

History of Science in Non-Western Traditions: India

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Introduction

A study of the scientific achievements that have taken place on the Indian subcontinent will certainly surprise and perhaps entertain most persons. Surprised by the relevance of scientific discovery by Hindu, Islamic, and Buddhist philosophers to their everyday lives, they sometimes raise their eyebrows as they learn about the unique ideas that developed in a dynamic culture with many languages and religious points of view. Many scientific discoveries attributed to European origin actually came from India via Arab translators. Other ideas, such as how to prevent some plant diseases with boiled milk, had little influence on scientific thought beyond the local region, yet they are unique and quite interesting.

A vast number of individuals have contributed to the rich scientific heritage of India. People like Alberuni, though an Arab, worked extensively in India to introduce a new paradigm of experimentation to scientific investigation during the Middle Ages in his relentless pursuit of truth. Modern researchers like C.V. Raman, who won the Noble Prize for his work in physics in the 1920s, established India as a respected international player in a highly competitive research environment. In a society where science and culture are so intimately woven together, politicians such as Jawaharal Nehru played a significant role in the establishment of educational and governmental programs and institutions that have given science a place of respected priority among a people with a long tradition of scientific inquiry.

Topics are not arranged chronologically. Rather, we begin with an introduction to the human side of science: scientists. From there we consider modern scientific issues. With a contemporary perspective in place, we examine the historical foundation and developments occurring from ancient through Medieval times to give us a sense of appreciation for the significant place held by India's scientific tradition. A key topical focus is presented for each class. The readings reinforce or challenge this focus.

A secondary aim in the organization of this chapter is to strengthen the student's ability to conduct independent, original research.

Resources

1. *Bharati ki Chaap* is a Hindi TV serial in thirteen fifty-minute programs on five videocassettes, devoted to the history and development of science and technology in the subcontinent. It is in Hindi with English subtitles (published by South and Southeast Asia Video Archives of Madison, Wisconsin, in 1992).
2. *Census of the Exact Sciences in Sanskrit* (series A & B), by David Pingree. Philadelphia: American Philosophical Society, 1970.
3. *A Dictionary of Indian History* by Sachchidananda Bhattacharya. New York: George Braziller, 1967.
4. *History of Science and Technology in India*. (12 volumes: v.1 health and medicine, science and religion; v.2 mathematics, astronomy; v.3 technology; v.4 science; v.5 science and technology; v.6 metals and metal technology; v.7 industries; v.8 coins, metallurgy; v.9

building construction; v.10 irrigation; v.11 geology; v. 12 environment and ecology.) Delhi: Sundeep Prakashan, 1990.

5. *History of Science in India: Analytical Database of Information Sources* by Shailendra Kumar. Published by Gyan Publishing House of New Delhi in 1994.
6. *Symposium on the History of Sciences in India* (Calcutta, 1961). New Delhi: National Institute of Sciences of India, 1963.
7. *Trimurti Science, Technology & Society: A Collection of Essays*, by A. Rahman. New Delhi: People's Publishing House, 1972.

Getting started with such a huge topic is challenging in and of itself. One must of necessity leave out a great deal in order to avoid a serious problem with information overload. My suggestions for getting started with developing a good working knowledge of the history of science in India will not find universal agreement among those interested in the topic, yet I have found these few sources to be extremely helpful, generally available, and sufficiently thorough.

Beginning with G. Venkataraman's *Journey Into Light: Life and Science of C.V. Raman* (Day 1), one is able to get a quick grasp of the modern issues facing Indian scientists. Familiarity with important personalities puts the subject into perspective and forms a solid basis for further study. The book is written in such a way that if you are interested in developing an understanding of the science involved, you may do so but you are not compelled to, if your main interest is in the people, places, and politics of modern Indian science. This work is valuable in making us appreciate the way scientific information was disseminated prior to the advent of electronic networks that span the globe. The race for priority documentation was intense, yet the quality of communication describing the research performed was not sacrificed.

Another work with which to acquaint yourself at the outset would be *Trimurti: Science, Technology, and Society*, a collection of essays by A. Rahman. The relationship between culture and scientific progress has been particularly strong in India and extensively researched. This particular contribution to the field introduces the political and educational issues with clarity. The future outlook and historical context is also presented in light of the unique challenges faced by developing countries in a rapidly changing technological culture.

