The Phonology of Voicing in Japanese: Theoretical Consequences for Morphological Accessibility
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The Phonology of Voicing in Japanese: Theoretical Consequences for Morphological Accessibility

It is uncontroversial that phonological and morphological rules applying to a form have only very limited access to its morphological composition. Various principles and conventions have been proposed to restrict the accessibility of internal structure (Siegel (1978), Pesetsky (1979), Mohanan (1981), Kiparsky (1982), Broselow (1983)). Williams (1981) argues for a condition (given in (1)) that treats all forms as "atoms" and in effect rules out all access to internal structural information.

(1) *The Atom Condition* (Williams (1981, 253))
A restriction on the attachment of af_x to Y can only refer to features realized on Y.

(Given the independently motivated percolation of features through heads, features of the head of Y percolate up to Y and are therefore accessible; see Williams (1981, 253).)

Although the Atom Condition (1) is restricted to derivation by affixation, it seems entirely natural to generalize it as in (2) to all kinds of lexical derivation, both morphological and phonological.

(2) In lexical derivations from X, only features realized on X are accessible.

Such a strong condition, though appealing in its simplicity and desirable on theoretical

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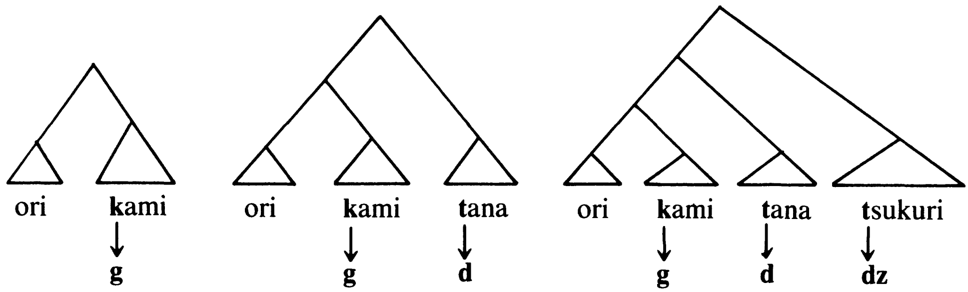
grounds, faces many empirical obstacles.[1] In this article we will take up prima facie counterevidence of a particularly problematic nature, namely Japanese compound voicing.

As shown in (3), a rule of sequential voicing—*Rendaku*—voices initial obstruents in second elements of compounds.

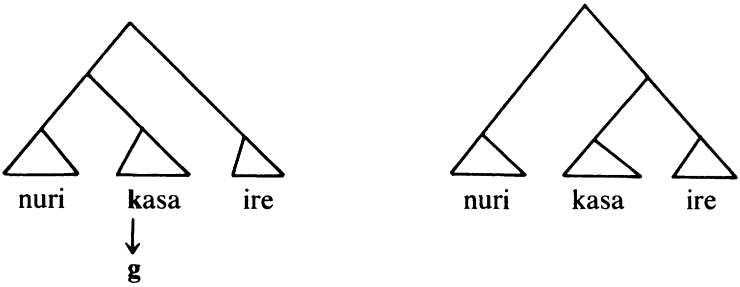
(3) a. ori + gami 'paper folding'
b. ori + gami + dana 'origami shelf'
c. ori + gami + dana + dzukuri 'origami shelf making'



[fold paper] [[fold paper]shelf] [[[[fold]paper]shelf]making]

Otsu (1980) argues that Rendaku applies only to elements that are on a right branch at the lowest level of compound structure (Right Branch Condition; see Otsu (1980, 219)). This is illustrated by the following minimal pairs:

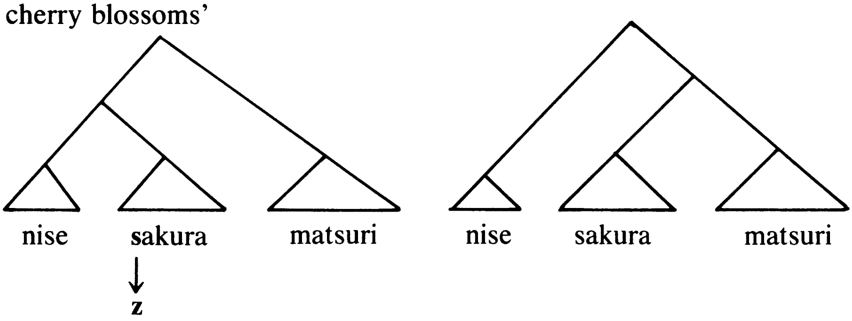
(4) a. nuri + gasa + ire 'a case for lacquered umbrellas'
b. nuri + kasa + ire 'an umbrella case that is lacquered'



[lacquered umbrella] case lacquered [umbrella case]

[1] Condition (2) is essentially equivalent to the strong form of the Bracket Erasure Convention formulated in Pesetsky (1979), where internal brackets are cyclically erased (as originally proposed in Chomsky and Halle (1968)).

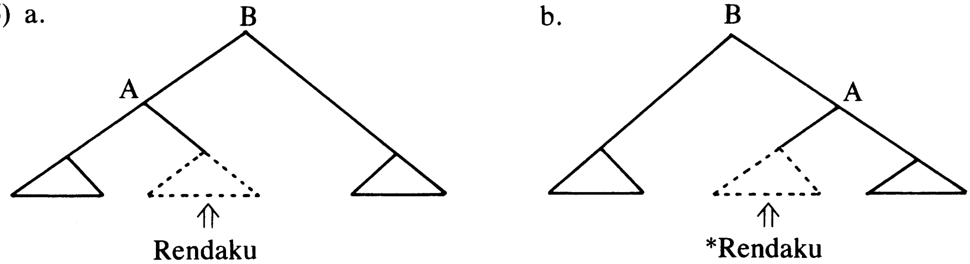
nise + zakura + matsuri 'a festival for fake cherry blossoms'	nise + sakura + matsuri 'a fake festival for cherry blossoms'



[fake cherry] festival	fake [cherry festival]

The marked elements in (4a) fulfill this condition, whereas those in (4b) do not, as schematically shown below.

(5) a. b.



It is clear that the Right Branch Condition is incompatible with the Atom Condition. In order to block Rendaku on the compound cycle B in (5b), the Right Branch Condition must have access to the internal structure of A, exactly the kind of information that should be unavailable.

In this article we will offer a prosodic analysis of Rendaku that makes crucial use of the phonological cycle, multitiered phonological representations (McCarthy (1979; 1981), Clements and Keyser (1983)), and underspecification of redundant features (Kiparsky (1982)). Our strategy will be to factor Rendaku, hitherto viewed as a complex rule with specific conditions (McCawley (1968), Otsu (1980)), into several simple and independently motivated autosegmental rules and to explain the voicing phenomenon as the result of intersecting generalizations. In particular, all right branch effects will follow from the cyclic interaction of the rules, without specific stipulation. Besides allowing us to maintain strict morphological inaccessibility, the prosodic analysis to be proposed will also have interesting theoretical consequences in Japanese phonology and morphology.[2]

[2] But see Mohanan (1981), Kiparsky (1982), and Poser (1984) for other views on the accessibility of morphological information.

1. Preliminaries

Before turning to our analysis, we will present the facts germane to our discussion. All obstruents are susceptible to Rendaku voicing irrespective of the nature of the following vowel. The compounds in (6) show the *k* ~ *g* alternation.

(6)	a.	iro 'color'	+ kami 'paper'	→	irogami 'colored paper'
	b.	asa 'morning'	+ kiri 'mist'	→	asagiri 'morning mist'
	c.	de 'leave'	+ kuči 'mouth'	→	deguči 'exit'
	d.	eda 'branch'	+ ke 'hair'	→	edage 'split hair'
	e.	unari 'moan'	+ koe 'voice'	→	unarigoe 'groan'

Although the other obstruent alternations are no less regular than the *k* ~ *g* alternation, the paradigms appear more complicated on the surface due to systematic allophonic variation. In (7) and (8) the basic alternations are *s* ~ *z* and *t* ~ *d*, respectively.

