Span-Based Constituency Parsing with Provably Optimal Dynamic Oracles

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EMNLP, Austin, TX
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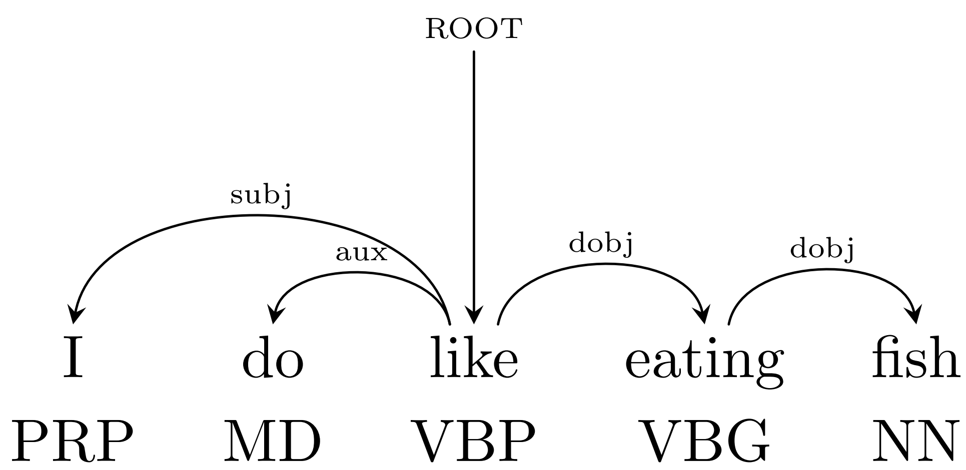
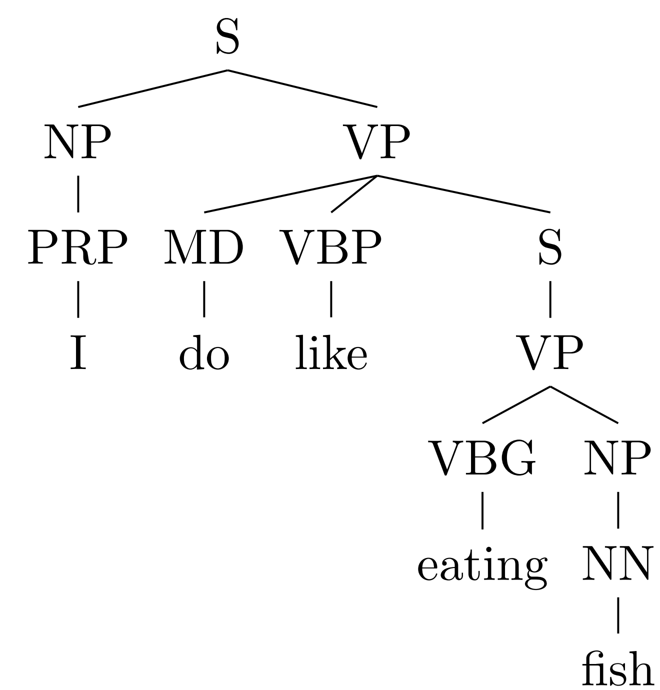
Oregon State UNIVERSITY

Dependency vs. Constituency





	search	UAS
Zhang & Nivre 2011	beam	92.9
Chen & Manning 2014	**greedy**	91.8
Zhou et al. (2015)	beam	93.3
Weiss et al. (2015)	beam	94.0
our work (ACL 2016)	**greedy**	93.4
Andor et al. (2016)	beam	**94.4**

	search	F_1
Carreras et al. (2008)	cubic	91.1
Shindo et al. (2012)	cubic	91.1
Thang et al. (2015) (A*)	~cubic	91.1
Watanabe et al. (2015)	beam	90.7
Vinyals et al. (2015) (WSJ)	beam	90.5

Red = Neural

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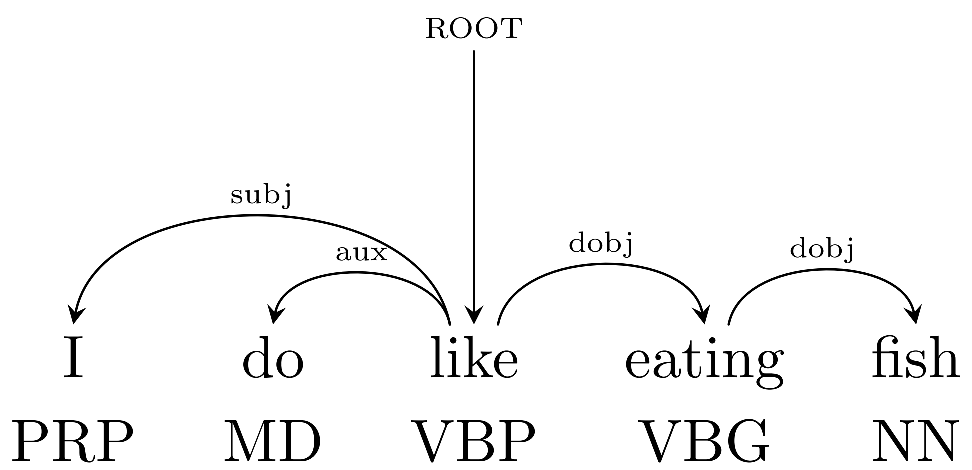

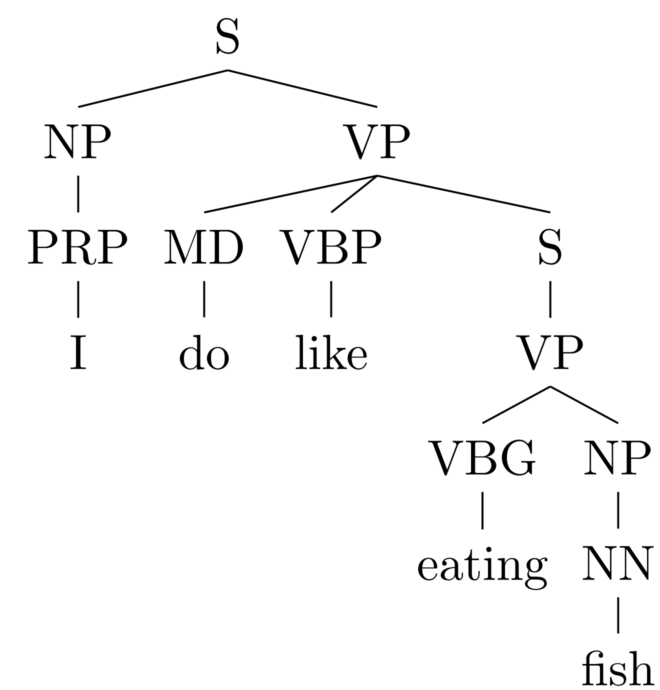

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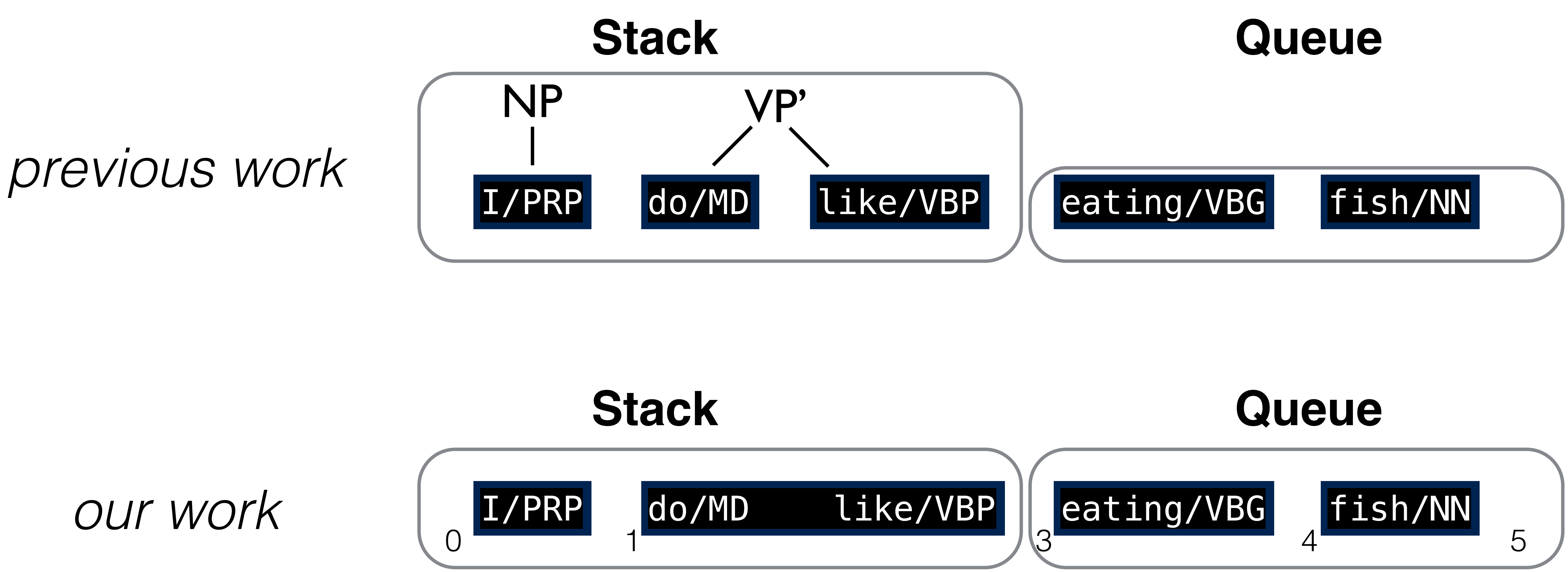
Outline

- Span-Based Constituency Parsing
- Bi-Directional LSTM Span Features
- Provably Optimal Dynamic Oracle
- Experiments

Span-Based Parsing

- Previous work uses tree structures on stack
- We simplify to operate directly on sentence spans
- Simple-to-implement linear-time parsing



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Label (odd step)	Label-*X*
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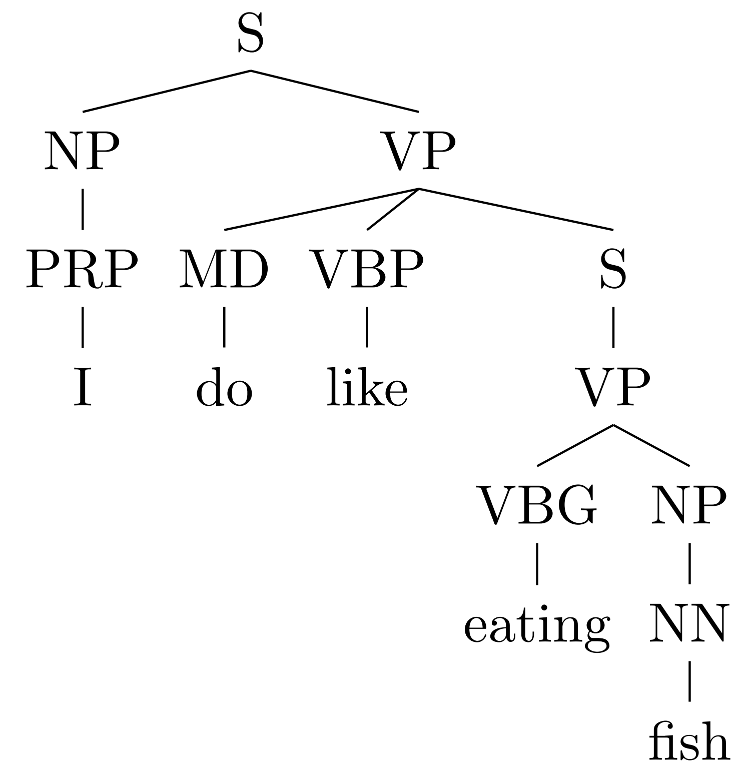

current brackets t = {}

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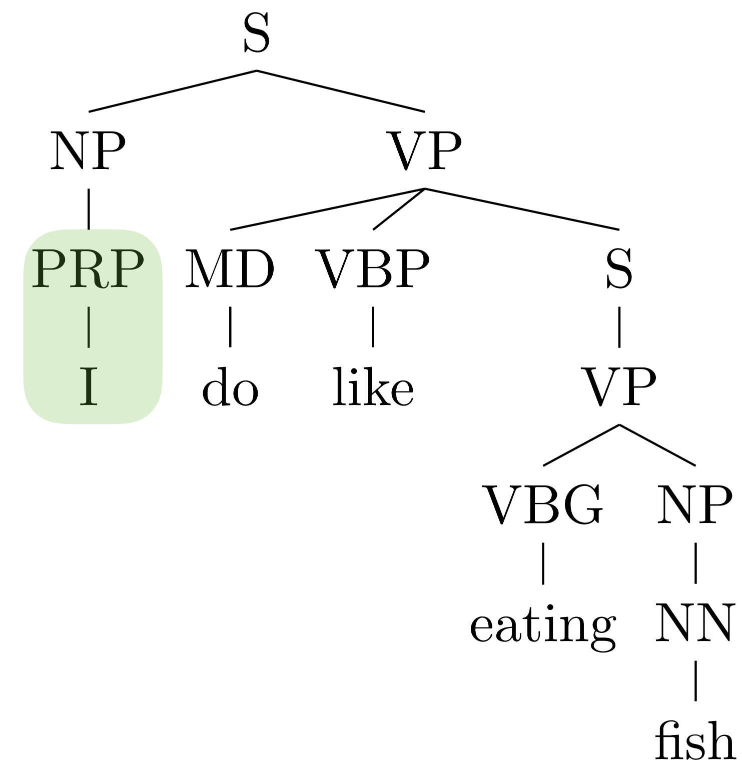

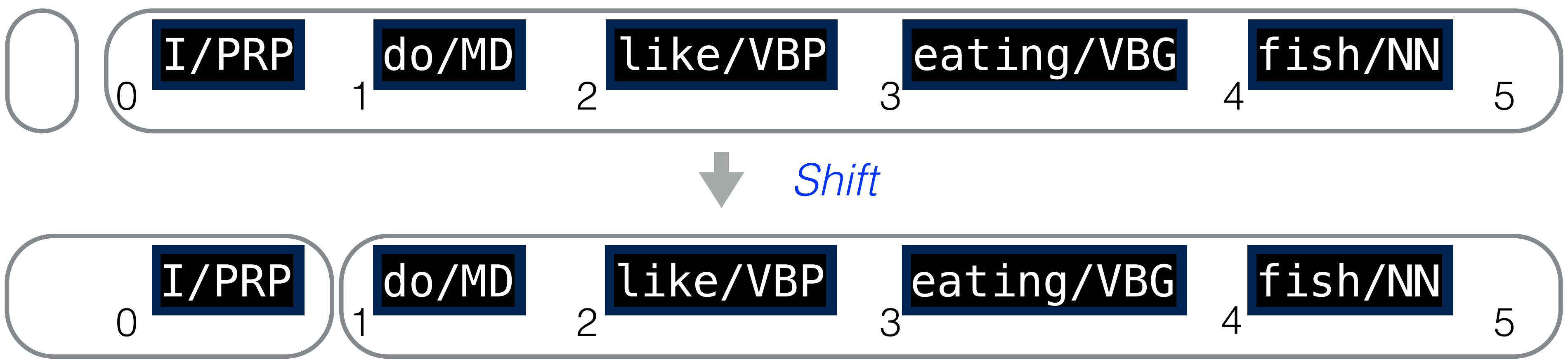

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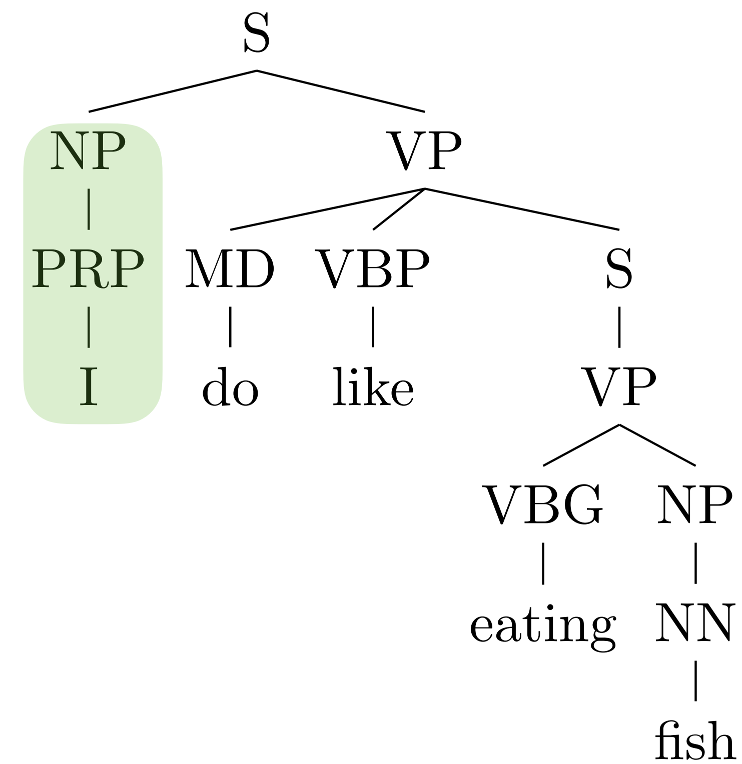

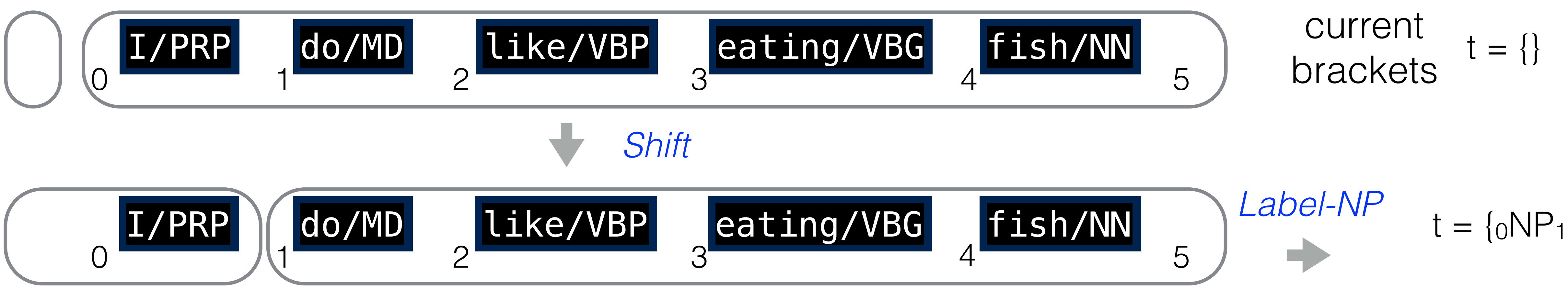

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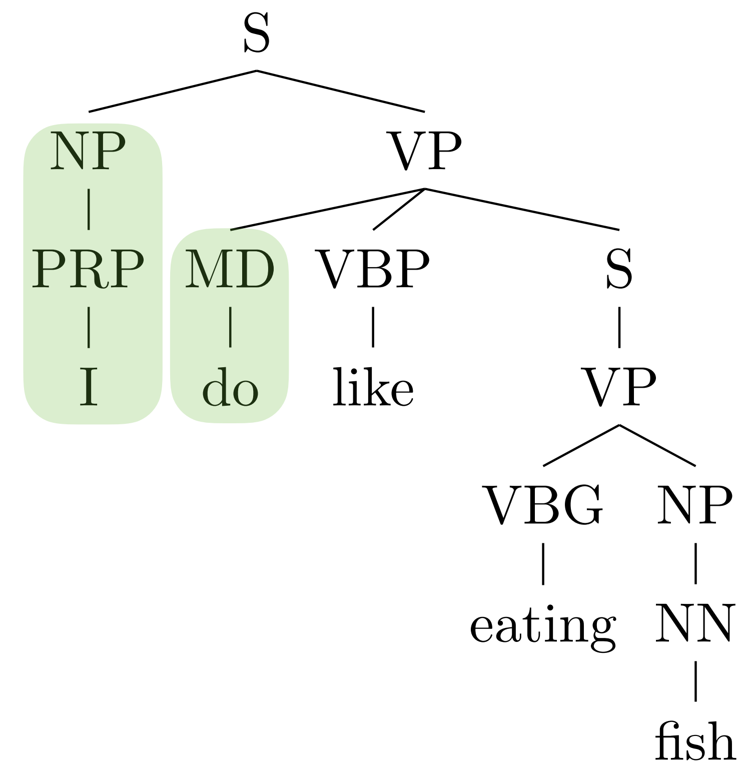

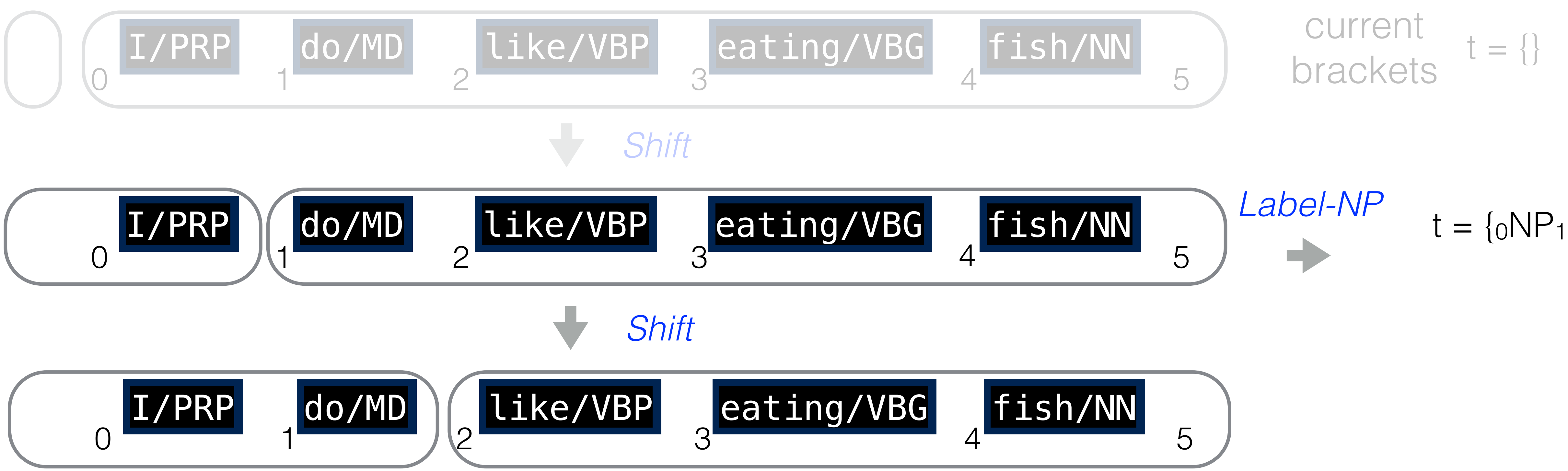

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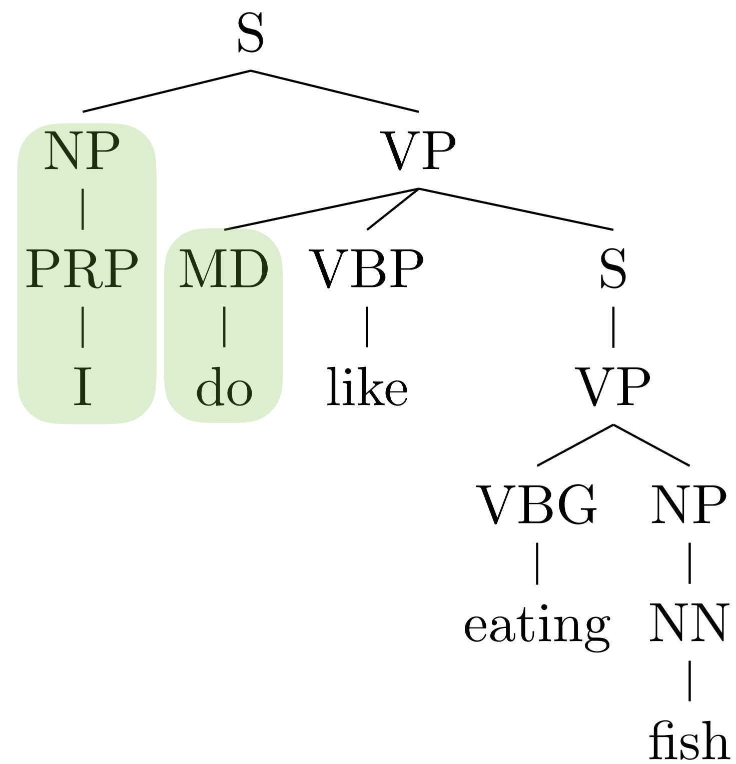

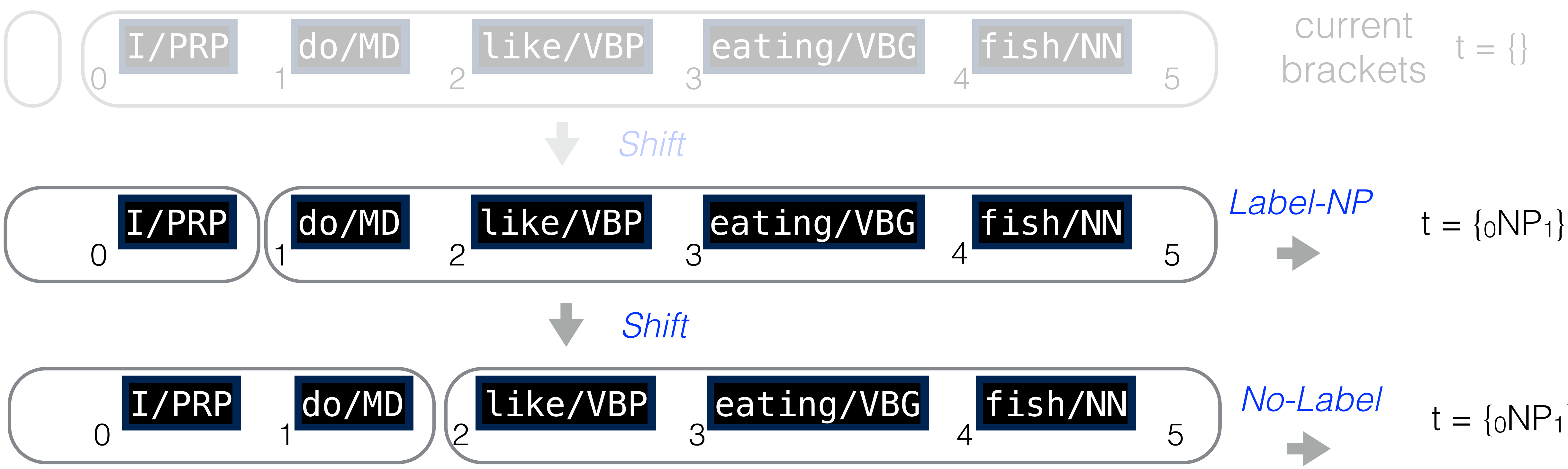

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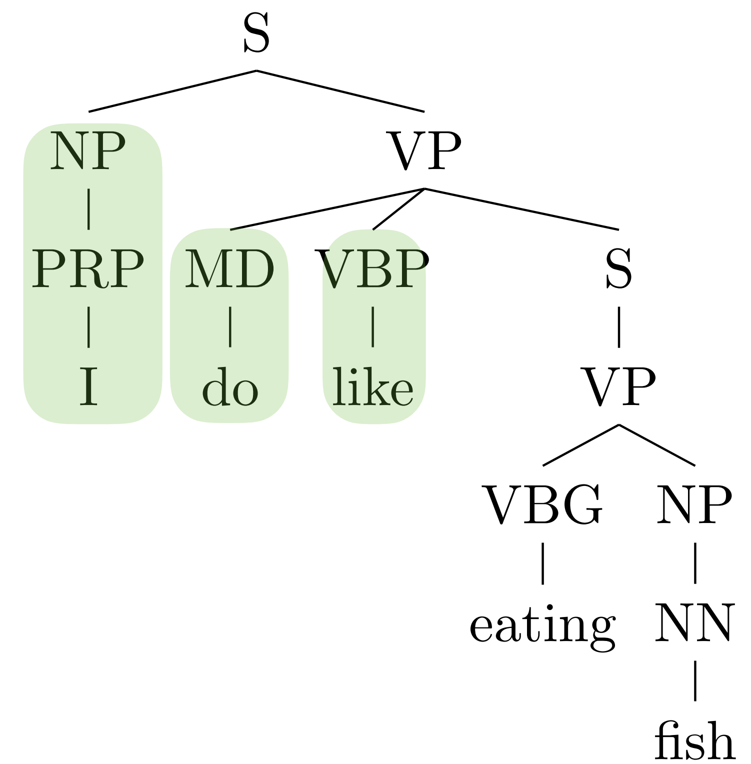

