A Typological Overview of Consonant Mutation

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Consonant mutation describes a system of alternation between consonant phonemes that is not predictable based only on the phonological environment. An oft-cited example comes from the West African language Fula, in which the initial consonant of nouns can change from singular to plural.

sg.	*pl.*	
gor-ko	wor-ɓe	'man'
mbaal-u	baal-i	'sheep'
haak-o	kaak-e	'leaf'

What follows is a typological survey of consonant mutation in the world's languages. We will begin by giving an overview of the various phenomena that have been called consonant mutation in the literature, along with a brief discussion of the proposed synchronic analyses of each phenomenon and, where possible, its diachronic origins. We will then explore the various ways in which these mutation systems differ from each other, and establish a set of descriptive properties that will be useful in categorizing consonant mutation phenomena.

1 Consonant mutation in the world's languages

It is often remarked that consonant mutation is a rare phenomenon in the world's languages (e.g. Iosad 2010: 127). It is nonetheless noteworthy that unlike some other linguistic rara, mutation systems have developed independently in almost all corners of the world. In discussing these systems it will be useful to establish some basic terminology. The linguistic entity responsible for inducing mutation in a consonant is known as the *trigger*. It will be seen that this trigger can be a lexical item, an affix, a morphological category, or even a specific syntactic configuration. The set of consonants that can appear alongside a trigger or set of triggers is known as a *mutation grade*. Sometimes the consonants of a mutation grade are characterized by some shared phonetic property, though this is often not the case. The set of consonants that can alternate between each other is known as a *mutation series*. There will always be as many members of each series as there are mutation grades; for example, a three-grade mutation system will have series consisting of three consonants, e.g. /w~b~mb/ and /f~p~p/. Mutation systems are here represented in a tabular fashion, with each row representing a grade, and each column a mutation series.

1.1 Celtic

1.1.1 Irish

The most frequently cited systems of consonant mutation are found in the Celtic languages. All Insular Celtic languages (Irish, Scottish Gaelic, Manx, Welsh, Breton, and Cornish) exhibit alternations in initial consonants triggered for the most part by a preceding grammatical word or morpheme. The nature of the alternations themselves varies markedly from language to language, involving changes in continuancy, voicing, nasalization, and to a lesser degree place. Irish (Ní Chiosáin 1991) exhibits a three-grade mutation system, generally described as the result of two mutation processes which can operate on an unmutated consonant:

lenition, which has the effect of spirantizing, voicing, or otherwise weakening a consonant, and "eclipsis" (also known as nasalization) which voices or nasalizes a consonant.

unmutated	p p^j	t t^j	k c	b b^j	d d^j	g ɟ	m m^j	s ʃ	f f^j
lenition	f f^j	h h^j	x ç	w v^j	ɣ j	ɣ j	w v^j	h h^j	Ø Ø
eclipsis	b b^j	d d^j	g ɟ	m m^j	n n^j	ŋ ɲ			w v^j

Figure 1: Mutation grades of Irish

As indicated by the blanks in the above chart, eclipsis does not trigger any change in some phonemes. Eclipsis also has the effect of adding a prothetic /n/ or /n^j/ to vowel-initial roots. Besides the unmutated phonemes given, words can underlyingly begin with /n, n^j, r, r^j, l, l^j/, and these are never effected by either process.

Mutation is lexically triggered by certain high-frequency words on a following content word. Triggers include prepositions, articles, possessive pronouns, numerals, and forms of the copula. Each such lexical item is associated with a particular mutation grade, completely independent of the segments contained within that word. An example involving numerals (Ní Chiosáin 1991: 18, 74):

(1) t^jax 'a house'
t^jr^ji: h^jax 'three houses'
ʃaxt d^jax 'seven houses'

'Three' is lexically specified for assigning lenition, and 'seven' eclipsis. In some cases mutation is triggered to mark some morphological category, even in the absence of a preceding morpheme. Most notably, preterite, imperfect, and conditional verb forms exhibit lenition, originally triggered by a preverbal particle which is preserved only in the Munster dialect (Hickey 1995). In addition, compounding and all instances of prefixation trigger lenition in the second morpheme (Ní Chiosáin 1991: 30).

1.1.2 Welsh

The situation in Welsh (Morris Jones 1913, Ball and Müller 1992) is somewhat more complicated, both in terms of the alternations and the triggers. Welsh initial consonants are subject to three mutation processes: soft mutation induces voicing or frication, nasal mutation induces nasality, and spirant mutation (also "aspirate mutation") induces frication of voiceless stops. There is a further 'mixed' mutation grade, described as the result of spirant mutation on voiceless stops, and soft mutation on other consonants.

unmutated	p	t	k	b	d	g	m	ɬ	r̥
soft	b	d	g	v	ð	Ø	v	l	r
nasal	m̥^{h}	n̥^{h}	ŋ̊^{h}	m	n	ŋ			
spirant	f	θ	x						
mixed	f	θ	x	v	ð	Ø	v	l	r

Figure 2: Mutation grades of Welsh

As in Irish, mutation is commonly triggered by a preceding word. In the following examples (Ball and Müller 1992: 1), three of the possessive pronouns differ phonologically only in the mutation that they assign:

(2)	i kaθ	'their cat'	(no mutation)
	i gaθ	'his cat'	(soft mutation)
	və ŋ̊ʰaθ	'my cat'	(nasal mutation)
	i xaθ	'her cat'	(spirant mutation)

In addition to lexically specific triggers, certain inflectional information on a preceding word can act as the trigger for mutation. For example, adjectives undergo soft mutation when preceded by a feminine singular noun. There are also morphologically-conditioned mutations where no preceding word acts as an overt trigger, for example mixed mutation is triggered on any negated verb. Mutation can in addition be triggered by syntactic factors; e.g. soft mutation is triggered on the first word after an immediately post-verbal constituent (Iosad 2007: 2).

(3a)	gwɛl-ʊɨd	**d**raig	[ar ə mɨnɨð]
	see-IMPERS.PST	dragon	on the mountain
	'a dragon was seen on the mountain'		

(3b)	gwɛl-ʊɨd	[ar ə mɨnɨð]	**ð**raig
	see-IMPERS.PST	on the mountain	dragon
	'a dragon was seen on the mountain'		

1.1.3 Synchronic analyses

Most analyses of Celtic languages attribute mutation to abstract phonological entities which are associated with the triggering word or morpheme. One solution is to take each mutation as triggered by an abstract phoneme located at the end of lexical items which trigger mutation. This analysis is proposed by Hamp (1951) for Celtic languages in general. In the case of Irish, a phoneme /L/ induces lenition, and /N/ induces eclipsis. Thus, the word *mo* 'my' which triggers lenition, is underlyingly /moL/. This approach has been criticized for proposing a phoneme which fails to surface in environments where is has no reason not to; for example, Scottish Gaelic has no prohibition on word-final nasal consonants, so why should /N/ fail to surface when it is utterance-final? Furthermore, why should word-final /N/ trigger mutation, while other word-final nasal consonants do not (Stewart 2004: 43)? Other proposals avoid this problem by assuming that the trigger of mutation is not a full phoneme, but rather some less-than-phonemic phonological entity such as a floating feature (Lieber 1983) or an "anchored autosegment" which is only partially featurally specified (Swingle 1993). As in Hamp's proposal, these phonological entities are underlyingly present at the end of words which trigger mutation.

A somewhat different approach is to simply associate individual lexical items with a diacritic feature that signals the application of a mutation process on a following word (Oftedal 1962). Under Oftedal's analysis, Hamp's /moL/ is represented as /mo^{L}/. This feature is not part of the phonology of the word, and thus is not linearized with respect to the phonemes of the word. As such, the phonological effects of mutation are not the result of the interaction of phonological features between morphemes. In addition, Oftedal allows these diacritics to be associated with particular morphological and syntactic constructions, rather than only lexical items. Focusing on the syntactic conditioning of mutation, Iosad (2007, 2008a, 2010) argues for a similar sort of analysis, whereby mutating roots have multiple underlying allomorphs which are lexically inserted during the course of the syntactic derivation. This sort of analysis can still attribute the mutation patterns themselves to phonological processes (as in Ní Chiosáin 1991), the application of which is signaled by the triggering context; but the environment for these changes is completely divorced from phonology. The basic distinction is thus between analyses which attribute mutation to some phonological entity in the input which triggers a phonological process, and those that see the phonological alternations as effectively pre-defined, with the different allomorphs of a given morpheme determined by its morphosyntactic environment.

1.1.4 Diachronic origin

The ultimate origin of mutation in Celtic languages is well understood. In each language, certain regular sound changes which operated within words operated also across word boundaries between especially "tightly-bound" pairs of words. In essence, each modern mutation process is the direct result of a regular historical sound change. Morris-Jones (1913: 161-176) gives an account of these sound changes in Welsh. The soft mutation is the result of lenition in the environment between a vowel and a following vowel or sonorant; thus, words ending in a vowel triggered the soft mutation in a following word. The nasal mutation is the result of the assimilation and subsequent fusion of a nasal with a following consonant. The spirant mutation is the result of the spirantization of voiceless geminate stops (*pp, *tt, *kk > f, θ, x). The source of these geminates was in many cases the assimilation of an obstruent to a following stop, so that words ending in an obstruent such as **ak* > *a* 'and' became triggers of the spirant mutation (Ball and Müller 1992: 63). In Irish, lenition mutation was the result of intervocalic lenition, and nasal mutation (eclipsis) the result of nasal fusion, though the nasal was saved pre-vocalically. Regular degemination avoided the creation of a fourth mutation grade as in Welsh (Hickey 1995: 12). In summary, mutation arose in Celtic languages when the initial consonant of roots underwent a regular sound change in the environment of the final vowel or consonant segment of the preceding word. The identity of these final consonants can be determined with a high degree of certainty using comparative evidence from other IE languages. Because these consonants were 'swallowed up' by the regular sound changes, and final vowels were often subject to deletion, the resulting alternations were rendered completely phonologically opaque.

After the establishment of mutation as a grammatical system of alternation, it was subject to various analogical pressures. For example, because most feminine singular nouns were at one point vowel-final in Welsh, they triggered soft mutation. After these final vowels were lost, soft mutation was taken as a general marker of a preceding feminine singular noun, and extended to cases in which the noun was not historically vowel-final (Morris-Jones 1913: 176). Individual lexical triggers can also undergo changes in the mutation they assign. For example, Irish *ocht* 'eight' triggers eclipsis, despite having never ended in a nasal historically. This is due to the influence of the surrounding numerals 'seven,' 'nine,' and 'ten,' all of which were historically nasal-final, and thus triggered eclipsis by regular sound change (Windisch 1882: 29).

1.2 Numic

The Numic languages (Uto-Aztecan) of the western United States make use of systems of morpheme-initial consonant mutation. The best-known example is that of Southern Paiute, as described by Sapir (1930). In root-medial position, there is a phonemic contrast between the spirantized, geminated, and nasalized series of consonants. Word-initially, a subset of consonant phonemes is encountered, represented by the "underlying" grade in Figure 3. However, when preceded by another morpheme within the same word, whether due to affixation or compounding, the morpheme-initial consonant will appear in one of the three other grades.

underlying	p	t	k	k^w	ʦ	s	m	n
spirantized	β	ɹ	ɣ	$ɣ^w$	ʦ	s	$ŋ^w$	n
geminated	pp	tt	kk	kk^w	tʦ	ss	mm	nn
nasalized	mp	nt	ŋk	$ŋk^w$	nʦ	s	mm	nn

Figure 3: Mutation system of Southern Paiute

As the underlying grade is never contrastive with the other three, there is in fact only a three-way contrast possible for the initial consonant of each morpheme, which is neutralized to the underlying grade when word-initial. For the most part, the grade of the initial consonant is lexically determined by the preceding morpheme within the word. In Sapir's words, "...for the purposes of derivation and composition one needs to know always whether a given stem or suffix is one that spirantizes, geminates, or nasalizes" (1930:63). Thus, when the verbalizing suffix *-ka* is added to different nominal roots, the grade of its initial consonant is dependent on the preceding root, each of which arbitrarily assigns a particular mutation grade.

