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Part 4: The Sciences

Chapter 62: Geography

Philosophy in the past ages was not merely an academic subject studied by specialists; it was a living influence which guided men in their ideas about the universe and it included a variety of fields covering theology, law, society, and the sciences. To the Muslims during the Middle Ages philosophy and its various disciplines were all-embracing. Geographic ideas were inseparable from philosophic thinking as they were basic to a widening of horizons. Indeed, interest in geography is as old as recorded human history. This had its roots in ancient folklore, poetry, and travel. The geographical instinct in one form or another developed early among organized human communities, and the people of the ancient civilizations possessed a variety of geographic knowledge.

It is well known to historians that the culture of Greece was preceded by a continuous and composite culture in Western Asia and Egypt and that this culture in its turn was not the product of the genius of any one people, but was shaped by an ever-increasing human intercourse and was the fructification of a long evolution. Thus, Greek geographical ideas too had a basis in the past and in the experience of other peoples. Philosophy and poetry formed the tap-roots of the geographic knowledge of the Greeks. Similarly, in Arab times both Greek ideas and Islamic philosophy and literature were potent factors in the evolution of geographic concepts.

Early Greek contributions to geography were as varied as they were brilliant. Later on, Alexander's campaigns were of the nature of geographical exploration under arms. In the course of time the center of scientific activity shifted to Alexandria. Science and geography continued to flourish in the Greco-Roman age, though under somewhat different cultural atmosphere. In fact, the Greco-Roman culture was subjected to a terrible ordeal. It witnessed one of the greatest intellectual conflicts in history, the clash between Greek ideals and the various oriental religions, chiefly Judaism and Christianity.

But before Christianity could triumph, the great geographer Ptolemy (c. 150 A.D.) had accomplished his

work of coordinating the sum total of geographic knowledge up to his time, though a little earlier Strabo (c. 19 A.D.) had contributed even more brilliantly in terms of geographic analysis. He had also indicated the extent of the knowledge of the Romans about the land and people of Arabia. Describing Gellus' expedition in 25 B. C. to Haura on the Red Sea coast to the borders of Hadramaut, Strabo says that the Emperor Augustus was also influenced by reports of the wealth of the Arabs and their trading activity in spices, aromatics, and precious stones, and that he desired either to befriend or subdue such opulent people.1

By the third century A. D. distinct changes had taken place in the political, cultural, and religious spheres. The Roman Empire came near to utter breakdown. The legions, never too many for the long frontiers and made increasingly heterogeneous by local recruiting, lost their sense of mutual cohesion and failed to check stronger outside attacks. Many emperors rose and fell like ninepins, un-mourned, unsung. Rome was sacked by Goths in 410 A.D. By the middle of the sixth century A. D., Justinian's final efforts at consolidation of the Roman power had failed.

The commencement of the middle Ages is important in the history of science in general and geography in particular. A general retrogression is witnessed and gradually the so-called “Dark Age” of geography set in. It is common to begin the middle Ages from Constantine, but Paganism was tolerated almost until the division of the Roman Empire in 395A.D. The tradition of pagan literature and science, however, continued much longer, at least until Justinian closed the school of Athens.

The triumph of Christianity led its adherents to consider scientific research not only a useless occupation but also a pernicious one. Alexandria had lost its noble place as the center of scientific activity, and Egypt for the Christians had become a land of new wonders as the first home of hermits or desert men or monks; some visitors had no interest in anything else and dismissed the pyramids as mere “Granaries of the Kings.”2 A sailor turned monk took a hand at geographical writing and produced the crankiest of books, the famous Christian Topography, in 547 A.D.

The main purpose of this erudition was to disprove the pagan notion that the earth is a globe. Cosmas hailed from Alexandria and had in his younger days traded in the Red Sea and even beyond. Cosmas' earth was flat, rectangular, and oblong, twice as long from east to west as from north to south, and was surrounded by ocean. A high mountain rose in the north behind which the tiny sun played hide and seek to bring forth days and nights. Beazley rightly called Cosmas' work a “systematic nonsense.” Saint Ambrose saw no profit in investigations about the earth. Science, geography, and all such pursuits were dubbed as magic art. The spherical shape of the earth and the existence of antipodes were favorite subjects of ridicule.

Thus, the geography of the early centuries of the Christian era was a fascinating mixture. Perhaps it seldom represented the full amount of contemporary knowledge and was largely made up of traditional elements, Christian and classical, blended in various proportions. The first came from a literal reading of the Scriptures and other-worldly attitude of the protagonists of the Church. It appears that Christianity

spread first through the urban commercial population round the Mediterranean, whose lingua franca was Greek. It was only later on that it penetrated into the hinterland and overspread into the vast rural areas of outer provinces. Thus, Greek science received a frontal attack in its most important centers. In this refutation of earlier knowledge, interest in science and rational geographic concepts could be retained only by a handful of people in Christendom. Only the Nestorians, the Monophysites, and some of their adherents kept a semblance of Greek science preserved.

During the first/seventh century there arose an epoch-making movement from the depths of the Arabian Peninsula. It was Islam. It brought about the establishment of one of the greatest empires the world has seen. The Arabs conquered a large number of peoples who were superior to them in culture. Nevertheless, the conquerors did not lose their national characteristics and subjected Syria, Mesopotamia, Egypt, and North Africa to their ethnographical influences.

As soon as early conquests were over and cultural contact was established with Greek and Indian knowledge, Muslims became imbued with tremendous curiosity and took up the cause of science with enthusiasm at different centers of their culture. Early Islamic attitude to science was one of tolerance, even enlightened interest. It is evidenced by the continuance of the academy at Jundi-Shaper as a scientific center in the Muslim Empire. Scientists from this center in Persia were welcomed at Damascus, the capital of the Umayyad Caliphate. These men were mostly Christians and Jews.[3]

Further, the Arabs were traders, travelers, and lawyers, and they had somewhat positive minds and, therefore, practical sciences appealed to them. Arabic was suitable for exact and precise sciences and lent itself more easily to the formation of technical terms. Geography especially appealed to them because of its utility to serve the needs of commerce, the division of land, travel through the deserts, knowledge of the plants and animals, and to find the azimuth of Mecca and the phases of the moon.

The Arabs had a traditional interest in matters concerning geographical knowledge. Even before the birth of Christ and after, they were among the foremost traders and navigators of the Arabian Sea, Indian Ocean, and Chinese waters. The Arabic language of that period abounds in words for ships, boats, condition of the sea surface, storms, heavenly bodies, and commodities of exchange and trade. These activities were greatly influenced by the geography of the Arabian Peninsula and its midway position between the East and the West and the littoral situation of all its fertile lands in Yamamah, Oman, Bahrain, the Yemen, etc. Even the Hijaz, though largely arid, lay along the trade-routes from the Arabian and Red Seas to the Mediterranean world.

Pre-Islamic poetry contains references to navigation and sailings, and the Holy Qur'an itself abounds in navigational terminology and descriptions of conditions of the sea and ships and boats used. There was a close relationship between land journeys as well as between sea voyages and the knowledge of stars and other heavenly bodies. The inland Arabs with scanty agriculture and nomadic economy were always face to face with such problems as sources and extent of grazing opportunities, distribution of desert plants and animals, and the nature of geomorphological features. Therefore, Arab interest in geo-

graphical matters was a deep one. It needed various stimuli such as extension of territorial influence, expanded trading opportunities, greater cultural contacts, and a vigorous religious zeal to widen the frontiers of geographic knowledge.[4]

Within a century of the advent of Islam, the Arab victories brought them a rich reward in the conquest of prosperous lands and cultured communities, from the Mediterranean to India and Central Asia. On the one hand, the Arabs became the heirs to the Hellenistic culture for which a way was earlier opened by the conquest of Alexander. On the other, they reached the homeland of Indian culture and Buddhist and Indian thought. It is rightly assumed that the Arabs became the pupils of and successors to the Greeks in science and, through their own efforts and ingenuity perfected it for the future protagonists.

Indian influence in the first instance was the product of a continuing commercial contact via the sea-route from Ujjain, the town of Brahmagupta (c. 6/628), the famous writer of the astronomical manual Brahma Siddhdnta. Muslim conquest of Central Asia brought them into touch with Buddhism and old Greek colonies in the regions of Bactria, Sogdiana, Farghanah, and Merv.

The establishment of the 'Abbaside Caliphate in 132/750A.D. ushered in an age of glory, power, pomp, splendor, culture, and prosperity for the peoples under Muslim rule. Scientific activity took its birth and in this process the inauguration of translation activity in Baghdad, systematically organized under a Translation Bureau (Bait al-Hikmah), was a tremendous step forward. The Bureau had a library and permanent personnel, and translators were commissioned from far and wide. Manuscripts were even paid for their weight in gold. The main aim was to make available in the Arabic language the wisdom and the science of the Greeks and others.

Translations also included works in many sciences by an array of able translators. Among the sciences which received special attention were physics, meteorology, mineralogy, botany, astronomy, and geography. The early phase of translations was concerned more with medical and philosophical works, but later on mathematical, astronomical, and geographical subjects received more attention. The Caliph al-Mamum took active interest in the work of his translators and scientists. Among his great achievements were the measurement of a degree of the earth's arc on the plains of Sinjar, west of Mosul, and the construction of a world map. Both the tasks were of great geographical significance and were accomplished by a team of scientists.

The period of early translations was of great importance to the developing intellectual and scientific life of Muslim society. The Greek writers, who influenced the Arab scholars most were not poets, historians, or orators, but largely the scientists in various fields such as mathematics, astronomy, medicine, philosophy, and geography. For instance, the scientific works of Aristotle received far greater attention than did the writings of Plato and Socrates.

Before the content of Muslim contributions to geography is examined, a few points must be clarified. The birth of scientific activity under Islam has indispensable relevance to Muslim geographic thinking. The

passage of Greek science to the Arabs revealed to them Hellenistic geographic concepts which had received slashing denunciations from orthodox Christian writers. Therefore, the first task of Arab geographers was the revival of the older science.

Muslim geographers held Ptolemy in high regard and greatly valued his monumental work. But he did not escape their criticism, and numerous improvements in his concepts were suggested. Even Ptolemy was not able to combine the mathematical with the descriptive and statistical methods in geography. As regards the latter, Strabo was far more alive and was more critical in his writings than Ptolemy. These traditions were passed on to Arab writers and, therefore, quite a number of Muslim geographers can be categorized under them. But Arab geographers branched out into so many new directions and were so prolific in their output that a somewhat broader classification of their contributions is called for. Muslim interest in geography was stimulated by a variety, of factors such as environmental, religious or spiritual, administrative, political, and commercial.

Muslim military campaigns were well planned and superbly executed and the generals and commanders collected much geographical data before conducting their operations. The organization of administration, collection of revenue, and appraisal of resources of the newly conquered territories required detailed geographical information. It is said that the great Caliph 'Umar, hearing of the conquest of new lands, asked a scholar to describe to him the lands of the earth, their climates and positions, and the influence which land and climate exert upon their inhabitants.[5] Both scholars and religious leaders considered geography a laudable pursuit, as is borne out by the remark of Yaquit that as a science geography was pleasing in the eyes of God. Even the orthodox al-Ghazali believed that the votaries of science will find the road to paradise easy. Muslim religious interest in the determination of latitude and longitude of places and in the diurnal movement of the sun was indispensable both in connection with the time for daily prayers and the geographical co-ordinates of Mecca. With the expansion of the dominions of the Muslim Empire, commercial activity increased and geographical information of different types became vital for its growth and development.

Regional geography received early attention and contained an enormous wealth of details and information. It developed its own traditions, and the variety in approach to it and the ingenuity of the individual geographers make many contributions to it a fascinating reading. The writings of notable travelers, the specialist studies of the topographers, and the critical works of the sociogeographers lend an immense variety and color to Muslim geography. Therefore, it may be convenient to examine the Muslim contribution to geography under the following headings:

(A) General and Regional Geography.

(B) General Treatises and Scientific Geography.

(C) Mathematical Geography.

(D) Cartography and Map-making.

A – General And Regional Geography

Muslim interest in general geographical writing developed early. This class of geographical writing has a wide range and includes some of the earliest contributions in this field. General geographical descriptions of the Muslim world were a favorite theme and in view of the needs of administration and extension of the postal services many works were written as “Route Books.” Diaries and travel accounts were yet another category of geographical writing. As a result of the unsatisfactory basis of descriptions in relation to hypothetical “Climatic Divisions” in parallel latitudinal strips (a Greek legacy) many Muslim geographers felt the necessity of describing the dominions of Islam on the basis of regions of which they possessed more specific knowledge. It may be said to be the beginning of a regional consciousness.

Among the earliest known works dealing with geographical matters are those of 'Abd al–Malik ibn Quraib al–Asma'i and Hisham ibn Muhammad al–Kalbi. Al–Asma`i of Basrah (123–216/740–831) wrote on plants, animals, and the evolution of human society. Al–Kalbi (d. 205/820) was an authority on the history of pre–Islamic Arabia and it is said that his work Kitab al–Nawadir [6]contained observations on many geographical topics. Similarly, one of the early treatises on agriculture was ibn Wahshiyyah's (c.288/900) book on Nabataean agriculture. Abu Yusuf Ya`qub al–Kindi (c. 260/873–874), though primarily a philosopher and physicist, wrote a geographical work called Rasm al–Ma`mar min al–Ard (Description of the Inhabited Part of the Earth).

But the work of Muhammad ibn Musa al–Khwarizmi (d. 236/850) laid the foundation of Arab geographical science. By writing Kitdab surat al–Ard (Treatise on the Face of the Earth) he syncretized Greek and Hindu knowledge. He was a mathematician of great repute and is said to have collaborated in the degree measurements ordered by Caliph al–Mamun. He improved Ptolemy's geography, both as regards the text and the maps. His scientific attainments are universally acknowledged by the Orientalists. Another early geographical work which was concerned with Arabia was that of Arram ibn al–Asbaj al––Sulami (c. 231/845) who wrote Kitab Asma' Jibal Tihamah wa Makaniha dealing with the mountains of Tihamah in Arabia. This work was mentioned by al–Sirafi, and another book by the same author bearing the title Jazirat al–'Arab was mentioned by Yaqut in his “Dictionary of Learned Men” (Mu`jam at–Udabu') [7]

1. The Route Books

After the early geographical writings mentioned above had appeared and the initial phase of translations had come to an end, an interesting class of geographical literature was produced which is contained in the so–called “Route Books” (Kutub al–Masalik w–al–Mamalik). Quite a tradition developed in the writing of these route books and many later authors copied the technique of the earlier masters. In this respect, ibn Khurdadhbih (c. 300/912) blazed a new trail with his famous Kitdab al–Masalik wa–al–Mamalik (A Book on Routes and Kingdoms). He provided an excellent summary of the main trade routes of the Arab world and also wrote descriptions of China, Korea, and Japan. The work served almost as a source for

later writers. Unfortunately, only an abridged version of the book is extant.

Al-Marwazi (d. 274/887) also wrote a route book which was mentioned by ibn al-Nadim and Ya'qub. Sarakhsi (d.286/899), who was a pupil of al-Kindi, gave the same title to his geographical work and abu al-Faraj al-Baghdadi (d. 310/922) compiled Kitab al-Kharaj (Revenue Book) dealing with land tax and postal services in the context of the geography of the Arab Empire. Al-Jaihani (fl. c. 280-295/893907), the learned minister at the Samanid Court, wrote another revenue book replete with geographical explanations, and it is surmised[8] that it was one of the source materials for al-Idrisi. Abu Zaid al-Balkhi (d. 322/933) produced another route book along the traditional lines, but his real fame as a geographer rests on his somewhat more scientific contribution, namely, Kitab al-Ashkal or Suwar al-Aqalim (Figures of the Climates).

Al-Istakhri (fl. c. 339/950) followed in the footsteps of his senior contemporary al-Balkhi by writing a similar book and using the technique of explaining maps by the accompanying text. Ibn Haugal revised and rewrote Istakhri's book with considerable additional information in 367/977. These three geographers form an important group who combined their writings of descriptive geography with cartographic work and scientific analysis and, therefore, this category of their work will receive mention later on.

In Spain, al-Bakri (d. 487/1094) of Cordova used the same technique and method to write his route book and geographical dictionary notable for their useful information about Europe and North Africa.

2. Books of Countries and Dictionaries

The route books were written from an administrative angle but they invariably developed into geographical treatises. They were generally concrete, accurate, and detailed.[9] Closely related to the route books, yet enlarging on their scope and subject-matter, were the large number of "Books of Countries" and geographical dictionaries and gazetteers. Among the early writers of such tracts and a notable Arab geographer and historian was al-Ya'qubi who wrote Kitab al-Buldan (Book of Countries) in 278/891, giving a wide range of topographical and economic details and occasionally bringing out the relationship between physical factors and human activity.

Topographical details about the cities of Kifah, Baghdad, Samarrah, and Basrah and regional descriptions of many areas in Arabia, Syria, Egypt, Nubia, and North Africa, are some of the outstanding features of this book. His pioneer work as a geographer deserves high praise, and it is not surprising that modern European writers often call him the father of Muslim geography. Shortly before Ya'qubi an outstanding historical work with many geographical observations had been written by al-Baladhuri (in 256/869) under the title Futuh al-Buldan (Conquests of Countries). This work typifies Muslim interest in the history and geography of the newly acquired territories. Al-Hamadani's "Book of Countries" written in 290/902 was utilized by notable geographers like Mas'ndi and Yaqut; unfortunately, it is lost. A contemporary of al-Hamadani was ibn Rustah (fl. c. 291/903); his encyclopedia al-A'laq al-Nafisah dealt with geographical matters in its seventh volume. He discussed a variety of topics including the extent of

the earth, seas, rivers, climate, founding of Mecca and Medina, and the regional geography of Iran.

Ibn Rustah's account of the road system of the empire and particularly of the great Khurasan road remains outstanding for its clear details and geographic implications. A few years later ibn al-Ha'ik (d. 334/945) presented his regional geography of Arabia in Kitab Jazirat al-'Arab dealing with physical features, minerals, races, tribes, and settlements. He also contributed a semi-geographical work al-Ikhil on the archaeological aspects of the Yemen. Muhallabi (375/985) was the author of an outstanding geographical work dealing with the Sudan. It was the first work of its kind for this remote region and formed Yaqut's main source for the geography of the Sudan.

An interesting geographical work of the fourth/tenth century written in Persian was entitled Hudud al-'Alam (c. 372/982) by an unknown author. It is meant to be a world geography on a regional basis and was probably written as a preface to a map. Minorsky has produced an excellently edited and annotated version of this notable work.[10]

The western wing of Islam in Spain also produced many contemporary geographers who wrote route books, books of countries, and works of regional descriptions. Al-Tariqi (d. 363/973) wrote on North Africa. Al-Bakri of Cordova (d.487/1094) was a celebrated geographer who compiled a geographical dictionary, Mu'jam ma Ista'jam as well as a route book. These works incorporate fresh material on Central and Eastern Europe and North Africa. Al-Zuhri of Granada (c.532/1137) was the writer of a notable work, Kitab al-Jaghrafia (Book of Geography). It appears that al-Zuhri was able to utilize the work of the team of geographers of the reign of Caliph al-Mamun. Al-Munajjim (d. 456/1068) was the compiler of a geographical dictionary which both al-Idrisi and ibn Khaldun mention as one of their source materials. And there were many lesser lights who followed these masters in compilation.

But the art of depicting geographical and associated information in the form of a dictionary attained its highest form from the pen of Ya'qub Hamawi. His work was done almost at the crossroads of history, shortly before the Tartar invasion engulfed the eastern lands of Islam. After considerable travel in his younger days and study in several libraries, he produced his monumental geographical dictionary known as Mu'jam al-Buldun in 621/1224. This great work contains a geographical gazetteer, a regional world geography, and much topographical, historical, and archaeological information. It deals with geography in the broadest manner. His other well-known work Mu'jam al Udaba', dealing with lives of learned men, is also replete with geographical information. Yaqut utilized a variety of sources including many of those which are now extinct. His dictionary 'contains a treatise dealing with geography in general from many points of view.

3. Diaries and Travel Accounts

Travel has always been the easiest and the most natural means of acquiring and propagating geographic knowledge. In the medieval period of Islam travel was promoted in many ways. Religio-cultural affiliations with far-flung parts of the world, curiosity, commercial enterprise, and above all the

urge for pilgrimage excited widespread interest in travel. Thus, Muslim travel literature in the shape of diaries and descriptions and experiences of journeys contains a treasure-house of geographical information.

For Muslims, the pilgrimage to Mecca was not a matter of choice; it was their positive 1luty within the limits of possibility to undertake it. Mecca was the ever-present magnet to attract their thoughts and thus there ran into Arabia a constant stream of visitors from all parts of the Islamic world. The hay)' every year was a unique international assemblage by which people from distant lands, diverse environments, and varied experiences exchanged ideas and acquired knowledge of countries and inhabitants of the world. It was a tremendous incentive to the spread of geographical knowledge.

With the spread of Islam and the extension of its political influence, trade and commerce greatly expanded resulting in the knowledge of new lands. In the Euro-Asian continent these regions were the Volga-Caspian, Northern Europe, and Siberia on the one hand and Central and South-East Asia on the other. The African continent received far more attention from the Muslims than from their predecessors. The East African coast up to Madagascar, Egypt, Nubia, Abyssinia, the Sudan, Equatorial Africa, the Sahara, land of the Niger, and West Africa, all came within the range of their commercial, cultural, and religious activities.

Travel and commerce walked hand in hand. Each geographical discovery created new commercial opportunities, and these, with attendant competition and inherent ambitions, led to more travel and discoveries. At a later period the Crusades, besides their sordid side, provided for generations a great and prolonged avenue for contact between the East and the West for exchange of ideas and cultural assimilation. Trade, commerce, and travel were promoted and helped the circulation of geographical information.

Ibn Fadlan went as an envoy of Caliph al-Muqtadir to the Court of the Volga Bulghar in 309/921 and is credited with the first reliable account of Russia. He may, in fact, be regarded as one of the earliest Muslim traveler-geographers. His Risalah or diary is of great geographic significance. His description is the earliest reliable account of Russia and was incorporated into the works of many later geographers including Yaqut.[11] Another experienced early traveler was abu Dulaf who hailed from Yanbu' near Medina. He combined poetic talents with a wander-lust. After a stay at the Samanid Court at Bukhara, he went to South India across Tibet with a returning Indian embassy and the journey back was made via Kashmir, Afghanistan, and Sijistan (c. 331/942). His narrative of journeys was entitled `Aja'ib alBuldun (Marvels of Countries). Abu Dulaf's geographical impressions of the Indo-Pakistan sub-continent and the adjoining areas were utilized by Yaqut and Qazwini. Among early Muslim travelers, al-Idrisi mentioned Sallam who visited the region north of the Caspian Sea, Armenia, Georgia, land of the Khazars, and the Ural and Altai areas in the middle of the third/ninth century at the command of Caliph al-Wathiq.[12]

With increasing Muslim influence in Indian littoral areas and expanding commerce in South-East Asian

waters and on the Chinese mainland, more detailed and somewhat accurate geographical information was in demand. The busiest and flourishing ports on the Arabian coast and Persian Gulf were Aden, Oman, Suhar, Jeddah, Siraf, and Basrah. Their commerce and overseas relations were mainly with East Africa, Indian coasts, South-East Asia, and China. Siraf especially occupied a pre-eminent position and grew into a port-city of merchants, princes, and experienced sailors.

One of the early writings on trade and commerce and navigational matters in these regions was that on the journeys of Sulaiman the Merchant by an anonymous author (237/851) with the additional comments on it by abu Zaid al-Sirafi. The work gives us information with regard to duration of the journey, its various stages, ports of call, nature of commodity exchange, wind and weather, and conditions of the seas. The descriptions display an excellent geographical sense and an understanding of physical and human aspects. Sulaiman's description of the Chinese mainland, its products and economic resources is realistic. He also mentions the Chinese use of tea. Interest in the Indian Ocean and its bordering lands continued for generations and Muslim sailors and travelers wrote on many topics which encompass geography.

Abu Zaid al-Hasan of Siraf edited accounts of Muslim travelers and sailors in c. 308/920 in order to supplement Sulaiman's narratives. According to him, ibn Wahb travelled to China in 257/870 and there were other voyages in that direction. Abu Zaid's compilation was probably entitled Akhbar al-Sin w-al-Hind (Information about China and India). It may be said to be the most important work of its kind before that of Marco Polo or of ibn Battutah. Besides the Far East, it deals with the Arabian and the East African coasts. From such voyages and confirming somewhat earlier traditions also, gradually developed the stories and fascinating fables around the name of “Sindbad the Sailor” found in the All Lailah wa-Lailah. Another writer about the trade, commerce, navigation, peoples, and products of the Indian Ocean area from Arabia to Ceylon and beyond was Buzurg ibn Shahryar who compiled the interesting book `Aja'ib al-Hind [13] (Wonders of India) in about 342/953-954.

The famous “sea lions” (expert writers on nautical instructions), mentioned by Ahmad ibn Majid in the second half of the ninth/fifteenth century, were not mere expert navigators, but also writers on sea voyages and route books. Muhammad ibn Shadhan and Sahl ibn Aban belonged to the fifth/eleventh and sixth/twelfth centuries. Perhaps there were many more such writers; at any rate, later on, their successors were Ahmad ibn Majid (895/1489), Sulaiman al-Mahri (early tenth/sixteenth century), Piri Rais, Sidi 'Ali, and al-Sifaqsi (959/1551) who displayed a remarkable knowledge of the geography of the Indian Ocean.

The scene in the Mediterranean was somewhat different to that in the Indian Ocean. In the latter, trade, commerce, and adventure were the impelling factors in Muslim enterprise, but in the former prolonged political struggle, religious wars, commerce, and pilgrimages were motivating features behind sailings and voyages. There is record,[14] however, of the close co-operation between Muslims and Christians in the formation of joint partnerships and of commercial treaties, carriage of passengers in ships

irrespective of their religion, and the transport of products of skilled industry and luxury goods from the Islamic world to Europe.[15]

Before mention is made of the well-known traveler-geographers in the western lands of Islam, those in the east deserve attention. Among these intelligent globe-trotters and geographers, al-'Mas`udi (d. 346/957) deserves pride of place. He was born in Baghdad towards the end of the third/ninth century. Mas`udi acquired his knowledge through painstaking study of the existing sources as well as through extensive travels. His travels carried him to many parts of Arabia, Levantine coast, Caspian shores, Asia Minor, Iran, Iraq, India, South-East Asia, East African coasts, and Egypt. He met common men possessing practical knowledge and scholars of repute. Mas'udi's acute observations and views depicting a keen geographical sense are contained in his famous book, Muruj al-Dhahab wa Ma'ddin al-Jawahir (Meadows of Gold and Mines of Precious Stones), a historic-geographical encyclopedia written in about 336/947 and revised ten years later.

It seems to be an age of great travelers, as not many years later ibn Hauqal (fl. c. 332-367/943-977) completed a travel of thirty years which excited his interest in geography. His meeting with the celebrated geographer al-Istakhri was significant, as at the latter's request he re-wrote his geography and revised the accompanying maps. Ibn Hauqgal called this improved version, Kitab al-Masulik w-al-Mamalik (Book of Roads and Provinces), and added maps of each country to this remarkable treatise. .

Yet another outstanding geographer and traveler was al-Maqdisi or al-Muqaddisi, a native of Jerusalem. He travelled through many Islamic lands except perhaps Spain, Sijistan, and Sind. By all standards he was a careful observer and had an inborn geographical sense. On the culmination of his travels he wrote his famous geography Ahsan al-Taqasim fi Ma'rifat al-Aqulim (Best of Divisions as Regards Climates) at Shiraz in Fars in 375-376/985-986. His writings reveal much original information and are an attempt at analysis of physical and human factors. His sources include several earlier geographers like Khurdadhbih, Jaihani, Balkhi, Hamadani, and Jabiz. But he subjects his authorities to considerable criticism.

The tradition of travel and that as a medium for geographical work continued. One of the junior contemporaries of al-Biruni was Nasir Khusrau from Balkh, where he was born in 394/1003. Starting his travels from Egypt, he visited a large part of the Middle East including the Hijaz, Palestine, Syria, and Iran. Earlier, he had travelled in India[16] and lived at the Court of Sultan Mahmud. His travel diary, the famous Safar-Nameh, was written in Persian. He gives the best account of Jerusalem before the Crusades, and his description of Egypt is of high geographic value. Shaikh 'Ali al-Harawi (d. 611/1214) wrote a travel book dealing not only with the frequented places of pilgrimage in the eastern part of the Islamic world, but also of Byzantine Empire, North Africa, and Abyssinia. He was in Jerusalem in 569/1173 when it was in Christian hands. He visited the Christian parts of the world on several occasions.

The western world of Islam produced several traveler-geographers who also made journeys to the east

to perform the pilgrimage to Mecca. Al-Mazini al-Andalusi (d. 565/1169) was an intrepid traveler who came from Granada and journeyed through Spain, North Africa, Egypt, Iraq, Khurasan, and Russia. He travelled in the Volga region and in Hungary and gave information unobtainable elsewhere, such as the Russian trade in fossil bones or ivory.[17]He was the writer of at least four important geographical works.[18]

Another celebrated geographer ibn Jubair of Valencia (d. 625/1217) wrote a valuable account of his journey to the east. His accounts throw an interesting light on the geography as well as the commercial activity and culture of the Muslim communities of the Mediterranean lands. Ibn Jubair's writings were a source book for many later Muslim geographers and historians. His Rihkah (Travel Account) remains one of the best works of its kind in Arabic literature.[19] Ibn Jubair's fellow townsman al-'Abdari (fl. c. 688/1289) commenced a memorable journey to accomplish the pilgrimage.

