A History of the Ecological Sciences

Part 7. Arabic Language Science: Botany, Geography, and Decline

Botany and geography figured more prominently in medieval Arabic language science than did zoology, surveyed in Part 6 (Egerton 2002). Botany was pursued very little for its own sake, however; it was mostly studied in relation to plants used for medicines and food. Islamic civilization was geographically much larger than the earlier civilizations of Greece, Rome, and Byzantium, and its interest in geography was proportionately greater as well. Because Arabic language science spread from Iberia and North Africa to India and Central Asia, one might imagine that it would not be as vulnerable to decline as science was in the three earlier civilizations, especially because Islamic civilization did not actually end, as those three did. Yet its golden age lasted only from the 800s through the 1100s, and was followed by decline into traditionalism.

Recent surveys of medieval Arabic language botany (Egerton 1983, Fahd 1996:813–841, Kruk 1993, Nasr 1968:111–118, Nasr 1976:54–60, Sezgin 1971:301–346, Ullmann 1972:62–94) and agriculture (Fahd 1996:841–852, Shihabi et al. 1967, Ullmann 1972:427–451) indicate the extensive literature available in that language, some of which is also translated into European languages. Greek influence was most prominent on both the organization and content of these works, but scholars also drew upon North African, Mesopotamian, Persian, Indian, and Central Asian works to enlarge their knowledge, and Iberian authors may have drawn upon Roman agricultural literature.

An attempt was made to translate the botanical works of Theophrastos into Arabic, but if ever completed, it never became available to scholars and has disappeared. Therefore, the major Greek influences came from *De Plantis*, a brief treatise then attributed to Aristotle but now attributed to Nicolas of Damascus (64 BC to at least 4 BC), a court official (Longrigg 1974), and the *Materia Medica* of Dioscorides (active AD 60s–70s). To a modern reader, *De Plantis* reads like an exercise to prove that Aristotelian logic can explain everything, and its most memorable achievement is Nicolas' refutation of Empedocles' claim that plants have two sexes mixed together; instead, he explains why plants have no sex at all (817a). Nevertheless, to medieval scholars it was an important theoretical treatise on botany. The original Greek text has disappeared, yet it survives in whole or in part in Syriac, Arabic, Hebrew, Latin, and in a Greek translation made about 1300 from the Latin. A modern English translation was made from this Greek version and published with the minor works of Aristotle (1936)! However, the more recent editions of all five medieval translations contain an English translation of the Arabic text (Lulofs and Poortman 1989:126–215).

Arabic writings that *De Plantis* inspired include: the seventh section of *Kitab al-shifa* (Book of Healing), by physician-philosopher Ibn Sina (= Avicenna, 980–1037) on plant physiology: functions of roots, branches, leaves, fruits, seeds, thorns, gums, and so on (Fahd 1996:818; Ullmann 1972:78–79), *Kitab al-nabat* (Book of Plants) by philosopher Ibn Bajja (= Avempace, d. 1138/39), whose work is published in Arabic with an annotated Spanish translation (Asín Palacíos 1940), and a commentary by Ibn Rushd (= Averroës, 1126–1198) that survives in Hebrew translation (Lulofs and Poortman 1989:363–371, 440–443). It is difficult to say how far above the rather low level of their model these authors raised Arabic botany (Fahd 1996:818).

The modern species-by-species accounts of plants found in all floras goes back, as mentioned in part 3 (Egerton 2001*b*), to the organization of Dioscorides' *Materia Medica* (written in Greek despite the convention of giving the title in Latin). It has long been assumed that Stephanos, son of Basileos (= Istifan ibn Basil), translated it from Greek into Syriac and then Hunayn ibn Ishaq translated it into Arabic at Baghdad in the 800s (Dubler 1962), but Sadek (1983:7–18) presents a more complex history, although still involving these two translators. However it got into Arabic, it was improved upon in the 900s in Cordova and in Samarkand, at nearly opposite ends of Islamic civilization. The Cordova improvements were occasioned by the Byzantine emperor Romanus II presenting to Cordova caliph Abd al-Rahman III an illustrated Greek copy of *Materia Medica* in 948, and then sending a monk, Nicolas, in 951, who spent the rest of his life helping Hasday ibn Shaprut and others adapt the eastern Arabic version to Hispano-Arabic nomenclature. A similar readaptation was made at Samarkand by al-Husayn ibn Ibrahim al-Natili, who added Persian-inspired illustrations, and dedicated it to the new king Abu 'Ali in 990. There is a modern Arabic text (Dubler and Terés 1952–1957), and there are two concordances to correlate not only the Arabic and Greek texts but also texts in other languages (Dubler 1953, Sadek 1983:66–123).

