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Editorial

Indo-European Encounter and Features of Modern Science in Pre-Colonial & Colonial India

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The 'Emergence of Modern Science in Colonial India' [Thematic Issue, *IJHS*, 53.4 (2018)] is based on the papers of a conference organized at INSA campus (Delhi) on 14-16 March, 2018. The three-day conference was sponsored by the Indian National Science Academy (INSA) on behalf of the Indian National Commission for History of Science and the Science Engineering Board (SERB), and planned under the over-all guidance of Professor(s) Arnab Rai Choudhuri (IISc, Bangalore) and Deepak Kumar (JNU, Delhi). The papers are all revised and peer- reviewed following norms of *Indian Journal of History of Science* (*IJHS*) and accommodated giving an account of the emergence and impact of European science in the Colonial India from its various perspectives.

Modern science emerged in Europe during the period : 1450-1700 CE, and its upsurge was termed as 'Scientific Revolution' by well-known historians of science like Zilsel (1941-42), Hall (1954), Boas (1962), Kearny (1964), Bullough (1970), and others. As to the cause conducive to scientific spirit, majority opinion stressed on the rise of capitalism when its focus shifted to towns, to merchants and craftsmen along with the rise of great scholars. In other words, modern science was born when the two groups, members of the academies/universities and superior craftsmen came together under the sponsorships of capitalists or kings after about 1550 CE, thereby unifying the theoretical and experimental methods, which was not possible before. It was undoubtedly a unique event and European consciousness underwent a drastic change; the exact reason of course is not easy to explain. From this period however begins the ascendency of the West over the rest of the world.

The growth of knowledge depends mainly on two factors — innovation and the dissemination of the knowledge generated from its source and perpetual interactions through schools/centers or epicenters, trades, movement of techniques/ people, contact of individuals and so on. How the knowledge of modern science percolated and infused Indian minds during these periods is the objectives of the seminar.

The 15-16th centuries Renaissance Europe still believed in the Hellenistic image of 'the Indies' (the lands east of Indus) as exotic and fabulously wealthy countries. The 'Indies' subsequently became 'East Indies' or accepted as 'East India'. The period was also an age of great explorers because of the conditions then prevailed in Europe which is evident from the pioneering voyages of Columbus (crossed the Atlantic to America in 1492), Portuguese navigator Vasco da Gama's arrival at Calicut in 1498, and the voyages of John Cabot (Venetian navigator & explorer, 1497), Ferdinand Magellan (Spanish exploration to East Indies, 1519- 1522) and many others. They had drawn attention to the wealth of new territories awaiting discovery, while men have learnt to build

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ships nailed with iron which could defy the worst fury of the ocean, the effective use of artillery fired from their ships, as well as their navigation skill.

After the voyage of Vasco da Gama, the Portuguese missionaries renewed efforts in Southeast Asia including Mughal empire in India to explore new lands for resources from the middle of the16th century onwards. In the process, they had successfully explored the Red Sea, the Persian Gulf, shores of Sri Lanka, sailing through eastern seas from the Cape of Good Hope to China (Cathay) and later to Japan (Cipangu). The Portuguese Lords coordinated their work from Goa. The Dutch (natives of Holland) and Danish (Denmark & Norway) religious groups and others were also quite active in Indonesia and spread their influence on Indian subcontinent on Coromandel, Surat, Bengal, Ceylon, Malabar and other coastal areas during the same period. However, in the seventeenth century, Indian ocean regions were flooded with four East India Companies—British (1600), Dutch (1602), Portuguese (1614) and French (1664). All these companies encouraged missionary members and activities to their own interest and slowly beginning their operations as Chartered companies to dominate maritime trades on cotton goods, raw silk, spikenard, borax (settling like corals in the river bed), indigo (used for dyeing woolens and other goods), fennel, ginger, thousands of drugs to name a few, spices, the details of which could be found in Pelsaert's *Remonstrantie* and many other works during the Mughal empire.

From 17th century onwards, trade interests made these companies create problems against each other. The Dutch evicted successively the British traders from Indonesia in order to control the supply of spices. The French East India Company established its grip over Pondichery, Karaikkal and Yanaon on the Coromandel Coast, Mahe on the Malabar Coast and Chandernagar in Bengal. French India also included several 'lodges' (subsidiary trading stations) in other towns, but were attached under British administration after 1816. The British East India Company merchants spread their trading across the Indian Ocean from Arabia and East Africa to the Malay peninsula and further east to southern China. They established several 'factories'(trading centres) by 1700 in Calcutta (Fort William), Madras (Fort St. George), Bombay, and later Surat, having a council of traders in each of them to manage the Company's affairs in each portion of the subcontinent, headed by a President, known as Presidency.

With decline of Mughal power in India in the 18th century, the British East India Company and its counterpart, the French East India Company, struggled for supremacy during the Carnatic Wars of the 1740s and 1750s. The British Company however established its major political hegemony after the defeat of Nawab of Bengal at the Battle of Plassey in 1757, led by Robert Clive, and followed by Battle of Buxar in 1764. This helped the British East India Company to have military control over Bengal and a major political power in India taking advantage of India's socio-political conditions. The British Company rule in India effectively began in 1757, its control of other parts of India began to increase after the defeat of the Mysore rulers (Haider Ali, reigned 1761-82, & Tipu Sultan, reigned 1782-99), Maratha confederacy (Anglo-Maratha Wars: 1774-83, 1803-05, 1817-18) and Dal Khalsa exigencies (Ranjit Singh, 1792-, d.1839), and lasted until 1858. With the Government of India Act 1858, the British Crown assumed direct control of the Indian subcontinent in the form of British Rāj ending in 1947. Our interest is to find here some features of modern science in India in three phases, Pre-Colonial Phase: 1601-1757, Colonial Phase: 1757-1900, and Colonial Phase *vis-à-vis* Indian Responses to Modern Science: 1900-1947.

Pre-Colonial Phase: 1601-1757

The period witnessed an upsurge of European Jesuit missionaries in India playing an

important role in the advancement of secular learning—in astronomy and geography, natural history and oriental studies beside others.

The contributions on terrestrial latitude and longitude in connection to map-making however appear to be worth noting. Fathers Johann Grubner and Albert d'Orville, belonging to the team of Jesuit astronomers working in China, came to Agra, and devoted time on the determination of latitudes of a number of places in northern India including Patna. The valuable observations of Fathers Bouchet, Mandeslo and Noel enabled D'Anville to prepare a reliable map, *Carte de l'Inde* (1762) of peninsular India at the request of the French East India Company (Phillimore,1945,Vol. I). Father Claude Boudier of Chandernagore rendered signal service to the cause of Indian geography by determining latitudes and longitudes. These elements were considered important for fixing locations in map-makings and position of ships on the sea. Father Joseph Tieffenthaler, who stayed in India from c.1743 till his death in 1785 in Lucknow, and his *Geography* as summarized by Jean Bernoulli, a distinguished mathematician of the Academy of Sciences at Berlin, had informed that Tieffenthaler compiled data on latitude and longitude of places in India from both Indian and Persian works. Being skilled in the use of astronomical instruments including quadrant, the armillary astrolabe and the magnetic compass, he however improved and added geographical latitudes and longitudes of a number of places by his observation of Pole star, eclipses, transits of inferior planets, the sun-spots. The measurement of latitude was comparatively easier and was found from the altitude of the Pole star or altitude of the Sun at noon (at its highest point) when a declination table for sun at different latitudes are known. The determination of longitude was however essentially the determination of time at a given location relative to the time at a standard location. The central Asian practices of prime meridian line passing the coast of the Atlantic Ocean or through the Canary Islands (or Fortunate Islands), or through Ujjain used by the Indians, were given less importance or converted after the establishment of Greenwich Royal observatory at Greenwich Park, London (John Flamsteed was appointed First Astronomer Royal in 1676). The prime meridian passing through Greenwich or the Greenwich Mean Time began to be considered as the standard time. The time difference between Greenwich and a new place fixes the longitude of a new location. The Mariners' mechanical clock (chronometer) was only available by 1730. Efforts were started since then through mariners and other astronomical observatories to fix up longitude of new locations with reference to Greenwich at 0° longitude.

