India Discovery Center

Study of the Hindu Period (500AD-1500AD)

Science and Technology

Bijoy Misra

References:

Classical texts:

Astronomy:

Aryabhaṭṭiyam (आर्यभट्टियम्) - Aryabhaṭṭa – 5th century AD

Vṛhatsaṁhitā (वृहत्संहिता) – Varāhamihira – 6th century AD

Siddhāntaśiromaṇi (सिद्धान्तशिरोमणि) – Bhāskara II – 12th century AD

Mathematics:

Brahmasphuṭasiddhānta (ब्रह्मस्फुटसिद्धान्त) – Brahmagupta – 7th century AD

Gaṇitasārasaṁgraha (गणितसारसंग्रह) – Mahāvīrācārya – 9th century AD

Siddhahemaśabdānuśāsana (सिद्धहेमशब्दानुशासन) – Hemachandra - 12th century AD

Language:

Vākyapadīyam (वाक्यपदीयम्) - Bhartṛhari – 5th century AD

Dhvanyāloka (ध्वन्यालोक) – Anandavardhana – 9th century AD

Abhinavabhāratī (अभिनवभारती) – Abhinavagupta – 10th century AD

Poetics:

Kāvyālaṅkāra (काव्यालङ्कार) - Bhāmaha – 7th century AD

Kāvyādarśa (काव्यादर्श) – Dāṇḍī – 7th century AD

Bhaṭṭikāvyam (भट्टिकाव्यम्) – Bhaṭṭi – 7th century AD

Kāvyaprakāśa (काव्यप्रकाश) - Mammaṭa – 11th century AD

Sāhityadarpaṇa (साहित्यदर्पण) – Viśvanātha – 14th century AD

References (contd.):

Classical Texts (contd.)

Musicology:

Bṛhatdeśī (बृहत्देशी) –Mataṅga – 8th century AD

Saṅgītaratnākara (सङ्गीतरत्नाकर) - Sāraṅgadeva – 13th century AD

Medicine:

Ayurvedadīpikā (आयुर्वेददीपिका) - Cakrapāṇi – 11th century AD

Botany:

Vṛkṣāryuvada (वृक्षार्युवद) - Surapāla – 10th century AD

English Language texts:

A History of Hindu Chemistry – Prafulla Chandra Ray, 1902.

Studies in the Medicine of Ancient India – A. F. Rudolf Hoernle, 1907

A History of Indian Shipping – Radhakumud Mookerjee, 1912

Designs from Orissan Temples – A. Goswami, 1950

A Concise History of Science in India – Edited by D.M.Bose, S.N.Sen, B.V. Subbarayappa, 2009.

(Reference help is acknowledged from Prof JSR Prasad of University of Hyderabad, India)

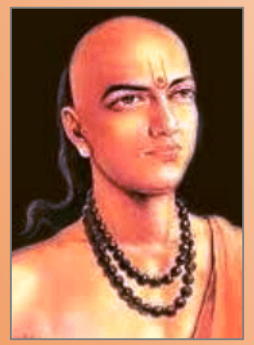
Miscellaneous internet resources.

Scientific research spanned the following fields:

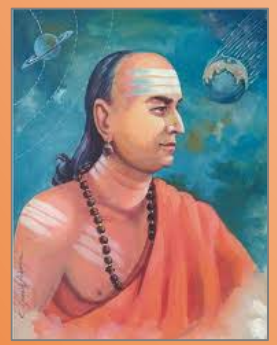
- Astronomy
- Mathematics
- Science of Human Expression
- Science of Poetics
- Science of Melody
- Physical Sciences
- Medical Science
- Agriculture, Botany and Veterinary Science
- Chemistry and Alchemy
- Metallurgy and Metal Science

Astronomy

Aryabhatta is credited to have observed that the apparent motion of the stars in the sky is due to the earth's rotation from west to east. His dates are estimated as 476AD-550AD. He is the author of the major text entitled *Aryabhatiya*. He lived around the modern city of Patna in Bihar.

