International Journal of History and Philosophy of Medicine 2015; 5: 10510

www.ijhpm.org
doi: 10.18550/ijhpm.011515.0510

FULL ARTICLE

Rhazes Doubting Galen: Ancient and Medieval Theories of Vision

Mohammadali M. Shoja, M.D.,[1,2,3]
Paul S. Agutter, Ph.D.,[4]
R. Shane Tubbs, M.Sc., P.A.-C., Ph.D.[5]

[1]*Tuberculosis and Lung Disease Research Center, Tabriz University of Medical Sciences, Tabriz, Iran*
[2]*Medical Philosophy and History Research Center, Tabriz University of Medical Sciences, Tabriz, Iran*
[3]*Rhazes, LLC., Birmingham, AL, USA*
[4]*Theoretical Medicine and Biology Group, Glossop, Derbyshire, UK*
[5]*Seattle Science Foundation, Seattle, WA, USA*

Rhazes' *Al-Shukuk 'Ala Jalinus* (Doubts on Galen), although an important and controversial contribution in his era and thereafter, has seldom been examined in the literature. In this article, we give a brief account of Rhazes' life and works, and provide an English translation of a passage from his treatise "Doubts on Galen," concerning the theory of vision. An overview of the evolution of vision theories in ancient and medieval times is given with respect to both intromission and extramission theories. Refuting the Stoic and Platonic conjectures, which were then followed by Galen, Rhazes adopted Pythagoras' and Aristotle's views of the intromission theory and for this, his own reasoning was sufficient to cast doubt on Galen. The bearing of this notion is even more palpable if one realizes what an avid follower of Galen Rhazes was in his diagnostics and treatments, praising him in almost any of his writings. The extramission theory ultimately gave way to an intromission thesis with emerging empiricism, but the history of evolution of theories of vision has witnessed a dramatic fluctuation of old scientific thoughts across centuries and among philosophers. This article also gives a brief historical snapshot on how vision theories lead to the development of geometrical and physical studies that further contributed to advances in ophthalmology.

Key words: Eye, History, Light, Medicine, Vision

Submitted 15 July 2015; Revision received 7 August 2015; Accepted for publication 12 August 2015; Published online 31 October 2015

Address correspondence to Mohammadali M. Shoja, MD, 1120 Beacon Parkway East, Apt 200, Birmingham, AL 35209, USA. Phone: +1-205-767-0575. Fax: 01-888-316-2919. E-mail: shoja.m@gmail.com

"I never wrote about things unless I first examined them myself."

Rhazes, 9th century AD[1]

INTRODUCTION

While no scientific activities were evident in Europe, the medieval Muslim and non-Muslim physicians from Persia and the Arab regions made major advances in medicine.[2] Apart from translations of Greek and non-Greek medical resources, they contributed to this progress by adding their own experiences and correcting the errors of their predecessors.[3–6] Many of their observations were original and novel, but "their comments were often attributed to Galen, perhaps an illustration of Renaissance bias".[7] Among Arab-speaking scholars, the most illustrious was Rhazes (Fig. 1), who was a native of Persia[8] and who was renowned in the Islamic world as an "Experimenter"[9], the "Arab Hippocrates"[10] or the "Arabian Galen."[11] Notwithstanding his loyalty to Galen, who was highly praised and deemed infallible by Muslims, Rhazes was the first to contest some of Galen's theories systematically in his work entitled *Doubts on Galen* (*Shokouk ala Jalinous*).[2,12] A substantial part of this small treatise dealt with theories on vision.

