2 Ṯābit: Seas and Mountains

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2.1 Ṯābit, His Scientific Career and Impact

If we consider the significant impact of Ṯābit's extensive work in the fields of scientific translation and original research,[1] it can be argued that the available information on his life in his hometown of Ḥarrān and his adopted city of Baghdad is limited. The main source on Ṯābit's life is a biographical account written by Ibn al-Qifṭī (d. 568/1172-646/1248) in his *Ta'rīḫ al-ḥukamā'* (History of the Judges).[2] Ibn al-Qifṭī's record is based on the testimony of Ṯābit's great-grandson Abū Hilāl al-Ṣābī, who allowed him to read family documents on Ṯābit's ancestry and scholarly output. Overall, Ibn al-Qifṭī's account is not disputed by other biographical sources on Ṯābit, except for a few minor discrepancies, which will be discussed later.

Ṯābit was born in 826 in Ḥarrān,[3] located in upper Mesopotamia near the sources of the Balīḫ river in nowadays Turkey. His hometown of Ḥarrān was predominantly Hellenistic and the centre of the Sabian community,[4] to

1 Rashed, "Thābit bin Qurra: Scholar and Philosopher (826-901)".

2 Al-Qifṭī, *Ta'rīḫ al-ḥukamā'*, 115-22.

3 Arabic sources are not in agreement on this date, for a discussion on this see Rashed, "Thābit bin Qurra: from Ḥarrān to Baghdad", 24.

4 The term Sabian in Arabic sources can refer to several groups without much in common, such as the Christian Ṣabians of South Arabia or the Ṣabians of the Iraqi marshes around Wāsiṭ. Here we will always refer to the Ḥarraniān Ṣabians and their descendants in Baghdad. For an overview of the other groups see Bladel, *The Arabic Hermes*, 67.

DOI 10.30687/978-88-6969-790-6/002

which Ṯābit's family belonged. The religious beliefs and practices of the Sabians have garnered significant interest in modern scholarship, as has their philosophical and scientific activity, despite the fact that we are more or less limited to external descriptions of their beliefs and practices.[5]

Arabic sources provide little information on Ṯābit's life in Ḥarrān. According to one account, he was working as a money changer when the renowned Baghdadi mathematician Muḥammad b. Mūsā (d. 259/873), on his way back from a trip to Byzantium to acquire manuscripts, met him and was impressed by his language abilities. Muḥammad b. Mūsā invited Ṯābit to live with him in Baghdad, where he and his brothers al-Ḥasan and Aḥmad, who were known as the Banū Mūsā, mentored him in the fields of science, philosophy, and particularly mathematics. While it is always advisable to approach later biographical sources with caution, the key details of this story are generally accepted: Ṯābit had exceptional language skills and formed a close partnership with the Banū Mūsā.[6]

During his time in Baghdad, Ṯābit's life and career were closely tied to the renowned translation activity from Greek and Syriac to Arabic of a sizeable corpus of late-antique philosophical and scientific text.[7]

According to Ibn al-Qifṭī (568-646/1172-1248), Muḥammad b. Mūsā allowed Ṯābit to study in his house and introduced him to the astronomers at the caliphal court. This educational and social patronage greatly benefited Ṯābit, who was previously a simple money-changer in Ḥarrān. In a few years, he rose to become one of the most influential men of science at the court of Caliph al-Muʿtaḍid (r. 892-902/279-289). This depiction of his success in Baghdad is somewhat confirmed by al-Bīrūnī, who, alone among Arabic writing authors, credits Ṯābit with nothing less than the salvation of the school of the Banū Mūsā, since, as he writes in his *Kitāb al-Āṯār al-Bāqiya*, the Harranian "was the man who steered their scientific work back to right course" in scientific and methodological terms.[8] In other words, al-Bīrūnī understood Ṯābit's contribution to the work of his patron to amount to a significant change in theoretical and methodological perspective. Broadly speaking, a certain empirical attitude may be seen as a common thread between the two scholars. This is not just a mechanical consequence of human empiricism. Just as al-Bīrūnī shaped his models of fluvial regimes on actual rivers of the *dār al-islām*, Ṯābit touches on a few practical and concrete examples and cases rooted in his Mesopotamian environmental background, even in a highly theoretical work such as the treatise *On Why Seawater Was Made Salty*. For example, he describes seafaring vessels unable to venture into a river mouth. In ninth-century Iraq, the Shaṭṭ al-ʿArab river saw the passage of seafaring vessels and coastal boats heading towards the burgeoning port

5 As noted by Jan Hjärpe, much of the available information on the religion of the Sabians in Ḥarrān is derived from Syriac Christian heresiography. Hjärpe, *Analyse critique des traditions arabes*, 43-9. Of course, some caution should be exercised when using these sources, although Arabic testimonies suggest that it can provide valuable insights into Sabianism. Bladel, *The Arabic Hermes*, 68. See also Burnett, "Ṯābit Ibn Qurra the Ḥarrānian on Talismans".

6 Abdukhalimov, *Bayt Al-Ḥikma*, 204-12.

7 Bsoul, *Translation Movement and Acculturation*; Vagelpohl, "The ʿAbbasid Translation Movement in Context"; Gutas, *Greek Thought, Arabic Culture*. On the relations or lack thereof between the translation movement and the equally famous Bayt al-Ḥikma see Di Branco, "Un'istituzione sasanide?"; Bladel, Gutas, "Bayt Al-Ḥikma"; Gutas, *Greek Thought, Arabic Culture*, 53-60.

8 Al-Bīrūnī, *Kitāb al-āṯār al-bāqiya*, 52.

of Baṣra or the older city of Ubulla. This was a common sight at the time, but not all boats coming from the sea were able to enter sweet waters due to the double threat of shallows and less buoyancy.[9] Possible precedents for the same example demonstrating the higher density of salty water do not erase the link between Ṯābit's scientific writing and the experiences or direct observations at his disposal. The validity of this connection remains regardless of whether he derived the example independently or obtained it through external sources and subsequently verified its accuracy.

Thus, Ṯābit echoes the influence of the everyday experience in his theoretical scientific writing by discussing the use of salt as a preserving agent. This pertains to an argumentative and knowledge-based method that clearly reflects the scholar's empiricist approach, with techniques that have frequently been recognised as distinctive of al-Bīrūnī.[10] He notes that it was commonly used in large quantities to treat putrescent still waters or small marshes in order to prevent the spread of pestilences. To the best of our knowledge, there is no other evidence for this widespread practice. It is worth mentioning that during the first centuries of Islamic presence in Mesopotamia, there was a significant effort to improve the state of the hydrological network, including the marshes of southern Iraq. This effort, which was costly in terms of both finances and human resources, followed the collapse of the ambitious infrastructure built by the Sasanians. This collapse took place in the decades preceding the emergence of Islam, and it may very well have led to a diffusion of putrescent ponds such as those mentioned by Ṯābit.[11]

At any rate, al-Bīrūnī's assessment of Ṯābit's overarching contribution made by Ṯābit to the scientific endeavours of the Banū Mūsā naturally begs the question of how much Ṯābit's education owed to his Sabian and Ḥarranian background. As noted by R. Rashed, the only certainty on this subject is that Arabic sources do not give the slightest hint that Ṯābit received any scientific education whatsoever in Ḥarrān or prior to his fortunate encounter with Muḥammad b. Mūsā.[12] The picture is further blurred by our ignorance about the actual scientific activity ongoing in ninth-century Ḥarrān, a religiously diverse centre with a strong classical tradition. Al-Masʿūdī (b. 280-345/b. 893-956), who visited the city some seventy years after Ṯābit left it described them as philosophers of some kind.[13] In the eighties Tardieu argued that a Platonic academy had been active in Ḥarrān.[14] His

9 Agius, *Classic Ships of Islam*, 65-9.

10 Hatami, "Empirical Horizons in Islamic Historiography"; Malagaris, *Biruni*, 84-108; Mirza, *The Quest for Knowledge*.

11 It would be an oversimplification to suggest a direct causal link between say the Aristotelian doctrine of the water cycle and the environmental features of the Mediterranean basin. The doctrine argues that precipitation alone is not sufficient to explain the availability of fresh water, and that a significant portion must be the result of underground processes. Meanwhile, the Mediterranean basin experiences more evaporation than precipitation. While these factors may be related, it is difficult to maintain a direct connection between them. Nevertheless, it also seems untenable to deny any room to the interactions between environmental contingencies and how scholars think about nature, or creation, as they inhabit those very environments.

12 Rashed, "Thābit bin Qurra: from Ḥarrān to Baghdad", 21.

13 Al-Masʿūdī, *Murūǧ al-ḏahab*, §§ 1394-5 = 2.293.1-8, trans. 2.536-7, cited in Bladel, *The Arabic Hermes*, 72.

14 Tardieu, "Ṣābiens Coraniques et 'Ṣābiens' de Ḥarrān".

thesis sparked considerable debate. We cannot hope to do it justice here. It will suffice to say that K. van Bladel conclusively argued that al-Masʿūdī's account does not in any way suggest the presence of a Platonic academy in Ḥarrān.[15] For what concerns us here, Tardieu argued that the diffusion of Platonic philosophy in Ḥarrān could be the main factor behind Ṯābit's learning. Given the Neoplatonic,[16] rather than Aristotelian, outlook of the Sabian doctrine in Baghdad, Tardieu argued that the Ḥarranian tradition played a role, but this is not sufficient to explain Ṯābit's learning in the scientific realm. This thesis seems to be far-fetched as well, since only two works by Ṯābit seem to have dealt with Plato,[17] among a production of over two hundred works.[18]

In this regard, it is worth recalling that Arabic sources describe the Sabians in particular as monotheists and star worshippers. The information about their beliefs and practices is far from exhaustive, but, according to ninth-century philosopher and scientist al-Kindī (d.c. 256/870) they maintained that

> the world has a cause who has never ceased to be, who is one, not manifold, who cannot be described by means of attributes which apply to the things caused […] the movement of the heaven is conditioned by its free choice and intelligence.

Al-Kindī further describes the religious practices of the Sabians as astrolatrical:

> They offer sacrifices, slaughtering them in honour of the stars. Some say that it is a bad omen for the sacrifice to be offered in the name Creator; for, in their opinion, He undertook only the major task inferior matters to the mediators appointed by Him to administer the world.[19]

Moreover, the thirteenth-century historian Bar Hebraeus (ar. Ibn al-ʿIbrī), relays a prideful praise to the Sabians in which Ṯābit himself attributes to his co-religionists unrivalled skills in a few technical and scientific realms. The list comprehends engineering, both in terms of town-building and construction of harbours and canals, occult sciences, divination and medicine, for the benefit of both the body and soul. For the purpose of the present book, it is worthy to keep in mind the connection drawn here between the Sabians and water-related engineering, even though too many centuries separate Ṯābit and Bar Hebraeus for us to lend unconditional credibility to the exact wording of this praise.

15 Bladel, *The Arabic Hermes*, 70-8.

16 Or, even better, Gnostic-Neoplatic, founded on the idea that knowledge of the self is a prerequisite for knowing in general. This Gnostic-Neoplatic strain in Sabian thought was, in Tardieu's view, diverging from the mainstream Sabian beliefs in Ḥarrān. Tardieu, "Ṣābiens Coraniques et 'Ṣābiens' de Ḥarrān", 16.

17 For instance in his treatise *On Resolving the Allegories in Plato's "Republic"* (*Risāla fī ḥall rumūz kitāb al-siyāsa*). Reisman, "Plato's 'Republic' in Arabic", 265.

