Catching the Ocean in a Cow’s Hoofprint

All the rituals performed in the sacrifice, all that are linked to the rite, all this was performed in and by Speech on what was speech-made and speech-gathered, and consisted only of Speech.

– *Śatapatha Brāhmana* (“Commentary of One Hundred Paths,” circa 800-600 BCE)

vedāṅga

"The limbs of the Veda," auxiliary disciplines

- *jyotiṣa*, astronomy
- *kalpa*, ritual
- *śikṣa*, phoenetics
- *chandas*, metre
- *vyākaraṇa*, grammar
- *nirukta*, etymology

aṣṭādhyāyī
(“Eight Chapters,” circa 500 BCE)

- Written by Pāṇini.
- 3976 rules.
- The *ashtādhyāyī* has three associated texts:
  - *śivasūtra* (also *akṣarasamāmnāya*, “Recitation of phonemes”)
  - *dhātupāṭha* (lexical list of verbal roots)
  - *gaṇapāṭha* (list of nominal stems)

Śivasūtra, recitation of phonemes

a i u *ṇ*
ṛ ḷ *k*
e o *ṅ*
ai au *c*
ha ya va ra *ṭ*
la *ṇ*
ña ma ṅa ṇa na *m*
jha bha *ñ*
gha ḍha dha *ṣ*
ja ba ga ḍa da *ś*
kha pha cha ṭha tha ca ṭa ta *v*
ka pa *y*
śa ṣa sa *r*
ha *l*

Red letters are meta-language: *anubandhas* or *it* markers.

Within the rules, "a*c*" refers to the letters: { a i u ṛ ḷ e o ai au }

So, "a*c*" = all vowels

- ha*l* = all consonants
- jha*ś* = voiced consonants
- jha*ṣ* = voiced aspirated consonants
- ya*ṇ* = semi-vowels

Pāṇini uses 42 of these *pratyāhāra*s in the *aṣṭādhyāyī*

6.1.77 *iko yaṇ aci*

ik is replaced by *yaṇ* if a*c* follows

{ *i k ṛ ḷ* } is replaced by { *ya va ra la* } if a vowel follows

i → *ya*

k → *va*

ṛ → *ra*

ḷ → *la*

śiva sutra, recitation of phonemes

a i u *ṇ*
ṛ ḷ *k*
e o *ṅ*
ai au *c*
ha ya va ra *ṭ*
la *ṇ*
ña ma ṅa ṇa na *m*
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kha pha cha ṭha tha ca ṭa ta *v*
ka pa *y*
śa ṣa sa *r*
ha *l*

- Mathematically optimal: Wiebke Petersen, “A Mathematical Analysis of Pāṇini’s *Śivasutra*s”, *Journal of Logic, Language, and Information* 13: 471-489 (2004), and “How Formal Concept Lattices Solve a Problem in Ancient Linguistics” (2006).

- Linguistically optimal: Paul Kiparsky. “Economy and the Construction of the *Śivasutra*s," *Pāṇinian Studies: Professor SD Joshi Felicitation Volume*. Center for South and Southeast Asian Studies, University of Michigan, Ann Arbor, Michigan (1991).

dhātupāṭha

A list of verbal roots. In this lexicon, roots are grouped in their stem form in the present tense.

1.1 *bhū sattāyām*: "*bhū* in the sense of existence (*sattā*)."

- *kṛ* = do, make, perform
- *rud* = weep
- *śaas* = rule
- *labh* = get
- *pa* = drink
- *path* = read
- *gam* = go
- *nrit* = dance
- *prachchh* = ask
- *likh* = write
- *spṛiś* = touch

gaṇapāṭha

- A collection of 261 nominal stems.