Of the 237 treatises and books written by Rhazes, only 37 are extant.[11] His *Kitab al-Mansuri* (*Liber Mansuri*), a 10 volume book, was translated into Latin by Gerard de Cremona and received great attention in Europe.[13,14] His largest medical work, composed of 22 volumes, was the *Kitab al-Hawi* (*Liber Continens*), the Latin translation of which became a canonical medical textbook in Europe from the 13th to the 16th centuries.[11,15,16] Rhazes was the first to use chemical preparations as therapeutics[9,17] and to comment on the utility of clinical trials (i.e., administering a therapeutic measure to a group of patients and comparing the outcomes with a group that did not receive the measure) for identification of effective and legitimate therapies.[18] He is credited with discovering or being the first to give accurate descriptions of the pupillary light reflex,[19] venous valves,[7] spina bifida,[20] smallpox and measles,[21] chickenpox,[22] and the surgical removal of cataracts.[23]

In this article, we give a brief account of Rhazes' life and works and provide an English translation of a passage from his "Doubts on Galen" concerning the theory of vision; Rhazes' "Doubts on Galen," although an important and controversial contribution in his era, has seldom been examined in literature. We follow our discussion by overviewing the evolution of vision theories in ancient and medieval times.

Figure 1: Iranian post stamp of 1992 commemorating Rhazes in the International Congress of the History of Medicine in Islam and Iran (with permission from Iranian Post Office).

An account of intromission and extramission theories is given. The present review attempts to cover three periods-before Galen, between Galen and Rhazes, and after Rhazes. It also gives a brief historical snapshot on how vision theories lead to the development of geometrical and physical studies that further contributed to advances in ophthalmology.

BACKGROUND

Abubakr Mohammad ibn Zakariya Razi (Figure 1), whose name is Latinized as Rhazes, was born in Ray, Persia on the 27th of August, 865.[2,13] His father, with whom he worked, was a goldsmith. As a young boy, he showed little interest in science, and played music. Later, however, he began to study literature, philosophy, alchemy and mathematics.[8,24] Once he was medically literate, it is said that he traveled to distant regions such as Africa, Spain and Jerusalem studying and practicing medicine.[8] He became a renowned physician and was appointed chief physician to the Royal Hospital in Ray.[25] He then accepted the directorship of a large hospital in Baghdad, the Muqtadari Hospital.[18,25] Rhazes taught many students, including foreigners, who often followed him home debating scientific topics.[8,24] During the last years of his fruitful life, Rhazes suffered from an eye disease (probably glaucoma or a cataract) and died blind in Ray on the 26th of October, 925 A.D.[8,13,18] After his death, more than 50,000 pages from his personal records and writings were retained.[24] One of his students gathered 900 case histories in a book called the *Kitab al-Tajarib*, based on Rhazes' original clinical observations.[13]

The significance of Rhazes' work, as Prioreschi has written, lies in the "clarity and logic" with which he expressed his ideas.[13] For his original contributions to medicine and philosophy, Rhazes is regarded as "the most original physician-philosopher

among Arab-speaking peoples."[18] Rhazes' writings have been translated into various languages including Syriac, Latin, Greek, French, Russian, Czech and English.[8,16] The largest of these works, the *Kitab al-Hawi*, was in fact an anthology of previous Greek, Indian and Arabian medical authorities[26] to which Rhazes added his own views and occasionally original, brief clinical cases to highlight the efficacy or inefficacy of the proposed therapy. Notably, Rhazes' treatise on smallpox and measles was printed probably more than any other ancient medical treatise in Europe in different languages between the 15th and 19th centuries.[8,27]

Al-Shukuk 'Ala Jalinus (Doubts on Galen)

Al-Shukuk 'Ala Jalinus (literally meaning Doubts on Galen) can be safely regarded as one of the least studied scientific treatises of the medieval times and one that has surprisingly received far less attention among scholars than its breadth legitimately deserves. Mehdi Mohaghegh, a renowned Iranian scholar, linguist and historian, highly praises this book and gives an interesting account of its history.[12] Apparently, only three copies of this book are extant, of which Mohaghegh believes that all might have descended from a single copy.[12] The beginning passage of Al-Shukuk presents a unique admiration of Galen:

> *[In writing this book], I am faced with opposing one who is in my eyes the greatest of men, and who has benefitted me more than any other person. It was through him that I was guided; I trod in his footsteps and drank of his knowledge as if from an ocean! I am faced with this, knowing that the slave must not oppose his master, nor the student his master, nor he who receives grace the one who granted it."*[12, p109]

Despite such an admiration of his master, Galen, Rhazes argues that real philosophers should not simply accept the knowledge conveyed to them, but should question everything before them. Al-Shukuk 'Ala Jalinus, in its unprecedented nature, reflects the mental liberty of its author, attempting to balance his scientific criticisms with a loyal but no less professional an attitude. What follows is an excerpt from Al-Shukuk pertaining the subject of forthcoming discussion.

