

Anatomy of the eye from the view of Ibn Al-Haitham (965-1039)

The founder of modern optics

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ABSTRACT

يعتبر ابن الهيثم (البصرة – 965 القاهرة 1039) والذي يعرف في العالم اللاتيني باسم "Alhazen" من العلماء الذين لعبوا دوراً كبيراً في العالم الإسلامي خلال القرون الوسطى. قام بتأليف العديد من الكتب، إلا أنه لم يعرف منها سوى 90 كتاباً. كتاب "المناظر" والذي تعتبر من أهم مؤلفاته، وتمت ترجمته إلى اللغات الغربية خلال الفترة من نهاية القرن 12 وبدايات القرن 13. وذكر ابن الهيثم في كتابه هذا الكثير من الفرضيات المتعلقة بعلم البصريات. ويعرف هذا الكتاب أيضاً باسم "كنز البصريات" حيث أثر على العلماء الغربيين المشهورين كثيراً، بل كان يعتبر مرجعاً علمياً حتى القرن 17 سواء في المغرب أو المشرق. ويعتبر روجر بيكون (1212-1294)، والذي غير علم البصريات التقليدي في الغرب مكرراً للاكتشافات التي توصل إليها ابن الهيثم. وقد بدأ ابن الهيثم كتابه "المناظر" متناولاً تشريح العين وكيفية أدائها لوظائفها، كما وضع تعاريف للقرنية، الرطوبة المائية، العدسة والجسم الزجاجي. كما بحث تأثيرات الضوء على الرؤية مغيراً الأفكار التي كانت سائدة حتى ذلك الوقت، مبيناً أن الضوء يصدر من الأجسام وليس من العين. وأورد في هذا الكتاب معلومات عن العصب البصري، الشبكية، القرنية والملتحمة. وأوضح كذلك العلاقة التي تربط بين أجزاء العين المختلفة، فضلاً عن كيفية عملها كجهاز للتجميع البصري للضوء خلال عملية الإبصار. وكان ابن الهيثم عند تأليفه للكتاب خلال ذلك القرن عالماً بكل ما يتعلق ببنية العين، ويعتبر تمثيله للعين التي رسمها من أفضل الأعمال التي قام بها.

Ibn Al-Haitham (known as Alhazen in Latin [965 Basra, Iraq-1039, Cairo, Egypt]) was a scientist who played an important role in the middle age Islam world. He wrote many books and novels, but only 90 of them are known. His main book "*Kitab al-Manazir*" was translated into Western languages in the late twelfth century, and in the early thirteenth century. In this book, he formulated many hypotheses on optical science. The book, which is also known as "Optic treasure" (*opticae thesaurus*), affected many famous Western scientists. He became an authority until the seventeenth century in the Eastern and

Western countries. Roger Bacon (1212-1294), who made radical changes in the Western optical traditions, reconfirmed Ibn Al-Haitham's findings. Ibn al-Haitham began his book *Kitab al-Manazir* with the anatomy and physiology of the eye. He specifically described cornea, humor aqueous, lens, and corpus vitreum. He examined the effect of light on seeing. He caused changes in the prevailing ideas of his age, and suggested that light came from objects, not from the eye. He provided information regarding the optic nerve, retina, iris, and conjunctiva. He showed the system of the eye as a dioptric, and the relations between the parts of the eye. It is understood that he mastered all knowledge on the structure of the eye in his century. The best proof of this is the eye picture that he drew.

