Nature and Purpose of Scientific Knowledge: The Indian and Greco-European Perspectives

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Introduction

While there is a significant corpus of modern scholarship on the history and achievements of the Indian tradition of sciences, there has not been much discussion on their philosophical foundations. Traditionally, such issues have been dealt with in the detailed *bhāṣyas* or commentaries, which continued to be written till recent times and played a vital role in the traditional scheme of learning. An attempt is made here to present some highlights of the Indian perspective on the nature and purpose of scientific knowledge as expounded in the basic source-works of Indian tradition.

The first thing that we notice when we study the canonical texts of Indian scientific tradition is that they are not mere compilations of propositions or universal truths. Instead, they are mainly concerned with presenting a series of rules which characterise systematic procedures in order to accomplish specific ends. These systematic procedures are generally referred to as *vidhi*, *kriyā* or *prakriyā*, *sādhana*, *karma* or *parikarma*, *karaṇa*, *upāya*, etc. It is these procedures—which are directed at *vyavahāra* or practical applications—that constitute core of the instruction that is offered in the canonical texts of any of the Indian sciences.

The canonical texts of Indian sciences invariably begin with a statement of the purpose of the discipline, which serves to demarcate the topics that legitimately come under its purview. For instance, the grammarians characterise their discipline as *śabdānuśāsana*, instruction of the valid utterances, which is accomplished by presenting a set of rules which enable the derivation of any valid utterance of the language. This is stated for instance in the *Pradīpoddyotanavyākhyā* of Annaṃbhaṭṭa (c. 17th century):[1]

Atha śabdānuśāsanam.

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[1] M. S. Narasimhacharya, *Mahābhāṣyapradīpavyākhyānāni*, Institut Francais d'Indologie, Pondichery 1971, p.7.

Anuśāsanaṃ prakṛtipratyayādivibhāgena vyutpādanaṃ, tad vyākaraṇena sākṣāt- kriyata iti sākṣāt prayojanam.

Now, the instruction of utterances.

Instruction [here, is explaining the] formation (of utterances) making use of the division into *prakṛti* (stem) and *pratyaya* (suffix) etc. This is realised by grammar, and that is its direct purpose.

The astronomers characterise the purpose of their discipline to be the determination of time, place and direction, by the study of the motion of celestial bodies. For instance, Bhāskara II (c.1150) defines the purpose of the science of astronomy, right at the beginning of his treatise *Siddhāntaśiromaṇi*, by declaring that it is concerned with the determination of time: "*Śāstrādasmāt kālabodho yataḥ syāt*". [2] The commentator Nṛsiṃhadaivajña (c.1600) further explains that the word '*kāla*' should be taken to include direction, and location: *"Kālaśabdo'pi digādyupalakṣanārthaḥ*".[3] In fact, Indian astronomy, *Jyotiḥśāstra*, is the science of determination of *dik*, *deśa* and *kāla*: direction, location and time; and these are to be determined by observing the motion of celestial bodies.

The *Āyurvedic Saṃhitās* characterise the goal of their discipline as amelioration of diseases of the sick and the protection of the healthy. According to *Carakasaṃhitā* (*Sūtrasthāna* 1.42-43):[4]

hitāhitaṃ sukhaṃ duhkhaṃ āyustasya hitāhitam mānaṃ
ca tacca yatroktam āyurvedaḥ sa ucyate
śarirendriyasattvātmasaṃyogo … āyurucyate.

Āyurveda is the science which discusses the beneficial and non-beneficial life, happy and unhappy life, and what is beneficial or not beneficial for them. It also discusses the span of life and life itself. Life is the combination of body, senses, *sattva* (the mind) and the *ātman*.

According to the *Suśrutasaṃhitā* (*Sūtrasthāna* 1.14-16):[5]

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[2] Muralidhara Chaturvedi, *Siddhāntaśiromaṇi of Bhāskarācārya, with Vāsanābhāṣya and the Commentary Vāsanāvārttika by Nṛsiṃha Daivajña*, Sampurnanand Sanskrit University, Varanasi 1981, p.10.
[3] *Ibid*. p.11.
[4] R. K. Sarma and B. Dash, *Carakasaṃhitā*, Vol. I, Chaukhambha Sanskrit Series, Varanasi, 2011, p.25.
[5] P. V. Sarma, *Suśrutasaṃhitā*, Vol. I, Chaukhambha Viswabharati, Varanasi 1999, p.12.

Iha khalu āyurvedaprayojanaṃ vyādhyupasṛṣṭānāṃ vyādhiparimokṣaḥ, svasthasya rakṣaṇaṃ ca.

Here, the purpose of *Āyurveda* is indeed to render those who are under the spell of diseases free from all diseases, and to protect those who are healthy.

The *Āyurvedic* texts have a clear view of the limitations of their science. They classify diseases into those which are curable, those for which only palliation is possible, and those which are beyond medical treatment. Thus *Suśrutasaṃhitā* instructs that (*Sūtrasthāna* 10.6):[6]

Evamabhisamīkṣya sādhyān sādhayet, yāpyān yāpayet, asādhyān naiva upakrameta, parisaṃvatsarotthitān ca vikārān prāyaśo varjayet.

After examining thus, [the physician] should try to cure diseases that are curable; adopt palliative measures where palliation is all that can be offered; and not take up a case which is not curable. Mostly diseases which have persisted for more than a year should be avoided.

Thus, the systematic procedures enunciated in different sciences are clearly designed to accomplish specific ends. In other words, these sciences are very much grounded in *vyavahāra* or the mundane demands of living competently in the world. This basic feature of being grounded in *vyavahāra*, indeed enables all the Indian sciences to have a great degree of flexibility in devising multiple approaches to the solution of problems and not get bogged down by any dogmatic belief in the uniqueness, universality and the inviolability of any of the theoretical formulations that are employed in the discipline concerned.

While the canonical texts of Indian sciences clearly assert the validity and the efficacy of the various procedures and theoretical formulations enunciated in them, they also emphasise that these procedures and formulations are only *upāyas*, means for accomplishing specific ends, and that there are no other restrictions which need to be imposed on them. A clear characterisation of the goals and limitations of each science also enabled the Indian scientists to develop the appropriate theoretical frameworks and procedures, which were continuously tested and refined in practice.

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6 *Ibid*. p.111.

This pragmatic and open-ended approach to scientific knowledge of the Indian scientific tradition is markedly different from the quest for inviolable, eternal and absolutely-true regularities of nature which has dominated the Greco-European scientific tradition. We shall now elucidate this pragmatic and open-ended approach to scientific theorisation in the Indian tradition by considering the case of *Śabdaśāstra* (Science of Language) and *Jyotiṣa* (Astronomy).

The Methodology of Pāṇini's *Aṣṭādhyāyī*

There is the popular dictum, "*Kāṇādaṃ pāṇinīyaṃ ca sarvaśāstropakārakam*", which reflects the traditional view that the *Aṣṭādhyāyī* of Pāṇini (c.500 BCE) and the physics and metaphysics and the logic and epistemology as discussed in the Nyāya-Vaiśeśika schools of philosophy, are essential for the understanding of all the *śāstras.* In the Greco-European tradition, it is the *Elements* of Euclid which has been acknowledged to be the paradigmatic example of the axiomatic deductive methodology which serves as the ideal for all sciences. In the same way, the *Aṣṭādhyāyī* of Pāṇini—with its symbolic techniques, the sophisticated conventions governing rule-formulation, rule-application and rule-interaction, and the recursive and generative formalism—serves as the ideal for formulating and characterising the systematic procedures that are expounded in the various *śāstras* in Indian tradition.

