

# Role of Experiments in the Progress of Science: Lessons from our History

D. P. Roy

Homi Bhabha Centre for Science Education (TIFR)

- ❖ I shall discuss how downgrading experiments from scientific learning lead to the decline of ancient Indian science and civilization.
-



In his address as the Sectional President in Physics and Mathematics of the Indian national Science Congress (1926) Meghnad Saha quoted the following lines from a 9<sup>th</sup> century Sanskrit text on Chemistry, called 'Rasendra Chintamani' by Dhunduknath, brought to his notice by his teacher P. C. Ray:

---

- ❖ I have heard much from the lips of savants, I have seen many formulae well-established in scriptures, but I am not recording any which I have not done myself. I am fearlessly recording only those that I have carried out before my elders with my own hand. Only they are to be regarded as real teachers who can show by experiments what they teach. They are the deserving pupils who can actually perform them after having learned from their teachers. The rest are merely stage actors.



# Review of the Indian calendar Reforms Committee of M. N. Saha et al on the three periods of ancient Indian Astronomy: Vedic(->1300BC), Vedanga(1300BC-400AD), Siddhanta(400-900AD)

---

- ❖ During the Vedanga period emphasis had shifted from collecting observed data to achieving more computational precision. The Sakas and Kusanas brought the contemporaneous knowledge of Astronomy from Bactria to north-west India. This latest exposure initiated the great spurt of activities in the Siddhanta era. Surya Siddhanta is assigned to 3<sup>rd</sup> century AD, followed by blazing luminaries: Aryabhatta & Varahamihira (500 AD), Brahmagupta & Bhaskara I (600 AD). Aryabhatta authored Aryabhatiya and a revised version of Surya Siddhanta. He also had a profound influence on the development of Islamic Astronomy. So there was a two-way interaction with other civilizations.



# Scientific Influence from other Civilizations

(Wikipedia)

---

- ❖ The Yavanajataka was translated from Greek to Sanskrit by Yavanesvara during 2<sup>nd</sup> century AD under Saka king Rudradaman. His capital Ujjain was the “Greenwich of Indian Astronomy”.
- ❖ Later in the 6<sup>th</sup> century, Romaka Siddhanta and Paulisa Siddhanta were 2 of the 5 main treatises of Varahamihira called Pancha-Siddhanta.
- ❖ He wrote “The Greeks, though impure, must be honoured since they were trained in sciences and therein excelled others”. Gargi-Samhita says “The Yavanas are barbarians, yet the science of Astronomy originated with them and for this they must be revered like Gods”.



# Scientific Influence on other Civilizations

(Wikipedia)

---

- ❖ Indian Astronomy reached China with the expansion of Buddhism during Han dynasty (25-220 AD). Further translation of Indian works on Astronomy was completed in China during the Three Kingdoms era (220-265 AD). However, most detailed incorporation of Indian Astronomy occurred only during the Tang dynasty (618-907 AD).
- ❖ Arabs adopted the sine function (inherited from Indian mathematics) instead of chords of arc used in Hellenistic mathematics. Another Indian influence was an approximate formula used for timekeeping by Muslim astronomers. Indian Astronomy had an influence on European Astronomy via Arabic translations.



# Decline of Siddhanta Astronomy after 900 AD:

Bhaskara II (12<sup>th</sup> cent.), Kerala School (15-16<sup>th</sup> cent), Samanta Chandra Sekhar (19<sup>th</sup> cent.)

---

- ❖ The last exponent of Siddhanta Astronomy, Samata Chandra Sekhar, lived in Orissa from 1835 to 1904. He constructed his own instruments, acquired great skill in using them for accurate observations of sun, moon, planets and stars. When he found by repeated observations that the measured positions in most cases do not agree with results computed using the famous Siddhantas, he boldly concluded that the latter are in error, not his experimental determinations. He wrote his findings in Siddhanta Darpana on palm leaves in Sanskrit using Oriya script. Prof. J. C. Ray of Ravenshaw College, Cuttack, arranged to publish it in Devanagari script through a Calcutta press thirty years later, in 1899.

