Principal parts and morphological typology

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I. What are principal parts?

Intuitively, a set of PRINCIPAL PARTS for a paradigm P is a minimal subset of P's members from which all of P's other members can be deduced. The practical utility of principal parts for language pedagogy has long been recognized. Generations of Latin students have learned that each verb in Latin has four principal parts, namely those exemplified in Table 1. By memorizing these four forms for a given Latin verb, one should be able to predict all of the other forms in its paradigm. Principal parts can therefore be seen as a pedagogical idealization of an important feature of first language acquisition: language learners' reliance on the implicative relationships among the forms in a lexeme's paradigm to deduce that lexeme's full inventory of forms.

TABLE 1. Principal parts of five Latin verbs

	1st person singular present indicative active	Infinitive	1st person singular perfect indicative active	Perfect passive participle (neuter nominative singular)
1st	laudō	laudāre	laudāvī	laudātum
2nd	moneō	monēre	monuī	monitum
3rd	dūcō	dūcere	dūxī	dūctum
3rd (*-iō*)	capiō	capere	cēpī	captum
4th	audiō	audīre	audīvī	audītum

But should linguists take any interest in principal parts, or are they a device whose utility is purely pedagogical? We believe that linguists should take an interest in principal parts.

On the assumption that speakers store some of a lexeme's forms and use these stored forms to deduce that lexeme's other forms, the question naturally arises: how many of a lexeme's forms could be stored? At one extreme, there could be full storage. At the opposite extreme, there could be storage of the minimum of forms needed to deduce the remaining, unstored forms. Principal parts embody this notion of a lower extreme. Postulating principal parts does not, of course, commit one to the assumption that speakers store a lexeme's principal parts and nothing more--only to the assumption that they are the minimum that could be stored if unstored forms are deducible from stored ones. Thus, principal parts are a distillation of the implicative relations that exist among the members of a lexeme's paradigm.[1] As such, they reveal an important domain of typological variation in morphology. Here, we shall identify five dimensions of typological contrast among languages relating specifically to their systems of principal parts. Throughout, our focus is on the principal parts of verbs; nevertheless, the general principles under discussion here should apply equally in the analysis of principal parts for other lexical categories.[2]

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[1] For discussion of the theoretical importance of a paradigm's implicative relations, see Wurzel 1989, Blevins 2006, and Ackerman & Blevins 2006.

[2] An earlier version of this paper was presented at the 12th International Morphology Meeting, May 25-28, 2006, Budapest; we wish to thank the participants at this conference for several helpful comments. Thanks also to Matthew Baerman and Greville Corbett for insightful comments on an earlier draft.

Before considering the details of this typological framework, we need to introduce three different ways in which one might define the notion of principal parts.

II. Alternative kinds of principal-part systems

Traditional principal-part schemes are STATIC in that the same morphosyntactic property sets identify the principal parts for every conjugation class. Imagine a language having the system of conjugations in Table 2. In this table, W-Z represent distinct morphosyntactic property sets, I-VI represent different conjugations, and **a-o** represent the different inflectional exponents realizing the intersection of a particular conjugation with a particular morphosyntactic property set. For a language having this system of conjugations, we might propose the system of principal parts schematized in Table 3, in which the exponent of each principal part is shaded. The principal parts in this system are static: the same three morphosyntactic property sets (W, X, and Y) identify the principal parts in each conjugation. For the identification of this language's principal parts, the set {W, X, Y} of morphosyntactic property sets is ADEQUATE: in any verbal paradigm in any of the six conjugations in this language, the word forms realizing W, X, and Y uniquely determine all of the other word forms in the paradigm. The set {W, X, Y} is also MINIMAL in the sense that no subset of {W, X, Y} is adequate. By contrast, the set {Y, Z} is not adequate (because the word forms realizing Y and Z distinguish neither conjugations I and II nor conjugations III and IV), and the set {W, X, Y, Z}, though adequate, is not minimal. If a set of morphosyntactic property sets is both adequate and minimal, we say that it is OPTIMAL.

Given the intersecting realizations of the morphosyntactic property sets W, X and Y and the conjugations I-VI in Table 2, lexical listings for lexemes in this language must specify a list of three static principal parts, as in (1) (where L_x represents that member of L's paradigm bearing the exponent x).

TABLE 2. A hypothetical system of conjugations

	W	X	Y	Z
I	**a**	**e**	**i**	**m**
II	**b**	**e**	**i**	**m**
III	**c**	**f**	**j**	**n**
IV	**c**	**g**	**j**	**n**
V	**d**	**h**	**k**	**o**
VI	**d**	**h**	**l**	**o**

TABLE 3. Static principal parts for the hypothetical system

	W	X	Y	Z
I	**a**	**e**	**i**	**m**
II	**b**	**e**	**i**	**m**
III	**c**	**f**	**j**	**n**
IV	**c**	**g**	**j**	**n**
V	**d**	**h**	**k**	**o**
VI	**d**	**h**	**l**	**o**

(1) Sample static principal-part specifications:

For lexeme L belonging to conjugation I : $L_{\mathbf{a}}$, $L_{\mathbf{e}}$, $L_{\mathbf{i}}$
For lexeme M belonging to conjugation IV : $M_{\mathbf{c}}$, $M_{\mathbf{g}}$, $M_{\mathbf{j}}$
For lexeme N belonging to conjugation VI : $N_{\mathbf{d}}$, $N_{\mathbf{h}}$, $N_{\mathbf{l}}$

Instead of a static system of principal parts, however, we could design an ADAPTIVE system. In a system of this latter sort, all lexemes have the same member of their paradigm as their first principal part, but the exponence of principal part *n* determines the morphosyntactic property set used to identify principal part *n*+1. For the hypothetical language in Table 2, we might propose the system of adaptive principal parts in Table 4. In this system, the morphosyntactic property set W identifies the first principal part of a given lexeme L. If L's exponence for W is **a**, then we need go no further: this exponent unequivocally identifies L as a member of conjugation I. On the other hand, if L's exponent for W is **c**, then the morphosyntactic property set X identifies L's second principal part; if L's exponent for X is **f**, then L belongs to conjugation III. But if L's exponent for W is **d**, then property set Y (rather than X) identifies L's second principal part; if L's exponent for Y is **k**, then L belongs to conjugation V.

In this adaptive system, exponents of principal parts act as branches in a tree having morphosyntactic property sets as its nonterminal nodes and conjugations as its terminal nodes, as in Figure 1 (or equivalently, as in Table 5). In this system, no lexical item needs a list of three principal parts; indeed, some lexemes have a single principal part (those belonging to conjugations I and II), and others have two (those belonging to conjugations III-VI), as in (2).

For a given static system of principal parts, there is always a single set of morphosyntactic property sets that is both adequate and minimal (and therefore optimal); for the static system of principal parts in Table 3, this is the set {W, X, Y}. For an adaptive system of principal parts, however, the adequacy and minimality (hence also the optimality) of a set of morphosyntactic property sets may vary from one inflection class to another, subject only to the requirement that they share one property set. In the adaptive system of principal parts in Table 4, the set {W} is adequate and minimal (hence optimal) for conjugations I and II, since a word form realizing W in either of these conjugations uniquely determines all of the other word forms in its paradigm. For conjugations III through VI, by contrast, the set {W} is inadequate; instead, it is the larger set {W, X} that is adequate and minimal (hence optimal) for conjugations III and IV, and the set {W, Y} that is adequate and minimal (hence optimal) for conjugations V and VI. Thus, while a static system of principal parts has a single, optimal set of morphosyntactic property sets, an adaptive system has several optimal sets: these are alike in sharing at least one property set, but may otherwise differ.

TABLE 4. Adaptive principal parts for the hypothetical system

	W	X	Y	Z
I	**a**	**e**	**i**	**m**
II	**b**	**e**	**i**	**m**
III	**c**	**f**	**j**	**n**
IV	**c**	**g**	**j**	**n**
V	**d**	**h**	**k**	**o**
VI	**d**	**h**	**l**	**o**

FIGURE 1. The adaptive principal parts in tree form

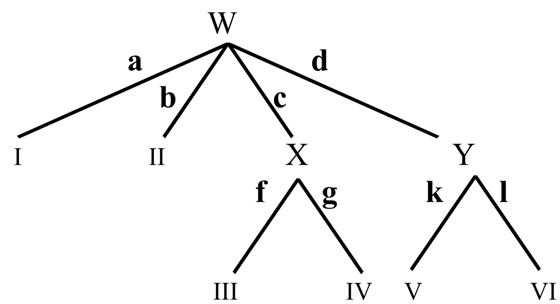

TABLE 5. The adaptive principal parts in tabular form

<table>
<tr><th colspan="4">Principal parts</th><th rowspan="3">Conjugation</th></tr>
<tr><th colspan="2">First</th><th colspan="2">Second</th></tr>
<tr><th>Morphosyntactic property set</th><th>Exponent</th><th>Morphosyntactic property set</th><th>Exponent</th></tr>
<tr><td rowspan="6">W</td><td>a</td><td colspan="2"></td><td>I</td></tr>
<tr><td>b</td><td colspan="2"></td><td>II</td></tr>
<tr><td rowspan="2">c</td><td rowspan="2">X</td><td>f</td><td>III</td></tr>
<tr><td>g</td><td>IV</td></tr>
<tr><td rowspan="2">d</td><td rowspan="2">Y</td><td>k</td><td>V</td></tr>
<tr><td>l</td><td>VI</td></tr>
</table>

(2) Sample adaptive principal-part specifications:

For lexeme L belonging to conjugation I : $L_{\mathbf{a}}$
For lexeme M belonging to conjugation IV : $M_{\mathbf{c}}$, $M_{\mathbf{g}}$
For lexeme N belonging to conjugation VI : $N_{\mathbf{d}}$, $N_{\mathbf{l}}$

Yet a third way of conceiving of principal parts organizes them into a DYNAMIC system. Dynamic principal parts are neither linearly ordered nor necessarily parallel from one conjugation to another. The hypothetical system of conjugations given in Table 2 could have the system of dynamic principal parts in Table 6. Here, each conjugation has only a single principal part: thus, if a lexeme L has exponent **a** for the morphosyntactic property set W, we deduce that L belongs to conjugation I; if L has exponent **f** for property set X, we deduce that L belongs to conjugation III; if L has **k** as its exponent for the property set Y, we deduce that L belongs to conjugation V; and so on.