Making use of about 4,000 sutras or rules, Pāṇini gives a complete derivational system for deriving all the valid utterances of Sanskrit language; and the same can also be used to analyse or parse any valid utterance of the language. Paul Kiparsky has presented the following succinct account of 'the architecture of Pāṇini's grammar':[7]

> Pāṇini's grammar is universally admired for its insightful analysis of Sanskrit. ... Theoretical linguists of all persuasions are in addition impressed by its remarkable conciseness, and by the rigorous consistency with which it deploys its semi-formalized meta-language, a grammatically and lexically regimented form of Sanskrit. ... Generative linguists for their part have marvelled especially at its ingenious technical devices, and at intricate system of conventions governing rule

[7] P. Kiparsky, 'On the Architecture of Pāṇini's Grammar', in G. Huet, A. Kulkarni and P. Scharf (eds.), *Sanskrit Computational Linguistics,* Springer-Verlag, Berlin, 2009, pp.33-94 (the cited passage appears on pp.33-37).

application and rule interaction that it presupposes, which seem to uncannily anticipate ideas of modern linguistic theory (if only because many of them were originally borrowed from Pāṇini in the first place). ...

The grammar has four distinct components:

- *Aṣṭādhyāyī*: a system of about 4,000 grammatical rules.
- *Śivasūtras*: the inventory of phonological segments partitioned by markers (*anubandhas*) to allow for classes of segments (*pratyāhāras*) to be designated by a set of special conventions.
- *Dhātupāṭha*: a list of about 2,000 verbal roots, with sub-classification and diacritic markers encoding their morphological and syntactic properties.
- *Gaṇapāṭha*: a list of 261 lexical items which are idiosyncratically subject to certain rules. Some of the lists are open ended, and (like the *Dhātupāṭha*) they have to some extent been modified by later grammarians.

... [T]he grammar analyses sentences at a hierarchy of four levels of description [semantic, morpho-syntactic, morphological and phonological] ...The grammar is a device which starts from meaning information ...and incrementally builds up a complete interpreted sentence.

The *Mahābhāṣya* of Patañjali (c. 2nd century BCE) presents a detailed explanation and analysis of the *sūtras* of Pāṇini. Right at the beginning of *Mahābhāṣya*, Patañjali raises the question as to how one can give an exposition of all the valid utterances. Arguing that it is not possible to list them, he concludes that one will have to take recourse to formulating some general rules (*utsarga*). Since there will always be exceptions to such general rules, one should also formulate special rules for exceptions (*apavāda*), and so on:[8]

Athaitasmin śabdopadeśe sati kiṃ śabdānāṃ pratipattau pratipadapāṭhaḥ kartavyaḥ. Gauraśvaḥ puruṣo hastī śakunirmṛgo brāhmaṇa ityevamādayaḥ śabdāḥ paṭhitavyāh.
Netyāha. Anabhyupāya eva śabdānāṃ pratipattau pratipadapāṭhaḥ. Evaṃ hi śrūyate bṛhaspatirindrāya divyaṃ varṣasahasraṃ pratipadoktānāṃ śabdānāṃ śabdapārāyanaṃ

[8] S. D. Joshi and J. A. F. Roodbergen, *Vyākaraṇa-Mahābhāṣya-Paspaśāhnika,* University of Poona, Pune 1968, pp. 74-77.

provāca nāntaṃ jagāma. Bṛhaspatiśca pravaktā indraśca adhyetā. Divyaṃ varṣasahasraṃ adhyayanakālo na cāntam jagāma. ... Tasmād anabhyupāyaḥ śabdānāṃ pratipadapāṭhaḥ. Kathaṃ tarhi ime śabdāḥ pratipattavyāḥ. Kiñcit sāmānyaviśeṣavat lakṣaṇaṃ pravartyaṃ yenālpena yatnena mahato mahataḥ śabdaughān pratipatteran. Kiṃ punastat. Utsarga apavadau. Kaścid utsargaḥ kartavyaḥ, kaścid apavādaḥ.

Kathaṃ jātīyakaḥ punarutsargaḥ kartavyaḥ, kathaṃ jātīyako apavādaḥ.

Sāmanyena utsargaḥ kartavyaḥ. Tadyathā. Karmaṇyaṇ (3.1.1). Tasya viśeṣeṇa apavādaḥ. Tadyathā. Āto'nupasarge kaḥ (3.2.3).

If this instruction of valid utterances is to be made, then for understanding the valid utterances is it the case that a word-by-word list is to be made? (That is to say) should the (correct) words such as 'cow', 'horse', 'man', 'elephant', 'bird', 'deer', 'brahmin', etc. be listed? No, he says. For the instruction of valid utterances, this word-by-word listing of correct words is no good. As has been heard by us, Bṛhaspati recited the valid utterances, by speaking word after word to Indra for thousand divine years, but could reach nowhere near the end. (Here) it is Bṛhaspati who was the teacher and Indra who was the student. And the time of study was one thousand divine years. And still he could not reach the end That is why the method word-by-word listing of (correct) words is no good.

How are these (correct) utterances to be known? Some collection of rules containing the general and particular (conditions) is to be formulated, by means of which [the students] are able to know, with a small effort, larger and larger sequences of utterances.

What is that (collection of rules)? *Utsarga* (general rule) and *Apavāda* (special/ exceptional rule). That is, some general rule has to be formulated and (wherever necessary) an exceptional rule (will have to be formulated).

Again, what kind of general rule is to be formulated, and what kind of exceptional rule? A general rule should be formulated with general conditions, as in, *karmaṇyaṇ* (3.2.1). [The suffix *aṇ* is added after a verbal base (*dhātoḥ*, from 3.1.91), when a grammatical object (when functioning as an *upapada*, from 3.1.92) precedes. Ex. *kuṃbhakāraḥ*]

The exception to that general rule is to be formulated with a special condition, as in *āto'nupasarge kaḥ* (3.2.3) [The suffix *ka* is added after a verbal base, which ends

in a long *ā* and which is not preceded by a pre-verb (*upasarga*), when a grammatical object (when functioning as an *upapada*, from 3.1.92) precedes. Ex. *dhanadaḥ*]

The *Mahābhāṣya* also has a very elaborate discussion on how the utterances, meanings and their relation are firmly established. The main point, according to Patañjali, is that this is so by the usage of people in the world. Having conceived of a meaning that they want to convey, people use the words naturally without seeking the help of a grammarian:[9]

Kathaṃ punarjñāyate siddhaḥ śabdaḥ sambandhaśca iti. Lokataḥ.
Yalloke arthaṃ upādaya śabdān prayuñjate naiṣām nivṛttau yatnaṃ kurvanti. Ye punaḥ karyā bhavā nivṛttau tāvat teṣām yatnaḥ kriyate. Tadyathā. Ghaṭena kāryaṃ kariṣyan kumbhakārakulaṃ gatvā āha kuru ghaṭaṃ kāryam anena kariṣyāmi iti. Na tadvat śabdān prayuyukṣamāṇo vaiyākaraṇakulaṃ gatvā āha kuru śabdān prayokṣya iti. Tāvatveva arthaṃ upādāya śabdān prayuñjate.

But how is it known that the utterances, the meanings and the relation between them are firmly established? On account of (the usage in the world) by the people.

While people, after conceiving different things, use words, they do not put any effort in making these (words). On the other hand, they do put in an effort to make things which are to be produced. For instance, one who needs pots for some purpose, goes to the house of a potter and says: Make a pot. I need it for some purpose. However, one who needs to use words, does not go to the house of a grammarian and say: Make words, I need to use them. On the other hand, having brought to mind a thing, he straight away uses words.

