

# Discourse and Coreference

LING 571 — Deep Processing Methods in NLP

Shane Steinert-Threlkeld

# Announcements

- **No class Wednesday!**
- Relatedly: no Shane OH on Wednesday
- HW8: now **due Nov 29**
  - No HW due this week; HW9 (final one) out on Nov 29

# Ambiguity of the Week

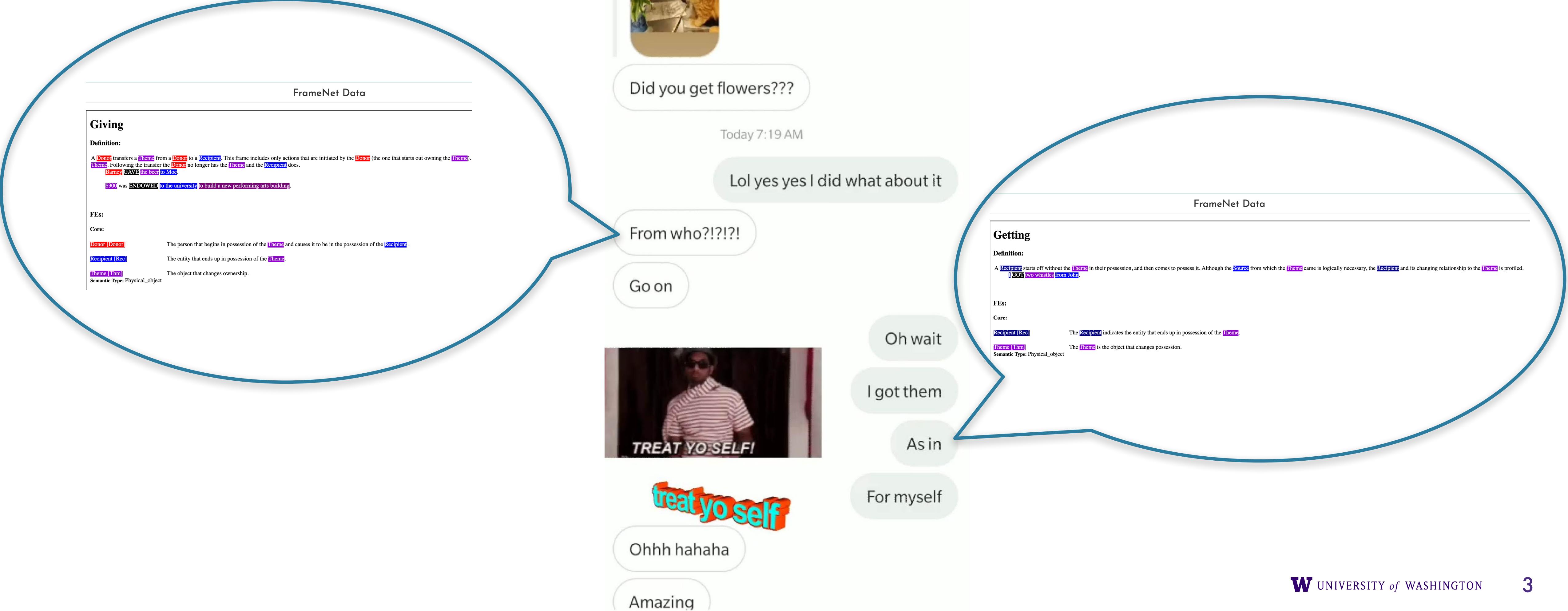
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# Roadmap

- Introduction to Discourse
- Coreference Resolution
  - Phenomena
  - Pronominal Anaphora Resolution
  - Hobbs' Algorithm

# Introduction to Discourse

# What is Discourse?

- Discourse is “a *coherent structured group of sentences.*” (J&M p. 681)

# What is Discourse?

- Discourse is “a *coherent structured group of sentences.*” (J&M p. 681)
- Discourse is language *in situ*
  - rather than synthetic, isolated sentences.
  - language use *toward a goal*

# Different Parameters of Discourse

- Number of participants
  - Single author/voice → Monologue
  - Multiple participants → Dialogue

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- **Modality**
  - Spoken vs. Written
- **Goals**
  - Transactional (message passing) vs. Interactional (relations, attitudes)
  - Cooperative task-oriented rational interaction

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- Understanding depends on context
  - Word sense – *plant*
  - Intention – *Do you have the time?*
  - Referring expressions – *it, that, the screen*
  - Domain restriction – “All of the students read the announcement.”

# Why Discourse?

- Applications: Discourse in NLP
  - Question-Answering
  - Information Retrieval
  - Summarization
  - Dialogue / Conversational AI
  - Automatic Essay Grading

# Reference Resolution

User: Where is **A Bug's Life** playing in **Summit?**

System: A Bug's Life is playing at the Summit Theater.

User: When is **it** playing **there?**

System: It's playing at 2PM, 5PM, and 8PM.

User: I'd like 1 **adult** and 2 **children** for **the first show**. How much would **that** cost?

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From Carpenter and Chu-Carroll, [Tutorial on Spoken Dialogue Systems](#), ACL '99

# Not All Sentences Are Created Equal

- *First Union Corp. is continuing to wrestle with severe problems.<sup>[1]</sup> According to industry insiders at PW, their president, John R. Georgius, is planning to announce his retirement tomorrow.<sup>[2]</sup>*

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- Summary:
  - *First Union President John R. Georgius is planning to announce his retirement tomorrow.*

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- Summary:
- *First Union President John R. Georgius is planning to announce his retirement tomorrow.*
- Inter-sentence coherence relations:
  - **Second sentence:** main concept (nucleus)
  - **First sentence:** background

# Coherence Relations

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- **Assumption**

- Segments of discourse should have meaningful connection.
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# Discourse: Looking Ahead

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## Coreference

# Discourse: Looking Ahead

Coreference

Cohesion

# Discourse: Looking Ahead

Coreference

Cohesion

Coherence

# Discourse: Looking Ahead

Coreference

Cohesion

Coherence

Structure / Segmentation

# Coreference Resolution

# Reference: Terminology

Queen Elizabeth set about transforming her husband, King George VI, into a viable monarch. Logue, a renowned speech therapist, was summoned to help the King overcome his speech impediment.

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    - *Logue, a renowned speech therapist*
  - Entities in **purple** do not corefer to anything.

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- ***Antecedent:***

- An expression that introduces an item to the discourse for other items to refer back to
- Queen Elizabeth... her

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\*Not all anaphora is referential! e.g. “*No dancer hurt their knee.*”

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# Referring Expressions

- Many forms:
  - *Queen Elizabeth*
  - *she/her*
  - *the Queen*
  - *HRM*
  - *the British Monarch*

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(...i.e. likely a different interpretation during a *RPDR* viewing party.)

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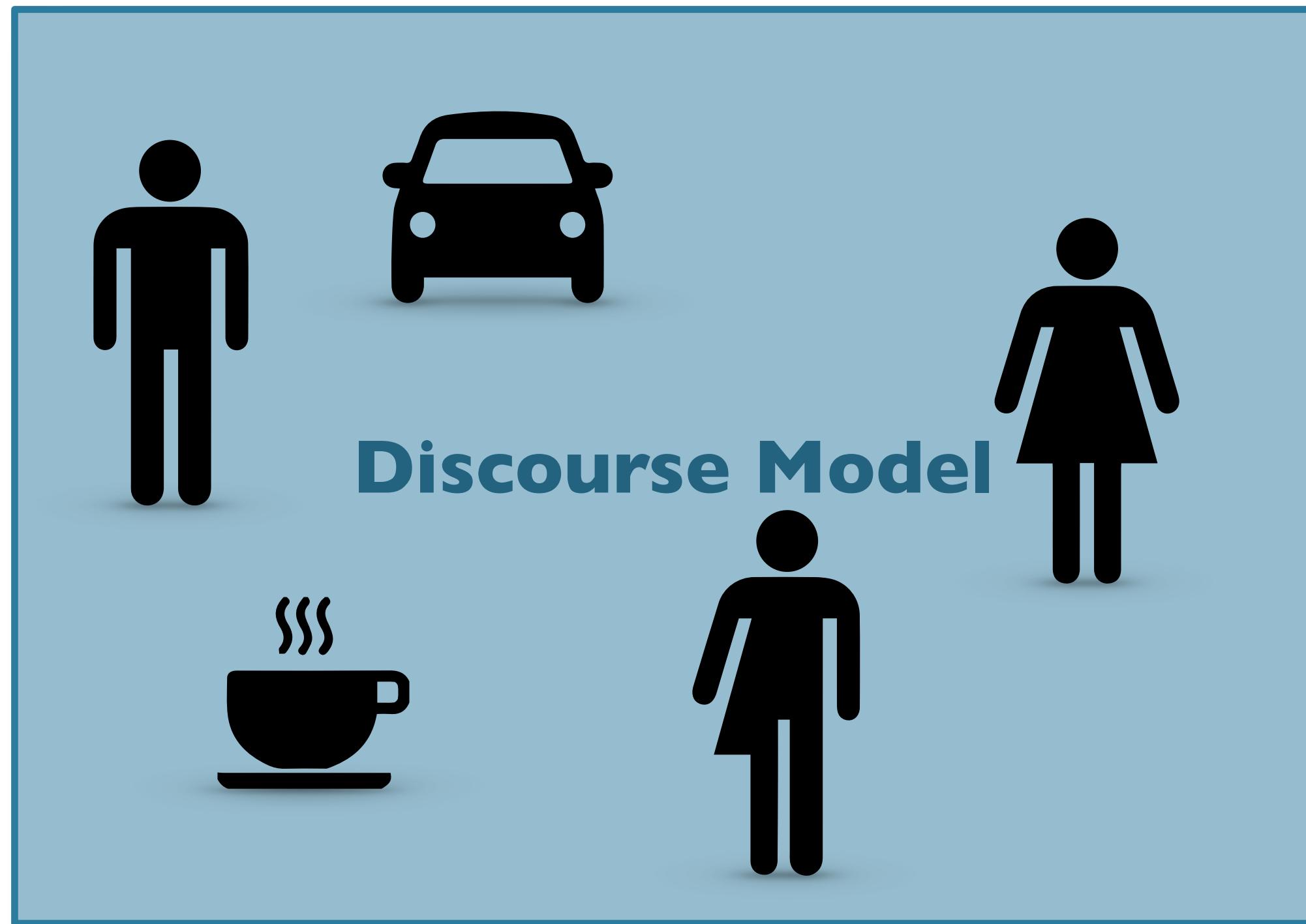
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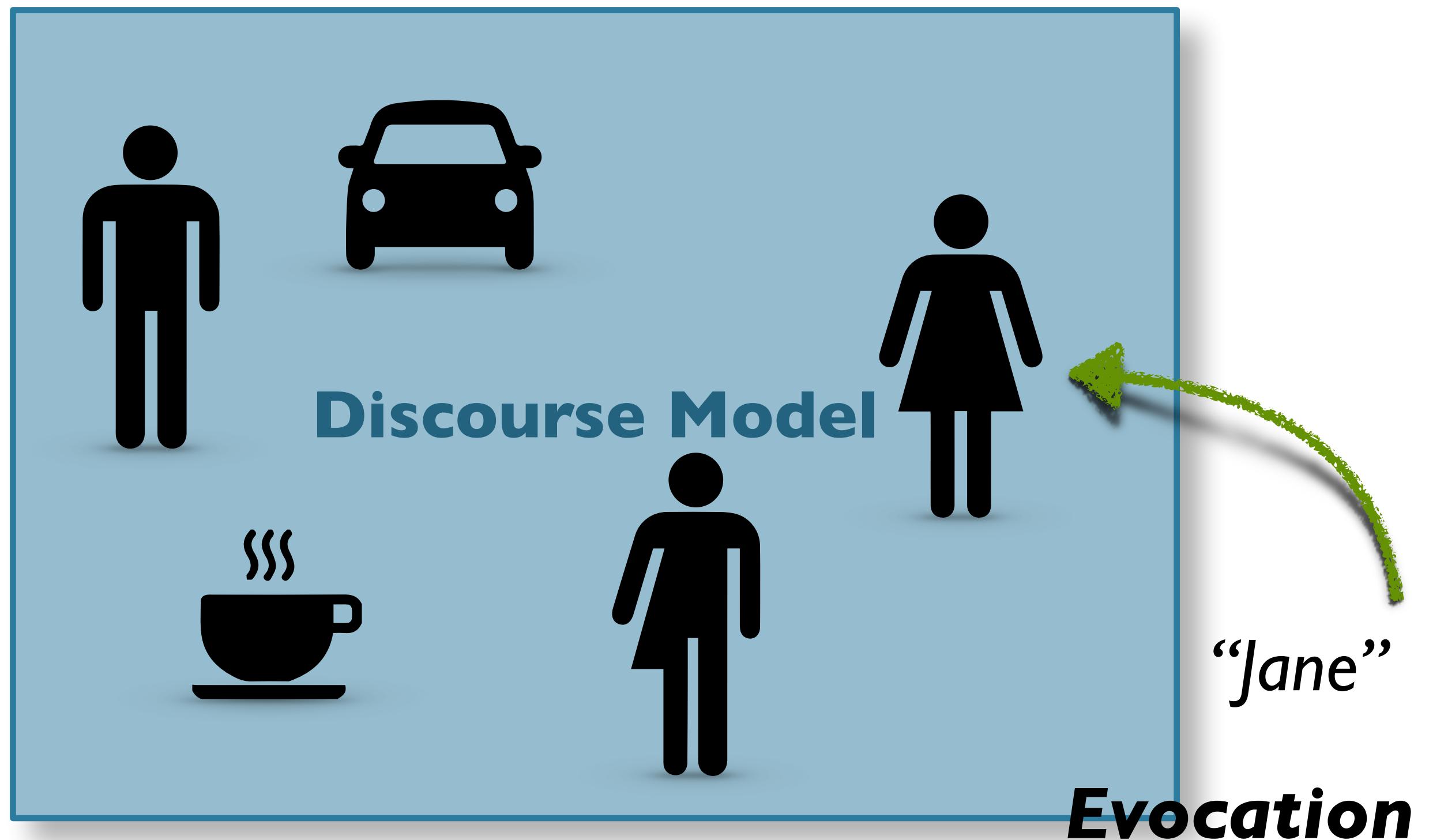
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    - [“introduces a discourse referent (dref)”]
  - Subsequent mentions **access** entity *from* the model.

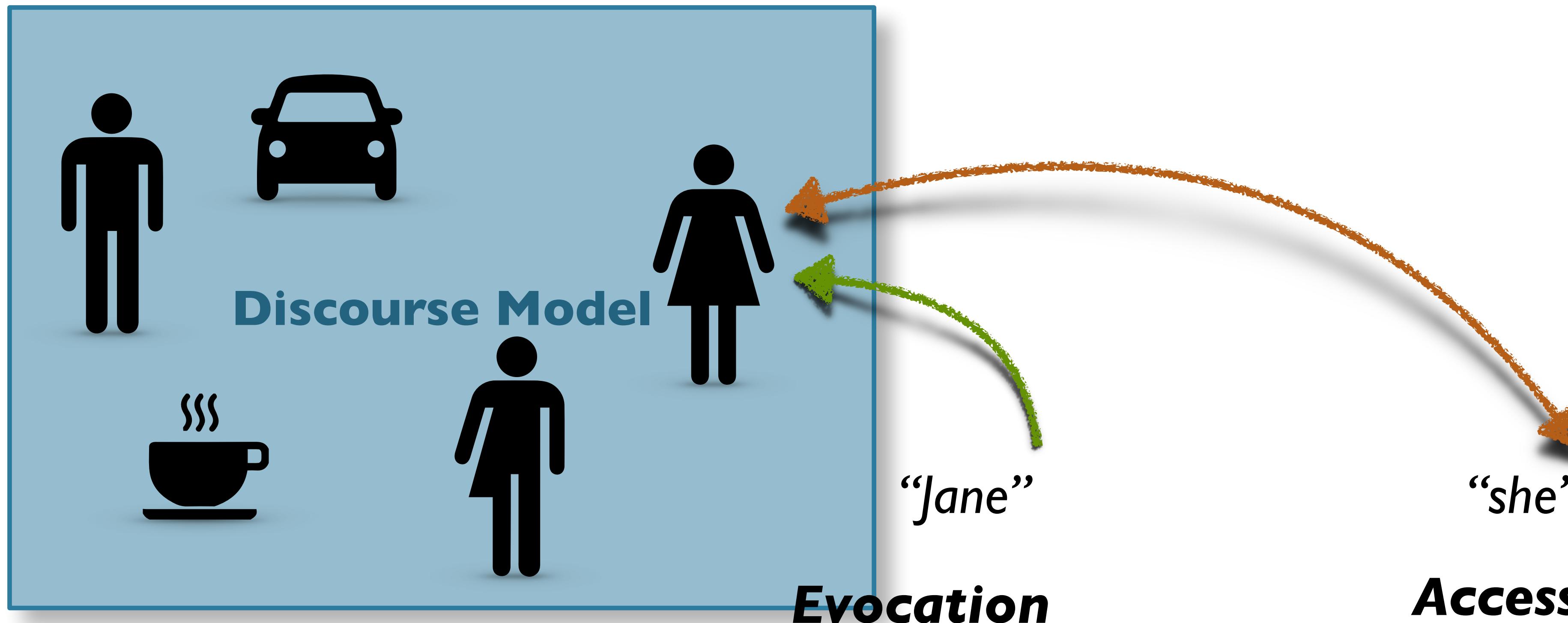
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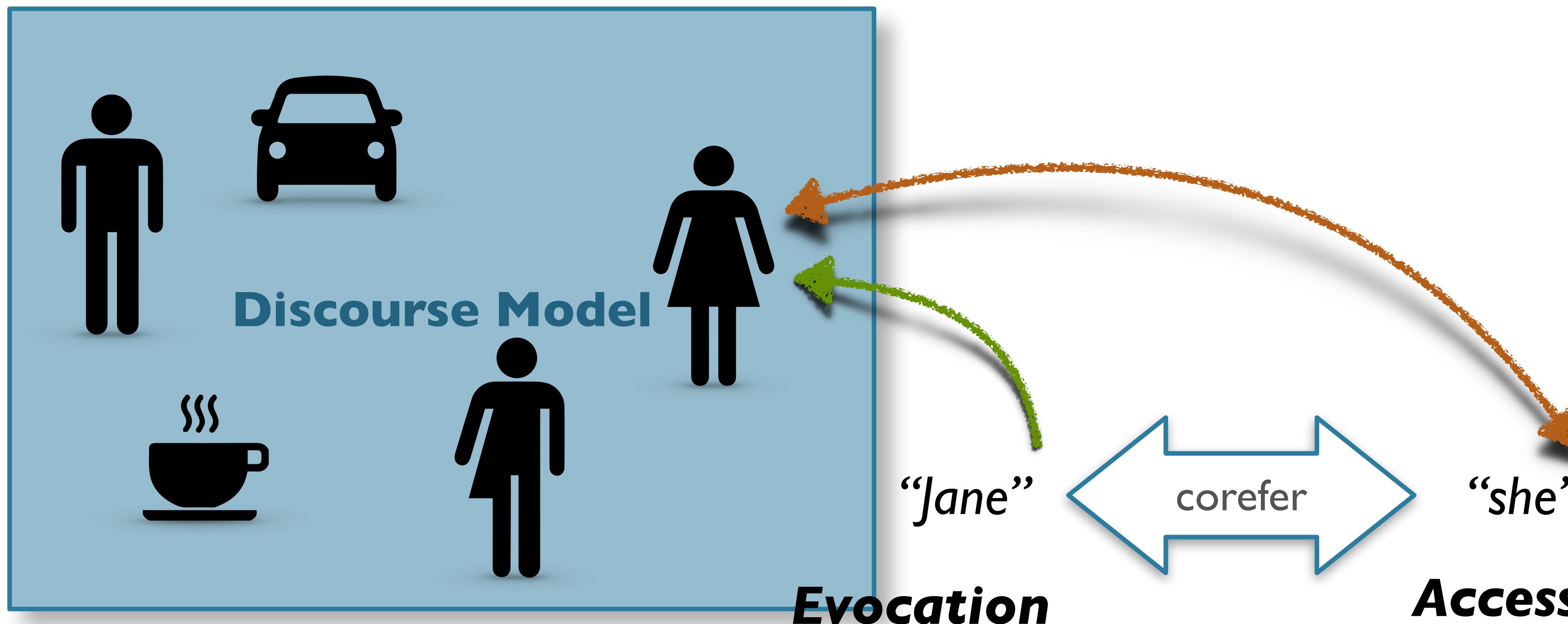
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- **Pronominal anaphora resolution:**

- Find antecedent for a single pronoun.
- Subtask of coreference resolution

# Pronominal Anaphora Resolution

# Reference Phenomena

Expression Type	Examples	Constraints
Indefinite NP	“ <i>a cat</i> ”, “ <i>some geese</i> ”	Introduces new entity to context
Definite NP	“ <i>the dog</i> ”	Refers to entity identifiable by hearer in context
Pronouns	“ <i>he</i> ,” “ <i>them</i> ,” “ <i>they</i> ”	Refers to entity, must be “ <b>salient</b> ”
Demonstratives	“ <i>this</i> ,” “ <i>that</i> ”	Refers to entity, sense of distance (literal/figurative)
Names	“ <i>Dr. Woodhouse</i> ,” “ <i>IBM</i> ”	New or old entities

# Reference Phenomena: Activation/Salience

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- d) is problematic because **the Falcon** has lost its salience.
- e) is acceptable because the definite NP has a further range for salience.