Another area— flora, fauna, drugs and *materia medica*, was of great interest to Portuguese, Dutch and Latin scholars, the detail investigations of which were started following their methodology. The Portuguese work, *Colloquies dos Simples e drogas cousso medicinalis da India by* of Garcia da Orta published in 1565 explored the eastern drugs and fruits that were new to the men in the west. The Dutch work, *Hortus Malabaricus* by Heinrich Van Rheede, published in 12 volumes with 794 plates (Amsterdam, 1678 -1703), gives description in Malabar language and its translation in Latin and West European languages. The other works, *Herbarium Amboinense* by Georg Eberhard Rumphius, *Paradiscus Batavus* by Paul Herman (1698), and *Thesaurus Zeylanicus* by John Burmann (1737) might have influenced the Swedish scientist Karl Linnaeus (1707-78) to include Indian works in his classification system. Linnaeus's works, *Species plantarum* and *Genera Plantarium* (6th edition, 1764), established a basis for his binomial nomenclature for plants and animals, indicating that every plant or animal has two Latin names, a generic name designating its genus and a specific name indicating the species, e.g. *Magnifera indica*, L (mango, L = Linnaean)

derived from generic name, 'manga', 'mangai' (from Malayalam and Tamil names); *Felis tigris,* L (the tiger). This binomial classification became internationally popular, and more than 250 Von Rheede's plants were reflected in the descriptions of Linnaean plant names showing distinct reference from India (Jain et al, 2014, p.35).

The stone astronomical observatories of Raja Sawai Jai Singh (1688-1743) in Delhi and Jaipur attracted the attention of a number of Jesuit missionaries who were commissioned by the Raja. They were : Fathers Manuel de Figuerado (Portuguese , 1727-), Pedro de Silva (Portuguese 1730-), Joseph de Bois (French, 1730-), Pons (French, 1734- 36), Claude Boudier (French, 1734-36), Antoa Gebelsperger (Bavarian,1740-43), Andre Stroble (Bavarian,1740-43) and others to help the Raja in the observation of astronomical phenomena like occultation, transits, planetary positions, shadow measurements and so on, and to improve the *Zījes* of the Maragha observatory of Central Asia (1259) and Ulug Beg's observatory at Samarkand collected by him. He had also sent a delegation in 1727 to Portugal to collect new materials from Europe, which returned in 1731 with tables and instruments having no materials on Tycho Brahe (1576), Kepler, Paris observatory (c.1662-1672), or Royal Greenwich Observatory of London (1675). Neither was he given any idea of Copernicus' heliocentric concept, nor Kepler's *New Astronomy* propounding first two laws of planetary motions (1609), or Galileo's book, *Discourses* (1638) containing remarkable description of the Venetian arsenal leading to scientific thinking of the time, or of Newton's *Principia* (1687). However the mission helped him to procure at least one telescope (vide inventory of his library), but the European Jesuit astronomers engaged by Jai Singh in Delhi observatory could not use it meaningfully because of the chromatic aberration of lenses and related problems. Whether it could at all be utilized for astronomical observations is not clearly known (Sharma, 1995).

The Indian response to European science and technology in the phase: 1601-1757, was mostly naive. The emperor, Jahāngīr, and Asaf Khān, and other dignitaries of the Mughal dynasties received presents like Telescope, Magnetic Compass, Clocks (weight-driven and spring-drawn for measuring time), Globes, Burning glasses, spectacles and other articles (Qaiser, 1982, pp. 34-46). How and to what extent these presents including magnetic compass made impact to Indian society is not clearly known.

Colonial Phase: 1757-1900

The period under the Company rule (Colonial India) had many eventful activities. It began with the initial phase of conflict, and the disagreement often between the Court of Directors in London and the representative of the British East India Company in Calcutta over the process of control and management on financial involvement. The political and climatic conditions then existed in India were not easy to handle. Whatever science has percolated through the extension of state sponsored scientific activities like mapping, activities of voluntary organizations, health care facilities, technical personnel or others were planned to serve their own purpose. According to some scholars, 'India became a testing ground of state-sponsored application of science and technology projects, and a vast storehouse of information for other parts of the Empire' (Dionne and MacLeod, 2007, p.160).

As regards survey and mapping of territorial boundaries in Colonial India it is often argued why was it given a major priority so early? The opinions, as per experts, suggest that the trading company possibly had a clear intention to transform the occupied territory into a state (Embree, 1989, p.69). Obviously the role played by James Rennel, the first surveyor General for 10 years (1767-1777), in the Bengal Presidency under Robert Clive was important. His *Map of Hindoostan* (London, 1782) and *Map of South*

India (1792) following Islamic geography created a geographical entity defined by the extent of British dominated states and provinces set the tone. His provincial *Map of Bengal* was drawn on a scale of 5 miles to an inch (1º = 5 miles). Michael Topping, the marine surveyor of Fort St George in Madras, made a survey school which became a civil engineering school later. The successive work in the area inspired (i) distinct surveys under the professional charge of the Inspector of Revenue surveys or Superintendent of Tank Repairs under the Board of Revenue, (ii) military institutions and military surveys under the Quarter Master General, (iii) Great Trigonometrical Survey (GTS) under William Lambton, as the greatest 'Geodetic' surveys. By 1822, the surveys encompassed the boundaries of each large estate or village with a loop of straight lines, the angles measured by a theodolite, and the length by a 66 feet long Guntur's chain. GTS became a proper institution by 1830, when its 'Great Arc Experiment' was started to prove that that the earth was a spheroid, and (iv) by 1843, Topographical Surveys under Colin Mackenzie, John Everest, Andrew Waugh had a permanent instrument maker to repair the GTS instruments, and a large establishment of mathematical computers. Most notable of this computer office was Radhanath Sikdar, a Calcutta Brahmin & a brilliant student, who discovered through his computation the Peak XV (height 29,029 feet) in the Himalayas as the highest peak of the world and brought before the notice of GTS (intentionally named after Everest by Andrew Waugh), (Edney, 1997, p.262). Nain Singh Rawat, a lama hailing from Jawar Valley of Kumaun, became also well known for his role on the preparation of a road map of the Upper Himalayas and beyond (vide *Geographical Magazine*, Montgomerie, 1868). The Department of Posts, Government of India, launched a postal stamp on 27 June 2004, commemorating Nain Singh Rawat and Radhanath Sikdar of the Great Trigonometric Survey of India (Vide **Appendix**).

Towards the end of 18th century two voluntary organizations and a few individuals made an interesting impact on scientific activities in Indian society. The first organization is the Baptist Mission School in Chandannagar (Frederiks-nagar) and the other is the Asiatic Society, Calcutta. The Baptist Mission School established under the patronization of a Danish Colony was set up by William Carey near Calcutta (1780) and earned considerable reputation as a translator, social reformer (champion against the practice of *Sati* & others) and for his translation of the Hindu classics into English, and the Bible into many Indian languages. Even his use of wood-block printing, steam engine (10 HP) to run his printing press and his encouragement for publication of the first newspaper by an Englishman was noteworthy events, though private printing presses were not encouraged by the Colonial government. By 1817, steam engines and steam boats began to appear, and the steam vessels were finally introduced by the Company in 1822 for Indian maritime activities. Ardaseer Cursetjee belonging to a Parsee family of shipbuilders in Bombay who was a great innovator, installed 1-HP engine to pump out water from a well, 10-HP engine in a vessel (named *Indus*), and gas lighting in a bungalow and garden in Mazgaon (Bombay) in 1833-34 and his appointment as Chief Engineer and Inspector of Machinery in the Company's steam Factory and Foundry at Bombay made him the first Indian to become a Fellow of the Royal Society (FRS) on 27 May, 1841.The Asiatic Society (1784) established by Sir William Jones, FRS, a puisne judge of the Supreme Court at Fort William, Bengal, with a charter 'to study Man and Nature of the Region' based on western methodology perhaps ushered the beginning of modern science in India. It created facilities of

> 'a commodious house for scholars, the making of a library, of a collection of ancient coins and medals, of a collection of pictures and busts, and the formation of archaeological, ethnological,

geological, and zoological collections or museums. In addition, the Asiatic Society had published 354 volumes of works of various kinds' [ASB, Year Book, I (1935): 9-22].

The *Asiatic Researches* (20 volumes, 1788-1839) alone published 219 articles in sciences compared to only 148 in humanities, which testify the great services rendered by the society to the cause for scientific revival in India. The native educationists, thinkers and authorities were impressed with the work of both the Baptist Mission and the Asiatic Society so much that they were caught between two currents of thought: whether to revive Indian learning or to go for European education.

