Chinese Syllable Structure

San Duanmu

In this chapter I introduce basic facts about the syllable in Chinese and discuss some descriptive and theoretical issues that concern scholars today.

1. Syllables and morphemes

Written Chinese is made of a sequence of graphs, each taking up a fixed amount of space. Each graph is called a *zi* (字) or 'character', which represents both a syllable and a morpheme. Exceptions exist but are not many. Consider the examples in (1) and (2). For clarity I use a hyphen to separate syllables in the Pinyin spelling system.

(1) Two syllables (morphemes) per graph

Pinyin	Character	Gloss
qian-wa	千瓦 or 瓩	'kilowatt'

(2) Polysyllabic morphemes

Pinyin	Character	Gloss
ma-nao	玛瑙	'amber'
bian-fu	蝙蝠	'bat'
jia-na-da	加拿大	'Canada'
jia-li-fu-ni-ya	加利福尼亚	'California'

The compound 'kilowatt' can be written as two characters or as one, although the latter is still pronounced as two syllables. Such cases are rare and seem to be innovations in competition with

the standard expression. In contrast, there are more examples of polysyllabic morphemes, especially translated names. However, polysyllabic morphemes can often be truncated to a monosyllable, typically in a compound. This is illustrated in (3).

(3) Truncation of polysyllabic morpheme to monosyllabic ones

Non-truncated	Truncated	Gloss
bian-fu chao	*bian chao*	'bat nest'
蝙蝠 巢	蝙 巢	
jia-na-da yuan	*jia yuan*	'Canadian dollar'
加拿大 元	加 元	
jia-li-fu-ni-ya zhou	*jia zhou*	'California State'
加利福尼亚 州	加 州	

The compound *bian-chao* 'bat nest' is made up by me but seems quite acceptable. The compounds *jia-zhou* 'California State' and *jia-yuan* 'Canadian dollar' are real ones.

Overall, it is fair to say that every syllable is a morpheme (or a perceived morpheme) in Chinese. In addition, since most morphemes are also words in Chinese, it is fair to say that most Chinese syllables are words, or that most Chinese words are monosyllabic.

The close relation between syllables and words in Chinese raises an interesting question. If we find a generalization for the Chinese syllable, how do we know it is indeed a generalization for syllables, and not a generalization for words instead? For example, should we say that every syllable in Chinese has a tone, or should we say that every word in Chinese has a tone? The answer has implications for language typology. For example, in the African language Mende, every word has one of five tones, regardless of the length of the word (Kenstowicz 1994). In

contrast, in Standard Chinese, every syllable has one of four tones. Should we say that there are two types of tone languages, one having word tones (like Mende) and one having syllable tones (like Chinese)? Or should we say that there is just one type, because Chinese also has word tones, except that all (or most) its words are monosyllabic?

2. Textual sources: Old Chinese and Middle Chinese

Historical Chinese can be reconstructed by comparing modern dialects and examining loan words (such as Chinese loans in Tibetan, Korean, and Japanese, or Chinese translations of Sanskrit terms in Buddhist texts). In addition, there are three important sources of textual data.

The first is *Shi Jing* 'The Book of Odes', which contains some 300 poems collected from various parts of the country around 1,000 BC, many probably for songs originally. By examining the riming patterns we can determine which syllables used to have the same rimes. The phonology of this period is referred to as Old Chinese.

A second source is riming books, which group words into different sets based on whether they rime with each other. Some riming books also group words according to their initial consonants. Three well known riming books are *Qie Yun* (LU Fayan 601), *Tang Yun* (SUN Mian 723), which was an expansion of *Qie Yun*, and *Guang Yun* (CHEN Pengnian & QIU Yong 1008), which was yet an expansion of the previous two. These works represent the phonology of Middle Chinese. Unfortunately, only *Guang Yun* survived, but from it scholars can reconstruct the systems of *Qie Yun* and *Tang Yun*.

A third source is the orthography of Chinese characters. Although Chinese characters are often thought to be pictographic, most of them are in fact partly phonetic, in that they contain a portion (usually a common word by itself) that indicates its pronunciation. This regularity,

known as ‘same graph, same pronunciation’, can still be seen in many modern Chinese words. Consider the examples in (4), from Standard Chinese.

(4) Phonetic component in Chinese characters

[ma]	馬	‘horse’	[ʈ͡ʂuŋ]	重	‘heavy’
[ma]	媽	‘mother’	[ʈ͡ʂuŋ]	種	‘seed’
[ma]	罵	‘scold’	[ʈ͡ʂuŋ]	鐘	‘bell’
[ma]	螞	‘leech’	[ʈ͡ʂuŋ]	腫	‘swollen’

All the words on the left contain the graph 馬 and all are pronounced as [ma] (ignoring tonal variations). All the words on the right contain the graph 重 and all are pronounced as [ʈ͡ʂuŋ].

Many scholars believe that when Chinese characters were created, this regularity was very consistent, if not completely consistent. Therefore, by examining the shapes of Chinese characters, we can get some idea of which ones used to have the same or similar pronunciation.

3. The maximal size of a syllable

A Chinese syllable can contain up to four phonemes, or CGVX, where C is a consonant, G a glide (a positional variant of a high vowel), V a vowel, and X either a consonant or the second part of a diphthong. Some examples are shown in (5) from Standard Chinese, where [k^h, t^h, ts] are single phonemes and a diphthong is counted as two vowels.

(5) Maximal length of a syllable in Standard Chinese: CGVX

[kʰwai]	[tʰjan]	[kwaŋ]	[tswan]
'fast'	'day'	'light'	'diamond'

Different Chinese dialects can use different phonemes to fill the four slots of a syllable. In (6) I compare three representative dialects.

(6) Dialect variation: phonemes to fill each position in a syllable

	C	G	V	X
Standard Chinese	most Cs	[j, w, ɥ]	any V	[i, u, n, ŋ, ɚ]
Cantonese	any C	[w]	any V	[i, u, n, m, ŋ, p, t, k]
Shanghai	any C	[j, w, ɥ]	any V	([ʔ, ŋ])

In all dialects, the C position can be filled by almost any consonant, with occasional exceptions; for example, [ŋ] is not used in the C position in Standard Chinese (English has a similar restriction). The G position can be filled by one of three glides in Standard Chinese and Shanghai. In Cantonese, there are two glides [w, j], which can occur without C, but when the C is filled, only [w] can be used. This is illustrated in (7).

(7) G in Cantonese

Without C	With C
[wa] 'child'	[kwa] 'melon'
[ja] 'also'	*Cj (not found)

The V position can be filled by any V, and sometimes by a syllabic consonant, such as [n] 'fish' in Shanghai. For the X position, Cantonese is among the most conservative dialects, which has kept a full set of nasals and a full set of unreleased stops. In contrast, Shanghai is among the most advanced dialects with regard to the X position, which only allows a glottal stop or a nasal; in addition, these two sounds often combine with the preceding vowel to form a single sound, i.e. a glottalized V or a nasalized V. Therefore, all syllables in Shanghai behave like open syllables. I shall return to this issue below.