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<b><i>it</i></b>	<b><i>this</i></b>	<b><i>that N</i></b>	<b><i>the N</i></b>	
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# Information Status

- **Accessibility scale:** ([Ariel, 2001](#))

- More salient elements easier to call up, can be shorter
- correlates with length: more accessible, shorter refexp

Full name+modifier  
↓full name  
↓long definite description  
↓short definite description  
↓last name  
↓first name  
↓distal demonstrative+modifier  
↓proximate demonstrative+modifier  
    ↓distal demonstrative+NP  
    ↓proximate demonstrative+NP  
        ↓distal demonstrative(-NP)  
    ↓proximate demonstrative (-NP)  
        ↓stressed pronoun+gesture  
            ↓stressed pronoun  
            ↓unstressed pronoun  
            ↓cliticized pronoun  
        ↓verbal person inflections  
            ↓∅

# Complicating Factors

- **Inferredables**
  - refexp refers to inferentially related entity:
  - *I bought a car today, but a door had a dent, and the engine was noisy.*
    - **a door, the engine** ∈ **a car**

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- **Non-referential cases:**
  - *It's raining.* (Pleonasm)
  - *It was good that Frodo carried the ring.* (Extraposition)

# Features for Anaphora Resolution: Constraints

- Number:

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- Gender:

- *Janae plays the guitar.*      *She sounds great.*
- *Janae plays the guitar.*      *It sounds great.*

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    - *Aaron bought **themself** a new car.*
    - *Aaron bought **them** a new car.* [them ≠ Aaron]
    - *Jen said that Imani bought **herself** a new car.* [herself = Imani]

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- *He<sub>1</sub> said that he<sub>2</sub> bought **Willie** a new car.*

[He<sub>1</sub> ≠ Willie, he<sub>2</sub> ≠ Willie]

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- Reflexives do corefer with subject of containing clause

# Features for Anaphora Resolution: Preferences

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  - Prefer closer antecedents.
  - *The doctor found **an old map** in the captain's chest. Jim found **an even older map** on the shelf. **It** described an island.*

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- **Grammatical role:**
  - Saliency hierarchy of roles
  - e.g. *Subj > Object > Ind. Object > Oblique > AdvP*
    - *Billy Bones went to the bar with Jim Hawkins.*      **He** called for a glass of rum.
    - *Jim Hawkins went to the bar with Billy Bones.*      **He** called for a glass of rum.

# Features for Anaphora Resolution: Preferences

- **Repeated Mention:**
  - Once entity is focused, likely to continue to be focused → more likely pronomialized.
  - *Billy Bones had been thinking of a glass of rum. He hobbled over to the bar. Jim Hawkins went with him. He called for a glass of rum.*

# Features for Anaphora Resolution: Preferences

- **Repeated Mention:**

- Once entity is focused, likely to continue to be focused → more likely pronomialized.
  - *Billy Bones had been thinking of a glass of rum. He hobbled over to the bar. Jim Hawkins went with him. He called for a glass of rum.*

- **Parallelism:**

- Prefer entity in same role.
  - *Silver went with Jim to the bar. Billy Bones went with him to the inn.*

# Features for Anaphora Resolution: Preferences

- **Verb Semantics**
  - Some verbs semantically bias for one of their argument positions.

***John telephoned Bill.***    ***He had lost the laptop.***

***John criticized Bill.***    ***He had lost the laptop.***

# Features for Anaphora Resolution: Preferences

- **Verb Semantics**

- Some verbs semantically bias for one of their argument positions.

*John telephoned Bill.*    *He had lost the laptop.*

*John criticized Bill.*    *He had lost the laptop.*

- **Selectional Restrictions**

- Other kinds of semantic knowledge

- *John parked his car in the garage after driving it around for hours.*

- Understood that a car has the ability to *drive* whereas garage does not.

# Reference Resolution Approaches

- Common features:
  - Use of a “Discourse Model”
    - Referents evoked in discourse, available for reference
    - Structure indicating relative salience
  - Syntactic & Semantic Constraints
  - Syntactic & Semantic Preferences
- Differences:
  - Which constraints/preferences? How to combine? Rank?

# Hobbs' Algorithm

# Hobbs' Resolution Algorithm

- **Requires:**
  - Syntactic parser
  - Gender & number checker
- **Input:**
  - Pronoun
  - Parse of current and previous sentences
- **Captures:**
  - Preferences: Recency, grammatical role
  - Constraints: binding theory, gender, person, number

# Hobbs Algorithm

- Summary:
  - English-centric, rule-based algorithm.
  - Exploits English features of:
    - Agreement
    - Right-branching
    - SVO order
  - Inter-sententially, exploits notions of recency.

# Hobbs Algorithm Detail ([Hobbs, 1978](#))

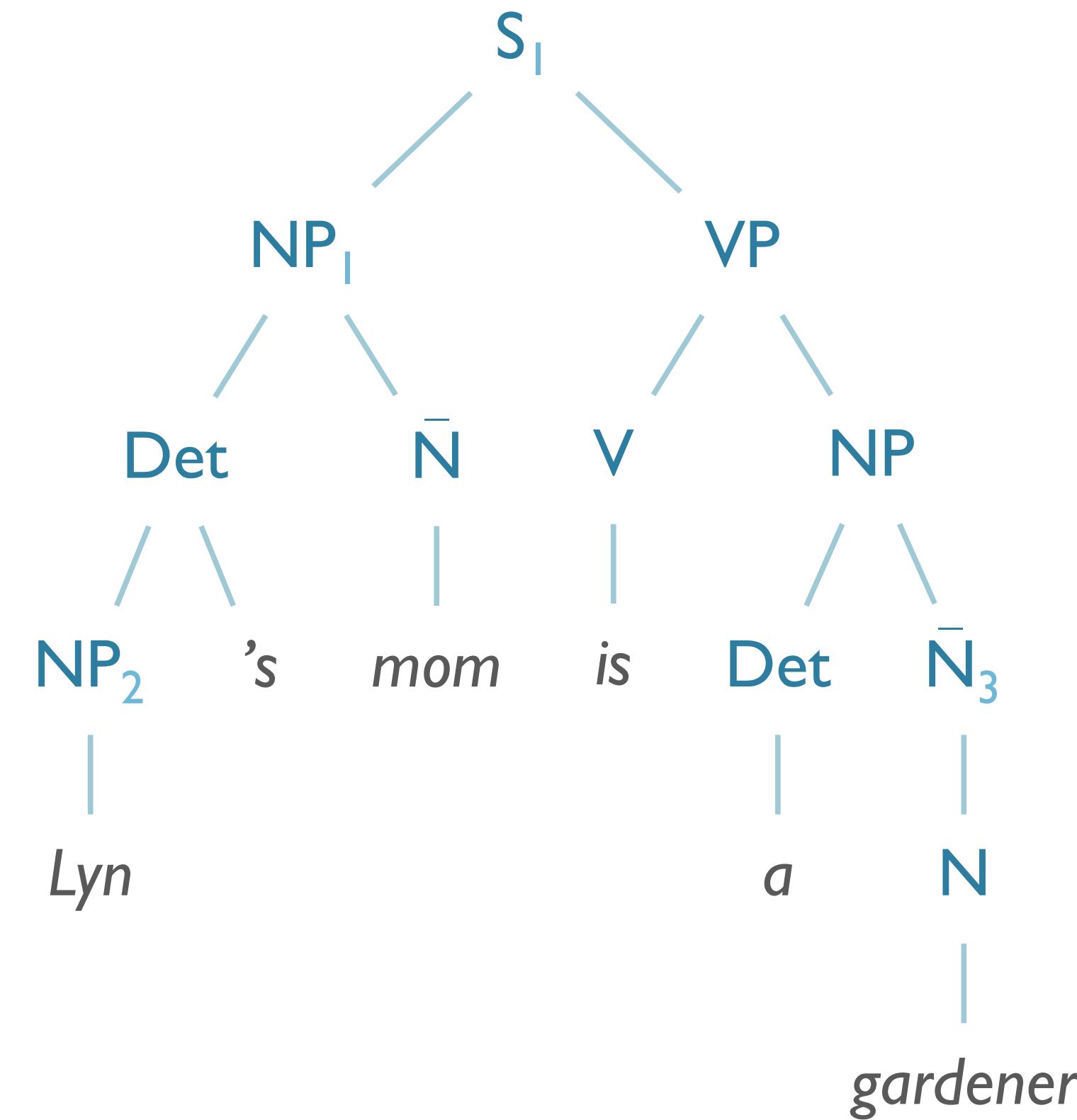
1. Begin at the noun phrase (NP) node immediately dominating the pronoun
2. Go up the tree to the first NP or sentence (S) node encountered. Call this node **X**, and call the path used to reach it  $p$ .
3. Traverse all branches below node **X** to the left of path  $p$  in a left-to-right, breadth-first fashion. Propose as the antecedent any encountered NP node that has an NP or S node between it and **X**.
4. If node **X** is the highest S node in the sentence, traverse the surface parse trees of previous sentences in the text in order of recency, the most recent first; each tree is traversed in a left-to-right, breadth-first manner, and when an NP node is encountered, it is proposed as antecedent. If **X** is not the highest S node in the sentence, continue to step 5.

# Hobbs Algorithm Detail ([Hobbs, 1978](#))

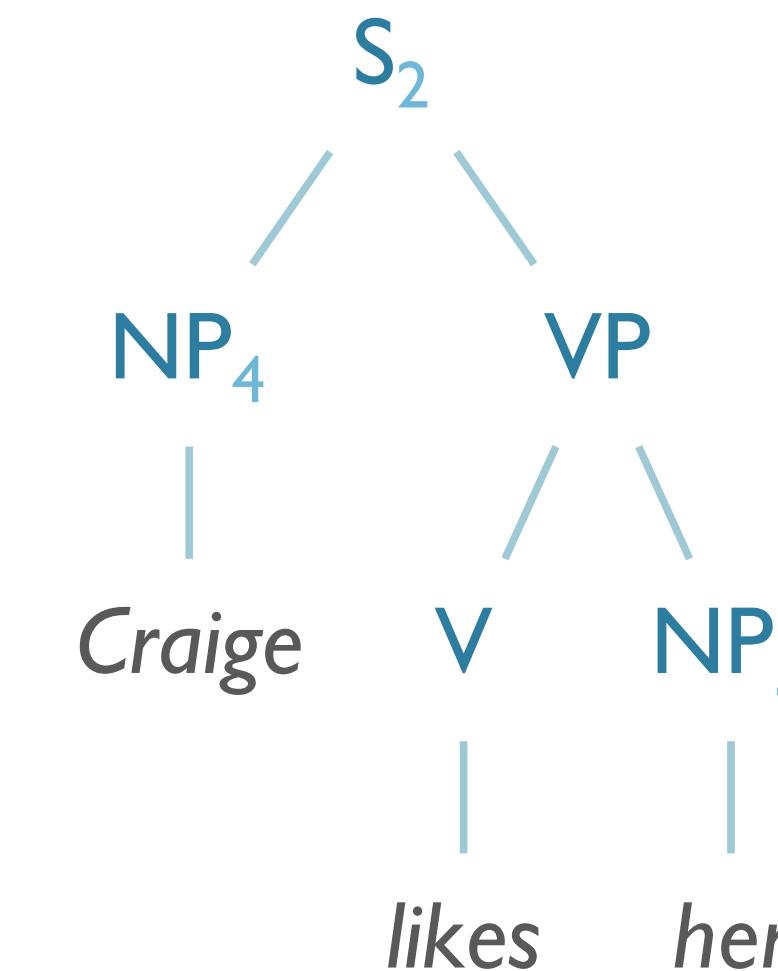
5. From node **X**, go up the tree to the first NP or S node encountered. Call this new node **X**, and call the path traversed to reach it  $p$ .
6. If **X** is an NP node and if the path  $p$  to **X** did not pass through the Nominal node that **X** immediately dominates, propose **X** as the antecedent.
7. Traverse all branches below node **X** to the *left* of path  $p$  in a left-to-right, breadth-first manner. Propose any NP node encountered as the antecedent.
8. If **X** is an S node, traverse all branches of node **X** to the *right* of path  $p$  in a left-to-right, breadth-first manner, but do not go below any NP or S node encountered. Propose any NP node encountered as the antecedent.
9. Go to step 4.

