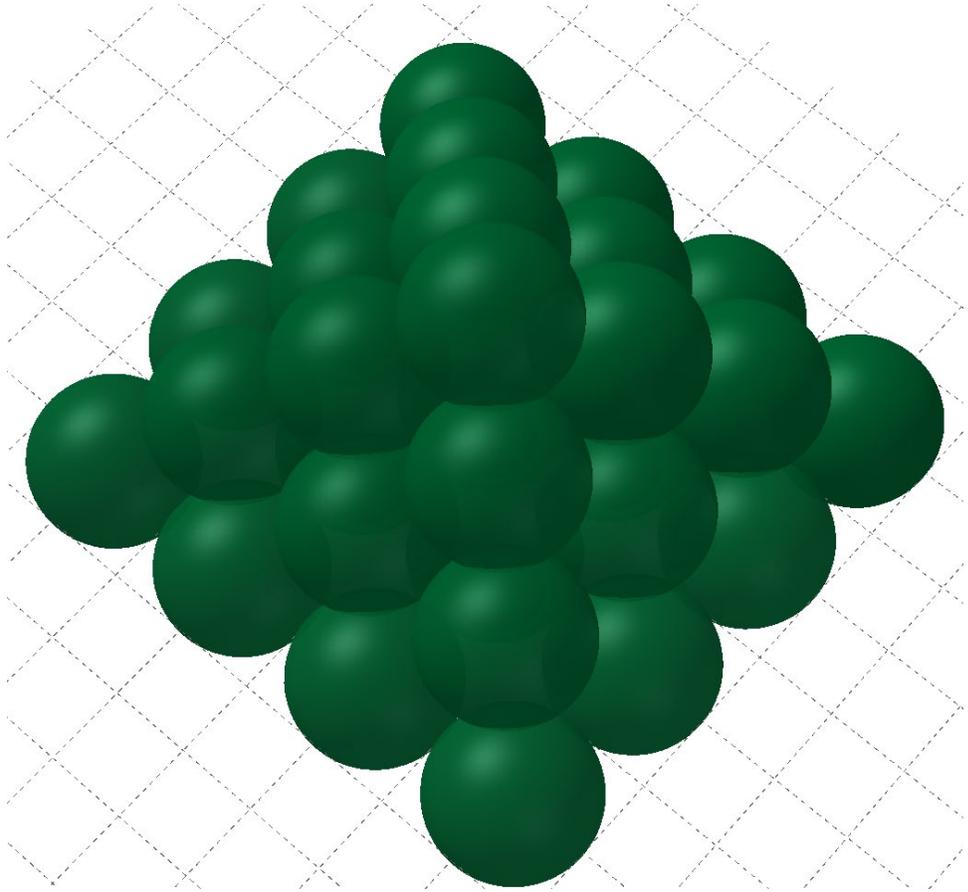


Some reflections on the history of Indian science

- The language of science: A brief look at notations of the ancients
- The centers of science in the ancient world
- Origin of the Indians and kindred populations
- The periods of Indian science
- Religion as the substratum of science: not something different from it
- The common origins and parallel developments of Indian and Greek science
- The early Indian scientific (philosophical) schools
- Some examples of early concepts:
 - Early mathematics, astronomy and cosmogonic ideas
 - Hindu Atomism and physical theories
 - Theories in physiology, zoology and medicine
 - Linguistic thinking
 - Illustration of modern relevance: An e.g. from computational biology
- Scientific principles
- Indian scientific culture

The language (notation) of science



$$\sum_{j=1}^n j^2 = \frac{n(n+1)(2n+1)}{6}$$

How many balls are there in the above pile?

The language of Indian science: Sanskrit

अ आ अः क ख ग घ ह । ङ → कण्ठः (Glottal)

इ ई च छ ज झ य श । ञ → तालुः (Soft Palate)

ऋ ॠ ट ठ ड ढ र ष । ण → मूर्धा (Hard Palate)

ल लृ त थ द ध ल स । न → दन्तः (Dental)

उ ऊ प फ ब भ । म → औष्ठः (Labial)

व → दन्तः + औष्ठः

ए ऐ → कण्ठः + तालुः

ओ औ → कण्ठः + औष्ठः

अं → अनुनासिकम्

कृ + ष = क्ष ञ



Periodic functions
of position of the
tongue

Origins of ontological
principles

Letters can denote
numbers

Inspired Mendeleev's periodic table of elements

The language of Indian science: Religio-cultural milieu should be understood



व्यासे भनन्दाग्रिहते विभक्ते खबाणसूर्यैः परिधिः स सूक्ष्मः ।
द्वाविंशतिघ्ने विहते ऽथ शैलैः स्थूलो ऽथवा स्याद् व्यवहार-योग्यः ॥

An expression for the value of π : the ratio of the perimeter of a circle to its diameter
Note: Use of special cultural encodings to refer to numerical values.

If you are curious...

Bhanandāgni: bha+ nanda+agni: bha =27; nanda= 9; agni= 3 → 3927

Khabāṇasūrya: kha+bāṇa+sūrya: kha=0; bāṇa=5; sūrya=12 → 1250

$$\pi \approx \frac{3927}{1250} = 3.1416$$

Śailaḥ=7; dvāviṃśati=22

$$\pi \approx \frac{22}{7} = 3.142$$

nanda = 9 Nanda emperors of Magadha; agni = 3 ritual fires; kha = space=0; bāṇa = 5 arrows of Kāmadeva etc; sūrya = 12 Āditya-s, solar deities; Śailaḥ: 7 mountains in tradition (Mahendra, Malaya, Sahya, Śuktimat, Ṛkṣa, Vindhya and Pāripātra.)

