UNIT 23 TECHNOLOGY AND ECONOMY*

Structure

23.1 INTRODUCTION

In the present Unit our concern will largely be with technology as had more or less direct economic effects or implications, that is, with the technology of the process of production, of transport and of war. On the purely theoretical aspects of technological design (for example, the technological devices described on paper by theorists or experimenters) and sciences such as medicine and astronomy we will have little here.

Now, it would be foolish, even if detailed evidence has not been studied, to deny that India during the seventeenth century had been definitely surpassed by Western Europe, which had fully entered what Joseph Needham felicitously calls the palaeotechnic age. Yet the moment one seeks to go beyond this bald statement, detailed evidence becomes a clear requisite. If Europe was advancing at a tempestuous pace, it does not follow that other countries were not advancing at all in relation to their own past attainments, if not in relation to Europe. If one asks why there was no urge to follow Europe on the part of India, the question calls for even closer scrutiny, for we must separately define the areas where imitation did not occur, or, if it did occur, was only partially successful. Furthermore, there would be the possibility that in a few areas Indian technology might still have had something to give to the West. Clearly, then, before climate, caste, despotism, anarchy, inertia, etc., are called upon individually or severally to explain India's lag in technological progress, these essential details must be worked out.

23.2 AGRICULTURE

It is difficult to understand today that Indian agriculture, with the extensive introduction of modern technology was in quite a different position in the earlier period. In the main

* Present Unit is an adapted version of Prof. Irfan Habib's articles on technology in Medieval India. We are grateful to Prof. Irfan Habib for allowing us to use his article in the form of the present Unit. All the footnotes are intentionally removed (unless otherwise essential).

the agricultural technology of Mughal India was determined to by the prevalence of peasant farming. The peasant undertook production with an extraordinary combination of superstition with knowledge, rude equipment with ingenious devices. The result was quite creditable to him. Henry M. Elliot, the great historian, who in 1844, had this to say on the Indian technique of agriculture:

> Of the operations of this simple (Indian) plough, Dr. Tennant…observes, ('Indian Recreations', Vol. II, p. 78): 'Only a few scratches are susceptible here and there, more resembling the digging of a mole than the work of a plough;' yet this prejudiced and superficial observer remarks in another place that the average produce of the Province of Allahabad is fifty-six bushels of wheat to the English acre: as if these 'scratches and diggings of a mole' could by any possibility produce double the average of the scientific cultivators of England. He had also forgotten to remark that the drill, which has only within the last century been introduced into English field husbandry, and has even yet in the northern countries to combat many native prejudices, has been in use in India from time immemorial. If he had only reflected on this single fact (leaving out of consideration the universal practice of rotation and complete expulsion of cornweeds), he would have saved the poor Hindus from much of the reproach which has been so lavishly heaped upon them by (James) Mill and his other blind followers.

To this short and effective catalogue of Indian agricultural practices one may add dibbling, that is the dropping of seeds into holes driven into the ground by sticks, a method mentioned in connection with cotton cultivation by Amanullah Husaini in his *Ganj-i Bad-awurd*, an early seventeenth century tract on agriculture. In the peasant's equipment, the use of iron was minimal and wood predominated. There is little doubt that the efficiency of the wooden implements was greatly affected by the minimal use, or even virtual absence of iron. All of them would have functioned better with the use of iron screws, hinges, clasps, etc. The lack of use of iron was, however, only because of costs. Although India produced good iron, its price at about 1595 is estimated, in terms of wheat, to have been three times what it was in 1914. This was sufficient to inhibit its use by a peasantry hard-pressed for resources, and, perhaps, often unable to maintain a blacksmith, in addition to the village carpenter.

Introduction of New Crops

The Indian peasant cultivated a very large number of crops for both the harvesting seasons. Few countries (excluding, perhaps China) could have compared with Mughal India in the great multiplicity of and variety of products of the soil. A significant point to note is the capacity of Indian agriculture to accept new crops, which it displayed strikingly during the seventeenth century. The extension of the cultivation of tobacco, received from the New World, was rapid; its cultivation began on the western coast soon after 1600, and the crop was being cultivated in almost every part of the Mughal Empire by about 1650. The other crop to be acclimatized was maize. It was long believed that maize was introduced in India mainly during the nineteenth century. But P.K. Gode has established the existence of maize cultivation in seventeenth century Maharashtra, and under its usual name *makka* it was listed among the crops assessed for revenue as early as 1664 in Eastern Rajasthan.

Horticulture

The seventeenth century was also a period of considerable innovation in horticultural practices. It was not only that certain fruits, among which the pineapple was pre-eminent, were introduced from the Western Hemisphere. There was an extensive application of grafting with important results for the yield and quality of certain fruits. Grafting is an old practice, known in classical antiquity and in ancient India. It was mentioned as the method of propagation of various fruits in medieval Persian tracts on horticulture and agriculture. Yet one should recognize that grafting is not a single practice but comprehends a number of different methods, namely, tongue grafting, side, crown, deft, saddle and root grafting, and veneering, inarching and inlaying. It is therefore, not ruled out that what was diffused in the seventeenth century was not simply the principle of grafting, but specifically new methods of giving effect to that principle.

For the coming of these new methods there were two distinct channels: the Mughal court and nobility, influenced by the Persian and Central Asian horticultural traditions, and the Portuguese, with their roots in European horticulture. Jahangir tells us that the sweet cherry was not found in Kashmir before its conquest by Akbar; his offical Ali Quli Afshar brought it from Kabul and propagated it by means of grafting. By the same means he increased the cultivation of apricots; and, while the Kashmir mulberry did not yield an edible fruit, this had been obtained from grafted mulberries. Sadiq Khan, after referring to this earlier experiment, adds that during the reign of Shahjahan the practice of grafting became very widespread; and as a result of its application, the quality of the three oranges, namely, the *sangtara, kaunla*, and *narangi*, which were previously mere varieties of lemons, was now greatly improved.

It is singular that the grafting of mango is not mentioned in Mughal-period texts. It is true that Amanullah Husaini, writing presumably in Jahangir's time, says that the same practices that are prescribed for the peach, etc., are also possible, though not necessary, in the case of the mango; and grafting is elsewhere prescribed for the peach. But the very words used show that grafted mangoes were not then much prized. A further passage in some manuscripts describing the method of mango-grafting in and around Murshidabad is quite obviously an eighteenth-century interpolation. In the chronicler's account of Muqarrab Khan's great mango orchard at Kairana (district Muzaffarnagar, Uttar Pradesh), boasting of varieties from all parts of the country, and visited by Jahangir in 1619, only simple propagation by seeds is mentioned. It is probable that it was only when inarching was applied that grafting proved successful. The famous grafted variety, Alfonso, developed by the Portuguese on the western coast, is mentioned by Niccolao Manucci, about 1700; and it is certain that this is not the earliest reference. It would thus appear that at least one grafted variety of the mango began to be cultivated during the seventeenth century, the impulse for this coming from the Portuguese.

Sericulture

India has not been deficient in silk-producing insects: The tasar and eri silks still flourish. But the true silk, produced by the worm feeding on the mulberry worm, was not cultivated in ancient India. The earliest reference to sericulture proper in India is found in Ma Huan's account of Bengal (1432). The famous Moroccan traveller Ibn Battuta, writing of Bengal in some detail a hundred years earlier, has no reference to silk, so that the introduction of mulberry silk in Bengal can be assigned with some certainty to the intervening period. It is not certain whether Bengal received true silk directly from China, the home of that fibre or from Iran, where sericulture particularly flourished during the 13^{th} and 14^{th} centuries under Mongol patronage. After Ma Huan the production of true silk in Bengal is continuously attested by subsequent authorities, down to the 17^{th} century when Bengal emerged as one of the great silk exporting regions of the world. Since sericulture was a peasant-industry, its development in Bengal brought the peasant increasingly under the influence of long distance and even international market.

23.3 IRRIGATION TECHNOLOGY

Large scale irrigation in sixteenth and seventeenth century India was of two kinds: (1) tanks created by embankments, from which canals of relatively short lengths would run to carry overflow for agricultural purposes; and 2) long canals taking off from undammed rivers and traversing fairly long course. Those of the first kind were mainly found in the Deccan and Central India, and followed the lines of traditional Indian construction, being largely the work of Hindu rulers and chiefs; the latter were largely found in northern India, and exhibit Central Asian and Iranian influences; they were entirely laid out by kings and nobles. The description of the Madkal Lake in Dharwar district created by the Vijaynagar emperors in the fifteenth or sixteenth century shows the massiveness of construction that could be attempted in building irrigation works of the first kind. On the other hand, some of the canals excavated by the Mughal rulers were very long and impressive works. Shahjahan's Nahr-i Faiz, rejoining the Yamuna at Delhi, was over 150 miles long; his Shah nahr similarly serving Lahore, a little less than 100 miles. Both these canals took off from the parent rivers close to the hills where the river-channel was firmly fixed; none of the canals drew its water with the aid of a dam at its head, so that those which took off in the plains could not have been sure of continuous supply of water. Further, the Mughal canals in the plains tended to flow like rivers and drains, below the level of the surrounding country. Any water drawn from them or their distributaries had therefore to be lifted out, and not obtained by simply opening the sluices. Part of the objective of the Mughal emperors and their nobles in building canals was to bring water to their orchards and gardens.

