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7 Sino-Japanese phonology

1 Introduction

This chapter takes up the Sino-Japanese substratum of the Japanese lexicon (*kango* 漢語, henceforth SJ), historically the result of intensive borrowings from Chinese at different periods. Large-scale and systematic borrowing began in the pre-Nara period (6th century AD) in connection with the introduction of Buddhism, followed by a second period in the 8th century, and a third one in the 14th century closely associated with Zen. For the written language, this means that it is not unusual for a given Chinese character (*kanji* 漢字) to have, besides a native-Japanese reading (*kun-yomi* 訓読み), several different but similar Sino-Japanese readings (*on-yomi* 音読み) traceable to different times of borrowing, different stages and dialects of Chinese dominant at the time, and different adaptation strategies. Thus 京 'capital' can be read as *kyoo*, *kee*, and *kin*. The role of SJ in Modern Japanese is comparable in English to that of the distinct but massive borrowings of Latinate/Romance vocabulary following the Norman Conquest and of Greek vocabulary during the Renaissance. In terms of its contexts of use, the SJ vocabulary ranges from items found in informal everyday conversation to items exclusive to formal discourse (see Shibatani 1990: 142–147 and work cited there), and its size is considerable (ca. 60% of a modern dictionary, and 20% of ordinary speech). Surprisingly, despite its very long history within Japanese, SJ has preserved many of the characteristics that distinguish it from the other two major constituents of the Japanese lexicon (see Nasu, this volume, and Kubozono, Ch. 8, this volume), the native Japanese vocabulary (*wago* 和語, or *yamatokotoba* 大和言葉) and Western loans (*gairaigo* 外来語). Rather, SJ continues to form a separate lexical stratum with unique morpheme-structural, prosodic, and segmental characteristics (Martin 1952; McCawley 1968; Ito and Mester 1996) many of which can be traced back to the monosyllabic shape of the Chinese source words, with subsequent adaptations throughout the history of the Japanese language.[1]

The goal of this chapter is to outline these special phonological properties and alternations within the synchronic grammar of Japanese, summarize previous work, and sketch new developments towards a better understanding of both the segmental and prosodic properties characterizing SJ phonology. Section 2 introduces the main prosodic characteristics of SJ items in terms of root and word size restrictions, and gives an overview of the special segmental make-up of SJ roots. Section 3 is devoted to the phonology of SJ compounding: Compounding at the root level gives rise to an

1 See Nasu (this volume) for discussion of the core-periphery model (Ito and Mester 1995) of the stratified lexicon of Japanese, and see also Takayama (this volume) and the History Volume in the same series for details about the history of the language.

interesting set of phonological alternations due to root-syllable alignment conditions, and higher-level compounding at the word level provides evidence for crisp prosodic word edges, and shows how interface mapping constraints play a key role in the analysis of SJ compounding.

2 Root structure and segment distribution

2.1 Root and word size

Two closely related prosodic characteristics are crucial to the understanding of the phonological properties and alternations found in SJ items. The first is a limit on the size of SJ roots stated in (1),[2] unsurprising given their monosyllabic Chinese sources. Individual SJ roots are either a single light syllable (e.g., /ka/ 科 'field', /ki/ 気 'spirit'), a single heavy syllable (e.g., /kan/ 館 'building', /nai/ 内 'internal', /kuu/ 空 'void'), or two light syllables with a monosyllabic allomorph (e.g., /gaku/~/gak/ 学 'study, scholarship', /betu/~/bet/ 別 'separate'), corresponding to the (maximally) bimoraic foot shown to play a central role in Japanese morphology and phonology (see Ito and Mester, Ch. 9, this volume, and Otake, this volume).

(1) Root size: $|\,root_{SJ}\,| = ft$
$ft \leq 2\mu$, i.e., $ft = \sigma_\mu\sigma_\mu, \sigma_{\mu\mu}, \sigma_\mu$

We return later to the question of why this prosodic limit needs to be stated in terms of the phonological foot and not directly in terms of moras.

The second characteristic, less discussed but nevertheless also critical for the proper understanding of both accentual and segmental alternations, is the size of words composed of SJ roots. Most SJ roots occur only in combination with other SJ roots (e.g., *dai+gaku* 大学 'great+study, university', *gaku+nai* 学内 'study+inside, school-internal', *gaku+see* 学生 'study+person, student', *sen+see* 先生 'previous+person, teacher'), not in isolation or compounded with items from the rest of the lexicon. A close parallel in English is the combinatorics of Greek roots (e.g., *cosmo+logy, micro+cosm, helico+pter, ptero+saur*, etc.), which are mostly not independent words and combine overwhelmingly only with other Greek roots.[3] Since SJ roots rarely

2 The notation |x| refers to the prosodic size of element x.

3 Hybrids do exist, such as /ba+syo/ 場所 'place' (native+SJ) or /zyuu+bako/ 重箱 'layered serving box' (SJ+native), (the latter is even used to refer to this kind of mixed formation in *juubako yomi* 重箱読み 'mixed reading'). However, it is our impression that their number is smaller than that of corresponding hybrids of Latin and Greek morphemes in English, which are rather frequent, perhaps because both are loans whose exact etymological pedigree is not clear to many users of English: E.g., *sociology* from the Latin *socius* 'comrade' and the Greek λόγος (logos) 'reason', or *television* from the Greek τῆλε (tēle) 'far' and the Latin *visio* 'seeing'.

occur in isolation, the roots themselves are only listed in specialized SJ root dictionaries (*kanwa-jiten* 漢和辞典). Regular Japanese dictionaries (*kokugo-jiten* 国語辞典) list independently occurring morphologically complex SJ lexical items composed of two SJ roots, which, given the root size restriction, are prosodically two feet.

(2) Word size: | $word_{SJ}$ | = | $root_{SJ}$ + $root_{SJ}$ | = 2ft

As we will see below in section 3, these prosodic characteristics, both root size and word size, turn out to have implications for the realization of SJ items, with theoretical consequences for our understanding of the way prosodic structure is regulated.

2.2 Segmental composition

In addition to their prosodic size limit, SJ roots are highly restricted in their segmental composition, as shown in (3)–(5).[4]

(3) a. CV

ka	科	'department'
i	胃	'stomach'
gu	具	'material'
ke	家	'house'
ko	古	'old'

b. CVV

bee	米	'rice'
kyoo	京	'capital'
huu	風	'wind'
dai	大	'big'
sui	水	'water'

c. CVN

kon	今	'this'
ken	県	'prefecture'
kan	完	'complete'
kin	金	'money'
gun	軍	'army'

The basic generalization for CVV roots is that V_2 must be a high vowel, /i/ or /u/. The two sequences */ii/ and */oi/ are excluded, and most of the remainder are subject to

4 Since onsets are optional, "CV" in what follows should be understood as comprising both CV and V, etc.

monophthongization (4) (or gliding+compensatory lengthening, see Poser 1988 and Kubozono, Ch. 5, this volume).