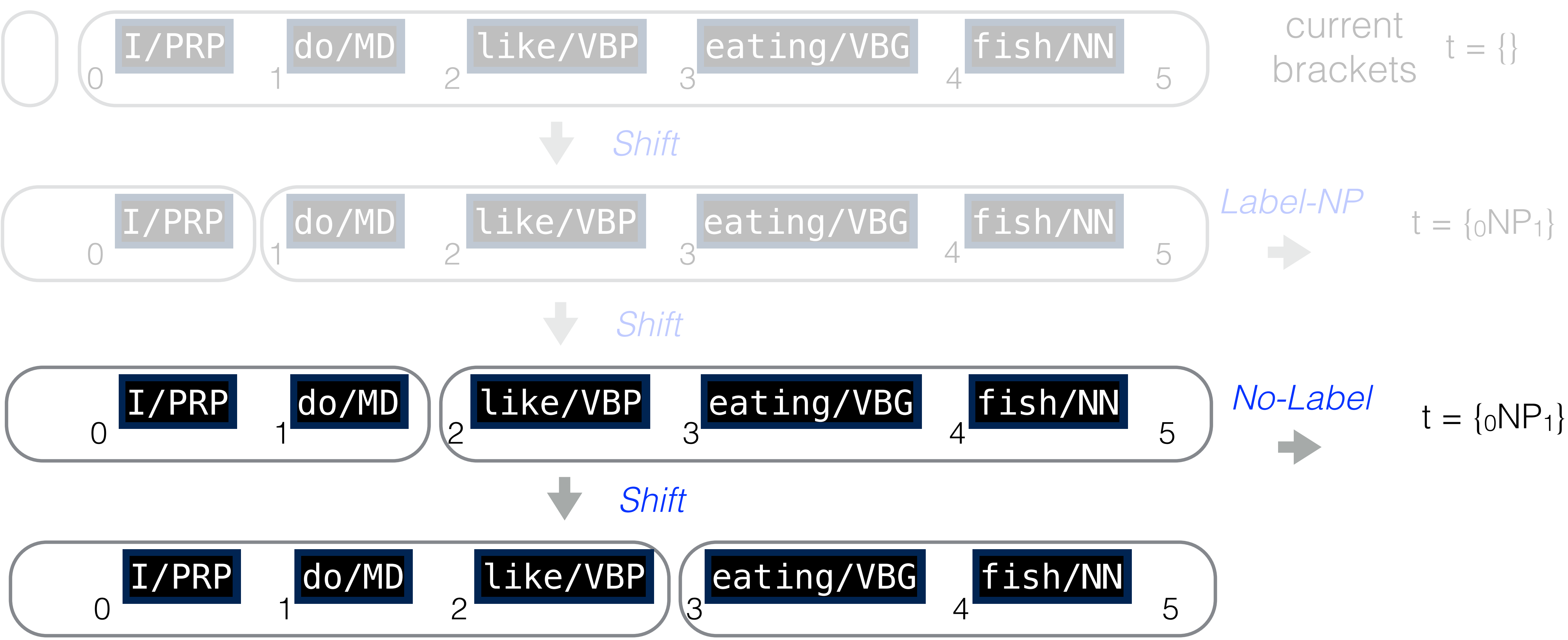

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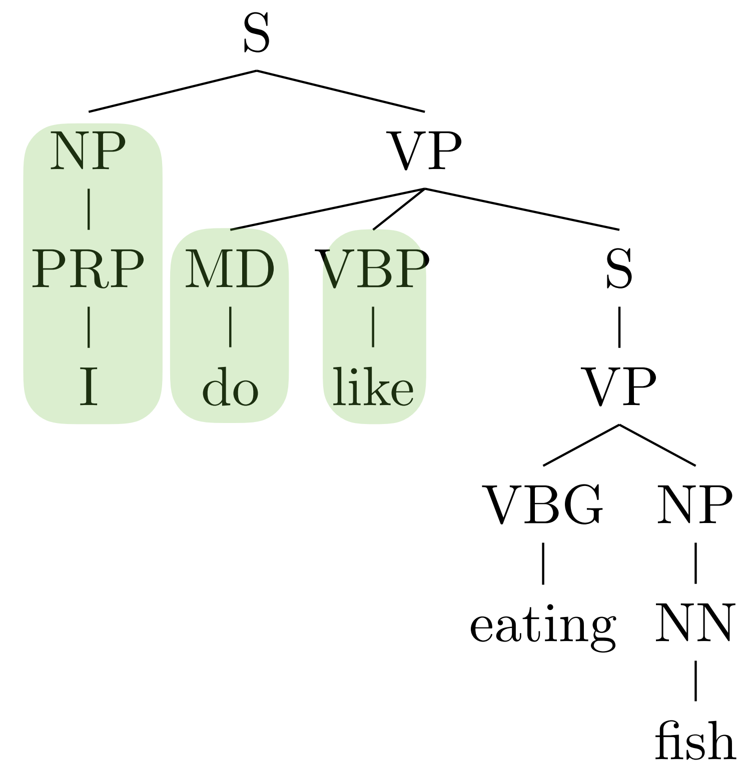

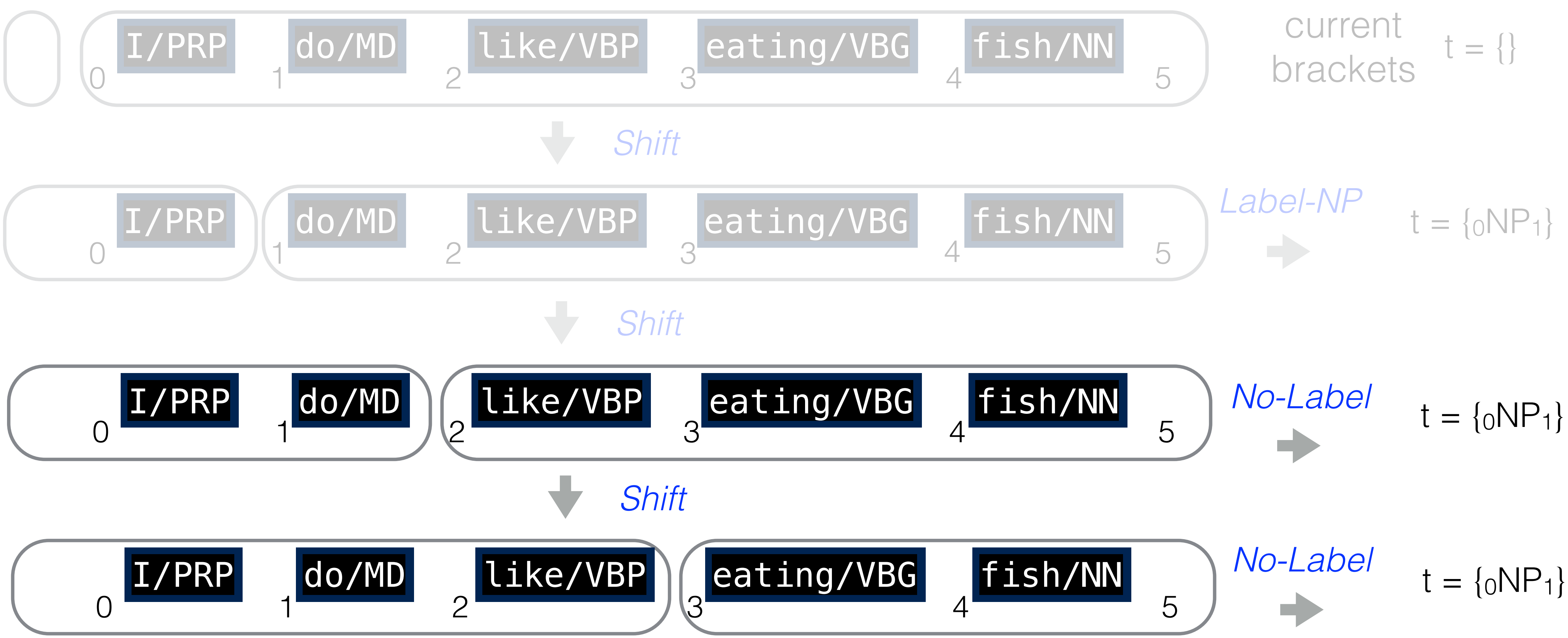

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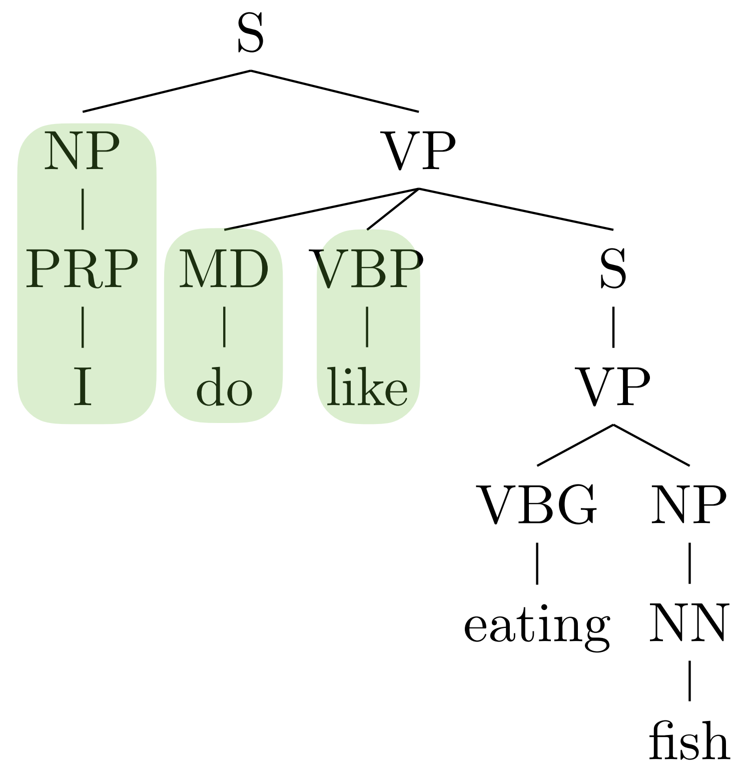

$_0$ `I/PRP` $_1$ `do/MD` $_2$ `like/VBP` $_3$ `eating/VBG` $_4$ `fish/NN` $_5$

$t = \{{}_0\mathrm{NP}_1\}$

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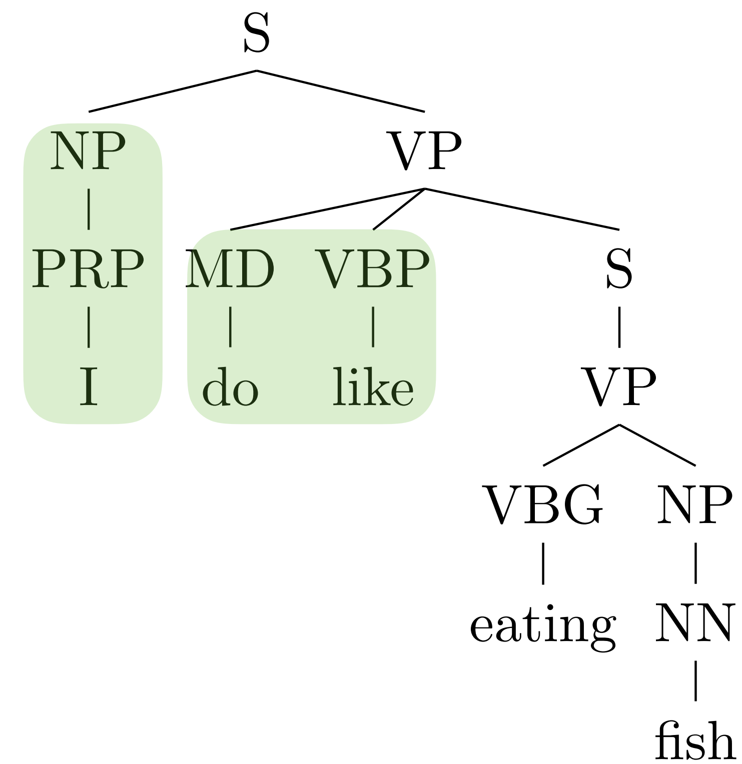

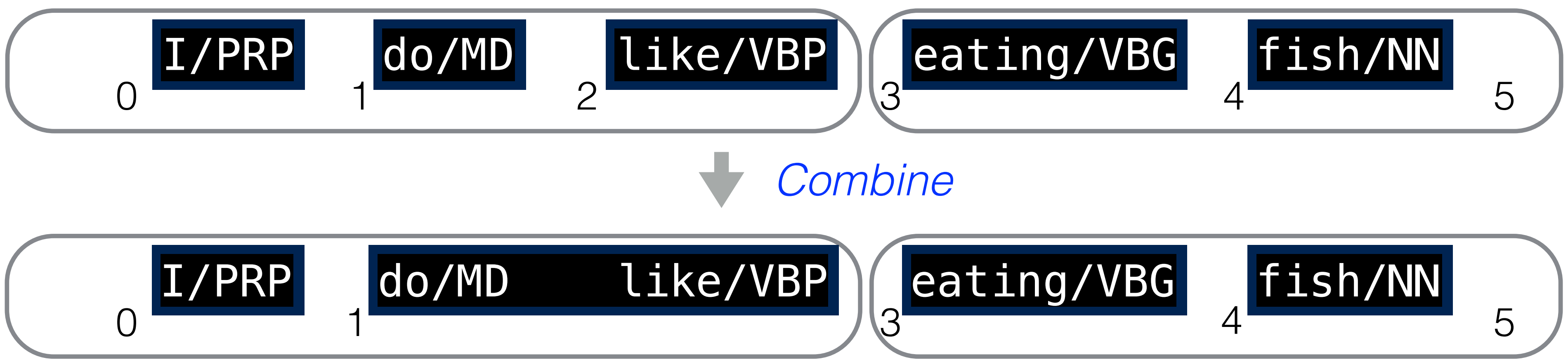

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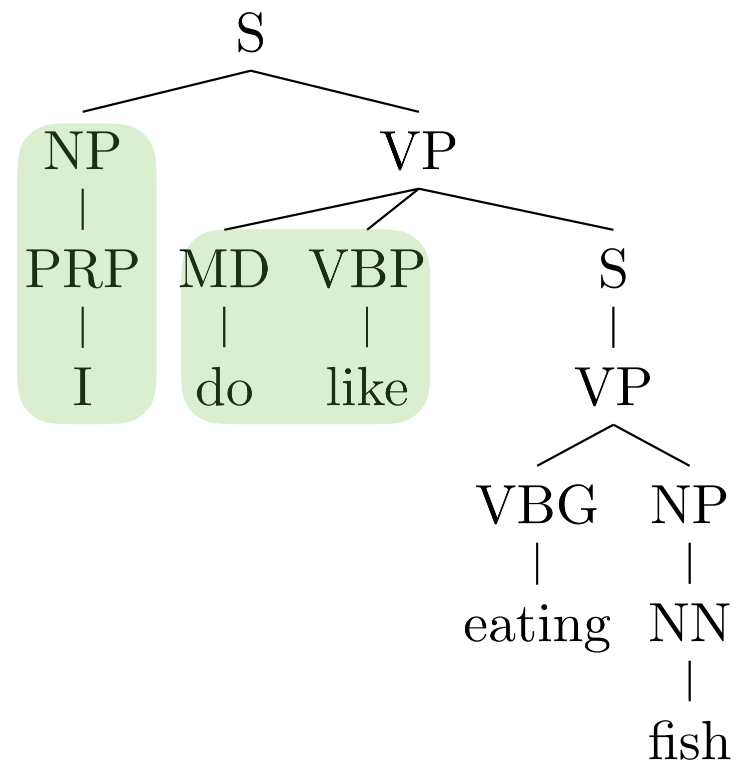

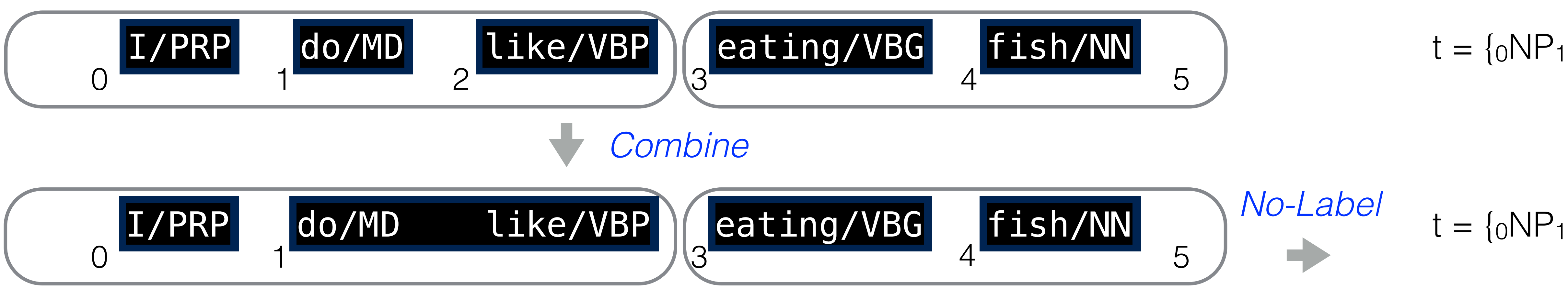

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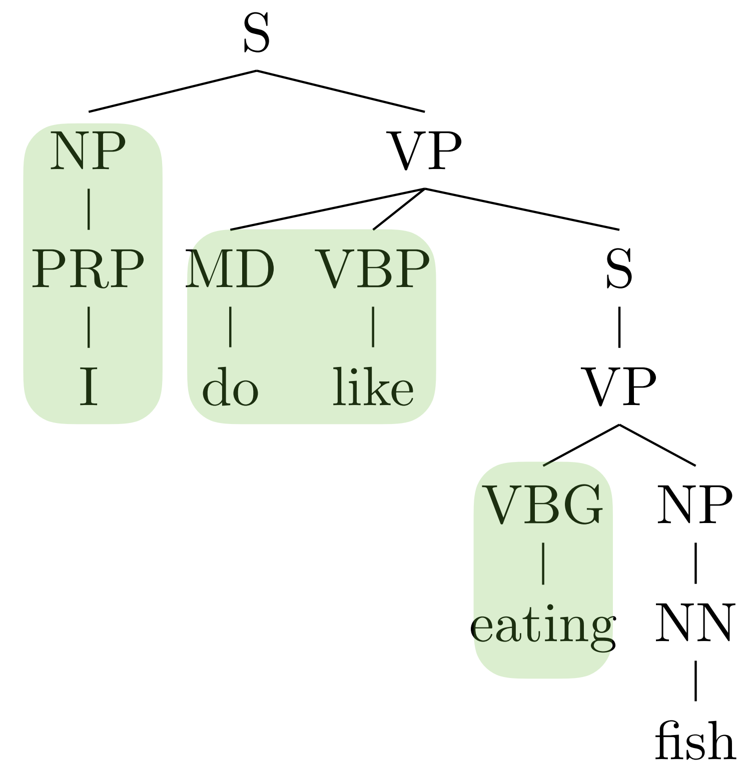

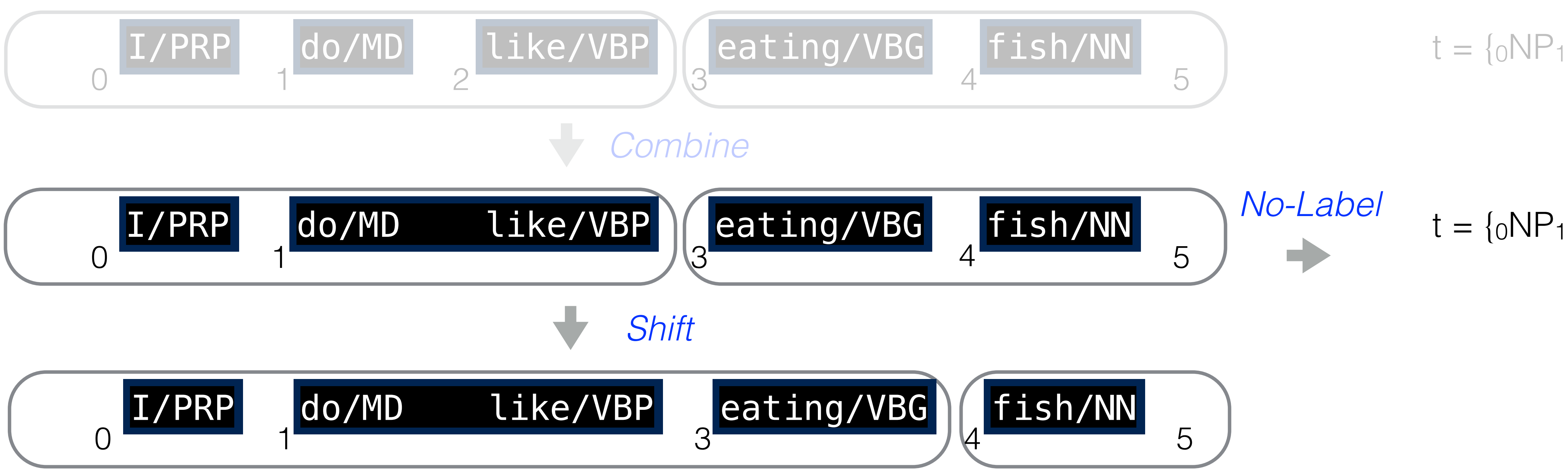

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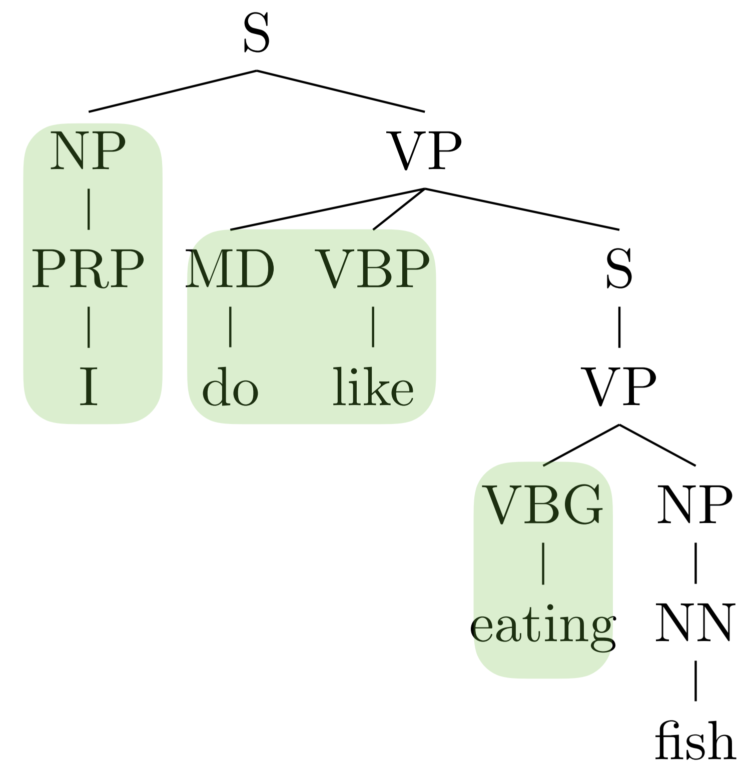

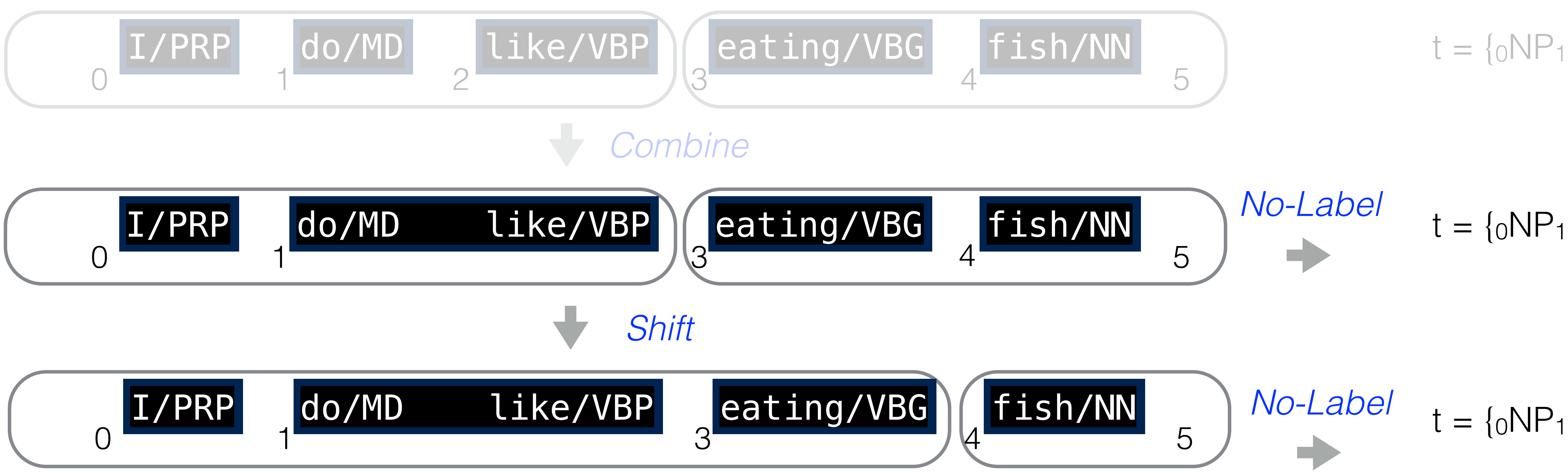

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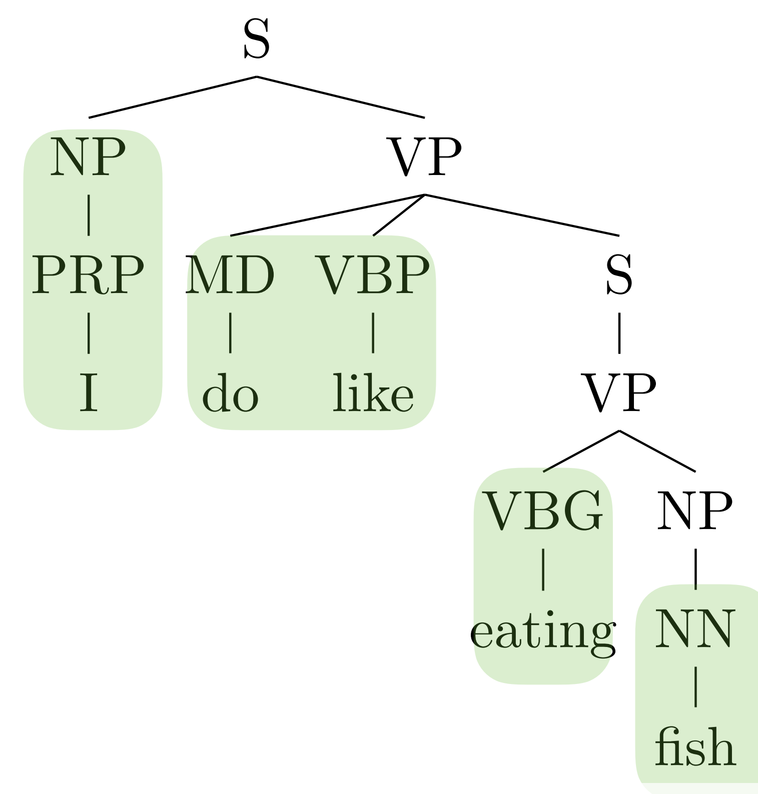