It is believed that Old Chinese allows more sounds to fill G and X, or has more positions in a syllable. For example, many linguists believe that G could be filled by a liquid ([l] or [r]). In addition, Baxter (1992) proposes that Old Chinese had 'post-coda' consonants, one of which was [s], and the loss of them created four tones in Middle Chinese.

4. Riming

In Chinese two syllables rime if they have the same VX. Some examples are shown in (8).

(8) Syllables that rime share the same VX

[laŋ]	[maŋ]	[jaŋ]	[waŋ]	[ljaŋ]	[k^hwaŋ]
'wolf'	'busy'	'sheep'	'king'	'grain'	'crazy'

All the syllables share the VX [aŋ]. The case is similar to that in English. It can be seen that the identity of G is not required for riming, a fact that is relevant for determining syllable structure.

5. Syllable-internal structure

Traditional riming books are aware of the internal parts of a syllable, or CGVX. For example, syllables have been grouped according to the initial consonant (the C part), the medial glide (the G part), and with whom they rime (the VX part). In addition, distinctions have been made as to whether a syllable ends in a nasal consonant, a stop consonant, or neither (the X part).

Opinions differ on whether CGVX form additional sub-structures and if so what they are. Several proposals are shown in (9).

(9) Proposals on the structure of CGVX

a. [C [G [VX]] Cheng (1973)

b. [C [GVX]] Xu (1980: 80)

c. [[CG][VX]] Bao et al. (1997: 87)

d. [[C^G][VX]] Duanmu (1990, 2007)

In (9b) GVX form a flat structure. In others VX form a subunit. Since VX is the basis for riming, (9b) does not seem optimal. The remaining three proposals differ in the treatment of G. It has closer affiliation with VX in (9a) and with C in (9c) and (9d). In addition, in (9c) G remains a separate sound. In (9d) G shares one position with C: when C is present, G is realized as its secondary articulation, and when C is absent, G is the onset by itself. Arguments have been drawn from cooccurrence restrictions, language games, and phonetic properties. A review of various positions can be found in Duanmu (1990, 2007).

6. Syllables and phonemes

Chao (1934) argues that there is often no best way to analyze the phonemes of a language. Instead, competing solutions may be available. Whether Chao is correct or not, the analysis of syllable structure is influenced by the analysis of phonemes. For example, if one treats a diphthong as one vowel, the syllable [mai] is CV, but if one treats a diphthong as two vowels, [mai] is CVV. Similarly, a non-nuclear high vowel can be treated as a vowel or a glide, which can lead to may possible analyses. Some examples are shown in (10).

(10) Influence of phonemic analysis on syllable analysis

[uai] VVV (no diphthong or triphthong); VV ([ai] as a diphthong); V (triphthong)

[wai] GVV or CVV (no diphthong); GV or CV ([ai] as a diphthong)

[waj] GVG or CVC (no diphthong)

Phonemic analysis can in turn be influenced by syllable analysis, too. For example, Li (1983) proposes that CG should be treated as two sounds in Standard Chinese but one in Cantonese. The reason is that Standard Chinese has many CG pairs, whereas Cantonese has two, which are [kw, k^hw]. If we treat CG as one sound in Cantonese, we increase the consonant inventory by two but can simplify the syllable structure to CVC. In contrast, if we treat CG as one sound in Standard Chinese, we would increase the consonant inventory by a lot.

You et al. (1980) go further and propose that not only can diphthongs be treated as single phonemes, but VC rimes can as well, such as [an] and [aŋ] in Standard Chinese. They call such VC units ‘rime phonemes’. The advantage, they argue, is that the syllable can be simplified even more. For example, the maximal syllable is not CGVX but CGV.

7. Heavy and light syllables

In Standard Chinese, most syllables have a long rime, which can be VC, a diphthong, a long vowel, or occasionally a long syllabic consonant. Some examples are shown in (11). Such syllables typically also bear a lexical tone.

(11) Syllables with long rimes

[njau]	[wa:]	[mau]	[ai]	[ɤ:]	[m:]
'bird'	'frog'	'cat'	'love'	'goose'	'yes?'

In contrast, some syllables have a reduced rime, where the consonant coda is deleted or the vowel is shortened, and they do not carry (or hold onto) a lexical tone. Such syllables are often function words or the second part of a compound, both being prosodically weak. When such syllables are pronounced with stress, their rime becomes long (and their lexical tones are retained). Some examples are shown in (12).

(12) Rime reduction in unstressed syllables

Strong	Weak	Example
[kə:]	[kə]	a classifier, as in [ʈ͡ʂei.kə] 'this (one)'
[ma:]	[mə]	a question marker, as in [twei.mə] 'right?'
[fãŋ]	[fə̃]	[ti:.fə̃] 'land-direction (place)'
[t^hou]	[t^ho]	[muu.t^ho] 'wood-head (wood)'
[tai]	[te]	[nau.te] 'head-bag (head)'

If we compare the two kinds of syllables, then those with long rimes are stressed and those with short rimes are unstressed. Native judgment is quite clear in this regard. Phonetic studies also show that the coda of unstressed syllables is dropped and the rime duration is reduced by about 50 per cent (Woo 1969, Lin & Yan 1988). Let us refer to the two kinds of syllables are heavy and light. In (13) I summarize their differences.

(13)

	Rime	Duration	Reduction	Lexical tone
Heavy syllable	VX	long	no	yes
Light syllable	V	short	yes	no

There is a lack of studies on the phonetic differences between heavy and light syllables in other Chinese dialects. My own sense is that a similar contrast exists in them, too.

8. Super-heavy rimes

Rimes that are longer than VX have been reported. Let us call them super-heavy rimes. Some examples are shown in (14).

(14) Super-heavy rimes

Standard Chinese	[maaa]	‘horse’
Cantonese	[sa:m]	‘shirt’ (vs. [sam] ‘heart’)
Fuzhou	[eiŋ]	‘friend’

However, super-heavy rimes can be seen as special cases. For example, in Standard Chinese, the super-heavy rime is found only when a syllable carries the tone LLH and is before a pause; therefore, its extra duration can be attributed to the complexity of the tone and final lengthening. In addition, as Chao (1933: 132) points out, such a syllable 'often breaks into two syllables', e.g. [maaa] → [maa.ʔa]. Similarly, in Cantonese, the vowel length contrast can be attributed to one of vowel quality. For example, Huang (1970) represents the [sam]-[sa:m] contrast in Cantonese as [sʌm]-[sam] instead. Finally, in Fuzhou, the only final nasal is [ŋ]. Therefore, we can analyze [eiŋ] as a nasalized diphthong [ẽĩ]. It is worth noting, too, that super-heavy rimes are often shortened in non-final positions, where they may have become regular rimes. This happens in Cantonese (Wang 1999), Fuzhou (Wright 1983), and Thai (Leben 1971).