Starting from Mogadore on the West African coast of Morocco he made the journey both ways by land and thus crossed North Africa twice. His travel geography al-Rihlah al-Maghribiyah contains valuable topographical information.[20] Al-Mausili wrote 'Uyun al-Akhbar (a book of travels) at Ceuta after his travels through Syria, Palestine, and Egypt during 537-585/1142-1189.

Though al-Idrisi was an all-round geographer and his proper place is among the writers of scientific geography, his travels were an indispensable part of his geographic experience. He was born at Ceuta in 493/1099 and educated at Cordova. His travels covered a vast compass stretching from Muslim Spain and North Africa to Christian Europe as well as other parts of the Islamic world. Rich in experience and mature in his outlook, al-Idrisi settled down at Palermo in Sicily at the Court of his worthy patron King Roger II. He died in 562/1166. His famous geography Nuzhat al-Mushtaq fi Ikhtiraq al-Afaq (known as al-Kitab al-Rujari), written shortly before 549/ 1154 is the most elaborate description of the world of medieval times. According to Sarton[21], al-Idrisi was the author of another geographical work entitled Raud al-Uns wa Nuzhat al-Nafs (Pleasure of Men and Delight of Soul), a kind of a route book which the author compiled for William I, King of Sicily, in 557/1161. This geographical work was said to be larger than the Kitab al-Rujari but unfortunately it has been entirely lost.

Abu al-'Abbas al-Nabati of Seville and his pupil ibn al-Baitar of Malaga were biographers and they travelled in Spain, North Africa, and along the shores of Red Sea with the purpose of scientific exploration in connection with their work.

Ibn Said al-Maghribi was another indefatigable traveler, profoundly interested in geography. He was born near Granada in 611/1214 and died in Damascus in 674/1275. His Kitab al-Jaghrafiya embodies the experience of his extensive travels in the Muslim world, and the geographical information and views in it added to al-Idrisi's knowledge. He also gives an account of parts of northern Europe including Iceland. Ibn Said visited Armenia also and was at the Court of Hulagu from 654/1256 to 664/1265.

Half a century later, in 704/1304, was born ibn Battutah, one of the outstanding travelers of all times.

Starting from his home town, Tangier, in 726/1325, when he was barely twenty-two years old, he travelled in Africa, Asia, and Europe for thirty years. His journeys included several pilgrimages to Mecca and travel to and residence in many parts of the Middle East, India, Ceylon, Maldives, Bengal, China, North Africa, Spain, and the lands of the Niger. The extent of his wanderings is estimated at about 75,000 miles[22] without allowing for deviations, a figure which surpasses Marco Polo's travels. Ibn Battutah's dictated accounts of his experience to ibn Juzaiy at the Court of Sultan abu 'Inan at Fez constitute his Rihlah (Travels). The book contains references to the economic and human geography of the areas visited, trade, commerce, ports, navigation, and numerous physical facts with occasional analysis of causes and effects. His memory was astounding and geographical sense remarkable. Ibn Battutah died in Fez in 779/1377. In the western world of Islam, the tradition of travel leading to geographic writings was handed down to ibn Khaldun who was born in Tunis in 733/1332 and died in 809/ 1406. Much of his well-known writings as a geographer, historian, and sociologist was based on his travels in Spain and North Africa. The scientific significance of his "Introduction to Universal History" (Kitab al-'Ibar) will be discussed later.

In the East, Muslim travel-cum-geographical accounts from the eighth/ fourteenth century to the tenth/sixteenth century are represented by Hafiz Abru, `Abd al-Razzaq Samarqandi, abu al-Fadl'Allami, and Amin Ahmad Razi of Rayy. Hafiz Abru wrote his regional geography in Persian, entitled Zubdat al-Tawarikh, which was modelled on the earlier Arabic classical style. Barthold[23] has a high opinion of the material in it relating to the author's time. 'Abd al-Razzaq was born in Herat in 816/1413 and died there in 887/1482. He travelled to India and enjoyed a diplomatic career; on his return he wrote an excellent diary Mafia' al-Sa'dain wa Majma' al-Bahrain in Persian. In the generations that followed the advent of the Europeans into the Indian Ocean, Muslim interest in geography and travel was not dimmed. Abu al-Fadl, born at Agra in 958/1551, was a leading light at the Court of Akbar the Great. His A'in-i Akbari written in Persian remains an outstanding geographic contribution of his age, a parallel to which is hard to find in the contemporary West.[24] Amin Akimad Razi of Rayy visited India in Akbar's time and later in 1002/ 1593 produced his Halt Iqlim (Seven Climates), an exhaustive geographical dictionary in Persian. Another contemporary author who wrote at Damascus in 1007/1598 on the basis of personal travels was al-'Ashiq, the writer of Manazir al-'Alan (Description of the World).

B – General Treatises And Scientific Geography

The climax of Muslim geographical contribution is represented by the formulation of geographical theories and the compilation of treatises in which attempts were often made to assemble facts and put forward theories. Indeed, their level and scientific value are unequal; none the less, the attempts as such are interesting and praiseworthy. The later half of the fourth/tenth century was productive of many such efforts and it would not be too much to assert that such abundant activity in science and geography had never occurred before, not even in the best days of Alexandria. The "Keys of the Sciences" (Mafatih al-'Ulum) of al-Khwarizmi, the "Encyclopedia" (Fihrist) of ibn al-Nadim and the "Tracts of the Brethren of Purity" (Rasa'il Ikhwan al-,safa) remain the monumental examples of these efforts.

Throughout the ages arm-chair geographers have made mistakes which have been easily recognized by practical men. Ptolemy was no exception and so were many Arab literary geographers, but, on the other hand, many Muslim geographers, rich in their personal experience and deep in learning, pointed out flaws in the works of their predecessors. Mas'udi,[25] for example, is well known for such criticism as sprang from his universal outlook, and al-Biruni, Maqdisi, abu al-Fida', and others expressed opinions contrary to established notions.

In their geographical writings, new methods were evolved and new shape was given to traditional treatment. The arbitrary division of the then known world on the basis of "climates" originated by the Greeks was quite often copied by Muslim geographers. But the careful and discerning ones like al-Istakhri, al-Balkhi, Maqdisi, and several others found this method unsatisfactory and somewhat confusing and felt that these divisions in geometrical strips, more or less along the latitudes, were without consideration of the geographical factors. The need of some other method of treatment was realized.

Al-Istakhri initiated a regional approach to his descriptive geography by selecting either geographical units or political divisions closely corresponding them. His own words explain his technique:[26] "I do not take the 'seven climates' as a basis for the division of the earth because the geometrical shapes, even though correct intrinsically, lead to great confusion; so I have resorted to the study of the earth country wise." In fact, most of the leading Muslim geographers of the fourth/tenth century on the basis of their writings would have done credit to any period.

Arab regional geography developed a tradition of its own by describing the physical environment of an area as well as its people and their cultural and social activities, though sometimes the treatment of cultural matters led to rather deterministic generalizations, reflecting on people's characters and peculiarities. Surprisingly enough, many modern geographers, historians, and sociologists are not immune from this weakness; they often build their cultural theories on foundations of sand. The method and technique of geographic descriptions of diverse lands evolved by al-Istakhri, ibn Hauqal, al-Maqdisi, al-Mas'udi, and others was later adopted by al-Qazwini, abu al-Fida', and ibn Khaldun, especially the last named who, by his analysis and interpretation, anticipated modern sociology and human geography.

A few examples of scientific geographical writing deserve mention. The tracts produced by the Ikhwan al-Safa (Brethren of Purity) had considerable geographical information and views. Theirs was a rationalist approach to many problems. Their secret association was founded at Basrah in about 373/983. This encyclopedic effort by several anonymous writers, many of whom were interested in scientific geography, is noteworthy. Their treatises include numerous references to the then current geographical conceptions and attempt to explain them for popular understanding. Among their physical treatises meteorology receives much attention, and explanations are offered for the occurrence of rain, the march of seasons, and layers of the atmosphere[27] Geological processes are explained and attention is devoted to weathering and denudation. Plant-geography, distribution of animals, and a general

consideration of ecological conditions does not escape their notice.[28]

The influence of physical environment on human activity and animal behavior and their relationship with health and material well-being were subjected to somewhat critical analysis by several fourth/tenth-century writers on geography. Al-Jahiz (d. 254/868) of Basrah had a real interest in the natural and anthropological sciences. In his "Book of Animals" (Kitab alhayawan), besides writing on a variety of subjects, he interestingly tackled questions of evolution, struggle for existence, and adaptation. Abu Zaid al Balkhi writing in 309/921 was a maker as well as an interpreter of maps. His remarkable work Suwar al-Aqalim (Figures of Climates) was a critical study based on maps. A few years later Mas'udi (d. 345/956) used his vast experience and critical abilities remarkably well in dealing with geographical matters. Mas'udi has often been designated[29] as the Muslim Pliny, but he displayed far greater critical ability and scientific curiosity[30] than Pliny in his description of earthquakes, waters of the Dead Sea, geological phenomena, navigational problems, and ebb and flow of tides.

He also made the first mention of wind power and windmills in Sijistan. Another work of al-Mas'udi's, Kitab al-Tanbih w-al-Ishraf (Book of Indication and Revision), sets forth his views on evolution. Akhbar al-Zaman contains discussion on the origin of seas, cycle of river erosion, etc. Al-Maqdisi (375/985) was yet another scientifically minded geographer who derided the arm-chair conceptions of some of his great predecessors[31] and took upon himself the task of writing a geography of the Islamic world based on travel and observation. The result was one of the finest geographical treatments of regions and provinces of the Muslim domains in medieval Arabic literature.[32] He stressed the point that geography was a subject of great usefulness and was, therefore, of interest to people in all walks of life. "The Model City" (al-Madinal al-Fadikah) of al-Farabi (d. 339/950) is a fine sociological study of urban conditions of his time in which he envisages better future town-planning.

Ibn Sina (370-428/980-1037) expressed views and expounded ideas on almost all subjects with equal clarity. He made a profound study of various physical questions. His views on the origin of mountains and valleys have a flare of modern concepts and his treatise on minerals remained one of the chief sources of geological knowledge in Western Europe until the Renaissance. Ibn Sina's al-Urjuzat al-Sina'iyyah (Cantica) displayed an excellent understanding of human and environmental factors. But ibn Sina's contemporary abu Raihan al-Biruni (363-440/973-1048) who has his place among world scientists of all times was a traveler, philosopher, mathematician, astronomer, geographer, and encyclopedist.

Sarton rightly remarks[33] that his critical spirit, toleration, love of truth, and intellectual courage were almost without parallel in medieval times. His works were written in Arabic, partly in Khwarizm, the town of his birth, and largely in Ghazni and India where he spent the rest of his life. Through the patronage of Sultan Mahmud and his two successors Mas'ud and Maudud he was able to visit India, learn Sanskrit, and acquire knowledge of Indian sciences. His Kitab al-hind (Book of India), written in 421-22/1030, provides numerous instances of his geographical concepts covering such matters as the origin of the

plains of Northern India, nature of rainfall, commercial activity, roads, frontiers, and boundaries.[34]

Among his many other writings the “Chronology of Ancient Nations” (al–Athar al–Baqiyah) was written at Khwarizm in 391/1000, “Canon Masudicus” (alQdnun al–Mas'iidi) at Ihazni in 421/1030, and the “Book on Mathematics” (Kitab al–Talhim) like the one on stones [35](Kitab al–Jamahir fi al–Ma'rifat al–Jawahir) towards the later years of his life, during the reign of Sultan Maudud. Al–Biruni was truly a scientific geographer and discussed all matters from a critical point of view.[36]

Yet another contemporary was ibn Sa'id al–Qartabi al–Andalusi (420–463/–1070) who lived and worked in Toledo. Though he was a leading astronomer and historian, he tackled geographical problems scientifically. His Tabaqat al– Umam paid special attention to the history of science. The ethnographical and sociological views expressed by him in this work were based on environmental considerations. A few generations later, al–Idrisi, with a background of Andalusian education, extensive travels, and cultural contact with Christendom, produced his elaborate geographical works. His work can be said to be the most notable example of the fusion of ancient, Arab, and medieval geography. He was critical of Ptolemy's ideas. Ibn Jami described Alexandria and discussed its climate.

'Abd al–Latif's book on Egypt may be considered to be one of the most important topographical works of the Middle Ages. In this work attempts at analysis on the basis of known facts and theories are discernible though they are not necessarily geographical. A1–Zamakhshari's (d. 539/1144) Kitab al–Amkinah w–al–Jibal w–al–Miyah was a worthy geographical dictionary. Ibn Sa'id al–Maghribi s main work was a geographical treatise entitled Kitab al–Jaghrafiya. Though it was based upon Ptolemy and al–Idrisi, it contained many facts which had been discovered since then and included the geographical co–ordinates of every important place. His extensive travels and long residence in the east and later the patronage of Hulagu gave him the opportunity to become a connecting link between his predecessors and the mathematical geographers led by Nasir al–Din al–Tusi at Maraghah. Some of his ideas were derived from al–Hasan al–Marrakushi (627/1229).

A notable writer of scientific geography was Zakariya al–Qazwini (600–682/ 1203–1283). He is noted for his two works,[37] namely, 'Aja'ib al–Makhluqat wa Ghara'ib al–Maujudat (Cosmography, or Marvels of Created Things) and 'Aja'ib al–Buldan (Marvels of Countries). A later enlarged edition of his geography was called Athar al–Bilad. Qazwini's works exerted a deep influence upon the Arabic–speaking people as well as on those reading Persian and Turkish. Muhammad ibn Mahmud al–Tusi also wrote a cosmography in Persian. A notable treatise on commercial geography was written by 'Abd al–Rahman ibn Nasr under the title Nihayat al–Rutbat al–Zarifah.

In the seventh/thirteenth century, abu al–Fida' al–Ayyubi (b. 672/1273) was an outstanding geographer who had thoroughly assimilated the earlier geographical contributions, especially those of Ptolemy, al–Idrisi, and ibn Said. His main geographical work Taqwim al–Buldan displays extensive knowledge and balance in the selection of information. Abu al–Fida's geographical work has earned high recognition among modern European geographers.[38] The geographical work of Hamd Allah Mustaufi, Nuzhat al–

Qulub, written in 741/ 1340 in Persian is a comprehensive geography of the Islamic world. Iran and Central Asia receive special treatment, changes in the course of the Oxus are mentioned, and descriptions are given of the hot springs and oil-wells of Baku and the islands of South-East Asia.[39] His historical work, Tarikh-i Guzideh (Select History) also contains useful geographical interpretations. A contemporary of Mustaufi was al-Dimashqi (d. 728/1327). His cosmographical work, Nukhbat al-Dahr fi 'Aja'ib al-Barr w-al-Bahr, was in the traditional style, but is remarkable for its knowledge about the Coromandal Coast of South India.[40]

Ibn Khaldun's "Universal History" (Kitab al-'Ibar) with its masterly Prolegomena raised the art of geographic interpretation to new heights and made him the forerunner of modern human geography and sociology. He not only wrote a critical history but combined ethnography and geography with it.[41] Ibn Khaldun recognized different types of habitats and explained the influence of environment on human development. He marked the rise and growth of cities and noted examples of bad siting leading to rapid decay.[42] He also gave a critical appraisal of the industrial and agricultural resources of Andalusia.

Though the ninth/fifteenth and the tenth/sixteenth centuries witnessed epoch-making geographical discoveries and the frontiers of knowledge of the European people were rapidly widened, yet the scientific traditions of Muslim geography did not cease abruptly. The Turkish school of geography achieved much by way of prolific writing as well as scientific treatment. Some of these works are al-'Ashiq's Manazir al-'Alam (Descriptions of the World) written at Damascus in 1007/1598, Haji Khalifah's encyclopedia, Kashf al-Zunun, and Auliya Chelebi's travel book, Tarikh-i Saiyah. Before an evaluation of Muslim geographical conceptions is made and its influence on European mind and thought briefly indicated, two other aspects of their work may be briefly outlined, namely, mathematical geography, and map-making and cartography.

C - Mathematical Geography

Muslim astronomical and mathematical work extends over several centuries and is enormous in its content and commendable in quality. Here only a brief outline is presented in so far as it concerns geographical matters, i.e., latitudes, longitudes, eclipses, and tides; shape, size, and the movements of the earth; and the general mathematical implications in geodetic work.

Historically, Muslims devoted early attention to astronomy and mathematics; the first period of translations led to contributions in these fields. Eventually certain centers and areas developed strong traditions of their own. For example, Baghdad in particular and Iraq in general got an early start in this respect. But later on, with the decline in the influence and prestige of Baghdad, many other parts of the eastern world of Islam became centers of mathematical work and its application in associated fields. The Ghaznawids, Buwaihids, and Mongol princes patronized these sciences. Similarly, works and traditions in North Africa from Egypt to Maghrib and in Andalusia achieved their own characteristics.

The Indian, Iranian, and Greek influences played their part in stimulating early attempts. Al-Fazari's

Kitab al-Zij (Tables) reflects strong Indian influence. The first series of regular observations with accurate instruments were conducted at Jundi-Shahpar during the first half of the third/ninth century and were utilized by Ahmad al-Nahawandi and others. Ya'qub al-Kindi's works and those of others such as Yahya ibn Mansur, Sanad ibn 'Ali, and al-Marwarzuri were concerned with the preparation of astronomical tables. Earlier, Ptolemy's Almagest had also been translated by al-Nairizi.

But the outstanding event in the field of mathematical geography was the measurement of a degree, under the orders of Caliph al-Mamun, to determine the size of the earth, in latitude 36° north.[43] An observatory was built on the plain of Tadmur (Palmyra) for geodetic as well as astronomical work. On the Caliph's instructions two degree measurements were made near Tadmur and Raqqah under the supervision of the sons of Musa ibn Shakir. The result of these two measurements was the calculation of the earth's circumference as 20,400 miles and the diameter 6,500 miles[44] respectively.

A large map of the world was also drawn. The three sons of Musa ibn Shakir, besides being men of means, were practical scientists. One of their books was concerned with the measurement of the sphere and the trisection of the angle. Besides al-Khwarizmi and al-Kindi, the great astronomer abu Ma'shar of Balkh (d. c. 272/836) was especially interested in celestial phenomena. Al-Mahani (fl. 240-254/854-868) studied the eclipses of the sun and the moon and also the conjunction of the planets.

In later generations, particularly under the patronage of the Buwaihid Court, a great deal of astronomical and mathematical work was done and the making of observations with better designed and perfected instruments became common. A glorious period in this respect was the time of 'Adud al-Daulah and Sharaf al-Daulah, when measurements and observations relating to equinoxes, solstices, eclipses, and the form of the earth were undertaken. Ibn al-'Alam, al-Razi, al-Kuhi, and abu al-Waft' were among the leading lights of this wonderful age.

In the course of time, Cairo also developed into an important center fo work in mathematical geography. The Caliph al-'Aziz (365-386/975-996) founded an observatory near Cairo and al-Hakim continued to patronize it. Ibn Yunus (d. 399/1009) was a great mathematician and astronomer and ibn al-Haitham a notable physicist. In point of time, al-Biruni's work again needs a mention here, for his monumental work "Canon Masudicus" was written in 421/1030. He was a great mathematical geographer and devoted himself to many problems, including the accurate determination of latitudes and longitudes, geodetic measurements, simple method of stereographic projections, earth's shape, axis and rotation, and laws of hydrostatics. Al-Biruni's contemporary, ibn Sina, the celebrated philosopher, produced treatises on astro-nomical instruments, earth's position in the universe, and heavenly bodies.

In North Africa, Tangier, Ceuta, Fez, and Morocco became centers of scientific work relating to mathematics. An outstanding scholar and practical geographer was al-Marrakushi, the writer of Jumi' al-Mabadi w-al-Ghayah (The Uniter of the Beginning and the End) which is considered to be one of the greatest scientific contributions of the seventh/thirteenth century. It includes terrestrial co-ordinates of 135 places of which thirty-four were conducted by the author himself. Al-Marrakushi was fully

conversant with scientific methods and made use of many instruments. In Spain, mathematical geography flourished like the other sciences.

Among outstanding votaries was Maslamah al-Majriti (d. 398/1007) of Madrid who made a synopsis of al-Battani's tables. His works were translated into Latin under Alfonso. Al-Zarqali (420/1029-481/1088), besides being well up in theoretical ideas, was a maker and designer of many instruments and astrolabes. He also became well known in Europe through profuse Latin translations of his treatises. The philosophers and rationalists Jabir (Geber), ibn Aflah (d. 535/1140), ibn Rushd (Averroes) (d. 595/1198), and ibn Bajjah (Avempace) (d. 533/1138) were all interested in the mathematical side of geography.

In the eastern Islamic lands, in later generations, the Saljuq period was productive of much scientific work in mathematical geography, particularly the reign of Jalal al-Din Malik Shah (r. 465-485/1072-1092). The Mongol princes turned out to be great patrons of scientific activity. Hulagu Khan (d. 664/1265) had many mathematicians at his Court and a great observatory was set up at Maraghah on the shores of Lake Uruniyeh, fifty miles from Tabriz. Nasir al-Din Tusi was the leading light. The Maraghah astronomers were greatly interested in geography. For example, al-Tusi's Tadkirah (History) in its third chapter deals with geodetic matters and seas and winds. Qutb al-Din al-Shirazi s (634-711/1236-1311) Nihayat al-Idrak is devoted to astronomical, meteorological, and geographical questions. Al-Qazwini and al-Watwat also wrote on cosmogeographical and geographical matters.

1. Instruments and Their Use

The work in the field of mathematical geography would not have been possible without instruments and observatories. Therefore, it is not surprising to find the mathematicians and geographers working in observatories and using self-made as well as standard instruments and devices. Some of the common needs and requirements included measurement of distance between two points, determination of latitude and longitude, levelling and measurement of heights, geodetic measurements, and co-ordinates of Mecca. An account of the instruments devised, developed, and used will be given in the next chapter on “Mathematics and Astronomy” of this work.

2. Determination of Latitudes and Longitudes

Muslim efforts in the measurement and determination of latitudes and longitudes were considerable. They contrived methods as original as the results which were often accurate. The view that the work of Muslim geographers and astronomers in no way surpassed the Almagest of Ptolemy, is undoubtedly without any basis.[45]

The early Arab astronomers, al-Khwarizmi, al-Farghani, Habash al-Hasib, and al-Battani, made use of Indian and Greek methods of finding latitude. But better techniques soon began to be employed. The sons of Musa ibn Shakir at Baghdad determined the city's latitude, accurate within a minute, and ibn Yunus at Fustat (near Cairo) did remarkably accurate work. He drew attention to the fact that while

reckoning latitude from the shadow of the gnomon, errors up to 15 minutes crept in as the shadows were cast from the upper edge of the sun and not from the central point.

Ibn al-Haitham (355430/965-1038), known in Europe as Alhazen, wrote a notable work on the calculation of latitudes. He recommended the method of taking a fixed star for the precise determination of the altitude of the pole, and he was fully aware of the errors due to refraction. Al-Biruni suggested the method of determining latitude by reference to the relation of the circumpolar stars to the sun. But in the measurement of longitude, he advocated as well as demonstrated the use of the terrestrial calculation. By this method he presented a correction in the distance in longitude between Alexandria and Ghazni.

The difference in longitude between Baghdad and Ghazni found by al-Biruni by the terrestrial method was remarkably accurate. Qanun al-Mas'udi, Kitab al-Hind, and Kitab al-Tafhim are the repositories of calculations. Other almost exact calculations were those of the three sons of Masa ibn Shakir at their observatory in Baghdad, of al-Mahani at Surra Man-Ra'a, of ibn Yunus at al-Muqattam, and of Ulugh Beg at Samarqand. An outstanding correction as a result of Muslim calculation was the elimination of the Ptolemaic exaggeration of about 17 degrees in the length of the Mediterranean.

3. The Earth's Shape, Size, and Movements

Opinion on the sphericity of the earth was divided in the early Middle Ages. Cosmas' fantasies were opposed to it, while St. Augustine reluctantly conceded the globular shape, but vehemently rejected the concept of people inhabiting the antipodes. Muslim geographers and other scientists had a firmer belief in the sphericity of the earth as they continued to support, in general, the Eratosthenian theory of climate. Probably, the majority held the idea of an earth globe floating in space. Outstanding examples of Muslim experiments based on belief in the sphericity of the earth and the measurement of a degree were those conducted by the geodetists of al-Mamun in the plains of Sinjar, and al-Biruni's measurement of 56 miles 0' 50" 6" for a degree conducted in India was remarkable for its accuracy.[46] Early Muslim opinions on the question of the earth's shape are summarized by the geographer ibn Rustah in his famous treatise "Work of Costly Treasures" (c. 291/903).

As regards the movements of the earth, the position was somewhat different. The question whether the earth was at rest or not, was not discussed in Europe either in the early or later Middle Ages. Generally, the earth was assumed to be at rest in the center of space. Al-Biruni, assuming the vague Babylonian and Indian conceptions, believed in the turning of the earth on its own axis. He also believed in the movement of the sun round the earth, though he did not reject the suggestion of abu Said Sinjari regarding the possible movement of the earth round the sun.

In the second half of the seventh/thirteenth century the question of rotation was taken up by 'Umar al-Katibi al-Qazwini (d. 676/1277), who was connected with the Maraghah observatory and prepared an edition of the Almagest. His work Hikmat al-'Ain contains argument for the heliocentric theory. Unfortunately, he finally rejected the idea of the circular motion of the earth and, therefore, failed to

anticipate Kepler and Galileo. Among others, who took up this question, was Qutb al-Din, a pupil of Nasir al-Din Tusi. His semi-geographical work, Nihayet al-Idrak, contains a discussion of these questions. Thus, Muslim mathematical geographers often expressed doubts on Greek and Ptolemaic concepts about the earth. Sarton[47] rightly emphasizes that the doubts expressed in Arabic writings were not sterile as they eventually paved the way for the Copernican reform in 950/1543.

D-Cartography And Map-Making

Muslims inherited the Greek and Babylonian traditions in map-making. In the past, there had existed a close relationship between extension of maritime activity and navigation and the development of cartographic skill.

The Arab and Muslim knowledge of the seas far surpassed that of their predecessors. It encompassed familiar areas from the Mediterranean to the Atlantic and from the Red Sea, Arabian Sea, and Persian Gulf to the Indian Ocean and the Pacific. Their extensive sailings on these waters were not merely naval expeditions, but were made in pursuit of an extensive commercial and maritime activity in which the crossings of the Mediterranean formed but a small part. This necessitated the use of sea charts, coastal information, and knowledge of wind and weather. Therefore, one class of Muslim mapmaking was devoted to these objectives, while geographers and others made many maps to depict land information and the political and regional composition of the Islamic world as well as of the then known inhabited areas.

On the whole, Muslim map-making and cartography generally advanced the older knowledge and techniques. The traditions of Roman cartography were poor. Even Ptolemy had made a fundamental error in underestimating the earth's size. He had accepted the figures of Posidonius (1 degree = 500 stadia) on the basis of which Europe and Asia were supposed to extend over one-half of the surface of the globe, while their extension covered only 130 degrees. He had also estimated the length of the Mediterranean to be 62 degrees instead of 42 degrees. The Muslim geographers had corrected this error, but European cartography persisted with this mistake up to the end of the tenth/sixteenth century.[48]

Muslim geographers constructed celestial and terrestrial globes and studied the problem of projections. Their maps were superior to those of Ptolemy, and it became a somewhat general practice to draft maps to accompany the geographical treatises. This is borne out by many examples. Al-Khwarizmi's Kitab Surat al -Ard was written in explanation of maps which might have been based on Syriac versions of Ptolemy. The world map, prepared at the behest of Caliph al-Mamun and embodying the collaboration of no less than seventy experts, can be considered to be a notable example of scientific mapmaking. Unfortunately, this map is not extant. It has also been suggested[49] that there was a collection of maps of Iran including a pre-'Abbasid world map, which may very well be called “Iran Atlas.” In order to indicate the possibility of such a series of maps, it may be pointed out that ibn al-Faqih mentions a map of

Dailam which was made for Hajjaj ibn Yusuf, and al-Baladhuri notes in his Futuh al-Buldan that a petition to Caliph al-Mansur was supported by a map of the canals of the Basrah area.

