Computational Phonology Workshop

Introduction & Tutorial

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Outline

Computational View of Language

In formal language theory, string sets are classified according to their formal complexity.

$$\text{regular} < \text{context-free} < \text{mildly context-sensitive} < \cdots$$

Phonology

Morphology

Syntax

This allows predictions for

- typology (e.g. no center embedding in phonology)
- learning (required input, what must be in UG)
- cognitive architecture (type of memory, structural inference rules)

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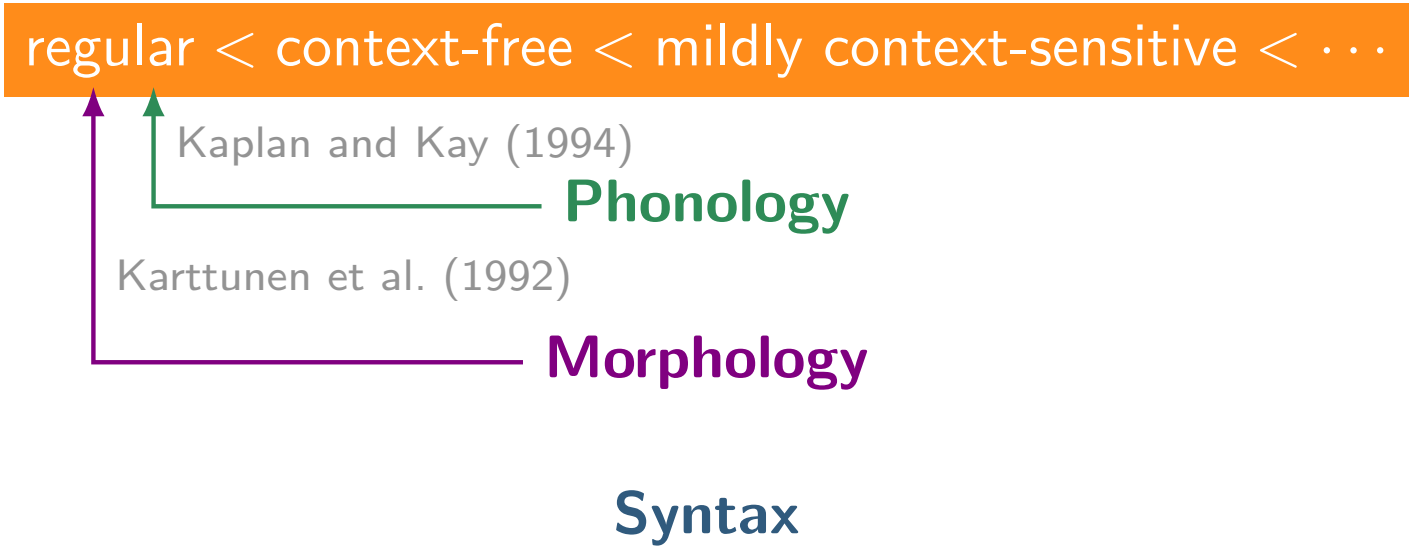

