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**THE TREATISE OF AL-JAZARĪ  
ON AUTOMATA**



MUSEUM OF FINE ARTS, BOSTON  
COMMUNICATIONS TO THE TRUSTEES, VI

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# THE TREATISE OF AL-JAZARĪ ON AUTOMĀTA

LEAVES FROM A MANUSCRIPT OF THE KITĀB FĪ MA'ARIFAT  
AL-HIYAL AL HANDASIYA IN THE MUSEUM OF  
FINE ARTS, BOSTON, AND ELSEWHERE

BY

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IN THE MUSEUM



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## PLATES



**THE TREATISE OF AL-JAZARĪ  
ON AUTOMATA**



## I. INTRODUCTION

THE Museum of Fine Arts possesses six leaves of a well-known Arabic manuscript on "Automata," which are here reproduced. Another leaf of the same manuscript belongs to the Wetzel Collection in the Fogg Art Museum, Cambridge, another to Dr. Paul J. Sachs in Cambridge, and still another to Mrs. John L. Gardner in Boston. Some of these leaves have formed a part of the Goloubew Collection, and all originally belonged to Dr. F. R. Martin, who obtained them in Constantinople.

Of the other known leaves which have been stated to belong to the same manuscript, the most important are:

1. The so-called 'guard page.' This page is perhaps a myth. It is referred to by Anet (C., 2): but in fact, Dr. Martin has never said that the page which bears the name of Sulṭān Muḥammad was a guard page, and, in an unpublished communication recently forwarded to this museum he states explicitly that "it is not the guard page of the manuscript which bears the name of the Urtuqīd Sultan . . . . This description is found round a double-page design for a wooden door." If a guard page with Sulṭān Muḥammad's name had existed, we should have had to suppose that it came from some other book, since al-Jazarī's work was only compiled in 1206. In fact, however, there is no evidence for the existence of any such page. The inscription honoring Sulṭān Muḥammad, on which Dr. Martin (M., pp. 7, 12) rests the weight of his argument forms part of the double-page door design referred to above and in the next paragraph.

2. The double-page illustration, reproduced in S. M., pl. III, and referred to above, represents the door in the Āmīda palace which is described in Section 6 of al-Jazarī's work (W. H., 3). The text, in kūfic characters, reads, on the right-hand side *'Iz li maulānā as-sulṭān al-mālik, al-'ālm al-'ādil*, continuing on the left-hand side *al-mū'ayyad Nūru'd-Dīn Abu'l-Faṭḥ Muḥammad ibn Qarā-Arslān*; together, "Glory to our master the Sulṭān regnant, the learned, the just, the well-served, Nūru'd-Dīn Abu'l-Faṭḥ Muḥammad ibn<sup>1</sup> Qarā-Arslān," as correctly indicated by Dr. Martin, who

<sup>1</sup> Not "abu" as carefully quoted in B. S., p. 79, where it is not made clear that the inscription is taken from one leaf, the supposed heraldic device (really the falcon and cup of the first water-clock, our pl. I) from another.

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does not, however, supply the reading. The inscription along the top reads: *al-maliki 'ulāhi 'l-wāhidu'l-qahhār*, "The sovereignty is Allah's, the One, the Mighty."

Now, inasmuch as al-Jazarī's text was only completed for Sulṭān Maḥmūd in 1206, long after Sulṭān Muḥammad's death, this page, if a title page, must be derived from some older book. In fact, however, the page is not a title page at all, but an illustration of the door in the Āmida palace which is described in Section 6 of al-Jazarī's work (W. H., 3). And in fact the lintel inscription quoted above tallies exactly with that which is said to have been on the door (W. H., 1, p. 51, footnote). No doubt this door had been designed by al-Jazarī and constructed in the reign of Sulṭān Muḥammad: and the representation with the inscription in his honor is a picture of the door as it was designed and made, affording us no more evidence of the date of the manuscript than does the occurrence of Sulṭān Muḥammad's name in the Oxford Graveley MS. 27 written in 1486 (W. H., 1, p. 50 *et infra*, p. 9). Al-Jazarī was not restricted to a description of objects made in the reign of Sulṭān Maḥmūd, but included in it some of the "ingenious contrivances" which he had constructed in the reign of his father.<sup>1</sup>

3. The supposed portrait of Saladin (M., frontispiece). This representation is not a portrait of any Sulṭān, though no doubt it offers us in a general way the likeness of a contemporary Sulṭān or nobleman. Al-Jazarī himself calls it "a man seated in a balcony": and the representation is really an illustration of a part of a water-clock, viz., the "Elephant Water-Clock" of Section I, ch. 4 of his book. The man is seated in a balcony, below a semicircle of fifteen circular openings; he leans to one side, touching a circular object; according to the text this object should be a falcon, and so too on the opposite side, but Dr. Martin's reproduction and the Oxford Graveley MS. 27 illustration (W. H., 1, fig. 67) tally exactly, showing two spheres instead of two falcons. At the end of each half hour

<sup>1</sup> Al-Jazarī's description of the door is translated in W.H., 3. The illustration from the Oxford Graveley MS. 27 omits the lateral inscriptions but shows the lintel text, as given above. Wiedemann and Hauser do not discuss the inscriptions, and merely conjecture (W. H., 3, p. 215, note 1) that the palace in question must have been Sulṭān Suqmān's or Sulṭān Maḥmūd's, "probably the latter's." But the inscription honoring Sulṭān Muḥammad as regnant, shows that the door must have been made before his death. Al-Jazarī merely calls it "a door in the king's house in Āmida." Most likely Sulṭān Muḥammad's palace, and the door, were still in occupation and use in 1206.

