Science in India during the Muslim Rule

Zakaria Virk, Kingston, Canada

Islamic World welcomed Christians and Jewish students equally with Muslims, not only that, but entertained them at the Government expense and that hundreds of Christian students from South of Europe and the countries of the East took advantage of that chance to escape from ecclesiastical leading strings; we can easily perceive what a debt of gratitude modern European progress owes to Islam, while it owes nothing whatsoever to the Christian Church, which persecuted, tortured, even burnt the learned.

(Marmaduke Pickthall, The Cultural Side of Islam, Lahore, 1969, p 76)

The scientific cooperation between India and the Arabs dates back to the time of Abbasid Caliphate of Baghdad when a number of books on astronomy, mathematics, and medicine were translated from Sanskrit into Arabic. From then on the ancient scientific knowledge of India continued to influence Muslim scientists. Arab interest in Hindu sciences was parallel to their interest in Greek learning.

When Sind was under the dominion of Caliph al-Mansur (753-774), there appeared before him a scholar who had come from India. He was skilled in the calculus of the stars known as Sindhind (i.e. *Siddhanta*), and possessed methods for solving equations founded on the kardagas (i.e. sines) calculated for every half degree, also methods for computing eclipses and other things. Al-Mansur ordered the book *Brahma-siddantha* in which all this contained to be translated into Arabic, and that a work should be prepared from it which might serve as foundation for computing the motions of the planets. This was done by Ibrahim al-Fazari (d770) and Yaqub Ibn Tariq (d796) in cooperation with Hindu pundits in 750 and the book was called *Al-Zīj 'alā Sinī al-'Arab, or Sindhand al-Kabir*. (1) In fact the Hindu scholars had brought two books with them.

This Siddhanta translation was possibly the vehicle by means of which the Indian numerals were transmitted from India to Baghdad. With the help of these Hindu Pundits, Al-Fazari, translated Brahmagupta's other book *Khandakhadyaka* and gave it the Arabic name of A*rkand*. Both works were extensively used, and exercised great influence in the development of astronomy in the Islamic world. It was on this occasion that the Arabs first became acquainted with the Hindu system of astronomy. They learned astronomy from Brahmagupta (d.668) earlier than Alexandrian scientist Ptolemy.

The Greek and Sanskrit texts on mathematics and astronomy were used by Muslim scientists as bedrock to develop new fields. Hindu mathematics left a more lasting impression on the Arab sciences. What we call today Arabic numerals, were in fact Indian numbers. The Arabic word for numbers is *Hindsah*, which means from India. This way of writing numbers, including the way to write a 'zero', was very exciting to mathematicians. Arab scientists in Iraq, especially Muhammd ibn Musa al-Khawrizmi (d.840) used the new numbers to develop algebra around 830. The English word algorithm is derived from his name. Some mathematical and astronomical terms were borrowed from Sanskrit. Ethical writings of Chankya (Shanaq) and works on logic and

magic were translated as catalogued by ibn Nadim in his 10th century *Kitab al-Fihrist.* Ibn al-Muqaffa translated *Pancatantra* into Arabic as *Kalila wa Dimna*. The fascinating story of Sindbad was partly of Indian origin. Parts of *Mahabharata* were rendered into Arabic by Ali Jabali, c.1026. (2)

A large number of Sanskrit medical, pharmacological and toxicological texts were translated into Arabic under the patronage of Khalid Barmaki, the vizier of Caliph Al-Mansur. Indian medical knowledge was given a further boost under Caliph Harun al Rashid (786-809) who ordered the translation of *Susrata Samhita* into Arabic. For over five hundred years Muslim & other writers continued to apply to works on arithmetic the name Indian. Prime Minister Yahya bin Khalid Barmaki deputed ambassadors to India to invite distinguished scholars, physicians, & philosophers to Baghdad. In appointing translators, the Caliph made no distinction of creed or color.

The Muslims were very keen on informing themselves of the customs, sciences, and religions of the people whom they came into contact with. Yaqoob Kindi's (873) account of India was based on the evidence of the envoys sent to India to procure medicines and to report on Indian religions. Ali Ibn Hyusayn Masudi (956) visited India and wrote about Hindu beliefs, their history from legends, and complimented them on their achievements in their sciences as the 'cleverest among the dark people'. Baghdad's book seller Ibn al-Nadim, al-Biruni, al-Ashari, Shahrastani and many other writers devoted chapters in their books to Indian religions and sciences. Al-Nubakhti's *Kitab al-ara-I wal adnya-i-Madhahib al-Hind* mentioned by Masudi was perhaps the earliest study of Hindu sects. Sulayman the merchant visited India about 851 and praised Hindi proficiency in medicine, astronomy and philosophy. Contact with Hindu sciences came to an end when the political grip of Baghdad on Sind was loosened.

During the Mughal rule of India, science & technology developed mainly due to the interests of Emperors and Sultans, particularly in astronomy, agriculture, engineering, architecture and medicine. A number of encyclopaedias and dictionaries were penned. Initially dictionaries were needed as new ideas were being developed as a result of interaction between Sanskrit and other languages. During the later period of Mughal rule, new ideas were accepted from European science and technology.

