna and Alhazen sufficiently striking to persuade me that either of them influenced the other."<sup>1</sup>

Again, the same author says, "Alhazen's refutation of the extramission theory of vision is certainly not as extensive as Avicenna's. Nevertheless, it had great persuasive force, . . ."<sup>2</sup> Here they have certain common elements in their arguments, but these were not

<sup>1</sup> David C. Lindberg, *Theories of Vision from Al-Kindi to Kepler*, University of Chicago Press, 1976, pp. 60-61.

<sup>2</sup> Lindberg, *op. cit.*, p. 61.

original with either one of them. They therefore do not constitute any evidence that they influenced one another. They seem to share ideas related to the psychology of vision, i.e., to the theory of the perception of the forms of external objects, but this apparently is because the ideas of both bore the stamp of strong Aristotelian influence, and this also represented quite a wide-spread view.<sup>3</sup> Wiedemann who made a detailed study both of Ibn Sīnā's and Ibn al-Haytham's explanations of the rainbow and halo points out that they bear no similarity to one another.<sup>4</sup> Indeed, none of them makes a substantial contribution to the knowledge of the subject, but while Ibn Sīnā chooses to emphasize his dissatisfaction with the knowledge available in the subject, Ibn al-Haytham boldly introduces the unsatisfactory *ad hoc* hypothesis of the existence of a cloud, spherical in shape, as a necessary condition for the formation of the rainbow.

The field of optics gained in rigor by being based on geometry already in Antiquity. This status of optics became definite and clear, especially beginning with Euclid in the third century B. C., through the adoption of the principle of rectilinear propagation, representing rays of light by geometrical lines, and thanks to the knowledge of the law of reflection. But the process of this geometrization of light is seen to go back to Aristotle and the Pythagoreans. Not all branches of optics had been geometrized, however. For geometrical optics was largely synonymous with an elementary kind or field of perspective, or, more generally speaking, with sight, and it also contained catoptrics dealing with phenomena related to the reflection of light. Dioptrics could not be treated geometrically before the discovery of the law of refraction in the seventeenth century, and Ibn al-Haytham was responsible to a large extent for the mathematization of physiological optics.

Ronchi points out that in the theory of vision of Antiquity there were two weak but basic points on which everybody agreed, though more or less in an implicit manner. One was that objects were seen

<sup>3</sup> Mark Smith, "Getting the Big Picture in Perspectivist Optics", *Isis*, vol. 72, 1981, pp. 568-589.

<sup>4</sup> Eilhard Wiedemann, "Beiträge zur Geschichte der Naturwissenschaften, 38", *Sitzungsberichte der Physikalisch-Medizinischen Sozietät in Erlangen*, vol. 46, 1914, p. 39.

as a whole, that vision involved a process in which the outside objects were perceived in their totality, and the other concerned the idea of the perspective cone or pyramid. The vertex of this pyramid represented the eye and the base was constituted by the object viewed. The simplification of the entire eye so as to reduce it to a mere geometrical point was extremely useful from the standpoint of perspective, but it had serious disadvantages from the viewpoint of the mathematization of physiological optics.<sup>5</sup>

Both these defects were remedied thanks to Ibn al-Haytham's contributions to this field of optics. His achievements in this domain may be said to have made the geometrization of physiological optics possible. He has therefore been acclaimed as and given the title of the founder of physiological optics. Such is the verdict of the specialists of the subject and the general belief prevailing at present,<sup>6</sup> and there is no reason to doubt the veracity of this claim, except for acknowledging the contributions of certain precursors of Ibn al-Haytham for having to some extent prepared the way for him.

In the process of placing geometry at the foundation of physiological optics, Ibn al-Haytham's achievement may be represented by or resolved into two major components or constituent parts. One of these is that visual perception involves the formation of an optical image in the seeing eye. As to the process or manner in which this image is formed, instead of treating the object seen as an indivisible whole, Ibn al-Haytham considered it as made up of a large number of minute parts and assumed or supposed the optical image forming in the eye to consist of the sum-total of the innumerable partial images of the minute parts of the object seen. The second component of the innovation brought about by Ibn al-Haytham concerns the nature and the location of the image forming in the eye. Ibn al-Haytham believed this image to be located on the front surface of the eye-lens. As to the manner in which this image comes into being, Ibn al-Haytham does away with the perspective pyramid or cone of old, which was made up of visual rays, and substitutes for it a multiplicity of cones with their vertices on the innumerable

<sup>5</sup> Vasco Ronchi, *Histoire de la Lumière*, tr. Juliette Taton, Librairie Armand Colin, Paris 1956, pp. 31-32.

