



Simulated Segment Evolution using the TKF91 Model

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ABSTRACT

It all started in a little town called Madrid...

INTRODUCTION

In this paper, we attempt to do the impossible!

METHODS

We used any and all means necessary.

CONCLUSION

Vene Vidi Vici

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```
#####  
# RevBayes Source File for Linguistomics Project #  
#####  
clear()  
outpath = "C:/Users/shawn/Documents/Code/Linguistomics/Nytril/Output/"  
inpath = "C:/Users/shawn/Documents/Code/Linguistomics/Nytril/Input/"  
gammapath = outpath + "Gamma.trees"  
  
# Read in discrete character data  
data = readDiscreteCharacterData(inpath + "Characters.nex")  
  
# Get some useful variables from the data. We need these later on  
num_taxa <- data.ntaxa()  
  
# Number of branches in an rooted tree  
num_branches <- 2 * num_taxa - 2  
taxa <- data.taxa()  
  
# Create helper variables  
moves = VectorMoves()  
monitors = VectorMonitors()  
  
#####  
# Substitution Model #  
#####  
  
# create a constant variable for the rate matrix  
Q <- fnJC(32)  
  
#####  
# Tree Model #  
#####  
  
# Outgroup is a clade consisting of one species  
out_group = clade("Latin")  
  
# Prior distribution on the tree topology  
topology ~ dnUniformTopology(taxa, outgroup=out_group, rooted=TRUE)  
  
# These are moves that change the tree topology  
moves.append(mvNNI(topology, weight=num_taxa/2.0))  
moves.append(mvSPR(topology, weight=num_taxa/10.0))  
  
# Branch length prior  
for (i in 1:num_branches) {  
  bl[i] ~ dnExponential(10.0)  
  moves.append(mvScale(bl[i]))  
}  
TL := sum(bl)  
psi := treeAssembly(topology, bl)
```

```
#####
# Gamma model for among-site variation #
#####
alpha ~ dnUniform(0, 10.0)
moves.append(mvScale(alpha, weight=1))
site_rates := fnDiscretizeGamma(alpha, alpha, 4)

#####
# PhyloCTMC Model #
#####
seq ~ dnPhyloCTMC(tree=psi, Q=Q, type="Standard", siteRates=site_rates)
seq.clamp(data)

#####
# Analysis #
#####

# You can use any node as the argument of model()
mymodel = model(psi)
n_gen = 10

# This prints monitors to the screen
monitors.append( mnScreen(TL, printgen=n_gen) )

# This monitors the trees and puts them in a file
monitors.append(mnFile(psi, filename=gammapath, printgen=n_gen))

# Model monitor
monitors.append( mnModel(filename=outpath+"Gamma.log", printgen=n_gen))
mymcmc = mcmc(mymodel, moves, monitors, nruns=1, combine="mixed")
mymcmc.run(generations=1000)

# Summarizes the MCMC runs
mymcmc.operatorSummary()

#####
# Post processing #
#####
treetrace      = readTreeTrace(gammapath, outgroup=out_group)
map_tree       = mapTree(treetrace, outpath+"Gamma_MAP.tree")
mcc_tree       = mccTree(treetrace, outpath+"Gamma_MCC.tree")
consensus_tree = consensusTree(treetrace, outpath+"Gamma_Consensus.tree")
```

Appendix 2 - Character file

```
#NEXUS
begin data;
  dimensions ntax=10 nchar=22;
  format datatype=STANDARD gap=- missing=? symbols="ABCDEFGHIJKLMNOPQRSTUVWXYZabc
d";

