UNIT 17 SCIENCE, TECHNOLOGY AND ENVIRONMENT[1]

Structure

17.0 OBJECTIVES

After reading this Unit, you will learn about:

- the achievements that took place in the fields of mathematics, astronomy, chemistry and medical sciences in the early medieval period;
- the vigorous translation activity which marked the inter-borrowing between the Arab world and India;
- changes in technology; and
- the growing importance of the Arid Zone in the medieval period which impacted the ways sedentary societies and nomadic lands intersected.

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17.1 INTRODUCTION

Many achievements took place in the field of science and technology in the early medieval India. The beginning of Muslim rule in India changed the learning traditions. The indigenous learning traditions slowly eclipsed and its place was taken by the *Maktabs* and *Madrasas*. However texts continued to be composed indigenously. Texts in mathematics, astronomy, chemistry and medical sciences enlivened the learning atmosphere. Many Indian texts were translated into Arabic. In this Unit we will be looking at the achievements that were attained in the fields of mathematics, astronomy etc. We will also examine the changes in technology that the Muslim rule initiated.

How did the environment of South Asia map out in the medieval period will be a subject of study in the latter part of the Unit. South Asia became a part of the larger Arid Zone which encapsulated the regions of Central Asia, Middle East, North Africa. There was complementarity between the nomadic lifeways and sedentary agricultural societies in this Arid Zone. The dry regions were apt for the breeding of horses, oxen, sheep, goat and dromedaries. These were in high demand by the agriculturally rich societies. Some polities that emerged in the medieval period depended on the good horses from Arabia and the dromedaries were excellent means of transport. Stronger war-horses, dromedaries, and cattle tremendously enhanced the existing capacity for warfare, trade, and expansion of agriculture. By fully exploiting these resources, new warrior states emerged at the interface of jungle and arable land.

17.2 SCIENCE AND LEARNING IN THE EARLY MEDIEVAL PERIOD

With the coming of the Muslim rule in India, the indigenous classical learning traditions received a setback. In the Arab countries, the pattern of education was characterized by *Maktabs* and *Madrasas*. These institutions came to be established in India as well and royal patronage was extended to them. While locals who were specialists in various branches of learning were made to head these institutions, learned men from Arabia, Persia and Central Asia were also invited to take charge of the *Madrasas*. Muslim rulers reformed the curriculum of primary schools. Subjects like Arithmetic, Mensuration, Geometry, Astronomy, Accountability, Public Administration and Agriculture were taught as part of primary education. A new kind of learning emerged which was a synthesis between the traditional Indian scientific culture and the prevalent medieval approach to science. Large workshops called *karkhanas* were maintained to supply provision, stores and equipment to the royal households and government departments. The *karkhanas* were functioning not only as manufacturing agencies, but also as centres for technical and vocational training to people. Many artisans and craftsmen were trained by the *karkhanas* in different branches and later these people set up their own independent *karkhanas*.

17.2.1 Mathematics

As was the case in the earlier period, in this period too many achievements took place in the field of mathematics. The various works produced in Mathematics were *Ganitakaumudi*, *Bijaganitavatamsa* by Narsimha Daivajna; *Lilavati Karamdipika*, *Suddhantadipika*, *Lilavati Vyakhya* by Gangadhara of Gujarat. These works gave rules for trigonometrical terms such as sine, cosine, tangent and cotangent. Another text, *Tantrasamgraha*, by Nilakantha Somasutvan contained rules of trigonometrical functions. A commentary on *Lilavati* called *Buddhivilasini* by Ganesa Daivajna contained a number of illustrations. Krishna of the Valhalla family brought out *Navankura* on the *Bijaganit* of Bhaskara-II and elaboration of the rules of indeterminate equations of the first and second orders. Nilakantha Jyotirvida compiled *Tajik*, introducing a large number of Persian technical terms.

17.2.2 Influence on Arabic Sciences

The Arabs right from the time of Abbasid Caliphate translated a number of books on astronomy, mathematics and medicine from Sanskrit into Arabic. Indian scientific knowledge had a deep impact on Muslim scientists. The scientific cooperation between India and the Arabs initiated a fruitful phase in science and learning. The Arabs were not only interested in Greek learning but also looked up to Hindu sciences for meeting their growing interest in knowledge acquisition. Caliph al-Mansur (753-774 CE) initiated the translation of *Brahma-siddantha* into Arabic. He wanted the scientists to prepare a work based on this text which would serve as a foundation for computing the motions of the planets. This was done by Ibrahim al-Fazari and Yaqub Ibn Tariq in cooperation with Hindu *pundits* in 750 CE and the book was called *Al-Zij ala Sini al- Arab*, or *Sindhand al-Kabir*.

