Science and Technology
in Islam

V

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Arabic-Islamic Science

Edited by
Fuat Sezgin

Science and technology in Islam

V

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Institut für Geschichte der Arabisch–Islamischen Wissenschaften
an der Johann Wolfgang Goethe-Universität
Frankfurt am Main

SCIENCE AND TECHNOLOGY IN ISLAM

VOLUME V

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of instruments of the Institute for the History
of Arabic and Islamic sciences

by

Fuat Sezgin

in collaboration with

Eckhard Neubauer

Translated by

Renate Sarma

and

Sreeramula Rajeswara Sarma

10. PHYSICS AND TECHNOLOGY
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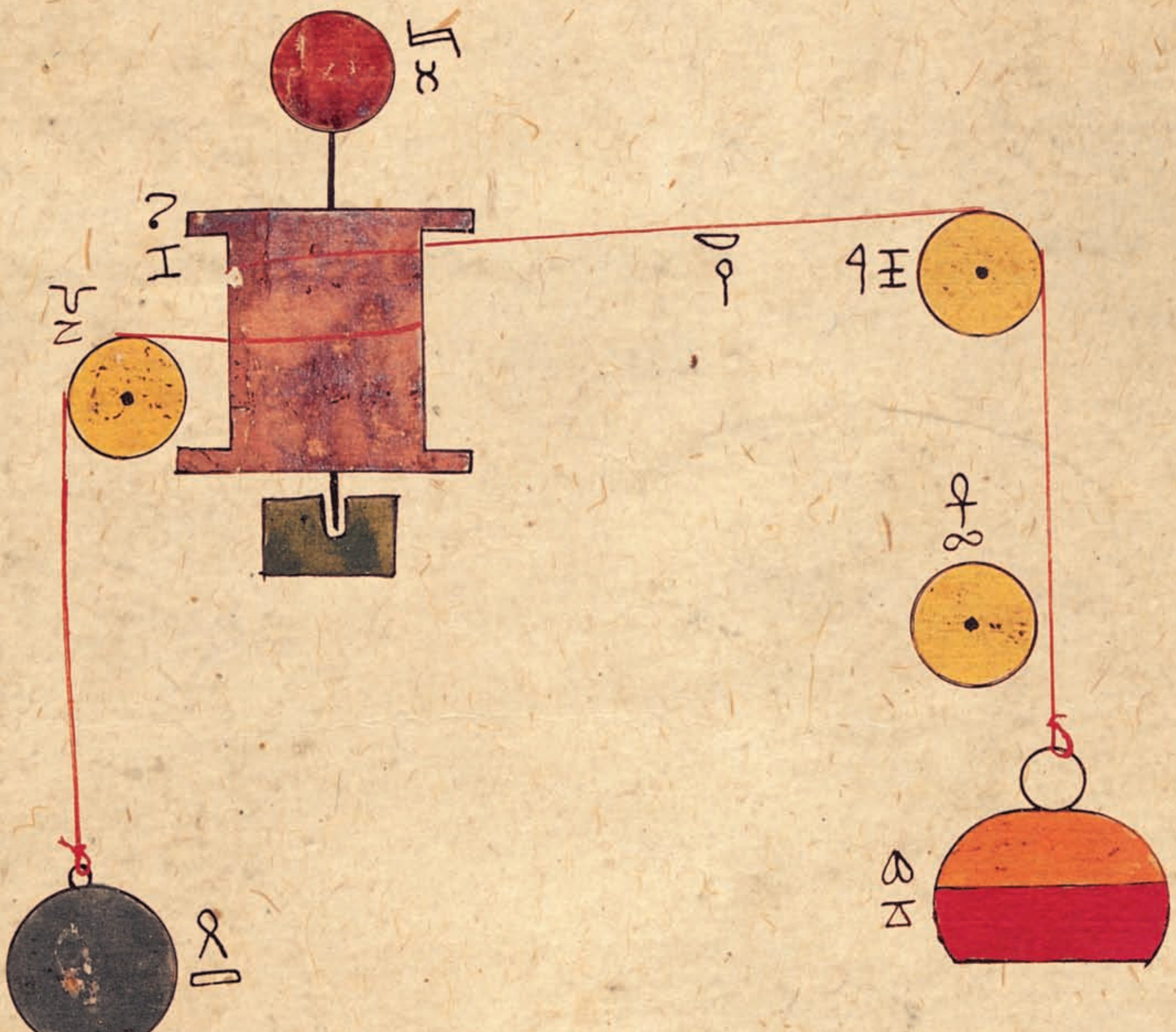


Chapter 10

Physics & Technology

Weighing Balances

"All the weighing balances occuring in Antiquity and the Middle Ages are lever balances and consist of a beam (*'amūd*, also *qaṣaba*) that can be turned around a horizontal axis (*miḥwar*), that is to say, a lever whose centre of gravity lies below the axis. The object to be weighed (the load) is suspended from one arm of the beam, and the weights which weigh it are suspended from the other, usually in pans. Here the arms can be of equal length or not; thus the balances are of equal arms or of unequal arms."[1]

"While dealing with the theory of balances we have to consider first the definition of the heavy and light bodies, the determination of the centre of gravity, that of the stable, the unstable and the indifferent equilibrium caused by the opposite positions of the centre of gravity and the fulcrum, the investigation of the question of any likely impact when the loads are attached directly to the lever arm itself or to staves connected to this lever, staves which are perpendicular to the beam and are inclined towards it."[2]

There can be no doubt that the Arabs possessed a functioning form of balances before the advent of Islam and in Early Islam. They also make no secret of the fact that they borrowed the theoretical discussion of balances from the Greeks. In the middle of the 3rd/9th century, the author and natural philosopher al-Ǧāḥiẓ mentions the steelyard or the Roman balance (*qarasṭūn*) among the objects inherited from the Greeks.[3]

Al-Qarasṭūn (χαριστίων) "is a two-armed, unequally armed lever whose point of gravity lies under the fulcrum. The object to be weighed, the load G_1, is situated on the shorter arm at a distance of l_1 from the fulcrum; the weight G_2 that serves for the weighing, viz. the sliding weight (*rummāna*), can be moved on the longer arm. When equilibrium is achieved at a distance l_2, then $G_1 \bullet l_1 = G_2 \bullet l_2$ or $G_1 : G_2 = l_2 : l_1$, i.e. at equilibrium the weights G_1 and G_2 are inversely proportionate to the distances $l_1 : l_2$."[4]

The law of the lever, which was apparently first formulated by Archimedes, appears to have been recognized in its full significance in the Arab-Islamic world from the 3rd/9th century, perhaps even from the 2nd/8th century. Although the Arabic works written on this subject in the 3rd/9th century are all lost but for a few, among the survivals of the genre which have been made available to research so far there is one of their most important representatives. It is the *Kitāb al-Qarasṭūn*[5] by Ṯābit b. Qurra (d. 288/901), one of the greatest scholars of the Arab-Islamic world.[6] Like many of his writings, this book by Ṯābit b. Qurra also had a considerable impact in its Latin translation in the West, even though the most important achievement of the author is lost on the reader because of the inaccuracy of the translation. It is his line of argumentation which, in its conclusion, leads to the concept of the infinitely small, a method of studying the infinitesimal processes which was unknown to the Ancients.[7]

The advances made in the theoretical discussion and in the practical achievements in dealing with the weighing balance in the Arab-Islamic region until the beginning of the 6th/12th century can be traced, thanks to the excellent extant work on the *mīzān al-ḥikma*, the "Balance of Wisdom" by 'Abdarraḥmān al-Ḫāzinī (written 515/1121).[8]

[1] Eilhard Wiedemann, *ḳarasṭūn* entry in: *Enzyklopädie des Islām*, vol. 2, Leiden and Leipzig 1927, col. 810 b.

[2] ibid., col. 811 a.

[3] *Kitāb al-Ḥayawān*, ed. 'Abdassalām Hārūn, vol. 1, Cairo 1938, p. 81; E. Wiedemann, op. cit., col. 811 b.

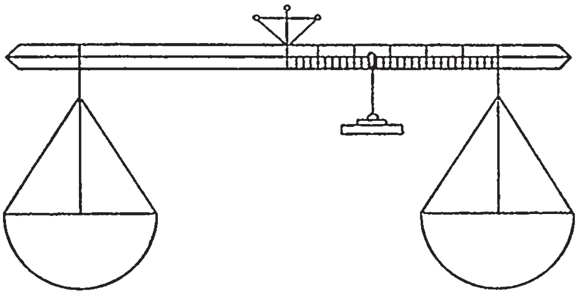
[4] E. Wiedemann, op. cit., col. 811 a.

[5] Ferdinand Buchner, *Die Schrift über den Qarastûn von Thabit b. Qurra*, in: Sitzungsberichte der Physikalisch-medizinischen Sozietät (Erlangen) 52–53/1920–21/141–188 (reprint in: Islamic Mathematics and Astronomy, vol. 21, Frankfurt 1997, p. 111–158); Khalil Jaouiche, *Le livre du qarasṭūn de Ṯābit ibn Qurra. Étude sur l'origine de la notion de travail et du calcul du moment statique d'une barre homogène*, Leiden 1976.

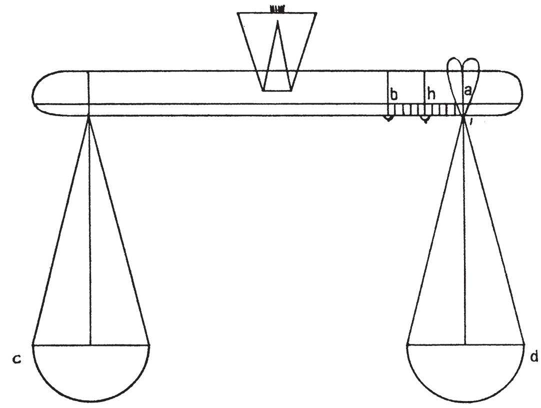
[6] F. Sezgin, *Geschichte des arabischen Schrifttums*, vol. 3, pp. 260–263; vol. 5, pp. 264–272; vol. 6, pp. 163-170.

[7] F. Buchner, op. cit., p. 162–163 (repr., op. cit., pp. 132–133).

[8] Nicolas Khanikoff, *Analysis and extracts of* Kitāb Mīzān al-ḥikma [en arabe dans l'original] *"Book of the Balance of*



mīzān Aršimīdis after al-Ḫāzinī (Th. Ibel, *Die Wage*, p. 52).



The ‹physical balance› described by ar-Rāzī[12] (Th. Ibel, *Die Wage*, p. 154).

[4] The work also gives a rather good overview of the preceding literature on the subject. At first al-Ḫāzinī describes a balance designated as Archimedean (*mīzān Aršimīdis*).[9] It is “a common equal-armed balance with two equal pans, the left pan for gold and the right one for silver. On the right arm a weight slides in order to create the equilibrium.”[10] The decisive factor for a continuous development both in the technical and in the literary field was the testing of gold, silver and other metals and their alloys. The balances serving this purpose with sliding pans and sliding weights, which were undoubtedly based on the Archimedean tradition, led to the concept of “physical balance” (*mīzān ṭabīʿī*). The physician and natural philosopher Abū Bakr Muḥammad b. Zakarīyāʾ ar-Rāzī (d. 313/925)[11] was probably the first person in the Islamic world to make use of these balances.

Wisdom”, an Arabic work on the water-balance, written by al-Khâzinî, in the twelfth century, in: Journal of the American Oriental Society (New Haven) 6/1860/1–128 (repr. in: Natural Sciences in Islam, vol. 47, Frankfurt 2001, pp. 1–128); Thomas Ibel, *Die Wage im Altertum und Mittelalter*, Erlangen 1908, pp. 73–162 (repr. in: Natural Sciences in Islam, vol. 45, Frankfurt 2001, pp. 77–166); C. Brockelmann, *Geschichte der arabischen Litteratur*, 1st suppl. vol, p. 902. The text was published in Hyderabad 1940, after a manuscript from a mosque in Mumbai (repr in: Natural Sciences in Islam,vol. 47, Frankfurt, 2001 pp. 219–510).

[9] *Mīzān al-ḥikma*, ed. Hyderabad, pp. 78–79 (repr., op. cit., pp. 392–395).

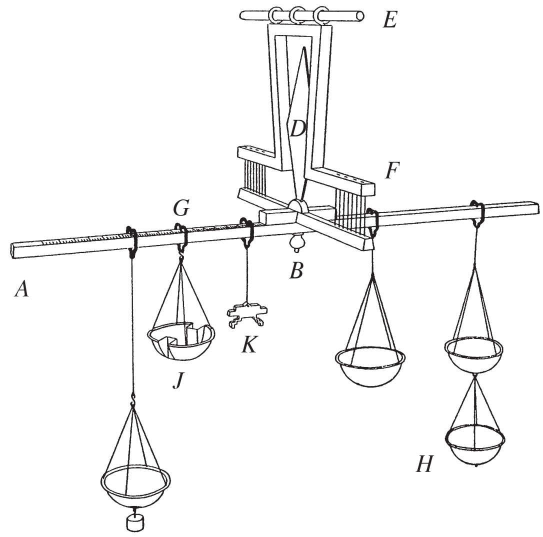
[10] Th. Ibel, *Die Wage*, p. 51 (repr., op. cit., p. 55).

[11] v. F. Sezgin, *Geschichte des arabischen Schrifttums*, vol. 3, pp. 274–294; vol. 4, pp. 275–282, 345; vol. 5, pp. 282, vol. 6, pp. 187–188, vol. 7, pp. 160, 271–272.

[12] Al-Ḫāzinī (Arabic text, Hyderabad, p. 83, repr., p. 386) quotes ar-Rāzī’s description in the following way: “For the determination of each body and its excess of [weight] over another body and for determining this characteristic through the physical balance, we take a balance that has been tested as carefully as possible; the expression “careful testing of the balance” means that we take two weighing pans which hold the same volume of water and that we make them equal in weight, to be precise, in such a manner that we file off something from the outside, and not by cutting off something from it because then we would reduce its capacity for holding. When both pans are equal, we take a uniform, carefully tested beam; the entire beam has the shape of the *qabbān* (steelyard) which is made in a convex shape. Then we suspend one of the pans from it. We assign a place to the second pan at the end of the beam, this one being suspended by means of the ring through the end of the thread on this pan. The ring has a pointed end.” (Translated from Th. Ibel, *Die Wage*, op. cit., p. 153; repr., op. cit., p. 157). “On the scale pan at the left it says ‹pan for silver, it is fixed›, on the right pan ‹pan for gold, it is movable› … The substance to be weighed is placed in the fixed pan, in the movable pan a weight that corresponds to it. The fixed pan is now submerged in water and the sliding pan is moved so long, approximately up to h, until the balance is again at rest. Once we have thus established the point a or b where the pan rests if pure silver or pure gold is used, then the amount of alloy can be easily determined. If for the experiment with the alloy the pan is at *h*, then the proportion of the amount of gold to that of silver is like *ah* : *hb* ” (Th. Ibel, *Die Wage*, op. cit., p. 154; repr., op. cit., p. 158). Al-Ḫāzinī (Arabic text, Hyderabad, between pp. 86 and 87, repr., p. 380) gives a second illustration of ar-Rāzī’s balance. It apparently shows the alternative use of iron weights (cf. Th. Ibel, Die Wage, op. cit., p. 154; repr., op. cit., p. 158).

The ‹Balance of Wisdom›

(*mīzān al-ḥikma*)



The ‹balance of Wisdom› (*mīzān al-ḥikma*) of al-Ḫāzinī, after the *Encyclopédie de l'Islam*, vol. 3, column 611 (art. *mīzān*).

Our model:
Total height: 135 cm.
Brass, partly gilded, with ornamentation.
Balance beam (Momentenarm) with engraved millimetre scale and numbers, length: 98 cm.
5 gilded scale pans besides the weight.
(Inventory No. E 1.01))

The highest stage in the development of balances proves to be the actual "Balance of Wisdom" (*mīzān al-ḥikma*) which was developed around 500/1115 by Abū Ḥātim al-Muẓaffar b. Ismāʾīl al-Isfizārī[13] and perfected by his contemporary ʿAbdarraḥmān al-Ḫāzinī.[14]

"Al-Ḫāzinī gives the beam *A* of the balance (see fig. above) a thickness of 6 cm and a length of 2 m. In the centre it is strengthened by an additional piece *C*, obviously intended to avoid any bending at this point. *A* cross-piece *B* (*ʿarīḍa*) is let in here. Corresponding to it is a similar cross-piece *F* on the lower part of the fork, in which the tongue *D* moves, itself about 50 cm long."

[13] v. al-Baihaqī, *Taʾrīḫ ḥukamāʾ al-islām*, Damascus 1946, pp. 125–126; C. Brockelmann, *Geschichte der arabischen Litteratur*, 1rst suppl.-vol., p. 856. His book on balances with the title *Iršād ḏawi l-ʿirfān ilā ṣināʿat al-qabbān* is preserved in an incomplete manuscript, Cairo, Dār al-kutub al-miṣrīya, riyāḍ. 1021 (9 ff.).

[14] C. Brockelmann, *Geschichte der arabischen Litteratur*, suppl., vol. 1, p. 902.

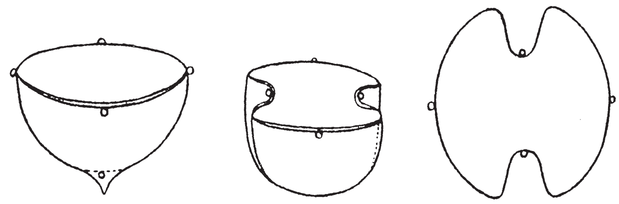


Fig. 5a Fig. 5b Fig. 5c

Scales after al-Ḫāzinī, in: *Enzyklopädie des Islam*, vol. 3, col. 611 (art. *mīzān*).

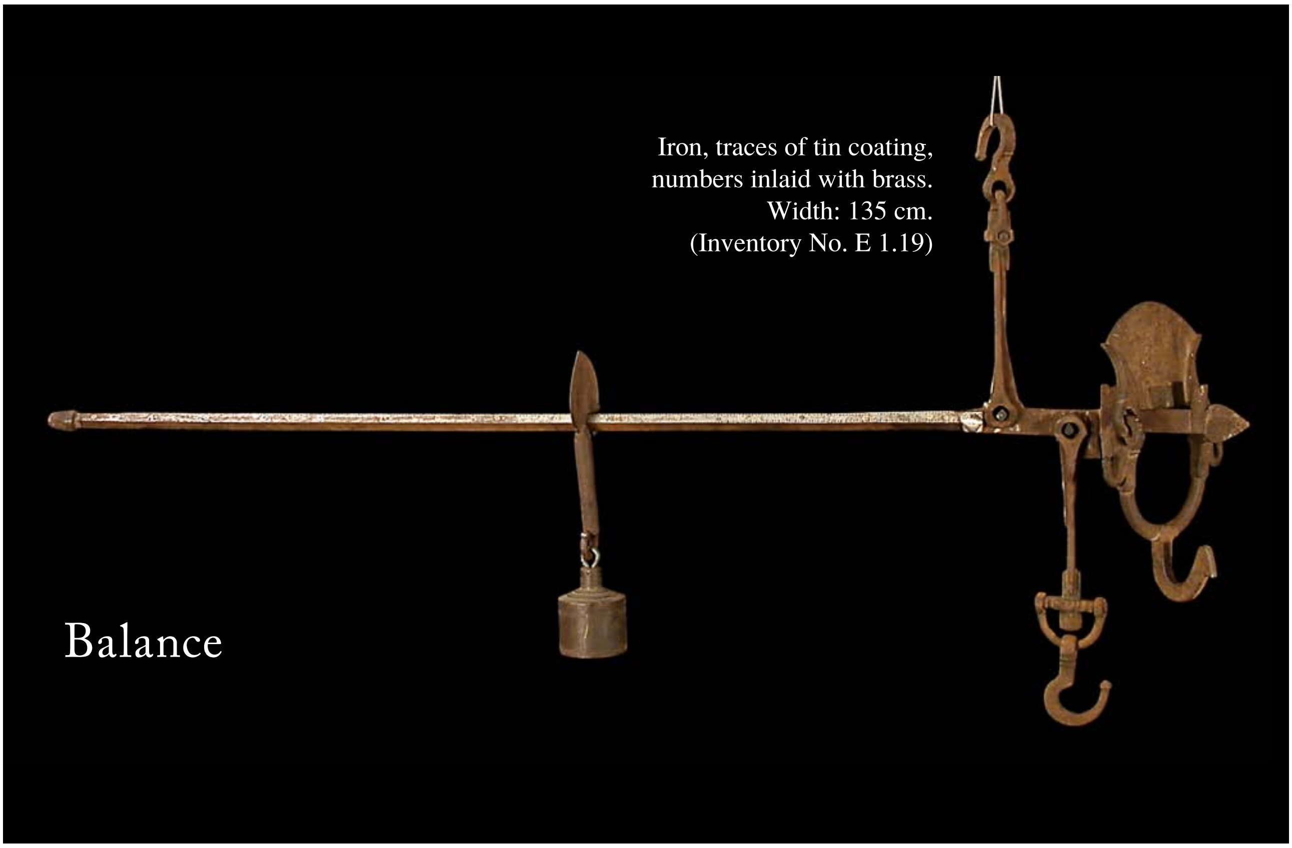
"The upper cross-piece *E* is hung by rings to a rod which is fastened in some way. Pegs or small holes are placed at exactly opposite places of the cross-pieces *B* and *F*, to which threads are tied or drawn through. The friction at an axis is thus avoided, which, in view of the great weight of the beam, is quite considerable. The knob visible below the beam under its centre is used to secure the tongue to the beam or to take it out in order to adjust it evenly. The tongue has for this purpose a peg at the foot which goes through a hole in the beam. Al-Ḫāzinī also observes that shorter beams could also be taken, but then all the other dimensions must be proportionately smaller. The beam is divided not on one side only, as in the illustration, but on both. The scales are hung on very delicate rings of steel (*ġurāb*, "ravens"), the points of which fit into little niches on the upper surface of the beam."

"Five scales are used in ascertaining specific gravities, i.e. in investigating alloys and examining precious stones. Of these, the scale *H* (fig. 5a) is called the cone-shaped or *al-ḥākim*, ‹the judge›, as it is used to distinguish false from true. It goes into the water, and in order to meet less resistance in sinking, is cone-shaped and pointed below. The scale *J* is called the winged one (*muğannaḥ*) (fig. 5b and 5c, side and top view)."

"It had indented sides so that it can be brought very close to the adjoining scales. It is also called the moveable piece (*munaqqal*). There is also a moveable running weight *K* (*rummāna saiyāra*) which serves, if necessary, to adjust the weight of the lighter beam; it is therefore also called the *rummāna* of the adjustment (*taʿdil*). The other scales are used to hold weights. Al-Ḫāzinī attained an extraordinary degree of accuracy with this balance. This was the result of the length of the beam, the peculiar method of suspension, the fact that the centre of gravity and axis of oscillation were very close to each other and of the obviously very accurate construction of the whole. Al-Ḫāzinī himself says that when the instrument was weighing 1,000 miṯqāls, it could show a difference of 1 *ḥabba* = $1/68$ *miṯqāl*, i.e. about 75 cg. in 4.5 kg. We thus have accuracy to $1/60000$."

"Al-Ḫāzinī used his scales for the most varied purposes. Firstly, for ordinary weighing, then for all purposes connected with the taking of specific gravities, distinguishing of genuine (*ṣamīm*) and false metals, examining the composition of alloys, changing of dirhams to dīnārs and countless other business transactions. In all these processes, the scales are moved about until equilibrium is obtained and the desired magnitudes in many cases can at once be read on divisions on the beam."[15]

[15] Eilhard Wiedemann, article *al-mīzān* in: Encylopaedia of Islām, new edition, Leiden and New York 1993, vol. 7, pp. 197 a-198 a; al-Ḫāzinī, *Mīzān al-ḥikma*, ed. Hyderabad 1359/1940, pp. 92 ff., repr., op. cit., from p. 367 backwards; abridged English translation: C. N. Khanikoff, *Analysis and Extracts of ..., Book of the Balance of Wisdom ...* in: Journal of the American Oriental Society (New Haven) 6/1860/1-128; Th. Ibel, *Die Wage*, op. cit., pp. 112 ff.; repr., op. cit., pp. 116 ff.

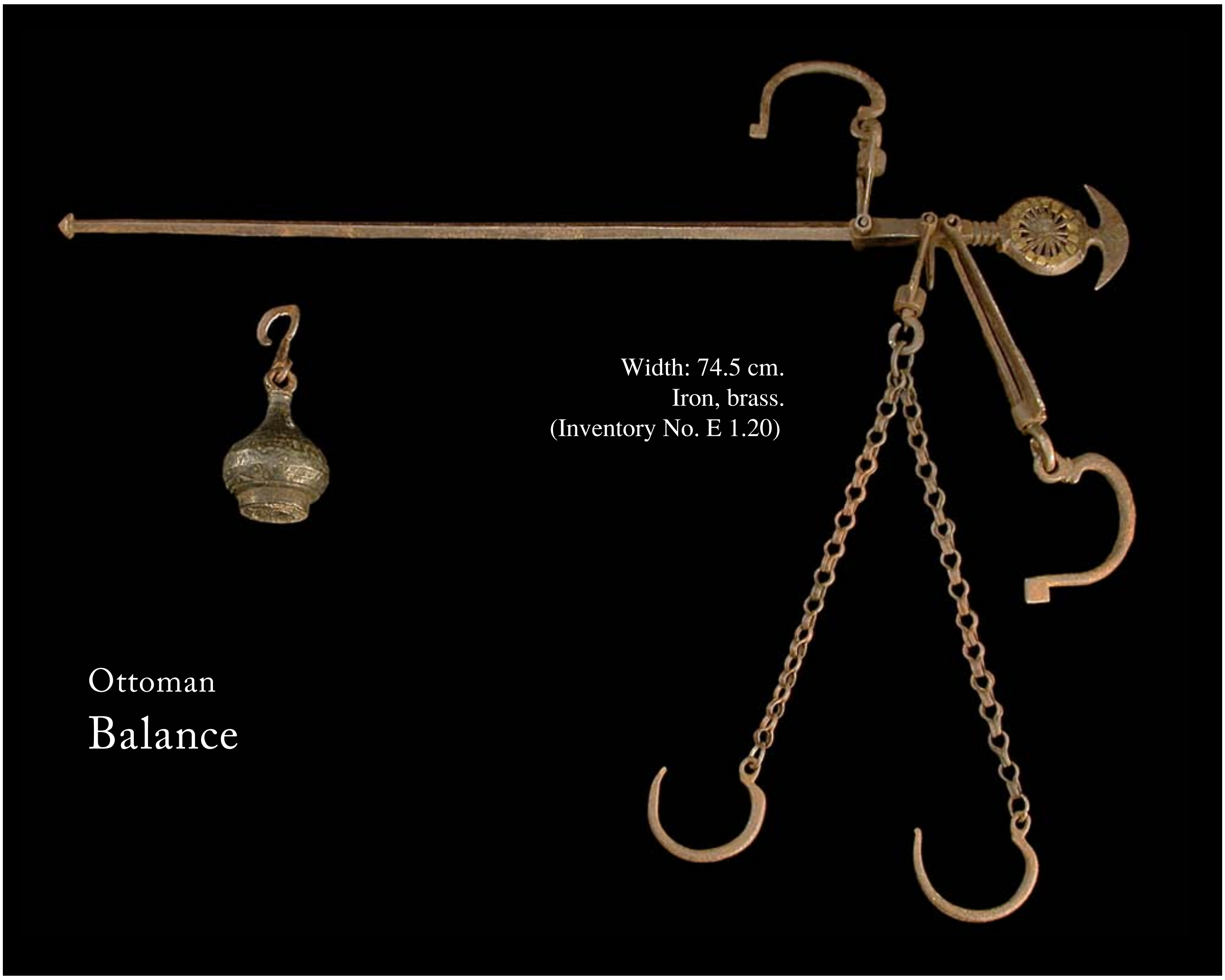


One specimen is said to have come down from the early stages of development of the balance in the early centuries of Arab-Islamic culture. The specimen preserved in the Science Museum in London is dated 4th/10th century (see fig. below). The length of the beam is about 2.5 m.[16]

Our balance, acquired in Egypt, shows a striking similarity to the London specimen. Its age is not known, but the provenance, workmanship and state of preservation allow for hardly more than 150 years. The arm is divided into 34 units of about 2.9 cm (according to the labels: 60-230); these units are subdivided into 5 points each.

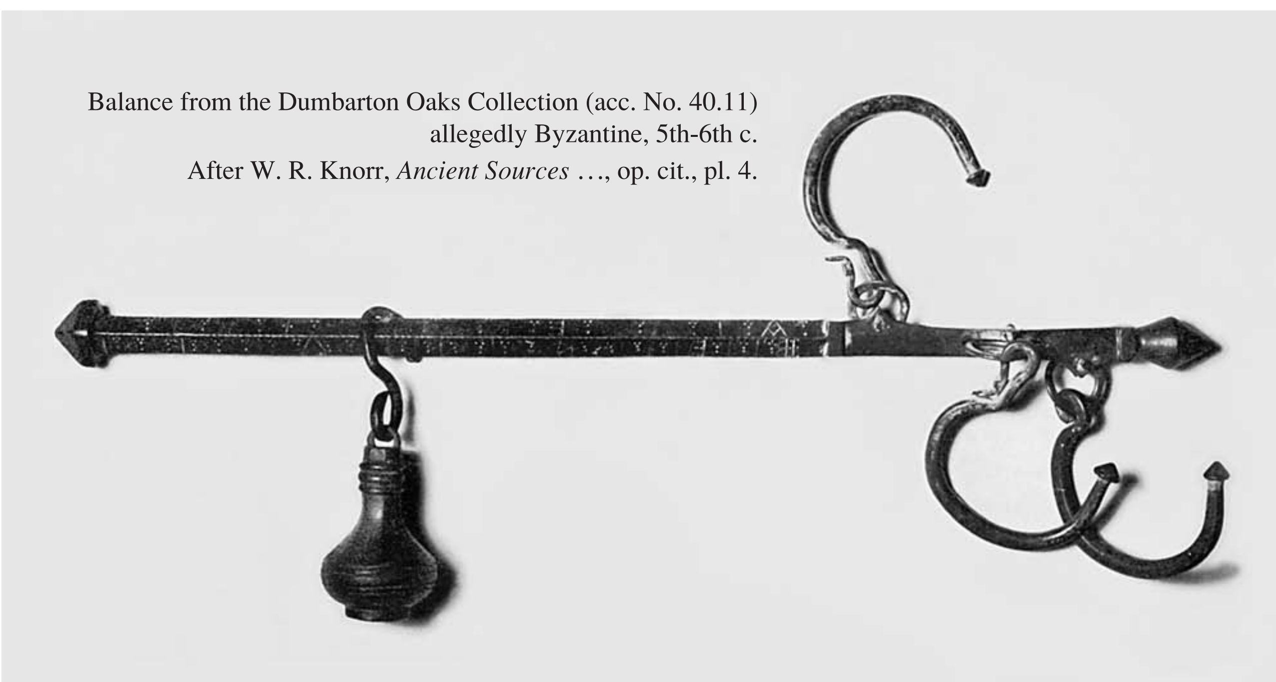
Fig. from W.R. Knorr, op. cit., pl. 11.

[16] v. Wilbur Richard Knorr, *Ancient sources of the medieval tradition of mechanics. Greek, Arabic and Latin studies of the balance*, Florence 1982, plate 11 after p. 117.



Width: 74.5 cm.
Iron, brass.
(Inventory No. E 1.20)

Ottoman
Balance



Balance from the Dumbarton Oaks Collection (acc. No. 40.11)
allegedly Byzantine, 5th-6th c.
After W. R. Knorr, *Ancient Sources* ..., op. cit., pl. 4.

Numerical determination of the specific gravity

Our model:
Glass vessel, height: 34 cm with measuring beaker.
Balance of brass on hardwood, height: 48 cm.
(Inventory No. D 1.23)

“The scholars of Antiquity undertook numerous and precise measurements; e.g. Archimedes, because otherwise he could not have solved the task assigned to him of determining the composition of Hieron’s wreath [the crown of King Hieron of Sicily]; likewise Menelaus. No figures have come down to us …”

“The numerical values achieved by the Muslim scholars mentioned by al Bîrûnî have not survived. Of Abu ’l-Faḍl [Ǧaʿfar b. ʿAlī ad-Dimašqī], we know at least the method employed. The first data, both for metals and for precious stones, which we know are from al Bîrûnî …”

“Al Bîrûnî experimented with the greatest care. He performed all the weighings and measurings at the same place and in the same season, thus avoiding quite a few errors. He selected the metals to be compared in as pure a form as possible. Thus he purified gold five times in fire until it became difficult to melt any further and solidified quickly. He pressed mercury through sheets of cloth for so long until it seemed quite pure to him. Before using the purified lead, he also removed the layer of oxide that was forming. He knew quite well that a little bit of silver was still admixed in it but he could not remove its last traces. He treated silver, copper, iron and tin with the same care. Because of their importance he also examined two alloys: bronze (*ṣufr*), composed of copper and tin, and brass (*šabah*)”

"After these preliminary procedures, al Bîrûnî set himself the task of ascertaining the weights of equal volume. For this he at first employed the methods adopted by his predecessors, but he gives detailed information only about the method of Aḥmad ibn al Faḍl [al-Buḫārī],[1] who used a casting mould which was commonly employed in metal casting. The casting mould of al Bîrûnî held 40 *miṯqāls*[2] of iron. Probably the choice of this volume came about by chance. He gave it the shape of a lentil. He filled the empty space of the model with different molten metals and then weighed them. He repeated this several times to convince himself of the accuracy of the results. Every time he got different values because the form did not remain completely stable. Therefore he gave up this method ‹since it gave only surmises, not certainties.› In order to arrive at a more stable form, he cut a hollow cavity in the shape of a hemisphere into a steel anvil and filled it up with molten metals, hammered the mass and filed off the excess. He tested it with a ruler until the surface of the metal coincided with the level of the anvil. But here too he arrived at variable results when he repeated the procedure. Then al Bîrûnî tried to achieve results with a completely different procedure. Into two steel plates A and B round holes of the thickness of a finger were bored. Then A and B were fastened onto two iron cylinders in such a way that the holes were exactly opposite to one another. The holes were used to draw wires of a certain thickness through them, with wires being given the same length each time. He thus hoped to achieve volumes of consistently the same dimensions. But repeated experiments showed him that the weights of the wires of the same metal did not quite agree with one another; therefore he abandoned this method as well."[3]

[1] Probably lived in the 4th/10th cent., quoted by al-Ḫāzinī, *Mīzān al-ḥikma*, ed. Hyderabad, p. 56 (repr., op. cit., p. 437).
[2] 1 *miṯqāl* ≈ 4.5 g.
[3] Heinrich Bauerreiß, *Zur Geschichte des spezifischen Gewichtes im Altertum und Mittelalter*, Erlangen 1914, pp. 28-29 (repr. in: Natural Sciences in Islam, vol. 45, Frankfurt 2001, pp. 224-225).

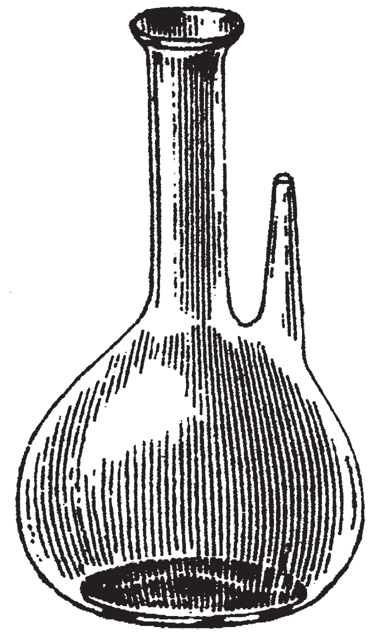
Then al-Bīrūnī turned to the possibility of ascertaining the specific gravity by means of the displacement of water when the material to be measured was submerged in a measuring beaker:

al-Bīrūnī's pycnometer from MS Beirut 223..

"As the inventor himself mentioned, he only succeeded after several attempts in giving the final shape to the vessel (v. fig.)." "He gave it a conical shape; through the large base it had corresponding stability and could hold a great deal of material. On the top is attached a narrow neck of uniform width. […] The smallest objects had the shape of a millet seed. To the middle of the neck, a tube is soldered, which has the form of a quarter circle, and its end is situated above a bowl, which is meant for collecting the displaced water. Holes were bored into the tube from above to prevent the water from remaining in the tube. However, al Bîrûnî remarks that this objective was not always fully achieved."[4] During his experiments, al-Bīrūnī always took into account the nature and the tem

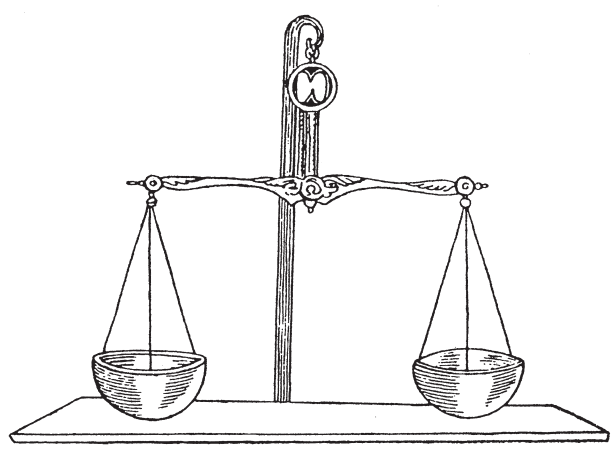
[4] H. Bauerreiß, op. cit., p. 41 (repr., op. cit., p. 237).

perature of the water [11] and he used to perform all his experiments "with the same kind of water and in the same season".[5]
The specific gravities of many metals and precious stones ascertained in the course of time by al-Bīrūnī and by other scholars of the Islamic world with minor variations agree completely or almost completely with the corresponding modern values.[6]
E. Wiedemann was convinced that these methods of experimentation of the Arab-Islamic world also reached Venice and from there the scholars of Italy, among them Galileo Galilei.[7] In his view[8] "in his *Bilancetta* Galilei used almost exactly the same methods" which were used widely in the Islamic world.
The instrument invented by al-Bīrūnī which functions according to the principle of displacement of the volume of water is basically nothing but the pycnometer,[9] well-known in our times. Its first known pictorial depiction in the West (see fig.) can be traced to Wilhelm Homberg (1699). Here, in the same way as in the case of al-Bīrūnī, "the liquid is filled until it reaches just up to the tip of the small capillary tube."[10]
The pycnometer attained its subsequent accuracy in the work of Johann Heinrich Geißler (1815 -1879).[11]



Early European pycnometer by Wilhelm Homberg (1699) after Gerland and Traumüller..

A balance similar to our model is printed here (see fig.) after the Lucknow edition of 1893 of the *Āʾīn-i Akbarī* by Abu l-Faḍl ʿAllāmī (c. 1010/1600), as reproduced by Th. Ibel.[12]



Balance of Abu l-Faḍl ʿAllāmī after Th. Ibel.

[5] H. Bauerreiß, op. cit., p. 55 (repr., op. cit., p. 251).
[6] v. E. Wiedemann, *Arabische specifische Gewichtsbestimmungen*, in: Annalen der Physik (Leipzig) 20/1883/539-541 (repr. in: *Gesammelte Schriften*, vol. 1, pp. 30-32); idem, *Über das Experiment im Altertum und Mittelalter*, in: Unterrichtsblätter für Mathematik (Frankfurt) 12/1906/73-79, 97-102, 121-129, esp. p. 125 (repr. in: *Gesammelte Schriften*, vol. 1, pp. 147-168, esp. p. 164).
[7] *Arabische specifische Gewichtsbestimmungen*, op. cit., p. 541 (repr., p. 32); *Über das Experiment im Altertum*, op. cit., p. 125 (repr., p. 164). On the treatment of the subject by Galileo in *La Bilancetta* v. H. Bauerreiß, *Zur Geschichte des specifischen Gewichtes*, op. cit., pp. 62-64 (repr., pp. 258-260); Galileo Galilei. *Schriften, Briefe, Dokumente*, ed. by Anna Mudry, vol. 1, Munich 1987, pp. 45-49.
[8] *Über das Experiment im Altertum*, op. cit., p. 125 (repr., p. 164).
[9] v. E. Wiedemann, *Die Naturwissenschaften bei den orientalischen Völkern*, in: Erlanger Aufsätze aus ernster Zeit, 1917, pp. 49-58, esp. p. 54 (repr. in: *Gesammelte Schriften*, vol. 2, pp. 853-862, esp. p. 858).
[10] E. Gerland, F. Traumüller, *Geschichte der physikalischen Experimentierkunst*, Leipzig 1899 (repr., Hildesheim 1965), p. 255.
[11] ibid.

[12] *Die Wage*, op. cit., p. 111 (repr., p. 115).

Areometer

Our model:
Brass, engraved.
Height: 304 mm.
Diameter: 44 mm.
Specific gravities of some liquids in Arabic characters.
Glass cylinder with a gilt brass lid.
Next to it on the right a modern areometer in a glass vessel.
A hardwood board with slots for the vessels.
(Inventory No. D 1.24)

Al-Ḫāzinī, frequently referred to above, mentions in the 7th chapter of the first treatise of his *Mīzān al-ḥikma*[1] the instrument which is called areometer in our times for the determination of the specific gravity of liquids (*miqyās al-māʾīyāt fi ṯ-ṯiqal wa-l-ḫiffa*). He mentions a certain Qūqus ar-Rūmī as the inventor of this instrument, who can probably be identified with Pappus; he was active at the turn of the 3rd to the 4th century in Alexandria. Such an instrument seems to have been known in Late Antiquity even before 415,[2] but the name of the inventor is mentioned only by al-Ḫāzinī.

Al-Ḫāzinī begins his description of the instrument with the physical principle on which it is based: "The ratio of the volumes of bodies of the same weight (and of the same substance) submerged in water behave [read: behaves] inversely to those [read: that of the] specific gravities.[3]"
"[13] If one accepts this principle, one can then construct an instrument which shows us the proportion of the weights of all liquids with the least trouble, provided the bodies have the same volume. It is also extremely useful in matters ben-

[1] ed. Hyderabad, pp. 28-33 (repr., op. cit., pp. 472 -481).
[2] E. Gerland, F. Traumüller, *Geschichte der physikalischen Experimentierkunst*, op. cit., p. 58; H. Bauerreiß, *Zur Geschichte des spezifischen Gewichtes*, op. cit., p. 96 (repr., op. cit., p. 292).

[3] The precise wording goes back to H. Bauerreiß (op. cit., p. 98; repr., p. 294) who proposes it as a correction to the version handed down in the surviving text which runs thus: "The ratio of the volume of any heavy body to the volume of another heavy body when they are equally heavy in air corresponds to the inverse ratio of the weight to the weight in water" (al-Ḫāzinī, *Mīzān al-ḥikma*, ed. Hyderabad, p. 28; repr., op. cit., p. 481).

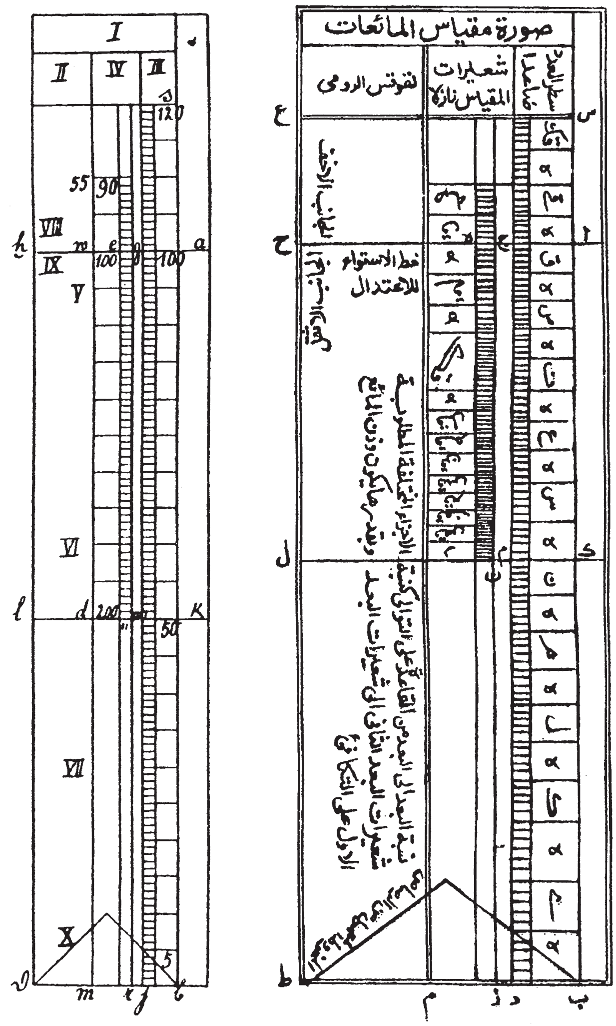
eficial to the health of the human body; all of this without the need to use weights and a balance."[4]

"The instrument consists of a hollow cylinder which is about half a cubit long (ca. 28 cm) and which has a diameter of 2 fingers' breadth (ca. 4 cm) or less. The material is copper (nuḥās, sometimes also used for copper alloys[5]). The cylinder is turned on the lathe and is as light as possible. Its ends are closed by two bases which resemble the light frame drums (*duff*) and are fitted on the lathe as carefully as possible. On the lower surface a cone of lead (*raṣāṣ*) is attached in the inside … When the instrument is placed upon a liquid in a vessel, it stands exactly vertically on that surface and does not tilt to any side."[6]

By a diagram al-Ḫāzinī illustrates the precise description of how he proceeded in drawing the lines on the instrument.[7] We reproduce the description here from the edition of the Arabic text and from the version of Bauerreiß (see figs. on the right):

On the surface of the instrument it is necessary to draw "first of all a line *s a b* along the entire cylinder. About ⅙th part or less of the cylinder is above the surface of the water (near *a*). To a b the parallel lines *g j, e r, n m, ḫ ϑ*, are drawn, running from the top to the bottom. *a b* is halved at *k; n r, d m* and l *ϑ* are made equal to *a k*. Through *k*, m_1, *n*, *l* is drawn a circular line with the help of a curved ruler placed against the cylinder, likewise a circle is drawn through *a g e ḫ*. This line is called the equator of equilibrium. The part lying above the equator represents specific gravities lower than that of water, the part below represents those higher than that of water."

"Then the line a b is divided into 10 parts, which are labelled with letters according to their numerical value, and through the dividing points are drawn arcs terminating at *g j* and *a b*. The area between each two dividing lines on *g j* is again subdivided into 10 parts so that *g j* is divided into 100 parts. Now through the 100 parts of *g j* are



Labels (scales) of the areometer according to al-Ḫāzinī (from the Arabic edition and German translation by Bauerreiß).

drawn small equidistant arcs, which are parallel to the circles at the bases. In the area between the lines *a b* and *g j* are written the numbers in letters of the alphabet, beginning with *b* and proceeding towards *a*; [14] this is called the line (the scale) of the regularly proceeding numbers (*saṭr al-ʿadad al-mustawī*)".

"In order to find from these data a norm for the numbers proportionate to the (specific) gravities which are then inscribed upon the instrument, the procedure is the following. It is imagined that a vessel is present, such as a *dauraq* (water pitcher) [in our model a glass cylinder], which holds 100 *miṯqāls* etc. The height of the vessel is assumed to be 100, corresponding to the water contained therein. In order to arrive at the above mentioned

[4] al-Ḫāzinī, op. cit., p. 28 (repr., p. 481); H. Bauerreiß, op. cit., p. 98 (repr., p. 294). In the following, the translation is slightly modified.

[5] v. J. W. Allan, *Persian Metal Technology 700-1300 AD*, Oxford 1979, p. 52.

[6] al-Ḫāzinī, op. cit., p. 29 (repr., p. 480); H. Bauerreiß, op. cit., p. 100 (repr., p. 296).

[7] al-Ḫāzinī, op. cit., between p. 30 and p. 31 (repr., p. 477); H. Bauerreiß, op. cit., p. 100 (repr., p. 296).

proportionate numbers, one multiplies 100 with 100, thus arriving at 10 000; this number is divided by the numbers inscribed earlier on the areometer up to where it is submerged in the liquid. The results of the division are put together in a table, in fact, along with the values from which they are computed, and they are then inscribed on the areometer itself between *n m* and *e r*. The graduations themselves are incorporated with a curved ruler. The numbers continue in the direction from *a* to *b*. Those above the line of equilibrium correspond to liquids lighter than water and those below to liquids heavier than water. The basis of the calculation is subsequently proved. Abu r-Raiḥān [al-Bīrūnī] pointed to it in his treatise."[1]

"The table which gives the specific gravities corresponding to the volumes of 110 to 50 is calculated very carefully according to the formula $s = 10\,000 : a$, where s is the specific gravity, a the volume which is read off."[2]

[1] al-Ḫāzinī, op. cit., pp. 29-30 (repr., pp. 479-480); translated by H. Bauerreiß, op. cit., pp. 101-102 (repr., pp. 297-298).
[2] H. Bauerreiß, op. cit., pp. 102-103 (repr., pp. 298-299).

Wood, iron; ∅ on top: 5-30 cm
(Inventory No. J 2.27-32.)

Six
measures of capacity

Egypt, 13th/19th – early 20th cent.?

The vessels, of different sizes and resembling bushels, are put together with thin strips of wood like very thin-walled drums or tubs, though completely encased outside with iron. From this we may infer that they were meant for measuring liquids. Their age can hardly be estimated; a fairly new branding stamp (see right) of the Egyptian municipal authority shows that they were still in use at any rate in the 14th/20th c. The construction possibly represents an older tradition.

Screw pump

Our model: Wood and plastic.
Size: 101 × 62 cm with table and transparent cover.
Electric motor for demonstration.
(Inventory No. E 1.15)

The screw is set in motion by a water wheel which is driven by the river current. The transmission takes place via two gearwheels which allow an inclination of about 30 degrees for the screw. The screw itself rests in a wooden cylinder and can be rotated. With its rotation water from the river is raised to a higher level, from where it can be directed to the fields.

A simple screw pump without a water wheel and gearwheels is described by the Roman scholar Vitruvius (Marcus Vitruvius Pollio, d. ca. 25 B.C.)[1] in his *De architectura*.[2] In more recent times (1886) Hugo Blümner[3] drew attention to the instrument: "Moreover, for draining the water from pits the so-called Egyptian screw (κοχλίας, cochlea) was used, an invention which Archimedes is supposed to have made during an Egyptian journey but which was most probably a piece of equipment that was known for a long time in Egypt which Archimedes merely brought back to Europe."

In 1914 F. M. Feldhaus[4] expressed reservations: "Screw-pump, also called Archimedean snail or Egyptian screw. Archimedes got to know the screw pump during a journey to Egypt around 250 B.C. (Strabo, book 17, 807; Diodor. Sicul., book I, 34 and 5, 37; Vitruvius, book 10, 11). Accordingly the machine should be Egyptian. But it is not known from any Egyptian painting; the screw is not known in Egypt either." As regards the first of the two reservations recorded here, we may say that it is nothing but a misuse of the argumentum ex silentio. As far as the second is concerned, it has not yet been established that the screw was not known to the Egyptians.

[1] v. G. Sarton, *Introduction to the History of Science*, vol. 1, pp. 223-225.

[2] Book 10, chapter 11, v. *Vitruv: Baukunst*, transl. August Rode, 2 vols., Leipzig 1796 (repr. Zurich and Munich 1987), vol. 2, pp. 265-268.

[3] *Technologie und Terminologie der Gewerbe und Künste bei Griechen und Römern*, vol. 4, Leipzig 1887, pp. 122-123, with references to Strabo and Diodorus.

[4] *Die Technik. Ein Lexikon der Vorzeit*, ..., op. cit., cols. 834-835.

[17] Again in 1919 Albert Neuburger[5] expressed the following view in connection with the use of the inclined plane in pyramid construction: “The inclined plane attained special importance by its use in the form of the screw, which is said to have been invented by Archimedes during an Egyptian journey. However, it is to be assumed that it had been in use there for a long time, for draining water in mines.” In 1956 E. J. Dijksterhuis,[6] in his work on Archimedes, also expressed the view that the machine was probably invented much earlier and that Archimedes merely first became familiar with it in Egypt.

In the same year A. G. Drachmann[7] reached a radically opposite conclusion: “ So I suggest that in the absence of even the faintest evidence to the contrary, and in the presence of both direct and indirect evidence of the most convincing character, it is safe to conclude that Archimedes really did invent the water-snail, and that it is called by rights the screw of Archimedes.”[8]

On the other hand, the historian of technology R. J. Forbes (1963),[9] who was certainly aware of the discussion on this question, restricts himself to the following statement: “It is said that Archimedes, when visiting Egypt about 220 B.C., saw such screws in action for pumping water onto the fields, and they are still in use throughout the Nile Valley for irrigation purposes.”

I myself consider it unlikely that Archimedes should have invented the screw pump on his journey to Egypt. In my view, its invention should be seen as the result of many years of experience the Egyptians had in the use of the inclined plane in pyramid construction and in water drainage in mines.[10] Archimedes may probably be given the credit for recognizing the importance of this achievement and for giving an impetus for its diffusion in Europe. Even Strabo[11] reports the use of the screw pump in Iberian mines.

The screw described by Vitruvius was driven by a treadmill.[12] In a mural[13] discovered in Pompeii in 1929 a screw pump seems to be propelled likewise by a treadmill.

Conrad Kyeser (1405) calls the screw “Testudo” and says that it was used for emptying trenches.[14] In his illustration[15] a crank serves as the drive.

Although there would have been the possibility for the screw pump to find its way to other parts of Europe via the Romans, there is some weight in the assumption that the type widely known in the Arabic world, particularly in Egypt, only reached the Western European countries in Islamic times via Northern Africa.[16] It is therefore surprising that Geronimo Cardano could claim in his *De subtilitate* (1500) that a smith from his hometown, Pavia, a certain Galeaz de Rubeis, had rediscovered the screw pump.[17]

A more advanced form of the instrument with a water wheel and two gearwheels is to be found among the drawings of instruments and machines made by Leonardo da Vinci:

[5] *Die Technik des Altertums*, Leipzig 1919, p. 211.

[6] Archimedes, Copenhagen 1956, pp. 21-22.

[7] *The Screw of Archimedes*, in: Actes du VIIIe Congrès international d’histoire des sciences Florence-Milan 3-9 septembre 1956, vol. 3, Florence 1958, pp. 940-943.

[8] Ibid., p. 943.

[9] *Studies in Ancient Technology*, vol. 7, Leiden 1963, p. 213.

[10] v. A. Neuburger, *Die Technik des Altertums*, op. cit., p. 211.

[11] Strabo, book 3, 147; *The Geography of Strabo* (Loeb), vol. 2, p. 45; Feldhaus, *Die Technik*, op. cit., col. 835.

[12] Book 10, chapter 11, v. *Vitruv: Baukunst*, transl. August Rode, 2 vols., Leipzig 1796 (repr. Zurich and Munich 1987), vol. 2, p. 267.

[13] v. R. J. Forbes, *Studies in Ancient Technology*, op. cit., vol. 7, p. 213.

[14] Conrad Kyeser, *Bellifortis*, after Feldhaus, *Die Technik*, op. cit., col. 835.

[15] Feldhaus, *Die Technik*, op. cit., col. 834.

[16] v. Charles Singer et al. (eds.), *A History of Technology*, op. cit., vol. 2, p. 677.

[17] Geronimo Cardano, *De subtilitate* libri XXI, in: *Hieronymus Cardanus. Opera omnia*. Facsimile repr. of the Lyons 1663 edition with an introduction by August Buck, vol. 3, Stuttgart - Bad Cannstatt 1966, p. 366; R. J. Forbes, *Studies in Ancient Technology*, op. cit., vol. 7, p. 215.

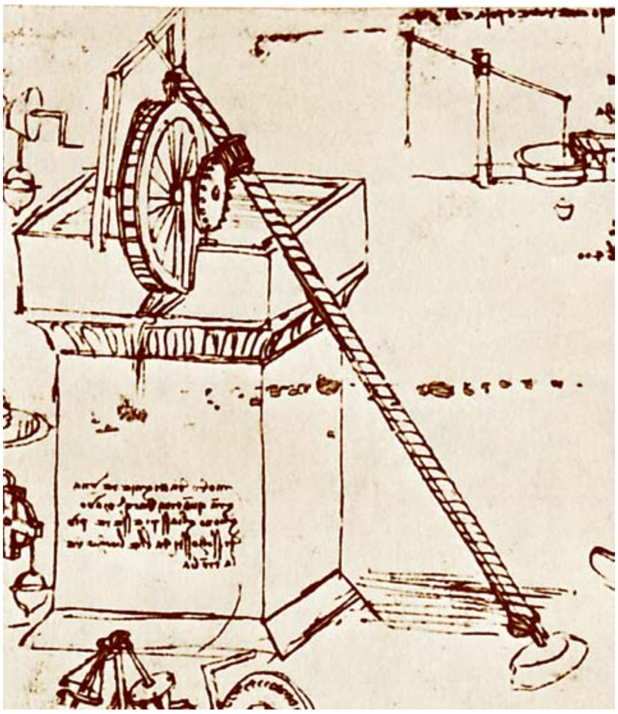


Fig. from *Leonardo da Vinci*, *op. cit.,* p. 480.

His screw-pump clearly reminds us of the screw-pump of his younger contemporary Taqīyaddīn (1553)[18] in Istanbul:

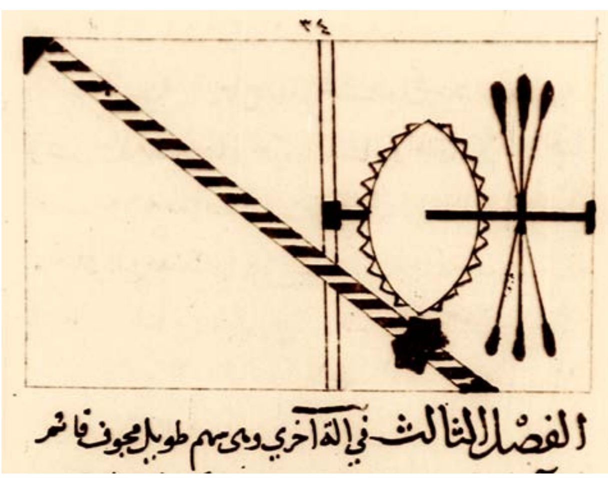


Fig. from Taqīyaddīn

In my view Leonardo as well as Taqīyaddīn reproduce the type of screw-pump developed in the Arab-Islamic world.
The simple version rotated by a crank handle is still used today in Egypt for irrigating the fields.

Contemporary Egyptian screw-pump.

[18] Aḥmad Y. al-Ḥasan, *Taqīyaddīn wa-l-handasa al-mīkānīkīya al-ʿarabīya*, op. cit., p. 34; idem and D.R. Hill, *Islamic Technology*, p. 243.

Our model:
Wood and plastic.
Measurements:
71 × 64 cm.
Electric motor for demonstration.
(Inventory No. E 1.14)

Bucket Chain for Lifting Water

We know this device in a much simpler form from Vitruvius (d. ca. 25 B.C.).[1] The description of our instrument is from an anonymous Arabic book which was written apparently after the 6th/12th century. Its highly dubious title runs thus: "That is what Īrūn (Hero) extracted from the work of the two Greeks, Philon and Archimedes, viz. about the hauling of loads, the spheres, the waters, the bowls."[2] We may assume that the devices dealt with in this anonymous work were partly associated with the Greek scholars who are mentioned as the inventors. But what needs to be clarified is the question of the development which the instruments mentioned underwent later on, particularly in the Arab-Islamic world.

Our apparatus is a device for lifting water with two chains of buckets driven by a treadmill. A graphic reconstruction by Carra de Vaux[3] in 1903 turned out later to be not quite correct. In 1918 E. Wiedemann[4] called parts of his drawings "erroneous" or "arbitrary". We should not be surprised that the wrong version took root in the historiography of technology [20] and that, for instance, F. M. Feld-

[1] Book 10, chapter 9, v. *Vitruv: Baukunst*, op. cit., vol. 2, p. 262.

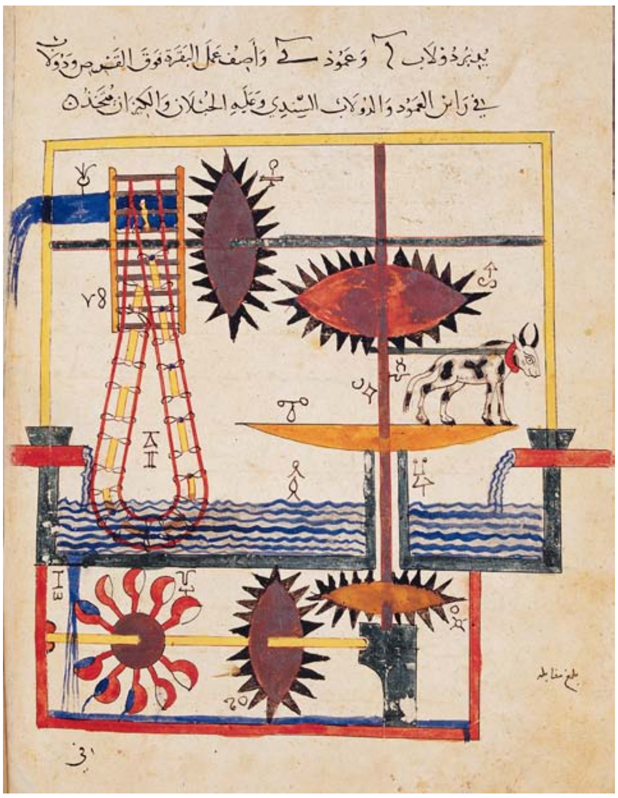
[2] v. Hans Schmeller, *Beiträge zur Geschichte der Technik in der Antike und bei den Arabern*, Erlangen 1922, p. 2 (repr. in: Natural Sciences in Islam, vol. 39, Frankfurt 2001, pp. 197-247, esp. p. 202).

[3] Bernard Carra de Vaux, *Le livre des appareils pneumatiques et des machines hydrauliques, par Philon de Byzance, édité d'après les versions arabes d'Oxford et de Constantinople et traduit en français*, in: Notices et extraits des manuscrits de la Bibliothèque Nationale et autres bibliothèques (Paris) 38/1903/27-235, esp. pp. 209-212 (repr. in: Natural Sciences in Islam, vol. 37, Frankfurt 2001, pp. 101-309, esp. pp. 283-286).

[4] *Über Vorrichtungen zum Heben von Wasser in der islamischen Welt*, in: Beiträge zur Geschichte der Technik und Industrie (Berlin) 8/1918/121-154, esp. p. 151 (repr. in: *Gesammelte Schriften*, vol. 3, Frankfurt 1984, pp. 1483-1516, esp. p. 1513).

haus[5] speaks of three types of bucket chains for lifting water in the writings of Philon, which were driven either by an undershot water wheel, a crank handle or a treadmill.

A considerable improvement to the bucket chain for lifting water can be seen among the machines for lifting water described and illustrated by al-Ǧazarī[6] (ca. 600/1200):



Bucket chain water-lifting machine of al-Ǧazarī, *al-Ǧāmiʿ baina l-ʿilm wa-l-ʿamal an-nāfiʿ fī sināʿat al-ḥiyal*, facs. ed., Frankfurt 2002, p. 486.

He says that, the third type (see fig.) is a model to which he added the figure of a rotating wooden draught ox to mislead the onlooker; the mechanism is not driven by a draught animal, but by water power. Some of the water of a brook is channelled through a pipe into a basin, falls from there upon the flywheel that lies lower and flows off through a channel. All or part of the last third of the inflowing water goes into the buckets which transport it further upwards.

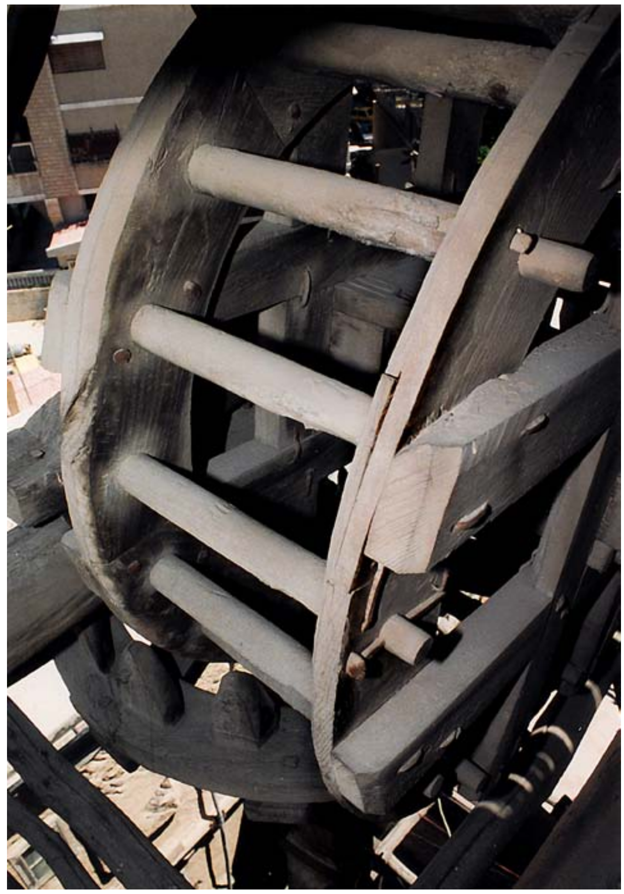
Our model represents the climax in the history of the development of the water-lifting bucket chain as known so far. It is more or less an improved variety of the device described by al-Ǧazarī. The main difference lies in the fact that here water power is used to drive a paddle wheel (instead of a bucket wheel) and that it involves flowing (instead of falling) water. However, the main prototype for our model is not an illustration or description in a literary source but an original water-lifting apparatus which was fully functional from the first half of the 7th/13th century until the middle of the previous century. Known by the name Manšaʾat Šaiḫ Muḥiyiddīn, it is situated on the banks of the Yazīd river in aṣ-Ṣāliḥīya, a locality in Damascus, and supplied a hospital and a mosque with water, until it ceased operation some 40 years ago (see the following page).

For constructing our model we used the detailed sketches and the description by A. Y. al-Ḥasan[7] from Aleppo of 1976.

[5] *Die Technik*, op. cit., col. 831; v. also A. P. Usher, A History *of Mechanical Inventions*, revised edition, New York 1954, p. 164.

