THE ISTANBUL MUSEUM FOR THE HISTORY OF SCIENCE AND TECHNOLOGY IN ISLAM

Prof. Dr.
FUAT SEZGİN







Dedicated to Memory of Fuat Sezgin

PROF. DR. FUAT SEZGİN İSLAM BİLİM TARİHİ ARAŞTIRMALARI VAKFI

TÜBA
Türkiye Bilimler Akademisi
Turkish Academy of Sciences

The Istanbul Museum for the History of Science and Technology in Islam



An Overview

Ankara 2024

TÜBA
Türkiye Bilimler Akademisi
Turkish Academy of Sciences

The Istanbul Museum for the History of Science and Technology in Islam

Prof. Dr. Fuat Sezgin

Turkish Academy of Sciences©
Science and Thought Series: 56
Ankara, 2024

ISBN 978-625-8352-94-8
DOI: 10.53478/TUBA.978-625-8352-94-8

This Edition: Turkish Academy of Sciences, 2024.
Vedat Dalokay Cad. No: 112 Çankaya 06670 Ankara
Tel: 0312 442 29 03 Fax: 0312 442 23 58

www.tuba.gov.tr
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Sezgin, Fuat
The Istanbul Museum for the History of Science and Technology in Islam : an overview / Fuat Sezgin. -- 3. ed. -- Ankara : Turkish Academy of Sciences, 2024.

228 s. : res. ; 19 x 27 cm. – (Science and Thought Series: 56)
ISBN 978-625-8352-94-8
1.Science —Turkey -- History. 2. Bilim — Türkiye -- Tarih. 3. Technology – Turkey – History. 4. Teknoloji — Türkiye — Tarih. 5. Technology -- Islamıc countries – History. 6. Teknoloji -- İslam ülkeleri – Tarih. 6. Science--Islamic countries—History. 7. Bilim--İslam ülkeleri—Tarih.

Q127.T9 S49 2024
509.17671

First Edition: Institut für Geschichte der Arabisch–Islamischen Wissenschaften an der Johann Wolfgang Goethe-Universität Frankfurt am Main, 2010
Second Edition: İstanbul Metropolitan Municipolity, 2010

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Third Edition, 1000 pcs.
Date of Printing: 2024
Place of Printing: Yenifikir Matbaa, Ankara-TÜRKİYE

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Foreword

Civilization is humanity's collective legacy. While Europe has long depicted the Middle Ages as a universal "thousand years of darkness," recent studies reveal that the Islamic world was experiencing a significant enlightenment, marked by advancements in science and intellect. This Islamic enlightenment significantly influenced Europe's intellectual revival and helped catalyze the Renaissance and Reformation. These contributions have challenged the traditional Eurocentric view of scientific history, highlighting the need to acknowledge diverse perspectives in the history of science. Understanding these contributions from the Islamic world is essential for a more inclusive and accurate portrayal of global intellectual heritage.

The late Prof. Fuat Sezgin, an honorary member of the Turkish Academy of Sciences (TÜBA), dedicated his career to highlighting the significant impact of Islamic civilization on Western development. His work, including seminal texts such as "Science and Technique in Islam," originally written in German and later translated into Turkish under the auspices of TÜBA, emphasized the depth of Islamic contributions to science. Prof. Sezgin's efforts culminated in the opening of the "History of Islamic Science and Technology Museum" in Istanbul's Gülhane Park in 2008. The museum, which features approximately 600 tools, device replicas, and models, serves as a testament to the enduring scientific legacy of Islamic scholars and the broader importance of acknowledging all contributions to the history of science.

This publication, derived from Prof. Sezgin's seminal "Science and Technology in Islam," includes detailed drawings and photographs of instruments housed in the museum, emphasizing the historical significance of these artifacts. The museum and its associated library underscore the concrete contributions of the collaboration between TÜBA and İBTAV to the scientific community. It is both meaningful and valuable that the library and museum, which host the works, scientific tools and the book archive of Professor Sezgin, -a figure celebrated for his valuable contributions to the history of science, is located in a historically rich place that is Gülhane Park, which is situated within Topkapı Palace. We are proud to present this scholarly work and commemorate Prof. Fuat Sezgin with deep respect.

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Board of Trustees of İBTAV

Prof. Dr. Muzaffer ŞEKER
President
Turkish Academy of Sciences

TÜBA
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❧ *Preface*

The catalogue of the Museum of the Institute for the History of Arabic-Islamic Science at the Johann Wolfgang Goethe University, Frankfurt am Main, which is the mother of the Istanbul Museum for the History of Science and Technology in Islam, was completed and published in five volumes in January 2003 under the title *Wissenschaft und Technik im Islam*. The French translation of the catalogue came out in 2005; it was prepared for an exhibition planned for the year 2006 at the Palais de la Découverte at Paris. The first volume of the Arabic translation was published in 2007 and the second volume will appear in print shortly. The Turkish translation of the catalogue was prepared by the Turkish Academy of Science and was published in collaboration with the Ministry of Culture and Tourism in 2007. A reprint was brought out by the Department of Culture of the Istanbul City Administration in 2008. I hope the English translation of the catalogue, prepared at the Frankfurt Institute, will be ready for the press in a few months.

The present Short Overview, which is printed separately in five editions (Turkish, English, German, French and Arabic), was compiled out of extracts from the large catalogue, as a handy guide for the visitors to the museum. It does not, however, contain the dates of origin of the apparatuses and instruments, their method of function and the bibliographic references; such information is available in the above-mentioned catalogue in five volumes.

The first volume of the large catalogue consists of an "Introduction to the History of the Arabic-Islamic Sciences" and aims to provide an adequate idea of the importance of these sciences in the general history of science.

Frankfurt, 8 July 2009 — Fuat Sezgin

❧ *Prof. Mehmet Fuat Sezgin* [1] *(1924-2018)*

Prof. Mehmet Fuat Sezgin, Honorary Member of the Turkish Academy of Sciences (TÜBA), was born on October 24, 1924 in the Kızıl Mescit district of Bitlis. His father Mirza Mehmet Efendi, who served as the Mufti of Doğubeyazıt, and his mother Cemile Hanım, Sezgin's ancestry goes back to the Shirvan beys who served the Ottoman Empire for centuries and whose origins go back to the Hasankeyf branch of the Ayyubids. Sezgin, whose father passed away in 1943 and mother in 1976, had four siblings, Süphiye, Mehmet Servet, Meliha and Refet.

Sezgin started his education in 1936 in Doğubeyazıt and upon his father's death, he completed secondary school in a boarding school with a scholarship in Bitlis. He then continued his high school education, again with scholarship and boarding, in Erzurum in the science department. In 1943, Sezgin, who came to Istanbul with the intention of becoming an engineer, attended the seminar of the German orientalist Hellmut Ritter (1892-1971) and this experience influenced his life. As a matter of fact, he decided to leave his engineering dreams aside and become Ritter's student. Despite the difficulties and Ritter's discipline, he enrolled at Istanbul University's Institute of Oriental Studies and began his undergraduate studies in Arabic and Persian Philology at the Faculty of Literature.

Although Türkiye had not participated in the World War II, the effects of the war had reached Türkiye. When education was temporarily suspended at Turkish universities in 1943, Sezgin used this period to compare the difficult Arabic commentary on the Qur'an by the Islamic scholar Jarîr al-Tabari with Turkish translations. After six months, Sezgin was able to read al-Tabari's commentary with ease. Ritter advised Sezgin, who had a natural talent for language learning, to learn a new language every year, and Sezgin continued this disciplined study throughout his life.

In 1945, when Sezgin started his third year at the university, he enrolled in the undergraduate programs in Arabic Philology with a thesis as well as Old and New Turkish Literature and French Literature without a thesis. When Ritter noticed Sezgin's dedication

1 Retrieved from https://fse.fsm.edu.tr/Prof-Dr-Fuat-Sezgin-Islam-Bilim-Tarihi-Enstitusu-Enstitu-Hakkinda--Fuat-Sezgin-Kimdir- and Şeyma Nur Ünal. "Prof. Dr. Mehmet Fuat Sezgin's Contribution to Arab-Islamic Literature". Unpublished Master's Thesis, Ankara University, 2020.

and determination to scholarly work, he encouraged him to study manuscripts in libraries. These studies gave Sezgin the opportunity to identify the deficiencies in the studies on the history of Islamic science. Especially after reading Carl Brockelmann's Geschichte der Arabischen Litteratur (History of Arabic Literature), he felt the need to complete the missing aspects of the work, and his teacher Ritter accompanied him in this regard. While he was still a student, Sezgin began to collect sources for his research topics in this field, and this is where his project, Geschichtedesarabischen Schrifttums shortened as GAS (History of Arabic-Islamic Sciences), began to take shape.

Fuat Sezgin graduated from the Department of Arabic and Persian Philology at Istanbul University's Faculty of Literature in 1947. For his graduation thesis, he wrote a study on the development of the art of eloquence in classical Islamic civilization, entitled "Bedî' İlminin Tekâmülü ve İstanbul'da Bulunan Bedî'iyyat Yazmalar Kataloğu". In October of the same year, he started his doctoral studies under the supervision of Hellmut Ritter and focused on the Arabic language and on the *Mecâzü'l-Kur'ân* of tafsir scholar Abu Ubaydah Ma'mar ibn al-Muthanna al-Taymi'. This study focused on the figurative expressions used in the Qur'an and he completed his doctoral thesis in 1950. During this period, Sezgin worked at the Istanbul University Library and in the same year he started working as an assistant at Ankara University Faculty of Theology.

He worked as an assistant at Ankara University Faculty of Theology, Department of Basic Islamic Sciences, where Prof. Muhammet Tayyib Okiç was a faculty member, between 1950 and 1953. While continuing his assistantship, he stayed in Cairo for a while to publish his work titled "Mecâzü'l-Kur'ân". He served his military service as a sub-lieutenant between 1951 and 1952. In 1953, he left his assistant position and returned to Istanbul University and on February 28, 1953, he started to work as an assistant in the General Turkish History Chair headed by Prof. Zeki Veli Togan. During this time, he discovered that some parts of al-Bukhārī's book of hadith contained quotations from *Mecâzü'l-Kur'ân*. Sezgin's discovery proved that the common belief that hadith books were based solely on oral tradition was wrong. As a matter of fact, Sezgin, together with Tayyib Okiç at Ankara University, where he worked as an assistant, chose the subject of "Nassların Tedvini" as his associate professorship thesis and this study was published in 1956 under the title "Buhari'nin Kaynakları Hakkında Araştırma".

In 1955, he was appointed as an associate professor at the Institute of Islamic Studies, where he served as the deputy director of the institute.

In 1957, he won a scholarship from the Alexander von Humboldt Foundation and spent 1957-58 as a visiting associate professor in Germany to deepen his scientific research and improve his German. In 1960, as a result of the military coup d'état in Türkiye, Prof. Sezgin was included in the list of 147 academics who were expelled from universities, and after this event, he had to continue his studies outside Türkiye. Prof. Sezgin wrote letters to universities in the United States and Germany, inquiring about the possibility of working at universities in these countries, and received acceptance from Frankfurt, Berkeley and Yale universities and preferred Frankfurt University.

At Frankfurt University, Fuat Sezgin focused on the history of Arab-Islamic natural sciences. A decision taken in 1962 allowed him to return to his post at Istanbul University,

and although he resumed his post in 1964, he resigned soon afterward and returned to Frankfurt University, ending his academic life in Türkiye for good. In 1965, he completed his habilitation thesis on Jabir ibn Hayyan at the Institute for the History of Natural Sciences at the University of Frankfurt, and the following year he was awarded a professorship in the history of science. In 1967, he published the first volume of his comprehensive and pioneering series on the History of Arabic-Islamic Sciences, *Geschichte des Arabischen Schrifttums*, as a result of his work on improving Carl Brockelmann's *Geschichte der Arabischen Litteratur*, which he had begun as a student. This 17-volume work covers fields as diverse as the Qur'an, hadith, history, fiqh, theology, mysticism, poetry, medicine, pharmacology, zoology, veterinary medicine, alchemy, chemistry, botany, agriculture, mathematics, astronomy, astrology, meteorology and grammar. In his evaluation of Sezgin's work, Hellmut Ritter congratulated his student, stating that such a profound work had not been done before and would not be done again. Fuat Sezgin was awarded the King Faisal Prize for Islamic Sciences in 1978, and after receiving this award, he founded the Institute for the History of Arabic-Islamic Sciences at Johann Wolfgang Goethe University in 1982.

The German physicist Eilhard Wiedemann, who began his studies in 1900, had made an effort to introduce the instruments of the history of Islamic science by making accurate models of them. In this process, which lasted about 30 years, he was able to complete the models of only five instruments. Aiming to do more in this field, Prof. Fuat Sezgin set out with the dream of establishing a museum in Frankfurt. Sezgin achieved great success by successfully modeling more than 700 instruments in the Museum of the History of Islamic Science, which he founded himself. The museum is also home to the History of Sciences Library, which houses a collection of 45,000 volumes of books that Sezgin collected from around the world and meticulously organized throughout his life.

Prof. Fuat Sezgin decided to open a Museum of the History of Islamic Science in Istanbul, Türkiye, similar to the one he had successfully established in Germany. His aim was to enable the Turkish people to experience in a tangible way the contributions of their own civilization and Muslim scientists to the history of science. Upon his return to Türkiye, he began work on the museum's establishment, and his long-held dream, the Museum of the History of Islamic Science and Technology, was inaugurated by Recep Tayyip Erdoğan on May 25, 2008. The museum is located in Istanbul's Gülhane Park and contains approximately 600 artifacts. These museums comprehensively showcase developments in various disciplines of the history of Islamic science and the inventions and discoveries that Muslim scientists have brought to humanity over the centuries.

In 2010, The Prof. Dr. Fuat Sezgin Institute for the History of Science İn Islam was established to support the work of Prof. Dr. Fuat Sezgin's Museum of the History of Islamic Science. Under Prof. Fuat Sezgin's leadership, the Department of History of Science was opened at Fatih Sultan Mehmet Vakıf University in 2013 and this department started to offer undergraduate, graduate and doctoral education. In 2017, Sezgin, together with his wife Dr. Ursula Sezgin, founded the Prof. Dr. Fuat Sezgin and Dr. Ursula Sezgin History of Sciences Library, which consists of 27,000 volumes, in order to contribute to the history of science studies in Türkiye. Fuat Sezgin received continuous support from his wife Dr. Ursula Sezgin during this process. In addition, Fuat Sezgin often visited the students of the History of Science Department of Fatih Sultan Mehmet Vakıf University, supported by

the foundation, emphasizing that they should maintain their commitment to the history of Islamic science and explaining the importance of their studies. He maintained his interest in the history of Islamic science and books until the last days of his life.

The Turkish Academy of Sciences, as the most important representative of science in Türkiye and its representative in the world, was one of the institutions where Prof. Fuat Sezgin gave a conference for the first time in Türkiye. On April 12, 2004, his conference titled "İslam Kültür Dünyasının Bilimler Tarihindeki Yeri" was published by TÜBA.[2] Prof. Fuat Sezgin has written a 5-volume catalog entitled "İslam'da Bilim ve Teknik" published by the Turkish Academy of Sciences. This museum catalog was published in four languages: Turkish, English, German and French. The first volume was also translated into Russian and Kyrgyz by TÜBA.[3]

According to the Presidential Circular published in the Official Gazette, 2019 was declared as the "Prof. Dr. Fuat Sezgin Yılı"(Year of Prof. Dr. Fuat Sezgin)[4] and many scientific events were organized throughout Türkiye in this year. Based on this decision, TÜBA also established the "Fuat Sezgin Awards" on behalf of Fuat Sezgin.

Prof. Fuat Sezgin married Ursula Stein, a scholar like himself, whom he met at the Frankfurt Muslim Students' Association in 1966, and they had a daughter named Hilal. Prof. Mehmet Fuat Sezgin continued his studies in Istanbul in the last years of his life and died on June 30, 2018. Sezgin, who led a life full of rare perseverance and hard work that pushed the limits of human capacity, dedicated his life to science and left behind valuable works and thoughts. Known for his contributions to the history of Islamic science and thought, Sezgin was a special personality who was followed with great interest by scientists and left an important legacy through his works.

Publications & Scientific Achievements of Prof. Fuat Sezgin

- **(1955).** "Hadith Musannafâtının Mebdei ve Ma'mer b. Rashid'in Camii", Türkiyat Mecmuası, XII, (1955): 115-134.

- **(1956).** "The Value of Narratives in Islamic History", V. Turkish History Congress, (1956): 243-252.

- **(1956).** "Research on the Sources of Bukhārī", Istanbul: İbrahim Horoz Publications, 1956; Bukhārī's Sources. Ankara: Otto Publications, 2019.

- **(1957).** "The Importance of Hadith as a Source of Islamic History". Journal of the Institute of Islamic Studies, II, (1957): 31-35.

- **(1967).** "Geschichte Des Arabischen Schrifttums" (GAS), I-IX, Leiden: Brill Publications, 1967-1984; X-XVII, Frankfurt: Institut für Geschichte der Arabisch Islamischen Wissenschaften an der Johann Wolfgang Goethe Universität Publications, 2000-2015; History of Arab-Islamic Sciences, I, Istanbul: Islamic Science History Research Foundation Publications, 2015; Tarîhu't-Turâsi'l-Arabî, X, Riyadh: Câmiatu'l-Imâm Muhammad b. Su'ûdi'l-Islamiyya Publications, 1991.

2 İslâm Kültür Dünyasının Bilimler Tarihindeki Yeri | Türkiye Bilimler Akademisi (tuba.gov.tr)

3 TÜBA'dan 6 Dilde İslam'da Bilim ve Teknik | Türkiye Bilitüba fuat sezginmler Akademisi (tuba.gov.tr)

4 20180906-6.pdf (resmigazete.gov.tr)

- **(1986).** "Bibliographie der deutschsprachigen Arabistik und Islamkunde von den Anfängen bis 1986 nebst Literatur über die arabischen Länder der Gegenwart, Bibliographie der deutschsprachigen Arabistik und Islamkunde: 1987-1994, XXI+V, Institut für Geschichte der Arabisch- Frankfurt am Main: Islamischen Wissenschaften an der Johann Wolfgang" Goethe Universität Yayınları, 1990-2001.

- **(1993).** "The Importance of Isnād in Arabic Language and Islamic Sciences". UÜİFD, V/V, (1993): 301-310.

- **(1993).** "Old Arabic poetry between authenticity and plagiarism (Authenticity)". transl. Hasan Taşdelen, UÜİFD, V/V, (1993): 311-313.

- **(1998).** "The Importance of Isnad in Arab-Islamic Science", transl. Habil Nazlıgül, EÜİFD, X, (1998): 251-263.

- **(2002).** "The Issue of the Causes of the Dulling of Islamic Civilization", transl. Dursun Hazer, HUIFD, II, (2002): 295-303.

- **(2003).** "Wissenschaft und Technik im Islam, Frankfurt: Institut für Geschichte der Arabisch-Islamischen Wissenschaften an der Johann Wolfgang Goethe-Universität Yayınları, 2003; Science and Technique in Islam", transl. Abdurrahman Aliy, Istanbul: Istanbul Metropolitan Municipality Kültür A.Ş. Publications, 2008; Science and Technique in Islam, transl. Abdurrahman Aliy, Ankara: TÜBA Publications, 2015.

Organizations Established under the Leadership of Prof. Fuat Sezgin

- Prof. Fuat Sezgin, the world's greatest historian of science, wrote the most comprehensive work on the history of Islamic science, **the 17-volume Arap-İslam Bilim Tarihi** (History of Arab-Islamic Science), the product of 65 years of work in the field of Islamic history of science. He is also a great founder who pioneered the establishment of important institutions.

- In 1982, he founded **the Institute for the History of Arabic-Islamic Sciences at Frankfurt Goethe University.**

- In 1983, he founded **the Museum of the Institute for the History of Arab-Islamic Sciences**, where more than 800 objects are on display.

- Throughout his life, he established a library with 45 thousand volumes of books and nearly 10 thousand microfilm archives, which he bought from all over the world with his own means, which is unique in the world in the field of history of sciences.

- In 2008, he founded **the Istanbul Museum of the History of Islamic Science and Technology.**

- In 2010, Prof. Fuat Sezgin established **the Foundation for Research on the History of Islamic Science.**

- In 2013, he ensured the establishment of **the Department of History of Science** at Fatih Sultan Mehmet Vakıf University.

- In 2013, he ensured the establishment of **Prof. Dr. Fuat Sezgin Institute of Islamic History of Science** within FSMVU.

- In 2015, he ensured the establishment of **Prof. Dr. Fuat Sezgin Islamic History of Science Research Foundation Publishing House.**

Awards and Memberships

- Republic of Türkiye Presidential Culture and Art Grand Prize
- Honorary Member of Turkish Academy of Sciences
- Ministry of Culture and Tourism 2016 Special Award
- Honorary Member of Cairo Academy of Arabic Language
- Honorary Member of Damascus Academy of Arabic Language
- Honorary Member of the Royal Academy of Rabat, Morocco
- Honorary Member of Baghdad Academy of Arabic Language
- German Federal Service Medal First Class
- Germany Distinguished Service Medal
- Iranian Islamic Sciences Book Prize
- Hessian Culture Award
- King Faisal Award

❧ *The Foundation of the Museum*

Shortly after the foundation of the Institute of History of Arabic-Islamic Science at the J.W. Goethe-University in Frankfurt in 1982, and in the context of that Institute, the idea emerged to reconstruct the instruments and devices which had been used in the creative period of Arabic-Islamic Science, between the beginning of the ninth and the end of the sixteenth centuries. In the course of the assimilation of science from other cultures, the Muslims adapted a series of instruments and devices, in particular from ancient Greece. Most of these instruments were further developed in the Islamic civilization, and the Muslims invented many new instruments on their own. From this very rich tradition, only a few instruments in astronomy, medicine, chemistry and time measurement have come down to us. But it is very fortunate for the history of science that many of the instruments and devices which were used by the Arabic-Islamic scientists, were described by them in numerous treatises and large works, often accompanied by detailed drawings. Some of these works have been preserved, including the large medical work *Kitāb at-Taṣrīf* of Abu l-Qāsim az-Zahrāwī (10th century CE), the *al-Jāmiʿ bain al-ʿilm wa-l-ʿamal* of Ibn ar-Razzāz al-Jazarī (1200 CE) on physics and time measurement, and the astronomical work *Jāmiʿ al-mabādiʾ wa-l-ghāyāt* von Abu l-Ḥasan al-Marrākushī (13th century CE).

Already in the nineteenth century, several orientalists have drawn attention to the importance of these works and of other treatises on instruments. The most important of them is the physicist and historian of science Eilhard Wiedemann from Erlangen, who devoted more than half a century, between 1875 and 1928, to the investigation of the Arabic-Islamic scientific achievements, and who published more than 200 articles on the subject. For me it is a very pleasant duty to mention with recognition and with gratitude that Wiedemann was the first who began, around 1900, with the reconstruction of some of the instruments that had been made by the Arabic-Islamic scientists. Five of these replicas were purchased in 1911 by the Deutsches Museum in Munich.

When I started in 1983 to reconstruct the instruments and devices which were known to me from original sources and modern studies, I was thinking of a goal

which now, in hindsight, appears to have been too modest: a collection of 20 or 30 reconstructions of instruments which have not been preserved, or which were unknown to my orientalist predecessors or had not been described by them. I had to trace them down in manuscripts and then find the persons who could rebuild them: mere patience was not enough.

Already in 2003, the crammed rooms of the Institute in Frankfurt contained a museum with 800 exhibits related to the history of science and technology in Islam. This museum has not yet been officially opened, but every year it receives several thousands of interested visitors by appointment. About 12 years ago it was stimulating and encouraging for me to experience the great interest and surprise of about 1500 persons who visited the museum on the occasion of the Day of the Open Door (Tag der Offenen Tür) of the universities in the German province of Hesse.

This museum had already become known, to some extent, when a comprehensive catalogue in five volumes was published in 2003 under the title "*Wissenschaft und Technik im Islam*" (*Science and Technology in Islam)*. The French translation appeared one year later, and since two years, a Turkish translation has also been available. The English translation will soon go to the press. The first volume of the Arabic translation has appeared two years ago; the second volume will be printed in two or three months.

I have been asked several times by institutions in other countries if the objects of our museum could be displayed for a certain period, or if a museum could be established with copies of the objects in our museum at Frankfurt. Thus, Mr. Attila Koç, the Turkish minister for culture and museums, who visited the Institute in Frankfurt in 2005, expressed his wish to found a similar museum in Istanbul. For me, this was the fulfillment of a dream, but unfortunately, the building proposed at that time appeared to be inappropriate. Similar wishes to establish a museum were expressed by the Turkish Academy of Sciences (TÜBA) and (the Turkish Association for Technology, Science and Research (TÜBITAK).

It was a great fortune when I heard, during a visit to Istanbul in September 2006, through my friend Mr. Cevdet Akçali about a historic complex of buildings in Gülhane Park, namely the Sultan's stables, the restauration of which had been nearly finished after six years of work. When I visited the place, I was fascinated by the buildings and their location. Then it was important to obtain the support of the City of Istanbul, which owns the buildings of the Sultan's stables (Has Ahırlar Binalar), for the museum. The mayor, Dr. Kadir Topbaş, was abroad at that time, but less than a week after he had been informed about the idea, he came to Frankfurt – I mention this with gratitude – in order to visit the Institute and especially the museum. A few days after his return to Istanbul, he informed me of the approval by the City, on the condition that the foundation of the museum and the installation of the instruments would be carried out as soon as possible. In January 2007, the contract for the foundation of the museum was signed. The next day I was able to visit the Turkish president, Mr. Recep Tayyip Erdoğan, who was very interested and

gave his full approval. The cabinet decided to approve the foundation of a center for the history of science in the two buildings adjacent to the museum.

By a happy coincidence we had started, 23 years earlier, with the preparations for an exhibition in the USA at the request of a generous Arab friend and with his financial support. With permission of this sponsor we could donate approximately 80 per cent of the instruments to the Istanbul Museum. The remaining part of the exhibition has been financed by the Turkish government, who never hesitated to generously allocate the necessary funds to this project.

The foundation of the museum for the history of science and technology in Islam in Istanbul and previously in Frankfurt was inspired by our conviction that the universal history of science is a united whole. With this we wish to supply a missing link in the historiography of science, namely the gap due to the incorrect notion that the European Renaissance is an immediate continuation of Greek antiquity. We want to present the original contributions of the creative scientists in the Arabic-Islamic civilization, which were made between 900 and 1600, after a period of reception and assimilation. These contributions have created the conditions for creative work in Europe from the second half of the sixteenth century onwards.

In the eighteenth century, the historiographic concept of a scientific "Renaissance" became increasingly widespread in Europe; this concept implied ignoring or rejecting the scientific contributions of the entire Middle Ages, in Europe as well as in the Islamic civilization. But at the same time, the scientific orientation of the scholars of Arabic and Islamic studies, from the seventeenth century onwards, was also beginning to bear fruits. Through the valuable work of these pioneers and their tireless successors, who increased in number in the following centuries, several important corrections were made in a few areas in the history of science. Nevertheless, even the educated people today do not know enough about the real importance of the Arabic-Islamic civilization within the universal history of science. Therefore, the common incorrect view of "Renaissance" has not been challenged.

I hope that this museum which has been founded at such a beautiful location in Istanbul will contribute to a correction of this wrong and outdated historical view.

Frankfurt/Main, 17 April 2009 Fuat Sezgin

❧ *One of the addresses delivered*
at the inauguration of the Istanbul Museum
for the History of Science and Technology in Islam
on 24 May 2008

Honorable Prime Minister, dear guests,

Ever since the appreciation of history is sufficiently developed, people began to ask themselves when and where certain type of devices and instruments were developed for the first time. For a long time, however, historiography understood its task to be the recording of primarily political, military and up to a certain degree also economic events and changes, and treated the developments in the fields of science and technology in a step-motherly manner.

It is not easy to trace the individual stages of development undergone by science and technology before the Greek period. The Greeks themselves give us hardly any clues about the predecessors of their own important stage of development of the sciences which lasted for roughly eight hundred years. The custom of citing the sources did not develop strongly enough among them.

The attitude of the modern historiography of science of the last three hundred years to regard the important position of the Greeks as the starting point has hardly experienced any significant revision despite the archeological discoveries related to the cultures of the Sumerians, Babylonians, Assyrians, Hittites, Canaanites, Aramaeans and Egyptians, and the insights gained by the decipherment of inscriptions. Little attention was paid even to the thesis postulated during almost half a century by the eminent Austrian historian of science, Otto Neugebauer, that the Greeks did not stand at the starting point of the scientific development but belonged to its middle phase, that is to say, that we should add to the 2500 years which passed since the Greeks assumed the leading role in the history of science, an earlier period of once again 2500 years for forerunners of the Greeks.

In the first half of the seventh century, after the sciences which had reached a

high standard among the Greeks had developed in a weaker form in the Eastern Mediterranean and in Sassanid Persia, Islam entered the arena of history as a force that encompassed these cultural centres. Since the representatives of those cultural centres were integrated, regardless of their belief, with great tolerance and understanding by the Muslims and were accorded the status of teachers, the sciences experienced a new impetus. In the middle of the eighth century Indian sources were added. Thus after a phase of reception and assimilation that lasted for two hundred years, the Muslims entered a period of creativity.

The Islamic world reached the phase of creativity in certain fields already in the second half of the eighth century, in certain others only towards the middle of the ninth century. This period of creativity lasted roughly eight hundred years until the end of the sixteenth century, although there was later on some decline in speed and quantity. Of its total achievements, only relatively few are known today. Instead of enumerating them one by one, we can describe their importance in the following way. The Muslims developed the sciences further which they had taken over from other cultures, particularly from the Greeks; they opened up new areas of knowledge and, during the period of their predominance, they prepared the way for some of the sciences which were to emerge in the succeeding cultural world. In this phase of the history of science which we call "great" and "creative", a not insignificant role was played by the Christian and Jewish fellow citizens who wrote in Arabic.

We are far from knowing everything or even a large part of all that was achieved in this creative phase of the history of science, and perhaps we shall never learn all of it. But that which we know already now is enough to make us realize that we encounter here one of the most significant phases of the history of science. There is no doubt that the character and nature of these achievements were influenced by factors of time and other prerequisites, and by the achievements of the predecessors and the successors. In general it is also not easy for the historian of science to define the fundamental values that characterize a significant phase of culture. For my own part, I believe to have found out in the course of time the following specific characteristics of the Islamic period of science:

1. The principle of objective criticism.
2. The notion of a clear law of development.
3. A greater readiness than in other cultures to name one's sources.
4. Historiography of sciences, beginning in the tenth century and developing further.
5. The principle of achieving a balance between the experiment and theory, and to draw upon the experiment as a resource for research, to be employed systematically.
6. The principle of long-term observation of astronomical phenomena; as a con-

sequence of it the creation of observatories.

7. Acquiring knowledge not merely from books, but from books in association with a teacher and, as a consequence of this, the emergence of the first universities.

One of the most important traces of the beginning of the history of science could be seen in the fact that since the second half of the tenth century books, instruments and medicaments from the Islamic cultural sphere reached Western Europe via Spain. Through the conquest of the Iberian peninsula in 711 the Arabs established a connection of the Islamic culture area with Europe, and thus pre-determined the future destiny of the sciences, which had been developed by them to spread out several centuries later in another culture area.

In the course of time, the number of channels connecting the two cultural spheres increased. The most important channels passed through Sicily, Italy and Byzantium. The crusades played a role primarily in the introduction of technology of the Islamic world in Europe.

The phase in which science and technology from the Islamic world reached Europe – and which consisted of the two steps of reception and assimilation – lasted for at least five hundred years. Strictly speaking, the period of creativity in Europe began only in the sixteenth century and in the second half of the same century began the stagnation of sciences in the Islamic world. Only at the beginning of the seventeenth century the Europeans reached their dominant position in sciences.

In this connection I should draw attention to a historical fact, though with some reluctance. The absorption of Arabic-Islamic sources did not take place in the Latin culture area with the same kind of openness that the Muslims had displayed towards their Greek sources. The Muslims called Aristotle the "first teacher"; what they took over from the books by Hippocrates, Galen and others, they cited with the appellation "highly esteemed Hippocrates", "highly esteemed Galen" and so on. As against this, in the case of quite a few of the Latin translations of Arabic books, even the names of the true authors were not retained. There was also practically no habit of citing the sources correctly.

As a consequence of this, Europeans in the seventeenth century were not aware of how they had reached their dominant position. Both the Europeans and the Muslims believed that this was a heritage stemming from a superior past going back several centuries. Because of this there arose among the Europeans a feeling of superiority towards the Muslims, and among the Muslims gradually a feeling of inferiority. The feeling of superiority of the Europeans found already after a short while in the eighteenth century a fixed notion in the term Renaissance which it has hardly lost until our own days. As a consequence, the new phase of sciences in Europe known since a few centuries was viewed as the new beginning which went back directly to the Greek sciences. With sincere gratitude we may recall that in

the same century a reaction emerged against this attitude which was ridiculed by the French philosopher Etienne Gilson as the "Renaissance of the Professors". This reaction, inspired by the humanistic spirit, came from scholars like the French philosopher and historian Voltaire and the Germans Johann Gottfried Herder, Johann Wolfgang von Goethe and Alexander von Humboldt.

Arising partly from these humanists, growing partly and primarily from being unaffected by the Eurocentric historiography of science, there emerged a new important humanist current. Here it was no longer a question exploring the Islamic sciences through Latin translations of Arabic, Persian and Turkish books, but through the direct study of original sources. This current emerged, though only slowly, already in the seventeenth century and gained such strength in the nineteenth century that the conservative historiography of sciences saw itself forced to make revisions in some fields. In the field of philosophy, the historian of religion and philosophy, Ernest Renan, in his book *Averroès et l'Averroïsme*, published in 1852, demonstrated unambiguously how deeply Ibn Rušd from Arabic Spain influenced philosophical thought in Western Europe and Italy. Renan's contemporary, the philosopher Heinrich Ritter, propounded the thesis that the influence of the Islamic (Arabic) sciences on Europe had been very great even outside philosophy and that the physical side of Arabic philosophy had brought about a strong change in the knowledge of the Christian Middle Ages. The Frenchman Jean-Jacques Sédillot and his son Louis-Amélie astonished their contemporary colleagues with their research spanning sixty years during which they could show a large part of the successes achieved by Muslims in the field of astronomy. At the same time Joseph-Toussaint publicized the achievements of the Islamic culture in the field of geography through his studies, lasting more than fifty years.

In the field of mathematics the young Franz Woepcke, whom Alexander von Humboldt had sent to Paris to work for his PhD under the above named scholars, forced the conservative historians of mathematics of his days to make serious revisions with his forty studies which caused a sensation. In the most popular contemporary book on the history of mathematics there was to be found, e.g., the contention that in the field of algebra the Arabs had not gone beyond the quadratic equations. With his edition and French translation of the algebra of 'Umar Khayyām of the eleventh century which contains a systematic treatment of cubic equations, Woepcke furnished a positive proof to show how unfounded the judgments were in his field.

In the second half of the nineteenth century vigorous efforts were undertaken to publicize Islamic science. Thus, for example, in the field of geography the Dutchman Michael Jan de Goeje and the German Ferdinand Wüstenfeld, in the course of their studies spanning half a century, edited the extant works of almost all important

Arabic geographers and translated certain parts into European languages. Having found a manuscript of the book by the traveller and geographer al-Maqdisī from the tenth century in India in 1864, Alois Sprenger, a contemporary of Goeje and Wüstenfeld, declared al-Maqdisī as „the greatest geographer of all times". In his subsequent studies Sprenger could easily establish that the standard which had been achieved in the human geography by the Islamic world as early as the tenth century could be reached in Europe only in the nineteenth century. Since 1875 the physicist from Erlangen, Eilhard Wiedemann, took part in the research of the history of natural sciences in Islam. With his more than 200 studies, published until 1928, this indefatigable scholar holds an immortal place in the history of science. The Islamic world cannot be thankful enough to him. We may also recall here that he was the first to reconstruct some instruments from the Islamic world. As far as I know, some of his models are preserved in the stores of the Deutsches Museum in Munich.

In their works spanning several centuries, the orientalists had produced enough convincing results to show that the Muslims hold an important position in the history of science. Even so, we are far from knowing in an adequate manner how important in fact this position was, and perhaps we will never find out. In order to proceed a step forward on the path of gathering information, we founded the Institute for the History of Arabic-Islamic Science at the Johann Wolfgang Goethe University in Frankfurt in 1982. In the course of our work arose the idea of reconstructing devices and instruments improved or newly invented by Muslims. Thus a museum was established at the institute in Frankfurt. Now we hope that many visitors will be able to see the corresponding instruments in the *Istanbul Museum for the History of Science and Technology in Islam*, which is being inaugurated today, and we believe that this is a unique place to demonstrate our basic idea that the history of science is a common heritage of all mankind.

I thank Dr. Kadir Topbaş, the Mayor of Istanbul, for the very special building which he provided for the museum. The Prime Minister, Recep Tayyip Erdoğan, took keen interest in the establishment of the museum and assured financial support to it. I should like to express my heartfelt thanks to him. I am especially grateful to the Minister of Culture and Tourism, Mr. Ertuğrul Günay, for having accompanied and supported the realization of the museum project to its final completion with infatigable interest. Finally, I wish to express my sincere thanks to Prof. Dr. Nüket Yetiş, the president of the Türkiye Bilimsel ve Teknolojik Araştırma Kurumu (TÜBITAK) and to Prof. Dr. Engin Bermek, the president of the Turkish Academy of Sciences (Türkiye Bilimler Akademisi), for their contribution to the setting up of the museum from its foundation to its inauguration.

Fuat Sezgin

❧ *The Istanbul Museum for the History of Science and Technology in Islam*

This museum is established on the basis of the firm belief that the history of science and technology represents a common heritage of mankind. The part played therein by the Islamic Culture Area is highlighted here by means of historical instruments, tools and devices. Yet one should not lose sight of the fact that Muslims did not create these from scratch, but they adopted at first the inheritance of the preceding cultures, above all, that of the Greeks and the early Byzantines, and then developed this inheritance further. To a large extent, the exhibits displayed here are original inventions from the period extending from the ninth to the sixteenth century CE, a period in which Muslims themselves were creatively active.

The exhibits were reconstructed by the *Institute for the History of Arabic–Islamic Science at the Johann Wolfgang Goethe University, Frankfurt am Main*. Most of the exhibits were prepared on the basis of illustrations and descriptions found in literary sources, and a small number were copied from original specimens that are still extant.