Through such translations Indian numerals were transmitted from India to Baghdad. Al-Fazari with the help of Hindu *pandits* translated Brahmagupta's *Khandakhadyaka* and called it by the Arabic name *Arkand*. Both of these works exercised profound influence on the development of astronomy in the Islamic world. The Arabs learned astronomy from Brahmagupta (7th century CE) earlier than Alexandrian scientist Ptolemy.

In mathematics too, Arabs learnt from Hindu systems. Arabic word for numbers is *Hindsah*, which means 'from India'. In fact what we call today Arabic numerals, were in fact Indian numbers. Arab scientists in Iraq, Mahummad Musa al-Khawrizmi (CE 9th century) used the new numbers to develop algebra. The English word algorithm is derived from his name.

Some of the noteworthy translated works were: works on logic and magic were translated by Ibn Nadim in the tenth century as *Kitab al Fihrist*; Ibn al-Muqaffa translated *Pancatantra* into Arabic as *Kalila wa Dimna*; parts of *Mahabharata* were rendered into Arabic by Ali Jabali, in CE 1026; 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 text *Susrata Samhita* was translated under Caliph Harun al-Rashid (786-809 CE).

Many Arabs travelled to India to procure medicines and get information on Indian customs. This knowledge was encapsulated in various accounts. Yaqoob Kindii's account (873 CE) is one such account. Ali Ibn Hyusayn Masudi (956 CE) 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 wrote on 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 was a merchant who visited India in 851 CE. He was appreciative of the Hindus' proficiency in medicine, astronomy and philosophy. Hindu astronomers took from the Muslims a number of technical terms, the Muslim calculation of longitudes and latitudes, and various other items of calendar, *Zij*.

Abu Rehan al-Biruni (d.1053) was the first scientist of Islam who made a deep study of Hindu sciences. He has been described as the founder of Indology. He became so proficient in Sanskrit that Hindu scholars gave him the title of *Vidya-sagar* (ocean of knowledge). In his *Tahqiq-al-Hind*, he described India's cultural, scientific, social and religious history. Due to the military incursions of Mahmud of Ghazna in India, Hindu scholars had moved to remote religious centers. 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 always mixed up with the silly notions of the crowd. He was the first to introduce the study of *Bhagavad Gita* to the Muslim world, and the first Muslim to study the *Puranas* and to translate Patanjali and *Samkhya* into Arabic. In considerable detail he outlined the principles of Hindu astronomy, geography, mathematics and medicine. Biruni translated a Sanskrit book *Batakal*, as *Batanjal*. From this work he extracted a great deal which he made use of in his magnum opus *Qanun Mas'udi*, a 1500 page work on mathematics, geometry and astronomy. All that the sages of India have said about numbers, ages, and eras (*tawarikh*), has been exactly given by Abu Rehan in his translation of the *Batakal* (Sathpathy, not dated).

17.2.3 Astronomy

During the early medieval period a host of astronomer scientists flourished in India. These were Govindasvamin, Sankaranarayana, Aryabhata II, Sripati, and Satananda. From their works one can know about the flourishing state of mathematics and astronomy in India during this period

Govindasvamin (CE 800-850) wrote a commentary on the *Mahabhaskanya*. He mastered the Aryabhatian system. He was at the court of King Ravivarman of Kerala. He also wrote *Govindakrti* which was an original work on astronomy and mathematics. His disciple Sankaranarayana's (825-900 CE) commentary on the *Laghubhaskariya* is also noteworthy. He was appointed as the chief astronomer at the court of Ravivarman of the Chera dynasty of Kerala. **Aryabhata II** (CE 950) wrote a work called *Mahasiddhanta*. It is a compendious work based largely on orthodox views, showing some originality in the treatment of indeterminate equations.

Sripati (CE 999) wrote works which included (i) *Dhikoti*, a Karana work on the *Aryabhatiya*, (ii) a fuller astronomical work entitled *Siddhanta Ukhara*, and (iii) a mathematical treatise, *Ganitatilaka*. He is credited with the discovery of the moon's second inequality. ***Satananda*** (eleventh century CE) hailed from Puri in Odisha and wrote a Karana work called *Bhasvati*, more or less in the style of the *Surya-siddhanta*. This work enjoyed great popularity among the astronomers and almanac-makers of the eastern region.