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A great deal of scientific works from the Islamic world, including medical books, became known in Europe in the early periods. These works translated in Latin language, have reached our present day as well. However, in 1908, the great expert of Islamic ophthalmology, Julius Hirscheberg,¹ complained on the manuscripts published without any original text drawings, and wrote as follows: "the Arabs have begun in the earlier periods to add anatomic drawings of the organ of sight into their textbooks of ophthalmology." According to the information from the Caliphate, the son of Hunayn's sister, Hubeish Baghdadi (9th century)

wrote "The Description of Eye Diseases" (it did not reach us), which was full of eye drawings. Ali Bin-Isa Baghdadi's (early eleventh century) work, which is the classical textbook of ophthalmology for the Arab world, does not involve any figures except for one schematic description of the vitreous body enclosing the retina. However, this picture does not exist in all of the 5 manuscripts that are available today. We have the same problem with Ammar Maslawi's work from the same period.¹ Only the Hebrew translation of this text mentions figures, however, it includes only blank spaces in which these figures should have been available. The 3 eye drawings of Hunayn Bin-Ishaq (809-873) (Figures 1a) in his Cairo manuscript, which are available today, were not known to Julius Hirschberg, the great expert of the Arab-Islamic ophthalmology. It was Max Meyerhof, the younger colleague of Hirschberg from the same field of expertise, who discovered these drawings. The most ancient anatomic eye drawing that is available today came from Hunayn Bin-Ishaq.¹

Sezgin¹ cited some information on Polyak and Meyerhof in his book. He said that in 1941, Polyak explained the importance of this eye diagram as follows: "in his book of the Ten Treatises on the Eye (*kitadb al-ashr makadladt fi al-ain*), he gives a good description of

the parts composing the eye, of the optic nerve, and its connection with the brain, and also of the physiology of the visual system, besides the pathology and the treatment of eye diseases. In an Arabic manuscript of this book, it was noted that diagrams of the eye are noteworthy.¹ The best figure of Hunayn Bin-Ishaq (Figure 1b) shows the inner structures of the eyeball in an imaginary horizontal cross-section, enclosed in a frame representing the 2 lids, as seen in a living person. Of the several circular layers, or coats, the most outward is the conjunctiva, to which the oculomotor nerve is attached on each side; the next is the sclera, together with the cornea; then the chorioid membrane, with the uvea (iris); and finally the retina, the innermost. This latter membrane, according to the text, is made up of 2 components - a hollow nerve, which apparently is the retina proper, and the blood vessels. The inner space of the eye is divided by a cross-partition into an anterior compartment, filled with the aqueous humor, and a posterior compartment, the vitreous. The crystalline lens is represented in the very center of the eyeball as a circular sphere, whereas in the text it is correctly described as flat. A thick semicircular line in front of the lens and continuous with the cross-partition represents the arachnoid membrane - in modern terminology the "anterior capsule" of the lens - together with the ciliary zonule, and perhaps also the ciliary body. The most anterior portion of the outward tunic, facing upward and correctly showing the cornea with a smaller radius of curvature. The pupillary opening is represented by a small circle behind the cornea. This opening is enclosed in a crescent-shaped structure called the iris. The optic nerve is hollow. The 2 sheaths enveloping the nerve, the dura and the pia. The dura continues directly into the scleral tunic while the pia continues as choroid tunic. In the same time, the optic nerve itself spread out into the retina.¹⁻³ The obvious mistakes in this Arab diagram which, like the text, is in all probability a copy, or an adaptation from the Greek original of Galen's "On the Utility of the Parts of the Human Body," or from a similar treatise now lost, are at once apparent.^{1,4,5} First, the eyeball is too small in comparison with the palpebral fissure. Its walls are disproportionately thick, the anterior chamber too spacious, the posterior absent, and the vitreal cavity far too small. The 2 major errors of the Greek anatomy - the location of the lens in the center of the eyeball, and the channeling in the center of the optic nerve - were faithfully copied by the Arabs.^{1,5} Yet, in spite of this, the figure gives a fair idea of the disposition of the minute structures of the eye, and is unquestionably more correct than the confused geometrical diagrams, which decorated numerous Latin manuscripts in Europe from the thirteenth-fifteenth century, and even later. Thus, for instance, the