(7)	a.	yo 'night'	+ sakura 'cherry'	→	yozakura 'blossoms at night'
	b.	inu 'dog'	+ šini 'death'	→	inužini 'useless death'
	c.	maki 'rolled'	+ suši 'sushi'	→	makizuši 'rolled sushi'
	d.	mizu 'water'	+ seme 'torture'	→	mizuzeme 'water torture'
	e.	hoši 'star'	+ sora 'sky'	→	hošizora 'starry sky'
(8)	a.	e 'picture'	+ tako 'kite'	→	edako 'picture kite'
	b.	hana 'nose'	+ či 'blood'	→	hanaǰi 'nosebleed'
	c.	kokoro 'heart'	+ tsukai 'usage'	→	kokorodzukai 'consideration'
	d.	yama 'mountain'	+ tera 'temple'	→	yamadera 'mountain temple'
	e.	yu 'hot water'	+ toofu 'tofu'	→	yudoofu 'boiled tofu'

The coronal obstruents *s* and *t* undergo various allophonic rules before high vowels:

-*s* becomes *š* before *i* (by Palatalization), as in (7b)

-*t* becomes $\begin{cases} ts \text{ before } u \text{ (by Affrication), as in (8c)} \\ \check{c} \text{ before } i \text{ (by Palatalization and Affrication), as in (8b)} \end{cases}$

The contrasts *ž*/*ǰ* and *z*/*dz* (see (7b,c), (8b,c)) are neutralized, generally in favor of *ǰ* and *z* (see Grignon (1980) for detailed discussion).

The basic alternation in (9) is *h* ~ *b*, where *h* behaves morphophonemically like a labial and is arguably derived from underlying /p/; see McCawley (1968, 77–79).

(9) a.	ike	+	**h**ana	→	ike**b**ana
	'arrange'		'flower'		'ikebana'
b.	tabi	+	**ç**ito	→	tabi**b**ito
	'journey'		'person'		'traveler'
c.	kake	+	**f**uton	→	kake**b**uton
	'cover'		'futon'		'top futon'
d.	hanaši	+	**h**eta	→	hanaši**b**eta
	'talk'		'bad'		'poor talker'
e.	suna	+	**h**okori	→	suna**b**okori
	'sand'		'dust'		'storm dust'

Whereas the voiced counterpart is uniformly *b*, *h* itself undergoes allophonic rules:

-*h* becomes $\begin{cases} \c{c} \text{ before } i \text{ (by Palatalization), as in (9b)} \\ f \text{ before } u \text{ (by Labialization), as in (9c)} \end{cases}$

We are using *f* for bilabial [Φ] as a typographical convenience. In what follows we will use surface forms in examples and representations except when this would obscure the issue under discussion.[3]

Apart from sporadic and lexicalized exceptions, Rendaku is a productive phonological rule of Japanese (see Martin (1952), McCawley (1968), Otsu (1980), Vance (1982), Sano (1982), and references cited therein). It is, however, governed by several morphological factors, in particular, word-formation type and morpheme class.

The compounds that show Rendaku effects are endocentric; that is, their parts stand in a modifier-head relation.[4] Comparing the examples in (10i) with those in (10ii), we

[3] We note in passing that Rendaku bleeds the devoicing rule that affects high vowels (*i*,*u*) in voiceless environments. Thus, although Vowel Devoicing applies in (ia), the corresponding vowels in (ib) remain voiced.

(i) a.	tsu̥kai	b.	kokoro + **dz**ukai	(cf. (8c))
	çi̥to		tabi + **b**ito	(cf. (9b))
	fu̥ton		kake + **b**uton	(cf. (9c))

An anonymous reviewer points out that for many speakers *h* is palatalized only before voiceless i̥.

[4] The linear order of modifier and head is irrelevant here. Right-headed compounds with Rendaku voicing on their head constituent are the unmarked case in Japanese, but left-headed compounds (such as *ire* + *zumi* 'tattooing (lit. 'inserting ink')') do occur, exhibiting Rendaku voicing on their modifier constituent.

see that the latter, which are dvandva compounds (coordinate compounds), do not undergo Rendaku.[5]

(10)	i.		ii.	
a.	morai + **ko** ↓ **g**	'adopted + child' "adopted child"	oya + **ko**	'parent + child' "parent and child"
b.	mizu + **hana** ↓ **b**	'water + nose' "running nose"	me + **hana**	'eye + nose' "eyes and nose"
c.	yama + **tera** ↓ **d**	'mountain + temple' "mountain temple"	yama + **tera**	'mountain + temple' "mountain and temple"

The examples in (10c) constitute an often cited slightly archaic minimal pair (see Martin (1952, 49)).

The second morphological factor that must be taken into account is morpheme class. The Japanese lexicon is characterized by a fundamental bifurcation into Yamato (native Japanese) and non-Yamato morphemes.[6] Rendaku voicing is restricted to [+Yamato] morphemes, as shown by the near minimal pairs given in (11). The [+Yamato] examples in (11i) undergo Rendaku, whereas the [−Yamato] examples in (11ii) do not.

(11)	i.		ii.	
a.	nise + **kane** ↓ **g**	'counterfeit money'	nise + **kin**	counterfeit money'

[5] In Lexical Phonology it is natural to account for this by level ordering, under the assumption that dvandva compounds are formed in a later stratum than modifier-head compounds. But notice that dvandva compounds can occur as parts of ordinary (headed) compounds, as in (i).

(i)	[[oya + ko] **kenka**] ↓ **g**	'parent + child quarrel' "quarrel between parent and child"

Here *genka*, in contrast to the dvandva member *ko*, has undergone Rendaku, posing a problem for a level-ordered account (see Mohanan (1981) for a similar phenomenon in Malayalam). Ueda (1985) advances the interesting hypothesis that dvandva compounds in Japanese are characterized not by a special word-formation stratum but by a particular form of representation (an across-the-board-type representation in the sense of Williams (1978)), as illustrated in (ii).

(ii) $\begin{bmatrix}[\text{oya}]\\ [\text{ko}\ ]\end{bmatrix}\begin{bmatrix}\\ \textbf{kenka}\end{bmatrix}$
↓
g

This explains why rules that make reference to linear adjacency (like Rendaku or the Compound Accent Rule) do not apply to dvandvas, but do apply to ordinary compounds containing dvandvas. It seems to us that Ueda's (1985) representational approach is a viable alternative to Mohanan's (1981) loop model, which constitutes a weakening of level-ordered phonology.

[6] The feature [Yamato] is comparable to such features as [Latinate] in English and finds ample justification in Japanese phonology and morphology. In fact, a finer classification into Yamato, Sino-Japanese, Foreign, and Ideophonic is called for; see Martin (1952) and McCawley (1968) for motivation and discussion.

b.	garasu + **t**ana ↓ **d**	'glass shelf'	garasu + **k**eesu	'glass case'

It should be noted that only the [+Yamato] status of the second compound element counts for Rendaku. The first compound element in (11b)—*garasu* 'glass'—is transparently [−Yamato], but this does not prevent Rendaku voicing.

2. Rendaku and Voicing Spread

In order to retain explanatory force, multitiered phonology should disallow the use of essential variables in the formulation of phonological rules. This entails that all nonlocal effects are to be analyzed autosegmentally. Viewed from such a perspective, there is strong motivation for an independent voicing tier in Japanese. Crucial evidence comes from a phonological phenomenon known as Lyman's Law.[7] Lyman (1894) points out that Rendaku obeys a systematic voicing constraint. If the second compound member contains a voiced obstruent, Rendaku does not apply. Thus, the initial obstruents remain voiceless in the following examples:

(12)	a.	kami + ka**z**e	*kami + **gaz**e	'divine wind'
	b.	mono + ši**z**uka	*mono + **ǰiz**uka	'tranquil'
	c.	siro + ta**b**i	*siro + **dab**i	'white tabi'
	d.	maru + ha**d**aka	*maru + **bad**aka	'completely naked'

In fact, forms like *gaze* (12a) are not possible Yamato morphemes, a point of great significance to which we will return in section 4.

The minimally contrasting pairs in (13) confirm the regularity of the Lyman's Law phenomenon.

(13)		i.		ii.	
	a.	nuri + **f**uta ↓ **b**	'lacquered lid'	nuri + **f**u**d**a	'lacquered sign'
	b.	oharai + **k**uši ↓ **g**	'purification comb'	oharai + **k**u**ǰ**i	'purification ticket'

A striking property of Lyman's Law is its nonlocal influence on Rendaku voicing. In (14ii), for example, the blocking obstruent is found in the third syllable.

