The Strict Locality of Phonological Processes

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What is possible?

How can we distinguish phonological patterns from logically-possible but non-phonological ones?

- Phonetic naturalness
- Simplicity
- Computational properties

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Objectives

- Identify **Strict Locality** as a strong computational property of the UR $\mapsto$ SR mapping in local phonological processes.
- Discuss the empirical coverage of this property based on a database of phonological patterns (P-base v1.95, Mielke 2008).
- Describe the utility of this property in the domain of learning.

Phonological Mappings

underlying form $\mapsto$ *surface form*

	u
Rule A:	u'
Rule B:	u''
Rule C:	s

u	Con A	Con B
☞ s		
s'	!*	
s''	*	!*

Phonological Mappings

$A \Rightarrow B \;/\; C \_\_ D$ *CAD >> FAITH(A⇒B)[1]

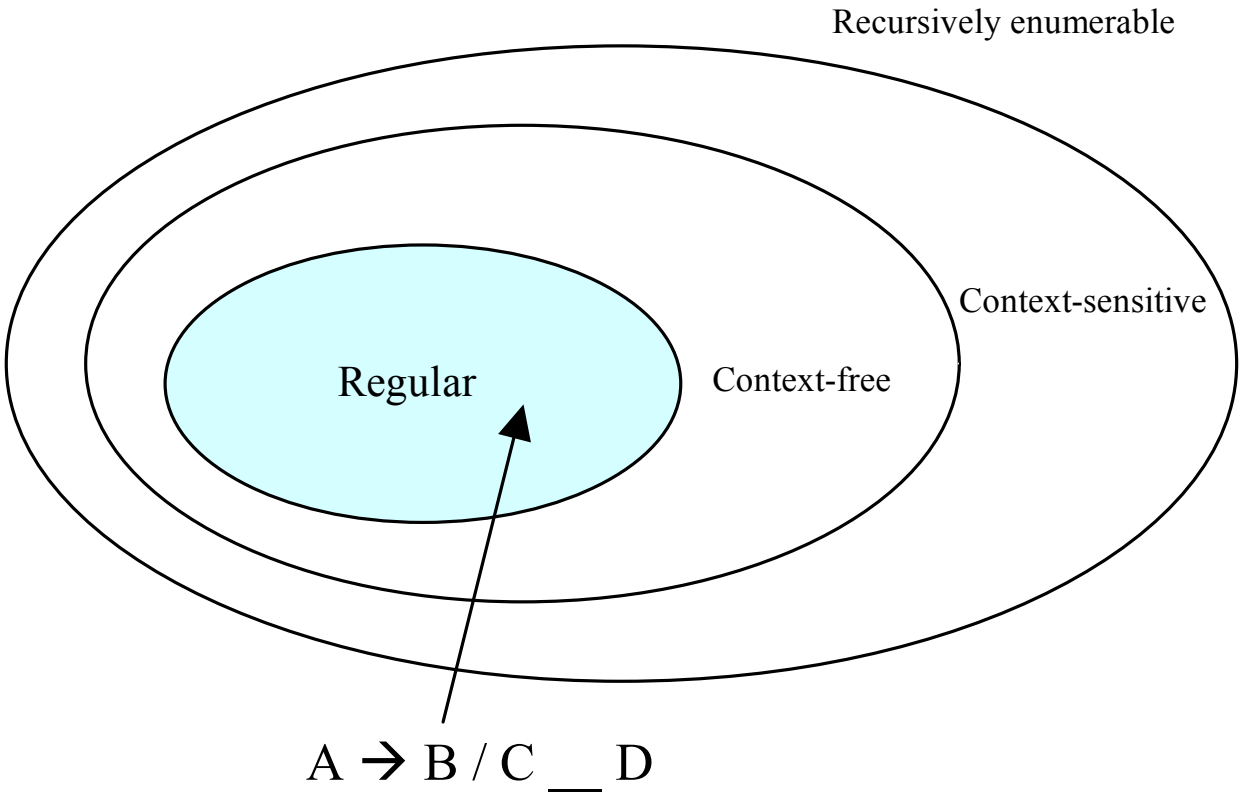
$$f(\text{CAD}) = \text{CBD}$$
$$f(\text{CBD}) = \text{CBD}$$
$$f(\text{CADCAD}) = \text{CBDCBD}$$
$$\ldots$$

[1](Baković 2013)

Phonological Mappings

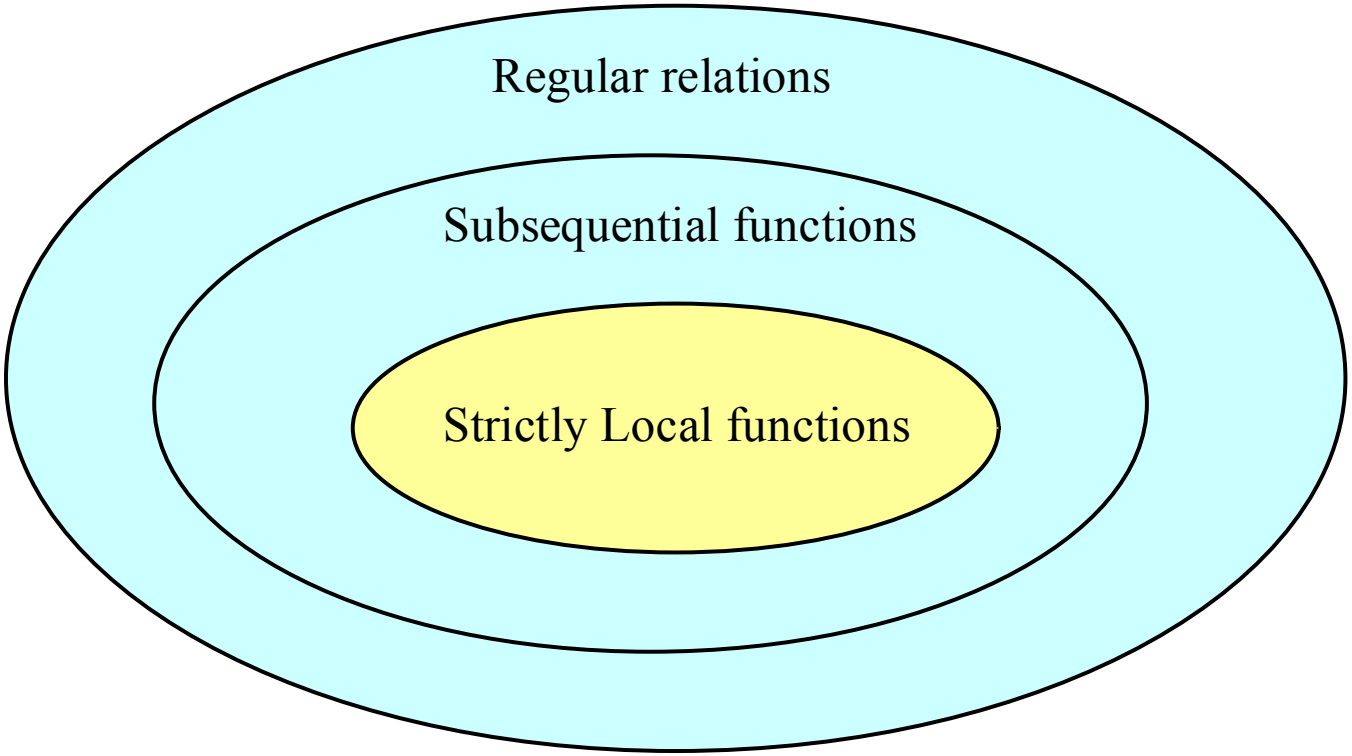
Strict Locality is a property of f.

Formal properties of grammars



(Johnson 1972, Koskenniemi 1983, Kaplan and Kay 1994)

Formal properties of grammars



(Mohri 1997, Chandlee in prep.)

Strictly Local Languages

- The 'Strictly Local' designation comes from the class of formal languages known as Strictly Local languages.
- SL languages can be described with a grammar in the form of a set of substrings up to certain length k (called k-factors).