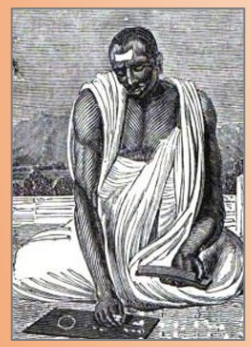


Varahamihira calculated the distances of the planets from the earth and their diameters fairly well. He developed detailed methods of time measurement through shadows and water drops. His dates are estimated as 505AD-587AD. He is believed to have lived in Ujjain.



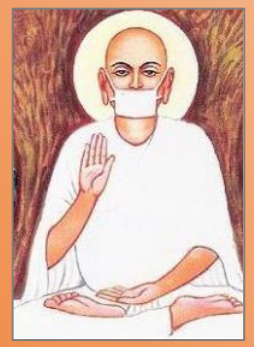
Bhaskaracharya (Bhaskara II) developed the techniques of infinitesimals and applied them to spherical trigonometry thus systematized the astronomical calculations. His contributions to mathematics are prolific. He is estimated to have lived 1114AD-1185AD and also worked in Ujjain.

Mathematics



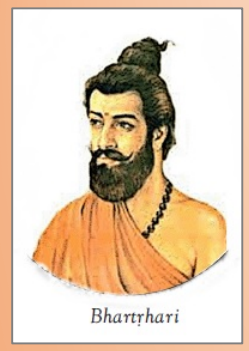
Brahmagupta is credited to have introduced the arithmetic of zero and the algebra of negative numbers. He set up indeterminate quadratic equations and solved for paired solutions. His dates are estimated as 598AD-670AD. He came from Gujarat and worked in Ujjain.

Mahāvīrācārya, a Jaina teacher, introduced the decimal system in number representation. He developed algorithms for permutations and to solve complex problems in geometry. His dates are estimated as 800AD-870AD. He is believed to have lived and worked in Mysore.

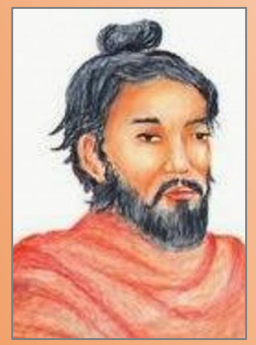


Hemachandra was a Jaina Acharya, a prolific author and a grammarian. From the observations of short and long time measures in language syllables, he deduced the formulae that are later known as Fibonacci numbers. His dates are given to be 1089AD-1173AD. He lived in Gujarat.

Science of Speech Communication



Bhartrhari analyzed and reintroduced the old *sphota* (bursting forth) theory of sound perception. A letter or a word or a sentence is not literal but conveys a meaning "bursting" in context. Bhartrhari lived around 5th or 6th century AD and possibly was a King.



Anandavardhana was a Kashmiri scholar and is dated to 9th century AD. He enunciated what has been called the *dhvani* (suggestion) theory of sound. A communication has in it an intended result that the proper expression would help produce. "Suggestion" is the basis of poetics.

Abhinavagupta was a 10th century Shaiva scholar from Kashmir and reintroduced the *rasa* (poetic aesthetics) theory of sound. The goal of communication is to convey rasa to the listener through rhythm, diction and metaphors. The rasa school became dominant in later literature.

Science of Poetics

- Research on word and communication led to a complete analysis of poetics, unique in the world literature. (Aristotle did Poetics in 3rd century BCE).
- **Principal contributions:**
  - **Bhamaha**, a scholar from Kashmir in 7th century, examined the principles of rhetorics in analyzing poetic compositions in a book entitled काव्यालङ्कार *Kavyālaṅkāra.* He came up with a detailed analysis of the errors in poetry.
  - **Daṇḍī**, a scholar in Kanchi also in 7th century, compiled the magnificent काव्यादर्श *kāvyādarśa*, a complete book on classification of the qualities and methods of poetic compositions. He enumerated 36 parameters that can be applied in evaluating the गुण guṇa (sweetness) in a poetic composition.
  - **Bhatti** checked on the grammar and words in poetry through his illustrative composition entitled भट्टिकाव्यम् bhaṭṭikāvyam, a retelling of Ramayana with an eye in teaching Paninian grammar. He lived in Gujarat in 7th century.
  - **Mammaṭa,** an 11th century teacher from Kashmir, compiled the analytic information on linguistics and psycho-acoustics in a book entitled काव्यप्रकाश kāvyaprakāśa. It is a comprehensive text on अलङ्कार alaṅkāra, रस rasa, and ध्वनि dhvani.
  - **Vishwanatha Kaviraja,** a court-poet of 14th century in Kalinga, helped combine the poetics with the visual expressions of drama as enumerated in the earlier literature. His book साहित्यदर्पण sāhityadarpaṇa is the principal text on aesthetics in Indian literature. Connecting रस to ध्वनि, he argued the importance of ध्वनि in poetry.

