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The Segments and Skeleton in Chinese

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1. INTRODUCTION

This paper will discuss the skeleton, segments and feature system in the standard contemporary Chinese language (henceforth Chinese).

The Chinese phonological system is based on the Beijing Mandarin. Phonetically there are 37 segments: 23 consonants, 3 glides and 11 vowels. They are listed with some of their features in tables (1) and (2) on next page. (The fricative [h] and the approximant [`] will be explained in sections 3.1 and 3.2 respectively. The apical vowels [ï] and [i̲] will be treated in section 4.1.) In addition to these segments, there are some rhotacized segments and nasalized segments. They will be discussed in section 5.

As a lexical tone language, Chinese has four contrastive tone types. When necessary, they will be denoted respectively by the superscript ^{1}, ^{2}, ^{3} and ^{4} at the end of a syllable. In addition, there is a neutral tone, which will be denoted by ^{0} if necessary. (See table (3) on next page for the tone types.)

(1) Consonants in Chinese

	Labial	Dental/ Alveolar		Retroflex	Alveolo-palatal	Velar/ Glottal
Unaspirated	p	ts	t	tʂ	tç	k
Aspirated	ph	tsh	th	thʂ	thç	kh
Fricative	f	s		ʂ	ç	h
Nasal	m		n			ŋ
Approximant			l	r		
FEATURES						
Anterior	+	+	+	-	-	-
Coronal	-	+	+	+	-	-
Back	-	-	-	-	-	+
Distributed	+/-	+	-	-	+	

(2) Glides and Vowels in Chinese

Apical (dental)	Apical (retro)		Front [-round]	Front [+round]	Central [-round]	Back [-round]	Back [+round]
			j	ÿ			w
ï	i̱	(High)	i	y			u
		(Mid)	e		ë	ê	o
		(Low)	a			α	

(3) Tones in Chinese

Types	Shapes	Examples	Glosses
1	High level	ma^1	mother
2	High rising	ma^2	hemp, flax, etc.
3	Low falling-rising	ma^3	horse
4	High falling	ma^4	curse, scold
0	pitch various	ma^0	Question particle

Syllable boundaries are quite clear in Chinese. There are only four possible syllable templates.

(4) Syllable Templates in Chinese

Templates:	CCVC	CCV	CVC	CV
Examples:	$hwan^1$	hwa^1	han^1	ha^1
Glosses:	merry	flower	snore	breathe out with the mouth open

The four templates can be summarized as C (C) V (C). The longest one, CCVC, may be considered to be typical. (In fact this general syllable template is appropriate even for all Chinese dialects.) For convenience, segments at the four positions will be called Initial, Medial, Nucleus and Coda respectively.

The sequence of segments appearing in any Chinese syllable always obeys the Sonority Sequencing Generalization as stated in Selkirk (1982:16), with the V as the sonority peak. For instance, any syllable containing four segments always bears the major class features as follows:

```
(5)            C              C              V           C
               |              |              |           |
    [+consonantal]   [-syllabic]   [+syllabic][-syllabic]
                     [-consonantal]
```

2. MEDIALS AND CODAS

2.1 Medials

Medials must bear two major class features: [-consonantal, -syllabic]. That is to say, they must be glides. There are three glides in Chinese. Any of the three glides can appear at a medial position. They can be differentiated with two features: Back and Round.

(6) Glides in Chinese

j	[-back, -round]
ÿ	[-back, +round]
w	[+back, +round]

When no glide precedes a vowel, we may talk of a 'zero' glide. Maybe the zero glide comes from a glide with the features [+back, -round] through deletion. Diachronically, some linguists think that the ancient Chinese used to have such a medial glide.[1] Synchronically, some dialects do have such a medial glide. However, the standard contemporary Chinese has only three glides, without the unrounded back one (at least in surface).

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[1] Ancient Chinese linguists classified all syllables into four deng (grades). Zhengzhang Shangfang (personal communication) thinks that the syllables in the second deng used to have an unrounded back glide in the medial position.

2.2 Codas

Codas in the standard Chinese must bear two major class features: [-syllabic, +sonorant], although the feature [+sonorant] is not required for codas in some dialects. That is to say, a coda must be a glide, a nasal stop or a liquid. Usually a coda is a glide [j] or [w], or a nasal [n] or [ŋ]. The labial nasal [m] appears as a coda only in quite limited cases. That is a result of assimilation of an underlying coda [n] to an initial [m] in a following syllable. For example:

(7) /tsên-mê/ --> tsëmmë (how)
/s̲ên-mê/ --> s̲ëmmë (what)

The liquid [r] can serve as a coda, but in most of the cases it is a retroflex suffix. This will be discussed in section 5. The round front glide [ÿ] and the alveolar liquid [l] do not serve as codas.