(1) The language *a# is SL-2 with $\mathcal{G} = \{$#a, #b, aa, ab, bb, ba, b#$\}$

(McNaughton & Papert 1971, Rogers & Pullum 2011, Heinz et al. 2011, Rogers et al. 2012)

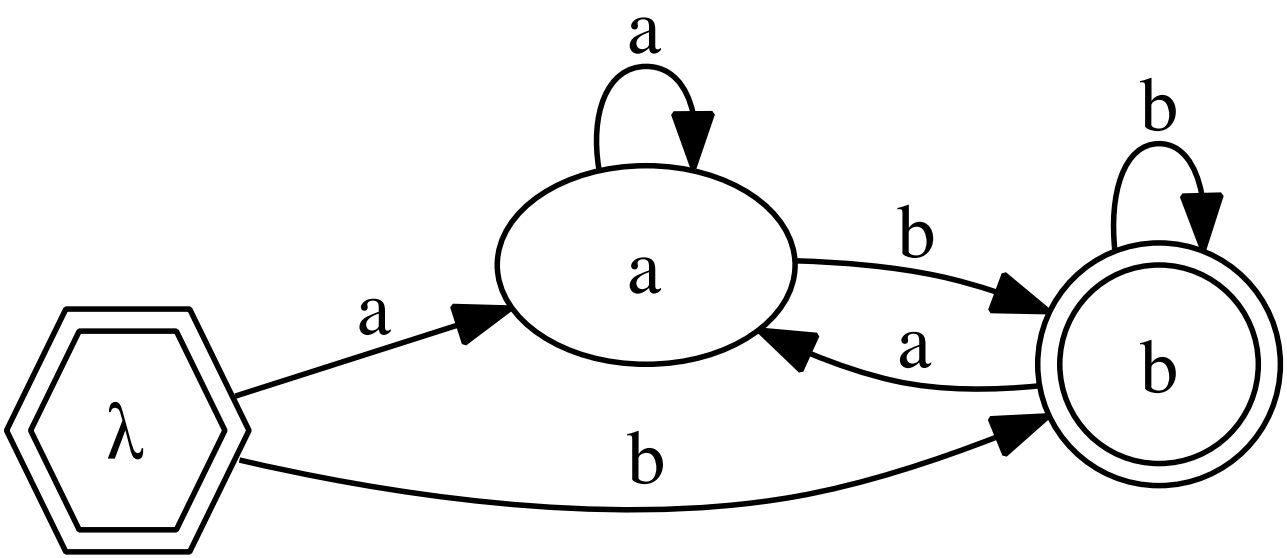
Strictly Local Languages

The language *a# is SL-2 with $\mathcal{G} = \{\#a, \#b, aa, ab, bb, ba, b\#\}$

aba	{#a, ab, ba, a#}	×
aab	{#a, aa, ab, b#}	✓

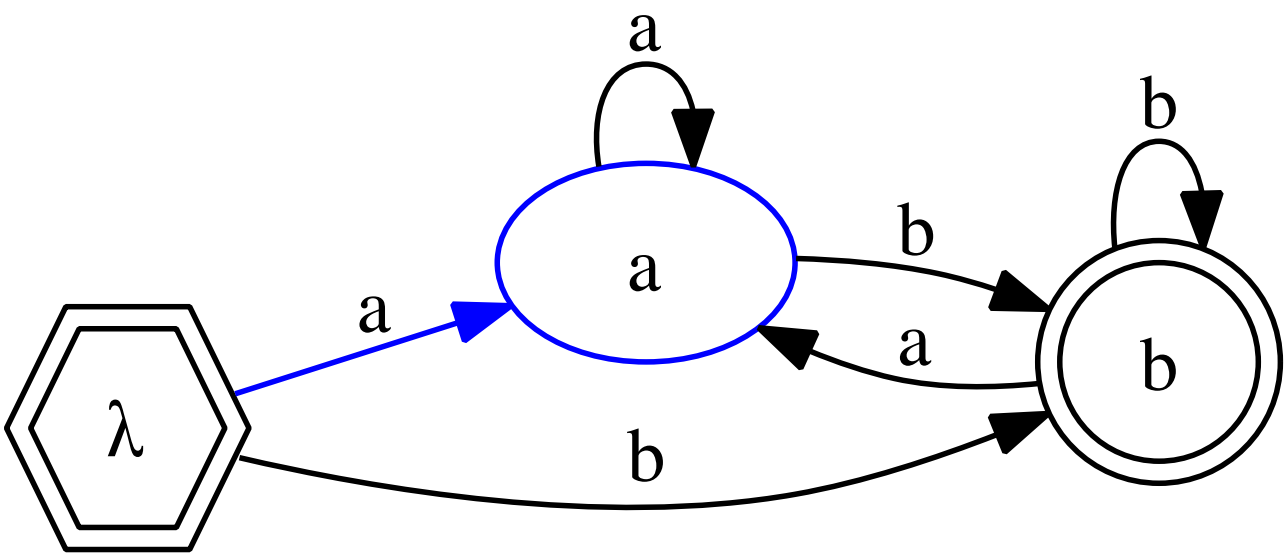
SL Finite State Acceptor

