Linearity and the simplicity of language

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Overview

- 10 years of debate - Hauser, Chomsky and Fitch:
  - recursion is a unique design feature of human languages
  - associated with a compositional 'Merge' operation
  - the property of generating 'a discrete infinity'
- Competing speculations:
  - genetic introduction of recursion in the Paleolithic era?
  - development of broader cognitive abilities?
  - coincides with the introduction of writing?
- Various qualities of argumentation
  - often without further definition of recursion
    - nested self-embedding?
    - iterative (left or right, head or tail) recursion?
    - simply any hierarchical pattern, finite depth or not?

Claim

- In any case: when considering only syntagmatic combinatorics, not semantic interpretation, centre-embedding in human languages is
  - very rare in spoken language (various corpora investigated)
  - only possible in human languages if one or more of the following constraints are fulfilled:
    - finite depth
    - register-specific rehearsal (e.g. public speaking)
    - register-specific medium (e.g. additional written memory)
- Counter-claim:
  - Those are performance issues
- Counter-counter claim:
  - only performance provides empirical evidence
  - complexity and simplicity of structure and issues of memory and processing time are highly inter-dependent

Claims

- Recursion is ubiquitous in the 'discrete infinity' sense
  - not only in language, also in music and art (cf. Escher)
  - simply depends on inductive / recursive definitions – *Merge*?
- Linearity is pervasive through all levels of language:
  - phonology, prosody, morphology, morphosyntax
  - even phrasal syntax: cross-linear dependencies, long-distance dependencies, non-relative *traces*
  - easily modelled by, regular grammars, FSAs, FSTs
- Hierarchical modelling has the functionality needed for
  - abbreviation (FS models tend to be large)
  - generalisation (capturing properties of regions in FS models)
  - semantic interpretation (anaphora can take the place of centre-embedding)
  - but rarely for syntagmatic patterns in the strict sense

Levels of abstraction

- It is sometimes stated that hierarchies are recursive, as in many characterisations of *Merge*. But:

  A given hierarchy is not necessarily recursive

  A given hierarchical rule system is not necessarily recursive:

  Syll → Ons Nuc
  Ons → Sib Obs Son
  Nuc → Vow Cod
  Cod → Son Obs Sib

  At a higher level of abstraction the class of rule systems may indeed be defined recursively:

  $\alpha \rightarrow \gamma$, where $\alpha \in N$ and $\gamma \in (N \cup T)^*$

- Let's not confuse levels of abstraction.

Design features

- Recursion as nested self-embedding is
  - not a central design feature of language
  - peripheral to all varieties, particularly spoken language
  - neither necessary nor sufficient for language:
    - occurs in other domains: music, art
  - a semantic property of general cognitive procedures
    - logic and mathematics, general problem-solving
    - requires anaphora (relative pronouns)
    - is replaceable by other forms of anaphora
  - largely restricted to memory-enhanced modalities:
    - rehearsed speech, writing

But let's take a look at centre-embedding

- Centre-embedding is available to human language communities ...

  But at the cost of

  - additional time – performance and learning (e.g. rehearsal)
  - additional space – memory storage (e.g. writing)

- Under these constraints, centre-embedding may occur
  - in everyday behaviour:
    - multiple levels of interruption associated with different contexts ('lift conversation')
    - in nature ...

Design features

- The major unique, central, necessary and sufficient central design feature of languages is the concept of rank:

  - differently structured strata in languages from phonology to discourse:

    - generalisation of Hockett's design feature 'duality'

    - Martinet's 'double articulation' of language

Hockett's Design Features

So what are the design features of language? Cf. Hockett's list

1. Vocal-auditory channel
2. Broadcast transmission and directional reception
3. Transitoriness
4. Interchangeability
5. Total feedback
6. Specialization
7. Semanticity
8. Arbitariness
9. Discreteness
10. Displacement
11. Productivity
12. Traditional transmission
13. Duality of patterning
14. Prevarication
15. Reflexiveness
16. Learnability

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Channel

Semiotic

Structural

Acquisition

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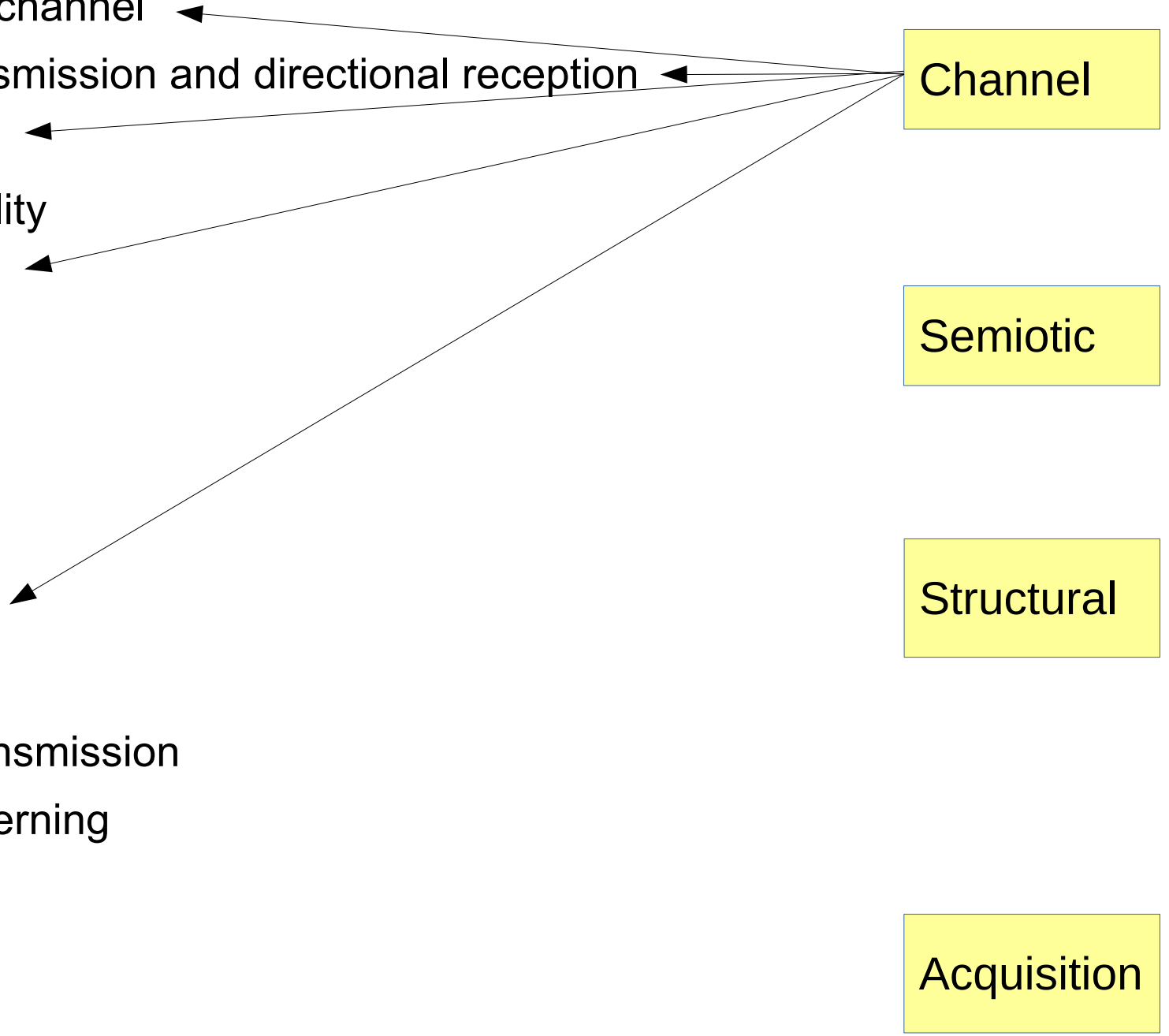

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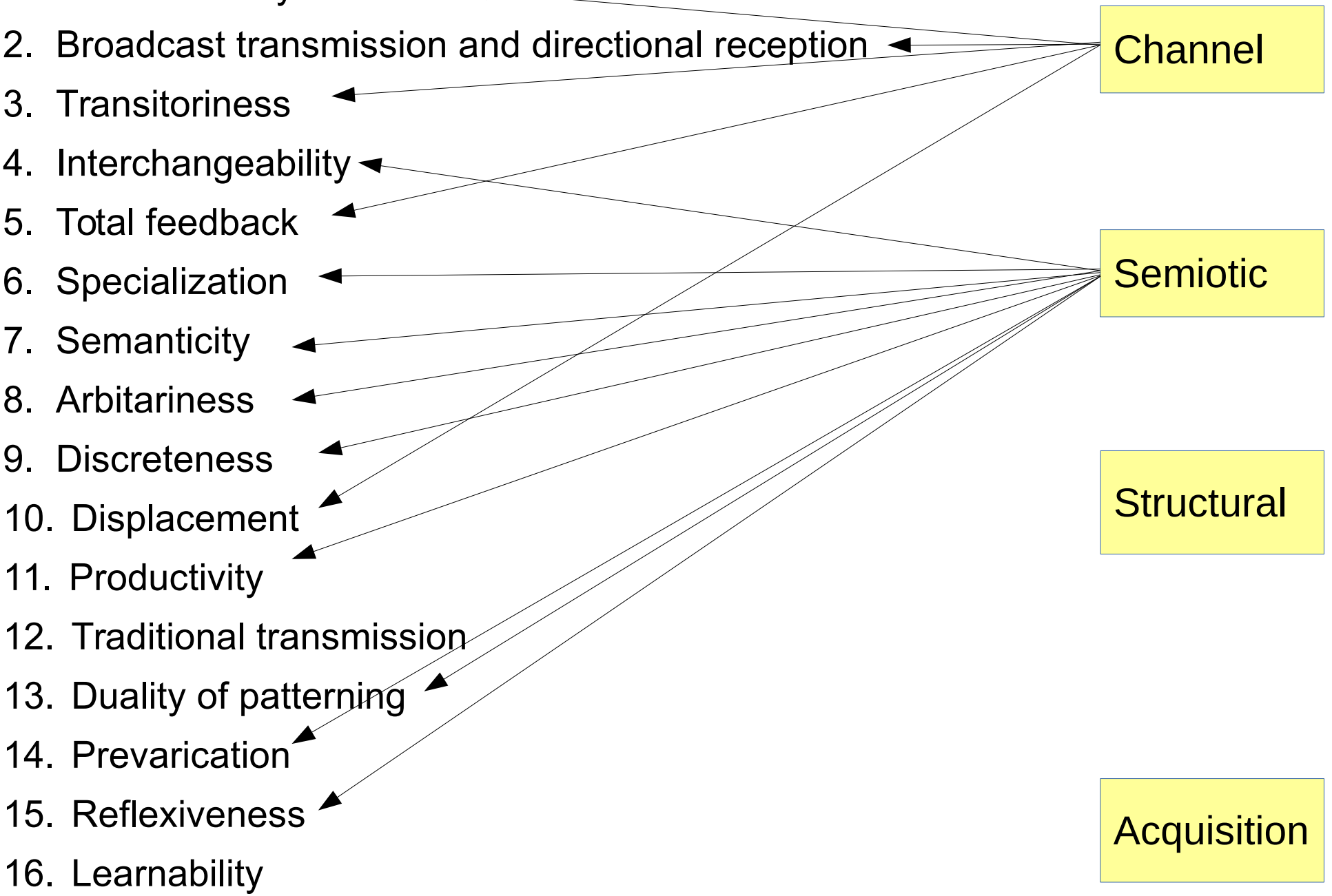

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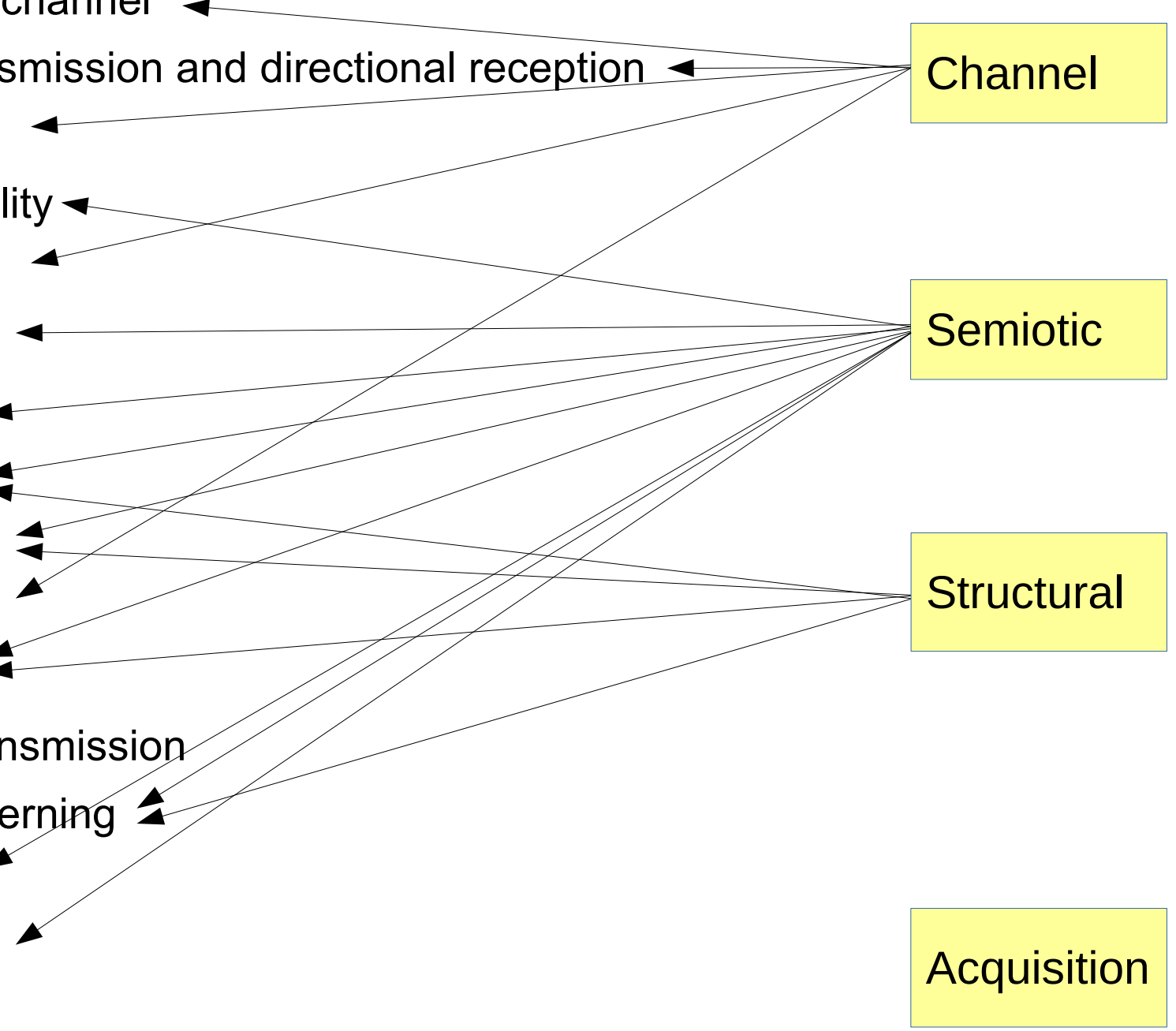

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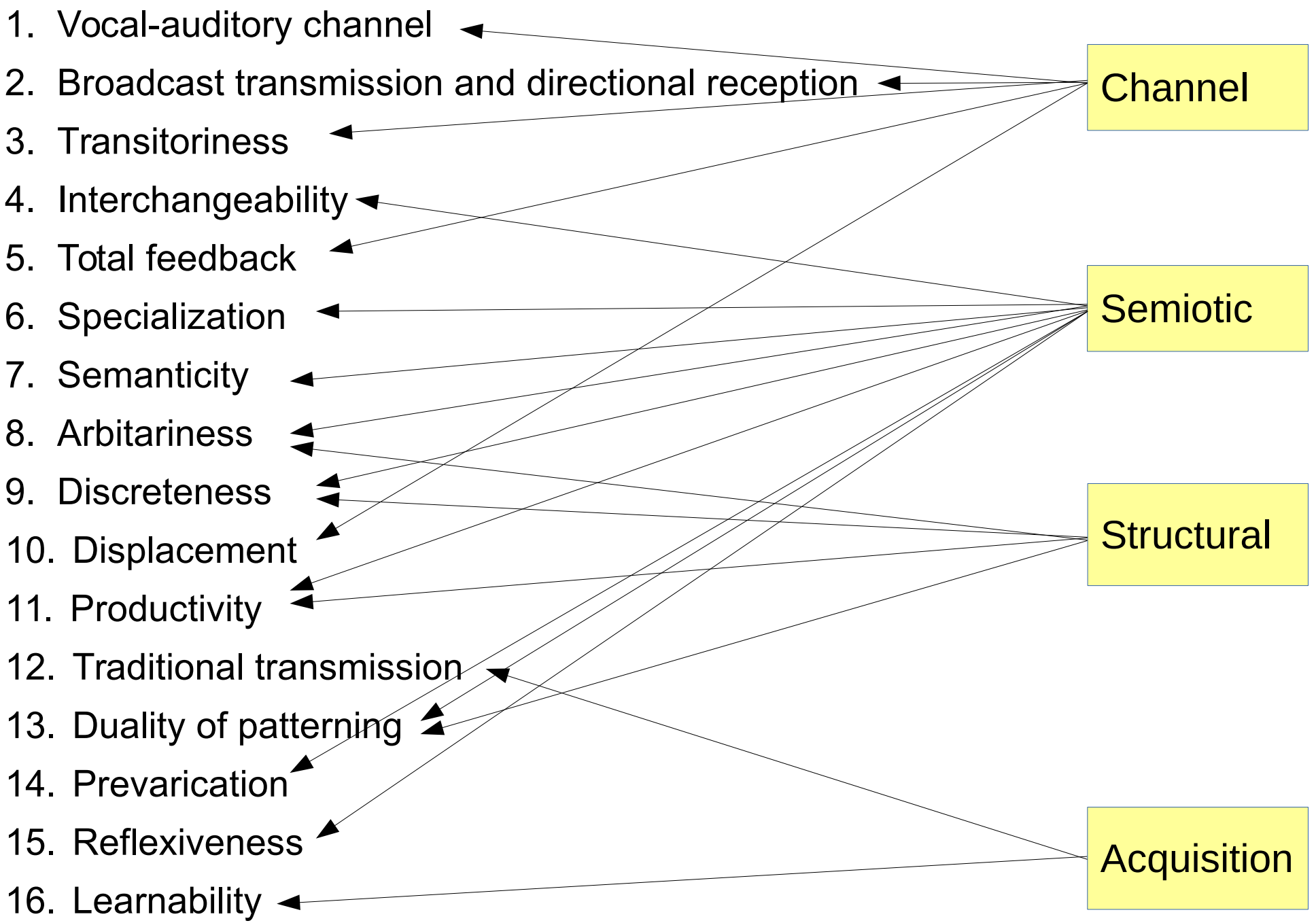