18 Bladel, *The Arabic Hermes*, 78.

19 Al-Nadīm, *Kitāb al-fihrist*, 318-20. Cited in Bladel, *The Arabic Hermes*, 87.

The astrolatry of the Sabians finds confirmation in several authors[20] and makes it tempting to postulate at least some sort of scientific education during Ṯābit's Ḥarrānian years, but there is not much to confirm this. The only indirect clue that Ṯābit already had independent opinions and already belonged to the 'philosophers' of Ḥarrān met by al-Masʿūdī comes from Ibn Ḫallikān (608-681/1211-1282), a renowned biographer of the thirteenth century. The lateness of this source contributes to the uncertainty. Be it as it may, Ibn Ḫallikān mentions in his *Wafayāt al-Aʿyān* (The Obituaries of Eminent Men) that Ṯābit had to leave Ḥarrān for the nearby village of Kafr Tūṯa because he had differences with the Sabians of his native town. According to this version, Kafr Tūṯa is where he would meet Muḥammad b. Mūsā, according to the *Wafayāt*.[21]

Building on this disagreement with the Sabians in Ḥarrān, Hjärpe suggests that a split may have occurred between Ṯābit's native community and the Baghdadi Sabian community that he fostered in the following years as he took the lead of the Banū Mūsā school after the death of the two brothers. According to Hjärpe's thesis, the Baghdadis' religious tradition had been grounded more in esoteric philosophy, than the religious practices of Ḥarrān.[22] T.M. Green is probably correct in downplaying the importance of this split given that Ṯābit continued to act as a high-level advocate at al-Muʿtaḍid's court for the interests of the Ḥarranian Sabians.[23]

In sum, the precise amount of the debt owed by Ṯābit to his Ḥarranian years remains as foggy as the question is suggestive. The importance of his input to the scientific endeavours of the Abbasid age contributes to explain the interest of many modern scholars in the intellectual landscape of Ḥarrān, which could very well be one of the main entry points for Greek philosophical and scientific tradition into Abbasid learned society. Against this background, Ṯābit's stature among the scientists of ninth-century Baghdad is hardly overestimated. This is meant both in terms of the consideration that he enjoyed in his life, and the influence that his work was set to impress on later scientists in the Muslim world and beyond it. Ṯābit's work developed in agreement with the *modus operandi* of his age through a synergy between translation, innovative research, and teaching.[24]

Ṯābit's contribution to the scientific endeavours of the Abbasid age is a favourite of scholarly research on the history of science in Islamdom. His work on water-related science – we will address the status of this scientific branch in the Arabic tradition further on – has not, however, received as much attention as the three main fields of activity: astronomy, mathematics, and infinitesimal geometry. Much of the lasting impact of Ṯābit's work is due to his foundational, methodological character. An exhaustive treatment of his production is beyond the purpose of the present research, however it is useful to highlight a few aspects that give a general idea of his approach.

As an astronomer, he moved towards a reconciliation of physical and mathematical astronomy reflecting on the relationship between theory and continuous observation. As a mathematician, he pushed for a reconciliation

20 Pingree, "The Ṣābians of Ḥarrān and the Classical Tradition".

21 Ibn Ḫallikān, *Wafayāt al-aʿyān*, 1: 313.

22 Hjärpe, *Analyse critique des traditions arabes*.

23 Green, *The City of the Moon God*, 113-14.

24 Rashed, "Problems of the Transmission of Greek Scientific Thought".

of geometry and algebra, providing geometrical demonstration of algebraic procedures. Furthermore, on request of al-Qāsim b. ʿUbaydallāh b. Wahb (d. 291/904), he developed a method of invention to complement the Euclidian axiomatic method in mathematics and all demonstrative science which will influence the work of many others, such as his grandson Ibrāhīm b. Sinān (d. 335/946), al-Siǧzī (fourth-tenth century), and Ibn al-Ḥayṯām (d. 430/1039). Last but not least, it is worthwhile to mention his thought on infinity, as it bears consequences on his understanding of Creation, as we will see, and showcases Ṯābit's openness to challenge the established philosophical tradition. Ṯābit argued in a collection of answers to questions posed by Ibn Usayyid, a student of his, that, against Aristotelian tradition, there is actual infinity and that there can be one infinity larger than another infinity.[25]

Ṯābit's influence reverberated through his leadership in the school of the Banū Mūsā and the establishment of a Sabian learned community in Baghdad, whose importance is described by Ibn al-Nadīm (d. 385/995 or 388/998) in clear terms: "The source of leadership of the Sabians in this country and their proximity to the caliphs was Ṯābit".[26] In addition to this didactic and institutional influence, Ṯābit's work was conveyed by his translations and original writings. Ibn al-Nadīm mentions in his *Fihrist* (Index) – an index of Arabic books composed in 377/987-8 – only a few titles by our author. Ibn al-Qifṭī reports an impressive list of original books and treatises composed by Ṯābit in the sciences of his age. Of interest here are a book on meteorology (ar. *anwāʾ*), which appears to be lost, a treatise on the usefulness of the mountains, of which we only have a summary by Miskawayh, and the treatise *On Why Seawater was Made Salty*. The latter is by far the most important text at our disposal to understand how this foundational figure of the intellectual and scientific life of premodern Islam understood the environment and the functioning of the natural world.

The long-term impact of Ṯābit's understanding of the water cycle and the role of water in the ecosystem cannot be assessed fully at this point of research. To accurately evaluate this impact necessitates a more profound exploration of the water cycle's conceptualisations in post-classical philosophy specifically, as well as in sources extending beyond the thirteenth century more generally. Nevertheless, the enduring success of his teachings in other branches of the sciences, and the fact that the treatise *On Why Seawater was Made Salty* was still being copied centuries later makes it credible that his views on the subject remained a point of reference. A more direct clue in this sense is that Miskawayh and al-Bīrūnī openly referred to him when discussing the same subjects a century and a half later, as we will see.

25 Rashed, "Thābit ibn Qurra sur l'existence et l'infini"; Sabra, "Thābit Ibn Qurra on the Infinite and Other Puzzles".

26 Al-Nadīm, *Kitāb al-fihrist*, 647.

2.2 The Salinity of the Sea in Graeco-Arabic Thought

Before addressing Ṯābit's ideas on the salinity of the sea, it is necessary to provide a description of the views on the subject held by the philosophical tradition of the Islamic world. This tradition draws heavily on Greek thought, particularly Aristotelian doctrine, as a starting point. This is both because of the well-known importance of Greek philosophy among Muslims and because of Ṯābit's own familiarity with Greek thought.[27] The question of the salinity of the sea is often linked with the origin of rivers, which as we have seen leads our thinkers to conceptualise different models of the water cycle. In this book we will deal with both aspects of premodern Arabo-Islamic hydrology, therefore it seems more practical to address them together here. This summary is largely based on the work of Paul Lettinck, specifically his book Aristotle's *Meteorology and its Reception in the Arab World*. Lettinck's book offers a comprehensive analysis of the Aristotelian doctrine on sublunar phenomena within the Arabo-Islamic tradition. His work provides valuable insight into the reception and interpretation of Aristotle's ideas in this context, and serves as a precious resource for understanding the role of Meteorology in shaping the understanding of natural phenomena in the Arabo-Islamic cultural space.

The outline that follows begins by examining the Aristotelian doctrine, with a focus on the concepts presented in the Arabic translation of Aristotle's works. In addition to Ṯābit and al-Bīrūnī, who are the primary subjects of this chapter and the next, other authors who addressed the issue of the salinity of the sea and the origins of rivers include Ḥunayn b. Isḥāq (192-260/808-873), Ibn Sīnā and his students Abū al-Barakāt al-Baġdādī (d. after 560/1164-5), Ibn Rušd (d. 595/1198), and Abū al-Faḍl b. al-ʿAmīd (d. 360/970). A review of their views on this topic allows for a more comprehensive understanding of the significance and relevance of the contributions made by Ṯābit and al-Bīrūnī.

Aristotle addresses the issues of salinity and the origin of rivers in the *Meteorology*. As he does with many other topics, Aristotle critiques previous theories and presents his own perspective on these subjects. For the purpose of clarity, this summary will provide an overview of Aristotle's theory on rivers and the sea, including the role of sea salinity within it and the twofold exhalation doctrine that serves as the foundation of the *Meteorology*.

The concept of two types of exhalation is a central principle of the *Meteorology*. According to this doctrine, the Sun causes the earth to emit a dry, highly flammable exhalation composed of air and earth, as well as a moist, vaporous exhalation derived from moisture. These two exhalations are responsible for various meteorological phenomena, such as winds and thunderbolts.[28] According to Aristotle, the salinity of seawater results from the contribution of both exhalations. He explains that salinity is brought to the sea through rain, which contains a mixture of these two exhalations. Aristotle further elaborates on the topic of seawater and its salinity, providing examples to demonstrate that seawater is heavier than fresh water. This suggests that salty water is a mixture of water and other substances that

27 Goodman, "The Translation of Greek Materials into Arabic", 485-6; Gutas, *Greek Thought, Arabic Culture*.

28 Frisinger, "Aristotle and His 'Meteorologica'".

can exhale under the effect of the heat of the Sun and increase the weight of the water with which they are combined.

In the *Meteorology*, Aristotle addresses the issue of the source of rivers, or the origin of the water that sustains them. He rejects the idea that all rivers on Earth are fed by a single or multiple underground reservoirs of rainwater, arguing that such reservoirs would have to be as large as the Earth or larger. In contrast to this exogenous model, which posits that "no water at all is generated, but the volume of the rivers consists of the water that is gathered into such reservoirs in winter",[29] Aristotle proposes an endogenous model, in which the water that forms rivers is generated within the Earth itself. In chapters I,13-II,3 of the *Meteorology*, Aristotle discusses the idea that some of the water that sustains sources and rivers is derived from underground condensation of vaporous air, that is an ambiguous stage between water and air, in addition to being supplied by rainfall.

Aristotle's *Meteorology* was highly influential in Arabo-Islamic thought, with much of its impact owed to the mediation of Abū Zakariyyāʾ Yaḥyā b. al-Biṭrīq (d. c. 215/830). Al-Kindī, Ibn Suwār (d. a. 407/1017),[30] and Ibn Sīnā all engaged with the text based on his translation. However, Yaḥyā b. al-Biṭrīq's translation was not the only version available, and Isḥāq b. al-Ḥunayn's translation of a lost Hellenistic compendium of a Hellenistic version of the Meteorology served as an alternative source. Both translations were based on Syriac versions of the *Meteorology* and its lost Hellenistic compendium, but they differ on certain points of Aristotelian doctrine. Given our focus here, we will primarily consider the theses presented in these two Arabic versions of the Aristotelian doctrine, as they formed the foundation for the Aristotelian understanding of the water cycle within Arabic scientific and philosophical thought.

We do not know much about the origin of the family of Yaḥyā b. al-Biṭrīq, himself the son of a well-known translator, apart from the fact that they came from a Latin Christian family in the former territories of the Byzantine empire, perhaps from North Africa. Likewise, we do not know much about his life.[31] It seems that Ibn al-Biṭrīq converted to Islam at the hands of al-Maʾmūn, entering the entourage of the vizier al-Ḥasan b. Sahl (236/850-1). His work as a translator covers a dozen titles, according to Arabic biographers and mentions in the introductions of manuscripts, and, according to Ibn al-Nadīm, he authored two pharmacological treatises, one on poisons (*K. al-sumūmāt*) and the other on insects (*K. al-aǧnās al-ḥašarāt*).

Ibn al-Biṭrīq's translation of the *Meteorology* diverges significantly from the Greek text in several instances, even presenting perspectives that are not present in the Greek version. In his review of Casimir Petraidis' edition of the text,[32] Endress has suggested that the Hellenistic version on which Ibn al-Biṭrīq relied, through Syriac mediation, may have already incorporated adaptations and corrections of Aristotle's views.[33] It is also possible that

29 Aristotle, *Meteorology*, I, 13. See a summary of this in Lettinck, *Aristotle's "Meteorology" and Its Reception*, 120-7.

30 Also commonly known as Ibn al-Ḫammār.

31 On Yaḥyā b. al-Biṭrīq and his contribution to the translation movement of the Abbasid age see Dunlop, "The Translations of Al-Biṭrīq and Yaḥyā (Yuḥannā) b. Al-Biṭrīq".

