

Arab and Muslim Physicians and Scholars

Ibn Al-Haytham: Father of Modern Optics

Abdelghani Tbakhi, MD* Samir S. Amr, MD†

From the *Department of Pathology and Laboratory Medicine, Hôtel-Dieu Grace Hospital, University of Western Ontario, Windsor, Ontario, Canada and †Pathology Services Division, Dhahran Health Center, Saudi Aramco Medical Services Organization, Dhahran, Saudi Arabia

Correspondence and reprint requests: Abdelghani Tbakhi, MD · Department of Pathology and Laboratory Medicine · Hôtel-Dieu Grace Hospital · 1030 Ouellette Avenue · Windsor · ON-N9A 1E1 · Canada · T: +1-519-973-4411 ext. 3579 · Abdelghani.Tbakhi@hdgh.org

Ann Saudi Med 2007; 27(6): 464-467

The Arab Muslim scholar Abu Ali al Hasan ibn al-Haytham, known in the west as Alhacen or Alhazen was born in 965 in the city of Basra in Southern Iraq, hence he is also known as Al-Basri.¹ He was educated in Basra and Baghdad, and died in Cairo, Egypt in the year 1040.²

Many details of the life of Ibn al-Haytham have been lost over time. The stories related to his life are often contradictory, depending on the historian relating them. Most of the data on the biography of Ibn al-Haytham came from the writings of the thirteenth century Muslim historian Ibn al-Qifti (1172-1248). Initially, Ibn al-Haytham was trained for a civil service job and was appointed as a judge for Basra. Due to the presence of various religious movements with diverse

and conflicting views at that time, he became disillusioned with religious studies and decided to dedicate his time and effort for the study of science. His knowledge in mathematics and physics became legendary and he was well known in Iraq, Syria and Egypt. He was invited by Al-Hakim bi-Amr Allah, the Fatimid Caliph of Egypt to help in regulating the flow of the Nile during the floods. Al-Hakim, a Shiite of the Ismaili sect, was known to be an eccentric ruler who issued several arbitrary edicts and laws, prohibiting the consumption of certain foods, preventing women from leaving their homes, killing all the dogs, and forcing people to work during the night and rest by day. He was quite brutal and had killed his tutors and ministers on a whim. When Ibn al-Haytham realized on his field work along the Nile that his scheme to regulate the Nile's water flow by building a dam south of Aswan was impractical, he feared for his life. To avoid the potential of the deadly wrath and anger of his temperamental and mentally unstable patron, he faked insanity. He was stripped of his possessions and books, and was kept under house arrest for about 10 years until the time of Al-Hakim's death in 1021, when he was assassinated in mysterious circumstances.

Following his release from house arrest, he lived in a domed building (Qubbah) close to the Azhar Mosque in Cairo, teaching mathematics and physics, writing science texts, and making money by copying texts.³

During his period of incarceration, he wrote his influential "*Kitab Al Manazer*" or the Book of Optic, in addition to several significant books and chapters on physics, mathematics, engineering, astronomy, medicine, psychology, anatomy, visual perception and ophthalmology. He wrote his introduction of the scientific methods.⁴

Ibn al-Haytham was a prolific author. He wrote more than 200 works on a wide range of subjects, of which at least 96 of his scientific works are known, and approximately 50 of them have survived to date. Nearly half of his surviving works are on mathematics, 23 of them are on astronomy, and 14 of them are on optics, with a few



Original image, Diagram of the Eyes and Related Nerves, from *Kitab al-Manazer* (Book of Optics) by Ibn al-Haytham, Istanbul, Eleventh Century.