(4)	aŋka-ɣa	'to be red'
	kutʦa-kka	'to be gray'
	paɨ-ŋka	'to be smooth'

There are however some complications to this system. Some suffixes appear consistently in a particular grade, regardless of the preceding stem, e.g. *-βaa* 'future,' and *-kka* 'plural subject.' In compounds, the second member often exhibits the geminated grade even when the preceding root calls for some other grade, e.g. *aŋka-ppayɨ* 'red-fish = trout,' despite *aŋka* being a spirantizing root (Sapir 1930: 70). Certain postpositions mutate based on the animacy of the preceding noun, disregarding the noun's inherent mutating effect (Press 1980: 45).

A very similar system to Southern Paiute's is found in the closely related Chemehuevi language (Press 1980). Unlike in Southern Paiute, mutation in compounding is apparently regular, but Chemehuevi has its own set of notable exceptional conditions on mutation. For example, "In Chemehuevi... the form of the past tense suffix *-vɨɨ* ~ *-mpɨɨ* is determined (for some verbs) by whether the verb is to be interpreted as inchoative or not" (Press 1980: 45). Other Numic languages exhibit similar three-grade mutation systems, though often involving different featural mutations, such as preaspiration in Tümpisa Shoshone (Dayley 1989) and Comanche (Armagost 1989). The Comanche system is notable for involving far fewer alternations than most of its relatives. As described by Armagost, only the five stops undergo any alternation, and of these only the labial and coronal stop alternate with a sound in the 'voiced spirant' series.

stop	p	t	ʦ	k	k^w
presaspirated stop	^hp	^ht	$^hʦ$	^hk	$^hk^w$
voiced spirant	β	ɾ			

Figure 4:Mutation system of Comanche

Furthermore, in most analyses of the language, including Armagost (1989), the preaspirated stops are analyzed as sequences of two phonemes, /h/ and a stop. Thus, it could be argued that morphemes which trigger preaspiration simply end in /h/, which would reduce the true mutation system to a /p ~ β/ and a /t ~ ɾ/ series.

1.2.1 Synchronic analyses

There are two basic approaches to analyzing Numic consonant mutation, which are in effect quite similar to each other. The first is to assign a feature to each morpheme which determines which mutation it triggers. Whether this feature is linearized with respect to the phonemes of the morpheme in question varies by analysis. Sapir (1930) employs this analysis for Southern Paiute, and Press (1980) argues for a featural analysis of Chemehuevi mutation. The other strategy is to attribute mutation to abstract morpheme-final consonants which are simply unrealized in word-final position. Under this analysis, nasalization is triggered by a preceding nasal consonant /N/, and gemination by a stop /T/. Dayley (1989) analyzes Tümpisa Shoshone in this way, giving words like /sikkih/ = [sikki] 'right here' (triggering preaspiration) and /ümatün/ = [ɨw̃arɨ] 'rain' (triggering nasalization). Chomsky and Halle (1968) analyze Southern Paiute mutation in this way. Press (1980: 41) summarizes the various representations of spirantizing, geminating, and nasalizing morphemes in Southern Paiute under three different analyses.

	Sapir	Nichols	Chomsky & Halle		
spirantizung	na^{s}-	na-	na-	[na]	'reflexive'
geminating	pɨŋka^{g}-	pɨ"ka'-	pɨNkaT-	[pɨŋka]	'keep on'
nasalizing	nɨ^{n}	nɨ"	nɨN	[nɨ]	'person'

Figure 5: Various analyses of Southern Paiute mutation

Sapir makes use of non-linearlized features associated with each root, Nichols (1973) makes use of linearized final features (<"> causes nasalization, <'> causes gemination, spirantization is automatic intervocalically), and Chomsky and Halle employ abstract phonemes. Because in Numic languages (unlike in Celtic) mutation always operates in the presence of a preceding morpheme, whatever abstract phonological entity is responsible for mutation can be safely docked at the right edge of morphemes which are otherwise composed of pronounced phonemes. For this reason, the featural and segmental analyses of Numic mutation seem rather less abstract than the phonological-trigger analyses of Celtic discussed in section 1.1.3.

1.2.2 Diachronic origin

For any given Numic language, it is easy to imagine that its system of mutation arose somewhat recently, and even from internal reconstruction on that single language, a historical account in line with the synchronic segmental-trigger account would be straightforward. For example, for Southern Paiute we could propose that morpheme-final consonants were abundant at an earlier stage, and when these consonants came in contact with a following morpheme-initial consonant, the cluster underwent some fairly simple sound changes. A coda stop would combine with a following consonant to yield the geminate series, a coda nasal would give rise to the nasalized series, and no coda consonant at all would yield the spirantized series, as the initial consonant of the following morpheme would be in an intervocalic environment. Similarly, in

Comanche a coda laryngeal consonant, perhaps simply [h], could trigger preaspiration of the following consonant, and so forth. These coda consonants need simply be subject to word-final deletion, as proposed in Dayley's (1989) synchronic analysis of Tümpisa Shoshone, and we would be left with the modern mutation systems. That many of these mutation systems are so amenable to synchronic analyses whereby mutation is triggered by an abstract phoneme might tempt us to assume that not long ago, these phonemes were synchronic realities, realized as a consonant segment in all contexts. Comparing a more limited mutation system like Comanche's to a more robust system like Southern Paiute's, we could hypothesize that Comanche is more conservative, simply having undergone less sound changes involving these coda consonants.

While it is almost certainly the case that the ultimate origins of mutation in the Numic languages can be attributed to these sorts of segmental interactions, such a naive mapping of the synchronic segmental-trigger analysis to a historical explanation is anything but straightforward. As it turns out, these elusive coda consonants cannot be reconstructed to Proto-Numic, where a system of mutation must have already been in place (Babel et al. 2013).

lenis[1]:	*p	*t	*ʦ	*k	*k^w	*s	*m	*n	*ŋ	*w	*y
fortis:	*pp	*tt	*tʦ	*kk	*kk^w	*ss	*mm	*nn	*ŋŋ		
nasal:	*mp	*nt	*nʦ	*ŋk	*ŋk^w					*ŋw	*ɲy

Figure 6: Proto-Numic mutation system

Furthermore, the sound changes affecting morpheme-initial consonants are in many cases not what we would assume given the synchronic alternations. For example, the preaspirated series of Central-Numic languages like Comanche and Tümpisa Shoshone is *not* the result of an earlier morpheme-final [h]-like segment, but arose from the earlier geminate series by a stress-conditioned sound change, as demonstrated by Miller (1980). McLaughlin (1992) convincingly shows that the relatively limited mutation system of Comanche evolved from an earlier system with much more robust alternations, and thus a system like Southern Paiute's is in fact more conservative when compared with the proto-language.

Even in the earliest identifiable ancestor of Numic, Proto-Uto-Aztecan (PUA), spoken 3000-5000 years in the past (Hill 2001), the hypothesized coda consonants responsible for mutation cannot be reconstructed. Whorf (1935), in his treatment of PUA writes, "...we can divide final vowels into two classes, "ordinary" or spirantizing and those which exert an "antispirantizing" influence." He goes on to note that these "antispirantizing" vowels are of two types, nasalizing and non-nasalizing. Whorf proposes that these three classes of vowels are the result of the earlier existence of coda consonants, and that "these final and unknown consonants disappeared but left their reflexes in anti-spirantizing and nasalizing powers attendant upon certain final vowels in daughter languages." He represents these different vowels as *V, *V^x, and *V^n; essentially describing the same system for PUA as is attested in modern Numic languages. Hale et al. (1962) come to the same conclusion, using the symbols *V$_s$, *V$_n$ and *V$_u$. Thus, the ultimate historical origin of mutation in Numic remains elusive.

1.3 West Africa

Systems of initial consonant mutation are encountered in the West Atlantic languages of West Africa, as well as many of the nearby Mande languages. Initial consonant mutation is also

[1] The lenis stops were likely allophonically voiced and perhaps spirantized in intervocalic position.

a feature of some Senufo languages, which Carlson (1994) attributes to the fact that "*nasal+voiceless obstruent clusters of the proto-language are realized as voiced obstruents" (140), but these will not be explored further here.

1.3.1 West Atlantic

A number of West Atlantic languages of Senegal and Guinea use systems of initial consonant mutation to mark noun class in the nominal system, and various inflectional categories in the verbal system. Mutation systems are found in Fula and its closest relative Sereer, the Tenda languages (Konyagi, Basari, and Bedik), Biafada, the two Buy languages (Kobiana and Kasanga), and (in a limited role) Wolof.

1.3.1.1 Fula

The most famous system is that of Fula (Arnott 1970, examples from De Wolf 1995), in which an underlying consonant in grade I can alternate with the corresponding grade II or III consonant.

I	b	d	j	g	f	s	h	w	r	y	ʔ/y/w
II	b	d	j	g	p	c	k	b	d	j	g
III	mb	nd	nj	ng	p	c	k	mb	nd	nj	ng

Figure 7: Mutation system of Fula

Roots which underlyingly begin with an implosive, nasal, voiceless stop, or /l/ are invariant. The mutation grade of the initial consonant is determined for nouns by the noun class, which is additionally marked by a suffix. Each noun class consistently triggers a specific grade, for example the *ndi* class triggers grade III, and *ngal* triggers grade II.

	ndi nouns (grade III)		*ngal* nouns (grade II)	
(5)	ngaa-ri	'bull'	gerto-gal	'fowl'
	njum-ri	'honey'	jardu-gal	'pipe'
	kaa-ndi	'lion'	koy-ngal	'foot'
	coo-ndi	'powder'	caƴ-al	'bamboo fence'
	ndoo-ndi	'ash'	dew-gal	'marriage'
	mbom-ri	'girl'	baas-al	'need'

Alternations of initial consonants can be seen when the noun changes class, most often to mark number, diminutives, and augmentatives.

	sg.	*pl.*	*dimin. sg.*	*dimin. pl.*	
(6)	hon-ndu	koll-i	koll-el	koll-oñ	'finger'
	gor-ko	wor-ɓe	gor-gel	ngor-koñ	'man'
	bal-ol	bal-i	bal-el	mbal-oñ	'ridge'
	yees-o	jees-e	jees-el	njees-oñ	'face'
	sekk-ere	cekk-e	cekk-el	cekk-oñ	'cheek'

In the verbal system, agreement with a plural subject triggers grade III.

(7)	*singular*	*plural*	
	rew	ndew	'follow'
	war	mbar	'kill'
	fen	pen	'lie'
	haaɗ	kaaɗ	'be bitter'

This subject need not be adjacent to the verb, or even overtly expressed in the clause.

Fula also exhibits a separate system of mutation in the initial consonants of the noun class suffixes (Churma: 1988). Each nominal root is lexically specified for triggering a certain grade of suffix. There are four suffix grades: stop, continuant, nasal, and zero. For example, the same noun class suffix can appear as *-el, -yel, -gel,* or *-ngel* depending on its base.

(8)	*sg.*	*pl.*	*suffix grade*	
	mol-u	mol-i	zero	'foal'
	ɓalee-wu	ɓalee-ji	continuant	'black'
	ngor-gu	gor-ɗi	stop	'male'
	ndulu-ngu	dulu-ɗi	nasal	'wild pig'

1.3.1.2 Sereer

Sereer initial mutation is somewhat similar to Fula, but sees changes in voicing as well as continuancy and nasality.