*a#



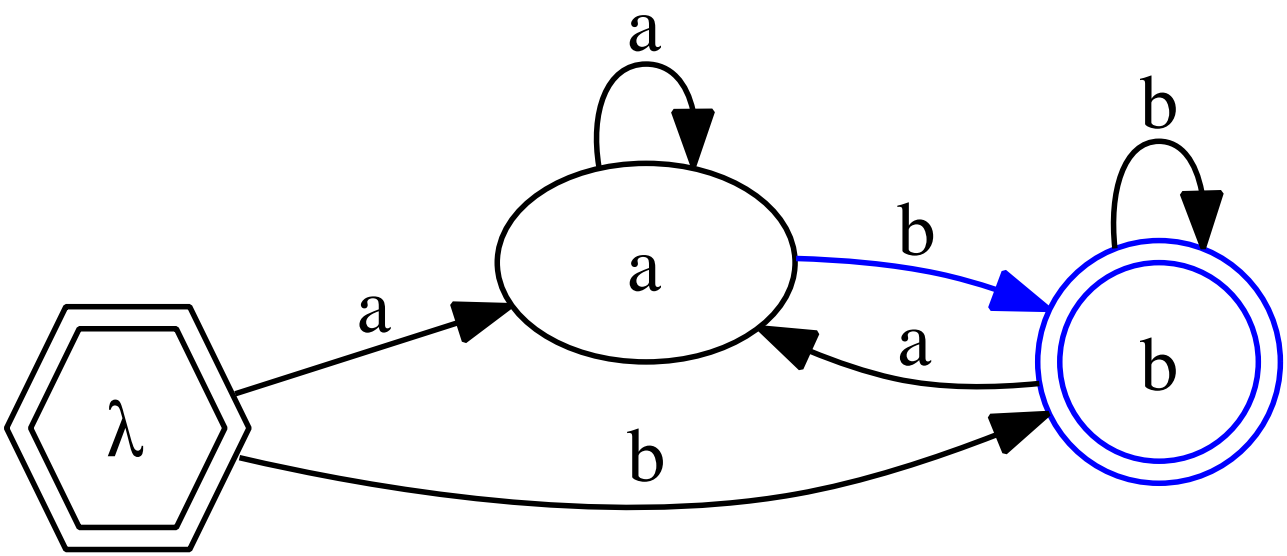
SL Finite State Acceptor

Input: aba



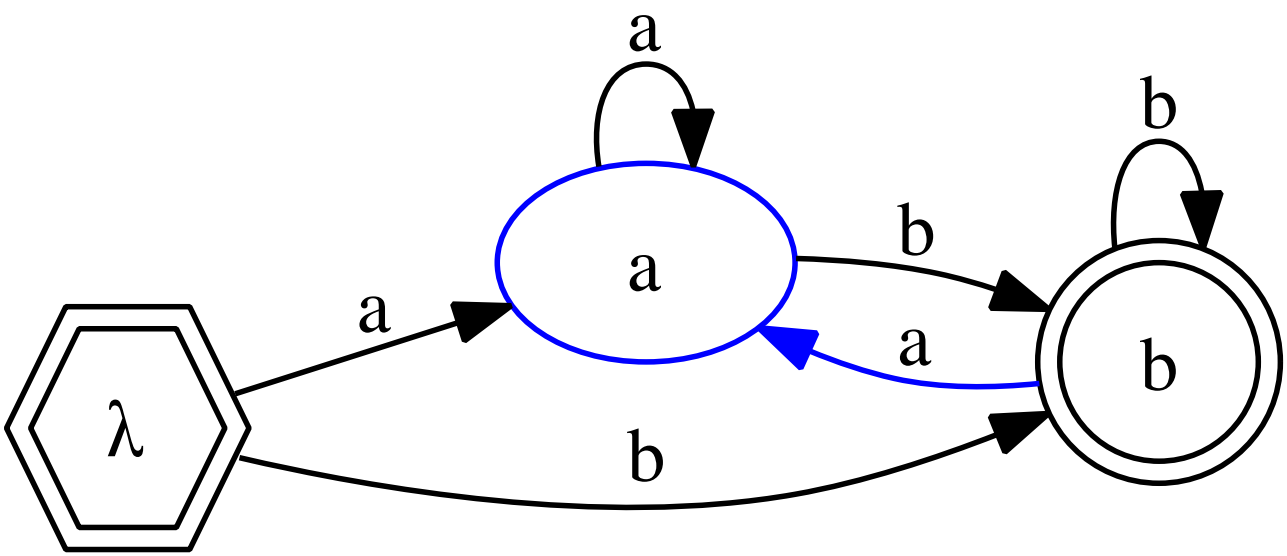
SL Finite State Acceptor

Input: aba



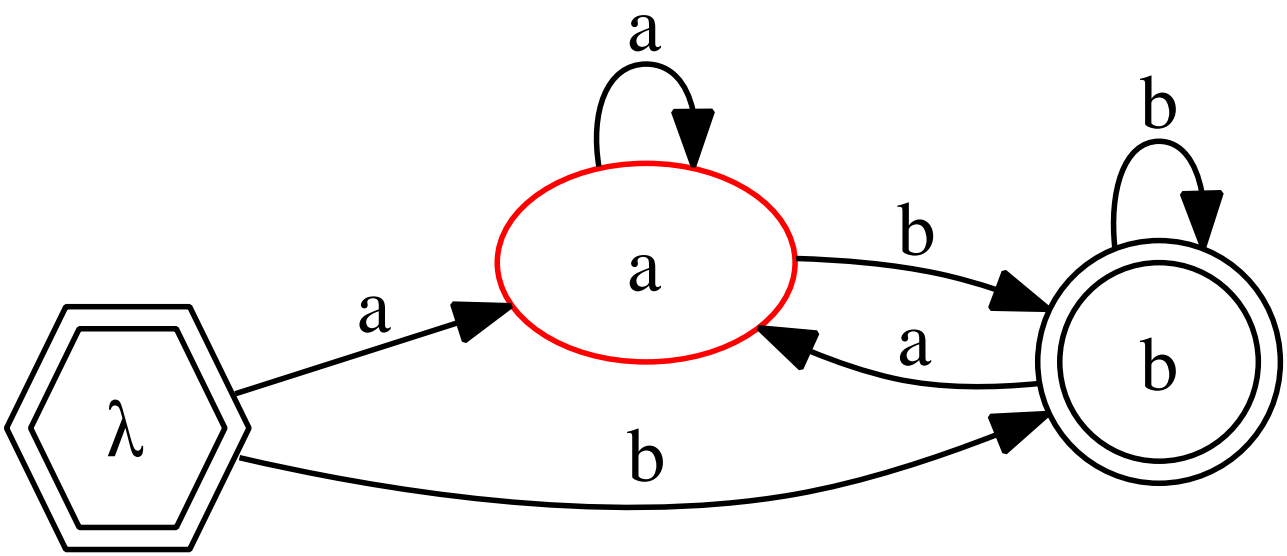
SL Finite State Acceptor

Input: aba



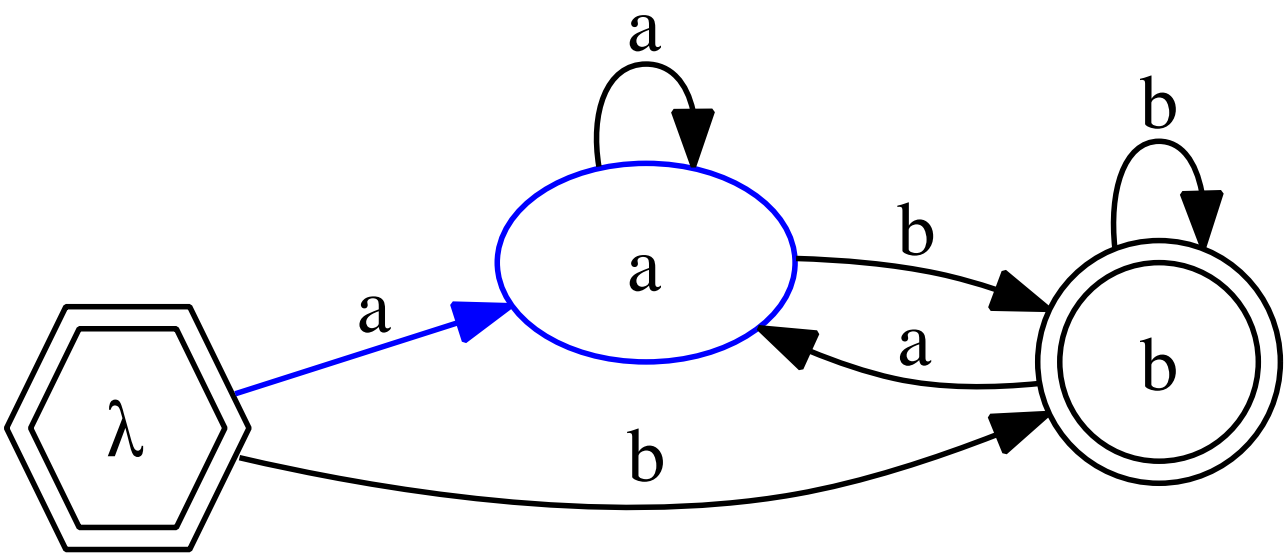
SL Finite State Acceptor

Input: *aba



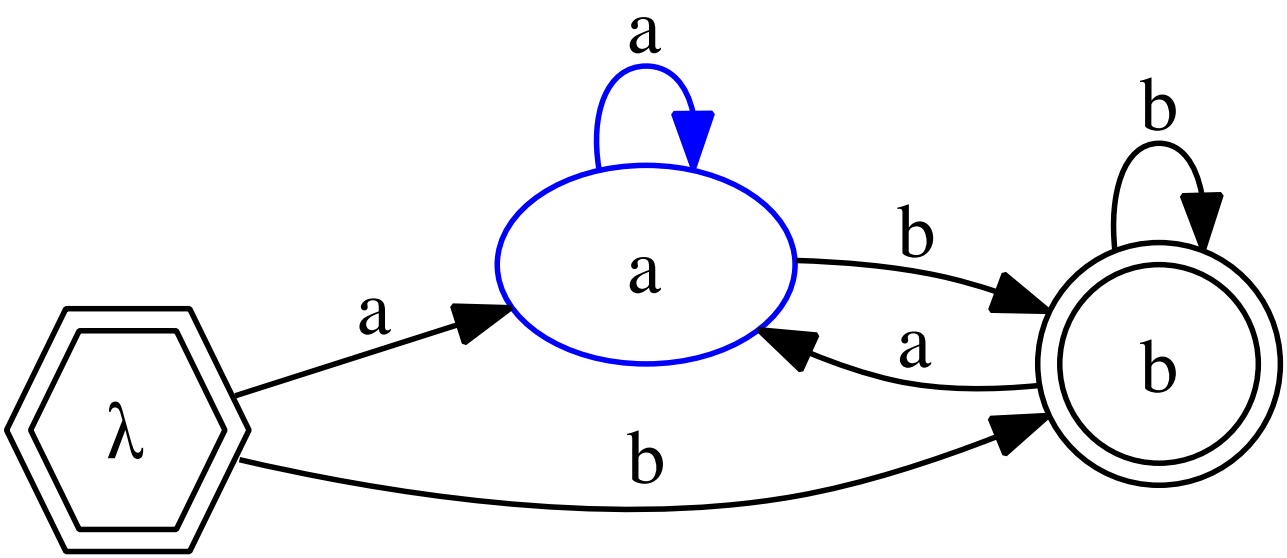
SL Finite State Acceptor

Input: aab



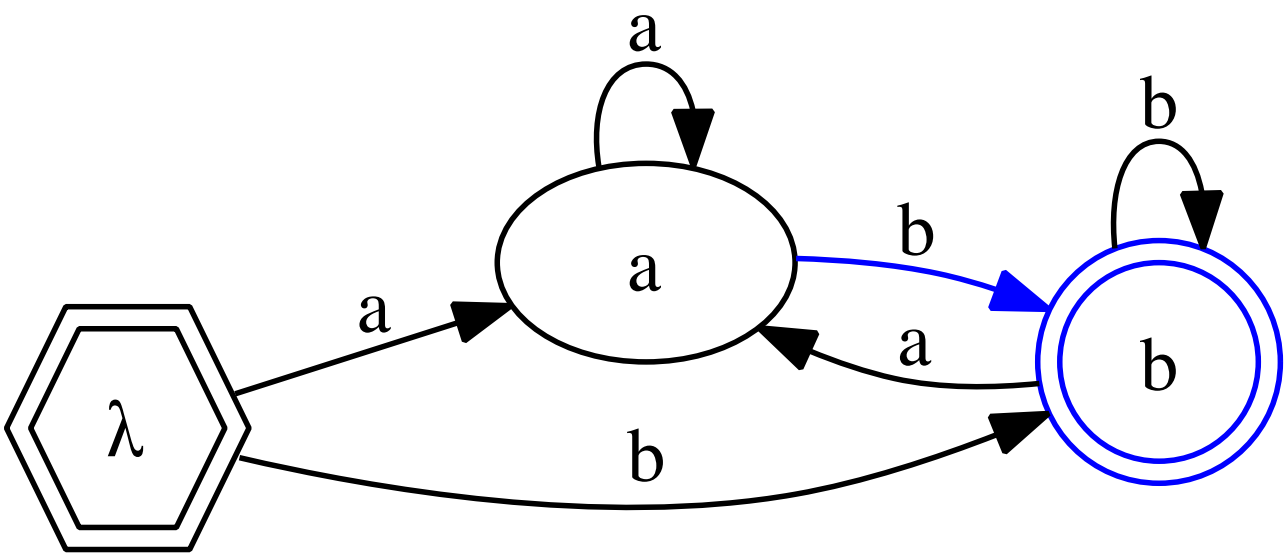