(14)		i.		ii.	
	a.	taikutsu + **h**araši ↓ **b**	'boredom + dispel' "time-killing"	taikutsu + šinogi	'boredom + endure' "time-killing"

[7] Named after Benjamin S. Lyman, the first Western scholar to have called attention to this phenomenon. Its original discovery, however, is due to the Japanese linguist and philologist Motoori Norinaga (1730–1801). (We would like to express our gratitude to Forbes Library, Northampton, Massachusetts, for granting us access to the Benjamin S. Lyman Collection.)

b. onna + **k**okoro 'woman + heart' onna + kotoba 'woman + word'
$\downarrow$ "feminine feelings" "feminine speech"
g

It is important to distinguish between the redundant voicing of vowels and sonorants and the distinctive voicing of obstruents: vowels and sonorants, though phonetically voiced, never block Rendaku via Lyman's Law, as can be seen from many of the examples already given.[8] In our approach this does not require special stipulation but is an automatic consequence of the theory of underspecification (Kiparsky (1982)). Redundant features (in the present context, [+voi] for sonorants and [−voi] for obstruents) are not present underlyingly or during the cyclic phonology but are filled in by postcyclic default rules. Since only the distinctive [+voi] of obstruents is present during the cyclic derivation, Lyman's Law can be understood as a simple restriction on the voicing tier.

(15) Rendaku is blocked if the voicing tier of the second compound member is not empty.

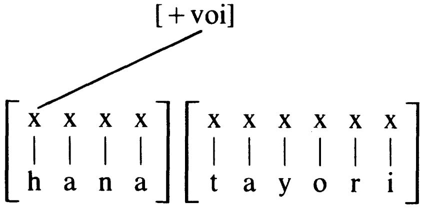
Given that Rendaku only involves voicing, it is attractive to hypothesize that the rule simply inserts a [+voi] autosegment into the voicing tier, as in (16).[9]

(16)
Voicing Tier	[+voi]	
Skeleton	[x x x x	x x x x x x]
	| | | |	| | | | | |
Melody Tier	h a n a]	[t a y o r i]

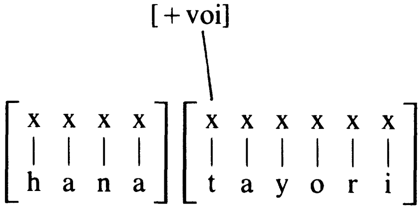
'flower tidings'

Such an approach faces a fundamental problem, however. Assuming standard left-to-right association, the floating [+voi] would dock onto the first compound member, resulting in *[*bana*][*tayori*] (17a) instead of the correct [*hana*][*dayori*] (17b).

(17) a.



b.



[8] In the Japanese *kana* syllabaries, only the voicing of obstruents is diacritically marked by the addition of two dots (*dakuten*) to the *kana* representing a mora of the form "voiceless obstruent + vowel." This can be interpreted as an intuitive appreciation of the distinction between redundant and distinctive voicing in Japanese. A revealing minimal contrast is given below, where *samui/sabui* and *samurai/saburai* are variant pronunciations.

(i) waka + zamurai waka + saburai 'young warrior'
hada + zamui hada + sabui 'skin cold, chilly'

[9] We assume that a skeleton element is in the unmarked case a "pure position, unconstrained by C/V content" (Prince (1984, 244)). For further discussion, see Levin (1983), McCarthy (1979; 1981), and Prince (1984). In our notation the symbols appearing on the melody tier are used as convenient abbreviations for "archisegmental" feature matrices without voicing specification. The contrast between /p t k s/ and /b d g z/ disappears on the melody tier, and we represent the archisegments by the former set.

Rendaku is essentially a morphological process introducing a linking morpheme in a certain morphological context. Postponing the discussion of alternative analyses, we formulate the rule in (18) as an insertion of a [+voi] autosegment bound to its skeletal anchor at the compound juncture.[10]

(18) *Rendaku*

$$\text{Insert } \begin{array}{c}[+\text{voi}]\\ |\\ \text{x}\end{array} \; / \;] \underline{\quad\quad} [$$

Output:

$$\begin{array}{c}\\ \\ \left[\begin{array}{cccc}\text{x}&\text{x}&\text{x}&\text{x}\\ |&|&|&|\\ \text{h}&\text{a}&\text{n}&\text{a}\end{array}\right]\end{array}\begin{array}{c}[+\text{voi}]\\ |\\ \text{x}\\ \\ \\ \end{array}\begin{array}{c}\\ \\ \left[\begin{array}{cccccc}\text{x}&\text{x}&\text{x}&\text{x}&\text{x}&\text{x}\\ |&|&|&|&|&|\\ \text{t}&\text{a}&\text{y}&\text{o}&\text{r}&\text{i}\end{array}\right]\end{array}$$

The x in (18) marks a position in the phonological string but plays no role in the timing of the utterance. In our conception, skeleton elements intrinsically express only positionality, not timing. Their status as timing units is entirely derivative, acquired through syllabification. Since segmentally impoverished x's such as the one inserted by (18) cannot be syllabified, they remain pure positions that either are deleted at the end of the derivation or are simply invisible for phonetic interpretation.[11]

Rule (18) introduces Rendaku voicing as an autosegment linked to its x. Nonlinear phonology recognizes a fundamental distinction between free (unlinked) and bound (linked) autosegments. Both types occupy independent tiers, but they differ in their relation to the core. Free autosegments (familiar from tonal studies, for example Goldsmith (1976) for Igbo tonal morphemes and Clements and Ford (1979) for Kikuyu downstep) are associated by universal convention and enjoy great syntagmatic freedom. Bound autosegments (familiar from harmony processes, for example Clements (1981) for Akan opaque vowels and Poser (1981) for Guarani nasal harmony), being always linked to a skeletal anchor, are positionally stable. Rendaku voicing has the properties of a bound autosegment, and crosslinguistic evidence suggests that voicing in fact never shows the drastic variation in surface segmental affiliation that is characteristic of free autosegments.

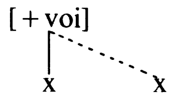
Inserting Rendaku voicing between the compound members as in (18), however, does

[10] Alan Prince points out that such linking morphemes are widely attested in languages (for example, Igbo associative tone (Goldsmith (1976), Clark (1979)) and German "Fugen-*s*" (e.g. *Liebesbrief* 'love letter')). As an alternative to the insertion analysis in (18), he suggests that it would be natural to consider the Rendaku morpheme as a suffix to the first compound member, in line with the suffixing character of Japanese. The historical origin of most instances of Rendaku voicing, namely the genitival postposition *no*, is suggestive of such a suffixal analysis. The historical development may be roughly: *no* > moraic N > prenasalization + voicing > voicing (see Vance (1982)). For our purposes, nothing hinges on the choice between the two alternatives, and we will adopt the insertion analysis for ease of exposition.

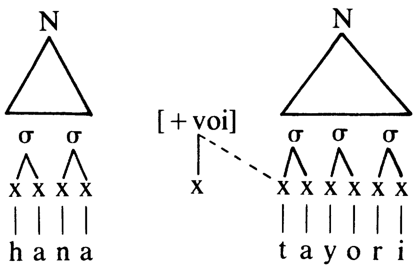
[11] We are assuming that phonological strings are not underlyingly syllabified, but undergo syllabification rules in the course of the phonological derivation. Even fully specified segments sometimes remain unsyllabified because of sonority restrictions of a partly language-particular nature (see Steriade (1982) for discussion).

not automatically solve the association problem. To arrive at the surface form, we must link the [+voi] autosegment introduced by Rendaku (18) to the initial segment of the second compound member. That is, *hana*[+voi]*tayori* is realized as *hana dayori*. Japanese has a fully productive rule of voicing assimilation (19) that will establish the desired association (20).

(19) *Voicing Spread*



(20)



hana + dayori 'flower tidings'

Voicing Spread (19) accounts for regular morphophonemic alternations found in the Japanese verbal paradigm. When the gerundive suffix /te/ and the past tense suffix /ta/ are added to vowel-final verb stems (21), both stem and suffix appear essentially in their underlying form.