9. Syllabic consonants

Many Chinese dialects have syllabic consonants. Some examples are shown in (15).

(15) Syllabic consonants

Standard Chinese	[m]	'yes?'
Shanghai	[n]	'fish'
Cantonese	[m]	'without'

The word in Standard Chinese is an interjection and seems to be a marginal example, but those in Shanghai and Cantonese are regular words and cannot be dismissed. Such words are pronounced without the opening of the mouth and it is hard to claim that they contain a vowel.

Some phonologists believe that every syllable must have a vowel and that there are no syllabic consonants (e.g. Luo & Wang 1957, Cheung 1986, Hsueh 1986, and Coleman 1996,

2001). For them, the words in (15) should have a hidden vowel. For example, Cheung (1986: 150) proposes that the Cantonese word [m] is underlyingly [mi:m], where the hidden vowel [i:] is not pronounced. Since such proposals lack phonetic predictions, they are hard to justify.

Different views on syllabic consonants can also affect the analysis of several other syllables in Standard Chinese. Consider the cases in (16). The transcription is based on many analyses, such as Dong (1958: 37), Chao (1968: 24), Pulleyblank (1984), Ramsey (1987), Wiese (1997: 239-44), and Duanmu (2007: 34).

(16) Syllabic [z] and [z̩] in Standard Chinese

[z]:	tsz	tz^{h}z	sz	
	'self'	'time'	'four'	
[z̩]:	ʈʂz̩	ʈʂ^{h}z̩	ʂz̩	ʐz̩
	'paper'	'tooth'	'history'	'sun'

For those who do not recognize syllabic consonants, the rimes in the above words are not [z] and [z̩], but two special sounds [ɿ] and [ʅ], which are called 'apical vowels'.

10. Casual speech: new syllables and voiceless syllables

In casual speech, new syllables can be created owing to sound deletions or changes. For example, in careful speech no syllable in Standard Chinese ends in [m], but in casual speech such syllables are found, such as [wom], shown in (17).

(17) wo mən → wom

'I plural (we)'

Similarly, devoicing of non-low vowels often happens for syllables that have an aspirated onset (including voiceless fricatives) and a low tone. Some examples are shown in (18). The transcription is based on Duanmu (2007). HL, H, LH, and L are four lexical tones in Standard Chinese. When a sound is devoiced, the tone cannot be heard, which is indicated by Ø.

(18)		L-LH	Ø-HL	
	[ɤ]→[x]	k^hɤ-nəŋ →	k^hx-nəŋ	'possible'
		HL-L	HL-Ø	
	[i]→[ɕ]	ji-t$ɕ^h$i →	ji-t$ɕ^h$ɕ	'together'
		H-L	H-Ø	
	[y]→[ɕ^w]	ʈʂəŋ-t$ɕ^{hw}$y →	ʈʂəŋ-t$ɕ^{hw}$ɕ^w	'strive for'
		L-H	Ø-H	
	[y]→[ɕ^w]	ɕ^{w}y-t^{w}o →	ɕ^{w}ɕ^w-t^{w}o	'many'
		L-HL	Ø-HL	
	[u]→[x^w]	ʂ^{w}u-tɕa →	ʂ^{w}x^w-tɕa	'summer vacation'
		H-L	H-Ø	
	[u]→[x^w]	ɕin-k^{hw}u →	ɕin-k^{hw}x^w	'working hard'
		L-HL	Ø-HL	
	[u]→[x^w]	t^{hw}u-t^{j}i →	t^{hw}x^w-t^{j}i	'land'

Devoicing can happen to syllables in any position (initial, medial or final). Devoiced [i, ɤ, u, y] sound like [ɕ, x, x^w, ɕ^w] respectively. Devoiced syllables have similar durations to the originals

(although rime length is not indicated in the above transcription), and therefore they still sound like separate syllables. If one assumes that every syllable must have a vowel, one must propose devoiced vowels [i̥, ɤ̥, u̥, y̥].

Syllabic consonants can be devoiced, too. Some examples are shown in (19).

(19)

	HL-L	HL-Ø	
[ʊ]→[f]	təu-fʊ →	tou-ff	'tofu'
	HL-L	HL-Ø	
[z]→[s]	ʂaŋ-ts^{h}z →	ʂaŋ-ts^{h}s	'last time'
	HL-L	HL-Ø	
[z̩]→[ʂ]	li-ʂz̩ →	li-ʂʂ	'history'

Again, if one does not recognize syllabic consonants, one might want to propose devoiced apical vowels, instead of [s] and [ʂ].

11. Suffixation and rime changes

Some Chinese dialects have suffixes that merge with the preceding syllable, and the changes can be quite complicated. The most common case is the diminutive suffix. Some examples in Standard Chinese are shown in (20), where the suffix is represented as [ɚ].

(20) Diminutive suffix in Standard Chinese

[njau] + [ɚ] → [njaɚ] '(little) bird'

[jan] + [ɚ] → [jaɚ] '(little) eye'

[jɑŋ] + [ɚ˞] → [jɑ̃ɚ̃˞] ‘(little) lamb’

[t^hu:] + [ɚ˞] → [t^hu$^{ɚ˞}$:] ‘(little) rabbit’

In the first two cases the suffix replaces the coda. In the third case the suffix replaces the coda, but part of the coda is preserved as nasalization on the rime. In the fourth case the suffix is realized as a retroflex color to the main vowel. A number of questions arise about the suffixation process. For example, is the suffix a syllable, a vowel, a consonant, or a just feature? Why is the coda completely replaced in some case but partially retained in others? Can the suffixation process create syllables not found in unsuffixed words? A discussion of the suffix in Standard Chinese can be found in Lin (1989) and Duanmu (2007). For a recent analysis of a fairly complicated case in Pingding Chinese, see Lin (2008).

12. Syllable inventory, homophone density, and frequency data

Chinese has a fairly small inventory of syllables, compared to that in English. Consider the data in (21) and (22). A simplex word is one that contains one morpheme.

(21) Monosyllabic simplex words in English (CELEX lexicon, Baayen et al. 1993)

(All simplex words:	7,401)
Monosyllabic simplex words:	3,834
Different pronunciations:	3,219

(22) Syllables in Standard Chinese

Vocabulary type:	All	Common
Characters:	12,041	2,500
Syllables (with tones):	1,334	1,001
Syllables (without tones):	413	386

English has 7,401 words that are labeled as single morphemes, of which 3,834 are monosyllabic, which include 3,219 different pronunciations, or different syllable forms. In contrast, in *Xiandai Hanyu Cidian* 'Modern Chinese Dictionary' (Chinese Academy of Social Sciences Institute of Linguistics 1978), Standard Chinese has 1,334 syllables including tonal contrasts, or 413 syllables without tonal contrasts. In addition, the dictionary includes many uncommon words, and the most common 2,500 characters cover 99% of all occurrences in modern non-literature texts. If we only count common characters, the list of Chinese syllables is still smaller. In other words, English can distinguish several times more morphemes by pronunciation than Chinese.