As in an adaptive system of principal parts, the adequacy and minimality (hence the optimality) of a set of morphosyntactic property sets may vary from one inflection class to another in a dynamic system. But while the optimal sets of morphosyntactic property sets must share at least one property set in an adaptive system, there is no such requirement in a dynamic system. Thus, in the dynamic system of principal parts in Table 6, the set {W} is adequate and minimal (hence optimal) for conjugations I and II, the set {X} is adequate and minimal (hence optimal) for conjugations III and IV, and the set {Y} is adequate and minimal (hence optimal) for conjugations V and VI. Thus, the criteria of adequacy, minimality and optimality vary according to which of the three sorts of principal part systems is at issue.

This dynamic scheme is, in a sense, the most parsimonious conception of principal parts, since it allows us to assume a much smaller system of principal parts than is possible under the static or adaptive conceptions. One might hope that here too, a lexeme's principal-part specification is simply a list of one or more word forms (just as it is a list of word forms under the static and adaptive conceptions of principal parts). But the dynamic scheme forces us to represent lexical specifications of principal parts as pairings of property sets with their realizations. Consider the hypothetical system of conjugations in Table 7. Exponents of the dynamic principal parts for each of the conjugations are shaded, as before; in this system, however, it doesn't suffice to say that a given lexeme L has $L_{\mathbf{g}}$ as its principal part, because in this system, **g** is ambiguous, serving both as the exponent of the morphosyntactic property set X in conjugation IV and as the exponent of the morphosyntactic property set Z in conjugation VII. Thus, a lexeme's dynamic principal-part specification must be a set of (one or more) pairings of word forms with the morphosyntactic property sets that they realize, as in (3).

TABLE 6. Dynamic principal parts for the hypothetical system

	W	X	Y	Z
I	**a**	**e**	**i**	**m**
II	**b**	**e**	**i**	**m**
III	**c**	**f**	**j**	**n**
IV	**c**	**g**	**j**	**n**
V	**d**	**h**	**k**	**o**
VI	**d**	**h**	**l**	**o**

TABLE 7. Dynamic principal parts for a slightly larger system of conjugations

	W	X	Y	Z
I	**a**	**e**	**i**	**m**
II	**b**	**e**	**i**	**m**
III	**c**	**f**	**j**	**n**
IV	**c**	**g**	**j**	**n**
V	**d**	**h**	**k**	**o**
VI	**d**	**h**	**l**	**o**
VII	**c**	**e**	**j**	**g**

(3) Sample dynamic principal-part specifications:

For lexeme L belonging to conjugation I :	W: $L_{\mathbf{a}}$
For lexeme M belonging to conjugation IV :	X: $M_{\mathbf{g}}$
For lexeme N belonging to conjugation VI :	Y: $N_{\mathbf{l}}$
For lexeme O belonging to conjugation VII :	Z: $O_{\mathbf{g}}$

In summary, the specification of a lexeme's principal parts depends upon which of these three conceptions of principal parts one employs. Under the static conception, a lexeme's principal-part specification is a sequence of word forms realizing a list of morphosyntactic property sets that is invariant across conjugations. Under the adaptive conception, a lexeme's principal-part specification is a sequence of word forms realizing one path through a hierarchy such as that in Figure 1/Table 5; there is no expectation that the morphosyntactic property sets realized by a given sequence of principal parts is invariant from one conjugation to the next. Finally, under the dynamic conception, a lexeme's principal-part specification is an unordered set of word forms paired with the morphosyntactic property set that each realizes. Thus, the traditional conception of Latin principal parts in Table 1 is a static conception, but it's not the only possible conception (a point that we will return to below).

Whichever of these three sorts of principal-part systems one employs, there are nearly always additional choices in the analysis of a language's principal-part system. First, whether one restricts one's attention to static, adaptive, or dynamic principal parts, the same system of conjugations typically admits a number of alternative principal-part analyses.

Consider, for instance, the system of verb inflection in Ngiti, a Nilo-Saharan language spoken in the Democratic Republic of the Congo. Table 8 lists some partial paradigms of two verbs in Ngiti: the verbs 'push' (a member of conjugation v1a) and 'write' (a member of conjugation v4.tr). The representative forms given here include the 2sg and 1pl inclusive forms across a range of different tense/aspect/mood combinations as well as several nonfinite forms. Close inspection of these examples reveals that there's not really any morphological variation from one conjugation to the next in Ngiti except with respect to the tone of the root-final vowel. (The members of each conjugation are also generally restricted with respect to the quality of their stem-initial vowel.) We can therefore abstract from the rest of the morphology of these forms as in Table 9, whose horizontal axis lists the different morphosyntactic property sets that vary in their realization from one Ngiti conjugation to the next and whose vertical axis lists the conjugations themselves. The latter are, again, distinguished by the quality of a verb's stem-initial vowel and by the tone of the root-final vowel in the realization of different morphosyntactic property sets.

TABLE 8. Partial paradigms of two verbs in Ngiti (Kutsch Lojenga 1994:455-511)

	‘push’ (v1a)		‘write’ (v4.tr)	
Infinitive	i^{M}dzi^{L}-ta^{M}		a^{M}ndi^{H}-ta^{H}	
	2sg	1pl incl	2sg	1pl incl
Imperative	i^{H}dzi^{L}	k-i^{L}dzi^{L}	a^{H}ndi^{LM}	k-a^{L}ndi^{LM}
Perfective present	ny-i^{L}dzi^{L}	k-i^{L}dzi^{L}	ny-a^{L}ndi^{LM}	k-a^{L}ndi^{LM}
Perfective recent past	ny-i^{L}dzi^{L}-na^{L}	k-i^{L}dzi^{L}-na^{L}	ny-a^{L}ndi^{LH}-na^{L} (1)	k-a^{L}ndi^{LH}-na^{L} (1)
Perfective intermediate past	ny-i^{H}dzi^{L}-na^{H}	k-i^{H}dzi^{L}-na^{H}	ny-a^{H}ndi^{LM}-na^{H}	k-a^{H}ndi^{LM}-na^{H}
Perfective remote past	ny-i^{H}dzi^{L}	k-i^{H}dzi^{L}	ny-a^{H}ndi^{LM}	k-a^{H}ndi^{LM}
Perfective narrative past	ny-i^{M}dzi^{L}	k-i^{M}dzi^{L}	ny-a^{M}ndi^{H}	k-a^{M}ndi^{H}
Imperfective near future	ny-i^{M}dzi^{L}-na^{M}	k-i^{M}dzi^{L}-na^{M}	ny-a^{M}ndi^{H}-na^{M}	k-a^{M}ndi^{H}-na^{M}
Imperfective distant future	ny-i^{M}dzi^{L}-ya^{M}	k-i^{M}dzi^{L}-ya^{M}	ny-a^{M}ndi^{H}-ya^{M}	k-a^{M}ndi^{H}-ya^{M}
Imperfective past continuous	ny-i^{M}dzi^{L}-na^{M}	k-i^{M}dzi^{L}-na^{M}	ny-a^{M}ndi^{H}-na^{M}	k-a^{M}ndi^{H}-na^{M}
Imperfective past habitual	ny-i^{M}dzi^{H}-na^{L}	k-i^{M}dzi^{H}-na^{L}	ny-a^{M}ndi^{H}-na^{L}	k-a^{M}ndi^{H}-na^{L}
Imperfective past conditional	ny-i^{H}dzi^{L}-na^{M}	k-i^{H}dzi^{L}-na^{M}	ny-a^{H}ndi^{L}-na^{M}	k-a^{H}ndi^{L}-na^{M}
Subjunctive	r-i^{M}dzi^{L}		r-a^{M}ndi^{H}	
Nominalized stem1	n-i^{H}dzi^{L}		n-a^{H}ndi^{LM}	
Nominalized stem2	n-i^{H}dzi^{L}		n-a^{H}ndi^{M}	
1. LM → LH by tone sandhi.				

TABLE 9. The tone of the root vowel in Ngiti conjugation (Kutsch Lojenga 1994:217ff)

Conjugation	Stem-initial vowel	Infinitive	Imperative singular	Imperative plural	Perfective present	Perfective recent past	Perfective intermediate past	Perfective remote past	Perfective narrative past	Imperfective near future	Imperfective distant future	Imperfective past continuous	Imperfective past habitual	Imperfective past conditional	Subjunctive	Nominalized stem1	Nominalized stem2	Example (infinitive form)
v1a	a/I/U	L	L	L	L	L	L	L	L	L	L	L	H	L	L	L	L	afà-ta 'to cry out'
v1b	O	L	L	L	L	L	L	L	L	H	H	L	H	L	H	L	L	obhì-ta 'to cultivate'
v2a.tr	a/I/U	M	M	M	L	L	L	L	M	M	M	M	H	L	M	M	L	ada-ta 'to cross'
v2a.itr	a/I/U	M	M	M	L	L	L	L	M	M	M	M	H	L	M	M	M	upo-ta 'to climb'
v2b.tr	O	M	M	M	L	L	L	L	L	M	M	L	H	L	M	M	L	ɔdɔ-ta 'to guard'
v2b.itr	O	M	M	M	L	L	L	L	L	M	M	L	H	L	M	M	M	ɔdzɨ-ta 'to cry'
v3.tr	a/I/U	M	LM	M	M	M	M	M	M	M	M	M	H	L	M	LM	M	ʉdhɔ-ta 'to pour'
v3.itr	a/I/U	M	LM	M	M	M	M	M	L	L	L	L	H	L	L	M	M	ʉdhɔ-ta 'to sleep'
v4.tr	a/I/U	H	LM	LM	LM	LM	LM	LM	H	H	H	H	H	L	H	LM	M	andí-tá 'to write'
v4.itr	a/I/U	H	LM	LM	LM	LM	LM	LM	H	H	H	H	H	L	H	LM	LM	akpé-tá 'to whistle'
The archisegment I is realized as [i] or [ɨ]; U, as [u] or [ʉ]; and O, as [o] or [ɔ].																		