Panels and Objects displayed in

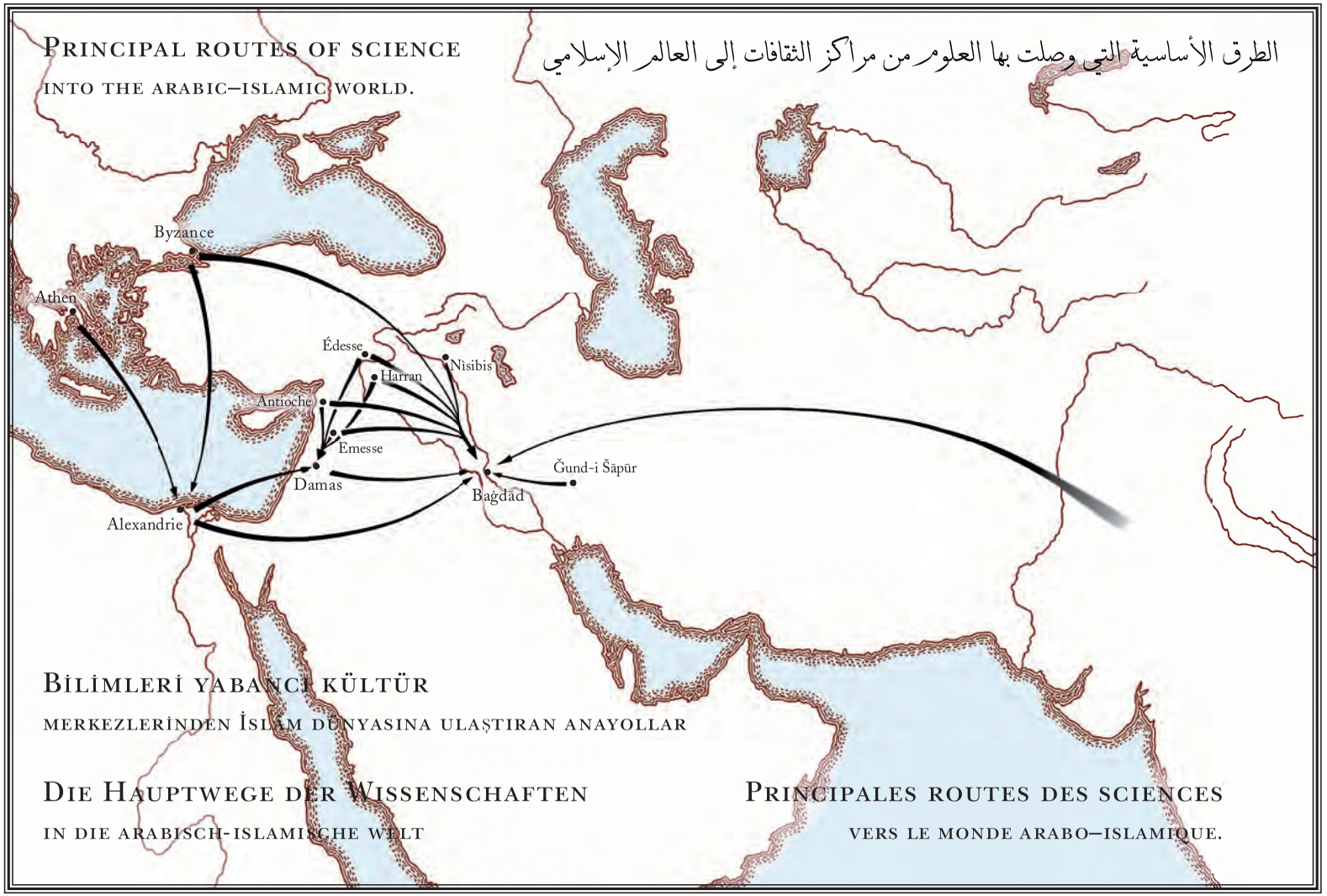
The Istanbul Museum for the History of Science and Technology in Islam

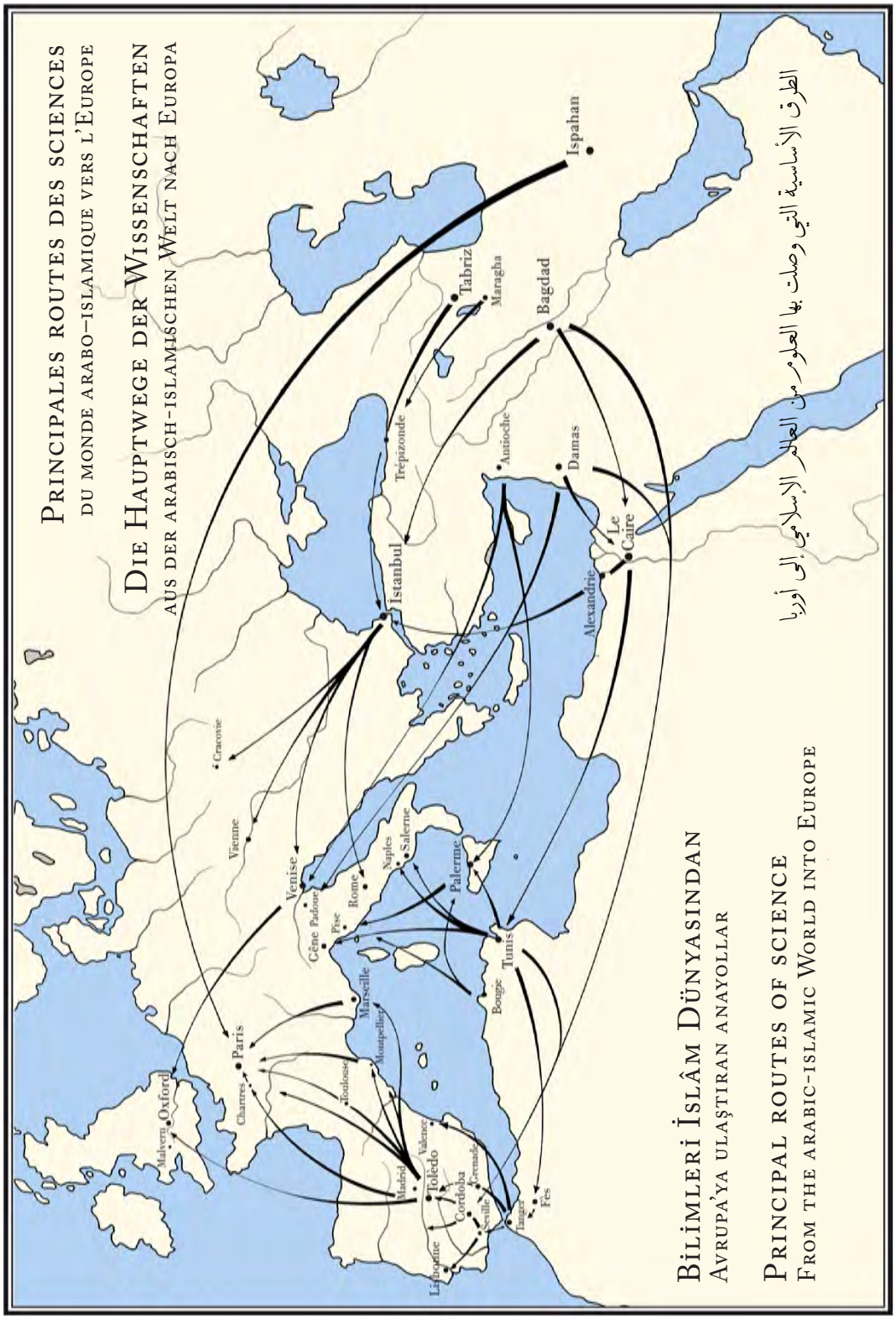
The Representation of Islamic Culture in the History of Science

In the first hundred years of their appearance in history, i.e. the 7th century CE, Muslims began – without reservation or bashfulness, keen on learning and with an insatiable appetite for knowledge – to inherit the scientific legacy of other cultures, notably the Greek. Already by the mid 9th century CE they had progressed beyond reception and assimilation towards a period of genuine creativity. What they had received they perfected to the highest degrees, creating new fields of learning and initiating the development of further disciplines. Yet like all great civilisations they also failed to escape the ultimate fate of decline, of becoming exhausted and feeble and of eventually having to pass the lead to one or several heirs. The order of succession was determined when Muslim culture spread to Spain in the year 711 CE. By the 10th century CE, when large scale translation of Arabic writings into Latin started, the ground for the education of the European heirs was prepared. In the early 16th century CE, when Muslim culture was still unequivocally dominating the sciences, their European successors entered the stage of creativity. Only one century sufficed then to make the old culture yield to the younger.

The historic relation, the actual unity of predecessor and successor, has unfortunately not yet been taken account of on either side. The grand task of disseminating this insight awaits the science–historian. The way for this has already been paved by his orientalist colleagues who tried to dispell the firmly entrenched notions left over from the 18th century CE.




Principal routes of science
into the arabic–islamic world.
الطرق الأساسية التي وصلت بها العلوم من مراكز الثقافات إلى العالم الإسلامي
Byzance
Athen
Édesse
Nisibis
Harran
Antioche
Émesse
Damas
Ğund-i Šāpūr
Bağdād
Alexandrie
Bilimleri yabancı kültür
merkezlerinden İslâm dünyasına ulaştıran anayollar
Die Hauptwege der Wissenschaften
in die arabisch-islamische welt
Principales routes des sciences
vers le monde arabo–islamique.


Principales routes des sciences
du monde arabo-islamique vers l'Europe
Die Hauptwege der Wissenschaften
aus der arabisch-islamischen Welt nach Europa
Bilimleri İslâm Dünyasından
Avrupa'ya ulaştıran anayollar
Principal routes of science
From the arabic-islamic World into Europe
الطرق الأساسية التي وصلت بها العلوم من العالم الإسلامي إلى أوربا
Ispahan
Tabriz
Maragha
Bagdad
Trépizonde
Istanbul
Antioche
Damas
Alexandrie
Le Caire
Tunis
Bougie
Palerme
Naples
Salerne
Venise
Padoue
Cêne
Pise
Rome
Vienne
Cracovie
Paris
Chartres
Oxford
Malvern
Marseille
Montpellier
Toulouse
Valence
Tolède
Madrid
Cordoba
Grenade
Séville
Lisbonne
Tanger
Fès

Muslim Scholars on Science and the scientific Method

Science is not going to yield anything unless you devote yourself completely. But even if you do devote yourself entirely, it remains uncertain whether you will get anything from it.

(an-Naẓẓām, d. ca. 840 ce)

However variable its aspects may be, the whole universe obeys a permanent law, and its elements, however variegated they may be, are governed by harmony.

(Ibn al-Haitham, d. ca. 1040 ce)

❖

It appears that with many a problem we do not possess the prerequisites to draw secure conclusions. However, in such cases, it is necessary to conclude as far as possible. It is not inconceivable that things may occur later that will ultimately lead to certainty in matters in which we cannot succeed today.

(Ibn Rušd, d. 1198 ce)

I have done what everybody should do in his profession: accept the achievements of your predecessors gratefully, don't shrink from correcting eventual blunders and bequeath, what seems worthy, to your successors and future generations.

(al-Bīrūnī, d. 1048 ce)

❖

Although Galen was the first in science to examine and be most careful and exact in what he said and reported, yet the witness of our senses is better than reading Galen.

(ʿAbdallaṭīf al-Baġdādī, d. 1231 ce)

Ibn al-Haitham's Emphasis on A critical Attitude towards the Use of the Sources

Whosoever seeks the truth will not proceed by studying the writings of his predecessors and by simply accepting his own good opinion of them. Rather, the truth-seeker will mistrust his established opinion. He will rely solely on his understanding of the texts by following the criteria of logic rather than the statements of authors who are, after all, human, with the errors and faults which this naturally involves. Whosoever studies works of science must, if he wants to find the truth, transform himself into a critic of everything he reads. He must examine texts and explanations with the greatest precision and question them from all angles and aspects. But he must also observe himself with a critical eye in this process, so that his judgement is neither too strict nor too lax. If he follows this path, the truths will reveal themselves to him and the possible inadequacies and uncertainties in the works of his predecessors will come to the fore.

(Ibn al-Haitham, d. ca. 1040 CE)

On Errors with Measuring Instruments

Since in the manufacture of measuring instruments one cannot achieve the precision one has in mind, be it with the evenness of the surfaces or with the marking of the divisions or holes at the right place, it is but natural that errors occur, as with the adjustment of the instruments. In almost every construction inaccuracies exist, whether visible ones or hidden. If the instrument is made of wood, then it will warp, particularly when it stands at a place exposed to sun and humidity. The errors are larger or smaller, according to the theoretical knowledge, craftsmanship and experience. Added to this, there is the expertise of the observer in setting up and measuring, the precision of the adjusting apparatus and much more. Whosoever believes that everybody can execute measurements on order and without previous practice, and that each measuring instrument delivers correct results, is in error. Whosoever wishes to achieve this must, first of all, spend a long time in the study of the instruments and in the practice in measuring, until finally his measurement rests on the knowledge of the precision of his instrument and on his experience in measuring.

(Ibn Yūnus, d. 1009 CE)



Al-Bīrūnī's Book on India

In the field of historiography we shall mention al-Bīrūnī's (d. 1048) book on India, which bears witness to its author's exemplary veracity, critical mind, keen observation and a remarkable cosmopolitan openness and objectivity. Al-Bīrūnī deals with the culture, religions and sciences of the Indians on the basis of his own research and observations made over many years while living in India. In the introduction, he states: "*This is not a polemical book but a plain factual report. I shall describe the theories of the Hindus as they are and in that connection mention similar theories of the Greeks in order to demonstrate the relationship between the two.*" Al- Bīrūnī's book appears to stand in the tradition of the spirit we already encounter in the early Abbasid period, the spirit which aims at getting to know foreign cultures and religions, the spirit that found expression in many travelogues, in the masterworks of al-Masʿūdī, and in al-Bīrūnī's "Chronology of Eastern People". Al-Bīrūnī's book on India marks an apex that – perhaps not only in Islamic culture – could never be surpassed.

Ibn an-Nadīm's Fihrist Historiography of Science

Among the most significant achievements of the 10th century was also a fundamental work on the history of science. It is the "Catalogue" (*Fihrist*) by Muḥammad b. Abī Yaʿqūb Isḥāq Ibn an-Nadīm (d. ca. 1010) which, under its modest title, aims to list the scientific literature of all known culture areas. Such a work on the history of science – which astonishes us with its capacity to survey the material on a broad basis and which deals with foreign cultures objectively – would be inconceivable without an older tradition that made its appearance possible. We are reasonably familiar with this tradition today. We might also think, for instance, of the works by the widely travelled encyclopaedist ʿAlī b. al-Ḥusain Masʿūdī (d. ca. 956), which can be seen as an attempt to describe all known cultures and civilizations past and present. Ibn an-Nadīm himself quite frequently offers interesting clues that help us understand how his book came about. In the second part of his 9th treatise on the cultures of India and China, he cites a passage about the religions and sects of India and their sacred places from a book written by an envoy whom the statesman Yaḥyā b. Ḫālid al-Barmakī (d. 805) had sent to India to report on its religions and to bring back medical drugs.(Catalogue I, p. 23)*

* „Catalogue" refers to the German book *Wissenschaft und Technik im Islam*, vols. 1-5, Frankfurt/Main 2003 (translation „Science and Technology in Islam" forthcoming).

The Geographer and Historian of Culture al-Masʿūdī (d. 956 CE) and the Progress of Science

"Even if our own age is inferior to that of our predecessors among the writers and is far from them, yet we do hope that we are not inferior to them in the tasks we undertake and in the goals we follow. If they have the advantage of the beginning, we have the luck of being able to use their work. Thus we have in common the ideas and the contents. A younger writer will be able to write more agreably and more thoroughly, because he has become more experienced, more discerning and more cautious against pitfalls. This explains the growth in the sciences, (which progresses) without hindrance and limitation, because a later generation discovers things which the previous generation did not find. This is expressed in the words of God when it is said: 'Above every knower there is one who knows more' (Quran XII, 76). The habit of praising the old, of extolling their books (excessively), and of decrying the present, even when there is much that is more useful and instructive in the books of the contemporaries, is but human nature."

(al-Masʿūdi, *Tanbīh*, p. 76)

Natural Sciences According to Ibn al-Haiṭam (d. around 1041)

The contemporary historian of medicine, H. Schipperges, agrees with M. Schramm "that it was indeed Ibn al-Haiṭam (d. ca. 1041) who introduced for the first time a new methodical character into the natural sciences, a methodology which clearly distinguishes him from the Greek approach and which, passing beyond the epoch of Galileo, links up with modern experimental physics".

The Importance of the Acknowledgement of the Reception of Islamic Science in the West

For the historian of medicine Schipperges "Arabism is a the phenomenon that has exerted powerful influence over the centuries and still continues to do so and without which we will not understand the configuration of the modern world".

A Debt of Gratitude

If Muslims have become aware over the last hundred and, particularly, the last fifty years of the great, nay, paramount importance of their culture in the history of sciences, they owe this to a number of orientalists who devoted their lives to the study of the natural sciences in Islam.

While great humanists like J.G. Herder (1744–1803), J.W. von Goethe (1749–1832) and Alexander von Humboldt (1769–1859) defended the view that the artificial term "renaissance"—which failed or refused to recognize the crucial contribution the Islamic culture made over a period of almost 800 years—absolutely contradicted the facts of history, a group of orientalists who will always be remembered with gratitude by Muslims made themselves heard with their investigation of Arabic sciences.

Jean-Jacques Sédillot (1777–1826) and his son Louis-Amélie Sédillot (1808–1876), Paris, who were mainly concerned with Muslim contributions to astronomy.

Joseph Reinaud (1795–1867), Paris, who worked on geography, military technology and archaeology.

Ernst Renan (1823–1892), Paris, who was an eminent contributor to the study of philosophy.

Franz Woepcke (1826–1864), a German scholar, who worked mainly in Paris and died prematurely, succeeded even in those days in establishing the vast contribution made by Muslims to the history of mathematics in his some 40 published treatises.

Eilhard Wiedemann (1852–1928), Erlangen (Germany), bequeathed a monumental body of publications—numbering almost 200—on practically all subjects of natural sciences, which Muslims will remember forever. He also gained merit as the first scientist to build models of reconstructed Islamic instruments.

Carl Schoy (1877–1925), Frankfurt, Islamic mathematics and astronomy.

Julius Ruska (1867–1949), Heidelberg, dealt with several areas of Islamic natural sciences.

Paul Kraus (1907–1946), Cairo – Paris, Islamic chemistry and alchemy.

Julius Hirschberg (1843–1925), Berlin, ophthalmology in Islam.

Alfred von Kremer (1828–1889), Vienna, cultural history of Islam.

Heinrich Suter (1848–1922), Zurich, Islamic mathematics.

Michael Jan de Goeje (1836–1909), Leyden, Islamic geography.

Carlo Alfonso Nallino (1872–1938), Turin – Naples, Islamic astronomy.

Ignatius J. Kratchkovsky (1883–1951), Petersburg, Islamic geography.

After these, some other scholars made substantial contributions in the second half of the 20th century.

Goethe encourages the Study of Islamic languages

Johann Wolfgang von Goethe (1749––1832) exppressed his admiration for the Arabic-Islamic sources known to him in the following manner:

"If we should wish to partake in those productions of the most exalted minds we would have to orientalise ourselves, as the Orient is not going to approach us. And even though translations are utterly commendable, yet it becomes clear from the aforesaid that in this particular literary tradition language as such is pivotal. Who wouldn't desire to make himself acquainted with such treasures in the original!"



Who knows himself and others
Here is rightly guided;
Orient and Occident
Are no more divided.

(J.W. von Goethe, East-West Divan)

Veneration and Promotion of Science in Islam

In 1965 Franz Rosenthal explained the motivation for the urge to acquire foreign knowledge in the following words:

"Probably neither the practical utilitarianism which made the acquaintance with medicine, alchemy and the exact sciences desirable for the Muslims, nor the theoretical utilitarianism that induced them to occupy themselves with philosophical theological questions, would have been adequate to motivate the extensive activity of translation, had not Muḥammad's religion, from the very beginning, emphasized the role of knowledge ('ilm) as the main force in religious life and thus for human life in general… Without this pivotal position of knowledge, which is characteristic of Islam and which indeed almost borders on religious reverence, the translation activity would presumably have been less scientific, less comprehensive and have been limited rather to what was absolutely necessary than was actually the case." (Catalogue, vol. I, p. 5)

The Art of Experimenting among Muslim Scholars

The fact that experiments come strongly to the forefront has also to do with the entirely different mental attitude of Muslim scholars. Quite likely Archimedes, while examining Hiero's crown, conducted experiments and other Greeks must have done the same. But Antiquity cannot offer such carefully conducted experimental work as that of Bīrūnī on specific weights …, or that of ibn al-Haitham on different types of shadows, or that of Kamāl al-Dīn on the movement of light rays in globes, where theory and experiment go hand in hand in an exemplary manner, especially in the case of ibn al-Haitham and Kamāl al-Dīn. Roger Bacon took them as role models, but did not attain their level, when he expounded his general ideas on experiments as the basis of research in the natural sciences. However, he did not substantiate this method; he merely described it systematically, although in a manner somewhat different from that of the Arabs. He certainly did not invent the experimental method just as Francis Bacon of Verulam did not invent the inductive method, even though the English would like to attribute both these methods to their compatriots.

(Eilhard Wiedemann, 1917)

al-Farghānī



Aḥmad b. Muḥammad al-Farghānī, author of a handbook on astronomy, which was probably the first such work in Arabic. He was active in the first half of the 9th century CE. His book was one of the earliest astronomical treatises translated into Latin. Through repeated translations, it enjoyed a great popularity in the Occident and he became famous unter the latinised name Alfraganus. Woodcut from the translation by Johannes Hispalensis, Ferrara 1493.

Jābir ibn Ḥayyān



Idealized picture of Jābir ibn Ḥayyān (8th century CE) who established chemistry as a branch of science of its own in the Islamic world. His name was latinized as Geber. Picture from the Codex lat. Ashburnham 1166 of the Biblioteca Laurenziana in Florence.

ʿAbdarraḥmān aṣ-Ṣūfī

After the work accomplished by the Greek predecessors, fixed star astronomy reached a new climax in the second half of the 10th century in the work of ʿAbdarraḥmān aṣ-Ṣūfī, in particular through his *Ṣuwar al-kawākib at-tābita*. This eminent astronomer verified the



Recontructed model of the Celestial Globe of ʿAbdarraḥmān aṣ-Ṣūfī (A 1.02)

data in the catalogue of Hipparchus-Ptolemy on the basis of his own observations and measurements, and compiled a new catalogue with largely revised scales of brightness, coordinates and magnitudes of stars. A further revision of the star catalogue was made on the basis of fresh observations at the observatory of Uluġ Beg (d. 1449) in Samarqand. This new catalogue distinguished itself from its predecessor primarily through more precise coordinates. ʿAbdarraḥmān aṣ-Ṣūfī, together with Ptolemy and Argelander (d. 1875), is considered one of the three great pioneers of fixed star astronomy. For centuries, he deeply influenced the subject not only in the Islamic world but in Europe as well.

As one of his contemporaries reports, there was in the year 1044 in Cairo a silver celestial globe which aṣ-Ṣūfī had constructed for the statesman ʿAḍudaddaula.

Our model was made according to the manuscript at Oxford, Bodleiana, Marsh 144. This manuscript was copied, together with the illustrations of the constellations, by Ḥusain a son of the author in the year 1010. In his catalogue aṣ-Ṣūfī gives two illustrations for each constellation. One shows it from the horizontal plane, the other is reversed like a mirror image, produced by transfer with a stencil.

The relief exhibited in the Museum was prepared on the basis of the woodcut made in 1515 by Albrecht Dürer, the famous German artist and author of books on art.



Woodcut made in 1515 by Albrecht Dürer.

The Planetarium of as-Siǧzī

To the Arabic-Islamic astronomers who believed that the Earth turns around itself belonged Abū Sa'īd Aḥmad b. Muḥammad as-Siǧzī (2nd half 10th c.). As al-Bīrūnī reports, as-Siǧzī constructed also an astrolabe in the form of a boat (*al-uṣṭurlāb az-zauraqī*) according to the principle of the Earth's rotation. Whether as-Siǧzī himself built a planetarium is not known; our model serves to illustrate his ideas of the Earth's rotation.
(Catalogue II, p. 16)



Recontructed model of the Planetarium of as-Siǧzī (A 1.05)

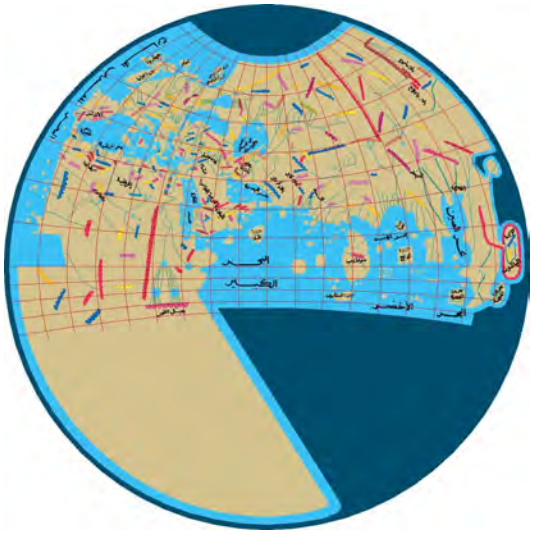


Ibn Sīnā (Avicenna), together with Hippocrates (d. 377 BCE), Galen (2nd c. CE) and Aetius (6th c. CE), on the title page of the Latin translation of his *Qānūn* in the edition Venice 1608.



The World Map of Caliph al-Ma'mūn (reigned 198-218/813-833)

During his reign the Abbasid caliph al-Ma'mūn (r. 813-833 CE), who was resident in Baghdad and was fascinated by the sciences, commissioned a large group of geographers and astronomers with the task of creating a comprehensive geographical work and a new world map. The work was carried out by the scholars involved on the basis of contemporary geographical knowledge and with the help of data collected from geodesic measurements and astronomical and mathematical information, taking as its starting point the well-known world map of Marinos (1st half of 2nd c. CE) and Ptolemy's (2nd half of 2nd c. CE) geography. The map of the Ma'mūn geographers was rediscovered in 1984 in a copy dating back to the year 740 of the Hijra (1340 CE). Together with several surviving regional maps from the Ma'mūnian geographical work and contemporary tables of co-ordinates based on its world map which have also survived, it opens up a completely new horizon in cartographic history. The progress made thanks to the work commissioned by the Caliph can be ascertained when it is compared with the world map bearing Ptolemy's name. The scholars commissioned by al-Ma'mūn had the advantage of covering South and Central Asia, East and North Africa as far as possible by means of their own observations and measurements from Baghdad, which practically lay in the centre of the then known world. Thus the Ma'mūn map, for manifold reasons, is of epoch-making significance.



Reconstruction of the World Map of Caliph al-Ma'mūn

The map illustrated here was reconstructed on the basis of the data given in the original book of co-ordinates. Both maps together—even when we take into account that the later copy no longer reflects the quality of the original—can clearly convey a sense of humanity's achievements in the cartographic representation of the surface of the Earth in the first quarter of the 3rd/9th century. The Ma'mūn map thereby provides us with a solid basis for assessing the further development of cartography, while at the same time itself becoming of great importance for this development, both in the Arab world and the West. Apart from its fairly advanced shape of the Earth's surface, its cartographic aids, such as its globular projection and its cartographic scale, and the representation of mountains in perspective, help us to bring forward appreciably our previous dating estimate for the time when these aids were developed. In addition, the axis of the Mediterranean is reduced to 52° compared with that in Ptolemy of 62° or 63°; moreover, it shows Africa in the south, Europe and Asia in the north as being circumnavigable and the Indian and Atlantic oceans are no longer portrayed as inland seas as was the case in Ptolemy.



Model of a terrestrial globe with the reconstructed world map

Terrestrial Globe

with the world map which Caliph al-Ma'mūn (reigned 813–833 CE) had commissioned a large group of astronomers and geographers to make. (A 1.05)



Model of the reconstructed elephant clock

Elephant Clepsydra

Model reconstructed after the description in al-Jazarī's book (ca. 1200 CE). Hidden inside the elephant is a water-powered mechanism which causes the figurine of the driver to move its whip and strike the drum every half an hour. Moreover it makes a bird on top turn and two other birds drop metal balls from their beaks into the gaping mouths of two snakes. The weight causes the latter to decline slowly and ultimately drop the balls in sonorous bowls and from there further down. A clerk figurine on the back of the elephant points out the elapsed time with his pen on a dial by ticking a bit to the right every half hour.
(Catalogue III, p. 101; Nr. B 1.06)



Fig. from al-Jazarī, *al-Jāmi'*. MS Istanbul, Topkapi Saray, Ahmet III 3472, p. 90.



Naṣīraddīn aṭ-Ṭūsī (d. 1274) and his team of astronomers. Miniature from the *Tansūqnāma-Ilḫānī,* MS. British Library, Or. 3222, fol. 105a.

Astronomy





Observatories

The first observatories known to the history of astronomy were erected by the Abbasid Caliph al-Ma'mūn (r. 813–833 CE). He founded two observatories: one in Baghdad in the Šammasiya quarter and the other in Damascus on Mount Qāsiyūn. The relevant reports give the impression that Caliph al-Ma'mūn, who occupied himself with astronomy and used to commission and even take part himself in the astronomical observations and measurements which he considered important and who let the necessary instruments be constructed, did not entertain the idea of an observatory for a long time. The enormous development of the observatories which we can follow well into the 16th century found the first significant emulation in the Occident in the second half of the 16th century. It carried the name of Tycho Brache as the founder. (Catalogue II, p. 19)



Reconstructed model of the observatory of Raiy

The Observatory of Raiy (ancient Teheran)

founded on the request of the eminent astronomer Ḥāmid al-Ḫuğandī (2nd half of the 10th century CE) by the statesman Faḫraddaula (r. 976–997 CE). It was built in order to solve the problem of whether the Earth's inclination is permanent or changing, using a sextant of ca. 20 m radius. After meticulous observations it was concluded that the obliquity of the ecliptic was decreasing over the course of time.

Our sextant consists of two vertical walls erected along the meridian at a distance of 7 ells (3.5 m). At the uppermost part, that is to say, 20 ells (10 m) above ground, there is a dome; in it is a hole with a diameter of 1/6 ell (1/12 m). Above the hole is fastened an iron rod, and from it is suspended a high rectangular box made of planks with two rings at one end. It has a length of 20 m. (Catalogue II, p. 25; A 5.03)



Reconstructed model of the observatory of Marāgha

The Observatory of Marāgha

After the conquest of Baghdad in 1258, where the old Abbasid observatory existed for about 450 years, the ruler Hülägü commissioned the scholar Naṣīraddīn aṭ-Ṭūsī (d. 1274) to build a new observatory in Marāgha, the capital of the western Mongol empire. According to one tradition the initiative for the foundation of an observatory in Marāgha is said to have come from Möngke, the Great Khan and Hülägü's brother. It is more likely that the plan originated with Naṣīraddīn himself. The construction of the observatory began in 1259; it is not known when it was completed. Presumably it began functioning already around 1270, i.e. a few years after Hülägü's death (1265).

The observatory was situated ca. 80 km south of Tabriz and 29 km east of Lake Urmia. It was erected on a hill, whose length lies exactly on the meridian. Around 1880 there were to be seen of it "only the foundations of the 4 ½ – 5 feet [= ca. 1.5 m] thick walls and a few circular heaps of rubble," as A. Houtum-Schindler reports who drew a ground plan of the ruins according to the knowledge of those days (see annexed figure).

Today we have at our disposal a detailed plan and a rather fair knowledge of the construction of the observatory, thanks to the excavations conducted in 1972, 1975 and 1976 under the supervision of Parviz Vardjavand.

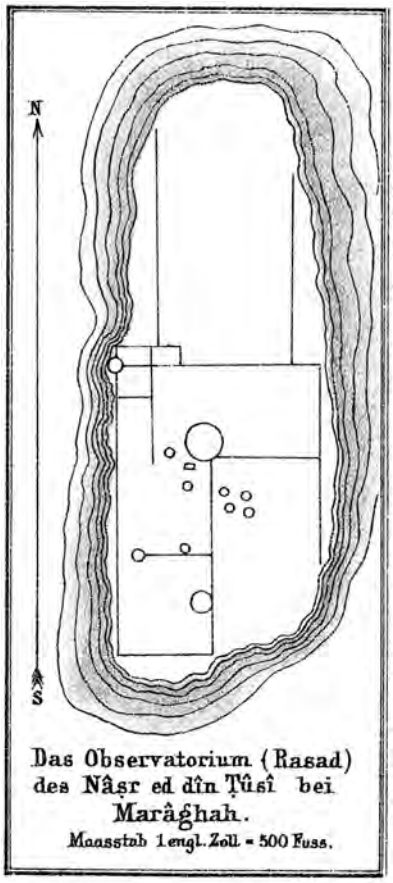
The hill on which the observatory was erected is called even today Raṣad dāġī ("observatory mountain"). It lies ca. 500 m to the north of the last houses of the city of Marāgha, is 512 m long, 220 m wide and 110 m high.

The parts of the whole complex revealed through the excavations, called "16 unites differentes" by Vardjavand, are named by him as follows:

A) East–west and north–south walls.
B) Central tower of the observatory.
C) Five circular units.
D) Rectangular hall.
E) Library (?).
F) Conference hall.
G) Workshop.

H) Building with the central iwan.
I) Stone pavement.
J) Village settlement from the time after the destruction of the observatory.
On these units, he gives the following details: The hill of the observatory is divided into two parts through a wall 139 m long and 1.10 m wide.
1) The southern part containing all the buildings and the places meant for the observatory instruments has a surface area of 280 × 220 m.
2) The northern part is ca. 220 m long, its width diminishes towards the north and varies between 220 m and 50 m. The central tower has a diameter of 28 m. Of the sextant installed therein and of the stairs built on both sides, only a part of 5.55 m survives. But it becomes clear from the ruins that this sextant was not partially constructed underground, as those of the observatories of Raiy and Samarqand were. Its radius probably measured between 10 m and 12 m. The other five circular foundations seem to indicate the ruins of cylindrical towers in which astronomical observations were carried out with special large instruments like the armillary sphere, the mural quadrant, the solstitial armilla and the equinoctial armilla. The extant ruins also indicate the foundation of a library mentioned in the historical sources. The rooms in the central tower, on both sides of the sextant, were probably working places and living quarters of the astronomers. (Catalogue II, pp. 28-31; A 5.05)





Ground plan of the Marāgha observatory (ca. 1270) after Houtum-Schindler



Aerial view of the hill with the Marāgha observatory

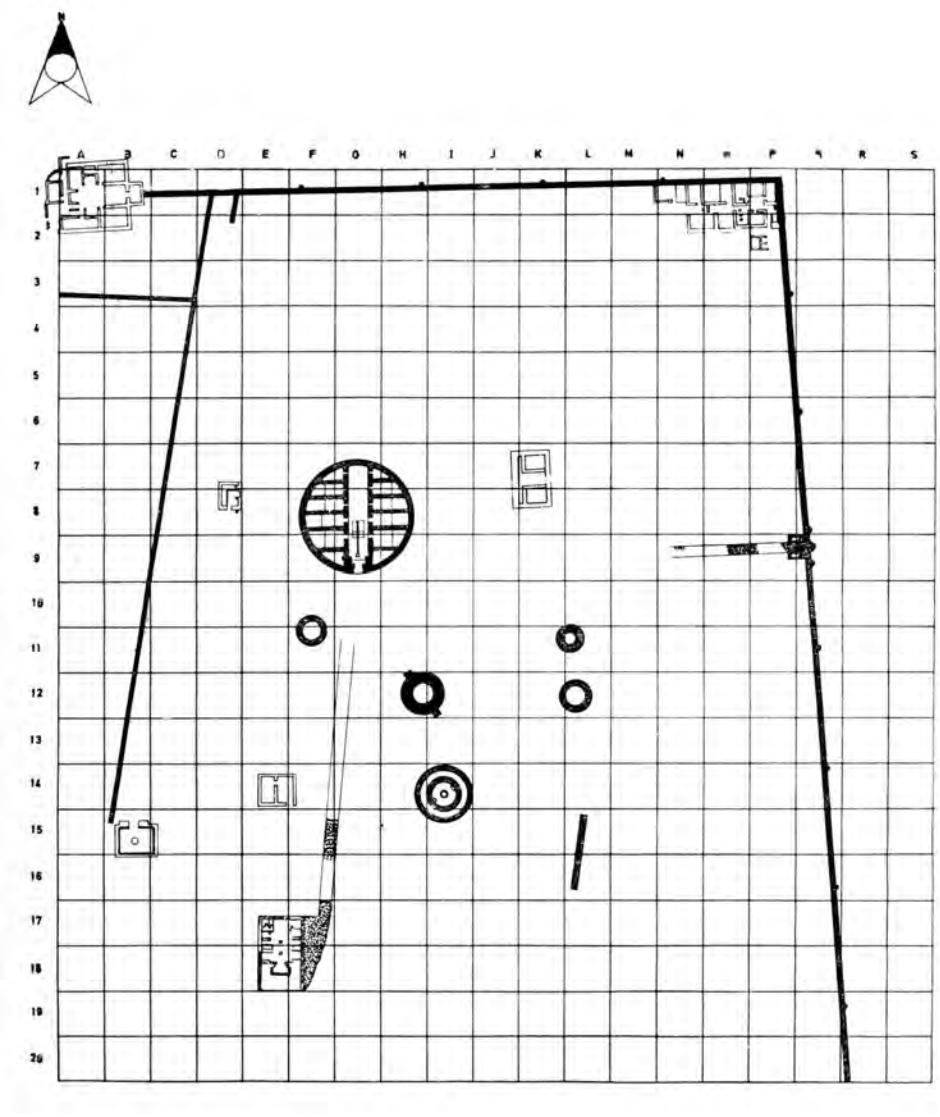


The ruins of the central tower

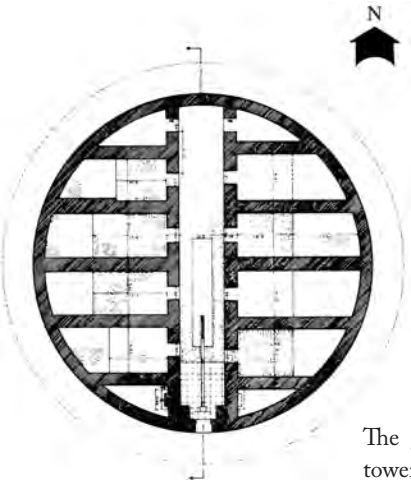


The hill of the observatory seen from the plain

Photos: P. Vardjavand, *Rapport préliminaire sur les fouilles de l'observatoire de Marâge*



The ground plan of the entire complex of the observatory, oriented to the north



The ground plan of the central tower with the sextant



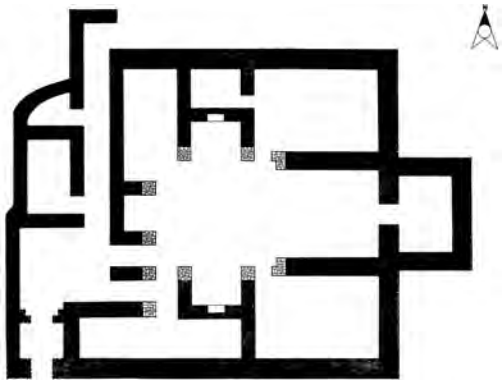
The foundations of one of the five smaller towers which were probably meant for observations with special large instruments



The ruins of the sextant in the middle of the tower, towards the north



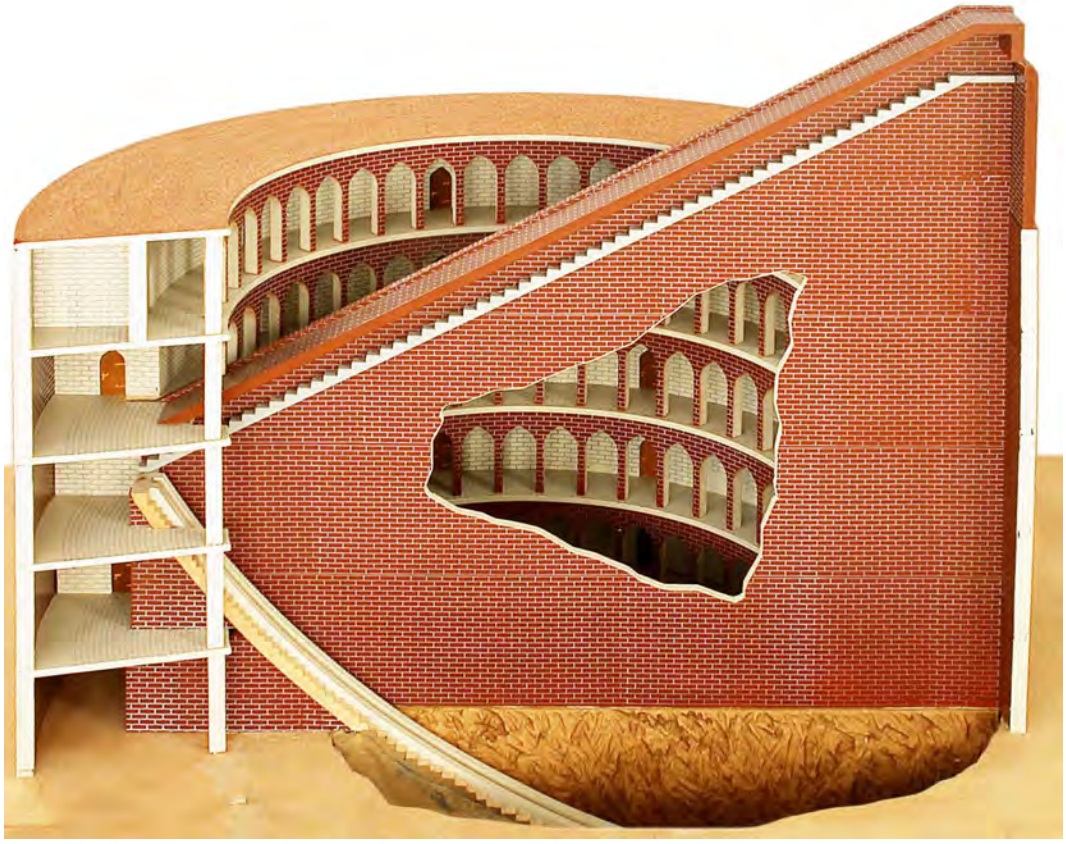
The ruins of the sextant, towards the south



Ground plan of the presumed library



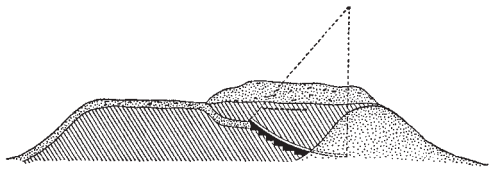
Foundation walls of the building which was presumably the library



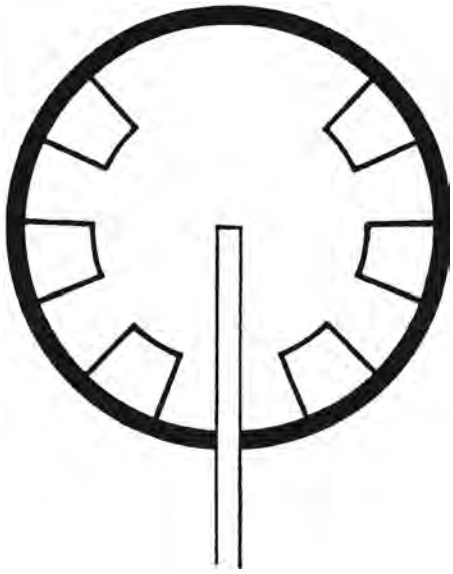
Reconstructed model of the observatory of Samarqand

The Observatory of Samarqand

The observatory was founded by Muḥammad Ṭaraġāy b. Šāhruḫ Uluġ Beg (1394-1449), a grandson of Timur. Uluġ Beg himself was an astronomer and was, no doubt, inspired for his enterprise by the Marāgha observatory. The exact time of the construction and of the completion of the work is not known. "'Abd ar-Razzāq [as-Samarqandī in his *Maṭlaʿ as-saʿdain wa-maǧmaʿ al-baḥrain*] reports about the construction of an observatory, while describing the events of the year 1420, namely in connection with the mosque and university or lodging for dervishes which was constructed in that year, although one can hardly conclude that the observatory really originated at the same time with these buildings." It became one of the most famous observatories of the Arabic-Islamic culture area, yet its ruins were thought to be lost until the first decade of the 20th century. "A part of the observatory was excavated under the supervision of the government official Wjatkin, who was able to ascertain the location of the observatory only on the basis of hints in an old document, and the well-known astronomer Ossipoff, of the Tashkent observatory, could take the first, although still very rough, measurements on the spot." The observatory was situated on a flat hill with a height of ca. 21 m, an east-western width of ca. 85 m and a north-southern length of ca. 170 m. (Catalogue II, pp. 69-71; A. 5.04)



Section of the hill on which the observatory of Samarqand stood



Ground plan of the foundation of the tower of the observatory of Samarqand

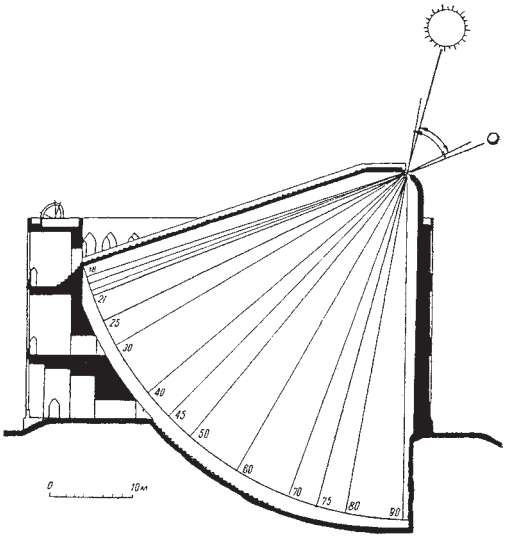


Diagram of the observation with the sextant of the observatory of Samarqand, after G. A. Pugačenkova



The sextant of the observatory of Samarqand, partially restored after excavations

The Observatory of Istanbul

The great observatory founded in Istanbul between 1575 and 1580 under the Ottoman sovereign Murād III is one of the achievements of the 16th century to be mentioned. The idea was suggested to the Sultan by the versatile scholar Taqīyaddīn Muḥammad b. Ma'rūf ar-Raṣṣād. With a "new kind of observation" (*raṣad ǧadīd*) using newly built instruments of large dimensions, the latter intended to collect substantially improved results. The surviving Turkish book on the observatory and its instruments contains the description and illustrations of eight observational instruments of hitherto unknown proportions. It was probably first dictated in Arabic by Taqīyaddīn (who had only settled in Istanbul in the 1550s after sojourns in Damascus and Cairo). Two of the instruments seem to have been devised by Taqīyaddīn himself, the other six already figure in the instruments book of the observatory at Maragha built three hundred years earlier. One may assume that the news about the Istanbul Observatory soon reached Europe and that the great astronomer Tycho Brahe (1546–1601) also heard about it. At any rate, the similarity between two of the instruments in the observatories of Taqīyaddīn and Tycho Brahe (viz. the instrument for measuring the distances between celestial bodies and the wooden quadrant) create this impression (Catalogue, II, pp. 64-68).