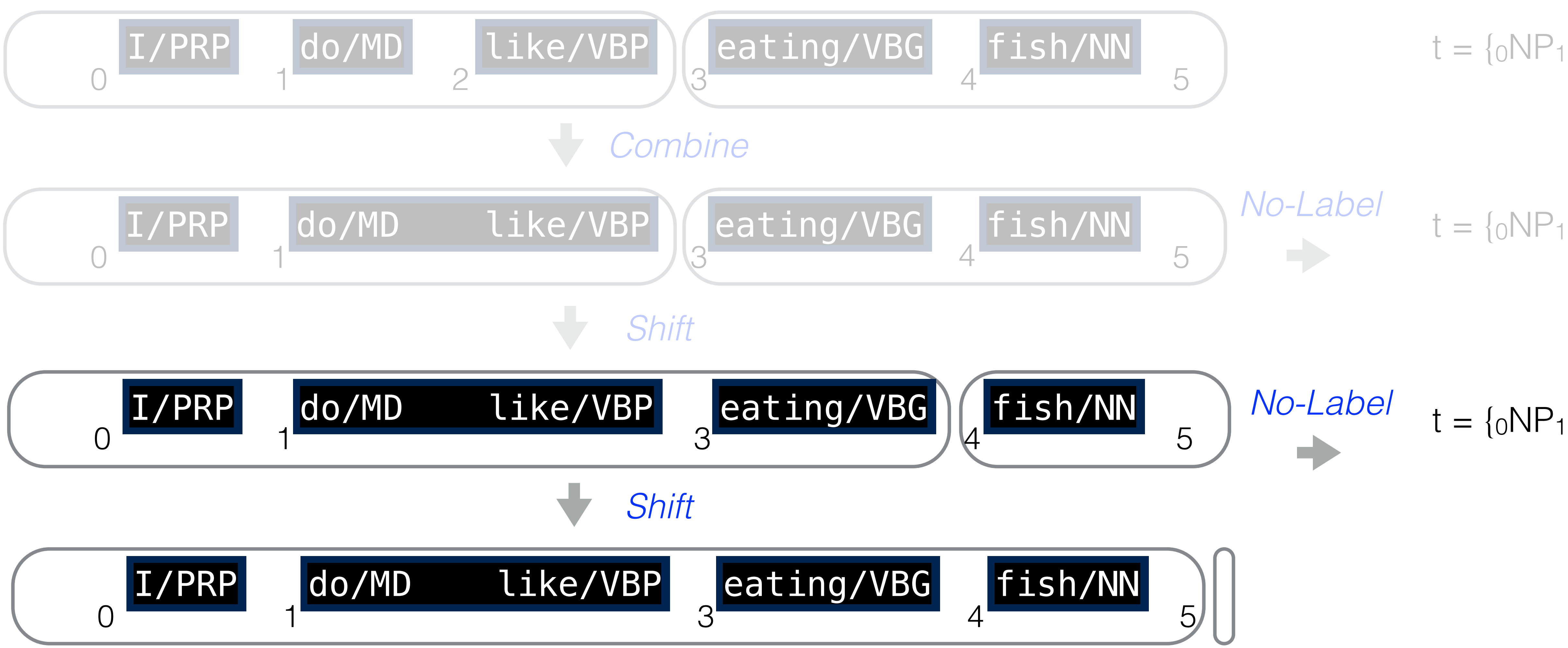

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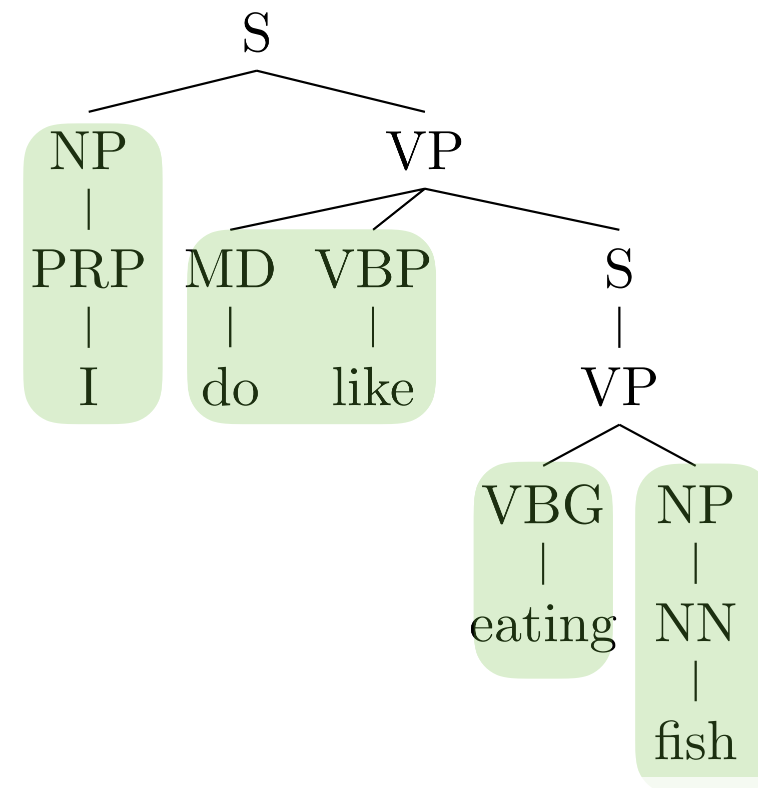

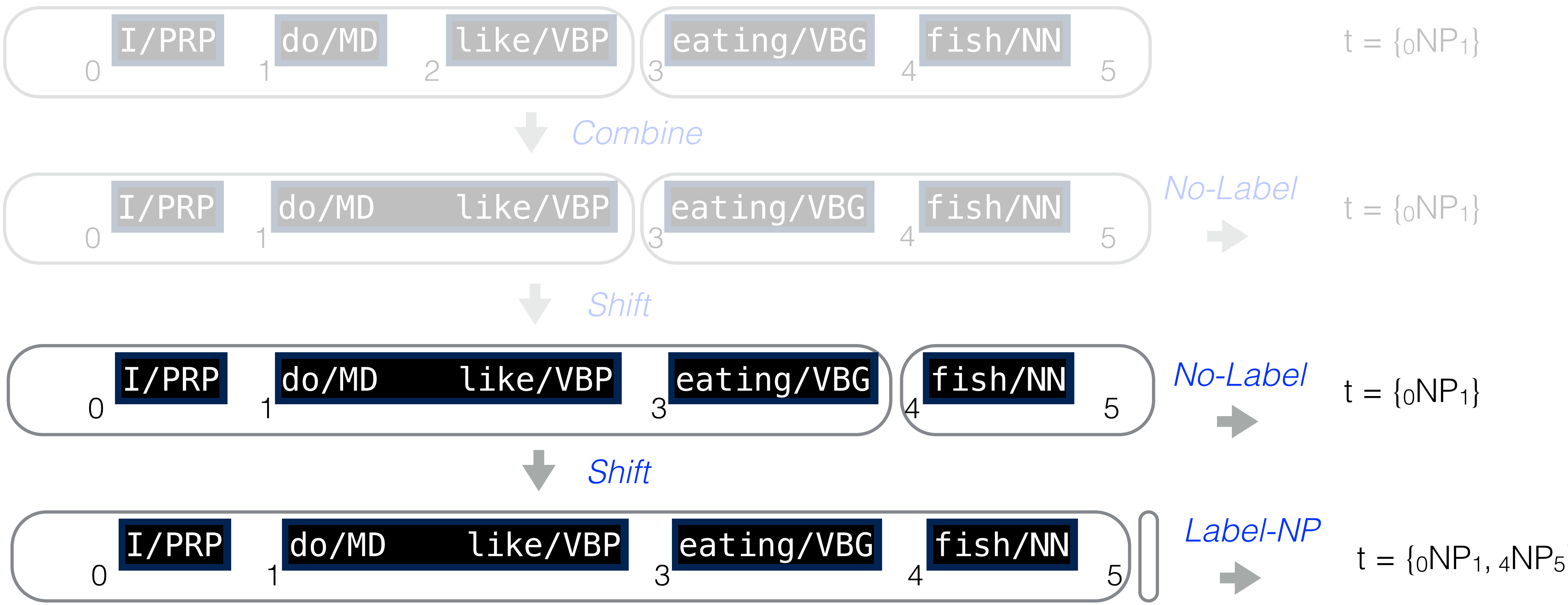

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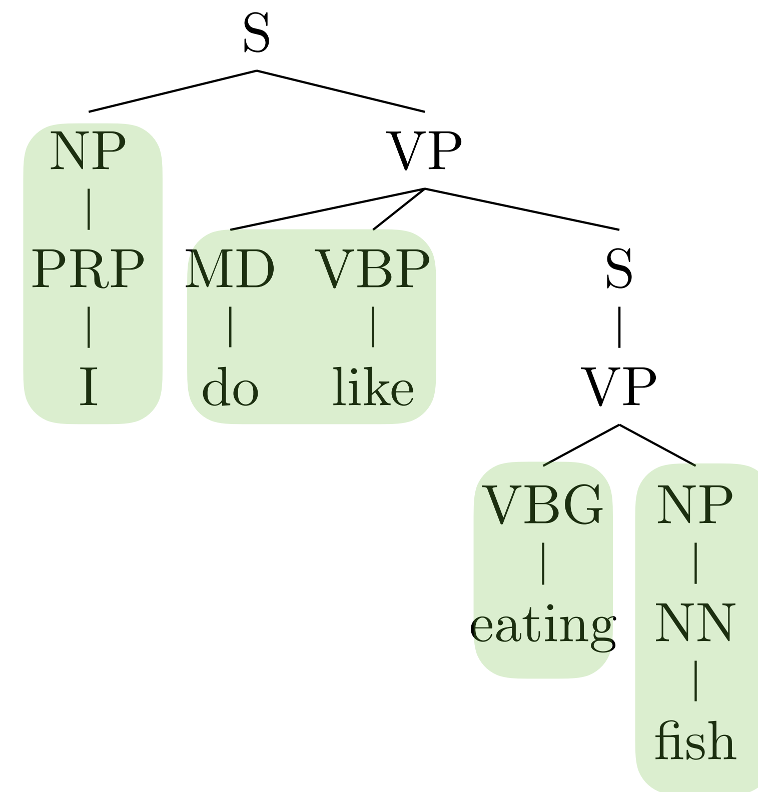

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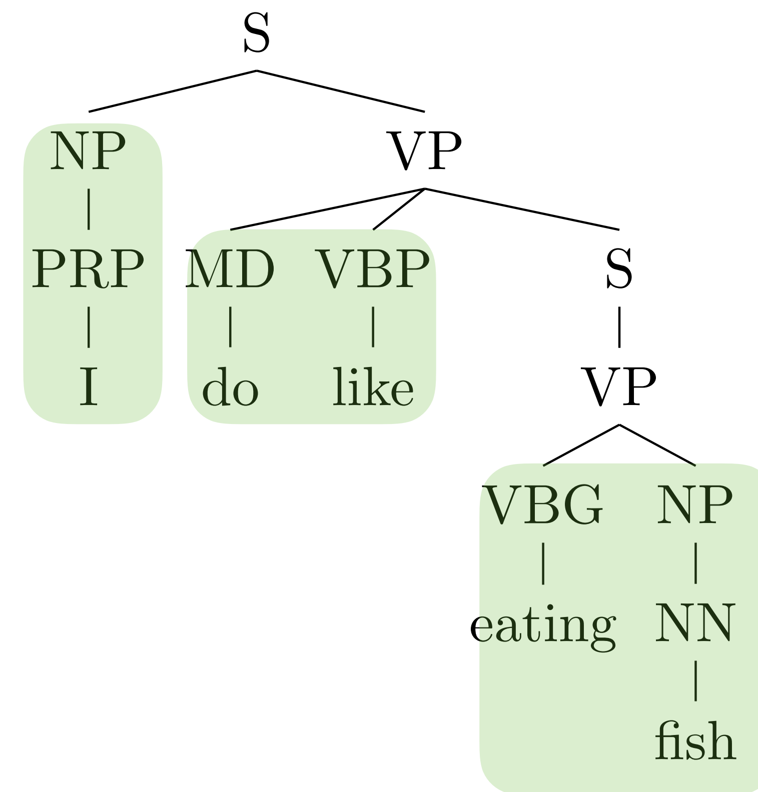

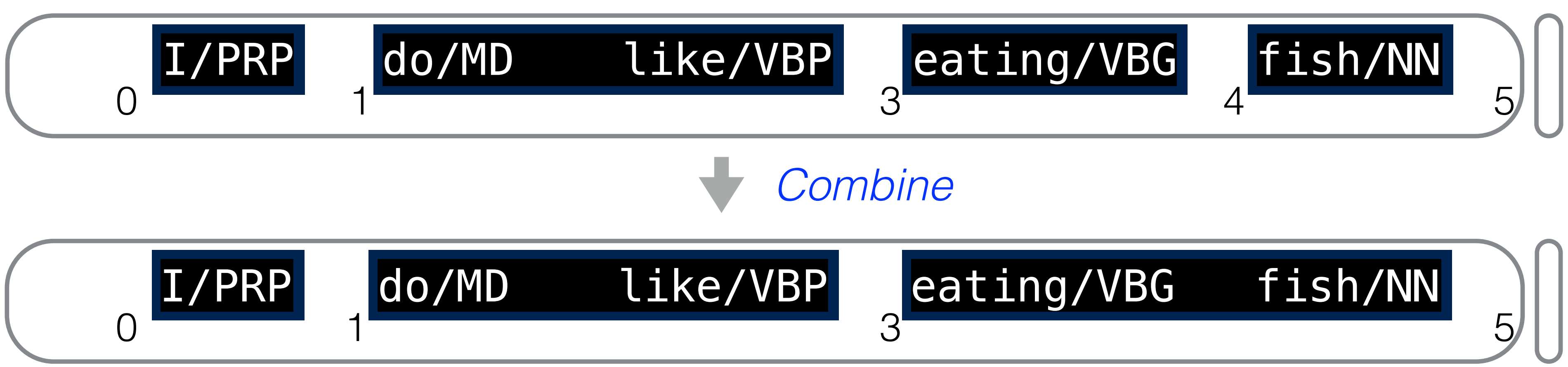

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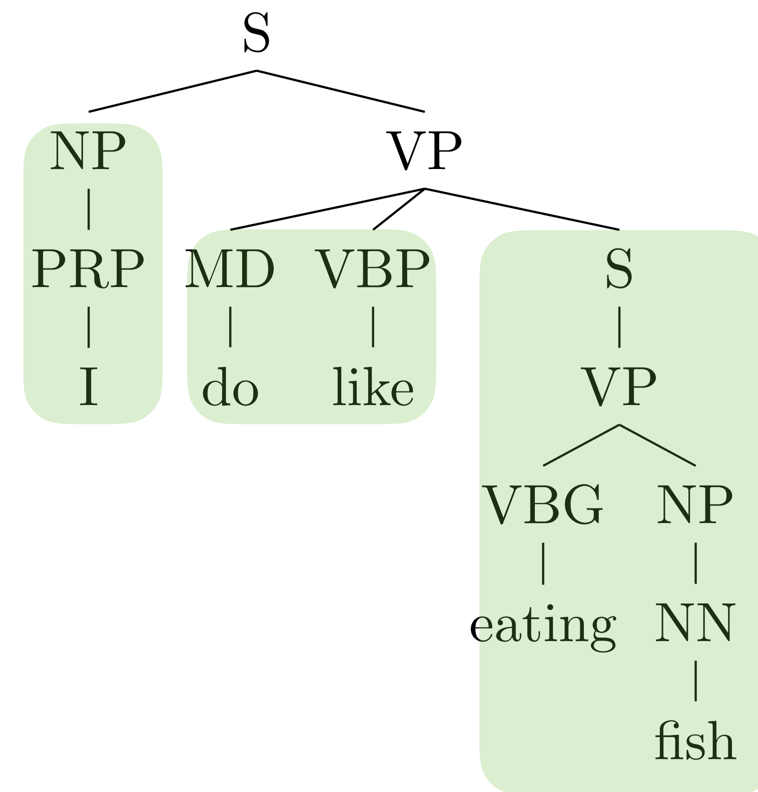

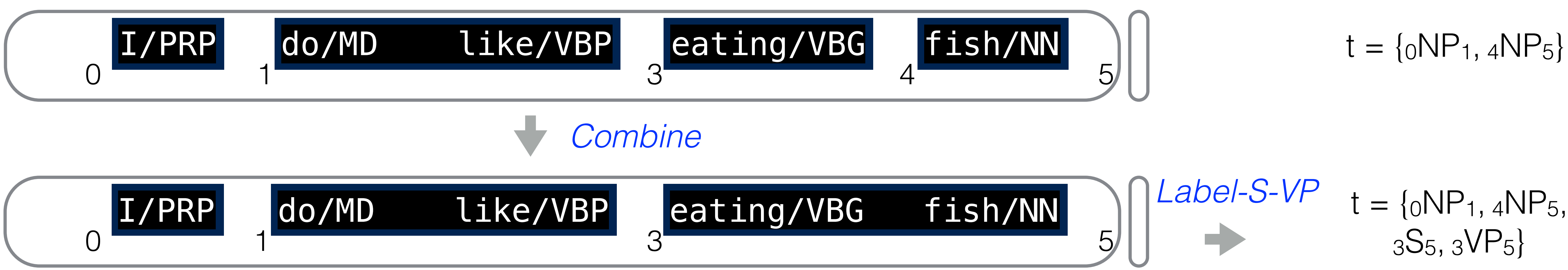

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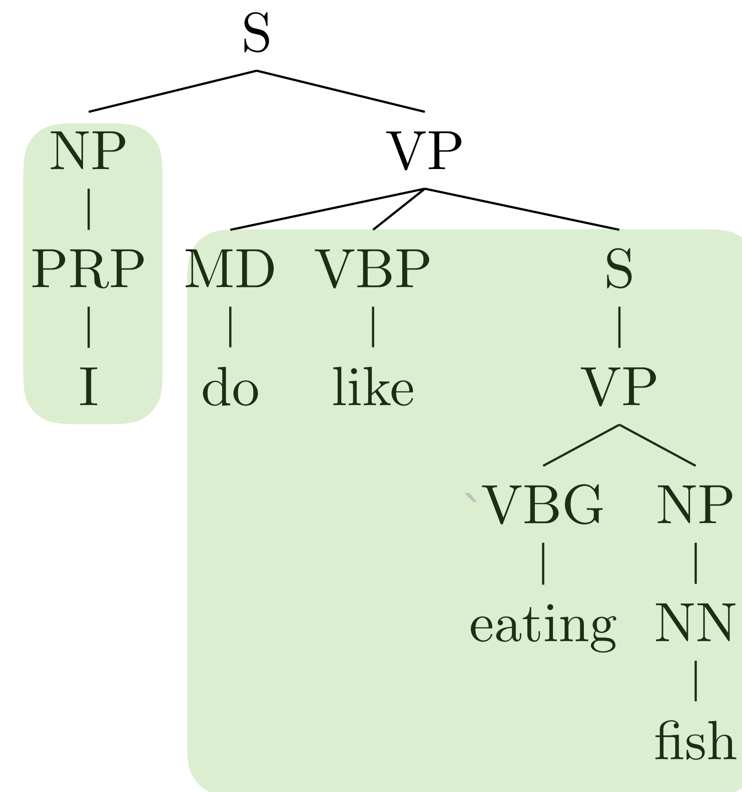

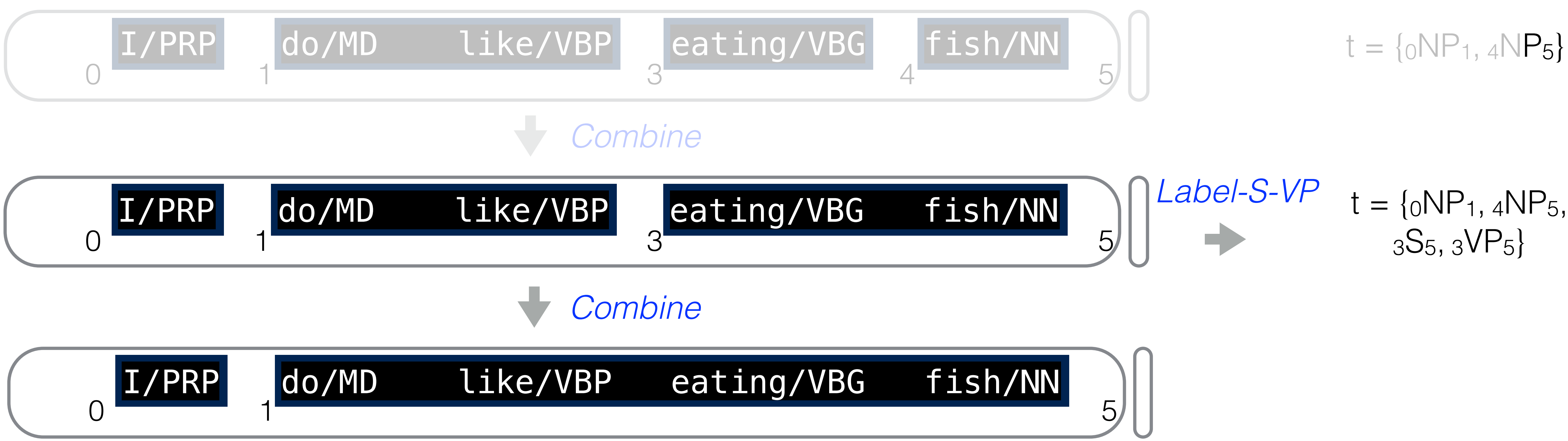

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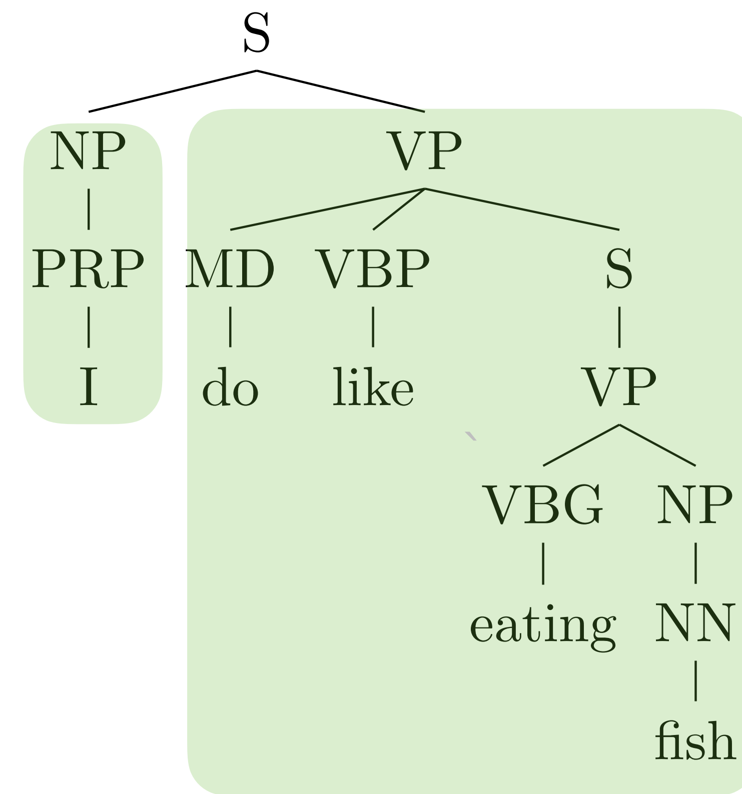

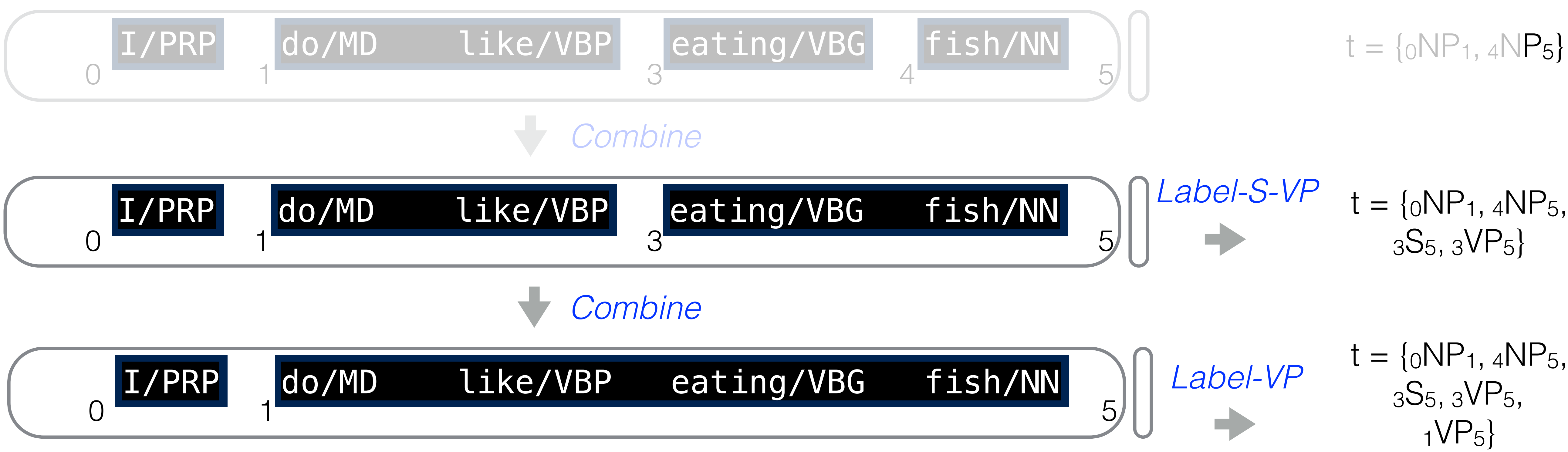

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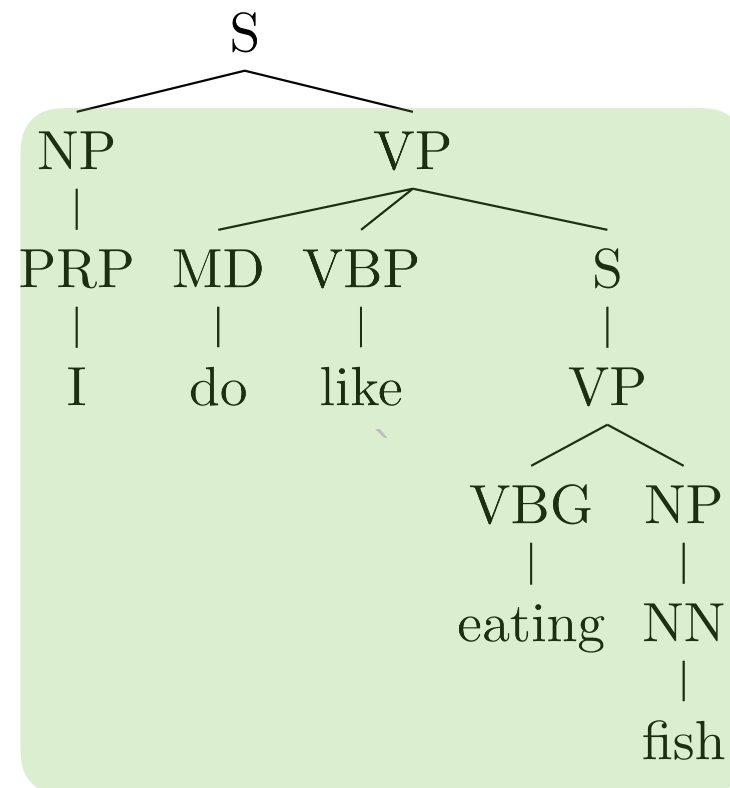