Science of Melody

- **Sound production and sound perception**:
  - Production is a function of discipline in human voice, while perception is a function of the environment, the season and the time of day.
- **Definitions of terms:**
  - *Rasa* is a psychological perception and is universal in its effect.
  - The production of rasa in sound is through melody.
  - The melody is created by *rāga*, a technical term has its structure defined through scientific empiricism. Broadly it can be considered as a function of intonation, duration and order. A *rāga* has a spread of expressiveness that is subjectively performed by the vocalist or the musician.
  - A *rāga* is produced, *rasa* is perceived.
- **Principal exponents:**
  - **Matanga,** in about 8th centure in South India compiled the the book बृहद्देशी bṛhaddeśī , a text reference for *rāga* delineating the structure, notes and its discipline. Hundreds of *rāga* have been identified from the existing compositions.
  - **Sāraṅgadeva,** a 13th century scholar from Kashmir who lived in Maharastra, created a systematic study of all *rāga* structures from the performance point of view. His book संगीतरत्नाकर *saṁgītaratnākara* is considered the textbook of Indian musicology.

Physical Sciences

- **Cosmological Speculations**:
  - Boundedness of the universe
  - Discrete structure of matter
  - Symmetry, transformation
  - Principle of conservation, cause and effect
- **Observational Deductions:**
  - Gravitational pull
  - Speed of light
  - Size of the Earth
  - Period of revolution of Earth
- **Material Science:**
  - Effect of heat, burning, oxidation
  - Mercury –plating, metal-plating, gold-plating
  - Production of steel and rust-proof iron
  - Production of glue, adhesives to be used in construction

Medical Science

- **Mind and Body in Ayurveda:**
  - Mind was accepted as the integral part of physical health.
  - Mind was analyzed through the principles of साङ्ख्य sāṅkhya.
  - Healing of the mind is accomplished through योग yoga with प्राणायाम prāṇāyāma.
  - Body is healed by balancing the triad of वात vāta (air), पित्त pitta (bile), and कफ kapha (phlegm) in the body. Healing must result in wellness.
  - Treatment is customized to the individual and also as a function of season, time and age.
- **Preparation and Application of Ayurveda Medicine:**
  - Freshness is the most important parameter.
  - Medicine preparation targets customization – grinding, pounding, distillation.
  - Honey and ghee from cow's milk were determined as healers to the body in transporting medicine.
  - Alcohol and opium were used as anesthetizers.
- **Greek-Arab influence – Unani Medicine:**
  - Arab and Greek medicine was more treatment-based to restore the body health.
  - Temperament was detected as a symptom of a disease than a mental disorder.
  - Four kinds of body fluids are recognized- phlegm, blood, yellow bile and black bile.
  - Unani adopted a large amount of Ayurvedic herbal products in treatment planning.

Agriculture, Botany and Veterinary Science

- **Agriculture:**
  - Grains of appropriate nutritional qualities were empirically studied.
  - Seeds were seasoned with protein-rich compost in order to produce better harvest.
  - New crops were tried by creating proper soil mixture and irrigation.
  - Plant diseases were studied and remedies determined.
  - A book entitled वृक्षार्युवेद vṛkṣāryuveda by Surapala in 10th century documented caring of plants.
- **Botany:**
  - Rice, wheat, barley, lentils, oil-seeds, sugarcane and black-pepper were the native products.
  - Mango was the popular fruit though the varieties were less.
  - Chilli-pepper, coffee, tobacco were introduced by the Arabs.
  - Plant morphology was studied and medicinal use of different parts was explored.
  - Dried herbs were a big export item.
- **Veterinary Science:**
  - Animal health was mapped similar to the human health.
  - Books were compiled for taking care of cows, horses and elephants.
  - Animal care books were translated to Arabic and used in the Arab countries.