Taqīyaddīn's team of astronomers. After the manuscript of *Šamā'ilnāma*, Istanbul, University Library, T.Y. 1404, fol. 57a

The observatory in Istanbul was established in succession to the two precursors in Maragha and Samarqand, whose fame had spread beyond the Islamic world. After many years of work as an astronomer and physicist, its founder, Taqīyaddīn, moved to Istanbul in the 1550s to place his knowledge and abilities in the service of Murād III. The latter was intelligent enough to grant the request and have the costly observatory built, but he was not intelligent enough to appreciate its true merits. Thus he could be persuaded by fanatical advisers and the adversaries of Taqīyaddīn to demolish the observatory as an alleged instrument of astrology with a corrupting influence on the state only a few years after its foundation. (Catalogue II, pp. 34-35).

The Observatory of Uranienburg on the Island of Hven

Under the patronage of the Danish king Frederick II, Tycho Brahe (1546–1602) began with the establishment of an observatory on the island of Hven (today Swedish Ven), benefiting from a recommendation of the landgrave of Hesse who had established the first observatory of Central Europe in Kassel. While studying in various European cities, Tycho Brahe had already made a name for himself through his excellent skill in making astronomical instruments. The foundation stone of the observatory was laid in August 1576. The number of instruments Tycho Brahe got manufactured between 1577 and 1597 was around eighteen. However, most of them were imitations of already known instruments with minor variations or improvements. Therefore the actual number can be reduced to nine or ten. In this connection, Johann Repsold says: "One has the impression that instruments were constructed merely in order to create work, just as after Weistritz, Tycho let poems, which he dedicated to good friends, be printed in order to keep his paper mill busy. This way of keeping house with little sense for economy probably contributed to the fact that Tycho fell into disfavour; and after a few decades the whole splendour of Hven had sadly disappeared." While judging Tycho Brahe's achievements, emphasis is laid on four of his instruments: his two movable azimuthal quadrants, his mural quadrant, his astronomical sextant for measuring distances, and his equatorial armillary sphere. In evaluating them, one proceeds from the question how far they were known already to Greek astronomy, while possible precursors in the Arabic-Islamic culture area are ignored. On this issue, the following may be mentioned: the two movable azimuthal quadrants had their predecessors among the instruments of the observatories of Marāgha and Istanbul. The mural quadrant was known in the 10th century already in the Arabic-Islamic culture area, as we learn from al-Battānī. It appears furthermore among the instruments of large dimensions in the observatories of Marāgha and Istanbul. The astronomical sextant for measuring distances betrays great similarity to the *āla mušabbaha bi-l-manāṭiq* of the Istanbul Observatory. Leaving aside the similarity in construction and function, what is striking is particularly the common use of two wooden sticks for propping the movable sextant up against the ground in the correct position. It is instructive that Tycho did away with the two wooden sticks in his later versions of the instrument. It is highly probable that the knowledge of not merely this instrument of the Istanbul Observatory reached Tycho Brahe in a short time. We know of the use of the sextant for astronomical observation in the Arabic-Islamic culture area since the 10th



Tycho Brahe's team.
From: Joan Blaeu, *Atlas major*, Amsterdam etc. 1662, vol. I

century when the astronomer al-Ḥuǧandī used the Faḫrī sextant for the precise determination of the obliquity of the ecliptic. A sextant was also among the astronomical instruments mentioned by Ġiyāṯaddīn Ǧamšīd al-Kāšī (d. 1436) in his book on the description of observational instruments. Tycho Brahe's large equatorial armillary sphere which he calls *armillae aequatoriae maximae* in his book is essentially "quite a strange simplification of the armillary instrument. What are retained are just the circle of declension and half of the hour circle."The result of the comparison of the instruments constructed by Tycho Brahe between 1577 and 1597 for the observatory of Hven with those of the two observatories of Marāgha (1260–1270) and Istanbul (1576–1580) may be summed up here: Basically, the instruments of Hven are further reproductions of those models which we know from the two observatories of Marāgha and Istanbul. The striving for large dimensions for the sake of greater precision in measurements is characteristic for the instruments of all the three observatories. One difference is particularly striking in comparison, namely, the exaggerated ornamentations and engravings which are displayed in Tycho Brahe's instruments in contrast to the simplicity of the models from Marāgha and Istanbul, and which were certainly not advantageous when using the instruments. A common feature in the method of observation of Tycho Brahe and Taqīyaddīn is the taking into account of time as an element of its own with the help of a portable clock. (Catalogue II, pp. 36-37)



Reconstructed model of the Jaipur observatory

The Observatory of Jaipur

Astronomy and mathematical geography, cultivated very meticulously in Timur's Samarqand by Sultan Ulug Beg and his astronomers, shifted to India along with the political power as a consequence of the establishment of the Moghul empire by Babur in the year 1526. The astronomical observational instruments and the tables of localities which were prepared there until the beginnings of the 18th century should be considered the continuation of the Samarqand school of astronomers.
This work, continued in India from the middle of the 16th century onwards, came to a close with the intense and spectacular activities of the Hindu scholar and statesman Jai Singh Sawā'ī (1686-1743). Inspired by the fame of the grandly laid out Samarqand observatory, he caused massive observatories to be built in Delhi, Jaipur, Benares, Ujjain and Mathura, equipped with instruments of huge dimensions. They were founded between 1722 and 1739. The first one came up in Delhi and was called Jantar Mantar (distorted from Yantra Mantra). (Catalogue I, pp. 72-77; A 5.02)

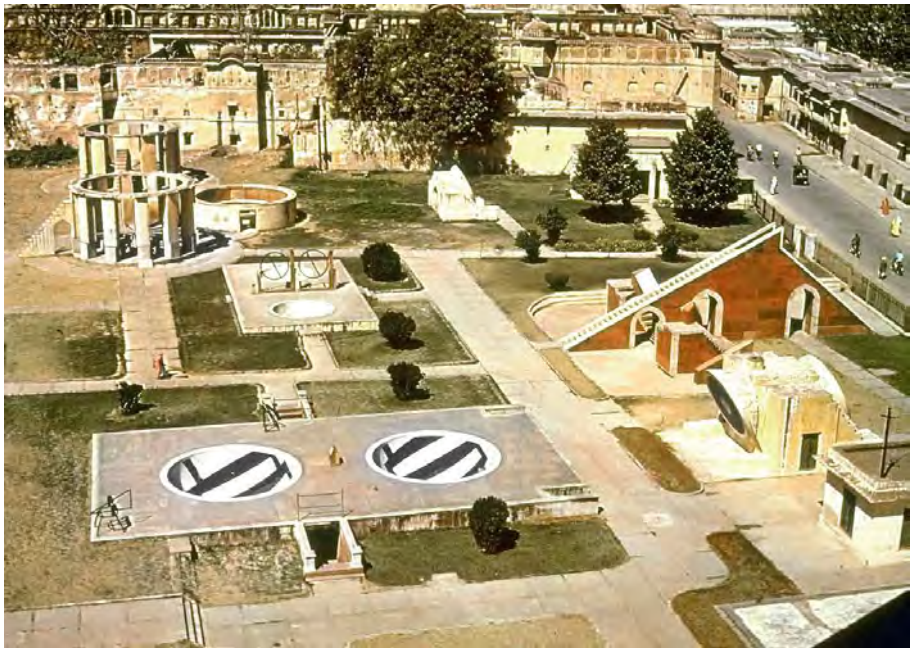


Photo of the Jaipur observatory

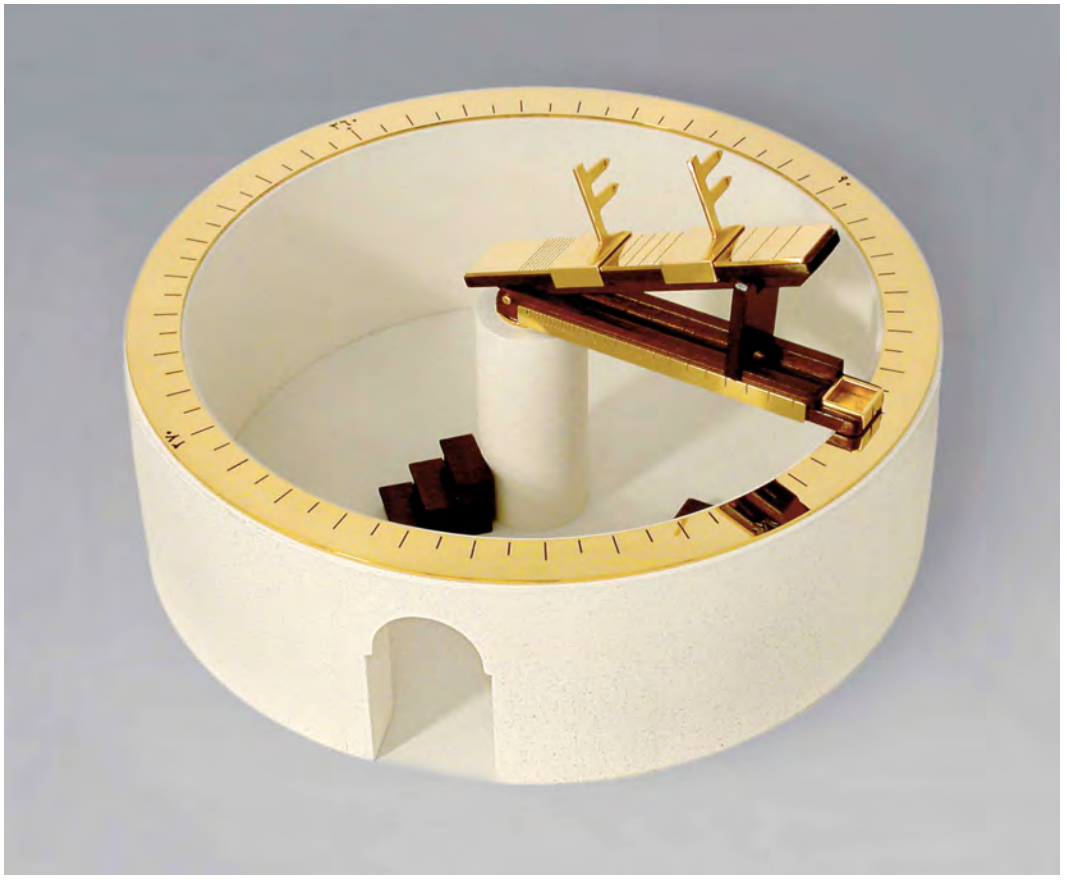


Reconstructed model of the Coronelli globe

The Celestial Globe of Coronelli

The Franciscan priest Vincenzo Coronelli (1650–1718), who had made a name for himself as a cartographer and globe maker, produced a celestial globe with a diameter of 3.85 m for Louis XIV. The star map inscribed on it is based on the depiction of ʿAbdarraḥmān aṣ-Ṣūfī (10th c.). The fourteen constellation figures in the southern hemisphere are based on subsequently acquired knowledge. The work on the globe was executed between 1681 and 1683 in Paris. The constellations figures were painted by Jean-Baptiste Corneille (1649–1695). They are painted on papier mâché. The names of the constellations are written in Greek, Latin, French and Arabic. The original made for Louis XIV is preserved today in the Bibliothèque nationale in Paris. It must have been very popular, because there exist so far some 60 smaller replicas with a diameter of 110 cm in European museums and libraries.

The construction of our model was made possible through a CD-ROM published by the Bibliothèque nationale. (Catalogue II, p. 18; A 1.04a).



Reconstructed model of the observational instrument developed by Ibn Sīnā

The Observational Instrument developed by Ibn Sīnā

This observational instrument (*āla raṣadiyya*) that was developed by Abū ʿAlī al-Ḥusain b. ʿAbdallāh Ibn Sīnā (d. 1037) was constructed for ʿAlā'adddaula's observatory. With this instrument astronomical altitudes were to be ascertained as accurately as possible. Its long arms make possible an observational result that can be read off not only in degrees, but in minutes and seconds as well. For this purpose Ibn Sīnā chose the length of the arm of ca. 7 m. (Catalogue II, pp. 26-27; A 5.06)

Time as a Parameter in Astronomical Observations

The Ottoman astronomer Taqīyyaddīn (d. 1585) was possibly the first to introduce time as a distinct parameter in his observations. For this purpose he built a large astronomical clock (*bingām raṣadī*) as an addition to the instruments of the observatory.
(Catalogue I, p. 75; III, p. 118)



The First Astronomical Instrument invented in the Islamic World

The invention of the first astronomical instruments in the Arabic–Islamic culture area occurred in the last quarter of the 9th century. One of these was the spherical astrolabe, the invention of which is attributed to Ǧābir b. Sinān al-Ḥarrānī. His contemporary al-Faḍl b. Ḥātim an-Nairīzī claims to be the first to have invented instruments with which the distance between objects situated in the atmosphere or projecting from the Earth's surface can be measured. (Catalogue I, p. 16; II, pp. 120-124).



Spherical Astrolabe of Arabic-Islamic provenance. It was made in the year 1480 by a master called Mūsā. Original in the Museum of History of Science, Oxford.

(Cat. II, 131; A 1.12)



Spherical Astrolabe from the year 1660. Original in the Museum for Islamic Art at Cairo.

(Cat. II, 133; A 1.13)

❧ *Astrolabes*



Astrolabe by Nasṭūlus
Model of the oldest surviving astrolabe made by Muḥammad Nasṭūlus in the year 927 CE. The original is in the Museum of Islamic Archeology in Kuwait.
(Cat. II, 86; A 2.25)



Another Astrolabe by Nasṭūlus
Model of a fragmentary astrolabe by Muḥammad Nasṭūlus from the early 10th century CE. The original is in the Museum of Islamic Art at Cairo.
(Cat. II, 87; A 2.26)



Astrolabe by Ḥāmid b. ʿAlī al-Wāsiṭī from the early 10th century CE, after an original in the Museum of Islamic Art at Cairo.
(Cat. II, 88; A 2.27)



Astrolabe constructed on the basis of an original made in ca. 950 by Aḥmad b. Ḫalaf. The original is in the Bibliothèque Nationale, Paris. (Cat. II, 89; A 2.14)



Astrolabe made in 984 CE by the great mathematician and astronomer Ḥāmid b. al-Ḫiḍr al-Ḫuğandī. The original is in the National Museum of Qaṭar.

(Cat. II, 90; A 2.28)



Astrolabe, based on a Catalanian model from the 10th century CE. It is the oldest Latin astrolabe and a copy of an original Arabic astrolabe. The original is in the Institut du Monde Arabe, Paris.

(Cat. II, 91; A 2.18)



Model of the oldest known imitation of an Arabic astrolabe, depicted in a Latin book of the 10th century CE, inscribed in Arabic and Latin.

(Cat. II, 92; A 2.29)



Astrolabe based on a specimen attributed to Pope Sylvester II, allegedly made in France in 990 CE. The original is in the Museo di Storia della Scienza at Florence.

(Cat. II, 94; A 2.11)



Model of an astrolabe, made 1029 CE in Toledo by Ibn al-Ṣaffār. Original in Berlin. The original is in the Staatsbibliothek, Berlin

(Cat. II, 95; A 2.12)



Astrolabe, based on a specimen made in 1079 CE by Aḥmad b. Muḥammad al-Naqqāš in Saragossa. The original is in the Germanisches Nationalmuseum, Nuremberg.

(Cat. II, 96; A 2.13)



Astrolabe, based on a specimen made in 1086 CE by Ibrāhīm b. Saʿīd al-Sahlī in Valencia. The original is in the Naturwissenschaftlich-technische Sammlung, Kassel.

(Cat. II, 97; A 2.05)



Model of an original astrolabe made in Sevilla in 1216 CE by Muḥammad b. Futūḥ al-Ḥamāʾirī. The original is in the Technical University at Istanbul.

(Cat. II, 98; A 2.30)



Astrolabe
Model of another specimen made by Muḥammad b. Futūḥ al-Ḥamā'irī in Sevilla (1228). The original is in the Museum of Islamic Art at Cairo.

(Cat. II, 100; A 2.31)



Astrolabe
Model of the largest astrolabe extant from before 1600, made in Damascus by ʻAbdarraḥmān b. Sinān al-Baʻlabakkī an-Naǧǧār in 1222. The original is in the Navy Museum at Istanbul.

(Cat. II, 101; A 2.24)



Astrolabe, based on a specimen made in Egypt by ʻAbdalkarīm al-Miṣrī for the Ayyubid al-Ašraf Muẓaffaraddīn Mūsā in 1252. Original at the Museum of the History of Science, Oxford.

(Cat. II, 103; A 2.15)



Astrolabe, based on an original made in Ḥamāh, Syria, by as-Sahl al-Asṭurlābī an-Nīsābūrī in 1299. The original is in the Germanic National Museum, Nuremberg, WI 20.

(Cat. II, 104; A 2.17)



Astrolabe, based on an original made in Yemen by al-Malik al-Ašraf in 1291, which is in the Metropolitan Museum of Art, New York.

(Cat. II, 105; A 2.07)



Astrolabe, based on an Arabic original presumably dating from the 13th century, which is in the British Museum at London.

(Cat. II, 106; A 2.06)



Astrolabe

Replica of one of five extant astrolabes made towards the end of the 15th century by Šamsaddīn Muḥammad Ṣaffār. The original of our model is in the Museum of Islamic Art at Cairo; it is dated 1477.

(Cat. II, 107; A 2.33)



Model of an astrolabe made for the Safavid ruler ʿAbbās II. in 1629 CE. The original is in the Museum of the History of Science at Oxford.

(Cat. II, 108; A 2.16)



This Ottoman astrolabe was made in the year 1680 for Sulṭān b. Aʿẓam b. Bāyazīd. The original is in the Museum for Islamic Art at Cairo.

(Cat. II, 109; A 2.32)



Considered to be the most beautiful and most advanced astrolabe produced in the Islamic culture area, made by ʿAbdalqādir Muḥibb in the first half of the 17th c. AD.

A 2.35



Astrolabe by Muḥammad Ḫalīl with five plates, dated 1698 AD.
Original in Frankfurt.

A 2.36



Astrolabe of 974 AD
Made by the brothers Muḥammad b. Ibrāhīm and Aḥmad b. Ibrāhīm of Isfahan. The original is at Oxford. (cf. Gunter, *Astrolabes of the World*, vol. 1, pp. 8-9)

A 2.37



Byzantine Astrolabe
The only known Byzantine astrolabe, preserved in Brescia (Italy), presumably from the 14th century AD.

(Cat. I, 152, A 2.22)



Astrolabe, based on a Spanish instrument in Gothic style from the 14th century, which betrays strong influences from the Arabic culture area. The original is in the Society of Antiquaries, London.

(Cat. II, 111; A 2.08)



Astrolabe, made in the style of a European astrolabe of ca. 1500.

(Cat. II, 112; A 2.09)



Astrolabe, based on an instrument made by Erasmus Habermel around 1600. The back is engraved with a "disc of az-Zarqālī". The original is in the Museum of the History of Science at Oxford.

(Cat. II, 114; A 2.04)



Saphæa
A device developed in Arabic-Islamic Andalusia. Our model represents a specimen made in Murcia by Muḥammad b. Muḥammad b. Huḍail in 1252 CE. The original is in the Observatorio Fabra at Barcelona.
(Cat. II, 116; A 2.03)



One of several universal discs, called *Ṣafîḥa zarqālīya* or *šakkāzīya*, made by Muḥammad b. al-Futūḥ al-Ḫamā'irī in the year 1216 (Sevilla).



Example of the highest stage of the astrolabe's development, made by Aḥmad Ibn al-Sarrāǧ (d. 1329 CE). The original is in the Benaki-Museum, Athens.
(Cat. II, 119; A 2.01)



Dastūrquadrant was made by ʿAlī b. Ibrāhīm al-Muṭa''im in the year 1334. The original is in the Museum for Islamic Art at Cairo.
(Cat. II, 142; A 3.10)

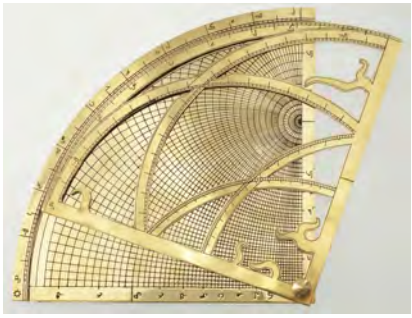
❧ *Quadrants*



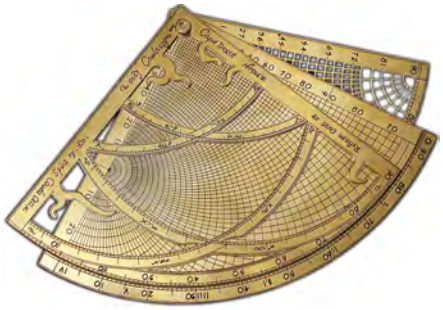
Sine Quadrant, based on an original made by Muḥammad b. Aḥmad al-Mizzī in 1334 and now preserved in St. Petersburg.
(Cat. II, 136; A 3.03)



Sine Quadrant, based on an original made in 1335 by ʿAlī b. aš-Šihāb, which was in Damascus until shortly before 1859.
(Cat. II, 137; A 3.04)



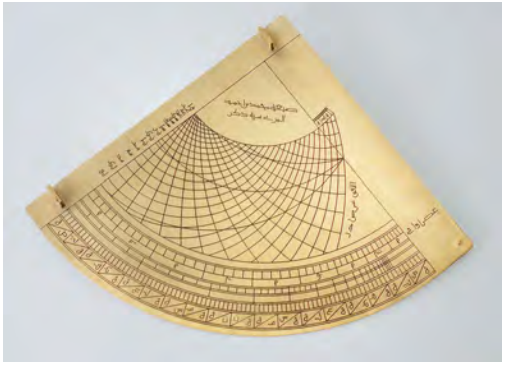
Double Quadrant, made after the description by Ǧamāladdīn al-Māridīnī (d. 1406 CE).
(Cat. II, 139; A 3.07)



Double Quadrant, based on a European original which appears to have been made in the 15th century in imitation of al-Māridīnī's instrument (no. A 3.07) or another Arab model. Original at the Adler Planetarium, Chicago. (Cat. II, 140, A 3.01)



Model of the meteoroscope, being an imitation of an Arabic–Islamic double quadrant, after the description by Peter Apian (d. 1552 CE). (Cat. II, 141; A 3.02)

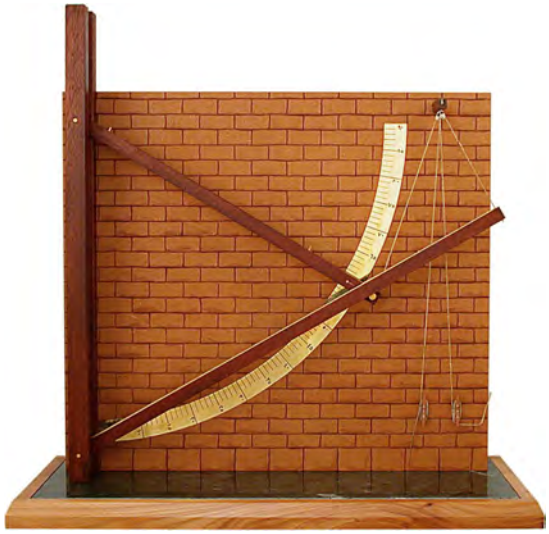


Sine quadrant made by Mu ammad b. A mad al-Mizz in the year 1326. The original is in the Museum for Islamic Art, Cairo.
(Cat. II, 202; A 3.12)

❧ *The Instruments of the Marāgha observatory (ca. 1265)*



Model of the mural quadrant
from the Marāgha Observatory used for the determination of the solar altitude, obliquity of the ecliptic and the latitude of the site. Reconstructed after the description and illustration in al-ʿUrdī's book on the Marāgha Observatory. (Cat. II, 38; A 4.27)



Instrument with two beams
Model of a device from the Marāgha Observatory invented by Muʾaiyadaddīn al-ʿUrḍī. In combination with a mural quadrant it was used for the determination of culmination altitudes. Reconstructed after al-ʿUrdī.
(Cat. II, 45; A 4.26)



Instrument for the determination of altitudes and azimuths
Model of a device from the Marāgha Observatory with two movable measuring rulers pivoted on a 360° scale. Reconstructed after al-ʿUrdī.
(Cat. II, 46; A 4.07)



Instrument for the determination of the sine on a vertical scale
Model of a variant of the previous instrument A 4.07 devised by Muʾaiyadaddīn al-ʿUrḍī for the Marāgha Observatory. Reconstructed after al-ʿUrdī.
(Cat. II, 48; A 4.30)



Instrument with two quadrants
Model of an instrument from the Marāgha Observatory devised by Mu'aiyadaddīn al-ʿUrḍī for taking altitudes and azimuths of celestial bodies by two observers at the same time. Reconstructed after al-ʿUrdī.
(Cat. II, 44; A 4.15)



Model of the equinoctial armilla from the Marāgha Observatory used for the determination of the sun's entry into the equinoxes. Reconstructed after al-ʿUrdī.
(Cat. II, 42; A 4.28)



Model of the armillary sphere of the Marāgha Observatory, used for the determination of fixed star coordinates. Reconstructed after al-ʿUrdī. (Cat. II, 39; A 4.18)



Model of the solstitial armilla from the Marāgha observatory used to determine the inclination of the ecliptic. Reconstructed after al-ʿUrdī. (Cat. II, 41; A 4.17)



Instrument with movable sights
Model of a device from the Marāgha Observatory used for the determination of the apparent diameters of the sun and the moon. Reconstructed after al-ʿUrdī.
(Cat. II, 43; A 4.16)



The perfect instrument of the Marāgha Observatory. Model of a parallactic ruler originally devised by Muʾaiyadaddīn al-ʿUrḍī in 1252 which can be adjusted for any azimuth. Reconstructed after al-ʿUrdī.
(Cat. II, 50; A 4.29)



Model of the Celestial Globe, constructed at the observatory of Marāgha in 1279 CE and preserved in Dresden since 1562.
(Cat. II, 52; A 1.03)

❧ *The Instruments of the observatory of Istanbul (1576)*



Wooden Quadrant
Model of an instrument of the Istanbul Observatory that was adjustable in the vertical and horizontal planes and thus suited also for the determination of celestial bodies not aligned to the meridian. Reconstructed after the description and illustration in the book on the observatory.

(Cat. II, 58; A 4.03



Instrument for the measurement of distances between celestial bodies. Model of a measuring device of the Istanbul Observatory. Its constructional flexibility allows to take measurements in three dimensions. Reconstructed after the description and illustration in the book on the observatory.

(Cat. II, 61; A 4.01)



«Instrument with Chords»
Model of an instrument devised by Taqīyaddīn for the Istanbul Observatory. It was intended to replace the equinoctial armilla of his predecessors (v. no. A 4.28). Reconstructed after the description and illustration in the book on the observatory.

(Cat. II, 60; A 4.32)



Parallactic Ruler. Model of an instrument going back to Ptolemy. The improved construction used at the Istanbul Observatory featured a ruler pivoted to allow for west-east adjustments. It served not only for the measurement of the lunar parallax in the meridian but its large scale also made very precise measurements of celestial altitudes possible.

(Cat. II, 59; A 4.05)



Model of the mural quadrant of the Istanbul Observatory which was used to determine the diurnal culmination of the sun and the meridional altitude of the planets. Reconstructed after the description and illustration in the book on the observatory.

(Cat. II, 54; A 4.13)



Model of the armillary sphere from the Istanbul Observatory, used to determine fixed star coordinates. Reconstructed after the description and illustration in the book on the observatory.

(Cat. II, 53; A 4.09)



Device for the determination of the altitudes and azimuths of celestial bodies. Model of an instrument of the Istanbul Observatory going back to Muʾaiyadaddīn al-ʿUrḍī (cf. no. A. 4.15). Reconstructed after the description and illustration in the book on the observatory.

(Cat. II, 55; A 4.11)



Instrument with two beams. Model of an instrument of the Istanbul Observatory apparently going back to Muʾaiyadaddīn al-ʿUrḍī (cf. no. A. 4.26). It was used to observe the positions of celestial bodies during day and night in all directions and for taking altitudes and parallaxes of the sun and moon. Reconstructed after the description and illustration in the book on the observatory.

(Cat. II, 56; A 4.31)

❧ *The Instruments of Tycho Brahe*



Model of Tycho Brahe's Zodiacal Armillary Sphere (possibly before 1570). Made after the description by Tycho Brahe.
(Cat. II, 63; A 4.10)



Parallactic Ruler. Model of an improved version of Ptolemy's *órganon parallaktikón* by Tycho Brahe (ca. 1577-1597), used for the measurement of distances close to the zenith. Made after the description by Tycho Brahe.
(Cat. II, 65; A 4.06)



Instrument for the measurement of altitudes and azimuths
Model of a measuring device of the Uranienburg Observatory (1577-1597), which, in its function as well as construction, matches the "instrument with sine and azimuth" of the Marāgha observatory (v. no. A 4.07). Made after the description by Tycho Brahe.
(Cat. II, 62; A 4.08)



Mural Quadrant
Model of Tycho Brahe's main instrument (presumably around 1587), used for the determination of culmination altitudes. It was known in the Islamic world from the 10th century (cf. also A 4.27 und A 4.13). Made after the description by Tycho Brahe.
(Cat. II, 67; A 4.14)



Model of Tycho Brahe's Astronomical Sextant (1577-1597). Like the corresponding instrument of the Istanbul Observatory (v. no. A 4.01) this one was adjustable in the vertival and horizontal planes and thus allowed not only the determination of altitudes in the meridian but also of distances between celestial bodies and thereby their positions. Made after the description by Tycho Brahe.

(Cat. II, 64; A 4.02)

Large azimuth-semicircle

Model of an instrument by Tycho Brahe (presumably around 1587), resembling the corresponding instruments from Marāgha and Istanbul (A 4.15 und A 4.11), which too were designed for the determination of altitudes and azimuths. Made after the description by Tycho Brahe.

(Cat. II, 66; A 4.12)



Large wooden quadrant

Model of an instrument by Tycho Brahe (supposedly from 1576), closely related to the one devised by Taqīyaddīn for the Istanbul Observatory (no. A 4.03; cf. also A 4.15). Made after the description by Tycho Brahe.

(Cat. II, 68; A 4.04)



❧ *Other Observational and Measuring Instruments*



The Encompassing Instrument invented by Ḥāmid b. al-Ḫiḍr al-Ḫuǧandī (2nd half of the 10th CE). This instrument allows the measurement of the longitudes of the planets.
(Cat. II, 151; A 1.06)



Instrument with a sphere revolving uniformly on its axis. Model of a device described by Muḥammad b. Aḥmad al-Ḫāzimī (11th c. CE) in which a celestial globe with zodiac, ecliptic and celestial equator is brought to slow, uniform rotation powered by sand.
(Cat. II, 172; B 3.02)



Model of an instrument invented by Ǧābir b. Aflaḥ (12th century CE), known in Europe as torquetum (= turcicum, ‹turkish› device?).
(Cat. II, 154; A 4.20)



«Instrument with the Triangle»
Model of a device described by ʿAbdarraḥmān al-Ḫāzinī (1st half of the 12th cent.) which was used for determining celestial altitudes like a quadrant and for the determination of the angular distance at which an object is perceived. (Cat. II, 147; A 4.24)



Indian Circle

A gnomon is fixed at the centre of the circle. The direction of the meridian is determined by the straight line drawn through the middle of the line between the point where the gnomon shadow enters the circle, the point of its exit and the centre of the circle. This instrument was known amongst the Greeks and in other culture areas. (Cat. II, 145; A 4.25)



Ibn al-Haiṯam's method to determine the meridian line

At the beginning of the 11th century, both al-Bīrūnī and Ibn al-Haiṯam independently came to the conclusion that the traditional method of determining the meridian line by means of the Indian circle was unsatisfactory due to errors caused by variations in the sun's declination. Ibn al-Haiṯam, unaware of the method proposed by al-Bīrūnī, found a way to determine the meridian by observing the corresponding altitudes of a fixed star and devised an instrument for this purpose. Ibn al-Haiṯam's method appeared in Europe for the first time in the work of Regiomontanus of the second half of the 15th century. (Catalogue I, p. 26; II, p. 146; A 4.21)



Mechanical sun and moon-calendar by al-Bīrūnī, reconstructed after his description.

(Cat. II, 164; B 3.05)



Mechanical-astronomic calendar
Model of an advanced version of al- Bīrūnī's mechanical-astronomic calendar (A. 3.05), designed by Muḥammad b. Abī Bakr al-Iṣfahānī in 1221. The Original is in the Museum of the History of Science at Oxford (No. 1221-22, CCL 5).

(Cat. II, 168; B 3.07)



Instrument for the determination of stellar altitudes in minutes. The earliest such portable instrument was invented by ʿUmar b. Sahlān as-Sāwī (1st half of the 11th century CE). Our model was made according to his description.

(Cat. II, 166; A 2.21)



The "casket of rubies" was constructed by the famous astronomer ʿAlī b. Ibrāhīm Ibn aš-Šāṭir (d. ca. 1375) in 1366 in Damascus for one of the Mameluk governors. Today the original is with the Auqāf Library at Aleppo.

(Cat. II, 155; A 4.36)



Instrument for measuring altitudes by Abū Naṣr as-Samau'al b. Yaḥyā al-Maġribī (d. 1175). It gives the cosine of the angle of altitude.

(Cat. II, 148; A 4.33)



Linear astrolabe by Šarafaddīn al-Muẓaffar b. Muḥammad b. al-Muẓaffar aṭ-Ṭūsī (d. after 1209).

(Cat. II, 134; A 1.14)



Instrument for measuring altitudes by Abū Naṣr as-Samau'al b. Yaḥyā al-Maġribī (d. 1175). It gives the sine of the angle of altitude.

(Cat. II, 149; A 4.34)



Instrument for measuring altitudes by Abū Naṣr as-Samau'al b. Yaḥyā al-Maġribī (d. 1175). It gives the cosine of the angle of altitude of the object sighted.

(Cat. II, 150; A 4.35)

❧ *Equatoria*



Equatorium by Abū Ǧaʿfar al-Ḫāzin (10th century CE). Based on a fragmentary specimen and al-Ḫāzins treatise.

(Cat. II, 177; A 6.01)



Equatorium by Muḥammad b. al-Samḥ (d. after 1035 CE), after extant description and drawings.

(Cat. II, 181; A 6.12)



Equatorium by Ibrāhīm b. Yaḥyā al-Zarqālī (2nd half of the 11th century CE), after his description.

(Cat. II, 183; A 6.02)



Equatorium by Abu ṣ-Ṣalt al-Andalusī (d. 1135 CE), after his description.

(Cat. II, 185; A 6.03)



Equatorium by Campanus of Novara (2nd half of the 13th century CE), after his description.

(Cat. II, 187; A 6.11)



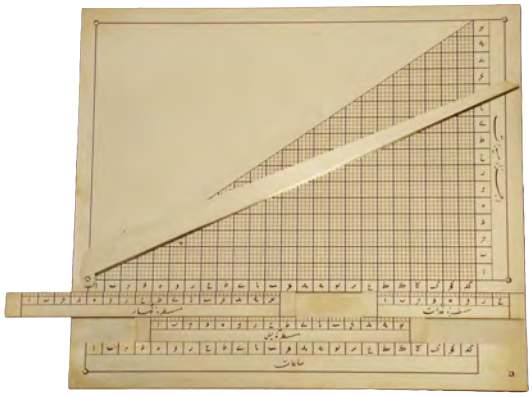
Equatorie by Geoffrey Chaucer (d. ca. 1400 CE), after a description attributed to him.

(Cat. II, 189; A 6.04)



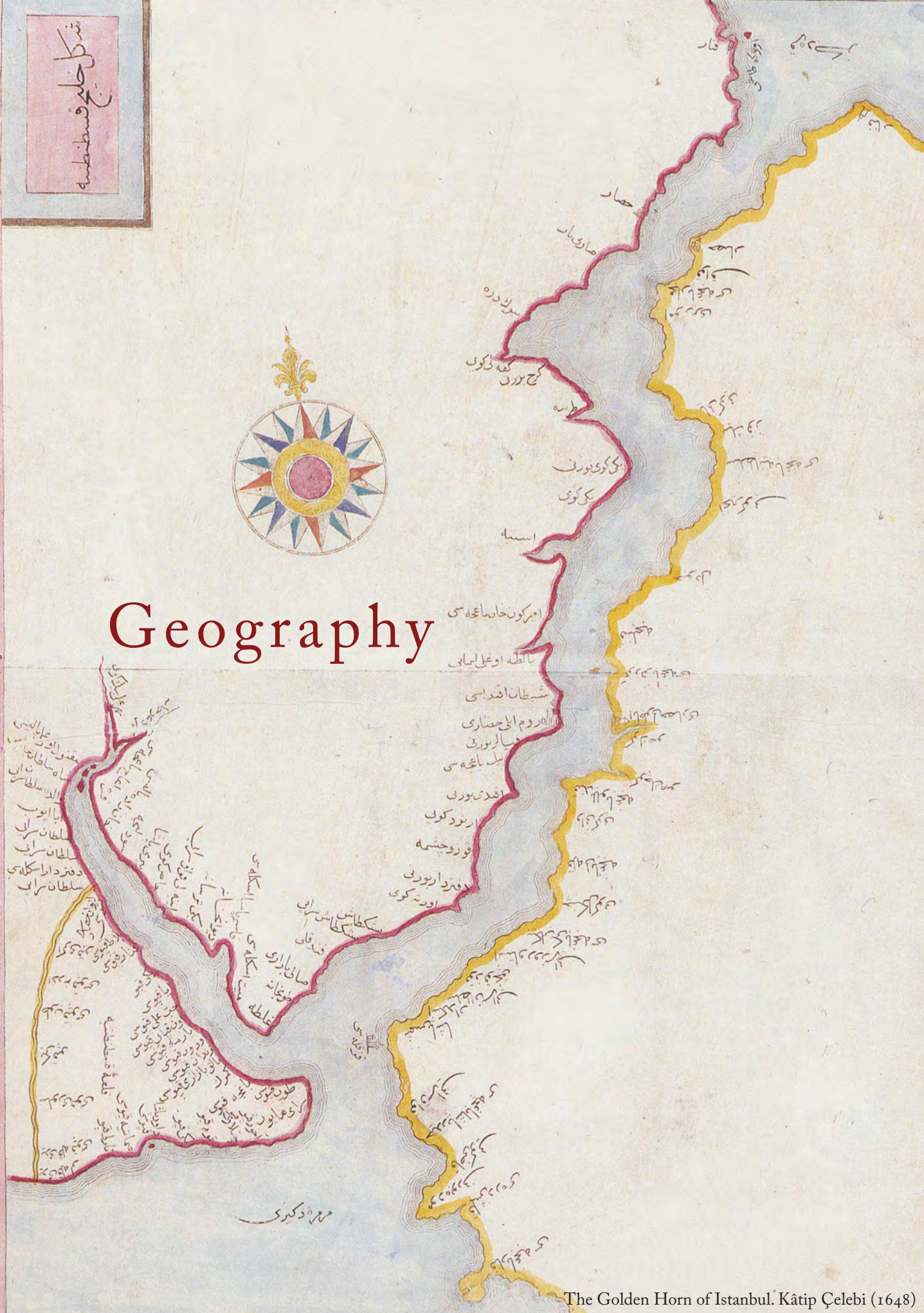
Ġiyāṯāddīn al-Kāšī's (d. 1429 CE) equatory, a sophisticated form of an instrument invented in the Arabic–Islamic culture area in the 10th century CE for the geometrical determination of the longitudes of celestial bodies (in this case also providing a means for the calculation of planetary latitudes!). Our model is based on the description and illustrations from al-Kāšī's text.

