Derivational Morphology in Inheritance-based Lexica: Insights from Pāṇini *

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Abstract: This paper demonstrates that the treatment of nominal derivational morphology in Pāṇini’s grammar of the Sanskrit language (ca. 500BC) is based on an architecture strikingly similar to that of modern inheritance-based lexica. Specifically, Pāṇini adopts a single inheritance network with defaults to account concisely for intricate cases of affix homonymy and affix synonymy with minimal redundancy. The result is a hierarchy with an interleaving of formal and semantic word formation rules at multiple levels. Affix homonymy is treated by subsumption of semantic rules under formal rules, while affix synonymy is handled in terms of morphological blocking. Formally, this architecture yields an elegant representation of the complex derivational facts of Sanskrit. Moreover, the interleaving of formal and semantic rules along a single inheritance path presents a novel way to model derivational relations in a constrained manner.

Keywords: derivational morphology, inheritance networks, Panini

1 Introduction

My first claim in this paper is that the section on nominal derivational morphology in the Aṣṭādhyāyī of Pāṇini — the taddhita section — is structured as a default inheritance hierarchy. The use of inheritance networks in the representation of the derivational lexicon is not a new idea and has been explored fruitfully in different approaches (Hippisley, 1999; Krieger and Nerbonne, 1993; Riehemann, 1993, 1998,

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What distinguishes Pāṇini’s approach is not only temporal priority, but a novel method of interleaving formal and semantic specifications along a single inheritance path to model many-to-many correspondences between the formal and semantic properties of derivational affixes.

Inheritance networks can perspicuously represent morphological generalizations over classes of linguistic objects and regular and non-regular exceptions to these. The formal features of a particular network (e.g. the use of single vs. multiple inheritance, defaults vs. total subsumption) partially depend on theoretical assumptions about morphological phenomena.¹ My second claim is that the organization of Pāṇini’s taddhita derivational hierarchy, while not exactly articulating a distinct theoretical choice, presents an interesting alternative to existing theories of the relation between affixal form and affixal meaning in derivational morphology — an alternative I will call Constrained Separationism. The idea does not consciously underlie Pāṇini’s conception of the hierarchy, which is driven primarily by considerations of brevity. It has been demonstrated that strict adherence to brevity of description leads Pāṇini to maximal generalization and significant insights about the organization of linguistic knowledge (Kiparsky, 1991, 2002; Kiparsky and Staal, 1969). The hierarchical network in the taddhita section is yet another instance where brevity produces an insightful proposal about the organization of morphology.

To support my first claim, I explicate the structure of the taddhita section, and show that its organization reveals that the text is a linearized representation of hierarchical relationships. To support my second claim, I briefly review two main theoretical trends in morphology and their approach to many-to-many correspondences between form and meaning in morphology. I then demonstrate that Pāṇini’s analysis presents an alternative way of representing these correspondences, which results in an elegant description of complex derivational facts in Sanskrit.

This paper is organized as follows. In §2, I discuss the Sanskrit data that illustrates form-meaning mismatches in derivational morphology. This is a subset of the empirical data that Pāṇini models through the taddhita hierarchy. In §3 and §4, I spell out the principles underlying the organization of the taddhita section, and show how it functions as an inheritance network. In §5, I review a subsumption-based account of derivational morphology and briefly discuss the possible compatibility of modern default-based frameworks with Pāṇini’s hierarchy.

¹For instance, theoretical issues such as whether affixes are treated as lexical entries with form-meaning pairings (e.g. Lieber, 1981) or whether formal exponence is completely divorced from semantic derivation (e.g. Beard, 1995) may lead to distinct representational choices based on the same formal architecture, such as Krieger and Nerbonne (1993) or Riehemann (1993) respectively.
2 Morphological issues

Data from Sanskrit morphology illustrates a set of well-discussed facts about asymmetric correspondences between morphological form and meaning. The first set of correspondences is between a single affixal form and multiple senses, which may be considered to be either polysemous or homonymous. The other set of correspondences is between a single semantic sense which may be realized by multiple forms.

2.1 Sanskrit relational adjectives

Sanskrit has a productive process of forming relational adjectives from nouns. Relational adjectives, also called non-predicate adjectives (Levi, 1973), have the general meaning of ‘pertaining (relating) to/connected with what is denoted by the base noun’, e.g. *industrial* or *budgetary* (Szymanek, 1985; Ljung, 1970; Isitt, 1983).\(^2\) Relational adjective formation is a very regular derivational process, targeting most nominal base forms. Sample base forms and their derived forms are given in (1). The examples in (1) and all later examples are sourced from Wackernagel (1954) and Katre (1987).

(1) Relational Adjectives

<table>
<thead>
<tr>
<th>Base</th>
<th>Derived form</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>sibi ‘a tribe’</td>
<td>saib-ā ‘of the Sibis’</td>
<td>sāibā-ḥ deśah ‘Sibi country’</td>
</tr>
<tr>
<td>upagu a name</td>
<td>aupagav-ā ‘of Upagu’</td>
<td>aupagavā-m gṛham ‘Upagu’s house’</td>
</tr>
<tr>
<td>kalaśa ‘metal pot’</td>
<td>kālaś-ā ‘of a metal pot’</td>
<td>kālaśā-m odanam ‘rice cooked in a metal pot’</td>
</tr>
<tr>
<td>aśman ‘stone’</td>
<td>aśm-ā ‘of stone’</td>
<td>aśmā-ḥ kumbhaḥ ‘stone pot’</td>
</tr>
<tr>
<td>mṛttikā ‘clay’</td>
<td>mṛttik-ā ‘of clay’</td>
<td>mṛttikā-ḥ ghaṭaḥ ‘clay pot’</td>
</tr>
</tbody>
</table>

The affix deriving these relational adjectives is characterized as –ā (with truncation of the base), which triggers ablaut (*vṛddhi*) on the first syllable of the base.\(^3\) Semantically, the affix –ā, as illustrated in the examples in (1), shows a consistent mapping to the general relational meaning, relating the referent of the derived form to the base noun.

\(^2\)For a detailed description of the syntactic properties of these derived forms as distinct from other adjectives, see Levi (1973).

\(^3\) *vṛddhi* is an ablaut process in Sanskrit where the vowels *a*, *i*, *u* are strengthened to the long vowel *ā* and the diphthongs *ai* and *au*, respectively.
2.2 Affix polysemy and homonymy

The distributional properties of the Sanskrit affix –á are not as straightforward as presented in (1). The same affix is used productively to derive denominal qualitative adjectives (see Beard (1995); Szymanek (1985) for the distinction between relational and qualitative adjectives), patronymics (also matronymics), and provenance-denoting nouns. The use of the same affix to denote related senses is termed *affix polysemy* (Plag, 1999; Booij, 1986).

Beard (1995) refers to cases of *affix homonymy*, where the same affix is used in distinct and unrelated semantic contexts. The affix –á in Sanskrit may also be used in semantic contexts that are not related to the general relational meaning. For instance, –á can derive collective nouns, abstract nouns, and agent nouns, none of which are prototypically associated with the semantics of relationality.\(^4\) Cases of polysemy and synonymy are given in (2).

(2) Affix Polysemy and Homonymy

<table>
<thead>
<tr>
<th>Base</th>
<th>Derivation</th>
<th>Meaning</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>parvata</em> ‘mountain’</td>
<td>pārvat-á</td>
<td>‘a mountainous region’</td>
<td>Qualitative Adjective</td>
</tr>
<tr>
<td><em>mathurā</em> ‘a city’</td>
<td>māthur-á</td>
<td>‘native of Mathurā city’</td>
<td>Provenance noun</td>
</tr>
<tr>
<td><em>upagu</em> a name</td>
<td>aupagav-á</td>
<td>‘Upagu’s offspring’</td>
<td>Patronymic</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Homonymy</th>
<th>Derivation</th>
<th>Meaning</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>śuka</em> ‘parrot’</td>
<td>ūṣauk-á</td>
<td>‘a group of parrots’</td>
<td>Collective Noun</td>
</tr>
<tr>
<td><em>chandas</em> ‘metrics’</td>
<td>chāndas-á</td>
<td>‘metrics scholar’</td>
<td>Personal Noun</td>
</tr>
<tr>
<td><em>nipuṇa</em> ‘skilled’</td>
<td>naipun-á</td>
<td>‘expertise’</td>
<td>Abstract Noun</td>
</tr>
</tbody>
</table>

In (2), the same formal affix –á is used to denote a variety of related and unrelated derivational categories. The derived forms under the polysemy label (provenance, patronymic) can be construed as derived from a polysemous affix, with relational semantics. Under the homonymy label are forms where the affix clearly does not contribute a relational meaning. A comparable illustration in English is the use of the affix –ian to derive provenance-denoting nouns/adjectives (*arabian*, *italian*) and relational adjectives (*miltonian*, *proletarian*) on the one hand, and personal nouns (*grammarian*, *logician*) from base nouns on the other (Marchand, 1960).