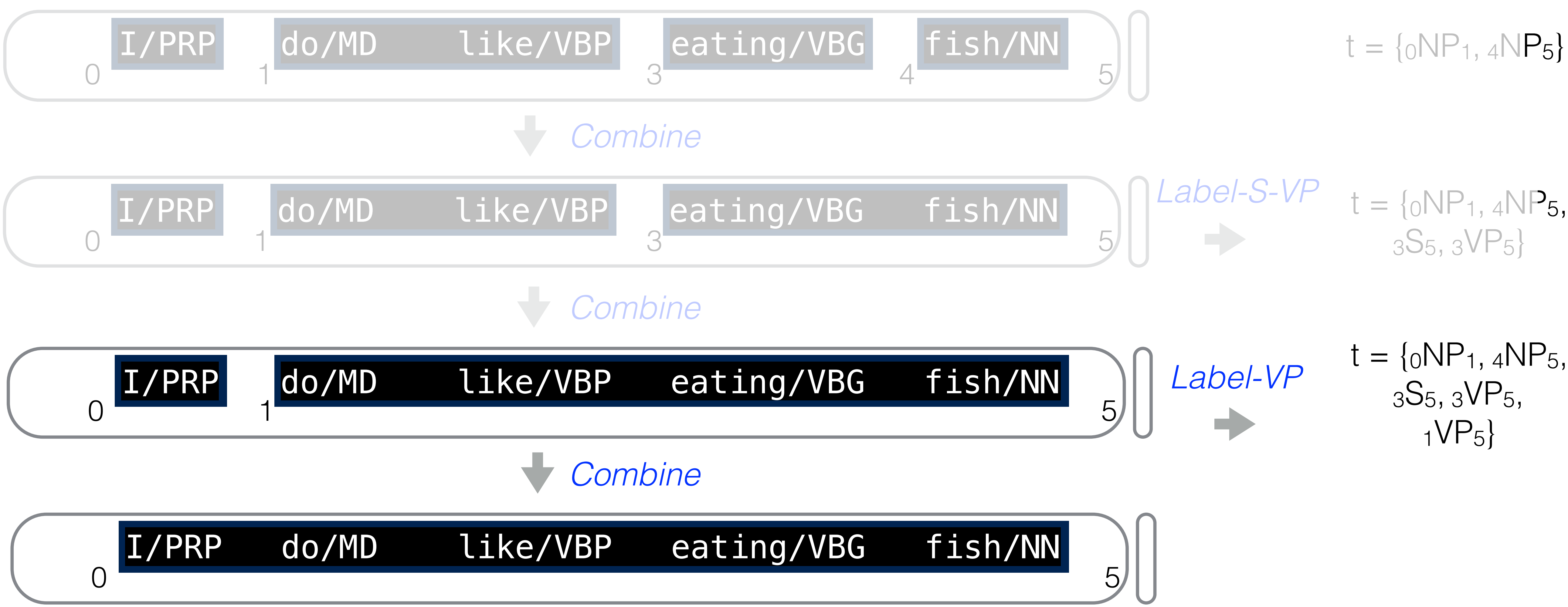

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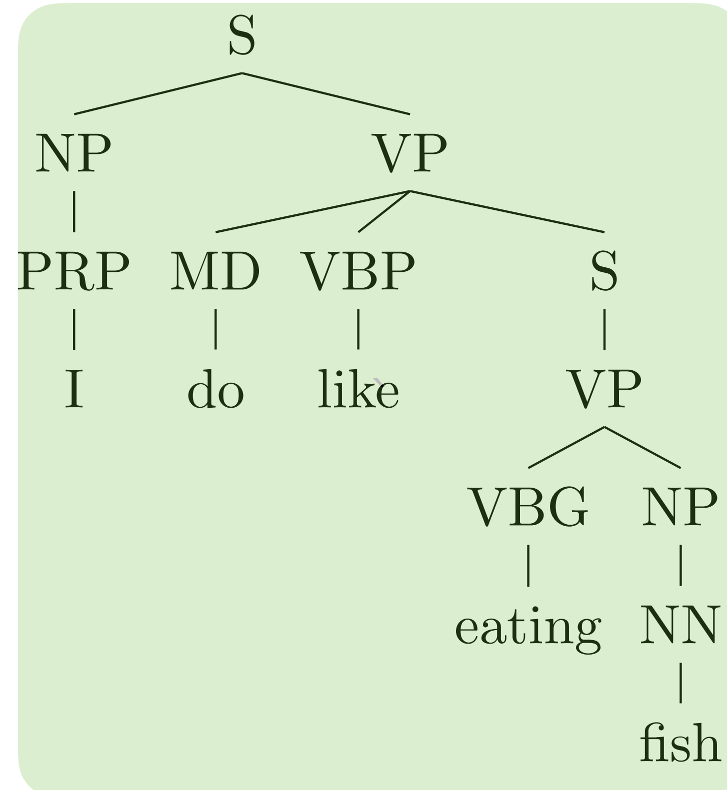
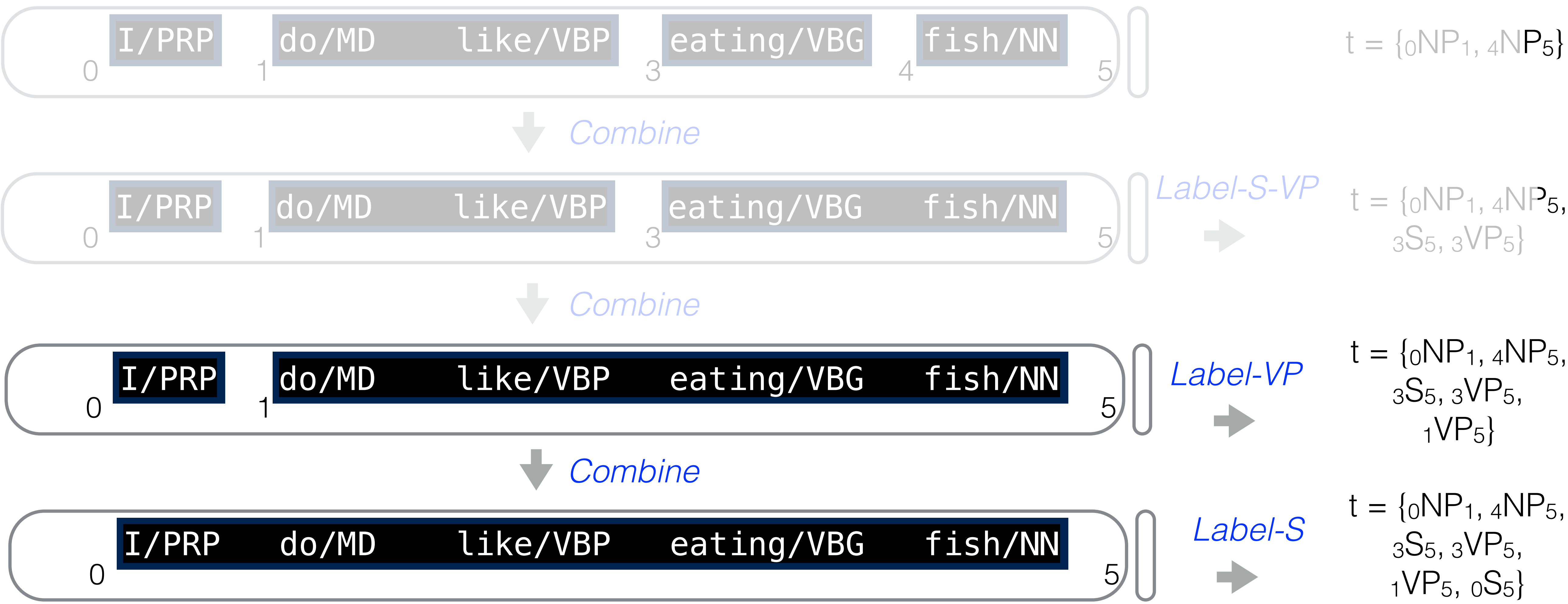
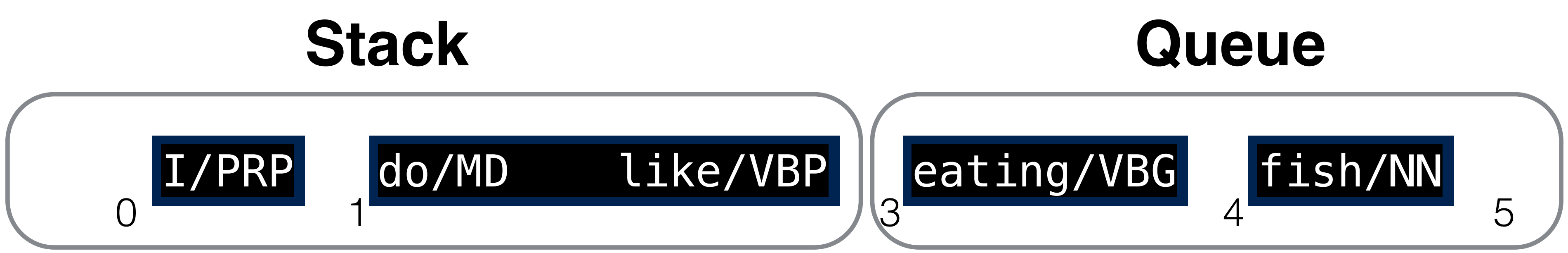




Advantages of Span-Based System

- Linear-time and fixed number of steps (well-suited for beam search)
- Separates prediction of structure and labels
- Predicts rules of arbitrary arity with no binarization



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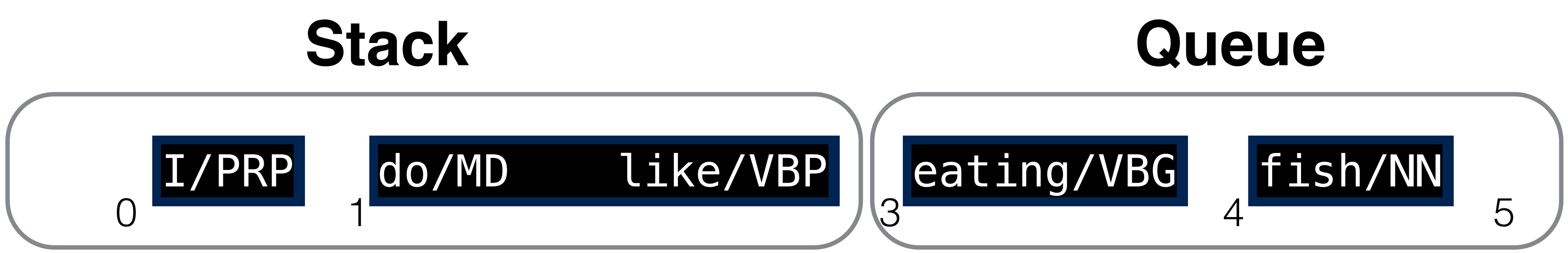

Q: How to decide which action to take?
What features represent spans?

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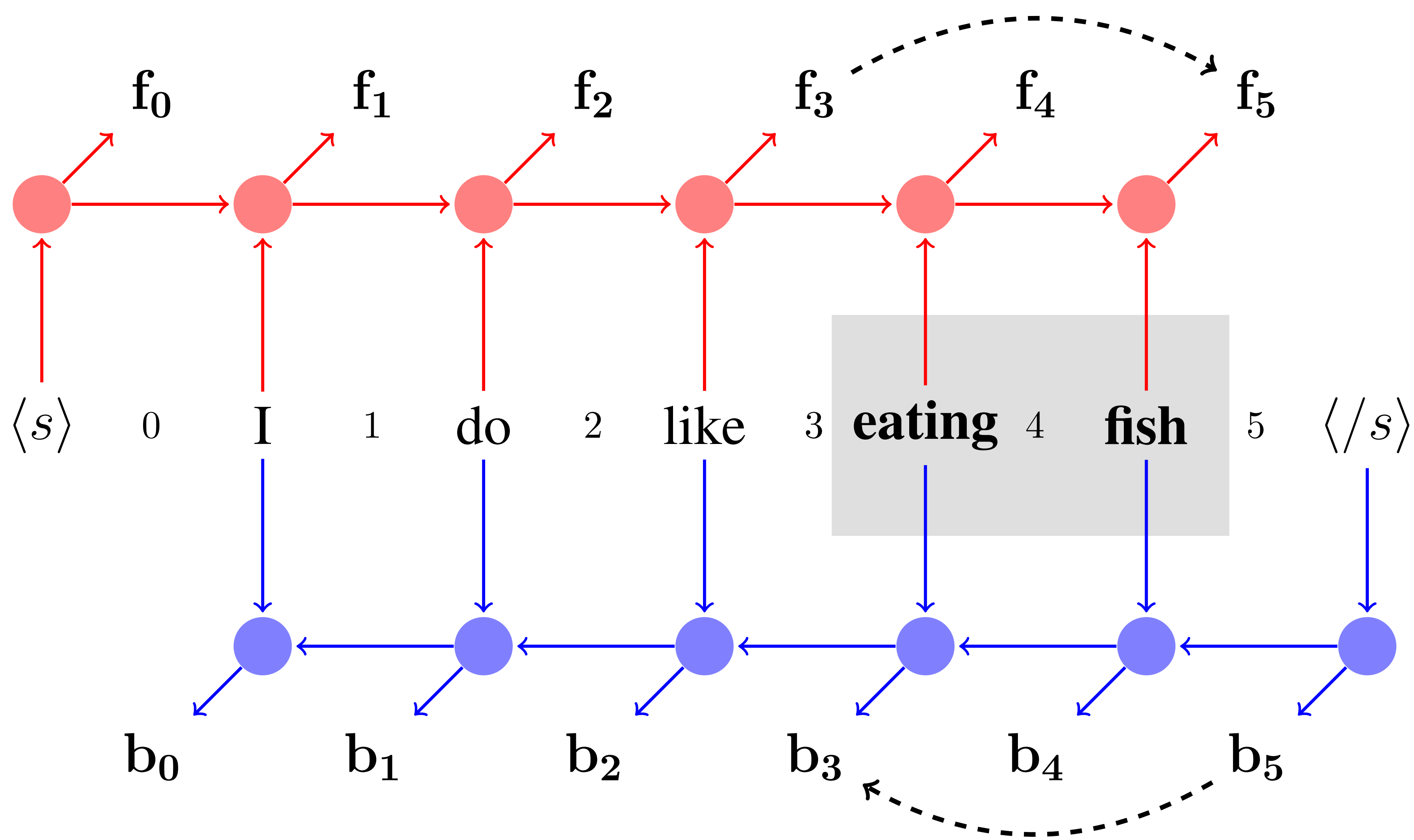
- Span-Based Constituency Parsing
- **Bi-Directional LSTM Span Features**
- Provably Optimal Dynamic Oracle
- Experiments

Bi-LSTM Span Features

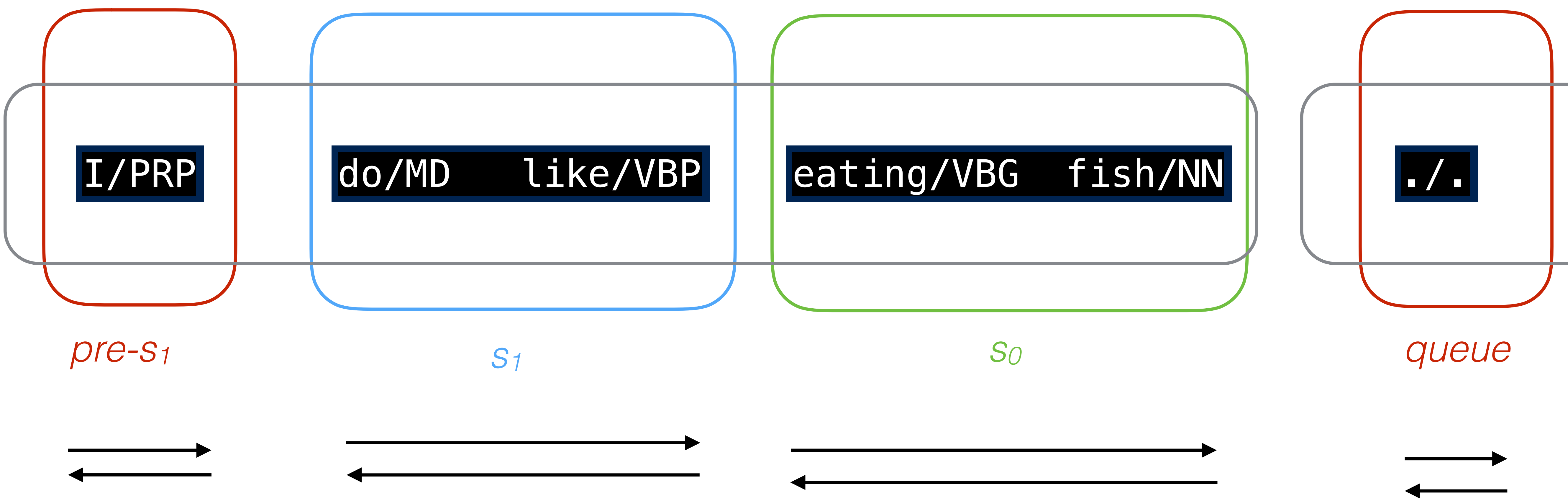


Sentence segment “eating fish” represented by two vectors:

- Forward component: f_5 - f_3 (Wang and Chang, ACL 2016)
- Backward component: b_3 - b_5

Span Features for Structure Action

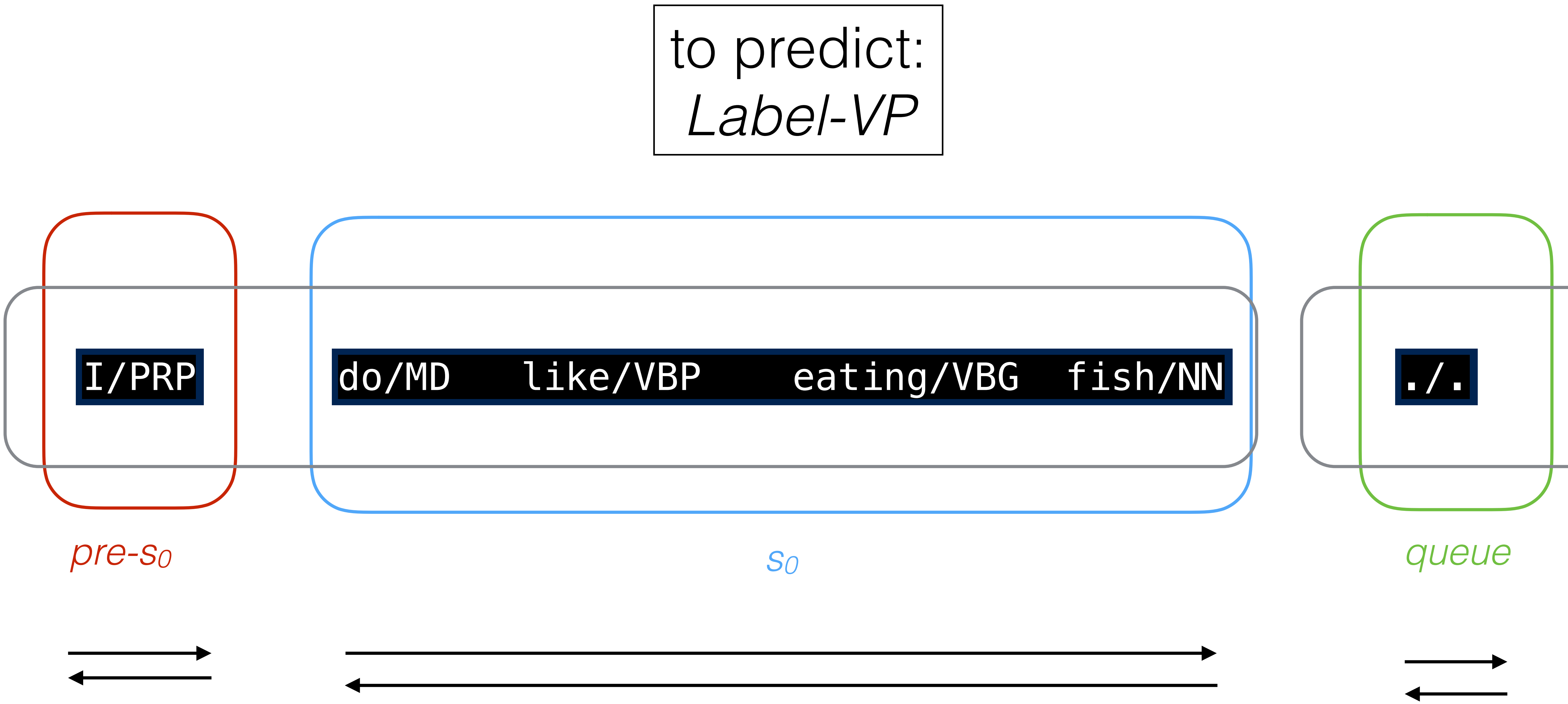
to predict:
Combine



4 bi-LSTM span features

(no tree-structure information used)

Span Features for Label Action

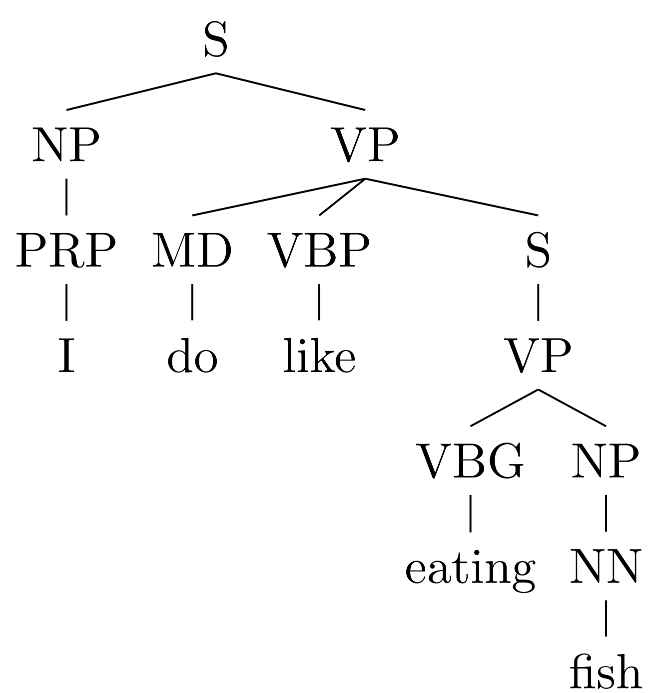


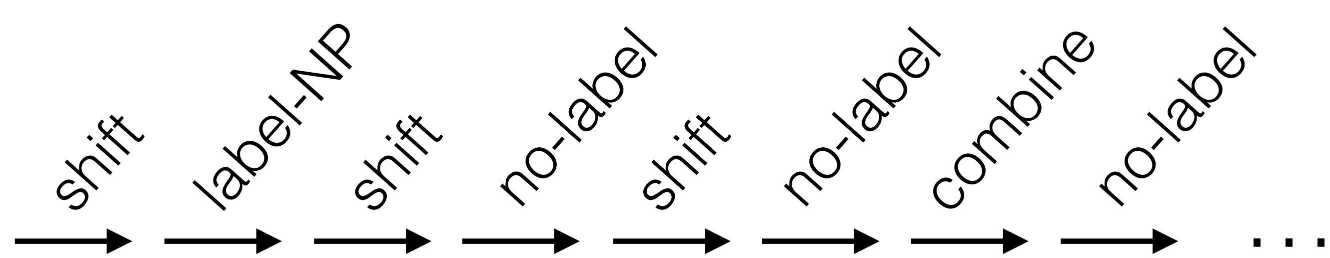
3 bi-LSTM span features

(no tree-structure information used)

Training Scheme: Local

- Every parser state is paired with a correct action
- Separate multilayer perceptron for each action type
- Baseline training scheme (static oracle) uses canonical order with short-stack preference





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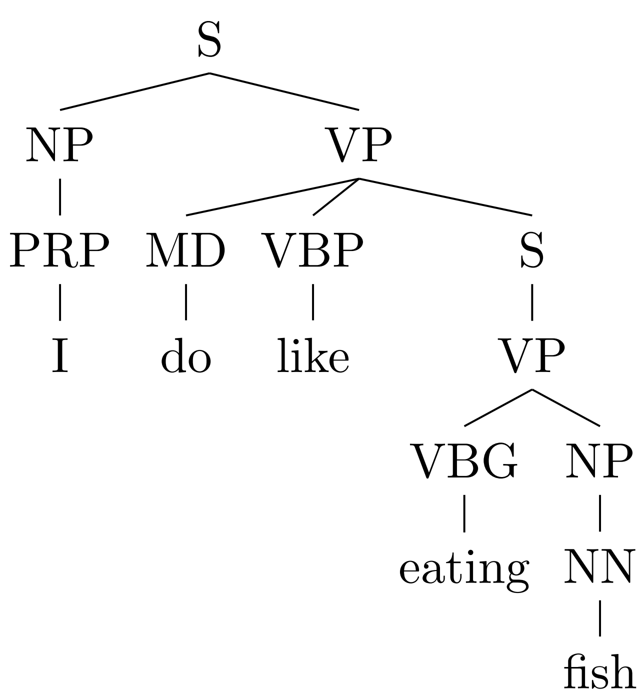

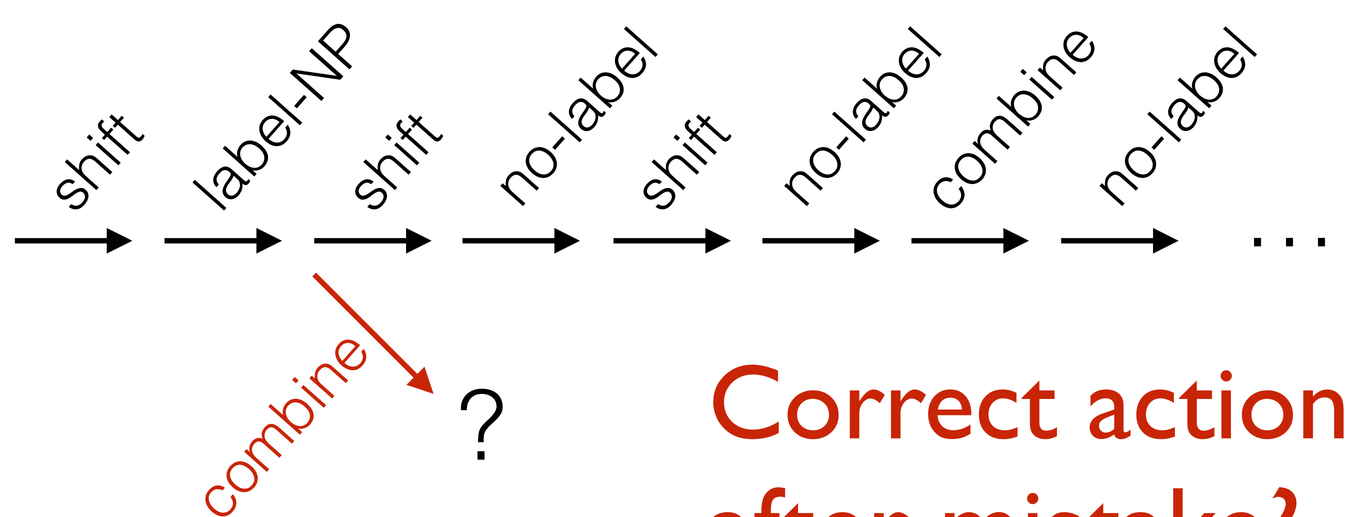

Correct action after mistake?

