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Research Article

The Role of the Banū Mūsā Family in the Development of Science

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ABSTRACT

The Banū Mūsā family, consisting of three scholarly brothers—Muḥammad, Aḥmad, and Ḥasan ibn Mūsā ibn Shākir—were among the most prominent scientific figures of the third century AH during the Abbasid era. They conducted scientific and research activities in Baghdad, particularly at the Bayt al-Ḥikma (House of Wisdom). This study aims to examine the role of the Banū Mūsā family in the development of the sciences, explain their contribution to linking theoretical knowledge with practical applications, and investigate the impact of their scientific and engineering activities on Islamic civilization. The research employs a descriptive-analytical methodology based on library research. Historical sources and scholarly works related to the Banū Mūsā family were used to examine and analyze their activities, writings, inventions, and scientific methods. The findings indicate that through their work in mathematics, astronomy, geometry, and mechanics, the Banū Mūsā brothers played a significant role in transforming theoretical sciences into applied knowledge. By studying Greek and Syriac works, critically reviewing and revising theoretical principles, and subsequently designing and testing practical devices, they developed an integrated approach combining theory and experimentation in scientific research. Their most important achievement was the *Kitāb al-Ḥiyal* (The Book of Ingenious Devices), which contains descriptions of mechanical designs, devices, and automatic control systems. Furthermore, their support for the translation movement and their efforts in educating scholars and translators contributed significantly to the transmission and development of knowledge from earlier civilizations within the Islamic world. Accordingly, the Banū Mūsā family may be regarded as pioneers in connecting science, engineering, and technology in Islamic civilization.

1. Introduction

The history of science in Islamic civilization represents one of the most brilliant periods in the history of human knowledge. During this period, knowledge inherited from earlier civilizations was combined with the ideas and creativity of Muslim scholars, creating new foundations for the advancement of various sciences. Among the scholars of this era, the Banū Mūsā family holds a special position, as Muḥammad, Aḥmad, and Ḥasan ibn Mūsā ibn Shākir were among the earliest scholars to pursue scientific activities through family collaboration and a relatively organized approach. During the third century AH, within the intellectual environment of Baghdad, particularly at the Bayt al-Ḥikma (House of Wisdom), they worked in fields such as mathematics, astronomy, geometry, and mechanics and sought to transform theoretical knowledge into practical tools and applications.

The formation and scientific development of the Banū Mūsā family cannot be examined without considering the intellectual conditions of the Abbasid era. During the second to fourth centuries AH, Baghdad became one of the most important scientific and cultural centers of the Islamic world, and the Bayt al-Ḥikma played a significant role in collecting, translating, and producing knowledge. At this institution, scientific works from Greek, Persian, and Syriac traditions were translated into Arabic, while scholars from different regions worked together in research and authorship. The Banū Mūsā brothers were also educated within this intellectual environment and benefited from the instruction of prominent scholars.

The significance of the Banū Mūsā family was not limited to translating or preserving earlier knowledge. Their scientific importance lies particularly in the fact that they went beyond theoretical knowledge and applied it to the construction of mechanical devices,

fluid-level control systems, hydraulic mechanisms, and astronomical instruments and designs. They employed methods such as studying scientific texts, analyzing and critically evaluating theoretical principles, and subsequently constructing and testing devices. This approach demonstrates a form of interaction between theory, experimentation, and technology that played an important role in the development of applied sciences in Islamic civilization.

In view of this subject, the main research question is: How and through what means did the Banū Mūsā family contribute to the development of science and technology in Islamic civilization? Alongside this main question, the following sub-questions are addressed:

1. What role did the scientific and educational environment of the Bayt al-Ḥikma play in shaping the intellectual development of the Banū Mūsā family?
2. In which scientific and technical fields did the Banū Mūsā brothers make significant achievements?
3. What role did the Kitāb al-Ḥiyāl and their mechanical designs play in the development of applied sciences and engineering?
4. What contribution did the Banū Mūsā family make to the transmission, preservation, and development of knowledge inherited from earlier civilizations?

The importance of this subject lies in the fact that examining the activities of the Banū Mūsā family involves more than simply studying three prominent scholars of the Abbasid period; it also constitutes an investigation into an important example of the transformation of science from the theoretical stage to practical application in Islamic civilization. Their works demonstrate that scholars of this period were not merely collectors or translators of earlier knowledge; rather, through criticism, analysis, experimentation, and the construction of devices, they were able to expand and develop existing knowledge. From this perspective, studying the intellectual legacy of the Banū Mūsā family is particularly significant for understanding the historical development of engineering concepts, automatic control, and the relationship between mathematics and technology. Furthermore, the collaborative work of the three brothers and their support for translators and scholars provide a notable example of the role of institutions, financial patronage, and scholarly cooperation in the advancement of knowledge.

2. Research Methodology

This research adopts a descriptive-analytical methodology, grounded in library-based historical research. The primary objective is to systematically document and analyze the scientific contributions of the Banū Mūsā family.

2.1 Research Design

This is a qualitative, historical-analytical study. The design focuses on the collection, verification, and interpretation of primary and secondary historical sources to reconstruct the

scientific activities and intellectual contributions of the Banū Mūsā brothers within their historical context.

