Elements of Proto-I.E. phonology

1. The phonemic inventory (traditional look)

1.1. Non-sonorants (obstruents and laryngeals):

Stops	Tenues (voiceless-nonaspirated)	Tenues aspiratae (voiceless-aspirated)	Mediae (voiced-nonaspirated)	Mediae aspiratae (voiced-aspirated)
Labials	*p*	p^h	*b*	b^h
Dentals	*t*	t^h	*d*	d^h
Palatals	*ḱ*	$ḱ^h$	*ǵ*	$ǵ^h$
Velars	*k*	k^h	*g*	g^h
Labiovelars	k^w	k^{wh}	g^w	g^{wh}
Sibilants	voiceless	voiceless-aspirated	voiced	
Dental	*s*	/	/	
Laryngeals	h_1	h_2	h_3	

1.2. Sonorants (vowels, nasals and liquids):

Nasals and Liquids	*r*	*l*	*m*	*n*

Vowels	front		central		back	
	short	long	short	long	short	long
Non-high	*e*	*ē*	*a*	*ā*	*o*	*ō*
High	*i*	/			*u*	/

1.3. The ablaut system:

	Primary (*e*-) grades	Secondary (*o*-) grades	(*a*-) grades
Long grades	*ē*	*ō*	(*ā*)
Normal (full) grades	*e*	*o*	(*a*)
Zero (reduced) grade	Ø		

1.4. PIE phonemes arranged by distinctive features

	p	*p*^{h}	*b*	*b*^{h}	*t*	*t*^{h}	*d*	*d*^{h}	*ḱ*	*ḱ*^{h}	*ǵ*	*ǵ*^{h}	*k*	*k*^{h}	*g*	*g*^{h}	*k*^{w}	*k*^{wh}	*g*^{w}	*g*^{wh}	*s*	*h*$_1$	*h*$_2$
consonant	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
syllabic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
nasal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
obstruent	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
low	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
high	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-
back	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	-	-	-
round	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	-	-	-
anterior	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	+	-	-
coronal	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
lateral	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
continuant	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+
fricative	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+
aspirated	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	-	+
voiced	-	-	+	+	-	-	+	+	-	-	+	+	-	-	+	+	-	-	+	+	-	-	-
tense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	r	*l*	*m*	*n*	*i*	*u*	*e*	*ē*	*o*	*ō*	*a*	*ā*
consonant	+	+	+	+	-	-	-	-	-	-	-	-
syllabic	-	-	-	-	-	-	+	+	+	+	+	+
nasal	-	-	+	+	-	-	-	-	-	-	-	-
obstruent	-	-	-	-	-	-	-	-	-	-	-	-
low	-	-	-	-	-	-	-	-	-	-	+	+
high	-	-	-	-	+	+	-	-	-	-	-	-
back	-	-	-	-	-	+	-	-	+	+	+	+
round	-	-	+	-	-	+	-	-	+	+	-	-
anterior	+	+	+	+	-	-	-	-	-	-	-	-
coronal	+	+	-	+	-	-	-	-	-	-	-	-
lateral	-	+	-	-	-	-	-	-	-	-	-	-
continuant	+	+	-	-	+	+	+	+	+	+	+	+
fricative	+	+	-	-	-	-	-	-	-	-	-	-
aspirated	-	-	-	-	-	-	-	-	-	-	-	-
voiced	+	+	+	+	+	+	+	+	+	+	+	+
tense	-	-	-	-	-	-	-	+	-	+	-	+

1.5. PIE phonemes grouped under cover symbols:

	p	p^h	b	b^h	t	t^h	d	d^h	$\acute{k}$	$\acute{k}^h$	$\acute{g}$	$\acute{g}^h$	k	k^h	g	g^h	k^w	k^{wh}	g^w	g^{wh}	s	h_1	h_2	h_3
C	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Ξ	+	+	-	-	+	+	-	-	+	+	-	-	+	+	-	-	+	+	-	-	+	+	+	
Γ	-	-	+	+	-	-	+	+	-	-	+	+	-	-	+	+	-	-	+	+	-	-	-	+
Δ	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	+	-	-
Φ	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	-	+	-
P	+	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-	+	-	-
P^h	-	+	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-	-	-
B	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-	+
B^h	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-
S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-
H	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+
Π	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Ξ	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-
Ḱ	-	-	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
X	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-
Q	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	-	-	-	-
K	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-
K^h	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-	-	-
G	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-	-
G^h	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-

	r	l	m	n	i	u	e	$\bar{e}$	o	$\bar{o}$	a	$\bar{a}$
C	+	+	+	+	-	-	-	-	-	-	-	-
V	+	+	+	+	+	+	+	+	+	+	+	+
U	-	-	-	-	+	+	+	+	+	+	+	+
Ω	-	-	-	-	-	-	+	+	+	+	+	+
E	-	-	-	-	-	-	+	+	-	-	-	-
O	-	-	-	-	-	-	-	-	+	+	-	-
A	-	-	-	-	-	-	-	-	-	-	+	+
V̆	-	-	-	-	+	+	+	-	+	-	+	-
V̄	-	-	-	-	-	-	-	+	-	+	-	+
R	+	+	+	+	+	+	-	-	-	-	-	-
L	+	+	-	-	-	-	-	-	-	-	-	-
N	-	-	+	+	-	-	-	-	-	-	-	-
I	-	-	-	-	+	+	-	-	-	-	-	-
J	-	-	-	-	+	-	+	+	-	-	-	-
W	-	-	-	-	-	+	-	-	+	+	-	-

2. Phonemes and their phonetic realization (overview)

2.1. Non-sonorants (obstruents and laryngeals)

Stops	Tenues	Tenues aspiratae	Mediae	Mediae aspiratae
	voiceless-nonaspirated	voiceless-aspirated	voiced-nonaspirated	voiced-aspirated
Labials	*p*	*p*^{h}	*b*	*b*^{h}
	[p, b^{1}]	[p^{h}, p^{2}]	[b, p^{3}]	[b^{h}, b^{2}]
Dentals	*t*	*t*^{h}	*d*	*d*^{h}
	[t, d^{1}, d^{h4}, t^{h5}] [ts^{6}, dz$^{6+1,3}$]	[t^{h}, t^{2}] [ts^{6+2}]	[d, t^{3}] [dz^{6}, ts^{6+3}]	[d^{h}, d^{2}] [dz^{6+2}]
	[þ^{7}, ð$^{7+1,3}$]	[þ$^{7+2}$]	[ð^{7}, þ$^{7+3}$]	[ð$^{7+2}$]
Palatals	*ḱ*	*ḱ*^{h}	*ǵ*	*ǵ*^{h}
	[ḱ, ǵ^{1}, ǵ^{h4}, ḱ^{h5}]	[ḱ^{h}, ḱ^{2}]	[ǵ, ḱ^{3}]	[ǵ^{h}, ǵ^{2}]
Velars	*k*	*k*^{h}	*g*	*g*^{h}
	[k, g^{1}, g^{h4}, k^{h5}]	[k^{h}, k^{2}]	[g, k^{3}]	[g^{h}, g^{2}]
Labiovelars	*k*^{w}	*k*^{wh}	*g*^{w}	*g*^{wh}
	[k^{w}, g^{w1}, g^{wh4}, k^{wh5}]	[k^{wh}, k^{w2}]	[g^{w}, k^{w3}]	[g^{wh}, g^{w2}]
Sibilants	voiceless	voiceless aspirated	voiced	voiced aspirated
Dental	*s*	/	/	/
	[s, z^{1}, z^{h4}] [š^{8}, ž$^{7+1}$, ž$^{h7+4}$]			
Laryngeals	*h*$_{1}$	*h*$_{2}$	*h*$_{3}$	/
	[ʔ; ʔə$_{e}$^{9}, ə$_{e}$^{9}ʔ]	[h, hə$_{a}$^{9}, ə$_{a}$^{9}h]	[ʕ, ʕə$_{a}$^{9}, ə$_{a}$^{9}ʕ]	
	[Ø^{10}]			