# Hobbs Example

*Lyn's mom is a gardener.*

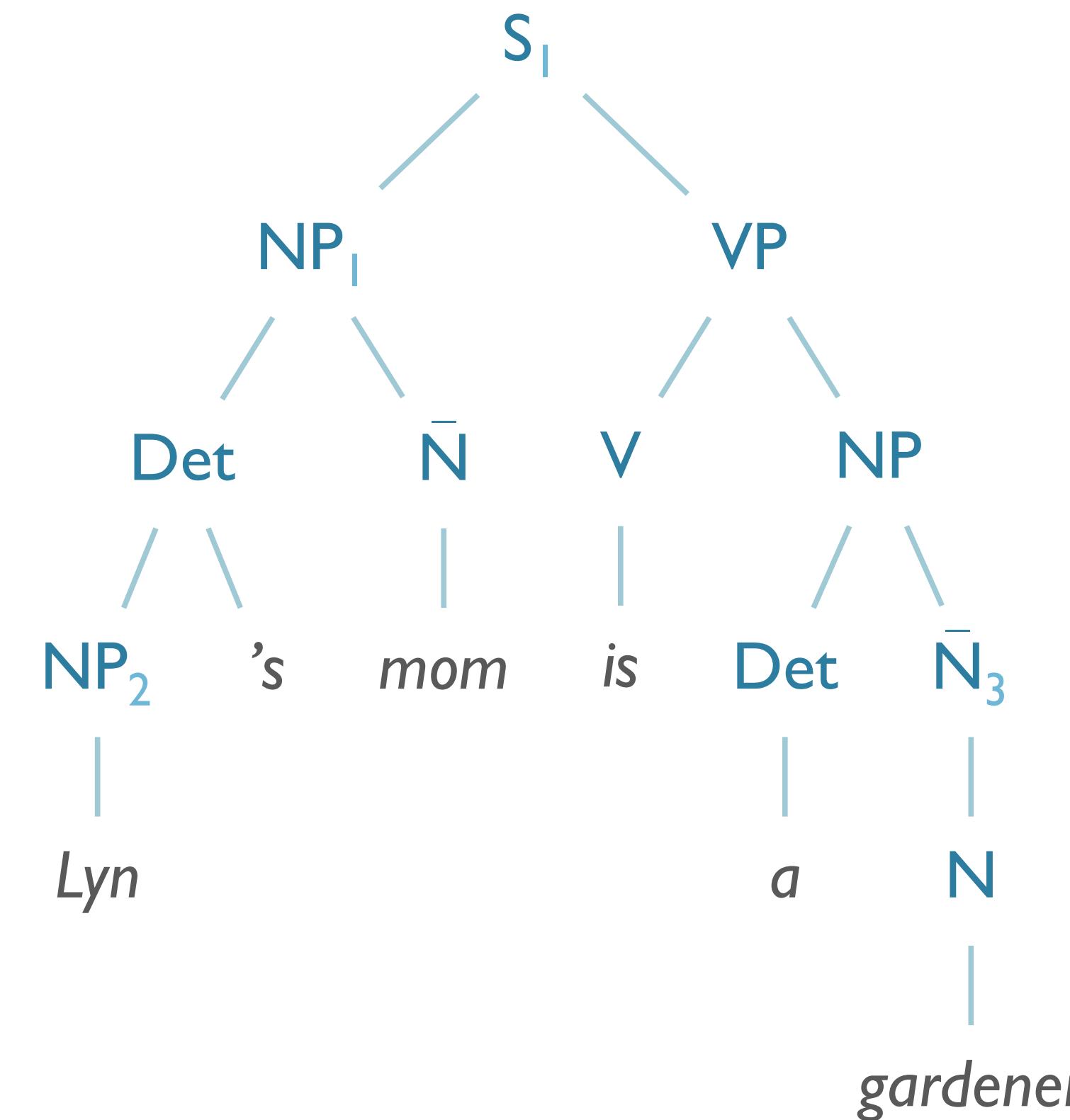


*Craig likes her.*

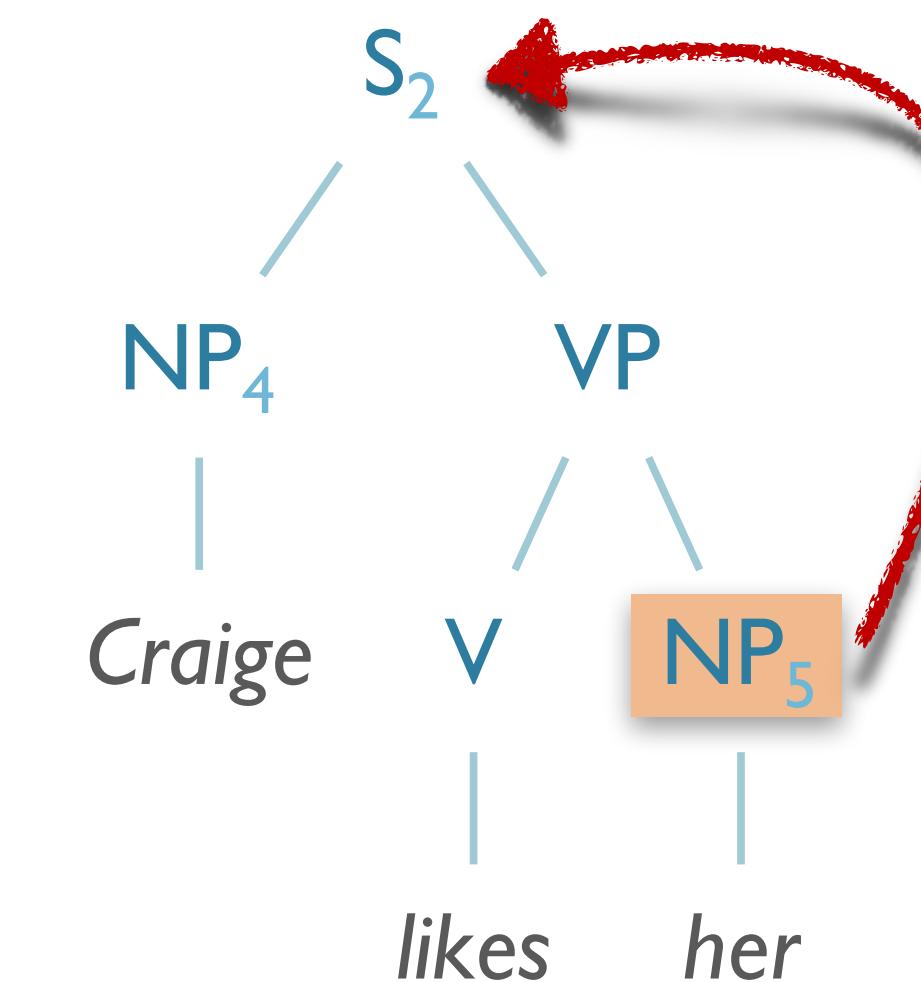


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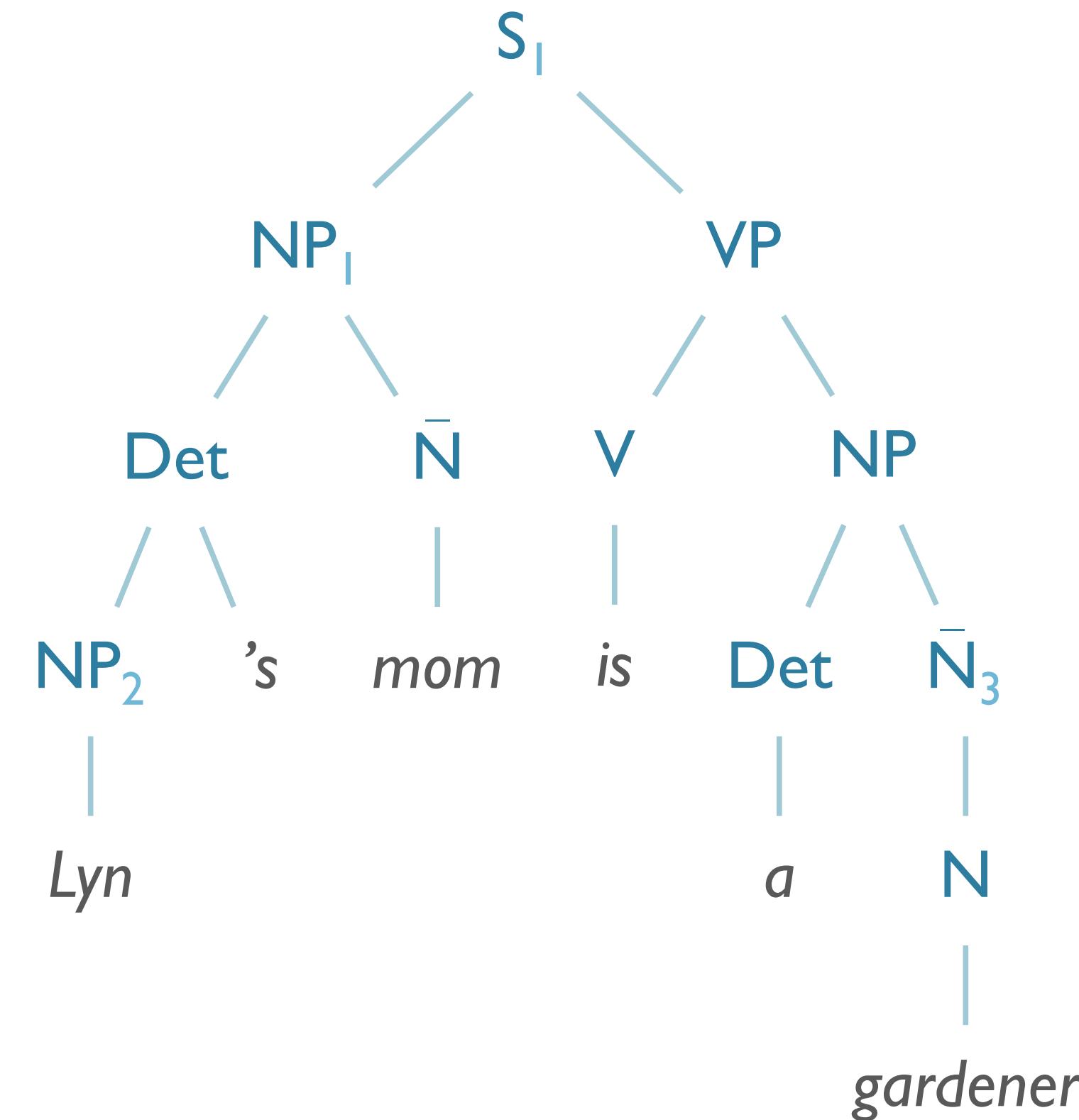


*Craigie likes her.*

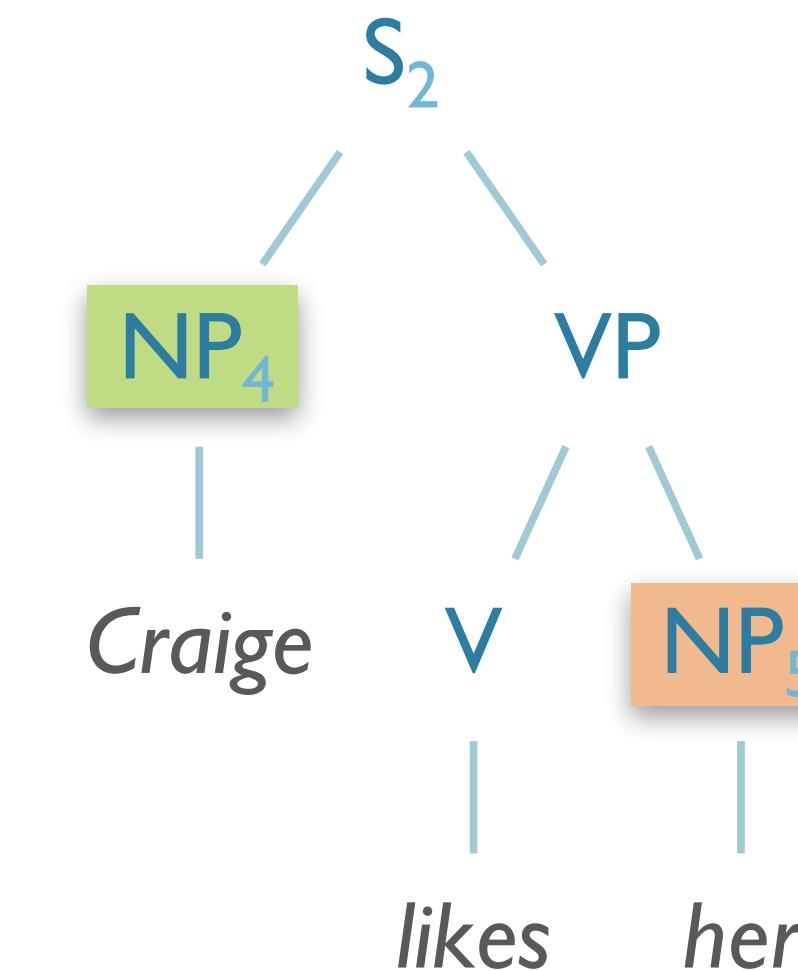


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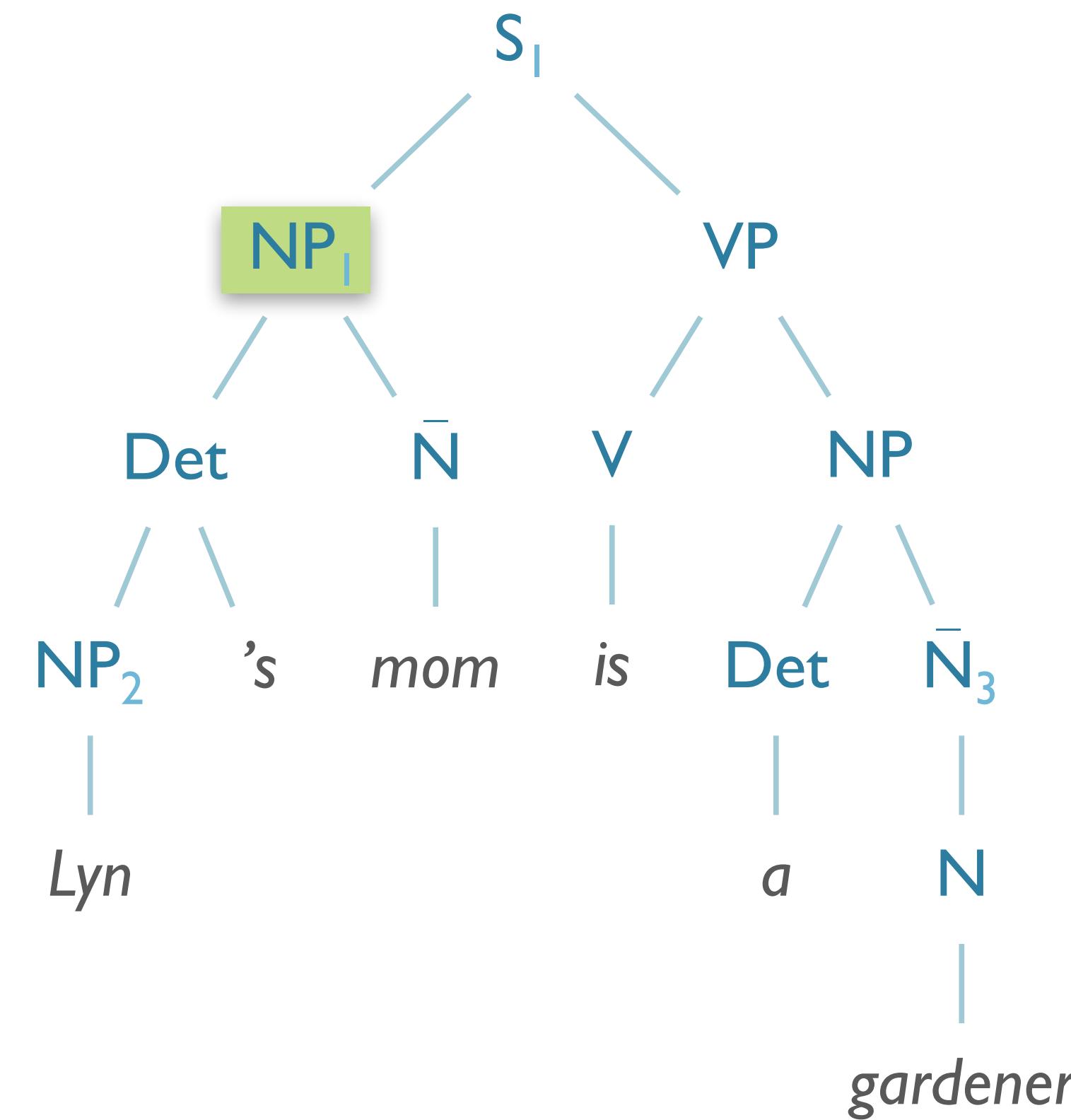


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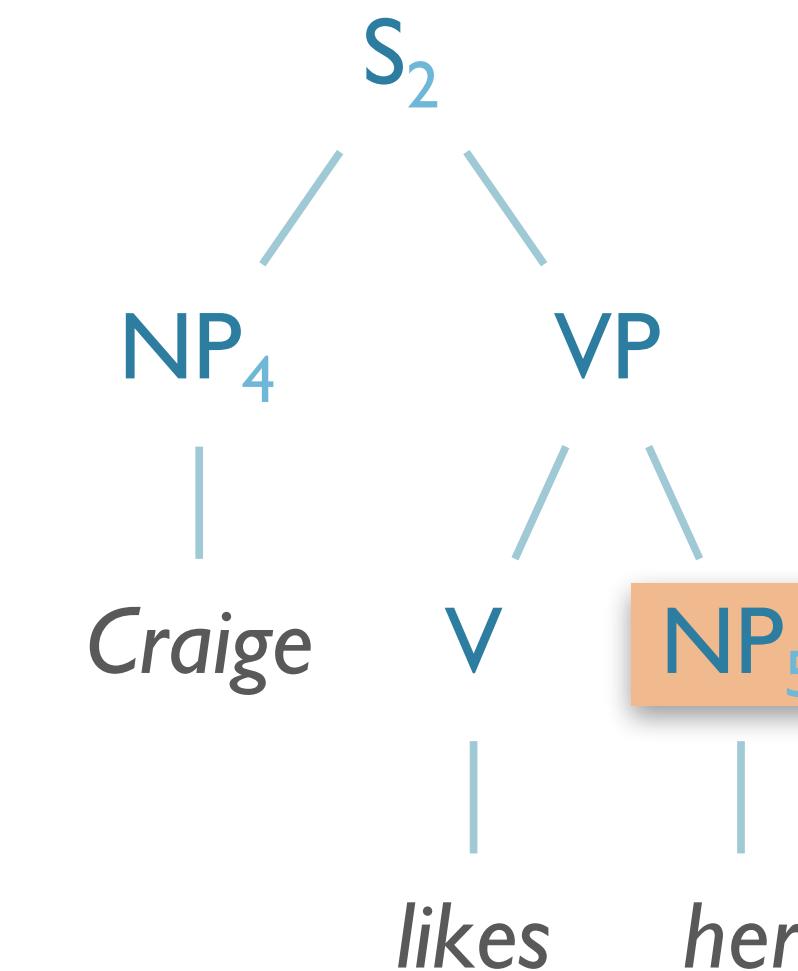


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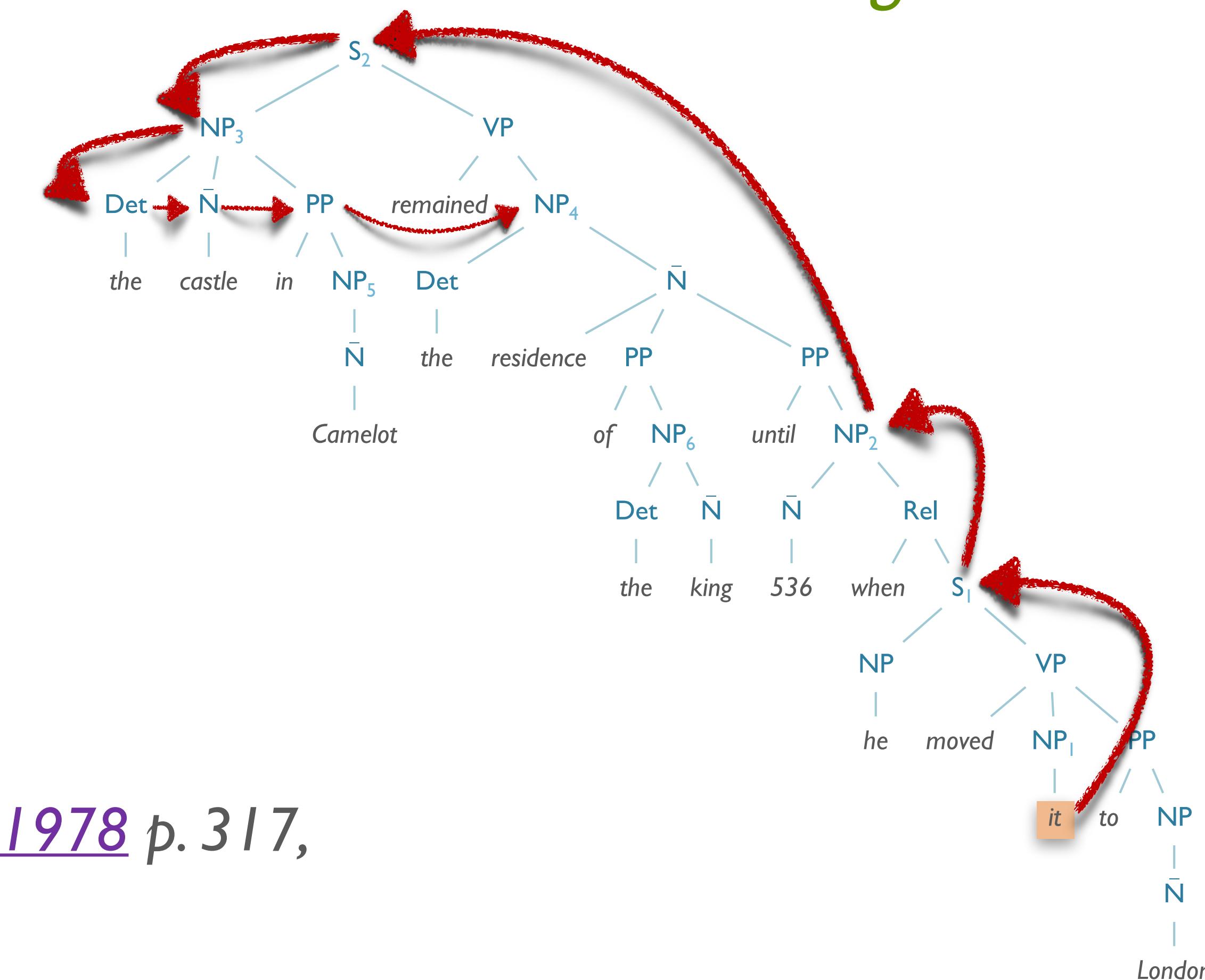


*Craig likes her.*



# Another Hobbs Example

*...the castle in Camelot remained the residence of the king until 536 when he moved **it** to London.*



for full walkthrough see [Hobbs, 1978](#) p. 317,  
and the end of today's slides

# Hobbs Algorithm

- Results: 88% Accuracy; 90% intrasentential
  - ...on perfect, manually parsed sentences
- Useful ***baseline*** for evaluating pronomial anaphora
- Issues:
  - **Parsing:**
    - Not all languages have parsers
    - Parsers not always accurate
  - **Constraints/Preferences:**
    - Captures: Binding theory, grammatical role, recency
    - But not: parallelism, repetition, verb semantics, selection

# Hobbs Algorithm

- Other issue: does not implement world knowledge
  - *The city council refused the women a permit because they feared violence.*
  - *The city council refused the women a permit because they advocated violence.*
- (Winograd, 1972)\*
  - \*more on this later
- Get this reading by knowledge of city councils and permitting, and reasons why permits would be refused.

# Hobbs Algorithm: A Parable

- Was actually one of the first instances in NLP where a researcher tried an informed, if “naïve” baseline
  - ...found that (in 1972) no system he could build could beat it!
- *“the naïve approach is quite good. Computationally speaking, it will be a long time before a semantically based algorithm is sophisticated enough to perform as well, and these results set a very high standard for any other approach to aim for.*

*“Yet there is every reason to pursue a semantically based approach. The naïve algorithm does not work. Any one can think of examples where it fails. In these cases it not only fails; it gives no indication that it has failed and offers no help in finding the real antecedent.” – Hobbs (1978), Lingua, p. 345*

# Coreference and World Knowledge

# W The trophy doesn't fit into the brown suitcase because it's too small. What's too small?

the trophy

the brown  
suitcase

Total Results: 0

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Start the presentation to see live content. For screen share software, share the entire screen. Get help at [pollev.com/app](https://pollev.com/app)

# W The trophy doesn't fit into the brown suitcase because it's too large. What's too large?

the trophy

the brown  
suitcase

Total Results: 0

Powered by  Poll Everywhere

Start the presentation to see live content. For screen share software, share the entire screen. Get help at [pollev.com/app](https://pollev.com/app)

# W Joan made sure to thank Susan for all the help she had given.

## Who had given help?

Joan

Susan

Total Results: 0

Powered by  Poll Everywhere

Start the presentation to see live content. For screen share software, share the entire screen. Get help at [pollev.com/app](https://pollev.com/app)

**W Joan made sure to thank Susan for all the help she had received.**  
**Who had received help?**

Joan

Susan

Total Results: 0

Powered by  **Poll Everywhere**

Start the presentation to see live content. For screen share software, share the entire screen. Get help at [pollev.com/app](https://pollev.com/app)

# Coreference and World Knowledge

# Coreference and World Knowledge

- The trophy doesn't fit into the brown suitcase because it's too [small/large]. What is too [small/large]?

# Coreference and World Knowledge

- The trophy doesn't fit into the brown suitcase because it's too [small/large]. What is too [small/large]?
  - Answers: The suitcase/the trophy.