Arab and Muslim Physicians and Scholars

on other areas of science.⁵ Not all of his surviving works have yet been studied, but some of his most important ones are described below. These include:

- *Kitab Al Manazer* (Book of Optics)
- *Risalah fi al-Dawa'* (Treatise on Light)
- *Mizan al-Hikmah* (Balance of Wisdom)
- *Maqalah fi al-Qarastun* (Treatise on Centers of Gravity)
- *Risalah fi al-Makan* (Treatise on the Place)
- *Al-Shukuk al Batlamyus* (Doubts concerning Ptolemy)
- On the Configuration of the World
- The model of the Motion of the Seven Planets

Scientific Method

Elements of modern scientific methods are found in early Islamic philosophy, in particular, using experiments to distinguish between competing scientific theories, and a general belief that knowledge reveals nature honestly. Islamic philosophy developed in the Middle Ages and was pivotal in scientific debates. The key figures for these debates were scientists and philosophers. Ibn al-Haytham was quite influential in this regard. An important observation in his book "*Kitab Al Manazer*" led him to propose that the eyes receive light reflected from objects, rather than emanating light themselves, contradicting contemporary beliefs, including those of Ptolemy and Euclid. The way in which Ibn al-Haytham combined observations and rational arguments had a great influence on Roger Bacon and Johannes Kepler in particular. Bacon (1214-1296), a Franciscan friar working under the tuition of Grosseteste, was inspired by the writings of Ibn al-Haytham, who preserved and built upon Aristotle's portrait of introduction.

Ibn al-Haytham developed rigorous experimental methods of controlled scientific testing in order to verify theoretical hypotheses and substantiate inductive conjectures. Ibn al-Haytham's scientific method was very similar to the modern scientific method and consisted of a repeating cycle of observation, hypothesis, experimentation, and the need for independent verification.^{5,6}

Gorini wrote the following on Ibn al-Haytham's introduction of the scientific method: "According to the majority of the historians, al-Haytham was the pioneer of the modern scientific method. With his book, he changed the meaning of the term 'optics', and established experiments as the norm of proof in the field. His investigations were based not on abstract theories, but on experimental evidences. His experiments were systematic and repeatable."⁷

Physics and Optics

Ibn al-Haytham's theory of light and vision is neither identical with nor directly descendant from any one of the theories known to have previously existed in the antiquity or in Islam. The first real appreciation of the action of a lens, in particular the ability of a convex form to produce a magnified image of an object, appears to be credited to Ibn al-Haytham.^{8,9} It was not until the late 13th century that spectacles were invented, representing the first practical use of magnification in society.^{9,10} Ibn al-Haytham made a thorough examination of the passage of light through various media and discovered the laws of refraction. He also carried out the first experiments on the dispersion of light into its constituent colors. Ibn Al-Haytham's seven volume treatise on optics, *Kitab al-Manazer* (Book of Optics), which he wrote while incarcerated between 1011 to 1021, which has been ranked alongside Isaac Newton's *Philosophiæ Naturalis Principia Mathematica* as one of the most influential books ever written in physics, drastically transformed the understanding of light and vision.^{8,9}

He dealt at length with the theory of various physical phenomena like shadows, eclipses, the rainbow, and speculated on the physical nature of light. He also attempted to explain binocular vision, and gave a correct explanation of the apparent increase in size of the sun and the moon when near the horizon. He is known for the earliest use of the camera obscura and pinhole camera.¹¹ As stated above, he contradicted Ptolemy's and Euclid's theory of vision that objects are seen by rays of light emanating from the eyes; according to him the rays originate in the object of vision and not in the eye.

Structure of the eye, by Ibn al-Haytham, from the Book of Optics.



Arab and Muslim Physicians and Scholars

Through these extensive researches on optics, he has been considered as the father of modern optics.

In addition to the Book of Optics, Ibn al-Haytham wrote a supplement entitled "*Risala fi l-Daw*" (Treatise on Light). This supplement contained further investigations on the properties of luminance and its radiant dispersion through various transparent and translucent media. In his treatise, *Mizan al-Hikmah* (Balance of Wisdom), Ibn al-Haytham discussed the density of the atmosphere and related it to altitude. He also studied atmospheric refraction. His optical writings influenced many Western intellectuals such as Roger Bacon, John Pecham, Witelo, and Johannes Kepler.^{11,12,13}