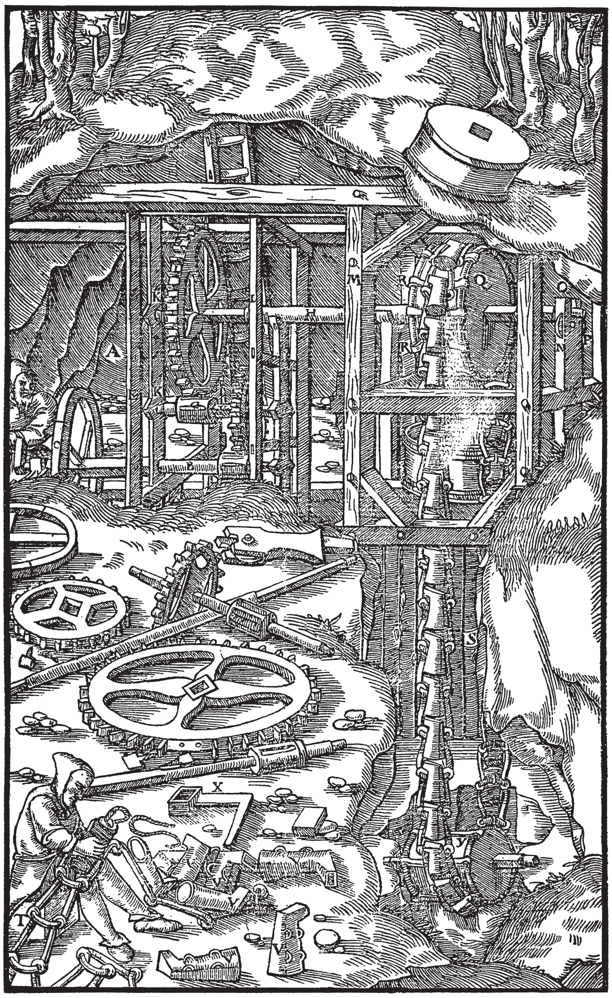
[6] *al-Ǧāmiʾ baina l-ʿilm wa-l-ʿamal*, facs. ed. Ankara 1990, fol. 159 b; E. Wiedemann, *Über Vorrichtungen zum Heben von Wasser*, op. cit., pp. 141-143 (repr., op. cit., pp. 1503-1505); D. R. Hill, *The Book of Knowledge of Ingenious Mechanical Devices*, op. cit., pp. 182-183; idem, *Mechanik im Orient des Mittelalters*, in: Spektrum der Wissenschaft, July 1997, pp. 80-85, esp. pp. 80-81.

[7] *Taqīyaddīn wa-l-handasa al-mīkānīkīya al-ʿarabīya*, op. cit., pp. 55-70; v. also A. Y. Al-Hassan, D. R. Hill, *Islamic Technology*, op. cit., pp. 45-47.



Manša’at Šaiḫ Muḥyiddīn in Damascus.

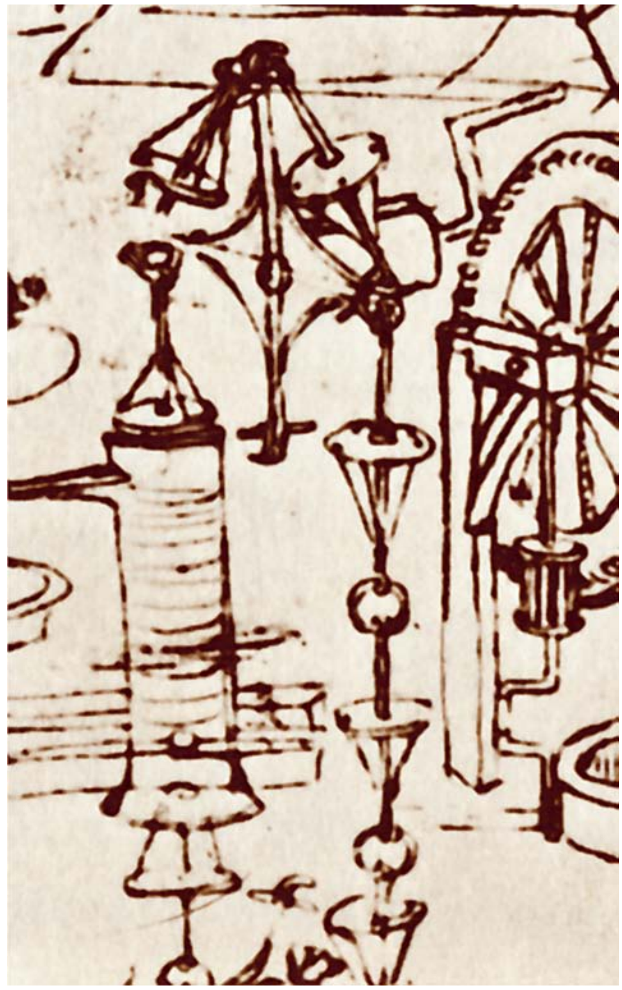
The oldest known pictorial depiction of a similar device from Europe is to be found in the De re metallica[8] by Georgius Agricola (1556):



A—Iron frame. B—Lowest axle. C—Fly-wheel. D—Smaller drum made of rundles. E—Second axle. F—Smaller toothed wheel. G—Larger drum made of rundles. H—Upper axle. I—Larger toothed wheel. K—Bearings. L—Pillow. M—Framework. N—Oak timber O—Support of iron bearing. P—Roller. Q—Upper drum. R—Clamps. S—Chain. T—Links. V—Dippers. X—Crank. Y—Lower drum or balance weight.

Agricola, *De re metallica*, p. 173

From Leonardo da Vinci[9] (1519) we know of the water-lifting bucket chain driven by a crank handle:



[8] Georgius Agricola, *De re metallica*, translated by Herbert Clark Hoover and Lou Henry Hoover, New York, 1950, p. 173; A.P. Usher, *Machines and Mechanisms*, dans: *A History of Technology*, ed. Ch. Singer et al., op. cit., vol. 3, p. 325.

[9] *Leonardo da Vinci*, op. cit., p. 480.

Our model:
Wood and plastic.
Size: 68 × 52 cm.
With table and transparent hood.
Electric motor for demonstration.
(Inventory No. E 1.18)

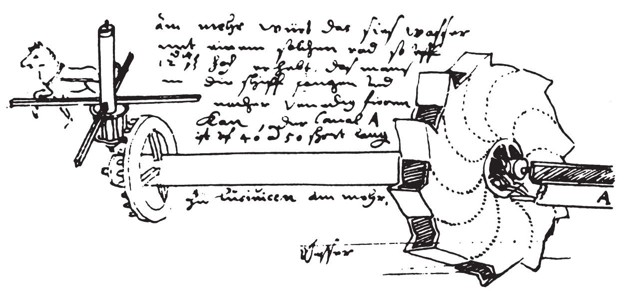
Tympanum

A drum-shaped water-lifting wheel, probably called *nāʿūra* or *sāqiya* in Arabic. In this type of water-lifting device spiral-shaped chambers turn around the axle of the wheel, collecting water, and transportng it to a tube in the hub of the wheel. It is suitable for lifting large quantities of water over small heights. It has a high degree of efficiency, and there are very few signs of wear and tear. The origin of this construction is unknown at present. A water wheel of this type, driven by two oxen, appears in the miniatures in the Paris manuscript of the *Maqāmāt* by al-Ḥarīrī (634/1237), Bibl. Nat., MS arabe 5847, fol. 69.[1] Water wheels like this are said to have been widespread in Egypt.[2]

[1] P.J. Müller, *Arabische Miniaturen,* Geneva 1979, plate 12.
[2] D.R. Hill, *Mechanik im Orient des Mittelalters,* in: Spektrum der Wissenschaft (Weinheim), July 1991, p. 81; idem, *Islamic Science and Engeneering*, Edinburgh 1993, pp. 95–96; A. Delpeche, F. Girard, G. Robine, M. Roumi, *Les norias de l'Oronte. Analyse technologique d'un élément du patrimoine Syrien*. Damascus 1997, p. 226; Thorkild Schiøler, *Roman and Islamic Water-lifting Wheels,* Odense University Press, 1973, pp. 78–79.

Illustration of a spiral-type water wheel, driven by oxen, miniature by Yaḥyā b. Maḥmūd al-Wāsiṭī in the *Maqāmāt* of al-Ḥarīrī (634/1237), Bibl. Nat. Paris, MS arabe 5847, fol. 69. After P. J. Müller, *Arabische Miniaturen*, Geneva 1979..

[24] The German architect Heinrich Schickardt (1558-1635) sketched a spiral-type water wheel near Milan during his Italian journey in 1598-1600 in connection with the local canals and water works.[3].



Sketch of the water-lifting works at Breta (Northern Italy) by H. Schickardt, 1600. After E. Kluckert.

[3] v. E. Kluckert, *Heinrich Schickardt, Architekt und Ingenieur*, Herrenberg 1992, p. 47.

Installation for Lifting Water

from a pool wit a draught animal (mule-operating gin)

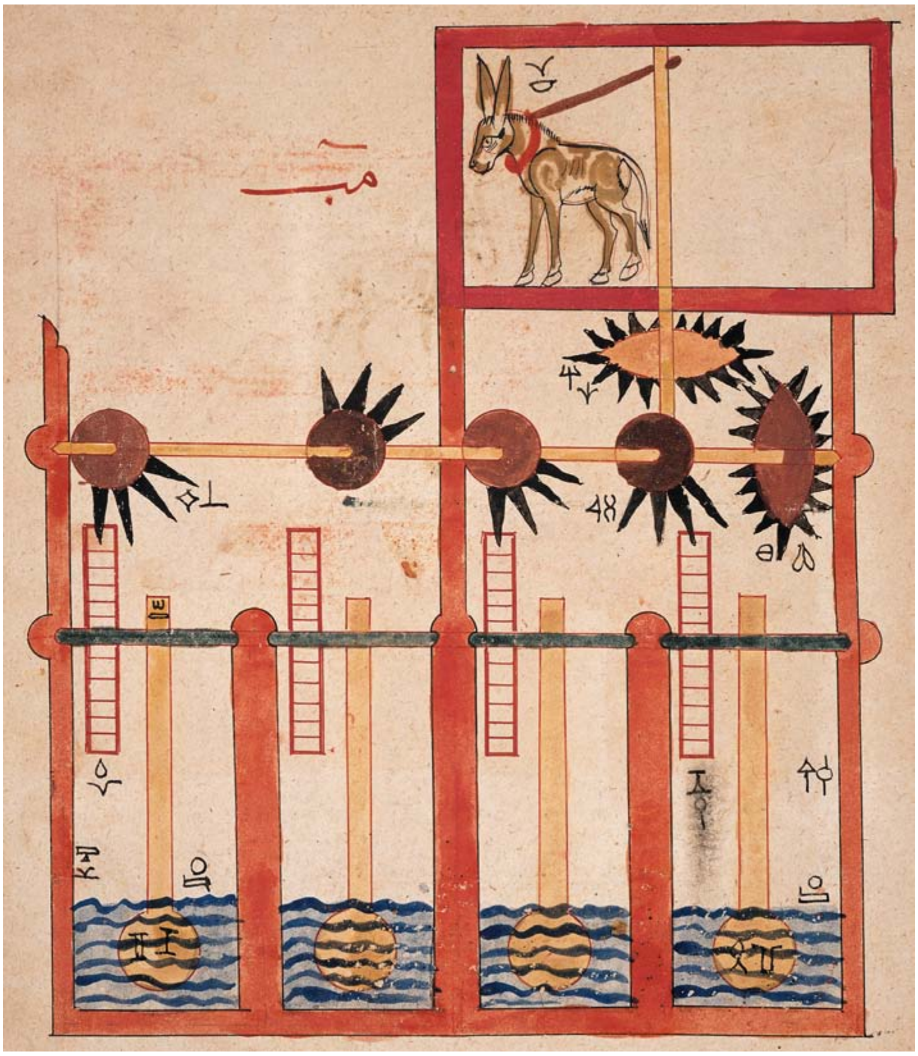
Our model:
Wood and plastic.
Dimension 145 × 80 cm with table and transparent hood.
Mechanism of hardwood, sealed.
Electric motor for demonstration.
(Inventory No. E. 1.07)

In the fifth part of his book on water-lifting devices,

Ibn ar-Razzāz al-Ǧazarī (ca. 600/1200) describes five types, the first four of which are driven by a draught animal. Our model represents the second[1] of the types described there.

"On the horizontal axle (k), which is mounted above the water level between the pillars (λ and q) and which is made to rotate by the draught animal by means of the vertical axle (w) and the gear-wheels (h and ϑ) four discs are set up which are provided with cogs for a quarter of their circumference, instead of just one single disc, which is provided partially with cogs. Their cog system is staggered by 90° from one to another. Under each of the four discs [26] there is a small axle each with the lantern

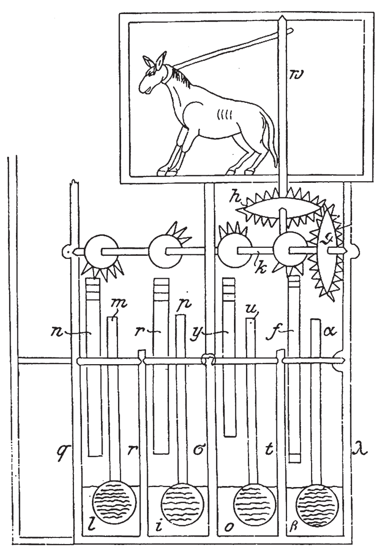
[1] *al-Ǧāmiʿ baina l-ʿilm wa-l-ʿamal*, facs. ed., Frankfurt 2002, pp. 478–483; Ankara 1990, pp. 310–314; D.R. Hill, *The Book of Knowledge of Ingenious Mechanical Devices*, op. cit., pp. 180–181.



Illustr. of the mule-operated gin in al-Ǧazarī, *al-Ǧāmiʿ bain al-ʿilm wa-l-ʿamal an-nāfiʿ fī ṣināʿat al-ḥiyal*, facs. ed., Frankfurt 2002, p. 481.

gear wheels (*n, r, y, f*) and the scoops (*lm, ip, ou, βα*). The individual axles, in their reciprocal extension, are mounted between a row of five pillars (*q, r, σ, t, λ*)."

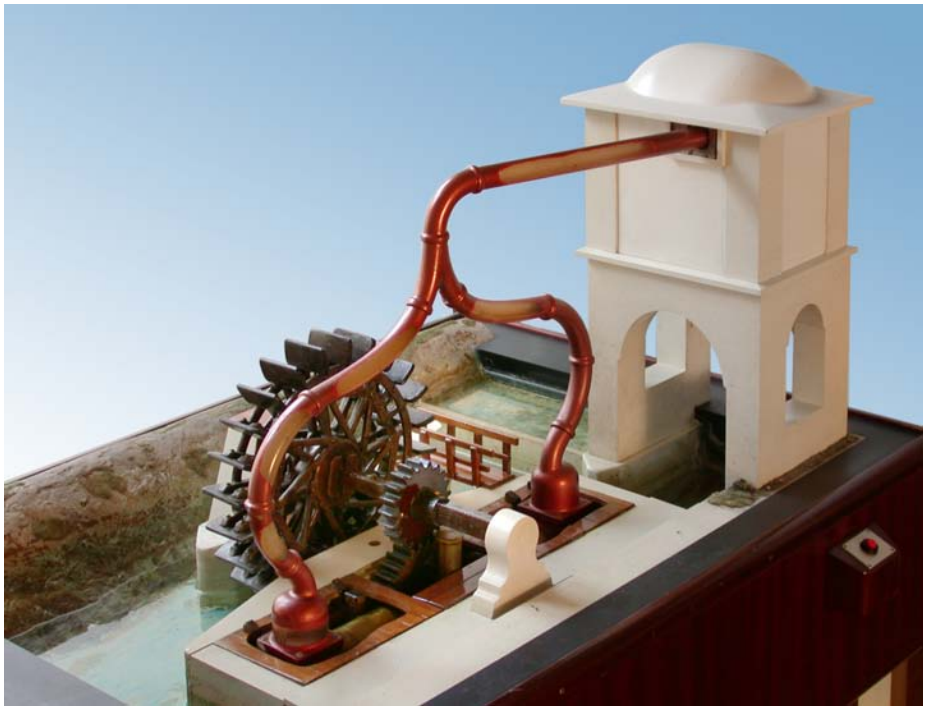
"Because the cogs of the discs in one fourth of their circumference are staggered by 90° from one another, one of the same is in action all along so that the power of the draught animal is used more economically than with the arrangement of the previous section, where the animal works only during one-fourth of the revolution." [2]



Redrawing of al-Ǧazarī's illustration by E. Wiedemann.

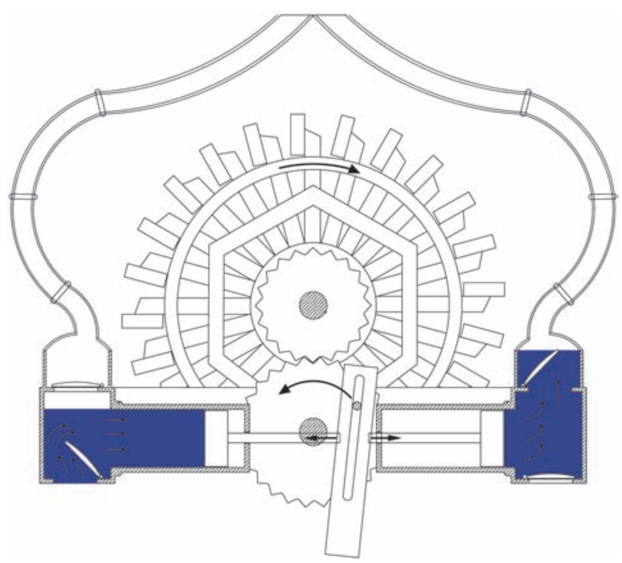
[2] Translated by E. Wiedemann, *Über Vorrichtungen zum Heben von Wasser in der islamischen Welt*, in: Beiträge zur Geschichte der Technik und Industrie 8/1918/121–154, esp. pp. 140–141 (repr. in: *Gesammelte Schriften*, vol. 3, pp. 1483–1516, esp. pp. 1502–1503).

Pumping Station
driven by a water wheel



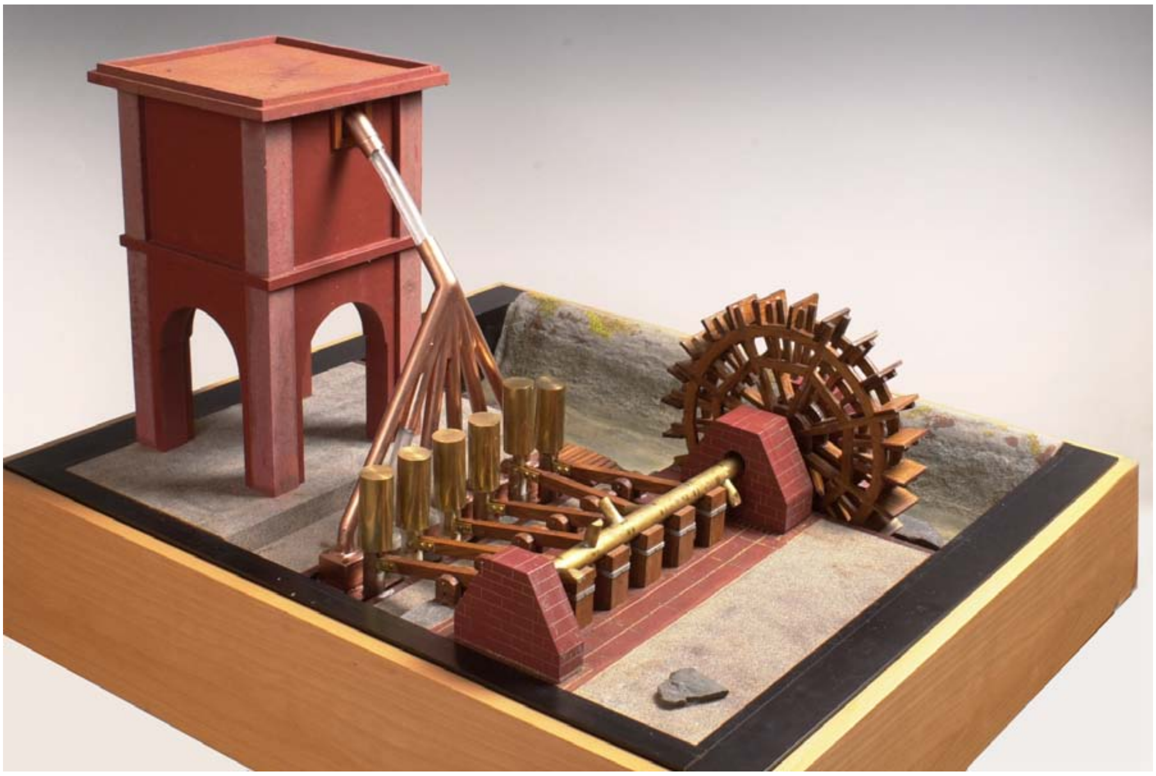
Our model:
Wood and plastic. Brass valves with leather gaskets. Brass weights and camshaft. Measurements: 89 × 79 cm, with table and transparent cover. Electric motor for demonstration.
(Inventory No. E 1.13)

After the machines driven by draught animals, al-Ǧazarī[1] (ca. 600/1200) describes a machine that lifts water by means of a wheel from a river to a height of up to 20 ells (ca. 11 m). This machine is also listed by Taqīyaddīn[2] among the hydraulic appliances.
The system uses the natural current of a river. A water wheel standing in the current produces a uniform rotary motion which continues into a shaft. A gearwheel attached to the shaft transmits the motion to another gearwheel, to which a pivot is fastened. A piston rod which is loosely connected to the pivot transforms the rotary motion mechanically into a thrusting motion. Two pistons connected to the piston rod use the horizontal thrusting motion to suck in water from the river and to pass it on to a chamber each. With each motion one piston sucks in water, the other displaces it. The chambers have two valves each, one entry-valve and one exit-valve. After the piston has sucked the water in, the entry-valve closes the chamber, during the displacement the water reaches the rising pipe, which is attached to the chamber. From there water cannot flow back when the piston moves in the opposite direction, since the exit-valve closes. Meanwhile the second pump sucks up water. Thus a uniform stream of water flows into the rising pipe which in turn leads to a reservoir from where the water can be diverted to the houses or to the fields.



Drawing of the construction of al-Ǧazarī's pump.

[1] al-Ǧazarī, op. cit., pp. 321-327; D. R. Hill, op. cit., pp. 186-189; E. Wiedemann, *Über Vorrichtungen zum Heben von Wasser*, op. cit., pp. 145-147 (repr., pp. 1507-1509).
[2] Aḥmad Y. al-Ḥasan, *Taqīyaddīn wa-l-handasa al-mīkānīkīya al-ʿarabīya*, Aleppo 1976, repr. 1987, facs., pp. 29-32.

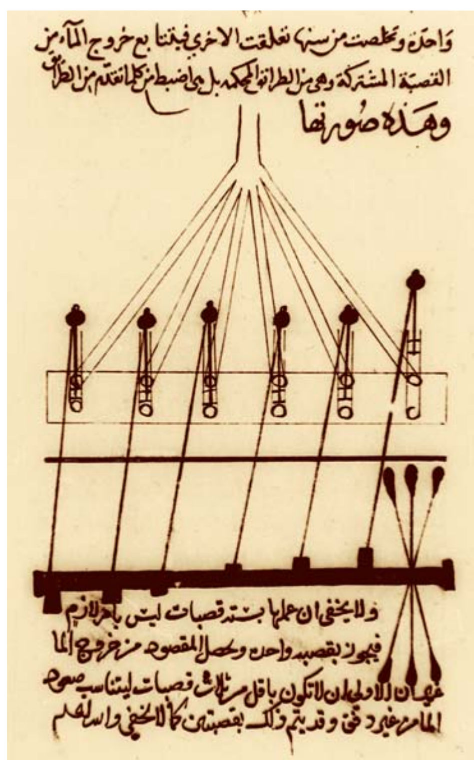


Pump with six pistons

by Taqīyaddīn (1553)

Our model:
Wood and plastic. Brass valves with leather gaskets. Brass weights and camshaft.
Measurements: 89 × 79 cm,
with table and transparent cover.
Electric motor for demonstration.
(Inventory No. E 1.13)

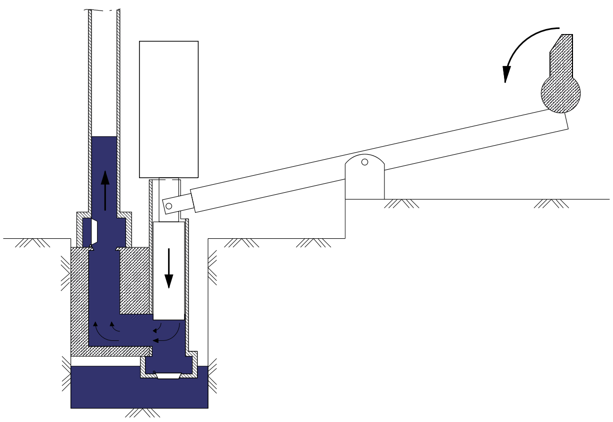
The Ottoman universal scholar of Arab descent Taqīyaddīn Muḥammad b. Maʿrūf (d. 993/1585) describes in his book on pneumatic devices (*aṭ-Ṭuruq as-sanīya fi l-ālāt ar-rūḥānīya*[1]), which he wrote in 960/1553, two versions of water pumps, one of which lifts water from a river by means of two pistons and the other with six pistons. The first is already known to us thanks to the book by Ibn ar-Razzāz al-Ǧazarī (see the preceding pump-works). The second version appears to have emerged in the phase of development after al-Ǧazarī. The natural current of a river drives the system through a water wheel. The six pumps convey the water up to a certain height, from where it can be transmitted further.



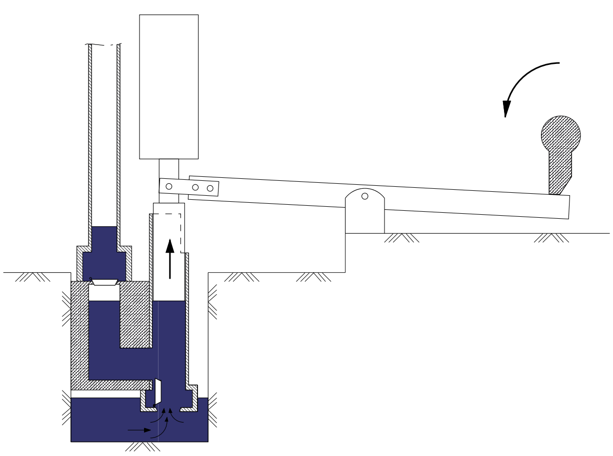
Page from Taqīyaddīn, *aṭ-Ṭuruq* …, MS Dublin, Chester Beatty Lib. 5232.

[1] ed. A.Y. al-Ḥasan in *Taqīyaddīn wa-l-handasa al-mīkānīkīya al-ʿarabīya*, op. cit., pp. 36–38; A.Y. al-Hassan, D.R. Hill, *Islamic Technology*, op. cit., pp. 50–52.

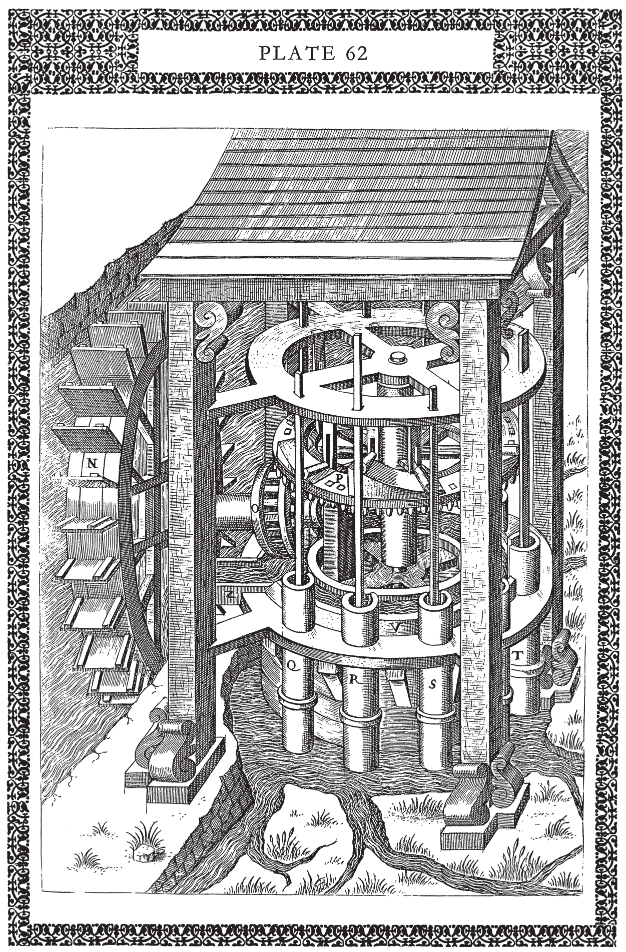
In this model the rotary motion generated by the water wheel is transmitted to a camshaft. [29] The cams operate individual levers through which the rotary motion is converted to a linear motion. They are set up on the shaft in a staggered manner so that the water power is distributed uniformly. When one of the levers is operated it causes a piston and a weight attached to it to be pressed upwards. A vacuum is thereby created in the pump chamber belonging to it, as a result of which the entry valve opens and water is sucked in. When the cam has released the lever once again, the piston is pressed downwards by the weight attached to it. This closes the entry valve, and the water is pumped upwards through the rising pipes. While this is happening, an exit valve opens and closes at the end of the process once again, thus preventing the water from flowing back. Moreover, the repeated sucking of the pump creates an air blockage through which the vacuum can be built up again and water can be sucked in. Because of the fact that six pumps are driven one after the other a continuous flow of water is guaranteed. A similar water-lifting works with several pistons is described and illustrated in the book by Agostino Ramelli[2] in 1588.



Water rising while the piston is sinking.



Water being sucked in while the piston is rising.



Pumping station by A. Ramelli (1588).

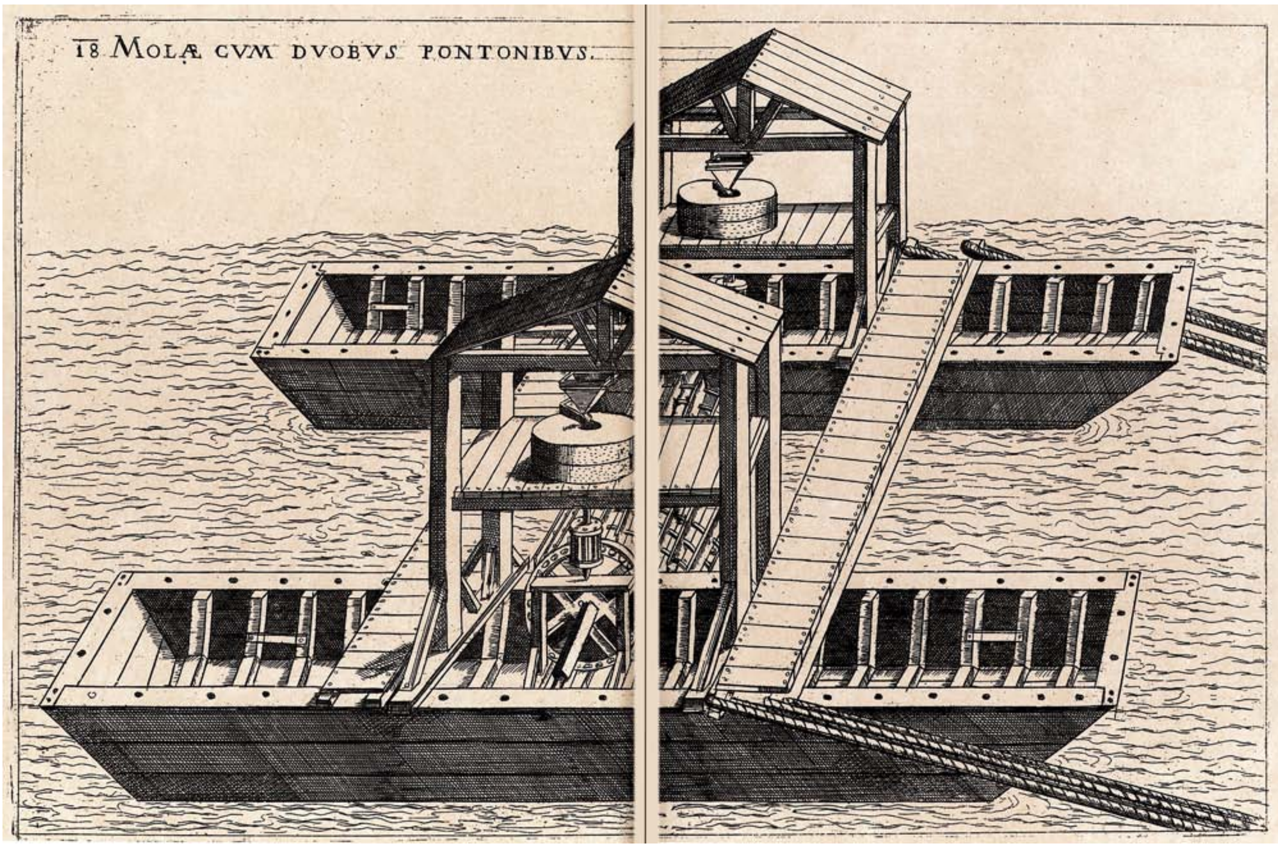
[2] *The Various and Ingenious Machines of Agostino Ramelli. A Classic Sixteenth-Century Illustrated Treatise on Technology*. Translated from the Italian and French with a biographical study of the author by Martha Teach Gnudi. Technical annotations and a pictorial glossary by Eugene S. Ferguson, Baltimore 1976, p. 184 and plate. 62.

Ship's Mill

The three "sons of Mūsā" (Banū Mūsā) speak of a ship's mill (*ʿaraba*) in their treatise on a "wind instrument that plays by itself"[1] written around the middle of the 3rd/9th century (on this, see part I of the Museum Catalogue: Musikinstrumente, p. 202 ff.). In the 4th/10 th century the geographer Ibn Ḥauqal[2] reports that on the Tigris near Mosul there were ship's mills (here pl. *ʿurūb*) "the like of which one gets to see rarely anywhere in the world." They were made of wood and iron; secured by iron chains, they lay in the current in the middle of the river and were equipped with two pairs of mill-stones each. The reports collected by E. Wiedemann show that ship's mills were widespread in the Islamic world for centuries.

Our model:
Ship of hardwood, with watertight seal.
Length: 80 cm.
Water wheels attached on the sides (driven by an electric motor for demonstration purposes), connected to the mill-stones (here only one pair) via gear transmission. Tub of plastic material in a hardwood table.
Measurements: 120 × 86 × 80 (height) cm.
(Inventory No. E 1.03)

[1] *al-Āla allatī tuzammiru bi-nafsihā*, ed. L. Cheikho, in: al-Mašriq (Beirut) 9/1906/444-458, esp. p. 454 (repr. in: Natural Sciences in Islam, vol. 42, Frankfurt 2001, pp. 19-33, esp. p. 29), v. E. Wiedemann, *Über Schiffsmühlen in der muslimischen Welt*, in: Geschichtsblätter für Technik, Industrie und Gewerbe (Leipzig) 4/1917/25-26 (repr. in: *Gesammelte Schriften*, vol. 2, pp. 863-864).
[2] *Kitāb Ṣūrat al-arḍ*, ed. J. H. Kramers, Leiden 1939, vol. 1, p. 219.



Ship's mill in F. Veranzio (1615).

In the first half of the 15th century Mariano Taccola drew sketches depicting the component parts of ship's mills (fig. on the right).[3] A detailed illustration of a mill with two pairs of mill-stones, as described by Ibn Ḥauqal, is to be found in the Machinae novae of 1615 by Fausto Veranzio[4] (fig. above).

From D. Taccola, *De ingeneis*.

[3] Mariano Taccola, *De ingeneis*, vol. 2, facs. Wiesbaden 1984, fol. 104 v.
[4] Fausto Veranzio, *Machinæ novæ*, Munich 1965, No. 18.

Windmill

Our model:
Wood, lacquered.
Height: 60 cm.
5 sails of linen
on a vertical axis inside.
Electric fan for demonstration.
(Inventory No. E 1.04)

Windmills (*raḥā*, pl. *arḥā*) were apparently widespread in Persia even before the advent of Islam, and the knowledge of them also reached other parts of the Islamic world quite early. As the historian Muḥammad b. Ǧarīr aṭ-Ṭabarī (d. 310/923) reports in his annals,[1] ʿUmar, the second Caliph (ruled 13/634-23/644), is supposed to have said to the Persian Abū Luʾluʾa, who was known as a painter, joiner and metalworker and who became later the assassin of this Caliph: "It was reported to me that you claimed you could build a mill that grinds with wind power if I desired it," to which Abū Luʾluʾa answered: "Yes, that is true." Then ʿUmar is supposed to have said: "Then build me such a mill."[2]

References to windmills in Siǧistān (or Sīstān, North-Eastern Persia) are to be found in the Arabic writings of several geographers like al-Iṣṭaḫrī (1st half of the 4th/10 th cent.) or his younger colleague Ibn Ḥauqal.[3] Ruins of such mills are to be found in this area until today.

Windmills in Sīstān, North-East Persia, ill. from *al-ʿUlūm fi l-islām*, Tunis 1978, p. 204.

[1] *Taʾrīḫ ar-rusul wa-l-mulūk*, ed. M. J. Goeje, series 1, vol. 5, Leiden 1879 (repr. ibid., 1964), p. 2722; E. Wiedemann, *Zur Mechanik und Technik bei den Arabern*, in: Sitzungsberichte der Physikalisch-medizinischen Sozietät (Erlangen) 38/1906/1-56, esp. p. 44 (repr. in: *Aufsätze zur arabischen Wissenschaftsgeschichte*, vol. 1, pp. 173-228, esp. p. 216).

[2] For another version of this incident, v. al-Masʿūdī, *Murūǧ aḏ-ḏahab wa-maʿādin al-ǧauhar*, ed. C. Barbier de Meynard, Paris 1864, vol. 4, p. 227, v. ibid., vol. 2, p. 80; E. Wiedemann, op. cit., p. 44 (repr., p. 216).

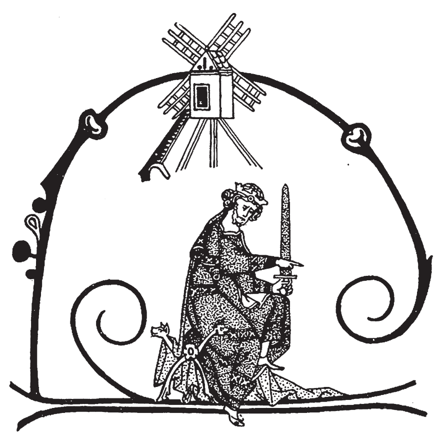
[3] E. Wiedemann, op. cit., p. 217.

Illustration of the windmill from ad-Dimašqī.

To the geographer Šamsaddīn Muḥammad ad-Dimašqī (d. 727/1327) we owe the most detailed description of a windmill together with an illustration.[1] It reads thus in translation: "In Siğistān there is an area where wind… are frequent. The people living there use the winds for turning the mills… To construct the mills which turn in the wind they proceed as follows. They erect [a building] as high as a minaret, or they take a high mountain top or a similar hill or a castle tower. On these they construct one room above the other. In the upper room there is the mill (*raḥā*) that turns and grinds, in the lower one there is a wheel (*daulāb*) that is turned by the wind, which has been harnessed. When the wheel below is turning, the mill on the wheel above turns. No matter what kind of wind blows, those mills turn, although only a single [mill]stone is present, and the picture of it looks like this …"

"When they have carried out the construction of the two rooms as shown in the illustration, they make four embrasures (*marmā*) in the lower room like the embrasures in the walls (*aswār*), only here the embrasures are the other way round, as their broad part is turned to the outside and their narrow part to the inside, [thus forming] a channel for the air so that through it the air enters inside with force as in the goldsmith's bellows. The broad end is situated towards the mouth and the narrow one towards the inside so that it is more suitable for the entry of the air which enters into the room of the mill, from whichever area the wind may be blowing."[5]

With great probability the windmills of Persian origin found their way to the west of the Islamic world quite early. The geographer Abū ʿAbdallāh al-Ḥimyarī from Moorish Spain (writing in 866/1461) mentions, among the special features of the port of Tarragona, the existence of mills driven by wind power.[6]

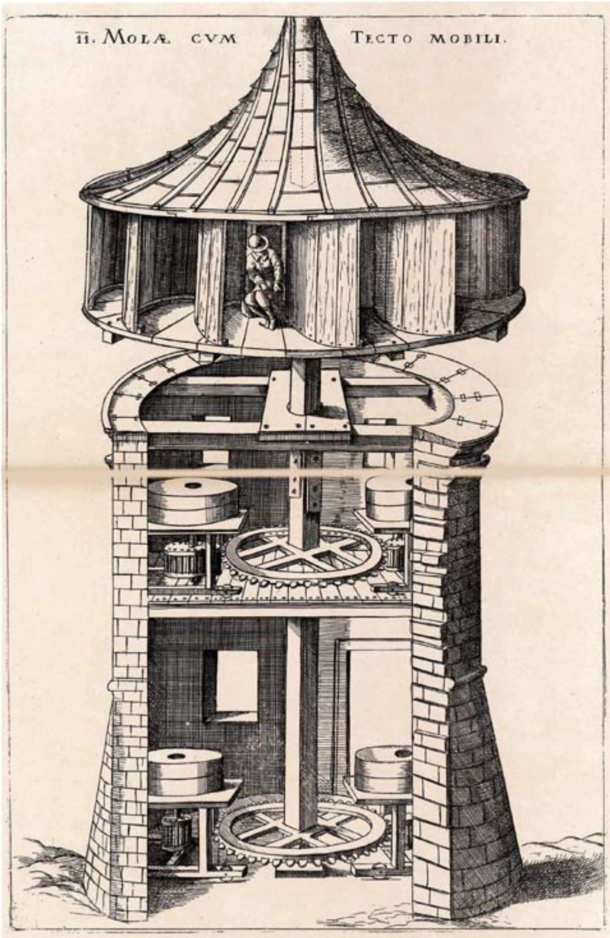


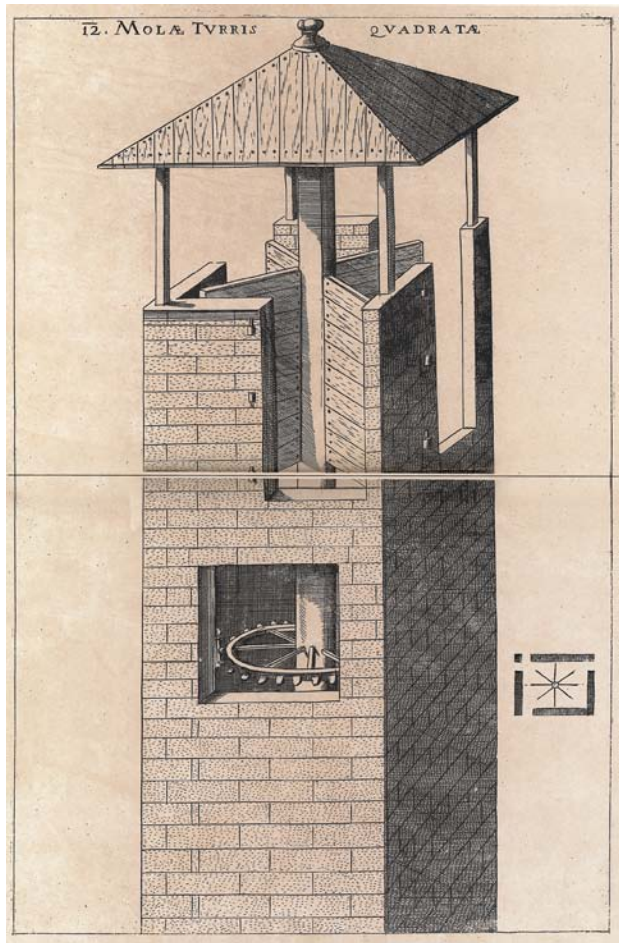
Windmill in the Canterbury Psalter (1270) from Ch. Singer (ed.), *History of Technology*, vol. 2, p. 623.

[4] *Nuḫbat ad-dahr fī ʿağ'ib al-barr wa-l-baḥr*, ed. A. Mehren, *Cosmographie de Chems-ed Din … ad-Dimichqui*, Petersburg 1866 (repr. Islamic Geography, vol. 203, Frankfurt 1994), pp. 181-182; French transl. A. F. Mehren, *Manuel de la cosmographie du Moyen-Âge*, Copenhagen 1874 (repr. Islamic Geography, vol. 204, Frankfurt 1994), p. 247.

[5] Translated from E. Wiedemann, *Zur Mechanik …*, op. cit., p. 46 (repr. p. 218).

[6] *ar-Rauḍ al-miʿṭār fī ḫabar al-aqṭār*, ed. E. Lévi-Provençal, *La Péninsule ibérique au Moyen-Âge*, Leiden 1938, p. 126; French transl. ibid., p. 153.





‹Horizontal› windmills from Veranzio (1615).

As far as further diffusion of this type is concerned, there is some evidence in favour of the assumption[7] that it reached China from about the 7th/13th century onwards. The earliest known development of the windmill in Europe goes back to the 12th century. A book of psalms written in 1270 in Canterbury shows the first English illustrations of a mill with vertical arms.[8]

Several drawings of the "Persian" type are to be found among the *Machinae novae* by Fausto Veranzio (1615).[9]

It is still an open question whether this type of windmill was in fact really constructed in Europe.[10] According to the description by ad-Dimašqī which we reproduced above, the millstone was to be found in the upper part of the mill, while the wind apparatus was installed below. Further development led to a reversal of this order, as newer illustrations show (see fig. above).[11]

During his journey through Persia Sven Hedin counted as many as 75 windmills of this type as against a total number of 400 houses in the small town of Neh in Sīstān. (cf. fig. above, p. 32).[12]

[7] Joseph Needham, *Science and Civilisation in China*, vol. 4, part 2, Cambridge etc. 1965, p. 560

[8] Rex Wailes, *A Note on Windmills*, in: Charles Singer et al. (eds.), *A History of Technology*, vol. 2, Oxford 1956, pp. 623-628, esp. p. 623; Hans E. Wulff, *The Traditional Crafts of Persia*, Cambridge (Mass.) 1966, p. 286.

[9] *Machinae novae*, Munich 1965, No. 11, 13.

[10] v. also R. J. Forbes, *Studies in Ancient Technology*, vol. 2, Leiden 1955, pp. 111-116; Hugo Th. Horwitz, *Über das Aufkommen, die erste Entwicklung und die Verbreitung von Windrädern*, in: Beiträge zur Geschichte der Technik und Industrie 22/1933/93-102; A. Y. al-Hassan, D. R. Hill, *Islamic Technology*, op. cit., pp. 54-55.

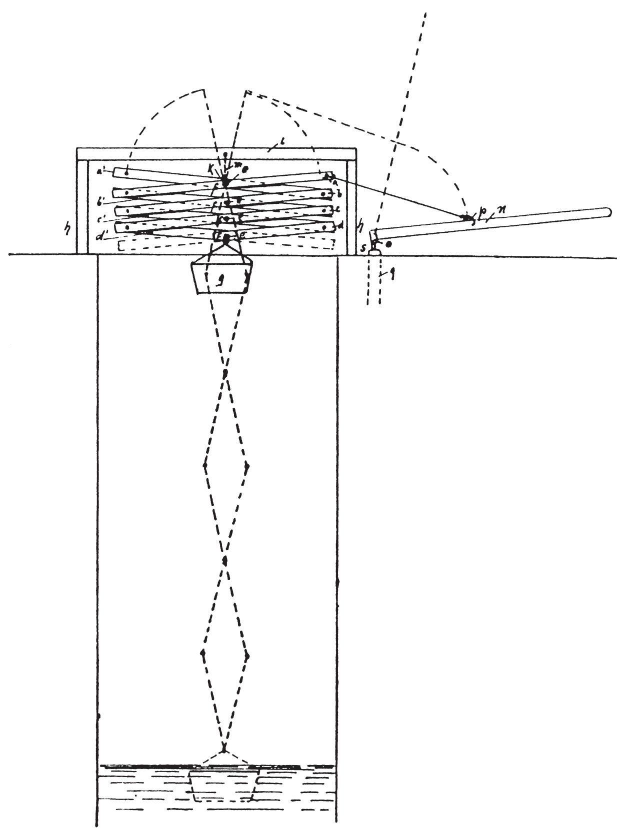
[11] H. E. Wulff, op. cit., pp. 286-289.

[12] *Eine Routenaufnahme durch Ostpersien*, Stockholm 1926, vol. 2, p. 141; cf. H. E. Wulff, op. cit., p. 286.

Lever in form of scissors

Our model:
Wood, laminated,
and brass.
Height 57 cm.
(Inventory No. E

The device known in German-speaking areas as ‹Nuremberg scissors› (Nürnberger Schere) is described in the anonymous Arabic book which was mentioned above (p. 19), the content of which is partly associated with Greek scholars like Archimedes, Philon and Hero, but also with Alexander the Great. Hans Schmeller,[1] who is inclined to see in the author an Arab living in Syria or in Iraq, translated[2] the description of this device from the Arabic into German and depicted it graphically. According to the text, by means of this device one single man should be able to lift water weighing 500 *raṭl* (ca. 220 kg) in one go.[3]
Feldhaus[4] mentions that the Nuremberg scissors can also be used as a pontoon bridge, ladder, or scissors for the transmission of motion in machinery.
For the construction of our model we used the drawing by H. Schmeller.



Drawing by H. Schmeller, *Beiträge zur Geschichte der Technik*, p. 9 (repr., p. 209).

[1] *Beiträge zur Geschichte der Technik in der Antike und bei den Arabern*, op. cit., p. 2 (repr., op. cit., p. 202).
[2] ibid., pp. 9-10 (repr., op. cit., pp. 209-210).
[3] *Die Technik*, op. cit., col. 910.
[4] *Die Technik*, op. cit., col. 910.

Apparatus
for lifting water by means of fire

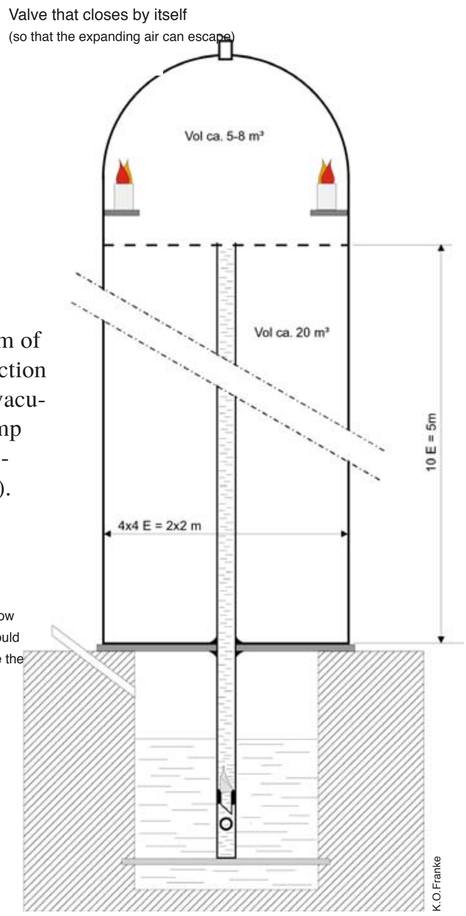


Diagram of the function of the vacuum pump (reconstructed).

Our model:
Wood, laminated, plastic, copper and brass, tallow candle.
Height: 61 cm.
(Inventory No. E 1.23)

Among the four extant manuscripts of the anonymous anthology[1] which describe, with much variation, Greek, pseudo-Greek and Arabic inventions in the field of technology, the Codices Gotha 1348 and Leiden, Warn. 449 offer an apparatus for lifting water by means of fire.[2]

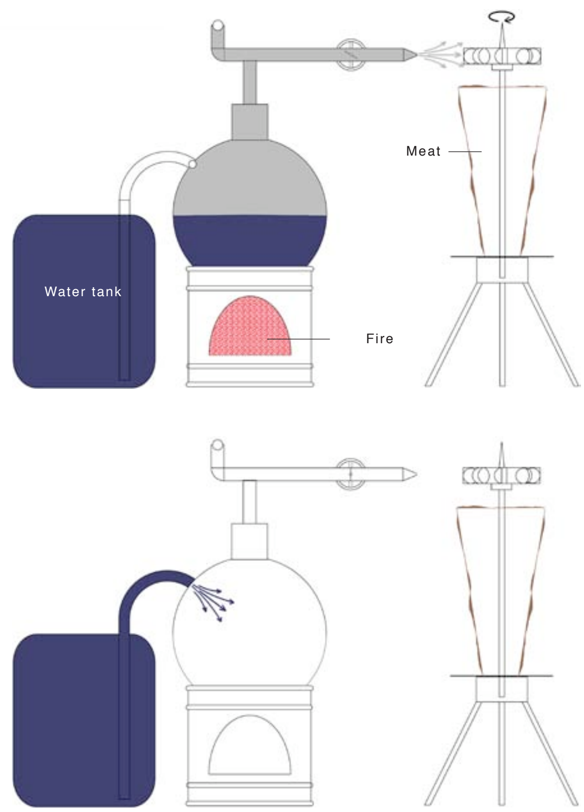
The function of the pump, which we represent in a model of greatly reduced size, is described by H. Schmeller thus: “As a consequence of the increase in temperature due to the burning of naphthalene lamps, the air in the upper space is expelled or consumed. In the subsequent cooling, the pressure decreases and the external air pressure pushes the water in the channel upwards.”[3] According to the description in our source, this device is supposed to be able to lift water from a 5 to 25 m deep well. The question must remain open to what extent practical use could be made of this procedure.

[1] Istanbul, Ayasofya 3187, Oxford, Bodl. Marsh 669, Gotha 1348, Leiden, Warn. 499 (= or. 499, v. P. Voorhoeve, *Handlist of Manuscripts*, Leiden 1957, pp. 116-117).

[2] v. H. Schmeller, *Beiträge zur Geschichte der Technik in der Antike und bei den Arabern*, op. cit., pp. 26 ff. (repr. in: Natural Sciences in Islam, vol. 39, pp. 197-247, esp. 226-227).

[3] ibid., p. 27.

Our model:
Copper, brass, stainless steel.
Diameter of the boiler 30 cm.
With a heating spiral and
shut-off valve.
(Inventory No. E 1.25)



Diagrams of the cross sections through our model..

Steam-driven

Apparatus for turning roast meat

The Ottoman astronomer and engineer Taqīyaddīn describes three devices for turning a roasting spit in the sixth chapter of his *Kitāb aṭ-Ṭuruq as-sanīya fi l-ālāt ar-rūḥānīya* (953/1546). The first device is turned by harnessing steam power. The second is driven by a weight whose movement is regulated by a hot air turbine. The third one was built according to the principle of transferring a relatively low power via gearwheels which are set in motion by a hand crank.

Fig. 1 (above): Reconstruction of the steam cart by P.-M. Grimaldi.

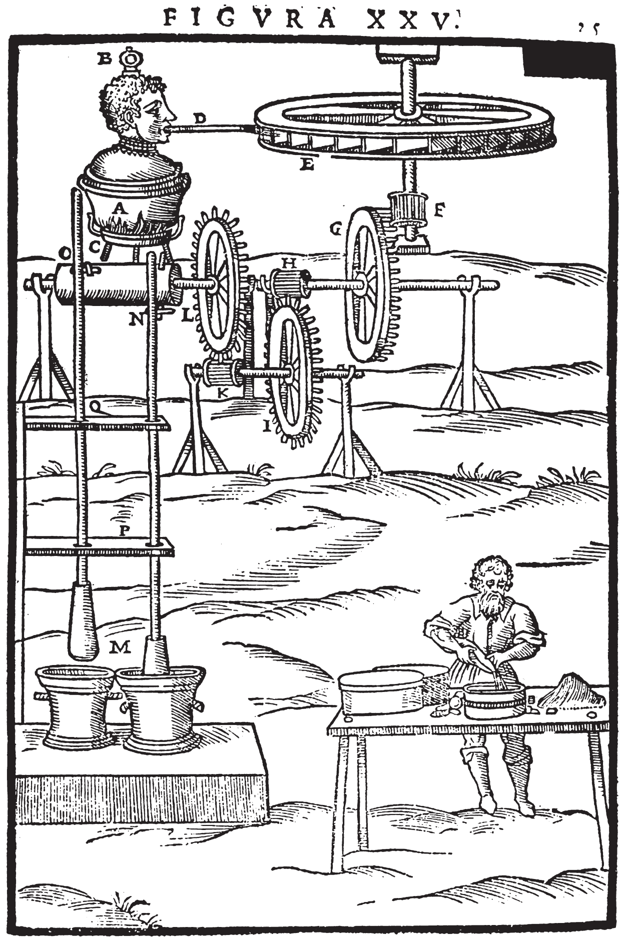


Fig. 2 (on the right): Sketch of the steam-driven wheel by Giovanni Branca.

In our model of the first device the spit is moved, together with a paddlewheel-like turbine, by the steam, which escapes through [38] a pipe from a closed boiler which is heated. According to Taqīyaddīn's description, the water in the boiler is replenished by putting the mouth of the pipe into a water container. That was sufficient to fill the cauldron once again. Taqīyaddīn reports that this type of steam device was in widespread use in his day. In 1629 Giovanni Branca[1] drew the sketch of a steam-driven wheel (see fig. 2) in which the steam blows from a metal mouth towards a paddlewheel. The device is designed to set in motion a pounding machine.[2]

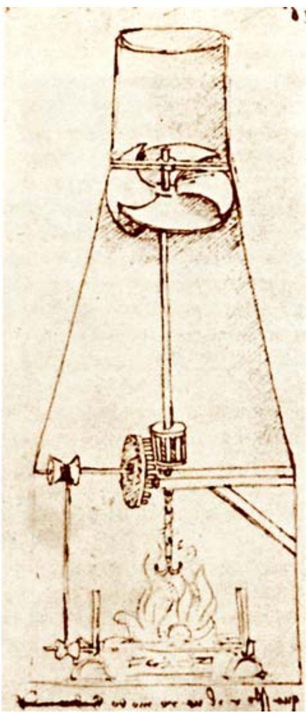
The utilization of steam power apparently made a further advance in the work of Philippe-Marie Grimaldi. Around 1671, he is said to have demonstrated a cart driven by steam power to the Manchurian Emperor K'ang Hsi. A reconstruction (see fig. 1) produced in the 19th century by Giovanni Canestrini (1835-1900) is preserved in the Museo Nazionale della Scienza e della Technica at Milan.[3]

[1] *Le machine. Volume nuovo e di molto artificio da fare effetti maravigliosi* ..., Rome 1629, fig. XXV.
[2] v. F. M. Feldhaus, *Die Technik*, op. cit., p. 182.

[3] v. J. Needham, *Science and Civilisation in China*, op. cit., vol. 4, part 2, pp. 225-228.

Apparatus for turning roast meat
by means of hot air

Our model:
Copper, brass, stainless steel.
Diameter of the shaft 30 cm.
With heating spiral and shut-off valve.
(Inventory No. E 1.26)

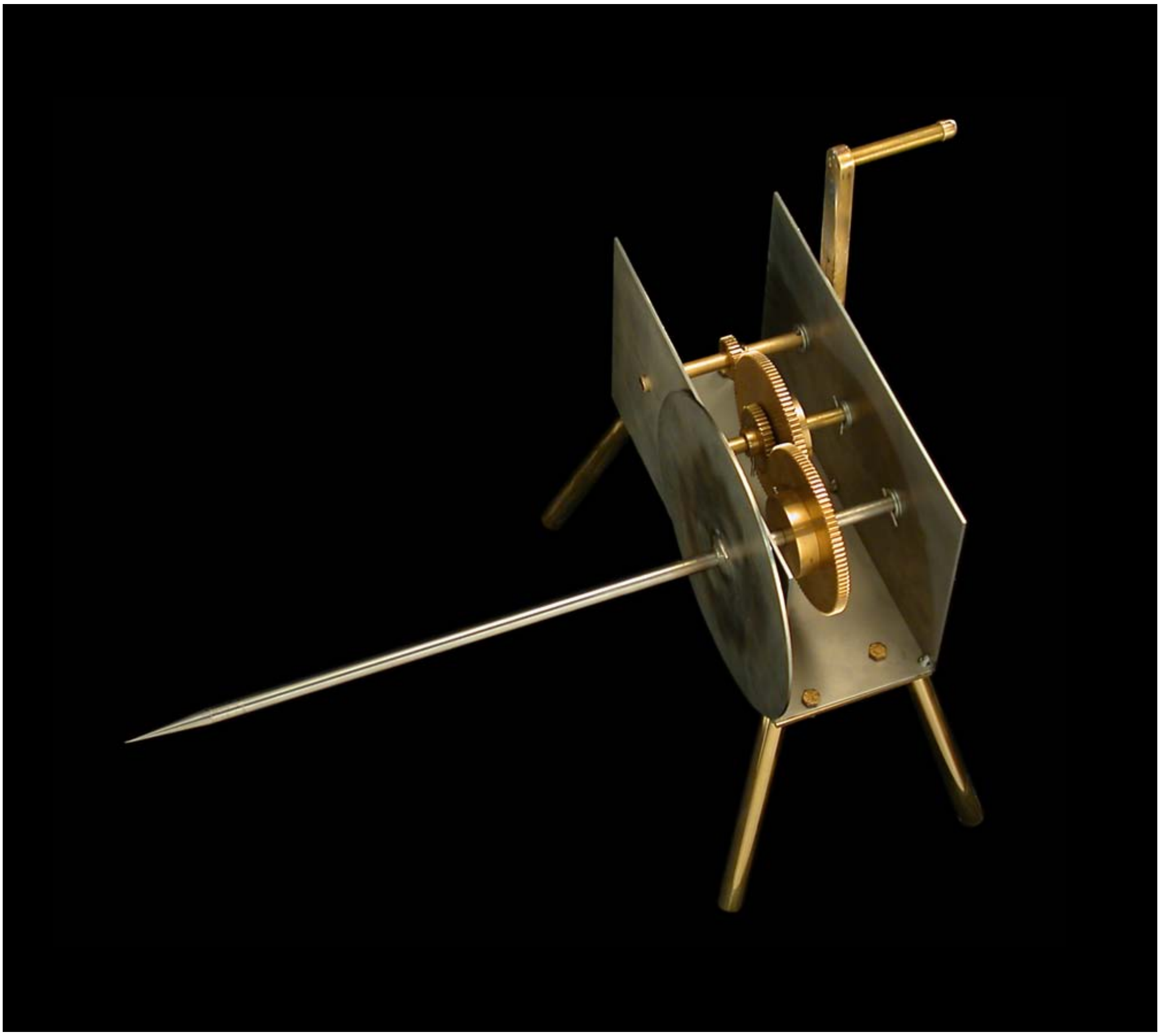


Illustr. from *Leonardo da Vinci*, op. cit., p. 503.

Taqīyaddīn describes only briefly the second type of device for turning a roast spit, which was as common as the first type at that time. Instead of the steam turbine, here the hot air rising up through the chimney is used to turn the spit. As in the case of bucket conveyors for water, additional energy was supplied by a lead weight. One can probably imagine this as involving the weight running over a pulley as in a clock. The power transferred through a gear system to the spit will therefore not have been adequate to turn the roast sufficiently fast.

The Codex Atlanticus (fol. 5) of the work by Leonardo da Vinci[1] preserves the sketch of an apparatus for turning roast meat (see illustration) which is powered by smoke or rather by the heated air ascending from the fire beneath the roast spit.[2] This sketch, in which the gear transmission can also be seen, was very useful for our reconstruction. I doubt, however, whether an apparatus built according to the sketch would function because apart from the hot air no other source of energy is apparently provided for.

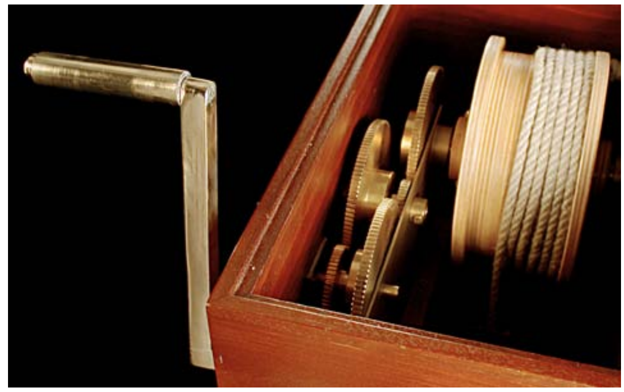
[1] *Leonardo da Vinci*, op. cit., p. 503.
[2] Theodor Beck, *Beiträge zur Geschichte des Maschinenbaues*, Berlin 1899, pp. 425-426.



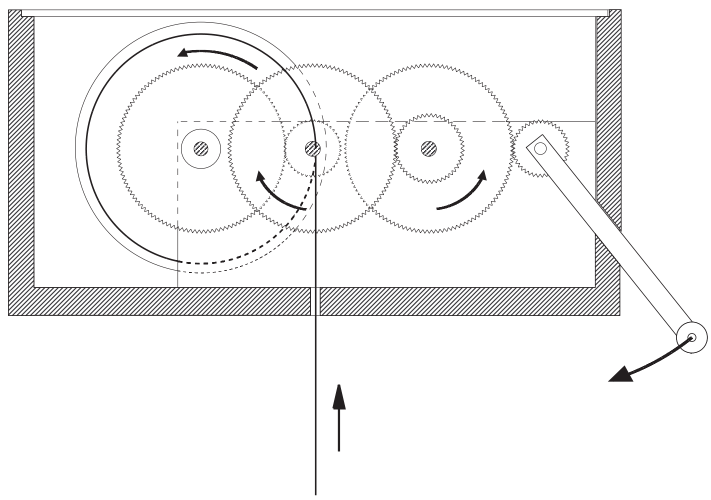
Apparatus for turning roast meat
with a crank and gear drive

Our model:
Brass, stainless steel.
Height: 35 cm.
(Inventory No. E 1.27)

After his description of the first two mechanical devices for turning roast meat which he had first seen in Istanbul, Taqīyaddīn adds that he and his elder brother had invented an instrument there in 953/1546 which was supposed to be easier to transport than the conventional apparatus. The new apparatus for turning roast meat functions with a crank and a system of four gearwheels which produce a transmission ratio of 1:10 and thus make it easy to turn a heavy roast slowly.



Our model:
Wood and brass,
Copper weight (8 kg)
(Inventory No. E 1.12)



Hoist with gear drive

In his book on pneumatic devices (*aṭ-Ṭuruq as-sanīya fi l-ālāt ar-rūḥānīya*[1]) written in 960/1553, the Ottoman scholar Taqīyaddīn describes a gear wheel system (*ad-dawālīb al-mutadāḫilat al-asnān*) which makes it possible to lift a weight of 3000 *raṭl* (ca. 1450 kg) by the application of one-thousandth of the power. In our model with a drive consisting of several steps the transmission ratio is 1:150.

