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Table of Contents

Summary

Tonogenesis is the development of distinctive tone from earlier non-tonal contrasts. A well-understood case is that of Vietnamese (similar in its essentials to that of Chinese and many languages of the Tai-Kadai and Hmong-Mien language families), where the loss of final laryngeal consonants led to the creation of three tones, and the tones later multiplied as voicing oppositions on initial consonants waned. This is by no means the only attested diachronic scenario, however. There is tonogenetic potential in various series of phonemes: glottalized vs. plain consonants, unvoiced vs. voiced, aspirated vs. unaspirated, geminates vs. simple (and, more generally, tense vs. lax), and even among vowels, whose intrinsic fundamental frequency can transphonologize to tone. But the way in which these common phonetic precursors to tone play out in a given language depends on phonological factors, as well as on other dimensions of a language's structure and on patterns of language contact, resulting in a great diversity of evolutionary paths in tone systems. In some language families (such as Niger-Congo and Khoe), recent tonal developments are increasingly well-understood, but working out the origin of the earliest tonal contrasts (which are likely to date back thousands of years earlier than tonogenesis among Sino-Tibetan languages, for instance) remains a mid- to long-term research goal for comparative-historical research.

Keywords

tone; diachronic phonology; transphonologization; prosody; intrinsic f_0

1. Introduction

Tonogenesis is the process by which tonal contrasts emerge from earlier non-tonal contrasts. Tonogenesis has been detected through the use of the Comparative Method, but has also been documented as an on-going process in some languages. In order to understand how tonal contrasts may emerge, it is helpful therefore to look at both diachronic and synchronic studies. Comparative-historical studies are used to deduce the original conditioning environments which resulted in the present tonal contrasts. Synchronic studies can help us understand how factors such as vowel height, aspiration, phonation type, etc. can affect the fundamental frequency (f_0) of a vowel. Automatic phonetic effects may be amplified and phonologized, which can lead to a reanalysis of the underlying phonological contrast. For instance, a lowering of f_0 on a vowel due to a preceding voiced consonant may be reanalyzed as being due to a low tone rather than due to voicing, and the original voicing contrast may be lost.

Contrasts which have tonogenetic potential include: glottalized vs. plain consonants, unvoiced vs. voiced, aspirated vs. unaspirated consonants, and geminates vs. simple (and, more generally, tense vs. lax). Laryngeal contrasts on stops may pattern differently than the same contrast on fricatives or sonorants. There is also tonogenetic potential in contrasts in phonation, height and tongue root position of vowels. There is a great diversity of evolutionary paths in tone systems, as the phonetic precursors to tone are not deterministic but interact with phonological factors as well as other aspects of linguistic structure. For example, while aspirates may be associated with higher tones in one language, they may be associated with lower tones in another language.

The most familiar tonogenetic scenarios involve the loss of a laryngeal contrast on initial consonants. We will illustrate this scenario in Section 2.1, by looking at the case of Vietnamese (which is similar in its essentials to that of Chinese and many languages of the Tai-Kadai and Hmong-Mien language families). The loss of laryngeal contrasts on syllable-final consonants may also lead to the development of tonal contrasts, as we will show in Section 2.2.

In subsequent sections, we detail cases of tonogenesis from outside of Asia, in part because these tend to be less well-known. We look at tonogenesis in Dene (Athabaskan), as well as in a number of African languages. We pay particular attention to tonal contrasts that have emerged or are emerging from the loss of an initial voicing contrast in some Chadic and Khoe languages, as well as in Afrikaans (a Germanic language).

2. Tonogenesis in East Asian Languages

Many East Asian languages have a rich system of lexical tones. As shown in Table 1, Northern Vietnamese currently has six lexical tones, plus a separate system of two tones for stop-final syllables. How did such a system arise? In Section 2.1, we will survey the historical linguistic work that determined how this developed out of an earlier system with three lexical tones, and a voicing contrast on initial consonants.

Major topics to consider in the tonogenesis of East Asian languages include the role of initial consonants, consonant manner, phonation and final consonants. In Section 2.1.1, we highlight the role that initial continuants have played in tonogenesis looking at data from other East Asian languages such as Khmu, Dong, and Cao Bang, a Tai dialect. It is important to consider the role of consonant manner in tonogenesis, as laryngeal contrasts may be lost on continuants before being lost on stops, for instance, leading to different patterns of tonal contrasts. In Section 2.1.2, we discuss the role of phonation in tonogenesis, looking at phonetic data from lax voiced initial stops in Chru. A contrast may pass through a middle stage on its way to becoming a tonal contrast. For instance, a voiced initial may induce lax voicing on a following vowel, and be associated with some lowering of f_0 before voicing is lost and before low f_0 becomes the primary (or only) cue to the contrast. In Section 2.1.3, we discuss tonogenesis in Proto-Tai, showing that an earlier two-way laryngeal contrast need not manifest as a two-way tone contrast, or tone split, but that a distinct pitch pattern may emerge on only one series of contrastive consonants. In Section 2.2, we return to Vietnamese to illustrate the role that a laryngeal contrast on syllable-final consonants may play in tonogenesis.

Table 1. The six tones of present-day Northern Vietnamese: self-referential Vietnamese names, description, transcription in IPA and tone numbers (after Kirby 2011), and example.

name	description	IPA	tone numbers	example
ngang 'level'	mid level	˦˦	44	*ma* 'ghost'
sắc 'sharp'	high rising	˨˦	24	*má* 'cheek, mother (southern)'
huyền 'hanging'	low falling (often breathy)	˧˨	32	*mà* 'but'
hỏi 'asking'	mid dipping	˧˩˨	312	*mả* 'tomb, grave'
ngã 'broken'	medial glottal constriction, ends on high pitch	˧˨˥	325	*mã* 'code'
nặng 'heavy'	glottal constriction cuts short the syllable	˨˨	22	*mạ* 'rice seedling'

2.1. Tonogenesis by Loss of Voicing Contrasts on Initial Consonants

Based on the study of Chinese loanwords into Vietnamese dating from the 1st millenium AD, Maspero showed that these six tones can be divided into two series (Maspero, 1912, pp. 95–96): one series consisting of *ngang*, *hỏi* and *sắc* was associated with former voiceless initials, and another consisting of *huyền*, *ngã* and *nặng* occurred with former voiced initials. This allows to give a first level of structure to the list provided in Table 1: see Table 2.