I	b	d	j	g	f	h	χ	w	r	ɓ	ɗ	ƴ
II	p	t	c	k	p	k	q	b	t	ƥ	ƭ	ƈ
III	mb	nd	nj	ng	mb	ng	nɢ	mb	nd	ƥ	ƭ	ƈ

Figure 8: Mutation system of Sereer

Underlying (grade I) voiceless stops, nasals, /l/, /y/, and in most cases /s/ show no alternations, but unlike Fula, the implosives alternate with their typologically rare voiceless counterparts in grades II and III. The triggers of mutation are essentially the same as in Fula, but in Sereer noun classes are marked with prefixes or mutation alone, rather than suffixes.

sg.	*pl.*	*dimin. sg.*	
daɓ	a-taɓ	o-ndaɓ	'navel'
o-koor	goor	o-ngoor	'man'
wil	a-bil	o-mbil	'hair'
o-ɓay	xa-ƥay	o-ƥay	'hand/arm'
a-baaƥ	a-baaƥ	o-mbaaƥ	'tree hollow'
mbaal	paal	o-mbaal	'sheep'

As in Fula, verbs undergo mutation to grade III to agree with a plural subject, and unlike in Fula, this is seen even in multi-clausal constructions where the lower verb appears in a non-finite form.

(9)	goor	we	a=	**mb**aaga	**mb**ug	o=	**nd**et
	men	the	3rd	can.pl	want.pl	INF	go.pl

'The men might want to go'

Mutation in Fula and Sereer has been analyzed most often in terms of featural affixes (McLaughlin 1994 for Sereer, Lieber 1987, Wiswal 1989 among others for Fula). Breedveld (1995) proposes abstract segmental prefixes for Fula (e.g. ʔ- triggering grade II), and Paradis (1986) makes use of empty timing slots to trigger the alternations.

1.3.1.3 Tenda languages

The Tenda languages (Basari, Bedik, Konyagi) make use of mutation for similar purposes (noun class in the nominal system and tense and aspect in the verbal system), but are noteworthy in that they do not have a single non-mutating initial consonant; every consonant phoneme in each language will alternate between grades.

I	f	s	ʃ	x	x^w	w	r	y	ɣ	w̃	l	ỹ	ɣ̃
II	p	t	c	k	k^w	b	d	j	g	ɓ	ɗ	ƴ	ŋ
III	p	t	c	k	ng^w	mb	nd	nj	ng^w	m	n	ɲ	ŋ

Figure 9: Mutation system of Basari

This situation is extremely rare, and perhaps unique among mutation systems. Furthermore, there is a very low degree of phoneme overlap between series; that is, a phoneme generally appears in only one mutation series, so that by hearing the initial consonant of a root regardless of the grade, there is rarely any question as to which consonants it will alternate with. Basari exemplifies both of these properties.

1.3.1.4 Wolof

Wolof exhibits what has been described as a “diminished” mutation system in comparison with its neighbors (McLaughlin 1994). In Wolof, initial consonants alternate to mark two morphological processes: the diminutivization of nouns, and the conversion of verbs to nouns.

unmutated	b	d	j	g	(f)	s	Ø
mutated	mb	nd	nj	ng	(p)	c	k

Figure 10: Initial mutation system of Wolof

The /f~p/ alternation does not take place for diminutives. Other initial consonants (voiceless stops, nasals, prenasalized stops, /x/, and voiced continuants) do not alternate. Mutation is productive in diminutive formation, but not in deverbal nominalization. Wolof also exhibits gemination and hardening of root-final consonants triggered by certain derivational suffixes, or in some intriguing cases, the absence thereof.

(10)	*unaffixed*		*causative*	
	jàpp	‘burn’	jafal	‘burn’
	mucc	‘be saved’	musal	‘save’
	àbb	‘borrow’	abal	‘lend’
	tëdd	‘lie down’	tëral	‘lay down’
	dugg	‘enter’	dugal	‘make enter’
	sonn	‘be tired’	sonal	‘tire’

Here, the absence of the causative suffix *-al* triggers gemination of the final consonant. However, these root-final alternations are not productive, and must be lexically specified for a minority of roots in the language. Furthermore, the root-final alternations do not interact with the initial ones, and thus it is not accurate to speak of a three-grade mutation system in Wolof, as is sometimes presented in the literature (e.g. Sapir 1971) — at best there are two independent two-grade systems.

1.3.2 Mande

A two-grade system of initial consonant mutation is found in many South-Western Mande languages, and some Western Mande languages. Mende (South-Western) shows the following alternations (Iosad 2008):

strong	p	t	k	kp	f	s	mb	nd	nj	ng
weak	w, β	l	g, w	gb	v	ʤ	b/ɓ	l	y	w, y

Figure 11: Mutation system of Mende

Nouns, verbs, adjectives, and postpositions are subject to mutation, dependent on their immediate syntactic environment. In verbs, a weak initial consonant is used when it is preceded by an object. Nouns show weak grade when preceded by a possessor noun in a genitive construction, and in the second member of a noun-noun compound. Adjectives and postpositions show weak grade when following a noun. In the following example, weak grade is triggered on the verb only when its object immediately precedes it.

(11a) ngúlɛ́-í mìa ndòpó-ì **kp**àndì-á
oil-DEF FOC child-DEF heat-PERF
'the child has heated the oil'

(11b) ndòpó-ì ngúlɛ́-í **gb**àndì-á
child-DEF oil-DEF heat-PERF
'the child has heated the oil'

Similar systems of alternation are found in other South-Western Mande languages like Loma, Loko, and Bandi (Kastenholz 1996). In others like Kpelle, a simpler system of initial consonant voicing operates to mark morphological categories such as 3rd person singular possession. While synchronic analyses of Mende generally take the strong grade as basic (though see Iosad 2008 for a counterargument), Hyman (1973) demonstrates that the historical development of these systems is the result earlier nasal prefixes (still found in some of the modern languages) which gave rise to the strong grade, while a general process of intervocalic lenition reshaped the un-prefixed weak grade. Tateishi (1990) gives essentially a synchronic version of this historical analysis, attributing Mende mutation to a prefix which surfaces only in the appropriate syntactic contexts.

Some Western Mande languages make use of an altogether different pattern of mutation. Jɔ (Carlson 1993) exhibits initial alternations between a nasal and non-nasal grade:

non-nasal	b	d	r	ʤ	gb	f	s	ʃ	y	w
nasal	m	n	n	ɲ	ŋm	v	z	ʒ	ɲ	ŋ

Figure 12: Mutation system of Jɔ

All voiceless stops are prenasalized in nasal grade. In Jɔ, nasal grade is triggered by lexically-specified preceding nouns (and some pronouns and adjectives). Approximately one fifth of nouns exert this effect, and only when they are "syntactically linked" to the following word. Carlson attributes this mutation to earlier final nasal consonants which were lost in the modern language.

1.4 Bantu

Many Bantu languages of Sub-Saharan Africa exhibit consonant alternations that have been described as mutation. Two unrelated processes are relevant: stem-initial alternations (most commonly nasalization), and stem-final spirantization.

1.4.1 Initial Alternations

1.4.1.1 Nasalization

Most Bantu languages have certain prefixes which nasalize the initial consonant of the stem. The historical prefixes which can trigger this nasalization are the 1st person singular prefix **N*- in the verbal system, and in the nominal system the noun class 9/10 prefix **N*-. In some languages, secondary nasalization arises from the class 1, 3, 4, and 6 prefixes **mu*-, **mu*-, **mi*-, and **ma*- when the vowels of these prefixes are deleted. The resulting nasal alternations are occasionally referred to as consonant mutation in the literature (e.g. Peng 2003 for Kikiyu).

In some Bantu languages, the addition of a nasal prefix is described as the straightforward addition of a nasal phoneme /N/, unspecified for place (Odden, to appear). There are often different allophonic realizations of some phonemes after a nasal, but the nasal behaves very much like a separate consonant, in some cases even functioning as a syllable nucleus. In these languages, NC sequences can simply be seen as consonant clusters. However, in other Bantu languages prenasalized stops are best analyzed as single segments rather than clusters, and thus when a prenasalized stop alternates with some other consonant at the beginning of a stem, it need not be analyzed as the prefixation of a phoneme, but can rather be treated as the replacement of one phoneme with an entirely different one. Herero (R30: Möhlig and Kavari 2008) is one such language, in which the majority of stem-initial consonants alternate with a prenasalized stop when put in noun class 9 (*o*-) or 10 (*oðo*-).

basic	p	t	t̪	k	(h)	ʃ	w	v	r	ð	y	Ø
prenasalized	mb	nd	nd̪	ng	(nʤ)	nʤ	mbw	mb	nd	nd̪	nʤ	ng

Figure 13: Initial nasal alternation in Herero

Some examples (from Möhlig and Kavari 2008 and Kolbe 1883):

(12) *other noun class*		*class 9*	
oʃi-pé	'new'	o-mbé	'new'
oʃi-t̪ít̪í	'small'	o-nd̪ít̪í	'small'
e-andá	'family name'	o-ngandá	'family/house'
oka-ðérá	'little bird'	o-nd̪érá	'bird'
oʃi-re	'long'	o-nde	'long'
oʃi-ví	'bad'	o-mbí	'bad'
oka-hupa	'little calabash'	o-ndʒupa	'calabash'

The nasals /m, n, n̪, ɲ/, fricative /θ/, and in most cases /h/ do not undergo any alternation.

Umbundu (R10: Schadeberg 1982) exhibits a similar system of alternation, but here the voiceless stops alternate with plain nasals (though note /k~h/).

basic	p	t	ʧ	k	v	l	y	Ø
nasalized	m	n	ɲ	ŋ/h	mb	nd	ndʒ	ng

Figure 14: Initial nasal alternation in Umbundu

In the verbal system, a 1st person singular subject or object is marked by nasalizing the initial consonant of the stem.

(13) *imperative*		*1st sg. subj.*	
vàndʒá	'look!'	mbàndʒa	'I look'
làndá	'buy!'	ndànda	'I buy'
yéva	'hear!'	ndʒéva	'I hear'
èndá	'go!'	ngènda	'I go'
pópya	'speak!'	mópya	'I speak'
túma	'send!'	núma	'I send'
cíl̰a	'dance!'	ɲíl̰a	'I dance'
kwátá	'take'	ŋwátà	'I take'

In the nominal system, a number of irregular alternations exist between singular/plural pairs where one is in a historically nasalizing class, e.g. *e-téké* / *olo-néké* 'night(s)' (class 5/10) (Schadeberg 1996). A regular alternation exists when forming agentive nouns in the nasalizing class 1. Note that in the nominal system, /k/ nasalizes to /h/, rather than /ŋ/ as in the verbal system.

(14) *root*		*agentive noun*	
-pónda	'slay'	ó-móndi	'murderer'
-túnga	'construct'	ó-núngi	'inhabitant'
-cítiwà	'be born'	ó-ɲítiwe	'native'
-kémba	'lie'	ó-hémbi	'liar'

1.4.1.2 Class 5 alternations

Some Bantu languages exhibit initial alternations that are not the result of nasalization. In Luganda (JE15: Clements 1986), the class 5 prefix, used in forming augmentatives, results in the gemination and in some cases hardening of stem-initial consonants.

(15)	*noun root*	*augmentative*	
	-kubo	-kkubo	‘path’
	-tabi	-ttabi	‘branch’
	-bala	-bbala	‘spot’
	-sajja	-ssajja	‘man’
	-fumu	-ffumu	‘spear’
	-langa	-ddanga	‘lily’
	-yinga	-jjinga	‘stone’
	-wanga	-gg^{w}anga	‘nation’

In Shona (S10: Fortune 1980: 50), the phonological exponent of class 5 is simply the voicing of an initial /p, t, k, pf, ʧ, ʦv/.

