INDIAN APPROACH TO LOGIC

It is a widely held view that the Indian tradition in sciences had no sound logical or methodological basis. For instance, the following is a summary assessment of Indian logic, which is typical of what one finds in most of modern scholarship:

> Compared with the logic of the ancient Greeks, Indian logic is not very impressive… The development of Indian logic was severely handicapped by the failure of its logicians to make use of variables. As a result, no logical principles could be stated directly. Finally in Indian thought logical topics were not always separated from metaphysical and epistemological topics (on the nature of being and knowledge respectively)… Both in the West and in the East, the origin of logic is associated with an interest in the grammar of language and the methodology of argument and discussion, be it in the context of law, religion or philosophy. More is needed, however, for the development of logic. It appears that logic can thrive only in a culture that upholds the conviction that controversies should be settled by the force of reason rather than by the orthodoxy of a dogma or the tradition of a prejudice. This is why logic has made much greater progress in the West than in the East. [1]

We know that the Western tradition in theoretical sciences is founded on the logic of Aristotle and the deductive and axiomatic formalism of Euclid's *Elements*, both of which have been further refined in the course of especially the last hundred years or so. We need to evolve a clear idea about the foundational methodologies of the Indian scientific tradition.

On the question of foundational methodology, the classical Indian position is summarised by the popular dictum:

Kāṇādaṁ Pāṇinīyañca sarvaśāstropakārakam

The *śāstras* expounded by Kaṇāda and Pāṇini are the basis for all other *śāstras*. Here the *śāstras* expounded by Kaṇāda refers to the *nyāya-vaiśeṣika-darśana*s, i.e., the 'physics and metaphysics' as expounded mainly in *vaiśeṣika-darśana,* and 'epistemology and logic' as in *nyāya-darśana.* The *śāstra* of Pāṇini refers to *śabda-śāstra*, the science of language. In Indian view these are the foundational disciplines which must be mastered before taking up any serious study of other *śāstras.* To understand the logical and methodological foundations of Indian sciences, therefore, we need to have an understanding of the methodologies, theories and techniques developed in *nyāya*, *vaiśeṣika* and *śabdaśāstra.*

In this article we attempt to present an outline of the Indian approach to a particular logical and methodological issue: how the foundational problems associated with what are known as 'formal methodologies' or 'formal techniques' in the Western

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[1] Czeslaw Lejewski, 'History of Logic', in the *Encyclopaedia Britannica*, XV Edition, Chicago 1973.

tradition are handled in the Indian tradition. The foundational disciplines of logic and mathematics in the Western tradition are considered rigorous, mainly because they are formulated in a content-independent, purely symbolic or 'formal' language. All sciences in the Greco-European tradition try to cast their theoretical framework into a 'formal system' and thus attain standards of rigour comparable to logic or mathematics.

Below, we describe some of the methodologies and techniques developed in the Indian tradition of logic and linguistics and compare them with the formal methodologies and techniques developed in the Western tradition. We discuss how Indian logicians provide a logical analysis of cognition in terms of a technical language and use it to explicate logical relations between cognitions. We also describe how Indian logicians achieve a precise and unambiguous formulation of universal statements in terms of their technical language, without taking recourse to quantification over unspecified universal domains. Then we consider the Indian tradition in linguistics, especially as enshrined in *Aṣṭādhyāyī*, the grammatical treatise of Pāṇini, as a paradigm of theory construction in India. We indicate the manner of systematic exposition as also the techniques employed in *Aṣṭādhyāyī*, which appear to be the ideal for all *śāstras*. We also explain how the Pāṇinian grammar serves not only as a 'generative device' for deriving all valid utterances but also as a 'parser' for arriving at a precise and unambiguous 'knowledge representation', in terms of a technical language. It is this systematic analysis of the Sanskrit language, which enabled Indians to develop a precise technical language of logical discourse.

The Indian tradition did not move in the direction of the development of purely symbolic and content-independent formal languages, but achieved logical rigour and systematisation by developing a precise technical language of discourse founded on the ordinary Sanskrit language. This technical language is so designed as to reveal the logical structures which are not transparent and often ambiguous in the natural language, and yet retain the rich structure and interpretability of the natural language, Sanskrit, from which it is constructed. The Indian approach is thus largely free from the philosophical and foundational problems inherent to the formal methodologies developed in the Western tradition.

I. INDIAN APPROACH TO LOGIC

Logic in India and the West

The essential features of logic in the Western tradition are well captured in the following statement by a famous logician:

> Logic is the systematic study of the structure of propositions and of the general conditions of valid inference by a method, which abstracts from the content or matter of the propositions and deals only with their logical form. This distinction between form and matter is made whenever we distinguish between the logical soundness or validity of a piece of reasoning and the truth of the premises from which it proceeds and in this sense is familiar from everyday usage. However, a precise statement of the distinction must be made with reference to a particular

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language or system of notation, a formalised language, which shall avoid the inexactness and systematically misleading irregularities of structure and expression that are found in ordinary (colloquial or literary) English and other natural languages and shall follow or reproduce the logical form. [2]

Thus, the basic features of Western logic are: It deals with a study of 'propositions', specially their 'logical form' as abstracted from their 'content' or 'matter'. It deals with 'general conditions of valid inference', wherein the truth or otherwise of the premises have no bearing on the 'logical soundness or validity' of an inference. It achieves this by taking recourse to a symbolic language that has little to do with natural languages.

The main concern of Western logic, in its entire course of development, has been one of systematising patterns of mathematical reasoning, with the mathematical objects being thought of as existing either in an independent ideal world or in a formal domain.

Indian logic, however, does not deal with ideal entities, such as propositions, logical truth as distinguished from material truth, or with purely symbolic languages that apparently have nothing to do with natural languages. The central concern of Indian logic as founded in *nyāya-darśana* is epistemology, or the theory of knowledge. Thus Indian logic is not concerned merely with making arguments in formal mathematics rigorous and precise, but attends to the much larger issue of providing rigour to the arguments encountered in natural sciences (including mathematics, which in Indian tradition has the attributes of a natural science and not that of a collection of context-free formal statements), and in philosophical discourse.

Inference in Indian logic is 'deductive and inductive', 'formal as well as material'. In essence, it is the method of scientific enquiry. Indian 'formal logic' is thus not 'formal', in the sense generally understood: in Indian logic 'form' cannot be entirely separated from 'content'. In fact, great care is exercised to exclude from logical discourse terms, which have no referential content. No statement, which is known to be false, is admitted as a premise in a valid argument. Thus, the 'method of indirect proof' (*reductio ad absurdum*) is not accepted as a valid method−neither in Indian philosophy nor in Indian mathematics−for proving the existence of an entity whose existence is not demonstrable (even in principle) by other (direct) means of proof. Indian logicians grant *tarka* (which incorporates the method of indirect proof) the status of only a subsidiary means of verification, helping us to argue for something that can be separately established (though often only in principle) by other (direct) means of knowledge.

The Indian logicians' attitude to the method of indirect proof is brought out in the following excerpt from Udayanācārya's *Ātmatattvaviveka* (10th century AD) - The text is in the form of an argument between a *Naiyāyika* ('proponent', who does not accept the method of indirect proof) and a *Bauddha* ('opponent', who is arguing for the method of indirect proof):

[2]Alonzo Church, 'Logic', in the *Encyclopaedia Britannica*, XIV Edition, Chicago 1959.

(Proponent)…There cannot be any means of knowledge to establish a non-entity (i.e., a fiction, *avastu*). If it could be established by some means of knowledge, it ceases to be non-entity.

Opponent: If so, then your talk about the non-entity becomes self-contradictory.

Proponent: Does this self-contradiction point out that there is a means of knowledge to establish the non-entity? Or, (second question) does it reject the prohibitive statement that we should not talk about non-entity? Or (third question) does it imply that we must concede such statements (about non-entity), which are unauthenticated, i.e., not established by any means of knowledge? The first alternative is not tenable. Even a thousand of self-contradictions cannot conceivably show that (the non-entity like)… rabbits' horn… is amenable to (a means of knowledge, such as) perception and inference. If it could, what is the use of this silly fight over the nature of non-entities? The second alternative is acceptable to us, because we admit only valid means of knowledge.

Opponent: If the prohibitive statement is rejected, no statement with regard to non-entities will be possible.

Proponent: What else can we do but remain silent in regard to a matter where statement of any kind will be logically incongruent? Silence is better in such cases… you yourself may please consider as to who is the better of the two: One who is making statements about entities that cannot be established by any means of knowledge? Or, the other person who remains speechless (on such occasions)?

Opponent: But although you are a wise man you have not remained silent yourself. You on the other hand have made a prohibitive statement with regard to our talk about non-entities.