Persian Wheel

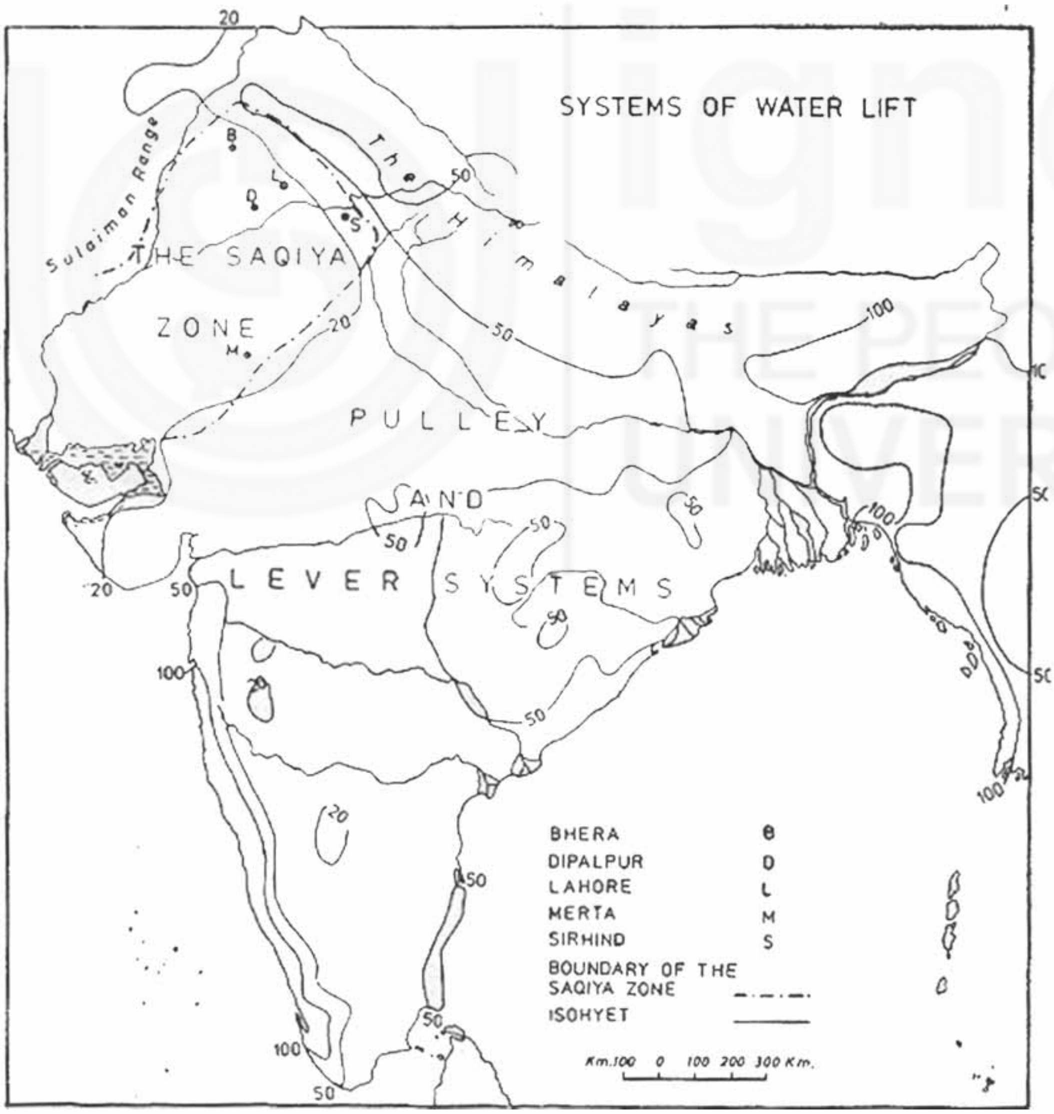
Another and far more important addition was the Persian wheel. This device, which in the form of a wooden machine, represented a notable example of pin-drum gearing, was probably an importation of the thirteenth or fourteenth century. By the sixteenth century, when it was enthusiastically described by Babur, it had become the peasant's principal means of water-lift in the Indus and trans-Jamuna regions. To these limits it was to remain confined until the latter part of the nineteenth century, when with the coming of the metallic Persian wheel, the device spread to many other parts of the country. In the Persian wheel, while the chain makes it possible to raise water from some depth, the gearing mechanism enables animal power to be employed and the speed of the movement of the chain properly controlled. The bucket chain was of double rope to which were tied wooden strips carrying earthen pots to contain and discharge water. The gearing mechanism was entirely of wood, the animals turning a horizontal pin-drum, or lantern wheel carrying the chain at the top of the well. Its first detailed description is given by Babur (d. 1526) in his Memoirs.

In modern works on ancient India the use of the 'the Persian wheel' is often assumed to be of very early date, though A.L. Basham does express some reservation about it. The references in the literary sources are, however, vague that although they establish that a water-raising device known as *araghatt* or *ghati-yantra* was in use at least since the time of Christ, and that this involved successive discharge of water from earthen pots upon the motion of the wheel. The chain of pots arrived by the sixth century, when it is mentioned in an inscription and, in the next, by Bana. But there is no evidence of gearing: its absence may be seen in the Mandaur freezes (12th century).

In view of all this, the case for assigning the introduction of the geared Persian wheel in India to the period of the Turkish conquests and the centuries immediately following

(13th and 14th centuries) would seem unassailable. We are, therefore, well entitled to speculate on the economic consequences that flowed from its introduction and generalization in the Indus region.

Abul Fazl, writing *c.* 1595, says that the Punjab was unrivalled in the prosperity of its agriculture most of which was based upon irrigation from wells. A hundred years later Sujan Rai Bhandari says of the Punjab that most of its cultivation depended on the rains. Inundations or canals were, therefore, not significant factors in its agriculture, contrary to what one would think of as natural today. This would mean that any improvement in the mechanism of raising water from wells, like the Persian wheel, was bound to have considerable effect on the extension or development of cultivation in the Punjab. The presumption that the Persian wheel did have such an effect also makes intelligible a tradition preserved by Sujan Rai. According to this, Punjab had been a desolate region, with settlements in a few pockets, and these were also harried by Mongol raiders (13th and 14th centuries). But during the 15th century a large-scale reclamation took place, its progress in the Upper Bari Doab being especially described, possibly because the author himself belonged to the area. Sujan Rai did not, of course, attribute this development to the Persian wheel, but we can now perhaps quite plausibly see it as a major factor behind this phenomenon.



***Cf.* Irfan Habib, 'Technology and Barriers to Social Change in Mughal India', *Indian Historical review*, Vol. V, Nos.1-2, 1978-79, p.155.**

23.4 TEXTILE TECHNOLOGY

There is evidence that the two important instruments for ginning and cleaning cotton, namely, the wooden worm-worked roller or gin (*charkhi*) and the bow-scutch (*kaman*) had come into use much before the Mughal period. At Ajanta Cave I (6th century AD) there is a panel of frescoes showing women at work, one of whom is working on the *charkhi*, though the first textual reference to it is only in an eighteenth century lexicon, *Bahar-i Ajam* (the cotton-cleaner's wheel/roller). There is a description of its use (where it is called *charkhi*) in a Persian report from Bengal of a later date but within the same century (1788-96). For the bow-string device the references are more definite and continuous, going back to the Persian poet Akhsikati (eleventh century, d. *c*. 1183), and there are possible references to it in two Sanskrit dictionaries, *Vaijayanti* and *Abhidhanachintamani* of about the same time. Yet even by the seventeenth century, the bow-string was not the sole device for carding cotton in India; the older method of beating it (with sticks) was mentioned side by side with it in an English commercial report from Gujarat, of 1666. No mechanical change in these devices can be traced except for the fact that at some unknown period, in a small locality (Pakhli, in Hazara District, between the Indus and the Jhelum), the *charkhi*, locally called *belna*, came to be driven by water-power. The innovation being purely local had no particular economic significance, but the use of water-power in the same locality for driving two other important mechanical devices will call for notice later on.

Women ginning with processing of cotton. Detail from Ajanta Fresco, Cave I, *c.* 600 AD. *Cf.* S.P. Verma, *India at Work in Sculpture and Painting*, Aligarh, 1994

Spinning Wheel

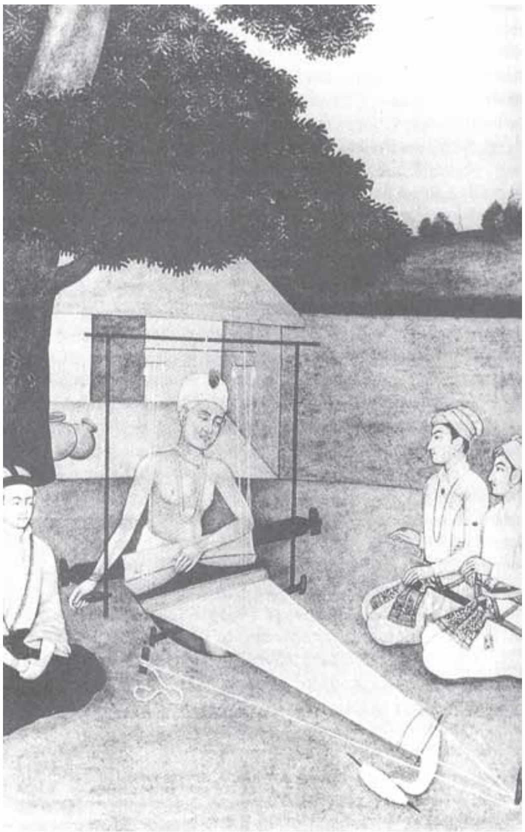
The first textual reference to the spinning wheel is found in the metrical history of the Delhi Sultanate by Isami, who wrote his work in 1350. It was an ancient Chinese invention, which seems to have made its way slowly to India. The first illustration of the spinning wheel occurs in a Persian dictionary written in 1469 in Malwa. India, however, never came to know either the multi-spindle wheels, illustrated in China from 1313 onwards, or the U shaped flyer rotating around the spindle attached to it in Europe by *c*. 1480 or, again, the connecting rod and treadle, developed in Europe by 1524. But, to go by the evidence of Mughal miniatures, during the seventeenth century the Indian spinning wheel appears to have been furnished with the crank handle, which in Europe too definitely appears only by 1524. It can easily be seen that the handle immensely increases the efficiency of the spinning wheel.