Two works of broad interest include the twelve volume set *History of Science and Technology in India* and the *Proceedings of the Symposium on the History of Sciences in India* held in Calcutta in 1961. Both works provide an extensive review and survey of the literature though the former was published nearly 30 years after the symposium took place. Each provides quick access to a wide range of interesting topics by a wide variety of scholars.

Finally, Shailendra Kumar's work, *History of Science in India: Analytical Database of Information Sources* provides a fascinating collection of resources, people, and insight into the historiography of Indian science. This is an excellent source for becoming familiar with the research literature in the field and those who publish in these journals. Though many will not profit from the bibliometric analysis of the vast body of literature on the history of Indian science due to a lack of interest in this subject, all will appreciate this handy reference tool with its indexes by keyword, journal title, article title, and author. The numerous tables and charts clearly illustrate trends in the study of the history of Indian science, primarily since the formation of the Asiatic Society of Bengal in 1784.

For a list of biographical references, see **Day 1**.

The following libraries are known for their significant collections of South Asian materials. Print or electronic sources can establish network connections for searching these libraries via a WWW, Gopher, or Telnet connection.

- Cambridge University
- Center for Research Libraries (CRL), Chicago
- Cleveland Public Library
- Columbia University
- Cornell University
- Harvard University
- Library of Congress
- New York Public Library
- Oxford University
- University of California, Berkeley
- University of Chicago
- University of Hawaii
- University of Minnesota
- University of Pennsylvania
- University of Texas at Austin
- University of Toronto
- University of Washington

Major Journals

1. Biographical Memoirs of Fellows: National Institute of Sciences of India
2. Fellows of the Indian National Science Academy: Biographical Notes
3. Harvard Journal of Asiatic Studies
4. Indian Journal of Physics
5. Indian Journal of Technology
6. Indian National Science Academy Year Book
7. Indian Science Cruiser
8. Journal of the Asiatic Society of Bombay
9. Journal of the Asiatic Society of Calcutta
10. Journal of the Indian Institute of Science
11. Proceedings of the Indian Academy of Science
12. Proceedings of the Indian National Science Academy
13. Proceedings of the Indian Science Congress Association

Electronic Resources

You may like to examine the Asian Studies Information Server on the World Wide Web at the following URL: <http://coombs.anu.edu.au/WWWVL-AsianStudies.html>.

The History of Science link on the World Wide Web Virtual Library is also very good, though broader in scope: <http://coombs.anu.edu.au/SpecialProj/ASAP/WWWVL-HSTM.html>

Day 1

Modern Men and Women of Indian Science: Key Personalities and Significant Achievements

Science happens when people seek to discover and learn about the world and their place in that world. These people formulate theories, test hypotheses, examine issues, manipulate experiments, and eventually apply the knowledge gained to improve life. Regardless of the type of system explored: physical, chemical, or biological, the work and the thoughts are accomplished at the hands and in the minds of people, both individually and in teams. In order to gain a sound appreciation and respect for the achievements of Indian science, one needs an introduction to the people who made it happen across the pages of history. People are the priority of science both to carry it out and to benefit from its occurrence.

The key topical concepts are that of “brain drain” and “scientific temper”. In a country as culturally diverse as India, there must be a mechanism in place to maintain its intellectual and scientific integrity for 5000 years in the face of sudden invasion and the slow march of time.

Hindu philosophy is dominant in India and is capable of assimilating new ideas while remaining true to itself. Modern researchers have tackled a wide variety of theoretical and practical problems in all fields of inquiry. The struggle for political independence, however, has taken its toll on scientific achievement such that only one man in India has received a Nobel Prize for scientific research in this century.

A vast number of ancient theorists as well as modern experimentalists, from Hindu and non-Hindu belief systems, have made significant contributions to India’s scientific tradition. While they are unique individuals, consider how their science has been woven together in a tapestry of Hindu assimilation.