1. Voiced realization by regressive assimilation to following voiced obstruent.
2. Non-aspirated realization by neutralization in word final position (also before *s*).
3. Voiceless realization by regressive assimilation to following voiceless obstruent.
4. Aspirated realization according to Bartholomae's law.
5. Aspirated realization by regressive assimilation to following h_2.
6. By assibilation in position before dental stops.

7. By dissimilation in position before velar (/ palatal / labiovelar) stop ("thorn")?

8. Under unclear conditions: "ruki".

9. Shewa-anaptyxis with colouring.

10. In word final position (facultative realization according to Kuiper’s law).

2.2. Sonorants (vowels, nasals and liquids):

Nasals and Liquids	*r*	*l*	*m*	*n*
	[r; $\underset{\circ}{r}^{1}$, $\overline{\underset{\circ}{r}}^{1+2}$]	[l; $\underset{\circ}{l}^{1}$, $\overline{\underset{\circ}{l}}^{1+3}$]	[m; $\underset{\circ}{m}^{1}$, $\overline{\underset{\circ}{m}}^{1+4}$]	[n; $\underset{\circ}{n}^{1}$, $\overline{\underset{\circ}{n}}^{1+5}$]

Vowels	front		central		back	
	short	long	short	long	short	long
Non-high	*e*	$\bar{e}$	*a*	$\bar{a}$	*o*	$\bar{o}$
	[e, a^{6}, o^{7}] [$\bar{e}^{9}$, $\bar{a}^{10}$, $\bar{o}^{11}$]	[$\bar{e}^{8}$]	[a] [$\bar{a}^{12}$]	[$\bar{a}$]	[o] [$\bar{o}^{12}$]	[$\bar{o}$]
High	*i*	/			*u*	/
	[i; $\bar{i}^{12}$]				[u; $\bar{u}^{12}$]	
	[$\underset{\frown}{i}^{13}$]				[$\underset{\frown}{u}^{13}$]	

1. When syllabic.

2. In position before tautosyllabic laryngeal.

3. In position before tautosyllabic laryngeal.

4. In position before tautosyllabic laryngeal.

5. In position before tautosyllabic laryngeal.

6. By assimilation to adjacent h_2 (*a*-"colouring").

7. By assimilation to adjacent h_3 (*o*-"colouring").

8. No assimilation to adjacent laryngeals ("colouring") according to Eichner's law.

9. Substitutional lengthening in position before tauto-syllabic h_1.

10. "*a*-Colouring" plus substitutional lengthening in position before tauto-syllabic h_2.

11. "*o*-Colouring" plus substitutional lengthening in position before tauto-syllabic h_3.

12. Substitutional lengthening in position before tauto-syllabic laryngeals.

13. Non-syllabic realization in position before or after syllabic segment.

3. Regular development

3.1. Obstruents

PIE			Attested I.E. languages												
phonolog. input	phonetic output	condition	Ved.	Avest.	Greek	Arm.	Latin	OIr.	Goth.	OHG	OCS	Lith.	Hitt.	Toch.A	Toch.B
p	p	#_V	p	p	π	h	p		f	f	p	p	p	p	p
p'otis	pótis		*pátiḥ*	*paitiš*	πόσις		*potis*		*faþs*		*-pod-*	*-pats*		*pats*	*petso*
ph$_2$t'ēr	pə$_a$(h)tḗr		*pitā́*	*(p)tā*	πατήρ	*hayr*	*pater*	*athir*	*(fadar)*	*vater*				*pācar*	*pācer*
p'ōds *p'odm*	pṓts podm̥		*pā́t* *pā́dam*	*pādəm*	πούς πόδα	*otn*	*(pēs)* *(pedem)*		*(fōtus)*	*fuoz*			*patan*	*(pe)*	*(pai)*
p'elh1u- *plh1'u-*	pélᵊu- pl̥ᵊú-		*purú-*	*pouru-*	(πολύ-)			*il*	*filu*	*filu*					
p'eḱus	péḱus		*páśuḥ*	*pasuš*			*pecus*		*faihu*	*fihu*		*pekùs*			
p'ontēh$_2$s *pnth$_2$'es*	pónte(h)s pn̥t^{h}h$_2$as		*pánt^{hāḥ}* *pat^{h}áḥ*	*pantā̊* *paϑō*	(πόντος)	*hown*	*(pons)*				*pǫtĭ*				
p	p	_V*K^w	p	p	π		c	c	f	f	p	p	p	p	p
p'enk^{w}e	pénk^{w}e		*páñca*	*pancaπ*	πέντε		*quīnque*	*cóic*	*fimf*	*fimf*	*(pętĭ))*	*(penkì)*		*päñ*	*piś*
p'ek^{w}eti *-p'ok^{w}os*	pék^{w}eti -pók^{w}os		*pácati*	*pacaiti*	-κόπος		*coquit*				*pečetŭ*	*(kẽpa)*		*(pakät)*	*(pakṣäṃ)*
p	p	_V*K	p	p	K*π		p	u̯	p	p	p	p	p	p	p
(s)p'eḱieti	(s)péḱi̯eti		*páśyati*	*spasiieiti*	σκέπτεται		*specit*			*(spehōt)*					
p	p	#_C	p	f	π		p		f	f	p	p	p	p	p
pr'o	pró		*prá*	*frā*	πρό		*pro-*	*ro-*	*fra-*	*fir-*	*pro-*	*pra-*			
pl'eueti	pléu̯eti		*(plávate)*	*(frauua-)*	πλέει		*(plovet)*			*(flew-)*	*plovetŭ*				
p	p	V́_V	p	p	π	v,w	p		f	f	p	p	p	p	p
'uperos	úperos		*úparaḥ*	*uparō*	ὕπερος		*(superus)*		*(ufaro)*						
n'epōts *n'epotm*	népōts népotm̥		*nápāt* *nápātam*	*napā̊* *napātəm*	(νέποδ-)		*nepōs* *(nepōtem)*	*nia*		*neuo*		*(nepuotis)* *(nepuotį)*			
p	p	V_V́	p	p	π	v,w	p		b	b	p	p	p	p	p
up'er(i)	upér(i)		*upári*	*upairi*	ὑπέρ	*ver*	*(super)*	*for-*		*ubir*					
h$_1$ep'i	ᵊepí		*ápi*	*aipi*	ἔπί	*ew*									
p	p	V_TV́	p	p	π	v,w	p		b	b	p	p	p	p	p
sept'm	septḿ̥		*saptá*	*hapta*	ἑπτά	*ewt^{c}n*	*septem*	*(secht)*	*(sibun)*	*(sibun)*	*sedmĭ*	*(septynì)*		*ṣpät*	*ṣukt*
p	p	V_nV́	p	p	π	v,w	p	u̯	f	f	p	p	p	p	p
su'opnos *s'upnos* *su'epnos*	su̯ópnos súpnos su̯épnos		*svápnaḥ*	*x^{v}afnō*	ὕπνος	*k^{c}own*	*somnus*	*(suan)*	*(svefn)*	*(swefn)*	*sŭnŭ*	*sãpnas*		*späṃ*	*spane*
p	b	V_D	b		β		b	b							
-pdo-	-bdo-		*upá-bda-*	*fra-bda-*	ἔπί-βδα-										
p'iph$_3$enti	píb^{c}onti		*píbanti*				*bibunt*	*ibat*							
h$_2$eph$_3$ōn	hab^{c}ōn							*aub*							
septm'ih$_2$	sebdmíh										*sedmĭ*				

