A chronology-sensitive approach to subgrouping: The case of Southwestern Tai*

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1. Background on subgrouping

1.1. What is subgrouping?

- Subgrouping is "the internal classification of language families to determine which sister languages are most closely related to one another" (Campbell 1998: 166).
- The task of subgrouping is "to select, from among all possible trees T with roots *L and leaves L, the one tree that T $\in$ *T* **that best represent the genetic history (order of speciation)** of L" (Harrison 2003).

1.2. Standard shared-innovation method

1) A shared-innovation is "the result of a change which took place in a single daughter language which then subsequently diversified into daughter languages of its own, each of which inherits the results of the change." (Campbell 1998: 170).
2) Procedures (e.g. Campbell 1998)
    1) Identify innovations among some but not others of the languages.
    2) Factor out shared retentions, parallel innovations, and areal innovations.
        - Shared retentions do not provide any information on subgrouping.
        - Some represent changes that are so natural and frequent cross-linguistically that they may be parallel innovations.
        - Areal innovations are changes that spread through diffusion from one language to another across subgroup boundaries.

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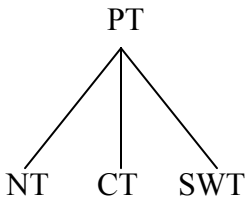
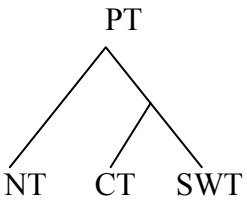
3) Use one or more of the "informative" innovations to define a subgroup. This step must be repeated until all languages are assigned to their places in the tree.

2. Southwestern Tai (SWT) languages

2.1. Subgroup of the Tai language family



Li (1960, 1977)



Gedney (1989)

2.2. Spoken in Vietnam, China, Laos, Thailand, Myanmar, India, and Malaysia (see Appendix A).

2.3. Gedney's tone box (1972)

		*A	*B	*C	*DS	*DL
I	vcl. aspirated **f-, hm-, ph-,…*					
II	vcl. unaspirated **p-,…*					
III	glottalized vd. **ʔb-,…*					
IV	plain voiced **v-, m-, b-,…*					

2.4. Patterns of tone splits and mergers

a) Example: Lue dialect of Chiang Rung (Hudak 1996)

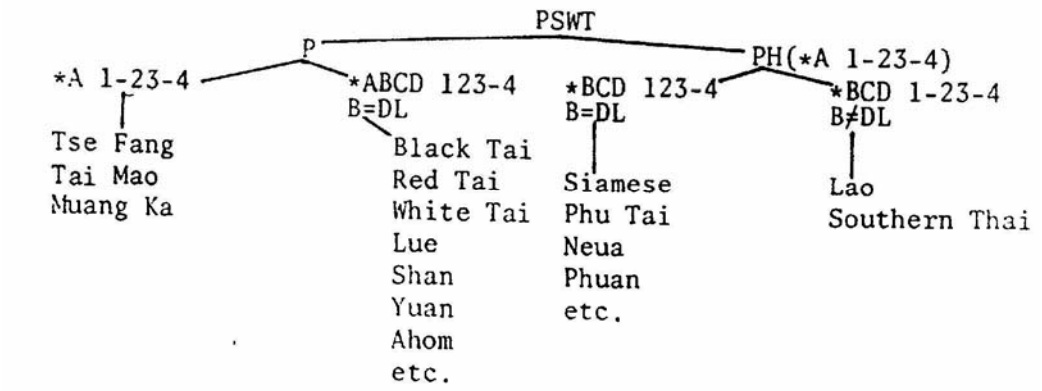
Initials at time of split		*A	*B	*C	*DS	*DL
	Voiceless	1	2	3	1	2
	Voiced	4	5	6	5	

b) Example: Shan dialect of Muong Khawn (Hudak1994)

	*A	*B	*C	*DS	*DL
vcl. aspirated	5	2	3	5	2
vcl. unaspirated	1				
glottalized vd.					
Plain voiced	4	1	3	3	1

2.5. Previous proposals for SWT subgrouping: Brown (1965); Chamberlain (1975); Hartmann (1980); Robinson (1994); Kullavanijaya and L-Thongkum (1998), Jonsson (1991).