The data show that although Standard Chinese has just 1,334 syllables, the average speaker still might not know all of them, or be sure of all of them. This is confirmed by the study of Myers & Tsay (2005), which found that acceptability judgments on possible syllables in Standard Chinese are gradient and influenced by lexical frequency.

Next consider homophones density. In Chinese each character has a different meaning, although some characters can have two or more meanings. For simplicity let us assume that each character represents one word or morpheme. Since there are many more characters than syllables, an average Chinese syllable represents quite a few words, or homophones, as shown in (23).

(23) Homophone density in Standard Chinese

Vocabulary type:	All	Common
Av. # of homophones (with tones):	9.0	2.5
Av. # of homophones (without tones):	29.2	6.5

Because the homophone load is not distributed evenly, some syllables represent more homophones than others. Let us use "homophone density value" to refer to the number of characters a given syllable represents. Some results are shown in (24) and (25), where tones are indicated by the digits 1-4 in the transcription.

(24) Top five and bottom two homophone density values in Standard Chinese, including tonal contrasts, and the number of syllables with these values, based on the 2,500 common characters (1001 syllables)

Density value	# of such syllables	
20	1	[ʂʐ̩4]
15	1	[i4]
13	2	[fu4, tɕan4]
12	3	[tɕi2, tɕi4, y4]
11	2	[li4, ʈʂʐ̩1]
2	229 (23% of all)	
1	432 (43% of all)	

(25) Top ten homophone density values in Standard Chinese, excluding tonal contrasts, and the number of syllables with these values, based on the 2,500 common characters

Density value	# of such syllables	
38	1	[ʂz̩]
36	1	[tɕi]
33	1	[tʂz̩]
32	1	[i]
31	1	[tɕan]
29	1	[fu]
27	1	[y]
23	1	[ɕi]
22	4	[jan, ɕan, tɕ^{h}i, li]
20	4	[tʂu, wəi, tɕe, tɕau]

Several interesting remarks can be made. First, nearly half of the syllables do not have homophones. Second, what are often thought to be the most "natural" or "unmarked" syllables, namely, those that children learn early or those that are thought to be most common in the world's languages, such as [ma], [pa], and [ta], are not among those with high homophone density values. In particular, Hooper (1976: 225) proposes that (a) the optimal syllable is CV, where C is a stop, and (b) the optimal syllable should also occur most frequently. However, the most frequent syllable in Standard Chinese is [ʂz̩], which is CC and whose onset is not a stop. In addition, [fu], [i], and [y] do not have a stop onset and so would be ranked less optimal than [pa]

and [ti], yet the former are far more frequent than the latter. Third, the most frequent syllable [ʂz̩] is made of [ʂ] and [z̩], which are not very common cross-linguistically. Fourth, most English monosyllables represent just one word each. Since Chinese has so many homophones, one might wonder how Chinese avoids ambiguity in speech. The answer seems to be that most ambiguities are resolved by context. For example, although *sun* and *son* are homophones in English, there is hardly any context in which they would cause ambiguity.

Next consider onset and rime frequencies. If we split each of the 2,500 common characters (morphemes) into an onset and a rime, we get 2,500 rime tokens and a slightly smaller number of onset tokens (some syllables do not have an onset). The onset frequencies are shown in parentheses in (26), based on Duanmu (2009), where CG is transcribed as a single sound. The symbol Ø indicates lack of an onset, which is found in thirty characters.

(26) Fifty-five onsets ranked by frequencies, in the basic lexicon of 2,500 characters in Standard Chinese.

tsʲ (177)	j (143)	sʲ (120)	tʂ (107)	ʂ (107)	tʂʰ (78)	w (77)
tsʰʲ (75)	p (75)	lʲ (75)	xʷ (72)	f (60)	kʷ (58)	ɥ (54)
t (54)	k (54)	m (53)	tʰ (49)	tʂʷ (46)	x (42)	ts (41)
l (41)	tsʰ (40)	pʲ (38)	tʷ (36)	tʲ (36)	tʂʰʷ (34)	ʂʷ (34)
tsᶣ (33)	pʰ (33)	kʰʷ (33)	kʰ (33)	sᶣ (32)	tʰʷ (30)	fʷ (30)
Ø (30)	tʰʲ (29)	s (29)	lʷ (29)	sʷ (28)	pʰʲ (27)	mʲ (26)
tsʷ (24)	tsʰᶣ (24)	z̩ (23)	mʷ (22)	nʲ (18)	n (18)	tsʰʷ (17)
z̩ʷ (15)	pʰʷ (14)	lᶣ (10)	pʷ (8)	nʷ (8)	nᶣ (1)	

It is interesting, and perhaps surprising, to see that the plain coronal sounds [t], [t^h], and [s] are not among the most frequent onsets, yet the retroflex sounds [ʈʂ], [ʈʂ^h], and [ʂ] are.

The 2,500 rimes fall into twenty-one types, which can be grouped into three general types: VC, VG, and V or C. Their frequencies are shown in (27). Two of them are syllabic consonants [z̩] and [z]. The rimes [o, e, ɤ] are allophones of the phoneme [ə]: [o] occurs after [u] or a labial consonant, [e] occurs after [i] or [y], and [ɤ] occurs in other open heavy syllables.

(27) Twenty-one rimes ranked by frequencies, in the basic lexicon of 2,500 characters.

an (349)	u (206)	aŋ (194)	i (192)	au (189)	əŋ (178)	a (134)
əu (120)	əi (116)	ən (109)	uŋ (96)	o (96)	ai (93)	e (89)
z̩ (84)	ɤ (78)	y (74)	in (71)	z (27)	aɤ (4)	ə (1)

Type:	VC	VG	V or C	All
Count:	1001	518	981	2500

Two observations can be made. First, the vowels [i, a, u] are often thought to be the most basic, but none of them occurs as the most frequent rime by itself. Second, 61% of the rimes are VC or VG, while just 39% of the rimes are V or C.

Next consider tonal frequencies in the basic lexicon of 2,500 common characters. The data in Standard Chinese are shown in (28), from Duanmu (2009), where the values of T1-T4 are H, LH, L, and HL respectively, and T5 indicates the lack of a lexical tone.

(28) Tonal frequencies in the basic lexicon of 2,500 morphemes in Standard Chinese.

Tone type	T1	T2	T3	T4	T5	All
Tone values	H	LH	L	HL	Ø	
Count	587	627	444	837	5	2,500
	23.5%	25.1%	17.8%	33.5%	0.2%	100.0%

Most syllables have T4 and only about half as many have T3. The T5 syllables include three interjections (*la*, *me*, and *ne*) and two grammatical particles (the aspect marker *le* and the nominal modification marker *de*), which usually occur in unstressed forms. One might get the impressions that most words in Chinese are stressed. But my own examination of a natural speech corpus (Duanmu et al. 1998) shows that about one third of all syllables are unstressed. This is because many full syllables can become unstressed in context (especially in compounds), in which case they lose their lexical tones and become T5. The data above do not reflect de-stressing in natural speech. If we ignore homophones, there are 1,001 syllables, which divide into the four full tones fairly evenly. The data are shown in (29).