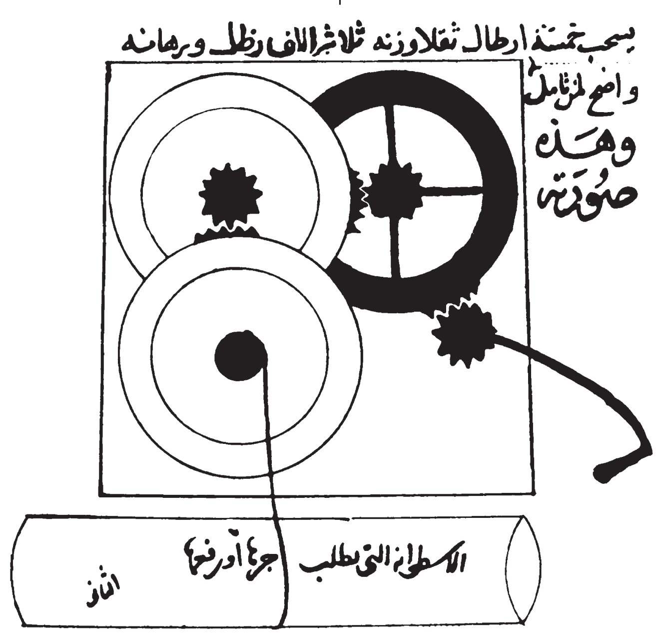
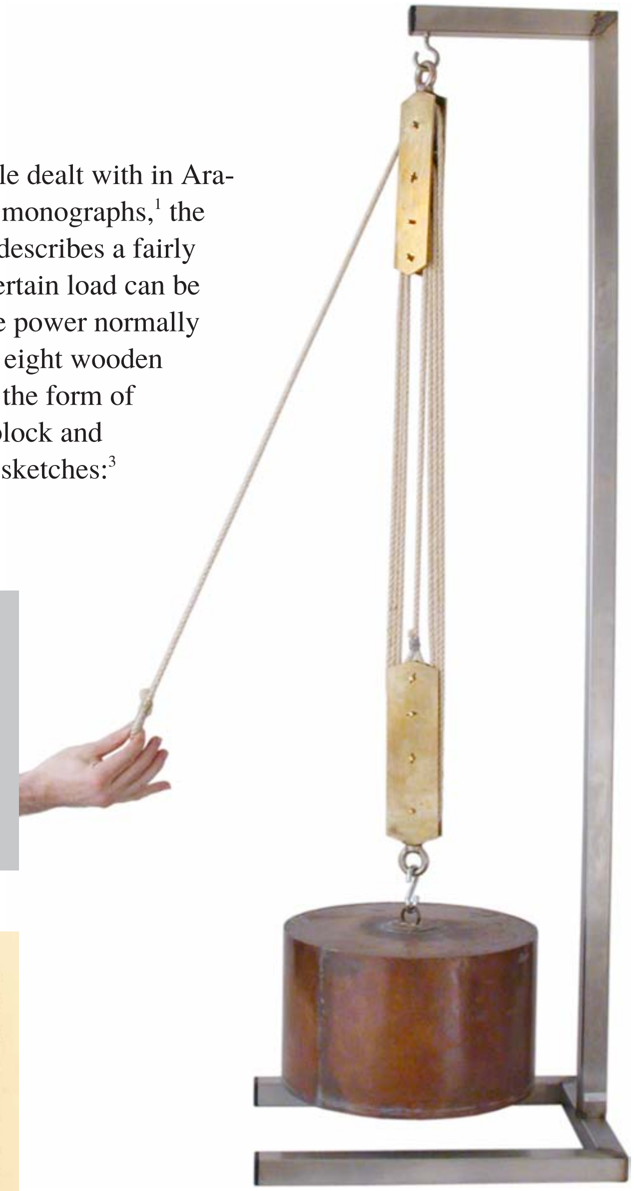


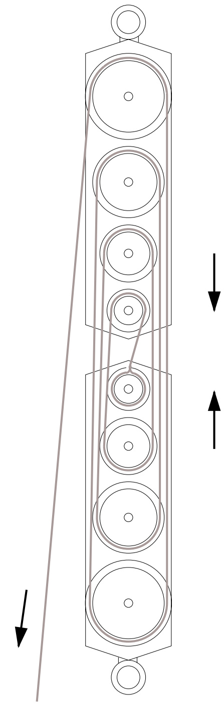
Fig. from:
Taqīyaddīn, *aṭ-Ṭuruq as-sanīya*, p. 26.

[1] ed. A. Y. al-Ḥasan in *Taqīyaddīn wa-l-handasa al-mīkānīkīya al-ʿarabiya*, op. cit., pp. 25-26.

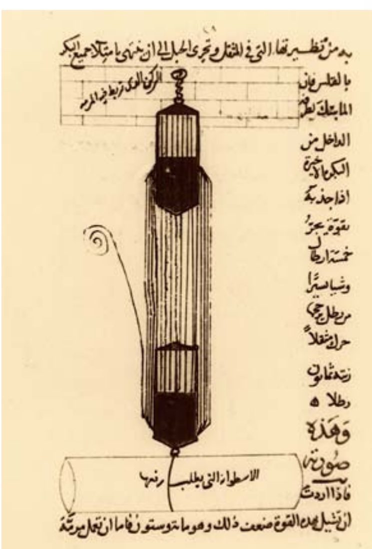
Block and tackle

Of the types of block and tackle dealt with in Arabic books on technology or in monographs,[1] the Ottoman scholar Taqīyaddīn[2] describes a fairly advanced type with which a certain load can be lifted with one-sixteenth of the power normally needed. For this he uses twice eight wooden pulleys and combines them in the form of a cylinder. There is a similar block and tackle in Leonardo da Vinci's sketches:[3]





Our model:
Brass and steel.
Copper weight ca. 15 kg.
Frame of stainless steel,
Height: 130 cm.
(Inventory No. E 1.11))



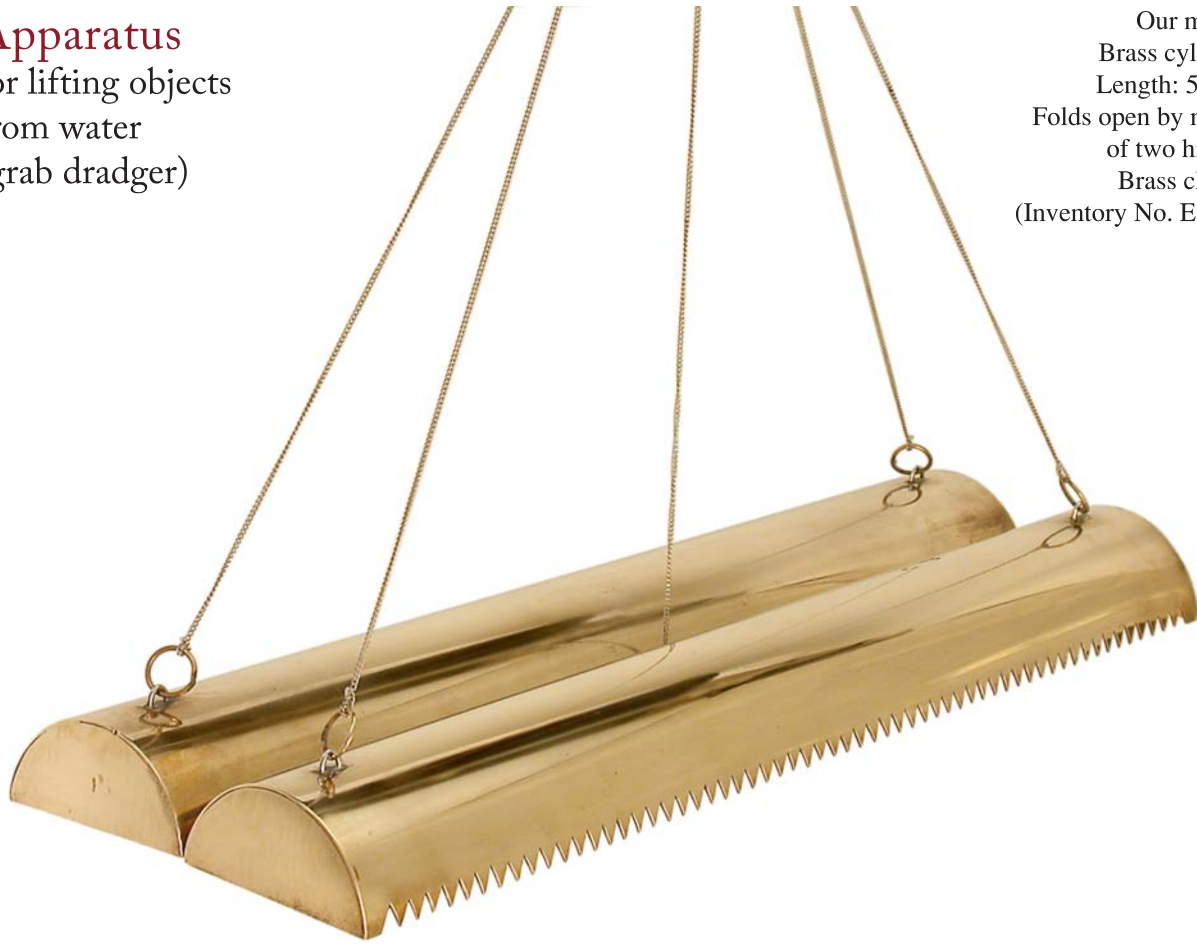
Page from:
Taqīyaddīn,
aṭ-Ṭuruq as-sanīya,
MS Dublin,
Chester Beatty
Lib. 5232

Fig. from:
Leonardo da Vinci, p. 490.

F. M. Feldhaus's view[4] that improvements to ancient pulleys were not made until the 19th century is therefore invalid.
In our model we used only half the number of pulleys envisaged in the original.

[1] They are dealt with using the terms *bakra* ("reel") or *ǧarr al-aṯqāl* ("pulling of weights"), v. E. Wiedemann, *Zur Mechanik und Technik bei den Arabern*, in: Sitzungsberichte der Physikalisch-medizinischen Sozietät (Erlangen) 38/1906/1–56, esp. p. 20 (repr. in: *Aufsätze zur arabischen Wissenschaftsgeschichte*, vol. 1, pp. 173–228, esp. p. 192).
[2] *Kitāb aṭ-Ṭuruq as-sanīya fi l-ālāt ar-rūḥānīya*, facs. ed. A.Y. al-Ḥasan, *Taqīyaddīn wa-l-handasa al-mīkānīkīya al-ʿarabīya*, op. cit., pp. 27–28.
[3] *Leonardo da Vinci*, p. 490.
[4] *Die Technik*, op. cit., col. 332.

Apparatus
for lifting objects from water (grab dradger)

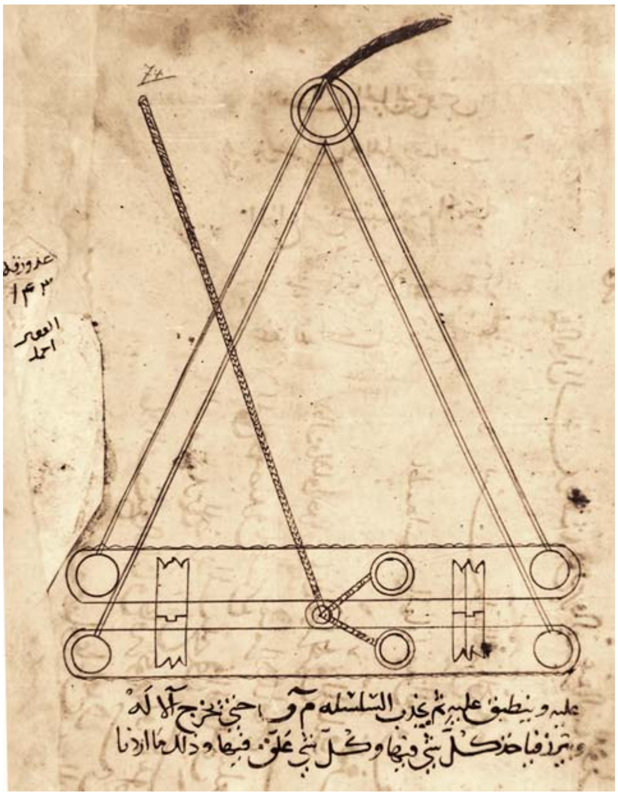


Our model:
Brass cylinder,
Length: 50 cm.
Folds open by means of two hinges.
Brass chains.
(Inventory No. E 1.05)

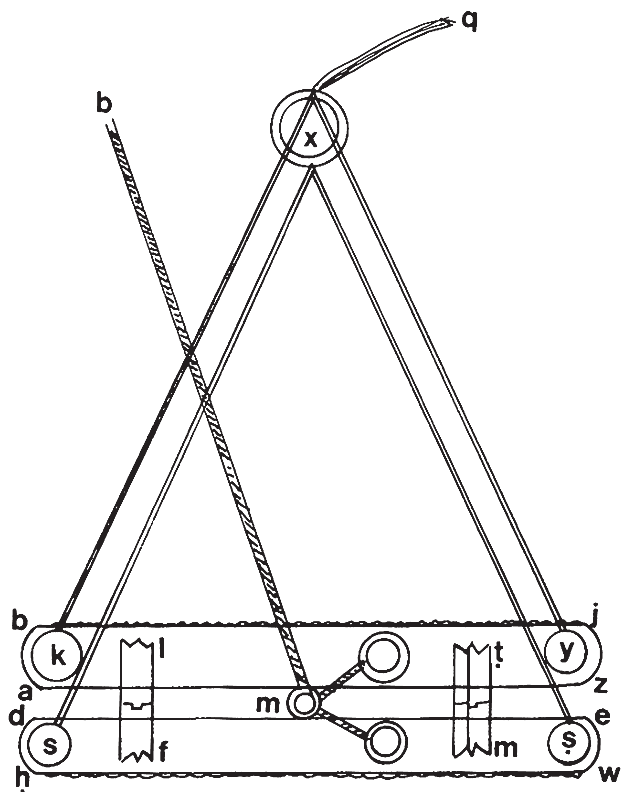
The three sons of Mūsā b. Šākir (Muḥammad, Aḥmad and al-Ḥasan), known as Banū Mūsā ("sons of Mūsā"), who lived in the first half of the 3rd/9th century, describe in their *Kitāb al-Ḥiyal*[1] as the hundredth device an apparatus which serves to lift objects from water. They say: "We want to show how make an instrument with which a person, when he lets it down, can take out material (*ǧauhar*) from the ocean and those objects that have fallen into wells and those that have sunk into rivers and oceans. For this purpose we construct the two halves *abjz* and *wḥde* of a [hollow] cylinder of copper, which are equal to one another; if one half exceeds the other a little in weight then that is better for the present purpose so that one half may take the other one into it (devour it) and [the second one] may enter into the first one a little. Each of the two cylinders should be 1 ell long or longer... One half of the cylinder is adjusted (split) according to the other so that there is not even a small gap between them. Then two hinges (*narmāḏaǧatān*) are attached to them ..."[2] When the apparatus is lowered into water with the help of the four chains that are attached on the outside, the grab cylinder opens. When it reaches the ground, it is pulled up again by means of the chain which is attached in the middle. As a result the cylinder closes and traps the objects which it has enclosed.

[1] ed. Aḥmad Y. al-Ḥasan, Aleppo 1981, pp. 376-379; Engl. transl. Donald R. Hill, *The Book of Ingenious Devices*, Dordrecht etc. 1979, pp. 242-243.

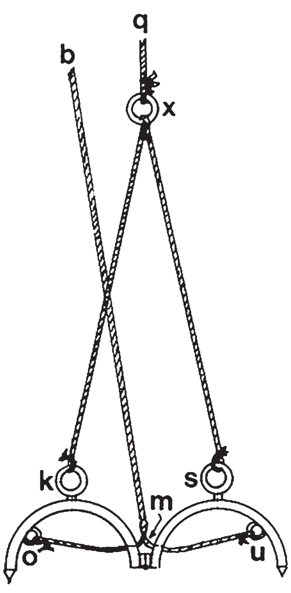
[2] German transl. E. Wiedemann (with slight changes) in: Apparate aus dem Werk *fi l'-Ḥijal der Benû Mûsâ* (*Zur Technik bei den Arabern*. 7), in: Sitzungsberichte der Physikalisch-medizin ischen Sozietät (Erlangen) 38/1906/341-348, esp. pp. 343-345 (repr. in: *Aufsätze zur arabischen Wissenschaftsgeschichte*, vol. 1, pp. 306-313, esp. pp. 308-310).



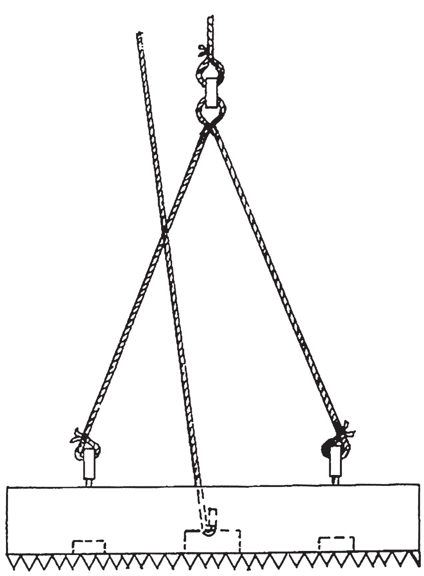
Grab dredger of the Banū Mūsā (MS Berlin).



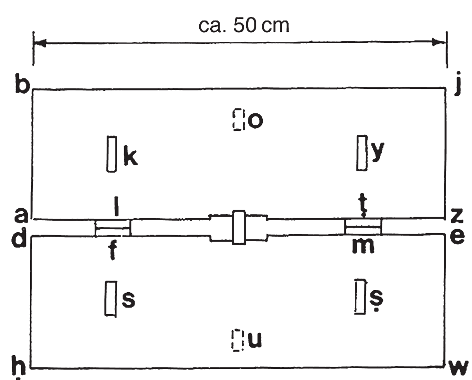
Construction diagrams
(D. R. Hill after E. Wiedemann)



Grab cylinder opened
(end view)

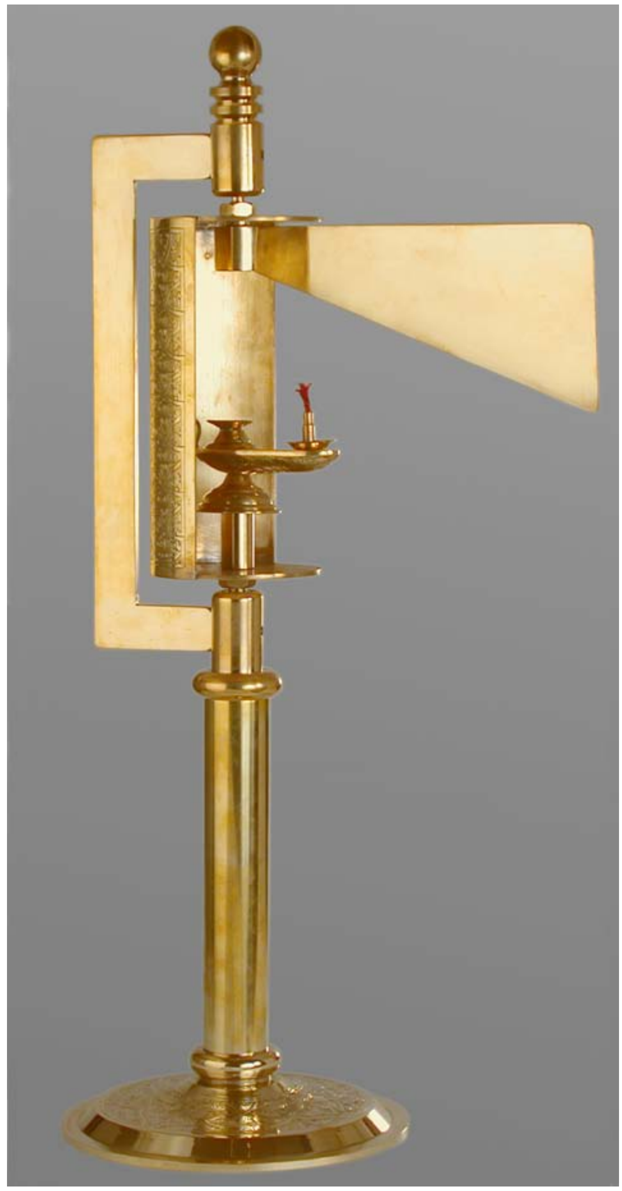


Grab cylinder opened
(side view)



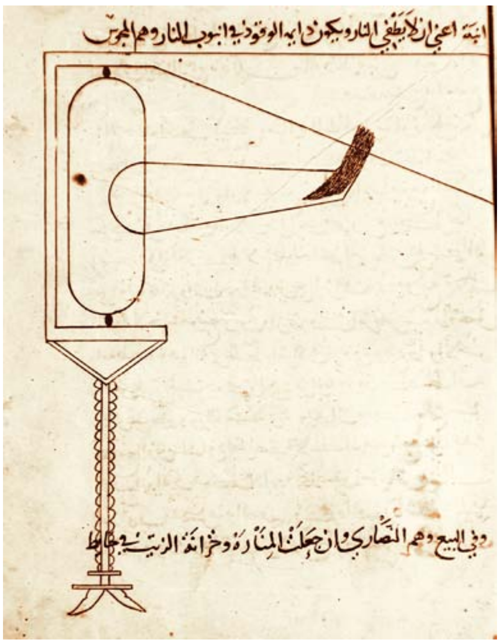
Vertical section
(without ropes)

a Lamp
that does not go out even in strong wind



Our model:
Brass
Height: 63 cm.
(Inventory No. E 1.16)

Fig from:
Banū Mūsā, *K. al-Ḥiyal*
(MS Berlin, or. quart. 739).



Around the middle of the 3rd/9th century the Banū Mūsā (Muḥammad, Aḥmad and al-Ḥasan b. Mūsā b. Šākir) described, in their *Kitāb al-Ḥiyal*,[1] a lamp[2] that does not go out even when it is used in a strong wind.

Our model was constructed according to the description and the illustration by the Banū Mūsā and as interpreted by E. Wiedemann and D. Hill.
The half-cylinder which encloses the lamp is inserted in a frame in such a way that it turns easily. The brass flag attached to it causes the half-cylinder to turn with the closed side towards the wind whenever there is a movement of air, with the effect that the lamp cannot be extinguished by the draught of air. The easy movement of the bearings plays a decisive role so that the flag can turn even in a soft breeze.

[1] ed. Aḥmad Yūsuf al-Ḥasan, Aleppo 1981, esp. pp. 372-373.
[2] Eilhard Wiedemann, *Über Lampen und Uhren* (Beiträge zur Geschichte der Naturwissenschaften. XII), in: Sitzungsberichte der Physikalisch-medizinischen Sozietät (Erlangen) 39/1907/200-225, esp. pp. 204-205 (repr. in: *Aufsätze zur arabischen Wissenschaftsgeschichte*, vol. 1, pp. 351-376, esp. pp. 355-356); *The Book of Ingenious Devices (Kitāb al-Ḥiyal) by the Banū (sons of) Mūsā bin Shākir*. Translated and annotated by Donald R. Hill, Dordrecht, Boston, London 1979, pp. 238-239.

God’s Lantern

(Eternal light)

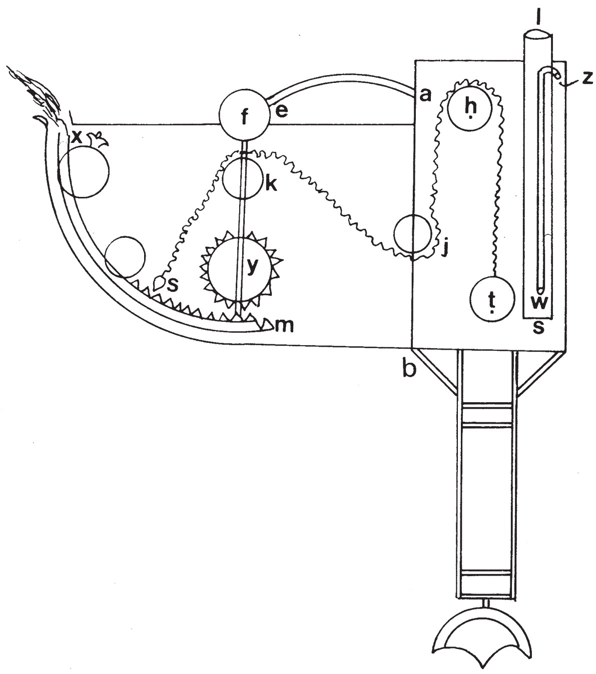
Our model:
Brass, height: 60 cm.
Glass window for viewing.
Wooden wall, height 80 cm.
(Inventory No. E 1.06)

The Arabic term *sirāǧ Allāh* (“God’s lantern”) designates an oil-lamp “whose wick comes up by itself and whose oil flows into it by itself. Everyone who sees it believes that absolutely none of the oil and the wick is consumed.”[1]
The three “sons of Mūsā” (Banū Mūsā) described a lamp like this in the first half of the 3rd/9th century in their *Kitāb al-Ḥiyal*.[2] It could burn for days without anyone having to push the wick forward. The oil continued to flow automatically, seemingly without any decrease in quantity.
A sophisticated technical system ensures that the lamp replenishes itself from a concealed reservoir of oil. In this reservoir a vacuum is created after the filling through the valve *lwz* (see fig. p. 47), which prevents the oil from flowing off through the spout *e*. As soon as the sinking level of oil uncovers the opening *j*, the vacuum is removed, oil flows into the lamp until the opening submerges again and renews the vacuum in the reservoir. In this way the actual oil supply in the lamp remains always constant. The float *ṭ* causes the wick to be automatically pushed forward when the level of oil in the reservoir drops.

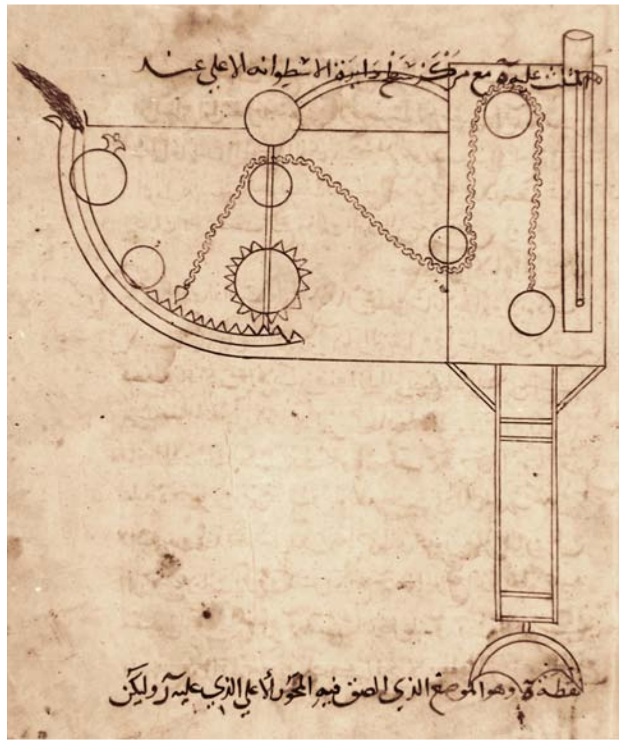
About the purpose of its use the Banū Mūsā say: “People who conduct religious affairs light this lamp. They believe that this provides an eternal lamp in which the fire is not extinguished, in fact, it burns uninterruptedly in the fire pipe that is the case among the Zoroastrians, and it is the case among the Christians in the church. If the lamp-holder (the carrier of the lamp) and the container of oil are set up hidden in the wall so that only the lamp is seen, it makes a better impression on the onlooker.”[3]

[1] E. Wiedemann, *Über Lampen und Uhren*, in: Sitzungsberichte der Physikalisch-medizinischen Sozietät (Erlangen) 39/1907/200-225, esp. 203-204 (repr. in: *Aufsätze zur arabischen Wissenschaftsgeschichte*, vol. 1, pp. 351-376, esp. pp. 354-355).
[2] *K. al-Ḥiyal*, op. cit., pp. 368-371; Engl. transl. D. R. Hill, *The Book of Ingenious Devices*, op. cit., pp. 236-237.

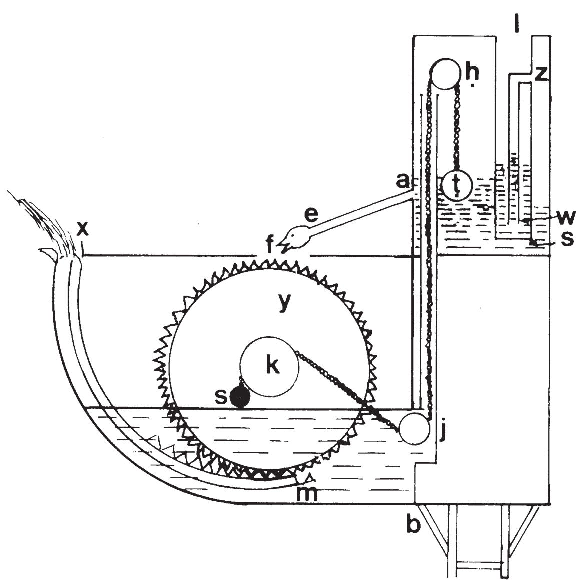
[3] Translation E. Wiedemann, op. cit., pp. 203-204 (repr., pp. 354-355).



Redrawing by D.R. Hill.



Banū Mūsā, *K. al-Ḥiyal* (MS Berlin, or. quart. 739).



Sketch of a functional model proposed by D. R. Hill.

Banū Mūsā, *K. al-Ḥiyal* (MS Istanbul, Topkapı Sarayı, Ahmet III, 3474).

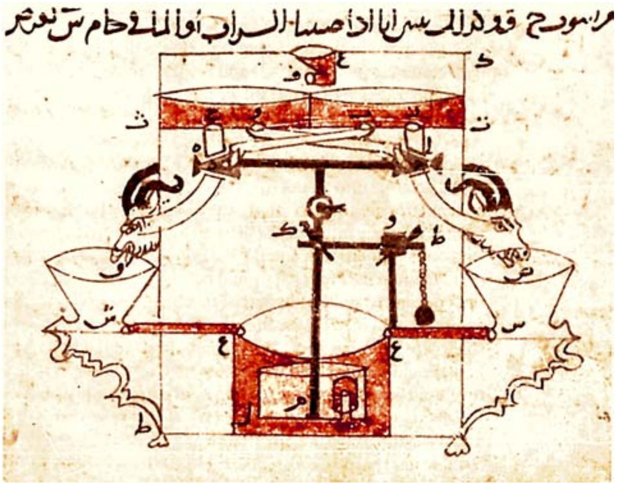
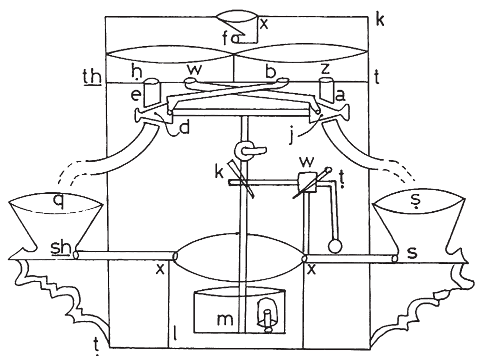


Illustration from Banū Mūsā (MS Topkapı



Redrawing by D.R. Hill.

An astonishing drinking vessel

Our model:
Wooden box 43 × 45 × 100 cm.
Two ornate brass containers, gilded.
Pipes of brass and plastic.
(Inventory No. E 1.09)

The ‹sons of Mūsā› (Banū Mūsā) describe in their *Kitāb al-Ḥiyal*[1] fifteen appliances for drinking vessels and centerpieces which show “in what ingenious manner” they “knew how to solve the most diverse tasks.”[2] The eleventh of their appliances served as our model.

The drinking vessel was displayed on social occasions and served for entertainment. The way it worked was based on hydraulic calculations. When wine is poured into it slowly from the top, water will flow out on the left-hand side and wine on the right. When one pours water quickly into it, then wine will flow from the left side and water from the right. We should visualise that in the original the container is covered so that we cannot look inside to see how the apparatus functions.

[1] *Kitāb al-Ḥiyal*, op. cit., pp. 319-323; D. R. Hill, The Book of Ingenious Devices, op. cit., pp. 212-213.

[2] E. Wiedemann, *Über Trinkgefäße und Tafelaufsätze nach al-Ǧazarî und den Benû Mûsà*, in: Der Islam 8/1918/55-93, 268-291, esp. pp. 284-286, 291 (repr. in: *Gesammelte Schriften*, vol. 3, pp. 1517-1579, esp. pp. 1572-1574, 1579).

Automatic vender
for dispensing warm and cold water alternatively

Our model:
Table 84 × 62 cm.
Total height 170 cm.
Brass fittings.
(Inventory No. E 1.28)

Muḥammad, Aḥmad and al-Ḥasan, the three sons of Mūsā b. Šākir, who were active in the first half of the 3rd/9th century in Baghdad as mathematicians, astronomers and physicists,[1] describe, in their book on mechanical devices,[2] an apparatus which serves the purpose of preparing and regulating the flow of water from two different sources or vessels [50] so

[1] v. F. Sezgin, op. cit., vol. 5, pp. 246–252; vol. 6, pp. 147–148.
[2] *K. al-Ḥiyal*, ed. Aḥmad Y. al-Ḥasan, Aleppo 1981, pp. 385–388; Engl. transl. Donald R. Hill, *The Book of Ingenious Devices*, London 1979, pp. 246–247.

that from each one of two pipes the water flows alternately warm or cold at specific intervals, while it flows from the other pipe in the same intervals but in the contrary sequence. By shortening the intervals an effect can be achieved similar to that of the water mixer.

From a container for hot water on the right-hand side and a container for cold water on the left of the apparatus, water flows to a water wheel which is attached horizontally beneath the containers.

By means of the rotation of the wheel a tub fixed under it is also set in motion. The tub is divided in the middle into two chambers. At first hot water flows into the right-hand chamber, then after half a rotation the cold water. At the same time cold water flows into the left chamber at the beginning and after half a rotation hot water.

From these chambers the water runs through two large openings into a tub which lies below and which is also divided into two chambers. Because of the rotation of the upper tub the water flows out alternately. After only one fourth of a turn of the upper tub the inflow in the lower one changes.

From the lower tub the water is piped to a basin where for one single turn of the water wheel and of the upper tub the inflow from each of the two water pipes changes four times. Hot and cold water flows alternately in short intervals.

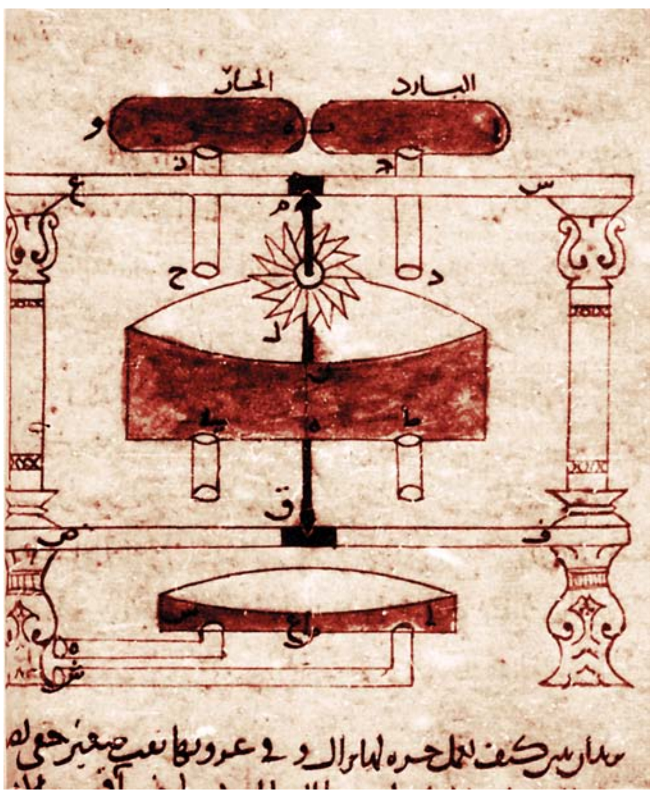


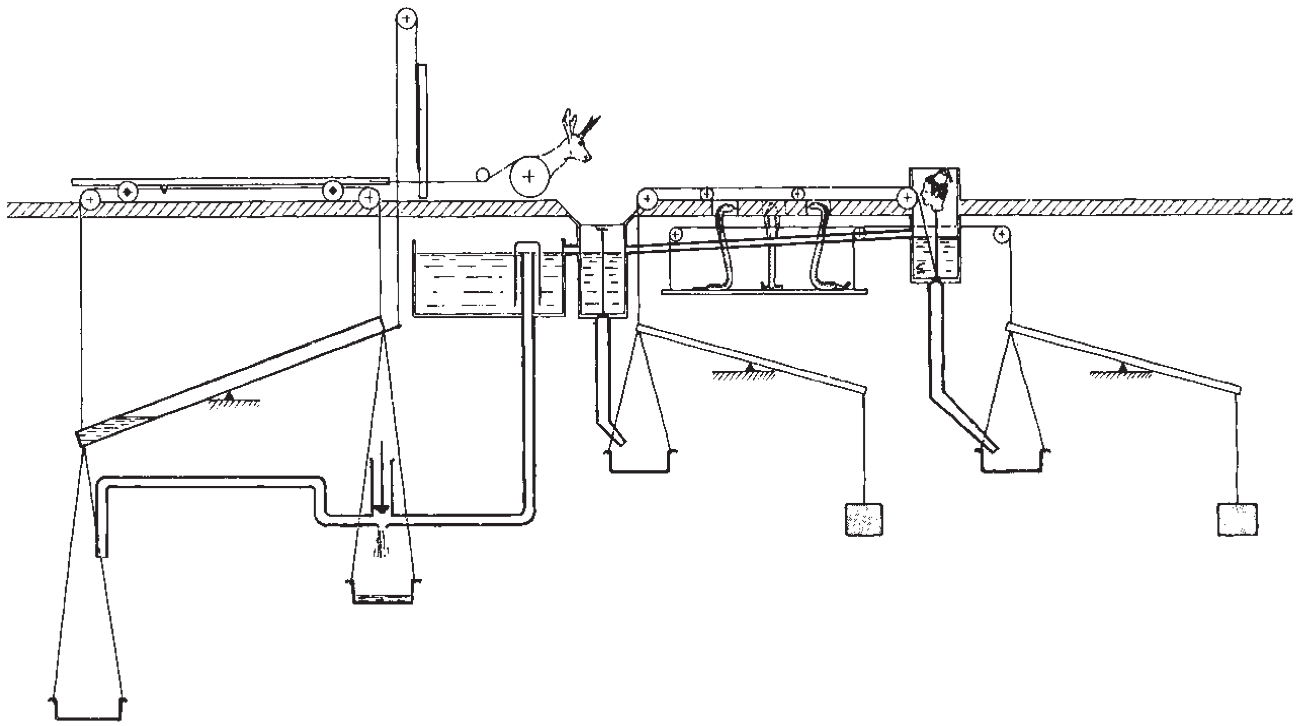
Illustration from Banū Mūsā
(MS Topkapı Sarayı, Ahmet III, 3474).

An automaton for entertainment

Our model:
Width of the wooden box: 110 cm.
Water container and pipes of Perspex.
Bowls of hammered copper.
Figures of cast tin.
(Inventory No. B 1.09)

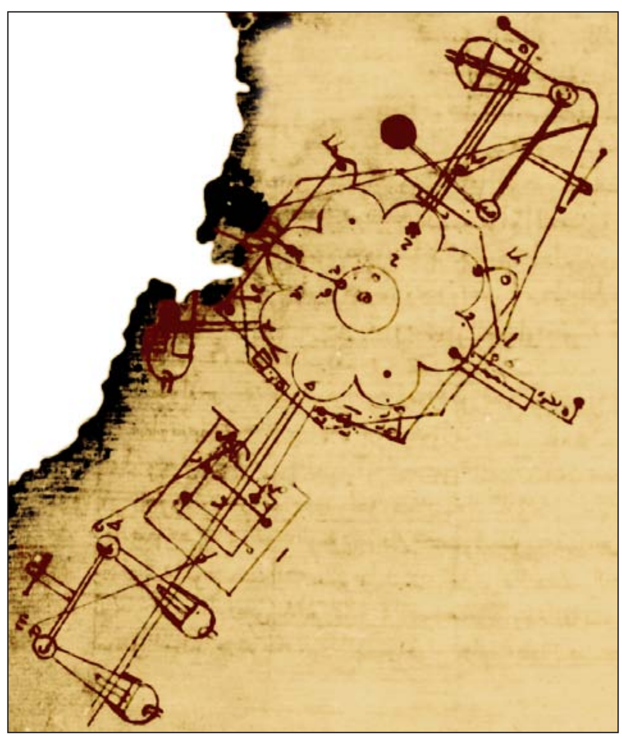
It is the first of the 31 models described and sketched by a certain Muḥammad or Aḥmad b. Ḫalaf al-Murādī (probably 2nd half of the 5th/11th c. in Andalusia) in his book *Kitāb al-Asrār fī natā'iğ al-afkār*. Together with the following four models of the book, it resembles a water clock, since certain actions appear at fixed intervals, but the function of a precise measurement of time is missing.[1] The model was reconstructed by Eduard Farré (Barcelona),[2] based on the explanations and sketches by J. Vernet, R. Casals and M.V. Villuendas.[3] The use of mercury in this automaton is noteworthy; this establishes a connection between this device and the Alphonsine mercury clock (see above, III, 110 ff.).[4] On the other hand it is striking that typical elements of Arabic technology are absent, such as "conical valves, delay systems, feedback controls, or use of small variations in atmospheric pressure."[5]

[1] Donald R. Hill, *Arabic Water-Clocks*, op. cit. p. 37.
[2] J. Vernet and J. Samsó (eds.), *El Legado Científico Andalusí,* pp. 304–309.
[3] *El capítulo primero del "Kitāb al-asrār fī natā'iğ al-afkār"*, in: Awrāq (Madrid) 5–6/1982–83/7–18.
[4] D.R. Hill, *Arabic Water-Clocks*, p. 39.
[5] Ibid., p. 39.



The complicated movement triggers a mechanism after about half an hour (in our model the time is reduced to five minutes). Then the two doors open and two dancing girls appear. At the same time four he-goats lower their heads for drinking. Thereupon a snake-charmer emerges out of a well and the dancing girls move back into the house and the doors close at the same time. The goats also lift their heads once again. Then three snakes rise in front of the well; after some time the snake-charmer disappears first and then the snakes.

On the book by al-Murādī: D. R. Hill, *A Treatise on Machines by Ibn Muʿādh Abū ʿAbd Allāh al-Jayyānī*, in: Journal for the History of Arabic Science (Aleppo) 1/1977/33-46; A. I. Sabra, *A Note on Codex Biblioteca Medicea-Laurenziana Or. 152*, ibid. pp. 276-283; M. V. Villuendas, *A Further Note on a Mechanical Treatise Contained in Codex Medicea Laurenziana Or. 152*, in: Journal for the History of Arabic Science (Aleppo) 2/1978/395-396; J. Vernet, *Un texto árabe de la corte de Alfonso X el Sabio. Un tratado de autómatas*, in: Al-Andalus (Madrid, Granada) 43/1978/405-421; D. R. Hill, *Arabic Water-Clocks*, op. cit. pp. 36-46; R. Casals, *Consideraciones sobre algunos mecanismos árabes*, in: Al-Qantara (Madrid) 3/1982/333-345; D. R. Hill, *Tecnología andalusí*, in: El Legado Científico Andalusí, pp. 157 ff., esp. pp. 163-168, 304-309; J. Samsó, *Las ciencias de los antiguos en al-Andalus*, Madrid 1992, pp. 250-257; J. Casulleras, *El último capítulo del* Kitāb al-asrār fī natāʾiŷ al-afkār, in: *From Baghdad to Barcelona*. Studies in the Islamic Exact Sciences in Honour of Prof. Juan Vernet, Barcelona 1996, vol. 2, pp. 613-653.



Drawing from al-Murādī, *Kitāb al-Asrār*
(MS Florence, Biblioteca Medicea Laurenziana, orient. 152).

Fountain
with varying appearance

Our model:
Total height: 110 cm.
Brass frame around Perspex.
Ornate bowl and lid,
also see-saw of gilt brass.
Copper float and pipes.
(Inventory No. B 1.07)

I.

This is one of the two devices originally described in the 3rd/9th century by the Banū Mūsā which Ibn ar-Razzāz al-Ǧazarī (ca. 600/1200) found deficient and replaced with his own constructions.

The water, which was originally supplied from outside, is piped back into the model from the lower water container and flows in the upper part over a see-saw into the right-hand one of the two chambers. When this is completely full, the see-saw, regulated by a float, swings round so that the left chamber is filled. In this time, which is precisely calculated, the water of the right-hand chamber flows out of a pipe and rises as a single jet out of the central nozzle of the lower basin. Then the see-saw turns around, so that the water of the left chamber empties through the second pipe and rises as five jets out of the lower nozzle ring. The interval was originally half an hour, in our model it is shortened to three minutes.

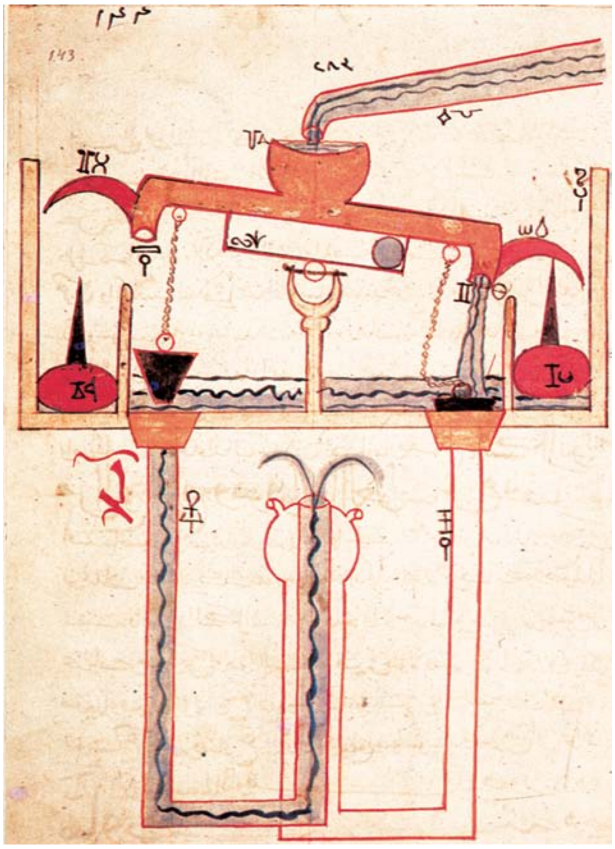
Literature: al-Ǧazarī, *al-Ǧāmiʿ*, facsimile, Ankara 1990, pp. 276-277; E. Wiedemann, *Die Konstruktion von Springbrunnen durch muslimische Gelehrte*. II. *Anordnungen von al Ǧazarî für Springbrunnen, die ihre Gestalt wechseln*, in: Festschrift der Wetterauischen Gesellschaft für die gesamte Naturkunde, Hanau 1908, pp. 29-43, esp. 36 ff. (repr. in: E. Wiedemann, *Gesammelte Schriften*, vol. I, pp. 241-255, esp. p. 248 ff.; D. R. Hill, *The Book of Knowledge of Ingenious Mechanical Devices*, p. 158 ff.

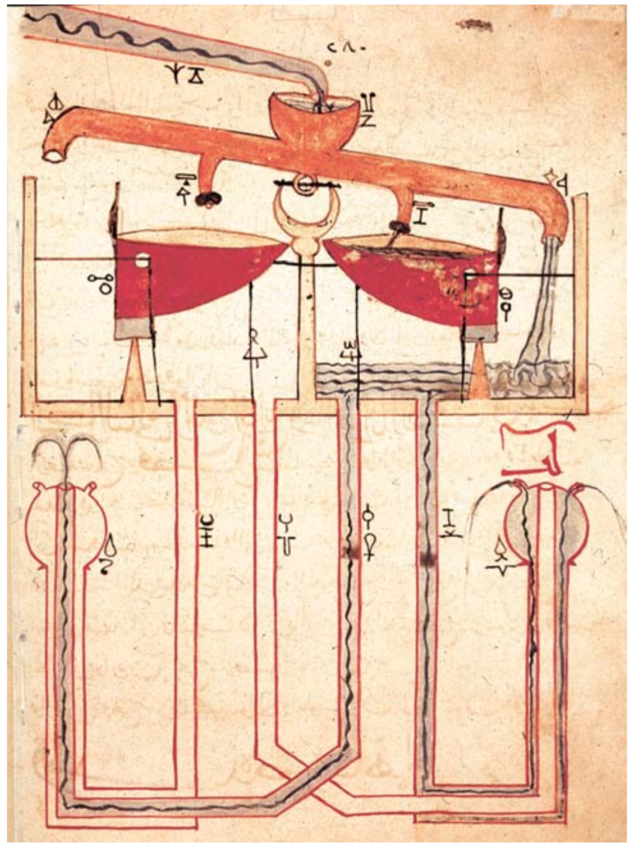
2.
The second
of the fountains
constructed and described by al-Ǧazarī

Our model:
Total height: 130 cm.
Brass frame around Perspex.
Copper tub and shovel.
Ornate lid and pipes gilded.
(Inventory No. B 1.08)

Here also the water flows over a see-saw first into the right-hand chamber. At the same time a scoop is filled with water until it is so heavy that it tips over, thereby tilting the see-saw and enabling the chamber to be drained. While the left chamber is filling, the water bubbles out as two jets: a mushroom of water forms on the left side, a jet on the right-hand side. After a specific time the water of the left chamber empties. Now the mushroom of water is to be seen on the right-hand side, the jet on the left. Here too the interval was originally half an hour; it is shortened in our model to three minutes.

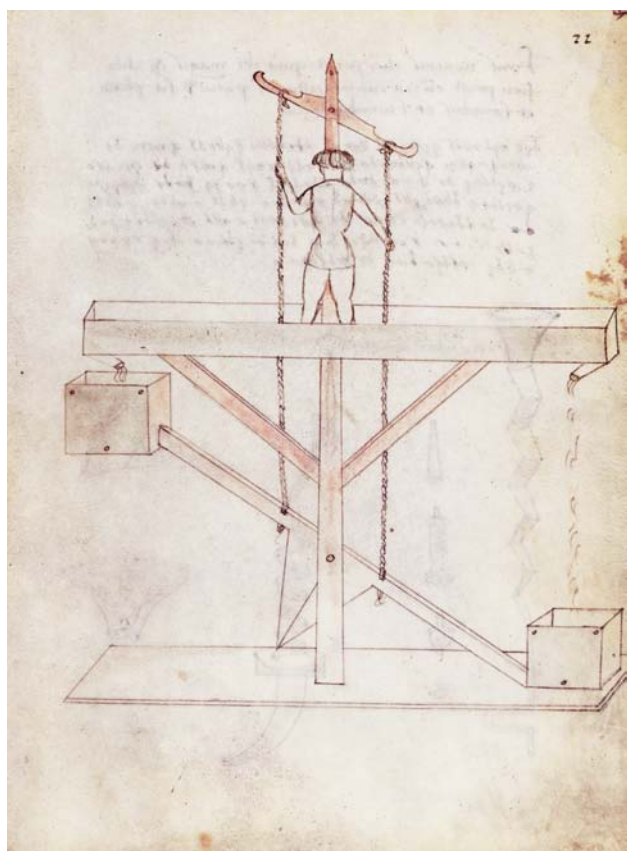
Literature: al-Ǧazarī, *al-Ǧāmiʿ baina l-ʿilm wa-l-ʿamal*, facs. ed., Ankara 1990, pp. 278-279; E. Wiedemann, *Anordnungen von al Gazarî*, op. cit., p. 36 ff. (repr., p. 248 ff); D. R. Hill, *The Book of Knowledge*, op. cit., p. 158 ff.



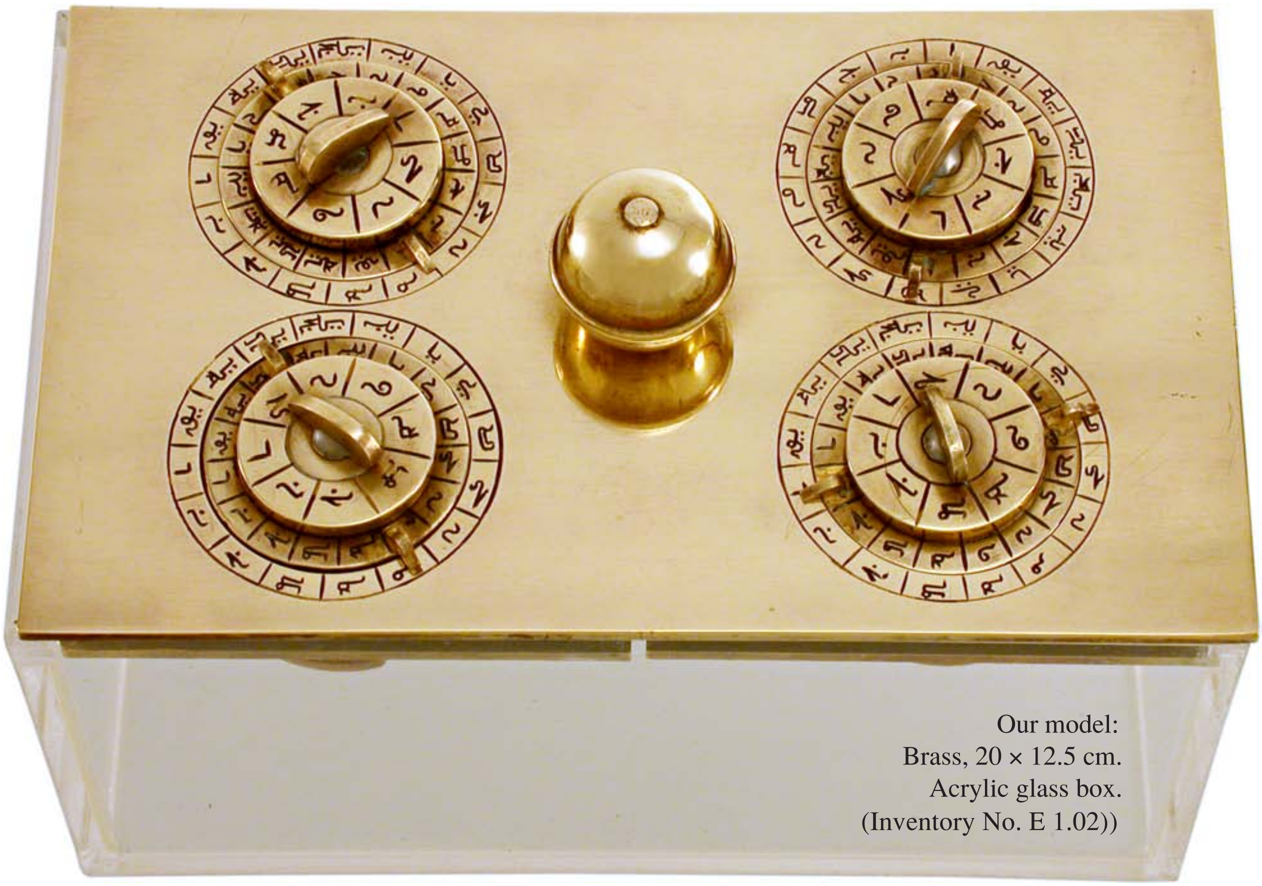


Illustrations from al-Ǧazarī, op. cit., pp. 280, 283.

On folio 22r of his *Bellicorum instrumentorum liber*, Giovanni Fontana (1st half of 15th cent.)[1] draws the main features of a fountain which betrays his knowledge of an Arab model (see fig. on the right).



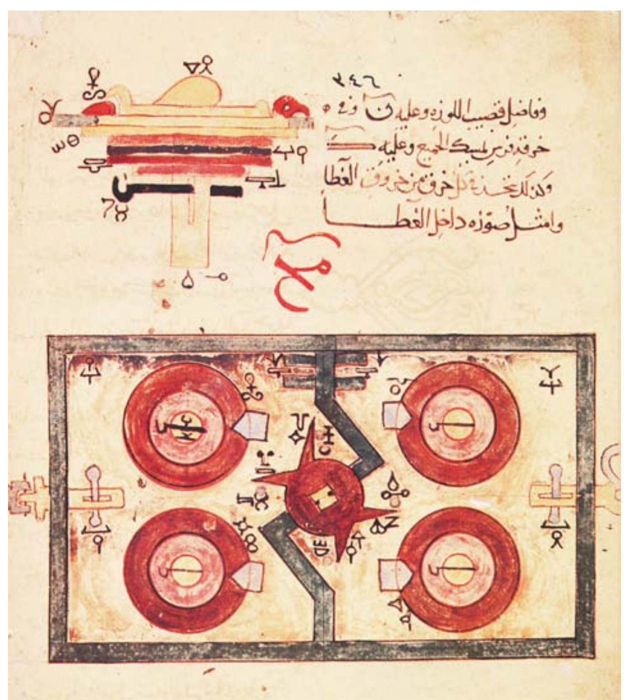
[1] Eugenio Battisti and Giuseppa Saccaro Battisti, *Le macchine cifrate di Giovanni Fontana*, Milan 1984, p. 118.



Our model:
Brass, 20 × 12.5 cm.
Acrylic glass box.
(Inventory No. E 1.02))

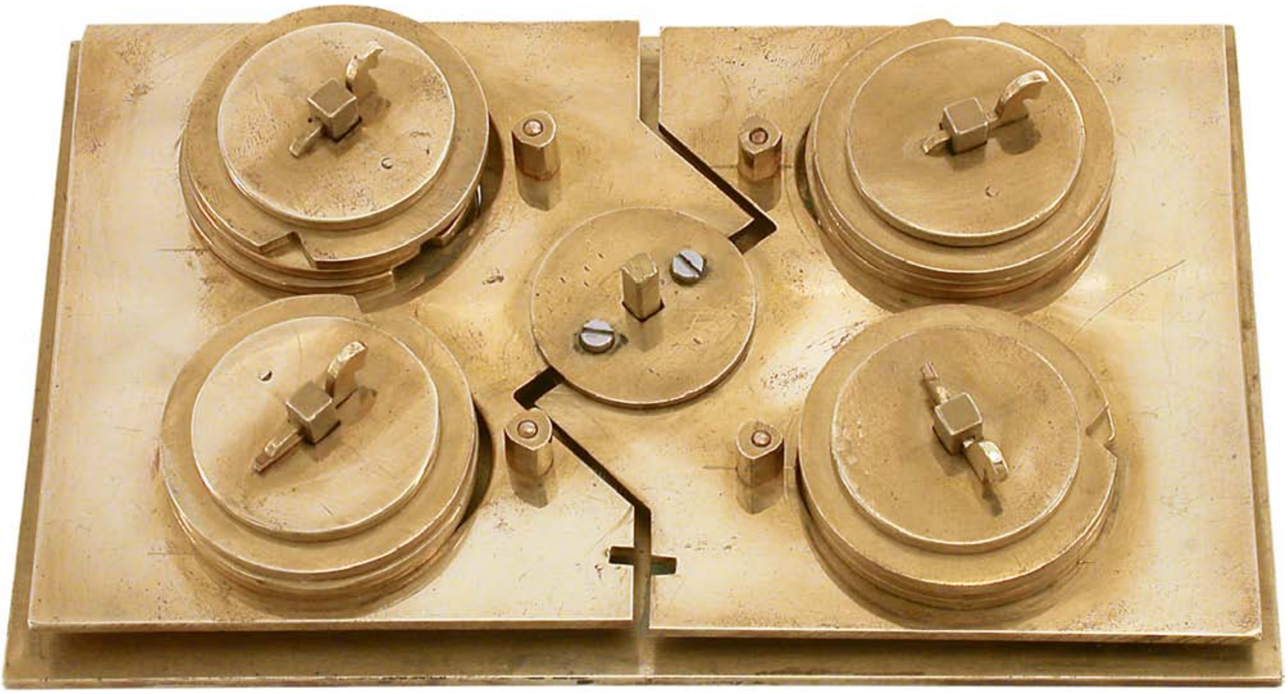
A combination lock

In the last chapter of his book Ibn ar-Razzāz al-Ǧazarī (ca. 600/1200) deals with a number of mechanical devices, among them a letter-lock, a ‹lock with twelve letters which serves to lock a box› (*qufl yuqfalu ʿalā ṣandūq bi-ḥurūf iṯnā ʿašar min ḥurūf al-muʿǧam*)[1].



Drawing from al-Ǧazarī, *al-Ǧāmiʿ baina l-ʿilm wa-l-ʿamal,* op. cit., p. 346.

[1] *al-Ǧāmiʿ baina l-ʿilm wa-l-ʿamal*, facs. ed. Ankara 1990, pp. 340–348; German transl. E. Wiedemann, *Über eine Palasttüre und Schlösser nach al-Ǧazarī*, in: Der Islam 11/1921/213–251, esp. pp. 232–244 (repr. in: *Gesammelte Schriften*, vol. 3, pp. 1670–1708, esp. pp. 1689–1701), Engl. transl., D. R. Hill, *The Book of Knowledge of Ingenious Mechanical Devices*, op. cit., pp. 199–201



The lid consists of two plates which are connected with four combination locks and a turning knob. The cover plate serves as a clamping device. The plate lying underneath consists of two halves which can be pushed apart with the knob. However, this is only possible when the locks are adjusted to a certain combination. Then the rings in the locks set free a groove into which the security pegs, which are affixed to the lower plate, can slide. When the combination lock is placed upon a box for which it is intended, the lower plate can slide into the two recesses by means of the knob. At the same time a cylinder is pushed into a guideway attached on the side so that the lower plate cannot be pushed together any more. By altering the combination the cylinder is secured. The twelve-digit combination of Arabic characters, each of which corresponds to a numerical value, can be easily changed when the lid is opened.

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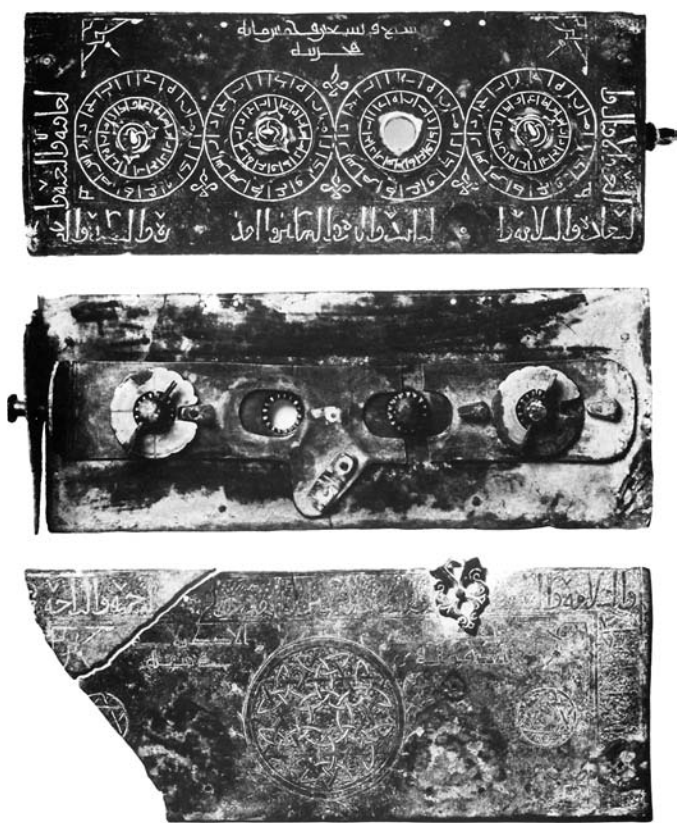
ثم يتخذ في ثقب الفلس شنبر خارجة بملا ثقب الفلس
وطرفه مساوي وجه الفلس والطرف الآخر بارز عن ظهر الفلس
ضعف سمك الفلس
ويلحم بحاله وهذه صورة ثابتة
لسمك الفلس والشنبر ثم يتخذ
فلس أصغر من هذا الفلس ويتخذ عليه دائرة دون حرفه
ويكتب بينهما الحروف الستة عشر ويثقب وسطه ثقبا
واسعا وهذه
صورته ثم يتخذ في هذا
الثقب شنبر خارجة بملا داخل الثقب وطرفه مساوي وجه
الفلس والطرف الآخر بارز عن ظهر الفلس أربعة أقدار
سماكة الفلس ويتخذ على حرفه لوزة نصفها على مسطح وجه الفلس
ونصفها خارج عن حرفه ليمر على الحرف
من الفلس الأول ويتخذ بحيال هذه اللوزة
على حرف هذا الفلس أيضا زرناني ليمسك

Page with the description and illustration of the number lock from al-Ǧazarī, *al-Ǧāmiʿ baina l-ʿilm wa-l-ʿamal*, facs. ed., Frankfurt 2002, p. 523.

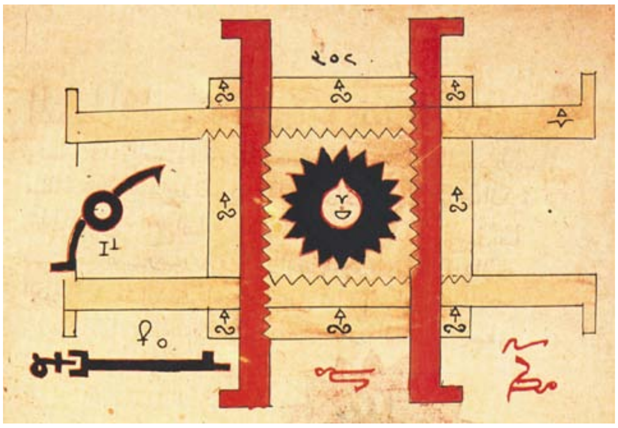
Small ivory casket preserved from the period of al-Ǧazarī (ca. 600/1200) with a combination lock of Arabic characters (191 × 201 × 375 mm). Metal mounts and lock of gilded copper alloy. Maastricht, Stichting Schatkamer Sint Servaas (Belgium).



Two more caskets with combination locks from the 7th/13th cent.; on the left: Khalili Collection, London, op. cit., vol. 12, No. 344. Above: part of a small box by Muḥammad b. Ḥāmid al-Iṣfahānī, dated 597/1200, Copenhagen, David Collection, ref. No. 1/1984.

Door lock

with four bolts



Drawing from al-Ǧazarī, op. cit., p. 352.

In the last chapter of his *Ǧāmiʿ baina l-ʿilm wa-l-ʿamal* Ibn ar-Razzāz al-Ǧazarī (ca. 600/1200) describes a door lock with four bolts: “There are four bolts made of wood or iron, on the back of a door; they are on four sides, but placed in different directions. They are pushed forward and opened by a key. One bolt opens to the right, one to the left, one upwards and another downwards. There is no space in the four bolts which a malicious person (*ṭāriḥ*) can infiltrate. When the key is taken out of the hole in which it fits in order to open and to push the bolts forward, nobody is in a position to achieve what is the purpose of the bolting and to push the bolts with the hand upwards or downwards or to the right or to the left; then they cannot be moved, either for bolting or for opening. The only thing with which one can move them is the key.”[1] After this description of the function of the key, al-Ǧazarī gives a detailed description of the mechanism and its component parts.

Our model:
Wood, brass and Perspex.
Measurements: 51 × 43 × 58 cm.
(Inventory No. E 1.10))

[1] al-Ǧazarī, *al-Ǧāmiʿ bain al-ʿilm wa-l-ʿamal*, facs. ed., Frankfurt 2002, pp. 532–537; Ankara 1990, pp. 348-352; German transl. E. Wiedemann, *Über eine Palasttüre und Schlösser nach al-Ǧazarī*, in: Der Islam 11/1921/213-251, esp. pp. 244-250 (repr. in: *Gesammelte Schriften*, vol. 3, pp. 1670-1708, esp. pp. 1701-1707), Engl. transl. D. R. Hill, *The Book of Knowledge of Ingenious Mechanical Devices*, op. cit., pp. 202-203.

Our model (a):
Wood, weights of lead, brass bearing.
Diameter 80 cm.
(Inventory No. E 1.21)

Perpetuum Mobile

The depiction of various forms of perpetua mobilia in the three extant manuscripts of the anonymous Arabic anthology of technical content (probably from the 6th/12 cent., see above, p. 35)[1] creates the impression that the idea of something ‹continuously moving›, of a machine that turns without any external supply of energy, was fairly widespread, even at that time, indeed, it was part of a certain tradition. How far this tradition goes back to Greek or Byzantine sources is not known at present. The same idea with which Europeans up to the 19th century occupied themselves so passionately[2] appears in Europe shortly before the middle of the 13th century in the work of the French engineer Villard de Honnecourt[3] and then in the work of his younger compatriot Peter Peregrinus.[4]

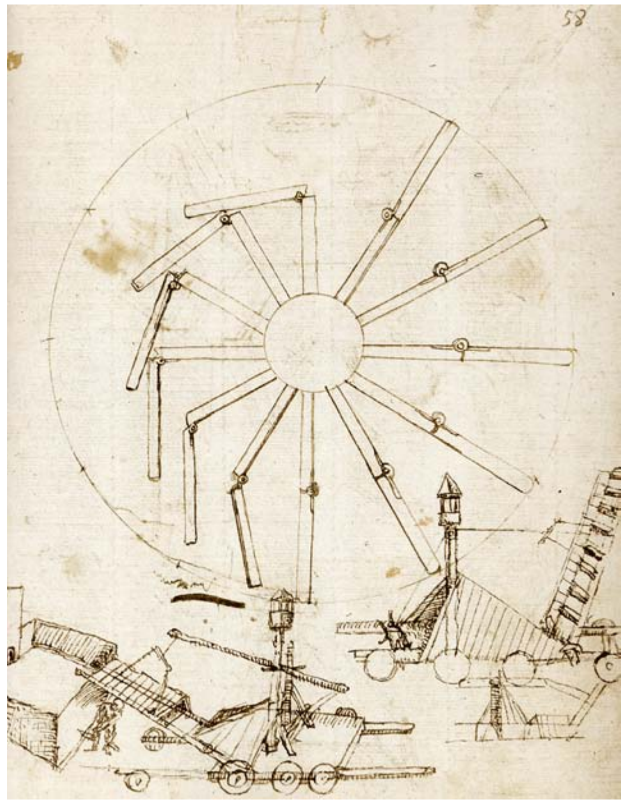
[1] According to MS Gotha 1348, fol. 105b; Leiden, Warn. 499 (= or. 499), fol. 80 a. Cf. H. Schmeller, *Beiträge zur Geschichte der Technik in der Antike und bei den Arabern*, Erlangen 1922, p. 21 (repr., op. cit., p. 221).