2.6. Chamberlain (1975) proposes that reflexes of devoicing and patterns of mergers and split can be used as criteria for subgrouping.



2.7. Summary of Chamberlain (1975)

a) Devoicing of PSWT voiced obstruents is the criterion for splitting PSWT into two branches: languages whose reflex is unaspirated (P) and whose reflex is aspirated (PH).

b) Observed patterns of tones and split and mergers are used as criteria for further subgrouping because they are "peculiar enough."

c) No innovation in the consonantal system or in the vocalism is used.

3. Practical problems in subgrouping

3.1. Subjectivity

- Choosing innovations and ordering them appropriately is subjective and dependent on the researcher's a priori assumption about the subgroup structure. The researcher develops the intuition about the subgroup structure under the influence of their knowledge about geography, ethnonyms, number of shared features, etc. (see §4)
- Phylogenetic methods are used with language data to solve the subjectivity problem but the innovations used in the computation are still selected selectively.

3.2. Inadequacy of "naturalness" and "frequency" as criteria for identifying shared innovations.

- "Naturalness" and "frequency" are subjective and non-categorical measurements, e.g. is *A > A1-234 uncommon enough?
- "Naturalness" and "frequency" are highly contextual, e.g. tonogenesis is rare in Europe but very common in Southeast Asia.

SWT example

Other types of changes are at least as informative. Incorporating non-tonal innovation as criteria leads to different subgrouping tree structure.

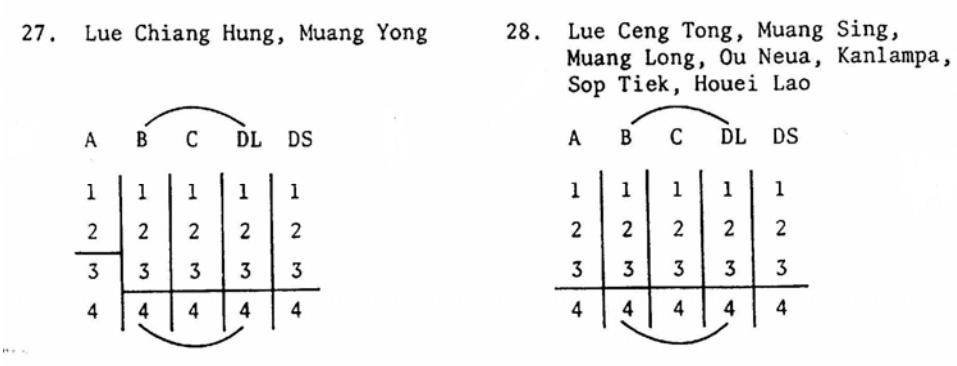
	Features	TH	ST	NY	LA	PH	PT
1	*ɲ-, *hɲ- > j-	✓					
2	*j-, *hj- > ɲ-			✓	✓	✓	✓
4	*ml- > m-			✓	✓	✓	✓
5	*ml- > l-	✓					
6	B=DL	✓		✓		✓	✓
7	B≠DL		✓		✓		

Some features found in the "PH" group

3.3. Lack of universally-accepted heuristics for detecting areal innovations

SWT example

It is very hard in practice to identify which tonal changes are true shared innovations and which changes are areal features.



Patterns of tone splits and mergers in Lue (from Chamberlain 1975:50)

3.4. Lack of explicit criteria for ordering the selected innovations, especially when chronological information is not available.

SWT example

Using as a primary criterion one of the innovations that occurred prior to the devoicing will lead to a conflicting tree.

