Graph Transductions and Typological Gaps in Morphological Paradigms

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MOL 2017
July 13–14, 2017

Prelude: So Many Boring Problems

- Theoretical linguists obsess about many problems that are boring to mathematical linguists.

Example: Person Case Constraint (PCC; Bonet 1994)

The well-formedness of clitic combinations is contingent on their person specification.

(1)	Roger	*le/*me*	*leur*	a	présenté.
	Roger	3SG.ACC/1SG.ACC	3PL.DAT	has	shown

‘Roger has shown me/him to them.’

- The existence of the **PCC is unremarkable**.
  - captured by bigram model (very simple)
  - small problem space ⇒ no learnability issues

Take-Home Message: Boring = Interesting At Close-Up

- Boring problems are interesting once we take a closer look.

Why the PCC is Interesting

- Out of 64 conceivable PCC variants, only 4 are attested.
- The attested PCCs form a mathematically natural class.
- And the mathematical account extends to seemingly unrelated phenomena in morphosyntax.

- **Moral:** We should **study all linguistic phenomena**, not just the usual suspects.

Technical Insight: Base Orders & Graph Transductions

Morphosyntactic phenomena can be given a natural explanation via **three components**:

1. an independently motivated base hierarchy
   person, number, adjectival gradation, . . .
2. maximally simple graph transductions to modify this hierarchy
3. a simple interpretation of the output graphs

Outline

A Case Study: *ABA in Morphological Paradigms

Syncretism multiple forms built from same base

***ABA Generalization (Bobaljik 2012)**

Two paradigmatic cells cannot be syncretic
to the exclusion of any intervening cell.

Example: Adjectival Gradation

(2)
a. smart, smarter, smartest (AAA)
b. good, better, best (ABB)
c. * good, better, goodest (ABA)

*ABA Across Morphological Paradigms

Example: Pronoun Syncretism (Harbour 2015, 2016)

(3)
a. mi, ni, ehi (ABC) — Jarawa
b. n!aa, n!uu, n!uu (ABB) — Damin
c. ne, ne, e (AAB) — Winnebago
d. * I, you, I (ABA)

Example: Case Syncretism in Russian (Caha 2009)

Case	window.Sg	teacher.Pl	100
Nom	okn-o	ucitel-ja	st-o
Acc	okn-o	ucitel-ej	st-o
Gen	okn-a	ucitel-ej	st-a
Dat	okn-u	ucitel-jam	st-a
Inst	okn-om	ucitel-ami	st-a

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*ABA: A First Account

- A mapping that produces ABA violates **monotonicity**.

Monotonicity for Pronoun Syncretism

- Suppose $3 < 2 < 1$ (Zwicky 1977)
- A function **f** is **monotonic** iff $\mathbf{x} \leq \mathbf{y}$ implies $\mathbf{f}(\mathbf{x}) \leq \mathbf{f}(\mathbf{y})$.
- No monotonic function from $\{1, 2, 3\}$ to $\{\mathsf{A}, \mathsf{B}, \mathsf{C}\}$ can produce ABA!
- This holds irrespective of the ordering of $\{\mathsf{A}, \mathsf{B}, \mathsf{C}\}$.

Illustrating Monotonicity

Monotonicity is similar to No Crossing Branches constraint in autosegmental phonology. (Goldsmith 1976)

1 2 3

A B C

Patterns:

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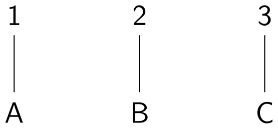

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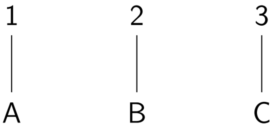

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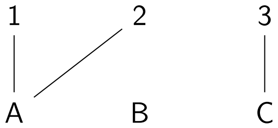

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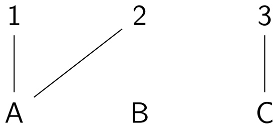

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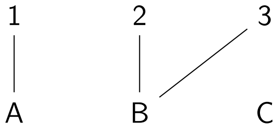

