Pāṇini

1 Pāṇini's grammar and its goals

Pāṇini's grammar seeks to provide a consistent, exhaustive, and maximally concise formal analysis of Sanskrit. It is the most complete generative grammar of any language yet written, and a source of many of the key ideas in Western linguistics in the last two centuries.

The grammar deals with the standard spoken Sanskrit of Pāṇini's time (approximately 500 B.C.), a stage between Vedic and classical Sanskrit. Its method and content builds on prior works on phonetics, phonology, and morphology that had grown out of the project of codifying complex Vedic rituals in the concise *sūtra* format.

The phonetic treatises *(śikṣā)* had been developed to help fix the pronunciation of Vedic texts (Allen 1953, Bare 1976, Deshpande 1993). They classify vowels and consonants by a single unified set of place features, crossed with an multi-valued aperture feature that distinguishes consonants from vowels, height within vowels, and stops from fricatives within consonants. Each place has a characteristic resonance *(dhvani)*, activated by tone *(nāda)* if the throat aperture is closed, and by noise *(śvāsa)* if it is open, producing respectively voicing *(ghoṣa)* and voicelessness (*aghoṣa*). Increased airflow *(vāyu)* produces aspiration. High pitch *(udātta)* is ascribed to tenseness of the articulatory organs, resulting in constriction of the glottis *(kaṇṭhabila)*; low pitch *(anudātta)* from relaxation of articulatory effort with consequent widening of the glottis. The grammar presupposes phonetic categories and refers to them, but imposes its own phonological classification on sounds based on how they pattern in Sanskrit.

In phonology, Pāṇini's work was preceded by the construction of word-by-word (*padapāṭha*) versions of Vedic texts, and the formulation of rules for converting these man-made texts back to their divinely revealed orally recited originals, in which the words run together by sandhi. Their breakdown of sentences into words, and their substitution rules of the form A $\rightarrow$ B / C___D to reconstitute the running text, reveal considerable grammatical sophistication, showing that the extant *padapāṭhas* were completed when grammar had already reached an advanced stage.[1]

In morphology, Pāṇini drew on the fundamental idea that words are composed of meaningful parts, which appears in Vedic exegesis from the earliest prose (the *Brāhmaṇas)* culminating in Yāska's *Nirukta*.[2] However, Yāska's focus is on textual interpretation and his imaginative analyses can be cavalier about phonology and morphology.[3]

Pāṇini's achievement was to extend and formalize these initiatives in a vastly more ambitious undertaking: a grammar of the entire language that relates sound and meaning through rules for building words and sentences from their minimal parts. It is not intended to be a practical reference grammar, still less a

[1] For the philosophical background to substitution rules, see Candotti 2012.

[2] Contrast the Greek philosophers' and grammarians' "amorphous" view of word structure.

[3] E.g. *kīkaṭāḥ kiṃkṛtāḥ* 'the (name of the) *Kīkaṭas* is from "what have they done"', *śaknoter śākhā* "branch" is from *śaknoti* "is able"' (*Nirukta* 6.32).

textbook; simplified and condensed works suitable for these purposes were produced later. It seeks solely to extract all grammatical regularities, rigorously guided by the twin imperatives of complete coverage and the principle of Minimum Description Length. The latter requires the grammar to be the shortest overall representation of the data, crucially including the principles and abbreviatory conventions by which it the data is encoded (details in section 4 below).

The grammar consists of four components:

a. *Aṣṭādhyāyī*: 3,981 brief rules (9,737 words altogether), in eight chapters.

b. *Dhātupāṭha*: a list of about two thousand underived verbal roots, with morphological and syntactic properties indicated by diacritic markers *(anubandhas)* and elaborate subclassification.

c. *Gaṇapāṭha*: a list of the lists of stems available for reference in rules.

d. *Śivasūtras*: a list of phonological segments, partitioned into 14 groups by consonantal markers which support the generation of terms for classes of segments as described below.

The rules of the *Aṣṭādhyāyī* make reference to classes defined on the other three components by means of conventions introduced in the *Aṣṭādhyāyī* itself. Thus, while none of the components is intelligible in isolation, together they constitute a complete integrated system of grammar.

The *Aṣṭādhyāyī* component of the grammar is not rigidly divided into modules or subcomponents, though its rules fall roughly into two main blocks. Chapters 1-5 contain the rules which build up words and sentences, and chapters 6-8 contain the rules which determine how morphemes are modified in combination with each other in words, and how words are modified in combination with each other in sentences. But affixation and phonology can be freely interleaved. When I will refer to Pāṇini's treatment of "syntax", "morphology", and "phonology" in what follows, it is with the understanding that these are themselves emergent constellations of rules rather than predetermined components into which the description is organized.

The grammar takes as input a semantic analysis of a sentence and generates the phonological representations that correspond to it via two intermediate levels of representation, syntactic and morphological. These do not correspond to any components or modules of the grammar, but simply emerge from the analysis as a consequence of maximizing economy. About a third of the rules are optional; most of these single out one option as preferable (Kiparsky 1979), and many are tagged for style, region, or sociolinguistic use. This covers a massive amount of variation very precisely. All told, the system generates several thousand ways of expressing even a simple proposition such as *I made it*.

The output of the grammar is the set of grammatical sentences as actually pronounced, e.g. (1):[4]

(1) vánānmahānagarámadyópétyaudanáxkáuñjāyanenā́trāpāci 'today Kauñjāyana returned from the forest to the city and cooked rice here' (lit. 'having returned to the city from the forest today, rice was cooked here by Kauñjāyana')

[4]I follow the standard IAST system for romanizing Sanskrit in using an underdot to mark both the syllabicity of liquids (*ṛ*, *ḷ*) and the retroflexion of consonants *ṭ, ṭh, d, ḍh, ṇ*. The symbol *ḥ* is a glottal (or placeless) approximant that replaces /s/ in some word-final contexts. Before pause it is usually pronounced as voiced with a copy of the preceding vowel after it. The symbol *ṃ* is a nasal offglide that neutralizes place of articulation. The aspirates transliterated as *bh, dh...* are phonologically single segments [b^h], [d^h].... Macrons in the transliteration indicate vowel length.

The *padapāṭha*-style word-by-word pronunciation is not a level of representation or otherwise privileged in the grammatical system, but it can be obtained from it by undoing the external sandhi rules that apply in connected speech. In (2) words are separated by spaces and '-' shows the division of compounds into parts, which is also indicated in the *padapāṭha* in a special way:

(2) vánāt mahā-nagarám adyá upa-ā-ítya odanáḥ káuñjāyanena átra apāci

(1) is one of four connected speech pronunciations derived from the morphological representation (3).[5]

(3) vána-as mahát-nágara-am adyá-i upa-ā-i-tvā odaná-s kúñja-i-phá-ā etád-i
forest-LOC big-town-ACC today-LOC Prt-Prt-go-ABS rice-NOM Kuñja-PATR-PATR-INST this-LOC
á-pac-i-ta
AUG-cook-AORPASS-3SG

In the grammar, many roots and affixes appear with abstract markers (added in capitals in (4)) which encode their grammatical properties:[6]

(4) vána-ÑasI mahát-nagará-am adyá-Ñi upa-āÑ-iÑ-Ktvā odaná-sU kúñja-iÑ-phaÑ-Ṭā etád-Ñi áṬ-ḌUpacAṢ-CiṆ-ta

The markers are pronounced in doing derivations and talking about grammar, but they are not part of the phonological representation and they are deleted in the output. They are chosen so that they cannot be confused with real phonemes, by exploiting the gaps in the Sanskrit phoneme inventory and phonotactics. For example, because no suffix has retroflex and palatal consonants, these consonants can be used as markers in suffixes and categorically deleted in them, e.g. *Ṭā* → *ā*. The inventory of markers and whether they are attached to the befinning or end of morphemes indirectly reflects accurate generalizations about Sanskrit morpheme structure which are not directly stated in the grammar (Kiparsky 2007).

Morphological structures like (4) are derived from representations of sentence structure in terms of thematic roles (*kārakas*) and abstract tense/mood categories *(lakāras)* – in effect morphosyntactic representations. The morphosyntactic representation (5) is mapped into (3), as well as into other variants, among others with an active verb instead of passive, and with locative case *-Ñi* instead of accusative case *-am* on 'city'.

(5) a. Subordinate clause
upa-āÑ-iÑ 'approach, reach' (absolutive verb)
kúñja-iÑ-PHáÑ 'Kauñjāyana = junior descendant of Kuñja': agent *(kartṛ)*
vána 'forest': source *(apādāna)*
mahát-nágara 'big-town': agent's primary target *(karman)*
adyá-Ñi 'today': temporal location (*adhikaraṇa, kāle*)

b. Main Clause
ḌUpacAṣ-luÑ 'cook': aorist tense
odaná 'rice': agent's primary target *(karman)*
kúñja-iÑ-pháÑ 'junior descendant of Kuñja': agent *(kartṛ)*
etád-Ñi 'here': location (*adhikaraṇa*)

[5]Four because the assimilations *ḥ* → *x* and *d* → *n* in (1) are optional (rules 8.3.27, 8.4.45). Note that the velar approximant *x* is ordinarily written as *ḥ*, from which is assimilated before a following velar.