Student Reading

1. *Journey into Light: Life and Science of C.V. Raman*, G. Ventataraman. Bangalore: Indian Academy of Sciences, 1988. (Chapters 1 – 3, 5, 12, 14)
2. “Of India, Indians, and Science,” Pushpa M. Bhargava and Chandana Chakrabarti. *Daedalus* 118 (4):353-368, fall 1989.

Extended Reading

1. “A Gentleman of the Old School, Homi Bhabha and the Development of Science in India,” George Greenstein. *The American Scholar* 61(3):409-419, summer 1992.
2. “A Portrait of the Scientific Community in India: Historical Growth and Contemporary Problems,” V.V. Krishna. In *Scientific Communities in the Developing World*, Jacques Gaillard, V.V. Krishna, and Roland Waast (eds.). New Delhi: Sage Publications, 1997.

Further Resources

1. *Dictionary of Indian Biography*, C.E. Buckland. New York: Haskell House, 1968.

2. *Fellows of the Indian National Science Academy, 1935-1993: Biographical Notes*. New Delhi: Indian National Science Academy, 1994.
3. *Indian Scientists: Biographical Sketches with an Account of their Researches, Discoveries and Inventions*. Madras: G.A. Natesan & Co., 1929.
4. *Science and Scientists in India; Vedic to Modern*, Nem Kumar Jain. Delhi: Indian Book Gallery, 1982.
5. *Who's Who in Indian Science*, H. Kothari (ed.). Calcutta: Kothari Publications, 1969.

Possible Topics for Student Research

1. Describe “scientific temper” in its Indian context.
2. How does Indian culture and religion foster or hinder scientific inquiry?
3. Summarize the life and work of India’s only Nobel Prize winner in science.
4. C.V. Raman’s discovery could be described as a race against another research team. Which country did this other team represent and how did C.V. Raman win?
5. What role did Homi Bhabha play in the development of nuclear power in India?
6. Though not a scientist, what contribution to Indian science did Jawaharal Nehru make?
7. Botanist J.C. Bose proved that plants have life. True or False? Much of the equipment he used in his work was specially designed for him. Who was the designer and was it a common practice to use such design methods?
8. P.C. Ray had difficulty finding a university appointment in India after completing his doctoral work in chemistry in England. Why?
9. How did the development of special Indian research groups foster the creation of a local scientific community?
10. What is “brain drain” and what measures were taken in India to prevent it?

Day 2

Modern Science in India: Relevant Issues and Concerns from Colonial Rule to the Present

Some of the best science occurs under the most challenging circumstances when a people determine to overcome the odds and make a difference. Economic and resource limitations, political inefficiency, cultural and religious diversity, language barriers, and educational reforms are some of the significant factors influencing the development of modern Indian science.

The key topical concept in this section is the role of science in culture and the influence of culture on scientific development. How did politics, education, and culture work to advance and retard science as India struggled for independence in the middle of the 20th century?

Student Reading

1. “Factors in the Development of Scientific Research in India Between 1906 and 1930,” S.N. Sen. *Indian Journal of the History of Science* 27(4): 379-387, 1992.
2. “Science ‘Gone Native’ in Colonial India,” Gyan Prakash. *Representations* 40:153-178, fall 1992.
3. *Science in India: 50 Years of the Academy*, C.N.R. Rao and H.Y. Mohan Ram (eds.). New Delhi: Indian National Science Academy, 1985. pp 1-50.

Extended Reading

1. *Botany in India: History and Progress* (2 volumes), B.M. Johri (ed.). Lebanon, NH: Science Publishers, 1995.
2. *Development of Mathematical Sciences in India During the Twentieth Century*, J.N. Kapur. *Indian Journal of History of Science* 27 (4): 389-408, 1992.
3. "History of Accelerators in India," A.S. Divatia. *Indian Journal of Physics A* 62A(7): 748-774, October 1988.
4. "Indian Botanic Gardens." In *Science and Social Science Research in British India 1780-1880: The Role of Anglo-Indian Associations and Government* (pages 115 – 131), Edward W. Ellsworth (*Contributions in Comparative Colonial Studies*, No. 28). New York: Greenwood Press, 1991.
5. "Introduction of Western Science into Colonial India: Role of the Calcutta Medical College," Mel Gorman. *Proceedings of the American Philosophical Society* 132(3): 276-298, 1988.