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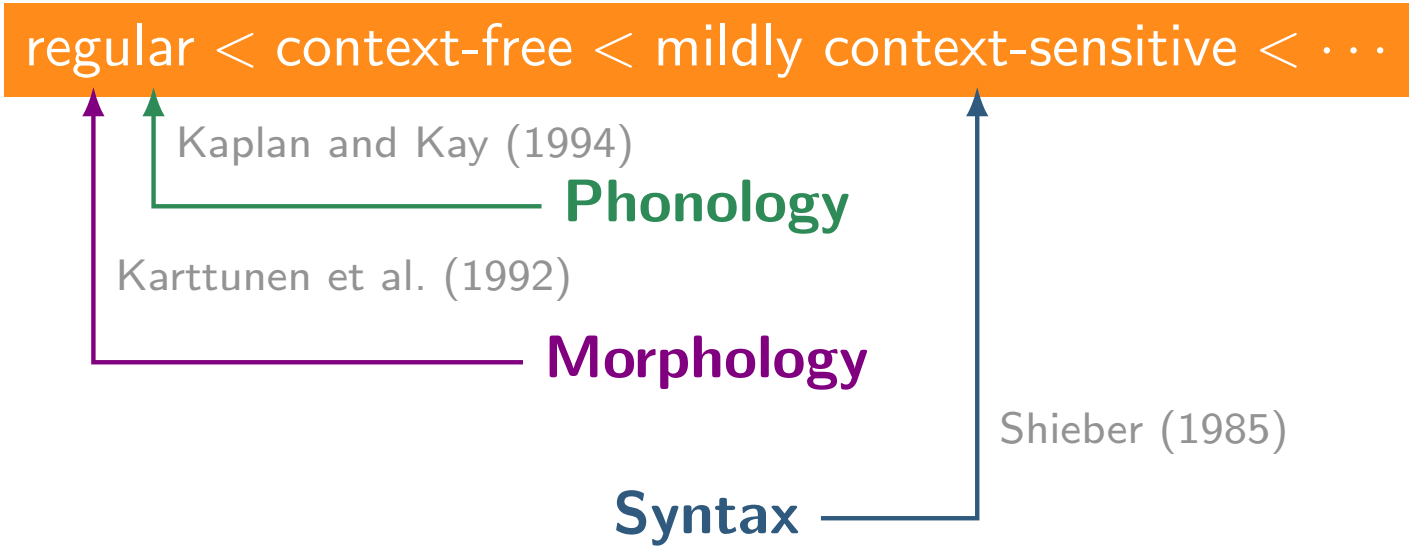

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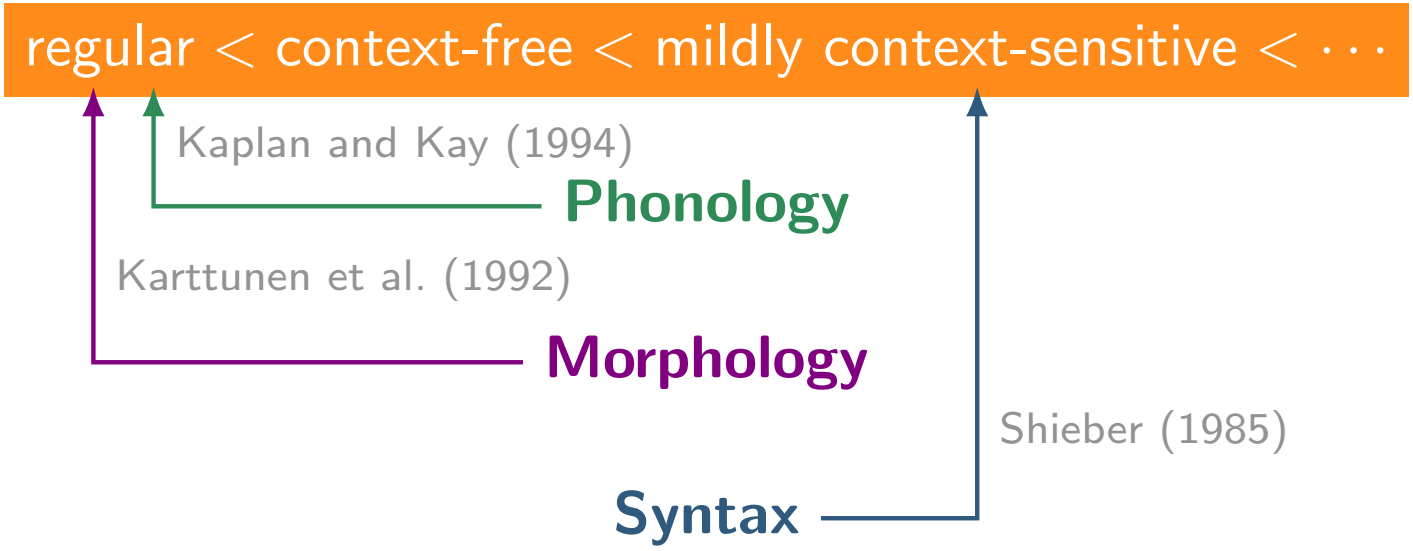

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Too Many Patterns are Regular

- **Problem**
  - All phonological and morphological patterns are regular.
  - But not all regular patterns occur in phonology.
- Regularity is **too loose an upper bound**.

