As the periodization of history is controversial, there might be a difference of opinion regarding the date when the ancient period of the history of India ends and the medieval one begins but the period under consideration is actually the late ancient and early-medieval. Prithviraj lost the second battle of Tarain in 1192 A.D. and this is considered a turning point in the history of India as it led to the conquest of northern India by the Turko-Afghans between 1192 and 1206 A.D.

India already had commercial and cultural relations with Greece, Iran, Afghanistan and Central Asia since pre-historic times. A characteristic feature of this period is that with the advent of the Muslims, seeking service and opportunity in India, it came into close contact with the Muslim intellectual world and the cross fertilization of scientific ideas started. Muslims started migrating to India more and more after 1258 A.D. due to the Mongol invasion of Iran, Iraq and Central Asia; some of them were also astronomers, mathematicians and physicians.

"With the establishment of the Ghaznavid and Mughal rule in India the Greek or rather more advanced Ptolemaic astronomy in Arabic version reached India and began to be studied and taught at first exclusively among the Muslims and gradually among the selected Hindu astronomers who appreciated its merit."\(^1\) Al-Bīrūnī (d. 1050 A.D.) claims that he had translated the *Elements* of Euclid and the *Almagest* of Ptolemy into Sanskrit but these translations are not available.\(^2\) In any case, the Arabic version of these two books were first introduced by the Muslims in India. It is stated

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* Professor of History of Science, India.
“towards the close of the 12th Century A.D. mathematical books in Arabic began to trickle into India. One of the most important of these treatises was an Arabic recension of Euclid’s *Elements: Taḥrīr Kitāb Uṣūl al-Handasa wa’l-Hisāb al-Mansūb ilā Uqlīdas* (commonly called *Tahrir Uqūdas*) composed by Naṣīr al-Dīn Ṭūsī (d. 672/1274) belonging to the Marāgha School of Astronomy. During Ṭūsī’s life time itself Ṭūsī al-Dīn (d. 710/1311) prepared a Persian translation.”

Some Indian Muslim mathematicians and astronomers settled in India knew these Arabic translations and they translated them into Persian. These translations and several commentaries mostly in Persian on the works of Euclid, Archimedes, Theodosius, Apollonius and Ptolemy are available in manuscripts in the different libraries of India and abroad. Thus the Greco-Arab astronomy and mathematics were introduced into India and studied. Some of them were taught as text books in the educational institutions in late medieval India from the time of Akbar (d. 1605 A.D.) who made astronomy and mathematics compulsory subjects to be studied.  

Another characteristic worth mentioning is that the first substantial contact between the Ayurveda and Unānī (*Greco-Arab*) systems of medicine started during this period which resulted in the mutual enrichment of both in therapeutics, materia medica and pharmacology. These two systems of medicine flourished because they brought relief to the suffering and the sick. The two main causes of the development of chemistry and alchemy were the practice of Ayurveda and the need of textile industry.

Among other characteristics mention may be made of the development of the *Rasacikitsā* school of medicine with emphasis on mercurial and other inorganic preparations and the development of Tantras and the knowledge of nervous system as developed by them.

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3. C.A. Storey, *Persian Literature, A Bibliographical Survey*, (London 1972), Vol. II, pt 1, p. 1, Jagannatha (b. 1652 A.D.) translated the *Elements of Euclid* and the *Almagest* of Ptolemy into Sanskrit and they were entitled as *Rekhāganiya* and *Samrāt-Siddhānta* respectively, see CHSI, p. 171.


Mathematics and Astronomy

Both Mathematics and Astronomy were used by the Hindus and Muslims for religious purposes. Mathematics specially was studied for its practical utility, as for example, for the construction of religious and secular buildings and monuments. Later, geometry was much developed in India for this purpose. It was used also for technological development.