[6]For example, in the root *ḌUpacAṢ* 'cook, bake', *ḌU-* says that the root takes the suffix *-tri-ma* (*paktrima* 'produced by baking'), and *-(A)Ṣ* says that the root takes a nominalizing suffix *-a*, with fem. *-ā*.

Morphosyntactic representations like (5) are in turn derived from semantic information such as (6). Unlike the derived morphosyntactic, morphological, and phonological representations, semantic information is not generated by the grammar but presupposed by it and constitutes the input to it.

(6) a. *kúñja-iÑ-PHáÑ* is the independent participant
b. *odaná* 'rice' is the primary target of the agent of the cooking event
c. *mahát-nágara* 'city' is the primary target of the agent of the going event
d. *vána* 'forest' is the fixed point with respect to a separation event
e. *adyá* 'today' is the temporal locus of the coming event
f. *etád* 'this' (place) is the substratum of the cooking event
g. the cooking event occurred earlier on this day
h. the coming event preceded the cooking event
i. the cooking event and the coming event have the same agent

Semantics is also the direct input to derivational affixation. For example, the suffix *-iÑ* is added to denote a descendant, e.g. *kunja-iÑ* → *káuñj-i* 'descendant of Kuñja'. This in turn takes the suffix *-phaÑ* (which always turns to *-āyana*) to form *Kauñjāyana* in (1), the proper name of a descendant of Kuñja who is not the oldest living descendant in his lineage.

Compounding is derived indirectly from semantics via case-inflected nominals, with deletion of the case morphology. The nominal stem *mahānágara* 'city' in (2) is derived by combining the phrase *mahát-sU nágara-sU* 'big town', dropping the case endings, and doing some allomorphy on the adjective.

The grammar has no syntactic movement: passives are not derived from actives but both are derived from the same semantic base. Derivations start from meanings and build up complete phonologically specified sentences that express those meanings. This is the simplest way, for three interconnected reasons. First, morphology and phonology allow destructive (non-monotonic, information-erasing) operations, such as deletion and neutralization, whereas the other levels of representation do not. Secondly, many morphological and phonological rules are optional, so that the grammatical realizations of a semantic input multiply in the course of the derivation. Third, and most importantly, the mapping between levels may depend on information from earlier levels, but not on information from later ones. Phonology can be sensitive to syntax and to morphology, and even to meaning,[7] but not conversely. So, the higher the level, the sparser the structure, and the less the computation needs to know. That makes top-to-bottom processing of rules most economical.

Even though Pāṇini's grammar is in principle a complete self-contained system, the later commentaries are in practice indispensable for an understanding of it. The basic later work on grammar is Patañjali's *Mahābhāṣya*, the "Great Commentary" (150 A.D.?), which incorporates and comments on Kātyāyana's earlier *vārttikas* "succinct comments" on Pāṇini. It discusses issues arising from the text of the *Aṣṭādhyāyī*, ranging from seeming minutiae to major philosophical questions, and proposes reinterpretations, or, if none can be found, revisions of it to remedy its apparent lapses. It is also a remarkable literary achievement, reminiscent of works such as the *Bṛhadāraṇyaka-Upaṇiṣad* in its elegant dialectic structure and luminous Sanskrit style. Its conclusions are adopted in all later works. Pāṇini, Kātyāyana, and Patañjali are considered authoritative by later grammarians; where these "three sages" *(munitraya)* disagree, the tradition usually sides with Patañjali, as the latest of the three.

[7] For example, one rule states that in a response to a respectful greeting, except to a *śūdra* [a member of the fourth caste], the last vowel is high-pitched and extra-long.

The *Kāśikā*, written by Vāmana and Jayāditya, is another key text for learners and scholars. It provides an explicit rule-by-rule paraphrase of the *Aṣṭādhyāyī*, explaining the function of every word in each rule, with appropriate examples to motivate the formulation, and summarizing the conclusions of the intricate discussions in the *Mahābhāṣya*.

The text most commonly used to teach the system in India is Bhaṭṭojī Dīkṣita's *Siddhānta-Kaumudī*. The rules, which in any particular derivation are likely to be scattered all through the *Aṣṭādhyāyī*, are here reorganized according to grammatical topics and the student is walked through them in an orderly way. The drawback of this method is that the architecture of the grammar is obscured. For example, the wording of a rule usually must be completed in the context of the rules that precede it according to the conventions of *anuvṛtti* to be explained below, but this context is lost when the rules are rearranged as in the Siddhānta-Kaumudī. Although the Siddhānta-Kaumudī tells you the completed wording of each rule, it does not make it obvious where the missing words actually come from.

The principles and metarules *(paribhāṣās)* of the system are discussed in the *Paribhāṣenduśekhara* of the great 18th century grammarian Nāgojībhaṭṭa (a.k.a. Nāgeśa). At an even higher level of generalization, Bhartṛhari's *Vākyapadīya* deals with the philosophy of language from a grammatically sophisticated point of view.

These texts, while claiming only to interpret Pāṇini, in reality have many original contributions to make. It seems that even the earliest commentators are not connected directly to Pāṇini by an unbroken teacher-student chain. This means that they cannot be used as first-hand testimony to the original intent of Pāṇini's text. Their value lies in their argumentation, which is based on deep knowledge of the system and makes them important contributions to the theory of Sanskrit grammar in their own right.

The innovations they introduce are prompted by several circumstances.

- Careful analysis of Pāṇini's grammar reveals occasional small inaccuracies in its formulations, both at a descriptive level and in matters of theoretical principle.
- After Pāṇini's time, new words and forms appeared in the Sanskrit language which were not covered by his rules.
- The original intent of some rules had become misunderstood because of discontinuities in the early grammatical tradition.

Since Pāṇini's grammar came quite early to be regarded as normative, and its text was canonized, only rather insignificant and easily detectable changes were made in the wording his rules. For the most part, grammarians after Pāṇini dealt with these problems by proposing clever reinterpretations of the rules, rather than by altering their wording. Naturally these reinterpretations, while allowing the grammar to derive more forms of the language, sometimes cause complications and the inadvertent generation of unwanted forms. An exciting task of current Pāṇini research is to recover the original system behind these commentatorial accretions. This is being done by a combination of philological and analytic research. One method is to recover the original intent of doubtful rules by examining the relevant usage in the surviving Sanskrit literature of Pāṇini's time. Another is careful internal analysis of the system. The combination of these methods has revealed underlying principles in the *Aṣṭādhyāyī* of which the commentators and the earlier Western scholars who followed them were quite unaware. It shows the *Aṣṭādhyāyī* to be even more rigorous, simple, and beautiful than was thought.

2 Rules

2.1 Types of rules

The derivation of even a simple sentence requires the application of hundreds of rules. If we include the definitions of the terms in the rules, the metarules that determine their operation and interaction, and the substitution rules that must be taken into account because they are potentially applicable but are blocked by the ones that actually take effect, the mapping from (6) to (1) involves on the order of a thousand rules.

The metalanguage of the *Aṣṭādhyāyī* augments ordinary grammar with special conventions to express rules. An extension of ordinary-language "gapping" (*anuvṛtti*) is used systematically to eliminate repeated items in successive rules, and co-ordination, compounding, and the cases are assigned standardized technical meanings, as described below.[8]

There are four types of rules: derivational rules, definitions, headings, and metarules (rules which constrain the application of other rules throughout the grammar).

The workhorse of derivational rules is the substitution operation:

(7) A_{Gen} B_{Nom} C_{Abl} D_{Loc} = 'A is replaced by B in the environment C ___ D'

where A, B, C, D are segments, morphemes, words, or classes of such items, possibly null. They are identified in rules by the cases they bear as shown. Every substitution has a substituend A (marked by genitive case) and a substitute B (nominative), but not all have a context. Deletion is substitution by a null element called *lopa*, defined in the grammar as 'invisibility'.[9] Individual segments, morphemes, and words are designated by themselves; for example the vowel *i* is referred to in rules as *i*, inflected as an *i*-stem, and a consonant *C* is referred to in rules as *C* or *Ca*, respectively inflected as a consonant stem and as an *a*-stem. For example, rule (8) deletes *s* (*sa*) before *dh* (*dh*), e.g. *(lū+sīC+dhvam* →) *a+lav+is+dhvam* → *a+lav+i+dhvam* (→ *a+lav+i+ḍhvam*) 'you cut for yourselves'. (The parenthesized parts of rules here and below are omitted in the text of the grammar and supplied from the context by dittoing, as we'll see in a moment).

(8) 8.2.25 dhi_{Loc} ($sasya_{Gen}$) ($lopaḥ_{Nom}$) '*s* is deleted before *dh*'

The format of rules inserting suffixes is the same as that of substitution rules except that since nothing is replaced there is no genitive:

(9) A_{Nom} B_{Abl} D_{Loc} = 'A is (inserted) in env. B ___ D'

Augments differ from suffixes in that they become part of the element they are added to. Augmentation rules have the same format (7) as substitution rules but a different interpretation:

(10) A_{Gen} B_{Nom} C_{Abl} D_{Loc} = 'A is augmented by B in the environment C ___ D'

[8] The grammar also uses some primitive (*aśāstrīya*) technical terms, whose meaning is assumed to be known from outside grammar, partly from other sciences and partly from ordinary language. They include *vidhi* 'rule', *ādeśa* 'substitute', 'replacement', *sthānin* 'substituendum, item to be replaced', *(a-)siddha* '(not) effected', *vipratiṣedha* 'conflict (between rules)'.

