INDIAN TRADITIONAL KNOWLEDGE

Department of IT

4-Traditional Production and Construction Technology

Unit-2 Lecture-11

ny of the advances in the sciences that we consider today to have de in Europe were in fact made in India centuries ago.

-Grant Duff (British Historian of India)

earliest evidence of technological progress in the Indian sub-continen found in the remains of the **Harappan** civilization (4000-3000 B.C.).

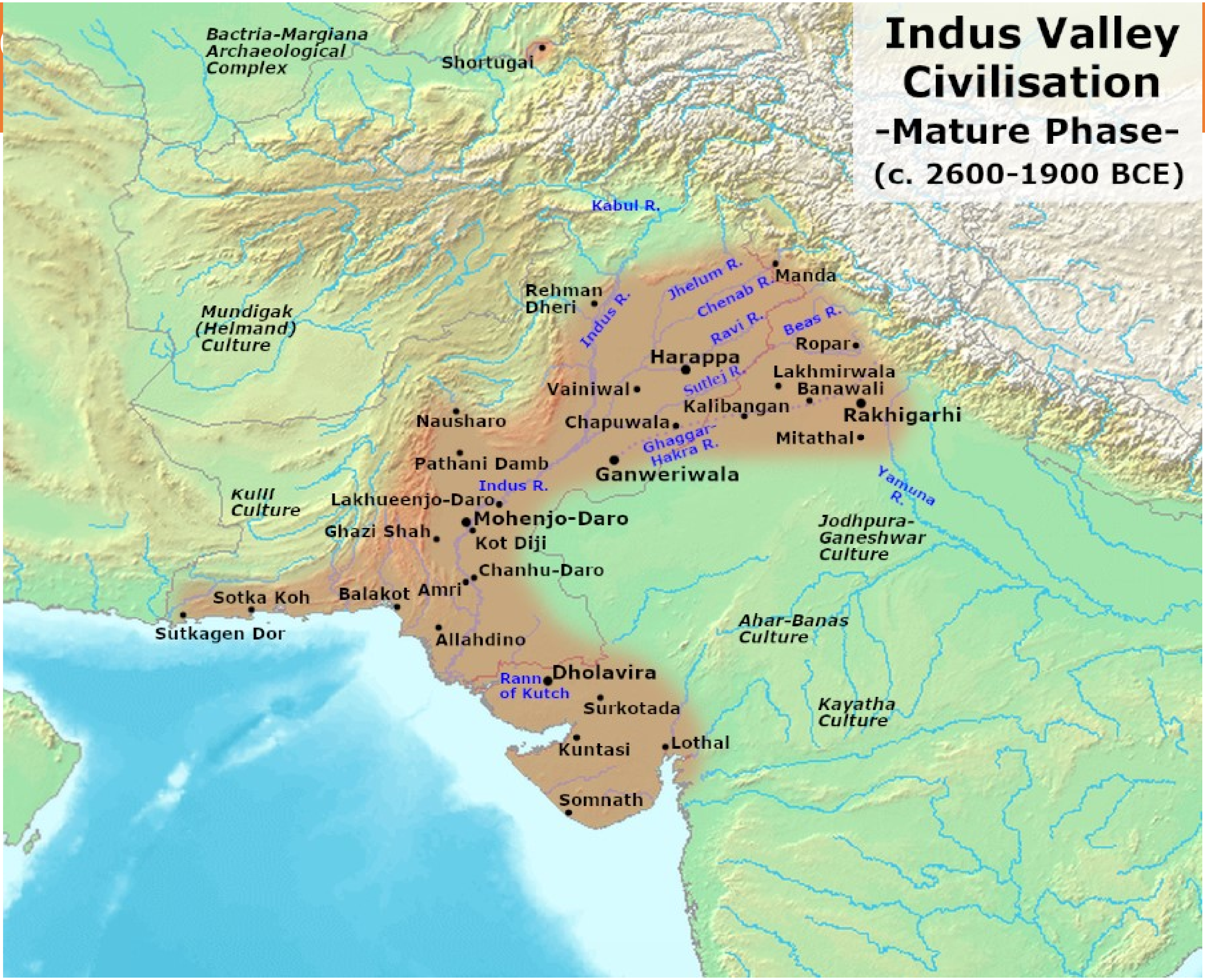
haeological remains point to the existence of well-planned urban c t boasted of private and public dwellings(living place/నివాసం) laid erly fashion along with roads and drainage systems complementing th

drainage systems were remarkable for the times since they wer lerground and were constructed in a manner to allow for regular clean

aller drains from private homes connected to the larger public drains.

ger private dwellings were multi-storied and all homes were const n standardized fired bricks and had separate cooking areas and toilets.

4-Tra



Indus Valley Civilisation
-Mature Phase-
(c. 2600-1900 BCE)
Bactria-Margiana Archaeological Complex
Shortugai
Kabul R.
Mundigak (Helmand) Culture
Rehman Dheri
Indus R.
Jhelum R.
Chenab R.
Manda
Ravi R.
Beas R.
Ropar
Harappa
Sutlej R.
Lakhmirwala
Banawali
Vainiwal
Kalibangan
Rakhigarhi
Nausharo
Chapuwala
Ghaggar-Hakra R.
Mitathal
Pathani Damb
Ganweriwala
Indus R.
Yamuna R.
Kulli Culture
Lakhueenjo-Daro
Mohenjo-Daro
Ghazi Shah
Kot Diji
Jodhpura-Ganeshwar Culture
Chanhu-Daro
Sotka Koh
Balakot
Amri
Sutkagen Dor
Allahdino
Ahar-Banas Culture
Rann of Kutch
Dholavira
Surkotada
Kayatha Culture
Kuntasi
Lothal
Somnath

rage facilities for grain and goods for trade were built as were public other buildings intended for various public functions.

an centres were often planned near riverine or seaports.

urate weights and measures were in use and ports such as Lotha eloped as export centres of early manufactured products from s ొగించింది)copper and bronze.

s(furnace) for smelting copper ingots(rods,..) and casting tools w stence as were metal tools such as curved or circular saws, pierced n most significantly, bronze drills with twisted grooves.

drill enabled the production of items with unparalleled precision and regarded as an ancient precursor of the modern machine tool.

re is also evidence of planned irrigation systems and it appears that fi od control measures to protect farms and villages were also in place.