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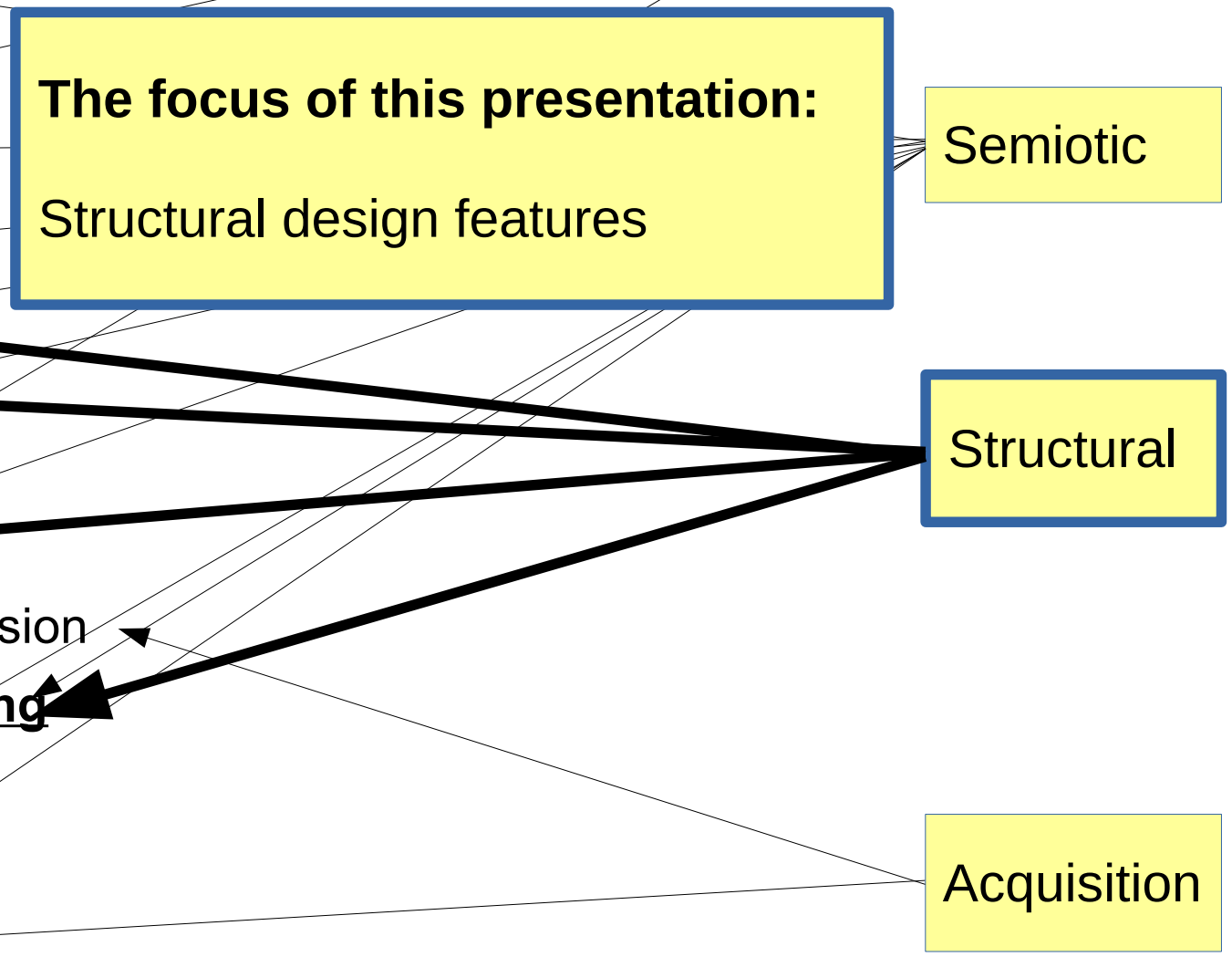

Structural design features

- Arbitariness
  - means: in the present context this means that we can look at the structure of forms without considering semantics
- Discreteness
  - means: we have to do with atomic, linear, hierarchical, cross-hierarchical units rather than signal streams
- Productivity
  - implies: inductive / recursive definition of ‘discrete infinity’
    - flat / iterative / regular / left-or-right-branching recursion
    - centre-embedding recursion
    - indexed recursion
- Duality of patterning
  - states: phonemes and morphemes are semantically independent
  - generalisable to Jespersen and Halliday type ranks

Productivity vs. Complexity

Chomsky-Schützenberger Hierarchy

Grammar	Languages	Automaton	Production rules (constraints)
Type-0	Unrestricted (Recursively enumerable)	Turing machine	$\alpha \rightarrow \gamma$ (no restrictions)
Type-1	Context-sensitive	Linear-bounded non-deterministic Turing machine	$\alpha A \beta \rightarrow \alpha \gamma \beta$
Type-2	Context-free	Non-deterministic pushdown automaton	$\mathbf{A \rightarrow \gamma}$
Type-3	Regular	Finite state automaton	$A \rightarrow a$ and either $A \rightarrow a B$ or $A \rightarrow B a$

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Chomsky-Schützenberger Hierarchy

Pervasive Linearity Principle:

Spoken Language is pervasively linear.

Hierarchies have finite depth. Recursion is iterative.

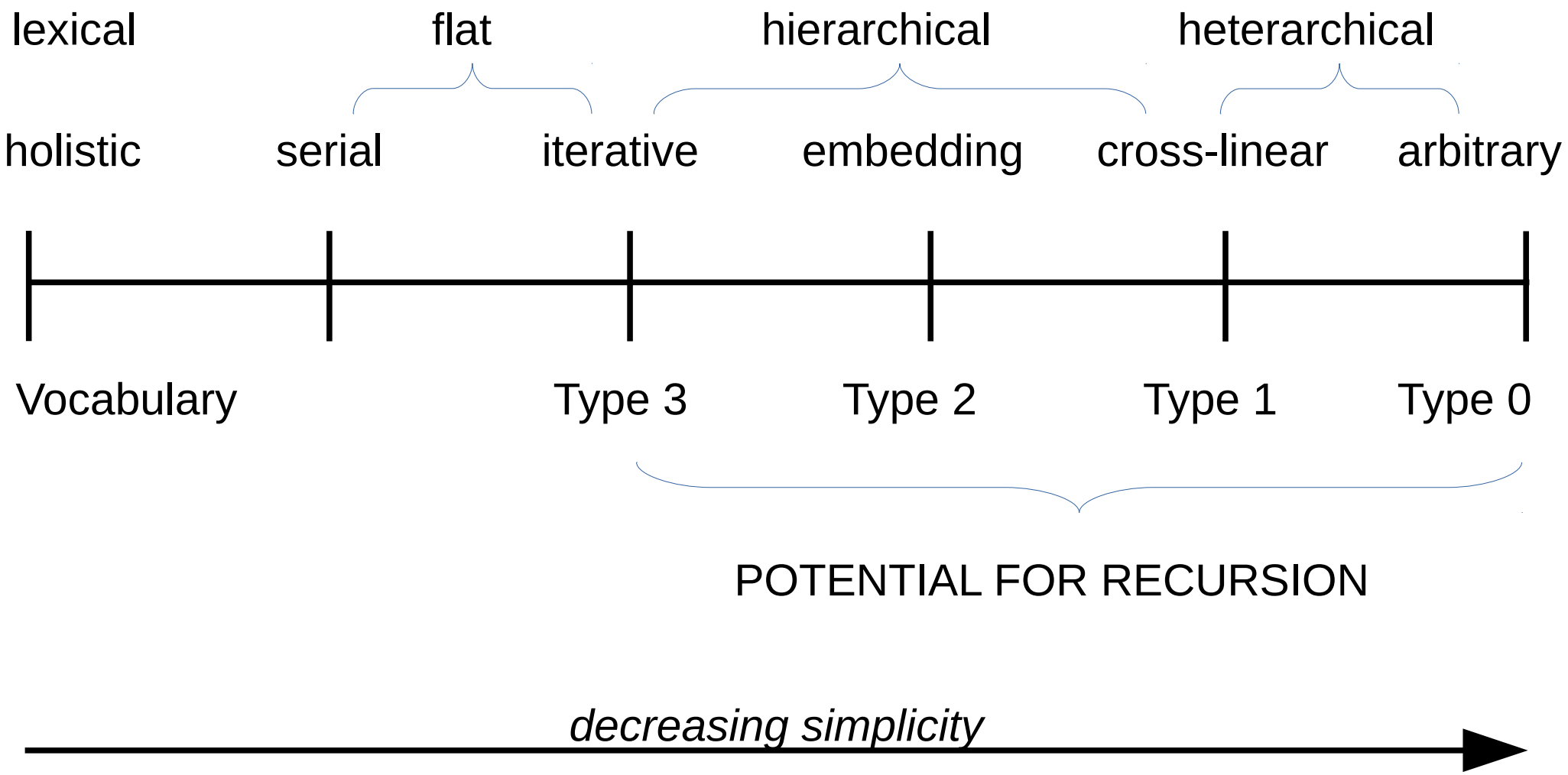
Centre-embedding beyond depth 1 requires additional memory support (rehearsal, writing).

Grammar			rules nts)
Type-0			ions)
Type-1			γ β
Type-2	Context-free	pushdown automaton	A → γ
Type-3	Regular	Finite state automaton	A → a and either A → a B or A → B a

Linearity and Everett's analysis of Pirahã

- Everett initiated the lengthy debate about whether a language must *necessarily* have recursion:
  - No evidence for recursion in Pirahã
- Clearest and most detailed recent discussion of formal aspects, with link to corpus data, in:
  - Futrell, R., Stearns, L., Everett, D. L., Piantadosi, S. T., Gibson, E. 2016. A Corpus Investigation of Syntactic Embedding in Pirahã. PLoS ONE 11(3) e0145289. doi:10.1371/journal.pone.0145289 http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0145289
  - Objective:
    - to find out whether Pirahã can be modelled as a (sub-)regular language
    - with respect to combinatorial properties of sentences alone
    - without regard to semantic or discourse properties

Scale of syntagmatic simplicity



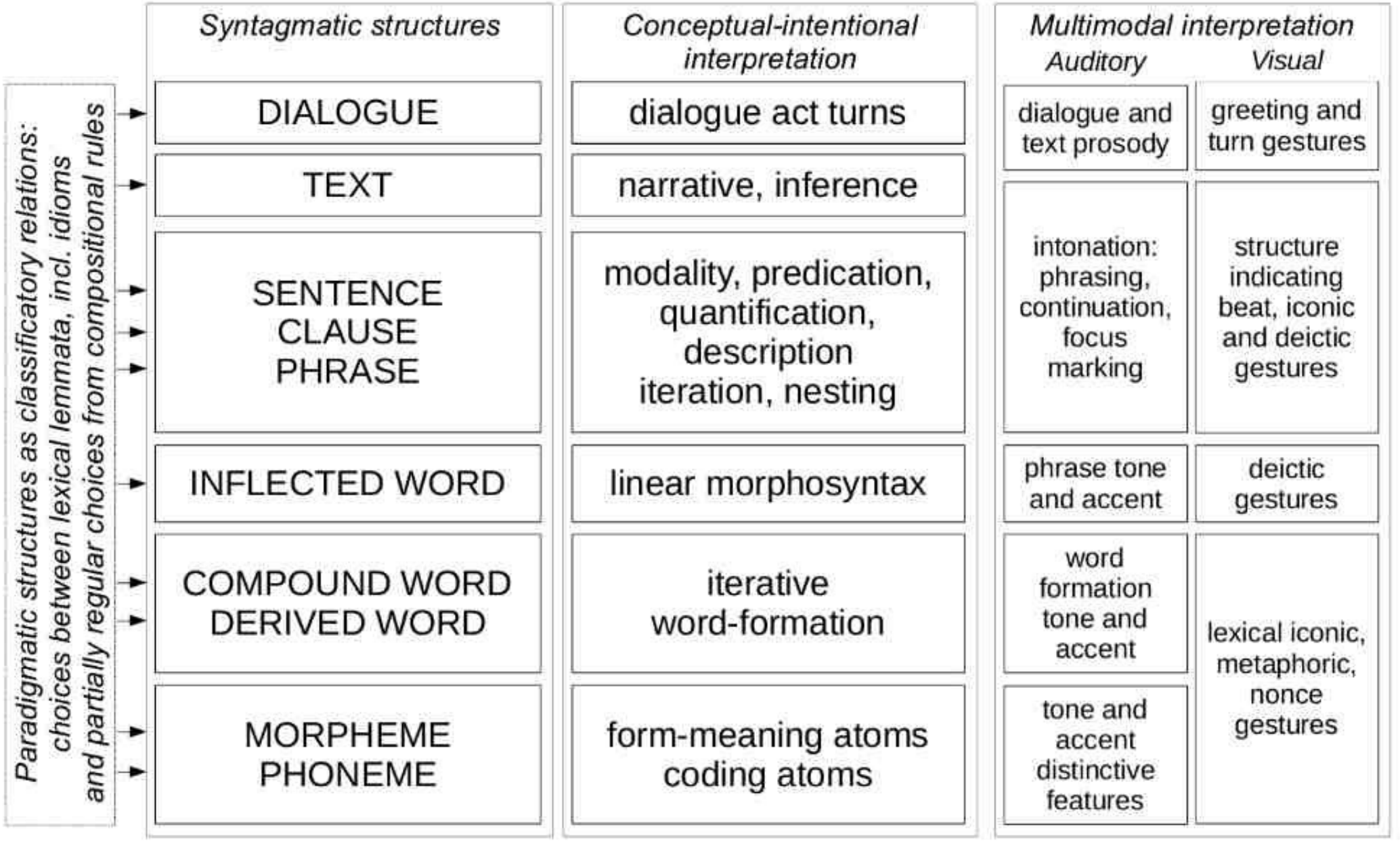
Generalising ‘double articulation’ to a Rank Hierarchy

Generalising Duality: Rank Interpretation as a Design Feature

- The Duality Principle (principle of *double articulation*)
  - phonemes and morphemes are semantically independent
  - phonotactics and morphotactics are structurally independent

- The Rank Interpretation Principle
  - the two levels of phonemes and morphemes can be generalised to multiple ranks
  - each ranks has its own structural principles
  - simplifying:
    - phoneme
    - morpheme
    - word
    - phrase, clause, sentence
    - text, turn
    - discourse
  - at each rank, the Pervasive Linearity Principle holds

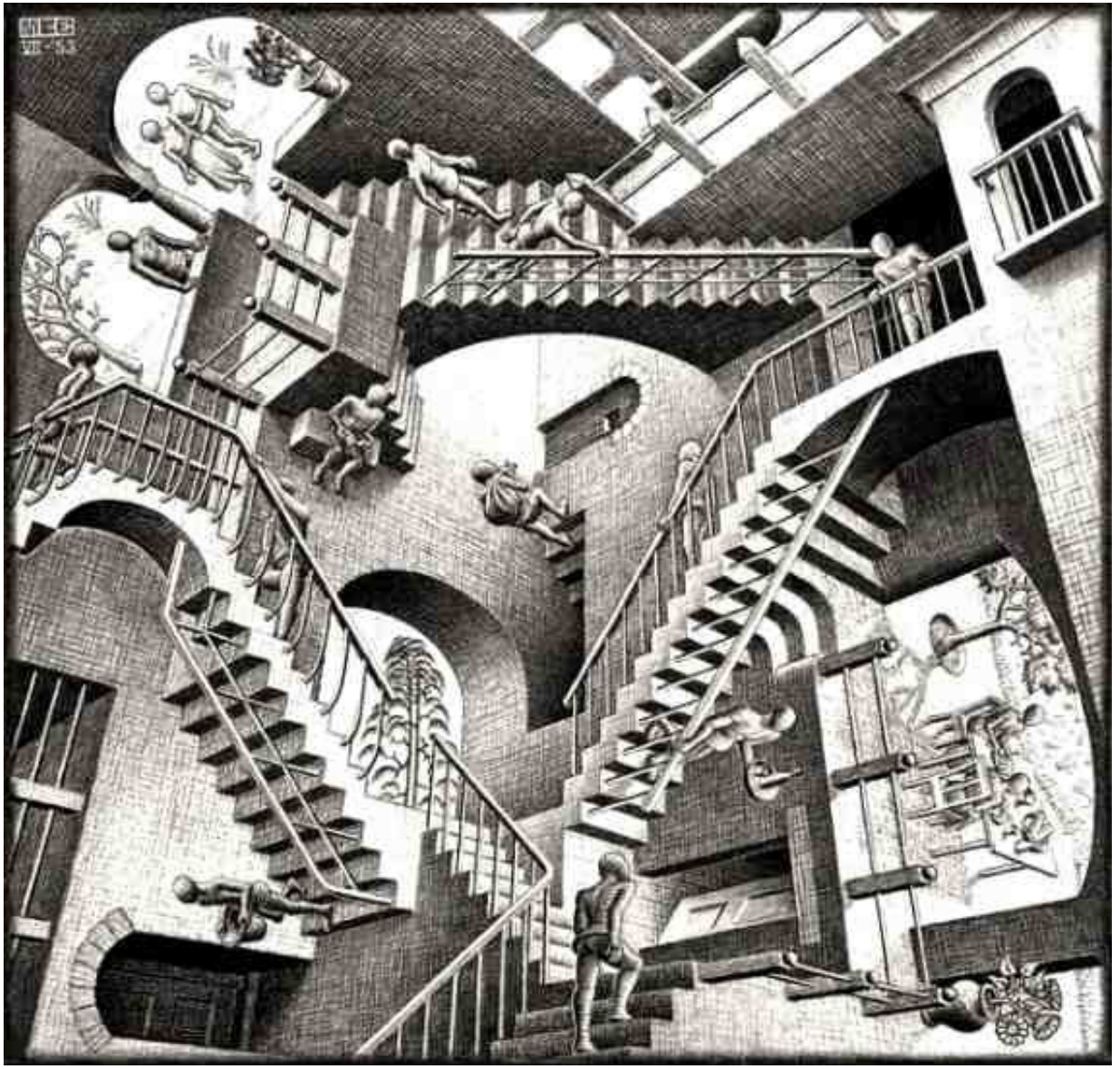
Generalising Duality: Rank Interpretation as a Design Feature



Interlude:

Other domains of recursion ...

Art



Music

- Currently I have no specific example in music
  - but the anaphora condition would have to be fulfilled
  - for example by repetition of a leitmotif
- Iterative patterns in music are common:
  - repeat, Da Capo al Fine, Da Capo al Segno: loops in loops
- Is centre-embedding present? With ‘anaphora’ in the form of recurring leitmotifs? Not sure:
  - Lerdahl & Jackendoff 1983
  - Katz & Pesetzky 2009:

Identity Thesis for Language and Music

All formal differences between language and music are a consequence of differences in their fundamental building blocks (arbitrary pairings of sound and meaning in the case of language, pitch-classes and pitch-class combinations in the case of music).

In all other respects language and music are identical.

Centre-embedding is common in nature ...

There is only one centre of recursion, so the structure may as well be a concatenation of one left branching and one right branching regular grammar.

On the other hand, not only centre-embedding but indexed: each leaf has equal numbers of points left and right.

But, you may say, the index is not only finite but fixed at 11...

Centre-embedding is common in nature ...

There is only one centre of recursion, so the structure may as well be a concatenation of one left branching and one right branching regular grammar.

Similarly with pine trees...

On the other hand, not only centre-embedding but indexed: each leaf has equal numbers of points left and right.

But, you may say, the index is not only finite but fixed at 11...

Centre-embedding is common in nature ...

But consider a more sophisticated tree like the birch.

The birch follows Chomsky's Merge: it not only branches, the branching is apparently binary.

Centre-embedding is common in nature ...