(Cat. II, 192; A 6.05)



Device for the computation of planetary conjunctions, also by al-Kāšī, made according to his description.

(Cat. II, 196; A 6.13)

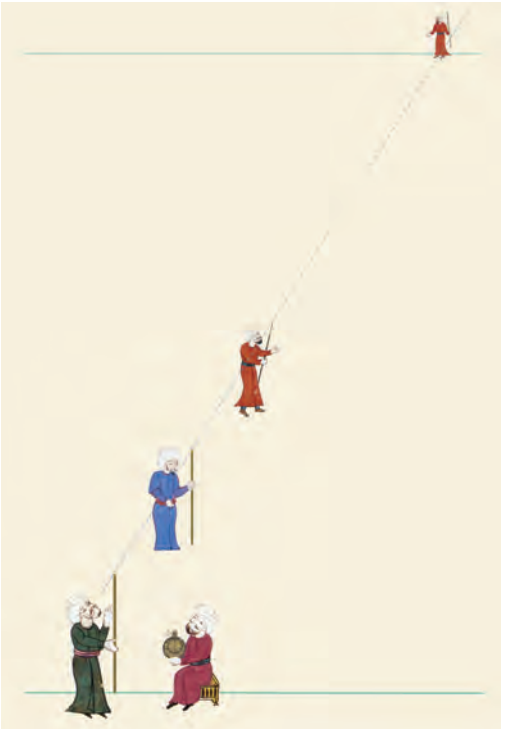


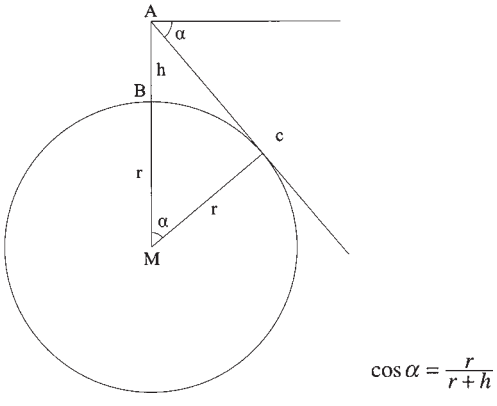
Geography

The Golden Horn of Istanbul. Kâtip Çelebi (1648)

How Muslim Scholars Determined the Circumference of the Earth at the Equator

At the beginning of the 9th century CE Caliph al-Ma'mūn ordered a group of scientists to determine the exact distance between two degrees of longitude (i.e. 1/360 of the equator) for the projected world map. This work was carried out in the plain of Sinjār in northern Iraq, later once again near Palmyra, Syria, using astrolabes, rods and stretched line. The average of several measurements came to 56 ⅔ Arabic miles for one degree and hence ca. 40000 km for the whole circumference of the Earth at the equator. The figure known by modern geography is still indebted to this utterly thorough scientific measurement.





$$\cos\alpha = \frac{r}{r+h}$$

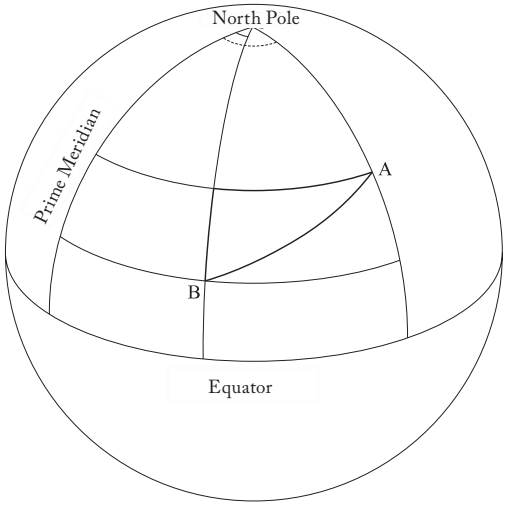
Calculation of the Earth's radius by Sind b. 'Alī

Another Method of Measuring the Length of the Equator

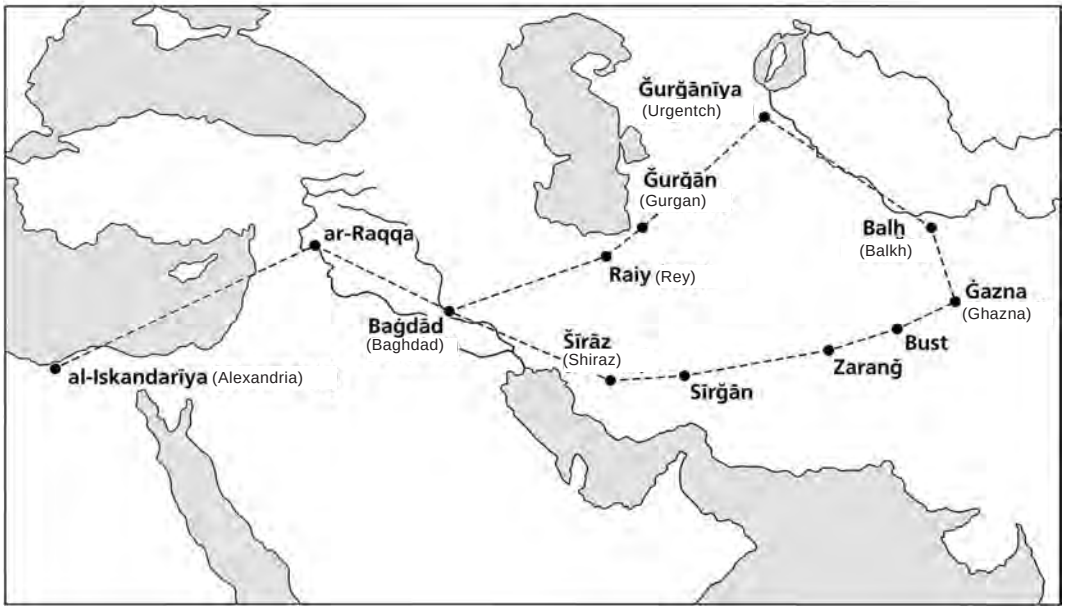
The astronomer and mathematician Sind b. 'Alī employed a new method for the measurement of a degree of the meridian during a campaign of Caliph al-Ma'mūn against Byzantinum and on commission by the ruler. On a coast high above sea level, Sind b. 'Alī measured the depression of the sun when it was setting and with that calculated trigonometrically the size of the Earth's circumference. Al-Bīrūnī also used this method on a mountain rising high above a plain. Later, the method was connected with the names of Francesco Maurolico (1558), Sylvius Belli (1565) and Francesco Giuntini (d. 1580). (Catalogue II, pp. 4-5)

al-Bīrūnī's Method for Measuring Latitudes

The geographic positioning of places which was carried on intensively and with scholarly meticulousness in the Islamic world led in the first quarter of the 11th century to the emergence of mathematical geography as an independent discipline. The credit is due to al-Bīrūnī, one of the most important scholars of the Islamic world. He made the attempt, unique in the history of geography, to determine the longitudes and latitudes of major places located between Ghazna (in modern Afghanistan) and Baghdad (within a radius of approximately twice 2000 kms) on the basis of astronomical observation, the measurement of routes and the use of the rules of spherical trigonometry (Fig.). The errors he made in the data of longitudes of about 60 places, when compared with modern values, only amount to between 6 and 45 minutes. His data were used as the basis for the determination of coordinates which was continued unbroken for centuries in the eastern part of the Islamic world. (Catalogue III, p. 12)



(Sezgin, *Geschichte des arabischen Schrifttums* vol. X, p. 157)

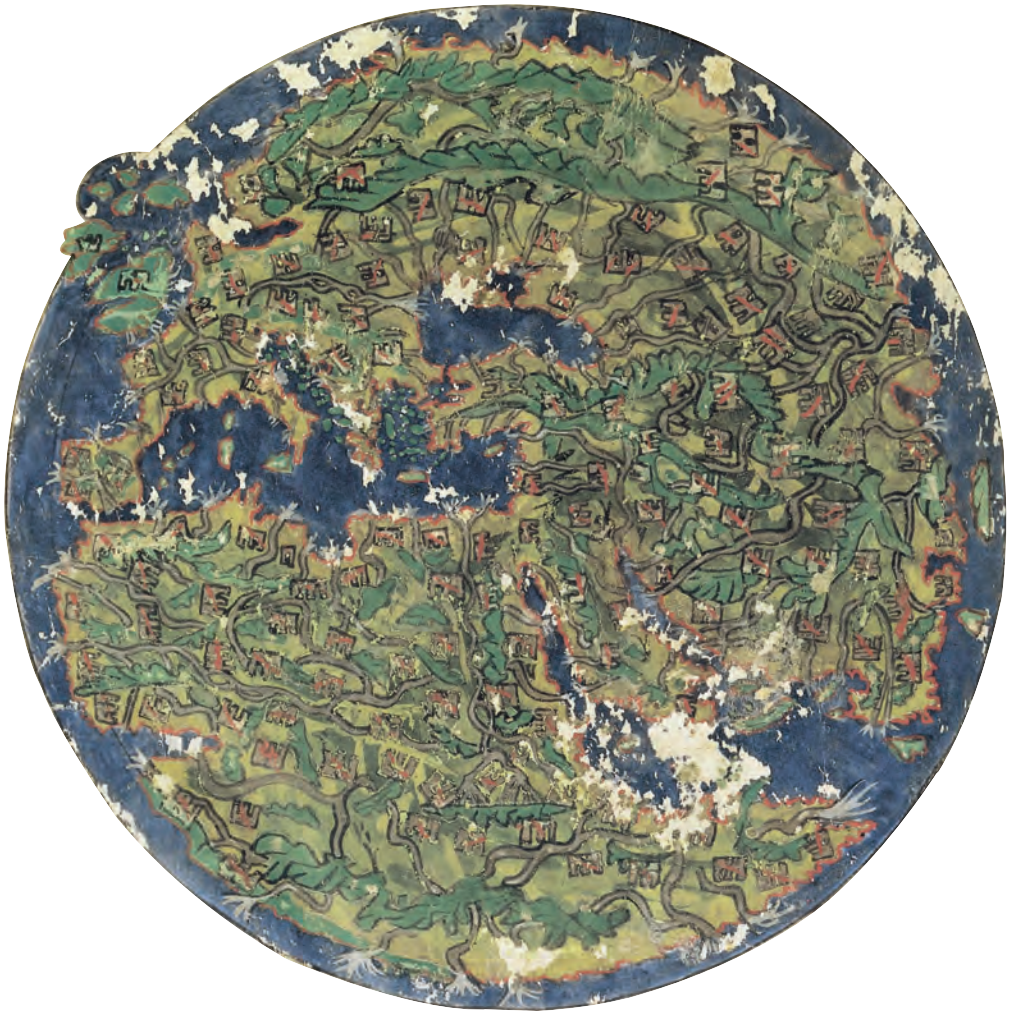


Schematic diagram of the routes measured by al-Bīrūnī in the first quarter of the 11th century and of latitudes ascertained astronomically for calculating the longitudes of ca. 60 places between Baghdad and Ghazna.



Sailing Line from North-West Africa to China

Using a particular type of vessel built near Basra in Iraq, Muslim merchants established as early as the 9th century a regular trading route from Māssa in Morocco via South Africa to China. From maps of Africa and the Indian Ocean which were introduced from the Muslim World the Portuguese were encouraged to follow that pass aiming at a sea route to India. Vasco da Gama reports enthusiastically how he had seen excellent maps of the Indian Ocean featuring circles of longitude and latitude, compasses and other instruments in the hands of Muslim voyagers. From Malindi to Calicut across the ocean he was guided by a Muslim navigator.



The Oldest Known European Copy of the World Maps of al-Ma'mūn and al-Idrīsī

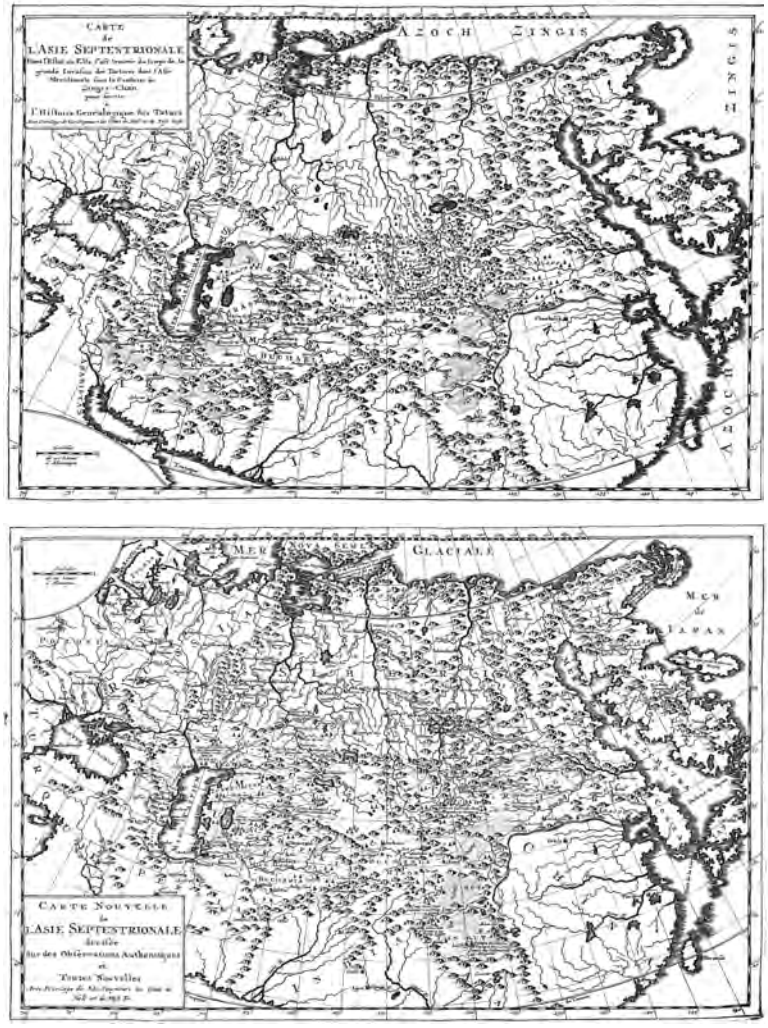
One world map to which insufficient attention was paid by the history of cartography appeared in the *Livres dou Tresor* (ca. 1265) of the Italian scholar Brunetto Latini, interestingly without any specific relationship to the book as such. Its configurations, the delineation of the oceans, mountains and rivers and the shape of the continents cause us to assume a model in the tradition of the world maps of the Ma'mūn geographers and al-Idrīsī, but already showing some further development in respect of the shape of the Mediterranean, the Black Sea and Asia Minor. The image of the world as depicted in this map, preserved in Brunetto Latini's work—as a whole and in the detail—must have been perceived as entirely new and strange in the non-Spanish West, as can be shown by a comparison with all the other surviving European world maps of the 13th century. A comparison of this map with the depiction of the oikoumene by Latini's contemporary Albertus Magnus (d. 1280) would alone be sufficient to elucidate how unusual this depiction must have been for the Occident. (Catalogue I, p. 114)



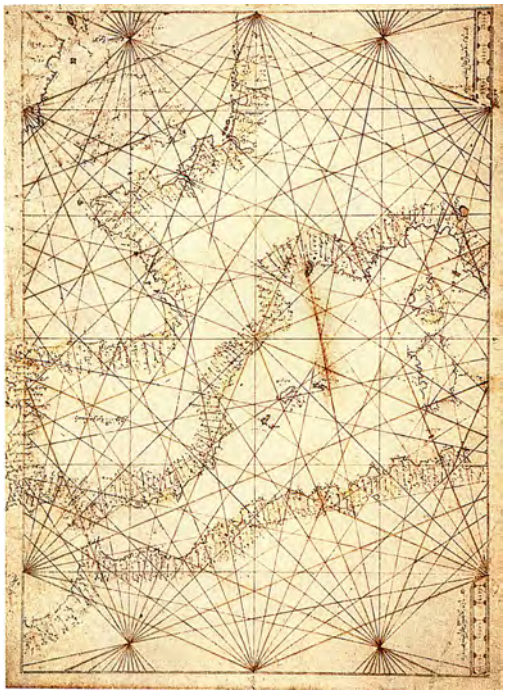
The Map of Persia–East Anatolia translated by Adam Olearius from the Arabic in 1637

According to our present knowledge, it was the German scholar Adam Olearius who was the first to unambiguously state that he had converted maps from Arabic script into Latin. Those in question were a map of Persia and one of Anatolia to which his attention had been drawn in 1637 during his stay in Shamakhia (in the Caucasus), together with additional regional maps. This kind of transmission of maps from the Islamic world intensified in Paris between ca. 1650 and 1750. (Catalogue III, p. 18)

The Two Most Important and Oldest Extant Maps of Northern Asia

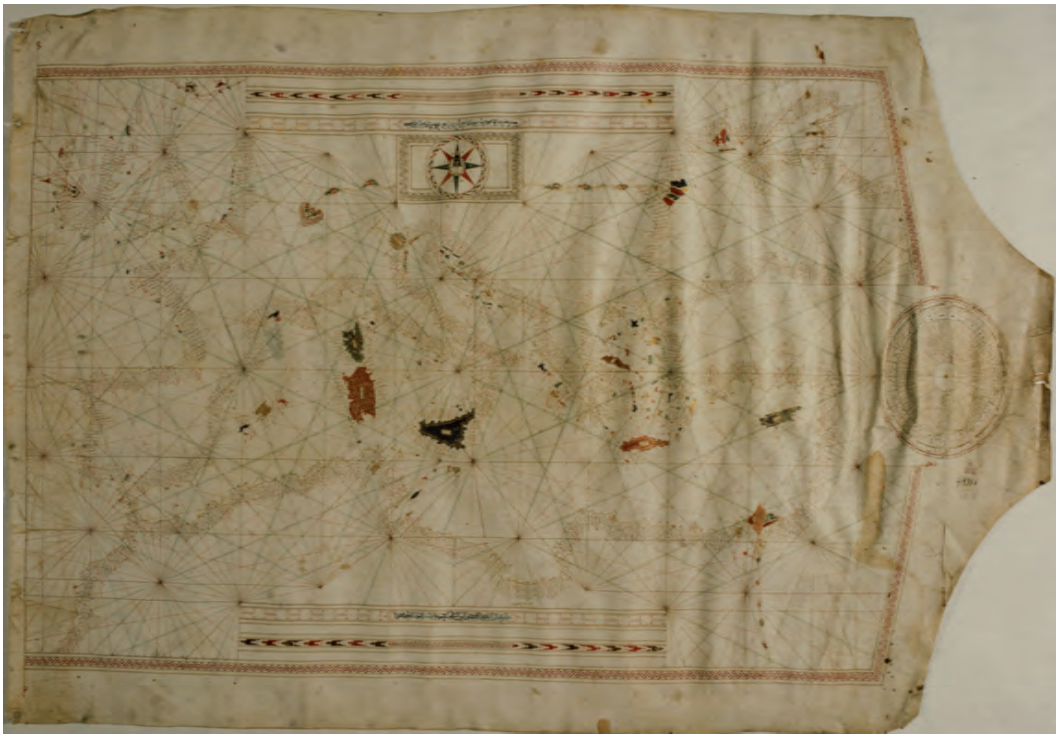


Two maps of northern Asia reached Europe around 1715 and circulated there in a French translation. One could call them the oldest maps of Siberia if they did not go beyond Siberia and included Asia up to 25° in the south and if they did not contain the oldest and almost accurate representations known to us of the Black Sea, the Caspian Sea, the Aral Sea and the Transoxanian river system. As a part of the book on the genealogy of the Turks by Abu l-Ġāzī Bahādur ˆån (b.1603, d. 1663), both maps found their way from Turkestan to Tobolsk. There the book came to the notice of Philipp Johann Strahlenberg (b. 1676), a Swedish officer who had been held captive by the Russians in 1710 and banished to Siberia in 1711. He saw the book with a "Tatar Mohamedan priest", a clergyman of the Siberian Tatars with the name of Agun Asbackewitz (Āḫund Özbekoğlu?) who had received it from the delegates from Turkestan and had "preserved it with their documents". Together with a fellow prisoner by name Peter Schönström and with the help of the Tartar cleric, Strahlenberg saw to it that the book was translated through Russian into German. The fame of the book must have spread so fast and so wide in the European geographical circles that the German translation, together with the maps prepared in the German edition by Strahlenberg in 1715 and 1718, was published already in 1726 in an anonymous French translation. According to its own legend, the older map goes back to the Mongol period (around 13th-14th c.), the second map is probably from the 16th century (Catalogue I, 130; III, 29)



The Oldest extant realistic Sea Map

The oldest extant Arabic document of the youngest period of development of the realistic sea maps is a map from the Maghrib. It shows the westernmost part of the Mediterranean with a complete configuration of the Iberian peninsula and the western edge of Europe with some parts of the coastal areas of England and Ireland. This map from the Maghrib is possibly older than the oldest known "portolan chart" the origin of which is supposed to date around 1300 CE. In any case, the first scholar who wrote about it, Gustavo Uzielli, introduced it as a work of the 13th century.
(Catalogue I, 48; Sezgin, *Geschichte des arabischen Schrifttums* XIII, p. 74)



The second oldest extant realisttic sea map made by Aḥmad aṭ-Ṭanǧī (1413), Topkapı Sarayı (Sezgin, *Geschichte des arabischen Schrifttums* XIII, p. 75)



Osmanlı Karadeniz haritası (16cı yüzyıl)
Bu – bildiğimize göre –, enlem, boylam derecelerini taşıyan en eski Karadeniz haritasıdır. Bu, Karadenizin Osmanlı haritacılığında hemen hemen günümüzün tanıdığı boyutları bulduğunu gösteriyor. Aynı harita 18ci yüzyılın başlarında Fransız haritacılarına ulaşmıştı.

Ottoman–Turkish map of the Black Sea (16th century C.E.)
To our knowledge this is the oldest map of the Black Sea with latitudinal and longitudinal graduation. It demonstrates that Ottoman map making had reached almost the same coordinates that we know today. This map found its way to French cartographers in the 18th century C.E.

خريطة عثمانية–تركية للبحر الأسود
(القرن ١٦م)

هذه الخريطة هي بحسب معرفتنا أقدم خريطة للبحر الأسود بخطوط الأطوال والعروض. وهي تظهر أن الكارتوغرافيا العثمانية كانت قد وصلت إلى نفس الإحداثيات تقريباً التي نعرفها اليوم. وصلت هذه الخريطة إلى بداية القرن ١٢م إلى كارتوغرافيين فرنسيين.

Carte turque ottomane de la mer Noire (XVIe siècle)
Il s'agit, à notre connaissance, de la plus ancienne carte de la mer Noire munie de degrés de longitude et de latitude. Elle montre qu'on a déjà obtenu, dans la cartographie ottomane, presque les mêmes coordonnées que celles que nous connaissons aujourd'hui. La même carte est parvenue à des cartographes français au début du XVIIIe siècle.

Osmanisch-türkische Karte des Schwarzen Meeres (16. Jh.)
Unseres Wissens ist dies die älteste Schwarzmeerkarte mit Längen- und Breitengraden. Sie zeigt, daß man in der osmanischen Kartographie bereits nahezu die gleichen Koordinaten erreicht hat, die man heute kennt. Die gleiche Karte gelangte zu Beginn des 19. Jahrhunderts zu französischen Kartographen.

Very successful Map of the Black Sea made by the Ottomans in the 16th century

Exact Ottoman map of the Black Sea whose zero meridian lies 28°30' west of Toledo in the Atlantic, in accordance with Arab-Persian tradition. The longitudes and latitudes given in the margins prove that the representation of the sea by the Ottoman geographers has almost attained perfect dimensions. The French cartographer G. Delisle made use of a copy or of the original of this map, which had reached Paris before 1700. (Catalogue III, p. 20)

The "Javanese" Atlas of the Islamic World (15th century?)

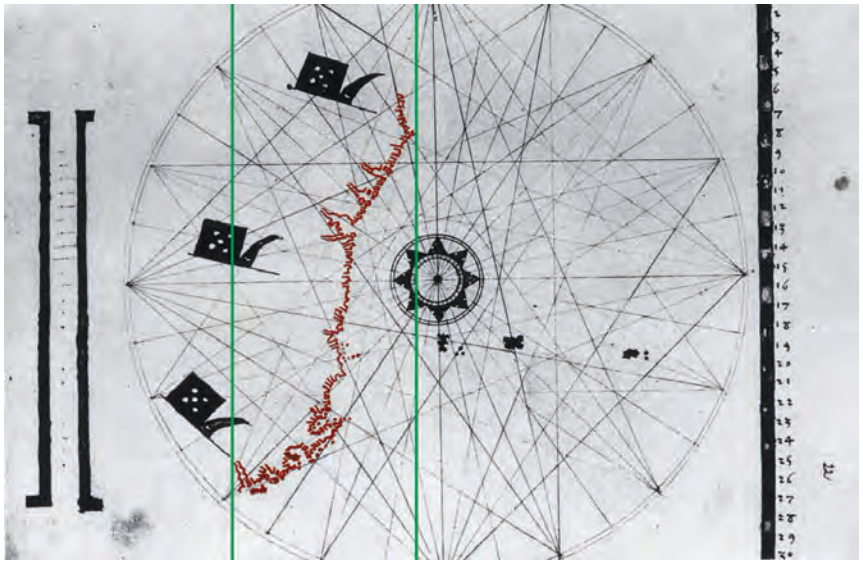
A most important document for the history of Islamic cartography is the "Javanese" atlas, which depicts, among others, the Brazilian coast line. The atlas fell into the hands of the Portuguese shortly after the conquest of Malacca in 1511 and was sent to King Emanuel I (d. 1521) by the conqueror Alfonso de Albuquerque. In his accompanying letter to the king Alfonso writes: "I am sending you part of the copy of a large map made by a Javanese pilot representing the Cape of Good Hope, Portugal, the country of Brazil, the Red Sea, the Persian Sea, the Spice Islands (the Moluccas), the sailing routes with the direct route to China and Formosa which the ships take, along with the interior [of these countries] which adjoin one another. It seems to me that this is the most beautiful thing which I have ever seen. Your Majesty will be greatly pleased to see it. The place names are in Javanese characters, I had a Javanese who can read and write. I am sending Your Majesty this part, which Francisco Rodrigues copied from the original, in which Your Majesty will be able to see for yourself where the Chinese and the inhabitants of Formosa come from, what route your ships need to take to reach the islands of cloves, where the goldmines are, the islands of Java and Banda, the island of nutmeg and mace, the empire of Siam, the Cape of the Chinese, which they sail round and where they turn round and do not go beyond. The original was lost with the Frol de la Mar (when it was shipwrecked). I have discussed the content of this map together with the pilot and Pero Dalpoem so that I might describe it to Your Majesty clearly. This map is very precise and well known because it is used in navigation. On it the archipelago of the islands known as 'Selat' is missing [between Malacca and Java]". (Catalogue I, pp. 70-71)



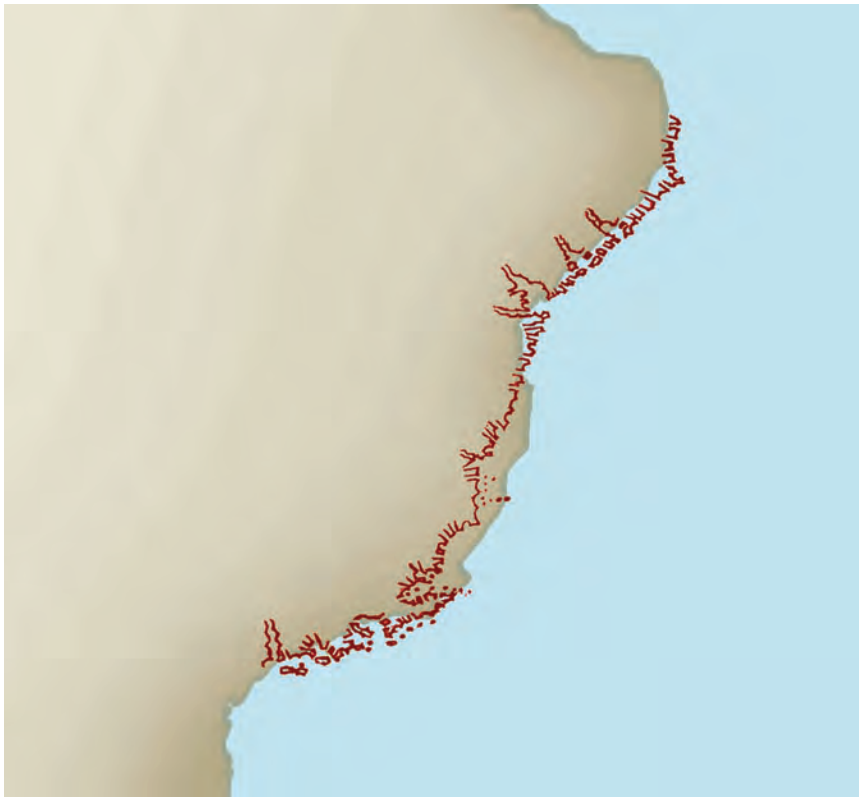


The Islamic Forerunners of Christopher Columbus

When Portugal was still under Muslim protection, many Islamic explorers attempted to reach China from Lisbon on the western route across the Atlantic. Before 1154 CE there was even a street named after these voyagers "Strayers Road" (*Darb al-maġrūrīn*) in Lisbon. The great scholar al-Bīrūnī (d. 1048 CE) hinted at a remarkable concept, of particular interest in this context: *"The Ocean separates the inhabited landmass known to us from possible other continents or inhabited islands that might be located beyond it in both directions."*



A map, produced by Muslims in the 15th century, of a part of the Brazilian coast, preserved in the Portuguese translation of the Javanese atlas

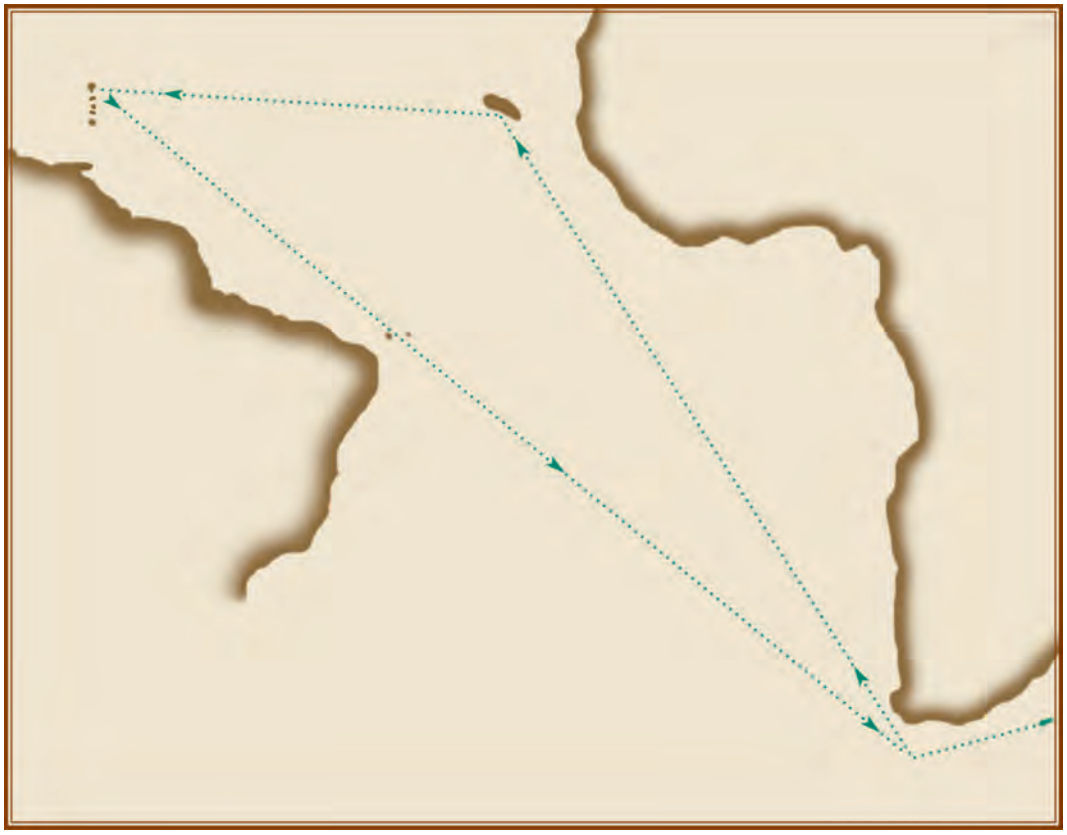


The coast line of Brazil from the Javanese atlas superimposed on a modern map in red strokes



The Map of Pîrî Re'îs (d. 1554)

Its original consisted of an Arabic map, whose Italian redaction was sent by Paolo Toscanelli in 1474 from Florence to Lisbon and which made possible the westward journey of Columbus. In the present form it contains some additions. (F. Sezgin, *Geschichte des arabischen Schrifttums* XIII, pp. 163-164).



The part traversed by a ship from the Islamic world to America in 1420.

Anthropo–Geography

In the 10th century, the previous development in geography led to the appearance of an anthropo-geography such as developed in Europe only in the 19th century. This genre of Arabic–Islamic geography with its stencil-like didactic maps may have been influenced by the Sassanid–Persian cultural area but appears completely autochthonous in its development. It was represented by Abū Zaid al-Balḫī, al-Ğaihānī, al-Iṣḫaḫrī, Ibn-Ḥauqal and al-Maqdisī (al-Muqaddasī). The youngest of these, al-Maqdisī, was described as "the greatest geographer ever" by the Arabist Alois Sprenger around the middle of the 19th century after he had discovered the first manuscript of al-Maqdisī's book in India and studied it. (Catalogue I, p. 23)

Ibn Baṭṭūṭa—the Greatest World Traveller in all Antiquity and the Middle Ages

One of the important contributions by the Arabic–Islamic world in the field of geography is the extensive travelogue by Muḥammad b. ʿAbdallāh Ibn Baṭṭūṭa (b. 1304, d. 1369), who hailed from Tangiers in Morocco. Aged 22 he left his native town bound for Mecca, visited Alexandria and Cairo, went up the Nile to Syene (now Aswan), from there to Syria and Palestine, crossed Arabia up to Mecca, turned towards East Africa and reached Mozambique, visited Asia Minor and Byzantium, southern Russia (up to the 55° northern Lat.), Central Asia, India, the Malay peninsula and China, made extended sojourns and visited certain places repeatedly. After 24 years he returned to Tangiers. A second journey took him to Andalusia, a third to Northern Africa. With his travels lasting all in all 27 years, Ibn Baṭṭūṭa was, in the words of Richard Hennig "in fact the greatest world traveller in all Antiquity and the Middle Ages". Through Ibn Baṭṭūṭa's gift for keen observation and his highly developed sense for matters of historical geography, anthropology and cultural history, his extensive travelogue became an invaluable document in the history of geography. (Catalogue I, p. 61; III, p. 8)





Nautical Science

Scientific Navigation

According to Ibn Māğid (one of the two outstanding Arab navigators of the 15th and 16th c.), navigation, which he calls *ʿilm al-baḥr* (nautical science), is a "theoretical and empirical science, as opposed to a mere paper tradition" (*ʿilm ʿaqlī taǧrībī lā naqlī*). He divides navigators into three groups. The first are the simple pilots whose voyages turn out sometimes well, sometimes not, whose answers are sometimes right and sometimes wrong. These mariners do not deserve the title *muʿallim* ("master", sing.). The members of the second category, the average *maʿālima* ("masters", pl.) are known for the range of their knowledge. They are proficient, completely at home with the routes of the localities to which they sail, but once they die they are forgotten. The third class of navigators is the highest. Those who belong to it are widely known, command all the operations performed at sea and are scholars "writing treatises" from which one can benefit during their life time and also afterwards. Ibn Māğid also mentions the regulations a captain has to observe during his voyage and the moral principles expected of him. He is conscious that an important position is assigned to his own person in the history of navigation and that his achievements shall not be without impact upon subsequent generations. ("There will come a time after us when it shall be possible to judge which position is due to each of us in our profession.") (Catalogue I, p. 71-72)



Law of Evolution in Ibn Māǧid

Ibn Māǧid (15th c.) is convinced that he himself had advanced his field, notwithstanding his earlier works containing points that require correction. Interestingly he calls the material from his earlier writings he no longer wishes to uphold in his present higher level of knowledge—"revoked" (*mansūḫ*) and that what replaces them "revoking" (*nāsiḫ*), thus using terms usually employed in connection with the revelation of the Qurʿān. (Catalogue I, p. 72)

Origin of the Compass

The time when the knowledge of the compass reached the Islamic culture area cannot be precisely determined, but it was presumably in the 9th or 10th century. It seems that the magnetic needle in its primitive form originated in China, but was first systematically used for navigation by the navigators of the Indian Ocean. Besides the numerous references in Arabic sources, the Portuguese also frequently provide perspicuous information on the various types of compasses used in the Indian Ocean. The Portuguese historian Hieronimus Osorius (1506–1580) gave a particularly impressive account of the three stages in the development of the compass with Arab navigators. (Catalogue I, p. 80)

Ibn Māǧid's Improved Compass (15th century)

In one passage of his extensive work he discloses that some inventions in the field of nautical science are his own achievements, including an improvement of the compass where the magnetic needle itself is put on the compass, that is to say, it moves on top of the cardboard disc inscribed with the thirty-two bearing marks, rather than being fixed underneath. (Catalogue I, p. 72; III, p. 65; C 1.08)



The Climax of Mathematical–Astronomical Nautics

The specifics of this navigation based on trigonometric–astronomical methods were expounded only in the first quarter of the 16th century in the works of Sulaimān al-Mahrī. This latest master navigator known to us also regarded navigation as a science consisting of theory and experience, and, particularly as regards details, subject to the law of evolution. From this discipline, which over the centuries developed into an independent branch of science, we shall mention the three pillars on which it rests:

1. Determining the latitude at sea using the pole star and the circumpolar stars whose upper and lower culminations serve for determining the altitude of the pole which in turn yields the geographical latitude of a place.

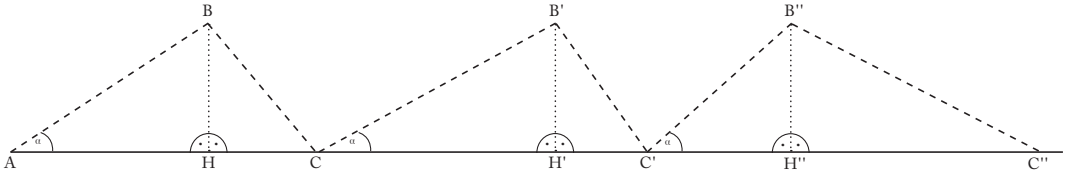
2. Mathematical–astronomical measurements of distances on the open sea, distinguished by Sulaimān al-Mahrī with the term *ḥisābī* ("mathematical") from those that are achieved empiricallly "according to experience" (*taǧrībī*).