In the evolution of Muslim cartography, the Balkhi School represents a distinct advance. Al-Balkhi's atlas included, besides a map of the world, maps of Arabia, the Indian Ocean (Baler Fars), Maghrib, Egypt, Syria, the Mediterranean Sea, and several other parts of the Islamic world. This atlas was devoted to the geographic description of the areas covered by the maps and also presented a division of the world into the so-called "Climatic Zones." Konrad Miller in his Mappae Arabicae fittingly calls it "An Islam Atlas." It is most unfortunate that the fruits of Balkhi's effort have been lost and only the copied material by al-Istakhri and ibn Hauqal has been handed down to posterity. A follower of these traditions was al-Maqdisi who explained the basis of the drawings of al-Istakhri and then made his own regional maps of the world, using symbols and a color scheme for physical features which made his maps almost similar to modern maps. 50

Al-Biruni made a round map of the world in Kitab al-Tafhim to illustrate the position of seas, and in al-Athar al-Baqiyyah (Chronology of Ancient Nations) he discussed methods of celestial and terrestrial projections. Al-Idrisi s fame as a map-maker has found universal recognition. He is said to have made seventy maps of climatic divisions, a celestial sphere, a globe of silver, and a world map on a silver plate with great cartographic skill. His maps give a better representation of the western world of Islam than that of the eastern. His cartographic effort influenced his European contemporaries and successors in many ways. In later generations, al-Qazwini and al-Wardi made maps based on the lingering traditions of the Balkhi School. Two celestial globes were made by 'Abd al-Rahman al-Sufi in Cairo in about 432/1040; a bronze globe was made by ibn Hula of Mausil in 674/1275. Mahmud Kashghari, in his Diwan Lughat al-Turk, made a world map in 734/1333.

Finally, a brief mention of the Arab sea charts, navigation manuals, and the early development of the portolani (European sea charts) is relevant to the subject. The most extensive Arab navigational activity was from the Red Sea and the Persian Gulf to the various parts of the Indian Ocean along East Africa and South-East Asia. Sailing ships were exposed to the hazards of wind and weather and were directly influenced by the subtropical and equatorial changes in meteorological conditions. The monsoons were a great factor in these sailings. Therefore, it is not only a fair guess but has a basis in fact that safe sailings were conducted with the accumulated experience of generations of seamanship as well as sea charts and instruments. As regards instruments, the compass may be considered fairly certain, and the greatly perfected astrolabe was also put to use. In the East, the peak of Muslim navigational achievement was reached on the eve of the Portuguese incursion into these waters. In the West, the Mediterranean sailings were most common. There are also on record some attempts to probe into the mysteries of the Atlantic.

The dream to reach the riches of India and China by sailing round Africa was an ancient one, but the Muslims' mastery of North Africa, their dominion in the Iberian Peninsula, and the urge to spread Islam

and commerce to yet newer lands, revived a new interest in the venture. The sailors and navigators of Muslim Spain were the first in the field, the Genoese sailors came after them. The Portuguese maritime activity took a still later place in history. Among Muslim writers, al-Mas'udi and al-Idrisi have mentioned the attempts of their co-religionists. Al-Mas'udi mentions in his Muruj al-Dhahab the venture into the Atlantic before 346/957 by Khashkhaf of Cordova, and al-Idrisi relates the story of the Maghrurin (the deceived ones). These sailors were eight cousins who set out from Lisbon (before 439/1147) and sailed westward for about eleven days, then in a southerly direction for twelve days when they reached the inhabited Isle of Sheep (Jazirat al-Ghanam); after further navigation of twelve days they landed on another island where they were made prisoners. It may be a fair surmise that the first island was the Madeira and the second the Canaries.

To turn once again to the East, there were successive generations of professional Muslim pilots and writers of nautical instructions throughout the fourth/tenth to the sixth/twelfth century. The pilots (mu'allim or musta'mil al-markab) and "Lions of the Sea" acquired great fame from the first half of the sixth/twelfth century onward. To this period belong Sahl ibn Aban, Mubammad ibn Shadhan, and Laith ibn Kablan. Later, Ahmad ibn Majid wrote Kitab al-Fawa'id fi Usul al-Bahr in 895-896/1489-1490 and Sulaiman al-Mahri produced his ' Ulum al-Bahriyyah in the early tenth/sixteenth century. Shihab al-Din Ahmad ibn Majid was an expert sailor as well as a writer of nautical instructions and his role in guiding Vasco da Gama's ship across the Arabian Sea in 904/1498 is well recognized. According to Barros, ibn Majid showed the Portuguese admiral a map of the whole coast of India indicating meridians and parallels. He also expressed no surprise or sense of admiration on seeing the Portuguese navigational instruments and is said to have commented that Muslim sailors in the Indian Ocean possessed more efficient devices and instruments. In fact, ibn Majid and al-Mahri may be regarded among the early modern writers on nautical matters. Their knowledge of the geography and meteorology of the Red Sea and the Indian Ocean was extensive.

Between 867/1462 and 896/1490, ibn Majid wrote thirty nautical texts. Of these, the most important work was Kitab al-Fawa'id. The book is a compendium of knowledge relating to the principles of navigation both theoretical and practical. It deals with matters connected with the origin of navigation, use of magnetic needle, routes across the Indian Ocean, latitudes of harbors in that ocean, the China Sea, regional description of large islands, monsoons and their dates, and banks and reefs of the Red Sea. This work was of great use to those engaged in navigation and preceded the European navigation in Eastern waters.[51]

Sulaiman al-Mahri was a younger contemporary of ibn Majid. He wrote five treatises on sailing instructions. Of these the third was entitled al-' Umdat al-Mahriyyah fi Dabt al-'Ulum al-Bahriyyah. This work deals with nautical astronomy, sea-routes in the Arabian Sea and Indian Ocean, monsoons, and some outstanding voyages.

One of the main cartographical achievements of the Middle Ages was the preparation of sea charts

which were extensively used by seamen and sailors in the Mediterranean and the Black Sea, from the end of the seventh/thirteenth century onward. These are known as “portolani” and were largely produced by the Genoese, Pisans, and Italians. The languages used in these early Western maps are Latin, Catalan, Italian, or a sort of Mediterranean lingua franca composed of various Romance elements.[52] Their origin appears to be debatable, though many Western scholars stick to a single source theory, namely, European Christian. Perhaps the Western portolani owed their development to sailors and cartographers in their own area. But it is almost certain that the Arab pilots, guiding ships across the Indian Ocean and South-East Asian waters, must have very keenly felt the need of such maps. In the form in which Western portolani have been handed down, it is not possible to say which ones were earlier.

But as related above, Muslims had been actively engaged in navigating the extensive and dangerous Eastern seas up to China and across the mesh of islands in South-East Asia since the third/ninth century onward; they had sea charts as mentioned by al-Maqdisi in the later part of the fourth/tenth century. While writing about his extensive sea journey over the Indian Ocean, he says[53] that he was often in the company of shipmasters and pilots and other experts who had long experience of sailings in these areas and possessed a detailed knowledge of wind and weather and the physical and commercial geography of these seas and their adjoining lands. He adds that he had seen in their possession sailing charts, directories, and nautical instructions, many of which he himself utilized to compile his own work.

Marco Polo also refers to the Arabs' use of sea charts and maps. It is said that Qutb al-Din Shirazi, the geographer of the Itkhans of Persia, used one such map to mark the progress of the Mongol envoy to Christendom. Indeed, it is quite conceivable that the early portolani were made after centuries of experience before their Mediterranean and Atlantic samples came to be drafted. It is, however, true that the number of Muslim portolani is small as compared with the Western ones.

As a criticism of the quality of Muslim cartography it may be admitted that often it overemphasized decoration at the expense of accuracy. But it will be well to remember that contemporary Western cartography was most rudimentary by comparison and the latter mappae mundi were a mixture of fact and fancy. Much has been written in recent years to throw light on the achievement of Muslim map-makers. The labors of Konrad Miller, Prince Youssouf Kamal, and Kramers have been very rewarding and have presented Muslim cartography in a new light.[54]

E – Influence Of Muslim Geography

The question of the extent of the influence of Muslim geography on the European mind is an interesting one. Usually it is claimed that the development of medieval European as well as that of early modern geography was somewhat independent. This view appears to be untenable and is rather out of date, as its basis is emotional and it disregards the inevitable links of history. Moreover, a brilliant galaxy of European scholars including many Orientalists, through their painstaking researches into the sources of

modern science, have produced indisputable evidence of the transmission of Muslim science to European communities. Here it is possible to present only the main points of the transmission of Muslim geographical knowledge and concepts to the West.

Even during the first half of the fifth/eleventh century, necessary conditions for scientific work did not exist in the Latin West, or for that matter in the whole of Christendom, as they did in the Islamic world. It was only Jewish thought which was moving forward due to direct contact with Muslim culture and under the stimulus of its progressive impulses. No doubt, some Christians in the Muslim world did contribute to these efforts.

There were two important sources of the transmission of Muslim science and geography to Latin Europe and other areas in the West. The points of cultural and physical contact in Spain, Italy, Sicily, and the Aegean Islands were strengthened by intermixing of people during the prolonged period of the Crusades. Secondly, as an earlier translation activity at Baghdad had paved the way for a fruitful synthesis, so the numerous translations of Arabic works in Spain, Italy, and Sicily proved to be harbingers of scientific advance.

Latin geography before the early sixth/twelfth century was on a much lower level than the Muslim. It was too simple and childish. This remark applies especially to those writers who were not influenced by Arab ideas and continued to follow the Roman and early medieval traditions, e.g., Henry of Mayence, Guido, and Lambert of Saint Omer. On the other hand, those who showed a somewhat better geographical sense like Herman the Dalmatian, Bernard Sylvester, and William of Conches had been influenced by Arab ideas.

The major proportion of European geographical writings of sixth/twelfth century in the West consisted of Latin and other Christian pilgrim literature, though there were also a few other contributions. John of Wurzburg was a German pilgrim in the late sixth/twelfth century, Joannes Phocas was a soldier turned monk who wrote of castles and cities from Antioch to Jerusalem, and Richard the Lion-hearted was a crusader king. Sigurd, King of Norway and a crusader, made a remarkable journey to Palestine and back between 501/1107 and 505/1111. The outward journey was a fighting cruise through the North Sea, the Mediterranean, and the Aegean waters. He fought the Muslims around Spain and visited the cultured Court of Roger H of Sicily before his return home by an overland route through Europe. His saga is somewhat geographical in its content and bears traces of contact with the Orient.

Pedro Alfonso made a sketch-map of the world clearly derived from Muslim models, copying the seven climates and putting south on the top. Henry of Mayence compiled a treatise in 504/1110 which included a map. A geographic encyclopedia was prepared in 513/1119 by Guido who was probably an Italian geographer. Lambert of Saint Omer compiled another encyclopedia with maps; in this work he propounded his belief in the sphericity of the earth. Herman the Dalmatian in 538/1143 prepared his cosmographical compilation, which included astronomical and geographical information, and Bernard Sylvester produced his De Mundi.

Nearly all the above-named writers and their contemporaries who dealt with geographical matters were steeped in patristic and Latin traditions. But by the middle of the seventh/thirteenth century, a distinct change was perceptible, as by that time the full impact of the translations was evident in the more readily available Arab knowledge in Europe. Scholars were not only aware of it, but were beginning to feel the need of it. The new knowledge, of which Muslim geographical information and notions were an indispensable part, began to work as a great stimulus to new ideas in the Latin world.

Henceforward, the level of geographic thinking and writings was definitely raised. Vincent of Beauvais, Albert the Great, Roger Bacon, and others were all sufficiently influenced by Arab knowledge of geography and its associated fields.[55] Joannes Sacrobosco (John of Hollywood), the English astronomer and mathematician, wrote his Sphaera Mundi in about 631/1233. This work was slavishly based upon al-Farghani and al-Battani; it became immensely popular in the West, was translated several times, and remained in use in schools up to the eleventh/seventeenth century. William the Englishman in 629/1231 mainly interpreted al-Zarqali and al-Bittani. Vincent of Beauvais, the French Dominican scholar who died in 663/1264, compiled an encyclopedia. It was a monumental work and much of its geographical and geological information was derived from Arab sources.

Albert the Great (d. 679/1280) was another outstanding Dominican intellectual and prolific writer. He knew neither Greek nor Arabic, but acquired vast knowledge through Latin translations, seriously studied Muslim thought, and was considerably influenced by their geographical ideas. Roger Bacon's Opus Majus is replete with geographical references[56] to Arab sources. Gossuin of Metz or Walters' L'image du monde, written in about 644/1246, was derived from existing sources largely based on Muslim knowledge.

Konungs Skuggsja is an outstanding geographical and encyclopedic treatise in Old Norwegian written by an unknown author between 614/1217 and 659/1260 or about 647/1247. The author was either a priest or a Court chaplain and a good deal of his material was based upon the accounts of returned crusaders and pilgrims. It displays good geographical sense, particularly in physical geography. He believed in the sphericity of the earth. The work is not entirely without Arab influence. The travel accounts of the Englishman Sir John Mandeville, though verging on the fantastic, are a rehashing of common Arab knowledge in geography.

The fact remains that gradually most of the basic and current geographical ideas of the Muslims were passed on to the West. These were with regard to the size of the earth and its sphericity, oceans, geological processes, climate, vegetational and zoological distributions, knowledge of new lands in Africa, Far East, and Central Asia, techniques of cartography, and uses of instruments.[57] All this knowledge in various degrees of assimilation is depicted in the leading geographical works and forms the background of the so-called mappae mundi, and also in some of the maps of later generations preceding the Columbian era, viz., the Psalter map (c. 597/1200), Hereferd map (c. 679/ 1280), the world map of Marino Sanuto (721/1321), the Borgian world map (c. 854/1450), Este world map[58] (e. 854/1450),

Fra Mauro's Africa (864/1459), and the diagrams of L'image du Monde (885/1480). Though these maps were far from being real maps and mirrored more the shadows of patristic and traditional notions, yet acquaintance with Arab cartography and geographic information is revealed in them.[59]

On the whole, the period from the sixth/twelfth to the ninth/fifteenth century was a period of transition and compromise, a time of absorption and fusion, because it was during this period that the conflicting Muslim and Christian cultures were brought most closely together. The result was the creation of the core of new Europe. This was essentially Graeco–Arabic–Latin. After the invention of the art of printing in the second half of the ninth/ fifteenth century, many Graeco–Arabic scientific works were eagerly and repeatedly printed. In fact, the influence of Arab science remained paramount in Europe, till, towards the middle of the tenth/sixteenth century, Copernicus published his revolutionary concepts, and experimental science emerged. But Arab science as a factor in European thinking lingered on much longer, almost up to the eve of the Industrial Revolution.

The lesson of history is clear. In the ages following the voyages of Columbus and the intellectual ferment at the end of the Middle Ages, Europe surged forward to penetrate through the barriers of ignorance and acquired a cultural and material leadership. But Europe learnt its lessons from those who were at one time masters of the world. The Muslims were its cultural ancestors in the domain of science, geographical knowledge, discovery, and world commerce.

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59. Keane, The Evolution of Geography, p. 48

Chapter 63: Mathematics and Astronomy

A – Introduction

It is generally recognized that human knowledge took its organized and systematic form with the Greeks. It is equally well known that the Greeks inherited a considerable body of knowledge from their Eastern predecessors, especially the Egyptians, Babylonians, Chinese, and Indians.

The histories of science and culture, written by some Western writers, however, show a gap between the period of the Greeks and the Renaissance. They give the impression that the history of science was blank for nearly one thousand years, and scientific knowledge made a sudden leap, taking a millennium in its stride. These histories ignore the fact that the intervening ages from the first/seventh to the eighth/fourteenth century constituted the era of the Arab and other Muslim peoples.

The latest researches of Muslim and non-Muslim scholars are bringing to light the work of the Muslims in the various branches of knowledge throughout the Middle Ages. These researches are, however, scattered in various journals and books which are not easily accessible to the average educated person. Two good works of reference published are the Encyclopedia of Islam and George Sarton's Introduction to the History of Science. On a thorough study of the information available on the subject, one is struck by the magnitude as well as importance of the contributions made by the Muslims to the various branches of science, especially to mathematics and astronomy.

The magnitude of these achievements is so vast that it is giving rise to another tendency among the historians of science. It is incomprehensible to them that the Arabs who were so backward and ignorant in the centuries preceding the advent of Islam could have become so enlightened and scholarly in such a short time after adopting the new faith. One of the great exponents of this line of thought is Moritz Cantor who has written an encyclopedic history of mathematics in the German language. The chapter on the Arabs in Cantor's book begins as follows:

“That a people who for centuries together were closed to all the cultural influences from their neighbors, who themselves did not influence others during all this time, who then all of a sudden imposed their faith, their laws, and their language on other nations to an extent which has no parallel in history–all this is such an extraordinary phenomenon that it is worthwhile to investigate its causes. At the same time we can be sure that this sudden outburst of intellectual maturity could not have originated of itself.”

Laboring under this fixed idea, Cantor proceeds to attribute almost everything done by the Muslim scholars to the Greeks and other nations. We must confess that this kind of argument introduces an extremely dangerous principle in historical research, and can be employed only by one who is predisposed to demolish an exalted and established reputation. If Cantor had really investigated the cause of the "sudden outburst of intellectual maturity" of the Arabs, he would have realized that it was primarily due to the revolution caused by Islam in the whole outlook of the people. We have elsewhere described the attitude of Islam towards knowledge.[1] By making it incumbent upon the believer to acquire knowledge and by enjoining upon him to observe and to think for himself, Islam created an unbounded enthusiasm for acquiring knowledge amongst its followers. The result of this revolution can be best described in the words of Florian Cajori, who says in his History of Mathematical Notation: "The Arabs present an extraordinary spectacle in the history of civilization. Unknown, ignorant, and disunited tribes of the Arabian Peninsula, untrained in government and war, are, in the course of ten years, fused by the furnace-blast of religious enthusiasm into a powerful nation, which in one century extends its dominion from India across northern Africa to Spain. A hundred years after this grand march of conquest, we see them assume the leadership of intellectual pursuits; the Muslims become the great scholars of their time."

It is under this stimulus of the Islamic injunction for acquiring more and more knowledge that the Arabs and other Muslim peoples turned to the learning of the various branches of knowledge, preserving and improving upon the heritage left by preceding civilizations and enriching every subject to which they turned their attention. In the following pages we give an account of their contribution in the domain of mathematics and astronomy. It may be pointed out that this is only a brief chapter in the general history of Muslim philosophy. The account will, therefore, be of a descriptive nature, shorn of all technicalities and confined to some of the fundamental ideas put forward by the Muslim peoples in the fields of arithmetic, algebra, geometry, trigonometry, and astronomy. It is neither possible nor desirable to give here an exhaustive account of the work done by each and every Muslim scholar. We have restricted ourselves to important contributions of the prominent Muslim mathematicians and astronomers.

B – Arithmetic

The Arabs started work on arithmetic in the second/eighth century. Their first task in this field was to systematize the use of the Hindu numerals which are now permanently associated with their names. Obviously, this was an immense advance on the method of depicting numbers by the letters of the alphabet which was universal up to that time and which prevailed in Europe even during the Middle Ages. The rapid development in mathematics in the subsequent ages could not have taken place without the use of numerals, particularly zero without which all but the simplest calculations become too cumbersome and unmanageable. The zero was mentioned for the first time in the arithmetical work of al-Khwarizmi written early in the third/ninth century. The Arabs did not confine their arithmetic to integers only, but also contributed a great deal to the rational numbers consisting of fractions. This was the first extension of the domain of numbers, which, in its logical development, led to the real, complex, and

hyper-complex numbers constituting a great part of modern analysis and algebra. They also developed the principle of error which is employed in solving algebraic problems arithmetically. AlBiruni (363-432/973-1040), ibn Sina (370-428/980-1037), ibn al-Sam$ (d. 427/1035), Muhammad ibn Husain al-Karkhi (d. 410/1019 or 420/1029), abu Said al-Sijzi (c. 340-c. 415/c. 951-c. 1024) are some of the arithmeticians who worked on the higher theory of numbers and developed the various types of numbers, such as:

Tamm (perfect numbers), i.e., those which are equal to the sum of their divisors, e.g., 6 = 1 + 2 + 3.

Muta`ddilan (equivalents), i.e., two numbers, the sum of the divisors of which is the same, e.g., 39 and 55: 1 + 3 + 13 = 1 + 5 + 11.

Mutahdbban (amicable numbers), i, e., two such numbers in which the sum of the divisors of one equal the other, e.g., 220 and 284:

1+2+4+71+142=220

1+2+4+5+10+11+20+22+44+55+110=284.

(iv) Muthallathat (triangular numbers), e.g., the numbers 1, 3, 6, 10, 15, 21, 28, 36, 45, which are the sum of the first one, first two, first three, first four and so on, natural numbers.2

The Arabs also solved the famous problem of finding a square which, on the addition and subtraction of a given number, yields other squares.3

The extent of their knowledge of arithmetic can be gauged from the fact that al-Biruni was able to give the correct value of 1616-1.4

C - Algebra

The ancient mathematicians, including the Greeks, considered the number to be a pure magnitude. It was only when al-Khwarizmi (d. 236/850) conceived of the number as a pure relation in the modern sense that the science of algebra could take its origin. The development of algebra is one of the greatest achievements of the Muslims, and it was cultivated so much that within two centuries of its creation it had reached considerable proportions. The symbolical process which it idealizes is still called "Algorithm" in modern mathematics. Al-Khwarizmi himself formulated and solved the algebraic equations of the first and second degree, and discovered his elegant geometrical method of finding the solution of such equations. He also recognized that the quadratic equation has two roots. Ibrahim ibn Sinn (296-335/908-946) worked on geometry, especially on conic sections. His quadrature of the parabola was much simpler than that of Archimedes, in fact the simplest ever made before the invention of the integral calculus in the eleventh/seventeenth century.5 Abu Kamil huja' al-Misri developed the algebra of al-Khwarizmi, and determined the real roots of quadratic equations and their interpretations.

Al-Khazin (d. c. 350/961) solved the cubic equation by employing the conic sections.[6] Abu al-Wafa' (al-Bizjani) (329-388/940-998) investigated and solved algebraic equations of the fourth degree of the type x4 = a, and that of x4 + ax3 = b. Al-Kuhi (fl. c. 378/988) investigated the solvability of algebraic equations. Abu Mahmud al-Khujandi (fl. 382/992) proved that the so-called Fermat's problem for cubic powers, i,e., x3 + y3 = z3, cannot be solved by rational numbers. Ibn al-Laith, who was a contemporary of al-Biruni, solved the problem which leads to the equation: x3 + 13.5x + 5 =10x8, and founded geometrical methods for solving cubic equations. Al-Biruni introduced the idea of "function," which, since the time of Leibniz (eleventh/seventeenth century), has become the most important concept in modern mathematics. Abu Bakr al-Karkhi, who is considered one of the greatest Arab mathematicians, wrote a book on algebra, called al-Faihri, in which he developed approximate methods of finding square-roots; the theory of indices; the theory of surds; summation of series; equation of degree 2n; the theory of mathematical induction; and the theory of indeterminate quadratic equations.

The next important figure is ibn al-Haitham (c. 354-431/c. 965-1039), who is recognized as the greatest physicist and expert on optics of the Middle Ages, and who solved the algebraic equation of the fourth degree by the method of intersection of the hyperbola and the circle.

Then came 'Umar al-Khayyam (c. 430-517/c. 1038-1123), who has recently become the most glamorous figure of the fifth/eleventh century on account of his poetry, but who, according to Moritz Cantor, has better claim to immortality as a very great mathematician. He made what was for his time an uncommonly great progress by dealing systematically with equations of the cubic and higher orders and by classifying them into various groups according to their terms.[7] He described thirteen different classes of cubic equations. He investigated the binomial expression for positive integral indices, i.e., in modern terminology, the expansion of (1 + x)n, when n is an integer. The next significant advance on this problem was made by Newton (eleventh/seventeenth century) when he proved the binomial theorem for any rational number. As stated by Cantor, Khayyam has a very exalted place in the history of algebra.[8]

At about this time, Muslim scholars founded, developed, and perfected geometrical algebra, and could solve equations of the second, third, and fourth degree before the year 494/1100.

Moritz Cantor, who is by no means partial to the Muslims, remarks that "the Arabs of the year 494/1100 were uncommonly superior to the most learned Europeans of that time in the mathematical sciences.[9] He goes on to relate the story that in the seventh/thirteenth century, Frederick II Hohenstaufen sent a special deputation to Mosul to ask Kamal al-Din ibn Yunus (d. 640/1242), the mathematician of a college later on called after him the Kamalic College, to solve some mathematical problems. Kamal al-Din solved these problems for the Emperor.[10] One of the questions solved by him was how to construct a square equivalent to a circular segment.

D –Geometry

In the subject of geometry, the Arabs began by translating the Elements of Euclid and the Conics of Apollonius, thus preserving the work of these Greek masters for posterity. This task was satisfactorily accomplished in the early third/ninth century. Soon after this they launched on making fresh discoveries for themselves. The three brothers, Muhaammad, Ahmad and Hasan, sons of Musa bin Shakir, may be regarded as pioneers in this field. They discovered a method of trisecting an angle by the geometry of motion, thus connecting geometry with mechanics. That this problem is not solvable by means of the ruler and compass alone, has been well known from the time of the Greek mathematicians. The brothers also worked on the mensuration of the sphere and on the ellipse.

In the fourth/tenth century, abu al–Wafa', al–Kuhi, and others founded and successfully developed a branch of geometry which consists of problems leading to algebraic equations of a degree higher than the second. Al–Kuhi solved the problems of Archimedes and Apollonius by employing this new method. Abu Kamil Shuja' al–Hasib al–Misri investigated geometrical figures of five and ten sides (pentagon and decagon) by algebraic methods. This co–ordination of geometry with algebra and the geometrical method of solving algebraic equations, like the application of geometry to algebra by Thabit bin Qurrah, a Sabian astronomer of the court of the Caliph Mu'tadid, was the anticipation of Descartes' great discovery of analytical geometry in the eleventh/seventeenth century. Abu Said al–Sijzi "made a special study of the intersections of conic sections and circles. He replaced the old kinematical trisection of an angle by a purely geometrical solution (intersection of a circle and an equilateral hyperbola)".[11]

Abu al–Wafa developed the method of solving geometrical problems with one opening of the compass, and of constructing a square equivalent to other squares. He made many valuable contributions to the theory of polyhedra, which is even now considered to be a very difficult subject.[12]

Ibn al–Haitham, known in Europe as Alhazen, also made many discoveries in geometry. His famous book on optics contains the following problem, known as Alhazen's problem: from two points in the plane of a circle to draw lines meeting at a point of the circumference and making equal angles with the normal at that point. This problem leads to an equation of the fourth degree, and ibn al–Haitham solved it by the aid of a hyperbola intersecting a cirele.[13]

The later Muslim mathematicians developed the geometry of the conic sections to some extent, but their great contribution was connected with the appraisal of Euclid's postulates. It is well known that in each science or logical system (such as the Euclidean geometry), the beginning is made with some fundamental concepts (like points and lines) and a few assertions or statements, called "postulates," which are accepted without demonstration or proof, and on the basis of which further statements (called theorems) are established. Now it is recognized that some of Euclid's postulates are quite self–evident. For instance, no one questions the validity of the statement that the whole is greater than a part or that equals added to equals result in equals. But the same cannot be said about Euclid's parallel postulate.

Fakhr al-Din Razi (d. 606/1209) made a preliminary critique of Euclid's postulate, but it was Nasir al-Din Tusi (d. 673/1274), who, in the latter half of the seventh/thirteenth century, recognized the weakness in Euclid's theory of the parallels. In his efforts to improve the postulate, he realized the necessity of abandoning perceptual space. It was in the thirteenth/nineteenth century that such studies, continued by Gauss, Bolyai, Lobachevsky, and Riemann, resulted in the discovery and development of the various non-Euclidean geometries, culminating in the Theory of Relativity in our own time.

E - Trigonometry

Trigonometry, both plane and spherical, was developed to a great extent by the Arabs. Al-Khwarizmi himself compiled trigonometric tables, which contained not only the sine function, as done by his predecessors, but also that of the tangent, for the first time. These tables were translated into Latin by Adelard of Bath in 520/1126.[14]

Al-Battani (d. 317/929), known in Europe as Albategnius, devoted a whole chapter of his book on astronomy to the subject of trigonometry. He used sines regularly "with a clear consciousness of their superiority over the Greek chords. [15]"The previous works contained only the full arc, but al-Battani remarked that it was more advantageous to use the half arc. Cantor considers this "an advance in mathematics which cannot be appreciated highly enough."[16] Al-Battani completed the introduction of tangents and cotangents in trigonometry, and gave a table of cotangents by degrees. He knew the relation between the sides and angles of a spherical triangle which we express by the formula:[17]

cos a = cos b cos c + sin b sin c cos a.

Abu al-Wafa's contribution to the development of trigonometry is well known. Most likely he was the first to show the generality of the sine theorem relative to the triangles. He introduced quite a new method of constructing sine tables, the value of sin 30' being correct to the eight decimal places. He knew relations equivalent to the present ones for sin (a ± b), and to

2 sin' 2 =1- cos a,

sin a = 2 sin cos 2.