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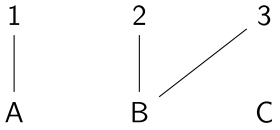

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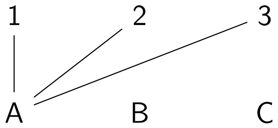

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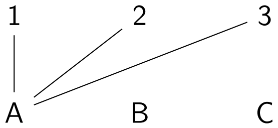

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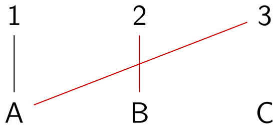

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Why Monotonicity?

- Why should spell-out functions be monotonic?
- **Idea:** Monotonicity matters in other areas.
  - NPI licensing in downward entailing contexts
  - Direction-preserving nature of movement in MGs
- **But:** Those are just-so stories.
  - Downward entailingness is neither necessary nor sufficient.
  - Various MG movement types are not direction-presevering.
- Maybe monotonicity is not the best characterization...

A More General View: Graph Structure Preservation

The General Idea

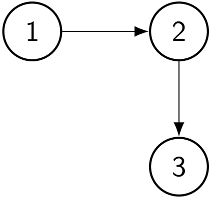
- *ABA is about structure preservation.
- Syncretism is modification of a base graph.
- Modification must not contradict orderings of base graph.

Definition (Weakly Non-Inverting Graph Mappings)

- Given input graph G and output graph G'
  - $x \triangleleft y$ iff y is reachable from x in G,
  - $x \blacktriangleleft y$ iff y is reachable from x in G'.
- A mapping from G to G' is **weakly non-inverting** iff $x \triangleleft y \wedge y \blacktriangleleft x \rightarrow x \blacktriangleleft y$

Weakly Non-Inverting Graph Mappings

- Since we want graphs to encode hierarchies, they must be *weakly connected*: ignoring the direction of arrows, all nodes are mutually reachable.
- And the mapping must be weakly non-inverting:
  $x \triangleleft y \wedge y \blacktriangleleft x \rightarrow x \blacktriangleleft y$



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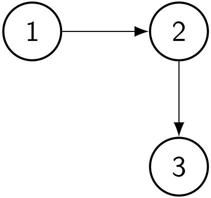

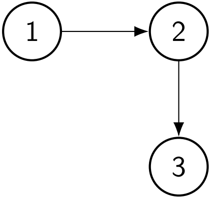

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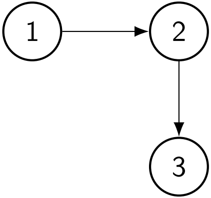

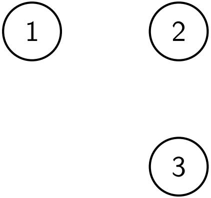

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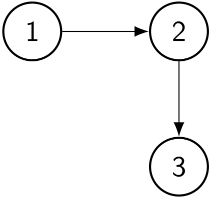

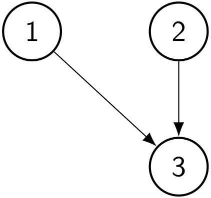

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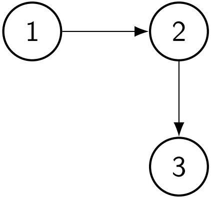

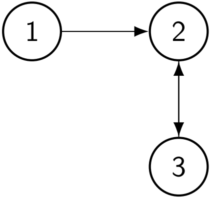

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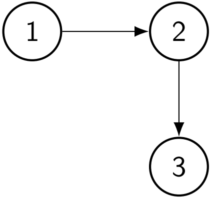

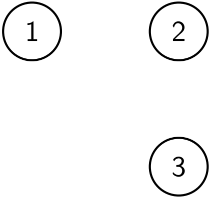

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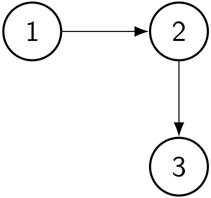