Some centers of science in the pre-modern world



The ancient cosmopolis: Mediterranean, Iran, India, East Asia

The genesis of Indians



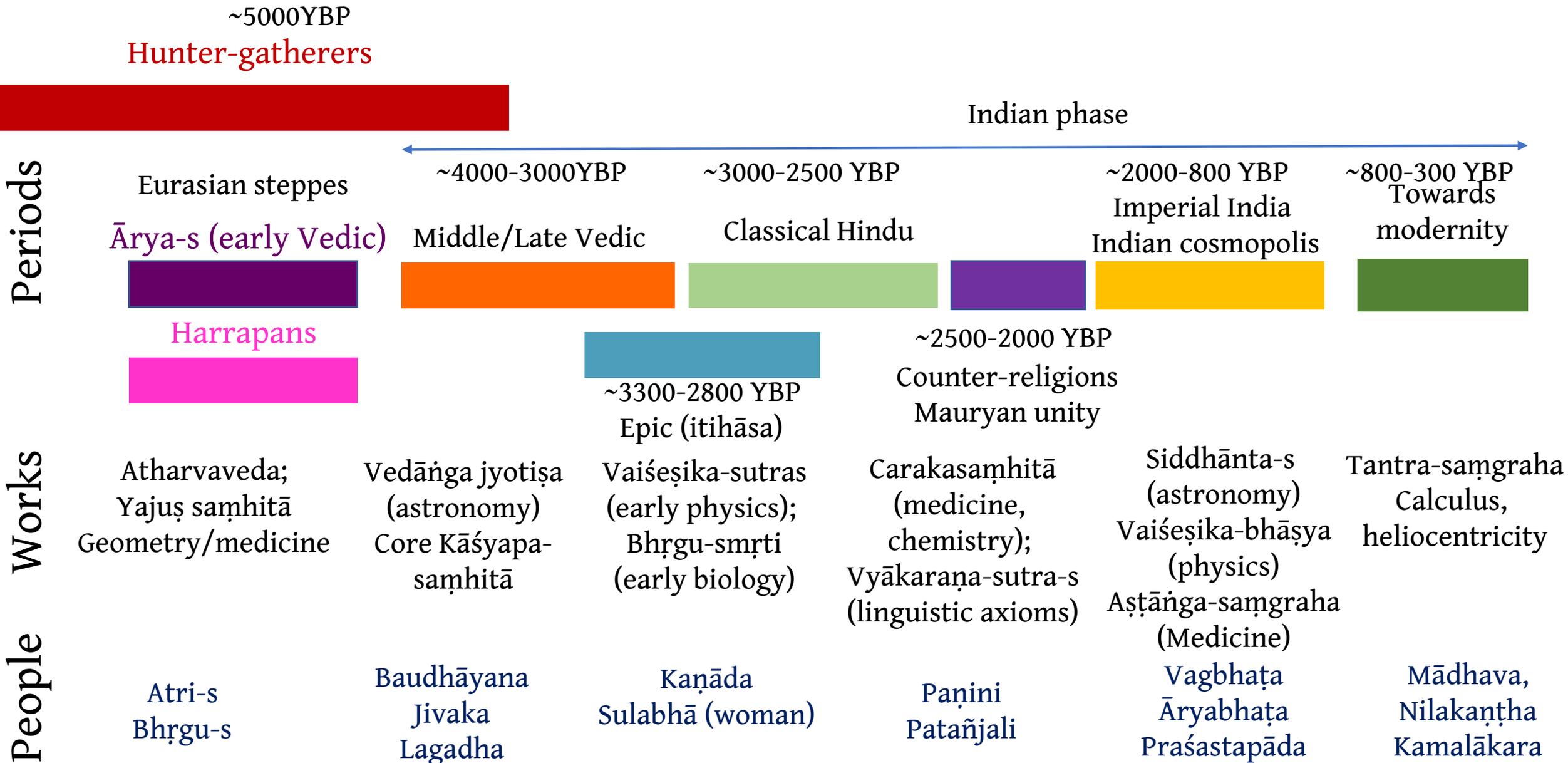
— Ancient hunter-gatherers
>35 KYA

— Iranian hunter-gatherer → Neolithic transition (farming) → Harappan Civilization ? 11KYA-4KYA

— Indo-Europeans: Defining cultural force → Emergence of Indian scientific tradition as we know it 3900-3500 YA

— Austro-Asiatic tribes ~3000 YA onwards

Broad periods of Indian scientific tradition



Indian and Greek science arose from substratum of religion and not something different from it

- Performance of rituals at right time: calendrics → astronomy
- Accurate construction of altars for rituals: mensuration → Geometry;
- Animal sacrifice: careful offering of dissected parts of animals → Anatomy
- Accurate preservation of incantations for ritual: Linguistics → Axiomatic principles
- Classification of ritual actions and economical communication → Ontology
- Use of biologically active plants (E.g. soma) → Botany, medicine
- Philosophical meditations on rituals → Theories on nature of existence

Religion and science were not at loggerheads in old India

उद्भट-बुद्धिर् भाट्टे सांख्ये ऽसंख्यः स्वतन्त्रधीस् तन्त्रे ।
वेदे ऽनवद्य-विद्यो ऽनल्पः शिल्पादिषु कलासु ।
स्वच्छन्दो यश् छन्दसि शास्त्रे वैशेषिके विशेषज्ञः ।
यः श्री-प्रभाकर-गुरुः प्रभाकर-दर्शने कविः काव्ये ॥
बहु-गुण-गणित-प्रभृति-स्कन्ध-त्रितये त्रिनेत्र-समः ।
विबुधाभि-वन्दित-पदो जयति श्रीभास्कराचार्यः ॥

Learned in the bhāṭṭa-doctrine (i.e. mīmāṃsā of bhaṭṭa Kumārila), unlimited in Sāṃkhya, and an independent thinker in the tantra; of unblemished knowledge in the Veda, and not inferior to any in architecture and other arts; he who could deploy meters as he wished, a special knower of Vaiśeṣika; he was a respected teacher of the Prabhākara doctrine and poet in the realm of poetry; in the manifold mathematical procedures of the three branches of the [mathematical] sciences he was like the three-eyed [god]; triumphant is this respected Bhāskarācārya whose feet are worshiped by the wise.

An account the scholarship and the breadth of knowledge of Bhāskara-II by one of his successors found on an inscription attached to a college of mathematics founded by his grandson in the late 1100s of CE

Several parallels between Greek and Indian scientific traditions

Periods of interaction

- Shared Indo-European ancestry: Common ideas inherited from ancient Indo-European days on the steppe
- Pre-Alexandrian exchange via the Iranian Achaemenid empire (especially in north-west) which employed both Greeks (yavana-s) and Indians
- Alexandrian collision of the Greek and Indian worlds

Common ground and exchange of ideas

- Platonism closely parallels Indian philosophical traditions
- Sāṃkhya-yoga and Empedocles: evolution of organisms from individual organs
- Pāṇini and Euclid: Axiomatic thinking as the foundation of knowledge
- Influence of Hindu medicine on Greek medicine: the theory of doṣa-s (bodily substances)
- Influence of Greek astrology (yavana-jataka) on Indians. Acquisition of geometry concepts from astrological texts.

Pāṇini and Euclid

- Pāṇini: Attempt to create a description of all of language from a small number of starting axioms (Māheśvara-sūtrāṇi)
- Euclid: Attempt to create description of the geometric and number world with a small number of axioms: the famous 5 postulates
- Pāṇini: Proving grammatical forms through serial application of axioms
- Euclid: Proof of geometric theorem