Scholars were much concerned about proper identification of plants used in preparing medicines, and little concerned about whether the medicines actually were effective; they assumed efficacy. Because Islamic civilization did absorb botanical and medical knowledge from practically all regions, there was an urgent need for a Linnaeus in botany that was not felt in zoology. For example, al-Kindi (c.800–870) wrote a medical formulary, *Aqrabadhin*, in which the pharmacological names (including plant names) were 33% Mesopotamian (transmitted through Syriac, Aramaic, Hebrew, and Persian), 23% were Greek, 18% Persian, 13% Indian, 5% Arabic, and 3% Egyptian, with the remainder of unknown origin (Levey 1966:20). His modern editor was able to define and explain 319 terms, most of which are either plant names or names of plant parts (Levey 1966:225–345). To meet this botanical need, there appeared a scholar and a treatise roughly comparable to al-Damiri's *The Life of Ani-*

mals. That is, Abu Hanifa al-Dinawari (d. 895), from Dinawar, Iraq, wrote his most important work, *Kitab al-nabat* (Book of Plants), from literary and oral research (Lewin 1967), rather than from literary, oral, and botanical research, as Linnaeus would do in the 1700s. It was still valuable, because it was a detailed synthesis of the work of many scholars (Bauer 1988), and it was widely used. Reflecting the greater urgency in botany than in zoology, al-Dinawari wrote his book about 500 years before al-Damiri's work. Part I of *Kitab al-nabat* is an alphabetical list of plant names (al-Dinawari 1953), and Part II discusses various plants and their uses or environmental significance (al-Dinawari 1974). For example, certain plants make camels and sheep sick if they eat much of them. Because locust plagues are so destructive of vegetation, he quoted authorities on the insect's life history. Because honey bees feed on flowers, he also quoted information on bees from Aristotle's *Historia Animalium* (625b). There were also important studies of pharmacological synonyms that shed light on botanical names (Levey 1973: 146–169).

The accumulated knowledge from interrelated traditions of Dioscorides and al-Dinawari, carried down through the centuries, was again synthesized, on a larger scale, by Ibn al-Baytar (c. 1190–1248), an Iberian pharmacologist who settled in Cairo in 1224 as chief herbalist to Sultan al-Kamil. Among his several surviving works, the most important is *Kitab al-jami fi al-adwiya al-mufrada* (translated into French as *Traité des simples*, 1877–1883). He drew upon about 150 authorities to describe alphabetically some 1400 vegetable, animal, and mineral medicines (Vernet 1970, Hamarneh 1973:93–96, Torres 1986, Calvo 1997). About 200 of his species of plants were newly described or newly described as sources of medicines (Sarton 1931:663).

During the Islamic Middle Ages, neither pure botany nor medical botany provided contexts as favorable for ecological thoughts as did agriculture. Agricultural treatises drew upon Greek sources such as Kassianos Bassos' *Georgika*; however, its main early source was the *Nabatean Agriculture* which Ibn Wahshiyya supposedly translated from Syriac. Because nothing is known about such a person, the real author or translator may have been Ibn Wahshiyya's alleged pupil and secretary, Abu Talib al-Zayyat (d. c. 951). This work synthesized Greek, Persian, and Indian science and folklore (Fahd 1971). For each domesticated species, it attempted to provide seven kinds of information: description, best soil, time of planting and harvest, how to plant, required care, favorable winds and seasons, manuring, usefulness and harmfulness, and properties (Fahd 1996:821). Although critical knowledge and understanding of these factors was far beyond what *Nabatean Agriculture* achieved, the attempt served as a model for later authors.

