Prosody: speech rhythms and melodies

4. Pitch Patterns: Notations and Models

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Forms of prosody: tone and intonation

An intonation lexicon: boundary tones and pitch accents

Level Tone Notations and Contour Tone Notations (e.g. English)

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H* **L*** **L*H** **LH*** **H*L** **HL*** **H*H**

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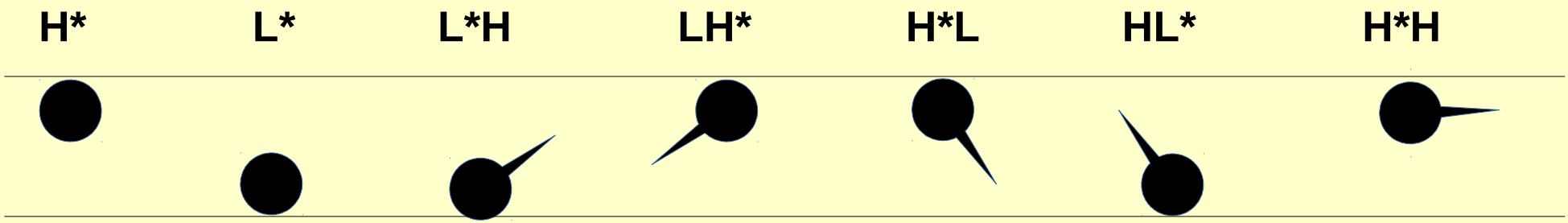

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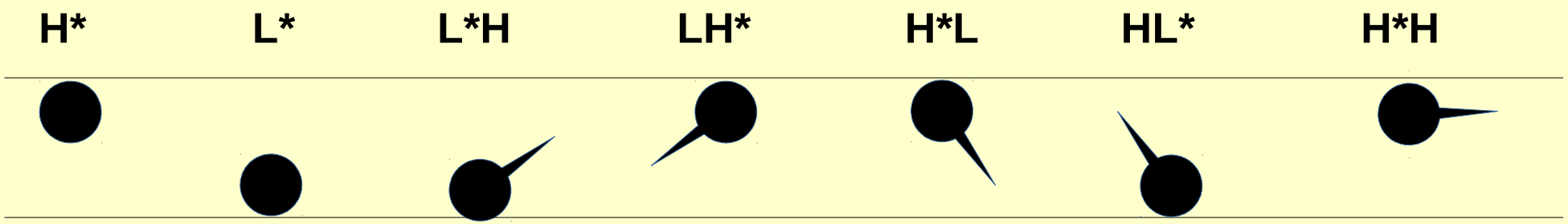

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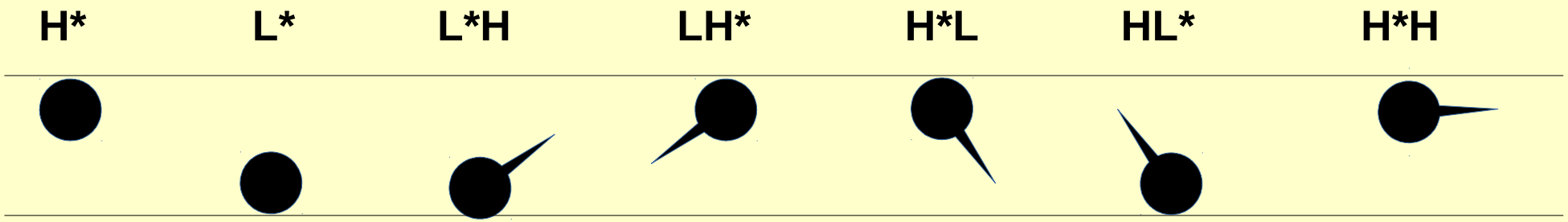

The information can also be represented by a Feature notation

shape=point
place=H

shape=rise
anchor=start
place=L

shape=fall
anchor=start
place=H

shape=level
anchor=start
place=H

shape=point
place=H

shape=rise
anchor=end
place=L

shape=fall
anchor=end
place=L

Inductive analysis: from pitch patterns to categories

Phonetic mode (signal analysis):
- Domains:
  - time functions (articulatory, acoustic, auditory)
- Analysis:
  - time domain
  - frequency domain (spectrum)

Tonal tokenisation (e.g. Tobi):
BoundaryTone PitchAccentTone PitchAccentTone* BoundaryTone
Boundary tone: { **H%**, **%L%** }
PitchAccentTone: { **H***, **L***, **L*H**, **LH***, **H*L**, **HL***, **H*H** }

Contour parsing (Tonetics):
prehead head body nucleus tail

Categorial interpretation (prosodic phonologies):
- Configurative: Initial/final boundary; ip, IP boundary
- Contrastive: accents
- Culminative: accent placement

The syntax (= structure) of prosody

- The forms of a language (morphemes, words, sentences, ...) are described by a grammar.
- The components of a grammar:

  Vocabulary (Lexicon, Dictionary, Inventory)

  - List of items (phonemes, morphemes, words, idioms, …)
  - Set of paradigmatic (classificatory, similarity) relations

  Constructor (Rule system, Constraint system)

  - Generator / Parser (creation and analysis of structures)
  - Set of syntagmatic (compositional) relations

The syntax (= structure) of prosody

- Example:

  Language = {ba, ma, bi, mi, am, im, du, nu}

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  Constraints:

  *{d,n} ^ {a,i}, *{a,i,u} ^ *{d,n}

  *{b,m} ^ {u}

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  Syntagmatic relation: concatenation

  - {C ^ V}, {V ^ C}

NOTE

I am not using a fashionable ‘theory’.

Just very basic mathematics.

The syntax (= structure) of prosody

- Compositional operations in prosody:
  - Sequencing:
    - concatenation of tokens (cf. standard phonologies & grammars)
  - Parallelism:
    - synchronisation; overlap (cf. autosegmental phonology)
  - Grouping:
    - generalisation; domain (cf. metrical phonology)
- Formal principles, e.g. event logic:
  - Steven Bird: Event phonology
  - Julie Carson-Berndsen: Time-Map phonology

Three key parameters

- Phrasing (boundary placement)
  - ‘tonality’
- Accentuation (stress/accent placement)
  - ‘tonicity’
- Shape (sequence of levels/contours)
  - ‘tone’:
    - global intonation contour
    - shape of pitch accents and boundary tones

Removing some terminological confusion!

- The assignment of prominence to words is confusingly referred to by different scholars as

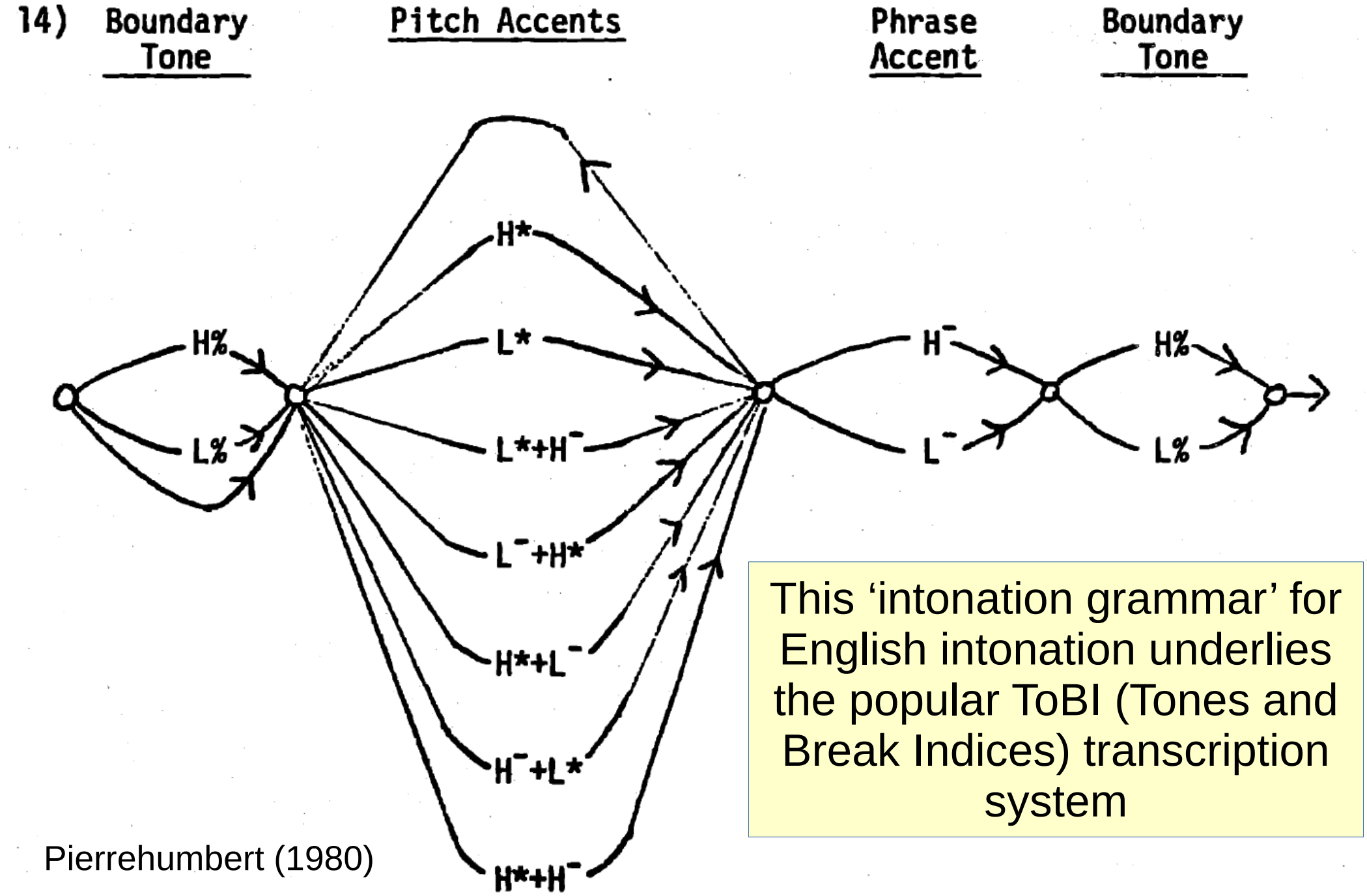
  Stress – **Accent** – **Focus** – **Tone**