Mathematics, astronomy and astrology were not separate subjects as they are today. More often than not, the mathematician, astronomer and astrologer were all combined in one and the same person. The outstanding mathematician-astronomers of this period were Śrīdhara (c. 991 A.D.); Sripati (1039-1056 A.D.), Satānanda (fl. 1099 A.D.) Bhāskarachārya II (1150 A.D.), the major and minor mathematicians and astronomers cannot even be mentioned here and their contribution cannot be discussed due to shortage of space. “For multiplication, he uses a new term Pratyutpanna (reproduced) and discusses the Kapāta-Sandhi (door-junction, Geolosia) method which became very popular among later Hindu writers and was transmitted to the West through Arabic works. It is known from Bhāskara that Śrīdhara was the discoverer of a method of solving quadratic equations in which the two sides require to be multiplied by four times the coefficient of X²”.8

There was at least one foreign scientist al-Būrūnī (d. 1050 A.D.) who studied the Indian sciences in original Sanskrit texts and translated some of them into Arabic. He had a working knowledge of Sanskrit and his well-known book Kitāb al-Hind9 gives valuable information not found elsewhere specially about astronomical methods and Indian astronomers some of whom were personally known to him. Some of the twenty-five books and treatises dealing with Indian subjects attributed to al-Būrūnī10 are either lost or are available in MSS only. Among those available The Rasā'il,11 the al-Qānūn al-Masūdi12 contain useful source material for the history of

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7 See notes 13 and 14 in M.S. Khan's paper mentioned in note 4 above.
8 S.N. Sen, "Mathematics", in the CHSI, p. 168.
9 The full title is: Kitāb fi'l-Tābiqīq mā l-il-Hind min Maqālātīn Maqālātān fi'l-'Aql wa Mardūla (book giving an account of India about facts acceptable to reason or to be rejected by it).
science in India in the first half of the the eleventh century. His Arabic translation of the Karana Tilaka of Bijayananda should be mentioned here.\textsuperscript{13} Another work which has been edited and published is the Fī Rashīkāt al-Hind\textsuperscript{14} which deals with the Indian Rule of Three.

A new development in astronomy was the introduction of Arabo-Persian-Greek Zīj literaturre in India namely astronomical tables. Abu’l-Faḍl mentions 86 Zījes in his A’īn-i Akbari. There were several Zījes prepared in pre-Mughal India.\textsuperscript{15}

There is no evidence to show that astrolabes were used in India before the advent of the Muslims. It was during the reign of Sultan Fīrōz Shāh Tughluq that an astrolabe was constructed in 1370 A.D. and named Uṣūrlāb-i Fīrōz Shāhī which testifies to the fact that Indians possessed adequate knowledge of applied technology during the fourteenth century.\textsuperscript{16}

People seem to be more interested in astrology than astronomy and there were more astrologers than astronomers in Delhi. Diyā ad-Dīn Baranī writes about the horoscopes which they constructed of the sons and daughters born to the kings, ministers and noblemen which was an important source of their income. They earned their livelihood not as astronomers but as astrologers. He also records the names of those astronomers and astrologers both Hindus and Muslims who flourished during this period\textsuperscript{17} and adds that pseudo-sciences such as Ramal geomancy and al-Kimyā (alchemy) also flourished during this period.\textsuperscript{18}

\textsuperscript{13} Also entitled Ghurrat as-zijat edited by N.A. Baloch (Sind: Institute of Sindhology 1973), pp. 94 (Arabic text) + pp. 74 (English Introduction and Bibliography) + pp. 7 (Errata). Other editions of this text have been published with English translations in the Islamic Culture of Hyderabad. Henceforth IC.


\textsuperscript{17} See the Tarikh-i Firoze Shahi, ed. by Saiyid Ahmad Khan (Calcutta: Asiatic Society 1862), pp. 362-366.

\textsuperscript{18} Ibid, p. 364.
SCIENCE AND TECHNOLOGY IN INDIA

Medicine, Chemistry and Alchemy

The Ayurvedic system of medicine including the Siddhā were practised extensively and in the beginning of the 13th century the Unānī system of medicine was also introduced in India when the period of growth and standardisation of Ayurveda had almost come to an end. The four standard works Çaraka Samhitā, Susruta Samhitā, Aṣṭāngahardaya, Nidāna and their commentaries were used by the general medical practitioners of India (Vaids).