[2] v. F. M. Feldhaus, *Ruhmesblätter der Technik*, Leipzig 1910, pp. 217-230.

[3] Sarton, *Introduction* II, op. cit., p. 1033.

[4] v. E. Grant, in: Dictionary of Scientific Biography X, 1974, col. 536[b].

Our model (b):
Wood and brass.
Diameter 26 cm.
(Inventory No. E 1.22)



Drawing from Mariano Taccola's notebook (1st half of 15th cent.).[6] At the bottom of the page there are sketches of war machines. The perpetuum mobile is, due to its striking similarity with the one depicted in our model, another piece of documentary evidence of the decisive importance of older Islamic sources for the protagonists of the ‹Renaissance›.

Later the interest in perpetua mobilia grew to such an extent that the Académie Française decided in 1775 not to examine any proposals for the solution of this problem any more.
As far as we know, the astronomer and physicist Taqīyaddīn b. Maʿrūf was the first scholar in the Islamic world to point out, in the middle of the 10th/16th cent., the absurdity of the perpetuum mobile.[5]

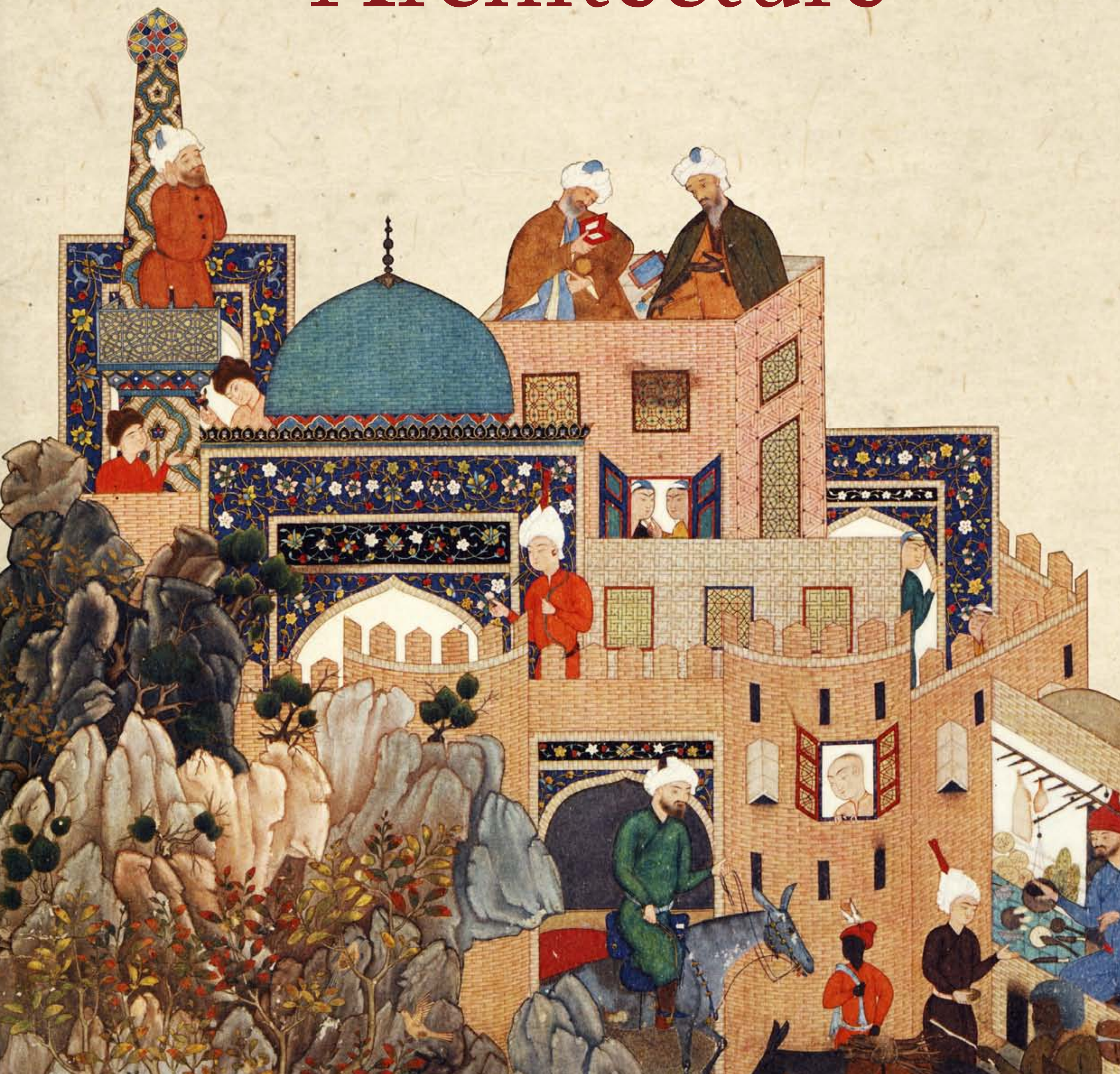
Our Arabic anthology describes seven types of perpetua mobilia, four of which were meant to be set in motion by mercury.
Although the models presented here—whose friction loss could, of course, have been reduced further—do not by definition function, they are of interest in so far as they document an advanced knowledge of the principle of the lever and the calculation of the momentum.

v. Sevim Tekeli, *16'ıncı asırda Osmanlılarda saat*, Ankara 1966, p. 218.

[6] *De ingeneis,* vol. 2, facsimile ed., Wiesbaden 1984, fol. 58a.

Chapter 11

Architecture



In lieu of an introduction

The author of these lines does not feel sufficiently competent to write an introduction to the material presented here. An introduction, moreover, is not necessary in view of the small number of our models compared to the numerous extant architectural monuments of the Arab-Islamic world. Our selection concentrates on a few functional public buildings which were exemplary for their times. These were always endowed by prominent personalities, mostly the rulers themselves; therefore they represent not only the advanced architecture and engineering in each case, but also demonstrate the enormous cultural importance which was attached, not only to mosques, but primarily to hospitals and academies of higher learning.

The Mustanṣirīya University in Baġdād

Our model:
Wood and plastic.
Scale ca. 1:50.
Measurement of the base plate:
100 × 60 cm.
Steel frame and transparent hood.
(Inventory No. F 05)

This great university was founded in 625/1227 on the banks of the Tigris in Baghdad by the penultimate Abbasid Caliph al-Mustanṣir billāh. It is probably the oldest Arab-Islamic university where, besides the syllabus of the four orthodox law schools, medicine and mathematical sciences were also taught.[1] The maintenance of the University was secured by an endowment founded by the Caliph. The number of lecturers and other staff was ca. 400. The University had a large and important library which was plundered after the conquest of Baghdad by the Mongols. The Caliph often visited the University and «heard the lectures and the disputations of the scholars from a special place. Every now and then he held official receptions for state guests there.»

Yaḥyā b. Maḥmūd al-Wāsiṭī: illustration to the Maqāmāt by al-Ḥarīrī, *Lecture in a library at Basra* (634/1237), Bibl. Nat. Paris, MS arabe 5847, fol. 5.

[1] For the references to the sources, see Nāǧī Maʿrūf, *Tārīḫ ʿulamāʾ al-Mustanṣirīya*, 3rd ed. Cairo, n.d., vol. 1, pp. 25, 48.

General view of our model,
seen from the East.

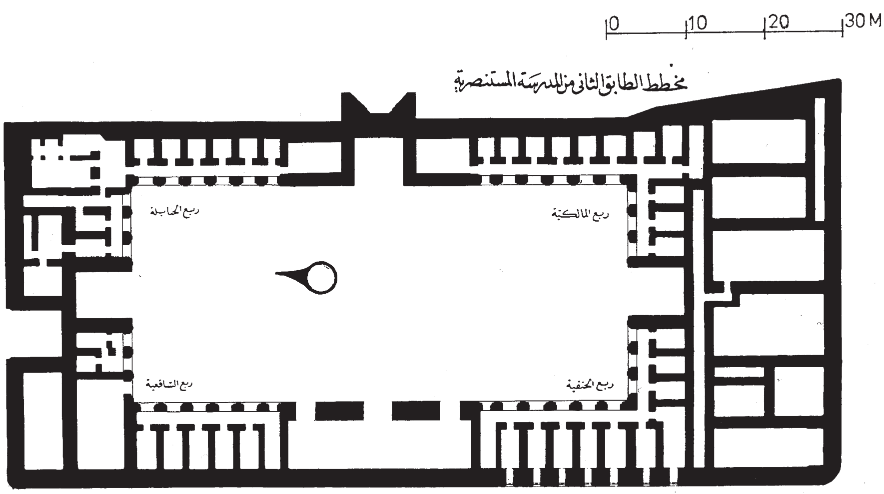


Fig. 1: Plan of the second storey of the Madrasa al-Mustanṣirīya, after the building survey by the Department of Antiquities of Iraq.

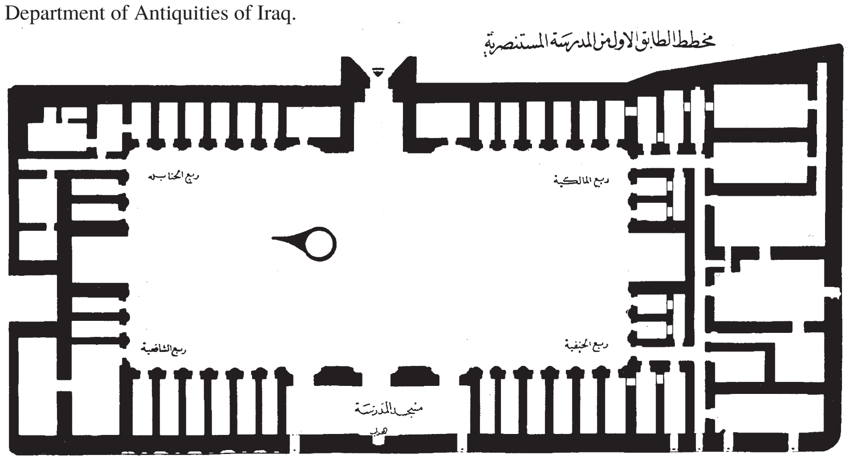


Fig. 2: Ground plan of the first storey of the Madrasa al-Mustanṣirīya, after the building survey by the Department of Antiquities of Iraq.

Plan from Hansjörg Schmid,
Die Madrasa des Kalifen al-Mustansir in Baghdad. Eine baugeschichtliche Untersuchung der ersten universalen Rechtshochschule des Islam. Mit einer Abhandlung über den sogenannten Palast in der Zitadelle in Baghdad,
Mainz 1980.

«The building survived the destruction of the capital and the downfall of the Abbasid dynasty at the conquest by the Mongols in 1258, ...» A decade later the University started functioning once again. It seems to have been much neglected in recent centuries. After its restoration between 1945 and 1962 the building is now part of the Museum of Islamic Culture and Art.[2] Our model was built on the basis of the commendable work by Hansjörg Schmid.

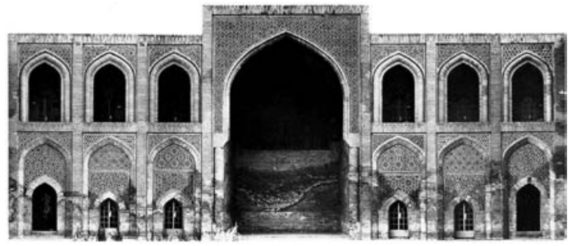


Photo of the façade and a view of the courtyard from Hansjörg Schmid, op. cit.

[2] Hansjörg Schmid, *Die Madrasa des Kalifen al-Mustansir in Baghdad*, op. cit., p. 1.

Our model:
Wood and plastic.
Scale ca. 1:50.
Measurement of the base plate: 100 × 70 cm.
Steel frame and transparent hood.
(Inventory No. F 07)

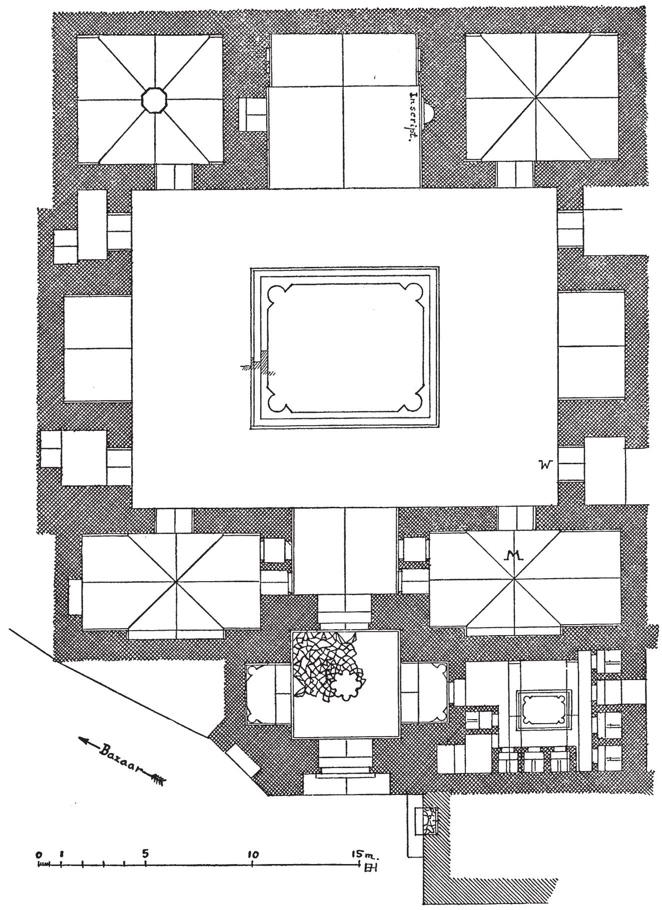
The Nūraddīn hospital
in Damascus

This hospital, known by the name of al-Bīmāristān an-Nūrī, was founded in 549/1154, immediately after the liberation of the city, by Amīr Nūraddīn Maḥmūd b. Zangī, who was of Turkish descent and the predecessor of the Ayyubid Ṣalāḥaddīn (Saladin).[1] It was one the most famous hospitals in the Islamic world and functioned up to the 13th/19th century. Besides the Great Mosque and the Citadel, it is counted among the most important monuments of the Islamic period in Damascus. On the manner of functioning and the organization of the hospital, the Andalusian scholar Ibn Ǧubair (d. 614/1217) wrote the following account in his travelogue on the occasion of his visit to Damascus in 580/1184:[2] «In this place (Damascus) there are about twenty schools and two hospitals, an old one and a new one. The new one is more frequented and is larger. Its [69] daily upkeep costs about fifteen dinars. There are employees who look after the registration of the names of the patients and the necessary

[1] see E. Herzfeld, *Damascus: Studies in Architecture*, in: Ars Islamica (Ann Arbor) 9/1942/1-53, esp. p. 4.

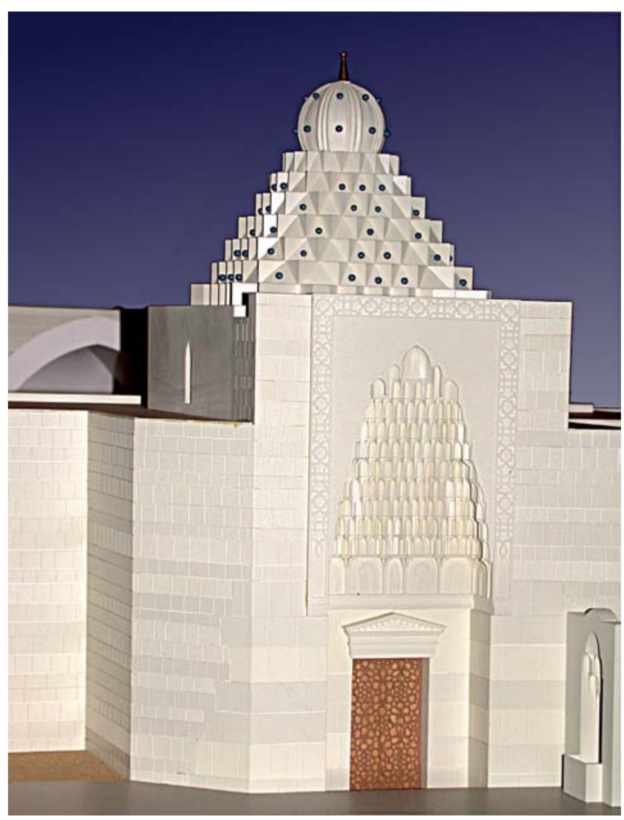
[2] *The Travels of Ibn Jubayr*, ed. W. Wright, 2nd ed., rev. M. J. de Goeje, Leiden 1907, p. 283; E. Herzfeld, *Damascus: Studies*, op. cit., p. 5; A. Issa Bey, *Histoire des Bimaristans (hôpitaux) à l'époque islamique*, Cairo 1928, p. 98.

expenditure on medicines, food etc. The doctors come every day early in the morning, examine the patients and prescribe the medical care with the requisite medicines and food, taking into consideration the condition of each patient … There is also treatment for mental patients …»

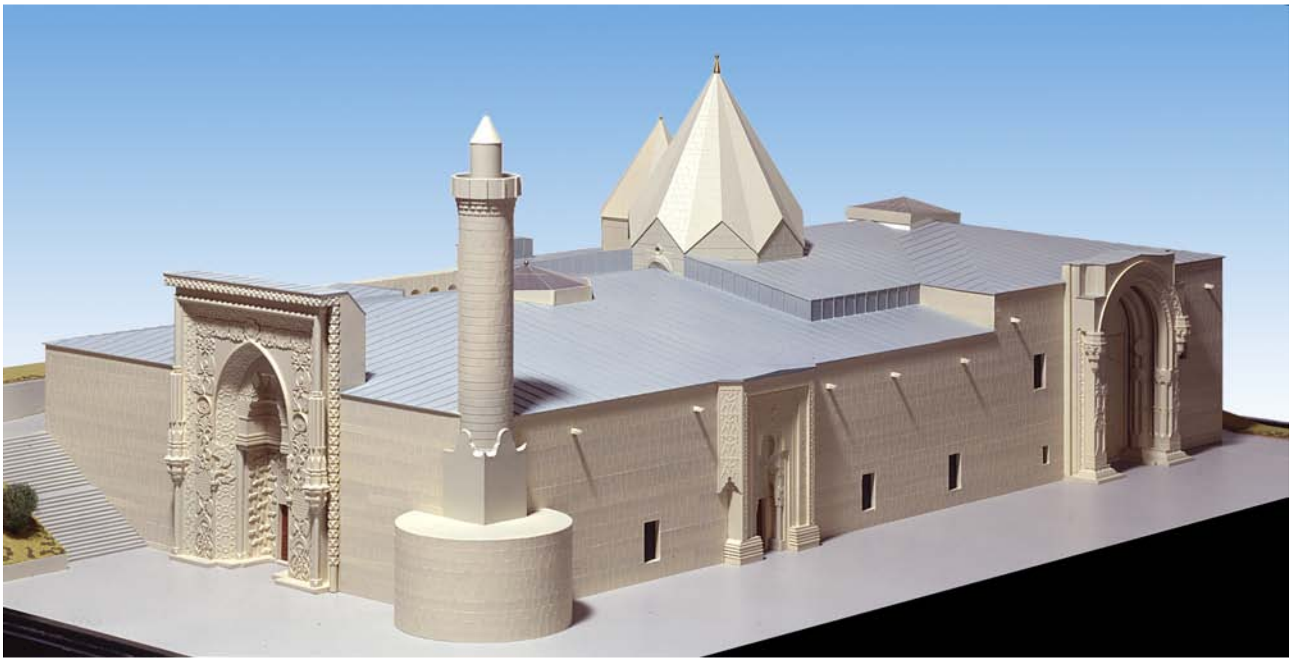


Ground plan of the hospital after E. Herzfeld.

«In the ground plan of this oldest hospital preserved until now, four īwāns (vaulted halls) are grouped symmetrically around an inner courtyard and together they form a cross. There is a water basin at the centre of the inner courtyard.» «Through the muqarnaṣ portal situated in a flat niche you enter into a square anteroom with a muqarnas vault. From this room the visitor goes into the western īwān. The eastern īwān facing it was, according to an inscription, the examination or consulting room. The four vaulted rooms in the corners, with no windows to the outside, were wards.»[3]



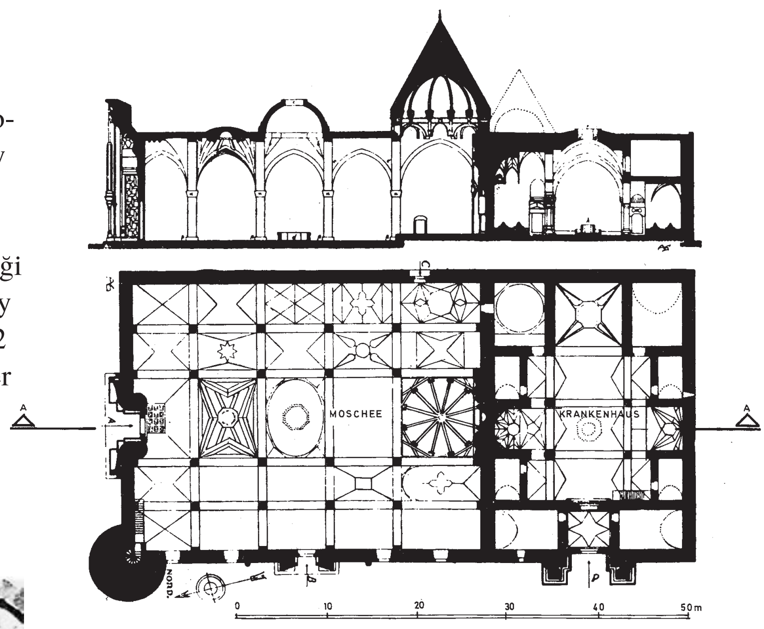
[3] Arslan Terzioğlu, *Mittelalterliche islamische Krankenhäuser unter Berücksichtigung der Frage nach den ältesten psychiatrischen Anstalten*, PhD diss., Berlin 1968, p. 80; cf. J. Sauvaget, *Les monuments historiques de Damas*, Beirut 1932, pp. 49-53.



The hospital
of Princess Tūrān

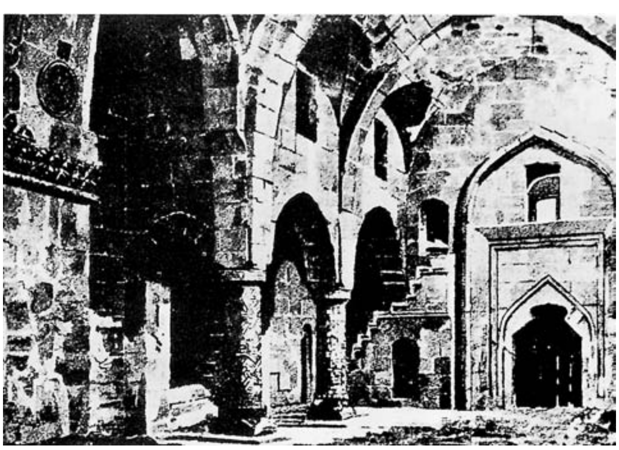
Our model:
Wood and plastic. Scale ca. 1:50.
Steel frame and transparent hood
(Inventory No. F 04).

The oldest completely preserved hospital of Anatolia was erected by Aḥmad Šāh of the local dynasty of Mengüček in 625/1228 on the instructions of Princess Tūrān, a daughter of Faḫraddīn Bahrām Šāh and wife of Aḥmad Šāh. It is situated in Divriği (south-east of Sivas) next to the mosque erected by Aḥmad Šāh. The hospital part covers an area of 32 × 24 metres; the area of the total complex, together with the mosque, amounts to 32 × 64 metres.[1]



Ground plan and longitudinal section of the entire complex (after Terzioğlu)

Inner view of the hospital (historical photo after Terzioğlu).



[1] Arslan Terzioğlu, *Mittelalterliche islamische Krankenhäuser*, pp. 121–125.

Our model:
(of the preserved portion):
Wood and plastic.
Base plate 94 × 119 cm.
(Inventory No. F 08)

The Qalāwūn hospital
in Cairo

The most famous and most important hospitals in the Arab-Islamic world undoubtedly include the al-Māristān al-kabīr al-Manṣūrī in Cairo, which is known in modern publications as Qalāwūn Hospital. Its founder was the Mamluk Sultan al-Malik al-Manṣūr Saifaddīn Qalāwūn (ruled 678/1279-689/1290). He was inspired to build the hospital by his visit to the Bīmāristān an-Nūrī in Damascus in 675/1276. Five years after his accession to power in Cairo, i.e. in 683/1284, he ordered the work to begin.[1] A madrasa was attached to the

[1] On the foundation and the progress of the construction, the historian al-Maqrīzī (766/1364- 845/1442) informs us at length in his book *al-Ḫiṭaṭ wa-l-āṯār* (Būlāq 1270, vol. 2, pp. 406-408). His report, of high documentary value for the history of hospitals, is reproduced here in parts, after the translation by F. Wüstenfeld (*Macrizi's Beschreibung der Hospitäler in al-Câhira*, in: Janus [Breslau] 1/1846/28-39, esp. pp. 32-38, reprint in: Islamic Medicine, vol. 93, pp. 126-145, esp. pp. 138 ff.) with certain modifications:
«The reasons for the construction were the following: when al-Malik al-Manṣūr was still an amīr and was fighting against the Franks during the reign of Malik aẓ-Ẓāhir Baibars in 675/1276, he had a violent attack of colic in Damascus and the physicians healed him with medicines brought from the hospital of … Nūraddīn. After his recovery, he rode up to the hospital, admired it and vowed that he would build a hospital if God granted him the throne. Later when he became Sultan he set out to fulfil the vow, and his choice fell on the Quṭbīya building. He gave the ‹emerald castle› to the owners in exchange and entrusted Amīr ʿAlamaddīn Sanǧar aš-Šuǧāʿī with the responsibility for the construction. He left the central court as it was and equipped it as a hospital; it consisted of four wards, in each ward there was a fountain, and in the middle of the courtyard there was a container into which the water of the fountains flowed … When the building was completed

[72] Plan of the entire complex after Terzioğlu.

1. Pillared courtyard
2. Ward (Īwān) for bedridden patients (men).
3. Ward (Īwān) for bedridden patients (women).
4. Ward (Īwān) for convalescents (men).
5. Ward (Īwān) for convalescents (women).
6. Nursing staff.
7. Stairs to the residence of the chief physician.
8. Kitchen and side rooms.
9. Room for coffins.
10. Room for washing corpses.
11. Stores.
12. Seat of the chief physician.
13. Seat of the surgeon.
14. Seat of the ophthalmologist.
15. Covered well.
16. Pillared courtyard.
17. Latrine courtyards.
18. Cells for mental patients (men).
20. Cells for mental patients (women).
21. Stairs to the terrace.
22. Water basins.

al-Malik al-Manṣūr endowed for it so much landed property in Egypt and other countries that every year an income of nearly one million dirhams was received, and he determined the places where the money for the hospital, the house of prayer, the academy and the school for orphans should be paid. After this he ordered a cup of wine to be brought from the hospital, drank from it and proclaimed: This I have endowed for my equals and for those lesser than I am, I have designated it as an endowment for the king and for the servant, for the soldier and for the amir, for the big and for the small, for the free man and for the slave, for men and women. He determined for it all the medicines, the physicians and all the rest which anyone could be in need of during any illness. The Sultan employed male and female bed-makers for the service of the patients and he determined their salaries; he erected the beds for patients and provided them with all kinds of blankets which were necessary in any disease. Each class of patients was given a special room. He assigned the four wards of the hospital for those suffering from fever and similar illnesses, one ward for those suffering from eye diseases, one for the wounded, one for those who suffered from diarrhoea and one for women; he divided a room for those who are on their way to recovery into two parts, one for men and the other one for women. Water is piped to all these areas. One special room was for cooking the food, medicines

Details of our model, left: façade from the north-west; right: reconstructed inner hall (No. 4 in the plan above)..

hospital [73], which Wüstenfeld correctly understands as an academy. It is not certain whether medical lectures were held there or in special rooms of the hospital. Probably the staff included the physician and versatile scholar ʿAlī b. Abi l-Ḥazm Ibn an-Nafīs (d. 687/1288), the discoverer of pulmonary circulation,[2] who donated his house and his library to the hospital.[3]
The hospital was still in good condition in the 17th century and seems to have fallen into disrepair only in the 18th century. Today the supporting walls are still standing for the most part. At the beginning of the 20th century a new hospital with the same name was built as an extension of the old building.[4] The Egyptian government also plans to restore the old building once again.

Pascal Coste, a French engineer who was commissioned to build factories by the Egyptian government in1818-1825, left behind some valuable drawings of the views and a sketch of the ground plan of the hospital.[5]
The three endowment documents of the hospital from the years 684/1285, 685/1286 and 686/1287 were rediscovered in 1913 in Cairo and are now with the Ministry of Endowments there. The excerpts translated into French by the historian of medicine Ahmad Issa Bey[6] testify to the high standard of the hospital organization in the Arab-Islamic world in the 7th/13th century.

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and syrups, another for mixing the confectionery, balsams, eye ointments etc. The supplies were stored at various places, in one room there were only syrups and medicines, in one room the chief physician had his seat to hold medical lectures. The number of patients was not restricted, with any needy or poor person who came there being admitted. Likewise the time a patient spent there was not fixed, and even those who were lying ill at home were supplied from there with all that they needed.»

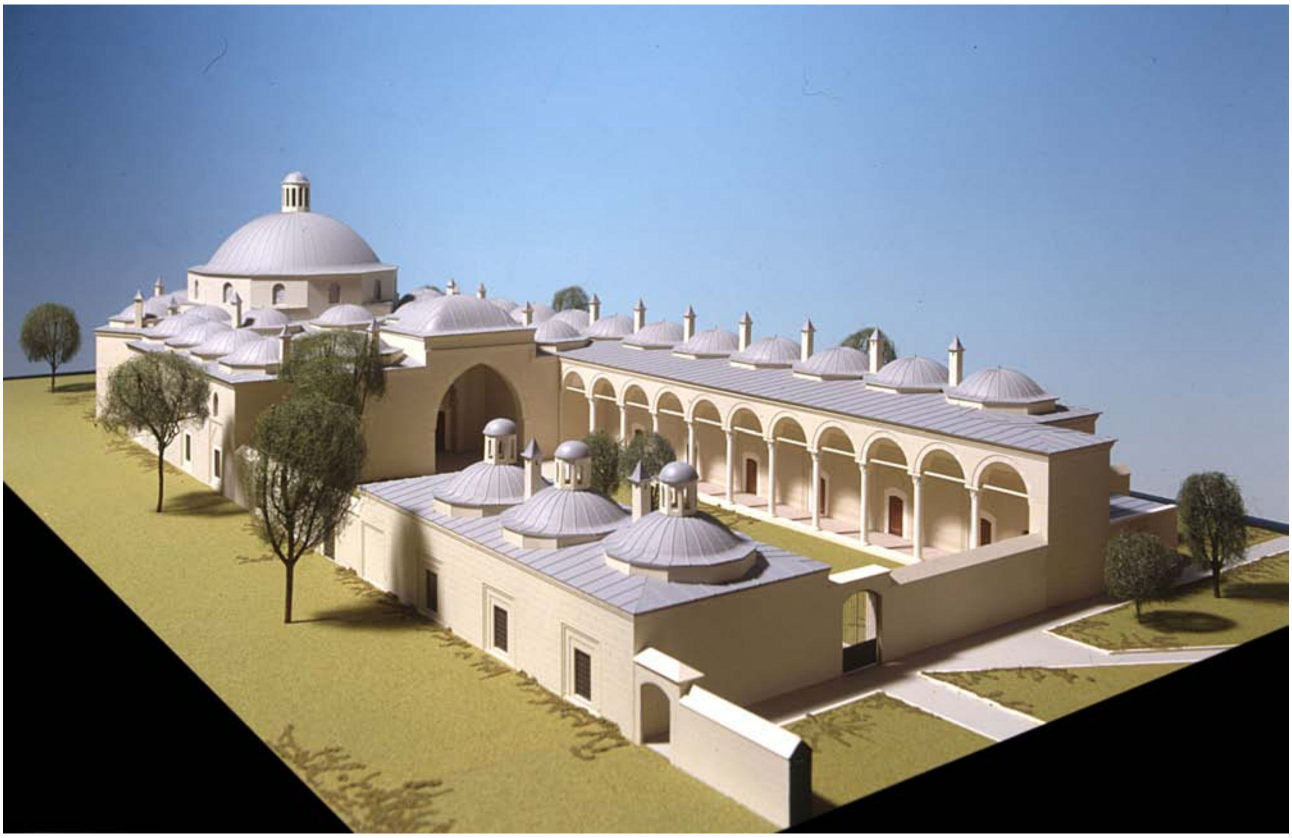
[2] On some relevant articles, see vol. 79 of the series Islamic Medicine (Frankfurt).

[3] Ibn Faḍlallāh al-ʿUmarī, *Masālik al-abṣār fī mamālik al-amṣār*, facs. ed., Frankfurt 1988, vol. 9, p. 350

[4] Arslan Terzioğlu, *Mittelalterliche islamische Krankenhäuser*, op. cit., pp. 88-106.

[5] *Architecture arabe ou monuments du Kaire, mesurés et dessinés de 1818 à 1825*, Paris 1839 (repr. Böblingen 1975), pp. 74-81.

[6] *Histoire des bimaristans (hôpitaux) à l'époque islamique*, Cairo 1928, pp. 61–72.



The hospital
of sultan Bāyezīd II in Edirne

Our model:
Wood and plastic. Scale 1:50.
Measurement of the base plate: 103 × 55 cm.
Steel frame and transparent hood.
(Inventory No. F 06))

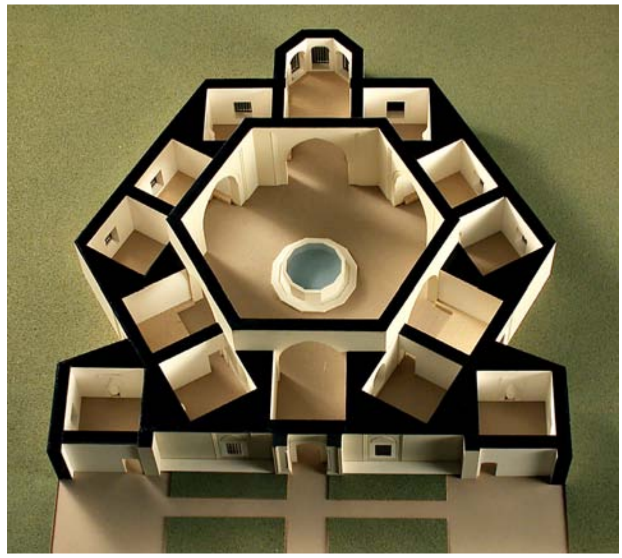
The hospital was founded in 889/1484 together with an academy (*madrasa*), a mosque and a canteen for the poor (*‘imārat*) on the banks of the river Tunca in Edirne. «Behind the mosque on the banks of the Tunca Sultan Bayezid II arranged for a harbour to be built so that he could go by ship from this building complex to his castle in Edirne.»[1]
According to Terzioğlu the hospital consists of three parts: The «hospital proper (Dār aš-šifā’) with a large central dome and 12 small ones». Next to it, a «part of the building, grouped around a small inner courtyard, which primarily serves administrative purposes». And «adjoining the madrasa, a part of the building with a large inner courtyard, kitchen and laundry.»
«The hospital proper is a large hexagonal building, about 30 metres in diameter, with six rooms as closed rooms for patients and with five recesses in the form of īwāns. The rooms for the patients and the recesses surround a middle hall, which is vaulted over by a dome. This made it possible to look after several patients with limited nursing staff … Here the architect Hayreddin primarily created a functional building. While the adjoining academy exhibits once again the old madrasa type, the peculiar form of the hospital testifies to the fact that the architect broke new ground, while taking the functional aspect into account.
[75] Thanks to an endowment document of 52 pages from 893/1488, we know in detail about the nature and manner of the work at the hospital and about its organization and finances.[2] A valuable description of the hospital is given by the famous traveller Evliyā Çelebī (11th/17th c.). It was translated

[1] A. Terzioğlu, *Mittelalterliche islamische Krankenhäuser*, op. cit., p. 190.

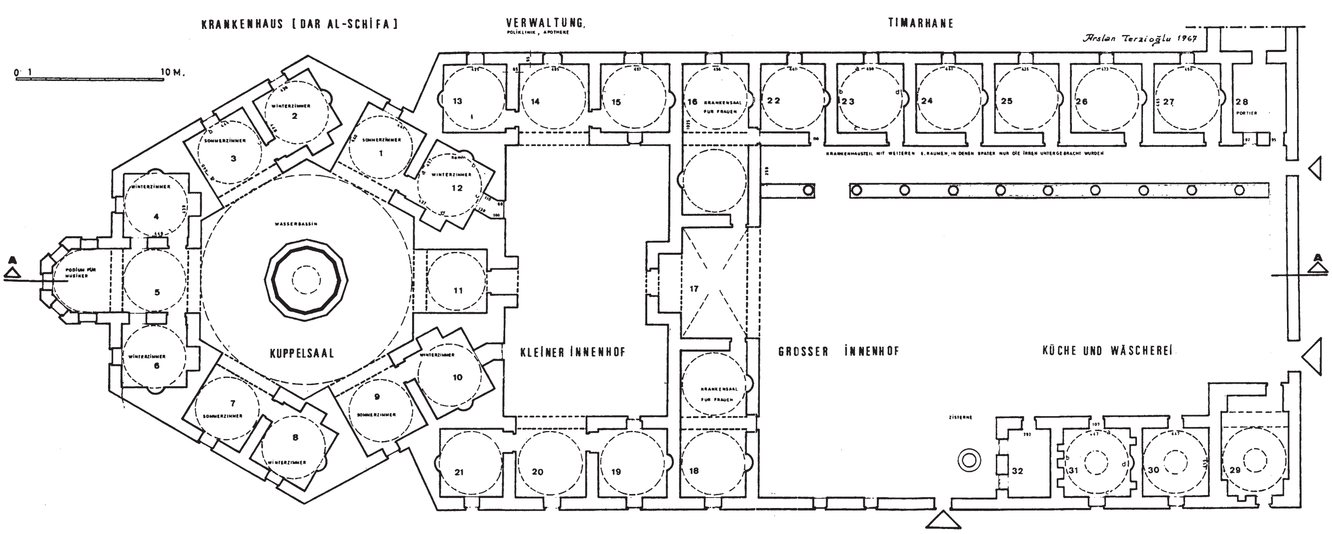
[2] For the literature on the document, see A. Terzioğlu, op. cit., pp. 190-191.

into German in 1912 by Georg Jacob.[3] From this we will cite here, with some slight modifications, his observations on the music therapy of mental patients: «I have seen a remarkable thing: His late majesty, Bajezid II … has employed 10 musicians for the cure of patients in the endowment document, for the recovery of those suffering from pain, for strengthening the mind of the insane and for repelling the gall; 3 of them are singers; of the remaining, one player each of the reed flute (*nāyzen*), the fiddle (*kemānī*), the panpipes (*mūsīqārī*), the dulcimer (*ṣantūrī*), the harp (*čengī*), the harp psalterion (? *čengī-ṣantūrī*) and of the lute (*ʿūdī*). They come three times a week and play for the patients and the insane. By the grace of the Almighty many of them feel relief. In fact, according to the science of music, the makams *nevā*, *rāst*, *dügāh*, *segāh*, *čārgāh* and *sūzināk* are intended for these [patients and insane]. But when the makams *zengūle* and *būselik* [are played] and concluded with the makam *rāst*, then it is as if they have brought new life. In all instruments and modes there is food for the soul.»

The hospital was functioning until shortly before the beginning of the First World War, with a brief interruption between 1876 and 1894 because of the Russo-Turkish war. At the beginning of the second half of the 20th century it underwent a radical renovation.

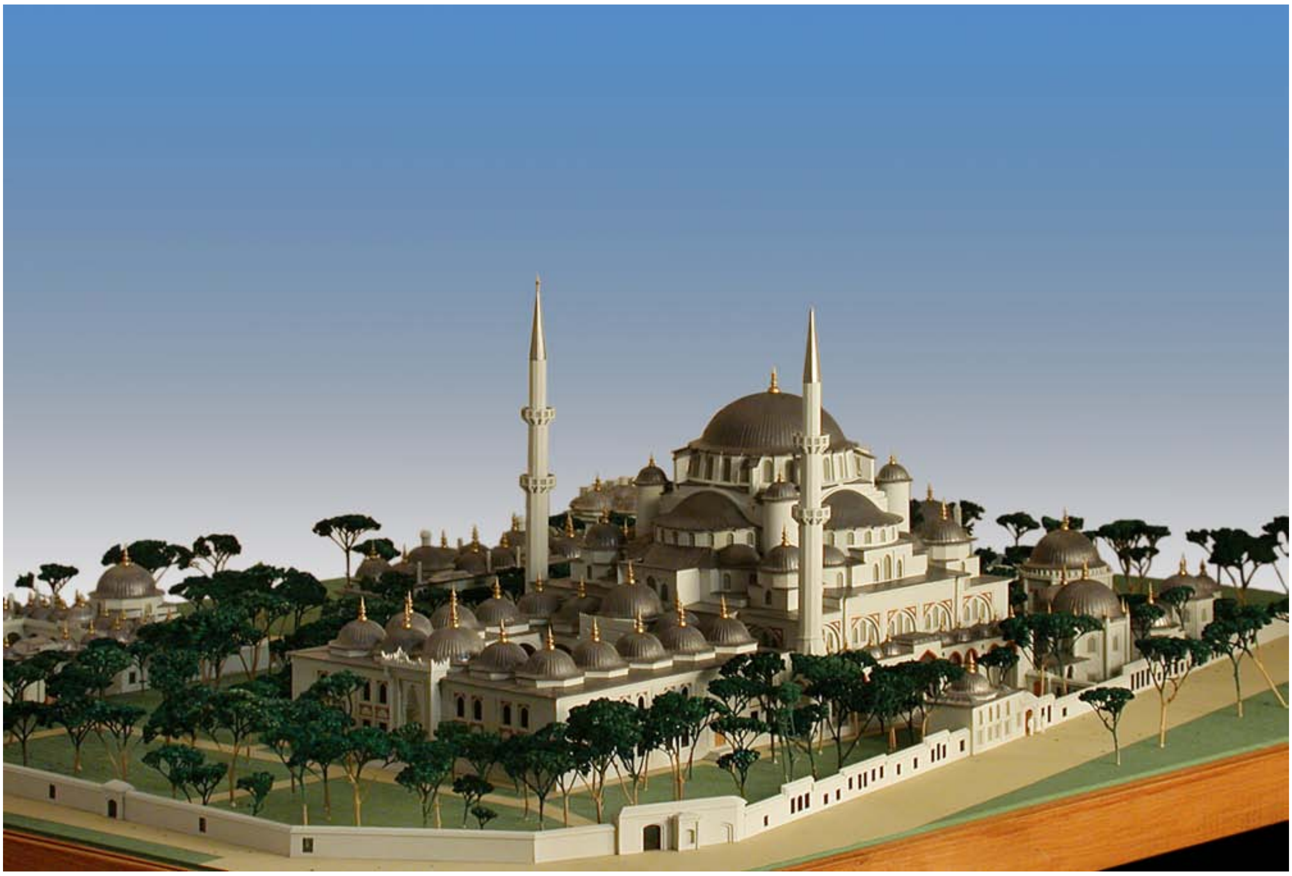


Part of the model of the domed hall with rooms 1-13 and 21, 31 × 31 cm.



Ground plan of the hospital of Bāyezīd II (after Terzioğlu).

[3] *Quellenbeiträge zur Geschichte islamischer Bauwerke*, in: Der Islam 3/1912/358-368, esp. pp. 365-368; cf. W. F. Kümmel, *Musik und Medizin*, Freiburg and Munich 1977, pp. 258-259.



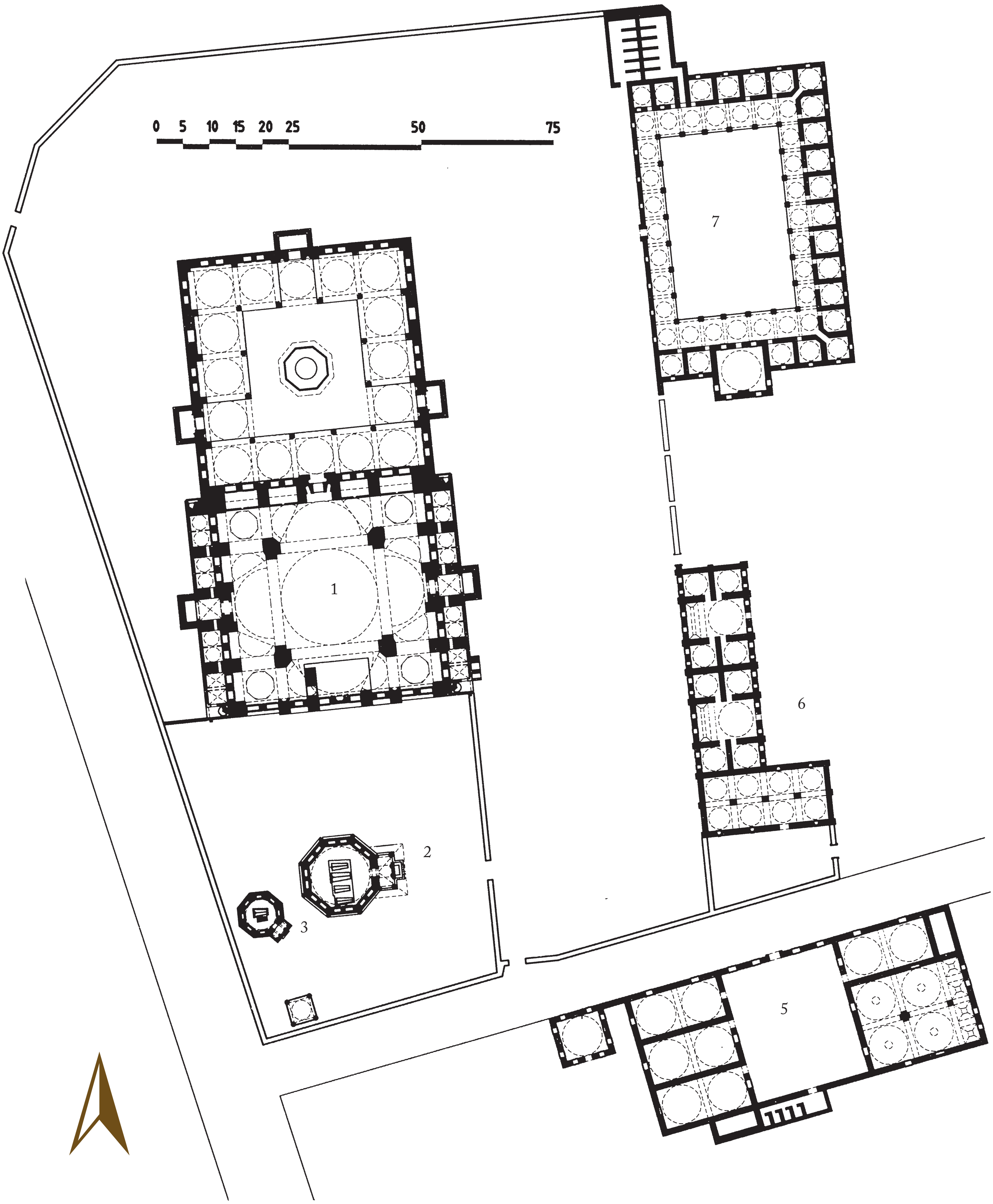
The
Şehzāde Mosque
in Istanbul

Our model:
Wood and plastic.
Domes of cast lead.
Scale 1:50.
(Inventory No. F 09)

Our model conveys the simple lines of the external form of a mosque complex in which many historians of architecture see the beginning of the period of the grand mosques of Istanbul. As to the question of its emergence, scholars distinguish between two important stages of development of Ottoman architecture: the beginnings from ca. 700/1300 in Anatolia and in Edirne up to the conquest of Byzantium in 857/1453, and the subsequent ingenious and monumental style, which was inspired by the direct acquaintance with Hagia Sophia and other ancient monuments of the new capital.[1] The Şehzāde Mosque is the first of the three grand mosques built by Miʿmār Sinān (b. 895/1490, d. 996/1588), the greatest architect of the Ottomans. The mosque complex was erected by Qānūnī Süleyman (‹the Magnificent›) in memory of his first son Prince Meḥmed, who died in 950/1543. The year when the construction began is in dispute; but the building was completed in 955/1548. A higher officer, Sinān by name, who had made a name for himself as a pioneering engineer [78] and had already built some smaller mosques, was entrusted with the planning and the execution. He himself remarked later

[1] Doğan Kuban, *Sinan'in sanatı ve Selimiye*, Istanbul 1997, pp. 57 ff.

[1] Doğan Kuban, *Sinan'ın sanatı ve Selimiye*, Istanbul 1997, pp. 57 ff.



Plan of the parts of the Şehzāde Complex which go back to Sinān (after Kuban)

1: Mosque
2: Mausoleum (*türbe*) of Şehzāde (Crown Prince) Meḥmed
3: Mausoleum (*türbe*) of (Chancellor) Rüstem Paša
4: Primary school (*mekteb*)
5: Canteen for the poor (*imaret*)
6: Caravanserai
7: Academy (*medrese*)

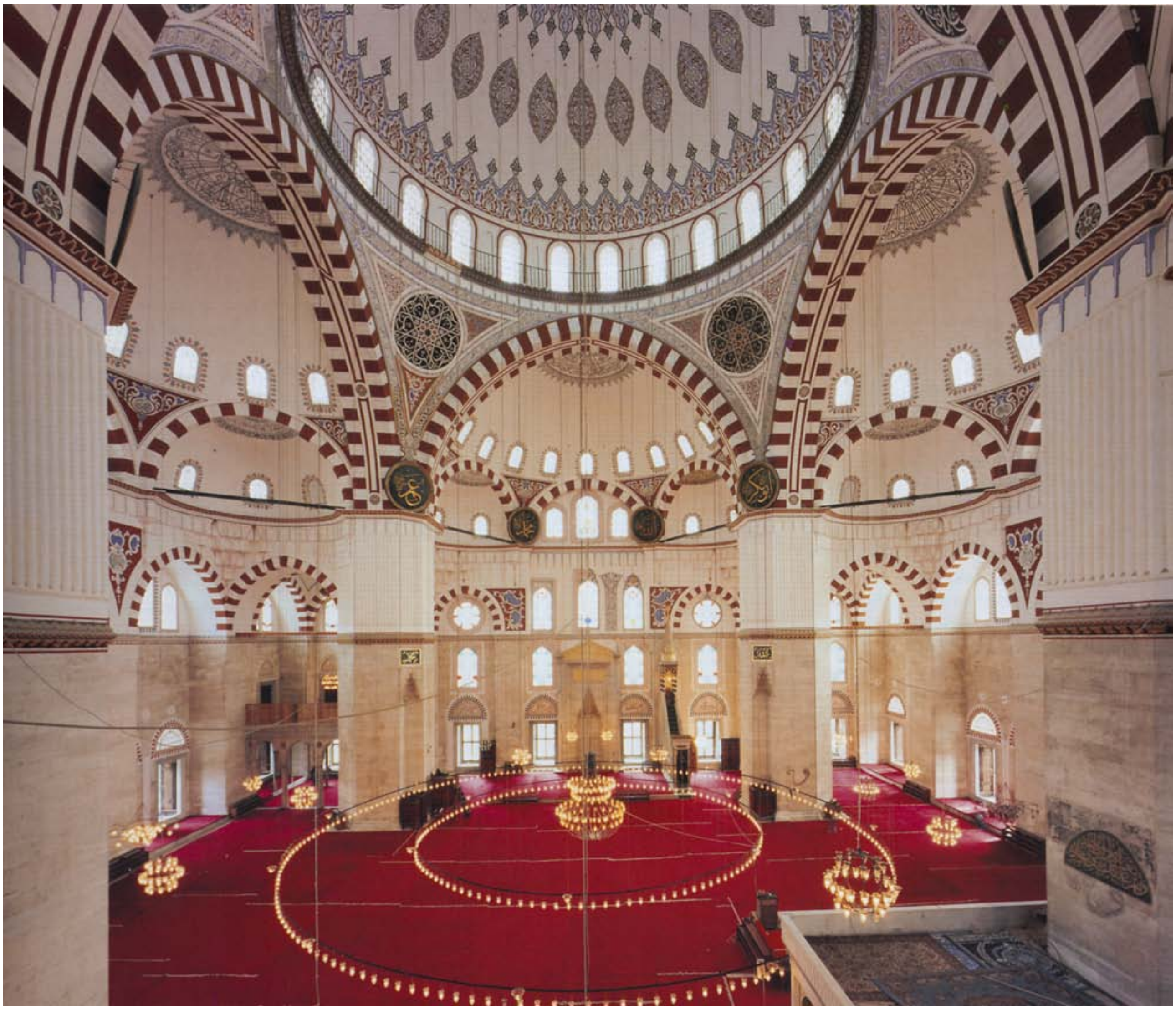
Figs.: epitaphs of the mausoleum (türbe) of Şehzāde Meḥmed and that of Rüstem Paša in the Şehzāde complex.

that this «first imperial mosque on a truly monumental scale» was his «apprentice work».[2]
«Sinān, who from the very first envisaged a centralized ground plan, adopted the expedient of extending the space under the dome not by two but by four separate half domes. This was the most obvious and logical way of combining the centralization with the enlargement of space; but this also contained the danger of producing too much uniformity and symmetry, which could easily become tiresome. Furthermore, the four great pillars that support the dome look stranded and isolated in the middle of the vast space; thus their inevitably large size becomes accentuated in an almost excessive manner. Sinan appears to have realized these aesthetic shortcomings after the construction was over, for he never repeated them again. On the other hand, the whole complex gives the impression as if a systematic attempt was made here to explore the entire range of possibilities of laying the ground plan. This leads to the assumption that perhaps the idea here was to create something like a prototype model of a mosque from which in gradual stages a wide variety of more lively ground plans could be derived.» [3]

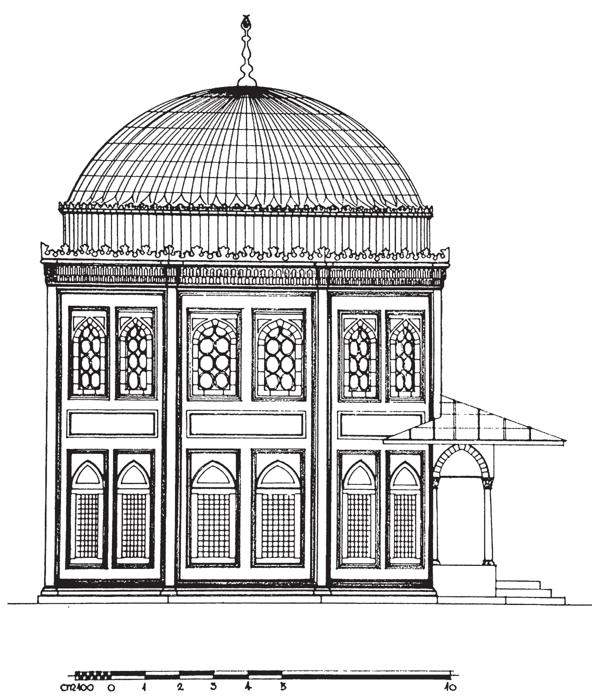
The mosque has a total of 183 windows, «which let in uniform brightness to the homogeneous space in all parts. The windows still have their old glass panes with delicate lattice windows and some parts of colour painting.»[4] The length of the main dome measures 19 metres, its vertex is 37 metres high.[5] Besides the mosque, the whole complex includes an academy (medrese), a children's school, a canteen for the poor and a caravanserai. They are located outside the walls of the courtyard. In the courtyard of the mosque there is the mausoleum of Prince Meḥmed.

[2] John Freely, Hilary Sumner-Boyd, *Istanbul*, German transl. Wolf-Dieter Bach, Munich 1975, p. 237.
[3] ibid., p. 238.

[4] Cornelius Gurlitt, *Die Baukunst Konstantinopels*, text volume, Berlin 1907, p. 68.
[5] D. Kuban, *Sinan'in sanatı*, op. cit., p. 69.



Interior of the Şehzāde Mosque with a view into the main dome, from Yerasimos, *İstanbul*[6].



Türbe (mausoleum) of Şehzāde Meḥmed (A.S. Ülgen).

[6] St. Yerasimos, *İstanbul İmperatorluklar Başkenti*, İstanbul 2000, p. 257.

The Süleymānīye
in Istanbul

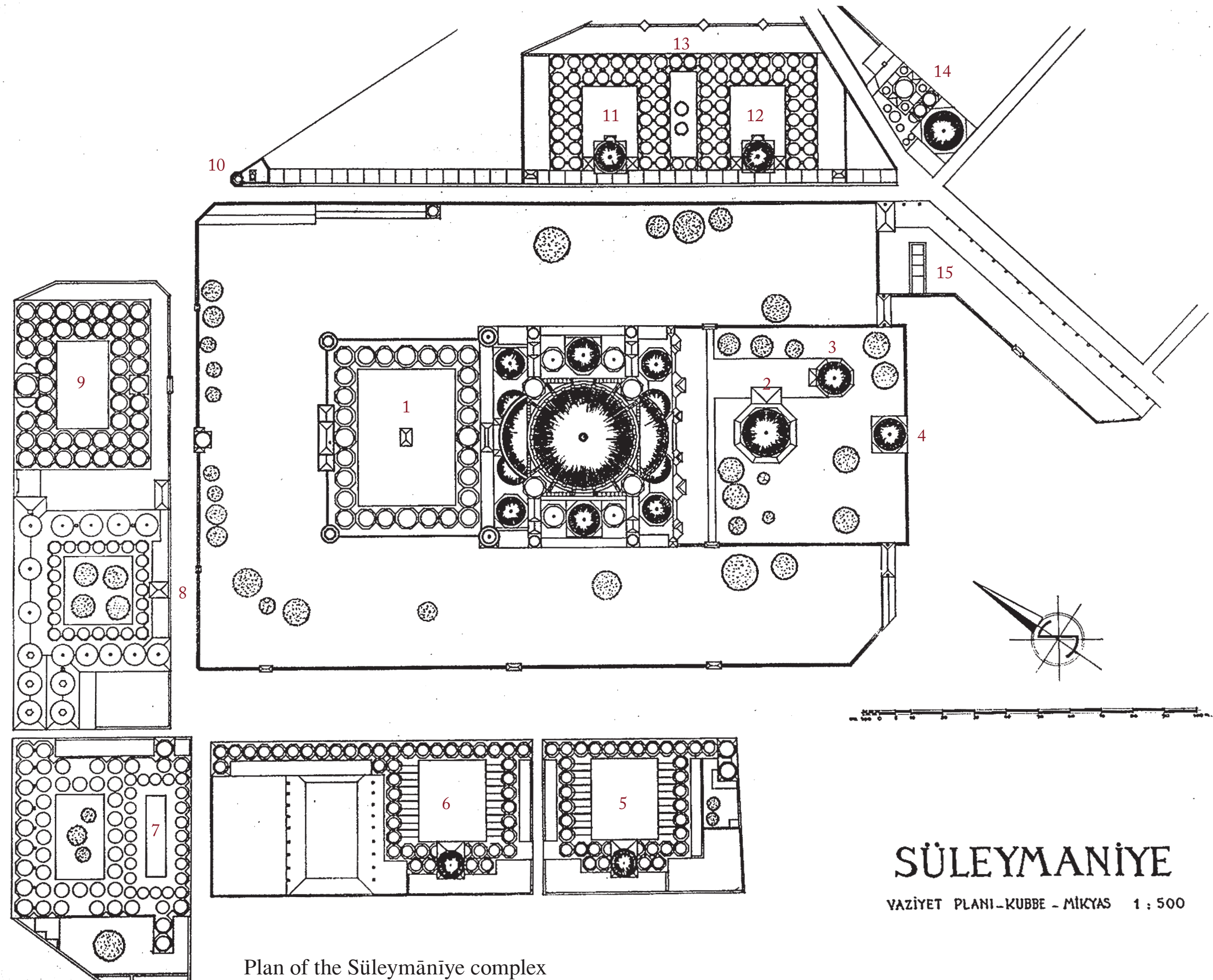
Our model:
Wood and plastic.
Domes of cast lead.
Scale ca. 1:150.
Measurement of the base plate: 155 × 125 cm.
Steel frame.
(Inventory No. F 01)

The Süleymaniye Camii (this is how the name of the mosque is written in modern Turkish) is, chronologically, the second grand mosque built by the architect Sinān. Together with its social and cultural institutions, it is perhaps the largest architectural complex created in the Ottoman Empire. The construction began in 957/1550 and was completed in 964/1557.[1] It is reported that Sultan Süleymān himself suggested the location for the construction and that he entrusted his architect Sinān with the ceremonial opening of the building at the time when the keys were handed over.[2]

Sinān raised the number of minarets to four. The two higher ones (76 metres each) facing the courtyard of the mosque have three balconies each (*şerefe*), the two smaller ones (56 metres each) towards the outer side of the courtyard have two balconies each.
Cornelius Gurlitt[3] finds the design of this mosque an improvement over that of the Bāyezīd Mosque in Istanbul: «The main dome and two half domes as cover of the central area.

[1] D. Kuban, *Sinan'in sanatı*, op. cit., p. 78.
[2] ibid., p. 78.

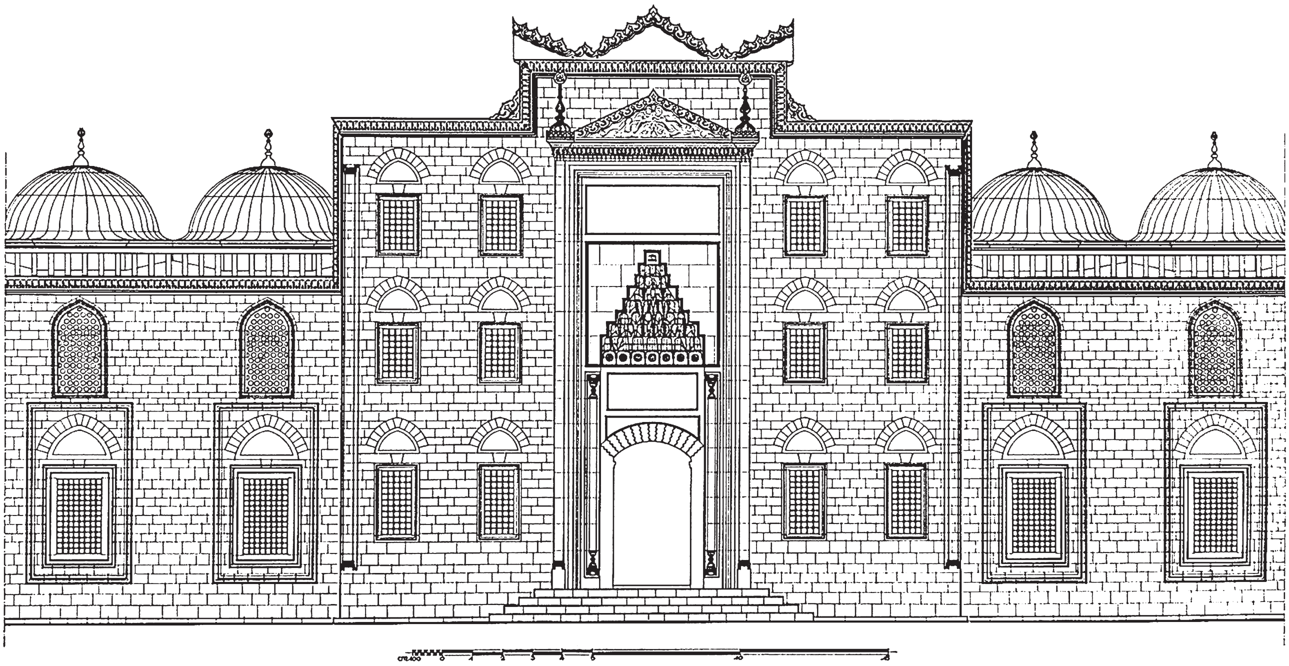
[3] *Die Baukunst Konstantinopels*, op. cit., p. 69.



Plan of the Süleymānīye complex (A.S. Ülgen).

1: Mosque.
2: Mausoleum of Sultan Süleymān.
3: Mausoleum of Ḫürrem Sultan.
4: Lodge of the guards of the mausoleums.
5: First medrese.
6: Second medrese.
7: Hospital.
8: House for the poor.
9: Kitchen wing.
10: *Sebil* (well) and mausoleum of Sinān.
11: Third medrese.
12: Fourth medrese.
13: Caravanserai.
14: Bath wing (*ḥammām*)
15: Theological seminary (*dār al-ḥadīṯ*).

[81] The latter are supported by two diagonally placed half domes each so that a space [of] 52.4 metres is vaulted. The pillars, which have a strength of 7.44 to 7.56 metres in their broadest parts, however, do not give the impression of heaviness as a result of the structuring of the outline and the insertion of niches; in a very ingenious manner they are formed in such a way that each of the side aisles could be covered with five domes of different diameters. The arrangement shows the most complete mastery of composition so that the vaults could be formed organically everywhere. Of course, contemporary masters of the Renaissance, such as San Gallo, would have objected to the fact that the axes of the arches on which the domes rest do not coincide with those of the domes. Look at the arrangement of the middle domes of the side aisles: the difficulty is overcome clearly and plausibly by inserting an arch across those resting [sic] on the pillars of the external side, and through the extremely flexible shape of the stalactite spandrels.»
[82] «The domed areas at the four corners serve as entrance halls of the mosque. You enter the mosque through a door and before that through an arcade of the most delicate formation. The arcade in front of the Sultan's podium, particularly is decorated



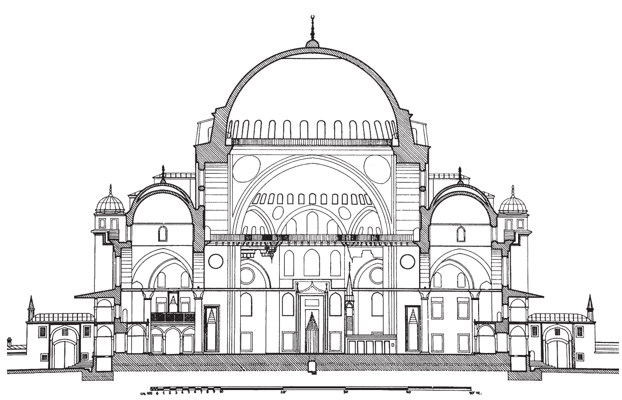
Main portal of the Süleymānīye (A.S. Ülgen).

with great care. Between the corner rooms built-in balconies extend inside and outside; on the outside in two storeys, inside in one. The architecture of the pillars and arches belongs to the most noble and perfect of all that has been accomplished by Turkish architecture. The juxtaposition of the finely structured arcades with the massive structure of the main building which soars over them is likewise of the highest artistic subtlety.»[4]

All in all 138 windows provide light to the hall.[5]

«Behind the mosque, adjoining its kiblah side there is a garden enclosed by a wall with barred windows. Here is situated Süleymān's mausoleum, completed in [974/]1566, which is one of the most magnificent edifices of this type. Besides Süleymān himself, Sultana Süleymān (Ḫürrem Sultan, d. [965/]1558) and Aḥmed II (d.[1106/]1695) … are buried there.»