(16)	*class 5 (sg.)*	*class 6 (pl.)*	
	ɓángá	ma-pángá	‘knife’
	ɗangá	ma-tangá	‘pen for animals’
	goré	ma-koré	‘cloud’
	bveni	ma-pfeni	‘baboon’
	ʤírá	ma-ʧírá	‘cloth’
	ʣvaʦváʦva	ma-ʦvaʦváʦva	‘spider sp.’

When used to form augmentatives, this prefix induces voicing in an even wider range of consonants: /ʦ, f, s, ʃ/, in addition to those listed above.

(17)	*augmentative (cl. 5)*	*root*	
	ʣíru	-ʦíru	‘big, fat heifer’
	bvuro	-furo	‘large amount of grass’
	ʣíkaná	-síkaná	‘large girl’
	ʤiri	-ʃiri	‘large bird’

Voicing of initial consonants as the mark of class 5 is also found in Aka (C104: Akinlabi 2011), spoken at the opposite extreme of the Bantu-speaking area.

1.4.1.3 Synchronic analyses

It is standard in the Bantu literature to treat initial nasalization as the result of a prefix of the form *N*-, even in languages where prenasalized stops are analyzed as single segments (e.g. Peng 2013). Though not often stated in these terms, this is essentially an abstract phoneme-trigger analysis of the same sort used by Hamp for Celtic. Other analyses intentionally avoid proposing a segmental prefix, describing the alternations as the substitution of one phoneme for another. In describing what is essentially the same process in Umbundu and Herero, Schadeberg (1982) identifies a segmental prefix *N*- in Umbundu, and terms the resulting prenasalized stops “consonant clusters,” whereas Möhlig and Kavari state for Herero, “When nouns and adjectives are constructed in class 9/10, a stem initial consonant is substituted by its homorganic pre-nasal” (2008: 36). These alternations could also be analyzed as the affixation of a nasal feature, which is perhaps the spirit by which *N*- is to be interpreted in some analyses. For the class 5 gemination in Luganda, Clements (1986) proposes that the class 5 prefix is a mora, to which the initial consonant of the stem is linked by a general phonological process of the language. For Shona, Lafon (1994) analyzes the class 5 prefix as having a featural allomorph *V[oice]-*.

1.4.1.4 Diachronic origin

In the case of initial nasalization, prefixes consisting of a single homorganic nasal segment can be reconstructed for the class 9/10 marker and the 1st person singular marker (Schadeberg 2003). Because Proto-Bantu roots were all consonant-initial, it is impossible to know what the un-assimilated value of this nasal would have been at some earlier stage. In the case of Umbundu, some of the *N-* prefixes which trigger nasalization can be traced back to an original **mV-* prefix, as in the class 1 prefix **mu-* responsible for nasalization in agentive nouns, which survives as /mu-/ in most of the surrounding languages.

The origin of the initial alternations in class 5 can be attributed to sound changes triggered by the original class 5 prefix **į-*. The exact phonetic nature of this so-called "super-high" vocalic segment is disputed, but it was certainly a high front vowel which was likely accompanied by frication of some sort (Maddieson 2003). In Luganda, it developed first into a glide, perhaps simply [j], and then this segment assimilated to a following consonant. It is retained as a glide in closely related languages, c.f. Lusoga *e-i-gumba* = Luganda *e-ggumba* 'bone' (Clements 1986: 64). In Shona and Aka, this same original prefix is ultimately responsible for the voicing of following consonants, though the pathway by which **į-* came to uniquely voice consonants in these languages has to my knowledge not been explored.

1.4.2 Spirantization

Many Bantu languages exhibit stem-final spirantization of consonants before the causative suffix **-į*, and in some cases also the agentive **-į*, adjectival **-ų*, and perfective **-įd-e*. This process is commonly referred to as consonant mutation in the literature (see Zoll 1995). The effects of mutation in the causative can be seen in Bemba (M42: Hyman 2003: 54) as a change of /p, b/ to /f/ and /t, l, k, g/ to /s/.

(18)	*stem*	*causative stem*	
	leep-a	leef-y-a	'be long'
	lub-a	luf-y-a	'be lost'
	fiit-a	fiis-y-a	'be dark'
	lil-a	lis-y-a	'cry'
	buuk-a	buus-y-a	'get up'
	lúng-a	lúns-y-a	'hunt'

Other languages exhibit somewhat different patterns: in Luganda (JE15: Hyman 1997) /t, k/ become /s/, and /l, g/ become /z/ before *-y* 'causative,' *-i* 'agent,' and *-y-e* 'perfective.' As the /y/ in these suffixes is not pronounced after /s, z/, mutation is the sole exponent of the causative in /t, k, l, g/-final roots. The adjectival suffix *-u* triggers a different mutation pattern whereby /p, t, k/ become /f/, and /b, l, g/ become /v/. Crucially, these mutations cannot be considered an automatic result of the following high vowel, as other suffixes containing high vowels do not trigger mutation.

Zoll (1995) analyzes these mutations in terms of consonantal features on the vowel of the mutating suffix, which are spread to the preceding root-final consonant. Thus, a vowel /i/ can be given two featural specifications, one for a 'normal' vocalic segment, and one for a "consonantal" vowel inducing mutation. This synchronic analysis in many ways parallels the historical origin of these mutation patterns. The original phonemic distinction between the super-high vowels *į and *ų, which were likely produced with accompanying frication, and the plain high vowels **i* and **u* was lost on the vowels themselves, merging to /i, u/ in the languages in question, but the spirantizing effect of the super-high vowels on the preceding consonants was maintained even after the vowels themselves lost their frication.

1.5 Austronesian

Many Austronesian languages have developed stem-initial consonant alternations resulting from prefixes which historically (and often synchronically) contained nasals. Most of these alternations are treated as simple sandhi processes subsumed under the general term "Nasal Substitution," and are not considered consonant mutation in the literature. However, the Central Vanuatu languages as well as the Nias language of Sumatra have developed clear systems of consonant mutation.

1.5.1 Nasal Substitution

Blust (2004) gives an extensive overview of Nasal Substitution in Austronesian languages. These patterns arise when a nasal-final prefix, most commonly one descended from Proto-Austronesian **maŋ-* 'active verb' or **paŋ-* 'agent/instrument,' precede a consonant-initial root. A commonly cited example is that of Malay/Indonesian, in which root initial /p, t, s, k/ appear to be replaced by a homorganic nasal /m, n, ɲ, ŋ/ when prefixed with *meŋ-* 'active verb,' e.g. *pukul* → *me-mukul* 'to hit.' Before other consonant-initial roots, the final nasal of this prefix either assimilates or is deleted depending on the consonant. Before vowel-initial roots, it surfaces as /meŋ-/ (*ikut* → *meŋ-ikut* 'to follow'), and before monosyllabic roots as /meŋe-/. Because /ŋ/ is preserved as an overt consonantal segment in these environments, there is no mystery as to why many initial consonants are nasalized. Phonological rules of assimilation and deletion affecting /ŋC/ sequences can account for the root-initial consonant alternations, and as such they are to my knowledge never considered to be consonant mutation.

1.5.2 Central Vanuatu

A large number of the languages of Central Vanuatu exhibit a system of initial consonant mutation that cannot be analyzed synchronically as the phonological interaction of two segments. Crowley (1991) provides an excellent overview of these systems, along with a discussion of their historical origin. These languages make use of a two-grade mutation system for verbal roots, whereby certain morphosyntactic categories are marked by mutating the initial consonant of the verb. Taken as a whole, these two grades can be termed oral and nasal, but as these terms are often not particularly accurate in describing the individual patterns of each language, the terms "primary" and "secondary" are employed.

In the Epi languages Lewo, Bierebo, Baki, and Bieria, mutation to the secondary grade is used to mark realis.

primary	v	w	t	c	k	h	
secondary	p	p^w					(Lewo)
secondary	p	p^w	nd	nj	nk		(Bierebo)
secondary	mb		c	s			(Baki)
secondary	mb		nd			m	(Bieria)

Figure 15: Mutation systems of Epi languages

Conspiciously, the Epi language Maii exhibits mutation only of /v, t/ to /b, d/, with realis being marked elsewhere by an overt prefix *m-*.

In the closely related languages of Namanamanga and Nakamir, primary grade is triggered on a verb following the conditional marker *pe* (Nam.), *pe/be* (Nak.), intentional marker *ŋa* (Nam.), *pa/pu/ba* (Nak.), imperative marker *p^{w}a* (Nam.), *Ø* (Nak.), nominalizing circumfix *na-/-ana* (Nam.), *na-/-ean* (Nak.), and when used as a modifier or in the second part of a compound.

	Namanamanga				*Nakamir*				
primary	v	w	k	r	v	w	k	r	t
secondary	p	p^w	ŋ	t	b	b	ŋ	d	d

Figure 16: Mutation systems of Namanamanga and Nakamir

In Nāti, secondary grade is triggered by the future tense prefix *a-* and the negative prefix *sa-*. Interestingly, /t/ and /k/ mutate only in active verbs, and not stative verbs.

primary	v	t	r	w	ʔ	k
secondary	mp	nt	ntr	mpw	ŋk	ŋk

Figure 17: Mutation system of Nāti

In each of the above languages, a number of initial consonants are invariant, for example /p, m, n, ŋ, l, s, h/ in Nāti.

1.5.2.1 Historical source

Crowley traces most of these mutation patterns back to a Proto-Central Vanuatu realis marker **m(V)-*. In a few languages like Maii, it is preserved as a segemental prefix, but in most others it has fused with following consonants, yielding the modern mutation patterns. Mutation in some languages carries on the original function of this realis marker, as in the Epi languages. In other languages mutation has developed a more complicated function, as in Namanamanga and Nakamir, but here the morphology that triggers the primary endings would have been roughly those that did not occur with the realis marker at some earlier stage. In some other cases, the source of mutation may not have been the realis marker **m(V)-*. For Nāti, Crowley proposes that an earlier irrealis marker **na* may have come to mark future tense, and then fused with the following verb, resulting in the modern mutation pattern. In an altogether different type of pattern from those described above, alternations of the type *biles~viles~hiles* 'turn' (Southeast Ambrym) can straightforwardly be explained as the development of prefixed forms *ba-hiles, va-hiles* (still found in Paamese).

The fact that so many Central Vanuatu languages make use of superficially similar mutation patterns had led others to propose a system of oral vs. nasal grade mutation for the proto-language. Crowley however shows that it is impossible to reconcile the various phonological developments across these languages with an original mutation system in the proto-language. The development of mutation must have technically been a separate innovation in a large number of sub-branches and individual languages. Crowley admits that, "Given the widespread distribution of patterns of verb-initial mutation in the languages of Central Vanuatu, it is almost too much to expect that systems that seem in very many ways to be so similar should have evolved completely independently since the breakup of Proto-Central Vanuatu" (209). Reconciling the necessity of independent developments of mutation with its widespread distribution, Crowley proposes that the proto-language likely exhibited allophonic alternations triggered by the nasal prefix **m(V)-*; for example, heteromorphemic sequences of **mt*, **mk*, and **mv* may have been pronounced as [md, mg, mb] respectively, but could not have neutralized with the proto-prenasalized stops, which often show completely different reflexes. From this "inherently unstable" starting point, a system of mutation was a natural development. Crowley summarizes, "...there was no original oral-nasal grade alternation, but as a result of a morphophonemic asymmetry that had developed in Proto-Central Vanuatu [...] the descendent languages were in a sense predisposed toward the development of nasal grade-like mutated roots in certain morphosyntactic contexts" (179).