"Feeling of patients' pulse as a method of diagnosis of diseases was possibly first introduced during this period as discussed in a text of Ayurvedic medicine, Cikitsātilaka (12th century) by Tisatācaryā."20

Physicians (Ṭabīb) expert in the Unānī (Greco-Arab) system of medicine began to migrate from the beginning of the 13th century and this was the first major contact between Ayurveda and Unānī medicine in India. Both the systems of medicine were now practised. Two different sets of hospitals were established by the Turko-Afghan rulers there the patients were treated according to these systems. There were seventy hospitals only at Delhi under Sultan Muḥammad bin Tughluq (1297-1348 A.D.) having 1200 Vaids and Tabībs paid by the State.21 The mutual co-operation and direct contact of the Vaids and Tabībs produced substantial results and led to the mutual enrichment of knowledge. Indian pharmacology, materia medica and therapeutics were enriched by the Unānī system and camphor, sublimate of landanum and some anesthetics were introduced into the Ayurveda.22

Botany and Agriculture

Information about advances made in botany and agriculture are not available due to paucity of source material. The works of Amīr Khusrav

19 R.C. Majumdar, "Medicine", in the CHSI, p. 262.
(651-725/1253-1325 A.D.) and and the Persian historical chronicals contain some information about these two subjects.

Medicinal herbs and plants were much cultivated. Al-Bîrûnî’s *Kitâb as-Saydanah fi’t-Ṭibb*, published recently with an English translation contains useful information for the pharmacographia Indica.23 Compiled in the middle of the eleventh century, it is an encyclopedia of simple drugs containing medicinal herbs and minerals used in the Unânî system of medicine arranged in alphabetical order. There are names of hundreds of medicinal herbs and plants of India which are used in Ayurvedic materia medica. The Sanskrit name is given in each case and the location is indicated where they were found at time of al-Bîrûnî. The first traceable medical book on Unânî medicine written in India was a Persian translation of the *Kitâb as-Saydana* of al-Bîrûnî. This was translated by Abû Bakr bin ʿAlî bin ʿUsmân who lived at the Court of Sulţân Iltutmîsh.24

Technology

Without doubt, there was progress in technology but the results of technological advancement were not much applied to solve the socio-economic problems. There is no denying the fact that in so far as technology is concerned, advent of the Turko-Afghans in India resulted in some development due to mutual co-operation between the Hindus and the Muslims and the introduction of new and more advanced technique from Iran, Afghanistan and Central Asia the Muslims. It is evident that technology during this period was almost the same as in ancient India which was somewhat improved after the Ghorian conquest.

Metallurgy

Iron, copper, brass, gold, silver and other minerals were extracted from the ores found in mines in different parts of India even by a primitive technology with the help of a furnace made of clay in which wood and charcoal were used for fire. As the army was important, iron was much in use for the manufacture of arms and armour.


Production Technology

In so far as production technology is concerned, a fact to be taken into consideration is that cheap skilled labour was available in abundance in India perhaps due to the institution of the Kārkhāna introduced by the Muslims which made this labour easily available.

Minting of Coins

For minting of coins, mostly gold, silver, lead, bronze, brass, bullion and copper were used and Iltutmish struck the silver Tanka and Copper Jital. Abū’l-Faḍl mentions a small round gold dīnar issued by Sultān ‘Ala’uddīn Khaljī whose refinement was considered to be 12 degrees but it was actually 10 1/2 degrees. The technology of Indian coinage in ancient and medieval periods has been thoroughly discussed in a paper published recently. The details are known from a Sanskrit work written during the reign of ‘Ala’uddīn Khaljī.

Textile Technology/Spinning Wheel

The premier industry in India was cotton textile and dyeing, printing and painting of clothes was done since ancient times. In connection with the innovation in textile technology, the general use of the spinning wheel is to be mentioned. It would not be possible to ascribe its origin to ancient India due to lack of positive evidence. Moreover, the word used for it is Charkha which is a Persian word. In the absence of any other evidence, the literary ones from Indo-Persian works can be put forward to show that the spinning wheel was in use at the end of the 12th century in which belt-drive technique was used. Another equipment which was much used in this period was the bow-string (Tānt and Kamān) for cleaning the cotton and separating the seeds from it or ginning. This primitive technique is used in India to-day.