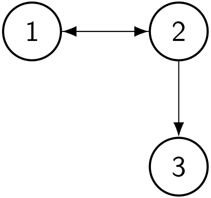

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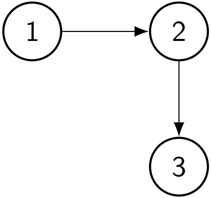

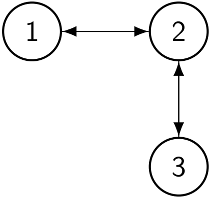

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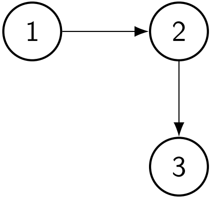

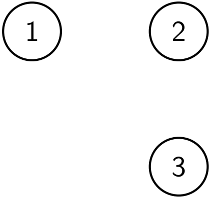

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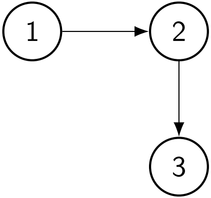

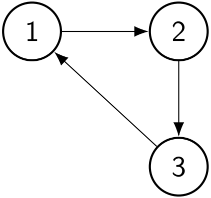

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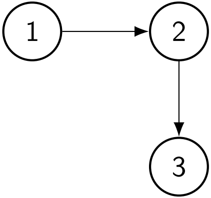

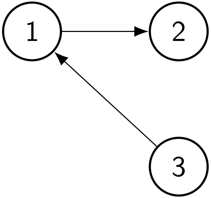

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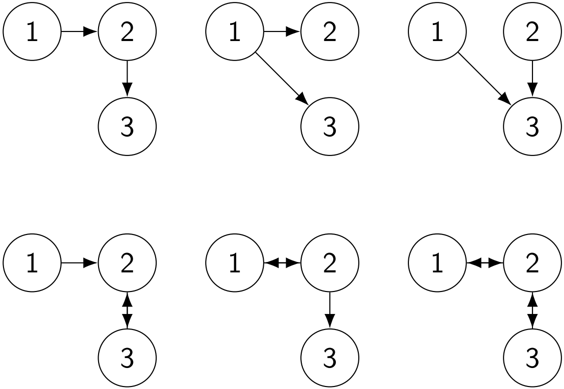
- Suppose two cells may be syncretic iff they are mutually reachable in a graph.
- Then the previous set of graphs describes the **class of attested syncretisms**.



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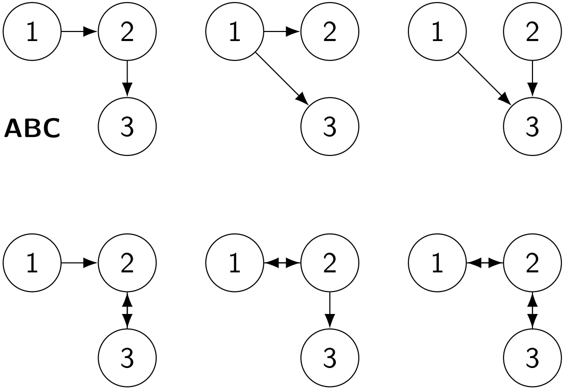

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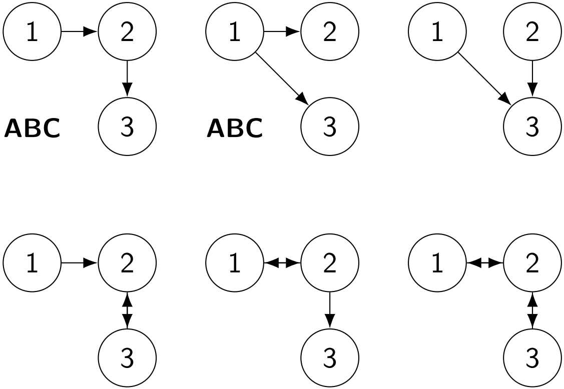