2.3 Glide Co-occurrence Restriction

Chinese has a dissimilatory co-occurrence restriction between the medial and the coda glides in a syllable: they cannot share a common feature [α back] or [α round]. That is to say:

```
(8)      *(C) C   V   C                *(C) C   V   C
              |       |                     |       |
          [-cons] [-cons]              [-cons] [-cons]
         [α back] [α back]           [α round] [α round]
```

e.g. *jaj *jej *ÿaj *ÿej (Both glides are [-back].)[2]
*waw *wow *ÿaw *ÿow (Both glides are [+round].)

2.4 About the Semivowels in Hartman(1944)

Hartman(1944:118) thinks that the front rounded [ÿ] is not a single phoneme, but a cluster of two

[2] Some people accept [jaj] as an exception, but it is not a standard pronunciation. Even in those dialects which do have [jaj], it appears only as a literary pronunciation. It is a survival of the ancient pronunciation. The corresponding colloquial pronunciation, being [ja] [ŋa] [aj] or [ŋaj], etc., does not violate the glide co-occurrence restriction.

semivowels (=glides) [jw]. On the other hand, he regards the retroflex [r] as a semivowel. The reason is that the [r] "may appear in either pre-nuclear or post-nuclear position... In initial position it is parallel to [j]" (Hartman 1944:121). The other retroflexes, [ts̲] [ths̲] and [s̲] are derived respectively from the dentals [ts] [ths] and [s] plus [r], just as the alveolo-palatals [tç] [thç] and [ç] are derived from the dentals preceding [j].

I will not accept Hartman's approach in this paper. The reasons are as follows:

(a) Phonetically, the retroflexes [ts̲ ths̲ s̲] and the glide [ÿ] are single segments rather than sequences of two segments.

(b) Phonologically, his approach can simplify the underlying phoneme inventory by removing these four segments. But now we represent segments with feature matrices. His approach cannot simplify the whole feature system at all.

(c) His analysis needs an ad hoc rule or special constraint to stipulate that the only consonants which are allowed to precede his semivowel [r] are the dentals [ts ths s]. It is hard to explain why other consonants are not allowed to be followed by [r]. It is also hard to explain why there are semivowel cluster [jw] (=[ÿ]) and [rw] but no [wj], [wr], [jr] or [rj].

(d) It is not the case that only semivowels may appear in either pre-nuclear or post-nuclear position. For example, the nasal [n] may appear in either position but it is not a semivowel. The features shared by all segments which may appear in either position are [-syllabic, +sonorant], not [-syllabic, -consonant]. It is not necessary to assume [r] to be a semivowel just because its appearing in either position.

(e) As shown in last section, an co-occurrence restriction makes it impossible for a glide to appear in both medial and coda positions in a syllable. But [r], just as [n], is not subject to that restriction or any similar restriction. For example:

(9)	ts̲ër	(here)
	ts̲ar	(dregs)
	çjaw ths̲êr	(small vehicle)
	ts̲aw ths̲ar	(pick a quarrel)
	s̲ër	(matter,thing)

s̱ar	(color)
çiŋ-rër	(apricot kernel, almond)
nên	(tender, delicate)
nan	(south; difficult)

As for Hartman's approach to the alveolo-palatals, I will discuss in section 3.2.

3. INITIALS

3.1 Simple and Complex Initials

A segment appearing at initial position must bear the major class feature [-syllabic]. When it is followed by a glide, the initial must bear two major class features: [-syllabic, +consonantal]. All the consonants in table (1), except the velar nasal [ŋ], can normally serve as initials.[3] That is to say, there are 22 initial consonants.

(10) Initial Consonants in Chinese

p	ph	m	f		ts	ths	s		t	th	n	l
ts̱	ths̱	s̱	r		tç	thç	ç		k	kh	h	

The symbol [h] following a stop denotes aspiration. The independent [h] is used to represent a voiceless fricative. Its actual point of articulation varies from velar to glottal position rather freely. It is often (not always) pronounced as the glottal [h] when preceding [a] [ɑ] [e] or [ë], but pronounced as the velar fricative [x] when preceding [w] [u] or [ê], which share the features [-low, +back].

An initial slot may be associated with one or two segments. A one-segment initial is a simple initial. A two-segment initial is a complex initial. The two segments associated with a single initial slot must be a stop followed by a fricative. (The order still obeys the Sonority Sequencing Generalization.) They form an affricate.

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[3] Halliday (1959) accepts [ŋ] as one of the normal initial consonants. In fact it is dialectal pronunciation. In standard Chinese [ŋ] can serve as an initial merely in very few cases, where it is not underlying but derived from the coda of a preceding syllable. (See section 3.3.)