Table 2. Vietnamese tones grouped into two etymological series based on voicing features of initial consonants at an earlier historical stage.

earlier voicing feature of initial consonant	
unvoiced	*ngang, hỏi, sắc*
voiced	*huyền, ngã, nặng*

Furthering this observation, Haudricourt (1954) concluded that in Old Vietnamese, before the 10th century, there were only three tones, each of which later split into two through a *consonant shift* involving initial consonants: a merger between voiced and unvoiced initial consonants. This is summarized in Table 3. (The three tones are referred to by letters: A, B and C, remaining noncommittal as to the phonetic realization of these reconstructed tones. The origin of tones, A, B and C, will be addressed further below, i.e. working back in time from the present-day system.) This analysis is decisive, because it applies in its essentials to Chinese dialects (Sinitic) and to languages of the Tai-Kadai and Hmong-Mien families, as will be explained further below. The Middle Vietnamese system, shown in Table 3b, is preserved in present-day Hanoi Vietnamese, whereas one of the tones was lost in Southern Vietnamese.

Table 3. The evolution of the Vietnamese tone system: from three tones to six (in Middle Vietnamese).

Table 3a: the situation prior to the two-way splitting of the tone system: three tones; no distinctive tone on obstruent-final syllables.

ta	tone A	ta	tone B	ta	tone C
da		da		da	

tap, tat, tak	category D (no tone)
dap, dat, dak	

Table 3b: the tone system of Middle Vietnamese: number and traditional name in Vietnamese writing. Tones A1 to C2: appear only on sonorant-final syllables; tones D1 and D2: appear only on obstruent-final syllables.

ta	tone A1 *(ngang)*	ta	tone B1 *(sắc)*	ta	tone C1 *(hỏi)*
ta	tone A2 *(huyền)*	ta	tone B2 *(nặng)*	ta	tone C2 *(ngã)*

tap, tat, tak	tone D1 *(sắc)*
tap, tat, tak	tone D2 *(nặng)*

Three points appear especially worth emphasizing about this tonogenetic scenario.

2.1.1. *The Role of Unvoiced Continuants in Consonant Shifts*

The tone splits conditioned by initial voicing are often illustrated using stops, as here in Table 3, where /t/ and /d/ serve as examples of unvoiced and voiced initials, respectively. But this convenient choice unwittingly draws attention away from continuants, which constitute a key element in many cases of tonogenesis. Two or more series of continuants were present in many languages prior to consonant shifts. In non-tonal varieties of Khmu, three series of nasals remain synchronically attested: glottalized ʔm ʔn ʔŋ, voiceless m̥ n̥ ŋ̊, and plain (voiced) m n ŋ. Confusions between three series yield remarkably rich tone systems, as in the case of Dong (Tai-Kadai), reproduced in Table 4: an earlier system with three tones (referred to as A, B and C, as in the case of Vietnamese described above) undergoes three-way splitting, yielding nine tones. A syllable’s tone in the resulting nine-tone system depends on (i) which tone the syllable formerly had: A, B or C, and (ii) whether its initial was formerly a preglottalized consonant or a plain unvoiced stop; a voiceless continuant or an aspirated stop; or a plain voiced continuant, stop or fricative. (Other examples are reviewed by Haudricourt 1972.)

Table 4. Dong: three-way split of the tonal system resulting in a system of nine tones

initial consonant (prior to the three-way split)	Tones		
	A	B	C
preglottalized, or plain unvoiced stop: (*ɓ>)m, (*ʔm>)m, (*ʔn>)n, (*ɗ>)l, (*ʔʀ>)j, k, t, p	55 ˥	53 ˥˧	323 ˧˨˧
voiceless continuant, or aspirated stop: (*m̥>)m, (*n̥>)n, (*ɲ̊>)ɲj, (*ŋ̊>)Ø, kʰ, tʰ, pʰ	35 ˧˥	453 ˦˥˧	13 ˩˧
plain voiced continuant, stop or fricative: m, n, ɲ, l, (*b>)p, (*d>)t, (*g>)k, (*ʀ>)j	212 ˨˩˨	33 ˧	31 ˧˩

Moreover, even in simpler cases of merger between two series of initials (voiced and unvoiced), continuants deserve special attention: unvoiced continuants such as m̥ n̥ ŋ̊ l̥ arguable tend to *initiate* the consonant shift. Phonetically, voiceless continuants are somewhat complex sounds, containing a voiced portion after the initial unvoiced portion, reflected in their traditional transcription as *hm*, *hn*, *hŋ* and *hl*. While this transcription can be misleading, in that the unvoiced part of the sound is not a glottal fricative /h/ (as the nasal or lateral articulation is already into place), it draws attention to the phoneme's composite nature and phonetic complexity, which constitutes a seed for sound change. Sifting tonogenetic data from Southeast Asian languages brings out a remarkable case in the Tai dialect of Cao Bang: "[w]hile the initial sonorants have completely lost their historical voicing distinction and developed a six-way tonal contrast, the obstruent series still preserves the original voicing contrast, leaving the tonal split incomplete" (Pittayaporn & Kirby, 2017, p. 65). A likely interpretation is that the merger of initial sonorants, not initial stops, initiated the change. On this topic, in addition to Pittayawat & Kirby (2017), see L-Thongkum (1997) and Hyslop (2009).

