Assembling Syntax: Modeling Constituent Questions in a Grammar Engineering Framework

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SigTyp Lecture Series

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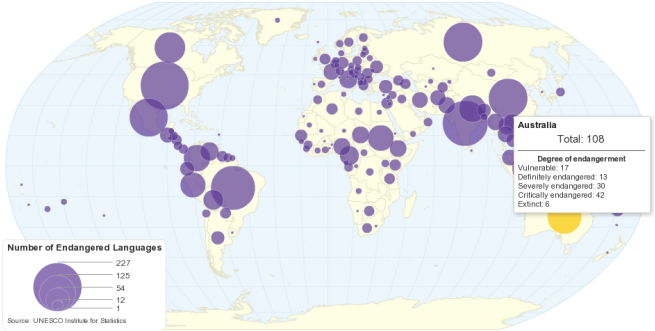
Range of language variation

- There are over 7000 languages in the world[1]
- 90% of people speak about 10% of them
  - Many languages are being spoken less and less and may disappear



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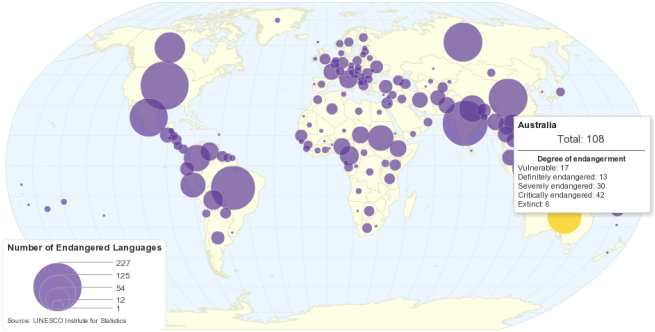
1 *Language Files 12 ed.*

Understanding the range of language variation is important:

- For culture and society
- For science
  - One of the **fundamental goals of linguistics**
  - What about natural language processing?



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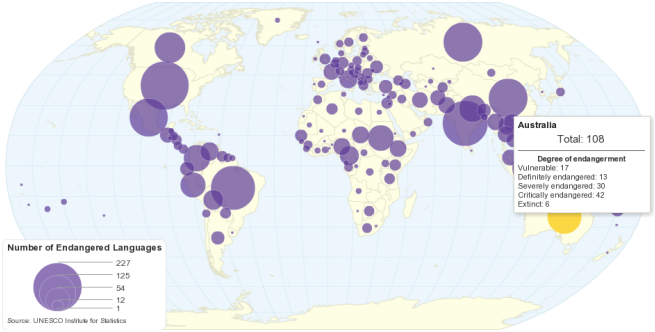
    - Sure, but how do we **evaluate** the performance?

Understanding the range of language variation is important:

- For culture and society
- For science
  - One of the **fundamental goals of linguistics**
  - Core to evaluating NLP models
  - Can transfer a model from English to another language but still need systematic knowledge about that other language to evaluate



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We need to study more languages...

- To learn more about human language, via linguistics or via NLP
  - ...just like other sciences do in their domains [3]

Pongo tapanuensis. Pic credit: Tim Laman

[3] Nater et al. 2017

We need to study more languages...

- Studying a small set of languages is also valuable! (In both linguistics and NLP!)
- ...but it biases the questions we ask [4]

Pic credit: https://englishlive.ef.com/blog/language-lab/question-words/

[4] Idiatov 2007; Bybee 1985

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  - How do we combine them?

Combining breadth and depth

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- Computational modeling
  - of the theory
  - ...for reproducibility and rigor
  - ...when assembling fragments of in-depth analyses
  - ...into a typologically diverse system

Computational syntax

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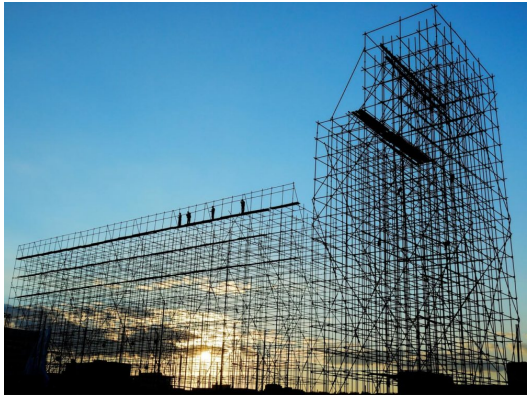
Philosophy: Method of fragments