32 Petraitis, *The Arabic Version of Aristotle's "Meteorology"*.

33 Endress, Review of "The Arabic Version of Aristotle's 'Meteorology'" by C. Petraitis, 506-9.

some of the deviations may be due to the Syrian translator, to Ibn al-Biṭrīq's himself or to mistranslations and misunderstandings. As a side note, it is worth considering whether there may be a connection between these mistranslations and misunderstandings and Ibn Abī Uṣaybiʿa's critical comment that Ibn al-Biṭrīq did not have a strong command of Greek, given his Latin background (ar. *Laṭīnī*).[34]

Be it as it may, the resulting description of the origin of salt in seawater is twofold. On the one hand, it is said that the heat of the Sun acts on the warmer and thicker part of the water that does not exhale. This thicker part contributes to making seawater saltier than fresh water. On the other hand, rain water could carry some salinity to the sea, due to an admixture of dry and moist exhalations. As Fontaine noted, there is an implicit notion that, while "they do not deny that the salty part of sea water remains behind, but that in their view this fact does not explain the cause of its salinity i.e., that the presence of salinity is not due to evaporation alone".[35]

Ibn al-Biṭrīq ascribes this description of the causes of the salinity of the sea contained in the *Kitāb al-Āṯār al-ʿUlwiyya* (The Meteorological Phenomena) to Aristotle. In the case of the origin of rivers, or the water cycle, Ibn al-Biṭrīq explicitly presents his own theory, which follows an endogenous model.[36] According to Ibn al-Biṭrīq, water rising as vapour from the earth transforms into clouds and eventually falls as rain and snow. This water replenishes rivers after being stored in the depths of the earth, where air also transforms into water, allowing the two substances to mix and contribute to the sustenance of rivers. The most salient departure from the original Aristotelian doctrine in the Greek text lies in the origin of clouds, which Ibn al-Bitrīq asserts to be on land rather than at sea.

Another important translator in the transmission of Aristotelian doctrine regarding the salinity of the sea and the cycle of water is Ḥunayn b. Isḥāq, a Nestorian Christian Arab from the southern Iraqi city of al-Ḥīra who translated a Hellenistic compendium of the *Meteorology*. The relationship between this translation and Ibn al-Biṭrīq's translation of the *Meteorology* is complex. To some extent, the *Compendium* is based on the same Greek treatise, but there are substantial differences in the organisation of the subjects, the phraseology and even, at times, between the contents presented in these two treatises. Daiber compared the two texts, arguing that the *compendium* is based on a shorter version of the Greek treatise whose Syriac translation formed the basis of Ibn al-Biṭrīq's *Aṯār al-ʿUlwiyya*.[37]

With regard to the cycle of water, Lettinck pointed out that subterranean vapour condensation plays no part according to Ḥunayn b. Isḥāq's *Compendium*. This departure is marked by a rather assertive statement:

> We will mention and assert the cause of rivers, sources, and wadis: the cause of these is rain For, when much rain falls on the earth, much water gathers as a result. And when it meets with a place where (it) can pour

34 Ibn Abī Uṣaybiʿa, *ʿUyūn al-anbāʾ fī ṭabaqāt al-aṭibbā'*, 282. Online edition and translation Ibn Abī Uṣaybiʿa, *A Literary History of Medicine Online*, ch. 10: 3.

35 Fontaine, "Why Is the Sea Salty?", 204.

36 Lettinck, *Aristotle's "Meteorology" and Its Reception*, 134.

37 Lettinck, *Aristotle's "Meteorology" and Its Reception*, 261-6; Daiber, *Ein Kompendium der aristotelischen Meteorologie*, 6-17. See also Daiber, *Naturwissenschaft bei den Arabern* on the identity of the translator. Cited in Lettinck, *Aristotle's "Meteorology" and Its Reception*, 9.

> to some extent, the wadis and rivers arise from it; for it is a property of water to slide down. Then, when it meets soft earth in its vicinity, it perpetually seeps in until it meets hard earth or a mountain which it cannot penetrate and then stops at it. Then, when the water becomes abundant, it takes away the soft earth around it, so that it pierces its location and flows out of it. That location is then called a spring. […] Sometimes the wadis and the rivers are formed from masses of snow falling on mountains. And then, when the warmth comes to them, they gradually melt. Then the wadis and rivers are formed from them.[38]

When rain falls on soft earth, says the *Compendium*, it penetrates into the ground until it reaches solid earth or mountains that it cannot penetrate further. The water collects there, and if there is a sufficient amount, it can erode the surrounding soft earth and flow out, forming a source. If there is a large volume of water, the source will provide water year-round; if there is less water, it may dry up in the summer. Sometimes, a source may provide water for many years and then run dry, either due to a lack of rain or because the rain flows in a different direction. If the water flows away in a wide bed, the source will remain dry; if it encounters a mountain or high place, the water will be blocked and return to the source, restoring it to its previous state. Rivers and wadis may also be formed from melting snow on mountains.[39] A possible source for Ḥunayn b. Isḥāq adoption of an exogenous model of the water cycle may be Teophrastus, who is often credited with the first formulation of this model. Teophrastus' *Meteorology* is lost, but a few Arabic and Syriac translation survives, and his work was being translated precisely at the time of Ḥunayn b. Isḥāq and Ṯābit.[40] Theophrastus' influence on the *Compendium* can only be hypothetical, but it is worthwhile to note that the Peripatetic philosopher argued that compression of clouds as winds push them against the mountains as a cause of precipitation.[41] As we will see, the same argument as made by Ṯābit in his treatise *On the Benefits of the Mountains*. There is, nevertheless, reason to be cautious. The most authoritative Arabic translation, from Syriac, of Theophrastus' *Meteorology* at our disposal seems to envisage an exogenous cycle that is not purely reliant on evaporation:

> The clouds come into existence for two causes: because of the accumulation and thickness of air and its transformation into the nature of water, or because of much vapour which ascends and with which the ascending vapours of the seas as well as the remaining fluids become mixed.[42]

Returning to Ḥunayn b. Isḥāq's *Compendium*, another stark departure from Aristotelian doctrine pertains precisely to the salinity of the sea.

38 Daiber, *Ein Kompendium der aristotelischen Meteorologie*, 214-17. This represents a revised and enhanced edition of the 1975 version. Further commentary can be found in Lettinck, *Aristotle's "Meteorology" and Its Reception*, 135-6.

39 Lettinck, *Aristotle's "Meteorology" and Its Reception*, 135.

40 Daiber, "The 'Meteorology' of Theophrastus".

41 Lettinck, *Aristotle's "Meteorology" and Its Reception*, 20.

42 Daiber, "The 'Meteorology' of Theophrastus", 373. In passing, Daiber argues cautiously that the translator may be Ibn Ḫammār (d. after 407/1017), who met al-Bīrūnī at the court of the Ḫwarazmshāh and was equally brought to the court of Sulṭān Maḥmūd in Ghazna. His hypothesis appears rather convincing.

Interestingly, on this matter, the *Compendium* does not mention the dry exhalation. This is a remarkable omission, given the importance of dry exhalation in Aristotle's doctrine. Instead, the *Compendium* argues that salinity is an effect of evaporation, as the light and fresh part of seawater leaves behind salty and bitter parts. This also has an effect on taste. Heat causes humidity to become salty, by mixing with it, and if, heat increases enough, it can cause even bitterness.

Thus, the *Compendium* contain two departures from Aristotelian doctrine that are relevant here: the water cycle, which is endogenous in Aristotle and exogenous in the *Compendium*, and the salinity of the sea, which is not caused by dry exhalation in Ḥunayn b. Isḥāq's version. However, the *Compendium* is not the only work in which Ḥunayn b. Isḥāq touches on these two subjects. His translation of a Greek or Syriac paraphrase of Olympiodorus, commonly referred to as Pseudo-Olympiodorus, states that a portion of the water that sustains rivers "actually exists" in the depths of the earth, meaning that it is already contained there, while other parts come to be there. Pseudo-Olympiodorus's treatment of the sea is organised into eighteen paragraphs and two of them show a striking resemblance to Ṯābit's treatise on the salinity of water. Specifically, Pseudo-Olympiodorus discusses the fact that sea does increase or decrease overall, because the rivers that flow into it compensate for evaporation, envisaging a self-regulation of the marine environment. Furthermore, salt water is denser than fresh water, and Pseudo-Olympiodorus brings the same example as Ṯābit: ships that float on seawater may not float on rivers or lakes. Pseudo-Olympiodorus does not entirely neglect causal arguments, however, and posits that the salinity of the sea is caused by smoky exhalation mixed with water. A lesser cause of salinity is the presence of earthy matter in seawater. The presence of this earthy substance in seawater is precisely why salty water is denser than fresh water, as demonstrated by the example of boats floating in it.

A stricter follower of Aristotle's doctrine on these points is certainly Ibn Sīnā. In terms of water cycle, he focuses on the role of mountains in the formation of sources and clouds. According to his *Kitāb al-šifā'* (The Book of Healing), in the fifth section of the *Ṭabīʿiyyāt* (Natural Philosophy), it is in the mountains or, more rarely, under solid earth, that the vapours contained in the depths of the earth rise due to the heat of the Sun and the stars. As these vapours cannot escape and disperse as they do under soft earth, they condense into the water that will eventually overflow from water sources.[43]

Ibn Sīnā does not delve into the processes that lead to the salinity of the sea in depth. He simply states that salinity in water is due to the mixture of bitter, burnt earthy particles, and notes that this causes seawater to be heavier and denser than fresh water. Interestingly, he asserts that the salinity of seawater serves a purpose: preventing water from deteriorating and spreading this corruption to all water on earth.

Disciples of Ibn Sīnā, such as the Jewish philosopher and physician Abū al-Barakāt al-Baġdādī, who converted to Islam later in life, also discussed the water cycle and salinity in seawater. Notably, in his treatise *Kitāb al-muʿtabar fī al-ḥikma* (The Book of What Has Been Established Personal

43 Ibn Sīnā, *Kitāb al-šīfā'*, 10-11.

Reflection),[44] Abū al-Barakāt rejects the theory of subterranean condensation. This work, which programmatically title as a book based on personal reflections, rarely relies on the principle of authority. Instead, as Lettinck observes, Abū al-Barakāt presents challenges and alternatives to many of the theses in the *Kitāb al-Šifāʾ*, including the water cycle.[45]

This is not unusual at all for Abū al-Barakāt. He is increasingly acknowledged as a significant innovator in the post-classical phase of the Arabo-Islamic philosophical tradition. Abū al-Barakāt's work has been most recently brought to prominence by F. Griffel, whose contributions this section heavily relies upon.[46] It is well-known that Abū al-Barakāt converted from Judaism to Islam around the age of sixty or seventy. However, the precise date remains uncertain. Moreover, ambiguity surrounds the exact location of his birthplace, Balad, as there were two centres with this name in Mesopotamia during that era. Abū al-Barakāt did not receive a formal education within the traditional madrasa system in his later years. Instead, his advanced studies focused on philosophy and natural sciences to support his career as a physician, which continued to be his primary means of sustenance throughout his life.

Regarding Abū al-Barakāt's conversion, Griffel posits that it was likely a meticulously planned event and possibly even officially commemorated. It definitely did not occur at the end of his life, contrary to what Ibn Ḫallikān, among others, related.[47] The lack of clarity concerning the dates of his life can be attributed to the delayed appreciation of his contributions by his contemporaries, which only increased posthumously, although he enjoyed a reputation as a philosopher even prior to his conversion. Therefore, determining whether Abū al-Barakāt's magnum opus, the *K. al-muʿtabar*, was written before or after his conversion to Islam and the adoption of Ashari views proves to be a challenging endeavour.[48] Griffel highlights that this work encompasses both Jewish and Muslim elements, although other scholars maintain differing perspectives on the matter. Nevertheless, this issue is only tangentially related to Abū al-Barakāt's views on natural philosophy, specifically the hydrological cycle, which constitutes the primary focus of this book.