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the man leans to the opposite side, and touches the other object ("falcon"), and at the end of each hour one of the circular openings above him changes color.

Dr. Martin supports the argument for Saladin by referring to the name recurring on the cupolas of certain of the illustrations (here, pl. IV and Sch., pl. IV), which, however, reads *Sālihi Aṣli va'd-Dunyā va'd-Dīn*, rather than *Salāh al-Dīn (Ṣalāḥu'd-Dīn)*. Moreover as pointed out by Blochet (B) followed by Claude Anet (C., 2), Saladin, if intended, should have been given his own title of *al-Malik un-Nāṣir* instead of *al-Malik aṣ-Ṣāliḥ*. Dr. Martin assumes an error on the part of the scribe: but it is improbable that a Musalmān scribe should have made an error in the titles of a regnant Sulṭān; and incredible that he should have hit upon the proper titles of a Sulṭān who came to the throne fifteen or twenty years later, and was actually the patron of al-Jazarī's book.

M. Blochet (B., pp. 193 ff.) states definitely, presumably on the authority of Dr. Martin, that the leaves which the latter possessed and of which the Museum of Fine Arts possesses six (two reproduced by Blochet, B., figs. 6 and 9) were "fragments of an illuminated Arabic book in Santa Sophia" and "had been detached, solely for the purpose of selling the pictures, from an example" — as he incorrectly describes it — "of the treatise of Philon of Byzantium on Hydraulic Automata, translated from Greek into Arabic." M. Blochet assigns the detached leaves, and therefore the whole manuscript, to the fourteenth century; the improbability of this dating is discussed below in Section IV.

Wiedemann and Hauser (W. H., p. 57) repeat the statement that the Martin leaves are derived from the Santa Sophia manuscript of al-Jazarī's treatise. This Santa Sophia manuscript is referred to by Carra de Vaux (d. V., B. M.), as follows: "the superior treatise on mechanics of *Bēdī az-Zamān el Djazarī*. It bears the number 3606. It is illustrated with numerous figures colored with the greatest care after the Persian and Indian fashion. It is one of the finest Arabic manuscripts I have ever seen." He gives no estimate of the date. The mention of "Persian and Indian style" is indefinite. I have tried in vain to obtain information about this manuscript, which may have a dated colophon.

The pages of our manuscript now distributed in various collections are or were twenty in number. Nine are accounted for above: there are said

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to be two in the Stoclet Collection (Brussels), two in the Berenson Collection (Florence), one in the Tony Smith Collection, and some or all of the remainder are still in Dr. Martin's possession. Besides the eight reproduced here (three for the first time), other pages have been published as follows:

- B. Fig. 5, representing Sec. II, no. 3 of al-Jazarī; fig. 7, representing Sec. III, ch. 10, of al-Jazarī; fig. 8, representing Sec. III, ch. 7 of al-Jazarī; fig. 10, representing Sec. I, ch. 2 of al-Jazarī.
- M. Frontispiece, detail of Sec. I, ch. 4 of al-Jazarī (like W. H., 1, fig. 67); pl. II = B., 5; pl. III, perhaps a detail of Sec. II, ch. 10 of al-Jazarī; pl. IV, representing Sec. I, ch. 6 of al-Jazarī.
- S. M. Pl. III, the door in the king's palace (al-Jazarī, Sec. VI).
- Sch. Pl. IV, left hand, representing Sec. I, ch. 7 of al-Jazarī; right hand, like Sec. I, ch. 4, and fig. 37 of W. H., 3.

The total number of published pages, including those now reproduced, is therefore eighteen. A leaf found in Constantinople by Professor Würschmidt and illustrated in W. H., 3, can hardly be from the same MS.

I append a list of dates and titles of the Urtuqid Sultāns of Āmida, 1174-1222.

- Nūru'd-Dunyā va'd-Dīn, Abu'l-Faḥ Muḥammad, 1174-1185.
- al Malik al-Mas'ūd, Quṭbu'd-Dīn, Abu'l-Muzaffar Suqmān, 1185-1200.
- al Malik aṣ-Ṣāliḥ, Nāṣiru'd-Dunyā va'd-Dīn, Abu'l-Faḥ Maḥmūd, 1200-1222.

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### II. AL-JAZARĪ'S "BOOK OF THE KNOWLEDGE OF INGENIOUS GEOMETRICAL (MECHANICAL) DEVICES"

THE work represented by six leaves in the Museum of Fine Arts, and the other leaves above referred to, is the *Kitāb fi ma'arifat al-ḥiyal al-handasīya* ("Book of the knowledge of ingenious geometrical contrivances"), otherwise called the *Al-jāmi' bain al-'ilm va'l-'aml al-nāfi' fi šinā'at al-ḥiyal* ("Work that combines theory and practice and is profitable to the craft of ingenious contrivances"), of which the text was compiled by al-Jazarī in the year 1206 for and by command of the Urtuqid Sulṭān Maḥmūd, al-Malik aṣ-Ṣāliḥ. This Sulṭān reigned in Āmida from 1200–1222, succeeding his brother Suqmān (1185–1200) and father Muḥammad (1174–1185). The author, Abu'l-'Izz Isma'īl ibn ur-Razzāz ("son of the rice merchant") al-Jazarī (the Mesopotamian) Badī'az-Zamān, "incomparable of the age," had been in the service of the Sulṭāns of Āmida from the year 1181/2, that is, as he himself says in the preface to our treatise (W. H. 1, p. 50), for twenty-five years preceding its completion.