He specially studied the tangent; drew up a table of tangents, introduced the secant and the cosecant in trigonometry, and knew those relations between the six trigonometric lines which are now often used to define them.[18]

Al-Khujandi is considered to be the discoverer of the sine theorem relative to spherical triangles. This sine theorem displaced the theorem of Menelaos[19]

Ibn Yunus (d. 400/1009) made considerable contributions to trigonometry, and solved many problems of spherical astronomy by means of orthogonal projections. He discovered the first of those addition-

subtraction formulae which were indispensable before the invention of logarithms, namely, the equivalent of

cos a cos b =1/2 (cos (a – b) + cos (a + b)]

He also gave a formula for the approximate value of sin 1'.[20]

Kushyar ibn Labban (fl. c. 361–420/971–1029) took an important part in the elaboration of trigonometry. For example, he continued the investigations on the tangent, and compiled comprehensive tables.[21]

Al–Zarqali (fi.c.420–480/1029–1087) explained the construction of the trigonometric tables, and compiled the Toledan Tables, which were translated into Latin by Gerard of Cremona and enjoyed much popularity.[22]

Al–Hasan al–Marrakushi (fl. c. 661/1262) introduced in 627/1229 the graphic method in trigonometry and prepared the tables of trigonometric functions.

Nasir al–Din Tusi wrote on plane and spherical trigonometry as a subject independent of astronomy.

Baba' al–Din (954–1032/1547–1622) gave in his book trigonometric methods for calculating heights and distances as well as for the determination of the breadth of a river.

F – Astronomy

The Arabs claimed astronomy to be their own special subject. Indeed even at the beginning of Islam, they possessed sufficient astronomical knowledge to be able to use the position of stars in their wanderings and agriculture. But it was only in the second/eighth century that the scientific study of astronomy was begun.[23] From this time up to the eighth–ninth/fourteenth–fifteenth century the contributions of Muslims to astronomy were so numerous that they can be dealt with adequately only in a separate volume. Here we summarize only some of the most important facts.

First of all let us take the observatories. Western historians have pointed out that before the advent of Islam, only one more or less well–known observatory existed in Alexandria, and even that was not doing much work. In the course of a few centuries, the Muslims erected innumerable well–equipped observatories all over their vast empire. Some of these observatories are as follows:

(i) The solar observatory built by al–Mamum in Iraq in 214/829.

(ii) The Ispahan observatory built by abu Hanifah al–Dinawari (d. 282/ 895).

(iii) The Khwarizm observatory built by al–Biruni.

(iv)The Baghdad observatory of Thabit ibn Qurrah.

(v) The Baghdad observatory built by Caliph al-Mustarshid, where the well-known astronomer Badi' made his observations.

(vi) The observatory erected by ibn Sina.

(vii) The al-Raqqah and Antakiyah (Antioch) observatories where al-Battani made observations from 264/877 to 306/918.

(viii) The banu Musa observatory at Baghdad.

(ix) The Sharaf al-Daulah observatory where al-Saghani and al-Kuhi made their observations.

(x) The Tabitala observatory where abu Isbaq worked and made observations.

(xi) The Buzjan observatory associated with the name of abu al-Wafa'.

(xii) The ibn A'lam observatory built at Baghdad in 351-352/962-963.

(xiii) The Egyptian observatory where ibn Yunus produced his famous almanac.

(xiv) The Mamnni observatory, associated Bataihi (d. 519/1125).

(xv) The Maraghah observatory erected by Nasir al-Din Tusi in 658/ 1259. It is said that several kinds of instruments were installed in this observatory, and that a library containing four hundred thousand volumes was attached to it.

(xvi) The observatory of Taqi al-Din.

(xvii) The Kashmir observatory.

(xviii) The Firuzshahi observatory.

(xix) The Samarqand observatory erected by Sultan Ulugh Beg Mirza in 823/1420.

An account of these observatories lies scattered in various books, such as: Khuldsah Tarik al-'Arab; Tamaddun-i 'Arab; Kitab al-Kitaf w-al-Athar; Sharh Chaghmani; Jami' Bahadur Khani; Mu'jam al-Buldan; Iktifa' al-Qunu'; Fuwat al-Wajnat; Raudat al-safa; Wafayat al-A'yan; Kashf al-Zunun.

Next to the observatories come the astronomical instruments; and the books on history record a large number of instruments constructed by the Arabs and other Muslim peoples. Work on astronomy of such magnitude could not be carried out with the rough instruments existing at the time. They had, therefore, to concentrate all their practical skill on devising elaborate instruments for making various observations. These have also been described in the books mentioned above. We shall confine ourselves to the enumeration and description of some important instruments.

(i) Libnah, built on a square base, served to measure the declination, latitude, and distances of the stars.

(ii) Halqah I'tidal (Meridian Circle), fixed in the plane of the meridian, and devised to determine the distances of the heavenly bodies.

(iii) Dhat al-Autar, constructed by Taqi al-Din, served as an. alternative for the Meridian Circle which was useful during night as well as day.

(iv) Dhat al-'Alq (the Astrolabe) was one of the most important instruments. It consisted of two circles, one of which represented the ecliptic and other the celestial meridian.

(v) Dhdtal-Samt w-al-Irtifa' (Alt-azimuth) consisted of a semi-circle and bad the diameter of an equi-surfaced cylinder. Taqi al-Din has mentioned it in his work, to have been constructed by Muslim astronomers.

(vi) Dhat al-Shu'batain.' It had three faces on one base and served to determine the altitude of the heavenly bodies.

(vii) Dhat at-Jaib consisted of two faces and was used for the determination of the altitude.

(viii) Al-Mushabbah bi al-Natiq constructed by Taqi al-Din and used for determining the distance between two stars.

(ix) Tabaq al-Manatiq constructed by Ghiyath al-Din Jamshid and used for determining the position of the stars, their latitudes, distance from the earth, and movement. It was also useful for obtaining data relating to lunar and solar eclipses.

(x) Zarqalah constructed by Shaikh Isbaq ibn Yabya, generally known as al-Naqqash al-Andalusi (the Spanish painter). It was a very useful instrument for observing the movement of the heavenly bodies.

(xi) Dhat al-Kursi constructed by Badi' of the Astrolabe (Badi' al-Asturlabi), as described by 'Abd al-Rabman al-Sufi.

(xii) Al-Alat al-Shamilah constructed by al-Khujandi and used for determining the latitudes.

(xiii) The several types of quadrants as described in Kashf al-Zunun.

(xiv) Asturlab Sartani Mijnah, the transit instrument described by Muhammad ibn Nasr and Mansur ibn 'Ali.

(xv) Al-Jaib al-Gha'ib consisting of a semi-circle the circumference being divided equally.

(xvi) Suds-i Fakhri, a sextant associated with the name of Fakhr al-Daulah Dailami.

Now we shall describe briefly the investigations carried out by the Muslim astronomers. Although the

work of regular observations and construction of astronomical instruments was started as early as the second/eighth century by Ibrahim al-Fazari (d. c. 180/796), the most brilliant period of Muslim astronomy commenced in the early part of the third/ninth century in the observatories constructed by the Caliph al-Mamiin (198-218/813-833). The observatory of Baghdad under Yahya bin abi Mansur (d. c. 216/831) made systematic observations of the heavenly bodies and found remarkably precise results for all the fundamental elements mentioned in Ptolemy's Alma jest, such as the obliquity of the ecliptic, the precession of the equinoxes, the length of the solar year. After recording these observations, Yahya compiled the celebrated "Tested Tables."[24] He was also the author of several works on astronomy.

Under the orders of al-Mamun, the Muslim astronomers carried out one of the most delicate and difficult geodetic operations, the measuring of the arc of the meridian. The mean result gave 562/3 Arab miles as the length of a degree of meridian, which is a remarkably accurate value, for the Arabic mile is 6,473 ft. This value is equal to 366,842 ft., exceeding the real length of the degree between 38° and 36° latitudes by 2,877 ft.

Habash al-Hasib was an astronomer under al-Mamun and al-Mu'tasim; he compiled three astronomical tables, including the famous "Verified Tables." Apropos of the solar eclipse of 214/829, Habash gave the first instance of a determination of time by an altitude which was generally adopted by the astronomers.[25]

'Ali bin 'Isa al-Asturlabi was a famous maker of astronomical instruments. He took part in the degree measurement ordered by al-Mamun, and wrote one of the earliest Arabic treatises on the astrolabe.[26]

Al-Marwarrudhi was one of those who took part in the solar observations made at Damascus in 217-218/832-833.[27]

The three sons of Musa bin Shakir made regular observations in the observatories in Baghdad between 236/850 and 257/870.[28]

Al-Farghani was one of the most distinguished astronomers in the service of al-Miman and his successors. His famous work, Kitab fi Harakat al-Samawiyyah wa Jawani' 'Ilm al-Nujum (Book on Celestial Motions and the Complete Science of the Stars), was translated into Latin in the sixth/twelfth century. It exerted marked influence on European astronomy. He accepted Ptolemy's theory and value of the precession but was of the view that it affected not only the stars but also the planets. He determined the diameter of the earth to be 6,500 miles, and found the greatest distances and also the diameters of the planets. [29]

Al-Mahani (d. between 261/874 and 271/884) made a series of observations of lunar and solar eclipses and planetary conjunctions during the years 239-252/ 853-866; these were later used by ibn Yunus.[30]

Al-Nairizi (d. c. 310/922) compiled astronomical tables, made systematic observations, and wrote a book on atmospheric phenomena. He wrote a treatise on the spherical astrolabe which is very elaborate and

is supposed to be the best Arabic work on the subject.[31]

Thabit ibn Qurrah published solar observations, explaining his methods. He revised the theory of the movement of the sun.[32] To the eight Ptolemaic spheres, he made the addition of a ninth one (primum mobile) to account for the imaginary trepidation of the equinoxes, which was, however, later found to be an erroneous theory.[33]

Al-Battani was one of the greatest astronomers of the Middle Ages. He wrote many books but his main work, the famous De Numeris stellarum et motibus, exerted great influence in Europe up to the time of the Renaissance. From 264/877 onwards he made astronomical observations of remarkable range and accuracy. His tables contain a catalogue of fixed stars for the year 267-68/880-81. He investigated the motion of the sun's apogee and found that its longitude had increased by 16° 47' since the time of Ptolemy. This implied the discovery of the motion of the solar apsides, and of the slow variation in the equation of time. He determined many astronomical coefficients with remarkable accuracy, and corrected the previous values of the precession of equinoxes and the obliquity of the ecliptic. He proved the possibility of the annular eclipses of the sun. He did not believe in the trepidation of the equinoxes, although the followers of Copernicus at a much later date did believe in it. Modern astronomy has shown that the Copernicans were wrong.[34] He determined the moon's nodes and discovered the wobbling motion of the earth's orbit.[35]

Ibn Amajur (abu Qasim 'Abd Allah) together with his son abu al-Hasan 'Ali made many observations between 272/885 and 321/933 which were recorded by ibn Yunus. They produced many astronomical tables, including the table of Mars according to Persian chronology.[36] Abu al-Hasan discovered that the moon's distance from the sun is not constant as assumed by Ptolemy.[37]

Al-Kuhi was the leading astronomer working in 378/988 at the Sharaf al-Daulah observatory.[38]

'Abd al-Ralrman al-Sufi (291-376/903-986) was one of the most eminent Muslim astronomers. His chief work, Kitab al-Kawdkib al-Thabitah al-Musawwar (Book of the Fixed Stars Illustrated), is regarded as one of the three masterpieces of Muslim observational astronomy, the other two being one by ibn Yanus and a work prepared for Ulugh Beg.[39]

Ibn al-A'lam (d. 375/985) has been praised for the accuracy of his observations; his tables continued to be very popular for at least two centuries.[40] He determined the stellar motion by observing that the stars traverse one degree in seventy solar years.[41] He also determined the latitude and longitude of many stars,[42] and measured the greatest declination of the planet Mercury.[43] He found that the earth is spherical and may, therefore, be supposed to be inhabited everywhere. [44] He discovered the satellites of Jupiter, discussed the motion of the sun-spots, and determined the eccentric orbit of the comets.[45]

Abu al-Wafa' al-Buzjani determined accurately the obliquity of the ecliptic in 344/955, and calculated the variation in the moon's motion. There is a difference of opinion about his discovery of the third liberation in the moon's motion. Some of the older writers believed that he discovered the third liberation and that

Tycho Brahi rediscovered it in the tenth/sixteenth century.[46] But Sarton remarks that abu al-Wafa' did not discover this variation, but simply spoke of the second part of the evection, which is essentially different from the variation discovered by Tycho Brahi.[47]

Al-Khujandi made astronomical observations, including a determination of the obliquity of ecliptic, in Rayy, in 384/994.[48]

Maslamah ibn Ahmad al-Majriti (d. c. 398/1007) edited and corrected the astronomical tables of al-Khwarizmi replacing the Persian by the Arabic chronology. He wrote a treatise on the astrolabe and a commentary on Ptolemy's Planisphaerium both of which were later translated into Latin.[49]

Ibn Yunus has been described by Sarton as the greatest Muslim astronomer. A well-equipped observatory in Cairo enabled him to prepare improved astronomical tables, called al-Zij al-Kabir al-Hakimi, completed in 398/1007. They describe observations of eclipses and conjunctions, old and new, and improved value of astronomical constants (obliquity of the ecliptic 23° 35'; longitude of the sun's apogee 86° 10'; solar parallax reduced from 3' to 2'; precession of the quinoxes 51.2" per annum), and give an account of the geodetic measurements made under al-Mamun's orders.[50] He is specially noted for his method of longitude determination. As time difference is equivalent to longitude difference, the determination of local time at the same instant at two stations widely separated in longitude is sufficient. But there were no telegraphs or radio signals to give simultaneity. Ibn Yanus proposed and used a signal from the moon-the first contact of a lunar eclipse. In this way he corrected many errors in longitudes in Ptolemy's geography.[51]

Al-Biruini is regarded by Western historians of science as "one of the greatest scientists of all times whose critical spirit, toleration, love of truth, and intellectual courage were almost without parallel in medieval times."[52] He made accurate determination of latitudes and longitudes and also other geodetic measurements. He discussed in his book Qanun al-Mas'udi for the first time the question that the earth rotates around its axis. The translation of the relevant Arabic passages is as follows: "When a thing falls from a height, it does not coincide with the perpendicular line of its descent, but inclines a little, and falls making different angles. When a piece of earth separates from it and falls, it has two kinds of motions: one is the circular motion which it receives from the rotation of the earth, and the other is straight which it acquires in falling directly to the centre of the earth. If it had only the straight motion, it would have fallen to the west of its perpendicular position. But since both of them exist at one and the same time, it falls neither to the west nor in the perpendicular direction, but a little to the east." This book of al-Biruni, viz., al-Qanun al-Mas'udi, was written in 42211030, and gave the true explanation of the rising and setting of the heavenly bodies as being due to the rotation of the earth, thus pointing to the error in the geocentric conception of the solar system. The heliocentric doctrine was not entirely unknown to the Arabs, who knew that the earth revolved round the sun and that the orbits of the planets were elliptic.[53] It should be noted that Copernicus gave the scientific formulation and detailed working out of the heliocentric theory some three centuries later.

Al–Zarqali was “the best observer of his time. He invented an improved astrolabe called safihah; his description of it was translated into Latin, Hebrew, and many vernaculars. He was the first to prove explicitly the motion of the solar apogee with reference to the stars; according to his measurements it amounted to 12.04” per year (the real value being 11.8”).” He edited the planetary tables called the “Toledan Tables.” 54

'Umar Khayyam was called to the new observatory of Rayy in 467/1074 by Sultan Malik Shah Jalal al–Din Saljuqi to reform the old calendar. Moritz Cantor remarks that the calendar prepared by 'Umar Khayyam, called alTarikh al–Jalali, was more accurate than any other proposed before or after his time. Its date was 10th Ramadan 471, i.e., 16th March 1079. The modern interpretation of Khayyam's calendar is that eight intercalary days should be introduced in thirty–three years, resulting in an error of one day in about 5,000 years. The Gregorian calendar leads to an error of one day in 3,330 years.55

Chingiz Khan erected a magnificent observatory at Maraghah near Tabriz far surpassing any built by his predecessors. Nasir al–Din Tusi was the greatest genius of this institution. He was quite original and independent, and criticized Ptolemy quite severely, “paving the way for the overthrow of the geocentric system.”56

Ulugh Beg, grandson of Timur, established an observatory at Samarqand, Turkestan, in 823/1420, which was best equipped. A great work produced at this observatory was an independent star catalogue, known as the “Ulugh Beg Tables,” based entirely upon new observations, the first in about sixteen hundred years, i.e., since the time of Hipparchus, second century B.C. The positions were given to the nearest minute of arc, and attained a high degree of precision for that period. Instruments used in this observatory are considered the best made up to that time.57 It is said that his quadrant was so large that its diameter was equal to the height of the St. Sophia Church in Constantinople. This work on astronomy is regarded as one of the best books of the Muslim astronomers. It was written in 841/1437, and from it one can have a fair account of the knowledge possessed by the Muslims in the ninth/fifteenth century. The first part deals with the general principles of astronomy. The latter part contains the practical methods of calculating the lunar and solar eclipses and the construction of the tables and their applications; a list of the stars; the motion of the sun, the moon, and the planets; and the terrestrial latitudes and longitudes of the big cities of the world.58

The Mughuls inherited their fondness for astronomy from Ulugh Beg. Farishtah remarks that Humayun was a keen astronomer and spent a good deal of time in its pursuit.59 An observatory was founded in Delhi under the orders of Muhammad Shah in 1137/1724, which was in the charge of the wellknown mathematician Mirza Khair Allah. By this time the West had made great progress in astronomy as in other branches of knowledge, and therefore a commission consisting of the ablest men of the time was sent to Europe to study the new methods followed there and new results obtained through the then latest researches. The commission brought back with it some telescopes and other instruments and a few books prepared in Europe. The King of Portugal also deputed a European astronomer to go to Delhi with

the commission. But when his data were checked at the Delhi observatory, local people detected errors and made corrections in his tables and calculations of the lunar and solar eclipses. This is ascribed to the fact that the instruments made in Europe at the time were of a smaller size than those available in the Delhi observatory.60

The Nizamiyyah observatory was erected at Hyderabad Deccan in the thirteenth/nineteenth century, and was the biggest institution of its kind in the East. It contained a sixteen-inch refracting telescope, a transit instrument, a Meridian circle, and a good deal of other equipment essential for a modern observatory. Its unique position was recognized by international organizations, and it had an important share in the preparation of the International Catalogue of Stars. After the establishment of the Osmania University, it became a constituent unit of that University.

The influence of the Muslims in this field is traceable from the many Arabic names and words that have become an integral part of the astronomical sciences. A long list of such words can be compiled, but it would be sufficient to mention a few: almanac (al-munakh), almacantar (al-muqantarah), nadir (nadir), zenith (samt al-ras), algol (al-ghul), altair (al-ta'ir), aldebaran (aldabaran), fomalhaut (jam al-hut), denab (dhanab), vega (waqi'), and the various names of Muslim astronomers given to the craters of the moon.61

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Chapter 64: Physics and Mineralogy

The Muslims contributed enormously to exact sciences such as mathematics, astronomy, physics, chemistry, botany, and zoology since they had succeeded in acquiring the knowledge of the sciences which had developed before the advent of Islam.

Abu Yusuf Ya'qub ibn Ishaq al-Kindi[1] was the first Muslim scientist-philosopher. His pure Arabian descent earned him the title "The Philosopher of the Arabs." Indeed, he was the first and last example of an Aristotelian student in the Eastern Caliphate who sprang from the Arabian stock. His principal work on geometrical and physiological optics based on the optics of Euclid in Theon's recension was widely used both in the East and the West until it was superseded by the greater work of ibn al-Haitham. He was the first Muslim to write in Arabic a book on music in which he designed a notation for the pitch of notes. Al-Kindi's three or four treatises on the theory of music are the earliest extant works in Arabic showing the influence of Greek writings on that subject. Of al-Kindi's writings more have survived in Latin translations than in the Arabic original.[2]

An observatory was opened by the three sons of Musa ibn Shakir (236-257(850-870) in their house at Baghdad. The Buwaihid Sultan Sharaf al-Daulah (372-379/982-989) instituted another in his palace at Baghdad where 'Abd al-Rahman al-Sufi (d. 376/986), Ahmad al-Saqhhani (d. 380/990), and abu al-Wafa' (d. 387/997) carried out their astronomical observations. At the Court of another Buwaihid, Rukn al-Daulah (320-366/932-976) of al-Rayy, flourished abu Ja'far al-Khazin of Khurasan who ascertained the obliquity of the ecliptic and solved a problem in Archimedes which led to the discovery of a cubic equation. Other astronomers made a systematic study of the heavens in Shiraz, Nishapur, and Samarqand.[3] Banu Musa published a work on the balance.

'Utarid ibn Mubammad al-Hasib wrote a book on lapidary which is reckoned among the oldest Arabic works on this subject; abu Zakariya al-Razi quoted from 'Utarid in his famous book al-Hdwi. Al-Razi the Iranian was one of the greatest medical men of the Middle Ages. He was an expert chemist and physicist.

Al-Hakim the Fatimid was personally interested in astronomical calculations. He built on the Muquttam an observatory to which he used to ride before dawn. The intellectual lights of his Court were 'Ali ibn Ydnus (d. 400/ 1009), the greatest astronomer Egypt has ever produced, and abu 'Ali alHaitham (Latin Alhazen), the principal Muslim physicist and student of optics. The latter was undoubtedly the foremost physicist of the Middle Ages. His researches into geometrical and physiological optics were considered to be the most important and useful up to the time of Renaissance. His explanation of the vision and functions of the eye was far in advance of the ideas of the ancients. The chief work for which he is noted is one on optics, Kitab al-Manazir, of which the original is lost but which was translated into Latin in the sixth/twelfth century. Almost all the medieval writers on optics in the West based their works on ibn

Haitham's Opticae Thesaurus. In this work he opposed the theory of Euclid and Ptolemy that the eye sends out visual rays to the object of vision, and presented experiments for testing the angles of incidence and reflection. In certain experiments he approached the theoretical discovery of magnifying lenses which were manufactured in Italy centuries later.[4]

Ibn al-Haitham was the greatest Muslim physicist and one of the foremost opticians of the world. He found out the law of refraction in transparent bodies; laws of reflection of light; spherical and parabolic aberrations; and the law of refraction which later came to be known as Snell's Law. He discussed the magnifying power of a lens, refraction of light in the earth's atmosphere, and beginning or termination of twilight when the sun is 19° vertically below the horizon. He tried by these means to estimate the height of the homogeneous atmosphere. He gave a better explanation of vision, though he erroneously assumed the lens of the eye to be the organ of sight. Later on ibn Rushd corrected this error and showed that sight is the function of the retina. Ibn al-Haitham explained the vision of a body by the aid of two eyes and the more magnified appearance of heavenly bodies when near the horizon than when vertically higher.

Muslim scientists evinced much interest in the determination of specific gravity of bodies. At Ghaznah in eastern Afghanistan lived abu al-Raiban Muhammad ibn Ahmad al-Biruni (363-440/973-1048), considered one of the most original and profound scientists that the medieval world produced in the domains of physical and mathematical sciences. Al-Biruni found accurately the specific gravity of eighteen different precious substances and metals. He realized that the velocity of light was enormously greater than that of sound. Al-Biruni developed the mathematical part of geography, improved mensuration, and determined quite accurately the latitude and longitude of a number of places; he devised easy methods of stereographic projection. He showed how water flows in natural springs and how it comes out in artificial wells, and explained these facts in accordance with the laws of hydrostatics. His observations led him to the conclusion that the Indus Valley was at one time a part of the sea which became solid by the deposit of alluvial soil.

The most illustrious name in Arabic medical annals after al-Razi is that of ibn Sina (Latin Avicenna) (370-428/980-1037). Al-Razi was more of a physician than ibn Sina, but ibn Sina was more of a philosopher. In this physician, philosopher, philologist, and poet, medieval Arab science culminates and is, one might say, incarnated. Ibn Sina wrote on the theory of numbers. For accurate measurement of distances he invented an apparatus involving the same principle as our modern Vernier. He made a masterly study of a number of physical subjects like motion, contact, force, vacuum, infinity, light, and heat. Ibn Sina expressed his views on all the information that could be gathered in physics philosophically. He showed that however great the velocity of light may be, it must be limited. He did valuable research in music also, but his principal subject was medicine for which he earned the title of Shaikh al-Ra'is.

Jalal al-Din Malik Shah patronized astronomical studies. He established in 467/1074 at Rayyan

observatory where there was introduced into the civil calendar an important reform based on an accurate determination of the length of the tropical year. To this task of reforming the Persian calendar he called to his new observatory the celebrated 'Umar al-khayyam. Umar al-Khayyam was born between 430/1038 and 440/1048 at Nishapur where he died in 517/1123. He is known to the world primarily as a Persian poet. Very few people realize that he was a first-class mathematician and astronomer as well. The researches of al-Khayyam and his collaborators resulted in the production of the calendar named, after his patron, al-Tarikh al-Jalali, which is even more accurate than the Gregorian calendar. As mentioned in the preceding chapter, the latter leads to an error of one day in 3,330 years whereas al-Khayyam's leads to an error of one day in about 5,000 years. 'Umar al-Khayyam performed experiments to find the specific gravity of various substances.

The attraction of iron by natural magnet was known to the Greeks; magnet's acquiring a definite direction when suspended freely was known to the Chinese. But it appears that this property was first utilized by Muslims in their marine navigation. Muhammad al-'Aufi was the first to mention it in his Jawami'. The directive position of the magnetic needle was known to the Chinese from a very long time, but they used it only for geomantic purposes. Most probably Muslim sailors were the first to employ it in navigating their ships as is evident from Chu Yu's account of sailing vessels using it between Canton and Sumatra.

Nasir al-Din Tusi's most brilliant pupil Qutb al-Din Shirazi (634-711/ 1236-1311) wrote Nihayat al-Idrak fi Dirayat al-Aflak which is largely a development of the former's Tadhkirah, a work on astronomical topics; it also contains valuable discussions on geometrical optics like those on the nature of vision and the formation of the rainbow. He was the first scientist to give a correct and clear explanation of the formation of a rainbow. The primary bow was explained by him to be due to two refractions and one internal reflection, and the secondary to two refractions and two internal reflections of solar rays in minute spherical drops of water suspended in the air; essentially the same explanation was given by Descartes in the eleventh/ seventeenth century. The colours of the rainbow for their correct interpretation had to wait Newton's experiments on the dispersion of light.

Kamal al-Din Farisi (d. 720/1320) was a famous pupil of Qutb al-Din and under his inspiration wrote Tangih al-Mandzir (a commentary on ibn alHaitham's classical work on optics, Kitab al-Mandzir), which was published with notes by the Da'irat al-Ma'irif, Hyderabad, in 1928-30.

Muslim scientists were deeply interested in Archimedes' works on mechanics and hydrostatics. In these subjects they determined the density of a number of substances. Sanad ibn 'Ali, al-Biriini, 'Umar al-Khayyam, Muzaffar alAsfuziri5 and several others did some work on these branches of physics, but the most important work was done by 'Abd al-Rahman al-Khazini in his Mizan al-Hikmah, written in 618/1221 and considered among the masterpieces of the Middle Ages. In this work al-Khazini discussed mechanics, hydrostatics, and physics in a masterly way. He gave tables of specific gravities of liquid substances (on the lines adopted by al-Biruni) and detailed studies of the theory of gravitation (universal force directed towards the then considered centre of the universe, i.e., the centre of the earth); weight

and buoyancy of air; rise of water in capillary tubes; aerometric measurement of densities and the temperature of liquids; theory of the lever; levelling by balance; and measurement of time.

The Muslims took keen interst in clocks to find out the correct times for prayers. Their artisans acquired great mastery in this work, as may be judged from Harun al-Ras_bid's presenting Charlemagne with a water-clock in 192/807.

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Chapter 65: Chemistry

Alexandrian Alchemy.-With the advent of Islam, the Arab tribes, many of them still nomadic, were united into one nation. Their conflicts with the neighbouring peoples which used to end as skirmishes bringing immediate defeat on the scattered tribes, now changed into regular wars often crowning them with success. What that meant can be realized from the fact that within a hundred years of the Prophet's death, which occurred in 11/632, Islam had spread from Spain in the West to Sind in the East. As an advancing nation the Arabs came in contact with different races, and when Egypt was conquered, during the regime of the Caliph 'Umar, in 21/641, they came to know the Hellenized Egyptian culture as it then existed. Its centre was Alexandria, founded by Alexander in 332B.C.

Very soon it became an emporium of international trade attracting merchants from all over the world. Above all, the Greeks had migrated there in numbers, giving rise to a mixed culture of Egyptian and Greek origin. The Egyptians used idols in their temples and chapels, preferring those of bronze, particularly when they were gilded. The artisans of Alexandria excelled in this craft, and the manufacture of gilded bronze statues apparently became a lucrative industry.

From gilding bronze some of the artisans began to dream of making gold itself and devoted their main attention to achieve this end. Thus arose alchemy, not found before either in Egypt or in Greece. It was existing when the Arabs acquired Egypt and was one of the elements of Alexandrian culture which diffused into Arabian civilization.

There are several treatises and even books which suggest that Greek science, which flourished between 300 B. C. and 200 A. D., subsequently passed on to the Arabs who functioned as its intermediate preservers delivering it to Europeans during the Middle Ages. Such is the accepted origin of alchemy.

It now becomes necessary to offer a brief sketch of alchemy as it was founded at Alexandria. The oldest existing manuscript on alchemy is not prior to about 391/1000. But it is supposed to be a copy of a work originally written in about 100 A. D. During this early period alchemy was a semi-secret science pursued by a few obscure persons. As Taylor[1] says, "although the earlier alchemists wrote in Greek, they were not Greeks, but in all probability Egyptians or Jews. They were not Christians." And what did they call their art? This knotty problem is conspicuous by its absence in Taylor's book. When Wilson[2] came to review it, he supplied the missing information on "the derivation of the Greek name of the art." "The word unmistakably goes back to the craft of the foundryman and metal-worker.