– Prof. M. K. Pal



## Determination of the 4 Cardinal Points (Wikipedia):

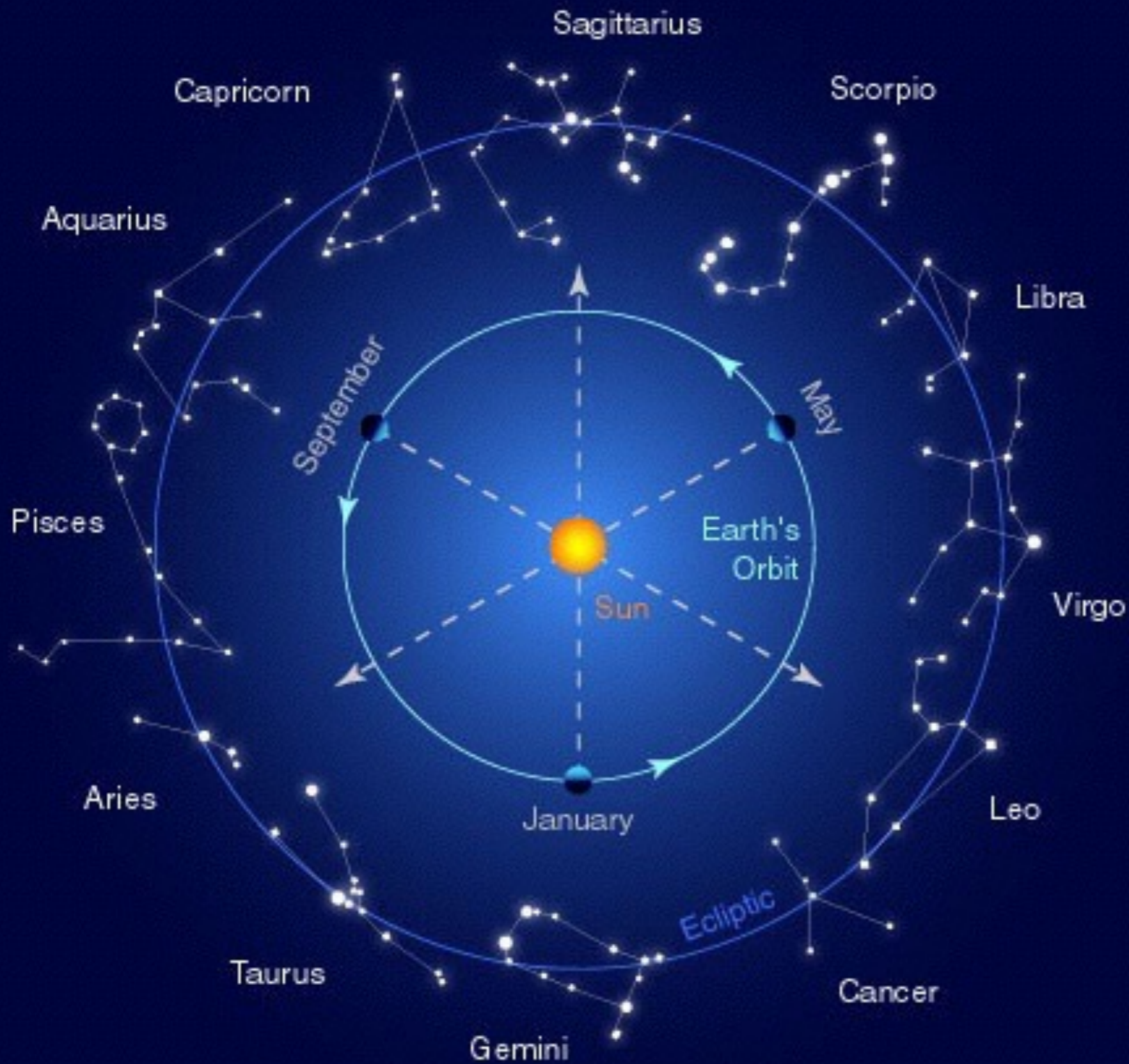
Summer and Winter Solstice (Makar Samkranti),  
Autumn and Vernal Equinox (Vishuv Samkranti).

---

- ❖ The simplest device used in astronomy was Gnomon, called Sanku, in which the direction and length of the shadow of a vertical rod were measured to find the cardinal directions, the latitude and time.
- ❖ The time of the shortest shadow marks midday.
- ❖ In the tropical region, the 2 days of the longest midday shadows along north and south mark winter and summer solstices respectively.
- ❖ The 2 midpoints of the summer and winter solstices mark the 2 equinoxes.
- ❖ At the time of this calibration around 500 AD, the Helial (Sun synchronous) rising of the constellation Capricorn (Makar) corresponded to winter solstice day (Makar Samkranti).
- ❖ But precession of earth's rotation axis has resulted in a 23 days gap between these terrestrial and celestial markers over the past 1500 years!
- ❖ This is a glaring example of how blind following of text without experimental recalibration leads to wrong solstice and equinox times.