Interior with the main dome (Original photo)



Section through the Süleymānīye (A.S. Ülgen).

[4] C. Gurlitt, *Die Baukunst Konstantinopels*, op. cit., pp. 69-70.
[5] ibid., p. 71.

Interior with view towards the miḥrāb (from St. Yerasimos, *Istanbul*, op. cit. p. 263).

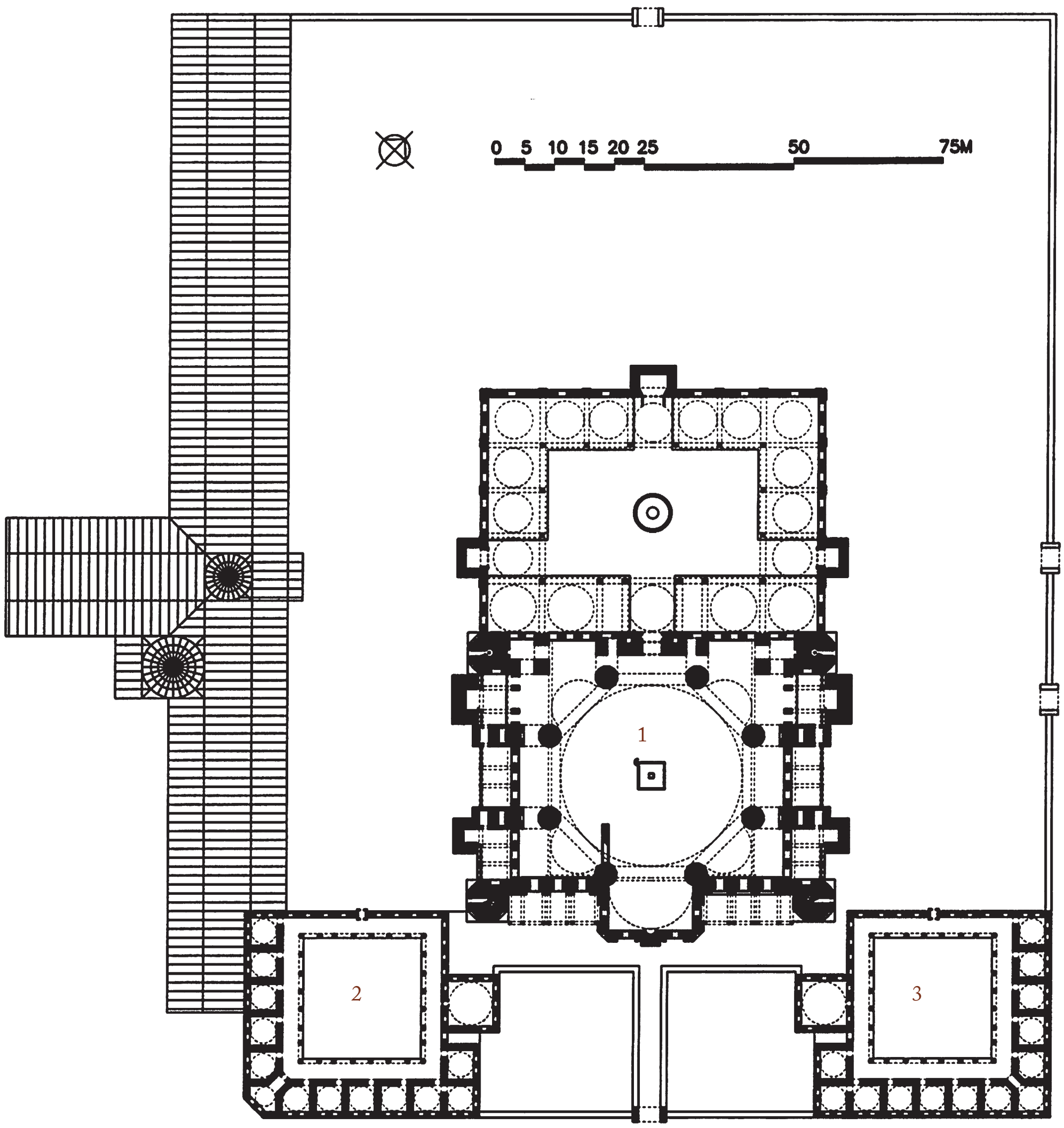
The Selīmīye

Mosque

Our model:
Wood and plastic.
Domes of lead.
Scale ca. 1:100.
Measurement of the base plate:
100 × 100 cm.
(Inventory No. F 02)

The mosque in Edirne, written Selimiye Camii in modern Turkish, is the third grand mosque built by Miʿmār Sinān. It was built on the orders of the Ottoman Sultan Selīm II. The construction lasted from 976/1568 to the end of 982/(March 1575).[1] The seriously ill Sultan had passed away three months previously. The Selīmīye Mosque is generally thought to be the culmination of Sinān's life-work and of his experience and mastery of the architecture acquired during nearly half a century of intensive work. [85] He is said to have expressed himself in this spirit when he remarked that he had built the Şehzāde Mosque during his apprentice-

[1] D. Kuban, *Sinan'in sanatı*, op. cit., p. 133.



Plan of the Selīmīye complex after D. Kuban:

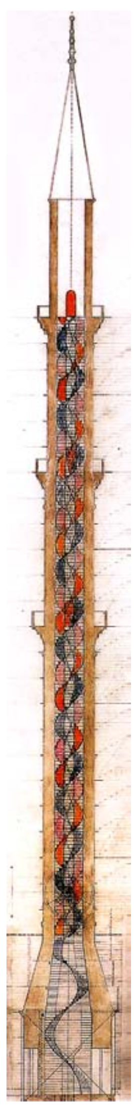
1. Mosque.
2. School building..

ship, the Süleymāniye Mosque during his period as a master architect, but he had reached the climax of his ability as an architect with the construction of the Selīmīye Mosque.[2]
«The mosque contains the main features common to all the larger complexes: the forecourt (haram) and the congregation hall or the prayer hall (cami). Both lie on the same level, approximately 1 metre above ground, and together form a closed rectangle of 60 metres width and 95 metres length, from the sides of which only the substructures of the minarets and an apse on the southern side protrude slightly. Almost half of this area is taken up by the forecourt. It is of rectangular shape and lies at right angles to the main axis of the building. The vaulted halls of roughly 8 metres or 9 metres width, to be found on all the four sides, surround an open courtyard of 37.40 to 24.80 metres.»
[86] «The basic form of the prayer hall also appears in its outer perimeter as a rectangle lying at right angles to the main axis, but it takes the shape of a regular octagon in the middle. This octagon

[2] D. Kuban, *Sinan'in sanatı*, op. cit., p. 127.

constitutes the basic form for the development of the centre of the hall proper. The remaining parts of the ground plan on both the sides of the octagon are used to extend the space for the hall, the side halls and balconies. The internal measurements of the main hall, when measured on the level ground in the rectangle, amount to about 45 to 35.90 metres. The width of the octagon is roughly 31.40 metres, the distance between the pillars being 10.50 metres.»[3]

«Three mighty main arches, separated by two smaller intermediate arches, are borne here by stately and polished granite pillars and reach, in rhythmic alternation, almost twice the height of the side halls. Crowned with three domes over the main arches, the middle one of which is raised to an even greater height and is structured particularly richly with ribbing, this part of the forecourt is an independent entrance hall of finely shaped proportions and monumental treatment and thus prepares the entry to the place of worship in a unique manner.»[4]



«A magnificent portal with niches, adorned with the richest forms of Ottoman art, decorated with stalactite formations and rich ornamentation, leads us now through the entrance hall into the main hall of the mosque, the hall of prayer or congregation. After passing through a semi-dark vestibule, formed by hanging carpets, we find ourselves immediately below the wide vault of the main dome. We find that our boldest expectations, already enhanced by the entrance hall that led us in, are far surpassed by this dome, which is vaulted above us. Eight massive pillars, which are almost cylindrical in outline, but structured in multiple ways, soar up, and from there two rows of mighty pointed arches rise in tiers one above the other, all of them serving the common purpose of bearing the vaulted dome, and producing an impressive effect due to the uniformity of their purpose.»[5]

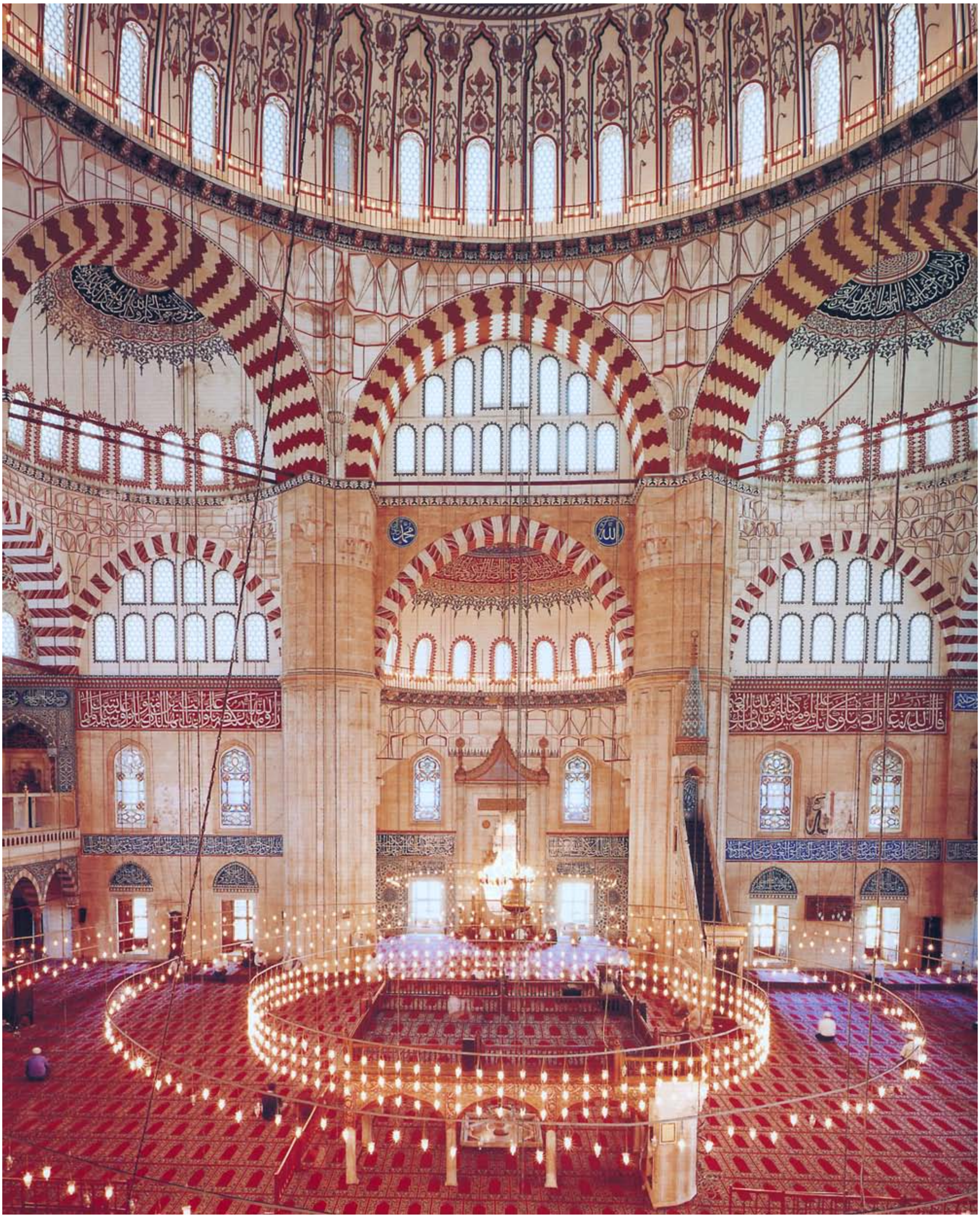
The inner length of the diameter of the main dome, i.e. the distance of the walls and the pillars supporting the dome, is 31.50 metres.[6]

[3] Armin Wegner, *Die Moschee Sultan Selim's II. zu Adrianopel und ihre Stellung in der osmanischen Baukunst*, in: Deutsche Bauzeitung (Berlin) 25/1891/329-331, 341-345, 353-355, esp. p. 341.

[4] ibid., p. 341.

[5] ibid., p. 341.

[6] ibid., p. 342; D. Kuban, *Sinan'ın sanatı*, op. cit., p. 137. The corresponding length of the Ayasofya (Hagia Sophia) is 31.40 metres.



Interior of the Selīmīye Mosque, view to the west, with minbar (from St. Yerasimos, Istanbul, op. cit. p. 271).

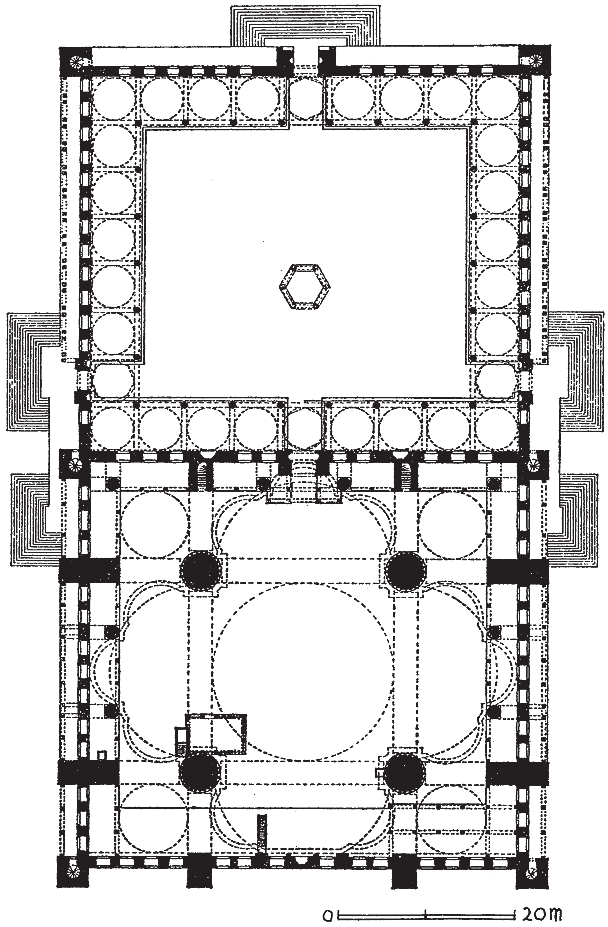
The Sultan Aḥmed Mosque

Our model:
Wood and plastic.
Scale 1:100.
Measurement of the base plate: 130 × 100 cm.
Steel frame.
(Inventory No. F 03)

The Sulṭān Aḥmed Cāmiʿi is also known as the Blue Mosque because of the light blue colour of the interior. It was built at the orders of the Ottoman Sultan Aḥmed I (ruled 1012/1603-1026/1617). The architect was Meḥmed Āġā. The construction was commenced in 1609 when the ruler who ordered the construction of the mosque was but 19 years old. It was completed in 1616, and the Sultan lived only a year longer. It is reported that he took part in the foundation laying ceremony with a golden hoe.[1]

[1] Mücteba Ilgürel, art. *Ahmed I* in: Islâm Ansiklopedisi, vol. 2, İstanbul: Türkiye Diyanet Vakfı 1989, p. 33.

«Many consider this building to be the most beautiful of all imperial mosques; it may be so. Certainly the terraced arrangement of domes and half domes provides a magnificent view with the soft silvery grey of the stone and of the leaden roofs, with the gold of the ornaments added on the minarets and domes. This rich impression of the exterior is intensified even more by the number of minarets: there are six of them, that is, two more than those dis-



Plan from J. Freely and H. Sumner-Boyd: *Istanbul*, Munich 1972, p. 152.

View into the main dome (Photo: K. O. Franke)

played by the other imperial mosques in Istanbul. Therefore this structure appears imposing without being [89] heavy. The charm which the observer vaguely feels retains more of the atmosphere in view of the massive size of these forms which are just a little bit softer and smoother than those of Sinān's grand mosques.»[2]

«The Blue Mosque is an almost square hall (51 metres long, 53 metres wide), vaulted over by a dome of 23.5 metres diameter and 43 metres height at the vertex. It is supported by four wide pointed arches which transmit the curvature of the dome over four spandrels to the square ground plan of the main hall, which is marked by the massive supporting pillars at its corners.»[3]

«Light streams into the interior through 260 windows which were once filled with coloured glass like the wall of the mihrab. There are plans for filling more windows once again with coloured inlaid glass so that at least some of the old impression is recreated of a hall that is not dim but lit in a subdued way.»[4]

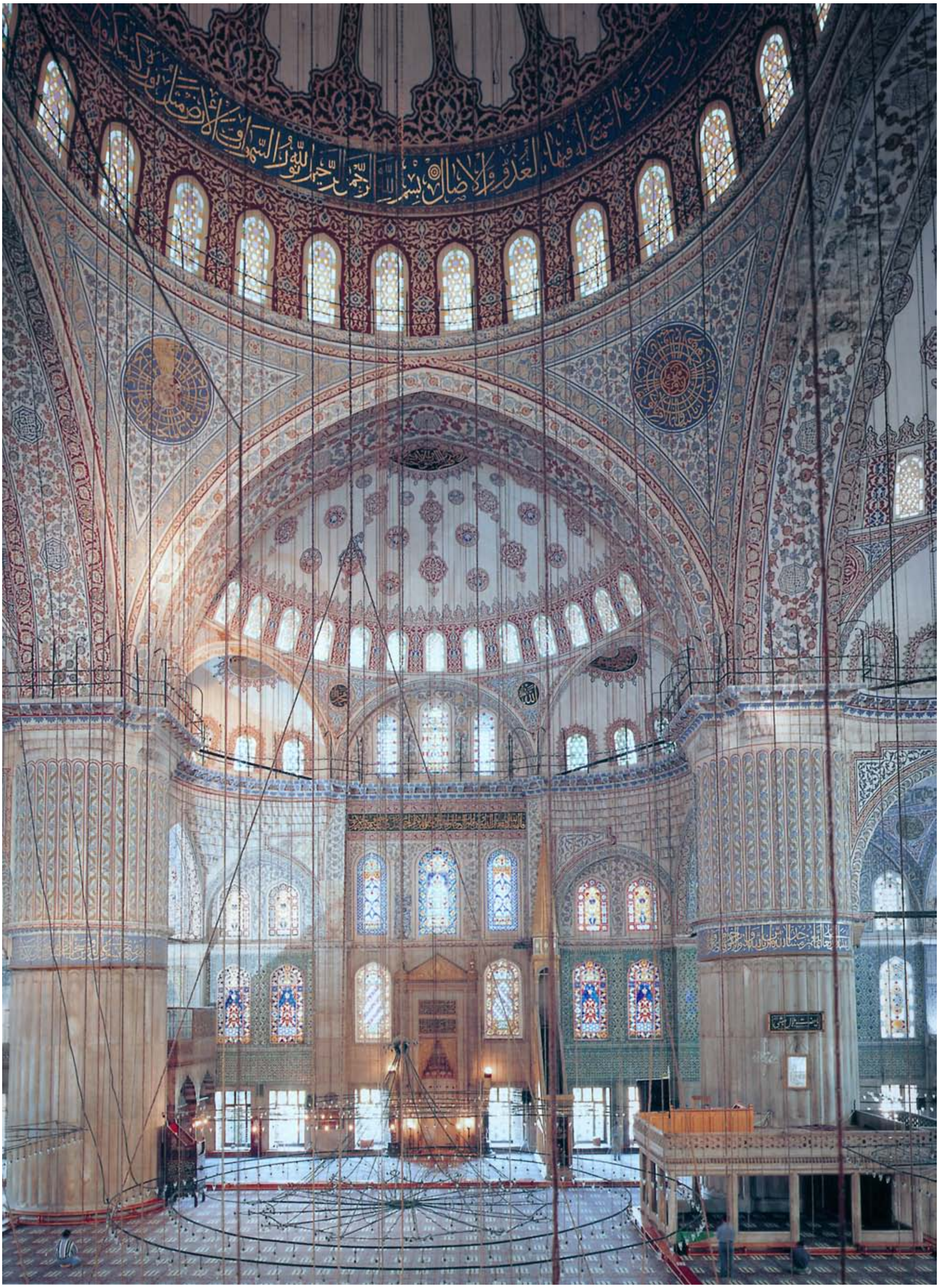
«The endowments belonging to the entire complex of the mosque (küllīye) were appropriate to the size and cover a medrese (…), the Sultan's mausoleum, hospital and caravanserai, primary school, canteen for the poor and a bazaar. The hospital and the caravanserai were demolished in the 19th century, the canteen for the poor was incorporated into the building of the School of Industrial Arts on the southern side of the At Meydanı. The primary school was renovated recently; it is the building on the northern side of the outer enclosure wall of the mosque. The medrese, which is in fact rather big but appears small in relation to the mosque, lies outside the enclosure wall of the complex towards the north-east, very close to the exceptionally large mausoleum with the square ground plan. In this mausoleum … lies Aḥmed I next to his consort Kösem Sultan and three sons: Murād IV, ‘Os̱mān II and Prince Bāyezīd.»[5]

[2] J. Freely, H. Sumner-Boyd, *Istanbul*, op. cit., p. 149.

[3] ibid., p. 151.

[4] ibid., p. 152.

[5] ibid., pp. 153-154.



Interior of the Sulṭān Aḥmed Cāmiʿi, with view of the *miḥrāb* (from St. Yerasimos, *Istanbul*, op. cit., p. 333).

Chapter 12

Military Technology

Introduction

Probably in no other domain were the knowledge and achievements of other cultures adopted as quickly as in military technology. The rapid and wide-scale expansion resulting from the conquests by Muslims in the first century after their appearance on the stage of world history leads us to assume—of course not without historical documentation—that they quickly recognized the superior quality of their adversaries' weapons and appropriated that knowledge.

The adversaries who were initially superior to them included, besides the Byzantines, also the Persians. It is therefore not surprising that the oldest books preserved in Arabic literature on military technology turn out to be translations of works by the Persians of the Sassanid period or by Indians.[1] Moreover, the historian of science Ibn an-Nadīm, who lived in the 4th/10th century mentions an Arabic work on the use of a certain type of Greek fire (*Kitāb al-ʿAmal bi-n-nār wa-n-nafṭ wa-z-zarrāqāt fi l-ḥurūb*[2]) and a book on battering rams, catapults and «military stratagems» (*Kitāb ad-Dabbābāt wa-l-manǧanīqāt wa-l-ḥiyal wa-l-makāyid*[3]).

Against such a background we can appreciate better the report of the historian aṭ-Ṭabarī (d. 310/923) to the effect that the Abbasid Caliph al-Muʿtaṣim had deployed mobile battering rams at the conquest of the city of Amorium (southwest of Ankara) in 213/837 (see above, pp. 137 f.).

Without wishing to overrate the contribution in this field which is due to the Arab-Islamic world in the universal history of science, we must emphasize that the military technology also underwent a significant development in the Arab-Islamic area in the period between Late Antiquity and the so-called Renaissance. It goes without saying that the advances in fields like physics, chemistry and technology, made continuously for centuries since the 3rd/9th century in the Arab-Islamic world, would not remain without an impact on military technology. In their writings published between 1845 and 1858,[4] Joseph-Toussaint Reinaud and Ildephonse Favé have been able to extract, to a large extent, the contribution of the Islamic countries to the technology of weaponry. The results obtained by them from the study of the manuscripts of Arabic works on military technology which were accessible to them at that time and from information in historical works are to a large extent valid even today. Moreover, a few other important manuscripts and historical data that have in the meantime become available take us further. The results achieved by Reinaud and Favé and the views they held on the Arab-Islamic world in the history of military technology were taken into consideration rather well in the non-Arabist studies on the subject in the second half of the 19th century and the first half of the 20th century. On the other hand, it is striking that in studies from the second half of the 20th century onwards hardly any of it was taken note of,[5] with the exception of the commendable *History of* [94] *Greek Fire and Gunpowder* by J. R. Partington (1960), the relevant parts of *Science and Civilisation in China* (vol. 5, part VI, 1994) by Joseph Needham and *Zur Geschichte des mittelalterlichen Geschützwesens aus orientalischen Quellen* by Kalervo Huuri.

[1] *Fihrist* by Ibn an-Nadīm, ed. G. Flügel, Leipzig 1872, pp. 314-315.

[2] ibid., p. 315; J. Reinaud, *De l'art militaire chez les Arabes au moyen âge*, in: Journal Asiatique, sér. 4, 12/1848/193-237, esp. p. 196.

[3] *Fihrist*, op. cit., p. 315; J. Reinaud, *De l'art militaire*, op. cit., p. 196.

[4] Reinaud and Favé, *Histoire de l'artillerie*. 1ère partie: *Du feu grégeois, des feux de guerre et des origines de la poudre à canon*, vol. 1 (texte), vol. 2 (planches), Paris 1845; Reinaud and Favé, *Du feu grégeois, des feux de guerre, et des origines de la poudre à canon chez les Arabes*, les Persans et les Chinois, in: Journal Asiatique, sér. 4, 14/1849/257-327; Reinaud, *De l'art militaire chez les Arabes au moyen âge*, in: Journal Asiatique, sér. 4, 12/1848/193-237; Reinaud, *Nouvelles observations sur le feu grégeois et les origines de la poudre à canon*, in: Journal Asiatique, sér. 4, 15/1850/371-376.

[5] This was also noted with regret by Kalervo Huuri (*Zur Geschichte des mittelalterlichen Geschützwesens aus orientalistischen Quellen*, Helsinki and Leipzig 1941, p. 25): «In this history of artillery there are many lacunae. First of all it restricts itself exclusively to the situation in Antiquity and in Europe and does not deal with Oriental developments …»

As I now undertake to discuss some new elements which, in my view, were developed or discovered in the military technology of the Arab-Islamic world, I restrict myself at this point to the large crossbow, the counterweight trebuchet, gunpowder and firearms These are elements which appear as new inventions in the history of European military technology in the 13th or the 14th century.

a) Windlass Crossbow

Of the diverse types of the crossbow which already formed part of the artillery of the Greeks, Romans and Sassanid Persians, I mention here only the windlass crossbow which was drawn through a windlass (rack-and-pinion gear).[6] This crossbow, which is a variant of the large crossbow (qaus az-ziyār), is described in detail and illustrated in the extant *Tabṣirat arbāb al-albāb fī kaifīyat an-nağāt fi l-ḥurūb* by Marḍī b. ʿAlī b. Marḍī aṭ-Ṭarsūsī, which was partly edited and translated into French by Claude Cahen in 1948.[7] The bow was called qaus bi-l-laulab. Its description in this book, which was written under Ṣalāḥaddīn (Saladin, ruled 569/1174- 589/1193), gives the impression that it was a well known weapon even at that time. It is also listed by the historian Ibn aṭ-Ṭuwair (b. 524/1130, d. 617/1220) among the weapons in the arsenal of the youngest Fatimid Caliph in Egypt of 467/1071.[8] According to his statement, an arrow weighed about 2200 grams The French historian Jean de Joinville reports that during the crusade of Louis IX in 1249 the Egyptians had shot at the French near Manṣūra, among others, four times from the windlass crossbow with Greek fire.[9]

The description of our Arabic sources confirms G. Köhler's[10] assumption that the windlass crossbow was «a normal crossbow which differed only in its larger dimensions from the stirrup crossbow [Arabic *qaus al-yad*] and was tautened by a windlass (tour) [Arabic *laulab*].» We can well imagine that it was this type which Emperor Frederick II in 1239 ordered a captain who was sailing to Accon to purchase there *tres bonas balistas de torno et de duobus pedibus* (Arabic *qaus al-ʿaqqār*).[11]
In the above-mentioned Arabic book[12] on military technology dedicated to Prince Ṣalāḥaddīn (Saladin) a crossbow with large dimensions is described in quite some detail. If I understand the author correctly, he is of the view that it was an achievement of his older contemporary Abu l-Ḥasan b. al-Abraqī al-Iskandarānī. Claude Cahen,[13] who edited the text, translated it into French and examined it, also understands the author's statement in the same sense and, based on this, refutes the view of Kalervo Huuri,[14] who claimed that the Mongols had brought the [95] Chinese pedestal crossbow to Persia in the 13th century.[15] The fact of the matter was the other way round, with the Mongols borrowing this improved crossbow from the Muslims.
According to the description of the book, that large crossbow (*qaus az-ziyār*) is said to have been the largest in its dimension, the farthest in its range and the most lethal in its effect. The edges of the square gun carriage are said to measure about 5.6 metres.

[6] G. Köhler, *Die Entwickelung des Kriegswesens und der Kriegführung in der Ritterzeit von Mitte des 11. Jahrhunderts bis zu den Hussitenkriegen*, vol. 3, Breslau 1887, p. 174.
[7] *Un traité d'armurerie composé pour Saladin*, in: Bulletin d'Études Orientales 12/1947-48/103-163, esp. pp. 110, 131-132, 156.
[8] ʿAbdassalām b. al-Ḥasan Ibn aṭ-Ṭuwair, *Nuzhat al-muqlatain fī aḫbār ad-daulatain*, ed. A. F. Saiyid, Cairo 1992, p. 134; Taqīyaddīn al-Maqrīzī, *al-Mawāʿiẓ wa-l-iʿtibār bi-ḏikr al-ḫiṭaṭ wa-l-āṯār*, Būlāq 1270, vol. 1, p. 417; K. Huuri, op. cit., p. 126.
[9] Reinaud and Favé, *Histoire de l'artillerie*. 1ère partie: *Du feu grégeois*, pp. 53-60; Joinville, *Histoire du roy saint Loys*, Paris 1668, pp. 39 ff.; K. Huuri, op. cit., p. 126; G. Köhler, *Die Entwickelung des Kriegswesens*, op. cit., pp. 175,187.
[10] *Die Entwickelung des Kriegswesens*, op. cit., p. 174.
[11] v. G. Köhler, op. cit., p. 175.
[12] *Tabṣirat arbāb al-albāb*, op. cit., p. 106.
[13] op. cit., p. 129.
[14] *Zur Geschichte des mittelalterlichen Geschützwesens*, op. cit., p. 123.
[15] Cahen (op. cit., p. 151) says: «Kalvero Huuri, n'ayant rencontré d'allusion certaine au qaus az-ziyār que dans des auteurs postérieurs à l'apparition des Mongols, considérait cet engin comme apporté par eux. Notre chapitre nous oblige à adopter une conclusion contraire, et à considérer cette arme comme née au plus tard sous Saladin, et par conséquent vraisemblablement apprise des Musulmans par les Mongols lorsqu'on la trouva employé chez eux. K. H. avait relevé un certain nombre de mentions du *ziyār* dans d'autres auteurs contemporains de Saladin (…), mais pensait que le mot avait un sens vague; nous sommes en droit de conclure qu'il avait dès lors son sens précis et que l'arme figure donc normalement dans les guerres contre Saladin et les Croisés entre 1187 et 1192, période à laquelle se réfèrent toutes les citations.»

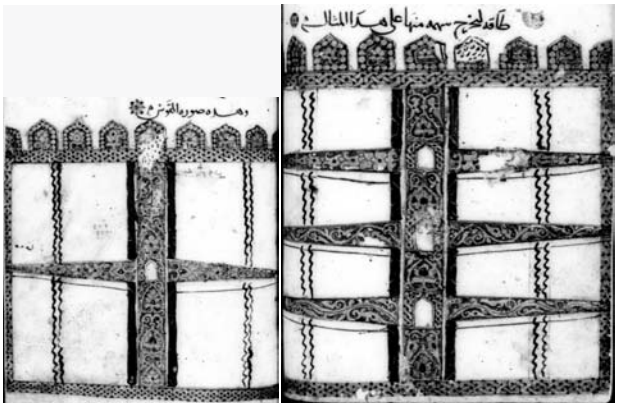


Fig. from Marḍī, *Tabṣira*, MS Oxford, Bodl., Hunt. 264.

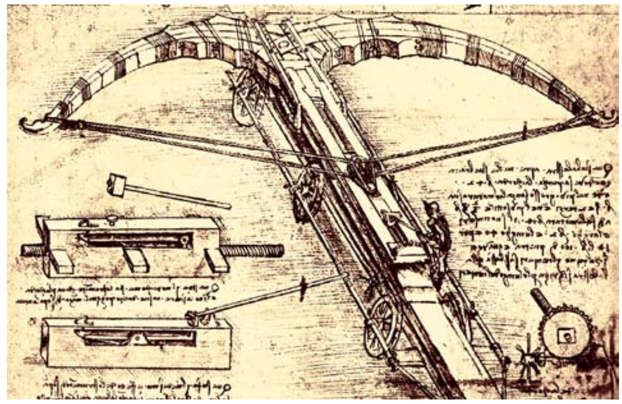


Illustration from *Leonardo da Vinci*, p. 291.

For operating it a team of about 20 persons was actually needed, but thanks to the technology used, one single man was sufficient to set it in motion. Its technical equipment included a windlass construction for drawing the bow. The length of the parts of the bow lying to the right and to the left of the shaft was about 3.3 metres each. The bows were made of several layers of thin plates of oak wood and animal horn which were sawn into shape and glued together.[16]

The strength of the bow amounted to about 35 cm in the large crossbows, about 24 cm in the medium pieces and about 12 cm in the small ones. The author states that the number of bows can be increased up to three and demonstrates this with the following illustrations (see fig. on the right above): This type of large crossbow seems to have inspired the imagination of Leonardo da Vinci to think of a gigantic construction:[17]

From the Islamic world a wooden bow with a length of about 2 metres is preserved in the Musée de l'Armée (Hôtel National des Invalides) in Paris, which institution kindly provided us with the following illustration. The bow is said to come from Syria and belongs to the 6th/12th century (see ill. p. 96). Composite bows (laminated with wood, horn, sinews and glue) had been the preferred weapons for hunting and warfare in the Middle East since pre-Islamic times. It is therefore unlikely that to this method of construction was only restorted for the bows of very large crossbows. Moreover, there is the possibility that the smaller crossbows contained bows of steel. Our 12th century source is silent on this count but its illustrations create the impression that the smaller crossbows must have been of metal (steel in our case). The earliest mention known so far of a steel bow goes back to the first half of the 8th/14th century. The anonymous source dating from that time enumerates the steel bows as «Indian bow» (*qisīy hindīya*) in a list of weapons indispensable to the army.[18] It is likely that bows of Damascene steel were meant by this.[19] We learn about the earliest known use of steel bows in Europe from an inventory dating from 1435.[20]

[16] *Tabṣirat arbāb al-albāb*, op. cit., p. 108; French transl. pp. 129-130; Bernhard Rathgen, *Das Geschütz im Mittelalter*, Berlin 1928, p. 635; Volker Schmidtchen, *Kriegswesen im späten Mittelalter. Technik, Taktik, Theorie*, Weinheim 1990, p. 169.

[17] *Leonardo da Vinci. Das Lebensbild eines Genies*, Wiesbaden and Berlin: Emil Vollmer 1955, p. 291.

[18] v. Ferdinand Wüstenfeld, *Das Heerwesen der Muhammedaner nach dem Arabischen*, in: Abhandlungen der Königlichen Gesellschaft der Wissenschaften (Göttingen) 26/1880, Historisch-philologische Classe, No. 1 and 2, esp. No. 2, p. 2 (reprint in: Ferdinand Wüstenfeld, *Schriften zur arabisch-islamischen Geschichte*, vol. 2, Frankfurt 1986, pp. 1-109, esp. p. 79).

[19] K. Huuri, *Zur Geschichte des mittelalterlichen Geschützwesens*, op. cit., pp. 120, 208.

[20] G. Köhler, *Die Entwickelung des Kriegswesens*, op. cit., pp. 181-182.

Fig.: Bow, Paris, Musée de l'Armée (6th/12th c.).

b) Counterweight Trebuchet

In his attempt to explain the progress in the technology of weaponry which gradually took place in Europe in the 7th/13th century, G. Köhler[21] in 1887 argued with regard to the new artillery system of that time: «However, at the beginning of the period we encounter the Arabs everywhere as those who have the most experience in things of this kind.» But he thought it necessary to remark: «Although it is very likely that the Byzantines were the inventors of the new machines and that the Arabs adopted these new machines from them, the Byzantine influence cannot be proved in this case.» In the following passage he explains[22] the innovation of ballista with counterweight used since the beginning of the 7th/13th century as compared to the catapults already known to the Greeks and the Sassanids: «The human strength applied to the short lever in the case of the Petraria is replaced by a counterweight, due to which not only is the operating team reduced but the initial velocity of the projectile is also increased considerably, because the falling counterweight attached to the short lever arm increases its speed as a consequence of the velocity of fall, and this is also transmitted to the projectile on the long arm of the lever.»

In the course of his rather detailed treatment of the subject, Köhler expresses the assumption that this piece of artillery reached Europe via Italy[23] and the Spanish Arabs.[24]
Compared to the much more extensive material on the European side until the middle of the 20th century researchers did not have many Arabic sources at their disposal. For a chronological evaluation of counterweight trebuchets used in both Europe and the Arab world, to judge from illustrations and descriptions, [97] it was primarily the book on the military technology by the Mamluk tournament master Ḥasan ar-Rammāḥ (d. 694/1295) which since 1845 has offered (see below, p. 99) a terminus a quo or ad quem.
The book, which was dedicated to the ruler Saladin in the second half of the 6th/12th century, and which was partly edited by Claude Cahen in 1948, gives us short descriptions of various types of catapults, an «Arabic one», a «Persian or Turkish one» and a «Byzantine or Frankish one». The most reliable was the Arabic catapult, the easiest to use was the Turkish variety. Unfortunately the descriptions are very brief and do not permit an exact idea of details. Among the illustrations added in profile, the form of the beam of a counterweight trebuchet is remarkable. On the other hand the book offers a complete pictorial depiction of a «Persian» counterweight trebuchet which served as a crossbow and at the same time as a catapult. It is a very advanced type. The brief description and the illustration of parts of the catapult known as «Byzantine or Frankish» give the impression of a projectile with small levers.[25]
Clearer illustrations of counterweight trebuchets are provided a century later by the Mamluk tournament master Naǧmaddīn Ḥasan ar-Rammāḥ (d. 694/1295, see below p. 99). More advanced versions of this type appear in the *al-Anīq fī l-manāǧnīq* by Ibn Aranbuġā az-Zaradkāš (written 775/1374). This author, who was in the service of the Mamluks,

[21] G. Köhler, *Die Entwickelung des Kriegswesens*, op. cit., pp. 173-174.
[22] ibid., p. 190.
[23] ibid., p. 194.
[24] ibid., pp. 195-196.
[25] cf. the remark by Cl. Cahen on the text of the *Tabṣirat arbāb al-albāb*, op. cit., p. 158.

gives illustrations of two highly advanced forms of the counterweight trebuchets. He calls one of these *qarābuġā* («black bull»). It served for hurling heavy stone balls and was provided with a degree-meter for regulating the range and for calculating the aim, and also with a block and tackle and a windlass for increasing its effectiveness.

After these brief remarks on the origin and development of counterweight trebuchets, we may draw attention to some reports on their dissemination outside the Islamic world as well.

K. Huuri[26] compiled some information on the quite early use of the counterweight trebuchet in Europe at the beginning of the 7th/13th century. He also refers to several European sources in which the very advanced type is mentioned[27] at the siege of Acre (ʿAkkā) by the Muslims in 1291 as a large sensational machine under the name *caraboga* (*caabouhas*, *carabaccani*); on this weapon more details are available now in the book by Ibn Aranbuġā az-Zaradkāš. According to Arabic sources, 92 (or more) stone catapults (*manǧanīq*) were employed at the siege.[28] Of great importance in this connection are doubtless the reports of the Chinese and Persian sources on the question when and how the type of the large counterweight trebuchet reached the Chinese. It is reported that Kublai Khan, the grandson of Genghis Khan and founder of the Eastern Mongol empire, encountered bitter resistance at his attempt, begun in the year 1268, to take Sūng-China. He encountered this resistance particularly at the siege of the two northern, strategically important, cities of Hsiāng-Yáng and Fán-Chéng.

At the suggestion of one of his commanders, Kublai ordered two engineers «from the West», from the Arab-Islamic territories, to be fetched with the order to build large counterweight trebuchets. With the help of the machines built by these two engineers, Ì-Ssū-Mǎ-Yīn (Arabic Ismāʿīl) and À-Lǎo-Wǎ-Tīng (Arabic ʿAlāʾaddīn), Kublai succeeded in conquering the two cities in 1272 and 1273, and thus the Mongols secured their rule over China. The trebuchet introduced in this manner into China was called *huí-huí* («Muslim») *phao*.[29]

[98] Chèng Ssū-Hsìao, a contemporary chronicler wrote the following about this:

«The [Mongol] bandits used Muslim trebuchets against the city of Hsīang-Yáng, whose towers and walls they destroyed with alarming effect, so that [the governor and commander] [Lǚ] Wén-Huàn was very concerned … The type of ‹Muslim trebuchet› originally came from the Muslim countries. It was stronger than the common trebuchets. In the case of the largest of them, the wooden frame stood over a depression in the ground. The projectiles measured several feet in diameter. When they fell to the ground they made a hole three or four feet deep. When [the artillerists] wanted to shoot over a large distance, they raised the [counter] weight and pulled it further back [on the stock]; when they had a shorter aim, they put [the weight] further to the front, closer [to the fulcrum].»[30] In conclusion, it may be mentioned that Leonardo da Vinci left behind a remarkable sketch of a counterweight trebuchet (see our model below, p. 119).[31] There he puts a wheel around the axis of the beam, which seems to fulfil the function of a distance regulator. D. Hill[32] drew attention to this sketch. J. Needham[33] takes the view that Leonardo heard about the trebuchet via Mariano Taccola[34] (d. ca. 1458). In my opinion, however, Leonardo's sketch is far removed from Taccola's account. His distance regulator and the beam strengthened with several bundles of rope are reminiscent of an Oriental model.

[26] *Zur Geschichte des mittelalterlichen Geschützwesens*, op. cit., pp. 62 ff.

[27] ibid., pp. 174-175.

[28] Al-Maqrīzī, *Kitāb as-Sulūk li-maʿrifat duwal al-mulūk*, vol. 1, part 3, Cairo 1939, p. 764; E. Quatremère, *Histoire des sultans mamlouks de l'Égypte*, vol. 2, Paris 1842, p. 125; cf. K. Huuri, op. cit., p. 173.

[29] Reinaud and Favé, *Du feu grégeois, des feux de guerre, et des origines de la poudre à canon chez les Arabes*, les Persans et les Chinois, in: Journal Asiatique, sér. 4, 14/1849/257-327, esp. pp. 292-304; J. Needham, *Science and Civilisation in China*, vol. 5, part 6, pp. 219-221.

[30] J. Needham, op. cit., p. 221.

[31] *Leonardo da Vinci*, op. cit., p. 294.

[32] *Trebuchets*, in: Viator. Journal of the Center for Medieval and Renaissance Studies (Los Angeles) 4/1973/99-114 (reprint in: D. R. Hill, *Studies in Islamic Technology*, Variorum Collected Studies Series 555, 1998, No. XIX), esp. p. 104.

[33] *Science and Civilisation in China*, vol. 5, part 6, pp. 204-205.

[34] See G. Sarton, *Introduction to the History of Science*, vol. 3, part 2, p. 1552.

c) Fire Arms

In the first decade of their expansion when they laid siege to cities, Muslims made use of catapults (*manǧanīq*) inherited from the Sassanids or the Yemenites;[35] likewise they did not fail to make use of the ‹Greek fire› which they had taken over from the Byzantines. It is recorded that at the siege of Constantinople in 97/715 they used the pyrotechnical effect of *nafṭ* (naphta).[36] As was already mentioned (see above, p. 94), an Arabic book on Greek fire was written in the early Abbasid period, certainly before the 4th/10th century.

To be sure, for this effective weapon, which was used for centuries not only in the Arab-Islamic world, different formulas were developed in the course of time. About a rather elaborate composition from the 13th century, we are informed by the Liber ignium ad comburendos hostes,[37] which probably originated at the end of the century. The little booklet, preserved in Latin and containing about 6 pages, is ascribed to a certain Marcus Graecus and consists of a collection of formulas without any recognizable order.[38] According to J. R. Partington,[39] the author was a «Jew or Spaniard» of the 12th or the 13th century.[40] The main formula of the Liber ignium consists of «pure sulphur, cream of tartar, Sarcocolla (the resin of a Persian [99] tree of the same name), pitch, sodium chloride and paraffin (naphta), besides common oil.»[41] From the most advanced formula of the Liber ignium, the knowledge of saltpetre and gunpowder can be deduced. However, saltpetre is not mentioned in connection with Greek fire, but leads «in combination with sulphur and coal to real gunpowder», and this is restricted to the «manufacture of the rocket and the cannon cracker.»[42]

On the approximate date and the value of the little book for the history of science, Joseph-Toussaint Reinaud and Ildefonse Favé covered the essential points in their studies[43] published in 1845 and 1849. They were able to refer to a wealth of historical reports from Arabic, Persian and Chinese sources, above all to the book on military technology by Ḥasan ar-Rammāḥ (d. 694/1295) which is preserved in different editions with the title *Kitāb al-Furūsīya wa-l-manāṣib al-ḥarbīya*.[44] Reinaud and Favé came to the conclusion that the date or origin of the *Liber ignium* should be adduced as between 1225 and 1250.[45] After many years of study of the subject, the two scholars reached the following conclusion on the question of the origin of firearms: «In Antiquity the Greeks and the Romans used certain materials for burning, the composition of which was, however, restricted to very simple formulas. The military art of fireworks, which was made use of by the Byzantines in late Antiquity and which did them at first the greatest service, had been improved remarkably, but the final improvements seem to have come from the Chinese. At least this much is beyond doubt, that the Chinese were the first to recognize that substance which was to change the production of incendiary material, namely saltpetre. When the Arabs took over from the Chinese a certain number of incendiary materials, they learnt from them how to mix the three substances which constitute gunpowder: saltpetre, sulphur and coal.»[46] Their progress in the field of chemistry or at least in its application had made it possible for the Arabs to improve the purification of

[35] K. Huuri, *Zur Geschichte des mittelalterlichen Geschützwesens*, op. cit., p. 134 ff.

[36] v. anon., *al-ʿUyūn wa-l-ḥadāʾiq fī aḫbār al-ḥaqāʾiq*, ed. J. de Goeje, Leiden 1869, p. 24; Marius Canard, *Textes relatifs à l'emploi du feu grégeois chez les Arabes*, in: Bulletin des Études Arabes (Algier) 6/1946/3-7.

[37] On most of the editions and translations, see Sarton, *Introduction*, op. cit., vol. 2, part 2, pp. 1037-1038; the most recent edition with an English translation is by Partington, *A History of Greek Fire*, op. cit., pp. 42-57.

[38] Partington, op. cit., p. 58.

[39] ibid., p. 60.

[40] Partington (p. 60) says: «[Henry V. L.] Hime thought that the author or translator was not a Greek or Muslim (who never used the name ‹Greek fire›), but a Jew or Spaniard who either did not know the Latin names for some Arabic words or thought them so familiar that they need not be translated (alkitran and zembac are untranslated; the Arabic nuḥās aḥmar for copper becomes aes rubicundus not cuprum, …).»

[41] G. Köhler, *Die Entwickelung des Kriegswesens*, op. cit., p. 168.

[42] ibid., p. 169.

[43] *Histoire de l'artillerie*. 1ère partie: *Du feu grégeois*, *des feux de guerre et des origines de la poudre à canon*, Paris 1845 and *Du feu grégeois, des feux de guerre, et des origines de la poudre à canon chez les Arabes, les Persans et les Chinois*, in: Journal Asiatique, sér. 4/1849/257-327.

[44] cf. C. Brockelmann, *Geschichte der arabischen Litteratur*, 1 suppl. vol., p. 905; ed. by ʿĪd Ḍaif al-ʿAbbādī, Baghdad 1984 and Aḥmad Y. al-Ḥasan, Aleppo 1998.

[45] *Du feu grégeois*, op. cit., (1849), p. 282.

[46] Reinaud and Favé, *Du feu grégeois*, op. cit., (1849), p. 260.

saltpetre considerably.[47] According to Reinaud and Favé, the Chinese discovered saltpetre and were the first to use it for the manufacture of fireworks. They were also the first to mix this substance with sulphur and coal and to recognize the propulsion power produced by burning the mixture. This led them to the idea of constructing rockets. As far as the Arabs are concerned, they had recognized the explosive power of gunpowder, used it, and had thus invented firearms[48]

Despite the observation that the Chinese had known saltpetre and its explosive character even before the 13th century, the question still remains as to whether the Arabs owe this knowledge to the Chinese or whether it is an independent development on their part. Until now the discussion of the subject started from the assumption that saltpetre, the main element of gunpowder, was unknown before the 13th century in the Arab-Islamic world. The discussion relied primarily on the earliest mention of saltpetre outside China, namely in the book of simple remedies (*al-Ǧāmiʿ li-mufradāt al-adwiya wa-l-aġḏiya*) by ʿAbdallāh b. Aḥmad Ibn al-Baiṭār[49] (d. 646/1248) where it is mentioned that the substance was known by the name of *bārūd* among the scholars of the Maghrib.

[100] However, we learn from a quotation in the history of medicine by Ibn Abī Uṣaibiʿa (d. 668/1270) that the physician ʿAbdallāh b. ʿĪsā Ibn Baḫtawaih (d. ca. 420/1029) described in detail the use of saltpetre for the manufacture of artificial ice in his book *Kitāb al-Muqaddimāt* or *Kanz al-aṭibbāʾ*.[50] E. O. von Lippmann pointed this out in 1906.[51]

The earliest mention in Arabic writings known so far of the use of saltpetre for the manufacture of gunpowder was identified by Reinaud and Favé[52] (middle of the 19th century) in the Paris manuscript of the book by Ḥasan ar-Rammāḥ (d. 694/1295). They also found the description of a cannon and a gun (see below, p. 133) in the manuscript of an important anonymous book on the art of warfare (*al-Maḫzūn fī ǧamīʿ al-funūn*), preserved at St. Petersburg.[53] This convinced the two scholars that the discovery of the propulsion power of gunpowder had taken place in the Arab-Islamic world. They had to revise their opinion that the place where gunpowder was first used is said to have been in Eastern Europe, in the region along the Danube.[54]

On the basis of the Petersburg manuscript, Reinaud and Favé came to the conclusion that the power of propulsion of gunpowder must have been known in the Arab-Islamic world at the latest in the second half of the 8th/14th century and this conclusion was confirmed by the *Kitāb al-Anīq fi l-manāǧnīq* by Ibn Aranbuġā az-Zaradkāš (written in 774/1373), the manuscript of which was discovered subsequently. This illustrated manuscript, preserved in the library of the Topkapı Sarayı (Ahmet III, 3469),[55] contains illustrations of quite advanced types of cannon. Of course, neither the lifespan of Ibn Aranbuġā az-Zaradkāš nor the likely date of composition of the anonymous *Kitāb al-Maḫzūn*

[47] ibid., p. 261.

[48] Reinaud and Favé, *Du feu grégeois*, op. cit., (1849),p. 327.

[49] ed. Cairo 1291 H., vol. 1 (reprint Islamic Medicine, vol. 69, Frankfurt 1996), p. 30; French transl. L. Leclerc, *Traité des simples*, vol. 1, Paris 1877 (reprint Islamic Medicine, vol. 71, Frankfurt 1996), p. 71; see Reinaud and Favé, *Histoire de l'artillerie*. 1ère partie: *Du feu grégeois*, op. cit., pp. 14-15.

[50] *ʿUyūn al-anbāʾ fī ṭabaqāt al-aṭibbāʾ*, ed. A. Müller, vol. 1, Cairo 1299 H. (reprint Islamic Medicine, vol. 1, Frankfurt 1995); pp. 82-83.

[51] in: *Abhandlungen und Vorträge zur Geschichte der Naturwissenschaften*, vol. 1, Leipzig 1906, pp. 122-123, see F. Sezgin, *Geschichte des arabischen Schrifttums*, vol. 3, p. 335.

[52] v. particularly *Du feu grégeois* ... (1849), op. cit., p. 261 and *De l'art militaire*, op. cit., p. 200.

[53] Current shelf mark number C 686, see A. B. Chalidov, *Arabskije rukopisi Instituta Vostokovedenija*, vol. 1, Moscow 1986, p. 493.

[54] *Du feu grégeois* ... (1849), op. cit., p. 309. For the analysis of the MS (here with the title *Kitāb al-maḫzūn wa-ǧamīʿ al-funūn*) see Alexis Olénine, *Notice sur un manuscrit du Musée Asiatique de l'Académie Impériale des Sciences de St.-Pétersbourg*, in: Bernhard Dorn, *Das Asiatische Museum der Kaiserlichen Akademie der Wissenschaften zu St. Petersburg*, St. Petersburg 1846, pp. 452-460; J. Reinaud, *De l'art militaire chez les Arabes au moyen âge*, in: Journal Asiatique, sér. 4, 12/1848/193-237, esp. pp. 203-205, 218-219, 221, 223, 226-227 and Reinaud and Favé, *Du feu grégeois* ... (1849), op. cit., pp. 309-314 (where the authors revise their earlier view on the discovery of the propulsion power of gunpowder in favour of the Arabs).

[55] v. H. Ritter, *La Parure des Cavaliers und die Literatur über die ritterlichen Künste*, in: Der Islam 18/1929/116-154, esp. pp. 150-151. The date on the title page of the manuscript is erroneous; the book was dedicated to Mängli Buġā (d. 782/1380); «on fol. 58b and 126a there is a colophon each of 21st Ram. 774, fol. 181b one of Ǧum. II 775» (Ritter).

(8th/14th c.) can serve as the upper limit of the emergence of the first firearm. Both authors, like their predecessors and successors, recorded in their respective books the knowledge of their times and of their geographical regions. They were not concerned with the question of the origin and the time of appearance of the objects, but with the description of the state of affairs as it was known to them at that time. Consequently the manuscript of the book by Ibn Aranbuġā with its date 774/1372 gives us a terminus ad quem, not a terminus a quo for the origin of firearms in the Arab-Islamic world.

The earliest reference to date to the use of a firearm in the Arab-Islamic world is to be found in connection with the siege of the city of Siǧilmāsa in 672/1273. The well-known historian Ibn Ḫaldūn reports in his historical work that against Siǧilmāsa the Merinid Sultan Abū Yūsuf Yaʿqūb (ruled 656/1258-685/1286) had employed manāǧnīq (counterweight trebuchets), *ʿarrādāt* (crossbows) and *hindām an-nafṭ*, a weapon where iron bullets were discharged out of a «magazine» (*ḫizāna*) after igniting the gunpowder.[56] Reinaud and Favé, who were the first to draw attention to this statement, doubted its veracity [101], primarily because it was not confirmed by contemporary sources.[57]

As reported by Lisānaddīn Ibn al-Ḫaṭīb in his history of Granada, roughly 60 years later, in 724/1324, the Nasrid Sultan Abu l-Walīd Ismāʿīl (ruled 713/1314-725/1325) bombarded the fortress of Iškar (Huescar, ca. 110 km to the north-east of Granada) held by Christians, «and hurled a hot iron bullet out of the largest instrument that functioned with naphta …» (*ramā bi-l-āla al-ʿuẓmā al-muttaḫaḏa bi-n-nafṭ kurat ḥadīd muḥmāt* …).[58] In a following verse the thunder of the cannons is compared to the thunder of the heavens.

The information by Ibn al-Ḫaṭīb attracted the attention of scholars even in the 18th century. The Spanish orientalist M. Casiri[59] translated it into Latin. From him it was taken over, among others, by the historian José Antonio Conde[60] (1765-1820). In Casiri's reproduction of the passage the word «iron» is missing, probably as a consequence of the manuscript used by him. That was one reason why a number of scholars wondered whether Ibn al-Ḫaṭīb could really have meant a cannon[61] or whether it could not have been a large trebuchet instead.[62] Some reports in Spanish chronicles give information about the firearms used in the battles between Christians and Muslims in the years 1331, 1340 and 1342.[63] I shall let G. Köhler[64] make the concluding remark on this subject: «These statements have to be understood in the context of Arabic literature in order to conclude that since 1325 they actually refer to firearms and that the Arabs are the ones who introduced them to the Occident.»

d) Grenades and hand grenades

The sphero-conical vessels unearthed in archeological excavations in Central Asia, in Persia and in the Volga region were considered for a long time to be architectural ornaments, containers of quicksilver or holy water, or even lamps. That they are grenades and hand grenades is an idea which began to only gain ground towards the end of the 1920s. The pioneer of this new interpretation was Wsewolod von Arendt.[65] The vessels, large numbers of which

[56] *Ta'rīḫ Ibn Ḫaldūn* ed. Ḫalīl Šaḥāda and Suhail Zakkār, Beirut 1981, vol. 7, p. 249.
[57] *Histoire de l'artillerie.* 1ère partie: *Du feu grégeois*, op. cit., pp. 73-77; cf. J. R. Partington, *A History of Greek Fire*, op. cit., p. 191.
[58] *al-Iḥāṭa fī aḫbār Ġarnāṭa*, ed. M. ʿA. ʿInān, vol. 1, Cairo 1955, p. 398; E. Quatremère, *Observations sur le feu grégeois*, in: Journal Asiatique, sér. 4, 15/1850/214-274, esp. pp. 255-257; I.-S. Allouche, *Un texte relatif au premiers canons*, in: Hespéris (Paris) 32/1945/81-84; G. S. Colin in: Encyclopaedia of Islam. New Edition, vol. 1, Leiden 1960, col. 1057.
[59] *Bibliotheca Arabico-Hispana Escurialensis*, vol. 2, Madrid 1770, p. 7.
[60] *Historia de la dominación de los Arabes en España*, Paris 1840, p. 593 (not seen), see Reinaud and Favé, *Histoire de l'artillerie.* 1ère partie: *Du feu grégeois*, op. cit., p. 70.
[61] Thus Quatremère, *Observations sur le feu grégeois*, op. cit., pp. 258 ff.; G. Köhler, *Die Entwickelung des Kriegswesens*, op. cit., pp. 222-223.
[62] On this, v. J. R. Partington, *A History of Greek Fire*, op. cit., pp. 191-193, 228.
[63] Reinaud and Favé, *Histoire de l'artillerie.* 1ère partie: *Du feu grégeois*, op. cit., pp. 70-72; G. Köhler, *Die Entwickelung des Kriegswesens*, op. cit., p. 223; J. R. Partington, *A History of Greek Fire*, op. cit., pp. 191, 193-195.
[64] *Die Entwickelung des Kriegswesens*, op. cit., p. 223.
[65] *Die sphärisch-konischen Gefäße aus gebranntem Ton*, in: Zeitschrift für historische Waffen- und Kostümkunde (Dres-

are preserved, show unusual strength and have a strikingly thin neck. Some specimens found in Syria carry inscriptions like *fatḥ – fatḥ* («victory – victory»), *bi-Ḥamā* («in [the city of] Ḥamā») or blessings.

Referring to the places where these grenades originated from or where they were found, Arendt says the following: «We encounter the form of the sphero-conical vessels throughout the Muslim East.»

«Indeed, Islam confronts us as a factor in the dissemination of this object which Islam employed in its victorious march as a weapon of war until it is superseded by firearms»[66]

[102] According to Arendt's conjecture, those vessels contained both incendiary materials like «Greek fire» and explosives: «There is no doubt about the explosive power of the contents of the grenades; this is attested by the fragments of these extraordinarily hard vessels piled up in the moats of old fortresses. Therefore we cannot consider the old clay grenades as mere incendiary projectiles. Their effect would have been too little for Asian cities and fortresses, which had too little inflammable material.»[67]

«That almost all the vessels are provided with a neck which has a narrow part allows us to draw conclusions about the way the grenades were thrown. The narrow part seems to have been intended to be encircled by a fine cord. It is quite likely that the grenades were carried during the campaign on a cord which encircled the neck of the vessel and whose other end was fastened to the belt or the saddle and that the cord was then used for throwing.»

«The grenade may have been hurled with a circular sweep, with the cord playing the role of a sling, which must have enhanced the flight range of the grenade.»[68]

Arendt was able to base his research on the material at his disposal in the Historical Museum in Moscow. He assumed that there was a connection between this material and the type of grenade found in Damascus, which was known to him indirectly.[69] He dated the vessels, richly decorated with ornaments, between the 7th/13th and the 8th/14th centuries.[70] He regretted that he did not succeed «in analyzing the minute parts which could be taken out of the vessel.»[71]

Arendt's wish was fulfilled in the subsequent decades thanks to the efforts of Maurice Mercier.[72] As a French naval officer in Syria he had, since 1916, been in frequent contact with the curators of the Cairo museum and had secured possession of a number of such vessels which had been found during archeological excavations in the old part of Cairo.[73] In the course of his examinations he was convinced that the specimens found in Cairo belonged to the weaponry used by the Egyptians at the siege of the city[74] by Amalrich I in 1168.[75] For this conclusion he relied on the report of the historian al-Maqrīzī, according to which Šāwir b. Muǧīr as-Saʿdī, the governor of Upper Egypt (d. 564/1169), had sent 20,000 *qārūrat nafṭ* and 10,000 *mašʿal nār* to Cairo on that occasion.[76] He makes a distinction between grenades with gunpowder and those with liquid incendiary material. He found both these varieties in the above-mentioned (see above, p. 94) defences of al-Manṣūra against the army of Louis IX in 1249.[77]

Chemical analyses which Mercier commissioned of preserved grenades of Cairo, Alexandria, Jerusalem, Damascus and Tripoli (in modern Lebanon) convinced him—of course not without the support of historical evidence—that the knowledge of the Arab-Islamic countries regarding saltpetre goes back to a considerably earlier period than is generally supposed. In 1937 he published the result of

den) N. F. 3/1931/206-210.

[66] ibid., p. 209.

[67] *Die sphärisch-konischen Gefäße*, op. cit., p. 209.

[68] ibid., p. 210.

[69] ibid., p. 209.

[70] ibid., p. 209.

[71] ibid., p. 209.

[72] He recorded his results in his *Le feu grégeois. Les feux de guerre depuis l'antiquité. La poudre à canon*, Paris 1952.

[73] ibid., p. 94.

[74] v. René Grousset, *Histoire des croisades et du Royaume Franc de Jérusalem*, vol. 2, Paris 1935, pp. 525-534.

[75] M. Mercier, op. cit., pp. 98 ff., 104, 125 ff.

[76] *Kitāb al-Mawāʿiẓ wa-l-iʿtibār bi-ḏikr al-ḫiṭaṭ wa-l-āṯār*, op. cit., vol. 1, p. 338; M. Mercier, *Le feu grégeois*, op. cit., p. 73.

[77] M. Mercier, *Le feu grégeois*, op. cit., pp. 77, 125.

the analysis of the grenades found in 1798 in the «old castle of the lighthouse of Alexandria».[78] He published the reports of the chemical institutes which made the necessary analyses, together with photos of a number of preserved grenades from the Arab-Islamic world, in the appendix of his *Le feu grégeois*, which appeared in 1952.

[103] Among his various conclusions,[79] what is important for us is view that the year 1168 is the terminus ad quem for grenades filled with dry explosives, because the Egyptians used grenades of this type at the siege by Amalrich I. It was the grenade or the hand grenade which is mentioned in the book by Ḥasan ar-Rammāḥ as *qawārīr* («vessels», singular *qārūra*,) or as *karrāz šāmī* («Syrian vessel»).[80]

Then in 1959, as part of an article on the *Antiquités syriennes*, Henri Seyrig,[81] an archeologist, posed the question about the function of these sphero-conical vessels of burnt clay, which had been understood until then in quite different ways as containers for liquids (quicksilver, perfume or beverages), as grenades or as aelopiles (see below). He is inclined to dismiss the first two explanations because of the physical composition of the vessels. He points out that, first of all, they are pointed at the bottom and could, therefore, not be placed in an upright position, secondly that they could not hold enough liquid to serve as drinking vessels and thirdly that they had very narrow necks with a diameter of 3 to 5 mm, mostly between 4 and 5 mm, so that liquids could not be poured in easily.[82]

Seyrig[83] also sees an obstacle in the narrow neck for the possibility of their being hand grenades. It was difficult to fill them with large quantities of powder, and he was not aware if such an experiment had ever been undertaken. M. Mercier, who was in favour of this hypothesis, did not give any indication of a practical experiment of this kind.[84] Moreover, he calls attention to the fact[85] that only in rare cases was incendiary material found in the specimens preserved. A chemical analysis had shown disappointing results in this respect, adds Seyrig.

With regard to his last objections, it must be remarked that he does not seem to have read Mercier's book[86] completely. It also seems that Seyrig to a certain extent contradicts the content of his own footnotes, which are related to this question.