\(^4\)The boundary between related meanings (polysemy) and unrelated meanings (homonymy) of a form is not always clear. The distinction I make here for the Sanskrit case is based on the following facts: The semantics of abstract nouns is not easily derivable from a more general relational meaning; moreover, cross-linguistically, abstract nouns are often derived with affixes distinct from those deriving relational adjectives. In English, the abstract noun deriving affixes (*–ness, –ity*), never overlap with the affixes deriving relational adjectives (such as *–an, –ese*).
The same derived form may also have distinct semantic denotations. The form \( \text{\textit{sauk-á}} \) may denote a ‘collection of parrots’, as well as ‘a region full of parrots’. Similarly, the derived form \( \text{\textit{chändas-á}} \) denotes both a ‘metrics scholar’ and something ‘pertaining to metrics’ (e.g. a text about metrics).

### 2.2.1 Non-compositionality

The affix \( \text{\textit{–á}} \), in the case of some derived forms, may also denote senses which are not regular, and must be construed as idiosyncratic. \( \text{\textit{–á}} \), when attached to the base stem, \( \text{\textit{sthan.dila}} \) ‘ground’, derives the form, \( \text{\textit{sthan.dil-á}} \), which means ‘a person who sleeps on the bare ground, because of a religious vow he has taken’. This denotation is semantically specialized and applicable only to one base noun, \( \text{\textit{sthan.dila}} \).

This example illustrates another morphological fact which falls under the rubric of form-meaning mismatches, viz. non-compositionality. Non-compositionality involves the same kind of asymmetric correspondence as affix homonymy; the same form is used to denote a specialized, idiosyncratic meaning in the case of one or two lexemes. Regularly derived forms such as \( \text{\textit{transmission}} \) (Aronoff, 1976) have idiosyncratic properties which do not result from their constituent morphemes, and hence the particular denotations of these derived forms must be specified at the level of the individual forms themselves. However, these forms resemble regularly derived forms in every characteristic other than their semantic idiosyncracy. Therefore, it is important to capture the generalization that they are derived by regular morphological processes, although general processes available in the lexicon such as semantic extension or metaphorical change may apply to them.

### 2.3 Affix synonymy

The phenomenon of morphological variance but semantic/grammatical identity of affixes is known as affix synonymy. The claim that affixes are synonymous has been made most strongly in discussions of affixation morphology deriving nouns and adjectives from nominal bases (Beard, 1995; Szymanek, 1985). Synonymous affixes tend to be in a blocking relation to each other, where the general, or the more productive affixes are blocked by either systematic or idiosyncratic special affixes. Van Marle (1985) distinguishes between type blocking, which is a label for systematic special cases of blocking, definable by type (i.e. by indicating one or more definitional properties of the words which are input to the affixation rule) and token blocking, which refers to idiosyncratic special cases. A paradigmatically regular domain in Sanskrit derivational morphology, the patronymics, shows instances of both type and token blocking, as illustrated in the examples in (3).
Affix Synonymy

<table>
<thead>
<tr>
<th>Name</th>
<th>Affix</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upagu</td>
<td>auppagav-á</td>
<td>‘Upagu’s male offspring’</td>
</tr>
<tr>
<td>Daks.a</td>
<td>daks-i</td>
<td>‘Daks.a’s male offspring’</td>
</tr>
<tr>
<td>Aditi</td>
<td>adit-yá</td>
<td>‘Aditi’s male offspring’</td>
</tr>
<tr>
<td>Aśvapāli</td>
<td>āśvapāl-ika</td>
<td>‘Aśvapāli’s male offspring’</td>
</tr>
<tr>
<td>Naḍa</td>
<td>nāḍ-āyana</td>
<td>‘Naḍa’s male offspring’</td>
</tr>
<tr>
<td>Suparn.ā</td>
<td>sauparn-eya</td>
<td>‘Suparn.ā’s male offspring’</td>
</tr>
</tbody>
</table>

Patronymic formation in Sanskrit is paradigmatic in that every proper name (and some common nouns) can be the base for a patronymic. Semantically, this derivation is uniform and does not show much variation. In (3), the affixes –i, –yá, –ika, –āyana, and –eya are also used to form patronymics, blocking the application of the general patronymic affix –á. The affixes –i and –eya are in a type blocking relation to –á, because they are definable over a phonological or morphological property of the input. The affix –i attaches after a-stems (stems which end in the vowel a), while the affix –eya is used after feminine stems. The affixes –yá, –ika and –āyana are instances of token blocking. They are idiosyncratic in that their domain is determined only by enumeration of the bases to which they attach. Patronymic formation is thus characterized by two kinds of subregularities — type and token blocking — in which classes of stems override the default affix in a particular domain of morphological derivation.

2.3.1 Partial blocking

Affix competition may be restricted to partial semantic domains of a polysemous or homonymous affix. In these cases, formal blocking is limited to sub-domains of the meaning associated with a general affix, thus requiring that these sub-domains be specified in the grammar. I call this partial blocking.

As seen in (3), at least four different affixes are used in varying degrees of productivity to derive Sanskrit patronymics. The most general of these is –á. However, this process may be blocked by other affixes, such as –i, which attaches to a-stems. The crucial point is that this phonologically conditioned affix does not block the general affix –á in its entire semantic domain, but only in patronymic formation. In other domains, such as relational adjective formation, or in the derivation of place names from a-stems, the general affix –á may be used. In defining semantic domains, I use those specified by Pāṇini in his organization of the patronymic system is complex and the morphology makes a distinction between immediate offspring and offspring separated by more than one generation, but that does not concern us here, because the affixes described are affixes used to denote only immediate offspring.

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5The patronymic system is complex and the morphology makes a distinction between immediate offspring and offspring separated by more than one generation, but that does not concern us here, because the affixes described are affixes used to denote only immediate offspring.
of the taddhita section. The approximate meanings of the semantic domains concerned are given in (4).

(4) a. *tasya* apatyam (4.1.92)
He-GEN-SG offspring-NOM-SG
‘X’s offspring’ (where X is the base).

b. *tasya* nivāsah (4.2.69)
He-GEN-SG dwelling-NOM-SG
‘X’s dwelling.’

c. *tasya* idam (4.3.120)
He-GEN-SG this-NOM-SG
‘X’s property’ or ‘relating to X’

These meanings are arguably related and may be coherently associated with a single polysemous affix. However, blocking affixes make reference to different sub-domains of this possibly unified semantic domain, necessitating a formal account that distinguishes between semantic sub-domains. Both total and partial blocking are illustrated in (5). In the column for semantics, Pāṇini’s semantic rules are given in translation. The gray cells in the table represent (sub-)domains in which the specific affixes override the default affixes.

(5) **Total and partial blocking in derivational morphology**

<table>
<thead>
<tr>
<th>Semantics</th>
<th>Default</th>
<th>Blocking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>Base</td>
<td>šibi</td>
<td>diti</td>
</tr>
<tr>
<td>X’s offspring (4.1.92)</td>
<td>šaib-á</td>
<td>dait-yá</td>
</tr>
<tr>
<td>X’s dwelling (4.2.69)</td>
<td>šaib-á</td>
<td>dait-yá</td>
</tr>
<tr>
<td>X’s property (4.3.120)</td>
<td>šaib-á</td>
<td>dait-yá</td>
</tr>
</tbody>
</table>

The derivatives of the proper name *diti* are formed with the affix –yá that blocks the application of –á in all the listed semantic sub-domains (an instance of total blocking). In the case of the base *dakša*, the affix –i is used only to form patronymics, with the default affix –á being used elsewhere, instantiating one type of partial blocking. In the case of *kátri*, on the other hand, the patronymic is

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6In (4), and throughout the paper, the numbering for rules (*sūtras*) reflects their position in the Āṣṭādhyāyī. The Āṣṭādhyāyī is divided into eight books (*adhyāyas*), each of which has four chapters, which contain a varying number of *sūtras*. *Sūtra* 4.1.92, for instance, refers to the ninety-second *sūtra* of the first chapter of the fourth book in the Āṣṭādhyāyī.
formed regularly, but the relational adjective is formed with a different affix –eyaka. The affix –eyaka thus occupies a different sub-domain from the affix –i within the domain of the general affix –a.

Partial blocking illustrates clearly that affixes in a blocking relation overlap, but need not necessarily apply over identical semantic domains. Partial blocking requires that morphologically relevant semantic sub-domains be specified, so that blocking facts can be accurately captured in the representation of the lexicon.

2.4 Theories of form-meaning mismatch

The data from Sanskrit illustrates a set of well known morphological problems about the nature of form-meaning mapping in affixes. The question that this data poses has to do with whether the mapping from the form to the meaning of affixes is isomorphic or whether it allows for non-isomorphism. How should asymmetric correspondences in affixal morphology be represented? There appear to be two main theoretical positions on this issue. The Separationist position, better known as the realizational approach to morphology, argues for a complete separation between form and meaning of affixes (Beard, 1995; Stump, 2001). The Non-Separationist position, on the other hand, posits instantiations of multiple form-meaning pairings in order to preserve the isomorphic nature of the form-meaning relation (Lieber, 1996; Plag, 1999). My labels are based on the ‘Separation Hypothesis’ (Beard, 1988, 1995), which proposes a complete separation between semantic and morphological derivation.

The differences between these two theoretical approaches to the form-meaning mapping may be delineated as follows. In non-separationist theories, the associations between a morphological form and its semantic properties are located in the lexicon, in the form of affixal lexical entries. This association closely resembles the association between a lexeme and its grammatical and semantic properties. Affixal lexical entries are identical to lexical entries of roots, with respect to category information, semantics, and subcategorization restrictions (Lieber, 1981, 1992; Plag, 1999; Selkirk, 1982).