Muslim Spain, called Andalusia, was a flourishing region from the Arabic conquest in the 700s through the 1100s, and it became the center of important cultural advances that included pharmacological and agricultural writings (Glick 1979:253–257). Paper was introduced into Andalusia by the mid 900s, and paper mills were established there within the next century (Bloom 2001:87). Ibn Wafid (c. 1008–1075) was a pharmacologist who studied in Cordoba and then established a botanical garden in Toledo for his patron, al-Mamun (Vernet 1996, Calvo 1997*b*). Ibn Wafid wrote works on pharmacology, and one on agriculture is uncertainly attributed to him (Bolens 1981:21–23). His contemporary, Ibn Bassal, wrote a *Libro de Agriculture* that is now published in Arabic with Spanish translation (1955; English summary in Sarton [1956]). Its 16 chapters covered traditional topics in practical language, as he wrote for farmers, and without references to the literature that he seems to have used (Bolens 1981:23–25). The culmination of the tradition in agricultural treatises was written by Ibn al-'Awwam (fl. second half of 1100s) in 35 chapters. His treatise does include his own observations, but it is primarily a very capable synthesis of the agricultural literature stretching back to the Greeks and including many Arabic language authors (Vernet 1970*a*, Bolens 1981:29–31). It is possible that he had some knowledge from Columella (a fellow Iberian from the first century AD), because Bolens (1981:chart after p. 1) indicates that Columella's book was translated into Arabic during the 800s. However, Vernet and Samsó (1996:247, 261) doubt that he had direct knowledge from Columella. Ibn al-'Awwam's most important sources were the *Nabatean Agriculture* and the *Kitab al-mughni fial-Filaha* of Abu 'Umar ibn Hajjaj (fl. 1073). Ibn al-'Awwam discussed 585 kinds of domesticated plants, including 50 different kinds of fruit trees. His treatise is translated into Spanish (1802; sponsored by the government for the benefit of Spanish farmers) and French (1864–1867), and there is an extensive English summary (Khan 1950, 1954) based on the Arabic text (1927). His first two chapters reflect a long-standing Arab concern for the quality of water and soil used for agriculture (Olson and Eddy 1943, Bolens 1981: 58–123). What we could call ecological comments included "Avoiding certain combinations of plants which tended to have a damaging effect on each other, such as palms and junipers, and combining others that furthered each other's growth" (Kruk 1993:832).

Although Ibn al-'Awwam wrote the most comprehensive agricultural encyclopedia in Arabic, it was not the end of Arabic agricultural writing. The farmer's almanac is another format that attracted authors. The format itself goes back more than 3500 years to the Sumerians (Kramer 1963:105–109, 340–342). More widely known were the *Works and Days* of Hesiod (c. 700 BC) and the *Georgics* of Virgil (c. 37–29 BC), but none of these three works was likely to have been available in Arabic. The Arabic tradition of almanacs began in the 800s, when both al-Dinawari and a fellow Iraqi, physician Ibn Masawayh, compiled almanacs (Varisco 1994:7, 128, 262). Our knowledge of this genre is based on the almanac written by the Rasulid sultan of Yemen, Al-Malik al-Ashraf

(c. 1242–1296, r. 1295–1296), in 1271; it was the first of eight Rasulid almanacs. Yemen, in the southwestern corner of Arabia, is the most fertile part of the peninsula, but it has a variable terrain, extending from coastal plain to mountains and inland plateau, that requires careful consideration of which plants should be planted in particular places and in which month. Furthermore, farmers must beware a variable climate. For example, in 1295 a cold rainstorm killed many sheep and there was also a major locust infestation (Varisco 1994:13). Al-Malik therefore discussed rain patterns, rain predictions, winds, periods of greatest heat, and other aspects of climate, using a profusion of terms (Varisco 1994: 105–127). He was equally interested in the heat and moisture in both the surface and subsurface of soils, the varieties of native plants that grew in different locations, when the sap flows, and when leaves sprout and fall (Varisco 1994:128–132). Yemen has the richest flora of the Arabian Peninsula, and Al-Malik's father, Yusuf ibn 'Uman (d. 1295), had compiled an important herbal that is published in Arabic (1982). An interesting intersection between the domestic and the natural seasonal cycle is in Al-Malik's discussion of six kinds of honey obtained from domestic honey bees, depending upon the types of flowers that they visited. The flowers bloomed at different times. He recorded the time of the year in which each kind of honey was made, and the flowers that provided the nectar for it (pages 148–149).