On the introduction and institutionalization of English education and of European science in Colonial India, the Company showed no interest and had almost remained silent towards the end of 18th and first half of the 19th centuries. The first *Vidyālaya* (a public school of learning) or Hindu College for education was formally opened on 20 January 1817 (later the name changed to Presidency College in 1855) with the patronization of David Hare, Ram Mohan Roy and other dignitaries of Calcutta for teaching 'in English, Indian languages , European and Asiatic science and literature'. However, the Board of Directors of the British East India Company was more sympathetic to revive Indian learning but not English education. What they did, they encouraged Calcutta Mādrāsā to teach 'Mohammadan laws & culture' and Sanskrit School (college) the laws, literature … of the Hindus, to train their own officers, and provided a facility of one lakh of rupees for the revival and encouragement of learning. From 1823 onwards, a few oriental schools were allowed to English teaching, English classes, which was strongly protested by Raja Rammohan Roy (vide his letter of 11 December 1823, Sharp, 1920). He demanded to the Government to promote a more liberal and enlightened system of instruction, embracing mathematics, natural philosophy, chemistry, anatomy with other useful sciences by employing men of talents and learning educated in Europe and providing a college furnished with necessary books, instruments and other apparatus. The protest possibly set the tone of a national goal. The British India Society of London also donated a few scientific equipments to Hindu College for teaching astronomy, optics, mechanics and chemistry. The second institution, the Serampur College, opened on 15 August 1818 (with Royal Charter from King Frederick VI of Denmark) by William Carey, J Marshman and W Ward for the propagation of Theology and European science. John Mack, appointed by Ward, gave a series of lectures in chemistry from 1821 onwards in Calcutta and Serampur largely based on the works of Lavoisier (1743-94) and Priestley (1733-1804) and other subjects which became quite popular. The great impetus towards introduction of western learning came also from the Christian Missionaries, the Wilson School at Bombay (1834), and the Madras Christian College (1837). With Lord Bentinck's effort from1835 onwards (Sharp, 1920, pp.107-117) secondary schools and colleges in the country were allowed to function through the medium of English adopting a policy of subsidizing private educational institutions by giving them a grant-in-aid.

Bringing in Western Medicine the Europeans in Mughal India depended more on the small units, so called hospitals, and followed their own pattern of treatment. Portuguese, Dutch, French and British had their own hospitals, but Portuguese hospital at Goa was considered to be 'finest in the world' in the 17th century, according to Francois Payrard, a French traveler (Bhattacharya, 2017 p.38). The British Government in Colonial India however assumed a dominant role by bringing medical men and surgeons from Europe for the purpose, even though it was highly expensive. To cut the cost, the British Surgeons trained a few Indians in the elementary principles of diagnosis and treatment

of common diseases and appointed them as Native Doctors to help them. In the first-half of the 19th century, a medical school of British India was first opened in October 1824 at the Calcutta Sanskrit College on orthodox lines using wax models and in native language to teach anatomy and other areas with facilities of dissection of inferior animals under Dr. James Jamieson as the first Superintendent. This however did not last long. Similar attempt by Elphinstone to build a medical institution in Bombay at the same time also failed. With the initiative of Lord William Bentinck, Governor General, first Medical College of Bengal was set up in 1835, later known as Calcutta Medical College (CMC), with various branches of medical science following European model. Drs H H Goodeve (anatomy & physiology, physics), Nathaniel Wallick (structural botany) and W B O'Shaughnessy (chemistry, pharmacy & *materia medica*), and Eggerton (operative surgery) were appointed teachers for specified subjects in CMC with Dr M J Bramley as Superintendent. For clinical practices a small hospital was attached to the college. The use of stethoscope (invented by Laennec in 1816), microscope (with its scope of discovering microorganisms in 1676) and pathological anatomy became popular among the CMC doctors. In 1844 the first batch of four graduates from CMC— Bhola Nath Bose, Gopal Chandra Seal, Dwaraka Nath Bose and Surji Coomar Chuckerbutty were sent to England under the guidance of Dr Goodeve for medical training in the University College of London. The first dissection of human bodies were started in CMC under Dr Goodeve and within a few months of the discovery of chloroform in 1847, both 'ether and chloroform' began to be used in surgery at CMC (Bhattacharya, 2017, pp.47-48). (Drs) Madhusudan Gupta, Umacharan Set, Rajkrishna De, Dwarakanath Gupta and Nabin Chandra Mitra, graduated subsequently from CMC and qualified in western medicine, were given government appointments as Sub-Assistant Surgeons to different hospitals to minimize the cost on British medical doctors. The Madras Medical College (MMC) started as a medical school, and the university degrees and diplomas were introduced later. The first batch of students from Madras Medical School obtained Diploma in 1852, and graduation status in 1857. The Grant Medical School (Bombay) was similarly upgraded to a College, and then affiliated to Bombay University in 1860. Medical papers were published in *Transactions of the Medical and Physical Society* (Calcutta, 1825-45), *Indian Journal of Medical Science* (Calcutta, started by Pearson, 1834-36), *Indian Annals of Medical Science* (Calcutta, 1853-1877), *Indian Medical Gazette* (Calcutta, 1866-), *Madras Quarterly Journal of Medical Science* (1860-1868), *Madras Monthly Journal of Medical Science* (1870-73) and so on.

Three universities were established in 1857, following Sir Charles Wood's Despatch (1854), in Calcutta, Madras and Bombay, with recommendation from the Government 'to create a properly articulated scheme of education from the primary school to the university, resulting to the establishment of Department of Public Instruction in different provinces for the efficient inspection of all educational institutions'. Before 1857 there were as many as 27 colleges; a few more colleges were opened in different parts of India during the 2nd half. The Calcutta university in its Bachelor of Arts (BA) introduced two courses; Course A was purely literary, and Course B introduced much later included mathematics, inorganic chemistry, geography and English as compulsory papers and one optional papers out of physics, zoology, botany and geology. Bombay University introduced BSc degree in 1879 without any laboratory facilities. The Calcutta and Madras Universities did not have BSc degree but both revised their syllabus from time to time. The University of Punjab (1882) and Allahabad (1887) were set up with a separate faculty of science. MSc degree was instituted only in 1911 in the

universities. In the 2nd half, there was however no encouragement on advance learning, and the universities were just examining bodies.

A few astronomical observatories also continued to give services to the Company. The Madras observatory**,** a private observatory of William Petrie at Egmore, acquired by the Company on the advice of Michael Topping, became active under a number of European astronomers—John Goldingham (1796-1830), T G Taylor (1830-1848) and W S Jacob (1848-1860). Goldingham had at his disposal a circular instrument (diameter 15 inches), a vertical and horizontal circle (made by Troughton), one portable transit instrument (by Ramsden), a few astronomical clocks and telescopes (by Donald). His discovery of the longitude of Madras as 80°18′54″ and efforts followed by other astronomers were focused to charter Indian seas & their geographical locations, navigational safety of sea passages, including transits of planets, and compilation of fixed star catalogues of the region. This led to the publication of *Madras General Catalogue* of 11015 stars (1844), greatly appreciated by the Royal Astronomical Society. Subsequently, Pogson (1862-1891) discovered variable stars and minor planets, while Evershed (1899-1923) worked on solar spectroscopy and solar physics. Chintamani Ragoonathachary (1820 (?) -1880) , the only Indian who made names working under Pogson and other Directors for 35 years, discovered two new variable stars (*R . Retieuli* in 1867, and *V. Cephei* in 1878), participated in the observation of total solar eclipses of 1868 and 1871, published a few articles. For his contribution, Chintamani was elected a Fellow of the Royal Astronomical Society (Ansari, 1985, p.383; Kochhar, 1995 p.10). From 1899, the Kodaikanal observatory under Evershed was converted to an astrophysical or rather a solar physics observatory, fitted with a new photoheliograph (received on loan) from Greenwich observatory on the condition that daily photographs of the Sun are to be sent. The Mahārāj Takhtasingji observatory (Poona,1888-), affiliated to Elphinstone college and Bombay university, and the St Xavier college observatory (Calcutta,1879), affiliated to St Xavier College and Calcutta university, mainly focused on the education of elite Indians and Anglo-Indians. The Dehra Dun observatory (1878) under the British Rāj was fitted with two spectro-heliographs under the auspices of Survey of India for viewing the Sun's disc, and was asked to send the photographs to Royal Astronomical Society, England every week. Both Kodaikanal and Dehradun working under direct government services were converted to solar physics observatories to cater to the needs of the Royal Astronomical Society. The Kodaikanal observatory however became world-famous after the Colonial rule as one of the constituent units of Indian Institute of Astrophysics (Bangalore).