The above exposition by Patañjali of the methodology of the *Aṣṭādhyāyī* reveals clearly the "most essential feature of the Indian scientific effort", as has been emphasized by Jitendra Bajaj in his pioneering study of the Indian scientific tradition: [10]

Patañjali ... explains the rationale for the Pāṇinian exercise. According to *Mahābhāṣya*, the purpose of grammar is to give an exposition of all valid

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9 *Ibid*. pp. 114-117.
10 J. K. Bajaj, 'The Indian Tradition of Science and Technology: An Overview', *PPST Bulletin*, Nos. 13-14, 1988, pp.32-42. See also, J. K. Bajaj, 'Science and Technology Up to 1800', in F. Robinson (ed.), *Cambridge Encyclopaedia of India, Pakistan and Bangladesh*, Cambridge Universities Press, Cambridge 1989, pp.496- 7.

utterances. An obvious way to do this is to enumerate all valid utterances individually. This is how the celestial teacher Bṛhaspati would have taught the science of language to the celestial student, Indra. However for ordinary mortals, not having access to celestial intelligence and time, such complete enumeration is of little use. Therefore, it is necessary to lay down widely applicable general rules (*utsarga-sūtras*) so that with a comparatively small effort men can learn larger and larger collections of valid utterances. What fails to fit in this set of general rules should, according to the *Mahābhāṣya*, then be encompassed in exceptional rules (*apavāda-sūtras*), and so on.

In thus characterising grammar, Patañjali expounds perhaps the most essential feature of the Indian scientific effort. Science in India starts with the assumption that truth resides in the real world with all its diversity and complexity. For the linguist, what is ultimately true is the language as spoken by the people in all their diverse expressions. As Patañjali emphasises, valid utterances are not manufactured by the linguist, but are already established by the practice in the world. One does not go to a linguist asking for valid utterances, the way one goes to a potter asking for pots.

Linguists make generalisations about the language as spoken in the world. These generalisations are not the truth behind or above the reality of the spoken language. These are not idealisations according to which reality is to be tailored. On the other hand what is true is what is actually spoken in the real world, and some part of the truth always escapes our idealisation of it. There are always exceptions. It is the business of the scientist to formulate these generalisations, but also at the same time to be always attuned to the reality, to always be conscious of the exceptional nature of each specific instance. This attitude, ...permeates all Indian science and makes it an exercise quite different from the scientific enterprise of the West.

Patañjali's exposition of the methodology of *Aṣṭādhyāyī* was further elaborated by the great philosopher-linguist Bhartṛhari (c.500 CE) in his seminal treatise *Vākyapadīya*. We shall here recount only one famous principle expounded by Bhartṛhari—that the procedures taught in *śāstras* are just the means (*upāya*) to accomplish desired

objectives in the world, and they are not constrained or regulated in any other manner:[11]

upādayāpi ye heyā tānupāyān pracakṣate
upāyānāñca niyamo nāvaśyam upatiṣṭhate

[The procedures taught in *śāstras* for accomplishing various objectives] are called the *upāyas* (means), as they are to be [first] accepted and then abandoned. There is no [other] necessary constraint which needs to be imposed on these *upāyas*.

In this context, Puṇyarāja, the commentator on *Vākyapadīya*, notes:

Śāstram upāyaḥ śabdaparijñāne. Jñāteṣu teṣu prayojanasaṃpatteranupayogaḥ iti tasya parityāgaḥ. Upāyāśca na niyatā ityāha. ... Kaścidācāryaḥ pāṇiniviracitena lakṣanaśāstreṇa śabdān adhigacchati, kaścid anyena iti na niyamaḥ.

The science of grammar is a means for knowing the valid utterances. Once these are known there is no further use and hence it is said that they are to be discarded. He also states that there is no limitation on these *upāyas.* One preceptor (*ācārya*)
arrives at the utterances by means of the grammatical framework of Pāṇini and another by means of another framework and thus there is no rule [that only a particular grammar is to be followed].

Thus, the Indian Grammarians are not willing to accede to the uniqueness and universality of even Pāṇini's *Aṣṭādhyāyī*, whose efficacy as a Grammar has been universally acclaimed.

The Status of Theoretical Models in Indian Astronomy

The tradition of astronomy in India goes back to the period of the Vedic texts which record several features of the motion of the celestial bodies such as the motion of the Sun and the Moon in the background of stars, the phenomena of eclipses and so on. The *Taittirīyāraṇyaka* (II.19.1) refers to the star Abhaya Dhruva (the star also known as Thuban or Alpha-Draconis) as the pole star—which was indeed the case during early third millennium BCE. There is also an indication of the knowledge of the 18 year

11 Raghunatha Sharma, *Vākyapadīyam with Puṇyarāja Commentary*, Part II, Sampurnanand Sanskrit University, Varanasi, 1980, pp.78-81.

eclipse cycle (the so called 'saros cycle') and the shift in the position of the solstices (*ayanacalana*). Later texts such as *Parāśaratantra* (of second millennium BCE) describe the motion of Sun and Moon along the ecliptic in terms of the 27 *nakṣatra* division. They divide the year into six seasons which is also a characteristically Indian way of understanding the annual cycle of climatic changes.

The *Vedāṅgajyotiṣa* (original version going back to c.1300 BCE) discusses the mean motion of the Sun and the Moon over a five-year *yuga* cycle, and gives simple algorithms for the calculation of the elements of Indian calendar (*pañcāṅga*), such as the *tithi* and *nakṣatra*, and also the rules for intercalation (*adhikamāsa*). The *Vedāṅgajyotiṣa*, as well as the later elaborate treatises on Indian astronomy, astronomy is "*kālavidhāna- śāstra*",[12] the science of determination of time—as well as position and direction on the earth, based on the study of the motion of celestial bodies. The ancient *Vṛddhagārgīya Jyotiṣa* emphasised that observation of the motion of celestial bodies and computation should go in tandem—"*darśanaṃ gaṇitaṃ caiva yugapad yogasādhakam*" [13] — an important principle which was emphasised in all the later texts as the requirement of *dṛg-gaṇitaikya*,[14] or concordance between the observations and computations.

The earliest known datable text of the so called *siddhāntic* astronomy is the celebrated *Āryabhaṭīya* (499 CE) of Āryabhaṭa, which is a very cryptic work of 108 verses. Detailed expositions of the mathematical astronomy are to be found in the *Āryabhaṭīyabhāṣya* and other works of Bhāskara I (c.629 CE) and from the *Brāhmasphuṭasiddhānta* (c.628 CE) of Brahmagupta. By then, the Indian astronomers had developed a sophisticated theoretical and mathematical framework—including the use of the decimal place value system with zero and negative numbers, algebra, the sine function and spherical trigonometry—for describing the motion of the Sun, Moon and the planets and for the computation of phenomena such as the eclipses.

The Indian astronomical texts predominantly use flexible analytical calculation procedures as contrasted to the fixed geometrical models found in the Greco-European tradition. While the Greek philosophers and astronomers insisted that a planetary theory ought to describe the movement of the celestial bodies in terms of uniform

12 T. S. Kuppanna Sastry and K. V. Sarma, *Vedāṅgajyotiṣa of Lagadha,* Indian National Science Academy, New Delhi, 1985, p.27.

13 R. N. Iyengar, H. S. Sudarshan and A. Viswanathan, '*Vṛddhagārgīya Jyotiṣa* Part I', *Tattvadīpaḥ, Res. Jour. Acad. Sans. Res. Melkote*, 25 (1), 2019, pp.60-95 (the cited passage appears on p.78*fn*).

14 Muralidhara Chaturvedi, No. 2, p.97.

circular motions, the Indian astronomers freely employed models involving variable epicycle radii etc., which led to non-circular orbits for planets in a very natural way. The analytical models of Indian astronomers enabled them to make computations of velocities, conjunctions etc., by means of simple algorithms; they could also device ingenious approximations and simpler computational procedures which were presented in the practical manuals, referred to as *karaṇas*, widely used by practitioners of astronomy in every locality.