Separationist (or realizational) theories, on the other hand, relate systematic formal relations between roots and their morphologically related forms via morphological rules. The association of particular grammatical or semantic properties with the formal properties of the complex forms is a function of the rule and not of the fact that these properties are associated with the ‘affix’ itself. A separation between the formal and grammatical/semantic properties of affixes allows these theories to open the path for modeling non-isomorphic relations between the formal and semantic properties of affixes (Anderson, 1992; Aronoff, 1994; Beard, 1995; Stump, 2001).
The difference in the theoretical assumptions of the two approaches is reflected in their devices to capture mismatch phenomena. In the non-separationist approaches (Lieber, 1981, 1992), partially identical (homonymous or synonymous) affixes are treated as distinct affixes, because the underlying assumption is that an affix is a *pairing* of form and meaning. The pairings of the same form with many semantic denotations, or the same semantics with many forms are treated as distinct *pairings*, and, consequently, as distinct affixal entries in the lexicon. The conception of affixes as form-meaning pairs, or signs, forces non-separationist theories to posit multiple homonymous or synonymous affixes without capturing the partial regularities that may characterize classes of such affixes.\(^7\)

Separationist approaches split formal and semantic aspects of affixes into distinct rules, and allow for associations between these rules, thereby reducing redundancy in the representation of affixes. However, by modeling the formal and semantic derivations in morphology as completely separate levels of derivation (e.g. Beard, 1995), this theoretical position is unable to account for the regularities in the semantic domains of affixes. Another disadvantage of this approach is that it cannot adequately explain the absence of particular form-meaning pairings in languages, since in principle, any form may be associated with any semantic representation, given that they belong to two different tiers of derivation, and there are no constraints on how formal and semantic representations may be related.

Looking at the intricate nature of the morphological data to be modeled, it is clear that some kind of a separation between formal and semantic rules is necessary in order to avoid redundancy. However, a complete separation between the two results in an unconstrained mechanism of form-meaning mapping. The way towards a solution that can constrain possible form-meaning mappings lies in modeling formal and semantic properties of affixes as related, but non-isomorphic. By allowing for flexible, many-to-many correspondences between affixal form and semantics, and at the same time, constraining the range of these correspondences, it might be possible to map out a minimally redundant, yet constrained model of derivational morphology. In the following sections, I show that Pāṇini’s treatment of derivational morphology provides an inheritance-based model of mapping the relation between form and meaning — Constrained Separationism.

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\(^7\)Plag (1999) makes a strong claim arguing that there is no affixal synonymy, based on a detailed examination of verbalizing affixes in English. He demonstrates how the affixes *–ize, –ate, –ify* have overlapping, but distinct semantics. Such an argument, however, does not hold in affixal synonymy in semantic domains such as patronymic formation where the semantic contribution of different affixes is exactly the same.
3 The Aṣṭādhyāyī as an inheritance network

Morphological generalizations are characterized by defeasible regularities and sub-regularities. Lexical representation languages, organized around the principle of inheritance of information between the nodes of an inheritance network, allow for the representation of partial generalizations at a node and their inheritance to successively lower nodes. The view of the lexicon as an inheritance network provides a concise representation of lexical/morphological information and a formalism to capture linguistic generalizations. Default inheritance, in particular, is useful in the statement of subregularities, and idiosyncratic exceptions, without sacrificing morphological generalization.

3.1 The Aṣṭādhyāyī

The Aṣṭādhyāyī of Pāṇini is the oldest existing grammar of Sanskrit, dated to around 500 B.C. It is a concise, relatively complete description of the language, and has theoretically influenced western grammatical theory of the last two centuries in many areas. Stem-suffix analysis (and the idea of sub-lexical elements in its entirety), the elsewhere condition, and linking theory are some of the theoretical ideas that modern linguistics owes to Pāṇini (Kiparsky, 1995, 2002). The grammar itself has four components.

a. Sūtrapātha: A system of about 4000 grammatical rules (sūtra).
b. Śivasūtra: the inventory of phonological segments, partitioned by diacritic markers (anubandhas) to allow for the abbreviation of classes of segments.
c. Dhātupātha: a list of two thousand verb roots, divided into classes, and marked by diacritics encoding their morphological and syntactic properties.
d. Gaṇapātha: An inventory of (sometimes overlapping) classes of nominal lexemes to which particular rules of the Aṣṭādhyāyī may apply.

The Aṣṭādhyāyī is a detailed exposition of the phonology, morphology, and morphosyntax of Sanskrit using basic principles of organization that are consistently applied throughout the grammar. The dominant underlying principle in this grammatical system is descriptive brevity. The theoretical insights that might emerge from this strict adherence to brevity have yet to be unearthed in their entirety. But the descriptive accuracy of the grammatical system based on this principle is considerable, judging from the sophisticated analysis of Sanskrit that it results in.
3.2 The taddhita section

The taddhita section\(^8\) covers chapter four and five of the sūtrapāṭha of the Aṣṭādhyāyī, and consists of approximately 1115 sūtras (rules). It contains many general rules which derive hundreds of lexemes, as well as specialized rules which derive a handful, and at times only one or two forms. These rules derive deadjectival and denominal nouns and adjectives, making reference to the lexical classes listed in the gaṇāpāṭha. The taddhita section is subsumed under a larger section that deals with affixation morphology in general. This domain inclusion classifies the taddhita derivational affixes as a sub-type of a general affix class which includes both verbal and nominal inflectional and derivational affixes.

Within the Pāṇinian system, both nouns and adjectives are analyzed as a unitary category (comparable to +N) called prātipadika. Therefore, the taddhita affixes are not category-changing affixes in the system and are not treated as such.\(^9\) Word formation rules in this section are of the type in (6).

\begin{equation}
[\text{Stem}_{\text{nom}} + \text{Suffix}] \rightarrow [\text{Stem}_{\text{nom}}]
\end{equation}

The bulk of the taddhita section contains rules prescribing affixes that denote appurtenance or some other relation to the base (paralleled by affixes deriving denominal adjectives such as –al, –ic, –an in English). The difficulty of characterizing the relation between the base and the derived form in a unified abstract way has been noted in earlier work on denominal adjectives in other Indo-European languages (Isitt, 1983; Ljung, 1970; Szymanek, 1985). The semantics of such affixes ranges from general meanings such as ‘connected with’ (the base) to extremely specific meanings such as ‘stained by’ or ‘mixed with’ (the base). It is a matter of debate whether the vast number of meanings that are associated with denominal adjective formation should be included in the lexicon or pragmatically determined based on real world reference. Nevertheless, in an exhaustive descriptive lexicon, shared semantic regularity must be abstracted over lexical classes, however nuanced the regularity, or small the class. Pāṇini’s taddhita rules have been defined in this spirit, leading, at times, to very specific conditions on both base forms and semantic contexts for derivation.

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\(^8\)The term is due to Pāṇini’s label for this class of affixes — the taddhita affixes.

\(^9\)Aronoff (1976) (also Scalise (1984)) argues that a word formation rule which operates on nouns and adjectives is not a counterexample to the Unitary Base Hypothesis because nouns and adjectives form a natural class sharing the feature [+N] to which the rules may refer unitarily. For instance, the verb forming affix -ize attaches to both nouns and adjectives, while the affix -ian may derive both nominal and adjectival forms (the Unitary Output Hypothesis (Scalise, 1984)). The class prātipadika in the Pāṇinian framework is just such a class of bases on which word formation rules may operate. Pāṇini’s rules, in fact, are consistent with the unitary base hypothesis since homophonous affixes which attach to syntactically distinct categories (e.g. nouns and verbs) are treated as different affixes.
The organization of the Asṭādhyāyī is complex and assumes a number of logical and interpretive principles, most of which the grammar does not explicitly state. Rule ordering in the grammar is a product of detailed computation regarding the optimal placement of rules. The taddhita section, in particular, is intriguingly similar to an inheritance hierarchy in that it isolates multiple levels of abstraction and factors out the maximal information that can be abstracted away from classes of complex lexemes to reveal the hierarchical organization of the Sanskrit nominal derivational system. There is, however, a subtle difference to be noted between Pāṇini’s hierarchy and inheritance-based lexica — in most modern accounts, inheritance is used to specify properties common to classes of lexical items. The taddhita hierarchy, on the other hand, is a hierarchy of procedural word-formation rules ordered on the basis of increasing specificity along a single path of default inheritance. While this is a significant difference, as I will discuss in §4.5, it does not necessarily complicate the comparison of the two approaches.

3.3 Devices used in the Aṣṭādhyāyī

3.3.1 Anuvṛtti

Likened by the tradition to ellipsis in day-to-day speech (Joshi and Bhate, 1984), anuvṛtti is a device used in the Asṭādhyāyī for omitting information that is recoverable from immediately prior rules. Rules are compressed by systematically omitting partial elements that constitute them, because this information is assumed to ‘continue’ from prior rules. Anuvṛtti is one of the most important methods of obtaining brevity in the formulation of the rules. The rules in the Asṭādhyāyī are always linearly ordered by virtue of the linearity of the text itself. Pāṇini exploits this linear ordering by factoring out common information in consecutive rules, and locating this information explicitly in the first rule at the top of the rule block that shares this information. Later rules within the block inherit this information and may add more specific information that is compatible to the inherited information. The Anuvṛtti gets discontinued if the information from a later rule is incompatible with the inherited information and overrides it. Moreover, rules may also override only part of the inherited information by specifying information that conflicts with only a subset of the inherited information.