Other Surveys and Services were also set up during this phase to serve government activities. A Public Works Department (PWD) was started by Lord Dalhousie, the Governor-General of India from 1848-56, for construction of canals, roads in the Gangetic plain, electric telegraph (1851) with help of W B O'Shaughnessy (professor of chemistry in Calcutta Medical College), railway lines (1853), and to train civil engineers for the purpose. The Roorkee Engineering College, (1848), Poona Engineering College (1856), Madras Civil Engineering College (1859, originally survey school) and the Shibpur Engineering College or Bengal Engineering College, Shibpur (1854) came up but they offered Licentiateship only till to the end of the 19th century. The Indian Railway Company following a Despatch (dated 7 May, 1845) was established, and the first lines were built inland in major ports of Bombay (1853), Calcutta (1854) and Madras (1856). By 1867, out of twenty major cities (according to Census of 1872), nineteen were on railway lines. The objective of course was to meet military, commercial and administrative

exigencies. Railways had helped some public awareness and movement of the people.

The Geological Survey of India, the oldest service organization in the world of the Colonial government, was established in 1851 for investigation of the 'Coal and Mineral Resources in India'. Thomas Oldham, the first director remained in the service for the period: 1851-1876 discovering many types of coal, iron, minerals including laterite, manganese and gold fields, followed by others. By 1890 GSI was divided into Scientific and Economic sections. Important information on the *Geology of India* (by H S Medlocott and W T Blanford, 1879), *Economic Geology* (by Valentine Ball, 1881) and *Minerology* (by F R Mallet) were reported. Pramatha Nath Bose, after his degree from Royal School of Mines, London, joined GSI in 1880. He worked on the Siwalik fossils, known for his discovery of petroleum in Assam and was instrumental in the setting up of iron factory in Jamshedpur by bringing to J N Tata the information about the rich iron ore reserves. However, there were no teaching facilities. A post of professorship in Geology was instituted in the Presidency College, Calcutta by the government only in 1893.

The botanical interests in the first half of the 19th century was at its peak and the Company workers did commendable service under the influence of Joseph Banks (President of the Royal Kew Botanic Gardens, London for 41 years, 1778-1820) for international transfer of plants of economic, commercial and medicinal value to Kew Gardens across continents. Robert Kyd (the founder of Calcutta Botanic Garden, originally from Kew Gardens), Roxburg (well known for his Catalogue: *Hortus Bengalensis* , joining Calcutta Garden after Kyd's death), France Buchanan (Company botanist in Madras, *Plants of the Coast of Coromandel*, 3 volumes with descriptions of plants and over 300 drawings), even the Royal Horticultural Society of India (1820-) were all searching for new plants for Kew Gardens in London. The second half also witnessed the publications of *Flora Indica* by T Thomson (1855), *Forest Flora of North-West and Central India* by J L Stewart (1874), *Discovery of Economic Products of India* by George Watt (6 vols, 1889-1896) collected with the same objectives. However, the Botanical Survey of India was only established as late as 1899. On botanical history in India, Burkill's study up to 1900 is equally interesting.

In agriculture, the great boost came after Great Southern India Famine of 1876–78 which, due to faulty British economic policies in exporting grain out of India, high tax, crop failure and no facilities for farmers, caused the death toll of 5.5 million people in the Deccan Plateau (Madras, Mysore, Hyderabad and Bombay). On the Famine Commission's recommendations (presided over by R Strachey, 1880), the British Rāj established departments of Land Revenue and Agriculture, and a secretariat at the centre in 1881 and opened new departments in Bombay (1885), Madras (1889), Bengal (1896) and other provinces, with J A Voelker (agricultural chemist,1889), J W Leather (field analyst, 1892) and others to assist them for the purpose. The institution like, the Imperial Bacteriological Laboratory for Veterinary Research, Poona (1890), moved to Mukteswar (Kumayun Hills, Uttarakhand, later shifted to Izzatnagar in 1913) in 1893 to avail of the benefits of cold climate for culture of organisms and other reasons. Here Robert Koch, a German bacteriologist and an exponent of new germ theory of diseases, was involved helping to develop a number of serums for vaccination to protect cattle deaths, and find causative agents for cholera, tuberculosis and anthrax. The plague vaccine was soon discovered by Haffkine Institute (Bombay). The Pusa Agricultural Institute in Bihar (1903) was also set up as an experimental crop farm and arrangement for training of students with the financial assistance of Henry Phipps, an American

philanthropist. However, the productivity effort was a failure, and the crop production remained unsatisfactory. Norman Lockyer, the famous astronomer known for his discovery of helium, and founder & first editor of the famous Journal, *Nature*, came to India on a solar eclipse expedition in 1896, and his report to India Office (London), after touring all the Company astronomical observatories and other government service-centers, revealed that most of the scientists working in government services were unhappy, for there was no yearly increment in their salary. The stringent government budget for public health was held responsible for the increase of epidemics like malaria, plague, small pox, cholera, black fever (*kālāzar*) in many parts of Bengal and other places between the hey day of British period:1870-1930 (Ray, 1908, pp.58-63). Even champions of medical personalities like Ronald Ross, Crawford, Haig, Bentley, Wilcocks, Fry, Cristopers and others blamed the railway embankments, lack of sanitation, use of water from rotting ponds, and various administrative omissions and held responsible for such epidemics. The wining of Nobel Prize in Medicine in 1902 by Ronald Ross, FRS, FRCS [of Indian Medical Service, born in Almora in 1857, for his identification of Malaria parasite and its mode of disease causation], and Nobel Prize in Medicine in 1905 by Robert Koch [for his discovery of causative agents for infectious diseases], brought credit for the government. However, the British Rāj till then had no incentives for their scientists, no fresh educational policy to make up the dearth of experienced science teachers and to give quality science education in the colleges. Universities remained just as examining bodies.

What then was the intellectual climate towards the end of the 19th century as far as modern knowledge in science is concerned? Some scholars believe that there was a type of Cultural Renaissance or movement taking place in Bengal at the time. The debates initiated in all fronts in the society by the Bengali intellectuals on philosophy, religion, internationalism, humanism, and other aspects including modern science were worth noting. Questions were repeatedly raised and discussed on the value of Baconian philosophy of investigative method developed by Francis Bacon (1620); the importance of observation and experiment, heliocentric theory of Copernicus, new discoveries of Galileo & Herschel, laws of Kepler, law of universal gravitation and other contributions of Newton, the scientific methodologies of Charles Darwin, T H Huxley, John Stuart Mill (1850); and of many others by scholars like Rammohan Roy (founder of the socio-religious movements), Akshay Kumar Datta (editor of *Tattvabodhinī Patrikā*), Rajendra Lal Mitra (Secretary of the Asiatic Society and one of the pioneers of the Bengal Renaissance), Bankim Chandra Chatterjee (a nationalist, novelist and deputy magistrate of the British Rāj), Iswar Chandra Vidyasagar (a great philanthropist, Principal and Secretary of the Sanskrit College, Calcutta in his *Jīvan Carita*, *Bodhāyana)*; Bhudev Mukhopadhyay (a brilliant student of Hindu college, Chief Inspector of Schools in British India, and classmate of rebel poet Madhusudan Dutt in his *Sāmājik Prabandha* in Bengali) and by many others. So were efforts for the revitalization of Hindu religion and social reforms by Keshub Chandra Sen (one of the members of *Brāhma Samāj*) on the gospel of truth, living beings as embodiment of divine-self and soul as a metaphysical identity by Sri Ramakrishna and Vivekananda (the great ascetics); and others. Beside these, call for *Bande-mātaram* (worship or service for Motherland) by Bankim Chandra, *Swarāj* (India for Indians) by Dayananda Saraswati, a Hindu reformer and later by Bal Gangadhar Tilak, a social reformer and on the question of internationalism and humanism by Rabindranath Tagore and others, possibly raised an awareness for reforms. The situation was differently assessed by Dr Mahendralal Sircar, a graduate of the Calcutta Medical College in 1869,

who turned away from the scholastic theological discussions, and got convinced about the importance of scientific research for national development. He established with public support the Indian Association for Cultivation of Science (IACS) in 1876, made a good library of printed books and journals, and a scientific laboratory, a panel of technicians and instrument-makers, which was a landmark for developing a system of teaching and research in modern science under national management and control. The contributions of Sir Asutosh Mookerjee in mathematics, Father Lafont (St Xavier College) & Sir Jagadish Bose (Presidency college) in physical and chemical sciences, Mohendralal Sircar on thermo-electricity & medicine, Rajani Kanta Sen on the metals and their separation and so on, were unique in many ways in IACS. The laboratory facilities for work in low temperature physics, discharge tube experiments, X-ray and other areas attracted Sir C V Raman and many other young scholars. This reminds us a small scale version of what happened during the Renaissance 1450-1700 in Europe. There is a great need for a deeper study of this phase from social, economical, technological and intellectual perspectives, which I am sure, will be of great historical interest.