<sup>6</sup> Ronchi, *op. cit.*, pp. 31-42.

points of the object, their common base being the pupil of the eye. The point-images of these point-objects are determined, according to Ibn al-Haytham, by the rays incident perpendicularly upon the eye-lens.

Ibn al-Haytham's optics has a modern outlook in many of its parts. But this idea of image formation in the eye is, as we see, rather bizarre and outlandish. It is natural therefore to wonder how Ibn al-Haytham hit upon this strange idea of image formation. Indeed, Ronchi answers this inevitable question by supposing that Ibn al-Haytham wished thereby to avoid the awkward situation of having an inverted image on the retina.<sup>7</sup> This explanation does not seem very convincing, however. For firstly the knowledge of image formation with lenses was clarified in a satisfactory manner only through the investigations carried out by Kepler, as Ronchi himself has elucidated and emphasized.<sup>8</sup> And secondly, the idea of an inverted image on the retina is far too modern to go back to Ibn al-Haytham.

The idea of the sensitiveness of the retina seems to have been set forth by Ibn Sînâ.<sup>9</sup> Galen too spoke of retinal sensitivity, however, even if somewhat vaguely. According to Galen visual power is propagated outward to the visible object through the optic nerve, the eye, and other transparent media, and, conversely, visual perceptions or impressions are returned to the brain along the same route. After Ibn Sînâ, Ibn Rushd refers more specifically to the retina and its sensitiveness. So much so that, in the opinion of Fukala and Kœlbing, Platter and Kepler, in the late sixteenth and early seventeenth century, should be credited merely with the rediscovery, after Ibn Rushd, of the fact that the retina rather than the crystalline humor should be considered the photosensitive part of the eye.<sup>10</sup> This is a controvertible assertion, but even if its veracity should be unequivocally established or substantiated, still, there remains the fact that the recognition of the photosensitiveness of the retina is a far cry from the

<sup>7</sup> Ronchi, *op. cit.*, p. 39.

<sup>8</sup> Ronchi, *op. cit.*, pp. 50, 53, 83-90.

<sup>9</sup> See, Enrico Cantore, "Genetical Understanding of Science: Some Considerations About Optics", *Archives Internationales d'Histoire des Sciences*, year 17, 1966, pp. 335-336; Roger Bacon, *Opus Majus*, tr. R. B. Burke, vol. 2, 1928, pp. 432-433.

<sup>10</sup> Lindberg, *op. cit.*, pp. 56, 54-55.

knowledge that visual perception is a result of the formation of an inverted image on the retina, and apparently there is no clear and concrete case of referring to the retina as the seat of image formation in the eye before Giulio Cesare Aranzio's assertion of this fact which was based on an actual observation made in 1587, apparently the first such observation ever to be made.<sup>11</sup>

It is of great interest that Ibn Sînâ too speaks of the image formed on the anterior surface of the eye-lens, just as Ibn al-Haytham does, and incidentally, Wiedemann is of the opinion that perhaps Ibn Sînâ meant to say that the image is formed on the retina, but he has no evidence with which to back up this speculation of his.<sup>12</sup>

One may speculate that the inspiration for the supposition of the formation of images on the anterior surface of the eye-lens may have something to do with the observation of one's image in an eye one looks into, a circumstance that has given rise to the term pupil and its different forms or equivalents in various languages such as Latin, back in classical Antiquity, and, later on, in English, French, Italian, and German, and the homunculus of the eye in Persian, and the doll of the eye in Turkish.

It may be of interest in this connection that according to David C. Lindberg, in *De sensu* Aristotle wrote that "Democritus is right when he says that the eye is water but wrong when he supposes vision to be mere mirroring." Lindberg makes the following comment in this connection: "Of course, Aristotle only denies in this passage that vision is *mere* mirroring, but the thrust of his position is to dismiss the Democritean theory that associated vision with the formation of a mirror image in the eye."<sup>13</sup>

I quote in full the following passage taken from Lindberg because it is quite relevant to the particular question we are considering just now. He writes:

"Before leaving the visual theory of the atomists, I must call attention to a conception of Democritus that was to have considerable

<sup>11</sup> Fielding H. Garrison, *An Introduction to the History of Medicine*, 1929, p. 261.

<sup>12</sup> Eilhard Wiedemann, "Ibn Sinas Anschauung vom Sehvorgang", *Archiv für die Geschichte der Naturwissenschaften und der Technik*, vol. 4, 1912, p. 240.

<sup>13</sup> Lindberg, *op. cit.*, pp. 236-237, note 111.

subsequent influence. Democritus attached great significance in the act of sight to the pupillary image, that is, the image of outside objects mirrored in the cornea. Aristotle reports:

“Democritus . . . is right in his opinion that the eye is of water; not, however, when he goes on to explain seeing as mere mirroring. The mirroring that takes place in an eye is due to the fact that the eye is smooth, and it really has its seat not in the eye which *is seen*, but in the eye which *sees*. For the case is merely one of reflection. . . . It is strange too that it never occurred to him to ask why, if his theory be true, the eye alone sees, while none of the other things in which images are reflected do so.