(4) iu → yuu *ii
eu → yoo ei → ee
au → oo ai → ai
ou → oo *oi
uu → uu ui → ui

As a result, besides the two diphthongs /ai/ and /ui/, SJ has the three long vowels /ee/, /oo/, and /uu/, but no */aa/ or */ii/. The situation contrasts both with the native stratum, where long vowels are rare, and with the stratum of Western loans, where all five long vowels are common (see Moreton, Amano, and Kondo 1998 and Kubozono, Ch. 8, this volume). Several experiments (Moreton and Amano 1999; Gelbart and Kawahara 2007) have shown these distinctions between lexical strata (in particular, the absence of /aa/ in SJ vs. its presence elsewhere) to be psychologically real.

The only possible word-final consonant in Japanese is the moraic nasal (realized with dorso-uvular closure, see Vance 2008: 99–100), transcribed with *n* in (3c), and it is the only final consonant in monosyllabic SJ roots. Chinese, however, especially the historical varieties that SJ is based on, allowed a larger range of coda consonants including voiceless plosives, and source items with such codas gave rise to SJ items as in (5), which occur either as disyllabic CVCV or as monosyllabic CVC, depending on the phonological context (as explored below in section 3). We represent SJ roots in accordance with a conventional view of their underlying representations, in effect close to the *kunrei* style of transliteration (so /y/ indicates the palatal glide, etc.). Slashes (/. . ./) indicate underlying forms in the sense of generative grammar, not structuralist phonemic transcriptions. For example, /yaku/ corresponds to phonetic [jakɯ], /butu/ to [bɯtsɯ], /hati/ to [hatʃi], /tyaku/ to [tʃakɯ], etc., see sections 2 and 3 of the introduction by Kubozono (this volume).

(5) a. CVtu
atu 圧 ‘press’
betu 別 ‘different’
hitu 筆 ‘writing’
butu 物 ‘thing’
sotu 卒 ‘graduate’

b. CVti
hati 八 ‘eight’
kiti 吉 ‘luck’

c. CVku

iku	育	'be raised'
tyaku	着	'arrival'
huku	服	'luck'
hoku	北	'north'

d. CVki

teki	敵	'enemy'
riki	力	'power'

C_2 is always a voiceless stop (/t, k/), and V_2 is always a high vowel (/i, u/), as shown in (6).

(6) Segmental composition:

$$C_1\ V_1\ C_2\ V_2$$
$$\qquad\quad\ \ |\qquad |$$
$$\qquad\quad \begin{Bmatrix} t \\ k \end{Bmatrix}\ \begin{Bmatrix} u \\ i \end{Bmatrix}$$

The C_2 restriction to voiceless plosives is inherited from the Chinese source words (the third voiceless stop /p/ was historically lost in Japanese), and the V_2 restriction is a reflection of the fact that this vowel was inserted in Japanese, due to a coda condition more stringent than the one found in the source dialect of Chinese. We can capture the V_2 restriction by means of a constraint on vowel sonority in weak positions of feet such as (7) (following de Lacy 2002: 118, see also de Lacy 2006).

(7) *NONHEAD(ft) ≥ {e, o}
Assign a violation for every foot nonhead that is equally or more sonorous than mid vowels (i.e., /e o a/).

It turns out, however, that the choice of V_2 is even more restricted: Not only is V_2 always high, its backness is also almost totally predictable from other properties of the form. The relevant generalizations are due to the study of Martin (1952), with further refinements in Tateishi (1990) and Ito and Mester (1996). The situation is summarized in (8).

(8) Cooccurrence table for V_2

V_1 = \ C_2 =	t	k
a	*u*†	*u*
o	*u*	*u*
u	*u*	*u*
e	*u*	*i*
i	*u*†	*i*/*u*††

†very few occurrences of *i* as V_2

††genuine contrast between *u* and *i* as V_2

In the overwhelming number of cases, V_2 is /u/: For *t*-roots, this is exceptionless when V_1 is /o/, /u/, and /e/, and there are only a handful of exceptions when V_1 is /a/ or /i/ (the number words /hati/ 八 'eight', /iti/ 一 'one', /siti/ 七 'seven', and two other isolated examples, /niti/ 日 'sun' and /kiti/ 吉 'good luck'). *k*-roots also show uniform /u/ after the back vowels /a, o, u/. After front vowels in V_1 position, there is something resembling a harmony pattern, as Tateishi (1990) has recognized: We find /i/ as the only option when V_1 = /e/ (e.g., /seki/ 石 'stone'), and as an option alongside /u/ when V_1 = /i/. The environment /*ik*_ is therefore the only environment where a genuine contrast between /i/ and /u/ is found in V_2-position: Examples include /siki/ 式 'ceremony' vs. /ziku/ 軸 'axle', and /tiku/ 蓄 'accumulate' vs. /riki/ 力 'power'. The default color of the high V_2 vowel is thus [+back], i.e., /u/, arguably the unmarked vowel of the SJ and the Foreign lexical strata. Different from the native stratum, where /i/ is the prime candidate for the default vowel (see Poser 1984), the bulk of the /i/-cases in SJ arise through harmony, with [–back] harmony holding either uniformly or as a lexical option.

The almost total predictability of V_2 in SJ roots of the form CVCV implies that specifying this vowel in underlying representations is redundant and misses a major generalization. Earlier work therefore hypothesized that V_2 is underlyingly absent in all cases besides the exceptional cases involving /i/, and posits /bet/, /gak/, etc., as underlying representations. Under this view, vowel insertion is prosodic epenthesis triggered by an obstruent exclusively liked to the coda (Ito 1986; Tateishi 1990), a scenario which has become known in Optimality Theory (OT) as the coda condition (CodaCond). The default vowel /u/ is epenthesized to make forms like /bet/ syllabifiable, resulting in the disyllabic form /betu/.

In the current context, a number of possible analyses arise. Option 1 is to carry on with the traditional epenthesis analysis, positing monosyllabic SJ roots where V_2

is underlyingly absent and /bet/, /gak/, etc., are the unique underlying representations. For *k*-roots, but not *t*-roots, the epenthesized vowel agrees in backness with V_1 = e due to a constraint demanding harmony. Only truly exceptional cases (like /hat, hati/ 'eight') have both a monosyllabic CVC-allomorph and a disyllabic CVCV-allomorph. Option 2 is like Option 1, but with allomorph listing playing a larger role. V_2 = /u/ continues to be supplied by epenthesis to underlyingly monosyllabic roots. Allomorph listing applies to all roots with a monosyllabic CVC-form and a disyllabic CVCi-form, both to the unpredictable cases like /hat, hati/ 'eight', as well as the predictable backness harmony cases like /sek, seki/ 'stone'. Option 3 extends allomorph listing to all SJ roots and posits pairs of URs, /CVC, CVCi/ or /CVC, CVCu/, in all instances, treating the exceptional cases (like /hat, hati/ 'eight'), the backness-harmony cases (like /sek, seki/ 'stone'), and the regular cases with V_2 = /u/ (like /bet, betu/, /gak, gaku/), in the same way.