Mayank Vahia  
DNA, 9 March 2014





# Non-recording of purely Empirical Phenomena in Indian Astronomical Texts

---

- ❖ The Chinese have kept data of meteoric showers, 29 appearances of Halley's comet, 90 novae and supernovae and intense sun spot activities.
- ❖ Yet there is no Indian record of these purely empirical phenomena.
- ❖ In particular the spectacular Crab supernova explosion of 11<sup>th</sup> century appeared as the 2<sup>nd</sup> brightest object of night sky after the moon for several weeks. It is recorded by Chinese, Arab and even Mayan astronomers of Mexico.
- ❖ Yet there is no credible evidence of Indian astronomical record of this event, presumably because it was not amenable to any theoretical explanation at that time.



# Ancient Indian Metallurgy

India was a major exporter of Ferrous metals throughout ancient History.

---

The Iron Pillars of Delhi and Dhar, dating back to 400 AD, stand living testimony to the skills of ancient Indian metallurgists.

The Delhi pillar is 7 m high and weighs 6.5 tons. It is 98% pure Iron with a high phosphorous content to make it rust-free.

No other country had the capability to produce an iron mass of this size and purity till the Industrial Revolution of 18<sup>th</sup> century.





# Aurvedic Biology – M. S. Valiathan

---

- ❖ The Samhita phase from 1<sup>st</sup> to 8<sup>th</sup> century AD is generally regarded as the golden age of Ayurveda.
- ❖ It had three major texts called the Brihatrayi.
- ❖ Caraka Samhita (1<sup>st</sup> cent.) is a redaction by Caraka of a treatise composed by Agnives several centuries earlier.
- ❖ Susruta Samhita (3<sup>rd</sup> -4<sup>th</sup> cent.) is a redaction by Nagarjuna of the surgical treatise of Susruta, who is said to have lived around 700 BC!
- ❖ Astanga Samgraha & Astanga Hrdaya (8<sup>th</sup>-9<sup>th</sup> cent.) are composed by Vagbhata.



# Charaka Samhita (1<sup>st</sup> century AD)

---

- ❖ Caraka's redaction was so highly creative that the new text was acclaimed as Caraka Samhita.
- ❖ Here Ayurveda got its name for the first time, and it moved from a faith-based to a reason based platform.
- ❖ It was encyclopedic in the coverage of medicines, and recognized as the last word in internal medicine.
- ❖ It was translated into Persian, Arabic and Tibetan within 2-3 centuries and spread its influence to central Asia, where Bower Manuscript of 400 AD with numerous quotes from Caraka was discovered in 1890.
- ❖ It was translated into English in 19<sup>th</sup> century.
- ❖ Its popularity continues in the 21<sup>st</sup> century, when a digital version was prepared by Prof. Yamashita of Kyoto Univ.