Colonial Phase *vis-à-vis* Indian Responses to Modern Science: 1900-1947

The period begins with Governor General Lord Curzon's Board of Scientific Advice (1902) and government approval of the University Act of 1904. It opened the floodgates of university teaching and research at the three universities in Calcutta, Madras and Bombay. This Act of 1904 empowered the universities—

> 'to appoint university professors and lecturers, to hold and manage educational endowments, to erect, equip and maintain university libraries, laboratories, and museums, to make regulations relating to the residence and conduct of students, and to do all acts, consistent to the Act of Incorporation and this Act, which tend to the promotion of study and research'.

The struggle of Sir Asutosh Mookerjee, a Fellow of the American Mathematical Society (1900) cum Puisne judge of the Calcutta High Court (1904), and his service and role as the Vice-Chancellor of the Calcutta University (for four successive terms, 1906-14; and appointed fifth time, 1921-23) is well known. His efforts in establishing the terms of endowments, extending the bounds of knowledge, to increase the qualities of BSc (Hons), MSc and DSc degrees, and for the recruitment of whole-time professors, active research workers, research guides, research scholars and the facilities for their research work involved a lot of courage and conviction. From the endowments of Tarak Nath Palit, Rasbehary Ghosh and others, he created Palit and Ghosh Professorships and many other facilities for the university. With his guidance, a large number of teachers/research students were encouraged for higher training and degrees in European universities. They were well received in comparatively free atmosphere of Edinburg, Oxford, Cambridge, London (UK), Berlin (Germany), Sorbonne (France) and other European scientific centers. Scientific services and departments also began to feel for a change and training to avoid geographical isolation. A number of universities-in Benares & Mysore (1916), Patna (1917), Lucknow (1919), Dacca & Aligarh (1921), Delhi (1922), Andhra (1926), Agra (1927), Annamalai (1929) and other places were established imbued with national spirit. The Indian Institute of Science or Tata Institute for Research and Higher Education in Science was established in Bangalore in 1909. The Bose Institute (Calcutta, 1917) was set up by Sir Jagadish Chandra Bose for interdisciplinary research in science with guidance from Nobel Laureate Rabindranath Tagore, Prasanta Chandra Mahalanobis and others. The research activities in modern science also resulted in the formation of many societies. The Indian Science Congress Association (ISCA) played a significant role during 1914-1938. The Jubilee session of ISCA in 1938 had 13 scientific sections

as against 6 in 1914. The number of scientific papers rose from 35 in 1914 to 800 in 1938. The National Institute of Sciences of India (NISI), renamed later as Indian National Science Academy (INSA), was originally established in 1935 in Calcutta (shifted to Delhi in 1945, recognized in the same year as a premier scientific body by the Government of India) to encourage interest in all branches of science. The Indian Science News Association (ISNA) under *Science and Culture* (Calcutta) was also set up in 1935 to create awareness in science, for science research and also training for scientists. Even nominations of Indian scholars were called by the Royal Society for Fellowship (FRS) and the Nobel Committee, of which a small number were successful. Publications were mostly done in top international journals like *Transactions of the Royal Society* (Edinburg), *Transaction of the Optical Society* (London), *Transaction of the Faraday Society* (London), *Transactions of the Chemical Society* (London), *Nature* (London), besides Indian journals e.g. *Proceedings of the Asiatic Society of Bengal*, *Bulletin of the Calcutta Mathematical Society* and others. Disciplines and subject areas of research expanded enormously. A glimpse in each discipline with names of experts with their specializations will give an idea how the knowledge in modern science had grown in the period (Vide **Supplement** for Details).

Concluding Remarks

It will not be out of place to emphasize that two important shifts were found in the attitude in the beginning of the 20th century. One was the idea that science in India could be cultivated without supervision from London, and the other was the role of Indian universities to go beyond the University Act (1904) in matters of public sponsorship to expand the horizon of modern science and industrial technology. To what extent the Indian Independence or *Swadeshi* Movement starting from 1885 onwards, gave a boost for modern science and Indian development is a matter of serious study. However, Mahatma Gandhi's emphasis as President of the Indian National Congress in 1920 and some of his resolutions like, 'non-violence', apathy on 'machinery', 'carkhā' as a social program, and his opinion on industry, science and technology created some extraordinary situations. His non-cooperation against Subhas Chandra Bose on his election as the President of the National Congress Party in 1930 for which Bose had to resign, made Gandhi an uncompromising leader or 'a dictator' of the Congress Party, according to 'Bombay Chronicle' and other sources. There were various criticisms raised against the Gandhian policy on science and industrialization. Meghnad Saha was very vocal and advocated that industrial progress was only possible through careful and deliberate planning backed by scientific research. The 3rd annual meeting of the Indian Science News Association (ISNA) [*Science and Culture*, 4, 1938, Supplement on ISNA], presided by Subhas Chandra Bose was asked for Bose's opinion on the matter. Bose said that he was greatly interested in the application of science to the problems of reconstruction, and confessed that it cannot be done without the aid of science and scientists. On the question of large scale industrialization, Bose advocated the need of a national planning commission. The Second World War II (1939-45) however changed the perspectives and relative significance of science & technology, society, and science policy in the developing countries including that of India. It is also true that the emphasis on planning of science and industry changed accordingly with the independence of India in 1947. However, it is to be admitted that science has no boundaries and that modern science germinated effectively in Indian soil only in the first half 20th century. A little freedom from the colonial government and the genuine efforts by the Indian scientists themselves helped them to achieve and expand the horizon of modern science what colonial rulers could not do in earlier phases.

The lesson is that miracles can happen only when science, technology and government come together for human welfare and move hand-in-hand looking towards each other's support. In this wide expanding scientific knowledge in our universe, science and technology together have become an important part in our life and culture.

I am thankful to Professor D Balasubramanian for going through the manuscript and suggesting some improvements with modification. Thanks are also due to Professor(s) Arnab Rai Choudhuri, Deepak Kumar and other members of the Organizing Committee for arranging such an important conference. The editorial is planned in such a manner that each historical phase of pre-Colonial and Colonial science in India could be examined with proper perspectives. I am grateful to my students/ colleagues, Dr P K Majumdar, Dr Sukta Das of Kolkata and Sri Madhvendra Narayan of INSA for collecting some useful source materials on my request. The collection, I am sure, will be a valuable addition to the available literature in the field.

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Supplement

Ramification of Modern Science in Colonial India during 1900-1947

In **Physical science,** the teaching and research in the period centered round Sir Jagadish Chandra Bose [professor of physics in the Presidency College & Bose Institute, Calcutta, FRS (1920)], C V Raman [used research facilities of IACS from 1911-33, even during his tenure of Palit Professorship of Physics from 1916 onwards; elected FRS (1924), Hughes Medal of the Royal Society and Nobel Prize (1930) in physical science]. D M Bose [Ph D from Berlin University, Palit Professor, 1933—38 and Director, Bose Institute, 1938-], M N Saha [Professor at Allahabad university, FRS], S N Bose [DCU & CU, FRS], S K Mitra [Ghosh Professor, FRS] and B B Ray [Khaira Professor, CU] and others who contributed immensely and diversified the field of physical science. Sudhansu Kumar Banerjee, Nalini Mohan Basu, J C Kameshwara Rao (university scholars), Phanindra Nath Ghosh, S K Mitra, B B Ray (CU Professors), S C Sirkar and many others had all their initial training from IACS. How the knowledge expanded may be seen from the area-wise distributions with names of contributors.