3. Determining the position on the open sea. Here the distances to be measured and the methods of measurement are of three kinds:

a) The first and most simple case is the latitudinal distance, running parallel to the meridian. For its determination it is sufficient to meas-

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ure the altitude of the pole while setting out and once again after sailing for some time; the measurements are taken either in degrees or the thumb-width unit *iṣbaʿ* (1 *iṣbaʿ* = 1°36'26" or 1°42'51"), the difference can be converted into distances (1° = 56 2/3 miles).
b) In the second case the distance may run at any angle oblique to the meridian. It is found by taking, in degrees, the altitude of the pole and measuring the angle of the course to the meridian at the time of putting to sea. After sailing for some time on that course, the altitude of the pole is again taken. With this data, a right-angled triangle is constructed. The hypotenuse, i.e. the side opposite to the right angle, is the sought distance.
c) In the third case the distance is longitudinal. This was used for measuring distances between places of the same latitude situated on opposite seacoasts, i.e. determining distances parallel to the equator. The method is equivalent to the determination of longitudinal differences between two points on the coast or at sea.
(Catalogue I, p. 79)



Measure of distance in the open sea

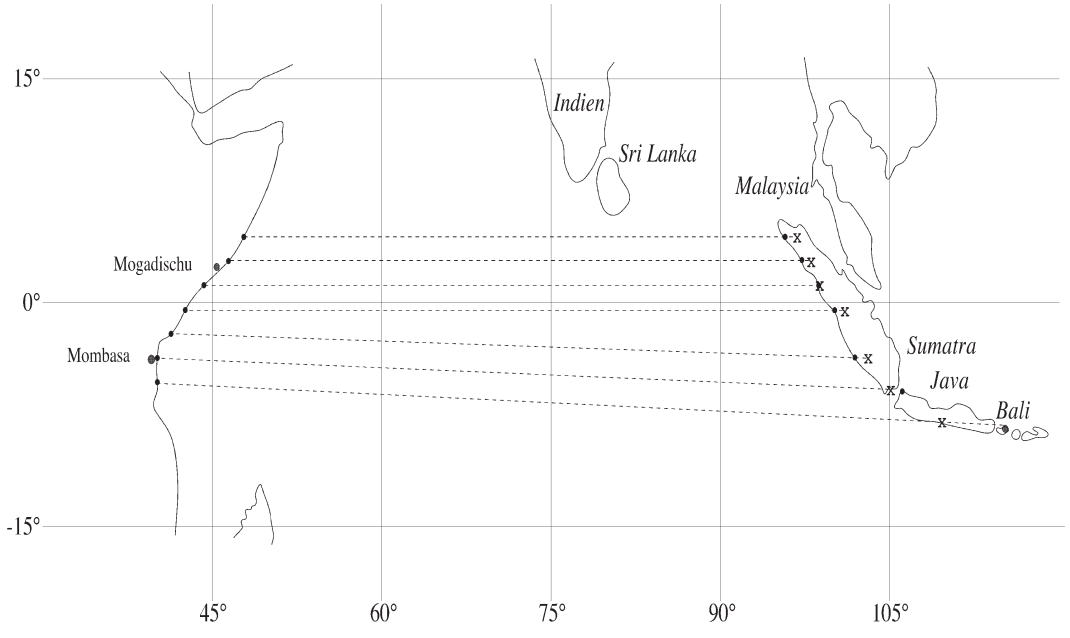
Amazingly Precise Distance Measurements in the Indian Ocean by Arab Navigators in the 15th Century

The Arab navigators preserve for us fairly long tables for small and great distances in the Indian Ocean in the corresponding chapters of their books. When compared with today's values their data prove largely to be very good, sometimes relatively good, and sometimes, where they refer to less frequented areas, to be erroneous. Yet on the whole, together with the latitudes and the directions given, they reveal a mathematical record of the Indian Ocean which accords astonishingly closely to reality. In the fourth chapter of his *Minhāǧ al-Fāḫir* Sulaimān al-Mahrī gives us clear information about the question of how far the mathematical record of the configuration of the Indian Ocean had progressed in the Arabic-Islamic world and how successfully the seafarers operated with their measurement of distances. There, in a section exclusively devoted to distances between the east coast of Africa and Sumatra-Java he lists 60 distances between headlands, gulfs, islands and ports in the Indian Ocean which are located on the same geographical latitudes. The table comes only really into its own when its data are compared with today's coordinates.
The comparison is scarcely impaired by the fact that not all the ancient names can be identified in a modern atlas. Even without place names we would have been able to carry out a comparison, since al-Mahrī recorded distances between corresponding latitudes at opposing points of the African and the Sumatran-Javanese coasts. If we convert the sums given by Sulaimān al-Mahrī from *zāms* … into degrees, we arrive at the values in the following table.
(Catalogue III, p. 39-40)

			al-Mahrī			Modern values					
	Point on the African coast	Point on the coast of Sumatra/Java	Lat	Distance in *zām*	Distance in degrees	Lat	Long	Lat	Long	Distance in degrees	Deviation
1	Muqbil Atoll (Mareek?)	Mākūfāngğ (Meulaboh)	4°24'	234	50°09'	3°46'	47°15'	4°10'	96°09'	48°54'	**+1°15'**
2	Murūtī	Fanṣūr (Barus)	2°47'	248	53°09'	(2°47')	46°21'	2' 02'	98°20'	51°59'	**+1°10'**
3	Barāwa	Priaman	1°10'	264	56°34'	1°02'	44°02'	S 36'	100°	55°58'	**+0°36'**
4	Malawān (Imāma)	Indrapura	- 0°30'	278	59°34'	- 0°03'	42°44'	- 2°02'	100°56'	58°12'	**+1°22'**
5	Kitāwa (Pale Island)	Sundabari (Sillebar)	- 2°07'	292	62°34'	- 2°04'	41°05'	- 4°10'	102°20'	61°15'	**+1°19'**
6	Mombasa	Sunda (Šūnda)	- 3°44'	306	65°34'	- 4°04'	39°40'	- 6°	106°	66°20'	**−1°14'**
7	Ğazīrat al-Ḥaḍrā' (Pemba)	Bali	- 5°21'	317	67°56'	(-5°21')	39°44'	- 8°	115°	75°16'	**−7°20'**

Distances of places with corresponding degrees of latitude on the east coast of Africa and in Java/Sumatra according to Sulaimān al-Mahrī and the modern map

In order to properly grasp the importance of the distances listed by al-Mahrī for the history of geography, cartography and navigation we need to look at how they diverge from the corresponding modern values (cf. the following fig.). (Catalogue III, p. 40)



Distances between Africa and South-East Asia according to Sulaimān al-Mahrī, with reference to modern maps

Instruments of Navigation



(1) Balistilha

(Cat. III, 45; C 2.08)



(2) Jacob's staff

(Cat. III, 47; A 4.22)

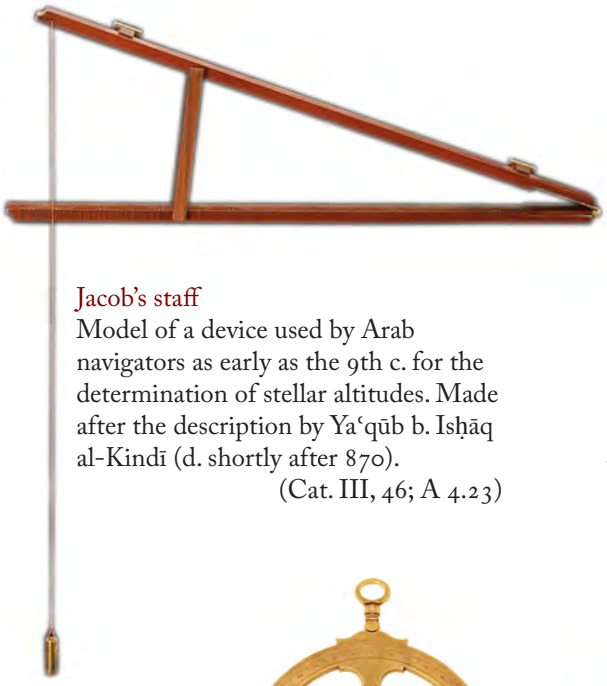
For the determination of altitude on the reeling deck of a ship, navigators in the Indian Ocean did not use the astrolabe but simple wooden devices one of which became known later as balistilha (1) in Europe, the other as Jacob's staff (2).



Dāw (Dhau, Dau)

For this kind of vessel, which dominated the sea-trade in the Indian Ocean for centuries, the "Latin" rig is, inter alia, characteristic, as well as the elastic joining of the planks of the hull with ropes.

(Cat. III, 55; C 3.02)



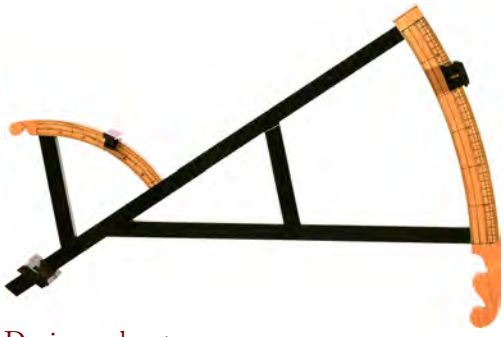
Jacob's staff
Model of a device used by Arab navigators as early as the 9th c. for the determination of stellar altitudes. Made after the description by Ya'qūb b. Isḥāq al-Kindī (d. shortly after 870).
(Cat. III, 46; A 4.23)



Simple hour glass
Replica of a nautical hour glass as used for time keeping on ships.
(Cat. III, 53; C 2.09)



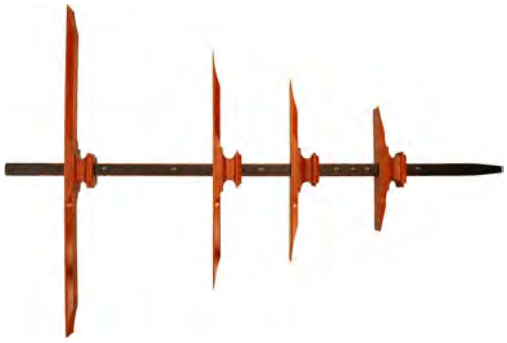
Marine astrolabe, made on the basis of a Portuguese specimen from the 16th century.
(Cat. III, 51; Nr. C 2.01)



Davis quadrant
Model of a more developed type of Jacob's staff, named after its inventor, John Davis (1607).
(Cat. III, 48; C 2.07)



Vasco da Gama's nautical astrolabe
(Cat. III, 49; C 2.02)



Jacob's staff
with four cross-pieces for determining the height of stars; based on two Spanish specimens at the Museo Naval in Madrid and the Museu Marítim in Barcelona.
(Cat. III, 47; C 2.06)



Compass with fish-shaped needle
Model of an early mariner's compass as used from the 1st half of the 13th c. at the latest in the Arabic-Islamic culture area.
(Cat. III, 57; C 1.01)



Floating compass, described by the Yemenite ruler al-Malik al-Ašraf around 1291 CE: a piece of wood swimming in a bowl carries the magnetic needle.
(Cat. III, 58; C 1.04)



Floating compass described around 1270 CE by Petrus Peregrinus, a crusader, in a letter to his friend Syger de Foucaucourt. It is the oldest known description of the compass in Europe, which was apparently introduced by returning crusaders.
(Cat. III, 59; C 1.05)



[1] The most simple form of a needle compass as used by Muslim navigators in the Indian Ocean. Built after various sources.
(Cat. III, 61; C 1.02)



[2] More advanced form of needle compass as used by Muslim navigators in the Indian Ocean. Built after various sources.
(Cat. III, 62; C 1.03)



[3] Third stage of the compass as used by Muslim navigators in the Indian Ocean. Built after various sources.
(Cat. III, 63; C 1.07)



[4] Most sophisticated type of compass known in the Arabic-Islamic tradition, invented by the eminent navigator Ibn Māǧid in the 15th century CE, reconstructed according to the sources.
(Cat. III, 65; C 1.08)





Two types of Ottoman Compass
Built after the description by Ḥāǧǧī Ḫalīfa (1609-1658) in his Ottoman-Turkish book and after illustrations in the first Müteferriqa-edition of 1732.
(Cat. III, 71; C 1.12+C 1.24)

Presumed early lay-outs of Arab mariner's compasses, as adopted from the navigators of the Indian Ocean and introduced to Europe:



a) After the description by the Spaniard Pedro de Medina (1545 CE).

(Cat. III, 68; C 1.09)



b) After the description by Georges Fournier (1643 CE).

(Cat. III, 69; C 1.10)



Ship's Compas

Replica of a compass from the 19th century. Original in the Museu Marítim, Barcelona.

(Cat. III, 73; C 1.14)



Ship's Compas

Reconstruction of a European compass from the 18th century; after Nicholas Bión.

(Cat. III, 72; C 1.13)



Ship's Compas
Replica of a compass from the 19th century. Original in the Museu Marítim, Barcelona.
(Cat. III, 74; C 1.15)



Ship's Compas
Replica of a compass from the 19th century. Original in the Musée de la Marine, Paris.
(Cat. III, 75; C 1.16)

Geographical Compass
An English compass with direction finding, from the 20th century.
(Cat. III, 81; C 1.21)



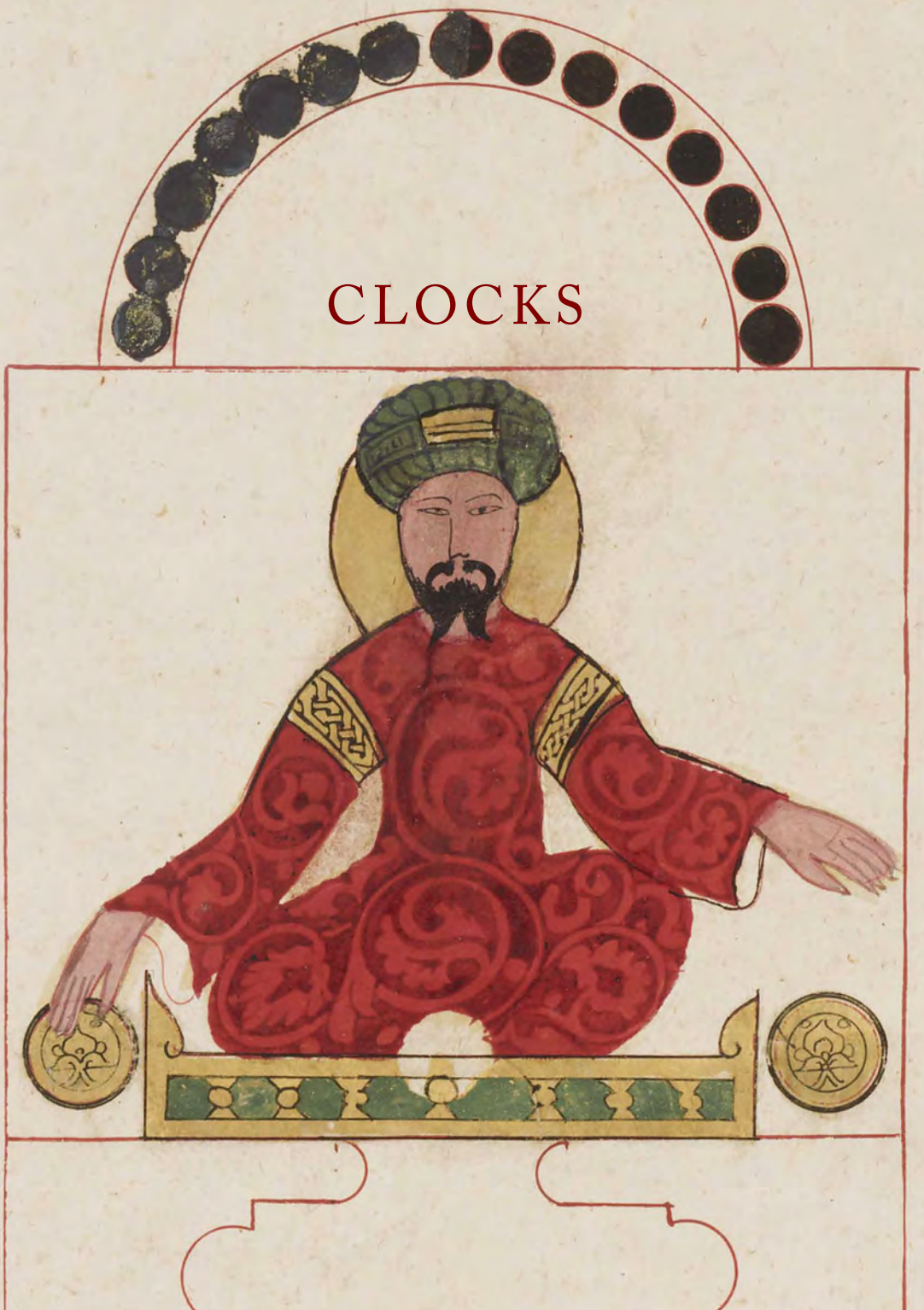


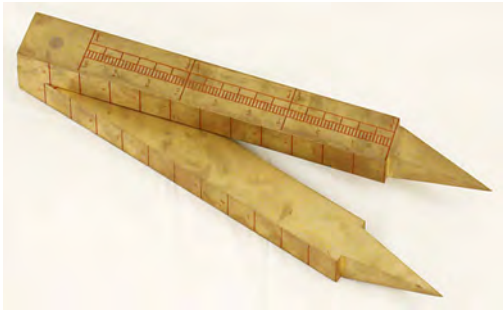
Compass for Surveying
An English compass, with direction finding and water level, from the 20th century.
(Cat. III, 78; C 1.22)



Prayer Compass
Replica of a 19th c. Ottoman-Turkish compass. The original is in the Rautenstrauch-Joest-Museum at Cologne.
(Cat. III, 77; C 1.18c)

CLOCKS





Dividers for the determination of prayer-times. Made after the description in an as yet unpublished manuscript, authored probably by Abū ʿAbdallāh Muḥammad b. Mūsā al-Ḫwārizmī (1st half of the 9th c.).
(Cat. III, 85; B 2.08)



Sundial, known as the ‹Locust's leg›
A simple pocket-sundial, as described by Abu l-Ḥasan al-Marrākušī (13th c.).
Our model was made according to a Syrian specimen dating from 1159, now preserved in the Bibliothèque nationale, Paris.
(Cat. III, 90; B 2.06)



Sundial
Combined with a floating compass; model after a description and drawing by Abū ʿAbdallāh Muḥammad b. Ibrāhīm ar-Raqqām (d. 1315), active under the Nasrids in Granada.
(Cat. III, 114; B 2.13)

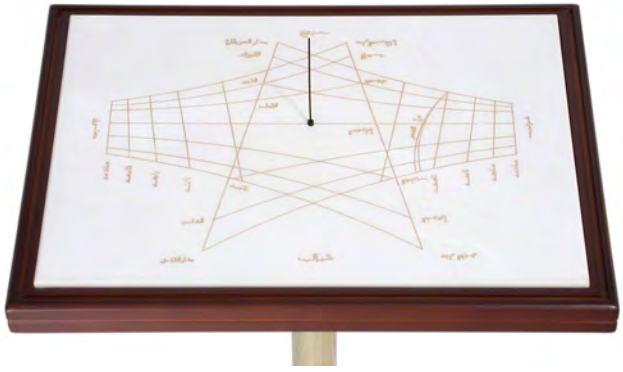


Sundial
After an instrument dating from 1537 ascribed to Pedro Nunes.
(Cat. III, 115; B 2.15)



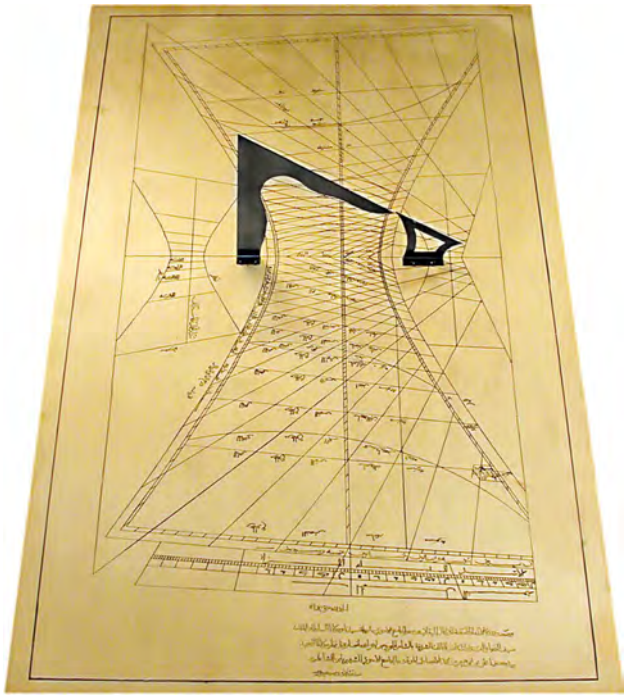
Sundial from the Ibn Ṭūlūn Mosque in Cairo (1296). The sundial, does not exist anymore. The model is constructed according the Napoleonic *Description de l'Égypte* from the year 1798.
(B 2.16)

Sundial
Made after a description and drawing by the Egyptian mosque-astronomer *(muwaqqit)* Zainaddīn ʿAbdarraḥmān b. Muḥammad Ibn al-Muhallabī al-Mīqātī, in his book dating from 1426. Calibrated for the latitude of Cairo (30°).
(Cat. III, 93; B 2.02)





Spanish-Arabic Sundial
After a description and illustration in the *Libros del saber de astronomía* (1267-1268) by the Castilian King Alfonso X, being a compilation of predominantly Arabic-Islamic sciences.
(Cat. III, 113; B 2.04)



Sundial, made by the astronomer Ibn al-Šāṭir (d. 1375 CE) for the Umayyad Mosque at Damascus. It represents the apex of the sundial's development. The original is broken in three pieces and now kept in the National Museum of Syria in Damascus.

(Cat. III, 91; B 2.01)



Sundialonstructed by al-Malik al-Ašraf ʿUmar b. Yūsuf (reigned 1295-1296), the third Sultan of the Yemeni Rasulid dynasty, for the latitude of Cairo; reconstructed after a drawing in his book *Muʿīn aṭ-ṭullāb ʿalā ʿamal al-aṣṭurlāb.*

(Cat. III, 87; B 2.03)



Chandelier Clock
Replica of a device described by the well-known astronomer ʿAlī Ibn Yūnis (d. 1009) who was active in Egypt; he called this device for time-measurement *ṭuraiya*.
(Cat. III, 86; B 3.03)



The Andalusian "Candle Clock with Twelve Doors" for night hours according to Lisānaddīn Ibn al-Ḫaṭīb (d. 1374).
(Cat. III, 97; B 3.09)



Spanish-Arabic Candle Clock
After the description and illustration of the *Libros del saber de astronomía* (1267-1268) of the Castilian King Alfonso X, which essentially represents a compilation of Arabic-Islamic sciences.
(Cat. III, 112; B 3.08)



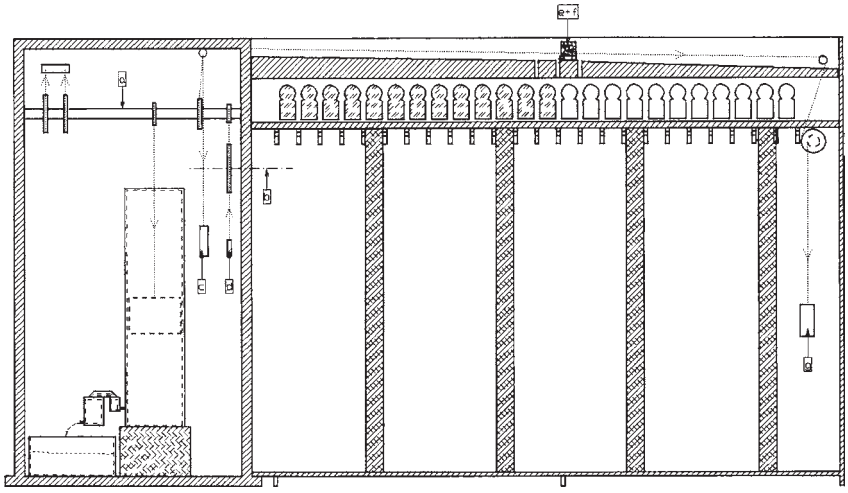
The «Candle Clock with the Scribe»
In his book al-Ğazarī (ca. 1200) describes a candle clock made by a certain Yūsuf al-Asṭurlābī. (Cat. III, 96; B 3.10)



Model of the Water Clock from Fez

This is, as far as we know, the oldest extant water clock. It was constructed in 1362 and belongs to the room allocated to the astronomer of the Qarawīyīn Mosque in Fez who is in charge of the calculation of prayer times. The water inflow was calculated so exactly that it remained uniform every second through 24 hours. The sinking of the float in the basin causes a minute pointer on a dial to move every four minutes and this, on the other hand, causes the pulling of two carriages, one loaded with small balls, the other with big ones. By falling into ringing bowls, the big balls indicate the full hours, while the small ones indicate intervalls of four minutes. Moreover, at every full hour one of the doors behind the bowls opens.

(Cat. III, 106; B 1.04)



Construction scheme of the water clock from Fez



Model of al-Ǧazarī's Goblet Clepsydra (ca. 1200 CE). The sophisticated water-powered mechanism is hidden inside.
(Cat. III, 103; B 1.10)



A Balance Clepsydra indicating Minutes
Al-Ḫāzinī describes in his book written in 1121 CE a kind of balance for "weighing" minutes. Suspended on one side of the beam is a basin which leaks water in a calculated amount. Its decreasing weight thus becomes a measure of elapsing time that can be evaluated by counterbalancing a weight on the other side of the lever.
(Cat. III, 117; B 1.11)



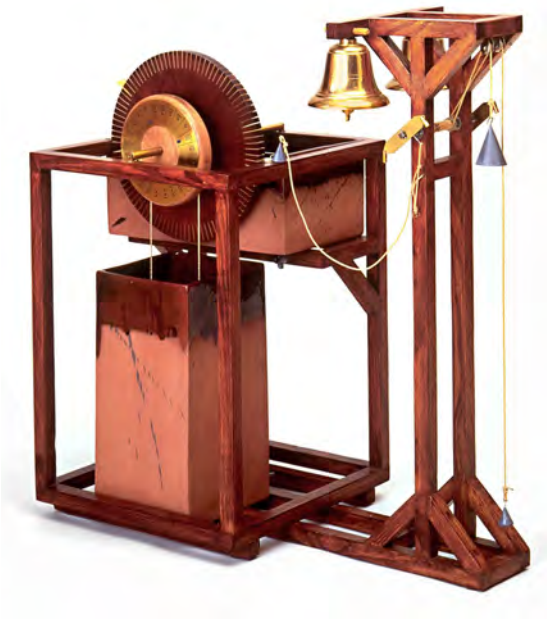
Spanish-Arabic Water Clock
After a description and illustration in the *Libros del saber de astronomía* (1267-1268) by the Castilian King Alfonso X, being a compilation of predominantly Arabic-Islamic sciences.

(Cat. III, 109; B 1.03)



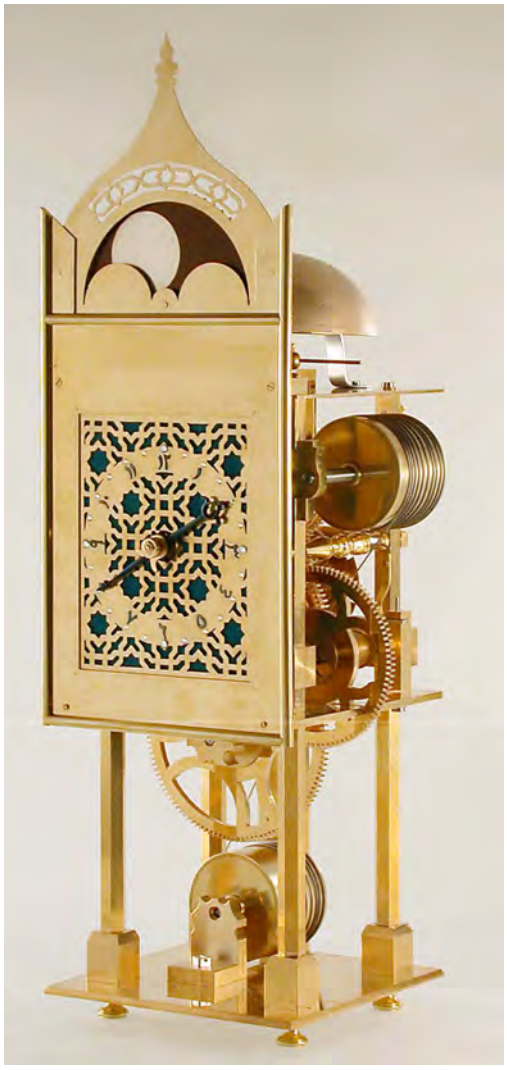
Mercury Clock
After a description and illustration in the *Libros del saber de astronomía* (1267-1268) by the Castilian King Alfonso X, being a compilation of predominantly Arabic-Islamic sciences.

(Cat. III, 110; B 3.04)



Water Clock with the alarm function described in a Latin manuscript from the 13th century. The mechanism of the clock betrays similarity with the water clock described in al-Ğazarī's book.

(Cat. III, 116; B 1.05)



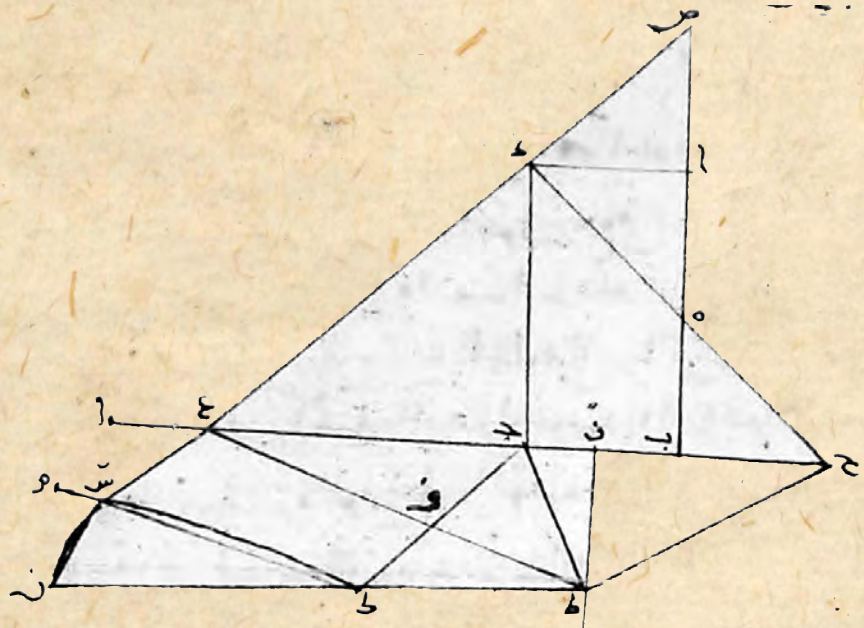
Mechanical Clock with Spring Tension and Striking Mechanism made by the Ottoman scholar Taqīyaddīn, reconstructed according to the description and illustrations in his book on clocks.

(Cat. III, 119; B 3.14)



Mechanical Weight driven Clock made by the Ottoman scholar Taqīyaddīn, reconstructed according to the description and illustrations in his book on clocks.

(Cat. III, 119; B 3.12)



Mathematics

Algebra

Mathematics, which already had made substantial progress in the second half of the 8th century, particularly after the introduction of the "zero" with the translation of the Indian *Siddhānta* into Arabic, was enriched in the first two decades of the 9th century by the almost simultaneous appearance of three works on algebra. Their authors were Muḥammad b. Mūsā al-Ḫwārizmī, Sind b. ʿAlī and ʿAbdalḥamīd b. Wāsiʿ Ibn Turk. Their works had the same title, *Kitāb al-Ğabr wa-l-muqābala* which means "reconstruction and juxtaposition". These were the first treatments of algebraic linear and quadratic equations, independent of arithmetic. Al-Ḫwārizmī states that he wrote his book on commission by Caliph al-Ma'mūn. All three works seem to be based on a syncretistic tradition which had evolved in the Hellenistic Orient absorbing Greek, Indian and late-Babylonian elements directly or indirecty. The algebra of al-Ḫwārizmī and his arithmetic have, after their translation into Latin, deeply influenced mathematics in the Occident from the 12th century.
(Catalogue I, p. 13)

The first Step to reduce a Geometrical Problem to an Equation of the third Degree

The mathematician and astronomer Muḥammad b. ʿIsā al-Māhānī (lived possibly up to 888) took a crucial step forward in the history of mathematics when he reduced a problem which could not be solved with a pair of dividers and a ruler to an equation of the third degree. However, he did not succeed in solving the equation. Al-Māhānī was also the first mathematician to arrive at a method of using the law of the spherical cosine for the mathematical determination of the azimuth when he calculated one of the angles of a spherical triangle from its sides. As Paul Luckey was able to demonstrate in 1948, al-Māhānī was a forerunner of Johannes Regiomontanus (1436–1476) in this respect. (Catalogue I, p. 16)

❖

Generalization of the Theorem of Pythagoras

In the second half of the 9th century Ṯābit b. Qurra achieved outstanding results not only in astronomy but in mathematics as well. He generalized the theorem of Pythagoras for all triangles; in the Occident, however, the relevant theorem bears the name of John Wallis (1616–1703). (Catalogue I, p. 16)

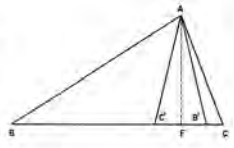
$\overline{AB}^2+\overline{AC}^2=\overline{BC}^2+2BA.AC.\cos A$

$=\overline{BC}^2+BA.AC(\cos C'+\cos B')$

$=\overline{BC}^2+BA.AC.\frac{FC'+FB'}{AB'}$; and from the similarity of triangles AB′B and ABC we have $\frac{BA}{AB'}=\frac{BC}{CA}$

$\therefore \overline{AB}^2+\overline{AC}^2=\overline{BC}^2+\frac{BC}{CA}\cdot AC(FC'+FB')$

$=BC(BC+C'B')=BC(BB'+CC')$



Beginning of Infinitesimal Calculus in the Islamic World (9th century)

Without being aware of the results already achieved by Archimedes in this area, Ṯābit made use of infinitesimal calculus in his two treatises on the quadrature of the parabola and on the cubature of the paraboloid. His quadrature of the parabola corresponds to the calculation of the integral $\int_0^a \sqrt{px}$. Through a brilliant step which he applied there, "the summation of integrals that had fallen into oblivion was revived; and with its help Ibn Qurra calculated, indeed for the first time, an integral of the power x^n, for a fractional exponent, namely $\int_0^a x^{1/2}\,dx$, where he, again for the first time, undertook the division of the integration interval into unequal units. In the middle of the 17th century, P. de Fermyyat undertook the quadrature of the curves $y = x^{m/n}$ for $m/n < 1$ through a similar procedure, where he divided the abscissas into units forming a geometrical progression." Ṯābit's procedure for the calculation of the volume of paraboloids also differs substantially from that of Archimedes. His calculation of the volumes of domes with pointed or depressed crowns gained by the rotation of a parabola around a secondary axis is also novel, whereas Archimedes merely dealt with the rotation of paraboloids with an axis of rotation identical to the axis of the parabola. (Catalogue I, p. 16)

❖

A Further Step in the Infinitesimal Calculus

Another one of the great mathematicians of this period, who with their contributions defined the standard of the subject in the 10th century, was Abū Sahl Waiǧan b. Rustam al-Kūhī. Continuing the work of his predecessors in the field of infinitesimal calculus, he calculated the volume of parabolic domes by a simple method. Among the contemporary attempts to

find solutions for geometric problems leading to equations of the third order, Abū Sahl solved the problem of finding a segment of a sphere the volume of which equals that of a given segment and the surface of which equals that of another given segment. "He solves them with the help of an equilateral hyperbola and a parabola, whose points of intersection are used to measure the unknown quantity. He also includes a discussion of the precise conditions under which the problem can be solved." Abū Sahl al-Kūhī also left us an elegant solution for the problem of trisecting an angle with the help of a hyperbola. (Catalogue I, p. 21)

The First Solution of an Equation of the Third Order

In the field of mathematics great success was achieved in the 10th century. Thus the mathematician and astronomer Abū Ǧaʿfar al-Ḫāzin was the first to succeed in solving an equation of the third order with the help of conic sections. (Catalogue I, p. 20)

❖

Decimal Fractions

Around the middle of the 10th century, Aḥmad b. Ibrāhīm al-Uqlīdīsī dealt with decimal fractions. A more advanced treatment of the matter is found in Ġiyāṯaddīn al-Kāšī (15th c.). To our knowledge, decimal fractions only came to be commonly used in the Islamic world after al-Kāšī. In Europe, decimal fractions were introduced by the Jewish mathematician Immanuel Bonfils (mid 14th c.). How he got into this position has yet to be explained. However, according to Juschkewitsch, his brief sketch was "utterly insignificant compared with al-Kāšī's treatment of decimal fractions." There can hardly be any doubt that al-Kāšī's algorithm of decimal fractions must soon have reached Asia Minor and Constantinople through his disciples and successors or even through Byzantine travellers to Persia. In this connection we shall mention a surviving 15th century Byzantine arithmetic book whose anonymous author knows how to reckon with decimal fractions and mentions that the Turks ruling the former Byzantine dominions commonly used such operations. The first systematic treatment of decimal fractions in Europe appeared in the small volume *De Thiende* ("The Tenth Part"), written in Flemish by the Dutch merchant, mathematician and engineer Simon Stevin (1548–1620). (Catalogue I, p. 67)

Spherical Trigonometry

The great achievements in mathematics of the 10th century also include those in the field of plane and spherical trigonometry even though they are usually regarded as part of astronomy. The first systematic treatment of elements of trigonometry is to be found in the work of Abu l-Wafāʾ Muḥammad b. Muḥammad al-Būzaǧānī (940 – ca. 998). He treats the trigonometric functions uniformly and introduces a new method for the calculation of tables by a method of interpolation, with which he calculates the tables of sines, tangents and cotangents. His sine table has an interval of 15 minutes. Abu l-Wafāʾ, at the same time as his contemporaries Ḥāmid b. Ḫiḍr al-Ḫuǧandī and Abū Naṣr Manṣūr b. ʿAlī Ibn ʿIrāq, claims priority in the discovery of the fundamental law of spherical trigonometry. This has primarily to do with the determination of the sides of a spherical triangle from its angles. It appears that Abu l-Wafāʾ really has the priority here. Moreover, he was also the first mathematician to attempt a solution of geometric problems with a pair of dividers of fixed gauge.
(Catalogue I, p. 21)

The question of whether an infinite Continuous Motion is possible on a finite straight Line

Abū Sahl al-Kūhī (10th c.) also sought a geometrical answer for the physical–geometrical question of whether an infinite continuous motion was possible on a finite straight line. His affirmative answer and the method used recall the approach by Giovanni Battista Benedetti (1530–1590). Maybe Abū Sahl intended, without saying so, to refute Aristotle, who had expressed the view that a continuous motion on a finite line was impossible. (Catalogue I, p. 21)

Ibn al-Hai am and the Postulate of Parallels (11th c.)