Possible Topics for Student Research

1. What influence did the caste system have on the development of modern Indian science?
2. Identify at least three factors in the development of scientific research in India and discuss their relative merit.
3. Identify two governmental agencies established in the twentieth century to foster scientific research in India. Have they been effective? Why or why not?
4. How were the agencies identified in #3 started? What was their political basis of support and who were the key players in their establishment?
5. Identify two research institutes established in the twentieth century in India and describe their effectiveness.
6. How were the research institutes identified in #5 started. What was the economic basis for their establishment and what opposition did they face?
7. Identify two learned societies that were established in the twentieth century in India and discuss the motivation for their establishment.
8. Identify two scholarly publications that began in India in the twentieth century.
9. Cite examples of scientific mentoring in India.
10. How would you define colonial science?
11. Describe the shift from science as avocation to science as enterprise in India during colonial times.

Day 3

Ancient Indian Philosophy: The Foundation of Science

Generally speaking, ancient Indians who theorized about scientific principles formulated a number of logical, abstract systems to explain the observed phenomena of natural processes. They developed two doctrines of elements. The Samhya, Nyaya, and Vaisheshika schools proposed five fundamental elements while the Jaina, Buddha, and Carvaka schools, like the Greeks, proposed that there were four basic elements that constituted matter. Much thought was also given to the attributes of these elements.

The key topical concept is this Doctrine of Elements and a consideration of whether or not it was the Greeks or Hindus who first proposed that four basic elements formed all material substances. Who influenced whom and is it significant? What were the material attributes associated with these elements and are there modern theoretical counterparts to such substances as akasa?

Student Reading

1. *A Concise History of Science in India*, D.M. Bose (ed.). New Delhi: Indian National Science Academy, 1971. pp. 1-50.
2. "Glimpses of Science and Technology in Ancient and Medieval India," B.V. Subbarayappa. *Endeavour New Series* 6(4): 177-182, 1982.

Extended Reading

1. *History of Science and Technology in Ancient India – The Beginnings*, Debiprasad Chattopadhyaya. Calcutta: Firma K.L. Mukhopadhyaya, 1986.
2. *Natural Science of the Ancient Hindus*, Debiprasad Chattopadhyaya (ed.). (ICPR series in Philosophy of Natural and Social Sciences #2). New Delhi: Indian Council of Philosophical Research, 1987.
3. *Phonetics in Ancient India*, Allen. London: Oxford University Press, 1953.
4. *Sanskrit and Science*, Raja Ramanna. Bombay: Bharatiya Vidya Bhavan, 1984.
5. *Science and Civilization*, A.K. Bag. New Delhi: Navrang, 1985.
6. *Science and Technology in Indian Culture: A Historical Perspective*, A. Rahman (ed.). New Delhi: National Institute of Science, Technology and Development Studies, 1984.

Possible Topics for Student Research

1. Discuss the application of mathematical knowledge in ancient India. Were the priests also mathematicians or did they rely on another class of technicians?
2. Describe the origin of our decimal system by the Hindus and how it was transmitted to Western culture.
3. How was health and disease defined in ancient India?
4. Three constituents formed the body according to ancient Indian doctors. What were they and what did each control?
5. Define normal and abnormal speech.
6. By what process is voice produced?
7. To what causes were speech disorders attributed?
8. How were speech disorders treated?
9. List the elements and their properties based on the theory of four fundamental elements.
10. What additional element was found in the theory of five fundamental elements?
11. Are there modern theoretical counterparts to the substance akasa?

Day 4

Ancient Indian Science Applied

Once a theoretical framework had been established, the application of scientific principles could be applied to daily life through agriculture, engineering, and medicine. Specialization could also take place in such fields as astronomy, biology, chemistry, mathematics, and physics.

The key topical concept is that of atoms. How did substances behave at the atomic level? What were dyads and triads? Each “moment” in the life of atoms was important. Could you describe what the ancients believed took place in an atomic moment?

Student Reading

1. *A Concise History of Science in India*, D.M. Bose (ed.). New Delhi: Indian National Science Academy, 1971. pp. 50-100.