1.5.3 Nias

The Nias language (Brown 1994) makes use of mutation to mark case. The initial consonant of nouns appears in one of two grades depending on its case— unmutated in the ergative, and mutated in the absolutive and genitive, e.g. *siʔo* 'stick (erg.),' *ʤiʔo* 'stick (abs./gen.). Nouns also appear in mutated form as the object of certain prepositions, but not others. Verbs apparently also undergo initial consonant mutation to mark tense, but this is not explained further.

unmutated	t	k	f	s	b	d	r	ʔ	ʔ
mutated	d	g	v	ʤ	mʙ	nr	nr	g	n

Figure 18: Mutation system of Nias

The remaining stem-initial consonants /w, l, m, n, g, h, ʤ/ do not mutate. Whether /ʔ/ alternates with /g/ or /n/ is lexically determined. Historically, certain velar and uvular consonants became /ʔ/, yielding the /ʔ ~ g/ alternation, while originally vowel-initial and ʔ-initial roots gave rise to the /ʔ ~ n/ alternation. Brown proposes that the origin of this pattern can be found in earlier case prefixes containing a nasal segment. For the genitive case, this is Proto-Austronesian **ni*, and Brown assumes that some similar nasal morpheme marked absolutive case at an earlier stage.

1.6 Iwaidja

The Australian language Iwaidja (Evans 1998) exhibits a two-grade mutation system within both verbal and nominal paradigms.

unmutated	m	w	y	ŋ	w	ɹ̣
mutated	b	b	ʤ	k	k	ɹ

Figure 19: Mutation system of Iwaidja

In verbs, mutation marks a 3rd person singular subject on intransitive verbs, as well as 3rd singular objects on transitive verbs (provided the subject is not also 3rd person). In the nominal system, mutation marks the singular of certain lexically-specified nouns, adjectives, and prepositions e.g. *baryun / maryun* ‘young man/men,’ as well as a few noun > noun derivations involving metaphorical extension, e.g. *maŋartalk* ‘flame,’ *baŋartalk* ‘foliage.’

In all cases, mutation can be traced to historical gender prefix **aK-* which is synchronically seen only in the hardening of a following consonant— historically the blocking of intervocalic lenition. An overt gender prefix is used in related languages to mark the same morphological alternations that mutation marks in Iwaidja, and the final consonant of this prefix also causes hardening of following stops. This final consonant surfaces as /w/ in some languages before a vowel, but is otherwise deleted before another consonant, and thus the exact identity of **K* is apparently unknown.

1.7 Uralic

A number of Uralic languages (most Finno-Saamic languages and Nganasan) show morphologically-conditioned medial consonant alternations known in the literature as “consonant gradation.” Medial consonants can appear in either strong or weak grade depending on their morphological environment. The gradation system of Finnish (Pöchtrager 2001) involves geminates weakening to singletons, and voiceless singletons weakening to voiced consonants, or assimilating to preceding nasals, /l/, and /r/. The weak grade of /k/ presents some further complications which will not be detailed here.

strong	pp	tt	kk	p	t	k	mp	nt	nk	lt	rt
weak	p	t	k	v	d	Ø	mm	nn	ng [ŋŋ]	ll	rr

Figure 20: Finnish consonant gradation system

The conditioning of weak grade in Finnish is both phonological and morphological in nature. Gradation only targets stops between voiced segments, and never occurs before a long vowel. Weak grade is often triggered by suffixes that create a closed syllable in which the mutating consonant is the onset, such as the genitive suffix *-n*.

(19)	*nominative*	*genitive*	
	matto	mato-n	‘carpet’
	katu	kadu-n	‘street’
	ranta	ranna-n	‘beach’

However, there are numerous exceptions to this phonological tendency. For example, weak grade is triggered in imperatives (*kerto-a* ‘to tell,’ *kerro!* ‘tell!’), as well as the negative, despite having no overt segmental suffix. Some suffixes which create a closed syllable fail to trigger weak grade, such as the 1st person plural possessive suffix *-mme*.

Finnish consonant gradation is usually regarded as a case where a once-regular phonological alternation is still influenced by phonological factors, but has become obscured by various historical changes to the point that certain morphological constructions must be associated with one consonant grade or the other. However, analyses at two opposite extremes also exist in the literature: Skousen (1971) sees Finnish consonant gradation as completely morphologically conditioned, with speakers simply memorizing various paradigmatic forms rather than being influenced at all by phonology, and Pöchtrager (2001) argues forcefully that consonant gradation is to be seen as an entirely phonologically-conditioned phenomenon, with the apparent exceptions being "illusion[s] resulting from an inadequate model of syllable structure" (32). Nonetheless, even Pöchtager would have to admit that the alternations are only predictable one speakers have learned a number of patterns which are on the surface arbitrary, and thus it seems best to treat Finnish consonant gradation as a form of mutation.

In the Estonian gradation system (Trosterud and Uibo 2005, Gordon 1997), the original phonological conditioning of the alternation is even further obscured, such that segmentally identical case suffixes can trigger different gradations, e.g. genitive *-e* triggers weak grade, but partitive *-e* triggers strong grade. The types of attested alternations between strong and weak grade are also more numerous in Estonian, in part due to the fact that it has developed a three-way length distinction.

strong	ppp	ttt	kkk	ppp	ttt	kkk	p	t	k
weak	pp	tt	kk	p	t	k	v/Ø	j/Ø	j/Ø

Figure 21: Partial Estonian gradation system

These are the possible alternation patterns involving stops when not in consonant clusters. Sonorants and /s/ also mutate, and the mutations of consonants in clusters are somewhat complicated. While alternations within an inflectional paradigm are generally two-way, because of the overlap of consonants in each grade, a strong grade consonant (e.g. /p/) may be interpreted as weak for the purposes of some other morphological operation, and further strengthened, leading to a three-way alternation within a single root. For this reason Estonian is often described as having a three-grade gradation system, though only a two-grade system (strong vs. weak) can be referenced by morphological processes. Some roots exceptionally show no alternations at all.

The historical origin of consonant gradation in Finnish, Estonian, and Saami has been discussed extensively in the literature. Gordon (1997) provides an overview of the traditional account alongside his own historical account. These differ most notably in that the traditional account holds that gradation is essentially the result of a lenition sound change, while Gordon attributes it to fortition. All accounts agree that as a result of certain regular sound changes, there was a phonologically regular alternation between weaker consonants in the onset of closed syllables, and stronger ones in the onset of open syllables. Certain further sound changes and analogical reshapings of this transparent system yielded a more opaque system of alternation in the modern languages, e.g. Estonian *jalk ~ *jalan > jalk ~ jala 'foot (nom./gen.)' after the regular loss of final /n/ (c.f. Finnish *jalka ~ jalan*).

1.8 Nivkh

The Nivkh (Gilyak) language of eastern Siberia exhibits root-initial alternations between stops and fricatives (Shiraishi 2000, 2006).

stop	p^h	p	t^h	t	c^h	c	k^h	k	q^h	q
fricative	f	v	r̥	r	s	z	x	ɣ	χ	ʁ

Figure 22: Mutation system of Nivkh

Underlyingly, stops and fricatives are lexically contrastive root-initially[2], and this distinction surfaces phrase initially (e.g. *xu-* ‘kill’ vs. *k^{h}erqo-* ‘catch’). However, when preceded by another word, this contrast is subject to a phonologically-conditioned neutralization. After a word ending in a vowel, glide, or stop, initial stops become fricatives, and if the preceding word ends in a fricative or nasal, initial fricatives become stops. These alternations can be seen as dissimilatory between two obstruents, and assimilatory between an obstruent and a preceding sonorant or vowel.

(20)	*unmutated*		*mutated*	
	t^{h}om	‘fat’	hɨjk r̥om	‘hare fat’
	kujva	‘ring’	toto ɣujva	‘silver ring’
	ciɣr̥	‘tree’	qoj ziɣr̥	‘larch tree’
	r̥xɨrp-	‘forget’	ɲɨŋ t^{h}xɨrp-	‘forget us’
	xu-	‘kill’	c^{h}xɨf k^{h}u-	‘kill a bear’
	za-	‘beat’	xan ca-	‘beat a dog’

However, this phonological rule of alternation applies only within certain syntactic domains, qualifying the process as consonant mutation rather than a simple phonologically-automatic alternation. Specifically, mutation applies only between a verb and its preceding complement, a noun and its preceding modifier or possessor, and a noun and a postposition, as well as after prefixes and in reduplication. The following two examples exemplify the syntactic contrastiveness of mutation.

(21a)	eɣlɲ	r̥o-	(21b)	eɣlɲ	t^{h}o-
	child	hold		child	hold
	‘the child holds (something)’			‘(someone) holds the child’	

In the first example, mutation does not apply to the verb, as the preceding noun is the subject, whereas in the second, the object noun triggers mutation.

1.9 Mundurukú

The Tupi language Mundurukú (as well as the closely related Kuruáya) uses consonant mutation in much the same way as Nivkh (Picanço 2005). Seven of the language’s 17 consonant phonemes participate in a two-grade alternation between root-initial voiced and voiceless sounds (the alternations in Kuruáya are similar, and not discussed further).

[2] For the most part, nouns are stop-initial, and verbs are cited as fricative-initial, but there an appreciable number of fricative-initial nouns, and a few stop-initial verbs. It is noteworthy that the fricative-initial nouns never undergo mutation, while the few stop-initial verbs do. Shiraishi (2000) proposes that all verbs are in fact underlyingly stop-initial, so that the only active phonological process is spirantization, and never hardening. This is analysis must be historically correct, as transitive verbs were at one point obligatorily prefixed with an object marker *i-* when not preceded by an overt object, which induced post-vocalic spirantization. It is unclear what the explanation is for verbs with stop-initial citation forms.

	Mundurukú			Kuruáya		
voiced	b	d/n	ʤ	b	l [l, ð, ɭ]	d [ɖ, ʤ]
voiceless	p	t	ʧ	p	t	ʧ

Figure 23: Mutation systems of Munduruku and Kuruáya

The trigger of each grade is in part phonological: the voiceless consonants appear after a stop (oral or nasal), and the voiced variants appear elsewhere. The choice of /d/ vs. /n/ is completely dependent on the quality of the following vowel (oral vs. nasal). When phrase initial, only /p, ʧ, d~n/ surfaces, and thus mutation can be seen as voicing of an underlying /p, ʧ/ as well as devoicing of underlying /d~n/.

(22a)	ayáʧát	pətét	(22b)	toʃáw	bətét
	woman	name		chief	name
	'woman's name'			'chief's name'	

However, mutation occurs only in the second of two words or morphemes that are especially closely linked syntactically: a possessor followed by an inalienable noun, a verb and its preceding internal argument, a noun followed by a postposition, any word and a following enclitic particle, a verb with the causative prefix *mə-*, and in compounds. In other syntactic environments, mutation apparently fails to occur, though unfortunately Picanço provides no examples of mutation failing to operate in a relevant phonological environment. Picanço speculates that this pattern originated as the regular intervocalic voicing of /p/ and /ʧ/, and the resulting alternations were spread by analogy to /d/-initial roots.

1.10 Western Nilotic

A number of Western Nilotic languages show mutation of final consonants. An overview is given by Trommer (2011). One characteristic of these mutation systems is a large number of mutation grades, with each grade often specific to a small set of suffixes or constructions. Nuer presents a rather simple system, in which final consonants of both noun and verb roots can appear in three grades (Lieber 1987: 78).

voiced	β	ð	d	ɟ	ɣ
voiceless continuant	f	θ	r̥	ç	h
voiceless stop	p	t̪	t	c	k

Figure 24: Mutation system of Nuer

Underlyingly, final consonants can be in any of these grades, and so there is in truth a fourth "unmutated" grade consisting of most of the consonants found in the other grades. In nouns, mutation is highly irregular, with individual roots exhibiting different grades in the genitive or plural, but apparently with no consistent pattern. In the verbal system, specific mutation grades are assigned by different tense and aspect suffixes; for example, the past participle is associated with mutation to the voiceless continuant grade. Some examples (Crazzolara 1933):

(23)						
		‘overtake’	‘hit’	‘pull out’	‘scoop hastily’	
	infinitive	coβ	ja:ç	guð	kêp	(no mutation)
	neg. pr. ptc.	còp	ja:c	gut̪	kep	(voiceless stop)
	past ptc.	cof	ja:ç	guθ	kɛ̀f	(voiceless continuant)

Lieber analyzes these alternations as the result of the affixation of feature bundles, e.g. [+cont, -voi] or [-cont, -voi] which fill in underspecified root-final segments. Trommer (2011) makes it clear that the root-final consonants must in fact be prespecified for all features to account for the underlying contrasts that surface in unmutated forms (e.g. the infinitive), but supports the featural affixation approach.