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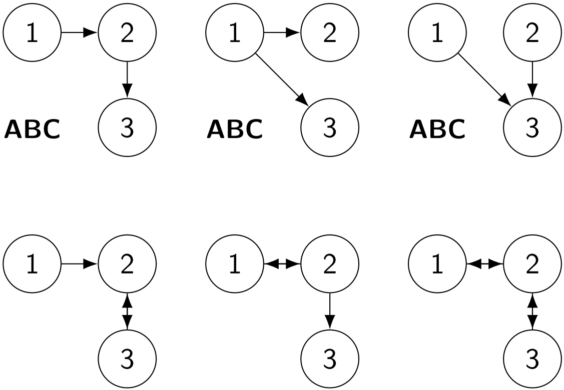

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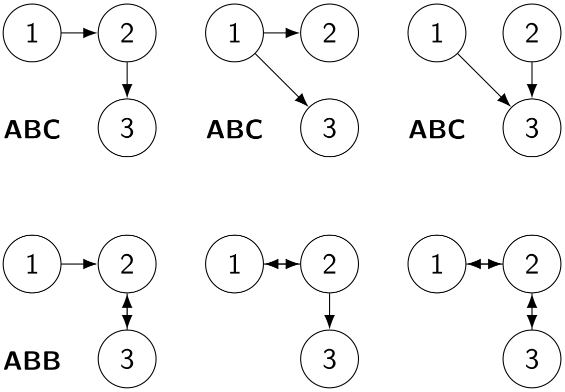

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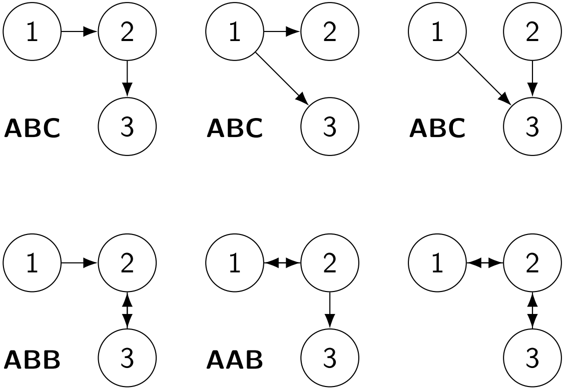

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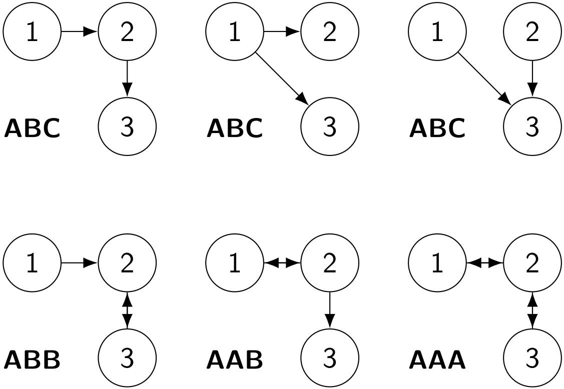

Scaling to Larger Systems

- The previous account works for any 3-cell paradigm.
- Some morphosyntactic phenomena have many different cells.
  case syncretism, noun stem allomorphy
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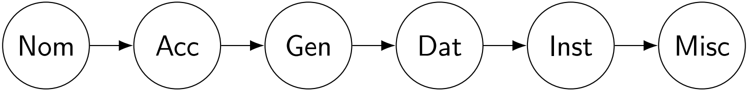

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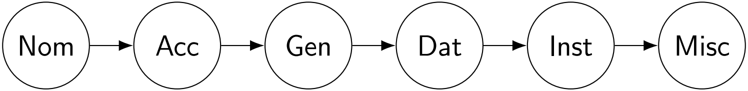