Most Asṭādhyāyī rules are procedural; they contain the description of some phonological/morphological change, and a structural context — the environment necessary to trigger the change. The case-marking system of Sanskrit has a highly formalized role in the Asṭādhyāyī, and represents the structural description of a given rule. Rule constituents may appear in the nominative, genitive, ablative, or locative cases. The genitive denotes the target of a structural change, the nominative represents the change, whereas the ablative and the locative denote the
left and right structural context respectively. A rule such as $A \rightarrow B / — C$ would be represented in the Astadhyayi as $A_{gen} \rightarrow B_{nom} / — C_{loc}$. The discontinuation of information inheriting across a rule block occurs typically through the use of incompatible values for the same case marker in a rule. A useful analogy can be made to the inheritance of information in the form of attribute-value pairs, where a conflicting value for the same attribute at a lower node results in overriding of the information from the higher node. A short illustration of how anuvṛtti works is given in (7). The columns, genitive, nominative, and locative stand for the cases in which constituents appear.

(7) Inheritance in Anuvṛtti

<table>
<thead>
<tr>
<th>GEN</th>
<th>NOM</th>
<th>LOC</th>
<th>rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target</td>
<td>Change</td>
<td>Context</td>
<td></td>
</tr>
<tr>
<td>ikah</td>
<td>yan</td>
<td>aci</td>
<td>$[i u r] \rightarrow [y v r] / + \text{vocalic} ~ (6.1.77)$</td>
</tr>
<tr>
<td>ecah</td>
<td>ayavayavah</td>
<td></td>
<td>$[e o ai au] \rightarrow [ay av ay \dot{a}] / + \text{vocalic} ~ (6.1.78)$</td>
</tr>
<tr>
<td>vantaḥ</td>
<td>yipratyaye</td>
<td></td>
<td>$[o au] \rightarrow [ay av] / \text{y (affixal)} ~ (6.1.79)$</td>
</tr>
</tbody>
</table>

(7) contains three consecutive phonological rules, the latter two of which inherit partial information from prior rules. The first rule, 6.1.77, describes an automatic phonological change, where vowels are realized as glides in vocalic environments. The next rule, 6.1.78, introduces a new phonological process, but the right structural context (the locative marked constituent) stays the same. This context is inherited from the earlier rule (6.1.77), and does not need to be repeated in 6.1.78. In 6.1.79, the phonological target and structural change are retained, but the structural context changes from $[+ \text{vocalic}]$ to the semivowel $y$, which is specified as belonging to an affix. This discontinues the inheritance of the earlier context $aci$ (vocalic right context), while the remaining information is inherited.

3.3.2 Adhikāra

Anuvṛtti involves inheritance of information based on the factoring out of common information from rule blocks. The adhikāra is another form of inheritance, where classes of rules belonging to the same thematic domain inherit their category label or type from a statement which is placed at the top of the relevant rule block. For instance, all rules of automatic phonology are governed by an adhikāra which categorizes them as such. The adhikāras in the Astadhyayi organize the rules of the grammar into different categories, corresponding to their types. All affixation morphology is dealt with under the same thematic label pratyayah (affixes). Within

---

10The terms *ikah*, *yan* etc. are abbreviations of the sets of phonemes they stand for. These abbreviations are governed by a set of conventions that are not relevant to the discussion here.
this adhikāra of affixes, there are sub-adhikāras for inflectional morphology and
different kinds of derivational morphology. The adhikāra device in the Āśṭādhyāyī,
unlike anuvṛtti, does not facilitate the information of procedural information in
rules, rather, serves a classificatory purpose. Joshi and Bhate (1984) characterize
this difference as follows.

The device of anuvṛtti aims at avoiding repetition of the same item.
The device of adhikāra is used to indicate homogeneity of topic. The
adhikāra stand for a subject-wise division of the Āśṭādhyāyī (Joshi and
Bhate, 1984).

An adhikāra is a special kind of anuvṛtti, because although it has a classifi-
catory function that anuvṛtti lacks, it also facilitates inheritance of information
across rules. The adhikāra usually carries information that organizes a section
thematically or unifies the rules within its domain under a single, linguistically rel-
levant category. In this sense, an adhikāra corresponds to a non-terminal node or
a partially specified entry in an inheritance network, which is not actually instan-
tiated in the real language, but expresses a linguistic generalization that may be
factored out for a class of objects. The rule taddhitāḥ (4.1.76) is one such adhikāra
that classifies a set of affixes in the language as taddhita or nominal derivational
affixes. All the rules in the domain of taddhitāḥ (4.1.76) are subsumed by this
rule, and inherit this classification.

The anuvṛtti lacks this classificatory function and purely serves to maximize
brevity. It is based on linear ordering, and does not have many hierachical re-
strictions. Inheritance of information based on anuvṛtti, being ultimately based
on linear ordering, may occur between sister nodes as well as from mother nodes
to daughter nodes; though anuvṛtti rarely continues outside the domain of the
adhikāra it inherits information from.

This inheritance mechanism executed via the two-fold devices of adhikāra and
anuvṛtti in the Āśṭādhyāyī is almost identical to other inheritance networks where
properties shared by a class of objects are represented only once to allow for a
compact representation in a particular linguistic domain. The objects in this case,
may be either procedural linguistic rules or linguistic classes — the anuvṛtti or the
adhikāra.

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11One of the distinction made between the adhikāra and the anuvṛtti is that an adhikāra
does not necessarily continue in each of the rules located in its domain. It may be temporarily
cancelled (Joshi and Bhate, 1984). I do not discuss this here, because there is no instance of a
temporary cancellation (inheritance blocking) of an adhikāra in the section under discussion.

12An exception to this is the anuvṛtti of dīrghah (6.3.111) into the domain governed by aṅgasya
(6.4.1).
3.3.3 Single vs. multiple inheritance

A key difference between the organization of inheritance in the Aṣṭādhyāyī and the inheritance mechanism as assumed in other inheritance-based lexica is the absence of multiple inheritance in the former. The logic of multiple inheritance allows a single node to inherit from more than one super-category (Krieger and Nerbonne, 1993; Richemann, 1993). Single inheritance, on the other hand, ensures that each node may inherit from only a single higher node, although a given node may have any number of sub-classes.

The Aṣṭādhyāyī is a single inheritance hierarchy. Given the linear, unidimensional ordering of rules in the organization of the Aṣṭādhyāyī, the question of whether the inheritance mechanism in the Aṣṭādhyāyī allows multiple inheritance or is restricted to single inheritance is determined as follows.

(8) Given a set of linearly ordered rules, rule\textsubscript{a} \ldots rule\textsubscript{n}, governed by adhikāra A and adhikāra B, a subset of the rules inherit from multiple adhikāras if the domains of adhikāra A and adhikāra B are non-identical and not in a nesting relation to each other.

The rules in the Aṣṭādhyāyī must be ordered in this relation for multiple inheritance to obtain. However, the fact of the matter is that they are not. A single adhikāra may have multiple adhikāras nested within its domain. Similarly, two adhikāras may have (linearly) contiguous domains; however, it is rare in the Aṣṭādhyāyī for two or more adhikāras to partially overlap in their domains, which is crucial if multiple inheritance is to be represented in a linearized setting. This shows that the Aṣṭādhyāyī relies on single inheritance for representing shared information. This difference is important in the comparison between modeling of morphological generalizations in the Aṣṭādhyāyī and in other inheritance-based lexica.

3.3.4 Utsarga-Apavāda

The utsarga-apavāda principle is used in the Aṣṭādhyāyī for the statement of default (general) and specific information. Literally translated as the general case-special case relation, this principle captures the type of phenomena that involve non-total regularities, where the application of default rules may be blocked by systematic or idiosyncratic exceptions. This relation between the special rule and the general rule has been variously described as Blocking (Aronoff, 1976), the Elsewhere Principle/Condition (Kiparsky, 1968, 1973) or Pāṇini’s Principle (Stump, 2001).

In rules based on this principle, the general condition is stated as simply as possible, and may be overridden by particular special case conditions, which apply
over a restricted context. The default applies to all unspecified contexts that fit the structural description of the rule. Linguistic generalizations, particularly morphological ones, tend to be of this kind, where categorical application of rules is almost impossible, unless the rules themselves are stated so as to exclude all the exceptions to them. The specific condition, apavāda, always overrides the general condition, the utsarga. The formulation of this interaction between general and specific rules is stated below.

(9) If the inputs to which rule A is applicable are a proper subset of the inputs to which rule B is applicable, A is in an apavāda relation to B (the utsarga), and therefore applied to the exclusion of B.

This is a convention whereby the more specific rule takes precedence over the general rule in applying to the class of contexts that fit the specific rule. Flickinger (1987), in articulating such a convention, in fact, dates it back to Pāṇini and other recent work inspired by Pāṇini (Kiparsky, 1968). In the Aṣṭādhyāyī, it is not crucial to order the utsarga (default) and the apavāda (special) rules with respect to each other, or even within the same thematic domain. Ordering of rules is motivated by maximal brevity, and is governed by the principles of anuvṛtti (in order to enable maximal inheritance of information). Since application of a rule is dependent on narrowness of context or specificity of description, the special rule always overrides the general rule, whatever its linear location in the Aṣṭādhyāyī.