2.1.2. Voicing and Phonation Types

A second point well worth emphasizing concerning tonogenesis by loss of voicing contrasts on initial consonants is that the transfer of contrastiveness from initial voicing to tone is mediated by an intermediate stage, during which phonation-type characteristics play a role in the contrasts. Haudricourt phrases his interpretation of the process as follows: after voiced initials, "the relative laxness of the laryngeal-oral muscles is prolonged from the articulation of the initial consonant into that of the following vowel. The relaxation of the larynx lets breathy voice come through and lowers the pitch of the voice, while the relaxation of the muscles of the mouth results in a "lax" vowel quality" (Haudricourt, 1965, translated by Paul Sidwell and Alexis Michaud). The role of phonation types in tonogenesis is crucial: *tonogenesis* is related to *registrogenesis*, the process whereby phonation-type registers become distinctive. Loss of distinctive voicing on initial consonants can lead to two related types of consonant shift: a type which Haudricourt calls "Far Eastern" (split of the tone system) and one which he calls "specifically Mon-Khmer" (a split of the vowel system): see Ferlus (1979). Both processes can be hypothesized to have a common stage where the phonetic cues to the opposition include, in addition to phonation type proper, some differences in pitch, as well as differences in vowel articulation, as was already noted for a conservative variety of Khmer by Henderson (1952). At a later stage, one or the other of the cues becomes dominant: this is where the evolution branches into the "Mon-Khmer" type (where vowel quality stabilizes as the new distinctive property) and the "Far Eastern type" (where the distinctions become tonal). Synchronic phonetic studies of register systems reveal patterns of coexistence of different cues to the phonological contrast: thus, in Chru (a Chamic language), registers are distinguished by fundamental frequency, phonation type and vowel quality. As shown in Figure 1 (reproduced from Brunelle et al., 2019, with permission), there is a difference in f_0 at vowel onset after high and low register stops; this difference fades about 75 milliseconds into the vowel. As shown in Figure 2 (same source), vowels following low register plain stops have a much higher difference between the amplitude of the first two harmonics (i.e. are more whispery/breathy) than those following their voiceless counterparts.

Figure 1. Mean f_0 in the first 200 ms following low and high register plain stops in Chru (sonorants given as reference). Shading: 95% confidence interval. From Brunelle et al. (2019) *(reproduced with permission)*.

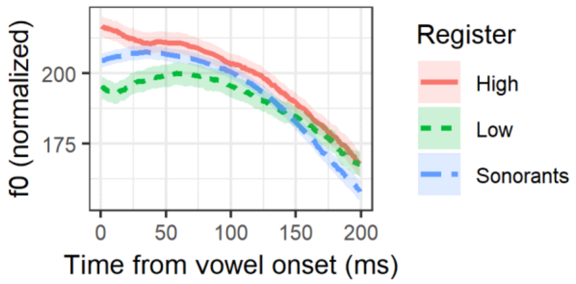
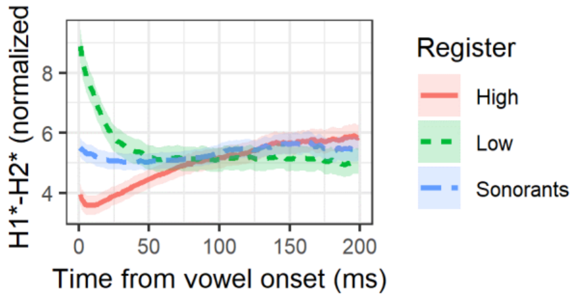


Figure 2. Spectral slope measurement (H1*-H2*) in the first 200 ms following low and high register plain stops in Chru (sonorants given as reference). Shading: 95% confidence interval. From Brunelle et al. (2019) *(reproduced with permission)*.



An extension of the general theory of the changes associated with "registrogenesis" has been proposed by Ferlus (2009: 192) to shed light on vowel changes from Old Chinese to Middle Chinese. (Note that there are attested cases of sound change in the reverse direction, from tone to phonation, as in Quiaviní Zapotec: Uchihara, 2016.)

2.1.3. *How a Middle Series Can Emerge During a Consonant Shift*

A third point worth emphasizing (already implicit in what precedes) is that Asian languages present a wide range of variants on the common scenario outlined above. Conditioning factors include differences in consonant inventories at the stage when tonogenetic processes take place, as well as the relative timing of these processes. One specificity that was emphasized by Haudricourt (1954) but that receives relatively little attention in overviews is that of *middle series* in tonal splits. A middle series can emerge during an initial-consonant shift in a three-tone system. In Proto-Tai, there were voiceless initials (voiceless stops **p**, **t**, **k**, **pʰ**, **tʰ**, **kʰ**... and voiceless continuants **m̥**, **n̥**, **l̥**) as well as voiced initials (**b**, **d**, **g**... and **m**, **n**, **l**...). In Siamese (Thai) and in neighbouring Lao dialects, voiced stops became aspirated as they devoiced: **b**, **d**, **g** became **pʰ**, **tʰ**, **kʰ**, also imparting a lowered f_0 to the following vowel. There was no pressure to generalize a distinct pitch pattern for syllables with Proto-Thai-Tay unaspirated voiceless stops ***p**, ***t**, ***k** because they were not at risk of merging with syllables with the former voiced stops. They do not belong to the high series because they do not contrast with a low series of syllables with identical consonants and vowels. They constitute an intermediate series, called “middle series” (for further information, see Haudricourt, 1972).

Let us now work back in time and progress to the first stage of tonogenesis in Vietnamese (and in Chinese and many other East and Southeast Asian languages), explaining the origin of the three tones A, B and C.

2.2. Tonogenesis by Loss of Final Laryngeal Consonants

Table 5 provides a complete picture of tonogenesis in Vietnamese through loss of final laryngeal consonants and loss of voicing oppositions on initial consonants. Table 5 also provides information on stop-final syllables in order to dispell widespread misunderstandings.[i]

Table 5. Late Proto-Viet-Muong rhyme types: nonglottalized open syllable; glottally constricted ending; /h/ ending; /p/ /t/ /k/ ending (after Ferlus, 2004).

ta	taˀ	tah
da	daˀ	dah

tap, tat, tak
dap, dat, dak

“We can safely assert that all tone systems in modern Viet-Muong languages derive from a fundamental three-way contrast of Proto-Viet-Muong between -Ø (unmarked voiced ending rhyme), -ˀ (constricted voiced ending rhyme) and -h (laryngeal spirant ending rhyme). Checked syllabes in -C (voiceless ending rhyme) are apart” (Ferlus, 2004, p. 298). Final laryngeals being located at the end of the syllable, they result in a *final* modification of pitch contour (falling for ***-h**, rising for ***-** ˀ). The former (in category C) must have been “a laryngeal /h/ produced by an abrupt slackening of the larynx. The slackening of the vocal folds produced a drop in the pitch of the preceding vowel, i.e. a falling tone” (Haudricourt, 1954). As for category B, the opposite change takes place: a glottal stop or glottal constriction following a vowel “is produced by an increase in vocal fold tension (the opposite of what we have seen for final h). (...) [T]he increase in vocal fold tension in anticipation of the coda glottal stop produces a rising tone” (Haudricourt, 1954).