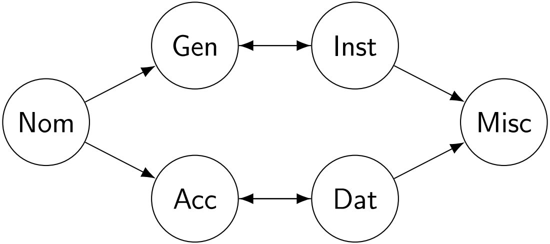

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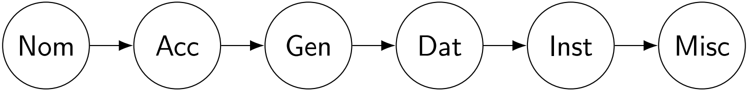
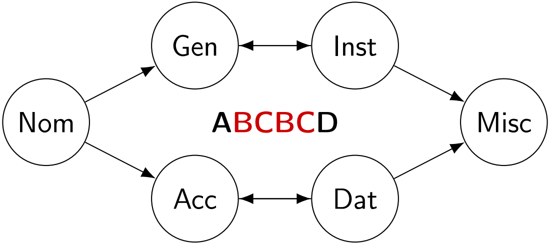


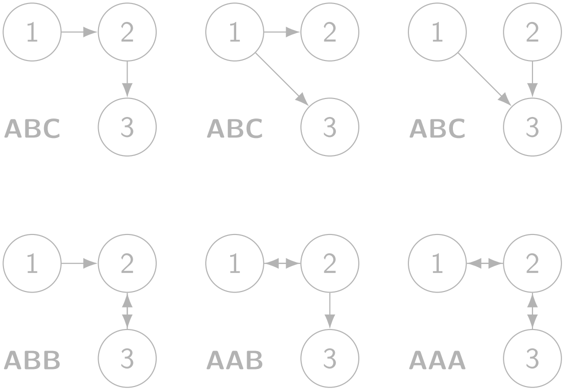


The Fix: A Stronger Connectivity Requirement

- Weakly non-inverting maps still obey *ABA if output graphs must be **connected**:

$$\forall x, y[x \blacktriangleleft y \vee y \blacktriangleleft x]$$

- We can also assume this for 3-cell paradigms.



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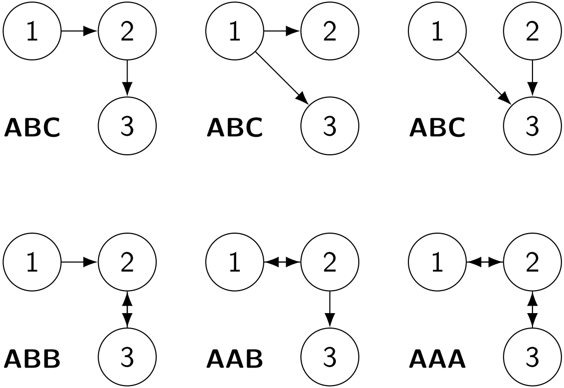

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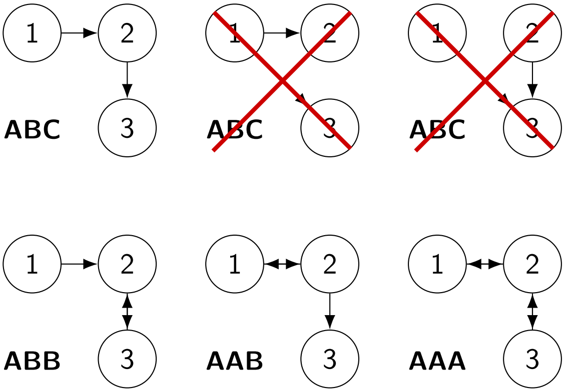


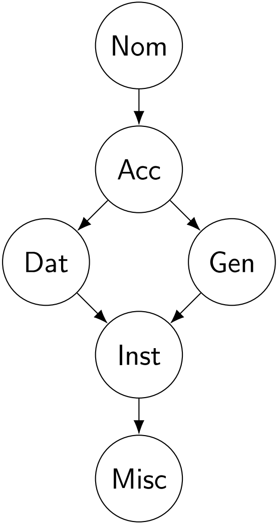
A Note on Case Syncretism

- Attested syncretisms of **Acc & Dat and Acc & Gen** in Icelandic (Harðarson 2016)