SL Finite State Acceptor

Input: aab



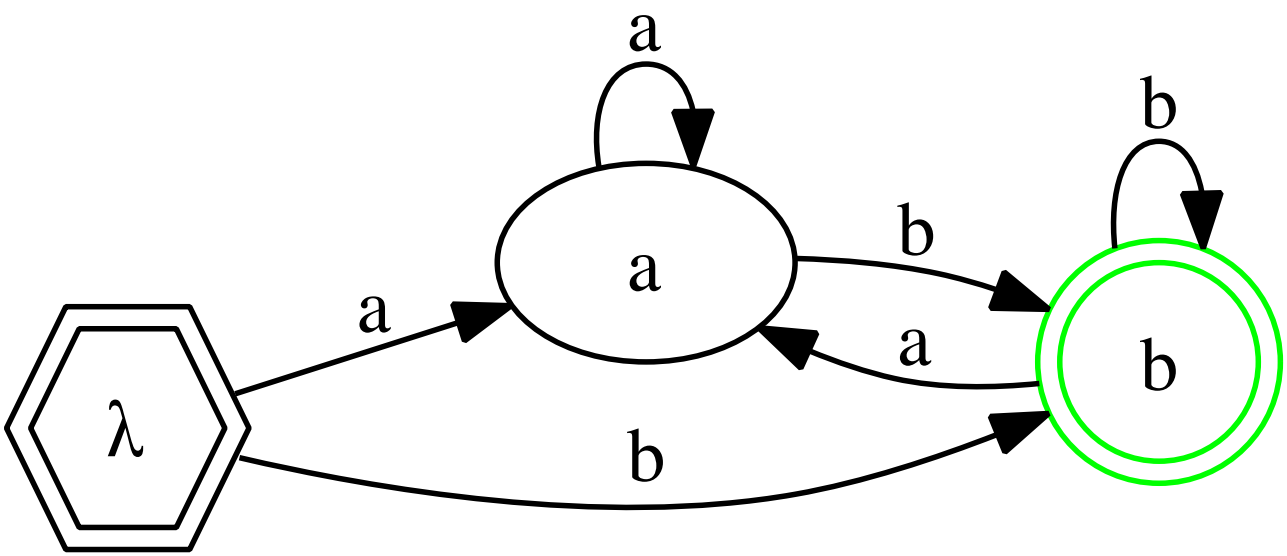
SL Finite State Acceptor

Input: aab



SL Finite State Acceptor

Input: ✓ aab

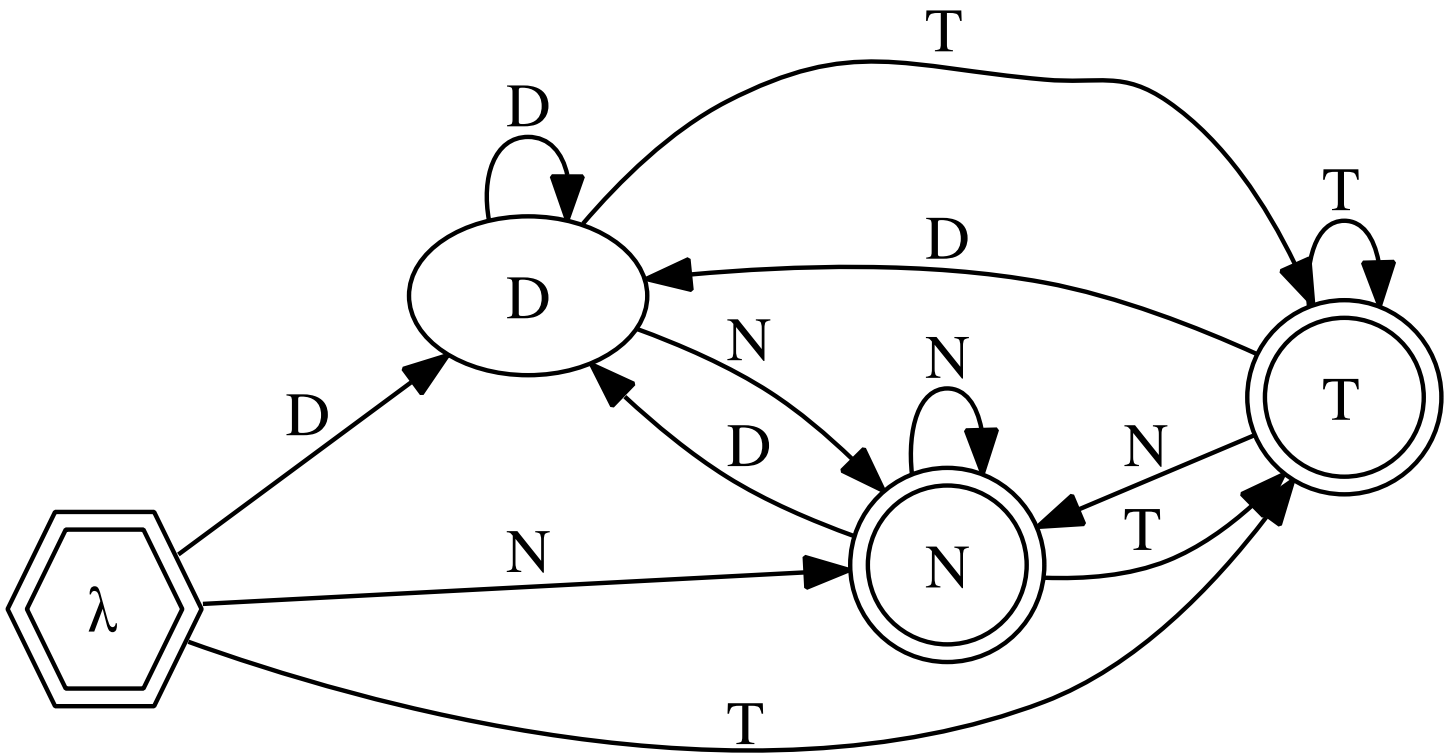


SL Languages and Phonotactics

- SL Languages and FSAs can model natural language phonotactics provided the illegal sequence is a contiguous substring bounded by some length k (i.e., it is local) (Heinz 2010).

