# Indian Foundations of Modern Science

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## INTRODUCTION

Scholars see India and Greece as the two principal birthplaces of science [1]. School textbooks tell us about Pythagoras, Aristotle, Euclid, Archimedes, and Ptolemy, geometry of the Vedic altars, the invention of zero in India, Yoga psychology, and Indian technology of steel-making that went into the manufacture of the best swords. But if you take the trouble of reading scholarly books, articles and encyclopedias, you will find that in many ways the early Indian contributions are the more impressive for they include a deep theory of mind, Pāṇini's astonishing Sanskrit grammar, binary numbers of Piṅgala, music theory, combinatorics, algebra, earliest astronomy, and the physics of Kaṇāda with its laws of motion.

Of these, Kaṇāda is the least known. He may not have presented his ideas as mathematical equations, but he attempted something that no physicist to date has dared to do: he advanced a system that includes space, time, matter, as well as observers. He also postulated four types of atoms, two with mass and two with little mass, and the idea of invariance [2] [Note 1]. A thousand or more years after Kaṇāda, Āryabhaṭa postulated that earth rotated and advanced the basic idea of relativity of motion [3].

And then there is India's imaginative literature, which includes the Epics, the Purāṇas and the Yoga Vāsiṣṭha (perhaps the greatest novel ever written), that speaks of time travel, airplanes, exoplanets (that is many solar-like systems), cloning of embryos, sex change, communication over distances, and weapons that can destroy everything [4]. Some nationalists take these statements to mean the literal scientific truth, which claim is ridiculed by their political opponents who then use this broad brush to tar all Indian science.

There are also anomalous statements in Indian texts whose origin is not understood. Just to mention a few: the correct speed of light, the correct

distance to the sun, cosmological cycles that broadly correspond to the numbers accepted currently, the fact that the sun and the moon are approximately 108 times their respective diameters from the earth [5], the correct number of species on earth (about 8.4 million), and so on [6]. Historians either ignore them or say that they are extraordinary coincidences. We will come to these anomalies later in the essay.

To return to the history of mainstream science, the discovery of infinite series and calculus by Newton and Leibniz heralded the Scientific Revolution that was to change the world. But new research has shown that over two centuries prior the Kerala School of Mathematics had already developed calculus [7][8] and some historians suggest that this and advanced astronomical knowledge from Kerala went abroad via the Jesuits and provided the spark for its further development in Europe. Other historians discount this saying that clear proof of the transmission of this knowledge to Europe is lacking.

There is more agreement about the many achievements of Indian medical sciences. For example, the Royal Australia College of Surgeons in Melbourne, Australia has a prominent display of a statue of Suśruta (600 BCE) with the caption "Father of Surgery". The ancient Ayurveda texts include the notion of germs and inoculation and also postulate mind-body connection, which has become an important area of contemporary research.

Indian medicine was strongly empirical; it used Nature (which is governed by Ṛta) as guide, and it was informed by a sense of skepticism. In the West the notion of skepticism is usually credited to the Scottish philosopher of science, David Hume, but scholars have been puzzled by the commonality between his ideas and the earlier Indian ones. Recently, it was shown that Hume almost certainly learnt Indian ideas from Jesuits when he was at the Royal College of La Flèche in France [9].

There are also indirect ways that Indian ideas led to scientific advance. Mendeleev was inspired by the two-dimensional structure of the Sanskrit alphabet to propose a similar two-dimensional structure of chemical elements [10].

A Vedantic vision guided Jagadis Chandra Bose in his pathbreaking discoveries in a variety of fields. Bose is considered the true father of radio science which, as we know, has changed the world [11]. Bose also discovered millimeter length electromagnetic waves and was a pioneer in the fields of semiconductor electronics and biophysics [12].

Erwin Schrödinger, a founder of quantum theory, credited ideas in the Upanishads for the key notion of superposition [13] that was to bring about the quantum revolution in physics that changed chemistry, biology, and technology [13][14].

I now briefly touch upon Indian influence on linguistics, logic, philosophy of physics, and theory of mind.

## LINGUISTICS, ALGORITHMS AND SOCIETY

Pāṇini's work (4th or 5th century BCE) showed the way to the development of modern linguistics through the efforts of scholars such as Franz Bopp, Ferdinand de Saussure, Leonard Bloomfield, and Roman Jakobson. Bopp was a pioneering scholar of the comparative grammars of Sanskrit and other Indo-European languages. Ferdinand de Saussure in his most influential work, Course in General Linguistics (Cours de linguistique générale), that was published posthumously (1916), took the idea of the use of formal rules of Sanskrit grammar and applied them to general linguistic phenomena.