In sciences the Hindus had developed elaborate systems in mathematics, astronomy and medicine; the Muslims were obliged to Hindus and Greeks for these departments of knowledge. In due time Muslims built up original structures of their own scientific systems. When Muslims arrived in India they brought their own knowledge which was not inferior to Hindus. The Hindus did not disdain to incorporate what they found new. Thus the Hindus astronomers took from the Muslims a number of technical terms, the Muslim calculation of longitudes and latitudes, and various other items of calendar, Zij. (3)

Al-Biruni

Abu Rehan al-Biruni (d.1053) was the first scientist of Islam who made a deep study of Hindu sciences. He was the first scholar to study India and the Hindu scientific literature.

He has been described as the founder of Indology. He studied Sanskrit diligently and was so proficient in it that he could translate into, as well as from Sanskrit. Hindu scholars gave him the title of Vidya-sagar (ocean of knowledge).

Until the 10th century, history most often meant political and military history, but this was not so with him. In his *Kitab fi Tahqiq ma li'l-Hind* (*Researches on India*), he described India's cultural, scientific, social and religious history. Due to military incursions of King Mahmud of Ghazna in India, Hindu scholars had moved to remote religious centres. In this charged atmosphere Biruni imposed upon himself the strict discipline of scientific objectivity. He tried to explain Hindu doctrines without any bias, avoiding any kind of polemics.

Biruni's approach to Hindu sciences was comparative, making analogies between Greek and Hindu civilizations. His comparison of two civilizations led him to the conclusion that Hindus could not bring sciences to classical perfection, and that scientific theories of the Hindus "*are in a state of utter confusion, devoid of any logical order, and in the last instance always mixed up with the silly notions of the crowd".* (Kitab al-Hind)

Biruni regarded the essence of Hindu religion as a form of monotheism, idol worship as ignorant passions of the people. He was the first to introduce the study of *Bhagavad Gita* to the Muslim world, and the first Muslim to study the *Purana*s and to translate *Patanjali* and *Samkhya* into Arabic. In considerable detail he outlined the principles of Hindu astronomy, geography, mathematics and medicine. (4)

Biruni translated a Sanskrit book *Batakal*, as Bátanjal. From this work he extracted a great deal which he made use of in his magnum opus Q*ánún Mas'údi*, a 1500 page work on mathematics, geometry and astronomy. All that the sages of India have said about numbers, ages, and eras (*tawárikh*), has been exactly given by Abú Rehan in his translation of the Bátakal. (5)

Sultans of Delhi

Jalal al-Din Khilji (d.1296) is the first Muslim sultan of Delhi to have showed some intellectual curiosity for Hindu learning and Sanskrit studies. Sultan Muhammad bin Tughlaq (1351) was a great scholar versed in logic, Greek philosophy, mathematics, astronomy and physical sciences. He had knowledge of medicine and was skillful in dialectics. He also was an expert calligrapher. He enjoyed the society of Hindu yogis and extended his patronage to Jain divines. Zia al-Din Nakhsabi's adaptation of 52 short stories from Sanskrit into Persian in 1330 entitled *Tuti Nama* (Book of Parrot) is the outstanding achievement of Tughlaq's reign in this field.

The Sultans of Delhi were very much interested in mechanical machines like pulleys and piers. In the book *Sirat Feroz Shahi* (1370) 13 such instruments were listed which were used in transporting stones and heavy building materials. A manuscript of *Sirat* is preserved at Bankipur library. During the rule of Sultan Nasir Shah (1500-11) a scholar

by the name of Muhammad ibn Daud translated many Arabic books into Persian which was then the official language of the state.

Sultan Firoz Shah Tughlaq (1388) allowed more than a third of a million pounds (36 lacs) to learned men and pious endowments. (6) A number of Madrassas were opened to encourage literacy. He set up hospitals for free treatment of the poor and encouraged physicians in the development of Unani medicine. He commissioned translations of medical works from Sanskrit. He ordered a work on Hindu astronomy and astrology to be translated into Persian under the name of *Dalaile Firoz Shahi*. Works on music and wrestling were also translated. Ziya al-Din Barani (1357), wrote a chronological history of Tughlaq's rule, entitled *Tarikh-i-Firoz Shahi*. Genuine interest and patronage of Sanskrit learning began with Sultan Zain al-Abidin of Kashmir (1420-1470) who commissioned the translations of *Mahabharta* and *Raja-tarangini* into Kashmiri language, which was first indication of Muslim interest in the pre-Muslim Hindu history of India.

Intellectual curiosity of Emperor Akbar

The Mughal Emperors (1526-1858) took a keen interest in the development of astronomy. They patronized astronomers in their royal courts. The works thus produced were mainly *zije*s (astronomical tables) and calendars. Many scientific works brought from outside of India like Bahauddin Amuli's (1574-1621) *Khulasa tul-Hasab*, and Tusi's *Tahrir Uqlidis* and *Tahrir al-Majisti*. Attempts were made to write commentaries and translate these works. As a result the intermingling of Indian mathematical tradition with Arabic & Persian did take place enriching the country.

Emperor Humayun (1556) built a personal observatory near Delhi, while Jahangir and Shah Jahan were also intending to build observatories but were unable to do so. Mulla Chand, a court astronomer of Emperor Nasiruddin Humayun produced "*Tashil Mulla Chand*", which was a redaction of *Zije Ulugh Beg*.