4 A translation procedure

Although the devices of Pāṇini’s system are identical in spirit and partially in implementation to other inheritance-based lexica, the taddhita section, as it stands, does not resemble an inheritance hierarchy. Inheritance networks are familiar as two-dimensional objects that are represented using a tree-based notation with multiple branches emerging from a single node to represent the sister-node relationship. The taddhita section (and the rest of the Aṣṭādhyāyī, for that matter) does not employ this mode of representation. How can a two-dimensional hierarchical branching be induced from this set of rules? Inducing a two-dimensional hierarchy from the unidimensional ordering of rules requires an explicit translation algorithm. This translation algorithm has been partially explicated in the formulation of Pāṇini’s rules and must be partially reconstructed from the implicit assumptions of the grammatical tradition in its interpretation of the Aṣṭādhyāyī. These assumptions follow from the basic principle of inheritance and blocking as explained in §3.3.1.

In the taddhita section, the tradition distinguishes between two kinds of adhikāras that head different rule blocks and are interleaved with each other. These
are the pratyādhikāra or the domain of the (formal) affix, and the arthādhikāra or the domain of meaning.

4.1 Pratyādhikāra

A pratyādhikāra is a general rule that specifies the formal affixal morphology for the set of specific rules falling within its domain. This information is inherited by all the rules under that pratyādhikāra. However, the pratyādhikāra also specifies its own domain boundary. This information is not part of the representation of lexical generalizations, but rather, part of the convention for modeling these generalizations, which allows for the interpretation of the rule’s position in a rule hierarchy. A pratyādhikāra must therefore be divided into two distinct parts — the content, which is relevant to linguistic representation, and the domain specifying convention — which allows for the interpretation of the rule’s location as part of a hierarchy. An illustration is given in (10).

13This rule has two constituents, the latter of which is the prescribed affix, $aN$. In the first part of the rule, prāgdīvyataḥ, divyataḥ refers to a rule later in the section which contains the word divyati. The particle prāk ‘until’ specifies that the domain of the affix $aN$, or the domain of the $aN$ pratyayādhikāra, continues until the rule which contains the word divyati. The literal translation of the rule is accompanied with its detailed interpretation based on information inherited from prior rules. The numbers in the brackets give the source of inheritance.

(10) prāgdīvyataḥ  āN (4.1.83)
uptil-divyati-ABL āN-NOM
lit: $aN$ is the default affix until divyati (rule 4.4.2)

13(10) inherits information from prior rules under which it is subsumed. The structural context in which the rule is applied (nominal stems) is inherited from a statement higher up in the ordering (rule 4.1.1). The rule itself is construed as a product of all the inherited information added to the actual information that the rule contains.

14Pāṇini uses diacritics to mark accentual, ablaut-trigerring, and other properties of Sanskrit affixes. $aN$ represents the affix –ā, already familiar from earlier examples, with the diacritic ā signifying that it is accented and triggers vyādhi. These diacritics are an integral part of the morphophonological description of an affix and I will refer to all affixes (e.g. -iN, -PHAīN, -yaN) in the form that Pāṇini assigns them.

15It has been pointed out by a reviewer that this kind of domain specification is never seen in the organization of modern inheritance-based lexica. I believe the possibility of two-dimensional representation in modern hierarchical networks obviates the need for domain specification of a node, since, in such hierarchies, subsumption is expressed on the vertical dimension, while the sister-node relationship is expressed on the horizontal one. Pāṇini, limited by linear presentation, uses only the override mechanism to express both kinds of relations. The multiple levels of interleaved formal and semantic rules in the taddhita section appear to have compelled Pāṇini to introduce domain specification as an additional device in the construction of the taddhita hierarchy.
The taddhita (4.1.76) affix (3.1.1) ́aN is introduced after (3.1.2) a nominal stem (4.1.1) (in the semantic contexts listed) prior to rule 4.4.2’ (the rule which contains the word ‘divyati’).

There are five pratyayādhikāras in the taddhita section, and each specifies its domain boundary by referring to a specific future rule. This allows us to induce a sister-node relation between individual pratyayādhikāras in the following way. Inheritance of information is possible only within the domain specified by the pratyayādhikāra. For instance, the information contained in the rule stated in (10) continues by default through its domain (through rule 4.4.1). However, this information may not continue beyond rule 4.4.1 because of the specified domain boundary. In other words, ́aN cannot be the formal affixal material inherited by default beyond the domain of the pratyayādhikāra that delimits it. The boundary marks the beginning of another affixal domain — the next pratyayādhikāra. The clear delineation of a boundary for each affixal domain makes it possible to assign distinct sister nodes to each affixal domain.

Moreover, each of the pratyayādhikāras inherit information from common earlier adhikāras, within whose domain they are located. The information that each of the pratyayādhikāras prescribe different affixes, which are suffixal in nature, that they belong to a particular type of affixes (taddhita affixes), which attach only to nominal stems, is shared information inherited by the pratyayādhikāras from earlier rules (which are also higher in the hierarchy.) This further reinforces the induction of a sister-node relation between the affixal domains that stretch linearly across multiple rules, but are in fact, hierarchically constructed. This is illustrated in figure (1). The pratyayādhikāras (labeled here by the affix they prescribe) at the lowest nodes in the tree in figure (1) inherit from the nodes that classify them as non-category-changing, nominal derivational suffixes. Affixes such as aN, ThaK and yaT are located under the rules which are stated earlier in the system and also appear higher in the hierarchy. The adhikāra ‘pratyayā’ (3.1.1) classifies these forms as suffixes. The adhikāra ‘nī-āp-prātipadikā’ (4.1.1) classifies these affixes as nominal, non-category-changing suffixes, together with the inflectional and feminine forming affixes, while the adhikāra ‘taddhitaḥ’ (4.1.76) classifies them as a subset of the derivational affixes.

4.2 Arthādhikāra

Within the domain of each pratyayādhikāra are stated a number of arthādhikāras, or domains of meaning, which specify the semantic condition under which the default affixal form prescribed by the pratyayādhikāra attaches to a stem. The formal affixal information is inherited by each of the arthādhikāras. The arthādhikāra,
therefore is a more specified node than the pratyayādhikāra node, since it contains information about both the formal affix prescribed (via inheritance) as well as the semantic conditions under which it is attached to bases to derive complex forms.

By subsuming semantic conditions for derivation under the formal derivation rules, Pāṇini models the one-to-many correspondence relation between form and meaning, where the same affix may be used in multiple semantic contexts (affix homonymy). This organization separates affixal form from the semantics it is associated with, thus resembling the Separationist approach (§2.4), but at the same time, it constrains possible linkings between form and meaning through the inheritance relation.

An example of an arthādhikāra, the rule for Sanskrit patronymic formation, is given in (11). This is a general rule prescribing the affix \( \dot{a}N \) to denote the ‘father-offspring’ semantic relation between the base and derived form. The literal translation is followed by the interpretation which takes into consideration inherited information from higher nodes.

(11) **tasya** apatyam (4.1.92)

He-GEN-SG offspring-NOM-SG

**lit:** His offspring

‘The taddhita (4.1.76) affix (3.1.1) \( \dot{a}N \) (4.1.92) is introduced after (3.1.2) a nominal stem (4.1.1) in the semantic context ‘his offspring’.

An important distinction between the pratyayādhikāra and the arthādhikāra is that the latter does not employ a formal device to specify its domain boundary. How is the domain of an arthādhikāra determined? In this case, it is the principle...
of anuvṛtti that facilitates inheritance of information to the following rules as far as it is not blocked by incompatible information. The occurrence of the following arthaḥdiḥikāra automatically signals the boundary of the preceding arthaḥdiḥikāra, since it contains information that is incompatible with the inherited semantic information. In other words, a later arthaḥdiḥikāra blocks the application of the previous arthaḥdiḥikāra by the principle of anuvṛtti. Since the set of arthaḥdiḥikāras under a given pratyayādiḥikāra do not inherit information from each other, but inherit common information from the same pratyayādiḥikāra, they are construed as sister-nodes in the taddhita hierarchy.

### 4.2.1 Blocking and non-compositionality

It is by now clear that there are other rules within the rule block headed by an arthaḥdiḥikāra. What is the substance of these rules? The rules falling under the arthaḥdiḥikāra domain are of two kinds: formal blocking rules and rules that specify a semantically specialized function of an affix in a restricted context. In the case of partial blocking, the default affix, inherited by the arthaḥdiḥikāra node from the pratyayādiḥikāra, may be blocked only in the precise sub-domain of that arthaḥdiḥikāra for a class of stems. In the other case, the use of a regularly derived form is restricted to a sub-domain of the general semantic meaning productively associated with the arthaḥdiḥikāra. Both these possibilities are illustrated in the rules in (12). It is useful to keep in mind that the default pratyayādiḥikāra for all the rules in (12), is the aN pratyayādiḥikāra translated in (10).