2.2 Data Collection (Source Selection)

The data for this study were collected through systematic library research. The sources were selected based on their relevance to the Banū Mūsā family, the Abbasid scientific environment, and the history of Islamic science and technology.

Primary Sources: The analysis is primarily based on the surviving works of the Banū Mūsā brothers, most notably their treatise on mechanics, *Kitāb al-Ḥiyāl* (The Book of Ingenious Devices). Biographical and historical information was drawn from medieval Arabic biographical dictionaries, including the works of Ibn al-Nadīm and al-Qifṭī, specifically *Ta'rikh al-Ḥukamā'* (History of the Sages).

Secondary Sources: The study relies extensively on modern scholarly interpretations and analyses, including the works of Hill (1979), Al-Hassan and Hill (1986), Nasr (1980), Sarton (1975), and Motamedi (2019). These sources were used to contextualize the primary texts, verify historical claims, and understand the broader scientific, cultural, and political environment of the 9th-century Islamic world.

2.3 Data Analysis

The collected data were analyzed using the following analytical approaches:

Content Analysis: The technical content of the primary texts, particularly the mechanical designs described in *Kitāb al-Ḥiyāl*, was systematically analyzed to identify specific inventions, mechanical principles, and engineering innovations.

Comparative Analysis: The findings derived from primary sources were compared with secondary scholarly works to ensure historical accuracy, identify potential historiographical debates, and assess the originality of the Banū Mūsā's contributions in relation to earlier and later scientific traditions.

Contextual Analysis: The activities of the Banū Mūsā were situated within the socio-political and intellectual context of the Abbasid Caliphate, with particular attention to the role of the Bayt al-Ḥikma, the Translation Movement, and the patronage system that supported scientific inquiry.

2.4 Limitations of the Study

The primary limitation of this study is its reliance on translated and compiled sources, as access to original manuscripts of the Banū Mūsā's works is restricted. Furthermore, historical records regarding specific dates, personal details, and the exact circumstances of certain inventions are often fragmented or ambiguous, requiring interpretive analysis. The study is limited to the historical narrative and does not involve experimental reconstruction or physical testing of the devices described. Additionally, this research focuses primarily on the scientific and engineering contributions of the Banū Mūsā and does not extensively explore their philosophical or theological writings.

3. Historical Background of Science in the Abbasid Period and the Formation of the Bayt al-Ḥikma

The Abbasid period can be regarded as a turning point in the history of world science. During the second to fourth centuries AH, Baghdad became the intellectual and cultural center of the Islamic world and played a role comparable to that of ancient Athens and Alexandria in classical civilization. During this period, rational inquiry, empirical investigation, and interest in the natural sciences reached a high point among Muslim intellectual elites. Unlike many other political systems, the Abbasid caliphate regarded knowledge as an instrument of political power and civilizational prestige. Consequently, scholars and translators enjoyed an exceptional status at the Abbasid court (Motamedi, 2019, p. 4).

The Abbasid caliphs, particularly Hārūn al-Rashīd and al-Ma'mūn, adopted deliberate policies in support of science and philosophy. Hārūn al-Rashīd was among the early Abbasid caliphs to promote the translation of Greek and Persian works. During his reign, Baghdad experienced considerable economic and cultural prosperity, while scholarly connections with major centers of learning such as Jundishapur, Alexandria, and Antioch expanded (Nasr, 1980, p. 82). The reign of al-Ma'mūn (r. 198–218 AH), however, may be regarded as a golden age of knowledge in the Islamic world because it was during this period that Greek intellectual traditions became increasingly integrated with Islamic approaches to logic and mathematics, while new centers of scientific investigation were established (Hill, 1986, p. 43; Al-Hassan).

Al-Ma'mūn not only provided financial support to scholars but also personally participated in intellectual and scientific discussions. He believed that scientific advancement constituted an important foundation of caliphal power. Accordingly, he ordered the construction of observatories in Baghdad and Damascus and placed groups of astronomers and mathematicians in the service of the state. It was within this intellectual environment that the Banū Mūsā brothers later developed and became important participants in this scientific system.

The most important scientific institution of the Abbasid period was the Bayt al-Ḥikma (House of Wisdom). The origins of this institution can be traced to the private libraries associated with Hārūn al-Rashīd; however, during the reign of al-Ma'mūn, it developed into a more formally organized center of scholarship. The Bayt al-Ḥikma incorporated a library, translation activities, astronomical observation facilities, and accommodation for scholars. Researchers from various regions, including Khurasan, Syria, and Egypt, traveled to Baghdad and worked in this intellectual environment. Al-Ma'mūn entrusted its scholarly administration to Yaḥyā ibn Manṣūr, a prominent astronomer from Khurasan, and provided him with substantial financial resources (Motamedi, 2019, p. 5).

At the Bayt al-Ḥikma, scholars not only translated existing works but also produced new scientific writings. Mathematical, philosophical, medical, and astronomical works from the Greek and Syriac traditions were translated into Arabic. At the same time, Muslim scholars critically examined and analyzed these works and introduced new ideas and interpretations. According to al-Qifṭī, "al-Ma'mūn rewarded

the translator of each book with its weight in gold" (al-Qifṭī, 1992, p. 231). This account illustrates the extraordinary importance attached to scholarship and translation within Abbasid cultural policy.