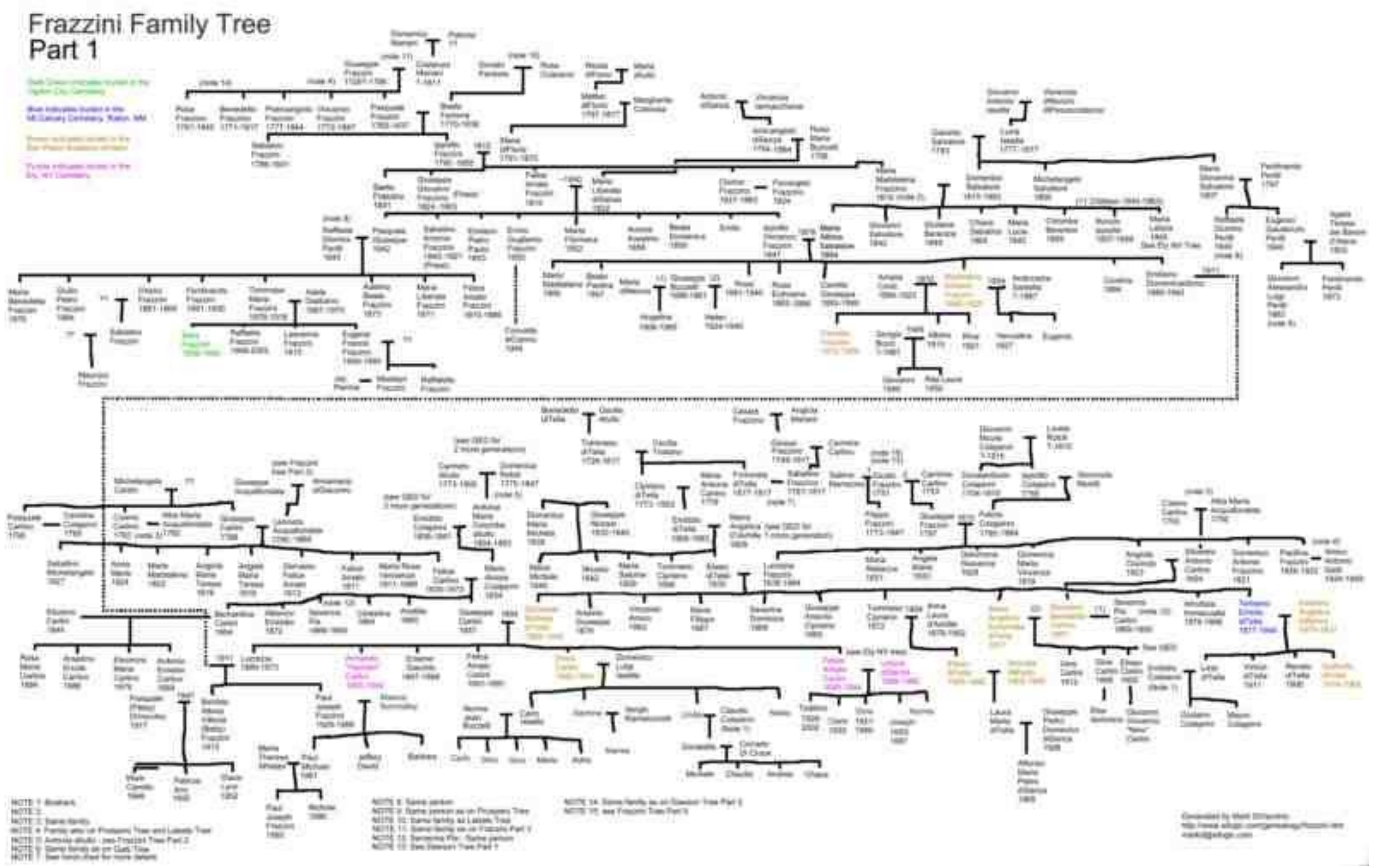
Centre-embedding is common in nature ...

And now the oak – is this binary branching?

Not clear ...

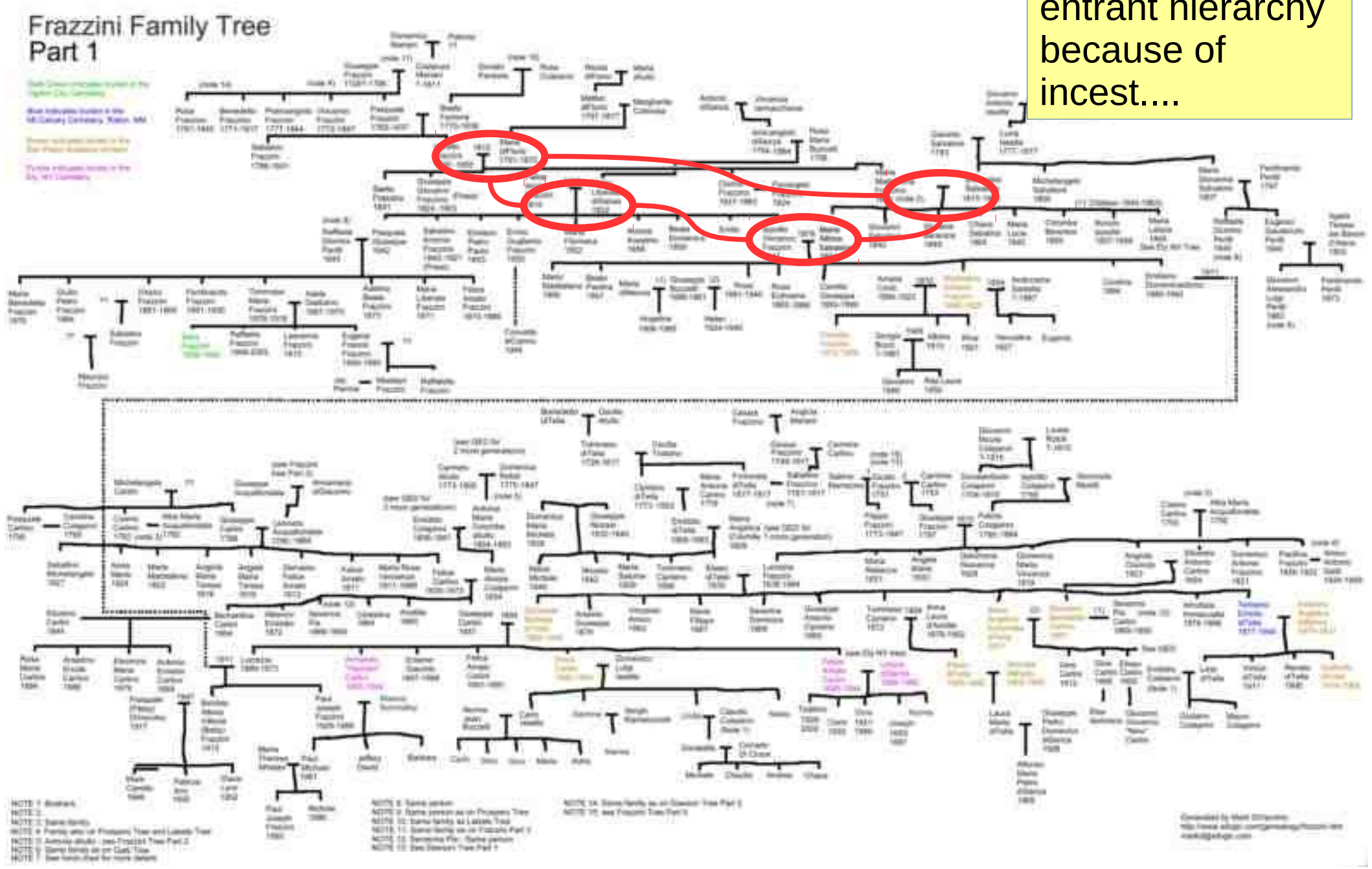
Maybe a “performance” issue – too much centre-embedding requires additional support ...

Centre embedding in evolution … ?



Centre embedding in evolution … ?

Actually a re-entrant hierarchy because of incest....

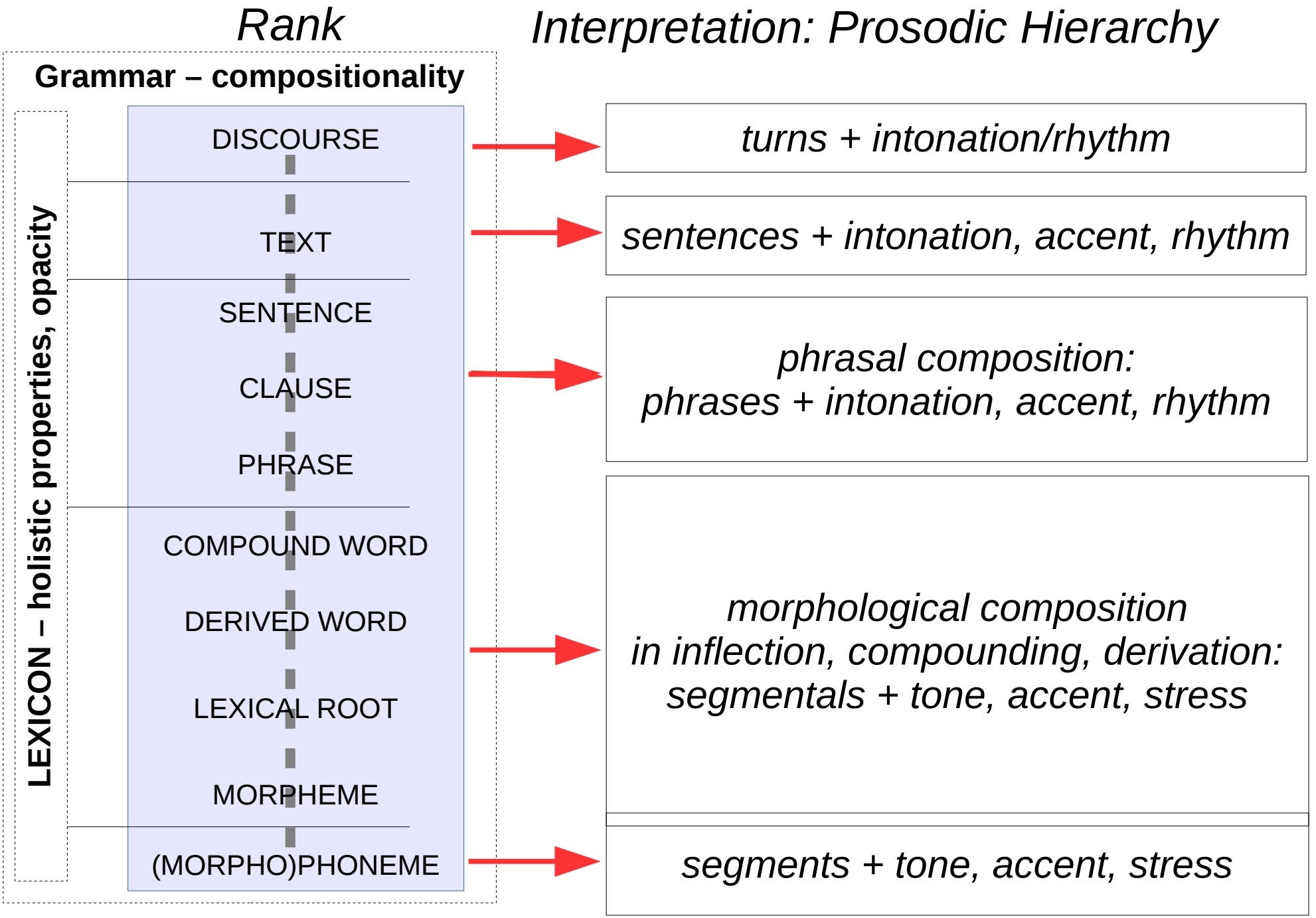


Sounds and Prosodies

Linearity of Sounds and Prosodies

- Early descriptions were linear: CV, CVC, …
- Then: syllable hierarchies
- Sound Pattern of English:
  - linear segment sequences (cf. Johnson 1972 on FS equivalence)
- Autosegmental Phonology:
  - parallel autosegment sequences (cf. Kay 1987 on FS equivalence)
- Finite State Phonology:
  - Johnson 1972, Kay & Karttunen (individual rules are FS equivalent)
  - Whorf (1940)
- Finite State Prosody:
  - Tone: Gibbon (1987 & passim on tone)
  - Intonation: Cohen & al. (1967), Fujisaki & al. (1969), Reich (1989), Pierrehumbert (1980), Gibbon (1981)

Rank-Interpretation Hierarchy: Phonetic / Prosodic interpretation



Ordered rules:

$$N \rightarrow \left\{ \begin{array}{c} m \,/\, \_\ p \\ n \end{array} \right\}$$

$$p \rightarrow m \,/\, m\ \_$$

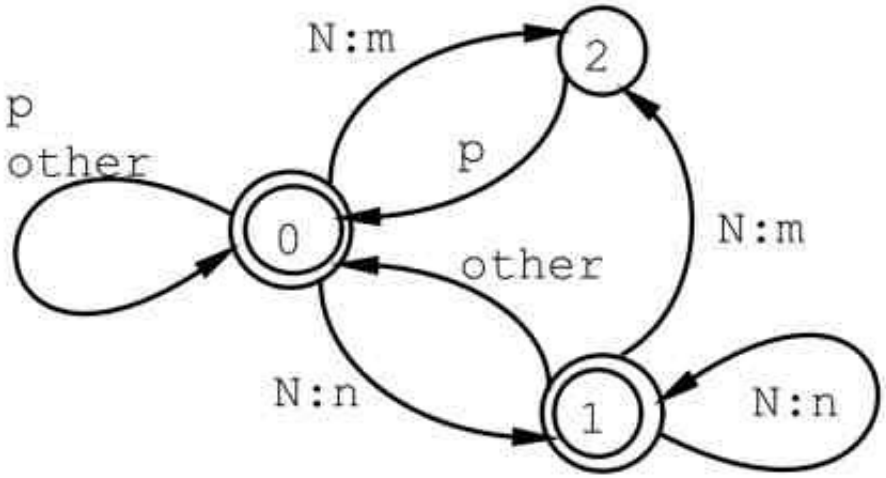
e.g.:

aNp → amp
aNk → ank

amp → amm
alp → alp

Ordered rules:

$$N \rightarrow \left\{ \begin{matrix} m / \_\ p \\ n \end{matrix} \right\}$$



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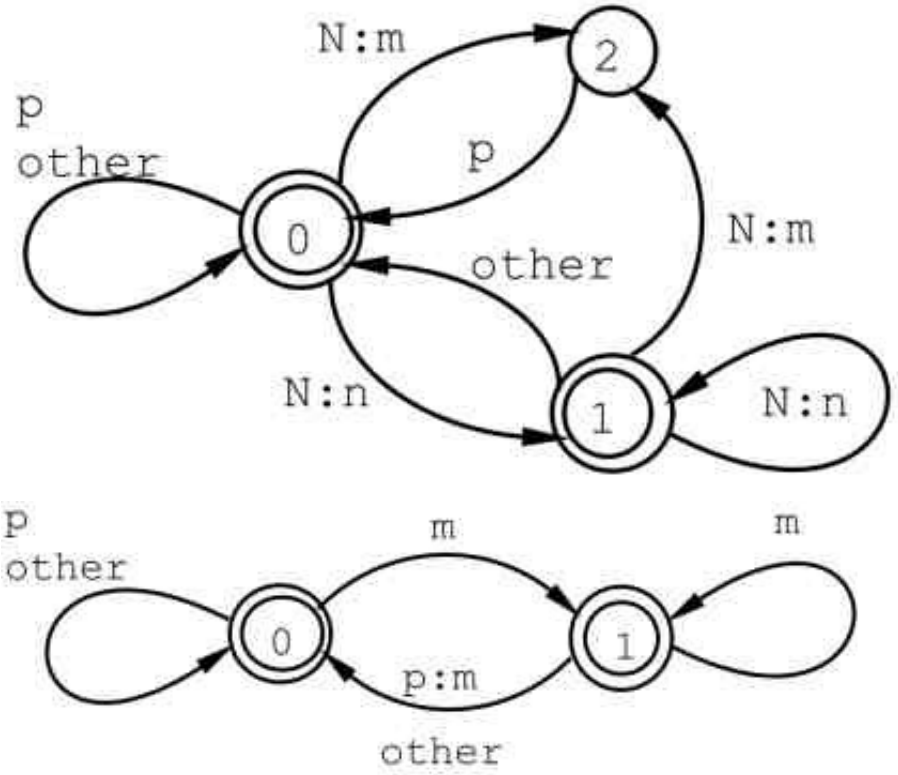

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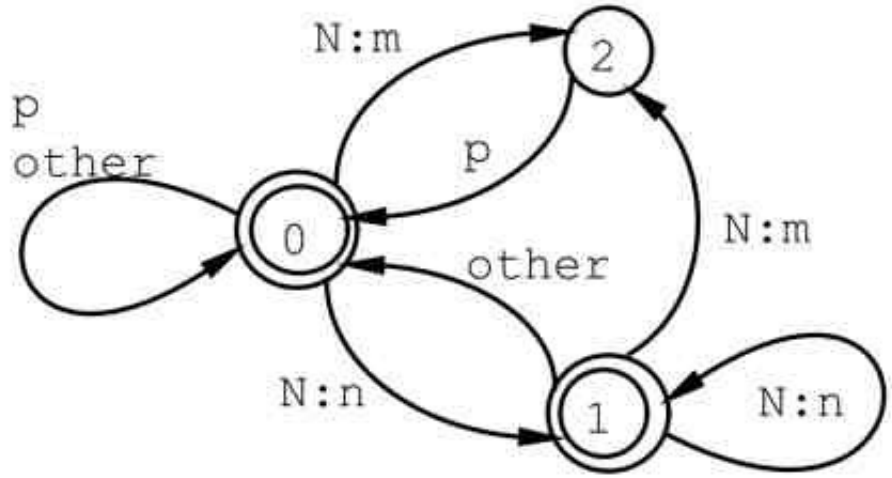

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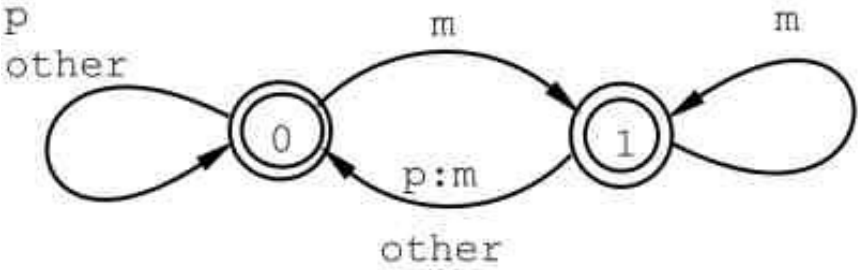

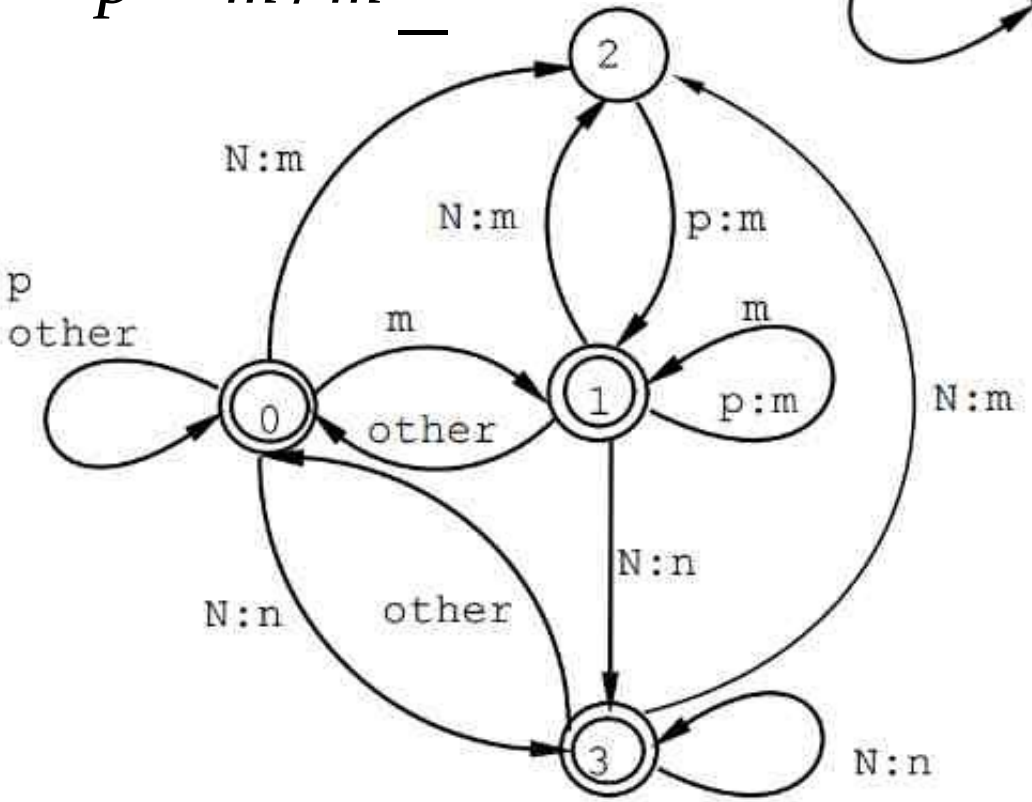

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Syllable phonotactics

- The finite state modelling principle applies not only to segments in linear contexts, but to entire syllables

- The following examples refer to
  - Mandarin
  - English (including a FS analysis by Whorf 1940)