Proponent: True, in order to avoid a self-contradictory object not established by any means of knowledge, you have conceded that one can make statements about the non-existent. Similarly, in order not to allow any statement about the non-entities in our discourse on the means of knowledge, we concede that a self-contradictory statement (prohibiting the use of non-entities) is possible, although it is not supported by any means of knowledge. If you treated both the cases in the same manner, we would not have said anything about non-entities. (We have made the above self-contradictory statement because you first raised the question). [3]

This is a clear statement of the Indian logicians' position that they would put up with self-contradiction rather than accept the existence of entities that are inaccessible to any (direct) means of knowledge (as demanded by those who argue for the validity of

[3]Cited from B.K. Matilal, *Logic, Language and Reality*, New Delhi 1985, p.103-4.

'indirect proof' as a means of knowledge). The Indian logician would however prefer to avoid such self-contradictions by not admitting these *aprasiddha* entities into his discourse altogether.

Indian logic does not make any attempt to develop a purely symbolic and content independent or 'formal language' as the vehicle of logical analysis. Instead, what Indian logic, especially in its later phase of *navya-nyāya* starting with the work of Gāṅgeśa Upādhyāya of 14th century, has developed is a technical language, which is based on the natural language Sanskrit, yet avoids 'inexactness' and 'misleading irregularities' by various technical devices. This technical language, being based on the natural language Sanskrit, inherits a certain natural structure and interpretation, and sensitivity to the context of enquiry. On the other hand, the symbolic formal systems of Western logic, though considerably influenced in their structure (say, in quantification, etc.) by the basic patterns discernible in European languages, are professedly purely symbolic, carrying no interpretation whatsoever–such interpretations are supposed to be supplied separately in the specific context of the particular field of enquiry 'employing' the symbolic formal system.

Logical analysis of cognition (jñāna) in Indian Logic

Indian logic deals with entities and facts directly. It is logic of *jñāna*–translated as knowledge, cognition, or awareness. Western logic, in contrast, deals with terms, sentences or propositions. Indian thought does distinguish a sentence from its meaning, and also admits that sentences in different languages could have the same meaning–which are some of the arguments used in the West in order to introduce the notion of proposition. However, Indian philosophers refuse to posit or utilise ideal entities such as propositions in their investigations. They prefer to deal directly with the *jñānas*; though philologically the Sanskrit word *jñāna* is cognate with the English word 'knowledge', a more preferred translation of *jñāna* appears to be 'cognition' or 'awareness', as *jñāna* unlike 'knowledge' can be either *yathārtha* ('true') or *ayathārtha* ('false').

Further, *jñāna* is of two types: *savikalpa* (often translated as determinate) and *nirvikalpa* (indeterminate or non-relational). A *savikalpaka-jñāna* is the cognition of an object as qualified by a qualifier–for instance the cognition of a pot (*ghaṭa*) as a pot, i.e., qualified by pot-ness (*ghaṭatva-viśiṣṭa*). On the other hand a *nirvikalpaka-jñāna* is the cognition of an object with no qualifier–for instance the cognition of a pot as 'something' (*kiṃcit*). More precisely a *savikalpaka-jñāna* can be defined as a cognition that comprehends the relation between a qualificand and a qualifier (*viśeṣya-viśeṣaṇayoḥ sambandhāvagāhi-jñānam*).

Savikalpaka-jñāna is not to be identified with a sentence or proposition. Indeed it is important to note that:

> The *jñāna*, if it is not a *nirvikalpa* perception, is expressed in language, if it is *śabda,* it is essentially linguistic. But it is neither the sentence which expressed it, nor the meaning of the sentence, the proposition; for there is in the (Indian) philosophies no such abstract entity, a sense

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as distinguished from reference, proposition as distinguished from fact.[4]

Below we give a brief outline of Indian logical analysis of *jñāna*.[5] Though *jñāna* is a concrete occurrent in Indian philosophy (a *guṇa* or *kriyā* of the *jīva* in some systems, a modification or *vṛtti* of the inner senses the *antaḥkaraṇa* in some other systems of Indian philosophy), it does have a logical structure of its own, a structure that becomes evident after reflective analysis. This logical structure of a *jñāna* is different from the structure of the sentence which expresses it in ordinary discourse. There are always logical constituents in a *jñāna* that are not expressed in the usual sentential structure. For instance the *jñāna* usually expressed by the sentence '*ayaṁ ghaṭaḥ*' ('this (is) a pot'), the feature that the pot is being comprehended as a pot, that is as qualified by pot-ness (*ghaṭatva*) is not expressed in the sentential structure. Thus the logical structure of a *jñāna* is what becomes evident after reflective analysis, and the sentential structure of ordinary discourse only provides a clue to eliciting this epistemic structure of the cognition.

According to Indian logic, every cognition (*jñāna*) has a content-ness (*viṣayatā*). For the case of a *savikalpaka jñāna* this *viṣayatā* is of three types: qualificand-ness (*viśeṣyatā*), qualifier-ness (*prakāratā* or *viśeṣaṇatā*) and relation-ness (*saṁsargatā*). For instance, in the *jñāna* expressed by "*ghaṭavad bhūtalam*" (Earth is pot-possessing), the *prakāra* is *ghaṭa*, the pot (not the word '*ghaṭa*' or 'pot'), the *viśeṣya* is *bhūtala,* the earth (not the word '*bhūtala*' or 'earth'), and since the pot is cognised as being related to the earth by contact, the *saṁsarga* is *saṁyoga,* the relation of contact. Thus the *prakāratā* of the *jñāna,* "*ghaṭavad bhūtalam*", lies in *ghaṭa,* the *viśeṣyatā* in *bhūtala* and *saṁsargatā* in *saṁyoga*.

Thus, in Indian logic, any simple cognition can be represented in the form *aRb* where *a* denotes the *viśeṣya*, *b* the *prakāra* and *R* the *saṁsarga,* or the relation by which *a* is related to *b*. This analysis of a simple cognition as given by the Indian logicians is much more general than the analysis of the traditional subject-predicate judgement in Aristotelian logic or that of an elementary proposition in modern logic (say in the system of first order predicate calculus). The Indian logicians always incorporate a *saṁsarga* or relation that relates the predicate to the subject.

Identifying the *viśeṣya, prakāra* and *saṁsarga* of a *jñāna* is not sufficient to fully characterise the *jñāna*. According to the *Naiyāyika*, one has also to specify the modes under which these ontological entities become evident in the *jñāna*. For instance while observing a pot on the ground one may cognise it merely as a substance (*dravya*). The qualifier (*prakāra*) of this *jñāna*, which is still the ontological entity pot, is said to be *dravyatva-avacchinna* (limited by substance-ness) and not *ghaṭatva-avacchinna* (limited by pot-ness), which would have been the case had the pot been cognised as a pot. The Indian logician insists that the logical analysis of a *jñāna* should reveal not only the ontological entities which constitute the *viśeṣya, prakāra* and *saṁsarga* of the *jñāna*, but also the mode under which these entities present themselves, which are specified by the so called 'limitors' (*avacchedakas*) of the *viśeṣyatā, prakāratā* and

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[4]J.N. Mohanty*, '*Indian Theories of Truth', Phil. East and West 30, 440, 1980.
[5]For further details of the *Naiyāyika* analysis of cognition see, D. C. Guha, *Navya-nyāya System of Logic*, New Delhi 1979; Sibajiban Bhattacharya, *Doubt, Belief and Knowledge,* New Delhi 1987.

saṁsargatā. The argument that Indian logicians give for demanding that the *avacchedakas* should be specified in providing a complete logical characterisation of a *jñāna* is the following: Each entity which is a *prakāra* or *viśeṣya* or *saṁsarga* of a *jñāna* possesses by itself innumerable attributes or characteristics. In the particular *jñāna* any entity may present itself as a possessor of certain attributes or characteristics only, which will then constitute the limitors (*avacchedakas*) of the *prakāratā* etc. of the *jñāna*.