- I clarify as follows:
  - **Stress** is a lexical or grammatical position in a word, phrase, sentence, text (cf. 'Nuclear Stress')
  - **Accent** is a phonetic interpretation of a stress position as a pitch-intensity-duration pattern
  - **Focus** is the information-relevant semantic interpretation of an accent at a stress position
  - Finally:
    - **Tone** is reserved for contrastive lexical and morphosyntactic functions of fundamental frequency.

Syntagmatic structure of English intonation:

Pierrehumbert's Finite Machine Model

Syntagmatic structure: a Finite Machine Model



This ‘intonation grammar’ for English intonation underlies the popular ToBI (Tones and Break Indices) transcription system

Pierrehumbert (1980)

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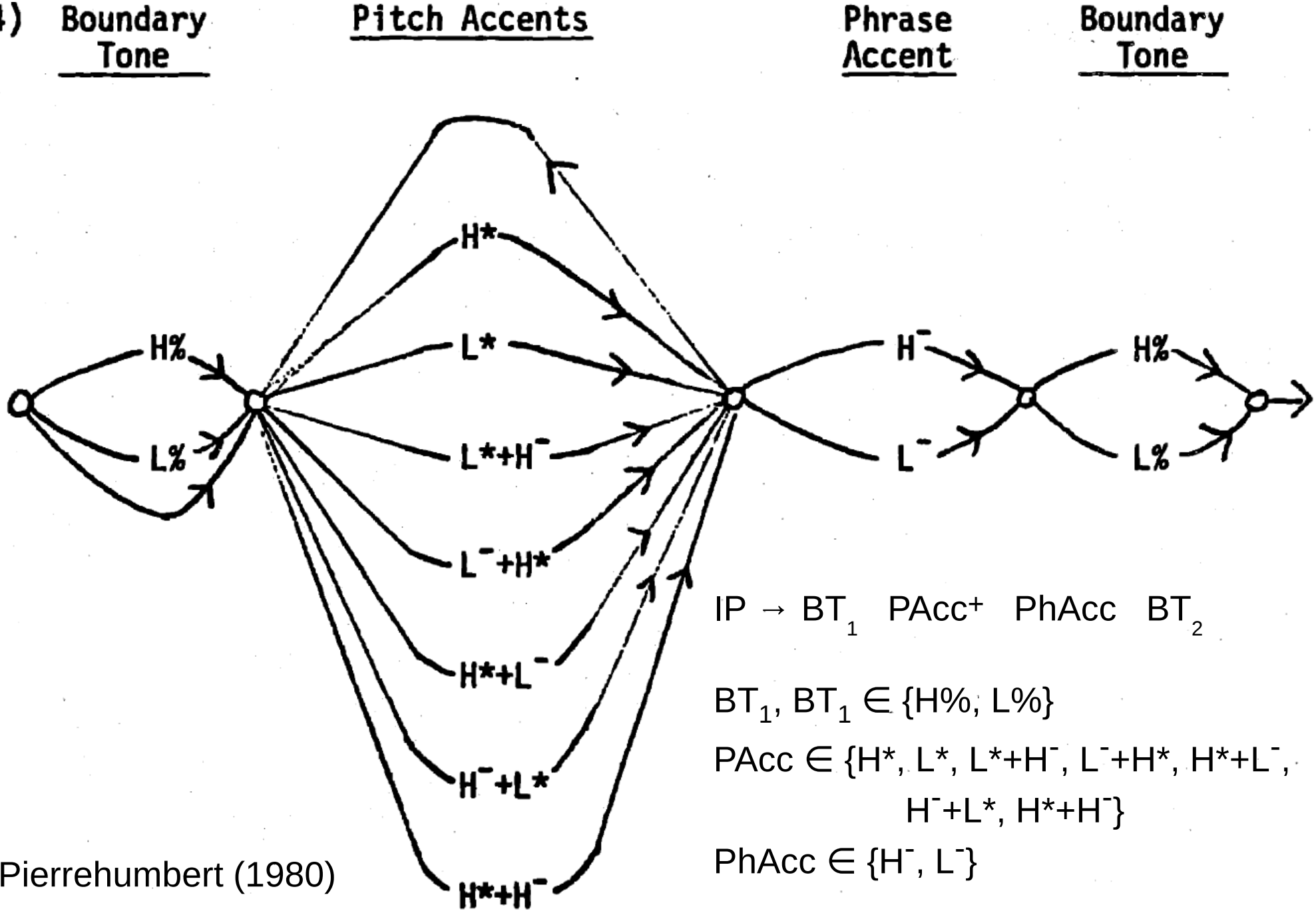

IP → BT_1 PAcc⁺ PhAcc BT_2

BT_1, BT_1 ∈ {H%, L%}

PAcc ∈ {H*, L*, L*+H⁻, L⁻+H*, H*+L⁻, H⁻+L*, H*+H⁻}

PhAcc ∈ {H⁻, L⁻}

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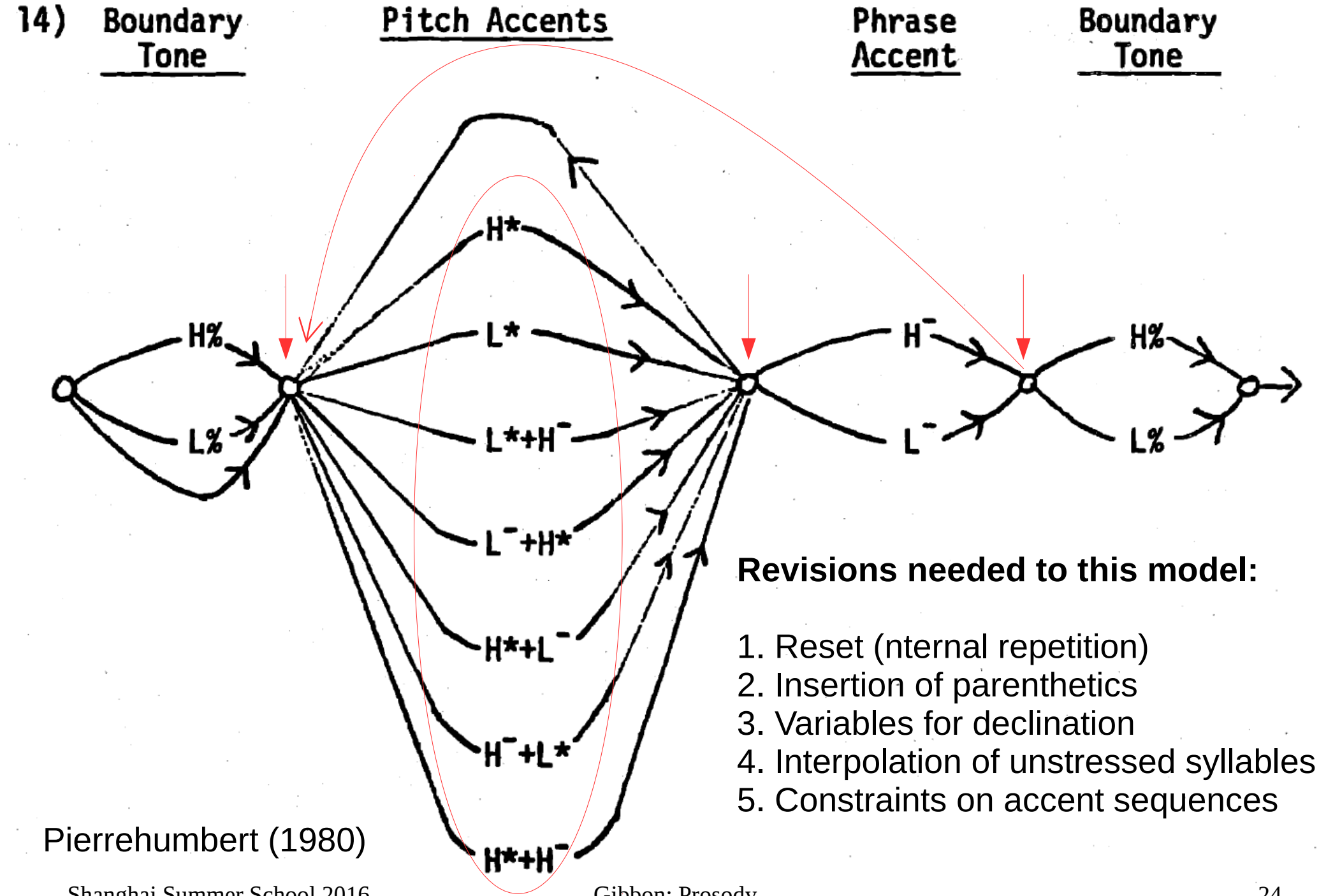