Extended Reading

1. *Health Sciences in Ancient India*, B.L. Raina. New Delhi: Commonwealth Publishers, 1990.
2. *A Historical View of the Hindu Astronomy: The Earliest Dawn of that Science in India to the Present Times*, John Bentley. New Delhi: Cosmo Publications, 1981.
3. *Mensuration in Ancient India*, Saradha Srinivasan. Delhi: Ajanta Publications, 1979.
4. *The Positive Sciences of the Ancient Hindus*, Brajendranath Seal. London: Longmans, Green and Co., 1915.
5. *Science and Secrets of Early Medicine: Egypt, Mesopotamia, India, China, Mexico, Peru*. Jurgen Thorwald (Richard and Clara Winston, trans.). New York: Harcourt, Brace & World, 1963.
6. *Science and Society in Ancient India by Debiprasad Chattopadhyaya*. Calcutta: Research India Publications, 1977.
7. “Science of Botany in Ancient India”, *Studies in the History of Science in India*, vol. 1, Debiprasad Chattopadhyaya (ed.). New Delhi: Editorial Enterprises, 1982. pp. 366 – 381.
8. “Some Aspects of Agricultural Practices in Ancient India (3250 B.C. – 800 A.D.),” S.P. Raychaudhuri. In *Bulletin of the National Institute of Sciences of India* (Proceedings of the Symposium on the History of Sciences in India held at Calcutta on 4 -5 August, 1961). New Delhi: National Institute of Sciences of India, 1963.

Possible Topics for Student Research

1. What were the attributes of atoms according to ancient Indian philosophers?
2. Were atoms considered material objects or an energy force?
3. Describe the changes that occurred through a series of atomic moments when an object such as a clay pot was heated.
4. Describe the basis for early medical practitioners accepting the notion of an organic sap of life.
5. What principles were involved with the idea of unity between nature and humans in ancient Indian medicine?
6. How were physics and meteorology relevant to therapeutics in the medical practices and theories of ancient India?
7. What evidence is there to suggest that rational medical treatment was more likely to be found with adherents to Buddhism rather than Hinduism?

8. Soils and humans were similarly classified in ancient India. Why?
9. Describe the variety of irrigation practices in ancient India.
10. Describe the variety of fertilizing methods among ancient Indian farmers.
11. Describe some of the methods of treating plant diseases among ancient Indian farmers.

Day 5

Medieval India: Science Maturing

The study of science in Medieval India, from the 8th to the 18th centuries, is met with many challenges, not the least of which is fixing a date for this period. Most historians begin the period with the advent of Muslim conquerors in India. Others date it from the 13th to the 18th centuries. Based upon generous and broad strokes across the historical canvas, the period is long, nearly 1000 years and characterized by great change.

The key topical concept is the beginning of experimentation. In order to further theory, it must be refined by testing and manipulation. This gradual shift in focus was accompanied by further refinements in mathematical accuracy and precision. Consider major paradigm shifts and what must be overcome to reach for and eventually accomplish the stuff that discoveries are made of.

Student Reading

1. *Alberuni's India: An Account of the Religion, Philosophy, Literature, Geography, Chronology, Astronomy, Customs, Laws, and Astrology of India about A.D. 1030*, Edward C. Sachau (ed.). London: Kegan Paul, Trench, Trubner & Co., 1914. Chaps. 1, 4, 15, 36, 54.

Extended Reading

1. "Arabic and Persian Source Materials for the History of Science in Medieval India," M.S. Khan. *Islamic Culture* 62(2-3): 113-139, 1988.
2. *The Chronology of Modern India, for Four Hundred Years from the Close of the Fifteenth Century A.D. 1494 – 1894*, James Burgess. Edinburgh: John Grant, 1913.
3. *Medicine in Medieval India (History of Science, Technology and Medicine, vol. 8)*, O.P. Jaggi. Delhi: Atma Rham, 1986.
4. *Science and Technology in Mediaeval India – A Bibliography of Source Materials in Sanskrit, Arabic, and Persian*, A. Rahman, M.A. Alvi, S.A. Khan Ghorri, and K.V. Samba Murthy. Delhi: Indian National Science Academy, 1982.
5. *Science and Technology in Medieval India (History of Science, Technology and Medicine, vol. 7)*, O.P. Jaggi. Delhi: Atma Ram, 1986.
6. *The Science of Medicine and Psychological Concepts in Ancient & Medieval India*. New Delhi: S.K. Manchanda, 1974.