SL Languages and Phonotactics

*D#



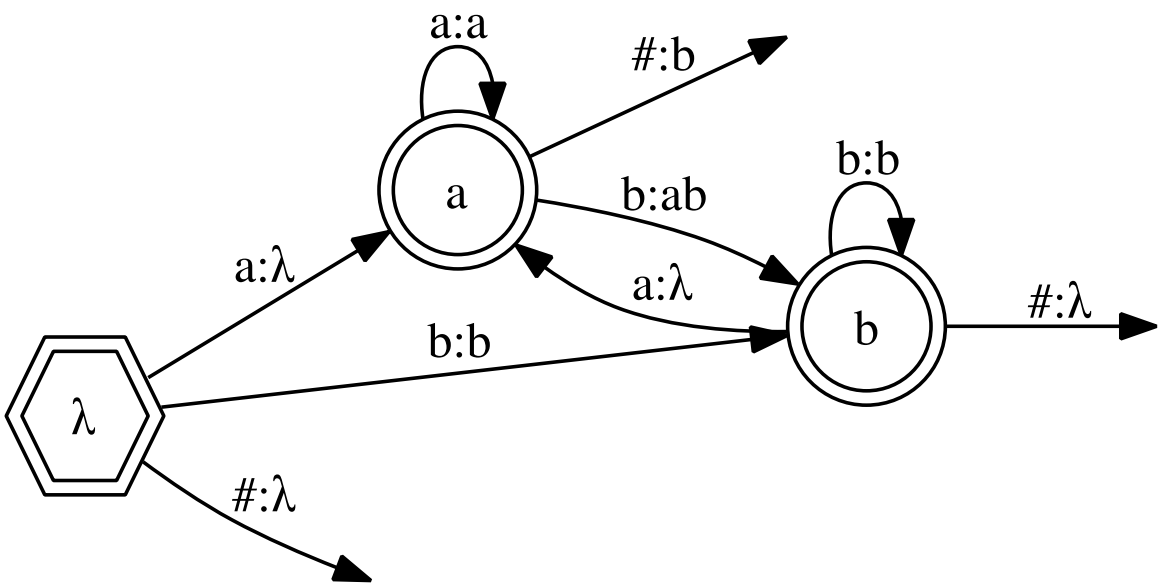
Strictly Local Functions

(2) $a \Rightarrow b \;/\; \_\_ \#$

(3)
a. $f(aba) = abb$
b. $f(aab) = aab$
c. $f(baa) = bab$
d. ...