Despite a few original works, this period witnessed by and large the production of a number of commentaries and secondary works. It would, however, be unrealistic to characterize this period as one of commentaries only. This type of literature started appearing from the eighth or ninth century, if not earlier. The prolific writing by the commentators are the following:

- Utpala specialized on Varahmihira and wrote commentaries on his works;
- Prthudakasvamin (860 CE) wrote commentaries on Brahmagupta;
- Aryabhattan scholar Suryadeva Yajvan (1191-1250 CE) wrote commentaries on Manjula's *Laghumanasa*, Bhaskara I and Aryabhata;
- Suryadeva, an astrologer of repute, wrote commentaries on Varahmihira and Sripati's *Karmapaddhati*.

17.2.4 Astrolabe in India

The use of astrolabe (astronomical instrument) in India is credited to the Arabs. This instrument was brought to India by the Muslim astronomers. It was a Greek invention. Ptolemy was familiar with it and he wrote a tract on stereographic projection which was translated into Arabic in the tenth century and from Arabic into Latin in the twelfth. The Arab astronomers popularized the use of astrolabe from the ninth century CE. Thus al-Fazari (CE 800), one of the earliest Muslim astronomers, wrote a tract on the subject. Other notable early astronomers of Arab culture areas who wrote important tracts on the astrolabe include Abu'l-Ma'shar, Umar al-Balkhi, Ali ibn Isa of Baghdad, al Farghani (CE 830), al-Biruni (973-1048), al-Majriti of Cordova (CE 1000), al-Zarkali (CE 1029), and Nasir al Din al-Tusi (1201-74). Al-Biruni's two tracts on the instrument, 'Comprehensive Study on Possible Methods for the Construction of the Astrolabe' and 'The Book of Instructions in the Elements of the Art of Astrology', attained great popularity and are available in translations in European languages.

The astrolabe can help in the calculation of time during day and night, find positions of the sun and stars, solve problems of heights and distances, make other computations, and, above all, teach the elements of astronomy with its plates and various graduations.

17.2.5 Chemistry

Though Alchemy was known in the Vedic period, its practical application became popular during the Tantric phase. Various Tantric treatises dealt with the methods for the transmutation of base metals into gold. The *Rasaratnakara*, attributed to the famous Buddhist alchemist Nagarjuna, contains descriptions of alchemical processes and preparations of many mercurial compounds. It gives an account of many chemical processes like the extraction of zinc, mercury, and copper, and the preparation of crystalline red sulphide of mercury (*svarnasindura* or *makaradhvaja*). This medicament is still used in indigenous system of medicine.

The treatise also describes more than two dozen varieties of apparatuses (*yaniras*) for carrying out various physico-chemical processes like distillation, sublimation, extraction, calcinations, digestion, evaporation, filtration, fumigation, fusion, pulverization, heating by steam and by sand, and the preparation of many metallic compounds.

The *Rasarnava* or *Devishastra* (twelfth century), a *Tantra* of the Saiva cult dealing with alchemy and chemistry, gives a description of the colours imparted to flames by various metallic compounds like those of copper, tin, lead, and iron. A variety of minerals and ores, the extraction of copper from pyrites and zinc from calamine, the distillation of alum (possibly giving rise to sulphuric acid), and the purification of mercury by distillation are described in this Tantric text. The alchemical ideas and treatises of India spread to China and Tibet. The *Dhatuvada* (eighth-ninth century), a Tantric text in Sanskrit, found translated in the Tanjur division of Tibetan literature, gives an account of the deposition of copper on iron from a copper salt solution and the preparations of amalgams of copper and of white lead. The *Sarvekararasayana*, another Tantric text in Sanskrit of the same time explains the process of making cuprous sulphide. The preparation of antimony by heating a mixture of stibnite and iron is mentioned in the *Rasendracudamani* (thirteenth century). This shows that the process was known in India much earlier than its discovery in Europe by Basil Valentine (1604). The preparations of calomel and of oil of vitriol (sulphuric acid) from alum, the use of alum as a mordant for dyes, and the extraction of zinc from calamine are described in the *Rasaprakasa-sudhakara* (thirteenth century) (Satpathy, not dated).