Revisions needed to this model:

1. Reset (nternal repetition)
2. Insertion of parenthetics
3. Variables for declination
4. Interpolation of unstressed syllables
5. Constraints on accent sequences

Pierrehumbert (1980)

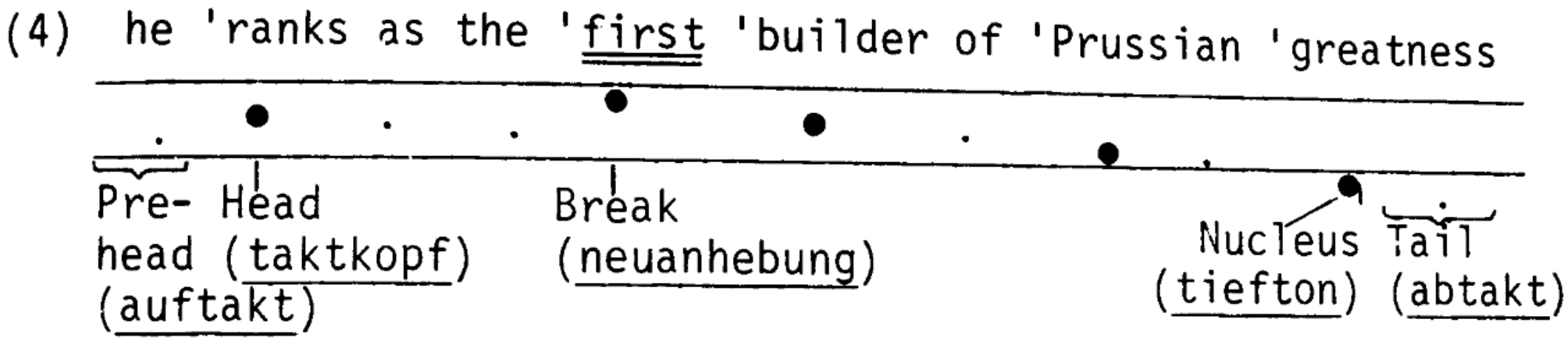
Older textbook approaches:

'iconic transcription' in teaching materials

Older textbook approaches: 'iconic' transcription

- Intonation vocabulary items represented iconically in graphic transcriptions:
  - dots or dashes for 'stressed' syllables
  - smaller dots for 'unstressed' syllables
- Intonation Group represented iconically:
  - sequence of vocabulary items
  - declination as sloping sequence
  - reset or 'break' to re-start Intonation Group
  - final 'nuclear' stress/accent/tone

Graphical 'iconic' transcription



Top: Klinghardt & Klemm (1920)
Bottom: Armstrong & Ward (1926)

IG → NonFinal* Final

NonFinal → Bk Ana* Accent (Str)* Unstr

Final → Ana* Nucleus Unstr*

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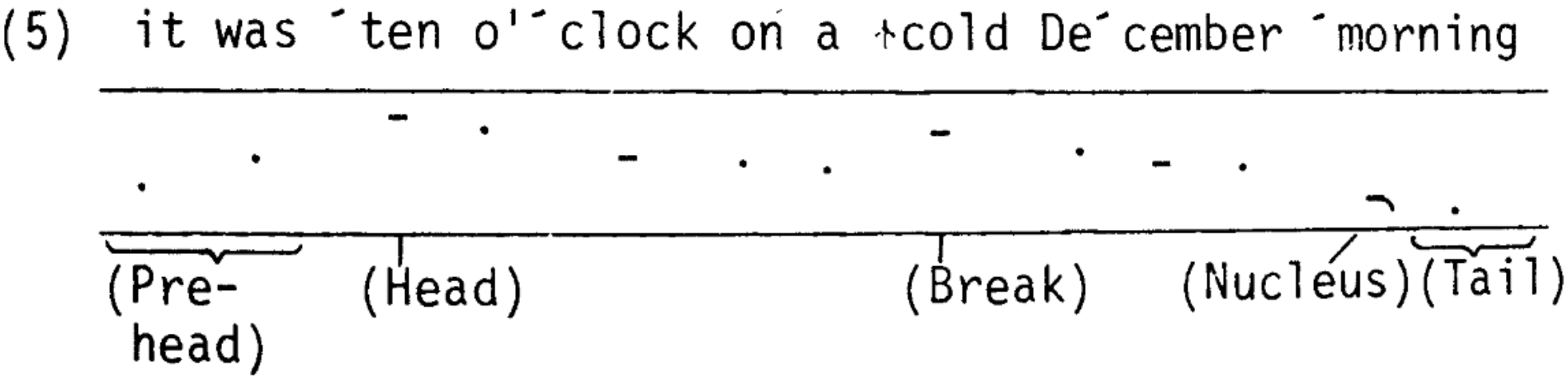

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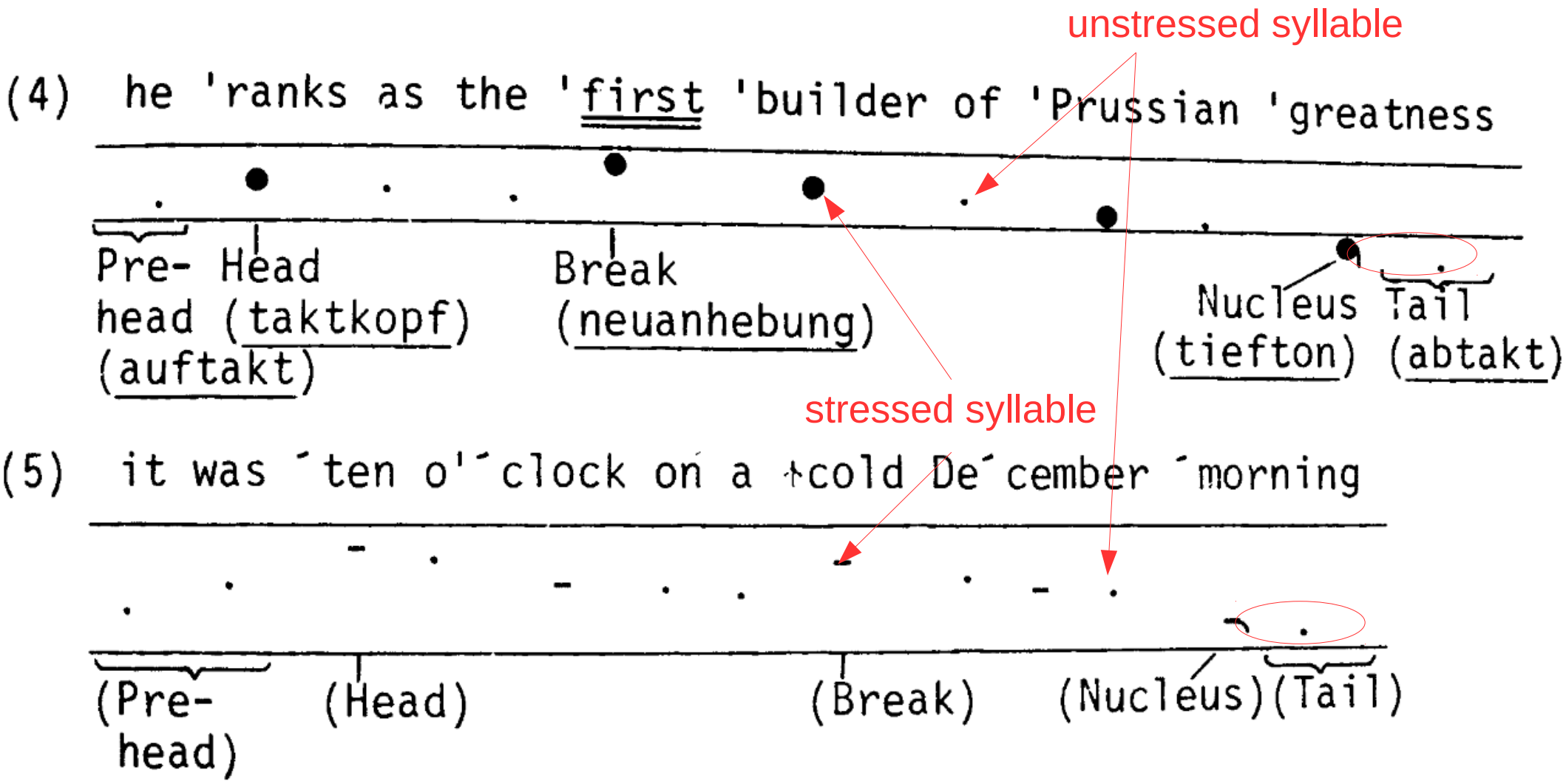

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Hierarchical syntagmatic structure

an integrative view of the prosodic hierarchy

in the context of the Rank Interpretation Architecture

Phonological Hierarchy – Prosodic Hierarchy

- The Prosodic Hierarchy is implicitly contained in the Rank Interpretation Architecture:
  - Prosodic hierarchy of associated units:
    - phonological segment – vowels, consonants; distinctive features
    - syllable – stress, accent, tone
    - foot – basic unit of rhythm in stress languages
    - prosodic word – domain of lexical phonological rules
    - prosodic phrase – domain of intonation: onset – body - nucleus
    - paratone – (larger intonation domain, analogous to ‘paragraph’)

The Prosodic Hierarchy: an integrative view

Utterance (Utt): constituent of turn-taking, Q&A etc.