Muslim patronage of Hindu learning reached its highest watermark in the court of Emperor Jalal al-Din Akbar (d.1605). Some of the Hindu nobles in his court wrote in Persian and Sanskrit, like Raja Manohardas and Raja Todar Mal (d.1589) who translated *Bhagavata Purana* into Persian. Akbar had a stupendous library composed entirely of manuscripts written and engraved by skilful penmen. The volumes in his library numbered only 24,000 but they valued at $3,500,000. He patronized poets and learned men. He supervised the translation of *Mahabharta* into Persian. (7). In the preface to his Persian translation of *Mahabharata,* Abul Fazl says: "Akbar initiated a policy so that in his age the pillars of blind following were demolished and a new era of research and enquiry in religions matters commenced". (8) In 1578 he ordered Abul Fazl to translate the *New Testament into Persian*. No copy of this translation is extant, but it appears he made the translation with the help of the Catholic Fathers. (9) The translation of Ramayana was undertaken by Abdul Qadir Badauni on the express command of Akbar in 1585 and completed in 1590. The *Harivamsa Purana*, supplement to *Mahabharta,* was translated by eminent Persian poet Mulla Sheri.

A translation bureau *Maktab Khana* was established in the Diwan Khana of Fatehpur Sikri, its members included Faizi, Abul Fazl, Naqib Khan, Badauni and Shirazi. The Sanskrit scholars explained the original to the Persian scholars, who made the translation s into a literary language. All the translations of Sanskrit works prepared during Akbar's reign were illustrated by the court painters. An illustrated copy of Ramayana is now in the Freer Gallery, Washington DC.

Some Muslim nobles like Abdul Rahim Khani-i- Khana, Abul Fazl and Faizi knew some Sanskrit and translated from it. In 1584 Akbar ordered Mulla Abdul Qadir Badauni to translate from Sanskrit into Persian *Singhasan Battisi*, embodying the stories of Bikarmajit and the 32 statutes. A learned Brahmin was appointed to be Badauni's collaborator to interpret Sanskrit text for him. The Persian work was entitled *Naama-i-Khirad* (The Wisdom Augmenting Book). Next year Akbar ordered Abul Fazl to translate from Arabic into Persian *Hayatul Haiwan*, the celebrated zoological dictionary, compendium of folklore, and popular medicine, authored by Musa al-Damiri (d1406). Faizi paraphrased the first two *puranas* into Persian verse. Taj al-Ma'ali translated a Sanskrit work and called *Mufarrih al-Qulub,* manuscript is at Indian Office library, MS 3350. (10)

Father Monserrate presented to Akbar an *Atlas* sent to him by Archbishop of Goa. He had written in his travelogue that he had seen Akbar working on machines and giving instructions on how to make new machines. This is how he described Emperor Akbar:

> "*He is a great patron of learning, and always keeps around him erudite men, who are directed to discuss before him philosophy, theology, and religion, and to recount to him the history of great kings and glorious deeds of the past. He has an excellent judgment and a good memory, and has attained to a considerable knowledge of many subjects by means of constant and patient listening to such discussions. Thus he not only makes up for his ignorance of letters (for he is entirely unable either to read or write), but he has also become able clearly and lucidly to expound difficult matters. He can give his opinion on any question so shrewdly and keenly, that no one who did not know that he is illiterate would suppose him to be anything but very learned and erudite." The Commentary of Father Monserrate, on his Journey to the Court of Akbar 1591.*

http://www.columbia.edu/itc/mealac/pritchett/00generallinks/txt_monserrate_akbar.html#letters

Shaikh Abu al-Faiz ibn Mubarak – pen name Faizi (1547-95) was a poet laureate of Emperor Akbar. At the suggestion of Akbar, Faizi translated Bhaskar Acarya's (1114-60) Sanskrit work on mathematics *Lilavati* into Persian in 1587; containing theorems of arithmetic and algebra. The translation was so popular that Ataullah Rashdi Lahori translated Bhaskar Acarya other books on algebra and measurement. Faizi, a prodigious author of 100 books, translated few mathematical problems from Latin into Persian also.

The famous book covering the administration of Emperor Akbar, A'*eenay Akb*ari written by Abul Fazl Allami ibn Mubarak (d.1602), described West and Central Asian

astronomy. Abū al-Fażl's greatest literary accomplishment was the monumental *Akbar-nāmah* in 3 volumes. Among his many works is a Persian translation of the Bible. Authors of later generations admired his style and sought to imitate it. *Zije Ulugh Beg,* prepared by Sultan Ulugh Beg (1393-1449) in Samarkand was translated into Sanskrit, entitled *Ulakabegijica*.

Astronomy

The Persian-Indo polymath, Fatehullah Sherazi (d.1582), a scientist at the court of Emperor Akbar (d.1605) reformed the Calendar. One of his inventions, a military weapon, was designed for killing infantry, an early volley gun with multiple gun barrels similar to hand cannons. Another cannon-related machine he invented which could clean sixteen gun barrels simultaneously, and was operated by a cow. He also developed 17 barrelled cannon, fired with a matchlock.