4. Rules of phonetic realization

4.1. Neutralizations and assimilations among obstruents

4.1.1. Regressive voice assimilation:

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ -\ vcd \end{bmatrix} \rightarrow \begin{bmatrix} +\ vcd \end{bmatrix} \ / \ \underline{\quad} \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ vcd \end{bmatrix}$$

Notation with cover symbols:

$$\Xi \rightarrow \Gamma \ / \ \_ \ \Gamma$$

Examples:

PIE			Attested I.E. languages												
phonolog. input	phonetic output		Ved.	Avest.	Greek	Arm.	Latin	OIr.	Goth.	OHG	OCS	Lith.	Hitt.	Toch.A	Toch.B
nisd′os	nizdós	n.sg.m.	*nīḍáḥ*			*nist*	*nīdus*	*net*		*nest*					
h_2′osdos	hózdos	n.sg.m.			ὄζος				*asts*	*ast*			*(ḫašduer)*		
misd^{h}′om *misd^{h}′eh_2*	mizd^{h}óm mizd^{h}áh	a.sg.mn. n.sg.f.	*mīḍ^{h}ám*	*mĭždəm*	μισθόν				*(mizdo)*	*(miata)*	*mĭzdá*				
-pdo-	-bdo-		*upá-bda-*	*fra-bda-*	ἔπί-βδα-										
p′iph$_3$enti	píb^{c}onti		*píbanti*				*bibunt*	*ibat*							
$h_2$eph$_3$ōn	hab^{c}ōn							*aub*							
septm′ih$_2$	sebdmíh										*sedmĭ*				

4.1.2. Regressive devoicing:

4.1.2.1. General rule:

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ +\ vcd \end{bmatrix} \rightarrow \begin{bmatrix} -\ vcd \end{bmatrix} \ / \ \underline{\quad} \begin{bmatrix} +\ cons \\ +\ obstr \\ -\ vcd \end{bmatrix}$$

Notation with cover symbols:

$$\Gamma \rightarrow \Xi \ / \ \_ \ \Xi$$

4.1.2.2. Restriction: LACHMANN's law (valid for Latin):

$$\begin{bmatrix} -\ cons \\ -\ tense \end{bmatrix} \rightarrow \begin{bmatrix} -\ cons \\ +\ tense \end{bmatrix} / \_\_ \begin{bmatrix} +\ obstr \\ -\ fric \\ -\ vcd \\ -\ asp \end{bmatrix} \begin{bmatrix} +\ obstr \\ -\ fric \\ -\ vcd \end{bmatrix}$$

Examples:

PIE		Proto-Latin			Latin	
phonological input	phonetic output	regular development	morphological reanalysis	Lachmann's lengthening	Old Latin	Classic
/teg-tos/	[tektos]	**tektos*	**teg-tos*	*[te·gtos]	**tēctos*	*tēctus*
/h$_2$eǵ-tos/	[haḱtos]	**aktos*	**ag-tos*	*[a·gtos]	**āctos*	*āctus*
/u̯id-tos/	[u̯itstos]	**u̯itstsos*	**u̯id-tsos*	*[u̯i·dtsos]	**u̯īssos*	*uīsus*

4.1.2.3.
Unification of rules of assimilation of non-aspirated stops:

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ \alpha\ vcd \end{bmatrix} \rightarrow \begin{bmatrix} -\alpha\ vcd \end{bmatrix} / \_\_ \begin{bmatrix} +\ cons \\ +\ obstr \\ -\alpha\ vcd \end{bmatrix}$$

4.1.3. Deaspiration in word final position (also before word final *s*):

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ +\ asp \end{bmatrix} \rightarrow \begin{bmatrix} -\ asp \end{bmatrix} / \_\_ \begin{bmatrix} +\ cons \\ +\ cont \\ +\ fric \\ -\ asp \end{bmatrix}_{0-n} \#$$

Notation with cover symbols:

$$\Phi \rightarrow \Delta\ /\ \_\ \#\ |\ \_\ s\ \#$$

4.1.4. Progressive aspiration (BARTHOLOMAE's law):

$$\begin{bmatrix} +\ cons \\ +\ obstr \end{bmatrix} \rightarrow \begin{bmatrix} +\ asp \\ \alpha\ vcd \end{bmatrix} / \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ asp \\ \alpha\ vcd \end{bmatrix} \_\_$$

Notation with cover symbols:

$$\Delta \rightarrow \Phi\ /\ \Phi\ \_ \rightarrow\rightarrow \Phi \rightarrow B^h\ /\ B^h\ \_$$

4.1.5. Regressive aspiration by assimilation to following h_2:

$$\begin{bmatrix} +\ cons \\ +\ obstr \end{bmatrix} \rightarrow \begin{bmatrix} +\ asp \end{bmatrix} \ / \ \_\_ \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \\ +\ asp \end{bmatrix}$$

Notation with cover symbols:

$$\Delta \rightarrow \Phi \ /\_ \ h_2$$

4.1.6. Assibilation of dental stops before dental stops:

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ +\ cor \\ -\ cont \end{bmatrix} \rightarrow \begin{bmatrix} +\ fric \end{bmatrix} \ / \ \_\_ \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ cor \end{bmatrix}$$

Notation with cover symbols:

$$T \rightarrow T^{S} \ / \ \_ \ T$$

4.1.7. Dissimilation of dental stops before velar stops ("thorn" rule):

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ +\ cor \\ -\ cont \end{bmatrix} \rightarrow \begin{bmatrix} +\ fric \\ +\ high \\ -\ cor \end{bmatrix} \ / \ \_\_ \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ high \end{bmatrix}$$