(29) Tonal frequencies in the basic lexicon of 2,500 morphemes, excluding homophones.

Tone type	T1	T2	T3	T4	T5	All
Count	249	220	245	282	5	1,001
	24.9%	22.0%	24.5%	28.2%	0.5%	100.0%

In principle, every full syllable can take one of the four lexical tones. In fact, however, only a fifth of the syllables have four tones each. This is shown in (30).

(30) Tonal density in the basic lexicon of 2,500 morphemes, excluding homophones.

Tones per syllable	1	2	3	4	5	All
# of such syllables	74	91	135	85	0	385
	19%	24%	35%	22%	0%	100.0%

Most syllables have three tones each and over 40% of the syllables have just one or two tones each. One might wonder why no syllable has all five tones. The reason is that only unstressed syllables have T5, and unstressed syllables may appear to have a different vowel. For example, the T5 syllable [mə] (an interjection) is spelled as *me*, instead of *ma*. If it is spelled as *ma*, then this syllable would have all five tones (ignoring vowel length).

13. Missing syllables

I use missing syllables to refer to those that are not used in the language, although their structure seems to be fine. An issue that has not attracted many studies is that there is a large number of missing syllables in Chinese; in fact, the majority of conceivable syllables are missing. I shall use Standard Chinese to illustrate the point. The phonemes of Standard Chinese is shown in (31) and (32), based on Duanmu (2007).

(31) Consonants in Standard Chinese

Initial: p, p^h, t, t^h, k, k^h, ts, ts^h, $t\underset{\sim}{s}$, $t\underset{\sim}{s}^h$, f, s, $\underset{\sim}{s}$, $\underset{\sim}{z}$, x, m, n, l

Final: n, ŋ

(32) Vowels in Standard Chinese

i, y, u, a (ɑ), ə (ɤ, e, o), (ɚ)

(ai, au, əi, əu)

Most consonants can occur in syllable initial position but only two can occur in syllable final position. The palatals [tɕ, tɕ^{h}, ɕ] are not included, because they can be represented as combinations of [tsj, ts^{h}j, sj]. The high vowels [i, u, y] can occur before a nuclear vowel, in which case they are often represented as glides. The vowel [ɑ] is an allophone of [a] and [ɤ, e, o] are allophones of [ə]. The vowel [ɚ] is in parentheses because it has limited distribution; in some analyses it is seen as an allophone of [z̩]. Diphthongs are also in parentheses because they can be seen as two vowels each.

A syllable in Standard Chinese can have up to four phonemes CGVX, where C is a consonant, G a glide, V a vowel, and X an offglide of a diphthong or a consonant. In addition, each syllable can carry one of four tones. In principle, there are 1,900 possible full syllables without tonal contrasts, or 7,600 including tonal contrasts. The calculation is shown in (33). Since [y] does not occur in the coda, and [ɚ] is mostly limited to suffixed words, they are not included in the choices for X. In addition, I have excluded unstressed syllables and consider there to be four possible tones per syllable.

(33) Possible combinations of syllables in Standard Chinese

Position	Choices	Notes
C	19	One of 18 Cs, or no C
G	4	One of [j, u, ɥ], or no G
V	5	One of five vowels
X	5	One of [i, u, n, ŋ] or no X
Total:	1900	without tonal contrasts
	7600	with tonal contrasts (four tones per syllable)

The actual number of syllables is much smaller, as shown in (34).

(34) Actual and predicted numbers of full syllables in Standard Chinese

	Actual	Possible	% missing
Without tonal contrast:	404	1900	79%
With tonal contrast:	1297	7200	82%

With or without tonal contrasts, just one fifth of the possible syllables are used.

The data raise an interesting question: Why are so many possible syllables missing? The question is especially puzzling because it is often thought that Chinese has such a shortage of syllabic contrasts that it has created many disyllabic words (Wang 1944, Karlgren 1949, Lü 1963, Li & Thompson 1981, Chen 2000a).

To see which syllables are missing, let us focus on the GVX part. In Standard Chinese there are 100 possible GVX forms, calculated in (35). I have ignored tonal contrasts. In addition, I have omitted the vowel [ɚ] and syllabic consonants.

(35)

Position	Choices	Notes
G	4	One of [j, u, ɥ], or no G
V	5	One of five vowels
X	5	One of [i, u, n, ŋ] or no X
Total:	100	

The 100 possible GVX forms are shown in (36). The first column indicates choices for X, the top row indicates choices for G, and 0 indicates lack of G or X. High vowels are written as glides before the nuclear vowel.

(36)

		0-	j-	w-	ɥ-	
[-0]	i	+	(+)	-	-	ji = i
	u	+	-	(+)	-	wu = u
	y	+	-	-	(+)	ɥy = y
	ə	+	+	+	+	
	a	+	+	+	-	

[-n]	in	+	(+)	-	-	jin = in
	un	-	-	-	-	
	yn	+	-	-	(+)	qyn = yn
	ən	+	-	+	-	
	an	+	+	+	+	
[-ŋ]	iŋ	-	-	-	-	
	uŋ	+	+	(+)	-	wuŋ = uŋ
	yŋ	-	-	-	-	
	əŋ	+	+	+	-	
	aŋ	+	+	+	-	
[-i]	ii	(+)	(+)	-	-	ii = i, jii = ji
	ui	-	-	-	-	
	yi	-	-	-	-	
	əi	+	-	+	-	
	ai	+	+	+	-	
[-u]	iu	-	-	-	-	
	uu	(+)	-	(+)	-	uu = u, wuu = wu
	yu	-	-	-	-	
	əu	+	+	-	-	
	au	+	+	-	-	

Actual +:	35
Missing - or (+):	65
Total:	100

The symbol (+) indicates missing form that one might expect. For example, if we assume that a high vowel will automatically spread to the onset, then there is no contrast between [ji] and [i], because [i] will become [ji]. Similarly, because vowel length is predictable (long in open syllables and short in closed syllables), there is no contrast between [uu] and [u]. Even so, many GVX forms are missing.

Some attempts have been made to explain the missing forms by phonology. For example, Wiese (1997) proposes that many of them can be ruled out by the Obligatory Contour Principle. In contrast, Duanmu (2007) proposes that many missing forms have opposite values of the same feature. For example, [yi] is a bad combination because [y] is [+round] and [i] is [-round].

It seems clear that some missing forms are due to phonology. On the other hand, it is unrealistic to expect that all or most missing syllables are due to phonology. For example, I am not aware of any reason why some syllables in Standard Chinese have four tones but some have fewer, or why [m^{j}an], [p^{j}an], and [p^{hj}an] are used in Standard Chinese but [f^{j}an] is not. Therefore, some missing forms are likely to be simply accidental gaps.