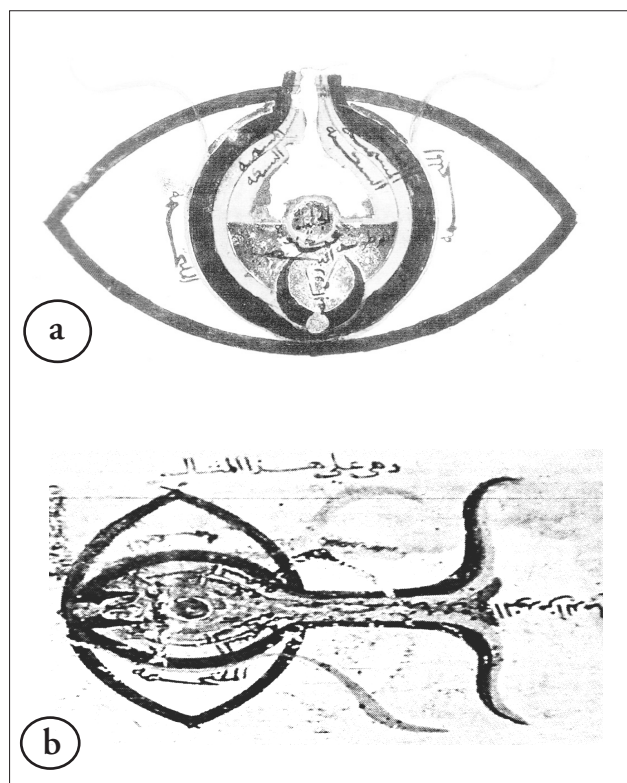


Figure 1 - The view of the eye a) diagram according to Hunayn Bin-Ishaq^{1,13} b) horizontal cross-section figure of Hunayn Bin-Ishaq.¹

arrangement or sequence of the tunics of the eyeball and of the optic nerve is correct. Even the positions of the lens, with its suspension in the araneal tunic, and of the zonular ligament are nearer in actuality than those represented in the above-mentioned geometrical schemes of the early European writers. All together, this venerable Arab diagram is more natural than the later, highly schematized, artificial Western figures. The diagram of Ibn Al-Haitham (Alhazen) was translated, and its copy were published. (Figures 2a & 2b).¹

Ibn Al-Haitham. Ibn Al-Haitham, who established the science of optics on new grounds in the ninth-century, is known as the "Father of Optics."⁵ This great scientist, known as Alhazen in the West, was born in Basra in 965. He became known during the reign of Al-Hakim (996-1020) in Egypt, and died in Cairo in 1039.⁴ He received education in Baghdad and Cairo, the art and culture centers of that age. During his education, he studied mathematics, astronomy, physics, and philosophy. Completing his education, he wrote commentaries on the prominent scientists of the Turkish-Islamic and Greek worlds, who preceded him. He produced a great deal of works on mathematics, astronomy, physics, and philosophy. Ibn Al-Haitham wrote works on some basic issues in

positive science such as conics, positional astronomy, trisection, lenses, distance geometry, center of gravity problems, isoperimetric problems and ellipse, and circle combination. He proved some basic physical phenomena, such as the refraction of light in water and in air. He explained the varieties of lenses and mirrors, and their magnification values. It was Ibn Al-Haitham who launched the idea of establishing a dam on the Nile River, and submitted a project of this idea to the rulers of the age. This shows that Ibn Al-Haitham had a strong competence in engineering as well.^{1,4,5}

The other aspects of Ibn Al-Haitham's scientific personality will be clear in the light of information on his works. Here, we cited some major points in his science: 1) owing to his investigations on gravity, he served as a pioneer approximately 700 years ago for the English physician, Newton, who introduced gravity as a force.⁵ 2) he played a pioneering role approximately 600 years ago for the Italian astronomer and physician, Galileo, who introduced the law of falling bodies, and led to encouragement and acceleration in his research.⁴ 3) he pioneered the experimental physics research of the famous mathematician and physicians of his century, the English Roger Bacon and the German Johannes Kepler, and encouraged them to carry out ground breaking scientific activities. Further, he inspired these scientists to become his followers.^{5,6}