(21)	*Stem*	*Gerund*	*Past*
a.	/tabe/ 'eat'	tabe-te	tabe-ta
b.	/mi/ 'see'	mi-te	mi-ta

When these suffixes are added to consonant-final stems (22), however, several morphophonemic processes occur: Velar Vocalization, Gemination, and—most importantly in the present context—Voicing Spread.[12]

(22)	*Stem*	*Gerund*	*Past*
a.	/tog/ 'sharpen'	/tog + te/ → toi-de	/tog + ta/ → toi-da
b.	/tok/ 'solve'	/tok + te/ → toi-te	/tok + ta/ → toi-ta

In (22a) *tog + te* becomes *tog + de* by Voicing Spread (19), then *toi + de* by Velar Vocalization. In (22b), on the other hand, Voicing Spread (19) cannot apply, and Velar Vocalization changes *tok + te* to *toi + te*. Note that the stem-final consonant /g/ in (22a), which originally carried the [+voi] autosegment, is lost, and the voiced-voiceless contrast within the stem (e.g. *tog* vs. *tok*) is carried over to the suffix (e.g. *de*/*da* vs. *te*/*ta*).

[12] Other *t*-initial suffixes (/tara/ 'conditional' and /tari/ 'representative') exhibit exactly the same morphophonemic behavior.

In the verbal forms of (23), just as in the case of Lyman's Law (15), distinctive and nondistinctive voicing differ crucially in their phonological properties. We have here again evidence that only distinctive voicing is present on the voicing tier during the cyclic phonology (but see appendix I).

(23)	*Stem*	*Gerund*	*Past*
a.	/tob/ 'fly'	/tob + te/ → ton-de	/tob + ta/ → ton-da
b.	/tor/ 'take'	/tor + te/ → tot-te	/tor + ta/ → tot-ta
c.	/kaw/ 'buy'	/kaw + te/ → kat-te	/kaw + ta/ → kat-ta

In (23a) the distinctive voicing of the stem-final /b/ is spread onto the suffix-initial /t/ by Voicing Spread (19). Since the default rule that voices sonorants has not yet applied, the stem-final sonorants in (23b,c) are not associated to [+ voi] at this point, and Voicing Spread (19) is inapplicable. Surface forms are arrived at through melody loss in the syllable coda, the remaining empty position being filled by gemination.[13] Thus, the stem-final melody elements are lost in (23), and the /t/-melody of the suffix spreads to the vacated slot, yielding *todda, totta*, and *katta*. The initial part of the voiced geminate undergoes Coda Nasalization, and thus *todda* becomes *tonda*.[14]

Both Voicing Spread (19) and underspecification of redundant features play a crucial role in our analysis of Rendaku, and we have now seen that they receive further motivation in the verbal paradigm of Japanese.

Notice that Voicing Spread (repeated as (24)) has been formulated with maximal generality.

(24) *Voicing Spread* (= (19))

[+ voi]

x   x

We specify neither that it applies only between obstruents nor that it applies only once. Given the assumption that redundant features cannot be specified underlyingly or in the cyclic phonology as the result of a phonological rule (in accordance with Kiparsky's (1983) Principle of Structure Preservation), it follows that a voicing autosegment can have an obstruent, but not a sonorant, as its segmental bearer. Sonorants neither spread

[13] In the syllable coda all melody features are lost except for [nasal]. Since [− nas] is supplied by a default rule, this in effect means that only [+ nas] can remain attached to the skeletal core. (See appendix I for further discussion.)

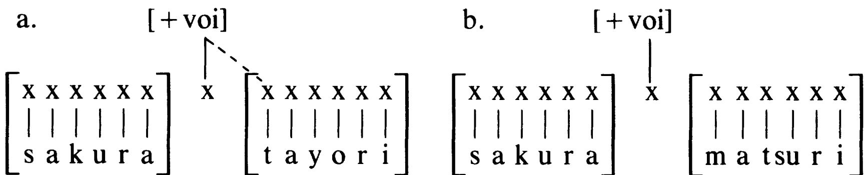
[14] Coda Nasalization is a regular phonological process in Japanese responsible for the surface absence of voiced geminates. They are found only in a few unassimilated loans (e.g. *handobaggu* 'handbag', *beddo* 'bed'), where they are degeminated or devoiced in casual speech. The clearest manifestation of Coda Nasalization is found in Intensive Infixation (Martin (1952, 69–70), Kuroda (1965, 201–228), McCawley (1968, 97)), exemplified below. Intensive Infixation can be viewed autosegmentally as insertion of a skeletal slot, followed by gemination (spreading) of the adjacent consonantal melody.

(i)	karakaze	'dry wind'	karakkaze	'dry wind (int.)'
(ii)	togaru	'be pointed'	tongaru	'be pointed (int.)'

Note that Coda Nasalization must apply when a voiced geminate is derived, as shown by the form in (ii).

nor receive a [+voi] autosegment and are excluded from both skeleton positions in (24). An important consequence of this is that Voicing Spread is limited to strictly local domains and never applies iteratively, Japanese syllable structure allowing neither complex onsets nor complex codas. For the [+voi] introduced by Rendaku (18), this means that Voicing Spread applies once in (25a)—to the initial obstruent /t/ in *tayori*—but not at all in (25b), since the initial segment of *matsuri* is a sonorant.

(25)



'cherry blossom tidings' 'cherry blossom festival'

In sum, we propose to analyze Rendaku voicing as a [+voi] autosegment linked to a skeletal slot and associated with its surface bearer by the general rule of Voicing Spread (19). As a technical point, we should note that there are two alternative ways of introducing the autosegment. First, in what might be called a direct linking analysis, [+voi] could be immediately linked to the first segment of the second compound member. We will see in section 3 that this approach encounters serious difficulties. As a second alternative, a floating analysis might be considered. The [+voi] would be introduced as an unattached autosegment, and the association problem noted above (see (17)) could be circumvented by positing a special association rule that treats first members of compounds as extrametrical. We will show in section 4 that such an analysis would entail the loss of an important generalization.

3. The Right Branch Condition and Lyman's Law

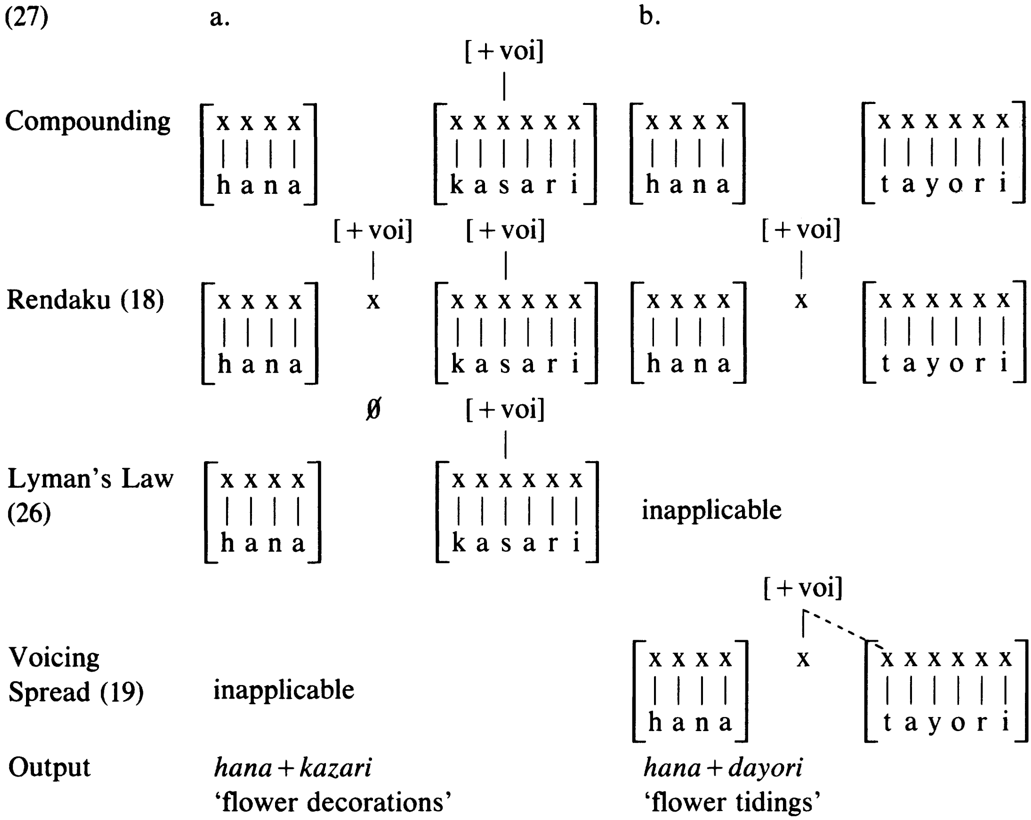
In Otsu's (1980) analysis and implicitly also in earlier work (Lyman (1894), Martin (1952)), Rendaku has a rule-specific condition, namely Lyman's Law, that prohibits Rendaku voicing in cases where the second compound element already contains a voiced obstruent. We consider Rendaku to be a rule of maximal generality without phonological constraints, and we formulate Lyman's Law in (26) as an independent rule that—as we will see shortly—has applications over and above the Rendaku cases.