It is in the chapter entitled "On Generation and Corruption" within the second book of *K. al-muʿtabar* that Abū al-Barakāt's viewpoint on the hydrological cycle is elucidated. The treatise encompasses a range of subjects within three books that focus on Logic, Natural Philosophy, and *Ilāhiyyāt* or 'rational theology', each displaying structural distinctions. Pertinent to this book is the second book, which adheres to the principal themes of Aristotelian works, featuring chapters devoted to topics such as Heaven, Generation and Corruption, and Meteorology, among others.

Although categorised as an Avicennian philosopher, Abū al-Barakāt finds himself in disagreement with numerous principles of both Ibn Sīnā's and

44 On the theoretical aspects of the *Kitāb al-muʿtabar* and Abū al-Barakāt's biography see Pavlov, *Abū'l-Barakāt al-Baghdādī's Scientific Philosophy*. See also `http://www.muslimphilosophy.com/ip/rep/J008.htm` which reproduces his entry in the *Routledge Encyclopedia of Religion*. Langermann, "Al-Baghdadi".

45 Lettinck, *Aristotle's "Meteorology" and Its Reception*, 84-5.

46 Griffel, "Between al-Ghazālī and Abu l-Barakāt"; *The Formation of Post-Classical Philosophy in Islam*.

47 Ibn Ḫallikān, *Wafayāt al-aʿyān*, 6: 74; references to additional authors who concurred with this statement can be found in Griffel, *The Formation of Post-Classical Philosophy in Islam*, 208-9.

48 On Asharism see Shihadeh, Thiele, *Philosophical Theology in Islam*.

Aristotle's philosophies, including some fundamental aspects.[49] This is explicitly articulated in the introductory section of the work, where the philosopher and physician asserts his reliance solely on concepts he has meticulously examined and corroborated through rational inquiry. He dismisses any ideas that he has failed to comprehend or verify, even if they stem from esteemed scholars.[50] In the context of the water cycle as well, Abū al-Barakāt deviates from Ibn Sīnā's perspective. More specifically, according to Abū al-Barakāt, we can identify different exogenous sources of water for the flowing of rivers, which influence the fluvial regime:

> Some of the streams flow when rain falls upon elevated places of the earth and mountains. They cease to flow shortly after the rain has stopped. There are others that flow from snow that melts in the highest places of the mountains. These keep flowing as long as there is snow on the mountain. They increase with the increase of snowmelt and decrease according to its decrease. There are other rivers that flow from water that falls in low places and depressions as rain or snow and remains confined there. The water leaks through the lowest and least dense of these places, and it accumulates little by little until it becomes a river that flows with a continuous stream. The summer flow connects with the winter flow, and the previous one with the following one, without interruption, but rather growing and diminishing.[51] It happens that this percolation and this flowing in the depth of the earth are such that the accumulated water comes out as a gushing spring, like the water retained in elevated places that find an opening. This goes down and gushes as much as it has descended. Water arrives at its reservoir as rain, and it flows and gushes at a certain moment and not at another according to the rain. If it has come down as snow, it grows and decreases, flows, or stops depending on the melting snow, its increase or its decrease.
>
> People say and many ancient and modern philosophers believe that the air trapped inside the mountains cools down and changes into water that flows. Air is further sucked in, cooled down, and changed into water, and this happens continuously and incessantly. The answer to them is that springs dry up, and wells desiccate, and rivers and wadis cease to flow when snow or rain become too little and why they increase when the latter increases, and why they decrease as the latter decreases. The intensity of the cold is not helpful against the lack of rain and snow to increase the water in springs and wells and its persistence.[52]

All of these sources of water are ultimately exogenous. Furthermore, Abū al-Barakāt discusses the origin of water in wells, which also lies in rain and snow. Rain and snowmelt seep into cavities and this is proven by the fact that

49 Street, Abū 'l-Barakāt Hibat Allāh al-Baghdādī, "The Traditions of Arabic Logic"; Benevich, "Perceiving Things in Themselves"; McGinnis, "Mind the Gap".

50 Al-Baġdādī, *Muʿtabar*, 2: 4-7. For a translation and comment on this epistemological declaration see Griffel, "Between al-Ghazālī and Abu l-Barakāt", 66.

51 Further research is needed on what appears to be a scientific categorisation of fluvial regimes. The Arabic text mentions two flows (ar. *jaryān*) here, one being *al-ṣayfī* and the other *al-šitawī*. It is left to wonder whether this distinction is merely a device to emphasise the river's continuous flow all year long in this particular passage or if it corresponds to a formal distinction that is useful for the study of fluvial regimes.

52 Al-Baġdādī, *Muʿtabar*, 2: 209-10; Lettinck, *Aristotle's "Meteorology" and Its Reception*, 146-7.

water can be found only in certain places, and it is not distributed equally under the earth. Abū al-Barakāt further confutes the theory of air condensation by looking at wells. He counters those who believe that air condenses into water under the effect of the coolness of the air dialectically:

> If things were like that, why do wells dry up in the summer and receive more water in the winter with the arrival of rains, increasing with the latter's increase and diminishing as they diminish? In fact, the bottom of the well is colder in summer than it is in winter. So, why does it not turn more [air into water] in the summer than in winter?[53]

Abū al-Barakāt's viewpoint on the hydrological cycle distinguishes him from his contemporaries within the Arabo-Islamic Aristotelian tradition and the *falsafa* movement. In contrast to his fellow scholars, he dismisses the notion of subterranean water formation, attributing all freshwater sources to the process of precipitation, percolation, and evaporation. To the best of my knowledge, he is the sole disciple of Ibn Sīnā to adopt an exogenous model of the hydrological cycle. Abū al-Barakāt adopts a resolute position on this issue, emerging as the only author among those examined here to question the validity of subterranean water generation. Inversely, the other authors addressed in this context seem to disregard or overlook the prominence of the endogenous model among their peers. Even the much earlier *Filāḥa Nabaṭiyya* (The Nabatean Agricolture), despite acknowledging the differing opinions, as we will see, refrains from engaging in the debate.

A less outspoken recognition of the exogenous cycle may have been recognised by Ibn Rušd, although the cycle of water received less attention in his works compared to the topic of seawater salinity. The Cordoban philosopher discusses the origin of the salty taste in seawater in his commentary on the Meteorology, titled *Kitāb al-āṯār al-ʿulwiyya*, and in his commentary on the Aristotelian *De Interpretatione*, entitled *Talḫīṣ al-āṯār al-ʿulwiyya*. Despite both works addressing the issue of seawater salinity, they differ in their explanation of the actual cause of this characteristic.

In the *Kitāb al-āṯār al-ʿulwiyya* (Short Commentary), Ibn Rušd distinguishes between the burnt earthy part (ar. *al-ǧuzʿ al-ardī al-muḥtaraq*) of the dry exhalation and the smoky exhalation (ar. *al-buḫār al-duḫānī*) or burnt smoky part (ar. *al-ǧuzʿ al-duḫānī al-muḥtaraq*),[54] arguing that the first is the main cause of seawater salinity, since it is produced everywhere on earth.[55]

Interestingly, Ibn Rušd specifies that sometimes the smoky and earthy parts combine, citing the case of the Dead Sea (ar. *buḥayr Filisṭīn*), as Ṯābit does in his own treatise. As we have seen, according to Ibn Rušd celestial bodies draw up dry exhalation and its earthy part everywhere on earth, meaning both on land and under the sea. This leads the philosopher to conclude that salinity in seawater is due to the earthy part of the dry exhalation given off by the earth under the sea and prevented from rising by the presence of the large mass of water above it.[56]

53 Al-Baġdādī, *Muʿtabar*, 2: 212.

54 Ibn Rušd did not believe in the reality of the hot and dry exhalation. Mcpeak, "Meteorology in the Islamic World".

55 Ibn Rušd, "Kitāb al-āṯār al-ʿulwiyya", 28-30.

56 Lettinck, *Aristotle's "Meteorology" and Its Reception*, 149-52.

Ibn Rušd exposes a slightly different theory in the *Talḫīṣ kitāb al-ʿulwiyya* (Middle Commentary).[57] Whereas in the *Kitāb al-āṯār al-ʿulwiyya* salinity is due to the earthy part of the dry exhalation drawn up from the seabed, in the *Talḫīṣ* it is the product of the heat of the Sun on the dry exhalation already present in seawater. This theory is of course closer to Aristotle's, but differs on when and where the salinity is produced. According to Aristotle heat produces salinity in rainwater, and according to Ibn Rušd's *Talḫīṣ* heat produces salinity in seawater directly. This contradiction between the *Kitāb* and the *Talḫīṣ* is not especially surprising. It has been noted that the latter is generally a much closer paraphrase of Aristotle than the first, which Ibn al-Rušd probably wanted to be a sort of introduction to broadly understood philosophical questions.[58] The *Kitāb* differs from Aristotelian doctrine on another point that is important here. Ibn Rušd, while admitting the possibility of water being generated from air, states that "that water of all rivers originates from the sea by means of rain, and returns to it", implying an exogenous model of the water cycle.[59]

Abū al-Faḍl b. al-ʿAmīd, a scholar known for his written production in the form of short treaties or *risālas*, addressed the topic of seawater salinity in a *risāla* written for the Buyid *amīr* ʿAḍud al-Dawla (324-356/930-967). In addition to his administrative and military duties as the vizier of Rukn al-Dawla (d. 366/976) for 32 years, Ibn al-ʿAmīd was also known as the 'second Ǧāḥiẓ' due to his literary ability.[60] Despite the recognition of the quality of his works and, according to the sources, the widespread circulation of his treatise collections, most of his production seems to be lost. It is fortunate that one of Ibn al-ʿAmīd's treatises on the topic of the salinity of the sea has been preserved and has received an edition and German translation by Hans Daiber.[61]

Ibn al-ʿAmīd discusses the salinity of the sea in a *risāla* for ʿAḍud al-Dawla "about the reason why there are drinkable wells and sweet springs on the sea islands".[62] The treatise is purposefully short and concise, since, the author informs us, he already addressed in a previous *risāla* some of the basic notions needed to understand the subject at hand. The basic notions that are omitted here are likely to include an in-depth discussion of the theories of the four elements.[63] After a customary profession of support and greetings for the *amīr* ʿAḍud al-Dawla, Ibn al-ʿAmīd deals with the question of whether the original taste of water is salty or sweet. It is imperative, he argues, to determine which one is the original taste of water before investigating how sweet water comes to be in sea islands. The matter was evidently not settled, at least among non-specialists, at the time of Ibn al-ʿAmīd, since he dedicates some space in his short treatise to a summary of the thesis, held by

57 Ibn Rušd, *Talḫīs al-āṯār al-ʿulwiyya*, 73,10-89,18. Cited in Lettinck, *Aristotle's "Meteorology" and Its Reception*, 152-5.

58 Cruz Hernández, "El sentido de las tres lecturas de Aristoteles por Averroes".

59 Ibn Rušd, "Kitāb al-āṯār al-ʿulwiyya", 28.

60 While we have limited information on Ibn al-ʿAmīd's administrative role, more is known about his military tasks. Cahen, "Ibn al-ʿAmīd".

61 Daiber, *Naturwissenschaft bei den Arabern*.

62 Daiber, *Naturwissenschaft bei den Arabern*, 48.

63 This latter treatise concerning the scientific notions to be taken into account upon founding and planning a city seems to be lost.