The structure of Pāṇini's grammar contains a meta-language, meta-rules, and other technical devices that make this system effectively equivalent to the most powerful computing machine [15]. Although it didn't directly contribute to the development of computer languages, it influenced linguistics and mathematical logic that, in turn, gave birth to computer science.

The works of Pāṇini and Bharata Muni also presage the modern field of semiotics which is the study of signs and symbols as a significant component of communications. Their template may be applied to sociology, anthropology and other humanistic disciplines for all social systems come with their grammar.

The search for universal laws of grammar underlying the diversity of languages is ultimately an exploration of the very nature of the human mind. But the Indian texts remind that the other side to this grammar is the idea that a formal system cannot describe reality completely since it leaves out the self.

## MODERN LOGIC

That Indian thought was central to the development of machine theory is asserted by Mary Boole — the wife of George Boole, inventor of modern logic — who herself was a leading science writer in the nineteenth century. She claimed that George Everest, who lived for a long time in India and whose name was eventually applied to the world's highest peak, was the intermediary

of the Indian ideas and they influenced not only her husband but the other two leading scientists in the attempt to mechanize thought: Augustus de Morgan and Charles Babbage. She says in her essay on Indian Thought and Western Science in the Nineteenth Century (1901): "Think what must have been the effect of the intense Hinduizing of three such men as Babbage, De Morgan, and George Boole on the mathematical atmosphere of 1830–65." She further speculates that these ideas influenced the development of vector analysis and modern mathematics [16].

Much prior to this, Mohsin Fani's Dabistani-i Madhahib (17th Century) claimed that Kallisthenes, who was in Alexander's party, took logic texts from India and the beginning of the Greek tradition of logic must be seen in this material [17]. In Indian logic, minds are not empty slates; the very constitution of the mind provides some knowledge of the nature of the world. The four pramāṇas through which correct knowledge is acquired are direct perception, inference, analogy, and verbal testimony.

## UNIVERSAL GRAVITATION

Indian physics, which goes back to the Vaiśeṣika Sūtras (c. 500 BCE), is not believed to have directly influenced the discovery of physical laws in Europe, but these ideas were an integral part of Indian sciences so they must have played a role in the formulation of scientific questions as Indian ideas traveled west. Kaṇāda had spoken of how objects fall due to gravitation, and his ideas included those of symmetry and invariance that arose from the premise that the universe consisted of innumerable star-systems like out solar system, in contrast to the Western idea of earth being the center of the universe. We have no explicit knowledge that Kaṇāda believed that gravitation worked beyond the earth, although it appears to be implicit in the idea that other solar systems exist [18].

The great Bhāskara (1114–1185) in his Siddhānta-Śiromaṇi presented gravitation as a universal principle:

> ākṛṣṭiśaktiśca mahī tayā yarakhasthaṃ guru svābhimukhaṃ svaśakyā ।
> ākṛṣyate tapatatīva bhāti same samantāt patatviyaṃ khe ॥ 6 ॥
>
> "The earth exerts an attractive force, by which other massive objects in space fall on it. But when attractive force on objects in space balances out, how would they fall?" (Golādhyāya 6) [This explains why planets do not fall on

earth or on other massive bodies.]

Just so that there is no misunderstanding, Bhāskara did not present a mathematical expression for gravitational force.

If Bhāskara's idea of universality of gravitation reached Europe via the Jesuits, then he should be credited with one of the most significant advances in physics before Newton.

## PHYSICS WITH OBSERVERS

Indian ideas that place the observer at center prefigure the conceptual foundations of modern physics, and this is acknowledged by the greatest physicists of the twentieth century.

In the West, the universe was seen as a machine going back to Aristotle and the Greeks who saw the physical world consisting of four kinds of elements of earth, water, fire, and air. This model continued in Newton's clockwork model of the solar system. Indian thought, in contrast, has a fifth element, ākāśa, which is the medium for inner light and consciousness. With the rise of relativity theory and quantum mechanics, the observer could no longer be ignored. In one sense, the journey of science is the discovery of self and consciousness [19].

Kaṇāda's Vaiśeṣika Sūtras speak of how properties of matter are to be derived from substances, their attributes and motions, but our perception of these properties derives from how the mind interacts with the physical system.

It is one of those obscure footnotes to the history of physics that Nikola Tesla, who was very famous in the 1890s, was asked by Swami Vivekananda to find an equation connecting mass and energy. We know that Tesla didn't quite succeed at this but he was to work on various models of wireless transfer of energy for the remainder of his career.

## COSMOLOGY AND EVOLUTION

The Ṛgveda speaks of the universe being infinite in size. The evolution of the universe is according to cosmic law. Since it cannot arise out of nothing, the universe must be infinitely old. Since it must evolve, there are cycles of chaos and order or creation and destruction. The world is also taken to be infinitely old. Beyond the solar system, other similar systems were postulated, which appear to have been confirmed with the modern discovery of exoplanets.