Intonational Phrase (IP): boundary tones, association with Grammatical Phrase

Phonological phrase (PhP), Intermediate Phrase (ip): phrase boundary tone, domain of phrase stress

Sentential domain prosody

Phonological word, Prosodic Word (PW, PrWd, ω): domain of word stress, prosodic morphology, clitics

Foot (φ): Domain of primary, secondary, fixed stress, prosodic morphology

Lexical domain prosody

Syllable (σ): phonotactic patterns, stress-bearing unit, (phonetically: local sonority peak)

Mora (μ): tone placement, phonotactic patterns

Segment: smallest 'leaf' element in prosodic hierarchy

Subsegment: affricates, diphthongs; (phonetic: stop closure-pause-release)

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The grammar of the Prosodic Hierarchy

Prosodic Category inventory:

PC = {Utt, IP, PhP, PrWd, omega, Ft phi, syll, mora, segment}

Prosodic Hierarchy ordering:

L = <Utt, IP, PhP, PrWd, omega, Ft phi, syll, mora, segment>

l1 = Utt, l2 = IP, … l9 = segment

Structural constraints on Prosodic Hierarchy

Strict Layering Hypothesis:

PC at L_i dominates only PCs at L_{i+1}i

- Fixed depth (no recursivity): No PC at L_i dominates a PC at L_{i+1}
- Exhaustivity: All PCs at L_i are dominated by a single PC at L_{i-1}

Headedness:

- Every PC at L_i immediately dominates a PC at L_{i+1}

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But iterative recursion at the same rank is ok.

A formal note on two main kinds of recursion

(a popular topic these days)

from the point of view of a computational linguist

A formal note on two main kinds of recursion

- Linear recursion (left or right branching, not both)

  {*the car*, *Jim's car*, *Jim's dad's car*, *Jim's dad's mate's car*, ...}

  Left-branching: A → B *car*, B → B {dad*'s*, mate*'s*}, B → {*the*, Jim*'s*}

  Right-branching: A → {*the*, Jim*'s*} B, B → {dad*'s*, *mate's*} B, B → *car*

  - Equivalent to iteration (flat recursion):
    - Jim's (dad's, mate's)* car

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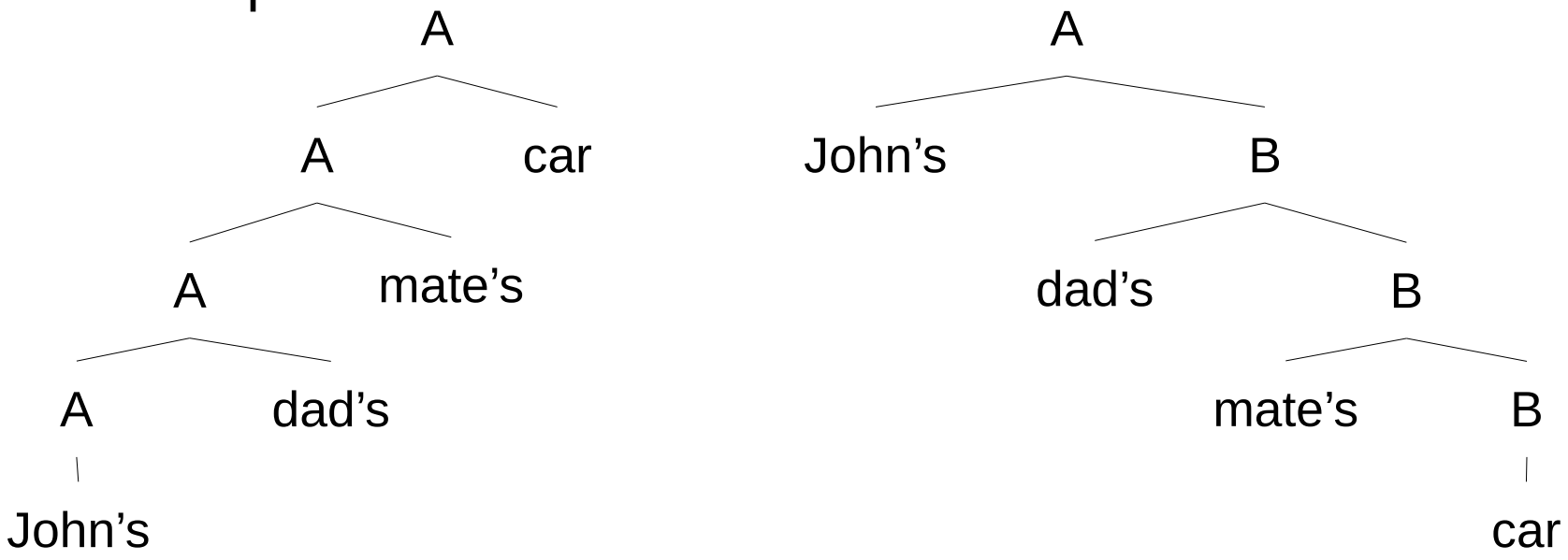
  - Tree structures are not necessary, but helpful for semantic interpretation and/or information structure:



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… → {*the*, Jim*'s*}

ate's} B, B → *car*

- E…

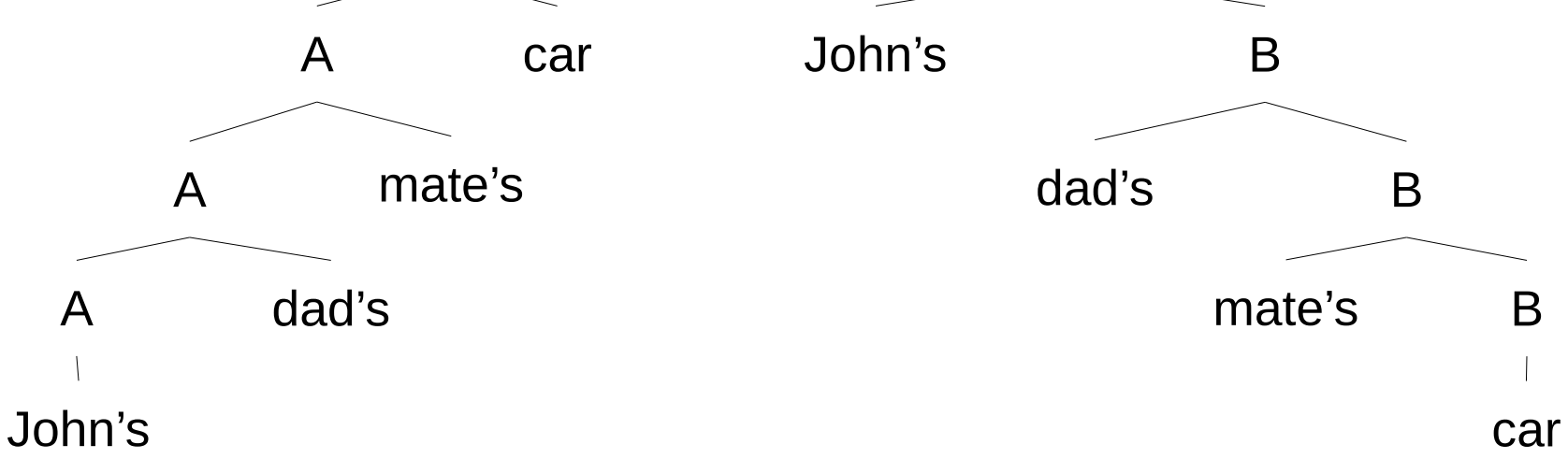
- T… for semantic

in…

Unilaterally branching trees of arbitrary depth are not a problem for prosodic marking.

They are equivalent to flat recursion / iteration and can be represented by:
- sequence of phrases
- with breaks
- with final nucleus

Unilaterally branching trees cornform to the *Strict Layering Hypothesis*.