Spinning Wheel (see crank-handle), ***Cf.*** **S.P. Verma,**
India at Work in Sculpture and Painting**, Aligarh, 1994**

Looms

The Indian weaver's loom, with its horizontal frame, and foot-treadles (levers operated by foot) to control the shedding mechanism, is illustrated in seventeenth century paintings of the saint Kabir at work. It is nearly identical with the ordinary loom developed in Europe by the thirteenth century. Its first use in India is attested by the Malwa dictionary of 1469 just mentioned. Such a loom was practically incapable of further development, in so far as simple or tabby weave was concerned, until the coming of Kay's flying shuttle in the first half of the eighteenth century. This at least revolutionized the entire mechanism and opened the way for the automatic power-loom.

Where varied developments could occur were the looms used for fancy or complex weaves, involving threads of various colours both in the warp and the weft. Draw-looms had been invented in antiquity in China and the Middle East in two possibly divergent



forms. While we know that figured silks, cottons, and brocades of the highest quality were woven in India during the seventeenth century, there is no evidence of the use of draw-looms. Even in 1800 the Dacca weavers wove flowered cloth on the ordinary horizontal loom; they laboriously counted and lifted together appropriate numbers of the warp threads, through a bamboo stick, for each operation of the shuttle. The loom used to weave patterned shawls in Kashmir carefully described by William Moorcraft and George Trebeck in 1822, again lacked any features of the draw-loom, the driving of the woof through the warp to create patterns being done in a manner akin to embroidery.

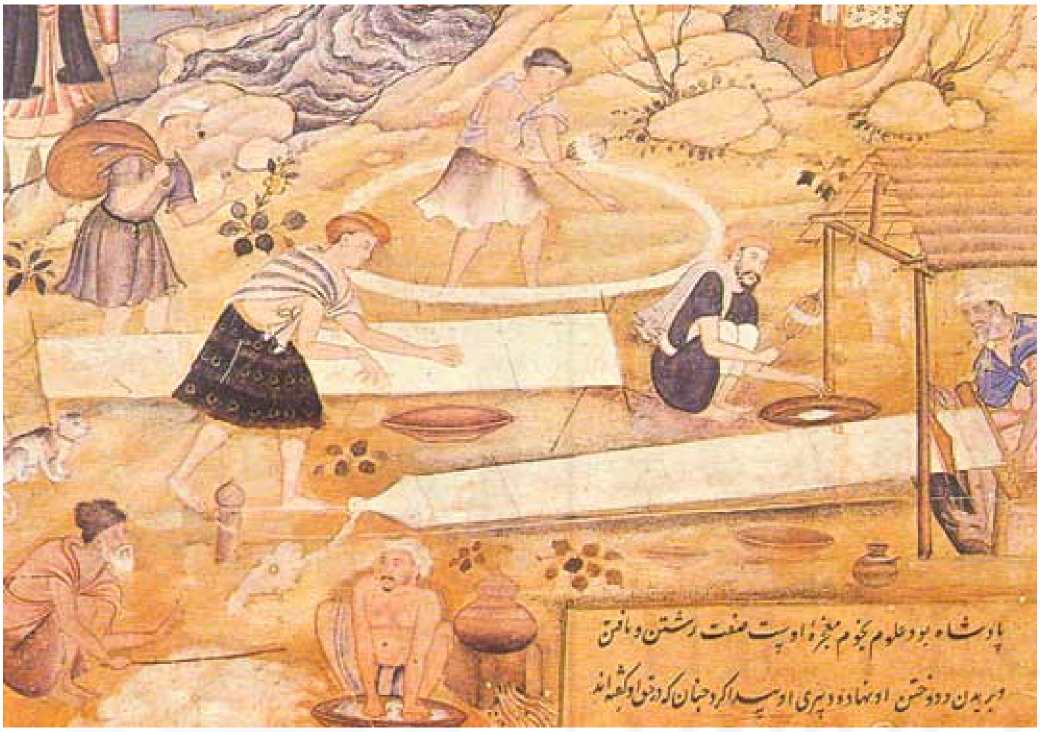
Kabir with Loom, Mughal school, mid-17th Century, miniature in the Leningrad Branch of the People of Asia, *Cf.* Irfan Habib, *The Agrarian System of Mughal India,* OUP, Delhi 1999, p.382.

There is a view that the manufacture of Indian figured silks (and therefore, very possibly the draw-looms proper) is a relatively recent importation from Persia, but no direct documentary evidence is available in support of the view. However, in 1679 Master Streynsham (1675-80) observed at Ellur (Andhra) the manufacture of carpets on upright looms with coloured woollen weft-threads woven in accordance with patterns set on paper; and he was told that the industry had been established there a century earlier by Persian immigrants. Importation of Persian weaving devices and techniques during the Mughal period is, therefore, quite likely. In any case, it is beyond doubt that the Indian looms and the craftsmen were by now sufficiently equipped to "exactly imitate the nicest and most beautiful patterns that are brought from Europe."

Dyeing and Cloth Printing

The two basic methods of the multi-colour or pattern dyeing in India, namely, the application of resists to confine colours to patterns and of mordants to take colours, are described in seventeenth century accounts. Printing blocks might have been used to apply the resists and mordants since early times; there is evidence for this from Egypt and Iran of third-fourth century A.D. Whether the mordants and resists were applied by painting or by printing, they gave far better results than the simple colour-printing from wooden blocks which became popular in Europe in the seventeenth century. The latter had, however, an obvious advantage in that it saved time and cost, especially if the cloth receiving the pattern was not fine or of high value.

It is singular that there should be practically no evidence for cloth-printing in ancient Indian literature. Moti Chandra finds the word *chhimpaka* for a female calico-printer and *chhipa* for a calico-printer in a 14th and 15th century source respectively. The term *chhapa* for calico-printing occurs in Malik Mohammad Jaisi (16th Century). In the *Bahar-i Ajam* (18th century), *chhapa* is said to be a Hindi word for the printing-block accepted only recently in Persian as *chapa*. That the printing-block was being used for direct colour impressions on cloth is established by what Jean de Thevenot (1666) says in his account of Agra. While noticing the same process in Isfahan (Iran), he says significantly that such cloth used to come there from India. The primacy of India in cloth-printing at this time is suggested also by the use of the word *chit* (Persian form of the Hindi *chhint*) for calico printed in Isfahan itself. Tavernier (1667) makes it clear that in his time calico-painting was a small localized industry, while it was the printed calico which was produced in large quantities for the internal as well as foreign (including Persian) markets. Irwin might be right in his suggestion that calico-printing was a comparatively late arrival, coming possibly from Persia, but the arrival was not as late as he suggests, since it seems to have been practised in India in the 14th century at any rate. By the seventeenth century the practice had become so extensive that India now appeared to be the home par excellence of all printed cloth, even that when viewed from Iran, from where India might have originally borrowed the technique.



Weavers at Work, beating cotton, dyeing thread, stretching yarn and working with treadles on loom (see pit-loom) (*c.* 1590). Johnson Album, India Office Library, London, Vol.8, No. 5. *Cf.* S.P. Verma, *India at Work in Sculpture and Painting*, Aligarh, 1994.

The change in the quantity of clothing which seems to have occurred some time between *c.* 1000 and 1500, must surely be attributed at least partly to the spinning wheel and the bowstring, just as the other change, since 1850, has been due to the modern mechanization of the spinning and weaving industry.

This is important in itself; but there are other aspects of the matter to consider as well: the expansion of cotton cultivation would mean an expansion in the area of a non-food, essentially market crop, and, therefore, in the volume of commodity production within the village. Such a process fits in with the view ventured on other grounds, that an extension in commodity production appears to have taken place during the 13th and 14th centuries.

23.5 LAND TRANSPORTATION

The Indian transport system showed two surprising lags, which it did almost nothing to make up during our period. For carrying heavy loads over short distances, no use was made of wheel-barrows; and for conveyance over longer distances, horse-power was not employed to drive carts or carriages.

The wheel-barrow, which substitutes a wheel for the front man carrying a hod or stretcher, appeared in Europe only in the late 12th or in the 13th Century, while in China it has been traced back to the 3rd Century. Its efficacy for hauling small loads, particularly in building construction, should have popularized it in the Mughal period, which has such large edifices to its credit. Yet depictions of construction sites in Mughal miniatures show only hods, but never wheel-barrows.

Horse Drawn Vehicles

Equally surprising is the absence of horse-hauled carriages. The collar-harness, which appeared in Europe about the beginning of the 10th century, after a much longer history in China, immediately made the horse an efficient draught-animal. However, whereas in earlier times horse-driven chariots were an important element in Indian armies, they appear to have gone out of use well before the appearance of the horse-caller in Europe; and they did not return. Carts and carriages in Mughal India were pulled almost exclusively by bullocks; and European travellers expressly mark the fact that horses in India were not used for draught purposes. Chariots, even for princely conveyance, were pulled by bullocks, the horse-drawn chariots of Akbar being an obvious exception. That the Mughal artists had neven seen a horse-carriage is shown by the way in which, when called upon to depict the chariots used by the heroes of the *Mahabharata*, they faithfully reproduce the yoke of the bullock cart, thus revealing their total ignorance of the collar-harness.