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sans(శిల్పకారుడు) made use of the wheel and clay pottery was decorat
ety of colors and designs.

ton was grown and used to produce textiles.

an centres in the Harappan region traded with each other as well a
nterparts in Babylon(Iraq), the Persian Gulf, Egypt and possib
diteranean(South Europe/North Africa).

span of the Harappan civilization was quite extensive, and included m
dern Sindh, Gujarat, Rajasthan, Haryana, Punjab and Western UP.

prior to its disappearance, there is also evidence of considerable
ay and disintegration.

avations from the later phases of the Harappan civilization sugges
pulation pressures led to greater anarchy in building construction.

an dwellings became smaller and settlements became more hap
icating a breakdown of social mores (customs)

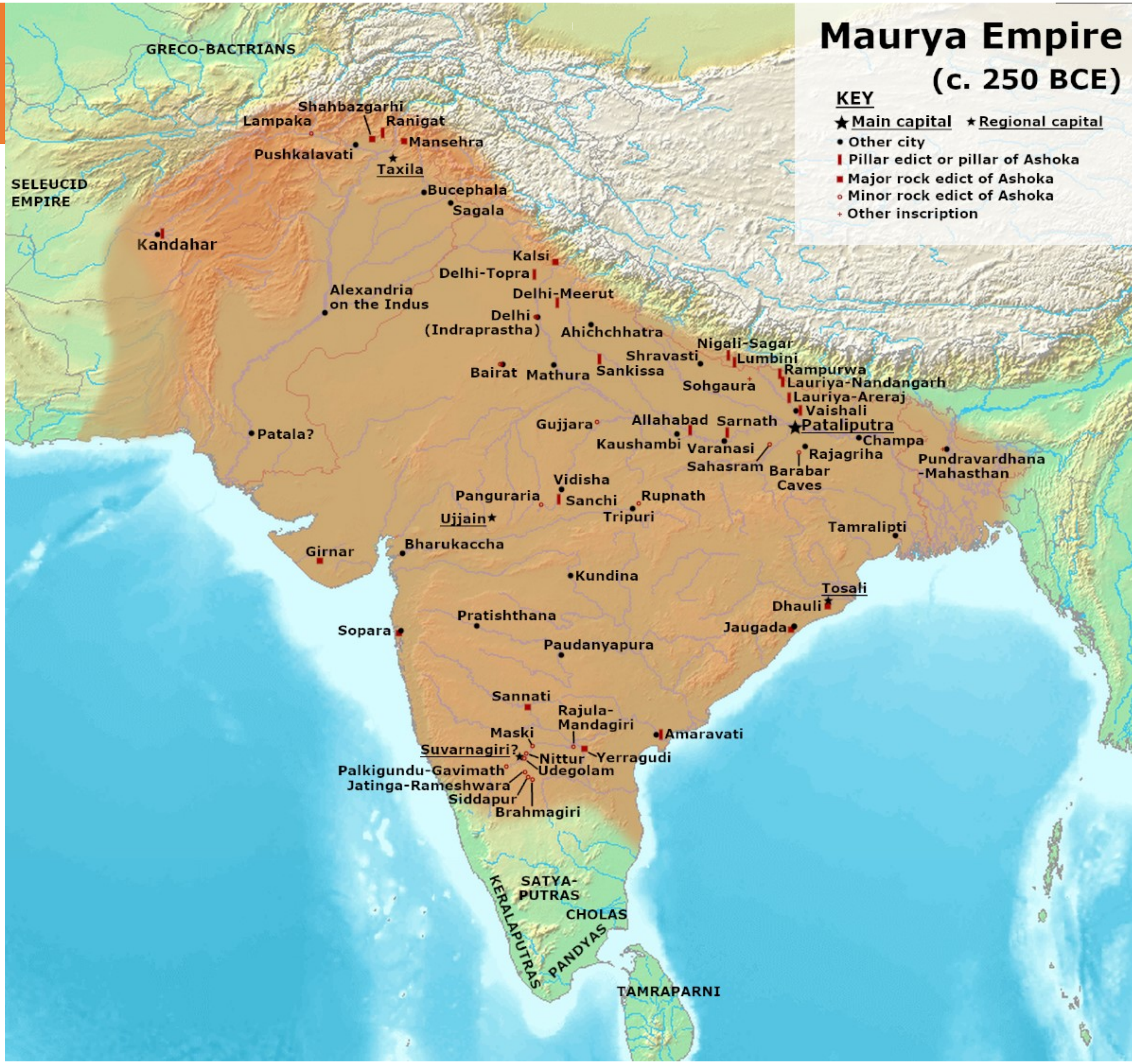
Conditions and Technological Progress

quite possible that the decline in civil society extended to other area agricultural planning and maintenance of irrigations systems maki lization more vulnerable to natural disasters such as droughts, flood earthquakes- thus contributing to the eventual extinction of that lization.

s suggests that technological progress cannot be divorced from ditions that may either encourage the progress of technology or con se civilizations that may be (in relative terms) quite advanced to st even decline.

instance, 3,000 years after Harappa, we find anecdotal(stories) evide pressive urban settlements constructed during the **Mauryan** period. vellers have left behind admiring descriptions of Patliputra--the M ital. But **social strife** brought a precipitous end to the grand civilizatio