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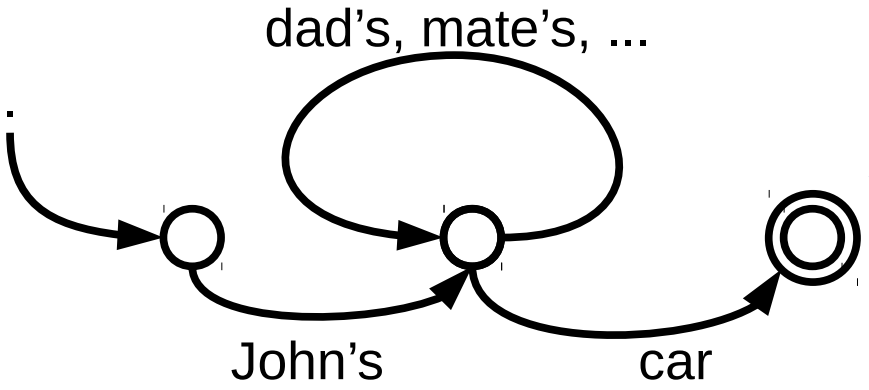

This simple grammar, a finite state machine represented as a transition diagram, is compatible with both left and right branching grammars

A formal note on two main kinds of recursion

- Centre-embedding recursion has different properties:
  - Logical centre-embedding:
    - if - then
    - (why -) because
  - Descriptive centre-embedding:
    - relative clauses (restrictive, non-restrictive)
      - The man whose brother, who married Jane, is a doctor is a teacher.
  - Declarative centre-embedding:
    - Indirect speech:
      - That what I said is true is obvious.
  - Parenthetic centre-embedding:
    - Rosie’s birthday, by the way, was last Tuesday.
    - Last Tuesday, which, by the way, was Rosie’s birthday, I left.

A formal note on two main kinds of recursion

- Centre-embedding recursion
  - is rarely necessary at the level of language forms: replaceable by a linear sequence of flat forms with pointers – delegated to semantics and thus to general cognitive processes

Try to find an intonation which marks the structure of this sentence!

If, if it rains tomorrow then we'll visit the museum, then, if it rains the day after then we'll go to the art gallery, ok?

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Try to find an intonation which marks the structure of this sentence!

> If, as you say, if it rains tomorrow then we'll visit the museum, then, please listen closely, if it rains the day after then we'll go to the art gallery, ok?

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a "structure-marking" strategy

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Try to find an intonation which marks the structure of this sentence!

You said, if it rains tomorrow we'll visit the museum. So if it rains the day after, we'll go to the art gallery, ok?

a "de-embedding" strategy

A formal note on two main kinds of recursion

- Centre-embedding recursion:
  - is rarely necessary at the level of language forms: re… s with p… o general c…

Centre-embedded trees of arbitrary depth are a real problem for prosodic marking, which only works to a depth of about 2 or 3.

This is not an accident, and affects more than prosody.

Even with the memory enhancement of written language, centre-embedded constructions with depth more than 2 or 3 are very difficult to understand.

Try… sentence!

…m. So if it rains the day after, we'll go to the art gallery, OK?

a “de-embedding” strategy

A formal note on two main kinds of recursion

- In fact marking any kind of hierarchy with prosody is a problem, beyond depth 2 or 3
  - stress levels are usually limited to 2 or 3 (primary, secondary, unstressed)
  - Bierwisch and others criticised unlimited derivation of stress levels from generative gramar hierarchies:

the man in the car saw Mary

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4	3	4	5	2	3	1
the	man	in	the	car	saw	Mary

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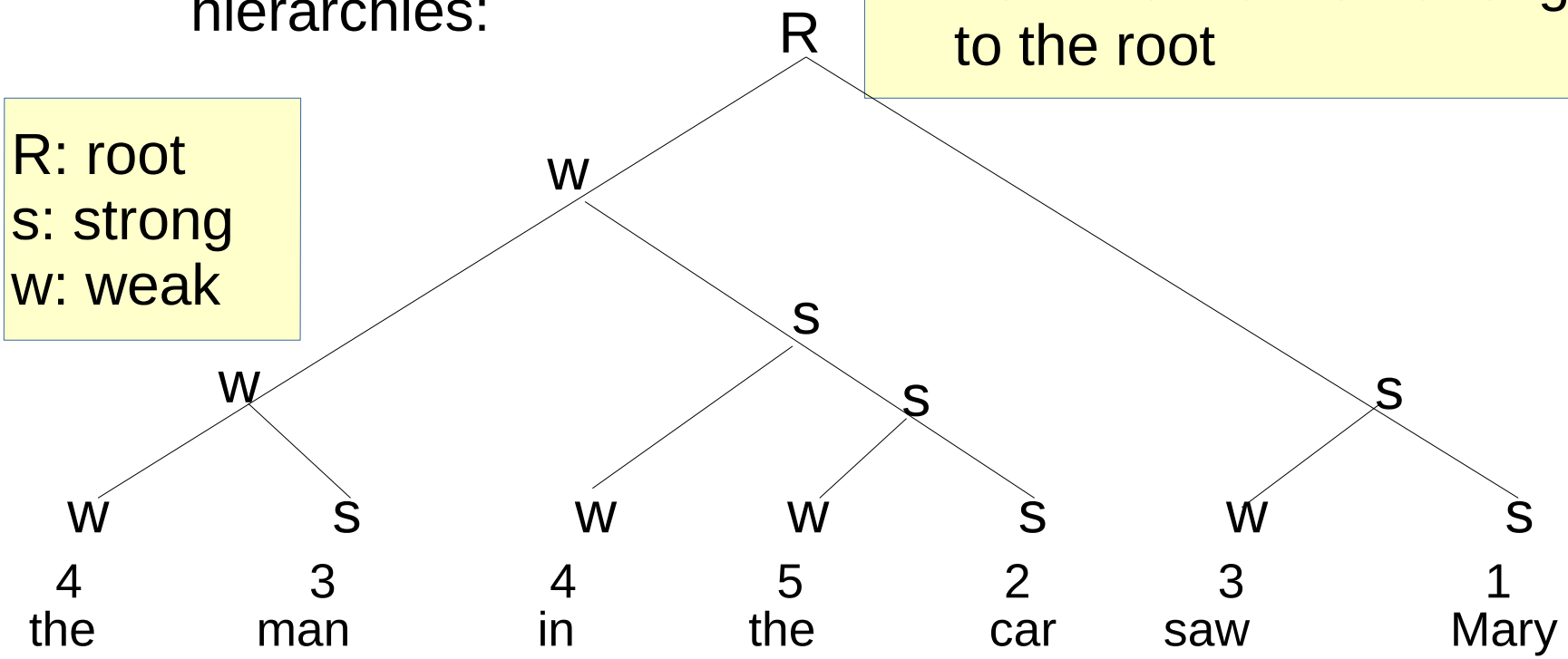
  - Bierwisch and others critic sentence and word stress hierarchies:

Liberman's bottom-up algorithm for the Nuclear Stress Rule:

for each leaf in the tree:
  stress level =
    number of nodes in the path
    from the first non-strong node
    to the root

R: root
s: strong
w: weak



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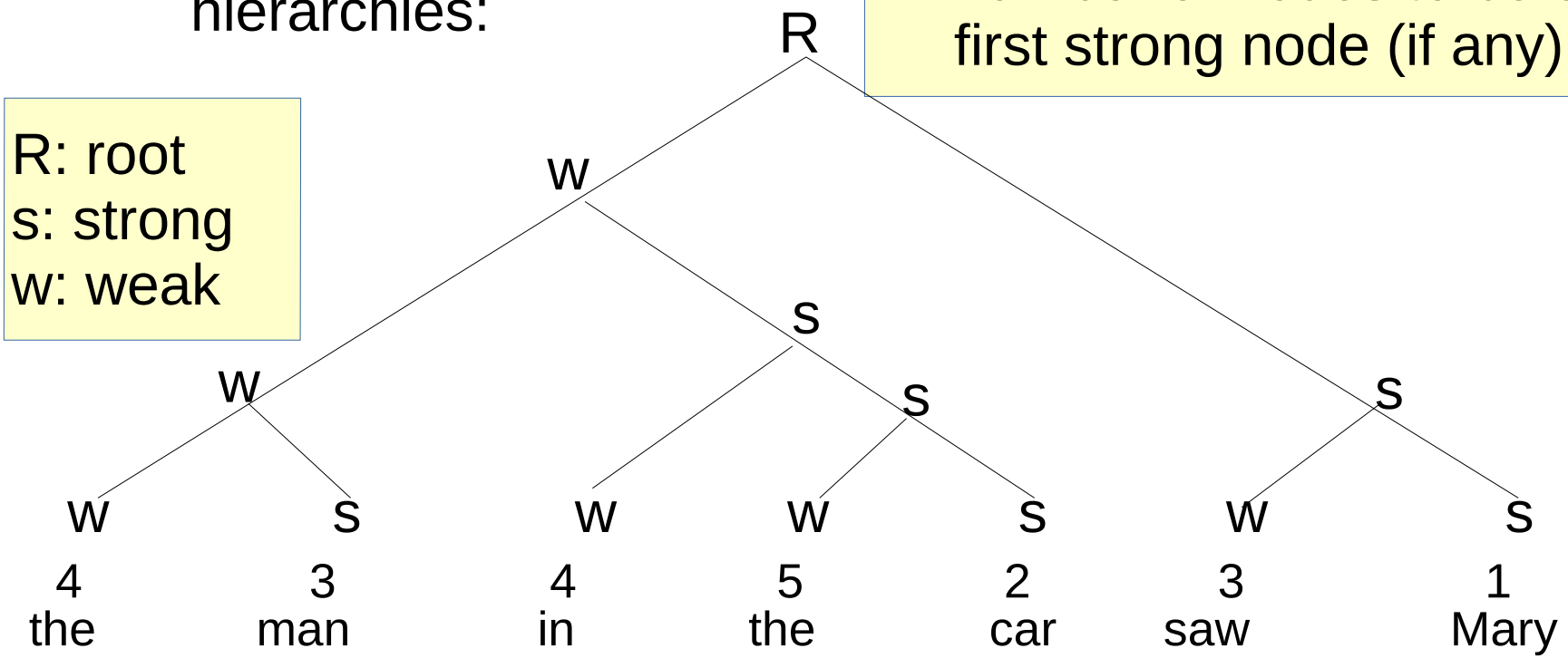
Equivalent top-down algorithm for the Nuclear Stress Rule:

starting at the root:

for each path to a leaf:
stress level =
number of nodes to before the first strong node (if any)

