

# ARCHIMEDES ARABICUS. ASSESSING ARCHIMEDES' IMPACT ON ARABIC MECHANICS AND ENGINEERING

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**ABSTRACT** Archimedes is an author who is frequently quoted in Arabic texts in relationship with mathematics and mechanics, including hydraulic devices such as water-clocks. The present study traces transmission paths and evidence for an assessment of the impact of the Archimedean works on the Arabic tradition of mechanics and hydraulics.

## 1. INTRODUCTION

The impact of Archimedes of Syracuse (ca. 287 – ca. 212 BCE) on medieval mathematics, sciences and engineering has been discussed in several overviews (e.g. I. Schneider 1979) as well as in comprehensive studies (e.g. Clagett 1964) published during the last decades. The actuality of the Archimedean mechanical concepts and the contribution of Archimedes to what is called in modern terms design of mechanisms has been a frequent subject of current studies (e.g. Chondros 2009).

Concerning the perception and tradition of the Archimedean works in the Arabic literature, scholar assessments and interpretations diverge considerably. A first, although rather superficial, attempt to assess the influence of the works and the fame of Archimedes on the Arabic-Islamic science could be based on some kind of statistics with respect to (a) mentioning the name or the treatises of Archimedes, as well as to (b) copying, quoting, commenting or compiling the work of the Syracusan scholar in the Arabic grammarology. However, pseudepigrapha, corrupted texts, lost links in the tradition and difficulties in reconstructing the treatises scattered in several manuscripts or codices demand for more thorough and balanced considerations. Most of the studies focus on the tradition of mathematics – perhaps

due to the fact that the study of the cultural transfer of mathematics from Greek into Arabic as well as the development of the science itself in the Arabic environment has a longer and broader scholar tradition. The present study will focus on Archimedean mechanics and engineering with a major goal consisting in revisiting and elucidating the relations among Greek, Arabic, Iranian, and Byzantine traditions or influences with respect to Arabic treatises attributed to Archimedes.

## 2. ARCHIMEDES IN ARABIC TRANSLATIONS

The most frequent and common transcription of Archimedes' name in Arabic is *Aršimīdis*. In Arabic texts *Aršimīdis* is mentioned not as a certain author (somebody vaguely known under this foreign name), but as an author who is expected to be well-known to the reader. A conventional way of listing the Arabic translations of Archimedes' works is given by Clagett (1964, pp. 3–4) in respect to the names of the treatises as known in modern scholarship:

- a) Works known also in Greek (Byzantine) tradition: “*On the sphere and the cylinder*” (with at least a portion of Eutocius' commentary), “*The measurement of the circle*” (with perhaps Eutocius' commentary), a fragment of “*On floating bodies*”.
- b) Some indirect material from the treatise “*On the equilibrium of planes*” found in mechanical works of other authors translated into Arabic (e.g. the “*Mechanics*” of Heron, nowadays extant only in Arabic).
- c) Works (perhaps) based on original treatises of Archimedes which are not extant in Greek: “Lemmata”, “Book of triangles”, “On the seven-part division of the circle”, “On touching circles”, “On parallel lines”, “On data”, “On properties of a right-angled triangle” and the treatise “On the construction of water-clocks” which will be discussed below.

Controversial on its philological and interpretative background is the last category – depending on the focus, the method of examining the extant manuscripts and the evidence available to the scholars. Folkerts (2009), for example, mentions only “*Lemmata*” and “*On touching circles*”, whereas the treatise known under the title “*On the construction of water-clocks*” has been classified as pseudepigraphic or, at least, as a compilation of pseudepigraphic and Archimedean parts (s. below).

### 3. CATEGORIES OF IMPACT ON THE ARABIC-ISLAMIC SCIENCE

In the 1990s Roshdi Rashed summarised the impact of Archimedes on the Arabic-Islamic science by proposing a threefold categorisation. The first group comprises the “inspiring legends”, to which Rashed counts the military triumph of the catoptrics marked by the story about Archimedes putting fire on the Roman fleet attacking Syracuse by means of gigantic mirrors, as well as the story about Hieron’s golden crone. These as well as similar stories were reported in Greek and Roman *literary* texts (e.g. Plutarch, Cicero), sources of minor interest for the Muslims in comparison to the higher estimated texts of purely scientific content. However, they should have undoubtedly accompanied and inspired Arab and Iranian scholars such as al-Kindī (9<sup>th</sup> century CE), Ibn Sahl (10<sup>th</sup> century CE) and al-Birūnī (10<sup>th</sup> century CE) in research activities on optics (catoptrics), mechanics and hydrostatics.

The second category of scientific works comprises a large amount of Arabic treatises ascribed in the Arabic bibliography to Archimedes. These treatises are most probably – partial or complete – pseudepigrapha, occasionally considered erroneously as translations of lost Greek versions of Archimedean treatises. The most representative treatise of this category is the treatise on hydraulic clocks. Another group of texts of this category are related to cosmological models quoted by authors of the (Greek) late antiquity in the field of alchemy. In this context Archimedes was quoted as author of a treatise on “*Pneumatics*”, e.g. in texts ascribed to the 4<sup>th</sup> century CE alchemist Zosimos of Panopolis (Lippmann 1919, p. 85), an author who was very “popular” in Arabic alchemical and occult treatises.

The third category comprises Arabic translations from the Greek of Archimedean treatises such as “*The measurement of the circle*” or “*On the sphere and the cylinder*”, which influenced considerably the Arabic geometry and mechanics. This influence has been demonstrated in the case of “*The knowledge of the measurement of plane and spherical figures*” of the brothers Banū Mūsā (9<sup>th</sup> century CE), as well as in the works of Thābit ibn Qurra (9<sup>th</sup> century CE) and the numerology of the Ikhwān aṣ-Ṣafā’, a group of Muslim scholars whose encyclopaedic activities are dated to the 10<sup>th</sup> century CE in ‘Abbasid Basra in Iraq (Bafioni 1997).