This does not exhaust all possible options, and here is not the place to argue for or against any of them, which differ mainly in terms of how much of the overall pattern they attempt to derive from general principles, potentially earmarked for the SJ vocabulary stratum. For concreteness, we will proceed by assuming Option 2, noting that this choice does nor rest on a principled argument (see Kurisu 2000 for more discussion of these issues, and a specific proposal).

3 Compounding and its prosody

3.1 Root compounding and alignment

As discussed in section 1, SJ roots occur mostly compounded with other SJ roots, and are listed in such collocations in regular dictionaries. The situation is similar to that of Greek roots in the English lexicon, where whole compounded forms (e.g., *pentagon*, *helicopter*) are listed in the dictionary as lemmas, not the individual roots (*penta-*, etc.). In both cases, the meanings are often non-compositional (e.g., /ben+kyoo/ 勉強 'effort-hard, to study', /sen+see/ 先生 'previous+born, teacher', or *helico+pter* 'curved+wing', *anthropo+logy* 'human-study', etc.). On the other hand, whereas in Greek compounds cross-morpheme syllabification *he.li.co+p.ter* and cross-morpheme footing (*anthro*)(*po+lo*)*gy* often make the prosodic boundaries of the two roots opaque, such cross-morpheme syllabification does not occur in SJ, even with vowel-initial morphemes as second members. Thus, /man/+/in/ 満員 'full capacity' and /gak/+/i/ 学位 'academic degree' do not appear as **ma.n+in* and **ga.k+i*, but as *man.+in* with a nasal coda, and as *ga.ku.+i* with its first member appearing in its vowel-final form allomorph to avoid an obstruent coda violation **gak.+i*. As a result, SJ root boundaries in compounds are impermeable to syllabification, and the two roots remain clearly recognizable as prosodic units in the output form.

The situation is undoubtedly at least in part influenced by the writing system, where each SJ root is represented by a single *kanji* and has a clear and separate orthographic identity. In phonological terms, it is unlikely that this behavior is due to cyclic syllabification, given that one of the most central results of Lexical Phonology is the very fact that roots do not constitute cyclic domains (see Brame 1974, Kiparsky 1982, and Inkelas 1989 for discussion and argumentation). The reason for the syllabic closure of SJ roots is rather to be sought elsewhere, viz., in the size restrictions governing SJ roots and words discussed in the previous section (and repeated here in (9)).

(9) a. Root size: $|\ root_{SJ}\ | = ft$
$ft \leq 2\mu$, i.e., $ft = \sigma_\mu\sigma_\mu,\ \sigma_{\mu\mu},\ \sigma_\mu$

b. Word size: $|\ word_{SJ}\ | = |\ root_{SJ} + root_{SJ}\ | = 2ft$

Related to (9a), there are alignment constraints (interface mapping constraints) requiring root edges to match syllable edges (10), and it is these constraints that are responsible for the resistance to resyllabification.

(10) ALIGN-ROOT$_{SJ}$-TO-SYLLABLE
a. Align-Left (Root$_{SJ}$, Syllable)
b. Align-Right (Root$_{SJ}$, Syllable)

ALIGN-ROOT is a two-partite constraint governing both edges, left and right. It disallows syllabification across root boundaries by requiring root-initial elements to be syllable-initial (10a), henceforth ALIGN-ROOT-L(EFT), and root-final elements to be syllable-final (10b), henceforth ALIGN-ROOT-R(IGHT).[5] Both ALIGN-ROOT-L and ALIGN-ROOT-R are observed when the first root ends in a nasal (11a) or a vowel (11b). Alignment is satisfied when the syllable edge "." and the root edge "|" are not separated by segmental material.

(11)	a.	/san+po/	|.sam|.po.|	'scatter+walk', 'stroll'	散歩
		/san+koo/	|.saŋ|.koo.|	'go+think, reference'	参考
		/han+mee/	|.ham|.mee.|	'understand+light, reveal'	判明
		/han+bai/	|.ham|.bai.|	'trade+sell, sale'	販売
	b.	/koo+kan/	|.koo|.kan.|	'associate+replace, exchange'	交換
		/tai+kai/	|.tai|.kai.|	'big+event, convention'	大会

5 Constraints of this type were first explored in OT by Prince and Smolensky (1993 [2004]) and McCarthy and Prince (1993). The edge-based form of such interface constraints linking grammatical and prosodic categories was originated by Selkirk (1986).

The surface assimilation pattern (/np/ → [mp], /nk/ → [ŋk], etc.) still fulfills alignment in terms of the last segment of the root, and place-assimilated coda nasals are allowed in Japanese (Ito and Mester 1993; see also the introduction by Kubozono, this volume, and Ito and Mester, Ch. 9, this volume). Alignment is enforced even when the second root is vowel initial, and the resulting C.V juncture persists in the output form, as the examples in (12) show (there is no systematic insertion of a default phonetic onset filler, laryngeal ([ʔ]) or other; only the relevant medial junctural alignment is indicated here).[6]

(12)

	Aligned	Disaligned		
/sin+an/	sin|.an	*si.n|an	'new plan'	新案
/kan+i/	kan|.i	*ka.n|i	'simplicity'	簡易
/hon+ee/	hon|.ee	*ho.n|ee	'headquarters'	本営
/man+in/	man|.in	*ma.n|in	'full capacity'	満員

In OT terms, root alignment (10) outranks the onset requirement (ALIGN-ROOT$_{SJ}$ » ONSET), resulting in an internal open juncture utterly foreign to Yamato (native) items, where we find cross-morpheme syllabification to fulfill ONSET. For example, the final consonants in verb roots such as /kik/ 'to hear' and /tanom/ 'to request' syllabify with the vowel-initial suffixes (*ki.k+u*, *ta.no.m+u*), showing that no comparable root alignment is in force, undoubtedly also related to the fact that the native vocabulary knows no root-size restriction.