“As von Fritz has pointed out, this theory undoubtedly originated in the observation that we can see in a person’s eye a miniature reflected picture of his visual field. If we are to understand what Democritus meant by it, we must construe reflection (*emphasis*) not according to our modern understanding as a process of rebound or deflection, but simply as visibility or presence in something. Thus for Democritus the mirror image in the eye signified nothing more than real presence of the image in the cornea (or perhaps in the interior humors) and hence the visibility of the object.”<sup>14</sup>

There seem to be no specific clues, however, indicating that, in speaking of the image forming in the eye and underlying the act of sight, Ibn Sînâ and Ibn al-Haytham were continuing or reviving the Democritean tradition. For although they may have received some inspiration from that tradition, their respective ideas are presented together with certain specific details that seem to give them a novel stamp or fresh appearance. Moreover, they do not refer at all to the image visible in the eye from without.

It seems rather difficult, one way or another, to find a reasonably satisfactory explanation for Ibn al-Haytham’s assumption that an image forming on the anterior surface of the eye-lens constitutes the basis of visual perception. It is so much the more interesting therefore that Ibn Sînâ too speaks of a visual image of exactly the same or closely similar nature as that fancied by Ibn al-Haytham. Let us see then what Ibn Sînâ has to say on these aspects or details of visual perception.

<sup>14</sup> Lindberg, *op. cit.*, p. 3.

Ibn Sînâ does not speak of conceiving the objects seen by the eye as made up of innumerable minute parts, and neither does he think of the image as composed of the totality of the images of these point-like minute parts. But, like Ibn al-Haytham, he believes the formation of optical image in the eye to underlie visual perception, and, again, Ibn Sînâ, like Ibn al-Haytham, supposes this image to be located on the anterior surface of the eye-lens. Ibn Sînâ says:

“The eye is like a mirror, and the visible object is like the thing reflected in the mirror by the mediation of air or another transparent body; and when light falls on the visible object, it projects the image of the object on to the eye. . . . If a mirror should possess a soul it would see the image that is formed on it.”<sup>15</sup>

According to Ibn al-Haytham, the rays issuing from the point-like minute parts of the visible object fall on the anterior surface of the eye-lens with varying angles, but the ones contributing to the image formed are those falling perpendicularly on the eye-lens and penetrating it without refraction, the non-perpendicular rays being weakened by reflection and refraction. These latter can therefore be ignored.

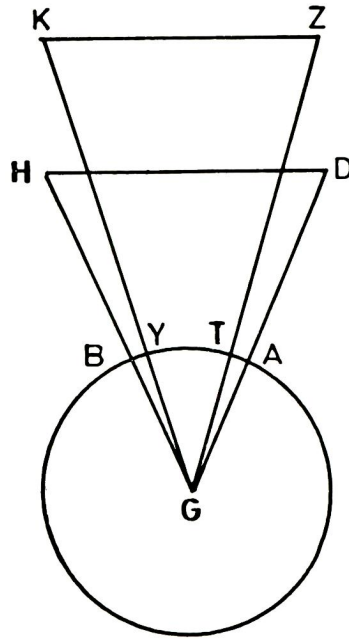
Now, this manner of image formation is rather strange, as said before, and it shows that Ibn al-Haytham did not have sufficient knowledge concerning images formed when light passes through a convex spherical surface separating two transparent media and is refracted in so doing. And it is particularly difficult to find an explanation for his erroneous decision that such an image would form upon the spherical refracting surface in question separating the two media.

Coming back to Ibn Sînâ, in criticizing the extramission theory of light, he makes a very interesting approach to the subject, an approach which, though indirectly, bears heavily on the particular question that concerns us here. Ibn Sînâ refutes the theory of visual rays in a very extensive and elaborate manner. Among his arguments to support the theory of intromission, i.e., rays issuing from outside objects and entering the eye from without, he has recourse to the figure which is reproduced here. KZ and HD are the same object at

<sup>15</sup> Lindberg, *op. cit.*, p. 49.



different distances from the eye represented by the circle with G at its center. The rays entering the eye from the extremities of the object at its nearer position HD intersect the circle with a greater arc than that corresponding to KZ at a greater distance. Ibn Sīnā calls these arcs, BA and YT, the images of the object at these two particular distances. We seem to have here therefore a concept of a visual image of the outside object which is very much the same as that found in Ibn al-Haytham.<sup>16</sup>



It is of great interest to see that Ibn Sīnā too, like Ibn al-Haytham, considers the image formed on a spherical refracting surface to be located on that very surface, and, again like Ibn al-Haytham, supposes the rays perpendicular to the spherical surface to trace the boundary of the image formed. These are striking similarities, although Ibn Sīnā does not always specifically mention whether the spherical refracting surface representing the eye is that of the eye-lens or of some other similar part of the eye. That it is the eye-lens is rather clear, nevertheless.