4-Traditi gy



Maurya Empire
(c. 250 BCE)
KEY
Main capital
Regional capital
Other city
Pillar edict or pillar of Ashoka
Major rock edict of Ashoka
Minor rock edict of Ashoka
Other inscription
GRECO-BACTRIANS
SELEUCID EMPIRE
Shahbazgarhi
Lampaka
Ranigat
Mansehra
Pushkalavati
Taxila
Bucephala
Sagala
Kandahar
Kalsi
Delhi-Topra
Alexandria on the Indus
Delhi-Meerut
Delhi (Indraprastha)
Ahichchhatra
Nigali-Sagar
Lumbini
Shravasti
Bairat
Mathura
Sankissa
Rampurwa
Sohgaura
Lauriya-Nandangarh
Lauriya-Areraj
Vaishali
Patala?
Gujjara
Allahabad
Sarnath
Pataliputra
Kaushambi
Varanasi
Champa
Sahasram
Rajagriha
Barabar Caves
Pundravardhana -Mahasthan
Vidisha
Panguraria
Sanchi
Rupnath
Tripuri
Ujjain
Tamralipti
Girnar
Bharukaccha
Kundina
Tosali
Dhauli
Pratishthana
Jaugada
Sopara
Paudanyapura
Sannati
Rajula-Mandagiri
Maski
Amaravati
Suvarnagiri?
Nittur
Yerragudi
Palkigundu-Gavimath
Udegolam
Jatinga-Rameshwara
Siddapur
Brahmagiri
SATYA-PUTRAS
KERALAPUTRAS
CHOLAS
PANDYAS
TAMRAPARNI

e growth of a parasitic, exploitative and socially oppressive elite ssive social upheavals.

he course of the civil wars, fires and looting destroyed virtually all od-based dwellings including grand palaces and public buildings.

s, an entire tradition of wood-based urban construction (which ma en several centuries to develop) was destroyed.

it also led to a greater emphasis on the use of more lasting constr terials.

very social conditions that destroyed technological progress i ection gave birth to technological progress in another.

lptural finds from the Mauryan period indicate that Mauryan sculpt t time had achieved a high degree of proficiency in working with stone y must have had tools and implements that enabled them to oothly modelled and highly polished representations of human and res.

er civilizations in India employed these skills not only for the purpo lpting but also for creating entire monuments constructed from a var d building materials.

instance, various methods for preparing cements were developed, a 7th century, cement of highly durable quality came into use struction of important monuments that survive to this day.

npetus for Metallurgy

numental architecture required considerable advances in the techno ng, loading and transportation, building construction ramps, scaffoldin ted tools and implements. As in ancient Egypt or Babylon, appro nniques also had to be developed and implemented in India.

4-Traditional Production and Construction Technology

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more importantly, stone-based construction presupposes the existe
d metal-based tools and implements for cutting and shaping stone.

discovery of iron thus played an essential role in the developm
numental architecture in India, which may have in turn given a f
petus to the development of metallurgical skills.

early as the 4th century B.C., Kautilya's(Chanakya) Arthashastra
tion' outlining the processes for metal extraction and alloying.

er Sanskrit texts talk about assessing metal purity and describe tech
achieving metal purity.

5th century Iron Pillar of Delhi is a remarkable example of those
nding over 23 feet high it consists of a single piece of iron and has wea
r 1500 monsoons without showing any signs of rust. The pillar is m
ought iron with an iron content of 99.72 per cent and appears to have
tected from rust by the application of a thin coating of manganese dio

4-Traditional Production and Construction Technology

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the 12th century, construction engineers were using iron girders and a scale unknown in any other part of the world.

most significant use of iron beams was in the temples of Puri and Ko Puri temple contains 239 iron beams and one of the beams in Konara t long.

are 99.64 per cent iron and were produced in a similar manner to the n pillar.

ring the middle ages, India acquired a reputation for producing ver lity steel and was also able to extract zinc from its ore by the 14th cen

ious alloying techniques were in use and Abul Fazl in Aini Akbari me coating of copper vessels with tin.

ari (an alloy of copper, lead and tin developed in the Deccan) wa ensively used.

surprisingly, developments in metallurgy also had their impact on a
duction.

ording to A. Rahman (Science in Medieval India), by the 16th centu
viest guns in the world were being cast in India and a variety of we
re being manufactured in the sub-continent.

Jaigarh cannon factory was one of India's best and before the crucial
857, the Jaipur Rajputs laid claim to owning Asia's largest cannon.

Needs and Technological Applications

re often than not, social needs (as arising from geographic, climactic o
ditions) have been the primary impetus for technological progress in s

long dry months that most regions of India had to deal with,
nerous innovations in water-management techniques.

gation canals, wells of different types, storage tanks and a variety of
vesting techniques were developed throughout the sub continent.

Harappans were not alone in creating water management sol
gation works of enormous size were undertaken time and time again.

reservoirs at Girnar in Kathiawar (south Gujarat) (built in the 3rd c
.) had an embankment over 100 feet thick at the base.

artificial lake at Bhojpur (near Bhopal) commissioned by Raja Bhoj
h century covered 250 sq. miles.

he South, also in the 11th century, an artificial lake fed by the Kave
a 16-mile long embankment with stone sluices and irrigation channel

out kings built artificial lakes throughout the desert state of Rajastha
gation schemes were essential to agricultural prosperity even in Ka
gal and the delta regions of the South.

4-Traditional Production and Construction Technology

Unit-2 Lecture-12

need for accurate prediction of the monsoons spurred developme ronomy while the intense heat of the summer led to innovati hitecture.