[9] Locative case also expresses semantic and usage conditions such as "in the sense of an action", "according to the Easterners", "in Vedic literature", "in a derogatory sense". Instrumental case refers to a "mirror-image" context.

A marker on B identifies the rule as an augmentation rule and shows where the augment goes. E.g. (5) *pac-luN̄* 'cooked' → *á-pac-* (→ (2) *ápāci*)

Rules of the form (11), forming a small group of their own, effect phonological coalescence.

(11) A_{Abl} B_{Loc} C_{Nom} = 'A B is replaced by C'

Two such coalescence rules are:

(12) a. 6.1.101 *akaḥ savarṇe dīrghaḥ (saṃhitāyām)* '(in close contact) *aK* (a vowel or syllabic liquid) + a sound with the same oral articulation are replaced (together) by a long (vowel or syllabic liquid). E.g. (2) *káuñjāyanena átra apāci* → (1) *káuñjāyanenátrāpāci*.

b. 6.1.87 *ād (aci) guṇaḥ (saṃhitāyām)* '(in close contact) *a* (short or long) + *aC* (a vocalic nucleus) are replaced (together) by *guṇa* (*a, e, o*)'. E.g. (2) *adyá upa-ā-ítya* → (1) *adyópétya*.

The format of a compounding rule, such as e.g. forms (2) *mahā-nagará* 'great town', 'city' is (13).

(13) A_{Nom} B_{Instr} = 'A is compounded with B'

The semantics of compounds is thus inherited from the semantics of the case-marked noun phrases from which they are derived.

2.2 Applying rules

When there is no specific statement to the contrary, a rule applies if and only if the conditioning context and the undergoing element are adjacent. If something may intervene between them, this must be expressly stated. Phonological rules may place other conditions on the relation between A and C, D, such as requiring them to form a base+suffix combination, to be within the same word or within the same metrical unit, to be in close contact, or to be semantically related. Each such relation determines a different kind of phonological domain. Rules which have one of these domains in common are listed together, in so far as possible, under a heading that specifies that domain for all of them.

A rule can feed and bleed itself in a derivation (Penn and Kiparsky 2012). It will reapply to its own output unless some rule or principle prevents it. For example, in the derivation of 3.Sg. precative *bhū-yās-t* → *bhūyās-st* → *bhūyāst* → *bhūyāt*, final cluster simplification (rule (22) below) applies twice. The reapplication of a rule to its own output is however limited by an (unstated) constraint:

(14) A rule cannot be conditioned twice in a derivation by the same context.

(14) restricts self-feeding in cases like the following. In *atra* 'here', *t* is optionally geminated between a vowel and a non-vowel. The output *attra* may not undergo gemination again (**atttra, *attttra* etc.), since the left-hand context "after a vowel" would be the same vowel each time.

(14) also holds when other rules intervene in the derivation. Thus, like other principles to be described below, it has a global character. In the perfect of *āp* 'obtain', the vowel of the reduplicated syllable is shortened and loses its consonant. After vowel contraction, shortening cannot reapply to give incorrect **apa*:

(15) $\xrightarrow{3.2.115}$ āp-lIṭ $\xrightarrow{3.4.78}$ āp-tiP $\xrightarrow{3.4.82}$ āp-a $\xrightarrow{6.1.8}$ āp-āp-a $\xrightarrow{7.4.59}$ ap-āp-a $\xrightarrow{7.4.60}$ a-āp-a $\xrightarrow{6.1.101}$ āp-a $\not\rightarrow$ *ap-a

(14) holds even when the first application is vacuous. In general, vacuous application must count as application. As the tradition puts it, rules of grammar are like the rain: they fall both on the empty and the full. For example, in the derivation of *āṭa*, like (15) except that the root vowel is short, shortening applies vacuously at the stage *aṭ-aṭ-a*, and therefore cannot reapply to the output *āṭa*.

Even though (14) is not stated in the grammar, we can tell that it was presupposed as a constraint on rule application (rather than invented later to make the rules work). For when (14) would give wrong results, explicit restrictions are formulated to counteract its unwanted effects. This can be seen in the derivation of 3.Sg.Perfect *vivyādha* 'pierced'. Rule 6.1.17 vocalizes a glide in the reduplicant of this root, and 6.1.108 merges the vocalized glide (called *samprasāraṇa*) with the following vowel. Vocalization must not apply twice if the root begins with two glides. For example, the output *vi-vyādh-a* in (16) must be prevented from undergoing the vocalization rule a second time to yield **u-vyādh-a*.

(16) vyadh $\xrightarrow{3.2.115}$ vyadh-lIṬ $\xrightarrow{6.1.8}$ vyādh-vyādh-a $\xrightarrow{7.4.59}$ vyadh-vyādh-a $\xrightarrow{7.4.60}$ vya-vyādh-a $\xrightarrow{6.1.17}$ via-vyādh-a $\xrightarrow{6.1.108}$ vi-vyādh-a (and now not $\xrightarrow{6.1.17}$ *ui-vyādh-a $\xrightarrow{6.1.108}$ *u-vyādh-a).

(14) does not prevent this undesired reapplication of vocalization. Therefore the grammar needs a special restriction to block it from reapplying to its own output:

(17) 6.1.37 A semivowel is not vocalized before a vocalized semivowel.

This restriction stops reapplication of rules exactly where (14) fails to do so. From that we conclude that (14) was adopted as a principle in the construction of the grammar. Confirming implicit principles of grammar by reasoning from the wording of the explicit rules and Minimum Description Length is a powerful method of Pāṇini interpretation.

2.3 Building classes

Most rules refer to whole classes of elements. Instead of listing them *ad hoc* for each class, the grammar defines ways to generate the needed terms from lists of elements. The most interesting of these is the *pratyāhāra* device (Staal 1962, Kiparsky 1991). If a list contains the sequence of elements $\ldots x_p$, x_{p+1}, $\ldots x_q Q \ldots$, where Q is a marker, then $x_p Q$ is a *pratyāhāra* that denotes the set x_p, x_{p+1}, $\ldots x_q$. For example, the *Śivasūtras* list the underlying segments of the language and group them into classes:

(18)	1.	a	i	u			Ṇ
	2.				ṛ	ḷ	K
	3.		e	o			Ñ
	4.		ai	au			C
	5.	h	y	v	r		Ṭ
	6.					l	Ṇ
	7.	ñ	m	ñ	ṇ	n	M
	8.	jh	bh				Ñ
	9.			gh	ḍh	dh	Ṣ
	10.	j	b	g	ḍ	d	Ś

11.	kh	ph	ch	ṭh	th	
			c	ṭ	t	V
12.	k	p				Y
13.		ś	ṣ	s		R
14.	h					L

The procedure just described generates 292 *pratyāhāras* of two or more segments from the *Śivasūtras*, of which 42, including the ones in (19), are used in the rules of the *Aṣṭādhyāyī*.

(19) a. iK = *i, u, ṛ, ḷ*

b. aK = *a, i, u, ṛ, ḷ*

c. aC = *a, i, u, ṛ, ḷ, e, o, ai, au*

d. aṆ = *a, i, u, ṛ, ḷ, e, o, ai, au, h, y, v, r, l*

e. yaṆ = *y, v, r, l*

f. haL = consonant

g. khaR = voiceless obstruent

h. jhaL = obstruent

i. aL = segment

Pratyāhāras can function as constituents A, B, C, and D in rules of the form (7), like any other expression:

(20) 6.1.77 iko$_{\text{Gen}}$ yaṇ$_{\text{Nom}}$ aci$_{\text{Loc}}$ (72 saṃhitāyām) '*i, u, ṛ, ḷ (iK)* → *y, v, r, l (yaṆ)* before a vowel, syllabic liquid, or diphthong (*aC*), in close contact'

This rule replaces the entire *class* of high vowels and syllabic liquids by the *class* of their nonsyllabic cognates. A metarule of the grammar ensures the correct mappings *i* → *y* etc. by requiring substitutions to be minimal.

Since there are 24 obstruents, the following rule compresses 24×24 = 576 atomic rules:

(21) 8.2.26 jhalo$_{\text{Abl}}$ jhali$_{\text{Loc}}$ (sasya$_{\text{Gen}}$) (lopaḥ$_{\text{Nom}}$) '*s* (*sa*) is deleted (replaced by *lopa* 'null') before and after *jhaL*, i.e. between obstruents'

Deletion in two separate environments, before *jhaL* as well as after *jhaL*, could be expressed by adding the particle *ca* 'and' to the second *jhaL*, or by the Instrumental case (fn. 9).

The underlying representations of morphemes contain only sounds listed in the Śivasūtras, the "phonemes" of Sanskrit. However, there is no phonemic "theory" behind the list, no concept of contrast and complementary distribution, no commutation tests or other discovery procedures. The list simply contains those phonological segments which the simplest complete grammar of the language must have in the lexical entries of its morphemes, not including what we now would classify as the suprasegmental features of pitch, length, and nasality. As often, an analog to a key theoretical concept of Western linguistics emerges in Pāṇini's grammar as a sheer byproduct of minimizing description length.