The *Naiyāyika* therefore sets up a technical language to unambiguously characterise the logical structure of a *jñāna*, which is different from the way the *jñāna* is expressed in the language of ordinary discourse. For instance, the *jñāna* that the earth is pot-possessing which is ordinarily expressed by the sentence "*ghaṭavad bhūtalam*", is expressed in the technical form:

> *saṁyoga-saṁbandhāvacchinna   ghaṭatvāvacchinna   ghaṭaniṣṭha prakāratā nirūpita bhūtalatvāvacchinna bhūtalaniṣṭha viśeṣyatāśāli jñānam*

> A cognition whose qualificand-ness (*viśeṣyatā*) is present in earth (*bhūtala*), which is limited by earth-ness (*bhūtalatva*) and is described *(nirūpita)* by a qualifier-ness (*prakāratā*) present in pot (*ghaṭa*) and limited by pot-ness (*ghaṭatva*) and relation of contact (*saṁyoga saṁbandha*)

The *Naiyāyika*'s analysis of more complex cognitions can now be briefly summarised. Each cognition reveals various relations (*saṁsargas*) between various entities (*padārthas*). Thus a complex cognition has several constituent simple cognitions, each of which relates some two *padārthas* (one of which will be the *prakāra* and other *viśeṣya*) by a *saṁsarga*. The *viśeṣyatā* and *prakāratā*, present in any pair of *padārthas*, are said to be described (*nirūpita*) by each other. Thus the various entities (*padārthas*) revealed in a complex cognition have in general several *viśeṣyatās* and *prakāratās*, which are characterised as being limited (*avacchinna*) by the various modes in which these entities present themselves. Further a detailed theory is worked out–with there being mainly two different schools of opinion associated with the Navadvīpa logicians of 17th-18th century, Jagadīśa Tarkālaṅkāra and Gadādhara Bhaṭṭācārya–as to how the different *viśeṣyatās* and *prakāratās* present in the same entity (*padārtha*) are related to each other.

Thus a detailed theory was evolved by the Indian logicians to unambiguously characterise the logical structure of any complex *jñāna* in a technical language. For instance the *Naiyāyikas* characterise the cognition that the earth possesses a blue-pot, which is ordinarily expressed by the sentence "*nīla-ghaṭavad bhūtalam*" as follows:

> *Tādātmya-saṁbandhāvacchinna   nīlatvāvacchinna   nīlaniṣṭha prakāratā nirūpita ghaṭatvāvacchina ghaṭaniṣṭha viśeṣyatvāvacchinna saṁyoga-saṁbandhāvacchinna   ghaṭatvāvachinna   ghaṭaniṣṭha prakāratā nirūpita bhūtalatvāvacchinna bhūtalaniṣṭha viśeṣyatāśāli jñānam*

A cognition whose *viśeṣyatā* present in *bhūtala* is limited by *bhūtalatva*, and is described by *prakāratā* present in *ghaṭa* which *prakāratā* is limited by *ghaṭatva*, and *saṁyoga-saṁbandha*, and by the *viśeṣyatva* in *ghaṭa* which in turn is limited by *ghaṭatva* and is described by *prakāratā* present in *nīla* (blue) and limited by *tādātmya-saṁbandha* (relation of essential identify) and *nīlatva* (blueness).

The above logical analysis worked out by the Indian logician serves to provide a representation of a *jñāna* which is free from the various ambiguities which arise in the sentences of ordinary discourse, and also makes explicit the logical structure of each *jñāna* and its logical relations with other *jñānas*. This can be seen, for instance, in the way the *Naiyāyikas* formulate a sophisticated form of the law of contradiction through their notion of the *pratibadhya* (contradicted) and *pratibandhaka* (contradictory) *jñānas*. For this purpose we need to consider the theory of negation in Indian logic, which is based on the concept of *abhāva* (absence).

Negation (abhāva) in Indian Logic

Abhāva is perhaps the most distinctive as also the most important concept of Indian logic. Negation in Western logic is a naive and simplistic truth-functional concept in which all the varieties of negation are reduced to the placing of "not" or "it is not the case that" before some proposition or proposition-like expression. This does not, for instance, allow a subject term to be negated in a sentence; in fact, most cases of 'internal negation' in a complex sentence seem to be entirely outside the purview of Western formal logic. In contrast, the Indian concept of *abhāva* is much more sophisticated. The essential features of *abhāva* and its role in Indian logic are summarised below:

> The concept of absence (*abhāva*) plays larger part in *navya-nyāya* (new-*nyāya*) literature than comparable concepts of negation play in non-Indian systems of logic. Its importance is apparent from a consideration of only one of its typical applications. *Navya-nyāya*, instead of using universal quantifiers like 'all' or 'every', is accustomed to express such a proposition as 'all men are mortal' by using notions of absence and locus. Thus we have: "Humanity is 'absent' from a locus in which there is absence of mortality", (in place of "All humans are mortal")…

> Absence was accepted as a separate category (*padārtha*) in the earlier *nyāya-vaiśeṣika* school. The philosophers of that school tried always to construe properties or attributes (or to use their own terms: *guṇa*, quality; *karma*, movement; *sāmānya*, generic property; *viśeṣa*, differentia; etc.) as separate entities over and above the substrate or loci, i.e., the things that possess them. They also exhibited this tendency in their interpretation of negative cognitions or denials. Thus they conceived of absence as a property by a hypostasis of denial. The negative cognition, "There is no pot on the ground", or "A pot is absent from the ground", was interpreted as "There is an 'absence of pot' on the ground". It was then easy to construe such an absence as the object

of negative cognitions–and hence as a separate entity. Moreover, cognitions like "A cloth is not a pot"... were also treated and explained as "A cloth has a mutual absence of pot, i.e., difference from pot". And a mutual absence was regarded as merely another kind of absence…

In speaking of an absence, *nyāya* asserts, we implicitly stand committed to the following concepts: Whenever we assert that an absence of an object '*a*' (say a pot) occurs in some locus (say, the ground), it is implied that '*a*' could have occurred in, or, more generally, could have been related to, that locus by some definite relation. Thus, in speaking of absence of '*a*' we should always be prepared to specify this such-and-such relation, that is, we should be able to state by which relation, '*a*' is said to be absent from the locus. (This relation should not be confused with the relation by which the absence itself, as an independent property, occurs in the locus. The latter relation is called… a *svarūpa* relation). The first relation is described in the technical language of *navya-nyāya* as the "limiting or delimiting relation of the relational abstract, counter-positive-ness, involved in the instance of absence in question (*pratiyogitā-avacchedaka-saṁbandha*)". Thus, a pot usually occurs on the ground by the relation of *saṁyoga* or conjunction. When it is absent there, we say that a pot does not occur on the ground by conjunction or that pot is not conjoined to the ground. By this simple statement we actually imply, according to *nyāya*, that there is an absence on the ground, an absence the counter-positive (*pratiyogin*) of which is a pot, and the delimiting relation of "being the counter-positive" (i.e., counter-positive-ness – *pratiyogitā*) of which is conjunction. While giving the identity condition of an instance of absence, *nyāya* demands that we should be able to specify this delimiting relation whenever necessary. The following inequality statements will indicate the importance of considering such a relation:

"Absence of pot ≠ Absence of cloth".

"An absence of pot by the relation of conjunction ≠ An absence of pot by the relation of inherence".[6]

Thus for the Indian logician, absence is always the absence of some definite property (*dharma*) in a locus (*dharmī*) and characterised by a relation – technically, either an occurrence-exacting relation (*vṛtti -niyāmaka-saṁbandha*) or identity (*tādātmya*) – by which the entity could have occurred in the locus, but is now cognised to be absent. Thus each *abhāva* is characterised by its *pratiyogī* (the absentee or the entity absent, sometimes-called the 'counter-positive') as limited (i) by its *pratiyogitā-avacchedaka-dharma* (the limiting attribute(s) limiting its counter-positive-ness), and (ii) by the *pratiyogitā-avacchedaka-saṁbandha* (the limiting relation limiting its counter-positiveness). Thus in the cognition "*ghaṭābhāvavad bhūtalam*" (the ground possesses pot-absence), the *pratiyogī* of *ghaṭābhāva* (pot-absence) is *ghaṭa* (pot) whose *pratiyogitā* is *ghaṭatvāvacchinna* and *saṁyoga-saṁbandhāvacchina* – as what is

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[6]B. K. Matilal, *The Navya-nyāya Doctrine of Negation*, Harvard 1968, p.3-4.

being denied is the occurrence of pot as characterised by pot-ness in relation of contact with the ground.

Thus, it is important to note that:

> [In Indian logic] what is negated is an object, which is the second term of dyadic relation… Let us consider the form *a*-(R*b*)… What can be negated is *b* as the second term of the relation R. To say that "the counterpositiveness resident in *b* is limited by the limiting relation R" is equivalent to saying that "*b* is the second term of the relation R". So what is negated is *b* as the second member of relation R… *nyāya* theory of negation… cannot be said to be a term negation, or a sentence negation, or a propositional function negation in the usual sense of these terms [in Western logic]. [7]

Further, it is always stipulated in Indian logic that *abhāva* of some property (*dharma*) is meaningful only if that property is not a universal property which occurs in all loci (*kevalānvayi-dharma*), or an empty property which occurs nowhere (*aprasiddha dharma*). Thus 'empty' or 'universal' terms cannot be negated in Indian logic, and many sophisticated techniques are developed in order that one does not have to employ such negations in logical discourse.