The *siddhāntic* tradition of astronomy continued to flourish with treatises being composed by Lalla (c.750), Vaṭeśwara (c.900), Muñjāla (c.932) Āryabhaṭa II (c.950), Śrīpati (c.1039) and others. A comprehensive review of Indian mathematics and astronomy was presented by Bhāskara II (c.1150) in his works, *Līlāvatī*, *Bījagaṇita* and *Siddhāntaśiromaṇi*. Bhāskara also wrote an auto-commentary, *Vāsanābhāṣya*, which presents detailed explanations and demonstrations (*upapattis*), and thus serves as a basic source-book for understanding the methodology of Indian astronomy as practised in the twelfth century.

We now turn to the celebrated Kerala School of Astronomy which (as we shall see) made notable progress during the 14-15 centuries in the development of calculus and non-geocentric models of planetary motion — both of which are generally regarded as the seminal discoveries of modern science during the 16-17 centuries. Saṅgamagrāma Mādhava (c.1340-1420), the founder of the Kerala School, is famous for his discovery of the infinite series and fast convergent approximations to π, and the sine and cosine functions. Mādhava's disciple Parameśvara (c.1380-1460) is reputed to have made continuous and careful observations for a period of over fifty-five years; he developed the so called *Dṛggaṇita* system. Nīlakaṇṭha Somayājī (c.1444-1544), a disciple of Parameśvara's son Dāmodara, carried out an even more fundamental revision of the traditional planetary theory. In his work *Tantrasaṅgraha* (1500 CE), Nīlakaṇṭha presents a better formulation of the equation of centre and the latitudinal motion of the interior planets (Mercury and Venus) than was available either in the earlier Indian works, or in the Islamic or the Greco-European traditions of astronomy till the work of Johannes Kepler (c.1609), which was to come more than a hundred years later. The *Āryabhaṭīyabhāṣya* of Nīlakaṇṭha is perhaps the first work in the history of astronomy which presents an argument on the basis of the observed planetary motion (and not

from any speculative cosmological considerations) that the interior planets go around the Sun and the period of their motion around Sun is also the period of their latitudinal motion. In a later tract called *Grahasphuṭānayane Vikṣepavāsanā*, Nīlakaṇṭha presents a cosmological model of the planetary system according to which the planets go around the (mean) Sun in an eccentric orbit, and the Sun, in turn, goes around the earth—similar model was later proposed by Tycho Brahe (c.1588).

The most detailed exposition of the work of the Kerala School (especially the contributions of Mādhava and Nīlakaṇṭha), along with demonstrations (*yukti*), can be found in the celebrated Malayalam text *Gaṇita-Yuktibhāṣā* (c.1530) of Jyeṣṭhadeva, which has been hailed as the "first textbook of calculus". The Kerala School managed to survive well into the nineteenth century, when Śaṅkaravarman, the Raja of Kadattanad, wrote perhaps the last important work emanating from the School, *Sadratnamālā*, in 1819 CE.

Having presented a brief overview of the development of Indian astronomical tradition, we now focus on the pragmatic and tentative approach to scientific theorisation as is expounded in the canonical source-texts of Indian astronomy. These texts in fact reiterate, almost in the same words, the famous dictum of Bhartṛhari (that was cited above), that there is no necessary limitation or constraint to be imposed on the theoretical models and procedures employed in astronomy, which are only the means (*upāya*) to obtain results that are in accordance with observations (*dṛg*-gaṇitaikya).

While explaining the planetary model of Āryabhaṭa in his *Āryabhaṭīyabhāṣya* (c.629 CE), Bhāskara I states that notions such as the apsides (*ucca, nīca*), mean (*madhyama*), epicycles (*paridhi*) etc., are conceptual tools which serve the purpose of arriving at the observed motion of planets and there are no constraints on them except that they should lead to observed planetary motions. He even emphasises that the procedures are not to be considered as elements of reality (*sarvā prakriyā asatyā*), even while they lead to the true motion of the planets (*grahāṇām sphuṭagati*). After explaining that the same is the case in other disciplines also— such as the sciences of grammar, medicine, etc.—he concludes that there is nothing unusual about the fact that the *upāyas* (theories and procedures) taught in the *śāstras* are not to be taken as elements of reality, even while

they do enable us to know aspects of reality (*upāyeṣvasatyeṣu satyaprati- pādanapareṣu*):[15]

...ucca-nica-madhyama-paridhirityevamādi-sphuṭagatisādhanopaya[bhutānāṃ ca] upāyānāṃ nai[va niyamo]ktirvā vidyate. Kevalaṃ tu upeyasādhakā upāyāḥ. Tasmādiyaṃ sarvā prakriyā astyā, yayā grahāṇāṃ sphuṭagatiḥ sādhyate. [Evañca paramārthajijñāsubhiḥ astyopaye]na satyaṃ pratipadyate. Tathā hi bhiṣajo hyutpalanāladiṣu vedhādīnyabhyasyante, nāpitāḥ piṭharādiṣu muṇḍanādīni, yajñaśāstravidaḥ śu[ṣkeṣṭyā] yajñādīni, śābdikāḥ prakṛti-pratyaya-vikārāgama- varṇa-lopa-vyatyayādibhiḥ śabdān pratijānate. Evam atrāpi madhyama-mandocca- śīghrocca-tatparidhi-jyā-kāṣṭha-bhujā-koṭi-karṇādivyavahāreṇa sāṃ-vatsarā grahāṇām sphuṭagatiṃ pratijānate. Tasmād upayeṣu asatyeṣu satyapratipādana- pareṣu na codyamasti.

...[T]here are no constraints or limitations imposed on the notions such as *ucca*, *nīca*, *madhyama*, *paridhi* and so on, which are essentially means (*upāyas*) to calculate the observed motion of the planets. Such means (*upāyas*) are only meant for accomplishing the desired ends (*upeyasādhaka*). Hence this entire procedure is fictitious (*sarvā prakriyā asatyā*), by means of which the observed planetary motion is arrived at. Even the seekers of ultimate reality get to realise the truth by means which is [in the realm] of the unreal. Similarly, the doctors employ lotus stalks etc., to practise venesection etc., the barbers practice tonsures with pots, the experts in the science of *yajña* practice with dry wood, and the linguists utilise notions such as *prakṛti*, *pratyaya, vikāra, āgama, varṇa*, *lopa*, *vyatyaya*, etc., to comprehend well-formed utterances. In the same way, in our science also astronomers employ notions such as *madhyama, mandocca, śīghrocca, śīghraparidhi, jyā, kāṣṭha, bhujā*, *koṭi*, *karṇa*, etc., in order to comprehend the observed motion of planets. Hence, there is indeed nothing unusual that fictitious means are employed to arrive at the true state of affairs [in all these *śāstras*].

It is not merely the followers of Āryabhaṭa who held such views on the status of theoretical models in Astronomy. We find Pṛthūdakasvāmin (c.864), the famous commentator of Brahmagupta's works expounding the same view, almost in similar

15 K. S. Shukla, *Āryabhaṭīya of Āryabhaṭa with the Commentary of Bhāskara I and Someśvara,* Indian National Science Academy, New Delhi, 1976, p.217.

words.[16] Nīlakaṇṭha also expresses the same view in his *Āryabhaṭīyabhāṣya* and goes on to cite the dictum of Bhartṛhari that there are no limitations that need to be imposed on the theoretical procedures (*upāyānāmaniyamaḥ*). [17] In his other notable work, *Jyotirmīmāṃsā*, Nīlakaṇṭha has highlighted the importance of preparing the practitioners of the science of astronomy for the onerous task of continuously observing the skies, continuously checking their computations against observations, and repeatedly re-adjusting their parameters and theoretical procedures so as to make their computations stay in tune with observations.