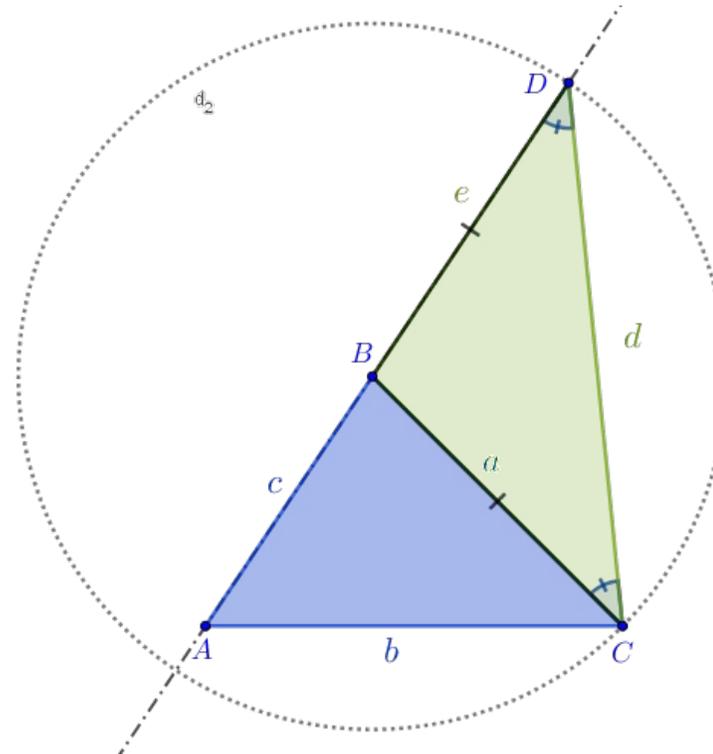
महोरस्कः broad-chest

महत्~सु + उरस् ~सु →

महत्~सु + उरस् ~सु + क~प् →

महत् + उरस् + क -(आन्महतः) →

महा + उरस् + क → महोरस्कः ॥



Donkey's theorem for $\triangle ABC$
In $\triangle BDC$, $\angle BDC = \angle BCD$
 $\angle ACD > \angle BDC$
 \therefore in $\triangle ADC$, $\overline{AD} > \overline{AC}$
 $\therefore c + e > b$
 $\therefore a + c > b$ Q.E.D

Some Insights from the earliest Indian scientific texts

Vedāṅga-jyotiṣa

- Composed ~3300 Ybp by Lagadha in the Pāñcanada region (the Greater Panjāb)
- First clear-cut demonstration of computational algorithms in Indian astronomy: e.g. use of Modulo function in computation: (e.g. $13 \bmod 4 = 1$)
- The water-clock as measure of time (a very Indian way of time keeping): the volume of water of weight 50 pala-s, at room temperature, is one ādhaka (a volume measure). In this water-clock that volume of water that drains in one 1 nāḍikā. This ancient time unit corresponds to 24 minutes. 60 nāḍikā-s in a day
- Reasonable determinations of lunar periods: synodic month, the period between two new moons=29.51 days (modern value= 29.530). Sidereal month (time taken by Moon to complete one full revolution around the Earth with respect to the background stars) = 27.31 (modern value=27.32)

A verse as a stop-watch

मा कान्ते पक्षस्यान्ते पर्याकाशे देशे स्वाप्सीः
कान्तं वक्रं वृत्तं पूर्णं चन्द्रं मत्वा रात्रौ चेत् ।
क्षुत्क्षामः प्राटंश् चेतश् चेतो राहुः क्रूरः प्राद्यात्
तस्माद् ध्वान्ते हर्म्यस्यान्ते शय्यैकान्ते कर्तव्या ॥ (कामक्रीडा/लिलाखेलः)

Do not, pretty girl, at the end of the [bright] fortnight sleep in a place open to the sky.
Should at night taking [your] beautiful face to be the round full moon,
the hunger-stricken cruel Rāhu wandering about here and there eat you up.
Therefore, at nightfall you ought to make your bed in an isolated place inside the house.

If you recite the above continuously in the “madhyma-gati” it should take you
24 seconds: an ancient Indian unit of time called viṇāḍikā

Science in the Bṛḡu-smṛti

- A text today preserved as part of the Mahābhārata
- Presented as the knowledge emerging from teaching of ancient teacher Bṛḡu to his student Bharadvāja
- Covers a wide range of scientific, philosophical and social questions
- One of the key proto-scientific texts in Indian tradition: begins with the below questions marking curiosity about existence

ससागरः सगगनः सशैलः सबलाहकः | सभूमिः साग्निपवनो लोकोऽयं केन निर्मितः ॥ ७॥

How has the universe, with all its oceans, its firmament, its mountains, its clouds, its lands, its fire, its wind come into being?

कथं सृष्टानि भूतानि कथं वर्णविभक्तयः | शौचाशौचं कथं तेषां धर्माधर्मावथो कथम् ॥ ८॥

How did the elements come into being and how did the distinction into various categories come to be? What are the [rules] of cleanliness and proper conduct?

कीदृशो जीवतां जीवः क्व वा गच्छन्ति ये मृताः | परलोकमिमं चापि सर्वं शंसतु नो भवान् ॥ ९॥

What is the nature of life of the living beings and what happens upon their death?

Tell us every thing about this world and the yonder world [3].

Science in the Bṛḡu-smṛti

Concept of vast space with numerous self-luminous bodies

ते चाप्यन्तं न पश्यन्ति नभसः प्रथितौजसः । दुर्गमत्वादनन्तत्वादिति मे विद्धि मानद ॥ २५॥

Even the above [celestial bodies] of great luminosity do not illuminate the limits of the nebulous sky, due its inaccessibility and infinity. It is so, O giver of respect.

उपरिष्टोपरिष्टात्तु प्रज्वलद्भिः स्वयम्प्रभैः । निरुद्धमेतदाकाशमप्रमेयं सुरैरपि ॥ २६॥

Arrayed after the other are the blazing self-luminous bodies which fill space whose measures incognate to the very celestials.

Science in the Bṛḡu-smṛti

First physical theory for the origin of the universe

पुरा स्तिमितनिःशब्दमाकाशमचलोपमम् | नष्ट चन्द्रार्कपवनं प्रसुप्तमिव सम्बभौ || ९||

In the beginning there was only the motionless and immovable space. Without bodies like the sun or moon or the gaseous element it was as though in a state of dormancy.

ततः सलिलमुत्पन्नं तमसीवापरं तमः | तस्माच्च सलिलोत्पीडादुदतिष्ठत मारुतः || १०||

Then the liquid element emerged, like something denser than the existing emptiness[11]. From the outward pressure in the liquid element arose the gaseous element.

सशब्दं

यथा भाजनमच्छिद्रं निःशब्दमिव लक्ष्यते | तच्चाम्भसा पूर्यमाणं सशब्दं कुरुतेऽनिलः || ११||

Like a vessel without a fissure the universe was without sound. But when filled with the liquid element sound was transmitted gaseous element.

Science in the Bṛḡu-smṛti

तथा सलिलसंरुद्धे नभसोऽन्ते निरन्तरे । भित्त्वारणव तलं वायुः समुत्पतति घोषवान् ॥ १२॥

Thus the space permeated throughout by the liquid element, and from it [liquid element] penetrated by waves arose the vibrating gaseous element.

स एष चरते वायुरणवोत्पीड सम्भवः । आकाशस्थानमासाद्य प्रशान्तिं नाधिगच्छति ॥ १३॥

The gas thus by the pressure of the waves in water keeps moving. In the midst of space where there is no countering force it never stops.

तस्मिन्वाय्वम्बुसङ्घर्षे दीप्ततेजा महाबलः । प्रादुर्भवत्यूर्ध्वशिखः कृत्वा वितिमिरं नभः ॥ १४॥

Where the gas encountered the liquid element, there was friction and this gave rise the light and heat filled with energy. These radiated forth with upward-directed rays and dispelled the darkness from the space.

Science in the Bṛḡu-smṛti

अग्निः पवनसंयुक्तः खात्समुत्पतते जलम् । सोऽग्निमरुत संयोगाद्धनत्वमुपपद्यते ॥ १५॥

The heat acting on the gaseous element spread the liquid element into space. Through the combination with heat and the gaseous element it [the liquid element] gave rise to dense structures.