- Linguistic evidence (feeding relationship)

	*ɣɯ:nA		*ɣɯ:nA
Occlusivization (*ɣ- > *g-) Devoicing	*gɯ:nA *kɯ:nA2	Devoicing *ɣ- > *g-	*xɯ:nA2 -
	kɯ:n4		xɯ:n4

Development of *ɣɯ:nA ‘night’ in Black Tai

- Philological evidence (Thai orthography): Ayutthaya inscriptions dated from 15th century CE (Fine Arts Department 1986) reflect PSWT distinction between voiceless and voiced consonants but do not show trace of the distinction between PSWT **ʔbl-* and **ʔd-* and between **khr-* and **kh-*, cf. <hna:> for **hna:C* 'face' and <na:ŋ> for **na:ŋ*A 'lady' but <dɯən> for **blɯən*A 'moon, month', and <k^h> **khrɔ:*A 'to beg'.

Using heuristics that are not based on chronological considerations is highly problematic for subgrouping in general.

4. Theoretical problems in subgrouping

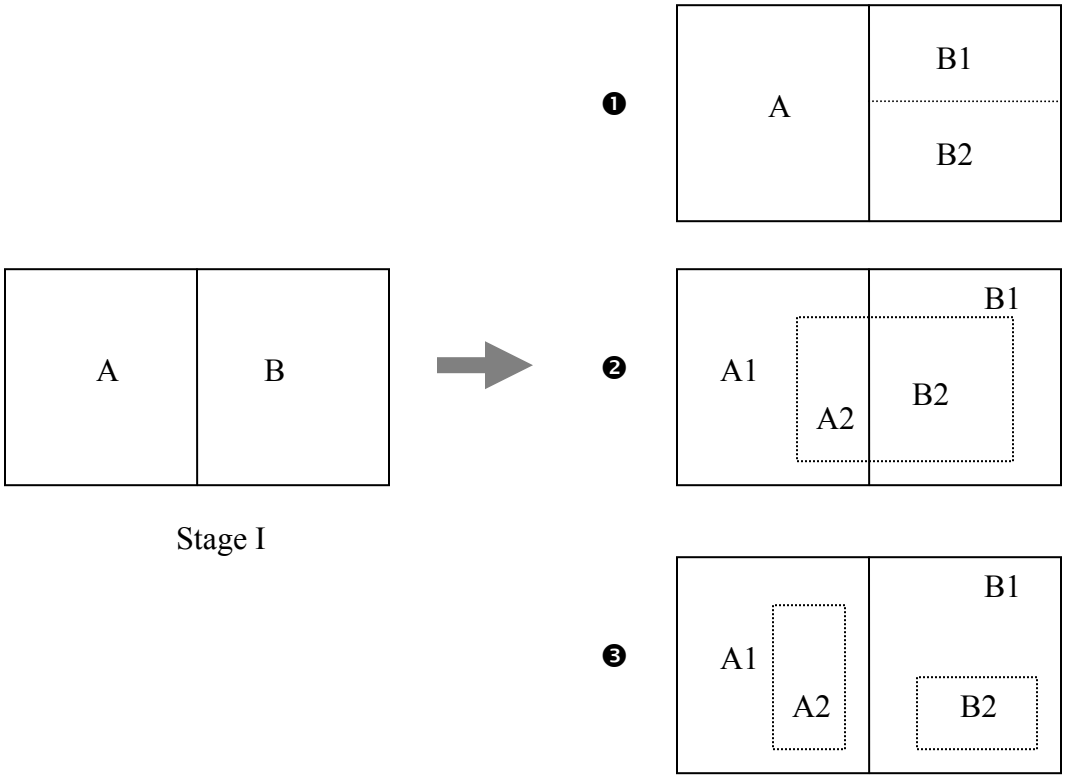
4.1. The true difference between the three types of innovations is their relative chronology.