(12) a. atah īN (4.1.95)
   ending in a-ABL-SG īN-NOM-SG
   lit: affix īN after a-stems
   ‘The taddhita affix (3.1.1) īN, (which overrides áN (4.1.92)), is introduced after (3.1.2) a nominal stem prātipadika (4.1.1), ending in the vowel a, in the semantic context ‘his offspring.’

b. bhargāt traigarta (4.1.111) (PHāN (4.1.110))
   bharga-ABL-SG traigarta clan-LOC-SG (PHāN-NOM-SG)
   lit: after Bharga in the semantic context of Traigarta
   ‘The taddhita (4.1.76) affix (3.1.1) PHāN (4.1.110), (which overrides áN (4.1.92) and īN (4.1.95)), is introduced after (3.1.2) the nominal stem prātipadika (4.1.1) bharga, in the semantic context ‘his offspring’, provided the derived form designates a member of the traigarta clan.’

c. sthañdílāt śayitari vrate (4.2.15)
   bare ground-ABL-SG sleep-AGENT-LOC-SG religious vow-LOC-SG
   lit: after sthañdíla in the semantic context ‘sleeping on a religious vow’
‘A taddhita (4.1.76) affix (3.1.1), āN (4.1.92), occurs after the syntactically related nominal stem sthāndila, provided the derived form denotes an agent of sleeping (sleeper), who sleeps on the bare ground under the obligation of a religious vow.’

The rules in (12a) and (12b) inherit semantic information from the arthādhikāra of patronymic formation (11). (12a) is an instance of type blocking, where the more specific affix iN (by overriding the default affix aN) attaches to the class of a-stems in the expression of patronymic semantics. This is the same affix that derives the form dākṣ-i from the base daksā, discussed under (3). (12b) is a case of semantic specialization. The affix PhaN attaches to the base to denote a semantically specialized and narrow sense of the patronymic meaning; the form derived with this rule bhārg-āyana refers to an offspring of the base form bharga only in case the individual is a member of the specific clan. (12c) is located outside the patronymic arthādhikāra. The default affix āN attaches to a single stem sthāndila, generating the form sthāndila which denotes the idiosyncratic sense indicated in the rule.

4.3 The inheritance hierarchy

The arthādhikāra factors out partially common information from rules that derive both formal and semantic exceptions. This allows for a non-redundant expression of such exceptions that otherwise would be represented as isolated entities in the lexicon, in spite of sharing partial similarities with their more regular counterparts. The resulting network involves an interleaving of pratyāyahārikās and arthādhikāras into an intricate hierarchy. A fragment of this hierarchy is presented in figure (2).

At every relevant node in figure (2), I have included, in addition to the specific semantic or formal rule, an example of a derived form generated by the rule. The topmost node represents the category of affixes, the taddhita or the nominal derivational affixes. The pratyāyahārikās are listed in the tier directly below the taddhita affixes. The general affixes prescribed are of the category taddhita because they inherit from the taddhita rule. The familiar aN pratyāyahārika or the domain of the affix aN is illustrated in most detail. The aN affix is used in denoting multiple senses as shown by the semantic rules inheriting from the hierarchically higher formal rule prescribing the affix aN. The paraphrases ‘X’s offspring’, ‘X’s dwelling’ etc. are the semantic contexts in which an affix attaches to the base (X). Thus, the pratyāyahārika serves as the domain for handling affix homonymy, since multiple arthādhikāras may inherit formal information from it. The rule block headed by the arthādhikāra contains both formal and semantic blocking rules, which facilitates the modeling of affix synonymy as well as semantically specialized meanings for regularly derived forms. The arthādhikāra
illustrated here is *tasya apatyam*, dealing with patronymic formation. The general rule, stated in 4.1.92, prescribes the default affix *aN* to nominals to derive patronymics. Exceptions to this general rule are dealt within the domain of this arthādhiṣṭāna by more specific formal rules that override the default, such as 4.1.95, 4.1.105 and 4.1.110. 4.1.95, discussed under (12a), is a productive blocking rule, that prescribes the affix *-iN* to the class of stems that end in the vowel *a* in the patronymic semantic domain (4.1.92). 4.1.105 and 4.1.110 are formal blocking rules defined over a lexically specified class of stems. These rules allow the specified classes of stems to inherit the patronymic semantic information from 4.1.92, but override the formal affix *aN* (4.1.83) to apply the specific affixes that these rules prescribe — *-yaN* and *-PHaN* for 4.1.105 and 4.1.110 respectively. 4.1.111 is a semantic specialization rule (discussed in (12c)) that applies to an isolated stem. This rule inherits the patronymic semantic information from 4.1.92 and the formal affix *-PHaN* from its immediate parent node 4.1.110, and then adds further semantic information that the derived patronymic form *bhṛg-āyan.a* for the stem *bhṛga* is valid only in the case it denotes a person belonging to the *traigarta* clan. 4.1.112 is a lexically specified sub-class of *a*-stems, which exceptionally retains the default affix *aN*, in spite of meeting the formal condition stated in the specific rule 4.1.95 that triggers the exceptional *iN* affix.

### 4.4 Determining defaults

Arthādhikāras in the taddhita section do not repeat across different pratyayādhikāras. Every pratyayādhikāra node heads a unique set of arthādhikāras, which implies that every affixal form is associated with a unique (set of) meaning/s. Panini’s ordering assumes a non-overlapping relation between the affixes introduced by a pratyayādhikāra and the semantic contents they are associated with. The question that arises is: how does Panini determine which pratyayādhikāra may head a given set of arthādhikāras? This question is important because a general affix introduced by a pratyayādhikāra may also occur as a more specific affix under an arthādhikāra of another pratyayādhikāra. Let us see how this works.

The affix *-ika* is introduced by a pratyayādhikāra and is the default affix to derive, in Panini’s terms, the semantic meaning ‘mixed with’ the base. Examples in (13a) and (13b) illustrate this derivation. (13c) exemplifies a formal exception to this default affix. The word *kulattha* does not derive the semantically complex form meaning ‘something mixed with *kulattha*’ using the default *-ika* affix, but with the affix *-á*, which, in fact, is a default affix heading another pratyayādhikāra

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16This is an instance of token blocking (van Marle, 1985), where the blocking rule is stated over an enumerated set of items. The terms, *gargādi*, *āsvādi* and *śivādi* are abbreviations used to denote an extensionally defined set of stems, beginning with the stem mentioned in the terms, i.e. *garga*, *āsava* or *śiva*. 
Figure 2: A fragment of the taddhita hierarchy of Pāṇini
— (the aN pratyayādhiṁkāra).

(13) a. dadhi ‘yoghurt’ dādh-ika ‘mixed with yoghurt’
b. śṛṅgavera ‘ginger’ śāṛṅgaver-ika ‘mixed with ginger’
c. kulattha ‘a kind of lentil’ kaulatth-ḍa ‘mixed with kulattha’

The derived form kaulatth-ḍa is an exception and is dealt with by a blocking rule at the level of an arthādhiṁkāra subsumed under the pratyayādhiṁkāra of –ika. The relevant rules are in (14).

(14) a. prāgvahates THaK (4.4.1)
before-vahat-ABL THaK-NOM
lit: THaK is the default affix until vahati
‘The taddhita (4.1.76) affix (3.1.1) THaK is introduced after (3.1.2) a nominal stem prātipadika (in the semantic contexts to be listed ahead) prior to the rule which contains the word vahati 4.4.76’

b. saṁskṛtam (4.4.3)
mixed-NOM
lit: mixed with it
‘The taddhita affix THaK is introduced after (3.1.2) a nominal stem prātipadika (3.1.1) in the semantic context ‘mixed with (4.4.2) the base’.

c. kulattha- ka-upadhāt (aN) (4.4.4)
kulattha- bases with penultimate k-ABL-SG áN
lit: aN after kulattha and bases with penultimate phoneme k.
‘The taddhita (4.1.76) affix (3.1.1) áN is introduced after (3.1.2) the nominal base kulattha (a kind of lentil) and a nominal stem prātipadika (3.1.1) with the penultimate phoneme ‘k’, in the semantic context ‘mixed with it (the base)’.

Since the affix –ḍa is exceptional in this particular semantic context, applying to a very limited class of base forms, its occurrence here is modeled by a blocking rule. The affix –ika, on the other hand, is the default affix used to derive forms with the semantic content ‘mixed with (the base)’ and so the relevant arthādhiṁkāra is located under the –ika pratyayādhiṁkāra.

4.5 The objects in Pāṇini’s hierarchy

The taddhita section is a fragment of a derivational inheritance hierarchy for nominal stems in Sanskrit. So far, I have been referring to the objects in this inheritance
hierarchy as ‘rules’. Pāṇini’s taddhita sūtras seem to most closely resemble word formation rules, which are not lexical entries for individual forms, but abstractions over classes of lexical entries with common partial information factored out.

However, there are two main issues that must be taken into consideration here. First, individual rules in the system do not stand independent; they must be reconstructed using the information inherited from prior rules. Secondly, Pāṇini’s rules are procedural in that they serve to derive complex lexemes from base (simple or complex) lexemes. In this sense, Pāṇini’s hierarchy is distinct from other inheritance-based lexica, which are, in fact, hierarchies of complex lexemes and not rules that derive such lexemes. Non-terminal nodes in modern inheritance-based hierarchies are partially specified lexical entries (for instance, Koenig (1999)) or redundancy rules (as in Riehemann (1993, 1998)), but not procedural rules. Rule-based hierarchies have been introduced in modern inheritance networks in the formalization of construction grammar rules (Sag, 1997), but not in lexical description (but see Sag (to appear) for a brief discussion).