Electricity Conduction, Discharge & Biophysics: Jagadish Bose (PC & BI), and his students- P C Mohanti (CU), S K Kulkarni CU), and others*;*

Accoustics: C V Raman (IACS, CU & IISc), R N Ghosh (ALLU), and others;

Light Scattering, New Radiation and Raman effect, Quantum nature of light, Crystal Structure, Dynamics of Reflections in Crystals —C V Raman (CU & IISc), K S Krishnan (DCU & IACS & ALLU),, S Bhagavantam (BEL, & OU), K R Ramanathan (IMD & KO), G R Paranjpe (ISB) and others;

Heat, Thermodynamics & Cryogenics: M N Saha (ALL U & CU), D S Kothari (DU), B N Srivastava ((IACS), Akshayananda Bose (IACS), and others;

Atomic and Molecular Structure: D M Bose (CU & BI), C V Raman (IACS, CU & IISc), K R Ramanathan (IMD & KO) and others;

X-ray Spectroscopy: C V Raman, B B Ray (CU), P N Ghosh (CU), B Venkatesachar (MU & IISc)), S Datta (PC), W Mohammad (AMU), A Lakshmi Narayan (KO), Kedareswar Banerjee (DCU & IACS), S C Sirkar (IACS), M Ishaq (AMU), P K Kichlu (PNL), P C Mahanti (CU), K R Rao (AU), N R Tawde (ISB) and others;

*Cosmic Ray, Particle Physics, Radioactivity, α-, β-, γ- rays, High Energy Physics***:** D M Bose (CU& BI), Meghnad Saha (ALLU & CU), H J Bhabha (IISc, TIFR), P S Gill (AMU & TIFR) and others;

*Astronomy, Astrophysic & Statistical Mechanicss***:** Meghnad Saha (ALLU & CU) , N R Sen (CU), V V Narlikar (BHU), T Royds (KO), A C Banerjee (ALLU), D S Kothari (DU), T P Bhaskara-Sastry (NO), R C Majumdar (DU);

*Atmospheric Physics, Radio, Wireless, Meteorology and Seismology***:** S K Mitra (CU), Meghnad Saha (ALLU & CU), K R Ramanathan (IMD & KO), C W B Normand (MO), S K Banerjee (CU), G Chatterjee (AGU), S R Khastagir (PC, DCU & CU), K G Ramanathan (IMD & KO), L A Ramdas (MEK & MEP), Anil Kumar Das (KO), H Rakshit (NPL), S C Roy (CO & IMD), S R Savur (IMD &AU), V V Sohoni (IMD), N K Sur (MEP), G R Toshniwal (TIP) and others;

Quantum Statistics, Wave Mechanics and Wave Statistics, Relativity **:** S N Bose (DCU), V V Narlikar (BHU), S M Sulaiman (ALL & AMU), and others.

In **Chemical science,** the Palit Chair of the Calcutta University was offered to Prafulla Chandra Ray, a DSc from Edinburg, after his retirement from the Presidency college in 1916. He had already distinguished himself as a teacher and original investigator of chemistry for his isolation of mercurous nitrite and studies of metallic elements & organic sulphur derivatives. His establishment of Bengal Chemical and Pharmaceutical Works and efforts to make it a public sector undertaking made him a role model in the field of chemical research and industry. The number of his research scholars also increased including Jatindra Nath Sen (won Premchand

Roychand Scholarship and later joined Agricultural Institute at Pusa), Rasik Lal Dutta and Pancanan Neogy (obtained D Sc degree from CU). The total contributions in chemistry increased to a respectable size under his guidance and patronization of other scholars for which he used to refer it as 'Calcutta School of Chemistry'. Through his encouragement, his students—Brojendra Nath Ghosh, H K Sen, B B Dey, Nilratan Dhar went out and obtained doctorate degree from London, while P C Mitter obtained their degrees from Berlin university. After his retirement in 1937 from the university, Palit, Khaira and Ghosh professors of chemistry in Calcutta were occupied by P C Mitter (organic chemistry), Priyada Ranjan Ray (Inorganic chemistry), and J N Mukherjee (Physical chemistry). B B Dey (professor of chemistry in Calcutta and subsequently) became professor of chemistry in Madras university. P C Ray was the Founder-President of the quarterly *Journal of Indian Chemical Society* established in 1924. He is considered as one of the founders of modern chemical research in universities and research institutions. The Royal Society of Chemistry (RSC) released a Plaque in his honour, 1st outside Europe, on his 150th Birth Anniversary at Presidency College, Calcutta. S S Bhatnagar, FRS and an expert on physical and magneto-chemistry, became the President of INSA during the crucial period: 1947-48. The areas of research in chemistry also enlarged immensely, and the experts in each field during the period will be of interest:

> *Inorganic and Analytical Chemistry* (structural, magneto-chemistry, metal compounds, porphyrin derivatives including design and synthesis, polymers, colloids, etc): P C Ray (PC & CU), H B Dunncliff (KA & GL), P R Ray (CU), R C Ray (SP), P B Sarkar (CU), N N Ray, (CU), Mata Prasad (ISB) and others;
>
> *Physical Chemistry* (soil chemistry, electrolytes, colloids, electrochemistry, magneto-chemistry): N R Dhar (ALLU), J C Ghosh (DCU & IISc), J N Mukherjee (CU & IARI), S S Bhatnagar (BHU & PU), B Sanjiva Rao (CB & IISc), P B Ganguly (SP), S S Joshi (BHU), B N Ghosh (CU) and others;
>
> *Applied Chemistry* (Biochemistry, Industrial chemistry): H K Sen (CU & LCRI), B C Guha (BC & CU), B Mukerji (CU);
>
> *Organic Chemistry* (natural products of medicinal values, essential oils, natural colouring materials relating to their isolation and determination of structure): P C Mitter (CU), Ramnath Chopra, B C Guha, S Ghosh (STM), J C Bardhan (CU), P K Bose (IMS & LCRI) [Calcutta school]; B B Dey (PM), and his students T R Seshadri (AU), S N Chakravarti (ANNU) [South school]; M O Forster (IISc), P C Guha (CU & IISc) [Bangalore school] ; T S Wheeler (ISB & BU), R C Shah (ISB), K Venkataraman (BU), K Ganapathi (HI) [Bombay school]; K G Naik (BR), Salimuzzaman Siddiqui (TD), S B Dutt (ALLU), B Kartar Singh (GD, GL & SP),Sri Krishna, J N Ray & N A Yajnik (PNL), and others; *Photo-chemistry :* P S Macmahon (CL),

In **Mathematical Science**, the first PhD thesis was produced from the Calcutta university as early as 1900. The Calcutta Mathematical Society was founded in 1908, and its nurture and development was done by the dynamic leader, Sir Asutosh Mookerjee, who was its president during 1908-28. The *Bulletin* of the Society started publishing from 1909 and earned great international repute in mathematics within short span of time. Applied mathematics teaching and research in the Calcutta University flourished with professors: Ganesh Prasad (1914-17), B M Sen, N R Sen and others, so is Pure Mathematics under Levi, S Mukhopadhyay, N R Sen, and others. The Indian Mathematical Society with its headquarters at Madras was started by a band of highly enthusiastic persons, not researchers, concentrating on problems and their solutions. Madras produced Srinivas Ramanujan, a contemporary of Sir Asutosh and the self-taught mathematical genius. He was encouraged by the Mathematical Society, G H Hardy of the Cambridge University and became FRS. Some of his early papers were published in the *Journal of the Mathematical Society* and his three note books are printed by Springer-Verlag. However, the

Madras University delayed the PhD program considerably, and it actually started when R Vaidyanathswamy joined the reorganized mathematics department in 1927. Areas also expanded and what is shown below is the contributions made by scholars in different areas:

Analytical Theory of Heat & Expansion, Fluid Dynamics, Solid Mechanics, Elasticity, Relativity and Biomathematics: Ganesh Prasad (CU) , C E Cullis & D N Mallick (CU), B M Sen (PC & CU), N R Sen (CU), B R Seth (IIT Kharagpur), V R Thiruvenkatachar (DMB), P L Bhatnagar (ALLU), Jyotirmoy Ghosh (PC) & others;

Geometry, Geometry of Manifolds, Functions, Differential geometry: Haridas Bagchi (CU), S Mukhopadhyay (CU), S C Bhar (CU), H N Dutta (CU), R C Bose (CU), Ram Behari (DU), Ramaswami Aiiyar, G S Mahajani (RU), R N Sen (CU);

Number Theory: Srinivasa Ramanujan, K Ananda Rau (PM), S S Pillai (ANNU & CU), P K Menon, T Vijayaraghavan (DCU & AU), C T Rajagopal, R Vaidyanathaswamy (MU& ISI); Hansraj Gupta (PNL), S Chowla (PSU & BHU) and others;

Algebra, Algebraic Equations & Analysis : W H Young & F W Levi (CU), A Narasimha Rao (AU), V S Krishnan, S Chakravarthy (BE), N N Ghosh (CU), K G Ramanathan (TIFR), B N Prasad (ALLU), M R Siddiqi (Osmania, Peshwar & universities of USA), P L Srivastava (ALLU) and others;

Statistics, Probability, Combinatorics and Quality Control: P C Mahalanobis (PC & ISI, Calcutta), S N Bose (DCU), R C Bose (CU),C R Rao (ISI & CU), D D Kosambi (BHU, TIFR), ,S N Roy (ISI & CU), P V Sukhatme (ICMR), PVK Iyer (PU), K B Madhava (MSU), U S Nair (TU) and others.