Al-Malik's almanac shows that even in the traditional period, original observations that we could call ecological were still being made. That claim has also been made by a modern historian of pharmacy, Sami Hamarneh, about a work written over two centuries later, in his article, "Medicinal plants, therapy and ecology in Al-Ghazzi's *Book on Agriculture*" (1978). Al-Ghazzi (1457–1529) was a well-educated scholar and official in Damascus who visited Egypt to compare its agriculture and horticulture with those of Syria. Hamarneh concluded that al-Ghazzi's *Jami' al-filaha* showed "profound interest in landscaping, gardening and ecology" which "entitles him to the highest rank attained in good farming and horticulture in the entire region during the late Mamluk and early Ottoman periods in Islam" (Harmaneh 1978: 229). Perhaps so; however, Hamarneh's (1978:232–237) summary of its contents provides only the briefest examples of ecological observations. It would be interesting to know of any advances made during the four centuries since Ibn al-'Awwam wrote his treatise, but Hamarneh's summary merely indicates a Damascan variation on the Andalusian achievement.

The study of geography was more highly developed in the Islamic world than in its Byzantine and West European neighbors. Muslim civilization covered a much larger region than did either of the others. Muslims were engaged in significant long-distance commerce, and sometimes conquests, and they wanted to understand where they were headed. Furthermore, two of the five pillars of Islam stipulated that they pray toward Mecca regardless of where they were, and that they make a pilgrimage, hajj, to Mecca if they were able; the achievement of these stipulations required an understanding of locations. Muslims were assisted in their geographic quest by important scientific instruments (astrolabe, celestial sphere, gnomon, quadrant, and sundial, which they borrowed from the Byzantines by the early 800s) and the compass (which they borrowed from the Chinese by the mid-1100s). The geographic and cartographic literature cannot be surveyed here to the same extent as zoological and botanical literature because it is too diverse and diffuse, and emphasizes cultural rather than physical geography (Ahmad 1965, Miquel 1967–1987, 1996, Nasr 1968:98–108, 1976:36–48, Kish 1978:199–235, Sezgin 1987*a*, Buang 1997). Instead, relevant Greek geographical themes discussed in Parts 1 and 3 (Egerton 2001*a*, *b*) will be followed in their Arabic continuations, emphasizing three leading geographers.

Arabic language geography and cartography began with the translation of the *Geography* by Klaudios Ptolemaios (c. AD 100 to c. 178) into Arabic by three scholars during the 800s (it would be retranslated by two other scholars in 1465 [Ptolemaios 1987:14–16]). This was a mathematical geography that treated the earth in a way analogous to that in which his *Almagest* treated the heavens; in fact, astronomy was needed for determining latitudes and longitudes. Ptolemy had great skill in synthesis, and his treatise was well organized, although he accepted the very inaccurately small size of the earth that Posidonios had calculated, rather than the more accurate earlier calculation by Eratosthenes (Ptolemaios 1987:4, Egerton 2001*b*:202). He also believed that people living in the hot tropics and cold northern regions were savages because of adverse climates; civilization only developed in temperate regions (Kish 1978:106).

These latter claims reinforced the Hippocratic notions found in *Airs, Waters, Places*, discussed in Part 1 (Egerton 2001*a*:94–95), and both authors exerted a significant influence. "The notion of the relation between environmental circumstances and the development of living beings is deeply ingrained in the outlook of Arab scholars from the 9th century onwards" (Kruk 2001:129), including al-Kindi, al-Jahiz, and Ibn abi l-Ash'ath. This outlook applied to the local, as well as the regional, level. A physician would be "consulted not only concerning healthy surroundings for the individual patient, but in selecting the site for a new city or an institution such as a school or a hospital" (Hamarneh 1973*b*:127). Another source of environmental influence that was taken seriously by many, though not all, Arabic-speaking scholars was the heavenly bodies; astrology was widely studied and discussed in many writings (Lemay 1997). Geographical location, including climate, was also important. Ibn Sina thought that cabbages change their appearance if carried into different regions, and that geographical location determines whether a palm shoot develops into a date or coconut palm (Kruk 1993:833). Three outstanding contributors to Arabic language geography indicate what was achieved: al-Biruni (973–1050), al-Idrisi (1100–1166), and Ibn Battuta (1304–1368).