  matrix
  Latin      (ABC)(DE)(FKF--)(FGHIJ--)(LMNGJ)
  Romanian  (AN-)(DG)(FPQ--)(GHAOA--)(LMN--)
  Catalan   (RM-)(DG)(FIUVQ)(GHSTQ--)(LMG--)
  Portuguese (AG-)(DG)(SBVF-)(MHFTF--)(LMWG-)
  Spanish   (XM-)(DG)(FBVF-)(MHAYF--)(LGAWM)
  French    (ZQ-)(DI)(M----)(MHA----)(LGWM-)
  Walloon   (aA-)(DA)(SNQ--)(MHAXA--)(LMWSb)
  Romansh   (XFN)(DI)(FNQ--)(GHATQ--)(LMc--)
  Friulian  (XM-)(DG)(FBS--)(MHAbI--)(dGc--)
  Italian   (IM-)(DG)(FONF-)(MHAOOXM)(LNMWM)
  ;
end;
```

Appendix 3 - Language Tree File

#NEXUS

begin taxa;

dimensions ntax=15;

taxlabels Latin Nuorese Cagliari Romanian Arumanian Walloon French Provençal
Portuguese Spanish Catalan Ladin Friulian Romansh Italian;

end;

begin trees;

tree LanguageTree = (Latin:0.81,((Nuorese:411.2,Cagliari:410.52):755.27,(
(Romanian:526.1,Arumanian:526.97):579.53,(((Walloon:200.55,French:192.63):243.09
,Provençal:437.74):333.32,((Portuguese:369.61,Spanish:369.4):256.8,Catalan:626.07
):146.55):133.85,((Ladin:582.91,(Friulian:403.47,Romansh:403.37):180.58):178.13
,Italian:760.59):144.66):199.54):60.6):958.67):1324.32;

end;

Appendix 4 - Concepts Used in the Experiment

	I	You	Water	Ear	New
Latin	ego:	tu:	ak ^w a	auris	nowus
Romanian	ew	tu	ap ₃	ureke	now
Catalan	3o	tu	aixw̃ ₃	ureʎ ₃	nou
Portuguese	eu	tu	egw̃a	oraʎa	novu
Spanish	yo	tu	agw̃a	oreha	nuevo
French	j ₃	ti	o	ore	nuvo
Walloon	çe	te	ew ₃	oreye	novel
Romansh	yaw	ti	aw ₃	ureʎ ₃	nof
Friulian	yo	tu	age	oreli	łuf
Italian	io	tu	akwa	orekkyo	nwovo

Appendix 5 - Segments used in the word list

Char.	Segment	Words containing this segment
A	e	ego:, ew, ureke, eu, oreha, nuevo, ore, ɕe, te, oreye, ureʎɜ, oreli, orekkyo
B	g	ego:, egw̃a, agw̃a, age
C	o:	ego:
D	t	tu:, tu, ti, te
E	u:	tu:
F	a	auris, ak ^w a, apɜ, aixw̃ɜ, oraʎa, egw̃a, oreha, agw̃a, yaw, awɜ, age, akwa
G	u	auris, nowus, tu, ureke, ureʎɜ, nou, eu, novu, nuevo, nuvo, ureʎɜ, ʈuf
H	r	auris, ureke, ureʎɜ, oraʎa, oreha, ore, oreye, ureʎɜ, oreli, orekkyo
I	i	auris, aixw̃ɜ, ti, oreli, io
J	s	auris, nowus
K	k ^w	ak ^w a
L	n	nowus, now, nou, novu, nuevo, nuvo, novel, nof, nwovo
M	o	nowus, now, ɜo, nou, oraʎa, novu, yo, oreha, nuevo, ore, o, nuvo, oreye, novel, nof, oreli, io, orekkyo, nwovo
N	w	nowus, ew, now, ewɜ, yaw, awɜ, akwa, nwovo
O	k	ureke, orekkyo, akwa
P	p	apɜ
Q	ɜ	apɜ, ureʎɜ, aixw̃ɜ, jɜ, ewɜ, ureʎɜ, awɜ
R	ɜ	ɜo
S	ɛ	ureʎɜ, egw̃a, ewɜ, novel, age
T	ʎ	ureʎɜ, oraʎa, ureʎɜ
U	x	aixw̃ɜ
V	w̃	aixw̃ɜ, egw̃a, agw̃a
W	v	novu, nuevo, nuvo, novel, nwovo
X	y	yo, oreye, yaw, orekkyo
Y	h	oreha
Z	j	jɜ
a	ɕ	ɕe
b	l	novel, oreli
c	f	nof, ʈuf
d	ʈ	ʈuf

Appendix 6 - Feature change in first segment

Concept: **I**

	e	ɜ	ɛ	y	j	ç	ɣ	ɣ	ɣ	i
Rounded										
Vocoid										
Semivowel										
Long										
Voiced										
Velarized										
Ejective										
Pulmonic										
Nasal										
Tenuis										
Lateral										
Sibilant										
Fricative										
Approximant										
Implosive										
Central										
Tap/Flap										
Trill										
Stop										
Click										
Affricate										
Vowel										
Rhotic										
Occlusive										
Strident										
Obstruent										
Continuant										
Vibrant										
Liquid										

Concept: **You**

	t	t	t	t	t	t	t	t	t	t
Rounded										
Vocoid										
Semivowel										
Long										
Voiced										
Velarized										
Ejective										
Pulmonic										
Nasal										
Tenuis										
Lateral										
Sibilant										
Fricative										
Approximant										
Implosive										
Central										
Tap/Flap										
Trill										
Stop										
Click										
Affricate										
Vowel										
Rhotic										
Occlusive										
Strident										
Obstruent										
Continuant										
Vibrant										
Liquid										

Concept: **Water**

	a	a	ɛ	ɛ	o	ɛ	a	a	a	a
Rounded										
Vocoid										
Semivowel										
Long										
Voiced										
Velarized										
Ejective										
Pulmonic										
Nasal										
Tenuis										
Lateral										
Sibilant										
Fricative										
Approximant										
Implosive										