As has been emphasised by Jitendra Bajaj:[18]

> The reasons for the simplicity and accuracy of the Indian astronomical techniques are again to be found in the pragmatic attitude of the Indians towards the sciences. The Indian astronomers were in the business to calculate and to compute, not to form pictures of the heavens as they ought to be in reality. Indian astronomers do use some geometrical models, but for them these are no more than artefacts in their calculations. It is obvious that the astronomical parameters obtained in such a pragmatic approach will get out of tune with reality sooner or later and the calculated positions of the planets will start deviating from actual. Indian astronomers are aware of this and were quite willing to take up the onerous task of continuously observing the skies, continuously checking their computations against observations and repeatedly re-adjusting their parameters so as to make their calculations accord with reality.

Greco-European Perspective on Scientific Knowledge

We had so far discussed a few selected passages from the great classical works of Indian scientific tradition in order to understand their perspective on scientific knowledge. We now take a look at some of the great scientific classics of ancient Greece as well as early modern Europe, with a view to understand some of the fundamental features of the Greco-European perspective on scientific knowledge. Our discussion will mainly focus on the quest for indubitable, eternal and absolutely true regularities or 'laws', which has dominated the Greco-European tradition all through history, in marked contrast to the

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16 Muralidhara Chaturvedi, No. 2, p.48.

17 K. Sambasiva Sastri, *Āryabhaṭīyabhāṣya of Nīlakaṇṭha, Part II Kālakriyāpāda*, Government Press, Trivandrum 1931, p.31.

18 J. K. Bajaj, No. 10.

Indian philosophers' and scientists' pragmatic and open-ended approach to scientific knowledge, that we have highlighted above.

To understand the Greek philosophers' view of scientific knowledge, we may refer to the well known passage from *Republic*, the famous dialogue of Plato, where Socrates speaks on the ideal education that is to be imparted to the philosopher-statesmen. It is Socrates firm view that they should be imparted only such knowledge of Arithmetic, Geometry and Astronomy and Harmony, which aim at the "knowledge of the eternal and not of aught perishing and transient", which has the "great and elevating effect" of "compelling the soul to reason about the abstract ... rebelling against the introduction of visible or tangible objects"—thereby ruling out any concern that these disciplines may have with the reality of the mundane world:[19]

One of the greatest scientific works of ancient world is the *Mathematikê Syntaxis* (c.150 CE) of Claudius Ptolemy—more popularly known by its Arabic name *Almagest* (The Greatest)—which presents the most systematic and comprehensive exposition of mathematical astronomy in the Greek tradition; it remained as the most influential work on astronomy in the Greco-European and Islamic world till the work of Copernicus and Kepler in the 16-17 centuries. In the preface to Book I of the *Almagest*, Ptolemy summarises the Aristotelian classification of theoretical philosophy into Physics, Mathematics and Theology. Of these, Physics, which dealt with the "corruptible bodies…below the lunar sphere" could never be an exact discipline worthy of philosophers' attention; and Theology, which dealt with "the first cause of the first motion of the universe …is completely separated from perceptible reality". Only Mathematics (by which is meant Mathematical Astronomy), which concerned itself with "eternal things with an ethereal nature", or "divine and heavenly things", can provide "sure and unshakeable knowledge to its devotees". Thus the study of motion of the divine celestial bodies above the lunar sphere, is worthy of philosophers' attention as that alone is "eternal and unchanging (which is a proper attribute of knowledge) in its own domain, which is neither unclear nor disorderly":[20]

The true philosophers, ...were, I think, quite right to distinguish the theoretical part of philosophy from the practical. ...Aristotle divides theoretical philosophy

19 B. Jowett, *The Dialogues of Plato,* Vol. III, Clarendon Press, Oxford 1892, pp. 227-234.
20 G. J. Toomar, The Almagest of Claudius Ptolemy, Duckworth, London 1984, pp.35-37.

too, very fittingly, into three primary categories, physics, mathematics and theology. For everything that exists is composed of matter, form and motion; none of these [three] can be observed in its substratum by itself, without the others: they can only be imagined. Now the first cause of the first motion of the universe, if one considers it simply, can be thought of as an invisible and motionless deity; the division [of theoretical philosophy] concerned with investigating this [can be called] 'theology', since this kind of activity, somewhere up in the highest reaches of the universe, can only be imagined, and is completely separated from perceptible reality. The division [of theoretical philosophy] which investigates material and ever-moving nature, and which concerns itself with 'white', 'hot', 'sweet', 'soft' and suchlike qualities one may call 'physics'; such an order of being is situated (for the most part) amongst corruptible bodies and below the lunar sphere. That division [of theoretical philosophy] which determines the nature involved in forms and motion from place to place, and which serves to investigate shape, number, size, and place, time and suchlike, one may define as 'mathematics'. Its subject-matter falls as it were in the middle between the other two, since, firstly, it can be conceived of both with and without the aid of the senses, and, secondly, it is an attribute of all existing things without exception, both mortal and immortal: for those things which are perpetually changing in their inseparable form, it changes with them, while for eternal things which have an aethereal nature, it keeps their unchanging form unchanged.

From all this we concluded: that the first two divisions of theoretical philosophy should rather be called guesswork than knowledge, theology because of its completely invisible and ungraspable nature, physics because of the unstable and unclear nature of matter; hence there is no hope that philosophers will ever be agreed about them; and that only mathematics can provide sure and unshakeable knowledge to its devotees, provided one approaches it rigorously. For its kind of proof proceeds by indisputable methods, namely arithmetic and geometry. Hence we were drawn to the investigation of that part of theoretical philosophy, as far as we were able to the whole of it, but especially to the theory concerning divine and heavenly things. For that alone is devoted to the investigation of the eternally unchanging. For that reason it too can be eternal and unchanging (which is a

proper attribute of knowledge) in its own domain, which is neither unclear nor disorderly.

Moving on from ancient Greek astronomy, let us consider the origins of modern science in 17th century Europe. Modern scholarly work on the history of science has uncovered how the quest for "immutable and divine laws of nature" lay at the very roots of modern science when it emerged in 17th century Europe. In 1942, Edgar Zilsel, published a seminal paper on 'The Genesis of the Concept of Physical Law', where he drew attention to the distinctive 'spiritual' feature of modern Western civilisation that it had made the "investigation of basic laws of nature the unique task of science". Zilsel argues that the modern concept of 'laws of nature' originated in 'theological ideas' that "the observable recurrent associations of physical events ...were interpreted as divine commands and were called natural *laws*".[21]

Zilsel's investigations were carried forward by the renowned British scientist and historian of science, Joseph Needham. In the second volume of his highly acclaimed series on *Science and Civilisation in China*, Needham highlighted the fact that while the notions of 'natural law' and 'laws of nature' go back to a common root in the Western civilisation, they seem to have been virtually absent or marginal in the Chinese civilisation—notwithstanding the fact that the Chinese had a highly sophisticated and accomplished traditions of jurisprudence as well as sciences and technologies. Needham draws particular attention to the fact that "the laws of nature which Kepler, Descartes, Boyle and Newton believed that they were revealing to the human mind ...were edicts which *had* been issued by a supra-personal supra-rational being":[22]

> In Western civilisation the ideas of natural law (in the juristic sense) and the laws of Nature (in the sense of natural sciences) go back to a common root. For without doubt one of the oldest notions of Western civilisation was that just as earthly imperial lawgivers enacted codes of positive law, to be obeyed by men, so also the celestial and supreme rational creator deity had laid down a series of laws which must be obeyed by minerals, crystals, plants, animals and the stars in their courses. Unfortunately, if one turns to the best books and monographs on the

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21 E. Zilsel, 'The Genesis of the Concept of Physical law', *The Philosophical Review,* 51, 1942, pp.245-279 (the cited passage appears on pp.245-247).

22 J. Needham and W. Ling, *Science & Civilisation in China*, Vol. 2, Cambridge University Press 1956, pp.518, 562-564.

history of science, asking the simple question, when in European or Islamic history was the first use of the term "laws of Nature" in the scientific sense, it is extremely hard to find an answer. By the 18th century it was of course current coin—most Europeans are acquainted with these Newtonian words of 1796 [English Hymnal of the Foundling Hospital Collection]:

Praise the Lord for he hath spoken Worlds his
mighty voice obeyed; Laws which never shall
be broken For their guidance he hath made.