Al-Biruni was a versatile scientist from Central Asia (Kennedy 1970) who is best remembered for his valuable history–geography, *India.* He was an important mathematical geographer who developed an original method to determine the size of the earth based on measuring the height of a mountain and the visual angle from the mountain top to the horizon (Mercier 1992:182–188). His *India* has brief passing remarks that are ecologically interesting, such as: "The life of the world depends upon the sowing and procreating. Both processes increase in the course of time, and this increase is unlimited, whilst the world is limited ... single species of plants and animals occupy the earth and spread ... over as much territory as it can find" (1887:I, 400). He identified water as the most important cause of change in the landscape and he saw that water carries more sediment when it flows rapidly, which explains why slowly flowing water at river mouths deposits silt (Samian and Siddiqi 1997: 159). Al-Biruni also wrote on both astronomy and astrology. When compiling his *Materia Medica* (1973), perhaps he had access to al-Natili's version of Dioscorides; both men worked in the same region, and they encountered medicinal plants unknown to Dioscorides (Hamarneh 1973*a*).

Al-Idrisi was born and died in Ceuta, Morocco, at the eastern end of the Strait of Gibraltar; he was related to the rulers (Ahmad 1973). He was educated in Cordova and traveled to Asia Minor at age 16. Later, he traveled in Christian Europe, and in 1138 he accepted an invitation by Roger II of Sicily to reside at his court in Palermo, where he remained until Roger's death in 1154. Roger himself was deeply interested in geography and encouraged al-Idrisi to compile a world map and geography; Roger sent envoys to various places to collect information. Al-Idrisi and his assistants constructed a large relief map in silver which has disappeared, but there is a smaller version in his geography book; he also drew a large-scale world map in 70 sections (Ahmad 1992). This was a unique synthesis of Arabic and European knowledge.

Ibn Battuta was from Tangier, Morocco, at the western end of the Strait of Gibraltar. He was well educated in Islamic law. In 1325, he made his hajj to Mecca, which changed his life. He discovered that he loved to travel, and he, not Marco Polo, became the most widely traveled explorer of the Middle Ages. He traveled from one end of Islamic civilization to the other, and on beyond at both ends, into Christian Europe and China, covering some 73,000 miles (Dunn 1986:3). He also sailed along the coast of East Africa as far south as Kilwa, below the equator, exploding the common belief that the equatorial region was too hot for human habitation. His *Rihla* (*Travels*) provides our only medieval account of many places that he visited. He was not a scientist, and at times his comments on plants and animals were occasioned by what struck him as unusual, but he was also interested in important food plants (Fahd 1996: 819–820) and he provided a systematic treatment of trees, fruits, and grains of South Arabia, India, and the Maldives (Rosenthal 1970:517).

The decline of Arabic language science into traditionalism occurred at about the same time that Islamic civilization ceased expanding and instead began to contract under the attacks, first by Christians and later by the Mongols. Christian reconquest of Andalusia began soon after the breakup of the caliphate in 1031 and continued until 1492 (Reilly 1993). The onslaught of the Crusades began in 1096 and occurred off and on for more than three centuries (Setton 1969–1989, Riley-Smith 1987). The Mongols devastated Harat in 1222 and Baghdad in 1258, but were defeated in Palestine in 1260 (Donner 1999:58–61). Historians have understandably seen a causal relationship between these invasions and the decline of science, but historical sociologist Huff (1993:202–236) dismisses geopolitical disasters and argues that Islamic social structure and institutions were unfavorable for the continued development of science. However, there is no clear reason why geopolitical and social factors could not have had a negative synergistic effect, causing the decline of scientific momentum.

Be that as it may, while Islamic civilization declined, Muslims, Jews, and Christians collaborated in translating Arabic science into Latin. This happened primarily in Toledo, Sicily, and Italy, beginning after the Christian conquest of Toledo in 1085 (Benoît and Micheau 1995:213–221, Haskins 1927:Chapters 1–7, Levey 1973:179–177). The use and making of paper were also transmitted from Muslims to Christians at about the same time and places (Bloom 2001:204–209). Arabic language scholars had absorbed Greek natural history and added greatly to it. In total, this heritage was too diffuse to become a foundation for an ecological science. However, the achievements of Latin natural history were heavily indebted to this Arabic language legacy.

Literature cited

Ahmad, S. M. 1965. Djughrafiya, geography. Encyclopaedia of Islam **2**:575–587.