Emperor Noor al-Din Salim Jahangir (d.1627) continued the patronage of translations from Sanskrit into Persian as well as of Hindu scholars who wrote on Hindu law, sciences and lexicography. Jahangir was an excellent writer and loved nature. He recorded various details of flora and fauna from all over India. He was not only curious, but a scientific observer of minute details of species. A number of his observations are detailed in his autobiography *Tuzk-e-Jahangiri*.
http://persian.packhum.org/persian/main?url=pf%3Ffile%3D11001080%26ct%3D0

Fariduddin Munajjum, a court astronomer of Shah Jahan (d.1666), compiled *Zije Shah Jehani.* The first section of the tables dealt with various calendars, second section dealt with spherical astronomy, third section dealt with determination of the motions of the planets and their positions in the sky. The Zij was translated into Sanskrit under the title *Siddhanta-Sindhu*, by Nityananda at the command of vizier Asaf Khan & completed in 1635. A copy of the manuscript at Jaipur Museum once belonged to Emperor Shah Jahan, his seal is on folio 1. The Sanskrit translations consisted of 440 pages, 11 copies of this written on 'jahazi' paper, 45x33 cm were distributed among the aristocrats of North India. Four copies are at Jaipur palace library. Nityananda explained the Arabic and Persian technical terms for the benefit of Hindu astronomers while giving differences between islamic and Hindu astronomy. He devised new technical terms during the translations, which were later used in the translations Phillipe de Hire's Latin tables into Sanskrit.

Malajeet was an astronomer at Shah Jahan's court. He wrote *Parsiprakasa* (1643) which gave Arabic, Persian astronomical terms and their Sanskrit equivalents. Two Hindu scholars namely Nitya Naad, & Menisvara, used Arabic, Persian and Greek works to synthesize Islamic traditions with those of India. Mulla Mahmud Jaunpuri was a versatile scholar, expert in mathematics and astronomy. His book *Shamsay Bazegha* and *Shamsey Baligha* bring out outstanding features of astronomy. Emperor Shah Jehan wanted to construct an observatory for Mulla Jaunpuri, but could not do so on account of financial constraints on the royal treasury.

Maharajah Sawai Jai Singh

Maharajah Sawai Jai Singh (d.1743) was an astronomer of the first order. He had some Greek works on mathematics (including Euclid) translated into Sanskrit as well as more recent European works on trigonometry, logarithms and Arabic texts on astronomy. As he found the prevalent tables in use at that time defective, he decided to prepare new ones. First he built metal instruments which, however, did not come up to his idea of accuracy. Therefore he constructed at Delhi huge masonry instruments. Subsequently, to verify the correctness of his observations, he constructed instruments of the same type in Jaipur, Mathura, Banaras and Ujjain observatories. In his five observatories Hindu and Muslim observers were employed and produced a set of astronomical tables called *Zijey Jadid Muhammad Shahee*. He was fluent in Persian and Arabic and was acquainted with *Zij-i-Ulugh Beg*. He incorporated in his works latest European astronomical knowledge as is evidenced from the Zij which was based on Latin tables of Phillipe de Hire. *Zije-i-Jadid* first section deals with calendars, the second deals with determination of heavenly bodies and third covers the motions of the Sun, Moon and the rest of the planets, eclipses of the Sun & Moon, the appearance of the new Moon.

This is how his accomplishments are described in Wikipedia:

"*In 1719, he was witness to a noisy discussion in the court of Mughal emperor Muhammad Shah Rangeela. The heated debate regarded how to make astronomical calculations to determine an auspicious date when the emperor could start a journey. This discussion led Jai Singh to think that the nation needed to be educated on the subject of astronomy. It is surprising that in the midst of local wars, foreign invasions, and consequent turmoil, Sawai Jai Singh found time and energy to build astronomical observatories.*

the author of this article visited this observatory Jantar Mantar in Delhi in March 2009.

No less than five massive structures were built at Delhi, Mathura (in his Agra province), Benares, Ujjain (capital of his Malwa province), and his own capital of Jaipur. In all of these only the one at Jaipur is working. Relying primarily on Hindu astronomy, these buildings were used to accurately predict eclipses and other astronomical events. The observational techniques and instruments used in his observatories were also superior to those used by the European Jesuit astronomers he invited to his observatories. Termed as the Jantar Mantar they consisted of the Ram Yantra (a cylindrical building with an open

top and a pillar in its center), the Jai Prakash (a concave hemisphere), the Samrat Yantra (a huge equinoctial dial), the Digamsha Yantra (a pillar surrounded by two circular walls), and the Narivalaya Yantra (a cylindrical dial).

The rajah also translated works by people like Scottish mathematician John Napier (1601). For these multiple achievements Sawai Jai Singh II is remembered even to this date, as the most enlightened king of 18th Century India. These days Jai Singh's observatories at Jaipur, Varanasi, and Ujjain are functional. Only the one at Delhi is not functional and that at Mathura disappeared long time ago."

There is evidence that Rajah used a telescope for his observations of the celestial bodies. This telescope was brought by Father Bandier who had visited Jaipur. His observations of Venus and Mercury, the rings of Saturn and Sunspots are proof that he employed a telescope. The 16th and 17th centuries saw a synthesis between Islamic astronomy and Indian astronomy, where Islamic observational techniques and instruments were combined with Hindu computational techniques. While there appears to have been little concern for theoretical astronomy, Muslim and Hindu astronomers in India continued to make advances in observational astronomy and produced nearly 100 Zij treatises.