Example

- drottning-∅/-u/-ar/-u ‘daughter’
- arm-ar/-a/-a/-um ‘arm’

- Modified case hierarchy as base (Blake 2001)
- **Prediction:** some language has Acc & Dat and Gen & Inst, or Acc & Gen and Dat & Inst



Interim Summary

- Weakly non-inverting graph mappings preserve aspects of the base order.
- This structure preservation derives the *ABA generalization.
- Some ad hoc stipulations are still needed in certain cases.
- Those reflect aspects of the grammatical machinery, which the graph-theoretic view abstracts away from.

Phenomenon	Target graph	Constraints
Pronoun allomorphy	(weakly) connected	none
Adjectival gradation	(weakly) connected	$2 \blacktriangleleft 1 \rightarrow 3 \blacktriangleleft 1$
Case syncretism	connected	none
Noun stem suppletion	connected	$\exists \mathsf{z} [\mathsf{z} \triangleleft \mathsf{x}] \rightarrow (\mathsf{x} \blacktriangleleft \mathsf{y} \leftrightarrow \mathsf{y} \blacktriangleleft \mathsf{x})$

The Graph-Theoretic View of the Person Case Constraint

- There are **four attested variants** of the PCC:

  S(trong)-PCC DO must be 3.
  (Bonet 1994)

  U(ltrastrong)-PCC DO is less prominent than IO,
  where 3 is less prominent than 2,
  and 2 is less prominent than 1.
  (Nevins 2007)

  W(eak)-PCC 3IO combines only with 3DO.
  (Bonet 1994)

  M(e first)-PCC If IO is 2 or 3, then DO is not 1.
  (Nevins 2007)

- But symmetric variants have been discovered.
  (Stegovec 2016)
- This looks like a mess!

A More Systematic Perspective (Walkow 2012)

IO↓/DO→	1	2	3
1	NA	✓	✓
2	*	NA	✓
3	*	*	NA

U-PCC

IO↓/DO→	1	2	3
1	NA	*	✓
2	*	NA	✓
3	*	*	NA

S-PCC

IO↓/DO→	1	2	3
1	NA	✓	✓
2	✓	NA	✓
3	*	*	NA

W-PCC

IO↓/DO→	1	2	3
1	NA	✓	✓
2	*	NA	✓
3	*	✓	NA

M1-PCC

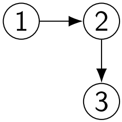
Graph-Theoretic Unification

Generalized PCC
y must not be reachable from x.

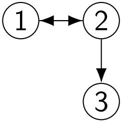
Standard PCCs:
y = IO, x = DO

Symmetric PCCs:
y = DO, x = IO

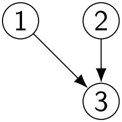
U	1	2	3
1	NA	✓	✓
2	*	NA	✓
3	*	*	NA



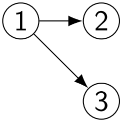
S	1	2	3
1	NA	*	✓
2	*	NA	✓
3	*	*	NA



W	1	2	3
1	NA	✓	✓
2	✓	NA	✓
3	*	*	NA

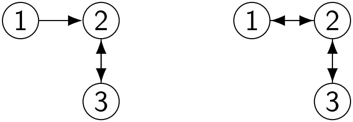


M1	1	2	3
1	NA	✓	✓
2	*	NA	✓
3	*	✓	NA



Extending the PCC

- What about the other two graphs?



- The first is currently unattested.
- The second blocks all clitic combinations, as in Cairene Arabic. (Shlonsky 1997:207, Walkow p.c.)
- So 5 out of 6 graphs are attested PCCs.

Summary of Relevant Graph Classes

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PCC	w-connected	$3 \blacktriangleleft 2 \rightarrow 3 \blacktriangleleft 1$

- This is a fairly natural characterization.
- Generative accounts are too fine-grained, only mathematics allows for this unification.