Al-Jazarī writes as follows (W. H., 1, p. 59):

I am in the service of al-Malik aṣ-Ṣāliḥ Nāširu'd-Dīn Abu'l-Faḥ Maḥmūd ibn Muḥammad, ibn Qarā-Arslān, ibn Dāwud, ibn Suqmān, the Urtuqid, king of Diyār Bekr, moreover I have served under his brother and his father before him. Since I entered this service in the year 577 [1181/2], twenty-five years have passed.

One day I brought to Malik aṣ-Ṣāliḥ an object with the preparation of which he had charged me. He looked at me, and considered the work according to my pains; without my remarking upon or emphasizing what I had been aiming at he recognized it and discovered what I had created. He said "You have invented incomparable contrivances and translated them from theory to actuality, so that your labor had not been wasted, and you have united incongruous things. I wish you to prepare a well-arranged treatise in which you shall deal with that of which the actual construction has been your concern."

Since I might not gainsay him, I have applied all my skill thereto and made this treatise.

We infer that al-Jazarī was first and foremost a craftsman, and only secondarily an author. The intelligibility of his writing and the clarity of the diagrams are to be explained by his practical knowledge of the contrivances described. He states that he himself invented the reversible

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cup (see pp. 16, 19) and many other devices. That his labors were greatly appreciated is shown not only by the patronage of three Urtuqīd Sultāns but by the fact that many copies of his treatise were made in the several centuries following its completion, and that translations exist in Persian and Turkish.

It may be mentioned that some of al-Jazarī's clocks were meant to be used in the palaces; others, particularly the candle clocks and portable clocks, in the private rooms. Other clocks described by Ridwān were made for the exteriors of buildings, and gave information to the people at large.

The contents of the whole work are as follows:

- Section 1. On the construction of clocks from which can be told the passage of the regular secular hours (10 chapters). (Translated, W. H., 1.)
- Section 2. On the construction of vessels and figures suitable for use at carousals (10 chapters). (Translated, W. H., 2.)
- Section 3. On the construction of ewers and cups for bloodletting and washing (10 chapters). (Translated, W. H., 4.)
- Section 4. On the construction of fountains in tanks, which change their form; and on perpetual flutes (10 chapters). (Translated in *Berichten der wetterauischen Gesellschaft*, 1908, and *Amari-Festschrift*, 1909.)<sup>1</sup>
- Section 5. On the construction of instruments for raising water from shallow bodies of water, and from running water (5 chapters). (Translated, W. H., 5.)
- Section 6. On the construction of various things of different sorts (5 chapters).  
The first of these chapters describes a door in the Āmida palace. (Translated W. H., 3.)

For the earlier history of water-clocks and other automatic contrivances, and an account of the works of earlier authors on this subject, the introduction to the works of Wiedemann and Hauser (W. H., 1 and W. H. 2) may be consulted. It need only be remarked here that al-Jazarī's work is partly based on the works of Archimedes and Apollonius and on earlier Arabic works, including that of Benū Mūsā, but not directly on the Greek writers, Heron, and Philon of Byzantium (W. H., 1., p. 57).

<sup>1</sup> I have not been able to consult these works, and quote the references at second-hand.

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### III. OTHER MANUSCRIPTS

The most important manuscript of our text is that of Oxford Graveley MS. 27, which has been translated in full by Wiedemann and Hauser (W. H., 1, 2, 3, 4, 5). This manuscript is fully illustrated, the figures corresponding exactly to those of our text, but so far as can be judged from the reproductions (W. H., 1, 2, 3, 4, 5) not nearly so well drawn. The manuscript is dated 1486 and was copied from another manuscript dated 1341.

This manuscript affords an important piece of evidence in respect of the names of Sultāns appearing in the form of inscriptions on certain of the apparatus represented. For although the original text was only completed in 1206 and the Oxford Graveley MS. 27 in 1486, the name of Nūru'd-Dīn Muḥammad (Sultān Maḥmūd's father, r. 1174–1185<sup>1</sup>) is thus represented on one of the principal figures (W. H., 1, p. 50).<sup>1</sup> From this it appears that the illustrations in the manuscript represent contrivances already made or intended to be made for particular Sultāns, and that these illustrations were copied from one manuscript to another, without reference to the Sultān regnant at the time of copying. In other words, these inscriptions, which are no part of the text of the work, do not by themselves offer any evidence of the date of the manuscript, but only of the date of the construction of a particular contrivance.

<sup>1</sup> In W. H., 3, fig. 1, the name is omitted in the reproduction of the drawing of the daqr.