An Excerpt from a Translation from Rhazes' *Doubts about Galen*

> *"I have to mention some facts relating to the theories that Galen presented about vision, in order to make them clear and vivid for everyone. He wrote in his book "Animal Dissection (Anatomy)" that a "radiation" arises from the soul and travels to the eye. If we assume that there is a substance flowing inside the two eye nerves (optic nerves), how did he know this substance shines intrinsically? How can a substance shine without being hot?*
>
> *To explain this, Galen acknowledged some of Plato's words and concluded that the object shines but does not burn. However, even this conclusion does not solve the problem, because if the light itself does not scatter or flow and if it accumulates in an area, it will burn because it possesses the characteristics of its source (e.g., heat). Thus, no one can find a light unless it is moving or emanating from a burning object. But the glow-worm or other similar things do not shine intrinsically; their light is created via the lights of other objects that shine on them. And even if the glow-worm shone by nature, this still would not support Galen's opinion; he could prove no more than that the production of light in the eye is similar to the glow-worm's.*
>
> *Light, according to Galen's theory, could not reach anywhere because this weak beam of light cannot affect the air (atmosphere) in order to reach the stars and the sky without the effect of time, but he claimed that "the air brightened by the sun has senses."*
>
> *So the inadequacy of this idea is clear and Hunain has freed us from proving this fact and has revealed his [Galen's] errors and contradictions in his book, in which he wanted to provide excuses for Galen: Hunain did not believe that Galen held such opinions, and he had spoken those words only to concur with the people of his age.*
>
> *I also say that he [Galen] did not believe what he said and those words were spoken to agree with the people of his age. But this theory on vision is not true, because he mostly emphasized the concept that a shining substance constantly flows in the optic nerves in the form of a spirit, and that is why it can reach to far objects too.*
>
> *So the excuses that Hunain offered for Galen's idea cleared up the basis of his scientific religion and demolition of his theories, and this was necessary for Hunain to prove that the bright air (atmosphere) does not have any senses."*

This account of Rhazes is compelling enough to persuade a curious reader for a more subtle study of evolution of the theories of vision. In accord with the historical timeline of the debate set forth by Rhazes, we proceed with our undertaking to examine such concepts prevalent in the eras before Galen, between Galen and Rhazes and after Rhazes. The following background enables us to interpret the comments that Rhazes made about Galen's theory of vision and to understand his motivation.

Theories of Vision Before Galen

Lenses of quartz or water-filled spheres of glass were made throughout the ancient Middle East and in Egypt, and subsequently in the Greek and Roman empires, but their value as visual aids is uncertain. However, they testify to a fascination with the nature of light and vision that probably dates back to pre-history. Philosophical schools in India developed rival theories of light during the 6th–5th centuries BCE, one of which held that light is the primary element from which the elements of gross matter emerge, while the other (the atomic theory) supposed that light is a stream of high-velocity atoms of the element fire.[28] It is tempting to speculate that Empedocles and other philosophers in Pre-Socratic Greece, and the Greek and Roman atomists, were aware of these ideas and were influenced by them (see below).

