

# Éléments de mathématiques en sanskrit IV

## Formation Doctorale

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'Adhérer a la pensée indienne, c'est d'abord penser en grammairien'  
(Louis Renou)

- Importance of language : Limbs of veda
  - 1 ritual and geometry,
  - 2 phonetics and phonology
  - 3 etymology
  - 4 grammar,
  - 5 prosody
  - 6 astronomy.
- Comparable to influence of Euclid in western system of knowledge (Frits Staal, 1965)
- Tradition continued in :
  - Philosophy *navya nyaya*
  - Exegesis and other grammars ..jaina, buddha, tamil,...
  - Sciences and mathematics

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- 1 *Pāṇini* 4th cent BCE
  - This was not a sudden happening, but inscribed in a long tradition.
  - Many references to older grammarians exist in *Pāṇini* itself.
  - Unfortunately, all prior work is lost.
- 2 *Kātyāyana* : *Vārttika*. (3rd cent BCE)
- 3 *Patañjali* : *Mahābhāṣya*. (2nd cent BCE)
- 4 *Bhartṛhari* : *Vākyapadīya*, *Mahābhāṣya-dīpikā* (5th cent CE)

1,2,3 constitute the trinity of wise-men *munitraya* of grammar.

- 1 Finite grammar to generate infinite language.

*Valid utterances cannot be taught by stating each of them individually. Br̥haspati tried to teach Indra valid utterances by thousand divine years, but reached nowhere near the end.*

[ Mahābhāṣya of Patañjali] .

- 2 Precise

- 3 Concise (*lāghava*)

*Grammarians rejoice over the saving of the length of half a short vowel as over the birth of a son.*<sup>1</sup>

- 4 Can not be understood without commentaries like *Vārttika*, *Mahābhāṣya* or later ones *Siddhāntakaumudī* of *Bhaṭṭojī Dīkṣita* of 17th century. Not a grammar for learning the language.

- 5 Like a computer programme.

- 6 Considered the most perfect grammar by many modern linguists (Chomsky, Bloomfield, Saussure..) and a prototype of a computer (Huet).

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<sup>1</sup>*ardhamātrālāghavena putrotsavaṃ manyante vaiyākaraṇāḥ*

The grammar has four components:

- 1 *Aṣṭādhyāyī*: Contains 8 chapters, with 4 sections
  - Technical terms.
  - Operational rules (4000)
  - Meta rules
- 2 *Śivasūtras* : the inventory of phonological segments.
- 3 *Dhātupātha*: a list of about 2,000 verbal roots.
- 4 *Gaṇapātha*: a list of 261 lists of lexical items.

- 42 phonological segments and consist of 14 *sūtras*.
- a sequence of phonological segments (in small letters) bounded by a marker (in capital letter), called *it* in *Pāṇini* and later named *anubandha*. Phonological classes are denoted by abbreviations, called *pratyāhāras*, consisting of a phonological segment and an *anubandha*.
- 305 pairs can be constructed consisting of a phonological segment followed by an *anubandha*. Due to the double occurrence of *ha* 10 of the pairs denote the same set of phonological segments (e.g. 'aL' and 'aR'). If we exclude classes containing a single element, then the number of phonological classes which can be expressed by *Pāṇini*'s system reduces to  $305 - 10 - 14 = 281$ .
- *Pāṇini* has chosen an optimal style representation with 42 *pratyāhāras* (Petersen 2004, using planar graphs).

# Phonological Classes

1	a	i	u			Ṇ
2				ṛ	ṝ	Ḳ
3		e	o			ṅ
4		ai	au			Ḷ
5	ha	ya	va	ra		Ṭ
6					la	ṅ
7	ña	ma	ña	ṇa	na	Ṃ
8	jha	bha				ṅ
9			gha	ḍha	dha	Ṣ
10	ja	ba	ga	ḍa	da	Ṣ
11	kha	pha	cha ca	ṭha ṭa	tha ta	V
12	ka	pa				Y
13		ṣa	śa	sa		R
14					ha	L

The 14 classes according to *Śivasūtra* of *Pāṇini*'. Notice that *ka* is the name of the consonant *k* and belongs to the metalanguage (a language used to describe another language) of grammar.

## Metarule (a rule about rules) : *paribhāṣa*

- The element that is substituted, is expressed by the Nominative Case.
- The Genitive case ending is used for that in the place of something which is substituted.
- When something is referred to by the Locative ending the substitute appears in the place of preceding element (defines RIGHT context)
- When something is referred to by the Ablative ending the substitute appears in the place of the following. (defines LEFT context)



# Metarule for conjunction

Conjunction (*Sandhi*) An initial sound joined to a final (indicatory) sound (denotes the intervening sounds as well).