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- Span-Based Constituency Parsing
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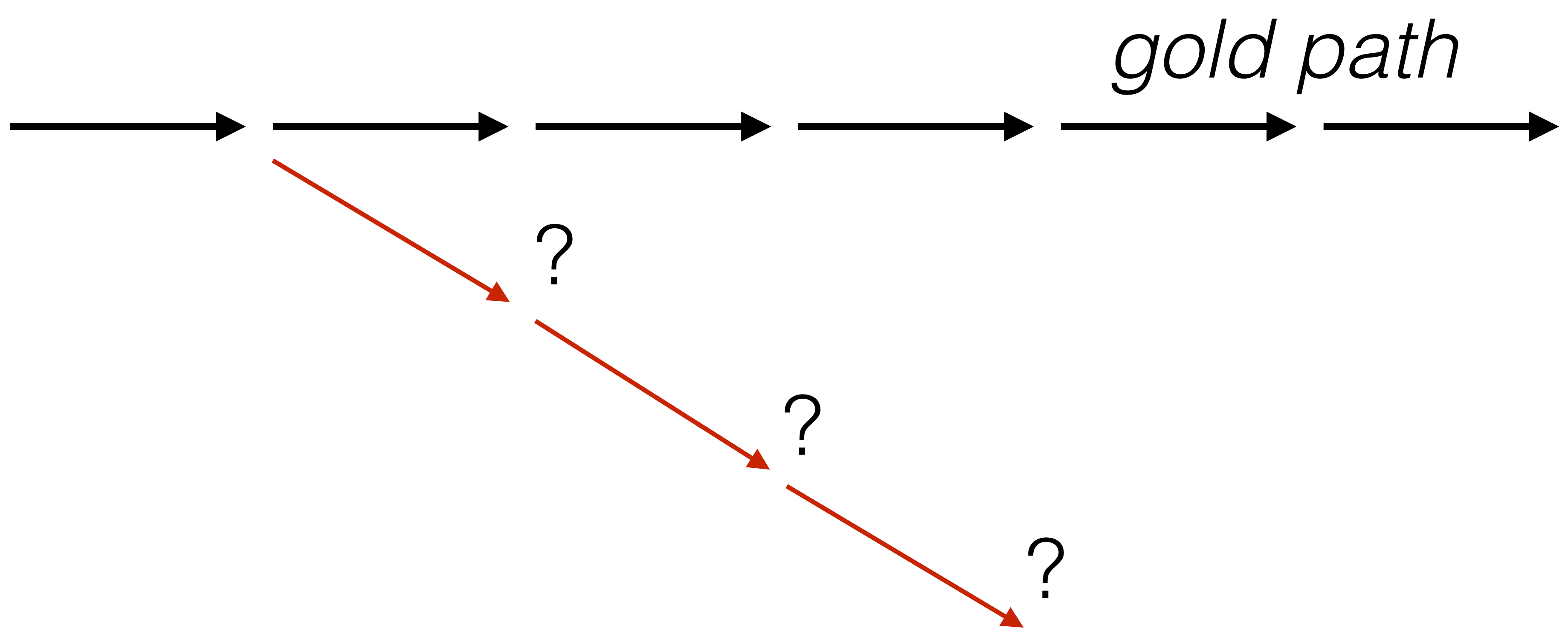
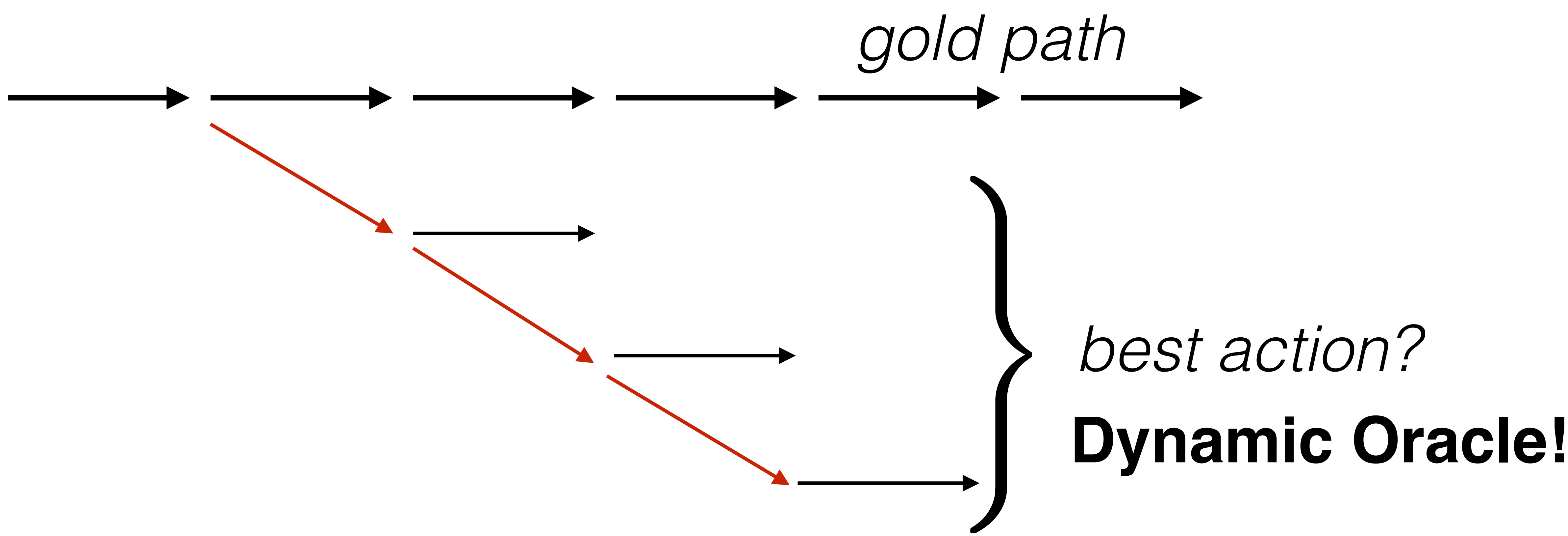
Dynamic Oracle: Motivation

- Static oracle training assumes all correct actions
- What to do after decoding mistakes?

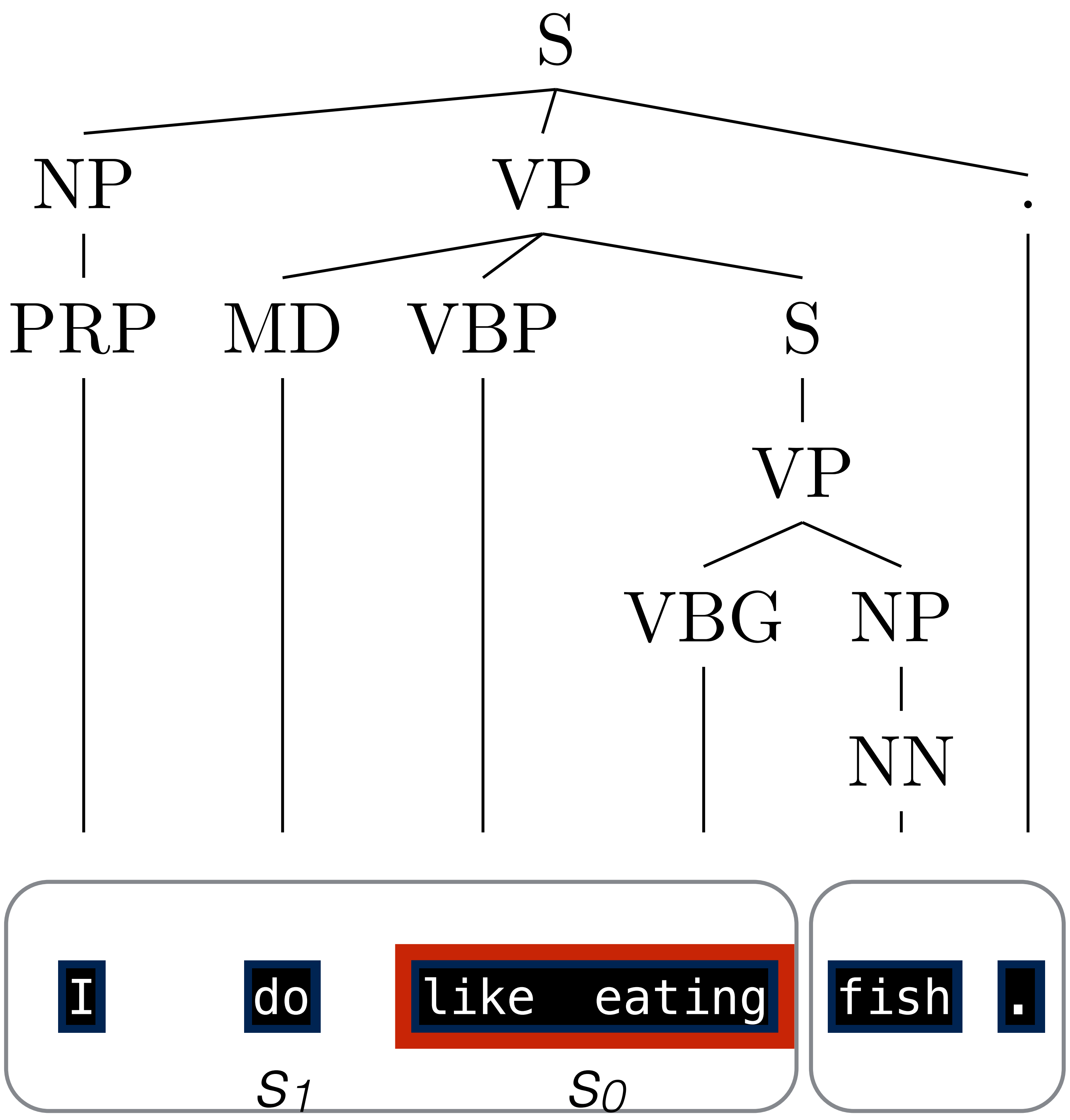


Dynamic Oracle: Motivation

- Static oracle training assumes all correct actions
- What to do after decoding mistakes?
- Need a way to decide best action in arbitrary state:
  Dynamic Oracle (everywhere-defined optimal policy)



Dynamic Oracle: Example



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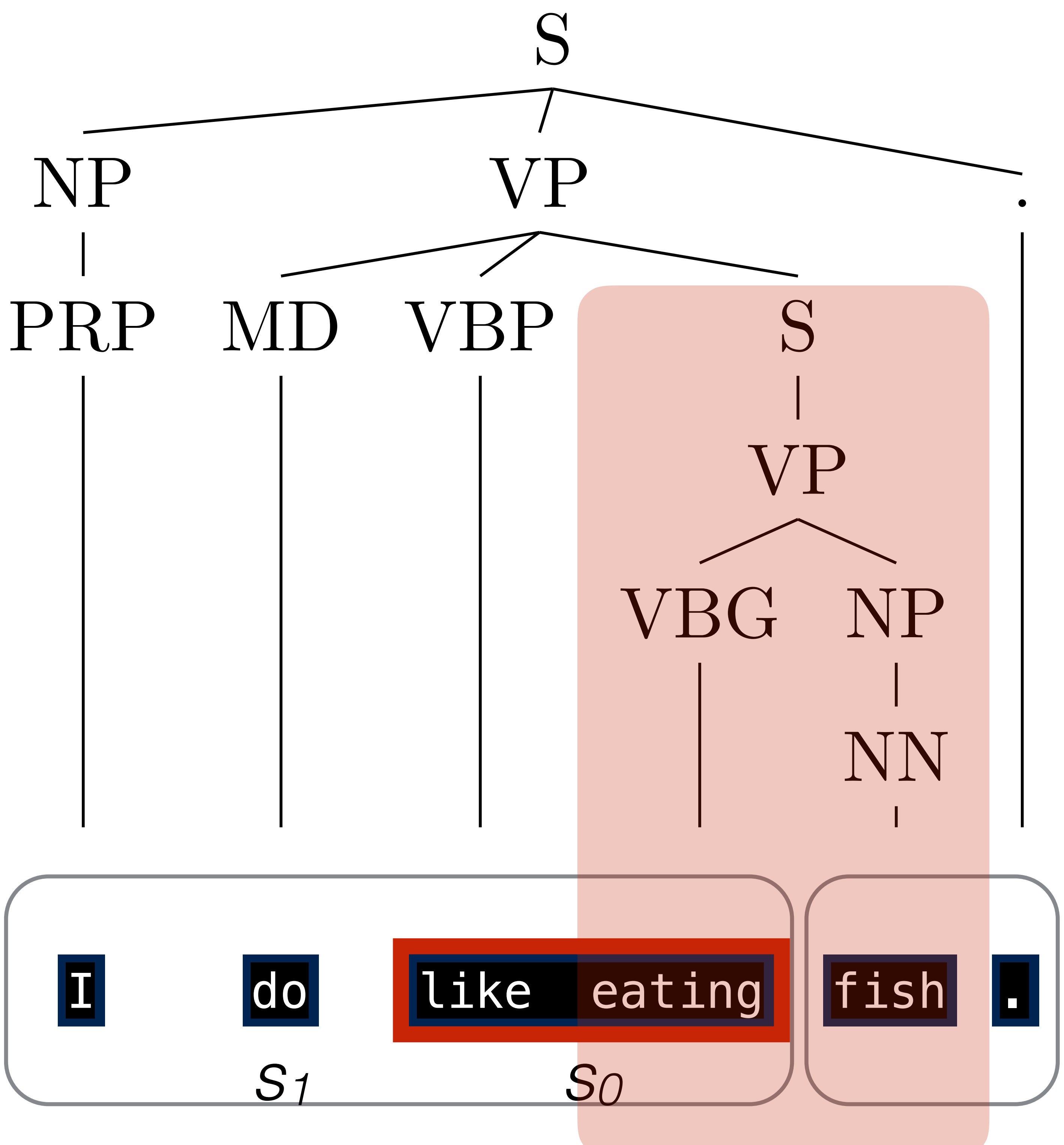

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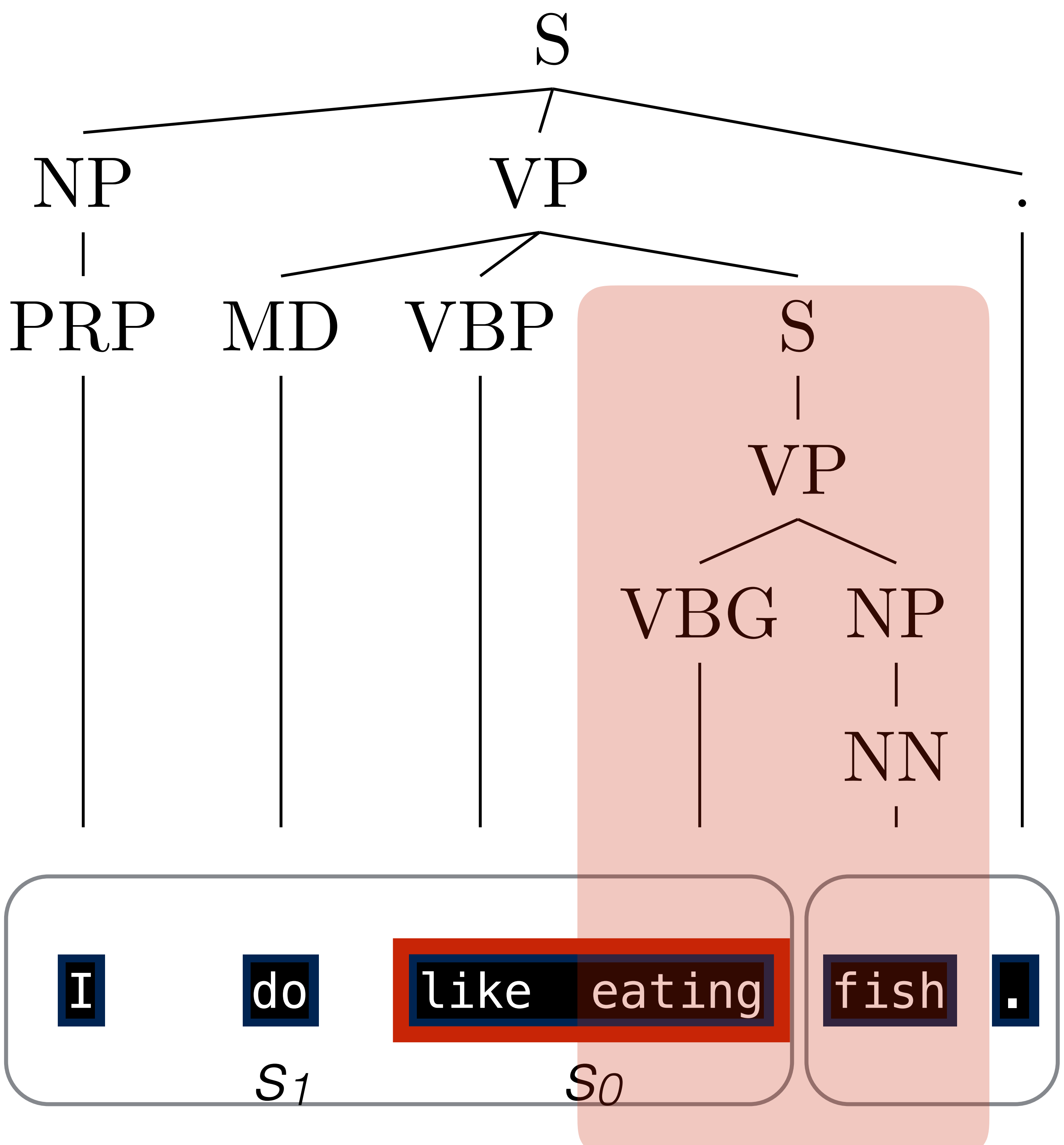

smallest reachable gold bracket incl. s_0

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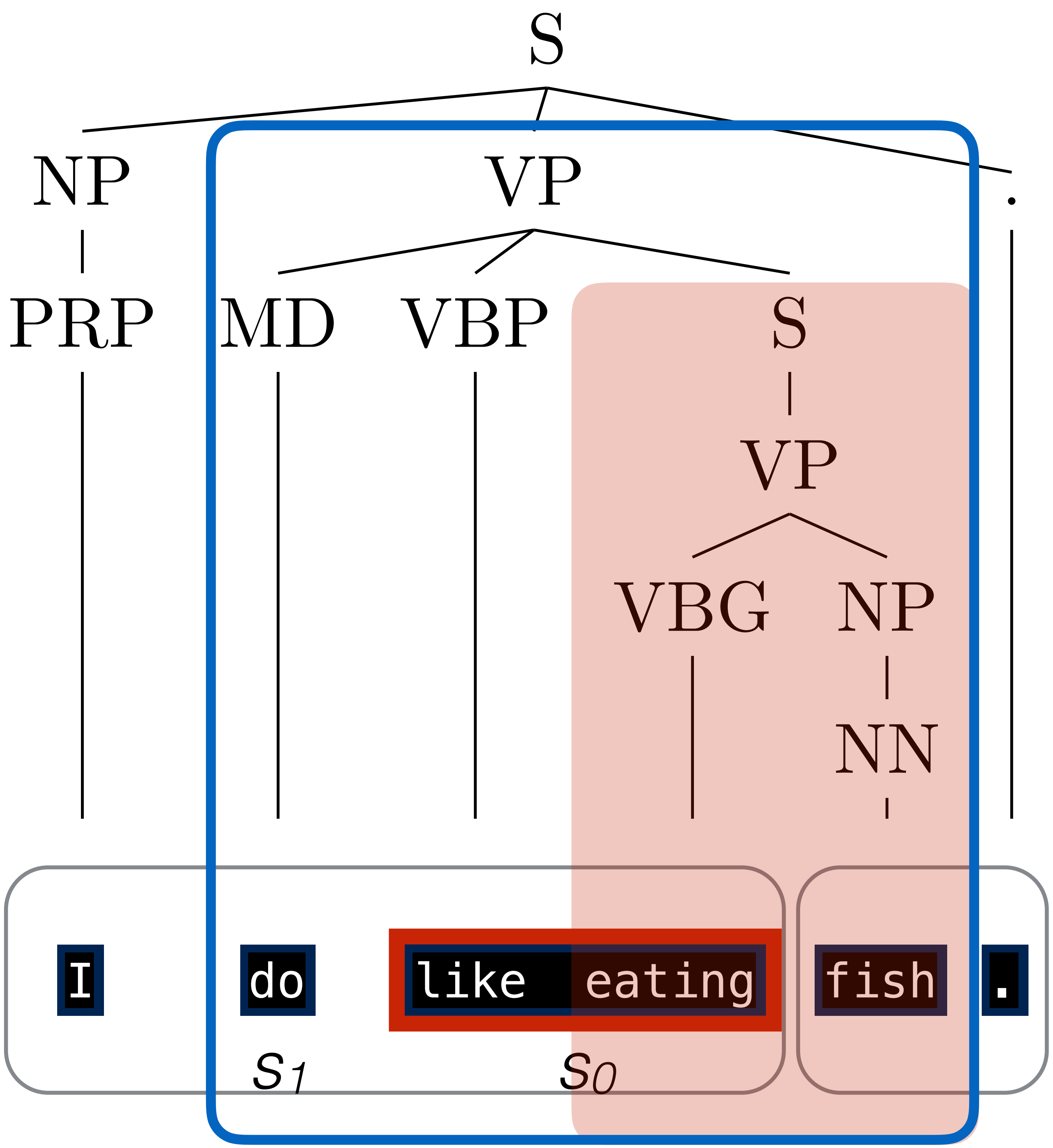
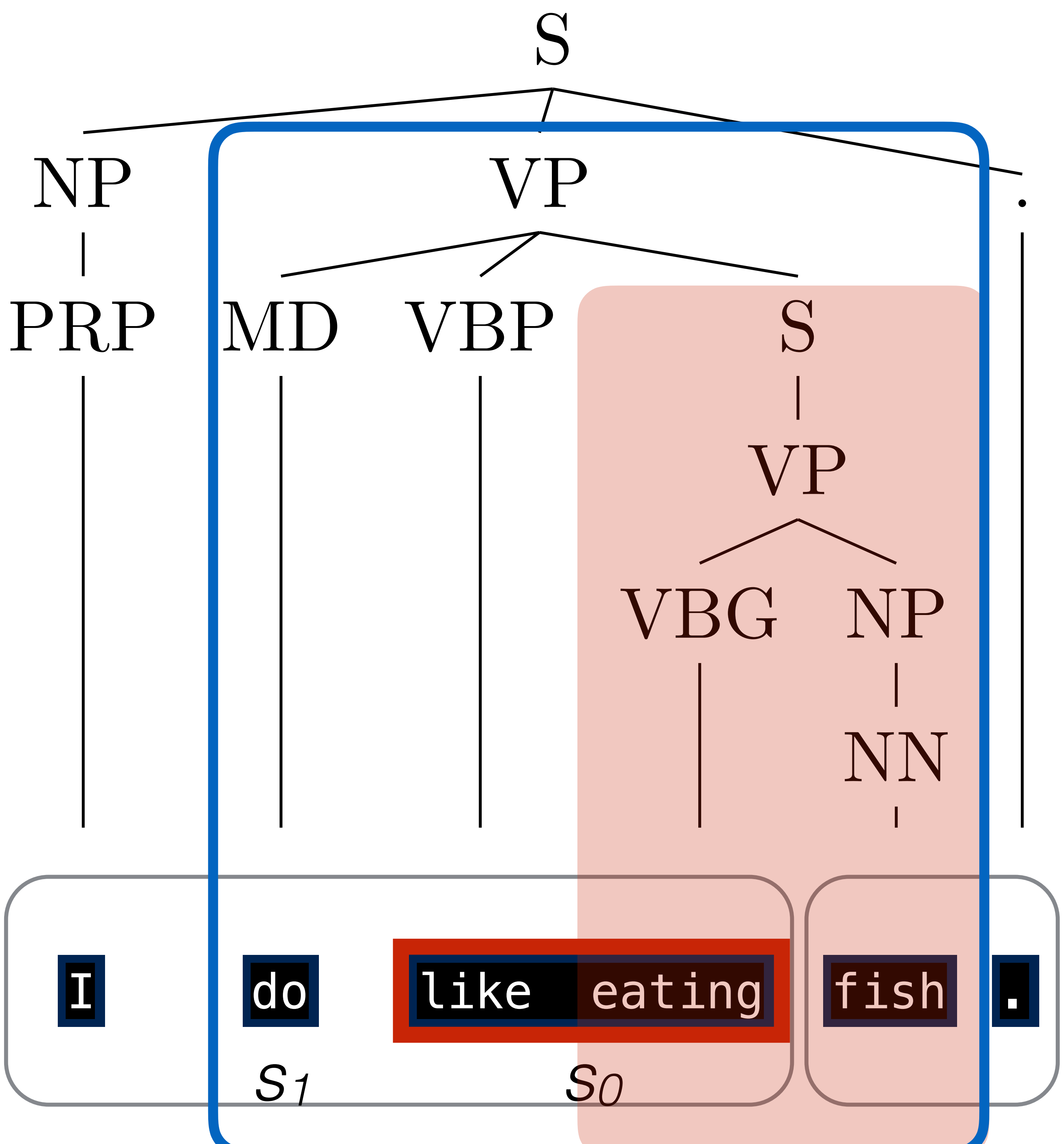
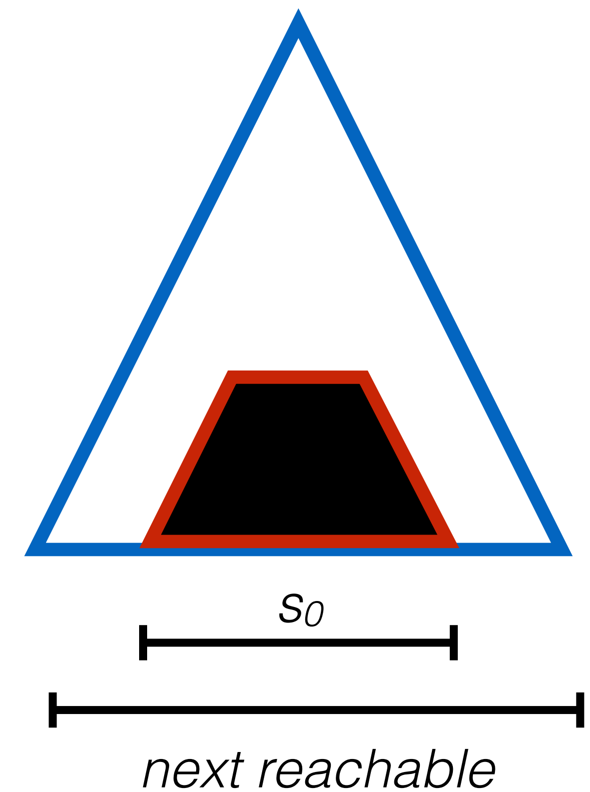