Rajasthan and Gujarat step-wells were built deep into the ground-som cending as much as a hundred feet.

ge-scale observatories were built in Benaras, Mathura and Ujjain to fa ances in the astronomical sciences.

ngal became known for its fine muslins that were light and airy to wear rm and humid climate of the state.

hniques for pickling and preserving fruits, vegetables, fish and meat eloped throughout the country to prevent or delay spoilage.

nually operated cooling devices were also invented. The Artha ntions the variyantra (probably a revolving water spray for cooling the

4-Traditional Production and Construction Technology

Unit-2 Lecture-12

ific Rationalism and Technological Efficacy (success)

technological progress also requires a favorable social milieu (backgro

foundation of scientific knowledge, rational thinking and pr erimentation can be essential to the process of making techno coveries.

s is not to say that Indian society was entirely rational.

ll ancient societies (and even modern ones), superstitions, religious b ance on astrology, numerology or the advice of seers', palmists and fo ers have impinged on the scientific process and consequently hinder gress of technology.

the civilizations of ancient Egypt, Babylon and India-we see nur ances of scientifically accurate statements and practical truths mix n religious myths and popular superstitions.

s was especially true in the science of medicine. Genuine cures were
n unscientific practices without clear distinction.

vas the more determined adoption of the scientific approach that e
'an medicine to make a quantum leap over the older medical systems
e.

gress in medicine also led to developments in chemistry and ch
nnologies.

manufacture of alkaline substances, medicinal powders, ointmen
ids was systematized, as were chemical processes relating t
nufacture of glass.

vances in food processing (such as manufacture of sugar, condiment
stard,..) and edible oils) took place as did the manufacture of pe
iene products and beauty aids (such as shampoos, deodorizers, pe
cosmetics).

al Mores (norms/rules) and Technological Innovation

tural preferences also impelled technological innovations.

analysis of moods and emotions led to elaborate theories on the
or and design in inducing psychological well-being.

atises on art and architecture emphasized the importance of colo
ult, the use of color in decorating household artifacts, textiles, furnitu
blic and private dwellings became widely prevalent and a matter of co
ice.

coveries concerning the manufacture and application of natural and a
s quickly followed.

ck printing, tie and dye, and other textile-dyeing techniques
pularized.

use of mordants(for dyes) in color-fast dyeing of textiles became kno knowledge of lacquers that could be applied to wood or leather.

nts that could be used on different building materials were develope
porate techniques were employed to prevent fading and loss of color
heavy monsoons.

ntings in the Ajanta caves have survived almost 1500 years, but what i
re noteworthy is how the paint on some of the exterior sections of
nples has survived 1200 years.

richness of color is well-preserved. Indian miniatures continues to
astonish.

nay be noted that for many centuries, color-fast dyes made up an imp
nponent of India's exports, and export of these to ancient Rome ha
umented in Roman records.

4-Traditional Production and Construction Technology

Unit-2 Lecture-12

Support of Technology

hout the support of technologically inclined nobility(kings), without m the royal treasuries, many of the technological developments tha ce in the field of water-management, construction and metallurgy uld not have taken place.

gress in astronomy also benefited from active state support.

a Bhoja (1018-60 of Dhar, Malwa, Madhya Pradesh) who was himself a ineer and was the architect of Bhojsagar-(one of the largest a gation lakes of medieval India) was a great patron of engineering proje

outed to be a fine scholar, he was well-educated in the sciences and th was responsible for the commissioning of a university (Bhoj Shala) at

eral monumental temples in the Malwa region, including one at Bh ch has a cast iron Shiva Linga of very impressive proportions.

wing town planning as an important aspect of government, he prov
ailed network of roads connecting villages and towns in his magnun
ster piece), Somarangana Sutradhara(book).

book also included chapters on mechanical engineering, soil t
entation of buildings, the selection of building material, architectural
the vertical and horizontal components of buildings.

book also describes machines and mechanical devices such as c
onometers (putrika nadiprabodhana), and in his Yuktikalpataru, Raja
o warned ship-builders about using iron along the bottom of the vess
would render them vulnerable to magnetic rocks at sea.

wever, state support for technological innovation was not
hcoming and depended considerably on the attitude of individual rule

and large, **arms manufacturing and the production of luxury goods re
maximum support from the rulers**.

4-Traditional Production and Construction Technology

Unit-2 Lecture-12

ghal rulers like Akbar and Aurangzeb invested heavily in the produc llery and other weapons as did some of the Rajputs and the Deccan ki

estments were also made in high quality manufactured goods that or in the courts such as fine textiles, carpets, lamps, glassware, marb ne quarrying, jewelry, decorated metalware, etc.

cialized manufacturing towns were promoted almost throughou ntry.

tions of Pre-industrial Manufacturing

hough Indian artisans could produce goods of exceptional quality, **nufacturing (much of the world also) was highly labor intensive**.

re was **insufficient investment in** augmenting and expanding the ra ilable **labor-saving tools**, manufacturing in medieval India in siderable specialization of labor.

4-Traditional Production and Construction Technology

Unit-2 Lecture-12

ia had a very large pool of relatively cheap skilled labor trained in a var
cialized tasks.

ce **most manufactured goods catered largely to the elite, deman
ntively limited** and the available labor pool was more than sufficient to
se needs.

nplacency ruled the day. India's great manufacturing strengths thus b
gnificant obstacle in transitioning towards the modern industrial era.

ere demand growth was considerable, there were successful attem
proving manufacturing techniques. The textile industry was one
ustry where steady improvements in manufacturing technology took p

ian textiles commanded a worldwide market and prior to coloni
ia's manually operated textile machines were amongst the best in the
 the **early textile machines produced in newly industrialized Brita
rmany were modelled on the best of these Indian machines**.

huge demand for Indian exports also gave a fillip to the ship-buildi kaging industry and during the 18th century, the Wadias of Bomba ding ships as good as any in the world.

and the Industrial Revolution

haps the most important **forces that inhibited the growth of scien nnology in India was the relative prosperity that India enjoyed** vis-à- of the world.