Astronomy

While not counted among the greatest Arab astronomers, his works show that he had mastered the techniques of Ptolemaic astronomy. Some of these works also reveal his ability to solve the problems that received attention from Arab astronomers, such as determining the Qiblah (direction of prayer). His critique of Ptolemaic planetary models, as presented in the *Almagest* and *Planetary Hypotheses*, appears to have inspired research that led to their replacement by non-Ptolemaic arrangements in the 13th century Maragha and 14th century Damascus. This astronomical work was written between 1025-1028 "*Al-Shukūk 'alā Batlamyūs*", and then translated as *Doubts concerning Ptolemy* or *Aporias against Ptolemy*.¹⁴ He considered that some of the mathematical devices Ptolemy introduced into astronomy, especially the equant, failed to satisfy the physical requirement of uniform circular motion.¹⁴

Astronomers of the European Renaissance were influenced by his work "*On the Configuration of the World*", where he continued to accept the physical reality of the geocentric model of the universe, presenting a detailed description of the physical structure of the celestial spheres: "The earth as a whole is a round sphere whose center is the center of the world. It is stationary in its [the world's] middle, fixed in it and not moving in any direction nor moving with any of the varieties of motion, but always at rest".¹⁵

Ibn al-Haytham's *The Model of the Motions of Each of the Seven Planets*, written in 1038, was an important book on astronomy. The surviving manuscript of this work has only recently been discovered, with much of it still missing, hence the work has not yet been published in modern times. His reform excluded cosmology, as he developed a systematic study of celestial kinematics that was completely geometric. This in turn led to innovative developments in infinitesimal geometry.¹⁶

Mathematics

In mathematics, Ibn al-Haytham built on the mathematical works of Euclid and Thabit ibn Qurra, and went on to systemize infinitesimal calculus, conic sections, number theory, and analytic geometry after linking algebra to geometry. His contribution to mathematics was extensive. He developed analytical geometry by establishing linkage between algebra and geometry. He studied the mechanics of motion of a body and was the first to maintain that a body moves perpetually unless an external force stops it or changes its direction of motion. This is strikingly similar to the first law of motion described centuries later by Isaac Newton.

His work on catoptrics in Book V of the *Book of Optics* contains the important problem known as *Alhazen's problem*. It comprises drawing lines from two points in the plane of a circle meeting at a point on the circumference and making equal angles with the normal at that point. This leads to an equation of the fourth degree. This eventually led Ibn al-Haytham to derive the earliest formula for the sum of fourth powers; and by using an early proof by mathematical induction, he developed a method for determining the general formula for the sum of any integral powers. This was fundamental to the development of infinitesimal and integral calculus.¹⁷

In geometry, Ibn al-Haytham developed analytical geometry by establishing the linkage between algebra and geometry. Ibn al-Haytham also discovered a formula for adding the first 100 natural numbers.

His contributions to number theory include his work on perfect numbers. In his *Analysis and Synthesis*, Ibn al-Haytham was the first to realize that every even perfect number is of the form $2^{n-1}(2^n-1)$ where 2^n-1 is prime, but he was not able to prove this result successfully. It was proved later on in the 18th Century by Euler.¹⁷

Medicine and Psychology

Ibn al-Haytham was the first to describe accurately the various parts of the eye and give a scientific explanation of the process of vision. In medicine and ophthalmology, Ibn al-Haytham made important advances in eye surgery, and he studied and correctly explained the process of sight and visual perception for the first time.^{18,19} He described in detail the various parts of the eye and introduced the idea that objects are seen by rays of light emanating from the objects and not the eyes, as was popularly believed. "Sight perceives the light and color existing on the surface of the contemplated object. Vision perceives necessarily all the objects through sup-

Arab and Muslim Physicians and Scholars

posed straight lines that spread themselves between the object and the central point of the sight".¹⁰

Ibn al-Haytham is considered by some to be the founder of psychophysics and experimental psychology, for his pioneering work on the psychology of visual perception.²⁰

Philosophy

In philosophy, Ibn al-Haytham is considered a pioneer of phenomenology. He articulated a relationship between the physical and observable world and that of intuition, psychology and mental functions. His theories regarding knowledge and perception, linking the domains of science and religion, led to a philosophy of existence based on the direct observation

of reality from the observer's point of view. Much of his thought on phenomenology was not further developed until the 20th century.²¹ In fact, he is well known to have articulated a comprehensive theory of knowledge.²²

Ibn al-Haytham is said to have been a supporter of the Asha'ri school of Islamic theology, and opposed to the teachings of the Mu'tazili school, though he may have been a Mu'tazili supporter himself at some point in his life.