The ideas of the alchemists about the possibility of transmuting base metals into gold gradually lost their charm because of repeated failure of experiments. But the numerous preparations of mercury, iron, copper, and other metals obtained in the process came to be used in medicine. As a result, the compilation of a number of medical treatises dealing with the use of metallic preparations were composed. One such work, the Buddhist treatise *Rasaratna-samuccaya*, contains a vast mass of the then existing chemical information but very little that is new and of intrinsic value. It talks about the treatment of mercury, minerals, metals, gems, liquefaction, incineration, construction of apparatuses, purification of metals, and extraction of essences (active principles). Unlike what happened in Europe, alchemy in India failed to develop into a rational, scientific chemistry. As a result, it gradually became extinct.

There is plenty of evidence on the application of chemical knowledge and processes in the medieval period, particularly relating to metallurgy and metal-working, gunpowder, salt peter, mineral acids, alum, paper, ink, soap, and cosmetics. Heavy guns and cannons made of copper, bronze, and brass were used by the Mughal emperors. Instances of working with wrought iron on a large scale by means of forging and hammering are provided by the following: the iron pillar at Dhar (fourteenth century); the pillar in Mount Abu (fourteenth century); the large iron beams at Konarak and in the temples of Puri (twelfth century); and the big iron guns and cannons of the Mughal period as found at Bijapur, Hyderabad, and Murshidabad. Records of the preparation of steel swords at various places in India arc found in the *Juktikalpataru* (eleventh century) and *Sarngadhara-padabali* (fourteenth century).

The tinning of copper vessels gained currency in India from the medieval period, possibly after the arrival of the Muslims. An alloy made of copper, lead, and tin, or of copper, lead, and zinc known as *bidery* (from Bider, a town in Andhra Pradesh), produced during this period, was used to make vases, basins, cups, etc. which were then inlaid with gold and silver. These products were made largely in Hyderabad, Bengal, and north-west India. Enamelling on gold and silver ornaments in different colours with metallic oxides mixed with soda-lead glass was known all over India.

Paper-making was introduced in India from China through Nepal in about CE1000 and became a flourishing industry during the Mughal and Peshwa periods. The raw materials used were mainly worn-out clothes, old tents, barks of certain shrubs and trees, and similar substances. These were beaten into a pulp in a lime-lined water reservoir and then made into paper sheets with the help of moulds. The preparation of cosmetics and perfumes was known from the sixth century CE. A detailed description of several aromatic ingredients for the preparation of cosmetics and perfumes, and the technical processes and recipes for the preparation of different perfumed products are given in the *Gandhasara*, which was composed around CE 1000 on the basis of earlier texts dating from CE 500 to 1000.

Thus Chemistry in India was developed empirically in India. It occupied itself, more or less, with the collection of accidentally discovered facts associated with various practical arts like ceramics, metallurgy, metal working, and medicinal preparations without any recognition of the chemical principles or nature of the chemical changes involved in their pursuit. The result was that the thoughts and ideas could not germinate into scientific laws and theories based on experimental observations and verifications (Satpathy, not dated). Likewise, the mechanical skill displayed in the pursuit of practical arts could not develop into technology in the absence of guidance and suggestions from scientific knowledge. Chemistry was dominated more by seeing and believing than by thinking and knowing. After the age of Nagarjuna, Indian treatises provide very little new chemical information, though quite a large number of commentaries and compilations were composed till the end of the sixteenth century. Nevertheless, India's achievements in the use of minerals, metallurgical techniques, processing of chemicals of everyday use, extraction of metals from their ores, and craftsmanship in the manufacture of certain metal products, which required mastery of some chemical processes, were quite remarkable. Some of the technical skills exhibited by ancient Indian chemists and metallurgists were indeed noteworthy.

17.2.6 Medical Science

It was during the medieval period that Indian medicinal science dominated earlier by Ayurveda, witnessed several changes. New medical practices such as Unani were brought in India by the Arabs. The Arabian influence brought changes in medical practice, primacy and pharmacology. 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 and 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 defined medicine, described the 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.

Check Your Progress Exercise 1

1) What were the achievements in the fields of mathematics and astronomy in the early medieval period?

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2) How did various translations of Indian texts into Arabic influence Arabic sciences?

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3) What is an Astrolabe? Describe its significance in astronomy.

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17.3 TECHNOLOGY

There has never been any human settlement which did not use some kind of technique or craft for its survival. In fact, the history of technology is no less important than political or economic studies. Technology is an inseparable part of the material culture of a society One thing that is important to note is that by and large the tools, devices and implements were made of wood and earth, while iron was employed only when most necessary. Ropes, leather and bamboo, too, were used when the need arose. That is why they were inexpensive.