- There has been a very rich tradition of writing *gaṇapāṭha*s by grammarians, so some more nominal roots are added later in the *gaṇapāṭha* which were not a part of the grammar written by Pāṇini. For example the "*udādi sūtrās*" are a part of the *shakatāyan* grammar.

anuvṛtti, rule ellipsis

Give Caitra a cow.
A blanket to Maitra.
Also to Gopal.

sūtrā 3.3.65: *kwanah vināyām ch*

After *anuvṛitti*:

kwanah vināyām ch pratyayah parah ch ādyuddātah ch dhāto krit kriyāyām kriyārthāyām bhāve akartari ch kārak sangyāyām ao upsarge vā naū

“The affix *ap* comes optionally after the verb *kwan* (‘to jingle’) when *ni* is in composition with it, as well as when it is without any *upsarg* or when ‘flute’ is meant.”

anuvṛitti

Number of *sūtrās*:	3976
Number of words with compounding (*samāsa*)	7007
Number of words without compounding	9843
Number of words after expanding through *anuvṛitti*	40,000

Types of rules:

- *saṃñja*, definitions.
- *paribhāṣā*, metarules.
- *adhikāra*, headings.
- *vṛtti*, operational rules: affixation, augmentation, compounding, replacement (including deletion, because replacement by a null element is possible)

When you see “L E R” then E is replaced by X

when L is the left context and appears directly before E (not all rules use this)
when R is the right context and appears directly after E (not all rules use this)

bhu

3.1.130, bhuvo bhave — Addition of “ghn”

bhu +ghn

1.3.8, laśakwātaddhite

1.3.31, halantyam

1.3.9, tasya lopah

Application of “it sangya” process
For “gh” and “n” respectively.
Application of “lop” process

bhu +a

7.2.115, achongniti — Application of “vruddhi” process

bhau +a

6.1.78, echoayvayavah — Conversion of “au” to “āv”

bhāv

Sanskrit: *saṃskṛta* (neuter of *saṃskṛtam*)

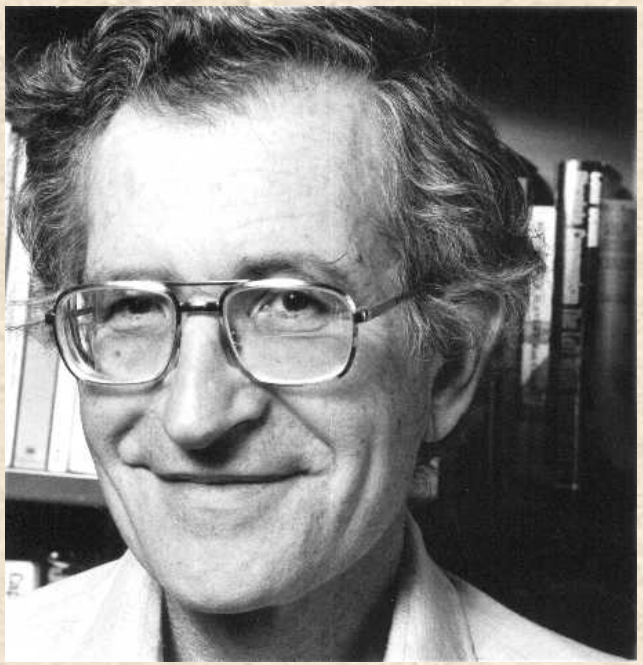
sam (together) + *kṛ* (to make, do, perform)

“Put together, well-formed, highly wrought, perfected.”

Leonard Bloomfield: “Around the beginning of the nineteenth century the Sanskrit grammar of the ancient Hindus became known to European scholars. Hindu grammar described the Sanskrit language completely and in scientific terms, without prepossessions or philosophical intrusions. It was from this model that Western scholars learned, in the course of a few decades, to describe a language in terms of its own structure.”

Paul Kiparsky: “Western grammatical theory has been influenced by [Pāṇini’s work] at every stage of its development for the last two centuries. The early nineteenth-century comparativists learned from it the principles of morphological analysis. Bloomfield modelled both his classic Algonquian grammars and the logical-positivist axiomatization of his *Postulates* on it.”

“The ingenious technical devices [of the grammar], and at intricate system of conventions governing rule application and rule interaction that it presupposes [seems] to uncannily anticipate ideas of modern linguistic theory (if only because many of them were originally borrowed from Pāṇini in the first place).”