## Example (General)

iko yan aci (6.1.77)

$iK \{i, u, r, !\}$

$yaN \{ya, va, ra, la\}$

$aC \{a, i, u, r, l, e, o, ai, au\}$

*ik-Gen yaṅ-Nom ac-Loc*

$[iK] \rightarrow [yN]/[aC]$ .

## Example (Exception, *apavāda*)

akaḥ savarṇe dīrghaḥ (6.1.101)

$aK \{a i u r !\}$

Merge an  $aK$  and the following same phoneme into a long.  $i+i=\bar{i}$ ,

$u+u=\bar{u}$  .. .

## Application

yadi api -> yadyapi, su āgataṃ -> svāgataṃ, dadhi ichhati-> dadhīcchati

# Metarule for Retroflexion

## Example

*raṣābhyāṃ no ṇḥ samānapade 8.4.1*

*After r and ṣ, n becomes ṇ in the same word (1)*

*Unless c, ṭ, t, ch, ṭh or th interfere. (2)*

## Example

*varṇa, dakṣiṇa*

*Rām-āyanaṃ (coming and going) => Rāmayaṇaṃ (retroflexion)*

*arcanaṃ (no retroflexion)*

# Table of consonants

Velar	Palatal	Retroflex	Dental	Labial
k	c	ṭ	t	p
kh	ch	ṭh	th	ph
g	j	ḍ	d	b
gh	jh	ḍh	dh	bh
ṅ	ñ	ṇ	n	m

The grammar of *Pāṇini* can be used to analyse the meaning of a sentence (non-positional).

## Example

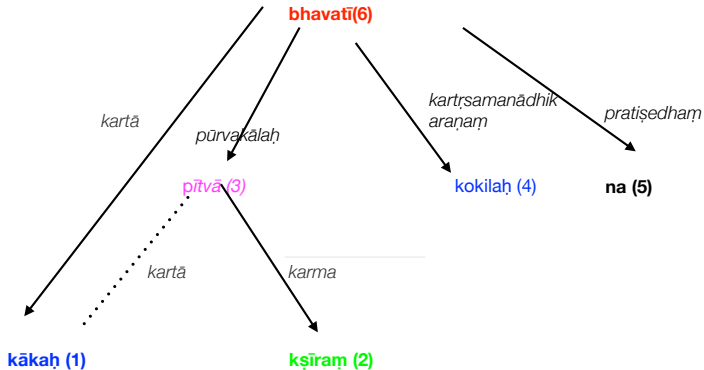
*kākaḥ kṣīraṃ pītvā kokilaḥ na bhavati*

*A crow does not become a cuckoo by drinking milk.*

- Verb *bhavati* (from √ *bhū* to become) 3rd person singular
- Agent *kākaḥ* crow
- Secondary Action *pītvā* gerund or past participle, having drunk from √ *pā* to drink)
- Object *kṣīraṃ* milk
- Predicative Adjective *kokilaḥ* cuckoo
- Negation *na* not

A programme developed by Kulkarni (2013) would give :

# Machine Analysis : Dependency Parser



## Example

*adarśanaṃ lopaḥ (1.1.60)*

*Non-appearance is zero.*

- *Lopa*, from the verbal root *lup* for suppression or elision, occurs explicitly 45 times.
- *adarśanam* : unseen from *drś* to see.
- Before writing (in 3rd cent BCE) what was 'unseen' ?
- Renou 1957 translates *adarśanam* in *Kātāyana's* text as *amuissement*. By then writing had probably appeared
- Grammatical zero is thought to be the precursor of the mathematical zero.
- Different spheres of zeros exist : in grammatical analysis, in meta-linguistic techniques or in non-mention.

### Example (Elision)

*khad-a-ti* : *khādati* (1)

*ad-0-ti* : *atti* (2)

Both roots  $\sqrt{khād}$  and  $\sqrt{ad}$  mean 'to eat', in the third person singular indicated by the *ti*, mean 'he/she eats'. But (1) contains an infix, *a*, absent in (2) and denoted by a '0'.

That (2) should be an exception and there should be an elision of the *vikarṇa* (suffix) follows from the rule 2.4.72.

*Mathematicians' apparent intelligence is due not to themselves but to the mathematical language that they have learnt.* Leibnitz