- Fully explicit **grammar fragments**[5] that can be extended
  - constitute research artifacts that can be literally built upon
  - together and over time, contribute to our understanding of syntax



https://www.theinformationlab.co.uk/2017/08/09/data-scaffolding-easy-steps-fill-missing-data/

5 Montague 1974

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  - Next: Combining syntactic theory and typology

Assembling Syntax: Part II

Computational syntax with Head-Driven Phrase Structure Grammar formalism

Computational syntax

- Implement **grammars** on the computer
- Run grammars automatically on sentences
  - ...as many sentences as you have
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- Grow grammars and accumulate **knowledge artifacts**
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- I am working somewhere in between...

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  - Rely on indispensable human knowledge but support it with computational framework

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  - Consider sentences (usually a few), hypothesize an analysis
  - Test in your head
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  - Revise hypotheses

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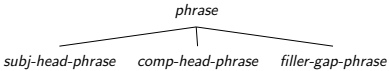
- **Method**: Meta-grammar engineering with Head-Driven Phrase Structure Grammar
- **Project**: Analysis of constituent questions for a grammar engineering system
- **Result**:
  - New library in the system; more complex hypotheses can be tested
  - Archived test suites and analyses for several languages
  - Some takeaways regarding the interaction of different analyses

Head-Driven Phrase Structure Grammar

- **Fully explicit** formalism[6]
- Lexicalist and surface-oriented
- A grammar is a hierarchy of **types** encoded as **feature structures** where features are constrained to have some values
- A structure licensing a sentence must be **well-formed**



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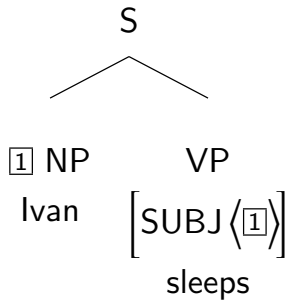
6 Pollard and I. A. Sag 1994

HPSG Phrase Structure Rule

- Describes a feature structure that is a phrase and can be visualized as a tree
- "Mother" and "daughter" nodes
- Identities (tags)



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HPSG: Theoretical and Computational

- Both types of research exist
- HPSG formalism can be used to posit multiple theories
- DELPH-IN HPSG 🐬
  - International research consortium[7]
  - Restricted version of HPSG formalism

[7] https://github.com/delph-in, http://moin.delph-in.net/wiki/

DELPH-IN main projects

- The English Resource Grammar (ERG) [8]
  - **Broad** coverage; used in NLP[9]
    - Semantic representations (ERS, MRS, DMRS) used widely for **evaluating semantic parsers**[10]

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- The Grammar Matrix:[12] Automated **starter** grammars; **typologically**-driven (Part III)
  - Bootstrap grammar development for more languages[13]

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13 Bender 2010; Crowgey 2019; Inman 2019

An analysis of constituent (wh) questions in DELPH-IN HPSG

- Classic 🏛 set of questions for syntactic theory:
  - How are question words ("wh-") distributed?
  - How to represent interrogative semantics?
    - Quantification, scope, wh-words as question parameters of different clauses...
  - How to model question word fronting (4)?
  - How to model optional fronting (5)?

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- Previously:
  - Nobody had put forth an analysis of **multiple fronting** as in Slavic languages
  - Nobody had offered a **unified** HPSG account of wh-questions in typologically different languages
  - ...and tested it rigorously 🤦 with a parser
  - 14

(4) Gde kto chto vidit?
where who.NOM what.ACC see.3SG
'Who sees what where?'[rus]

(5) Ty gde rabotaesh?
you where work.3SG
'Where do you work?'[rus]

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Questionnaire – Analysis – Semantics