Let us look at some technological features of the early medieval period.

17.3.1 Irrigation Technology

Early Indian agriculture depended on irrigation and natural rain. A lot of primary source of information as well as secondary data inform us a great deal about the irrigation technology in early medieval India. Irrigation may broadly be categorized into two i.e. natural irrigation and artificial irrigation. Natural irrigation is through monsoon rains, which feed river bodies and become a good source of irrigation.

Even otherwise, sprinkling of water over agricultural fields during rain is a great irrigational tool. Artificial irrigation is through human efforts like digging up of wells, canals, hydraulic engineering efforts etc. Digging of wells and tanks has been propagated in India as a charitable work of merit. Due to unpredictable natural means of irrigation, agricultural expansion and the consequent evolution of human civilization has been critically related to the availability of sufficient hydraulic resources. Hence, it is not surprising that during the medieval period of Indian history maximum attention was paid towards the adequate usage of hydraulic devices.

17.3.2 Textual Reference

Aparajitapriccha, a twelfth century work, seems to be the earliest text to devote a full chapter to the discussion of step wells, wells, ponds etc. The early medieval text *Brihatkalpasutrabhashya* shows a remarkable awareness of the variability of hydraulic devices and hence we find a multiplicity of storage systems and irrigation mechanisms in different regions. The region of Lata (southern Gujarat) depended entirely on rain, Sindhu (lower Indus valley and the Indus delta) relied on rivers, the Dravida country (far south India) was the land of reservoirs, and in Uttarapatha (generally north India) wells figured most prominently. Since the failure of rains was a common occurrence, dependence on artificial means of irrigation like wells, tanks and storage reservoirs was acute. Even al-beruni attests to the uneven rainfall patterns in India.

In Kashmir, the most outstanding irrigational project entailing inventive engineering skill belongs to king Avantivarman of Kashmir. His minister Suyya dammed the river Vitasta (Jhelum) to save Kashmir from the destructive floods of the Mahapadma Lake. Suyya deepened the bed of the Vitasta at its two ends, cleaned the river bed at its bottom after constructing a temporary stone dam at all threatened points and built protective stone embankments for seven *yojanas* along the river bank. Thus, he was able to shift the junction of the Vitasta and the Sindhu from the old to its existing position. On the land raised from water he founded many villages protected by circular dykes and constructed extensive projects. His works generated widespread prosperity, such that it was commented upon by Kalhana. Another king of Kashmir, Lalitaditya Muktapida reclaimed many hitherto water-logged areas by making an arrangement at Laksadhara for conducting the water of Vitasta and by constructing a series of water-wheels, distributing it to various villages. Besides, king Harsha is credited with the excavation of the big Pampa Lake, identified by Stein with the modern Pampasar.

Rajasthan received less rainfall than Gujarat. Here inscriptions from the 11th century onwards refer to the employment of irrigation technology which made possible the production of diverse crops in this arid zone. The Chalukyas of Gujarat also initiated many irrigational works. It seems that even the first king of the dynasty, Mularaja I paid due attention to the system of irrigation. Sridhara in his *prashasti* claims that one of his ancestors was appointed by Mularaja I (CE 941-996) to dig *vapis*, wells and tanks. A long list of tanks, *vapis*, reservoirs, lakes, wells were constructed by the kings and queens of Rajasthan. Some of these exhibit their great technological skill. For example Jayasimha Siddharja (CE 1099-1144) is credited with the construction of a large number of tanks and *vapis*. He constructed a large reservoir called Sahasralinga Lake at his capital. Archaeology confirms the high engineering skill employed in this irrigational project. The lake received water from the river Saraswati with which it was connected by a 300 ft. long channel. Excavations have brought to light the stone sluices through which water was conducted to the lake. Further, during the reign of Bhimadeva II (CE 1178-1242) an attempt was made to extend irrigational facilities to north-west Saurashtra and Kutch. Not only kings but also feudal lords and merchants showed great concern towards constructing vapis and providing other irrigational facilities. In fact construction of water devices in arid zones was deemed as a meritorious act.

However, there are also some instances of large scale or supra-local irrigation projects. *Lekhapaddhati* mentions the *varigriha karana* (official in charge of irrigation). It suggests that there was a department of irrigation and state took interest in irrigation works (satpathy, not dated).