We have devised a computer program which, given input such as Table 9, calculates all possible principal-part analyses admitted by that data.[3] (In the Appendix, we present the main characteristics of this program and demonstrate its effects for a fragment of Latin verb morphology.) This set of Ngiti data allows twenty-six different static principal-part systems that are optimal; each consists of three members, which we tabulate in Table 10. The vertical axis represents the different morphosyntactic property sets to be realized, and the horizontal axis represents the alternative static principal-part analyses admitted by this language. Thus, analysis 1 treats the static principal parts across all of the conjugations as consisting of the imperative singular, the perfective narrative past, and the second nominalized stem; analysis 2 takes the three principal parts as consisting of the imperative singular, the imperfective near future, and the second nominalized stem; and so forth. As Table 10 shows, some of the word forms in a Ngiti verbal paradigm aren't fit to serve as static principal parts; for instance, the infinitive, the imperfective past habitual, and the imperfective past conditional aren't informative enough to be able to figure as one of the principal parts in any static three-part system. Others, on the other hand, seem heavily informative; thus, in every one of the principal-part systems deduced by our program, the second nominalized stem must function as one of the static principal parts in this language.

[3] This program can be run online at http://www.cs.uky.edu/~raphael/linguistics/principalParts.html.

TABLE 10. Twenty-six possible static principal-part systems for Ngiti

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Infinitive																										
Imperative singular	■	■					■					■	■													
Imperative plural																										
Perf. present			■					■						■				■								
Perf. recent past				■					■						■				■							
Perf. intermediate past					■					■						■				■						
Perf. remote past						■					■						■				■					
Perf. narrative past	■																					■				
Imperf. near future		■	■	■	■	■																	■			
Imperf. distant future							■	■	■	■	■													■		
Imperf. past continuous												■													■	
Imperf. past habitual																										
Imperf. past conditional																										
Subjunctive													■	■	■	■	■									■
Nominalized stem1																		■	■	■	■	■	■	■	■	■
Nominalized stem2	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

This Ngiti example is typical in the sense that for any principal-part system proposed for a language--whether static, adaptive, or dynamic--there are nearly always alternative systems of the same kind to choose from. In some cases there is a good basis for arguing for one of these systems over another; in other cases the choice among these competing systems appears to be arbitrary. (It is, of course, perfectly imaginable that different speakers of the same language might assume different principal parts in their lexical representation of the same lexeme.)

Another recurring choice that must be made in the analysis of a language's principal-part system relates to the system's scope. In some instances, the inflection of a lexeme L is so irregular that one might be inclined to regard L as being outside the compass of the principal-part system that would otherwise govern it. In English, verbs are ordinarily assumed to have three static principal parts: the default present-tense form, the past-tense form, and the past participle. An ordinary verb's paradigm can be deduced from these three principal parts by means of a small number of simple inferences. But several additional, otherwise unmotivated inferences would be needed to deduce the full paradigm of the verb *be* from the three forms *are*, *was*, and *been*. One might therefore account for the special status of *be* in either of two ways. On the one hand, one might assume that the lexical entry of *be* simply specifies its full paradigm, placing it outside the scope of the English system of static principal parts. On the other hand, by adopting an adaptive or dynamic approach to principal parts, one can instead assume that the exceptionality of *be* resides in the fact that unlike other English verbs, it has more than three principal parts; in that case, *be* remains within the scope of the English system of (adaptive or dynamic) principal parts.

A final choice that recurs in the analysis of principal-part systems concerns the nature of the relation between a language's principal parts and its inflection classes. In some languages, each set of principal parts can be plausibly seen as realizing a single inflection class; in other languages, however, one might describe some of the lexemes possessing principal parts as heteroclitic (i.e. as having paradigms in which two or more distinct inflection classes are juxtaposed; cf. Stump 2006b). Thus, in English, the principal parts of *give* (*give/gave/given*), *move* (*move/moved/moved*) and *prove* (*prove/proved/proven*) might be seen as realizing three distinct conjugations or two conjugations that are juxtaposed in the paradigm of *prove*.

As the foregoing discussion shows, a range of alternatives is typically available in the analysis of an individual language's principal-part system. At the same time, there are also important differences among the types of analyses suited for particular languages. These differences are at the core of the typology of principal-part systems that we now propose.

III. A typology of principal-part systems

In order to elucidate the dimensions of typological variation across languages' principal-part systems, we propose five distinguishing criteria.

Criterion A: How many principal parts are needed to determine a lexeme's paradigm?

There are languages in which all verbs inflect alike; in languages of this sort, no verbal principal parts are even necessary, since there is no conjugation-class variation from one verb to another. There are also languages that require only a single principal part. A language of this sort is Kwerba, a member of the Trans-New Guinea family spoken in Irian Jaya. The only piece of verb morphology that distinguishes one Kwerba conjugation from another is the subject agreement morphology: this is abstracted from the rest of the verbal morphology in Table 11. Here, a verb can be said to have its first-person plural form as its only principal part, since this form alone decisively indicates which of the four conjugations that verb belongs to.

TABLE 11. Subject prefixes in Kwerba (De Vries & De Vries 1997: 18-21)

Class	Person	Singular		Dual	Plural
		Diminutive	Augmentative		
I	1st	a	a	ac	ec
	2nd				ac
	3rd				naN
II	1st	naN	a	aN	eN
	2nd				aN
	3rd				naN
III	1st	naN	a	aN	e
	2nd				a
	3rd				
IV	1st	naN	a	aN	era
	2nd				ara
	3rd				

N.B.: N is a nasal homorganic with the following consonant.
Exponents of principal parts are shaded.

Some languages that have a system of inflection classes require a larger number of principal parts. But the exact number and identity of principal parts required for a given category of lexemes in a given language depends on whether one wants a static, an adaptive, or a dynamic system of principal parts. Consider, for instance, the Koasati language, a Muskogean language spoken in the southern USA. Verbs in Koasati require at least two static principal parts, but only a single dynamic principal part. To see this, consider the schematic representation of Koasati agreement morphology in Table 12. For most conjugations, the second-person singular form suffices to reveal the conjugation to which a verb belongs. But three conjugations, here represented as 3A.ka, 3A.ki, and 3A.ko, are not distinguished in the second person singular, but are distinguished in the first person singular. Thus, if we want a static system of principal parts, we say that a Koasati verb has two principal parts: the first person singular and the second person singular. But if we instead want a dynamic system, we say that each verb in Koasati has a single principal part: in most conjugations, the second-person singular form, but in the particular case of verbs belonging to the 3A.ka, 3A.ki, and 3A.ko classes, the first-person singular form.

TABLE 12. Koasati affirmative agreement morphology (Kimball 1991:56-89)

Conjugation	Form of root	1sg	2sg	3	1pl	2pl	Example
1A	R	R-li	is-R	R	il-R	has-R	í:mon ‘gather’
1B	R	R-li	R<s>	R	R<l>	R<has>	ó:tin ‘gather’
2Ai	R	R-li	R-ci	R	R-híli	R-háci	pí:sin ‘suckle’
2Aii	Xli	Xli-li	X-ci	Xli	X-híli	X-háci	incokfolóhlin ‘be dizzy’
2B	Xli:ci	Xlí:ci-li	X:ci<cí>	Xlí:ci	X:ci<hilí >	X:ci<hací >	immammí:cin ‘be good-hearted’
2C	R	R-li	R<ci>	R	R	R<haci>	hofnán ‘smell something’
3A.ka	Xka	Xka-li	X-híska	Xka	X-hílka	X-háska	taníhkan ‘gamble’
3A.ki	Xki	Xki-li	X-híska	Xki	X-hílka	X-háska	fí:kin ‘pay’
3A.ko	Xko	Xko-li	X-híska	Xko	X-hílka	X-háska	ískon ‘drink’
3B	R	R-li	R-íska	R	R-ílka	R-áska	pakama:cin ‘tame’
3Ci	R	R-li	R-tíska	R	R-tílka	R-táska	míkkon ‘be a king’
3Cii	R	R-l-o	R-tísk-o	R-o*	R-tílk-o	R-tásk-o	sná:h-ǫ ‘be rich’

* paucal R-k-o, plural R-h-o.

N.B.: Y<Z> represents the result of infixing Z in Y.
Exponents of principal parts are shaded.

In general, a static system for a given language involves the largest number of principal parts, and a dynamic system for the same language involves the smallest. For six of the languages that we have examined for this study, the breakdown of static, adaptive, and dynamic principal parts is shown in Table 13. Thus, Kwerba has one principal part no matter whether we're talking about static, adaptive, or dynamic principal parts, but Fur, for example, has five principal parts of a static kind, but only three adaptive or dynamic principal parts.

TABLE 13. Numbers of principal parts in the verb systems of six languages

	Number of conjugations	Number of static principal parts	Depth of adaptive principal parts		Number of dynamic principal parts	
			Maximum	Average over all conjugations	Maximum	Average over all conjugations
Kwerba (Trans-New Guinea; Irian Jaya)	4	1	1	1	1	1
Koasati (Muskogean; USA)	12	2	2	1.25	1	1
Gadaba (Dravidian; India)	4	3	2	2	2	1.25
Ngiti (Nilo-Saharan; DR Congo)	10	3	3	2.40	2	1.6
Fur (Nilo-Saharan; Sudan)	19	5	3	2.32	3	1.58
Comaltepec Chinantec (Oto-Manguean; Mexico)	66	5	4	2.39	4	1.92

Our second criterion for distinguishing different types of principal-part systems is Criterion B.

Criterion B: Are the dynamic principal parts the same for all inflection classes?