mild climate meant that the peasantry and **working class could s tively cheaply**. And the **huge trade surplus** the country enjoyed enab ility and the middle classes **to live lives of relative luxury and comfor**

forces of parasitism and conservatism prevailed over more radical for

ry (Officer of the East India Company) described Bengal "The farm y, the artisan encouraged, the merchant enriched and the prince sati

in Europe, virtually all classes had an interest in bringing olutionary changes that could improve their lives.

g and harsh winters meant that even the peasantry and workin **eded more items of personal consumption just to survive**, let alo nfortably.

demand for cheap manufactured goods for mass consumptio ially far greater in Europe than in the warmer parts of the globe.

short days in the **long and harsh winters created a much more com ed for breakthrough inventions like the light bulb or electric heater o water and indoor toilets**.

centuries, the **Catholic Church in Europe had preached** the ideol rldly renunciation and taught its followers **to accept their earthly suffe** hange for a promise of redemption in the next world.

ional and scientific thinking was routinely condemned as sacrilegi
esy(opposite to orthodox). It was then little wonder that Europe had s
a period of intense stagnation and became inordinately depend
orts from the more developed nations of Asia.

it was precisely **this backwardness and internal oppression that l**
ss radicalization and calls for revolution or reform.

protestant movements were the first in a **series of movements call**
ater democracy and radical improvements in social conditions.

the same time, the European intelligentsia was no longer willing to w
emption after death but wanted to enjoy the good life right here on ea

ence and philosophy gradually liberated from the strangulating influ
rch. The knowledge of the East was translated in European languag
nd its way into university curriculums.

entific research and investigation began to thrive and techno
ovations followed. All the ingredients for the industrial revolution
inning to fall into place.

at first, **Europe still lacked a vital ingredient for industrial revolut** e off and succeed and **that was 'capital'(Money/wealth)**. For cen ope had to fund its negative trade balance (vis-à-vis Asia) by exportin er and precious metals.

make matters worse, exports from India (which made up an important uropean imports) heavily marked up by various intermediaries in the later by the Venetians.

the **15th century, this burden was becoming almost impossible** for th uses of West Europe to bear. It was **in response to this crisis that voya cover a new route to India were funded**, and eventually led to the cr he East India Companies.

pillage and plunder of the Americas (and later Africa as well) pla
nificant role in financing these voyages.

ile this made imports from India more affordable, it did not elimina
ative trade balance. European banks were initially not in a position t
new inventions that were waiting to find industrial sponsors.

onization provided the answer(wealth). Europe thus embarked
nplex transition where within its borders it followed a path of progre
ical reform, but externally, it raped and pillaged without mercy.

s occurred at a time when the rest of the world was largely ill-equip
ling with such a wily and complex enemy.

much of the world, large sections of society were moving in the op
ection (negative) and particularly so in the Islamic world. Mad
sted numerous attempts at introducing anything resembling scienc
son in the curriculum.

s was also true **in India**. In spite of repeated attempts by Akbar to intr ecular curriculum in the nation's Madrasahs, **the conservative cessfully resisted all attempts at change.**

ilar processes were at work in **many of the Buddhist monasteries a du Gurukuls who had succumbed to the influence of orthodox Vedar**

extreme versions of the **Vedantic world view the real world was m sion, and hence all efforts at changing it or transforming were d mportant**.

n in schools that escaped Vedantic influences, and where science an nained a part of the curriculum, religious instruction often took preced

ddition, **Brahminical notions of purity created a needless divide**, c tacles to experimentation and transfer of theoretical knowledge to pr lications. The fixation on astrology and other such superstitions also listract sections of the intelligentsia from more scientific pursuits.

4-Traditional Production and Construction Technology

Unit-2 Lecture-13

ust as **Europe was preparing itself to meet the challenges of the ind olution**, significant sections of society in **Africa and Asia were bec re resistant to studying science**.

s made the process of colonization much easier as those who re onization were technologically outmatched and outwitted.

ce colonization had taken hold of a nation's economy, educational c ame further limited. Often, the few who were keen to pursue a career ences could only do so under the auspices of their colonial masters.

Western educated individual played an important role in the c cess either as a manager or engineer in a company that produced che terials (or industrial goods) for export from the colony to the master na

as a representative of an import agency that imported exp nufactured goods and machinery into the colony.

great was this contradiction in some nations that science and tech ost came to be associated with treachery(betrayal/ ద్రోహం) and re curantism (deliberately hiding/అస్పష్టత) became synonymous riotism.

a result the masses were often denied the opportunity to deal w ustrializing Europe on anything even remotely resembling equality.

ny of the technological developments that have since taken place ir e been geared more towards the export market than bringing abo nd improvements in the quality of life for the Indian masses.

y when India is able to harness the power of technology and m ustry towards improving the quality of life for the vast majority of its p n we can say industrial revolution took place.

t will require not only major advances in the Indian education syste **ical social changes have yet to take place** in a systematic way.

ove all, the forces of religious fundamentalism, religious obscurantis
ial backwardness will have to be pushed back and defeated.

t is the real lesson of the industrial revolution that has yet to s
npletely in India.

5-History of Physics and Chemistry

Unit-2 Lecture-14

t Indian theories lacked an empirical(verifiable) base, but they were b
ative explanations of the physical structure of the world, and in a
re, agreed with the discoveries of modern physics.

-A.L. Basham, Australian Ind

all early civilizations, the study of the physical sciences was n
malized nor separated from other branches of knowledge.

most cases, **technological discoveries** took place without any knowle
underlying scientific principles, **through hit and trial, and by experien**

predominant focus remained on the utilitarian aspects of the technic
ctical efficacy(success), as opposed to how and why something wor
n't work.

ndia, the earliest applications of **chemistry** took place in the cont
dicine, metallurgy, construction technology (such as manufactu
nent and paints) and in textile production and **dyeing**.