The merit in having separate alignment constraints for left and right root edges lies in the fact that the two are not equal in strength: Whereas ALIGN-ROOT-L is never violated, there are many violations of ALIGN-ROOT-R when the root is obstruent-final (i.e., *t*-final or *k*-final). When these obstruent-final roots are second members of compounds, epenthesis takes place to avoid a violation of CODACOND. Such epenthesis is disaligning, leading to an ALIGN-ROOT-R violation in (13), where the right edge of the root ("t|") is not at the right edge of the syllable ("*u*."). The alignment-violating forms surface as optimal because of the ranking CODACOND » ALIGN-ROOT. Combined with ALIGN-ROOT » ONSET established earlier, the overall ranking is CODACOND » ALIGN-ROOT » ONSET.

6 There is a historical linking pattern where the root-final consonant occupies both coda and onset position, surviving in contemporary Japanese in isolated forms such as: *ten.n|oo* 'emperor' from /ten +oo/ 天皇 'heavenly sovereign'; *un.n|un* from /un+un/ 云々 'various'; *gin.n|a*n from /gin+an/ 銀杏 'silver+fruit, gingko seed'. A similar linking pattern has been observed in recent loanwords (e.g., *pin.n|appu* for 'pin-up', *ran.n|awee* 'run-away', see Vance 2010), but there is no general tendency or variation in most SJ compounds (i.e., **sin.n|an*, **kan.n|i*, **hon.n|ee* are not possible output forms in (12)).

(13)

	ALIGN-ROOT-R violation	CODACOND violation		
/hai+tat/	haitat|*u*.	*haita*t*.|	'delivery'	配達
/dai+gak/	daigak|*u*.	*daiga*k*.|	'university'	大学

In (14), the initial SJ root is *t*/*k*-final. Syllabifying the root-final obstruent consonant as the onset of the second root violates ALIGN-ROOT-L (and in addition ALIGN-ROOT-R). However, since the root-final consonant cannot remain a coda because of CODACOND, the optimal output is one in which ALIGN-ROOT-R is violated.

(14)

	ALIGN-ROOT-R violation	ALIGN-ROOT-L violation	CODACOND violation		
/bet+en/	bet|*u*.en	*be.*t*|en	*bet*.*|en	'farewell dinner'	別宴
/gak+i/	gak|*u*.i	*ga.*k*|i	*gak*.*|i	'academic degree'	学位
/kok+oo/	kok|*u*.oo	*ko.*k*|oo	*kok*.*|oo	'king'	国王
/hat+an/	hat|*u*.an	*ha.*t*|an	*hat*.*|an	'proposal'	発案

With *t*/*k*-final roots, epenthesis occurs not just with vowel-initial second members, but also with most consonant-initial second members because *t* and *k* cannot serve as codas, as shown in (15).

(15)

/bet+noo/	bet*u*.noo	*be*t*.noo	'separate payment'	別納
/bet+bin/	bet*u*.bin	*be*t*.bin	'separate carrier'	別便
/hat+den/	hat*u*.den	*ha*t*.den	'start electricity'	発電
/kat+yak/	kat*u*.yak*u*	*ka*t*.ya*k*	'live+leap, be active'	活躍
/gak+mee/	gak*u*.mee	*ga*k*.mee	'school name'	学名
/gak+gai/	gak*u*.gai	*ga*k*.gai	'outside of campus'	学外
/tok+bet/	tok*u*.bet*u*	*to*k*.be*t*	'special'	特別
/hak+too/	hak*u*.too	*ha*k*.too	'white sugar'	白糖
/gak+see/	gak*u*.see	*ga*k*.see	'student'	学生
/tok+tyoo/	tok*u*.tyoo	*to*k*.tyoo	'characteristics'	特徴
/hak+hat/	hak*u*.hat*u*	*ha*k*.ha*t*	'white hair'	白髪

The examples of *t*/*k*-final roots seen so far have all undergone epenthesis, raising the question of whether ALIGN-ROOT-R is ever active in the language at all. Obeying ALIGN-ROOT-R are the cases with nasal-final or vowel-final roots (see (11) above), where the constraint can be fulfilled without violating CODACOND. There is, however, one syllabic configuration where obstruent codas are allowed, namely, as the first part of a geminate, where coda licensing is not an issue (see Ito 1986, Goldsmith

1990, Ito and Mester 1993, and work cited there for justification and details). If a root-final /t/ and /k/ is followed by a root-initial /t/ and /k/, respectively, i.e., in the configurations /Vk+kV/ or /Vt+tV/, the obstruent codas are allowed because they are the first part of geminate structures (see Kawahara, Ch. 1, this volume, and Kawagoe, this volume). Right-alignment is fulfilled here, and resorting to epenthesis is not necessary. Unless other constraints (e.g., CODACOND) are at play, root alignment decides on the non-epenthetic candidate.[7]

(16)						
	…Vk+kV…	/gak+koo/	gak.koo	*gaku.koo	'school'	学校
		/hak+kot/	hak.kotu	*haku.koo	'skeleton'	白骨
		/gak+ki/	gak.ki	*gaku.ki	'musical instrument'	楽器
	…Vt+tV…	/bet+tak/	bet.taku	*betu.taku	'detached villa'	別宅
		/hat+tat/	hat.tatu	*hatu.tatu	'development'	発達
		/kot+too/	kot.too	*kotu.too	'antique'	骨董

Besides the identity cases, where underlying /CVk/ and /CVt/ surface as such, we also find underlying /CVt/ surfacing as /.CVs./, /.CVp./, and /.CVk./ before /s/, /p/, and /k/, respectively (17).[8]

(17)					
t+p → pp	/bet+puu/	bep.puu	'letter under separate cover'	別封
	/bet+poo/	bep.poo	'different message'	別報
	/hat+pyoo/	hap.pyoo	'announcement'	発表
t+s → ss	/hat+soo/	has.soo	'shipment'	発送
	/bet+sat/	bes.satu	'separate volume'	別冊
	/bet+syu/	bes.syu	'another kind'	別種
t+k → kk	/bet+koo/	bek.koo	'separate clause'	別項
	/hat+ken/	hak.ken	'discovery'	発見
	/bet+kyo/	bek.kyo	'separation, limited divorce'	別居

7 This is where the precise analysis of the vowel-zero alternations in SJ roots becomes important. While alignment is violated when the underlying form is /CVC/, as we are assuming here, this is not so in an allomorphy analysis where both /CVC/ and /CVCu/ are available as underlying forms. In the latter case, while right alignment is not an issue, some other element in the analysis (such as an allomorph preference relation, or a syllable minimization constraint) has to force roots to ever appear in the CVC form.

8 /p/ at the beginning of the second root in such forms alternates with /h/ in other contexts: /bep+*p*oo/ 別報 'different+information, another report' vs. /*h*oo+koku/ 報告 'information + announce, report', etc., see Nasu (this volume) on the /h/~/p/ alternation.