(26) *Lyman's Law*

$$[+\text{voi}] \rightarrow \emptyset \;/\; \underset{\substack{| \\ \mathrm{x}'}}{\underline{\qquad}}\; [+\text{voi}]$$

Lyman's Law (26) deletes a stray [+voi] followed by another [+voi] on the voicing tier. (We use *stray* to mean "syllabically unaffiliated," which is distinct from "floating" or "unassociated.") The following two derivations show how Lyman's Law (26) interacts with Rendaku (18) and Voicing Spread (19).

(27)



In (27a) Lyman's Law applies, preventing Rendaku voicing from appearing on the surface. In (27b) Lyman's Law cannot apply; therefore, the Rendaku [+voi] can spread and voice the initial segment of the second compound member.

The ordering of the rules in (27) is expected: Rendaku (18) is a morphological operation and therefore precedes all phonological rules in the cycle. Lyman's Law (26) must precede Voicing Spread (19) because in the opposite ordering Lyman's Law would have no surface effects (note that it applies only to *stray* autosegments), and consequently it would have no raison d'être.

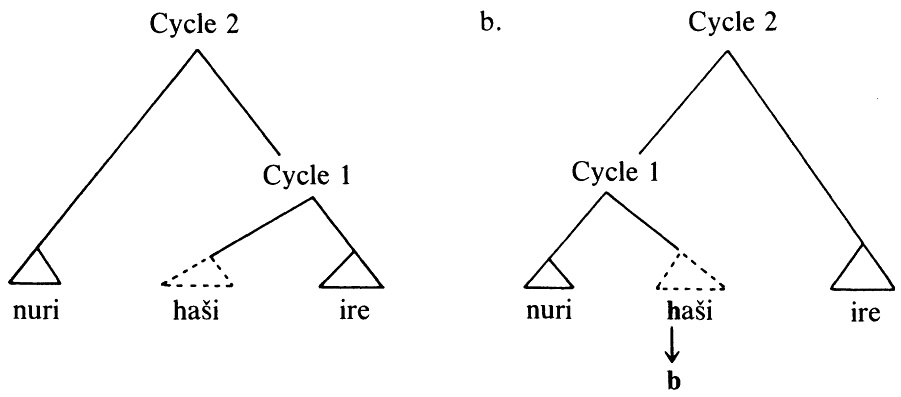
Reference to the stray status of the target [+voi] is necessary in Lyman's Law (26) because the rule never affects a [+voi] that is integrated into a syllable at its point of application. Thus, in cases where both compound members contain a voiced obstruent, the first [+voi] is immune to deletion.

(28)	kuzu + kago	*kusu + kago	'wastebasket'
	geta + bako	*keta + bako	'footwear case'
	naga + gutsu	*naka + gutsu	'long shoes, boots'

This yields the argument against the alternative direct linking analysis of Rendaku mentioned at the end of section 2. If Rendaku voicing were directly linked to the first segment of the second compound member, Lyman's Law (26) would not be able to distinguish between deletable Rendaku voicing (as in (27a)) and undeletable voicing in the first compound member (as in (28)).

We are now in a position to show how the right branch effects follow from our analysis. Let us first take a closer look at the crucial evidence presented by Otsu (1980) for his Right Branch Condition (RBC). Consider the pair of compounds given in (29).

(29) a.



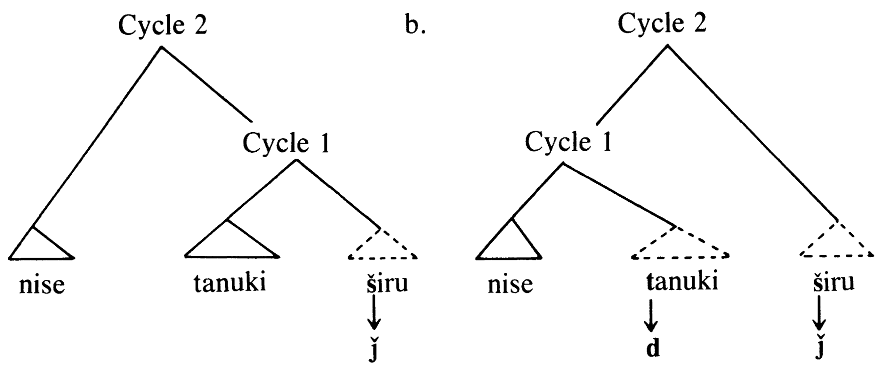
'lacquered [chopstick case]' '[lacquered chopstick] case'

The RBC distinguishes between the two occurrences of *haši* in (29) by appealing to constituent structure. In (29a) *haši* is on a left branch and therefore Rendaku cannot apply. In (29b), on the other hand, *haši* is on a right branch and undergoes Rendaku.

The RBC requires transparency of embedded morphological structure and is therefore incompatible with the Atom Condition (2). As a minor point, note also that within Otsu's (1980) framework, the RBC is a stipulation whose addition to the rule of Rendaku leads to redundancy in two respects. First, in all cases of compounding where the right-hand member is not complex, the RBC overlaps with the structural description of Rendaku. As a rule that voices the initial segment of the second compound member, Rendaku can by definition only affect "right branches." Second, in cases where the right-hand compound member is complex, the RBC overlaps with Lyman's Law. This is illustrated by examples (30a) and (30b) (attributed to Susumu Kuno in Otsu (1980, 218)). Though Rendaku applies on both cycles in (30b), it applies only on cycle 1 in (30a). As noted by Otsu himself, Rendaku voicing is doubly blocked on cycle 2 in (30a). Since *tanuki* is on a left branch, Rendaku is blocked by the RBC. It is independently blocked by Lyman's Law, because a voiced obstruent *ǰ* has been derived by Rendaku on cycle 1.

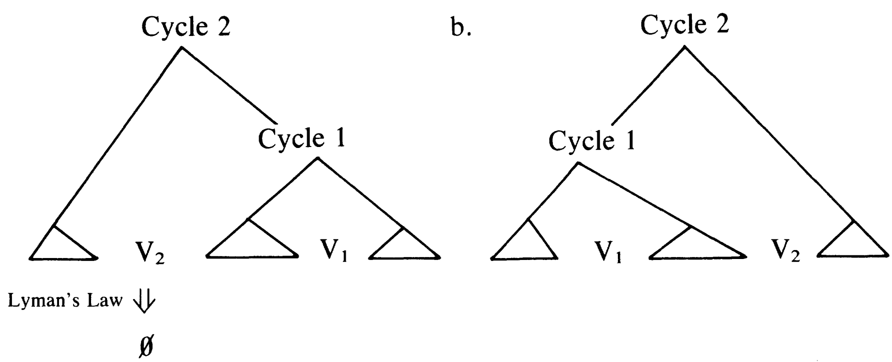
In our autosegmental analysis the RBC becomes superfluous, since all right branch effects follow from the principle of the cycle. Consider the structures in (31), which are schematic representations of the contrasting pairs in (29) and (30). Rendaku inserts a voicing autosegment on every compound cycle (indicated by the subscripts on V (= [+voi]) in (31)).

(30) a. b.



'fake [raccoon soup]' '[fake raccoon] soup'

(31) a. b.

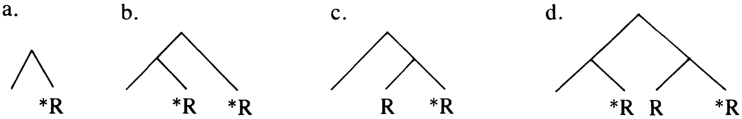


The prosodic structure created on cycle 1 is carried over to cycle 2, and in (31a) $[+\text{voi}]_2$ is deleted because it meets the structural description of Lyman's Law (26). This explains why Rendaku never appears on a "left branch." In (31b), on the other hand, $[+\text{voi}]_2$ cannot be deleted because it is not followed by another [+voi] on the voicing tier. In all relevant cases $[+\text{voi}]_1$ is immune to deletion by Lyman's Law (26) because it has undergone Voicing Spread (19) on cycle 1 and is therefore not "stray."