Sounds

	a					o			e					i									u								ü			
	a	ai	ao	an	ang	o	ong	ou	e	ei	en	eng	er	i	ia	iao	ie	iu	ian	iang	in	ing	iong	u	ua	uo	ui	uai	uan	un	uang	ueng	ü	üe	üan	ün
-	a	ai	ao	an	ang	o		ou	e		en	eng	er	yi				you	yan	yang	yin	ying	yong	wu	wa	wo	wei	wai	wan	wen	wang	weng	yu	yue	yuan	yun
b	ba	bai	bao	ban	bang	bo				bei	ben	beng		bi			bie		bian		bin	bing		bu											
p	pa	pai	pao	pan	pang	po		pou		pei	pen	peng		pi		piao	pie		pian		pin	ping		pu											
m	ma	mai	mao	man	mang	mo		mou		mei	men	meng		mi		miao	mie	miu	mian		min	ming		mu											
f	fa			fan	fang	fo		fou		fei	fen	feng												fu												
d	da	dai	dao	dan	dang		dong	dou	de	dei		deng		di		diao	die	diu	dian			ding		du		duo	dui		duan	dun						
t	ta	tai	tao	tan	tang		tong	tou	te			teng		ti		tiao	tie		tian			ting		tu		tuo	tui		tuan	tun						
n	na	nai	nao	nan	nang		nong	nou	ne	nei	nen	neng		ni		niao	nie	niu	nian	niang	nin	ning		nu		nuo			nuan				nü	nüe		
l	la	lai	lao	lan	lang		long	lou	le	lei		leng		li	lia	liao	lie	liu	lian	liang	lin	ling		lu		luo			luan	lun			lü	lüe		
z	za	zai	zao	zan	zang		zong	zou	ze	zei	zen	zeng		zi										zu		zuo	zui		zuan	zun						
c	ca	cai	cao	can	cang		cong	cou	ce		cen	ceng		ci										cu		cuo	cui		cuan	cun						
s	sa	sai	sao	san	sang		song	sou	se		sen	seng		si										su		suo	sui		suan	sun						
zh	zha	zhai	zhao	zhan	zhang		zhong	zhou	zhe	zhei	zhen	zheng		zhi										zhu	zhua	zhuo	zhui	zhuai	zhuan	zhun	zhuang					
ch	cha	chai	chao	chan	chang		chong	chou	che		chen	cheng		chi										chu	chua	chuo	chui	chuai	chuan	chun	chuang					
sh	sha	shai	shao	shan	shang			shou	she	shei	shen	sheng		shi										shu	shua	shuo	shui	shuai	shuan	shun	shuang					
r			rao	ran	rang		rong	rou	re		ren	reng		ri										ru	rua	ruo	rui		ruan	run						
j														ji	jia	jiao	jie	jiu	jian	jiang	jin	jing	jiong										ju	jue	juan	jun
q														qi	qia	qiao	qie	qiu	qian	qiang	qin	qing	qiong										qu	que	quan	qun
x														xi	xia	xiao	xie	xiu	xian	xiang	xin	xing	xiong										xu	xue	xuan	xun
g	ga	gai	gao	gan	gang		gong	gou	ge	gei	gen	geng												gu	gua	guo	gui	guai	guan	gun	guang					
k	ka	kai	kao	kan	kang		kong	kou	ke	kei	ken	keng												ku	kua	kuo	kui	kuai	kuan	kun	kuang					
h	ha	hai	hao	han	hang		hong	hou	he	hei	hen	heng												hu	hua	huo	hui	huai	huan	hun	huang					

http://eastasiastudent.net/256/china/pinyin-chart/

21 initial consonants
36 terminal sequence

Mandarin syllable phonotactics

	b	p	m	f	d	t	n	l	g	k	h	z	c	s	zh	ch	sh	r	j	q	x	∅
a	ba	pa	ma	fa	da	ta	na	la	ga	ka	ha	za	ca	sa	zha	cha	sha					a
o	bo	po	mo	fo																		o
e			me		de	te	ne	le	ge	ke	he	ze	ce	se	zhe	che	she	re				e
ai	bai	pai	mai		dai	tai	nai	lai	gai	kai	hai	zai	cai	sai	zhai	chai	shai					ai
ei	bei	pei	mei	fei	dei	tei	nei	lei	gei	kei	hei	zei			zhei		shei					ei
ao	bao	pao	mao		dao	tao	nao	lao	gao	kao	hao	zao	cao	sao	zhao	chao	shao	rao				ao
ou		pou	mou	fou	dou	tou	nou	lou	gou	kou	hou	zou	cou	sou	zhou	chou	shou	rou				ou
an	ban	pan	man	fan	dan	tan	nan	lan	gan	kan	han	zan	can	san	zhan	chan	shan	ran				an
ang	bang	pang	mang	fang	dang	tang	nang	lang	gang	kang	hang	zang	cang	sang	zhang	chang	shang	rang				ang
en	ben	pen	men	fen	den		nen		gen	ken	hen	zen	cen	sen	zhen	chen	shen	ren				en
eng	beng	peng	meng	feng	deng	teng	neng	leng	geng	keng	heng	zeng	ceng	seng	zheng	cheng	sheng	reng				eng
ong					dong	tong	nong	long	gong	kong	hong	zong	cong	song	zhong	chong		rong				
u	bu	pu	mu	fu	du	tu	nu	lu	gu	ku	hu	zu	cu	su	zhu	chu	shu	ru				wu *
ua									gua	kua	hua				zhua	chua	shua	rua				wa *
uo					duo	tuo	nuo	luo	guo	kuo	huo	zuo	cuo	suo	zhuo	chuo	shuo	ruo				wo *
uai									guai	kuai	huai				zhuai	chuai	shuai					wai *
ui					dui	tui			gui	kui	hui	zui	cui	sui	zhui	chui	shui	rui				wei * 1
uan					duan	tuan	nuan	luan	guan	kuan	huan	zuan	cuan	suan	zhuan	chuan	shuan	ruan				wan *
uang									guang	kuang	huang				zhuang	chuang	shuang					wang *
un					dun	tun	nun	lun	gun	kun	hun	zun	cun	sun	zhun	chun	shun	run				wen * 2
ueng																						weng *
i	bi	pi	mi		di	ti	ni	li				zi †	ci †	si †	zhi ‡	chi ‡	shi ‡	ri ‡	ji	qi	xi	yi +
ia					dia			lia											jia	qia	xia	ya +
ie	bie	pie	mie		die	tie	nie	lie											jie	qie	xie	ye +
iao	biao	piao	miao		diao	tiao	niao	liao											jiao	qiao	xiao	yao +
iu			miu		diu		niu	liu											jiu	qiu	xiu	you + 3
ian	bian	pian	mian		dian	tian	nian	lian											jian	qian	xian	yan +
iang							niang	liang											jiang	qiang	xiang	yang +
in	bin	pin	min				nin	lin											jin	qin	xin	yin +
ing	bing	ping	ming		ding	ting	ning	ling											jing	qing	xing	ying +
iong																			jiong	qiong	xiong	yong +
ü							nü	lü											ju ※	qu ※	xu ※	yu ※
üe							nüe	lüe											jue ※	que ※	xue ※	yue ※
üan																			juan ※	quan ※	xuan ※	yuan ※
ün																			jun ※	qun ※	xun ※	yun ※

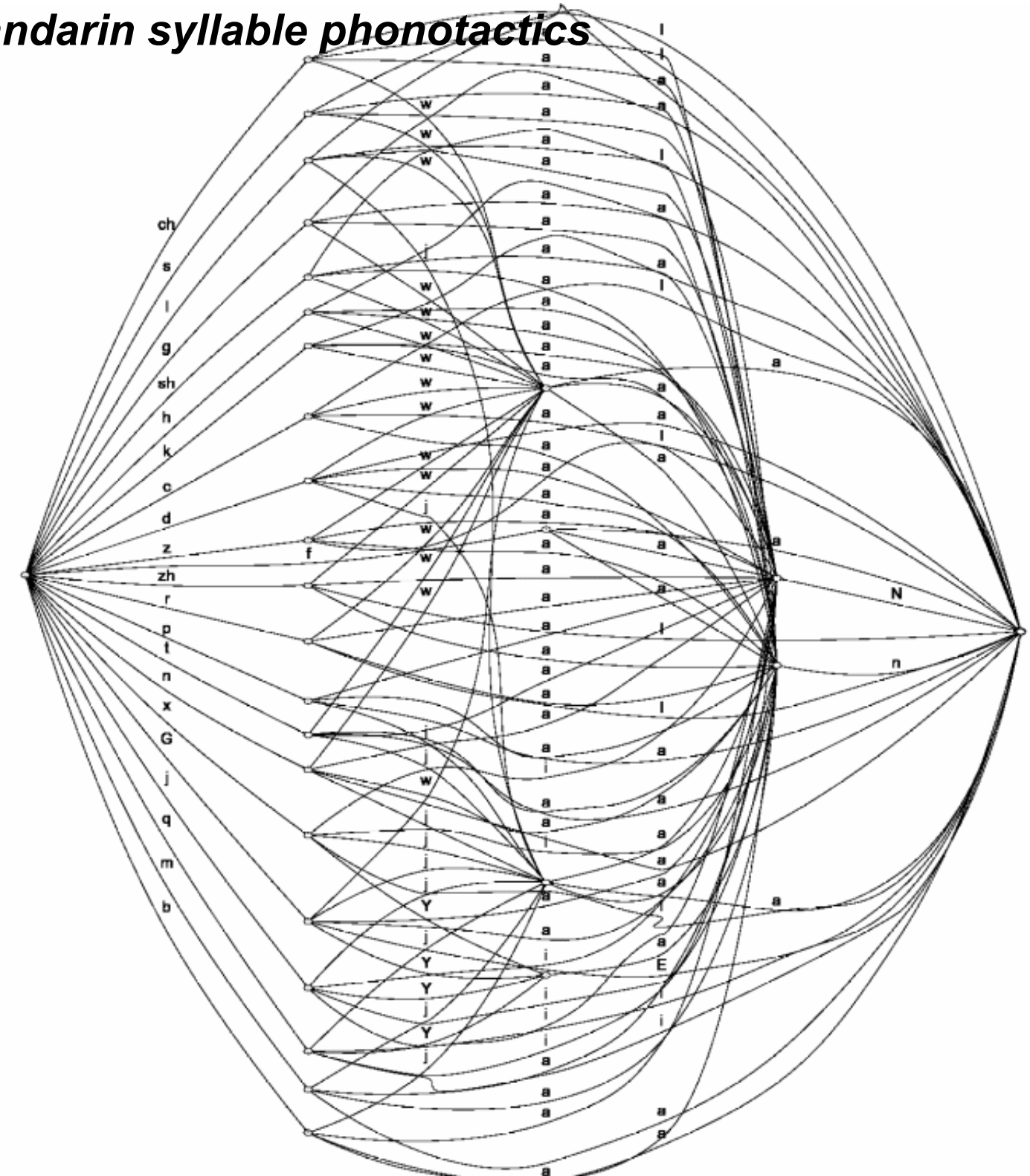
22 initials
35 / 36 / 39 finals
(depending on analysis)

Mandarin syllable phonotactics

NDFSA

Mandarin syllables

464 syllables
29 nodes
333 transitions

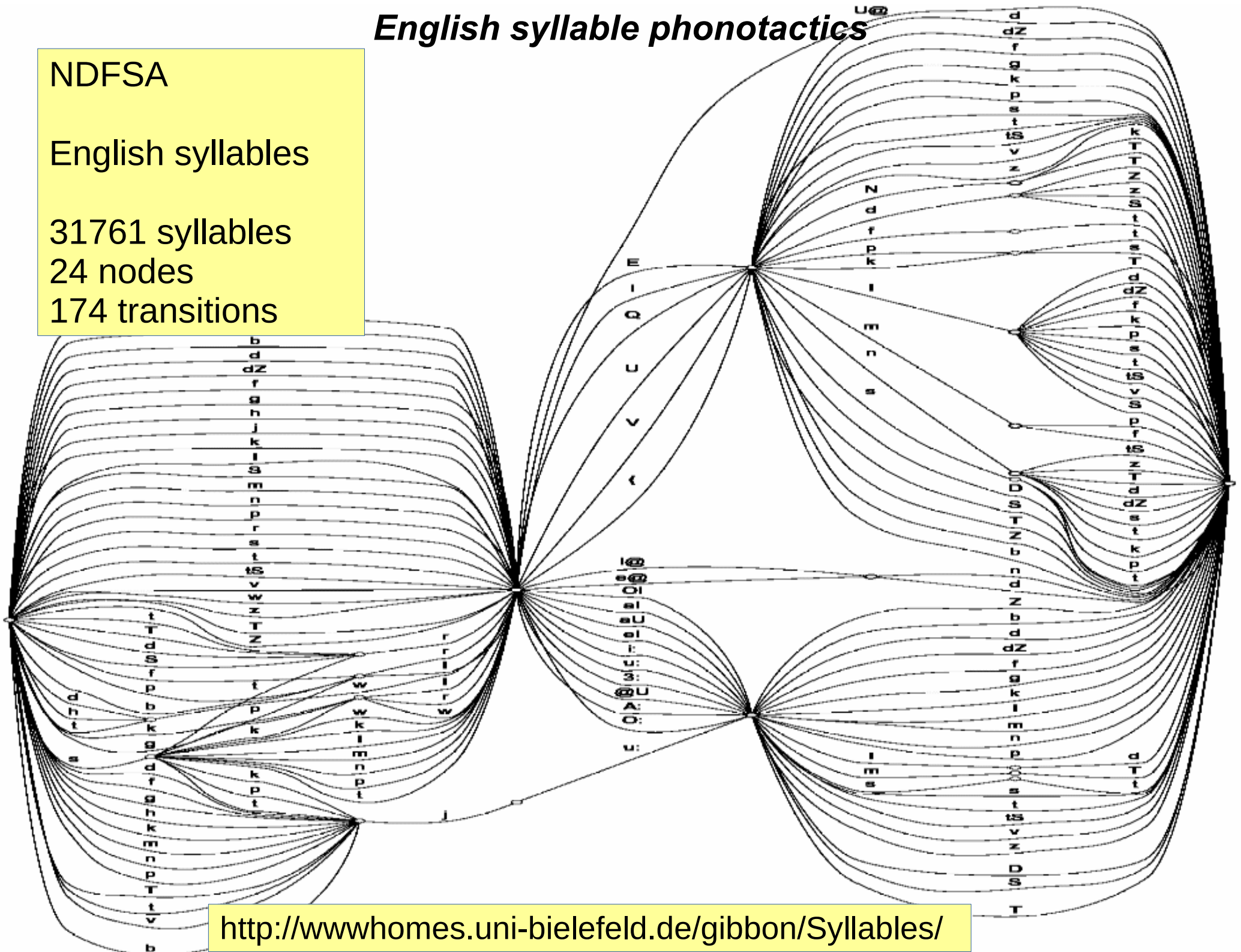


English syllable phonotactics

NDFSA

English syllables

31761 syllables
24 nodes
174 transitions



http://wwwhomes.uni-bielefeld.de/gibbon/Syllables/

English syllable phonotactics

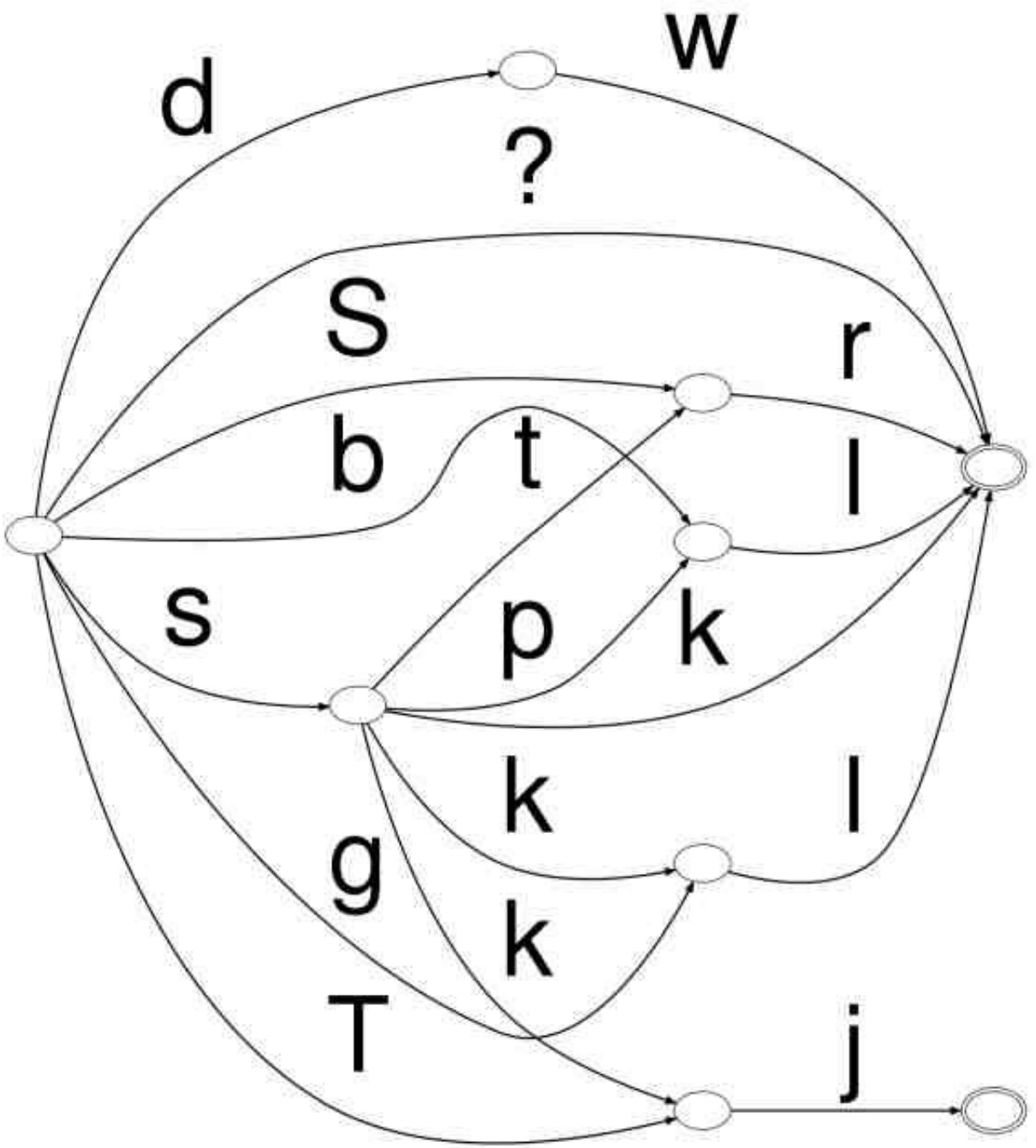
NDFSA

English complex onsets

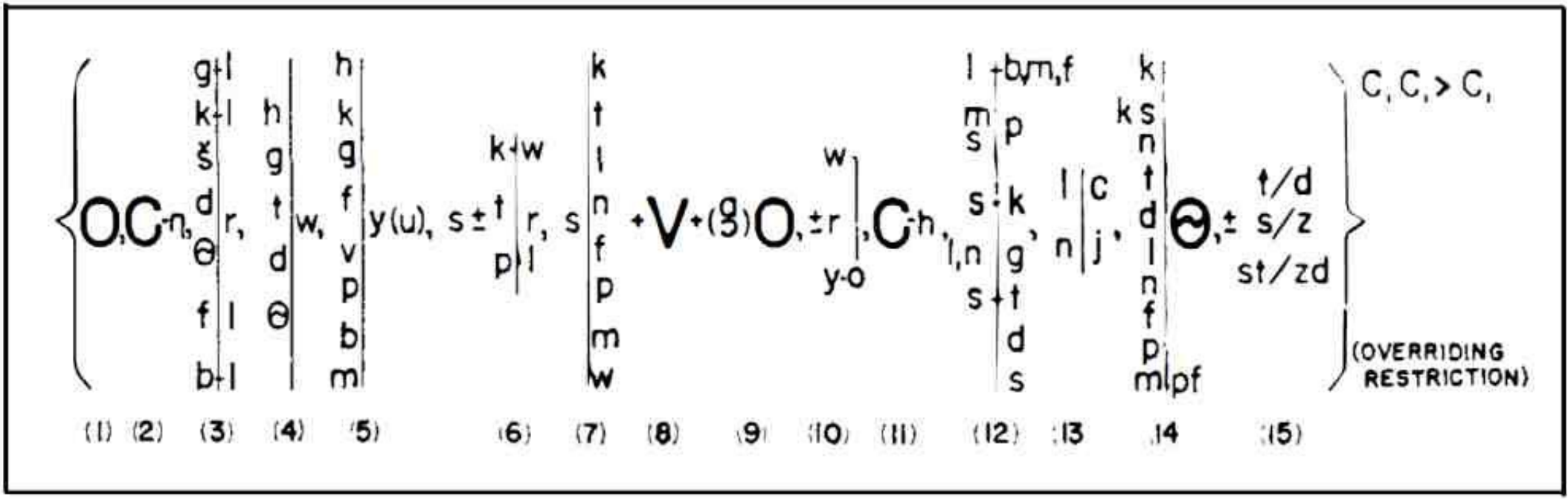
One edge per node pair

Each transition thus represents one context-specific allophone set

(Twaddell's 'microphonemes')