The *outputs* of rules, though, include additional non-phonemic contextually predictable sounds, such as [x], [ɸ], the raised pronunciation [ə] of *a*, the murmured word-final *ḥ (visarjanīya)*, the nasal glide *anusvāra*, and triple-length vowels *a3*, *i3*, *u3*. Yet a third layer, consisting of phonetic implementation details such as

release properties of consonants, allophonic variation in length, glide fortition, and the realization of pitch contours, is not dealt with in the grammar, but receives a full accounting in the phonetic treatises.

To combine items into a class, the grammar uses *ca* 'and', or *dvandva* compounding. Rule (22) deletes *s* and *k* (specified by the dvandva compound *sk-*) at the beginning of a consonant cluster if an obstruent follows *(jhali)* and *(ca)* if the end of a word follows (*padasya ante ca*), as in (23).

(22) 8.2.29 s-k-oḥ$_{\text{GenDu}}$ saṃyogādyor$_{\text{GenDu}}$ (jhali$_{\text{Loc}}$) (padasya$_{\text{Gen}}$) ante$_{\text{Loc}}$ ca lopaḥ$_{\text{Nom}}$

(23) a. (*takṣ-Kta* →) *tákṣ-ta* → *taṣ-tá* (→ *taṣṭá*) 'fashioned (pp.)'

b. *(śak-saN-tiP* →) *śisk-sa-ti* → *śik-sa-ti* (→ *śikṣati*) 'practises'

Another class-forming convention is that *Cu* (where C is any consonant) denotes the class of sounds which has the same oral articulation as *C*. E.g. *tu* refers to the dental stops *(t, d, th, dh, n)*, which differ only in their laryngeal and nasal articulation, and excludes the continuant *s*. Rule (24) replaces palatal stops by the corresponding velar stops before an obstruent and word-finally, e.g. *vac+tum* → *vaktum*, *vāc* → *vāk*:

(24) 8.2.30 coḥ$_{\text{Gen}}$ kuḥ$_{\text{Nom}}$ (jhal-i$_{\text{Loc}}$) (pada-sya$_{\text{Gen}}$) (ante$_{\text{Loc}}$ ca)
'a palatal (*cu*) is replaced by a velar (*ku*) before an obstruent (*jhaL*) and at the end of a word'

The abovementioned metarule again demands that the replacement be minimally different, resulting in the correct substitutions *c* → *k*, *j* → *g*, etc.

A metarule ensures that two or more parallel conjoined phrases in a rule are understood with a one-to-one correspondence between the members, with an implicit 'respectively' as it were. An example is rule (25), which is responsible for the place assimilation of *ḥ* to following velars and labials (for examples see the replacement of *ḥ* by [x] before *k* in (1) above and in (33) below).

(25) 8.3.37 kupvoḥ$_{\text{Loc}}$ x(k)aɸ(p)au$_{\text{Nom}}$ ca (visarjanīyasya$_{\text{Gen}}$) 'before *kU* (velar stops) and *pU* (labial stops), *ḥ* is optionally replaced by [x] and by [ɸ], respectively'

A key technique of the grammar is to organize rules into hierarchies of generality. There is always an "elsewhere" case, covered by the maximally general applicable rule *(sāmānya)*, restricted as necessary by special rules *(viśeṣa)*, each of which can itself be restricted by still more special rules. If the set of forms to which rule A is applicable is properly included in the set of forms to which rule B is applicable, then A is automatically interpreted as superseding B in the shared domain. A more restricted version of this principle has been imported into generative grammar as the Elsewhere Condition.

An example is the relation between rule [26], which deletes word-final C after C, and [27], which deletes just word-final *s* after *r*.

(26) 8.2.23 saṃyogāntasya (padasya) lopaḥ 'delete the last segment of a word-final cluster'
cluster-end-GEN (word-GEN) null-NOM

(27) 8.2.24 rāt sasya (padasya) (lopaḥ) 'delete word-final *s* after *r*'
r-ABL *s*-GEN word-GEN null-NOM

For example,

(28) a. *(go+matUP+sU* →) *go+mānt* → *gomān* 'having cows' (Nom. Sg.)

b. *(a+tsar+sīC+tiP* →) *a+tsār+s* → *atsār* 'he crept'

Having no independent domain of application, [27] constitutes a RESTRICTION *(niyama)* on [26], which means that after *r*, only *s* is deleted, not any other consonant, so that [26] does not apply to forms like (29):

(29) *(a+mṛj+sīC+tiP →) amārṭ (→ *amār)* 'he wiped'

If the context *rāt* were put last in [27], the rule would instead say that *s* is deleted only after *r* — a different restriction. Like a sentence of natural language, a rule can be parsed into a topic and a focus, and the restriction is associated with the focused, normally final element, as if it had an 'only' with it. Apart from such cases, word order is not relevant in Pāṇini's rules.

2.4 Dittoing

The rules, which we have been citing in an expanded form, are compressed in the actual grammar by systematically omitting the repeated expressions parenthesized above. The previously cited consonant deletion rules fall under the heading *(adhikāra)* [30]:

(30) 8.1.16 padasya$_{\text{Gen}}$ 'of (the end of) a word'

Putting the rules in the order enumerated in the grammar, lining up recurrent items, and erasing repetitions,

(31) 8.2.16				padasya		
8.2.23	saṃyogāntasya			—"—		lopaḥ
8.2.24	rāt		sasya	—"—		—"—
8.2.25	dhi (ca)		—"—			—"—
8.2.26	jhalo	jhali	—"—			—"—
8.2.29	skoḥ saṃyogādyor	—"—		—"—	ante ca	—"—
8.2.30	coḥ kuḥ	—"—		—"—	—"—	—"—

yields the abbreviated wording of the rules in the actual grammar:[10]

(32) 8.2.23 saṃyogāntasya lopaḥ (=(26))
8.2.24 rāt sasya (=(27))
8.2.25 dhi ca (=(8))
8.2.26 jhalo jhali (=(21))
8.2.29 skoḥ saṃyogādyor ante ca (=(22))
8.2.30 coḥ kuḥ (=(24))

For maximal concision, the rules throughout the grammar are arranged in such a way as to exploit dittoing to the hilt. Sets of rules that have part of their wording in common are grouped together, and the shared parts are stated once and for all in the first rule of the group. The device is flexible enough to allow dittoing of different overlapping partial commonalities in sequences of rules with variously interlocking combinations of environments. In principle any shared property (trigger, target, intervening element, other conditions) may be the basis for such a grouping of rules, wherever Minimum Description Length dictates.

[10]The discontinuation of the environment *padasya* in 8.2.25 *dhi ca* is indicated in the grammar by *ca* 'and'. Its resumption in 8.2.29 is required by *ante ca*, of which it is the implied complement.

2.5 Domains

By an extension of dittoing on a larger scale, recurrent items can be turned into separate *adhikāras* 'headings', which count as rules but do nothing on their own. In the original text of the *Aṣṭādhyāyī*, headings were marked with *svarita* accents (1.3.11 *svaritena adhikāraḥ*). The accents are no longer pronounced in reciting the rules, but they can be inferred by interpretation and they are identified in the commentaries. Every rule in the domain over which the heading is valid implicitly includes the expression in the heading, whenever it is compatible with the rule's wording. Rule (30) 8.1.16 *padasya* is such a heading, which extends for more than two hundred rules (up to 8.3.54).

The major difference between headings (*adhikāras*) and dittoing (*anuvṛtti*) is that headings are only temporarily set aside by incompatible items specified in rules in their domain, while dittoing is normally canceled permanently by an incompatible item. As a result, headings can extend over much larger stretches of the grammar (over a thousand rules in some cases). The major headings divide the *Aṣṭādhyāyī* into overlapping topical sections. For example, the 1822 rules in chapters 3-5, all dealing with suffixation, begin with headings that say once and for all that any item introduced in them gets the technical designation *pratyaya* 'suffix', is positioned after the base, and has a default accent on its first vowel. In principle any shared property of rules may be the basis for such a grouping – a trigger, a target, an intervening element, other contextual conditions, a specific mode of application. The most important groupings have to do with two kinds of shared properties of rules: their DOMAINS of application, and their mutual INTERACTION. Some of these emergent groupings resemble the types of rules and components of grammar that are posited in linguistics today.

Many phonological rules apply whenever there is close contact between trigger and undergoer, whether across word boundaries or word-internally. In contemporary prosodic phonology, these would be rules or constraints which apply anywhere in the domain of an intonation group. The phonological rules which are restricted to apply in close contact *(saṃhitā)* are termed *sandhi* rules (both words come from *sam-dhā-* 'put together, join'). The most important *sandhi* rules are found in three groups, each introduced by *saṃhitāyām* 'in close contact'. The close contact condition *saṃhitāyām* on phonological rules is in a way the counterpart to the *samartha* (semantic relationship) condition on morphology. However, this condition is not a heading that applies to a particular block of rules but a constraint that governs all *padavidhi* (word-building) rules.

Smaller blocks of rules are limited to applying anywhere within the domain of a *pada* 'word', or a metrical *pāda* 'verse'. All replacement rules apply within sentences (*vākya*). For example, rule 8.1.23 deaccents a finite verb if it is preceded by a word (excepting another finite verb), as *apāci* in (2). It is confined to the sentence domain, so it deaccents verbs which are not sentence-initial, not only verbs which are not discourse-initial. Words, metrical verses, and sentences are also domains whose *edges* can block or condition the application of phonological rules. A sentence-initial or non-sentence-initial environment is defined by the absence or presence of a word on the left or right.