Central										
Tap/Flap										
Trill										
Stop										
Click										
Affricate										
Vowel										
Rhotic										
Occlusive										
Strident										
Obstruent										
Continuant										
Vibrant										
Liquid										

Concept: **Ear**

	a	u	u	o	o	o	o	u	o	o
Rounded										
Vocoid										
Semivowel										
Long										
Voiced										
Velarized										
Ejective										
Pulmonic										
Nasal										
Tenuis										
Lateral										
Sibilant										
Fricative										
Approximant										
Implosive										
Central										
Tap/Flap										
Trill										
Stop										
Click										
Affricate										
Vowel										
Rhotic										
Occlusive										
Strident										
Obstruent										
Continuant										
Vibrant										
Liquid										

Concept: **New**

	n	n	n	n	n	n	n	ɲ	n
Rounded									
Vocoid									
Semivowel									
Long									
Voiced									
Velarized									
Ejective									
Pulmonic									
Nasal									
Tenuis									
Lateral									
Sibilant									
Fricative									
Approximant									
Implosive									
Central									
Tap/Flap									
Trill									
Stop									
Click									
Affricate									
Vowel									
Rhotic									
Occlusive									
Strident									
Obstruent									
Continuant									
Vibrant									
Liquid									

Appendix 7 - Word Lists by Language

Latin

Concept	IPA	Sounds
I	ego:	ay-g-O
You	tu:	t-U
Ear	auris	ah-u-r-e-s
Water	ak ^{wa}	ah-kw-ah
New	novus	n-oh-w-u-s

Romanian

Concept	IPA	Sounds
I	ew	ay-w
You	tu	t-u
Ear	ureke	u-r-ay-k-ay
Water	apɜ	ah-p-aeH
New	now	n-oh-w

Catalan

Concept	IPA	Sounds
I	ʒo	gzah-oh
You	tu	t-u
Ear	ureʎɜ	u-r-eh-yuh-aeH
Water	aixw̃ɜ	ah-e-xha-wh-aeH
New	nou	n-oh-u

Portuguese

Concept	IPA	Sounds
I	eu	ay-u
You	tu	t-u
Ear	oraʎa	oh-r-ah-yuh-ah
Water	egw̃a	eh-g-wh-ah
New	novu	n-oh-v-u

Spanish

Concept	IPA	Sounds
I	yo	eeh-oh
You	tu	t-u
Ear	oreha	oh-r-ay-h-ah
Water	agw̃a	ah-g-wh-ah
New	nuevo	n-u-ay-v-oh

French

Concept	IPA	Sounds
I	jɜ	jg-aeH
You	ti	t-e

Ear	ore	oh-r-ay
Water	o	oh
New	nuvo	n-u-v-oh

Walloon

Concept	IPA	Sounds
I	çe	sh-ay
You	te	t-ay
Ear	oreye	oh-r-ay-eeh-ay
Water	ewɜ	eh-w-ah
New	novel	n-oh-v-eh-l

Romansh

Concept	IPA	Sounds
I	yaw	eeh-ah-w
You	ti	t-e
Ear	ureʎɜ	u-r-ay-yuh-ah
Water	awɜ	ah-w-ah
New	nof	n-oh-f

Friulian

Concept	IPA	Sounds
I	yo	eeh-oh
You	tu	t-u
Ear	oreli	oh-r-ay-l-e
Water	age	ah-g-eh
New	luf	ssha-u-f

Italian

Concept	IPA	Sounds
I	io	e-oh
You	tu	t-u
Ear	orekkyo	oh-r-ay-k-k-eeh-oh
Water	akwa	ah-k-w-ah
New	nwovo	n-w-oh-v-oh

Appendix 8 - Segment Groups

Pulmonic Consonants													
Manner	Bilabial	Labial	Labio-Dental	Linguo-Labial	Dental	Alveolar	Post-Alveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal-Epiglottal	Glottal
Nasal	m̥ m		ɱ	ɳ		ɲ n		ɳ̌ ɳ̌	ɲ̊ ɲ̊	ŋ̊ ɳ̊	ɴ		
Stop	p̥ b	kʷ gʷ	p̥ b̥	t̥ d̥		t̥ d̥		t̥ ɖ	c̥ ɟ̥	k̥ g̥	q̥ ɢ̥	ʔ̥	ʔ̥
Sibilant, Fricative						s̥ z̥	ʃ̥ ʒ̥	ʂ̥ ʐ̥	ç̥ ʝ̥				
Fricative	ɸ̥ β̥		f̥ v̥	θ̥ ð̥	θ̥ ð̥	θ̥ ð̥	ɬ̥ ɮ̥	ɬ̥ ɮ̥	ç̥ ʝ̥	x̥ ɣ̥	χ̥ ʁ̥	ħ̥ ʕ̥	h̥ ɦ̥
Approximant			ʋ̥ u̥			ɹ̥ ɻ̥		ɻ̥ ɻ̥	ɹ̥ ɹ̥	ɰ̥ ɰ̥			ʔ̥
Tap/Flap	ɸ̥		ɸ̥	ɸ̥		ɸ̥ r̥		ɸ̥ ɻ̥			ɸ̥	ʔ̥	
Trill	ʙ̥ B̥					ɹ̥ r̥		ɹ̥ ɻ̥			R̥	H̥ ʕ̥	
Lateral, Fricative						ɬ̥ ɮ̥		ɬ̥ ɮ̥	ɬ̥ ɮ̥	ɬ̥ ɮ̥			
Lateral, Approximant						ɬ̥ ɮ̥		ɬ̥ ɮ̥	ɬ̥ ɮ̥	ɬ̥ ɮ̥	ɬ̥		
Lateral, Tap/Flap						ɬ̥		ɬ̥	ɬ̥	ɬ̥			

Shaded areas denote articulations judged to be impossible. Where symbols appear in pairs, the one to the right represents a modally voiced consonant.

Non-Pulmonic Consonants										
Manner	Bilabial	Labio-Dental	Dental	Alveolar	Post-Alveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal-Epiglottal
Ejective, Stop				t'		t'	c'	k'	q'	ʔ'
Ejective, Fricative	ɸ'	f'	θ'	s'	ʃ'	ʂ'	ç'	x'	χ'	
Ejective, Lateral, Fricative				ɬ'						
Tenuis, Click	ɸ̥ ɸ̥		ɬ̥ ɬ̥	ɬ̥ ɬ̥			ɬ̥ ɬ̥			
Nasal, Click	ɸ̥		ɬ̥	ɬ̥			ɬ̥			
Tenuis, Lateral, Click				ɬ̥ ɬ̥						
Implosive	ɸ̥ ɸ̥			ɬ̥ ɬ̥		ɬ̥ ɬ̥	ɬ̥ ɬ̥	ɬ̥ ɬ̥	ɬ̥ ɬ̥	

Shaded areas denote articulations judged to be impossible. Where symbols appear in pairs, the one to the right represents a modally voiced consonant.