English syllable phonotactics: Whorf's formula

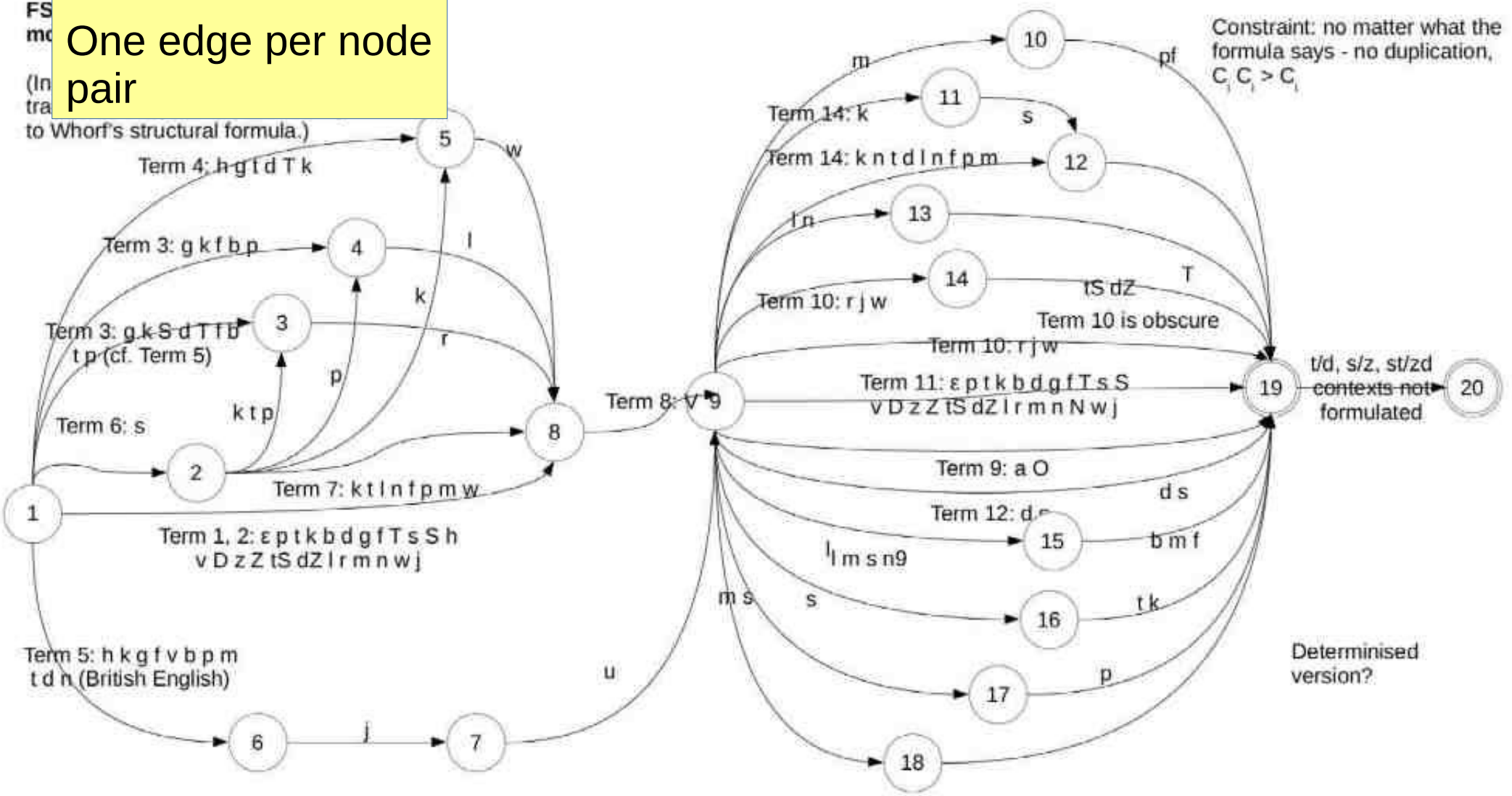


English syllable phonotactics: Whorf's English syllable onsets

NDFSA

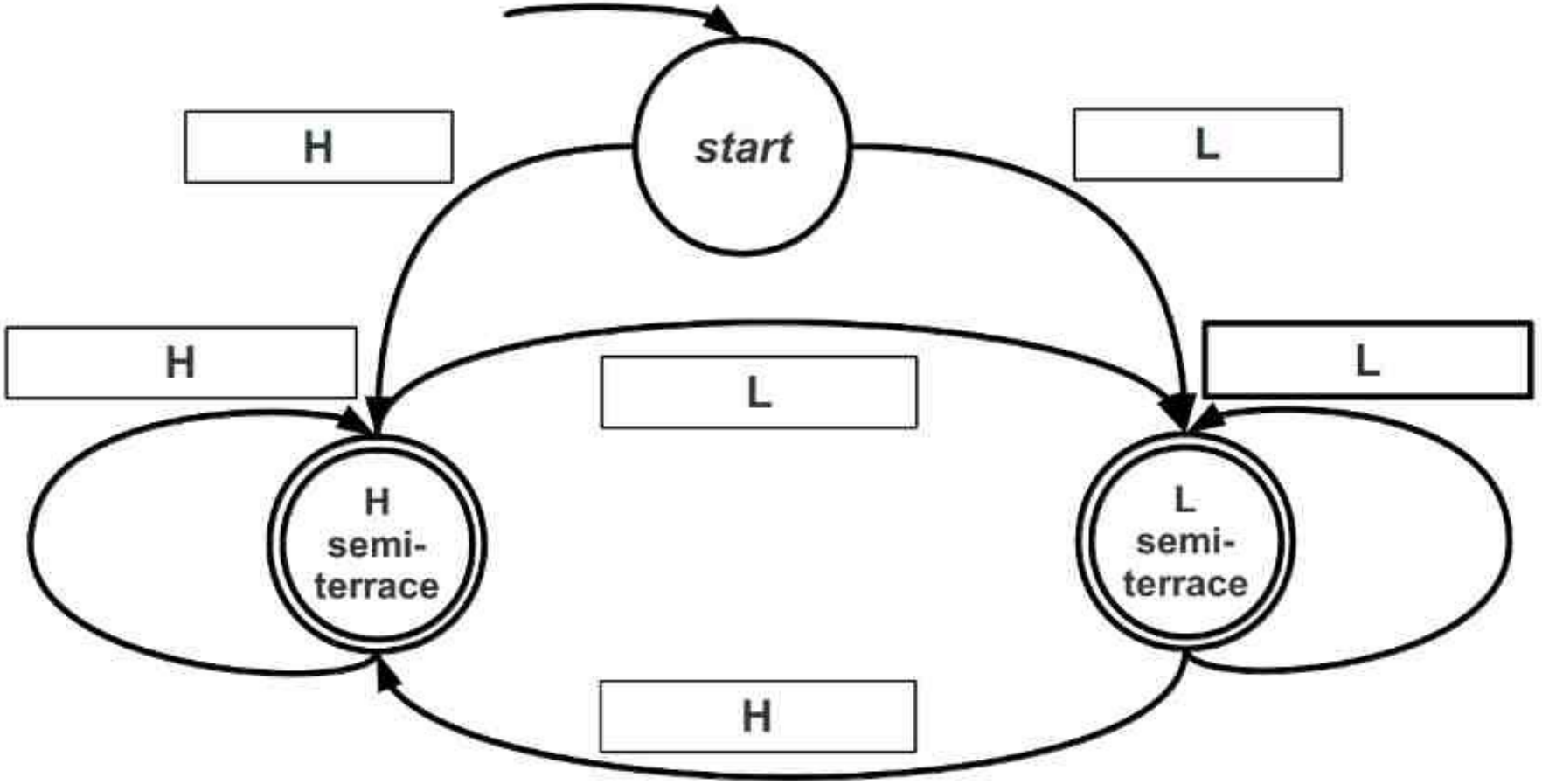
English complex onsets

One edge per node pair

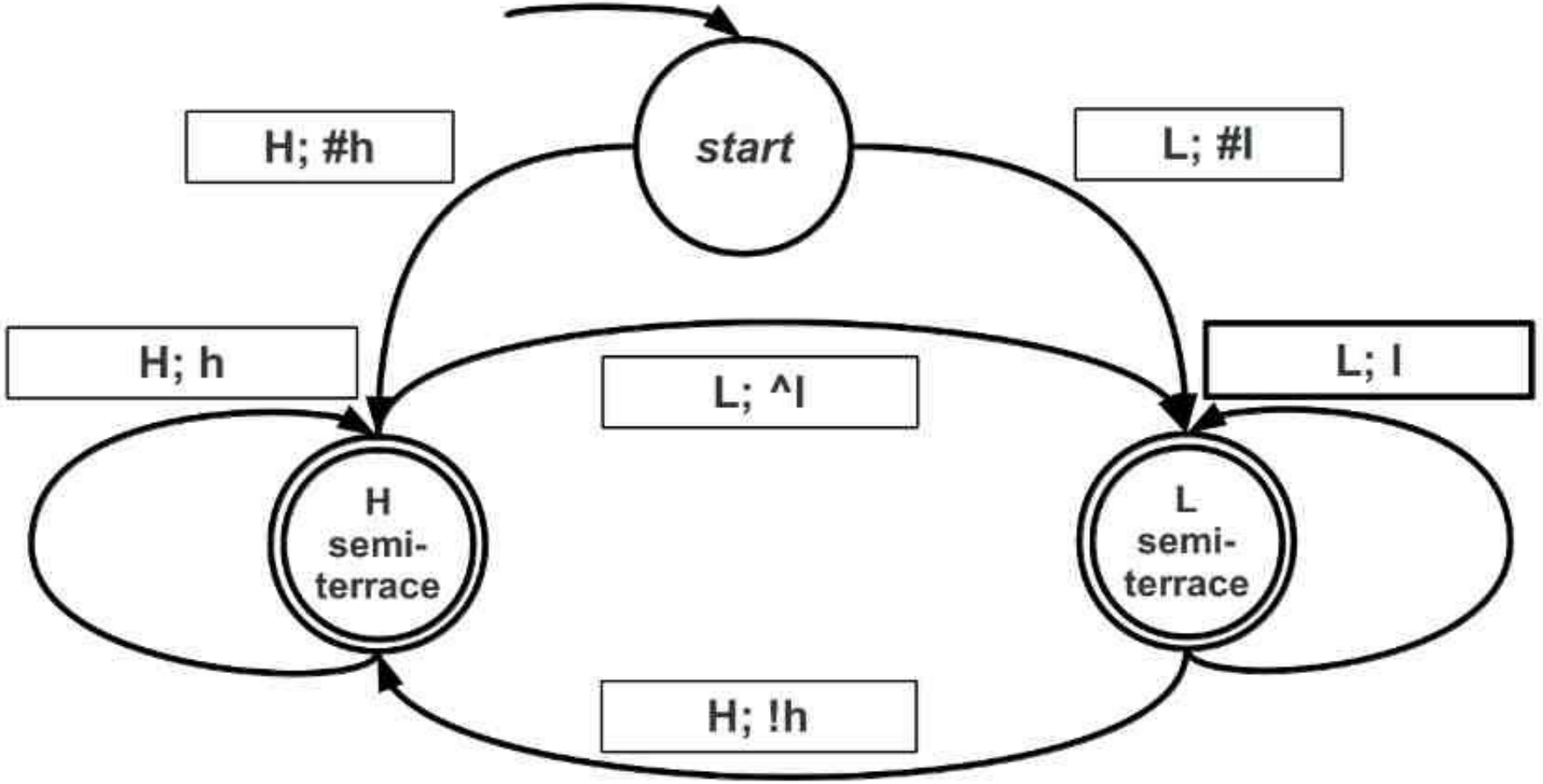


Prosody: Tonotactics

Niger-Congo tonotactics



Niger-Congo tonotactics



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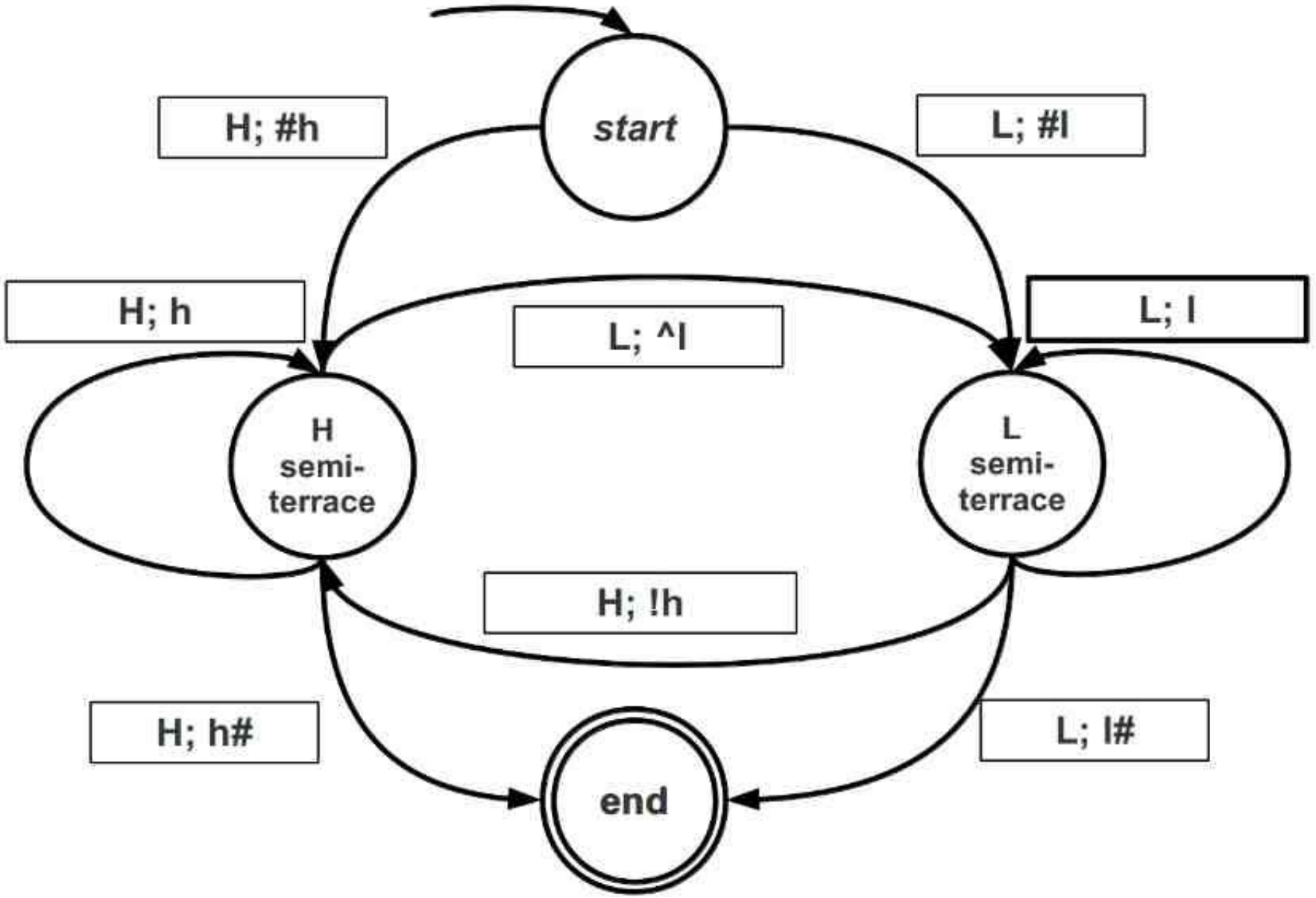

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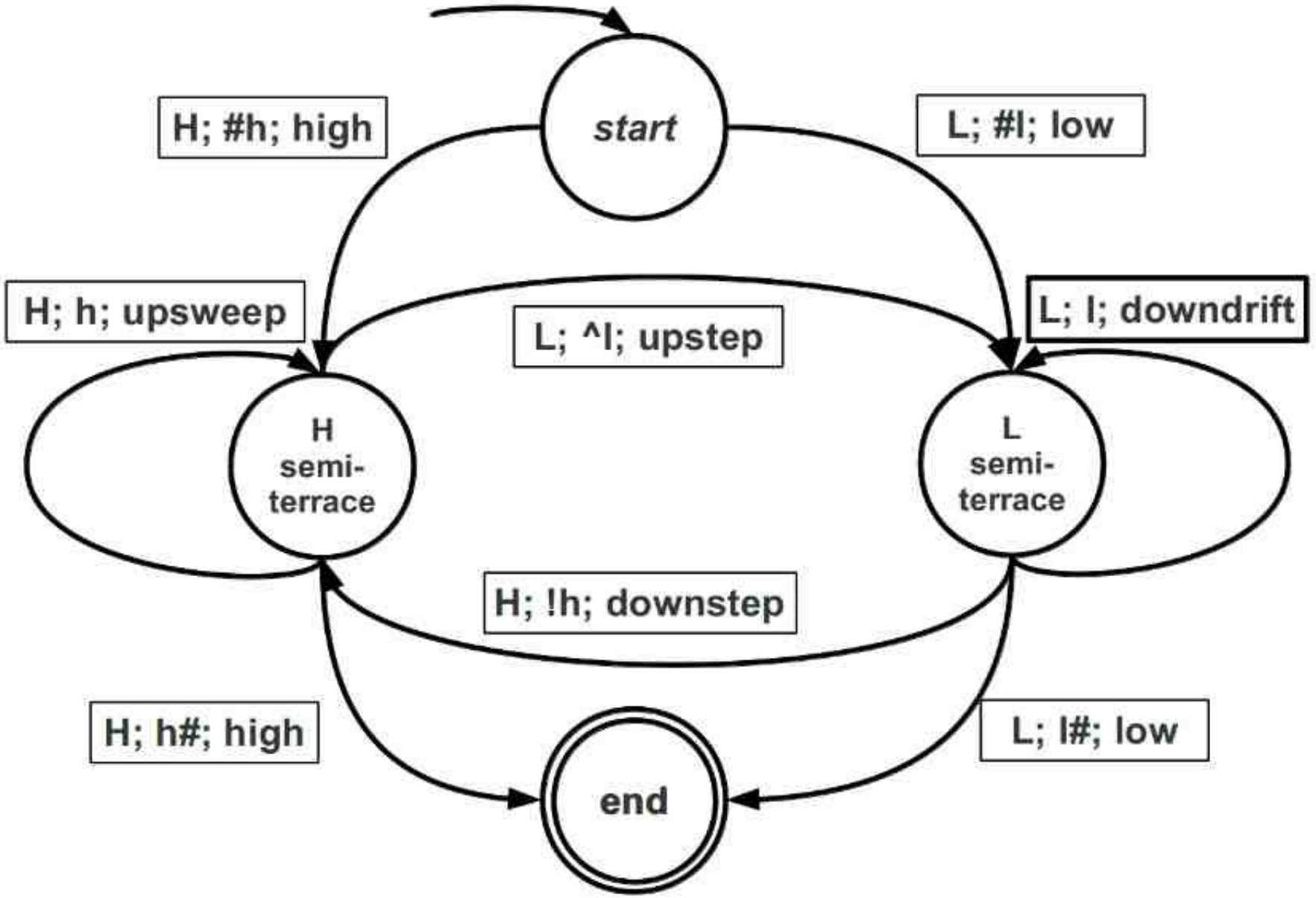