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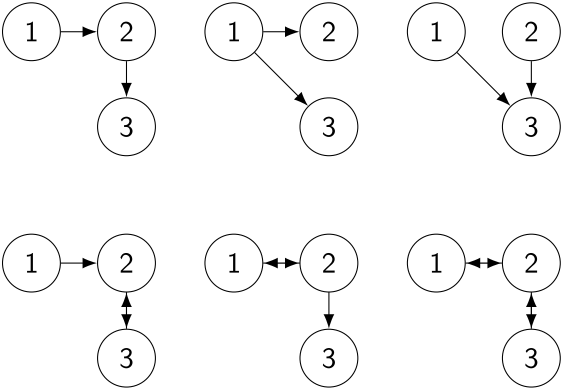
- From a certain perspective, being weakly non-inverting is computationally simple.
- All the required graphs can be represented as strings.



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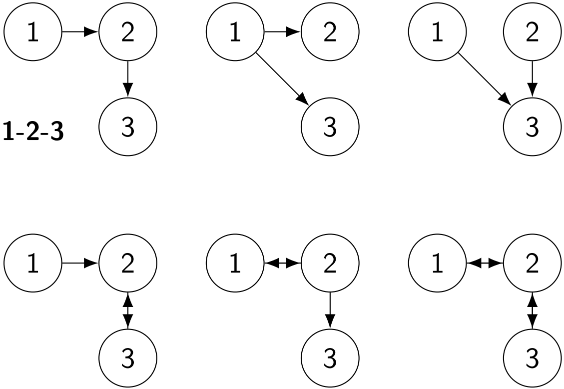

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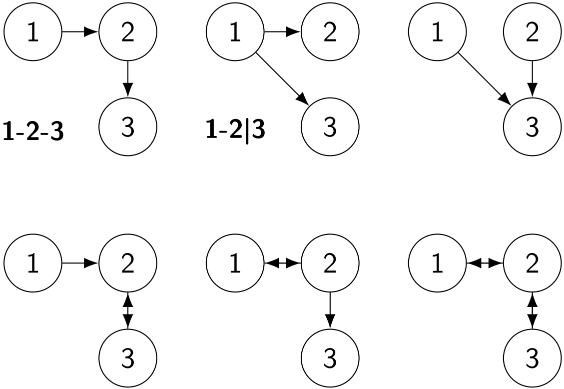

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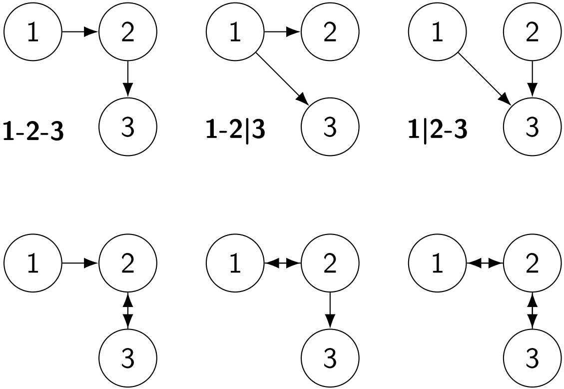

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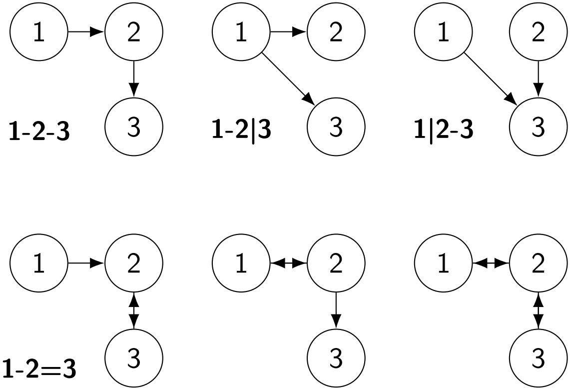