Chemistry and Alchemy

- **Chemistry:**
  - All chemical knowledge was empirical based on color or nutritional value.
  - Natural substances like water, milk, honey or urine were used as solvents.
  - Application of chemistry was is medicinal use through grounding, heating or distilling in creating new products.
  - Metal oxides were found to have health values and big vat burners were employed to produce ash from gold, silver, copper, tin and mercury.
  - Elaborate chemical processes involved cleaning, drying, pounding, fuming and slow heating.
  - There was large perfume industry with elaborate recipes using flower petals, fruits, bark and wood of different plants and seasonal herbs.
- **Alchemy:**
  - Chemical processes to create noble-looking material from base metals has been called alchemy.
  - Alchemy reached India via the Arabs who learned the idea from the Chinese workers.
  - Alchemy in India joined with the practitioners of *tantra* in looking for physical ways to attain nobility. Tantra practice looked for perfection in life, alchemy looked for miracles.
  - Elaborate books were compiled on the assumption that mercury had the effect of transforming objects and human life.
  - Laboratories and experts (Siddha) on the process existed, and new techniques were experimented.
  - Alloys and discolored materials did get produced and they had their utility.

Metallurgy and Metal Science

- **Metallurgy:**
  - High heat smelting of ores and purification through alkaline treatment were widely practiced.
  - Wrought iron with different Carbon and Phosphorus content were produced for use in construction.
  - Iron rods were coated with vegetable glues to create a film of rust-proofing.
  - Elaborate cleaning process was instituted for the noble metals like gold, silver and mercury, since they were used in health care. Cleaning was accomplished through vegetable and animal product reagents.
  - The chemistry of the processes have not been studied.
- **Metal Science:**
  - Alloys were popular. Alloys were used in utensils and every day applications.
  - Bronze was massively produced and was used in idol making and statues.
  - Empirical processes of liquid baths were designed for metal-plating.
  - Annealing was used in fabrication to harden the metal particularly in alloys.
  - Jewelry making used the property of malleability gold and silver in order that the material can be to be pulled as wires.
  - Metal soldering was known and was applied in jewelry making

Technological innovation spanned the following fields:

- Stone carving
- Temple construction
- Palm leaf art and writing
- Jewelry and metal craft
- Beads and bead-work
- Weaving and patterns
- Iron bar Technology
- Marine Technology

Stone Carving

Materials:

Stones like granites, marbles, quartzite, slates, and sandstone were used.

Carved Temple, Ellora

Granite, Karnataka

Marble, Rajasthan

Quartzite, Nepal

Slate, Odisha

Sandstone, Odisha

Tools:

Carving tool

Chisel

Sharpening tool

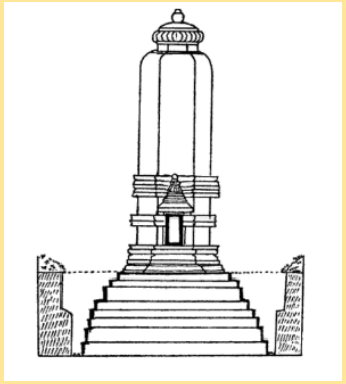
Hammer

Grouting tool

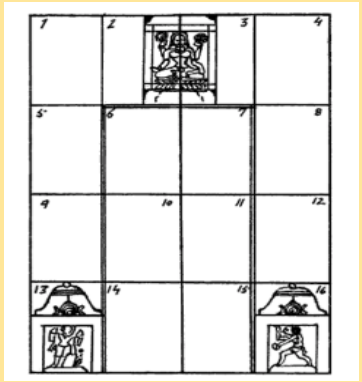
Divider

Temple Construction

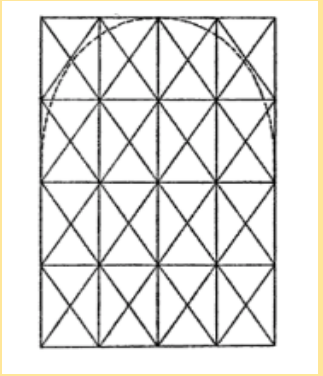
Design and Product:



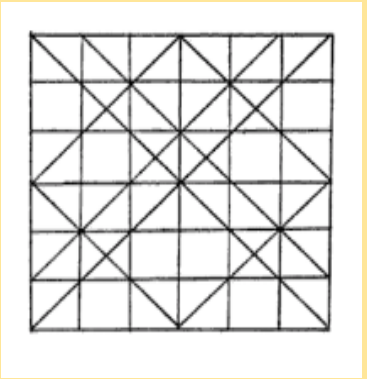
Foundation
1/3rd the height



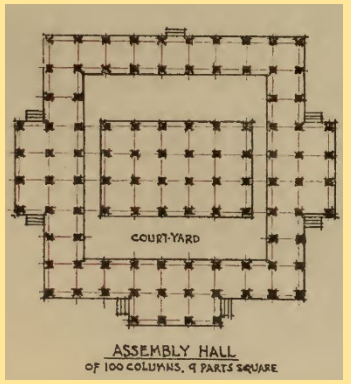
Door design



Deity Frame

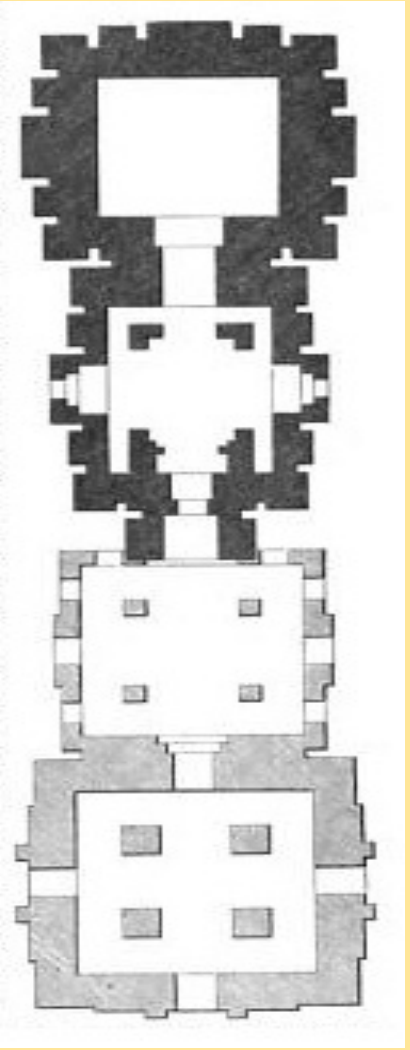


Teacher and student Frame



Assembly Hall

Lingaraja Temple, Bhubaneswar



Palm Leaf Writing and Art

Preparation:

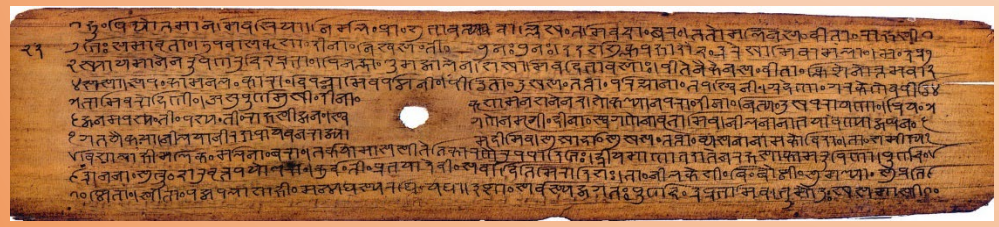
Raw Palm Leaf

Dried Palm Leaf

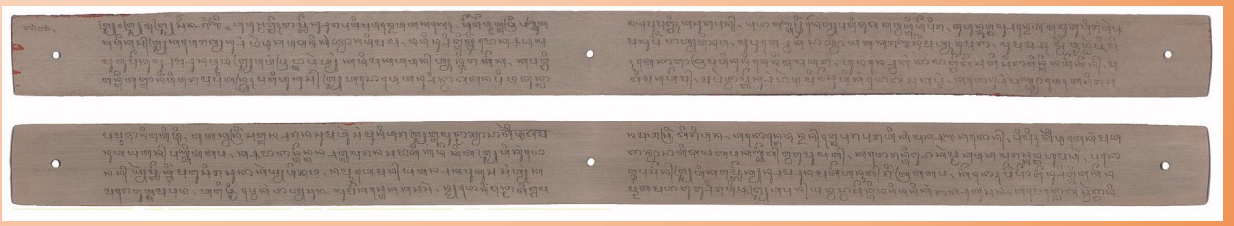
Strung in leaves

Etching and Painting

Products:



Nandinagari script 13th century



From Bali, Indonesia, 15th century

Jaina manuscript
Rajasthan, 12th cent.