The Sāṅkhya system describes evolution at cosmic and individual

levels. It views reality as being constituted of puruṣa, consciousness that is all-pervasive, and prakṛti, which is the phenomenal world. Prakṛti is composed of three different strands (guṇas or characteristics) of sattva, rajas, and tamas, which are transparency, activity, and inactivity, respectively.

Evolution begins by puruṣa and prakṛti creating mahat (Nature in its dynamic aspect). From mahat evolves buddhi (intelligence) and manas (mind). Buddhi and manas in the large scale are Nature's intelligence and mind. From buddhi come individualized ego consciousness (ahaṅkāra) and the five tanmātras (subtle elements) of sound, touch, sight, taste, smell. From the manas evolve the five senses (hearing, touching, seeing, tasting, smelling), the five organs of action (with which to speak, grasp, move, procreate, evacuate), and the five gross elements (ākāśa, air, fire, water, earth).

The evolution in Sāṅkhya is an ecological process determined completely by Nature. It differs from modern evolution theory in that it presupposes a universal consciousness. In reality, modern evolution also assigns intelligence to Nature in its drive to select certain forms over others as well as in the evolution of intelligence itself.

The description of evolution of life is given in many texts such as the Mahābhārata. I present a quote from the Yoga Vāsiṣṭha on it:

> "Remember that once upon a time there was nothing on this earth, neither trees and plants, nor even mountains. For a period of eleven thousand [great] years the earth was covered by lava. In those days there was neither day nor night below the polar region: for in the rest of the earth neither the sun nor the moon shone. Only one half of the polar region was illumined. [Later] apart from the polar region the rest of the earth was covered with water. And then for a very long time the whole earth was covered with forests, except the polar region. Then there arose great mountains, but without any human inhabitants. For a period of ten thousand years the earth was covered with the corpses of the asuras." [YV 6.1]

The reverse sequence, of the end of the world, is also described in various texts. First, the sun expands in size incinerating everything on the earth (quite similar to modern accounts of the aging sun becoming a red giant). The specific sequence mentioned is that the fireball of the sun transforms the Pṛthivī atoms into Āpas atoms, which then together change into Tejas atoms and further into Vāyu atoms, and finally to sound energy that is an attribute of space, and so on (Mahābhārata, Śānti Parva Section 233). In our modern language, it means that

as temperatures become high, matter breaks down becoming a sea of elements, then the protons break down into electrons, further into photons, and finally into neutrinos, and on to acoustic energy of space. At the end of this cycle the world is absorbed into Consciousness.

Vivekananda was aware of this sequence which is why he asked Tesla to find the specific equation for transformation between mass and energy.

## MIND AND YOGA

We are in the midst of a worldwide Yoga revolution. For many, it is about health and well-being but that is only a portal that leads to the understanding of the self and its relationship with the body.

Although the roots of Yoga lie in the Vedas, most read Patañjali's Yoga-sūtra for a systematic exposition of the nature of the mind. The text is logical and it questions the naïve understanding of the world. According to it, there is a single reality and the multiplicity we see in it is a consequence of the projections of our different minds. Therefore, to obtain knowledge one must experience reality in its most directness.

The Vedic texts claim to be ātmavidyā, "science of self" or "consciousness science" and they also provide a framework to decode its narrative, establishing its central concern with consciousness.

In the Vedic view, reality is unitary at the deepest level since otherwise there would be chaos. Since language is linear, whereas the unfolding of the universe takes place in a multitude of dimensions, language is limited in its ability to describe reality. Because of this limitation, reality can only be experienced and never described fully. All descriptions of the universe lead to logical paradox.

Knowledge is of two kinds: the higher or unified and the lower or dual. The higher knowledge concerns the perceiving subject (consciousness), whereas the lower knowledge concerns objects. The higher knowledge can be arrived at through intuition and meditation on the paradoxes of the outer world. The lower knowledge is analytical and it represents standard sciences with its many branches. There is a complementarity between the higher and the lower, for each is necessary to define the other, and it mirrors the one between mind and body [20].

## THE FUTURE OF SCIENCE

I have gone through a random list of topics to show that Indian ideas and

contributions have shaped science in fundamental ways. I hope to show now that they remain equally central to its future growth.

We first note that in spite of its unprecedented success and prestige, science is facing major crises. The first of these crises is that of physics for it has found no evidence for dark matter and dark energy that together are believed to constitute 95% of the observable universe, with another 4.5% being intergalactic dust that doesn't influence theory. How can we claim that we are near understanding reality if our theories are validated by only 0.5% of the observable universe?