smallest reachable gold bracket incl. s_0

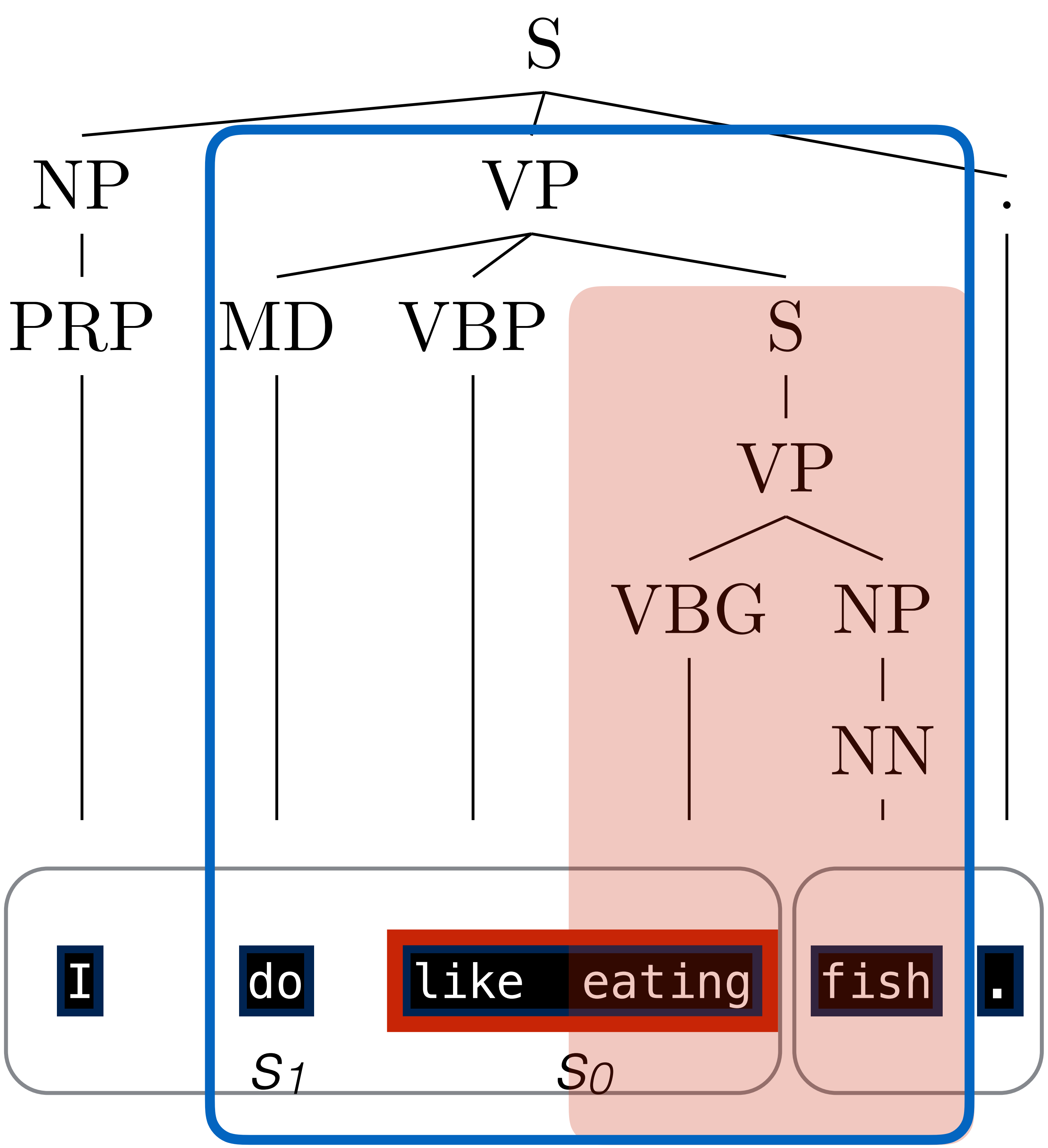
Dynamic Oracle: Example



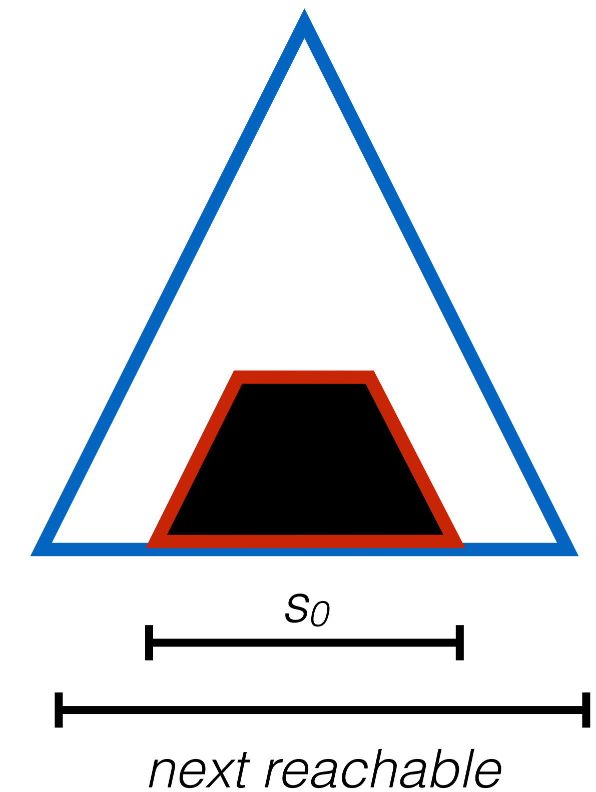
smallest reachable gold bracket incl. s_0



Dynamic Oracle: Example

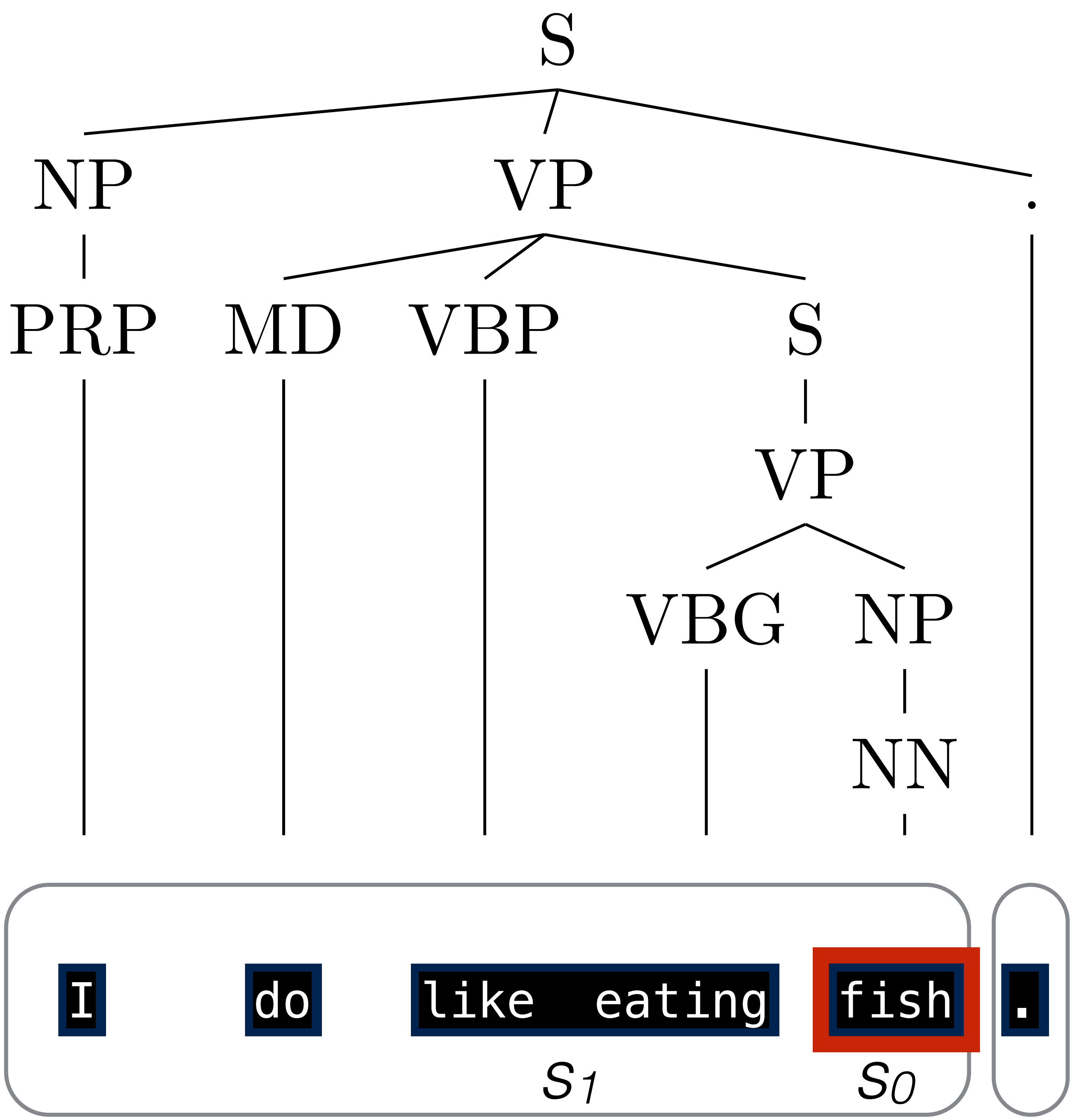


smallest reachable gold bracket incl. s_0

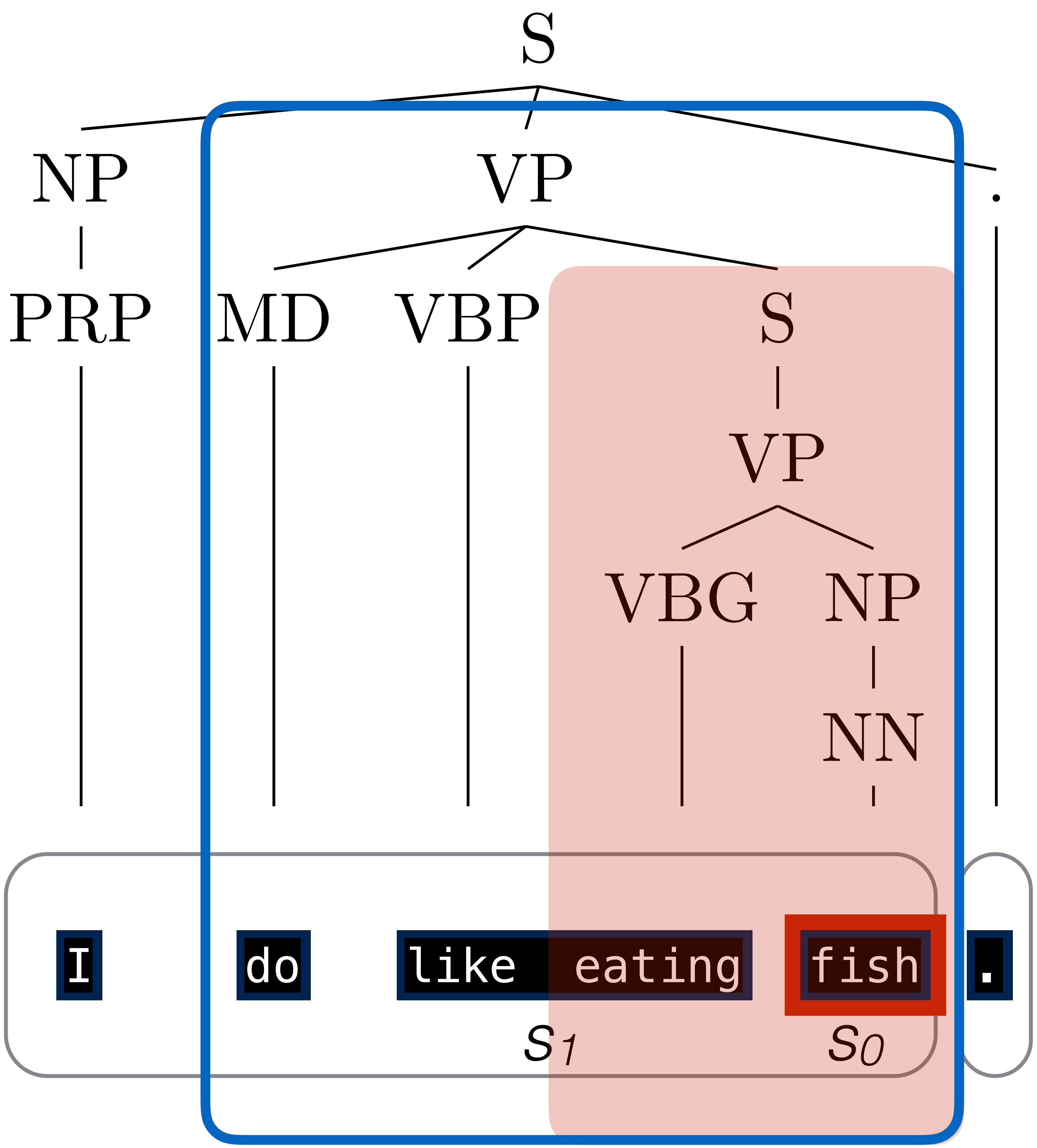


Dynamic Oracle: Shift or Combine

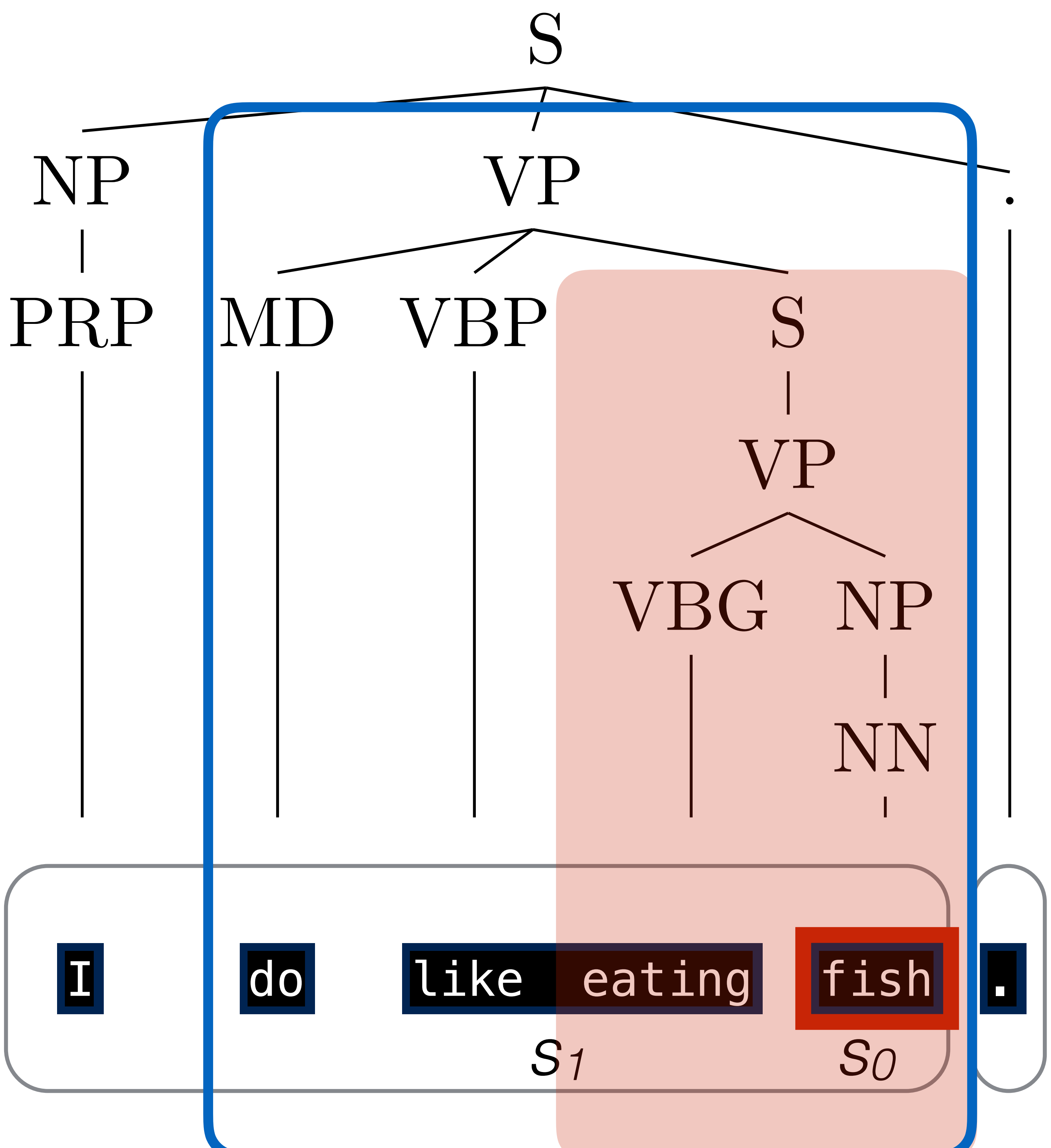
Dynamic Oracle: Example



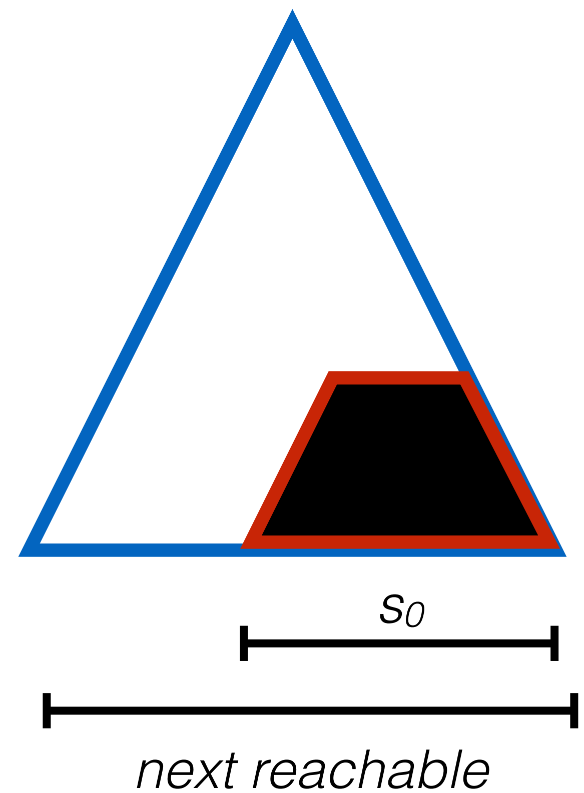
Dynamic Oracle: Example



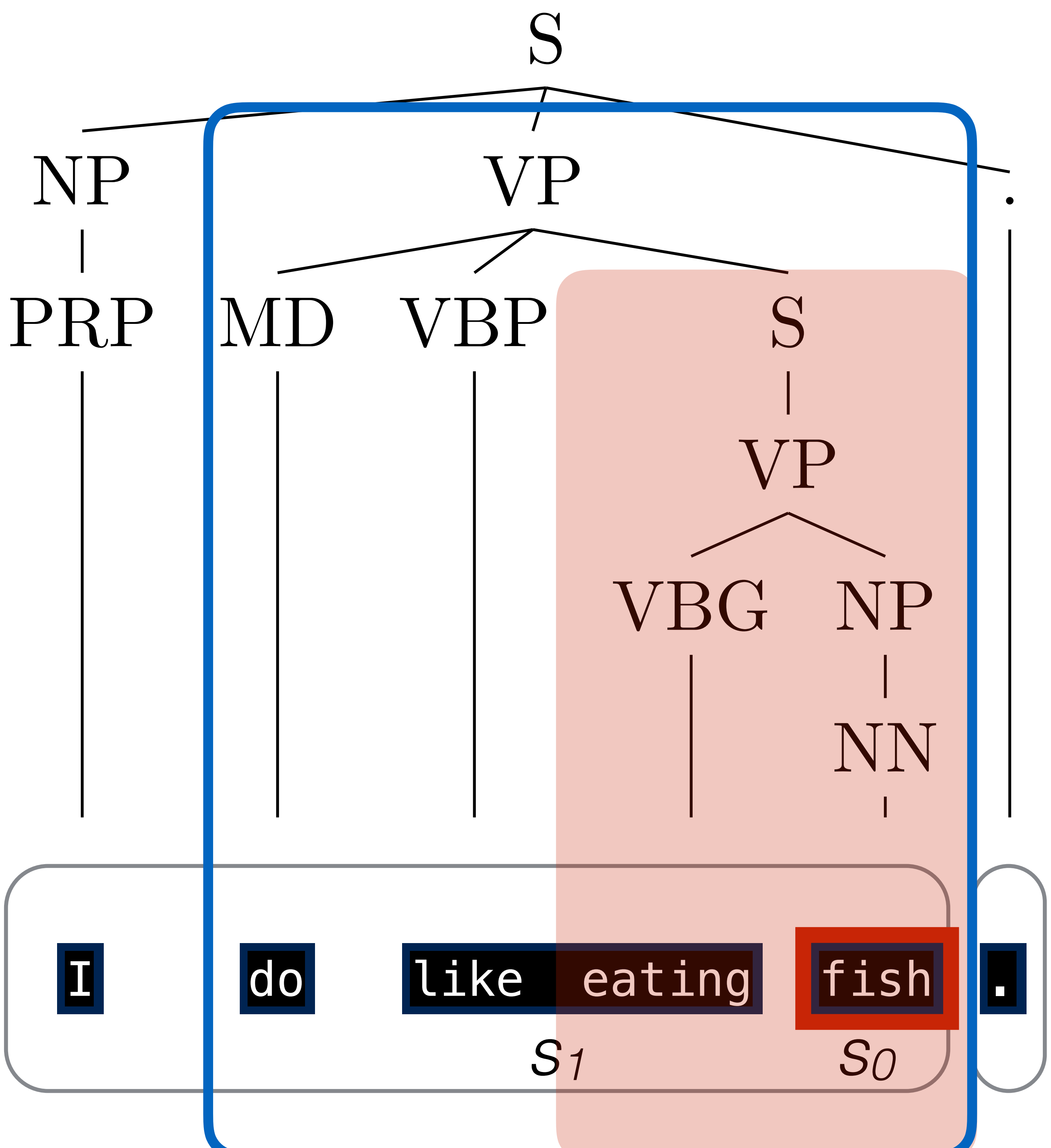
Dynamic Oracle: Example



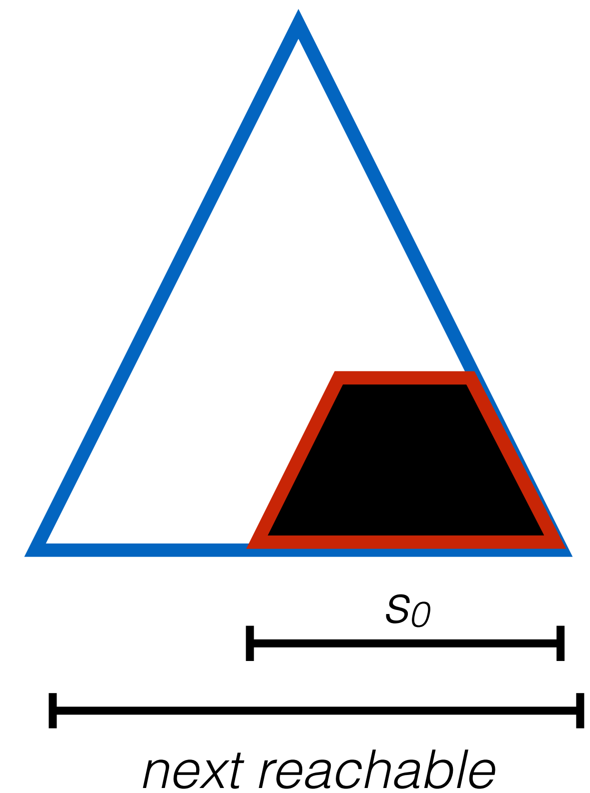
smallest reachable gold bracket incl. s_0