One of the distinctive characteristics of the Bayt al-Ḥikma was its relatively cosmopolitan intellectual environment. Muslims, Christians, Jews, and Zoroastrians participated in scholarly activities alongside one another. Arabic gradually became a common language of scientific communication, facilitating the transmission of knowledge from Greek and Syriac into the broader intellectual traditions of the Islamic world and, subsequently, into Latin Europe. According to Hunke, the scientific achievements of Muslim scholars played a significant role in transmitting ancient knowledge to Europe and contributing to the intellectual foundations of the later European Renaissance (Hunke, 1981, p. 273).

Within this environment, intellectual dynamism and scholarly inquiry flourished. Philosophical discussions concerning Aristotelian logic, Euclidean geometry, and Ptolemaic astronomy were accompanied by critical examination and modification by Muslim scholars. It was in this intellectual context that the Banū Mūsā brothers studied existing knowledge and subsequently developed innovative approaches. They were able to move beyond purely theoretical frameworks and apply geometrical concepts through mechanical and experimental devices.

Khurasani scholars played a particularly important role in the Abbasid scientific movement. Scholars originating from cities such as Marw, Nishapur, and Herat benefited from the region's long-standing intellectual and scientific traditions in philosophy and mathematics and consequently contributed significantly to the formation of Islamic sciences. The Banū Mūsā family also emerged from this broader Khurasani context. Their father, Mūsā ibn Shākir al-Khurasānī, was an astronomer who served at the court of al-Ma'mūn. Following his death, al-Ma'mūn summoned his three young sons to Baghdad and placed them under the supervision of Yaḥyā ibn Manṣūr at the Bayt al-Ḥikma (Nasr, 1980, p. 104).

This scholarly supervision enabled the Banū Mūsā brothers to grow up within an intellectually stimulating environment and to become familiar with logic, geometry, and astronomy from an early age. They were not merely students of the scholars associated with the Bayt al-Ḥikma; they later became influential scholars themselves, with figures such as Thābit ibn Qurra and Ḥunayn ibn Isḥāq benefiting from the intellectual environment they helped create.

Thus, the Abbasid period witnessed not merely the collection and preservation of knowledge but also an important stage in the development and transformation of science in the Islamic world. The Bayt al-Ḥikma functioned as a bridge between Greek intellectual traditions and Islamic scholarship, while the Banū Mūsā family represented a remarkable outcome of this cultural and scientific exchange. They emerged from an environment in which knowledge, language, and intellectual traditions were brought together in the service of human and civilizational advancement.

4. The Banū Mūsā Family and Their Scientific Education

The Banū Mūsā family had Khurasani origins and emerged from the broader cultural environment of Khurasan. Their father, Mūsā ibn Shākir al-Khurasānī, was regarded as an astronomer and mathematician at the court of the Abbasid caliph al-Ma'mūn (Motamedi, 2019, p. 4). According to al-Qifṭī's *Ta'rikh al-Hukamā'*, Mūsā ibn Shākir was initially a courageous young man involved in banditry, but after becoming acquainted with al-Ma'mūn, he developed an interest in astronomy and mathematics and eventually became one of the distinguished astronomers of his time (al-Qifṭī, 1992, p. 251). Mūsā ibn Shākir was reportedly among al-Ma'mūn's close associates and participated in the caliph's scientific and astronomical activities in Marw. He died during the period of al-Ma'mūn's reign, sometime between 198 and 218 AH.

Following his death, his three young sons were left without their father. Al-Ma'mūn, recognizing their intellectual abilities and potential, reportedly ordered that they be placed under the guardianship of Ishāq ibn Ibrāhīm, the governor of Baghdad. Ishāq subsequently entrusted their education to Yahyā ibn Manṣūr, a prominent astronomer and leading figure in the scientific milieu of the Bayt al-Ḥikma, who assumed responsibility for their intellectual and scientific training (Motamedi, 2019, p. 5).

The three brothers—Muḥammad, Aḥmad, and Ḥasan—were educated from an early age within the intellectual environment associated with the Bayt al-Ḥikma. They lived in an atmosphere in which Greek and Syriac texts were being translated into Arabic and scientific discussions concerning Euclid, Ptolemy, and Galen were taking place.

Muḥammad, the eldest brother, developed an early interest in mathematics and astronomy and established an intellectual relationship with Muḥammad ibn Mūsā al-Khwārizmī, the renowned mathematician associated with the development of algebra. This connection contributed to the influence of mathematical methods on Muḥammad's intellectual development and was reflected in works attributed to him, including writings on geometrical figures and conic sections.

Aḥmad, the second brother, possessed a strongly practical and technical orientation. He studied the structure and operation of mechanical devices as well as the behavior of liquids and gases and later became particularly associated with the famous *Kitāb al-Ḥiyal* (The Book of Ingenious Devices). Ḥasan, the youngest brother, demonstrated a particular interest in Euclidean geometry. According to al-Qifṭī, although he had studied only six books or sections of Euclid, he claimed that this knowledge was sufficient to solve all geometrical problems (al-Qifṭī, 1992, p. 256).

For the Banū Mūsā brothers, the intellectual environment of the Bayt al-Ḥikma functioned much like a multidisciplinary academy. Their teachers and intellectual associates included prominent astronomers, mathematicians, and translators. Among them was Yahyā ibn Manṣūr, who supervised their scholarly development, as well as translators and scholars involved in philosophy and medicine (Motamedi, 2019, p. 5).