Vowels					
	Front	Near-Front	Central	Near-Back	Back
Close	i • y		ɨ • ʉ		ɯ • u
Near-close		ɪ • ʏ	ɨ • ʉ	ʊ	
Close-mid	e • ø		ə • ɵ		ɤ • ɔ
Mid	ø̥		ə̥		ɔ̥
Open-mid		ɛ • œ	ɐ • ɜ		ʌ • ɔ̄
Near-open		æ • ɶ	ɐ̃		
Open		a • ɶ̃	ä		ɑ • ɒ

Where symbols appear in pairs, the one to the right represents a rounded vowel.

Long Vowels					
	Front	Near-Front	Central	Near-Back	Back
Close	iː				uː
Mid	eː				oː
Open			aː		

Pulmonic Affricates												
Manner	Bilabial	Labio-Dental	Dental	Alveolar	Alveolo-Palatal	Retroflex	Palatal	Palato-Alveolar	Velar	Uvular	Pharyngeal-Epiglottal	Glottal
Sibilant				ts dz	tɕ dʑ	tʂ dʐ		tʃ dʒ				
Non-Sibilant	pɸ bβ	pf ɸv	tθ dð	tɬ dɮ			cç ɲɟ	tɬ dɮ	kx gy qχ		ʕħ ʕh	
Lateral				tɬ dɮ		ɭɭ	cɻ		kɭ gɭ			

Shaded areas denote articulations judged to be impossible.

Ejective Affricates										
Manner	Bilabial	Labio-Dental	Alveolar	Retroflex	Palatal	Palato-Alveolar	Velar	Uvular	Pharyngeal-Epiglottal	Glottal
Central			ts'	tʂ'		tʃ'	kx'	qχ'		
Lateral			tɬ'		cɻ'		kɭ'			

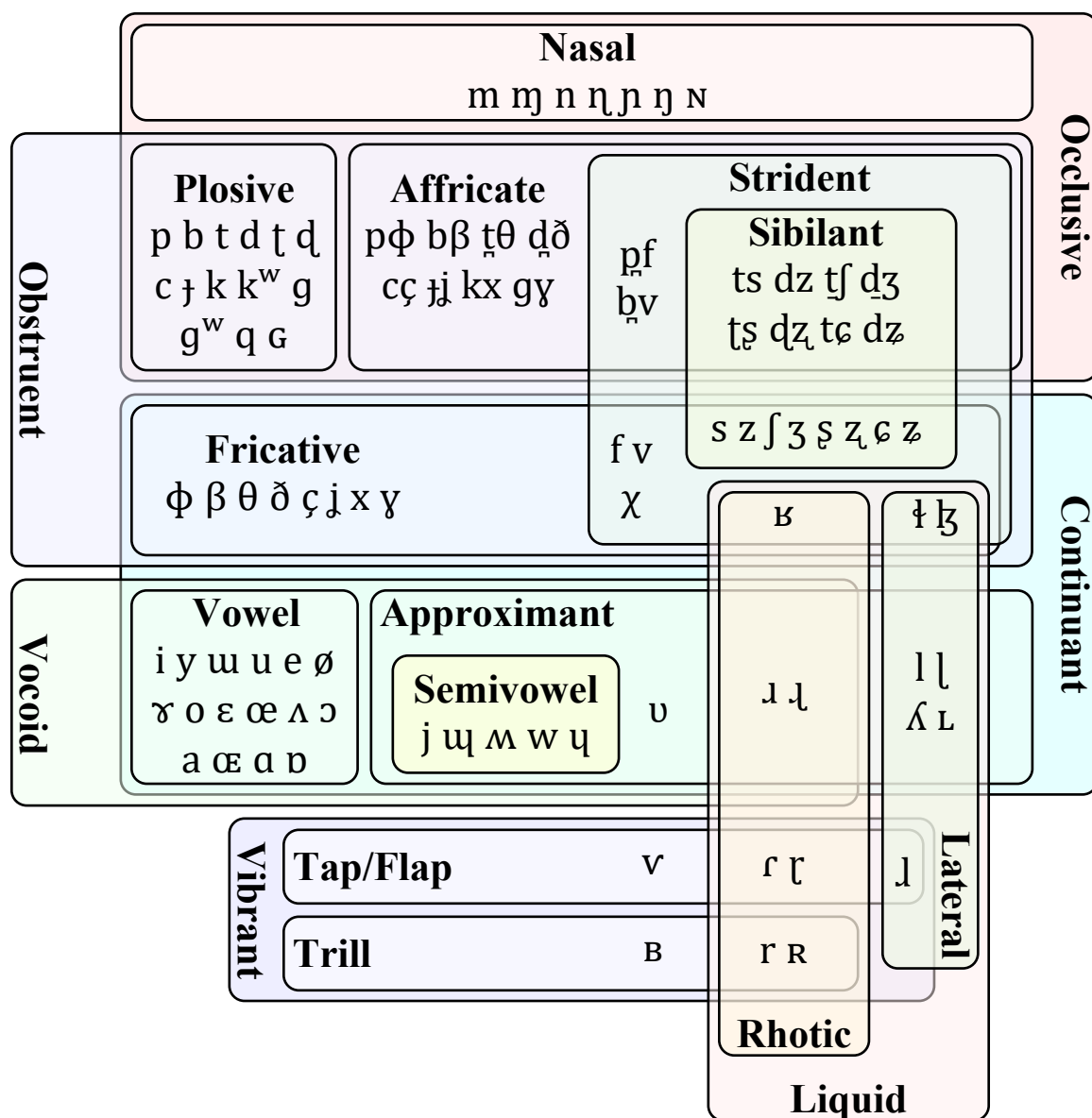
Shaded areas denote articulations judged to be impossible.

Other Segments	
ĩ Uvular Voiced Pulmonic Nasal Fricative	ɭ Alveolar Voiced Velarized Pulmonic Lateral Approximant
ᵐ Labial-Velar Vocoid Semivowel Approximant Continuant	Ẃ Labial-Velar Voiced Nasal Approximant

w	Labial-Velar Vocoid Semivowel Voiced Approximant Continuant	ɥ	Labial-Palatal Vocoid Semivowel Voiced Approximant Continuant
ʃ	Post-Alveolar Sibilant Fricative	ʕ	Pharyngeal-Epiglottal Voiced Fricative
ʔ	Pharyngeal-Epiglottal Ejective	p'	Bilabial Ejective Pulmonic Stop
œ̃	Open-mid Near-Front Rounded Nasal Vowel	ỹ	Close Front Rounded Nasal Vowel
ã	Open Near-Front Nasal Vowel	ẽ	Near-open Central Rounded Nasal Vowel
ɔ̃	Open-mid Back Rounded Nasal Vowel	ẽ̃	Open-mid Near-Front Nasal Vowel
ẽ	Open-mid Near-Front Nasal Vowel	ũ	Close Back Rounded Nasal Vowel
ẽ̃	Close-mid Front Nasal Vowel	ĩ	Close Front Nasal Vowel

Appendix 9 - Diacritics

Diacritics			
	Undefined escape character	~	Nasalized
+	Advanced	-	Retracted
°	Voiceless		Implosive
,	Ejective	ʕ	Pharyngealized
˘	Non-syllabic	ˀ	No audible release
ˆ	Advanced tongue root	ˁ	Apical
ˊ	Low rising tone	˂	Less rounded
˜	Velarized or Pharyngealized	↘	Global fall
ˈ	High tone	ˊ	High rising tone
˚	Palatalized	˞	Creaky voiced
ˠ	Lateral release	˝	Mid tone
ˡ	Linguo-Labial	ˎ	Nasal release
ˣ	Lowered	ˆ	Retracted tongue root
˥	Rising falling tone	˧	Raised
˦	Breathy voiced	˨	Voiced
˩	Extra short	˩˥	Mid-centralized
˩˥	Up-step	˩˨	Syllable break
˩˨	Secondary stress	˩˨˥	Long
˩˨˥	Indeterminacy in french vowels		Begin Non-segmental notation
˩˨˥˩	Voiced epiglottal fricative	!	Post-alveolar click
˩˨˥˩˥	Dental click		Major group
˩˨˥˩˥˩	Palatal click	˚	Voiceless descender
˩˨˥˩˥˩˥	Tie-bar below	˘	Tie-bar above
→	Becomes		Separator
		˙	Centralized
		˥	RisingTone
		˩	Syllabic
		˩˥	Falling tone
		˩˨	Rhotic hook
		˩˨˥	Extra low tone
		˩˨˥˩	Dental
		˩˨˥˩˥	Velarized
		˩˨˥˩˥˩	Aspirated
		˩˨˥˩˥˩˥	Low tone
		˩˨˥˩˥˩˥˩	Laminal
		˩˨˥˩˥˩˥˩˥	More rounded
		˩˨˥˩˥˩˥˩˥˩	Global rise
		˩˨˥˩˥˩˥˩˥˩˥	Extra high tone
		˩˨˥˩˥˩˥˩˥˩˥˩	Labialized
		˩˨˥˩˥˩˥˩˥˩˥˩˥	Down-step
		˩˨˥˩˥˩˥˩˥˩˥˩˥˩	Primary stress
		˩˨˥˩˥˩˥˩˥˩˥˩˥˩˥	Half-long
		˩˨˥˩˥˩˥˩˥˩˥˩˥˩˥˩	End non-segmental notation
		˩˨˥˩˥˩˥˩˥˩˥˩˥˩˥˩˥	Minor group
		˩˨˥˩˥˩˥˩˥˩˥˩˥˩˥˩˥˩	Alveolar lateral click
		˩˨˥˩˥˩˥˩˥˩˥˩˥˩˥˩˥˩˥	Combining macron
		˩˨˥˩˥˩˥˩˥˩˥˩˥˩˥˩˥˩˥˩	Ready made combination



Appendix 11 - International Phonetic Alphabet

IPA Segments			
<p style="text-align: center; font-size: 2em;">a</p> <p>Open Near-Front Vocoid Vowel Continuant 61</p>	<p style="text-align: center; font-size: 2em;">b</p> <p>Bilabial Voiced Pulmonic Stop Occlusive 62</p>	<p style="text-align: center; font-size: 2em;">c</p> <p>Palatal Pulmonic Stop Occlusive 63</p>	<p style="text-align: center; font-size: 2em;">d</p> <p>Alveolar Voiced Pulmonic Stop Occlusive 64</p>