As regards the technical devices used to raise water from wells there is a lot of evidence available. *Desinamamala* refers to such terms as *agatti*, *unkaddi* and *dhenka* which mean a contrivance for drawing water in which a horizontal beam with a bucket hung on the one end functioning as a see saw on a vertical post. This contrivance was operated probably by foot and could be used on wells and tanks where water was not deep. Bana refers to the irrigation of paddy fields through *ghati*. Merutunga also notices the use of water-wheels for irrigating the fields. By describing the rotation of water-wheel, he states-the empty buckets became full and the full buckets empty. (Satpathy, not dated) Inscriptions of southern Rajasthan especially from the regions of Jodhpur, Udaipur, Banswara, Sanchor and Sirohi repeatedly refer to irrigation with the help of *arahatta* or *araghatta* and *dhimada* or *dhiku*. The technical nature of *araghatta*, generally translated as a Persian wheel, is a matter of controversy. The essential part of the *araghatta* was the *ghatiyantra* or the device with pitchers, usually mounted on the wheel, but not attached to its rim. The *ghatiyantra* as an irrigational device is therefore often held as a pot-garland. The *Upamitibhavaprapanchakatha* of Siddharshi (CE 906) presents the most elaborate account of the device. The *araghatta*, according to the text, seems to have drawn water from a reservoir which in turn received its water from irrigation well. The text highlights the spokes (*arakas*) of wheel which was a revolving apparatus though it does not refer to any gearing mechanism enabling the conversion of the horizontal rotary motion into a vertical rotary motion. The latter feature which became visible from the fourteenth century onwards, represented the typical Persian wheel or the *saqia*. The prevalence of *araghatta* as a hydraulic machine is best demonstrated by an eleventh century panel from Mandsor (Pali district, Rajasthan) (Satpathy, not dated).

17.3.3 South India

One may recall here once again the recognition of the regional variations in the hydraulic resources and projects in the vast subcontinent in the early medieval text, *Brhatkalpabhasyasutra*, the text in question impressed upon the importance of tanks in the Dravida country, that is, the far south India, lying to the south of the river Krishna. The earliest Tamil poetry, the *Sangam* anthology, informs us of the five ecological divisions in ancient *Tamilakam*. These were *neidal* (agricultural tract), *marudam* (coastal area), *kurinji* (forested mountainous area), *mullai* (pastoral zone), and *palai* (dry and arid tract). Until the fifth century CE settlements in *Tamilakam* were mostly situated in the coastal and agricultural tracts. It is only during the post-600 CE period that permanent agrarian settlements spread outside the *neidal* and the *marudam* eco-zones. This became largely possible with the expansion of agriculture by issuing a large number of land grants. The expansion of agriculture is inseparably intertwined with the enlargement of the irrigated area. As the far south does not possess many rivers of perennial nature, the spread of irrigation agriculture in that region largely depended on tank irrigation. Though this was, in many cases, an initiative of the village community, there are known instances of support for tank irrigation at the rulers' level. A few illustrations on this point will be in order. The Pallavas and the Cholas are particularly noted for excavating tanks of impressive size. Royal inscriptions describing the construction of these tanks inform us about the sluices which were meant for regulating and distributing the water from the tanks to cultivated fields. The Tiryaneri tank had 23 sluices, while the Viraneri tank had as many as 74 sluices. Several sluices figure in the description of the Cholaganga tank in the Tiruvalangadu copper plate of Rajendra Chola. These channels, according to the inscriptions, were connected to irrigation channels. These sluices were dressed in granite slabs. The existence of many sluices, possibly of an impressive size, in the tanks, speaks of the large size of the tanks themselves and the substantial area irrigated by them (Satpathy, not dated).

17.4 ENVIRONMENT

One encounters, broadly speaking two different ways of life in the Indian subcontinent: the one predominantly pastoral-nomadic, the other mainly sedentary-agrarian. The expansion of the sedentary-agrarian frontier accelerated in the medieval period with the increasing practise of grants of land in hitherto unchartered territory. The brahmana donees under various polities helped the peasants to bring wasteland under cultivation and with artificial means of irrigation, they ensured agrarian surplus and prosperity in the countryside. However juxtaposed with these agrarian swathes of land, the arid landscapes too were present with their own dynamics. They were a witness to numerous cattle fights and skirmishes over pastures as many hero-stones in the Deccan and south India indicate. Bringing to mind the apparent bifurcation between the two realms: the settlement or *janapada* or the forest or *aranya*, in the early period, the complementarity between the riverine wet agricultural regions and arid landscapes similarly point to close interaction and symbiosis.