14. Syllable weight and tone split

When a Chinese syllable is pronounced alone, it has a tone, which is called the citation tone. A striking difference among Chinese dialects is that in many of them a citation tone stays the same whether a syllable is pronounced alone or with other syllables. In contrast, in some dialects citation tones often split into two parts, one of which is shifted to another syllable. A non-splitting dialect is Standard Chinese, illustrated in (37), and a splitting dialect is Shanghai, illustrated in (38).

(37) Stability of citation tones in Standard Chinese

Surface:	H	H		H	LH		HL	H		HL	LH
Citation:	H	H		H	LH		HL	H		HL	LH
	san	pei		san	p^han		sz	pei		sz	p^han
	‘three cups’			‘three plates’			‘four cups’			‘four plates’	

(38) Instability of citation tones in Shanghai Chinese

Surface:	H	L		H	L		L	H		L	H
Citation:	HL	HL		HL	LH		LH	HL		LH	LH
	se	pe		se	pø		sz	pe		sz	pø
	‘three cups’			‘three plates’			‘four cups’			‘four plates’	

It can be seen that while citation tones are stable in Standard Chinese, they all split in the Shanghai examples. A longer example is shown in (39), in fairly broad transcription, where | indicates a boundary between tonal domains in Shanghai.

(39) Tonal patterns in Shanghai and Standard Chinese

Surface	L-H	0	|	L-H	|	H-L	0	|	L-H
Citation	LH-LH	LH		LH-LH		HL-HL	LH		LH-HL
Shanghai	ku-po^{ʔ}	lu		la^{ʔ}-la^{ʔ}		t^hi-se	lu		pã-pi
Gloss	Gubei	road		be-at		Tianshan	road		vicinity
Standard	ku-pei	lu		zai		t^{hj}an-ʂan	lu		p^haŋ-p^{j}an
Citation	L-L	HL		HL		H-H	HL		LH-H
Surface	LH-L	HL		HL		H-H	HL		LH-H

‘Gubei Road is in the vicinity of Tianshan Road.’

We see again the stability of citation tones in Standard Chinese (except for one rule, which changes L to LH before L, as seen on the first syllable). In contrast, citation tones are lost in Shanghai unless they occur in the initial position of a domain; in addition, each surviving citation tone is split between the first two syllables of a domain.

There are two approaches to the difference between the dialects. The first is typological. For example, Yue-Hashimoto (1987) suggests that Shanghai has left-dominant tonal domains but Standard Chinese does not. Similarly, Chen (2000b) suggests that tonal domains in Shanghai are determined by left-headed stress whereas those in Standard Chinese are not. Moreover, Yip (1989) proposes that there are two kinds of tones: those in Standard Chinese are units that cannot be split, and those in Shanghai are clusters that can. However, the typological approach in effect restates the difference and offers no explanation why Shanghai behaves one way and Standard Chinese behaves another way.

In the second approach, proposed by Duanmu (1990, 1999), the difference in tonal behavior is related to an independent difference in rimes: Dialects that are like Shanghai in tonal behavior (with unstable citation tones) have no diphthongs or true codas, while dialects that are like Standard Chinese in tonal behavior (with stable citation tones) have diphthongs and/or true codas. In other words, Shanghai only has "simple rhymes" (V or C) while Standard Chinese has many "complex rhymes" (VC or VG). Consider the data in (40) and (41).

(40) Rime types in the basic vocabulary of 2,500 morphemes in Standard Chinese

VC or VG	1519	61%	e.g. [man] 'slow', [mai] 'sell'
V or C	981	39%	e.g. [ma] 'scold', [sz] 'four'
Total	2,500	100%	

(41) Rimes in Shanghai Chinese (Duanmu 2009)

[m, n, ɚ, z, u, ø, ɔ, y, i, o, ɤ, e, a, ỹ, ĩ, õ, ɤ̃, ã, iʔ, aʔ, oʔ]

The nasal vowels in Shanghai can be represented as [Vŋ] underlyingly, and the glottalized vowels can be represented as [Vʔ] underlyingly. Both [Vŋ] and [Vʔ] can merge into a single sound without loss of underlying segmental features.

Given the difference in rhyme structure between Shanghai and Standard Chinese, it is possible to explain their difference in tonal behavior. First, most rimes in Standard Chinese are inherently heavy. In contrast, syllables in Shanghai have no inherent weight: they can be heavy or light, depending on the prosodic environment. They are long when spoken in isolation or in a stressed position, such as the first syllable of a disyllabic word or compound; otherwise the syllables are short. Phonetic studies confirm the predictions (Zhu 1995).

The relation between syllable structure and tone is mediated by stress: heavy syllables have stress and stressed syllables can carry tone. The principles are stated in (42) and (43).

(42) Weight-Stress Principle:

Stressed syllables are heavy (long) and unstressed syllables are light (short).

(43) Tone-Stress Principle:

Stressed syllables can be accompanied by a lexical tone (pitch accent). Unstressed syllables are not accompanied by a lexical tone (pitch accent).

The Weight-Stress Principle has been proposed in various forms in the literature (e.g. Prokosch 1939, Kager 1989, Prince 1990, and Hammond 1999). The Tone-Stress Principle has also been proposed in various forms in the literature (e.g. Liberman 1975, Clements & Ford 1979,

Pierrehumbert 1980, and Goldsmith 1981). In Chinese, the Tone-Stress Principle is evidenced by the fact that unstressed syllables lose their lexical tones. In English, it is evidenced by the fact that only stressed syllables are assigned a pitch accent.

If a language has many complex rimes, then many syllables will remain heavy and stressed. And because they are stressed, they will keep their lexical tones. The chances for tone split will be low, because most syllables have their own tones and cannot take those from others. In contrast, if a language has no complex rimes, then many syllables can become light and unstressed (unless they occur in prosodically strong positions). And because they are unstressed, they will lose their lexical tones. The chances for tone split will be high then, because many syllables are toneless and can take a piece from another syllable. A detailed analysis is offered in Duanmu (2009, chapter 7).

15. Is the onset required?

When a syllable begins with a vowel, an onset of some sort is added, most commonly [ʔ]. Two examples are shown in (44).

(44) The zero onset effect in Standard Chinese

[ʔɤɤ] / [ɣɤɤ] / [ŋɤɤ]	‘goose’
[ʔæ̃n] / [ɣæ̃n] / [ŋæ̃n]	‘peace’

In initial position, [ʔ, ɣ, ŋ] do not contrast with each other and they only occur in syllables like ‘goose’. (There may be speakers who use [ŋ] for such syllables throughout; for them [ŋ] is a real

sound and there are no vowel-initial syllables.) The presence of such sounds has led some linguists to assume that every syllable has an onset, and those syllables that do not have a regular initial C or G have a "zero onset" (Chao 1948, 1968; Li 1966). It was also proposed in Duanmu (1990, 2007) that the zero onset effect is the result of an obligatory onset slot in the syllable structure, which needs to be filled with something.