<p style="text-align: center; font-size: 2em;">e</p> <p>Close-mid Front Vocoid Vowel Continuant 65</p>	<p style="text-align: center; font-size: 2em;">f</p> <p>Labio-Dental Pulmonic Fricative Strident Obstruent Continuant 66</p>	<p style="text-align: center; font-size: 2em;">h</p> <p>Glottal Pulmonic Fricative 68</p>	<p style="text-align: center; font-size: 2em;">i</p> <p>Close Front Vocoid Vowel Continuant 69</p>
<p style="text-align: center; font-size: 2em;">j</p> <p>Palatal Vocoid Semivowel Voiced Pulmonic Approximant Continuant 6A</p>	<p style="text-align: center; font-size: 2em;">k</p> <p>Velar Pulmonic Stop Occlusive 6B</p>	<p style="text-align: center; font-size: 2em;">l</p> <p>Alveolar Vocoid Voiced Pulmonic Lateral Approximant Rhotic Liquid 6C</p>	<p style="text-align: center; font-size: 2em;">m</p> <p>Bilabial Voiced Pulmonic Nasal Occlusive 6D</p>
<p style="text-align: center; font-size: 2em;">n</p> <p>Alveolar Voiced Pulmonic Nasal Occlusive 6E</p>	<p style="text-align: center; font-size: 2em;">o</p> <p>Close-mid Back Rounded Vocoid Vowel Continuant 6F</p>	<p style="text-align: center; font-size: 2em;">p</p> <p>Bilabial Pulmonic Stop Occlusive 70</p>	<p style="text-align: center; font-size: 2em;">q</p> <p>Uvular Pulmonic Stop Occlusive 71</p>
<p style="text-align: center; font-size: 2em;">r</p> <p>Alveolar Voiced Pulmonic Trill Rhotic Vibrant Liquid 72</p>	<p style="text-align: center; font-size: 2em;">s</p> <p>Alveolar Pulmonic Sibilant Fricative Strident Obstruent Continuant 73</p>	<p style="text-align: center; font-size: 2em;">t</p> <p>Alveolar Pulmonic Stop Occlusive 74</p>	<p style="text-align: center; font-size: 2em;">u</p> <p>Close Back Rounded Vocoid Vowel Continuant 75</p>
<p style="text-align: center; font-size: 2em;">v</p> <p>Labio-Dental Voiced Pulmonic Fricative Strident Obstruent Continuant 76</p>	<p style="text-align: center; font-size: 2em;">w</p> <p>Labial-Velar Vocoid Semivowel Voiced Approximant Continuant 77</p>	<p style="text-align: center; font-size: 2em;">x</p> <p>Velar Pulmonic Fricative Obstruent Continuant 78</p>	<p style="text-align: center; font-size: 2em;">y</p> <p>Close Front Rounded Vocoid Vowel Continuant 79</p>

<p>z</p> <p>Alveolar Voiced Pulmonic Sibilant Fricative Strident Obstruent Continuant 7A</p>	<p>ä</p> <p>Open Central Vowel E4</p>	<p>æ</p> <p>Near-open Near-Front Vowel E6</p>	<p>ç</p> <p>Palatal Pulmonic Fricative Obstruent Continuant E7</p>
<p>ð</p> <p>Dental Voiced Pulmonic Fricative Obstruent Continuant F0</p>	<p>ø</p> <p>Close-mid Front Rounded Vocoid Vowel Continuant F8</p>	<p>ħ</p> <p>Pharyngeal-Epiglottal Pulmonic Fricative 127</p>	<p>ŋ</p> <p>Velar Voiced Pulmonic Nasal Occlusive 14B</p>
<p>œ</p> <p>Open-mid Near-Front Rounded Vocoid Vowel Continuant 153</p>	<p>ɭ</p> <p>Dental Ejective Tenuis Click Affricate 1C0</p>	<p>ɭ</p> <p>Alveolar Ejective Tenuis Lateral Click Affricate 1C1</p>	<p>ɥ</p> <p>Palatal Ejective Tenuis Click Affricate 1C2</p>
<p>!</p> <p>Alveolar Ejective Tenuis Click Affricate 1C3</p>	<p>ə</p> <p>Near-open Central Rounded Vowel 250</p>	<p>ɑ</p> <p>Open Back Vocoid Vowel Continuant 251</p>	<p>ɒ</p> <p>Open Back Rounded Vocoid Vowel Continuant 252</p>
<p>ɓ</p> <p>Bilabial Voiced Ejective Implosive Click Affricate 253</p>	<p>ɔ</p> <p>Open-mid Back Rounded Vocoid Vowel Continuant 254</p>	<p>ç</p> <p>Palatal Pulmonic Sibilant Fricative Strident Obstruent Continuant 255</p>	<p>ɖ</p> <p>Retroflex Voiced Pulmonic Stop Occlusive 256</p>
<p>ɖ</p> <p>Alveolar Voiced Ejective Implosive Click Affricate 257</p>	<p>ə</p> <p>Mid Central Vowel 258</p>	<p>ə</p> <p>Close-mid Central Vowel 259</p>	<p>ɛ</p> <p>Open-mid Near-Front Vocoid Vowel Continuant 25B</p>

<p>3</p> <p>Open-mid Central Vowel 25C</p>	<p>Ɔ</p> <p>Open-mid Central Rounded Vowel 25E</p>	<p>ɟ</p> <p>Palatal Voiced Pulmonic Stop Occlusive 25F</p>	<p>ɠ</p> <p>Velar Voiced Ejective Implosive Click Affricate 260</p>
<p>ɡ</p> <p>Velar Voiced Pulmonic Stop Occlusive 261</p>	<p>ɢ</p> <p>Uvular Voiced Pulmonic Stop Occlusive 262</p>	<p>ɣ</p> <p>Velar Voiced Pulmonic Fricative Obstruent Continuant 263</p>	<p>ɤ</p> <p>Close-mid Back Vocoid Vowel Continuant 264</p>