Notation with cover symbols:

$$T \rightarrow Þ \ / \ \_ \ \Xi$$

4.1.8. "Ruki" rule:

4.1.8.1. a) after i,u:

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ +\ cor \\ +\ cont \\ +\ fric \end{bmatrix} \rightarrow \begin{bmatrix} +\ high \end{bmatrix} \ / \begin{bmatrix} -\ cons \\ +\ high \end{bmatrix} \underline{\quad}$$

Notation with cover symbols:

s → š / I _

4.1.8.2. b) after velars:

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ +\ cor \\ +\ cont \\ +\ fric \end{bmatrix} \rightarrow \begin{bmatrix} +\ high \end{bmatrix} \ / \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ high \end{bmatrix} \underline{\quad}$$

Notation with cover symbols:

s → š / Ξ _

Unification of rules a) and b):

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ +\ cor \\ +\ cont \\ +\ fric \end{bmatrix} \rightarrow \begin{bmatrix} +\ high \end{bmatrix} \ / \begin{bmatrix} +\ high \end{bmatrix} \underline{\quad}$$

Notation with cover symbols:

s → š / I | Ξ _

4.1.8.3. b) after r:

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ +\ cor \\ +\ cont \\ +\ fric \end{bmatrix} \rightarrow \begin{bmatrix} +\ high \end{bmatrix} \ / \begin{bmatrix} +\ cons \\ -\ obstr \\ +\ ant \\ +\ cor \\ -\ lat \end{bmatrix} \underline{\quad}$$

Notation with cover symbols:

s → š / r _

4.2. Rules of syllabification

4.2.1. Hierarchy:

Rank	Sound category	Conditions of syllabicity
I.	Non-high vowels	Always (wherever they appear)
II.	High vowels, nasals, liquids	When not adjacent to sound of category I and when not followed by syllabic sound of category II ("Schindler's rule");
		when, as second element of syllable, followed by sound of category I in word-final syllable ("Sievers'" and "Lindeman's" laws)
III.	Laryngeals	When not adjacent to sound of category I or syllabic sound of category II
IV.	"Shewa secundum"	Within remaining clusters of non-syllabic consonants (facultatively)

4.2.2. Schematic rule representation:

4.2.2.1. Non-high vowels ("syllabic" not regarded as an underlying feature)

$$\begin{bmatrix} -\ cons \\ -\ high \end{bmatrix} \rightarrow \begin{bmatrix} +\ syll \end{bmatrix}$$

4.2.2.2. Other sonorants ("sonorant" not regarded as an underlying feature): SCHINDLER's rule (*Die Sprache* 23 [1977], p. 56):

$$\begin{bmatrix} -\ obstr \\ -\ syll \end{bmatrix} \rightarrow \begin{bmatrix} +\ syll \end{bmatrix} \ / \ \left\{ \begin{matrix} \begin{bmatrix} -\ syll \end{bmatrix} \\ \# \end{matrix} \right\} \_\_ \left\{ \begin{matrix} \begin{bmatrix} -\ syll \end{bmatrix} \\ \# \end{matrix} \right\}$$

Notation with cover symbols ("colouring" not accountable for):

$$\mathrm{R} \rightarrow \underset{\circ}{\mathrm{R}} \ / \ (\# \mid \mathrm{C})\ \_\ (\mathrm{C} \mid \#)$$

(rule operating iteratively from right to left, with high vowels, nasals and liquids regarded as being underlyingly non-syllabic)

4.2.2.2.1. Subrule I: SIEVERS' law (after SCHINDLER, *o.c.*, p. 57):

$$\begin{bmatrix} -\ obstr \\ -\ syll \end{bmatrix} \rightarrow \begin{bmatrix} +\ syll \end{bmatrix} \ / \ \left\{ \begin{matrix} \begin{bmatrix} +\ syll \\ +\ tense \end{bmatrix} \\ \\ \begin{bmatrix} +\ syll \end{bmatrix} \begin{bmatrix} -\ obstr \\ -\ syll \end{bmatrix}_{1-n} \end{matrix} \right\} \begin{bmatrix} -\ syll \end{bmatrix}_1 \ \underline{\quad} \ \begin{bmatrix} +\ syll \end{bmatrix} \begin{bmatrix} -\ syll \end{bmatrix}_{0-n} \#$$

Alternative notation with cover symbols:

$$\boxed{R \rightarrow \underset{\circ}{R} \ / \ WC_1^n \_ \ VC_0^n\# \mid VRC_1^n \_ \ VC_0^n\#}$$

Same with notation of presumptive syllable boundaries (.):

$$\boxed{R \rightarrow \underset{\circ}{R} \ / \ W.C_1^n \_ \ VC_0^n\# \mid VR.C_1^n \_ \ VC_0^n\#}$$

N.B. Tautosyllabic obstruent clusters are no valid condition:

$$\boxed{R \rightarrow R \ / \ VPP. \_ \ VC_0^n\#}$$

4.2.2.2.2. LINDEMAN's law:

$$\begin{bmatrix} -\ obstr \\ -\ syll \end{bmatrix} \rightarrow \begin{bmatrix} +\ syll \end{bmatrix} \ /\ \#\ \ \begin{bmatrix} -\ syll \end{bmatrix}_{1-n} \_\_ \begin{bmatrix} +\ syll \end{bmatrix} \begin{bmatrix} -\ syll \end{bmatrix}_{0-n}\ \#$$

Notation by cover symbols:

$$\mathrm{R} \rightarrow \underset{\circ}{\mathrm{R}}\ /\ \#\mathrm{C}_1^n\ \_\ \mathrm{VC}_0^n\#$$

Example:

Paradigm *{ḱuon-} "dog"						
Case form	phonological input		phonetic output	Old Indic	Greek attested	Greek expected
Nom.Sg.	/ḱuō(n)/	→	[ḱu͡ō(n)] / [ḱuu͡ō(n)]	ś$_u$vā	κύων / †πῶν	
Acc.Sg.	/ḱuón-m/	→	[ḱu͡ónm̥]	śvā́nam	⟨κύνα⟩	†πόνα
Gen.Sg.	/ḱun-és/	→	[ḱunés]	śunás	(κυνός)	†κυνές
Nom.Pl.	/ḱuón-es/	→	[ḱu͡ónes]	śvā́nas	⟨κύνες⟩	†πόνες
Acc.Pl.	/ḱun-ns/	→	[ḱunn̥s]	śunás	κύνας	
Instr.Pl.	/ḱun-b^{h}ís/	→	[ḱu͡n̥b^{h}ís]	śvabhís		
Loc.Pl.	/ḱun-sú/	→	[ḱu͡n̥sú]	*śvasú	<(κῡσί)>	†πασύ

4.2.2.3. Laryngeals (N.B.: syllabicity of obstruents phonetically implausible) /h$_x$/ → [$\underset{\circ}{\mathrm{h}}_x$]