R: root
s: strong
w: weak



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R: root
s: strong
w: weak

Equivalent bracket-counting left-right algorithm for the Nuclear Stress Rule:

```
set counter to 1:
if item is left bracket:
   counter = counter + 1
if item is right bracket:
   counter = counter -1
if item is leaf:
   if previous item = left bracket:
        stress = counter
    if next item = right bracket:
         stress = counter - 1
```

(((the man) (in (the car))) (saw Mary))

A formal note on two main kinds of recursion

- In fact marking any kind
  prosody is a problem, be
  - stress levels are usually lir
    secondary, unstressed)
  - Bierwisch and others critic
    sentence and word stress
    hierarchies: and others crit
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         stress = counter - 1
```

4	3	4	5	2	3	1
(((the	man)	(in	(the	car)))	(saw	Mary))

Prosodic grammar – tone sandhi

Downstep, upstep in Niger-Congo tone systems

Tem (ISO 639-3 *kth*) as a clear case example:

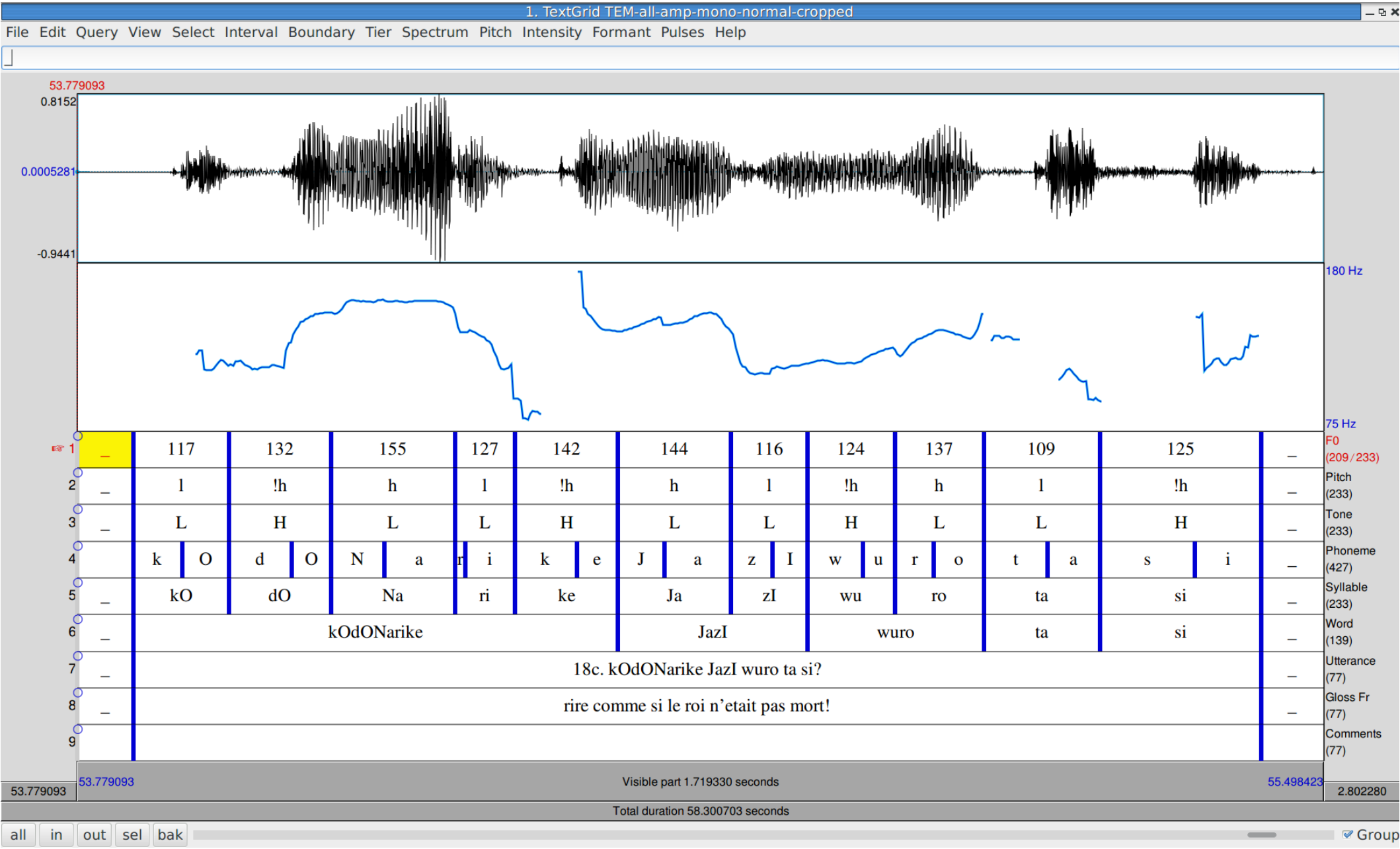
- Phonetic interpretation of Tem tone sequences:
  - inventory of 2 tones, H and L
  - L H: partial automatic downstep producing terracing
  - H L: complete automatic upstep