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### IV. DATING OF THE LEAVES IN THE MUSEUM OF FINE ARTS AND ELSEWHERE

We have seen that Dr. Martin assigned the manuscript to the reign of Sulṭān Muḥammad (1174–1185). The date of the completion of the text (1206), however, affords us a *terminus a quo* for the date of any manuscript. M. Blochet (B), probably unaware of the existence of al-Malik aṣ-Ṣāliḥ of Āmida, al-Jazarī's patron, has suggested that our leaves must have been written in Egypt for al-Malik aṣ-Ṣāliḥ Ṣalāḥu'd-Dīn Ṣāliḥ, a Māmluk Sulṭān of Cairo (1351–1354). There are many reasons against this dating. It is hardly likely that the manuscript should have been written for an unimportant Māmluk Sulṭān, and as Dr. Martin points out, the style of the illustrations is tantamount to proof of an earlier date. It is far simpler to accept the obvious, and identify the Sulṭān of the cupola inscriptions with Sulṭān Maḥmūd, al-Jazarī's patron: for if we suppose that the Cairene Sulṭān was intended, what are we to make of the occurrence of Sulṭān Muḥammad's name on certain of the representations?

M. Blochet (B) supports his theory of an Egyptian origin by reference to supposed Egyptian features on the work itself. He regards the technical reference alphabet used in lettering the diagrams as being derived from hieroglyphics. But only one of the signs has a markedly Egyptian character, and many of the others are strongly suggestive of Greek script: the Arabic authors, as we know, made use of Greek texts and it need not surprise us if they also adopted signs of Greek manuscript origin for technical purposes. Even if the Egyptian connection could be established and the existence of a cryptogrammic script based on hieroglyphics and surviving in the 13th century or later could be proved, it need not follow that any manuscript in which they are used must be of Egyptian origin. Egyptian peculiarities might equally well appear, as Dr. Martin suggests, in Mesopotamian art, for the Arabian artists who worked in Egypt under the Fāṭimids, neglected by their successors the Sunnite Aiyūbids, must have spread the influence of Fāṭimid art in Syria, Mesopotamia and Persia, when they sought new patrons. It is true that the scribe of the Oxford Graveley MS. 27 names himself an Egyptian: but in this manuscript, dated 1486, the signs in question no longer occur, but are replaced by

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ordinary Arabic characters. It seems to me that the affinities of the art, as well as of the text, are rather with Byzantium than Egypt, and this also holds good for the technical alphabet.

It is thus apparent that we have no definite evidence of the date of the manuscript from which our six leaves are derived, other than that afforded by the actual material and technique. The fact that the pseudo-hieroglyphic technical alphabet which occurs "in all the older manuscripts" (W. H., p. 52) is used in the lettering of our leaves, while in the Oxford Graveley MS. 27 dated 1486 and other late manuscripts these marks are replaced by ordinary characters, is perhaps sufficient evidence, if this were needed, that our manuscript is relatively early. In any case, from the style of the illustrations, very much like that of the "Dioscorides" manuscript, dated 1222, and those of some other well-known thirteenth-century books, and also from the quality of the paper, we can hardly hesitate to assign the leaves to the thirteenth century. The Nashki script offers no argument to the contrary. It is possible that we have before us leaves of the original manuscript written and illustrated by the author himself for Sultān Maḥmūd.

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### V. DETAILED DESCRIPTION OF THE SIX LEAVES IN THE MUSEUM OF FINE ARTS AND OF TWO OTHERS

#### PLATE I.

The first of the six leaves of the Museum of Fine Arts series (M. F. A. 14.533, pl. I) illustrates a very elaborate water-clock, the first to be described in al-Jazarī's work. It will be best explained in his own words:

"Its exterior forms a structure rising from the ground to about double the height of a man, and containing within itself all that is needful for the determination of the passage of the hours. There is a door in this structure about nine spans high by five and a half spans wide. This door is closed by a wooden or bronze wall. At its top there are twelve doors in a straight line, each door with two wings, which are closed at the beginning of the day. Below and parallel to these are twelve other doors, each with one wing, and all these wings are of the same color when the day begins. Below the doors is a ledge about the width of a finger, projecting from the wall. At the beginning of the ledge will be found a crescent, like a *dinār*. As the crescent passes along the ledge it passes in front of each of the doors until it reaches the end of the ledge. Under the ledge at each end of the wall are two hollows, like niches. In these are two birds with outstretched wings, standing on their feet. Between the two niches are twelve round glass orbs so arranged that they form a semicircle, the convex side of which is uppermost. In front of each of the falcons is a bowl standing firmly on a pedestal projecting from the wall. A cymbal is hung in each bowl.<sup>1</sup>

"Against the wall below there stand various figures, those of two drummers, two trumpeters and a cymbalist. Above the wall is placed a semicircle, convex above, and on its margin may be seen six of the twelve signs of the zodiac; below this is a circle with the sun — a golden orb; and under this a circle with the moon — a glass orb.

"The essentials are now as follows: at the beginning of the day the crescent (in front of the first door) begins its regular imperceptible move-

<sup>1</sup> As the bowl and falcon are not a heraldic device, I have not thought it necessary to refer to the designation *baighu*, or falcon, found in the inscriptions of the Urtuqid Sultāns of Āmida, nor to the use of single and double-headed falcons as heraldic devices in Āmida. The student interested in these matters may refer to B. S., and K.

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ment, until on its way it approaches another door and rests directly between the first and second doors. Then the two wings of the first door open, and there comes out a figure of such sort as it may have pleased the artist to make. It stands there as if it had suddenly appeared, and further, the first door is reversed and takes another color and the birds bend down and approach the bowls. Then they let fall from their beaks two pellets, onto the two cymbals (which are in the bowls), and a ring is heard. Then the birds return to their places. This happens at the end of every hour until the sixth hour is complete; then the drummers drum, the trumpeters blow their trumpets, and for a little while the cymbalist clashes his cymbals. The same thing happens after the ninth and twelfth hours.