Ahmad, S. M. 1973. Al-Sharif al-Idrisi. Dictionary of Scientific Biography **7**:7–9.

Ahmad, S. M. 1992. Cartography of al-Sharif al-Idrisi. Pages 156–174 *in* J. B. Harley and D. Woodward, editors. Volume 2, Book 1: Cartography in traditional Islamic and South Asian societies. The history of cartography. University of Chicago Press, Chicago, Illinois, USA.

Aristotle. 1936. On plants. Pages 141–233 *in* Minor works. [In Greek with translation by W. S. Hett.] Harvard University Press, Cambridge, Massachusetts, USA.

Asín Palacíos, M. 1940. Avempace Botántico. Al-Andalus **5**:255–299.

Bauer, T. 1988. Das Pflanzenbuch des Abu Hanifa ad-Dinawari: Inhalt, Aufbau, Quellen. Otto Harrassowitz, Wiesbaden, Germany.

Benoît, P., and F. Micheau. 1995. The Arab intermediary. Pages 160–190 *in* M. Serres, editor. A history of scientific thought: elements of a history of science. Blackwell, Cambridge, Massachusetts, USA.

Al-Biruni, A. R. 1887. Alberuni's India: an account of the religion, philosophy, literature, geography, chronology, astronomy, customs, laws and astrology of India about A.D. 1030. Translated by Edward Sachau. Two volumes. Trübner, London, UK.

Al-Biruni, A. R. 1973. Book on pharmacy and materia medica. [Arabic with English translation.] Edited by H. M. Said. Hamdard National Foundation, Karachi, Pakistan.

Bloom, J. M. 2001. Paper before print: the history and impact of paper in the Islamic world. Yale University Press, New Haven, Connecticut, USA.

Bolens, L. 1981. Agronomes andalous du Moyen-Age. Droz, Geneva, Switzerland.

Buang, A. 1997. Geography in the Islamic world. Pages 354–356 *in* H. Selin, editor. Encyclopaedia of the history of science, technology, and medicine in non-Western cultures. Kluwer Academic, Dordrecht, The Netherlands.

Calvo, E. 1997. Ibn al-Baytar. Pages 404–405 *in* H. Selin, editor. Encyclopaedia of the history of science, technology, and medicine in non-Western cultures. Kluwer Academic, Dordrecht, The Netherlands.

Dallal, A. 1984. Al-Biruni on climates.

Al-Dinawari, A. H. 1953. The book of plants: part of the alphabetic section. B. Lewin, editor. [Arabic text with some English translations.] A. B. Lundequistska, Uppsala, Sweden.

Al-Dinawari, A. H. 1973. Le Dictionnaire botanique. M. Hamidullah, editor. [Arabic text with French introduction.] Institut Français d'Archéologie Orientale, Cairo, Egypt.

Al-Dinawari, A. H. 1974. The book of plants: part of the monograph section. B. Lewin, editor. [Arabic text with English introduction and summary.] Franz Steiner, Wiesbaden, Germany.

Donner, F. M. 1999. Muhammad and the Caliphate: political history of the Islamic Empire up to the Mongol Conquest. Pages 1–61 *in* J. L. Esposito, editor. The Oxford history of Islam. Oxford University Press, New York, New York, USA.

Dubler, C. E. 1953. La 'Materia Médica' de Dioscórides: Transmisión Medieval y Renacentista. Volume 1. Tipografia Emporium, Barcelona, Spain.

Dubler, C. E. 1962. Diyuskurides. Encyclopaedia of Islam **2**:349–350.

Dubler, C. E., and E. Terés. 1952–1957. La 'Materia Médica' de Dioscórides: Transmisión Medieval y Renacentista. Volume 2. [Arabic text with Spanish notes.] Tipografia Emporium, Barcelona, Spain.

Dunn, R. E. 1986. The Adventures of Ibn Battuta: a Muslim traveler of the 14th century. University of California Press, Berkeley, California, USA.

Egerton, F. N. 1983. Islam. Pages 433–444 *in* E. L. Greene, editor. Landmarks of botanical history. Stanford University Press, Stanford, California, USA.

Egerton, F. N. 2001*a*. A history of the ecological sciences. Part 1: Early Greek origins. ESA Bulletin **82**:93–97.

Egerton, F. N. 2001*b*. A history of the ecological sciences. Part 3: Hellenistic natural history. ESA Bulletin **82**:201–205.