Jai Singh's brahman tutor Samrat Jagannath, translated Allama Nasiruddin Tusi's *Tahrir al-Majisti* into Sanskrit entitled *Samrat Siddhanta* in 1732. He also translated Tusi's *Kitab Usul al-Hindasa* which was based on Euclid's *Elements.* Nayansuk-hopadhaya translated Tusi's *Tahrir al-Ukar* into Sanskrit entitled *Ukara*. A manuscript is preserved at Jaipur Museum library. *Yantra-prakara* was composed for Raja Jayasimha in Dehli in 1729 based on *Tahrir al-Majisti,* later translated into Sanskrit by Jagannath.

Descriptions of 275 astronomical manuscripts still housed in the palace library of Jaipur help clarify how Raja Jayasimha was led to rely on observations for practical astronomy and on European theories for accurate calculations of celestial phenomena.

Sarahtjagkira Virjandi is a translation into Sanskrit of Chapter 11 of Book 2 of Tusi's *Tadhkira* with Birjandi's sharah completed by Nayanasukho-padhya assisted by Muhammad Abidda, completed in December 16, 1729. It is evident that Persian polymath Nasiruddin Tusi (1201-1274) and mathematician Bahauddin Amuli (1547-1621) books were very popular in India.

Following is a list of Arabic/Persian astronomical tables at Jaipur which were translated into Sanskrit in India.

1. Bist dar bab Usturlab by Tusi
2. Kitab al Ukarr, translation from Greek by Qusta ibn Luqa, 9th century
3. Risala dar Hai'ya
4. Risala dar Usutrlab
5. Sharah al-Tadhkira by Tusi (Resume on astronomy)
6. Tahrir al-Majisti by Tusi (Redaction of al-Majisti)
7. Tahrir Hisab usul al-Hindasa

8. Tahrir al-Ukarr by Tusi
9. Zij I Jadid by Ulugh Beg completed in 1437.
10. Zij-e- Khaqani by Jamshed al-Kashi
11. Zij-e-Shah Jahani

Ghulam Hussain Jaunpuri was the author of *Zijey Bahadur Kha*ni (1846) which was based on the observations made by the author himself. It also covered mathematics, trigonometry, optics and astronomy.

Technology

Fathullah Shirazi (c. 1582), a Persian-Indian polymath and mechanical engineer who worked for Akbar the Great in the Mughal Empire, developed a Volley gun. Considered one of the most remarkable feats in metallurgy, the seamless globe was invented in Kashmir by Ali Kashmiri ibn Luqman in 1589-90, and twenty other such globes were later produced in Lahore and Kashmir during the Mughal Empire. Before they were rediscovered in the 1980s, it was believed by modern metallurgists to be technically impossible to produce metal globes without any seams, even with modern technology. Another famous series of seamless celestial globes was produced using a lost-wax casting method in the Mughal Empire in 1659-1960 by Muhammad Salih Tahtawi (from Thatta, Sind) with Arabic and Persian inscriptions. It is considered a major feat in metallurgy. These Mughal metallurgists pioneered the method of wax casting while producing these seamless globes.

Instruments

Astrolabe used for astronomical observations was developed and improved upon in India. Humayun patronized astrolabe manufacturing. The astrolabe maker at his court was Allahdab Asturlabi Lahori whose sons and grandsons also made astrolabes. Lahore seemed to have been a major centre for the manufacture of astronomical instruments. Maharajh Jai Singh constructed a number of astrolabes which were made from masonry, i.e. Smarat Yantra, Jai Prakash, Ram Yantra, Misra Yantra.

Few years ago, I visited the Adler Astronomy Museum in Chicago, located near the banks of Lake Michigan. There were 31 astrolabes on display in the Islamic astronomy section. There was a map of the Islamic world on the wall, and a list of eminent Muslim astronomers, of whom Nasir al-din Tusi was on the top of the list. One could do experiments, like finding Mecca using an astrolabe, or using an alidade on the astrolabe one can determine the degree at which a certain star is located in the sky. I saw one astrolabe which had the following inscription on it: Amal Ziauddin Muhammad ibn Mulla Humayun asturlabi Lahori 1057 AH. (i.e. 1647 ad)

The instruments and observational techniques used at the Mughal observatories were mainly derived from the Islamic tradition, and the computational techniques from the

Hindu tradition. In particular, one of the most remarkable astronomical instruments invented in Mughal India is the seamless celestial globe.

Spanish astronomer & instrument maker Ibrahim Al-Zarqali's (1087) treatise on the universal astrolabe *Safiha* was translated into Sanskrit as *Jarakali-Yantra* by Nayansukhophadhaya and was incorporated into Jagan Nath's *Siddhanta Kaustubya* around 1730.

Mathematics

Most of the available Sanskrit literature was translated during the Muslim rule of India, and in some instances Muslims made significant contributions. Euclid's *Elements* was translated into Arabic by Allama Nasiruddin Tusi, while Qutub al-Din Sherazi had translated it in 1311into Persian. Based on these translations, Abdul Hamid Muharrar Ghaznavi wrote *Dastur al-Bab fee Ilm al-Hisab* after 26 years of intensive labor.

Taj Mahal designed by Ustad Ahmad Lahori.