Even though place and stricture features have changed, both alignment requirements still hold in these examples: Root-final segments are syllable-final, root-initial segments syllable-initial. The segment in the onset preserves its features because of positional faithfulness (IDENT-ONSET or IDENT-σ_1, see Beckman 1997, Casali 1997, and Lombardi 1999), but the coda *t* acquires the place and stricture features of the following consonant. Once it is the first part of a geminate, there is no need for epenthesis, and right-alignment is satisfied.

Feature-changing gemination of this type is only allowed between *t*-final roots and voiceless obstruent-initial roots, as listed in (17) above. The details of why feature-changing gemination does not apply to other combinations are explained by various other constraints governing the Japanese phonological system. Voiced geminates (voiced obstruent geminates like *gg*, *bb*, *dd*, and nonnasal sonorant geminates like *rr*, *ww*, etc.) as conceivable outcomes in examples like (15) violate a general constraint on Japanese syllable structure holding throughout the non-Foreign (i.e., Yamato, SJ, and Mimetic) vocabulary (see Kawahara, Ch. 1, this volume, Kawagoe, this volume, and Nasu, this volume). Nasal geminates (*nn*, *mm*) arise from assimilation with nasal-final roots (see (11) above), but not with *t*-final roots (/bet+noo/ appears as *betu+noo*, not **ben+noo*), hence feature-changing gemination must be restricted to obstruent-obstruent combinations, which indicates a high-ranking status of IDENT[sonorant] (and/or a markedness constraint against nasal geminates) as a recoverability condition.

Finally, in order to minimally distinguish the two root-final obstruents /t/ and /k/, with the former but not the latter assimilating to a heterorganic following voiceless obstruent, previous work such as Tateishi (1990), Padgett (1991 [1995]), and Ito and Mester (1996) has attributed the difference to featural underspecification, with /k/ specified as dorsal, but /t/ underspecified for place and acting as the default consonant (for crosslinguistic evidence for the choice of coronal as the default place, see Paradis and Prunet 1991 and references cited there). In OT terms, it is sufficient for the faithfulness constraint IDENT[dorsal] to be ranked higher than the alignment constraint, and IDENT[coronal] to be ranked lower (see Kurisu 2000 for statements of these IDENT constraints). Dorsality does not always trump coronality; this is rather subordinated to the onset-coda asymmetry. Thus the /t-k/ sequence in (17) – underlying /bet+koo/ – turns into *bekkoo* 'separate clause', but the /k-t/ case in (15) – underlying /hak+too/ – appears as *hakutoo* 'white sugar', not as **hakkoo*. Gemination is unidirectional, i.e., only from onset to coda, due to high-ranking IDENT-ONSET. Table (18) summarizes all changes at SJ compound junctures discussed in this section, with examples illustrating each case.

(18)

Rt-Final: / Rt-Initial:	V		n		k		t	
V	V.V	sai+ai 最愛	n.V	ren+ai 恋愛	k*u*.V	hak*u*+ai 博愛	t*u*.V	kat*u*+ai 割愛
r	V.r	kuu+ran 空欄	n.r	han+ran 反乱	k*u*.r	kyok*u*+ron 極論	t*u*.r	sot*u*-ron 卒論
w	V.w	gi+wak*u* 疑惑	n.w	kon+wak*u* 困惑	k*u*.w	tiku+wa 竹輪	t*u*.w	hat*u*+wa 発話
y	V.y	kyoo+yuu 共有	n.y	sin+yuu 親友	k*u*.y	gak*u*+yuu 学友	t*u*.y	kat*u*+yoo 活用
m	V.m	see+mon 正門	m.m	sem+mon 専門	k*u*.m	gak*u*+mon 学問	t*u*.m	sit*u*+mon 質問
n	V.n	zyoo+nai 場内	n.n	an+nai 案内	k*u*.n	kok*u*+nai 国内	t*u*.n	sit*u*+nai 室内
b	V.b	ee+bun 英文	m.b	rom+bun 論文	k*u*.b	sak*u*+bun 作文	t*u*.b	zat*u*-bun 雑文
z	V.z	kee+zai 経済	n.z	kan+zen 完全	k*u*.z	tyok*u*+zen 直前	t*u*.z	tot*u*+zen 突然
d	V.d	tee+den 停電	n.d	sen+den 宣伝	k*u*.d	syuk*u*+dai 宿題	t*u*.d	zet*u*+dai 絶大
g	V.g	dai+gak*u* 大学	ŋ.g	siŋ+gak*u* 進学	k*u*.g	dok*u*+gak*u* 独学	t*u*.g	tet*u*+gak*u* 哲学
p/h	V.h	koo+hai 後輩	m.p	sem+pai 先輩	k*u*.h	taku+hai 宅配	p.p	zip+pi 実費
s	V.s	ee+see 衛星	n.s	en+see 遠征	k*u*.s	gak*u*+see 学生	s.s	zis+sen 実践
t	V.t	kai+ten 開店	n.t	kan+tan 簡単	k*u*.t	dak*u*+ten 濁点	t.t	zit+tai 実態
k	V.k	koo+kan 交換	ŋ.k	buŋ+ken 文献	k.k	gak+koo 学校	k.k	zik.kan 実感

- Glosses for V-final column: *most beloved, empty column, doubt, joint ownership, front gate, on premises, English sentence, economy, power outage, university, one's junior, satellite, store opening, exchange.*
- Glosses for n-final column: *love, revolt, bewilderment, close friend, specialization, guide, thesis, perfect, advertisement, continuing education, one's senior, expedition, simple, reference.*

- Glosses for k-final column*: philanthropy, extreme argument, tube roll (of fish paste), school friend, study, domestic composition, immediately before, homework, self-taught, home delivery, student, turbid point, school.*
- Glosses for t-final column: *reluctantly delete, graduation thesis, utterance, conjugation, question, indoor, miscellaneous writings, sudden, enormous, philosophy, actual expense, actual practice, actual situation, realization.*

3.2 Word compounding and crisp edges

The previous sections outlined the segmental and prosodic properties of SJ roots and root compounds (i.e., instances of $word_{SJ}$ = $root_{SJ}$+$root_{SJ}$). At a higher level of SJ word structure, we find a rich system of word compounds (i.e., $compound_{SJ}$ = $word_{SJ}$#$word_{SJ}$). A first set of examples are what is commonly referred to as *yoji jukugo* 四字熟語, or 'four-character compounds', non-compositional idiomatic expressions as in (19), often borrowed from Classical Chinese and listed as such in dictionaries.