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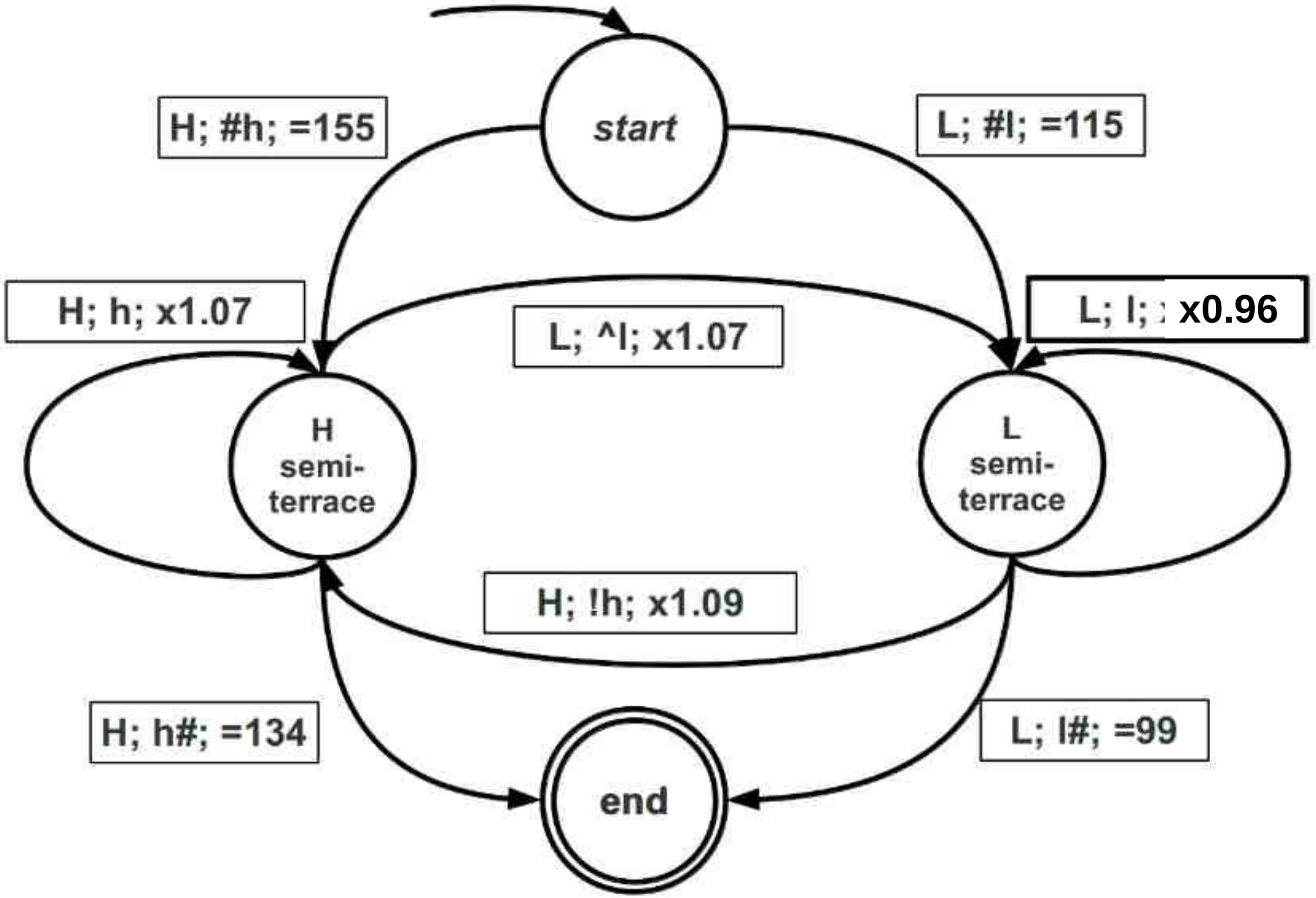
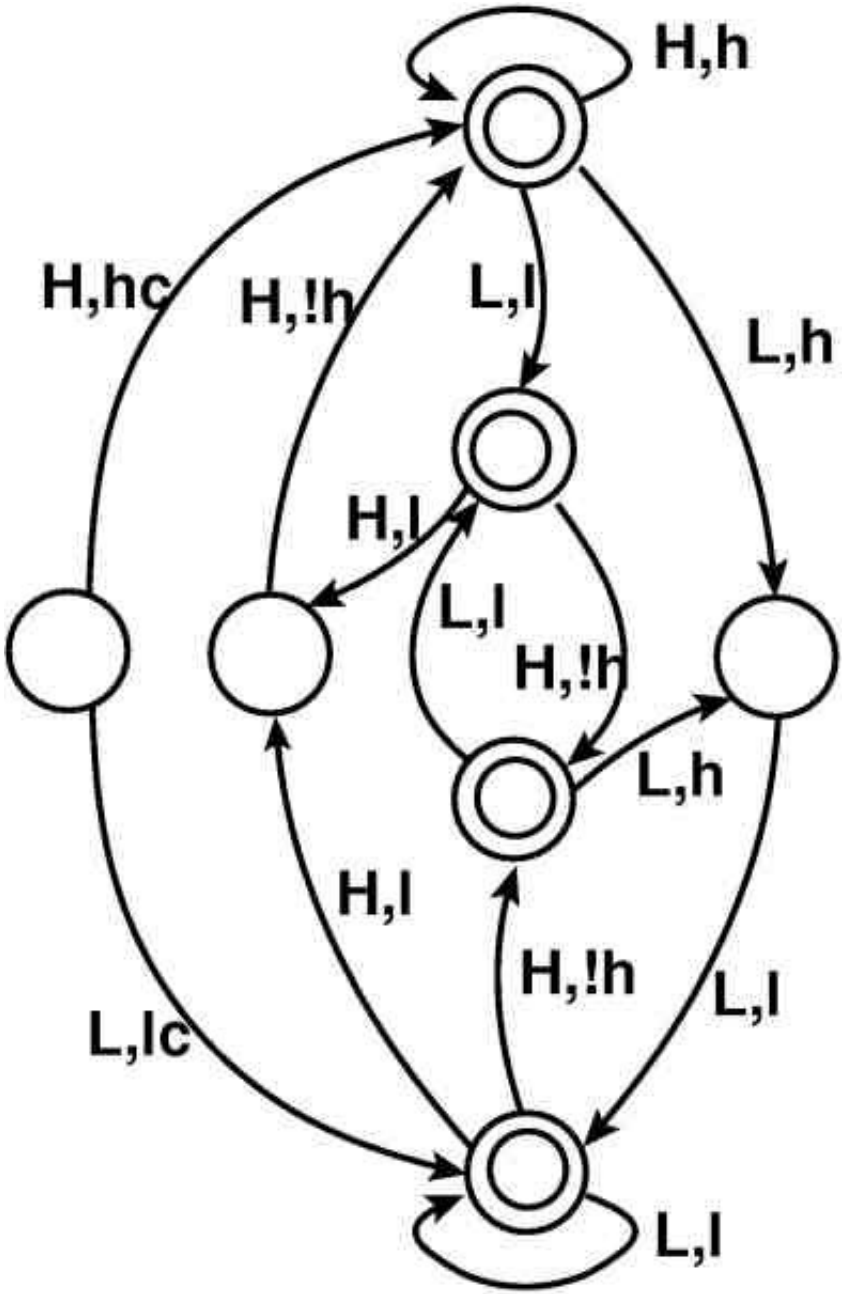


Niger-Congo tonotactics: Baule



Prosody: Intonotactics

English intonotactics: Prosodic Hierarchy

Standardly 5 levels, i.e. finite depth:

- Intonation Phrase
- intermediate phrase
- Prosodic Word
- Foot
- Syllable

A regular prosodic grammar, with iteration:

$$IP \rightarrow \left\{ \begin{array}{c} ip \\ ip\ IP \end{array} \right\}$$

$$ip \rightarrow \left\{ \begin{array}{c} PW \\ PW\ ip \end{array} \right\}$$

$$PW \rightarrow F^{+}$$

$$F \rightarrow s^{+}$$

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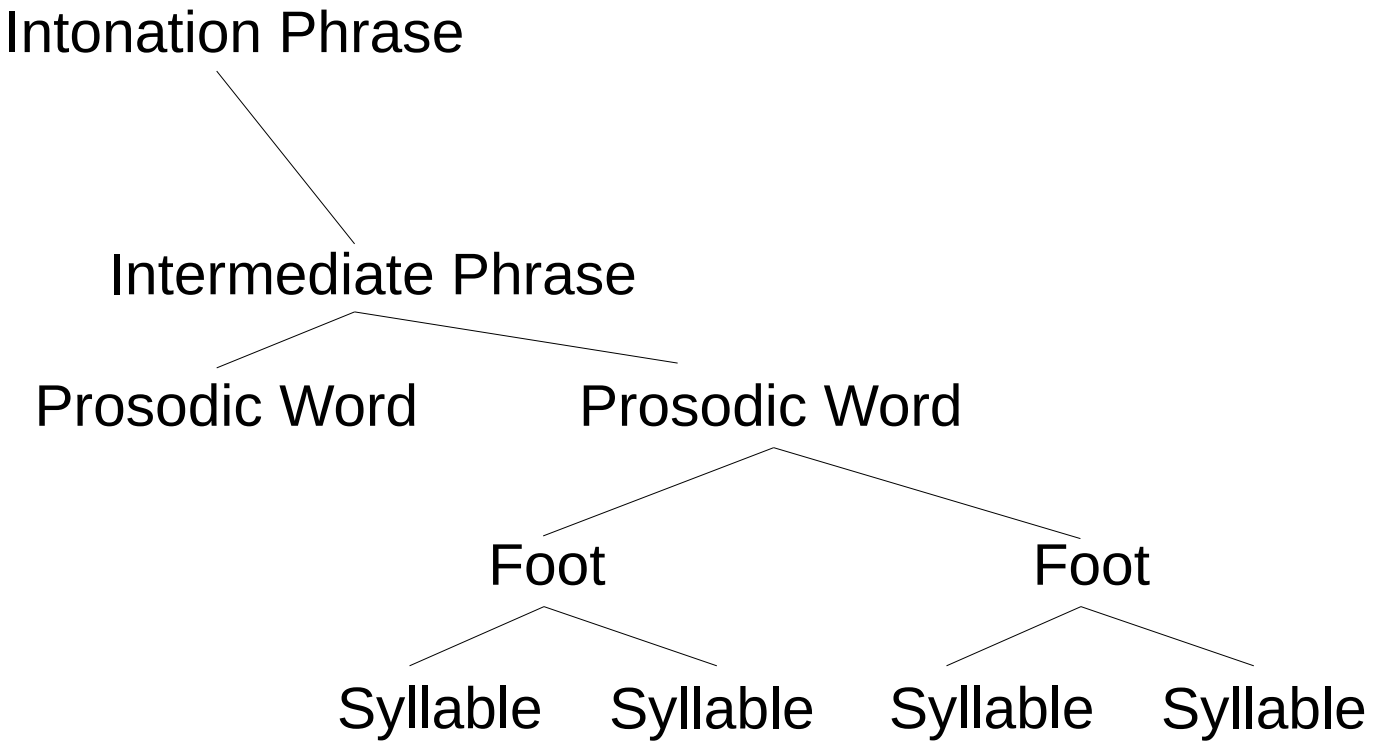

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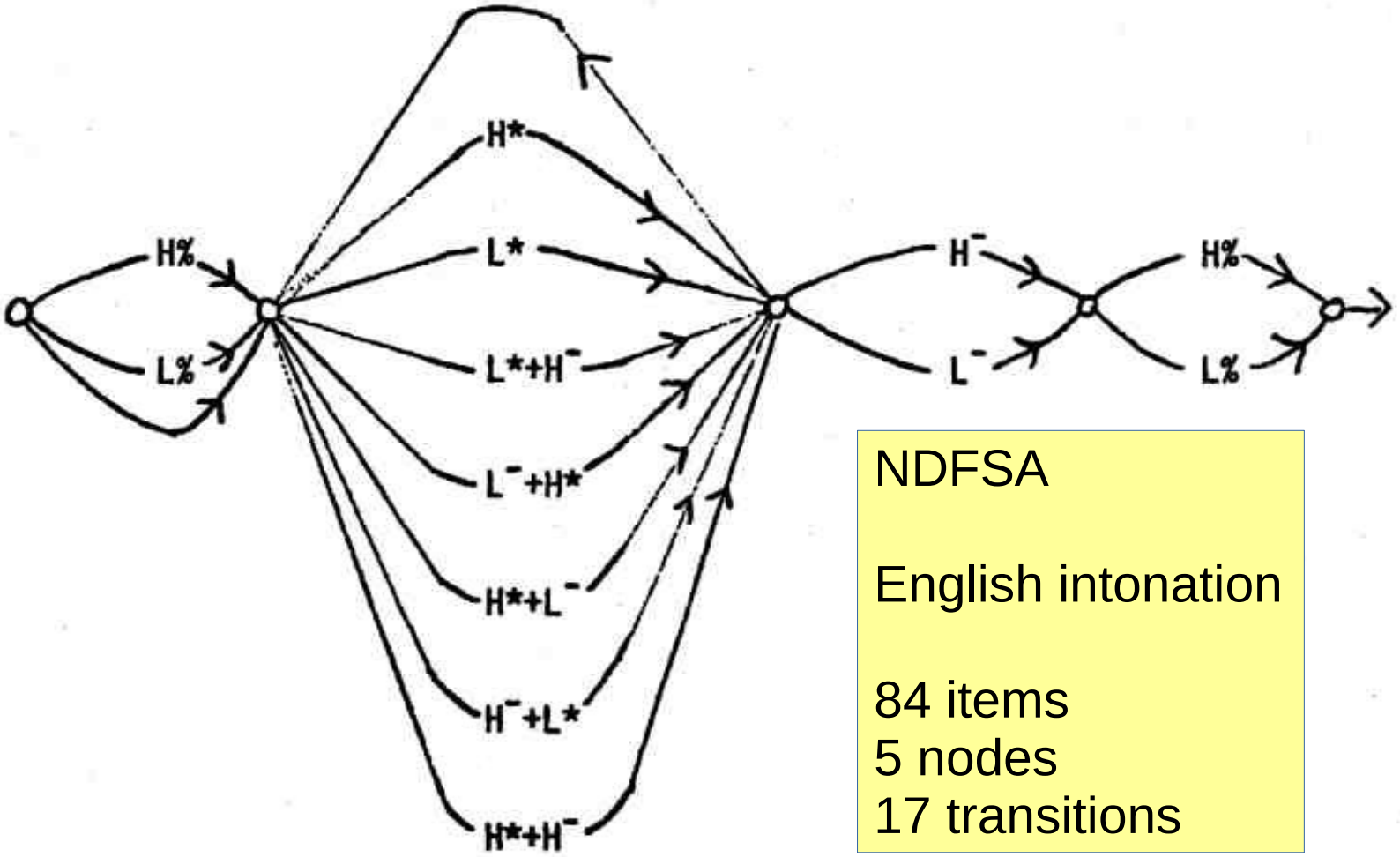
English intonotactics: Pierrehumbert's Finite State model