Al-Ma'mūn reportedly encouraged the three brothers to achieve a high level of competence in mathematics and astronomy and facilitated access to educational and translated materials. This combination of institutional support and their analytical intellectual abilities enabled them to develop rapidly and eventually attain prominent positions within the scholarly community.

Unlike some scholars of their time, the Banū Mūsā brothers did not regard science as purely theoretical. Their approach combined mathematical analysis, empirical experimentation, and the construction of practical devices. They were among the scholars who sought to establish a connection between theory and practice. Drawing on their financial resources, they assembled groups of translators, craftsmen, and technical specialists to transform their scientific ideas into functional devices and test them in practice.

Their research approach can be summarized in three stages:

1. Theoretical study of Greek scientific texts, particularly the works of Euclid and Ptolemy;
2. Critical examination and revision of theoretical principles through logical analysis and practical observation;
3. Construction of practical devices to test scientific conclusions, an approach that was later reflected most prominently in the *Kitāb al-Ḥiyal*.

This integrated approach contributed to the development of experimental and applied scientific practices in Islamic civilization and helped establish an intellectual foundation for later engineering works, including those associated with al-Jazarī and Taqī al-Dīn.

An important characteristic of the Banū Mūsā family was the systematic division of scientific responsibilities among the three brothers. Muḥammad concentrated on mathematical and astronomical theories; Aḥmad specialized in the design and construction of mechanical and hydraulic devices; and Ḥasan focused on complex geometrical problems and the analysis of geometric forms. This division of labor allowed the brothers to maintain a high degree of specialization while simultaneously conducting collaborative research across multiple disciplines (Motamedi, 2019, p. 6).

The historian of science George Sarton regarded the Banū Mūsā as an early example of organized scientific collaboration in the history of science, particularly because of their collective approach to research and knowledge production (Sarton, 1975, p. 214). Their intellectual and scientific collaboration contributed to the prominent position that the Banū Mūsā family occupied at the Abbasid court during and after the reign of al-Ma'mūn.

Among the scholars of Baghdad, the Banū Mūsā were recognized not only as researchers but also as patrons of scholarship. They used their wealth to support translations and the development of scholarly resources. Al-Qifṭī reports that Muḥammad ibn Mūsā regularly paid substantial sums to

translators to render Greek scientific works into Arabic (al-Qiftī, 1992, p. 258).

As a result of such patronage, the scholarly environment of Baghdad attracted prominent translators and scientists, including Thābit ibn Qurra, who worked in association with the Banū Mūsā. According to Motamedi, Thābit ibn Qurra stayed at Muḥammad ibn Mūsā's residence, where he learned Arabic and carried out some of his early translation activities.

In this way, the Banū Mūsā family fulfilled both the role of scientists and that of patrons of scientific knowledge, creating an important model of scholarly cooperation, financial patronage, and scientific production in the Islamic civilization of the Abbasid period.

5. Works of the Banū Mūsā

The Banū Mūsā brothers authored works in several fields, including mathematics, astronomy, mechanics, and philosophy. Some of their works include:

1. The Book of Circular and Rectangular Figures
2. The Book of Conics
3. The Book of the Geometrical Figure of Galen
4. Correspondence between Muḥammad and Thābit ibn Qurra
5. Correspondence between Aḥmad and Sind ibn 'Alī
6. On the Sphere
7. Measurement of Simple and Spherical Figures
8. Trisection of an Angle
9. The Book of the Beginning of the Universe
10. The Book of the Motion of the Planets
11. The Book of Orbits
12. Astronomical Tables
13. The Conditions of the Atmosphere
14. The Astrolabe
15. The Book of the Part
16. Quristun (Metal Balance)
17. *Kitāb al-Ḥiyal* (The Book of Ingenious Devices)
18. The Book of Military Devices
19. The Book of the Automatic Flute

6. The Banū Mūsā Astronomical Simulator

The Banū Mūsā brothers constructed what has been described as one of the earliest engineering simulators in the history of science. Their simulator consisted of a spherical framework containing objects representing prominent stars visible to the naked eye in the night sky. The device was powered by water and constructed on the basis of highly precise astronomical and mechanical calculations. When an actual star appeared in

the sky, its corresponding representation would appear in the simulator at approximately the same time.

The construction of such a simulator required sophisticated mechanical mechanisms for moving the representations of the stars, shifting them forward and backward, and controlling the periods during which they appeared. It therefore involved complex mechanical timing and control systems. The device demonstrates the Banū Mūsā brothers' ability to combine astronomical calculations with mechanical engineering and automated movement (Hassan, 2004, pp. 3–4).

7. Findings

The findings of this study indicate that the Banū Mūsā family contributed to the development of science in Islamic civilization in several fundamental areas:

7.1 Development within an Organized Scientific Environment

The Banū Mūsā brothers developed intellectually within the scientific environment of the Bayt al-Ḥikma (House of Wisdom), where the translation of scientific works, education, research, and the exchange of ideas among scholars from different regions took place. This environment provided favorable conditions for their intellectual development and helped transform them from students and participants in the scholarly milieu of the Bayt al-Ḥikma into prominent scientists.