  - L semiterrace sequences: quasi-constant low
  - Initial H, L: extra high, extra low, respectively
    - Notation:
      - Underlying *tone categories*: upper case (H, L)
      - Surface *phonetic pitch categories*: lower case (h, !h, l, ^l)

Thus, in a traditional notation:

H → !h / L __ (terrace restart by automatic partial downstep)

L → ^l / H __ (semiterrace extension by automatic total upstep)

Downstep, upstep in Niger-Congo tone systems



TEM kodoNa

Downstep, upstep in Niger-Congo tone systems

Generalisations over tone sequences:

Many possible formal tools:

- notations, symbolisms, formalisms (Carnap)
- alphabets (categories, features)

Visualisations are an aid to productivity and insight:

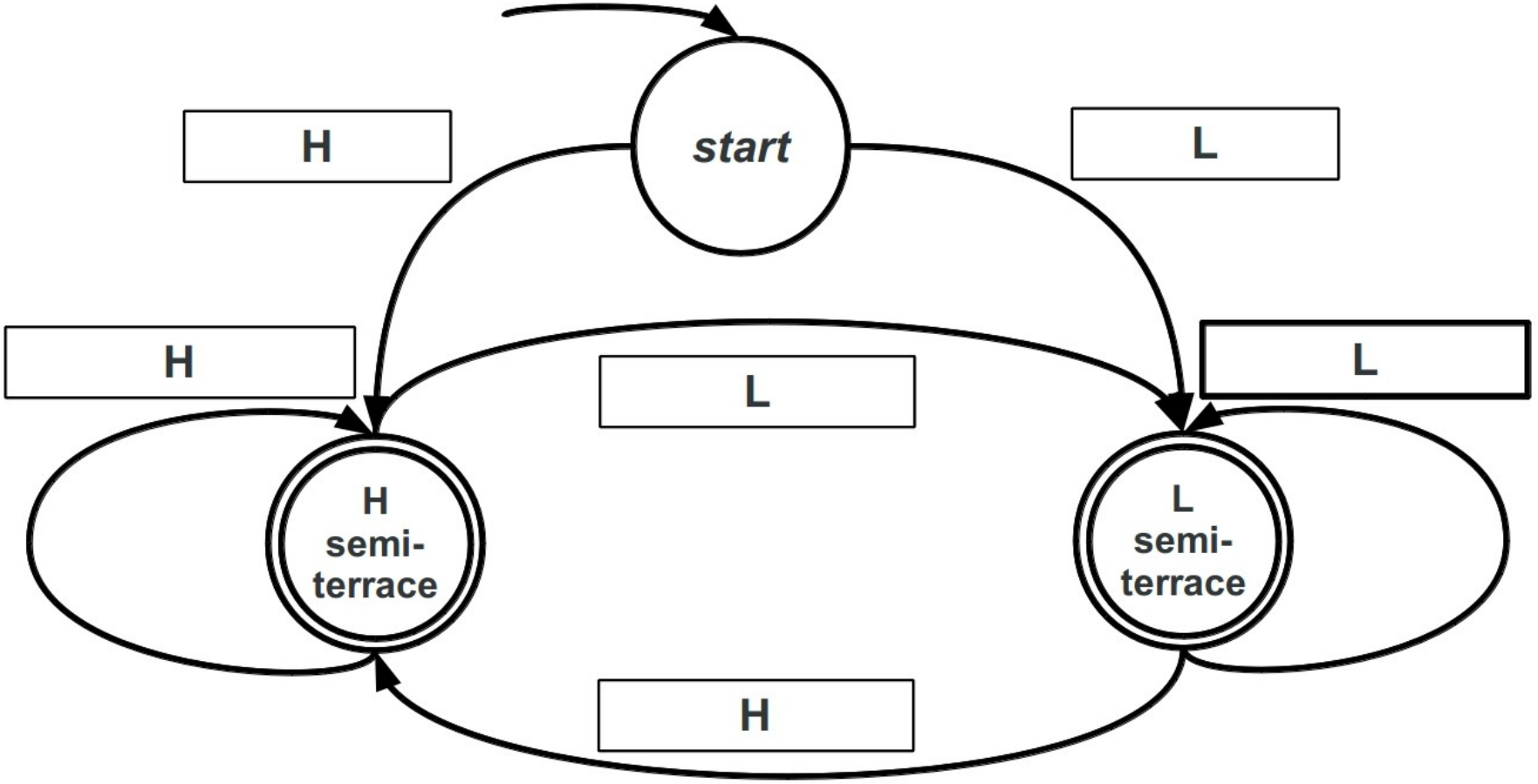
- *parse trees*, *metrical grids*, *autosegmental lattices*, *constraint tableaux* ...

But it is desirable to visualise

not only *data representations* for tonal sequences and associations, as listed above

but also *underlying grammars for tonal sequences and associations* ?

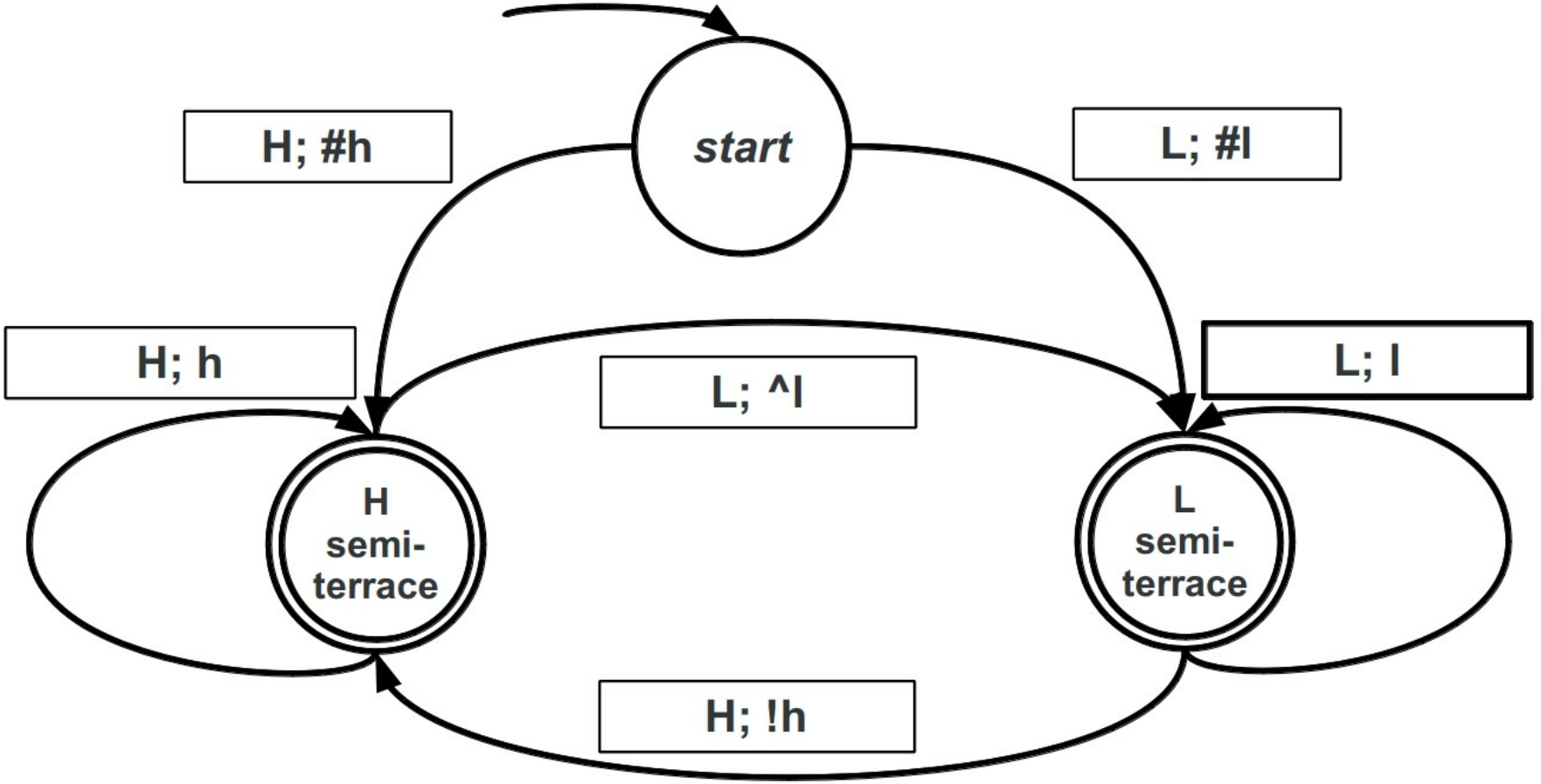
Downstep, upstep in Niger-Congo tone systems



Relevant contexts for tones
start and *end*
H and *L* terrace cycles
HL and *LH* terrace transitions