One of the distinguished families of Punjab that made significant contributions to mathematics was Ustad Ahmad Lahori, aka Ahmad al-Mima'r, (1580-1649) the architect of Taj Mahal & Red Fort. One of his sons Ataullah Rashedi translated Bij Ganita describing the reign of Emperor Shah Jehan. (reigned 1628–58) He also wrote *Khulasa Raaz* in Persian which dealt with arithmetic, algebra, and measurement. His other book *Khazinatul A'adad d*ealt with arithmetic, geometry of Euclid and algebra. Another son Lutfullah Muhandis wrote *Risala Khaws A'adad* dealing with properties of numbers. He was also author of *Sharah Khulasa al-Hisab* and his *Muntakheba*t was a translation of Persian mathematician Bahauddin Aamili's *Khulasa tul--Hisab* (epitome of mathematics).

Imad al-Din Riyadi, the grandson of Ustad Ahmad was also a versatile scientist. He wrote a commentary on Amuli's *Khulasa tul-Hisab*, entitled *Hashiya bar Sharah Khulasa* which consisted of a preface, ten chapters and an appendix. Besides these he wrote a commentary on *Sharah Chaghmani* entitled *Hashiya bar Sharah Chaghmani*. He also wrote a book on problems of spherical astronomy and geometry. On music he authored *Risala Dar Ilm Museekee* which covered a wide range of topics on philosophy.

It appears that mathematics was not only associated with accountancy and revenue collection, but with astronomy and architecture as well. A number of translations were made from Persian & Arabic into Sanskrit. Maharajh Sawai Singh made major contributions in trigonometry, which was to find the sine of one degree and its parts, namely minutes and seconds.

Abul Khair Khairullah, grandson of Ustad Ahmad Lahori, wrote a commentary on *Zij Muhammad Shahi,* translated *Almagest* as well as wrote a commentary on it. He was appointed director of the Dehli observatory in 1718. His other major works were: *Majmu'a al-Madkhil fil al-Najoom* & *Majmu'a al-Saboot al-Qudsia*.

Khazinatul Ilm (Treasury of Knowledge) was a Persian book by Khawaja Azimabadi dealing with arithmetic, geometry, astronomy along with English terminology and their translations into Persian. This is also reflected in the works of Fakhruddin Khan Bahadur, author of *Risala dar Biyan Amal al-Qata* and *Shamsul Hindsa*, which are on measurement, geometry and trigonometry.

Medicine

Muslim practitioners were known by their designation Hakim or Tabib. Hakim means a scientist or a learned man while Tabib means a physician. The Jarah was a surgeon, surgery was called Ilmey Jarahat. Most of the medical & scientific books were written in Arabic and Persian**.**

Islamic medicine in India was founded on books of two Persian physicians, namely Zakariya Razi and Hakim ibn Sena. During the rule of Tegin (1098-1127) a scholar from Khawrazm Hakim Zainuddin Ibrahim Ismail wrote a book on medicine called *Zakhirah Khawazim*. This compendium asserted great influence in India from 12th to the 15th century. The book described definition of medicine, diagnosis of an illness, reasons for illness, fevers, types of poisons and constitution of human body. He also wrote another book *Aghraz al-Tibb* which was also very popular among the local practitioners of medicine. His *Tibbey Yadgar* was an extensive pharmacopeia in 14 chapters. Physician Nafees Ibn Kirmani (d.1424) wrote a book entitled *Tibbey Akbari*.

Hakim Mansur ibn Ahmad was a Persian who had settled in Kashmir. He authored a book *Kafaya al-Mujahideen*, on the diseases of women and children and their treatment. This was dedicated to Sikandar Shah II of Dehli. One of the secretaries of Emperor Humayun Yusuf ibn Muhammad Herati wrote a book on various diseases and their remedies. Muhammad Momin wrote *Tuhfatul Mominin* which was a compilation of various Arabic & Sanskrit authorities, on the whole field of medicine. *Madan al-Shifa Sikandar Shahi* was written in 1512 by Beva-bin-Khas., a vizier of Sultan Sikandar Lodhi, synthesizing Islamic and Sanskrit medicine. Famous historian Hindu Shah wrote *Dastul al-Ittiba'a.* Hakim Nooruddin Abdulla was a nephew of abul-Fazl, vizier of Akbar. He wrote a book *Alfaz al-Adwiyy*a on material medica giving names in Hindi, Arabic, Persian, Latin, Spanish, Turkish and Sanskrit. The book was dedicated to Emperor Shah Jahan.

Hakim Ali Gilani (1554-1609) was not only a physician but a renowned mathematician and a scientist. He was attached to the court of Akbar who had given him the title of *Jalinoos al-Zaman* (Galen of the world). He was the only Indian physician to have written a commentary of all five volumes of *al-Qanun*. The first volume of the commentary *Jamay al-Sharahein* was published from Lucknow in 1850. Another book of

his on medicine is called *Mujarrabatey Gilan*i (tested remedies). Emperor Jahangir believed that Akbar was poisoned by Hakim Gilani.

Muhammad Raza of Shiraz wrote a treatise *Riaz-i- Alamgiri* on medicine, food and clothing, and was dedicated to Aurangzeb. Muhammad Akbar Arzani, court physician of Aurangzeb, wrote *Tibb-i-Akbari* in 1678, which was in fact translation of Sharh -ul-Asbab. Arzani also wrote *Tajriba-i-Akbari*, based on author's own experiences.
His Qarabadain Qadri was an extensive pharmacopeia of medicine extensively used in India. Imam Ghulam Hakim wrote in Persian *Elaj al-Ghura*ba (treatment of special diseases) which was reprinted several times during the 19th century due to its immense usefulness.