7.2 Establishing a Link between Theory and Practice

One of the most important findings of this study is that the Banū Mūsā brothers did not regard science merely as a collection of theoretical concepts. They first studied theoretical principles, then critically examined and analyzed them, and subsequently constructed practical devices to test their conclusions. This three-stage approach—theoretical study, critical examination and revision, and construction of practical devices—was a significant characteristic of their scientific methodology.

7.3 Advances in Mechanical Engineering and Automatic Control

The *Kitāb al-Ḥiyal* (The Book of Ingenious Devices) represents the most important manifestation of the Banū Mūsā family's engineering activities. The work contains 100 different designs and devices, including fluid-level control systems, fountains, automatic lamps, and mechanisms associated with water and wells. Designs 76 and 78 also demonstrate their use of float mechanisms, conical valves, crank mechanisms, and mechanical feedback for controlling fluid levels.

7.4 Development of Astronomy and the Construction of Astronomical Instruments

In addition to mechanics and mathematics, the Banū Mūsā brothers were active in astronomy. Through precise astronomical and mechanical calculations, they developed instruments and mechanical models for representing the movements of celestial bodies. This activity demonstrates their ability to combine theoretical astronomical knowledge with engineering and mechanical principles.

also emphasized their extensive use of conical valves for a variety of applications.

7.5 Contribution to the Translation Movement and the Transmission of Knowledge

Another finding of the study is that the Banū Mūsā brothers were not merely producers of knowledge; they also supported translators and the transmission of scientific knowledge. They used their financial resources to facilitate the translation of scientific works and supported scholars such as Thābit ibn Qurra and Hunayn ibn Isḥāq. In this way, they contributed to the transmission of Greek scientific knowledge and other intellectual traditions into Arabic and helped establish the foundations for its further development in the Islamic world.

7.6 Formation of a Model of Scholarly Collaboration

The division of responsibilities among the three brothers is another important finding of this study. Muḥammad focused primarily on mathematics and astronomy, Aḥmad on the design and construction of mechanical and hydraulic devices, and Ḥasan on geometry and the solution of complex geometrical problems. This specialization, combined with their close family collaboration, enabled them to conduct multidisciplinary research and address scientific problems from different perspectives.

7.7 Social Applications of Technology

An examination of the Banū Mūsā brothers' designs indicates that some of their inventions were developed for practical applications in society, including their potential use in bathhouses, mosques, and areas located near rivers. Therefore, their activities should not be regarded merely as entertainment or the construction of devices for royal courts. Rather, part of their scientific and engineering efforts was directed toward solving practical problems and addressing the needs of society.

7.8 Statements Concerning the Banū Mūsā's *Kitāb al-Ḥiyal*

Several historians and researchers have emphasized the significance and originality of the *Kitāb al-Ḥiyal*:

- **Al-Qifṭī:** Described it as "the most famous work attributed to the Banū Mūsā."
- **Ibn Khallikān:** Stated that in the field of ingenious devices, they possessed a remarkable and rare book encompassing numerous innovations.
- **Aḥmad Y. al-Hassan:** Observed that the Banū Mūsā primarily employed principles of hydrostatics and aerostatics. According to him, comparable devices to those described in the *Kitāb al-Ḥiyal* are difficult to find in later Arabic or Islamic writings.
- The Banū Mūsā's use of automatic valves, delay mechanisms, and principles of automatic control demonstrates their ingenuity, creativity, and technical sophistication.
- **Donald R. Hill:** Noted that in Models 80 and 85, the Banū Mūsā employed a mechanism resembling the modern crank mechanism, centuries before the crank was described in European technical literature. He

7.9 Designs in the *Kitāb al-Ḥiyal*

The *Kitāb al-Ḥiyal* of the Banū Mūsā contains 100 mechanical designs, which can be classified as follows:

- 69 mechanical jars, pitchers, vessels, and bottles
- 16 fluid-level control systems
- 7 fountains
- 4 automatic lamps
- 2 devices associated with wells and rivers

Total: 100 designs

These designs demonstrate the wide range of mechanical and hydraulic technologies developed by the Banū Mūsā. In particular, their fluid-level control systems and automatic mechanisms reveal an advanced understanding of mechanical feedback, fluid dynamics, and automated operation.

7.10 Translation of the *Kitāb al-Ḥiyal*

The *Kitāb al-Ḥiyal* attracted the attention of modern historians of science and technology, leading to its study and translation in the twentieth century.

- In 1918, Eilhard Wiedemann and Fritz Hauser published a collection of studies in German concerning the Banū Mūsā's *Kitāb al-Ḥiyal*. They explained the operation of Designs 75–87.
- In 1922, Hauser published a German-language work on the *Kitāb al-Ḥiyal*, providing explanations of the remaining designs.
- In 1979, Donald R. Hill published an English translation of the *Kitāb al-Ḥiyal*. His edition included all the designs along with detailed explanations of their mechanisms and functions. He also identified and discussed the fundamental scientific and engineering principles employed by the Banū Mūsā brothers in constructing their devices.

Overall, the *Kitāb al-Ḥiyal* represents one of the most significant surviving contributions of the Banū Mūsā family to the history of mechanical engineering. It demonstrates how mathematical knowledge, hydraulic principles, mechanical design, and practical experimentation could be combined to produce sophisticated automated devices in the medieval Islamic world.