The historians of science acknowledge that the twelfth century is the age of translation.^{1,7} In this century, the works of the Turkish-Islamic world produced in the eight-twelfth century were translated into Latin, the science language of the age. Ibn Al-Haitham's "*Kitab al-Manazir*" (Book of Optics) was translated into Latin in 1270.⁷ However, it was only in the sixteenth century, that Europe grasped the importance of the Latin translation of *Kitab al-Manazir*.^{5,7} Owing to the translation, the basic physical knowledge that Ibn Al-Haitham discovered was transformed into scientific laws as from the seventeenth century by Newton, Galileo, Roger Bacon, Kepler, and their contemporaries.⁵ Before Ibn Al-Haitham, various Muslim scientists were involved with optics, but they mostly followed the resources that they were more familiar with, namely, Euclid, Heron, Archimedes, Ptolemy, and Thenon.⁵ In a rather early period, Kindi^{4,5} wrote a work on optics on the basis of Euclid, and the Latin translation of this work, *De Aspectus*, introduced the optics of Euclid to the West for the first time. Physicians such as Hunayn Ibn-Ishaq and Razi conducted research on the anatomy and physics of the eye. However, it was Ibn Al-Haitham who led to a great transformation in this field of science, and who carried out several discoveries, which made him the most prominent scientist in this field between Euclid and Kepler.^{5,7}

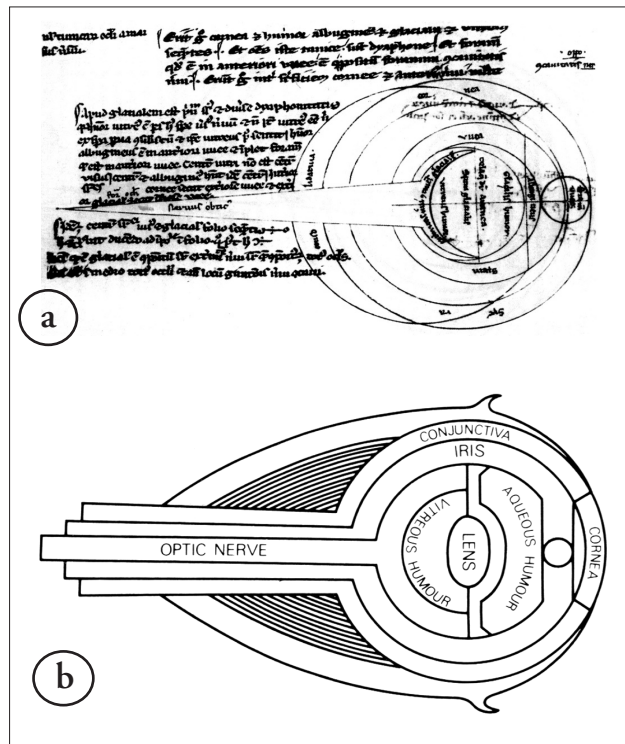


Figure 2 - The sagittal section of the eye a) schematic view¹ b) different schematic view in the translated book of Ibn Al-Haitham from Arabic to Latin.^{11,14}

For Ibn Al-Haitham, the eye does not send out light rays for visual perception as suggested by the preceding scientists, but the setting should be light for the eye to perceive visually. He explains it as follows: 1) it is not possible to see in dark, if the light came out of eye, it would be possible to see in dark. 2) we cannot look at powerful light resources, our eyes dazzle. 3) when light comes in from a hole on the wall of a dark room, we can just see the area illuminated by the light. 4) when we look at the stars, we see them at that very moment. However, if the rays came out of the eye, we would have to wait for the light to go, and come back to see the stars.⁷