It is, I believe, possible to reinterpret Pāṇini’s rules as declarative formulations or partially specified feature structures without much alteration to the content of the rules themselves.17 These rules can be conceived of as lexical redundancy rules in the fashion of Riehemann (1993). This conception of the inheritance hierarchy, I think, would constitute the simplest translation step from the hierarchically organized rules of Pāṇini to an actual type hierarchy of derived nominal lexemes in Sanskrit. On this view, the taddhita section, rather than being a set of hierarchically organized derivational rules, presents an inheritance hierarchy with redundancy rules (Jackendoff, 1975) that abstract away common information (phonological, morphological and semantic) from classes of complex lexemes so as to state generalizations over them. A formal restatement of Pāṇini’s rules as declarative constraints on word classes is necessary to facilitate the translation of Pāṇini’s hierarchy of rules into an actual hierarchy constructed an extant inheritance-based framework.

(15) a. prāgdīvyatah āN (4.1.83)
before-divyat-ABL āN-NOM
‘The taddhita affix (3.1.1) āN is introduced after (3.1.2) a nominal stem (in the semantic contexts listed) prior to 4.4.2’.

b. tasya apatyam (āN) (4.1.92)
He-GEN-SG offspring-NOM-SG āN-NOM

17The adhikāras in the taddhita section, in that they do not prescribe any operation themselves, are very much like declarative rules, or like partially specified feature structures, with which linguistic objects with more specific feature structures unify.
‘The taddhita affix (3.1.1) \( aN \) is introduced after a nominal stem (3.1.1) in the semantic context ‘his offspring’.

Restating the rules in (15) as (16), allows us to informally construe the procedural rules of Pāṇini as declarative constraints on classes of derived stems in Sanskrit.

(16) a. There is a class of affixed words in the language that are formed with morpho-phonological processes related to \( aN \).

b. There is a class of affixed words in the language that are formed with the morphophonological processes related to ‘aN, and that denote the semantic relation ‘offspring of (the base)’.

The idea is that these constraints can be organized along the same hierarchy that the taddhita section rules are structured in. Presenting an explicit formal proposal for the translation of the taddhita section into an inheritance hierarchy is the natural extension of this research; but that is beyond the scope of this paper. What this paper does bring out, however, is that the structure of Pāṇini’s rule hierarchy resembles modern inheritance-based lexica to a degree that makes translation between the two systems easily possible. Not only does Pāṇini explicate the defeasible nature of lexical generalizations, but he also describes them using a sophisticated inheritance network with override of default information that separates the formal and semantic contribution of affixal morphology in a constrained way. The peculiar properties of his network — default-based single inheritance with interleaving of formal and semantic information — are compatible in principle with modern inheritance-based frameworks, but have not been implemented, as far I know, in morphological accounts using inheritance. Recasting Pāṇini’s procedural rules as declarative constraints while essentially retaining the hierarchical structure of the taddhita section will allow us to determine the implementability of Pāṇini’s network as an inheritance-based lexicon.

5 Modern Inheritance-based lexica

In §3 and §4, I explicated the key properties of the taddhita section as an inheritance hierarchy. At this point, it will be useful to undertake a brief comparison of Pāṇini’s model with modern inheritance-based models of derivational morphology. Such accounts, in the main, use inheritance to capture lexical redundancy, and defaults to capture subregularities and exceptions (Krieger and Nerbonne, 1993; Hippisley, 1999; Flickinger, 1987, and others). I will first discuss a subsumption-based
account of derivational morphology within the framework of the HPSG Hierarchical Lexicon (Riehemann, 1993, 1998), and compare it with Pāṇini’s default-based model. Riehemann’s model is discussed in detail because it models some of the same morphological phenomena as Pāṇini, viz. semantic specialization and exceptions, using multiple inheritance rather than defaults. Comparing this multiple inheritance hierarchy with Pāṇini’s default-based hierarchy can clarify the ways in which multiple inheritance and defaults are used to capture blocking phenomena. In the next section, I discuss the comparability of default-based inheritance frameworks with Pāṇini’s approach — in particular, the interleaving of formal and semantic information.

5.1 The hierarchical lexicon in HPSG

The HPSG hierarchical lexicon presents one model of a structured lexicon embodied in an inheritance hierarchy. Lexical information is encoded via a set of attribute-value pairs, and organized into a hierarchy of classes of linguistic objects, called types. Linguistic generalizations are captured by grouping classes of linguistic objects under a type. Moreover, the hierarchical lexicon captures the fact that linguistic objects belong to several cross-cutting classes at once, by allowing for multiple inheritance.

I use Riehemann (1993, 1998)’s account of –bar adjectives in German to illustrate the properties of a subsumption-based hierarchy that uses multiple inheritance to capture form-meaning mismatches. The aspects of Riehemann’s analysis relevant to my discussion are the treatment of morphological facts such as semantic specialization and exceptions. Since the account concerns only one formal affix –bar, blocking phenomena are not directly captured by this analysis, although an idea for their treatment is presented.

In Riehemann’s model, affixes are not independent entities, but schemata which form generalizations over classes of complex lexemes. These generalizations most closely resemble the lexical redundancy rules of Jackendoff (1975). The relation between the base and the derived forms is expressed as a redundancy rule in the super-type for a class of derived lexemes. Formal information, such as there being a class of words ending in –bar, is expressed as a type. The semantic information that complex lexemes derived from the concatenation of –bar express the semantics of possibility is obtained from another type. Since the semantic and the formal

\[^{18}\text{Lexical redundancy rules, in the original analysis (Jackendoff, 1975), are envisaged as a device to minimize the cost of individual lexical entries, by factoring out the information common to a morphologically definable class of lexical entries. These rules, rather than being procedural or deriving one form from the other, are declarative in nature. They state relationships between lexical entries, and are representations of regularities in the lexicon, more than generative processes that derive new forms, although, they do operate secondarily as generative rules.}\]
properties of complex forms are inherited from different nodes, the hierarchy allows
for formal and semantic mismatches. Partially shared morphological or semantic
information can be stated separately, and need not be repeated for other affixes.
In fact, Riehemann suggests that the data for exceptional -bar adjectives (such
as haftbar ‘responsible’) as well as data from other affixes, such as -lich, justify
the separation of the semantic part of affixal information from their formal part
(Riehemann 1993: 42). In effect, Riehemann’s subsumption-based approach builds
in the assumptions of morphological separationism in an inheritance hierarchy.

By splitting up the information contained in a traditional lexical rule, Riehe-
mann can capture varying degrees of regularity in derived forms. For instance, by
divorcing the formal derivation of –bar adjectives from their semantics, semanti-
cally regular but morphologically irregular (non-transparent) and lexicalized –bar
adjectives can inherit the partial shared information that they are regularly derived
by a process of -bar affixation. –bar and –lich adjectives, on the other hand, inherit
information about their semantics from the same type (in Riehemann’s hierarchy,
possibility). It is also this splitting of information that enables this model to work
without using defaults.

5.1.1 Separation of form and meaning

The organization of the hierarchy in the taddhita section, and the model pro-
posed by Riehemann (1993, 1998) differ in the precise mechanism that implements
the separation of formal and semantic information in affixation. In the hierarchy
proposed by Riehemann, the semantic and formal parts of a lexical rule are in-
herited by multiple inheritance from distinct types. This is necessitated by the
non-transparent nature of some derived forms, as well as shared semantic proper-
ties with other affixes. On the other hand, in the Pāṇinian hierarchy, the informa-
tion about the semantic information an affix is located under a higher node that
contains the formal information corresponding to an affix.

This is a significant difference in terms of how the one-to-many correspondences
between the form and the semantics of an affix are conceived in the two systems.
The multiple-inheritance approach assumes that there is no constrained relation
between the formal and semantic properties of affixes, as we see below in (3)).
The unification of affixal properties is effected by means of multiple inheritance
so as to separate form and meaning. The taddhita hierarchy, on the other hand,
is based only on single inheritance. The formal information corresponding to an
affix is located at the super-node and is inherited by the sub-nodes which contain
information about the semantic contribution of the affix. This organization retains
the mapping between form and meaning, but relaxes the constraints on whether
an affix must map onto a semantically unifiable domain. It allows the same formal
affix to realize distinct semantic domains, which are not necessarily unifiable. At
the same time, it constrains the possible semantics that an affix may map onto by listing these semantic domains as sub-nodes under the higher node containing formal information. A multiple inheritance mechanism, as the one Riehemann assumes, on the other hand, is compatible with unconstrained correspondences of formal and semantic properties of affixes.

5.1.2 The domain of blocking

Riehemann develops a type-hierarchy fragment for a single affix, viz. the German adjective forming affix -bar ‘-able’. She avoids defaults by separating individual pieces of information in complex lexical rules, and locating the information at distinct nodes. The intersection of these categories determines the semantic and formal features of complex lexemes of the class of -bar adjectives.

The divorce between formal and semantic information, which allows this hierarchy to capture both formal and semantic regularities in isolation, however, prevents a meaningful modeling of blocking phenomena. Two formally distinct affixes, even when they inherit from the same semantic node, form distinct complex types in Riehemann’s hierarchy. Under this proposal, morphological regularities are indistinguishable from sub-regularities and exceptions and their distinct status cannot be expressed by complete separation between formal and semantic properties of affixes.