Egerton, F. N. 2002. A history of the ecological sciences. Part 6: Arabic language science—origins and zoological writings. ESA Bulletin **83**:142–146.

Fahd, T. 1971. Ibn Wahshiyya. Encyclopaedia of Islam **3**:963–965.

Fahd, T. 1996. Botany and agriculture. Encyclopedia of the History of Arab Science **3**:813–852.

Glick, T. F. 1979. Islamic and Christian Spain in the early Middle Ages. Princeton University Press, Princeton, New Jersey, USA.

Hamarneh, S. K. 1965. Al-Kindi, a ninth-century physician, philosopher, and scholar. Hamdard National Foundation, Karachi, Pakistan.

Hamarneh, S. K. 1973*a*. Al-Biruni's Book on pharmacy and materia Medica. Hamdard National Foundation, Karachi, Pakistan.

Hamarneh, S. K. 1973*b*. Origins of pharmacy and therapy in the Near East. Naito Foundation, Tokyo, Japan.

Hamarneh, S. K. 1978. Medicinal plants, therapy and ecology in Al-Ghazzi's book on agriculture. Studies in the History of Medicine **2**:223–263.

Harley, J. B., and D. Woodward, editors. 1992. The history of cartography. Volume 2, Book 1: Cartography in traditional Islamic and South Asian societies. University of Chicago Press, Chicago, Illinois, USA.

Haskins, C. H. 1927. Studies in the history of medieval science. Second edition. Harvard University Press, Cambridge, Massachusetts, USA.

Huff, T. E. 1993. The rise of early modern science: Islam, China, and the West. Cambridge University Press, New York, New York, USA.

Ibn al-'Awwam, A. Z. 1864–1867. Le livre de l'agriculture. Two volumes in three. [Translated by J.-J. Clément-Mullet.] A. Franck and A. Herold, Paris, France.

Ibn al-Baitar al-M. D. 1877–1883.

Ibn Bassal, A. 'A. 1955. Libro de Agricultura. [Arabic with Spanish translation by J. M. Millás-Vallicrosa and M. Aziman.] Instituo Muley el-Hasán, Tetuán, Morocco.

Ibn Battuta, M. 1958–1971. The travels of Ibn Battuta, A.D. 1325–1354. Translated by H. A. Gibb. Three volumes. Cambridge University Press, Cambridge, UK.

Khan, M. A. 1950. Ibn-al-Awwam's Kitab al-Filahah. Islamic Culture **24**:200–217, 285–299.

Khan, M. A. 1954–1956. Further elucidation of technical matters in Ibn al-Awwam's Kitab al-Filahah. Islamic Culture **28**:389–395; **29**:275–282; **30**:51–69.

Kish, G. 1978. A source book in geography. Harvard University Press, Cambridge, Massachusetts, USA.

Kramer, S. N. 1963. The Sumerians: their history, culture, and character. University of Chicago Press, Chicago, Illinois, USA.

Kruk, R. 1993. Nabat, plants. Encyclopaedia of Islam **7**:831–834.

Kruk, R. 2001. Ibn abi l-Ash'ath's *Kitab al-Hayawan*: a scientific approach to anthropology, dietetics and zoological systematics. Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften **14**: 119–168.

Lemay, R. 1997. Astrology in Islam. Pages 81–83 *in* H. Selin, editor. Encyclopaedia of the history of science, technology, and medicine in non-Western cultures. Kluwer Academic, Dordrecht, The Netherlands.

Levey, M., editor. 1966. The medical formulary or aqrabadhin of Al-Kindi: Translated with a study of its Materia medica. [Includes Arabic text.] University of Wisconsin Press, Madison, Wisconsin, USA.

Levey, M. 1973. Early Arabic pharmacology: an introduction based on ancient and medieval sources. Brill, Leiden, The Netherlands.

Lewin, B. 1962. Abu Hanifa Al-Dinawari. Encyclopaedia of Islam **2**:300.

Longrigg, J. Nicolaus of Damascus. Dictionary of Scientific Biography **10**:111–112.

Lulofs, H. J. D., and E. L. J. Poortman, editors. 1989. Nicolaus Damascenus, De Plantis: five translations. North Holland Publishing, Amsterdam, The Netherlands.