But, this could not, in fact, have been written by a Chinese scholar of the autochthonous tradition. ...

...[T]he laws of nature which Kepler, Descartes, Boyle and Newton believed that they were revealing to the human mind (the very word "revealing" is symptomatic of the spontaneous background of occidental thought), were edicts which *had* been issued by a supra-personal supra-rational being. The fact that this was later generally recognised to be a metaphor does not mean that it may not have had great heuristic value at the beginning of modern science in Europe.

It may be worthwhile to present a few brief quotations from some of the founders of modern science to illustrate how emphatically they declare that they were indeed discovering the divinely ordained laws of nature. We start with the founder of 'new astronomy', Johannes Kepler (1571-1630) who declares—in his *De Fundamentis Astrologiae Certioribus* (1601)—that the "chief aim of all investigations of the external world should be to discover the rational order and harmony which has been imposed on it by God and which He revealed to us in the language of mathematics."[23]

Then we have Galileo Galilei (1564-1642) writing to the Grand Duchess Christina of Tuscany in 1615 that "the Holy Scripture and nature derive equally from Godhead, the former as the dictation of the Holy Spirit and the latter as the most obedient executrix of God's orders". And, while the scripture could say many things that will have to be

23 M. Kline, *Mathematics: The Loss of Certainty*, Oxford University Press, Oxford 1980, p.31.

interpreted, “nature is inexorable and immutable, never violates the terms of the laws imposed upon her”.[24]

It is now generally acknowledged that Rene Descartes (1596-1850) was the pioneer among the 17th century scientists and philosophers in trying to formulate general "Laws of Nature", even though he did not achieve any notable success in this endeavour. In his letter of April 15, 1630 to Mersenne, Descartes explains that laws of nature, being divinely ordained, are "eternal and unchangeable".[25] In his first published work, *Discours de la Methode* (*Discourse on the Method*, 1637), Descartes talks about the “laws which God has so established in nature, and of which he has implanted such notions in our minds, that after adequate reflection we cannot doubt that they are exactly observed in everything which exists or occurs in the world”.[26]

Another important figure of 17th century is Robert Boyle (1627-1691)—renowned experimental scientist and a founding member of the British Royal Society in the 1660s —who is supposed to have had considerable influence on Newton. In a famous tract, *Of the Excellency and Grounds of the Corpuscular or Mechanical Philosophy* written in 1674, Boyle explains that his corpuscular philosophy is one where God not only gave motion to matter but also “established those rules of motion and that order among things corporeal, which we are wont to call laws of nature”, and that the “phenomena of the world thus constituted ...operate ... according to mechanical laws”.[27]

Unlike the other great pioneers of modern science in the seventeenth century, Isaac Newton (1643-1727) left a large corpus of unpublished manuscripts which included, apart from his researches on Physics, Optics and Mathematics, the huge output of his intense investigations and reflections on Alchemy and Theology. The extraordinary story of these Newton Manuscripts has been recounted recently by Sarah Dry. According to her, of the roughly 10 million words that Newton left, “around half of the writing is religious, and there are about 1 million words on alchemical material”.[28]

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[24] M. A. Finocchiaro, *The Galileo Affair: A Documentary History,* Hacket Publishing Company, Indianapolis 1989, p.93.

[25] J. Cottingham et al, eds., *The Philosophical Writings of Descartes,* Vol. III, Cambridge University Press, Cambridge, 1991, pp.22-23.

[26] J. Cottingham et al, eds., *The Philosophical Writings of Descartes,* Vol. I, Cambridge University Press, Cambridge, 1991, p.131.

[27] J. J. Macintosh, *The Excellencies of Robert Boyle*, Broadview Press, Peterborough 2008, p.230.

[28] “The Strange Secret History of Isaac Newton Papers, Interview with Sarah Dry, *Wired*, May 14, 2014”, at https://www.wired.com/2014/05/newton-papers-q-and-a/ (Accessed June 7, 2020). See also, Sarah

In one of his unpublished tracts, "*De Gravitatione et aequipondio fluidorum* (*The Science of Gravitation and of the Balance of Fluids*, which got published only in 1962), written during the early 1680s, Newton presents an extensive critique of Descartes' theory of substance and extension (space). The tract refers to "God" nearly sixty times. In a famous passage, Newton asserts that all our motions should be "only in accord with those laws which God has imposed on us".[29]

The first edition (1687) of *Philosophiae Naturalis Principia Mathematica* had just one reference to God. Newton added a "General Scholium" to the second edition of the *Principia* edition published in 1713, which includes his famous discussion about God which starts with the declaration that: "This most elegant system of the sun, planets, and comets could not have arisen without the design and dominion of an intelligent and powerful being"; and ends with the declaration that "to treat of God from phenomena is certainly a part of natural philosophy":[30]

"In the beginning ...God created the Newton's laws of motion", seems to have been the prevailing dogma among the scientists till the end of 19th century—as may be seen from the remarks of Albert Einstein (in his *Autobiographical Notes* written in 1946) describing the world of Physics around the time when he was an undergraduate student at Zurich during 1896-1900:[31]

Now to the field of Physics as it presented itself at that time. In spite of all the fruitfulness in particulars, dogmatic rigidity prevailed on matters of principles: In the beginning (if there was such a thing) God created Newton's laws of motion together with the necessary masses and forces. This is all; everything beyond this follows from the development of appropriate mathematical methods by means of deduction. ...

We must not be surprised, therefore, that, so to speak, all physicists of the last century saw in classical mechanics a firm and final foundation for all physics, yes, indeed, for all natural science ...

Dry, *The Newton Papers*: *The Strange & True Odyssey of Isaac Newton's Manuscripts*, Oxford University Press, Oxford, 2014.

29 A. Janiak, *Isaac Newton Philosophical Writings*, Cambridge University Press, Cambridge 2004, p.30.

30 I. B. Cohen and A. Whitman, *Isaac Newton The Principia Mathematical Principles of Natural Philosophy The Authoritative Translation*, University of California Press, Berkeley 1999, pp.586-589.

31 P. A. Schilpp (ed.), *Albert Einstein Philosopher Scientist*, MJF Books, New York, 1949, pp.19,21

Science and Technology as the Divine Bequest for Establishing the Dominion of Man over Nature

In 1967, Lynn White, a scholar of medieval history, created a major controversy when he wrote an article in the reputed journal, *Science*, tracing "the historical roots of our ecological crisis" to the fact that modern "science and technology have grown out of Christian attitudes towards man's relation to nature":[32]

> ... [W]e should try to clarify our thinking by looking in some historical depth, at the presuppositions that underlie modern technology and science. …
>
> Our daily habits of action, for example, are dominated by an implicit faith in perpetual progress which was unknown either to the Greco-Roman antiquity or to the Orient. It is rooted in, and is indefensible apart from, Judeo-Christian theology. The fact that communists share it merely helps to show what can be demonstrated on many other grounds: that Marxism like Islam is a Judeo- Christian heresy. …
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> Christianity inherited from Judaism not only a concept of time as non-repetitive and linear but also a striking story of creation. By gradual stages a loving and all powerful God had created light and darkness, the heavenly bodies, the earth and all its plants, animals, birds and fishes. Finally God had created Adam and, as an afterthought Eve to keep man from being lonely. Man named all the animals, thus establishing his dominance over them. God planned all this explicitly for man's benefit and rule: no item in the physical creation had any purpose save to serve man's purposes. And, although man's body is made of clay, he is not simply part of nature: he is made in God's image.[33]
>
> Especially in its Western form, Christianity is the most anthropocentric religion the world has seen. ...Man shares, in great measure, God's transcendence of nature. Christianity, in absolute contrast to ancient paganism and Asia's religions (except, perhaps, Zoroastrianism), not only established a dualism of man and nature but also insisted that it is God's will that man exploits nature for his proper ends. …

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32 Lynn White Jr., 'The Historical Roots of our Ecological Crisis', *Science*, 155 (3767), 1967, pp.1203-1207.