If the morphosyntactic property sets realized by a verb's principal parts are the same across all conjugations in some language, we say that the language has a PARALLEL system of verbal principal parts; but if the morphosyntactic property sets realized by a verb's principal parts vary from one conjugation to the next, then we say that the language has a SKEWED system of verbal principal parts. By definition, all static systems of principal parts are parallel; the same is not true, however, of adaptive or dynamic systems. Criterion B therefore serves to distinguish dynamic systems of principal parts that are parallel from those that are skewed.[4]

An example of a parallel system of dynamic principal parts is that of Sanskrit verbs. In Sanskrit, each verb has twelve dynamic principal parts, as listed on the vertical axis of Table 14. On first consideration, one might question the claim that this is a parallel system, since some of the verbs in Table 14 have blanks in their inventory of principal parts. *Īkṣ* 'look', for example, is a middle verb--it doesn't have active forms in its paradigm; *hā* 'abandon', on the other hand, is an active verb, lacking middle forms in its paradigm. While this might appear to suggest that middle verbs and active verbs have fewer principal parts than the *ubhayapadin* verbs (= those that have both middle and active forms), closer consideration reveals that the blanks in Table 14 themselves constitute principal parts. The reason is this: whatever forms a given principal part in this system is used to predict, a corresponding blank in either of the last two columns in Table 14 likewise predicts the absence of those very forms from the paradigms in question. So for

[4] One might regard a static system of principal parts as simply a dynamic system that is parallel; it is important to note, however, that an optimal static system is not necessarily optimal as a dynamic parallel system. For instance, the system in Table 3 is optimal as a static system; as a dynamic system, it is parallel but not optimal.

instance, if the third-person singular present indicative active form *ruṇaddhi* 'dhs/he obstructs' predicts all of the present indicative active forms in the paradigm of *rudh* 'obstruct', the blank in the principal-part system of *īkṣ* correctly predicts the absence of any present indicative active forms in the paradigm of this verb.[5] Once the blanks in Table 14 are seen as principal parts, then the parallelism of this system becomes clear.[6]

TABLE 14. Dynamic principal parts of some Sanskrit verbs (cf. Lanman 1884)

		Ubhayapadin verbs			Middle verb	Active verb
		jñā 'know'	dā 'give'	rudh 'obstruct'	īkṣ 'look'	hā 'abandon'
a.	3sg present indicative active	jānāti	dadāti	ruṇaddhi	--	jahāti
b.	… middle	jānīte	datte	runddhe	īkṣate	--
c.	3sg perfect active	jajñau	dadau	rurodha	--	jahau
d.	… middle	jajñe	dade	rurudhe	īkṣāṁ cakre	--
e.	3sg aorist active	ajñāsīt	adāt	arautsīt	--	ahāsīt
f.	… middle	ajñāsta	adita	aruddha	aikṣiṣṭa	--
g.	3sg future active	jñāsyati	dāsyati	rotsyati	--	hāsyati
h.	… middle	jñāsyate	dāsyate	rotsyate	īkṣiṣyate	--
i.	Past passive participle	jñāta	datta	ruddha	īkṣita	hīna
j.	Infinitive	jñātum	dātum	roddhum	īkṣitum	hātum
k.	Absolute gerund form	jñātvā	dattvā	ruddhvā	īkṣitvā	hitvā
l.	Conjunct gerund form	-jñāya	-dāya	-rudhya	-īkṣya	-hāya

But not all dynamic systems of principal parts are parallel in this way. Though it is customary to think of the Latin system of principal parts as being in some sense a canonical system, it is not, in fact, a parallel system. In Latin, the 1st-person singular present indicative active principal part is actually redundant in the first, second and fourth conjugations: that is, although all of the forms in Table 15 are traditionally thought of as principal parts, they only qualify as static principal parts. Under a dynamic conception of principal parts, *laudō* and *moneō* are unnecessary as principal parts: because these first-person present indicative active forms can actually be deduced from the corresponding infinitives, we can say for verbs in the first, second and fourth conjugations, there are at most only three principal parts, namely the infinitive, the first-person

[5] One might suppose that blanks among the principal parts of a verb such as *īkṣ* are deducible from its semantics and are therefore actually redundant; for instance, one might assume that it is unnecessary to stipulate the blanks among the principal parts of *īkṣ* because the forms of *īkṣ* are necessarily middle in voice--the action of looking does, after all, have a necessary effect (if only of a sensory nature) on the looker. But in general, it is not possible to infer a Sanskrit verb's status as an active verb, a middle verb, or an *ubhayapadin* verb from that verb's semantics; see Stump 2006 for discussion.

[6] One might argue that the system of principal parts in Table 14 is redundant (and therefore not optimal), on the grounds that some of the middle forms are predictable from their active counterparts (or vice versa)--on the grounds, for instance, that the active form *ruṇaddhi* implies the middle form *runddhe*. This redundancy is only apparent, however: *ruṇaddhi* implies *runddhe* IF IT HAS A MIDDLE COUNTERPART. But nothing about the form of *ruṇaddhi* guarantees that its middle counterpart isn't a blank; the stipulation of the form *runddhe* is instead needed to guarantee this fact.

singular perfect indicative active, and the perfect passive participle.[7] To this extent, the Latin system of dynamic principal parts must be seen not as parallel, but as skewed.

TABLE 15. Principal parts of five Latin verbs

	1st person singular present indicative active	Infinitive	1st person singular perfect indicative active	Perfect passive participle (neuter nominative singular)
1st	laudō	laudāre	laudāvī	laudātum
2nd	moneō	monēre	monuī	monitum
3rd	dūcō	dūcere	dūxī	dūctum
3rd (*-iō*)	capiō	capere	cēpī	captum
4th	audiō	audīre	audīvī	audītum
The shaded forms are static but not dynamic principal parts.				

A more dramatically skewed principal-part system is that of Fur, a Nilo-Saharan language spoken in the Sudan. In this system, dynamic principal parts vary considerably from one conjugation to another. The conjugation-class distinctions in Fur are schematized in Table 16. As this table shows, verbs in Fur inflect for subjunctive mood and perfect and present tenses, and the expression of subject agreement is cumulative with that of these modal and temporal categories. In general, the cumulative exponence of these different categories takes the form of (i) a particular pattern of tone marking on the verb root and (ii) a particular suffix; for instance, Table 16 shows that in conjugation I,1a, nonthird person subjunctive forms have the root tonality LH and the suffixal marking *-o*.

Table 17 indicates the dynamic principal parts in one possible analysis of Fur. In this table, the different morphosyntactic property sets realized by the exponents of root tonality and suffixal marking are identified on the horizontal axis, and on the vertical axis, the different intersecting conjugations are listed. At each intersection of a conjugation with a morphosyntactic property set there is an exponent, and the shaded exponents are the ones that identify dynamic principal parts in this analysis of Fur. In conjugation I,1a, for instance, it's the nonthird-person present form bearing the exponence LH-*èl* that is the sole principal part: because that exponence appears nowhere else in any of the conjugations as an expression of the nonthird-person present, it is absolutely distinctive of conjugation I,1a. On the other hand, the nonthird-person present form in conjugation I,2b is not distinctive of that conjugation, since its exponence HF-Ø appears as the exponence of the nonthird-person present in one other conjugation as well. For this reason, a different dynamic principal part is necessary for the conjugation I,2b, namely the third-person singular present form bearing the exponence LL-Ø. That exponence for that morphosyntactic property set is absolutely distinctive of conjugation I,2b. From this evidence (and from a range of similar examples that can be cited from Table 17), it is clear that the system of dynamic principal parts in Fur is skewed.

[7] Indeed, certain first-conjugation verbs apparently need fewer than three dynamic principal parts. In particular, those whose infinitive, first-person singular perfect indicative active form, and perfect passive participle are all based on a stem in *-ā* (thus, *laudāre* 'praise' [*laudāvī, laudātum*] but not *crepāre* 'rattle' [*crepuī, crepitum*] or *iuvāre* 'help' [*iūvī, iūtum*]) can seemingly be assumed to have a single principal part, namely the perfect passive participle.

TABLE 16. Tonal and suffixal exponents of verb classes in Fur (Jakobi 1990:103-113)

Class	Agreement	Subjunctive	Perfect	Present	Example	Class	Agreement	Subjunctive	Perfect	Present	Example
I,1a	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	LH-o HH-o HH-òl LH-òl	LH-ò HH-ò HH-ùl LH-ùl	LH-èl HH-èl HH-èl-à/-ì LH-èl-à/-ì	buuN ‘descend’	IIIa	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	HH-ì LH-ì LH-è HH-è	HH-à LH-à LH-e HH-e	HH-èl LH-èl LH-èl-à HH-èl-à	arr ‘measure’
I,1b	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	LH-o HH-o HH-òl LH-òl	LH-ò HH-ò HH-ùl LH-ùl	LF-Ø HF-Ø HH-è LH-è	jaan ‘wait’	IIIb	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	HH-ò LH-ò LH-è HH-è	HH-ò LH-ò LH-e HH-e	HH-èl LH-èl LH-èl-à HH-èl-à	awi ‘pound’
I,1c	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	LH-o HH-o HH-òl LH-òl	LH-ò HH-ò HH-ùl LH-ùl	LH-ì HH-ì HH-è LH-è	irt ‘shake’	IIIc	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	HH-ò LF-Ø LH-è HH-è	HH-ò LH-ò LH-e HH-e	HH-èl LH-èl LH-èl-à HH-èl-à	dus ‘tear’ (tr)
I,2a	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	HH-ò LL-o LL-òl HH-òl	HH-o LL-ò LL-ùl HH-ùl	HH-èl LL-èl LL-èl-à/-ì HH-èl-à/-ì	tall ‘chew’	IIId	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	HF-Ø LF-Ø LH-è HH-è	HH-à LH-à LH-e HH-e	HH-èl LH-èl LH-èl-à HH-èl-à	kair ‘stop’ (itr)
I,2b	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	HH-ò LL-o LL-òl HH-òl	HH-o LL-ò LL-ùl HH-ùl	HF-Ø LL-Ø LL-è HH-è	fuul ‘spin’	IIIe	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	HF-Ø LF-Ø LH-è HH-è	HH-à LH-ò LH-e HH-e	HH-èl LH-èl LH-èl-à HH-èl-à	tai ‘hold, seize’
I,2c	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	HH-ò LL-o LL-òl HH-òl	HH-o LL-ò LL-ùl HH-ùl	HH-ì LL-ì LL-è HH-è	kir ‘cook’	IVa	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	HF-Ø LF-Ø LH-Al HH-Al	HH-ò LH-ò LH-e HH-e	HH-èl LH-èl LH-èl-à HH-èl-à	jum ‘cover’
II,1a	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	LH-i HH-i HH-i-A(l) LH-i-A(l)	LH-i HH-i HH-i-è LH-i-è	LH-itì HH-itì HH-iti-A(l) LH-iti-A(l)	rii ‘snatch’	IVb	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	HH-ò LH-ò LH-Al HH-Al	HH-ò LH-ò LH-e HH-e	HH-èl LH-èl LH-èl-à HH-èl-à	bul ‘find’
II,1b	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	LH-i HH-i HH-i-A(l) LH-i-A(l)	LH-i HH-i HH-i-è LH-i-è	LF-Ø HF-Ø HH-è LH-è	tiir ‘meet’	IVc	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	HF-Ø LF-Ø LH-Al HH-Al	HH-à LH-à LH-e HH-e	HH-èl LH-èl LH-èl-à HH-èl-à	juuN ‘terrify’
II,2a	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	HH-ì LL-i LL-i-A(l) HH-i-A(l)	HH-ì LL-i LL-i-è HH-i-è	HH-itì LL-itì LL-iti-A(l) HH-iti-A(l)	faul ‘open’	IVd	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	HH-à LH-à LH-Al HH-Al	HH-à LH-à LH-e HH-e	HH-èl LH-èl LH-èl-à HH-èl-à	kur ‘touch’
II,2b	1/2 SG/PL 3 SG 3 PL [–HUM] 3 PL [+HUM]	HH-ì LL-i LL-i-A(l) HH-i-A(l)	HH-ì LL-i LL-i-è HH-i-è	HF-Ø LF-Ø LL-è HH-è	kaun ‘grind’						

A is a morphophoneme realized as [o] after a high vowel and otherwise as [a]; see Jakobi (1990:80f) for details.