The importance of the concept of *abhāva* is forcefully brought out in the formulation of the 'law of contradiction' in Indian logic. Instead of considering trivial truth-functional or linguistic tautologies of the form "either '*p*' or '*not-p*'", the Indian logician formulates the notion of *pratibandhakatva* (contradictoriness) of one *jñāna* (cognition) with respect to another. The relation of *pratibandhakatva* can be ascertained only when the appropriate logical structures of each cognition are clearly set forth, and can thus be stated precisely only in the technical language formulated by the Indian logician for this purpose.

For instance, it would not do simply to state that the cognitions "*ghaṭavad bhūtalam*" ('The ground possesses pot') and "*ghaṭābhāvavad bhūtalam*" ('The ground possesses pot-absence') are contradictory, because in the first cognition the pot could be cognised to be present in the ground by the relation of contact *(saṁyoga)*, while in the second the pot could have been cognised as being absent in the ground by the relation of inherence (*samavāya*).[8] These two cognitions do not contradict each other; they can both be valid. The law of contradiction can be correctly formulated only when the logical structure of both the cognitions are clearly set forth with all the *viśeṣyatā, prakāratā* and *saṁsargatā*-s and their limitors (*avacchedakas*) are fully specified and it is seen from their logical structures that certainty (*niścayatva*) of one cognition prohibits (*pratibadhnāti*) the possibility of the other cognition arising (in the same person).

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[7] J. L. Shaw, 'The *Nyāya* on Cognition and Negation', Jour. Ind. Phil. 8, 284-301, 1980.
[8] According to *Naiyāyikas, samavāya* (translated as 'inherence') is the relation that holds between qualities (*guṇa*) or action (*karma*) and substances (*dravya*), between a universal or genus (*jāti*) and individuals (*vyakti*), between a whole entity (*avayavī*) and its parts (*avayava*), etc.

Consider the case when for instance the cognition that the ground possesses pot ("*ghaṭavad bhūtalam*") has the logical structure:

> *saṃyoga-sambandhāvacchinna ghaṭatvāvacchinna prakāratā nirūpita bhūtalatvāvacchinna viśeṣyatāka jñānam.*

This cognition is prevented by the cognition that the ground possesses pot-absence ("*ghaṭābhāvavad bhūtalam*") only if the latter has the logical structure:

> *Svarūpa-sambandhāvacchinna saṃyoga-sambandhāvacchinna ghaṭatvāvacchinna pratiyogitāka abhāvatvāvacchinna prakāratā nirūpita bhūtalatvāvacchinna viśeṣyatāka jñānam.*

This prevented-preventor (*pratibadhya-pratibandhaka*) relation between these two cognitions is formulated in the following form by the Indian logician:

> *saṃyoga-sambandhāvacchinna ghaṭatvāvacchinna prakāratā nirūpita bhūtalatvāvcchinna viśeṣyatāka jñānatvāvacchinnam prati svarūpa-sambandhāvacchinna saṃyoga-sambandhāvacchinna ghaṭatvāvacchinna pratiyogitāka abhāvatvāvachinna prakāratā nirūpita bhūtalatvāvacchinna viśeṣyatāka niścayatvena pratibandhakatvam*

> With regard to the knowledge having its qualificand-ness limited by ground-ness and described by the qualifier-ness limited by pot-ness and the relation of contact, the knowledge having its qualificand-ness limited by ground-ness and described by qualifier-ness limited by constant absence-ness and the relation *svarūpa* (absential self-linking relation) the counter-positive-ness *(pratiyogitā)* of which absence is limited by pot-ness and the relation of contact, is the contradictory definite knowledge, contradictoriness resident in it being limited by the property of *niścayatva* (definite knowledge-ness).[9]

'Quantification' in Indian Logic

As another instance of the technical language developed by the Indian logicians, we consider the formulation of universal statements, i.e., statements involving the so-called universal quantifier 'all'. Such statements arise in any *anumāna* (inference), where one concludes from the cognition 'the mountain is smoky' (*parvato dhūmavān*) that 'the mountain is fiery' (*parvato vahnimān*), based on the knowledge expressed in the universal statement 'wherever there is smoke there is fire' (*yatra yatra dhūmaḥ tatra vahniḥ*). A careful formulation of this last statement, which expresses the knowledge of pervasion (*vyāpti-jñāna*) of smoke by fire, was a major concern of Indian logicians, who developed many sophisticated techniques in the course of arriving at a precise formulation of such *vyāpti-jñāna*.

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[9] See D.C. Guha, cited earlier, p.11. Note that *svarūpa-sambandha* is the relation between an *abhāva* (absence) and its *adhikaraṇa* (locus).

According to the Indian logicians a statement such as, 'All that possesses smoke possesses fire', is unsatisfactory as an expression of *vyāpti-jñāna*. Firstly, we have the problem that the statement as formulated above is beset with ambiguities, nowadays referred to as 'confusion in binders' or 'ambiguity in the scope of quantifiers'. For instance there is a way of misinterpreting the above statement–using the so-called *calanī nyāya* –by arguing that if all that possesses smoke possesses fire, what prevents mountain-fire from occurring in the kitchen where one sights smoke, or vice versa. In the Greco-European tradition some sort of a solution to this problem was arrived at only in late 19th century through the 'method of quantification'. In this procedure, the statement, 'All that possesses smoke possesses fire', is rendered into the form, 'For all *x*, if *x* possesses smoke then *x* possesses fire'.

The approach of the Indian logician is different from the above method of 'quantification'. The Naiyāyika insists that the formulation of *vyāpti-jñāna,* apart from being unambiguous, should be phrased in accordance with the way such cognition actually arises. Hence an expression such as, 'For all *x*, if *x* is smoky then *x* is fiery', involving a variable *x*, universally quantified over an unspecified universal domain, would be unacceptable to the Indian logicians.[10] What they do instead is to employ a technique, which involves use of two *abhāvas* (use of two negatives), which are appropriately characterised by their *pratiyogitā-avacchedaka-dharmas* and *sambandhas*. The steps involved may be briefly illustrated as follows: [11]

The statement, 'All that possesses smoke possesses fire', can be converted into the form, 'All that possesses fire-absence, possesses smoke-absence'. Here fire-absence (*vahnyabhāva*) should be precisely phrased as an absence, which describes a counter-positive-ness limited by fire-ness and the relation of contact:

> *saṃyoga-sambandhāvacchinna   vahnitvāvacchinna   pratiyogitā nirūpaka abhāvaḥ*

Now the statement that smoke is absent by relation of contact from every locus which possesses such a fire-absence is formulated in the following manner:

> *Samayoga-sambandhāvacchinna   vahnitvāvacchinna   pratiyogitā nirūpaka abhāvādhikaraṇa nirūpita saṃyoga-sambandhāvacchinna vṛttitā anavacchedakatā dhūmatve.*

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[10] Another reason why the quantified statement as formulated above is not acceptable to the *Naiyāyika* is that it does not take account of the relations that smoke and fire bear to their loci. The *Naiyāyika* scheme of inference allows us to infer a cognition of the form pR_ss (where *p* is the *pakṣa*, the mountain, *s* the *sādhya*, the fire, and R_s is the relation by which *s* occurs in *p*), from the cognition pR_hh (where *h* is the *hetu*, the smoke, and R_h the relation by which *h* occurs in *p*), if one has the *vyāpti-jñāna* that *sādhya* is pervaded by *hetu*. Even if one used the quantified form (as in Western logic) of the universal statement expressing the *vyāpti-jñāna*, it will have to be phrased in the form 'for all *x*, if xR_hh, then xR_ss', where the quantified variable *x* appears as the first member of the binary relations R_h, R_s.

[11] See for instance, D. H. H. Ingalls, *Materials for the study of Navya-nyāya Logic*, Harvard 1951, p.59-61.

> Smoke-ness is not a limitor of occurrent-ness limited by relation of contact and described by locus of absence of fire which absence describes a counter-positive-ness limited by fire-ness and contact.

In the above statement the 'locus of absence of fire' *(vahni-abhāva-adhikaraṇa)* is not the locus of absence of this or that case of fire, but indeed of any absentee limited by fire-ness and by the relation of contact *(saṁyoga-sambandhāvacchinna vahnitvāvacchinna pratiyogitā nirūpaka abhāvādhikaraṇa)*. This is what Indian logic employs instead of notions such as 'all the loci of absence of fire' or 'every locus of absence of fire'. In the same way, the phrase that 'smoke-ness is not the limitor of an occurrent-ness limited by relation of contact and described by locus of...', *adhikaraṇanirūpita saṁyoga-sambandhāvacchinna vṛttitā anavacchedakatā dhūmatve*, serves to clearly and unambiguously set forth that no case of smoke occurs in such a locus (of absence of fire) by relation of contact.