33 The Biblical passages sanctioning man's dominion over nature, that are frequently cited in this context, are from the *Book of Genesis*, I:26-28 and IX.1-3.

I personally doubt that disastrous ecological backlash can be avoided simply by applying to our problems more science and more technology. Our science and technology have grown out of Christian attitudes towards man's relation to nature which are almost universally held by not only Christians and neo- Christians and also by those who fondly regard themselves as post-Christians. ... We are superior to nature, contemptuous of it, willing to use it for our slightest whim.

Lynn White's article generated a wide-ranging debate amongst philosophers and Christian theologians. In a major study of the encounter between man and nature in the Western civilisation from ancient times, the Australian philosopher John Passmore highlighted the fact that in the Abrahamic faiths nature is not sacred, and this has often led to justification of irresponsible attitudes and actions. Passmore also argued that it was the large-scale adoption by Christian theologians of the views of Aristotle and the Stoic philosophers—that whatever exists, exists only for the sake of man as he alone is distinguished by 'rationality'—which has led to the view that has prevailed all along in the Western civilisation that man is free to deal with nature as it pleases him: [34]

Although the Old Testament … by no means suggests that whatever exists was created for man's sake, there is one point on which it is absolutely clear: nature is not sacred. And while the rejection of the view that nature is sacred does not justify an irresponsible attitude towards it, it at least leaves the way open to that attitude, does not at once condemn it as sacrilegious. ...

Traditional Greek religion, admittedly, did nothing to encourage the view that man either was or should seek to become master of the world. To seek that mastery would be *hubris*, an attempt on man's part to set himself up as a god; such presumption would undoubtedly bring calamities about his head, as the fate of Prometheus served to illustrate. The situation was very different, after the Greek Enlightenment, with its rejection of the concept of *hubris*. One then finds it explicitly maintained that animal life exists purely and simply for man's sake. Aristotle argues in his *Politics* that 'plants are created for the sake of animals, and the animals for the sake of men; the tame for our use and

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[34] John Passmore, *Man's Responsibility for Nature: Ecological Problems and Western Traditions*, Duckworth, 2nd Edition, 1980, pp. 9, 13-15, 27.

provision; the wild at least for the greater part, for our provision also, or for some other advantageous purpose, as furnishing us with the clothes and the like.'

… The universe as they [the Stoics] saw it is a vast body, providentially governed to serve the interests of its only rational members—men and gods. Like the argument from design still flourishing in the nineteenth century, this Stoic view that man's dominion over nature, his god-like superiority, is based upon his rationality, was destined to have a long life. It is constantly assumed that whatever else exists does so only for the sake of the rational. One finds this assumption not only in Augustine and Aquinas, but also in Kant. 'As the single being upon earth that possess understanding,' Kant was to write, 'he is certainly titular lord of nature and supposing we regard nature as a teleological system, he is born to be its ultimate end.' ...

The critics of Western civilisation are to this extant justified in their historical diagnosis: there is a strong western tradition that man is free to deal with nature as he pleases, since it exists only for his sake. But they are incorrect in tracing this attitude back to Genesis. … It is only as a result of Greek influence that Christian theology was led to think of nature as nothing but a system of resources, man's relationships with which are in no respect subject to moral censure.

The founding philosophers of modern science, whether they were imbued with the pride of human rationality as Rene Descartes (1596-1650) in France, or with Christian zeal like Lord Francis Bacon (1561-1628) in England, conceived of the emerging science and technology as fulfilling the mandate of man's mastery over nature sanctioned in the scriptures. Descartes was very positive that his new "practical philosophy" would help us "make ourselves as it were the lords and masters of nature".[35]

Lord Bacon, who is often hailed as the prophet of modern science and the guiding spirit of the Royal Society which was established in 1660, wrote extensively on the method and purpose of science. Bacon is well known for his exhortation to 'put nature on rack

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[35] J. Cottingham et al, No. 26, p.142.

and compel her to bear witness',[36] which epitomises an attitude that looks upon nature as an adversary, whose secrets man must unravel in order to control and conquer it. Bacon's vision of scientific research as the divinely ordained mission for establishing the empire of man over nature is best seen in the following passages from his *Novum Organum* (1620):[37]

> Further, it will not be amiss to distinguish between three kinds and as it were grades of ambition in mankind. The first is of those who desire to extend their own power in their native country… The second is of those who labour to extend the power of their country and its dominion among men. … But if a man endeavour to establish and extend the power and dominion of the human race itself over the universe, his ambition (if ambition it can be called) is without doubt both a more wholesome thing and a more noble than the other two. Now the empire of man over things depends wholly on the arts and sciences. ...
>
> Only let the human race recover that right over nature which belongs to it by divine bequest, and let power be given it; the exercise thereof will be governed by sound reason and true religion.

***Vijñānaṃ Yajñaṃ Tanute*: Science and Technology as the Discipline of Producing and Sharing in Plenty**

In conclusion, we shall briefly recount what the fundamental texts of Indian civilisation have taught us about the nature and purpose of scientific knowledge. *Taittirīya Upaniṣad*, one of the primary texts of Indian civilisation, teaches that the main purpose of *vijñana* (special knowledge or science) is to manifest *yajña*:[38]

> *Vijñānaṃ yajñaṃ tanute. karmāṇi tanute'pi ca*. *Vijñana* manifests *yajña*. It also manifests the actions.

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36 Will Durant, *The Story of Philosophy*, Simon and Schuster, New York, 1961, p.103. Durant does not provide any reference for the source of this quotation.
37 J. M. Robertson (ed.), *The Philosophical Works of Francis Bacon*, Routledge, Abingdon, pp.300-301.
38 N. R. Acharya, *Īśādiviṃśottaraśatopaniṣadaḥ*, Nirnayasagara Press, Pune, 1948, p.26

All *śāstra*, or systematic knowledge, is meant to sustain and augment *yajña*. And *yajña*, as the texts explain, is the discipline of producing an abundance and sharing it with all aspects of creation.[39]

The verses III.10-16 of the third chapter of *Bhagavadgītā* explain that *yajña* is the basic discipline which keeps the *dharmacakra* of Bhagavān Śrīkṛṣṇa, the cycle of mutual dependence among all aspects of creation, moving:[40]

sahayajñāḥ prajāḥ sṛṣṭvā purovāca prajāpatiḥ anena
prasaviṣyadhvam eṣa vo'stviṣṭakāmadhuk devān
bhāvayatānena te devā bhāvayantu vaḥ parasparaṃ
bhāvayantaḥ śreyaḥ param avāpsyatha iṣṭān bhogān hi vo
devā dāsyante yajñabhāvitāḥ tairdattānapradāyaibhyo yo
bhuṅkte stena eva saḥ yajñaśiṣṭāśinaḥ santo mucyante
sarvakilbiṣaiḥ bhuñjate te tvaghaṃ pāpā ye pacantyātma
kāraṇāt annād bhavanti bhūtāni parjanyād
annasaṃbhavaḥ yajñād bhavati parjanyo yajñaḥ
karmasamudbhavaḥ
karmabrahmodbhavaṃ viddhi brahmākṣarasamudbhavam tasmāt
sarvagataṃ brahma nityaṃ yajñe pratiṣṭhitam evaṃ pravartitaṃ
cakraṃ nānuvartayatīha yaḥ aghāyurindriyārāmo moghaṃ
pārtha sa jīvati

At the beginning of creation, Prajāpati—Brahman in the aspect of creator—created the human beings along with the *yajña*, disciplined action, and then blessed them thus: Flourish through *yajña*. Let the *yajña* be your *iṣṭakāmadhuk*, let it fulfil all your wishes and desires.