The second crisis is that neuroscientists have failed to find a neural correlate of consciousness. If there is no neural correlate, then does consciousness reside in a dimension that is different from our familiar space-time continuum? And how do mind and body interact with each other?

The third crisis is that there is no clear answer to the question if machines will become conscious. The fourth crisis is related to the implications of biomedical advances such as cloning on our notions of self.

It becomes clear that the three crises are actually interrelated when it is realized that consciousness is also an issue at the very foundations of physics. These questions also relate to the problem of free will.

Researchers are divided on whether conscious machines will ever exist. Most computer scientists believe that consciousness is computable and that it will emerge in machines as technology develops. But there are others who say there're things about human behavior that cannot be computed by a machine. Thus creativity and the sense of freedom people possess appear to be more than just an application of logic or calculations.

## QUANTUM VIEWS

Quantum theory, which is the deepest theory of physics, provides another perspective. According to its orthodox Copenhagen Interpretation, consciousness and the physical world are complementary aspects of the same reality. Since it takes consciousness as a given and no attempt is made to derive it from physics, the Copenhagen Interpretation may be called the "big-C" view of consciousness, where it is a thing that exists by itself — although it requires brains to become real. This view was popular with the pioneers of quantum theory such as Niels Bohr, Werner Heisenberg and Erwin Schrödinger.

The opposing view is that consciousness emerges from biology, just as biology itself emerges from chemistry which, in turn, emerges from physics.

We call this less expansive concept of consciousness "little-C." It agrees with the neuroscientists' view that the processes of the mind are identical to states and processes of the brain.

Philosophers of science believe that these modern quantum physics views of consciousness have parallels in ancient philosophy. Big-C is like the theory of mind in Vedanta — in which consciousness is the fundamental basis of reality and at the experienced level it complements the physical universe. The pioneers of quantum theory were aware of this linkage with Vedanta [21].

Little-C, in contrast, is quite similar to what many take to be standard Buddhism. The Buddha chose not to address the question of the nature of consciousness until the end of his life, and many of his followers believe that mind and consciousness arise out of emptiness or nothingness. Yet in the Mahāyāna Mahāparinirvāṇa-sūtra, the Buddha acknowledges a transcendent category underlying constant change which is quite similar to the conception of Vedanta.

## BIG-C, ANOMALIES, AND SCIENTIFIC DISCOVERY

Scientists question if consciousness is a computational process. More restrictively, scholars argue that the creative moment is not at the end of a deliberate computation. For instance, dreams or visions are supposed to have inspired Elias Howe's 1845 design of the modern sewing machine and August Kekulé's discovery of the structure of benzene in 1862, and these may be considered to be examples of the anomalous workings of the mind.

A dramatic piece of evidence in favor of big-C consciousness existing all on its own is the life of self-taught mathematician Srinivasa Ramanujan, who died in 1920 at the age of 32. His notebook, which was lost and forgotten for about 50 years and published only in 1988, contains several thousand formulas — without proof in different areas of mathematics — that were well ahead of their time, and the methods by which he found the formulas remain elusive. Ramanujan himself claimed that the formulas were revealed to him by Goddess Nāmagiri while he was asleep [22]. The idea of big-C provides an explanation for the anomalous scientific results from old Indian texts that were mentioned at the beginning of the essay.

The concept of big-C consciousness raises the questions of how it is related to matter, and how matter and mind mutually influence each other. Consciousness alone cannot make physical changes to the world, but perhaps it can change the probabilities in the evolution of quantum processes as was

first proposed by George Sudarshan and Baidyanath Misra in what they called the Quantum Zeno Effect. The act of observation can freeze and even influence atoms' movements, as has been demonstrated in the laboratory, and this may very well be an explanation of how matter and mind interact [23].

With cognitive machines replacing humans at most tasks, the question of what selfhood means will become more central to our lives. It appears to me that the only way to find fulfilment in life will be through wisdom of ātmavidyā. Vedic science will bring humanity full circle back to the source of all experience, which is consciousness. It will also reveal unknown ways mind and body interact and this will have major implications for medicine.

Indian sciences are universal and they have within them the power to inspire people to find their true potential and find meaning in life, as also having the potential to facilitate the next advances in both physical and biological sciences.

Historians may quibble about whether a certain equation should be called Baudhāyana's Theorem or Pythagoras Theorem, but in the larger scheme names do not matter. The direction of science is the more important thing and it is clear that the mystery of consciousness will be one of its major concerns.

## NOTES

1. The atoms of Kaṇāda turn out to have interesting parallels with current views in as much that two of them have mass and two have very little mass.
2. For a broad personal bibliography of Indian works that have contributed to modern science, see [24].

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