This simple cyclic interaction of the rules accounts for the contrasts in (29) and (30); no special restriction such as the RBC need be imposed on the rules. The cyclic explanation is by no means merely a descriptive alternative to the RBC approach. If the kind of free reference to internal structure implied by the RBC were permitted, we could just as well formulate a "Left Branch Condition" that would allow only left branches of complex embedded structures to be affected by Rendaku.[15]

[15] Rendaku with a Left Branch Condition would apply as follows:

(i) a. b. c. d.

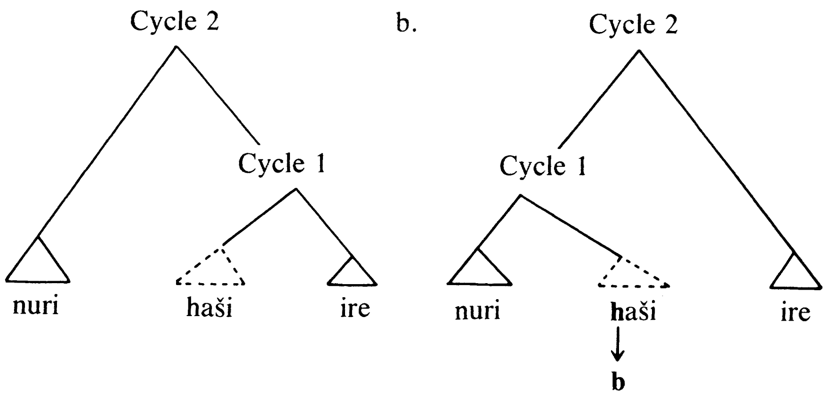


Note in particular that a Left Branch Condition would preclude Rendaku in simple compounds.

For such an imaginary "anti-Rendaku" voicing pattern, no cyclic explanation suggests itself, and this illustrates the inherent restrictiveness of the cyclic account.

As a concrete illustration, let us take up the examples in (29) (repeated in (32)).

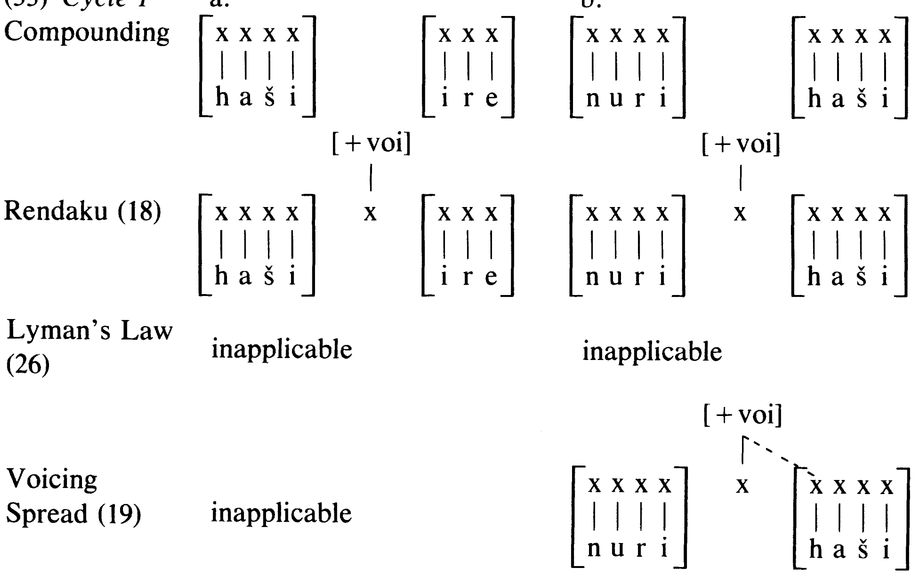
(32) a. b.



'lacquered [chopstick case]' '[lacquered chopstick] case'

All rules apply cyclically, and we consider first only the innermost compound cycles.

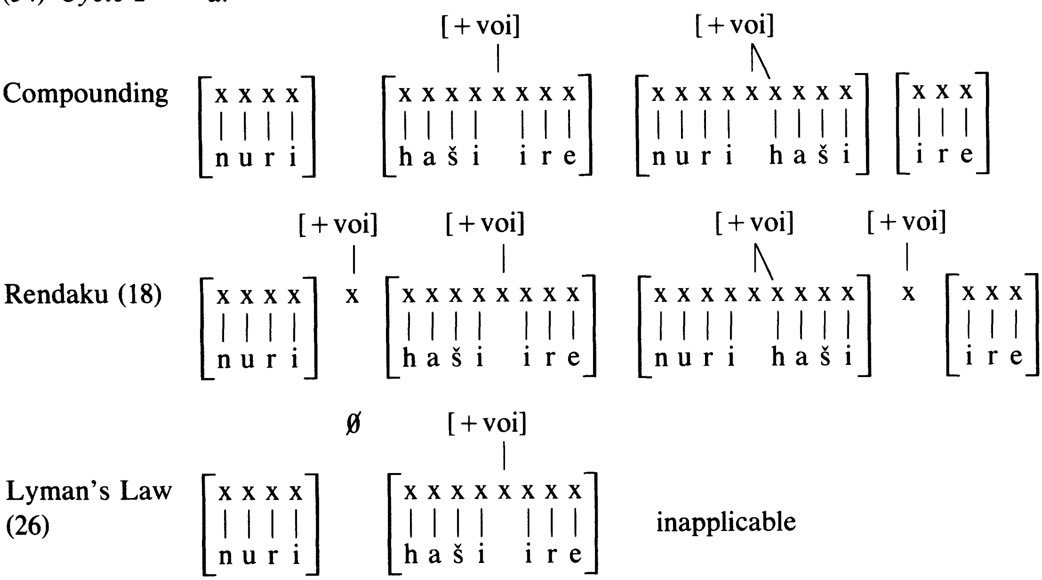
(33) *Cycle 1* a. b.



After Compounding, Rendaku applies in both (33a) and (33b). Being an autosegmental operation, Rendaku is blind to segmental information and inserts a [+voi] autosegment in the voicing tier. The nature of the initial segment of the second compound member is entirely irrelevant: even if it is a vowel, as in *haši ire* (33a), Rendaku applies. Lyman's Law is inapplicable in both derivations. Voicing Spread applies in (33b) but is blocked in (33a), because [+voi] can only be spread onto obstruents (see the discussion at the end of section 2).

On cycle 2 the derivations continue as follows:

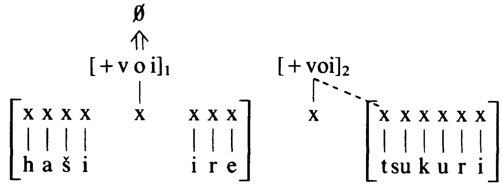
(34) *Cycle 2* a. b.



	a.	b.
Voicing Spread (19)	inapplicable	inapplicable
Output	*nuri haši ire*	*nuri baši ire*
	'lacquered [chopstick case]'	'[lacquered chopstick] case'

Rendaku again inserts [+voi] in both derivations in the juncture environment]____[. Lyman's Law applies in (34a), where the inserted [+voi] precedes another [+voi] on the voicing tier. In (34b), however, neither of the autosegments fulfills the structural description of the rule. The leftmost [+voi] autosegment, although followed by another [+voi], is not stray.[16] The rightmost autosegment, although stray, is not followed by

[16] Contrast this with the example in (i), where $[+\text{voi}]_1$ is stray and therefore deleted by Lyman's Law.