4.2. Types of innovations (Harrison 1986, 2003)

1) Innovations resulting from a single historical event in some ancestral language ("heirloom innovations")
2) Innovations resulting from diffusion after the diversification of some common ancestor has begun ("areal innovations")
3) Innovations resulting from (accidental or motivated) separated developments ("parallel innovations")

4.3. Following sociolinguistic approaches to language change (for example, Labov 1963; Milroy and Milroy 1985), the three types of innovations are the same in nature. A change is an innovation by a group of speakers and then spread through interactions among speakers.

4.4. Conceptually, the three types of change can all cause speciation.



Heuristics that are not based on chronological considerations but on the types of innovations may subvert the objectives of subgrouping.

5. Chronology-sensitive approach to subgrouping

Relative chronology must be the primary criterion for selecting and ordering innovations.

5.1. Principles of the chronology-sensitive approach to subgrouping

1) No innovations should be promoted on the basis of considerations other than relative chronology.
2) Structure of trees must be constrained by relative chronology of innovations represented as nodes in the trees.

3) If used at all, phylogenetic methods must be used only where linguistic analysis fails to provide information.

5.2. Phylogenetics

- Phylogenetic methods work with a large set of possible trees given a set of observed features in a set of languages.
- "For a given model of evolution, trees are evaluated according to their likelihood scores, which represent the probability of a specific tree giving rise to the observed data under the model. The greater the likelihood of producing the observed data, the more favorable the tree." (Gray and Atkinson, to appear)

5.3. Camin-Sokal Parsimony method in MIX version 3.63 (Felsenstein 2005)

- Ancestral states are known.
- Different characters evolve independently.
- Different lineages evolve independently.
- Changes 0 --> 1 are much more probable than changes 1 --> 0.
- Both of these kinds of changes are a priori improbable over the evolutionary time spans involved in the differentiation of the group in question.
- Other kinds of evolutionary event such as retention of polymorphism are far less probable than changes 0 --> 1.
- Rates of evolution in different lineages are sufficiently low that two changes in a long segment of the tree are far less probable than one change in a short segment.

5.4. Coding

- 0 = ancestral state, 1 = derived state (see appendix)

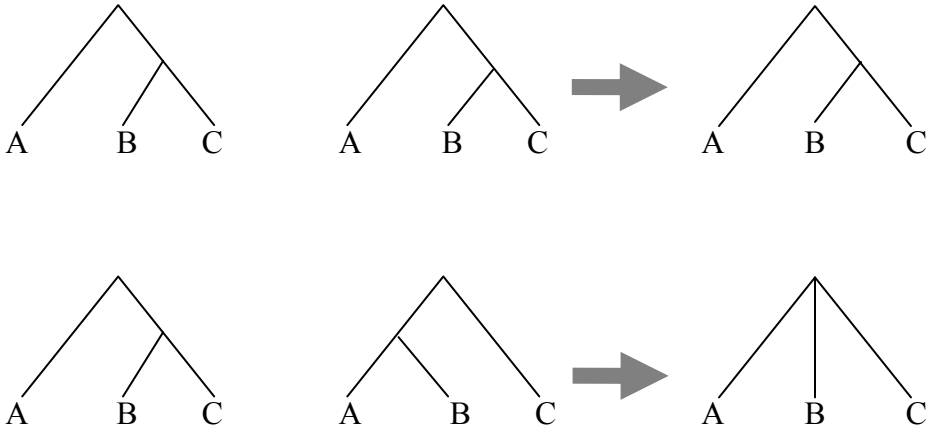
	YG	TL	BT	RT	WT	YU	LA	YO	NY	PT	TH
*aɯ	aj	aɯ	aɯ	ɤ	Aj	aj	aj	aɯ	aj	ɤ	aj
*aɯ > ɤ	0	0	0	1	0	0	0	0	0	1	0
*aɯ > aj	1	0	0	0	0	1	1	0	1	0	1

Coding of innovations that affected PSWT *aɯ

- Non-binary character (=innovation) are recoded using FACTOR version 3.63 (Felsenstein 2005).