तस्याकाशे निपतितः स्नेहस्तिष्ठति योऽपरः । स सङ्घातत्वमापन्नो भूमित्वमुपगच्छति ॥ १६॥

These condensates of the liquid element fell of from the sky and solidified to give rise to the solid element.

रसानां सर्वगन्धानां स्नेहानां प्रानिनां तथा । भूमिर्योनिरिह ज्ञेया यस्यां सर्वं प्रसूयते ॥ १७॥

This solid element as the earth is known to be the source from which all liquids, substances, smells and living beings originated.

Science in the Bṛghu-smṛti

Early (fairly accurate) ideas on plant biology: ascent of sap; sensory capacity
Growth using absorbed nutrients

वक्त्रेणोत्पल नालेन यथोर्ध्वं जलमाददेत् | तथा पवनसंयुक्तः पादैः पिबति पादपाः ॥ १६॥

Just as one can suck water through tubes in a bent lotus stalk, thus plants, by means of the force of the gaseous element suck water with their roots.

ग्रहणात्सुखदुःखस्य छिन्नस्य च विरोहणात् | जीवं पश्यामि वृक्षाणामचैतन्यं न विद्यते ॥ १७॥

They are affected by pleasures and pains and regenerate when cut up. Hence, I conclude that plants have life and are capable of sensory perception.

तेन तज्जलमादत्तं जरयत्यग्निमारुतौ | आहारपरिनामाच्च स्नेहो वृद्धिश्च जायते ॥ १८॥

The action of heat and the gaseous element cause the sap that has been thus sucked to be digested. Depending on the amount of sap that has been consumed there is an advance in [the plant's] growth.

Science in the early philosophical schools

School	Scientific questions	Other focus
Sāṃkhya-yoga	Origin of universe, structure of matter, origin of organisms, sensory perception	Alleviation of sorrow, acquisition of special capabilities
Vaiśeṣika	Physics, atomic theory of universe	Physical laws, understanding universe
Nyāya	Atomic theory, scientific logic	Logic in general, asceticism
Pūrva-mīmāṃsā	Theory of sound, logic	Logic, correct performance of rituals
Uttara-mīmāṃsā	Role of consciousness	Consciousness and soteriology
Vaiyyākaraṇa	Algorithmic and axiomatic thought	Grammar to understand ritual texts
Bauddha	Nature of consciousness	Alleviation of sorrow
Jaina	Zoology, nature of life, logic	kevalajñāna

Vaiśeṣika: physical theories

- Formal founder: Kaṇāda Kāśyapa ~2800 YBP
- Earliest text: Vaiśeṣika-sutrāṇi
- Famous expositors: Praśastapāda, Śrīdhara, Vācaspati Miśra, Jayanta

- All matter is made up fundamental atomic units called paramāṇu-s.
- Time, space and consciousness are also made of discrete units that are further indivisible
- Explain all of existence through physical laws: concepts like force and work operating on particles of matter.

- Completely physical explanation for the universe after the initial conditions that set the atomic interactions in motion

- Successfully explained several natural phenomena

Vaiśeṣika: concept of force and work

संस्कारो यावत् पतनम् अनुवर्तते | यथा यथा चास्य कार्य-करणात् शक्तिः क्षीयते तथा तथा कार्य-मन्दतरमादि-भेद-भिन्नम् उपजायते ।

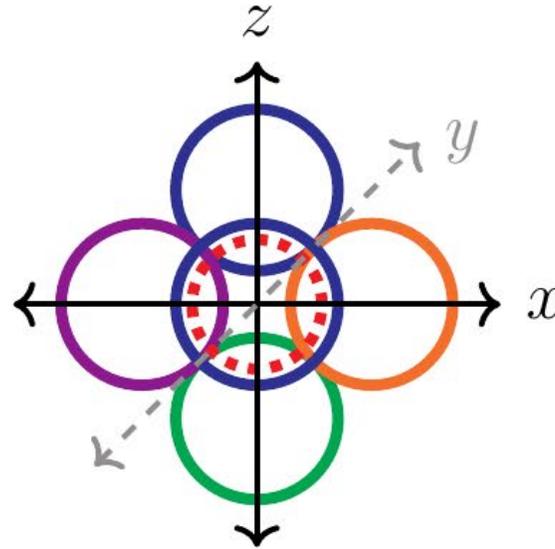
When the existing force “saṃskāra” causes motion, as it keeps performing work against a counteracting force when the energy is consumed it attains states of reduced work etc (i.e. culminating in rest)

- This, while in our modern language looks somewhat clumsy, was a central concept for the Vaiśeṣika-vādins. It might be seen as the closest one gets to the Newtonian first law of motion from classical physics in the ancient world
- The capacity to perform work depends on the available energy and when the force is balanced, motion decreases and rest is attained

Vaiśeṣika: use of coordinate system: atomic packing

एकत्वेऽपि दिशः आदित्योदयदेश प्रत्यासन्न-देश संयुक्तो यः स इतरस्माद्-विप्रकृष्ट-प्रदेश संयोगात् परमाणोः
पुर्वः । एवमादित्यास्तमय-देश-प्रत्यासन्न-देश-संयुक्तो यः स इतरस्माद् विप्रकृष्ट-देश संयोगात् परमाणोः
पश्चिमः तौ च पूर्वपश्चिमौ परमाणू अपेक्ष्य यः सूर्योदयास्तमय-देश-विप्रकृष्ट-देश-संयोगः स मध्यवर्ती ।
एवम् एतयोर्द्यौ तिर्यग्देश-संबन्धिनौ मध्यस्य आर्जवेन व्यवस्थितौ पार्श्ववर्तिनौ तौ दक्षिणोत्तरौ परमाणू ।
एवं मध्यन्दिन-वर्तिसूर्यसनिकर्ष-विप्रकर्षौ अपेक्ष उपर्यधोभावो द्रष्टव्यः । सम्युक्त संयोगाल्पत्व भूयस्त्वे च
सनिकर्ष विप्रकर्षौ पूर्वसंख्यावच्छिन्नत्वं व अल्पत्वम् परसंख्यावच्छिन्नत्वं च भूयस्त्वम्

Today known as “cartesian
system” after the French
philosopher-scientist Descartes



Explains octahedral packing
of atoms in a solid

Vaiśeṣika: theory of sound

सम्योग-विभाग-निष्पन्नाद् वीची-सन्तानवच् छब्द-सन्तान इत्य् एवम् सन्तानेन श्रोत्र-प्रदेशम् आगतस्य ग्रहणम् । श्रोत्र-शब्दयोर् गमनागमनाभावाद् अप्राप्तस्य ग्रहणं नास्ति । परिशेषात् सन्तान-सिद्धिर् इति ॥

Sound arising from conjunctions and disjunctions, like a series of water-waves, is indeed produced in a wave-series. When the wave-series arrives in the region of the ear it is sensed. As the ear does not go to the sound and the sound-source does not arrive at the ear, there would be no sensing [of the sound] if something does not [physically] reach the other. Therefore, one has to conclude that [sound is transmitted] as a waves-series.