(11) Complex Initial (Affricate):

```
                 C   (C)   V   (C)
                 |
     [-syllabic, -sonorant]
           /          \
     [-continu.][+continu.]
```

There are three kinds of affricates: dental, retroflex and alveolo-palatal. There are also independent fricatives but no stops at these points of articulation. The actual point of articulation of the stop portion in an affricate is predictable and decided by the fricative portion. We may formulate the following rule:

(12) Affricate Assimilation

$$[-\text{continuant}] \rightarrow [\alpha\ \text{place}]\ /\ \_\_ \begin{bmatrix} -\text{sonorant} \\ +\text{continuant} \\ \alpha\ \text{place} \end{bmatrix}$$

(No matter what the actual point of articulation is, the symbol [t] is used to represent the first part of an affricate.)

3.2 Alveolo-palatals

An alveolo-palatal consonant [tç] [thç] or [ç] must be followed by a glide with the feature [-back], i.e. [j] or [ÿ]. It is possible to assume that the alveolo-palatals are conditioned variants of dentals [ts ths s], retroflexes [t$\underline{s}$ th$\underline{s}$ $\underline{s}$] or velars [k kh h], because these three sets of consonants never precede the front glide [j] or [ÿ].

Diachronically, the modern alveolo-palatals have two origins in the ancient Chinese: some come from the dentals and others come from the velars. But the retroflexes are not an origin of the modern alveolo-palatals. On the contrary, the ancient alveolo-palatals became retroflexes in modern Chinese. (See Li 1956:116-128 and Wang 1980:62-74, etc.) However, any of the three sets, dentals, retroflexes or velars, may be synchronically regarded as underlying forms of alveolo-palatals.

For monosyllables, it seems possible to assume that all alveolo-palatals are derived from only one of the three sets. Which one should be chosen, however, is a big problem. Just as Chao (1934:40) points out, the grouping of sounds in a language into phonemes does not necessarily lead to one unique solution.

Some linguists think that all the alveolo-palatals come from dentals. Hartman (1944:121) gives some arguments for this solution: The velars should be excluded from the possible basic forms of the alveolo-palatals because there is not phonetic similarity between the two sets; the retroflexes [ts̲ ths̲ s̲] should be excluded because they themselves are derived from the dentals [ts ths s] plus a `semivowel' [r]. (See section 2.4.)

I do not adopt his approach in this paper. The reasons are as follows:

(a) It is not necessarily true that there is not phonetic similarity between alveolo-palatals and velars. Native speakers of different languages may have different feelings for the degree of similarity between some sounds. For example, in some Chinese dialects, e.g. Suzhou, dentals [ts ths s] can be followed by a front glide [j] or [ÿ] to form minimal contrastive pairs with alveolo-palatals [tç thç ç], while velars [k kh h] cannot. There are no retroflexes in those dialects. Thus the alveolo-palatals are in complementary distribution with the velars only. People think that velars and alveolo-palatals are similar to each other and treat them as allophones of the same phonemes, whereas dentals and alveolo-palatals are clearly distinguishable from each other and must be different phonemes. Anyway there is no sure proof to support Hartman's (1944) opinion that there is not phonetic similarity between velars and alveolo-palatals. Therefore velars have an equal right with dentals and retroflexes to be candidates for being the underlying forms of the alveolo-palatals.

(b) According to Hartman's approach, it is hard to explain some alliterative phenomena.

In Chinese the first and the third syllables in a quadrisyllabic onomatopoetic word are always alliterative. For example:

(13) a. ti-li-tu-lu (speak fast and unclearly)
b. phi-phi-pha-pha (crackle)

Then we have the following contrastive examples:

(14) a. tçi-tçi-tsa-tsa (chirp)
b. tçi-tçi-ka-ka (creak)

(15) a. çi-li-su-lu (rustle)
b. çi-li-hu-lu (slurp, sounds of eating noodles, etc., fast)

The alveolo-palatal [tç] is alliterated with [ts] in (14a) but with [k] in (14b). This shows that one [tç] is a variant of the retroflex [ts] while the other is a variant of the velar [k]. In (15), one [ç] is alliterated with [s] while the other with [h]. This shows that the underlying forms of the two [ç]'s are the dental [s] and the velar [h] respectively.

Any hypothesis which chooses only one of the three competing sets as the underlying forms of the alveolo-palatals will inevitably face this alliterative problem. Some of the alliterative phenomena may be regarded as survivals of the ancient Chinese and they can be explained etymologically. However, onomatopoeia is such an active way of forming new words that we can not think every onomatopoetic word has a particular historical origin. Many onomatopoetic words are invented in modern times. Some are even quite individual or temporary `idiolects'. Even in these cases the alveolo-palatals are not fixed to alliterate with only one particular set, although they would be alliterated with one of the three potential underlying sets.

Chao (1968:21) mentioned Fa-kao Chou's idea that the `feeling of the native' seems to favor the velars. (Contrary to what Hartman's `similarity' argument suggests!) He mentioned two `symptoms':

(a) There is a form of Chinese `pig Latin' in which a syllable CV is given as Cej-kV[4], e.g. [tha] --> [thej-ka]. When the [k] is followed by [j] [i] or [ÿ] [y], it has a free variant [tç], e.g. [ni] --> [nej-ki] or [nej-tçi].