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- Paul tried to call George on the phone, but he wasn't [successful/available]. Who was not [successful/available]?

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  - Answers: Paul/George.

# Coreference and World Knowledge

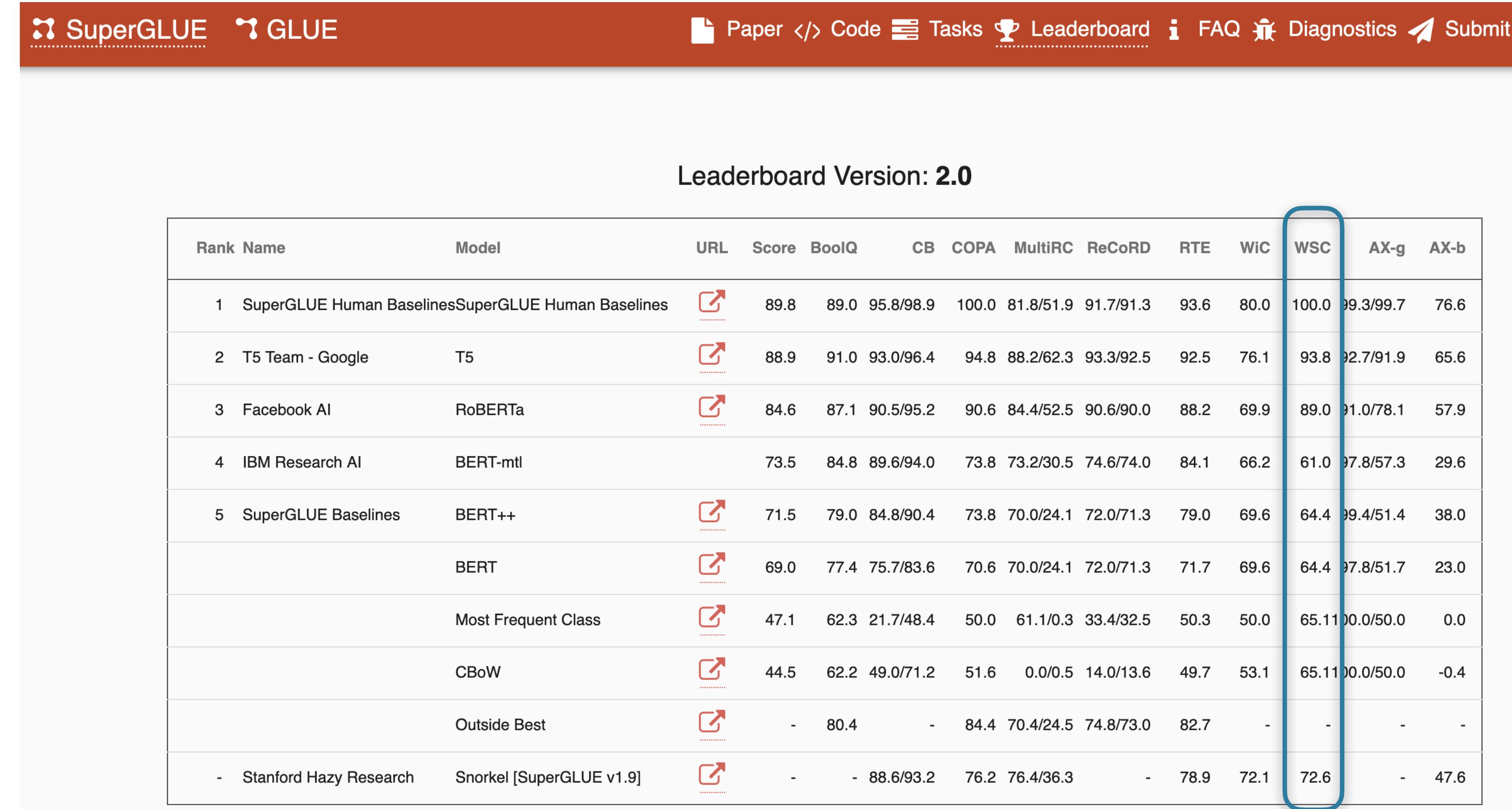
- The trophy doesn't fit into the brown suitcase because it's too [small/large]. What is too [small/large]?
  - Answers: The suitcase/the trophy.
- Joan made sure to thank Susan for all the help she had [given/received]. Who had [given/received] help?
  - Answers: Susan/Joan.
- Paul tried to call George on the phone, but he wasn't [successful/available]. Who was not [successful/available]?
  - Answers: Paul/George.
- The lawyer asked the witness a question, but he was reluctant to [answer/repeat] it . Who was reluctant to [answer/repeat] the question?

# Coreference and World Knowledge

- The trophy doesn't fit into the brown suitcase because it's too [small/large]. What is too [small/large]?
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  - Answers: Paul/George.
- The lawyer asked the witness a question, but he was reluctant to [answer/repeat] it . Who was reluctant to [answer/repeat] the question?
  - Answers: The witness/the lawyer.

# Winograd Schema Challenge

- Still hard!
- WSC
- Winogrande



The screenshot shows the Winograd Schema Challenge Leaderboard Version 2.0. The table lists models ranked by score, with columns for Rank, Name, Model, URL, Score, BoolQ, CB, COPA, MultiRC, ReCoRD, RTE, WiC, WSC, AX-g, and AX-b. The WSC column is highlighted with a blue border.

Rank	Name	Model	URL	Score	BoolQ	CB	COPA	MultiRC	ReCoRD	RTE	WiC	WSC	AX-g	AX-b
1	SuperGLUE Human Baselines	SuperGLUE Human Baselines	<a href="#">🔗</a>	89.8	89.0	95.8/98.9	100.0	81.8/51.9	91.7/91.3	93.6	80.0	100.0	99.3/99.7	76.6
2	T5 Team - Google	T5	<a href="#">🔗</a>	88.9	91.0	93.0/96.4	94.8	88.2/62.3	93.3/92.5	92.5	76.1	93.8	92.7/91.9	65.6
3	Facebook AI	RoBERTa	<a href="#">🔗</a>	84.6	87.1	90.5/95.2	90.6	84.4/52.5	90.6/90.0	88.2	69.9	89.0	91.0/78.1	57.9
4	IBM Research AI	BERT-mtl		73.5	84.8	89.6/94.0	73.8	73.2/30.5	74.6/74.0	84.1	66.2	61.0	97.8/57.3	29.6
5	SuperGLUE Baselines	BERT++	<a href="#">🔗</a>	71.5	79.0	84.8/90.4	73.8	70.0/24.1	72.0/71.3	79.0	69.6	64.4	99.4/51.4	38.0
		BERT	<a href="#">🔗</a>	69.0	77.4	75.7/83.6	70.6	70.0/24.1	72.0/71.3	71.7	69.6	64.4	97.8/51.7	23.0
		Most Frequent Class	<a href="#">🔗</a>	47.1	62.3	21.7/48.4	50.0	61.1/0.3	33.4/32.5	50.3	50.0	65.11	0.0/50.0	0.0
		CBoW	<a href="#">🔗</a>	44.5	62.2	49.0/71.2	51.6	0.0/0.5	14.0/13.6	49.7	53.1	65.11	0.0/50.0	-0.4
		Outside Best	<a href="#">🔗</a>	-	80.4	-	84.4	70.4/24.5	74.8/73.0	82.7	-	-	-	-
-	Stanford Hazy Research	Snorkel [SuperGLUE v1.9]	<a href="#">🔗</a>	-	-	88.6/93.2	76.2	76.4/36.3	-	78.9	72.1	72.6	-	47.6

# Winograd Schema Challenge

- Still hard!
- WSC
- Winogrande



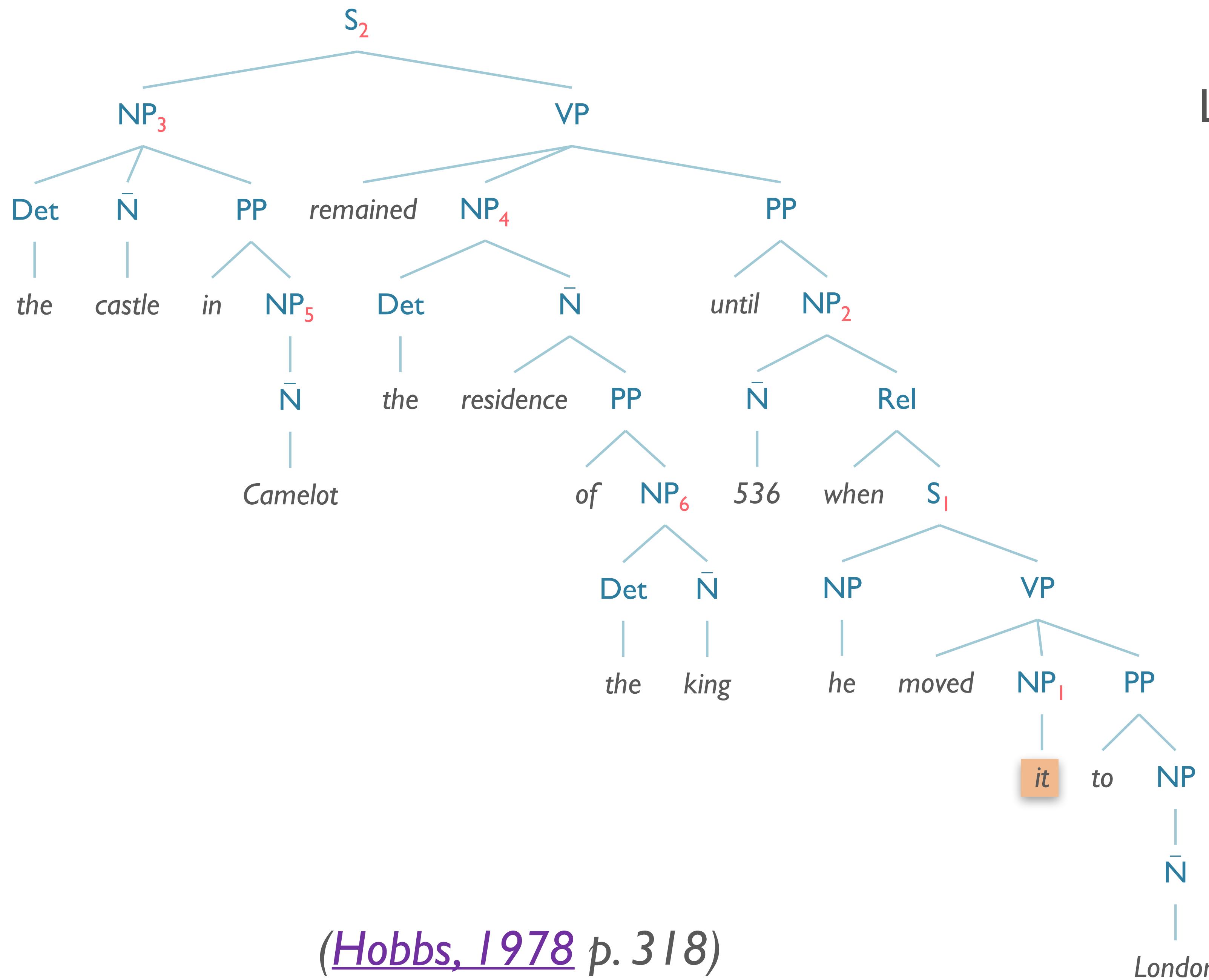
The screenshot shows the official leaderboard for the Winograd Schema Challenge. The top navigation bar includes links for SuperGLUE, GLUE, Paper, Code, Tasks, Leaderboard, FAQ, Diagnostics, and Submit. The main title is "Leaderboard Version: 2.0". The table lists various models and their performance across different tasks. The columns include Rank, Name, Model, URL, Score, BoolQ, CB, COPA, MultiRC, ReCoRD, RTE, WiC, WSC, AX-g, and AX-b. The WSC column is highlighted with a blue border. The table shows that SuperGLUE Human Baselines is at the top with a score of 89.8. Other models like T5 and RoBERTa follow, with scores decreasing as they rank lower.

Rank	Name	Model	URL	Score	BoolQ	CB	COPA	MultiRC	ReCoRD	RTE	WiC	WSC	AX-g	AX-b
1	SuperGLUE Human Baselines	SuperGLUE Human Baselines	<a href="#">🔗</a>	89.8	89.0	95.8/98.9	100.0	81.8/51.9	91.7/91.3	93.6	80.0	100.0	99.3/99.7	76.6
2	T5 Team - Google	T5	<a href="#">🔗</a>	88.9	91.0	93.0/96.4	94.8	88.2/62.3	93.3/92.5	92.5	76.1	93.8	92.7/91.9	65.6
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		CBoW	<a href="#">🔗</a>	44.5	62.2	49.0/71.2	51.6	0.0/0.5	14.0/13.6	49.7	53.1	65.11	0.0/50.0	-0.4
		Outside Best	<a href="#">🔗</a>	-	80.4	-	84.4	70.4/24.5	74.8/73.0	82.7	-	-	-	-
-	Stanford Hazy Research	Snorkel [SuperGLUE v1.9]	<a href="#">🔗</a>	-	-	88.6/93.2	76.2	76.4/36.3	-	78.9	72.1	72.6	-	47.6

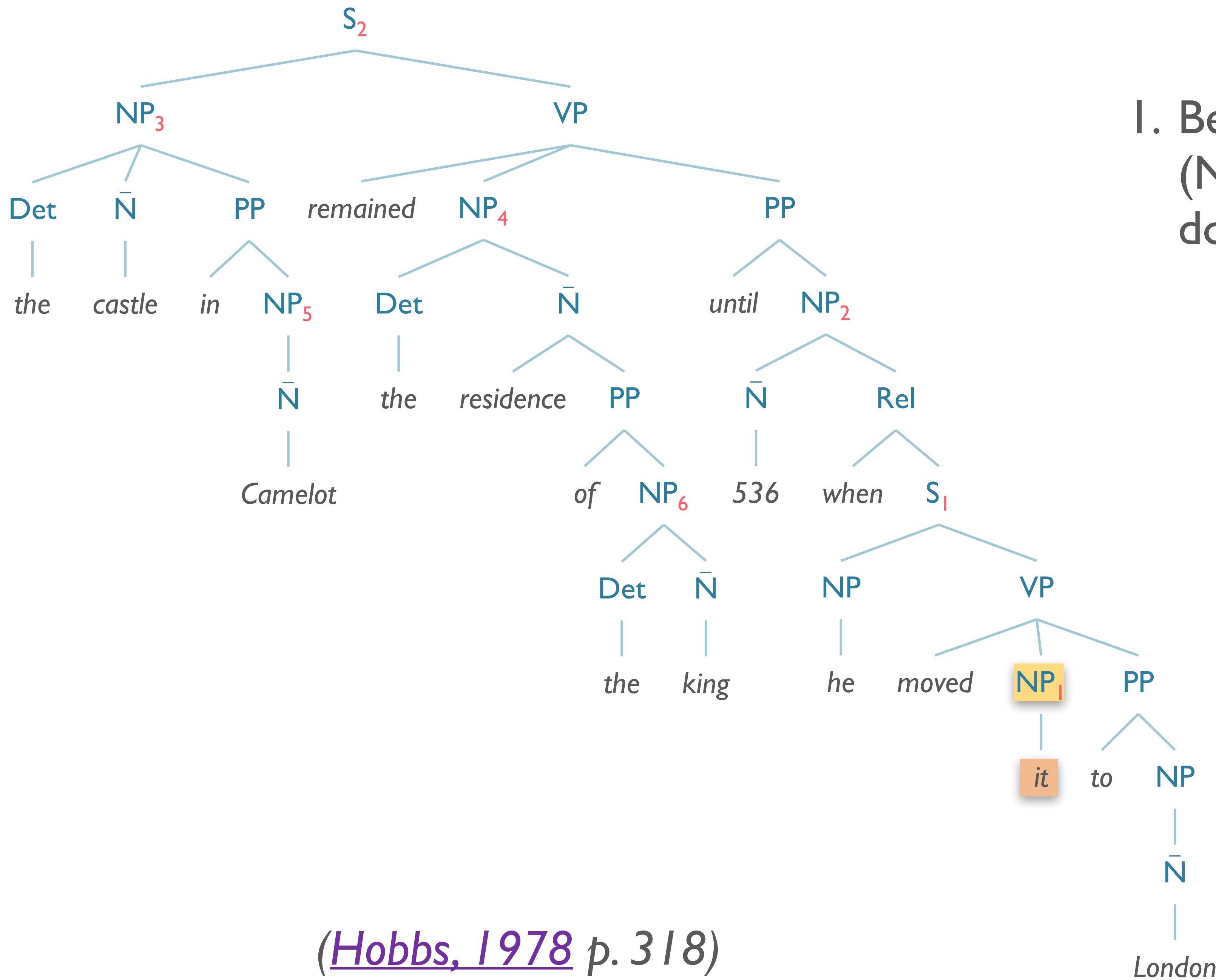
# Hobbs Algorithm Walkthrough

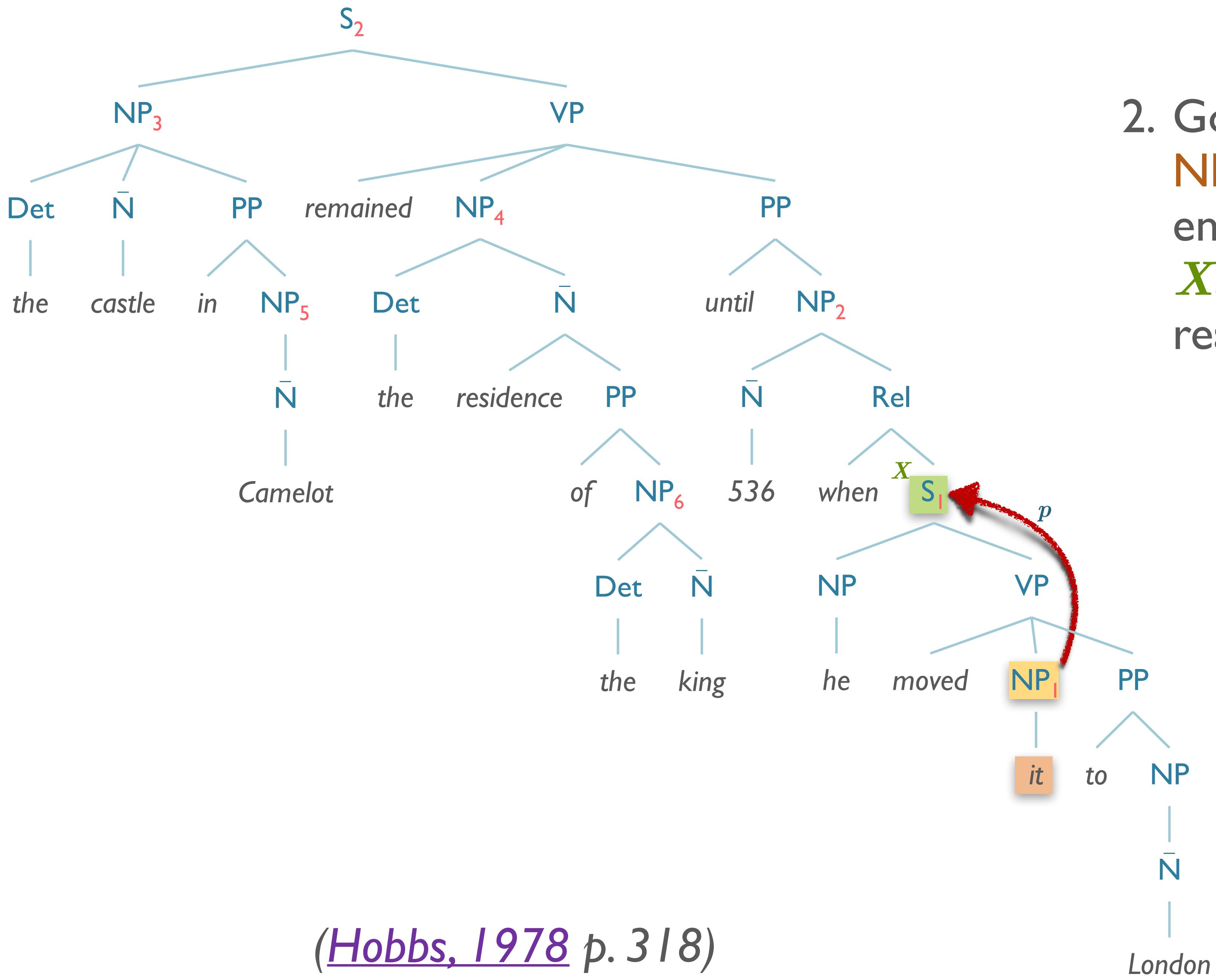
(h/t Ryan Georgi)