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \end{bmatrix} \rightarrow \begin{bmatrix} +\ syll \end{bmatrix}\ /\ \begin{Bmatrix} \begin{bmatrix} -\ syll \end{bmatrix} \\ \# \end{Bmatrix} \_\_ \begin{Bmatrix} \begin{bmatrix} -\ syll \end{bmatrix} \\ \# \end{Bmatrix}$$

Notation with cover symbols ("colouring" not accountable for):

$$\mathrm{H} \rightarrow \underset{\circ}{\mathrm{H}}\ /\ (\mathrm{C}\ |\ \#)\ \mathrm{H}\ \_\ (\mathrm{C}\ |\ \#)$$

4.2.2.3.1. Alternative solutions:

4.2.2.3.1.1. Shewa anaptyxis before laryngeals: /h_x/ → [$ə_x h_x$]

$$\varnothing \rightarrow \begin{bmatrix} -\ cons \\ +\ syll \\ +\ low \\ \alpha\ rnd \\ \beta\ back \end{bmatrix} / \left\{ \begin{matrix} [-\ syll] \\ \# \end{matrix} \right\} \_\_ \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \\ \alpha\ rnd \\ \beta\ back \end{bmatrix} \left\{ \begin{matrix} [-\ syll] \\ \# \end{matrix} \right\}$$

Notation with cover symbols ("colouring" not accountable for):

Ø → ə / (C | #) _ H (C | #)

4.2.2.3.1.2. Shewa anaptyxis after laryngeals: /h_x/ → [$h_x ə_x$]

$$\varnothing \rightarrow \begin{bmatrix} -\ cons \\ +\ syll \\ +\ low \\ \alpha\ rnd \\ \beta\ back \end{bmatrix} / \left\{ \begin{matrix} [-\ syll] \\ \# \end{matrix} \right\} \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \\ \alpha\ rnd \\ \beta\ back \end{bmatrix} \_\_ \left\{ \begin{matrix} [-\ syll] \\ \# \end{matrix} \right\}$$

Notation with cover symbols ("colouring" not accountable for):

Ø → ə / (C | #) H _ (C | #)

4.2.2.3.1.3. Shewa substitution (N.B.: "double" effects not accountable for): /h_x/ → [$ə_x$]

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \end{bmatrix} \rightarrow \begin{bmatrix} -\ cons \\ -\ obstr \\ +\ syll \end{bmatrix} / \left\{ \begin{matrix} [-\ syll] \\ \# \end{matrix} \right\} \_\_ \left\{ \begin{matrix} [-\ syll] \\ \# \end{matrix} \right\}$$

Notation with cover symbols ("colouring" not accountable for):

H → ∀ / (C | #) _ (C | #)

4.2.3. Other rules concerning laryngeals:

4.2.3.1. "Colouring":

$$\begin{bmatrix} -\ cons \\ +\ syll \\ -\ high \\ -\ back \\ -\ rnd \\ -\ tense \end{bmatrix} \rightarrow \begin{bmatrix} +\ back \\ \alpha\ rnd \end{bmatrix} \ / \left\{ \begin{array}{l} \_\_ \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \\ +\ back \\ \alpha\ rnd \end{bmatrix} \\ \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \\ +\ back \\ \alpha\ rnd \end{bmatrix} \_\_ \end{array} \right\}$$

Notation with cover symbols:

$e \rightarrow a\ /\ (\ \_\ h_2\ )\ |\ (\ h_2\ \_\ )$
$e \rightarrow o\ /\ (\ \_\ h_3\ )\ |\ (\ h_3\ \_\ )$

4.2.3.2. Loss of laryngeal in pausa position ("KUIPER's law", facultative; after colouring!):

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \end{bmatrix} \rightarrow \varnothing \ / \ \_\_\ \#\#$$

Notation with cover symbols:

$H \rightarrow \emptyset\ /\ \_\ \#\#$

4.2.3.3. "Compensatory lengthening":
4.2.3.3.1. a) coinciding with colouring:

$$\begin{bmatrix} -\ cons \\ +\ syll \\ -\ high \\ -\ back \\ -\ rnd \\ -\ tense \end{bmatrix} \rightarrow \begin{bmatrix} \alpha\ back \\ \beta\ rnd \\ +\ tense \end{bmatrix} \ / \ \_\_ \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \\ \alpha\ back \\ \beta\ rnd \end{bmatrix} \begin{bmatrix} -\ syll \end{bmatrix}$$

$e \rightarrow \bar{e}\ /\ \_\ h_1C$
$e \rightarrow \bar{a}\ /\ \_\ h_2C$
$e \rightarrow o\ /\ \_\ h_3C$

4.2.3.3.2. b) same, with laryngeals "absorbed":

$$\begin{bmatrix} -\ cons \\ +\ syll \\ -\ high \\ -\ back \\ -\ rnd \\ -\ tense \end{bmatrix} \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \\ \alpha\ back \\ \beta\ rnd \end{bmatrix} \rightarrow \begin{bmatrix} -\ cons \\ +\ syll \\ -\ high \\ \alpha\ back \\ \beta\ rnd \\ +\ tense \end{bmatrix} / \quad \_\_ \begin{bmatrix} -\ syll \end{bmatrix}$$

$eh_1 \rightarrow \bar{e}$ / _ C
$eh_2 \rightarrow \bar{a}$ / _ C
$eh_3 \rightarrow o$ / _ C

N.B. This cannot be the general rule of PIE because $*h_2$ has been preserved as *ḫ* in this position in Anatolian; cp., e.g. Hitt. *paḫš-* < **peh₂-ḱ-* vs. Lat. *pāscō* etc.

4.2.3.3.3. c) rule to be applied after colouring, including lengthening of i,u,r̥,l̥,m̥,n̥:

$$\begin{bmatrix} +\ syll \\ -\ back \\ -\ rnd \\ -\ tense \end{bmatrix} \rightarrow \begin{bmatrix} +\ tense \end{bmatrix} \quad / \quad \_\_ \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \end{bmatrix} \begin{bmatrix} -\ syll \end{bmatrix}$$

V → V̄ / _ HC

N.B. In the case of nasals and liquids, this rule can hardly represent the actual phonetic development if we consider the Greek development of -ενε- vs -νη- etc. (governed by accent? ablaut levelling?); rather a rule of shewa anaptyxis? Cp.