Thus, the Indian formulation of *vyāpti* always takes into account the relations by which fire and smoke occur in their loci. Indian logicians avoid quantification over unspecified universal domains, which is what is employed in modern Western logic. The statement that, 'All that possesses smoke possesses fire', is intended to say something only about the loci of smoke–that they have the property that they possess fire also. But the corresponding 'quantified' statement, 'For all x, if x possesses smoke then x possesses fire', seems to be a statement as regards 'all x' where the variable x ranges over some universal domain of 'individuals' or other entities. The Indian logicians' formulation of *vyāpti* avoids this sort of universalisation and strictly restricts its consideration to the loci of absence of fire, as in the *vyāpti* formulation given above (known as *pūrvapakṣa- vyāpti*), or to the loci of smoke in the more exact formulation known as *siddhānta-vyāpti,* which formulation is also valid for statements involving the un-negatable, *kevalānvayī,* or universally present, properties.[12]

The *Naiyāyika* method of formulating *vyāpti* does not employ quantification over some 'set' of individuals viewed in a purely 'extensional' sense. It does not talk of the 'set of all loci of absence of fire', but only of 'a locus, which possesses an absence, the counter-positive of which absence is limited by fire-ness and the relation of contact'. In this sense, the Indian method of formulating universal statements, takes into account the 'intensions' of all the properties concerned and not merely their 'extensions'. This feature of Indian logic has now been widely recognised:

> The universal statements of Aristotelian or mathematical logic are quantified statements, that is, they are statements about all entities (individuals, classes or statements) of a given sort. On the other hand, *navya-nyāya* regularly expresses its universal statements and knowledges not by quantification but by means of abstract properties. A statement about cause-ness to pot differs in meaning from a statement about all causes of pots just as 'man-ness' differs in meaning from 'all men'.[13]

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[12] See for instance, D.H.H. Ingalls, cited above, p. 61- 62.
[13] D.H.H.Ingalls, cited above, p.50.

Indian logicians do consider the notion of a collection of entities, especially in the context of their discussion of number and the *paryāpti* relation. But here again they refuse to base their theory on notions such as 'class' or 'set' viewed in purely extensional terms. The sophistication of the *navya-nyāya* formulation of the notion of number, which seems to originate from the work of the great Naiyāyika Raghunātha Śiromaṇi (c.1475-1550), was in fact noticed quite sometime ago:

> The New *nyāya* reaches its height of analytical power with Raghunātha Śiromaṇi … In his analysis of relation he comes on a discovery of the true nature of number…He distinguishes the relation by which two-ness is connected with the component of pairs (the relation of inherence) from the relation by which two-ness is connected with the pairs as abstracts. The latter relation, called *paryāpti* (which may be translated literally by coining the phrase "circumtaining relation"), corresponds to what Frege in 19th century Europe expressed by saying that a number belongs to a concept; it expresses in another form Frege's insight that, e.g., the number 2 should be attached to the concept, *satellite of Mars*, rather than to the concrete physical objects, Deimos and Phobos. [14]

Referring to the techniques of *navya-nyāya*, the same scholar remarked:

> The New *nyāya* units are never precisely propositions or classes; they are the referenda of abstract nouns. New *nyāya* techniques are parallel in many respects to those of modern logic: thus where the western mathematician or logician speaks of class of classes, the Naiyāyika speaks of the abstract of an abstract; but parallel lines do not actually meet. [15]

Indeed, the approach of Indian logicians (which does not seem to separate extensions from intensions) is very different from most of the approaches evolved in the Western tradition of philosophy and foundations of logic and mathematics.

II. AṢṬĀDHYĀYĪ: THE PARADIGM OF THEORY CONSTRUCTION IN INDIA

Just as the paradigm example of modern Western systems of axiomatised formal theories is found in Euclid's *Elements*, the *Aṣṭādhyāyī* of Pāṇini constitutes the paradigm for Indian method of theory construction. It is often said that this is what explains most of the basic differences between the two traditions:

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[14] D.H.H.Ingalls, 'Logic in India', in *Encyclopaedia Britannica*, XIV Edition, Chicago 1955. For more detailed exposition of *paryāpti* and the *navya-nyāya* theory of number, the reader may refer to: D. C. Guha, 1979, cited earlier, p.169-218; J. L. Shaw, 'Number: From the *Nyāya* to Frege-Russel', Studia Logica 41, 283-291, 1981; R. W. Perret, 'A Note on the *Navya-nyāya* Account of Number', Jour. of Ind. Phil. 13, 227-234, 1985; B. K. Matilal, 'On the Theory of Number and *Paryāpti* in *Navya-nyāya*', J.R.A.S.B. 28, 13-21, 1985; J.Ganeri, 'Numbers as Properties of Objects: Frege and the *Nyāya*', Stud. Hum. and Soc. Sc. 3, 111-121, 1996.
[15] D.H.H.Ingalls, 1955, cited above.

Historically speaking, Pāṇini's method has occupied a place comparable to that held by Euclid's method in Western thought. Scientific developments have therefore taken different directions in India and the West… In India, Pāṇini's perfection and ingenuity have rarely been matched outside the realm of linguistics. In the West, this corresponds to the belief that mathematics is the more perfect of the sciences. [16]

Aṣṭādhyāyī as a generative system

The *Aṣṭādhyāyī* of Pāṇini and other works of Indian grammarians have provided a rich source of ideas and techniques for the newly emerging discipline of linguistics, both in its 19th century phase of historical and comparative linguistics and in the 20th century phases of descriptive and structural linguistics, and later that of generative linguistics. Notwithstanding this borrowing of ideas and techniques over a long period of time, and much study, the basic methodology and the technical intricacies of Pāṇini's grammar were little understood till the advent and development of the modern theory of generative grammars in the last few decades. A recent study notes:

> The algebraic formulation of Pāṇini's rules was not appreciated by the first Western students; they regarded the work as abstruse or artificial. This criticism was evidently not shared by most Indian grammarians, because several of them tried to outdo him in conciseness by 'trimming the last fat' from the great teacher's formulations… The Western critique was muted and eventually turned into praise when modern schools of linguistics developed sophisticated notation systems of their own. Grammars that derive words and sentences from basic elements by a string of rules are obviously in greater need of symbolic code than paradigmatic or direct method practical grammars…
>
> It is a sad observation that we did not learn more from Pāṇini than we did, that we recognised the value and the spirit of his 'artificial' and 'abstruse' formulations only when we had independently constructed comparable systems. The Indian New Logic (*navya-nyāya*) had the same fate: only after Western mathematicians had developed a formal logic of their own and after this knowledge had reached a few Indologists, did the attitude towards the *navya-nyāya* school change from ridicule to respect. [17]

The founder of the modern generative and transformational grammars refers to *Aṣṭādhyāyī* as 'a much earlier tradition' of generative grammar, though 'long forgotten with a few exceptions'.[18] For another modern expert, Pāṇini's *Aṣṭādhyāyī* is 'the most comprehensive generative grammar written so far',[19] The generative aspects of

[16]J. F. Staal, *Euclid and* Pāṇini, Phil. East and West 15, 114, 1965.
[17]H. Scharfe, *Grammatical Literature*, Wiesbaden 1977, p.112, 115. Scharfe also mentions Obermiller's attempts in the 1920's to write a grammar for Russian in the Pāṇinian style.
[18]N. Chomsky, 'Principles and Parameters in Syntactic Theory', in N. Hornstein and D. Light Foot (ed.) *Explanation in Linguistics*, New York 1981, p.82.
[19]P. Kiparsky, *Pāṇini as a Variationist*, Boston 1979, p.18.

Pāṇini's grammar have been well recognised by modern scholarship. As one study notes:

> To Pāṇini … grammar is not understood as a body of learning resulting from linguistic analysis, but as a device, which enables us to derive correct Sanskrit words. The machinery consists of rules and technical elements, its inputs are word-elements, stems and suffixes, its outputs are any correct Sanskrit words. Thus the *Aṣṭādhyāyī* is a generative device in the literal sense of the word. Since it is also a system of rules, which allows us to decide the correctness of the words derived, and at the same time, provides them with a structural description, the *Aṣṭādhyāyī* may be called a generative grammar. [20]

According to another study:

> Pāṇini's *Aṣṭādhyāyī* … is a set of rules capable of formally deriving an infinite number of correct Sanskrit utterances together with their semantic interpretation… The entire grammar may be visualised as consisting of various domains. Each domain contains one or more interior domains. The domain(s) may like-wise contain one or more interior domains. The first rule of a domain is called its governing rule. These rules assist one in scanning. Given an input string, one scans rules to determine which paths should be followed within domains. These paths are marked by interior domains, each one headed by a rule that specifies operational constraints and offers selection in accordance with the intent (a set of quasi-semantic notions related to what we know about what we say before we speak… [denoted by] the Sanskrit term *vivakṣā*). Where choices are varied in operation and there are innumerous items to select from, an interior domain is further responsible for sub-branching in the path resulting in its division into interior domains. [21]

Though various attempts have been made to find parallels to notions such as 'deep structure', 'transformations', etc., in the Pāṇinian system, it is now becoming clear that the Pāṇinian system of linguistic description is very different from the various models that have been and are being developed in modern Western linguistics.