A more complicated system is found in Päri (Trommer 2011: 263).

1	p	t̪	t	c	k	m	n̪	n	ɲ	ŋ	r	l	j	w
2.0	b	d̪	d	j	Ø	m	n̪	n	ɲ	ŋ	r	l	j	w
2.1											d	d		
3.0	p	t̪	t	c	k	mb	n̪d̪	nd	ɲɟ	ŋg	jj	nd	jj	ww
3.1											t	t		
4.0	mm	n̪n̪	nn	ɲɲ	ŋŋ	mm	n̪n̪	nn	ɲɲ	ŋŋ	rr	nn	jj	ww
4.1											nn	nn	ɲ	mm(ww)
5	mb	n̪d̪	nd	ɲɟ	ŋg	mb	n̪d̪	nd	ɲɟ	ŋg	jj	nd	jj	ww

Figure 25: Mutation system of Päri

The consonants of grades 2.1, 3.1, and 4.1 differ from those of 2.0, 3.0, and 4.0 only where noted. Each of these eight grades is triggered by a handful of affixes (in some cases a single affix) in the verbal system. The phonological form of the affix does not correspond at all with the triggered mutations, in fact most of the relevant affixes are null. It is unclear whether Päri also exploits mutation in the nominal system, but the related languages Dholuo and Anywa make use of mutation in both the nominal and verbal systems.

Trommer treats all of these mutations as the result of featural affixation, or else the addition or deletion of a mora. In a few cases, he proposes a more or less abstract phonemic suffix. The ultimate historical origin of these alternations has not to my knowledge been determined.

1.11 Chaha

The Ethiopian Semitic language Chaha exhibits a number of morphologically conditioned consonant alternations, termed “sound mutations” by Banksira (2000). Certain derivational and inflectional forms trigger one of two common processes on root consonants: simple palatalization, and labialization with concomitant palatalization. Palatalization can be seen in 2nd person singular feminine verb forms, of which this process is the sole marker (191).

(24)

	stem	*2^{nd} sg. fem.*	
	wat'	wac'	'swallow'
	wɨt'a	wɨc'ə	'go out'
	dak'	dak^{j}'	'laugh'
	t'af	t'ɛf	'patch'
	k'am	k^{j}'am	'eat sth. small'
	faf	fɛf	'scrape'
	kɨtɨf	kɨtif	'hash'

Only coronal and velar consonants can be palatalized. A coronal consonant is palatalized only when it is the final consonant in the stem, though it may not be the final segment (as in 'go out'). A velar consonant, on the other hand, is palatalized even when it is not the final consonant, as in 'eat sth. small.' Only one consonant per word can be palatalized. If more than one palatalizable consonant is present, only the rightmost one is visible to the palatalization process, even if this means that no consonantal change is triggered. For example, in 'hash' the /k/ cannot be considered for palatalization because of the following /t/, which itself cannot be palatalized because it is not the final consonant in the stem.

One inflectional form which makes use of labialization with palatalization is the verbal participle.

(25)

	imperative	*verbal participle*	
	k'əmba	k'əmb^{w}a	'broken at once'
	t'ɨrək'	t'ɨnnɨk^{w}'	'dried a lot'
	a-mɨrt'	m^{w}ɨrc'	'escaped unnoticed'
	mət'ɨs	m^{w}ɨt'ɨʃ	'broken at once by pulling'
	gɨms	gɨm^{w}ɨʃ	'broken in big chunks'
	k^{w}'ənt'ɨs	k^{w}'ɨnt'ɨʃ	'pinched'

Only labial and velar consonants can be labialized, and only the rightmost labializable consonant will undergo the change. If the root contains a final coronal consonant, it will be palatalized. Final velars are not palatalized, as a consonant cannot be both labialized and palatalized, and labialization takes precedence. However, note that the stem-initial velar in 'broken at once' is not palatalized, where it would have been subject to change under simple palatalization. This same labialization+palatalization process accompanies some overt segmental suffixes, such at the deverbal nominalizer *-ə*, e.g. *kɨtɨf* > *kɨtf^{w}-ə* 'dish of hashed meat.'

There is in addition a distinct process of labialization without concomitant palatalization which targets the first non-final labializable consonant, employed only in forming the adjectival/nominal participle, e.g. *m^{w}ɨk-m^{w}ɨk* 'very ripe' from a root √*mk*. Independent of the three processes already mentioned, certain inflectional and derivation forms are marked by the devoicing of root-medial consonants, arising from an earlier process of templatic gemination. Some of the 'devoicing' alternations are not phonetically straightforward, e.g. [r] > [n]. Finally, jussive verb forms trigger depalatalization of underlyingly palatalized root consonants. In total then, Chaha makes use of five distinct processes of morphologically-triggered consonant alternation. But note that in Chaha we are not dealing with a 4 or 5 grade mutation system; rather, there are multiple distinct two-grade systems in operation. These can interact if some morphological environment calls for the application of two distinct mutation patterns; e.g.

devoicing of a root-medial consonant and labialization+palatalization can both be triggered within the same root by certain inflectional forms.

Banksira proposes that palatalization is the result of a suffix beginning with, or consisting entirely of a phoneme /I/, labialization+palatalization is the result of an affix containing /U/, and non-final labialization is the result of an infix /-U-/. These are not in fact meant to be abstract phonemes, but rather /I/ is the same phoneme that surfaces as [j] and [i] within roots, and /U/ is the phoneme underlying [u] and [w]. When appearing in a suffix, but *not* within a root, these phonemes behave somewhat idiosyncratically, in that their root node is deleted, leaving behind floating features: [high] for /I/ and [round] and [high] for /U/. Other analyzes of Chaha (e.g. Akinlabi 2011) treat these processes as the result of the direct affixation of floating features.

Banksira's analysis fits well with the historical origin of these processes, which lies in affixes beginning in a (semi-)vocalic segment. Compare for example the Chaha nominalizing suffix *-Uə* with Amharic *-o*, as in *kɨtf-o* 'hashed meat dish' (c.f. Chaha *kɨtfʷ-ə*), where /o/ is apparently the regular reflex of earlier **wə*. In the case of the proposed infix *-U-*, Amharic exhibits an infix *-u-*; compare Amharic *fɨs'sʼ-u-m* with Chaha *fʷɨc'ɨm* 'absolute' (206). Banksira does not speculate as to whether the palatalization and labialization of non-final consonants is the result of regular sound change or was introduced analogically.

1.12 Sino-Tibetan causatives

A number of Sino-Tibetan languages exhibit devoicing or aspiration of initial consonants in verb stems to signal the causative. Some examples from Burmese (VanBik 1999):

(26)	*stative root*		*causative form*	
	kye	'be ground'	kʰye	'grind up'
	lat	'be bare'	l̥at	'uncover'
	mrup	'be buried'	m̥rup	'bury'

In some languages only a handful of roots show this alternation, but in Burmese it is more robust, with over 50 such stative-causative pairs. Nonetheless, this process is apparently not productive in any modern language. These alternations are the result of the historical causative prefix **s-*.

1.13 Summary of synchronic analyses

Broadly speaking, there are two approaches to analyzing mutation synchronically. The first is to propose some phonological entity which induces mutation in the appropriate contexts. This may be in the form of an independently-existing phoneme of the language (Breedveld 1995 for Fula, Banksira 2000 for Chaha, De Lacy 2008 for Irish and Chaha among others), an abstract or 'defective' phoneme or timing slot (Hamp 1951 for Celtic, Evans 1998 for Iwaidja, Paradis 1986 for Fula), or a floating feature or feature bundle (Trommer 2011 for Western Nilotic, McLaughlin 1994 for Sereer, Lieber 1983). This phonological entity may itself be a morpheme, or else may be part of the underlying representation of morphemes which trigger mutation. These analyses treat mutation as a primarily phonological phenomenon, essentially being the result of the interaction between phonological entities in the underlying representation. This approach is especially attractive in cases where the trigger of mutation is consistently adjacent to the mutating consonant (e.g. Numic, most Central Vanuatu langauges).

The other approach is to use non-phonological diacritic features on triggering morphemes (Sapir 1930 for Southern Paiute, Oftedal 1962 for Celtic), or simply to specify in the grammar the morphological and syntactic environments associated with each mutation grade (Green 2003 for Celtic, Iosad 2007, 2008a, 2008b for Welsh, Mende, etc.). The mutations themselves can either be stated in the form of phonological rules (Ní Chiosáin 1991), or simply prespecified as allomorphy in the lexicon (Green 2003, Iosad 2008a), but in either case mutation is crucially not the result of a phonological trigger. This approach is attractive in dealing with syntactically-triggered mutation, as well as mutation patterns that are seemingly more phonetically arbitrary.

Finally, it seems desirable to clarify two terminological issues. First, there is no substantive difference between the terms “consonant mutation” and “consonant gradation” as used in the literature. The latter term is used consistently for the Uralic languages, but for other systems these two terms are used interchangeably. Second, “consonant mutation” is not to be contrasted with “featural affixation”; indeed almost all cases of mutation have been analyzed as featural affixation somewhere in the literature. Rather, consonant mutation is a phenomenon, and featural affixation is an analysis— one that is often used in analyzing consonant mutation systems, but also phenomena such as ablaut and tonal affixes.

1.14 Summary of diachronic development

In almost all cases (the notable exception being the Uralic languages), systems of consonant mutation arise when a consonant undergoes a regular sound change in the environment of some adjacent segment in another morpheme or word. The historical trigger is either lost in the process (as with Iwaidja), merges with some segment which did not trigger the alternation (as with Bantu spirantization), or else is deleted by a later sound change (as with Welsh soft mutation). Some common sound changes leading to mutation are intervocalic voicing and/or spirantization, assimilation between two adjacent consonants creating a geminate, and nasalization. There are two sources of evidence for the identity of the historical trigger. The best is comparison with related languages, as with Southwest Mande mutation, where some languages preserve the original nasal consonant prefix (section 1.3.2). It is also possible that the triggering sound be preserved in some other environment in the language (often pre-vocalically), as in the case of Irish eclipsis, which results in the epenthesis of an overt nasal segment before a vowel-initial root. Once a mutation pattern is established, it can be reshaped by analogical pressures.

The age of a language’s consonant mutation pattern cannot be reliably determined through internal reconstruction— this can only be achieved through comparison with related languages. We have seen that in Numic languages, the rather phonetically straightforward alternations in any one language might suggest a recent origin for mutation, but in fact mutation must be reconstructed even for the oldest identifiable mother language. On the other hand, the phonetically less transparent alternations of the Central Vanuatu languages led some to assume that a system of nasal mutation existed in the proto-language, but careful examination of the required sound changes suggests that mutation was a parallel but independent development in these languages.

2 Properties of consonant mutation systems

Having seen the various systems of consonant mutation that exist in the world’s languages, we now turn to what is meant by the term “consonant mutation,” what properties these systems share, and in what ways they differ from each other.