Let's figure out what the antecedent for "it" is



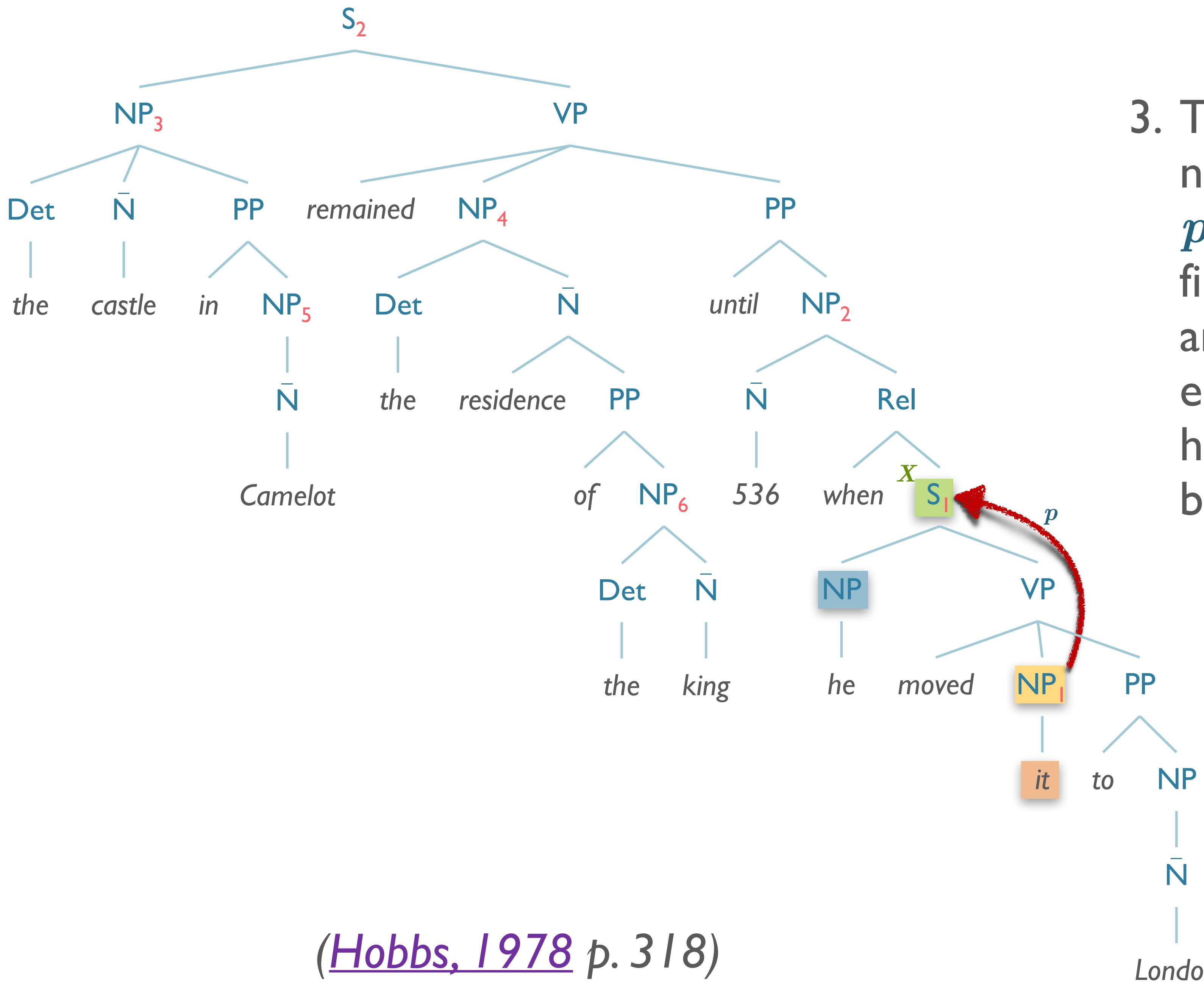
I. Begin at the noun phrase (NP) node immediately dominating the pronoun





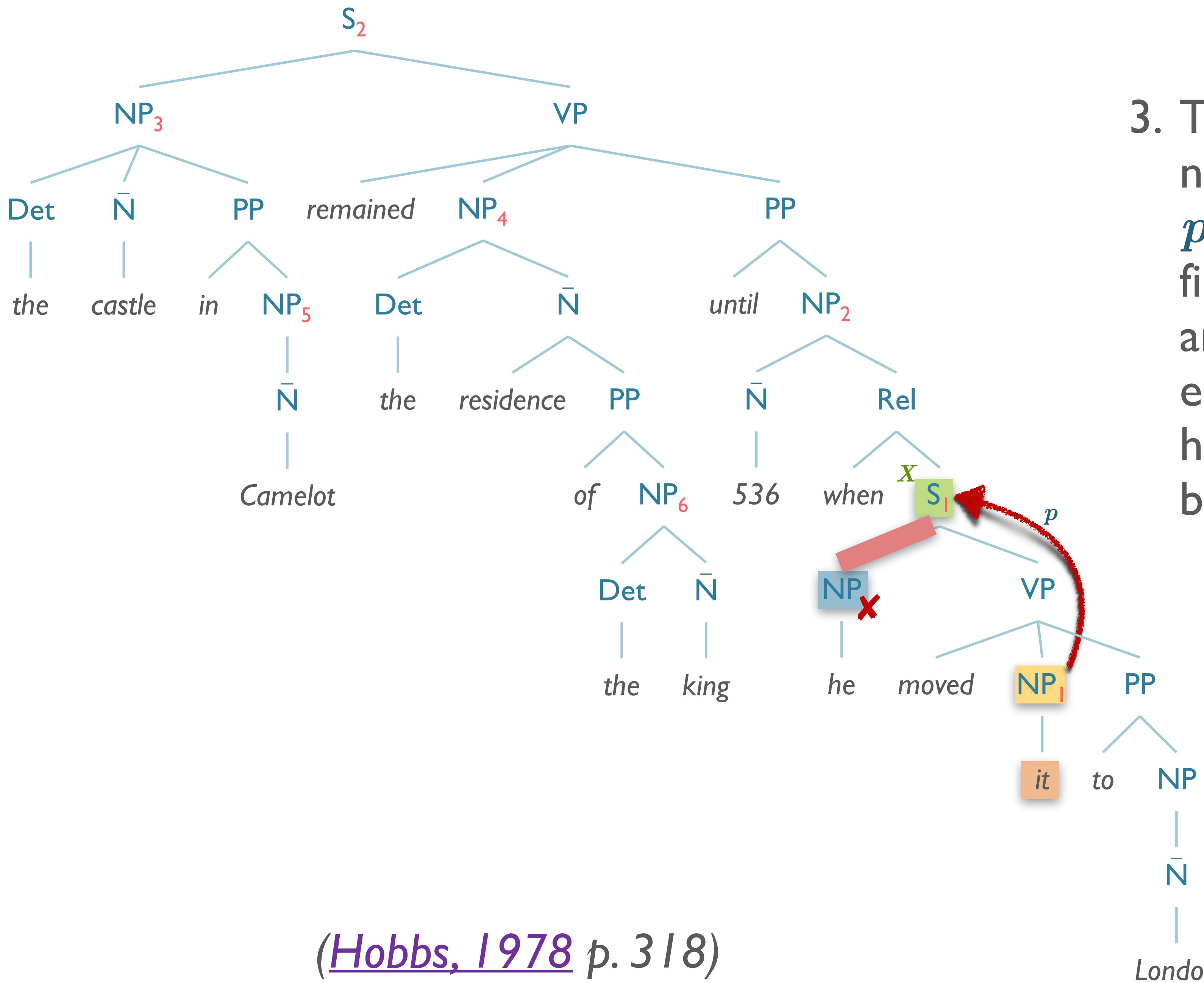
2. Go up the tree to the first **NP** or sentence (**S**) node encountered. Call this node **X**, and call the path used to reach it **p**.

(Hobbs, 1978 p. 318)



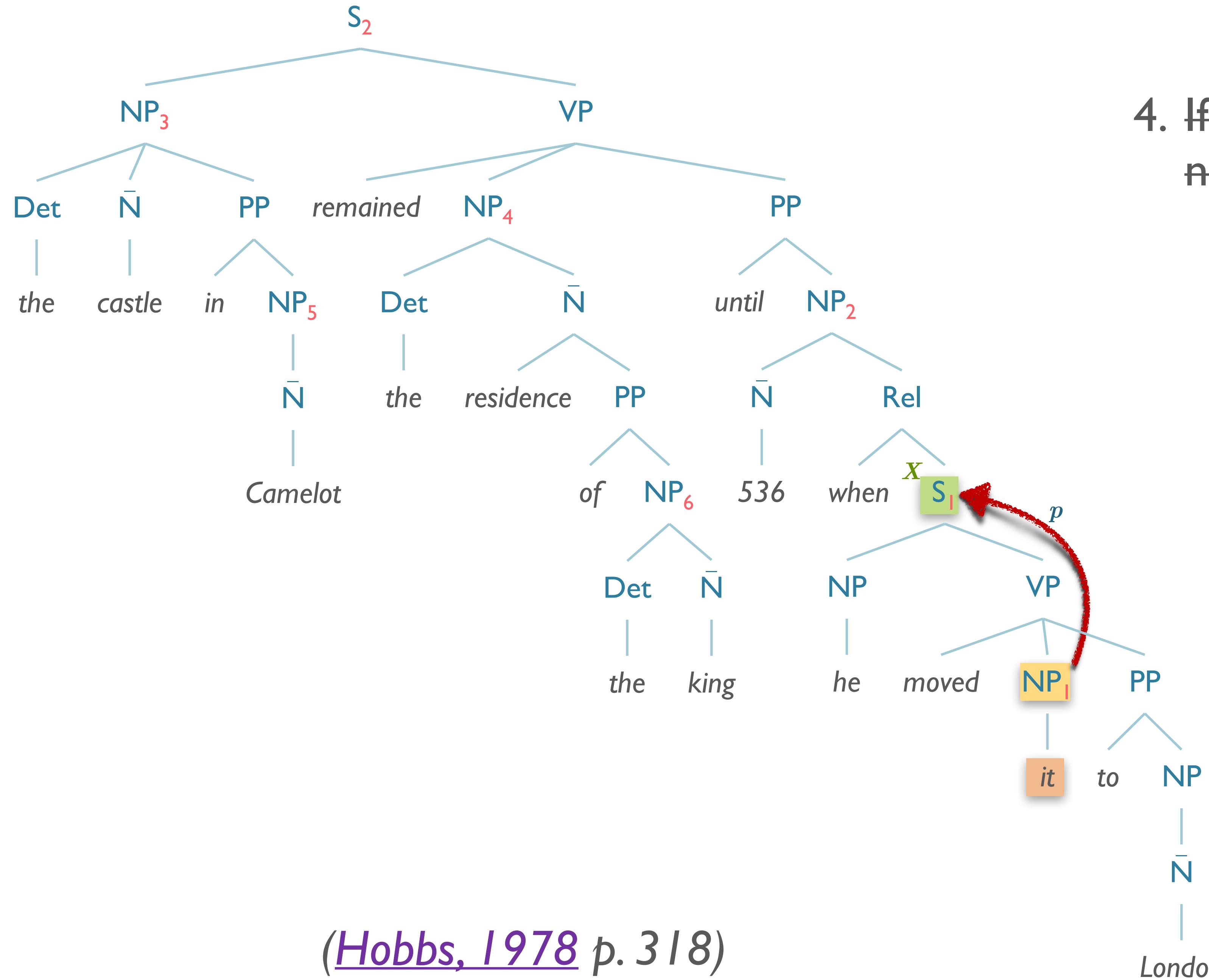
3. Traverse all branches below node  $X$  to the left of path  $p$  in a left-to-right, breadth-first fashion. Propose as the antecedent any encountered  $NP$  node that has an  $NP$  or  $S$  node between it and  $X$ .

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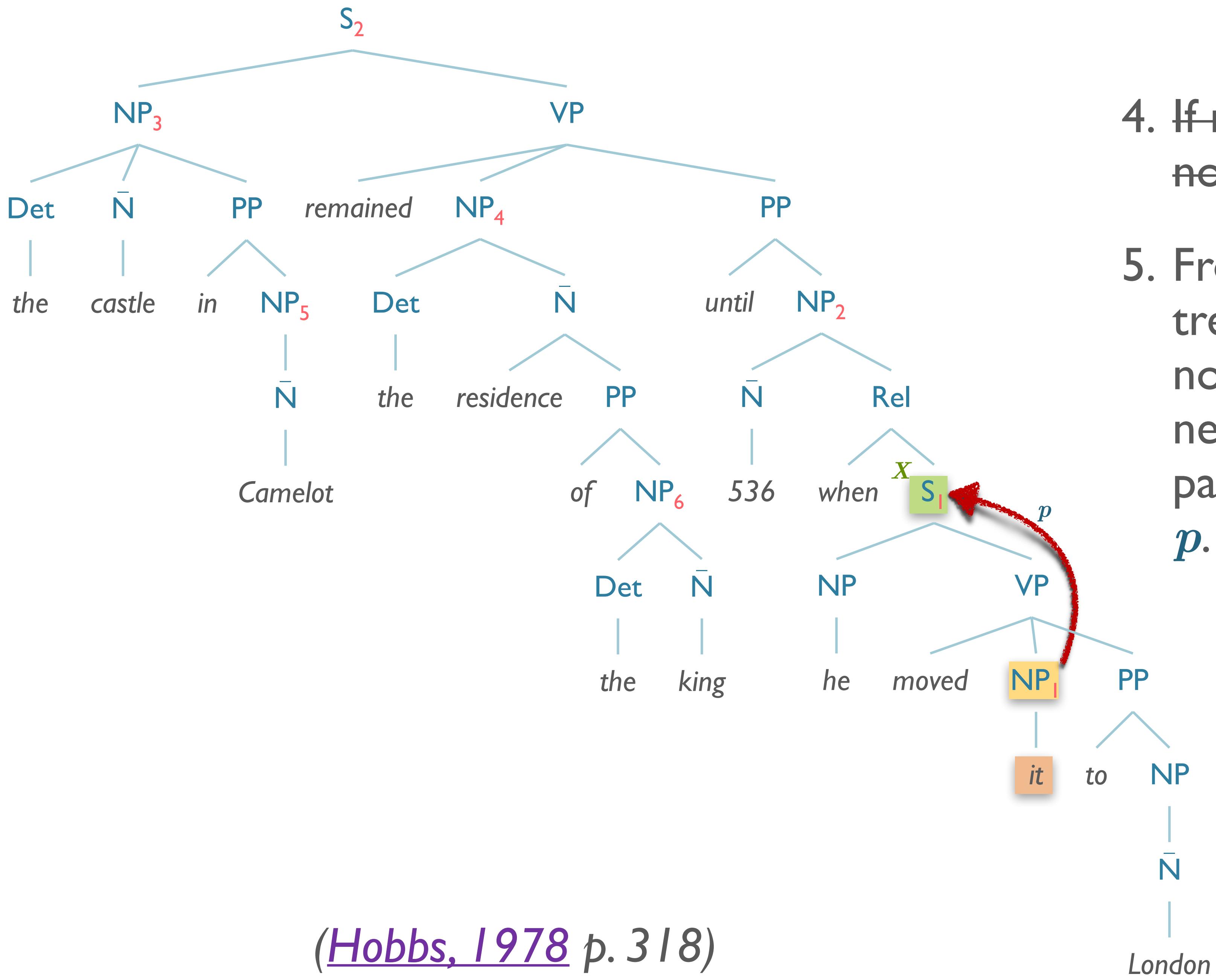
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No NP or S between “he” NP and  $X$



4. If node **X** is the highest **S** node in the sentence...

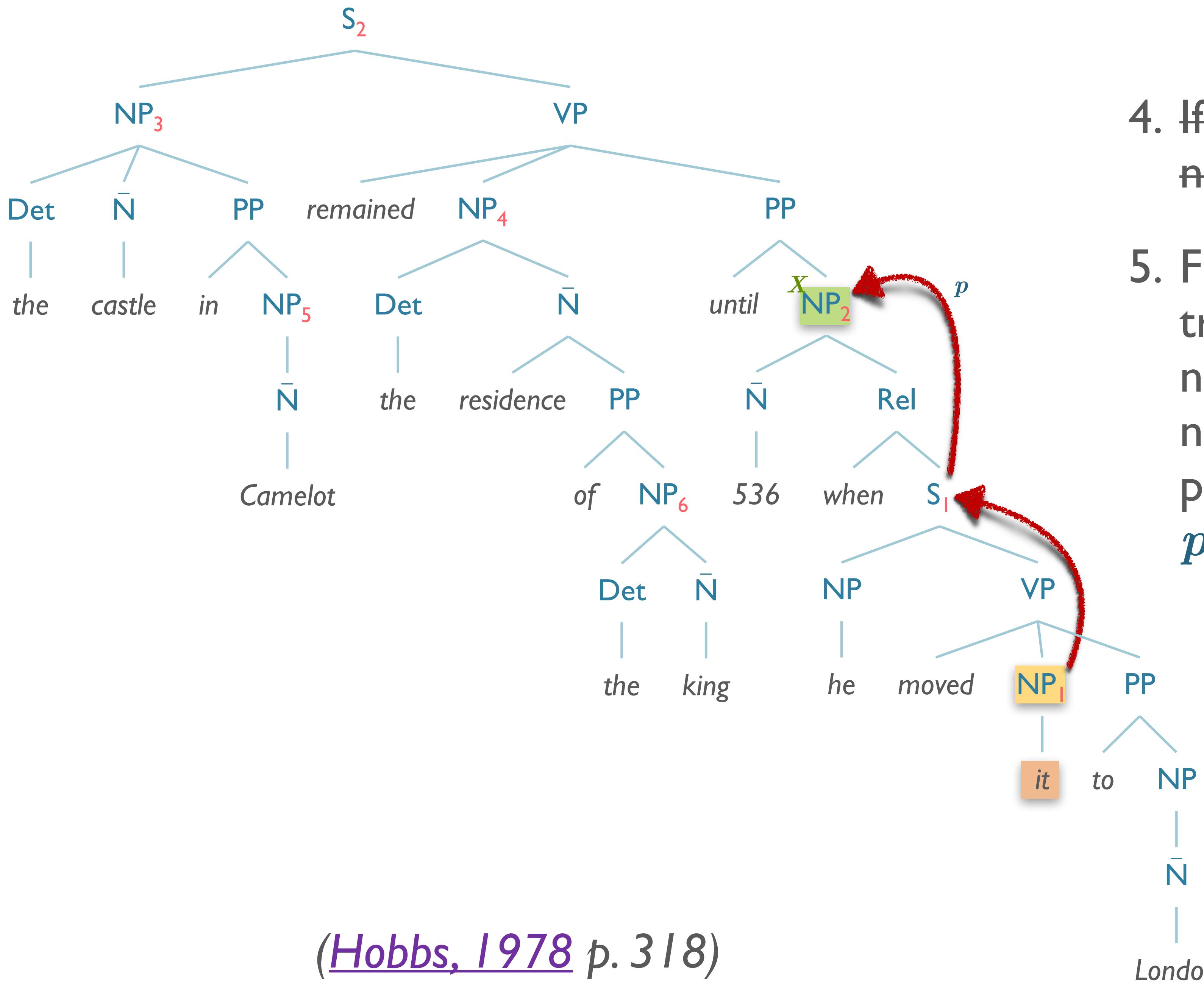
(Hobbs, 1978 p. 318)