First, there is the Greek verb cheo (xiw), to melt and pour, as in the casting of a bronze statue, then its derivative chump, an ingot of cast metal, and finally from this another derivative chumeia, the art of preparing metal ingots. This in time became a technical term for the artificial preparation of the precious metals, but at first, as in Zosimus, about 300 A.D., it acquired a qualifying phrase, the chumeia of silver or gold. Before the Arabic period, however, chumeia could stand alone to denote the art of transmutation.

Also before Arabic times, about 81/700 or earlier, it seems to have been confused with chemia, apparently a Greek derivative of the Egyptian word chem, meaning black. The reasons are obscure but the fact of the confusion is hardly to be questioned. Later, the Arabs took over both spellings, chumeia and chemia, prefixed their own definite article al, and handed the word on to the Europeans in about the sixth/twelfth century." Thus kimiya is the Arabicized form of the dual word chumeia/chemia.

The Greek and Arabic Terms Compared.-Now it is even more important to know what the Arabs received under the name kimiya from the Greekspeaking alchemists-to know what the word chemeia signifies and how the Arabic word kimiya compares with it in meaning. Gildemeister[3] explains that "kimiya with the Arabs primarily is not an abstraction (or the science of alchemy) but the name of a substance, of an agent, by which transmutation of metals is brought about, thus of the Philosophers' Stone, or rather of preparations made out of it. It is thus a synonym of ilcsir which likewise signifies a transforming agent. By contrast chumeia is never used by the Greeks in any other sense than transmutation of metals."[4]

There are two synonyms in Greek, chemeia and chumeia. Gildemeister refers to the use only of the latter, apparently taking it as identical with the former. In Arabic there are two terms kimiya and iksir, the latter not being represented in Greek literature. In fact, iksir occurs far more in Arabic than the word kimiya. Iksir or al-iksir has been Europeanized into elixir which has come to mean as an agent for prolonging life. According to Taylor,[5] "the alchemy of China was primarily concerned with the prolonging of life"; he adds[6] in this connection that "it is very probable that the Arab alchemists received some

information about it. It is certainly notable that the idea of the elixir as a medicine prolonging life was present amongst the Arabs and not known to their Greek-speaking predecessors."

P. Kraus[7] published a voluminous work on Jabir. Its reviewer[8] correctly noticed that "as to the origin of all those theories, Kraus maintains that not much of Jabir's alchemy can be traced to the extant fragments of Greek alchemistic literature, and that there are certain features in his alchemistic knowledge which are definitely unknown in classical antiquity." There has prevailed so much prejudice in favour of Greek that even the word "elixir," absent in Greek and therefore inconceivable as a loan-word in Arabic, has been given a Greek root. Iksir has accordingly been said to have come from the Greek word ksiron, meaning dry, and has been made to connote dry powder, while elixir means essence, spirit, or fluid. How the Arabs coined their word from Greek cannot be explained. All this tends to show that the primary source of Arab alchemy lies somewhere away from Alexandria.

The Urge to Pursue Alchemy.-There were two types of seekers after longevity. First, the ascetic who was his own grocer, cook, and doctor and to whom infirmity of old age meant lingering death. The second was represented by a prince who had wealth and power and desired long life, only to enjoy his possessions fully. Though for different reasons, the Sufis, the nearest to ascetics, also indulged in alchemy. In fact, Wiedemann[9] remarks that "the study of alchemy has had one undesirable result inasmuch as the representatives of the mystic movement in Islam studied alchemy, e.g., ibn al-'Arabi."

This, however, was expected, and the converse is also true, for about the master of alchemy, Jurji[10] states that "later tradition makes Jabir ibn Hayyan the first Sufi." Kraus[11] explains how Jabir, the alchemist, became interested in Sufism. He writes, "Alchemy is never practised by Jabir for the object of accumulating wealth and acquiring the power of gold. Its real mission is to bring about salvation." And how was this possible? He continues to say that "Salvation in the Manichaean sense means to oppose in all spheres of life the fatal mixture of light and darkness and to free the light from dark particles. The Manichaean natural history, especially alchemy, aims at the great work of salvation."

Let us now turn to the wealthy and the worldly class. According to Martin,[12] "Emperor Ts'in-She-Hwang (B. C. 220), the builder of the great wall of China, is the earliest historical sovereign who became a votary of alchemy." There are a few more Chinese emperors who believed in alchemy; a couple of them had to pay with their lives for trying alchemical drugs. In the life of Chingiz Khan it is stated that he sent for a Taoist priest all the way from China to Central Asia, where he was encamped, to discuss if life could be prolonged for ever.

Khalid, the Umayyad Prince (40-85/660-704).-There is a sub-class among the well-to-do who would like to enjoy as sport the transmutation of a base metal into gold. Such a motive on the part of a young prince can be easily imagined and one such prince appears to have been Khalid, son of the Caliph Yazid I and grandson of Mu`awiyah. In the Arabic literature on alchemy, compiled about 377(987 by the famous bookseller al-Nadim, it is stated, as translated by Fuck,[13] that "Khalid was the first Muslim for whom medical, astronomical, and (al)chemical writings were translated into Arabic. ..." He wrote a

number of treatises and books. Al-Nadim also saw the following four of his books: (1) The Book of Amulets, (2) The Great Book of the Scroll, (3) The Small Book of the Scroll, and (4) The Book of the Testament to His Son on the Art.

Introduction of Alexandrian Alchemy.–When Khalid wanted to learn alchemy at Damascus, his capital, he sent for a teacher from Alexandria, a Christian monk named Marianos, a pupil of another alchemist, also of Alexandria, named Stephanos, who lived in the reign of the Byzantine Emperor Herkleios I (610–641 A.D.). That the best available teacher of alchemy at the time was a monk is in full harmony with what has been said of alchemy and of Sufis here. A monograph of over fifty pages has been devoted to Khalid by Professor Ruska,[14] the famous German historian of alchemy.

The Oldest Alchemy and How it Reached the Muslim World.–A series of authors have established that alchemy is indigenous to China. Among the older writers may be mentioned Martin,[15] while the best historical evidence has been offered by Dubs.[16] From China alchemy reached Alexandria by the sea-route. In South China, the name of the dynasty that built the Great Wall is pronounced Ts'in, which became Tseen, the Arabic name for China. Likewise, the South Chinese term, kim-iya, Gold-making Juice, became the loan-word Icimiya, upon which Schneider[17] has published the most recent communication. It is probable that the word kimiya, instead of having been borrowed direct from the Chinese, was taken over from Arabic into Greek, being Hellenized there as chemeia. This is how it was written, but very probably its pronunciation was similar to that of kimiya. The pre-Islamic Arabs, bringing silk from South China, all along the sea-route, also imported Taoism and alchemy as the cults of immortality. To the pagan mind alchemy made a special appeal and this explains how it came to be imported. Some of the Arab alchemists of the type of what we call fakirs must have settled at Alexandria where it gradually spread mainly among monks and other ascetics. We have just seen that even centuries afterwards this character did not change for it was the monks who brought Alexandrian alchemy to Damascus.

Another way in which Chinese alchemy reached the Islamic world was via land-route. In Christianity one church tried to suppress another; and a community, speaking Syriac and calling themselves Nestorians, sought protection from outside and established an academy at Jundi-Sbapiir, in SouthWest Persia. The Nestorians migrated even up to China so that there must have been contact between the Nestorians of China and those of Persia. As an impact of Christianity upon Zoroastrianism there resulted the religion of Mani. The Manichaeans with their philosophy of dualism were close to the alchemists as they also believed in a similar doctrine. Briefly, Nestorian and Manichaean Persia was in intimate contact with China and was responsible for a fresh influx of Chinese alchemy. The Jundi-Shapur academy was by no means dead during the reign of Harun al-Rashid to which period Jabir also belonged. When Kraus and others notice that there was much in Jabir that was not found in Greek alchemy we have to turn to Chinese influence in Persia at that time.

The Beginning of Classical Islamic Alchemy.–The Umayyads ruling from Damascus had become very

unpopular. There were plots to replace them by the 'Abbasid dynasty. Such agents were active as far east as the province of Khurasan in Persia. One such emissary was Jabir's father, Hayyan, a druggist by profession. Jabir was born at Tds, in Khurasan, about 104/722, during the family's sojourn in Persia. When Jabir was a mere boy, Hayyan was arrested for his activity and had to pay with his life. Khurasan being the border province was a centre of foreign cultures like Mahayana Buddhism and other schools of mysticism. It may be pointed out in this connection that it was again at Tus, in Khurasan, where Imam Ghazali, one of the great Muslim mystics, was born. Above all, we find in Jabir one of the first persons to be formally called a Sufi and the first among Muslims to be recognized as the master of alchemy. Both alchemy and Sufism appear to come from the same source and to have long remained together. Some of those who have written upon the history of Sufism have noticed that in its early stages it flourished only where Neo-Platonism was found. Likewise, writers on the history of alchemy have also observed its earlier co-existence with Neo-Platonism.

While Sufism and Neo-Platonism can be directly and easily connected with each other, as pertaining to the same system of thought, it requires inquiring into what alchemy originally was in order to admit that alchemy did not develop from one craft to another, from gilding to goldmaking, but was a kind of applied mysticism. The Sufis wanted immortality in the next world by spiritual exercises; the alchemists wanted it by virtue of drugs in this world. This motive at once becomes evident by a study of Chinese alchemy which represents its earliest phase. Instead of associating Islamic alchemy with Alexandrian Neo-Platonism it is more fruitful to connect it with Manichaeism and with schools of mysticism influenced by Chinese mysticism.

Khurasan, rather than Egypt, was the centre from where Islamic alchemy got its real initiation. Between Khalid ibn Yazid and Jabir bin Hayyan was a period of seventy-five years. Historically, the political power shifted from Damascus to Baghdad. At this latter centre the so-called Persian influence, but really Chinese-Manichaean doctrines, rapidly promoted Islamic alchemy. Those who compare Greek alchemy with that of Jabir notice an obvious difference between the two. If comparison is made between the doctrines and achievements of Muslim alchemists with those of China, the difference is very much less. In so far as even the alchemy of Alexandria is Chinese, though a degenerated form of it, it still has features enough for it to stand comparison with that of China.

With Jabir begins a school of alchemy much nearer to its original source, with its centre at Tus, instead of at Alexandria. The first feature to be noticed here is that the ideal seems to be not to make gold but to prepare panacean drugs. Jabir's reputation as a physician grew after the services he had rendered at the Court of Harun al-Rashid. His alchemical writings on the contrary were misunderstood even by a savant like ibn Khaldun[18] who remarked that they read like puzzles.

The effect of the chemical mysticism, which was alchemy, was demonstrated in the form of life-saving iksirs; the theory of applied mysticism was obtained from other systems of mysticism, such as Sufism and Manichaeism. The existing literature shows that alchemy proposed to make gold only and this

seems to be true of Greek alchemy. The Arab alchemists, like the original Chinese masters, worked upon their preparations for making everything everlasting. When the omnipotent substance, iksir or kimiya, was applied to a base metal it became rust-proof and fire-proof, which meant it changed into gold. The same agent could also convert an ordinary stone into a permanent diamond. These features are not revealed in treatises on the history of alchemy and must be clearly pointed out.

Imam Ja'far al-Sddiq (81-148/700-765).-It will now be apparent how Jabir would venerate a master of mysticism like Imam Ja`far al-Sadiq, the sixth Imam, who lived like an internee at Baghdad. Of all the Imams he was the greatest mystic. He was deeply interested in alchemy and even composed treatises on the subject. Importance is attached to him here mainly because Jabir speaks of him as a Master and also because of the fact that alchemy and Sufism both aim at immortality. Since Jabir was both a Sufi and an alchemist, he could have received initiation from the Imam at least as a mystic. Ruska[19] has edited a treatise attributed to the Imam and discussed his position in the history of alchemy, devoting an introduction of sixty pages to the problem.

Jabir ibn Hayyan (104-200/722-815).-Our knowledge of Jabir's life is very sketchy. He was born at Tus, in Khurasan, about 104/722. He became an orphan while yet a boy and was brought up in the tribe of his father, Azd, which lived in South Arabia. Then we suddenly find him as a man of middle age active as a physician at the Court of Harun al-Rashid and as a companion of Imam Ja'far al-Sadiq. His special patrons were Harun's viziers, the Barmakids, who really introduced him to the Court. When the Barmakids fell into disfavour in 188/803, Jabir, then over eighty years old, returned to Kufah where he used to live before coming to Baghdad.

The early life of the man, say from twenty to thirty-five, must have been spent in the pursuit of alchemy probably at Tus. If he had merely been born there he would have hardly been called al-Tusi. Another designation of his, al-Sufi, also sets us inquiring as to where he acquired proficiency in this field. With Tiis as a common centre for both Sufism and alchemy, the search is reduced to the minimum. When he left Baghdad immediately for Kufah, as an old bachelor, he could have hardly found people with whom he was familiar. Without relatives and surviving friends his life must have been that of a stranger and he must have migrated from Kufah to Tao where Sufism and alchemy were very much at home. According to one source, he died at Tus, in 200/815, which appears most probable, at the ripe age of ninety-three.

Two centuries after his death some houses in a part of Kufah where Jabir used to live were demolished. The house which he used to occupy was found to contain a mortar of solid gold weighing two pounds and a half which went to the royal treasury of the time. This archaeological finding gives much reality to the personality of Jabir with his many-sided features. Those who have been prejudiced in favour of Greek culture have nourished myths such as given by Thompson,[20] who writes that “Jabir is said to have been either a native of Mesopotamia or a Greek who afterwards embraced Muhammadanism.” The fact that this theory originated from Suidas, who lived in the fifth/eleventh century, and continued to appear as late as 1351/ 1932, when Thompson published his book, indicates the persistence of prejudice

in favour of the Greek origin of alchemy.

The existing literature on the history of alchemy seems to be devoted mainly to textual criticism rather than to the subject proper. Hence, as late as 1353/ 1934 Hopkins[21] recorded that “the fundamental work of fact-finding has been so difficult and time-consuming that no real history of alchemy has yet appeared.” The same judgment continued to be repeated, when Taylor[22] wrote in 1371/1951 that “it may at once be said that alchemy still remains an unsolved problem.” And both these remarks apply even more forcibly to Muslim alchemy. We have not been told as yet what the Muslim alchemists were after and particularly what was meant by kimiya and iksir; whether they were identical or whether there was a subtle difference between them.

What the Europeans of the Medieval Ages got as alchemy was the system developed by the Arabs immediately before them so that observations upon the alchemy of any of these two apply to either. “Paracelsus taught,” as worded by Thompson,[23] “that the object of alchemy was not to make gold, but to prepare medicines.” He is the founder in Europe of iatro-chemistry, but it is being maintained here that this has always been the character of alchemy and is best illustrated by the popularity Jabir enjoyed among his contemporaries. The fact that Jabir could indulge in the use of a golden mortar and yet live the life of a vegetarian, bachelor, and a Sufi-ascetic shows how he was not concerned with the making of gold as a source of wealth. The other observation is from Liebig. Chickashige[24] writes, in this connection, that “the long history of alchemy clearly shows, as Liebig remarked, that alchemy was never anything else than chemistry proper to its own generation.” If instead of “chemistry” and “iatro-chemistry” as above we use the more familiar and precise term, pharmaceutical chemistry, then both Liebig and Paracelsus would be expressing the same idea. Here again, Jabir's career fully confirms the remarks of Parcelsus and Liebig.

Among those who spared no energy to study the writings of Jabir may be mentioned the late Dr. Holmyard. He observes that “Jabir ibn Hayyan has many claims to be considered the first to whom the title of chemist may legitimately be applied.”[25] Hopkins[26] is even more eloquent in his tribute when he states that “... if all that has been deduced from the writings of Geber (the Europeanized name of Jabir) is true, he was one of the greatest single constructive influences in science, particularly in the science of metals, that the world has ever seen. Perhaps he should be ranked with Lavoisier for instituting a great revolution in the attitude of the educated people of his time towards the study of chemistry, especially in their attitude towards experiments.

Whereas, since the days of Aristotle, to soil one's hands with labour has been considered, except in Egypt, despicable and proper only for slaves, it is related that Geber had some success in teaching his friends at Court that laboratory methods are necessary and the only foundation for exact and reasonable science.” Respect to practical work which Jabir must have preached is confirmed by the converse having continued to exist even afterwards. Fuck[27] explains that “al-Nadim had no high opinion of Alchemy or of its adepts.

Of a contemporary alchemist who was credited with having been successful, he tells us that he never found him otherwise than in straitened circumstances and dirty by reason of the chemical work he was in the habit of doing." We can now appreciate the wealth of praise due to Jabir. Hopkins rightly showers praises upon Jabir, the Master, who infused into his people a spirit for experimentation which raised the status of Muslim alchemists so much above others that later historians, like Schneider,[28] could admit that "it is certain that no other people have pursued alchemy with so much persistent zeal as the Arabs." The special urge on the part of the Arabs to devote to alchemy would be apparent from what follows.

Kimiya.–Man's earlier medicines came from the plant world; herbalism was then the system of medicine. From this developed the notion that herbs could even make man immortal. The Aryans idealized the soma plant, the Iranians called it homa; the Chinese believed in the mushroom chip; and the Hebrews in the tree of life. Late in this period must be reckoned the belief in a gold–making–plant juice or kim–iya in the Hakka dialect of South China, the original of the Arabic term ki–miya.[29]

How Kimiya worked.–The ancient religion of man was animism. Every substance, including trees and stones, was believed to have a body and a soul, and to be alive potentially. The soul was a highly refined matter, like a perfume, and it came from the sun. It was more of energy than matter, like light, which, according to some physicists, has a corpuscular nature. The soul in turn was an emanation of the cosmic positive energy, called yang, in Chinese, meaning light, while in the universe there was also negative energy, called yin, meaning darkness. Matter was frozen yin energy, and it was difficult to convert matter into energy.

Matter and spirit could form only a temporary union or mixture. But if matter received the impact of an energizing principle it was changed into reactive negative energy which would then unite with the positive energy, and the result would be a real compound or a permanent union. Even a drop of the gold–making juice was taken to be bubbling with yang energy so that if a coin of copper was heated with it its ineffective soul was expelled and the material body or copper was transformed into negative energy, and it combined with the soul or positive energy from the plant juice to make the resultant gold. Here the donor is exceptionally rich in yang energy and the ultimate transmutation of metal is due to it.

Further, the donor belongs to the plant world. In countries like China and India, with their rich flora, alchemists did depend upon fresh herbs for the transformations they wished to bring about. This being denied to an alchemist like Jabir, he exploited mainly, if not entirely, minerals and metals instead; hence the importance given to inorganic raw materials and metals in the works of Arabian alchemists. Instead of kimiya, inorganic preparations called iksirs were used.

Ruh.–It is necessary to describe how the minds of the alchemists worked in preparing a simple substance such as rich (soul, spirit, or essence). Every substance, they must have felt, has a soul which remains like a tenant temporarily in the substance, the container of the soul. On heating the soul can be made to leave the body; on distilling the soul can be recovered more or less concentrated in the distillate. Thus a rose gives out its soul or ruh. The flower is now a dead body and the soul is its perfume

or essence. When such an essence or rult is taken as a drug it temporarily strengthens the body of the user, like blood-transfusion or an injection of glucose. The donor here gives only one of the two elements; the material body, the flower, is discarded. When the soul of the flower is introduced into the body of another receiver it is like the temporary transmigration of the soul which must repeat at every stage if the soul is not to disappear in space.

Iksir.-Transmigration implies that the soul and the body do not come from the same source, the two are not permanently united, the balance between the positive energy contained in the foreign soul and the potentially negative energy existing in its present container is not ideal. All that is required is to convert the body into negative energy and reunite with it the soul previously separated from it. This is a regular art. For example, take common salt. It does not sublime. Now, if re-crystallized and mixed with alcohol, just as roses were mixed with water, and the mixture distilled, the essence of common salt evaporates along with the volatile vehicle, alcohol. The distillate is added again to the residual salt in the distilling vessel and the process of rectification is continued. A stage comes when all the salt becomes fluid, leaving no solid residue. This is the iksir of common salt.

The body, the material vehicle, has by now been converted into reactive energy, negative in character, and its soul, as the positive energy, has combined with it into an inseparable whole. Salt is a mixture of a material body, or of potential negative energy, and a soul, the positive energy. Its iksir contains a permanent union or compound of positive energy coming from the soul and reactive negative energy or the transformed material body.

Technically, two processes were most necessary: distillation in the first instance, to isolate the soul, the essence, or the positive element, and calcination, to purify the material vehicle, in order to convert the potential energy into the reactive negative element. Melting of metals is a very minor operation. In the case of an active gold-making plant juice, calcining of copper is limited to gentle heating. In the case of iksir of common salt no separate calcining is necessary, repeated distillation incorporates it. It is clear by now that rids or spirit contains one element only, the positive. Iksir contains two, the positive element and the negative one. Each of them belongs to the same substance and as such must necessarily contain enough quanta of both to balance like exact opposites or rather like exact supplements.

When iksir results, the substance becomes a spirituous preparation, sublimable, volatile, atomized, or potentized. Now being all energy, it represents a permanent union, inseparable for ever. When taken as a drug it makes the patient like itself, tending to become permanent. Naturally, according to the original substance, the total energy content in different cases differs and iksirs also vary in their pharmacological properties. In any case an iksir is stronger than the spirit or rich. Whereas kimiya is a natural substance, iksir is an artificial one. To meddle with the gold-making juice in any way would be to destroy its virtues, whereas iksirs can be produced only by chemical processes, above all by distillation and calcination.

Because substances like common salt are made to distil along with alcohol, such heterogeneous mixtures as contained alcohol were probably called “elixirs” by European alchemists of the Middle Ages.

It will be apparent why Jabir talked mostly, if not solely, of iksir and not of kintiya, its synonym. How iksir has been made to come from the Greek word, kseron, merely meaning dry, cannot be explained. By constitution iksir was taken to be the purified body with its soul returned to it. It was a revived body and a returned soul, where the two, on becoming identical, represented a third substance.

The picture was essentially the same as that of man after resurrection. The soul would return to the dead body which would revive and henceforward remain immortal. But the revived person would be a regular mutation, his body feeling neither thirst nor hunger. He would be like a spirit or ghost with a body no longer composed of matter. Iksir represents such a substance, material to look at but in fact become energy, and, what is important, also a donor of energy.

Whatever the substance iksir may have been, its uses mainly decide its virtues. Jabir prepared iksirs from one substance after another and as an indefatigable worker could not avoid studying the properties of inorganic acids into which he tried to dissolve his metals to purify them, instead of melting them alone or along with other metals. In India the metals were never purified by the use of inorganic acids but mainly by calcining them with boiled extracts of herbs. In order to have substitute a plant extracts or organic acids Jabir prepared inorganic acids not for their own sake but for making iksirs. His experiments spread over a wide range of substances. The preparations resulting from them must have maintained Jabir's enthusiasm and made him a master. Holmyard,30 a chemist and an author of standard text-books on chemistry, after a careful study of Jabir, rightly states that “like painting which reached its highest pitch of perfection while still in its infancy, Islamic alchemy never surpassed the level it attained with one of its exponents, Jabir ibn Hayyan.” We can represent him as a noble soul, seeing diseases all over, finding no herbs to treat them with, and so taking with a vengeance to minerals as the only source of supplying remedies. Enthusiasm born under such circumstances, incorporating the personality of the worker and the poverty of the country reacting upon it, resulted in the achievement with which the world today remembers the name of Jabir.

Those who do not know what iksirs mean, certainly not mere powders, cannot imagine the deep urge for or high aim in making them. At every stage we have to remember that Jabir was an ascetic-bachelor and a mystic-Sufi; acquisition of wealth or making of bullion gold could never have been his motive. In the absence of the right perspective much energy has been wasted in trying to separate historical data from Jabirian legends. What is still required is to isolate alchemy proper from Jabir's writings. Writers on alchemy, rather on Alexandrian alchemy, have rightly attached full importance to the early record of the word chemeia.

Likewise, in dealing with the history of Muslim contribution to alchemy we feel that the introduction of the word iksir played an even more significant role. Jabir apparently used it for the first time and demonstrated its claims. Paracelsus is credited with having founded iatro-chemistry or having taught that the real aim of alchemy was to prepare medicines and not to make gold. Jabir would have been surprised to hear that alchemy was anything but that, and his iksirs anything but highly potent, we may

say, omnipotent and multipurpose drugs. Kraus[31] has translated from Arabic into German a text revealing what iksir can prove to be; an extract from it has also been rendered into English by Holmyard.[32] Harun al-Rashid's ministers belonged to the Barmakid family.

One of them, Yahya, was much devoted to a lady in his harem. She fell ill. The case ultimately became so hopeless that Jabir was sent for. The report" as coming from Jabir himself maintains: "I had a certain elixir with me, so I gave her a draught of two grains of it in three ounces of vinegar and honey and in less than half an hour she was as well as ever. And Yahya fell at my feet and kissed them, but I said, `Do not do so, O my brother!' And he asked about the uses of the elixir and I gave him the remainder of it and explained how it was employed, whereupon he applied himself to the study of science and persevered in it until he knew many things." Having demonstrated such a dramatic achievement it is impossible for any sane person to have found interest in making gold instead. Jibir's alchemy consisted only in preparing iksirs or wonder-drugs which were more precious than gold.

The Philosophers' Stone (Hajr Mukarram).-The preparation which marks the zenith of alchemical achievement is the Benevolent Stone (hair mukar. rang). The alchemists called themselves philosophers or Ilakima as opposed to physicians or,tabibs. The Alchemists' Stone was correctly paraphrased as the Philosophers' Stone. This is the genesis of the term. In the historical survey of the chemical arts of China by Li,[33] we read that "Chin-tan, an alchemical term in Chinese, first appearing in Pao-p'u tzu (a work composed about 317-332 A. D.), comes to refer to a drug or elixir which was prepared by the alchemists for prolonging life and transmuting metals. It reminds us of the Philosophers' Stone because this was considered to have the same effect as Chin-tan.... The language of the ancient alchemists is very hard to understand [a confession recalling the judgment of ibn Khaldun upon Jabir]. It is supposed that Chin-tan may have consisted of mercury, sulphur, lead, etc., a compound or mixture prepared in accordance with a theory not unlike that of Jabir, who supposed that every metal contained mercury and sulphur." The admission seems to be to the effect that the theory, that metals are composed of mercury and sulphur, did exist in China but in a vague form.

Taking the simpler notion first, with Jabir all metals including gold were composed of mercury and sulphur. Davis[34] states that, "for the Chinese alchemists, positive yang was lead instead of sulphur; negative yin was mercury." Jabir died in about 184/800. The Chinese alchemist, Chang Po-tuan,[35] living later in 373-475/983-1082, still maintained the ancient Chinese theory that "our fellow workers must be able to recognize true lead and mercury." It is, therefore, clear that Jabir borrowed a theory as known to the Chinese but improved upon it, keeping mercury as the one element and changing the other from lead to sulphur.

The surprising feature of the Sulphur/Mercury theory about the origin of metals is that it has not been challenged by experimenters who have melted metals, calcined them, and even sublimated at least arsenic and mercury compounds. That they should have believed that iron consisted of sulphur and mercury, and that even gold consisted of the same elements, has received no explanation so far. The

primitive man accepted blood as the life-giving principle and further believed that its red pigment was the real agent. Thus redness was taken to be the active principle so that any red substance could generate blood. Of all red substances cinnabar was the nearest approach to blood in colour.

When it was established by actual synthesis that cinnabar consists of mercury and sulphur, its elements came to be considered to be the elements of all metals. Animism assumed that even metals were living things, having a soul as well as a body. When negative energy freezes it becomes matter and the body of the metal consists of it. The soul is represented by the positive element, one which is sublimable so that it can permeate the material body. Lead is not volatile, sulphur is; hence the Lead/Mercury theory was essentially defective and the justification of the Sulphur/Mercury modification.

Further, lead and mercury do not produce a red compound, while sulphur and mercury do. But if Jabir's theory is a modification of a previous Chinese theory, how is it that in its original form it accepted lead and mercury as the elements of metals? What was required as the end-product was redness, and theorizing depended upon this result. Lead heated by itself oxidizes in the air to red lead or minium. Likewise, mercuric oxide is obtained as red, orange, or yellow powder, consisting of minute crystals. Thus, the Chinese theory was, indeed, properly conceived, but it failed to include a spirituous element like sulphur, while lead obviously was not.

Alchemy as a philosophical system is based on a dualism, postulating that everything consists of two elements, of light (yang in Chinese) and darkness (yin). When the metals were ascribed their constitution, sulphur and mercury came to be taken respectively as positive (yang)'and negative (yin) elements. And the realistic basis of this theory, as has been explained, came from the actual knowledge of what constituted cinnabar and the identification of cinnabar with blood. When the cosmic forces, yang and yin, are in perfect balance, it means yin exists as a negative creative energy and not as frozen matter, while yang naturally always remains spirituous; the result of their union is like that of two substances, identical in nature but oppositely charged, like positive and negative electricity.