Seyrig also asks us to bear in mind that many grenades are decorated[87] and that some of them carry blessings or messages of congratulation.[88]

The answer of the adherents of the grenade theory «that some people decorate their arrows»[89] failed to convince him.[90] Without repeating his arguments here, we may say that most of the incendiary projectiles depicted in Arabic books on military technology are lavishly decorated, as in those by Ḥasan ar-Rammāḥ (MS Paris) or Aranbuġā az-Zaradkāš (MS Topkapı Sarayı). Among the «three hypotheses» known to him, Seyrig tends to favour that of the aelopiles or wind-balls (*aeolipila*). This steam blower is «a metal ball with a fine opening, which is filled with water and then put into fire in order to show ‹the violent blowing› of the steam».[91] The aelopile was already known to Heron and Vitruvius. In his article of 1951, W. L. Hildburgh[92] wonders whether our vessels of burnt clay could not be a type of aelopile. [104] Then, in 1965, Richard Et-

[78] *Quelques points de l'histoire du pétrole. Vérifications par le laboratoire*, in: IIme Congrès Mondial du Pétrole, Paris 1937, vol. 4, section 5: Économie et statistique, pp. 87-95; idem, *Le feu grégeois*, op. cit., p. 99.
[79] *Le feu grégeois*, op. cit., pp. 123-126.
[80] ibid., pp. 94, 126.
[81] in: Syria. Revue d'art oriental et d'archéologie (Paris) 36/1959/38-89; esp. pp. 81-89: 75. *Flacons? grenades? éolipiles?*
[82] ibid., p. 83.
[83] ibid., p. 85.
[84] ibid., p. 85.
[85] ibid., p. 85.
[86] *Le feu grégeois*, op. cit., pp. 131 – 150, see also the lists of contents of grenades no. 1-8 in Mercier's possession in the appendix of the book.
[87] *Antiquités syriennes*, op. cit., p. 85.
[88] ibid., p. 84.
[89] ibid., p. 85. He is refering here to Fr. Sarre (*Das islamische Milet* by Karl Wulzinger, Paul Wittek, Friedrich Sarre, Berlin and Leipzig 1935, p. 76) who emphasizes «that it is particularly in accordance with the character of Islamic creativity to decorate an object without taking into account whether its decoration will be noticed or not. Often the invisible underside of an instrument of metal is decorated in the same rich style as the visible side.» See also the earlier explanation by Fr. Sarre, *Keramik und andere Kleinfunde der islamischen Zeit von Baalbek*, in: *Baalbek. Ergebnisse der Ausgrabungen und Untersuchungen in den Jahren 1898 bis 1905*, vol. 3, by H. Kohl, D. Krencker, O. Reuther, Fr. Sarre, M. Sobernheim, Berlin and Leipzig 1925, pp. 133-135.
[90] ibid., p. 86.
[91] Franz Maria Feldhaus, *Die Technik. Ein Lexikon der Vorzeit, der geschichtlichen Zeit und der Naturvölker*, Wiesbaden 1914 (reprint Munich 1970), column 26.
[92] *Aelopiles as fire-blowers*, in: Archaeologia (Oxford) 94/1951/27-55; see H. Seyrig, op. cit., p. 89.

tinghausen[93] took up the subject from the point of view of art history. After the «sound objections» from Henri Seyrig, as he says, he himself now began to view with doubts the explanation of the vessels as hand grenades. Among other things, he points to one of the objections raised by Seyrig, namely the appearance of blessings like the *basmala* on the vessels.[94] Among the interpretations known to him, he considers that by E. von Lenz[95] to be the most likely one, although it was not the only possibility.[96] Lenz had opined that the vessels could possibly be containers for quicksilver. However, Ettinghausen does not commit himself to any one interpretation and expresses the hope that the study of manuscripts, chemical examination and aerodynamic trials might bring clarification in future.[97] Unfortunately he does not seem to have known the results of the chemical analyses recorded by M. Mercier. The most recent study on the subject known to me at this moment carries the title *A sphero-conical vessel as fuqqāʿa , or a gourd for* «*beer*» and is by A. Ghouchani and C. Adle.[98] From this article we learn more than we had known to date about the widespread usage of the word *fuqqāʿa* in Arabic-Persian literature in the sense of a drinking vessel. But the two authors also emphasize quite rightly the possibility that a *fuqqāʿa* can also have served for other purposes.[99] They give photos of a number of vessels with the inscription *išrab hanīʾan* («to your very good health!») and refer to them as sphero-conical vessels characterized by a «thick body, narrow opening, and short neck.» But not all of them have a sphero-conical form and the characteristics mentioned. In my opinion, the authors disregard one of the most important characteristics. The objects which we might consider as grenades are actually tapering to a point at the bottom so that one cannot put them upright without a support. No doubt, vessels of burnt clay designated as *fuqqāʿa* were used for various purposes, depending on the shape and size.[100] Unlike the large specimens which were hurled by machines, the small hand grenades, had a very narrow mouth of about 3 to 5 mm diameter which did not serve for filling the powder, but obviously for inserting the fuse. As we can observe in almost all hand grenades, a groove separates the button-like neck from the bulbous trunk. This leads us to the conclusion about the manner in which such grenades were made. The bulbous lower part was probably made separately in two halves and was joined together only later on. Likewise, the separately burnt upper part with the fuse was probably only joined to the lower part after it was filled with powder. The groove shows the joining of the two parts. Friedrich Sarre[101] has drawn attention to some casting moulds of stone which were found and described in the 1930s; he reproduced a photo of two such moulds (fig.) They were joined to each other with lead plugs. A chemical examination in Berlin had shown that the stone used consisted of chlorite, which «as a consequence of its low hardness can be worked easily» and which is «relatively resistant to heat».

[105] Sarre's opinion that these are casting moulds for the manufacture of hand grenades can hardly be endorsed since the preserved stone forms are meant for the shaping of «richly decorated vase-like vessels». Moreover, because of the lead plugs the forms are not suitable for firing in the oven; it is more likely that these were casting moulds for metal or glass.

«One of the stone forms carries an incised inscription with the name ‹Shech Pasha›».[102] One type of grenade, called *furqāʿa*, is described by the Rasʿlid king al-Muẓaffar Yūsuf b. ʿUmar (d. 694/1294) in his book *al-Muḫtaraʿ fī funūn aṣ-ṣunaʿ*. It consisted of a specially prepared hard cardboard which was

[93] *The uses of sphero-conical vessels in the Muslim East*, in: Journal of Near Eastern Studies (Chicago) 24/1965/218-228.

[94] ibid., p. 225.

[95] *Handgranaten oder Quecksilbergefäße*? In: Zeitschrift für historische Waffenkunde (Dresden) 6/1912-1914/367-376; refutation of W. Gohlke, *Handbrandgeschosse aus Ton*, ibid., pp. 378-387.

[96] R. Ettinghausen, *The use of sphero-conical vessels*, op. cit., p. 224.

[97] ibid, p. 226.

[98] Published in Muqarnas. An annual on Islamic art and architecture (Leiden) 9/1992/72-92; see also Edward J. Keall, «*One man's Mede is another man's Persian; one man's coconut is another man's grenade*», in: Muqarnas 10/1993/275-285.

[99] *A sphero-conical vessel*, op. cit., pp. 73,76.

[100] Emily Savage-Smith also makes this assumption in her attempt to provide a typology of such vessels and in her description of those in the Khalili collection. She rules out the possibility of grenades. See *Sphero-conical vessels: a typology of forms and functions*, in: *Science, Tools and Magic*. Part Two: *Mundane Worlds*, Oxford 1997 (The Nasser D. Khalili Collection of Islamic Art, vol. 12, part 2), pp. 324-337.

[101] *Das islamische Milet*, op. cit., pp. 77-78.

[102] At this point I should like to thank Mrs. Gisela Helmecke (Museum für islamische Kunst, Berlin) for her valuable explanations.

filled with gunpowder and provided with a fuse.[103] Finally we may refer to an informative passage in the book by Ḥasan ar-Rammāḥ (MS Paris, Bibl. Nat. 2825) to which E. Quatremère[104] drew attention more than 150 years ago. In connection with the use of gunpowder (*bārūd*), the author speaks of «pitchers» (*kīzān fuqqāʿ*) that were «fastened to the tips of lances» (*murakkaba ʿalā ruʾūs ar-rimāḥ*). Thus we learn that, when necessary, grenades (after ignition) were also fastened to lances and hurled at the enemy.

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[103] Ed. M. ʿĪ. Ṣāliḥīya, Kuwait 1989, pp. 206-207.

[104] *Observations sur le feu grégeois*, in: Journal Asiatique, sér. 4, 15/1850/214-274, esp. p. 246.

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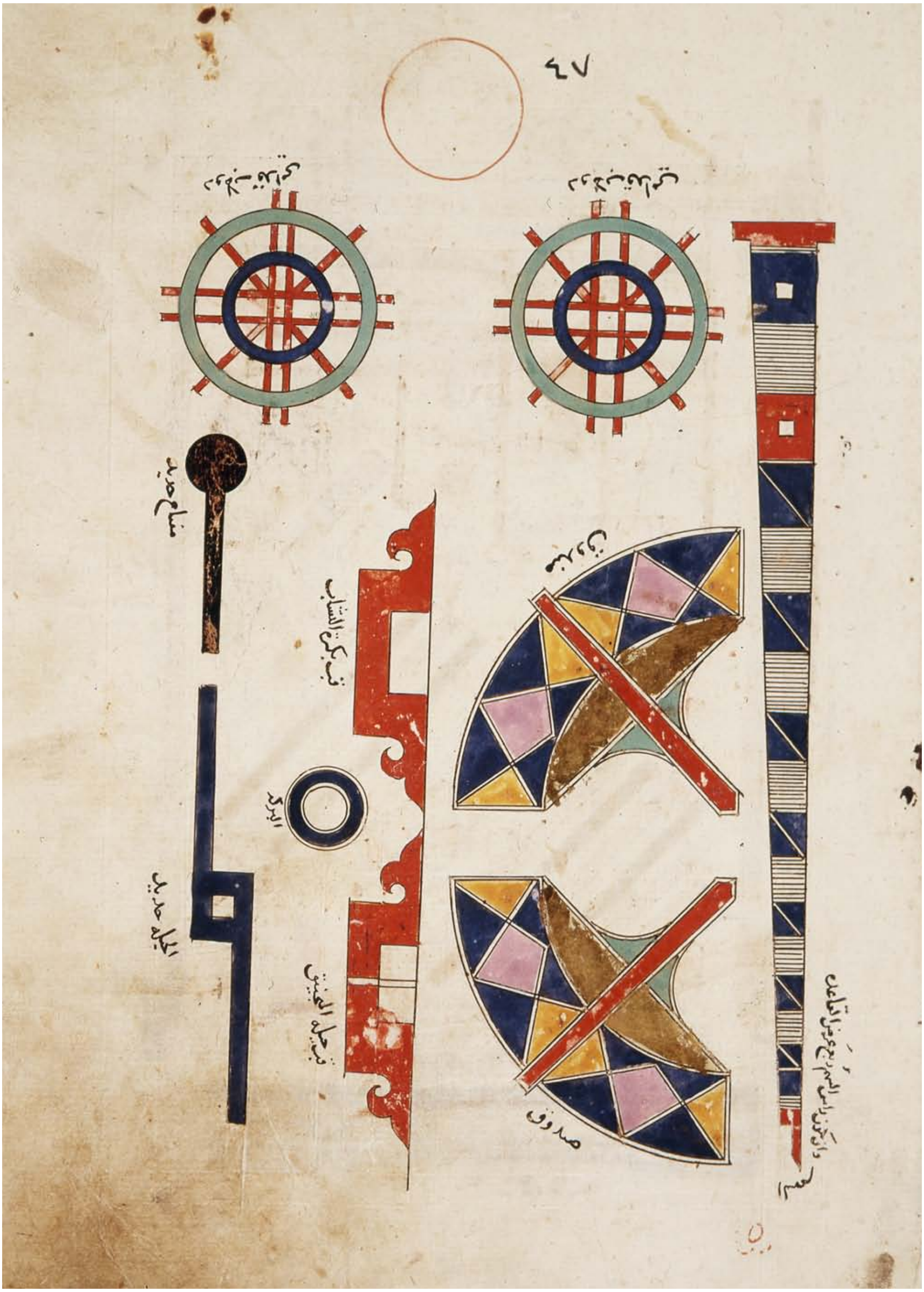
[3] *Observations sur le feu grégeois*, in: Journal Asiatique, sér. 4, 15/1850/214-274, esp. p. 246.



Illustr. from: az-Zardkāš, *al-Anīq*, MS Topkapı Sarayı, Ahmet III, 3469.

Traction Trebuchet

Our model:
Wood and steel.
Length of the ejector arm: 82 cm.
(Inventory No. G 1.01)

The traction trebuchet is designated as the «King's trebuchet» (*manǧanīq sulṭānī*) by az-Zaradkāš (ca. 775/1374).[1] Here the required leverage is provided by human power.[2] In our illustration the instrument was constructed in such a way that it was to be operated by ten soldiers. They tautened the ejector arm by pulling on the ropes fastened to rings on the right and on the left.[3]

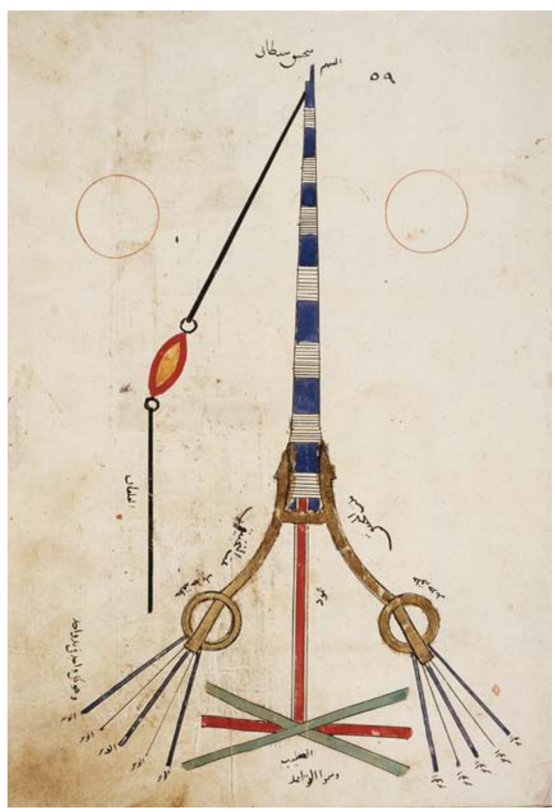


Illustration from:
az-Zardkāš,
al-Anīq, MS Topkapı Sarayı, Ahmet III, 3469.

[1] *al-Anīq fi l-manāǧnīq*, ed. I. Hindi, Aleppo 1985, pp. 100-102.
[2] G. Köhler, *Die Entwickelung des Kriegswesens*, op. cit., p. 164 ff.; K. Huuri, *Zur Geschichte des mittelalterlichen Geschützwesens*, op. cit., p. 171.
[3] A. al-Hasan, D. R. Hill, *Islamic Technology*, op. cit., p. 100.

Our model:
Wood and steel.
Length of the ejector arm: 70 cm.
(Inventory No. G 1.02)

Counterweight
Trebuchet

Az-Zaradkāš (ca. 775/1374) knows a particular form of the trebuchet called the «European catapult» (manǧanīq ifranǧī). Obviously here it has to do with the counterweight trebuchet (trebuchium) which the «Franks» used. We may assume that this type of catapult was known as early as the first half of the 13th century in Europe.[1] Az-Zaradkāš mentions that a special feature here is that it can be moved easily to any direction.[2] Two wooden boxes filled with stones produce the counterweight, while the ejecting momentum remains constant.

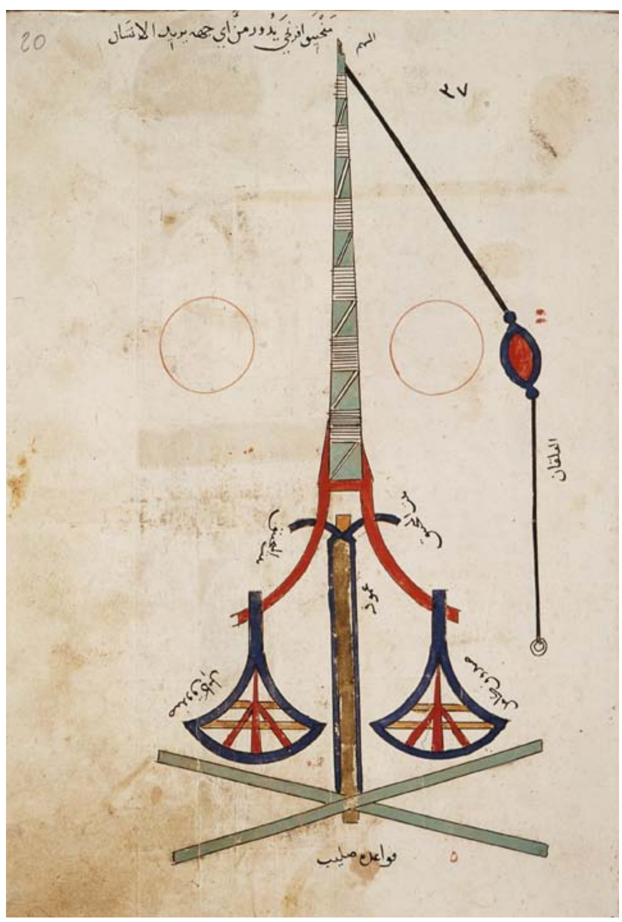


Illustration from:
az-Zardkāš, *al-Anīq*, MS Tokapı Sarayı, Ahmet III, 3469, p. 37.

[1] K. Huuri, *Zur Geschichte des mittelalterlichen Geschützwesens*, op. cit., pp. 64-65.
[2] *al-Anīq fi l-manāǧnīq*, op. cit., pp. 97-99.

Large
Counterweight Trebuchet

Our model:
Hardwood.
Scale: 1:20.
Length of the ejector arm: 80 cm.
(Inventory No. G 1.03)

The large catapult, called *qarābuġā* («black bull»), seems to be the highest stage of development of trebuchets which were gradually superseded by cannons from the 9th/15th century onwards. The characteristic features which distinguish it from its equally large predecessors are the use of force produced by the tread-wheel and block and tackle, the use of the protractor for taking aim and the use of a surveyor's levelling instrument when setting it up. Az-Zaradkāš[1] describes the function and use of this trebuchet and provides quite precise illustrations of its component parts. He also mentions another type of this large catapult which was called *manǧanīq az-ziyār* (see below, p. 110) and which was apparently quite widespread in the 7th/13th century in the Islamic world.
The trebuchet consists mainly of two supporting frames between which a horizontal beam, i.e. the axis of rotation, is fastened. Around this axis an

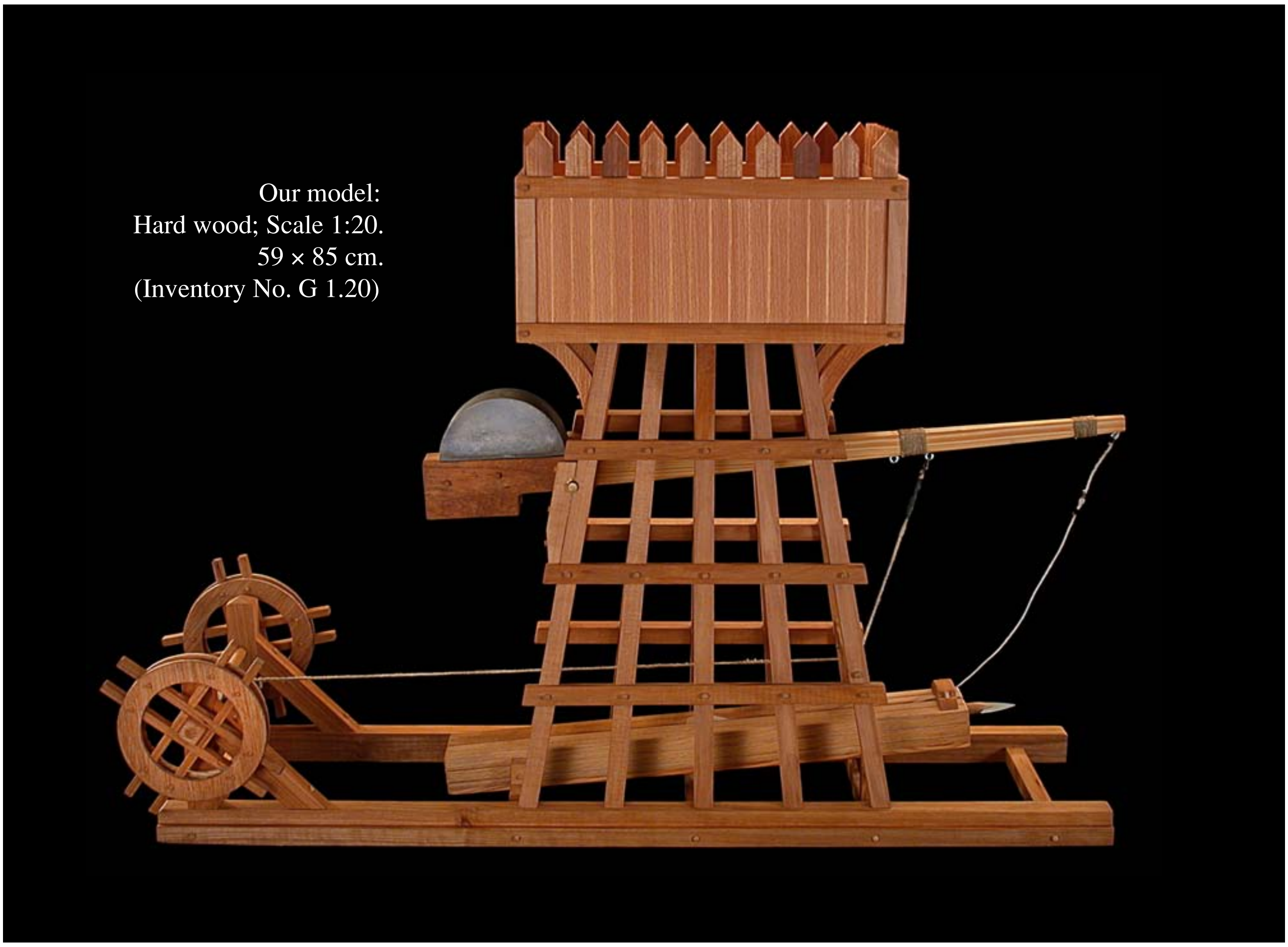
Illustration from: az-Zardkāš, *al-Anīq*, MS Ahmet III, 3469.

[1] *al-Anīq fi l-manāǧnīq*, op. cit., pp. 66-68.

Scene of siege from the World History (*Ǧāmiʿ at-tawārīḫ*) by Rašīdaddīn Faḍlallāh, MS Edinburgh University Library, Or. 20, fol. 124 b. The manuscript was copied and illustrated in 707/1306 during the author's lifetime.

Illustration from: *K. al-Furūsīya fī rasm al-ǧihād* by Ḥasan ar-Rammāḥ (m. 694/1295), Paris, Bibliothèque nationale, ar. 2825.

ejector arm can swing which is divided by the axis of rotation [109] into two parts of unequal length. A wooden box filled with stones is attached to the short end of the ejector arm; the end of the longer arm of the lever has a leather sling for receiving a stone or another kind of projectile. When the long lever arm is pulled downwards by means of ropes, windlasses and tread-wheels, the short arm with the counterweight goes up at the same time and keeps the long arm, which is anchored with a hook, under tension. Then after the projectile has been put in position and the hook released, the counterweight pulls the short arm downwards, the long arm leaps high at the same time and hurls the load, mostly stones or incendiary projectiles, in a high arc towards the target.



Our model:
Hard wood; Scale 1:20.
59 × 85 cm.
(Inventory No. G 1.20)

Counterweight Trebuchet
with Arrow Ejector

This type of trebuchet was a sub-variety of the *qarābuġā* already mentioned and was called *az-ziyār* in Arabic. The main difference between the two was that the latter was meant to hurl heavy arrows instead of stones or other voluminous objects. For this purpose the container which served as counterweight and which was filled with stones was replaced by a massive piece of iron. The arrows had flipper-like stabilizers at the end of the shaft. They were shaped in such a way that they could be pulled into a groove at the base of the trebuchet by means of a suitable hook on a rope that was fastened to the ejector arm. Apparently the slope of the groove used to be regulated according to the target. We may assume what [111] az-Zaradkāš, the author of

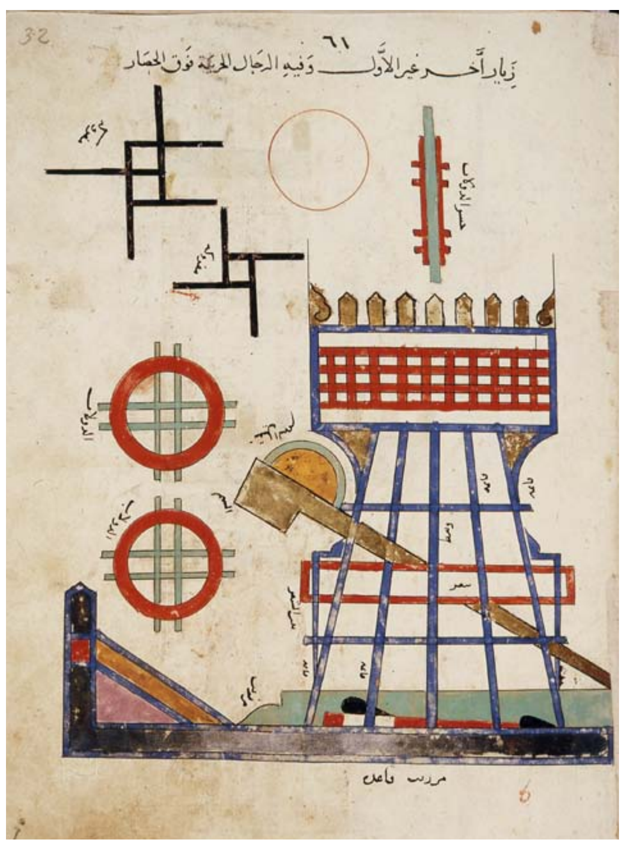


Illustration from: az-Zardkāš, *al-Anīq*, MS Ahmet III, 3469, p. 61.

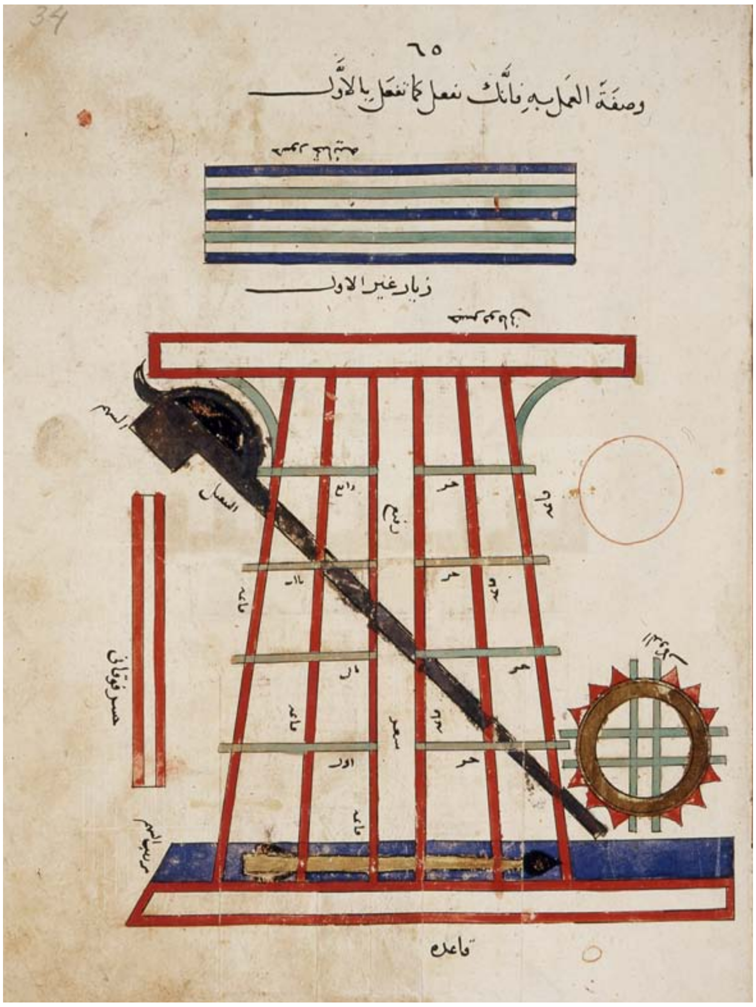
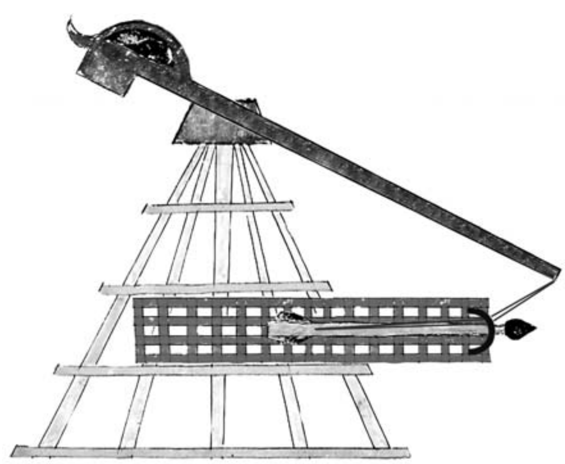


Illustration from:
az-Zardkāš, *al-Anīq*, MS Topkapı Sarayı, Ahmet III, 3469, p. 65.

the K. *al-Anīq fi l-manāğnīq*,[1] leaves unmentioned, namely, that at the front of the groove a suitable guideway was fastened, perhaps in the form of a bridge, so that the arrow was not pulled too far in the vertical direction.
The direction of the shot of this trebuchet was staggered by 180° compared to that of the other type of large trebuchet.
We do not know at present from when the increased momentum of the counterweight trebuchet began to be employed in the Islamic world for shooting arrows and other projectiles. From the statements in the *Tabṣirat arbāb al-albāb* by Marḍī aṭ-Ṭarsūsī (6th/12th c.), it is obvious (see below, p. 121 ff.) that this combination was even known at the time of Ṣalāḥaddīn (Saladin).



Attempt at a reconstruction of the arrow launching ramp with guideway (montage).

[1] *al-Anīq fi l-manāğnīq*, op. cit., pp. 92-96.

Counterweight Trebuchet
with Cross Bow

Our model:
Wood and laminating material
100 × 45 × 54 cm.
(Inventory No G 1.19)

This war engine is one of those described by the above-mentioned (see above, p. 94) Marḍī b. ʿAlī aṭ-Ṭarsūsī (6th/12th c.) in his book *Tabṣirat arbāb al-albāb fī kaifīyat an-naǧāt*[1] dedicated to the ruler Ṣalāḥaddīn (Saladin). He calls it «Persian counterweight trebuchet» (*manǧanīq fārisī*) and says that master Abu l-Ḥasan al-Abraqī al-Iskandarānī had described and drawn the device for him.

Here the windlass is replaced by a double block and tackle. The force needed for lifting the counterweight and for tautening the bow is transmitted by the block and tackle and by the sufficiently long arm of the trebuchet. The trigger simultaneously releases the stone projectile for hurling and the crossbow for shooting.

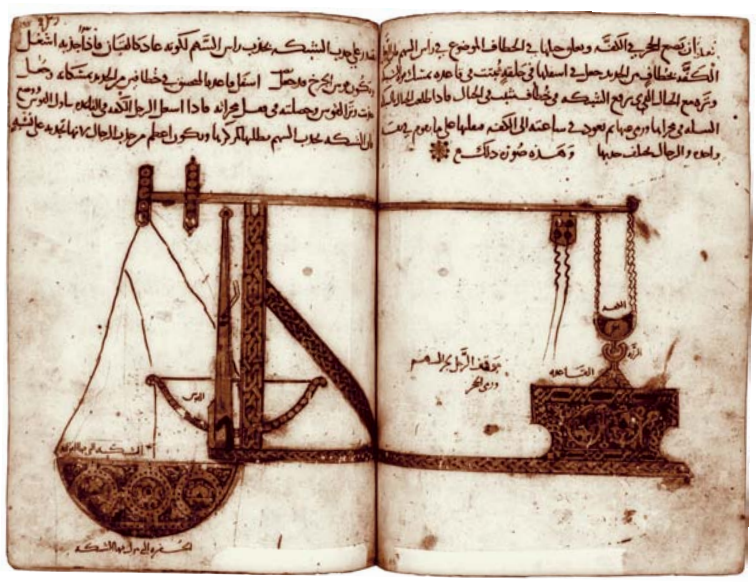
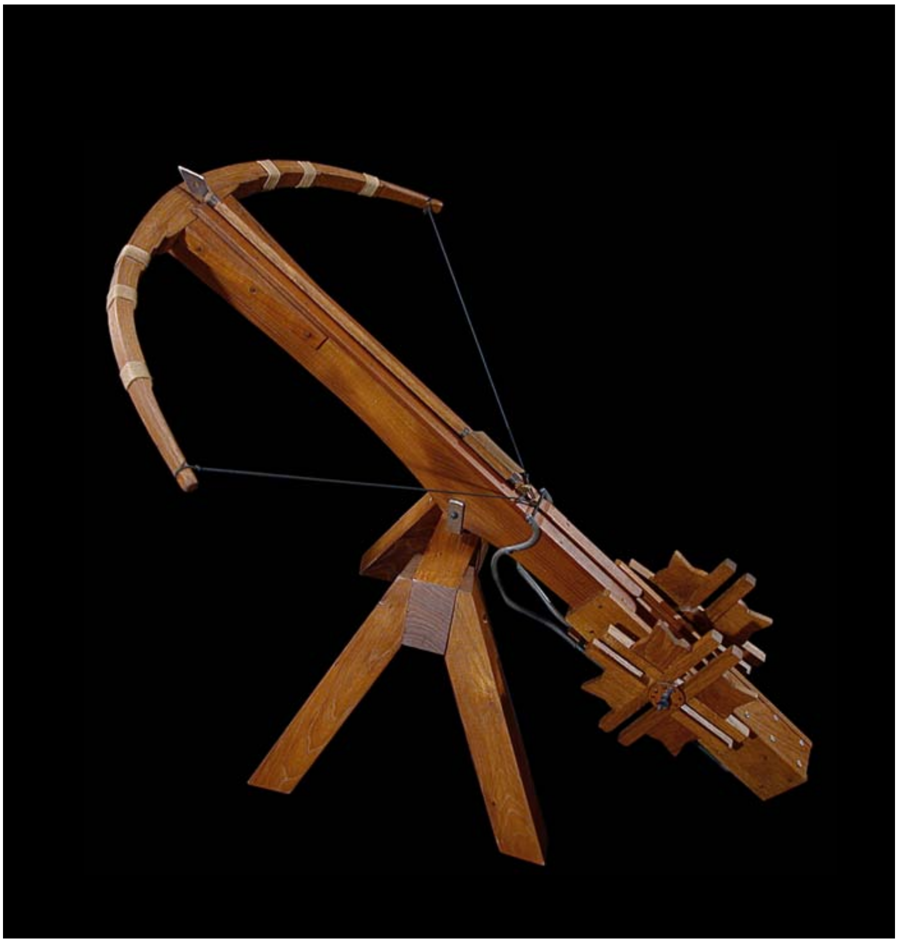


Illustration from: Marḍī, *Tabṣira*, MS Oxford, Hunt. 264, fol. 129 b et 130 a.

[1] MS Oxford, Bodleian Library, Hunt. 264 (fol. 133b-136b), see Cl. Cahen, Un traité d'armurerie, op. cit., pp. 119-120 and plate III, No. 14.



Windlass Crossbow

Our model:
Wood, metal. 110 × 80 cm.
String made of elastic rope
for demonstration purposes.
(Inventory No. G 1.17)

This type of crossbow, in Arabic *qaus bi-l-laulab*, which is tautened by one or several windlasses (rack-and-pinion gear), was popular as early as the 5th/11th century in the Arab-Islamic world (see above, p. 94). In the 6th/12th century it was described in detail by Marḍī b. ʿAlī aṭ-Ṭarsūsī in his book on military technology (*Tabṣirat arbāb al-albāb fī kaifīyat an-naǧāt*) dedicated to the ruler Ṣalāḥaddīn (Saladin). In our model we mainly followed the illustration provided in the *al-Anīq fi l-manāǧniq* of the 8th/14th century.

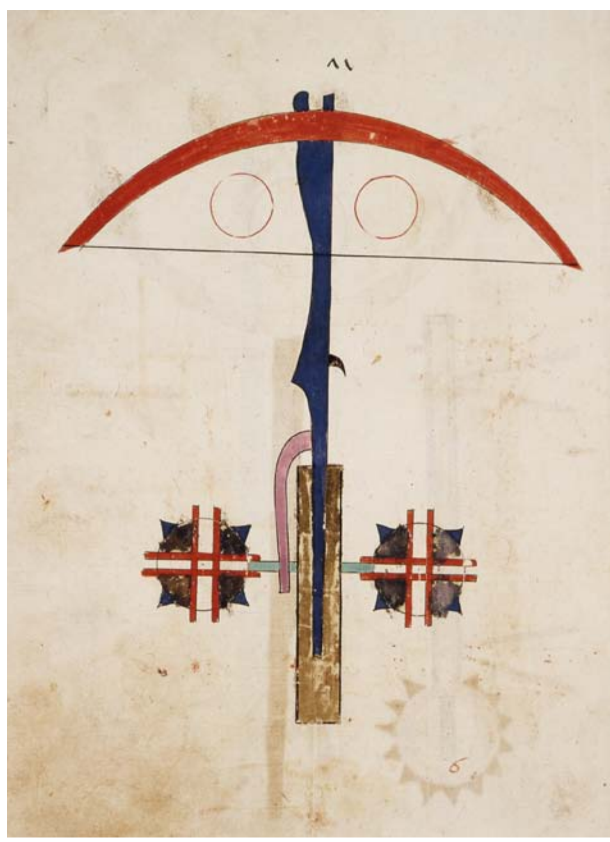
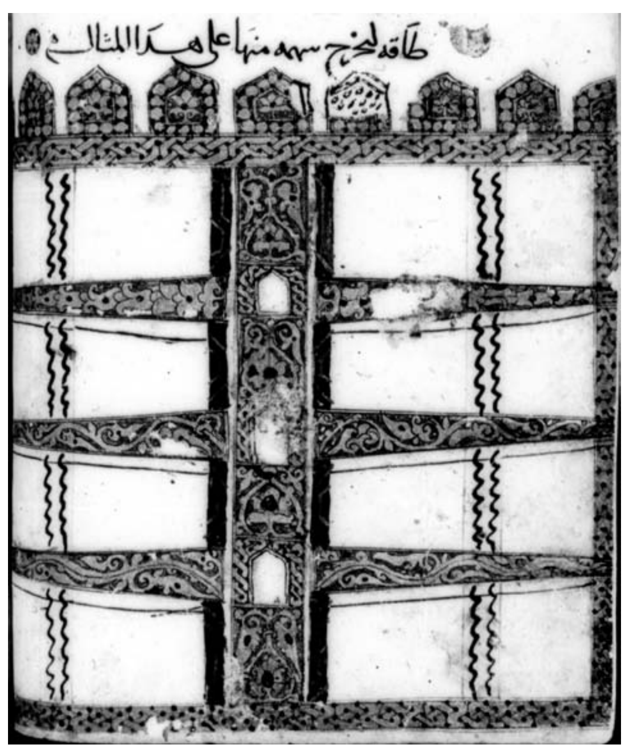


Illustration from:
al-Anīq fi l-manāǧnīq.

Illustration from:
Marḍī, *Tabṣira,* MS Oxford, Hunt. 264, fol. 112b.
The view from above seems to include the walls of the tower where this large crossbow is installed.

Our model:
Wood, reed, brass, string.
55 × 45 cm.
(Inventory No. G 1.18)

Illustration from: Marḍī, *Tabṣira,*
MS Oxford, Bodl., Hunt. 264.



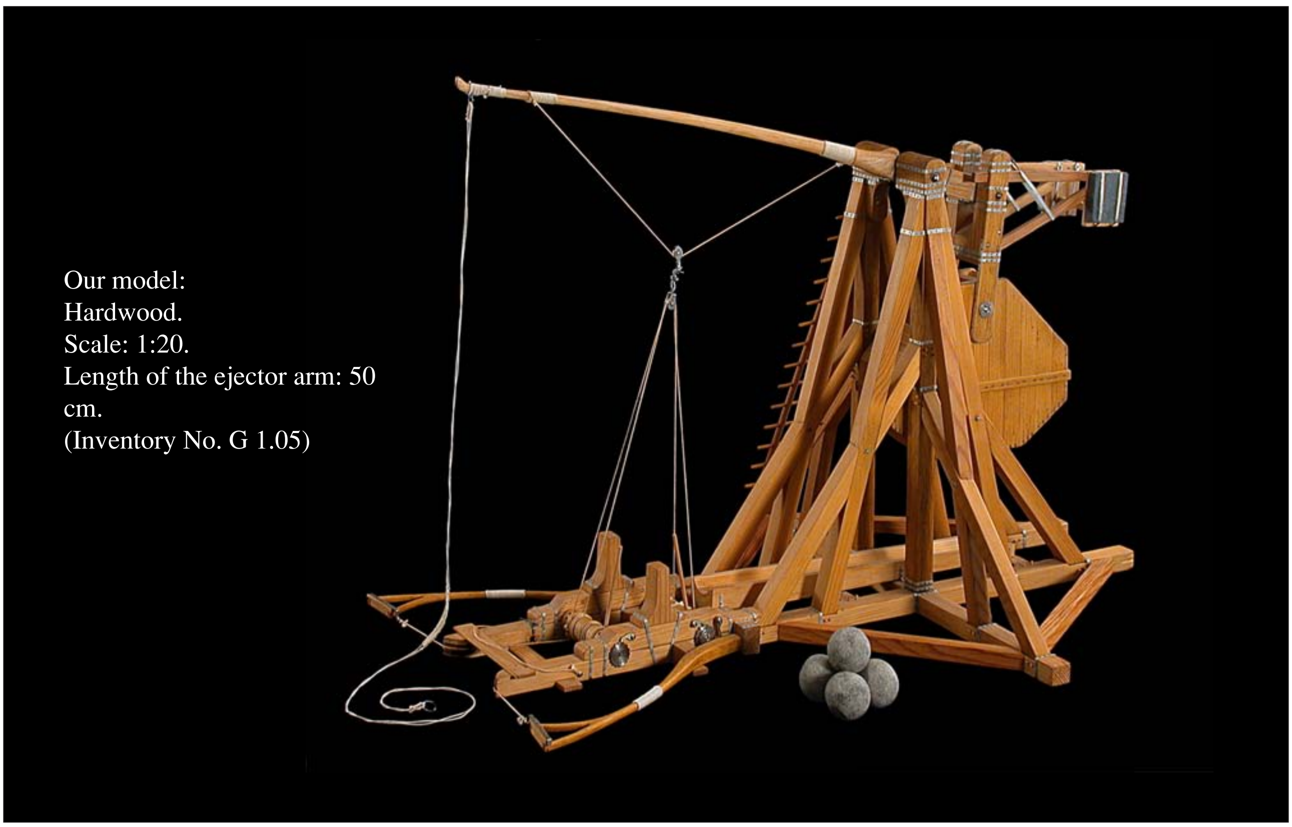
Large
triple Crossbow
(Ballista)

Among the various types of crossbows described by Marḍī aṭ-Ṭarsūsī (6th/12th c., see above, p. 94) in his book *Tabṣirat arbāb al-albāb*,[1] the most elaborate one consists of three large rampart crossbows (*qaus az-ziyār bi-l-laulab*) which could be installed one above the other and tautened with one single windlass and could therefore be operated by a single person alone.
Our model is simplified.

[1] MS Oxford, fol. 80 b; transl. by Cl. Cahen, op. cit., p. 131.

Arab Counterweight Trebuchets in Occidental tradition

The advanced form of the catapult, as compared to its predecessor (onager) known from Roman times, which was developed in the Arab-Islamic world, can be shown to have existed since the 6th/12th century on the basis of descriptions, illustrations and citations in sources; and it seems to have been known in the West at the latest in the first half of the 13th century (see above, p. 108). For comparison with the Arabic predecessors there are four models of occidental trebuchets in the Museum of the Institute for the History of Arab-Islamic Sciences; these were prepared by Werner Freudemann around 1990.



Our model:
Hardwood.
Scale: 1:20.
Length of the ejector arm: 50 cm.
(Inventory No. G 1.05)

1.

A trebuchet reconstructed according to the information given by Villard de Honnecourt (1st half of the 13th c., see above, p. 60). The often published reconstruction sketch by Eugène Emmanuel Viollet le Duc (1814-1879)[1] turned out to be unreliable. Our model was built by W. Freudemann according to improved technical data.

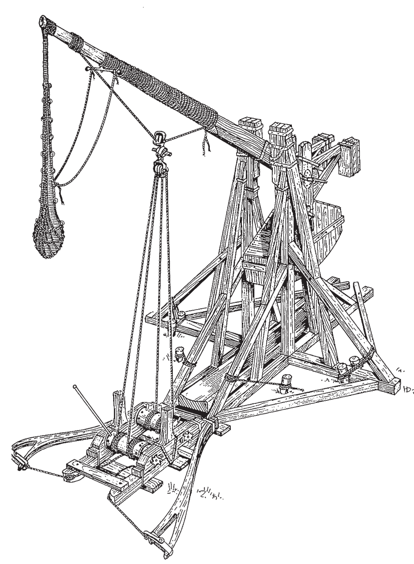
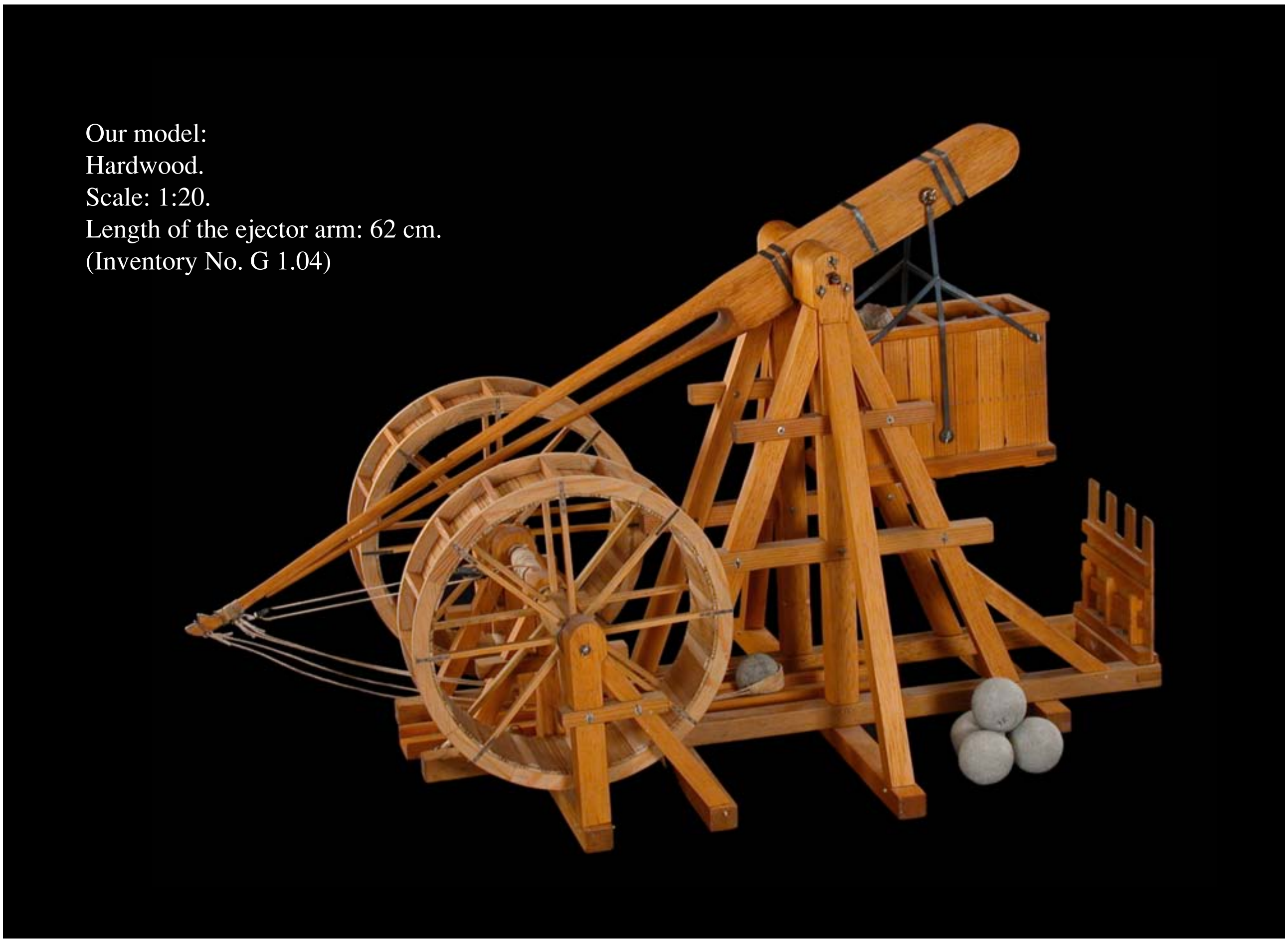


Illustration from:
R. A. Brown,
Castles. A History and Guide, Dorset 1980, p. 81.

[1] Reproduced, for example, in Rüstungen und Kriegsgerät im Mittelalter by Liliane and Fred Funcken, Gütersloh 1985, p. 54.



Our model:
Hardwood.
Scale: 1:20.
Length of the ejector arm: 62 cm.
(Inventory No. G 1.04)

2.

European trebuchet of ca. 1405, constructed on the basis of an illustration in Bellifortis[1] by Konrad Kyeser of Eichstätt (completed 1405). W. Freudemann improved the model as against the illustration, in order to make it functional.[2]

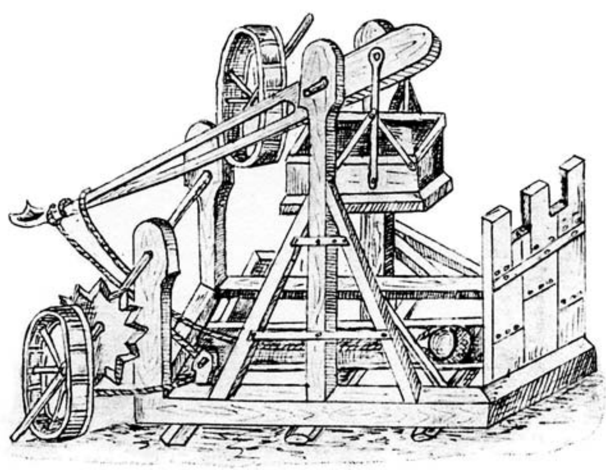
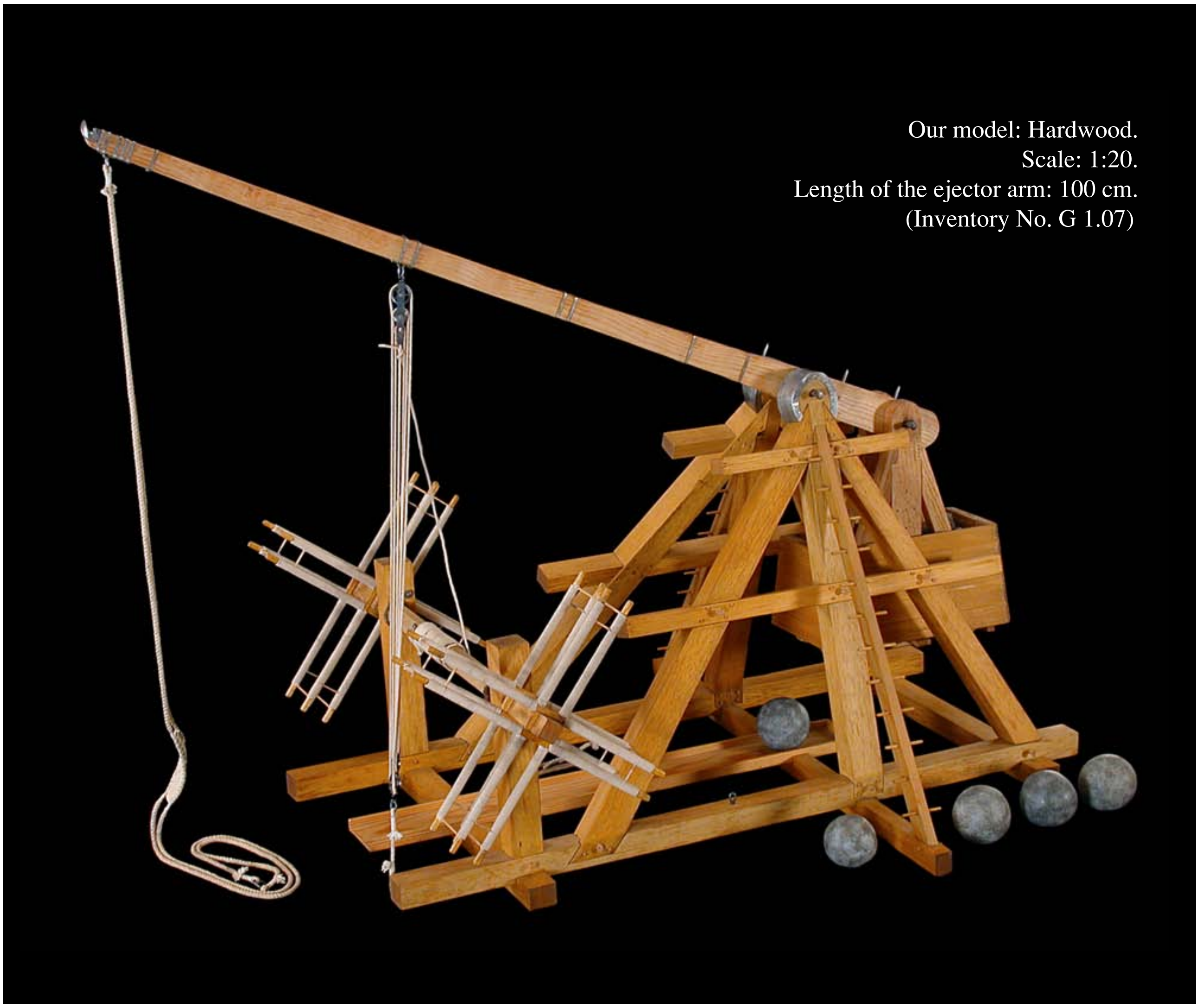


Illustration from: Kyeser, *Bellifortis* (Göttingen, Univ. Bibl., Cod. MS philos. 63, fol. 48a) after W. Gohlke, *Das Geschützwesen des Altertums und des Mittelalters*, in: Zeitschrift für Historische Waffenkunde V, 12 (Dresden 1909–1911) p. 385, illustr. 41.

[1] Ed. by Götz Quarg, Düsseldorf 1967 (see Hermann Heimpel, review in: Göttingische Gelehrte Anzeigen 223/1971/115-148); V. Schmidtchen, *Mittelalterliche Kriegsmaschinen*, Soest 1983, pp. 123, 192.

[2] Freudemann points out that a model built strictly according to the illustration could not work, because first «The connecting piece above the chute, which terminates at the left extremity of the guide beam would make the procedure of ejection impossible.» And secondly, «The catapult is much too long. The ropes of the catapult do not run freely under the windlass shaft». Furthermore, he added necessary details and «adjusted» the proportions, particularly those of the tread-wheels.



Our model: Hardwood.
Scale: 1:20.
Length of the ejector arm: 100 cm.
(Inventory No. G 1.07)

3.

One more European trebuchet of ca. 1405. It is also depicted and provided with measurements in Bellifortis (MS Göttingen, fol. 30) by Konrad Kyeser of Eichstätt and was reconstructed around 1990 by W. Freudemann. Moreover, it is of special interest here that the releasing mechanism is clearly discernable in the illustration and could be reconstructed exactly.

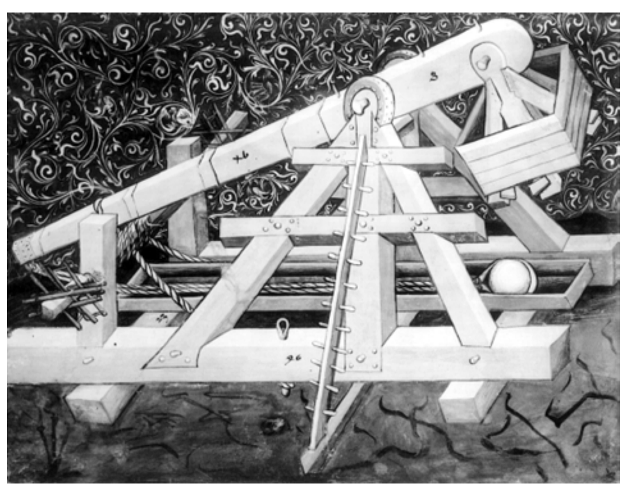


Illustration from:
Kyeser, *Bellifortis,* Göttingen, Univ. Bibl.,
Cod. MS philos. 63, fol. 30a.

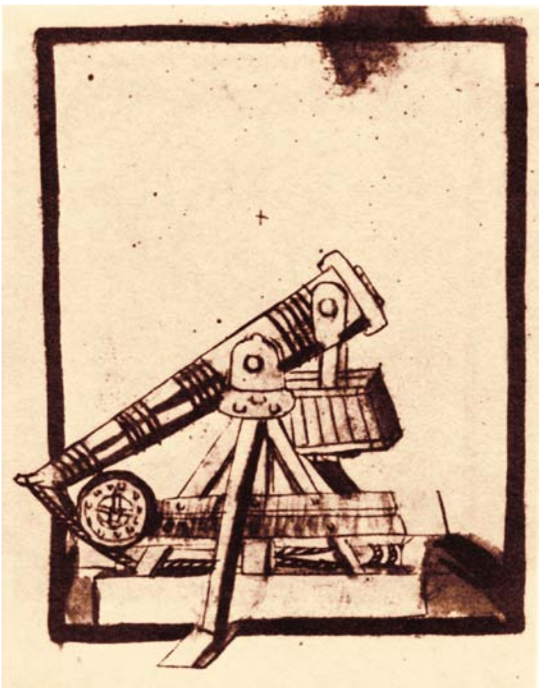


Illustration from MS Vienna, Cpv 3069, after Schmidtchen, *Mittelalterliche Kriegsmaschinen*, op. cit., p. 18

Our model: Hardwood. Scale: 1:20.
Length of the ejector arm: 100 cm.
(Inventory No. G 1.07)

4.

European trebuchet, constructed by W. Freudemann on the basis of the following models: Konrad Kyeser, Bellifortis (MS fol. 30 and 77) and one drawing each from Cod. germ. 600, Bayerische Staatsbibliothek, Munich (ca. 1390)[1] and manuscript Cpv 3069 in Vienna.[2]

Illustration from: Cod. germ. 600, Bayerische Staatsbibliothek Munich (ca 1390).

[1] Bernhard Rathgen, *Das Geschütz im Mittelalter*, Berlin 1928 (repr. Düsseldorf 1957), pp. 626–627, 719, fig. 2.

[2] V. Schmidtchen, op. cit., p. 189, fig. 58.

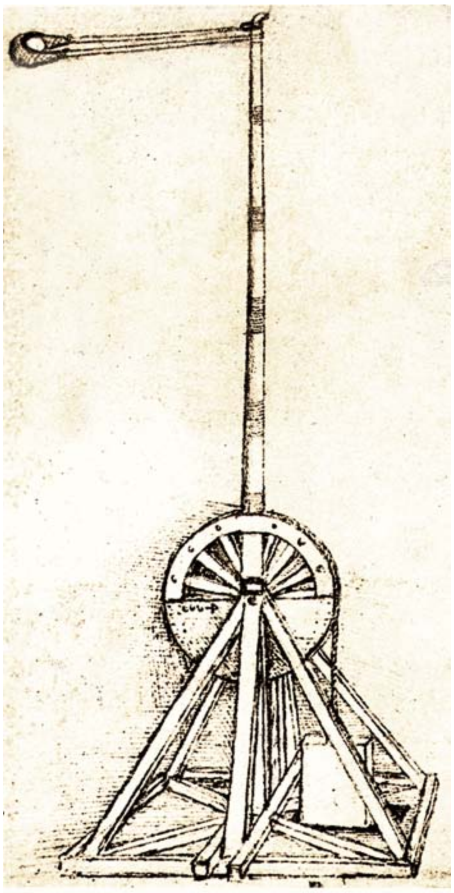
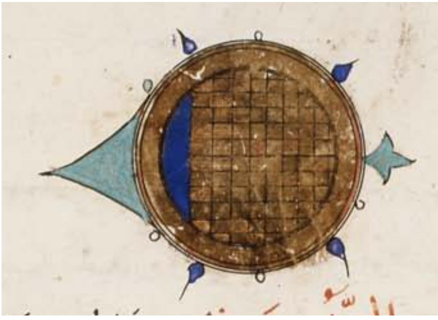


Illustration from: *Leonardo da Vinci*, p. 294.

Trebuchet
with distance regulator

Our model:
Wood, metal, yarn.
Height with vertical ejector arm: 1.17 metres.
(Inventory No. G 1.21)

The drawing of this trebuchet by Leonardo da Vinci has already been discussed above (p. 98). Our model is based on it. It may be recalled here that a distance regulator is used with this piece of artillery as we know it from Arab models at the latest since the 8th/14th century (see below, p. 134). Some progress can be seen here in that the distance regulator in the form of a wheel is attached to the trebuchet.



Illustr. extraites de: az-Zardkāš, *al-Anīq*,
MS Topkapı Sarayı, Ahmet III, 3469.

Our models:
Earthenware, slicker painting
a) ∅ 19 cm. (Inventory No. G 2.18).
b) ∅ 18.5 cm. (Inventory No. G 2.19).

Fire-pot
and ‹biological› grenade

A fire-pot (*qidr*) with rim, filled with a mixture containing saltpetre, was built primarily for the purpose of explosive effect. It has three small tubes (*ikrīẖ*) filled with a mixture of incendiary substances and is hurled after ignition from a trebuchet or by means of a lance.[1]

Model b) represents an early form of the ‹B-weapon›, a grenade filled with dangerous animals like scorpions or snakes, which is characterized by numerous small air holes.

[1] Reinaud and Favé, *Du feu grégeois*, op. cit., p. 44; illustrations section, plate II, fig. 23; S. J. von Romocki, *Geschichte der Explosivstoffe*. I. *Geschichte der Sprengstoffchemie, der Sprengtechnik und des Torpedowesens bis zum Beginn der neuesten Zeit*, Berlin 1895, pp. 71–72.

Illustration from: az-Zardkāš, *al-Anīq*, MS Topkapı Sarayı, Ahmet III, 3469.

Illustration of *qawārīr* (sing. *qārūra*, ‹pot›): *al-karrāz al-ʿirāqī* (‹Iraki pot›) and *al-karrāz aš-šāmī* (‹Syrian pot›) from Ḥasan ar-Rammāḥ, *K. al-Furūsīya,* MS Paris, Bibl. nat., ar. 2825, fol. 88.

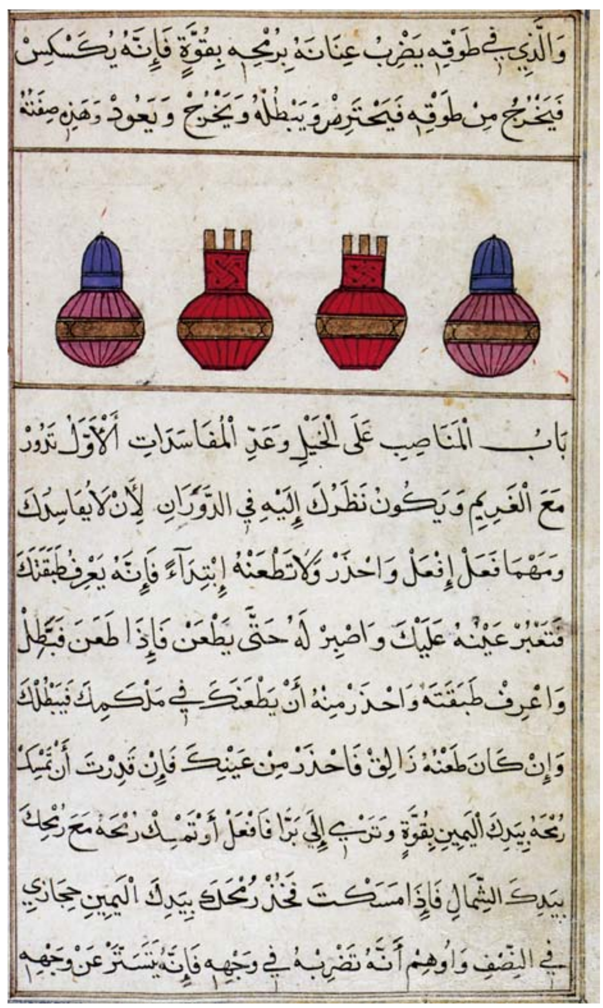
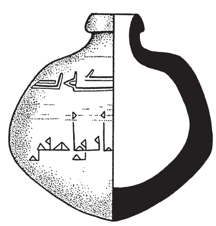
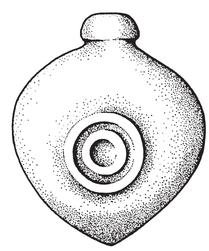
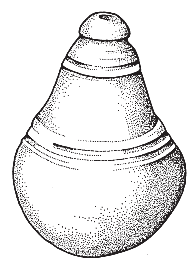


Illustration from:
al-Maḫzūn fī ǧāmiʿ al-funūn,
MS Leningrad, C686, fol. 146.

Our models:
Earthenware, brown engobe, wick.
Height 17-19.5 cm.
(Inventory No. G 2.03-06)

Grenades

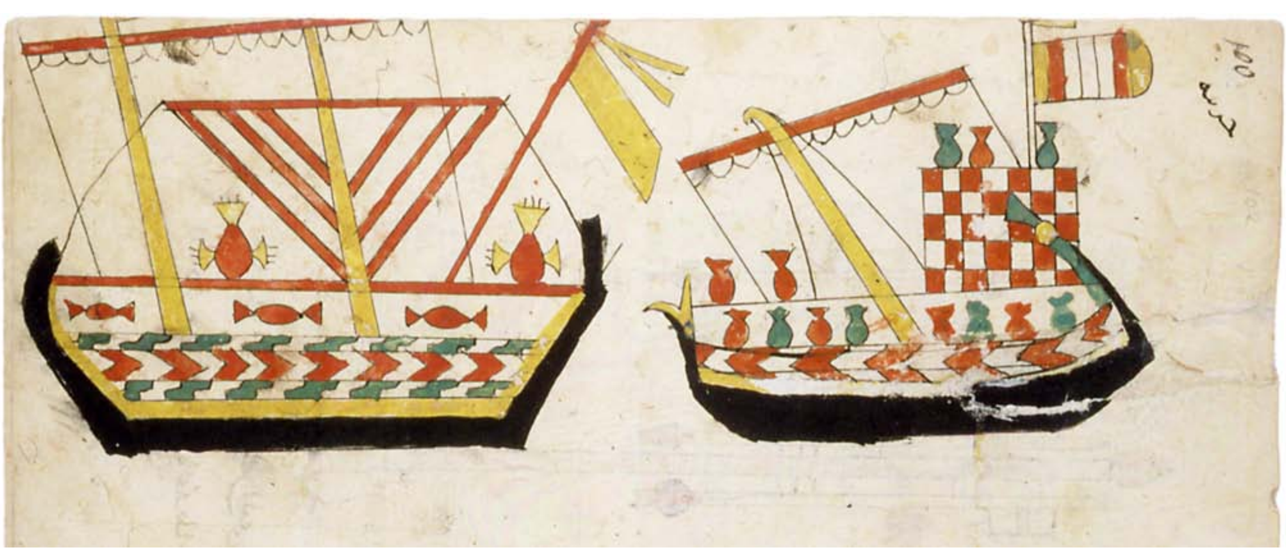




All illustrations from the *Khalili Collection*, op. cit., vol. 12.2, pp. 324, 334 ff.