“The orbs (of the sun and the moon) play their part as follows: at the beginning of the day the middle point of the sun rests at that point on the zodiac circle in which the sun on the eastern horizon actually is on that day; and this will rise while the opposite point will sink. Every time that a point of the zodiac circle rises, the corresponding point sinks. The sun climbs upward till midday, then sinks until the end of the day. The sun's centre then sinks. The six signs of the zodiac which rose now sink, and the six which sank now rise. According to the time, the sun stops at various heights. If it is the day of the Crab (for example), the sun reaches its highest point; if that of the Buck, its lowest position.

“At night the moon is seen in its proper zodiacal sign in that state of its figure which it has on that night. If it be crescent, this gradually changes to the full moon; if it is full moon, it passes gradually into new moon.

“Further, at the beginning of the night a light begins to shine in the first glass orb, as large as a nail paring; this light grows till the whole orb is filled with light. Then one hour of the night has passed. The same thing happens in one orb after the other up to the sixth. Then the band performs its duty by night as it did by day; and similarly after the ninth hour, and the twelfth hour, which ends the night; then all the orbs are fully lighted.”

The red Kūfic characters in the first door read *Alāihi'ṣ-ṣalāt* (On Him be blessing).

The lettering on the two bowls reads '*Iz li-maulānā' as-sultān al-mālik* (Glory to our master the Sultān regnant).

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The large letters in gold at the top of the page read *va hāzihi šūrat fi auṣaftuhu vādhatan* (and this picture I have drawn clearly).

The heading in gold at the back of the leaf is the title of the second part of the first chapter. In al-Jazarī's complete text there follow nine parts of this first chapter of the first section of the book, describing in great detail the mechanical devices by which a flow of water is made to operate the clock. It will be observed that the picture represents the clock with the sun in Aries and as indicating that the first hour of the day has elapsed.

### PLATE II.

The second leaf, M. F. A. 14.532, pl. II, in the Museum of Fine Arts series, is an illustration of the "Beaker-Clock" described in the fifth chapter of the first section of al-Jazarī's book; he mentions that it was made at the command of Sulṭān Maḥmūd, and describes the clock as follows:

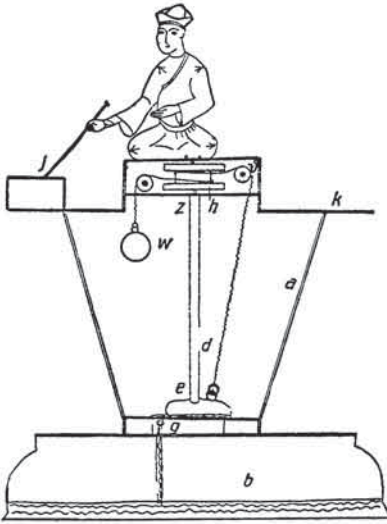


FIGURE 1. Mechanism of the Beaker-Clock. From Oxford Graveley MS 27, after W. H

"The clock consists of a beaker on a stand, covered above by a flat lid. Round the margin of this lid there runs an engraved parapet, and on the parapet rests an elegant horizontal ring divided into  $217\frac{1}{2}$  parts; every fifteen parts correspond to an even hour. In the middle is seated a scribe, holding in his hand a writing rod, the end of which rests upon the ring a little outside the first dividing line. From the beginning of the day onwards the rod moves regularly and im-

perceptibly to the left, until it reaches the first division of the fifteen divisions of each equal hour; and so goes on, division by division, until an hour of the day has passed."

The works and the water by which they are operated are contained in the beaker itself.

The text on the front of the page states that "the reservoir will hold water for about fourteen hours." The text at the back begins, "It is made from pieces of copper and hammered till it becomes a cup small at the bottom and broad at the top."

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The accompanying figure (W. H., 1, fig. 70) from the Oxford manuscript sufficiently explains the interior construction: when the vessel is full, the float is at the top, the weight at the bottom; and as the water flows out, the float sinks and the weight rises, causing the spindle to revolve.

### PLATE III.

The third leaf, M. F. A. 15.113, pl. III, is an instrument for use in blood-letting, to measure the amount of blood drawn; it is described in the sixth chapter of the third section of al-Jazarī's work (W. H., 4). It consists of a shallow bowl, from within which there rise four columns (two of which are shown, in section, in the picture). In the base of the bowl is set a pipe which opens into the chamber below; and within the bowl, the opening of the pipe is covered with a perforated dome. The two hollow columns communicate with the chambers forming the base of the instrument. Above, they support a hollow chamber, like a roof, upon which are seated two scribes. Through the left hand column runs a measuring rod, having a float attached to its lower end (in the chamber which forms the right hand half of the base of the instrument); passing upwards through the body of the right hand scribe, it terminates in the writing tablet which the scribe holds. A hundred and twenty figures are marked on this tablet, and as the tablet is pushed upwards by the blood which enters the lower chamber, a reed held in the scribe's right hand indicates upon this scale of numbers the corresponding amount of blood. There is also a thread attached to the float, and this thread, rising alongside the rod through the column, passes round a spindle in the upper chamber and thence down through the left hand column, and has attached to it a weight which hangs in the left hand chamber of the base of the instrument. The second scribe, seated to the left, rotates upon the axis of the spindle, and he, with his reed, measures on a horizontal scale, the same quantity of blood which has entered the lower right hand chamber. The total height of the instrument would be about sixty-five centimetres (the depth of the upper chamber being equivalent to the width of four fingers): the scales register from one to a hundred and twenty *dirhams* of fluid.