The resultant is everlasting. Pure sulphur and pure mercury are imagined to be existing as energy, even though they may not appear to be so, and their resultant, when ideal or when the two are perfectly balanced, means an everlasting union, which is gold. According to another tenet of animism, like makes like; gold, the everlasting metal, as a drug makes the consumer also immortal. Gold remaining in mines for millions of years loses this property of donation, its negative element, mercury, having become less spirituous or more material; hence gold, as a drug, must be freshly prepared.

Better still it must be in a stage prior to its becoming gold, so to say, in a nascent stage when it is the iksir of gold, a ferment-like substance which will convert any metal into gold. This is the Philosophers' Stone, converting matter into energy, energizing the material or the negative element until it comes to the same level as its positive or spirituous element.

We, thus, see that rich or spirit consists of only the positive element, the soul; and iksir consists of two

elements, the positive element and the purified material element sublimated into reactive negative energy. Philosophers' Stone is double iksir; it consists of sulphur as a substance, which has a body and a soul (or failing sulphur, its substitute, say lead), and mercury as a substance, likewise with two elements of its own, its body and soul. In all, there are two purified bodies and two souls returned to their respective bodies.

The question now arises that if there are four elements compounded to form a fifth substance, why not another which is double that of the Philosophers' Stone. There are only four cosmic elements–heat, cold, dryness, and humidity. The body and soul of sulphur and the body and soul of mercury represent all these four cosmic elements; hence, between themselves, mercury and sulphur fully represent the cosmic force, the highest imaginable.

We have seen that Islamic alchemy was almost non–existent at Damascus. Baghdad produced its first two masters without whom there would perhaps have been no alchemy in the Islamic world. If alchemy at Damascus meant an importation from Alexandria, alchemy at Baghdad was an importation from Khurasan, which in turn was really an importation from China. Now two substances used by Jabir reveal the alchemy which he borrowed and upon which he improved. Ammonium chloride has played a very important role in alchemical preparations to which Stapleton36 devotes a special monograph.

From Holmyard37 we learn that Jabir's "is one of the earliest Arabic mentions of sal–ammoniac which for a time was imported from inner Asia. Jabir, however, knew how to prepare it from organic matter." Inner Asia is a vague term which makes it difficult for the reader to locate the actual source of the product. However, Stapleton38 explains that the Arabic word, nushadar, for sal–ammoniac, is a loan word–from Chinese. The origin of the product is thereby assured.

Another substance Jabir used is what he named khar sini. Holmyard39 comments, "Muslim writers say that it was used in China to make mirrors. According to Laufer, it was an alloy composed of copper, zinc, and nickel, known as pai–t'ung in Chinese, or white–copper." Khar is salt and a loan–word in Arabic. It cannot be made to express any metal or alloy. An alloy comparable with pai–t'ung is called bidri in India, consisting of copper, lead, and zinc in the ratios of 1:1:16. To give it a dark surface, sodium sulphate is used. A similar salt may be used for giving a metallic white surface to a different alloy of copper and zinc. In fact, it is easier to give it a metallic shine than to make it dull black. This salt of Chinese origin further points to the source of Jabir's alchemy.

Jabir being a mystic incorporates numerology into his alchemy, a fact discussed by some writers, above all by Stapleton40 According to him, the square with the nine cells was found as a motif near Nineveh as early as 4000 B.C. But in China also from at least the seventh century B.C., if not actually from the eleventh century B.C., the nine rooms of the square of the Imperial Temple had assigned to them the first nine numbers arranged in the actual order of these numbers in the simplest Magic Square. Even Jabir's numerology can thus be safely classed as Chinese in origin.

The Emerald Table of Hermes.–Among Jabir's writings, Holmyard first discovered in 1342/1923 the Arabic original of the famous Latin work bearing the above name. It deals with the phenomenon of change in nature, a typical Taoist idea, couched in phrases like those used in the following quotation from it: “That which is above is like that which is below and that which is below is like that which is above.” Such mystical statements are more decorative than illustrative in any other context.

Turba Philosophorum.–A Latin work of this title was very popular with European alchemists. It contained many names which were cited by Jabir in one of his books. On that account Ruska, in 1352/1933, proved that there should be an Arabic original of the Turba and this was confirmed by Stapleton by indicating that a fourth/tenth–century authority, ibn 'Umail (see later) quoted passages from it. Plessner having studied the problem exhaustively says, as quoted by Holmyard,41 that “it is the three–fold result of the cosmological discussion, the Qur'anic Creator–God, the unified world, the four elements (heat, cold, dryness, and humidity) that gives the discussion its clear direction towards the chief subject of the Turba, alchemy.” From the contents of the two classical works of medieval alchemy, the Turba and the Emerald Table, incorporated in Jabir's writings, the reputation he enjoyed in the Middle Ages can be easily visualized.

Al–Razi (c. 251–313/865–925).–Engaged as he was in preparing elixirs, Jabir was called upon as a consultant to use them when ordinary drugs had proved ineffective. On the contrary, abu Bakr Muhammad ibn Zakariya al–Razi, an account of whose philosophy has been given in Volume I (Chapter XXII) of the present work, was a physician by profession. At the age of thirty lie went to Baghdad, where the achievements of Jabir must have been narrated almost as miracles. Al–Razi could not but have been inspired by the tradition existing at Baghdad in favour of Jabir's elixirs. At Baghdad he decided to become a physician. As a Muslim alchemist he comes next only to Jabir. His fame in the medical world became so high that he was consulted when a hospital at Baghdad was being extended and ultimately became its chief physician.

Holmyard unwittingly remarks that “like the majority of physicians of medieval times, Razi was led to the study of alchemy.” In fact, alchemy has been nothing else but pharmaceutical chemistry and the physicians of those times had to prepare their own medicines. When Razi decided to become a physician he was probably attracted by the reports about elixirs. In other words, he became an alchemist first and a physician afterwards. Among his writings only one book dealing with alchemy has reached us. It is entitled “The Book of the Secret of Secrets” translated into German by Ruska.42 “Stapleton,” says Holmyard'43 “places Razi on an intellectual level with Gallileo and Boyle.” There is an illuminating article on al–Razi and alchemy by Heym,44 where we read45 that “bodies are composed of invisible elements and of empty space that lay between them. These atoms were eternal and possessed a certain size.” The statement reminds us of the modern explanation of the structure of crystals.

Razi accepted Jfibir's Sulphur–Mercury theory of the constitution of metals but Heym says that “in the same way the attribute of salinity enters into Razi's scheme.” He comments at the same time that

“without doubt it is here [with Razi] that the origin of the popular conceptions of alchemy with its three elements–mercury, salt, and sulphur–can be found which reappears later in Europe and plays such an important part in the history of Western alchemy.” Without mentioning Razi's name, Thompson[46] writes, “This Sulphur–Mercury doctrine was accepted by most alchemists until about the twelfth century, when the theory was extended by the addition of a third elementary principle, to which the name “salt” was given.

It was believed to be a basic principle which gave solidity and resistance to fire. Mercury was considered to be the connecting link between the spirit and the body, and the element on which depended blood and life.” The source of the Sulphur–Mercury–Salt theory not mentioned in Thompson is revealed by Redgrove,[47] who writes that “Isaac Hollandus appears to be the earliest known writer who makes mention (c. 1063/1652) of the famous Sulphur–Mercury–Salt theory.”

Thompson places the theory in the twelfth century; Redgrove, makes it seventeenth century; while Razi, the real author of it, lived in the third/ninth century. An explanation can also be offered as to how an alchemist of Holland came to be credited as the propounder of this modified theory. Heym writes that “in Europe throughout the Middle Ages until the seventeenth century, Razi's works on medicine were still part of the curriculum at Dutch Universities.”

It has been casually indicated that alchemy as a system of thought is based on dualism which characterizes Manichaeism and which was at its best in China. At any rate, al–Razi was so much influenced by dualism that Heym says, “al–Razi was also called a Manichaean,” though he gives a different explanation for this appellation of his. Where Razi continued the tradition of Jabir, which rightly made an appeal to the judgment of Hopkins, was his love for practical work. Heym states that “even though al–Razi in his alchemy was not strictly empirical in our sense of the word, his great work mentioned above is a book of experiments; it is a book of practical alchemy.... There it can be said that al–Razi is the creator of a new alchemy for he seems to be the first to have transformed theoretical alchemy into a new strictly scientific system. Or, to be more definite, al–Razi transformed alchemy for the first time into a new and strictly scientific system.” To a practising physician and to one who was not a mystic like Jabir, it was practical phase of alchemy, which was inorganic pharmaceutical chemistry of the age that naturally appealed most.

Ibn Sinn (370–428/980–1037.)–Europeans in the Middle Ages had Latinized the names Jabir into Geber and Razi into Rhasis or Rhazes, and these easily passed on as those of their own masters in science and medicine. The greatest medical authority of the Muslim world was abu 'Ali Sina whose name was likewise adapted as Avicenna. Muslim physicians call him the Shaikh, meaning the Prince of Physicians. His career shows nothing revolutionary like that of Razi. He studied medicine in the routine way and became proficient enough to treat patients even by the age of sixteen. Being a genius he was called by one prince after another from Bukhara to Iran and served them even as a vizier. Enjoying Court life in every sense of the word, luxury above all, he could have hardly found time to experiment as a

pharmacist. In his classic entitled the “Canon of Medicine,” some seven hundred and fifty drugs are mentioned, but they are all simples or individual drugs, vegetable, animal, and mineral in origin. None of them are of the class of high potency or synthetic inorganic chemicals, or iksirs. In his writings alchemy is discussed but critically. As a physician he did not use any iksir; it is out of question that he could have believed in a substance changing base metals into gold.

Ibn 'Umail (250–300/864–912).–In a short contribution on the subject such as this we have to be strict in selecting the representatives of Islamic alchemy. In doing so we have dealt with authors whose works were translated into Latin during the Middle Ages. These are, so to say, the masters who served as progenitors of European alchemy. Now, Davis[48] has tried to prove by the common contents and even the common illustrations of the works on the subject that the alchemy of medieval Europe is almost identical with that of China. To connect European alchemy with that of the Chinese, it becomes necessary to place Islamic alchemy as the real connecting link between the two. It would at once explain a continuity of thought and give a complete sketch of the evolution of alchemy. As depicted at present, there seem to be at least two different systems of alchemy isolated and unconnected. For this reason we wish to mention one more author whose work was translated into Latin and printed in 1032/1622. He is ibn 'Umail. Stapleton[49] and his colleagues have edited 'Umail's three Arabic texts and also the Latin translation in 1032/1622, along with copious notes which together make the presentation a model of scholarship. When we compare 'Umail's treatise with an original European work on alchemy, Splendor Solis, a classic in itself, by Solomon Trismosin,[50] composed about 990/1582, we get the impression that the contents and even the style of presentation are the same in both the works. The influence of alchemical literature in Arabic on medieval European writers becomes thereby quite evident.

Our present contribution will serve its purpose better if we indulge in offering in modern phraseology what these alchemists were actually after. It is a problem of science to explain how one form of energy is converted into another, e.g., heat into light. Likewise, a far greater problem, but of the same category, is to explain how matter changes into energy and vice versa. Ibn 'Umail, like a typical alchemist, expresses this as follows: “Turn bodies into non–bodies and non–bodies into bodies.” Iksir was the energizing principle which could sublimate matter into energy. This was with regard to technique only. The aim was to energize the human body to make it immortal. When the soul is strengthened and the body merely reconditioned and not thoroughly purified, life is only prolonged. The agent that purifies the human body can purify the body of a base metal as well. With a purified body man mutates into an immortal being capable of flying about in the air, as Davis[51] has clearly emphasized. With the purified body a base metal mutates into an everlasting form which is gold. Alchemical improvement ended in the permanency of form. Thus, the active agent behaved in one and the same way, converting impure body into sublime energy, resulting in man's immortality and in the synthesis of gold. This is what ibn 'Umail actually meant.

Jildaki (d. 762/1360).–The last authority we propose mentioning here is Jildaki. One of his works, “End of Search,” has been the subject of detailed study by Dr. M. Taslimi of Teheran–a study which was accepted as a thesis for Doctorate by London University in 1954. Unfortunately, the thesis has not yet

been published. But Holmyard[52] summarizes it by saying, “That there is a great deal of similarity between the ideas contained in the quotations of Jabir given in the 'End of Search' and those found in the Latin works of Geber but the correspondence is not sufficiently close to establish a definite affiliation.” Our problem has been to find how, from author to author, alchemy has actually progressed. After al-Razi or at the most after 'Umail we find repetition of what had been said before in different words and with other illustrations. No wonder that Holmyard justly observes that “after Jildaki there is no outstanding figure in Muslim alchemy.”

Alchemy in Other Islamic Countries.-No writer to our knowledge has spoken of alchemy by Muslims outside the schools of Damascus and Baghdad. What about the impact of local schools of alchemy upon Muslims living in India, Burma, Indonesia, and elsewhere? Dr. Maung Htin Aung,[53] Vice-Chancellor of Rangoon University, speaks as follows: “Some members (of the Burmese Science) association may (be) also (among those who) consider the Burmese alchemist to be a charlatan and an impostor. But I will plead with you to spare him a sigh. Of all the religious cults that existed in Burma before the advent of Buddhism, alchemy was the noblest. Like modern science, Burmese alchemy aimed at the conquest of nature, and discovering for suffering humanity a way to preserve the human body in its vigour and beauty.” Jabrian alchemy was certainly that and it is impossible to think that any two systems in corporating such ideas did not fuse.

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Chapter 66: Natural History

A

Inasmuch as the sciences studied in any traditional civilization, that is, one based upon a divine revelation, depend upon the metaphysical and religious bases of that civilization, Muslim sciences have always echoed and reflected the central Islamic doctrine of unity (tauhid). Just as the Islamic religious and moral sciences have begun from and returned to the idea of divine unity, the natural sciences have tried to discover the interrelation of all created beings. It is a general feature of all medieval cosmological sciences[1] that they seek to express the “unicity of all that exists.” Especially in the Muslim natural sciences this goal has been central, and the idea of the unicity of nature and the interrelatedness of all parts of the universe has remained as a complement to and necessary consequence of the oneness of the Creator.

Since the most legitimate and meaningful way of studying a science is with respect to its ultimate aim and from the point of view of those who have cultivated it, we shall best understand the Muslim sciences if we keep in mind that their primary aim, unlike that of the modern natural sciences which are only analytical and quantitative, has been to arrive at the unity lying behind the veil of multiplicity of natural forms by a synthetic and qualitative study of nature.[2]

This search for unity is clearly manifested in a general science like natural history. As studied by the Muslims, natural history covers a large number of fields and includes not only such subjects as geology, botany, zoology, and anthropology, but also cosmogony and sacred history[3] Natural history means

essentially the history of nature in the vastest sense of the word, and because Muslims have never separated the spiritual and the mundane, they have usually written natural history within the context of sacred history as is seen so clearly in the universal histories like those of Tabari and Mas'udi. The many allusions in the Qur'an to natural phenomena and the fact that the verses of the sacred book as well as the phenomena of nature are called ayat (signs) signify that in the Islamic perspective there is a fundamental affinity between the divine and natural orders and indicate, therefore, the legitimacy of connecting sacred history with natural history.

The question of the “signs” of nature leads to another basic feature of Muslim natural history. Most Muslim scientists have sought to study nature in order to observe “signs” of the Creator in it, to witness directly the “vestiges” of God in His handiwork.[4] This is a feature which seems most irritating to some modern scientists who aim to discover only the immediate and the material causes of things. But from the point of view of Islam, no science can be considered legitimate which does not ultimately consider things in reference to their divine origin and which does not take into account the transcendent cause of all finite beings. The marvels and wonders of nature and the moral and spiritual lessons drawn from plant and animal life mentioned by the Muslim natural historians, which many modern historians have ridiculed, have been from the point of view of Islam itself the most beneficial and basic elements of natural history because they have led the reader to a recognition of the divine agent present in nature.

The Islamic perspective is in a way very practical. The sciences which this perspective has nourished and matured are all in a sense useful, that is, they correspond to a basic need of man as envisaged in Islam. They may, like agriculture, medicine, and the sciences of history and society, be useful in the limited sense and fulfil man's physical and social needs. Or, like logic and theology, they may be useful in preventing people from being misled by false reasoning. Or, finally, like the esoteric doctrines of Sufism, they may be useful in quenching the thirst for spiritual realization of the few, who seek God here and now. But Islam has never considered simple curiosity or intellectual passion either a virtue or a basic need of man and for this reason has never legitimized a science based only on curiosity.[5] The desire of natural historians to learn moral and spiritual lessons from the phenomena of nature is, therefore, legitimate from the point of view of Islam because it is spiritually meaningful and fulfils a need, whereas finding the weight of a certain leaf of a tree to be so many grams is from this point of view a secondary and unimportant inquiry unless it leads to higher knowledge. The modern criticism of Muslim natural historians on this point is, therefore, unjust and based on a misapprehension of their point of view.

There is yet another aspect of Muslim natural history which is difficult to understand from the modern point of view. It is the description of strange animals and plants and magical properties of nature which the medieval authors seem to have recorded so credulously. One finds similar accounts in ancient books like Pliny's Historia Naturalia. The creatures described in these texts, which appear strange today, are of several types. One type is of strange animals, especially sea animals, which could certainly have existed but later became very rare or extinct and the description of which, therefore, seems fantastic now for they can no longer be observed. Another type is of animals and plants like the dragon, unicorn, and

mandarine, which originally had symbolic meaning only, but the symbolism of which in certain cases was so forgotten that they came to be erroneously described as living creatures.6

As to the apparent frequency of “strange” phenomena within nature and the innocence with which medieval authors recorded them, it must be noted that the minds of those people were not as “hardened” as those of the moderns, and that nature in turn then was not taken to be so “dense” and “coagulated” and far separated from its psychic aspect as now.7 Therefore, while reading ancient and medieval texts it should be kept in mind that just as the people of those ages, like the people of certain parts of Asia, Africa, and America today, regarded nature from a point of view different from that of modern science, nature also revealed an aspect of itself to them different from that which it reveals to those moderns whose mental constitution is no longer capable of receiving nature's more subtle elements. There is, of course, much misinformation due to narrative and exaggerated style characteristic of the poetic mind of many Muslims. But on the whole most of the contents of Muslim natural history can be understood in terms either of direct observation of physical realities or of symbolism, i. e., the description of the subtle aspects of nature the reality of which is not in any way affected because the modern quantitative sciences refuse to consider it from their own peculiar point of view.

B

Types of writings which contain material on natural history, particularly on plants and animals that form the centre of our interest in this chapter, are quite diverse. Muslim authors have rarely had a taste for over–specialization so that one finds a discussion of the plant and the animal kingdoms not only in scientific texts but also in literary, historical, philosophical, and theological works. More specially, the sources for natural history include the writings of historians, geographers and travellers, physicians, alchemists, philosophers, encyclopedists, cosmographers, moralists, theologians, and Sufis, and, of course, authors writing specifically on the subject of natural history.

The Tarikh al– Reful w–al–Muluk, the universal history of Tabari, the Kitab al–Buldan, the book of countries of Ya`qubi, the Kitab al–Bad' w–al–Tarikh of Maqdisi, the Muruj al–Dhahab and Kitab al–Tanbih w–al–ishraf of Mas`udi, the Tarikh–i Jahan–gusha of Juwaini, and the geography of abu 'Abd Allah ibn al–Idrisi, all dealing with history and geography, contain valuable sections on natural history. Moreover, they provide, on the one hand, the perspective of time in the light of which Muslims have viewed the life of all creatures, a time stretching between the creation and the final annihilation of the universe on the Last Day, and, on the other, they mention the geographical setting, the seven climates, and other terrestrial conditions which form the matrix of natural history.8 They demonstrate, further, how closely the study of plants and animals is bound up with that of the other parts of the universe, both terrestrial and celestial,9 and how the history of nature is intrinsically related with the history of man as well as with sacred history.

Another source for the knowledge of natural history comes from the many books of travel which survive

from that period of Islamic history when the Muslim world was still more or less united and travelling from one place to another was easy. The accounts of the travels of abu al–Hasan al–Maghribi, ibn Jubair, Biruni, Nasir Khusrau, and ibn Battutah, to mention a few names, provide a wealth of information on plants and animals which these men observed themselves or the accounts of which they heard from others. The interpretation which they gave to their observations varied greatly, depending on their knowledge and experience as travellers. One often finds simple description as in the case of Maghribi, or detailed physical observation and inference based upon it as in the case of Biruni, or philosophical and metaphysical reflection upon natural forms as is found in the writings of Nasir Khusrau.

Besides these land travellers, there were several ocean travellers like Sulaiman the Merchant, who in the third/ninth century journeyed by sea to the coast of China and described many of the wonders of the Indian Ocean and the Chinese coast, and Shihab al–Din ibn Majid, Sulaiman ibn Mahri, and Phi Ra'is, who in the ninth/fifteenth and tenth/sixteenth centuries travelled extensively through the Mediterranean Sea and Indian Ocean and gave a detailed description of these areas. The accounts of sea animals found in books of natural history and the fables of the sea encountered so often in Arabian Nights, Sindbad Nameh, and other collections of stories, both Arabic and Persian, were originally taken from the accounts of the sea travels of merchants, adventurers, and occasionally military men who roamed the then known extremities of the world.

Another source of natural history, considered from quite another aspect of our subject, is medicine. Muslim medicine, the heir both to the Greek and to the Indian science of medicine, has always had a general theory of living beings; nearly all medical treatises have included in their introduction a general treatment of the constitution (mizdj) of animals, which provides a major source of information for the internal structure of animals and the functioning of their organs [10]Moreover, since much of the treatment of diseases in Muslim medicine is based on plants, medical books have usually contained sections on pharmacology treating of the medical properties of plants. In fact, one may say that, apart from the metaphysical and philosophical study of plants and animals, most of Muslim research in botany and zoology has been in the service of pharmacology, agriculture, medicine, and animal husbandry. The important medical treatises like 'Ali al–Tabari's Firdaus al–Hikmah (The Paradise of Wisdom), Muhammad Zakariya Razi's al–Hdmi (Continens), and ibn Sina's Qdnun (Canon) contain important chapters on zoology and botany.

Alchemy, a subject closely allied to medicine and botany in ancient times and later identified more with the study of the mineral kingdom, has also much to contribute to natural history. In Chinese alchemy we find a close link between the elixir and the plant life; certain modern scholars have even suggested that the Arabic word kimiya itself, from which the English word alchemy is derived, comes from the Chinese Chin–Ia, meaning the goldmaking juice of a plant.[11]Whatever the validity of this theory may be, there is no doubt that plant and animal symbolism has a major role to play in alchemy as the writings of so many alchemists like Jabir ibn Hayyan or in the Western world Flamel and Basil Valentine demonstrate. In Muslim alchemy certain authors like Jabir have written specific treatises on plants and animals dealing

with their hidden and “occult” qualities[12] Authors writing on the esoteric sciences (al-'ulum al-gharibah), like Jabir, Shams al-Din al-Buni, and Jildaki have all written treatises dealing with the psychic and symbolic aspects of both plants and animals and their influence on man's physical, psychic, and spiritual life.

The philosophers have also treated plants and animals in their general consideration of the world of “generation and corruption,” to use the terminology of Aristotle. It must be kept in mind that medieval philosophy is based upon the idea of hierarchy and the chain of Being which begins from the One and through the angelic and intellectual orders descends to material manifestations, to rise once again through the mineral, plant, and animal kingdoms to the origin of all things. The philosophers, especially the systematic Peripatetics (Masha'iyun), therefore, have always entered into a discussion of plants and animals from the point of view of their place in the great chain of being. We find examples of this type of discussion not only in the Peripatetics like Farabi, ibn Sina, and ibn Rushd but also in the philosophers of the Illuminationist (ishraqi) school like Suhrawardi Maqtul and Mulla Sadra, and in Sunni and hi`ah theologians like al-Qhazali and ghwajah Nasir al-Din al-Tusi. The most detailed and profound scientific account of plants and animals in these philosophical treatises appears in ibn Sina's Shifa' (Sulfcientia), the greatest encyclopedia of philosophy and sciences ever written by one man. Here, ibn Sina deals not only with the place of plants and animals in the cosmic hierarchy but also with their morphology, genesis, and growth. Sections seven and eight of the Shifa' on natural philosophy (Tabi`iyat) are among the most important pages of medieval natural history.

Writings similar to the Shifa in the universality of their subject-matter, but not so strictly systematized, are a number of encyclopedias which have been popular from the very early centuries of Islam. We find an early example of these in the Book of Treasures of Job of Edessa written at the end of the second Islamic century.[13] More important works are the Rasa'il of the Ikhwan al-Safa containing a wealth of information on plants and also on animals drawn from Indian, Persian, and Greek sources and integrated into a vast metaphysical and philosophical panorama.[14]

Also of great importance for natural history is the encyclopedia of Mustaufi Qazwini entitled Nuzhat al-Qulub (Delights of the Heart), written in Persian in the eighth/fourteenth century, which includes sections on plants and animals.[15]

Other works of this kind include the Kitab al-Await (Book of Primordial Knowledge) and al-Nuqayat al-Usud al-Muhimmah li 'Ulum Jammah (the encyclopedia of sciences) of 'Abd al-Rahman al-Suyuti, the ninth/fifteenth-century historian, and the Kashf al-Zunun (The Clearing of Doubts) of Haji Khalifah dealing mostly with scholars of all types including scientists of the medieval period. All these encyclopedias contain some sections on plants and animals while some like the Nuzhat al- Qulub and the Rasa'il have large chapters devoted specifically to natural history.

Works on cosmography are in a way similar to encyclopedias, but usually they do not cover as many subjects. Moreover, they are concerned more directly with the creation of the world and its subsequent

development as well as with the wonders of nature. This genre of writing became popular especially during the later centuries, the most famous examples being the `Aja'ib al-Makhluqat (The Wonders of Creation) of abu Yahya Zakariya al-Qazwini and the Nuhbat al-Dahr (Choice of the Times) of Shams al-Din al-Dimashqi, both written in the seventh/thirteenth century. These works represent a combination of natural history and mythology and provide an excellent example of the attitude of the Muslim mind, which takes nature to be as displaying at every turn the power and wisdom of the Creator.

To mention all the sources for natural history, one should include the moral, theological, and Sufistic texts in which the life and qualities of plants and animals are studied with the aim of learning a moral and spiritual lesson from them. Such use of natural history, particularly of the life of animals, is very frequent in Oriental literature as for example in the Kalilah wa Dimnah,16 the Shah

Nameh of Firdausi, the Thousand and One Nights, and the Gulistan of Sa'di. Likewise, in certain theological texts animals are discussed in the light of their moral virtues. The famous Kitab al-Hayawan (Book of Animals) of atJaliiz is above all a theological and moral discussion about animals.17 In Sufi writings also, plants and animals are discussed in the light of their cosmic qualities and in relation to the initiate's (salik's) journey through the cosmos. In these works plants and animals appear primarily in the light of their symbolic aspects which represent realities of a universal order. The Mathnawi of Maulanaa Jalal al-Din Rumi is particularly rich in this respect. There is also the Mantiq at-tair (Conference of the Birds) of Farid al-Din `Attar in which the whole spiritual quest of the Sufi disciple for the divine presence is presented in the language of thirty birds, each symbolizing a particular spiritual type.

Finally, among writings dealing with natural history, there are works devoted almost exclusively to plants and animals, 18constituting perhaps the most important sources of our knowledge of natural history. We mention here a few of these texts. These works concern agriculture, pharmacology, and botany, all dealing with plants, and zoology and animal husbandry.

In agriculture, the Filahat al-Nabattyyah (Nabataean Agriculture) of ibn Wabshiyyah is the most influential of all Muslim works on the subject. Written in the third/ninth century and drawn mostly from Chaldaean and Babylonian sources, the book deals not only with agriculture but also with the esoteric sciences, especially magic and sorcery, and has always been considered to be one of the important books in Arabic on the occult sciences. 19 The agricultural section of the work was systematized and elaborated by ibn 'Awwam in the sixth/twelfth century in his Kitab al-Falaltalt (Book of Agriculture) which is perhaps the most important Muslim work on agriculture. Ibn `Awwam describes over five hundred plants and fruit trees mostly from the point of view of their agricultural properties. These two works contain the experience of centuries of agriculture by the people of the Middle East and offer a great deal of descriptive material on the life of plants and animals.

In botany itself, early Arabic poetry has much descriptive material to offer. There were also many early works of a systematic nature most of which have now been lost. One of the most important of these early books was the Kitdb al-Nabdt (The Book of Plants) of abu Hanifah al-Dinawari (the celebrated

third/ninth–century historian and scholar) of which only fragments have survived.[20] Among later writings in which pharmacology and botany proper are combined, the most famous works are the Kitab al–Adwiyat al–Mujradah (The Book of Simple Drugs) of abu Ja'far al–Ghafiqi'[21] the writings of the seventh/thirteenth–century Andalusian author, ibn al–Baitar, the best of all Muslim botanists,[22] and the Hadiqat al–Azhar fi Sharh Maziyat al–'Ushb w–al'Aqqar (Garden of Flowers in the Explanation of the Character of Herbs and Drugs) of the tenth/sixteenth–century Moroccan author, Qasim al–ahhassani.