Consider the affixes -á and -i in Sanskrit. -á is the general affix occurring in a wide domain of meanings. The affix -i is both phonologically and semantically restricted. It occurs only after a-stems to derive patronymics. Being the more specific affix, -i blocks the application of -á for a specified class of stems. In Pànini’s model, the blocking relation between the two affixes is expressed by locating the specific affixation rule within the domain of the patronymic semantic rule (arthàdhikāra). In Riehemann’s hierarchy, this would be modeled by having two distinct complex types — one for the -a patronymic affix (the intersection of the suffix -á with the patronymic semantics), and one for the -i patronymic affix. The blocking relation between them, however, cannot be expressed by this organization.

Figure (3) gives an illustration of a hierarchy for Sanskrit affixes, which share partial properties. In the spirit of Riehemann, it separates formal and semantic information in lexical rules, which are then unified by the multiple inheritance mechanism. In principle, intersection between any of the semantic and formal types given in figure (3) is possible. Consider the specific affix -tā. This affix is used to derive collective nouns for a small class of stems, where it blocks the application of the general affix -á. This distribution can be captured by allowing the two classes of stems (those that take the affix -tā and those that take the affix -á) to inherit the semantic information from a single node and the formal
information from two distinct nodes. However, using multiple inheritance to model this distributional fact about affixes fails to express the blocking relations that characterize the distribution. The restricted status of the –tā affix is not expressible in a framework that uses multiple inheritance-based to model blocking, since affixes with restricted distribution cannot be differentiated from default, general affixes under this approach. On the other hand, defaults and overriding of defaults, as seen in the taddhita section as well as in some modern default-based inheritance lexica, provide a perspicuous mechanism to capture the blocking relations between affixes.

Moreover, by separating the semantic and formal aspects of lexical rules completely, Riehemann’s analysis assumes the stronger version of the Separation Hypothesis of Beard (1995), and provides no means to constrain the possible relations between morphological and semantic derivation.

In figure (4), I present a simplified version of a fragment of Pāṇini’s hierarchy for the taddhita derivatives. The inheritance of formal information from the pratyayādhikāra, to the arthādhikāra, which additionally provides semantic information about an affix, captures the one-to-many correspondences between affixal form and the semantics it may be associated with. Moreover, the inheritance relation constrains the possible semantic domain (although this domain may not be contiguous or expressible in a unified manner) for a given affix. Since every arthādhikāra inherits formal information from a pratyayādhikāra, it is blocking rules within the domain of an arthādhikāra (or abstracted over the domains of
multiple arthādhikāras) that capture partial and total blocking facts.

Figure 4: **Sanskrit derived forms: Single inheritance with defaults**

The affix –á is used to derive lexemes with at least three distinct semantic meanings: relational adjectives, collective nouns, and patronymics. In each of these cases, the affix –á is the general affix for morphological derivation. The form śaib-á, meaning ‘pertaining to śibi’, the derived form, aupagav-á, meaning ‘the son of upagu’, and the derived form śauk-á, meaning ‘a collection of parrots’ are examples of forms derived by the general affix –á. However, there exist exceptions, which block the application of the general case. These exceptions, being limited to partial domains, are located under the particular arthādhikāras. The affix –maya is used in the specific semantic context, for an idiosyncratic class of stems including āmra ‘mango’. It inherits the semantic information from the arthādhikāra, but overrides the default information inherited from the pratyatādhikāra aN by providing more specific information, in the form of the affix –maya. The exceptional rule for patronymic formation (with the affix –i as exemplified in dāks-ī) is similarly located under the arthādhikāra relating to patronymics. The exceptional collective noun case is dealt with in the same way, by deriving the word grāma-tā (a collection of villages), with a special rule located under the arthādhikāra deriving collective nouns. The use of defaults, thus, allows for a more constrained mapping between formal and semantic information by modeling affix synonymy as a blocking phenomenon.
5.2 Default inheritance frameworks

The previous section demonstrated that a multiple inheritance hierarchy based only on subsumption cannot provide an adequate account of the blocking relations that characterize multiple affixal exponents of a given semantic meaning in derivational morphology. The use of defaults is necessary to encode defeasible lexical generalizations as has been recognized for some time in default unification-based frameworks for representing lexical information (Lascarides et al., 1996; Lascarides and Copestake, 1999). DATR and morphological models written in DATR (e.g. network morphology) provide another appropriate framework for the non-redundant expression of lexical knowledge. The translation of Pāṇini’s approach into an actual hierarchy — particularly the reliance on interleaving of formal and semantic information in a single inheritance setting — must rely on a default inheritance-based framework.19

The default unification approach of Lascarides and Copestake (1999) would be particularly suited to the recasting of the taddhita section. It aims to fully integrate default unification into the inheritance structures used for lexical and grammatical description by defining it as supplementing an underlyingly monotonic, subsumption-based model of inheritance. Pāṇini’s unformalized model of default inheritance makes the same assumption about inheritance. Moreover, Lascarides and Copestake (1999) builds in a precedence ordering of defaults based on type specificity, a feature that also characterizes Pāṇini’s hierarchy, although not in terms of explicit typed feature structures. General exceptions to default rules are not non-defeasible in the Pāṇinian system, but may themselves be overridden by more specific information about a subclass of items. Pāṇini’s default-based rules, however, are crucially ordered because of his linearized representation and the contextual recovery required for their correct interpretation. On the other hand, a default unification framework such as Lascarides and Copestake (1999) is characterized by order independence and it is not immediately clear how Pāṇini’s hierarchy could be transparently accommodated to such a requirement.

19 Another issue in recasting Pāṇini’s hierarchy and adopting its structure in the construction of an inheritance-based lexicon of Sanskrit derivational morphology is whether Pāṇini’s hierarchy might not be more concisely represented by utilizing multiple inheritance in addition to the override of defaults. A reviewer suggests that this might be implemented by separating formal and semantic information (in the fashion of Riehemann (1993, 1998) and retaining the use of defaults to capture formal blocking and semantic specialization facts. However, such a network would lose the crucial property in Pāṇini’s hierarchy that uses interleaving of semantic and formal information rather than separation of the two kinds of information and their unification by multiple inheritance. Which of these possibilities results in a more concise representation of the Sanskrit facts is a question for further research.
Conclusion

The main contribution of this paper is an explication of how closely a particular part of Pāṇini’s grammar resembles a default inheritance hierarchy. I demonstrated that the organizational principles of the taddhita section of Pāṇini’s Āṣṭādhyāyī are comparable to those used in inheritance-based lexica. Pāṇini is concerned with the modeling of the very same phenomena in morphological organization that have motivated modern (default) inheritance-based networks — defeasible generalizations of the formal, semantic, and pragmatic kind. The limitations of Pāṇini’s linear representation, however, lead him to an approach that has not been experimented with in the context of lexical knowledge representation — the interleaving of formal and semantic information at different levels along a path of single inheritance. An apparent advantage of this approach is that it eschews the use of the multiple inheritance mechanism. Formalizing Pāṇini’s hierarchy within an extant default-based framework should be the next step in determining the value of this model for morphological description.
Appendix: The relative levels of embedding of the Aṣṭādhyāyī rules discussed in the paper

3.1.1 pratyayāḥ (adhitikāra)
   3.1.93 kṛd ā-tiN (adhitikāra for V → V affixes)
4.1.1 Ni-āP-pratipadik-āt (adhitikāra for N → N affixes)
   4.1.3 striy-ām (adhitikāra for feminine affixes)
   4.1.76 taddhit-āḥ (adhitikāra for taddhita affixes)
   4.1.83 prāg divyat-āḥ āN (pratyayādhitikāra for affix -ā)
   4.1.92 tá-sya āpatya-m (Patronymic artha-adhitikāra)
   4.1.95 aT-āḥ iN (formal exception to -ā)
   4.1.99 nādā ādi-bhyāḥ phāK (exception to -i)
   4.1.105 gargā ādibhyāḥ yaN
   4.1.111 bharg-āt traigar-τ-e
   4.1.112 sivā ādibhyāḥ āN
   4.2.15 sthan’d-il-āt śayit-r-ī vrat-ē (Special sense of -ā)
   4.2.69 tá-sya ni-vās-ā-h (artha-adhitikāra under -ā)
   4.3.25 tá-tra jā-tā-ḥ (artha-adhitikāra under -ā)
   4.3.120 tá-sya idām (artha-adhitikāra under -ā)
   4.4.1 prāg vāhate-s thāK (pratyayādhitikāra for affix -ika)
   4.4.3 sān-s-kṛ-ta-m (artha-adhitikāra)
   4.4.4 kulattha-kā upadh-āt āN (exception to -ika)
   4.4.75 prāk hi-t-āt vāT (pratyayādhitikāra for affix -ya)
   5.1.1 prāk krit-āt cha-ḥ (pratyayādhitikāra)
   5.1.18 prāk vāṭe-s ūṇ (pratyayādhitikāra)

6.1.77 iK-āḥ yāN aC-i (automatic phonology rules)
6.1.78 eC-aḥ ay-av-āy-av-āḥ
6.1.79 va anta-h y-i praty-ay-ē

References