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### PLATE IV.

The fourth leaf, M. F. A. 15.114, pl. IV, in the Museum of Fine Arts series, represents the ninth apparatus described in the second section of al-Jazarī's work. His description is as follows (W. H., 1, p. 88 and fig. 23):

"It consists of a throne with two men: each has a cup and a flask from which he pours out wine into the cup held by the other, which the latter then drinks.

"The dark-skinned men sit facing each other on the longer side of a rectangular throne, with a floor of copper and four angular feet of cast bronze. Each holds in his right hand a cup, and in his left a flask of which the neck is grasped by the palm of the hand and the fingers. The mouth of the flask is in each case directed downwards towards the cup of the man sitting opposite. The middle pieces of the corner posts of the throne are about four fingers long. The side walls of the throne rest on these middle pieces. They consist of brass plates; between them there is soldered a broader plate to form the floor, so that the throne forms a receiver for the wine which is drunk by the two figures. An engraved and painted railing goes round the throne. At the four corners of the throne stand four high brass pillars somewhat under two spans long. They support a "castle" about a span in height, whose lower surface is of the same shape as the throne. The "castle" is closed in by engraved pewter plates, and on its flat roof there rises an elegant dome, with a diameter corresponding to the middle of the "castle." This empty dome is filled from the container which holds the water to begin with; this container is filled through a slit at the top, which is, to all appearances, closed by a removable knob on the dome. The fluid flows through a short tube of narrow bore set in the middle of the floor of the dome along the channel, a finger wide and as light as possible. This channel is balanced in the middle on a partition which bisects the copper trough that occupies the floor of the "castle," and is about the height of two fingers side by side. Here the channel is set between two rods, each a thumb long, by means of a pivot soldered below into the space between the two rods. Inasmuch as this pivot is on the under side of the channel, the latter is in unstable equilibrium, so long as neither end is disturbed. It inclines accordingly to right or left till it rests on the edge of one of the two reversing cups, which contain

## AL-JAZARI'S TREATISE ON AUTOMATA

about twenty *dirhams* of water. Now let it rest on the right-hand cup. Then the fluid runs along it into this reversible cup, placed on the right-hand side of the partition. When it is full, it tips up and empties itself into the right-hand half of the trough. In tipping over, its rear edge lifts up the right end of the channel, and this then rests with its left end on the inner edge of the left-hand reversible cup. Now the fluid flows into this cup, till it is full and upsets, about every eighth part of the hour.

“Meanwhile the fluid which has been poured into one half of the trough flows out through a tube which goes down in one of the two pillars, right or left as the case may be. Below the floors on which the figures are seated, each of these tubes is bent, running under the floor till it reaches the nearest figure. Within this figure it rises up and finally opens into the neck of the flask as in the picture described above. Thence the drink flows into the cup of the figure seated opposite. The latter drinks from the cup, which he raises to his head several times. All this is accomplished by the mechanism described above, and which we came to in the ninth picture. The fluid which has been drunk flows through the empty body of the drinking figure into the container of the throne, where it accumulates. It can be removed from this container by means of a hole in the floor of the throne.”

The reading of the cupola text, already referred to more than once, is as follows:

“*Izz li-maulānā as-sultāni al-mālik al-malik aṣ-ṣālihi aṣli va'd-dunyā va'd-dīn*” (Glory to our Master, the Sultān Regnant, al-Malik aṣ-Ṣāliḥ, the Root of the State and Church).

These are the titles of Sultān Nūru'd-Dīn Maḥmūd of Āmida, for whom al-Jazarī prepared his text and for whom the automaton in question must have been designed.

### PLATE V.

The fifth leaf, M. F. A. 22.1, pl. V, is the peacock apparatus for washing the hands (on ordinary occasions, or for religious purification) described in the ninth chapter of the third section of al-Jazarī's treatise.

The body of the peacock is filled with water; the ring at the tip of the tail is attached to a plug which closes the body chamber, preventing the entry of air, so that no water can flow out until the plug is lifted by pulling

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the ring. The peacock stands on a "castle," consisting of a chamber which rests on four columns standing in a basin which rests on a hollow base. The dirty water flows into this hollow base and can afterwards be drawn off by the faucet.

The chamber ("castle") below the peacock has two doors side by side, each with two swinging wings opening very easily. The doors cannot be seen in the picture. Behind the first door (nearest to the spectator, and represented in the picture) stands a servant holding a bowl of alkaline vegetable ashes, used as soap. When water enters the base of the apparatus, it pushes up the lower float, and this raises the rod attached to it and pushes up the board on which the servant stands, so that the door opens and he emerges offering the "soap" for the king's use. Behind the second door stands another servant (not shown in the picture) with a towel. When still more water has entered the lower chamber (and by this time most of the water in the peacock has been used, and the king will have completed his ablutions) the second float, which is attached to a shorter rod, will also be raised, and in the same way as before the second figure with the towel will emerge. When the dirty water is drawn off, the two floats fall and the figures retire. The total height of the apparatus would be about six spans.

### PLATE VI.

The sixth leaf, M. F. A. 15.534, pl. VI, represents an apparatus for raising water by animal power; it is described in the second chapter of the fifth section of al-Jazari's treatise (W. H., 5).