(19) Idiomatic four-character compounds
   a. zyaku+niku # kyoo+syoku 弱肉強食
      'weak+meat#strong+eat, the law of the jungle, the great fish eat the small'
   b. i+ku#doo+on 異口同音
      'different+mouths#same+sound, with one voice, unanimously'
   c. ee+ko#see+sui 栄枯盛衰
      'blossom+wilt#prosperous+decline, ups and downs (of life), rise and fall'

Besides their non-compositionality, such idiomatic four-character compounds form two phonological (accentual) phrases, e.g., {i+ku}{doo+on} etc., and are not subject to the compound junctural accent rule found in the productive word compounds to be discussed below.[9]

Setting aside such idiomatic compounds, word compounding is highly productive, and we find many compounds made up of two SJ words (themselves compounds at the root level), such as $[koo+koo]_{SJ}$#$[ya+kyuu]_{SJ}$ 高校野球 'high school baseball', $[syuu+syoku]_{SJ}$ #$[si+en]_{SJ}$ 就職支援 'employment assistance', etc.[10] Different from root compounding, word compounding is not restricted to members of the

9 For details, see Ito and Mester (Ch. 9, this volume) on word formation and phonological processes, Kawahara (Ch. 11, this volume), and Kubozono, Ito, and Mester (1997).

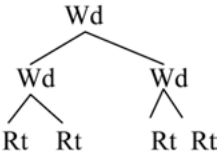
10 Here and below, square brackets [...] indicate the constituent structure of the word, following standard practice.

SJ vocabulary stratum. Alongside the usual SJ#SJ combinations, we find other combinations, such as SJ#YAMATO and FOREIGN#SJ (see Ito and Mester 2003: 143 for examples illustrating all possible combinations): [ki+setu]$_{SJ}$#[hazure]$_{Yamato}$ 季節はずれ 'off-season', [ken+kyuu]$_{SJ}$#[fooramu]$_{Foreign}$ 研究フォーラム 'research forum', etc.

It is also possible to add a non-compounded single root$_{SJ}$ to a word$_{SJ}$ either on the right or the left, as in (20b,c). These have the appearances of 'suffixes' and 'prefixes', but since they also occur as compound root members, there is no clear and compelling morphological reason to differentiate between those occurring in the innermost word compound and those adjoined outside.

(20) Morphological structure of complex compounds

a. [A B] [C D]



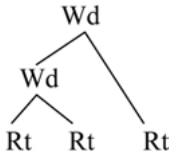
[koo+koo] [ya+kyuu]
高校野球
'high+school base+ball'

[syuu+syoku] [si+en]
就職支援
'employment assistance'

[nen+kin] [mon+dai]
年金問題
'annuity problem'

[ren+sai] [syoo+setu]
連載小説
'serialized novel'

b. [A B] C



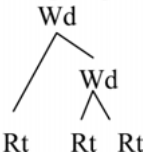
[kin+yuu] tyoo
金融庁
'financial agency'

[boo+ryoku] dan
暴力団
'gangster group'

[tan+ken] tai
探検隊
'expedition team'

[kai+ran] ban
回覧板
'circulation notice'

c. A [B C]



sin [hatu+mee]
新発明
'new discovery'

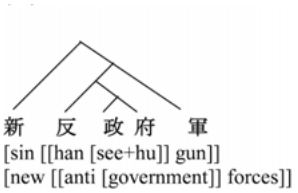
bee [see+hu]
米政府
'U.S. government'

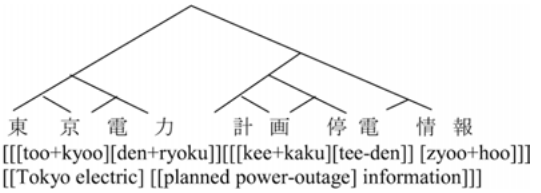
han [see+ki]
半世紀
'half century'

betu [sya+kai]
別社会
'separate society'

Thus, besides the doubly-branching four-member compound structure [A B] [C D] in (20a), there are two kinds of three-member compounds: the left-branching structure [A B] C in (20b), and the right-branching structure A [B C] in (20c). Still more complex cases as in (21) can be reduced to these elementary configurations.

(21)





These long compounds act syntactically as single lexical items, hence a recursive morphological structure is appropriate.[11] McCawley's (1968) careful study of complex compounds shows a pattern distinctly different from that predicted by the generalizations obtained so far from simple two-member SJ root compounds. As shown in (22), with relevant word compound junctures indicated by #, a sequence of SJ roots such as /bet/ and /tee/ in (22a) surfaces with epenthesis in the complex compound across the #-juncture (/…bet*u*#tee…/), where our analysis so far predicts not disaligning epenthesis, but alignment-preserving gemination (/…bet#tee…/). As also shown in (22), the predicted lack of epenthesis continues to be correct at root compound junctures (/bet+tee/, etc.).

(22) Epenthesis vs. no epenthesis

	Epenthesis	No Epenthesis
a.	[AB][CD]	[BC]
	[toku+betu]#[tee+en] 特別庭園	[bet+tee] 別庭
	*[toku+bet]#[tee-en]	*[betu+tee]
	'special garden'	'annex garden'
b.	[AB]C	[BC]
	[toku+betu]#seki 特別席	[bes+seki] 別席
	*[toku+bes]#seki	*[betu+seki]
	'special seat'	'different seat'
c.	A[BC]	[AB]
	betu#[koo+moku] 別項目	[bek+koo] 別項
	*bek#[koo+moku]	*[betu+koo]
	'separate item'	'different reference'

Table (23) shows in a similar way that the alignment-wise expected p-allophone does not appear following a #-juncture in complex compounds.

(23) h/p alternation

	h-allophone	p-allophone
a.	[AB][CD]	cf. [BC]
	[kan+zen]#[hai+boku] 完全敗北	[zem+pai] 全敗
	*[kan+zem]#[pai+boku]	*[zen+hai]
	'total defeat'	'all defeat'
b.	[AB]C	cf. [BC]
	[man+nen]#hitu 万年筆	[em+pitu] 鉛筆
	*[man+nem]#pitu	*[en+hitu]
	'10000-year pen, fountain pen'	'lead-pen'; 'pencil'

11 Longer compounds are accentually different and have some characteristics of phrases, see Kubozono, Ito, and Mester (1997) for the description and Ito and Mester (2007) for the analysis of so-called long and overlong compounds.

c.	A[BC]	cf. [AB]
	sin#[hatu+mee] 新発明	[ham+patu] 反発
	*sim#[patu+mee]	*[han+hatu]
	'new invention'	'opposite+start'; 'rebel'
	betu#[hyoo+ki] 別表記	[bep+pyoo] 別表
	*bep#[pyoo+ki]	*[betu-hyoo]
	'separate transcription'	'alternate list'

McCawley (1968), making imaginative use of the segmental boundary-based framework of SPE, developed an analysis whose essential insights are easily recaptured in the syntax-prosody interface theory (see Selkirk 2011, Ito and Mester 2013, and references cited there; see also Ishihara, this volume). In section 2, we stated the size restriction on SJ roots (1) (repeated in (24)) as demanding one foot.