Examples of Regular yet Unattested Patterns

- First-last consonant harmony
- Every word with a plosive contains an open syllable.
- Words with at least 3 suffixes must have exactly 5 prefixes.

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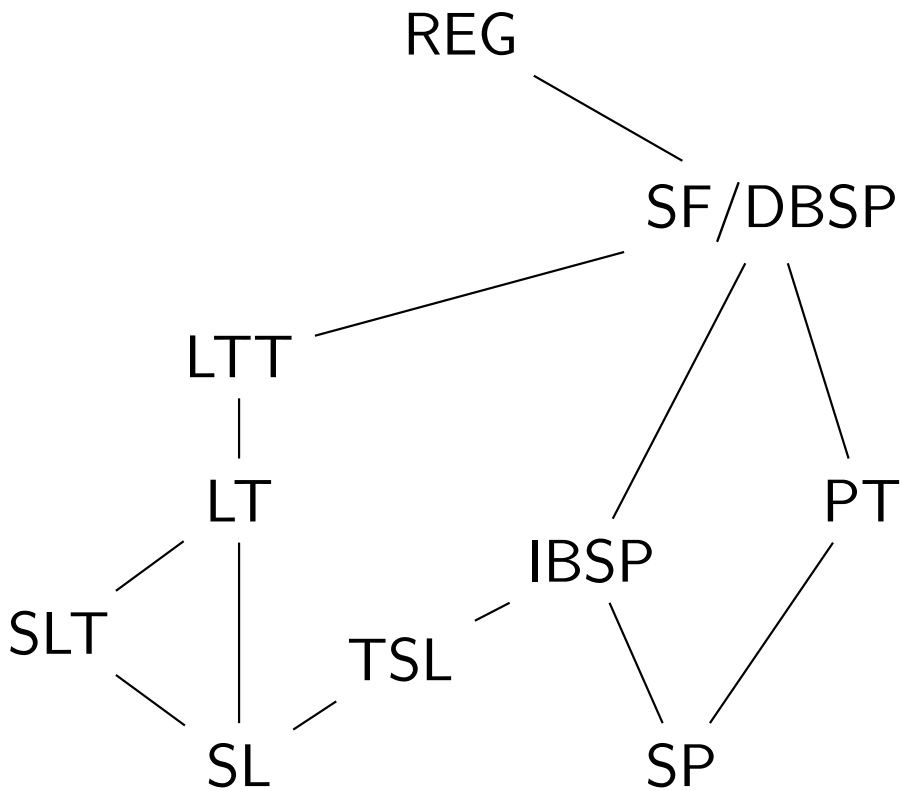
Often forgotten: hierarchy of **subregular languages**
(McNaughton and Papert 1971; Rogers et al. 2010; Ruiz et al. 1998; Rogers and Pullum 2011; Heinz et al. 2011; Graf 2016)