Dynamic Oracle: Example

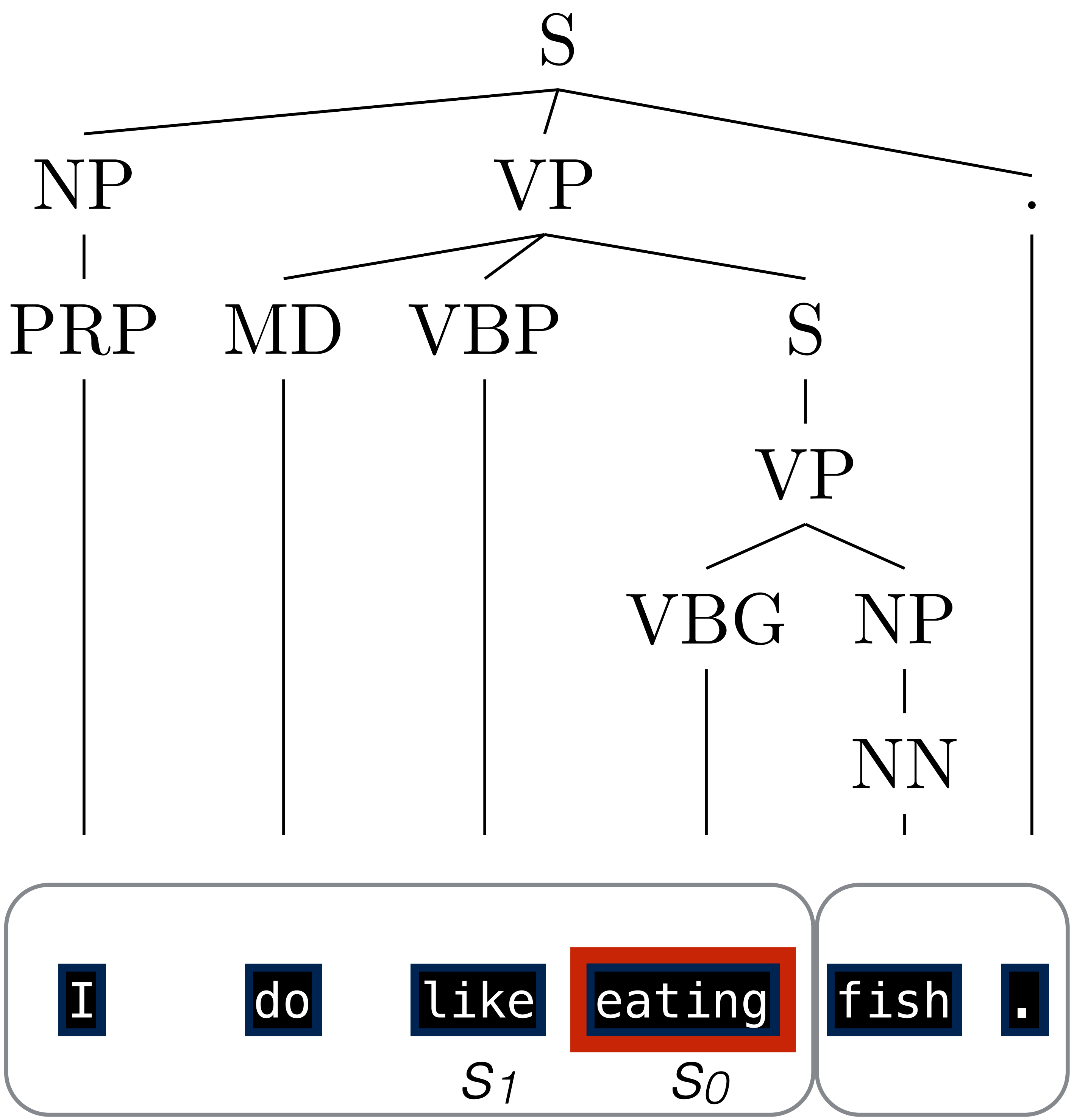


smallest reachable gold bracket incl. s_0

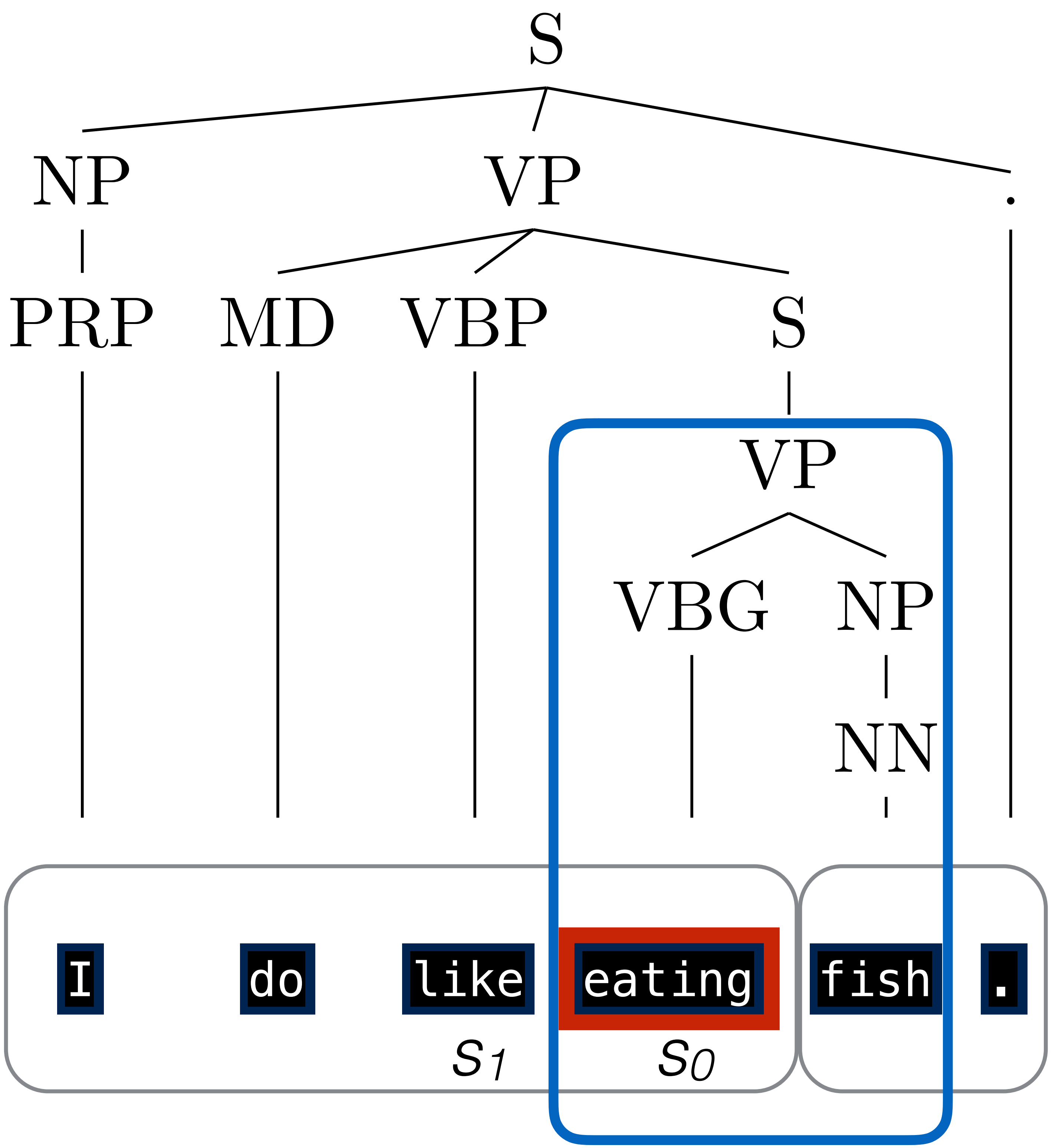


Dynamic Oracle: Combine

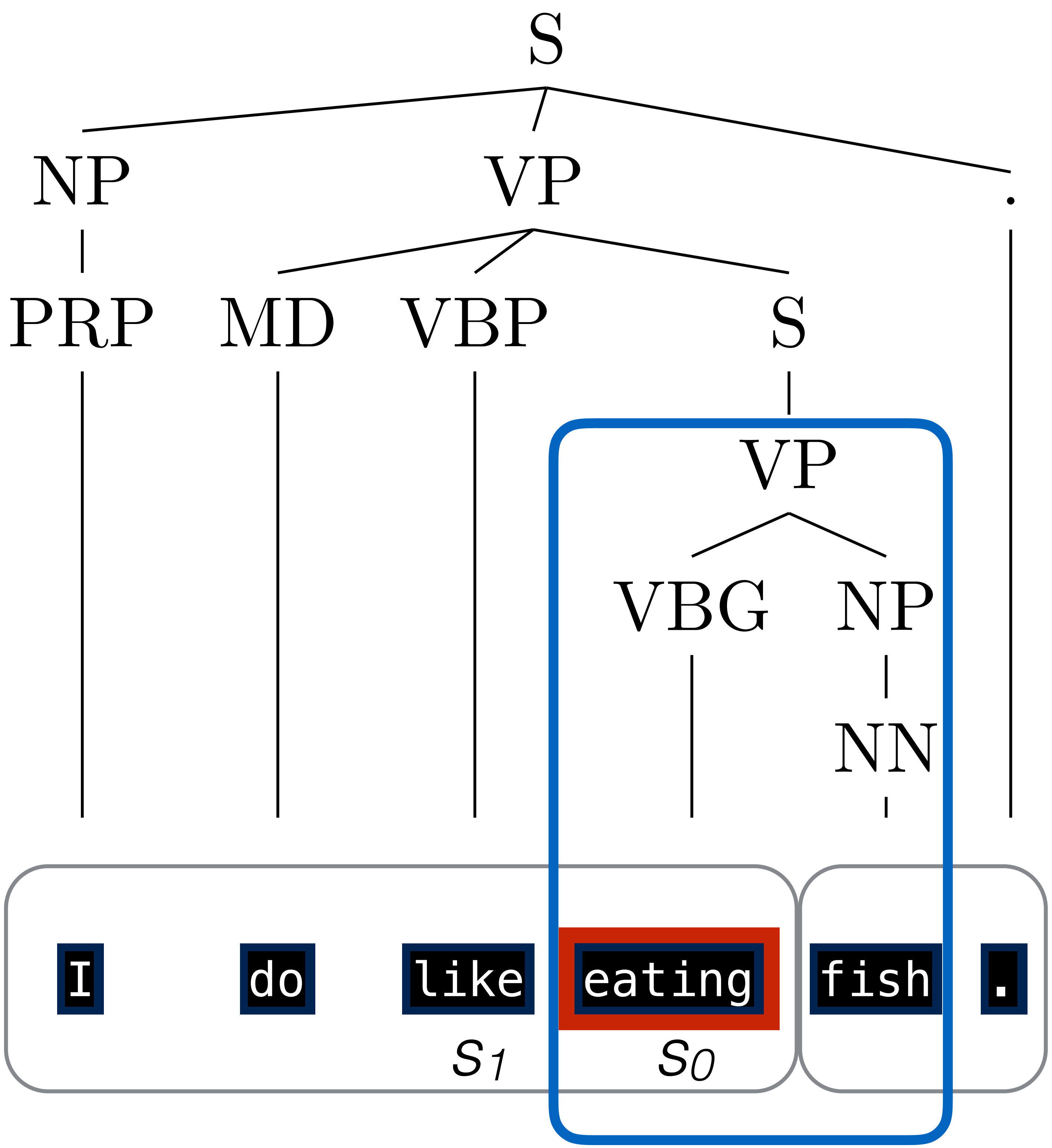
Dynamic Oracle: Example



Dynamic Oracle: Example



Dynamic Oracle: Example



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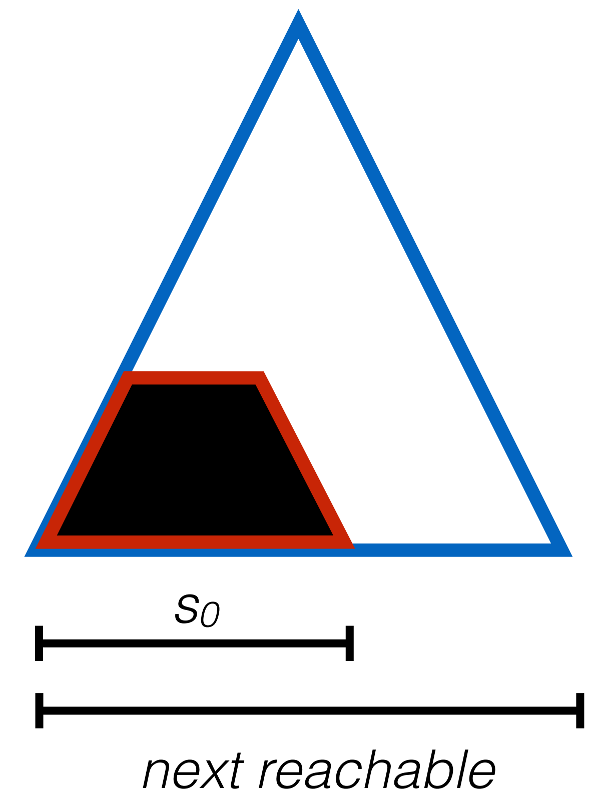

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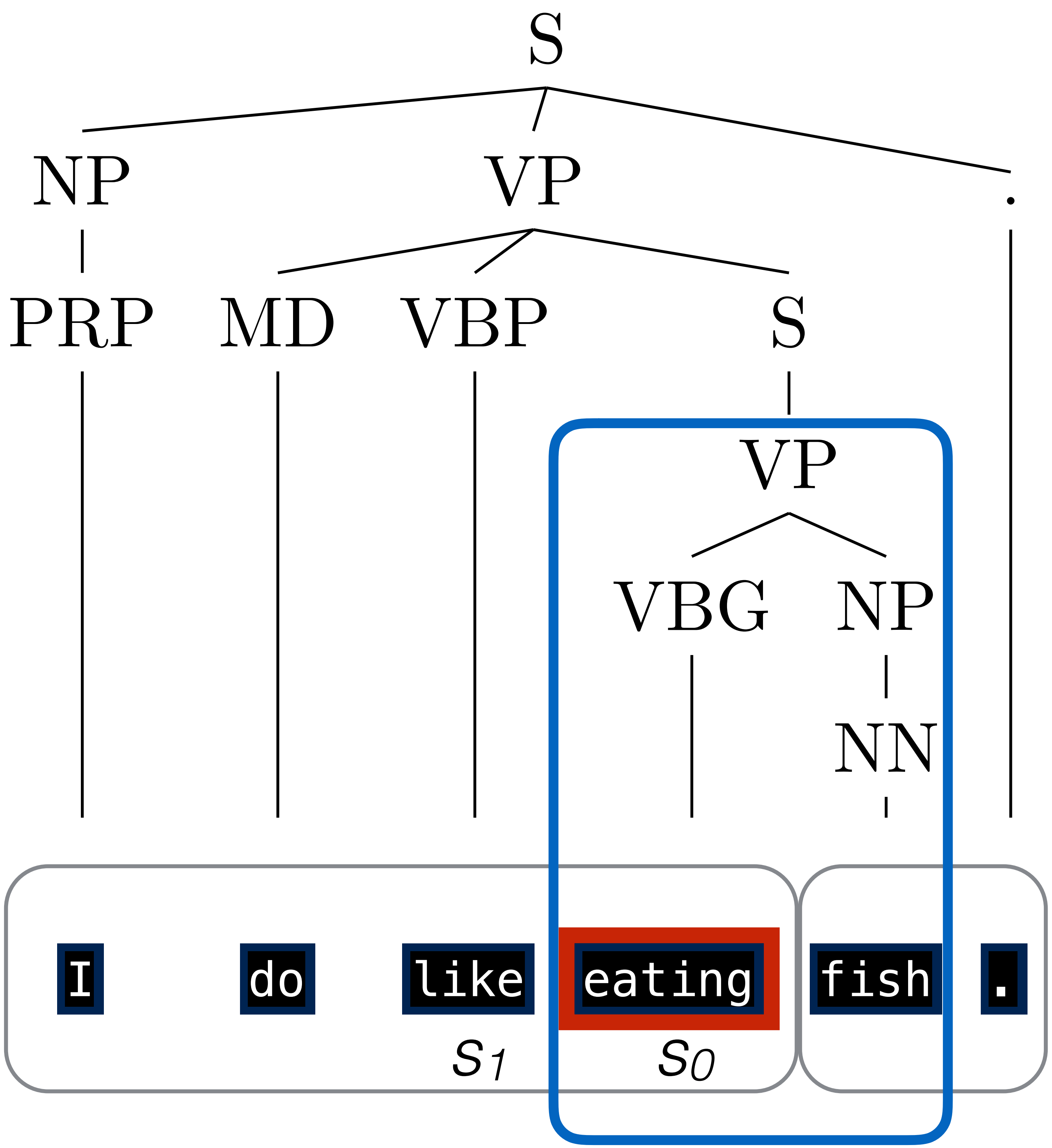

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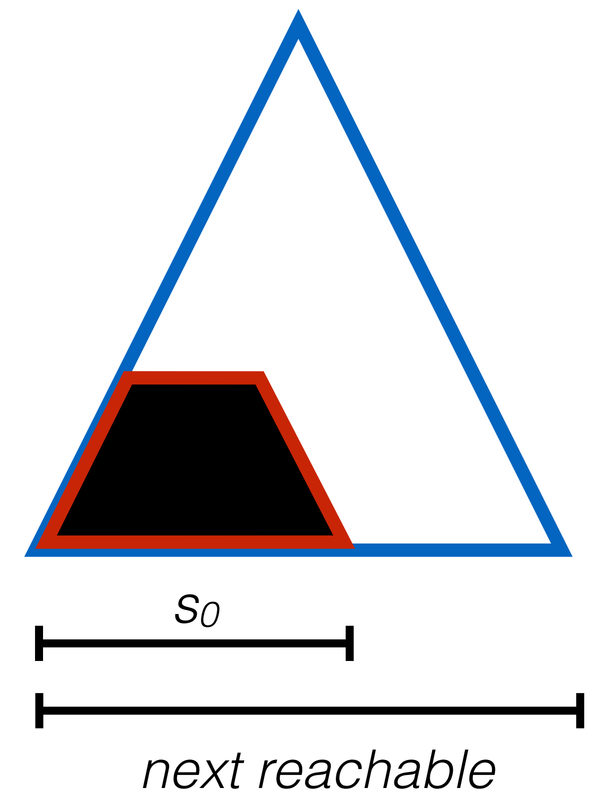
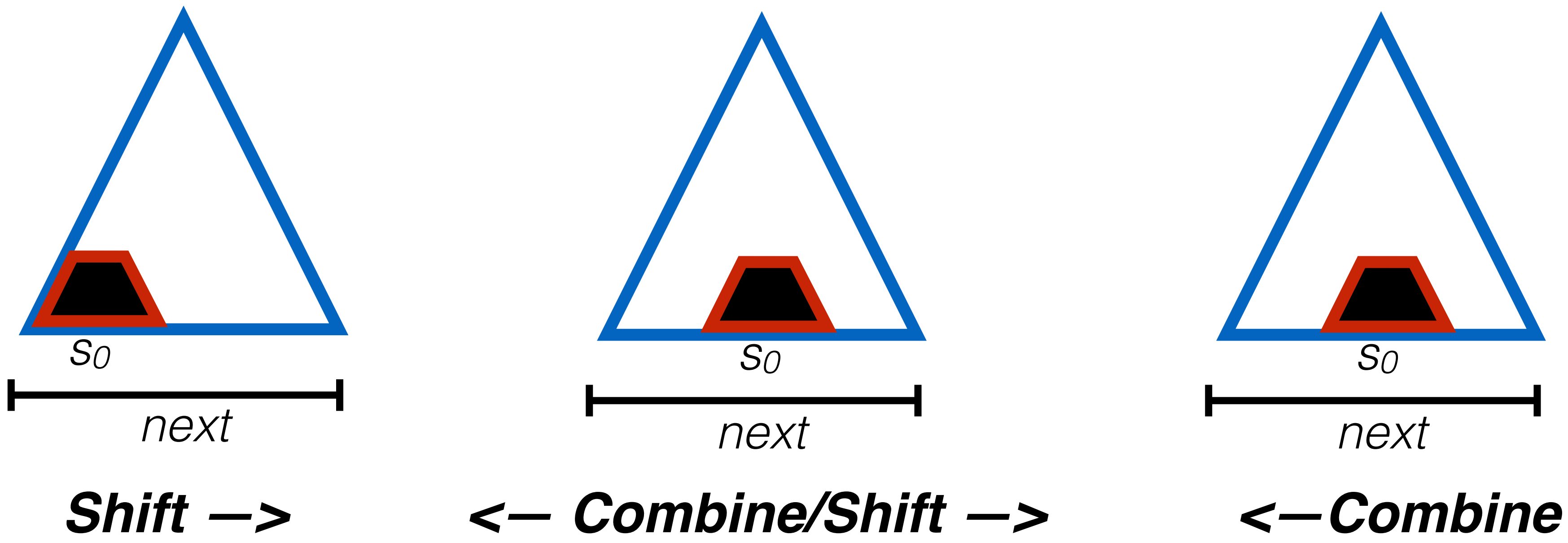


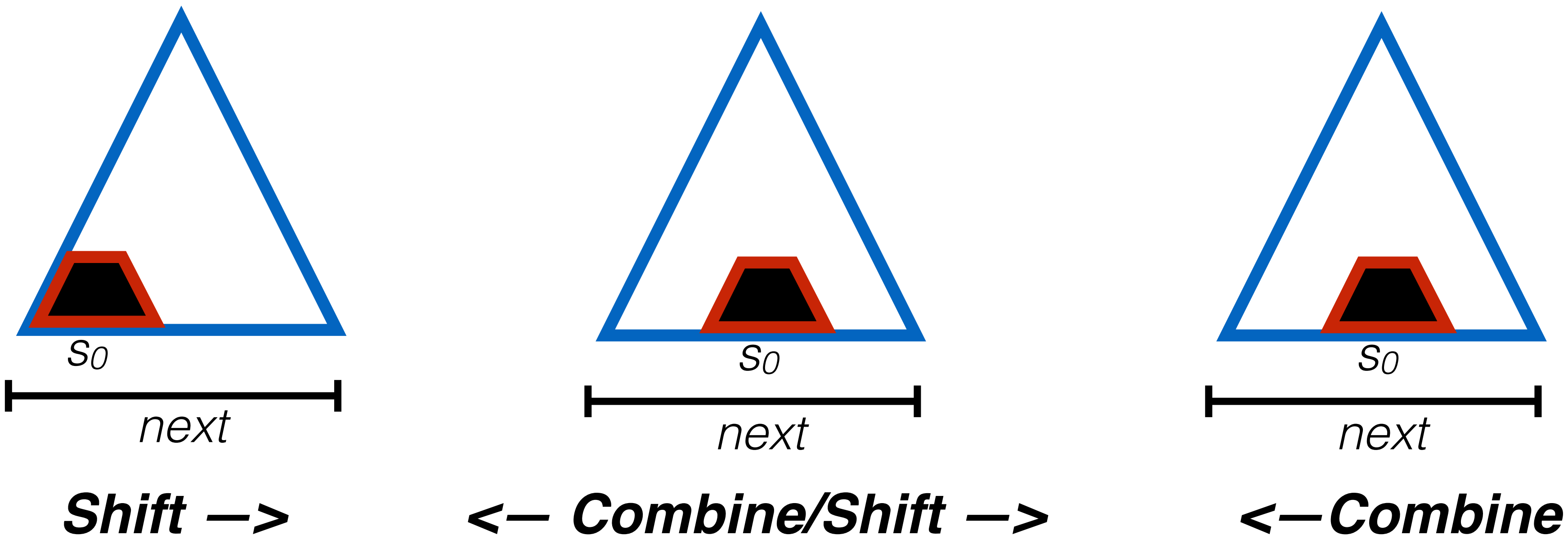
Dynamic Oracle: Shift

Dynamic Oracle: Full Definition



- Structure actions depend on next reachable bracket in gold tree
- All non-bracket label states —> *No-Label*
- All gold-bracket label states —> Correct label(s)

Dynamic Oracle: Full Definition



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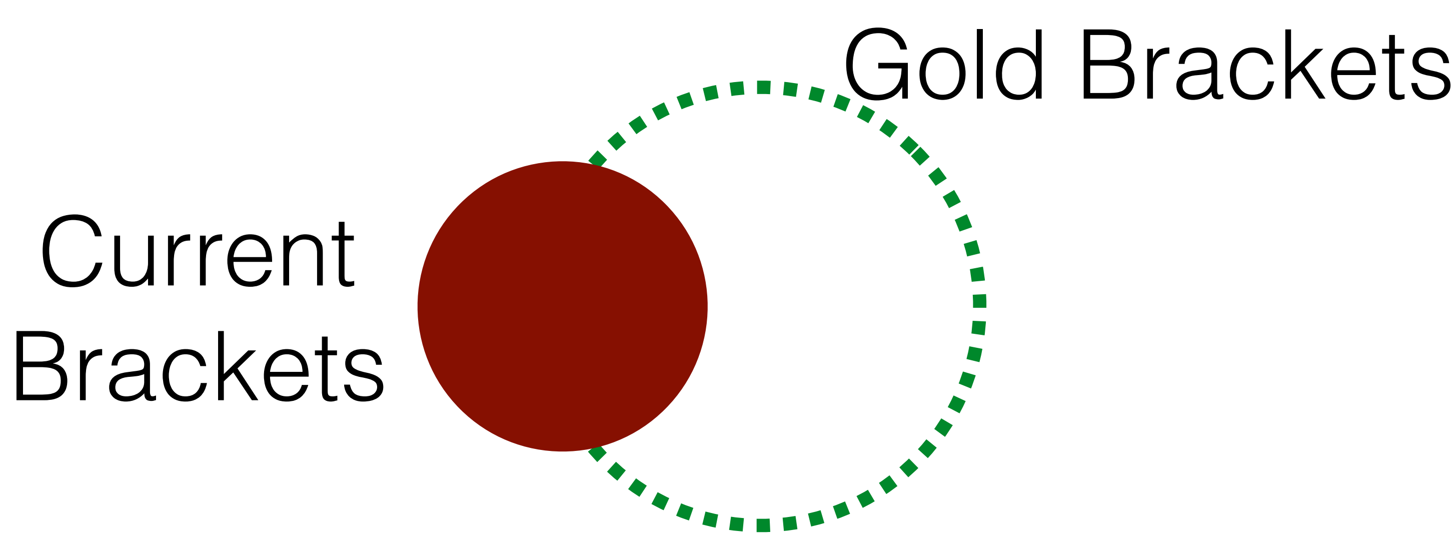

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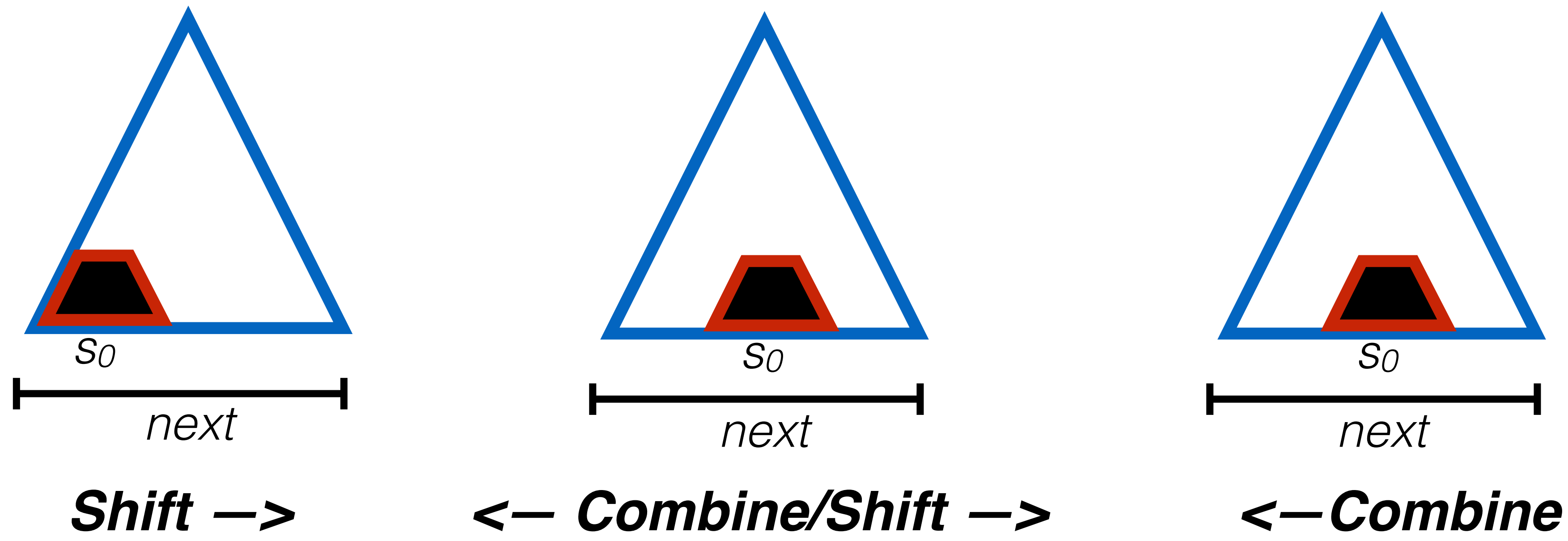

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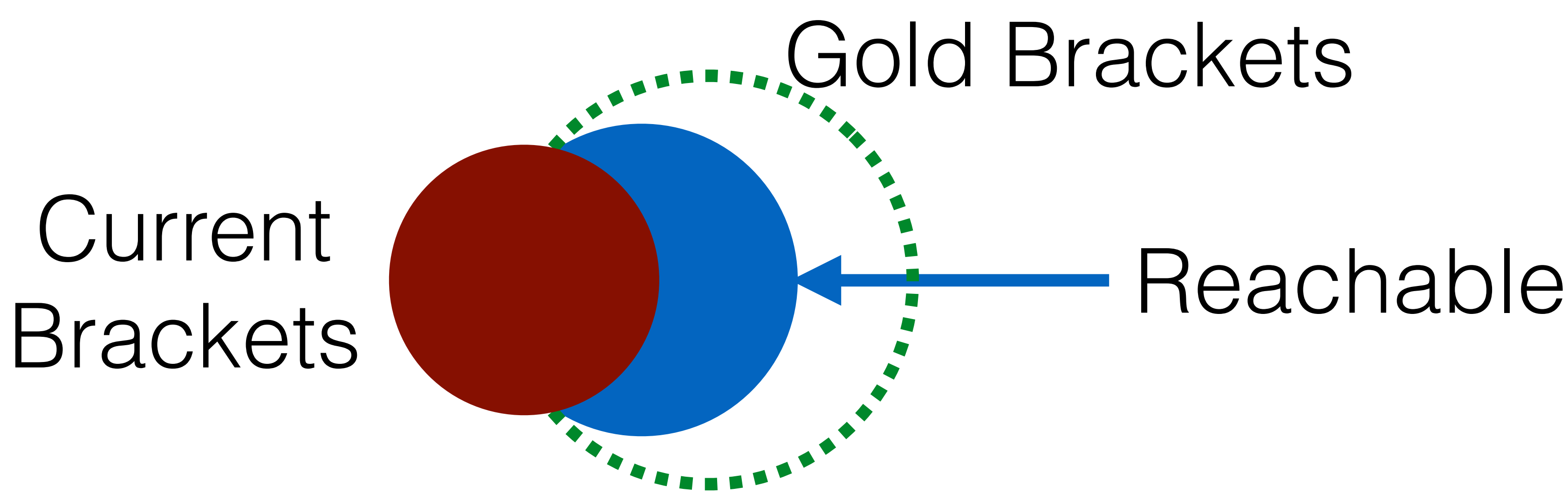