Phonation-type characteristics are, to this day, part of the definition of some of the tones of Northern Vietnamese (see phonetic studies of tone production, acoustics and perception by Brunelle, 2009; Kirby, 2010), but the synchronic distribution of glottalization does not reflect diachrony in a straightforward way. In Vietnamese, of the two tones that originate in glottal-stop-final syllables, B1 and B2, only one (B2) has glottalization; conversely, one of the tones that originate in syllables with final ***-h** (tone C2, orthographic *ngã*) has glottalization. The synchronic picture of phonation types is thus not a good guide to establish the diachronic origin of tones.

Tonogenesis in Dene (Athabaskan) offers further insights into the tonogenetic effect of final laryngeals.

3. Tonogenesis in Dene (Athabaskan)

Syllables contrast for High vs. Low tone in many Athabaskan languages. The historical source for these tones is an earlier contrast between two syllable structures, with and without final glottalization (a pre-tonal situation still attested in several Dene languages). From an East/Southeast Asian perspective as summarized in §2, one would expect syllables with final glottalization to have developed High tone: in Vietnamese and Chinese, final glottal constriction resulted in a high pitch target at end of syllable. Such is indeed the case in Dene, but not in all languages: the reverse situation (earlier glottal constriction being reflected in Low tone) is also attested. There are thus “high-marked” and “low-marked” tone languages in Dene (Kingston, 2003, p. 60), as illustrated in Table 6 by Chipewyan and Gwich’in (Hupa exemplifies the situation of non-tonal languages).

Table 6. Correspondences illustrating the difference between “high-marked” and “low-marked” Dene languages. /t’/ is an ejective dental stop.

gloss	Proto-Dene	Chipewyan	Gwich’in	Hupa
smoke	*ɬəd	ɬə̀r	ɬád	ɬid
belly	*wət’	bə́r	vàd	mət’

A likely interpretation is that these opposite developments arose from differing pronunciations of final glottal stop and glottalic sonorants at the point where they transphonologized into tone. In view of the Dene facts, Matisoff (2003, p. 11) surmises that “[t]here may well be at least two kinds of glottal stop”: strong *glottal constriction* tends to be associated with *tension*, and (perceptually) with high pitch, whereas lapse into *creaky voice* tends to be associated with *relaxation*, and with lower pitch. The tonogenetic effects of final glottalization depends on the overall state of the linguistic system: thus, in Vietnamese and Chinese (§2.2), evolution of final glottalization towards a *rising* tone (category B) was very probably influenced by the presence of a *falling/breathy* tone (category C, from an earlier final –h), whereas in Dene there was no such tone and thus no structural pressure for syllables with final glottalization to evolve towards a High rather than a Low tone. (See also Kingston, 2005.)

Examination of tonogenetic data from African languages confirms that the tonogenetic potential of certain consonants is mediated by the state of the phonological system as a whole (as well as by patterns of language contact).

4. Tonogenesis in Subsaharan Africa

4.1. Introductory Note

Unlike in East/Southeast Asia, where diachronic studies lead to reconstruct, with full confidence, *toneless* phonological systems at a certain time depth (§2), comparative work on individual branches of Subsaharan languages yields reconstructed languages that already have lexical tones. For instance, proposed reconstructions for the Ju-ǂHoan (Kx'a) group include tone (Starostin, 2018): four tonal levels are projected back into the linguistic past (as also in Heine & Honken, 2010). While it currently seems most plausible that the ancestor languages of major groupings such as Kx'a, Khoe and Niger-Congo had tone, verifying this hypothesis (and, ultimately, working out the origin of the earliest tonal contrasts) remains a mid- to long-term research goal for comparative-historical research. Thus, proposed reconstructions for Niger-Congo numerals (Pozdniakov, 2018, p. 293) do not contain any conjectures about tone: thus, proposed values are *ba-di for 'two', *tat/tath for 'three', *na(hi) for 'four'. Arriving at proposals for tone values for these and other items at the proto-Niger-Congo stage will require further progress in the reconstruction of intermediate stages. The time depth is considerable: tonogenesis in Niger-Congo probably predates tonogenesis among Sino-Tibetan languages by thousands of years. While most specialists would be cautious and avoid making a guess, a figure of 5,000 years or more can be (very tentatively) proposed in order to give a feel for the difficulty of unravelling the history of these tone systems all the way back to a proto-language and (even more problematically) to a possibly toneless stage. On the other hand, it is easier to gain insights into processes whereby new tones appear within a system that already had two or more tones: such will be the focus of the present overview, which draws on comparative-historical evidence, on synchronic evidence from alternations, and on experimental phonetic studies.

4.2.Salient Consonantal Effects on Tone

Sections 2 and 3 already touched upon the topic of consonantal effects on tone, which belong among *microprosodic* effects (a concept that also covers vowels' *intrinsic* f_0, discussed in §4.3). These effects are also referred to as 'pitch skip' and 'pitch dip' for raising and lowering of f_0, respectively (Haggard, Ambler, & Callow, 1970). In voiced-vs.-voiceless consonant oppositions, voiced consonants tend to cause lower f_0 at the onset of the following vowel than unvoiced consonants (a landmark in this area is the study by Hombert, Ohala, & Ewan, 1979). Differences in f_0 related to consonant manner and airstream mechanism can also occur, as shown in Figure 3, which displays f_0 tracks of vowels with H tone following different types of consonants in Kera, a Chadic language (Pearce, 2013). The f_0 after implosives and sonorants rises while f_0 after obstruents falls.