Mercier, R. P. 1992. Geodesy. Pages 175–188 *in* J. B. Harley, and D. Woodward, editors. The history of cartography. Volume 2, Book 1: Cartography in traditional Islamic and South Asian societies. University of Chicago Press, Chicago, Illinois, USA.

Miguel, A. 1996. Geography. Encyclopedia of the History of Arab Science **3**:796–812.

Miquel, A. 1967–1987. La géographie humaine du monde musulman jusqu'au milieu du 11e siècle: Le milieu Naturel. Mouton, Paris, France.

Nasr, S. H. 1968. Science and civilization in Islam. Harvard University Press, Cambridge, Massachusetts, USA.

Nasr, S. H. 1976. Islamic science: an illustrated study. World of Islam Festival, Westerham, UK.

Olson, L., and H. L. Eddy. 1943. Ibn-al-Awam: a soil scientist of Moorish Spain. Geographical Review **33**:100–109.

Ptolemaios, K. 1987. Geography: Arabic translation (1465 A.D.). F. Sezgin, editor. [Arabic with English introduction.] Institut für Geschichte der Arabisch-Islamischen Wissenschaften an der Johann Wolfgang Goethe-Universität, Frankfurt am Main, Germany.

Reilly, B. F. 1993. The medieval Spains. Cambridge University Press, Cambridge, UK.

Riley-Smith, J. 1987. The Crusades: a short history. Yale University Press, New Haven, Connecticut, USA.

Rosenthal, F. 1970. Ibn Battuta. Dictionary of Scientific Biography **1**:516-517.

Sadek, M. M. 1983. The Arabic Materia Medica of Dioscorides. Éditions du Sphinx, Quebec, Canada.

Samian, A. L., and A. H. Siddiqi. 1997. Al-Biruni. Pages 157–159 *in* H. Selin, editor. Encyclopaedia of the history of science, technology, and medicine in non-Western cultures. Kluwer Academic, Dordrecht, The Netherlands.

Sarton, G. 1931. Introduction to the History of Science, Volume 2: From Rabbi ben Ezra to Roger Bacon. Williams and Wilkins, Baltimore, Maryland, USA.

Sarton, G. 1956. Review of Ibn Bassal, Libro de Agricultura. Isis **47**:74–77.

Selin, H., editor. 1997. Encyclopaedia of the history of science, technology, and medicine in non-Western cultures. Kluwer Academic, Dordrecht, The Netherlands.

Setton, K. M., editor. 1969–1989. A history of the Crusades. Second edition. Six volumes. University of Wisconsin Press, Madison, Wisconsin, USA.

Sezgin, F. 1971. Geschichte des Arabischen Schrifttums. Volume 4: Alchimie, Chemie, Botanik, Agrikulture bis ca. 430. H. E. J. Brill, Leiden, The Netherlands.

Sezgin, F. 1987. The contribution of the Arabic-Islamic geographers to the formation of the world map. Institut für Geschichte der Arabisch-Islamischen Wissenschaften an der Johann Wolfgang Goethe-Universität, Frankfurt am Main, Germany.

Al-Shihabi, M., et al. 1967. Filaha, agriculture. Encyclopaedia of Islam **2**:899–910.

Torres, M. P. 1986. Autores y Plantas Andalusies en el "Kitab al-Yami'" de Ibn al-Baytar. Pages 697–712 *in* Actas del XII Congreso de la Union européenne d'Arabisants et d'Islamisants (Málaga, 1984). Madrid, Spain.

Ullmann, M. 1972. Die Natur- und Geheimwissenschaften im Islam. E. J. Brill, Leiden, The Netherlands.

Varisco, D. M. 1994. Medieval agriculture and Islamic science: the Almanac of a Yemeni sultan. University of Washington Press, Seattle, Washington, USA.

Vernet, J. 1970. Ibn al-Baytar al-Malaqi. Dictionary of Scientific Biography **1**:538–539.

Vernet, J. 1976. Ibn Wafid. Dictionary of Scientific Biography **14**:112–113.

Vernet, J., and J. Samsó. 1996. The development of Arabic science in Andalusia. Encyclopedia of the History of Arab Science **1**:243–275.

Frank N. Egerton
Department of History
University of Wisconsin-Parkside
Kenosha, WI 53141
E-mail: frank.egerton@uwp.edu