The graph defines 6 contexts (edges) for tone-allotone (tone-pitch) relations.

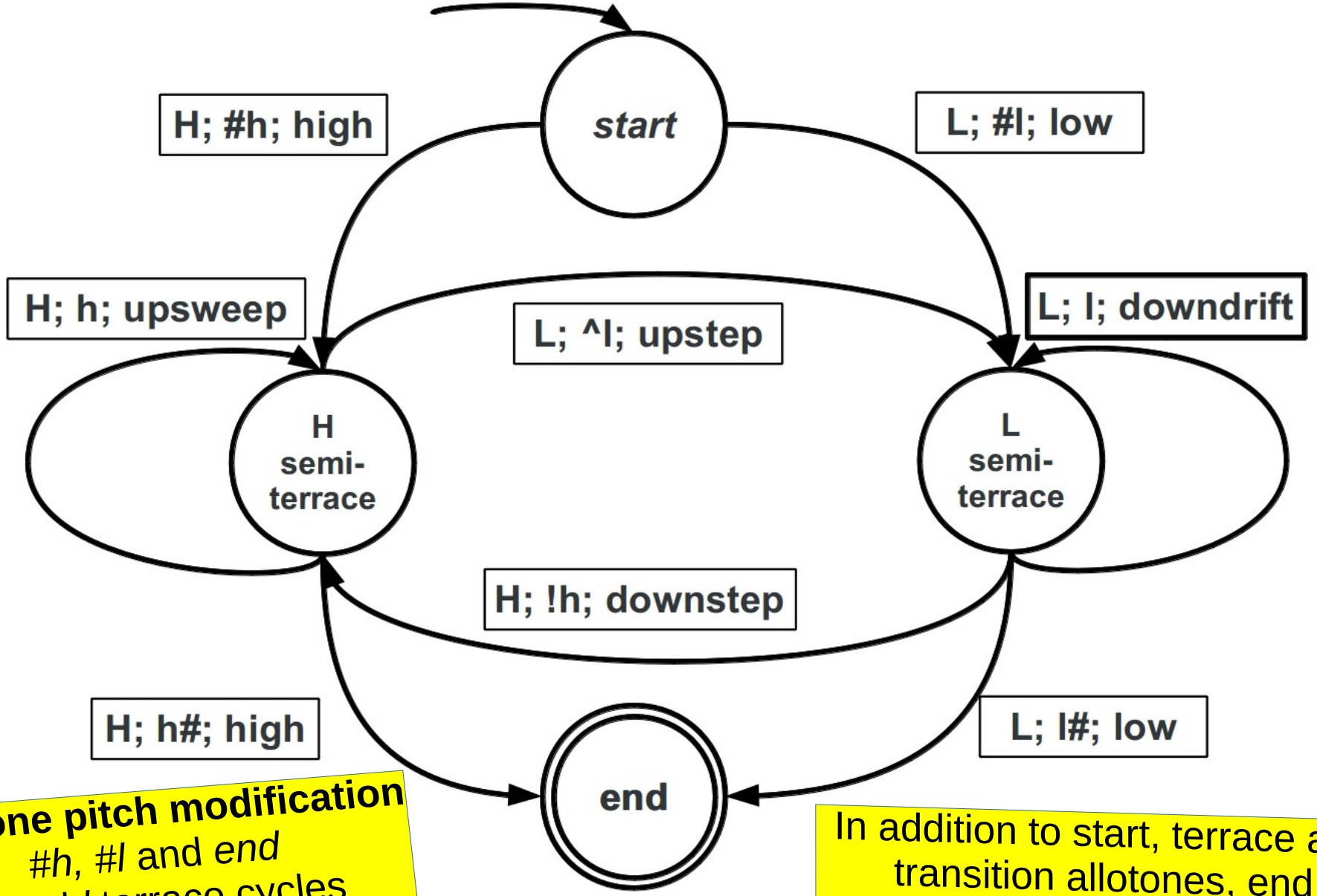
Downstep, upstep in Niger-Congo tone systems



Allotone pitch modification
#h, *#l* and *end*
h and *l* terrace cycles
^l and *!h* terrace transitions

In addition to start, terrace and transition allotones, end allotones also need to be made explicit.

Downstep, upstep in Niger-Congo tone systems



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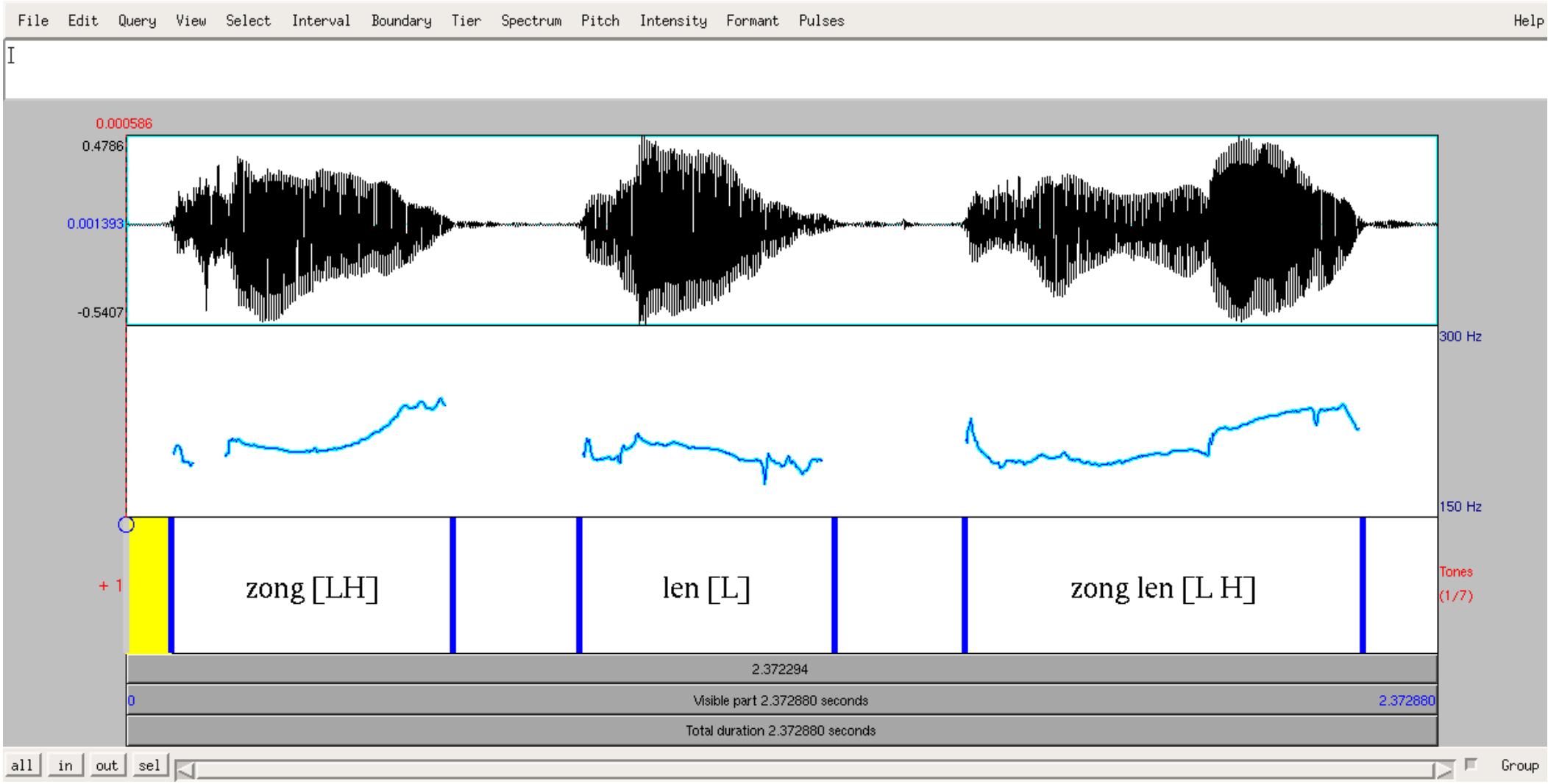
Sino-Tibetan tone

- Kuki-Thadou
- Tianjin Mandarin

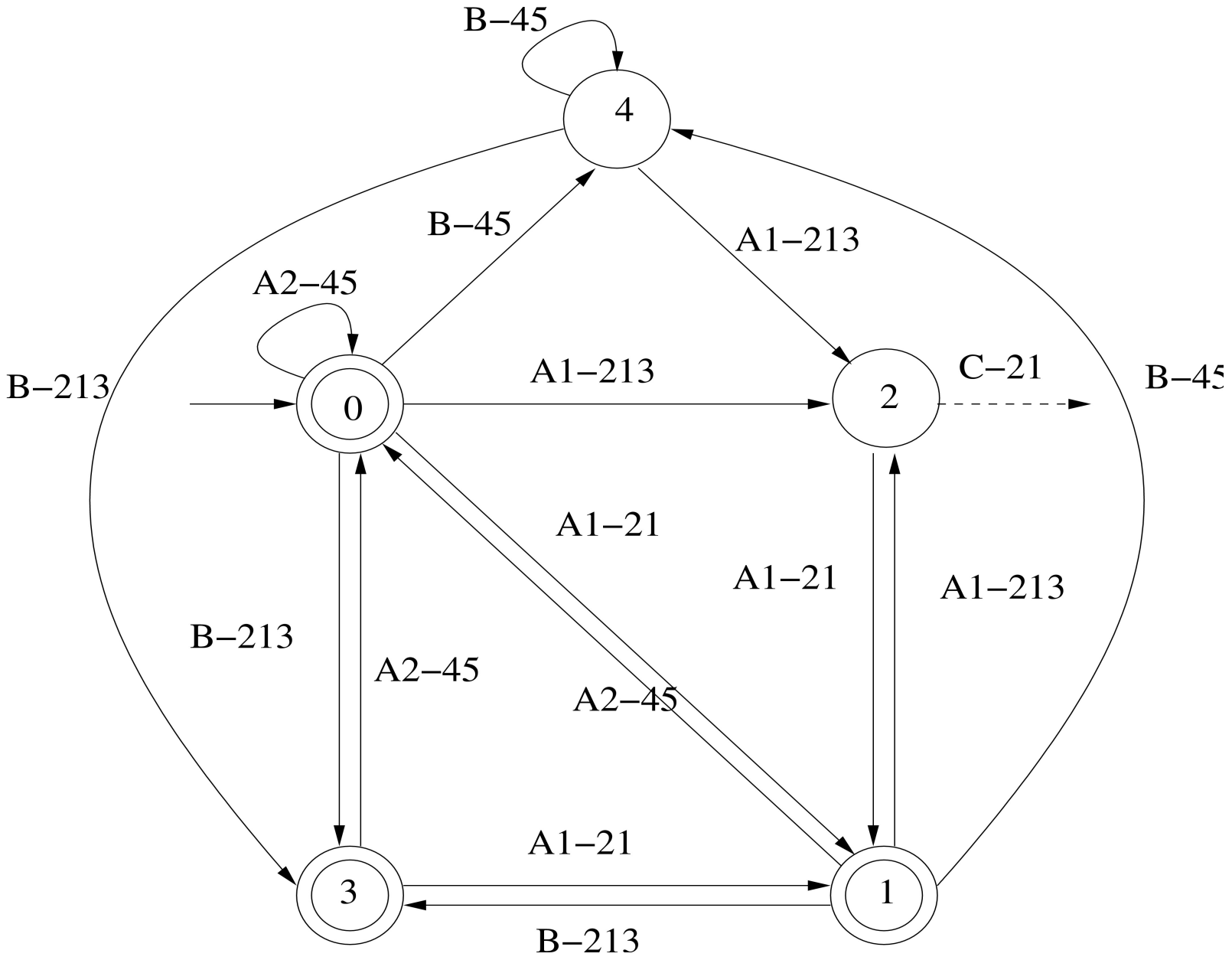
Kuki-Thadou



zong len zonglen

Tone sandhi rule: LH → L / _ H

Tone sandhi in Chinese tonal systems: Tianjin Mandarin



Jansche, M. 1998. A Two-level Take on Tianjin Tone. In: I. Kruij-Korbayova, ed. *Proceedings of the Third ESSLLI Student Session*. Chapter 12.

Summary: what you should know about by now

- Prosodic grammar:
  - Intonation
    - Linear syntagmatic relations
      - Finite State model of intonation
      - Older graphical models
    - Hierarchical syntagmatic relations
      - Prosodic hierarchy
      - Recursive patterns
  - Tone
    - Finite State models of tone
      - Tem (Niger-Congo)
      - Chinese (Tianjin Mandarin)