On the other hand, the initial glottal stop in vowel-initial words could be an unintended gesture: the vocal tract cannot assume the vowel gesture all of a sudden, and the glottal stop reflects an unintended state before the vowel is pronounced. One reason is that when there is a preceding word, the glottal stop is not used, unless one is speaking slowly or very carefully. An example is English is shown in (45).

(45) [ʔ] used when without a preceding word: [ʔaut] *out*

No [ʔ] after a preceding word: [rænaut] / *[rænʔaut] *ran out*

In Standard Chinese, when a vowel-initial syllable follows another syllable, there is no glottal stop either. Some examples are shown in (46), where [a] is an interjection.

(46) Standard Chinese: No [ʔ] after a preceding word

[nãn] + [a] → [nãna] / *[nãnʔa] 'Hard!'

[mãŋ] + [a] → [mãŋa] / * [mãŋʔa] 'Busy!'

[daa] + [ɤɤ] → [daaɤɤ] / *[daaʔɤɤ] 'big goose'

[maa] + [ãn] → [maaãn] / *[maaʔãn] 'horse saddle'

So far English and Standard Chinese behave the same. However, there is one place where they differ. In English, a nasal coda is retained when it occurs between two vowels, as seen in [rænaut] *ran out*. In Standard Chinese, on the other hand, a nasal coda loses its oral closure when the following syllable is long and starts with a vowel. This can be seen in (47).

(47) [t^hjæn] + [ɤɤ] → [t^hjæ̃æ̃ɤɤ] / *[t^hjæ̃nɤɤ] ‘sky goose (swan)’’

[xwɑ̃ŋ] + [ɤɤ] → [xwɑ̃ɑ̃ɤɤ] / *[xwɑ̃ŋɤɤ] ‘yellow goose’

In Standard Chinese, [an] will change to [æ̃n] and [aŋ] will change to [ɑ̃ŋ]. However, when a vowel-initial long syllable follows, the nasal coda must lose oral closer and lengthen the vowel as a result (Xu 1986 and Wang 1993).

It is not clear why a nasal is always retained in VNV in English, but it is retained in Standard Chinese only if the second V is short or unstressed, or if the N is the onset of the second V. Duanmu (2009) suggests that the two nasal codas in Standard Chinese are weak in the sense that their oral closure have little distinctive function, because they have already changed the frontness of the vowel ([æ] before [n] and [ɑ] before [ŋ]). In contrast, English has three nasal codas [m, n, ŋ], and they do not change the preceding vowel as much. Therefore, it is important to distinguish them by the oral closure.

Finally, it is interesting to consider how Standard Chinese maintains a three-way contrast in a VNV sequence, which is shown in (48), adapted from Xu (1986).

(48) Three-way contrast in VNV

V.NV	[faa] + [nãn] →	[faanãn]	‘raise trouble’
VN.V	[fãn] + [ãn] →	[fãããn]	‘overturn case’
VN.NV	[fãn] + [nãn] →	[fãnnãn]	‘overturn trouble’

Again, an oral closure is required for a nasal only when it is in the onset position. When a nasal coda occurs before a vowel, oral closure is not allowed. When a nasal coda occurs before a pause, oral closure is optional. When a nasal coda occurs before another nasal, it may add an additional duration for oral closure.

In summary, the zero onset effect in utterance-initial position is probably unintended, and in medial positions there is no evidence for an onset. Instead, some syllables seem to lack an onset and truly start with a vowel.

16. Summary

This overview does not cover all areas of research that is related to syllable structure in Chinese. For example, I have not discussed language games, loanwords, or judgment on non-words. Nevertheless, I hope to have shown that, despite its apparently simple structure, there are many interesting questions about the Chinese syllable, and many interesting proposals to address them, even though a consensus or satisfactorily solutions are sometimes still to be reached.

References:

Baayen, R. Harald, Richard Piepenbrock, and L. Gulikers. 1993. The CELEX lexical database (CD-ROM). Philadelphia, PA: Linguistic Data Consortium, University of Pennsylvania.

Bao, Zhiming, Jianguo Shi, and Debao Xu. 1997. Shengcheng yinxixue lilun jiqi yingyong [Generative phonology: theory and usage]. Beijing: Zhongguo Shehui Kexue Chubanshe.

Baxter, William. 1992. A handbook of Old Chinese phonology. Berlin: Mouton de Gruyter.

Chao, Yuen-Ren. 1933. Tone and intonation in Chinese. Bulletin of the Institute of History and Philology, Academia Sinica 4.2:121-134.

Chao, Yuen-Ren. 1934. The non-uniqueness of phonemic solutions of phonetic systems. Bulletin of the Institute of History and Philology, Academia Sinica 4.4: 363-397. Reprinted in Readings in Linguistics I, ed. Martin Joos, 1957: 38-54. Chicago: University of Chicago Press.

Chao, Yuen-Ren. 1948. The voiced velar fricative as an initial in Mandarin. Le maître phonétique 89:2-3.

Chao, Yuen-Ren. 1968. A grammar of spoken Chinese. Berkeley, California: University of California Press.

Chen, Matthew Y. 2000a. From tone to accent. *Cashiers de Linguistique—Asie Orientale* 29.2: 179-203.

Chen, Matthew Y. 2000b. Tone Sandhi: Patterns Across Chinese Dialects. Cambridge Studies in Linguistics, No. 92. Cambridge, UK: Cambridge University Press.

Cheng, Chin-Chuan. 1973. A synchronic phonology of Mandarin Chinese. Monographs on linguistic analysis no. 4. The Hague: Mouton.

Cheung, Kwan-Hin. 1986. The phonology of present-day Cantonese. Doctoral dissertation, University of London, England.

Chinese Academy of Social Sciences Institute of Linguistics. 1978. Xiandai Hanyu Cidian [A dictionary of modern Chinese]. Beijing: Shangwu Yinshuguan.

Clements, George N., and Kevin C. Ford. 1979. Kikuyu tone shift and its synchronic consequences. Linguistic Inquiry 10.2: 179-210.

Coleman, John. 1996. Declarative syllabification in Tashlhit Berber. In Current Trends in Phonology: Models and Methods, vol. 1, ed. Jacques Durand & Bernard Laks, 175-216. Salford: European Studies Research Institute, University of Salford Publications.

Coleman, John. 2001. The phonetics and phonology of Tashlhiyt Berber syllabic consonants. Transactions of the Philological Society 99 no. 1:29-64.

Dong, Shaowen. 1958. Yuyin changtan [Introduction to phonetics]. Beijing: Wenhua Jiaoyu Chubanshe.

Duanmu, San. 1990. A formal study of syllable, tone, stress and domain in Chinese languages. Doctoral dissertation, MIT, Cambridge, Mass. Distributed by MIT Working Papers in Linguistics.