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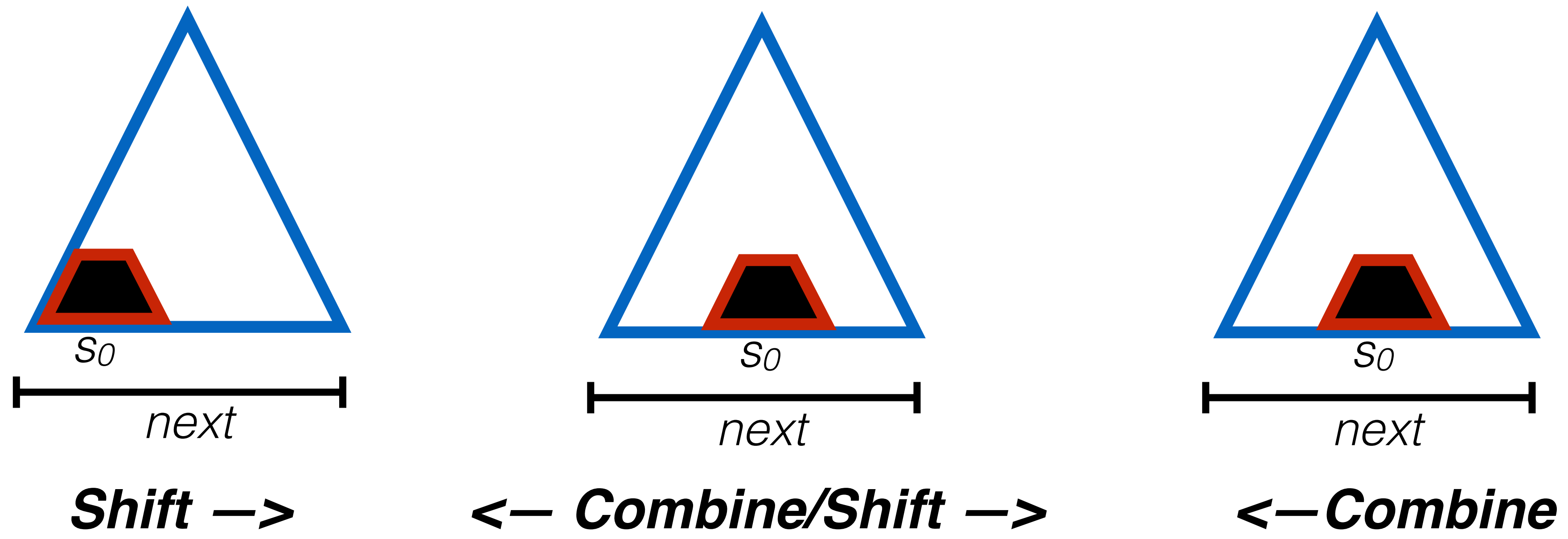

- Structure actions depend on next <u>reachable</u> bracket in gold tree
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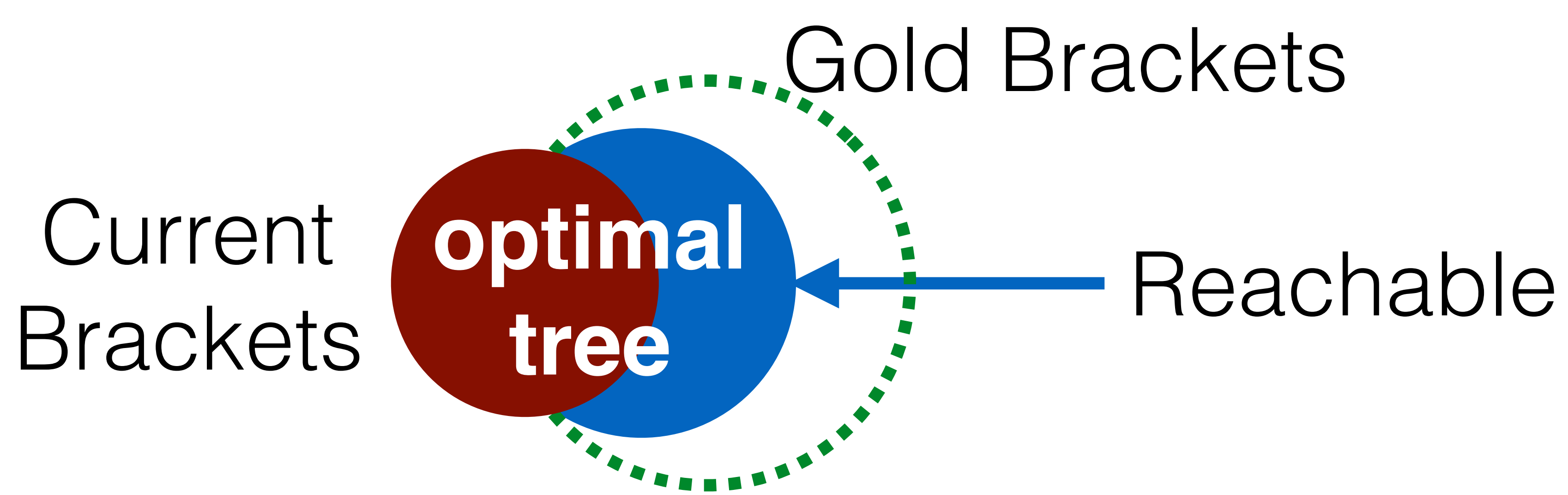
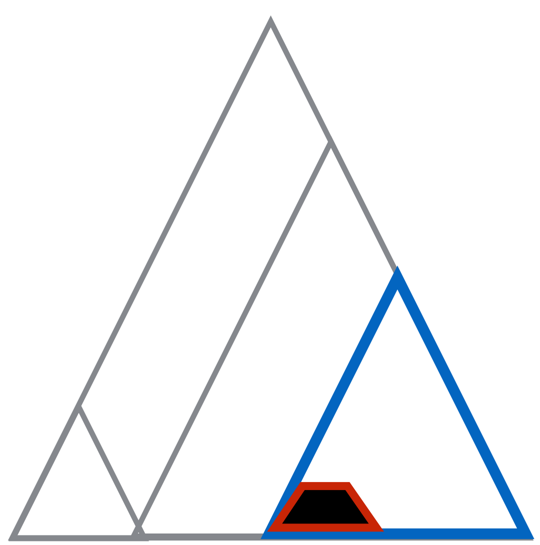


Dynamic Oracle: Optimality/Complexity

- First provably optimal oracle for constituency parsing (optimal in both precision and recall)
- After each action next reachable may (or may not) be updated by tracing parent link in gold tree
- Also $O(n)$ steps, thus amortized $O(1)$ time
- Dependency parsing oracle (arc-std): worst case $O(n^3)$ per step



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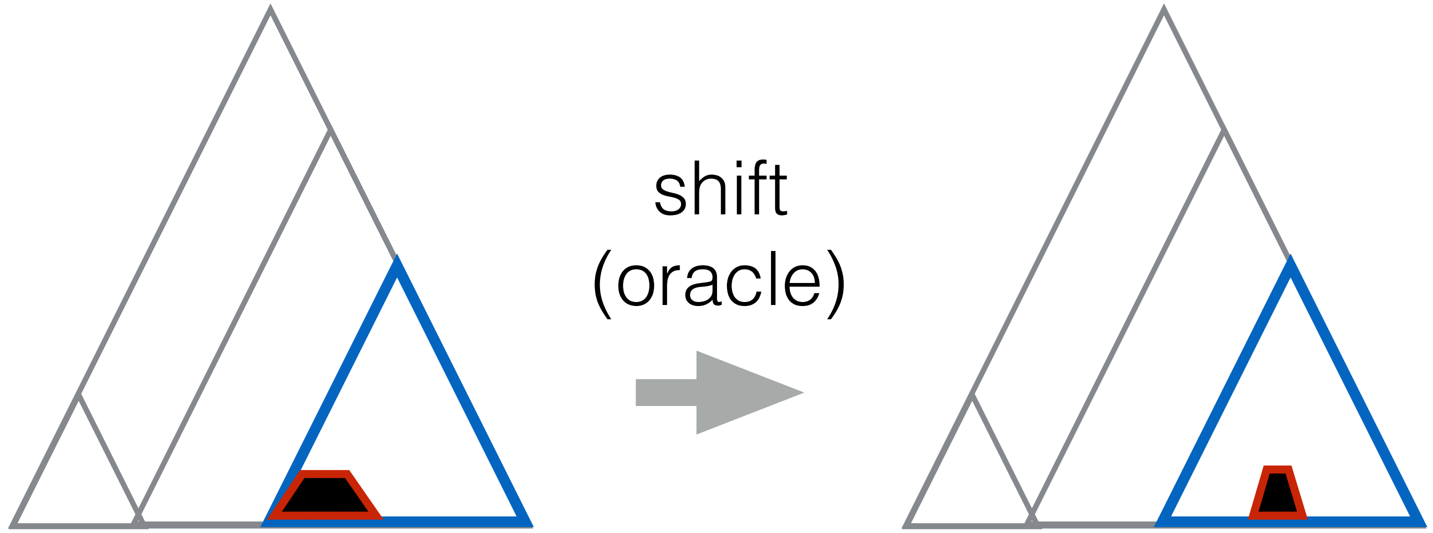

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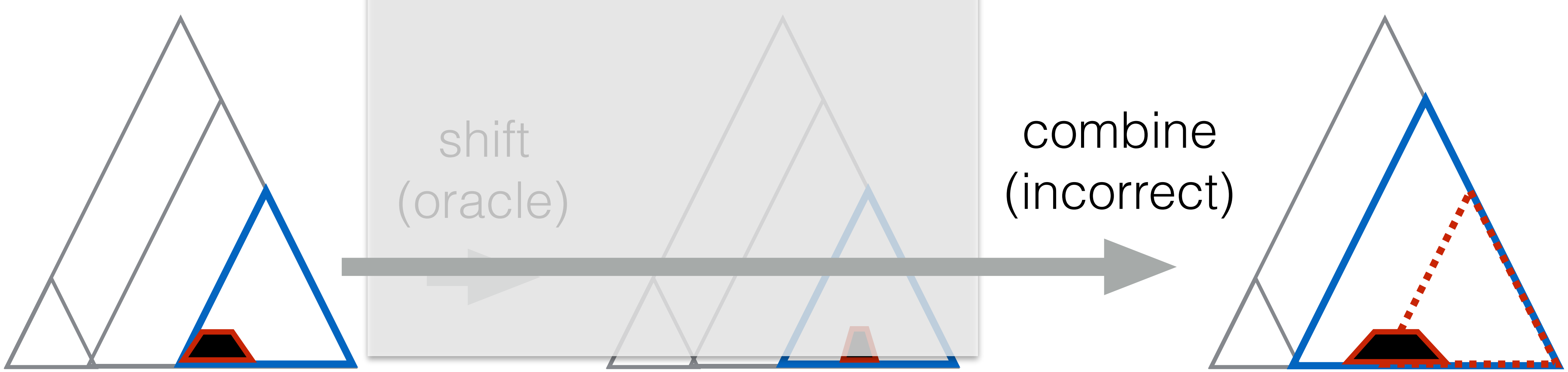
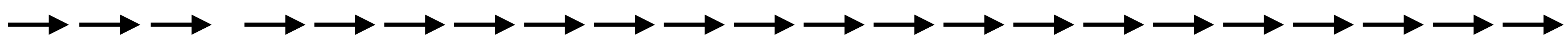


Training with Dynamic Oracle

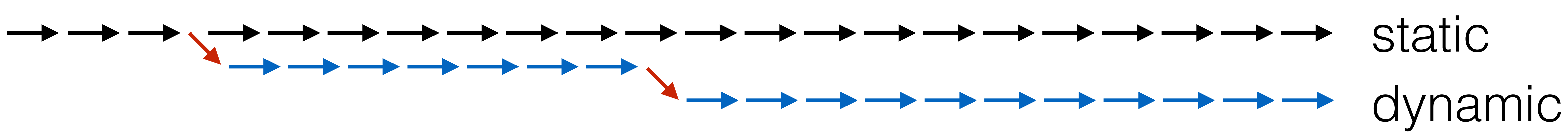


static

(scores on PTB 22)	Recall	Prec.	F_1
Static Oracle	91.34	91.43	91.38

Training with Dynamic Oracle

- Basic dynamic oracle: follow current model



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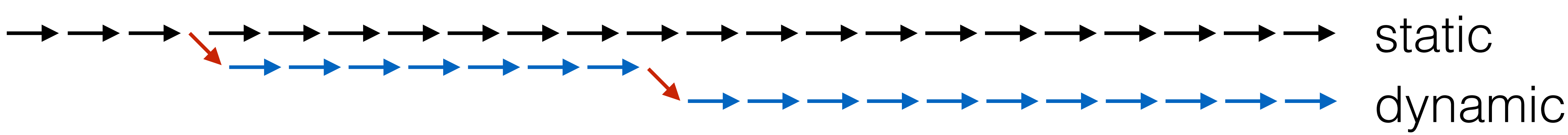
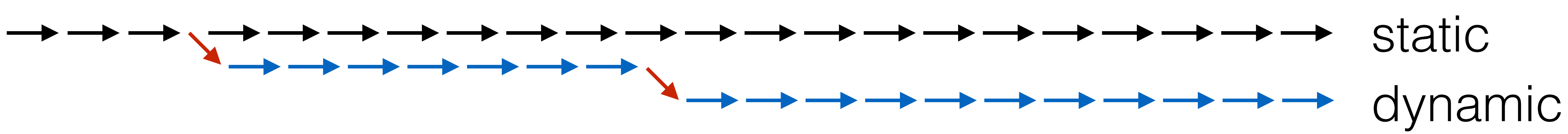


(scores on PTB 22)	Recall	Prec.	F_1
Static Oracle	91.34	91.43	91.38
Dynamic Oracle	91.14	91.61	91.38

Training with Dynamic Oracle

- Basic dynamic oracle: follow current model
- Problem: overfits training data, making fewer mistakes than test



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Training with Dynamic Oracle

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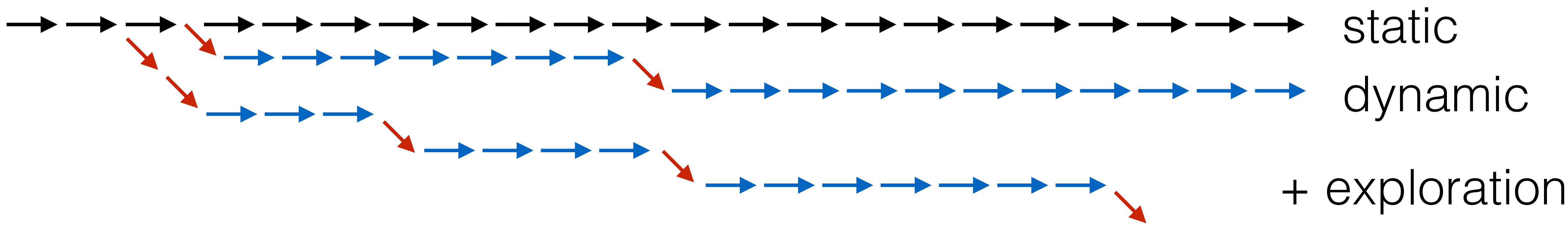
- Exploration: sample from softmax distribution (Ballesteros et al., 2016) to encourage more mistakes



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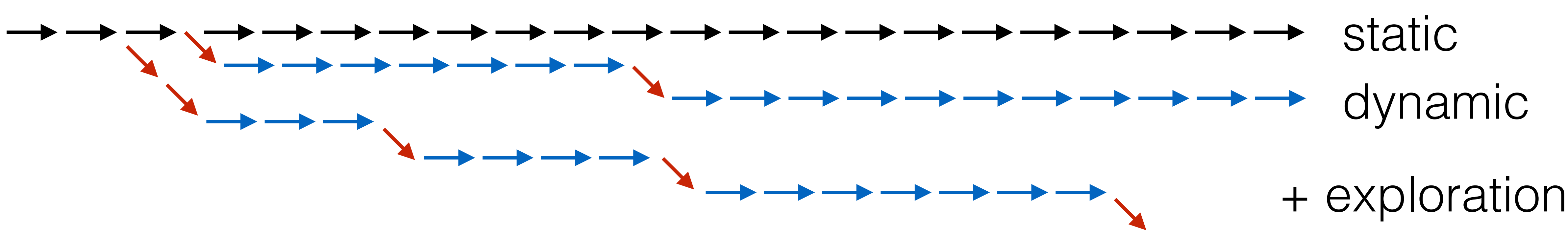
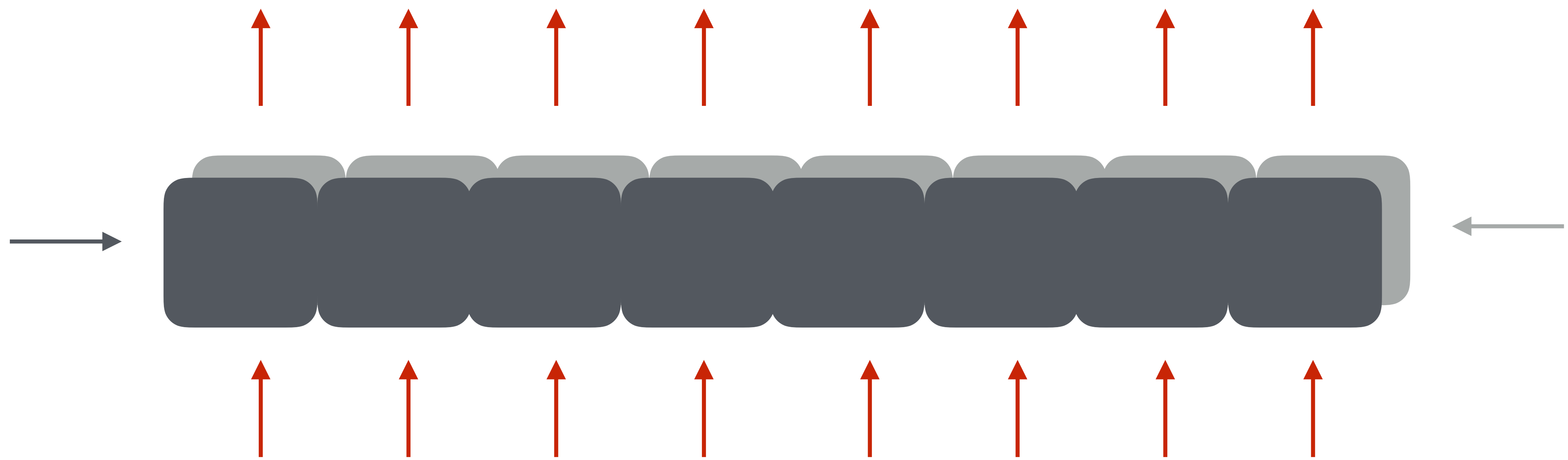


(scores on PTB 22)	Recall	Prec.	F_1
Static Oracle	91.34	91.43	91.38
Dynamic Oracle	91.14	91.61	91.38
Dynamic + Exploration	91.07	92.22	**91.64**

Outline

- Span-Based Constituency Parsing
- Bi-Directional LSTM Span Features
- Provably Optimal Dynamic Oracle
- **Experiments**

Architecture



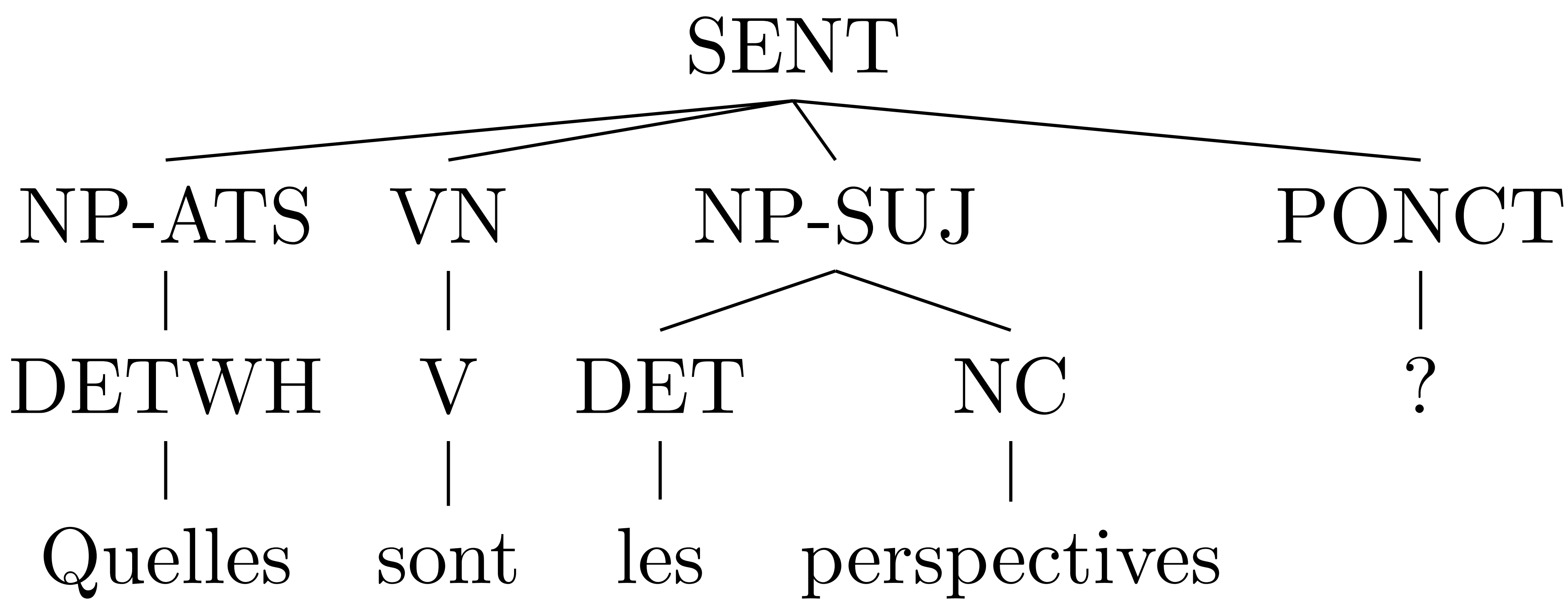
- 50-dim word and 20-dim tag embeddings
- No pre-training
- Each LSTM layer 200 units each direction
- 200 ReLU units for each of structure and label predictors

Results on Penn Treebank

Parser	Search	Recall	Prec.	F_1
Carreras et al. (2008)	cubic	90.7	91.4	91.1
Shindo et al. (2012)	cubic			91.1
Thang et al. (2015)	~cubic			91.1
Watanabe et al. (2015)	beam			90.7
Static Oracle	**greedy**	90.7	91.4	91.0
Dynamic + Exploration	**greedy**	90.5	92.1	**91.3**

- State of the art despite: simple system with greedy actions and small embeddings trained from scratch

Parsing Morphologically Rich Languages



lemma = perspective
coarse_POS = N
gender = feminine
number = plural
subcategory = common

Results on French Treebank

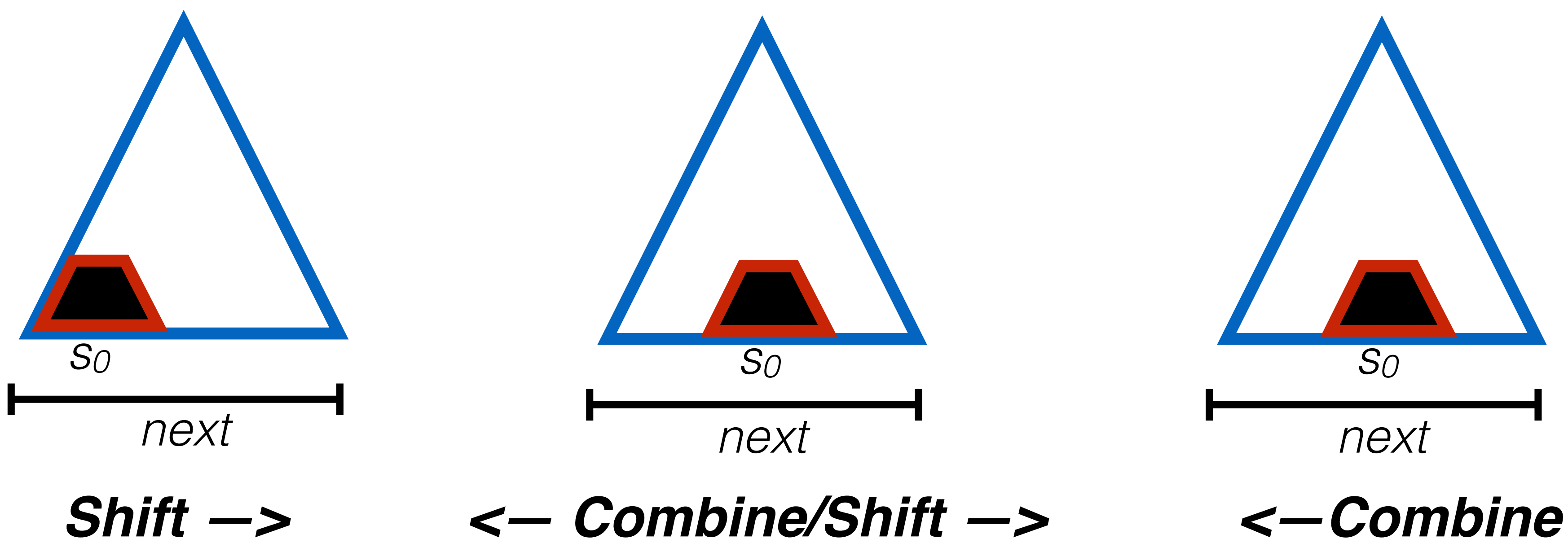
- Morphological feature embeddings (10 dim. each)
- Additional input to recurrent network
- For French, we used SPMRL 2014 predicted features

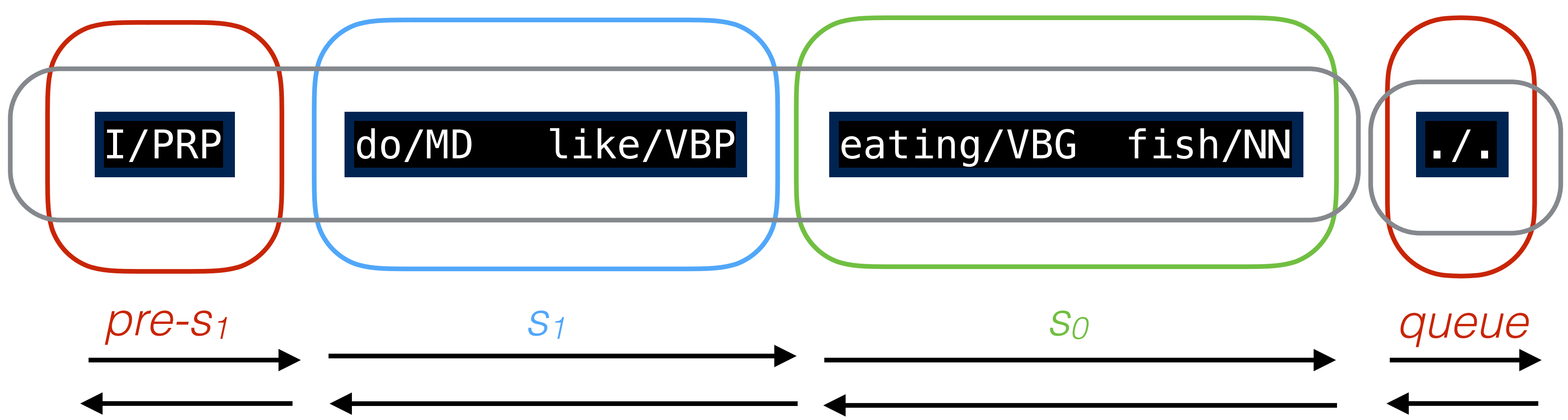
Parser	Recall	Prec.	F_1
Björkelund et al. (2014)			82.53
Static Oracle	83.50	82.87	83.18
Dynamic + Exploration	81.90	84.77	**83.31**

Summary

- Simple, easy-to-implement span-based parsing system
- No tree/label information in features (good candidate for dynamic programming)
- Linear time parsing with greedy decoding
- No pre-trained embeddings, small architecture, and minimal hyper-parameter tuning (trained on CPU)
- First optimal dynamic oracle for constituency parsing

Thank You!


s_0
next
Shift —>
s_0
next
<— Combine/Shift —>
s_0
next
<—Combine


I/PRP
do/MD like/VBP
eating/VBG fish/NN
./.
pre-s_1
s_1
s_0
queue