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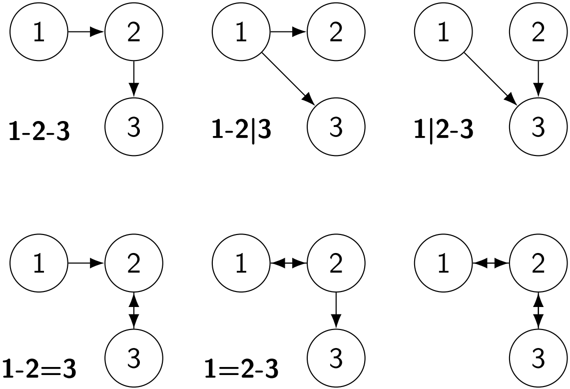

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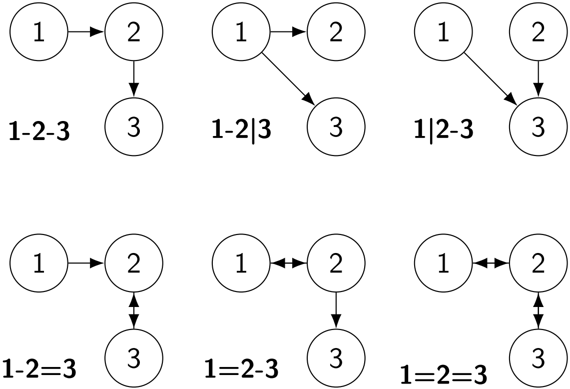
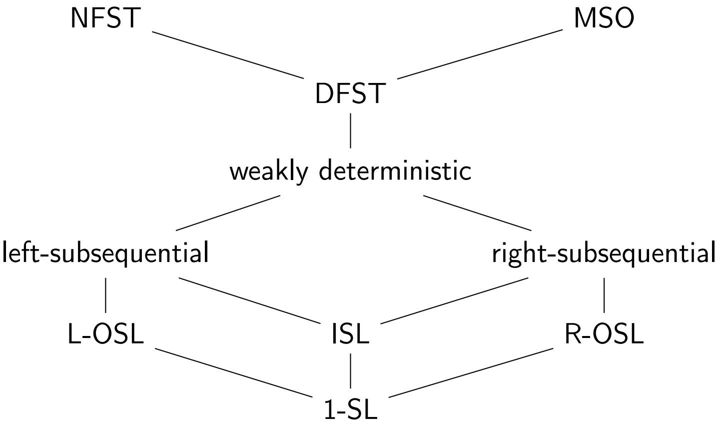


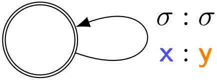
Subregular String Mappings

For weak mappings, we look at **subregular string transductions**.



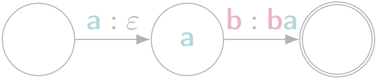
1-SL Mappings

- 1-SL relations/maps = state-free N/DFST transductions
- This is sufficient to compute weakly non-inverting maps over the string representations.



x, y $\in \{-, =, |\}$

- Switching the order of ab requires memorizing a $\Rightarrow$ not 1-SL



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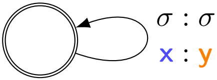

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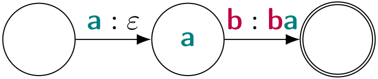

Extrapolating to Graph Mappings

- Of course 1-SL could reverse direction with a symbol for inverse order ($\leftarrow$) in the string representations.
- But strings capture the idea that **reversal is costly**, cf.:
  - impossibility of local rotations with LBUTTs
  - markedness of metathesis in phonology
- Current graph transductions don't capture this, deleting and adding edges is cheap.
- Maybe we need a different view of graph transductions, or a more restricted transduction class (DAG, tree, string).
- **Bottom line:** class of attested patterns should reduce to computational simplicity

Conclusion

- Graphs generalize across domains of morphosyntax
  - Base hierarchy
  - Maximally simple transduction (1-SL)
- Approach could be about markedness rather than well-formedness (weaker typological claim)
- **But:** a lot of work still to be done
  Gender Case Constraint, inverse marking, resolved agreement, . . .

Two General Points

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