Pythagoras is said to have believed that light is emitted or reflected from objects in the external world and enters the eye, causing the sensation of sight (the intromission thesis).[29] However, many Pythagoreans (notably Alcmaeon of Croton, early 5th century BCE) held that light is generated by the body and is emitted from the eye (the extramission thesis), and this position seems to have been adopted by most writers in Ancient Greece. For example, Theophrastus wrote: " . . . the eye obviously has fire within it, for when one is struck, this fire flashes out." Empedocles may have held both views - he certainly believed in the "fire within"—though he is the first commentator known to have claimed that light travels at a finite speed.[30]

Plato, in *Theaetetus*[31] and particularly in *Timaeus*,[32] developed the extramission thesis in detail. According to this view, the fire that arises from the soul emanates from the eye and 'coalesces' with sunlight to form a single homogeneous body in direct line with the eye. When this strikes an object, the resulting movement is transmitted back to the soul, creating the sensation of seeing.[33] Implicit in this account is the notion of an all-pervading medium that transmits the movement emanating from the object, and the light itself, which was reborn as the 'luminiferous aether' of 19th century physics.

This notion becomes explicit in Aristotle's *De Sensu*.[33] Aristotle rejected the extramission thesis and held that light proceeds from objects to the eye, but it must communicate via an all-permeating 'transparency', which is not itself visible but is the means by which we see. Aristotle's account implies that light does not 'travel' but is conveyed instantaneously; it is a state of the 'transparency', not an entity in itself.

The Greek and Roman anatomists, also proposed the intromission thesis, and the concept of a communicating medium; Aristotle's account is distinct from theirs because he rejected atomism and understood the 'transparency' in a different way. According to later commentators, Leucippus, Democritus and Epicurus held that a flow of corpuscles similar in shape to the perceived object was continuously emitted, compressing and stamping their forms on the air between the object and the eye. This account treats vision as analogous to the sense of touch.[34–37]

According to the Stoics, the optical pneuma was an all-pervasive entity compounded of air and fire.[38,39] It flowed from the soul to the eye, compressing the air in contact with the eye. In the resulting state of tension, the air made contact with the perceived object under the influence of sunlight. Thus, the air itself sees as and when we see. This account owed something to Plato, and like both Plato and Aristotle, the Stoics were particularly interested in the communicating medium or 'transparency'.

Galen was strongly influenced by the Stoic account, just as he was influenced by Stoic logic,[40] but he elaborated and modified it. In *De Placitis Hippocratis Et Platonis* (On the Doctrines of Plato and Hippocrates), he recognized the two earlier theses (intromission and extramission) and, like the Stoics, he clearly opted for extramission.[30,41] However, he was more specific about the source and transmission of the optic pneuma, which he said arises in the brain and passes out through the optic nerves, which are hollow. The local effects on the surrounding air are transmitted outwards to the perceived object. This account of vision was accompanied by a detailed anatomical description of the eye—eyelids, cornea, iris, uvea, aqueous and vitreous humors, retina—but in the light of modern-day beliefs, Galen showed some confusion about the functions of these various structures. In particular, he regarded the lens as the chief organ of vision.

Islamic Work on Light and the Eye Prior to Rhazes

In the ninth century CE, Islamic scholars began to develop ideas derived from this Greek tradition. Hunain ibn Ishaq (809-873 CE) was distinguished both as a translator of Greek texts into Arabic and as a physician, and he was a major influence on the acceptance of Galen's work in the Islamic world. He studied the anatomy of the eye and particularly the retina, which he believed was the supplier of nutrients to the vitreous humor. Echoing Galen, he considered the lens as the essential organ of vision, and believed that the retina served to conduct the optic pneuma through the optic nerve.[42,43] Nevertheless, his attitude to Galen seems to have been ambivalent. On the one hand, he regarded the great Greek physician as 'infallible', the teacher whom everyone should follow; on the other, he seems to have been uncomfortable about some aspects of Galen's theory of vision, notably the extramission thesis, suggesting that Galen had not really believed it but was echoing the consensus view of his times.

The polymath Al-Kindi, an almost exact contemporary of Hunain, delivered similar teachings. He asserted that all objects emit rays isometrically, and these rays fill the entire world; nevertheless, following Galen, he continued to maintain the extramission thesis. His work was an important influence on later Islamic scholars and subsequently on European scholars of the 12th and 13th centuries CE.[30,44,45] It testifies to the strong and continuing influence of Galen's thought in the Islamic world during the ninth century.