In zoology, the Manafi' al–Hayawan (The Benefits of Animals), by abu Sa'id Bakhtishu', and the treatises on various wild and domestic animals by Asma'i are among the earliest works on animals. To this early period belongsalso the Kitab al–Hayawan (Book of Animals) of al–Jahiz, the celebrated Mu'tazilite theologian and philologist. Being one of the most famous works of Arabic literature, this book, written in the third/ninth century, combines the account of the life of animals with tales, anecdotes, theological discussions, and frequent quotations from Arabic poetry. The sources of this book include the Qur'an, the Hadith, and Arabic poetry, especially pre–Islamic poetry, which last contains many descriptions of animals that al–Jahiz often quotes to refute Greek authors, personal observations of Aristotle, and information collected from various travellers.

Hayat al–Hayawan (Life of Animals) of Kamal al–Din al–Damiri, written five centuries after al– Jahiz, came to be acknowledged as the most important Muslim work on zoology, especially on animal psychology. It was based to a large extent upon the book of al–Jahiz as well as on the writings of the intervening encyclopedists and cosmographers already mentioned. Al–Damiri's is the most comprehensive work of its kind in Arabic literature and has, therefore, been taught and studied extensively since the date of its composition.

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The philosophical point of view in terms of which plants and animals have been studied by the great majority of the above–mentioned authors is nearly the same and is one derived mostly from the Greeks, particularly from Aristotle. According to this view, the universe is divided into two parts: the heavens and the world of change or generation and corruption; the latter occupies the sublunary region. This region is made of four elements, fire, air, water, and earth,[23] arranged in concentric spheres with fire at the highest and earth at the lowest sphere. These elements combine in various ratios and when a correct proportion is reached, one of the faculties of the world–soul or nature, as some authors have called it, joins them together into a nexus[24] and by this wedding, minerals, plants, and animals come into being, each having been brought about by the coming into play of a new faculty of the world–soul or, as some have called it, a new soul. [25]All the kingdoms of nature are, therefore, united in having been made of the same four elements and given life by souls or faculties which belong to the same single power called the world–soul or nature running through all the arteries and veins of the universe.

As minerals, plants, and animals lie in the hierarchical order of Being, they also come into existence by

means of causes which are dependent upon other orders of creation, although these causes may appear to be hidden.[26] The causes are the four already mentioned by Aristotle, namely, the material, the formal, the efficient, and the final. The material cause for plants consist of the four elements; the formal cause, the set of planetary influences symbolizing various cosmic intelligences and forces which are instrumental in sublunary changes; the efficient cause, nature or the world-soul; and the final cause, which last is their use by animals as food.[27] The causes for animals are the same except that their final cause is their use by man.[28]

The plants have the powers of the mineral soul (rise `aqdiyyah) as well as those of the vegetative soul (al-nafs al-nabatiyyah) which is possessed of the three faculties of feeding (ghadha'iyyah), growth (namiyyah), and reproduction (muunllidah).[29] The animals in turn possess all the faculties of the mineral and vegetative souls as well as the powers of motion (muharrikah) and comprehension (mudrikah). The animal faculties may be summarized as follows[30]:

The classification of plants and animals is closely allied with the study of their faculties and is based in certain cases upon the hierarchy of the powers of the soul mentioned above. Muslim authors have followed several principles of classification, some drawn from Aristotle, especially in the case of animals, and some devised by them independently.[31]

The plants have been divided usually into trees, shrubs, grass, and those intermediate between trees and shrubs and shrubs and grass. A most extensive discussion of this division is found in the seventh section of the Tabl'iyat of the Shifa' where each type is clearly defined; for example, the tree is defined as a plant which stands on its stem or trunk, the shrub the stem of which spreads over the earth, and the grass or herb that which has no stem. Ibn Sina divides plants also according to the climates of regional territories in which they grow, that is, of the desert, of the semi-tropical regions, etc.

In Mustaufi Qazwini's Nuzhat al-Qulub a distinction is made between trees of which only the leaves and fruit are renewed yearly and the seed-bearing plants of which everything changes every year except the roots. The trees are divided into those that bear fruit and those that do not [32] Furthermore, the seed-bearing plants are divided into the four classes of aliments (aqhdhiyah): (i) those which are daily used for food and create one of the four humours (akhlat)-cold, warm, dry, or moist-that soon becomes a part of the body; (ii) medicines and spices only a little of which can be eaten for medical purposes and which are mostly cold and wet; (iii) perfumes (mashmumat) which have a good odour and are derived mostly from flowers; and (iv) miscellaneous plants in which the qualities of aliments and medicines are present but in a lesser degree.

Most authors dealing with the classification of plants also treat of their morphology. We find an extensive treatment of this kind in the Shifa' where ibn Sina divides the parts of plants into primary and secondary organs. The primary or essential organs are root, trunk, branches, bark, wood, and pith or core and the secondary organs, fruit, leaves, and blossoms. In a somewhat different manner, the Ikhwan al-Safa divide the plant into nine parts-root, vessel, branch, bough, leaves, colour, fruit, shell, and germand hold

that only perfect plants possess all the nine of them.

Both ibn Sina and the Ikhwan make continuous comparison of plants with the animal world; in the case of the Ikhwan as well as in the case of many later authors comparison is also made with the celestial bodies so as to draw attention to the symbolic correspondence existing between various cosmic orders.[33]

In their comparisons of plants with animals, Muslim authors were quite aware of the presence of male and female parts of plants which in most cases are united in the same plant but which in higher plants like the palm become differentiated. Ibn Sina draws an analogy between seeds of plants and eggs of birds each of which has a centre that is the source of life and a periphery which provides food for the new generation. Likewise, he compares the growth of the branch of a tree from the trunk with the birth of a new generation in the animal world.

In the classification and description of plants, one can hardly fail to mention ibn al–Baitar, the greatest of the Muslim botanists. Basing himself on al––Ghafaqi and other previous authors like Dioseorides and Galen and making many observations of his own, he described extremely carefully over 1,400 plants from Andalusia, his homeland, as well as from the rest of the Islamic world. Furthermore, in the Kitab al–Mughni, following the example of ibn Sina's Qanun, he gave the medical uses of these plants. The influence of ibn alBaitar was felt everywhere within the Islamic world from Morocco to India. Three centuries later, the Moroccan botanist, al–Ghassani, was to give the best classification of plants found anywhere in Muslim literature, drawing mostly upon the information accumulated by ibn al–Baitar.

In the study of animals, like that of plants, interest evolved around the constitution of plants and their classification and description. The temperament (mizdj) of animals including man was studied in the light of the qualities and nature of which the other kingdoms are possessed. Their relation with the bodily humours may diagrammatically be represented as follows.[34]

The animal constitution has been understood in terms of the equilibrium of the four humours each of which is connected with a particular internal organ. The organs in turn have been studied in the light of their function of preserving internal equilibrium. Likewise, the effect of plants both as food and as medicine upon animals has been considered with respect to their nature, that is, coldness, moisture, etc., which the two kingdoms share in common. This is one example of the underlying unity in terms of which the diversities of nature have been understood.

In the classification of animals, as in that of plants, several principles have been followed, some of them based upon Aristotle's works on animals. Al–Jahiz, in his Kitab al–Hayawan divides animals according to how they move. There are, according to him, four classes of animals: those that walk, which include men, quadrupeds, beasts of prey, and insects; those that fly, which include wild birds, hunting birds, and gnats; those that swim; and those that crawl. The Ikhwan al–Safa give several types of classification. One type is similar to that of al–Jahiz, and divides animals into those living in the air like birds and

insects; those living in the sea, like fish, crabs, frogs, and snails; those living on land like the quadrupeds; and those dwelling in the earth like worms.[35] Another classification is according to the perfection of the senses, that is, the lowest animals having only the sense of touch; grubs and others having the senses of touch and taste; marine animals and certain land creatures occupying dark places having the senses of touch, taste, and smell; insects having all the senses except sight; and finally perfect animals having all the five senses.

Many Muslim authors have followed Aristotle in classifying animals according to the manner of their reproduction. We find a simplified version of it in the Rasa'il of the Ikhwan where animals are divided into three classes: those that are most complete, which conceive their young, suckle them, and foster them; those which do not perform such functions but leap at the female and lay eggs and hatch them; and those which do none of the above things and come into being in putrefaction. More elaborate classifications of the same type are found in the writings of ibn Sina, ibn Rushd, and many later commentators of the shifa which contain a detailed discussion of animals.

A rather general definition of animals including the jinn[36] and men is given by Qazwini in his 'Aja'ib al-Makhluqat. He divides animals into seven classes. First, there is man who possesses a rational soul (nafs natiqah) and whose body is a miniature model of the universe, a microcosm, each part of which has a spiritual meaning and purpose. For example, he stands erect because of his spiritual aspiration to transcend physical existence, and his head is round because of the perfection of the spherical figure. The second type is of the jinn who are composed of fire and appear in many forms. As Qazwini writes, God created angels from the light of fire, jinn from its blaze, and devils from its smoke. The jinn occupied the earth before the coming of man, that is, the fall of Adam, and had their own religion and prophets; but because of corruption God sent angels to purify the earth, and they were dispersed to remote islands. Satan or Iblis is himself from this species of animals.[37]

After the jinn come the beasts of burden like the horse, then cattle like cows, then wild beasts, then birds, and finally insects and reptiles. Qazwini has further a section on “strange” animals which are primarily mythological and symbolical and finally a chapter on angels, their forms, functions, and colour.[38]

In the description of animals, there is no book in Muslim writings that is as complete as Damiri's Haydt al-Hayawan in which he is concerned with the traits, instincts, and psychology of animals and their use, medical and spiritual, for man. Following ibn al-Baitar, by whom he was influenced, he classifies animals alphabetically and then gives their description drawing on Aristotle, the natural historians, theologians, esoteric writers like Shams al- Din al-Bfmi, Arabic poetry, and the Qur'an and the Hadith. In his description he often refers to the symbolic character of animals, like the royal quality of the lion, and, as is characteristic of similar descriptive works of natural history, intertwines the spiritual as well as the physical study of nature.[39]

In discussing the classification and morphology of plants and animals a comparison may be made

between the traditional concept of gradation and the modern notion of evolution. There is no doubt that many Muslim authors like Biruni and the Ikhwan were quite aware of the meaning of fossils and of the fact that during other periods of the history of the earth flora and fauna of a different kind existed on the earth. Moreover, the idea of the gradation of Being or the passage of the One Spirit through all the realms of nature has been expressed by many philosophers and Sufis.[40]

Some thinkers, especially the Masha'i philosophers, envisage, like Aristotle, the gradation of fixed spheres, while the Ishraqi philosophers connect, like Plato, this gradation of spheres with the conception of archetype belonging to the transcendent "world of ideas." There is yet another school of thinkers (al-Jahiz, the Ikhwan al-Safa, ibn Miskawaih, Jalal al-Din Rumi, etc.), whatever their persuasion otherwise, who believe in the continuous self-development of Being from stage to stage-a position nearest to the present-day theory of evolution.

The tradition of Muslim natural history upon which we have touched briefly has had a past going back to the first Islamic century. During this long history it absorbed much of the Greek and certain of the Indian and Persian sciences and created a science which was in every way superior to what had preceded it, except the biological studies by Aristotle. This tradition was to develop as a properly Muslim science, that is, one based upon the particular genius of the Islamic perspective which is centred upon unity. This tradition is manifest in Muslim natural history in many ways, for example in the vision of the unity of nature and interrelation of all things, which Muslim natural historians asserted so often in affirming the presence of the signs of God in nature and in the study of plants and animals for the purpose of seeing divine wisdom therein.

This tradition, especially that part of it which preceded the seventh/thirteenth century, was to have a profound influence on Latin Christianity and on the formation of the science of natural history in medieval times. It is well known how much seventh/thirteenth-century authors like Albertus Magnus and Roger Bacon were indebted to it and how even during the Renaissance men like Paracelsus and Agrippa were constrained to draw largely on Muslim sources. In the Orient, this tradition has continued until the present century although in a much weakened form after the ninth/fifteenth century. Scholars in India and Persia as well as those in the Maghrib have continued to study nature as the unified handiwork of God in order to discover His wisdom, to see "His sign upon the horizon" as the Qur'an states, and to learn spiritual lessons from it. Only in following this spirit has this tradition of natural history been able to be an integral aspect of Muslim learning and remain in harmony and conformity with the spiritual and intellectual perspective of Islam.

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1. By cosmological sciences we mean all sciences dealing with the cosmos, including the natural sciences. The traditional sciences should, properly speaking, be divided into the metaphysical, dealing with God and supracosmic realities, and the cosmological, dealing with beings in the cosmos. See T. Burckhardt, "Nature de la perspective cosmologique," Etudies Traditionelles, Vol. XLIX, 1948, pp. 216-19.

2. See Seyyed Hossein Nasr, introduction to the section on "Muslim Sciences" in the Mentor Foundations of Scientific Thought. Vol. II, Signet Books, New York, (in press). In his famous 'Aja'ib al-Makhlugat (The Wonders of Creation), abu Yahya Zakariya al-Qazwini writes that the presence of divine wisdom in every atom of the universe and in all forms of multiplicity is itself a proof of divine unity, and quotes the famous verse "un g kull-i s_hai'in lahu ayatun ta`dullu 'ala annahu wahidun" (that His sign exists in all things is a proof of His unity).

3. But in this chapter we are concerned only with botany and zoology.

4. The medieval Christian scientists had a similar aim in view when they sought to observe the vestigio dei in nature.

5. Our argument does not seek to make knowledge subservient to action. Knowledge is always superior to action in the Islamic perspective as is indicated by such sayings of the Prophet as "One hour of meditation is better than a thousand works of charity," or "The ink of the scholar is more valuable than the blood of the one who fights the Holy War." What we wish to show is that in Islam a mental activity for its own sake, divorced from the spiritual and religious needs of man on the one hand and from his social needs on the other, has never been encouraged.

6. Many medieval authors, especially certain alchemists, were quite aware of animal and plant symbolism and were conscious of what they were writing.

7. It is difficult for many to conceive of the possibility that nature and its laws may not have always been the same, but there is no logical or scientific reason to prove that they have been uniform. In fact, this uniformity is one of the assumptions upon which the historical aspects of modern science are based. On the other hand, sacred texts and metaphysical doctrines point to the "cyclic" change both in nature and in man's psychic and mental structure. R. Guenon, The Reign of Quantity and the Signs of the Times, Luzac & Co., London, 1953, and F. Schuon, Les Stations de la Sagesse, La Barque du Soleil,

Paris, 1958, pp. 119ff.

8. For general information regarding these and other authors whose names are to follow, see G. Sarton, Introduction to the History of Science, Vols. I to III, Williams and Wilkins Co., Baltimore, 1927–48; A. Mieh, La science arabe et son role dons l'evolution scientifique mondiale, E. J. Brill, Leiden, 1939; B. Carra de Vaux, Les penseurs de l'Islam, Librarie Paul Geutbner, Paris, 1921–27, Vols. II and IV. Among the texts mentioned above, the Muruj al–Dkahab (Prairies of Gold) translated into English by Sprenger, W. H. Allen Co., London, 1841, especially offers useful material on the historical and geographical framework of natural history.

9. Muslim natural historians not only divided the earth into several climates, each with its own flora and fauna in conformity with its particular terrestrial con – dition, but further assigned each climate to a particular planet which acted as the archetype and "guardian angel" for that particular climate. For an example of this astrological theory, see the Rasa'il of the Ikhwan al–Safa, Cairo, 1928, I, pp. 116ff. and P. Duhem, Le systeme de monde, Vol. 11, A. Hermann et fils, Paris, 1914, pp. 267ff.

10. Regarding the internal constitution of animals, perhaps no book is so masterly and complete as ibn Sind's Qanun. See the introduction to ibn Sins, A Treatise on the Canon of Medicine, Incorporating a Translation of the First Book, by 0. C. Groner, Luzac & Co., London, 1930; also ibn Sina, Poeme de la medicine–Urgdza f't–tibb, Societe d'edition "les Belles Letters," Paris, 1956.

11. See S. Mahdihassan, "Chemistry, a Product of Chinese Culture," Pakistan Journal of Science, 1957, Vol. IX, No. 1; also his "Alchemy, in Its Proper Setting, with Jinn, Sufi and Suffa, as Loan–words from the Chinese," Igbal, 1959, Vol. VII, No. 3.

12. See P. Kraus, Jabir Ibn Hayyan, 2 Vols., Imprimerie de l'Institut Francais d'Archeologie Orientale, Cairo, 1942–43.

13. A. Mingana, Encyclopaedia of Philosophical Sciences as Taught in Baghdad in c. 817 A. D. or Book of Treasures of Job of Edema, Cambridge, 1935.

14. An interesting section of the Rasa'il dealing with the discussion between man and animals has been translated into English as Dispute between than and the Animnals, by J. Platts, V. H. Allen Co, London, 1869.

15. See J. Stephenson, "The Zoological Section of the Nuzhat al–Qulub," Isis, 1928, Vol. NI, pp. 285–316.

16. This famous book of tales about the animals is the Sanskrit Panchatantra translated into Pahlawi and later into Arabic by ibn Muqaffa'. Various versions of it in Arabic and Persian like Anwar–i Suhaili of Husain Wa'iz Kashifi have remained very popular throughont the centuries.

17. This genre of writing has continued to recent times. A work called Insan ua Haiwan (Men and Animals) by Haji Mulls Isma'il Sabziwhri written during the last century, treating of the moral and spiritual qualities of animals, is still widely used by Persian preachers in their sermons.

18. By "exclusive" we do not mean so strict a limitation of the subject as is found in a modern text–book on botany or zoology. Muslim sciences have been too closely united to permit a complete separation of one subject from another so that in nearly every book dealing with plants and animals there are references to other sciences as well as to philosophy and theology.

19. Ibn Khaldum in referring to this book writes that "people learned the sciences of sorcery from the work and developed its manifold branches" (Muqaddimah, tr. F. Rosenthal, Pantheon, New York, 1958, Vol. III, p. 156). Many Western historians have refused to believe that ibn Wahshiyyah could know anything about the Babylonian civilization and therefore consider his claim to be a forgery.

20. M. Hamidullah, "Dinawari's Encyclopaedia Botanica (Kitab al–Nabat) in the Light of Fragments in Turkish Libraries," Melange F. Koprulu, pp. 195–200. See also B. Lewin, The Book of Plants of Abu Hannah al–Dinawari, A. B. Lundeguistska Bokhandeln, Upsala, 1953, introduction, in which is discussed the influence of this early work on the later Muslim botanists.

21. This sixth/twelfth–century Maghribi botanist lies given some of the most detailed descriptions of plants found anywhere in Muslim botanical literature.

22. His two most important books are the Kitab al–Jami' ft al–Adwiyat al–Mufradah (The Complete Book of Simple Drugs), dealing with the classification of plants, and Kitab al–Mughni fi al–Adwiyat al–Mufradah (The Sufficient Book of Simple Drugs), dealing with the medical properties of plants.

23. These are not elements in the modern sense but rather the principles. They are to the sensible substances of nature what the geometric points and lines are to points and lines actually drawn on a piece of paper.

24. The union of the soul, which in Muslim cosmology lies above the cosmic spheres, with a certain combination of the elements in the sublunary region is also considered to be ad extra and not as in a compound. As the combination of elements attains more harmony and greater equilibrium, it becomes purer so that the combination naturally attracts the soul to itself. In the minerals the elements are not as perfectly balanced as in animals so that they attract a lower soul unto themselves.

25. Although minerals have been considered by many Muslim authors to be trans. mutable into one another, plants and animals have been considered to be unchangeable. Each plant, according to the Ikhwan al-Safe, for example, has a chyme (kaimii8) formed from a particular combination of elements which always reproduces the same plant as each animal has a sperm which propagates the same species.

26. "Although plants are obvious and visible creations, the causes of their existence are hidden and veiled from the perception of man. It is what the philosophers call 'natural forces; what the Lari'ah calls 'the angels and troops of Allah appointed for the nurturing of plants, the generation of animals and the composition of minerals,' and what we call 'partial spirits.'" Ikhwan al-Safe, Rasa'il, II, p. 130; also R. Levy, The Social Structure of Islam, Cambridge, 1957, p. 490.

27. We are following here the teaching of the Ikhwan, but these views are shared by most Muslim authors writing on this subject.

28. The Ikhwan have a most interesting section in their Rasa'il in which the animals dispute with man over his right to use them for his own ends. They refute all of man's claims of superiority by demonstrating their own spiritual and bodily qualities and virtues. It is only by realizing that there are among men a few sages and saints who in their spiritual realization fulfil the purpose of the whole of creation that animals finally agree to submit to man. See the Dispute between Man and the Animals

29. The most thorough discussion of the vegetative and animal souls appears in the sixth part of the Tabi`iyat of the Shila' of ibn Sina where he deals in detail with all the faculties of plants and animals and their functions. Cf. J. Bakos La psychologie d'Avicenne, Editions de l'Academia Tschechoslovaque des Sciences, Prague, 1956. Ibn Sina and also most other authors writing on the faculties of the vegetative and animal souls derived many of their ideas from the De Anima of Aristotle. The Ikhwan, however, enumerate the faculties somewhat differently: as attraction, fixation, digestion, repulsion, nutrition, formation, and growth.

30. For a summary of ibn Sind's views on the souls and their faculties, see E. Gilson, "Les sources greco-arabes de l'augustinisme avicennant," Archives d'Histoire Doctrinale et Litteraire du Moyen Age, Vol. IV, 1929, pp. 5-149.

31. In general, the Muslims depended more upon the Greeks in the study of animals than that of plants. Whereas Aristotle's works on animals were studied extensively, the botany of Theophrastus was nearly ignored. Muslim authors had already created a science of plants drawing their terminology mostly from the Qur'an and Arabic poetry before the first important Greek text on plants, that is, the famous work of Dioscorides, was translated into Arabic.

32. See the botanical section of the Nuzhat al-Qulub, irazi, Bombay, 1311/1893, pp. 87 ff., where sixty-nine fruit-bearing trees and sixty-six fruitless ones are described in alphabetical order. Qazwini, like many other Muslim natural historians, gives not only the description of a tree, the quality of its fruit and its wood and the location where it is found, but also its medical uses, its nature, that is, whether hot or cold, dry or moist, and its appearance in literature and sacred books. As for seed bearing plants, Qazwini follows a similar procedure, describing altogether 280 kinds, each class arranged alphabetically.

33. The famous scientist and compiler, Biruni gives a good example of this astrological correspondence. He writes: "The various organs of a plant are distributed to different planets. Thus the stem of a tree is appropriated to the Sun; the roots to Saturn, the thorns, twigs, and barks to Mars; the flowers to Venus; the fruit to Jupiter; the leaves to the Moon; and the seed to Mercury" (Elements of Astrology, tr. R. Ramsay Wright, Luzac & Co., London, 1934, p. 236).

The correspondence between plants or animals and the planets is not to show astral "influences" as is done in contemporary astrology which is only a residue of the real subject known by the same name in medieval times. It is to show rather that the physical world is a symbol of the intelligible world, that there is an analogy between the archetypes symbolized by the planets and their earthly shadows which are the physical forms.

34. This is a schematization of ideas presented in ibn Sina's medical poem as well as in the Qanun to which we have already referred. Pathology based on the doctrine of humours is a heritage from the Hippocratic tradition of medicine as systematized by Galen.

35. Mustaufi Qazwini in the Nuzhat al-Qulub follows a somewhat similar procedure dividing animals into those living on land, in sea, and in air, and subdividing each of the classes according to its more specific features

36. They may be said to symbolize psychic forces.

37. A similar account is to be found in the Rasa'il of the Ikhwan

38. We see in Qazwini's writings a good example of the blending of the natural and supernatural order to which we have already referred. His description of the colours and forms of animals and angels served as an inspiration for later Persian miniaturists

39. Damiri also interrupts his discussion of animals at several places in order to write about Islamic history, prayers based on the divine names, the science of jafar (symbolism of letters), and other subjects.

40. A beautiful expression of this doctrine appears in the Mathnawi of Maulana Jalal al-Din Rami. See Book IV, verses 3637 to 3647 of the text of Mathnawi ed. R. A. Nicholson, E. J. Brill, Leiden, 1929.

Chapter 67: Medicine

A – Introductory

It was not until nearly a hundred years after the conquest and consolidation of their empire that the Muslims turned their minds towards creative pursuits. It is remarkable in this context to find how quickly they directed their activities to productive ploughshares and prolific pens. Soon the Muslim Empire extended from Andalusia to the Indus, and its various parts vied with one another in producing intellectual giants in every branch of art and science. Nearly half a century ago Fonahn1 enumerated no less than one hundred and fifty-one works on Persian medicine alone during this period and Max Meyerhof2 says that "the treasure-houses of Islamic science are just beginning to be opened. In Constantinople alone there are more than eighty mosque libraries containing tens of thousands of manuscripts.

In Cairo, Damascus, Mosul, Baghdad, as well as in Persia and India there are other collections.... Even the catalogue of the Escorial Library in Spain which contains a part of the wisdom of Western Islam is not yet complete." The subject of Muslim medicine is so vast that in the following pages only a bird's-eye view of it can be given.

For a proper appraisal of the Muslim contribution to medical science it is important to ascertain its position in Arabia at the birth of Islam. The country, as everyone knows, was at the time torn by internecine wars and family feuds. Ignorance was abysmal and education non-existent. The city surgeon (jarrah) cauterized wounds, sustained in war, or applied obscure ointments as healing balms, and the village apothecary administered simples for simple ailments. People generally were living under most unhygienic conditions. Such was the dismal medical background when the Prophet of Islam started preaching. Early in his career he said that knowledge was of two kinds, that of religions and that of the bodies (i.e., of medicine). Inspired by the Qur'anic injunction,3 he preached moderation in all walks of

life. Realizing the miserable lack of medical facilities, he advocated prophylactic measures as is evident from the following.

Sa'di,[4] the great Persian poet, philosopher, and traveller, relates the story of an eminent Persian physician who was sent by the Persian king to the Prophet to minister to his own as well as to his followers' needs. For a long time after the physician's arrival in Mecca no one called on him or sought his treatment. Driven by ennui he approached the Holy Prophet and complained of his forced odium. The Prophet's reply was: “These people do not eat until they are hungry nor drink until thirsty and then cease eating while a desire for food still remains.” That must be the reason for their perfect health, said the physician. But medicine was not the Prophet's mission. He had dedicated himself to the moral and spiritual uplift of humanity at large. Winwood Reade[5] says, “Muhammad's career is the best example that can be given of the influence of the individual in human history. That single man created the glory of his nation and spread his language over half the earth.

The words which he preached to jeering crowds are now being studied by scholars in London, Paris and Berlin ... and in obscure villages situated by obscure streams.” According to Browne,[6] the Prophet's biggest miracle was that he brought unity among the fighting Arabs with the result that they adopted one goal; and soon the Arabs as one nation became rulers of half of the civilized world. Care of the sick and wounded was but one facet of the Prophet's humanitarian personality. As pointed out by Wasti, the so-called Tibb-i Nabawi is not, therefore, to be confused with any medical treatise as such.[7] The book is not taught in any recognized medical Yunani institution (as remarked by Browne), nor is it credited by Hakims and scholars of Arabian medicine.

The only known physician in Prophet's time was al-Harith ibn Kaladah, an Arab Jew who later embraced Islam. He had studied medicine at Jundi-Shapar school of medicine in Persia. He used to be consulted at the time of dire necessity, and he mainly advised moderation. Among the surgeons of this time the last known was ibn abi Ramsiah of the tribe of Tamim.

The Arabs adopted their medical theory chiefly from the Hippocratic and Galenic systems, though there were plentiful translations from Syriac, Persian, Indian, and Egyptian authors as well. The Hippocratic system, as is well known, is based on the humoral theory, i, e., the four humours of the body: blood, phlegm, choler, and melancholy. This system served the Arabs and Persians for five hundred years as it had served the Greeks and Romans for a thousand years before that. The Persians carried the humoral theory a step further by identifying the four humours with the four elements of nature, i, e., air, fire, earth, and water. Browne[8] however, defines Arabic medicine as one which has been presented in Arabic and considers that a large portion of it has been derived from the Greeks, though contributions have also been made by Indians, Persians, and scholars of other countries. He further states that during the period between the downfall of the Greeks and the Renaissance of Europe, the Arabs kept up the medical traditions and subsequently Europe was benefited by their treasure of learning.

Wasti[9] remarks that the Arabs not only translated the old medical books but also prepared their

abstracts, commented upon them, enriched them, and improved upon them. In his support Cumston [10]states, “It has been regarded for a long time that the Arabs slavishly copied the Greeks, rather they stood in the way of progress in medicine. But this is a wrong conception, because when the Arabs came into the field, Greek medicine had completely vanished and everywhere charm and magic were practised. At that moment the Arabs not only saved the Greek knowledge from destruction but popularized Greek medicine by commenting and improving on it and subsequently created a taste for scientific learning in Europe. Even if the Arabs had only restricted their activities to collecting and translating Greek medical books into Arabic and had transmitted this knowledge to Europe again, it would not have been a mean achievement. But they stepped further and wrote original books.”