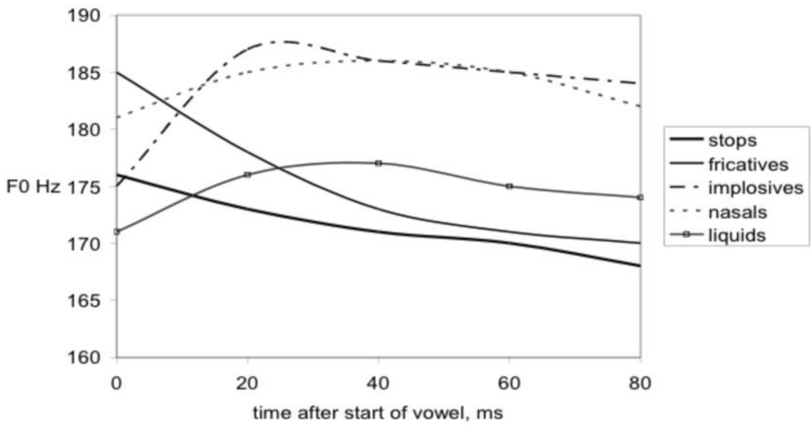


Figure 3: High (H) tone contours following different types of consonants in Kera (Pearce 2013: 175) *(reproduced with permission).*

Implosives and ejectives involve changes in larynx height and glottal constriction, and might therefore be expected to have effects on f_0 (note that there can be an inverse correlation between larynx height and f_0: Moisik et al., 2019). Variable creakiness and f_0 raising of a following vowel has been noted to occur with velar ejectives in Hausa (Meyers, 1976, p. 47). Voiceless implosives in the Central Sudanic language Lendu tend to raise the fundamental frequency at the beginning of a following vowel slightly more than voiced implosives do (Demolin, 1995). Initial voiced labial-velar stops [g͡b] have a higher f_0 during the closure of the consonant than bilabial stops [b] in one study of Yoruba, perhaps because they were realized as (creaky-voiced) implosives (Cahill, 2006, p. 40).

In tonogenetic work about Subsaharan languages, initial consonants are divided into two sets: depressor consonants – where ‘depressor’ refers to their lowering effect on the syllable’s tone – stand apart from non-depressor consonants. Phonologically voiced plosives occur as tone depressors in a number of African languages, particularly those belonging to the Bantu and Khoe families (Elderkin, 2004, 2013; Fehn, 2019; Haacke, 2008; Maddieson & Sands, 2019). Several Chadic languages have 'voiced' depressors, and possibly also voiceless 'raisers' (Pearce, 2013; Wolff, 1987). Phonetic studies are lacking for many African languages, but phonological effects of voiced obstruents (e.g. blocking the spread of H tone) have been noted for a number of African languages (Bradshaw, 2000). It must be emphasized that pitch differences are not dependent on phonetic voicing but are, in many cases, phonologized. Phonetically, 'voiced' depressors may be slack or breathy voiced (e.g., in Zulu: Traill, Khumalo, & Fridjhon, 1987) or voiceless (e.g. in Siswati: Kockaert & Goodwin, 1997; Traill, 1990) and depression often cannot be linked directly to a [voice] feature (Downing, 2009). Pitch differences associated with 'voiced'-vs.-'voiceless' consonants in Musey, a Chadic language, for instance, have been attributed to differences in subglottal pressure and longitudinal vocal fold tension, with the 'voiceless' consonants having greater tension (Shryock, 1995). The 'voiced' consonants in this language are more frequently realized as voiceless consonants than as either partially or fully voiced (Shryock, 1995, p. 17). Phonetically voiced implosives and prenasalized stops do not always pattern with voiced plosives with respect to pitch depression (Chen & Downing, 2011; Hyman, 2013). For instance, vowels following implosives in SiSwati have higher f_0 transitions than those following nasals and phonologically voiced stops, but lower than those after aspirated stops

(Wright & Shryock, 1993). Vowels after voiced prenasalized stops in Chichewa have higher f_0 transitions than those following phonologically voiced stops, but lower than after nasals and voiceless stops (Cibelli, 2015). In Gengbe (Niger-Congo), initial voiced obstruents and sonorants act as depressors on verbs, but only voiced obstruents behave as depressors in C1 position in nouns (Lotven & Berkson, 2019).

The role of voiced plosives as depressors plays out clearly in Khoe, where detailed scenarios can be proposed, tracing the evolution from a system where morphemes carry two successive tonal levels (H(igh) or L(ow), hence four categories: HH, HL, LH, LL) to present-day systems with more categories. Table 7 is adapted from Elderkin (2016, p. 121). Changes that look like clear instances of tonal depression include the Naro reflex LL for proto Khoe *HL after depressor consonants (whereas the default, non-depressed reflex is simply HL). In G|ui, there is only a modest historical effect of depressor consonants (the split of the *LL category into two modern categories, labelled as MM and LM, where M stands for a Mid tone); by contrast, in Naro, the number of tonal categories reaches a total 7, out of a total 8 theoretically possible distinct categories from the two-way split of the 4-tone proto-system. Tonal depression must have come into play after the break-up of Proto-Khoe, independently in different sub-branches of the family. Even very closely related Khoe languages such as Tsua and Kua differ in the presence or absence of depressors (Fehn, 2019, p. 27; Mathes, 2015).