- First physical theory of sound
- Correctly understood it as a transport phenomenon involving wave motion
- Widely used by other Indian traditions

Vaiśeṣika: use of molecular theory to explain state change

नैमित्तिकं च पृथिवी-तेजसोर् अग्निसंयोगजम् । कथं सर्पिर् जतु-मधूच्छिष्टादीनां
कारणेषु परमाणुष्व् अग्नि-संयोगाद् वेगापेक्षात् कर्मोत्पत्तौ तज्जेभ्यो विभागेभ्यो
द्रव्यारम्भक-संयोग-विनाशात् कार्य-द्रव्य-निवृत्ताव् अग्नि-संयोगाद्-औष्ण्यापेक्षात्
स्वतन्त्रेषु परमाणुषु द्रवत्वम् ॥

The emergent fluidity of solid [with] energy is produced by contact with heat. How is it produced in butter, lac, wax and the like? It is because when the atoms [of the substances come in contact with a heat source they acquire momentum, which results in a force; this produces a disjunction of their atoms and the destruction of their substance-forming bonds. From this the [original state of] the substance ceases to exist. [Thus,] from the conjunction with the heat-source and the effect of the heat, the atoms are freed [from their cohesive bonds] and fluidity [emerges].

- We find a rather “contemporary” explanation for the state change: i.e. liquefaction of a solid in the Vaiśeṣika tradition.
- Here the “atom” should be understood as the minimal molecular unit of the substance
- Theory of bonding of atoms

Vaiśeṣika: Recognition of gravity as force

गुरुत्वम् जल-भूम्योः । पतन-कर्म-कारणम् । अप्रत्यक्षम् पतन-कर्मानुमेयम् ।
सम्योग-प्रयत्न-संस्कार-विरोधि । अस्य चाबादि-परमाणु-रूपाद् इव नित्यानित्यत्व-
निष्पत्तयः ॥

The liquid and solid substance possesses gravity. It is the force for the action of falling. It is imperceptible [but] is inferable from the action of falling. It is neutralized by the conjunctive force [between atoms] or work done against it or the momentum possessed [by a body]¹. Its permanence and impermanence are like the appearance of color of the fundamental particles of liquid and other substances².

1. Commentators like Śrīdhara explain saṃskāra in terms of momentum using the example of the arrow shot from a bow.
2. Śrīdhara clarifies that by this Praśastapāda means that the gravity is an eternal, i.e. nitya, property of the fundamental particle of the liquid etc substance. Its anityatva relates to the gravity of the molecular state which is impermanent, insofar as it exists only till the molecule lasts.

Vaiśeṣika: the concept of elasticity

स्थिति-स्थापकस् तु स्पर्शवद्-द्रव्येषु वर्तमानो घनावयवसन्-निवेश-विशिष्टेषु
कालान्तरावस्थायिषु स्वाश्रयम् अन्यथाकृतं यथावस्थित स्थापयति । स्थावर-
जङ्गम-विकारेषु धनुः-शाखा-शृङ्ग-दन्तास्थि-सूत्र-वस्त्रादिषु भुग्न-संवर्तितेषु स्थिति-
स्थापकस्य कार्यं संलक्ष्यते । नित्यानित्यत्व-निष्पत्तयोस्यापि गुरुत्ववत् ॥

Now elasticity exists in substances with contact whose [molecules] are densely packed, and can come close and move away from each other, which when at a given time point they have their position changed tend to restore their original position. In products of plants and animals, [such as] a bow, a branch, a horn, teeth, bones, fibers, cloth etc, which contract and expand the force of elasticity is observed. The permanence of an impermanence of elasticity are like that of gravity.

- Earliest molecular account of elasticity (sthiti-sthāpakah)
- Based on density of molecular packing

Vaiśeṣika: end of the universe

ब्राह्मणे मानेन वर्ष-शतान्ते वर्तमानस्य ब्रह्मणो ऽपवर्ग-काले संसार-खिन्नानाम् सर्व-प्राणिनाम् निशि-विश्रामार्थम् सकल-भुवनपतेर् महेश्वरस्य संजिहीर्षा-समकालम् शरीरेन्द्रिय-महाभूतोप-निबन्धकानाम् सर्वात्मगतानाम् अदृष्टानाम् वृत्तिनिरोधे सति । महेश्वरेच्छात्माणु-सम्योगज-कर्मभ्यः शरीरेन्द्रिय-कारणाणु-विभागेभ्यस् तत् सम्योग-निवृत्तौ तेषाम् आपरमाण्वन्तो विनाशः ॥
तथा पृथिव्य् उदक-ज्वलन-पवनानाम् अपि महाभूतानाम् अनेनैव क्रमेणोत्तरस्मिन् उत्तरस्मिन् सति पूर्वस्य पूर्वस्य विनाशः । ततः प्रविभक्ताः परमाणवो ऽवतिष्ठन्ते धर्माधर्म-संस्कारानुविद्धा आत्मानस् तावन्तम् एव कालम् ॥

By the measure of Brahman, at the end of 100 years, at the time of the release of the existing Brahman, for the the [final] nightly rest of all beings fatigued by [their passage through] existence, the lord of all the worlds, Maheśvara, wishes to destroy. Simultaneously [with this wish], the cessation of the action of the unseen forces that are the cause of the existence of the bodies, [sensory and motor] organs and the fundamental matter of all beings happens. From Maheśvara's desire and the action arising from the conjunction of the molecules and the consciousness, the molecules comprising the bodies and organs undergo disjunction. From this destruction of the combinations of molecules comes about the destruction of all [matter] to the state of elementary particles.

Thus happens the successive destruction and reabsorption of the [particles] of the fundamental substances of the solid, liquid, radiant energy and gas state, one after the other into the next. Thereafter, only the elementary particles exist in the disjoint state and at the same time intermixed with these are units of consciousness with their potential dharma and adharma.

The span of Brahman
311,040,000,000,000 years

Dissolution into elementary
particles

Theories and ideas pertaining to biology in
early Indian science

Caraka's physiology of digestion

Reasonable understanding of the different stages of digestion in different parts of the digestive tract

अन्नस्य भुक्तमात्रस्य षड्रसस्य प्रपाकतः ।
मधुराद्यात् कफो भावात् फेनभूत ऊदीर्यते ॥

Immediately on consumption of food, six tastes are sensed and initial digestion begins. From that it becomes sweet and secretion of frothy mucus [to ingest it] takes place.

परं तु पच्यमानस्य विदग्धस्याम्लभावतः ।
आशयाच्चयवमानस्य पित्तम् अच्छम् उदीर्यते ॥

Then in the stomach the ingested food being further digested becomes acidic. The food descending from the stomach induces clear bilious secretion.

पक्काशयं तु प्राप्तस्य शोष्यमाणस्य वह्निना ।
परिपिण्डित-पक्कस्य वायुः स्यात् कटुभावतः ॥

The food reaching the intestines is then successively dehydrated physiological absorption. The digested food then clumped into solid lumps by the peristaltic force acquiring a pungent odor.