"one of the ancient scholars", that the original taste of water is salty. Those who maintain that the original taste of water is salty do so, according to Ibn al-ʿAmīd, on the ground that the greatest part of each element stay true to its original characteristics since they are "only partially changeable". In other words, if we want to look at what characteristics should be considered originary for each of the four elements, we will find them where the main part of each element resides. In the case of water, its greatest part resides of course, the sea and it is undeniably salty. Ibn al-ʿAmīd summarises this line of thought:

> the main part and the majority of water is present in the seas; for the water flowing from rivers is small and insignificant in comparison. (From this) the previously mentioned follows, namely that the taste present in the largest bodies of water, i.e. the taste of the sea, is the natural one.[64]

As we said, Ibn al-ʿAmīd disagrees with this assessment. Before explaining why the original taste of water is sweet and not salty, he notes in passing that the notion he just described makes it very difficult to explain the presence of sweet water in sea islands. Ibn al-ʿAmīd explicitly cautions the *amīr* against relying on those who believe that the original taste of water is salty, since they acratically accept premises and principles without uncovering "uncertainties and ambiguous formulations". This warning suggests that at the very least, it was possible to encounter individuals among courtiers or other learned men who held views on the nature of water and its role in nature that differed from those of Ibn al-ʿAmīd. In this context, Ibn al-ʿAmīd warns against the danger of assuming that the nature of water is immutable, as some of his contemporaries may have believed. He asserts that, while it is true that the essential properties of an element tend to remain constant, it is not accurate to claim that elements are incapable of change altogether. Rather, this principle applies only to the fundamental nature of an element, which it does not seem to comprise taste. Therefore, according to Ibn al-ʿAmīd, it is possible for water to acquire certain characteristics, as long as the majority of water maintains its inherent qualities as water:

> For water, while it is impossible for the majority of its parts to change into air, is not prevented from coming into the state of heat, cold, compression, and rarefaction.[65]

The same can be said about water acquiring a salty taste. In this regard Ibn al-ʿAmīd further argues that "simple things come by necessity before things that are composed by them" and that salty water, similar in taste to sea water, is evidently composed by sweet water and 'ashes' because it is possible to break their bond by means of evaporation.

Having discussed the basics of seawater salinity, Ibn al-ʿAmīd contends that the transformation of air into water is a process that can be observed on the surface and that it is also possible for this to occur in the depths of the sea and within the cavities of the earth. He asserts that sweet water can be generated in this way on islands, although it may later acquire a salty

64 Daiber, *Naturwissenschaft bei den Arabern*, 52.

65 Daiber, *Naturwissenschaft bei den Arabern*, 53.

taste. Consequently, the generation of water in the cavities of the earth, as described by Aristotle, is one possible explanation for the presence of sweet water on islands, but it is not the only one.

Ibn al-ʿAmīd presents two additional possible explanations for the presence of sweet water on islands. The first is the existence of springs that are fed by precipitation, such as snow, hail, or rain, which may accumulate on mountain tops or within mountains and eventually feed springs that are typically seasonal. The second scenario involves seawater directly. In this case, Ibn al-ʿAmīd describes an island with sides that are higher than sea level, but with a central area that is lower than sea level, allowing seawater to filter through. These types of sources can be either sweet or salty, depending on the properties of the soil that filters the seawater, either removing or retaining the salty component. In passing, it should be noted that the same model appears also in Isodore of Seville and constituted the basis for what has been called the "reverse hydrological cycle".[66]

Ibn al-ʿAmīd illustrates his point with a real-life example that is a staple of scientific discussions on salty water:

> We can testify to this from our own experience: As often as we have the real desire to obtain sweet water from the whole of the sea, we reach for the (sea) water and then filter it several times through the sand or in pottery so that it becomes sweet. Usually, we take vessels of wax to let them sink into the sea, because the wax pores are too fine and too thin for water-mixed and compounded and thick things to pour into the vessel; in this case its (waxy) side does not remain inaccessible to the substance of the sweet water.[67]

In sum, Ibn al-ʿAmīd approaches the specific question posed to him in agreement within the framework of an Aristotelian endogenous water cycle. It is worth mentioning that, despite being familiar with the scientist and philosopher Miskawayh, who held views on the water cycle that differed from those of Aristotle and aligned with the exogenous model proposed by Ṯābit, Ibn al-ʿAmīd did not adopt or mention Miskawayh's opinion in his treatise.

This summary would not be complete without mentioning the exogenous water cycle discussed in the *Kitāb al-filāḥa al-nabaṭiyya*, a work that covers a wide range of subjects from agriculture to occult sciences and has returned to garnering significant scholarly attention in recent years.[68] The *Kitāb al-filāḥa al-nabaṭiyya*, or *The Nabatean Agriculture* as is usually referred to in English, is traditionally believed to be the Arabic translation by Ibn Waḥšiyya[69] of a Syriac text with multiple authors of uncertain history. However, Isabel Toral has proposed that the text may actually be a pseudo-translation, as no corresponding original version in Syriac has been found

66 Duffy, "The Terrestrial Hydrologic Cycle", 4; Tuan, *The Hydrologic Cycle and the Wisdom of God*, 24-5. On the water cycle in medieval Western Europe see also Squatriti, *Water and Culture*, 160-4.

67 Daiber, *Naturwissenschaft bei den Arabern*, 62.

68 Dalen, "Scientific Method in Late-Antique Paganism"; Hämeen-Anttila, *The Last Pagans of Iraq*.

69 Little is known about Ibn Waḥšiyya, whose historicity has also been debated. See Fahd, "Ibn Waḥs̲h̲iyya".

despite extensive efforts.[70] Be it as it may, and even though the *Kitāb al-filāḥa al-nabaṭiyya* surely is not the two-thousand-year old repository of agricultural knowledge that it claims to be, this monumental work is widely considered a valuable and under-investigated source on sixth-to-ninth century Mesopotamian non-Muslim scholarship.[71] Interestingly, the Nabatean Agriculture describes an exogenous cycle, as Mohammad el-Faïz has noted.[72] It is worth noting that the ideas presented in the text, which are largely incompatible with Aristotelian doctrine,[73] are in line with Ṯābit's view of the water cycle and were already prevalent in Mesopotamia outside of the Arabo-Islamic philosophical tradition.

Hydraulics and hydrology, the two branches of water knowledge identified as *savoirs de l'eau* by M. el-Faïz, are introduced at the beginning of the primary chapters dedicated to agriculture. In these chapters, essential hydraulic and hydrological concepts provide a basis for further examination of irrigation techniques and agriculture, comparable to the approach taken by al-Karajī in his later work, *Kitāb inbāṭ*. However, the discussion of the hydrological cycle is presented in later chapters focusing on meteorological phenomena.

In the *Filāḥa*, the author(s) elaborate(s) on the influence of the Sun on the natural world, notably observing that clouds form as a result of evaporation, particularly wet evaporation, which is distinct from dry evaporation. This idea closely aligns with Aristotle's doctrine of double exhalation.[74] The text further explains that clouds undergo the effects of cooling and condensation, causing their vapours to return to a liquid state. The *Filāḥa* asserts that these two processes cause rain.[75] The text then describes the typical mechanisms of water percolation within the earth, the accumulation of water, and the formation of water sources and wells.

Interestingly, the *Filāḥa* also refers to a disagreement among the Kasdānians concerning the origin of water wells, stating:[76]

> This is the reason for the presence of water in existing springs and wells after they have been dug, according to some of our Kasdānian ancestors. However, others hold a different view, asserting that springs gushing forth in wells result from the compression of the dry element present in the earth's element. The two opinions bear similarities.[77]

It is important to highlight that the minority viewpoint mentioned above seems to be based on an endogenous model of the hydrological cycle. This

70 Toral, "The Nabatean Agriculture by Ibn Waḥšiyya".

71 Dalen, "Scientific Method in Late-Antique Paganism", 517.

72 El-Faïz, *Les Maitres de l'eau*, 32.

73 A possible source of the *Kitāb al-filāḥa al-nabaṭiyya*, at least for some of its varied materials, may be the fourth century collection of agricultural practices (*Synagoge georgikon epitedeumaton*) authored by Vindonius Anatolius of Beyrut and already recognised as the main source of the tenth-century *Geoponica*. See Rodgers, "Hail, Frost, and Pests in the Vineyard".

74 Wilson, *Structure and Method in Aristotle's "Meteorologica"*, 51-72.

75 Abū Bakr Aḥmad b.ʿAlī b. Qays al-Kasdānī, *Al-Filāḥah al-Nabaṭīyyah*, 263.

76 Kasdānian refers to the Nabatean community with which Ibn Waḥshiyya himself identified. As observed by J. Hämeen-Anttila, the name bears an etymological connection to the term Chaldeans. See Hämeen-Anttila, *The Last Pagans of Iraq*, 15-16.

77 Abū Bakr Aḥmad b.ʿAlī b. Qays al-Kasdānī, *Al-Filāḥah al-Nabaṭīyyah*, 264.

observation is particularly significant, as it establishes the *Filāḥa* as the earliest known source to recognise a disagreement or incompatibility between the two models, preceding al-Baġdādī's discussion of the same topic in the twelfth century.

In conclusion, in the works of Aristotle and his Arabic-writing disciples, the focus was on understanding the causes of the salinity in seawater. These arguments, despite their differences, aimed to provide a rational explanation for the natural phenomena that lead to salty taste in seawater. This focus on causation is distinct from the approach taken by Ṯābit in his treatise *On Why Seawater was Made Salty*, in which he approaches the subject from a teleological perspective, seeking to understand the purpose or end for which the sea was made salty. In other words, the Aristotelian philosophers were concerned with understanding how salinity in seawater arises, while Ṯābit was more interested in understanding the ultimate reason or purpose for the existence of salt in seawater.[78] However, it should not be assumed that the treatise *On Why Seawater was Made Salty* by Ṯābit is purely a theological work rather than a scientific one. In fact, the treatise provides a thorough explanation of the physical necessities behind God's plan in relation to seawater.

It is worth noting that, despite our current scepticism towards teleological approaches in science, Ṯābit's approach leads him to conclusions more in line with our modern understanding of the global environment. While the Aristotelian tradition of Arabic-writing philosophers presents a now-discredited, albeit intriguing, set of scientific categories, Ṯābit not only provides a water cycle that is closer to our current understanding, but also offers a comprehensive view of the role of the sea in the global environment that strongly resonates with modern environmental concepts.

2.3 Ṯābit's Treatise *On Why Seawater Was Made Salty*

The treatise *On Why Seawater was Made Salty* is preserved in a single manuscript of the Topkapı Saray library. The manuscript, composed of 13 *folia*, is part of a miscellanea mostly covering astronomical subjects. The handwriting, in *naḫšī* style, is fairly readable and denotes an expert and swift hand. There are a few misspellings and punctuation errors, but they do not damage the readability of the text.

The title of the treatise is transparent. The text is devoted to discussing to what ends the water of the sea is salty rather than sweet or any other taste. Ṯābit approaches a question that, as we have seen, sparked considerable interest in philosophers and scientists both earlier and later than himself. The text appears to be a didactic treatise,[79] probably dictated, and approaches its subject from a finalist or teleological perspective. This has been noted by R. Rashed, who highlighted how Ṯābit departed from the long-established tradition that addressed the subject in purely materialist and causal terms. As noted by Marwan Rashed, these Aristotelian explanations focused on determining the processes and substances that caused the

78 Rashed, "Le meilleur des mondes".

79 This is also other works attributed to Ṯābit, see Brentjes, "Wilbur R. Knorr on Thābit ibn Qurra", 125.

salinity of the sea, but did not consider the ultimate cause: the will of God and His design of the natural world.[80] In contrast, Ṯābit's finalist perspective emphasises the understanding of the usefulness and beauty of this natural phenomenon within the context of the Muslim-dominated Abbasid society in which he operated. This approach to scientific endeavours, of course, was in perfect agreement with the outlook of the Muslim-dominated Abbasid high society in which Ṯābit operated, and that understood theological matters to extend well into physics.[81]

The divine imprint in creation dominates Ṯābit's view of the natural world. Human souls cannot extinguish their desire to understand the usefulness and beauty of God's design, since divine knowledge is both unquantifiable and never fully attainable. Nevertheless, its pursuit is a source of constant amazement for those who "never cease to clarify things". Vividly, Ṯābit b. Qurra describes here what we would today call curiosity-driven research, and this curiosity and urge to clarify is the stated reason why he engaged in this topic.