The first computing language – again, for our purposes, a generic formalism, described through a metalanguage for representing exact generative symbolic procedures of any kind – was devised … by the Indian grammarian and linguist Pāṇini. The formalism is not identical with Pāṇini's Sanskrit grammar, but is a significant part of it, constituting the grammar's formidable derivational methods… Pāṇini's basic method was rediscovered, we can now say, in the 1920s and 1930s by Emil Post through his production/rewrite systems… The basic claim then is that Pāṇini's system is sufficiently structured to qualify as the *earliest known computing language*…

– John Kadvany, "Pāṇini's Grammar and Modern Computation," *History and Philosophy of Logic*, Volume 37, Issue 4 (2016).

…the greatest difference between Pāṇini's own formalism and the standard string-rewriting systems concomitant with Chomsky's hierarchy… is its built-in capacity for disambiguation. Pāṇini's grammar, through its use of rule precedence and other meta-conventions, generates a single derivation for every grammatical sentence of Sanskrit. Not even a single one of the standard Chomskyan systems possesses this property, and it is this lack of theirs, rather than some inherent quality of the syntax of human languages that is responsible for the now-widespread use of numerical reasoning and statistical pattern recognition methods in natural language processing. These are required in order to curb the natural propensity of these algebras to overgenerate. Through the lens of contemporary NLP [Natural Language Processing], the most amazing fact about the *Aṣṭādhyāyī* is not that it produces so many correct derivations, after all, but that it simultaneously avoids so many incorrect ones.

– Paul Kiparsky, "On Pāṇini and the Generative Capacity of Contextualized Replacement Systems," *COLING* (Posters, 2012)

“The sun has set.”

1. When said by the general to the king: “Now is the opportunity to attack the enemy.”
2. When said by the confidant to the girl in love: “You should set forth to meet your lover.”

...

10. When said by an impatient girl waiting for her beloved’s return from a journey: “My love has not come even today.”

The denoted meaning of a word is one and the same for all persons bearing it; so that it is fixed and uniform; the denoted or directly *expressed* meaning of the words “the sun has set” never varies (is fixed), while its *suggested* meaning varies with the variation in such accessory conditions as the context, the character of the speaker, the character of the person spoken to, and so forth… Thus, in fact, there is no end to the number of suggested meanings.

– Mammata, *Kāvyapṛakaśa* (“Light on Poetry,” 11th century CE)

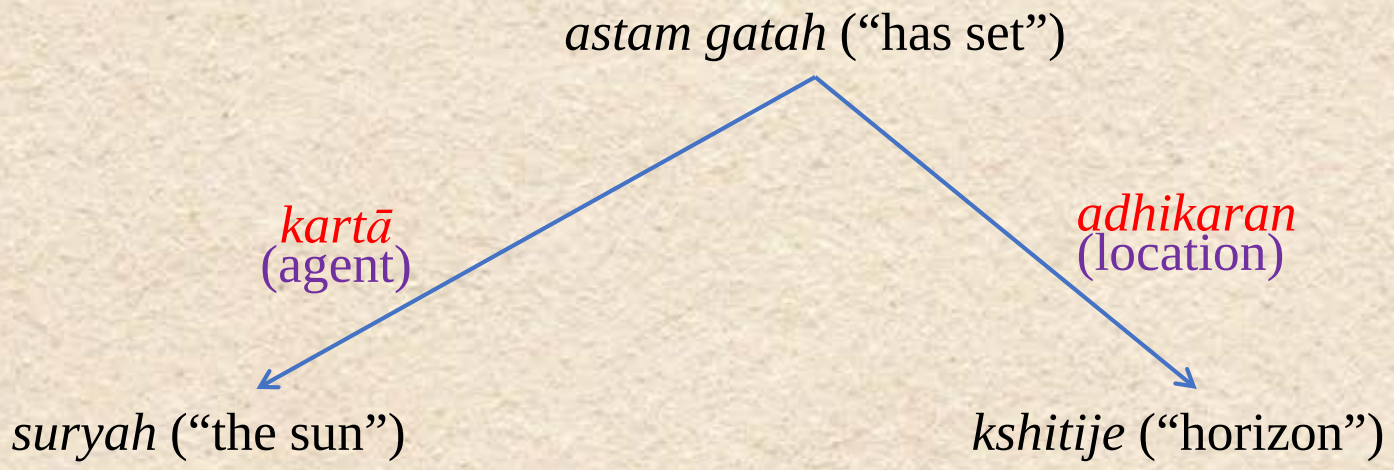
nyāya (“The School of Reason,” circa 200 CE)
navya-nyāya (“New Reason,” 1200 CE onwards)

“Caitra goes to the village.”