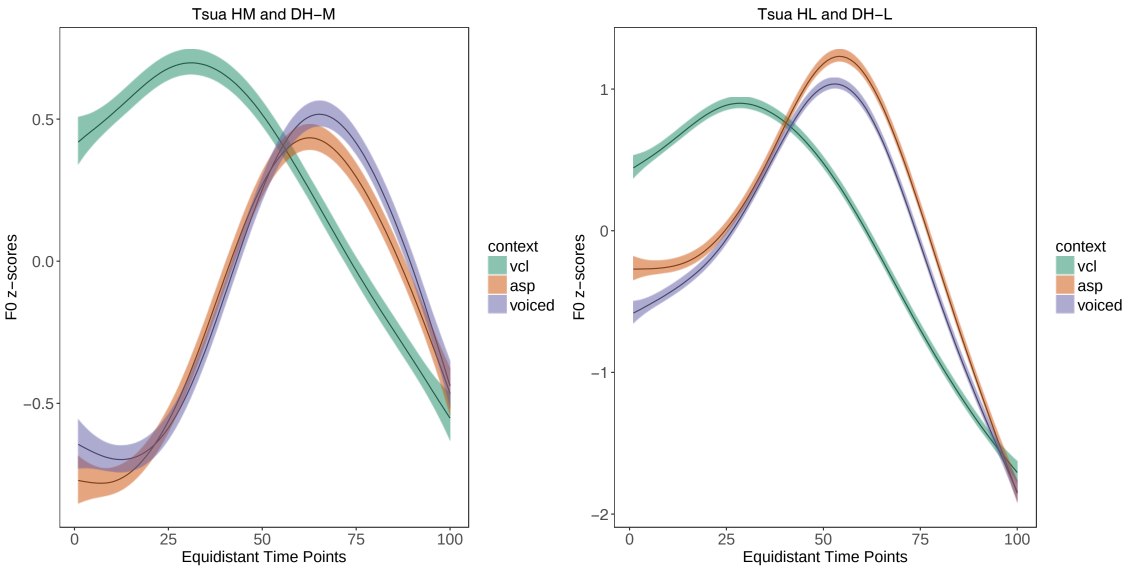
Table 7. Reflexes of proto-Khoe tones in the modern languages Khoekhoegowab, Naro, G|ui and Khwe.

	Khoekhoegowab		Naro		G|ui		Khwe	
proto Khoe	default	depressed	default	depressed	default	depressed	default	depressed
*HH	43	43	HH	**LH**	HH	HH	HH	HH/MH
*HL	32	**12**	HL	**LL**	HL	HL	HL	HH/MH
*LH	24	24	MM	LM	HM	HM	HH	LH
*LL	22	**13**	ML	LM	MM	**LM**	HM	LM

Phonetically, it is striking that all the Naro 'depressed' categories begin with L tone, in keeping with the expected effect of depressor consonants, whereas L is synchronically unattested in initial position in the 'non-depressed' categories. Such observations shed light on use of the term 'depressor' in Subsaharan phonology. The term suggests that the active role in tone splits is played by the depressor consonants, whereas non-depressor consonants do not affect a syllable's tone to a comparable extent: instead, changes in 'non-depressed' morphemes could be seen as responses to phonetic changes initiated by 'depressed' morphemes. At first glance, this degree of uniformity stands in contrast to the diversity of registrogenetic and tonogenetic processes reported in East and Southeast Asia. In Asia, the consonant series involved in splits of the tone system (referred to as the 'high' and 'low' series, or 'voiceless' and 'voiced' series, corresponding to 'non-depressors' and 'depressors' in Subsaharan parlance) are traditionally seen from a structural point of view, as terms within an opposition. Consonant shifts are viewed as changes to the system as a whole, without necessarily singling out one series or other as playing an active role. A one-sentence summary of this point of view, using the convenient simplified labels 'voiceless' for the high ("non-depressor") consonants and 'voiced' for the low ("depressor") consonants, is that "a certain tenseness is associated with the voiceless feature, while a laxness is associated with the voiced feature" (Ferlus, 2009, p. 191). Seen in this light, the way in which the contrast transphonologizes depends on the language: phonetically, the contrast can be a tense *high series* vs. a modal *low series* (a scenario in which the high series is the phonetic driver of change), as well as a modal *high series* vs. a lax *low series* (a scenario in which the low series is the phonetic driver of change). In light of the Subsaharan facts reviewed here, the former scenario appears slightly surprising. Indeed, Marc Brunelle (p.c. 2019) notes that there are no clear cases of development of tenseness "associated with the voiceless feature" in Southeast Asian languages (Chong and Bahnaric turn out to be less straightforward cases than they originally seemed). If the sifting of cases proved this scenario to be less common than Ferlus's description suggests, new paths would open for fine-grained modelling of tonogenetic processes in East and Southeast Asia. The cross-linguistic picture would then look more tidy, with clearer similarities between African 'depression' and Asian 'low series'.

Perhaps surprisingly, voiceless aspirated stops are also found to be depressor consonants in some southern African languages such as Tsua (Mathes, 2015), a Khoe language, and Xitsonga (Lee, 2015), a Bantu language. Breathy voiced aspirates are depressors in Ikalanga (Mathangwane, 1998). Although the f_0 of vowels following aspirated stops tends to raise cross-linguistically, synchronically aspirated stops lower tone in some Asian languages as well (e.g. Reetz, Mikuteit, & Lahiri, 2019; Zhou & Kirby, 2019). It is possible that such aspirates may be reconstructed as once having had breathy aspiration. N!aqriaxe, a Kx'a language spoken in southern Africa also has aspirated depressors, but those with 'delayed aspiration' show even greater tone depression (Gerlach, 2016, p. 209). Delayed aspiration contrasts with 'regular' aspiration on clicks, and is cross-linguistically associated with nasal venting and breathiness, and an inaudible release of the dorsal click constriction.

In Tsua, voiceless aspirates and voiced plosives both depress tone, in contrast to voiceless and glottalized consonants, as shown in Figure 4a-b. Note that the peaks in f_0 occur later for depressed melodies than for non-depressed melodies, which Mathes (2015) takes as evidence for L-tone insertion associated with depressors.



(a) (b)

Figure 4: Smoothing splines showing (a) HM and depressed-HM, and (b) HL and depressed-HL tone melodies. (The x-axis shows 100 equidistant time points and the y-axis shows normalized f_0 scores). Each curve is based on 3 repetitions of 5 lexical items produced by 3 speakers (n=45). The 95% confidence interval around each smoothing spline is shown in color: green for voiceless and glottalized consonants, orange for aspirated consonants, and purple for voiced consonants. Figure courtesy of Timothy Mathes, with methodology discussed in Mathes (2015).