(b) `There is often an alternation between palatals and velars' in some alliterative quadrisyllabic onomatopoetic words.

---

4 The phonetic symbols are transliterated with the system used in this paper.

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Although symptom (a) above does show that the velar is a basic form of the alveolo-palatal, it cannot prove that the velar is the only basic form of the alveolo-palatal. As for symptom (b), we already have some examples in (14) and (15), which show that not only the velars, but also the dentals and the retroflexes, can be alliterated with the alveolo-palatals. We do not have significant statistics to show that the native speakers of Chinese prefer to choose one set rather than the other two. Therefore the alveolo-palatals should have underlying forms at not only one, but three different points of articulation.

For the alveolo-palatals derived from [ts ths s] or [ts̲ ths̲ s̲], we need a rule to change [s] and [s̲] into [ç] only. (The [t] in affricates will vary with the fricatives according to rule (12) in section 3.1.) For the alveolo-palatals derived from velars, we need another rule. The rules are:

(16) Palatalization I

{s, s̲} --> ç / __ {j, ÿ}

i.e.

$$\begin{bmatrix}-\text{sonorant}\\+\text{continuant}\\+\text{coronal}\end{bmatrix} \dashrightarrow \begin{bmatrix}-\text{anterior}\\-\text{coronal}\end{bmatrix} / \_\_ \begin{bmatrix}-\text{syllabic}\\-\text{consonantal}\\-\text{back}\end{bmatrix}$$

(17) Palatalization II

{k, kh, h} --> {tç, thç, ç} / __ {j, ÿ}

i.e.

$$\begin{bmatrix}-\text{sonorant}\\+\text{back}\end{bmatrix} \dashrightarrow [-\text{back}] / \_\_ \begin{bmatrix}-\text{syllabic}\\-\text{consonantal}\\-\text{back}\end{bmatrix}$$

The treatment of loanwords gives some support to this approach. For example, the dental [s], the palato-alveolar [ʃ] and the glottal [h] are three different phonemes in English. When they are followed by [u], they are transliterated into Chinese dental [s], retroflex [s̲] and velar [h] respectively. But when they are followed by [i], all the three English consonants are transliterated into the same Chinese alveolo-palatal [ç]. For example, the transliterations of some English proper names in a dictionary (Ge et al. 1978:1658-1668) are as follows:

(18) Susie [ˋsu:zi] --> suçi
Seeger [ˋsi:gē] --> çikê
Shute [ʃu:t] --> s̲uthê

Sheila [ˋʃi:lë] --> çila
Hood [hu:d] --> hutê
Healy [ˋhi:li] --> çili

These phenomena are in favor of the analysis that a Chinese alveolo-palatal may have three different underlying forms. The only shortcoming of this approach is that it is impossible to identify the underlying form of an alveolo-palatal in a Chinese syllable which is not in an alliterative structure, nor borrowed from another language. That is to say, this approach lacks the `reversibility' (the term used in Chao 1934:49).

3.3 `Zero' Initial

Apparently `zero' initial means that there are no initial consonants and people may think that the first segment of some syllables are vowels. But in fact there are few Chinese syllables which really begin with a vowel. For example, the second syllable of the word [fan-i] (translate) seems to have no initial consonants preceding the vowel [i], but this [i] cannot be joined to the nasal [n] in the preceding syllable and pronounced as [ni]. That is to say, the word [fan-i] can not be pronounced as [fa-ni] or [fan-ni]. This is due to the glide [j]. We may think there is always a glide preceding a high vowel, because glides do not contrast with high vowels in Chinese.

However we also have examples in which the second syllable seems to begin with a mid or low vowel:

(19) thjan-ê (swan)
mjan-ɑw (cotton-padded jacket)

In these examples, the second syllables cannot be pronounced as [nê] or [naw]. In fact, nearly all syllables which seems to begin with a vowel have a glottal stop or a voiced fricative, glottal, uvular or velar, as initial. (I use the symbol [ˋ] to represent this initial despite these free variants.) It prevents the vowel from linking to the coda of its preceding syllable and makes syllable boundaries quite clear. The only exceptions are some sentence final particles (henceforth SFP). For example, Chinese has an SFP [a] and a prefix [ˋa] which is usually spelt as [a] too. They show difference in pronunciation when they are in some corresponding phonetic environments. For example:

(20) i. SFP [a]

```
laj-a  --> laj-ja  (Come!)
haw-a  --> haw-wa  (Good!)
khan-a --> khan-na (Look!)
thiŋ-a --> thiŋ-ŋa (Listen!)
```

ii. Prefix [`a] in [`a-ji] (aunt)

```
paj-`a-ji (Aunt Bai)     *paj-ja-ji
haw-`a-ji (good aunt)    *haw-wa-ji
han-`a-ji (Aunt Han)     *han-na-ji
tiŋ-`a-ji (Aunt Ding)    *tiŋ-ŋa-ji
```

The contrast shows that the two morphemes have different representations. The prefix has two segments, [`a], both underlyingly and phonetically, whereas the SFP has only a single segment [a] underlyingly but two segments phonetically. However, the two morphemes have the same two slots CV as their skeletons, because there is no syllable template containing only a single V slot in Chinese.