Kitab al-Manazir is the major work of Ibn Al-Haitham because the scientist introduces the evidence and laws on optics in this book. Even though it is uncertain how the book became known in the West and who translated it, we know that it was translated in the late twelfth century or the early thirteenth century, and had great impact in the West.^{1,7} The Latin text was published by Friedrich Risner (?-1580) in 1572 in Basel with the book of Witelo, under the title of *Opticae Thesaurus*.⁷ The book, which became famous thereafter as *Opticae Thesaurus* (the Optic Treasure) played an effective role in the development and formulation of the optic theories of many western scientist including Pecham, Witelo, Roger Bacon, Kepler, Snell, Fermat and Descartes. On the other hand, this impact was not confined to the West, and the book had deep traces in the East on Kamaluddin al-Farisi (?-1320), who wrote a detailed commentary regarding this work, and on the works of Taqi Al-Din Ibn Ma'ruf, the eminent sixteenth century Turkish astronomer who is the founder of the Istanbul Observatory. The book has many Arabic and Latin versions.⁶⁻⁸

Kitab al-Manazir. The book is composed of 7 parts. The first 3 parts are directly related with sight, parts 4 - 6 are on reflection, and part 7 is dedicated to refraction. The Latin translation of the book includes the terms "experimentum," "experimentare," and "experimentator" as the translations of the Arabic words "itibar," "itibare," and "mutabir," which suggests that an experimental method was used for setting proof. This is an obvious indicator of the scientific attitude that Ibn Al-Haitham adopted. The first part of *Kitab al-Manazir* is composed of 8 subtitles: subtitle one covers an introduction and the formation of eyesight in general. Further, this part examines the approaches of earlier scientists to sight, subtitle 2 is dedicated to the characteristics of sight, subtitle 3 explains the properties of light and its spread, subtitle 4 is on the effects of light and color on the eye, subtitle 5 is completely dedicated to the structure of the eye, subtitle 6 is on how the act of seeing realizes, subtitle 7 explains the function of each visual organ in sight, and subtitle 8 explains the preconditions of sight.

Anatomy of the eye in Kitab Al-Manazir. The 5 subtitles in the first part of *Kitab al-Manazir* are concerned with the anatomy of the eye. His explanations demonstrate that Ibn Al-Haitham was cognizant of all relevant knowledge in his age. His diagram of the eye puts the best evidence for this (Figure 3a). His work is a clear indicator of the fact that the eye anatomy and medicine in general, was very developed in the medieval Islamic world. Comparing Ibn Al-Haitham's eye anatomy with today's science, we see that his discovery was quite close to our modern-day knowledge: as it was known, the layers of the eyeball, from the exterior to the interior are the fibrous tunic (*tunica fibrosa [externa] bulbi*), the vascular tunic (*tunica vasculosa [media] bulbi*), and the nervous tunic (*tunica nervosa interna] bulbi*).^{2,3,9,10} It was further explained that 1) Ibn Al-Haitham named as *tabakatü'l sulbe*, the thick and tough part of the fibrous tunic that constitutes the fifth-sixth of this layer namely, the sclera, and as *tabakatü'l karniye* the transparent part, which constitutes the remaining one-sixth of the layer namely, the cornea. 2) in the vascular tunic, the choroid in the inner part of sclera is, in Haitham's words, *tabakatü'l müsemmiye*, the ciliary body (*corpus ciliare*) that extends towards the outer edge of iris in the middle layer is *tabakatü'l ankebutiye*; *rutubetü'l celidiye* (crystalline humor) is the name he gave to the lens attached to the zonular fibers (*fibrae zonulares*), clung to the ciliary body. He named *sukbü'l inebiye*, the pupil, which is the opening in the center of the iris in front of the vascular tunic. Between the iris and cornea takes place camera anterior; humor aqueous is the watery fluid that fills camera anterior and posterior, namely the space among iris, lens, vitreous body, and ciliary body. Ibn Al-Haitham names humor aqueous as *rutubetü'l beydiya*, which means the eggy fluid. 3) as for the parts of the nervous tunic, Ibn Al-Haitham used the term *tabakatü'l sebekiye*, which means the network layer, to refer to the retina, the light-sensitive inner layer of the eye. He named as *rutubetü'l zücadiye*, the vitreous body (*corpus vitreum*) which fills the camera vitrea, and refracts the light. He used *asabü'l mucvef* for the optic nerve from the retina, and distinguished it from *mahrutu'ul ebsar*, the fibers which run from the optic tract (*tractus opticus*) following optic chiasm (*chiasma opticum*). To refer to optic nerves in general, he used the term *asabü'l basar*. He used *mültehim* to name the conjunctiva in the inner part of the eyelids (Figures 3a, 3b, 4).^{2,3,7-10} Ibn Al-Haitham, who influenced his contemporaries and successors for centuries, shows the anatomy of the eye, the mutual relationships among various parts of the eye, and how the whole organ and the dioptric system works during visual perception.¹¹