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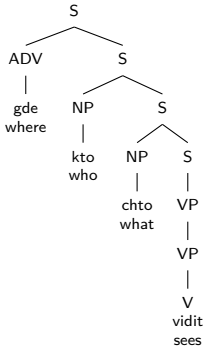
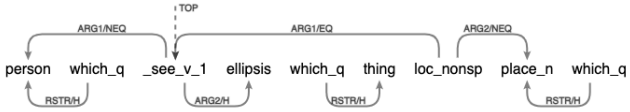
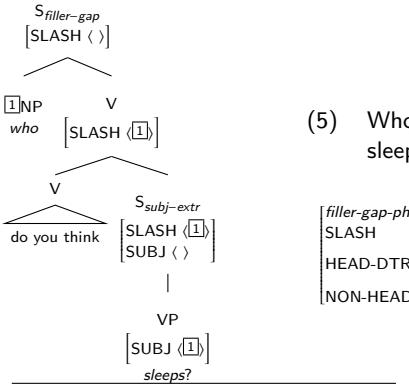




Fronting analysis in HPSG

- "Nonlocal" features are propagated up the tree[15]
- Feature SLASH creates a long-distance dependency at the level of the verb
- The *filler-gap* rule discharges the dependencies



(5) Who do you think sleeps? [eng]

$$\begin{bmatrix} \textit{filler-gap-phrase} & \\ \text{SLASH} & \langle\ \rangle \\ \text{HEAD-DTR} & \begin{bmatrix}\text{SLASH} & \langle\ \boxed{1}\ \rangle\end{bmatrix} \\ \text{NON-HEAD-DTR} & \boxed{1} \end{bmatrix}$$

15 Pollard and I. A. Sag 1994; Ginzburg and I. Sag 2000

Extending the fragment: Multiple question fronting

- Allow multiple extraction and recursive application of *filler-gap*[16]
- Takeaways:
  - "Optional" fronting is hard![17]
  - Simpler analysis of multiple fronting → less simple morphological marking[18]

$$\begin{bmatrix} \textit{filler-gap-phrase} & \\ \text{SLASH} & \boxed{1} \\ \text{ARGS} & \left\langle \boxed{2}, \left[\text{SLASH} \left\langle \boxed{2} \right\rangle \oplus \boxed{1} \right] \right\rangle \end{bmatrix}$$

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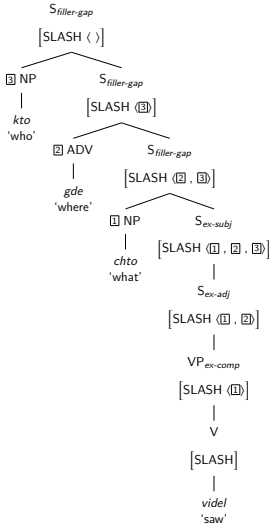

16 Zamaraeva and Emerson 2020; Crysmann 2015
17 Zamaraeva 2021
18 Zamaraeva to appear

An analysis of Slavic fronting in HPSG

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  - **Part III:** Assembling typologically diverse analyses and evaluating the result

Assembling Syntax, Part III

Assembling and evaluating typologically diverse analyses

Questionnaire – Analysis – Semantics

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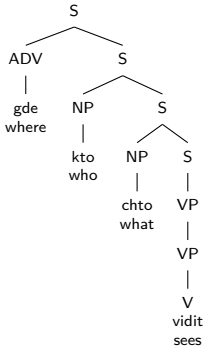

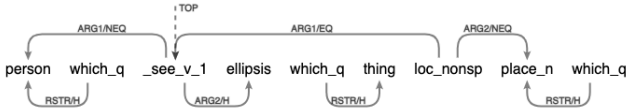

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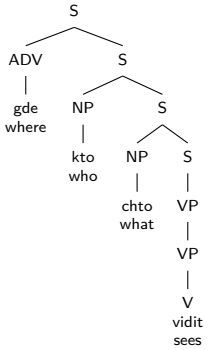
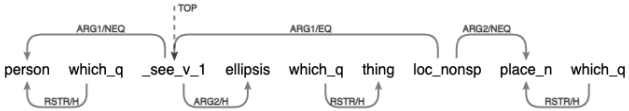


Choices regarding the position of question phrases

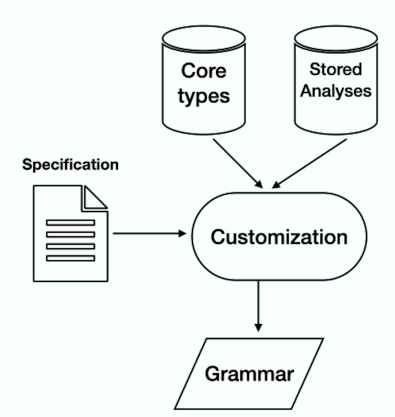
Question phrases can appear at the left edge of the sentence regardless of the position the questioned constituent would appear in (*Who did you see? I know who you saw* etc.):