Presented below are some observations, based on the work done by Jos Gommens on how the dynamic and fluid environments of South Asia within the larger context of Central Asia, Africa and the Middle East articulated its spatial and temporal dimensions in the pre-modern era.

17.4.1 Medieval South Asia

Much of the Indian subcontinent in the medieval period and even earlier was characterised by large, sometimes, uninterrupted expanse of wet agricultural lands. Wastelands were brought under the plough and forests were cleared for cultivation.

The fertile river valleys of the Ganges, Godavari, Krishna generated surplus which laid the foundation for the emergence of states. This was an exclusively sedentary domain and the incursions of nomads of Central Asia and the Middle East were only a few instances. Such inroads underlined the clash between the nomadic frontier and the agricultural society. Despite being predominantly a sedentary agricultural economy, the Indian subcontinent was also home to nomadic tribes, some of which lived on the margins of the settled society and others who were more closely integrated with the sedentary village life.

Gommans maintains that from the medieval period, the Indian subcontinent became a part of the larger Arid Zone which stretched from drier zones of Eurasia, extending from the Atlantic coast of northern Africa to the eastern and southern extremes of the Indian subcontinent. In this vast terrain the predominantly nomadic lifeways of Eurasia and the Middle East slowly transform into the more sedentary agricultural moist environment of the Indian subcontinent. Arabain, Persian and Turkish nomadic elements in the form of horse-warriors from Khurasan and Transoxania entered the Indian subcontinent from the northwest frontier region.

Most of the early medieval polities centred in the Kaveri delta in the south and the Ganges in the north benefitted from the fertile river valleys. However, these rich agrarian lands did not form an unbroken chain through the whole of the subcontinent, The arid regions of Sindh and Rajasthan in the west, with an extension southwards across the Thar desert, the dry western Deccan plateau extending into the Rayalseema region located in the midst of the Tungabhadra and Krishna and the Mysore plateau in the southwest formed a part of the Arid Zone which as mentioned earlier interlinked Central Asia, the Middle East with the Indian subcontinent.

The Arid Zone, due to the growth of nutritious grasses but uncertain subsistence possibilities, was just right for stock breeding. The people here bred horses, oxen and dromedaries. Apart from grasses and forest scrub, the stalk and leaf of dry millet, one of the major crops of the Arid Zone, served as excellent supplementary fodder. Hence, stockbreeding in South Asia took root in the scarcity ridden drier regions.

It was in the medieval period that the Arid Zone reached its full maturity as the conductor of people, animals, goods and ideas. "From this time onwards, South Asia witnessed breathtaking changes that involved large-scale migration of mostly Muslim and Telugu warrior groups and the emergence of previously marginal tribal groups, such as the Yadavas in the Deccan and the Kallars and Maravars in southeast India. Migrating warriors, pastoralists, and cultivators carried their various divinities with them into new territories, thereby helping to build complex interregional networks of devotion and pilgrimage" (Gommans, 2012). This was the time when temples emerged as major redistributive centres across the landscape. Extremely mobile traders and sectarian priests helped in the integration of far flung settlements into a closely knit economy and society.

The spread of Islam enabled the people of the Arid Zone to extend their control over sedentary societies. The scale and pace of human activities increased. Not only that but the animals being raised in the Arid Zone like the sheep, goat, oxen, horses and camels also came to play an important role in the developments taking place in this region.

17.4.2 Horses, Oxen and Dromedaries

From the second millennium CE, the role of horses, dromedaries and oxen greatly increased. The best war horses originated from Central Asia and Iran. The lack of nutritious fodder grasses in South Asia limited the possibilities for horse breeding. During this time the importance of war horses multiplied many fold. The successful campaigns of Muslim armies of Ghaznavids, Ghorids, and Khalijs proved the might of mobile warfare, especially of well-trained archers on horseback. In the initial period most of the horse warriors were from Iran and Central Asia. Their military and equine expertise helped them in being hired by the Indian armies. These were called as Muslims or Turks (*Turushka*). Mounted on horses they came to be known as *Asvapatis* (lords of horses) or *irauttars* (horsemen). The cavalry techniques of the Muslims were copied by the Rajputs, Marathas and the Nayakas and accounted for their military success. "At about this time, horses emerged in religious cults of warrior heroes, such as Khandhoba or Lord Aiyanar, and in other martial traditions of mobile pastoralists... . All this suggests the enormous impact of the mounted warrior on both politics and ritual in South Asia" (Gommans, 2012).