From Odisha 12th century

Science and Technology

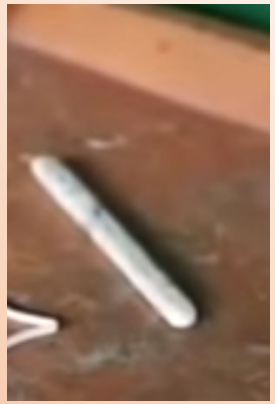
Hindu Periods

India Discovery Center

Jewelry and Metal Art

Silver filigree from Cuttack


Melting of Silver


Silver bar


Pulling into wire


Wire for Jewelry


Finished object

Lost wax metal art from Chennai


Creating the Wax mold


Casing with mud


Heating the Casing


Draining out the wax



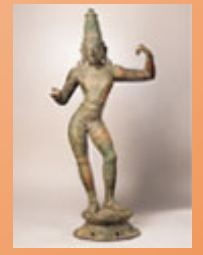
Heating the metal and pouring


Cooling


Removing the Casing


Brushing off the dirt






Finished objects

Beads and Bead-Work

Bead variety:

Beads are made of glass, lac, wood, bones, ivory and plant seeds

Glass beads
Gujarat

Lac beads
Kashmir

Wood beads
Chennai

Bone beads
Manipur

Ivory bead
Odisha

Rudrākṣa beads
Chennai

Bead in use:

Bead necklace

Bead embroidery

Embroidered cloth

Indigenous Women

Bead bag

Weaving and Patterns

Weaving:

Loom at Varanasi, UP

Loom and design
Kanchi, Tamil Nadu

Patola tie and dye loom
Patan, Gujarat

Double thread loom
Sambalpur, Odisha

Patterns:

Varanasi saree

Kanchi saree

Patola saree

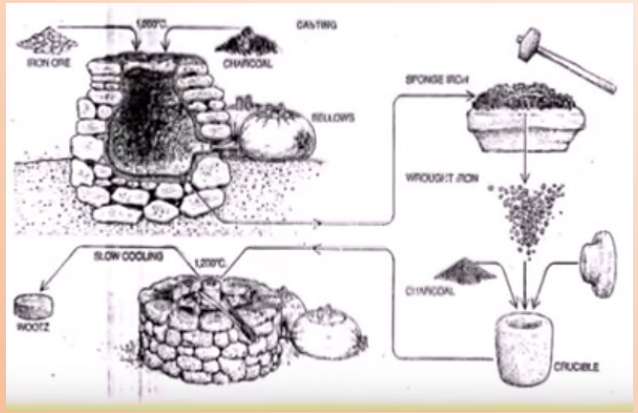
Sambalpur Saree

Iron Bar Technology

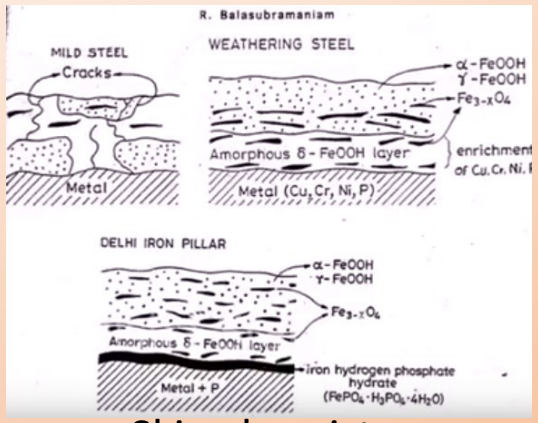
Technology:

- Small oven smelting technology, melting, forging and hammering
- Rustproofing process is unknown.
- Hydrated compounds and Phosphorus are noticed in the skin layer.