PIE		Greek		Latin	Slavic	Indo-Iranian		Toch.B
phonological input	phonetic output	Proto-Greek	Classic			OInd.	Avest.	
/ǵ̥nh₁-ti-s/ ← {ǵ̥enh₁-ti-s}?	[ǵə́ₑnᵊəₑtis]	**génetis*	γένεσις					
	[ǵnəₑᵊtis]			*nāti-ō*				
/ǵn̥h₁-t̥o-s/	[ǵnəₑᵊtós]	**gnātós*	(κασί-)γνητος	*nātus*				
	[ǵəₑnᵊtós]					*jātáḥ*	*jātō*	
/ḱr̥h₂s̥n-h₂/ ← {ḱ̥erh₂sn-h₂}?	[ḱəₐr̥hsn̥h]					*śīrṣā́*		
	[ḱə́ₐrhəₐsnəₐh]	**kárahna*	κάρηνα					
/ḱr̥h₂sn̥-̥es/	[ḱəₐrhsnés]					*śīr̥ṣnás*		
/ḱ̥rh₂sn̥-tos/	[ḱrə́ₐhsn̥tos]	**krā́hatos*	κρᾶατος					
/ḱ̥rh₂os/	[ḱə́ₐrhos]					*śíraḥ*	*sarə̄*	
/-str̥h₃-toi/	[-stəₒrᶜə₃toi]	**-storotoi*	ἐ-στόροται					
/str̥h₃-t̥o-s/	[strəₒᶜtós]	**strōtós*	στρωτός	*strātus*				
	[stəₒrᶜtós]					*(stīrṇáḥ)*	*starətas-*	
/p̥rh₃uos/	[pə₃rᶜuos]				*pĭrvŭ-jŭ*	*pū́rvaḥ*	*pouruuō*	*pärwe-ṣṣe*
/p̥rh₃tos/	[prə́₃ᶜtos]	**prōtos*	πρῶτος					

4.2.3.3.4. d) same in word final position: three (facultative) effects:

4.2.3.3.4.1. lengthening:

$$\begin{bmatrix} +\ syll \\ -\ back \\ -\ rnd \\ -\ tense \end{bmatrix} \rightarrow \begin{bmatrix} +\ tense \end{bmatrix} \quad / \quad \_\_ \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \end{bmatrix} \#$$

V → V̄ / _ HC

4.2.3.3.4.2. loss of laryngeal ("KUIPER's law"):

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \end{bmatrix} \rightarrow \varnothing \quad / \quad \_\_ \ \#$$

Notation with cover symbols:

H → Ø / V _ #

4.2.3.3.4.3. after *i,u*: shewa anaptyxis before laryngeal:

$$\varnothing \rightarrow \begin{bmatrix} -\ cons \\ +\ syll \\ +\ low \\ \alpha\ rnd \\ \beta\ back \end{bmatrix} \quad / \quad \begin{bmatrix} -\ obstr \\ +\ high \end{bmatrix} \_\_ \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \\ \alpha\ rnd \\ \beta\ back \end{bmatrix} \#$$

Notation with cover symbols ("colouring" not accountable for):

Ø → ə / R _ H #

Examples:

phonological input		phonetic output		Attested I.E. languages
*/p̩ih$_1$uerih$_2$/	→	[pí̯u̯erī]	>	OInd. *pívarī*
	→	[pí̯u̯eri]	>	OInd. voc. **pívari*
	→	[pí̯u̯eriə$_a$h]	>	Greek πίειρα
/p̩otnih$_2$/	→	[pótnī]	>	OInd. *pátnī*
	→	[pótni]	>	OInd. voc. *pátni*
	→	[pótn$_i$i̯ə$_a$h]	>	Greek πότνια
/plth$_2$u̯ih$_2$/	→	[pl̥t^{h}hə$_a$ui̯ī]	>	OInd. *pr̥t^h(i)vī*
	→	[pl̥t^{h}hə$_a$ui̯i]	>	OInd. voc. *pŕt^h(i)vi*
	→	[pl̥tə$_a$hui̯ə$_a$h]	>	Greek *πλαταῖα
/h$_3$k^{w}ih$_1$	→	[^{c}ə$_o$k$_w$ī]	>	(Arm. *ač^c-k^c*, Slav. *očī*, Lith. *akì*)
	→	[^{c}ə$_o$k$_w$i]		
		[^{c}ə$_o$k$_w$i̯ə$_e$^{ɔ}]	>	Greek ὄσσε

4.2.3.4. Occlusives ("shewa secundum"). Cf. PETERS, *Laryngale*, 98. N.B.: This "shewa" to be regarded as unrounded high vowel

$$\varnothing \rightarrow \begin{bmatrix} -\ cons \\ +\ high \\ -\ rnd \\ +\ back \end{bmatrix} /\ \# \begin{bmatrix} +\ cons \\ +\ obstr \\ -\ low \\ -\ fric \end{bmatrix} \_\_ \begin{bmatrix} +\ cons \\ +\ obstr \\ -\ low \\ -\ fric \end{bmatrix} \begin{bmatrix} -\ syll \end{bmatrix}$$

Notation with cover symbols:

Ø → ṭ / #Z_ZC

N.B. This rule is facultative; it alternates with cluster reduction:

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ -\ low \\ -\ fric \end{bmatrix} \rightarrow \varnothing /\ \# \ \_\_ \begin{bmatrix} +\ cons \\ +\ obstr \\ -\ low \\ -\ fric \end{bmatrix} \begin{bmatrix} -\ syll \end{bmatrix}$$

Notation with cover symbols:

Z → Ø / #_ZC

N.B. This rule must be applied before LINDEMAN's law.

4.3. Further rules concerning syllabification:

4.3.1. STANG's (second) law:

$$\begin{bmatrix} -\ cons \\ -\ high \\ -\ tense \end{bmatrix} \begin{bmatrix} -\ cons \\ +\ high \end{bmatrix} \rightarrow \begin{bmatrix} -\ cons \\ -\ high \\ +\ tense \end{bmatrix} /\ \_\_ \begin{bmatrix} +\ cons \\ +\ nas \end{bmatrix} \#$$

Notation with cover symbols:

EI → Ē / _ N

Examples:

phonological input		phonetic output		Attested I.E. languages
*/dieum/	→	[d(i)i̯ēm]	>	OInd. *d^{i}yām*, Greek ζῆν, Lat. **diēm* > *diem*
*/g^{u}oum/	→	[g^{u}ōm]	>	OInd. *gām*, Greek βῶν

4.3.2. STANG's law applied to laryngeals:

$$\begin{bmatrix} -\ cons \\ -\ high \\ -\ tense \end{bmatrix} \begin{bmatrix} +\ cons \\ +\ low \end{bmatrix} \rightarrow \begin{bmatrix} -\ cons \\ -\ high \\ +\ tense \end{bmatrix} / \_\_ \begin{bmatrix} +\ cons \\ +\ nas \end{bmatrix} \left\{ \begin{matrix} [-\ syll] \\ \# \end{matrix} \right\}$$

This rule is obviously facultative, alternating with syllabification of the nasal involved:

Examples:

phonological input		phonetic output		Attested I.E. languages
*/teh$_2$m/	→	[tām]	>	OInd. *tām*, Greek τήν, OCS *tǫ*
*/teh$_2$ns/	→	[tāns]	>	Greek τάς < τανς << τᾱνς;
	→	[tahn̥s]	>	PIIr. *tahas > OInd. *tās*;
*/h$_2$u̯eh$_1$ntos/	→	[hu̯ḗn̥tos]	→	Toch. *want* / *yente*; Goth. *winds*, Lat. *uentus*
	→	[hu̯éə̯n̥tos]	→	OInd. Avest. ⟨*vātas*⟩ [*u̯aatas*]