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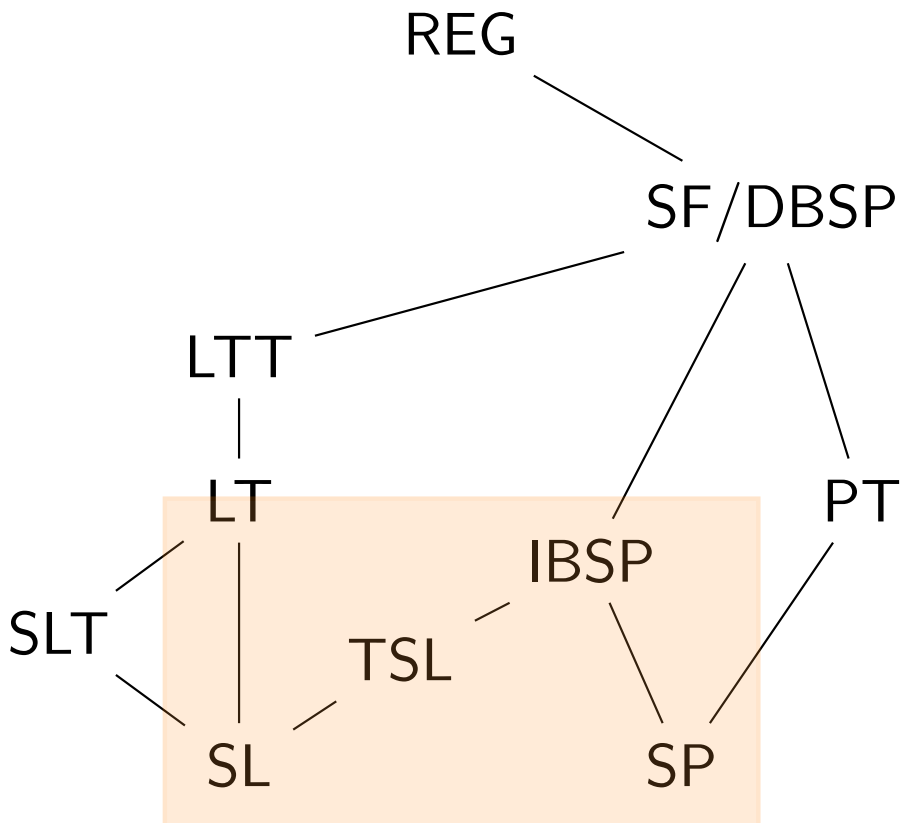

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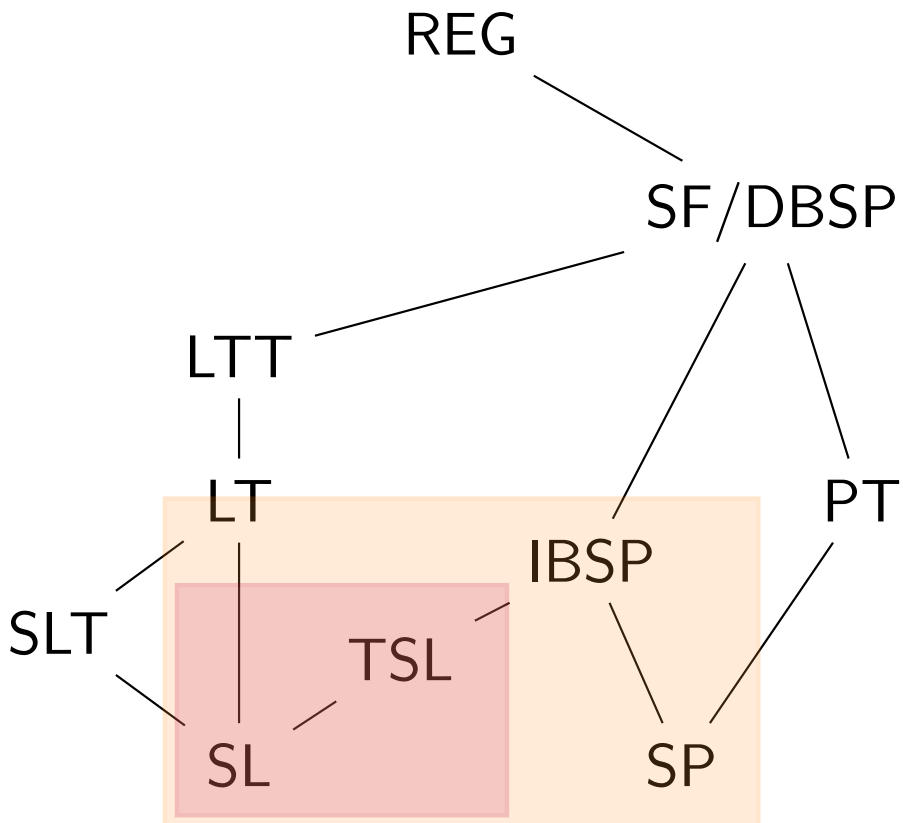

SL: Strictly Local

- SL formalizes **local dependencies**.
- SL grammars are collections of markedness constraints that are
  - hard/non-violable,
  - locally bounded.