A few rules require *both* close contact *and* semantic relationship between trigger and undergoer. This defines a domain equivalent to modern prosodic phonology's phonological phrase. Within this domain, certain sandhi processes that otherwise apply at word edges are suspended. For example, underlying word-final *-is* and *-us*, which would normally surface as *-iḥ*, *-uḥ*, and as *-ix, -ux* in close contact with a velar, are optionally treated as if they were word-internal if the following word is both semantically related and in close contact, in which case they are pronounced as *-iṣ, -uṣ*.

(33) a. sarpiṣ karoti ∼ sarpiḥ karoti ∼ sarpix karoti 'makes clarified butter'

b. tiṣṭhatu sarpiḥ, piba tvam udakam 'let the clarified butter stand, drink water'

The rules from section 6.4 through the end of chapter 7 are restricted to combinations of an *aṅga* 'base' plus a suffix. In today's terminology, they deal with morphophonology and allomorphy. Most of the purely phonological rules appear in chapter 8. So, although the *Aṣṭādhyāyī* makes no principled distinction among these rule types, something rather like it emerges in the grammar because the principle of economy forces certain groupings that correspond to it. Another distinction reminiscent of the morphophonology/allomorphy divide emerges, again as a result of minimizing description length, between substitutes consisting of one sound and substitutes consisting of more than one sound. In the format of substitution rules (7), A and B are typically either single segments or classes of segments, or single morphemes/allomorphs or classes of morphemes/allomorphs. This generalization is ingeniously exploited to shorten grammatical rules, by the convention that a substitute consisting of a single sound replaces the last sound of the input if the conditioning environment is on the right, and the first sound of the input if it is on the left. This simplifies a vast number of rules, allowing, for example, the replacement of *div-* by *diau-* before certain suffixes to be stated as *div-* → *au-* before those suffixes. (The substitutes that do not conform to this default generalization must be flagged by markers, but even so the convention achieves a net simplification.) Yet another reflection of the morphophonology/allomorphy divide is metarule 1.1.56, which states that non-phonological properties of an input are transferred from inputs to their replacements, while satisfaction of phonological properties is checked only on the actual output string (Joshi and Roodbergen 1985).

To repeat, Pāṇini has no hard and fast rule typology analogous to those developed in some modern linguistic theories. He simply dealt with the morphology/phonology interface phenomena of Sanskrit by means of his usual grammatical technique of substitution rules, driven by Minimum Description Length. Yet by consistently applying this formal technique he ended up framing conventions which in their own way reflect approximately the distinctions between what we would call allomorphic and morphophonological rules, between phonological and phonetic rules, and between different domains of phonological rule application.[11]

2.6 Underlying forms, blocking vs. substitution

The grammar sets up a basic underlying form for every morpheme and uses rules of the form (7) to replace them by their suppletive allomorphs and phonological variants. For example, in the nominal system the endings of the consonant stems are chosen as basic and allomorphs for vowel stems are derived from them by substitution rules: the allomorph *-āt* of the ablative ending selected by *-a* stems is derived from the consonant stem ending *-as*, which is treated as the underlying form of the morpheme, as in (2)-(3) *vána-ÑasI* → *vánāt*. Normally the simplest description results if an actually occurring form is chosen as underlying form, and among the actually occurring forms the one with the "elsewhere" distribution. But sometimes it is simplest to start from an underlying form which never occurs as an actual form, e.g. /masj/ 'submerge', which surfaces as *majj-*, *madg-*, or *mag-*, depending on the phonological context, in each case by independently motivated rules of the language. Taking any of the three actual output forms as underlying would require complicating the grammar with at least one additional rule.

An example of abstract underlying representation of phonology is short *a*. It is pronounced as a centralized [ə], whereas *ā* and extra-long *a3* are open. In order to simplify the many shortening, lengthening, and contraction rules of the grammar, all *a*-vowels are represented as open in the grammar. Short *a* then gets its correct phonetic value context-freely by the last rule of the *Aṣṭādhyāyī*:[12]

[11] Another example of an emergent morphology/phonology distinction in the grammar is the distinction between the general null element *lopa*, which leaves no trace, and the null replacements for suffixes, which retain special morphological properties encoded by their markers *luK, ślu*, and *luP*.

[12] To which the last line of Chomsky & Halle 1968 pays homage. Presumably the rule is to be read [a ə], but the Sanskrit writing system has no symbol for [ə].

(34) 8.2.68 *a a* '*a* is replaced by [ə]'

This rule ordering ensures that the raising of *a* is invisible to all other rules of the grammar. Overapplication to *ḥ*, which has the same *kaṇṭhya* 'pharyngeal' and *vivṛta* 'open' oral articulation, is averted by the convention that vowels and consonants do not have the same oral articulations (not even when they phonetically do).

The tradition recognizes a conceptual relationship between substitution and blocking. In the substitution method, the basic form of the morpheme is introduced by a general rule everywhere and then replaced by the morpheme alternants in specific contexts. In the blocking method, the basic form is introduced by a general rule and the alternants by special rules which block the general rule in specific contexts. Pāṇini mostly uses blocking in derivational morphology, and substitution in inflectional morphology, for two reasons. One reason is that substitutions by convention inherit the morphological properties of the elements they replace (for example, they have the same effects on the vowel shape and accent of the stem to which they are added). In Sanskrit, at least, these properties are typically invariant in inflectional alternants, but vary in derivational alternants (presumably at least in part because paradigmatic leveling is more frequent within an inflectional paradigm). The deeper reason is that derivational morphemes can be restricted to certain classes of stems or to certain phonological contexts. This is easily dealt with by restricting the rules that introduce them to those contexts. Inflectional morphemes, however, form an n-dimensional paradigm space without gaps. So it is essential to have a default ("elsewhere") allomorph for each cell in this space.

The substitution and blocking techniques can also be combined by setting up a wholly abstract underlying form, and a rule replacing it by the basic allomorph, which in turn is blocked by the special allomorph. An example of this is Pāṇini's treatment of the aorist formative, which has several variants: the basic allomorph *s (sIC)*, *sa*, *a* (with or without reduplication), and zero. All are derived from underlying *cli*, which never surfaces in that form. It is always replaced, either by the basic allomorph *s*, or in specific contexts by other allomorphs. The zero ending however is derived from *sIC* itself by a set of substitution rules which substitute the null element *luk* for it, which differs from the general null element *lopa* in its morphological features.

Pāṇini's grammar reveals an important morphological generalization: the locus of suppletion is the morpheme. Exceptional words may be listed as such, and there are gaps in some of the paradigms, but there are no rules in the grammar that replace a morphologically complex word by another morphologically complex word at a single stroke. If the description could be simplified by positing whole-word suppletions, they would be there. But there appears to be nothing in the language that would justify them. Should this generalization hold for languages in general, it would speak for morpheme-based approaches over whole-word or paradigm-centered approaches to morphology.

2.7 Summary

We have now seen five devices that compress the grammar: (1) ordering, (2) blocking, (3) generation of terms from lists, (4) dittoing, (5) headings. Their effect goes far beyond just shortening the rules. They are the formal engine behind the extraordinary insights about Sanskrit grammar and the organization of language that Pāṇini's work embodies. The downside is that these and other devices make the grammar hard to use. The import of a rule does not come just from its wording, but also from its relation to other rules in the system and from the organization of the grammar.

3 Rule interaction

We have the text of Pāṇini's grammar, but no contemporary presentation of the theory behind it. Some principles are stated in the grammar itself, others must be deduced from the way the material of the language is handled in it. Over two thousand years of commentatorial ingenuity has made good headway towards a solution, but much remains poorly understood. Recent research has been particularly active on this front. In the available space I cannot do justice to the controversies swirling around these complex questions. What follows is a review of selected issues in the theory of rule interaction, which is particularly germane to current debates about rule-based versus constraint-based phonology. To repeat, the principles discussed in this section are not presented explicitly in the grammar. They are inferred with varying degrees of certainty from the wording of its rules by relying on two main patterns of inference. Most importantly, if a principle is required for the rules of the grammar to generate the known correct forms, we assume that Pāṇini had it in mind when composing the grammar. Supporting evidence can then come by observing that an otherwise pointless complication in one or more rules becomes necessary if the principle is assumed to be valid.

Independently of the topical organization according to domains of application, rules fall into major groups on the basis of the way they interact with each other. Just as string adjacency is the unstated default relation between trigger and target, and those cases where some other relation between them obtains are specially provided for in the grammar, so there is an unstated default principle governing rule interaction, and those interactions which diverge from the default are specially provided for. The default principle is that rules apply wherever they are applicable, and that they are mutually visible and interact to the maximal possible extent. The default principle must be complemented by other prioritizing constraints, and in some cases defeated. This section shows how the default principle works and describes some of the special constraints that complement and defeat it.

3.1 Word phonology precedes phrase phonology

The WORD-INTEGRITY PRINCIPLE holds throughout the grammar:

(35) Rules apply first within words and then to combinations of words.