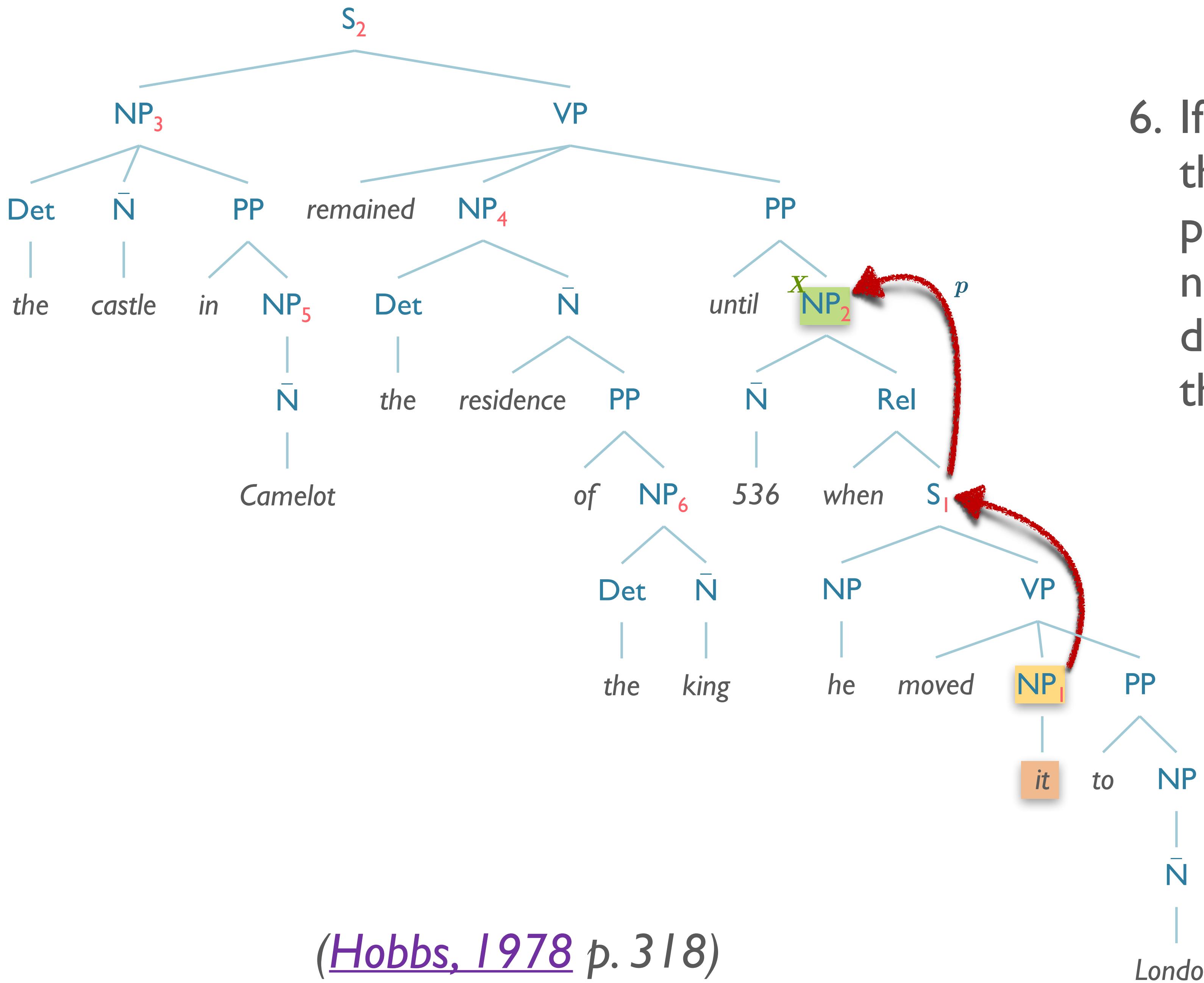
4. If node  $X$  is the highest  $S$  node in the sentence...

5. From node  $X$ , go up the tree to the first  $NP$  or  $S$  node encountered. Call this new node  $X$ , and call the path traversed to reach it  $p$ .

(Hobbs, 1978 p. 318)

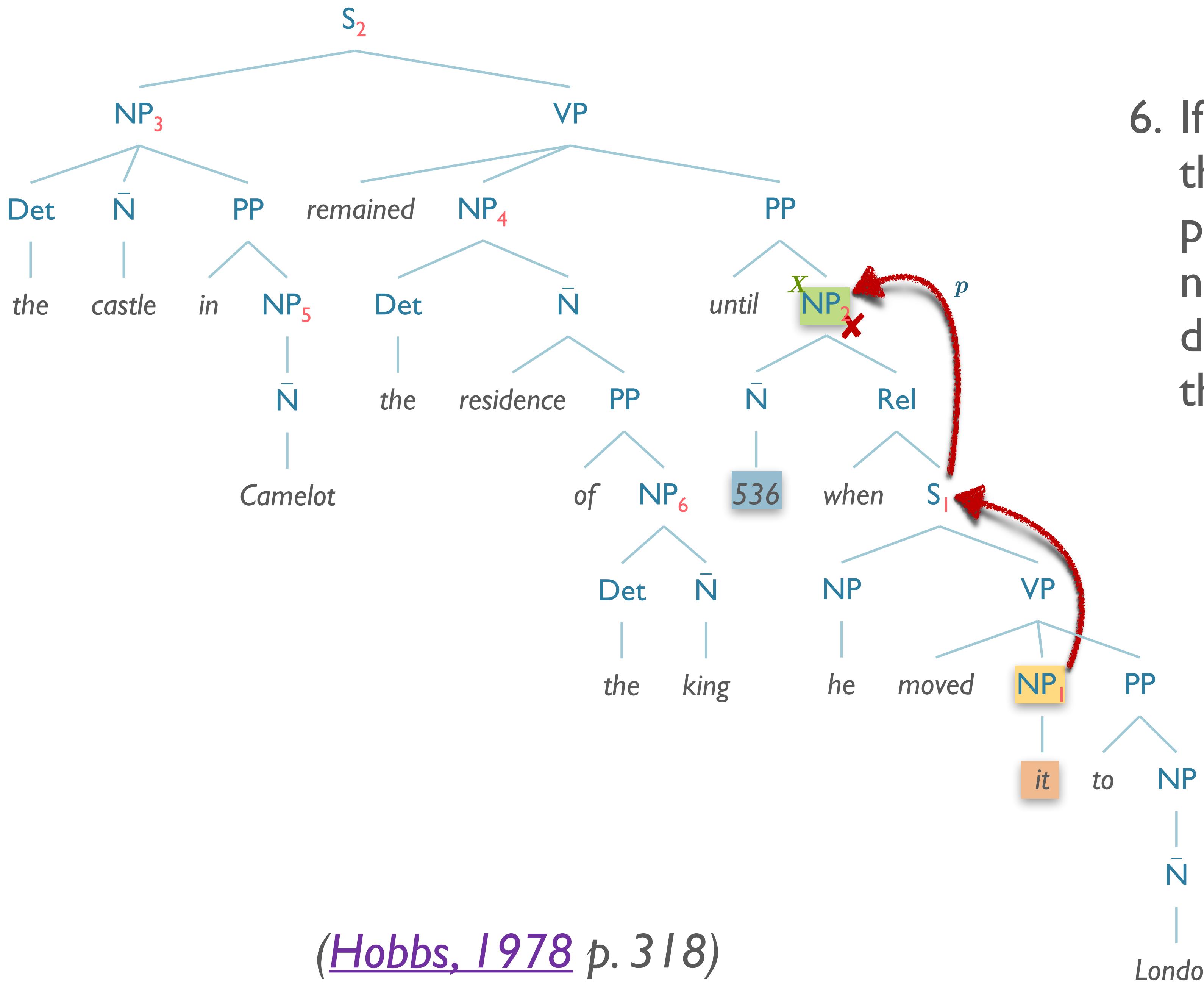


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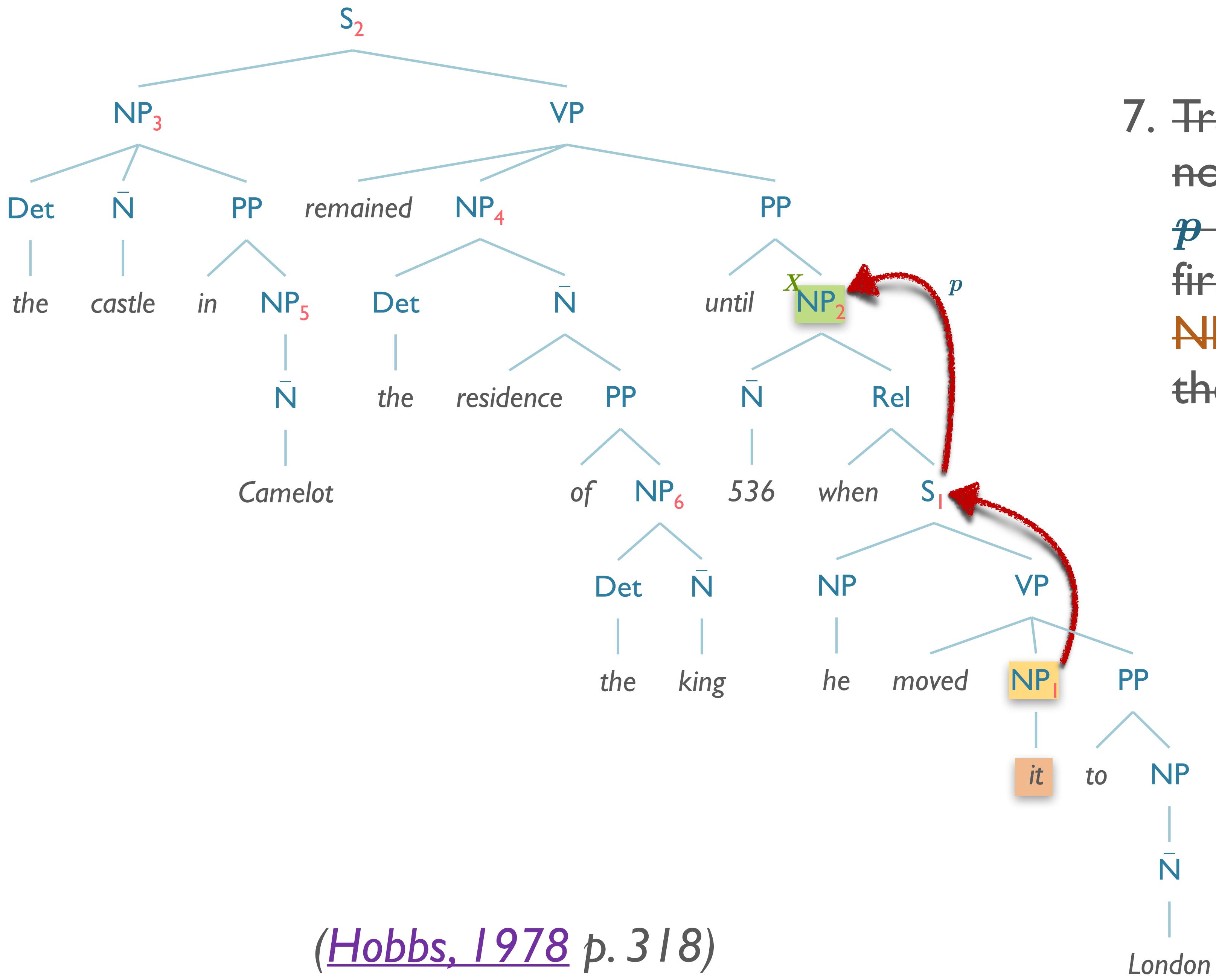
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(*Hobbs, 1978* p. 318)



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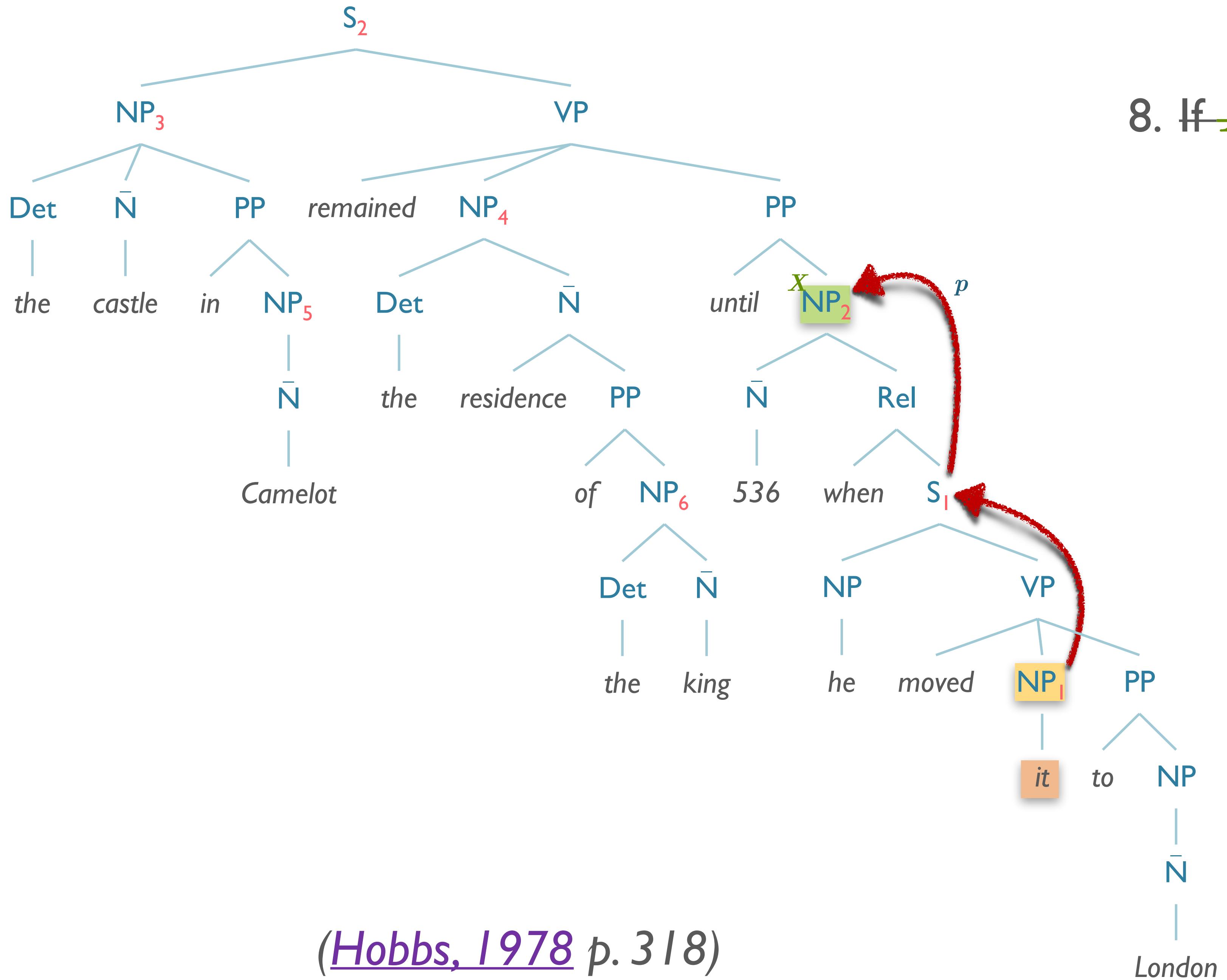
“536” can’t be “moved”!

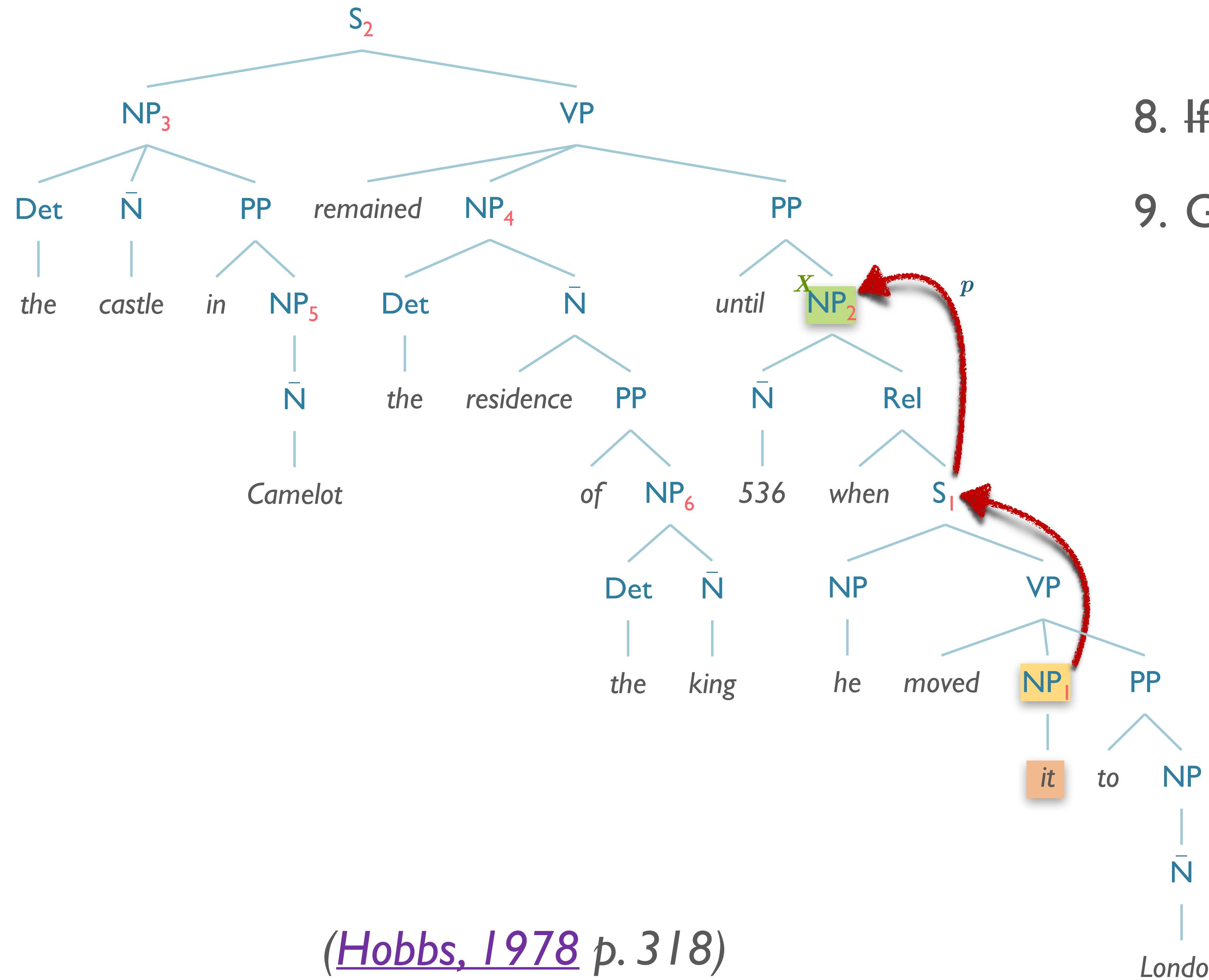


7. Traverse all branches below node **X** to the *left* of path **p** in a left-to-right, breadth-first manner. Propose any **NP** node encountered as the antecedent.