Umāsvāti's zoology

Group I invertebrates

apādika = nematodes

nūpuraka = annelids

Gaṇḍūpada = cnidaria

śankha, śutika, samubuka = molluscs

jalūkā = leeches

Group III ("higher arthropods")

bhramara, varaṭa, saraṅga = hymenopterans

Makṣika, puttikā, daṃṣa, maśaka = Diptera

Vṛścika, nandyāvarta, lūtika = scorpions and spiders

Kīṭa = lepidoptera

Pataṅga = orthoptera (locusts and hoppers)

Group II ("lower arthropods")

pipīlikā

Rohiṇika

upachikā, kunthu, tuburaka = bugs

trapusavija, karapāsāsthikā = beetles

śatapadi, utpataka = myriapods

Triṇapatra = plant hoppers

Kāṣṭha-hāraka = termites and cockroaches

Group VI (The vertebrates known as tiryagyoni-s)

matsya = fishes

uraga/nakra, godha, kūrma = crocodiles, lizards and

turtles

Bhujaṅga = snakes

Pakṣi = birds

Jarāyuja-s = mammals

Caraka's parasitology

विंशति कृमिजातय इति । यूका पिपीलिकाश् चेति द्विविधा बहिर्-मलजाः
केशादा लोमादा लोमद्वीपाः सौरसा औदुम्बरा जन्तुमातरश् चेति षट्
शोणितजाः । अन्नादा उदरवेष्टा हृदयादाश् चुरवो दर्भपुष्पाः सौगन्धिका
महागुदाश्चेति सप्त कफजाः । ककेरुका मकेरुका लेलिहाः सशूलकाः
सौसुरादाश् चेति पुरीषजाः ॥

There are 20 types of pathogenic organisms. Lice, mites are the 2 arising in external secretions. The keśādā, lomādā lomadvīpa, saurasa, audumbara and jantumātara are the 6 arising in blood. The antrādā, udaraveṣṭa hṛdayāda, curu, darbhapuṣpa, saugandhika mahāguda are the 7 arising in the mucosa. The kakeruka, makeruka, leliha, saśūlaka and sausurāda are the 5 arising in the lower gut.

अथास्मै प्रोवाच भगवान् आत्रेयः -- इह खल्व् अग्निवेश! विंशति-विधाः
क्रिमयः पूर्वम् उद्धिष्ट नानाविधेन प्रविभागेन+अन्यत्र सहजेभ्यः; ते पुनः
प्रकृतिभिर् विभज्यमानाश् चतुर्विधा भवन्ति; तद् यथा पुरीषजाः, श्लेष्मजाः,
शोणितजा, मलजाश् चेति ॥

The respected Ātreya then replied to him: “O Agniveśa” there are 20 varieties of pathogens previously taught to you classified in different groups in addition to normal ones in the body. Now again they are classified according to their nature into 4 classes. They are those that arise in the lower gut, in the mucosa, in the blood and the external secretions.

Observation and
inference of parasitic
organisms

Pippīlikā == mite here?

Existence of normal
“microbiome”/commensal
load inferred

Caraka and Suśruta: mosquitoes

मशकाः सामुद्रः परिमण्डलो हस्तिमशकः कृष्णः पार्वतीय इति पञ्चः । तैर् दष्टस्य तीव्रा कण्डूर् दंश-शोफश् च । पार्वतीयस् तु कीटैः प्राण-हरैस् तुल्य लक्षणः ॥

नखावकृष्टे ऽत् अर्थ पिडका-दाह-पाका भवन्ति । जलौकसां दष्ट-लक्षणम् उक्तं चिकित्सितं च ॥

-सुश्रुतः

Mosquito[-species are] five: sāmudra, parimaṇḍala, hasti-maśaka, kṛṣṇa and pārvatīya. From their bite there is sharp itching and swelling at the bite-mark. These symptoms of the pārvatīya are like the bite of a fatal insect. The bite-marks when excessively scratched by the nails result in pustule, a burning sensation and discharge. The symptoms of a leech bite and its treatment has already been stated.

कण्डूमान् मशकैर् ईषच् छोफः स्यान् मन्दवेदनः ।

असाध्य-कीट-सदृशम् असाध्य-मशक-क्षतम् ॥

-चरकः

From the itchy [bite] of the mosquito there is slight swelling and mild pain. The incurable-mosquito bite is quite like the incurable insect bite.

Both saṃhitā-s recognize the well-known effects of mosquitoes. Suśruta also recognizes the possibility of an inflammatory reaction which is today called Skeeter syndrome. Both also mention a “serious” type of fatal mosquito bite. That is odd. Is that a vague recognition of a mosquito-borne disease resulting in fatality?

Caraka and Suśruta: pharmacopeia/pharmacology

Ethnopharmacology: prospecting for potential drugs from
hunter-gatherers and forest dwellers in Suśruta

गोपालास् तापसा व्याधा ये चान्ये वनचारिणः ।
मूलाहाराश् च ये तेभ्यो भेषज-व्यक्तिर् इष्यते ॥

From those who are cowherds, ascetics, hunters, these and other forest-tribes,
and those who are root-eating foragers, the particulars of drugs may be known

Note how he is increasing the pH and obtaining an alcohol extract

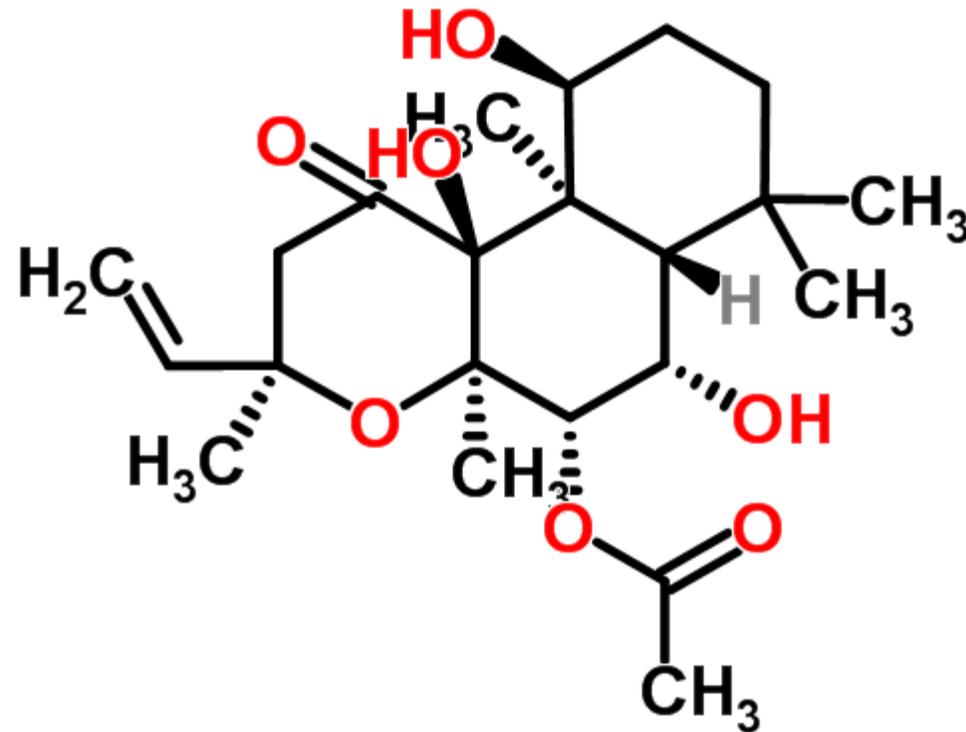
स्वर्जिका ऽज-शकृत्-क्षारः सुरसा ऽथाक्षिपीडकः ।
मदिरा-मण्ड-संयुक्तो हितः शतपदी-विषे ॥

Sodium Carbonate, alkali obtained from goat-shit, tulasi, Ctenolepis combined with the supernatant obtained from madirā alcohol is helpful [in treating] centipede poisoning.