Rhazes was born some 64 years after Al-Kindi; by that time, thanks to the great influence of his predecessors, Galen's account of vision was well established in the Islamic world.

After Rhazes: Further Developments in Optics and the Theory of Vision

A century after Rhazes, Galen's ideas were challenged further by the seminal contributions of Alhazen and Avicenna, both of whom agreed with Rhazes in dismissing extramission, and combined the study of vision with advances in geometrical optics.

Geometrical optics had its roots in Alexandria during its period of academic pre-eminence. Euclid used the same axiom-based reasoning that characterized his geometry to establish a basic account of optics, including the assumption

that light rays form straight lines between eye and object. From his axioms, Euclid was able to explain phenomena such as perspective and parallax.[30] Hero of Alexandria extended Euclid's geometrical optics to the study of reflection and images in plane mirrors; he too accepted the extramission thesis. Claudius Ptolemy also assumed extramission, but unlike Hero he regarded visual rays as continuous cones rather than separate lines. Using this model he extended geometrical optics to the phenomenon of refraction, performing experiments and recording the relationship between the angles of incidence and refraction.[46,47] Thanks to the translators such as Hunain, these works too found their way into the Islamic world. Alhazen's *Kitab al-Manazir* (Book of Optics), written during the second decade of the 11th century CE, extended the findings of Hero and Ptolemy and succeeded in combining geometrical optics with the anatomy and physiology of vision. Exploiting the 10th century Persian mathematician Ibn Sahl's development on Ptolemy's studies of refraction,[48] he generalized the relationship between incident and refracted rays in a form that presaged Snell's law. A pioneer of experimental method, he confirmed the physical validity of Euclid's axiom that light rays travel in straight lines, and he seems to have been the first writer to state that perception takes place in the brain not within the eye itself.[49,50] His acceptance of intromission was a consequence of his reliance on observation and experiment, for example on the observation that strong light injures the eye.

Avicenna's acceptance of the intromission theory may have been influenced not so much by his observations as by his acceptance of Aristotle's teachings. Avicenna also reasoned that if light rays are streams of particles emitted by a luminous source, the speed of light must be finite, recalling the belief of Empedocles (see above).[51] His critique of Galen was systematic, and he made new contributions to the anatomy of the eye, though unlike Alhazen he retained the Galenic belief that the optic nerves were hollow and that the lens was central to the sense of sight. The influence of Aristotle on Avicenna's voluminous works is well attested, but some scholars may have underestimated the influence of Galen. In particular, there is reasonable evidence that his contributions to logic were based on Galen's version of Stoic logic.[40]

CONCLUSION

Rhazes was a man of astute judgement and clarity, and such is nowhere more obvious than in his "Doubts on Galen." Refuting the Stoic and Platonic conjectures, which was then followed by Galen, he adopted Pythagoras' and Aristotle's and for this, his own reasoning was sufficient to cast doubt on his master, Galen. The bearing of this notion is even more palpable if one realizes what an avid follower of Galen Rhazes was in his diagnostics and treatments, praising him in almost any of his tracts. The extramission theory ultimately gave way to intromission thesis with emerging experimentalism, but the history of evolution of theories of vision has witnessed a dramatic fluctuation of old scientific thoughts across centuries and among philosophers.

CONFLICT OF INTEREST STATEMENT

The author has no conflict of interest to disclose.

SOURCE OF SUPPORT

This study was supported by a grant from Tuberculosis and Lung Disease Research Center, Tabriz University of Medical Sciences, Tabriz, Iran.

ACKNOWLEDGMENTS

The authors are grateful to Dr. Pamela Youssef, from St. George's University, Grenada for assisting them in preparing this manuscript.