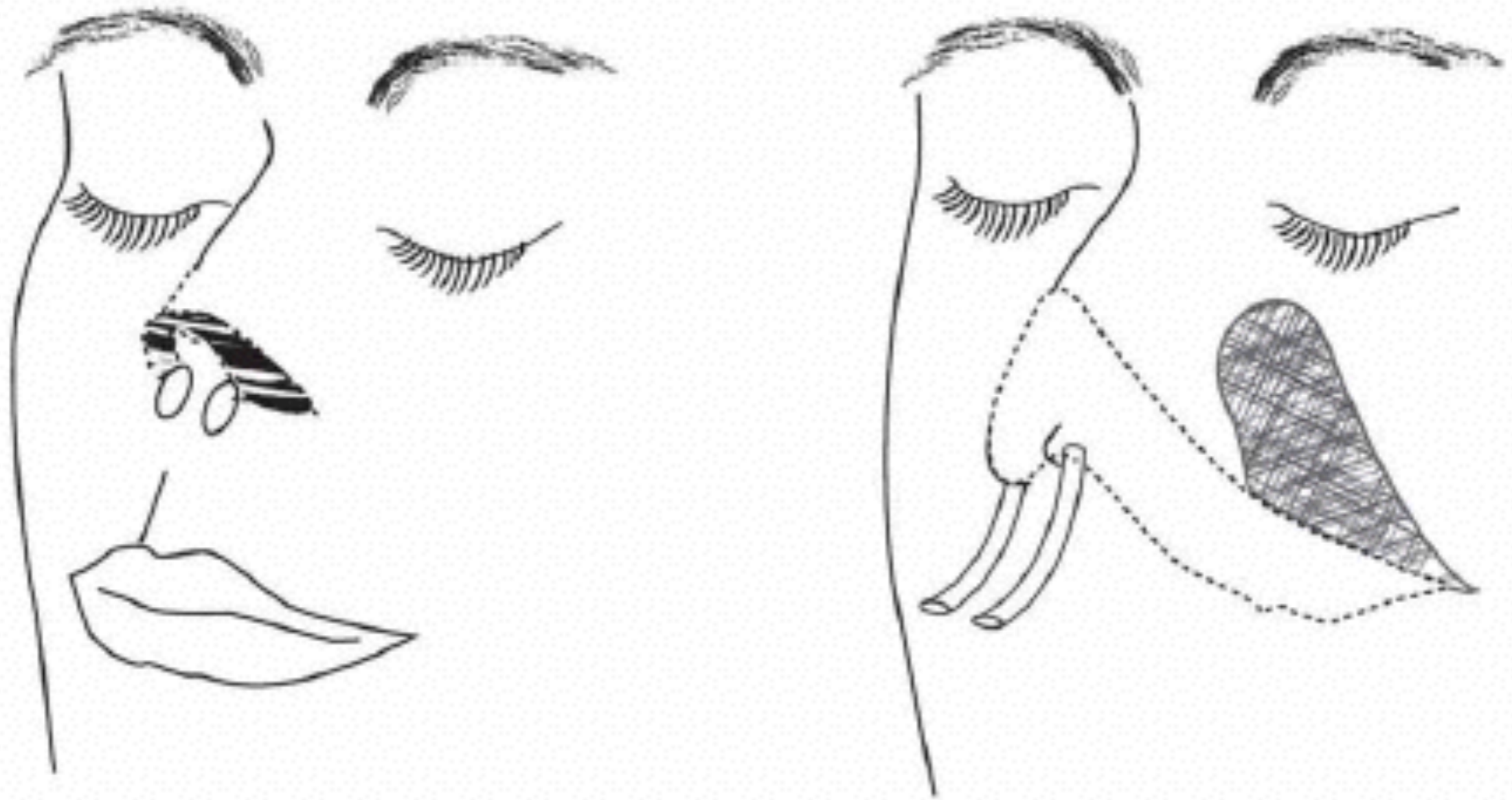


## Susruta Samhita (3<sup>rd</sup> - 4<sup>th</sup> century AD)

---

- ❖ Susruta's name is forever associated with Rhinoplasty (nose repair), the only surgical procedure from India to have won global recognition in 3 millenia!
- ❖ Susruta Samhita is a comprehensive medical treatise with heavy surgical orientation, dealing with surgical procedures, instruments, care of trauma, medications etc.
- ❖ Compared to Caraka Samhita it has simpler language and lower emphasis on the philosophical dimensions of medical practice.
- ❖ Susruta Samhita enjoyed great authority even beyond Indian borders because it was translated into Arabic under the Caliphate, when Indian physicians were believed to have lived in Baghdad.