Strictly Local Grammars & Languages

SL_n grammar finite set of forbidden n-grams

SL_n language all strings except those with forbidden n-grams

Example: SL Constraints

Process	Constraint	Forbidden n-grams
Word-final devoicing	*[+voice]⋉	z⋉, v⋉, . . .
Intervocalic voicing	*V[-voice]V	asa, asi, . . . , isa, isi, . . . , afa, afi, . . . , ifa, ifi, . . . ,
CV template	*⋊V	⋊a, ⋊i, . . .
	*CC	pp, pb, . . . bp, bb, . . .
	*VV	aa, ai, . . . , ia, ii, . . .
	*C⋉	p⋉, b⋉, . . .

SL is Too Weak

- SL grammars only handle locally bounded dependencies.
- But some processes in phonology are unbounded.

Samala Sibilant Harmony (Heinz 2015:16)

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TSL: Tier-Based Strictly Local

We can make Samala SL-like if we **create new locality domains**.

Tier-Based Strictly Local Grammars & Languages

TSL$_n$ grammar finite set of forbidden n-grams + tier alphabet

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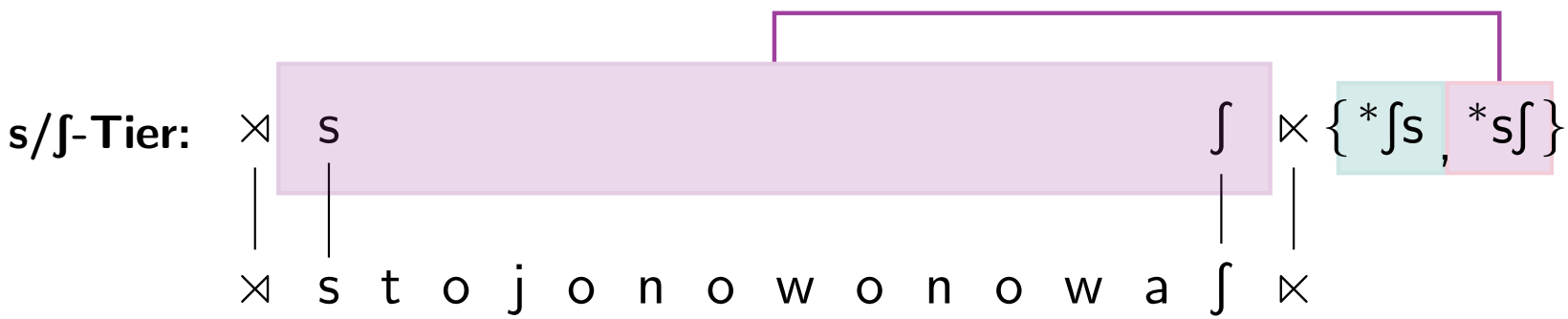
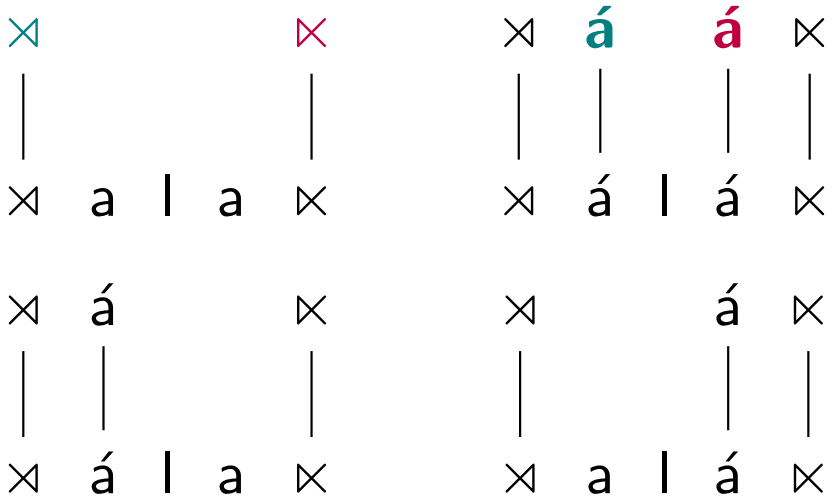