In Medical Science, the medical colleges affiliated under Calcutta, Madras and Bombay universities gradually grew on the lines Britishers had in their own country. Their objective was to provide good medical relief to themselves and also to people of India to some extent. Unlike researches in basic sciences in physics, chemistry and mathematics, the researches in medical science under university was a non-starter. Royal College of Physicians in medicine and surgery in Edinburg, London and other places were well known. So were famous the four medical men, William Osler the physician; W H Welch the pathologist; W S Halsted the surgeon and H A Kelley the gynecologist of the Johns Hopkins Medical School, Baltimore, for clinical training. However, Osler, FRS, FRCP, surpassed them all for his teachings and writings. London school was popular among experts in India. Dr B C Roy, MRCP, FRCS (1982-1962), an able physician, administrator & Chief Minister of WB, and Dr A Lakhshmanswami Mudaliar, FRCOG, FACS (1887-), who had his education in Madras Christian College and Vice-Chancellor of Madras University for long 27 years and as an able administrator, made immense contribution to medical education and research in the period. Calcutta School of Tropical Medicine was set up in 1914 to handle research on tropical diseases. Likewise few other centres were added throughout the country. By 1947, there were as many as 15 medical colleges established in India. Several medical schools were also started in various parts of the country. A few universities were under the full control of the government, others were under universities. By 1930 early medical colleges established by the government had a nominal affiliation by the universities. Indian government found it imperative to create some organization in order to maintain a uniform standard of medical education. This led to the creation of Imperial (Indian) Medical Council of India (ICMR) by Central Act (1933). The Council was empowered to inspect all medical colleges periodically to assess their teaching facilities and standard and to recommend to the government for recognition of medical qualification awarded by different universities. ICMR had helped greatly to raise the standard of medical education and to maintain some amount of uniformity and in furtherance of medical education and research.

Parasitoloy and Epidemiology (Fever, Kālāzar, Meningitis, Filariasis, Malaria, Leprosy & Syphilis, Dropsy, Cholera, Plague, Tuberculosis):

Upendra Brahmachari (CMC & CRMC), (Lt Col) A D Stewart (STM), (Lt Col) R Knowles (IMS & PI), (Maj Gen) J Taylor (IMS), (Brig) J A Sinton (MSI), R B Lal (GMP & AlPH); C G Pandit (KIM), (Lt Col) R Row (GMB & HI), (Lt Col) H E Shortt (IPM), Sahib Singh Sokhey (HI), S N Chatterjee (CSTM), A C Ukil (CMC) and others;

Pathology and *Bactriology*: G Panja (STM), (Lt Col) C Pasricha (STM), M B Soparkar (IMS), T S Tirumurti (MMS), B P Tribedi (CMC);

Physiology and Biochemistry: N M Basu (PC), B Narayana (PWMC), S S Sokhey (HI);

Psychoanalysis : O A R Berkeley-Hill (IMS), Girindra Sekhar Bose (CU), S C Mitra (CU), N N Sengupta (CU), K N Bagchi (NMC);

Pharmacology: R N Chopra (STC), Premkumar De (STC), J C Gupta (STC & CU), B B Dikshit (HI);

Midwifery, Obstetrics & Gynaecology: Kedarnath Das (CMC & CRMC), Subodh Mitra (CRMC & CSS);

Medicine: B C Roy (CMC & CMB); M N Dey (CMC), V R Khanolkar (GMB & TMH), G Panja (STM);

Surgery: M G Kini (MMS);

X-ray photographs/ *therapy*: M L Sircar (IACS), J C Bose (PC), Nilratan Sircar (IACS), Phanibhusan Mukherjee (PWMC), and others;

Genetics & Heredity: J B S Haldane;

Nutrition: M V R Rao (HI & GMB);

Veterinary Science & Animal Husbandry: J R Haddow (IVI), (Major) S Datta (IVI), (Col) A Oliver (IVI),F Ware ((IVS) and others.

In **Agriculture, Botany, Zoology, Anthropology, Geology, Technology & Engineering Sciences**, lot of important publications came out during the period on regional agriculture, floras, faunas, anthropometric studies, mines and minerals respectively. How the new universities/institutes took shape with the advent of trained personnel and contributed in different disciplines is a matter of great significance.

(a) Agriculture Science: Pusa institute in Bihar was relocated to Delhi 1919 as Imperial Agricultural Research Institute (IARI). Punjab Agricultural College Research Institute (Lyallpur, 1906-) and a few others including Indian Council of Agricultural Research (a society, 1929) were established and made important contributions. The experts and different areas of research during 1901-1947 may be seen as under :

Agriculture, Agronomy & Horticultural Research: B C Burt (IAS), D Henry (ICI),M S Randhawa (ICAR), B N Singh (IARB);

Agricultural Statistics: V G Panse (IPI);

Crop Diseases: B N Uppal (AGP & AGB);

Morphology of Rice & Inheritance: G N R Ayyangar (IARC);

Entomology: M A Husain (AGL & PNL);

Jute (High-yielding varieties, fibre in stem & physical structure): B C Kundu (PC & IARI);

Sugarcane Research: T S Venkataraman (IARC);

Herbarium (Plantation): C C Calder (BSI);

Hydrodynamics: N K Bose(AMU);

Soil Science, Soil Bacteriology, Colloid Chemistry: William Burns (IAS), J K Basu (AGP), B Viswanath (IARI);

(b) Botanical Science: Apart from Botanical Survey of India, different universities made important contributions:

Forestry & Forest Plants: K D Bagchee (FRI), N L Bor (IFS), C G Trevor (FRI);

Economic Botany: F J F Shaw (IARI);

Plant Anatomy, Taxonomy, Morphology, Cytology, Cytogenetics & Embryology : S P Agharkar (CU), I Banerjee (CU), P N Bhaduri (CU); Y Bharadwaja (BHU), A C Joshi (GP & PU), B S Kadam (Govt of Bombay), P Maheswari (DCU & DU), H S Rao (ZSI), H Santapau (KG & SXB),

Pathology & Ecology: F R Bharucha (ISB), H Chaudhuri (PU), G P Majumdar (PC), K C Mehta (AGC), B B Mundkur (IARI);

Algoloy: M O P Iyengar (PM);

Plant Physiology: R H Dastur (ISB), P Parija (RC & UC);

Plant Mycology: S L Ajrekar (ISB), S R Bose (RMC);

Genetics & Plant Breeding : B P Pal (IARI),K Ramiah (PI &RRC);

Paleobotany : Birbal Sahni (BHU & LU);

(c) Zoological Science : Two zoological journals were started in 1907, the *Records* and the *Memoires of the Indian Museum,* which encouraged the setting up of **Zoological Survey of India** (1916) by combining the activities of Zoological and Anthropological sections of the Indian Museum. Specialized areas were:

Entomology of Insects: C F C Beeeson (IFS), H G Champion (FRI), N C Chatterjee (FRI), H S Pruthi (AGL &IMC), B N Chopra ZSI & IMC),M L Roonwal (ZSI);

Ornithology: B C Law (ZC);

Ichthyology (*Fish & Fisheries*): Hamid Khan (PNL), S L Hora (ZSI), H K Mookerjee (CU), S B Setna (GFB), B Sundararaj (GFM);

Morphology, Embryology & Cytology: B L Bhatia (GH), R G Aiyar (TC), K N Bahl (LU), D R Bhattacharya ((ALLU),G Matthai (PNL), B R Seshachar (MSU), Vishwanath (GL);

Animal physiology: W Burridge (LU);

Marine zoology: P R Awasthi (ISB);

Paleontology: Baini Prasad (ZSI);

(d) Anthropological Science: From 1916 it was with ZSI, got separated in 1945 and concentrated more on physical and cultural anthropology.