5-History of Physics and Chemistry

Unit-2 Lecture-14

ural phenomena were studied in the context of **tides, rainfall, appe the sun, the moon and stellar formations, changes in season, w terns and agriculture**.

instance, Vedic literature mentions the condensation of water vapou s and oceans due to evaporation (caused by the sun's heat) ar sequent formation of clouds and rain.

s naturally led to theories about physical processes and the forces of t are today studied as specific topics within the fields of chemist sics.

ophy and Physical Science

ile it is hard to say **which precedes** which-**theory or practice**.

arly there is a dialectical (opposing) relationship between both, ar lect of either leads to the death of science.

5-History of Physics and Chemistry

Unit-2 Lecture-14

gious beliefs, particularly **religious taboos**(forbidden) and irr
octrination(teaching a set of beliefs) towards mystical or r
enomenon, or adherence to false superstitions can often pose as s
pediments(**obstruction**) to the advance of science, and play an imp
e in whether the **why and the how of physical causes** can be safe
fully explored.

ieties that believed that **only the “Gods" knew** the secrets of natur
t it was futile(useless) for humans to attempt to unravel the mysteries
verse were naturally **incapable of making any substantial progress**
lm(domain) of the **sciences**.

n in societies where there were no formal religious taboos in underst
l-world phenomenon in a scientific way, **the power and the influence**
ests could serve as **an obstacle to scientific progress**.

5-History of Physics and Chemistry

Unit-2 Lecture-14

ile **ancient India** did not generally suffer from the first affliction (of re
oosition to science), it did **suffer from** the second (the proliferation of
l **superstitions**).

progress of science in India was thus inextricably linked to challenges
nination of the priests, and resistance to the proliferation of ritua
rifices.

s therefore no accident that, by and large, **developments in scienc**
nnology came in parallel with the advance of rational philosophy in In

the scientific texts Vaisheshikas (6th century B.C. or earlier), there
imentary attempt at recording the physical properties of different ty
nts and natural substances. There was also an attempt at summarizin
sifying the observations made about natural phenomenon.

5-History of Physics and Chemistry

Unit-2 Lecture-14

uitive formulations and approximate theories about the composit
tter and physical behavior followed.

s, the earliest applications of physics and chemistry in India (as in
ient societies) took place without involving much theoretical knowle
ght into these branches of science, there were elements of basic sc
estigation and scientific documentation in these early rational treatises

mitive and tentative as these steps were, they were nevertheless cru
nanity reaching its present stage of knowledge in the fields of p
mistry, botany, biology and other physical sciences.

e Physics

hough particle physics is one of the most advanced & complicated bra
nodern physics, earliest atomic theories are at least 2500 years old.

5-History of Physics and Chemistry

Unit-2 Lecture-14

ndia, virtually every rational school of philosophy (whether Hindu, Bu
ain) had something to say on the nature of elementary particles, and v
ools of thought promoted the idea that **matter was composed of**
t were indivisible and indestructible.

er philosophers further elaborated on this notion by positing that
ld not only combine in pairs (dyads) but also in threes (triads)—and th
aposition(comparision) of dyads and triads determined the di
sical properties of substances seen in nature.

Jains also postulated that the combinations of atoms required s
perties in the combining atoms, and also a separate "catalyst" atom.

this way, the earlier atomic theories became converted into a mo
ory of matter.

5-History of Physics and Chemistry

Unit-2 Lecture-14

ile many details of these theories no longer stand the test of sc
dity, there was much in these formulations that was conceptually
anced and sophisticated for its time.

development of the Jain molecular theory appears to parallel pr
elopments in other fields such as medicine or metallurgy where th
of catalyst had been observed and carefully documented.

an medical texts had postulated that proper human digestion ar
cessful absorption of medicinal pills and potions also required the pr
catalytic" substances.

requirement of catalytic substances relating to the **manufacture o**
alkalis (relevant to medicinal and surgical applications) had also
umented, as had the role of suitable **catalysts in metallurgical proc**
in the manufacture of **colorfast dyes**.

5-History of Physics and Chemistry

Unit-2 Lecture-14

ay, a variety of minerals, vitamins and enzymes have been identif
ying a key role (as catalysts) in a range of essential chemical processe
e place in our bodies, as do catalytic compounds in other physical proc

mic/molecular theories were also utilized in (albeit speculative) explan
hemical changes caused by heat.

sastapada(6th century B.C Indian philosopher) proposed that the
at) factor affected molecular groupings, thus causing chemical changes

Pilupakavada theory, as proposed by the Vaisesikas(Indian sch
osophy) held that the application of heat (through fire, for ins
uced the molecules of the earthen pot into atoms; and the con
lication of heat caused the atoms to re-group creating new molecules
erent color.

Pitharapakavada of Nyayikas (of the Nyaya school) disagreed wi
ory that molecules are breaking up into atoms.

5-History of Physics and Chemistry

Unit-2 Lecture-14

harapakavada suggested that the molecular changes transformation ce without a breakdown of the original molecules into basic atoms, a t if that happened, there would also have to be a disintegration of t lf, which remained intact, but only changed color.

intuitive understanding of kinetic energy appears in the te sastapada and the Nyaya-Vaisesikas who believed that all atoms we e of constant activity.

concept of parispanda was propounded(presented) to describe lecular/ atomic motion, whether it be whirling, circling, or harmonic.

and Sound

earliest of the Indian rationalists also attempted to provide theories ure of light and sound. Like the ancient Greeks, the eye was assumed t rce of light by the early Indian philosophers, and this error wasn't cor il the **1st century A.D. by Sushruta**.