As the mule progresses round and round the upright to which it is attached, the horizontal toothed wheel below revolves, and interlocking with the vertical toothed wheel seen on the right hand side of the picture, causes the horizontal rod to which this wheel is attached, to revolve in turn. This rod carries four wheels, each of which is toothed on one quarter of its circumference only, the wheels being so arranged that the four sets of cogs point in four different directions. One revolution of the donkey causes each of these four wheels in turn to interlock with the corresponding vertical wheel below it (these wheels look like ladders in the picture); thus each section of the lower horizontal rod (which consists of four parts separately movable) revolves in turn. Now to each of these rods is attached a

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kind of scoop, the bowl of which is immersed, while the open channel end projects above the rod. When the rod revolves, the bowl is raised, that is to say, towards the observer and upwards; when the bowl reaches the level of the rod, the water flows back along the channel and escapes at the end into the area to be irrigated, or into an irrigation canal prepared to receive it. Then the empty bowl, released as the last cog leaves the wheel, falls back to be refilled. Al-Jazarī prides himself upon the fact that by means of this device the donkey is made to work all the time, each quarter turn raising one scoopful of water; whereas in the single apparatus described in the first chapter of the same section, the donkey raises only one scoopful in a complete revolution, and works only a fourth part of the time. The text at the back of the picture begins *idār dubāb kazā* "and the revolution of the dubāb (water-wheel) is thus."

### PLATE VII.

The seventh leaf, pl. VII, in the collection of Dr. Paul J. Sachs, represents an apparatus for raising water from a flowing stream to a height of about twenty ells: it is described in the fifth section of the fifth chapter of al-Jazarī's treatise (W. H., 5). The horizontal rod, a little above the middle of the picture, carried a paddle wheel and a cogwheel (working at right angles to the plane of the picture). The latter interlocks with a cogwheel below it, set at right angles to it, and eccentrically mounted. The supporting rod with which this wheel revolves works in a fixed socket at one end, in an open ring at the other; and as it does not pass through the centre of the wheel, this rod itself makes a circular movement as the wheel revolves. This circular movement is translated into a to and fro movement as follows: another rod is pivoted to the base of the triangular box, in which the wheel works and into which the two pumps are built, and this rod has in its upper part a slit, as long as the diameter of the circle described by the rod carrying the wheel; so that with each revolution of the wheel the rod moves to and fro. By this means the pistons of the two pumps are alternately driven in. The piston chambers communicate with upright pipes, open to the water below and continuing above in narrower pipes which meet above the paddle wheel. Valves in these uprights, level with the top and bottom of each piston chamber allow only of the upward

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passage of water. The outlet tube extends for some twenty ells above the junction of the two pipes, and narrows towards its opening, so that when the paddle wheel revolves, water is forced upwards under pressure and issues in a fountain.

### PLATE VIII.

The remaining leaf, pl. VIII, in the Fogg Art Museum (Wetzel Collection), represents the tenth apparatus described in the second section of al-Jazarī's work. His description is as follows (W. H., 2, p. 91):

"A girl who comes out of a chamber at regular intervals; she holds a cup of wine in her hand.

"It consists of a wooden house like a sentry-box, having four feet, painted all over, about seven spans in height and two and a half in width, on the top of which is a copper dome, tinned inside, about a span in height, serving as a wine-holder. This dome has an opening at the top for pouring in the wine; a wide tube, covered by a lid, is soldered into this opening. There is a small opening in the middle of the base of the dome, through which the wine drops into a reversible cup holding a hundred *dirhams* of wine. This reversing cup is placed in a container below the dome. About every eighth part of an hour the reversing cup is filled, tips over, and empties its contents into the said container. Thence it runs through a short tube set in an opening in the floor into the glass drinking cup, held in the right hand of the figure, which is that of a girl of about twenty years of age, is hollow, and as light as possible. This hand and the forearm belonging to it are made of thin copper, while the figure itself is made of paper fortified by *gesso*. The right arm is movable at the elbow joint about a pivot fixed within the sleeve of the garment: it can turn through an angle corresponding to the amount of free play allowed by the sleeve. The forearm has also a backward extension, in the form of a bar which emerges from a slit in the back of the figure of about a finger's length. The end of this extension is bent into a hook of which the point is directed downward. When the forearm is in its highest position, this hook engages with a horizontal iron rod fastened to the side wall of the house, thus holding the figure fast against the back wall, for the extension with the hook is heavier than the forearm with the empty cup. But when the latter is full, the forearm is the heavier and falls into its lowest position, the hook

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is disengaged from the iron rod, and the figure rolls out of the house down the slightly forward sloping plane of the base. To facilitate this movement there is a support for the feet, about two spans in length and as wide as the foot is long, provided with rollers at the four corners. The rollers are of cast bronze and of such size as to be grasped by the thumb and forefinger. They are of a thumb's thickness in the middle; at the edge they are only as big as a barleycorn. The rollers run in two copper grooves in the floor of the house.

“When the figure rolls down, its outstretched left hand opens the double doors of the house, which are about four and a half spans in height and move easily on their hinges; for it pushes against the left wing of the door, and this carries with it the right wing, which engages with the left wing when the door is shut.