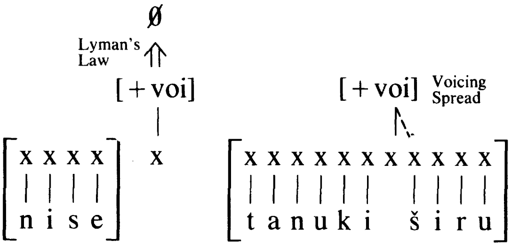
(i)


haši ire dzukuri
'chopstick case making'

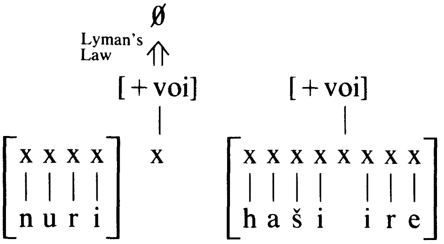
This has no consequence, however, because the following segment *i* is voiced by default. Moreover, if (i) undergoes further compounding, Lyman's Law will be triggered by $[+\text{voi}]_2$ in all relevant cases.

another [+voi]. The [+voi] inserted on cycle 1 in (33a) has no direct reflex in the surface form, since the following segment is a vowel with nondistinctive voicing. However, it crucially serves as a context for Lyman's Law on the next cycle, thereby systematically preventing Rendaku-derived voiced obstruents from appearing on a "left branch."[17] There are of course examples where the [+voi] inserted on the initial cycle not only triggers Lyman's Law but also has a direct surface manifestation. A case in point is *nise* [*tanuki ǰiru*] in (30a), which is derived in our analysis as schematically shown in (35). (For the sake of comparison, *nuri* [*haši ire*], discussed above, is given in (36).)

(35)

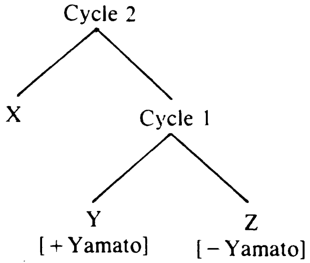


(36)



[17] Masanobu Ueda (personal communication) has directed our attention to structure (i), where the left branch Y does not seem to undergo Rendaku. (No actual examples with the relevant structure have been found, but native intuitions agree on this point.)

(i)



Z, being [−Yamato], is not affected by Rendaku on cycle 1 (see (11)), and if [YZ] does not contain underlying voiced obstruents, this could be construed as a problem for our analysis since the structural description of Lyman's Law (26) is apparently not met on cycle 2. Consider the case where Z is the head of [YZ]: [YZ] will itself have the feature [−Yamato] (by head percolation and the Atom Condition (2)) and hence will not undergo Rendaku. The interesting case arises when [YZ] is headed by Y and acquires the feature [+Yamato] by percolation. We assume that Rendaku (18) is sensitive only to the appropriate compound structure and inserts a [+voi] irrespective of the [±Yamato] distinction, whereas Voicing Spread (19), which actually affects the second compound member, is restricted to [+Yamato] elements. (In fact, Voicing Spread is only observed in [+Yamato] morphemes.) Under these assumptions, the structural description of Lyman's Law (26) is met in (i), and no problem arises.

In both (35) and (36), [+voi] is deleted in the context of [+voi] by Lyman's Law. The only difference is that Voicing Spread, though inapplicable in (36), can apply in (35), deriving the voiced obstruent *ǰ* from *š*.

The Right Branch Condition violates the Atom Condition (2) and imposes an essentially arbitrary constraint on internal morphological structure. Our prosodic analysis achieves a principled explanation for all right branch effects and is moreover compatible with strict morphological inaccessibility.

4. Further Implications: Lyman's Law in Yamato Morpheme Structure

An important generalization about the Yamato vocabulary of Japanese is that a morpheme may contain at most one voiced obstruent. For example, Yamato morphemes of the form CVCV can have the schematic structures in (37a–c) but not the structure in (37d).[18]

$$\begin{array}{llccccl}
 & & & & & & \textit{Examples} \\
(37)\ \text{a.} & & \text{C} & \text{V} & \text{C} & \text{V} & \text{futa 'lid'} \\
\text{b.} & & \text{C} & \text{V} & \text{C} & \text{V} & \text{fu}\textbf{d}\text{a 'sign'} \\
 & & & & | & & \\
 & & & & [+\text{voi}] & & \\
\text{c.} & & \text{C} & \text{V} & \text{C} & \text{V} & \textbf{b}\text{uta 'pig'} \\
 & & | & & & & \\
 & & [+\text{voi}] & & & & \\
\text{d.} & * & \text{C} & \text{V} & \text{C} & \text{V} & \text{*}\textbf{buda} \\
 & & | & & | & & \\
 & & [+\text{voi}] & & [+\text{voi}] & &
\end{array}$$

The constraint can be formally expressed as in (38).[19]

(38) $*[_{\mu}[+\text{voi}]\ [+\text{voi}]]$

It is clear that this voicing restriction in Yamato morpheme structure and Lyman's Law in compounds are closely related phenomena, and they were indeed viewed as such by Japanese grammarians (as noted by Lyman (1894, 1)). How can we avoid reiterating the effects of Lyman's Law (39) by a similar, but formally unrelated, constraint on Yamato morpheme structure (38)?

(39) *Lyman's Law* (= (26))

$$[+\text{voi}] \rightarrow \emptyset \ / \ \underset{\substack{| \\ X'}}{\underline{\qquad}}[+\text{voi}]$$

[18] Monomorphemic forms with two or more voiced obstruents either are foreign loans (*daburu* 'a double whiskey', *buzaa* 'buzzer') or have pejorative connotations (*debu* 'Fatty', *doǰi* 'blunder'). The latter should be considered as part of the ideophonic vocabulary.

[19] (38) holds for morphemes of any number of syllables. Two voiced obstruents do not cooccur within a morpheme, even if separated by a voiceless obstruent.

This situation seems to be another instance of the duplication problem discussed in Kenstowicz and Kisseberth (1977), where morpheme structure constraints duplicate the effects of phonological rules. For the case at hand, a simple solution suggests itself: let Lyman's Law (39) apply within morphemes. Since it deletes a [+voi] in the context of another [+voi], it already ensures that only one [+voi] can appear within a morpheme. An independent morpheme structure condition like (38) need no longer be stipulated. Suppose a certain morpheme, which we schematically represent as (40), contains multiple obstruent voicing.

$$(40)\quad [_{\mu}\ \ldots\ \underset{[+\text{voi}]}{\overset{\displaystyle c}{|}}\ \ldots\ldots\ldots\ldots\ \underset{[+\text{voi}]}{\overset{\displaystyle c}{|}}\ \ldots]$$

Lyman's Law (39) deletes the first [+voi] and changes (40) to (41).

$$(41)\quad [_{\mu}\ \ldots\ \underset{\emptyset}{c}\ \ldots\ldots\ldots\ldots\ \underset{[+\text{voi}]}{\overset{\displaystyle c}{|}}\ \ldots]$$

By neutralizing the feature [+voi] in the environment ___ [+voi], Lyman's Law (39) ensures that no morpheme can contain multiple [+voi]. Lexical representations designed to violate this restriction, like (40), are automatically "corrected." The morpheme structure constraint (38), though expressing a true generalization, is a mere corollary of the phonological rule of Lyman's Law (39) and thus has no independent theoretical status. (See appendix II for further discussion relating to the Obligatory Contour Principle.)

The idea of reducing morpheme structure conditions to phonological rules plays a central role in Natural Phonology (Stampe (1973), Lovins (1973), Churma (1984)). Within the framework of Lexical Phonology, Kiparsky (1982) argues that morpheme structure constraints do not exist as formal entities and that their functions are fulfilled by the corresponding phonological rules applying in a non-feature-changing fashion. Deletion rules like Lyman's Law (39) would prima facie appear to change features. However, noting that deletion of autosegments can be formally understood as delinking cum Stray Erasure, we can assume, as argued by Donca Steriade (MIT class lectures, Spring 1985), that delinking does not constitute a feature-changing operation.

Given the formulation of Lyman's Law and minimal assumptions about syllabification, the fact that the rule applies both in compounds and morpheme-internally is not at all accidental. Recall that Lyman's Law only deletes stray [+voi] (that is, [+voi] not integrated into a syllable). In the cyclic derivation the rule applies to forms that have already undergone syllabification and can therefore only delete the stray [+voi] inserted by Rendaku. In underlying representations of morphemes, on the other hand, every [+voi] that precedes another [+voi] is a target for Lyman's Law, because syllabification has not yet taken place.

Although the morpheme-internal targets of Lyman's Law lack syllabic affiliation, they are in no sense "floating," since the location of [+voi] in a morpheme is unpredictable and hence must be encoded by linking. Lyman's Law can therefore not in general be formulated as deleting a floating [+voi], and this provides an argument against the second alternative analysis of Rendaku mentioned at the end of section 2, which introduces [+voi] as a floating autosegment. To cover the compound and the morpheme case, Lyman's Law would have to be complicated so as to delete autosegments that are either floating or syllabically unaffiliated. Our analysis, on the other hand, succeeds in capturing the underlying unity of the voicing deletion rule in compounds and the Yamato morpheme structure constraint.