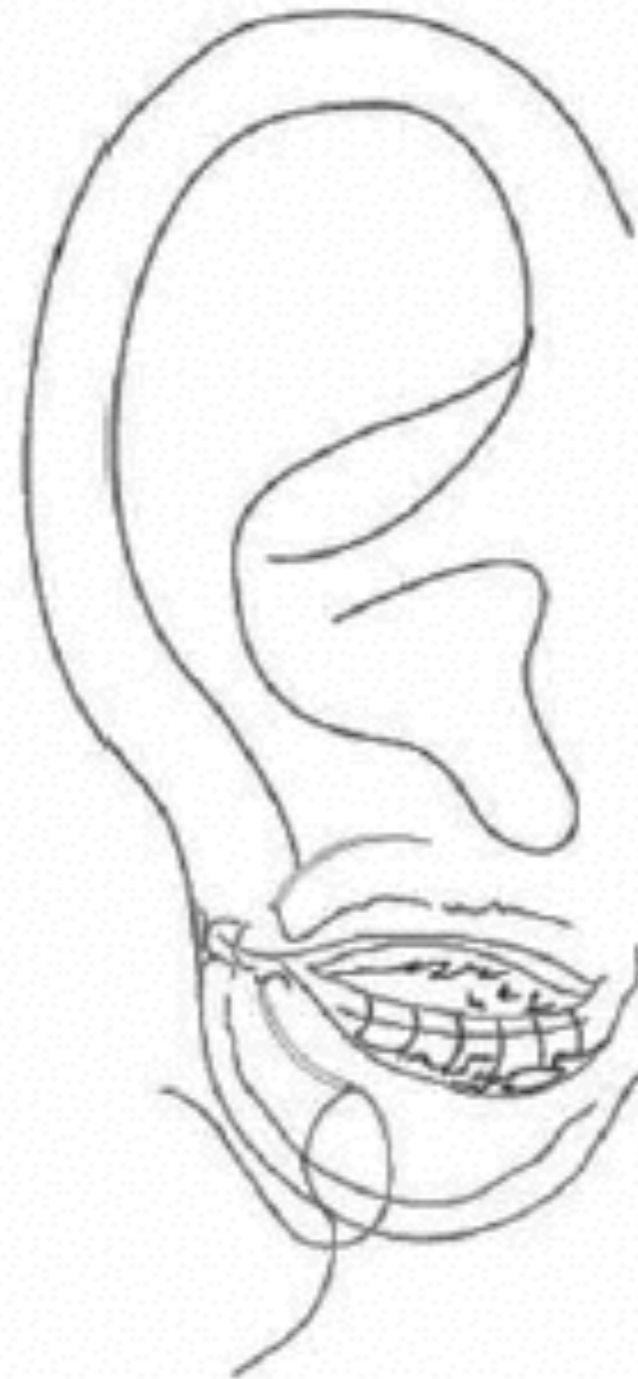
**Fig. 4 Plastic repair of nose**

Described by Susruta: a pedicle flap from the cheek was used; the eighteenth century practitioner in Pune took the flap from forehead





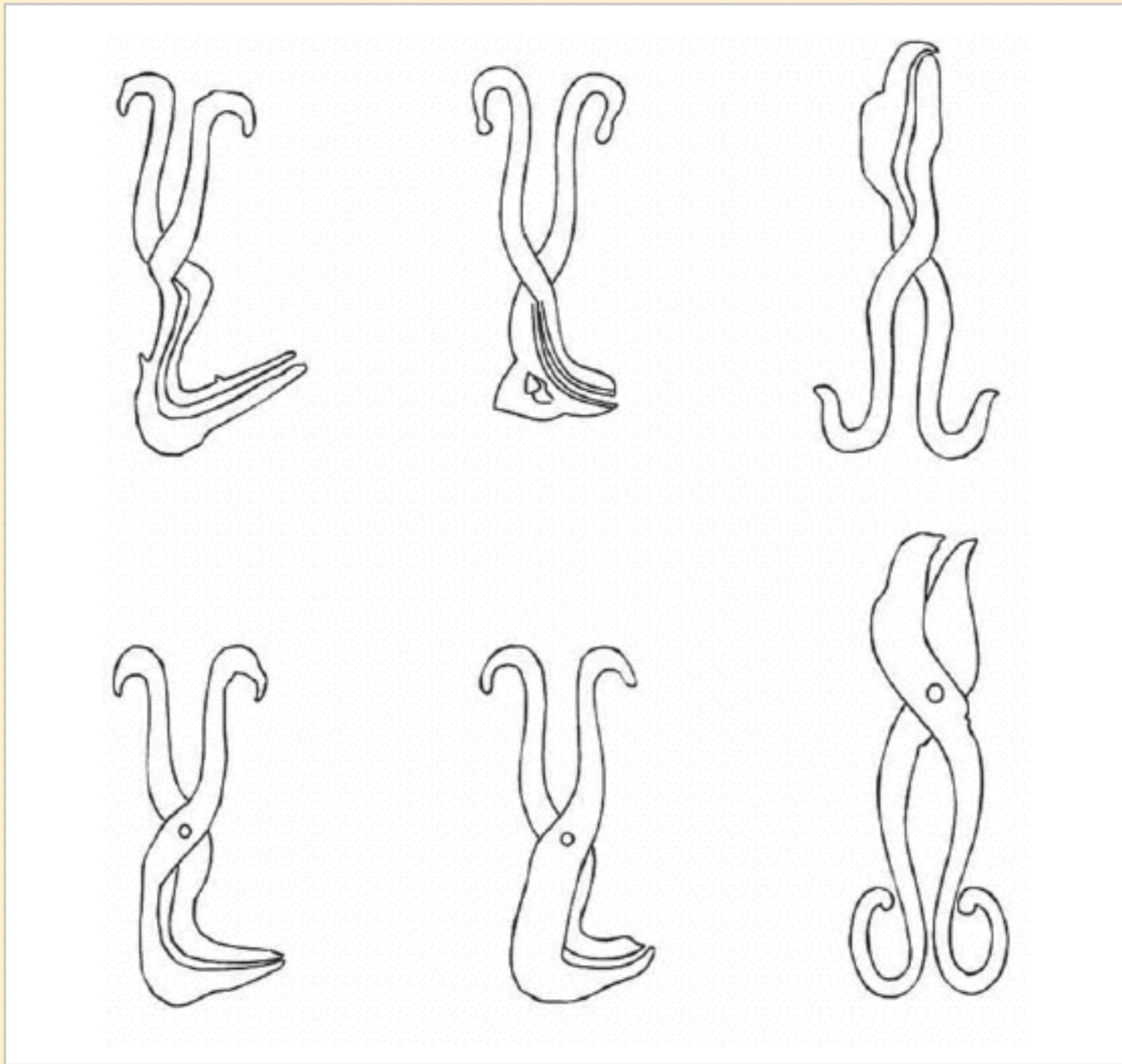
i.