Mughal Artist's Painting of Horse Drawn Vehicle of *Mahabharata*: See Yoke on the Neck of Horses, *Razmnama*, British Library, Or. 12076, f. 35b *Cf.* A. Jan Qaisar, *The Indian Response to European Technology and Culture,* OUP, 1982.

The only attempt to have the European horse-driven coach built in India appears to have been made by Jahangir who, for his own use, had an exact replica made of a coach obtained from England. Jahangir describes the coach as *rath-i tarji Farang-i Angrezi*, "the English-European style chariot". It was pulled by four horses. But the novelty seems soon to have worn off, though horses were used later to pull a few gun-carriages of the imperial artillery.

It is therefore, certain that the *ekka* and *tonga* are both post-seventeenth century innovations; and Mughal India completely lacked the cheap and quick means of passenger conveyance that these could have furnished.

Bullock carts thus constituted practically the sole form of wheeled traffic over the larger part of India. It is noteworthy that while spokes were put on the lighter chariots, the bullock-carts had wheels of "solid timber," it being apparently believed that this made the wheel stronger though heavier.

Mughal Roads

In studying Mughal roads, one must always keep in mind the fact that there were some essential differences in the Indian and European conceptions of what a good road should be like. But, speaking generally, as Tavernier tells us, "the manner of travelling in India" was "not less convenient than all the arrangements for marching in comfort either in France or in Italy." The ideal Indian highway was a broad avenue (40 ordinary paces are stated to be the width of the road heading east from Agra), with close ranks of trees planted on either side, wells to furnish water to travellers at convenient distances, the distances marked by towers (one at each *kuroh*, equal to a little over two miles), and *sarais* or inns at the end of each day's journey. The great imperial highways approximated in varying degrees to this ideal.

What the Indian roads most lacked was attention to their surface. "In these countries here," English Factors reported in 1666, "are no beaten roads or mending of highways." Carts could not be used in most parts in the rainy season, for the roads were reduced to mud; and the first cart to be used after the season had to cut the tracks anew with their wheels. But there were still some exceptions to this neglect. In certain stretches roads were cut through solid rock to make cart transport possible. This was done, for example, in the Khyber pass; on the imperial road crossing the Sindh Sagar Doab where the road was paved with "great masses of a hard bluestone well fitted in;" and on the Daulatabad-Elora road, where a 4-foot high wall ran along the edge of the road for protecting wheeled traffic. There were of course, no metalled roads at that time.

Bridges

A prominent feature of the Mughal road system, again designed mainly to facilitate cart-transportation, was the construction of stone and masonry bridges on the main roads. It will not be possible to enumerate here even the more important bridges whose existence was recorded in contemporary accounts or which have been preserved till our own time. These bridges spanned, besides the smaller streams, such rivers as the Degh, the Gomati and the (Central Indian) Sindh. On the larger rivers, like the Jamuna, the best that could be done was to build bridges of boats, the architectural technology of the time being apparently unable to attempt masonry construction on the requisite scale. A notable fault in the Mughal masonry bridges, which were otherwise very strongly built, was a consistent failure to allow for a sufficiently wide passageway for water. It had long been held in Europe that a width of the pier equal to 1/4 or 1/6 of the arch-span was quite adequate from the point of view of the strength of the bridge. In fact even this ratio was found to give too large a margin of safety, and was in the 18th century reduced by Jean Rodolphe Perronet (1708-94), the French engineer, to 1/10. In India, on the other hand, the view prevailed that the Pier-width must not be less than the arch-span.

Bridge	Date/Period of construction	Pier-Width	Arch-span
Jaunpur	1564-67	17' 0"	18' 3"
Nadaf, near Rajmahal (!)	c. 1650	17' 0"	11' 0"
Nurabad, between Gwalior and Agra	Latter half, 17th c.	16' 9"	18' 10"
Patti Ghati, near Narwar	-do-	20' 0"	19' 7"
Narwar	-do-	20' 0"	19' 5"

As Cunningham repeatedly points out in his descriptions of the Mughal bridges, the massive piers and narrow arches always tended to subvert the bridge by driving the channel to new course, out-flanking the bridge, and, therefore, often compelling a subsequent extension of the bridge, which, again, merely met the fate of the original construction. It is possible that the real reason for this faulty design lay in the fear that an arch with a relatively longer span would either have to be given a very large rise or would be unsafe. The latter fear was probably groundless, but the fact remains that it was not overcome, in spite of experience; and massive piers continued to thwart the longevity and utility of the bridges.

23.6 NAVIGATION

Quite in contrast to the largely static conditions of land transport, the seventeenth century saw considerable changes in the Indian shipping industry. At the beginning of the century, the principle type of sea-going Indian ship was called 'junk' by the Europeans. The junks, which counted among them some of the biggest ships in the world at the time, had immense main sails and were designed to take the best advantage of favourable winds. This fitted them for voyages across the Arabian Sea and the Bay of Bengal, where navigation was governed by the monsoons; but it also rendered them difficult to manouvre.

Among the instruments used on Indian ships was the astrolabe, the famous instrument for determining time and latitude by sighting the position of the sun and stars. It is not clear if it was a variant of the mariner's astrolabe, which was invented in Europe about 1535, or the astrolabe proper. It is probably the latter. An instrument held in the hands of a seaman in a painting by one of Akbar's court-artists may possibly be a magnetic compass, but it is very difficult to be sure of its nature. Also in use were mariner's cards, "lined and graduated orderly", to plot the ship's course. These instruments were not by any means absolete by 1600 in European navigation, but they became so very soon afterwards. During the course of the seventeenth century European ships came to be equipped with an almost totally new set of navigational instruments, namely, the telescope, perfected about 1608; gimbals for mouting compasses; Davis's quadrants and nocturnals; Mercator's projection-charts; and lanterns.

Shipbuilding

When we read the English commercial records we gain the impression that for most of the first half of the seventeenth century, the Indian ship-building industry continued on the old lines, while the Portuguese on the western coast organized a lucrative industry, building ships of European design for Indian customers. In 1636 it was thought that even small pinnaces of 100 or 200 tons would cost in England only a third of what they would cost in India to build.

But then took place what is practically an unchronicled revolution in the Indian ship-building industry. In 1668, the English factors, urging that the English East India company build its ships at Surat, declared that "if any shall object they may not have that shape, or be so profitable for storage and goods, as our English ships are, we answer that these carpenters are grown so expert and masters of their art that here are many Indian vessails that in shape exceed those that come out of England or Holland." Three years later, John Fryer (1672-81) observing at Surat more than a hundred sail of "good ships," including some "three or four Men of War as big as Third Rate ships," ascribed this to some indigent English shipwrights having taught the natives the new art, a kind of legend which is usual in cases of such technological imitation. J. Ovington writing on his visit in 1690-93, says enthusiastically that "the very ship-carpenters at Surat will take the Model of any English Vessel, in all the Curiosity of its Building and the most artificial Instances of Workmanship about it, whether they are proper for the convenience of Burthen, or of quick sailing, as exactly as if they had been the first contrivers."

What is interesting in this instance of copying is that certain methods of Indian carpenters proved to be equal or superior to those of the European shipwrights. It was found that the Indian method of riveting/ ribbeting planks one to the other gave much greater strength than simple caulking which, together with oakum, pitch and tar, was no longer needed; that water tanks made of wood-planks by Indian carpenters were as good as casks, which constantly required the presence of a cooper, whose art remained a purely European possession; and that a lime compound or *chunam* dabbed on planks of Indian ships provided an extraordinarily firm protection against sea-worms. For the haulage of ships from water to land for the purpose of carrying out repairs, the crab (a form of capstan) and tackle were used in a way that won an English traveller Thomas Bowrey's admiration (1669-1679).

Planks Joined Using the Rabetting Method and Use of Iron Nails: *Darabnama*, British Library, Or. 461, f. 76b; *Cf.* A. Jan Qaisar, *The Indian Response to European Technology and Culture*, OUP, 1982.

This advance in Indian ship-building industry, remarkable as it was, did not however do away with the lag between European and Indian shipping. Essentially, while they succeeded in having the same kinds of ships, the Indian navigators could not acquire the skill and instruments (both of which are, of course, inseparable) of their European counterparts. An Indian lexicographer, writing in 1740, recognizes that the telescope was a pilot's observational instrument; but no attempt was ever made to manufacture telescopes in India. The general deficiency in navigational instruments is well shown in a plea made by the English authorities at Bombay in 1677 for shipping stores to be sent from England, it being stated that these "are not only absolutely necessary, but not there to be procured, as compasses, lantornes, pilots instruments, log lines, saile, needles, and the like, the overplus of which we can at any time sell to advantage". There was a deficiency too in regard to the quality of iron materials, whether nails or anchors; the latter were a constant item of import from Europe. It was, therefore, inevitable that Indian ship-owners should often turn to Europeans, particularly Englishmen, and employ them to command and pilot their vessels.

23.7 ARTILLERY

In several ways artillery represented the highest achievements of industrial technology during the sixteenth and seventeenth centuries. While the manufacture of cannon was then the real "heavy industry," on the handgun were lavished all the fruits of the increasing mechanical sophistication attained during the period. Modern artillery was mainly brought to India, on the one hand, by Babur, who had received it from Persia, and, on the other, by the Portuguese early in the sixteenth century. Evidence has, however, now been adduced of the presence of cannon during the latter half of the fifteenth century.