Intonation Phrase

Intermediate Phrase

Prosodic Word

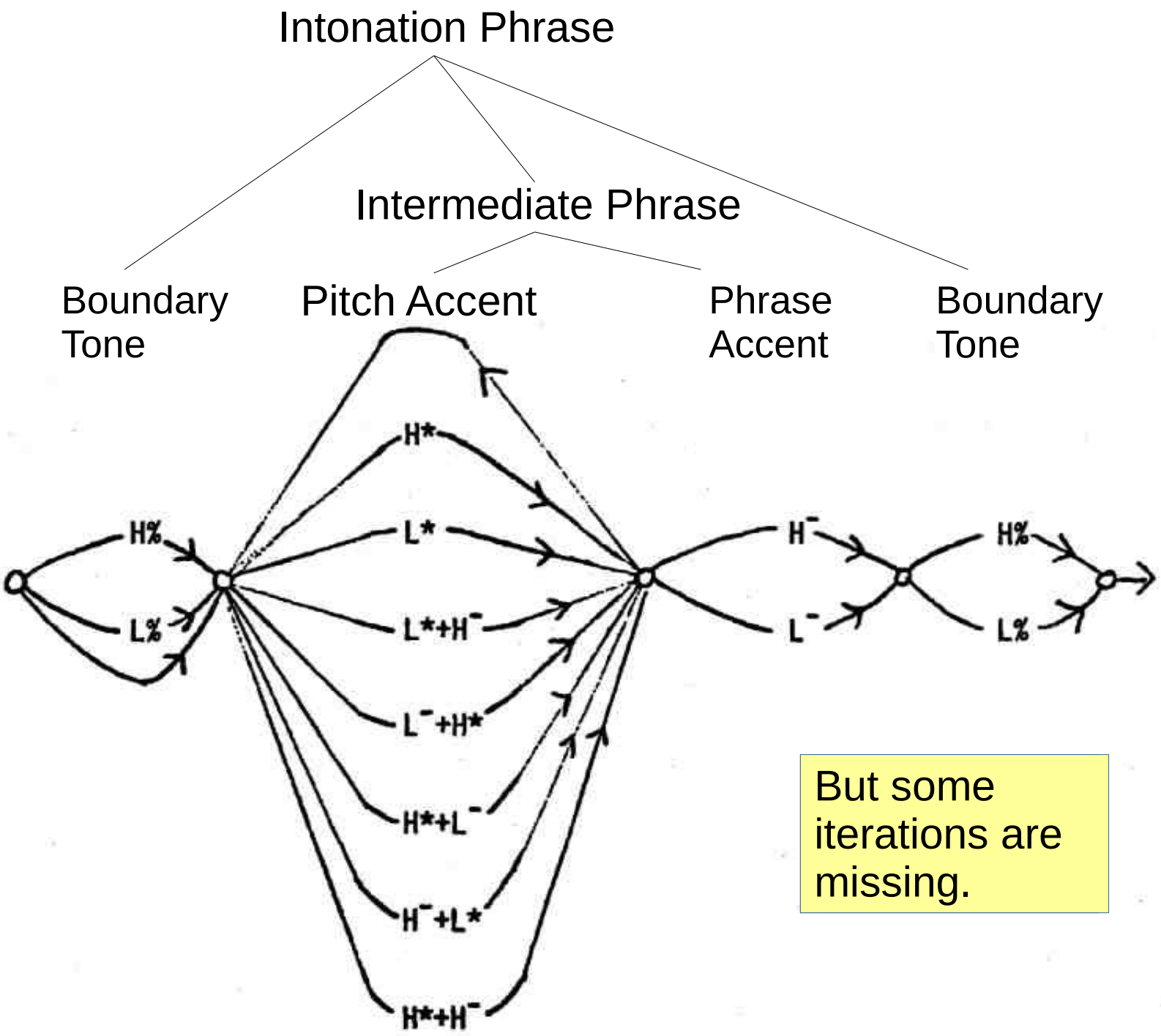


NDFSA

English intonation

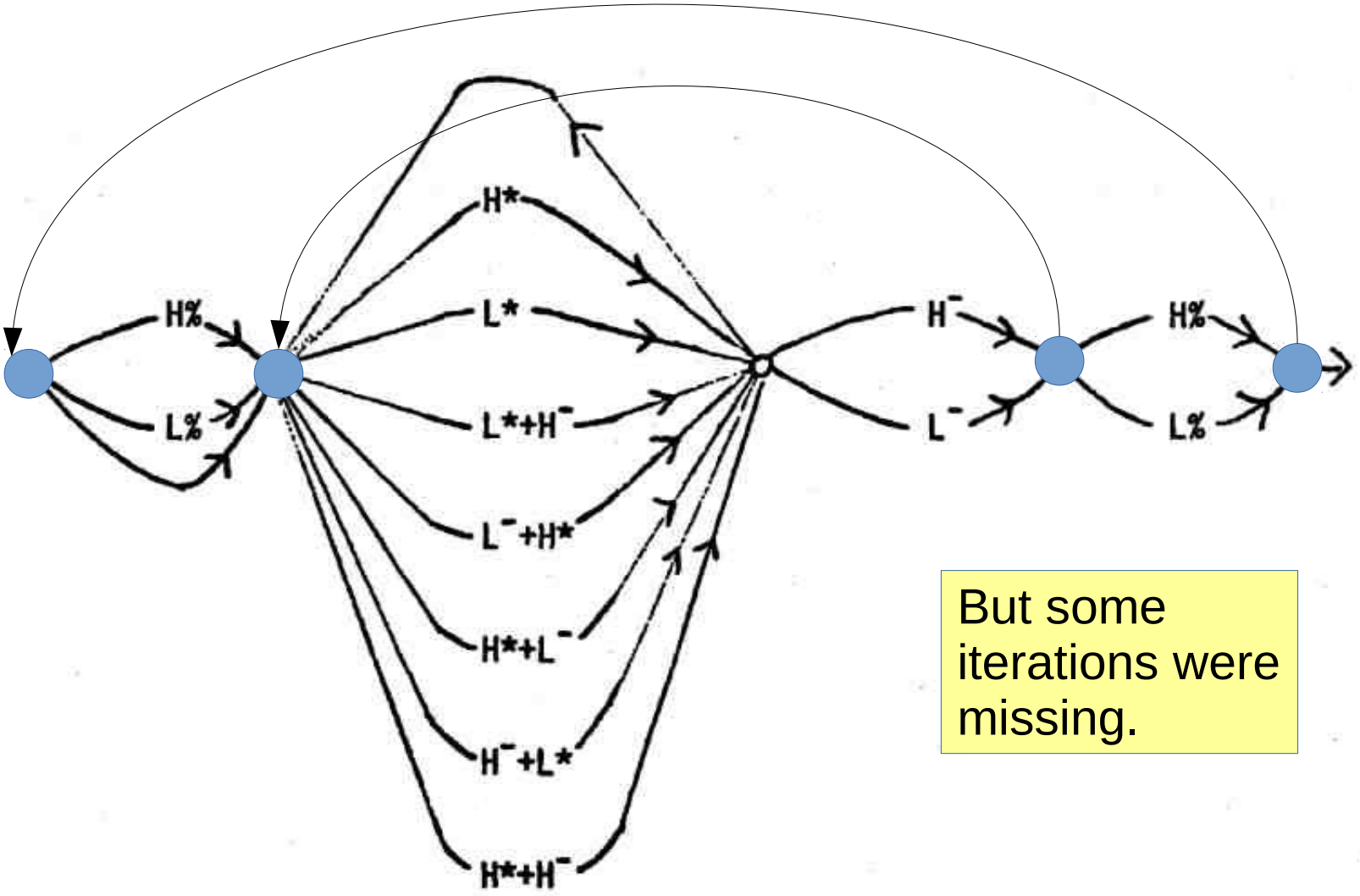
84 items
5 nodes
17 transitions

English intonotactics: Pierrehumbert's Finite State model



But some iterations are missing.

English intonotactics: Pierrehumbert's Finite State model



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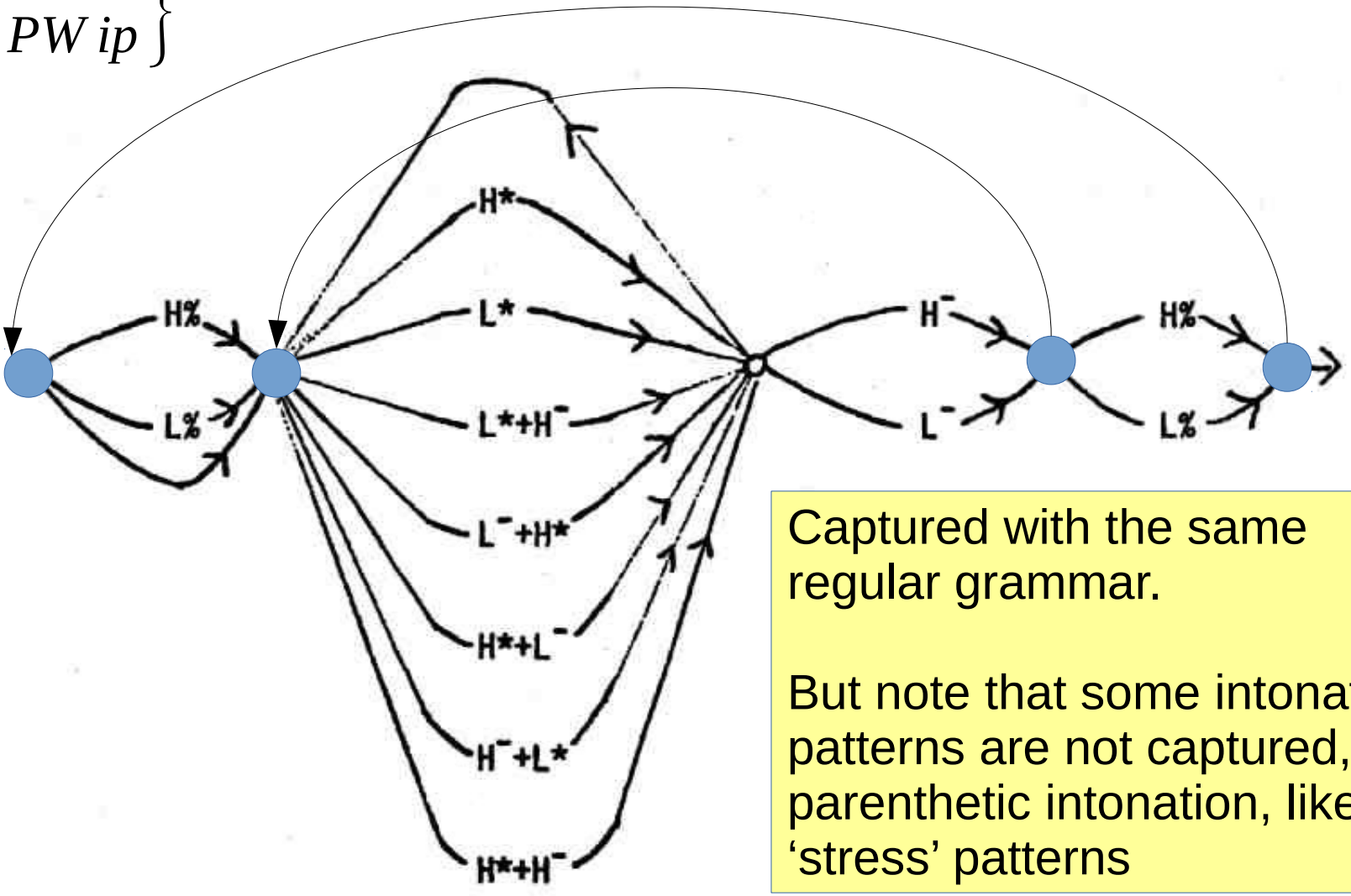
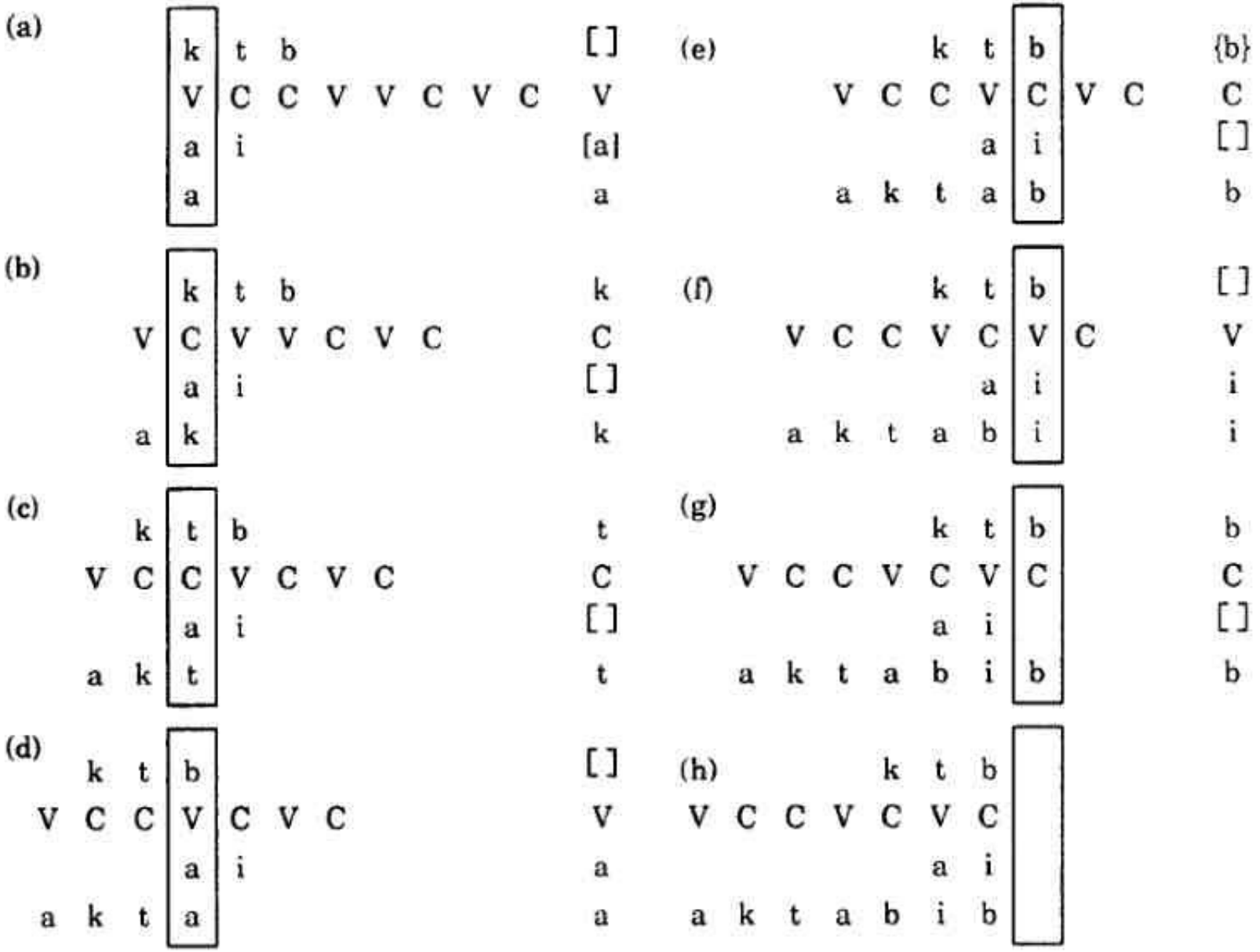


Captured with the same regular grammar.

But note that some intonation patterns are not captured, e.g. parenthetic intonation, likewise 'stress' patterns

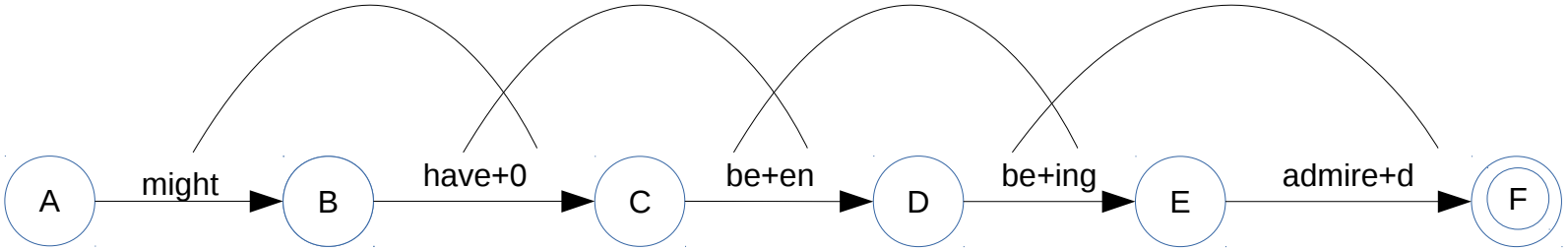
Words

Derivation and inflection – Arabic intercalation

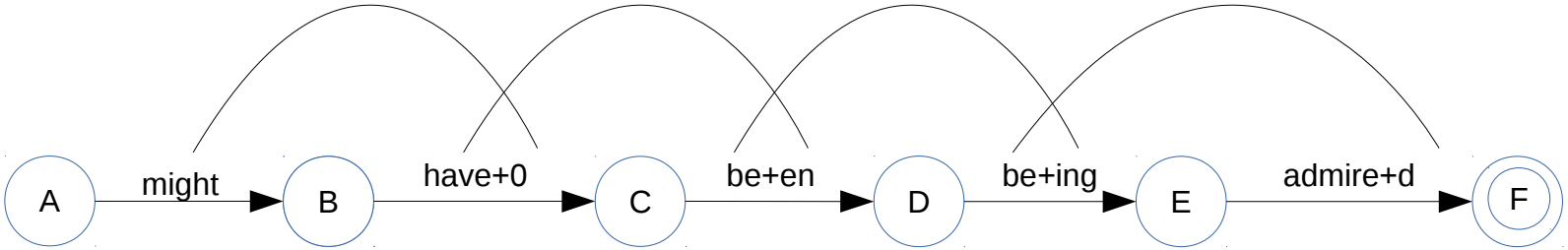


Compounding

Morphosyntax: English

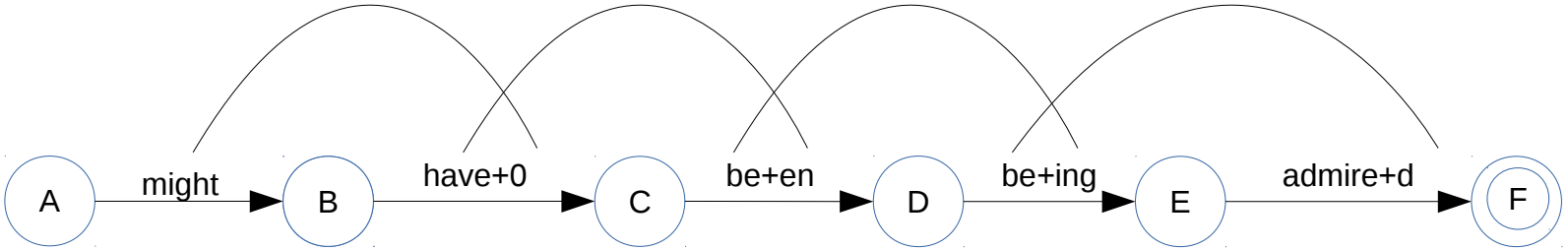


Morphosyntax: English



Chomsky's astute generalisation over the English suffix dependencies was formulated as the 'flipflop transformation' (1957:39):
Let *Af* stand for any of the affixes *past*, Ø, *en*, *ing*.
Let *v* stand for any *M* or *V*, or *have* or *be* (i.e. for any non-affix in the phrase *Verb*).
Then: *Af* + *v* → *v* + *Af* # , where # is interpreted as a word boundary.

Morphosyntax: English



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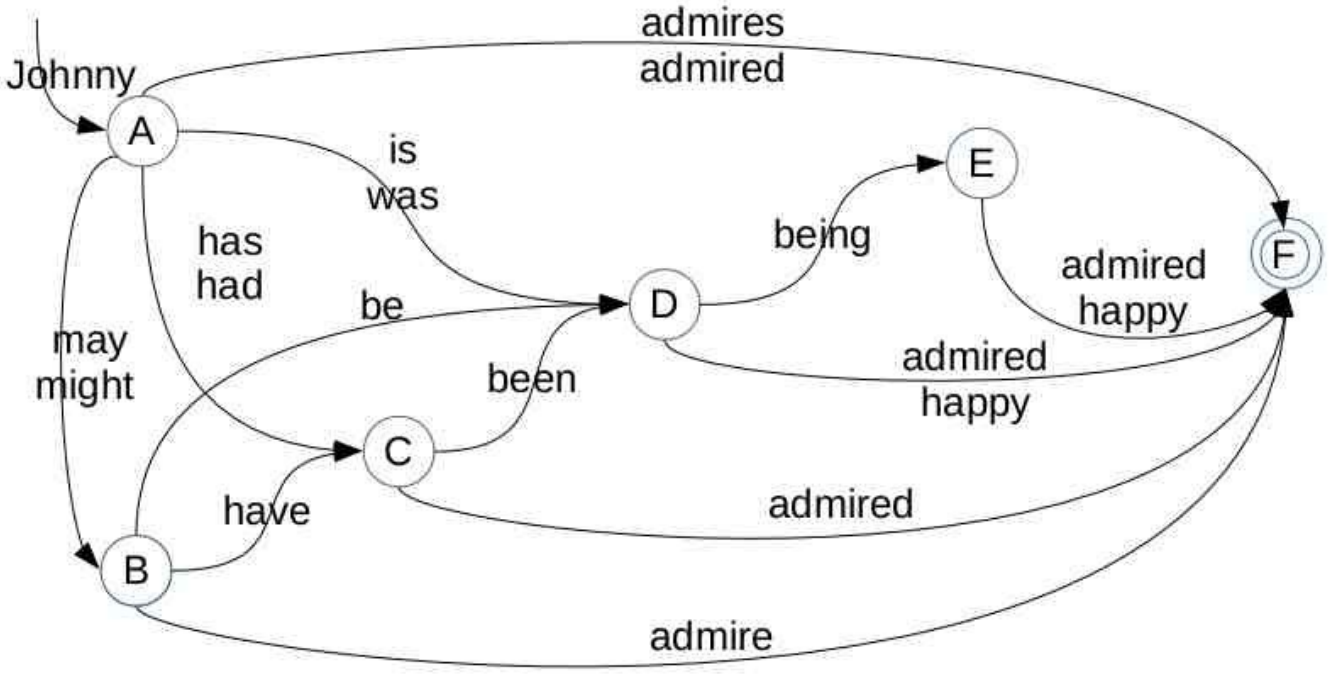
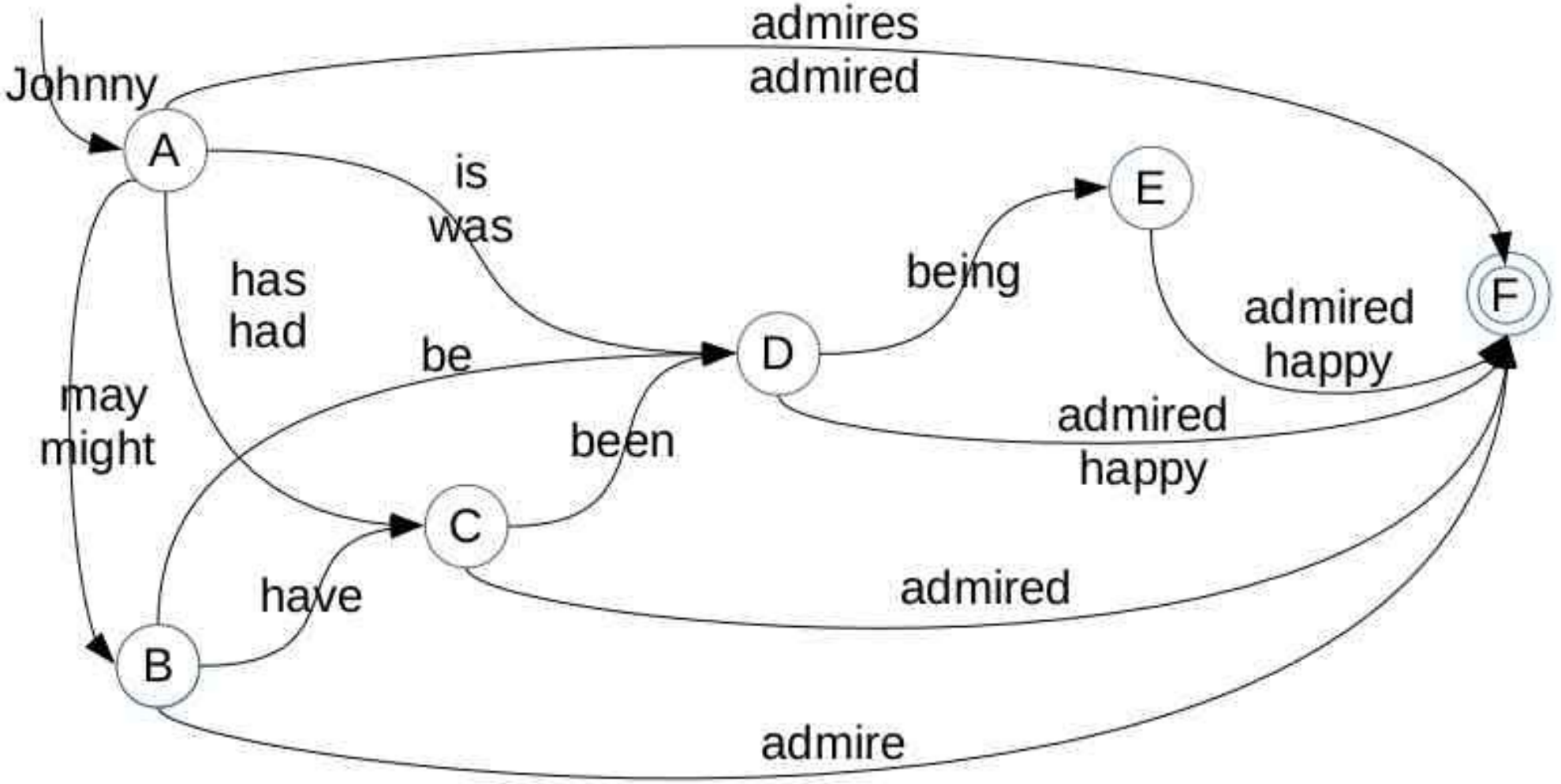
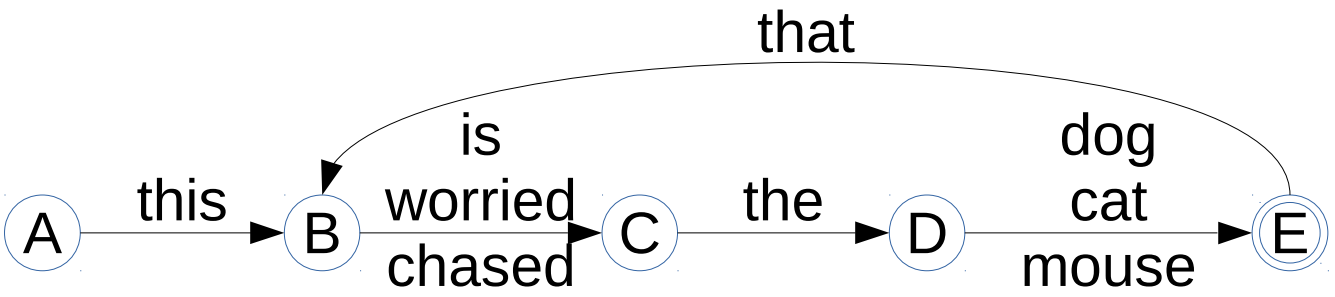