Hakim 'Alavi Khan was born in Shiraz, in Persia, in 1670. In 1699 he went to India and presented himself at the Mughal court of Afghans, where he was appointed physician to Prince Muhammad A'zam (who was later to rule for only three months in 1707). The Mughal ruler Bahadur Shah (ruled. 1707-12) gave him the title 'Alavi Khan. Muhammad Shah (reg.1719-1748), the Mughal ruler in Delhi, raised him to the rank of *Shash-hazari* and gave him the title of *Mu'tamad al-Muluk*. When the Persian ruler Nadir Shah defeated Muhammad Shah and sacked Delhi, 'Alavi Khan accompanied Nadir Shah when he left India and 'Alavi Khan accepted the position of *Hakim-bashi* ("chief physician") to Nadir Shah. After making a pilgrimage to Mecca, 'Alavi Khan returned to Delhi in 1743 and died there about four years later. He wrote four medical treatises in Arabic and four in Persian. His nephew Muhammad Husayn ibn Muhammad Hadi al-'Aqili al-'Alavi al-Khurasani al-Shirazi (fl. 1771-81), known as *Hakim Muhammad Hadikhan*, used 'Alavi Khan's pharmacopoeia titled *Jami' al-javami'-i Muhammad-Shahi*, which was dedicated to the Mughal ruler Muhammad Shah. A large portion of this comprehensive work written in 1771 is on simple and compound remedies.

Sihatul Amraz by Pir Muhammad Gujrati 1726 contained prescriptions for cure of all diseases.

Following is a list of *undated* medical manuscripts preserved in India.

1. *Khulasat –ut-Ti*bb: by Muhammad bin Masood, a short treatise on medicine, on the art of dying, and paper making.
2. *Asrar-i-Ittiba*: by Shihab al-Din, essays on the virtues of amulets, medicine, charm for averting disease.
3. *Shifa ar-Rijal:* Shihab al-Din, poetical treatise on medicine
4. *Bahr-ul-Manafia*: 1794 by Maulood Muhammad, dedicated to Tipu Sultan, treatise on midwifery, children, exorcising devils, enchantments etc.
5. *Qanun-dar-Ilm-Tibb*: a translation by order of Tipu Sultan, a complete pharmacopeia.
6. *Tarjuma Kitab-i-Farang*: a translation of Dr Cookburn's treatise on twist of the intestines.
7. *Mufradat dar-Ilm-Tibb*: on botany and natural history, translated by order Tipu Sultan from French & English.

8. *Risala Tib-i-Aspan*: translation from Sanskrit by Zain al-Din 1519 and dedicated to Shamsuddin Muzafar Shah on farriery.
9. *Kitab al-Sumum*: by Shanka of India, translated into Persian by Hatim, later by Abbas Saeed Jauhari.
10. *Sharah Hadae-tul-Hikma*: by Muhammad bin Ibrahim, qazi of Shiraz, contains the whole course on sciences read in schools. It was much esteemed by Muslims of India.
11. *Makhzanul Adwiyya*: by Hakim Muhammad Hussin, printed in Persian.
12. *Tazkira-tul-Hind*: by Hakim Razi Ali Khan, on materia medica in Persian, written in early part of 19th century, lighographed in 1866 Hyderbabad.

In the 17th and 18th century when Persian medicine almost died in Iran, it was kept alive in India. Cyril Elgood observes, " When Persian medicine almost died of inanition in Persia, it was kept alive by the Hakims of Delhi & Lucknow. Its literature was preserved by the printing presses of northern India. It was to them that we owe the first printed editions of such famous works as *Tashrih-i-Mansuri, Tuhfatul Momineen*, and *Tuhfatul Ashiqeen* of Avicenna." (11)

Pharmacy

Sultan Alauddin Khilji (1296-1316) had several eminent Hakims in his royal courts. This royal patronage was a major factor in the development of Unani practice in India, but also of Greco-Islamic (Unani) medical literature with the aid of Indian Ayur-vedic physicians.

During the reign of Moghul kings of India several Qarabadains were compiled like Qarabadain Shifae'ee, Qarabadain Zakai, Qarabadain Qadri and Elaj-ul-Amraz. In these pharmacopoeias quantities of drugs in a given prescription were specified, and methods of preparation. The court physicians supervised the preparations of royal medicine, which were sealed to ensure safety. Hakeem Ali Gilani was the chief physician of Emperor Akbar and used to accompany him in his travels. Hakim Gilani used to carry his pharmacy with him in these travels. He invented a kind of sweet wine for getting rid of traveling fatigue. During the reign of Emperor Jehangir, Itr-i-Jehangiri was discovered by Queen Noor Jehan. Hakim Ain-ul-Mulk Shirazi composed for his royal patron emperor Shah Jahan Alfaz-al-Adwiyya (vocabulary of drugs). It was printed in 1793 in Calcutta, and rendered into English by Gladwin. Hakim Akbar Arzani, was a court physician of Emperor Aurangzeb. He wrote Tibbe Akbari, and Mizan al-Tibb.

From an Ottoman manuscript, two doctors telling the pharmacist how to make different medicine.