When an initial C cannot be associated with any [-syllabic] segment within a morpheme domain, it will automatically associate with any [-syllabic] segment it can reach without crossing other association lines:

```
(21)  [-syll]# [+syll]    [-syll]# [+syll]
                  |    ==>        \    |
            #C    V               #C   V

      e.g.    han   a       han   a         Output: han-na
              |||   |  ==>  |||\  |                 (Shout!)
              CVC  CV       CVC  CV
```

If an initial C cannot reach any [-syllabic] segment, an glide [j] should be inserted.

(22) Glide Insertion Rule

0 -- j / [-syll]__[+syll]

```
      e.g.    la   a       la  ja           Output: la-ja
              ||   |  ==>  ||  ||                   (Pull!)
              CV  CV       CV  CV
```

At any rate, there is no syllable template with an initial V slot in Chinese, although there are a few SFPs as exceptions which have an initial vowel in the segmental tier.

3.4 Underlying Consonants

Given the analysis in this paper, the 23 surface consonants in table (1) can be reduced to 16 underlying consonants.

(23) Underlying Consonants in Chinese
p t k   ph th kh   f s s̲ h   m n ŋ   l r

Affricates [ts ths ts̲ ths̲] are complex initials consisting of two segments. Alveolo-palatals [tç thç ç] are conditioned variants of [ts ths s] [ts̲ ths̲ s̲] and [k kh h].

4. NUCLEUS

As shown in table (2), Chinese has 11 surface vowels. I would like to argue that Chinese has only two underlying vowel segments: a mid vowel [ê] with the feature [-low] and a low vowel [a] with the feature [+low].

4.1 `Zero' Vowel

Hartman (1944:118) considers that vowels [ï ï̲ i y u] are allophones of a single abstract high vowel. This phoneme varies according to its preceding consonant or glide. Hockett (1947:221) uses the concept `zero' instead of the abstract `high' vowel. In this paper I would like to argue for the `zero' concept with the autosegmental theory. `Zero' vowel means there are no underlying vowels in the segmental tier at all. The so-called `high vowels' in surface are derived by associating glides or consonants with the V in the skeletal tier.

When no vowels exist in the segmental tier, the V in the skeleton will automatically associate with the segment which is associated with the preceding C. High vowels [i u y] are derived respectively from the underlying glides [j w ÿ] in this way. For example:

```
(24) a.  j   n        j   n        Output: jin (print)
         |   |  ==>   |\  |
         C V C        C V C

     b.  w          w              Output: wu (fog)
         |    ==>   |\
         C V        C V
```

```
(24) c.  l ÿ          l ÿ
         | |    ==>   | |\
         C C V        C C V         Output: ly (green)
```

If there are neither vowels nor glides in the segmental tier, the initial consonantal segment will automatically associate with the V to form a syllabic consonant. If the initial is voiceless, it will become voiced automatically when it is associated with the V and changed into a syllabic consonant. For example:

```
(25)     r          r                  s          s
         |   ==>    |\                 |   ==>    |\
         C V        C V                C V        C V

Output:             rï̲ (sun, day)                 sï (four)
```

The `apical vowels' [ï] and [ï̲] are derived in this way. They are the natural prolongation of the initial consonants [ts ths s] and [ts̲ ths̲ s̲ r] respectively. They are in effect syllabic consonants [z] and [r].

Phonetically when a `vowel' [ï] [ï̲] [i] [y] or [u] is pronounced, the shape of the vocal tract is kept the same as when [s] [r] [j] [ÿ] or [w] is pronounced, respectively. Phonologically, there is no contrast between glides and high vowels in Chinese, nor is there between [r] and [ï̲], or even [s] and [ï]. It is not the phonetic reality but the opinion that there normally should be at least one vowel in a syllable that makes people usually use the vowel symbols [i y u] rather than the glide symbols to represent these three phonemes. For the same reason Chinese linguists usually follow Karlgren (1915-1923) in using two borrowed letters from Swedish dialects and calling them `apical vowels' as he proposed (pp.295-297, Chinese translation pp.197-199) instead of the syllabic consonants used in IPA.