One of the few achievements of Ibn al-Hai am in the field of geometry known so far assures him an outstanding position in the history of the discussion of Euclid's postulate of parallels. He attempts to prove the fifth postulate of the Elements according to the principle of motion, which leads to the assumption that lines of constant distance to a straight line must also be straight lines. Ibn al-Haiṭam "here takes a course which later many of his direct or indirect followers, including the geometers of the 18th century, pursued." (Catalogue I, p. 27)

Infinitesimal Calculus and Ibn al-Hai am

Ibn al-Hai am (d. around 1041) is also one of the pioneers of infinitesimal calculus. Going beyond his predecessors Archimedes, Ṯābit b. Qurra, Ibrāhīm b. Sinān b.Ṯābit and Abū Sahl al-Kūhī, he also calculates paraboloids "which are produced by the rotation of the parabola around any arbitrary diameter of itself, and then especially those which are produced by the rotation of a part of the parabola around the ordinate." His solution "in which the sum of the fourth power occurs, contains a calculation which equals the computation of the definite integral $\int_0^a t^4\,dt$."(Catalogue I, p. 27)

The Systematic Treatment of Algebraic Equations of the Third Order

Abu l-Ǧūd (1st half of 11th c.) was apparently the first mathematician who dedicated a treatise to forms of equations of the third order and methods for their solution. We learn this from his successor ʿUmar al-Ḫaiyām (2nd half of 11th c.), who himself had not seen the work but had been informed about it by a contemporary. The surviving work on algebra by ʿUmar al-Ḫaiyām (*al-Barāhīn ʿalā masā'il al-ǧabr wa-l-muqābala*) was edited, studied and translated into French by Franz Woepcke 150 years ago and can be considered the true reflection of the development which algebra underwent in Arabic-Islamic mathematics. Al-Ḫaiyām enumerates twenty-five types of equations of which twelve are of linear or quadratic type; the rest consists of equations of the third order which can be solved by conic sections and are treated systematically by him. He complains that no algebraic solution of those equations had yet been found, but expresses his hopes that future generations might perhaps succeed in this. Al-Ḫaiyām also points out that cubic equations which cannot be reduced to quadratic ones can generally not be solved with compass and ruler, i.e. through the properties of the circle. This view was later also expressed by René Descartes (1637) but was only proven by Pierre Laurent Wantzel (1837).
The fact that the "excellent book" by ʿUmar al-Ḫaiyām had remained unknown "until the most recent times" and that mathematicians like Fermat (around 1637), Descartes (1637), van Schooten (1659), E. Halley (1687) and others had "had to invent similar constructions over again" was regretted by the mathematician-historian Johannes Tropfke as late as 1937. (Catalogue I, p. 28)



Systematic Treatment of Equations of the 4th degree

In the history of algebra, Ġiyāṭaddīn al-Kāšī (d. 1429) holds a special position through his in-depth study of equations of the fourth order. From a brief discussion of the subject in his "Key to Mathematics", *Miftāḥ al-ḥisāb*, we learn that he knew 70 types (or 65) of equations of the fourth degree and that he planned to treat them in a separate volume.(Catalogue I, p. 66)

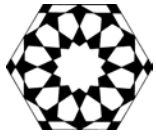
❖

Ġiyāṭaddīn al-Kāšī's Outstanding Result in the Mensuration of the Circle

Ġiyāṭaddīn al-Kāšī's (d. 1429) outstanding result in the mensuration of the circle has been known to the historiography of mathematics for fifty years. He criticizes the results of his predecessors Archimedes, Abu l-Wafā' and al-Bīrūnī and rejects their methods. He himself calculates the ratio of the circumference and diameter of a circle by help of an inscribed and circumscribed polygon each with $3 \cdot 2^{28} = 800335168$ sides and thus arrives at $\pi \approx 3.14159265358979325$. Prior to Paul Luckey making known this achievement, Johannes Tropfke had stated that only with F. Viète and Adriaan van Roomen (1561–1615) a "new, lustrous era" had begun for the mensuration of the circle "in which through ever more precise calculations the approximation to the true value had been improved to an unexpected extent". With a method involving polygon calculation, Viète established the value for π up to nine decimal points, von Roomen up to fifteen. Al-Kāšī in his days had already come up to seventeen decimal points. (Catalogue I, p. 66-67)

Volumes of Curvilinear Circumscribed Bodies

Regarding al-Kāšī's important achievements in the field of mathematics, we shall finally mention the chapter on regular and semi-regular bodies in his "Key to Mathematics". Of course, al-Kāšī had precursors in dealing with this matter; however, the complex calculations and constructions he presents with commanding skill, calculating the volumes of curvilinear circumscribed bodies, slanting cylinders and cones as well as other irregular hollow bodies, pointed arches, vaults, domes and stalactites, bear witness to the comprehensive expertise reached in Arabic–Islamic mathematics with al-Kāšī in the first half of the 9th/15th century. (Catalogue I, p. 67)



Geometrical Instruments



A Pair of Compasses
The model shows a replica of a specimen which is in the Museum for Islamic Art, Cairo.
(Cat. III, 156; D 1.17)



Compasses for drawing circles on globular surfaces. Our model was made after the description by al-Bīrūnī (d. 1048 ce).
(Cat. III, 160; D 1.26)



Collapsible Double Ruler for marking straight lines on both faces of astrolabe-disks in identical spaces. Our model was made after the description by the scholar al-Bīrūnī (d. 1048 ce).
(Cat. III, 159; D 1.34)



The Compasses of Nicomedes (ca. 2nd c. bc) for finding the two mean geometric proportionals to two given distances. Abū Ǧaʿfar Muḥammad b. al-Ḥusain gives a solution according to the geometrical method, and describes the geometric solution of the "method of the instrument".
(Cat. III, 154; D 1.14)



Compasses for drawing large semicircles and segments of circles by Ibn al-Haiṭam. (Cat. III, 149; D 1.11)



Trammel Compass invented by Abū Sahl al-Kūhī in the 2nd half of the 10th century ce for drawing ellipses, parabolas and related curves. Made after his description and illustration.

(Cat. III, 151; D 1.13)



Trammel Compass for drawing conic sections. One of the various instruments for this purpose described or made in Europe in the 15th and 16th centuries ce following the Arabic-Islamic tradition. Our model was made after a drawing by Francesco Barozzi (d. 1604 ce).

(Cat. III, 153; D 1.01)



Beam Compass
After illustrations found in late 16th c. Ottoman manuscripts.

(Cat. III, 148; D 1.10



Instrument for drawing angles on a globe, after the description in al-Jazarī's book (ca. 1200 ce).

(Cat. III, 150; D 1.12)



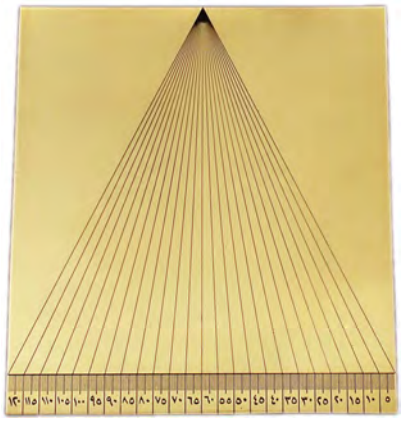
Protractor
This type of protractor is to be found among the tools of Ottoman astronomers shown in a miniature from the 16th century.

(Cat. III, 156; D 1.16)





Device for the Division of Circles
After the description and drawings by Abu r-Raiḥān al-Bīrūnī (d. 1048) in his book entitled «Comprehensive Treatment of the Possibles Methods for making astrolabes».
(Cat. III, 157; D 1.32, D 1.33)



Device for Dividing Diameters
after the description and the illustrations of Abu r-Raiḥān al-Bīrūnī's book «Comprehensive Treatment of the Possibles Methods for making astrolabes»
(Cat. III, 158; D 1.19)



Tripod
Our model belongs to the tools of Ottoman astronomers as they are shown in the well-known miniature from the 16th century.
(Cat. III, 160; D 1.21)

Two Levelling Instruments

Levels with a square or an equilateral triangle as the base according to Quṭbaddīn aš-Šīrāzī (d. 1311). (Cat. III, 140; D 1.04, D 1.05)





Three Levels, after the description by the Andalusian scholar Abū ʿUṯmān Saʿīd b. Aḥmad Ibn Luyūn (d. 1349) of Almeria.



1. «bat» (*murǧīqal* , Span. murciélago) (Cat. III, 142; D 1.06)



2. «balance» (*mīzān*) (Cat. III, 143; D 1.07)



3. «bowl and lath» (*ǧafna, qubṭāl*, Lat. cubitale) (Cat. III, 143; D 1.09)



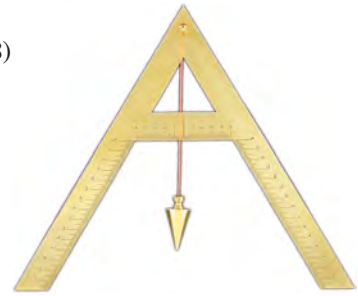
Ibn Sinā's levelling instrument for the levelling of astronomical observation instruments using water. (Cat. III, 141; D 1.27)



(Kat. III, 144; D 1.28)

(Kat. III, 145; D 1.30)





(Kat. III, 145; D 1.29)

Three Surveying Tools
After the description and drawings by Abu l-Ḥasan al-Marrākušī (d. around 1260-1280).



A circular levelling instrument after Mu'aiyadadd¬n al-ʿUrḍī (13th cent.), made according to his description.
(Cat. III, 146; D 1.08)



Plumbline with spool made after the Saljuq original (12th c.) from Eastern Anatolia. Original in the Institut für Geschichte der Arabisch-Islamischen Wissenschaften, Frankfurt.
(Cat. V, 152; D 1.25)

MUSIC

Division of the octave in seventeen unequal degrees

The 13th century also marks a climax in music theory as part of the natural sciences. After the assimilation of predominantly late antique sources by Yaʿqūb b. Isḥāq al-Kindī in the 9th century, and the masterly adoption of "classical" Greek sources in the service of a distinctly Arabic musical theory by Abū Naṣr al-Fārābī and Abū ʿAlī Ibn Sīnā in the 10th and early 11th century, it was Ṣafīyaddīn ʿAbdalmuʾmin b. Yūsuf al-Urmawī (d. 1294) whose influential *Kitāb al-Adwār,* a systematic compendium of musical theory, summarises and winds up the recent development. H.G. Farmer called him the founder of the "systematist school" with mathematical-physical inclination, which existed until around 1500. In al-Urmawī's *Kitāb al-Adwār,* we encounter for the first time the division of the octave in seventeen unequal degrees as a fully developed system. (Catalogue I, p. 52)



Physics



Technology



Physics

Despite admirable individual studies by Eilhard Wiedemann and his disciples and despite the excellent work by Matthias Schramm, *Ibn al-Haytẖams Weg zur Physik* (1963), the discipline of physics belongs to those areas of Arabic-Islamic science which still await a historical survey however modest in scope. Approaching Ibn al-Haiṯam (1st half of the 11th c.) from his main work on optics (*Kitāb al-Manāẓir*) and his astrophysical writings, Schramm came to the conclusion that in these works Aristotelian physics, applied mathematics, traditional astronomy and optics are combined, and that this can be considered as typical of Ibn al-Haiṯam's scientific research. On the other hand, he succeeded, according to Schramm, "in transforming Aristotelian metaphysics of nature, with the study of which he began his scientific endeavours, into a physical theory that provides a dynamic explanation of the kinematic model postulated by Ptolemy." With his efforts in this respect, Ibn al-Haiṯam had "taken the first step that was to lead to one of the most remarkable achievements of the human mind as such, from the metaphysics of nature and its mathematical description towards physics, towards exact natural science based on mathematical methods." (Catalogue I, p. 29)

A Book on Mechanical Devices:
Al-Ğāmiᶜ bain al-ᶜilm wa-l-ᶜamal an-nāfiᶜ



This book was written by the otherwise unknown Ibn ar-Razzāz al-Ğazarī (around 1200) upon commission by the local ruler of Āmid, Nāṣiraddīn Maḥmūd b. Muḥammad b. Qarā'arslān (r. 1200–1222), and was completed two years after the latter's accession to power. Several manuscripts of the book with illustrations in colour have come down to us. It is without doubt the most beautiful of the extant works in the field of mechanics. The author mentions amongst the contents of his book "water driven machines for equinoctial- and temporal hours" and devices used for "moving bodies from their natural position by means of [other] bodies"". He describes fifty machines and devices in all clarity from the point of view of an engineer and provides them with fifty complete and about a hundred partial drawings of such quality that one can reconstruct the machines without any substantial problems.

This book, originating in the eastern part of Asia Minor under the adverse political conditions of those times when the war against the crusaders impeded communication amongst the people and the exchange of books and knowledge between the countries of the Islamic world, probably does not reflect the state-of-the-art reached by Arabic–Islamic technology at that time or even in general. It is a book compiled by a capable engineer according to his talents and his understanding on the basis of his knowledge of the sources and within the bounds of the conditions of his environment. For instance, when the conical valve for regulating the water level in hydraulic devices appears for the first time in al-Ğazarī's book, this is no sufficient reason to consider him its inventor. Incidentally, this type of valve was not known in Europe until the 18th century. Whether it reached the West from the Arabic–Islamic area or whether it developed again independently remains a matter of speculation.

Some of the Instruments and Devices Constructed by Taqīyaddīn

Taqīyaddīn enjoyed considerable fame in the Ottoman Empire not only as *ar-rāṣid* (observing astronomer) but also as a *muhandis* (engineer). From his two extant treatises on pneumatic constructions and clocks he indeed emerges as an eminent physicist and technician. In his book on pneumatics, *aṭ-ṭuruq as-sanīya fi l-ālāt ar-rūḥānīya* written in 953/1546, Taqīyaddīn describes a number of machines and devices that reveal an already well-developed level of technology. (Catalogue I, p. 75; V, pp. 41-42)

Skewers

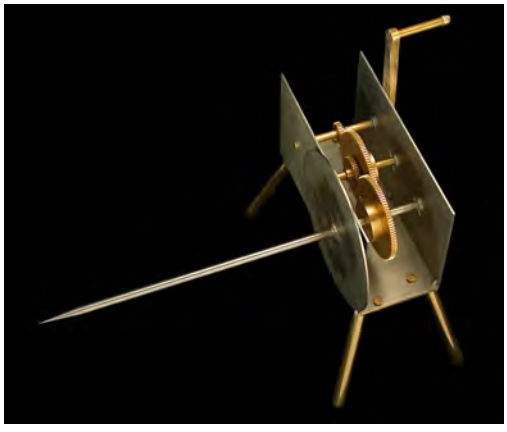
Taqīyaddīn describes the three types of mechanised skewers most common in his time, one of which is turned by steam and the other by hot air. The description of the second device resembles a turnspit-construction sketched by Leonardo da Vinci which was also intended to be powered by hot air. Moreover, Taqīyaddīn describes numerous devices functioning by transmission of force with cogwheels. They must have been very common in his days. He refers to one of them as his own invention. (Catalogue I, p. 77; V, pp. 37-40)



(E 1.25)



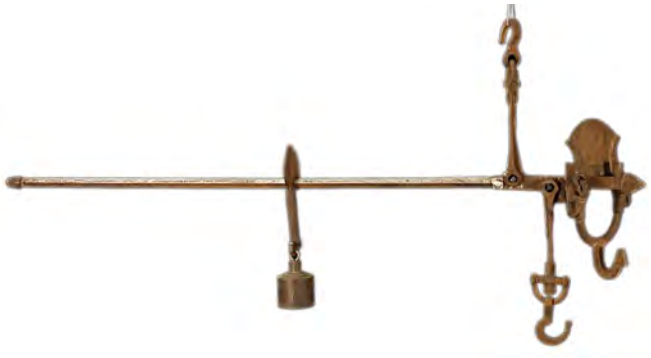
(E 1.26)



(E 1.27)



Balance with an exactitude of 1:60000. Designed in the 12th century CE by al-Khāzinī and called *mīzān al-ḥikma*.
(Cat. V, 5; E 1.01)



Balance,
constructed according to the original dated 10th century, which is preserved in the Science Museum at London.
(Cat. V, 7; E 1.19)



Device for the determination of the specific gravity of solid bodies. Invented by al-Bīrūnī (d. 1048 CE). Model reconstructed after the drawing and description contained in his book.
(Cat. V, 9; D 1.23)



Areometer
for the determination of the specific gravity of liquids after ʿAbdarraḥmān al-Khāzinī (12th century).
(Cat. V, 12; D 1.24)



Screw Pump
Archimedes (3rd century BCE) encountered a simple helical pump operated by a crank during his travels in Egypt where it was used for irrigation. A more elaborate type from the Islamic era which uses water power is found in the book by Taqīyaddīn (1553 CE).
(Cat. V, 16; E 1.15)



Machine for Raising Water by means of an endless chain of buckets. Our model was made after descriptions in Arabic manuscripts and a surviving structure in Damascus, dating from the 13th century CE. The latter was built in order to supply a hospital and a mosque with fresh water.
(Cat. V, 19; Nr. E 1.14)



Tympanum
A drum-shaped water lifting wheel, constructed according to the description in the manuscript *Maqāmāt* (1237) by al-Ḥarīrī (d. 1122)
(Cat. V, 23; E 1.18)



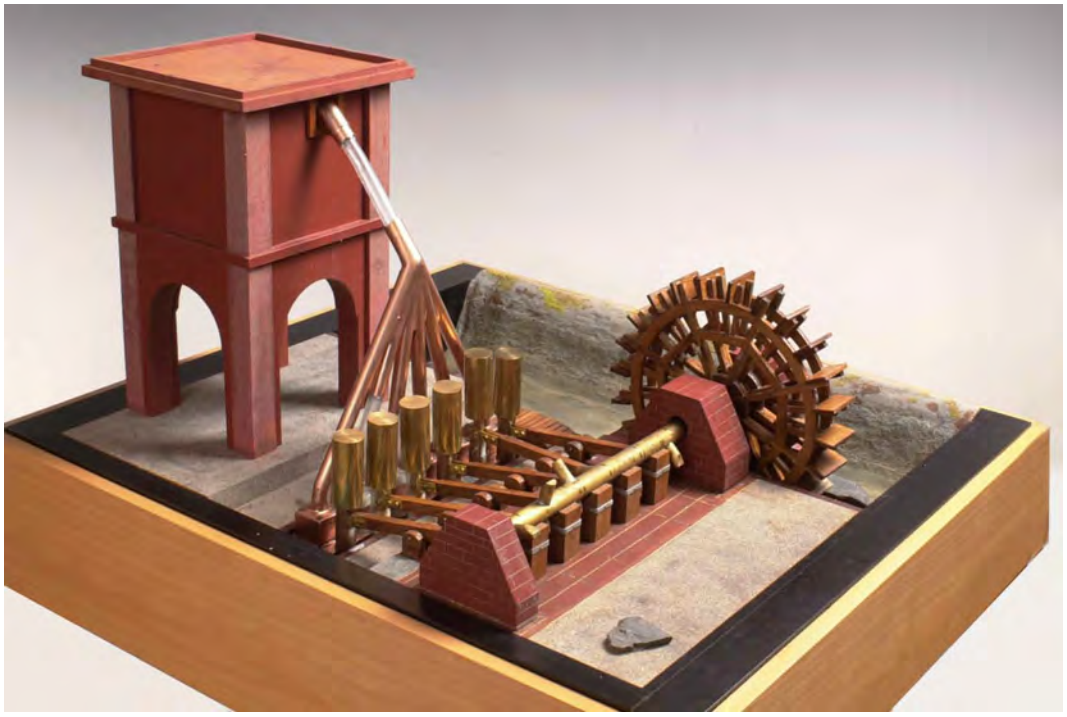
Machine for raising water from stagnant waters using animal power
This model of a gin which was in widespread use throughout the Muslim world and is occasionally still found in Egypt, Spain and India was built according to the description contained in al-Ğazarī's book (ca. 1200). The gear train is powered by a draught animal.

(Cat. V, 25; E 1.07)



Automatic Water Pump with Two Plungers
This type of water-works with two piston-like plungers driven by the current of a river is described in the books by al-Ğazarī (ca. 1200) and Taqīyaddīn (1553). The two plungers sit opposite to each other and, powered by a common water-wheel, raise water up to about 11 m.

(Cat. V, 27; E 1.08)



Pump with Six Piston-like Plungers
by Taqīyaddīn

The precise descriptions enabled us to reconstruct several devices without great difficulty; of these, we may first of all mention an automatic pump with six piston-like plungers powered by the current of a river, transferred through a waterwheel onto a camshaft. The cams in turn move six levers which drive the plungers. This type of waterwork with six plungers appears for the first time in Taqīyaddīn's book. About 350 years earlier Ibn ar-Razzāz al-Ğazarī had already known waterworks with two plungers. Thus it is possible that there was an intermediate stage of development in the period between the two authors. In this respect it is interesting that Taqīyaddīn praises a work by ʿAlī al-Qūšǧī (d. 1474) on pneumatics and mentions it as one of his sources. At the present time it is not known whether the concept of waterworks with multiple pistons as described shortly afterwards in Europe by Georgius Agricola (1494–1555) and Agostino Ramelli (1531–1600 ?) was connected with the Arab–Islamic world or whether it developed independently. (Catalogue I, p. 75)



Ship-mill. This type of mill was in widespread use throughout the Islamic world. Our model is based on a description found in the book *Ṣūrat al-arḍ* by the Arab geographer Ibn Ḥauqal (10th century CE).

(Cat. V, 30; E 1.03)



Windmill
Our model was made after the drawing and description in the 13th century CE geographical book by Šamsaddīn Muḥammad al-Dimašqī.

(Cat. V, 32; E 1.04)



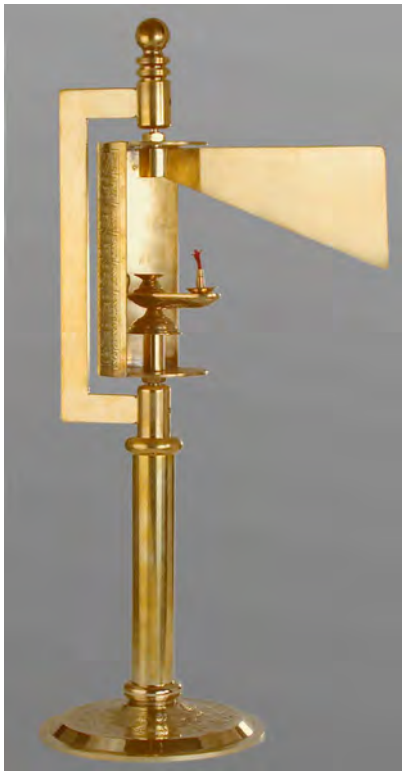
Lever with Scissors-like Construction
A device like multiple scissors, used to lift objects weighing up to about 200 kg. Built according to the description found in an Arabic manuscript from around the 12th century CE

(Cat. V, 35; E 1.17)



Apparatus for lifting water by means of fire. *(Codices Gotha 1348 und Leiden, Warn. 499)*

(Cat. V, 36; E 1.23)

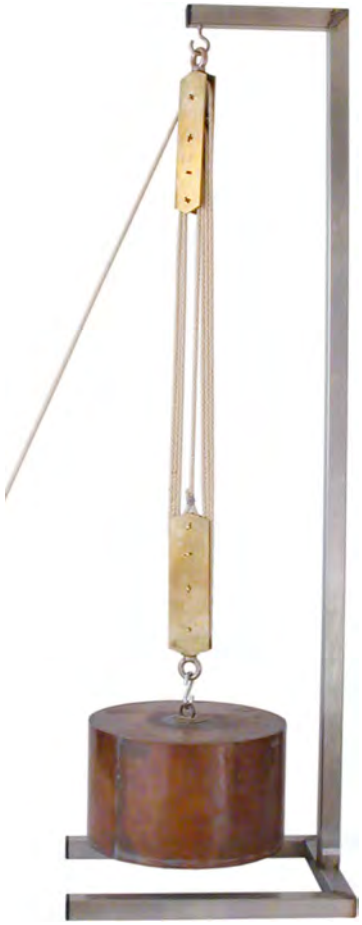


A lamp that does not go out even under strong winds, constructed according to the description and the illustration by the Banū Mūsā (9th century).

(Cat. V, 45; E 1.16)



Grab Dredger for lifting heavy objects from water, model made after the description of the Banū Mūsā (9th century CE).
(Cat. V, 43; E 1.05)



Pulley
Taqīyaddīn (1553 CE) describes a sophisticated type of polyspast in which two sets of eight wooden blocks are arranged cylindrically. Its strong gearing allows it to lift weights with only 1/16 of the force required normally.
(Cat. V, 42; E 1.11)



Lifting Screw (crane) with Cog-Wheel Gearing. Taqīyaddīn (1553 CE) describes and draws a mechanism with dented wheels that allows it to lift a weight of 1450 kg with a force of only 15 N (i.e. pull of 1,5 kg).
(Cat. V, 41; E 1.12)



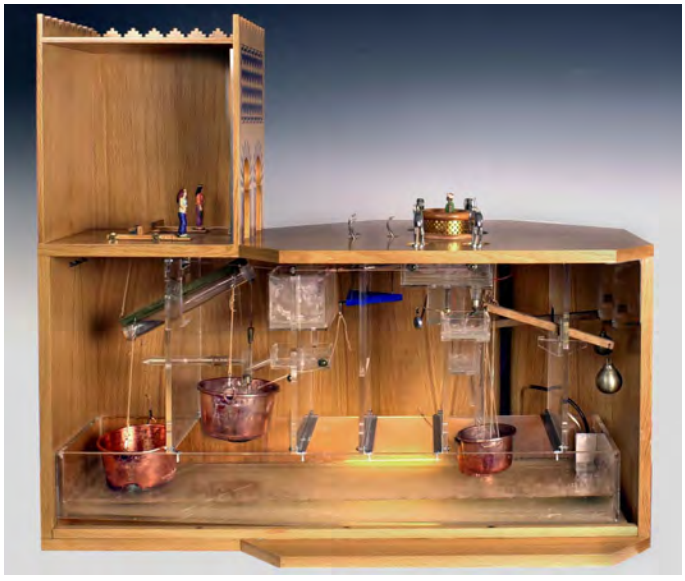
Fountain with varying appearance by al-Ğazarī.

(Cat. V, 53; B 1.07)



The second of the Fountains constructed and described by al-Ğazarī.

(Cat. V, 54; B 1.08)



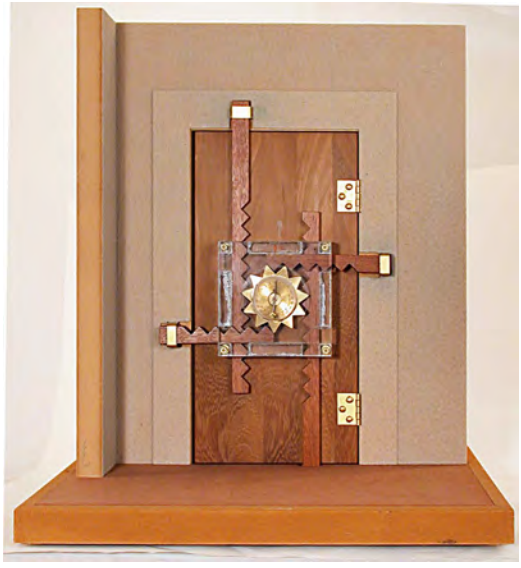
Entertainment Machine operating by waterpower a scene of moving figurines in set intervals. Made after the book on automata by al-Murādī (11th century CE)

(Cat. V, 51; B 1.09)



Security or Combination Lock. Our model was made after drawings and descriptions in al-Ğazarīs book (ca. 1200 CE)

(Cat. V, 56; E 1.02)



Model of a mechanical Door Lock with Four Bolts by al-Ğazarī (ca. 1200). The bolts are pushed forward and opened by a special key so that the door is protected on all sides.

(Cat. V, 59; E 1.10)



A Palace Door (before 1200 CE)
This artistically crafted door of a palace in Amid (Diyarbekir) is described by al-Ğazarī (ca. 1200 CE).

(E 1.29)





Perpetual Motion

An Arabic manuscript from the 12th century CE speaks of machines which upon an initial impulse keep moving by themselves forever for the first time. This idea was introduced to Europe and caused innumerable futile experiments well into the 19th century CE. Eventually the Académie Française declared all further attempts useless. In the Islamic world, however, it was Taqīyaddīn who rejected the concept as early as 1553.

(Cat. V, 60; E 1.21-22)



Ibn Firnās's Attempt at flying

Abu l-Qāsim Ibn Firnās (880 A.D.), the versatile physicist of Andalusia, constructed the glider consisting of a suit of feathers with wings, with which he flew some distance.



Optics



Optics

In 1890 Leopold Schnaase gave an excellent evaluation of Ibn al-Haiṯam's (d. around 1041) "Optics" and its significance, on the basis of its Latin translation. This evaluation was corroborated in a masterly way by Schramm's study. Referring to Ibn al-Haiṯam with the Latinized form of his name, Schnaase writes: "A comparison of Alhazen's achievements with those of Ptolemy shows what remarkable progress optics owe especially to the former; Alhazen was the first physicist to take into account the anatomy of the eye and to develop, on that basis, an elaborate theory of vision, a theory which—in spite of incorrect premises on the functions of the crystal lens—achieved results that almost agree with modern findings. The assumptions and experiments by which he determines the conditions of seeing single and double images must be regarded as his discoveries. Furthermore, he was the first to find definite proof that the theory of visual rays is incorrect, thus removing this theory once and for all from physics and establishing its opposite—a shift in the fundamentals of optics which was of far-reaching consequence. Even the claim that the transmission of light takes a certain time was already made by him. What a tremendous gap separates Ptolemy and Alhazen, the Greek and the Arabic school in this regard!" (Catalogue I, p. 30)

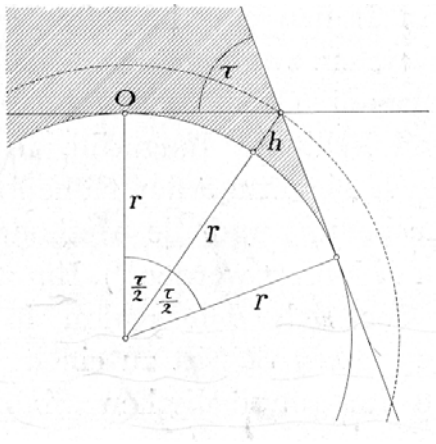


Visual Perception

Like his Arab predecessors Abū Bakr ar-Rāzī (d. 925), al-Fārābī (d. 950) and his contemporary Ibn Sīnā (d. 1037), and opposing Euclid and Ptolemy, Ibn al-Haiṯam (d. ca. 1041) supported the Aristotelian view according to which visual perception does not involve rays emanating from the eye but rays emanating from the object. Mathematics and experiment always remain in the foreground in all the problems he addressed, not only in the case of visual perception. According to Schramm, the "Optics" display the mathematical genius of their author. For experimental purposes, Ibn al-Haiṯam constructed several instruments and devices, including a *camera obscura*. (Catalogue I, p. 29)

Measuring the Height of the Atmosphere

Attempts by Arabic–Islamic scholars to measure the height of the atmosphere by optical and astronomical methods are known from the 11th century CE. The earliest treatment of the question is to be found in the Latin translation of the work by Muḥammad b. Yūsuf b. Muʿāḏ (11th c.). The basic idea and its reduction to a trigonometric equation has occupied the attention of many scholars in the Occident for centuries since the translation of the treatise under the title *De crepusculis ed nubium ascensionibus*. (Sezgin, *Geschichte des arabischen Schrifttums* VI, p. 44)



The height of the atmosphere *h* is to be measured

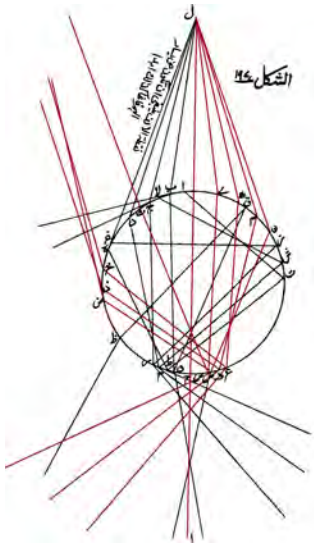
Use of Segments made of Glass

A particularly remarkable achievement of the experiments of Ibn al-Haiṯam (d. ca 1041) is the discovery of the magnifying power of spherical segments made of glass, a discovery that certainly had some influence on the early development of spectacle lenses.
(Catalogue I, p. 30)



Explanation of the Phenomenon of the Rainbow

In the field of optics in the 14th century the Arabic-Islamic world proved to be as creative as ever and produced one of the most important scholars of the time. We are referring to Kamāladdīn Muḥammad b. al-Ḥasan al-Fārīsī (b. 1267, d. 1318), otherwise known as an outstanding physicist and mathematician. He wrote a monumental commentary, *Tanqīḥ Kitāb al-Manāẓir*, on the "Optics" of Ibn al-Hai am which has not yet been exhaustively studied; in it we find an epochal explanation of the phenomenon of the rainbow, the like of which his predecessors Ibn al-Hai am and Ibn Sīnā in the 11th century, despite their attempts, had not been able to give. In Kamāladdīn al-Fārīsī's opinion, the perception of a rainbow is caused by the optical behaviour of fine transparent spherical drops close to each other in the air, through double refraction and single or double reflection of the sunlight as it enters into and comes out of the individual drop. Kam ladd n came to this conclusion after a series of systematic experiments conducted with a spherical ball made of glass or rock-crystal.
With regards to the history of reception of Arabic–Islamic sciences in the West, it is of particular significance that Kamāladdīn's explanation of the phenomenon of the rainbow appears again with a few minor alterations in the treatise *De iride et radialibus impressionibus* by Dietrich of Freiberg (Theodoricus Teutonicus), a little known Dominican monk in the first decade of the 14th century. (Catalogue I, p. 56; III, pp. 166-167)



Geometrical representation of the explanation of the light refraction in the generation of the rainbow, by Kamāladdīn al-Fārisī, *Tanqīḥ*, Haydarabad, Vol. 2, fig. 192.



Experimental Setup by Kamāl al-Dīn al-Fārisī (ca. 1300 CE) to demonstrate the generation of the rainbow by double fraction and one or two reflections of the sunlight in the raindrop. The model was made after his description.
(Cat. III, 165; E 2.02)

The "Problem of Ibn al-Haiṭam" (Problema Alhazeni)

The well-known optical-mathematical "problem of Ibn al-Haiṭam" is discussed here because of the fact that Leonardo da Vinci (1452-1519) constructed an apparatus for its mechanical-graphical solution. In 1910 Otto Werner expressed the view that Leonardo seems to have had amongst his sources the great book on optics (*Kitāb al-Manāẓir)* by Ibn al-Haiṭam and that from there he knew of the problem to find the point of reflection with spherical, cylindrical and conical mirrors and attempted their solution. Werner surmised that Leonardo used Ibn al-Haiṭam's book in an Italian translation.
The problem, treated in the 5th tract (*maqāla*) of Ibn al-Haiṭam's book, has to do with the definition of the point of reflection on spherical, cylindrical, conical, convex as well as concave mirrors when the two values of "eye" and "luminous point" are given. "The problem in its general form leads analytically to an equation of the 4th degree."

In the West the problem was included by Vitello in his book on optics already in 1270. His detailed treatment of the subject was "copied or rephrased" from the Latin translation of Ibn al-Haiṭam's *Kitāb al-Manāẓir*. After Leonardo da Vinci, it was Isaac Barrow (1669) who occupied himself with the problem. Then René François de Sluse (1673), Christiaan Huyghens (1695), Guillaume François Antoine d'Hospital (1720), Robert Simson (1st half 18th c.), Abraham Gotthelf Kæstner (1719–1800), Thomas Leybourn (1817) and Charles Hutton (1737–1823) attempted to solve the problem. Kæstner wanted "to solve the problem without the construction of the hyperbola which had no practical use." Five years after Kæstner, William Wales published a study "in which Alhazen's problem is used as an example for a method of solving equations of higher degrees through approximation with the help of trigonometric functions." (Catalogue I, p. 187)

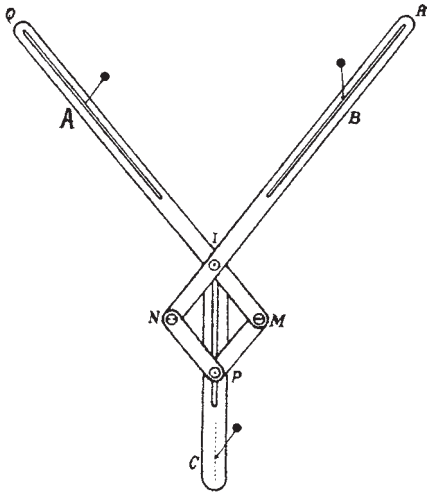


Fig. from *Leonardo da Vinci. Das Lebensbild eines Genies*, p. 410.



A pair of compasses
after Leonardo da Vinci (1452-1519) who constructed an instrument as a mechanical-graphical solution to the well-known optical-mathematical "problem of Ibn al-Haiṭam".
(Cat. III, 187; D 1.20)

Camera Obscura

That the historiography of sciences in our times considers Ibn al-Haiṭam (b. ca. 965, d. after 1041) the true inventor of the camera obscura was the result solely of the research on this subject done and inspired by Eilhard Wiedemann since the first decade of the 20th century. Before that several occidental scholars were considered its inventors, among them Roger Bacon (d. ca. 1290), Witelo (Vitellius, Vitellio, d. ca. 1280), John Peckham (Pecham, d. 1292), Levi ben Gerson (d. 1344), Leone Battista Alberti (1404-1472), Leonardo da Vinci (1452–1519), Francesco Maurolico (1494–1575) or Giambattista della Porta (d. 1615).

Our model serves to demonstrate the basic principles of the method of representation of the camera obscura, according to the descriptions of Ibn al-Haiṭam and Kamāladdīn al-Fārisī. The form of the model is the material expression of the image visualized by us. (Catalogue III, p. 184-186)





Apparatus for the study of the refraction of light designed by Ibn al-Haiṭam (d. after 1041 CE). Our model was made after his description.

(Cat. III, 178; E 2.03)



Device for the study of the reflection of light. Our model was made after the description of the eminent astronomer, mathematician, physicist and optician Ibn al-Haiṯam (d. after 1041 CE).

(Cat. III, 172; E 2.06)



Instrument for observing the moonlight according to Ibn al-Haiṯam (d. after 1041 CE).

(Cat. III, 174; E 2.07)



Experimental Setup by Ibn al-Haiṯam (d. after 1041 CE), in order to demonstrate that the rays of early morning light travel in straight lines. Model after Kamāladdīn al-Fārisī's description.

(Cat. III, 180; E 2.05)



Experimental Setup by Ibn al-Haiṯam (d. after 1041 CE) to demonstrate that accidental light travels in straight lines. Our model of this intricate setup follows the interpretation of Muṣṭafā Naẓīf.

(Cat. III, 182; E 2.04)

Medicine



History of Medicine

The second fundamental work of the 10th century on the history of science was written in 987, the same year as Ibn an-Nadīm wrote his book. It is the history of medicine (*Ṭabaqāt al-aṭibbā' wa-l-ḥukamā'*) by the Andalusian physician Sulaimān b. Ḥassān Ibn Ǧulǧul which likewise is not restricted to the Islamic period. Comparing this work with the treatise written by Isḥāq b. Ḥunain (d. 910) on the "History of Physicians" (*Tārīḫ al-aṭibbā'*), which appeared half a century earlier and was based on a pamphlet by the Alexandrian Johannes Grammatikos (1st half of the 6th century CE), we may understand how far the historiography of science had advanced in this short period and the dimension of universality it had gained. (Catalogue I, p. 23)

❖

Historiography of Medicine from a Universal Point of View

The maturity of the epoch with its widened horizon as well as the extent and the magnitude of the achievements accomplished in his culture area induced Aḥmad b. al-Qāsim Ibn Abī Uṣaibiʿa (d. 1270), a contemporary of Ibn an-Nafīs and ʿAbdallaṭīf al-Baġdādī, to compose, within the scope of his resources, a universal history of medicine. The medical historian Edith Heischkel, even though she unfortunately characterizes the epoch of the author incorrectly as "a late period of Arabic science in which existing knowledge was digested rather than being creative in its own right", described quality and character of this work entitled *ʿUyūn al-anbā' fī ṭabaqāt al-aṭibbā'* quite appropriately: "He has set himself free from the bias of antique and Jewish myths, knowing that each and every culture has its own peculiar theory of the origins of medicine. In his view, each culture also has its own special medicine, one yielding place to another in the course of centuries. He doubted whether it was at all feasible to deem the medical science of any one people the oldest. The Arab, in whose native region cultures of diverse people from East and West fused, possessed the universal historical scope which no physician before him ever had; in the writings of Ibn Abi Uṣaibiʿa the history of medicine is seen from the point of view of universal history for the first time." (Catalogue I, p. 51)

The First Comprehensive Handbooks of Medicine

In the field of medicine, it should be emphasized that the level reached in the 10th century led to the almost simultaneous yet independent publication of the first handbooks covering the entire field of medicine in world literature. These are the *Kāmil aṣ-ṣināʿa aṭ-ṭibbīya* by ʿAlī b. al-ʿAbbās al-Maǧūsī, *at-Taṣrīf li-man ʿaǧiza ʿan at-taʾlīf* by Abu l-Qāsim Ḫalaf b. ʿAbbās az-Zahrāwī and *al-Muʿālaǧāt al-Buqrāṭīya* by Abu l-Ḥasan Aḥmad b. Muḥammad aṭ-Ṭabarī. In the eleventh century, ʿAlī b. al-ʿAbbās al-Maǧūsī's book was translated into Latin as *Liber pantegni* by Constantinus Africanus in Salerno and circulated in Europe for centuries under the authorship of the translator. In the year 1127, it appeared once more in a translation by Stephanus of Antioch. The 30th chapter of the *at-Taṣrīf* by az-Zahrāwī, devoted to surgery, was translated into Latin by Gerard of Cremona in the 12th century. Its 28th chapter, dealing with materia medica and the 30th about surgery belonged to the most widely circulated books of Arabic medicine in Europe. The third title, *al-Muʿālaǧāt al-Buqrāṭīya*, did not reach Europe before modern times. (Catalogue I, p. 22)



Portraits of Some Famous Physicians



Dioscorides (2nd half 1st cent. BC), in a posture of teaching, from the Arabic translation of his *Materia Medica*, MS Istanbul, Topkapı Sarayı, collection Ahmet III, 2127 of 1229 (fol. 1b). (Cat. IV, 28)



Dioscorides and a pupil, from the Arabic translation of his *Materia Medica*, MS Istanbul, Topkapı Sarayı, collection Ahmet III, 2127 of 1229 (fol. 2b). (Cat. IV, 28)



An occidental portrait of Abū Bakr ar-Rāzī, Latinized Rhazes (physician, chemist and philosopher, d. 925), from the translation of his medical encyclopedia *al-Ḥāwī* (Liber Continens), printed often since 1486. (Cat. IV, 29)



Abū Bakr ar-Rāzī in a European illustration (Cat. IV, 30)



An occidental picture, dating probably from the 15th century, of Abu l-Qāsim az-Zahrāwī, Latinized Albucasis (10th c.). The chapter on surgery of his *Kitāb at-Taṣrīf* exercised a deep influence on occidental medicine. The original of the picture is in the Biblioteca Apostolica Vaticana, MS Chigi F. VII. 158 (fol. 49a). (Cat. IV, 30)



Isḥāḳ b. ʿImrān, a physician from Baġdād, who died before 907 in Qairawān. In Schedel's World Chronicle of 1493 he is portrayed as "the very famous physician Isaac benimiram" who, quite accurately, had "written of many things in medicine". His book on melancholy was plagiarized by Constantinus Africanus. (Cat. IV, 29)



"Auenzoar a physician", illustration and reference in Schedel's World Chronicle (1493). The reference is to ʿAbdalmalik Ibn Zuhr (d. 1162), who came to be known in the Occident as Avenzoar. Schedel also mentions his "Book of Medicine Theysir," that is *at-Taisīr fi l-mudāwāt wa-t-tadbīr*, which was translate into Latin. (Cat. IV, 34)



"Auerrois a physician and lover of wisdom", illustration and reference from Schedel's World Chronicle (1493). It is the versatile philosopher Muḥammed b. Aḥmed b. Muḥammed Ibn Rušd (d. 1198), Averroes of the Latins. Schedel has some historical and geographical knowledge about his life and achievements. (Cat. IV, 34)

al-Qānūn by Ibn Sīnā (d. 1037)

Julius Hirschberg described the "Canon" by this extraordinarily talented and diligent thinker as "distinguished by order and exactitude, a very extensive and comprehensive didactic system covering the entire science of medicine including surgery—almost without parallel in world literature." He goes on to add: "From the Greeks we have inherited only collections, extracts, compilations. The Canon is a work as of one mould. Nowadays a complete medical staff is required to produce a 'manual' like this. For half a millennium, the Canon remained effective and Ibn Sīnā reigned supreme, like Aristotle and Galen." The Canon was translated into Latin in the 12th century and influenced medical science in the West up to the 17th century. (Catalogue I, p. 32)



Ibn Sīnā sitting at a patient's bed
(Cat. IV, 32)

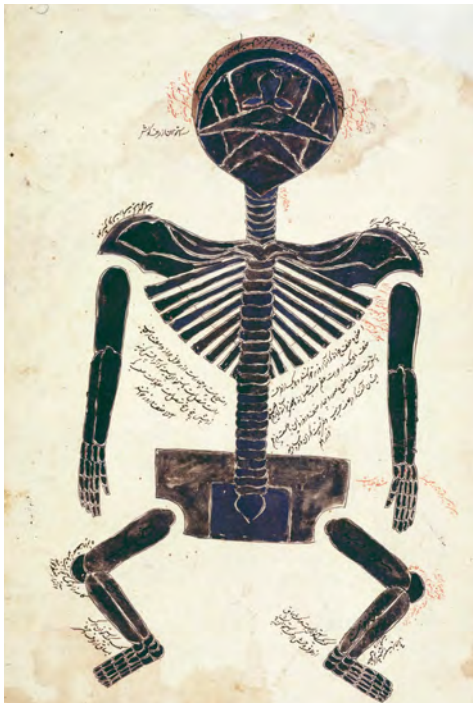


Reading the Latin translation of Ibn Sīnā's *Qānūn*, from an illuminated parchment manuscript of the *Canon Medicinae* from the 15th century. (Cat. IV, 33)



Ibn Sīnā in an European illustration
(Cat. IV, 31)

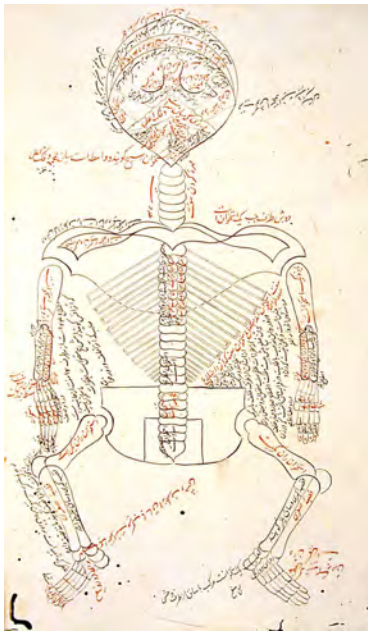
Series of Anatomical Drawings (Cat. IV, pp. 11-13)



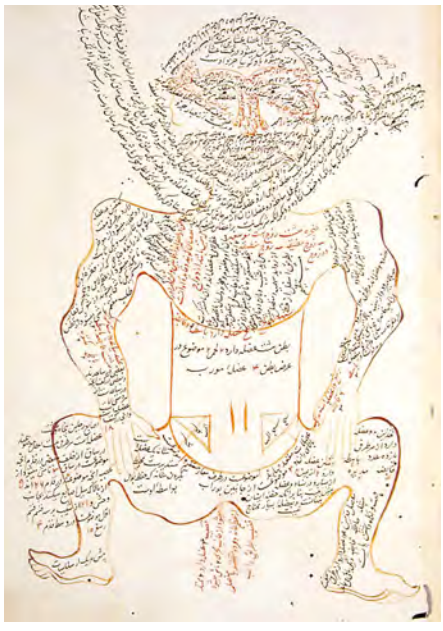
System of the bones, from *Tašrīḥ-i Manṣūrī* (ca. 800/1400), MS India Office (London) 2296.