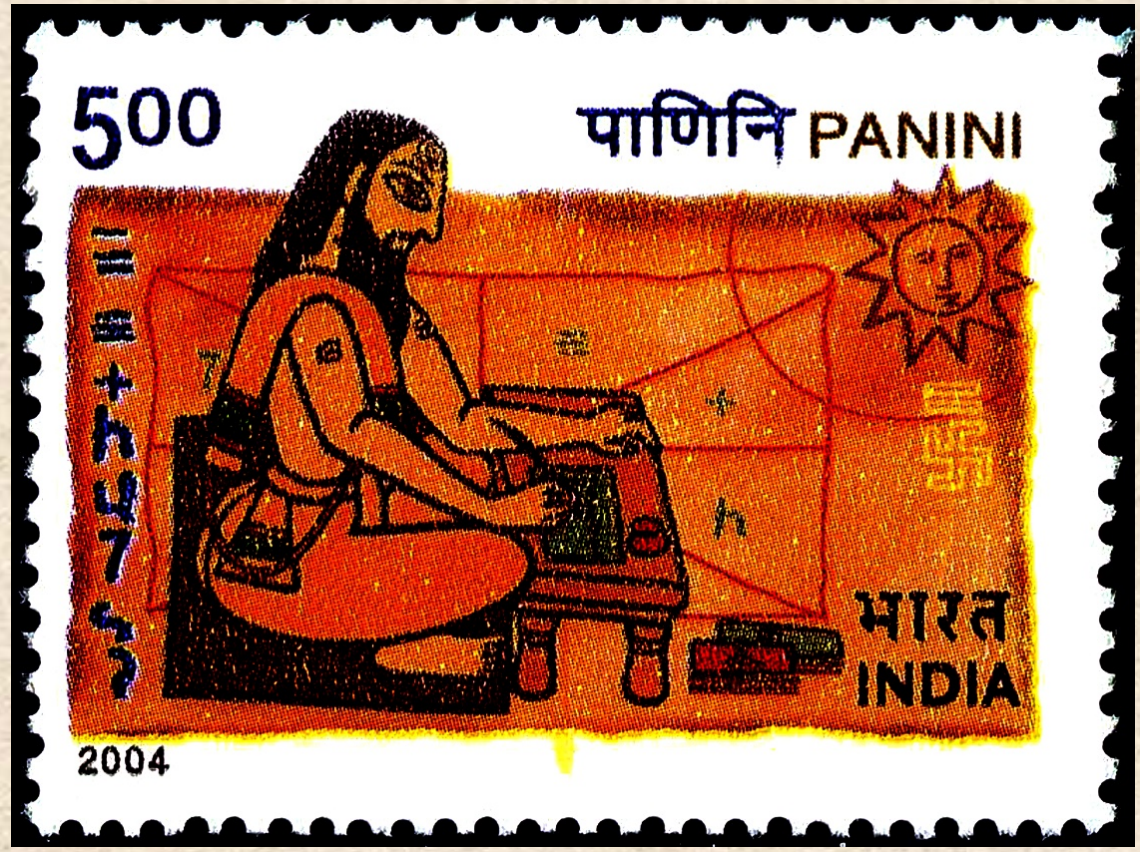
> “There is an activity which leads to a connection-activity which has as Agent no one other than Caitra, specified by singularity, [which] is taking place in the present and which has as Object something not different from ‘village.’”

“The sun has set over the horizon.”

suryah kshitije astam gatah



“There is an activity which leads to a connection-activity which has as Agent no one other than *surya* (the sun), specified by singularity, [which] has taken place in the past and which has as location something not different from ‘*kshitij*’ (horizon).”



“Grammar is the door to liberation.”

– Bhartṛhari, 5th century CE