Khoe languages vary as to whether 'voiced' depressor consonants are phonetically voiced or voiceless. They are voiced in G|ui and Naro but generally voiceless in Khoekhoegowab (Haacke, 2008; Nakagawa, 2006). Variable voicing of 'voiced' plosive occurs in another sub-Saharan African language, Afrikaans. Afrikaans has developed pitch differences in vowels after voiced and voiceless plosives, as shown in Figure 5, from Coetzee et al. (2018, p. 193). These differences are seen for both older and younger speakers. For some speakers of both age groups, the phonologically voiced plosives are realized as voiceless plosives, meaning that pitch is an important cue to the contrast between phonologically voiced and voiceless plosives. Younger speakers tend to produce both types of stops with a higher f_0 range than do older speakers. Coetezee et al. point out that younger speakers have a higher rate of devoicing than do older speakers, which indicates that f_0 is increasing in importance as a cue to the phonological contrast, and laryngeal differences are of decreasing importance. This, then, appears to be a case of tonogenesis in progress.

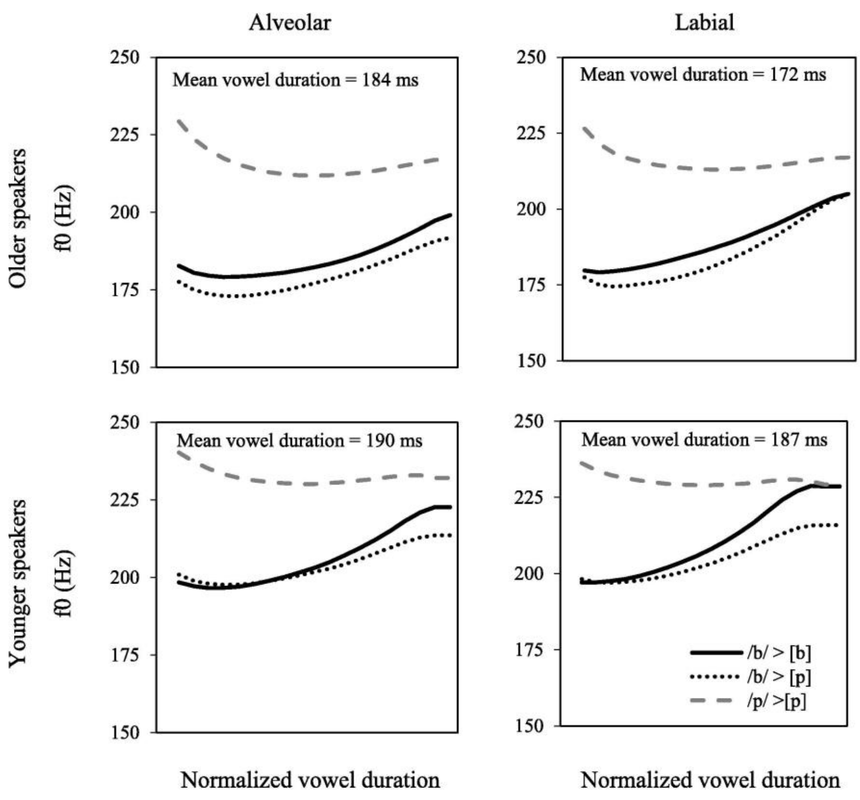


Figure 5: f_0 profiles of vowels after /b d p t/ based on 19 f_0 measures taken at equally spaced intervals across the vowel of older and younger Afrikaans speakers. The f_0 of phonologically

voiced stops are shown with a solid line for stops that have any voicing during the stop closure; otherwise, it a dotted line is used. Dashed lines represent the f_0 of phonologically voiceless stops. From Coetzee et al. (2018, p. 193) *(reproduced with permission).*

4.3.Tonal Effects of Vowel Intrinsic f_0

In addition to consonantal effects on the fundamental frequency of an adjacent vowel, *microprosodic* effects include *intrinsic* f_0 effects: the effect of vowel quality on fundamental frequency.[1] "The tendency for high vowels such as [i] and [u] to have higher fundamental frequencies than low vowels such as [a] has been found in every language so far in which it has been sought" (Whalen & Levitt, 1995, p. 349). The extent of intrinsic f_0 effect between high and low vowels is sizeable: on the order of 1.5 semitone (Whalen & Levitt, 1995, p. 356). In the Moru-Mangbetu group (Sudanic), Mangbetu has two level tones (High and Low), a state of affairs which is considered to reflect a proto-Moru-Mangbetu system of two tones, whereas the three-tone systems of languages of the Mangbetu-Asua subgroup are interpreted as resulting from a split of the earlier *H tone into two different levels, H and M: "High tones have a tendency to stay high (...) if they are mapped onto [+Advanced Tongue Root] vowels. When they are mapped onto [-Advanced Tongue Root] vowels, they have a tendency to become Mid tones (...). These facts support a hypothesis that tonogenesis was triggered by the intrinsic pitch of vowels which is higher for [+ATR] vowels and lower for [-ATR] vowels" (Demolin, 1999, p. 326). Andersen's (1986) analysis of Lugbara tones presents a similar picture. This echoes observations from Southeast Asia: vowel height oppositions were partially transphonologized to tone in U and Hu, two languages of the Angkuic branch of Austroasiatic languages (Svantesson, 1989), in a context of strong areal pressure towards tonogenesis, and in the absence of those consonantal oppositions that constitute the most common precursors to tone (such as a voicing opposition on initial consonants).

A number of African languages have super-high and/or super-low tones that contrast with H and L, and vowels appear to play some role in the development of these contrasts. High vowels have been argued to create higher tonemes in some Omotic languages (Tesfaye & Wedekind, 1994) and super-high is restricted to words with [i], [u] and diphthongs containing these vowel qualities in ǂHoan (Kx'a) (Collins, 2012). In Opo, a Koman (isolate or Nilo-Saharan) language, super-high tones have developed on [+high, +ATR] vowels after aspirated consonants (Otero, 2019, p. 168). In Juǀ'hoan (Kx'a), super-high tones only occur on plain vowels, never occur on guttural vowels (breathy, epiglottalized/pharyngealized, glottalized) but super-low tones occur on all but breathy vowels (Miller-Ockhuizen, 2003, p. 148).