Atra 'here' in (2) is the locative of *etad* 'this'. In pronouns, a second inflectional ending *-tra* is optionally inserted after the locative case ending by 5.3.10, resulting in *atra-i-tra*, which then loses its case ending *-i* by 2.4.71. Finally, 2.4.33 replaces *etád* by *á*. The derivation is shown in (36) (leaving out the markers).

(36) etád $\xrightarrow{2.3.36}$ etád-i $\xrightarrow{5.3.10}$ etád-i-tra $\xrightarrow{2.4.71}$ etád-tra $\xrightarrow{2.4.33}$ á-tra

Now consider *átra ījatuḥ* → *átrejatuḥ* 'the two of them sacrificed here'. The derivation of *ījatuḥ* is:

(37) yaj $\xrightarrow{3.2.115}$ yaj-lIṭ $\xrightarrow{3.4.78}$ yaj-tas $\xrightarrow{3.4.82}$ yaj-atus $\xrightarrow{3.1.3}$ yaj-átus $\xrightarrow{6.1.8}$ yaj-yaj-átus $\xrightarrow{6.1.15}$ yaj-iaj-átus $\xrightarrow{6.1.17}$ iaj-iaj-átus $\xrightarrow{6.1.108}$ ij-ij-átus $\xrightarrow{7.4.60}$ i-ij-átus $\xrightarrow{6.1.101}$ ījátus

If the derivation passes through a stage *etád-i i-ij-átus*, we risk applying (12a) twice to get **etádījatus*. If it passes through a stage *átra i-ij-átus*, we risk applying (12b) to get **átreijátus* → **átrayijátus*. If it passes through a stage *átra ij-ij-átus*, we risk applying (12b) to get **átrejijátus*. These and a host of other wrong forms are avoided at a stroke by (35), which prioritizes internal contraction *ii* → *ī*, followed by external contraction *aī* → *e* to give the desired *átrejátus*.

(38) átra i-ijátus $\xrightarrow{6.1.101}$ átra ī̆j-átus $\xrightarrow{6.1.87}$ átrejátus

In *á-yaj-a-i índram* 'I sacrificed to Indra' the same two rules compete, but this time *ai* → *e* is word-internal, and must precede *ii* → *ī* by (35):[13]

(39) a. Correct: á-yaj-a-i índra-am $\xrightarrow{6.1.87}$ áyaje índram $\xrightarrow{6.1.78}$ áyajay índram $\xrightarrow{8.3.19}$ áyaja índram

b. Wrong: á-yaj-a-i índra-am $\xrightarrow{6.1.101}$ áyaja índram $\xrightarrow{6.1.97}$ *áyajéndram

The tradition goes beyond Pāṇini in generalizing (35) to the *antarañga*-principle, which imposes cyclicity on word-internal derivations as well:

(40) If the conditioning context of rule A lies outside the conditioning context of rule B, rule A is *asiddha* (not effected) with respect to rule B.

By (40), if context B is included in context A, a rule applying in B takes effect before one applying in A, even if both A and B are word-internal. This principle is plausible and embraced in some contemporary theories of phonology and morphology, but appears not to have been adopted by Pāṇini.[14]

3.2 Blocking

Special rules block general rules in the overlapping domain, even if they are in different parts of the *Aṣṭādhyāyī*. The commentators point out that blocking can be inferred from the Minimum Description Length principle: if the special rules did *not* block the general rules in the overlapping domain, they would have no scope and they would be unnecessary complications in the grammar. There are, however, types of blocking where this inference is not straightforward. Two will be briefly mentioned here.

There are indications that the blocking of general rules by special rules, like (14), works on a global, "lookahead" basis.[15] An example is the derivation of *aśvakrītī* 'bought with a horse' (fem.), which must go like this:

(41) aśva-Ṭā krī-Kta-sU $\xrightarrow{2.1.32}$ aśvakrīta $\xrightarrow{4.1.50}$ aśvakrīta-ÑīṢ → aśvakrītī

The special rule 4.1.50 adds the feminine suffix *-ÑīṢ* to *krīta* in an instrumental compound. But at the input stage, prior to compounding, *krīta* runs the risk of getting the general feminine suffix *-Ṭā*. The feminine suffix must have the foresight to wait until compounding establishes the proper environment for it.

The tradition moreover extends the blocking relation to COLLECTIVE BLOCKING. Rules (20), (12a), and (12b) illustrate how the blocking relation between special and general rules is generalized from pairs of rules to sets of arbitrary size. According to this generalized form of the blocking principle — call it *collective blocking* — blocking is induced not only by a domain inclusion relationship between two rules, but also by a domain inclusion relationship between a rule and a *set* of rules (Kiparsky 1982:115 ff.).

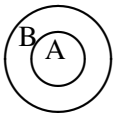
[13]Derivation of *á-yaj-e* 'I sacrificed': yaj $\xrightarrow{3.2.111}$ yaj-lAÑ $\xrightarrow{3.4.78}$ yaj-iṭ $\xrightarrow{1.3.3}$ yaj-i $\xrightarrow{3.1.68}$ yaj-ŚaP-i $\xrightarrow{1.3.8}$ yaj-a-i $\xrightarrow{6.4.71}$ á-yaj-a-i $\xrightarrow{6.1.87}$ á-yaj-e.

[14]In Joshi and Kiparsky 1979 and Kiparsky 1982 Ch. 3, we present numerous counterexamples to (40), and argue that all cases that do conform to it (such as (47)) are accounted for by the independently motivated *siddha*-principle presented below. The debate has narrowed to the controversial example *dhiyati* (Cardona 1990, 1997:xxiii, Kiparsky 1991, to appear).

[15]In the words of the grammarian Nāgeśa, "an *apavāda* supersedes, even though the causes of its (application) are still to present themselves, a general rule the causes of which are already present." (tr. Kielhorn 1974).

(42) *Collective blocking:* If the domain of rule A is properly included in union of the domains of a set of rules $\mathcal{R} = \{R_1, R_2, \ldots R_n\}$, A blocks each of the rules in $\mathcal{R}$.

So rule A blocks both B and C:



Regular blocking

Collective blocking

There is no proper inclusion relationship between the environments of any two of the three rules (20), (12a), (12b). Rules (20) and (12a) overlap for *i*+*i, u*+*u*, rules (12b) and (12a) overlap for *a*+*a*, and (20) and (12b) have no common domain. Taken pairwise, there is no possibility of blocking here. But if we take the three rules together, it is evident that the input to (12a) is a proper subset of the *combined* inputs to (20) and (12b). From this point of view, (12a) has no domain of its own, and by generalized blocking should set aside each of the other two rules in their respective shared domains. This is the correct result, for it is true that (12a) always wins both over (12b) (*a*+*a* → *ā*, not *a*) and over (20) (*i*+*i* → *ī*, not *yi*).

3.3 The *siddha*-principle

Pāṇinian rules are always applied strictly sequentially, one after the other (Bronkhorst 1980). In the default case, with word-priority (35) and blocking satisfied, the sequence is determined by the *siddha*-principle. Intuitively, the idea of the *siddha*-principle is that you apply rules in the order that takes into account the application of other rules as much as possible, consistent with sequential application. In other words, rules should interact as much as possible. The *siddha*-principle has a positive and a negative aspect. The positive aspect is that, if A creates inputs to ("feeds") B, the effects of A are taken into account when applying B. In ordering terms, it means that A takes effect before B. The negative aspect is that, if A deprives B of inputs ("bleeds" it), the effects of A are also taken into account when applying B. Thus, the *siddha*-principle says that rules interact in a TRANSPARENT way.

Since Sanskrit does have opaque rule interactions, it is sometimes necessary to suspend the *siddha*-principle, both in its positive and negative aspect. The *siddha*-principle is a violable default principle, defeatable at a cost. Most rules in which the *siddha*-principle must be thwarted are collected under two headings which specify a class of rules as *asiddha* "not effected", "invisible" (or *asiddhavat* "as if not effected") with respect to another rule or class of rules. The placement of a rule into either of these sections is invariably motivated either directly by the need to prevent it from feeding and/or bleeding an earlier rule, or indirectly by a relation that it bears to such a rule (Buiskool 1939).

The bigger of these groups extends from 8.2.1 through the end of the grammar (8.4.68), and is hence called the *Tripādī* 'Three Sections'. It is headed by the famous rule 8.2.1 *pūrvatrāsiddham*, which states that any subsequent rule is *asiddha* with respect to any rule that precedes it. This means that the rules in the *Tripādī* apply strictly in the order in which they are enumerated, after which the derivation terminates, as in classical generative phonology (Chomsky and Halle 1968).

In the other group, headed by 6.4.22, rules apply as if simultaneously. In this more radical form of non-interaction, no rule in the section feeds or bleeds any other rule in it. This is equivalent to all rules applying

simultaneously of input representations. This mode of non-interaction is motivated by a few cases of mutual bleeding, where rule A, if taking effect first, would change the way the rule B applies, and conversely.