ii.

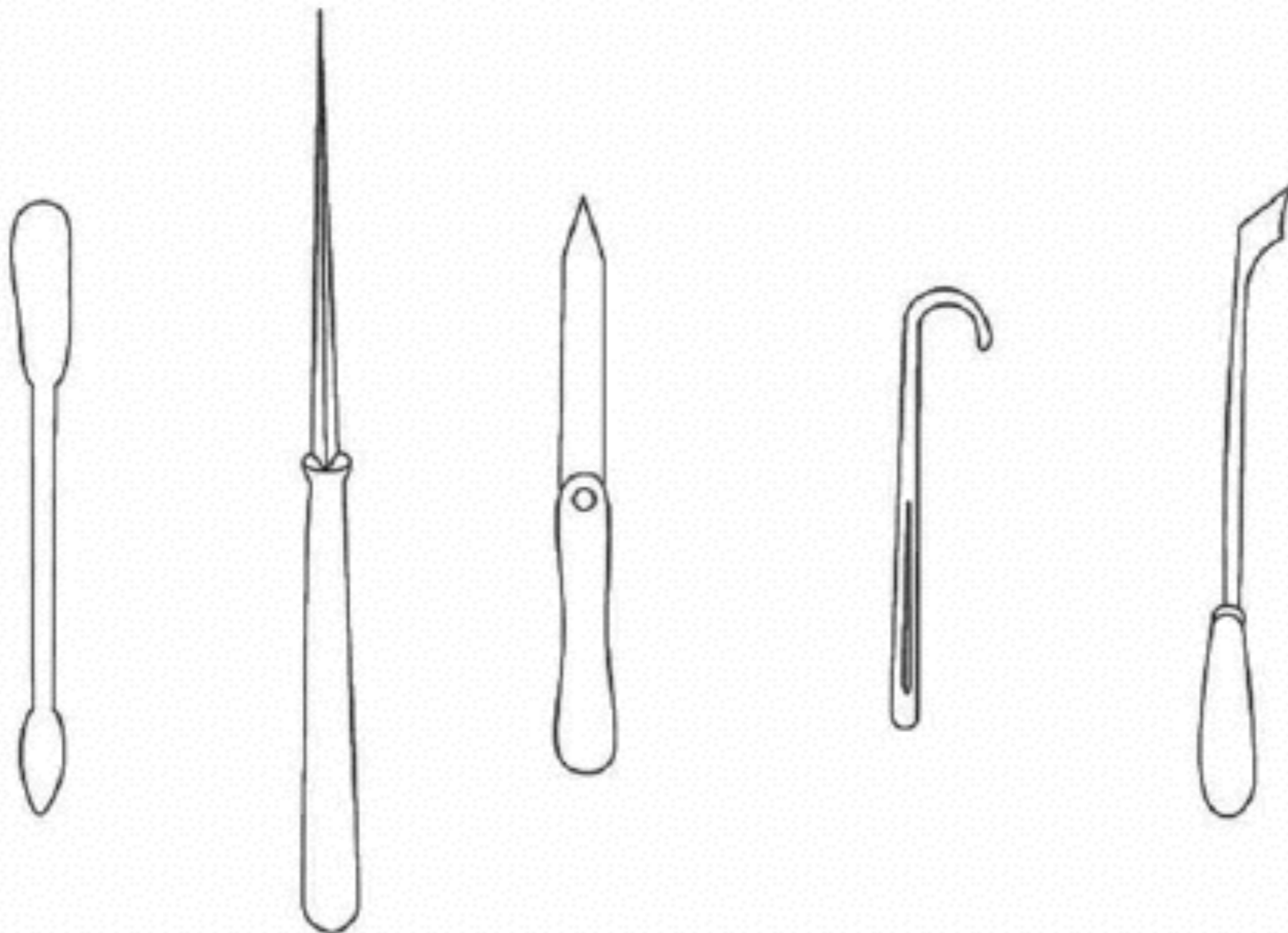
**Fig. 5 Plastic repair of ear lobe**  
was recommended by Susruta when the ear lobe was destroyed by infection following the piercing of ear