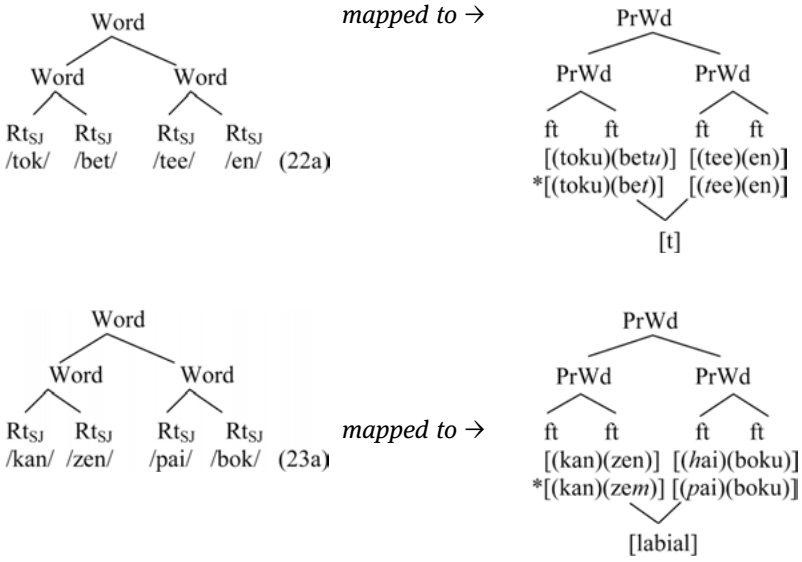
(24) Root size: | $root_{SJ}$ | = ft (where ft ≤ 2μ, i.e., $\sigma_\mu\sigma_\mu$, $\sigma_{\mu\mu}$, or σ_μ)

Seen in a larger context, (24) is the manifestation of an interface constraint (25a) matching a morphological entity (here $root_{SJ}$) to a phonological constituent (here, a moraic-trochaic foot).

(25) Interface constraints
- a. MATCH-$ROOT_{SJ}$-TO-ft
- b. MATCH-LXWD-TO-PRWD

In tandem with the general interface constraint (25b) matching lexical words to prosodic words, (25a) maps the morphological structure (26a) to the prosodic structure in (26b) (parentheses indicate footing).

(26) a. Morphological structure — *mapped to* → — b. Prosodic structure



Given this prosodic structure, it becomes apparent that the unexpected instances of epenthesis (instead of expected gemination) occur at the end of a prosodic word (PrWd), and the unexpected h-allophones at the beginning of a PrWd. What is avoided, then, is feature linkage across a prosodic word boundary, formally a consequence of the CRISPEDGE family of constraints (Ito and Mester 1999) requiring edges of prosodic constituents to be feature-wise closed. Crispness means that the constituent does not share features with (or is in other ways dependent on the properties of) adjacent prosodic constituents. The crucial member of the constraint family is CRISPEDGE(PRWD) requiring all PrWds, including the embedded ones in (26), to have crisp edges. In both [tokubet*u*][teeen] and [kanzen][*h*aiboku], every PrWd member has crisp edges, but in *[tokube*t*][*t*eeen] and *[kanze*m*][*p*aiboku], the geminate *tt* and the assimilated nasal-obstruent cluster *mp*, a partial geminate structure, share place features and violate the CRISPEDGE(PRWD) constraint. Without shared place features, CODACOND forces the epenthetic *u* in [tokubet*u*], and the *h*-allophone emerges initially in [*h*aiboku]. We interpret the nasal place assimilation sometimes found in the pronunciation of examples like [simbu*ŋ*][kookoku] 'newspaper advertisement' as a phonetic/fast speech phenomenon, as shown by its optionality and the fact that the genuinely phonological process resulting in /p/ for /h/ is not possible in this context (cf. [simbu*n*][*h*aitatu] 'newspaper delivery', *[simbu*m*][*p*aitatu], see Ito and Mester (1996: 38–39) and Kadono (2009) for discussion.

Geminate and partial geminate structures also violate CRISPEDGE(ft) and CRISPEDGE(σ). Both are low-ranking in Japanese, so simple PrWds like [(be*t*)(*t*ee)] and [(ze*m*)(*p*ai)] satisfy CRISPEDGE(PRWD) but violate the CRISPEDGE constraints for the smaller prosodic constituents. On the other hand, we saw in section 4 that ALIGN-ROOT-R (10) forestalls epenthesis at the right edge and creates geminate configurations whenever possible. This means that in terms of constraint ranking, ALIGN-ROOT-R is dominated by CRISPEDGE(PRWD), but in turn dominates both CRISPEDGE (ft) and CRISPEDGE(σ) (27).

(27) CRISPEDGE(PRWD) » ALIGN-ROOT-R » CRISPEDGE(ft), CRISPEDGE(σ)

The patterns of epenthesis and of the *h/p* alternation in complex compounds are thus straightforward consequences of (i) the mapping to prosodic structure through the interface constraints (25) and (ii) the interaction of the constraints governing this prosodic structure (27).

It is essential to conceive of the size restriction on $root_{SJ}$ in terms of a prosodic constituent – a single foot – and not in terms of raw mora counting. Even monomoraic SJ roots (like /si/ 詩 'poem' or /ku/ 句 'phrase') always constitute a foot, albeit a subminimal one. In OT terms, the FOOT BINARITY Constraint is outranked by the interface constraint demanding $root_{SJ}$ be matched with a foot (MATCH-$ROOT_{SJ}$-TO-ft » FTBIN).

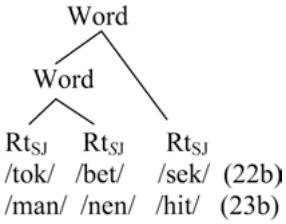
Once compounding has combined two such monomoraic roots into a PrWd, even though the absolute mora count is only 2, the word behaves as a two-foot struc-

ture $[\mu]_F$+$[\mu]_F$: CRISPEDGE(PRWD) ensures featural closure, and no geminate structure arises when further compounding takes place (see Kubozono 1993 for an independent argument from accentuation for the same conclusion). Thus, /ti+ku/ 地区 'locale' from monomoraic /ti/ 地 'land' and /ku/ 区 'division' is a prosodic word [(ti)(ku)] composed of two monomoraic feet, and as such is protected by CRISPEDGE (PRWD). This is why /bet#ti+ku/ 別地区 'different locale' is *betutiku* and not **bettiku*, and /bet#ki+ki/ 別機器 'different device' is *betukiki* and not **bekkiki*. The finding here reaffirms a fundamental tenet of prosodic phonology, viz., that the computation of prosody proceeds in terms of the constituents and categories of the prosodic hierarchy, and not in terms of an accounting system based on direct syllable or mora count (or some other unit measuring "weight" or "length").