4.3.3. RIX' law (concerning Greek):

4.3.3.1. Alternative interpretation 1: Shewa substitution:

$$\begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \\ \alpha\ back \\ \beta\ rnd \end{bmatrix} \rightarrow \begin{bmatrix} -\ cons \\ -\ obstr \end{bmatrix} / \#\ \_\_ \begin{bmatrix} +\ cons \\ -\ obstr \end{bmatrix} [-\ syll]$$

4.3.3.2. Alternative interpretation 2: Left shewa anaptyxis:

$$\varnothing \rightarrow \begin{bmatrix} -\ cons \\ +\ syll \\ +\ low \\ \alpha\ back \\ \beta\ rnd \end{bmatrix} / \#\ \_\_ \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \\ \alpha\ back \\ \beta\ rnd \end{bmatrix} \begin{bmatrix} +\ cons \\ -\ obstr \end{bmatrix} [-\ syll]$$

N.B. Must be applied before OSTHOFF's law?

4.3.3.3. Alternative interpretation 3: Right shewa anaptyxis:

$$\varnothing \rightarrow \begin{bmatrix} -\ cons \\ +\ syll \\ +\ low \\ \alpha\ back \\ \beta\ rnd \end{bmatrix} / \quad \# \begin{bmatrix} +\ cons \\ +\ obstr \\ +\ low \\ \alpha\ back \\ \beta\ rnd \end{bmatrix} \text{\_\_} \begin{bmatrix} +\ cons \\ -\ obstr \end{bmatrix} \begin{bmatrix} -\ syll \end{bmatrix}$$

Examples:

phonological input		phonetic output		Attested I.E. languages
*h_1*rsḱ'e-*	→	[ˀr̥sḱé-]	>	OInd. *r̥cchá-ti*
	→	[ˀə$_e$rsḱé-]	>	Greek ἔρχε-ται
*h_2*mb$^{h'}$i*)	→	[hm̥b^{h}í]	>	OInd. *abhí*, OHG *umbe*
	→	[hə$_a$mb^{h}í]	>	Greek ἄμφί
*h_3*nb^{h}l-*	→	[^{c}n̥b^{h}l-]	>	Lat. *umbilīcus*, OIr. *imbliu*
	→	[^{c}ə$_o$nb^{h}l̥l-]	>	Greek ὄμφαλός
*h_3*nobh-*	→	[^{c}ə$_o$nob^h]	>	OHG *nabulo*, OInd. *nābha-*
*h_3*nebh-*	→	[^{c}ə$_o$neb^h]	>	Arm. *aniw*

5. Rules concerning individual branches or languages

5.1. General tendencies in the development of the system of stops:

Proto-IE.	T	M	MA	Rules to be observed
Old-Indic	T	M	MA	4.1.4, 5.1, 5.1.1, 5.3
Old-Iranian	T	M		4.1.4, 5.1, 5.1.1, 5.5
Greek	T	M	TA	5.3
Italic	T	M	TA > F	
Celtic	T	M		
Germanic	F	T	M > F	5.1, 5.1.1, 5.2
Balto-Slavic	T	M		
Armenian	TA	TG	M	
Tocharian	T			
Anatolian	T?	M?		

5.1.1. Glottalistic reinterpretation:

Proto-IE.	TA	TG	MA	Rules to be observed
Old-Indic	T	M	MA	4.1.4, 5.1, 5.1.1 , 5.3
Old-Iranian	T	M		4.1.4, 5.1, 5.1.1 , 5.5
Greek	T	M	TA	5.3
Italic	T	M	TA > F	
Celtic	T	M		
Germanic	F	T	M > F	5.1, 5.1.1, 5.2
Balto-Slavic	T	M		
Armenian	TA	TG	M	
Tocharian	T			
Anatolian	T?	M?		

N.B.: T = Tenuis, M = Media, MA = Media Aspirata, TA = Tenuis Aspirata,
F = Fricative, TG = Tenuis Glottalis

5.1.2. Special rules for original mediae aspiratae in Latin:
5.1.2.1. Proto-Italic development:
5.1.2.1.1. Desonorization (as in Greek):

$$\begin{bmatrix} + & okkl \\ + & asp \end{bmatrix} \rightarrow \begin{bmatrix} + & okkl \\ + & asp \\ - & sth \end{bmatrix}$$

↓

$*b^h$	$*d^h$	$*\acute{g}^h/*g^h$	$*g^{uh}$
$*p^h$	$*t^h$	$*k^h$	$*k^{uh}$

5.1.2.1.2. Fricativization (as in later Greek):

$$\begin{bmatrix} + & okkl \\ + & asp \end{bmatrix} \rightarrow \begin{bmatrix} - & okkl \end{bmatrix}$$

↓

$*p^h$	$*t^h$	$*k^h$	$*k^{uh}$
$*f$	$*\vartheta$	$*\chi$	$*\chi^u$

5.1.2.2. Proto-Latin developments:
5.1.2.2.1. Sonorization in intervocalic position:

$$\begin{bmatrix} + & obstr \\ - & okkl \\ - & sth \end{bmatrix} \rightarrow \begin{bmatrix} + & obstr \\ - & okkl \\ + & asp \end{bmatrix} / \begin{bmatrix} + & son \end{bmatrix}_1 \_\_ \begin{bmatrix} + & son \end{bmatrix}_1$$

↓

$*f$	$*\vartheta$	$*\chi$	$*\chi^u$
$*\bar{b}$	$*\bar{\delta}$	$*\bar{g}$	$*\bar{g}^u$

5.1.2.2.2. Further development of dental fricatives:

$$\begin{bmatrix} + & obstr \\ - & okkl \\ + & dent \end{bmatrix} \rightarrow \begin{bmatrix} + & obstr \\ - & okkl \\ + & lab \end{bmatrix} / \left\{ \begin{array}{c} \# \_\_ \\ \begin{bmatrix} + & son \\ + & rund \\ + & hoch \\ + & post \end{bmatrix} \_\_ \\ \begin{bmatrix} + & vibr \end{bmatrix} \_\_ \\ \_\_ \begin{bmatrix} + & liqu \end{bmatrix} \end{array} \right\}$$

5.2. GRIMM's / VERNER's law

5.2.1. Rule A:

$$\begin{bmatrix} +\ obstr \\ \pm\ okkl \\ -\ sth \end{bmatrix} \rightarrow \begin{bmatrix} +\ obstr \\ -\ okkl \\ -\alpha\ sth \end{bmatrix} / \left\{ \begin{matrix} \# \\ \begin{bmatrix} +\ syll \\ \alpha\ akz \end{bmatrix} \begin{bmatrix} -\ syll \end{bmatrix}_0 \end{matrix} \right\} \underline{\quad}$$

5.2.2. Rule B:

$$\begin{bmatrix} +\ obstr \\ +\ okkl \\ +\ sth \\ +\ asp \end{bmatrix} \rightarrow \begin{bmatrix} +\ obstr \\ -\ okkl \\ +\ sth \end{bmatrix}$$