Ancient pharmacopeia: still relevant

Forskolin: A substance from the mākandika plant described in Indian medical texts

adenylyl cyclase inducing molecule



Vaiyyākaraṇa-s: Pāṇini

Pāṇini lived ~2500 YBP: Was born in a place called Śalātura (today Chota Lahur in Pakistan). A statue of his existed in the town when Chīna visitor Xuanzang visited India.

How did Pāṇini create his grammar of Saṃskṛta ?

- 1) Data collection: Collected and gathered usage of the Sanskrit language from what's today Tajikistan to Assam. Systematically classified the words into that was called the Gaṇapāṭha: the database
- 2) Then he extracted roots for all those classified words and created a library of roots called the Dhātupāṭha
- 3) From these he created a series of axioms the Māheśvara-sutrāṇi
- 4) He then derived all of the language through a series of rules (sutra-s) acting on the above: the śūtra-pāṭha

Vaiyyākaraṇa-s: Linguistic analysis: “principle of homology”

Pāṇini, Kātyāyana and Patañjali: ~2500-2180 YBP

पठति
paṭhati

Reads

पचति
pacati

Cooks

Homologous element: **ati**

पठनम्
paṭhanam

Reading

पचनम्
pacanam

Cooking

Homologous element: **anam**

पाठकः
pāṭhakaḥ

Teacher

पाचकः
pācakaḥ

Cook

Homologous element: **akaḥ**;
Note elongation of root

Identify homologous
root **paṭh-**

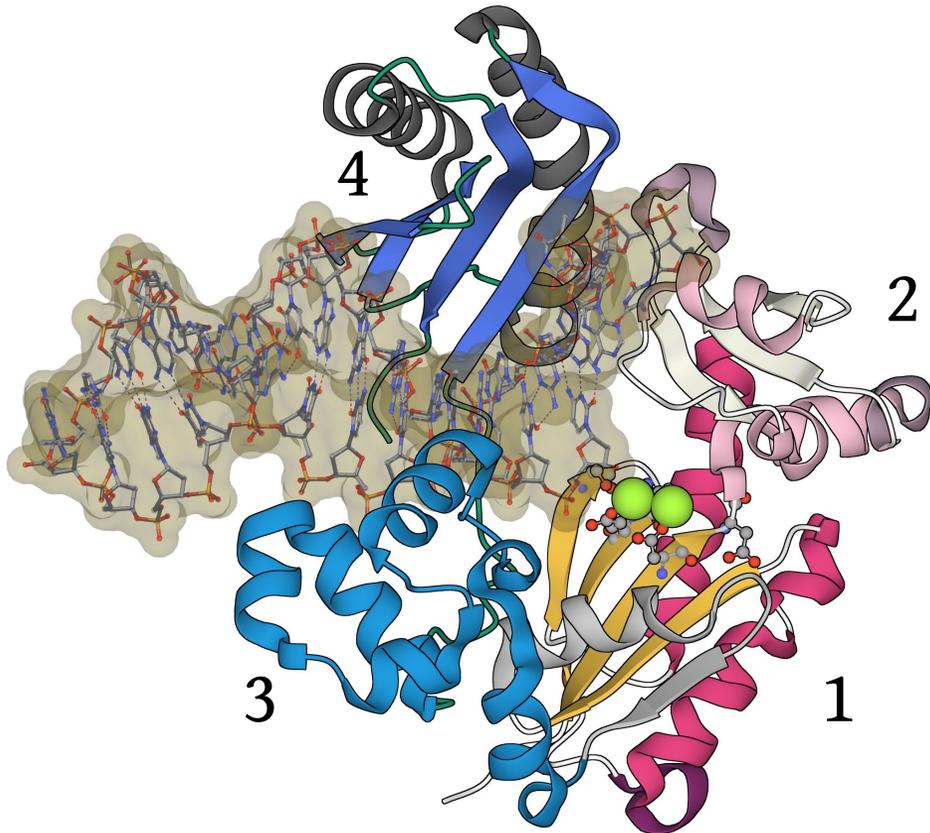
Identify homologous
root **pac-**

dhātu-s

pratyaya-s

Vaiyyākaraṇa-s: “principle of homology”: modern application

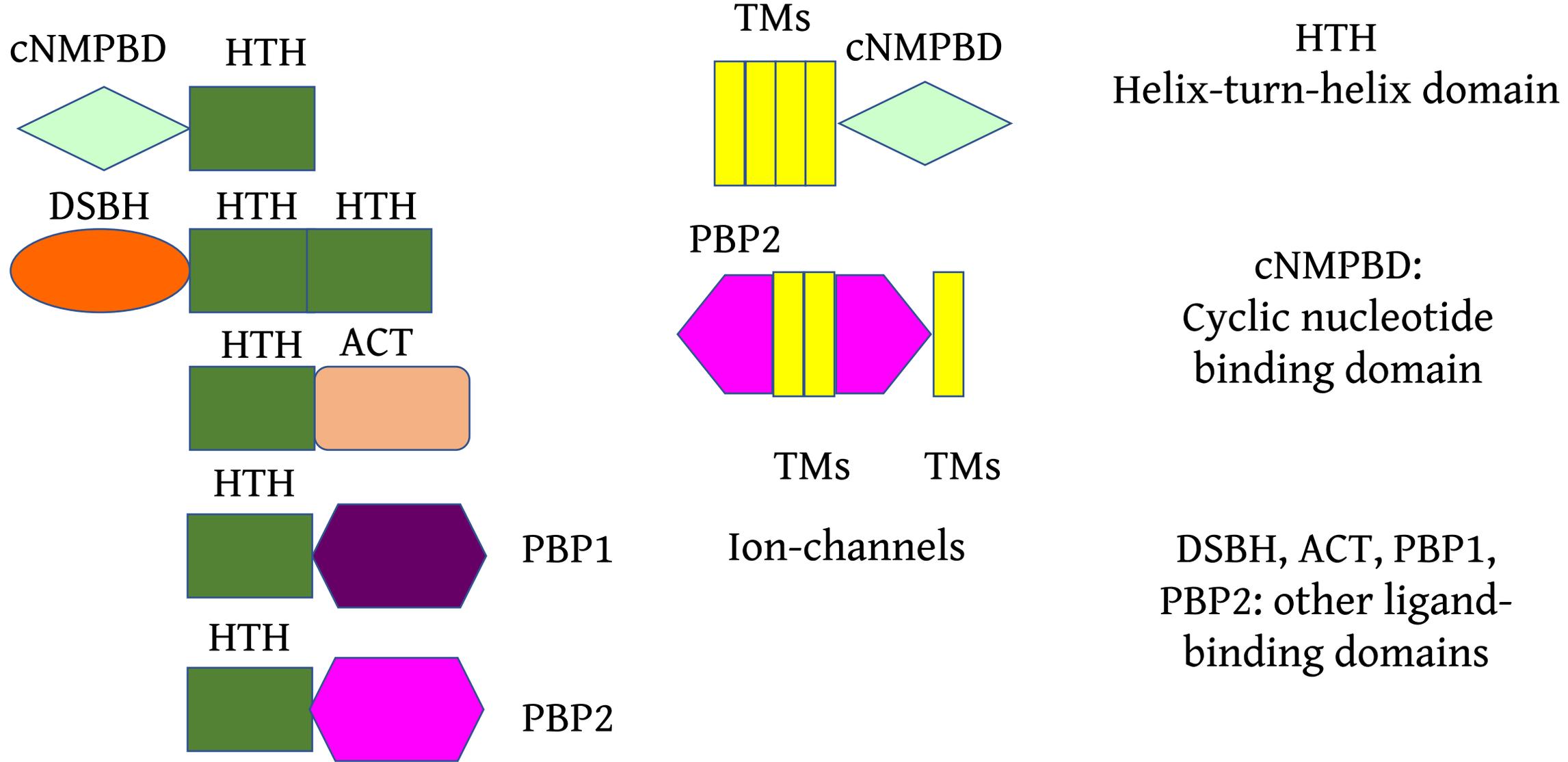
- Proteins are comprised of domains: These are structural, evolutionary and functional units
- Understanding the roles of domains leads to biochemical and biological understanding