- ○ Only one question phrase can be fronted
- ◉ All question phrases can be fronted
- ○ Question phrases cannot be fronted (stay *in situ*)



The Grammar Matrix

- Meta-grammar engineering framework[19]
- Input: Typological specification, lexicon, morphological rules
- Output: Implemented HPSG grammar fragment
  - Parse and generate sentences
  - Output syntactic and **semantic** representations
- Many syntactic phenomena are supported[20]

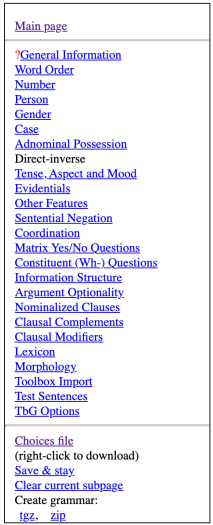


19 https://matrix.ling.washington.edu/customize/matrix.cgi

20 Zamaraeva 2021; Zamaraeva, Howell, and Bender 2019; Howell and Zamaraeva 2018; Saleem 2010; Song 2014; Nielsen 2018; Drellishak and Bender 2005; Crowgey 2013; Bender and Flickinger 2005

Matrix libraries

- Specify several phenomena at the same time
- Click to **get a grammar fragment** covering all of them[21]
- Test hypotheses **in interaction**
- Parse and **generate** data within fragment's area of coverage
  - Large lexicons can be imported



[21] There may be bugs 🐞

Matrix library development

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- Latest addition: Constituent questions[22]

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Meta-grammar engineering research question

RQ: *What constitutes a model of a range of typologically attested ways of forming constituent questions within the given framework?*

Evaluation: How well does the analysis generalize to a set of randomly picked "held-out" languages?

Constituent questions in the Matrix

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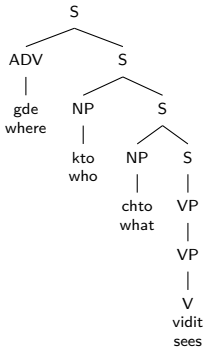
- New library[23]
- Typological scope:[24]
  - Position of question phrase
    - **Fronting**, *in situ*
    - Fronting optionality
  - Morphological marking
  - Question particles
    - position
    - obligatoriness
  - Question words



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24 König and Siemund 2007; Hagège 2008; Miyagawa 1987, *inter alia*

Assembling 🖼 fronting

Specification	Types	Core?	New?	Custom features
single oblig. front.	*wh-ques-phrase*	no	yes	SLASH
	subj-, obj-, adj-ex.	no	no	none
multi oblig. front.	*wh-ques-phrase*	no	yes	HDR|QUE MODIFIED *hasmod*
	subj-, obj-, adj-ex.	no	no	none
single opt. front.	*wh-ques-phrase*	no	yes	SLASH
	in-sutu-phrase	no	yes	none
	subj-, obj-, adj-ex.	no	no	none
multi opt. front.	*wh-ques-phrase*	no	yes	MODIFIED *hasmod*
	in-sutu-phrase	no	yes	HDR|L-QUE –
	subj-, obj-, adj-ex.	no	no	HDR|L-QUE –
in situ (no front.)	*in-sutu-phrase*	no	yes	none

The position of question phrases customization summary[25]

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Assembling particles

Specification	Types	Core?	New?	Custom features
clause-final or init.	*qpart-comp-lex*	no	no	none
	head-comp-phrase	yes	no	INIT
2nd pos.	*ques-clitic-lex*	no	yes	none
	non-local	yes	no	YNQ
	basic-binary-phrase	yes	no	L-PERIPH
	int-cl-phrase	no	yes	none
	in-situ-phrase	no	yes	none
obligatory	*in-situ-phrase*	no	yes	MC –
only in embed.	*qpart-comp-lex*	no	no	MC 1
				COMPS|MC 1
only in polar	*qpart-comp-lex*	no	no	WH|BOOL –
	ques-clitic-lex	no	yes	

Question particles customization summary[26]

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Assembling morphological marking