TABLE 17. Dynamic principal parts for Fur verbs

Conjugation	Subjunctive Non3	Perfect Non3	Present Non3	Subjunctive 3Sg	Perfect 3Sg	Present 3Sg	Subjunctive 3Pl Nonhuman	Perfect 3Pl Nonhuman	Present 3Pl Nonhuman	Subjunctive 3Pl Human	Perfect 3Pl Human	Present 3Pl Human
I,1a	LH-o	LH-ò	LH-èl	HH-o	HH-ò	HH-èl	HH-òl	HH-ùl	HH-èl-à/-ì	LH-òl	LH-ùl	LH-èl-à/-ì
I,1b	LH-o	LH-ò	LF-Ø	HH-o	HH-ò	HF-Ø	HH-òl	HH-ùl	HH-è	LH-òl	LH-ùl	LH-è
I,1c	LH-o	LH-ò	LH-ì	HH-o	HH-ò	HH-ì	HH-òl	HH-ùl	HH-è	LH-òl	LH-ùl	LH-è
I,2a	HH-ò	HH-o	HH-èl	LL-o	LL-ò	LL-èl	LL-òl	LL-ùl	LL-èl-à/-ì	HH-òl	HH-ùl	HH-èl-à/-ì
I,2b	HH-ò	HH-o	HF-Ø	LL-o	LL-ò	LL-Ø	LL-òl	LL-ùl	LL-è	HH-òl	HH-ùl	HH-è
I,2c	HH-ò	HH-o	HH-ì	LL-o	LL-ò	LL-ì	LL-òl	LL-ùl	LL-è	HH-òl	HH-ùl	HH-è
II,1a	LH-i	LH-i	LH-itì	HH-i	HH-i	HH-itì	HH-i-A(l)	HH-i-è	HH-iti-A(l)	LH-i-A(l)	LH-i-è	LH-iti-A(l)
II,1b	LH-i	LH-i	LF-Ø	HH-i	HH-i	HF-Ø	HH-i-A(l)	HH-i-è	HH-è	LH-i-A(l)	LH-i-è	LH-è
II,2a	HH-ì	HH-ì	HH-itì	LL-i	LL-i	LL-itì	LL-i-A(l)	LL-i-è	LL-iti-A(l)	HH-i-A(l)	HH-i-è	HH-iti-A(l)
II,2b	HH-ì	HH-ì	HF-Ø	LL-i	LL-i	LF-Ø	LL-i-A(l)	LL-i-è	LL-è	HH-i-A(l)	HH-i-è	HH-è
IIIa	HH-ì	HH-à	HH-èl	LH-ì	LH-à	LH-èl	LH-è	LH-e	LH-èl-à	HH-è	HH-e	HH-èl-à
IIIb	HH-ò	HH-ò	HH-èl	LH-ò	LH-ò	LH-èl	LH-è	LH-e	LH-èl-à	HH-è	HH-e	HH-èl-à
IIIc	HH-ò	HH-ò	HH-èl	LF-Ø	LH-ò	LH-èl	LH-è	LH-e	LH-èl-à	HH-è	HH-e	HH-èl-à
IIId	HF-Ø	HH-à	HH-èl	LF-Ø	LH-à	LH-èl	LH-è	LH-e	LH-èl-à	HH-è	HH-e	HH-èl-à
IIIe	HF-Ø	HH-à	HH-èl	LF-Ø	LH-ò	LH-èl	LH-è	LH-e	LH-èl-à	HH-è	HH-e	HH-èl-à
IVa	HF-Ø	HH-ò	HH-èl	LF-Ø	LH-ò	LH-èl	LH-Al	LH-e	LH-èl-à	HH-Al	HH-e	HH-èl-à
IVb	HH-ò	HH-ò	HH-èl	$\boxed{\text{LH-ò}}$	LH-ò	LH-èl	LH-Al	LH-e	LH-èl-à	HH-Al	HH-e	HH-èl-à
IVc	HF-Ø	HH-à	HH-èl	LF-Ø	LH-à	LH-èl	LH-Al	LH-e	LH-èl-à	HH-Al	HH-e	HH-èl-à
IVd	HH-à	HH-à	HH-èl	LH-à	LH-à	LH-èl	LH-Al	LH-e	LH-èl-à	HH-Al	HH-e	HH-èl-à

Shaded exponents indicate dynamic principal parts.
Both principal parts for Conjugation IVb are needed to deduce the boxed exponent; cf. Table 20 below.

Using Criteria A and B together, we arrive at the four-fold classification of principal-part systems in Table 18:

TABLE 18. The intersection of Criteria A and B

		Criterion A: How many principal parts are needed to determine a lexeme's paradigm?	
		1	>1
Criterion B: Are the dynamic principal parts the same for all inflection classes?	Yes (parallel)	Kwerba	Sanskrit
	No (skewed)	Koasati	Fur, Latin, Ngiti

Consider now the third criterion for classifying principal-part systems:

Criterion C: How many dynamic principal parts are needed to determine a given word form in a lexeme's paradigm?

This criterion distinguishes SEGREGATED principal-part systems (in which each word form in a lexeme's paradigm is deducible from a single one of its dynamic principal parts) from INTEGRATED principal-part systems (in which at least some of a lexeme's word forms must be deduced from a combination of its dynamic principal parts).

The dynamic principal-part system for Sanskrit verbs is segregated. Across all conjugations, each of the principal parts in Table 14 is associated with a particular morphosyntactically definable sector of the paradigm, and each word form in the paradigm is determined by the single principal part associated with the sector to which it belongs: in this way, principal parts (a) (the third-person singular present indicative active form) and (b) (the third-person present indicative middle form) determine all of the active and middle present-system forms, respectively; principal parts (c) and (d) determine all of the active and middle perfect forms, respectively; and so on. (See Table 19 for a full listing of the inferences associated with principal parts (a)-(l) in Table 14.) The "morphosyntactic coverage" of a Sanskrit verb's principal parts is essentially nonoverlapping. This, ultimately, is why the Sanskrit system of dynamic principal parts is parallel: the principal parts remain constant across all of the conjugations because from one conjugation to the next, there is a constant association between a given principal part and the particular sector of the paradigm whose forms it is used to predict.

TABLE 19. Inferences from the dynamic principal parts in Table 14

Principal parts	Inference
(a) / (b)	determine all active / middle present-system forms. (1)
(c) / (d)	determine all active / middle perfect forms. (1)
(e) / (f)	determine all active / middle aorist forms.
(g) / (h)	determine all active / middle future-system forms.
(i)	determines the past passive and past active participles.
(j)	specifies the infinitive form.
(k)	specifies the absolute gerund form.
(l)	specifies the conjunct gerund form.

1. If a verb with principal parts (a) / (b) exhibits a strong/weak stem alternation, (a) determines the strong stem and (b) the weak stem; similarly for the principal parts (c) / (d).

The principal-part system of Fur, by contrast, is integrated: many word forms are jointly determined by two dynamic principal parts. Here, the coverage of the principal parts is overlapping, as (for example) in Table 20. Table 20 relates to the boxed exponent in Table 17, at the intersection of conjugation IVb and the third-person singular subjunctive property set. In order to deduce the third-person singular subjunctive form of a verb belonging to conjugation IVb, it's necessary to know both of that verb's principal parts (= the shaded principal parts in row IVb in Table 17). We cannot deduce the third-person singular subjunctive form from just the first of the two principal parts (namely the nonthird-person subjunctive form having the exponence HH-*ò*): that exponent appears in several places in the nonthird-person subjunctive column, and is consistent with three different possible exponents of the third-person singular subjunctive (as indicated in the first row of Table 20); that is, from that first principal part for conjugation IVb, any of three third-person singular subjunctive exponents is deducible. Likewise we cannot deduce the third-person singular subjunctive form from just the second of the two principal parts for conjugation IVb (namely the third-person plural nonhuman subjunctive form having the exponence LH-*Al*): that principal part is itself consistent with three different third-person singular subjunctive exponents (as indicated in the second row of Table 20). Only by putting the two principal parts together--the nonthird-person subjunctive form and the third-person plural nonhuman subjunctive forms--can we narrow the range of possible exponents for a conjugation IVb verb's third-person singular subjunctive form to uniqueness (i.e. to LH-*ò*, as in the third row of Table 20). Clearly, this is a case (one of several such cases in Table 17) in which two principal parts are necessary to deduce a given form in a verb's paradigm.

TABLE 20. The need for both dynamic principal parts in deducing the Subjunctive.3sg form in Conjugation IVb

SUBJUNCTIVE.NON3: *HH-ò*	SUBJUNCTIVE.3PL.NONHUMAN: *LH-Al*	Exponence predicted for SUBJUNCTIVE.3SG:
x		LL-o, LH-ò, or LF-Ø
	x	LF-Ø, LH-ò, or LH-à
x	x	LH-ò

In the languages that we looked at in this study, there is a great deal of variation in exactly how many dynamic principal parts are necessary to deduce a given form's exponence. In Table 21 are the averages for seven languages. The most complex language we looked at in terms of its system of principal parts was Comaltepec Chinantec, an Oto-Manguean language of Mexico: on average, 1.16 dynamic principal parts are needed to deduce each of the nonprincipal parts in a verb's paradigm. The simpler languages that we looked at, Gadaba and Kwerba, actually have averages below 1: some of the verb forms in these languages involve default exponence that is invariant across conjugations. If a particular morphosyntactic property set is realized by default morphology that is insensitive to conjugation-class distinctions, then no principal part need be referred to in order to determine the exponence of that property set.