Duanmu, San. 2007. The phonology of Standard Chinese. 2nd Edition. Oxford: Oxford University Press.

Duanmu, San. 2009. Syllable structure: The limits of variation. Oxford: Oxford University Press.

Duanmu, San, Gregory H. Wakefield, Yiping Hsu, G. Cristina, and Shanping Qiu. 1998. Taiwanese Putonghua speech and transcript corpus (CD-ROM). Philadelphia, PA: Linguistic Data Consortium, University of Pennsylvania.

Goldsmith, John. 1981. English as a tone language. In Phonology in the 1980's, ed. Didier L. Goyvaerts, 287-308. Ghent, Belgium: E. Story-Scientia.

Hooper, Joan Bybee. 1976. An introduction to natural generative phonology. New York: Academic Press.

Hammond, Michael. 1999. The phonology of English: a prosodic Optimality Theoretic approach. Oxford: Oxford University Press.

Hsueh, Fengsheng. 1986. Guoyu Yinxi Jiexi [An anatomy of the Pekingese sound system]. Taipei: Taiwan Xuesheng Shuju.

Huang, Parker Po-fei. 1970. Cantonese dictionary: Cantonese-English, English-Cantonese, Yale University Press, New Heaven and London.

Kager, René. 1989. A metrical theory of stress and destressing in English and Dutch. Dordrecht: Foris.

Karlgren, Bernhard. 1949. The Chinese language: an essay on its nature and history. New York: The Ronald Press Company.

Kenstowicz, Michael. 1994. Phonology in Generative Grammar. Oxford: Blackwell.

Leben, William. 1971. On the segmental nature of tone in Thai. Quarterly Progress Report No. 101: 221-224. Research Laboratory of Electronics, Massachusetts Institute of Technology.

Li, Charles N., and Sandra A. Thompson. 1981. Mandarin Chinese: a functional reference grammar. Berkeley and Los Angeles: University of California Press.

Li, Fang-Kui. 1966. The zero initial and the zero syllabic. Language 42:300-302.

Li, Rong. 1983. Guanyu fangyan yanjiu de ji dian yijian [Some comments on dialectal studies]. Fangyan 1983.1:1-15.

Liberman, Mark. 1975. The intonational system of English. Doctoral dissertation, MIT, Cambridge, Mass.

Lin, Maocan, and Jingzhu Yan. 1988. The characteristic features of the final reduction in the neutral-tone syllable of Beijing Mandarin. Phonetic Laboratory Annual Report of Phonetic Research, 37-51. Beijing: Phonetic Laboratory, Institute of Linguistics, Chinese Academy of Social Sciences.

Lin, Yen-hwei. 1989. Autosegmental treatment of segmental processes in Chinese phonology. Doctoral dissertation, University of Texas, Austin.

Lin, Yen-Hwei. 2008. The morphophonology of Pingding Er infixation: An OT analiysis. In *Interfaces in Chinese Phonology*, ed. by Yuchao E. Hsiao, Hui-chuan Hsu, Lian-Hee Wee, and Dah-an Ho, 2008.161-182. Taipei: Institute of Linguistics, Academia Sinica.

Lü, Shuxiang. 1963. Xiandai Hanyu dan shuang yinjie wenti chu tan [A preliminary study of the problem of monosyllabism and disyllabism in modern Chinese]. Zhongguo Yuwen 1963.1: 11-23.

Luo, Chang-Pei, and Jun Wang. 1957. Putong yuyinxue gangyao [Outline of general phonetics]. Beijing: Kexue Chubanshe. New edition in 1981 by Shangwu Yinshuguan.

Myers, James, and Jane Tsay. 2005. The processing of phonological acceptability judgments. Proceedings of Symposium on 90-92 National Science Council Projects, pp. 26-45. National Science Council, Taipei, Taiwan.

Pierrehumbert, Janet. 1980. The phonetics and phonology of English intonation. Doctoral dissertation, MIT, Cambridge, Mass.

Prince, Alan. 1990. Quantitative consequences of rhythmic organization. CLS 26, Papers from the 26th Regional Meeting of the Chicago Linguistic Society Volume 2: The Parasession on the Syllable in Phonetics and Phonology, Chicago Linguistic Society, 1992, 355-398.

Prokosch, Eduard. 1939. A comparative Germanic grammar. Philadelphia, PA: Linguistic Society of America.

Pulleyblank, Edwin G. 1984. Vowelless Chinese? An application of the three-tiered theory of syllable structure. In Proceedings of the Sixteenth International Conference on Sino-Tibetan Languages and Linguistics, vol. II, 568-619. Seatle: University of Washington.

Ramsey, S. Robert. 1987. The languages of China. Princeton, NJ: Princeton University Press.

Wang, Jenny Zhijie. 1993. The geometry of segmental features in Beijing Mandarin. Doctoral dissertation, University of Delaware, Newark, DE.

Wang, Jenny Zhijie. 1999. Vowel Length in Cantonese. Paper presented at the 11th North American Conference on Chinese Linguistics, Harvard University.

Wang, Li. 1944. Zhongguo yufa lilun [Chinese grammatical theory]. Shanghai, China: Shangwu Yinshuguan.

Wiese, Richard. 1997. Underspecification and the description of Chinese vowels. In Studies in Chinese phonology, ed. Wang Jialing and Norval Smith, 219-249. Berlin: Mouton de Gruyter.

Woo, Nancy. 1969. Prosody and phonology. Doctoral dissertation, MIT, Cambridge, Mass.

Wright, Martha. 1983. A metrical approach to tone sandhi in Chinese dialects. Doctoral dissertation, University of Massachusetts, Amherst.

Xu, Baohua, Zhenzhu Tang, Rujie You, Nairong Qian, Rujie Shi, and Yaming Shen. 1988. Shanghai Shiqü fangyan zhi [Urban Shanghai dialects]. Shanghai: Shanghai Jiaoyu Chubanshe.

Xu, Shirong. 1980. Putonghua yuyin zhishi [Phonology of Standard Chinese]. Beijing: Wenzi Gaige Chubanshe.

Xu, Yi. 1986. Putonghua yinlian de shengxue yuyin texing [Acoustic properties of syllable junctures in Standard Chinese]. Zhongguo Yuwen 1986.5 (194):353-360.

You, Rujie, Nairong Qian, and Zhengxia Gao. 1980. Lun Putonghua de yinwei xitong [On the phonemic system of Standard Chinese]. Zhongguo Yuwen 1980.5 (158): 328-334.

Yue-Hashimoto, Anne O. 1987. Tone sandhi across Chinese dialects. In Wang Li memorial volumes: Chinese volume, ed. by Chinese Language Society of Hong Kong, 445-474. Hong Kong: Joint Publishing Co.

Zhu, Xiaonong. 1995. Shanghai tonetics. Doctoral dissertation, Australian National University, Canberra.