Specification	Types	Core?	New?	Custom features
Same mkg	*interrog-lex-rule*	no	yes	none
for polar and *wh-*	*indicative-lex-rule*	no	yes	none
Separate paradigms	*indicative-lex-rule*	no	yes	none
	polar-lex-rule	no	yes	none
	wh-subj-lex-rule	no	yes	none
	wh-obj-lex-rule	no	yes	none

Morphological question marking customization summary[27]

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- **How well can the system handle examples from an "unseen" language, as it is described in the reference grammar?**

Evaluating the constituent questions library[28]

Language	ISO-639-3	Family	Gram. items	Coverage%	Question typology
Apinajé	[apn]	Macro-Jê	17	82.3	single front.
Makah	[myh]	Wakashan	14	78.5	morphological,int. verbs
Pacoh	[pac]	Austroasiatic	26	84.6	single opt. front.
Paresi-Haliti	[pab]	Arawakan	64	56.0	single front., int. verbs
Jalkunan	[bxl]	Mande	33	78.8	*in situ*, particle, int. verbs

✓ Single fronting, particles, morphological marking, interrogative verbs

✗ Question words as predicates

− Did not come up: Multiple fronting and LDDs

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Evaluating the constituent questions library[29]

Language	ISO-639-3	Family	Gram. items	Coverage%	Handled phenomena
Apinajé	[apn]	Macro-Jê	17	82.3	evidentials, arg. drop, clausal modifiers
Makah	[myh]	Wakashan	14	78.5	clausal complements, arg. drop
Pacoh	[pac]	Austroasiatic	26	84.6	arg. drop
Paresi-Haliti	[pab]	Arawakan	64	56.0	**focus**, adnom. poss, coordination
Jalkunan	[bxl]	Mande	33	78.8	adnom. poss.

- ✓ Single fronting, particles, morphological marking, interrogative verbs
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- − Did not come up: Multiple fronting and LDDs
- 🐞 Bugs: in interaction with **information structure** and clausal complements

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Interim Summary

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- The Grammar Matrix facilitates grammar creation for a wide variety of languages 🌍
- Bigger grammar fragments now possible to obtain from the Matrix[30]
  - Further projects focused on polysynthetic languages are needed
  - What's next?

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Assembling syntax: Part IV

Future directions

Applying grammars in Natural Language Processing

- Ultimately, NLP relies on formal annotation
  - ERG is more robust than PTB/PSD and can be automatically rerun
  - We need this for more languages 🌍 as a long-term investment

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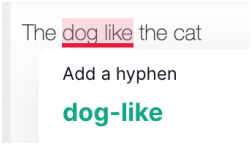

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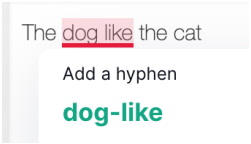

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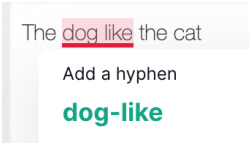

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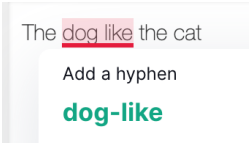

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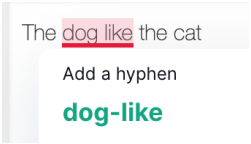

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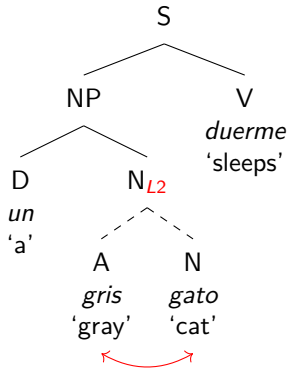
  - Map L2 productions to **useful** feedback[32]

[31] Schneider and McCoy 1998

[32] Bender, Flickinger, Oepen, et al. 2004; Morgado da Costa, Bond, et al. 2016; Morgado da Costa, Winder, et al. 2020

HPSG grammars for grammar coaching

- First step: Spanish and Galician
  - with Gómez Rodríguez and Alonso Ramos, U. of A Coruña
- Next step: More languages



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- **Assembling fragments of our understanding of language**

Acknowledgments

- The work presented today was partially funded by the United States National Science Foundation under Grant No. BCS-1561833 (PI Bender).
- This work would not be possible without the DELPH-IN community

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