Ismail Hakki Izmirli¹² wrote that the traces of Ibn Al-Haitham's works can be seen in the works of

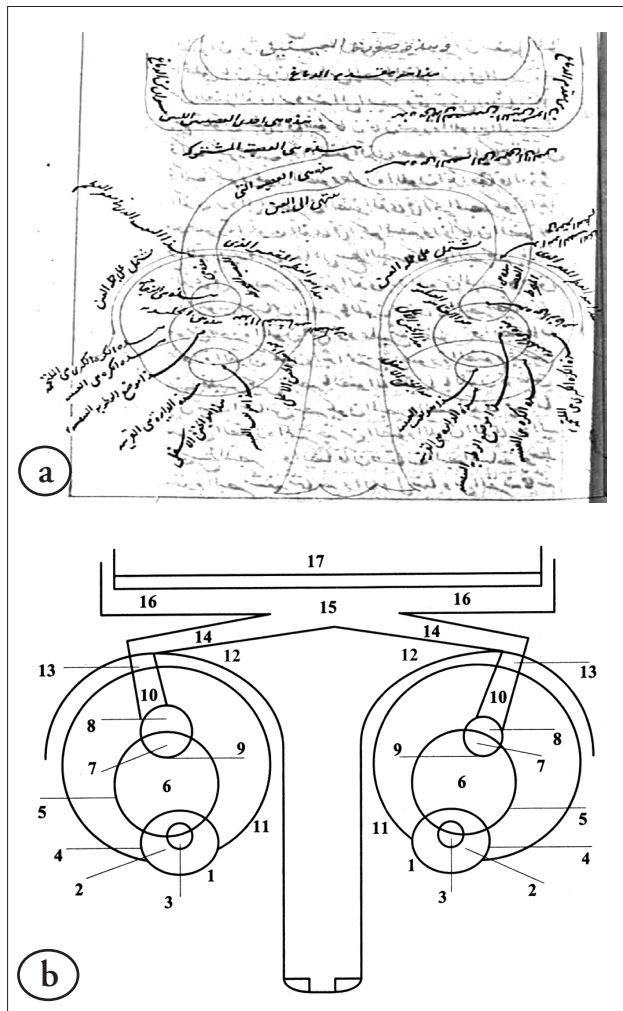


Figure 3 - The eye a) original picture hand drawn by Kitab al-Manazir.⁸ b) the schematic structure from Kitab al-Manazir.⁷ 1. lower eyelid 2. cornea 3. pupil 4. upper eyelid 5. eyeball 6. albugineous humor 7. crystalline humor 8. vitreous humor 9. the membrane surrounding crystalline humor 10. conic nerve 11. the conjunctive sphere surrounding eyeball 12. orbit 13. the space between eyeball and orbit 14. optic nerves 15. the combination point of the optic nerves 16. the optic nerve from the brain 17. front part of the brain.

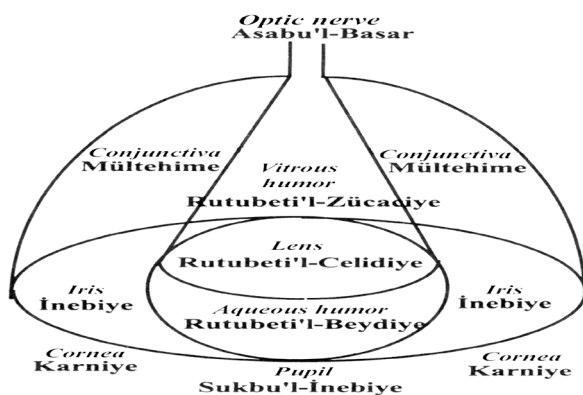


Figure 4 - The schematic structure of the eye and each element according to Ibn Al-Haitham.⁷