“The figure comes into view only when the doors are thus opened; it rests within the threshold and offers to the king,<sup>1</sup> who sits by the door, the full cup. In its left hand it holds a handkerchief with which the king may wipe his mouth after drinking. The king returns the empty cup and the handkerchief into the hands of the figure, and pushes it back into the house, where, by the rising and falling of the right hand, the figure makes the hook to fasten; and at the same time it closes the doors. The performance begins again and is repeated until the dome is emptied.”

<sup>1</sup> The house is supposed to be placed on the ground beside the king at a feast or carousal.

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<sup>1</sup> All of these works except d. V., B. M., d. V., J. A., W. H., 6, and W. H., 7, are to be found in the library of the Museum of Fine Arts.

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### PLATES

- Plate I. M. F. A. 14.533. A Water-Clock. No. 1 of the first section of al-Jazarī's treatise. Previously published: M., pl. I and M. V., pl. II. Bartlett Fund and special contribution.
- Plate II. M. F. A. 14.532. The Beaker Water-Clock. No. 5 of the first section of al-Jazarī's treatise. Previously published: Sch., pl. III; M. F. A. Bulletin, No. 74. Bartlett Fund and special contribution.
- Plate III. M. F. A. 15.113. An instrument for use in blood-letting, to measure the amount of blood drawn. No. 6 of the third section of al-Jazarī's treatise. Not previously published. Gift of Dr. Denman W. Ross.
- Plate IV. M. F. A. 15.114. An automaton, representing two men drinking, being No. 9 of the second section of al-Jazarī's treatise. Previously published: S. M., pl. III and B., fig. 9. Gift of Dr. Denman W. Ross.
- Plate V. M. F. A. 22.1. A peacock, used for washing the hands. No. 9 of the third section of al-Jazarī's treatise. Previously published: B., fig. 6. Hervey E. Wetzel Bequest.
- Plate VI. M. F. A. 15.534. A *dubāb* or water wheel. No. 2 of the fifth section of al-Jazarī's treatise. Not previously published. Bartlett Fund and special contribution.
- Plate VII. The leaf belonging to Dr. Paul J. Sachs. An apparatus for raising water from a flowing stream to a height of about 20 ells. No. 5 of the fifth section of al-Jazarī's treatise. Detail of a mechanism by which a flow of water operates a wheel. Not previously published.
- Plate VIII. The leaf in the Wetzel Collection, Fogg Art Museum. A girl who serves a cup of wine at regular intervals. Previously published: Sch., pl. III and B., fig. 4.



الجانات بالقبوة وهلك صورة ما وصفته واصحته



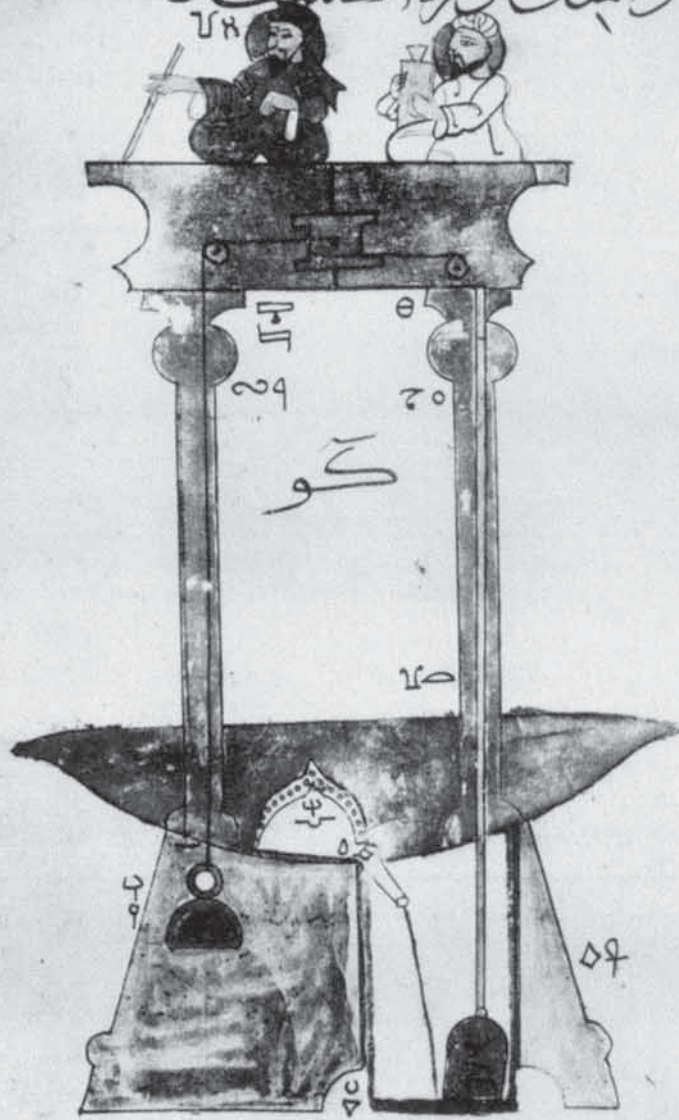






أول عدد من أعداد الدائرة والمخنة فارغة والعوامة في أرضها

وأمثلة صورة الطشت ٥





بين الحوضين وعليهما شطيتان وعليهما كس والميزان  
 يتحرك على محور طرفاه في تقبي الشطيتين وعليه كس وانوب  
 قصير يقطر منه الماء الى الميزان من اسفل الخزانة وعليه قف  
 والخزانة وعليها كس