The differences between the Pāṇinian approach and those of modern linguistic theories have to do with several methodological and foundational issues. For instance while the Pāṇinian system may be viewed as a generative device, the inputs to this device are not formal objects such as symbols and strings which are to be later mapped onto appropriate 'semantic' and 'phonological' representatives. Further the *vivakṣa* or the 'intent of the speaker' plays a prominent role in the Pāṇinian system and as has been noted recently:

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[20]S.D.Joshi and J.A.F. Rodbergen, *Patañjali's Vyākarṇa Mahābhāṣya: Kārakāhnika*, Poona 1975, p.i.
[21]R. N. Sharma, 'Referential Indices in Pāṇini', Indo-Iranian Jour. <u>11</u>, 31, 1975.

Pāṇini accounts for utterances and their components by means of a derivational system in which one begins with semantics and ends with utterances that are actually usable. [22]

Technical features of Aṣṭādhyāyī

Major elements of theory-construction in *Aṣṭādhyāyī* are: The technical terms of the theory (*samjñā*), the meta-rules (*paribhāṣā*) which circumscribe how the rules (*sūtras*) have to be used, the limitation of the general rules (*utsarga*) by special rules (*apavāda*), use of headings (*adhikāra-sūtra*), the convention of recurrence (*anuvṛtti*) whereby parts of rules are considered to recur in subsequent rules, the various conventions on rule-ordering, and 'meta-linguistic' devices such as the use of markers (*anubandhas*) and the use of different cases to indicate the context, input and change. These elements and many other technical devices employed in *Aṣṭādhyāyī*, are now recognised as the technical components of an intricate but tightly knit logical system.[23]

While the Pāṇinian system employs countless symbols, technical terms and innumerable meta-linguistic conventions and devices, it is still a theoretical system formulated in the Sanskrit language, albeit of an extremely technical variety. It is not a formal system employing a purely symbolic language. It is sometimes said that the language employed in Pāṇini's *Aṣṭādhyāyī* differs from ordinary Sanskrit so 'strongly that one must speak of a particular artificial language'.[24] This is a misunderstanding. Though the language of Pāṇini's *Aṣṭādhyāyī* abounds in technical terms and devices, and does differ considerably from ordinary Sanskrit, it remains a technical or *śāstric* version of Sanskrit. In fact, many a technical device of Pāṇini is arrived at through 'an abstraction and formalisation of a feature of ordinary language'.[25]

To clarify the relation between the technical language employed by Pāṇini and ordinary Sanskrit, it is instructive to look at the meta-linguistic use of cases in Pāṇinian *sūtras*. For instance, consider the rule, *ikoyaṇaci* (*sūtra* 6.1.77 of *Aṣṭādhyāyī*). Here *ik, yaṇ* and *ac* are symbols for groups of sounds, but are also treated as Sanskrit word-bases (*prātipadika*). The word-base *ik* occurs in the *sūtra* with genitive ending (*ikaḥ*), *yaṇ* with nominative and *ac* with locative ending (*aci*). The *sūtra* stipulates that the vowels *i, u, ṛ, ḷ* (denoted by *ik*), are substituends to be replaced by *y, v, r, l* (denoted by *yaṇ*) before a vowel (*ac*). The information as to what should serve as input, output and context is marked with various case-endings taken by the Sanskrit word-bases *ik, yaṇ*, and *ac*. Here, *ik* is used with the genitive ending (*ikaḥ*) to indicate that it is the substituend or input, as per the meta-rule (*paribhāṣā-sūtra*), *ṣaṣṭhī sthāneyogā* (*sūtra* 1.1.49 of *Aṣṭādhyāyī*). While there are various possible meanings indicated by the genitive case-ending, Pāṇini uses the meta-rule 1.1.49 to delimit the meaning of the genitive case-ending to indicate (wherever the meta-rule

[22] G. Cardona: *Linguistic Analysis and South Indian Traditions*, Poona 1983, p.117
[23] For a survey of modern scholarship on Pāṇini, see G. Cardona, *Pāṇini, A Survey of Research*, Hague 1976 (Delhi Reprint 1980); G. Cardona, *Recent Research in Pāṇinian Studies*, Delhi 1999.
[24] H. Scharfe, 'Pāṇini's Kunstsprache', Wissenschaft Zeit Martin-Luther University 1961, p.201.
[25] P. Kiparsky, cited earlier, p.3

applies) only the substituend or the input of a grammatical operation. As one scholar has explained:

> The rule 1.1.49, *ṣaṣṭhī sthāneyogā*, … assigns a meta-linguistic value to the sixth…(*ṣaṣṭhī*) endings. As noted… [the *sūtra, ṣaṣṭhī śeṣe*] 2.3.50, introduces genitive endings when there is to be denoted a non-verbal relation in general. There are of course many such relations, such as father-son, part-whole… etc.; …[The rule 1.1.49] states a particular relation to be understood when the genitive is used: the relation of being a substituend. [26]

In other words, these case conventions are not arbitrary or artificial–they serve only to fix a unique meaning where several interpretations are possible in the ordinary use of the language.

In this context the oft-quoted criterion of *lāghava* employed by the Sanskrit grammarians should also be properly understood. This has been interpreted as brevity and is sometimes seen as the *raison-de-etre* of Pāṇini's exposition. It is said that most of the techniques employed by Pāṇini are mere arbitrary devices to achieve brevity in exposition. The effort of the Indian grammarians to achieve brevity is often linked with other speculations concerning learning in ancient India, such as shortage of writing materials or the persistence of a purely oral tradition placing heavy demands on memory. It is of course true that Indian Grammarians did indeed rejoice, as the saying goes, at the saving of even half of a *mora* (*mātrā*) in their exposition.[27] But this saving of *moras* was not achieved by arbitrary devices. As has been noted, 'hundreds of *moras* could have been saved by selecting the accusative instead of the genitive case as marking the input of a rule'[28] – but that would have meant a deviation from the ordinary usage of the accusative.

Thus a 'meta-linguistic' device like the use of cases to indicate context, input and output in a grammatical operation, is not an arbitrarily chosen convention for achieving mere brevity, but is actually a technical device founded on the basic structures available in the ordinary Sanskrit language. This, we could perhaps assert, is true of all the technical devices employed in the Pāṇinian grammar. It has been argued, that the Pāṇinian use of *anuvṛtti* is not an artificial device for achieving brevity, but is a systematic and technical use of 'real language ellipsis'.[29] As regards the criterion of brevity itself, it has been remarked that 'the point is rather that the rules are strictly purged of all information that is predictable from other information provided in the system. What Pāṇini constantly tries to eliminate is not *mora*-s, but redundancy.'[30]

Apart from developing a technical or precision language system for the formulation of grammatical rules, Pāṇini's *Aṣṭādhyāyī* also employs several sophisticated devices to

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[26]G. Cardona, 'On Pāṇini's Meta-linguistic Use of Cases', in Charudeva Shastri Felicitation Volume, New Delhi 1974, p.307.
[27]*Ardhamātrālāghavena putrotsavaṁ manyante vaiyākaraṇāḥ*, Nāgeśa Bhaṭṭa in *Paribhāṣendu-śekhara*, K. V. Abhayankar (ed.), Pune 1962, *Paribhāṣā* 122.
[28]Kiparsky, cited earlier, p.227.
[29]Cardona, 1976, cited earlier, p.205.
[30]Kiparsky, cited earlier, p. 227, 228.

delimit the scope and application of these rules. Most of these techniques are common to the *sutra* form of exposition in the Indian *śāstric* literature. Brevity is a hallmark of the *sutra* technique of systematisation. But, there are other equally or even more important criteria that a *sutra* should satisfy. For instance, the *Viṣṇudharmottara Purāṇa* characterises a *sutra* as being 'concise (employing minimum number of syllables), unambiguous, pithy, comprehensive, shorn of irrelevancies and blemish-less':[31]

> *alpkāṣaram asandigdhaṁ sāravat viśvatomukham*
> *astobham anavadyañca sūtraṁ sūtravido viduḥ*

There are several technical aspects of the *sutra* method of systematisation – such as the use of *paribhāṣā, adhikāra, upadeśa, asiddha, vipratiṣedha*, etc. These are employed in Pāṇini's *Aṣṭādhyāyī*, but are not defined explicitly in the text. These and similar technical terms are 'meta-grammatical in the sense that they refer not to concepts about which grammatical analysis must theorise, but to the basic equipment which one brings to the very task of grammatical analysis. It should be noted that many of these terms are common property of the *sutra* technique as applied not only in grammar but also in ritual and elsewhere.'[32]

Lest the main achievement of Pāṇini's *Aṣṭādhyāyī* be lost amidst this discussion of its methodology and technical sophistication, we should state what *Aṣṭādhyāyī* achieves in about 4,000 *sutra*s: It provides a complete characterisation of valid Sanskrit utterances, a characterisation more thorough than what has been possible for any other language so far, by devising a system of description which enables one to generate and analyse all possible meaningful utterances. It also happens to provide the paradigm example of 'theory construction' in the Indian tradition.