As it is customary for works on natural sciences, the treatise begins by discussing the four-element theory. Ṯābit states that God imposed a fine balance between them, made it so that they cannot change to the point of "becoming null", and imposed on them a balanced order in terms of weight and consequently height.[82]

The concept of stability and balance among the elements, as discussed by Ṯābit, aligns with the Aristotelian doctrine prevalent among contemporary philosophers. However, Ṯābit's description of the order of the elements includes some unique elements. According to Ṯābit, the elements are arranged in a hierarchy based on their weight, with the lightest and highest element being fire, followed by air, water, and finally earth as the heaviest and lowest element. Faḫr al-Dīn al-Rāzī (d. 606/1209) reports that Ṯābit disputed the Aristotelian theory of natural place, which posits that each body has a natural place to which it strives. In contrast, according to al-Rāzī, Ṯābit stated:

> He who believes that the Earth is seeking for the place in which it is to be found holds a mistaken belief. This is because there is no need to conceive of any particular place as having a quality that distinguishes it from others. On the contrary, if one were to imagine all places to be empty and the whole earth arriving at any one of them, it would necessarily stop

80 Rashed, "Le meilleur des mondes", 706-8.

81 Golshani, "Islam and the Sciences of Nature"; Capezzone, "Amorous or Scientific Metaphors?". It is worthwhile to note in passing that Khalid Fazlun – one of the most influential environmental Muslim activist of our time through his Islamic Foundation for Ecology and Environmental Sciences – strikes very similar notes in his magnus opus *Signs on the Earth: Islam, Modernity and the Climate Crisis*, as the title itself makes abundantly clear. Khalid, *Signs on the Earth*.

82 In Islamic thought, the concept of *mīzān*, or 'balance', plays a central role in understanding the natural world and our place within it. The idea of *mīzān* refers to the interconnectedness and interdependence of all elements within the natural world, and the importance of maintaining balance and harmony within this system. The concept of *mīzān* has important implications for Islamic environmental ethics, as it emphasises the need for humans to act as stewards of the natural world and to use natural resources in a responsible and sustainable manner. In this way, several modern thinkers maintain that *mīzān* encourages a holistic and mindful approach to the environment, one that recognises the interconnectedness of all elements within the natural world and the importance of preserving the balance and harmony of the ecosystem. Parvaiz, "Scientific Innovation and Al-Mīzān"; Koláček, "The Qur'ān as a Source for Contemporary Islamic Environmental Ethics"; Akhtar, "Towards an Islamic Approach for Environmental Balance".

> there and not move on to another [place] because this one and all other places are equivalent.[83]

Instead of relying on the theory of natural place, Ṯābit explained the order of the universe by postulating the existence of two competing forces of attraction. The first attraction postulated by Ṯābit occurs between the lunar and sublunar elements. The second attraction occurs between each and all parts of the element separately, meaning between each body and in agreement with their size. Ṯābit's theory, which fascinatingly bears some comparisons with the modern understanding of gravity and the Galileian *causa reduci ad solam gravitatem*, had a few followers, such as al-Kūhī (tenth century),[84] Ibn Buṭlān (d. 458/1066), and the aforementioned Abū al-Barakāt al-Baġdādī.[85]

Ṯābit contends that the balance between the four elements, their hierarchical arrangement, and their stability are crucial elements of the fundamental components of the natural world as ordained by God. This was intended to ensure the perpetuation of both natural and human life, which are fundamental to God's design according to Ṯābit's perspective on the created world.

While many scholars within the premodern Islamic tradition held similar views,[86] Ṯābit's position appears to transcend a purely anthropocentric perspective. Rather, he posits that the ultimate aim of God's designs is the sustention of life in its entirety, not just human life. Therefore, the value and beauty of any aspect of the natural world should be judged by its ability to sustain life.[87]

It is not surprising that water occupies a special position within this framework, given its critical role in maintaining life. Water exhibits two deviations from the otherwise perfect order and stability of the elements in the service of sustaining life. Firstly, water infiltrates the ground and can be found beneath the earth, despite being lighter than earth. Secondly, it frequently becomes impure, a process that Ṯābit believes is necessary for the maintenance of life, but is not understood by humans at the time of his writing.

Ṯābit emphasises that these two peculiarities of water would represent instances of imperfection in God's design at a theoretical level. If water were to perfectly conform to the order and behaviour of the elements, all water would belong to the sea, resulting in the dehydration and death of all "animals and plants" on dry land. Therefore, given the stated ultimate aim of creation, formal perfection must be qualified in order to achieve the best of possible worlds, as R. Rashed has pointed out.[88] In other words, Ṯābit argues that it is necessary to reject the idea of sterile, and therefore imperfect,

83 Faḫr al-Dīn al-Rāzī, *al-Mabaḥīṯ al-mašriqiyya*, vol. 2; Rashed, "Kalam e filosofia naturale"; Abattouy, "Greek Mechanics in Arabic Context". On the same passage by Faḫr al-Dīn al-Rāzī, see also Rāšid, *Ibn al-Haytham's Geometrical Methods*, 499-500.

84 Abū Sahl Wayǧān b. Rustam al-Kūhī, also known as al-Qūhī.

85 Rashed, "Al-Qūhī Vs. Aristotle".

86 Kukkonen, "Averroes and the Teleological Argument".

87 Ṯābit's biocentrism and, to some extent, anthropocentrism is in line with the today prevailing Islamic view of the ecological crisis from a theological perspective. See Bagir, Martiam, "Islam: Norms and Practices".

88 Rashed, "Le meilleur des mondes".

perfection and recognise the productive potential of imperfection in order to understand God's design and how our ecosystem functions.

In the treatise *On Why Seawater was Made Salty*, the role of water in maintaining life on Earth is presented as another manifestation of divine wisdom. According to Ṯābit, all sweet water that supports life originates from either rain or underground reservoirs, which were created by God for regions where it does not rain enough. However, this does not appear as a repeated production of water, in line with the stability of the elements he previously discussed. This argument suggests an external model of the water cycle, which is further supported by the mention that, in accordance with divine wisdom, it was optimal for water to "go in its entirety to the seas and some of it return repeatedly to the land" as sweet water to sustain life. The requirement for water to be sweet for the benefit of animals and plants on earth allows Ṯābit to proceed to the central argument of his treatise: the salinity of the sea and its role in maintaining the natural balance.

Unlike the typical Arabo-Islamic Aristotelian tradition, which seeks to understand the salinity of seawater in terms of its causes and material properties, Ṯābit does not address the source of the salinity of seawater. Instead, he asserts that the ultimate cause lies in divine wisdom and the design of God. Therefore, the author believes that the most complete understanding of this issue requires comprehending the role played by salty seawater in the overall balance of creation, as ordained by divine wisdom.

Ṯābit approaches the topic from two angles. On the one hand, he identifies two requirements that the taste of sweetness must fulfil: it must prevent water from rotting, and maintain its quantity consistently. On the other hand, he discusses the effects of the other tastes on water, demonstrating that any other option would not satisfy these requirements.

Salinity is not the only distinguishing characteristic between seawater and fresh water on land. Ṯābit explains that seawater does not flow continuously like the water of rivers, and this feature is crucial in his analysis of God's design for water. As previously mentioned, the salinity of seawater prevents this large body of water from rotting and polluting the air essential to life on earth. Ṯābit appeals to experience to illustrate this point, describing the well-known effects of decay in stagnant water and the generation of plague when stagnant water contaminates the surrounding air.[89]

This is coherent with the medical understanding of his time of the miasma theory, maintaining that pestilences were ultimately due to the corruption of water, earth, or more frequently air.[90] Ṯābit noted in his medical treatise *al-Ḏākira fī ʿilm al-ṭibb* (The Compendium on the Science of Medicine)[91] that

89 This is coherent with the commonly-held belief that plagues and epidemics were caused by miasma. See Conrad, "'Ṭāʿūn' and 'Wabāʾ' Conceptions of Plague and Pestilence"; Ayalon, "Epidemics".

90 The topic touched here by Ṯābit is tangent to the debate on contagion. Qusṭā Lūqā (d. ca. 300/912-13), author of a treatise on contagion entitled *Kitāb al-iʿdāʾ*, openly acknowledges that there was a variety of opinion about whether contagion actually exists and whether it has a material or psychological basis. In the present treatise, Ṯābit mentions only the corrupted air as the direct cause of pestilence, but this is probably just a matter of briefness. In fact, he admitted the possibility of contagion in the *al-Ḏākira fī ʿilm al-ṭibb* and even expanded Galen's list of contagious diseases. Crucially, the debate on contagion has been a thorny subject in much of Islamic theology, as it is part of the wider discussion on secondary causation and (ʿAšarī) occasionalism. Stearns, *Infectious Ideas*, 70.

91 Meyerhof, "The 'Book of Treasure'". On the debate about the attribution of this text see Ullmann, *Die Medizin im Islam*, 1: 260-1.

analogous alterations of the elements can actually occur, and that meteorological events, such as excessive rain, lingering clouds, southern winds or stagnant air may cause them.[92]

Ṯābit supports the preserving effect of salinity with examples from experience. He mentions the common use of salt for preserving food, and then describes the apparently widespread practice of using large quantities of salt to prevent stagnant water from spreading pestilence. While I could not find confirmations of this practice to verify its prevalence, Ṯābit describes it as the application of "large quantities" of salt, which suggests that this practice was meant to prevent the spread of plagues and decay from stagnant stretches of water, rather than any water for domestic use that could spoil. These stretches of water seem to have been common in historic ʿIrāq, at the time of Ṯābit given the state of disarray of the hydrological network in late Sasanian times.[93]

Ṯābit discusses the level of salinity of seawater according to the biocentric principle in two ways. First, marine life requires that salinity be kept to a wise minimum, while life on land requires that the sea is salty enough to prevent the spread of pestilences, bugs, and decay similar to the case of brackish waters and swamps – it is possible that Ṯābit had in mind the Iraqi marshes of southern ʿIrāq, which were at the time at their historical maximum.[94] Second, salinity plays an important role in the stabilisation of sea levels. The first argument allows Ṯābit to conclude that not only is salty taste the best possible condition that God could impose on seawater, but that the precise measure of salinity found in the sea is the minimum and most beneficial measure. The second argument introduces an interesting discussion on the resilience of the ecosystem and its built-in ability to maintain its balance.

Furthermore, in Ṯābit's opinion, it is essential that the flow of the water cycle does not result in an increase in sea level for two reasons. The first is that all terrestrial life would perish if all water eventually ended up in the ocean, since there would not be a single drop left on earth. The second reason is that a huge rise of seawater would submerge the earth's surface; an observation that may ring familiar to modern readers.

Ṯābit is aware of the physical relation between density of a fluid and evaporation. He illustrates it again by experience, suggesting an experiment to prove that salty water evaporates more slowly than fresh water, and considering the evidence that some boats that float on the sea cannot float in rivers, thus proving that seawater is denser than sweet water.

In the treatise, the interplay of salinity, density, and evaporation showcase the ingenuity of God's design. These properties enable the water cycle to be self-regulatory. An increase in evaporation due to the decrease in salinity and, consequentially, density necessarily compensates for any increase in seawater from the discharge of fresh water from rivers, and vice versa.

Conversely, a decrease in salinity would trigger the production of harmful odours, since a small and imperceptible amount of these odours are said

92 Ṯābit, *Kitāb al-ḏakīra fī ʿilm al-ṭibb*, 177.

93 The subject has been most recently investigated by Peter Verkinderen. See also a blogpost by Preiser-Kappeler, who connects this with some climatological hypothesis for the Late Antique Eastern Mediterranean. Christensen, *The Decline of Iranshahr*; Preiser-Kapeller, "The Deluge"; Verkinderen, *The Waterways of Iraq and Iran*, 54.