While the Greeks surpassed all other peoples in their achievements in antiquity, the Muslims did so in the Middle Ages. Their works written in Arabic were, in Sarton's words, “the most original, the most valuable and the most pregnant.” Arabic became a most progressive and scientific language from the middle of the second/eighth to the end of eleventh/fifteenth century. In the contemporary West there were hardly any names as glorious as those of 'Ali al–Tabari, Ahmad al–Tabari, al–Razi (L. Rhazes), 'Ali ibn al.'Abbas (L. Haly), ibn al–Baitar, abu al–Qasim al–Zahrawi (L. Abulcasis), and ibn Sina (L. Avicenna). In fact, this was precisely the period which is known as the dark age of the West.[11]

The spread of Greek traditions was stifled in the West by the extreme Roman utilitarianism which was followed by the theological expediency and later by a theological domination which seemed for a long time to destroy every hope of genuine scientific revival. After the birth of Islam, the Arabs on the other hand were fired with the zeal for knowledge. The following sayings of the Prophet exhibit the importance he attached to the seeking of knowledge:[12]

1. Seek ye knowledge from the cradle to the grave.

2. To seek knowledge is the duty of every Muslim man and woman.

3. Seek ye knowledge even if it be in China.

4. The ink of the scholar is more holy than the blood of the martyr.

5. He who leaveth his home in search of knowledge walketh in the path of God.

6. He dieth not who seeketh knowledge.

In medicine the Arabs translated Hippocrates, Galen, and Dioscorides. Cumston says that the Arabs extracted the most important material from Greek writings and placed it in relief, leaving aside everything that was superfluous.[13] One has merely to read Galen and afterwards ibn Sina in order to see the difference. The former was obscure, the latter perfectly clear; order and method reign in the latter, which in the former we seek in vain.

Khairallah, in evaluating the contribution of Muslims to medical sciences, enumerates the reasons which

militated against their work. For instance, most of the Arabic books and manuscripts have been lost; a bare one per cent has been salvaged so far. The Mongol hordes carried death and destruction in their wake, and the fanaticism of European conquerors in the south-west of Europe destroyed the largest part of Arabic writings. Fortunately, most of the classics have survived. Many of the books that have come down to us have been distorted and mutilated either by bad copying or by spurious editions. “Repeated copying from copies and alterations and additions inserted by various teachers helped in their distortion so that one rarely sees two copies of the same book that read alike.”[14]

The manuscripts that have come down to us have not been studied with care and diligence. They require a thorough study before we can arrive at a fair estimate of Muslim contribution to medicine. The Latin translations from Arabic were often careless. Many of the Latin translators claimed as their own what they had only translated. Campbell believes that “the Latin translations failed to convey the true conception of Arabian medicine to the medieval scholastics”[15]; and Browne says that “it must be said once for all that no just idea of Arabian medicine can be derived from the imperfect renderings of standard Arabic books.”[16]

B – Collection And Translation Of Books

Before proceeding to examine the contribution of different Muslim scholars to medicine, a word might here be put in about the translators who laid the cornerstone of the edifice built by the subsequent authors.

The task of translating from foreign languages, e. g., Greek, Syriac, Pahlawi, etc., into Arabic was more difficult than would appear at first sight; but for the princely patronage and philanthropists' munificence, it might well have been impossible. In this connection the names of al-Mansur, Harnn al-Rashid, and al-Mamun in Baghdad, of Zangi in Damascus, of Sahib al-Din in Cairo and of 'Abd al-Rabman III and Hakam in Andalusia illuminate the pages of history. Their generosity and fair-mindedness made no distinction between Christians, Jews, Sabaeans, and Muslims. Their boundless bounty and complete lack of bigotry gravitated men of letters to their capitals.

But the immensity of the task of translation can be judged from the fact that the vehicle of the new Muslim civilization was the language which had never been used before for any scientific purpose and yet it was in this very language that every bit of knowledge had to be translated for proper assimilation. This necessitated the creation of a philosophic and scientific terminology which did not exist. The collection of manuscripts was carried on by the Muslims at that time with fervid zeal in every corner of the civilized world. Arab conquerors sometimes made the acquisition of manuscripts a part of the peace treaty. Thus, when Harun al-Ras_hid conquered 'Ammilriyah and Ankara, he collected all the manuscripts he could find,[17] and al-Mamfin sent a special mission to the Byzantine Emperor to collect manuscripts.[18] On several occasions books were sent and accepted as appeasing presents.[19]

After collecting all available manuscripts from Greece, Asia Minor, Egypt, Syria, Persia, and India, the

Caliphs, princes, and rich men appointed able men to study, edit, and translate the manuscripts, but before translation, several copies were thoroughly studied, compared, and edited. Ibn al-Ash'ath divided each of Galen's books into sentences, paragraphs, chapters, and divisions-a thing that was never done before-in order to facilitate the acquisition and understanding of Galen's teaching.[20]

According to Khairallah, two methods of translation were adopted. The first was that of ibn al-Batriq and 'Abd al-Masih Na'im al-Himsi who undertook literal translation. This was obviously unsatisfactory as there were many words which had no Arabic equivalent; besides the whole construction and syntax were different in the different languages. The second method was that of Hunain ibn Ishaq and al-Jauhari, who would read the whole sentence or paragraph, get its meaning or sense, and then put it in proper Arabic.[21] According to al-Nadim's Fihrist, Khalid ibn Yazid ibn Mu'awiyah was the first to encourage Greek philosophers in Egypt to translate works on medicine. He died in the beginning of the second/eighth century.

The early translations were made by Christians, Jews, and Sabaeans under the patronage of Muslim rulers. The first man to translate a medical work into Arabic was Masarjawaih (b. 61/680), a Jewish physician from Basrah. But the credit of being the greatest translator of medical works goes to a renowned Nestorian physician of remarkable scholarship, Hunain ibn Ishaq, who died in Baghdad in about 264/877. He was assisted by Ishaq, his son, Hubais_h al-A'sam, his nephew, Yabya ibn 'Adi, 'Isa ibn Yabya, and others. Other translators of repute were abu Yabya ibn al-Batriq (d. a. 191/806), Thabit ibn Qurrah (d. 289/901), a Christian from Ba'labakk.

The work of these translators and a host of others covered many subjects besides medicine. This great intellectual activity in due course brought its results, for gradually every large city developed a library which contained reading-rooms, quarters for translators, and meeting-places for scientific discussions. Such were Bait al-Hikmah (House of Wisdom) in Baghdad and Dar al-Hikmah (Hall of Wisdom) in Cairo. The library at Cordova had over a quarter of a million volumes. The library of Nuh ibn Mansur, ruler of Bukhara, contained books on all subjects together with their indices. Ibn al-Matron, the famous physician of Salah al-Din, had a library of 10,000 manuscripts. Ibn al-Tilmidh, author of the best known pharmacopoeia of his time, had 20,000 manuscripts in his library. The well-known medical historian al-Qifti had a library worth more than 50,000 dinars. Every large hospital possessed a library of its own.[22]

C - Hospitals

The hospital at Jundi-Shapdr in Persia was the first and foremost to influence the Arabs. Al-Harith ibn Kaladah, a relation of the Prophet practising during his time, was an alumnus of this hospital. Small hospitals for the blind and lepers were built during the Umayyad period, but they were little more than segregation camps. Proper hospitals, however, came to be built during the 'Abbasid period. Those at Baghdad, Damascus, and Cairo were the best known at the time. Besides the hospitals for the lepers and the blind, there were asylums for the insane and ambulatory clinics to minister to the needs of far-

flung places where there were no physicians. Prisons were not forgotten and physicians looked after prisoners since they were considered to be a State charge. First-aid stations were established near mosques where large numbers congregated. The army had its physicians, and field hospitals attached to the armies were carried on camel-back. Female nurses used to serve in the field hospitals.

General hospitals were established not only at Baghdad, Damascus, and Cairo, but also at Mecca, Jerusalem, Aleppo, Harran, and several cities in Andalusia. Patients in such hospitals were admitted on the sole criterion of their condition without prejudice to colour, creed, sex, or social status. AlMansiir Qalawun, the ruler of Egypt, dedicated the hospital erected by him for the benefit of "the king and the subject, the prince and the soldier, the great and the small, the freeman and the slave, for men and for women."[23] Foundations (auqaf) were created to support the hospitals and were administered by high dignitaries with the utmost care. Issa writes in his Histoire des bimaristans al'epoque Islamique:[24] "The furniture, bedding, and clothing at the Mansiiri hospital at Cairo, rivalled in their luxury and perfection those that adorned the palaces of the Caliphs and the princes. The nourishment consisted of flesh of fowl and mutton, and each patient was given the quantity of food that the state of his health permitted."

Sometimes musicians and singers were brought to hospitals to entertain the sick and convalescing patients.

The conditions prevailing in hospitals in those days can best be described in the words of Usaibi`ah[25] "Abu al-Hakam, the dean of the Nari hospital of Damascus, used to make the rounds of patients every morning, find out their condition and consider their affairs. With him were his assistants and orderlies and all that he wrote down as orders for the patients regarding medicine and diet were carried out on time and without delay.

After finishing his rounds he used to go to the citadel and treat whoever was sick among the nobility and government officials. He would then come back to the hospital and sit in the large auditorium, read his books, and prepare his lectures. Nur al-Din had installed in the hospital a large library with a collection of books and manuscripts placed in bookcases in the main hall. Several physicians and students used to come and sit at his feet. He taught the students and discussed medical topics and interesting cases with the physicians." Usaibi`ah continues: "Patients were examined in an outside hall and those who did not need hospital treatment were given prescriptions which were prepared at the hospital pharmacy.

Those who needed hospital treatment were registered and admitted. They were given a bath and made to put on clean hospital clothes, their own clothes being taken away and stored. They were kept at the hospital until completely cured. On their discharge from the hospital they were given a suit of clothes and some money to defray immediate and necessary expenses outside the hospital until they were able to work." Usaibi'ah proceeds: "A pharmacy under a competent and registered pharmacist was attached to every large hospital. It was well stocked with syrups, all sorts of drugs and drug preparations, fancy porcelain, and rarities. Pharmacists were licensed and registered and in each large town an inspector kept constant watch over pharmaceutical preparations and chemical products.

“Attached to large hospitals were medical schools where students gathered in the main hall and reviewed their studies and copied medical manuscripts which were compared and corrected by the teachers. The teachers lectured to them from the books of Galen and later from al-Razi and al-Majflsi until the advent of ibn Sina's Canon which eclipsed them all.”[26]

Several books were written on hospitals and hospital management. Unfortunately, most of them have been lost. A1-Razi wrote a book on Sif at alBimaristan and Zahid al-`Ulama' wrote Kitdb al-Bimaristan. The first regular hospital was built by Haran al-Rashid in Baghdad in 170/786, but a bigger and more up-to-date hospital was founded in 368-3691978-979 by `Adud alDaulah. In Damascus there was the al-Nuri, built by Nur al-Din Zangi; one was built by Salah al-Din at Jerusalem and another at Cairo. Qalawun built the al-Mansuri at Cairo. Besides these there were hospitals in Mecca, Medina, Harran, and other notable towns. In Andalusia there were over fifty hospitals in Cordova alone, besides those at Granada, Seville, and Toledo.

It will be seen from a brief description of the conditions obtaining at the time in hospitals that in many respects they were better than those prevailing even today. The Arabs may not have been the first to build hospitals but they were certainly the first to improve upon them. They started to give regular instruction in hospitals and to have out-patient departments. They were the first to have regular inspection over the administration and finances of the hospitals, the first to examine and license physicians, and the first to have regular pharmacies attached to hospitals. They went further by examining and licensing a physician for the practice of a speciality. The interest of Muslims in building hospitals was not limited to the Arab period; it continued throughout the ages.

D – Physicians And Surgeons

Let us now come to the most important part of our narrative, namely, the great authors and practitioners of the medical science whose theory and practice enlightened the path of scientific research and whose fame is indelibly imprinted on the pages of history. Here again, needless to say, we shall have to confine ourselves to the selection of a few of these geniuses.

The first great name amongst Muslim physicians is that of abu Bakr Zakariya al-Razi. He was a prolific writer and is said to have written no less than 117 books dealing with all the different branches of medicine. Of al-Razi's works, al-Hawi (Continens), running into twenty volumes, is undoubtedly the most important. This work was translated into Latin by Faraj bin Salim in 678/1279 and printed at Brescia nearly two centuries later. Al-Razi did not actually write this book; he left notes on his original observations, extracts from other peoples' works, and clinical notes of his medical experience. All this material was sold by his sister to ibn al-'Amid, the vizier of Rukn al-Daulah, who got the drafts of those rough notes properly arranged in book-form by the noted physicians of his time including al-Razi's own pupils. 'Ali ibn 'Abbas (Haly Abbas) was of the view that during his time only two copies of the book were in existence. He regarded al-Hawi the repository of medical knowledge concerning hygiene, diseases,

their symptoms, and treatment with medicine and diet, al-Razi's sources being Hippocrates, Galen, and all the physicians that preceded him. E. G. Browne translated some of its clinical notes into English and Max Meyerhof published the text and translation of some more.

Relatively speaking, the most important of al-Razi's minor treatises is Kitab al-Judari w-al-Haabah. It deals with smallpox and measles. It was translated into Greek and Latin and printed in several European countries. This work is particularly significant because it is the first to give a clear description of smallpox as a disease and also the first to give a symptomatic distinction between smallpox and measles. Al-Razi was the first to include in the pharmacopoeia the white-lead ointment, later on known in the Middle Ages in Europe as Album Rhases, and the first to use "animal gut as a ligature for surgical operations and was the first to recognize the reaction of the pupil to light."27

The next great physician was 'Ali ibn al-'Abbas al-Majfisi known in the West as HalyAbbas. Either he himself or his father was originally a Zoroastrian; hence the name al-Majfisi. He was a Persian by birth and flourished during the period of 'Adud al-Daulah and died in 384/994. After al-Razi and ibn Sina his is the greatest name in the Caliphate of Baghdad. His most famous work is the medical encyclopedia called the Kitab al-Maliki (Liber Regius). Sarton regards this work as more systematic and concise than al-Razi's al-Hawi and more practical than ibn Sind's Qanun by which it was superseded. Half of the book deals with the theory and half with the practice of medicine.

Most important parts of it relate to dietetics and materia medica. He made some original clinical observations and was the first to give close description of the capillary circulation long before Harvey. He says that during relaxation (diastole) the pulsating vessels (arteries) that are near the heart draw air and thinned blood from the heart by suction, because during their contraction (systole) the arteries empty themselves of blood and air, so that when they relax, air and blood is sucked to them to fill them. Those that are near the skin draw air from outside. Those that are in the middle, between the heart and the skin, have the property of drawing the thinnest blood from the non-pulsating vessels (veins).'

That is because the veins have pores communicating with the arteries. The proof of this is that if an artery is cut, all the blood that is in the vein is emptied through the cut. He was also the first to give proof of the motion of the womb during parturition and to show that child does not come out by itself, but it is the movement of the womb that pushes it out.28 In al-Qifti's words al-Maliki was the splendid work and the noble treasure of the theory and practice of medicine admirably arranged. It had been one of the most popular texts on medicine until it was replaced by ibn Sind's Qanun.

Al-Majusi gives a remarkably well-worded advice to the physicians. He says that the patient should be treated if possible with diet, not with drugs. If he can be treated with simple drugs he should not be administered compound ones, nor indeed strange or unknown ones. With regard to the relation between the physician, the patient, and the disease, he says that they are three. If the patient co-operates with the physician they would become two against one and would be able to beat the disease, but if he does

not listen to the physician nor follow his direction, he and the disease would be two against one, i.e., the physician; one can hardly beat two. He states that all physicians agree that the preservation of health is more important than the cure of disease and quotes Hippocrates that the curing force of disease is nature itself.29

Al-Majusi's surgical technique is no less remarkable. His lucid description of the surgical operation for the removal of tubercular glands is a fine specimen of his art. He says: "Cut the skin longitudinally down to the gland. Retract the skin with hooks. Dissect slowly and gently, freeing the gland from the tissues around it. Take care not to cut any vessel or puncture any nerve. If a vessel is cut, ligate it, lestt the haemorrhage obscure the field and prevent you from carrying out a proper and thorough operation." After removal of the gland, put your finger in to feel for any small glands that might be left. If there are any, remove them too. When all the glands are removed, suture the incision.

Al-Majusi recognized the gravity of cancer and says that medicines do not help in curing the disease. He advises removal of the whole area affected by cutting at a distance from the growth so that none of its roots are left. He advises that after removal blood should not be stopped from running but that the surgeon should see that the diseased blood is drained off.30

The famous physician who succeeded 'Ali ibn 'Abbas in the Muslim world was abu al-Qasim Khalaf ibn 'Abbas al-Zahrawi (d. 404/1013). He took his name from his birthplace al-Zahra', the famous suburb of Cordova. He was Court physician to the Caliph al-Hakam II. His fame chiefly rests on surgery for he was admittedly the greatest of all Muslim surgeons. He wrote one of the biggest medical encyclopedias, al-Tasrif, in thirty sections. One of the topics discussed in this work is the preparation of medicines by sublimation and distillation. It's most important part is, however, surgical wherein he "introduces and emphasizes such new ideas as cauterization of wounds, crushing stone inside the bladder, and the necessity of vivisection and dissection."31 He also deals with obstetrics and the surgery of eyes, ears, and teeth and gives a description of surgical instruments.

The surgical part of al-Tasrif was translated into Latin by Gerard of Cremona, and various editions of it were published at Venice, Basel, and Oxford from the ninth/fifteenth to the twelfth/eighteenth century. For centuries it was used as a text-book in surgery in the universities of Europe such as Salerno, Montpellier, and other schools of medicine.32

The man who is described by one Orientalist as "the most famous scientist of Islam and one of the most famous of all races, places and times" and by the other "the greatest man that this world has ever seen"33 is abu 'Ali al-Husain ibn'Abd Allah ibn Sina. William Harvey puts him in the same category as Aristotle and Cicero. At the age of eighteen he cured the Samanid Amir of Bukhara and as a result was appointed Court physician and given permission to use the royal library.

Ibn Sina's greatest medical work was the Qanun (Canon) used as "medical Bible for a longer period than any other book,"34 an encyclopedic work of about a million words covering the entire medical

knowledge, ancient as well as contemporary. In many ways he resembled Galen. Before ibn Sina's Qanun, the best work on medicine was al-Razi's al-Hawi but, according to all competent authorities, that work was superseded by the Qanun. Ibn Sina analysed for the first time pathological and psychological phenomena and made acute observations about the differential diagnosis of medastinitis and pleurisy, infectious nature of phthisis, skin diseases, sexual ailments and perversions (including love-sickness), diseases of the nervous system, and transmission of diseases through water, food, and soil.

Ibn Sina is the first to write a careful description of meningitis and differentiate between primary and secondary meningismus. He also gives a full description of the various types of diseases which cause jaundice. He differentiates between facial paralysis of central origin and that of local origin. He describes apoplexy as being caused by plethora. He gives a clear description of the symptoms of pleurisy and its differential diagnosis. The signs of pleurisy, he says, are: continuous fever; stitch in the side which many times does not appear except after a deep breath; shortness of breath; see-saw pulse; and cough, usually dry in the beginning, but may be wet and with expectoration from the start. He says: In as much as pleurisy might resemble hepatitis and pneumonia, we must differentiate between them. The difference between pleurisy and hepatitis is that in the latter the pulse is wavy, the pain is dull and heavy and not pricking, the face is yellowish, the urine thick and the stools "livery." There is heaviness in the right side over the liver region and no stitch in the side. The difference between pleurisy and pneumonia is that in the latter the pulse is wavy, the shortness of breath more marked, the breath hotter besides other symptoms?35

The Qanun is divided into five major sections. Briefly stated, the contents of these sections are as follows. The first section deals with definitions, elements, humours, temperaments, and spirits; anatomy (bones, muscles, nerves, arteries, and veins); diseases, their causes and symptoms; hygiene and pro-phylaxis; and general treatment. The second section deals with simples, in an alphabetical order. The third section gives a description of diseases from the head downwards, including the anatomy of the organs-head, brain, nerves, eyes, ears, nose and mouth; tongue, teeth, lips and gums; throat, chest, and lungs; heart, breast, oesophagus and stomach, liver, and gallbladder; spleen, intestines, male and female genital organs-and general diseases. The fourth section deals with fever, prognosis and crisis; swellings and ulcers, surgery, fractures and dislocations, poisons, skin diseases, and cosmetics. The fifth section deals with compound drugs and therapeutics.

Several commentaries on the Qanun are extant, the best known being by ibn Nafis under the title al-Mu'jiz. In the Asian part of the Muslim world, the Qanun held the sway, but in Spain it was played down by ibn Zuhr and ibn Rushd. It was translated into Latin by Gerard of Cremona36

Another unique book by ibn Sina is the Urjuzah fi al-Tibb, which is a medical poem that sums up the medical knowledge of the time. It was meant to facilitate the study of medicine. With their wonderfully tenacious memories the Arabs were able to memorize it. Its first part deals with the theory of medicine and hygiene, and the second with treatment. Another of his wellknown books is al-Shifa'. Usaibi'ah

credits him with having written nineteen medical and ninety non–medical books 37

The illustrious “Shaikh,” by which name ibn Sina is generally known throughout the Muslim world, died at Hamdin in 428/1037. He reigned supreme for more than six centuries not only in the Muslim world but also in Christendom. His theories, as propounded in the Qanuu, are still widely respected in the Orient by Hakims and form the cornerstone of the history of medical teaching in the Occident.

In Egypt flourished ibn al–Haitham (Alhazen of the West), “the greatest Muslim physicist and one of the greatest students of optics of all times.”38 He was born in Basrah but migrated to Egypt in the time of Caliph al–Hakim. “He was also an astronomer, mathematician, physician, and he wrote commentaries on Galen and Aristotle.” He corrected the Greek misconception about the nature of vision and taught, for the first time, that light does not “exude” from the eye but enters it. He also taught that the retina was the seat of vision and that the impressions made upon it were conveyed along the optic nerve to the brain forming visual images on symmetrical portions of both retinas.

In Spain there was a most famous family of physicians whose contribution to medicine was no less remarkable. Translations from the works of this family are found in the libraries of Western universities even to the present day. We are referring to the ibn Zuhr family that drew its name from their ancestor Zuhr. The first great physician of the family was abu Marwan 'Abd al–Malik (d. 470/1077–78). He was renowned as a diagnostician. His son abu al–'Ala' (d. 525/1130–31) was even a greater physician than him. He was first attached to the Court of Seville but was later raised to the rank of a vizier when that kingdom was conquered by Yusuf ibn Tashifin. He wrote several medical works, viz., Kitab al–Khwass (Book of Properties), Kitab al–Adwiyah al–Mufradah (Book of Simple Drugs), Kitab al–Idah (Book of Explanation), Mujarrabat (Personally Tested Prescriptions), Kitdb Hall Sukiek al–Rdzi 'ala Kutub Jalinus (Resolution of al–Razi's Doubts regarding Galen's Works), Kitab al–Nukdt al–Tibbiyyah (Book on Principles of Medicine). The last mentioned work among other things specially deals with climatological and anthropological conditions prevailing in Marrakush and with deontological guidance. He also wrote a treatise in refutation of certain points in ibn Sina's work on simple drugs.

The most illustrious member of this family was abu Marwan 'Abd al–Malik ibn abi al–'Ala' Zuhr (d. 556–557/1160–1161) known in Latin works as Avenzor. His supremacy as a physician was acknowledged not only in the Muslim world but also in Christendom. His medical theory had strong empirical tendencies. He may justly be said to be the greatest clinician of Islam after al–Razi. Only three of his at least six works are now extant.

1. Kitab al–Taisir fi al–Muddwat w–al–Tadbir (Book of Simplification on Therapeutics and Diet), written at the request of ibn Rushd, is the most important of them all. It deals elaborately with pathology and therapeutics and at the end gives a comprehensive collection of recipes. In this work ibn Zuhr makes acute clinical observations about mediastinal tumours, intestinal phthisis, pericarditis, scabies, pharyngeal paralysis, and inflammation of the middle ear.

2. Kitab al-Aqhdhiyah (Book on Eatables).

3. Kitab al-Iqtisad dealing with therapeutics, psychotherapy, and hygiene.

Ibn Zuhr is said to be the first physician to have described the itch-mite. He advocated artificial feeding through the gullet and rectum.

Ibn Zuhr's son abu Bakr Muhammad ibn al-Malik was a successful physician and his daughter and the daughter of that daughter were capable midwives. Medicine went into the family down to six generations. Ibn Zuhr's influence through Hebrew and Latin translations upon Western medicine lasted till the end of the eleventh/seventeenth century. The translations of Taisir like ibn Rushd's Kulliyat saw several editions.

The great Spanish philosopher ibn Rushd (Averroes) was a contemporary of ibn Zuhr. His greatness as a physician was eclipsed only by his greatness as a philosopher. His most important medical work Kitab al-Kulliydt fi al-Tibb (Latin Colliget) was a veritable encyclopedia of medicine. As mentioned above, the Latin translation of this work went through several editions in Europe. It was also translated twice in Hebrew. It had seven parts (books) dealing with anatomy, physiology, pathology, diagnostics, materia medica, hygiene, and therapeutics. He was the first to discover that no person can get smallpox more than once. He is also said to be the first to understand the working of the retina.

Ibn Tufail, ibn Rushd's predecessor in philosophy, was also a renowned physician; he wrote two books on medicine, neither of which is extant.

Another name worth mentioning in connection with the development of medicine in the Muslim West is that of ibn Baitar. He was born in Malaga and travelled all over Spain, North Africa, Egypt, Syria, and Asia Minor. He was a botanist rather than a pharmacologist. Most of his work was done in Egypt where he was appointed chief inspector of pharmacies. His two chief works, al-Mughni fi al-Adwiyah al-Mufradah and al-Jami' li Mufradat al-Adwiyah w-al-Aqhdiyah, embodied all the Greek and Arabic literature on botany and materia medica as well as the author's own wide experience and research. He describes more than one thousand and four hundred drugs from the vegetable, animal, and mineral kingdoms, three hundred of which are novelties. The book is arranged alphabetically. Usaibi`ah[39] describes the thoroughness of his teacher's methods; Usaibi`ah was not only al-Baitar's pupil but also herborized with him in Syria. His book al-Adwiyah al-Mufradah was translated into Latin, Simplicibus, printed in twenty-six editions during and after the ninth/fifteenth century, and was used in the formation of the first London pharmacopoeia issued by the College of Physicians during the reign of James I. Some parts of its Latin version were printed as late as 1172/1758 at Cremona.[40]

`Ala' al-Din abu al-Hasan `Ali ibn abi al-Hazm, better known as ibn alNafis, flourished during the first half of the seventh/thirteenth century. Born in Damascus, he spent most of his life in Cairo where he practised medicine and became dean of the Mansuri hospital. He wrote several books, the most important being al-Mu'jiz and Sharh Tashrih al-Qanun. In describing the anatomy of the pulmonary

vessels, ibn Nafis also described for the first time the pulmonary circulation and declared three centuries before Servetus that blood is aerated in the lungs. In his description of the anatomy of the heart he gives the nearest description in those times of the coronary circulation. He says that ibn Sinn's statement that the blood which is in the right side of the heart is to nourish the heart is not true at all, because the nourishment of the heart is from the blood that goes into the vessels that permeate the body of the heart.41

In this' section we have briefly touched upon the works of the great authors who have contributed so largely to the development of the various branches of the medical science. There are a host of others who played an equally important role. They live in history. We have also been unable to deal with the veterinary science, especially hippology, of which the Arabs were so fond and in which they displayed so great a mastery.

Arab biblio-biographers, like al-Qifti, ibn abi Usaibi`ah, and ibn Khallikan, have done a magnificent job in collecting the works of various authors, but it is a fact that scores and scores of manuscripts are still lying unexplored in libraries and mosques, palaces and museums and are awaiting careful examination; these may open fresh sluice-gates of knowledge regarding Muslim contribution to medical and other sciences. The need for more texts and more translations, more especially of those works which were composed after the Mongol hordes broke in upon Persia and Baghdad, is vey great indeed for the present renaissance of the Muslim world. The task is not easy; in fact, it is superhuman.

E - Influence

Muslim physicians, more particularly some of those who lived in Spain, contributed largely to the Renaissance in Europe. But in the matter of Muslim influence upon European medicine no names are greater than those of al-Razi and ibn Sina. Within a century and a half of the death of ibn Sina his works reached Spain and Sicily where they began to be translated. It was from these centres of learning that Arab science spread to the other parts of Europe. The spread of Arab science in the West was mainly due to the fact that the Eastern Caliphs were in constant touch with the rulers of Europe.

Harun al-Rashid sent an ambassador to the Court of the Roman Emperor. It is even said that Charlemagne came to Palestine incognito in order to consult the Arab physicians about his health. The medical scholars of the universities of Western Europe like Montpellier and Bologna particularly specialized in Arab learning and were responsible for the propagation of the teachings of al-Razi and ibn Sina. Montpellier had an immense library.

All the translations made by Constantine the African and Gerard of Cremona were housed in this library at a time when the Paris University library hardly contained more than a score of medical works. From these centres the teachings of the Arabs spread to all medical schools in Europe. From the sixth/twelfth to the eleventh/seventeenth century al-Razi and ibn Sina were considered superior even to Hippocrates and Galen.42

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