2.1 What qualifies as consonant mutation

Consonant mutation is a sub-type of the broader phenomenon of consonant alternation. In order to single out consonant mutation from other instances of consonant alternation, we would ideally have a set of criteria or perhaps a single criterion which is shared among cases of consonant mutation but not other consonant alternation phenomena. Such a set of criteria is, as it turns out, rather difficult to arrive at. The following definitions of consonant mutation are found in the literature:

> Grijzenhout (2011: 37): "a change in one phonetic property of a consonant that affects its degree of sonority and that does not depend on the position of the consonant within a prosodic domain (i.e. neutralization and enhancement phenomena are excluded), nor on the position immediately adjacent to a segment with which it forms a natural class (i.e. progressive and regressive voicing and place assimilations are not regarded as instances of "consonant mutations"). More specifically, the term "consonant mutation" refers to a class of processes by which a consonant turns into a segment with a different degree of voicing, continuancy, or nasality that is not due to neutralization or assimilation to a neighboring segment of the same natural class"
>
> Inkelas (2014): "alternations in [...] consonants that are too complex to be treated as simple assimilation, dissimilation, or contextual neutralization"
>
> Lieber (1983: 72): "mutations are phenomena in which lexical stems exhibit two or more allomorphs that differ only in a single marginal segment [...] and which appear in distinct morphological, syntactic, or phonological environments."
>
> Iosad (2010) for initial consonant mutation: "changes in the first consonant of a word which are not obviously caused by the phonetic / phonological context"

These definitions agree on some basic points, but otherwise seem to describe rather distinct ranges of phenomena. Inkelas and Iosad's definitions are rather vague in some respects, though this is not necessarily a fault. On the other hand, some of Grijzenhout and Lieber's requirements seem too strict— why should internal alternations be ruled out, or those involving place changes or consonant length?

A common criterion, both explicitly stated and implicitly assumed in treatments of consonant mutation, is that the alternations not be purely phonologically conditioned. That is to say, whether or not a consonant alternation is triggered must be arbitrary and unpredictable given only the phonological environment of the consonant in question. This criterion rules out cases of allophony, as these are by definition phonologically conditioned. It also rules out cases of phonologically determined allomorphy. Take as an example the alternation of certain root-final consonants in the Palor language (D'Alton 1984).

(27)	_*V*	*elsewhere*	
	ʔol-	ʔod-	'see'
	law-	lab-	'mount'
	pud-	pun-	'fly'
	xeg-	xeŋ-	'throw'
	vs.		
	wol-	wol-	'send'
	kod-	kod-	'raise'
	ben-	ben-	'accompany'

Whether or not a given root will exhibit any alternation at all must be lexically specified, but in cases where the final consonant can appear in two forms, the choice of allomorph is determined entirely by its phonological environment— one before a vowel, and the other elsewhere.

However, this criterion is by no means straightforward. Whether or not an alternation is conditioned entirely by phonology can depend on one's analysis. We have seen that the most common analysis of mutation systems involves positing phonological entities of some sort that interact with the mutating consonant, and as such, these analyses technically attribute mutation to phonological conditioning. Take Chomsky and Halle's (1968) analysis of Southern Paiute mutation, whereby nasal grade is triggered by an abstract phoneme /N/, and geminate grade by /T/ at the end of a preceding lexical item. If we accept these phonemes as part of the underlying representation, mutation is simply the effect of predictable and rather straightforward sandhi rules between two adjacent consonants. Thus we must constrain the notion of what it means to be "phonologically-conditioned" to cases in which the phonological environment can be stated in terms of *concrete* (i.e. non-abstract) phonological entities.

Even this constrained definition of phonologically-conditioned alternation leaves much room for interpretation. There are broadly speaking three grey areas:

1) Questions of segmentation:

In some cases it is possible to analyze the same sound as either a single consonant or a cluster. We saw that this is often the case with prenasalized stops in Bantu languages (section 1.4.1). As such, the Umbundu prefix *N-* might be taken as a concrete phoneme which surfaces as a nasal in clusters like /mb/, or else an abstract feature which causes one phoneme /v/ to be replaced by another, /^{m}b/.

2) Triggers which sometimes appear as a concrete phoneme:

If the trigger of mutation can surface as a concrete phoneme in some environments while triggering a segmental change in others, is the alternation necessarily disqualified as mutation? This was the reason given for dismissing the cases of Austronesian Nasal Substitution in section 1.5.1. Because the Indonesian prefix *meŋ-* surfaces as /meŋ/ in a form like *meŋ-ikut* 'to follow,' the change seen in *pukul* → *me-mukul* 'to hit' can be seen as triggered by an overt segment /ŋ/ which assimilates to and then deletes the following voiceless stop. However, if this is grounds for dismissing nasal substitution, it could also be used to dismiss Irish eclipsis (nasalization) for the same reason. Recall that eclipsis triggers changes in a following consonant, but also adds a prothetic /n/ or /n^{j}/ to a vowel-initial root. The Irish situation is thus in principle quite similar to that of Indonesian, and De Lacy (2008) argues that eclipsis is in fact the result of a morpheme /n/. Note that in both languages, sequences of a nasal and a following mutable consonant are permitted (Irish *banc* [baŋk] 'bank,' Indonesian *aŋkat* 'to lift'), but these could be explained as non-derived environment effects.

3) Which phonological entities count as abstract?

There will inevitably be disagreement over what qualifies a phonological entity as concrete vs. abstract. A prime example is the mora, which can be used to straightforwardly account for Luganda initial consonant gemination in class 5 (section 1.4.1). The mora is of course in a sense an abstract proposal of phonological analysis, but has very concrete realizations as vowel or consonant length. If cases of moraic affixation are included under the banner of consonant mutation, we must now include phenomena such as Semitic templatic gemination, which are never considered as such in the literature. And yet numerous uncontroversial cases of consonant mutation involve rather straightforward consonant gemination, as in the Numic languages and Biafada (West Atlantic).

While it is by no means easy to evaluate, the above criterion is the *only* one which can be said to be shared among all cases of consonant mutation in the literature. It seems impossible to identify any further criteria which would not result in the disqualification of some phenomenon which is generally referred to as mutation. For example, the alternation between palatal and non-palatal stem-final consonants to mark case and number in both Irish and Russian is generally not cited as consonant mutation. But what disqualifies them? If it is their final position, Western Nilotic mutation is ruled out. If it is the phonetically straightforward nature of their alternations, Nivkh is ruled out, among others. If it is the fact that they operate only within the nominal system, Central Vanuatu mutation is excluded for operating only in the verbal system. If it is the exploitation of only two grades, a whole host of mutation systems are disqualified. This is not to say that all instances of consonant alternation which fit this single criterion must be classified as mutation. However, it is clear that what determines whether a phenomenon falls under the rubric of consonant mutation is not a well-defined set of criteria, but a combination of properties, none of which are necessary to qualify an alternation as consonant mutation. In what follows, we will explore the ways in which mutation systems differ, and will find that some properties are more or less important in determining whether or not a given system is likely to be identified as consonant mutation.

2.2 Nature of the trigger: morphological, lexical, or syntactic

One of the most important ways that mutation systems differ is in the triggers of mutation. This variable provides perhaps the most basic and intuitively useful typology of mutation systems. There are in essence three types of triggers: morphological, lexical, and syntactic.

Morphologically-triggered mutation can be described as mutation that serves the same purpose as an affix, or co-occurs with an overt affix. This is seemingly the most common trigger of mutation cross-linguistically. Examples of morphological categories marked by mutation include (but are not limited to) noun class, tense/aspect, person/number agreement, case, and derivation between parts of speech. It seems that anything that could conceivably be marked with an affix can be marked by mutation. Note that in many cases, an overt affix accompanies mutation, but here mutation can still serve a morphological function by disambiguating otherwise homophonous affixes. The cases of Atlantic, Western Nilotic, Bantu, Chaha, Austronesian, Uralic, and Sino-Tibetan languages all involve morphologically-triggered mutation. Historically, these systems arise when an overt affix triggers some change in its base, and the affixal segments responsible for the sound change are either lost in the process, or lost in a subsequent sound change.

In lexically-triggered mutation, certain lexical items or affixes are inherently associated with a specific mutation grade, and impose this on another word or affix in its vicinity. This differs from morphologically-triggered mutation in that any morpheme (not only a grammatical one) can trigger mutation, and mutation cannot be triggered in the absence of some overt triggering word/morph. Thus, while lexically-triggered mutation can signal the presence of some grammatical morpheme, mutation is never the sole marker of some grammatical category. In theory this would lessen the functional load of lexically-triggered mutation when compared with morphologically-triggered mutation, but it often serves to distinguish otherwise homophonous morphs or lexical items. Note that lexically-triggered mutation may or may not operate across word boundaries; it may only operate between a lexical item and its affixes or between members of a compound, as in Numic. Of course, when the triggers of mutation are primarily grammatical words, as in the Celtic languages, the function of lexically-conditioned mutation can be much the same as morphologically-conditioned mutation. Lexically-triggered mutation is found in Numic, Celtic, Western Mande, Nias (with prepositional triggers only), and Fula (in the case of suffix mutation triggered by the preceding nominal root).

Syntactically-triggered mutation operates only when a word is placed in a certain syntactic configuration. For example, verbs in Mende exhibit weak grade only when immediately preceded by their object, and in Welsh, soft mutation is triggered on the first word after an immediately post-verbal constituent. Note that it is possible for multiple types of triggers to operate within a single language, as in Welsh (section 1.1.2).

2.3 Phonological transparency of the trigger's effect

In most cases, the relation between the trigger and the mutating consonant is completely phonologically opaque. However, this is not always the case. Consider the case of Bantu causative spirantization (section 1.4.2), in which assibilation of a preceding stop is triggered by a causative suffix *-i* or *-y*. Assibilation before a high front vowel or glide is a common process in the world's languages, and thus there seems to be some phonological connection between the shape of the trigger and the mutation induced. The process is in fact opaque, as certain other suffixes beginning with the same sounds do not trigger the mutation, but the relation between the phonological shape of the trigger and the change in the preceding consonant that it induces cannot be ignored. Cases like these are perhaps less likely to be analyzed as mutation, as they by definition involve alternations that seems less phonologically arbitrary.

Nivkh and Mundurukú present another somewhat extreme case in which the trigger for mutation can always be described in terms of the immediate phonological environment. These only qualify as mutation because the regular phonological process is blocked outside of specific syntactic configurations. Thus, when mutation applies in Nivkh and Mundurukú, it is always completely phonologically transparent; only when it fails to apply is there any opacity. Mutation in these two languages is in a way more similar to Japanese Rendaku than to mutation in other languages. It involves a straightforward assimilatory or dissimilatory phonological process, but the domain of its application is restricted to two words which are especially close morphologically (through compounding) or syntactically.

Another important consideration is the position of the trigger with respect to the mutating consonant. The trigger may be adjacent to the consonant, as is often the case with noun class prefixes in Atlantic; non-adjacent, as with Fula initial mutation triggered by noun class suffixes; or completely absent, as with case marking on Nias nouns, which is not accompanied by any overt affix. Systems in which the trigger is adjacent to the mutating consonant are more amenable to analyses in which an abstract phoneme or feature bundle is part of the affix itself.

2.4 Breadth of alternations

Another consideration is how widespread the mutation alternations are within the language. There are three dimensions involved:

1) Number of consonants subject to mutation

In some systems, only a minority of consonants exhibit mutation, as in Lewo, which has only two mutation series, /v ~ p/ and /w ~ p^w/. All other initial consonants are immutable; i.e. they undergo no alternation between mutation grades. At the opposite end of the spectrum, the Tenda languages have no immutable consonants at all. The more immutable consonants the language has, the less useful mutation is in signaling the relevant morphological, lexical, or syntactic information.

2) Number of lexical items subject to mutation

A basic distinction can be drawn between languages in which mutation is productive, and those in which it is not. Especially unproductive cases of alternation are less likely to be identified as consonant mutation at all, such as the voicing of final fricatives in English to signal N>V derivation (e.g. *mouth, house, proof~prove*). Even in productive systems, it is common for certain lexical items (often recent borrowings) to fail to undergo mutation. There is also the related question of which parts of speech are affected by mutation. Some languages exhibit mutation only on verbs or only on adjectives and nouns, while others exploit mutation in both the nominal and verbal system.