(Hobbs, 1978 p. 318)

8. If  $X$  is an  $S$  node...

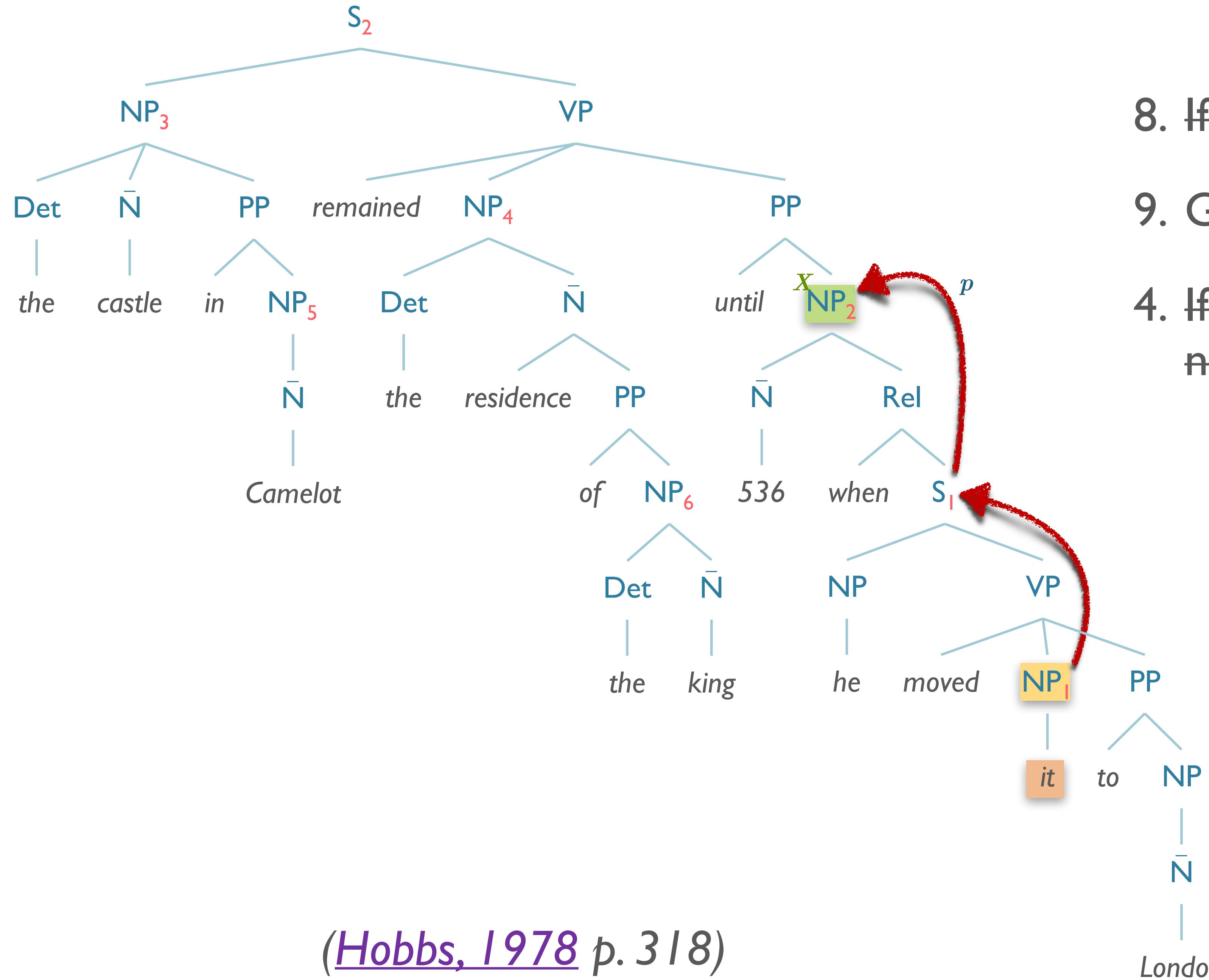




8. If  $X$  is an  $S$  node...

9. Go to step 4.

(Hobbs, 1978 p. 318)

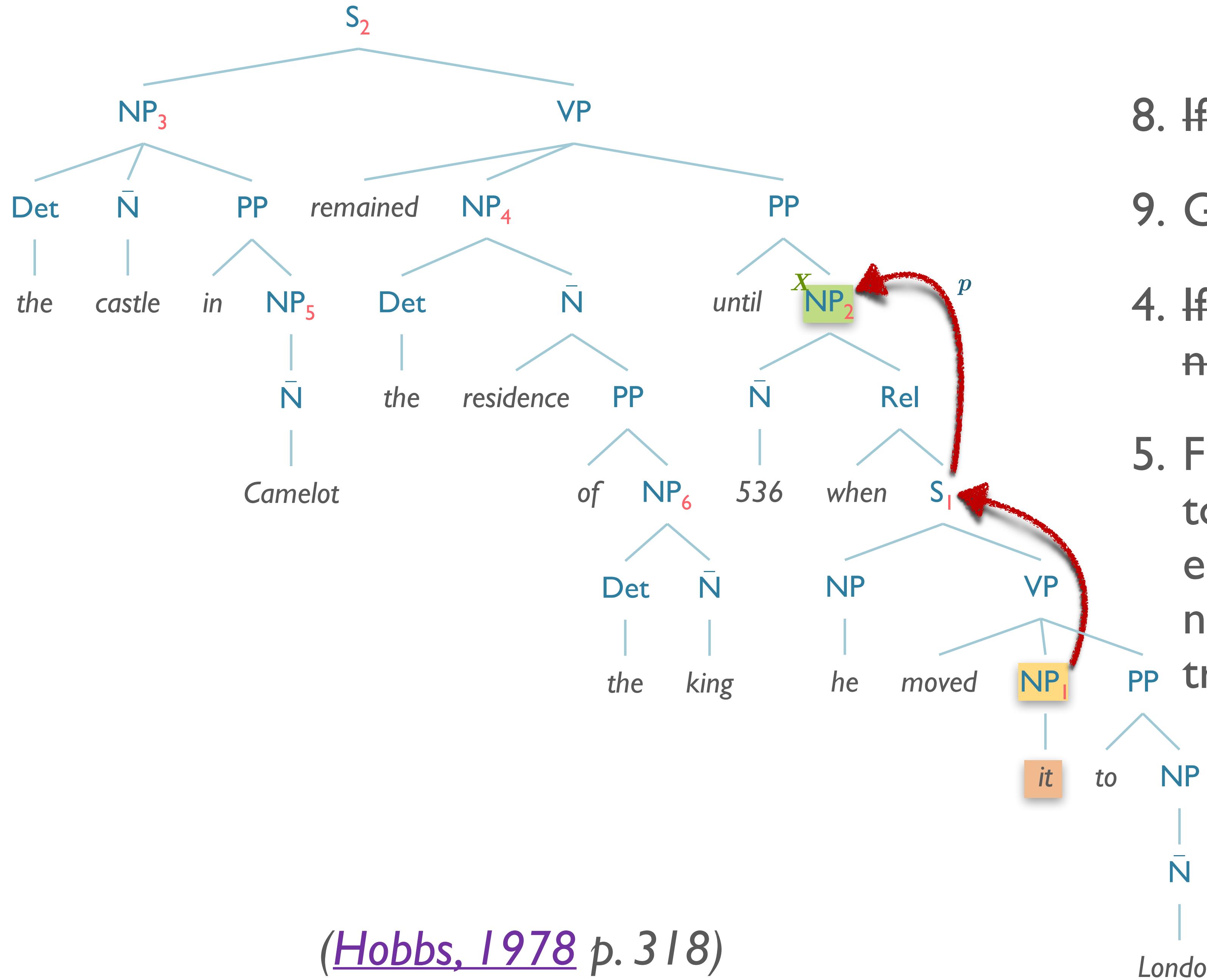


8. If **X** is an **S** node...

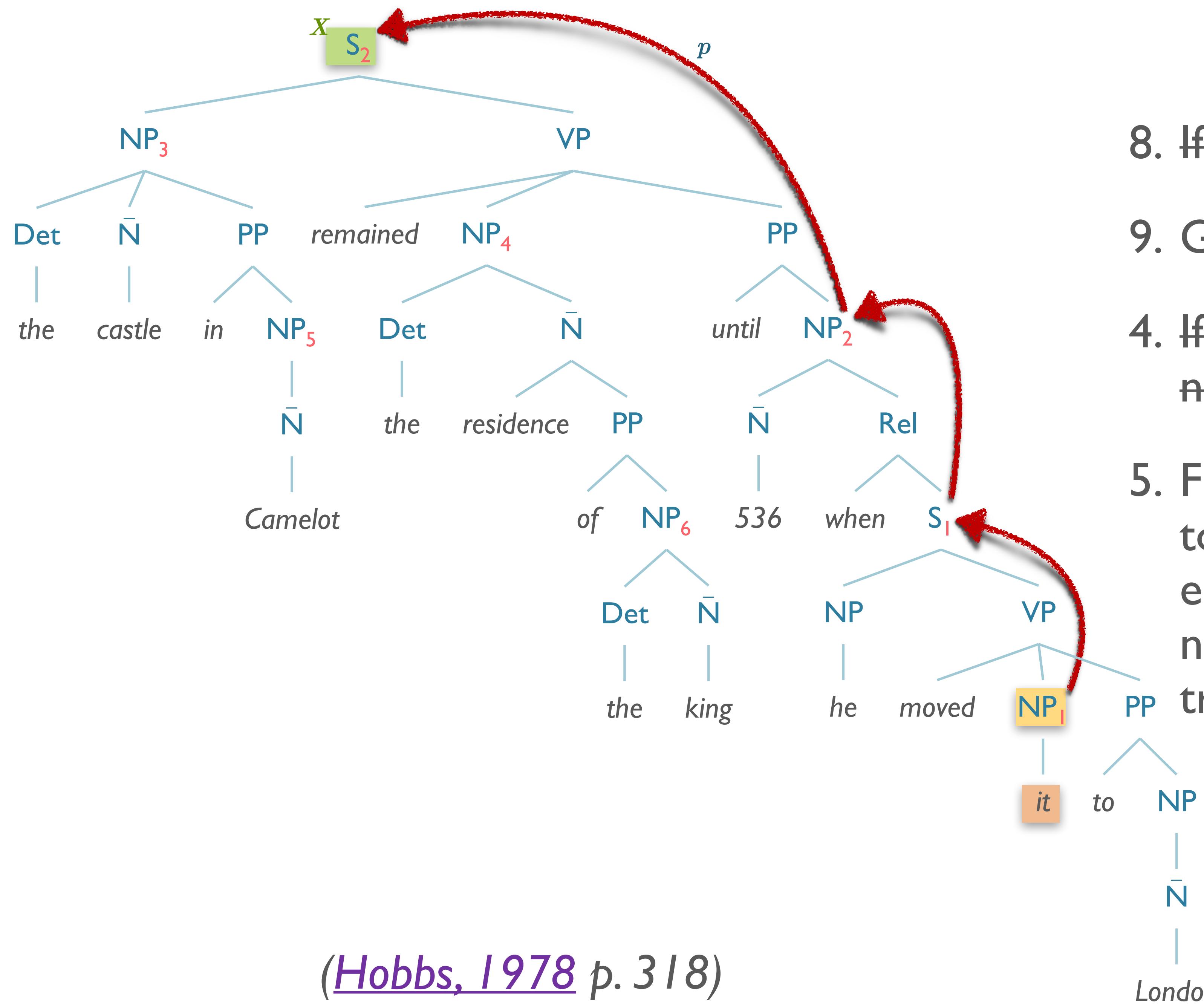
9. Go to step 4.

4. If node **X** is the highest **S** node in the sentence...

(Hobbs, 1978 p. 318)



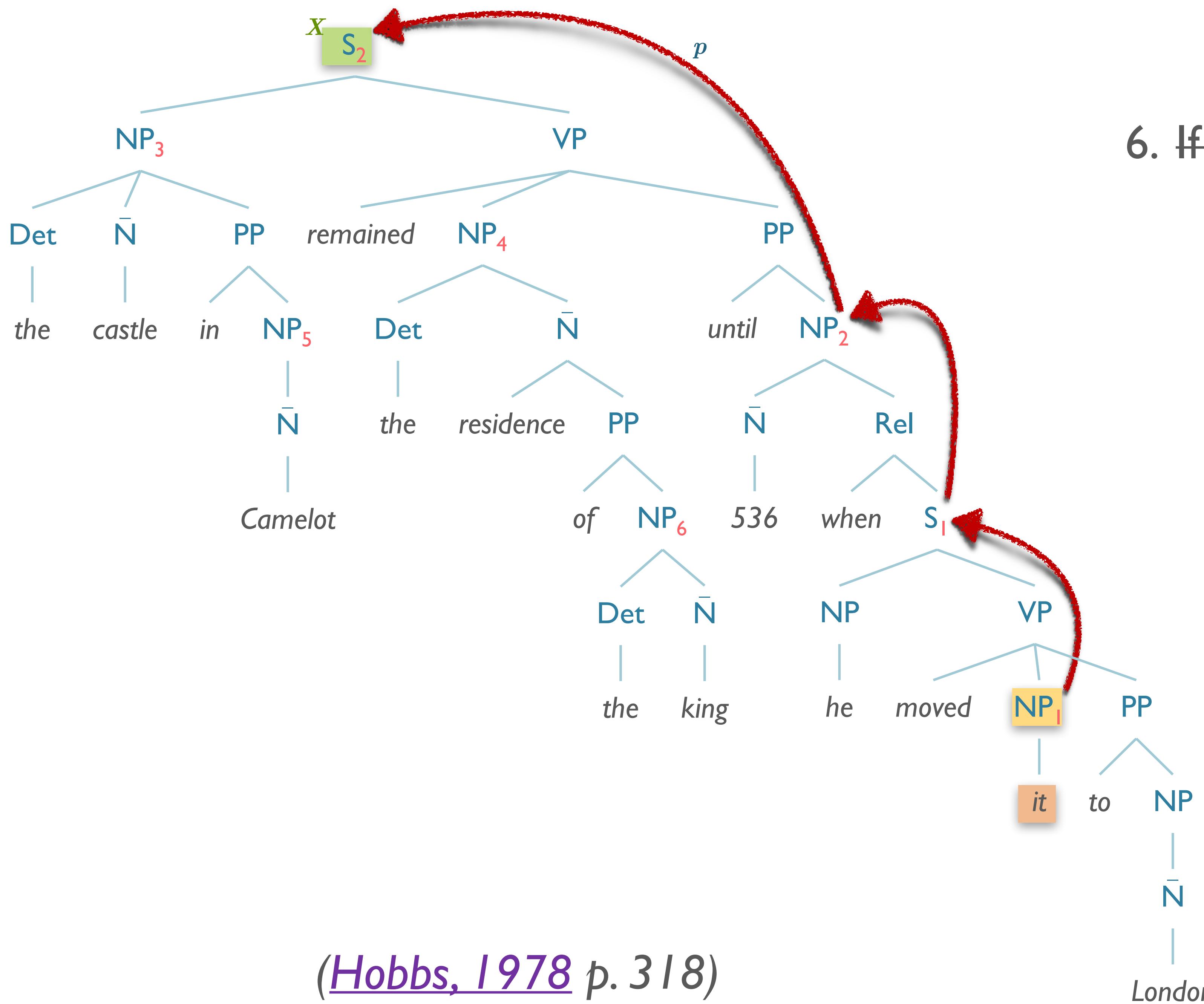
- 8. If  $X$  is an  $S$  node...**
- 9. Go to step 4.**
- 4. If node  $X$  is the highest  $S$  node in the sentence...**
- 5. From node  $X$ , go up the tree to the first  $NP$  or  $S$  node encountered. Call this new node  $X$ , and call the path traversed to reach it  $p$ .**

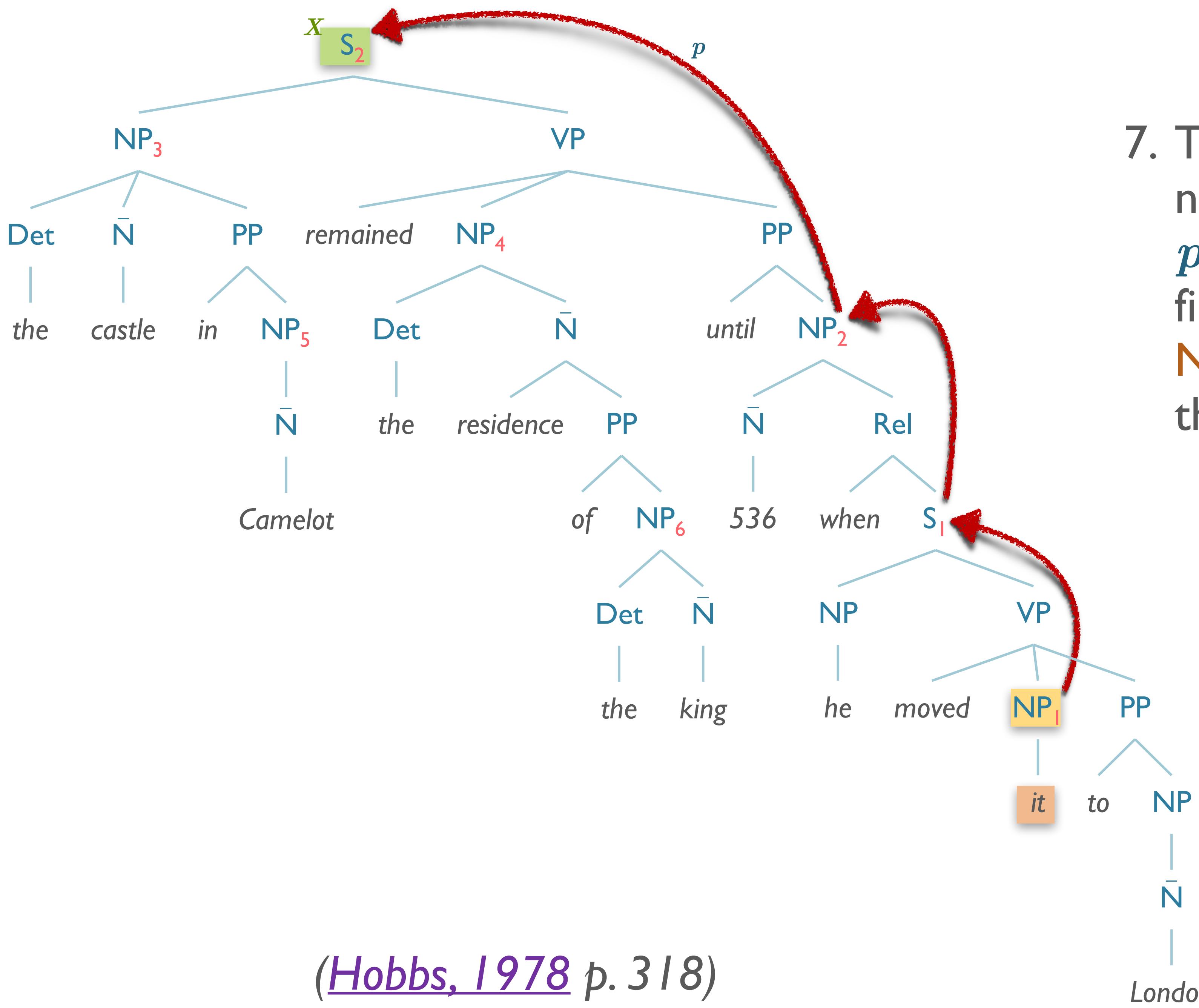


8. If **X** is an **S** node...
9. Go to step 4.
4. If node **X** is the highest **S** node in the sentence...
5. From node **X**, go up the tree to the first **NP** or **S** node encountered. Call this new node **X**, and call the path traversed to reach it **p**.