Descartes (1596-1650), the greatest French philosopher and mathematician of the age, the German philosopher Leibniz (1654-1716), and Immanuel Kant (1724-1804), and that he even served as a pioneer for some of these philosophers' works.^{12,13}

Ibn al Haitham influenced the English scientist Roger Bacon (1214-1294), and the German astronomer and physician Johannes Kepler (1571-1630).^{5,12,14}

According to the Ronan's book,¹⁴ Robert Grosseteste (1168-1253), the eminent physician of the thirteenth century, began his experimental physics studies with his research on lenses. The works of Ibn Al-Haitham constituted a resource for Grosseteste's research in this field. Like his professor Robert Grosseteste, the eminent English philosopher and physician Roger Bacon (1214-1294) became a follower of Ibn Al-Haitham.⁵

In the ninth part of his monograph titled "Arab diagrams of the eye, and their influence in Europe upon the anatomy and physiology of the visual organs,"^{1,13} According to Sezgin's book,¹ Polyak considers Ibn Al-Haitham and Kamaluddin Al-Farisi (980-1037),^{1,11} as the most significant representatives of physiological optics, and establishes a tie between the works of Ibn Al-Haitham and Ibn Sina,¹ the Latin translation of whose works was circulating for over one century, and the prominent works on optics produced in Europe in the thirteenth century.^{1,11,13} Witelo's book titled "Perpectiva," which is essentially "an analytical commentary on Ibn Al-Haitham's work and the first product of the optical efforts in Europe", interestingly overlaps in terms of its date of production and its content with the commentary that Kamaluddin Al-Farisi wrote in Iran. The translation of Ibn Al-Haitham's work and the publication of Witelo's book constituted the starting point for the publication of a long series of treatises of varying degrees on the importance of optics. The first and the most popular ones were written by Roger Bacon (1217-1297) and John Pecham (1235-1292), the archbishop of Canterbury. Polyak associates all diagrams of the eye drawn in the European resources until the sixteenth century, including the ones by Leonardo da Vinci, to the Arabic examples.^{1,11} Polyak, who is not an Arabist himself, is the first person that published and realized the importance of the eye diagrams of Ibn Al-Haitham and Kamaluddin Al-Farisi, which are available today in Istanbul libraries.¹

Following after Eilhard Wiedermann in the 1940's of the previous century, the Egyptian scientist Mustapha Nazif,¹ in Matthias Schramm's words, "treated the success of Ibn Al-Haitham in the field of optics in an exemplary and in the most comprehensive way." Another "perfect" work of Ibn Al-Haitham was published 20 years later. The name of this work is *Ibn Al-Haythams*

Weg zur Physik.^{1,15} The scientist who contributed to the enhancement of the literature on Arab-Islamic science is Matthias Schramm himself. Not in this work but in another work which is equally perfect, Schramm suggests completely new perspectives on the field. In the article titled *Zur Entwicklung der physiologischen Optik in der arabischen Literatur*, Schramm enlightens us on his efforts to associate Ibn Al-Haitham's thoughts on anatomy with his thoughts on optics.^{1,15}

In physiological optics, the spherical form of the transparent layer (cornea) "is not a pure phenomenon proved by anatomists, but it constitutes an obligation: this layer (cornea) allows the uninterrupted entry of lights penetrating into the center of the eye, and in the center of sight from all directions." This means that Ibn Al-Haitham developed "as a result of physical observation, the first definite hypothesis on the structure of the eye, outlined with its main frames, through geometric means."^{1,14-16}