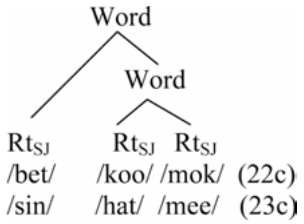
When we turn to three-member complex compounds, we find that another prosodic constraint may be at work, as argued in Ito and Mester (1996), namely, one militating against non-homogeneity of prosodic sisters. Applying the interface constraints (25) to the three-member compounds in (28) can in principle yield two kinds of prosodic structures, the adjunction structure in (29) and the homogeneous structure in (30). In (29), a right-adjoined foot (29a) and a left-adjoined foot (29b) are directly dominated by the highest PrWd. In (30), on the other hand, the lone foot projects a non-branching PrWd node, so that the immediate daughters of the highest PrWd are both PrWds, where the lone feet are type-lifted to be PrWds by themselves. Formally, the choice of structures would depend on the relative ranking of some prosodic structure minimization constraint (e.g., NORECURSIVITY or NOSTRUCTURE) and a general prosodic homogeneity principle militating against adjunction structures (see also Myberg's 2010 constraint NOADJUNCTION, and Selkirk and Elordieta's 2010 analysis of Japanese and Basque phrasal phonology).

(28) Morphological structures

a. Left-branching

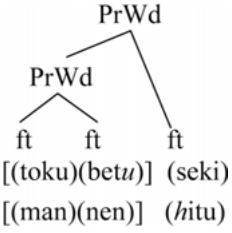


b. Right-branching

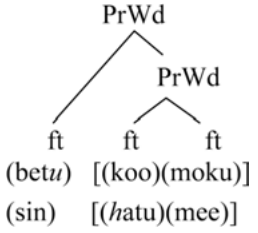


(29) Adjoined prosodic structures

a.

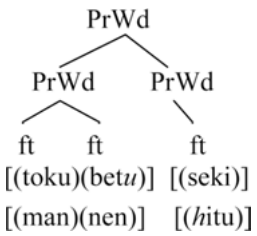


b.

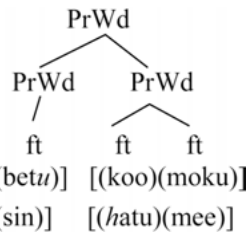


(30) Homogeneous prosodic structures

a.



b.



In the homogeneous prosodic structures (30), CRISPEDGE(PRWD) is directly responsible for all prosodic word edge effects: the epenthetic *u* in [[tokubet*u*]...] and [[bet*u*]...], and the *h*-allophone in [...[*h*atumee]] and [...[*h*itu]]. In the prosodic structures with adjunction (29), CRISPEDGE(PRWD) also directly ensures epenthesis at the end of the embedded PrWd ([[tokubet*u*]...] (29a) and the h-allophone at its beginning ([... [*h*atumee]] (29b)). The adjoined foot, on the other hand, even though itself not directly under the auspices of CRISPEDGE(PRWD), still cannot be linked to the adjacent featurally closed PrWd, and epenthesis is found in [(bet*u*) [...]] (29b), and the h-allophone in [[...](*h*itu)] (29a) as well. Lone adjoined feet and embedded PrWds thus pattern alike,[12] and either the adjunction structure or the homogeneous structure can explain the segmental alternations of SJ word compounding.

There seems to be no argument so far for the extra step of type-lifting to PrWd for reasons of homogeneity, contrary to Ito and Mester's (1996) earlier conclusions. However, looking beyond segmental alternations into the accentual arena, it turns out that the regular compound accentuation rules of Japanese apply in a way that argues for treating the lone foot as a type-lifted full-fledged PrWd, i.e., for the homogeneous structure (30) and against the adjunction structure (29). As is well known (see Kawahara, Ch. 11, this volume, and Kubozono 2008), in a compound word of the form $[[_{PrWd1}...][_{PrWd2}...]]$, compound accent is assigned at the juncture, namely, at the beginning of $PrWd_2$ (e.g., *nama-ta'mago* 'raw egg', *denki-ka'misori* 'electric razor'), except if $PrWd_2$ consists of only one foot, in which case, disregarding some complications, it is assigned to the end of $PrWd_1$ (*temuzu'-gawa* 'Thames river', *kamera'-man* 'camera man'). This generalization is fully obeyed for $word_{SJ}$ com-

12 See McCawley (1968: 116–118) for issues of optionality and sporadic counterexamples to this generalization. In a similar vein, Vance (1987: 161–162) gives examples such as zis#[sya+kai] 'the real world' as well as the well-known [san+kak]#kee '[three-angle] shape, triangle'. More detailed phonetic investigation along the lines of Beckman (1996) would be welcome to tease apart the relative roles in these cases of genuine vowel~zero alternation, a phonological process, and high vowel devoicing, a phonetic process, see Fujimoto (this volume). It will be important for any such investigation to take into account the fact that there are no counterexamples with /p/: zitu#[hee+ryoku], not *zip#[pee+ryoku] 'real [soldier strength], effective strength' but: zip-pi 'actual expenses', nor are there counterexamples in the middle of four-root combinations of the form [AB][CD] (i.e., between B and C) /[san+kak]#[kan+kee]/ 'triangular relationship, love triangle' is /[sankaku][kankee]/, never *[sankak][kankee].

pounds, so [[AB][CD]] structures receive accent on the initial syllable of the second member ([tokubetu][te'een] (22a), [kanzen][ha'iboku] (23a). Crucially, three-member compounds behave as if they are composed of two PrWd compound members: [[A][BC]] structures receive the accent on the initial syllable of the second member ([betu][ko'omoku]] (22c), [[sin][ha'tumee]] (23c)), and [[AB][C]] structures on the last syllable of the first member ([(toku)(betu**'**)] [(**s**eki)] (22b), [(man)(ne'n)][hitu]] (23b)), since the second member is (necessarily) one foot.

4 Concluding remarks

This chapter has outlined the basic characteristics of SJ roots, and their compounding behavior at the levels of the root and of the word. The alternations characteristic of SJ items are seen to be due (i) to the basic syllable structure constraints of Japanese and (ii) to alignment principles governing the mapping between morpho-syntactic structure and prosodic structure. With a proper understanding of the prosodic structures involved and of the principles governing them, the phonology of SJ items follows from a few rather natural basic assumptions.

The specific property that sets SJ roots apart from the rest of the Japanese lexicon is their one-foot size limit, which in turn manifests itself in terms of alignment and interface constraints. Although they constitute only a small subset of the Japanese lexicon, the phonological study of SJ roots and compounds provides a revealing window into many aspects of Japanese phonology as well as phonological structure in general, including their segmental (epenthesis, gemination, nasal assimilation) and prosodic aspects (edge effects, structural effects, accentual implications, etc.).

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