94 On the expansion of the marsh environment in the early centuries of the Islamic age, see Eger, "The Swamps of Home".

to be produced in the sea. Such odours would have dire consequences for all life on dryland if the entire cycle of water and its properties were not designed to keep seawater salinity exactly at the minimum required to support animal and plant life.

As we said, part of Ṯābit's treatise *On Why Seawater Was Made Salty* discusses the possibility that other tastes could have been chosen to prevent corruption and other damages to life, both marine and on land. The argument begins citing a disagreement among scholars on the number of tastes, with some arguing for eight tastes and other for less.[95] At any rate and excluding the taste of sweet water, he tastes mentioned in the following discussion are six: sweet, fat, sour, astringent, bitter, and salty. Of these six tastes, only five are discussed, as sour taste is mentioned only briefly. Sweet and fat are quickly dismissed as invalid options; they do not provide lasting protection from decay and are generally unstable, as sweet can turn sour and bitter, and fat can produce vapours and odours. Astringent taste not only fails to always prevent decay, but can also produce damaging vapours, as in the case of vitriol and yellow vitriol, which are known today as copper sulphate.[96] Towards the end of the treatise, Ṯābit mentions in passing the category *ḫamriyya*, which clearly indicates substances that are fermented or otherwise alcoholic. These types of moist substances almost seem to amount to an additional taste, which is, again, unsuitable for seawater. However, they are not included in the more systematic treatment of tastes presented earlier in the text. Above all, one gathers the slight impression from the treatise that the author did not have much interest in the precise categorisation of tastes, as if he did not deem it very consequential.

Lastly, the bitter taste may appear as a more viable alternative solution to salinity, since it protects from rottenness. Despite this desirable quality, Ṯābit observes that animals disdains bitter foods, while exhibiting a preference for salty things. These two observations lead him to argue that if seawater was bitter none of the "marvellous animals" that live in the sea could have been generated. A sea devoid of life would have been deprived of a significant portion of its beauty and would have revealed less of the divine wisdom.

Ṯābit addresses also the possibility of a mixture of bitter and salty. He does so again referring to experience, in this case describing the conditions of the Dead Sea because its waters present this very combination of bitter and extreme salinity. This results, he notes, in the inhabitability for any fish, and the fact that no animal drinks it. Ṯābit is not known to have visited Palestine and reports the absence of life in the Dead Sea and in its surroundings on the authority of Galen.[97] This description serves in the economy of his discourse to prove that bitterness in seawater would be detrimental to life. Additionally, he argues that the vast size of the sea serves to prevent the detrimental effects of bitterness from overcoming its natural salinity and harming the creatures that inhabit it.

95 Baffioni, "Les sens chez les Ikhwān al-Ṣafāʾ"; Carusi, "Les Cinq Sens Entre Philosophie".

96 On this substance see Ahmad Y. al-Hassan, "Tecnologia della Chimica".

97 Galen, who is said to have visited the Dead Sea, maintained that its waters were hostile to life because they are too briny. Grant, *Galen on Food and Diet*, 22.

2.4 Ṯābit's Lost Treatise *On the Benefits of Mountains*

The exogenous model of the water cycle is also described by Abū ʿAlī Miskawayh in his response to Al-Tawḥīdī's inquiry on why God created the mountains. Miskawayh's answer seems to be largely based on the other water-related treatise composed by Ṯābit, the treatise *On the Benefits of the Mountains*. While this work is no longer extant, the summary provided by Miskawayh appears to be consistent with the ideas presented in Ṯābit's Treatise *On Why Seawater Was Made Salty*.

Miskawyh's answer is reported in the *Kitāb al-hawāmil wa al-šawāmil* (The scattered and the gathered),[98] and opens with the very same biocentric statement already familiar in the argument on salinity:

> The benefits of mountains and their arrangement on the earth's surface are very numerous. For if they did not exist, there would be no plants or animals on the surface of the earth. For the cause of the existence of plants and animals, as well as their sustenance thereafter, is the fresh water that flows over the face of the earth. And the cause of the fresh water flowing out is the constriction of the vapours in the atmosphere, I mean the clouds, and what they undergo as a compression due to the cold, until either rain, snow, or hail comes out of them. And if you were to imagine the mountains removed from the face of the earth, and imagine the earth as a circular globe without cavities or protuberances, the vapours which would have risen from this globe would not be constricted in the atmosphere, nor compressed, nor would any fresh water come out of it. Hence the end of this vapour would be to be dissolved and turned into air before that which is the reason for the settlement of the face of the earth is accomplished from it.[99]

Then, Miskawayh explains the role of mountains in supporting life, citing Ṯābit's views on the subject. According to Miskawayh, the valleys between mountains serve to concentrate vapours and inhibit the free movement of air. As a result, the vapours are compressed and cooled, eventually turning into water.

> This takes place because the ascending vapour from the earth concentrates in the depressions of the earth, between the mountains which prevent its flowing out, owing to the subjection to the motion of the sky, and owing to the causes of the wind, which constitutes the motion of the air. I mean that the pockets of the high mountains preserve the air blocked in their valleys from the movement which the sky in its entirety tends to impose upon it, as well as the stars which it contains and their tributaries and subtle rays which tend to impose upon them to flow out. If, therefore, the air is thus concentrated between the mountains, the ascending vapour which it contains is also preserved from the dislocation and movement which there would be if the air were to move, so that some of the cold which the mountains store within them during the time of winter

98 Recently translated in English. Abū Ḥayyān al-Tawḥīdī, Ibn Miskawayh, *The Philosopher Responds*.

99 Abū Ḥayyān al-Tawḥidī, *Al-Hawāmil wa al-šawāmil*, 354-6.

cools and concentrates this vapour, and then presses it. It thus becomes water that stays there or flows

This passage may be subject to other interpretations. M. Rashed interpreted it as a summary of the Aristotelian doctrine of the endogenous water cycle.[100] However, the present author views it as describing an exogenous water cycle, or at least not envisioning any generation of water within the earth. There are some discrepancies between the English translation provided here and the French version offered by M. Rashed, which reads:

car cela a lieu parce que la vapeur ascendante issue de la terre se concentre dans les creux de la terre, entre les montagnes qui en empêchent l'écoulement, en raison de la soumission au mouvement du ciel, et en raison des causes du vent, qui constitue le mouvement de l'air. Je veux dire que les poches des hautes montagnes préservent l'air bloqué dans leurs vallées du mouvement que tend à lui imposer le ciel dans sa totalité, ainsi que les astres qu'il contient et leurs rayons influents et subtils qui tend à leur imposer de s'écouler. Si donc l'air se concentre ainsi dans les montagnes, la vapeur ascendante qu'il contient est elle aussi préservée de la dislocation et du mouvement qu'il y aurait si l'air se mouvait, en sorte qu'une partie du froid que les montagnes emmagasinent en elles durant le temps de l'hiver condense et concentre cette vapeur, puis la pressure. Elle devient donc de l'eau par transformation, ou quelque autre corps semblable.

The first point of divergence is the origin of the vapour discussed in Miskawayh's answer. The Arabic expression *al-buḫār al-murtafiʿ min al-arḍ* should be read in agreement with the earlier phrases "wa tuḫīlat al-arḍ kura mustadīra" (imagine the earth as a round globe)[101] and "al-buḫār al-murtafīʿ min haḏihi al-kura" (the vapours which would have risen from this globe).[102] Our translation and M. Rashed's do not differ on the meaning of these two phrases, and the first one indicates that Miskawayh is using at least in one instance the word *al-arḍ* to refer to the entire globe. The second sentence indicates that this passage is considering the entirety of the vapour produced on the Earth, not limited to vapour exhaled by the earth either in its depths or in the open air.

The second point of divergence is the translation of the Arabic term *ġawr* (pl. *aġwār*), which I suggest should be understood here as 'valley' or 'depression' in the earth, as Rashed indeed does in one instance of the term. In most instances throughout the text, however, Rashed understands it as 'cavity'. On its own the term could be understood both way,[103] so it is necessary to see how this term is used in the context of Miskawayh's answer.

Miskawayh uses the term *kura mustadīra* three times in this passage. In the first instance, it is used in the phrase "wa tuḫīlat al-arḍ kura mustadīra lā nutūʾ wa lā ġawr fīhā" (imagine the earth as a round globe without protuberances or depressions). Here, it should be understood as the opposite

100 Rashed, "Le meilleur des mondes", 705-6.

101 Rashed: "et que tu imaginais la terre comme un globe circulaire".

102 Rashed: "les vapeurs qui se seraient élevées de ce globe".

103 Lane, *An Arabic-English Lexicon*, 2306-7.

of *nutū*ʾ, meaning ‘protuberance’ or ‘elevation’, and thus as a depression or dip. Miskawayh is asking the reader to imagine an alternate Earth as a smooth, perfect sphere, with the focus being on the surface of the sphere rather than its inner structure. Therefore, it seems more appropriate to interpret “kura mustadīra lā nutūʾ wa lā ġawr” as “a [perfectly] round sphere without protuberances or depressions”.

The term *ġawr* is used a second time in the sentence “al-buḫār al-murtafiʿ min al-arḍ yaḥṣulu bayn aġwār al-arḍ wa bayn al-jibāl allatī tamnaʿuhu al-sayalā” (the vapour that ascends from the Earth concentrates among the depressions of the earth and between the mountains which prevent its flow). The interpretation of this usage is somewhat ambiguous, but two factors suggest that it should be read as ‘depression’ or ‘valley’. First, the use of the preposition *bayn* rather than *fī* indicates that the vapours collect *between* two or more sides rather than *within* a cavity. Second, the concentration of vapours “bayn aġwār” is presented as analogous to the concentration of vapours “bayn jabāl”, which clearly refers to the space between mountains.

The third occurrence of *aġwār* appears in the sentence “aʿnī an qulal al-jibāl al-šāhiqa yaḥfaẓ al-hawāʾ muḥtaqan bayn aġwārihā min al-ḥaraka” (I mean that the peaks of the high mountains prevent the air blocked between their valleys from moving…). M. Rashed translates this as “leurs vallées”, given that the pronoun clearly refers to the mountains. However, Rashed’s interpretation of “qulal al-jibāl al-šāhiqa” as “pockets of the high mountains” (fr. les poches des hautes montagnes) is somewhat surprising, as “qullat al-jibal” (pl. *qulal al-jibāl*) is the common Arabic expression for mountain peaks and only makes sense if one is attempting to align Miskawayh’s ideas with the Aristotelian endogenous water cycle. A closer reading of the text, however, suggests that Miskawayh’s views on the topic, as he developed them from his reading of Ṯābit’s lost treatise, support a fully exogenous water cycle or, at the very least, do not mention any underground generation of water.[104] Miskawayh goes on to explain the usefulness of this process, stating that it provides a constant source of water even during times of drought.

> And if the mountains did not exist, the waters subject to the regime we have described would not flow on the surface of the earth, at least not until the rain came and the earth absorbed it; as a result, it would happen that plants and animals would be deprived of water in the height of summer, at the very moment when they imperatively need it for their subsistence. It could then only be obtained in the same way as it is done in the remote mountain deserts, that is, by digging wells a hundred and two hundred cubits deep.

Miskawayh explicitly and specifically states the form in which this water, “subjected to the regimen we have described”, is stored. He asserts that it is snow and rain that do not immediately flow to the lowlands, rather than water generated within the earth. According to Miskawayh, mountains act as reservoirs and release water gradually:

> But now, with the existence of the mountains, the rains and snows remain on these mountains. So when the mountains have absorbed them,

104 The translation provided here, therefore, is in accordance with Lidia Bettini’s Italian translation of the work in question (Bettini, *Il libro dei cammelli errabondi*, 311-12).