<p>ɥ</p> <p>Labial-Palatal Vocoid Semivowel Voiced Approximant Continuant 265</p>	<p>ɦ</p> <p>Glottal Voiced Pulmonic Fricative 266</p>	<p>ɧ</p> <p>Post-Alveolar Sibilant Fricative 267</p>	<p>ɨ</p> <p>Close Central Vowel 268</p>
<p>ɪ</p> <p>Near-close Near-Front Vowel 26A</p>	<p>ɮ</p> <p>Alveolar Voiced Velarized Pulmonic Lateral Approximant 26B</p>	<p>ɬ</p> <p>Alveolar Pulmonic Lateral Fricative Strident Obstruent Continuant Liquid 26C</p>	<p>ɭ</p> <p>Retroflex Vocoid Voiced Pulmonic Lateral Approximant Rhotic Liquid 26D</p>
<p>ɮ͡</p> <p>Alveolar Voiced Pulmonic Lateral Fricative Strident Obstruent Continuant Liquid 26E</p>	<p>ɯ</p> <p>Close Back Vocoid Vowel Continuant 26F</p>	<p>ɰ</p> <p>Velar Vocoid Semivowel Voiced Pulmonic Approximant Continuant 270</p>	<p>ɱ</p> <p>Labio-Dental Voiced Pulmonic Nasal Occlusive 271</p>
<p>ɲ</p> <p>Palatal Voiced Pulmonic Nasal Occlusive 272</p>	<p>ɳ</p> <p>Retroflex Voiced Pulmonic Nasal Occlusive 273</p>	<p>ɴ</p> <p>Uvular Voiced Pulmonic Nasal Occlusive 274</p>	<p>ɵ</p> <p>Close-mid Central Rounded Vowel 275</p>











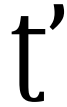

















<p>Œ</p> <p>Near-open Near-Front Rounded Vowel</p> <p>276</p>	<p>œ</p> <p>Open Near-Front Rounded Vocoid Vowel Continuant</p> <p>276</p>	<p>ϕ</p> <p>Bilabial Pulmonic Fricative Obstruent Continuant</p> <p>278</p>	<p>ɹ</p> <p>Alveolar Vocoid Voiced Pulmonic Approximant Rhotic Liquid</p> <p>279</p>
<p>ɭ</p> <p>Alveolar Voiced Pulmonic Lateral Tap/Flap Rhotic Vibrant Liquid</p> <p>27A</p>	<p>ɻ</p> <p>Retroflex Vocoid Voiced Pulmonic Approximant Rhotic Liquid</p> <p>27B</p>	<p>ɽ</p> <p>Retroflex Voiced Pulmonic Tap/Flap Rhotic Vibrant Liquid</p> <p>27D</p>	<p>ɺ</p> <p>Alveolar Voiced Pulmonic Tap/Flap Rhotic Vibrant Liquid</p> <p>27E</p>
<p>ʀ</p> <p>Uvular Pulmonic Trill Rhotic Vibrant Liquid</p> <p>280</p>	<p>ʁ</p> <p>Uvular Voiced Pulmonic Fricative Rhotic Strident Obstruent Continuant Liquid</p> <p>281</p>	<p>ʂ</p> <p>Retroflex Pulmonic Sibilant Fricative Strident Obstruent Continuant</p> <p>282</p>	<p>ʃ</p> <p>Post-Alveolar Pulmonic Sibilant Fricative Strident Obstruent Continuant</p> <p>283</p>
<p>ɸ</p> <p>Palatal Voiced Ejective Implosive Click Affricate</p> <p>284</p>	<p>ɖ</p> <p>Retroflex Pulmonic Stop Occlusive</p> <p>288</p>	<p>ʊ</p> <p>Close Central Rounded Vowel</p> <p>289</p>	<p>ʊ</p> <p>Near-close Near-Back Rounded Vowel</p> <p>28A</p>
<p>ʋ</p> <p>Labio-Dental Vocoid Voiced Pulmonic Approximant</p> <p>28B</p>	<p>ʌ</p> <p>Open-mid Back Vocoid Vowel Continuant</p> <p>28C</p>	<p>ɰ</p> <p>Labial-Velar Vocoid Semivowel Approximant Continuant</p> <p>28D</p>	<p>ʎ</p> <p>Palatal Vocoid Voiced Pulmonic Lateral Approximant Rhotic Liquid</p> <p>28E</p>
<p>ʏ</p> <p>Near-close Near-Front Rounded Vowel</p> <p>28F</p>	<p>ɮ</p> <p>Retroflex Voiced Pulmonic Sibilant Fricative Strident Obstruent Continuant</p> <p>290</p>	<p>ʝ</p> <p>Palatal Voiced Pulmonic Sibilant Fricative Strident Obstruent Continuant</p> <p>291</p>	<p>ʑ</p> <p>Post-Alveolar Voiced Pulmonic Sibilant Fricative Strident Obstruent Continuant</p> <p>292</p>

ʔ	ħ	⦿	ʙ
Glottal Pulmonic Stop 294	Pharyngeal-Epiglottal Voiced Pulmonic Fricative 295	Bilabial Ejective Tenuis Click Affricate 298	Bilabial Voiced Pulmonic Trill Vibrant 299
ɠ	ʜ	ɟ̞	ʟ
Uvular Voiced Ejective Implosive Click Affricate 29B	Pharyngeal-Epiglottal Pulmonic Trill 29C	Palatal Voiced Pulmonic Fricative Obstruent Continuant 29D	Velar Vocoid Voiced Pulmonic Lateral Approximant Rhotic Liquid 29F
ʕ	ʕ	ʕ̥	ʕ̥
Pharyngeal-Epiglottal Ejective 2A1	Pharyngeal-Epiglottal Pulmonic Stop 2A1	Pharyngeal-Epiglottal Voiced Pulmonic Trill 2A2	Pharyngeal-Epiglottal Voiced Fricative 2A2
β	θ	χ	ɪ̞
Bilabial Voiced Pulmonic Fricative Obstruent Continuant 3B2	Dental Pulmonic Fricative Obstruent Continuant 3B8	Uvular Pulmonic Fricative Strident Obstruent Continuant 3C7	Near-close Central Vowel 1D7B
ʊ̞	ɖ̞	v	aː
Near-close Central Rounded Vowel 1D7F	Retroflex Voiced Ejective Implosive Click Affricate 1D91	Labio-Dental Voiced Pulmonic Tap/Flap Vibrant 2C71	Open Central Vocoid Long Vowel Continuant 61, 2D0