With the invention of the north Arabian saddle and the integration of the camel breeding nomads in the settled society, the dromedary became one of the most important means of transport in the Middle East. Certain developments marked this phase. A new hybrid called *bhuktis* were bred which were more resistant to the cold and harsh conditions and linked the Central Asian region with the Middle East. Besides this the one humped camel was developed as a new breed well adapted to the colder climate of Iran and southern Central Asia. In South Asia, one humped camel became quite numerous from the 1000 CE onwards.

While good quality horses and dromedaries were available only outside South Asia, especially along the Steppes and deserts of Central Asia and the Middle East, the Ox was largely South Asian. The Oxen were bred in the drier climates of South Asia. While some of the breeds like those from Gujarat and Mysore were exemplary, most were mixed breeds. One category of cattle was the village one which was mostly unattended and grazed freely at local commons of wasteland and fallow lands. Though this constituted the bulk of the cattle and was the main source of dairy products, it was ill suited to the needs of agriculture and long distance transport. The other kind was that which was bred by professional pastoralists, both nomadic and sedentary. Selective breeding and access to open pastures led to the breeding of a select and higher quality of cattle. This breed of cattle were in high demand by the agriculturalists and travelling traders.

The ox played an important role in the expansion of agriculture throughout the Arid Zone from the twelfth century onwards. It also provided manure, raised the water from the village wells, trod out the cut crop on the threshing floor, and transported the produce to the local market. The black cotton soils of Karnataka and Deccan could not be ploughed by the ill-bred oxen. Only the good breed of oxen bred by professional pastoralists could help in the reclamation of land for agricultural purposes. Thus the spread of oxen, dromedaries and war horses led to the increase in the potential for agriculture, transport and warfare.

Burton Stein maintains that early medieval states in the Indian subcontinent were located in interstitial political zones which underlined the growing importance of the dry zones of the uplands in state formation. From the twelfth century, following the spread of war-horses, dromedaries and oxen, the inner frontier of the Arid Zone through the agency of merchants, pastoralists and warriors not only brought its surrounding territories of South Asia together but also made them part of the wider habitats of Turko-Persia.

The Delhi frontier is an example of the historical significance of the Arid Zone. The continued centrality of Delhi as the *dar al-sultanat* of Hindustan hinged on its own peripheral location at the junction of the unsettled areas to its west and the more stable territories to its east. The dilemma was that the rule of the Delhi rulers belonged to the settled order of sedentary society, through their actual power derived from the arid wastes (Gommans, 2012).

Check Your Progress Exercise 2

1) What were the different kinds of hydraulic devices in use in the early medieval Period?

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2) Describe the characteristics of the Arid Zone as observed by Jo Gommans.

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17.5 SUMMARY

In this Unit you learnt about the achievements that took place in the fields of mathematics, astronomy, medicine, chemistry etc. Most of the indigenous works were commentaries, however. New types of learning institutions emerged. The Arabs brought with them their own learning traditions. As a result of the fusion between Arabic learning traditions and Indic, a synthesis between the two enlivened the learning atmosphere. A large number of Indian texts were translated into Arabic. In the field of technology, many advanced in agriculture were marked by the construction of water devices and tanks with many sluices. The whole of South Asia became a part of the Arid Zone which extended from Central Asia, the Middle East to the extremities of South Asia. In this zone broadly speaking nomadic frontiers clashed with agricultural zones for dominance. However there was complementarity between the two also. The animals being bred in the dry lands were used by the agricultural societies and facilitated trade, agriculture and transport.

17.6 KEY WORDS

Dromedary : an Arabian camel, especially one of a light and swift breed trained for riding or racing.

Arid : Hot and dry regions where rainfall is scarce.

Madrasa : A college for Islamic instruction.

Maktab : an Islamic elementary school.

17.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1) See Sub-sections 17.2.1 and 17.2.3

2) See Sub-section 17.2.2

3) See Sub-section 17.2.4

Check Your Progress Exercise 2

1) See Sub-section 17.3.1,17.3.2 and 17.3.3

2) See Sub-section 17.4.1 and 17.4.2

17.8 SUGGESTED READINGS

Gommans, Jos (2012). The Silent Frontier of South Asia, c. 1100-1800 CE. In Rangarajan, Mahesh and Sivaramakrishnan, K, *India's Environmental History. From Anceint Times to the Colonial Period. A Reader*. Ranikhet: Permanent Black

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