7.11 Banū Mūsā Fluid-Level Control Systems

Of the 100 designs presented in the *Kitāb al-Ḥiyal*, 16 are related to fluid-level control systems. Two of these designs will be examined here.

Design No. 78: Fluid-Level Control System

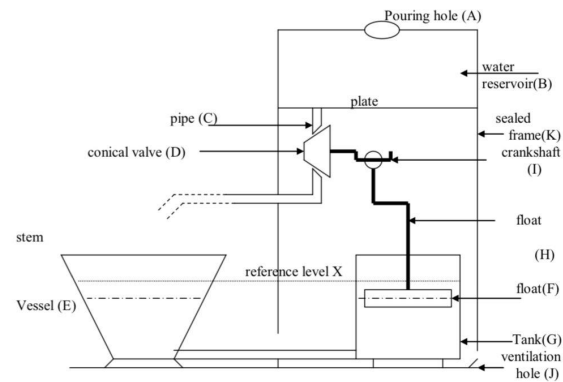
The fluid-level control system presented as Design No. 78 is shown in Figure 1. The system consists of the following components: water reservoir (B), supply pipe (C), conical valve

(D), outlet vessel (E), reservoir (F), float (G), float stem (H), crank (I), and sealed frame (K). The system operates as follows:

1. Water is poured through opening A into reservoir B. From there, it flows through pipe C and the open conical valve D—which remains open when there is no water in the system—into outlet vessel E.
2. The float (F) and reservoir (G) constitute the components of a mechanical level-sensing mechanism that measures the water level in the outlet vessel E.
3. The movement of the float, which represents the water level in the outlet vessel, is transmitted through the float stem (H) and crank (I) back to the conical valve D. The stem is connected to the crank by means of a loop, forming a rotational joint. The crank is firmly attached to the valve plug so that it can move the plug. The stem-and-crank sub-mechanism converts the translational movement of the float into angular movement of the valve plug, thereby providing a mechanical feedback signal to the control valve. This represents a distinctive mechanical control technique in the history of science and technology.
4. When the float reaches the predetermined level X, which serves as the reference level, the conical valve closes completely, thereby maintaining the water level at X.
5. When water is removed from vessel E, either continuously or intermittently, the float and stem move downward. Consequently, the crank rotates in the opposite direction and opens the conical valve, allowing water to flow into the outlet vessel again.
6. A small opening at the bottom of the sealed frame allows the interior of the frame to be ventilated, thereby enabling the feedback mechanism to operate properly.

The Banū Mūsā brothers stated in their book that this design was intended for use in bathhouses, mosques, and areas near rivers. This indicates that their control systems were designed as practical, full-scale applications, rather than merely as toys or devices intended solely for the entertainment of rulers. Their design therefore provides an important example of the practical application of mechanical feedback and automatic control in the medieval Islamic world.

Figure 1. Design No. 78 by the Banū Mūsā Brothers



Source: Reproduced from Hassan, G. A. (2004). *Banū Mūsā: The founders of automatic control in the 9th century*. Cairo University Conference on Mechanical Design and Production, p. 6.

Design No. 76

Design No. 76 represents another fluid-level control system whose operating mechanism differs from that of Design No. 78. Figure 2 illustrates Design No. 76 of the Banū Mūsā brothers.

The fluid-level control system (Design No. 76) consists of the following components: reservoir (G), tank (J), outlet vessel (L), supply pipes (F) and (M), two basins (D) and (E), a siphon consisting of two concentric elements—pipes (B) and (C)—shaft (H) for pipe (F), ventilation pipe (K), and conical valve (I).

The system operates as follows:

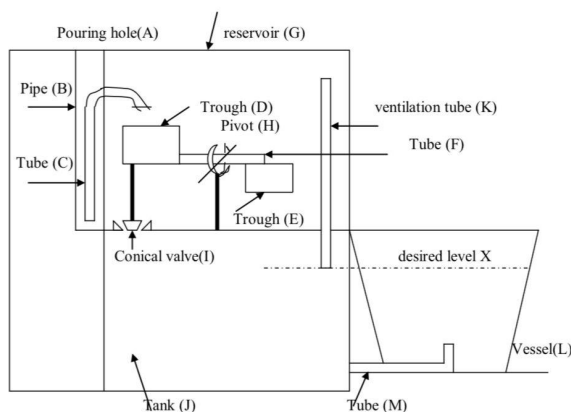
1. Liquid is poured through opening A into pipe B. It then flows through pipe C into basin D, and through the shafted pipe F into basin E. From there, the liquid flows into the upper reservoir G.
2. Since basin D is larger than basin E, and shaft H is positioned in the center of pipe F, the conical valve I remains progressively closed throughout the filling process. Consequently, the flow is directed so that the liquid is stored entirely in the upper reservoir G.
3. The relative positions of the two basins at the end of the shafted pipe F ensure that when the pouring of liquid stops, only basin E remains filled with liquid. It therefore becomes heavier than basin D. As a result, the lever associated with pipe F moves in a clockwise direction, allowing the conical valve to open. The liquid then flows from the upper reservoir G into the sealed tank J. The ventilation pipe K makes this process possible.
4. At the same time, liquid flows from tank J into outlet vessel L until the liquid reaches level X, the desired or reference level defined by the ventilation pipe K. At this point, ventilation of tank J stops, and the flow into both tank J and vessel L is interrupted.
5. When liquid is removed from vessel L, the liquid level falls below the desired level X. Ventilation of tank J

then takes place through pipe K, allowing liquid to flow through the conical valve until the level X is restored.