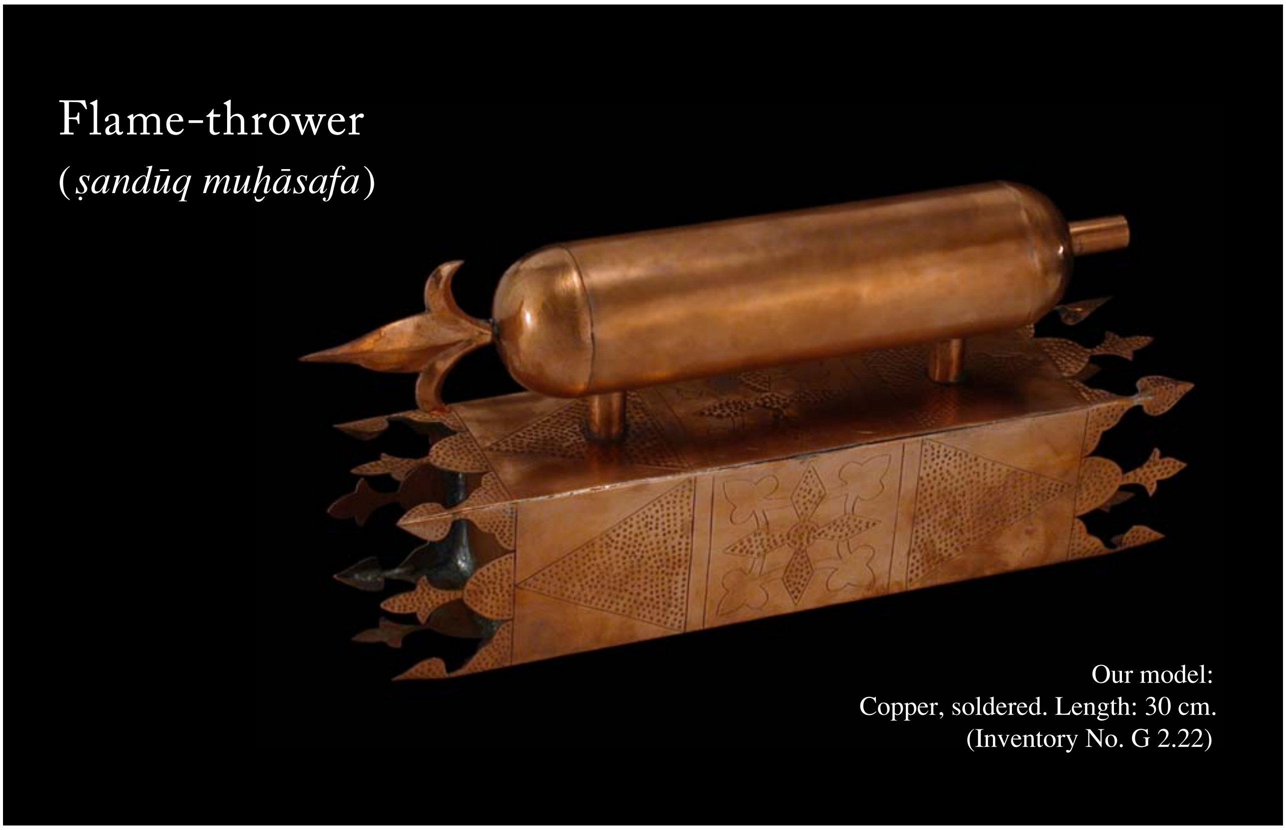
Our models:
Earthenware, brown engobe, fuse.
Height: 10-16 cm.
(Inventory No. G 2.11 -17)

Illustration of warships with incendiary and/or blasting mixture,
from Ḥasan ar-Rammāḥ, *K. al-Furūsīya*,
MS Paris, Bibl. Nat., ar. 2825, fol. 100.



Flame-thrower

(*ṣandūq muḫāsafa*)



Our model:
Copper, soldered. Length: 30 cm.
(Inventory No. G 2.22)

In the Kitāb *al-Anīq fi l-manāğnīq* by Ibn Aranbuġā az-Zaradkāš[1] (774/1373) a flame-thrower (*ṣandūq [al-]muḫāsafa)* is described which was used in close combat and which could produce a flame the length of a lance. It consists of a longish reservoir of metal for paraffin which is connected through two tubes with a cylindrical nozzle. From this the incendiary material is sprayed with a pump while it is lit by a small igniter.

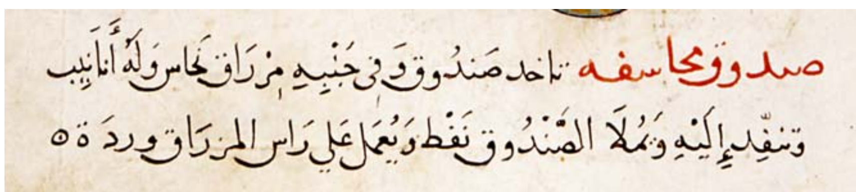
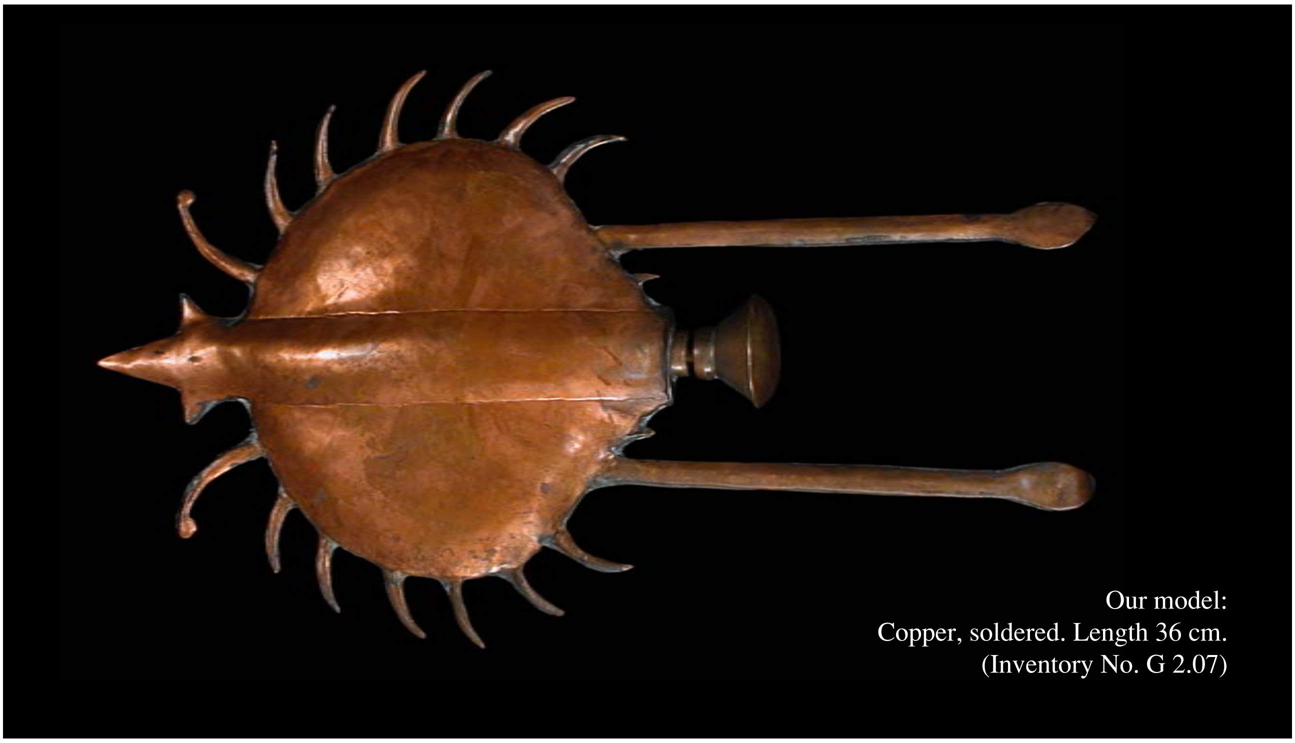


Illustration from az-Zardkāš, *K. al-Anīq*,
MS Topkapı Sarayı, Ahmet III, 3469, p. 99.

[1] MS op. cit., p. 98–99; A.Y. Hassan, D.R. Hill, *Islamic Technology*, op. cit., p. 108.



Our model:
Copper, soldered. Length 36 cm.
(Inventory No. G 2.07)

aṭ-ṭaiyār al-mağnūn

(Torpedo or rocket)

Illustration from
Ḥasan ar-Rammāḥ,
K. al-Furūsīya,
MS Paris, Bibl. nat.,
ar. 2825, fol. 101 b.

In the course of his discussion of rockets and projectiles which function with rocket propulsion elements of saltpetre, sulphur and coal, Nağmaddīn Ḥasan ar-Rammāḥ,[1] the famous tournament master of the Mameluk period (d. 694/1295), describes «a device which he calls ‹moving and burning egg›. It is also depicted in the copy illustrated. The text and the illustration (see ill.), particularly when combined with Occidental data which will be provided later, leave no doubt that this is a self-moving torpedo which, though primitive, is fully developed in all the essentials.»
«Two concave sheets of iron… are joined together and made tight with felt so that they form a flattened pear-shaped hollow body (…) which is loaded with ‹naphthalene, metal filings and good mixtures … by the latter phrase Hassan always refers to mixtures having a high content of saltpetreȘand is

[1] *Kitāb al-Furūsīya wa-l-manāṣib al-ḥarbīya*, MS Paris, Bibl. Nat., ar. 2825, fol. 101b; Reinaud and Favé, *Du feu grégeois*, op. cit., p. 45, illustrations section, plate II, fig. 32.

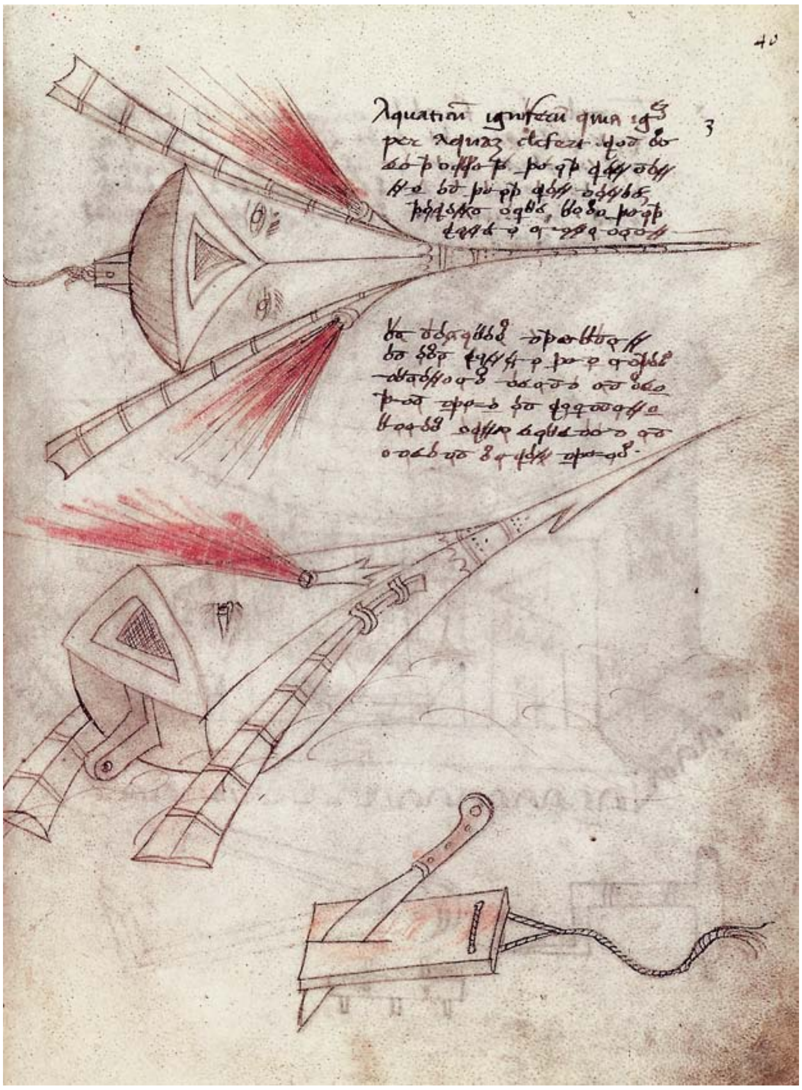


Illustration from Fontana, *Le macchine cifrate*, p. 126.

provided with two rods (…) and a large rocket (…). In his text Hassan does not say in which element [126] ‹the moving and burning egg› is supposed to move; but one glance at the illustration should suffice to show the device could have been destined neither for flying, as Reinaud and Favé hoped, nor for sliding forward, not even on the most favourable terrain …»[2]

In this connection, it is intriguing to note that a fairly simple description of a rocket-torpedo is to be found in Bellifortis by Konrad Kyeser (1405).[3] Even more remarkable seems to be the fact that torpedoes with rockets appear in *Bellicorum instrumentorum liber* by Giovanni Fontana (1st half of the 15th c.).[4]

Towards the end of the 19th century S. J. von Romocki[5] expressed the view that Fontana followed Ḥasan ar-Rammāḥ in this matter. In our view, it need not necessarily have been Ḥasan ar-Rammāḥ's book which formed Fontana's source. His book is merely the closest work on the subject known to us at this time which we can use for comparison. There cannot be any doubt about the fact that in the Arab-Islamic world numerous treatises were written on warfare and weaponry, some of which reached Europe, particularly during the Crusades. Moreover, the influence of Arab-Islamic culture on Fontana and other European scholars in respect of weaponry and other technological achievements did not come about by books alone.

The Crusades undoubtedly played an important role in this connection.

Cf. also Reinaud and Favé, Du feu grégeois, op. cit., pp. 311-313.

[2] S. J. von Romocki, *Geschichte der Sprengstoffchemie*, op. cit., pp. 70–71; A.Y. al–Hassan and D. R. Hill, *Islamic Technology*, op. cit., p. 118; J. R. Partington, *A History of Greek Fire and Gunpowder*, op. cit., p. 203.

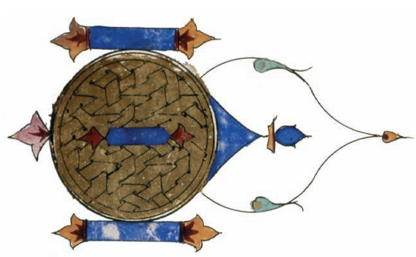
[3] Cf. Romocki, op. cit., p. 153, where the author, instead of thinking of a dependence on the Arab–Islamic world, concludes: «Here we have the prototype of the rocket–torpedo which is already improved by Hassan Alrammah. But here also the description obviously rests on an actual experiment and not merely on a plan; because theoretically the author could hardly have found that a much shorter rod was sufficient to keep a rocket in a straight direction on water than to achieve the same result in air.»

[4] E. Battisti and G. Saccaro Battisti, *Le macchine cifrate di Giovanni Fontana*, Milan 1984, p. 126.

[5] Romocki, *Geschichte der Sprengstoffchemie*, op. cit., p. 230, 236, 240.

2 illustrations from: az-Zardkāš, *al-Anīq*, MS Topkapı Sarayı, Ahmet III, 3469.

Our model:
Copper, soldered.
Length: 55 cm.
(Inventory No. G 1.12)



Grenades

with chemical war materials

In the Kitāb *al-Anīq fi l-manāǧnīq*[1] (8th/14th c.) the content of a «pot» (*qidr*) is described, which is put together from various substances, among them opium and arsenic; here «pot» is used in the sense of a bomb or grenade, and the substances are said to have a suffocating effect on the adversary. The bomb was called *al-qidr al-muntin li-l-muḫāsafa*.[2] It was probably hurled from trebuchets, shot with a crossbow or thrown by hand, as the occasion demanded.[3]

[1] Ed. Aleppo, op. cit., p. 174.

[2] in the manuscript *qidr muntin al-muḫāsafa*.

[3] Ḥasan ar-Rammāḥ's book also contains «instructions for the manufacture of poisonous and soporific vapours, the effective contents of which are arsenic and opium» (v. Ḥasan ar-Rammāḥ, *al-Furʿsīya wa-l-manāṣib al-ḥarbīya*, op. cit., pp. 141, 156, 161, 162, 163; Romocki, *Geschichte der Sprengstoffchemie*, op. cit., p. 74).

Both our models:
Copper, soldered.
Length: 67 cm.
(Inventory No. G 1.13)

Ottoman
Rockets

The Ottoman engineer Lāgarī Ḥasan Çelebī, under Sultan Murād IV (ruled 1032/1623-1049/1640, was certainly following the Arab-Islamic tradition when he built a rocket with seven small side-fins. The fuel of the rocket is said to have consisted of ca. 50 okkas (ca. 60 kg) of gunpowder. As reported by the contemporary Turkish historian Evliyā Çelebī,[1] Ḥasan Çelebī is said to have demonstrated to the Sultan that he could fly across the Bosporus with his rocket and that he could land with the help of additional wings. What is interesting in this connection is the fact that Ogier Ghislain de Busbecq, who was the Habsburg envoy in Istanbul between 1555 and 1562, reports about attempts at flying under Sultan Süleymān (‹the Magnificent›, ruled 926/1520-974/1566), as John Wilkins (1638) informs us.[2]

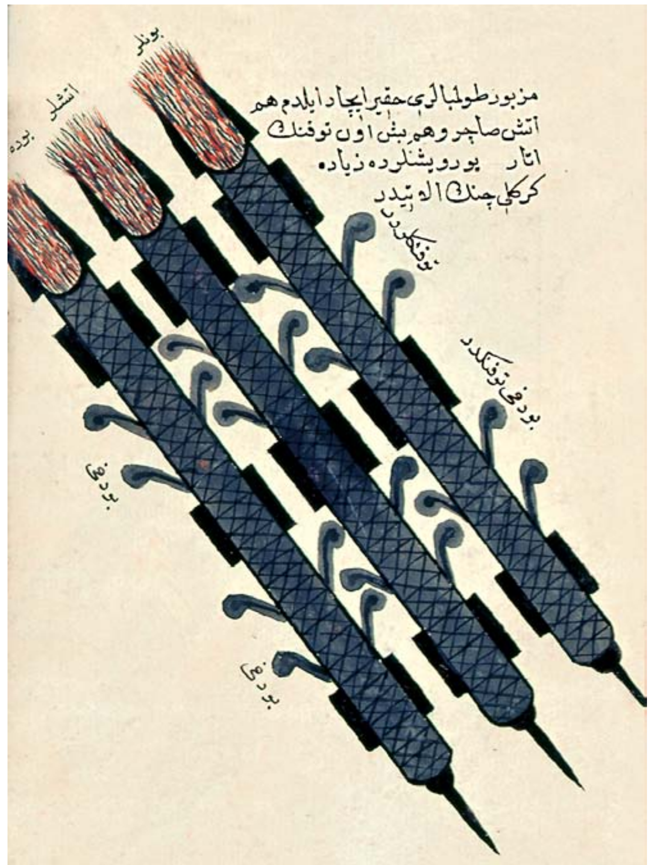
Detailed information about Ottoman rockets with interesting illustrations is given in his book *Umm al-ġazā*[3] by the engineer ʿAlī Āġā, who was active under Sultan Aḥmed III (ruled 1115/1703-1143/1730). The length of the rockets built by ʿAlī Āġā is said to have been 7-8 metres. About their circumference he says that a man could hardly encircle them with his arms.

Since this book was hardly known before now, it seemed appropriate to add a few more illustrations which are of interest for military history and the history of technology.

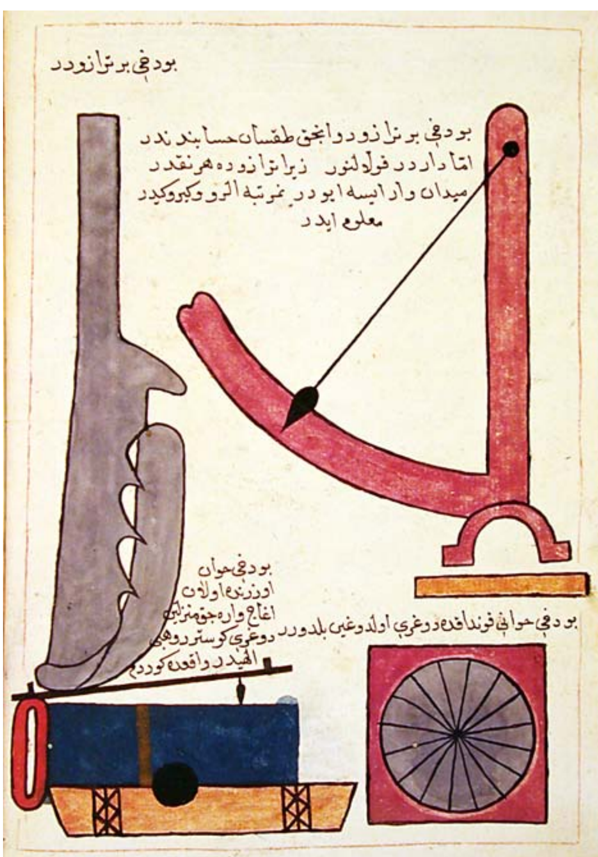
[1] *Seyâhatnâme*, Istanbul 1969, vol. 2, pp. 335-336; Arslan Terzioğlu, *Türk-islâm kültür çevresinde IX. yy'dan XVIII. yy*. sonuna kadar uçma denemeleri ve tekniğe ait elyazma eserler, in: İlim ve sanat (Istanbul) 8/1986/54-63, esp. 61-62; idem, *Handschriften aus dem Gebiet der Technik und Aerodynamik sowie der ersten Flugversuche im IX.-XVII. Jhd. im islamisch-türkischen Kulturbereich*, in: Istorija aviacionnoj, raketnoj i kosmiceskoj nauki i techniki, Moscow 1974, pp. 246-256, esp. pp. 253-255; Mustafa Kaçar in: İslâm Ansiklopedisi (Istanbul: Türkiye Diyanet Vakfı), vol. 16, 1997, pp. 315-316.

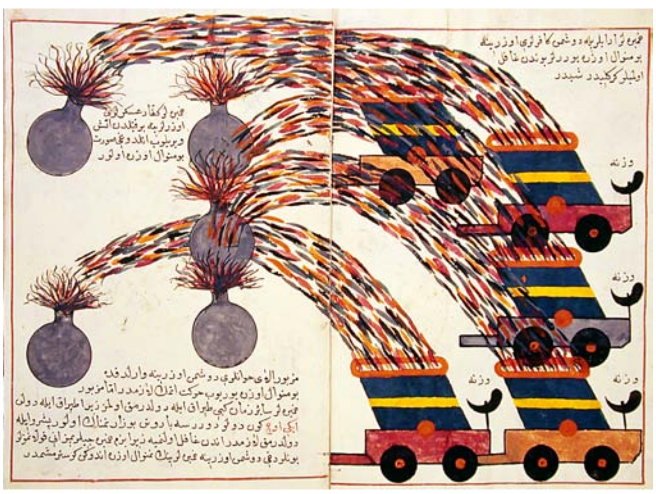
[2] John Wilkins, *Discovery of a New World*, London 1638 (not seen, v. H. K. Cook, *The Birth of Flight*, London 1941, p. 29, v. A. Terzioğlu, op. cit.).

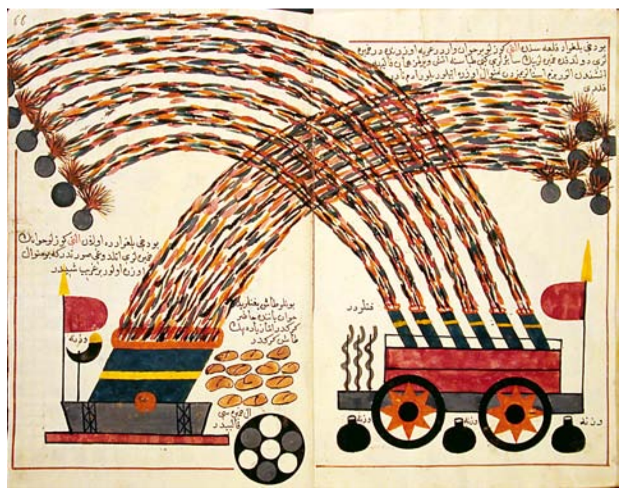
[3] Manuscript İstanbul, Topkapı Sarayı, Bağdat Köşkü nº 368.

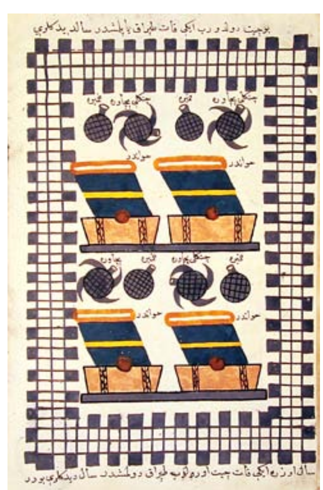


Illustrations from: ʿAlī Āġā, *Umm al-ġazā*, MS Topkapı Sarayı, Bağdat Köşkü nº 368.



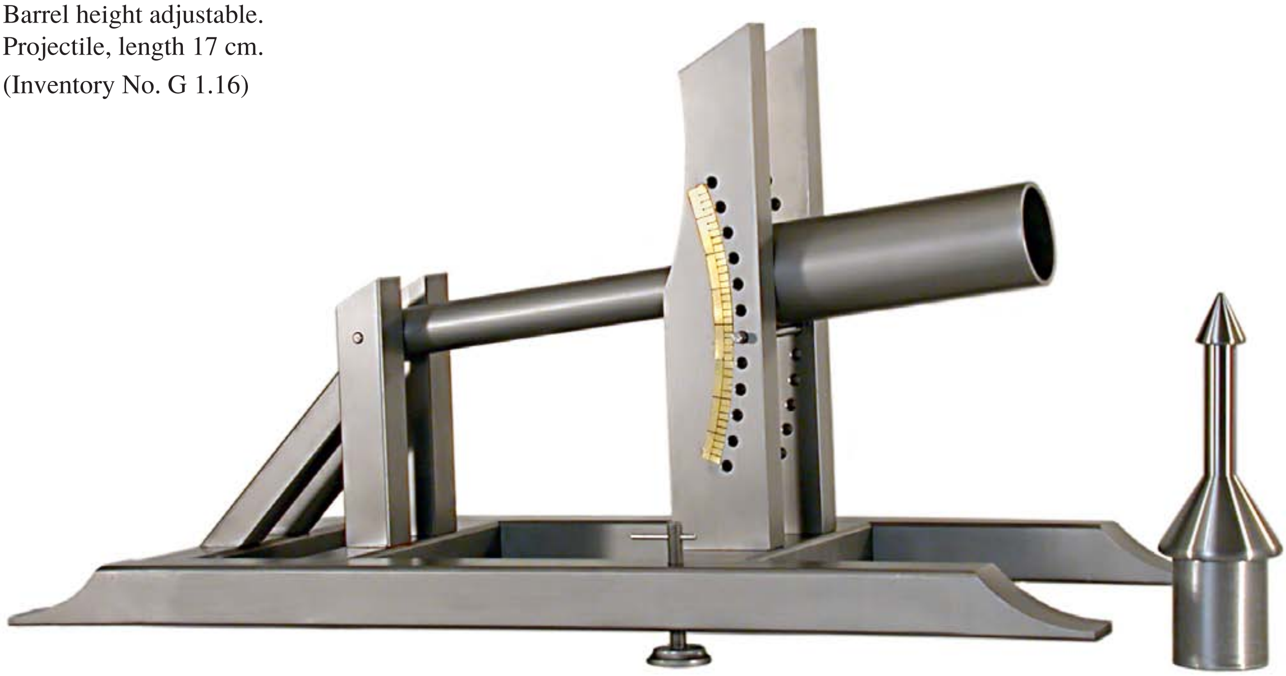






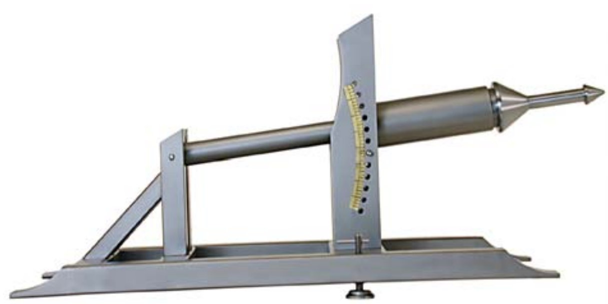
Illustrations from: ʿAlī Āġā, *Umm al-ġazā*, MS Topkapı Sarayı, Bağdat Köşkü nº 368.

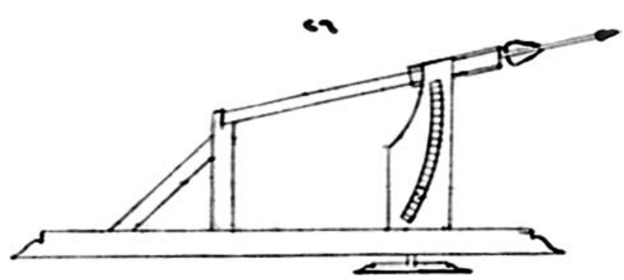
Our model:
Stainless steel, height: 30 cm.
Barrel height adjustable.
Projectile, length 17 cm.
(Inventory No. G 1.16)



Cannon

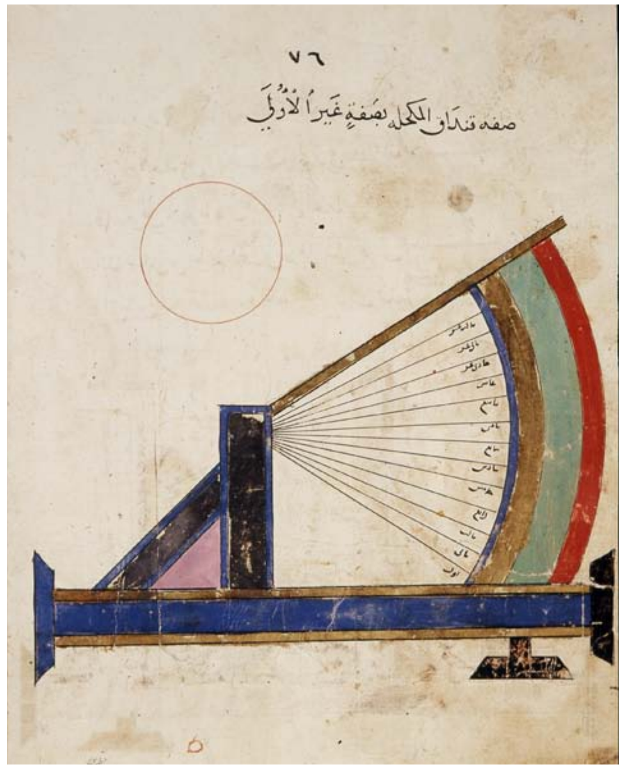
In the book *al-Anīq fī l-manāǧnīq* (8th/14th c.) a cannon with its components is depicted. It belongs to a stage of development which we can follow in the Arab-Islamic world up to the second half of the 7th/13th century (see above, p. 100). The cannon was called *midfaʿ* or *mikḥala*. The book *al-Anīq* shows three types which differ from one another in the graduations in their scales of distance. The scale of the first type has a division into eleven (illustration a), that of the second a division into fourteen (illustration b) and that of the third a division into ten, which is once again sub-divided (illustration c). The graduated mechanism for taking aim is called *qundāq*, a Turkish word which is still used today in the sense of the firing mechanism of firearms. In the brief description it is pointed out that the firing range increases in ascending order.



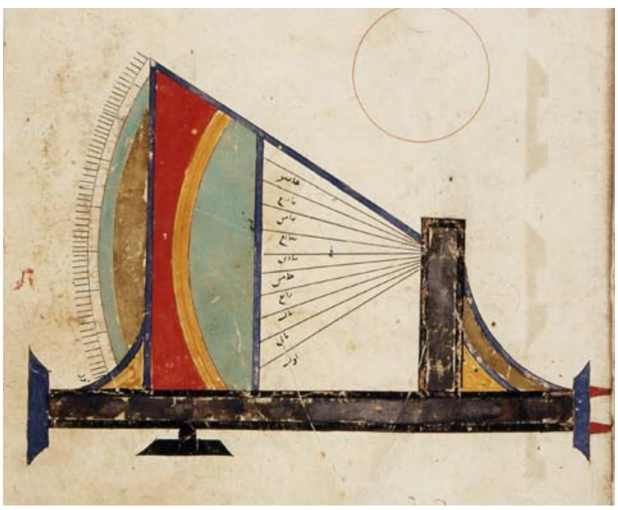


One more view of our model when loaded
and a sketch from the *al-Anīq*.

(Illustration a)



(Illustration b)



(Illustration c)

One more illustration from al-Anīq with a clear demarcation of the rifle.

Illustrations from: az-Zardkāš, *al-Anīq*, MS İstanbul, Topkapı Sarayı, Ahmet III, 3469.

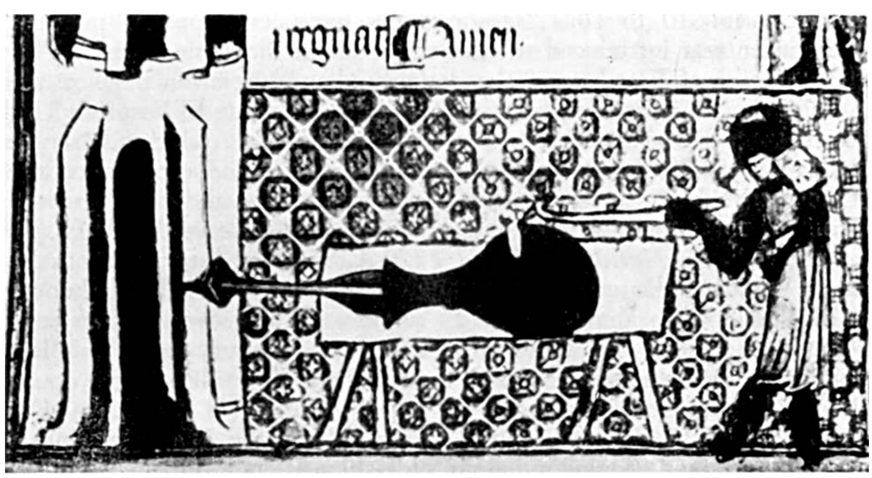
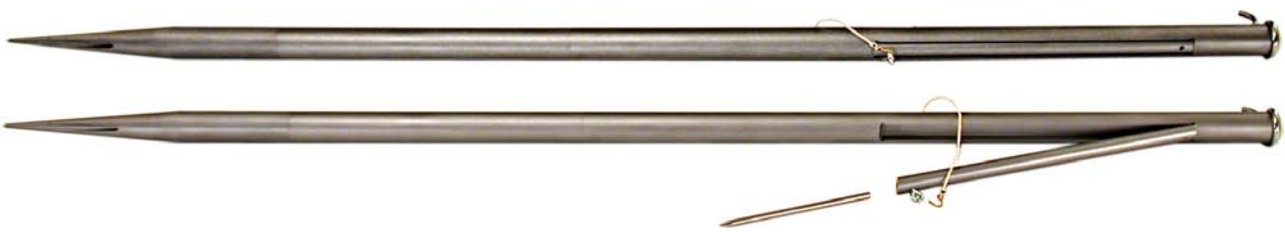


Illustration of an early European cannon with an arrow-like projectile, from: Walter of Milimete, *De nobilitatibus sapientiis et prudenciis regum*, ca. 1326; MS Oxford,



Hand firearm

Our model:
Steel, length: 81 cm.
(Inventory No. G 2.21)

The oldest description of a hand firearm known to us at present is to be found in the above-mentioned (p. 100) Petersburg manuscript. The French translation by Reinaud and Favé of 1849 was, unfortunately, not taken note of in an appropriate manner by the historiography of the technology of weapons. As far as I can see, O. Baarmann is a notable exception in this regard: «The oldest oriental weapons which operated with the chemical mixture of fireworks, namely the fire lance and the madfaa, can be called the precursors of the firearms which spread more and more in Europe in the second quarter of the 14th century; these were pieces of equipment of the simplest kind which were provided with handles for easy handling. For many decades this method of making firearms suitable for handling remained the only kind and still survived for a very long time next to the others which were just developing. Illustration 1 (after the Arabic manuscript from the beginning of the 14th century in the Asiatic Museum in Petersburg,) shows the handling of the last-mentioned short, wooden, mortar-like weapon.» However, Baarmann regards the illustration erroneously as a mortar-like hand firearm, whereas the illustration in the manuscript refers to a cannon; Baarmann was probably influenced by the poor drawing and he does not elaborate the details of the «fire lance» described there. Here it is a case of a combined hand firearm. In the farther end of a lance sufficient space is hollowed out so that a charge of gunpowder can be placed there. The projectile has the form of an arrow or a bolt. The lance is hollowed out from ca. 10 cm from its farther end up to the tip. This and other details of the text made it possible for us to reconstruct the model above.

Illustration from: *al-Maḫzūn fī ǧāmiʿ al-funūn,* MS Leningrad C686, fol. 156.

The illustration of a «fire barrel» preserved from the 15th century, which was in the possession of Robert Forrer in Germany at the beginning of the previous century is reminiscent of this oldest hand firearm from the Arab-Islamic world.[2]

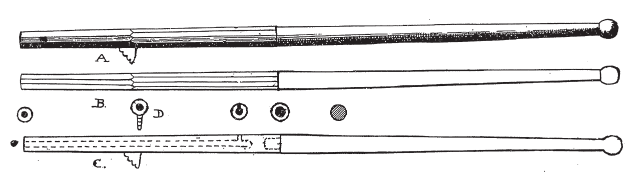


Illustration from Forrer, p. 26.

[1] *Die Entwicklung der Geschützlafette bis zum Beginn des 16. Jahrhunderts und ihre Beziehungen zu der des Gewehrschaftes*, dans: *Beiträge zur Geschichte der Handfeuerwaffen*. Festschrift zum achtzigsten Geburtstag von Moritz Thierbach, Dresden 1905, pp. 54–86, esp. p. 55.

[2] *Meine gotischen Handfeuerrohre*, dans: *Beiträge zur Geschichte der Handfeuerwaffen*. Festschrift zum achtzigsten Geburtstag von Moritz Thierbach, Dresden 1905, pp. 23–31. Cf. also Reinaud and Favé, *Du feu grégeois*, pp. 311–313.

ballistic Gauge

Our model:
Wood, stained and
Brass, etched.
Length: 40 cm.
(Inventory No. G 1.14)

The book *al-Anīq fi l-manāǧnīq*[1] (8th/14th c.) contains the earliest known illustration of a ballistic gauge. Such a device, which was called *mīzān al-qarīb wa-l-ba'id*, was used for the adjustment while taking aim with counterweight trebuchets.

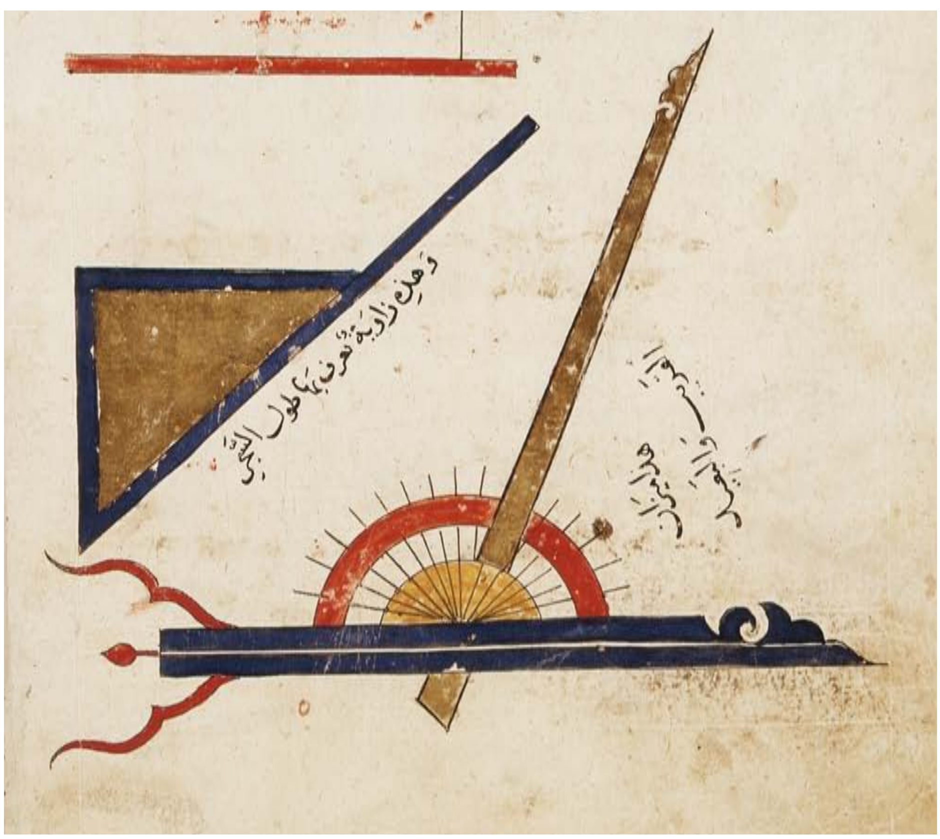


Illustration from:
az-Zardkāš,
al-Anīq fi l-manāǧnīq,
MS Topkapı Sarayı,
Ahmet III, 3469.

[1] Ed. Aleppo, op. cit., p. 48–49.

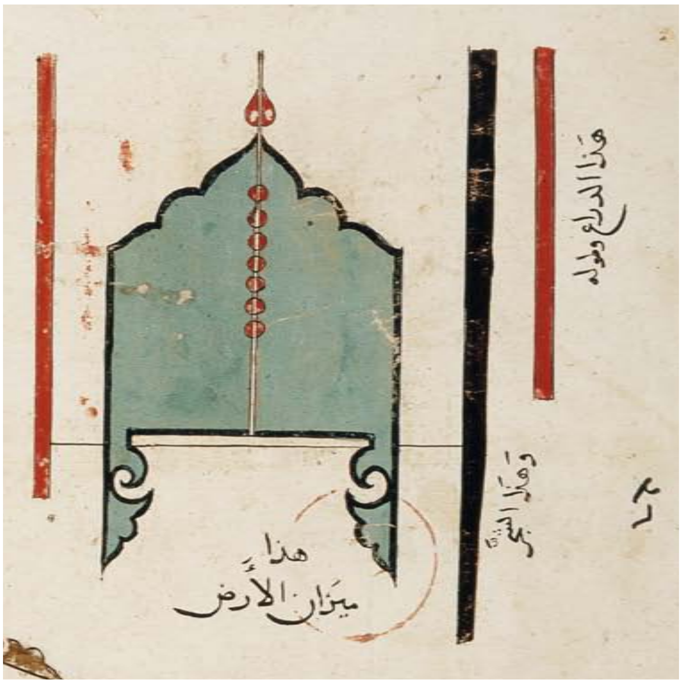


Illustration from:
az-Zardkāš, *al-Anīq*,
MS Topkapı Sarayı,
Ahmed III, 3469.

Ballistic Instrument for levelling

After the counterweight trebuchets of large dimensions had reached a high level of development in the Arab-Islamic world, a special instrument for levelling the ground was used when installing the catapults. The instrument for levelling was called *mīzān al-arḍ*[1].

Our model:
Brass, polished.
Height: 32 cm.
(Inventory No. G 1.15)

[1] az-Zardkāš, *al-Anīq fī l-manāǧnīq*, ed. Aleppo, op. cit., pp. 48–49.

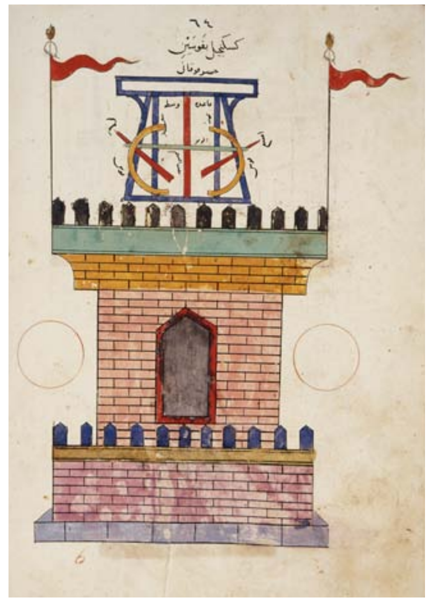
Fortification Towers

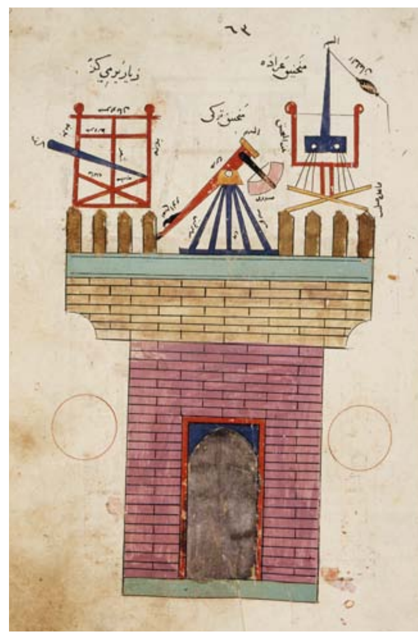
In the *Kitāb al-Anīq fi l-manāǧnīq*[1] *of* the 8th/14th century there are several illustrations of fortification towers and fortresses. One of these is shown in our model.

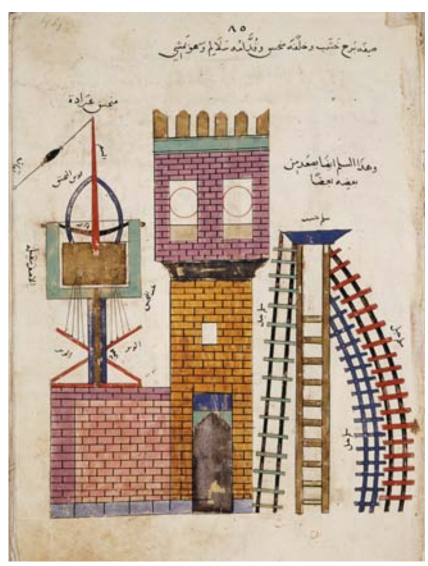
[1] Ed. Aleppo, op. cit., pp. 107–118.

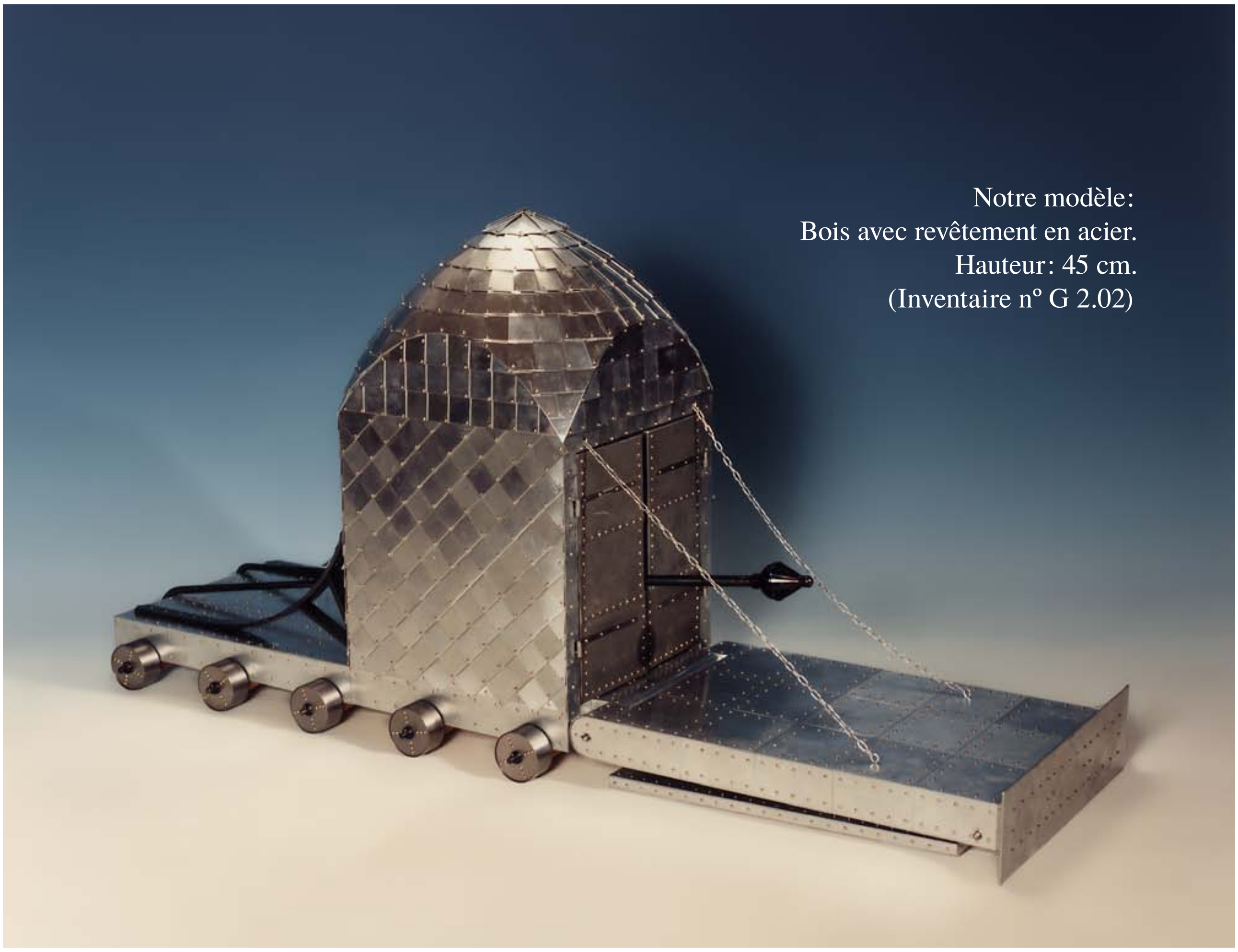
Our model:
Wood, lacquered.
75 × 75 × 75 cm.
(Inventory No. G 2.01)

On the right:
3 illustr. from: az-Zardkāš, *al-Anīq*, MS Topkapı Sarayı, Ahmet III, 3469.
Below: 2 illustr. from: Ḥasan ar-Rammāḥ, *K. al-Furūsīya,* MS Paris, Bibl. nat. ar. 2825.









Notre modèle:
Bois avec revêtement en acier.
Hauteur: 45 cm.
(Inventaire nº G 2.02)

zaḥḥāfa
(Armoured vehicle
with a battering ram)

A report from the early 4th/10th century gives a good insight into military technology, from which it emerges that the Abbasid army used big gun towers in the conquest of the city of Amorium[1] in 213/837. These gun towers consisted of movable trebuchets (*manǧanīq*) on wheeled gun carriages (*karāsī taḥtahā ʿaǧal*)[2] and were called *dabbāba*.[3]

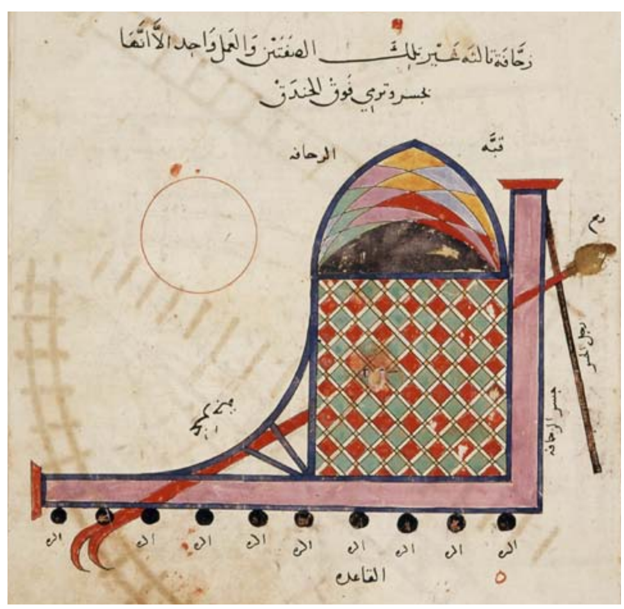


Fig. extraite de: az-Zardkāš, *al-Anīq*, MS Topkapı Sarayı, Ahmet III, 3469.

[1] Today Asar Kale, a place in ruins, south-west of Ankara, v. M. Canard in: Encyclopaedia of Islam, New Edition, vol. 1, 1960, p. 499.
[2] aṭ-Ṭabarī, *Taʾrīḫ*, ed. de Goeje, 3rd series, vol. 2, p. 1248; K. Huuri, *Zur Geschichte des mittelalterlichen Geschützwesens*, op. cit., p. 152.
[3] K. Huuri, op. cit., p. 152.

In this connection it should be noted that a moveable battering ram is depicted in a relief which can be dated as far back as 880-865 BC from Nimrud near Nineveh.[4]

The question of the various stages of development of this piece of war machinery in the Islamic world has not yet been examined. A fairly advanced form of battering ram, called *zaḥḥāfa*, is to be found in the *al-Anīq fi l-manāǧnīq*[5] from the 8th/14th century. It was used for breaking open the gates and walls of fortresses. The battering ram consisted of a covered internal space which was almost always protected against projectiles and incendiary mixtures; inside the space there was an operating team which pushed an enormous iron ram in continuous rhythm against the gate or the wall until it broke down. The extant illustration makes it clear that the battering ram was completely armoured. It contained a foldable bridge which was fastened with hinges in the front at the bottom plate; like a bridge for crossing moats, this too could be let down by means of iron chains.

A great similarity with this type of battering ram can be seen in the two following illustrations from the manuscript in the Bayerische Staatsbibliothek, Munich, cod. germ. 734:[6]

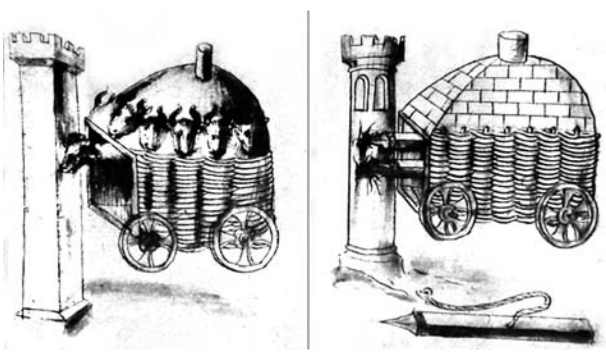


Illustration from V. Schmidtchen, *Mittelalterliche Kriegsmaschinen*, op. cit., p. 152, Ill. 21.

Illustration from J. Würschmidt, *Kriegsinstrumente*, p. 260.

It is remarkable that Giovanni Fontana (1st half of the 15th c.) depicts a moveable battering ram at the beginning of his *Bellicorum instrumentorum liber*.[7] He provides the following caption to the illustration: «War machinery which is called alphasat in Arabic.» I presume that the expression alphasat originated from a distortion of the Arabic term *az-zaḥḥāfa*.

Illustration from Fontana, *Le macchine cifrate*, p. 101.

[4] v. Franz M. Feldhaus, *Die Technik. Ein Lexikon* ..., op. cit., p. 1318; J. Würschmidt, *Kriegsinstrumente im Altertum und Mittelalter*, in: Monatshefte für den naturwissenschaftlichen Unterricht aller Schulgattungen (Leipzig and Berlin), 8/1915/256-265, esp. p. 260.

[5] ed. Aleppo, op. cit., p. 122.

[6] V. Schmidtchen, *Mittelalterliche Kriegsmaschinen*, op. cit., p. 152, illustration 21.

[7] v. Eugenio Battisti and Guiseppa Saccaro Battisti, *Le macchine cifrate di Giovanni Fontana*, op. cit., p. 101.

Chapter 13

Ancient Artefacts

(Metal, Glass, Ceramics, Wood and Stone)

Cosmetic Utensils

Late Antiquity/Byzantine?
Site where found: Anatolia

Bronze, bone.

(Inventory Nos. J 239–58)

Set of Medical Instruments

Umayyad – early Abbasid (2nd–3rd / 8th–9th c.)

Eight brass artefacts:

1. Curved tweezers
length: 7.4 cm
(Inventory No. J 39–4)

2. Tweezers
length: 8 cm
(Inventory No. J 39–5)

3. Tweezers
length: 7.7 cm
(Inventory No. J 39–6)

4. Tweezers
length: 8 cm
(Inventory No. J 39–7)

5. Tweezers with a hook?
Length: 6 cm
(Inventory No. J 39–8)

6. Scissors
length: 12.4 cm
(Inventory No. J 39–1)

7. V-shaped instrument with two holes
length: 10.6 cm
(Inventory No. J 39–2)

8. Needle
length: 10 cm
(Inventory No. J 39–3)

6 Zweezers/tongs

5th–6th / 11th–12th c.
Nīšāpūr

Bronze
Length: 12.5–21.4 cm.
(Inventory Nos. J 22–27)

Cf. *Khalili Collection*, vol. 12,
No. 364, p. 398.

Spatula

Early Islamic
Northern Anatolia

Bronze, length: 27.6 cm.
(Inventory No. J 64)

Fork

Sassanid or Umayyad
(1st–2nd/7th–8th c.)
Northern Iran (Ṭabaristān)

Bronze, length: 28 cm.
(Inventory No J 61)

Ladle and hook

Abbasid
(2nd–3rd / 8th–9th c.)
Syria

Bronze, length: 53 cm,
with hinge.
(Inventory No. J 63)

1.
Silver.
Length: 20,3 cm.
(Inventory No. J 37)

2.
Copper.
Length: 17,6 cm.
(Inventory No. J 32)

3. (Spatula)
Copper.
Length: 16, cm.
(Inventory No. J 36)

4.
Bronze.
Length: 18,2 cm.
(Inventory No. J 35)

5.
Bronze?
Length: 14,3 cm.
(Inventory No. J 34)

5 Flat Spoons

Ḫorāsān (5th–9th / 11th–15th c.)

Cf. James W. Allen, *Nishapur. Metalwork of the Early Islamic Period,* New York, 1984, p. 90.

1. Measuring Spoon?
Silver.
Length: 26 cm.
(Inventory No. J 38)

2.
Copper.
Length: 18,3 cm.
(Inventory No. J 33)

3.
Cuivre.
Length: 15,5 cm.
Volume: 25 ml.
(Inventory No. J 31)

4. Measuring Spoon?
Copper alloy,
inscription.
Length: 14,5 cm.
Volume: 25 ml.
(Inventory No. J 30)

4 Deep Spoons

Ḫorāsān (5th–9th / 11th–15th c.)

On the question of bronze in Iran in the Islamic period, see J. W. Allan, *Persian Metal Technology 700–1300 AD*, London, Ithaca Press, 1979, pp. 45–55.

Flat Spoon

Sassanid or Umayyad
(1st–2nd/7th–8th c.)
Northern Iran (Ṭabaristān)

Silver.
Length: 19 cm.
(Inventory No. J 62)

Mortar

Salǧūq
6th–7th / 12th–13th c.
Nīšāpūr?

Copper alloy (*batruy*?), red patina.
2 bands of writing (repeatedly: *al-ʿāfiya*, «health») against a floral background, interrupted by medallions with figures.

Diameter: 13 cm.
(Inventory No. J 29)

Published: Sotheby's, *Islamic Works of Art,* London, Avril 1990. Cf. *Khalili Collection*, vol. 12, No. 197, p. 314; no other piece is known which matches this shape. On the copper alloy with lead, zinc and tin, often erroneously referred to as bronze, cf. J. W. Allan, *Persian Metal Technology 700–1300 AD,* p. 53 ff.

Mortar

(Ottoman, 11th/18th c.?)

Common traditional form of a mortar.

Brass,
Diameter: 8 cm.
(Inventory No. J 365)

Cf. *À l'ombre d'Avicenne. La médecine au temps des califes,* p. 136 f.; A. U. Pope, *A Survey of Persian Art,* vol. 13, p. 1280 (Berlin, Staatliche Museen); Ö. Küçükerman, *Maden Döküm Sanatı,* İstanbul, 1994, p. 27.

Small Inkpot (*miḥbara*)

Salǧūq (6th/12th c.)
Nīšāpūr

Common type of inkpot from Khorasan that can be locked with three pairs of eyelets; while the form of many extant specimens is remarkably constant, the decorations display the entire range of contemporary techniques (besides, of course, openwork): relief casting, engraving, inlay of different coloured metal (or niello and resin); geometrical, floral and figurative, though calligraphy is given preference.

Copper Alloy,
2 bands with decorative inscriptions.
Traces of ink.
Diameter: 7,5 cm.
(Inventory No. J 40)

The alloy of brass from copper with the addition of *tūtīyā* (zinc oxide), as well as the lavish use of the latter is described by al-Biruni (362/973–440/1048) in his *K. al-Ǧamāhir fī ma'rifat al-ǧawāhir*. Bronze (i.e. an alloy of copper with zinc and a few additions of other metals) was rarely used in Islamic tradition, more frequently on the other hand a copper alloy that contained much lead; ; cf. R. Ward, *Islamic Metalwork*, London, British Museum Press, 1993, p. 29 f.; cf. also J.W. Allan, *Persian Metal Technology 700–1300 AD*, London, Ithaca Press, 1979, p. 39 ff.; A. Welch, *Calligraphy*… New York 1979, No. 40.

Cf. A.U. Pope, *A Survey of Persian Art*, op. cit., vol. 13, pp. 1311 f. and 1335; Christie's, London, Catalogue *Islamic Art*…, October 1997, No. 237 and October 1999, No. 306. *Masterpieces of Islamic Art in the Hermitage Museum*, Kuwait 1990, No. 29; K.v. Folsach, *Islamic Art: the David Collection,* Copenhagen 1990, Nos. 320–32.

2 Mortars

Egypt, early 15th/late 20th c.

Brass.
Diameter: 13 cm. Height: 19 cm.
Pestle: 23,5 cm.

(Inventory No. J 224)

Brass, coloured metal inlay.
Diameter: 12 cm. Height: 14,5 cm.
Pestle: 22 cm.

(Inventory No. J 225)

3 Bowls

Ottoman

Copper covered with zinc.
Diameter: 7,5 cm.
(Inventory No. J 234–36)

3 Steel Implements for Ignition

for producing sparks

Safavid
(11th / 17th c.)

Steel produced in a forge.
Length: 12,2–15 cm.
(Inventory No. J 57 - 59)

Glass Cutter

Safavid
(11th / 17th c.)

Diamond, set in steel.
Agate handle.
Length: 9,3 cm.
(Inventory No. J 60)

Seal

Seljukid (6th / 12th c.)
Nīšāpūr

Bronze?, Hexagram stamp.
Diameter: 1,6 cm.
(Inventory No. J 55)

Cf. James W. Allan, *Nishapur*, New York 1984, p. 72
(Metropolitan Museum 39.40.135).

Cupping glasses

Maġrib, older.

Brass, soldered.
Height: 9,6 cm.
(Inventory No.s J 90–1 and –2)

Cf. *À l'ombre d'Avicenne. La médecine au temps des califes,* op. cit., p. 293.

Protractor

Maġrib (?), older.

Brass, engraved, 50° scale.
Height: 11,2 cm.
(Inventory No. J 91)

Plumbline with spool

Seljukid (6th / 12th c.)
Eastern Anatolia

Bronze?
Length of the bob: 16,7 cm, width of the spool: 8,3 cm.
(Inventory No. J 65)

Cf. Önder Küçükerman, *Maden Döküm Sanatı*, op. cit., p. 40.

2 Dental Forceps?

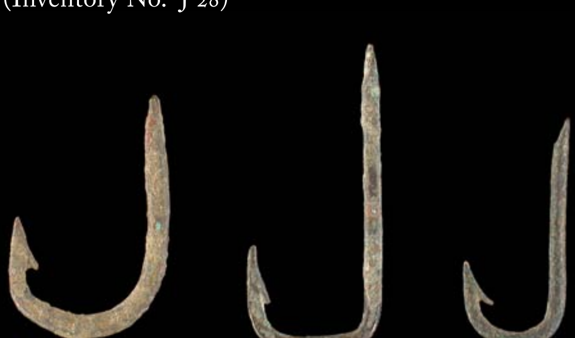
Age and provenance unknown.

Steel, length: 16 and 17 cm.
(Inventory Nos. J 93 and 94)

Wick Snuffer

Safavid
(11th / 17th c.)
Iran

Steel.
Length: 16,5 cm.
(Inventory No. J 28)



3 Fish hooks

Said to be early Islamic
Southern Iran

Bronze?
Length: 33–43 mm.
(Inventory Nos. J 84–1, 2 and 3)

2 Small Brass Weiging Balances:
1. Length of the beam: 11 cm, ∅ of the pans: 7,5 cm.
2. Length of the beam: 17 cm, ∅ of the pans: 6,5 cm.

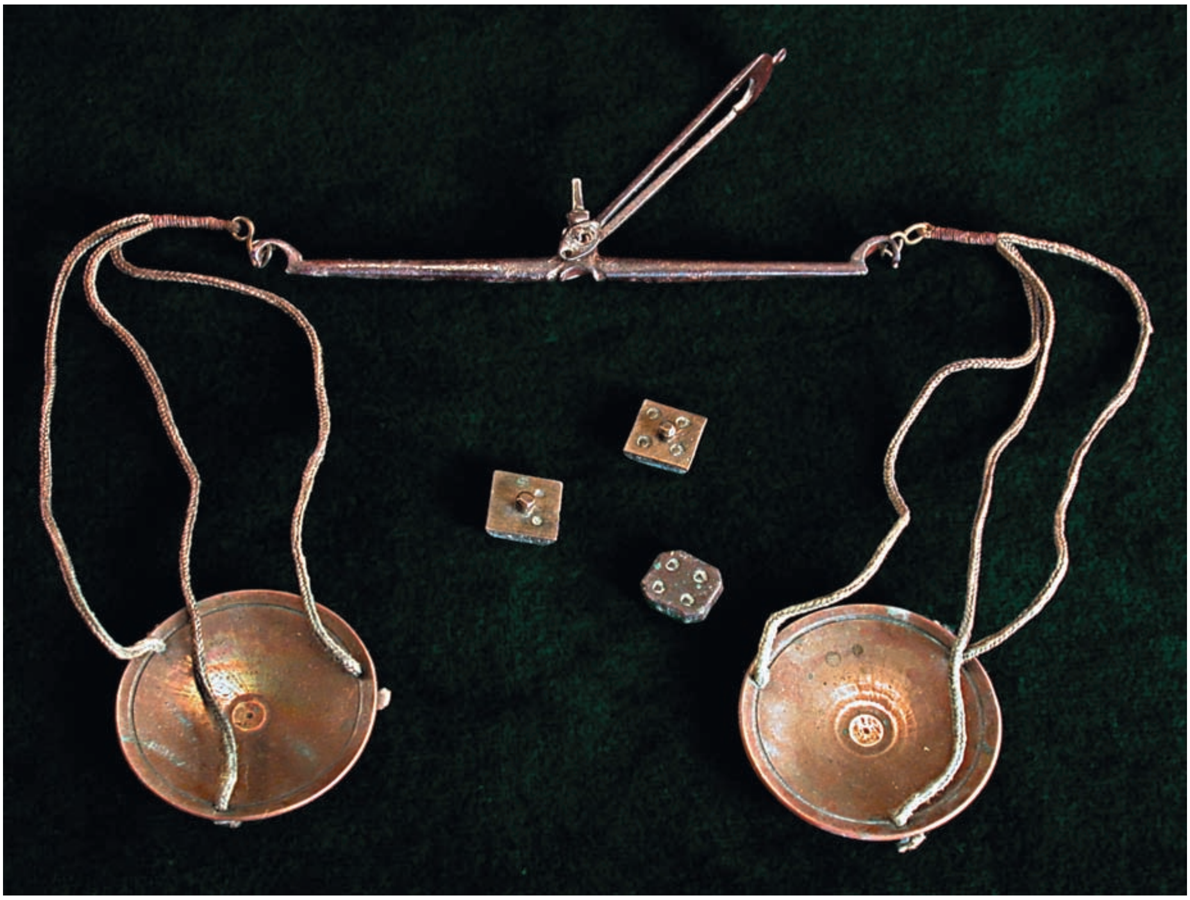
9 round weights:
1, 3, 5, 7, 12, 16, 21, 45, 92 g.
6 square weights: 0,3–1,6 g.
Tweezers, steel, length: 10,5 cm.

Golsmith's Balance Kit

Qādjār (13th / 19th c.)
Iṣfahān

Box with incised slots.
Dimensions: 23,5 × 14,5 × 4,5 cm.
(Inventory No. J 88)

Cf. *Khalili Collection,* vol. 12, No. 380, p. 404.



Golsmith's Balance Kit

Ottoman?

Box with incised slots, 12,5 × 7,3 × 2,2 cm.
(Inventory No. J 233)

9 Weights

Anatolia?

Brass.
Diameter: 56–160 mm.
(Inventory No. J 237–1 à 237–9)

6 Weights

Age and provenance unknown

Copper alloy.
Diameter: 16–64 mm.
(Inventory No. J 238–1 à 238–6)

9 Weights

ʿAbbāsid?

Copper alloy.
Diameter: 15-25 mm.
14, 26, 26, 28, 28, 29, 29, 30, 57 g.
(Inventory Nos. J 86, 1–9)

Cf. J.W. Allan, *Nishapur*, p. 90 f.