Finally, Ibn al-Haytham left his impact on many scientific disciplines through his genius insight, and novel and original observations. Without doubt, he is considered as the pioneering father of modern optics.

REFERENCES

1. Smith AM: Alhacen's theory of visual perception: a critical edition, with English translation and commentary, of the first three books of Alhacen's *De aspectibus*, the medieval Latin version of Ibn al-Haytham's *Kitab al-Manazir*. Vol. 1. Philadelphia: American Philosophical Society.
2. Hamarneh S; Review of Hakim Mohammad Said, Ibn al-Haytham. *Isis* 1972; 63(1): 118-119.
3. Sabra AI: Ibn Al-Haytham, Abu Ali Al-Hasan Ibn Al-Hasan. In: *Directory of Scientific Biography*, Vol. VI. Editor-in-Chief: Charles Coulston Gillispie. Publisher: Charles Scribner's Sons, New York, 1974. Pp. 189-210.
4. Bettany L: "Ibn al-Haytham: an answer to multicultural science teaching?" *Physics Education* 1995; 30: 247-252.
5. Steffens B: *Ibn al-Haytham: First Scientist*, Morgan Reynolds Publishing, Greensboro, NC, 2006.
6. El-Bizri N: "Ibn al-Haytham or Alhazen". In: *Medieval Islamic Civilization: An Encyclopedia*. Vol. II. Editor: Josef W Meri. Publisher: Routledge, New York, London, 2006. Pp 343-345.
7. Gorini R: "Al-Haytham the man of experience: First Steps in the Science of Vision" *J Inter Soc for the History of Islamic Medicine (JISHIM)*, 2003; 2(4): 53-55.
8. Mudry A; The history of the microscope for use in ear surgery. *Am J Otol* 2000; 21(6): 877-886.
9. Kriss TC, Kriss VM: History of the operating microscope: From magnifying glass to microneurosurgery. *Neurosurgery* 1998; 42(4): 899-907.
10. Kalderon AE: The evolution of microscope design from its invention to the present days. *Am J Surg Pathol* 1983; 7(1): 95-102.
11. Wade NJ, Finger S: The eye as an optical instrument: From camera obscura to Helmholtz's perspective. *Perception* 2001; 30 (10): 1157-1177.
12. Masoud MT, Masoud F: How Islam changed medicine: Ibn al-Haytham and optics. *BMJ* 2006; 332: 120.
13. Lehn WH, van der Werf S: Atmospheric refraction: a history. *Appl Opt* 2005; 44(27): 5624-5636.
14. Howard IP: Alhazen's neglected discoveries of visual phenomena. *Perception* 1996; 25(10): 1203-1217.
15. Crombie AC: Expectation, modelling and assessment in the history of optics: Part I. Alhazen and the medieval tradition. *Stud Hist Philos Sci* 1990; 21(4): 605-632.
16. Ross HE, Ross GM: Did Ptolemy understand the moon illusion? *Perception* 1976; 5(4): 377-385.
17. Qadir A: *Relativity: An Introduction to the Special Theory*. World Scientific Publishing Co. Singapore 1089.
18. Rashed R: The celestial kinematics of Ibn al-Haytham. *Arabic Science and Philosophy* 2007; 17(1): 7-55.
19. Katz VJ: Ideas of calculus in Islam and India. *Mathematics Magazine* 1995; 68(3): 163-174.
20. Saad A, Azaizeh H, Said O: Tradition and perspectives of Arab herbal medicine. A review. *Evidence-based Complement Alternat Med* 2005; 2(4): 475-479.
21. Arrington GE Jr. Three Arabs: their impact on ophthalmology: Hunain Ibn-Ishaq, Rhazes, Alhazen. *Int Rec Med Gen Pract Clin*. 1959; 172(6):337-338.
22. Khaleefa O: Who is the founder of psychophysics and experimental psychology? *Am J Islamic Social Sciences (AJISS)*1999; 16(2):