If we accept Hartman's(1944) approach in treating the five segments as variants of a single abstract high vowel, they should share the feature [+high]. But according to Chomsky & Halle (1968:304), `High sounds are produced by raising the body of the tongue above the level that it occupies in the neutral position'. Although the vowel [i u y] or glides [j w ÿ] are [+high], dentals and retroflexes are [-high], therefore the `apical vowels' should also be [-high]. Of course, one can make a revised definition to include the raising of the tip of tongue into [+high]. In this way the apical vowels can be assigned the feature [+high].

But at the same time, all dental and retroflex consonants should also be assigned the feature [+high], because the tongue position is kept unchanged through the whole syllables [sï sï ri] without lowering. It is not what we would expect.

Anyway, it is not quite appropriate phonetically, nor is it necessary phonologically, to invent an abstract high vowel for Chinese. With the autosegmental theory, we can explain the phonological process without any underlying high vowels.

One question is why I do not take another approach in which the high vowels are considered to be basic segments bearing the feature [+syllabic], which will become glides when they are associated with C in the skeleton.

One reason is that the phonemes which can be associated with either C or V should be distinguished from the true vowels, the mid vowel and the low one, which cannot be associated with C. Otherwise, it will be hard to explain why there is only one acceptable CV skeleton for a syllable having both high and nonhigh vowels. For example:

```
(26)  hua        hau          but  *hua     *hau
      |||        |||               |||      |||
      CCV        CVC               CVC      CCV
```

Another reason is that we can make the feature system of Chinese simpler: The feature `High' is redundant after high vowels are removed from the underlying inventory.

The transliteration of loanwords gives some support to the view that there are no high vowels in Chinese and some consonants and glides can become syllabic automatically. Following are some English proper names with their Chinese translation in Ge et al (1978:1655-1669).

```
(27)  Maas [ma:s]          --> masï
      Louise [lu(:)`i:z]   --> lujisï
      Nimitz [`nimits]     --> nimitsï
      Eads [i:dz]          --> jitsï
      March [ma:tʃ]        --> mathçi
      Page [pejdz]         --> phejthçï
      Nash [næʃ]           --> nasï
      Jay [dzej]           --> tçjeji
      Tanya [`tænjë]       --> tanija
```

Generally speaking, high vowels should be more sonorant than glides, therefore sequences of a glide plus a high vowel such as [wi] or [ju], in which the two segments are different on the sonority scale, do not violate the Sonority Sequencing Generalization. But in Chinese there are no high vowels, therefore there are no such sequences. When such sequences are transliterated into Chinese from other languages, a mid vowel will be inserted or substituted for the high vowel. For example, Ge et al. (1978:1655-1671) has the following English names:

(28) Eunice [ˋju:nis] --> jownisï
Windsor [ˋwinzë] --> wêntsê
Weekley [ˋwi:kli] --> wejkhêli

4.2 Low Vowels

There is no controversy on treating low vowels as one phoneme. The underlying low vowel bears the feature [-back] as default, but it varies with the coda if it is followed by a coda.

(29) Low Vowel Assimilation

$$a \rightarrow \alpha \; / \; \_\_ \; \{w, \eta\}$$

or $$[+\text{syll}, +\text{low}] \rightarrow [\alpha \text{ back}] \; / \; \_\_ \; [\alpha \text{ back}]$$

For example:

(30)

ma (horse)	ja (mute)	wa (tile)
maj (buy)		waj (sprain)
man (full)	jan (eye)	wan (bowl)
mαw (mortise)	jαw (bite)	
mαη (boa)	jαη (itch)	wαη (net)

4.3 Mid Vowels

As some linguists try to do, the four mid vowels [e ë ê o] may be regarded as allophones of one single phoneme. But there are some problems with respect to syllables having a mid vowel nucleus and a retroflex coda. I will discuss the mid vowel variation in monomorphemic syllables first and leave syllables with a retroflex suffix in section 5.

Since [ê] can appears without a medial glide and a coda, it may be regarded as the underlying form. That is to say, in addition to the feature [-low], the mid vowel takes the feature [+back, -round] as default. The three variants [e o ë] can be derived under the influence of medials and codas according to the following rules.

(31) Vowel Variation Rules

A. $\begin{bmatrix}\text{+syll}\\ \text{-low}\end{bmatrix} \rightarrow [\alpha\ \text{back}]\ /\ \begin{bmatrix}\text{-cons}\\ \alpha\ \text{back}\end{bmatrix}\ \_\_$

B. $[\text{+syll}] \rightarrow [\alpha\ \text{back}]\ /\ \_\_\ [\alpha\ \text{back}]$

C. $\begin{bmatrix}\text{+syll}\\ \text{-low}\\ \text{+back}\end{bmatrix} \rightarrow [\text{+round}]\ /\ \left\{\begin{matrix}[\text{+round}]\ \_\_\\ \_\_\ [\text{+round}]\end{matrix}\right\}$

D. $[\text{+syll, -low}] \rightarrow$ ë $/\ \_\_\ [\text{+coronal}]$

For example:

(32) nê (slow of speech)
nje (tweezers) nÿe (malaria) nej (inside)
nwo (promise) now (weeding hoe)
nën (tender)

Rules A and B are like mirror image rules if we consider mid vowels only. But the rule B as given above can also include the low vowel variation. Therefore we do not need rule (29) any more.