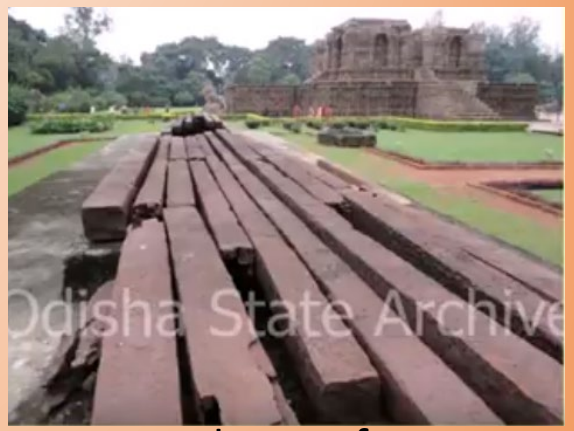
Iron smelting oven



Process flow

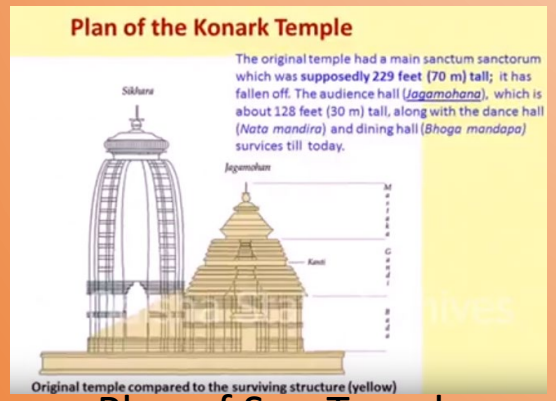


Skin chemistry

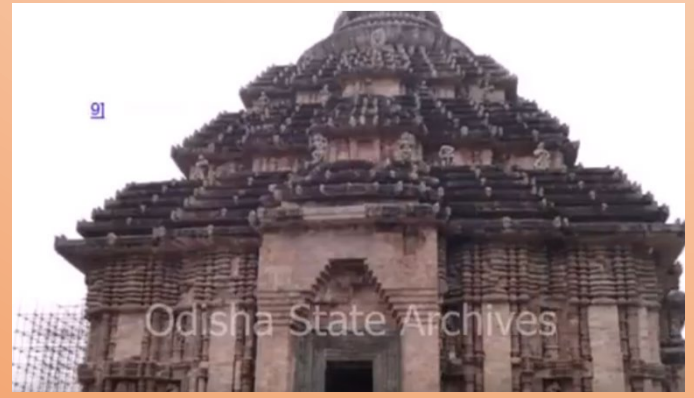


Iron beams from Sun Temple, Konarka

Use:



Plan of Sun Temple



The remnant section

Beams in the door-way

Iron beams from Dhar, MP

(Pictures from a lecture by Prof Omkar Mohanty at Odisha State Archives, 2017.)

Marine Technology

Technology:

- We reconstruct from scanty information.
- Boats were made of teakwood.
- Navigational tools were set up in the boat.
- The seasonal climatology was studied to project wind and water conditions.

Images:

Sketch from Puri, Odisha

Sketch from Borobodur, Indonesia

A reconstructed boat from Phillipines

The ingenious method of expressing every possible number using a set of ten symbols (each symbol having a place value and an absolute value) emerged in India. The idea seems so simple nowadays that its significance and profound importance is no longer appreciated. Its simplicity lies in the way it facilitated calculation and placed arithmetic foremost amongst useful inventions. the importance of this invention is more readily appreciated when one considers that it was beyond the two greatest men of Antiquity, Archimedes and Apollonius.

- Laplace (French Mathematician) 1810

Whole Person Science

- **Science as Natural Philosophy:**
  - Human being is a cosmic object.
  - Environment matters to the wellbeing of the humans.
  - Environment includes the sky and the heavens.
  - Any action and activity is a function of our mind and thinking.
  - All phenomena are causally connected.
- **Alchemy and Superstitions:**
  - Human lifespan can be arbitrarily extended.
  - Objects can be transformed to acquire new properties.
  - Elixirs to achieve immortality are possible to be discovered.
  - Individual life recycles.
  - The birth carries the memory of the past “lives.”
  - Religious and coded conduct supersedes personal conduct.

Thank you!