As is the case with laryngeal consonant features, the effect of ATR and other vowel features on f_0 can differ depending on the language. In the case of Ambel, an Austronesian language spoken in New Guinea, high tone has developed on [-high] vowels, in contrast to cases such as Opo mentioned above. A phonetic study looking at the relationship between f_0 and F1 in Twi (a register tone language with a high/low opposition spoken in Ghana) indicates that low

[1] Intrinsic f_0 is often referred to as 'intrinsic pitch', contributing to an enduring confusion between pitch and f_0. Pitch is a perceptual concept, and it is thus misleading to refer to f_0 tracings (plotted along the Hz scale) as 'pitch curves'. (This is a built-in confusion of the software package Praat, for instance.) To what extent a change in f_0 is heard as a change in pitch depends on various factors. Siddins's phonetic study of intrinsic f_0 effects on tone in Hong Kong Cantonese consistently distinguishes f_0 and pitch (Siddins, 2017).

toned vowels in that language tend to be produced with a larger pharyngeal cavity than those with high tone (Manyah 2006). These phonetic precursors to a possible sound change are in the opposite direction of those seen in Lugbara, for instance, where [+ATR] is instead connected with higher f_0.

To conclude the discussion of consonantal and vocalic effects on fundamental frequency, it is clear that "universal microprosodic properties of segments (...) are used in different ways by the different languages" (see also Kirby, 2018; Svantesson, 1989, p. 60).

4.4. Tonogenetic Effects of Morphotonological Alternations and Loss of Syllables

Consonantal and vocalic effects on tone are by no means the full story of tonogenetic processes. First, there can be *tonal morphology* (morphological information encoded specifically by tone) and more broadly *morphotonology* (tonal alternations conditioned by morphosyntax). Thus, in some tonal languages, possessive constructions (genitival syntagms) and compounds (complex lexemes) are distinguished by their tone patterns. In Kita Malinke (Mande branch of Niger-Congo), for instance, 'the meat of the cow' is /mìsí sùbû/, and 'beef, cow meat' is /mìsì-súbú/ (Creissels & Grégoire, 1993). The latter is characterized by tonal compactness *(compacité tonale)*: the tone pattern of the compound is determined by that of its first component, which is the determiner. Similar phenomena are also attested in other language families (e.g. in Sino-Tibetan: see for instance Michaud, 2017, pp. 94–133). A phonetic precursor to such tonal changes is found in the Mangastaa dialect of Sandawe: "in the genitive construction, the first constituent has a higher key, the second a lower key" (Elderkin, 2016, p. 139); "pitch patterns of a word in a lower key are identical to those in a higher key, except that they are phonetically on a lower pitch; to use a musical analogy, they are transposed down" (Elderkin, 2016, p. 138). It can be phonetically challenging to produce and recognize certain tone sequences in the low part of f_0 range. Some speakers skilfully anticipate register shifts so as to preserve tonal distinctions (Rialland, 2001): otherwise, the register shift whereby tones are "transposed down" can reduce the phonetic space within which tonal differences are realized to such an extent that it becomes difficult to make out the tones. This is apt to lead to tonal neutralization (loss of tonal contrasts in specific morphosyntactic contexts), as in the Malinke example cited above, and thus, in language history, to the creation of new tonal categories.

Lost syllables are another source of tonogenetic processes: tonal reassociation can lead to the appearance of contour tones from combinations of levels, or to the appearance of extra-high or extra-low tones from the phonologization of what used to be mere allotonic differences. A textbook example is provided by the Gur languages Moba and Gulmancema (Rialland, 2001). Phonetically, a H tone is often phonetically raised before a L tone: thus, Gulmancema /^{H}kan/ 'walk' is realized on a higher pitch in the sequence / ^{LM}o ^{H}kan ^{L}di / 'he walked on (sthg)' than in / ^{LM}o ^{H}kan ^{H}di / 'he walks on (sthg)'. This phenomenon does not alter the phonological nature of the tones. But in Moba, a language closely related to Gulmancema, the extra-high positional variant of the H tone acquired contrastive value when word-final vowels were lost. This resulted in the appearance of a new unit in the tonal system: an extra-high tone (see Table 8). For greatest clarity, two different transcriptions of tones are provided: in Africanist notation, and, in brackets, with tones in superscript before the syllable to which they are attached.

Table 8. Comparative data bringing out the origin of extra-high tone in Moba. Data and analysis from Rialland (2001, p. 317). XH = extra-high.

gloss	Gulmancema	Moba
he walked on (sthg)	õ kándì (^{LM}o ^{H}kan ^{L}di)	ũ ka̋nt (^{LM}u ^{XH}kant)
he walks on (sthg)	õ kándí (^{LM}o ^{H}kan ^{H}di)	ũ kánt (^{LM}u ^{H}kant)

This is a classical example of transphonologization (transfer of distinctiveness), from the tone of the final syllable to the preceding tone. Allophonic variation paves the way to phonological change; the change itself (modifying the tone system) results from the loss of final vowels.

5. Concluding Perspectives

Current research topics include (i) establishing the tonogenetic processes which have been at play in the many tone systems whose origin remains uncertain, (ii) reaching ever greater precision in the description and modelling of attested tonogenetic processes: their phonetic underpinnings and their phonological conditioning, as well as (iii) relating the diversity of diachronic scenarios to the great synchronic diversity of the world’s tone systems.

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Notes

[i] Some authors (e.g. Diffloth, 1989, p. 146; Thurgood, 2002, p. 335, 2007, p. 265) conflate tonal categories B and D, listing together their respective etymological sources, glottal stop and oral stop final. From there it is only a short step to attribute to Haudricourt the opinion that stop finals are the direct ancestor of the B tone. Such a misrepresentation of Haudricourt's model tends to find its way into textbooks, such as the "Tonogenesis" chapter of *The Blackwell Companion to Phonology* (Kingston, 2011, p. 2311). Although phonetically close, these tones are not identical (Brunelle, Nguyễn, & Nguyễn, 2010; Michaud, 2004).