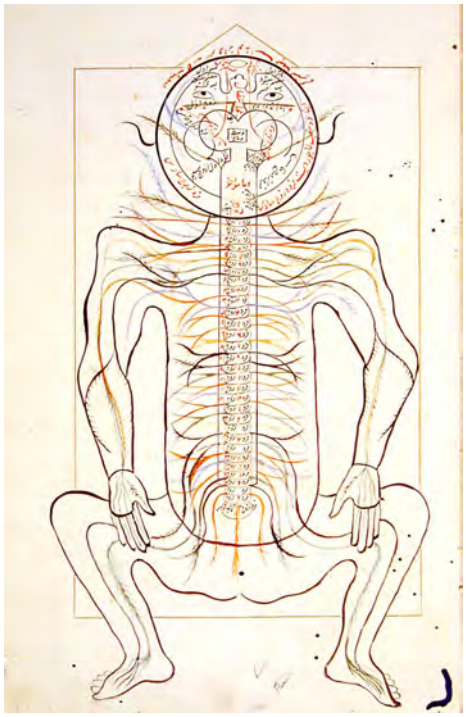
System of the muscles, from *Tašrīḥ-i Manṣūrī* (ca. 800/1400), MS India Office (London) 2296.



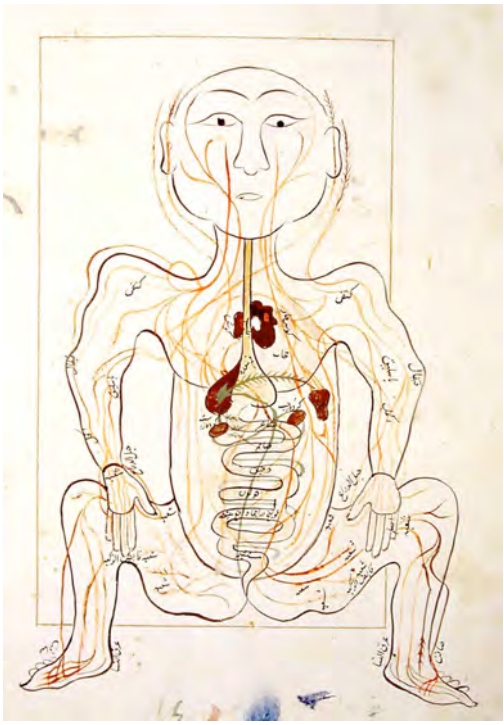
System of the bones, from *Tašrīḥ-i Manṣūrī* (ca. 800/1400), MS Ayasofya (Istanbul) 3598.



System of the muscles, from *Tašrīḥ-i Manṣūrī* (ca. 800/1400), MS Ayasofya (Istanbul) 3598.



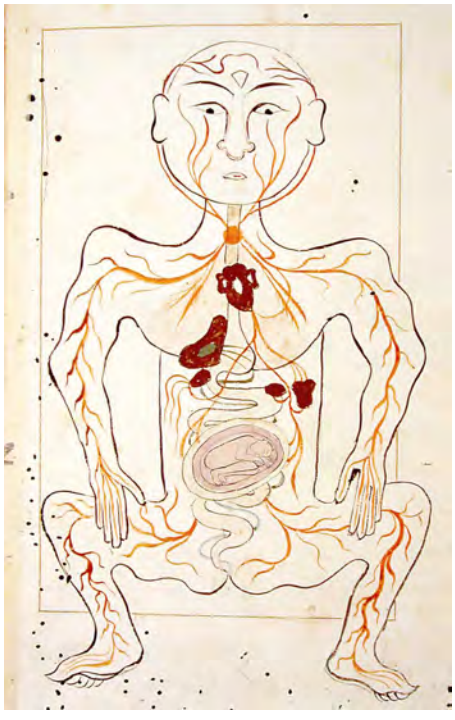
System of the nerves, from *Tašrīḥ-i Manṣūrī* (ca. 800/1400), MS Ayasofya (Istanbul) 3598.



System of the veins, from *Tašrīḥ-i Manṣūrī* (ca. 800/1400), MS Ayasofya (Istanbul) 3598.



System of the Arteries, from *Tašrīḥ-i Manṣūrī* (ca. 800/1400), MS Ayasofya (Istanbul) 3598.



System of the arteries of a pregnant woman with embryo, from *Tašrīḥ-i Manṣūrī* (ca. 800/1400), MS Ayasofya (Istanbul) 3598.



Some medical scenes (featuring a physician with his patient) from the Latin translation of Abu l-Qāsim az-Zahrāwī's anatomical work (10th cent.) in a manuscript kept at the Österreichische Nationalbibliothek, Vienna.

The Oldest Preserved Anatomical Illustration of the Eye is by Ḥunain b. Isḥāq (d. 873)



MS Cairo, Dār al-kutub, Taimūr 100, p. 319.



MS Cairo, Dār al-kutub, Taimūr 100, p. 346.

Ocular Surgery

One of the great advances in the medicine of the 10th century was made in ophthalmology and is associated with the name of ʿAmmār b. ʿAlī al-Mauṣilī. In his book, written towards the end of the century, Julius Hirschberg found particularly interesting "his clear and captivating descriptions of six cataract operations, which remain highly attractive even to the modern reader." Hirschberg goes on to add that in Greek literature there was nothing comparable and in modern literature it was only in the 18th century "that we encounter such precise and remarkable medical case histories again." ʿAmmār's most important operation, Hirschberg adds, was the radical operation of the soft cataract by suction with a metal syringe he had devised for that purpose. Remarkable was also the removal of the iris prolapse while retaining the faculty of vision, "whereas before him the Greeks and Arabs had undertaken this operation only for the improvement of looks but not for the improvement of sight." (Cat. I, p. 22)

Contraction of the Pupil upon Exposure to Light.

Julius Hirschberg, the eminent authority on Arabic ophthalmology, drew attention to the fact that ar-Rāzī in his *Kitāb aṭ-Ṭibb al-Manṣūrī* (9th century), was the first to speak of the contraction of the pupil upon exposure to light. Not only from the medical point of view but also from the history of optics, it is of epochal significance that ar-Rāzī in his treatise on optical perception and in his critique of Galen refuted Euclid's and Galen's theory of vision, according to which the process of seeing relies on rays emanating from the eye. (Cat. I, p. 18)

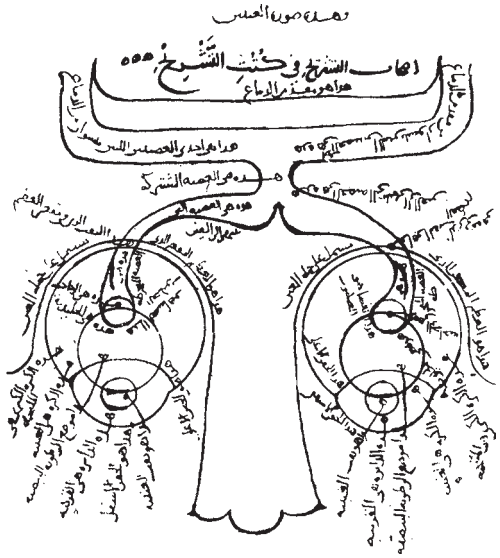
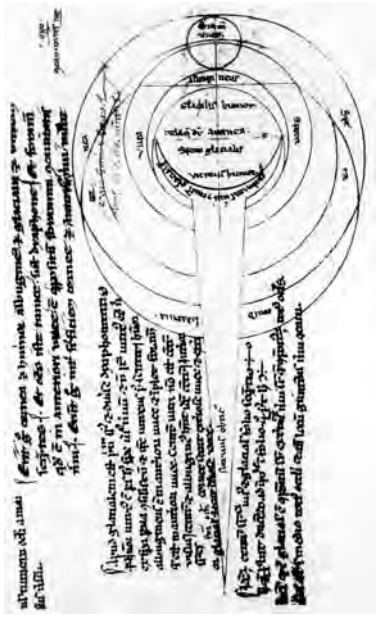
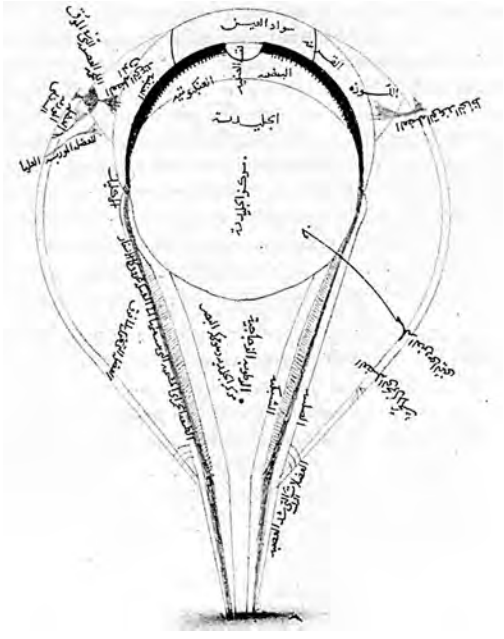


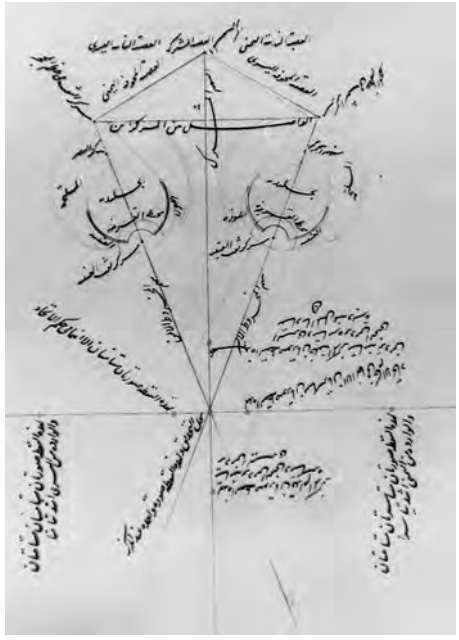
Illustration of the human organ of vision in the *Kitāb al-Manāzir* of al-Ḥasan Ibn al-Haiṭam (ca. 1041), MS Istanbul, Süleymaniye Kütüphanesi, collection Fatih 3212, fol. 81b (Cat. IV, 21)



Longitudinal section of the human eye according to Ibn al-Haiṭam in the Latin translation of his optics, MS Edinburgh, Crawford Library of the Royal Observatory. (Cat. IV, 21)



Longitudinal section of the human eye according to Kamāladdīn al-Fārisī (ca. 1300), *Tanqīḥ al-Manāzir*, MS Istanbul, Topkapi Sarayi, Ahmet III, 3340, fol. 24b. (Cat. IV, 22)



One more sketch of the human organ of vision according to Kamāladdīn al-Fārisī (ca. 1300), from his book *al-Baṣā'ir fī 'ilm al-manāzir*, MS Istanbul, Süleymaniye Kütüphanesi, collection Ayasofya 2451, fol. 42b. (Cat. IV, 22)

Medical Anaesthesia

Julius Hirschberg (d. 1925) points out that operations under anaesthesia belonged to the common medical procedures in the Arabic-Islamic civilization and regrets that surgically induced "sleep" (*tanwīm*) practised by the Arabs remained completely unknown to the historians of medicine. (Catalogue I, p. 32)

❖

The Discovery of the Minor Circulation of Blood by ʻAlī b. Abi l-Ḥasan Ibn an-Nafis al-Qurašī (d. 1288)

Researching for his thesis on Ibn an-Nafis' commentary on the surgery chapter of the *al-Qānūn fi ṭ-ṭibb* by Ibn Sīnā, Muḥyiddīn aṭ-Ṭaṭāwī, an Egyptian student, hit upon that fact in the year 1924. Thanks to several studies by Max Meyerhof and Joseph Schacht, we know today that this discovery by Ibn an-Nafis was borrowed by Michael Servetus (Miguel Servet) for his *Christianismi restitutio* (Vienna 1553); consequently the latter was considered its originator for centuries. Realdus Columbus (Realdo Colombo) in his *De re anatomica libri XV* (Venice 1559) also seems to have known about the discovery directly or indirectly from Ibn an-Nafis. Ibn an-Nafis' description of the pulmonary circulation which he gave in his commentary to the *Qānūn* of Ibn Sīnā supposedly reached Europe through a translation by Andreas Alpagus (Andrea Alpago, d. ca. 1520). During a thirty-year stay in Syria, he had acquainted himself with Arabic language and medicine. On his return to Padua he took with him several Arabic books and translated, inter alia, Ibn Sīnā's *Qānūn* into Latin, the same Canon which had already been translated by Gerard of Cremona. (Catalogue I, p. 50)

Study of Human Skeletons in Cairo

With regard to yet another medical scholar of the 13th century, research found clues of an important discovery. While staying in Cairo, the versatile physician and brilliant natural historian ʻAbdallaṭīf b. Yūsuf b. Muḥammad al-Baġdādī (1162-1232) seized the opportunity to examine the skeletons of people who had perished during a plague epidemic and famine in the year 1202. He wrote about his observations and the results of his examinations in his anthropo-geographical book on Egypt entitled *Kitāb al-Ifāda wa-l-iʻtibār fi l-umūr al-mušāhada wa-l-ḥawādif al-muʻāyana bi-arḍ Miṣr*, in which he dealt, inter alia, with stones, flora and fauna, antiquities, architecture and the local cuisine. In his anatomical study of thousands of skeletons he revised the errors and inaccuracies of his predecessors, in particular of Galen. One of his findings was that the human mandible consists of one bone only, rather than two bones joined at the chin as Galen believed. In this context al-Baġdādī points out that the evidence of one's own observation was more reliable than the doctrines of Galen, despite the high rank befitting the latter. (Catalogue I, p. 50)

❖

The First Known Book on Psychosomatics

Amongst the most important achievements of the 10th century should also be counted the book *Masāliḥ al-abdān wa-l-anfus* by Abū Zaid Aḥmad b. Sahl al-Balḫī (d. 934) in whom we encounter an early exponent of psychosomatics. (Catalogue I, p. 22)

Insight into the Nature of Infections

In the field of medicine, a clear insight into the nature of infections, amongst other achievements, calls for our attention. Several related treatises were written in Islamic Spain following the devastating plague that had infested the countries of the western Mediterranean in 1348. The following titles are amongst them: *Muqni'at as-sā'il 'an al-maraḍ al-hā'il* by Muḥammad b. 'Abdallāh Ibn al-Ḫāṭib (1313-1374), *Taḥṣīl al-ġaraḍ al-qāṣid fi tafṣīl al-maraḍ al-wāfid* by Aḥmad b. 'Alī Ibn Ḫātima (d. ca. 1369) and *Taḥqīq an-naba' 'an amr al-waba'* by Muḥammad b. 'Alī aš-Šaqūrī (b. 1327). Ibn al-Ḫāṭib says:

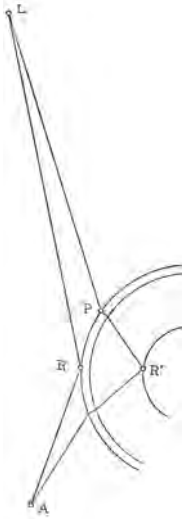
"The existence of contagion is established as a fact by experience, research, perception, autopsy and authenticated information, and those are the instruments of proof. Everybody who has seen the thing itself or gathered information about it knows that most of those who come into contact with people afflicted with the disease die and those with whom this is not the case remain healthy; furthermore that this disease occurs in a house or in a quarter because of a garment or a receptacle so that even an earring can cause the death of a person donning it and thus brings devastation upon the entire house; moreover that in one city the disease occurs in a single house and then blazes up in those individuals who have contact with the sick person, then in the neighbours and relatives and especially among those who pay visits to the house of the sick person, so that the breach becomes wider and wider; furthermore that the population of sea ports enjoys perfect health until an infected man arrives from another country where the plague prevails notoriously and the date of the outbreak of the disease in the town coincides with the date of his arrival."
(Catalogue I, p. 57-58)

Nucleus of Comparative Anatomy and Physiology of the Visual Organ

We encounter further evidence on the progress in medical science of those days in the Arabic-Islamic culture area in the comprehensive ophthalmologic textbook by Ṣadaqa b. Ibrāhīm al-Miṣrī aš-Šāḏilī (2nd half 14th c.) entitled *al-'Umda al-kuḥlīya fi l-amrāḍ al-baṣarīya*. In the sixth chapter of the first part concerning "the dissimilarity of animals' eyes and the human eye and the peculiar features of the latter," J. Hirschberg found "the nucleus of comparative anatomy and physiology of the visual organ" which was only to be found in scientific form in the textbooks of ophthalmology in the second half of the 19th century. (Catalogue I, p. 58; IV, p. 17)

Explanation of the Image seen in the Pupil

One of the most significant results of Kamāladdīn's (1267-1318) research in the field of optics known so far is his theory of the image seen in the pupil. Matthias Schramm first noticed that Kamāladdīn "rejected Galen's explanation as incompatible with the principles of optics" and investigated the true state of affairs by means of controlled experiments. To this end he used a mutton eye. Doing so, "he was the first to establish incontestably the reflection from the outer surface of the lens and he gave an excellent explanation in terms of his theory." Schramm points out that the results achieved by Kamāladdīn are the same "as those reached by Johannes Evangelista Purkynje again as late as 1823." (Catalogue I, p. 56)





Device for measuring the amount of blood collected after blood letting as described and illustrated by al-Ğazarī (ca. 1200 c.e.) in his book.

(Cat. IV, 35; H 3.02)

Instruments for Cauterization



Cauter in the form of a fingernail.

(Cat. IV, 36; H 1.01)



Cauter in the form of a fingernail.

(Cat. IV, 36; H 1.02)



Instrument for cauterisation in the case of «cold liver.»

(Cat. IV, 37; H 1.04)



Cauter for the treatment of the feet and the thighs.

(Cat. IV, 38; H 1.06-1)



Cauter for the treatment of the feet and the thighs.

(Cat. IV, 38; H 1.06-2)



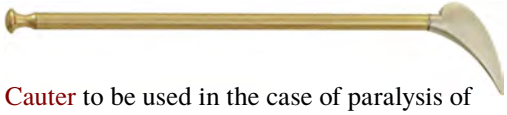
«Olive»-Cauter for a single cauterisation of the head.

(Cat. IV, 39; H 1.03)



Instrument for cauterisation on the head, at the temples and on the back of the skull.

(Cat. IV, 39; H 1.07)



Cauter to be used in the case of paralysis of the face.

(Cat. IV, 40; H 1.08)



Cauter to be used in the case of paralysis of the face.

(Cat. IV, 40; H 1.09)



Cauter in the shape of a scalpel.

(Cat. IV, 41; H 1.10)

Ophthalmological Instruments



Cauter for the treatment of fistulas in the tear gland.
(Cat. IV, 42; H 2.01)



Cauter for the treatment of fistulas in the tear gland.
(Cat. IV, 42; H 2.02)



Cauter for the tear gland fistula
(Cat. IV, 43; H 2.04)



Cleaner for the tear gland fistula.
(Cat. IV, 43; H 2.05)



Cataract needle
(Cat. IV, 44; H 2.13)



Cataract needle
(Cat. IV, 44; H 2.12)



Rose leaf «for cutting off the mulberry (n-tumour) of the lid, also used for cutting off the sebaceous cyst and for some other operations.»
(Cat. IV, 45; H 2.18)



Spear «This one cleaves the sebaceous cyst and reaches under it and cuts it off.»
(Cat. IV, 45; H 2.17)



Scissors for the eyelids «with broad blades. Their length is according to the measure of that which is cut off from the eyelid.»
(Cat. IV, 46; H 2.08)



Crescent-shaped Cauter «It is employed when the eyelids become limp.»
(Cat. IV, 46; H 2.07)



Myrtle leaf «With this the pterygium is lifted and skinned, while scissors are employed for cutting it off. Adhesions of the eyelids can also be cleaved with it.»

(Cat. IV, 47; H 2.10)



Scissors «for the gathering (cutting off) of the pterygium of the cornea circumference.»

(Cat. IV, 48; H 2.14)



Lancet «for the eradication of the blister. The chalazion and the like are also cleaved with it.»

(Cat. IV, 49; H 2.19)



Axe. A knife for bloodletting in the case of eye diseases, in particular «for opening the vein in the forehead.»

(Cat. IV, 50; H 2.22)



Cauter for Cauterizing the roots of the hair on the eyelid, when eyelashes grow into the eye.

(Cat. IV, 51; H 2.03)



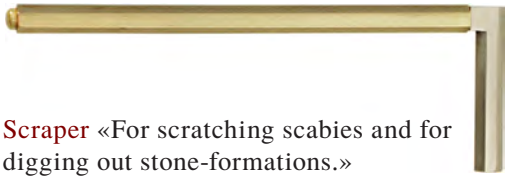
Scalpel «for cutting off the pterygium and for removing adhesions in the inner corner of the eye.»

(Cat. IV, 47; H 2.06)



Scissors «are used for cutting off the membrane of the conjunctiva.»

(Cat. IV, 48; H 2.15)



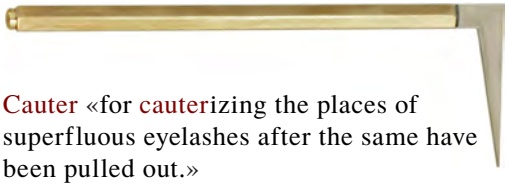
Scraper «For scratching scabies and for digging out stone-formations.»

(Cat. IV, 49; H 2.21)



Cauter for the vertex of the head «the head seam and the two veins on the two sides of the head are cauterized with this.»

(Cat. IV, 50; H 2.23)



Cauter «for cauterizing the places of superfluous eyelashes after the same have been pulled out.»

(Cat. IV, 51; H 2.24)



Sickle «for splitting adhesions between the two lids. It is also used in the case of the hare-eye.»

(Cat. IV, 52; H 2.09)



Ravens Beak «for removing whatever sticks to the eye or the inner side of the lid.»

(Cat. IV, 52; H 2.11)



Awn-Tongs «used when an awn or something of that kind falls into the eye.»

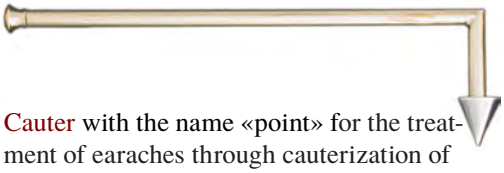
(Cat. IV, 53; H 2.20)



Gatherer «with this superfluous hair is gathered (plucked). Moreover, any foreign body fallen into the eye is also pulled out with this.»

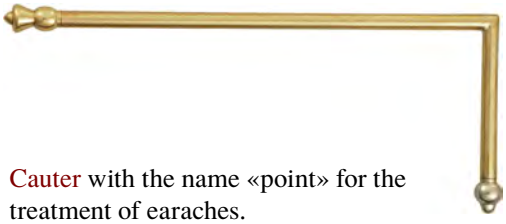
(Cat. IV, 53; H 2.16)

E.N.T.-Instruments



Cauter with the name «point» for the treatment of earaches through cauterization of various points on the auricle.

(Cat. IV, 54; H 4.08)



Cauter with the name «point» for the treatment of earaches.

(Cat. IV, 54; H 4.07)



Cauter with the name «point» for the treatment of earaches.

(Cat. IV, 54; H 4.01)



Scalpel «for splitting corns or seeds that have fallen into the ear and have swollen up due to the moisture inside the ear.»

(Cat. IV, 55; H 4.09)





Tweezers for the removal of foreign bodies in the auditory canal.

(Cat. IV, 55; H 2.02a, H 4.02b)



Cauter to be used in the case of nasal putrefaction.

(Cat. IV, 56; H 4.03)



«Scissor-like instrument for removing tonsils and other tumours of the pharynx.»

(Cat. IV, 57; H 4.05)



«Instrument shaped like a hook for the extraction of foreign bodies from the pharyngeal cavity.»

(Cat. IV, 58; H 4.13)



Cauter for use «in the case of diseases of the lungs and cough.»

(Cat. IV, 60; H 4.06)



Scalpel for removing tonsils.

(Cat. IV, 57; H 4.04)



«Instrument shaped like a hook for the extraction of foreign bodies from the pharyngeal cavity.»

(Cat. IV, 59; H 4.14)

Dental Treatment



Raspatories for the removal of tartar.



(Cat. IV, 61; H 9.01-H 9.14)



Instrument «like a small chisel» for lifting up broken teeth which cannot be extracted with a pair of tongs.

(Cat. IV, 63; H 9.15)



«Instrument with the fork» for lifting broken teeth which cannot be extracted with tongs any more.

(Cat. IV, 64; H 9.17)



Tongs for the extraction of teeth and for the removal of tooth fragments.

(Cat. IV, 65; H 9.21)



Tongs for the extraction of teeth and for the removal of tooth fragments.

(Cat. IV, 65; H 9.20)



Instrument for lifting up broken teeth which cannot be extracted with a pair of tongs.

(Cat. IV, 63; H 9.16)



Instrument «like a large fish hook» for lifting broken teeth which cannot be extracted with tongs any more.

(Cat. IV, 64; H 9.18)



Tongs for the extraction of teeth and for the removal of tooth fragments.

(Cat. IV, 65; H 9.19)



Tongs or Tweezers

(Cat. IV, 66; H 9.22)

Treatment of Nervous Disorders



Cauter with ring-shaped branding area «for the treatment of the lower area of the back in the case of painful diseases of the spinal column of children.»

(Cat. IV, 67; H 7.01)



Cauter for use in lumbar, used in the case of pain in the lumbar region (sciatica).

(Cat. IV, 67; H 7.02)



Cauter for the treatment of epilepsy

(Cat. IV, 68; H 7.05)

Urological Instruments



Balloon syringe for bladder irrigation.
(Cat. IV, 71; H 5.02a)



Scissors for the circumcision of boys.
(Cat. IV, 72; H 5.07)



Catheter «for relief when urine is retained in the bladder.»
(Cat. IV, 69; H 5.01)



Stamp syringe for instillation of the bladder; for the treatment of ulcers, blood clots or pustules in the bladder.
(Cat. IV, 70; H 5.06)



Balloon syringe for bladder irrigation.
(Cat. IV, 71; H 5.02b)

Gynaecological Instruments



The two-leaved speculum
«These are the two insets which are inserted into the cervix so that it is opened by them when you turn the two screws.»
(Cat. IV, 74; H 6.04)

Instrument «of the Ancients» (mentioned in connection with the extraction of the fetus) «a spoon-speculum with a screw arrangement for unscrewing its spoon-branches.»
(Cat. IV, 76; H 6.05)



«Scissors-speculum» (Cat. IV, 75; H 6.01)





Cephalotribe. An instrument resembling obstetric forceps «for crushing the head of a foetus» in case of miscarriages.
(Cat. IV, 78; H 6.02)



Cephalotribe. An instrument resembling obstetric forceps «for crushing the head of a foetus» in case of miscarriages.
(Cat. IV, 79; H 6.03)



Cephalotribe. An instrument resembling obstetric forceps «for crushing the head of a foetus» in case of miscarriages.
(Cat. IV, 79; H 6.06)



«Hook with two thorns» An instrument for the extirpation of dead foetuses from the uterus.
(Cat. IV, 80; H 6.07)

Orthopaedic Instruments



Cauter with «two spits» for branding the armpit in case of luxations (dislocations).
(Cat. IV, 81; H 3.03)



Cauter with «two spits» for branding the armpit in case of luxations.
(Cat. IV, 81; H 3.04)



Orthopaedic bench for the treatment of luxations (dislocations) of the dorsal vertebrae by az-Zahrawi (10th cent.).
(Cat. IV, 82; H 3.05)

General Surgery



Scarificator for cutting off and removing cysts, sebacaeus cysts and tumors.
(Cat. IV, 83; H 3.06)



Single hook for lifting vessels.
(Cat. IV, 84; H 3.08)



Triple hook for lifting vessels.
(Cat. IV, 84; H 3.10)



«Peeler» or «scraper» (raspatorium) for incision of bones.
(Cat. IV, 86; H 3.12)



Raspatory «with indentation», i.e. with a concave blade.
(Cat. IV, 87; H 3.14)



Compact hacksaw (Cat. IV, 88; H 3.16)



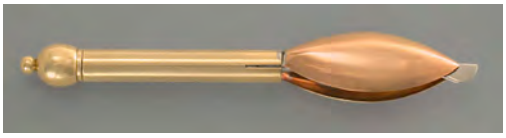
Pad saw (Cat. IV, 88; H 3.17)



Scalpel for the extraction of arteries at the temples.
(Cat. IV, 83; H 3.07)



Double hook for lifting vessels.
(Cat. IV, 84; H 3.09)



Covered scalpel with «secret chamber» for nervous patients.
(Cat. IV, 85; H 3.11)



Raspatory «bent at an angle at the end.»
(Cat. IV, 86; H 3.13)



Broad raspatory (Cat. IV, 87; H 3.15)



Large hacksaw (Cat. IV, 89; H 3.18)

Diverse Instruments from al-Fusṭāṭ

ca. 9th cent.?
(Originals in the Islamic Museum, Cairo)



(Cat. IV, 92; H 8.01-8.06)



(Cat. IV, 93; H 8.07-8.14)



(Cat. IV, 93; H 8.15-8.26)



(Cat. IV, 94; H 8.27-8.33)



(Cat. IV, 94; H 8.34-8.43)



(H 8.44)



(H 8.45-8.46)



(H 8.45-8.46)



(H 8.45-8.46)

Chemistry



al-Mīzān: One of the Fundamentals of Chemical Science According to Ǧābir b. Ḥaiyān

His belief in a mathematical order of the material world and in the possibility of explaining the transformation of substances on a quantitative basis finds its clearest expression in his theory of the proportions of equilibrium which he calls *ʿilm al-mīzān*. This, in Ǧābir's view, is "the fact that certain characteristics (*ḫawāṣṣ*) of substances, particularly in the field of chemistry, can be measured and are based on proportions which can be expressed in numbers. If, for example, vinegar loses its acidic taste when litharge is added, it shows that vinegar had originally a specific and quantifiable composition which is altered by the admixture of litharge that can likewise be represented numerically. The appearance of the specific characteristic, in this case the capability of litharge to alter vinegar, is not dependent on chance but on the internal constitution of the matter, and to change this arbitrarily is therefore the task of the chemical procedure (*tadbīr*). If the specific characteristics are based on a mathematical rationale, then the procedure also is justified, and its correctness, according to Gabir, is established."

"Thus the principle of measurability of bodies (*mīzān*) implies that everything in the cosmos conforms to mathematical laws. It indicates the rational order of things, their harmony. On the one hand, it appears in each and everything, even in the smallest object, on the other hand, it is the large abstract concept of our world. *Mīzān* is the symbol of the world order. Provided that there can be only <u>one</u> mathematical rationale of the specific characteristics, provided that it is clear in itself and cannot be defined now in one way, and now in another, in short, that there is only <u>one</u> type of *mīzān,* only <u>one</u> highest world principle." (P. Kraus 1930; see Catalogue IV, p. 101)

Experiment and Theory According to Ǧābir b. Ḥaiyān

"All the individual features of the natural sciences are enmeshed in a larger context and receive their significance and their justification only from this context. Here we have to do with a philosophical train of thought which is the actual starting point of the author and his strength throughout. Again and again he emphasizes that the application of technology and the practice of science (*ʿamal*) leads nowhere if theory (*ʿilm, qijās, burhān*) is not given its proper place." (P. Kraus 1930; see Catalogue IV, p. 100)

Arab Alchemy as Basis of the Alchemy of the Latin West

"It cannot be emphasized strongly enough that the alchemy of the Latin West owes practically nothing to the Greeks, but nearly everything to the Arabs. For decades, one fixed one's sight at the fragments of the Greek alchemical works as if from these the content and the nature of Latin alchemy could be explained and, while doing so, missed the most obvious task of tracing the occidental literature back to its direct and immediate sources. It is not the Greek alchemists but the translations of original works from the Arabic which constituted the foundation of Latin alchemy; over and again it is the translations and adaptations of Arabic authors which determined the course of developments in the Occident." (J. Ruska 1933; see Catalogue IV, p. 108).





Distilling plant for rose water from al-Mizza. The geographer Shams al-Dīn al-Dimashqī (13th c. CE) handed down a description and a delineation of a large multiple still for making rose petal extract commonly used in al-Mizza near Damascus. He tells us they were up to 1.5 times the size of a man. In the 16th century CE at the latest this type of device was introduced to Italy. (Cat. IV, 113; K 1.01-2)



Rose water still. A type of distilling plant common in the Islamic world is described in the *Kitāb at-Taṣrīf* written by the famous physician Abu'l-Qāsim al-Zahrāwī, who lived in Arabic Spain during the 10th century CE This sophisticated apparatus became known in Europe (outside Spain) later as ‹berchile›. Our model is based on al-Zahrāwī's description. (Cat. IV, 111; K 1.63)



Alembic with beak and receiver (Cat. IV, 116; K 1.64)



Destilling furnace, gently and evenly heating the flascs in a steam bath. After a description by the cosmographer Shams al-Dīn al-Dimashqī (d. 1327 CE). (Cat. IV, 117; K 1.65)

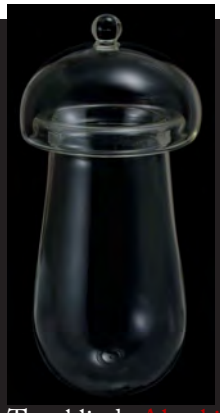


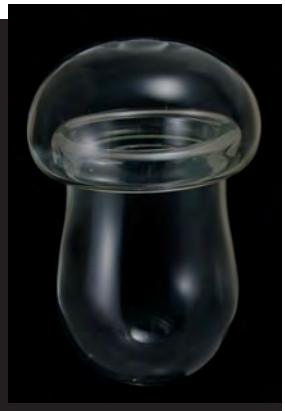
Alembic for the extraction of ethereal oils and alcohol. (Cat. IV, 120; K 1.66)





Receptacle made up of two similar glasses.
(Cat. IV, 124; K 1.40, K 1.29)





The «blind» Alembic
(Cat. IV, 125; K 1.33, K 1.51)



The «Duplicated Gourd»
(Cat. IV, 129; K 1.52)

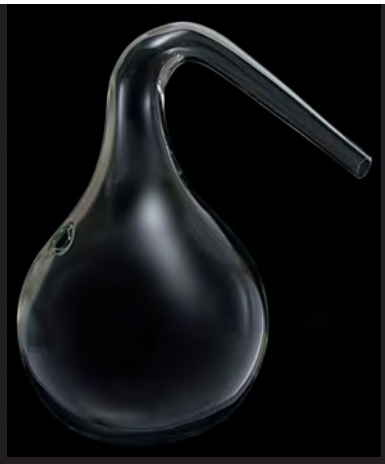


Alembic
(Cat. IV, 126; K 1.50)

Beaked Alembic
(Cat. IV, 128; K 1.68, K 1.68b)







Retort with markedly curved beak
(Cat. IV, 130; K 1.57)





Flask with bent neck (Cat. IV, 131; K 1.35)
Flask with curved neck (Cat. IV, 131; K 1.37)







Flat-Bottomed Flask
(Cat. IV, 132; K 1.34,
K 1.42,
K 1.54)



Round retort sheathed in clay
(Cat. IV, 134; K 1.49)



Flask with rounded bottom
(Cat. IV, 147; K 1.47, K 1.55)



Sphere-shaped Vessel
(Cat. IV, 136; K 1.44)



Wide-necked Receptacle (carafe)
(Cat. IV, 135; K 1.31)



Clubbed Glass Container
(Cat. IV, 136; K 1.36)



Capillary filter cup
(Cat. IV, 139; K 1.69)



Device for «dissolving spirits»
(Cat. IV, 138; K 1.39)



Receptacle for «dissolving spirits»
(Cat. IV, 137; K 1.38)



Cornu (probably a funnel)
(Cat. IV, 140; K 1.59b)



Model of a glass-blower stove
(K 1.04)



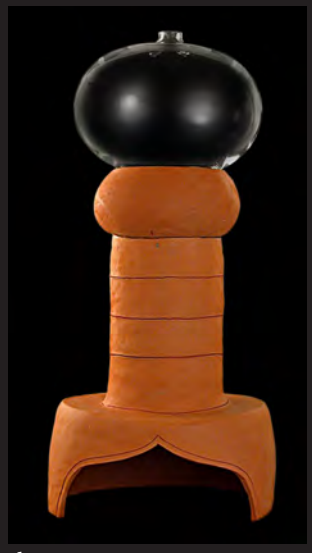
Breeding place
was very far spread particularly in Egypt in 15th c. The model shows the plant in Luxor, in which eggs were expenditure-bred. 100,000 chickens were hatched in the cycle of 10 days.
(L 1.01)



A spherical Apparatus for Dissolution
(Cat. IV, 140; K 1.60)



The «Self-Fanning Furnace»
(Cat. IV, 141; K 1.62)



Vas decoctionis mercuris
Kiln for heating mercury.
(Cat. IV, 142; K 1.23)



Aludel
Furnace for sublimation processes.
(Cat. IV, 143; K 1.70)



Furnace for heating solid matter
(Cat. IV, 145; K 1.10)



Stove with three flasks
(Cat. IV, 145; K 1.09)



Furnace for chemical processes
(Cat. IV, 144; K 1.07)



Furnace for heating a flask suspended over it.
(Cat. IV, 146; K 1.12)



Furnace with alembic
(Cat. IV, 146; K 1.14)



Kiln with a top piece of glass
(Cat. IV, 147; K 1.15)



Apparatus for unknown purpose
(Cat. IV, 150; K 1.11)



Vas decoctionis elixir
Flask for the preperation of the elixir.
(Cat. IV, 147; K 1.16)



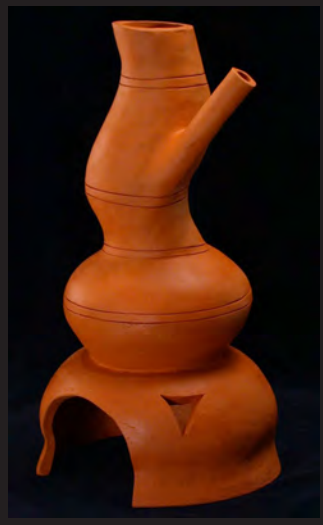
Pot with lions paws
(Cat. IV, 148; K 1.17)



Furnace with retort in helmet-form.
(Cat. IV, 148; K 1.20)



Bipartite Furnace with flask
(Cat. IV, 149; K 1.71)



Furnace shaped like a proboscis
(Cat. IV, 149; K 1.19)



Furnace
(Cat. IV, 151; K 1.21)



Furnace with two-beaked helmet
(Cat. IV, 144; K 1.08)



Furnace with alembic
(Cat. IV, 151; K 1.25)



Kiln for the production of artificial gems. After a fragmentary manuscript entitled *Ǧawāhir al-funūn wa-ṣ-ṣanāi' fī ġarīb el-'ulūm wa-l-badā'i'* (Gotha 1347, fol. 55a, 57a). The author Muḥammad b. Muḥammad Aflāṭūn al-Harmasī al-'Abbāsī al-Bisṭāmī is unknown so far.