5.5. Consensus

- A consensus method summarizes a collection of trees by taking a collection of trees and then returning a single tree. Most methods identify common substructures in the input trees and represent these in the output tree. Hence, by exclusion, they also identify areas of conflict in the input trees (Bryant 2003).



- A **bootstrap value** is a percentage of occurrences of a particular component that appears among the trees of the sample data set. It can be used as measure of confidence.

6. Experimental application of pure phylogenetics to SWT

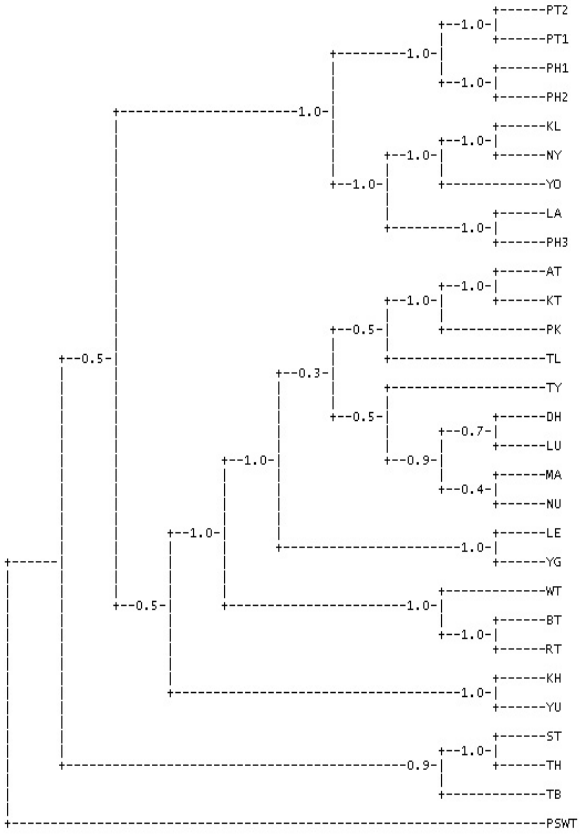
6.1. Procedure

1) Identify exhaustively phonological innovations in SWT (Total = 75).
2) Run MIX version 3.63 (Felsenstein 2005) on the selected innovations to find best trees.
3) Using Consense version 3.63 (Felsenstein 2005), find a consensus tree that identifies commonalities and the conflicts between the different trees.
4) Steps (1-3) should be repeated to each of the lower-level subgroups.

6.2. Data

- Phonological innovations (both split and mergers) in 28 SWT languages (see appendix).
- Divergent dialects of the same languages are included.
  1) Phuan: PH(1), PH(2), PH(3)
  2) Phu Thai: PT(1), PT(2)
  3) Lue: YG, LE

6.3. Result



- ✓ The languages in each group are spoken in a contiguous area.
- ✓ Able to detect early intense contact situation as suggested by the low bootstrap values at higher nodes.
- × No way to improve deeper-level subgrouping because no data cannot be added or filtered out.
- × Bootstrap values at lower-level nodes, as expected, are high but the classification is clearly wrong. PH(3) is classified as more closely related to LA but quite distant PH(1) and PH(2).

Phylogenetic methods without chronological information from linguistics cannot handle data from that involve contacts.