It is very important that Schramm produced a work of high quality on the basis of the commentary by Kamaluddin al-Farisi 300 years later, in the further development process of physics and physiological optics as a result of physical observation. It is required to cite here what Schramm said regarding the pupil doctrine of Kamaluddin,^{1,11} because it is specifically related to the topic of this paper. Believing that the thought of Galen and his supporters are indefensible, Kamaluddin Al-Farisi concludes that reflection occurs in the front surface of the lens on the basis of his pupil diagram describing the eye of a sheep. Schramm appreciates this success of Kamaluddin Al-Farisi as follows:^{1,11,12} "owing to his thoughts and experiments, Kamaluddin came to a conclusion which was re-achieved only in 1823 when Johannes Evangelista Purkynje studied again in this subject."¹⁴

Ibn al-Haitham, who developed the first definite hypothesis on the structure of the eye, and influenced his contemporaries and successors for centuries, shows the anatomy of the eye, the relationships among the parts of the eye, and how the whole organ and the dioptric system works during visual perception. However, Kamaluddin Al-Farisi explained Ibn Al-Haitham's book "*Kitab al-*

Manazir," and is the first person who undeniably found the reflection on the front surface of the lens.^{15,16}

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References

- Sezgin F. [Science and Technology in Islam]. Ankara (TR): Farsa Matbaasi; 2007. p. 17-20. Turkish
- Williams PL. Nervous System. In: Gray's Anatomy. 38th ed. Edinburgh (UK): Churchill Livingstone; 1995. p. 1322-1352.
- Snell RS. The head and neck. In: Clinical Anatomy. 7th ed. Baltimore (MD): Lippincott Williams & Wilkins; 2004. p. 831-833.
- Bayraktar M. [The history of Science and Technology in Islam]. Ankara (TR): Türkiye Diyanet Vakfı Yayinlari; 1989. p. 45-46. Turkish.
- Göker L. [The history of art science and the situations of Turks-Islamic scientists]. Ankara (TR): Milli Egitim Bakanligi Yayinlari; 1998. p. 421-426. Turkish.
- Kahya E, Erdemir AD. [Medical Societies from Ottoman to Turkey Public]. Ankara (TR): Türkiye Diyanet Vakfı Yayinlari; 2000; p. 36. Turkish.
- Topdemir HG. [The founder of modern optics Ibn al-haitham's life, books, theories]. Ankara (TR): Atatürk Kültür Merkezi Başkanligi Yayinlari; 2002. p. 6-19.
- Ibnü'l Heysem. [Kitab al Manazir] [CD-ROM]; Istanbul (TR): Ayasofya Archives; 2008. p.46-81. Arabic
- Arinci K, Elhan A. Sense of Organ. In: Anatomi (Anatomy). 2nd ed. Ankara (TR): Günes Kitabevi; 1995. p 446-456.
- Moore KL. Head. In: Clinical Oriented Anatomy. 3rd ed. Philadelphia (PA): Williams & Wilkins; 1992. p. 712-7141.
- Nasr SH. [Islam and Science]. Istanbul (TR): İnsan Yayinlari; 1989. p. 140-142. Turkish.
- Izmirli IH. [The comparison between the Islamic thinkers and the Western thinkers]. Ankara (TR): Diyanet Isleri Başkanligi; 1973. p. 42-56. Turkish.
- Arakça A. [The history of Islamic Medicine]. Istanbul (TR): Çağdas Basın Yayın; 2004. p. 270-284. Turkish.
- Ronan CA. Bilim Tarihi (Science History) (translated from Science: Its history and development among world cultures by Ihsanoglu E, Günergun F). 3rd ed. Ankara (TR): Tubitak; 2003. p. 252-284.
- Hunke S. Allahs Sonne über dem Abenland. 1st ed. Istanbul (TR): Kaynak Yayınları; 2008. p. 197-207. Turkish.
- Topdemir HG, Unat Y. [Science History]. 1st ed. Ankara (TR): Pegem Akademi Yayınları; 2008. p. 123-130. Turkish

Related topics

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Gedik S, Gur S, Atalay B, Colak M, Altinors N, Akova YA. Humphrey visual field analysis, visual field defects, and ophthalmic findings in patients with macro pituitary adenoma. *Saudi Med J* 2007; 28(9): 1380-1384.