(Cat. IV, 152; K 1.06)



Zosimos' Kiln
After an illustration in the manuscript Gotha 1347. This apparatus, though ascribed here to Zosimos (4th or 5th c.), seems to be the result of a development in the construction of chemical apparatuses that took place only from the 11th c. in the Arabic-Islamic culture area.

(Cat. IV, 153; K 1.05)

BOTANY

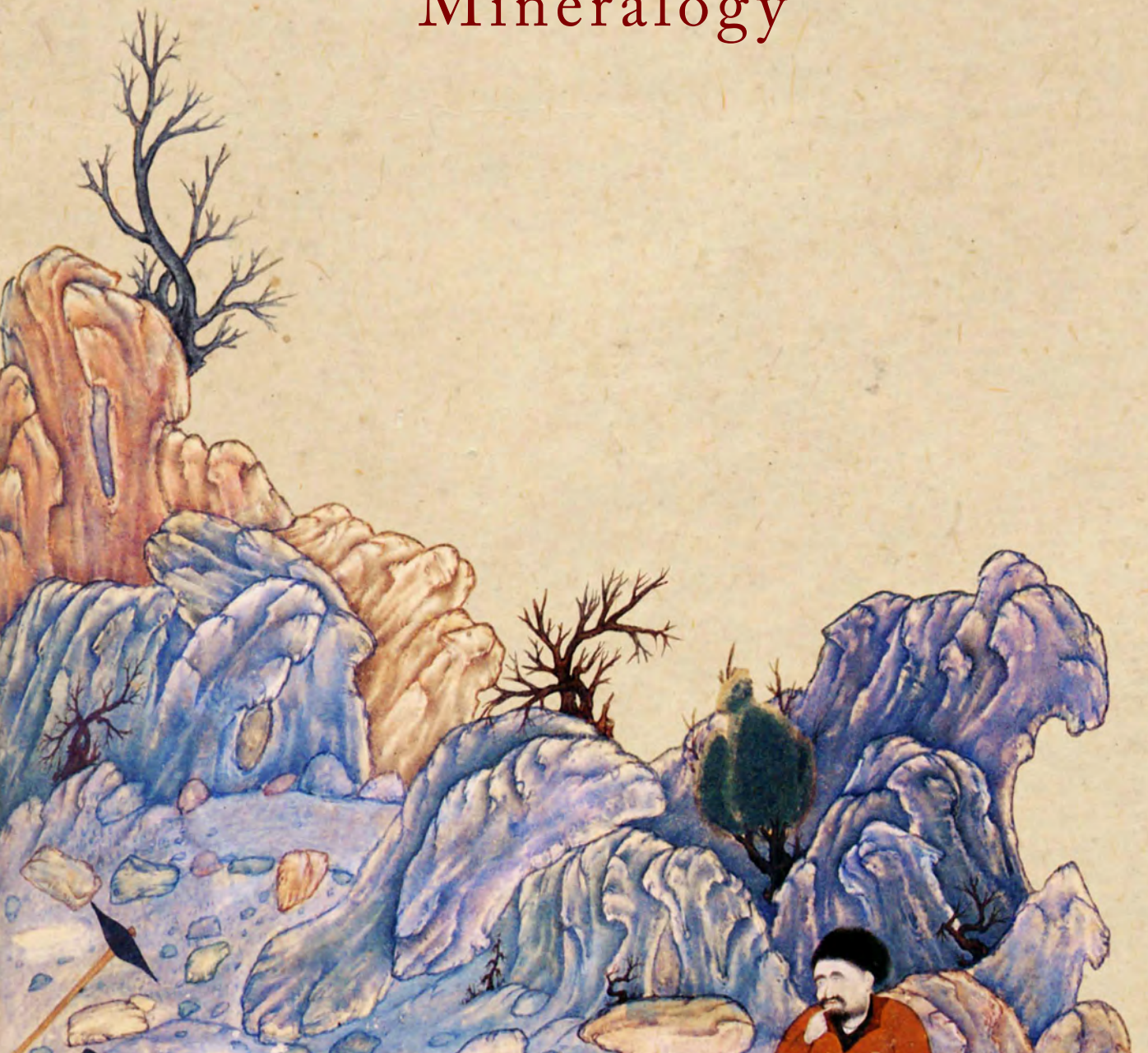
The Development of Botany by Philologists

An interesting example of this genre is the book of plants (*Kitāb an-Nabāt*) by Abū Ḥanīfa ad-Dīnawarī (d. ca 895). The surviving parts of this book, originally comprising 7 volumes, show clearly how far and how rapidly a branch of knowledge hitherto cultivated by the Greeks could already develop, in complete independence from the latter, amongst Arab philologists before the end of the 9th century. A study conducted in 1910–1911 by Bruno Silberberg exclusively on the basis of fragments of this book as cited in later dictionaries shows that Abū Ḥanīfa's botanical descriptions are equal to those of the *Materia medica* by Dioscurides. The descriptions prepared by Dioscurides had a different motivation from those in the *Kitāb an-Nabāt* of Abū Ḥanīfa. The purpose of the former was to help the reader in the identification of herbs in the field, i.e. purely practical, while Abū Ḥanīfa's presentation seems to have been inspired by a delight in the manifold varieties of plant morphology. In those days, Silberberg would still wonder: "How could the people of Islam reach in this respect the level of the brilliant Greeks or even surpass them at such an early period of their literature?"



Abū Ḥanīfa's book bears witness to the use of a scientific botanical terminology; "he knows a lot of specialised expressions for the diverse features of plants which in an unbiased reader evokes the impression that they were part of a scientific nomenclature created for the sake of greater precision." He displays an advanced scientific–morphological attitude, is familiar with the observation and description of physiological aspects and illustrates "complicated shapes in plants by comparison with familiar types." (Cat. I, 19)

Mineralogy





DIAMOND
(Cat. IV, 166; K 3.14)



BERIL CHRYSOLIT
(Cat. IV, 174 ; K 3.10)



SPINEL, RUBY SPINEL
(Cat. IV, 169; K 3.49)



JASPER
(Cat. IV, 175; K 3.22)



CAT'S EYE
(Cat. IV, 174; K 3.24)



AMBER
(Cat. IV, 209; K 3.09)



ZIRCON
(Cat. IV, 170; K 3.58)



AMETHYST
(Cat. IV, 171; K 3.04)



GARNET
(Cat. IV, 168; K 3.19a+b)



CORUNDUM (EMERY)
(Cat. IV, 167; K 3.27b)



EMERALD
(Cat. IV, 173; K 3.48)



ROCK CRYSTAL
(Cat. IV, 172 ; K 3.08)



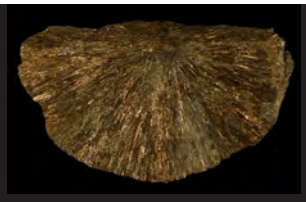
AGATE
(Cat. IV, 176; K 3.02)



QUARTZ
(Cat. IV, 172; K 3.42b)



ONYX
(Cat. IV, 178; K 3.37)



MARCASITE
(Cat. IV, 179; K 3.32)



COPPER PYRITE
(Cat. IV, 179; K 3.28)



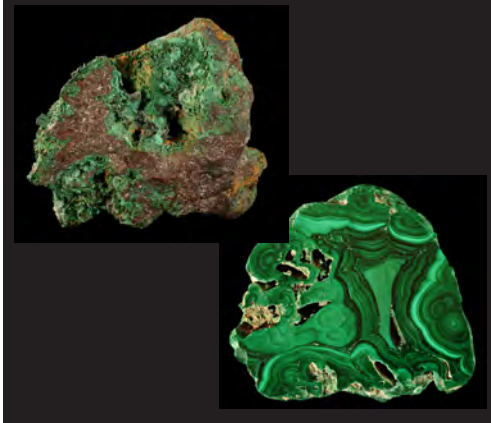
HAEMATITE
(Cat. IV, 180; K 3.21)



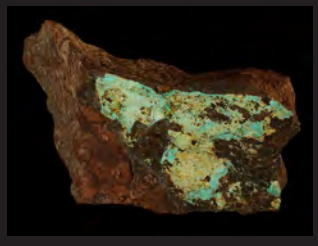
LOADSTONE
(Cat. IV, 181; K 3.30)



LAPIS LAZULI
(Cat. IV, 182; K 3.29)



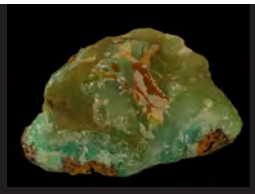
MALACHITE
(Cat. IV, 184; K 3.31)



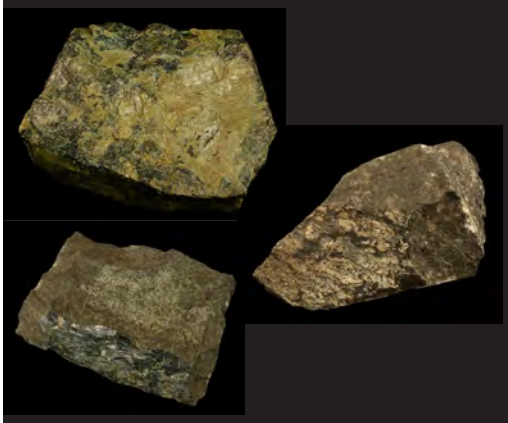
TURQUOISE
(Cat. IV, 183; K 3.53)



HEMIMORPHITE
(Cat. IV, 185; K 3.25)



ZINC SPAR
(Cat. IV, 185; K 3.56)



SERPENTINE (Snake Stone)
(Cat. IV, 186; K 3.47)



MARBLE
(Cat. IV, 187; K 3.33)



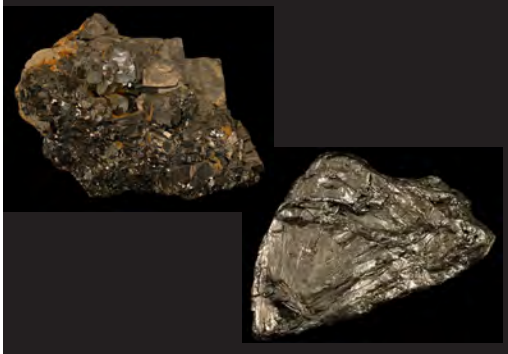
PYROLUSITE
(Cat. IV, 189; K 3.41)



YELLOW IRON
(Cat. IV, 188; K 3.15)



GRAPHITE
(Cat. IV, 194; K 3.20)



GALENA
(Cat. IV, 194; K 3.12, K 3.34)



BORAX
(Cat. IV, 196; K 3.13)



CINNABARITE
(Cat. IV, 195; K 3.57)



MUSCOVITE
(Cat. IV, 197; K 3.35)



ROCK SALT
(Cat. IV, 198; K 3.51)



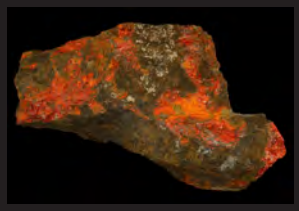
GYPSUM
(Cat. IV, 199 ; K 3.18)



SULPHUR
(Cat. IV, 200; K 3.45)



ORPIMENT
(Cat. IV, 201; K 3.07)



REALGAR
(Cat. IV, 201; K 3.44)



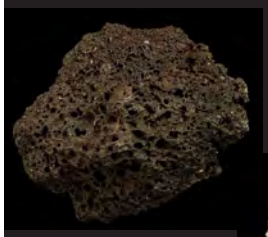
CHALCANTHITE
(Cat. IV, 192; K 3.59)



STEATITE
(Cat. IV, 202; K 3.50)



JET
(Cat. IV, 204; K 3.38)





PUMICE
(Cat. IV, 203; K 3.11)



ALUMINUM OXIDE
(Cat. IV, 205; K 3.52)



SEPIOLITE
(Cat. IV, 206; K 3.46)



GUM ARABICA
(Cat. IV, 210; K 3.61)





CORAL
(Cat. IV, 208; K 3.26)

Architecture

UNIVERSITIES
HOSPITALS
MOSQUES



TÜBA
TÜRKİYE BİLİMLER AKADEMİSİ
TURKISH ACADEMY OF SCIENCES

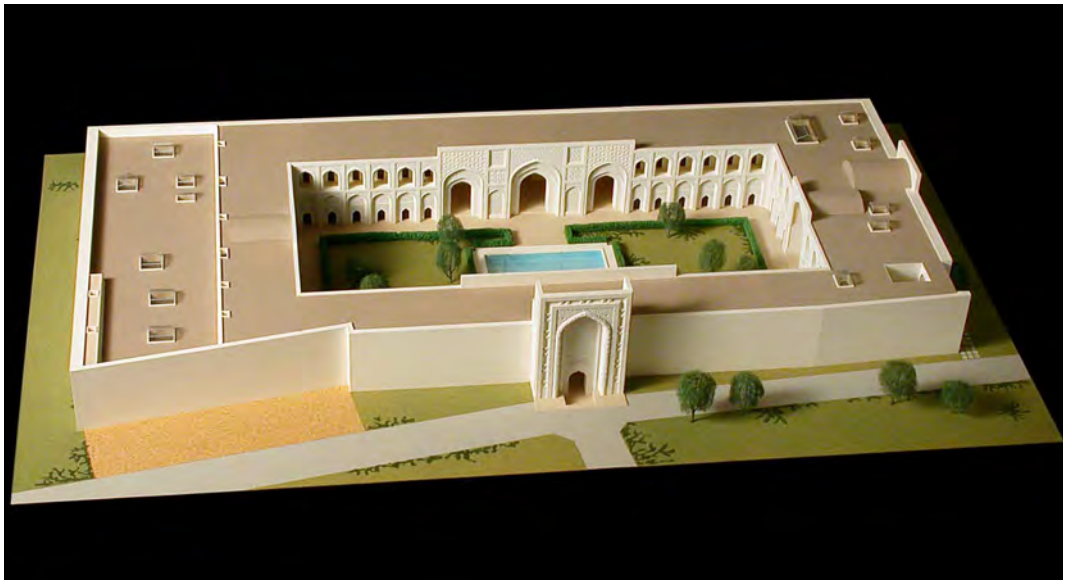
The Emergence of Universities

The mosques served as institutions of learning for centuries. Great scholars had their assigned places of teaching at certain pillars (*usṭuwāna*) in the mosques. The mosques had their own treasures of books and often their public libraries. The first state university was founded in 1065 in Baghdad. It was named al-Madrasa an-Nizamiya and was inaugurated in 1067 with great pomp. "We have detailed plans of similar school buildings. They were laid out as squares with a garden, contained lecture halls and conference rooms, a central library with all technical divisions, depots and magazines, a kitchen and the oriental bath (*ḥammām*)." (Catalogue I, p. 163)



Arabic–Islamic Models of the European Universities

"There cannot be any doubt that such renowned academies [of the Islamic world] became known in their external form also during the tumultuous reception of educational material from the middle of the 12th century and during the active Orient peregrinations of young scientists in the Occident. In Arabic Baghdad and in Arabic Cordova germinated the same kind of republics of letters as in Spanish Toledo and in Frankish Paris…" (Heinrich Schipperges 1963)



Model of the Mustanṣirīya university

The Mustanṣirīya University of Baghdad

This great university was founded in 1227 on the banks of the Tigris in Bagdad by the penultimate Abbasid Caliph Mustanṣirbillāh. It was probably the oldest Arabic–Islamic academy where, besides the syllabi of the four orthodox law schools, medicine and mathematical sciences were also taught. The maintenance of the academy was met through an endowment founded by the Caliph. The number of lecturers and other staff was about 400. The academy possessed a large and important library which was plundered after the conquest of Bagdad by the Mongols. The Caliph visited the academy often and "heard the lectures and the disputations of the scholars from a special place. Every now and then he held official receptions there for state guests."

"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 academy started functioning once again. It seems to have been much neglected in the last centuries. After its restoration between 1945 and 1962 the building is now part of the Museum of Islamic Culture and Art. Our model was built on the basis of the commendable work by Hansjörg Schmid. (Catalogue V, p. 65-67)

al-Mustanṣirīya University

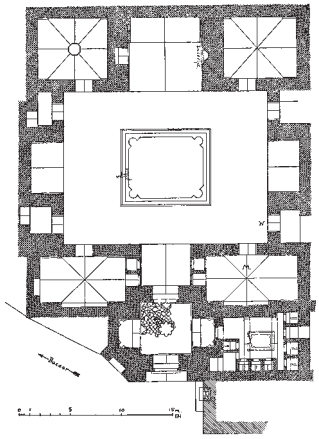






Photos of the façade and a view of the courtyard
(Hansjörg Schmid, *Die Madrasa des Kalifen al-Mustansir in Baghdad*)





The Nūraddīn Hospital in Damascus

This hospital, known under the name of al-Bīmāristān an-Nūrī, was founded in 1154, immediately after the liberation of the city, by Amīr Nūraddīn Maḥmūd b. Zangī who was of Turkish descent and the predecessor of the Aiyūbid Ṣalāḥaddīn (Saladin). It was one the most famous hospitals of the Islamic world and functioned up to the 19th century. Along with the Grand Mosque and the Citadel, it is counted among the most important monuments of the Islamic period (Catalogue I, p. 51; V, 68)



The Qalāwūn Hospital in Cairo

Finally, in the field of medicine of the 13th century, the hospital built 1284 in Cairo by the Mamluk Sultan al-Malik al-Manṣūr Saifaddīn Qalāwūn shall be mentioned. After the ʿAḍudī hospital in Baghdad (981) and the Nūraddīn hospital in Damascus (1154), it was the latest and the most advanced of the three major hospitals in the Islamic world established by that time. In some respects it seems almost modern. Such progressive features are its medical organisation with specialized treatments, the playing of music to patients suffering from mental illness or insomnia, in-house medical training, an elaborate administration, financial security through sufficient income from an endowment (with quite interesting conditions specified in the foundation deed) and, finally, the building itself and its equipment. This hospital with its dome (which seems to have collapsed after the 17th century) and its cruciform ground plan is believed to have served as the model for similar hospitals in Europe. (Catalogue I, pp. 51-52; V, pp. 71-73)



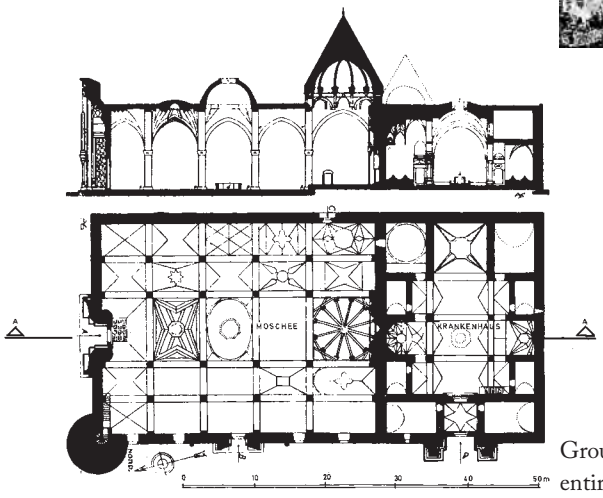
Model of the Princess Tūrān Hospital

The Hospital of Princess Tūrān in Divriği

The oldest fully preserved hospital of Anatolia was erected by Aḥmad Šāh of the local dynasty of Mengüček in 1228 on the instructions of Princess Tūrān, a daughter of Faḫraddīn Bahrām Šāh and his wife. 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 m; the area of the total complex, together with the mosque, amounts to 32×64 m. (Catalogue, V, 70)



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



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



Model of the Sulṭān Bāyezīd II Hospital

The Hospital of Sulṭān Bāyezīd II in Edirne

The hospital was founded in 1484 together with an academy (*madrasa*), a mosque and a kitchen for the poor (*'imārat*) on the banks of river Tunca in Edirne. A valuable description of the hospital is given by the famous traveller Evliyā Çelebī (17th c.). From this we may cite the description of the music therapy of mental patients: "I have seen a remarkable thing: His late majesty, Bayazid II… in the endowment document, has assigned ten musicians for the cure of the patients, for the recovery of those suffering from pain, for strengthening the mind of the insane and for pushing back the gall; three of them are singers; of the remaining, one player each of the reed flute (*nayzen*), the viol (*kemānī*), the pan-pipes (*mūsīqārī*), the dulcimer (*santūrī*), the harp (*çengī*), of a harp psalterion (*çengī-santūrī*?) and of the lute (*'ūdī*). 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, çārgāh*, and *sūzināk* are intended for these [patients and the insane]. But when the makams *zengūle* and *būselik* [are played] and concluded with the makam *rāst*, then it is as if they infused new life. There is food for the soul in all instruments and makams." (Catalogue V, p. 74)



Treatment of mental sickness by music in the Hospital of Bayezid II in Edirne (miniature by Nil Sarı).



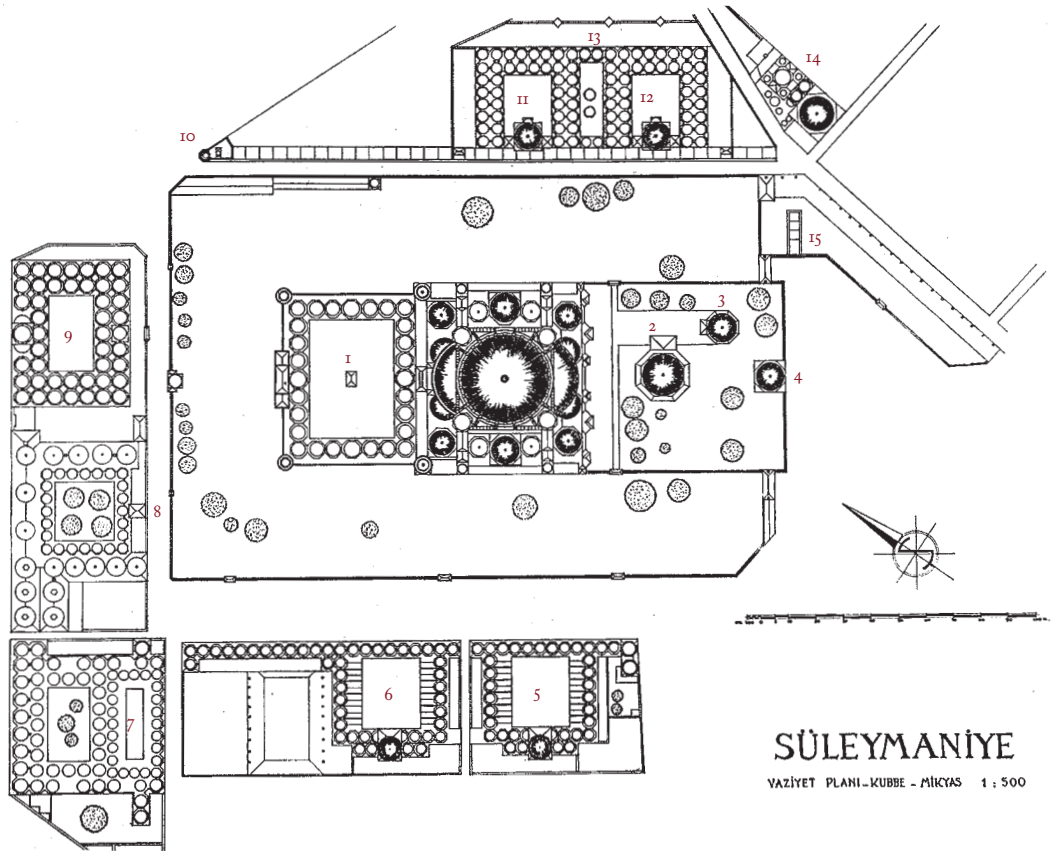
Model of the Süleymaniye

The Süleymaniye Mosque

The Süleymaniye Camii (thus the name of the mosque in modern written Turkish) is chronologically the second grand mosque built by the architect Sinān. With its social and cultural institutions it is perhaps the largest architectural complex created in the Ottoman Empire. The construction began in 1550 and was completed in 1557. It is reported that Sultan Süleymān himself suggested the location for the construction and that he entrusted his architect Sinan with the ceremonial opening of the building at the time of the handing over of the keys. Sinān increased the number of minarets to four. The two higher minarets (76 m each) facing the courtyard of the mosque have three galleries each (*şerefe*), the two smaller ones (56 m each) towards the outer side of the courtyard have two galleries each. (Catalogue V, p. 80)



Miniature showing a 16th century model of the Süleymaniye exhibited at the Surname-festival (*Surname-i Hümayun*, Topkapı, Sultan-Ahmet, fol. 190a).



Plan of the Süleymaniye Complex
(A. S. Ünver)

1. Mosque.
2. Mausoleum of Sultan Süleyman.
3. Mausoleum of Hürrem Sultan.
4. Residence of the Guardians of the Mausoleum.
5. First Madrasa.
6. Second Madrasa.
7. Hospital.
8. Almshouse.
9. Kitchen wing.
10. Sebil (well) and the Mausoleum of Sinan.
11. Third Madrasa.
12. Fourth Madrasa.
13. Caravanserai.
14. Bath Wing (*ḥammām*).
15. Theological Seminary
(*dār al-ḥadīṯ*).

Military Technology

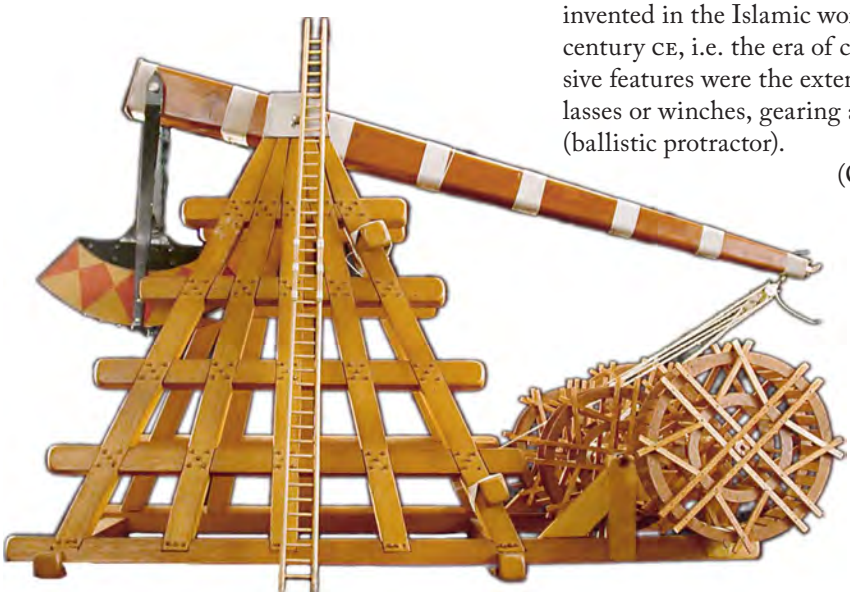




The traction trebuchet is designated as the «King's trebuchet» by az-Zardkāš (1374).
(Cat. V, 106; G 1.01)



Counterweight trebuchet
az-Zardkāš (1374) knows a certain form of the trebuchet called the «European catapult.»
(Cat. V, 107; G 1.02)



Large counter balance catapult
This type of siege engine seems to have been invented in the Islamic world during the 12th century CE, i.e. the era of crusades. Progressive features were the extended beam, windlasses or winches, gearing and clinometer (ballistic protractor).
(Cat. V, 108; G 1.03)



Counterweight trebuchet with arrow ejector. This type of trebuchet was a sub-variety of the model Qarābuġā. The main difference between the two was that the latter was meant to hurl heavy arrows instead of stones or other voluminous objects.

(Cat. V, 110; G 1.20)

Counterweight trebuchet with crossbow. This type of catapult has two functions; it hurls missiles as well as large arrows. It was developed in the 12th century.

(Cat. V, 112; G 1.19)





The large triple crossbow was popular already in the 12th century in the Arabic-Islamic culture area.

(Cat. V, 114; G 1.18)



The windlass crossbow was popular already in the 11th century in the Arabic-Islamic culture area.

(Cat. V, 113; G 1.17)



Arab counterweight trebuchets in occidental tradition (13th cent.).

(Cat. V, 115; G 1.05)



Arab counterweight trebuchet in occidental tradition has reached Europe already in the 13th century from the Islamic world. Our model was reconstructed after an illustration of 1405.

(Cat. V, 116; G 1.04)



One more Arab counterweight trebuchet in occidental tradition was reconstructed after an illustration of 1405.

(Cat. V, 117; G 1.06)



One more Arab counterweight trebuchet in occidental tradition was reconstructed after an illustration of 1405.

(Cat. V, 118; G 1.07)



Trebuchet with distance regulator, reconstructed according to a sketch by Leonardo da Vinci (1519).
(Cat. V, 119; G 1.21)



Fortification tower was reconstructed after an illustration from the book by az-Zardkāš.
(Cat. V, 136; G 2.01)



Ballistic gauge
Used for the adjustment while taking aim with counterweight trebuchets.
(Cat. V, 134; G 1.14)



Ballistic instrument for levelling used at the time of installing the catapults.
(Cat. V, 135; G 1.15)



Fire-pot and biological grenade, reconstructed according to the description and illustrations in the book of az-Zardkāš (14th century).

(Cat. V, 120; G 2.18-2.20)







Grenades
partially reconstructed according to the book *al-Furūsīya* by Ḥasan ar-Rammāḥ.

(Cat. V, 123; G 2.03-2.17)



The flame-thrower 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. Reconstructed according to the description and illustrations in the book of az-Zardkāš (14th century).

(Cat. V, 124; G 2.22)



Torpedo
according to Naǧmaddīn Ḥasan ar-Rammāḥ (d. 1295). The propulsion elements were saltpeter, sulphur and coal.

(Cat. V, 125; G 2.07)



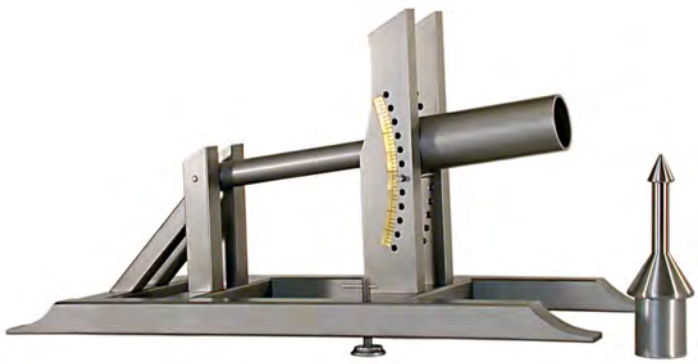
Grenade with chemical war materials by az-Zardkāš (1374).

(Cat. V, 127; G 1.12)



Rocket by the Ottoman engineer Lāgerī Ḥasan Çelebī, under Sultan Murād IV (r. 1623-1640).

(Cat. V, 128; G 1.13)



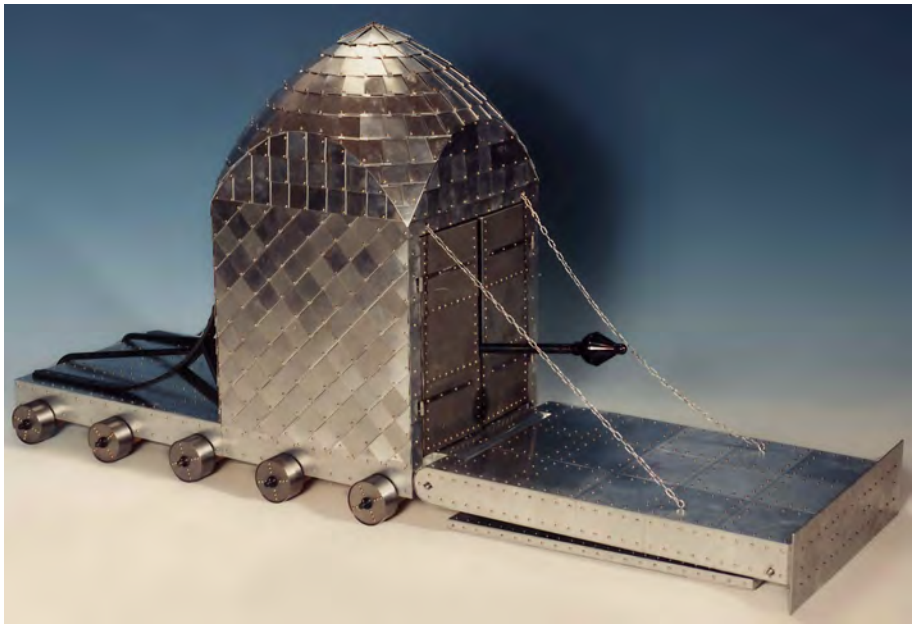
Advanced type of gun. Firearms came into use in the Islamic world from the 13th century CE. This model was made after drawings found in a 14th century CE manuscript, at which point the construction had already become rather sophisticated.

(Cat. V, 131; G 1.16)

Rifle. It seems that portable guns were developed in the Islamic world in the 14th century and introduced to Europe in the 15th century CE. Our model was built after the description contained in an Arabic manuscript of the 14th century CE.

(Cat. V, 133; G 2.21)





Armoured vehicle with battering ram, used for breaking down fortified gates under siege. After the illustration and description found in a 14th century CE Arabic Manuscript.

(Cat. V, 137; G 2.02)

Portraits of Notable Orientalists



Jacobus Golius
(1596 – 1667)

This celebrated Dutch orientalist was the first to edit an Arabic handbook of astronomy, namely that of Farġānī (from the first part of the 9th century), in Arabic. After a sojourn of several years in Arab countries and in Istanbul, he brought back a collection of 250 manuscripts which became the core of the oriental section of the university library at Leiden.



Johann Jacob Reiske
(1716 – 1774)

One of the oldest, most versatile, original and notable German Arabists.



Wilhelm Schickard
(1592 – 1635)

This versatile scientist and scholar of Arabic from Tübingen sought, inter alia, to replace the inadequate world maps of his time with a new world map on the basis of Arabic works on geography known to him, in particular Abu l-Fidā²s comparative tables of localities. Schickard's work remained incomplete because of his premature death.



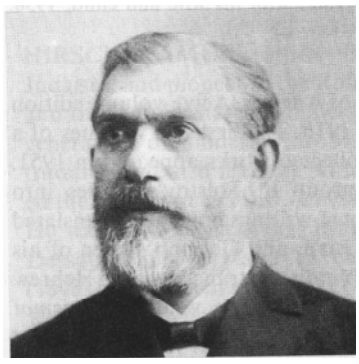
Joseph von Hammer-Purgstall
(1774 – 1856)

From Graz. Probably the most prolific and versatile Orientalist of all times, author of the first history of oriental literature (in 7 volumes) and of the ten-volume history of the Ottoman empire.



Joseph Ernest Renan
(1823 – 1892)

He is the French Arabist who clearly demonstrated in his book *Averroès et l'Averroïsme* (1852) how pervasively the Arabic-Andalusian philosopher Ibn Rušd (d. 1188 AD) had influenced the philosophy in the Occident.



Julius Hirschberg
(1843 – 1925)

This eminent historian of medicine has done great service in elucidating the outstanding achievements of the Arabic-Islamic physicians in the history of ophthalmology.



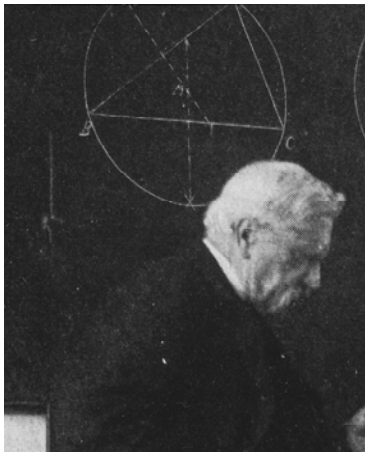
Michael Jan de Goeje
(1836 – 1909)

Famous orientalist from Holland. From 1866 to 1901 he edited, for the first time, more than ten fundamental works of Arabic–Islamic anthropogeography and translated parts of them into European languages. His edition of the history of the world by aṭ-Ṭabarī (d. 310/923), in fifteen volumes, is one of those masterpieces for which orientalists deserve great credit.



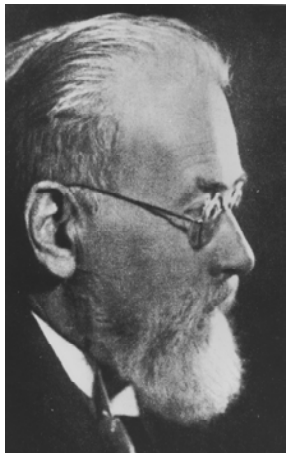
Eduard Sachau
(1845 – 1930)

From Neumünster. Besides several other publications, he is especially renowned through his edition and translation of the two important works *The Chronology of Ancient Nations* and *Indica* of al-Bīrūnī, one of the greatest scientists of the Islamic cultural sphere.



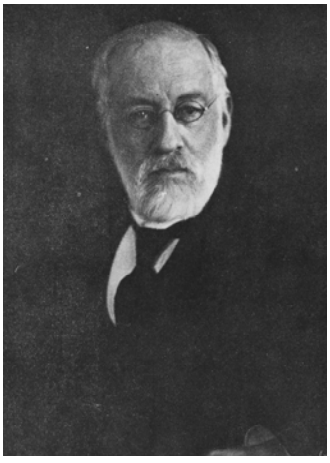
Heinrich Suter
(1848 – 1922)

Outstanding Swiss historian of Arabic mathematics, author of the first bio-bibliographical handbook of Arabic mathematicians and astronomers.



Julius Ruska
(1867 – 1949)

Historian of Arabic-Islamic sciences, especially of chemistry-alchemy.



Eilhard Wiedemann
(1852 – 1928)

This indefatigable and versatile physicist from Erlangen published, from 1879 onwards, more than 200 articles on Arabic–Islamic sciences. He was the first scholar who attempted to reconstruct Arabic–Islamic scientific instruments. The Islamic world owes him a great debt of gratitude.



Carlo Alfonso Nallino
(1872 – 1939)

From Italy, one of the most meritorious orientalists. He delivered lectures in Arabic at the University of Cairo in 1909–1910 on the history of Arabic astronomy; these lectures were published subsequently under the title *'Ilm al-falak*. This and his introductory volume to the edition of al-Batt n 's handbook are the first historiographic studies of Arabic astronomy.



Ignatij Kračkovskij
(1883 – 1951)

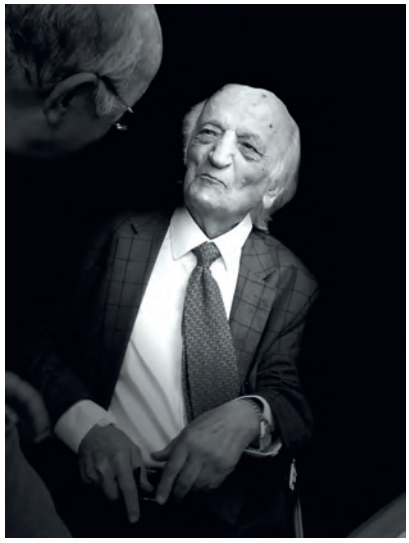
One of the most important and versatile Russian orientalists. His history of Islamic anthropogeography occupies an eminent position among his numerous publications. Produced after thirty years of labour, this monumental work is not only the best in this area, but also the best historical treatment of one of the areas of Arabic-Islamic sciences.



Hellmut Ritter
(1892 – 1971)

One of the most important Arabists of all times. He is the scholar who introduced Arabic Studies to Turkey and developed the modern method of critical editions of Arabic-Persian manuscripts.

On memory of Fuat Sezgin
























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