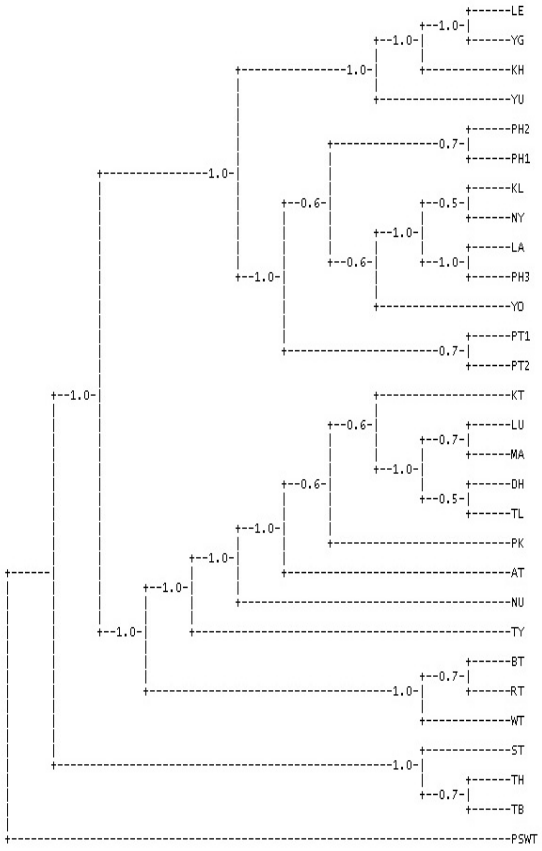
7. Experimental application of chronology-sensitive phylogenetics to SWT

7.1. Procedure

1) Identify exhaustively phonological innovations in SWT (Total = 75).
2) Filter out innovations that can be shown to have occurred after the binary tone split (Total – N = 75 - 43 = 32)

3) Run MIX version 3.63 (Felsenstein 2005) on the selected innovations to find best trees.
4) Find a consensus tree that identifies commonalities and the conflicts between the different trees.
5) Steps (1-3) may be repeated to each of the lower-level subgroups.

7.2. Result (without repeating step 1-3)



- ✗ Shan varieties and varieties in Vietnam are not spoken in contiguous areas but form a subgroup.
- ✗ The coincidental nature of the similarities between Shan and the varieties spoken in Vietnam is not detected as the bootstrap values for higher nodes are high.
- ✓ Possible to improve by developing a more sophisticated way of incorporating chronological information.
- ✓ Lower-level subgrouping is clearly wrong as expected but the bootstrap values are also low.

Phylogenetic methods that incorporate chronological data have the potential to discover deeper-level relationship and to detect convergence.

8. Conclusion

- The heuristics used in the standard shared-innovations method are practically and theoretically highly problematic.
- Heirloom innovations, areal innovations, and parallel innovation must all be included in the process of subgrouping.
- Bringing in phylogenetic computation may compensate for information not recoverable within linguistics but much more development is still needed.
- Relative chronology among changes is the only valid type of information that can be used as criteria for subgrouping.

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Appendix A

Languages

	Code	Language	Source
1	KT	Tai Khamti	Harris (1976)
2	PK	Tai Phake	Morey (2005)
3	AT	Tai Aiton	Morey (2005)
4	LU	Tai Lüa	Harris (1975)
5	MA	Tai Mao	Harris (1975)
6	NU	Tai Nüa	Harris (1975)
7	DH	Dehong Tai	Luo (1999)
8	TY	Tai Ya	Xing (2000)
9	LE	Lue	Hudak (1996)
10	YG	Yong	Gedney (1996)
11	TL	Tai Long	Gedney (n.d.)
12	BT	Black Tai	Gedney (n.d.)
13	RT	Red Tai	Gedney (n.d.)
14	WT	White Tai	Gedney (n.d.)
15	YU	Tai Yuan	Pittayaporn (fieldnote)
16	KH	Tai Khün	Phetsuk (1978)
17	LA	Lao	Gedney (n.d.)
18	PH(1)	Sukhothai Phuan	Trongrat (1988)
19	PH(2)	Suphanburi Phuan	Trongrat (1988)
20	PH(3)	Nongkhai Phuan	Trongdi and Thananan (1998)
21	PT(1)	Phu Thai Wang	Trongdi and Thananan (1998)
22	PT(2)	Phu Thai Kapong	Pittayaporn (fieldnote)
23	YO	Yooy	Boonsner (1984)
24	NY	Nyo	Boonsner (1984)
25	KL	Kaloeng	Thisaphong (1985)
26	TB	Tak Bai Thai	Trongdi and Thananan (1998)
27	TH	Thai (Siamese)	Gedney (n.d.)
28	ST	Southern Thai	Umar (2003)

(X) = The particular variety or varieties used in this language is spoken in Thailand but the concentration of this language is in the indicated area. The varieties found in Thailand are scattered around the country as results of forced or voluntary migrations.