Writing Material

It is al-Bīrūnī who gives the evidence around 1030 A.D. that the material used for writing in India were mainly black tablets palm-leaves, bark of the Tuz tree called Bhurja and silk. The manufacture of white paper started in India in the 13th century. Amir Khosraw mentions paper (Kāghaz) several times in his epistolary work entitled Ijâz-i Khusraw and in his above mentioned Qiran as-Sa’dayn. He states that paper was made with cotton, linen-cloth, silk (Qash, Harîr) and reed (Kilk). They were soaked in water, then pounded and turned into pulp with which the sheets of paper were made and dried. After that, they were cut out according to size with a sharp scissor and adds that this light paper was quite costly. As regards preparation of ink, the earliest recipes for hair dye making in India is found in the Navanitaka (Ca.2nd Cent. A.D.). From this Nityanath Siddha (1200 A.D.) derived his recipes for ink making as recorded in his Rasaratnâkara (1200 A.D.). The materials used for this were herbal substances or metallic ingredients. The ingredients used were lamp-black, charcoal, gum, burnt husk of almond, gold and silver powder and others.

Irrigation Technology

Generally, water was stored in tanks and wells, canals and channels were dug for irrigation in ancient India. Tank was used extensively in the South for irrigation and very large tanks were dug at this period. Among others, there was the Porumamilla tank of great dimension which bears an inscription dated 1291 A.D. There is a difference of opinion about the device for water raising used in Ancient India called Araghatta or Ghati-Yûntra which are Sanskrit words. On the basis of this, several scholars have argued that it was the same as the Persian wheel or sâqiyah and it was not...
introduced by the Turko-Afgans in India but these two words are nowhere clearly mentioned or explained in any early source.\textsuperscript{36} It was actually the simple noria a wheel carrying pots and buckets fixed on its rims which did not involve the technique of gearing. That it was noria and not exactly the Persian wheel has been confirmed by the extensive researches of Thorkild Schioler.\textsuperscript{37} The generally accepted view at present is that the Persian wheel was introduced by the Turko-Afghans in India in the 13th century. It was useful for raising the water from wells with the help of a chain of buckets in which the circular motion was obtained by animal power mainly bullocks using the technique of pin-drum gearing.

**Ship Building**

The technique employed for building of ships used in the Indian Ocean need not be discussed here. It would be sufficient to state that planks of the hull were sewn together by coir and generally not nailed.\textsuperscript{38} An Arab geographer Ibn Rustah (fl. ca. 290-300/903-913) records that planks of ships used by the Arabs in the Indian Ocean were sewn with cords of coconut and palm fibre and iron nails were not used till the beginning of the eighth century.\textsuperscript{39} The statement of the Arab geographer al-Mas\c{c}ûdî is quite clear on this point. He states "Now this kind of structure (stitching) is not used except in the Indian Ocean; for the ships the Mediterranean and those of the Arabs all have nails, whereas in ships of the Indian Ocean iron nails do not last because the sea-water corrodes the iron and the nails grow soft and weak in the sea and therefore the people on its shores have taken to threading cords of fibre instead and these are coated with grease and tar.\textsuperscript{40} "Ibn Ba\c{c}t\c{c}ûtah who arrived in India in September, 1333 have a detailed account of the technique used in the manufacture of Indian ships."\textsuperscript{41}


\textsuperscript{38} George Fadl\c{o} Hour\c{a}n\c{n}I, *Arab Seafaring in the Indian Ocean in Ancient and Early Medieval Times*, (Princeton 1951), pp. 91-94; Syed Sulaym\c{c}n Nad\c{v}I, *The Arab Navigation*, translated by Syed Sabahudd\c{d}n 'Abdu'r-Rah\c{m}\c{n}, (Lahore 1966), 1st ed., p.118.


\textsuperscript{40} George Fadl\c{o} Hour\c{a}n\c{n}I, *op. cit.*, p. 96 quoting the *Mur\c{u}j adh-Dhahab* of al-Mas\c{c}ûdî, (Paris ed.) Vol. I. p. 365.

Architecture

Magnificent stupas, temples and other sacred monuments both in the north and the south constructed during this period bear testimony to the highly developed building technology in India.

Without doubt, Indian builders were employed by the Muslim rulers for the construction of monuments but several expert masons and craftsmen were also brought from Persia and Afganistan introducing the Arabo-Persian architectural and decorative traditions. They had to build within the Islamic conceptual framework which strictly prohibited the representation of human figures in any building. They took recourse to the use of the beautiful lettering of the Qurânic verses and employment of leaves, flowers and buds drawn from the flora and from geometrical designs (arabesque). This brought about great changes in the technology and style of architecture in India. The imported style consisted of domes roofing, half-domed portals, minarets (minâr), pendentive and squinch arches introduced at the order of the Sultâns and nobles. In so far as building material is concerned stones and bricks were necessarily used and lime-mortar was employed perhaps for the first time in India by the Muslims. The Indian masons had to build false arches on trabeate principles.