TABLE 21. Degrees of integration in the principal-part systems of seven languages

	Average number of dynamic principal parts required to deduce a word form's exponence in a verbal paradigm
Gadaba	.58
Kwerba	.75
Sanskrit	1.00
Koasati	1.00
Ngiti	1.01
Fur	1.04
Comaltepec Chinantec	1.16

As noted in section II above, it regularly happens that the same system of conjugation can be given more than one principal-part analysis. Criterion C affords one basis for choosing among such alternatives. Thus, suppose that under either of two analyses, a lexeme L belonging to a particular conjugation has two dynamic principal parts; suppose, in addition, that a particular word form in L's paradigm can only be deduced from both principal parts in one analysis, but can be deduced from a single one of these principal parts in the other analysis. In that case, the latter analysis might reasonably be preferred because it allows nonprincipal parts to be deduced without unnecessary reference to more than one principal part.

Consider now the fourth criterion.

Criterion D: What is the morphological relation between a dynamic principal part and the nonprincipal parts that are deduced from it?

This criterion distinguishes MORPHOLOGICALLY COHERENT principal-part systems (in which each dynamic principal part has a distinct stem that it shares with the nonprincipal parts that are deduced from it) from systems that are MORPHOLOGICALLY INCOHERENT. The Sanskrit system is a good example of a morphologically coherent system: each of the principal parts has a different stem, and the forms that a given principal part predicts are precisely the forms that share that principal part's stem. Thus, consider Table 22, in which each dynamic principal part of the Sanskrit verb *rudh* 'obstruct' is listed with a characterization of the nonprincipal parts deducible from it. The first principal part *ruṇaddhi* (the third-person singular present indicative active form) has the stem *ruṇadh-* (and is the only principal part that has that stem), and the forms that it predicts are precisely the other forms in the paradigm that share that same stem. Analogous facts hold true of all of the other principal parts listed in Table 22. So this is morphologically a completely coherent system: each principal part has a separate stem, and it shares that stem with the nonprincipal parts that it is used to deduce.

TABLE 22. The morphological coherence of the dynamic principal parts of Sanskrit *rudh* ‘obstruct’

	Principal part	Its stem	Other forms based on the same stem that are deducible from the principal part	Examples
a.	ruṇaddhi	ruṇadh-	strong present-system forms	ruṇadhmi, ruṇatsi, …
b.	runddhe	rundh-	weak present-system forms	rundhvaḥ, rundhmaḥ, …
c.	rurodha	rurodh-	strong perfect forms	rurodha, rurodhitha, …
d.	rurudhe	rurudh-	weak perfect forms	rurudhiva, rurudhima, …
e.	arautsīt	arauts-	active aorist forms	arautsam, arautsīḥ, …
f.	aruddha	aruts-	middle aorist forms	arutsi, aruddhāḥ, …
g, h.	rotsyati, rotsyate	rotsya-	future forms	rotsyāmi, rotsyasi, …
i.	ruddha	ruddha-	case forms of the past passive participle; stem of the past active participle	ruddhaḥ, ruddha, ruddham, ruddhena, …
j.	roddhum	roddhum	--	--
k.	ruddhvā	ruddhvā	--	--
l.	-rudhya	-rudhya	gerunds of all compounds of *rudh*	anurudhya, avarudhya, nirudhya, virudhya, …

By this same criterion, the Fur system is morphologically incoherent. Consider, for instance, the single dynamic principal part of Conjugation I,1a in Table 17: this principal part has no formal characteristic in common with most of the nonprincipal parts that it predicts; these include forms whose tonality is different as well as forms whose suffixal exponence is different. That is, one cannot say that in Fur, each dynamic principal part has a distinct stem that it shares with the forms that it is used to deduce. This is therefore a morphologically incoherent system.

In Table 23, we cross-classify some of the languages that we have investigated according to their behavior with respect to Criteria C and D. Among the dynamic principal-part systems that we have examined so far, no system is both segregated and incoherent; there is, however, no logical reason why a system couldn’t possess both of these properties. Further investigation will therefore be necessary to determine whether the gap in Table 23 is merely an accident of our sample or instead reflects a genuine constraint on the relation between Criteria C and D.

TABLE 23. The intersection of Criteria C and D

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Criterion C: How many dynamic principal parts are needed to determine a given word form in a lexeme’s paradigm?</td></tr>
<tr><td>1 (segregated)</td><td>>1 (integrated)</td></tr>
<tr><td rowspan="2">Criterion D: What is the morphological relation between a dynamic principal part and the nonprincipal parts that are deduced from it?</td><td>coherent</td><td>Koasati, Kwerba, Sanskrit</td><td>Latin</td></tr>
<tr><td>incoherent</td><td></td><td>Fur, Ngiti</td></tr>
</table>

The final criterion that we employ in this typology of principal-part systems is Criterion E:

Criterion E: Are corresponding word forms in distinct paradigms determined by the same dynamic principal parts?

This criterion distinguishes ISOMORPHIC principal-part systems (in which a lexeme's nonprincipal parts are inferred from its dynamic principal parts in the same way from one conjugation to another) from NON-ISOMORPHIC systems. The Sanskrit system of dynamic principal parts is isomorphic. Consider again Table 19, which identifies the ways in which nonprincipal parts are inferred from principal parts in Sanskrit; the patterns in this table are uniform from one conjugation to the next.

The Latin system, however, is non-isomorphic. Consider, for instance, the problem of deducing the present active participle from a given verb's principal parts. The various solutions to this problem are represented schematically in Table 24. Three implicative relations are involved in these solutions; these relations are given in (4). By (4a), an infinitive in *āre* allows one to infer a present active participial stem in *ant* (e.g. *laudāre* ⊃ *laudant-*). By (4b), an infinitive in *ere* and a first-person present indicative active form in *o* together allow one to infer a present active participial stem in *ent* (e.g. [*dūcō* & *dūcere*] ⊃ *dūcent-*). According to (4c), a first-person singular present indicative active form in *iō* allows one to infer a present active participial stem in *ient* (e.g. *capiō* ⊃ *capient-*). These different implications are represented by the arrows in Table 24. Notice in particular that the relation (4a) deducing the present active participle *laudant-* is sensitive to the distinction between *laudāre* and *dūcere* (a distinction which isn't preserved between the corresponding first-person singular present indicative active forms). On the other hand, the relation (4c) deducing the present active participles *capient-* and *audient-* is sensitive both to the distinction between *dūcō* and *capiō* and to the parallelism between *capiō* and *audiō*, neither of which relations is preserved among the corresponding infinitives. And the relation (4b) deducing the present active participle *dūcent-* is sensitive both to the distinction between *dūcō* and *capiō* and to the distinction between *dūcere* and *laudāre*. The conclusion from all of this is that the present active participial stem is inferred in different ways in different conjugations.

TABLE 24. Deducing a Latin verb's present active participle from its dynamic principal parts

	Conjugation			
	1st	3rd	3rd (-iō)	4th
1sg present indicative active	laudō	dūcō	capiō	audiō
Relation (4c)	N. A.		↓	↓
Relation (4b)		↓		
Present active participle	laudant-	dūcent-	capient-	audient-
Relation (4b)		↑	N. A.	N. A.
Relation (4a)	↑			
Present active infinitive	laudāre	dūcere	capere	audīre
Dynamic principal parts are shaded; note that *laudō* is a static but not a dynamic principal part.				

(4) Three implicative relations in Latin verb morphology

a. INFINITIVE:*Xāre* ⊃ PRES.ACTIVE.PARTICIPLE:*Xant-*

b. [INFINITIVE:*Xere* & 1SG.PRES.INDIC.ACTIVE:*Xō*] ⊃ PRES.ACTIVE.PARTICIPLE:*Xent-*

c. 1SG.PRES.INDIC.ACTIVE:*Xiō* ⊃ PRES.ACTIVE.PARTICIPLE:*Xient-*

Criteria B and E cross-cut one another in Table 25:

TABLE 25. The intersection of Criteria B and E

		Criterion B: Are the dynamic principal parts the same for all inflection classes?	
		Yes (parallel)	No (skewed)
Criterion E: Are corresponding word forms in distinct paradigms determined by the same dynamic principal parts?	Yes (isomorphic)	Kwerba, Sanskrit	
	No (non-isomorphic)		Fur, Koasati, Latin, Ngiti

The upper gap in Table 25 is logically necessary: by definition, no principal-part system can be both skewed and isomorphic. The lower gap, however, is not logically necessary: one can imagine a system in which all inflection classes have the same principal parts but in which corresponding word forms in distinct inflection classes are determined by different principal parts. So far we have observed no such system.

IV. Summary

Past research in morphological typology has often focussed on the structure of individual word forms, invoking such criteria as the average number of morphemes per word form and the degree of morpheme fusion within a word form. The criteria proposed here extend the focus of typological classification from the structure of individual word forms to that of whole paradigms and to the implicative relations that paradigms embody.

We have proposed five different criteria for the comparison of principal-part systems; these are summarized in (5). Among the eight languages that we looked at, we've seen a range of different possible types. These are categorized in Table 26.

(5) Summary of typological criteria

Criterion A: *How many principal parts are needed to determine a lexeme's paradigm?*

Criterion B: *Are the dynamic principal parts the same for all inflection classes?*

Criterion C: *How many dynamic principal parts are needed to determine a given word form in a lexeme's paradigm?*

Criterion D: *What is the morphological relation between a dynamic principal part and the nonprincipal parts that are deduced from it?*

Criterion E: *Are corresponding word forms in distinct paradigms determined by the same dynamic principal parts?*

TABLE 26. Classification of eight languages according to Criteria A-E

	A	B	C	D	E
Kwerba	1	parallel	segregated	coherent	isomorphic
Koasati	1	skewed	segregated	coherent	non-isomorphic
Sanskrit	>1	parallel	segregated	coherent	isomorphic
Latin	>1	skewed	integrated	coherent	non-isomorphic
Gadaba	>1	skewed	integrated	incoherent	non-isomorphic
Fur	>1	skewed	integrated	incoherent	non-isomorphic
Ngiti	>1	skewed	integrated	incoherent	non-isomorphic
Comaltepec Chinantec	>1	skewed	integrated	incoherent	non-isomorphic
Throughout, classification relates to dynamic systems of principal parts in these languages.					