6. During the filling of the upper reservoir G, it is ventilated through pipes K and M. During the process of controlling the liquid level in the outlet vessel, tank J, siphon C, and pipe B participate in the operation of the system (Hassan, 2004, pp. 5–8).

This design demonstrates the Banū Mūsā brothers' sophisticated understanding of fluid pressure, siphoning, ventilation, mechanical balance, and automatic level regulation. Unlike a simple manually operated valve, the system is capable of responding automatically to changes in the liquid level and restoring the desired level without continuous human intervention.

Figure 2. Design No. 76 by the Banū Mūsā Brothers



Source: Reproduced from Hassan, G. A. (2004). *Banū Mūsā: The founders of automatic control in the 9th century*. Cairo University Conference on Mechanical Design and Production, p. 7.

8. Discussion

The findings of this study offer several critical insights into the scientific landscape of the 9th-century Islamic world and reaffirm the central role of the Banū Mūsā family. This section discusses these findings in relation to the research questions and existing scholarship, while also identifying the original contributions of this study.

8.1 The Bayt al-Ḥikma and the Intellectual Development of the Banū Mūsā

The findings demonstrate that the Bayt al-Ḥikma played a fundamental role in the scientific education and intellectual development of the Banū Mūsā brothers. This institution provided an environment in which scientific works from different civilizations were translated and studied, and scholars engaged in intellectual exchange and collaborative research. The Banū Mūsā brothers were educated in this environment and developed from students within the scholarly community into active and innovative scientists. Their scientific development was therefore the result of both

individual intellectual abilities and the availability of a suitable scientific, educational, and supportive environment.

This finding aligns with the broader historiography on the Abbasid scientific movement. As Nasr (1980) and Hill (1986) have argued, the institutional framework of the Bayt al-Ḥikma was essential for the flourishing of Islamic science. However, this study demonstrates that the Banū Mūsā were not merely passive beneficiaries of this environment but actively shaped it through their patronage and scholarly output. Their success was contingent upon institutional support, yet their contributions helped define and sustain that very institution.

8.2 Re-evaluating the "Mechanician" Stereotype

The analysis reveals that the Banū Mūsā's significance extends far beyond their reputation as master mechanicians. While their work in *Kitāb al-Ḥiyāl* is foundational to the history of engineering (as noted by Hill, 1979), the findings demonstrate that this was merely one component of their intellectual output. Their theoretical contributions to astronomy and mathematics challenge the sometimes narrow view of them as mere "engineers." This suggests a need for a more holistic evaluation of their work as a synthesis of theory and practice.

The specialization of the three brothers enabled their scholarly activities to encompass diverse scientific areas. Muḥammad focused primarily on mathematics and astronomy, Aḥmad on the construction of mechanical and hydraulic devices, and Ḥasan on geometry and theoretical problems. These areas of specialization, combined with their family collaboration, created the conditions for a form of multidisciplinary scientific activity that was remarkably comprehensive for its time.

8.3 The *Kitāb al-Ḥiyāl* and the Development of Applied Sciences

The *Kitāb al-Ḥiyāl* can be regarded as the most important manifestation of the Banū Mūsā brothers' engineering thought. With its 100 designs and devices, the work demonstrates their efforts to transform mathematical and mechanical principles into practical technologies. In particular, the fluid-level control systems presented in Designs 76 and 78 demonstrate the use of mechanisms such as floats, conical valves, and crank systems, together with forms of mechanical feedback, to regulate fluid flow and liquid levels. From this perspective, the *Kitāb al-Ḥiyāl* occupies an important position in the history of mechanical engineering and automatic technologies.

The significance of these designs extends beyond their technical sophistication. The Banū Mūsā stated that Design No. 78 was intended for use in bathhouses, mosques, and areas near rivers. This indicates that their control systems were designed as practical, full-scale applications, rather than merely as toys or devices intended solely for the entertainment of rulers. Their design therefore provides an important example of the practical application of mechanical feedback and automatic control in the medieval Islamic world.

8.4 Contribution to the Transmission and Development of Knowledge

It becomes clear that the Banū Mūsā brothers' contribution to the transmission of knowledge was not limited to translation. Through their financial support for translators and their efforts to facilitate the transmission of scientific works, they contributed to the preservation and expansion of the scientific heritage of earlier civilizations. At the same time, they did not merely reproduce this inherited knowledge; rather, through analysis, critical examination, experimentation, and practical application, they created conditions for its further development.

This finding aligns with the work of Sarton (1975), who recognized the Banū Mūsā as early examples of organized scientific collaboration. However, this study provides a more specific focus on how their family network facilitated a "knowledge pipeline" from translation to practical application, a nuance not fully explored in previous works. The Banū Mūsā's support for translators such as Thābit ibn Qurra and Hunayn ibn Ishāq demonstrates their commitment to the intellectual infrastructure of their time.

8.5 Original Contribution to Science and Technology

The originality of the Banū Mūsā lies not in isolated inventions, but in their interdisciplinary approach. They bridged the gap between pure mathematics (the theory of conic sections) and practical mechanics (automata and control systems like self-regulation). This theoretical-to-practical pipeline, demonstrated in their development of feedback mechanisms, represents a significant leap in the history of technology, predating similar mechanisms in the European Renaissance by centuries (Sarton, 1927).