Example: Stress Assignment

Culminativity every word has exactly one primary stress

Tier contains segments with primary stress

n-**grams** ⋊⋉ and **śś**



What TSL Cannot do

- **First-Last Harmony**
  because first/last is not a segmental property
- **Plosive implies open syllable**
  cannot enforce Boolean conditionals
- **Mix local and non-local depedencies**
  e.g. sibilant harmony does not apply to sibilants followed by a nasal

Attested Patterns Beyond TSL?

- **Tone Plateauing** (but IBSP; Graf 2016)
- **Non-Final RHOL [Baek's talk]**
- **Multiple Harmony [Aksënova's talk]**

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Complexity of Phonology

- All local phonological constraints are SL.
- All segmental long-distance constraints are TSL.
- Suprsegmental constraints (tone, stress) may go beyond TSL. (Graf 2010a,b; Jardine 2015)

Cognitive Implications

- SL and TSL languages are **learnable** from positive data. (Heinz et al. 2012; Jardine and Heinz 2016)
  - UG: specifies upper bound on size of n-grams
  - memorize which sequences have not been seen so far
  - induce tier (more complex)
  - learning input can be relatively small
- What cognitive resources are required?
  - Only memorization of the last n segments of a specific type
  - For most processes $n \leq 3$, and for all $n \leq 7$
  - Fits **within bounds of human working memory**

Interim Summary: Phonotactics

- Natural languages have **TSL phonotactics**.
- gives tighter bound on typology
- solves poverty of stimulus by greatly simplifying learning
- reduces cognitive resource requirements

Next

- phonological mappings
- SL & TSL syntax

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- SL & TSL syntax

Phonological Mappings

- So far we have only considered phonotactics.
- But mappings from underlying representations to surface forms can be studied, too.
- Regular mappings are enough.
  (Kaplan and Kay 1994)
- What about **subregular mappings**?

Strictly Local Mappings

Strictly Local (SL; Chandlee 2014)

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Example

	ISL Output	**OSL Output**
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Input string: CVCVCVCV		

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Strictly Local (SL; Chandlee 2014)

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- Rewrite x as y based on previous n symbols in...

  input string: input strictly local (**ISL**)
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SL_3-mapping: $V \rightarrow C \mid VC\_$
Input string: CVCVCVCV

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How Many Processes are SL?

- All locally bounded processes
  assimilation, dissimilation, vowel harmony, even metathesis
- **But:** mappings where local processes interact may not be SL
  multiple metathesis **[Takahasi's talk]**
- Some processes are not locally bounded and thus not SL.
  sibilant harmony, tone plateauing, sour grapes harmony

A Note on TSL

Every TSL_n grammar can be decomposed into

1. an **ISL_1** function (the tier projection), and
2. an SL_n grammar.

An Interesting Puzzle

- What happens if we use an ISL_k function for tier projection?
- Addressed in **Aniello De Santo**'s talk

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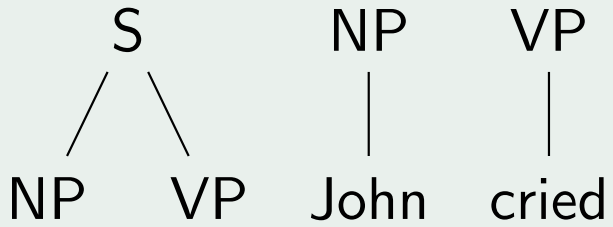
(Tier-Based) Strictly Local Syntax

- SL tree grammars are common in computational linguistics: **context-free grammars**
- By adding tier projection, we get TSL tree grammars.