Examples of domains in DNA polymerase:

- 1) “Palm”: RRM: Catalytic
- 2) “fingers”: holding template
- 3) ,4) DNA-binding domains

Vaiyyākaraṇa-s: “principle of homology”: modern application



Transcription factors

DSBH, ACT, PBP1, PBP2: other ligand-binding domains

Scientific principles and logic Nyāya: The law of excluded middle

Nyāya: promulgator: Akṣapāda Gautama

Later proponents: Udyotakara, Udayana, Jayanta

Given any proposition, either that proposition is true or its contradiction

तद् उक्तं तत् परिच्छिनति । अन्यद् व्यवच्छिनति ।
तृतीय-प्रकाराभावं च सूचयति । इत्य् एक-प्रमाण-व्यापारः ॥

That which is stated is the identity. The other is its contradiction.

The third type's exclusion is indicated (Aristotle: it will not be possible to be and not to be the same thing). This is the operation of the “one proof”.

Leibniz: Every judgment is either true or false

Nyāya: correlation and causation

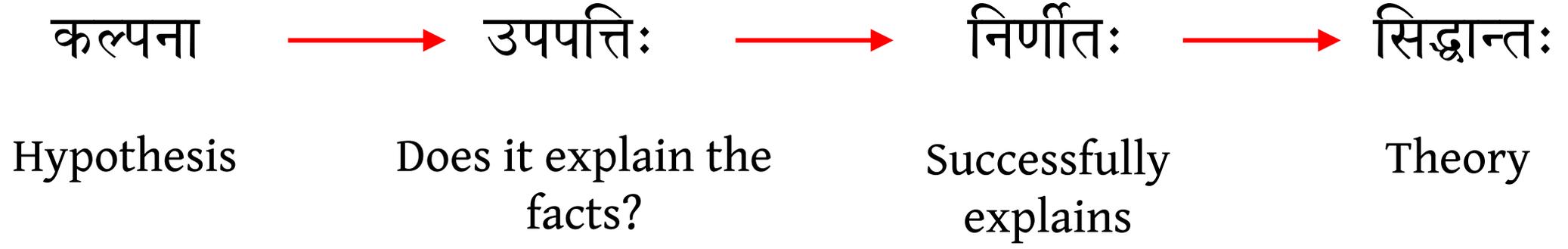
- Not every event which is correlated, even if strongly, implies a causal connection.
- Even when causality exists it is necessary to understand which causes what
- There could be a third common or related cause for observed events

अन्येषामपि हेतुनां भूम्नां जगति दर्शनात् । सूर्यास्तम् अयम् आलोक्य कल्पते तारकोदयः ॥
पूर्णचन्द्रोदयाद् वृद्धिर् अम्बुधेर् अवगम्यते । उदितेनानुमीयन्ते सरितः कुम्भयोगिनः ॥
शुष्यत् पुलिन-पर्यन्त-विश्रान्त-खग-पंक्तयः । पिपीलिकाण्ड-सञ्चारचेष्टानुमित-वृष्टयः ॥
भवन्ति पथिकाः पर्णकुटीर् अकारणोद्यताः ॥

Observation of strongly correlated events does not always mean causation [by the preceding]: Upon the Sun setting, the stars are seen rising. With the full moon rising the ocean swells (tides). The rivers dry up when the star Canopus rises. The flocks of birds stay put till the rivers dry. Ants carrying their eggs and the coming of rains. Etc.

- Which of the above are causal ?
- Nyāya tradition gives examples such as the above to illustrate the distinction: The ants carrying their eggs is correlated with arrival of rains, but it does not mean the action of the ants causes the rain.

Nyāya: Creation of scientific theory



दृष्ट-सिद्धये ह्य् अदृष्टं कल्प्यते न दृष्टविघाताय ।

An unseen postulate is considered valid only if it is consistent with observations not if it contradicts them

प्रथमोपस्तित्वम्; लाघव-न्यायः Principle of proximal explanation and parsimony for choosing between hypothesis

The Nyāya proposal for generation of a siddhānta resembles Karl Popper's philosophy of science and principle of hypothesis testing

Indian scientific cosmopolis: 250-1100 CE



Indian scientific knowledge spread widely via the vehicle of Sanskrit

Indian scientific system: ages of success of some notable figures

Name	Accomplishment	Age (years)
Jīvaka	biologist/physician: ācarya at Ujjaini	20
Lolimbarāja	Physician/teacher of medicine/poet; composed pharmacopeia	25
Aryabhaṭa	Astronomer, engineer, mathematician; ācarya	23
Vaṭeśvara	Astronomer, mathematician from Kāshmira	24
Mañjula	Astronomer, mathematician, early use of differential calculus	20
Gaṇeśa daivajña	Astronomer, mathematician, hyperbolic approximation of sine function	14
Jayanta	Philosophy of science, nyāya, vaiyyākaraṇa-treatise	10
Raghunātha paṇḍita	Scientific logic, atomism	18
Bhāskara-II	Astronomer, mathematician, Siddhānta shiromaṇi	36

- Most ancient Indian authors are not prone to giving any biographies but those who do present a striking pattern.
- List gives ages when they composed their first major treatise
- Lesson to learn: identify scientific talent early and fast track

Further reading

- The Positive Sciences of the Ancient Hindus by Brajendranath Seal
- Written in 1915 CE (more than 100 years ago!)
- Still remains a good wide-ranging survey citing the original sources with not fancy extrapolations

- Science Across Cultures: An Annotated Bibliography of Books on Non-Western Science, Technology, and Medicine by Helaine Selin

- More work needs to be done!

Proof of sum of squares: pyramidal numbers

Nilakanṭha somayājin's proof for formula of the sum of squares (slide 2)