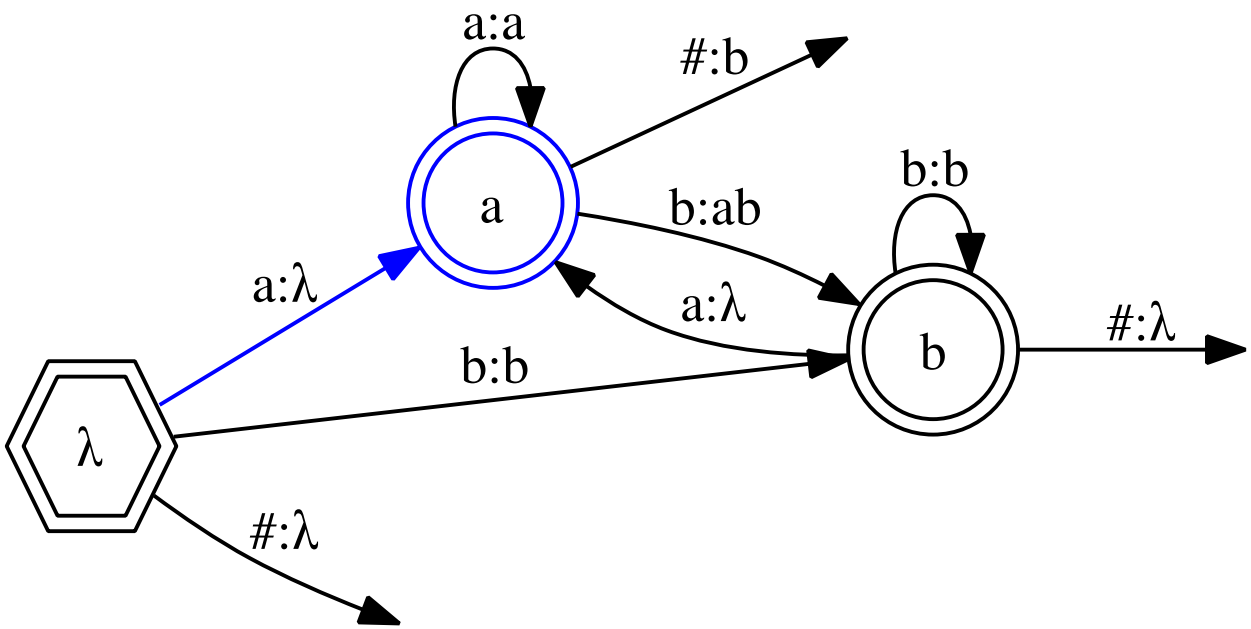
Strictly Local FSTs

(4) $a \Rightarrow b \;/\; \_\_ \#$



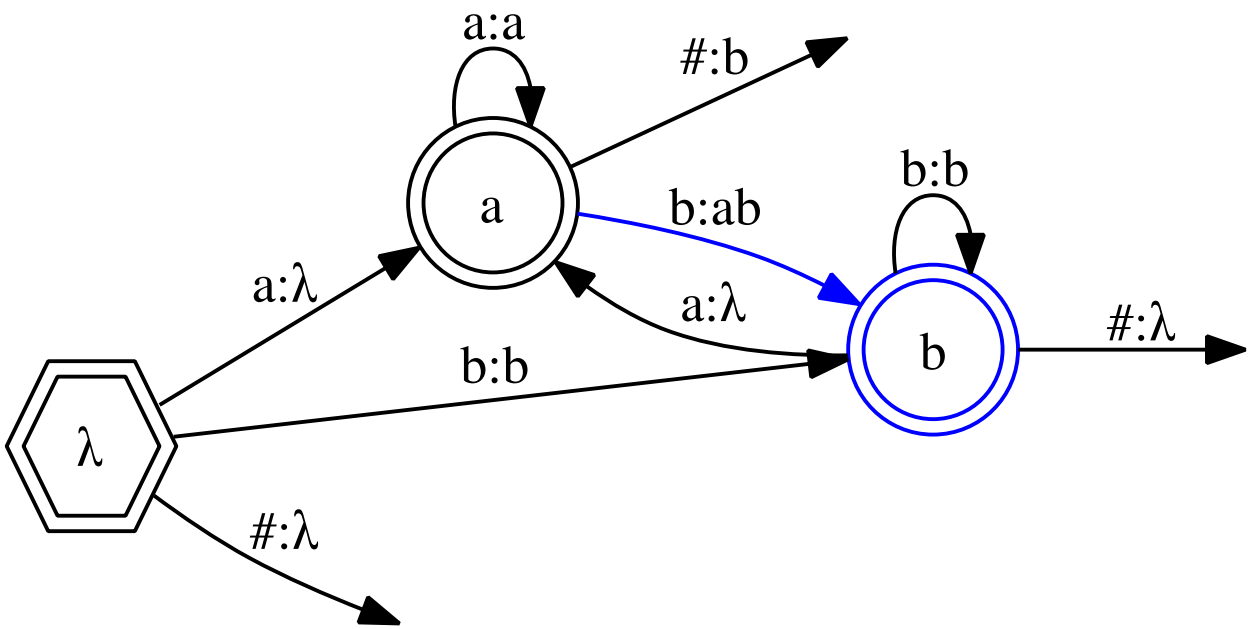
Strictly Local FSTs

Input:	a	b	a	#
Output:	λ			



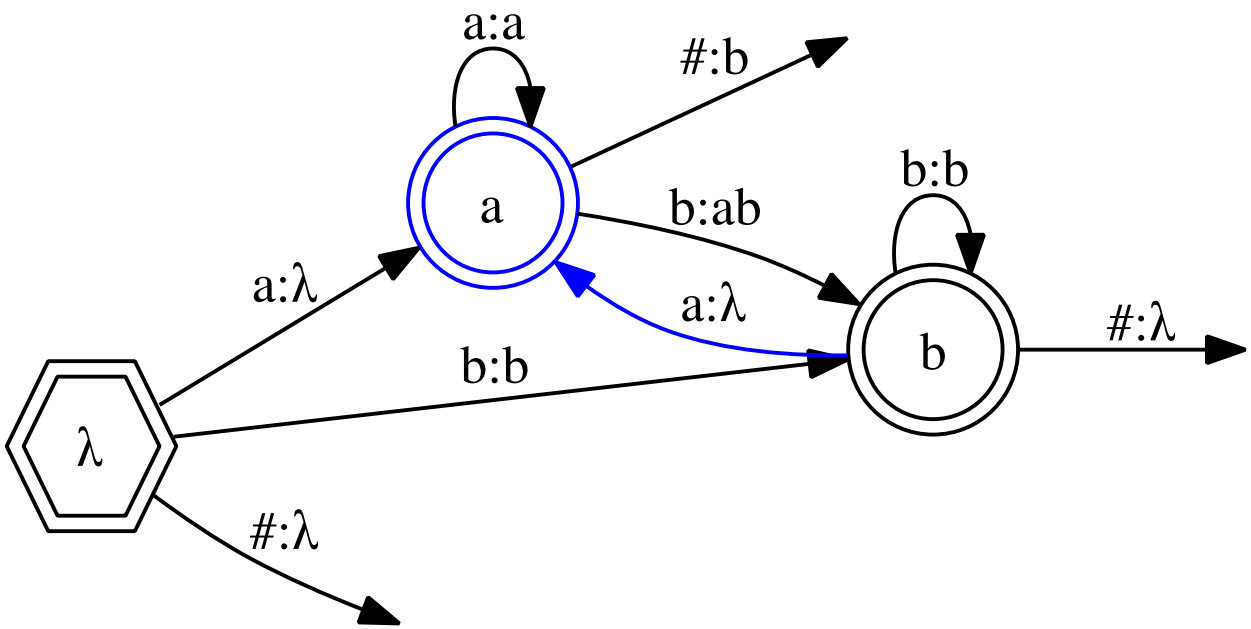
Strictly Local FSTs

Input:	a	b	a	#
Output:	λ	ab		



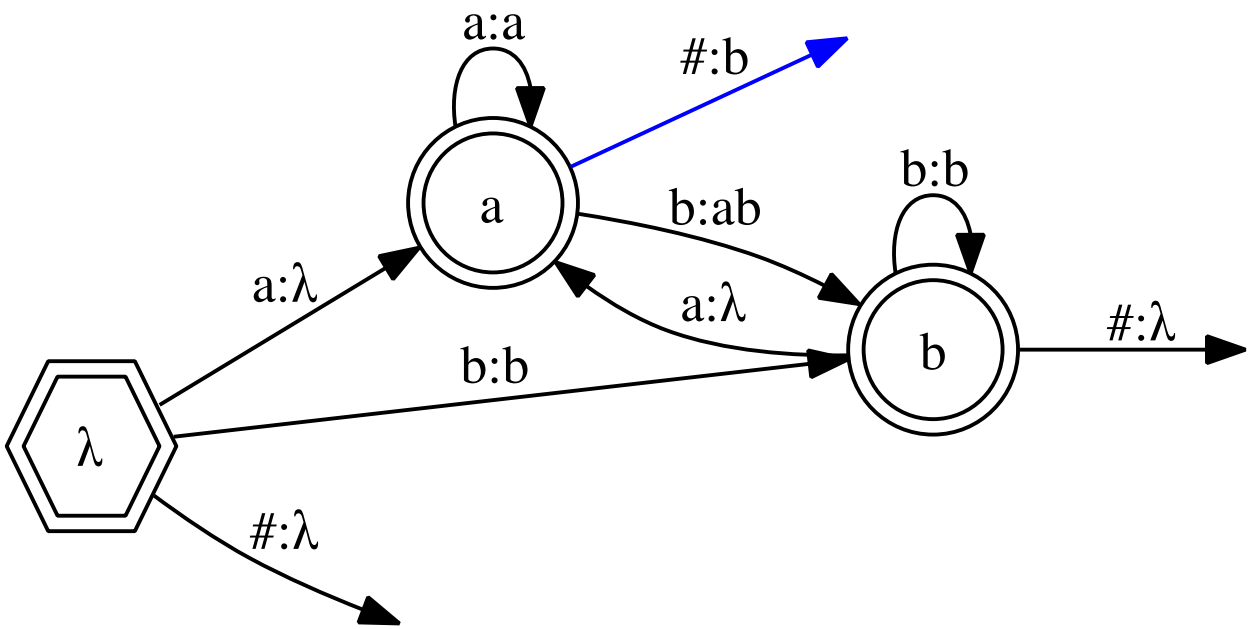
Strictly Local FSTs

Input:	a	b	a	#
Output:	λ	ab	λ	



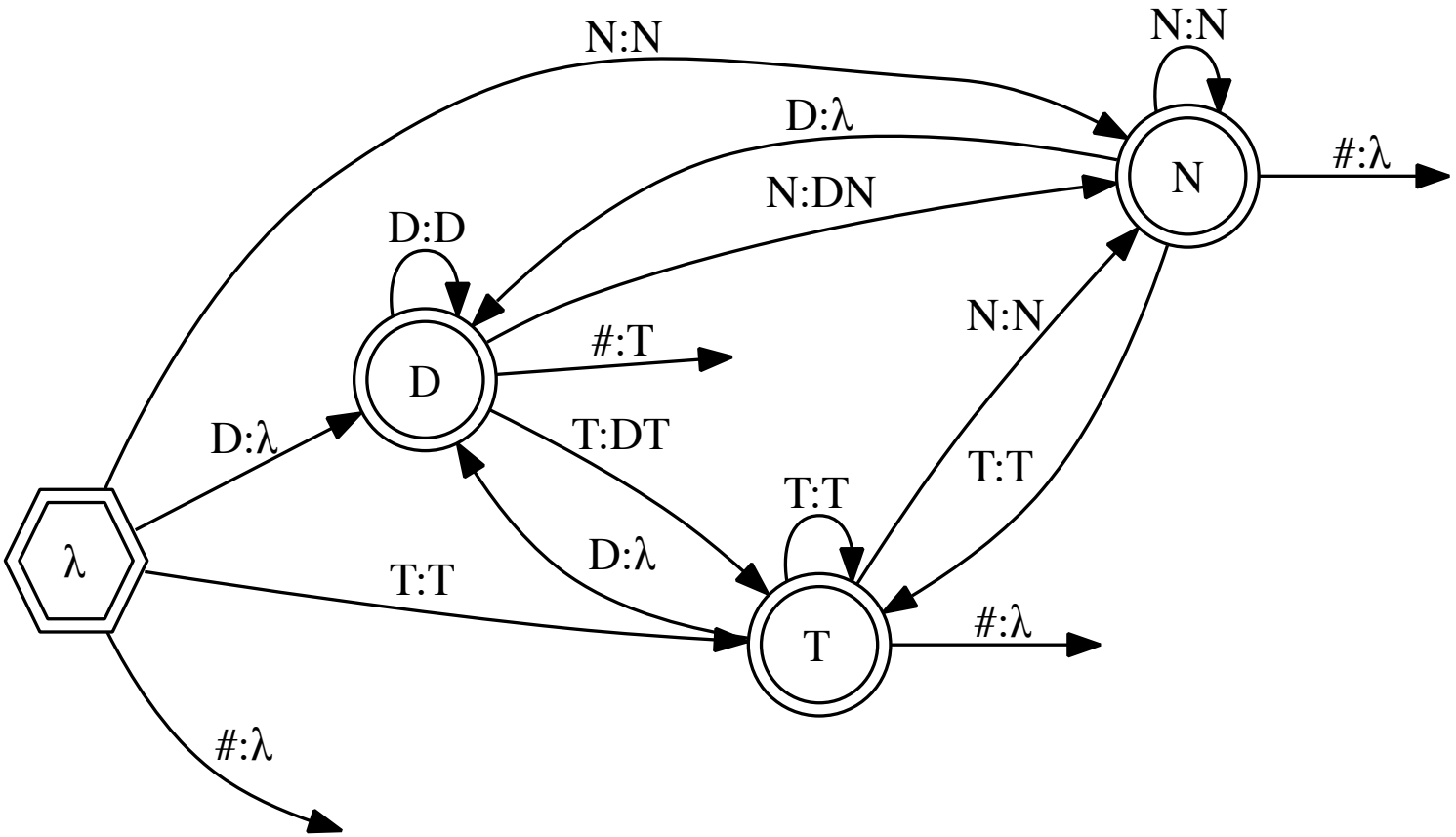
Strictly Local FSTs

Input:	a	b	a	#
Output:	λ	ab	λ	b

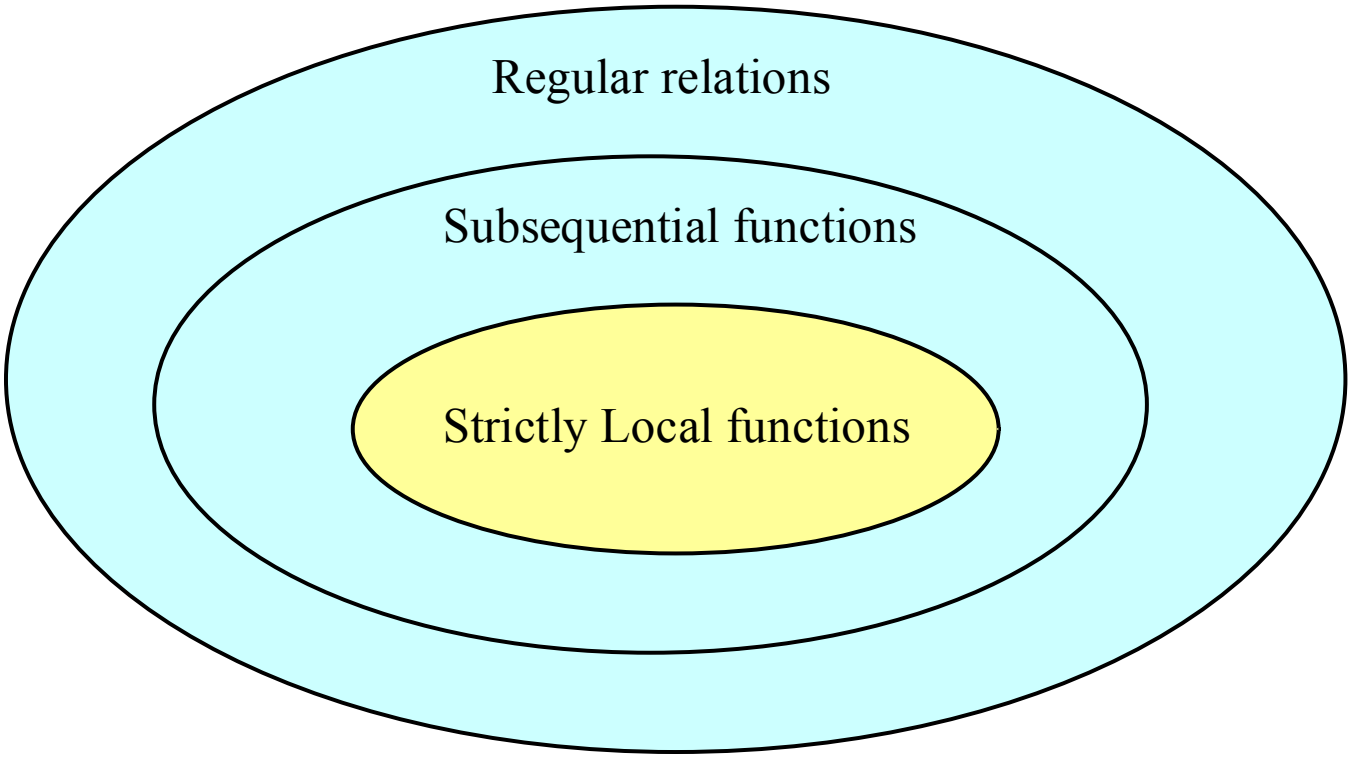


Strictly Local FSTs

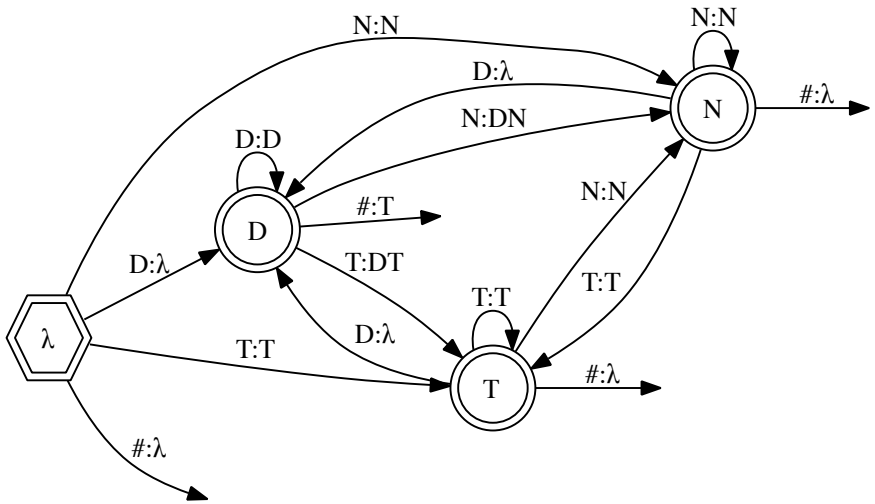
(5) $D \Rightarrow T \; / \; \_\_ \; \#$



Strictly Local FSTs



Strictly Local (Subsequential) FSTs



Subsequential
Deterministic
All states are final
Each state has a transition on #

Strictly Local
States are $k-1$-factors
Destination state of each transition $=$ the $k-1$ most recent input symbols

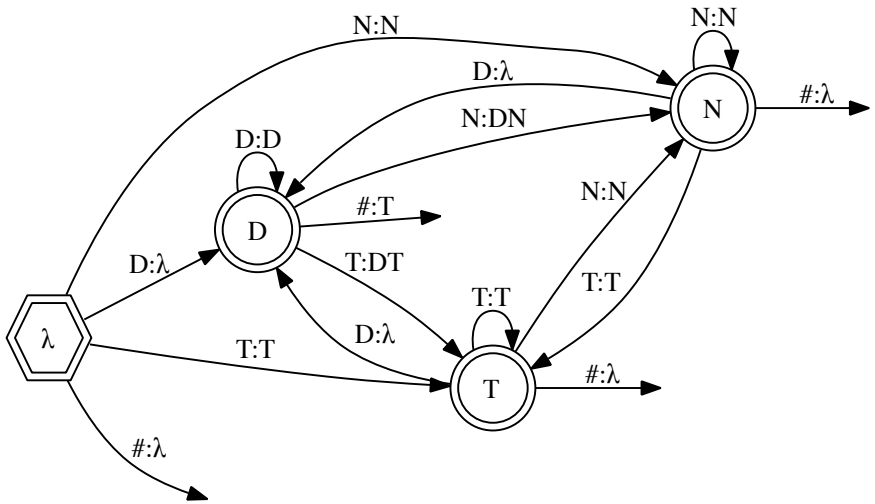
Mode of rule application

(6) $a \Rightarrow b \;/\; a \_\_ a$

Simultaneous	Left-to-right