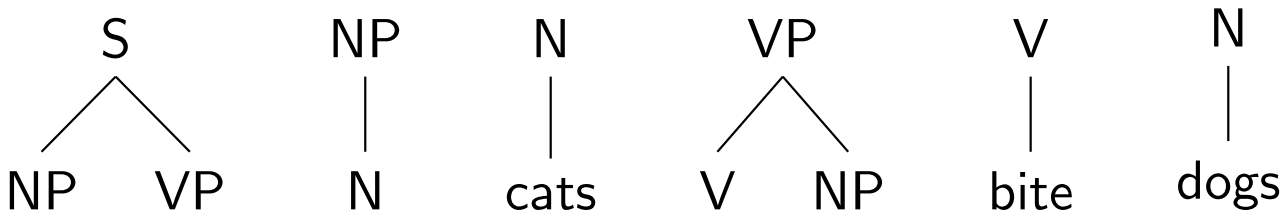
Example: CFGs as SL_2 Tree Grammars

$$\begin{aligned} S &\rightarrow NP\ VP \\ NP &\rightarrow John \\ VP &\rightarrow cried \end{aligned}$$

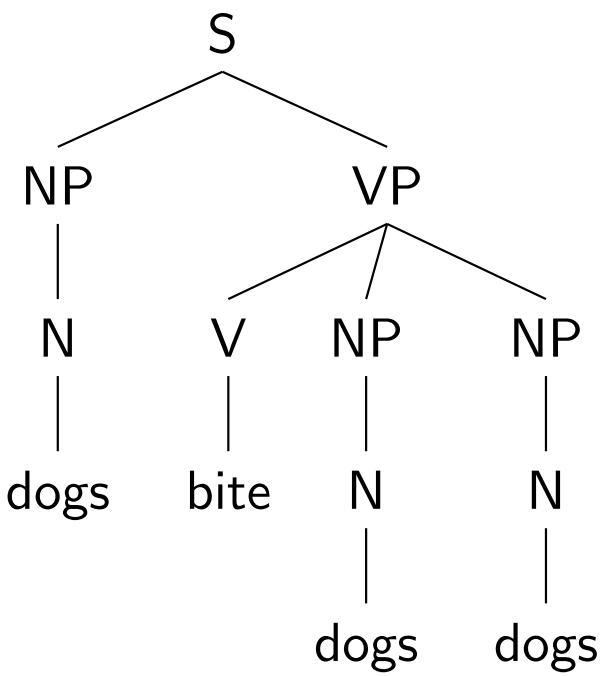


Example: An Illicit Tree

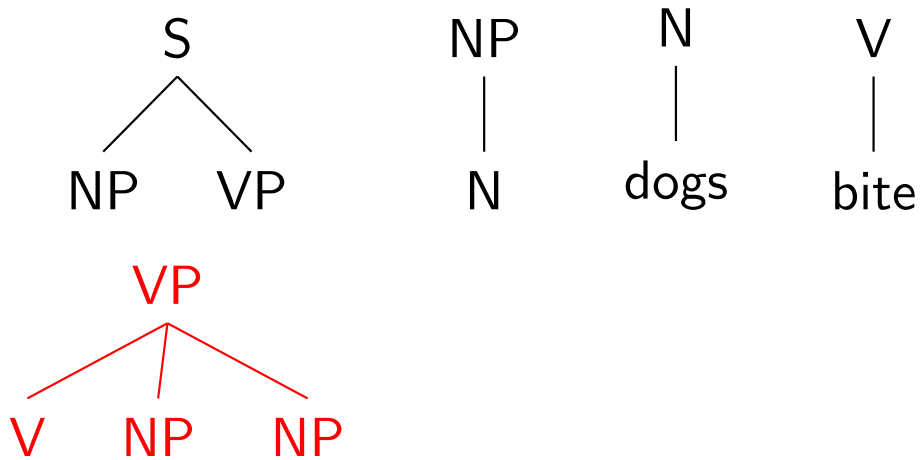
$\mathbf{SL}_2$ Tree Grammar



Example Tree

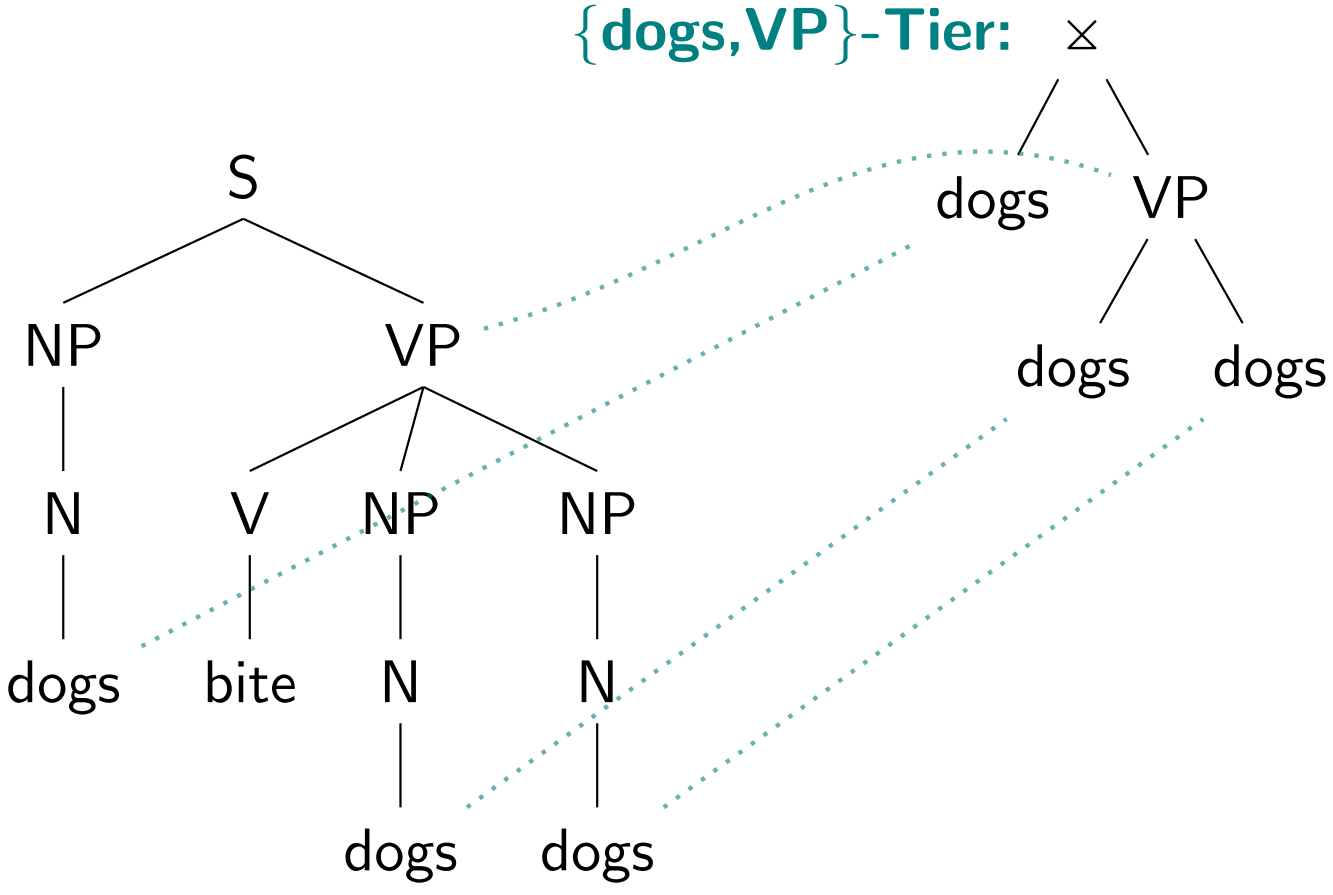


Tree Bigrams of Example Tree



Tier Projection for Trees

Just as for strings, we can project tiers for trees.
(Graf and Heinz 2016)



Towards TSL-Syntax

While TSL-Syntax is still young, it holds promise:

- movement dependencies are TSL (Graf and Heinz 2016)
- Mandarin negation in **Hongchen Wu's talk**
- scope ambiguities in **Lei Liu's blitz talk**

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