The Banū Mūsā demonstrated that science can contribute to civilizational advancement most effectively when it moves beyond theoretical inquiry and is applied to the solution of practical problems. The *Kitāb al-Ḥiyal*, their astronomical activities, mechanical designs, and support for translators and scholars collectively provide evidence of this approach. From this perspective, the Banū Mūsā brothers can be regarded as pioneers of engineering methods and the practical application of scientific knowledge in Islamic civilization.

8.6 Critical Historiographical Reflection

A critical examination of the sources reveals a bias in historiography. Western scholars (like Sarton) tended to emphasize the mechanical wonders, while others focused on the philosophical or religious aspects. This paper attempts to synthesize these views, arguing that the Banū Mūsā's legacy is best understood as a coherent intellectual project driven by a family unit that represented the highest ideals of Abbasid intellectual life: a combination of patronage, scholarship, and innovation.

The study also highlights the social dimension of their work. An examination of the Banū Mūsā brothers' designs indicates that some of their inventions were developed for practical applications in society, including their potential use in bathhouses, mosques, and areas located near rivers. Their activities should not be regarded merely as entertainment or the construction of devices for royal courts. Rather, part of

their scientific and engineering efforts was directed toward solving practical problems and addressing the needs of society.

8.7 Limitations and Future Research

While this research provides a comprehensive overview of the Banū Mūsā family's contributions, it is limited by its reliance on secondary literature and translated sources for the technical analysis of the engineering designs. Future research should focus on the potential for experimental archaeology to test the functional viability of the Banū Mūsā's mechanical devices. Additionally, further archival research on the socio-economic aspects of their patronage (the funding of translations) would provide a richer understanding of their impact on the intellectual infrastructure of the Islamic world.

9. Conclusion

The examination of the role of the Banū Mūsā family in the development of science demonstrates that this family made a significant contribution to both theoretical and applied knowledge during the Golden Age of Islamic civilization. In response to the main research question, it can be concluded that the Banū Mūsā brothers contributed to the advancement of science through their education and scholarly activities within the intellectual environment of the Bayt al-Ḥikma, their study and critical examination of earlier scientific traditions, their mathematical and astronomical research, their construction of mechanical devices, and their support for the translation movement. They went beyond the purely theoretical level of knowledge and, through experimentation and the construction of practical devices, helped establish a connection between science and technology.

Regarding the first research question, the findings demonstrate that the Bayt al-Ḥikma played a fundamental role in the scientific education and intellectual development of the Banū Mūsā brothers. This institution provided an environment in which scientific works from different civilizations were translated and studied and scholars engaged in intellectual exchange and collaborative research. The Banū Mūsā brothers were educated in this environment and developed from students within the scholarly community into active and innovative scientists. Their scientific development was therefore the result of both individual intellectual abilities and the availability of a suitable scientific, educational, and supportive environment.

In response to the second research question, the Banū Mūsā brothers were active in several fields, including mathematics, geometry, astronomy, mechanics, and engineering. The specialization of the three brothers enabled their scholarly activities to encompass diverse scientific areas. Muḥammad focused primarily on mathematics and astronomy, Aḥmad on the construction of mechanical and hydraulic devices, and Ḥasan on geometry and theoretical problems. These areas of specialization, combined with their family collaboration, created the conditions for a form of multidisciplinary scientific activity.

Regarding the third research question, the *Kitāb al-Ḥiyal* can be regarded as the most important manifestation of the Banū Mūsā brothers' engineering thought. With its 100 designs and

devices, the work demonstrates their efforts to transform mathematical and mechanical principles into practical technologies. In particular, the fluid-level control systems presented in Designs 76 and 78 demonstrate the use of mechanisms such as floats, conical valves, and crank systems, together with forms of mechanical feedback, to regulate fluid flow and liquid levels. From this perspective, the *Kitāb al-Ḥiyāl* occupies an important position in the history of mechanical engineering and automatic technologies.

Regarding the fourth research question, it becomes clear that the Banū Mūsā brothers' contribution to the transmission of knowledge was not limited to translation. Through their financial support for translators and their efforts to facilitate the transmission of scientific works, they contributed to the preservation and expansion of the scientific heritage of earlier civilizations. At the same time, they did not merely reproduce this inherited knowledge; rather, through analysis, critical examination, experimentation, and practical application, they created conditions for its further development.

Overall, the findings of this study demonstrate that the most significant contribution of the Banū Mūsā family to the history of science was their establishment of a connection between theoretical knowledge, experimentation, calculation, and practical technology. They demonstrated that science can contribute to civilizational advancement most effectively when it moves beyond theoretical inquiry and is applied to the solution of practical problems. The *Kitāb al-Ḥiyāl*, their astronomical activities, mechanical designs, and support for translators and scholars collectively provide evidence of this approach. From this perspective, the Banū Mūsā brothers can be regarded as pioneers of engineering methods and the practical application of scientific knowledge in Islamic civilization. Their intellectual legacy occupies a significant position in the history of science and technology and demonstrates the enduring importance of integrating knowledge, creativity, experimentation, and the practical needs of society.

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