Physical & Cultural Anthropology (Tribals & Aboriginal) : L K Ananthakrishsna Iyer (CU), S C Roy (Ranchi), J H Hutton (ASB),B S Guha (ANSI), V Elwin (ANSI),G S Ghurye(BU), D N Majumdar (LU), J P Mills (GA), P C Mohalanobis (PC & CU) and others ;

Anthropo-geography: Nirmal Kumar Bose (CU & ANSI).

(e) Geological Science: Apart from GSI, a few other organizations also made important contributions:

Mining (Coals, Minerals & Oil fields): E L G Clegg (GSI), J A Dunn (GSI), E R Gee (GSI), D Penman (SD), K K Mathur (BHU), B Rama Rao (GSI),F G Percival (TISCO), E Spencer(BRC), E T Vacheli (BO), Rajnath (BHU), V P Sondhi (GSI);

Himalayan geology: J B Auden (GSI), C S Fox (GSI), W D West (GSI & SU); *Precambrian geology*: C S Pichamuthu (MSU);

Igneous and Metamorphic rocks: L L Fermor (GSI), A M Heron (GSI);

Mineralogy: D N Wadia (GSI & Indian Bureau of Mines);C Mahadevan (AU);

Petrology: Percy Evans (BO), W E V Abraham (BO); J C Coates (BO),P K Ghosh (GSI), S K Roy (SD);

Geodesy & Surveying: G Bomford (GSI);

Stratigraphy & Palaeontology: L R Rao (MSU);

(f) Technology & Engineering Science: M Visvesvaraya received LCE equal to Diploma in Civil Engineering from Bombay University, had training from Aden, and became chief engineer responsible for flood protection system of the city of Hyderabad, construction of Krishna Raja Sāgara Dam over Kaveri river and other important projects during 1912-18. AMIE was introduced later in 1928 by Association of Indian universities as an undergraduate degree, and BE in Engineering Colleges in 1935-36 having two groups, group A was common and group B was recommended for specific engineering. The suspended cantilever Howrah bridge (1943) connecting Calcutta over Hoogly river in which R N Mookerjee (MBC) was involved was a pioneering marvel. The major areas of interest were:

Civil & Mechanical: F C Temple (MPW), M Visvesvaraya;

Sewage Treatment & Bio-chemical Engineering: G J Fowler (IISc), R D Desai (BU);

Metallurgical: D R Malhotra (IR), P Neogi (BES & PC);

Electricity Generation: R E Bell Crompton, B N Dey (CESC);

Electrical: F N Mowdawalla (IISc);

Biochemistry (Wood, Food Technology, Health & Nutrition): S N Kapur (FRI), V Subramanyan (IISc), P V Sukhatme (ICAR);

Cotton Textile & Instrumentation: Nazir Ahmad (CTR);

Chemical & Industrial Development: R N Mookerjee (MBC), A Ramaswami Mudaliar (MSE); *Standardization*: L C Verman (BSIR & NPL);

Abbreviations: AGB –Agricultural College, Bombay; AGC – Agra College, Agra; AGL – Agricultural College, Lyllapur; AGP – Agricultural College, Pune; AGU – Agra University; AIPH – All India Institute of Public Health, Calcutta; ALLU -Allahabad University; ASI – Anthropological Survey of India; AMU - Aligarh Muslim University; ANNU – Annamalai university; ANSI – Anthropological Survey of India, Calcutta; ASB – Asiatick Society of Bengal; AU – Andhra University; BC -— Bengal Chemical, Calcutta; BE – Bengal Engineering College, Shibpur; BHU – Benares Hindu University; BI – Bose Institute, Calcutta; BO – Burmah Oil Co; BR – Baroda College, Rajasthan; BRC – Bird Company, Calcutta; BSI – Botanical Survey of India, Calcutta; BSIR – Board of Scientific & Industrial Research, Delhi; BU – Bombay University; CB – Central College, Bangaloe; CESC – Calcutta Electric Supply Corporation; CL – Canning College, Lucknow; CMB – Chief Minister, West Bengal; CMC – Calcutta Medical College; CO – Colaba Observatory, Bombay; CRMC – Carmichael Medical College, Calcutta; CSS – Chittaranjan Sewa Sadan, Calcutta; CTR – Cotton Technological Research Laboratory, Bombay; CU – Calcutta University; DCU – Dacca University; DMB – Defense Ministry, Bangalore; DU – Delhi University; FRI – Forest Research Institute, Dehra Dun; GA – Govt College, Assam; GB – Govt College, Bombay; GD – Govt College, Dacca; GH – Govt College, Hoshiarpur; GFB – Govt Fisheries, Bombay; GFM – Govt Fisheries, Madras; GL – Govt College, Lahore; GMB – Grant Medical College, Bombay; GMP – Govt Medical College, Punjab; GP – Govt College, Patna; GSI – Geological Survey of India; HI – Haffkine Institute, Bombay; IACS – Indian Association for Cultivation of Science, Calcutta; IARB – Institute of Agricultural Research, Benaras; IARC – Institute of Agricultural Research, Coimbatore; IARI – Imperial (Indian) Agricultural Research Institute, Pusa; IAS – Indian Agricultural Service; IBM – Indian Bureau of Mines; ICAR – Imperial (Indian) Agricultural Research Institute, Delhi; ICI – Imperial Chemical Industries, India; ICMR – Imperial (Indian) Council of Medical Research; IFS – Indian Forest Service; IISc – Indian Institute of Science, Bangalore; IJHS—Indian Journal of History of Science; IMC – Indian Museum, Calcutta; IMS – Indian Medical Service; IMD - India Meteorological Department; IMS – Indian Military Service; IPI –Institute of Plant Industries, Indore; INSA – Indian National Science Academy, Delhi; IPM – Indian Institute of Preventive Medicine, Guindy, Madras; IR – Indian Railways; ISB – Institute of Science, Bombay; ISM – Indian School of Mines, Dhanbad; ISNA—Indian Science News Association; IVI – Indian Veterinary Research Institute, Izatnagar; IVS – Indian Veterinary Service; KA – Khalsa College, Amritsar; LCRI – Indian Lac Research Institute & Industrial Development, Ranchi; KG –Kew Garden, London; KIM – King Institute of Preventive Medicine, Madras; KO – Kodaikanal Observatory, Madras; LU – Lucknow University; MBC – Martin Burn Co; MEK - Meteorological Office, Karachi; MEP – Meteorological Office, Pune; MMS – Madras Medical Service; MSE – Mysore State Engineer; MSI – Malaria Survey of India; MSU – Mysore University; MPW – Military & Public Works Department of India; MU – Madras University; NMC – National Medical College, Calcutta; NO — Nizamia Observatory, Hyderabad; NPL – National Physical Laboratory, Delhi; PC – Presidency College, Calcutta; PI – Pasteur Institute, Kasauli; PM – Presidency College, Madras; PSU – Penynsylvania State University, USA; OU –Osmania University, Hyderabad; PNL - Punjab University, Lahore ; PU – Patna University; PWMC – P W Medical College, Patna; RC – Ravenshaw College, Cuttak; RMC – R G Kar Medical College, Calcutta; RRC –Rice Research Institute, Cuttak; RU – Rajasthan University; SB – Science College, Bombay; SD – School of Mines, Dhanbad; SP – Science College, Patna; STM – School of Tropical Medicine, Calcutta; SU – Saugar University; SXB – St Xavier College, Bombay; TC – Teachers' College, Madras; TD – Tibbia College of Unani, Delhi; TISCO – Tata Iron & Steel Co, Jamshedpur; TIP – Toshniwal Industries Private Ltd; TMH – Tata Memorial Hospital, Bombay; TU – Travancore University; UC – Utkal University, Cuttak; ZC – Zoological Garden, Calcutta; ZSI – Zoological Survey of India;

APPENDIX

Nain Singh Rawat (left) and Radhanath Sikdar (right)