Possible Topics for Student Research

1. Under what circumstances did Alberuni study in India?
2. Alberuni studied extensively in India. What was his assessment of Indian science up to 1000 AD?

3. What significant achievement is accorded to one of India's more energetic mathematicians, Madhava Sangamagrama?
4. How were scientific traditions generally transmitted during this time and why?
5. What was the connection between astronomy or astrology and medicine during the thirteenth century?
6. Discuss some of the early experiments of Alberuni.
7. Describe how accuracy was improved in various mathematical calculations such as the value of π (pi).
8. Alberuni and some of his contemporaries calculated the specific gravity of several substances. Describe their methodology.
9. What did scientists in India understand about the relationship between motion and heat at this time?
10. Which scientist in India addressed the problem of the velocity of light?
11. What significance did experimentation assume at this time in the history of science in India?

Day 6

Medieval India: Unique and Lasting Contributions

Many of the scientific accomplishments made in South Asia during the Medieval period have been credited elsewhere, yet it is with great interest that we turn to India for unexpected discoveries and scientific applications during the Medieval millennium. In fact, a number of unique scholarly exchanges took place across this region that facilitated the transfer of new and improved theories into what later became modern Europe and the Western world.

The key topical concepts are translation and collaboration. A number of important scholarly works were translated from Greek into an Indian dialect and vice versa during the Medieval period. This kind of collaboration facilitated an exchange of new ideas between India and surrounding regions.

Student Reading

1. *Indo-Soviet Seminar on Scientific and Technological Exchanges between India and Soviet Central Asia in the Medieval Period* (Proceedings in Bombay India, November 7 – 12, 1981). New Delhi: Indian National Science Academy, 1981. pp. 1-65.
2. *Medieval Technology Exchanges Between India and the Islamic World*, Irfan Habib. Aligarh: Viveka Publications, 1985. pp. 1-26.

Extended Reading

1. *India in Hispano-Arabic Literature: An Eleventh Century Hispano-Arabic Source for Ancient Indian Sciences and Culture*, M.Saber Khan. Calcutta, 1975. Reprinted from *Studies in the Foreign Relations of India from the Earliest Times to 1974*, P.N. Joshi and M.A. Nayeem (eds.). Hyderabad, 1975. pp.356-389.
2. *Interaction Between India and Central Asian Science and Technology in Medieval Times* (Vol. 1: *General Ideas & Methodology, Astronomy, Mathematics, and Physical Concepts*, and vol. 2: *Medicine, Technology, Arts & Crafts, Architecture, and Music*). New Delhi: Indian National Science Academy, 1990.

3. "Transmutation of Base-metals into Gold as Described in the Text Rasarnavakalpa and Its Comparison with the Parallel Chinese Methods," Vijaya Deshpande. *Indian Journal of History of Science* 19(2): 186-192, 1984.

Possible Topics for Student Research

1. Increased sea trade during this period fostered considerable opportunities for exchange of science and technology. What navigational instruments were introduced at this time and how did they influence the Indian economy?
2. By what route were new plants from Latin America introduced into India?
3. List some of the advancements which were made with textiles at this time.
4. What were some of the more important architectural developments of the period?
5. How successful was bridge construction at this time?
6. Present some of the important works translated from Greek to Indian dialects during the period and discuss their long term impact.
7. Present some of the important works translated from Indian dialects into Greek during the period and discuss their long term impact.
8. Long standing scientific traditions were heavily questioned by a leading researcher in India at this time. Who pursued objective truth in India with unequaled vigor during the middle ages and what success did he have in establishing a new paradigm of scientific inquiry?
9. Discuss the more common encyclopedic works produced at this time in India.
10. Summarize the scientific exchange between India and China or central Asia (Russia).
11. What contributions did the Portuguese make in our understanding of Indian botany?