Glass Technology

The more archaeological excavations ara carried out in different parts of the country, the more it is established that glass-making was widespread in ancient India. So many articles made of glass have been discovered, especially at Kopia in U.P., Taxila, Satavahana sites and others that it cannot be argued that all of them were foreign goods imported from outside. Most of them are beads, bangles, bowls, slags, small vessels, tiles, glass-flasks and others. But very little information is found concerning the technique of glass-making for example about raw materials, furnace and tools used. However, the raw materials used were soda, lime, alumina, excreta of mica, sand mixed with saline earth. Primitive open circular or square furnace was used and the temperature of heat was about 1000° centigrade.

42 'Irфан Ḥabīb, Symposium Lecture, p. 16.
43 'Irфан Ḥabīb, ibid., p. 17; James Fergusson, History of Eastern and Indian Architecture, (London 1910), Vol. II.
Military Technology

Two important equipments showing change or innovation or development in military technology of this period have to be mentioned first i.e. the flat iron stirrup and nailed horse shoe. It is generally asserted that stirrup because was in use in ancient India, but available evidence shows that the flat iron stirrup was introduced by Turkish conquerors in early 13th century. They had to use the iron stirrup because they laid emphasis on the cavalry and their tactic of battle was mounted shock combat. The nailed horse shoes were not used in India before the Turko-Afghan conquest although they were in use in Byzantium at the end of the 9th century A.D. Two statements in the Ādāb al-Harb of Fakhr Mudabbir suggest that the horse shoes were used in the beginning of the 13th century. The above work of Fakhr Mudabbir which was written around 1225 A.D. gives first-hand information about military technology specially about the manufacture of all kinds of arms and armour in which mostly iron and steel were used. In this work, there is one full chapter entitled “On the virtues and specialities of each weapon and the advantage of making use of it namely regarding the situation in which each one is useful. It runs into 34 closely printed pages of the present text.”

In modern terminology, the technique of manufacture of a sword will mean that the two ingots were covered with soft earth in order to prevent loss of carbon; both the ingots were made into one piece or forge-welded by hammering when iron/steel was made soft under a temperature of 1000°-1200° centigrade. The process of hardening of steel by quenching red hot metal into water or oil is employed even today. The first hammering was for preparing a blank while the second hammering was to give it the shape of a sword. The blunt sword was sharpened on an abrasive wheel and polished later on with oxymel.

Artillery and Gunpowder

The question arises whether artillery, gun and gun powder were used before Babar’s time (A.D. 1526) or not. This is a controversial issue. Some historians state that mechanical artillery was in use in India as early as the first quarter of the 13th century, others are of the view that it was used

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45 See ‘Irfān Ḥabīb, Presidential Address, p. 158 quoting Fakhr Mudabbir.
47 See Kitāb Ādāb al-Harb wasḥ-Shajā‘ah, Chapter XL pp. 249-273. Henceforth KAHWS.
48 Konasudaram near Hyderabad was well known for the manufacture of Wootz a kind of steel manufactured by mixing iron with carbonaceous matter.
in 1365/66 A.D. The *manjaniq* or *catapult* was used by the Muslims for hurling huge masses of stone towards the enemy or a fort. This worked by “three different principles of torsion, counterpoise and tension.” Naphta or Greek fire was used by the Turko-Afghan invaders but this also may mean gun-powder. Two historians express the view that artillery was used in India much before Babar in the reign of Sultán Iltutmish of Delhi.49 On the other hand, R.C. Majumder states that artillery was used in India in the 14th century.50

**Concluding Remarks**

One of the difficulties in writing this history is that the source materials especially the manuscripts in Sanskrit, Arabic and Persian have not been edited and published. Some of them are uncatalogued so that they are unknown even to those who do research work on the history of science in India. Therefore, it is evident that a thorough assessment of India’s contribution to scientific and technological development is not possible now. Thus it is not claimed that the history of science and technology in late ancient and early medieval India presented here is either thorough or complete.


50 See the Delhi Sultanate, *History and Culture of the Indian People*, (Bharatiyah Vidya Bhaban), Vol. VI, p. 460.