> either immediately or after a time, springs arise at their feet; from them proceed the streams and rivers, which flow over the surface of the earth, and finally flow into the sea from north to south. And when what the rivers have used as rain during the summer runs out, they benefit from the return of winter and the rains, and the cycle begins again. The sign that springs, streams and rivers all come from mountains is that you never go up a stream or river without ending up in a mountain. As for springs, they are only ever found near mountains. The same applies to what can be inferred from small canals and the like. The mountains play the part, in causing the water from the rains to flow over the earth, of sponges or wools which are soaked with water and which bear a great deal of it, and from which, when they are laid on a spot, the water flows out little by little, until, when they have become dry, they are soaked and watered again. In this way, the moisture that runs off the surface of the earth is perpetuated, and this regime is the reason for the settlement of the world and the existence of plants and animals in it.

As previously mentioned, Miskawayh concludes his response by referencing Ṯābit's treatise on the usefulness of mountains. He cautions al-Tawḥīdī, who posed the question being addressed, that his answer only covers the most significant aspect of the value of mountains:

> Mountains have many benefits. We have only mentioned the most important of these, and let us confine ourselves to that. However, a treatise on the benefits of mountains is due to Ṯābit. Let him who wishes to master this chapter exhaustively read it, if it pleases God.

As the treatise on the usefulness of mountains by Ṯābit is lost, it is impossible to determine the extent to which Miskawayh's response in the *Kitāb al-hawāmil wa al-šawāmil* accurately reflects Ṯābit's opinions. Interestingly, Miskawayh does not mention any other relevant sources, despite the fact that at least one of his acquaintances, Ibn al-ʿAmid, held different views on the topic. The overall consistency between this text and Ṯābit's treatise on the salinity of seawater suggests that Miskawayh's response likely reflects the lost treatise fairly accurately. M. Rashed also seems to hold this view, referring to the text as a summary of Ṯābit's treatise.

Support for the idea that Miskawayh's response accurately reflects Ṯābit's lost treatise can be found in the *Kitāb al-āṯār al-bāqiya*. In a lengthy digression on hydraulics and hydrology that departs from the chronological focus of his book, al-Bīrūnī connects the salinity of the sea to Ṯābit's treatise on the usefulness of mountains, suggesting that the two treatises were complementary. Furthermore, al-Bīrūnī's explanation of Ṯābit's thesis on the role of mountains in the water cycle confirms that the Sabian philosopher held an exogenous model in mind:

> Regarding the question why the water of springs is most copious in winter, it is because the all-wise and all-mighty Creator intended to place the mountains [on earth] for a number of beneficial uses, some of them mentioned by Ṯābit in his book on why the mountains were created. This reason [that interests as here] is to fulfil [his] intention of making the water of the seas salty. Clearly, precipitation in winter is higher than in summer, and they are higher in the mountains than in the plains. When [this

water] falls, a part of it flows away in the torrents and the remaining part seeps down into the pores in the mountain caves, and there it is stored up. Afterwards, it begins to come out from the holes that are called springs.[105]

Finally, al-Bīrūnī's digression and Miskawayh' answer to al-Tawḥīdī, show that Ṯābit's teaching on the water cycle and the role played by water in the ecosystem were still reverberating in the tenth and eleventh centuries.

2.5 The Role of Water in the Ecosystem: Competing Theories?

The foggy history of Ḥarrān makes it difficult to trace the origins of Ṯābit's understanding of the water cycle and the role of water in the ecosystem. He is the earliest known author in Arabic to propose an exogenous model of the water cycle that diverges from Aristotelian doctrine in this regard. While the Aristotelian model remained the dominant framework for understanding the water cycle among scientists and philosophers, Ṯābit had several influential followers, including al-Tawḥīdī, Miskawayh, and al-Bīrūnī.

The exogenous model of the water cycle also appears in the *Rasā'il* of the Iḫwān al-Ṣafā'. The Iḫwān, a group of philosophers who assembled in Baṣra in the second half of the tenth century, composed a collection of epistles known as *Rasā'il Iḫwān al-Ṣafā'* (The Epistles of the Sincere Brothers). Drawing on Shiʿī and Neoplatonist thought,[106] the *Rasā'il* cover different branches of knowledge and are regarded as the first encyclopaedic effort of premodern Islam.[107] There is no certainty on the identities of the Iḫwān and those associated with them, but their epistles enjoyed a widespread success in both the Islamic east and west.

As it has been already noted, the multifaceted vision of the creation exposed by the Iḫwān comprised an unusually non-anthropocentric vision of the natural world, which bears some echoes of Ṯābit's own bio-centric rather than anthropocentric view implicit in his *Treatise on Why Seawater Was Made Salty*. Another point of agreement is the theory of the water cycle, described as follows in the eighteenth *Risāla*:

> The root of all these beings is vapours and juices when they are mingled with each other. Vapours are what rise in the air from the subtle parts of the water of seas, rivers, and marshes because of the warming of the Sun and of the stars with the projection of their rays on the surface of seas, rivers, and marshes. Juices seep into the depth of the earth from rain waters, are mixed with the parts of earth, and thicken, and the warmth hidden in the depth of the earth ripens them [...] In fact, when the Sun and the stars warm water, irradiating the surface of the Earth as well as seas, rivers, and marshes, waters rarefy and the parts of earth become subtler and become vapour and smoke. Vapour and smoke become clouds, clouds

105 Borroni, Boselli, "Hydraulics and Hydrology", 178.

106 And much more. See de Callataÿ, *A Brotherhood of Idealists*, 73-81; Ikhwān al-Ṣafā', *On the Natural Sciences*, 30-4.

107 El-Bizri, "Prologue"; Netton, "The Rasā'il Ikhwān al-Ṣafā' in the History of Ideas". For a complete introduction to the thought of the Iḫwān al-Ṣafā' see Netton, *Muslim Neoplatonists*. On the relationship between the Iḫwān and the Sabians see Mattila, "Sabians, the School of al-Kindī".

> become rains, and when rains moisten the soil and the parts of earth are mixed with those of water, juices are formed from them.[108]

Unlike the perspectives of Abū al-Barakāt, Ṯābit, and al-Bīrūnī, the *Rasā'il* exhibit no scepticism regarding the conversion of air into water as a physical occurrence, nor any other elemental transformation. Within the same treatise, the authors assert that "the four elements undergo metamorphosis into each other, with water alternately transforming into air and earth".[109] The concept of air transmuting into water is further discussed in the *risāla* "On Mines and Minerals", where the authors expound on a process of water formation within the mountain depths. This explanation aims to account for the numerous sources found around the Bāmyān mountains, despite the region's scarcity of rain or snow:

> This is the proof that in the cavity of this mountain there are cold caves, cavers, and chasms, whose coldness is extreme, [whence] air congeals and becomes water, then it is poured into its lowest [part], is seeped from narrow pores, and from them those sources and creeks flow towards those steppes […] this mountain is far from seas, and clouds seldom arrive here owing to the long distance.[110]

One interpretation of this phenomenon could be that it represents an exceptional and infrequent instance of subterranean water generation within the context of an otherwise externally driven cycle. Alternatively, this could be a result of the multifaceted authorship of the *Rasā'il*.[111] Intriguingly, in a later section of the same treatise, the external cycle is examined from a distinct angle.

Subsequent to an analysis of several major rivers, the swelling of their waters is exclusively attributed to precipitation. For rivers flowing from north to south, an increase in water volume occurs during spring as a result of melting snow after winter. In contrast, the Nile demonstrates a different pattern; it swells in summer due to its sources being located south of the Equator, where seasons are inverted. Consequently, the Nile's sources experience increased rainfall during the northern hemisphere's summer months. The chapter culminates in a comprehensive description of the evaporation and precipitation processes, followed by an exclusively exogenous explanation for the origin of rivers:

> The rains that fall on the tops of the mountains they recede into the fissures and interstices of those mountains, and are poured into the caves, caverns, and chasms that are found there; [these] are filled, and in the lowest [parts] of those mountains narrow openings are formed, from which those waters are seeped, flow, and assemble together becoming wadis

108 Ikhwān al-Ṣafā', *On the Natural Sciences*, 180-1. The Rasā'il translations presented in this paper are by C. Baffioni. The processes that lead to the generation of clouds is further described in Ep. 18 Ch. 8. Ikhwān al-Ṣafā', 203.

109 Ikhwān al-Ṣafā', *On the Natural Sciences*, 180.

110 Ikhwān al-Ṣafā', *On the Natural Sciences*, 241-2.

111 The issue is described as 'vexing' by G. de Callataÿ in the "Brethren of Purity" entry of the third edition of the Encyclopedia of Islam, where a comprehensive and updated summary of the matter can be found. de Callataÿ, "Brethren of Purity".

> and rivers; those snows on the tops of the mountains are melted, flow towards those wadis and rivers, and return in their course to the seas, then vapours, winds, and rains are formed from them, as it had happened the preceding year. This is the decree of the Mighty, the Omniscient.[112]

It is notable that within the same treatise, an explanation for the sea's salinity is presented, which combines the aforementioned Aristotelian causal approach (briefly examining factors contributing to the saltiness of the sea) with a discussion on the purpose of seawater salinity in relation to divine wisdom. This explanation is strikingly similar to the central argument presented by Ṯābit in his work on seawater salinity. As per the Iḫwān's account, the salinity of seawater is of the utmost importance since, without it, terrestrial plants, animals, and humans would not survive; concurrently, this salinity does not pose a danger to marine life. While Ṯābit is not explicitly referenced in these sections, it is reasonable to hypothesise that there could be a direct or indirect link between this passage from the *Rasā'il* and his treatise on seawater and its salinity.

It appears that, at least until the eleventh century, two school of thought on water and its role in the ecosystem coexisted among learned Arabic-speaking communities. On one side, we find those who followed or tried to refine Aristotelian conceptions adopting an endogenous model of the water cycle, on the other side we have those who believed in an exogenous model.

Of these authors, Ṯābit appears to be the most prominent early advocate of the exogenous model, although he may not be the first known author to have written treatises based on this model; the *Filāḥa nabatiyya* and Ḥunayn b. Isḥāq's commentary predate Ṯābit's work on the subject and express implicitly similar views. Despite this, Miskawayh and al-Bīrūnī acknowledge the importance of these earlier treatises by citing them in their own work, while the Iḫwān do not. It is noteworthy that there is no evidence of any debate or disagreement between these two groups, given that Ibn al-ʿAmīd and Miskawayh were personally acquainted and al-Bīrūnī and Ibn Sīnā engaged in a well-known philosophical correspondence. It is possible that Ṯābit's ideas about the water cycle and related topics, such as the salinity of seawater and the usefulness of mountains, were passed down through scholar networks and served as a marker of educational background for members of later intellectual elites. This suggests the existence of a diversity of perspectives on the natural environment and the natural world more broadly within this period. This plurality of views has significant implications for contemporary discussions of the environment within the Arabo-Islamic tradition, as will be explored in the following chapter.

The Arabo-Islamic tradition inspired by Aristotle generally depicted the water cycle through an endogenous model and the idea that certain elements can transform into others. Specifically, it was believed that air could turn into water and vice versa, with vapour occupying an intermediate position. This perspective was often accompanied by a strong anthropocentrism, stating that the majority or all of the elements and processes that make up the natural world are intended for the benefit of humanity.

The view of nature conveyed in the two treatises by Ṯābit that are examined here is based on an exogenous model of the water cycle, the idea

112 Ikhwān al-Ṣafāʾ, *On the Natural Sciences*, 244.

that the water in the world is a fixed quantity and not continually generated, and an implicit biocentrism. According to this biocentrism, the elements and principles of the natural world are intended for the sustenance of all life, which is itself a part of the wisdom and beauty of creation. A similar understanding can be found in Miskawayh and the Iḫwān al-Ṣāfā. In the following chapter, we will explore how al-Bīrūnī expanded upon Ṯābit's understanding of the natural world. As we will see, the concept of the environment is a central point of convergence and agreement between these two important scientists in the Arabic-Islamic tradition. This convergence takes the form, concretely, of extensive paraphrases from the two treatises of the Sabaean mathematician and scientist that we are interested in here, and, more generally, of a significant similarity in approach both to knowledge in general and to the relationship between the scholar and nature/creation as objects of study.