An example of the anti-feeding function of the *asiddha* relation is Instr.Pl. *rājabhiḥ* 'by kings'. The final *-n* of the underlying stem *rājan-* is deleted by rule 8.2.7. Rule 7.1.9 substitutes the instrumental plural suffix *-ais* for *-bhis* after short *a*, e.g. *vṛkṣa-bhis* → *vṛkṣa-ais (→ vṛkṣais)* 'by the trees'. These rules potentially interact, for the result of applying 8.2.7 to the *n*-stem *rājan-bhis* is *rāja-bhis*, a form to which 7.1.9 is is applicable, but must not be allowed to apply, lest *-bhis* be wrongly replaced by *-ais*, as in *a*-stems. The grammar achieves this by putting the *-n* deletion rule 8.2.7 into the *Tripādī* section and ordering the allomorphy rule 7.1.9 before it. The restriction 8.2.1 *pūrvatrāsiddham* then blocks *-n* deletion from supplying new inputs to allomorphy (from FEEDING it, we shall say).

An example of the anti-bleeding function of the *asiddha* relation is *pakva* 'cooked'. In its derivation from *pac-ta*, two processes are applicable. Rule 8.2.52 requires the replacement of *-ta* by *-va* after the root *pac*, and rule (24) requires substitution of the root-final *-c* by *-k* when a *jhaL* consonant (an obstruent) follows. The *siddha*-principle predicts the wrong form **pacva*, with *-ta* → *-va* applying first, which would bleed *-c* → *-k*, since *v* is not a *jhaL* consonant. In order to ensure that the replacement *-ta* → *-va* is invisible to *-c* → *-k*, it is placed *after* it in the *Tripādī*. It is thereby *asiddha* with respect to it, i.e. it fails to bleed it. In this way, both types of opacity can be dealt with by designating a rule as *asiddha*.

In the derivation of *atra* in (36), at the point *etád-tra*, the unwanted output **etáttra* is avoided because the voicing assimilation rule 8.4.55 *khari ca* is in the *Tripādī*, hence *asiddha* at this point.

A metarule of the system which states an exception to the *siddha*-principle is 1.1.62 *pratyayalope pratyayalakṣaṇam*. For example, the grammar defines a word as that which ends in a case or verb inflection. Case endings which are deleted in compounds like *mahānagara-* 'city' and in indeclinables like *adya* 'today' (see (3)) must still count for purposes of defining wordhood. However, the *siddha*-principle would say that the deletion of the case endings should bleed the assignment of word status. For this purpose the grammar includes a metarule that suffixes which are deleted (that is, replaced by *lopa*) trigger the same effects as overt ones.

So imposing the *asiddha* relation on operations is equivalent to restricting the relative order in which the rules that enjoin those operations take effect. The restriction "A is *asiddha* (not effected) with respect to B" then has the same import as the restriction "B and A take effect in that order".

3.4 The global nature of the *siddha*-principle

We have seen that (14) and blocking must be applied in a global fashion. The same appears to be the case for the *siddha*-principle (Joshi and Kiparsky 2005).

The *siddha*-principle is not stated in the grammar itself but presupposed by it. We cannot know how Pāṇini formulated it, but we can tell from the grammar what he wanted it to do. An intuitive way to think of it is that rules take effect in whatever order yields a result that is *different* from the result of applying them simultaneously. That means applying rules in that order in which they interact as much as possible, which maximizes feeding and bleeding (Joshi and Kiparsky 1979, Kiparsky 1982, Joshi and Roodbergen 1987).

To facilitate the formal statement of the *siddha*-principle, we introduce a bit of notation. Let $\mathcal{C}(\phi)$ be the result of applying $\mathcal{C}$ to ϕ. Then B(A(ϕ)) is the result of first applying rule A to ϕ, and then applying rule B to the result. A,B(ϕ) is the result of applying A and B simultaneously to ϕ. Using this notation, the idea that *asiddha* means "crucially non-interacting" is captured by the following definition:

(43) In B(A(ϕ)),

a. A is *asiddha* with respect to B if B(A(ϕ)) = B,A(ϕ) and A(B(ϕ)) $\neq$ B,A(ϕ),

b. A is *siddha* w.r.t. B if B(A(ϕ)) $\neq$ B,A(ϕ)

c. otherwise the *siddha* and *asiddha* relations are undefined.

The *siddha*-principle can then be formulated as follows:

(44) Maximize *siddha* relations.

There are several ways to maximize *siddha* relations in derivations. We could assume that the *siddha*-principle applies at each point in a derivation to determine which of the rules applicable at that point should take effect. Or we could assume that it scans entire candidate derivations and chooses the one in which *siddha*-relations are maximized. There is evidence that the *siddha*-principle has the latter, crucially global "lookahead" character.

The active perfect participle of *sad* 'sit' is *sed-vas-*, where *sed-* replaces the reduplicated stem *sa-sad-*. In *bha*-stems, meaning before oblique vocalic suffixes such as Gen.Sg. *-as*, the suffix *-vas* is vocalized to *-us*, e.g. Gen.Sg. *seduṣaḥ*, see (45b). Otherwise, when *-vas* does not undergo vocalization, it receives an initial augment *i* under certain conditions by rule 7.2.67, as in Nom.Sg. *sedivān* (with deleted *-sU*), see (45c).

(45) a. 6.1.8 Before *lIṭ* suffixes, an unreduplicated root is reduplicated.

b. 6.4.131 The semivowel *v* of the suffix *-vasU* is vocalized in *bha* stems.

c. 7.2.67 The augment *iṭ* is inserted before *-vas* after a monosyllabic root.

The derivation of Nom.Sg. *sedivān* shows the insertion of the augment *i* before *-vas* by (45b).

(46) sad $\xrightarrow{3.2.115}$ sad-lIṭ $\xrightarrow{3.2.108}$ sad-KvasU $\xrightarrow{6.1.8}$ sasad-vas $\xrightarrow{6.4.120}$ sed-vas $\xrightarrow{4.1.2}$ sed-vas-sU $\xrightarrow{7.2.67}$ sed-ivas-sU $\rightarrow$ sedivān (other rules)

In the derivation of *seduṣaḥ*, vocalization of *-vas* to *-us* by (45a) bleeds *i*-insertion (the first part of the derivation is the same as in (46)):

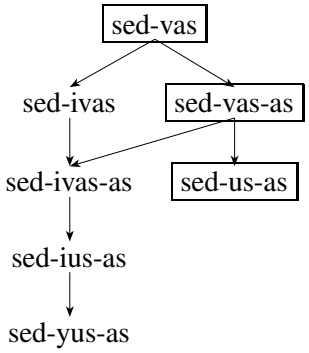
(47) sad $\xrightarrow{3.2.115}$ sad-lIṭ $\xrightarrow{3.2.108}$ sad-KvasU $\xrightarrow{6.1.8}$ sasad-vas $\xrightarrow{6.4.120}$ sed-vas $\xrightarrow{4.1.2}$ sed-vas-ñas $\xrightarrow{6.4.131}$ sed-us-as $\rightarrow$ sed-uṣ-aḥ (other rules)

This derivation requires the extended *siddha*-principle to prevent *i*-insertion from taking effect *while its conditioning environment is still present*, as in (48).

(48) sed-vas $\xrightarrow{7.2.35}$ sed-ivas $\xrightarrow{4.1.2}$ sed-ivas-ñas $\xrightarrow{6.4.131}$ sed-ius-as $\rightarrow$ *sed-yuṣ-aḥ (other rules)

Here are the possible derivations (beginning with the stage *sed-vas)*:

(49)



At the initial stage of (49) *sed-vas*, there is a choice between adding the case ending (*sed-vas-* → *sed-vas-ñas*) and adding the *i*-augment (*sed-vas-* → *sed-ivas-*). The correct output is derived only if case affixation takes effect first. For then, at the stage *sed-vas-ñas*, the *siddha*-principle favors vocalization over *iṭ*, so the output is *seduṣaḥ*. If, on the other hand, the *i*-augment is added first, the derivation proceeds inexorably by the left-hand path in (48) to the wrong output **sedyuṣaḥ*. So the question is why, at the stage *sed-vas*, case affixation gets priority over *i*-augmentation. (43) correctly characterizes the fact that derivation (47) is optimal because it maximizes rule interaction. It does not just avoid local violations of the *siddha*-principle, but it is makes the *siddha*-principle do as much work in the derivation as possible.

When the global *siddha*-principle predicts the *wrong* rule interaction, the grammar takes steps to fix the problem. The verb forms *agāt* 'he went' and *āyan* 'they went' offer a minimal pair which demonstrates that (for more evidence, see Joshi and Kiparsky 2005). Both verb forms have the underlying root *i*, replaced by *y* in *āyan*, and by suppletive *gā* in *agāt*. Thus, the originally vocalic root comes to begin with a consonant in both forms. By 6.4.71, the past tense augment is *ā-* before a vowel and *a-* before a consonant. The *siddha*-principle dictates that this distribution should be checked on the surface, or at least after *i* is replaced by *gā*, predicting a short augment in both forms. This is right for *agāt* 'he went':

(50) i $\xrightarrow{3.2.115}$ i-luN̄ $\xrightarrow{3.4.78}$ i-ti $\xrightarrow{3.4.100}$ i-t $\xrightarrow{2.4.45}$ gā-t $\xrightarrow{6.4.71}$ a-gā-t (now 6.4.71 inserts the augment *a)*

At the stage *i-ti* by the inflectional ending *-t(i)*, the local version of the *siddha*-principle does not give priority to the replacement operation *i* → *gā* over augment insetion, nor, for that matter, over *luN̄* → *ti* and subsequent *ti* → *t*. The global *siddha*-principle, however, correctly requires the augment rule to "look ahead" and to hold off inserting the augment until *gā* is in place, thereby maximizing *siddha* relations over the derivation.