**Fig. 6 Instruments – blunt (Yantras)**  
A few from the 100 blunt instruments of Susruta





**Fig. 7 Instruments – sharp (Sastras)**  
A few from the 20 sharp instruments of Susruta



# Susruta and Carak Samhitas (cont.)

---

- ❖ There is little doubt that the Susruta and Carak Samhitas were taught at Nalanda; and the large number of students from Tibet, China and other countries of East Asia would have carried home their copies and translations.
- ❖ Transfer of knowledge was also facilitated by Indian teachers accompanying these home-bound disciples.
- ❖ Even today several texts in medicine, philosophy etc, which are no longer available in the Sanskrit original, are available in their Chinese and Tibetan translations.
- ❖ What the barbarians destroyed in India had a resurrection in other countries. (Complete destruction of Nalanda by Bakhtiar Khilzi in 1200 AD)



# Astanga Samgraha & Astanga Hridaya (Vagbhata)

---

- ❖ Acharya P. C. Ray estimated the date of composition of these texts to be 8<sup>th</sup> – 9<sup>th</sup> century, when Ayurveda was on the threshold of Stagnation.
- ❖ The texts accept the authority of Caraka and Susruta in no uncertain terms and present their teachings in a simple and abridged manner for average students.
- ❖ Astanga Hridaya accomplished this objective admirably and became a popular favourite, thanks to the gift of poetic excellence that no other text could claim.
- ❖ After Vagbhata, the springs of creativity ran dry and a long phase of stagnation ensued for a thousand years in the history of Ayurveda.



## Stagnant Phase of Ayurveda (10<sup>th</sup> cent. ->)

---

- ❖ There were no more Carakas and Susrutas, nor the advent of power-houses of learning like Nalanda in this phase.
- ❖ Muslim rulers preferred Unani over Ayurveda.
- ❖ But the malady had roots deeper in the social history of India, because the surgical techniques of Susruta had more or less disappeared from the mainstream of Ayurveda already by the time of Vagbhata.
- ❖ Cadaveric dissections was no more mentioned; and the training of disciples did not include exercises on cucumber, jackfruit, animal skin etc for learning incision, extraction, scraping and other surgical procedures.
- ❖ So the Muslim conquest of India and destruction of Nalanda were not the causes but the consequences of the decline of Indian science and civilization.



# Alberuni's India (1000 AD)

---

- ❖ The Hindus believe that there is no country but theirs, no nation like theirs, no king like theirs, no religion like theirs, no science like theirs.
- ❖ They are haughty, foolishly vain, self-conceited, and stolid.
- ❖ They are by nature niggardly in communicating that which they know, and they take the greatest possible care to withhold it from men of another cast among their own people, still much more, of course, from any foreigner.
- ❖ Their haughtiness is such that, if you tell them of any science or scholar in Khorasan or Persia, they will think you to be both an ignoramus and a liar.
- ❖ If they traveled and mixed with other nations, they would soon change their mind, for their ancestors were not as narrow-minded as the present generation is.



# Subculture of Surgical Skills in Lower castes

## Valiathan

---

- ❖ The surgical procedure that disappeared from the main stream surfaced however among castes, which were low in the social hierarchy.
- ❖ Susruta's nose repair is an interesting example.
- ❖ Barring a perfunctory reference, it received no serious attention in the Aurvedic texts; nor was it performed by reputed Vaidyas.
- ❖ Its survival was “discovered” accidentally by British observers in Pune towards the end of 18<sup>th</sup> century.



# Pune nose repair episode

---

- ❖ Dr. Scott, a sympathetic British doctor residing in Mumbai, had heard from one Capt. Irvine in 1794 about the practice among “gentoos of putting new noses on people who have had them cut off”!
- ❖ He assured Dr. Scott that all the employees of the East India Company in Pune were witnesses to the operation which gave the man a “pretty good nose”.
- ❖ Dr. Scott wrote to Mr. Findlay, the company surgeon in Pune, to ascertain the veracity of this report because such an operation was unknown in Europe.
- ❖ Mr. Findley sent a detailed report on the basis of eyewitness observation by himself and Mr. Cruso on 1<sup>st</sup> January 1794.