The types listed in Table 26 are not, however, all of the possible types of principal-part systems that our criteria predict. There are certain types that are, of course, logically excluded. Logically, no principal-part system can be both skewed and isomorphic, nor can any have a single principal part and (a) be integrated rather than segregated or (b) be parallel and non-isomorphic. Taking these logical restrictions into account, there are still sixteen logically possible types of dynamic principal part systems, of which we have only observed five; cf. Table 27. We hope in future research to be able to examine a wider range of languages to be able to see how fully these other types of principal part systems are observable and to identify additional constraints and criteria relevant for this area of typology.

TABLE 27. Logically possible types of dynamic principal-part systems

	A	B	C	D	E	Observed examples
1.	1	parallel	segregated	coherent	isomorphic	Kwerba
2.	1	parallel	segregated	incoherent	isomorphic	
3.	1	skewed	segregated	coherent	non-isomorphic	Koasati
4.	1	skewed	segregated	incoherent	non-isomorphic	
5.	>1	parallel	segregated	coherent	isomorphic	Sanskrit
6.	>1	parallel	segregated	coherent	non-isomorphic	
7.	>1	parallel	segregated	incoherent	isomorphic	
8.	>1	parallel	segregated	incoherent	non-isomorphic	
9.	>1	parallel	integrated	coherent	isomorphic	
10.	>1	parallel	integrated	coherent	non-isomorphic	
11.	>1	parallel	integrated	incoherent	isomorphic	
12.	>1	parallel	integrated	incoherent	non-isomorphic	
13.	>1	skewed	segregated	coherent	non-isomorphic	
14.	>1	skewed	segregated	incoherent	non-isomorphic	
15.	>1	skewed	integrated	coherent	non-isomorphic	Latin

16.	>1	skewed	integrated	incoherent	non-isomorphic	Gadaba, Fur, Ngiti, Comaltepec Chinantec

Appendix: A program for principal-part analysis

This program was written in Perl by Raphael Finkel and consists of 827 lines of code.

Given an input of the following form,

	Morphosyntactic property set M_1	…	Morphosyntactic property set M_n
Inflection class C_a	$\text{exponent}_{a,1}$	…	$\text{exponent}_{a,n}$
⋮	⋮		⋮
Inflection class C_n	$\text{exponent}_{m,1}$	…	$\text{exponent}_{m,n}$

the program supplies the following output:

(1) A table showing the exponence of every morphosyntactic property set in every inflection class, abbreviating each unique exponent with a simple code (typically in the range a through z)
(2) The number of inflection classes
(3) The number of morphosyntactic property sets
(4) The number of unique exponents
(5) A list of the optimal systems of static principal parts
(6) For each optimal static system S of principal parts and each morphosyntactic property set M, a list of the subsets of S that suffice to determine the exponence of M across all inflection classes
(7) For each optimal static system S, a table of the subsets of S that suffice to determine the exponence of each morphosyntactic property set M in each inflection class C
(8) For each principal part P in each optimal static system of principal parts, a table of those inflection-class/property-set combinations whose exponence P determines or helps determine
(9) The tree structure T for one optimal adaptive principal-part analysis and a specification of its maximum depth
(10) A table of prefixes in T that suffice to determine the exponence of each morphosyntactic property set M in each inflection class C
(11) For each inflection class C, a list of the optimal dynamic principal-part systems for C
(12) For each inflection class C and each optimal dynamic principal-part system D for C, a table of the subsets of D that suffice to determine the exponence of each morphosyntactic property set M in C

For example, suppose we supply the following Latin input:[8]

[8] These are, of course, only fragments of the entire paradigms of the listed verbs; moreover, these fragments don't take account of the stem alternations to which these verbs are subject. But our purpose here is merely to illustrate the workings of the program.

Conjugation		PrsInf	PrsInd	ImpfInd	FutInd	PerfInd	PlupfInd	FutPerfInd	PrsSubj	ImpfSubj	PerfSubj	PlupfSubj	Supine
alere	‘nourish’	ere	ō	ēbam	am	uī	ueram	uerō	am	erem	uerim	uissem	tum
audīre	‘hear’	īre	iō	iēbam	iam	īvī	īveram	īverō	iam	īrem	īverim	īvissem	ītum
capere	‘take’	ere	iō	iēbam	iam	ī	eram	erō	iam	erem	erim	issem	tum
crepāre	‘rattle’	āre	ō	ābam	ābō	uī	ueram	uerō	em	ārem	uerim	uissem	itum
dēcernere	‘decide’	ere	ō	ēbam	am	ī	eram	erō	am	erem	erim	issem	tum
dēlēre	‘destroy’	ēre	eō	ēbam	ēbō	ēvī	ēveram	ēverō	eam	ērem	ēverim	ēvissem	ētum
dūcere	‘lead’	ere	ō	ēbam	am	sī	seram	serō	am	erem	serim	sissem	tum
fīgere	‘attach’	ere	ō	ēbam	am	sī	seram	serō	am	erem	serim	sissem	sum
iuvāre	‘help’	āre	ō	ābam	ābō	ī	eram	erō	em	ārem	erim	issem	tum
laudāre	‘praise’	āre	ō	ābam	ābō	āvī	āveram	āverō	em	ārem	āverim	āvissem	ātum
lūgēre	‘mourn’	ēre	eō	ēbam	ēbō	sī	seram	serō	eam	ērem	serim	sissem	tum
monēre	‘advise’	ēre	eō	ēbam	ēbō	uī	ueram	uerō	eam	ērem	uerim	uissem	itum
salīre	‘leap’	īre	iō	iēbam	iam	uī	ueram	uerō	iam	īrem	uerim	uissem	tum
venīre	‘come’	īre	iō	iēbam	iam	ī	eram	erō	iam	īrem	erim	issem	tum
vidēre	‘see’	ēre	eō	ēbam	ēbō	ī	eram	erō	eam	ērem	erim	issem	sum
vincīre	‘bind’	īre	iō	iēbam	iam	sī	seram	serō	iam	īrem	serim	sissem	tum

In that case, we get the following output.

(1′): The conjugation table for the Latin input. The significance of the abbreviations 1 through 12 and a through bd is indicated in the two tables that follow.

conj	1	2	3	4	5	6	7	8	9	10	11	12
audīre	a	b	c	d	e	f	g	d	h	i	j	k
capere	l	b	c	d	m	n	o	d	p	q	r	s
crepāre	t	u	v	w	x	y	z	aa	ab	ac	ad	ae
dēcernere	l	u	af	ag	m	n	o	ag	p	q	r	s
dēlēre	ah	ai	af	aj	ak	al	am	an	ao	ap	aq	ar
dūcere	l	u	af	ag	as	at	au	ag	p	av	aw	s
fīgere	l	u	af	ag	as	at	au	ag	p	av	aw	ax
iuvāre	t	u	v	w	m	n	o	aa	ab	q	r	s
laudāre	t	u	v	w	ay	az	ba	aa	ab	bb	bc	bd
lūgēre	ah	ai	af	aj	as	at	au	an	ao	av	aw	s
monēre	ah	ai	af	aj	x	y	z	an	ao	ac	ad	ae
salīre	a	b	c	d	x	y	z	d	h	ac	ad	s
venīre	a	b	c	d	m	n	o	d	h	q	r	s
vidēre	ah	ai	af	aj	m	n	o	an	ao	q	r	ax
vincīre	a	b	c	d	as	at	au	d	h	av	aw	s
alere	l	u	af	ag	x	y	z	ag	p	ac	ad	s

MPS abbreviations			
1 PrsInf 2 PrsInd 3 ImpfInd	4 FutInd 5 PerfInd 6 PlupfInd	7 FutPerfInd 8 PrsSubj 9 ImpfSubj	10 PerfSubj 11 PlupfSubj 12 Supine

Exponence abbreviations			
a īre b iō c iēbam d iam e īvī f īveram g īverō h īrem i īverim j īvissem k ītum l ere m ī n eram	o erō p erem q erim r issem s tum t āre u ō v ābam w ābō x uī y ueram z uerō aa em ab ārem	ac uerim ad uissem ae itum af ēbam ag am ah ēre ai eō aj ēbō ak ēvī al ēveram am ēverō an eam ao ērem ap ēverim	aq ēvissem ar ētum as sī at seram au serō av serim aw sissem ax sum ay āvī az āveram ba āverō bb āverim bc āvissem bd ātum

(2′), (3′), (4′): The numbers of conjugations, morphosyntactic property sets, and unique exponents in the Latin input.

There are 16 conjugations, each with 12 MPSs, a total of 56 exponences.

(5′): The forty optimal systems of static principal parts for the Latin input.

Best sets of static principal parts:			
1,2,5,12	1,4,5,12	2,5,9,12	4,5,9,12
1,2,6,12	1,4,6,12	2,6,9,12	4,6,9,12
1,2,7,12	1,4,7,12	2,7,9,12	4,7,9,12
1,2,10,12	1,4,10,12	2,9,10,12	4,9,10,12
1,2,11,12	1,4,11,12	2,9,11,12	4,9,11,12
1,3,5,12	1,5,8,12	3,5,9,12	5,8,9,12
1,3,6,12	1,6,8,12	3,6,9,12	6,8,9,12
1,3,7,12	1,7,8,12	3,7,9,12	7,8,9,12
1,3,10,12	1,8,10,12	3,9,10,12	8,9,10,12
1,3,11,12	1,8,11,12	3,9,11,12	8,9,11,12

(6′): For each system S in (5′) and each morphosyntactic property set M in (1′), a list of the subsets of S that suffice to determine the exponence of M across all of the conjugations in (1′); for instance--

How well does set 1,2,5,12 explain nonprincipal parts?