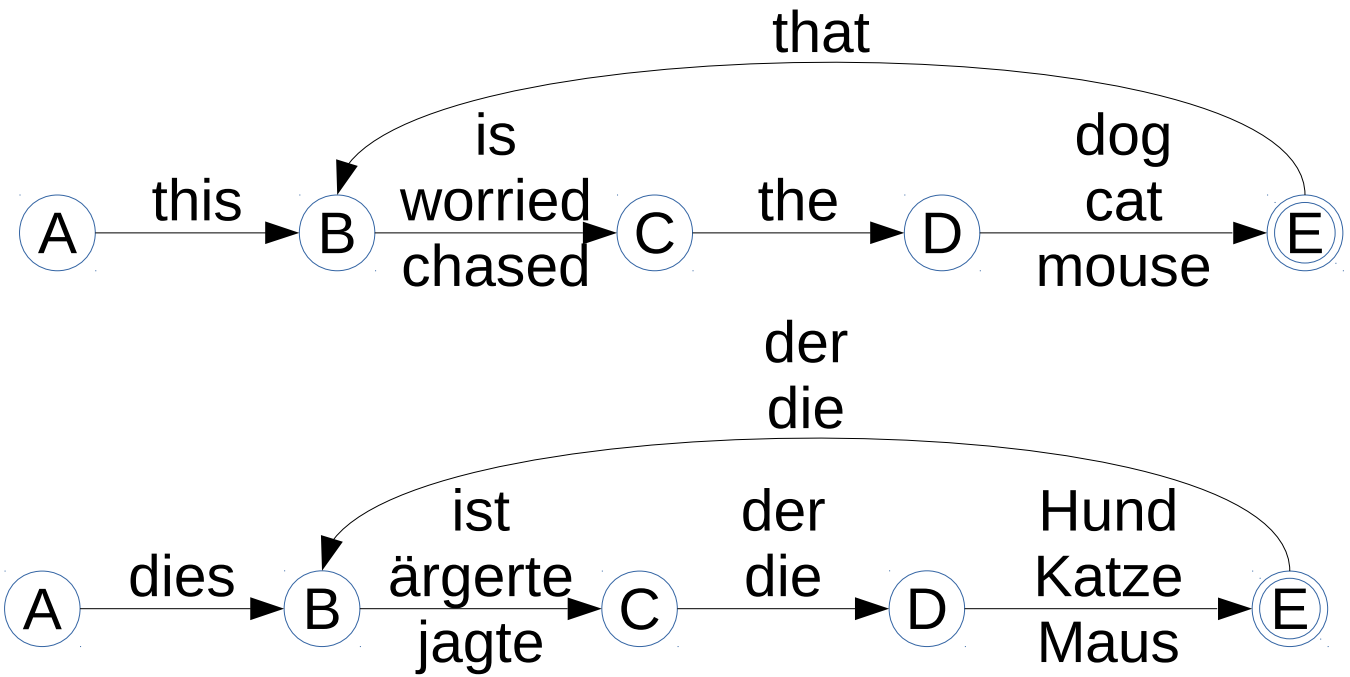
Morphosyntax: English



Phrasal syntax: works for English



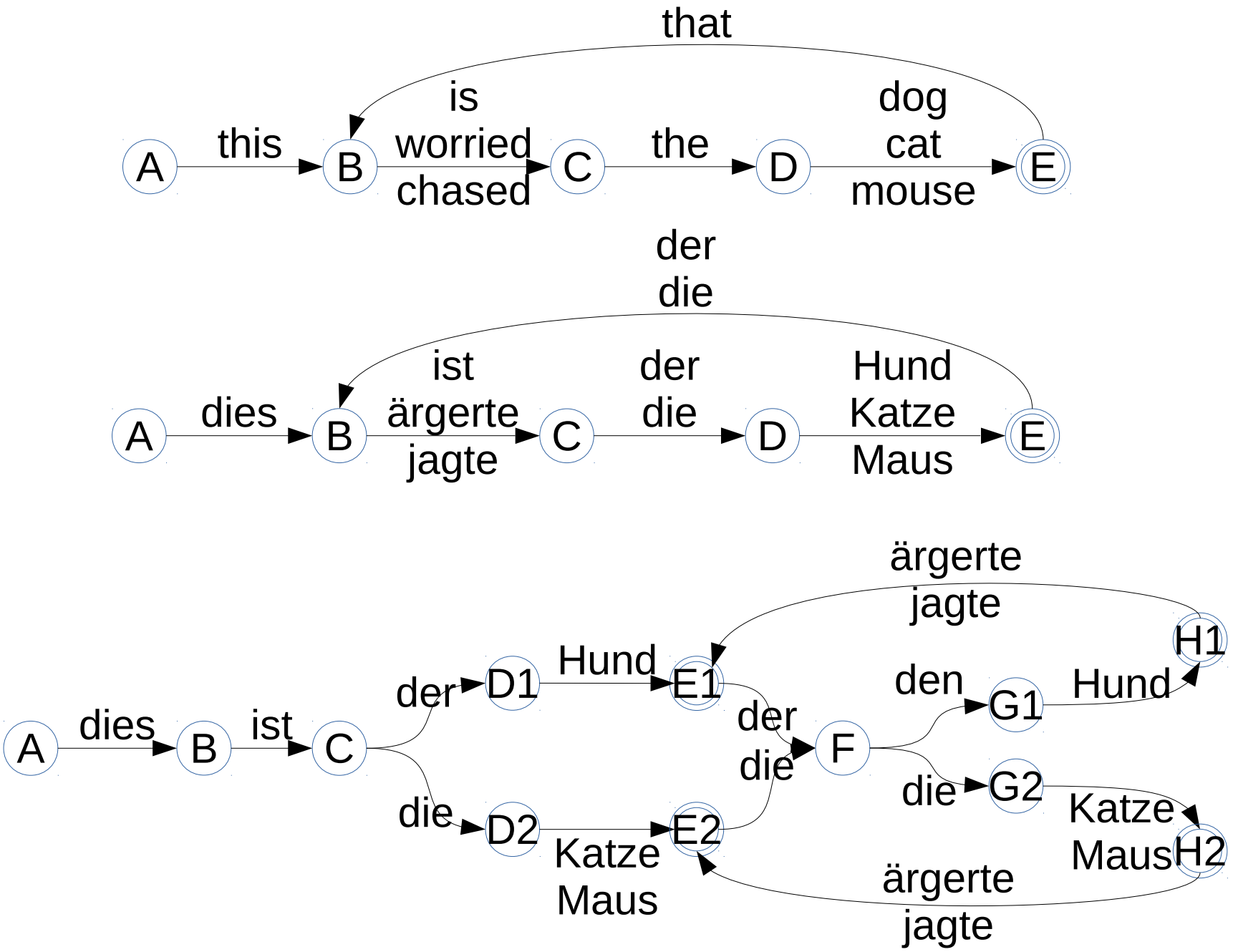
Phrasal syntax: works for English – for German, too?



How about context-sensitive' rules?

These are abbreviations for larger linear patterns.

Phrasal syntax



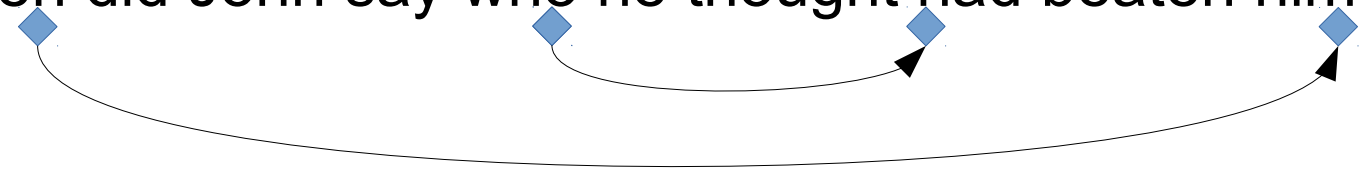
Long-distance dependencies and recursion

Long distance dependencies and recursion

- Fundamental linearity:
  - PRO anaphora
    - John would like to claim that Henry prefers to stay.

  - WH trace anaphora
    - Where did John say that he thought Henry had gone?

- Anaphoric centre-embedding? Just 1 additional level?
  - Mixed interrogative and relative pronominal anaphora:
    - When did John say who he thought had beaten him?



Purely left or purely right branching

- Remember that purely left or purely right branching
  - requires only finite memory
  - is FSA compatible
- Examples:
  - John's father's brother's car
  - This is the dog that chased the cat that ate the rat …
- Otherwise only finite additional memory may be needed (which can be compiled out to an FSA / regular grammar):
  - finite depth
  - interrogative traces
  - 'context-sensitive' rules
- Most of the load for recursion falls on semantics and general cognitive problem-solving

Sentences: a search for centre-embedding

Corpus search for recursion

A free-text search for indices of nested recursion

- marked by *wh*- items
- in Sampson's CHRISTINE1 treebank of informal spoken English (abt. 14,000 words from the CHRISTINE database of 35,000 words)

revealed hardly any wh-recursions of any kind:

- 145 *who*/*whose* pronoun occurrences (*whom* did not occur)
  - 129 sentence-initial interrogatives
  - 16 relative *who*/*whose* clauses
    - 9 interrupted fragments (missing mandatory constituents
    - 7 were complete relative clauses, but none nested
  - 1 (!) example of potential nesting
    which has an incomplete main clause and peters out incohesively

Corpus search for recursion

So what is going on with this potential nesting?

- we found out that the neighbours on the left hand side who were in fact an elderly couple and his was erm and he had his own business working at home
- main clause w object complement:
  "we found out that ..."
- subject of object complement:
  "the neighbours on the left hand side ..."
- rel. clause in subject:
  "who were in fact an elderly couple"

WHERE IS THE MAIN VERB FOR "the neighbours"?

Corpus search for recursion

The one example of attempted nesting is broken!

we found out

that the neighbours on the left hand side
who were in fact an elderly couple
and his was erm
and he had his own business working at home
… and where is the matching main verb ?

The speaker apparently regretted starting a nested relative clause, later ignoring the ‘who’ and reverting to coordination.

So what is the status of centre-embedding?

Where did centre-embedding come from? Conjecture!

- Two opposing views on the typology of centre-embedding:

  - The Chomskyite mutation approach:

    Genetic mutation around the time of the African emigrations

  - The processing approach:

    Generalisation enabled by memory enhancement through rehearsal of oral tradition and writing

  - A chicken and egg problem? Was the generalisation enabled by a mutation?

Where did centre-embedding come from? Conjecture!

- A chicken and egg problem? Was the generalisation enabled by a mutation?
- The Chomskyite approach embodies an all or nothing claim:
  - Is recursion (in the sense of centre-embedding):
    - necessary and sufficient feature of human languages
      - clearly not – cf. Hockett's design features
    - or a sufficient feature (along with other sufficient features)
      - again, clearly not – cf. Hockett's design features
    - or a necessary feature of human language (or languages)
      - Everett: apparently not – some languages apparently do not show recursion
- Not finding something does not mean it's not there:
  - the lost car key syndrome
  - try harder and you'll get it …

Recursing or not recursing – that is the question

- So do we have a choice of recursing or not recursing?

- Is recursion specific to certain registers of language?
  - Formality?
  - Rehearsed?
  - Written?
  - Logical and mathematical?

- Does centre-embedding depend on processing factors?
  - Time?
  - Memory?

- From a computational point of view – OF COURSE!

In defence of the processing view: a scale of simplicity

- Starting simple … prerequisites for centre-embedding

This should remind you of the order of structure acquisition by children!

1. Vocabulary item
2. Iterative sequence of vocabulary items
3. Finite sequence of vocabulary items
4. Iterative sequence of sequences
   - terminal rhematic extension on verbal adjuncts
   - Behaghel'sches Gesetz?
5. Generalisation over complementary distribution
   - generalisation by complementary distribution over S, O, Adv phrases to form NPs, rhematic extension becomes centre-embedding
   - hence: centre-embedding
   - BUT: processing is now too difficult
     - except if finite depth, rehearsed, and/or in writing

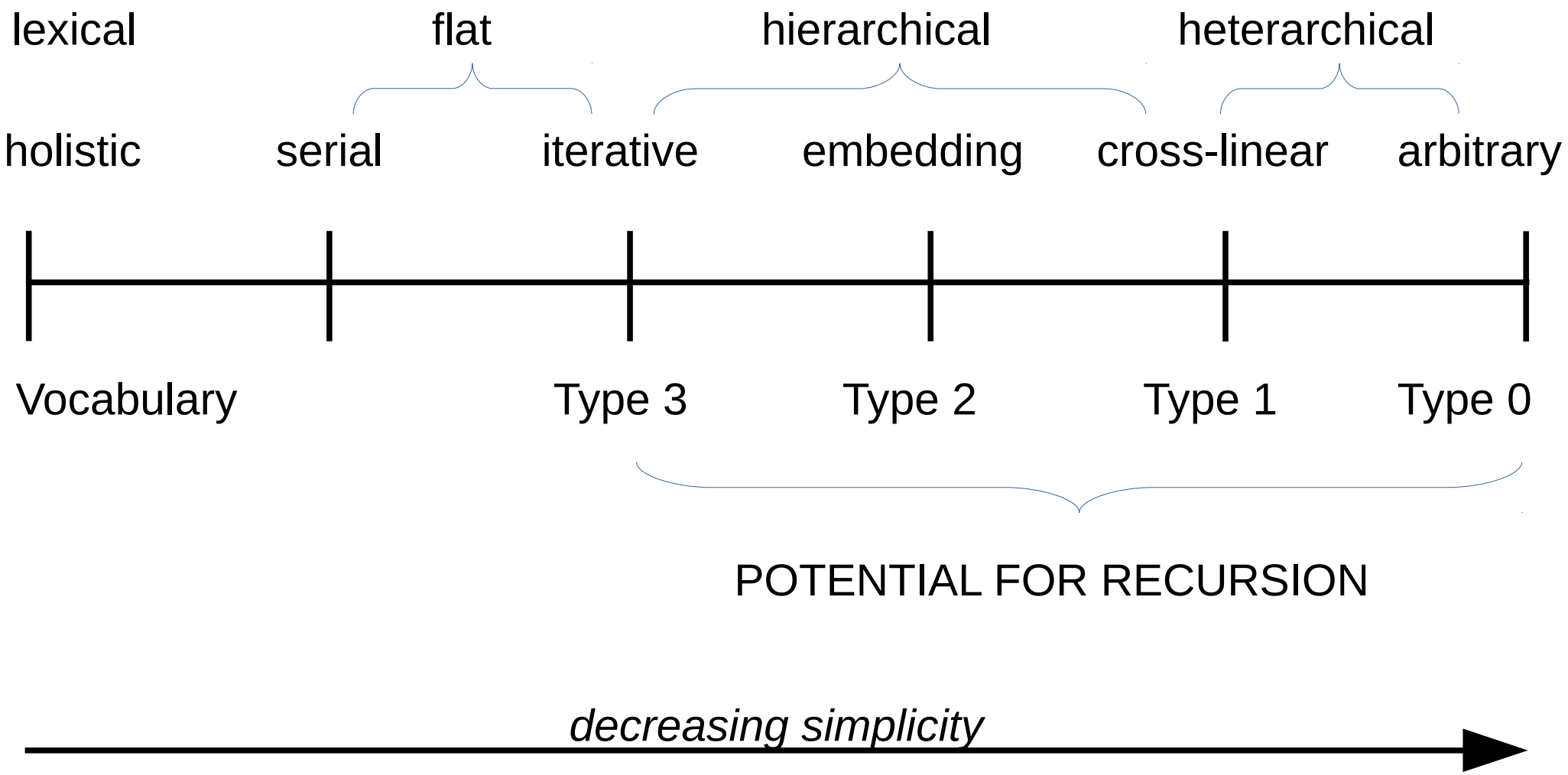
Similar generalisation, in principle:

- allophones in complementary distribution → phonemes

Chomsky-Schützenberger Hierarchy

Grammar	Languages	Automaton	Production rules (constraints)
Type-0	Unrestricted (Recursively enumerable)	Turing machine	$\alpha \rightarrow \gamma$ (no restrictions)
Type-1	Context-sensitive	Linear-bounded non-deterministic Turing machine	$\alpha A \beta \rightarrow \alpha \gamma \beta$
Type-2	Context-free	Non-deterministic pushdown automaton	$\mathbf{A \rightarrow \gamma}$
Type-3	Regular	Finite state automaton	$A \rightarrow a$ and either $A \rightarrow a B$ or $A \rightarrow B a$

Scale of syntagmatic simplicity



Conclusion

- In a nutshell:
  - Language is pervasively linear at all levels
  - Recursion of various types is possible
    - but only under extended memory conditions
    - communities may choose (not necessarily consciously) to use
      - recursion (and associated anaphora
      - other kinds of anaphora (Everett's case?)

      or not!
  - Recursion of different types is not specific to language