- ❖ The report described how a “koomar” caste man had borrowed an old razor for the occasion, dissected a flap from the forehead of the patient with much composure, freshened the edges of the nasal defect and applied the flap thereon by rotation with a cement “without the aid of stitches, sticking plaster or bandages”. The flap healed and “an adhesion has taken place seemingly in every part”.
- ❖ It was a report of this procedure, published in the “Gentleman’s Magazine” of London in 1794, which caught the attention of a surgeon, Dr. J. C. Carpue, FRS.
- ❖ He performed the operation for the 1<sup>st</sup> time in the West and published a full length paper on “An account of two successful operations for restoring a lost nose from the integuments of the forehead” in 1816 (H. Scott, Bombay, India Office Library, London).



# Other Surgical Skills

---

- ❖ A similar eyewitness report on Susruta's couching for cataract was given by Dr. Ekambaram of Coimbatore in 1910. He found that the procedure was done by itinerant Mohammedan vaidyas who followed the steps of Susruta's method.
- ❖ Note that the procedure in Pune and Coimbatore were done not by Ayurvedic physicians but by illiterate men, who had learned the techniques from an earlier generation.
- ❖ Treatment of fracture by bonesetters, child delivery by dais and many other procedures involving "dirtying of hand" were relegated to lower caste persons, who did not understand their anatomical basis or rationale.
- ❖ It was as if the nation's brain was decoupled from its hand, which ensured that there could never be innovation based on true understanding.



# Metallurgical Skills

---

- ❖ On the request of the Govt. of Bengal in 1828, James Franklin FRS, made a thorough study of the ore, charcoal and furnaces used by the natives of Central India for making iron.
- ❖ He wrote “ the smelting furnaces, though crude in appearance, are never the less very exact in the interior proportions, and it has often surprised me to see men who are unquestionably ignorant of their principle, construct them with such precision”.
- ❖ He went on to describe in detail the geometrical and practical construction of the furnace, the construction and use of bellows, construction of two refineries for each furnace, mode of smelting and refining etc.



- ❖ On getting the product evaluated at the Sagar mint he wrote "the bar iron was of the most excellent quality, possessing all the desirable properties of malleability, ductility at different temperatures and of tenacity of which I think it cannot be surpassed by the best Swedish iron".
- ❖ Though the workmen could not answer Franklin's questions or explain the procedures used for hundreds of years by their forefathers, he commented that the "original plan of this singular furnace must have been the work of advanced intelligence".
- ❖ Actually this was the relic of a civilization that had produced the iron pillars of Delhi and Dhar in 400 AD.



# Reflections of Valiathan

---

- ❖ The workmen doing nose repair in Pune, cataract couching in Coimbatore and ore smelting in Jabalpur were condemned to illiteracy, low social status, poor self-esteem and little hope of self advancement.
- ❖ Since this grim prospect claimed hundreds of thousands of citizens, who used their hands to make a living, ruin could be the only destination of their nation.



# Reflections of P. C. Ray

(History of Chemistry in ancient and medieval India)

---

- ❖ According to Susruta, the dissection of the dead bodies is indispensable to the students of surgery, and this high authority lays particular stress on knowledge gained from experiments and observations. But Manu would have none of it. According to Manu, the very touch of corpse is enough to contaminate the sacred person of a Brahmin. Thus we find shortly after Vagbhata, the handling of a lancet was discouraged and anatomy and surgery fell to disuse. They became for all practical purposes, lost sciences for the Hindus. It was considered equally undignified to sweat away at the furnaces.



- ❖ The sciences being thus relegated to the lower castes, and the professions made hereditary, a certain degree of fineness, delicacy and deftness in manipulation was no doubt secured. But this was accomplished at a terrible cost. The intellectual portion of the community being thus withdrawn from active participation in these sciences, the how and why of phenomenon – the coordination of cause and effect – were lost sight of. The spirit of enquiry gradually died out among the nation (naturally prone to speculation and metaphysical subtleties), and India for once bade adieu to experimental and inductive sciences. Her soil was made morally unfit for the birth of a Boyle, a Descartes, or a Newton; and her very name was expunged from the map of the scientific world for a time.
- ❖ Under these circumstances, India's rout at the East-West encounter of the 18<sup>th</sup> century was a foregone conclusion.