REFERENCES

1. Shoja MM, Tubbs RS. The history of anatomy in Persia. **J Anat** 2007; 210: 359–378.
2. Tubbs RS, Shoja MM, Loukas M, et al. Abubakr Muhammad Ibn Zakaria Razi, Rhazes (865–925 AD). **Childs Nerv Syst** 2007; 23: 1225–1226.
3. Wakim KG. Arabic Medicine in Literature. **Bull Med Libr Assoc** 1944; 32: 96–104.
4. Newman PB. *Daily life in the Middle Ages*. North Carolina/London, McFarland, 2001: p 245.
5. Saladin KS. *Human Anatomy*. Boston, McGraw-Hill, 2007: p 9.
6. Elsergany R. *Historical Development of Islamic Medicine*. Available from: URL: http://english.islamstory.com/article_print.php?id=1655. Accessed March 19, 2009.
7. Agutter PS, Wheatley DN. *Thinking about Life: The History and Philosophy of Biology and Other Sciences*. London, Springer, 2008: pp 75–78.
8. Greenhill WA (translator). *A Treatise on the Small-pox and Measles, Abū Becr Mohammed ibn Zacarī yā ar-Rāzī (Commonly Called Rhazes), Translated from the Original Arabic*. London, Sydenham Society, 1847.
9. Morewood S. *A Philosophical and Statistical History of the Inventions and Customs of Ancient and Modern Nations*. Dublin, William Curry, Jun and Company, 1838: p 24.
10. Keir L, Wise BA, Krebs C. *Medical Assisting: Essentials of Administrative and Clinical Competencies*. New York, Delmar Learning, 2003: p 6.
11. Buck AH. *The Growth of Medicine from the Earliest Times to about 1800*. New Haven, Yale University Press, 1917.
12. Mohaghegh M. *Kitab al-Shukuk ala Jalinus of Muhammad ibn Zakariyya al-Razi*. In: Hallaq WB, Little DP, editors. *Islamic Studies Presented to Charles J. Adams*. Leiden/New York, EJ Brill, 1991: pp 107–116.
13. Prioreschi P. *A History of Medicine, Vol. IV: Byzantine and Islamic Medicine*. Omaha, Horatius Press, 2001.
14. Browne AG. *Arabian Medicine*. Cambridge, Cambridge University Press, 1962.
15. Goonatilake S. *Toward a Global Science: Mining Civilizational Knowledge*. Bloomington, Indiana University Press, 1998: p 89.
16. Vauchez A, Dobson B, Lapidge M., editors. *Encyclopedia of the Middle Ages, Vol. II: K–Z* (translated by Walford A). Chigaco/London, Fitzroy Dearborn Publishers, 2000: pp 123–124.
17. Robinson V. *The Story of Medicine*. New York, The New Home Library, 1943: pp 134–193.
18. Iskandar AZ. *Al-Razi*. In: Young MJ, Latham DJ, Serjeant RB, editors. *The Cambridge History of Arabic Literature*. Cambridge, Cambridge University Press, 1990: pp 370–377.