A close study of the specific traditions, however, renders the limiting lines among the above categories less visible. In the following some “interaction” modes among the above influence paths around works on mechanical devices will be presented.

#### 4. ARCHIMEDES IN THE ARABIC TRADITION OF MECHANICS

The admiration of Muslim (Arab, Persian etc.) mathematicians for Archimedes may mislead our modern expectation concerning the alleged perception of the mechanical treatises of Archimedes in the Arabic-Islamic environment. Whereas he was designated by the title of “leader” (*al-imām*) in mathematical sciences (Abattouy 1997, p. 13, no. 18), his reputation among the Muslim scholars in the field of mechanics is still controversial. Tracing his role in the Arabic tradition of mechanics depends not only on our knowledge about the direct translation of relevant Archimedean treatises into Arabic, but also on the compilation of excerpts from his works together with other texts – whereas original Arabic or translations from other Greek treatises. It is characteristic in this context that in the Arabic text of Heron’s “*Mechanics*”, a treatise extant only in the Arabic translation, Archimedes is quoted several times. Typical subjects in conjunction with these quotations are questions on equilibrium, of distribution of loads and of centres of gravity (Abattouy 1997, p. 12, no.16). Heron of Alexandria quotes in the Arabic text the unknown “*Kitāb al-qawā’im (Book of the supports)*”, in which Archimedes should have treated these questions. Heron provides also the reader with more references of Archimedean treatises under unknown names, e.g. “*Kutub al-amḥāl (Books of the levers)*” – perhaps a problem of translating titles, of lost Greek originals, or of pseudepigrapha.

On the other hand Arabic bibliographers of mechanical treatises do not mention relevant Archimedean treatises – although Arabic works on the balances, a typical subject of Arabic mechanics, contain parts that leave little doubt about the acquaintance of the authors (e.g. al-Khāzinī) with the Archimedean ideas (Abattouy 1997, p. 12).

The perception of Archimedean mechanical concepts (e.g. levers) in Arabic is closely correlated with similar questions in the Arabic perception of the famous “*Problemata mechanica (Mechanical questions)*”, a Greek treatise ascribed to Aristotle. Although there is no extant Arabic translation, recent research has established relationship between this Greek pseudo-Aristotelian text and works of Thābit ibn Qurra, especially his “*Kitāb fī’l-qarastūn*”, a treatise on the steelyard lever, as well as the Arabic text of Heron’s “*Mechanics*” (Abattouy 1997, p. 10). The establishing of the interdependence between this corpus and the translations of Archimedean treatises by Thābit ibn Qurra is a topic of current research (see also Abattouy 2002).

A final remark concerns the relevance of the mechanical subjects for the corpus of Arabic treatises on ingenious mechanical devices (*ḥiyal*). These devices correspond to the Greek *automata* (e.g. those described by Heron in his “*Pneumatica*”). In the Arabic tradition the most common ones

are hydraulic clocks, one of which was ascribed by several authors to Archimedes.

## 5. THE WATER-CLOCK OF (PSEUDO-) ARCHIMEDES

In 1891 Carra de Vaux published an Arabic treatise attributed to Archimedes concerned with what the editor called “clepsydra”. Actually, the text of the edited, translated and commented manuscript treats a hydraulic clock. The treatise was re-examined and translated into German under the title “*The clock of Archimedes*” in 1918 by E. Wiedemann shortly after a treatment of the work in the more general context of clocks in the medieval Islamic world (Wiedemann 1915). The treatise was systematically collated by means of more manuscripts and published under the title “*On the construction of water-clocks*” by D. Hill (1976; 1981).

One result of Hill’s study is that the treatise almost certainly contains Hellenistic and Byzantine material, as well as material from the Arabic-Islamic tradition. The mechanisms described in the first two chapters, a water machinery and a ball-release mechanism for marking the hours, are, according to D. Hill, essentially the same as those presented by two other authors of Arabic treatises on water-clocks at the beginning of the 13rd century CE. Riḍwān describes in a treatise dated 1203 CE the water-clock built by his father in Damascus. In his treatise on ingenious mechanical devices (*ḥiyal*) completed in Diyār Bakr in 1206 CE al-Jazarī describes – among others – similar hydraulic-mechanical machines. Hill suggests that the basic machinery should be an invention of the historical Archimedes (or, at least, it should go back to the Greek/Hellenistic tradition under this name). He points out that the outlook of the clock follows Iranian and Indian styles, but also Syrian-Byzantine construction models as reflected at the hydraulic-mechanic clock of Gaza described by Procopius (5<sup>th</sup> century CE).

## 6. CONCLUSION

Combining functional elements of hydraulics and mechanics of one cultural tradition with aesthetic models of another according to a plan of a third one in the case of the water-clock of Archimedes resulted presumably to a device for which the name of Archimedes offers more than a famous affiliation. This hypothesis about the design practice could also explain the patchwork composition of some manuscripts, in which the pseudo-Archimedean treatise is just one part of a group of device descriptions and, eventually, also just

one of several theoretical considerations. The assessment of the impact of the Archimedean tradition on Arabic mechanics still remains an on-going quest, in which new evidence on contributions to the development of the Arabic tradition of mechanics and hydraulic clocks inevitably contain new aspects of the connection of this development with the Arabic tradition under the name of Archimedes.

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