Handguns

In spite of the great interest of the subject, the methods of manufacture of firearms in India have yet to be studied with due attention paid to the genuine surviving specimens from the Mughal period. To take the handgun first, its crucial part may be said to be its propelling mechanism. In the earliest guns the charge was fired by applying a "match" or burning rope or cord to the priming pan which communicated through the touch-hole with the barrel into which gun-powder had been previously rammed. During the 15^{th} and 16^{th} centuries the match-lock developed in Europe by first providing for a pivoted lever for holding the "match" and then converting it into an arm of a lever controlled by a spring.

So poor has been the study of our Indian evidence that we are not able so far to trace the development of the match-lock in India. It is not even certain whether the "arquebuses" found in wide use in India in 1640 and condemned by Fray Sebastian Manrique (1630's) as "poorly made" and "awkward arms" were true match-locks or mere forms of hand-cannon without locks. However, miniatures in the copy of the *Akbarnama* prepared for Akbar's own library show the muskets pretty distinctly as true match-locks.

In any case, Abul Fazl, writing in 1595 makes a statement which shows not only that match-locks were being manufactured by Akbar's arsenal, but that it was also turning out a lock in which the match was done away with: "Owing to the practical knowledge of the World-Emperor, they have so fashioned a gun that, without the use of the 'match' (*fatila-i atish*), but with just a slight movement of the *masha* (trigger), the gun is fired and the pellet (*tir*) discharged." Such a gun could either have been a wheel-lock or flint-lock. Since the latter had not yet appeared in Europe, it was probably the wheel-lock, which was an Italian invention of about 1520; in this the spring released by trigger caused a wheel with serrated edge to revolve against a piece of pyrite and so send sparks into the priming pan. In spite of its early date, it was too delicate a mechanism to obtain wide use. The apparent success of Akbar's arsenal in producing a wheel-lock must then be noted as a significant achievement.

Handguns

The early decades of the seventeenth century saw the appearance of the flint-lock in Europe, where it gradually, but not completely supplanted the match-lock during the latter half of the century. Its first appearance in India is difficult to date, but in 1623 it excited the great curiosity of the Zamorin of Calicut, for "their guns have only matches." The subsequent progress of the flint-lock in India, again, is not easy to trace, there being no direct statements on the matter in our sources. It would appear that Indian guns began to be equipped with flint-lock during the latter half of the seventeenth century. But the basis for this view is an inference from rather indirect evidence. Bernier says that Indians sometimes imitated perfectly articles of European manufacture, and then adds that "among other things, the Indians make excellent muskets, and fowling pieces." This statement made in 1663 at Delhi, is quite at variance with that of Manrique, who, as we have seen, had some twenty-three years earlier found Indian 'arquebuses' to be 'poorly made.' One is tempted to think that within this period about twenty years, Indian smiths had been successful in imitating the flint-Lock, and thus attaining respect for their products. It is, however, quite possible that the principal weapon in use in Indian armies still remained the match-lock.

The barrel of the gun posed another problem for the gunsmith, since while the barrel had to be very strong to stand up to the explosion within it, great accuracy had also to be provided with regard to its bore and alignment. It is interesting to find that Akbar's arsenal adopted the same technique of making the barrel, as was adopted in Europe. That is, it too abandoned the method of making the barrel merely by bending and joining the edges of a sheet of iron flattened by hammering, which was found to be defective, even when the bent sheet was twisted to one side. Instead of this, the barrel was now made by getting rolls of flat iron, twisted around with one edge running over the other, welded by heating and then bored from inside. This also remained the accepted technique in Europe until the eighteenth century.

The longer barrels, which were developed about the middle of the seventeenth century in Europe necessitating the use of rests for muskets, began to be made in India about the same time, since musketeers are now said always to have carried rests with them. Early eighteenth century miniatures frequently show an aristocratic sportsman resting the long barrel of his gun upon the shoulder of one of his retainers, and taking aim with it in this position. Of this human substitution for the wooden tripod, there were no precedents in European technology.

Cannons

In the manufacture of cannon, two trends were noticeable in the Mughal period. The first was to make very large pieces. This was possible as long as they were cast of bronze. The method of casting such cannon pieces was apparently similar to the one employed by the Ottoman Turks during the middle of fifteenth century, a method which lasted in Europe until about 1750. Babur's gun-founders cast cannon by precisely the same means. Whether the process of bronze-casting was further improved in India or the alloy used was better, it would appear that by the end of the sixteenth century, the heaviest guns in the world were being cast in India, the climax being reached with the famous *Malik*

Maidan cast in bronze at Ahmadnagar, with a length of 13' 4", diameter at the muzzle, 5' 5", and diameter of the bore, 2' 4 ½”. Jahangir says it threw stone balls weighing ten Indian maunds (550 lbs).

But such heavy guns were already obsolete by 1600. Not only did they lack mobility, but with their large bore and difficulty in positioning them, they lacked accuracy as well. Moreover, bronze was expensive and wore off more quickly than iron. As a result lighter cannon made of iron began to gain much greater currency in Europe during the seventeenth century. That even in India such realization had dawned is shown by claims made on Akbar’s behalf that he paid great attention to light cannon.

But the difficulties of casting large pieces of iron were never overcome in India. Even with bronze the mould had to be fed from a number of furnaces, a process which was criticized by Jean de Thevenot in 1666. Indian iron cannon thus generally consisted of wrought (not cast) iron bars or cylinders held together by rings.

In this respect, no advance seems to have been made in the seventeenth century. That the Mughal authorities were conscious of this weakness is shown by their employment of large numbers of European gunners, and import of European cannon-pieces. In 1666, on orders from the Imperial Court the English and Dutch were asked to recruit “five gunfounders and two engineers or pioneers” for imperial service, it being stipulated that they were to be “very experienced practical men,” while the pay was to be “inviting”. However, there is no evidence that any gun-foundry worked on European lines was ever actually established in the Mughal empire.

In another branch of the artillery, grenade shells were not in use in India, in spite of the fact that both in China and Europe they had a much older history. In 1640 they could excite great popular curiosity. In 1648, mortars similarly attracted Shah Jahan’s curiosity, although it was recognized that there were not likely to be of much service to him. The reason for the Indian lack of interest probably lay in the fact that in the *ban*, or rocket the Indian armies had an alternative weapon of very great effect. These rockets were made simply of bamboos, with iron cylinders containing combustible materials; they could also carry light grenades. In retrospect, the *ban* would seem to be of great technological interest particularly since the use of rockets in modern European armies dates from the Congreve rockets of early nineteenth century, which had been directly inspired by the Indian rockets.

23.8 SOURCES OF POWER AND FUEL

The pre-industrial evolution of modern Europe has often been seen as typified by the increasing utilization of non-human sources of power, particularly of water and wind, to be followed ultimately by steam.

Closer scrutiny has long established that the utilization of water and wind has not been confined to Europe. Both the watermill and windmill for grinding corn appeared in early medieval Persia and have continued in use until recent times. Both of these are mounted horizontally, and, therefore, involve no gearing.

Watermills

Whether watermills were introduced into India from Persia as early as the fourth or even the eleventh century depends solely on whether there is any substance at all in a statement of a late Byzantine historian, Kedernos. But by the seventeenth century, watermills were in use in the Dakhin, one of the best-known examples being Malik Ambar's watermill at Aurangabad. These were also used in Kashmir. If they did not come into use in the north Indian plains, it was only owing to the difficulty of getting water to flow with sufficient force; moreover, as Sir Thomas Roe pointed out, the rivers with their great seasonal fluctuations were most unsuitable to the setting up of the mills.

And yet the fact that technical ingenuity in using water-power was not lacking is shown by the use of water-power in one small locality, the Hazara district, which lay astride a route to Kashmir often used by the Mughal emperors. Here, apart from the conventional corn-grinding watermill, a water-driven wooden trip-hammer, called *pekoh*, has been in use for milling rice. Since the wheel in this case is vertical, it is an important departure from the horizontal mill. The device was probably introduced through contacts with the border regions of China, where it has had an ancient history. But the water-driven worm-worked cottongin (*belna*) of Pakhli could not have come from the same source, as China did not know of such gins, and it could only be a local attachment of the vertical wheel of the *pekoh* to the mechanism of the worm-gin.

Windmills

Since Seistan, the homeland of the eastern windmill, lay so close to the borders of the Mughal empire, it is to be assumed that the windmill was known in India at that time. Yet the Seistan windmill was only suited to a country where strong winds blew constantly in one direction, and water as an alternative source of power was not available. It, therefore, did not spread northeastwards into Afghanistan proper. But someone made an abortive attempt to install such a mill at Ahmadabad. This wind mill (*asya-i bad*), known locally as *pawan-chakki*, worked upon "the movement of the wind and the rotation of the curtains." It was, accordingly, a horizontal windmill of Seistan type. By 1761 only the millstone had remained, and it was no longer remembered when it had been originally installed.

The windmill could have hardly ever succeeded in India, but it is possible to argue that the watermill should have had better success. The horizontal mill could not undoubtedly have competed with the ordinary handmill; but the vertical mill with overshot waterwheel developed in Europe would have greatly economized on waterflow. No attempt to introduce such a watermill during the seventeenth century is recorded; but even here the absence of sophisticated gearing in Indian technological practice would have presented considerable difficulty. Wooden pin-drum gearing was incapable of transmitting greater power than was needed to rotate the Persian wheel. So unless metal gearing could be produced – and this, as we shall see, was not possible, in view of the exceptionally backward state of the Indian iron industry – vertical watermill's or any other mechanism seeking to tap water for substantial power could hardly have been thought of.