5.2.3. Rule C:

$$\begin{bmatrix} +\ obstr \\ +\ okkl \\ +\ sth \\ -\ asp \end{bmatrix} \rightarrow \begin{bmatrix} +\ obstr \\ +\ okkl \\ -\ sth \end{bmatrix}$$

5.2.4. Rules B and C unified:

$$\begin{bmatrix} +\ obstr \\ +\ okkl \\ +\ sth \\ \alpha\ asp \end{bmatrix} \rightarrow \begin{bmatrix} +\ obstr \\ -\alpha\ okkl \\ \alpha\ sth \end{bmatrix}$$

5.3. GRASSMANN's law (dissimilation of aspirated sounds, valid for Indo-Iranian and Greek)

$$\begin{bmatrix} +\ okkl \\ +\ asp \end{bmatrix} \rightarrow \begin{bmatrix} +\ okkl \\ -\ asp \end{bmatrix} / \underline{\quad} \begin{bmatrix} +\ son \end{bmatrix}_1 \begin{bmatrix} +\ okkl \\ +\ asp \end{bmatrix}$$

N.B. This rule must be applied after the desonorization of mediae in Greek:

$$\begin{bmatrix} +\ okkl \\ +\ asp \\ +\ sth \end{bmatrix} \rightarrow \begin{bmatrix} +\ okkl \\ +\ asp \\ -\ sth \end{bmatrix}$$

5.4. BRUGMANN's rule (valid for Indo-Iranian)

$$\begin{bmatrix} +\ syll \\ -\ kons \\ +\ post \\ +\ rund \\ -\ hoch \\ -\ lang \end{bmatrix} \rightarrow \begin{bmatrix} +\ syll \\ -\ kons \\ -\ post \\ -\ ant \\ -\ rund \\ -\ hoch \\ +\ lang \end{bmatrix} \ / \ \_\_ \ [-\ syll][+\ syll]$$

5.5. Spirantization of stops in Iranian:

$$[+\ okkl] \rightarrow [-\ okkl] \ / \ \_\_ \ [-\ syll]$$

5.6. The Indo-Iranian development of palatals ("palatal law"):

$$\begin{bmatrix} +\ okkl \\ +\ vel \end{bmatrix} \rightarrow \begin{bmatrix} +\ affr \\ +\ pal \end{bmatrix} / \_\_ \begin{bmatrix} +\ vok \\ +\ ant \end{bmatrix}$$

N.B. Must be applied before the merger of mid vowels:

$$\begin{bmatrix} +\ syll \\ -\ kons \\ -\ hoch \end{bmatrix} \rightarrow \begin{bmatrix} +\ syll \\ -\ kons \\ -\ post \\ -\ ant \\ -\ rund \\ -\ hoch \end{bmatrix}$$

Examples:

PIE		PIIr.		OInd.	Avest.	
phonological input	phonetic output	Early	Late		phonologically	graphically
–k^{u}e	[–k^{u}e]	*–če	*–ča	–ca	/-ca/	⟨-ca⟩
g^{u} ̥enh$_2$	[g^{u}énə$_a$h]	*ǰénə	*ǰánə	jáni-	/jani-/	⟨jaini-⟩
g^{uh} ̥en-ti	[g^{uh}énti]	*ǰ^{h}énti	*ǰ^{h}ánti	hánti	/janti/	⟨jainti⟩
ki ̥eue–toi	[kiéuetoi]	*čiéuetoi	*čiáuatai	cyávate	/šiaua-/	⟨š(ii)auua–⟩
iung ̥enti	[iungénti]	*iunǰénti	*iunǰénti	yuñjánti	*/iunjanti/	*⟨yunjinti⟩
g^{h} ̥edeti	[g^{h}édeti]	*ǰ^{h}édeti	*ǰ^{h}ádati	*hadati		

5.7. The Slavic palatalizations

5.7.1. First palatalization

$$\begin{bmatrix} \alpha\ okkl \\ +\ vel \end{bmatrix} \rightarrow \begin{bmatrix} \alpha\ affr \\ +\ pal \end{bmatrix} / \_\_ \begin{bmatrix} +\ vok \\ +\ ant \end{bmatrix}$$

N.B. The rule must be applied before the monophthongization of **oi̯*, **ai̯* > *ě* (cf. 5.7.2 below), but after the effects of the *ruki*-rule (cf. 4.1.8) leading from **s* > *x*:

$$\begin{bmatrix} +\ frik \\ -\ sth \\ +\ dent \end{bmatrix} \rightarrow \begin{bmatrix} +\ frik \\ -\ sth \\ +\ alv \end{bmatrix} / \left\{ \begin{matrix} \begin{bmatrix} +\ vok \\ +\ hoch \end{bmatrix} \\ \begin{bmatrix} +\ kons \\ +\ vibr \end{bmatrix} \\ \begin{bmatrix} +\ okkl \\ +\ vel \end{bmatrix} \end{matrix} \right\} \_\_ \begin{bmatrix} -\ okkl \end{bmatrix}$$

5.7.2. Second palatalization

5.7.2.1. East- and South-Slavic:

$$\begin{bmatrix} \alpha\ okkl \\ +\ vel \end{bmatrix} \rightarrow \begin{bmatrix} \alpha\ affr \\ +\ alv \end{bmatrix} / \_\_ \begin{bmatrix} +\ vok \\ +\ ant \\ +\ tief \end{bmatrix}$$

5.7.2.2. West-Slavic:

$$\begin{bmatrix} \alpha\ okkl \\ +\ vel \end{bmatrix} \rightarrow \begin{bmatrix} \alpha\ affr \\ \alpha\ alv \\ -\alpha\ pal \end{bmatrix} / \_\_ \begin{bmatrix} +\ vok \\ +\ ant \\ +\ tief \end{bmatrix}$$

N.B.: The conditioning vowel must be the result of *a* or *o* plus *i* (diphthong, later merging with *ě* or *ī*).

5.7.3. Third palatalization:

5.7.3.1. East- and South-Slavic:

$$\begin{bmatrix} \alpha\ okkl \\ +\ vel \end{bmatrix} \rightarrow \begin{bmatrix} \alpha\ affr \\ +\ alv \end{bmatrix} / \begin{bmatrix} +\ vok \\ +\ ant \\ +\ hoch \\ -\ akz \end{bmatrix} \_\_ \begin{Bmatrix} +\ vok \\ +\ tief \end{Bmatrix}$$

5.7.3.2. West-Slavic:

$$\begin{bmatrix} \alpha\ okkl \\ +\ vel \end{bmatrix} \rightarrow \begin{bmatrix} \alpha\ affr \\ \alpha\ alv \\ -\alpha\ pal \end{bmatrix} / \begin{bmatrix} +\ vok \\ +\ ant \\ +\ hoch \\ -\ akz \end{bmatrix} \_\_ \begin{Bmatrix} +\ vok \\ +\ tief \end{Bmatrix}$$