By the same token, however, the extended *siddha*-principle gives the wrong result for the other form, *āyan* 'they went', where the augment *ā* does get inserted, as if the root still begins with a vowel. The *siddha*-principle says that the relevant context is the surface *y*, which replaces *i* before a vocalic ending by 6.4. With this in mind, Pāṇini has put both relevant rules, 6.4.72 *āḍ ajādīnām* and 6.4.81 *iṇo yaṇ*, into the special section headed by 6.4.22 *asiddhavad atrā bhāt*, which states that all rules in this section are as if *asiddha* with respect to each other. This rule sets aside the *siddha*-principle and tells us to "pretend" that the root still begins with a vowel, ensuring that the augment *ā* is selected *as if* the root vowel had not been replaced by *y*. The derivation again skips a few steps for the sake of perspicuity.

(51) i $\xrightarrow{3.2.115}$ i-laN̄ $\xrightarrow{3.4.78}$ i-an (up to this point, the desired augment ā could be derived by 6.4.72 *āḍ ajādīnām*) $\xrightarrow{6.4.81}$ y-an $\xrightarrow{6.4.72}$ ā-y-an (in virtue of 6.4.22)

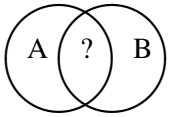
Such examples constitute evidence that the construction of Pāṇini's grammar assumes the extended *siddha*-principle. Rules have been put under the scope of 6.4.22 *only* in order to defeat the *siddha*-principle. Since only the global *siddha*-principle provides sufficient reason for putting 6.4.81 into that section, that is the version that Pāṇini must have worked with.

The *siddha*-principle, especially in its lookahead version, emerges rather naturally in nonderivational, constraint-based phonological theories. Harmonic Serialism, though, might have a struggle with lookahead effects, and perhaps Stratal OT as well, depending on whether and how the problematic Pāṇinian analyses transpose into level-ordered morphology and phonology.

3.5 Conflict between overlapping rules: an unsolved problem

The single most intractable problem in figuring out how the grammar works is what determines the precedence among rules with a symmetrically overlapping domain. In the following commonly occurring situation, which rule wins?

(52) Overlapping



Scharf (2009) has shown that many instances of this problem, though not all, yield to a LIMITED BLOCKING approach. The procedure is to determine the overlapping domain of the rules, and check their relative scope in it. The rule that has the more specific scope in the overlapping domain has priority.

4 Simplicity, brevity, and generalization

The simplicity principle adopted by Pāṇini – call it Pāṇini's Razor – is conceptually related both to Occam's Razor and to the simplicity criterion of Chomsky and Halle (1968). Occam's Razor, as understood in modern science, requires making the fewest assumptions and postulating the fewest entities. Pāṇini's Minimum Description Length principle relativizes Occam's Razor by pitting the cost of assumptions and postulates against the work they do. They are welcome as long as the complexity that their formulation incurs earns its keep by simplifying the overall grammar. This means that complexity is calculated on the entire grammar, not only the operative rules but also the conventions that govern their application and interpret their abbreviatory conventions, as well as the list of roots and the Śivasūtras. The idea is essentially what is known as Minimum Description Length (Rissanen 1998) or Kolmogorov Complexity (Li and Vitányi 2008), see Nannen 2010 for a concise review.

Generative grammar's simplicity criterion, on the other hand, is an empirical hypothesis internal to linguistic theory. It holds that the theory provides a format for grammars (requiring the use of phonological features and certain abbreviatory devices, among other things) in which the brevity of a grammar correlates with its goodness as judged by general scientific criteria such as elegance and predictive success (Chomsky 1955: 118). Like Pāṇini's principle, it applies globally to the whole grammar, for example in weighing complications of rules against complications of the lexicon, but unlike Pāṇini's principle it entirely omits from the calculation the complexity of the theory behind the grammar.

Pāṇini's Razor is not limited to the Minimum Description Length principle. It also subsumes a form of Occam's Razor, which requires selecting among equally simple descriptions the one that minimizes new theoretical terms. For example, the grammar uses the minimum necessary number of *pratyāhāras*, even though they are all generated free of charge by the general procedure described in section 2.3 above.

Another aspect of Pāṇini's Razor is the preference for SPECIFICITY. Among equally simple formulations compatible with the data, Pāṇini systematically chooses the most restricted one — if possible, one which covers only the actually occurring cases. Thus specificity is a conservative curb on overgeneralization.

Given that Occam's Razor (the minimization of terms) and Specificity are subordinated to Minimum Description Length in Pāṇini's Razor, what is their importance relative to each other? Consider metarule 1.1.48: *e, o, ai, au* (*eC*) shorten to *i, u* (*iK*). As the reader can check in (18), *iK* includes *ṛ* and *ḷ*, which can never replace *e, o, ai, au* by any shortening rule because they can never be closer cognates of them than *i, u* are. Pāṇini could have made 1.1.48 more specific by using instead of *iK* the already defined but unused

pratyāhāra *$iṆ$ = *i, u* (like $eN\bar{\imath}$ = *e, o*). The fact that he didn't do so suggests that Occam's Razor outranks Specificity. So I tentatively conclude that Pāṇini's Razor consists of the following ranked constraints:

(53) Pāṇini's Razor

Minimum Description Length ≫ Occam's Razor ≫ Specificity

From a modern perspective (which would have been totally alien to Pāṇini of course) Pāṇini's Razor offers an interesting approach to induction, especially in language acquisition, where the problem is to find a learning mechanism that avoids overgeneralization on the one hand, and undergeneralization by overfitting the description to the data on the other.

5 Pāṇini's impact on linguistics

Each period and school of linguistics has fashioned its own portrait of Pāṇini. Descriptive grammarians praise its accurate and complete coverage and its strictly synchronic perspective,[16] formal linguists its conciseness and rigor, empiricists like Bloomfield its lack of prior commitments to any scheme of "universal grammar", generativists its ingenious technical devices and conventions governing rule application and rule interaction, which seem such uncanny precursors of contemporary theory (though they were in truth for the most part inspired by Pāṇini in the first place).

"Influence" in science is usually not the simple adoption or transplantation of ideas, but their reconstruction in a framework that is already commensurable in the relevant respects and equipped to accommodate them. The understanding of the analytic principles behind Pāṇini's grammar has evolved in parallel with linguistic theory itself for over two centuries. A full picture of the multifaceted connections of linguistics with Pāṇini interpretation would be a major project for the history of linguistics. What follows are merely a few remarks on some of the milestones.

The story begins in the early 19th century, when linguists leaned from Pāṇinian grammar how words can be analyzed into morphemes – a major advance over the traditional model where words are inflected by applying processes to their citation form. Without this crucial innovation Bopp could not have developed the comparative method. Another 19th century insight from India may be the phonetic tradition of cross-classifying vowels and consonants by the same features (*a* is a velar vowel, *i* is a palatal vowel, and so on) – not adopted by the early British phoneticians and the IPA, but persisting in Uralic phonetics, among others, and later revived by Jakobson in his distinctive feature system.

It was not until the early 20th century that Pāṇini-style formal grammatical analyses were attempted, beginning with Bloomfield in his Algonquian work. His Menomini grammar is a level-ordered system. On the phonological side, it has three sequentially applying modules of rules: (1) Modification (allomorphy and morphophonology), (2) Internal combination (general phonological processes), and (3) Rules of actual speech, roughly equivalent to postlexical phonology and phonetic implementation rules in contemporary terms. The morphology follows Pāṇini's model closely. Primary derivation is based on the root, and is obligatory, whereas secondary derivation is based on derived stems, and is optional. Derivations of both types assign either a new grammatical category or a new meaning to the stem; inflectional affixes indicate the syntactic role of the derived category in the sentence, and are governed by grammatical processes.

[16] Whitney's attempt to discredit Pāṇini's grammar on matters of fact were refuted by Sanskritists long ago; more recent discoveries have added dramatic confimation of its accuracy (Kiparsky 1979:13).

Inflectional processes nearly always apply to derived stems, and do not themselves feed back into derivational morphology. Bloomfield's Pāṇinian analytic technique in turn influenced Jakobson's classic study of Russian conjugation (1948).

Bloomfield so-called "Postulates" (1926) are actually a Pāṇinian network of *definitions* that build up the universal grammatical concepts, such as PHONEMES and WORDS, from a small set of primitives, such as ACT OF SPEECH, COMMUNITY, ALIKE, EVERY. They are modeled on Pāṇini's (*saṃjñā*) rules, except that Bloomfield replaces the listing of phonemes and morphemes by operational definitions for inductively deriving them from the data.[17]

Only with the advent of generative grammar could linguistics begin to adopt the formal combinatoric devices and principles of Pāṇini's grammar: marked and unmarked rule ordering (Kiparsky 1969), the Elsewhere Condition (Kiparsky 1972), Thematic Roles (Ostler 1979), Inheritance Hierarchies (Deo 2007). There is much more to discover and we will find it when we are ready for it and know where to look.

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[17] It is sometimes falsely claimed that Bloomfield took his cue from his behaviorist colleague Albert Weiss. Weiss' own "Postulates", however, are simply a set of empirical theses; unlike Bloomfield's, they do not amount to a Pāṇinian deductive system.

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