Fuels

Of no less importance than sources of power, and somewhat similar in effect, are the fuels available to any technology. A notable disadvantage of Indian technology in the sixteenth and seventeenth centuries would seem to have been that, unlike China and Europe, it did not have coal. In 1611, "sea coale" was taken from the English ships at Surat and sent to the Mughal court "for a wonder". But the curiosity was one which could hardly be imported in large quantities. Why coal was not discovered and mined in India, when surface deposits could have been found at least in the Bir Bhum and Jharia belts, and why, when it had been in wide use in China for centuries previously, no one in India had started looking for it, are questions that are difficult to answer. It is perhaps possible that the surface coal was of an exceptionally inferior quality and the localities not those where it could have been put to much industrial use. Moreover, deep mining was not practiced in India, so that coal mining to any depth would have been quite forbidding, initially at any rate. Diamond mines were not carried below the water table, and were no deeper than 12 or 14 "spans" at Kollur, and 10 and 12 feet near Gollapallu, in Golkunda. The salt mines of the Salt Range had excavations 200 or 300 yards "deep", but the depth was horizontal, the mines being in the nature of caves dug at the sides of the hills. But the lack of availability of coal was only a grave potential disadvantage; it could not have had much relevance to contemporary technological progress, because even in England coal did not begin to replace charcoal in the major industrial processes until after the end of the seventeenth century.

23.9 METALLURGY AND CHEMISTRY

Zinc

If one wishes to begin with the credit side of Indian metallurgical practices, there is something that one can offer. Zinc was being produced and isolated in India, as in China; though the process could be undertaken in Europe only during the 18th century. Abul Fazl actually mentions the Jawar or Zawar zinc mines in Rajasthan, now so well-known. It is possible that Manucci was thinking of zinc alloys (brass), when he wrote that in India some musical instruments were made of "refined metals not employed in Europe." The Indian capacity for handling zinc alloys is well illustrated by the well-known Bidri ware. There is some doubt as to when exactly the ware began to be manufactured in India; no specific reference to it has been traced in sources of the Mughal period, but Heyne gave a description of it in 1817.

Indian methods of soldering were also found to be very effective; and Thevenot noted that the Indians had "a way" of working gold upon agates, crystals and other brittle materials "which our Goldsmiths and Lapidaries have not."

Iron

In regard to iron, India has been fortunate in the quality of its surface ores. It had what was reputedly the best ore in the world, from which the 'Damascus' steel was obtained. This was mined near Indur in Andhra. Steel was in fact exported to Persia and other countries. The Indian steel was crucible-cast, the process being described by two seveneteenth century English writers. Even after the middle of the nineteenth century the locally smelted Gwalior and Narwar iron was deemed soft and malleable and regret was expressed over its impending disappearance, owing to the growing shortage of wood for charcoal and competition from "the cheaper and more brittle English iron."

By the end of the Mughal period, the essentials of the production of cast iron had also begun to be understood, for Alexander Hamilton (1688-1723), visiting Orissa in 1708, found that "iron is so plentiful that they cast Anchors for ships in Moulds, but they are not so good as those made in Europe." It is not clear how the iron came to be cast in Orissa, and whether 'blast furnaces' had been built there. Probably they were not and their absence may explain the unsatisfactory character of the metal obtained. There is no other evidence, either in record or surviving specimens of their products, to suggest the existence of blast furnaces in India during the seventeenth century. Such furnaces, for one thing, required water powered forges to produce sufficient blast; and these would certainly have attracted notice, if they had been introduced during our period.

The failure to produce proper cast iron had a generally retarding effect on the entire progress of industrial technology. As we have seen, iron guns could not be cast. There was nothing to match European anchors. In general the quantity of iron available as material for fashioning tools and mechanical parts remained extremely restricted. The English at Bombay could truthfully say in 1668 that "the greatest scarcity in these parts we find to be iron worke."

Chemicals

The position in metallurgy found a very close parallel in that of chemical industries. Here some advanced techniques represented by lacquerware, distillation and refrigeration were balanced by failure in a very important sector, that of glass.

Lacquerware was a positive achievement; and it inspired varnish techniques in Europe. More detailed remarks are called for in respect of distillation and refrigeration.

Distillation

The Arabs (or rather Persians) of early Islam are credited with discovering the process of extracting rose-water through distillation. They transmitted their discovery to India, presumably with the foundation of the Sultanate and the accompanying thirteenth century immigrations. In Mughal India one celebrated discovery was that of the *Itr-i Jahangiri*, ascribed to Nur Jahan's mother (early seventeenth century); to judge from Jahangir's description, it was the essence obtained from distilled rose-water.

Needless to say, distillation also enables one to raise considerably the alcoholic content of wines. Liquor distillation was a widespread industry in Mughal India. Abu'l Fazl describes three ways of distilling *arq* from sugarcane juice. Liquor was also double-distilled, such being known as *do-atisha*. Bernier gives a description too of the 'arac' distilled from unrefined sugar; and the French traveller Abbe Carre (1672-74) tells us of 'arack' distilled from toddy, as we do brandy. The present scholarly view is that distilled liquor is a European invention of the twelfth-thirteenth century, and that the Islamic world until then, and much afterwards, lacked all knowledge of it. Indeed, Abu'l Fazl's description of liquor distillation is treated by Forbes as the first Arabic [sic] reference to the process. One may then well think that the process came here with the Portuguese and spread all over India in the sixteenth century. But the words of the historian Ziauddin Barani, writing in 1357 show that liquor distillation was being practiced in India much before the Portuguese had been heard of. When Sultan Alauddin (1296-1316) forbade the sale of wine, the people of Delhi, says Barani, "set up *bhattis* (Hindi word for furnaces, boilers, kilns, and stills) in their houses, made wine out of sugar-cane and then distilled it (lit., made it fall drop by drop)". Speaking of an earlier reign (of Kaiqubad, 1286-90), he enthusiastically describes the manufacture of "sweet-scented *'arq'* distilled (lit., made to fall drop by drop) through the wine-maker's pipe." This would mean that even if alcohol began to be distilled no earlier than the twelfth century and then also in Italy, the discovery had rapidly travelled through the Islamic world and reached India by the end of the next century. By the Mughal period, as we have seen, the technique was honourably and well established.*

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* Excavations at Sirkap (Taxila) and Shaikhan Dheri, now in Pakistan, confirm the presence of distillation apparatus like condensers and parts of stills far back to 2nd century BC - 2nd century AD. However, Turks are credited for its eastwards diffusion.

Refrigeration

Coming to refrigeration, the first known Indian reference to any chemical process of water-cooling is in Abu'l Fazl. He praises Akbar for adopting and popularizing the device of using saltpetre to cool water, before the transfer of his capital to Labore in 1586 enabled him to obtain snow for the purpose. European travellers found this method of refrigeration widely in use in India in the seventeenth century, and significantly enough it struck them as a novelty or curiosity. *Bahar-i Ajam* considered it a specifically Indian practice. Here then India might well be assigned precedence over Europe, where freezing mixtures came to be known at about the same time (c. 1600), but snow was still their major component, being mixed with nitre or salt.

Glass

In contrast stood, as we have said, the Indian backwardness in the manufacture of glass. The entire development of the European glass industry with its fine transparent glass and cast or plate glass, on the one hand, and fine lenses, on the other, does not seem to have provoked any attempt at imitation in India, in spite of the fact that European glassware fetched the highest value at the Mughal court. Jahangir records his admiration of European boxes of transparent 'crystal' received in gift, and over fifty years later Prince Shah Alam could not believe that the glass vessels brought from Bombay for him were not of rock crystal. The mirrors used in India were of steel, not glass.

23.10 BASIC TOOLS AND PRECISION INSTRUMENTS

Screw

We may begin by considering the screw. The use of the screw as a slow-motion (and, therefore, slow-pressure) device and as a water-raising mechanism, has been traced to Hellenistic texts. But its appearance as a means of fixing metal parts together belongs to the beginning or middle of the sixteenth century, when it was used in European armour. It could now replace soldering, rivets and wedge fittings, all of which had obvious disadvantages. One of the important factors for the development of the lathe in Europe was the need to cut proper grooves in the screw.

The screw, in its new role, could only have reached India during the fifteenth or sixteenth century. But either the screw adopted in India was derived from a primitive European ancestor or had been subjected to much modification in its travels. In 1666 Thevenot described it as follows:

> The Indians of Dehly cannot make a Screw as our Locksmiths do; all they do is to fasten to each of the two pieces that are to enter into one another, some Iron, Copper or Silver wire, turned Screw wise, without any other art than of souldering the Wire to the pieces; and in opening them, they turn the Screws from the left hand to the right, contrariwise to ours, which are turned from the right to the left.

Thus the Indian smiths avoided the use of the lathe to cut screw grooves, by the use of soldering of wire, at which, as we have seen, they were expert. With this limitation, the screw could not be used as effectively as in Europe. Yet the coming of this new device did represent a considerable technical advance, and it would be of much interest to find out, from surviving specimens of metal-ware of the period, as to where it was applied.

The attempt to make screws by soldering well illustrates the Indians' weakness at cutting and drilling tools during our period. There is no reference to the treadle lathe being used in India. Records and pictorial evidence both attest to the bow drill, which might go back in history to Hellenistic times. It was used for cutting sapphires and other precious stones. An improved drill for cutting diamonds at Surat is, however, described by Fryer (1674). This was driven by men turning a wheel, which rotated, through a driving belt ('String'), a 'lesser' horizontal wheel, to which the drill was fixed. The first appearance of the belt-drive in both Europe and India was in the spinning wheel, its use in other devices seems to be no older than the fifteenth century in Europe. There is therefore, strong reason to suppose that the drill described by Fryer was a comparatively recent addition to the Indian artisan's tools. But even this drill was by the late seventeeth century far out-distanced by the water-powered lathes and drills of Europe so that diamonds from India were now sent to Europe to be cut and returned.