Rule B is ordered after A to ensure that the coda has a stronger influence upon the backness of vowels than the medial. For example:

(33) /wêj/ --> wej (for) *wêj *woj

Rule C is ordered after A and B to ensure the correct outputs of some cases such as the following:

(34)

	A.		B.		C.	
/jêw/	--->	jew	--->	jêw	--->	jow (again)
/ÿên/	--->	ÿen	--->	ÿên	--->	ÿoŋ (use)

A strict order is not necessary between rules C and D, but rule D must be ordered after B to ensure that the mid vowel preceding a coronal consonant becomes a schwa. For example:

(35)

	B.		D.		
/\`ên/	--->	\`en	--->	\`ën	(press with the hand)
/wên/	--->	wen	--->	wën	(ask)
/\`êr/	--->	\`er	--->	\`ër	(two)

When foreign words are transliterated into Chinese, their mid vowels must be pronounced in the Chinese way too. Following are some English names in Ge et al (1978:1653-1671).

(36) Kerry --> khêli Curtis --> khêtisï
Curry --> khêli Colin --> khêlin
Yerkes --> jetçisï York --> ÿekhê
Warner --> wona Waugh --> wo
Ken --> khën Wendy --> wënti

4.4 Underlying Segments and Their Features

Given the analysis in this paper, the total number of the underlying segments in Chinese is twenty-one: 16 consonants, 3 glides and 2 vowels. They are listed in (38) with their features.

(37) Underlying Segment Inventory

	p	ph	m	f	t	th	n	l	s	s̱	r	k	kh	η	h	`	j	ÿ	w	ê	a
syllabic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
consonant	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
sonorant	-	-	+	-	-	-	+	+	-	-	+	-	-	+	-	+	+	+	+	+	+
anterior	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
coronal	-	-	-	-	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
back	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	-	-	+	+	-
low	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
round	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
continuant	-	-	-	+	-	-	-	+	+	+	+	-	-	-	+	+	+	+	+	+	+
nasal	-	-	+	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-
aspirated	-	+			-	+						-	+								

5. RETROFLEX CODAS

In Chinese there are syllables having retroflex codas. In monomorphemic syllables a retroflex coda can only appears after a mid vowel with a `zero' initial. That is to say, a monomorphemic syllable with a retroflex coda must be as follows:

(38) /\`êr/ --> \`ër

e.g. \`ër$^2$ (son)  \`ër^3 (ear) \`ër^4 (two)

Most syllables with retroflex codas are derived from a root morpheme plus a diminutive suffix, which is an asyllabic retroflex [r]. Adding this suffix brings about complicated changes in some rhymes. This suffix can make coda [j] or [n] delete and make coda [w] or [ŋ] change into a complex segment. The main problem is how to derive the four different mid vowels which can precede the retroflex code correctly. We think there is only one underlying mid vowel, but why does it appear as different allophones in the same phonetic environment such as shown in the following contrastive pairs.

(39)	kër^{1} (root)	vs	kêr^{1} (song)
	tçjër^{1} (chick)	vs	tçjer^{1} (street)
	hwër^{2} (soul)	vs	hwor^{2} (work)

In view of such problem, Chao (1968:52-53) considers mid vowels to be 'marginal phonemes'. I would like to keep the idea that there is only one underlying mid vowel in Chinese and explain the variants in different levels. The rules discussed in section 4.3 apply within the domain of a monomorphemic syllable. The rules that will be proposed in this section apply within the domain of a word, i.e. above the morpheme level. That is to say, the outputs of the application of the rules in section 4.3 should serve as inputs of the rules in this section.

The underlying form of the retroflex suffix has only a single segment:

```
r
|
C.
```

When the suffix is added to a root morpheme, the following rules will apply in the given order.

(40) Rhotacism Rules

```
E.      [-low, -back]  [-syll, -back] r
       (      |      )        |       |
              V               X       C

        [-low, -back]  [-syll, -back] r
   ==> (             )                |
              V               X       C

F.              ë
           ==>  |
          V     V

G.      x  r      x  r
       (|) |  ==> (|)/
        C  C      C  C
```

It is not necessary to make any rule to delete the unlinked segments in Rule E or the unlinked C at the end of Rule G, because any segment that is not associated with the skeletal tier can not get phonetic realization, and a slot in the skeletal tier can not get any sound if it is not associated with any segment.