19. Lin D. The development of medicine in medieval Islamic: a foundation for western ophthalmology [Abstract]. *Proceedings of the 14h Annual History of Medicine Days*, Calgary, Canada, 2005: pp 263–273.
20. Miller J. *The Principles of Surgery, fourth American edition*. Philadelphia, Blanchard and Lea, 1856: p 677.
21. Singer C. *A Short History of Science to the Nineteenth Century*. Oxford, Chlarendon Press, 1941: pp 133–134.
22. Ostrove JM. *Molecular biology of Varicella-Zoster virus*. In: Maramorosch K, Murphy FA, Shatkin AJ, editors. *Advances in Virus Research*, Vol 38. London, Academic Press, 1990: pp 45–98.
23. Husain M. *Islam's Contribution to Science*. New Delhi, Anmol Publications PVT. LTD, 2004: p 191.
24. Malardi MR, Moghaddam RA. *Tarikh-e Mokhtasar-e Elm-e Shimi* (A brief history of chemistry) [Persian]. Tehran, Entesharat-e Madraseh, 1990: pp 51–55.
25. Ede A, Cormack LB. *A History of Science in Society: From Philosophy to Utility*. New York, Broadview Press, 2004: pp 67–68.
26. Bryson J. The Hawi by Razi (ca. 865–965 CE), Book One on nerve, brain, and mental disorders: Arabic sources for the history of neuroscience [Abstract]. *Fifth Annual Meeting of the International Society for the History of the Neurosciences* (ISHN). Rhode Island, USA, 2000.
27. Kaadan AN. *Al-Razi book on Smallpox and Measles*. Available from: URL: http://www.ishim.net/articles.htm. Accessed March 19, 2009.
28 Anonymous. *Light*. *Wikipedia*. Available from: URL: https://en.wikipedia.org/wiki/Light. Accessed July 20, 2015.
29. Kingsley P. *Ancient Philosophy, Mystery, and Magic: Empedocles and the Pythagorean Tradition*. Oxford, Oxford University Press, 1997.
30. Lindberg DC. *Theories of Vision from Al-Kindi to Kepler*. London, University of Chicago Press, 1976.
31. McDowell J. *Plato, Theaetetus*. Oxford, Clarendon Press, 1973.
32. Zeyl DJ. *Plato, Timaeus*. Indianapolis, Hackett Publishing Company, 2000.
33. Ross GRT. *Aristotle, De Sensu and De Memoria; Text and Translation, with Introduction and Commentary*. Cambridge, Cambridge University Press, 1906.
34. Harry B. Epicurus: some problems in physics and perception. **Greece & Rome (Second Series)** 1970; 17: 58–63.
35. Avotins I. Alexander of Aphrodisias on vision in the atomists. **The Classical Quarterly (New Series)** 1980; 30: 429–454.
36. Bourni H (ed.) *Leucippus, Democritus: the Atomic Theory*. Athens, Eksantas, 1985.
37. Latham RE. *Lucretius, On the Nature of Things; Translation and Commentary*. London, Penguin Books, 1994.
38. Løkke H. The Stoics on sense perception. **Stud Hist Philos Mind** 2008; 6: 35–46.
39. Todd RB. *Alexander of Aphrodisias on Stoic Physics: A Study of the De Mixtione with Preliminary Essays, Text, Translation and Commentary*. Leiden and Boston, Brill, 1976.
40. Shoja MM, Rashidi MR, Tubbs RS, Etemadi J, Abbasnejad F, Agutter PS. Legacy of Avicenna and evidence-based medicine. **Int J Cardiol** 201; 150: 243–246.
41. Siegel RE. *Galen on Sense Perception, His Doctrines, Observations and Experiments on Vision, Hearing, Smell, Taste, Touch and Pain, and Their Historical Sources*. Basel, Karger, 1970.
42. Eastwood BS. The elements of vision: The micro-cosmology of Galenic visual theory according to Hunayn ibn Ishaq. **Trans Am Philos Soc** 1982; 72: 1–37.
43. Tschanz DW. Hunayn bin Ishaq: the great translator. **J Internat Soc Hist Islamic Med** 2003; 1: 39–40.
44. Lindberg DC. Alkindi's critique of Euclid's theory of vision. **Isis** 1971; 62: 469–489.
45. Corbin H. *History of Islamic Philosophy*. London, Kegan Paul, 1993.
46. Smith MA. Ptolemy's search for a law of refraction: a case-study in the classical methodology of 'saving the appearances' and its limitations. **Arch Hist Exact Sci** 1982; 26: 221–240.
47. Smith MA. *Ptolemy's Theory of Visual Perception: An English translation of the Optics with Introduction and Commentary*. Philadelphia, The American Philosophical Society, 1996.
48. Rashed T. A pioneer in anaclastics: Ibn Sahl on burning mirrors and lenses. **Isis** 1990; 81: 464–491
49. Gorini R. Al-Haytham the man of experience. First steps in the science of vision. **J Internat Soc Hist Islamic Med** 2003; 2: 53–55.
50. Lindberg DC. Alhazen's theory of vision and its reception in the west. **Isis** 1967; 58: 321–341.
51. Sarton G. *Introduction to the History of Science, vol. 1. Carnegie Institution of Washington Publication no. 376*. Baltimore, Williams and Wilkins, 1927: p 710.