Diamond Cutter (*c.* 1600), Gulshan Album, Imperial Library, Teheran, *Cf*. S.P. Verma, *India at Work in Sculpture and Painting*, Aligarh, 1994

Gearing

The only forms of gearing known to have been employed in India were the right-angled pin-drum gearing, found in the Persian wheel, and the worm, used in the cotton gin.

Since gears not only transmit, but control the direction, and increase or retard the speed of rotary motion, these have always constituted an essential element in working machines. There was a renewed interest in the use of gearing at Akbar's court: Akbar was said to have invented a travelling cart-mill and a machine designed to clean simultaneously a number of gun barrels. These inventions, in spite of their intrinsic interest, did not necessarily involve the use of any form of gearing other than the pin-drum, and did not therefore represent much advance in actual technique.

Crank

The development of the crank from the crank-handle to simple crank and connecting rod (already achieved in China and Europe by the fifteenth century), and then to compound crank, does not seem to have occurred in Indian technology, which therefore continued to lack any means of converting continuous rotary motion into reciprocatory motion. This prevented even the use of animal power for stamping coins, because the stamping mill would be inconceivable without crank and connecting rod. Since the Indian mints were called upon to turn out very large amounts of coins – an output of as many as 30,000 rupee-coins a day is recorded for the Surat mint in 1647 – the use of man-power for stamping them must be regarded as so much waste.

Piston

The principle of the piston is seen at work in its simplest form in the syringe. It is possible that the use of the syringe in India is of a very early date; it is certainly depicted in holi scenes in Indian miniatures of the Mughal period. But there is no evidence of any further development of the device or of its application in productive processes. Chain pumps, in which the balls on the chain acted as pistons for pushing up the water, could be seen in use on English ships visiting Indian ports at the beginning of the seventeenth century. In 1611 Muqarrab Khan "desired out (English) workmen and smith to make him a model of the chain pumps." But nothing apparently came of this.

Astrolabe

The greatest precision instrument in use in the Islamic countries and India had been the multi-purpose astrolabe, which represented an achievement of both the metal and wood-worker and the mathematical arts. Seventeenth century Indian astrolabes bear ample testimony to the great accuracy attained in graduation, which is notably more difficult when it is circular. Since the astrolabes were not only instruments for astronomical observation, but also for fixing time and determining latitudes, their accuracy can be checked by comparing the latitudes. The following table may serve for an illustration:

	***Ain-i Akbari* 1595**	**Petit Astrolabe 1661**	**True**
Agra	26º 43'	27º 13'	27º 10'
Delhi	28º 25'	28º 13'	28º 38'
Ajmer	26º 06'	26º 06'	26º 27'
Lahore	31º 15'	31º 56'	31º 37'

The deviations from the true latitudes are not very significant and in other cases where there appear to be large deviations, it is possible that the texts are corrupt. When in 1670 and 1671, Marshall worked out the latitudes of Patna and Hughly, with a wooden quadrant (apparently European), his latitude was higher than the true one, in one case by 22 minutes, and in the other by 15.

Time Reckoning Devices

Astronomers appearing in Indian miniatures of about the beginning of the 16th century are shown with two other instruments besides the astrolabe, namely, the altitude dial of the ring type and the sand-glass. While the first indicated unequal hours, the latter was a convenient substitute for various kinds of water-clocks, which gave equal units of time. Sand-glass was also in use in Aurangzeb's army to determine time; but apparently the less efficient sinking-cup measure also continued in use.

What particularly strikes one today is the failure to get excited by the European mechanical clock. Five clocks were included among the Persian ambassador's presents to Jahangir in 1616; and clocks were later deemed fit articles for presentation to Indian potentates on behalf of European Companies. But, as Ovington observed in 1690-93:

> The Indians have not yet attempted an imitation of our Clock-work in Watches; and may be it is, because they seldom continue their just Motions for any long time, by reason of the Dust that flies continually in the air, which is apt to clog and stop the Wheels. But the Chinese have undertaken to take our Clocks and Watches in pieces, to form new ones themselves and may be in some time to produce some fresh improvements in those Mechnical Operations.

The mechanical clock, with its refined gearing springs, screws, balances and escapement, represents the concentrated application of a large number of mechanical principles and devices. The diffusion of its manufacture could have led to the wider application of these principles. No less important would have been the immediate effect of its use, for the clock makes possible a far greater control over proper division of labour time, by enabling accurate time to be known 'at a glance' whenever required. So long as the mechanical clock remained an imported rarity, the Indian economy could have hardly derived any advantage of this kind from it.

23.11 PAPER AND PRINTING

Paper

Compared to the momentous consequences of the introduction of paper, little space can be devoted to it here. The history of its travels to various parts of the world from the time of its invention in China in the 1st Century A.D., has been the subject of considerable research. The Islamic world received it in the 8th century. The history of its journey to India has been studied by P.K. Gode in an almost definitive paper. His evidence supports Alberuni's statement that Indians used writing materials other than paper in his time (11th century), and the first appearances of paper recorded by him are practically all confined to the 13th century. Clearly, India failed to obtain paper directly from China; and it was only the Ghorian conquests which forced its acceptance. By the end of the 13th century Amir Khusrau would refer to paper manufacture as one of the contemporary crafts; and by the middle of the 14th century, the material would become so cheap that the Delhi sweetmeat sellers were giving their products packed in paper to their customers.

Printing

Before concluding this survey of the technology employed in the previous sectors of Indian economy during the Mughal period, I should like to refer to book-printing. Once paper had become available to any civilization, and the use of the ink-stamp generalized, it would be tempting to think that book-printing from blocks was bound to follow sooner or later, even if direct inspiration for this was not forthcoming from any other area. We have seen that block-printing of textiles was widespread in India during the seventeenth century. If with all these favourable circumstances, India failed to accept printing, the reasons for this rejection are not easy to find. Perhaps we will have to take a wider perspective than of India alone, since the rejection is a common phenomenon all over the Islamic world. But it may be said that Ovington's suggestion that printing was not undertaken for fear of throwing large numbers of scribes out of employment assumes too high standards of regard for the general welfare among the ruling classes of the time. The difficulties of the script, a particular obstacle to movable type, were also not insuperable, as was to be proved later.

23.12 NATURE OF TECHNOLOGICAL CHANGE IN INDIA

In interpreting the results of our survey of the technology of the various sectors of the economy outlined so far, the limitations of our description must of course be kept in mind. It has not by any means been comprehensive. However, on a very tentative basis the following two conclusions would appear to be justified:

First of all, there was no inbuilt resistance in the economic system to technological changes. In certain spheres, such as horticulture and artillery, such changes were encouraged by the Mughal court and ruling class. In other spheres, like ship-building, a strong competitive challenge led to considerable adaptation, probably induced directly by demands from merchants. Elsewhere again – and possibly in the largest range – technical innovation was adopted by the actual producers and craftsmen because of immediate economic advantage. Such was probably the case with new crops in agriculture, with the new tools and devices in the textile industry, and with the introduction of the screw in metal work and belt drive in the drill. Elsewhere, as in liquor distillation or water-cooling devices, human appetite or comfort was the direct driving factor. In most cases the changes required no large investment of resources (large, that is to say, in relative terms), though in ship-building this was possibly not true.

But at the same time, static conditions appear to have prevailed in a number of important sectors, where either the immediate advantage compared to investment was not considerable or there was no external challenge. These factors probably lay behind the failure to develop metallurgy and certain basic tools on lines already charted by Europe and also, quite possibly, behind the failure to accept book-printing.

It does then seem clear that while the Indian economy was not closed to innovation and invention, there was no overwhelming enthusiasm for technological change, which, in retrospect, appears so strikingly to mark sixteenth and seventeenth century Europe. This statement is one over which, except for the first clause, there would be little dispute. But the moment one seeks the sources of this limited technological inertia, one runs into considerable difficulty.

There would be a temptation to see it purely in ideological terms, and ascribe much to the lack of printing as a medium of diffusion of knowledge. Printing, however, would naturally only diffuse such knowledge as was available; and conceivably printing in the seventeenth century might only have caused a still easier dissemination of the minutiae of religious beliefs and superstitions. In spite of much greater attention to technological matters in the Chinese civilization and the prevalence of printing, the new industrial techniques from Europe could not after all be implanted there during our period. Moreover, there is the further question as to the effectiveness of the links between theoretical and practical technology.

Another factor which may merit consideration is the existence of a very numerous class of artisans and craftsmen able to live at very low wages. Bernier notes that while the Indian artisans were destitute of tools, they yet produced articles of the highest quality, even when these were imitations of European products. The highly specialized skill of the artisan thus seemed to serve as a substitute for his tools. Pelsaert speaks of a hundred crafts in Agra – "for a job which one man would do in Holland passes through four men's hands before it is finished." Thus the very numbers of the population of skilled craftsmen inherited from an earlier period would militate against labour-saving techniques, in that the immediate gain from these might be very slight or even illusory. A less favourable situation with regard to skilled labour, on the other hand, might have held out much greater incentive for technological innovation.

When we see this incomplete catalogue of the success of the Indian craftsmen alongside their failure to adopt important mechanical devices, we observe a contradiction that had also struck contemporary European observers. They too saw the crudeness of the Indian worker's equipment and, on the other, the excellence of his product. They naturally tended to see here a triumph of human skill over material equipment. "Numerous are the instances", says Bernier (1663), "of handsome pieces of workmanship made by persons destitute of tools... Sometimes they imitate so perfectly articles of European manufacture that the difference between the original and copy can hardly be discerned". In other words, there was an enormous supply of skilled labour available in India. A "good thing in Hindustan", Babur (1526-30) had said, "is that it has unnumbered and endless workmen of every kind". The large scale of skilled artisans had its natural corollary in low wages: the two phenomena necessarily existed together. The workmen hard-pressed with a barely subsistence-level income could not afford tools or materials calling for any expense. They, therefore, tended to compensate for the lack of these by putting in additional labour and application of skill.