3) Number of unique triggers of mutation

In most mutation systems, the same mutation grade is exploited by multiple contexts in the language. A morphologically-triggered mutation system may make use of numerous distinct affixes which trigger the same mutation grade, as with Fula noun class markers, of which eleven trigger a change to grade II, and nine a change to grade III. In other cases mutation is triggered in only a few, or even a single context. For example, the only trigger of mutation in Shona is noun class 5, and the only use of initial devoicing in Burmese is to signal the causative.

Along all three dimensions, systems which show more robust alternations are more likely to be seen as true consonant mutation, while those that are limited to a small set of consonants, lexical items, or contexts are inherently less systematic, and may be given some other name.

2.5 Nature of consonant alternation

We have seen that consonant mutation can involve changes in a variety of phonetic properties. The most common are voicing, continuancy, nasality, and gemination, but can also include aspiration and place of articulation. Often a mutation grade primarily involves the change of a single feature, e.g., [continuant] in Nivkh and [voice] in Shona. In other cases a single grade may be signaled by different featural changes depending on the mutating consonant, as with Irish lenition, signaled by spirantization, voicing, debuccalization, or deletion. Even in cases where a single featural change is considered primary, it can be accompanied by other "secondary" changes in some consonants. While these are often phonetically straightforward (e.g. geminate hardening, or voicing as an effect of nasalization), some are typologically unexpected, as with nasal grade inducing devoicing in the Tenda language Konyagi (/w~b~mp/, etc.) and trilling in Nias (/b~mʙ/, /d~nr/).

Some authors draw a distinction between cases where alternations from one grade to another are phonetically consistent across consonants, or else easily analyzable as the change of a single feature, and those which involve less straightforward changes. Lieber (1983: 111) singles out "phonetically quirky mutations," and Iosad (2010) distinguishes between "well-behaved" mutation systems which are easily treated in an autosegmental analysis, and those which involve more complicated alternations. While this is never explicitly given as a factor in whether a phenomenon is considered mutation or not, it is conspicuous that many of the phenomena often excluded from consideration (e.g. Chaha by Lieber 1983 and Bantu nasalization by Iosad 2010) involve rather simple alternations, such as the addition of a secondary articulation. It seems that the more phonetically unexpected or idiosyncratic the alternation, the more likely it is to be seen as mutation.

Another consideration is the position of the mutating consonant. It is most often domain-initial, but may also be final as in Nuer, medial as in Finnish, or variable as in Chaha. Lieber (1983) and Swingle (1993) restrict the term consonant mutation to cases of initial and final consonant alternation, but there seems no principled reason to treat the alternation of medial consonants as a different phenomenon.

2.6 Organization of mutation grades

Languages show a number of differences in how their phonemes are organized into mutation grades. Perhaps the most important is the number of grades themselves. There must by definition exist at least two grades, and some languages exploit only these two (e.g. Central Vanuatu languages, Nivkh, Finnish). Others make use of three (Irish, Atlantic languages), or even more (Welsh, Western Nilotic languages). While this might at first seem to be a somewhat trivial variable, it is in fact extremely important in determining whether a given alternation is considered to be consonant mutation. If a two-grade alternation exists, there is generally some more phonologically-descriptive name that can be given to the alternation, e.g. nasalization in Umbundu, or gemination in Luganda. This avoids the need for the term "mutation" to be employed. In three-grade systems which make use of these exact same changes (e.g. the Atlantic languages Biafada and Kobiana, each with a grade of nasalized consonants and a grade of geminated consonants), "mutation" is inevitably adopted in describing the system as a whole. There is to my knowledge no system of alternation involving three or more grades which has failed to be termed "mutation," while some two-grade systems which exhibit the same phonetic alternations, with the same sorts of triggers, escape this appellation.

A number of notable differences exist in how phonemes are organized within the system of mutation grades. The functional purpose of mutation is to signal some morphological, syntactic, or lexical information, and as such the way in which the grades are organized can greatly influence the degree to which the mutation system effectively conveys this information. It is here relevant to consider the idea of "canonicity" as defined by Corbett (2005). In general, a canonical instance of a phenomenon is not determined by the most frequent examples of it, but by a constellation of factors which converge to most effectively signal an intended linguistic feature. A canonical mutation system is then one in which the phonological alternations most clearly and unambiguously convey the intended information. Two factors are especially relevant:

1) Phoneme overlap within a series:

Each member of a mutation series should be distinct. This allows the initial consonant to consistently signal the mutation grade. If there is overlap within a series, the distinction signaled by mutation is neutralized. As an example, in Sereer, the singular class *ne* assigns grade III with no overt prefix, and its corresponding plural class *ke* assigns grade II with no overt prefix. Thus, the singular/plural distinction is signaled purely by mutation, e.g. *ndol* 'hare' *tol* 'hares.' However, some mutation series have the same consonant in grade II and III, e.g. /ɓ ~ β ~ β/, such that the plural of *βaak* 'baobab tree' is the homophonous *βaak*. There exists no mutation system of three or more grades with no overlap at all within series, though it is rather low in some (Irish, Southern Paiute).

2) Phoneme overlap within a grade:

Each member of a mutation grade should be distinct. This allows the other members of a mutation series to be accurately predicted given only one member of the series. Overlap within a grade can create lexical ambiguity. For example, in Sereer both /d/ and /r/ in grade I alternate with /t/ in grade II, and as such the word *a-tet* 'trip/border' is the homophonous nominalization of both *ret* 'go,' and *det* 'delineate.' Stated differently, a mutation grade should not neutralize distinctions made in some other grade. In some systems there is no such neutralization (Numic languages, most Central Vanuatu languages), but in others it is quite extensive, as in Bantu stem-final spirantization.

In addition, some of the variables described in sections 2.4 and 2.5 have clear canonical values. All consonants should be subject to mutation; i.e., there should be no immutable consonants. All lexical items in the relevant syntactic categories should exhibit mutation. Finally, each grade should be composed of phonemes which share some identifiable phonetic feature that clearly distinguishes them from other consonants in the language. Note that exhibiting these canonical properties does not entail that a system will be seen as more of a "paradigm example" of mutation; only that it most effectively exploits the alternations from a functional standpoint. Of the languages we have examined, Southern Paiute and Basari come closest to this canonical ideal.

2.7 Summary and conclusion

We have identified the following variable properties of mutation systems:

Trigger type: morphological, lexical, syntactic
Phonological transparency of trigger: transparent, opaque
Position of trigger: adjacent, non-adjacent (distant), absent
Number of consonants subject to mutation
Productivity of mutation
Word classes affected by mutation
Number of unique triggers of mutation
Phonetic features involved in mutation: nasality, voicing, continuancy, gemination, etc.
Phonetic straightforwardness of mutation: are there "quirky mutations" (Lieber 1983)?

Position of mutating consonant: initial, final, medial, variable
Number of mutation grades
Amount of phoneme overlap within mutation series (ignoring immutable consonants)
Amount of phoneme overlap within mutation grades

The properties of some of the mutation and mutation-like systems discussed above are given in Figure 26 on the next page. None of these properties can be used to separate systems which are clearly consonant mutation from those that are not; in fact, no such simple distinction can be made. Rather, it seems more productive to take a broader view of consonant mutation, which would include any system of consonant alternation that is in any way phonologically arbitrary (though of course there will always be borderline cases which regard to this criterion). Rather than trying to further separate systems of alternation into those are vs. are not consonant mutation, it is more fruitful to focus on the many often independent properties that distinguish these systems, and use these to more meaningfully describe and categorize the phenomena in question. If we recognize the full diversity of consonant mutation systems, we will likely find that it is not possible or even desirable to arrive at a single unified analysis of consonant mutation phenomena.

	trigger type	transparency of trigger effect	position of trigger	% of cons. involved	productive?	word class (Noun, Verb)	unique triggers	features (Nas Cont Voi, Gem)	phonetically straight-forward?	position of consonant	# of grades	overlap within series	overlap within grades
Irish	lex, mor	opaque	abs, adj	most	yes	N, V	many	NCV	no	initial	3	low	low
Welsh	lex, syn, morph	opaque	abs, adj distant	most	yes	N, V	many	NCV	no	initial	4 (5)	some	low
Sereer	morph	opaque	abs, adj.	most	yes	N, V	~20	NCV	no	initial	3	some	yes
Fula	morph	opaque	dist, abs	most	yes	N, V	~20	NC	mostly	initial	3	yes	yes
Fula suffix	lexical	opaque	adjacent	all	N/A	affix	many	NC	no	initial	4	yes	none
Basari	morph	opaque	adj, abs	all	yes	N, V	~20	NC	no	initial	3	some	1 (ng^w)
S. Paiute	lexical	opaque	adjacent	most	yes	N, V	many	NCG	yes	initial	3	low	none
Comanche	lexical	opaque	adjacent	some	yes	N, V	many	C, asp.	yes	initial	3	yes	none
Päri	morph	opaque	abs, adj	most	yes	V, N?	~20	NVG	mostly	final	5~8	some	yes
Mende	syntactic	opaque	adjacent	most	yes	N, V	~5	NCV	no	initial	2	N/A	low
Jɔ	lex, syn	opaque	adjacent	most	yes	N, V	many	NV	mostly	initial	2	N/A	low
Chaha	morph	opaque	adj, abs	most	yes	N, V	~10	V, place	yes	variable	2, 2, 2	N/A	no
Nivkh	syn, phon	trans	adjacent	most	yes	N, V	1 or 4	C	yes	initial	2	N/A	none
Mundurukú	syn, phon	trans	adjacent	few	yes	N, V	1 or ~5	V	yes	initial	2	N/A	none
Rendaku	mor, phon	trans	adjacent	some	yes	N, (V)	1	V	yes	initial	2	N/A	low
Wolof	morph	opaque	absent	some	somewhat	N	2	NC	yes	initial	2	N/A	none
Herero	morph	opaque	absent	most	somewhat	N	1	N	no	initial	2	N/A	yes
Umbundu	morph	opaque	absent	most	yes	N, V	3	N	yes	initial	2	N/A	none
Luganda	morph	opaque	absent	most	yes	N	1	G	yes	initial	2	N/A	none
Shona	morph	opaque	absent	some	somewhat	N	1	V	yes	initial	2	N/A	some
Lewo	morph	opaque	adjacent	few	yes	V	1	CV	yes	initial	2	N/A	none
Bierebo	morph	opaque	adjacent	most	yes	V	1	NCV	no	initial	2	N/A	none
Nakamir	morph	opaque	adj, abs	some	yes	V	5	NCV	~no	initial	2	N/A	yes
Nāti	morph	opaque	adjacent	some	yes	V	2	NCV	~no	initial	2	N/A	low
Nias	mor, lex	opaque	abs, adj	most	yes	N, V	~10?	NCV	no	initial	2	N/A	low
Finnish	morph	some	abs, adj	some	yes	N, V	~30?	CVG	mostly	medial	2	N/A	none
Estonian	morph	opaque	abs, adj	most	yes	N, V	~30?	CVG	mostly	med/fin	2 (3)	N/A	yes
Burmese	morph	opaque	absent	most	no	V	1	V	yes	initial	2	N/A	no
Eng. N>V	morph	opaque	absent	few	no	N>V	1	V	yes	final	2	N/A	no
Bantu spir.	morph	trans	adjacent	stops	yes	V, N	1-4	C, place	yes	final	2	N/A	lots
Astro. NS	morph	trans	adjacent	var.	yes	V	~2	N	yes	initial	2	N/A	yes

Figure 26: Properties of various systems of consonant alternation

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