Can explain [the form realizing property set] 3 by [the principal parts realizing property sets] 1,2,5,12 using 2 principal parts: [those realizing property sets] 1,2
Can explain 4 by 1,2,5,12 using 2 principal parts: 1,2
Can explain 6 by 1,2,5,12 using 1 principal parts: 5
Can explain 7 by 1,2,5,12 using 1 principal parts: 5
Can explain 8 by 1,2,5,12 using 2 principal parts: 1,2
Can explain 9 by 1,2,5,12 using 1 principal parts: 1
Can explain 10 by 1,2,5,12 using 1 principal parts: 5
Can explain 11 by 1,2,5,12 using 1 principal parts: 5
Total number of explanations needed by 1,2,5,12 is 11, for a score of 1.38

(7′): For each system S in (5′), a table of the subsets of S that suffice to determine the exponence of each morphosyntactic property set in (1′) in each conjugation in (1′). For instance, if the static principal parts are those realizing the property sets 1,2,5,12, then in the conjugation of audīre, principal part 1 determines the forms realizing property sets 3, 4, 8, and 9; principal part 5 determines the forms realizing property sets 6, 7, 10, and 11; and so on--

Conjugation	1	2	3	4	5	6	7	8	9	10	11	12	Ave.
audīre	1	2	1	1	5	5	5	1	1	5	5	12	1.00
capere	1	2	2	2	5	5	5	2	1	5	5	12	1.00
crepāre	1	2	1	1	5	5	5	1	1	5	5	12	1.00
dēcernere	1	2	1,2	1,2	5	5	5	1,2	1	5	5	12	1.25
dēlēre	1	2	1	1	5	5	5	1	1	5	5	12	1.00
dūcere	1	2	1,2	1,2	5	5	5	1,2	1	5	5	12	1.25
fīgere	1	2	12	1,2	5	5	5	1,2	1	5	5	12	1.17
iuvāre	1	2	1	1	5	5	5	1	1	5	5	12	1.00
laudāre	1	2	1	1	5	5	5	1	1	5	5	12	1.00
lūgēre	1	2	1	1	5	5	5	1	1	5	5	12	1.00
monēre	1	2	1	1	5	5	5	1	1	5	5	12	1.00
salīre	1	2	1	1	5	5	5	1	1	5	5	12	1.00
venīre	1	2	1	1	5	5	5	1	1	5	5	12	1.00
vidēre	1	2	1	1	5	5	5	1	1	5	5	12	1.00
vincīre	1	2	1	1	5	5	5	1	1	5	5	12	1.00
alere	1	2	1,2	1,2	5	5	5	1,2	1	5	5	12	1.25
Ave.	1.00	1.00	1.19	1.25	1.00	1.00	1.00	1.25	1.00	1.00	1.00	1.00	1.06

(8′): For each principal part P in each system in (5′), a table of those conjugation/property-set combinations whose exponence P determines or helps determine. For instance, as a principal part, the form realizing property set 1 determines the forms realizing property sets 3, 4, 8, and 9 in the conjugation of audīre, the form realizing property set 9 in the conjugation of capere, and so on--

Conjugation	1	2	3	4	5	6	7	8	9	10	11	12
audīre	O		X	X				X	X			
capere	O								X			
crepāre	O		X	X				X	X			
dēcernere	O		X	X				X	X			
dēlēre	O		X	X				X	X			
dūcere	O		X	X				X	X			
fīgere	O			X				X	X			
iuvāre	O		X	X				X	X			
laudāre	O		X	X				X	X			
lūgēre	O		X	X				X	X			
monēre	O		X	X				X	X			
salīre	O		X	X				X	X			
venīre	O		X	X				X	X			
vidēre	O		X	X				X	X			
vincīre	O		X	X				X	X			
alere	O		X	X				X	X			

(9′): The tree structure for one optimal adaptive principal-part analysis of the Latin input and a specification of its maximum depth--

We need 3 adaptive principal parts:
. if MPS 1 has variant l
.. if MPS 5 has variant as
... if MPS 12 has variant s
the conjugation is dūcere
... if MPS 12 has variant ax
the conjugation is fīgere
.. if MPS 5 has variant x
the conjugation is alere
.. if MPS 5 has variant m
... if MPS 2 has variant u
the conjugation is dēcernere
... if MPS 2 has variant b
the conjugation is capere
. if MPS 1 has variant ah
.. if MPS 5 has variant ak
the conjugation is dēlēre
.. if MPS 5 has variant as
the conjugation is lūgēre
.. if MPS 5 has variant x
the conjugation is monēre
.. if MPS 5 has variant m
the conjugation is vidēre
. if MPS 1 has variant t
.. if MPS 5 has variant x
the conjugation is crepāre
.. if MPS 5 has variant ay
the conjugation is laudāre
.. if MPS 5 has variant m
the conjugation is iuvāre
. if MPS 1 has variant a
.. if MPS 5 has variant as
the conjugation is vincīre
.. if MPS 5 has variant e
the conjugation is audīre
.. if MPS 5 has variant x
the conjugation is salīre
.. if MPS 5 has variant m
the conjugation is venīre

(10′): A table of prefixes in tree (9′) that suffice to determine the exponence of each morphosyntactic property set in (1′) in each conjugation in (1′). For instance, in the conjugation of audīre, the first principal part (that realizing property set 1) suffices to determine the exponence of property sets 2, 3, 4, 8, and 9 in that conjugation; the first two principal parts (those realizing property sets 1 and 5) together suffice to determine the exponence of property sets 6, 7, 10, 11, and 12 in that conjugation; and so on--

Conjugation	1	2	3	4	5	6	7	8	9	10	11	12	Ave.
audīre	1	1	1	1	1,5	1,5	1,5	1	1	1,5	1,5	1,5	1.50
capere	1	1,2,5	1,2,5	1,2,5	1,5	1,5	1,5	1,2,5	1	1,5	1,5	1,5	2.17
crepāre	1	1	1	1	1,5	1,5	1,5	1	1	1,5	1,5	1,5	1.50
dēcernere	1	1,2,5	1,2,5	1,2,5	1,5	1,5	1,5	1,2,5	1	1,5	1,5	1,5	2.17
dēlēre	1	1	1	1	1,5	1,5	1,5	1	1	1,5	1,5	1,5	1.50
dūcere	1	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1	1,5	1,5	1,5,12	1.92
fīgere	1	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1	1,5	1,5	1,5,12	1.92
iuvāre	1	1	1	1	1,5	1,5	1,5	1	1	1,5	1,5	1,5	1.50
laudāre	1	1	1	1	1,5	1,5	1,5	1	1	1,5	1,5	1,5	1.50
lūgēre	1	1	1	1	1,5	1,5	1,5	1	1	1,5	1,5	1,5	1.50
monēre	1	1	1	1	1,5	1,5	1,5	1	1	1,5	1,5	1,5	1.50
salīre	1	1	1	1	1,5	1,5	1,5	1	1	1,5	1,5	1,5	1.50
venīre	1	1	1	1	1,5	1,5	1,5	1	1	1,5	1,5	1,5	1.50
vidēre	1	1	1	1	1,5	1,5	1,5	1	1	1,5	1,5	1,5	1.50
vincīre	1	1	1	1	1,5	1,5	1,5	1	1	1,5	1,5	1,5	1.50
alere	1	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1	1,5	1,5	1,5	1.83
Ave.	1.00	1.44	1.44	1.44	2.00	2.00	2.00	1.44	1.00	2.00	2.00	2.12	1.66

(11′), (12′): For each conjugation C in (1′), a list of the optimal dynamic principal-part systems for C, and for each such system D, a specification of the subsets of D that suffice to determine the exponence of each morphosyntactic property set in C. For instance, the conjugation of dūcere has the optimal dynamic principal-part systems listed in the lefthand column in the following table. In the system in which dūcere's principal parts are those realizing property sets 1, 5, and 12, principal part 1 determines the exponence of property set 9; principal part 5 determines the exponence of property sets 6, 7, 10, and 11; principal parts 1 and 5 together determine the exponence of property sets 2, 3, 4, and 8; and so on--

Optimal dynamic system	1	2	3	4	5	6	7	8	9	10	11	12
1,5,12	1	1,5	1,5	1,5	5	5	5	1,5	1	5	5	12
1,6,12	1	1,6	1,6	1,6	6	6	6	1,6	1	6	6	12
1,7,12	1	1,7	1,7	1,7	7	7	7	1,7	1	7	7	12
1,10,12	1	1,10	1,10	1,10	10	10	10	1,10	1	10	10	12
1,11,12	1	1,11	1,11	1,11	11	11	11	1,11	1	11	11	12
2,5,12	2,5	2	2,5	2,5	5	5	5	2,5	2,5	5	5	12
2,6,12	2,6	2	2,6	2,6	6	6	6	2,6	2,6	6	6	12
2,7,12	2,7	2	2,7	2,7	7	7	7	2,7	2,7	7	7	12
2,10,12	2,10	2	2,10	2,10	10	10	10	2,10	2,10	10	10	12
2,11,12	2,11	2	2,11	2,11	11	11	11	2,11	2,11	11	11	12
4,5,12	4	4	4	4	5	5	5	4	4	5	5	12
4,6,12	4	4	4	4	6	6	6	4	4	6	6	12
4,7,12	4	4	4	4	7	7	7	4	4	7	7	12
4,10,12	4	4	4	4	10	10	10	4	4	10	10	12
4,11,12	4	4	4	4	11	11	11	4	4	11	11	12
5,8,12	8	8	8	8	5	5	5	8	8	5	5	12
5,9,12	9	5,9	5,9	5,9	5	5	5	5,9	9	5	5	12
6,8,12	8	8	8	8	6	6	6	8	8	6	6	12
6,9,12	9	6,9	6,9	6,9	6	6	6	6,9	9	6	6	12
7,8,12	8	8	8	8	7	7	7	8	8	7	7	12
7,9,12	9	7,9	7,9	7,9	7	7	7	7,9	9	7	7	12
,10,12	8	8	8	8	10	10	10	8	8	10	10	12
8,11,12	8	8	8	8	11	11	11	8	8	11	11	12
9,10,12	9	9,10	9,10	9,10	10	10	10	9,10	9	10	10	12
9,11,12	9	9,11	9,11	9,11	11	11	11	9,11	9	11	11	12

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