5-History of Physics and Chemistry

Unit-2 Lecture-14

hruta posited(put forward) that it was light arriving from an external the retina that illuminated the world around us. (**Aryabhatta in th tury** reiterated this.)

earlier philosophers were more on the mark, with **Chakrapani sugg t both sound and light traveled in waves**, but that light traveled at a her speed.

ers like the **Mimamsakas imagined light to comprise of minute pa** w understood to be **photons**) in constant motion and spreading th iation and diffusion from the original source.

wave character of sound was elaborated on by Prastapada othesized that sound was borne by air in increasing circles, **similar vement of ripples in water**. Sound was understood to have it ection-**pratidhvani (echo)**.

sical pitches (sruti)** were seen as **caused by the magnitude and freq vibrations.** A **swara (tone)** was believed to consist of a sruti (fundar e) and some anuranana (partial tones or harmonics).

he **6th century Varahamihira** discussed reflection as being caused b ticles arriving on an object and then back-scattering.

syayana referred to this phenomenon as **rasmi-paravartana**, ar cept was adapted to explain the occurrence of shadows and the opaci nsperant) of materials.

raction was understood to be caused by the ability of light to per er spaces of translucent or transparent materials and **Uddyotakara** c nparison with fluids moving through porous objects.

al-Haytham (10th Century A.D.) has been credited with advanced the ics using light rays, diagrammatically explaining the concepts of ref refraction.

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Unit-2 Lecture-14

opears that **Ibn al-Haytham** was familiar with the writings of **Aryabhat**

nomy and Physics

t as the study of Mathematics in India received an impetus from the st
ronomy, so did the study of Physics.

abhatta (5th-6th century) made pioneering discoveries in the rea
netary motion. This led to advances in the definition of space and
asuring units.

ich helped in **better comprehension of concepts such as gravi
tion and velocity.**

instance, **Yativrasabha's work Tiloyapannatti (6th century)** gives v
ts **for measuring distances and time** and also describes a system of **i
e** measures.

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re significantly, **Vachaspati Misra (circa A.D. 840)** anticipated soli
inate) **geometry** eight centuries before Descartes (A.D. 1644).

his **Nyayasuchi-nibandha**, he states that the **position of a particle in**
ld be calculated by assuming it relative to another and **measuring**
ee (imaginary) axes.

study of astronomy also led to a great interest in **quantifying very**
l very small units of time and space.

solar day was considered to be made up of **19,44,000 kshana** (u
e), according to the **Nyaya-Vaisesikas**. Each kshana thus correspond
4 seconds.

truti was defined as the smallest unit of time, i.e. 2.9623 x 10
asastra records the **smallest measure of length** as the **paramar**
49525 of an inch.

s measurement corresponds to the **smallest thickness** of the Nyaya-Va ool-**the trasarenu**, which was the size of the smallest mote(tiny ble on a sunbeam as it shone into a dark room.

ahamihira (circa A.D. 6th century) posited that **86 trasarenu** were eq e **anguli**, i.e. **three-fourths of an inch**. He also suggested that **64 tras** re **equal to** the thickness of a **hair**.

ws of Motion

hough the earliest attempts at classifying different types of motion de by the **Vaisesikas**.

sastapada took the study of the subject much further in the **7th c** ., and it appears that at least some of the concepts he enunciated mus erged from a study of planetary motion.

addition to linear motion, **Prasastapada also described curvilinear m mana), rotary motion (bhramana) and vibratory motion**.

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sastapada also differentiated motion that was initiated by some ex
on from that which took place as a result of gravity or fluidity.

was also aware of motion that resulted from elasticity or momentum
opposite reaction to an external force.

the **10th century Sridhara** reiterated what had been observ
sastapada, and expanded on what he had documented.

skaracharya (12th century), in his **Siddhanta Siromani and Ganitad**
k a crucial first step in quantification, and measured average velocity
(where v is the average velocity, s is distance covered, and t is time).

their time, Prasastapada's work, and Sridhara and Bhaskaracharya'
orations ought to be considered quite significant.

wever, one of the weaknesses of later Indian treatises was a failure to
with further attempts at quantification and conceptual elaboration.

instance, several types of motion had been earlier assigned to u
ses. There was no subsequent attempts to solve these mysteries, whi
ne by **Newton** a few centuries later.

mentation versus Intuition

14th century, Merton scholars at Oxford developed the conce
elerated motion (an important precursor to the understanding that f
ss acceleration) and measurement and quantification of heat in a rod.

e of the hallmarks of British (and European) science thereafter w
on of theory and practice, unlike the generally intuitive approach fo
ndian scientists.

nt up to the 16th century, Indian scientists continued to record
ntific observations, but without serious attempts at quantificati
per investigation into the physical and chemical causes of wha
erved.

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gnetism is referred to by Bhoja (10th-11th century) as well as by S
ra later.

ayana (10th-11th century) recognized solar heat as the heat-source
mical changes, and also that air had weight in a discussion of balloons
nawali.

abhacharya (13th century) in his Nyaya-lilavati pointed out the resista
ter to a sinking object, but did not go on to discuss the principle any fu

kara Misra (15th-16th century) noted the phenomenon of electr
action.

also recorded some awareness of the concept of kinetic energy and
askara dwelt on the properties of heat, and tried to relate the proc
ing to evaporation.

he same treatise, Sankara Misra also gave examples of capillary motion

kara Misra Cited the ascent of sap(liquid in a plant) from root to ste
nt and the ability of liquids to penetrate porous vessels.

also wrote about surface tension, and posited sandrata (viscosity)
se behind the cohesion of water molecules and the smoothness of
lf.

ocial Milieu(background)

unlike **in astronomy, where many Indian scientists got very int
olved**, and were driven to work towards a **considerable degree of acc**
such compulsions appeared to guide Indian scientists in other fields.

other fields of scientific investigation, Indian scientists seemed to
tent with intuitive and general observations, tolerating a far greater
agueness and imprecision.

answer to this inconsistency may lie in the social milieu.