Beaker with Foot

(3rd/9th-15th/11th c.)
Nīšāpūr

Greenish glass with fused decorative threds, repaired.
Height: 12,5 cm.
(Inventory No. J 21)

Cf. *Islamische Kunst* (=Berlin, Museum für Islamische Kunst, Catalogue), vol 1, *Glas*, No. 136; J. Kröger, *Nishapur*, No. 152 (5th/11th c.), similar applications on No. 160.

Lamp

Umayyad?
Syria

Free-blown, reenish glass; sintered,
otherweise undamaged.
allegedly be part of a 6-armed poly-chandelier.
Height: 8 cm.
(Inventory No. J 20)

Cf. Berlin, Museum für Islamische Kunst, Catalogue, vol. 1, *Glas,* No. 13. This type of lamp with a free-floating wick was probably a tradition of Late Antiquity, see Chr. Clairmont, *Benaki Museum. Catalogue of Ancient and Islamic Glass,* Athens 1977, Nos. 91–93.

2 Cupping glasses?

3rd/9th - 4th/10th c.
Nīšāpūr

Green glas, blown with the sucking pipe added on.
Diameter: 4,5 et 3,5 cm.
(Inventory No. J 03 et 05)

al-Ḥarīrī, *Maqāmāt*,
MS Leningrad, fol. 165^{a}

Cf. Berlin, Museum für Islamische Kunst, Catalogue, tome 1, *Glas,* Nos. 14–15; Qaddoumi, *La variété dans l'unité,* Kuwait 1987, p. 108; *Khalili Collection,* vol. 12–1, p. 42 f.; *À l'ombre d'Avicenne. La médecine au temps des califes,* p. 168; Chr. Clairmont, *Benaki Museum. Catalogue of Ancient and Islamic Glass,* No. 387; Sotheby's Catalogue, *Islamic Works of Art,* London 10th–11th octobre 1990, No. 45; A. v. Saldern, *Glassammlung Hentrich: Antike und Islam,* Düsseldorf 1974, No. 236 (Syria 2nd–3rd c.); J. Kröger, *Nishapur,* No. 239-243 (3rd/9th–5th/11th c.).

Funnel?

Early Abbassid?
Syria

Greenish glass with bubbles,
Undamaged, apparently there are no comparable pieces.
Length: 27 cm.
(Inventory No. J 01)

Cf. Science Museum, London: No. A79640, A79571, A638600, A6073.

Funnel

3rd/9th–4th/10th c.
Nīšāpūr

Greenish glass, spout slightly damaged.
Height: 10 cm.
(Inventory No. J 04)

We do not know of any other comparable piece.

Cupping glass?

$3^{rd}/9^{th}$–$4^{th}/10^{th}$ c.
Nīšāpūr

Blue glass, spout broken off.
Longueur : 9 cm.
(Inventory No. J 02)

Cf. Berlin, Museum für Islamische Kunst, Catalogue, vol. 1, *Glas,* No. 15, with most of the spout preserved.

3 Small pots and a small bottle

$3^{rd}/9^{th}$–$4^{th}/10^{th}$ c. , Nīšāpūr ?

Colourless glass, highly iridescent, on the extreme right: pot with fused decoration,
Height: 5, 3, 4,5 and 3,5 cm.
(Inventory No. J 09, 10, 11, 12)

Cf. Berlin, Museum für Islamische Kunst, Catalogue, vol. 1, *Glas,* No. 25, 92–94, 164–165; *À l'ombre d'Avicenne. La médecine au temps des califes,* No. 150; *Benaki Museum. Catalogue of Ancient and Islamic Glass,* op. cit., No. 274, 311; all are considered to be from the Levant; J. Kröger, *Nishapur,* op. cit., No. 42 and 100 $3^{rd}/9^{th}$–$4^{th}/10^{th}$ c.).

Small Ink Bottle

3rd/9th–4th/10th c. ,
Nīšāpūr?

Green glass, mould-blown.
Height: 8 cm.
(Inventory No. J 15)

Very similar: A. v. Saldern, *Glassammlung Hentrich: Antike und Islam,* No. 397 («Proche-Orient, 6th–8nd c.?»); Iran Bastan Museum, Téhéran, nº 6849: «Persia, 9th–10th c.» (voir *The Arts of Islam,* Hayward Gallery: The Arts Council of Great Britain, 1976, nº 118); Berlin, Museum für Islamische Kunst, Catalogue, vol. 1, *Glas,* No. 90, with additional literature.

Lamp

Early Islamic
Western Anatolia

Greenish glass with thick walls.
2 eyelets, broken area in a third one.
Height: 11 cm.
(Inventory No. J 17)

Lamp

Umayyad?
Syria (Aleppo?)

Greenish glass, glued together.
3 eyelets, cylindrical holder for the wick, added on the inside.
The chains of suspension probably not original.
Diameter: 8 cm.
(Inventory No. J 18)

Cf. Berlin, Museum für Islamische Kunst, Catalogue, vol. 1, *Glas,* No. 12, 135; K. v. Folsach, *David Collection,* No. 226 et 227; J. Kröger, *Nishapur,* No. 235 (10th–11th c.).

Inkpot?

3rd/9th–4th/10th c.
Nīšāpūr

Green glass, much erroded.
2 small handles, attached by squeezing.
Diameter: 11 cm.
(Inventory No. J 16)

Cf. *The Arts of Islam*, Hayward Gallery, No. 118 (Derek Hill Coll., «Inkwell of blue glass, Persia 9th–10th c.»); J. Kröger, *Nishapur*, No. 229.

Small Bottle

Umayyad?
Syria?

Yellowish glass with black-brown fusings (‹cowhide› ornament, here triangular).
Height: 12 cm.
(Inventory No. J 14)

Cf. A. v. Saldern: *Glassammlung Hentrich: Antike und Islam,* op. cit., No. 332 (Irak/Syrie? VII^{e}–IX^{e} s.); Berlin, Museum für Islamische Kunst, Catalogue, op. cit., vol. 1, *Glas,* No. 128, with additional literature. Since this and the following pieces are examples of ancient techniques continued without a break in early Islamic times, dating these is notoriously difficult.

Beaker

3rd/9th–4th/10th c. ?
Nīšāpūr?

Marbled glass, added on handle; excellent condition.
Height: 15 cm.
(Inventory No. J 06)

One of the oldest known forms of glass vessels, commonly called alabastron or vessel for ointments; mostly without a base, as here. Cf. Chr. Clairmont, *Benaki Museum. Ancient and Islamic Glass,* op. cit., No. 388; A. v. Saldern, *Glassammlung Hentrich: Antike und Islam,* op. cit., No. 399 («jug, North-East Iran?, 7th–8th c.»); *Europäisches und außereuropäisches Glas,* Museum für Kunsthandwerk, Frankfurt am Main, 2nd ed., 1980, No. 1 (ancient) with additional literature.

Bottle

5th/11th–6th/12th c.
Ḫorāsān

Yellowish glass, mould-blown (optically) with grooves gathered in folds (‹date bottle›).
Height: 22,5 cm.
(Inventory No. J 08)

Cf. A.v. Saldern, *Glassammlung Hentrich: Antike und Islam,* op. cit., No. 45 and 46 (Syria, 1st c.); Chr. Clairmont, *Benaki Museum. Ancient and Islamic Glass,* op. cit. n^{o} 211; Berlin, Museum für Islamische Kunst, op. cit., Catalogue, vol. 1, *Glas,* No. 40–46.

Small Bottle

III^{e}/IX^{e}–V^{e}/XI^{e} siècle
Ḫorāsān

Verre vert soufflé-moulé.
Décor de nervures entrecroisées et torsadées (motif ‹bossu›).
En excellent état.
Hauteur: 8,5 cm.
(Inventory No. J 07)

Cf. A. v. Saldern, *Glassammlung Hentrich: Antike und Islam,* n^{o} 41 et 286 («Proche-Orient, VIII^{e}–X^{e} s.»); C.-P. Haase et al. (éd.), *Morgenländische Pracht. Islamische Kunst aus deutschem Privatbesitz,* Hambourg 1993, n^{o} 87; *Europäisches und außereuropäisches Glas,* Museum für Kunsthandwerk, Francfort, n^{o} 79 («Perse? VIII^{e}–X^{e} s.»); J. Kröger, *Nishapur,* n^{o} 120 et 121 (IV^{e}/X^{e}–V^{e}/XI^{e} s.).

Small Bottle

Umayyad?
Syria?

Glas (highly eroded) with fused brown garlands.
Height: 9 cm.
(Inventory No. J 13)

quadruple Pigment Bowl

3rd/9th–4th/10th c.
Nīšāpūr

Stone.
6,5 × 7 × 3 cm.
(Inventory No. J 42)

Multiple bowls for spices, chutneys, sweetmeats etc. are often documented (e.g., *Art islamique dans les collections privées libanaises*, Beirut 1974, No. 36) but mostly of ceramics or metal. According to A. Schopen (oral communication), here it is a container for water colours.

Inkpot?

$6^{th}/12^{th}$–$7^{th}/13^{th}$ c.
Nīšāpūr?

Fritware (fragments not of natural clay, but of a mixture of ground minerals and glass with white clay and potash); monochrome, cobalt blue feldspar glazing.

Diameter: 11 cm.
(Inventory No. J 41)

cf. *Khalili Collection*, op. cit., vol. 9, No. 179–182.

No other specimens comparable in shape.

Example of an important ceramic technology where, primarily by the addition of ground glass, an effect was achieved similar to that of the Sung pottery, which was burnt at high temperatures.

4 Ring Stones

Zand/Qāğār

(12th/18th–13th/19th c.)
Iran

Carnelian, pious inscriptions
in white lacquer.
Width: 23–28 mm.
(Inventory No. J 75, 77, 78, 79)

Top row:

2 Ring Stones:

On the left:
Zand/Qāğār

(12th/18th–13th/19th c.)
Iran

Nephrite, engraved.
Width: 33 mm.
(Inventory No. J 76)

On the right:
Timurid
(9th/15th c.)?
Iran

Jade, engraved, apparently with
a drill. Well-worn (repolished?);
indistinct geometrical Kufi
inscription appears as mirror
image.
Width: 28 mm.
(Inventory No. J 74)

Bottom row:

2 Stones of Signet Rings

Zand/Qāğār

(12th/18th–13th/19th c.)
Iran

Carnelian, engraved.
Width: 17 and 20 mm.
(Inventory No. J 72 and 73)

Cf. *Khalili Collection,* vol. 16, No. 587
(set in a ring).

84 Glass seals

Umayyad and later.
Egypt and other provenances.

Diameter: 9-33 mm.
(Inventory No. J 87 1-84)

Glass with stamped-in inscriptions and patterns. Some Egyptian pieces from the Umayyad era can be dated with the help of the inscriptions[1]; others of bluish, iridescent glass with simple patterns (as made by signet stamps of the type of our (Inventory No. J 55) are probably from Iran.

Such discs were used since the early Umayyad period especially as official seals of medicines or food articles which were made according to norms and weights.
Our earliest specimen that can be dated is from the Director of Finances of Cairo, ʿUbaid Allāh ibn al-Ḥabḥāb (102–116/720–734).

[1] W. Dudzus: *Umayyadische gläserne Gewichte und Eichstempel aus Ägypten*… in: *Aus der Welt der islamischen Kunst,* Festschrift für Ernst Kühnel, Berlin 1957, pp. 274–282.

[2] S.K. Hamarneh and H.A. Awad, *Arabic Glass Seals on Early Eighth-Century Containers For Materia Medica,* in: ʿĀdiyāt Ḥalab, vol III, Aleppo 1977, pp. 32–41.

Amulet?

3rd/9th - 6th/12th c.?
Nīšāpūr?

Calcaire, inscription coufique gravée
li-ṣāḥibihī barakatun min ʿAllāh,
(«Que la bénédiction d'Allāh soit sur son propriétaire»)
and animal figure. Reminiscent of Pre-Islamic seals.
6,4 × 6,4 × 1,5 cm.
(Inventory No. J 52)

Cf. *Khalili Collection*, vol. 12, No. 79 (of metal), very similar: Bibl. nat. de France, Cabinet des médailles, Chab. 2262, in: *À l'ombre d'Avicenne. La médecine au temps des califes,* op. cit., No. 185.

Seal

6th/12th c.?
Nīšāpūr?

Copper alloy, inscription.
3,2 × 3,2 × 0,4 cm.
(Inventory No. J 54)

Width: 16 mm
(Inventory No. J 83)

Width: 34 mm
(Inventory No. J 80)

20 × 20 × 16 mm
(Inventory No. J 81)

10 × 10 × 16 mm
(Inventory No. J 82)

4 Seals

13^{th}/19^{th} c.
Ḫorāsān

Rock crystal, engraved, partly with drillings.

On Islamic crystal in general, cf. R. Pinder-Wilson, *Studies in Islamic Art,* London 1985, pp. 145–150.

4 Weights

Said to be Neo-Babylonian
(-7^{th} c.)
Mesopotamia/Elam

Haematite.
Width: 18–25 mm.
Weight: 4, 5, 7 and 16 g.
(Inventory No. J 85–1 to 85–4)

Weights of polished semi-precious stones were also common in Islamic times; cf. for instance *Khalili Collection*, vol. 12, No. 381 (Mughal India, 13^{th}/19^{th} c.).

Haematite weights,
‹Old Babylonian, 2000–1600 BC,
provenance unknown›,
British Museum, WA 117891–900.

Leather Press-Mould

(3rd/9th-6th/12th c.)
Nīšāpūr

Limestone, engraved, fragment.
7,5 × 10 cm.
(Inventory No. J 51)

Cf. R. Pinder-Wilson, *Stone press-moulds and leatherworking in Khurasan,* dans: *Khalili Collection,* vol. 12, pp. 338–355.

Jeweller's Tool?

(3rd/9th-6th/12th c.)
Nīšāpūr

Limestone, engraved on all the four longitudinal sides with figures with varying shape; 2,8 × 5,4 × 2,1 cm.
(Inventory No. J 47)

Casting Mould?

(3rd/9th-6th/12th c.)
Nīšāpūr

Stone.
7 × 5 × 2,5 cm.
(Inventory No. J 50)

Casting Mould?

(3rd/9th-6th/12th c.)
Nīšāpūr

Stone, engraved on both sides.
9 × 8,5 × 1,1 cm.
(Inventory No. J 46)

Stone.
9 × 5,5 × 1,5 cm.
(Inventory No. J 43)

Stone.
6,5 × 5 × 1,5 cm.
(Inventory No. J 44)

Stone.
4,5 × 7,2 × 1,5 cm.
(Inventory No. J 45)

Casting Moulds?

(3rd/9th-6th/12th c.)

Nīšāpūr

Striking Piece
and
3 Casting Moulds
for projectiles

(3rd/9th-6th/12th c.),
Nīšāpūr?

Brass.
3,4 × 1,5 × 0,8 cm.
(Inventory No. J 56)

Copper alloy.
7,1 × 2,4 × 0,4 cm.
(Inventory No. J 53)
Cf. Ö. Küçükerman, *Maden Döküm Sanatı*, p. 10 (Anatolia 13th/19th c.).

Stone.
4,2 × 2,4 × 1,3 cm.
(Inventory No. J 49)

Stone.
6 × 6 × 2,5 cm.
(Inventory No. J 48)

Mould/Model?

12th/18th c. (Zand)
Šīrāz

Stone, engraved, with wax impression.
Diameter: 9,5 cm.
Thickness: 3 cm.
(Inventory No. J 69)

Textile Printing Block

Early 3rd/9th c. (Qāǧār)
Iṣfahān

Wood, incised: Rustam's fight with the dragon.
18 × 20 × 5,5 cm.
(Inventory No. J 66)

Textile Printing Block

Early 3rd/9th c. (Qāǧār)
Iṣfahān

Wood, incised.
15,5 × 19 × 5,5 cm.
(Inventory No. J 67)

Stamp

for goods or customs

«No. 64» in the name of
Wakīladdaula

Dated [1]137 of the Hegira (=1725)
Kirmānšāh?

Wood, carved.
13 × 8 × 6 cm.
(Inventory No. J 68)

European Glass and Ceramics in Oriental style

Introduction*

In the 19th century European craftsmen realized that the handicrafts produced until then did not meet the requirements of the times. Through the French revolution new strata of society had become the main consumers of handicrafts. Thus the production of industrially made goods at low prices commenced, so as to cope with the larger number of consumers. Private producers as well as state–run enterprises realized that a wide–ranging reform movement had to come about in the field of handicrafts. Only thus could national styles be promoted at a time of emerging nation states. In the course of this development state–run schools for commercial art were founded. For the promotion and display of national styles and of international commerce, World Exhibitions were held from 1851, where not only European countries participated but also countries from the Far and Near East and other parts of the world. Thus the art of Islamic countries was discovered as something particularly exemplary. Art objects from these countries were bought by the many schools of arts and crafts and by the newly established museums of handicrafts. This also led to the emergence of large private collections and collections by business firms. Artists and theorists took note of all the genres of art and studied material technology, systems of decoration and colour design.

Every new theory requires publications in order to propagate and explain the exemplary pieces by select specimens. Thus a market arose for pattern books meant for further education. The most well–known works were those by Christopher Dresser,[1] Adalbert de Beaumont and Eugène Collinot,[2] Albert Racinet[3] and Achille Prisse d'Avennes,[4] which followed up Owen Jones' *Grammar of Ornament*.[5] Ceramics and glassware were the materials which had a great influence on the European market. Ceramic tiles were popular for decorating houses and apartments (Minton Hollins & Co., Tiles, Inventory No. J 360, v. infra, p. 200). However, the products of European firms were not only sold in the European market but found a clientele in the Orient as well. Thus it is known that the Egyptian Khedive gave commissions to the ceramic makers Ulisse Cantagalli (Florence), William de Morgan (London), Vilmos Zsolnay (Pécs) and to the New York glassware artist Louis Comfort Tiffany. The Ottoman Sultans commissioned ceramic artists like Théodore Deck for decorating their palaces and mausoleums, and also their mosques. In 1865 Eugène Collinot (Paris) received a medal of honour from Naṣīraddīn, the Shah of Persia, for his services in the revival of Persian ceramics. Hippolyte Boulenger (Choisy–le–Roi) was consulted for furnishing a part of the Yeni Cami («New Mosque») of Istanbul.

When we look today at European ceramics and glassware with regard to their relationship to the Islamic world, the results are striking: the majority of pieces produced by European companies were executed in the Ottoman style and in forms of decoration derived from it. That was primarily because the floral ornamentations of Ottoman art were captivating due to their exemplary manner of two–dimensional drawing. Moreover, European buyers found them attractive because they [178] could recognise the flowers used in ornamentation (such as roses, hyacinths, carnations and tulips). Such motifs of ornamentation could either be directly adopted or their details could be incorporated into one's own compositions.

* Introduction and the description of the objects by Annette Hagedorn, Berlin; edited at the Institute for the History of Arab–Islamic Science.

[1] *The Art of Decorative Design*, London 1862.

[2] *Recueil de dessins pour l'art et l'industrie*, Paris 1859 and *Encyclopédie des arts décoratifs de l'Orient*, 6 vols., Paris 1883.

[3] *L'ornement polychrome. Recueil historique et pratique*, 2 vols., Paris 1869.

[4] *L'art arabe d'après les monuments du Kaire depuis le VIIe siècle jusqu'à la fin du XVIIIe siècle*, Paris 1869–1877.

[5] *The Grammar of Ornament*, London 1856.

In the collection of the Institute for the History of Arab–Islamic Science, there are examples of the basic possibilities of transfer of the art forms of the Islamic world to Europe. These will be mentioned here: a plate like the one by Théodore Deck (Inventory No. J 358, see below, p. 198) originated in close proximity to Ottoman ceramics of the 10th/16th and 11th/17th centuries. Ph. J. Brocard produced a copy of Mamlūk glass work (vase J 340, see below, p. 180). In other pieces, only some elements were directly copied from the prototypes, but these were put together in a manner that was the maker's own achievement. Such objects were often used for the didactic purposes of learning from the prototypes, for understanding the principles of their ornamentation in order to be able to create something new on this basis. Significantly, the firm of Lobmeyr mentioned in each case the German translation of the Arabic texts on the underside of their glassware, thus endowing them with an academic character.

What was innovative and decisive for the future of European handicrafts were the technologies newly developed at this time, and these could be developed only because of such an intense encounter with oriental objects (cf. Th. Decker, plate J 361, see below, p. 201; Lobmeyr, various forms: J 343–345, 347 and 349, see below, pp. 184–186, 188, 190).

The third variant of the transfer is documented by specimens, for the ornamentation of which such motifs were borrowed which were traditionally part of the total design in Islamic art, but which were converted here into a free–standing single motif. Thus these were virtually «monumentalized». Such decorations corresponded to the spirit of the period of historicism. An example of this is the goblet by the firm Pfulb & Pottier in the collection of the Institute for the History of Arab–Islamic Science (Inventory No. J 342, see below, p. 183).

In the fourth type of transfer, the craftsman conspicuously drew upon Islamic prototypes, created nevertheless something of his own, such as the vase of the firm of Fritz Heckert (Inventory No. J 348, see below, p. 189) and the vase of the firm De Porceleyne Fles from Delft (Inventory No. J 363, see below, p. 202). These pieces in particular show that the designers had a more profound knowledge of Islamic art. For this they travelled throughout Europe and studied the objects in public and private collections, but they also went to countries of the Islamic world in order to improve their knowledge of the subject. Important pieces in the collection, which show a further advance towards the art of modern times, have their own style even though they show a conspicuous link to Oriental art. In this process, it is striking that the inspiration came not only from the art of the Islamic world but also from that of East Asia. In the case of the specimen from the production of Clément Massier, it is obvious how great an influence Arabic script could have on modern ceramics when it served as a repertoire of abstract patterns, detached from its original meaning (Inventory No. J 364, see below, p. 203). On the other hand, the long–necked vases of the firm of Lobmeyr (Inventory No. J 357–1 and 357–2, see below, p. 197) display influences from the East–Asian area and are very close to art nouveau in their ornamentation.

On the whole, the items of the collection provide examples of the path from direct copying of the prototype during the period of historicism to the new forms of ornamentation which already correspond to the forerunners of art nouveau. They show the importance of the art of the Islamic world and of East Asia for the development of a modern style of ornamentation in European arts and crafts.

Vase
in the form of a hanging mosque lamp

Anonymous, probably from France,
Second half of the 19th c.
Colourless glass, mould–blown.
Enamel painting in blue, red and gold.
Red contour lines.
On the base trademark or the name of the firm ground off.
Height: 23.5 cm; Diameter: 19.5 cm.
(Inventory No. J 339)

The vase follows the common shape and ornamentation of Egyptian mosque lamps of the 8th/14th and early 9th/15th centuries. In this period hundreds of hanging lamps for mosques were commissioned by rulers and members of the nobility in Maml‘k Egypt.[1] Because of the quality of the technique of enamelled glass and gold painting, the mosque lamps had been admired in Europe since the Renaissance. In the 19th century many of the lamps were brought from Egypt to Europe and sold, particularly at the Paris art market. Thus they were included in private collections, but were also sought-after objects of study for the newly emerging arts and crafts museums all over Europe. The lamps were either copied by many European glass manufactories or imitated more or less freely, following the Mamlūk style. In the late 19th century, vases were finally made in the form of mosque lamps with completely new European ornamentation. The ornamentation of the vase can be associated with an original mosque lamp of the Spitzer Collection in Paris, which Pfulb & Pottier could have personally seen at the Paris collection.[2] This hanging lamp was made around 760/1360 in Cairo. Here the external shape was borrowed as also the two bands of writing and the medallions with floral motifs. The ornamentation was altered. The vase is heavily decorated with gold, and at the beginning of the neck a band of quatrefoil blossoms was added in gold. This motif is often also used in the surface design of Mamlūk mosque lamps, though not with a gold background.
Similar mosque lamps were often copied in the 19th century. The well-known and larger glassware producers like Brocard (Paris),[3] Lobmeyr

[1] Gaston Wiet, *Lampes et bouteilles en verre émaillé*, Cairo 1912 (= Catalogue générale du Musée Arabe du Caire).
[2] cf. *La collection Friedrich Spitzer*, vol. 3, Paris 1893.
[3] cf. Hartford, Wadsworth Atheneum (Illustration in: Katharina Morrison McClinton, *Brocard and the Islamic Revival*, in: The Connoisseur 205/1980/278-281, esp. p. 280).

[180] (Vienna),[4] Heckert (Petersdorf),[5] Gallé (Nancy)[6] and Inberton (Paris)[7] stamped their copies with their signatures. But other firms made unsigned specimens as well. Often these reached the art market subsequently as counterfeits. The object described here originally had a trade mark on the base in a circular shape with a surrounding band. However, this signature was ground off at an unknown point of time so that the item could be sold as an original piece.

[4] see above, in the description of the parallel example.
[5] cf. Hirschberg, Kreismuseum, Inventory No. MJG 203/v. photo by the author; illustration in *Schlesisches Glas aus der 2. Hälfte des 19. Jahrhunderts: zur Sammlung schlesischen Glases im Kreismuseum Hirschberg (Riesengebirge)und zur Ausstellung im Haus Schlesien*, Königswinter 1992, Cat. No. 50.
[6] Cf. Nancy, Musée de l'Ecole de Nancy, Inventory No. 171 (illustration in: Doris Moellers, *Der islamische Einfluß auf Glas und Keramik im französischen Historismus*, Frankfurt/Main etc. 1992, Cat. No. 56).
[7] Cf. Kunstmarkt 1998 (illustration in: Auction Catalogue Sotheby's of 13. 7. 1987, lot 272).

Comparable objects in other collections, among many others: Vienna, Österreichisches Museum für angewandte Kunst, Inventory No. Gl. 553 (illustration in: Waltraud Neuwirth, Orientalisierende Gläser, vol. 1: J. & L. Lobmeyr, Vienna 1981, p. 54); Nuremberg, Gewerbemuseum der Landesgewerbeanstalt Bayern, Inventory No. 1623/1 (illustration in: Horst Ludwig, Moscheeampeln und ihre Nachahmungen, in: Weltkulturen und moderne Kunst, Munich 1972, pp. 80-93, esp. p. 83).

Vase

Philippe-Joseph Brocard, Paris
Free-blown,[1] greenish transparent glass.
Enamel painting in red, blue, white and green.
Gold lines within the enamel ornamentation.
On the base signature in red lettering:
Brocard Paris 1869.
Height: 31.8 cm
(Inventory No. J 340)

The egg-shaped body of the vase rises from a low profiled foot-ring and turns, without any transition, into the straight upright neck, which is profiled at its upper end with a pinched ring and terminates with a bowl-like spout.
The vase is decorated with two horizontal bands containing ornaments of tendrils with bifurcating leaves, executed in red, blue and green enamel. The broader lower band on the body of the vase is interspersed with three medallions on a white background; its ornamentation also consists of tendrils with bifurcating leaves. This motif had arisen in a succession of stages of development since Late Antiquity and was incorporated into Islamic art. It was employed in the entire area of the Islamic world as an ornament in architecture, in book illumination as well as in the ornamentation of many types of applied art.

[181] From the medallions on the body plant motifs emerge which terminate in stylized animal heads. Such motifs had been developed since the 5th/11th century in Seljuk art and had belonged since that time to the repertoire of ornamentation of all genres of Islamic art.

The vase is a copy of a long-necked Mamlūk vase of the 8th/14th century.[2] At the time when Brocard made his copy, this Mamlūk vase belonged to the large art collection of Baron Edmond de Rothschild (1827-1905) in Paris.[3] While visiting the collection, Brocard probably noticed the vase.

Brocard's vase is in its shape a true copy of the Mamlūk model. The ornamentation also follows the original in its structure. But Brocard changed the elements of the ornamentation by simplifying the line-work of the plant motifs within the ornament bands and medallions. An identical piece (but without the signature) was acquired for the Österreichisches Museum für angewandte Kunst at the World Exhibition of Vienna in 1873.[4] Since the vase in the collection with which we are dealing here was produced earlier in 1869, it follows that Brocard, once he had found suitable prototypes, copied them for many years. Whether the manufacture of pieces without signature allows the conclusion that Brocard glassware was either given as presents or sold by some of his customers as genuine Oriental glassware cannot be established, but is conceivable. In some important glassware collections in museums or in private possession such glassware as the one discussed here was assessed as genuine medieval glassware. Such glassware was also in the collection of Baron Edmond de Rothschild.

[1] K. Morrison McClinton, *Brocard and the Islamic Revival*, op. cit., p. 280.

[2] Carl Johan Lamm, *Mittelalterliche Gläser und Steinschnittarbeiten aus dem Nahen Osten*, 2 vols., Berlin 1929, plate 115, No. 14; Gaston Migeon, *Arts plastiques et industriels*, Paris 1927 (= Manuel d'art musulman, vol. 2); Ernst Kühnel, *Die Arabeske. Sinn und Wandlung eines Ornaments*, Wiesbaden 1949, pp. 223-227.

[3] Annette Hagedorn, *Die orientalisierenden Gläser der Firma Fritz Heckert im europäischen Kontext*, in: Mergl, Jan (ed), *Böhmisches Glas – Phänomen der mitteleuropäischen Kultur des 19. und frühen 20. Jahrhunderts*, Passau 1995 (= Schriften des Passauer Glasmuseums, vol. 1), pp. 84-89, esp. pp. 86 ff.; auction catalogue Christie's London 14. 10. 2000, p. 46.

4 Inventory No. Gl 1052; W. Neuwirth, *Orientalisierende Gläser*, op. cit., illustration 36.

Bowl

Philippe-Joseph Brocard
Free-blown,[1] colourless glass.
Enamel painting in red, blue, white and green. Within the enamel ornamentation, some decorative elements are executed in gold.
On the base signature in red lettering:
J. Brocard, Meudon[2] (1867 and later).
Diameter: 20.5 cm; height: 11.5 cm.
(Inventory No. J 341)

Without a foot ring, the bowl rises, protruding a little, beyond that up to a vertical strip; the wall of the bowl goes up steeply, drawn inwards. The upper end is formed by a narrow, vertical strip as well as a narrow, profiled rim of the mouth.

With this bowl Brocard drew upon Syrian metalwork of the 8th/14th century, without copying these outright.[3] Although in the case of this vessel he was inclined towards a common bowl shape used frequently in Syria and Egypt, he changed the Islamic ornamentation in a supposedly «improved Oriental style» (an expression popular in the 19th century). In the Islamic art of previous centuries the overlapping of ornamentation motifs like medallions and cartouches was unusual. These were placed next to each other and only interlinked by encircling rims. Multiple layers occurred only in the decoration of individual segments of facets. An interweaving such as Brocard used it in this piece was sought after and used only in Spanish-Moorish art. Good examples [183] of this are the stucco decorations of the Alhambra. In his *Grammar of Ornaments*

[1] K. Morrison McClinton, *Brocard and the Islamic Revival*, op. cit., p. 280.
[2] South-east of Paris. Here, in an ancillary building of the castle, Madame Pompadour established in 1756 the factory for refined glass, «Cristalleries des Sèvres». After her death, her brother continued the factory under the name «Royales de Sèvres». In 1870 the firm became the property of Alfred Landier and Charles Haudaille. The signature is meant to show that J. Brocard also worked at Meudon.
[3] A comparable piece for the shape is a water basin from the 8th/14th century from Syria/Egypt (Berlin, Museum für Islamische Kunst, Inventory No. I.921; see Klaus Brisch (ed.), *Islamische Kunst*, Mainz 1985).

(1856), Owen Jones mentioned these ornaments as ideal for surface division and for the colour design. It seems that Brocard closely followed the discussion on the reforms in arts and crafts. Thus he also produced pieces in the Spanish-Moorish style, which was admired by Owen Jones.[1]

Other objects of the firm in other collections:
Comparable pieces: In the same shape but with different ornamentation and larger size: Stuttgart, Württembergisches Landesmuseum, Inventory No. 1981-3.[5] In a somewhat modified form: Paris, private collection.

Glass Goblet

Pfulb & Portier, Paris and Nice
Colourless glass, mould-blown.
Coloured enamel painting on golden background.
On the base, signature in red enamel colour:
A. Pfulb 1877 170 [number of the model].
Height: 25.0 cm.
(Inventory No. J 342)

For the glass goblet of Pfulb & Pottier, a shape was developed that cannot be traced back to any actual prototype. Upon a wide foot, a glass cup was set up which rises almost at right angles from a foot ring. Although the shape of the upper part of the drinking vessel recalls Syrian straight glasses of the second half of the 7th/13th century, it should be noted that the proportions are changed here, as the glass cup was shaped narrower and taller. The decoration consists of five fields in gold, which are extended on to the foot and the cup, with enamelled ornamentation motifs. The main motif of the goblet is a medallion of interwoven stars with the terminations rounded up at the top.

Other objects of the Ṭrm in other collections: Warsaw, National Museum, Inventory No. 157. 478 (illustration in: A. Wesenberg and W. Hennig, *Historismus und die Historismen um 1900*, Berlin 1977, p. 99); Limoges, Musée National Adrien Dubouché, Inventory No. V 330, 331 (illustration in: D. Moellers, *Der islamische Einfluß*, op. cit., No. 77).

[1] cf. Frankfurt, Museum für Angewandte Kunst.
[5] Illustration D. Moellers, *Der islamische Einfluß*, op. cit., illustration 15.

Plate

J. & L. Lobmeyr, Vienna (No. 3873)[1]
(Design Johann Machytka and Franz Schmoranz 1878)
Colourless, so-called «crystal glass».[2]
Gold painting, blue enamel painting.
On the base, Lobmeyr monogram in white enamel paint.
Diameter: 38.0 cm.
(Inventory No. J 343)

The ornamentation of the plate consists of 12 pointed oval fields, the edges of which partly intersect with one another in the lower half. The pointed ovals are alternately decorated with blue enamel or gold ornaments. The blue fields are covered with abstract script, which proceeds inwards from the two ends; the patterns incorporate geometrical knots. The gold fields are filled with floral ornamentation constituted by two palmette blossoms, standing one above the other; on the sides there are other fanciful blossoms of gold and blue colour. In the spandrels between the pointed ovals there are similar floral ornaments. The blue ovals are surrounded by ornamentation with script in gold painting.
The centre of the plate is covered by a circular field formed by an ornamentation made up of a six-lobed star. The spandrels at the tips of the star are each intersected by circle-like formations. A script band runs around the field with the text: «Reason is the best foundation and the fear of God the best garment.»[3] The twelve pointed oval fields are framed with the following inscription: «He who says something about a matter that does not concern him hears what he does not like.»[4]

[1] Vienna, Österreichisches Museum für angewandte Kunst, Catalogue of Lobmeyr's work, vol. XV, page P.
[2] Information on a design sketch, Vienna, Österreichisches Museum für angewandte Kunst.
[3] The author wishes to thank Mrs. G. Helmecke (Berlin, Museum für Islamische Kunst) and Professor A. Karoumi (Berlin) for reading the inscriptions and for providing their literal translation. On the design sketch in Vienna, Österreichisches Museum für Angewandte Kunst, Catalogue of Lobmeyr's work, vol. XV, page P, the following (incorrect) translation is given: «Intelligence is the best foundation and the fear of God the most excellent trait of human beings.» On the back of the plate the following (likewise erroneous) translation is given in white enamel paint: «Intelligence is the most powerful support of man and honesty is his best trait.» It is not known who suggested this translation in the 19th century. In both cases instead of *libās* (dress, garment) *an-nās* (human being) was read.
[4] This inscription is translated in the same design sketch as follows: «He who interferes in other people's affairs will suffer for it.»

Plate
in ‹Arab style› (No. 5524)

J. & L. Lobmeyr, Vienna
(design J. Machytka and F. Schmoranz 1878)
Colourless glass.
Gold painting, blue enamel painting.
On the base Lobmeyr monogram in white enamel paint.
Diameter: 29.0 cm.
(Inventory No J 344)

The plate is decorated by a system of two bands of script (on the edge and around the centre) which are connected to each other by four circles which intersect the script friezes. The centre of the plate is covered with a star motif on undecorated glass. The areas between the circles are covered with enamel ornaments of tendrils with bifurcating leaves.
The style of the ornamentation goes back to Mamlūk metal or glass work.[1] Prisse d'Avennes had already reproduced such a plate in his work on the medieval art of Cairo.[2] It is not known whether the large plate described here is copied from an actual original prototype, or whether it is a pastiche of several Mamlūk originals studied by Machytka and Schmoranz. The ornamentation motifs of the script bands and the tendrils of bifurcating leaves were so well known at the time of production of this plate from many pattern books and also from originals preserved in the Kunstgewerbemuseum in Vienna that the designers could choose a combination of motifs and put them together as ornamentation. The combination of the blue and gold colours is known from the Spanish ceramic art of the 15th and 16th centuries and may have inspired the colour design of objects like the plate discussed here. Examples of Spanish ceramics of the 15th and 16th centuries, which were particularly popular in German-speaking countries, were to be found in all museums of arts and crafts.[2] In their designs Machytka and Schmoranz probably tried to combine different styles of the Islamic world in order to improve on the original models. The inscription in the middle of the plate runs as follows in translation: «The power is God's, the only one, the conqueror.»[4] On the edges of the four circular medallions it says twice each: «Save us from hypocrisy!»[5]

[1] Glass: Dish, middle of the 14th c., diameter 21.6 cm (New York, Metropolitan Museum, Bequest of Edward C. Moore, Inventory No. 1891 91.1.1533), illustration in: Stefano Carboni and David Whitehouse, *Glass of the Sultans*, New York etc. 2001, p. 273. Metal: Prisse d'Avennes, *L'art arabe d'après les monuments du Kaire*, see illustration in *The Decorative Art of Arabia*. Prisse d'Avennes. Foreword by Charles Newton, London 1989, plate 84.
[2] Prisse d'Avennes, *L'art arabe d'après les monuments du Kaire*, see illustration in *The Decorative Art of Arabia*, op. cit., pl. 84.
[3] The extensive collection of the Musée de Cluny, Paris, which was studied by all European producers of industrial art in the 19th century, was last published in: Robert Montagut, *El reflejo de Manises: cerámica hispano-moresca del Museo de Cluny de Paris*, Madrid 1996.
[4] A free translation is given on the back of the object in white enamel paint in German: «Gott ist leutseelig. Gott ist gut – rette uns vor der Heuchelei,» which translates as: «God is affable. God is good – save us from hypocrisy.»
[5] The author wishes to thank Mrs. G. Helmecke, Dipl.-phil. (Berlin, Museum für Islamische Kunst) for reading the inscriptions of this object and for the literal translation.

Plate

J. & L. Lobmeyr, Vienna
(Design by J. Machytka and F. Schmoranz 1878/79)
Free-blown, colourless glass.
Gold and enamel painting in blue.
On the base Lobmeyr monogram in white enamel paint.
Diameter: 18.0 cm.
(Inventory No. J 345)

The ornamentation of the plate is structured from elements of the so-called boteh patterns (Persian, written *būtah*, pronounced *bōte*). The boteh pattern is an important motif in Persian art of carpets and textiles. In its shape it recalls the tip of a tree bent to one side, or a drop; the word means bush.
The plate belongs to a group of models, designated as «Arab. decorirt [sic]» on the design sketches.[1]

[1] Vienna, Österreichisches Museum für angewandte Kunst, designs in the Catalogue of Lobmeyr's work, vol. XV. Walter Spiegl, Glas des Historismus, Brunswick 1980, p. 264, classifies an identical plate as «in Persian style». Although some of the design sketches by Machytka and Schmoranz are referred to as «Persian», the designs are different in respect of their floral ornamentation.

Vase

J. & L. Lobmeyr, Vienna
Colourless glass,
Gold painting, enamel painting in light and dark blue.
On the base, Lobmeyr monogram in white enamel paint.
Design ca. 1878.
Height: 13.5 cm; Diameter: 14.5 cm.
(Inventory No. J 346)

Small vase on a broad foot with a cylindrical body, slightly widened in the upper part, which terminates in a wide extended brim.

The ornamentation of the vase followed designs which Machytka and Schmoranz called Persian but without mentioning the prototype.[1] In this vase, the foot was decorated by a tendril with bifurcating leaves, which is interspersed with stylized motifs of leaves. The decoration of the body begins with a tendril with motifs of stylized blossoms. This tendril is repeated as the end of the body with denser foliage. On the body medallions alternate with compositions of leaves and blossoms in gold paint. The medallions are filled with arabesques. They are framed by a band of golden circles. In the areas containing painted leaves and blossoms, some abstract circular rings are added with enclosed pearl-like shapes. The rim of the vase is decorated by a wave-like tendril, filled with rosette blossoms. The special feature of the ornamentation is the juxtaposition of diverse Oriental and European motifs. What is characteristic of the design is, moreover, the fact that the arabesques, inspired by Moorish art,[2] were also executed by the artist in his own manner, since he filled the area symmetrically and with wide intervals in between.

[1] Vienna, Österreichisches Museum für angewandte Kunst, Catalogue of Lobmeyr's work, vol. XV, e.g., folio FF.

[2] On Moorish art, cf. Montagut, *El reflejo de Manises*, loc. cit.

Vase with double handles

J. & L. Lobmeyr, Vienna (probably designed in 1878 by Johann Machytka and Franz Schmoranz).[1]
Free-blown, colourless glass,
Gold and enamel painting in light and dark blue, pastel green, red and yellow.
On the base Lobmeyr monogram in white enamel paint.
Height: 22.5 cm.
(Inventory No. J 347)

The vase belongs to the glassware in oriental style distributed by Lobmeyr. It is related to the series in Arabic style,[2] but no model number is known for this vase. Often Lobmeyr also produced trial specimens as well as items sent as gifts to European and Oriental museums. Such specimens were not meant for sale; they served to demonstrate the Ṭrm's potential, and the museums used these gifts as study specimens.
On to a low foot is set the wide body of the vase, which terminates in a profile ring and then continues in the cylindrical neck that goes straight upwards. The vase terminates with a profile ring and a rim at the edge that is made wider towards the outside. Two undecorated handles join the body and the neck.[3] Because of the gold terminals the handles seem to be held by metal supports. The neck and the body are decorated with fields surrounded by golden frames. The surfaces of the body and the neck are structured with fields framed by blue bars with inset pastel green squares. The fields are decorated alternately with shrubs whose stems, rising up in curves, have pastel green stylized leaves and yellow rosette blossoms; or by shrubs with a kind of stylized carnation blossoms on stems from which deep blue leaves are growing. Both types of ornamentation go back to the art of Ottoman ornamentation of the 10th/16th to 12th/18th century.[4]
The foot and the profile rings are decorated with geometrical motifs of ornamentation.
The entire ornamentation consists of images juxtaposed to each other.

[1] The designer team worked from 1878 to 1880 (or longer) for the firm. Among the items mentioned in the archives of Lobmeyr's firm in the Museum für Angewandte Kunst at Vienna there is no design sketch of the vessel discussed here. Therefore it can only be inferred from stylistically similar objects by Machytka and Schmoranz that they were the designers. For comparison, design sketches of glassware of the same shape but with other ornamentation derived from Ottoman art are likewise preserved in the museum mentioned above.
[2] cf. W. Neuwirth, *Orientalisierende Gläser*, op. cit., illustrations, pp. 33, 36, 37, 44. Waltraud Neuwirth, Lobmeyr. *Schöner als Bergkristall*, Vienna 1999, illustrations, pp. 239, 358 ff.
[3] The shape of the vase was executed in at least four different styles of ornamentation. Cf. illustrations in: W. Neuwirth, *Lobmeyr*, op. cit., pp. 239, 358. W. Neuwirth, *Orientalisierende Gläser*, op. cit., illustration 14, Berlin, Kunstgewerbemuseum.

[4] Atasoy, Nurhan and Julian Raby, *Iznik. The Pottery of Ottoman Turkey*, London 1989.

Vase

Fritz Heckert, Petersdorf/Piechowice,
District of Hirschberg/Jelenia Góra
(formerly Silesia, now Poland)
1879/80 up to 1900.
Colourless glass, mould-blown.
Enamel painting in blue, green, mauve,
Gold paint in incised contour lines.
On the base signature in gold:
FH Co 67 [Serial number].
Height: 24.0 cm; diameter of the body of the vase: 17 cm.
(Inventory No. J 348)

Vase with a circular body and two decorative handles at the neck. The vase is covered all over the available surface with enamel paint in red, blue, yellow, and leaf-green as well as by gold contour lines in a dense, colourful ornamentation.

All elements of the plant motifs are realized in a very flat two-dimensional style. For the decoration of this object Heckert turned to Indo-Persian art for inspiration, whose elements he independently composed into a well-structured system of ornamentation. In the colours used for this vase Heckert obviously followed the theories developed by Owen Jones in his Grammar of Ornament. There Jones emphasized how important it was to use of the three basic colours red, blue and yellow, which could be enriched with secondary colours only in exceptional cases.[1] Here Heckert used a light leaf-green as subdued colour for filling in the less important motifs. He did the contour lines of the details of the ornaments in gold, in accordance with Jones's instruction: «Where different colours are used against a coloured background, the ornament is differentiated from the background […] with outlines of gold.»[2] This colour scheme is used primarily for the central area.

Further objects of the firm in other collections: Important examples for comparison of Heckert's, even though in completely different shapes, are to be found today in various museums of arts and crafts.[3]

[1] O. Jones, *The Grammar of Ornament*, London 1856, pp. 6-8, preposition [rule] 14-28.
[2] ibid, p. 81. Cf. A Hagedorn, *Die orientalisierenden Gläser der Firma Fritz Heckert*, op. cit., pp. 84 ff.

[3] There is a large collection in the Kreismuseum at Hirschberg. In an exhibition in «Haus Schlesien» (Königswinter) in 1992, 101 objects of Silesian glassware of the 19th and early 20th centuries of the museum (among them 26 Heckert glasses) were on display and catalogued in an accompanying brochure, cf. *Schlesisches Glas* … Königswinter 1992. Important specimens in Islamic style are owned by the Kunstgewerbemuseum, Berlin, v. Barbara Mundt, *Kunsthandwerk und Industrie im Zeitalter der Weltausstellungen*, Berlin 1973 (= Kataloge des Kunstgewerbemuseums, Berlin, vol. 6), Cat. Nos. 70, 71, 72.

Vase with double handles

J. & L. Lobmeyr, Vienna (Design J. Machytka and F. Schmoranz, 1878/79)
Colourless glass,
Gold painting, enamel painting in light blue, black and green.
On the base Lobmeyr monogram in white enamel paint.
Height: 17.5 cm.
(Inventory No. J 349)

On a gold covered foot ring is set a vessel with a flattened spherical body, which is fully covered with rich ornamentation. On both front sides there is, at the centre in each case, a multi-lobed medallion with a flowering shrub of tulip and carnation motifs executed in enamel paint against leaves painted in gold. In the spaces between the medallions carnation motifs were placed in different colour combinations. The stems are coloured realistically green, the flowers white and light blue. On the neck of the vase, a tendril with similar motifs was painted.
The shoulder is surrounded by a broad band with script which carries four times the words *mā šā' Allāh* («what God wishes»), an exclamation of admiration.[1] The two round handles are affixed on the shoulder band.

[1] On the base appears in white enamel the translation in German «Der Wille Gottes geschehe», which in English means "God's will be done.«

Occasional Table

with two sheets of glass held by a brass frame

Philippe-Joseph Brocard, Paris
Opaque glass.
Enamel painting in blue, light blue, white, red, green.
On the edge of the lower sheet, signature in red lettering: Brocard 1876 achat.
Total height: 78.0 cm.
(Inventory No. J 350)

Each of the two sheets with a curved twelve-lobed outline is decorated with a ring of medallions, consisting of eight circular forms, with two different types of patterns alternating with each other. In the middle of each sheet, parallel to the outline of the sheet, there is a curved twelve-lobed cartouche filled with arabesques.
The ornamentation elements of abstract plant motifs, which appear to be Arabic, are situated within a style of decoration which is selected from motifs of Ottoman Iznik ceramics of the 9th/15th-10th/16th centuries. The most striking elements of this decorative composition are the various fanciful flowers which grow on swinging stems with rich foliage. Parts of the foliage are leaves corresponding to the Ottoman sāz motif.
This unusual table, for which so far no comparable specimens are known, shows how large the variety of forms was which Brocard could supply to his customers.

Cylindrical Jug
with Handle

J. & L. Lobmeyr, Vienna, around 1875
Free-blown, colourless glass.
Gold coating, enamel painting in blue, white.
On the base Lobmeyr monogram
in white enamel paint.
Height: 15.0 cm
(Inventory No. J 351)

The jug follows a form which had been developed since the 16th century in German-speaking areas and is called a ‹Humpen›, i.e. tankard.[1] The ornamentation in the lower part of the jug consists of multi-lobed arches filled with floral elements. Although the jug reveals its origin in the period of historicism, it draws attention to the possibilities that existed to deviate from exuberant ornamentation and to decorate very plainly.[2]

[1] cf. Hugh Tait, *European: Middle Ages to 1862*, in: Masterpieces of Glass, London: British Museum 1968, pp. 127–192, esp. pp. 160, 167.
[2] cf. B. Mundt, *Kunsthandwerk und Industrie im Zeitalter der Weltausstellungen*, op. cit., no pagination, New Renaissance.

Vase

J. & L. Lobmeyr, Vienna, design ca. 1880
Colourless glass.
Gold painting, enamel painting in light blue and ultramarine, white.
On the base Lobmeyr monogram in white enamel paint.
Height: 23.0 cm.
(Inventory No. J 352)

The vase with retracted foot, protruding body and funnel-shaped neck is decorated with a combination of motifs of varying provenance. The body of the vase and the neck are covered with a composition of multi-lobed medallions into which quatrefoils are inserted that are open at the lower part. Four bands of ornamentation encircle the vase. The friezes on the foot of the vase and on the transitional zone from body to neck are antique geometrical motifs: on the foot, intersecting hexagons which are open on the top and into which two gable forms are inserted. On the neck a meandering motif was added. The frieze on the body of the vase shows a tendril with bifurcating leaves, on the neck there is a frieze of similar tendrils. The motifs of this vase are such that could be copied from pattern books. Each motif leads a life of its own, there is no connection between the different registers of patterns. Thus there is no unified concept for the entire vase.

Bowl

Probably J. & L. Lobmeyr,
Vienna, ca.1880, not signed.
Freely blown, colourless glass.
Gold painting, enamel painting
in blue and white.
Height: 10.0 cm;
diameter of the drinking bowl: 10.5 cm.
(Inventory No. J 353)

The shape starts with a wide foot from which a short broad tube rises. Directly under the bowl a profile ring divides the tube, which terminates on the top in a ṭat drinking bowl. The ornamentation of the glass is formed by brown tendrils reminiscent of lustre. The drinking bowl appears as if it was held by a wreath of blue stick-like pattern segments.

The most striking feature of this glass is the verse executed in attractive calligraphy within the two rectangular narrow script friezes (see illustration, second half of the verse). It is the oft-quoted verse from the beginning of a ghazal (*ġazal*) by the Persian poet Ḥāfiz of Šīrāz (d. 792/1390 or 791) which runs in translation thus: «Inspire, cup-bearer, our goblet with the light of wine. Sing, singer: ‹The affairs of the world run according to our wishes›».

Pitcher with two glasses

J. & L. Lobmeyr, Vienna, ca. 1885
Free-blown, medium blue glass.
Incised, gold and silver ornamentation.
On the base incised Lobmeyr monogram.
Height: pitcher: 26 cm; beaker: 10.5 cm.
(Inventory Nos. J 354-1, 354-2, 354-3)

The glassware described here was produced in differently coloured varieties of glass. Glassware in the colours medium blue, yellowish and green are known.
The ornamentation shows upright branches of blossoms in Ṭelds separated by bars. On the pitcher the branches of blossoms grow out of a shrub created by bands. On the beakers the ornamentation is enclosed above and below by decorative strips that go around. On the pitcher these decorative bands run across the foot, above the plant ornamentation on the body as well as on the neck of the vessel.
Glassware like this was also sold in various Oriental countries or presented as diplomatic gifts. We know, for example, of a gift by the firm to the Ottoman Sultan ʿAbdülḥamīd II (r. 1293/1876-1327/1909).[1]

J. & L. Lobmeyr, Vienne, dessin vers 1875

[1] cf. Göksen Sonat, *Bohemian Glassware*, in: Antika (Istanbul) 2/1985/8–10, esp. p. 10.

Vase and Pitcher

with Gold Net Ornamentation

J. & L. Lobmeyr, Vienna, design ca. 1875.
Slightly iridescent, colourless glass,
blown in gold net.
On the base Lobmeyr monogram in gold.

Vase: Height: 14.5 cm.
(Inventory No. J 356)

Pitcher: Height: 29.5 cm.
(Inventory No. J 355)

A bulbous bowl-like body is set up on the retracted and ascending foot of the vase. The short neck terminates in a wide-swinging brim.
In the upper part, the vase is decorated with a gold net with stylized tassel trimmings which give the appearance as if the net was thrown over the body of the vase.
At the upper end a decorative band is formed by a row of compressed circles put together. The foot is decorated by a band of intersecting oval forms. In literature, glassware decorated like this is assigned to the style of Neo-Renaissance. In comparison to similarly decorated glassware of the Lobmeyr Ṭrm, this vase is attractive due to the economy and the stylized elements of ornamentation.[1]
The pitcher belongs to the same series.

[1] W. Neuwirth, *Lobmeyr*, op. cit., p. 377, illustrates examples of the series «brown, green striped with enamel net blown in». Here the tassels of the trimmings are still three–dimensional.

Pair of Matching Vases

J. & L. Lobmeyr, Vienna, end of the 19th c.
Matt glass.
Gold painting, coloured enamel painting.
On the base Lobmeyr monogram
in white enamel paint.
Height: 42.0 cm.
(Inventory Nos. J 357-1, 357-2)

In their basic form the vases correspond to the long-necked vases known from the China of the 18th and 19th centuries.[1] The specimens discussed here consist of a slightly oval body set up on a foot ring. A perfectly circular neck rises vertically from the body of the vase. The foot of the vase is decorated with a band of swirling motifs. Inside this band there is a motif reminiscent of East Asian scripts. The swaying floral decoration on the body consists of small irregularly swirling blossoms on stems with circular leaf formations. The blossoms painted on the vase have slightly curved tips. The neck is adorned with motifs that rise like columns and are juxtaposed geometrically. The motifs seem to be inspired by the East Asian art which reached the European and North American market after the opening up of some Japanese ports after 1854. For this reason in 1867 Owen Jones published a supplementary volume[2] to his *Grammar of Ornament* of 1856 and consequently revised his earlier rejection of East Asian art.
A narrow band of diagonally positioned motifs of bifurcating leaves goes around the upper end of the neck. The individual sections of the vase are separated by five gold bands. Because of these gold bands the tectonics of the vase are completely thrown out of balance. The enamel colours are not painted thickly in a single shade as in other Lobmeyr glassware, but are partially shaded in an artistic manner.

The ornamentation of these vases is composed of elements of Islamic motifs (at the rim of the neck) and of East Asian motifs. Although their prototypes continue to exist, pieces of glassware like these with their decorations are very close to art nouveau. They are an example of the fact that designers continued to develop their own decorations on the basis of prototypes they had once seen, and now created new types of ornamentation. The ornamentation on the body comes close to the linear swinging floral ornamentation of art nouveau, and the geometrically abstract motifs of the neck of the vase come close to the purist variations of art nouveau ornamentation. Thus the vases show the path traversed by Lobmeyr's into modern times.

[1] cf. Donald B. Harden, *Masterpieces of Glass*, London 1968, No. 169.
[2] Owen Jones, *Examples of Chinese Ornament selected from Objects in the South Kensington Museum and other Collections*, London 1867.

Illustration from N. Atasoy and J. Raby, *Iznik*, op. cit., Nos. 404 and 255.

Plate

Théodore Deck, Paris, ca. 1860/65
Fritware.
Polychrome painting under glaze.
On the back engraved signature TH
• Deck •
Diameter: 30.5 cm.
(Inventory No. J 358)

The plate was created by Deck in the style of Ottoman Iznik ceramics; he follows examples as they were produced around 970/1560.[1] In the 19th century, examples of these ceramics were much sought-after objects of collections because of their well-balanced ornamentation and their perfect technique of glazing. The ornament field in the mirror of the plate is framed by a decorative band on the rim of the plate. The majority of Ottoman plates and bowls also have ornaments around the rims for the enrichment of the decoration. With its extreme stylization, the ornamentation on this part of the plate created by Deck does not correspond to Ottoman prototypes.[2] Here Deck tried to introduce innovative elements.

Further objects of the Ṭrm in other collections: Ceramics by Théodore Deck in Ottoman style are to be found in many collections in Europe. In Germany important specimens are preserved in Berlin (Kunstgewerbemuseum) and Cologne (Museum für Angewandte Kunst).

[1] cf. plate of the Ex-Adda collection in Rackham. Illustration in: N. Atasoy and J. Raby, *The Pottery of Ottoman Turkey*, op. cit., illustration 404.

[2] cf. the examples in N. Atasoy and J. Raby, op. cit., passim.

Flat square Bowl with retracted corners

Théodore Deck, Paris, ca. 1870
Fritware.
Polychrome painting in blue, red, blue-green, green, purple, black under the glaze.
On the base a red stamp mark TH • Deck •, a relief mark with the portrait of the producer after a design by Fr. Levillain[1] with slightly elevated contour lines, as well as a motif of a dot and a formation of three smaller dots.
Size: 21.5 × 21.5 cm.
(Inventory No. J 359)

The composition is put together from elements of decoration of Turkish Iznik ceramics of the 10th/16th century without directly copying any specific prototype. Instead, Deck put together his own combination of popular motifs of Iznik ceramics here. For his bowl he chose a composition of tulips, carnations, plum blossoms and a flower with six parts that cannot be identified more closely. Against this motif a circular rosette blossom is placed in the centre. The flower shrub follows the Ottoman typology. There too intersections of individual elements of ornamentation occurred somewhat arbitrarily.[2]
The shape of the bowl is unusual in Islamic art and leads us to assume that it was inspired by East Asian art. Because of the square shape the bowl could also be compared with tiles. However, in Ottoman tile ceramics, ornamentation which is complete in itself is unusual because the individual tiles were mostly part of a larger system of ornamentation.
On the whole the bowl with its composition consisting of diverse styles can be rated as a typical example of European historicism of the 19th century, where Deck demonstrates his familiarity with different types of non-European styles.

Further objects of the firm in other collections: ceramics by Théodore Deck with ornamentation derived from Ottoman art are to be found in a number of collections in Europe.
Until now a specimen comparable in shape is unknown. We know, however, that Deck produced wall plates and other decorative ceramics in very diverse styles and shapes.[3]

[1] At some unknown period, Ferdinand Levillain was among the staff of Th. Deck's studio (see Sandor Kuthy, *Albert Anker. Fayencen in Zusammenarbeit mit Théodore Deck*, Zürich 1985, p. 23).

[2] cf. Paris, Louvre, Inventory No. 6643 (illustration 363 in: N. Atasoy and J. Raby, *The Pottery of Ottoman Turkey*, op. cit.).
[3] cf. wall plate in East Asian style, collection Heuser, Hamburg, Munich 1974, Cat. No. 30.

Field of tiles
of four tiles
in a frame
of more recent times

Minton, Hollins and Co.
Stoke on Trent
Pressed clay.
Colours of the glaze in red, blue, yellow, reddish brown, pink, bluish green, leaf-green on white.
On the back pressed-in stamp:
Minton, Hollins & Co.
Patent Tile Works,
Stoke on Trent.
Each tile 20.0 × 20.0 cm.
(Inventory No. J 360)

The field consists of four square tiles. Apparently, the ornamentation follows models from the Islamic world. By the plasticity of the leaves and flowers and also by the strong colours the tiles clearly show their European provenance.
The division of the surface consists of two pointed oval systems of patterns which are filled with palmette and lotus flowers, rosettes and lancet leaves. Although details of the ornamentation are reminiscent of Ottoman and Mughal Indian types of the 10th /16th and the 11th/17th centuries, this new creation is nevertheless successful because of the free treatment of the sources of inspiration and above all because of a totally individual palette of colours.[1]
The design of the tiles could neither be traced within the large archival material of Minton's at Stoke on Trent among the preliminary sketches, nor could it be identified in the sales catalogues preserved. Since the new concept of ornamentation is so successful, it is possible to classify it as an early work by Christopher Dresser when he worked as a designer for Minton's. In his designs Dresser translated the Oriental models into very stylized forms. The example discussed here combines prototypes from Ottoman and Indian art into a unified surface design. The colour design of the tiles is very close to the Mughal Indian examples, and shows how well acquainted English artists and art historians were with the art of that part of the Islamic world. The example from Minton's is a pastiche of different artistic styles of the Islamic world.

Comparable examples from other collections:
Stoke on Trent, City Museum, Inventory No. 54 P 1954 and Stoke on Trent, archive and museum of Minton's, without Inventory No. The tile has the same decoration but is executed in a different combination of colours.

[1] Examples of Turkish and Indian art were known to 19th century designers from the above–mentioned (p. 177) pattern books by Jones, Racinet, Collinot/Beaumont, Prisse d'Avennes and Parvillée. However, many of them had also travelled in the Islamic world.

Two Flat Bowls

with a broad, flattened rim

Théodore Deck, Paris, ca. 1865
Fritware. Polychrome painting under the glaze.
Flat relief ornamentation in the central circular field, three surrounding decorative bands.

1. In dark and light blue, dark purple, red and honey-coloured, two white bands to separate the patterns. On the back an unstructured pattern of lines in the same colours as in the front. Diameter: 22.0 cm. (Inventory No. J 361)

2. In dark and light blue, two white bands to separate the patterns.
Monochrome back. Diameter: 21.5 cm.
(Inventory No. J 362)

On the base of both pieces the stamp mark THD in dark purple, the letters joined together.
In the ornamentation of the bowls different elements of Mamlūk art of Egypt from the time around 665/1265 were combined with one another. But the band with a free-standing motif of ornamentation on the outer rim was probably an invention of the workshop of Théodore Deck: a leaf is tied in such a way that it can be depicted as standing freely on the stem.
The main element of the plate is a script band in *Nasḫī* style. Here the name of the Mamlūk Sultan as-Sulṭān al-Malik aẓ-Ẓāhir (Baibars, ruled 658/1260-676/1277) is mentioned twice each with the addition «the righteous one, the fighter for the faith», before the inscription concludes in a jumble of letters without any meaning. It seems as if the Deck studio worked on the basis of specific models or illustrations from pattern books. Since until 1865 only the first edition of the work by Beaumont and Collinot was published[1] and since the model for the piece by Deck does not agree with the examples in this work, it is possible that Deck may have worked with originals, in any case he did not work on the basis of this pattern book.[2] In the centre of the plate, in a circular field, there is a tendril made up of vine leaves and grapes. Into the centre of this tendril a free-standing swirling rosette was incorporated.
Between the script band and the vine creeper, bands of single leaves were inserted. These leaves are also known from the repertoire of Mamlūk ornamentation, but here they are stylized.
Since Deck's studio also produced samples for the ornamentation and the colour scheme, we may assume that these specimens were such didactic pieces, because of the differing colour scheme.

Comparable piece in other museums:
An identical piece in dark blue and white is to be found in Guebwiller, Musée Florial.

[1] A. Beaumont and E. V. Collinot, *Recueil de dessins pour l'art et l'industrie*, Paris 1859.
[2] The author wishes to thank Stefan Heidemann, Chair of Semitic Philology and Islamic Sciences, University of Jena, for the evaluation of the inscription.

Vase
in the shape of a Persian or a Syrian Ewer

De Porceleyne Fles, Delft (Netherlands), after 1910
Earthenware, lustre ornamentation
(Nieuw Delfts Luster), under glaze colours in white, turquoise. On the base signature in blue and the trademark of the firm in the form of a bottle without spout, under a line: Delft.
Height: 15.0 cm.
(Inventory No. J 363)

In shape and colours, the vase follows Iranian ceramics of the 6th/12th-7th/13th centuries. The spout matches that of a pitcher from the 6th/12th century from Kāšān (Iran).[1] At that time in Kāšān and in other cities of Iran a large number of new ceramic technologies and shapes for vessels were developed, but despite the variety of Iranian vessels of that period no exact parallel piece could be located. It is to be assumed that the designers of the firm of De Porceleyne Fles developed their own decoration from many study objects.

Further pieces of the firm in other collections:
The Hague, Gemeentemuseum (various pieces).
Museum of the firm of De Porcelyne Fles, Delft (various pieces).
Illustrations in Herboren Oriënt. *Islamitischen Nieuw Delfts Aardewerk*, The Hague 1984, passim.

[1] Cf. pitcher, Washington, D. C., Freer Gallery of Art, Inventory No. 09.370 (illustration in: Richard Ettinghausen, *Medieval Near Eastern Ceramics in the Freer Gallery of Art*, Washington 1960, illustration 21 and E. Atil, *Ceramics of the World of Islam*, op. cit., No. 32).

Vase
in the form of a water basin

Clément Massier, Golfe-Juan (near Cannes)
Fritware.
Lustre glaze over an ochre coloured engobe, having a similar lustre glaze.
On the base signature in lustre:
C. M. Golfe Juan A. M. [=Al maritimes] France 1892.
Height: 23.0 cm; diameter 38.0 cm.
(Inventory No. J 364)

The shape of the vase can be derived from the inlaid water basins produced in Iran and Egypt from the 7th/ 13th to the early 9th /15th century.[1] Massier alters the shape in such a way that it looks altogether more elegant, and he achieves a more unified concept of the shape.

The decoration consists of elements that come close to the characters of Arabic script but they do not result in a legible text; rather, the characters give the impression of fragments of words and characters poured onto the vase. Because of the employment of Arabic script, an orientalised ornamentation emerges, which, however, reveals by its completely free use of the prototype models the possibilities for the development of a modern style of ornamentation. Arabic script now became the basis for abstract motifs of ornamentation. The encounter with Arabic script was also made use of by painters of the early 20th century for alienation effects.[2]
The technique of glazing with its combination of lustre applied in two layers had been employed by Massier since the World Exhibition of 1889.[3]

Items of the firm in other collections: Lustre technique: Berlin, Bröhanmuseum, Cat. No. 469 (Karl H. Bröhan, Kunst der Jahrhundertwende und der zwanziger Jahre. *Sammlung Karl H. Bröhan*, Berlin, vol. 2, part 1, Berlin 1976); Collection Heuser, Cat. No. 101 (*Sammlung Heuser* 1976); Oriental Ornamentation: *Sammlung Giorgio Silzer*, Cologne 1976, Illustration 273.

[1] Examples: Egypt, 1290–1310: Paris, Musée du Louvre, Inventory No. 331. In the 19th century in the collection Vasselot, Paris, illustration in: E. Atil, *Renaissance of Islam*, op. cit., p. 74 ff.; Iran, early 15th century: London, Victoria & Albert Museum, Inventory No. 1872–1874, purchased in 1874 from a private collector in London, illustration in: Assadullah Melikian–Chirvani, *Islamic Metalwork from the Iranian World, 8th–18th Century*, London 1982, p. 334.

[2] Artists who converted Arabic script into abstract pictorial idiom are, for example, Paul Klee and Wassily Kandinsky. Cf. Horst Ludwig, *Aspekte zur orientalischen Ornamentik und zur Kunst des 20. Jahrhunderts*, in: Weltkulturen und moderne Kunst, Munich 1972, pp. 122–138, esp. pp. 125–29. Ernst–Gerhard Güse (ed.) *Die Tunisreise*. Klee – Macke – Moilliet, Stuttgart 1982.
[3] K. H. Bröhan, *Kunst der Jahrhundertwende*, op. cit., p. 334.

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III. Titles of Books