5. Conclusion

The prosodic analysis of Rendaku defended here crucially relies on, and hence provides support for, underspecification theory, phonological cyclicity, nonsyllabified underlying representations, and autosegmentalization of laryngeal features. Furthermore, motivation is given for a theoretical distinction between floating autosegments and autosegments linked to an otherwise unspecified *x*-slot. In our analysis Rendaku itself is a morphological process inserting a [+voi] autosegment. The other rules involved—Voicing Spread (19) and Lyman's Law (26)—are simple autosegmental operations that have strong independent motivation (for Voicing Spread, the morphophonemic alternations in the verbal paradigm, and for Lyman's Law, the Yamato voicing restriction). By deriving all right branch effects without stipulating a Right Branch Condition, we have eliminated a prima facie counterexample to strict morphological inaccessibility. Our explanation turns on the fact that prosodic structure itself carries forward the crucial information that later phonology depends on. We speculate that other putative counterevidence will fall to the same sort of analysis, when the relevant prosodic structures are properly understood.

Appendix I

Unlike the other sonorants (*r* and *w*), nasals do voice an immediately following obstruent within the domain of a simplex word. Thus, the gerundive forms of /kam/ 'chew' and /šin/ 'die' are *kande* and *šinde*, not **kante* and **šinte*. This reflects a general constraint on Yamato morpheme structure requiring voicing agreement in NC clusters (e.g. *tombo* 'dragonfly', *kambašii* 'fragrant', *šindoi* 'tired', *unzari* 'disgusted', *kaŋgae* 'thought', but not **mp*, **nt*, **ns*, **ŋk*). We can formulate Postnasal Voicing as in (42).

(42) $C \rightarrow [+\text{voi}]\ /\ [+\text{nas}]\ \_\_\_$

A rule essentially identical to (42) is operative in Malayalam (Mohanan and Mohanan (1984, 599)) and in many other Dravidian languages (Lass (1984)).

In Japanese (42) is restricted to early levels of the morphology and applies morpheme-internally and to primary affixes. The rule is clearly not postlexical, since it operates neither in Sino-Japanese compounds (e.g. *sam+po* **sam+bo* 'stroll', *han+tai* **han+dai* 'opposition') nor in Yamato compounds (e.g. *hyootan+kago,* **hy-*

ootan + *gago* 'gourd basket'), where its effects would only be observable when Rendaku is blocked by Lyman's Law.

It would of course be desirable if the postnasal voicing phenomenon could be subsumed under Voicing Spread (19). Several versions of such an approach ((a)–(d) below) come to mind, but most are not easily reconcilable with a simple and explanatory formulation of Rendaku and Lyman's Law.

(a) *Abandonment of underspecification.* This would entail the loss of all explanations that crucially depend on underspecification. In particular, the invisibility of all redundant voicing for Lyman's Law remains a mere stipulation. Voicing Spread (19) would furthermore have to be complicated to exclude nonnasal sonorants as assimilation triggers.

(b) *Default feature specification by the Redundancy Rule Ordering Constraint (Archangeli (1984)).* Nasals are underlyingly unspecified for voicing, as are all sonorants. If default feature specification occurs the first time a rule mentions the relevant feature, the default [+voi] of nasals is correctly inserted before Voicing Spread (19) applies. However, default feature specification obliterates the crucial distinction: all the other stem-final sonorants (*r, w, e, i*) would likewise acquire [+voi] and incorrectly trigger Voicing Spread to *t*-initial suffixes (cf. (21) and (23)).

(c) *Optional underspecification of redundant features.* Nasals, but not other sonorants, are underlyingly specified for voicing. This approach amounts to a serious weakening of underspecification theory and has empirical problems as well. It succeeds in singling out the voicing assimilation triggers, namely voiced obstruents and nasals, but misses the correct generalization in the case of Lyman's Law: nasals behave exactly like all other sonorants in not blocking Rendaku (see for example (3)).

(d) *Lexical and postlexical default rules.* Kiparsky (1983) proposes that default rules can be ordered into blocks applying at different points in the derivation. This allows us to imagine an approach that subsumes Postnasal Voicing under Voicing Spread (19) and is consistent with our Rendaku analysis. The facts require two additional assumptions:

(I) Certain default rules, namely (DR1) and (DR2), already apply in the lexical phonology.

(43) *DR1*

$[+\text{nas}] \rightarrow [+\text{voi}]$

(44) *DR2*

$[-\text{son}] \rightarrow [-\text{voi}]$

(II) The level of compounding precedes the level of (verbal) affixation.

At the compound level no default rules apply; therefore, sonorant voicing is invisible for Rendaku, Lyman's Law, and Voicing Spread (19). At the level of (verbal) affixation, the default rules DR1 and DR2 apply. Voicing Spread (19) now correctly treats nasals and voiced obstruents as assimilation triggers. For example, [[šin]te] 'die + GERUND' becomes [[šin]de] by a feature-changing application of (19) in a derived environment. Voicing Spread (19) can no longer apply in compounds like *hyootan* + *kago* 'gourd basket' at this level because the *k* of *kago* is already specified as [−voi] by DR2, and the Strict Cycle Condition blocks feature-changing rule applications in underived environments. (Notice that the level of (verbal) affixation cannot be governed by Lyman's Law because the default rule DR1 must be able to apply.)

Although descriptively adequate, this analysis runs counter to the intuition that the boundary between verbal root and affix is much weaker than the boundary between compound members. Furthermore, the constraint on Yamato morphemes requiring voicing agreement in NC clusters remains unaccounted for. It cannot be reduced to Voicing Spread (19) because at the level of affixation, where nasals are assigned [+voi] and unmarked obstruents [−voi], the Strict Cycle Condition will prevent morpheme-internal applications of (19).

Despite these problems, we anticipate that a variant of (d) will turn out to be the correct approach. The status of nasals with respect to voicing assimilation and underspecification clearly deserves further study. (We are indebted to an anonymous reviewer for insightful comments and suggestions on this issue.)

Appendix II

Lyman's Law (with its morpheme structure corollary (38)) has a close affinity to the intuitive idea behind various versions of the Obligatory Contour Principle (Leben (1973), Goldsmith (1976), McCarthy (1979; 1981)). It is possible to recast our analysis in terms of the Obligatory Contour Principle (OCP), interpreted along lines pursued in McCarthy (to appear). McCarthy convincingly argues for a theory whose main tenets are summarized in (a)–(d).

(a) Different morphemes are segregated onto different autosegmental tiers.

(b) Identical units cannot be adjacent on a single autosegmental tier (OCP).

(c) Besides constraining the form of lexical representations, the OCP has an "antigemination" effect throughout the phonological derivation. Phonological rules (e.g. syncope) are blocked when their application would result in adjacency of identical autosegments on a tier. Crucially, the OCP is not an operation "fusing" adjacent identical autosegments.

(d) Morphemic tiers are conflated at some point during the phonological derivation.

In our case, an OCP explanation could proceed in the following way:

(i) *Lyman's Law effects in simple compounds.* If Rendaku voicing is understood as [+voi] entering the voicing tier of the second compound member, the process will be blocked by the OCP whenever a [+voi] is already present.

(ii) *The right branch effects.* The assumption that tier conflation is cyclic ensures that, on a higher cycle, complex second members of compounds occupy a single morphemic tier. The OCP will always block Rendaku voicing on such a "conflated" morphemic tier, which will inevitably contain either an underlying or a Rendaku-derived [+voi]. Compounds with two voiced obstruents like *kuzu*+*kago* 'wastebasket' (see (28)) are permitted, because the OCP blocks rules from applying but cannot change representations (cf. (c) above), and both voicing autosegments are already present prior to tier conflation.

(iii) *The Yamato voicing restriction.* This is a straightforward consequence of the OCP and of a constraint that prohibits multiply linked [+voi] underlyingly in Japanese, which, as pointed out to us by Alan Prince, can be viewed as Lyman's Law under the OCP approach. This constraint holds only for the Yamato morphemes; foreign loans with several voiced obstruents can be analyzed as containing a single multiply linked [+voi] and hence do not violate the OCP.

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