ã	ɓ̥	bβ	cç
Open Near-Front Nasal Vowel 61, 303	Labio-Dental Voiced Pulmonic Stop 62, 32A	Bilabial Voiced Pulmonic Affricate Occlusive 62, 3B2	Palatal Pulmonic Affricate Occlusive 63, E7

c'	dz	dʒ	dʒ̥
Palatal Ejective Stop 63, 28C	Alveolar Voiced Pulmonic Sibilant Affricate Occlusive Strident 64, 7A	Alveolar Voiced Pulmonic Lateral Affricate 64, 26E	Alveolo-Palatal Voiced Pulmonic Sibilant Affricate Occlusive Strident 64, 291
d̥	eː	ẽ	f'
Linguo-Labial Voiced Pulmonic Stop 64, 33C	Mid Front Vocoid Long Vowel Continuant 65, 2D0	Close-mid Front Nasal Vowel 65, 303	Labio-Dental Ejective Fricative 66, 28C
iː	ĩ	j	kx
Close Front Vocoid Long Vowel Continuant 69, 2D0	Close Front Nasal Vowel 69, 303	Palatal Pulmonic Approximant 6A, 30A	Velar Pulmonic Affricate Occlusive 6B, 78
k ^w	k'	ɭ	ɭ̥
Labial Pulmonic Stop Occlusive 6B, 2B7	Velar Ejective Stop 6B, 28C	Velar Voiced Pulmonic Lateral Tap/Flap 4C, 306	Alveolar Pulmonic Lateral Approximant 6C, 325
m̥	ɲ̥	ɲ̥	oː
Bilabial Pulmonic Nasal 6D, 325	Alveolar Pulmonic Nasal 6E, 325	Linguo-Labial Voiced Pulmonic Nasal 6E, 33C	Mid Back Rounded Vocoid Long Vowel Continuant 6F, 2D0
o̥	p̥	p'	p̥
Mid Back Vowel 6F, 31E	Bilabial Pulmonic Affricate Occlusive 70, 278	Bilabial Ejective Pulmonic Stop 70, 28C	Labio-Dental Pulmonic Stop 70, 32A

q'	qχ	ř	ɾ
Uvular Ejective Stop 71, 2BC	Uvular Pulmonic Affricate 71, 3C7	Uvular Voiced Pulmonic Nasal Fricative 72, 303	Alveolar Pulmonic Trill 72, 325
s'	ts	tɕ	t'
Alveolar Ejective Fricative 73, 2BC	Alveolar Pulmonic Sibilant Affricate Occlusive Strident 74, 73	Alveolo-Palatal Pulmonic Sibilant Affricate Occlusive Strident 74, 255	Alveolar Ejective Stop 74, 2BC
t̪	uː	ũ	w̃
Linguo-Labial Pulmonic Stop 74, 33C	Close Back Rounded Long Vowel 75, 2D0	Close Back Rounded Nasal Vowel 75, 303	Labial-Velar Voiced Nasal Approximant 77, 303
x'	ỹ	ǝ̣	ǝ̣̃
Velar Ejective Fricative 78, 2BC	Close Front Rounded Nasal Vowel 79, 303	Alveolar Voiced Pulmonic Fricative F0, 320	Linguo-Labial Voiced Pulmonic Fricative F0, 33C
ø̣	ŋ̊	œ̃	ɿ̣
Mid Front Vowel F8, 31E	Velar Pulmonic Nasal 14B, 30A	Open-mid Near-Front Rounded Nasal Vowel 153, 303	Dental Ejective Nasal Click Affricate 1C0, 303
↓	⇓	ɸ̣	ɸ̣̃
Dental Voiced Ejective Tenuis Click Affricate 1C0, 32C	Alveolar Voiced Ejective Tenuis Lateral Click Affricate 1C1, 32C	Palatal Ejective Nasal Click Affricate 1C2, 303	Palatal Voiced Ejective Tenuis Click Affricate 1C2, 32C

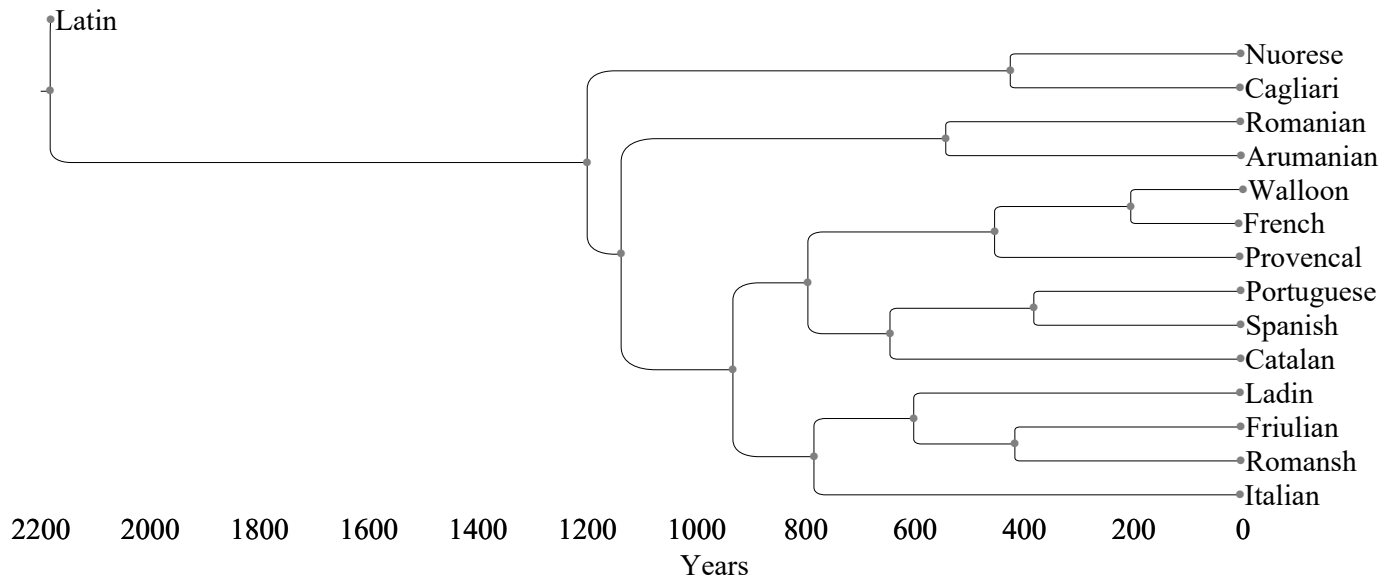
<p>ʔ</p> <p>Alveolar Ejective Nasal Click Affricate 1C3, 303</p>	<p>!↓</p> <p>Alveolar Voiced Ejective Tenuis Click Affricate 1C3, 32C</p>	<p>ẽ</p> <p>Near-open Central Rounded Nasal Vowel 250, 303</p>	<p>ɓ</p> <p>Bilabial Ejective Implosive Click Affricate 253, 325</p>
<p>õ</p> <p>Open-mid Back Rounded Nasal Vowel 254, 303</p>	<p>ç'</p> <p>Palatal Ejective Fricative 255, 28C</p>	<p>ɖz</p> <p>Retroflex Voiced Pulmonic Sibilant Affricate Occlusive Strident 256, 290</p>	<p>ɖ</p> <p>Alveolar Ejective Implosive Click Affricate 257, 325</p>
<p>ẽ</p> <p>Open-mid Near-Front Nasal Vowel 25B, 303</p>	<p>ẽ</p> <p>Open-mid Near-Front Nasal Vowel 25C, 303</p>	<p>ɟ</p> <p>Palatal Voiced Pulmonic Affricate Occlusive 25F, 29D</p>	<p>ɠ</p> <p>Velar Ejective Implosive Click Affricate 260, 30A</p>
<p>gɣ</p> <p>Velar Voiced Pulmonic Affricate Occlusive 261, 263</p>	<p>g^w</p> <p>Labial Voiced Pulmonic Stop Occlusive 261, 287</p>	<p>ǧ</p> <p>Uvular Voiced Pulmonic Tap/Flap 262, 306</p>	<p>ɬ'</p> <p>Alveolar Ejective Lateral Fricative 26C, 28C</p>
<p>ɭ⁺</p> <p>Retroflex Voiced Pulmonic Lateral Fricative 26D, 2D4</p>	<p>ɭ</p> <p>Retroflex Voiced Pulmonic Lateral Tap/Flap 26D, 306</p>	<p>ɭ</p> <p>Retroflex Pulmonic Lateral Approximant 26D, 30A</p>	<p>ɰ</p> <p>Velar Pulmonic Approximant 270, 30A</p>
<p>ɲ</p> <p>Palatal Pulmonic Nasal 272, 30A</p>	<p>ɲ</p> <p>Retroflex Pulmonic Nasal 273, 30A</p>	<p>ɸ'</p> <p>Bilabial Ejective Fricative 278, 28C</p>	<p>ɹ</p> <p>Alveolar Pulmonic Approximant 279, 325</p>