Propitiate the *devas* through *yajña*, and let the *devas* propitiate you. Propitiating each other thus, let both of you, the *devas* and the humans, achieve *paramaśreyas*, the best that there is.

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39 J. K. Bajaj and M. D. Srinivas, *Annaṃ Bahu Kurvīta, Recollecting the Indian Discipline of Growing and Sharing Food in Plenty*, Centre for Policy Studies, Chennai, 1996.
40 G. S. Sadhale, *Śrīmadbhagavadgītā with Eleven Commentaries,* Vol. I, Gujarati Printing Press, Mumbai, 1935, pp.288-303.

Propitiated by the *yajña* the *devas* enrich man with all desirable objects. Therefore, one who enjoys what is given by the *devas* without giving it back to them is indeed a thief.

Those who partake of the left-over of the *yajña*—those who eat after having offered the proper shares to all others and all of nature—are the virtuous. They are cleansed of all sins. Those who cook for themselves alone are the sinners: in eating alone they partake of only sin.

All beings are formed of *anna*; *anna* arises from the rains; rains arise from *yajña*; and *yajña* arises from *karma*, action.

Know that *karma* arises from Brahman in the aspect of *Veda*, the knowledge, and Brahman in this aspect arises from *akṣara*, the imperishable first sound. Therefore, know that Brahman, though he permeates all, is always resident in *yajña*.

This is the cycle of mutual dependence initiated by Brahman. He who does not act according to it, who does not keep it moving, is a sinner who is immersed merely in the pleasure of the senses. The living of such a one, O Pārtha, is a waste.

The teachings of Śrī Kṛṣṇa in these foundational verses of the Gita may be paraphrased thus:[41]

The universe is indeed a great cycle of give and take between different aspects of creation. Whatever is earned or produced by man is in fact taken from other aspects of creation and it may rightfully be consumed only after returning the shares of all, only after propitiating and fulfilling all other parts of creation. Consuming for oneself without having thus propitiated others is indeed stealing. Brahman, the creator, while initiating this great cycle of the universe enjoins upon human beings to keep it moving through *yajña*, disciplined action that propitiates and fulfils all aspects of creation. The one who does not keep this cycle of mutual dependence—the *dharmacakra*, as it is often referred to—moving is a sinner immersed merely in the pleasures of the senses. The living of such a one is a waste.

41 "J. K. Bajaj, 'Relevance of Mahatma Gandhi and his Thought in Modern times', CPS 2000" at http://cpsindia.org/index.php/art/118-articles-by-jk-bajaj-and-md-srinivas/relevance-of-mahatma- gandhi-and-his-thought-in-modern-times (Accessed on June 7, 2020).

Thus, it has been the Indian view that all scientific knowledge is for the purpose of sustaining and augmenting *yajña*, or the discipline of the discipline of producing an abundance and sharing it with all aspects of creation. Indeed, in the Indian view, the entire universe as a manifestation of divinity; and man or the human species is not privileged over the rest of creation. This is taught by the very first verse of the *Īśāvāsya Upaniṣad*:[42]

īśāvāsyamidaṃ sarvaṃ yatkiñca jagatyāṃ jagat tenatyaktena
bhuñjīthā mā gridhaḥ kasyasviddhanam

All this that we see in this great Universe is pervaded by God. Renounce it and enjoy it. Do not covet anybody's wealth or possession.

The instruction of the *Upaniṣad* to 'renounce ... and enjoy', is also the same as the above instruction of *Bhagavaddgītā* about the discipline of *yajña*.

What distinguishes the humans from the other living beings is that the humans unlike others are expected to follow *dharma*. As a popular maxim in *Hitopadeśa*, a basic text which teaches *nīti* or right conduct, states:[43]

āhāranidrābhayamaithunañca sāmānyametat paśubhirnarāṇām dharmo
hi teṣām adhiko viśeṣaḥ dharmeṇa hīnā paśubhissamānāḥ

Food, sleep, fear and mating, these are common between men and animals. It is *dharma*, performance of one's duties, which specially distinguishes men [from animals]; those who are bereft of *dharma* are no different from animals.

An important aspect of *sanātana-dharma* is that while it requires every person or group to follow his or their own *dharma*, yet at the same time it enjoins all not to hinder any other aspect of creation from following its *dharma*. The world is a manifestation of the divine; it has its own autonomous way, its own inborn discipline and harmony. It is the duty of man to try and learn of the ways of the world so as to ensure that his actions do not violate this inherent discipline, the inborn *dharma* of the world.

Indeed a study of the sciences and technologies as practised in the Indian civilisation would show that they have been carried out not with the urge to control and alter nature, but with the intention to learn of the ways of nature so as to ensure that human actions do not violate her essential balance and harmony. Indians have looked upon

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42 N. R. Acharya, No. 38, p.1.
43 N. R. Acharya, *Hitopadeśa of Nārāyaṇa Paṇḍita*, Nirnaya Sagara Press, Mumbai, 1944, p.5.

nature not as an adversary, but as the larger part of divine creation of which they are only a component. And, they have believed that nature has her own balance and harmony, her own autonomous ways, which they have known from the Vedic times by the name of *ṛta*. Indians have known that it is indeed their duty to observe and comprehend nature, acquire scientific knowledge, so that they may avoid violating the way of nature, so that they may not fall foul of *ṛta*.

An important feature of the Indian tradition of science and technology is the attitude of humility towards the world. Indians have believed that truth always resides in the world in all its complexity, and their theories are mere devices to help humans to comprehend the world and to order their life so as to not violate its essential balance and harmony. Indeed the fundamental texts of Indian civilisation have always emphasised the fundamental distinction between the contingent knowledge which is necessary in order to live competently in the material world and the absolutely true knowledge of the eternal unchanging reality. In the *Īśāvāsya Upaniṣad*, the former is called *avidyā* and latter the *vidyā*. And the *Upaniṣad* is emphatic that *avidyā* and *vidyā* are indeed very different, but it is essential to know them both together:[44]

andhaṃ tamaḥ praviśanti ye'vidyam upāsate tato bhūya
iva te tamo ya u vidyāyāṃ ratāḥ anyadevahurvidyayā
anyadāhuravidyayā
iti śuśruma dhīrāṇāṃ yenastad vicacakṣire vidyāṃ ca
avidyāṃ ca yastadvedobhayaṃ saha avidyayā mṛtyuṃ
tīrtvā vidyayā amṛtamaśnute.

Those who worship *avidyā*[alone] enter into blind darkness. Into darkness still greater than that, as it were, do they enter who delight in *vidyā* [alone].

One result they say is obtained by *vidyā* and quite another by *avidyā*. Thus we have heard from the wise who explained it to us.

Those who know both *vidyā* and *avidyā* together, they [alone] live through the mortal world through *avidyā* and enjoy the immortal through *vidyā*.

The Greco-European perspective on scientific knowledge which seeks to find absolute true representation of the world, a veritable transcription of the Divine mind, is clearly

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[44] N. R. Acharya, No. 38, p.1.

confusing between *avidyā* and *vidyā*.[45] The *Upaniṣad* declares that: "Those who worship *avidyā*[alone] enter into blind darkness. Into darkness still greater than that, as it were, do they enter who delight in *vidyā* [alone]." One wonders what the *Upaniṣad* would have said about the followers of Greco-European perspective of scientific knowledge, who are not even aware of the fundamental difference between *avidyā* and *vidyā*.

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[45] For an analysis of these issues, see, J. K. Bajaj, "Francis Bacon, the First Philosopher of Modern Science: A Non-Western View" in Ashis Nandy (Ed.), *Science, Hegemony and Violence: A Requiem for Modernity*, United Nations University, Tokyo, 1988; reprint, Oxford India Paperback, 1990, pp.24-67.