III ŚĀBDABODHA AND KNOWLEDGE REPRESENTATION

We have already noted how the *Aṣṭādhyāyī* serves as a generative device that enables us to derive valid Sanskrit utterances and at the same time provides us also with a structural description of these utterances. We shall now discuss how the Pāṇinian grammar helped Indian linguists develop semantic analysis of meaningful Sanskrit utterances and provide a characterisation of the cognition generated by an utterance (*śābdabodha*) in an unambiguous manner. The Indian tradition of linguistics has thus systematised both the generation of the form of an utterance starting from the intention of the speaker (*vaktṛ-vivakṣā*) as well as the analysis of the cognition caused by such an utterance (*śābdabodha*) in a hearer (*śrotā*) conversant with the Sanskrit language.

The semantic analysis of Sanskrit utterances is outlined in the great commentary *Mahābhāṣya* of Patañjali. A detailed exposition of the semantic theories of Indian linguists may be found in the *Vākyapadīya* of *Bhartṛhari* (believed to be of 5th century AD), which is in fact a treatise on *vyākaraṇa-darśana,* dealing with all aspects of the Indian philosophy of language. Since, *śabda-pramāṇa*, the utterance of reliable person

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[31] *Viṣṇudharmottara-purāṇam*, 3.5.1
[32] Kiparsky, cited earlier, p.218.

(*āpta*), was accepted as a valid means of knowledge by most schools of Indian philosophy, the analysis of *śābdabodha* (cognition caused by an utterance) was a major subject of enquiry. The analysis was further refined by the Indian logicians of the *navya-nyāya* school. During 16th-18th centuries, there arose three schools of analysts: the *Navya-vaiyākaraṇas* (such as Bhaṭṭojī Dīkṣita, Kauṇḍa Bhaṭṭa, Nageśa Bhaṭṭa, etc.), *Navya-naiyāyikas* (such as Raghunātha Śiromaṇi, Jagadīśa Tarkālaṅkāra, Gadādhara Bhaṭṭācārya, etc.) and *Navya-mīmāṁsakas* (such as Gāga Bhaṭṭa, Khaṇḍadeva Miśra and others). They developed systematic procedures for formulating *śābdabodha* of an utterance in a technical language based on ordinary Sanskrit. However, they held different views on: (a) The entities (*padārthas*) associated with the various words (*padas*) in an utterance; (b) Relations between these entities as revealed by the utterance; and, (c) The chief qualifier (*mukhya-viśeṣya*) of the cognition caused by the utterance.

The basic technique of *śābdabodha* is briefly summarised in the following extract from a recent study:

> A sentence is composed of words whether their existence is considered real, as in the case of the Logician (*Naiyāyika*), the *Mīmāṁsaka* and others, or mythical as in the case of the Grammarian (*Vaiyākaraṇa*)… *śābdabodha* is the cognition of the meaning of sentence. It has been defined as 'the cognition effected by the efficient instrumentality of the cognition of words' (*padajñāna-karaṇakaṁ jñānam*)…, 'the cognition resulting from the recalling of things derived from words' (*padajanya-padārthopasthitijanya bodhaḥ*)…, 'the knowledge referring to the relation between each of the substances recalled by the words in a sentence' (*eka padārthe apara-padārtha saṁsarga viṣayakaṁ jñānam*)…

> In order to have a clear idea of this theory the various stages of verbal cognition (*śābdabodha-krama*) may be studied with advantage. While comprehending the meaning of any sentence, first of all, we cognise the word and then its (denotative) potentiality (*śakti*), and from both of these put together the recalling of meanings is effected and thus import is generated. For instance in the sentence… "Chaitra worships Hari" (*Caitraḥ hariṁ bhajati*), there is first of all, the cognition of the several words: "Hari", the (accusative) case affix "*am*", the root "worship" (*bhaj*) and the verbal affix "*tip*". Next their (denotative) potentialities are comprehended in the following way: The word "Hari" by virtue of its denotative capacity (*abhidhāśakti*) denotes Hari, "*am*" the case affix denotes object-ness (*karmatva*), the root "*bhaj*" denotes activity favourable to love (*prītyanukūla-vyāpāra*), "*tip*" denotes activity (*kṛti*), of course, in addition to the meanings of number, tense, etc. This is the cognition of the potentiality of words, the second stage of verbal import (*śābdabodha*)… Subsequently as there exists among these several words (or among their meanings) mental expectancy (*akāṅkṣā*), compatibility (*yogyatā*) and juxtaposition (*sannidhi* or *āsatti*) a totality of comprehension is produced in the form, "Chaitra is the substratum

of activity favourable to love which has Hari for its object",
(*Harikarmaka prītyanukūla kṛtimān caitraḥ*).[33]

To elucidate the technique of *śābdabodha* let us consider the Naiyāyika method of *śābdabodha* of the sentence '*Caitraḥ hariṁ bhajati*' in some detail. There are six 'words'−*Caitra, sup, Hari, am, bhaj, tip*. In the Naiyāyika method of *śābdabodha*, '*Caitra*' refers to the individual Chaitra *(Caitra-vyakti)* as qualified by the genus Chaitra-ness *(Caitratva)* and form *(jatyākṛti- viśiṣṭaḥ)*. The same is true of the word '*Hari*'. The case affix '*sup*' refers to singular number *(ekatva-saṁkhyā)* and '*am*' refers to object-ness *(karmatva)*. The root '*bhaj*' refers to the activity favourable to devotion *(prītyanukūla-vyāpāra)*. The verbal affix *(ākhyāta)* '*tip*' refers to 'effort' *(kṛti)*, singular number *(saṁkhyā)* and present tense *(vartamāna-kāla)*. The Naiyāyika theory of *śābdabodha* further specifies the various relations by which all the above entities *(padārthas)* are related to each other. This can be illustrated by way of a diagram, where the directed arrows indicate the various relations, *anvaya-saṁbandhas*, between the *padārthas*:
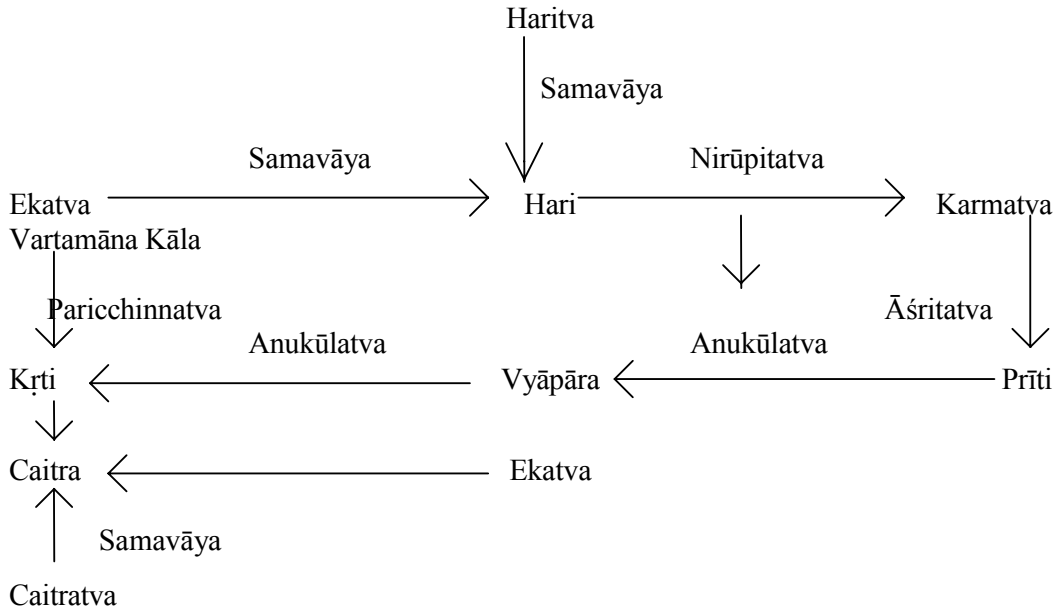
The Naiyāyikas would express the *śābdabodha* of the sentence '*Caitraḥ hariṁ bhajati*' in the form:

> *ekatva samaveta haritva samaveta hari-nirūpita karmatvāśraya prītyanukūla vyāpārānukūla vartamāna-kālikā yā kṛtiḥ tasyāśrayaḥ ekatva samaveta caitratva samavetaḥ caitraḥ*

> Chaitra as qualified by singularity and Chaitra-ness (through the relation of inherence) is the substratum of the effort which is

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[33]V.Subba Rao, *The Philosophy of Sentences and its Parts*, Delhi 1969, p.1-3. In the passage cited the author is using the *Naiyāyika* technique of *śābdabodha*.

favourable to activity favourable to devotion residing in the object-ness described by Hari, who is qualified by singularity and Hari-ness (through the relation of inherence).