Now we can derive the correct forms of syllables with retroflex suffixes. For example:

(41) Words without Medial Glides

```
Input:   k ë n -r    k ê -r    t ʂ   -r    t ʂ ë n -r
         | | |  |    | |  |    \|\    |    \| | |  |
         C V C  C    C V  C     C V   C     C V C  C

Rule E:  k ë n r               t ʂ    r    t ʂ ë n r
         | |   |         -     \|     |    \| |   |
         C V C C                C V   C     C V C C

Rule F:                        t ʂ ë r
             -           -     \| | |           -
                                C V C

Rule G:  k ë n r                           t ʂ ë n r
         | | /           -        -        \| | /
         C V C C                            C V C C

Output:  kër         kêr       tʂër        tʂër
         (root)      (song)    (twig)      (needle)
```

(42) Words with Medial Glide [j]

```
Input:   t ç j   n -r    t ç j   -r    t ç j e -r
          \| |\  |  |     \| |\   |     \| | |  |
           C C V C  C      C C V  C      C C V  C

Rule E:  t ç j   n r     t ç j   r
          \| |     |      \| |   |           -
           C C V C C       C C V C

Rule F:  t ç j ë n r     t ç j ë r
          \| | |   |      \| | | |           -
           C C V C C       C C V C

Rule G:  t ç j ë n r
          \| | | /            -              -
           C C V C C

Output:  tçjër           tçjër         tçjer
         (today)         (chick)       (street)
```

(43) Words with Medial Glide [w]

```
   k w e j -r      k w ë n -r      k w o -r      k w   -r
   | | | |  |      | | | |  |      | | |  |      | |\   |
   C C V C  C      C C V C  C      C C V  C      C C V  C

E: k w e j r       k w ë n r
   | |     |       | | |   |          -             -
   C C V C C       C C V C C

F: k w e ë j r
   | |   |   |          -             -             -
   C C   V C C

G: k w e ë j r     k w ë n r
   | |   |  /      | | |  /           -             -
   C C   V C C     C C V C C

Output:  kwër       kwër            kwor          kur
         (ghost)    (roll)          (fruit)       (drum)
```

If the root morpheme has a coda with the feature [+back], namely [w] or [ŋ], the coda will become a complex segment after suffixing. It does not meet the structural descriptions of rules E and F, therefore only rule G applies. For example:

```
(44) k o w -r       k o w r          k α ŋ -r       k α ŋ r
     | | |  |  ==>  | | |/           | | |  |  ==>  | | |/
     C V C  C       C V C C          C V C  C       C V C C

Output:        kowr (puppy)                 kαŋr (hillock)
```

In these cases rule G makes a complex coda, which is not a sequence of two segments, but one segment in which the two components are pronounced simultaneously. When we use a feature matrix to represent a complex coda, we may keep all the features that are shared by its two original components, and assign `+' to features which are controdictory originally. The feature values of the three original segments and the two derived complex segments are listed below for comparison.

(45) Features of Some Codas

	syll	cons	sono	ante	coro	back	low	round	cont	nasal
wr	-	+	+	-	+	+	-	+	+	-
w	-	-	+	-	-	+	-	+	+	-
r	-	+	+	-	+	-	-	-	+	-
ŋ	-	+	+	-	-	+	-	-	-	+
ŋr	-	+	+	-	+	+	-	-	+	+

Phonetically, [wr] is a rhotacized [w] or a labialized [r], and [ŋr] is a nasalized [r]. Actually the nasalization occurs not only with the coda, but also with the nucleus. So people usually add the nasality superscript ˜ at the vowel instead of the coda [r]. This is a phonetic phenomenon similar to the case that in the syllable [swej] (year old) we pronounce a labialized initial [s] but not a sequence 's-w'.

A Chinese syllable can have only one segment in coda position. Therefore, when there are two underlying segments following a nucleus, they must collapse into one if possible. If they are incompatible, one of them must be deleted. The segment [ŋ] and [w], which bear the feature [+back], are articulated mainly with the back part of the tongue. The retroflex [r] is produced with the tip of the tongue. So they can be articulated simultaneously and form a complex coda through the rule G. As for the codas [n] and [j], they bear the feature [-back] and are articulated with the raising of the front part of the tongue. Therefore they cannot co-exist with the retroflex [r]. They must be deleted by the disassociation rule E. Similar to the above case, the retroflex suffix [r] may co-exist with a [w] associated with V, but there must be a schwa inserted between a suffix [r] and a front glide [j] or [ỹ], etc., through rule F. So the three rhotacism rules are quite natural in the Chinese phonological system.

6. SUMMARY

Chinese has four syllable templates. They can be symbolized by C(C)V(C). There are no vowel initial syllables. Phonetically there are 23 consonants, 3 glides and 11 vowels, but underlyingly there are only 16 consonants, 3 glides and 2 vowels. An initial C may be associated with two segments to form an affricate. A coda C can be associated with two segments and realized as a rhotacized coda. A single vowel cannot form a syllable, whereas a single consonant sometimes can. Glides often have strong influence upon their adjacent vowels, and they also have some influence upon consonants.

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