 <p>Retroflex Voiced Pulmonic Fricative 27B, 2D4</p>	 <p>Retroflex Pulmonic Approximant 27B, 30A</p>	 <p>Retroflex Voiced Pulmonic Trill 27D, 72</p>	 <p>Retroflex Pulmonic Tap/Flap 27D, 30A</p>
 <p>Alveolar Pulmonic Tap/Flap 27E, 325</p>	 <p>Linguo-Labial Voiced Pulmonic Tap/Flap 27E, 33C</p>	 <p>Retroflex Ejective Fricative 282, 2BC</p>	 <p>Post-Alveolar Ejective Fricative 283, 2BC</p>
 <p>Palatal Ejective Implosive Click Affricate 284, 30A</p>	 <p>Retroflex Pulmonic Sibilant Affricate Occlusive Strident 288, 282</p>	 <p>Retroflex Ejective Stop 288, 2BC</p>	 <p>Labio-Dental Pulmonic Approximant 28B, 325</p>
 <p>Palatal Voiced Pulmonic Lateral Tap/Flap 28E, 306</p>	 <p>Palatal Voiced Pulmonic Lateral Fricative 28E, 31D</p>	 <p>Palatal Pulmonic Lateral Approximant 28E, 325</p>	 <p>Glottal Pulmonic Affricate 294, 68</p>
 <p>Glottal Voiced Pulmonic Approximant 294, 31E</p>	 <p>Bilabial Ejective Nasal Click Affricate 298, 303</p>	 <p>Bilabial Voiced Ejective Tenuis Click Affricate 298, 32C</p>	 <p>Bilabial Pulmonic Trill 299, 325</p>
 <p>Uvular Ejective Implosive Click Affricate 29B, 325</p>	 <p>Velar Voiced Pulmonic Lateral Fricative 29F, 31D</p>	 <p>Uvular Voiced Pulmonic Lateral Approximant 29F, 320</p>	 <p>Velar Pulmonic Lateral Approximant 29F, 325</p>
 <p>Pharyngeal-Epiglottal Voiced Pulmonic Affricate 2A1, 2A2</p>	 <p>Pharyngeal-Epiglottal Ejective Stop 2A1, 2BC</p>	 <p>Pharyngeal-Epiglottal Voiced Pulmonic Tap/Flap 2A1, 306</p>	 <p>Dental Ejective Fricative 3B8, 2BC</p>

<p>θ̱</p> <p>Alveolar Pulmonic Fricative 3B8, 320</p>	<p>θ̱̹</p> <p>Linguo-Labial Pulmonic Fricative 3B8, 33C</p>	<p>χ'</p> <p>Uvular Ejective Fricative 3C7, 2BC</p>	<p>ɖ̠</p> <p>Retroflex Ejective Implosive Click Affricate 1D91, 30A</p>
<p>v̱+</p> <p>Bilabial Voiced Pulmonic Tap/Flap 2C71, 31F</p>	<p>ḇv</p> <p>Labio-Dental Voiced Pulmonic Affricate Occlusive Strident 62, 32A, 76</p>	<p>ḏ</p> <p>Alveolar Voiced Pulmonic Affricate 64, 279, 31D</p>	<p>ḏʒ</p> <p>Palato-Alveolar Voiced Pulmonic Sibilant Affricate Occlusive Strident 64, 320, 292</p>
<p>ḏð</p> <p>Dental Voiced Pulmonic Affricate Occlusive 64, 32A, F0</p>	<p>kx'</p> <p>Velar Ejective Central Affricate 6B, 78, 2BC</p>	<p>p̱f</p> <p>Labio-Dental Pulmonic Affricate Occlusive Strident 70, 32A, 66</p>	<p>qχ'</p> <p>Uvular Ejective Central Affricate 71, 3C7, 2BC</p>
<p>ts'</p> <p>Alveolar Ejective Central Affricate 74, 73, 2BC</p>	<p>tɬ'</p> <p>Alveolar Ejective Lateral Affricate 74, 26C, 2BC</p>	<p>tʃ̱</p> <p>Palato-Alveolar Pulmonic Sibilant Affricate Occlusive Strident 74, 320, 283</p>	<p>ṯθ</p> <p>Dental Pulmonic Affricate Occlusive 74, 32A, 3B8</p>
<p>g̱</p> <p>Velar Voiced Pulmonic Lateral Affricate 261, 29F, 31D</p>	<p>ɭ̱</p> <p>Retroflex Pulmonic Lateral Fricative 26D, 30A, 2D4</p>	<p>ɟ̱</p> <p>Post-Alveolar Voiced Pulmonic Fricative 279, 31D, 30A</p>	<p>ɟ̱</p> <p>Post-Alveolar Pulmonic Fricative 279, 320, 30A</p>
<p>tɕ'</p> <p>Retroflex Ejective Central Affricate 288, 282, 2BC</p>	<p>ʎ̱</p> <p>Palatal Pulmonic Lateral Fricative 28E, 31D, 30A</p>	<p>ɭ̱</p> <p>Velar Pulmonic Lateral Fricative 29F, 31D, 30A</p>	<p>cʎ̱</p> <p>Palatal Voiced Pulmonic Lateral Affricate 63, 28E, 31D, 30A</p>

$k\underset{\perp}{l}^{\circ}$ Velar Pulmonic Lateral Affricate 6B, 29F, 31D, 30A	$t\underset{\perp}{i}$ Alveolar Pulmonic Lateral Affricate 74, 26C, 31D, 30A	$t\underset{\perp}{i}$ Alveolar Pulmonic Affricate 74, 279, 31D, 30A	$t\underset{\perp}{j}'$ Palato-Alveolar Ejective Central Affricate 74, 320, 283, 2BC
$\text{r}^{\circ}\underset{\circ}{r}$ Retroflex Pulmonic Trill 27D, 30A, 72, 325	$t\underset{\perp}{l}^{\circ}$ Retroflex Pulmonic Lateral Affricate 288, 26D, 30A, 2D4	$c\underset{\perp}{\Lambda}'$ Palatal Ejective Lateral Affricate 63, 28E, 31D, 30A, 2BC	$d\underset{\perp}{u}^{\perp}$ Palato-Alveolar Voiced Pulmonic Affricate 64, 320, 279, 320, 2D4
$k\underset{\perp}{l}^{\circ}'$ Velar Ejective Lateral Affricate 6B, 29F, 31D, 30A, 2BC	$t\underset{\perp}{i}^{\perp}$ Palato-Alveolar Pulmonic Affricate 74, 320, 279, 320, 30A, 2D4		

Appendix 12 - Language Tree



Appendix 13 - Feature Tree