An outstanding illustration of this "compensation" is offered by the Indian weavers' persistence in weaving patterns on their ordinary horizontal looms and so ignoring the drawloom, a device long used in Iran.

The substitution of the operation of tools and machines by human labour and dexterity called for an extreme degree of specialisation in skills. This implied the division of craftsmen into numerous categories, each concerned with some particular part or stage of manufacture. The division into the specialised skills was greatly facilitated by the caste system, which occasioned so much surprise to Babur who observes, "There is a fixed caste (*jati*) for every sort of work and for everything, which has done that work or that thing from father to son till now". The role that the guilds played in preserving and transmitting skills in Europe was thus here played by the caste system. At the same time owing to the barrier so raised between one craft and another, diffusion of techniques across the crafts must have been correspondingly difficult. An artisan, while laboriously following what his father had done before him, might not use a device, which, though useful to him, had not been sanctified by acceptance by his caste-peers. This negative aspect of skill, specialization through caste, that is, a segregation of skills – was emphasized by Max Weber in explaining the low level of Indian craft technology. Morris D. Morris has however challenged this view.

Morris is right, in stressing that the caste has not interposed any effective barrier to mobility of labour in the long run at any rate. In the Mughal period, the complaint is never heard of, in the voluminous commercial literature of the European Companies that workers in any skill were scarce because of caste restrictions. The restraint upon craftsmen crossing the sea, mentioned in a report of 1662 from Madras, loses much of its force when it is considered that the artisans were being asked to migrate from one region to another, that were as much apart as England and Spain. Moreover, castes could change their established professions. Fukazawa cites the case of the caste of tailors in Maharashtra, which during the earlier part of the eighteenth century took to dyeing, while a section of it separated to undertake indigo dyeing. Instances like this are rather exceptional; but this is probably only because the history of castes in so ill-documented, and not because such changes did not occur. Whenever the demand for the service of any profession was fairly powerful over a long enough period to make it advantageous for a caste, or a segment of it, to change its profession, the change would probably have always occurred. It would have mainly involved, perhaps, the assumption of a different traditional origin and the cessation of further marriage-ties with those who continued with the old craft.

It was not, therefore, any sacrcity of skilled labour brought on by the caste system, but its very opposite namely, its plenitude, that, as we have seen, constantly inhibited attention to labour and skill saving devices.

This inhibition would have been present whether the artisan was himself a commodity producer, as most often he was, or he was subjected in varying degrees to the merchant, so long as the conditions of domestic industry prevailed, that is so long as the artisan worked with his own tools in his hut or household.

Taking textiles, the major craft industry as an illustration, we can see that domestic conditions were practically universal. Even when the weaver produced for a long-distance market, he bought his own materials, worked at home, and then took his cloth, made according to commonly accepted specifications, to the market for merchants to buy. This was probably the most general practice, being reported from Lakhawar in Bihar to Thatta in Sind. A modification would be introduced, when a merchant, in order to ensure regular supply, gave advances either in money, or, rarely, in material. This, too, while subjecting the weaver to the merchant, had no effect on how the artisan worked; though if the merchant gave orders for unaccustomed specifications, the weavers might have had to alter their looms, and ask for money to meet the cost.

Finally, if the material to be worked was very expensive, or close supervision was needed to ensure manufacture to specifications, the artisan could be called up from his home and made to work in the *karkhana*, the employer's own workshop. The English factor Hughes established in 1620 a "Cor Conna" at Patna, for winding silk; he employed a hundred workmen and expected to keep two to three hundred silkwinders employed all the year round. Obviously, the practice was a common one; and subsequently the Dutch and the English followed it in their "silk factories" in Bengal.

The greatest separation from the domestic conditions seems to have been reached in the *karkhanas* of the court and the nobles where the costliness of material and variety of specifications for the needs of aristocratic consumption demanded close supervision.

Here then the artisan did not work at home, and so the labour of his family was not available. Since his employer was possessed of considerable resources, we may expect that labour-saving devices and improvements in technique might have been achieved.

Yet our knowledge of Akbar's imperial *karkhanas*, of which we obtain inestimable details from Abul Fazl's *A'in-i Akbari*, and of the Deccan diamond mines, where domestic conditions led necessarily to possibilities of technological improvement.

There is no evidence that a mere change from the artisan's "petty production" to employment by the aristocracy or mercantile capitalists had any significance for craft technology in Mughal India. In fact one could argue that the availability of cheap skilled labour prevented a true "capitalistic" organization, even when there were single men employing large numbers of persons on wages in productive undertakings. The conception that it was the obligation of the employer to furnish tools remained largely unborn; and this meant that there could be no investment by superior classes in potential machines.

It may first be suggested that if intellectual interests in technology had been greater than they were in Mughal India, mechanical improvements could have come from outside the range of purely economic impulses. After all, Cipolla has argued that modern industrial progress "accelerated dramatically (only) when the resources of craftsmanship were strengthened by the systematic application of scientific principles developed by more or less professional scientists". Whether this statement adequately explains the acceleration of technological change in the first but crucial phase of the English Industrial Revolution may be doubted. However it can be seen that in India the interest shown in technological matters by the educated strata of the population was very limited.

It is to be considered whether possibilities of development of technology were restricted, too, by the dependence of craft production on the vast system of agrarian exploitation in the Mughal empire. The towns and urban crafts subsisted on the large part of the agrarian surplus that was appropriated by the Mughal ruling class. There was no real exchange between town and country. The fortunes of commodity and therefore, *ipso facto*, craft production, were determined largely by the extent to which the Mughal system continued to function in a stable fashion. Once this system broke down amidst a severe agrarian crisis, during the latter half of the seventeenth century, the scale on which urban crafts had so far been pursued in the empire could no longer be sustained. Thus a technological backwardness was further compounded by an urban decline and a possible fall in the volume of craft production. This could not but set the seal on the future progress of technology in India.

23.13 SUMMARY

From the point of technology medieval period was significantly productive. The new technological devices brought by the Turks provided important impetus to Indian economy. The geared Persian wheel, on the one hand, made it possible to lift the water from much lower depths that eventually facilitated the expansion of agriculture in those areas as well where water table was comparatively low. On the other hand, new techniques in the field of textile production accelerated the production of coarse yarn. Considerable growth is also visible in the production of new crops. With new techniques of grafting quality of various varieties of fruits improved greatly. There was considerable development in sericulture.

However, there appears to have been comparatively less expansion in the areas of power and fuel technology. Indian backwardness in the field of glass manufacture is astonishing. Similarly, in the field of precision instruments screws were still crudely made. While India achieved greater accuracy in the field of astrolabes, there was little attempt to improve time reckoning devices. Paper began to be manufactured, but printing was not adopted.

23.14 GLOSSARY

Abul Fazl — Court chronicler and close associate of Akbar. He has number of works to his credit. The most important ones are: *Akbarnama, Insha-i Abul Fazl, Maktubat-i Allami*.

Bahar-i Ajam — A Persian dictionary written by Munshi Tek Chand 'Bahar' around 1739-40.

Barani, Ziauddin — A historian and theorist. He wrote *Fatawa-i Jahandari*, a work on state craft and *Tarikh-i Firuz Shahi*. Though *Tarikh* lacks in chronological details, it provides the most critical account of the Khalji and Tughuq periods.

Bushels — A bushel of wheat is = 60 lbs./27.21 kg.

Caulking and Riveting — Caulking is a technique of making joints leakproof by forcing oakum between parts that are not tightly fitted. In riveting planks are joined by making grooves or cut.

Congreve Rockets — Rocket developed in Britain under Colonel Congreve, 1805.

Drawloom — A developed variety of handloom with multiple sheds for weaving complex patterns.

Factory Records — Records of the East India Company's factories in India. These records mainly consist of consultations, Letters received, and copies of letters sent and collections of papers on particular subjects.

Flintlock — Handgun, with flint-lever to ignite gunpowder in the priming pan.

Kay, John — John Kay, an Englishman from Lancashire, invented flying shuttle in 1730 and got that patented in 1733. Kay's shuttle increased the speed of weaving yarn and now with Kay's shuttle it became possible to produce much wider cloth at a faster speed.

Khyber Pass — A 53 kilometers pass through the Sulaiman Range, connecting Pakistan and Afghanistan.

Ma Huan — Muslim interpreter of the famous Zheng He, admiral of the Chinese fleet. He belonged to Hui/Huihe group who were the Arab and Persian migrants settled in China (at Anxi in the present day Xinjiang).

Palaeotechnic Age — Age of Old Technology, based on wood as main component of tools and manual power as main driving force.

Pelsaert, Francisco — A factor of the Dutch East India Company at Agra, 1620-27. He wrote his *Remonstrantie* in 1626.

Pin Drum Gearing — Gearing based on wooden pegs on a wheel circumference enmeshing at right angles with vertical bars on a drum.

Roe, Sir Thomas — English ambassador to Jahangir 1615-19.

23.15 EXERCISES

1) Examine the development of agricultural technology during the medieval period.

2) In what respect Persian wheel and spinning wheel provided a big boost to the medieval economy? Analyse.

3) Discuss the growth of artillery under the Mughals.

4) Critically analyse the technology used in handling the basic tools and precision instruments during the medieval period.

5) Discuss the nature of technological change during the medieval period.

23.16 SUGGESTED READINGS

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