The above is only a simplified form of the more refined (*pariṣkṛita*) *śābdabodha*, which includes the statement of the qualificand-ness (*viśeṣyatā*) and qualifier-ness (*prakāratā*) resident in the above *padārthas* along with their limitors (*avacchedakas*)–both the limiting attributes (*avacchedaka-dharmas*) and the limiting relations (*avacchedaka-saṁbandhas*), which are nothing but the 'syntactical relations' (*anvaya-saṁbandhas*) between the various *padārthas* indicated in the above diagram.

The *Vaiyākaraṇa* and *Mīmāṁsaka* formulations of *śābdabodha* follow a similar scheme; but the various *padārthas* associated with different *padas* and chief qualifier (*mukhya-viśeṣya*) would be different. In the *Naiyāyika* formulation above, the chief qualifier is Chaitra; it would be the activity (*vyāpāra*) part of the meaning attributed to the verb-root (*dhātu*) *bhaj* in the case of the *Vaiyākaraṇas*; and the activity (*bhāvanā*) part of the meaning attributed to the verb-affix (*ākhyāta*) '*tip*' in the case of the *Mīmāṁsakas*. Each of the three schools have come up with detailed arguments to show how their formulation of *śābdabodha* is not only consistent but also superior to the formulations given by the other schools.

Whether it be the *Naiyāyika* formulation of *śābdabodha*, or the *Vaiyākaraṇa* or the *Mīmāṁsaka* formulation, all of them provide precise and unambiguous characterisation of the cognition caused by an utterance of Sanskrit language. If the utterance has ambiguities, due to the presence of polysemious words (*nānārthaka-śabdas*) or pronouns (*sarvanāmas*) or due to the sentence structure etc., then procedures are outlined for arriving at the actual import that is intended to be conveyed (*vaktṛvivakṣā* or *tātparya*) and the *śābdabodha* performed accordingly. The *śābdabodha* itself is formulated in a technical language and presents the full content (*viṣayatā*) of the cognition, the various *padārthas* and their *saṁbandhas* as manifested by the cognition, as well as its logical structure. The technique of *śābdabodha* can also be seen as a scheme for arriving at a 'knowledge representation' of every utterance in the natural language Sanskrit.[34] Most of the techniques of 'knowledge representation' which are currently being investigated in connection with natural language processing by computers are mostly *ad hoc* schemes applicable to a particular class of sentences.[35] While, the technique of *śābdabodha* is a systematic procedure based on a fundamental analysis of the nature of linguistic utterances, and the cognition they generate.

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[34] R. Briggs, 'Knowledge Representation in Sanskrit and Artificial Intelligence', The A. I. Magazine, 32-39, Spring 1985. The paper shows the parallelism between the 'semantic nets' technique of knowledge representation used in artificial intelligence and the *śābdabodha* technique of *Vaiyākaraṇas* by taking various examples.

[35] On the Pāṇinian approach to natural language processing and other formal aspects of Pāṇinian grammar see, Subhash Kak, 'The Pāṇinian Approach to Natural Language Processing', Int. J Of Approx. Reas. 1, 117-130, 1987; Saroja Bhate and Subhash Kak, 'Pāṇini's Grammar and Computer Science', A.B.O.R.I. 72, 79-94, 1991; Aksharabharati, Vineet Chaitanya and Rajiv Sangal, *Natural Language Processing: A Pāṇinian Perspective*, New Delhi 1995; T.R.N Rao and S. Kak, *Computing Science in Ancient India*, Louisiana 1998.

Our discussion of Indian logic has indicated how the Indian logicians, instead of seeking to develop content-independent and purely symbolic formal languages as in the West, have sought to develop a technical or precision language founded on the natural language Sanskrit, which avoids all inexactness and ambiguity. By means of the procedure of *pariṣkāra* (refinement), the Indian logicians describe the logical structure of cognition unambiguously in their technical language. The importance of this technical language was not understood till recently. It is now generally recognised that the technical language developed by the Indian logicians allows them to achieve much of what is supposed to be achieved through the symbolic formal languages of modern mathematical logic. According to one scholar:

> *Navya-nyāya* (the modern school of Indian logic started by Gāṅgeśa Upādhyāya in 14th century) never invented the use of symbols. It invented instead a wonderfully complex system of clichés by which it expresses a great deal that we would never think of expressing without symbols. [36]

According to another scholar:

> The technical language of *navya-nyāya* is not I suspect so much a language as the groping for a kind of picture of the universe of individuals in their relationships with one another… There seems to be a kind of continuity extending from vague, ambiguous, inaccurate ordinary languages, through languages filled with technical terms, to clear unambiguous, accurate maps of the kind exemplified by the mathematical physicists' formulas… Naiyāyika style, it may be conjectured, is not intended for the purpose of communicating more easily, any more than the mathematicians' is; it is intended rather to provide a simple accurate framework for the presentation of the world as it really is. In short, the *navya-nyāya* aim is not so far away from the apparent aim of those contemporary philosophers of this day and age in the West, who wish by use of techniques of symbolic logic to find a simple and accurate way of setting forth the picture of the world presented by the natural sciences. [37]

These estimates of the technical language employed in Indian logic seem to miss the basic methodological principles of the Indian approach. It appears to us that Indian logicians, instead of landing up somewhere in the 'continuum extending from vague… ordinary languages… to clear… mathematical physicists' formulas', deliberately avoided the purely symbolic and content-independent formal languages, just as they avoided postulation or use of ideal entities such as 'proposition', 'sense' as distinguished from 'reference', 'logical truth' as distinguished from 'material truth', etc. Indian tradition does not start with any pronounced contempt for the ordinary or natural languages. While it recognises the imperfections in the natural languages as vehicles for logical discourse, the attempt in Indian tradition has been to evolve a technical language which is constructed on the basis of the natural language, Sanskrit, and which is free of the ambiguities, inaccuracies, etc., which a natural

[36]D. H. H. Ingalls, 1951, cited above, p.2
[37]K.H. Potter, *The Padārthatattvanirūpaṇa of Raghunātha Śiromaṇi*, Harvard 1957, p.16-18

language might have. This technical language is so constructed as to reveal the logical structures that are not transparent and often ambiguous in a natural language, but at the same time has a rich structure and interpretability, which it inherits from the natural language from which it is constructed. Perhaps, to a large extent, it was the strong foundation laid by the Pāṇinian analysis of Sanskrit language, which enabled the Indian scientists and philosophers to: (i) Achieve an unambiguous representation of all natural language utterances in terms of a technical language; and, (ii) Systematically refine the natural language into a technical language with a transparent logical structure which could serve as a vehicle for precise technical discourse.

The Indian approach of converting the ordinary discourse by *pariṣkāra* (refinement) into a technical discourse, suitable for systematisation and logical analysis of knowledge, is in conformity with the larger philosophical and methodological principles that govern Indian thought. Instead of looking for 'ideal', 'context-free' and purely symbolic or 'formal languages' which have no relation with natural languages, as possible tools for attaining 'perfect' logical rigour, the Indian tradition sets out to systematically refine the natural language Sanskrit. The process of *pariṣkāra* is an evolving process depending on the demands of a particular problem and the kind of ambiguities needed to be resolved. This is how, for instance, the technique of insertion of *paryāpti*, got developed during 16th-19th centuries.

Modern Western formal logic has so far failed in describing logical relations within or between sentences as used in ordinary language or in most of philosophical and scientific discourse. The Indian tradition has handled this problem with much greater sophistication. A comprehension of the basic methodologies of the *śāstras* of Kaṇāda and Pāṇini will help in carrying forward this tradition.