aaaa $\mapsto$ abba	aaaa $\mapsto$ abaa

(Kaplan & Kay 1994)

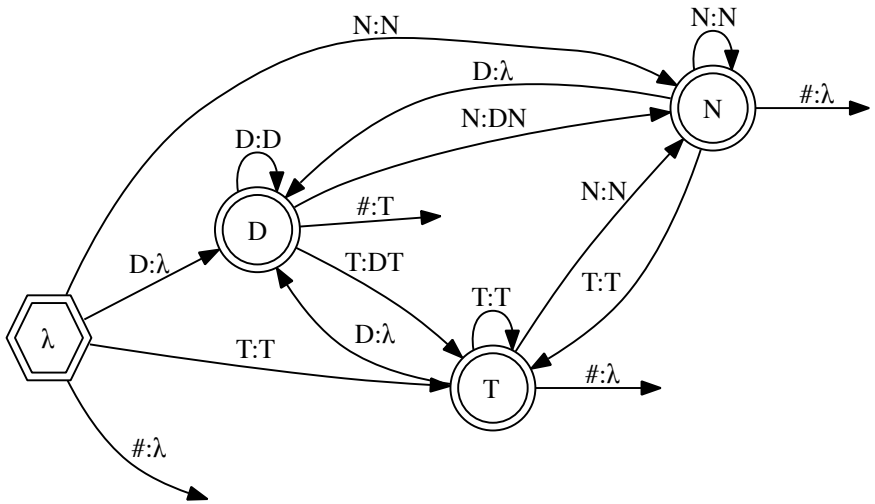
Strictly Local (Subsequential) FSTs



Subsequential
Deterministic
All states are final
Each state has a transition on #

Strictly Local (simultaneous)
States are $k-1$-factors
Destination state of each transition $=$ the $k-1$ most recent input symbols

Strictly Local (Subsequential) FSTs



Subsequential
Deterministic
All states are final
Each state has a transition on #

Strictly Local (left-to-right)
States are $k-1$-factors
Destination state of each transition $=$ the $k-1$ most recent output symbols

How many processes are SL?

- At least 96% of the approx. 5500 processes in P-Base (v1.95, Mielke 2008) are Strictly Local
- SL processes include substitution, deletion, epenthesis, bounded metathesis, local partial reduplication, and general affixation.

How many processes are SL?

(7) $A \Rightarrow B \;/\; C \_\_ D$

SL if CAD is a finite language.

How many processes are SL?