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Unit-2 Lecture-15

study of astronomy was triggered partly by practical considerations s need for accurate monsoon prediction and rainfall mapping, but p n more so, by the growing demand for "good" astrologers.

obsession with astrological charts-both amongst the royalty and mer sses led to considerable state patronage of intellectuals who wish sue the study of astronomy.

ronage was also available for alchemists for those attempting to disco xir" (magical or medicinal potion) of life. But support for modern sc earch was generally lacking.

situation prevalent in 15th-16th century Italy was not significantly dif Leonardo Da Vinci (1452-1519) was particularly frustrated that the sufficient interest in his many inventions.

Da Vinci was convinced that dedication to scientific truth would eve vail.

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a Bhoja's Somarangana-sutradhara (circa A.D. 1100) describes many chanical inventions, and the use of levers and pulleys is descril nerous other Urdu, Persian and Arabic texts in India and the Middle Ea

Vinci's notes on mechanics, the study of levers of different kinds, canti eys and gears in combination, varied gadgetry, bridges, and studies o re of a truly pioneering nature, and exceeded in complexity and bread l and mechanical engineering treatise that had preceded him.

l even though in his time, Da Vinci's works were not especially appre a century later, the ideas of Da Vinci and Francis Bacon (15-16th c land who stressed the importance of the experimental method in sc re able to blossom and flourish.

at the same time in India, several factors posed as hindrances elopment of modern science. India enjoyed a milder climate, ar duction of necessities was deemed sufficient to satisfy the population.

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courts-whether Mughal or regional spent a good part of the asuries on cultivating the fine arts and promoting the manufacture of ods and decorative objects of exquisite beauty.

ence and technology simply attracted little attention (except when it ca proving the tools of war).

growing influence of religion-whether Quranic or Brahminical also ative effect.

ile the Quran claimed that all the world's knowledge was already des t, Brahminical orthodoxy prevented scientists from going beyond ervation and intuition to practical experimentation, active theorizi ntification.

ereas Akbar and Jehangir were not averse to science, and the latter ve interest in books on botany and zoology, it appears that Aurangzeb idedly skeptical attitude towards the sciences.

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Unit-2   Lecture-15

hough some patronage was available in the regional courts (and outsi rts), alchemy, astrology, study of omens, numerology and other onal and irrational traditions drew much more attention, and thus dist n genuine scientific pursuits.

the other hand, European scientists drew on the best works produced t-studying foreign documents with due diligence, often accepting li e value-but instead verifying the results with apparatus and sc asuring tools of their own creation.

over time (due to both internal and external factors)-India's scientifi eroded. Thus, Europe was not only able to catch up with the knowle ia and the East, it was able to rapidly surpass it.

ce independence, Indian scientists have been provided the opportu rowing the gap, and in some fields have done especially well. Howev lity of science education for the masses needs considerable improvem

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study of the physical sciences in India needs to be accompanie ctical demonstrations and more experimentation, as is common prac West.

many instances, tools and apparatus used to demonstrate and qu entific phenomenon need to be modernized or improved.

terms of pedagogy, the standard Western texts are not always as en, the teaching of physics and chemistry becomes too esoteric(need wledge) for the average student.

re is excessive abstraction in most textbooks, and undue theo nplexity is thrust upon relatively young students.

contrast, the Indian approach with its stress on observation of enomenon, and epistemological (justified belief VS opinion) appro lerstanding each field are much easier for beginners and interm dents.

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ce the student understands the basics, and develops a good intuitive ceiving scientific phenomenon-the complexities and mather tractions can follow.

world of the physical sciences can be opened up to more than just t o are able to transcend the complexities and difficulties that accompa dy of these branches of science today.

vould be surprising for many Indians today to know that the conce m (Anu, Parmanu) and relativity (Sapekshavada) were explicitly stated ian philosopher nearly 600 years before the birth of Christ.

se ideas had been developed in India in a very abstract manner, a onents were not physicians. They were philosophers and their ideas physical reality were integrated with those of philosophy and the ture of God).

ve Basic Physical Elements

m the Vedic times, around 3000 B.C. to 1000 B.C., Indians (Indo-Aryar sified the material world into four elements, viz. Earth (Prithvi), fire (Maya) and water (Apa).

hese four elements was added a fifth one, viz. ether or Akasha.

ording to some scholars these five elements or Pancha Mahabhoota ntified with the various human senses of perception; earth with sm n feeling, fire with vision, water with taste and ether with sound.

Buddhist philosophers who came later, rejected ether as an eleme laced it with life, joy and sorrow.

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Ideas about Atomic Physics

ce ancient times Indian philosophers believed that except Akash (eth
er elements were physically palpable and hence comprised mi
ticles of matter.

last miniscule particle of matter, which could not be sub-divided, f
s termed Parmanu. The word Parmanu is a combination of Param, m
ond, and anu meaning atom.

ian philosophers in ancient times had conceived the possibility of split
m, which, as we know today, is the source of atomic energy.

s Indian concept of the atom was developed independently and prior
elopment of the idea in the Greco-Roman world.

first Indian philosopher who formulated ideas about the atom
tematic manner was Kanada who lived in the 6th century B.C.

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other Indian philosopher, Pakudha Katyayana who also lived in th tury B.C. and was a contemporary of Gautama Buddha, had pounded ideas about the atomic constitution of the material world.

se philosophers considered the atom to be indestructible and hence e Buddhists believed atoms to be minute objects invisible to the nak which come into being and vanish in an instant.

Vaisheshika School of philosophers believed that an atom was a mere pace.

us, the Indian theories lacked an empirical(verifiable) base, but in the A.L. Basham, the veteran Australian Indologist, "They were b ginative explanations of the physical structure of the world, and in asure, agreed with the discoveries of modern physics."