During the British rule, Eastern medicine in India declined. However the famous house of Hakim Sharif Khan of Dehli made a concerted effort to rejuvenate the decaying art of Unani medicine. Hakim Ajmal Khan founded the Hindustani Dawakhana and the Tibbiya College in Dehli. At the Tibbiya College, Dr Salimu-Zaman Siddiqui carried on chemical investigation of certain potent drugs and Ajmailain was produced. At Lucknow, the Talim al-Tibb college was established under the auspices of Hakim Abdul Aziz.

Hakim Kabir al-Din **was** a distinguished author who wrote four books on Eastern system of medicine: Masaela Dauran-ey-Khoon, Sharah Qanoon Shaikh, Tashrih Kabir, Ilm al-Adwiyya and Burhan.

Muhammad Husayn al-Aqili al-Alavi, a practitioner and grandson of a well-known Indian practitioner wrote in 1732 Makhzan al-adwiyah dar-i bayan-i adwiya. The illuminated Persian manuscript, now at the National Library of Medicine, USA is in alphabetical order.

At Lahore Hakim Ghulam Nabi and Hakim Ghulam Jeelani promoted Eastern medicine by writing books such as: Tarikh al-Ittiba, and Makhzan al-Adwiyya. After the demise of Hakim Ajmal Khan, Hakim Abdul Majid (d.1922) started a pharmacy in 1906 which blossomed into Hamdard Waqf Laboratories. Hamdard now is a leading pharmaceutical house in India and Pakistan.

Chemical Technology

Chemical technology during the Muslim rule was centred on five areas:

1. Preparation of drugs 2.preparation of perfumes and cosmetics 3.preparation of beverages including fermented ones 4.making of dyes 5.making gun-powder, and pyrotechnics.

Rockets were also made with gunpowder in them. Some rockets went in the air and some went along the surface. Tipu Sultan (d.1799) and his father Hyder Ali (d.1782) are regarded as pioneers in the use of solid fuel rocket technology or missiles for military use. A military tactic they developed was the use of mass attacks with rocket brigades on infantry formations. Tipu Sultan wrote a military manual called *Fathul Mujahidin* in which 200 rocket men were assigned to each Mysore a "cushoon" (brigade). Mysore had 16 to 24 cushoons of infantry. The areas of town where rockets and fireworks were manufactured were known as Taramandal Pet ("Galaxy Market"). It was only after Tipu's death that the technology eventually reached Europe.

The rocket men were trained to launch their rockets at an angle calculated from the diameter of the cylinder and the distance to the target. In addition, wheeled rocket launchers capable of launching five to ten rockets almost simultaneously were used in war. Rockets could be of various sizes, but usually consisted of a tube of soft hammered iron about 8 inches (20 cm) long and 1.5 to 3 in (3.8 to 7.6 cm) in diameter, closed at one end and strapped to a shaft of bamboo about 4 ft (1 m) long. The iron tube acted as a combustion chamber and contained well packed black powder propellant. A rocket carrying about one pound of powder could travel almost 1,000 yards. In contrast, rockets in Europe, not being iron cased, could not take large chamber pressures and as a consequence, were not capable of reaching distances anywhere near as great.[57]

Hyder Ali's father, the Naik or chief constable at Budikote, commanded 50 rocket men for the Nawab of Arcot. There was a regular Rocket Corps in the Mysore Army, beginning with about 1200 men in Hyder Ali's time. At the Battle of Pollilur (1780), during the Second Anglo-Mysore War, Colonel William Baillie's ammunition stores are thought to have been detonated by a hit from one of Hyder Ali's rockets, contributing to a humiliating British defeat.

After the fall of Srirangapattana, 600 launchers, 700 serviceable rockets and 9,000 empty rockets were found. Some of the rockets had pierced cylinders, to allow them to act like incendiaries, while some had iron points or steel blades bound to the bamboo. By attaching these blades to rockets they became very unstable towards the end of their flight causing the blades to spin around like flying scythes, cutting down all in their path.

These experiences eventually led the Royal Woolwich Arsenal to start a military rocket research and development program in 1801, based on the Mysorean technology. Their first demonstration of solid-fuel rockets came in 1805 and was followed by publication of *A Concise Account of the Origin and Progress of the Rocket System* in 1807 by William Congreve. http://en.wikipedia.org/wiki/Tipu_sultan.

Metallurgy

Various types of weapons were made in India. Zinc was not known in Europe, but extracted in India. Many alloys were made, iron, steel, brass, bronze used in making weapons. These kinds of weapons were produced in a plant called *Karkhana*. Descriptions of castings of cannons are found in *Babur Nama*.

Screw cannon: in order to carry heavy cannons on hill tops the cannon was made in pieces and assembled subsequently. Multi-barreled cannons were made in order to fire 17 barrels successively. For coating the surface of copper with a mixture of zinc and tin, threads were made from various metals like gold, silver which were used in textile. Gold & silver leaf was produced for use in goods and medicines. Another dimension of metallurgy was production of gold, silver and copper coins.

Conclusion

During the Muslim rule of India considerable work was done in mathematics, medicine, astrology, astronomy, and translations of various texts. Custodians of faith filled the minds of people with superficial things and did not allow enquiry into religious dogmas. Science was not patronized as a state policy by Kings or the Raja's. It is unfortunate science and technology was not pursued rigorously as it was being developed in Europe. No scientific institutions were set up, nor were students sent to Europe for higher studies. The money that was spent on constructing monumental edifices, had it been spent on creating scientific institutions, India could have become an advanced country long time ago.

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Zakaria.virk@ontario.ca