It is thus seen that, just as in the case of Ibn al-Haytham, Ibn Sīnā too did not have a sound grasp of the process of image formation in a convex spherical refracting surface. But in contradistinction to Ibn al-Haytham, it seems possible to find a reasonable account for Ibn Sīnā's erroneous idea of this image formation, to imagine a rationale for his peculiar manner of imagining the particular image in question. For apparently Ibn Sīnā did much thinking on the

<sup>16</sup> Lindberg, *op. cit.*, pp. 49-50. See also, Ibn Sīnā, *Dānishnāma-i 'Alā'i*, ed. Sayyid Muhammad Mashkūt, Tehran 1371 Hsh./1952, pp. 92-93, French tr. by Mohammad Achina and Henri Massé (*Le Livre de Science*), vol. 2, Paris 1958, p. 61; E. Wiedemann, "Ibn Sinas Anschauung vom Sehvorgang", pp. 239-249.

subject of optical images, and he came close to making a distinction between real and virtual images. In fact, he actually made such a distinction, but while he had a fairly good grasp of virtual images, he failed to understand or identify unequivocally the real images. He calls or styles virtual images as "ghost images" (*khayâl*) and defines them as images which change their places when the object or observer moves, while he imagined real images to be fixed in the body of the mirror or on the surface receiving the light rays. He believed that, in contrast to the virtual images, the locations of the "real" images were fixed, that such images were stationary.

Thus, the distinction he made between the two types of images was based on a fairly good grasp of virtual images. Should this distinction have been based on a proper understanding of the nature of real images, Ibn Sînâ would very likely have not fallen into the error he made. As is, his conception of a real image was of a rather empirical nature. Thus, he gives the example of a wall reflecting the green color of a lawn as due to an image of the lawn upon the wall.<sup>17</sup> A clear grasp of the natures of real and virtual images and of the distinction to be made between them was to be achieved for the first time by Kepler, who gave the names *picturae* and *pendulae* or *imagines rerum* to real and virtual images respectively.<sup>18</sup>

Now, since both Ibn al-Haytham and Ibn Sînâ seem to have fallen into practically the same or idencital error and since this error seems to fit in much more conveniently with Ibn Sînâ's ideas, it is natural to think that Ibn al-Haytham borrowed this item from Ibn Sînâ. Indeed, one could venture to say that Ibn al-Haytham might have been expected to feel dissatisfaction with the scheme of image formation which he adopted on this occasion. For although Ibn Sînâ seems to have pondered over and studied the subject of optical images with some care, Ibn al-Haytham had made a particular study of the passage of light through transparent spheres, and his rather far-fetched hypothesis that the rainbow must be forming in concave spherical clouds may be relevant to the topic of image formation in spherical mirrors as it occurs here in connection with visual per-

<sup>17</sup> Ibn Sînâ, *Kitâb al-Shifâ*, Tehran lithographic edition, Tehran 1303 Hsh./1886, vol. 1, pp. 261-262.

<sup>18</sup> Ronchi, *op. cit.*, pp. 79-80.

ception. For that hypothesis of his, connected with the rainbow, would seem to show that he had an idea concerning the shift suffered by focal points as the distances of rays parallel to the principal axis to that axis, i.e., the axis of symmetry of the mirror, changes.

As we have seen in the opening paragraphs of this paper, Ibn al-Haytham seems to have made an effort to achieve an extensive reading of the works on optics, and he apparently wrote his major work, which is the one that interests us in particular, some fifteen or twenty years after Ibn Sînâ wrote, or began to write, his *Kitâb al-Shifâ*. Ibn Sînâ started writing his *Kitâb al-Shifâ* with its Physics part wherein he deals with optical matters, and he speaks of his real and virtual images there. He expounded his idea of the image forming in the eye in his *Kitâb al-Najât*, in a short independent tract devoted to the eye, and in his *Dânishnâme-i 'Alâ'î*. All these were probably of later dates than the *Kitâb al-Shifâ*, and the latest among them was probably the *Dânishnâme-i 'Alâ'î*, which is in Persian and is estimated to have been written in 1021 or some later date. This date is considerably earlier than the date of composition of Ibn al-Haytham's *Kitâb al-Manâzir* wherein he expounds his theory of vision. It is quite possible therefore that one or more of these last-mentioned works of Ibn Sînâ came to the attention of Ibn al-Haytham.