Appendix B

Innovations in SWT

Innovations not filtered out, cf. 8.1

		KT	PK	AT	LU	MA	NU	DH	TY	LE	YG	TL	BT	RT	WT	YU	KH	LA	PH1	PH2	PH3	PT1	PT2	YO	NY	KL	TB	TH	ST
1	ph=f > ph	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0
2	pf = f > f	0	0	0	0	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	ʔb > w	1	0	1	1	0	1	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
4	ʔb > m	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
5	b > p	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1
6	b > ph	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
7	f > khw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	ʔd > l	0	0	0	?	1	1	?	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	ʔd > n	1	1	0	?	0	0	?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	n = l	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	s, (z) > sh	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	ch,(ʒ) > s	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
14	r = h	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
15	c > ts	0	0	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	ts > s	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	ɲ > j	1	1	1	1	1	1	1	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
18	j > ʒ	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
19	j > ɲ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0
20	kh = x > kh	1	1	1	0	1	0	0	?	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	kh = x > x	0	0	0	1	0	1	1	?	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	ɣ > g	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	?	?	?	?	?	?	?	?	?	?	?	?

		KT	PK	AT	LU	MA	NU	DH	TY	LE	YG	TL	BT	RT	WT	YU	KH	LA	PH1	PH2	PH3	PT1	PT2	YO	NY	KL	TB	TH	ST
23	hŋ > h	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	ŋ > ɲ	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	qh > x	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	1	1	1	1	1	1
26	qh > h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0
28	q > x	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
29	q > h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
31	pl > p	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
32	ʔbl > ʔd	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1
33	ʔbl > ʔb	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	ʔbr > ʔb/ʔd(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0
35	ʔbr > ʔb/ʔd(2)	1	1	1	1	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	ʔbr > ʔb/ʔd(3)	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	ml > m	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
37	ml > l	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
38	br > ph	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	?	?	?	?	?	?	?	?	?	0	0	0
39	gl, gr > ɟ	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	khr > ch	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	khr > kh	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
42	khwa > khua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0
43	khw > kw	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
44	ŋw > w	1	1	1	1	1	1	1	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
45	ŋw > ŋ	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	i:C = iC	1	1	1	1	1	1	1	1	1	1	1	1	?	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	V:N = VN	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	e:C > eC	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	iə > e(:)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0	1	1	0	0	0	0	1	0
50	iə > e(:)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0	1	1	0	0	0	0	0	0

		KT	PK	AT	LU	MA	NU	DH	TY	LE	YG	TL	BT	RT	WT	YU	KH	LA	PH1	PH2	PH3	PT1	PT2	YO	NY	KL	TB	TH	ST
51	eN > ɛN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
52	eN > iN	0	0	1	0	0	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	eC > iC	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	e = ɛ	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
55	e = je	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
56	ɛk > aik	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	aɯ > ʊ	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0
58	aɯ > ay	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	0	0	1	0	0	0	1	1	1	1	1
59	A1 □ A23(4)	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1
60	C1 □ C23(4)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	1	1	1	0	0	0
61	B1 □ B23(4)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
62	A12	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0
63	A1=B1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
64	A23=B23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	A4 = A(1)23	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
66	B4 = B(1)23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
67	C4 = C(1)23	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0
68	B4 = C(1)23	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0
69	C4 = DS4	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
70	DL4 = DS4	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0
71	DL123 = DS123	1	1	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	DL1 = DS123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	C123 = DL4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	A(1)23 = B4	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	A4 = B4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	A1 = B123	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77	C1 = B123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0