Nautical Science
Scientific Navigation

According to Ibn Māġid (one of the two outstanding Arab navigators of the 15th and 16th c.), navigation, which he calls ‘ilm al-bahr (nautical science), is a “theoretical and empirical science, as opposed to a mere paper tradition” (‘ilm ‘aqli tağribi lâ 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 mu‘allim (“master”, sing.). The members of the second category, the average ma‘ālima (“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 Māġid 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 Māgid

Ibn Māgid (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” (mansūḥ) and that what replaces them “revoking” (nāsiḥ), thus using terms usually employed in connection with the revelation of the Qurʾān. (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 Māgid’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 hisābī (“mathematical”) from those that are achieved empirically “according to experience” (taqribī).

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-
measure 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 *išba‘* (*išba‘* = 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)

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**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-Fāḥir* 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)
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)
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).

**Daw (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.
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. Ishāq 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-Asraf 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)

(Cat. III, 62; C 1.03)
(Cat. III, 63; C 1.07)

(Cat. III, 65; C 1.08)

Two types of Ottoman Compass
Built after the description by Hâǧǧî Hašîfâ (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)
**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)

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

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

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

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