(8) D ⇒ T / __ #

CAD = D# = {b#, d#, g#, z#, ʒ#, dʒ#}

How many processes are SL?

(9) D $\Rightarrow$ T / $\_\_x$ (x has an even number of obstruents)

Not SL.

What *isn't* SL?

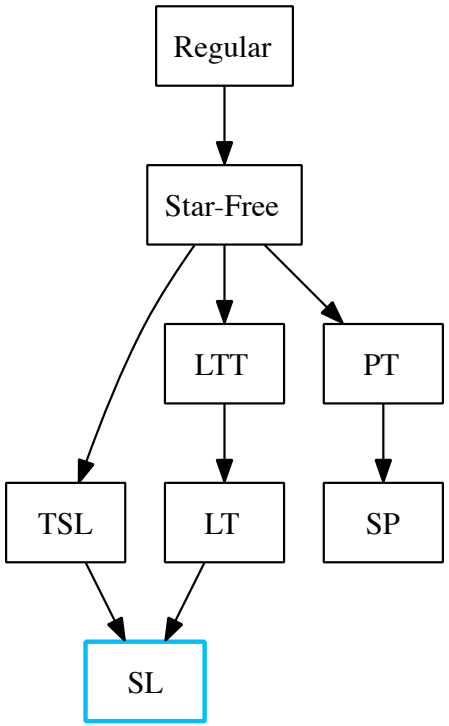
- Vowel harmony with transparent vowels
- Long-distance consonant harmony and dissimilation (Hansson 2001, Rose & Walker 2004, Suzuki 1998, Bennett 2013)
- Some tonal patterns
- Displacement/diachronic metathesis (Blevins & Garrett 1998, Hume 2000, Buckley 2011)
- Nonlocal partial reduplication (Riggle 2003)

What *isn't* SL?

All of these (except one tonal pattern) are still *subsequential*.

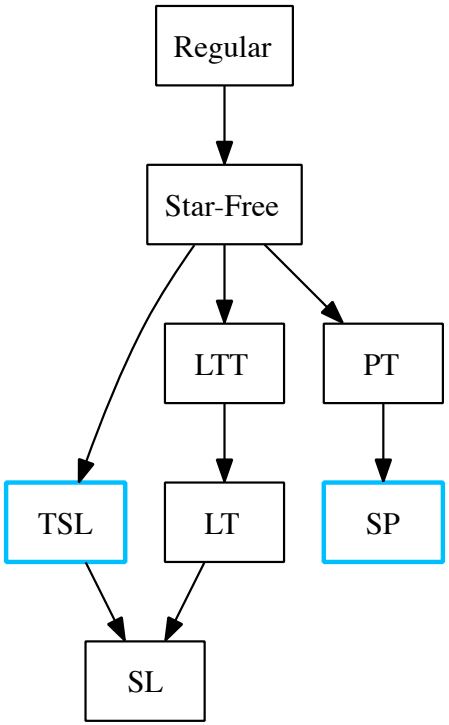
(Chandlee et al. 2012, Chandlee & Heinz 2012, Nevins 2010, Gainor et al. 2012, Heinz & Lai 2013, Luo 2013, Payne 2013, Jardine 2013)

Subregular Hierarchy



(McNaughton & Papert 1971, Rogers & Pullum 2011, Heinz et al. 2011, Rogers et al. 2012)

Subregular Hierarchy

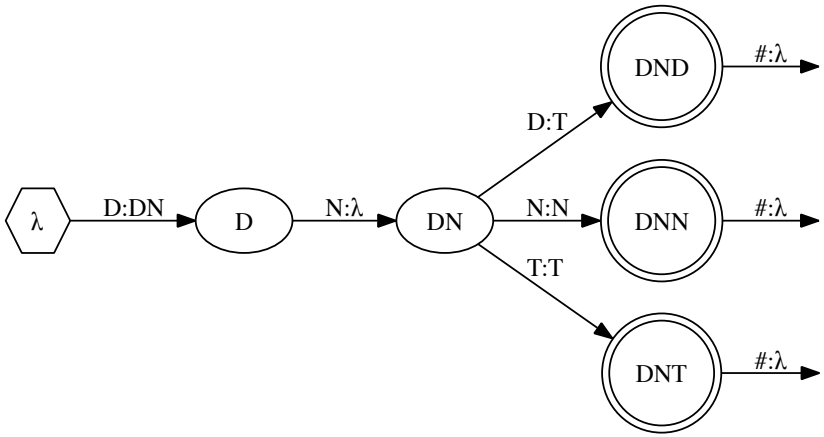


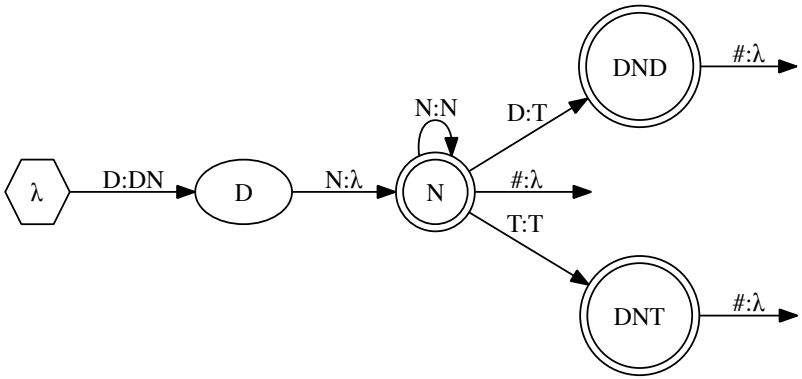
Long-distance phonotactics (Heinz 2010, Heinz, Rawal, Tanner 2011)

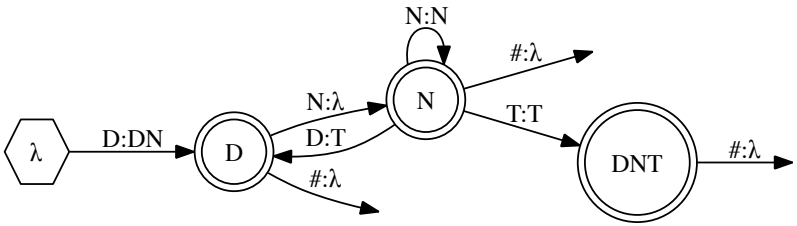
Learning SL

- An algorithm that uses strict locality as an inductive principle can generalize SL functions from finite data (Chandlee & Koirala 2014, Chandlee & Jardine 2014, Chandlee, Heinz, & Eyraud in prep.).
- Data: {(DND, DNT), (DNN, DNN), (DNT, DNT)}

Learning SL


λ
D:DN
D
N:λ
DN
D:T
N:N
T:T
DND
DNN
DNT
#:λ
#:λ
#:λ


λ
D:DN
D
N:λ
N
N:N
D:T
#:λ
T:T
DND
DNT
#:λ
#:λ


λ
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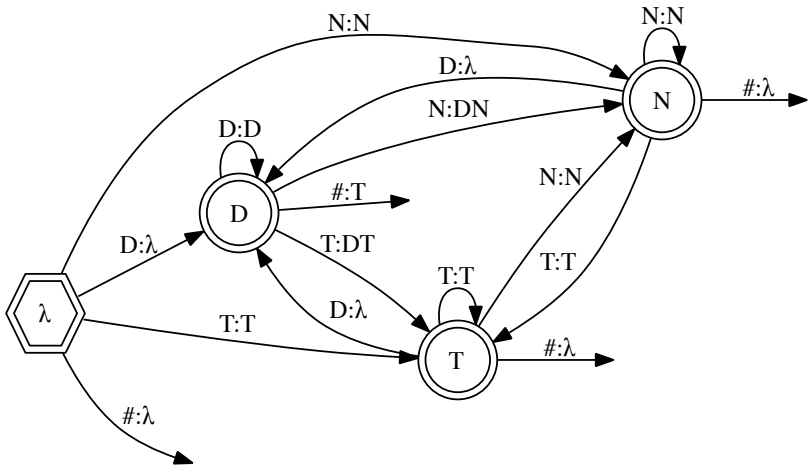
λ
D:λ
D
D:D
#:T
N:DN
N:N
N:N
D:λ
N
#:λ
T:DT
T:T
T:T
D:λ
T:T
T
#:λ
#:λ

Conclusions

- Modeling phonological processes with Strictly Local functions identifies locality as a defining property of many phonological UR $\mapsto$ SR mappings.
- This property 1) restricts the power of the grammatical formalism needed to account for local phenomena and 2) aides in learning.

Thank you!

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