(Hobbs, 1978 p. 318)

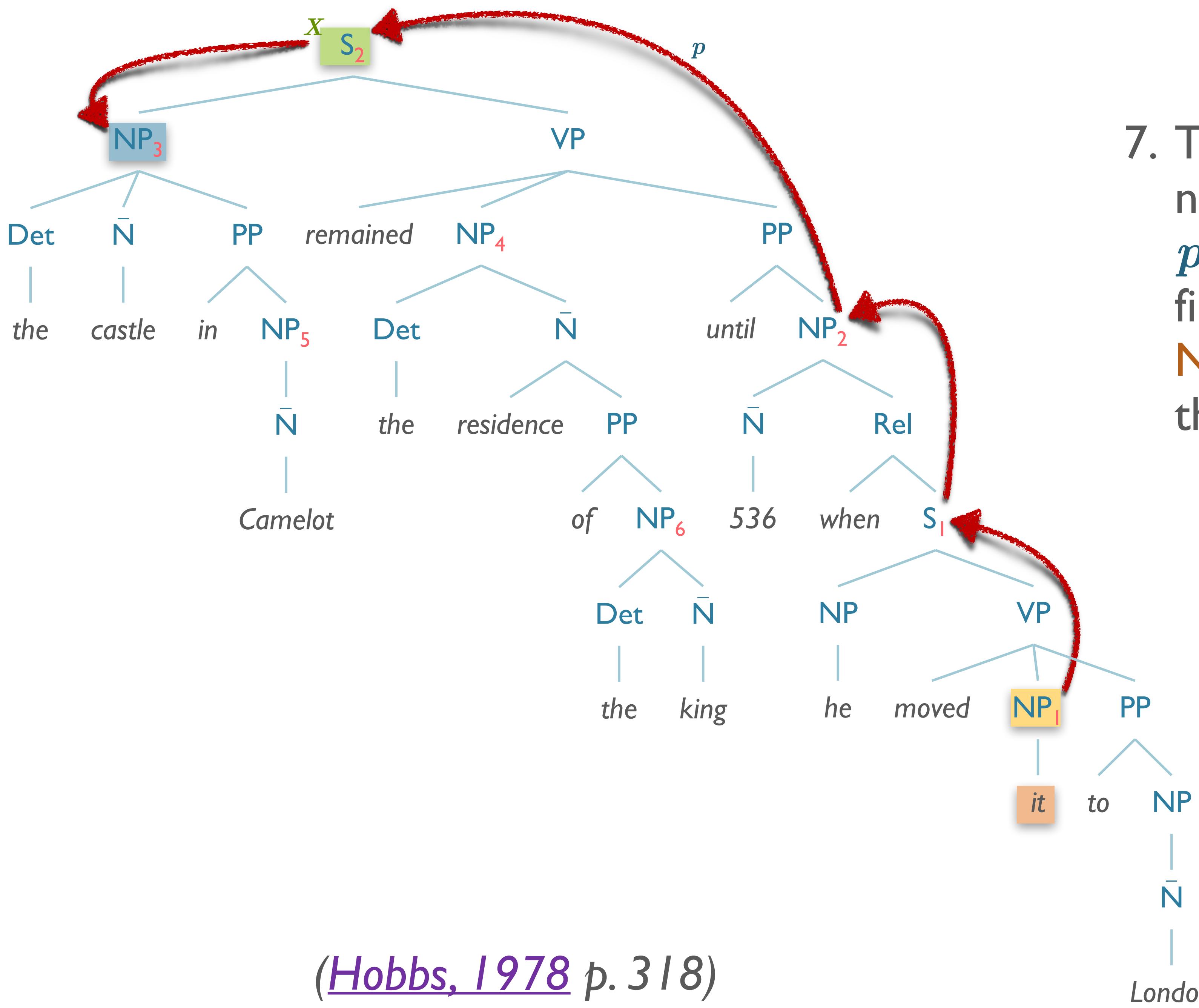
6. If  $X$  is an ~~NP~~ node...





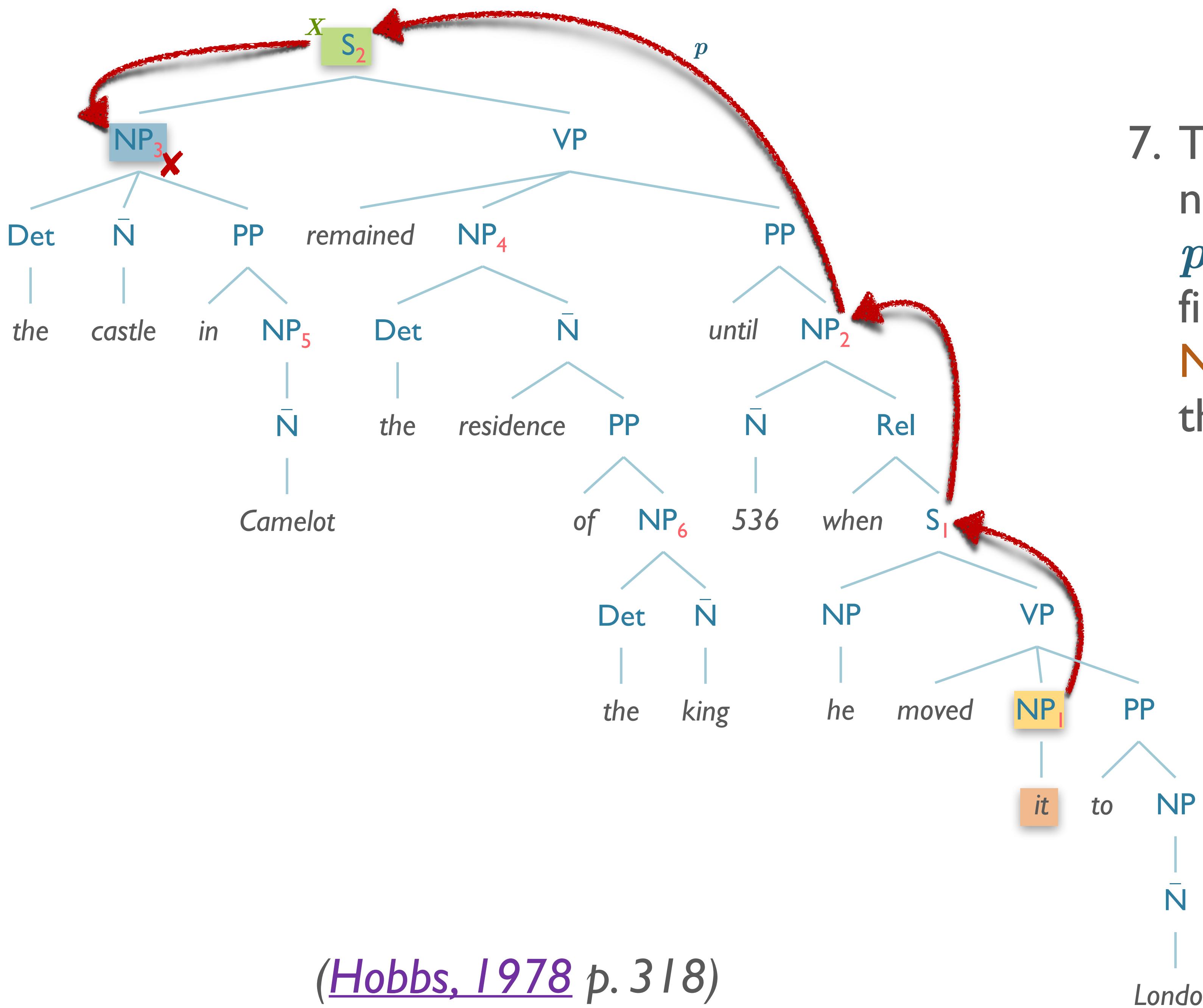
7. Traverse all branches below node  $X$  to the *left* of path  $p$  in a left-to-right, breadth-first manner. Propose any **NP** node encountered as the antecedent.

(Hobbs, 1978 p. 318)



7. Traverse all branches below node **X** to the *left* of path **p** in a left-to-right, breadth-first manner. Propose any **NP** node encountered as the antecedent.

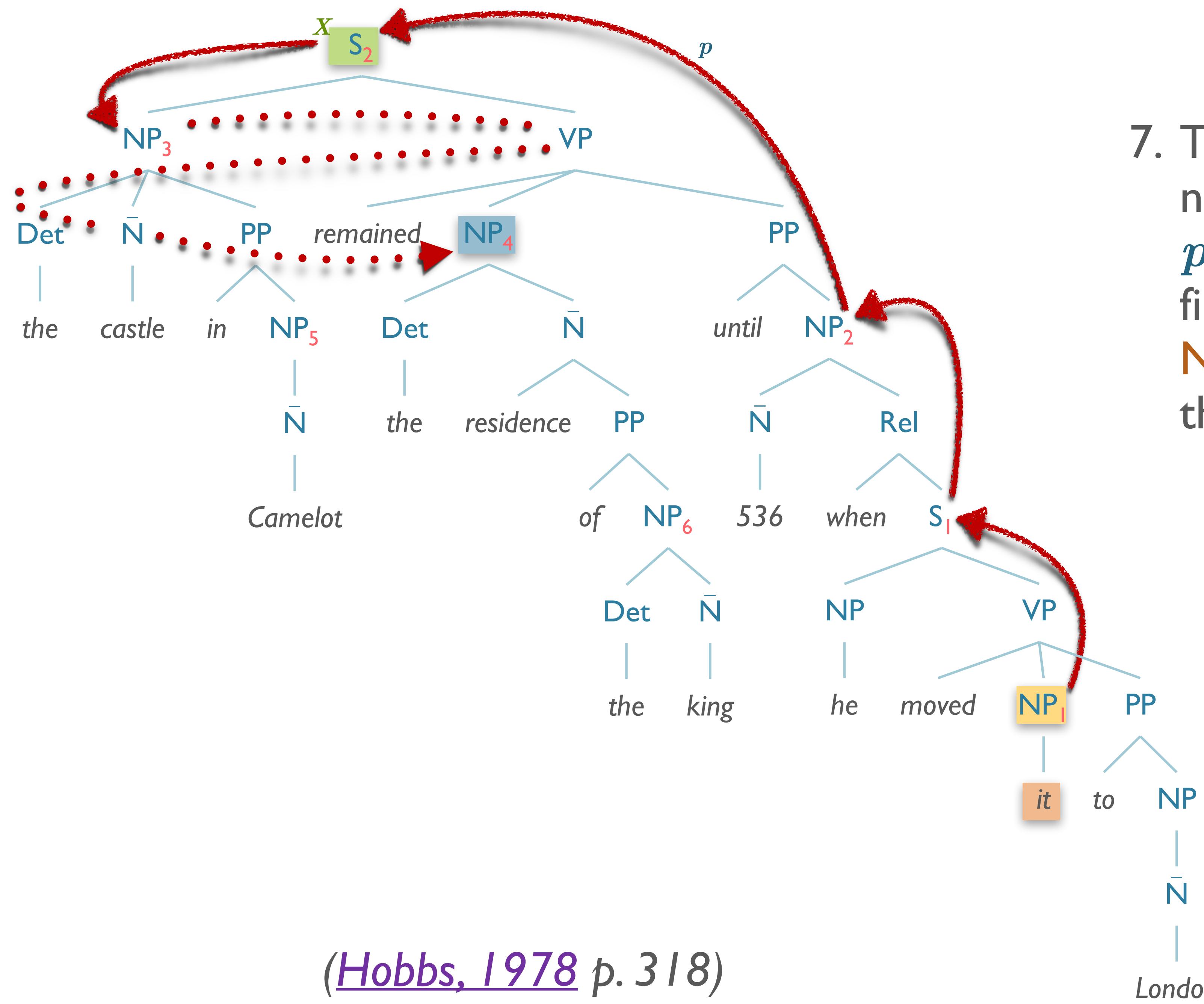
(Hobbs, 1978 p. 318)



7. Traverse all branches below node **X** to the *left* of path **p** in a left-to-right, breadth-first manner. Propose any **NP** node encountered as the antecedent.

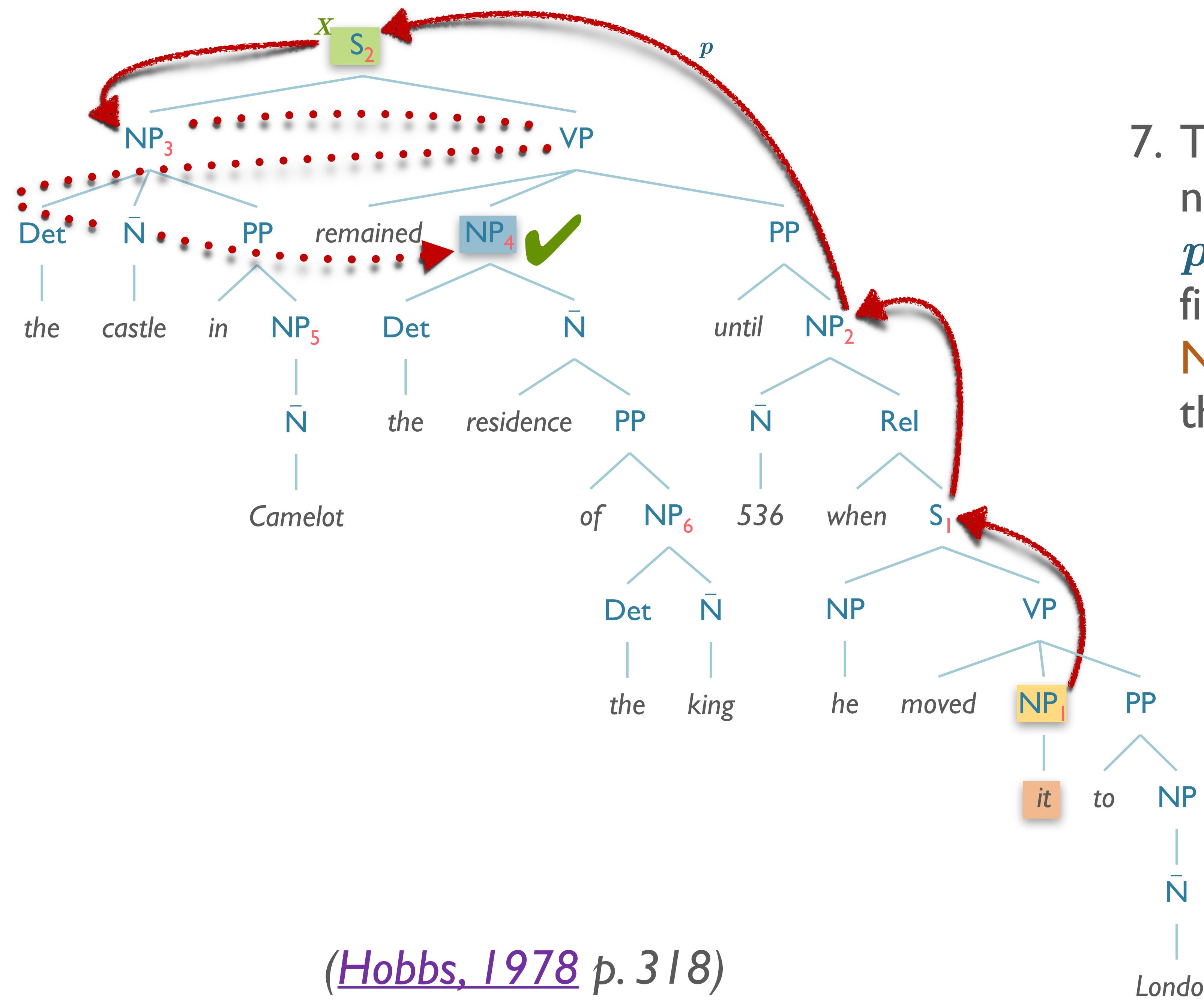
*Moving castles?* 🤔

(Hobbs, 1978 p. 318)



7. Traverse all branches below node  $X$  to the *left* of path  $p$  in a left-to-right, breadth-first manner. Propose any **NP** node encountered as the antecedent.

(Hobbs, 1978 p. 318)



7. Traverse all branches below node  $X$  to the *left* of path  $p$  in a left-to-right, breadth-first manner. Propose any  $NP$  node encountered as the antecedent.

*"the residence of the king"*

(Hobbs, 1978 p. 318)

# Hobbs Algorithm Detail ([Hobbs, 1978](#))

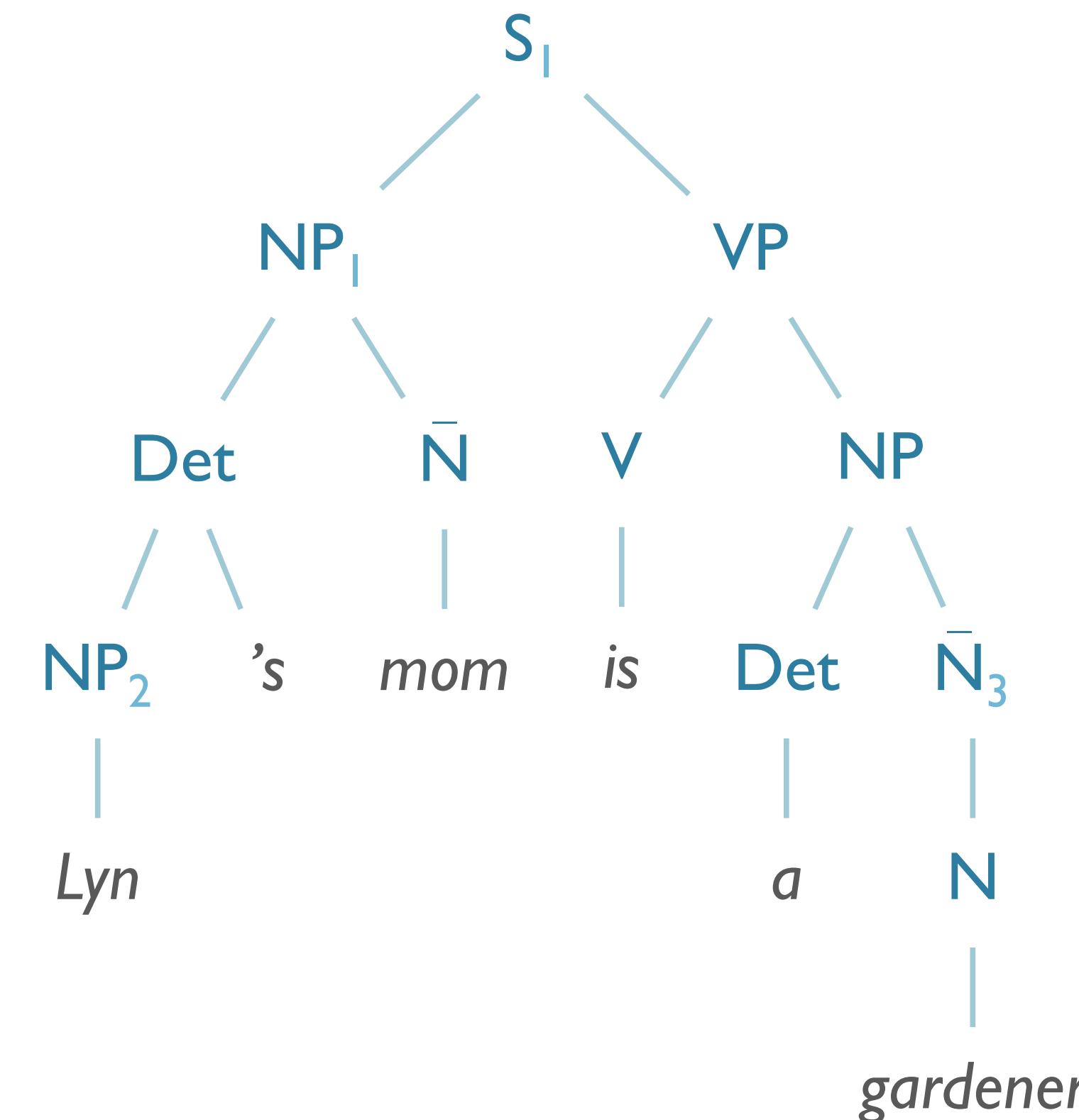
1. Begin at the noun phrase (NP) node immediately dominating the pronoun
2. Go up the tree to the first NP or sentence (S) node encountered. Call this node  $X$ , and call the path used to reach it  $p$ .
3. Traverse all branches below node  $X$  to the left of path  $p$  in a left-to-right, breadth-first fashion. Propose as the antecedent any encountered NP node that has an NP or S node between it and  $X$ .
4. If node  $X$  is the highest S node in the sentence, traverse the surface parse trees of previous sentences in the text in order of recency, the most recent first; each tree is traversed in a left-to-right, breadth-first manner, and when an NP node is encountered, it is proposed as antecedent. If  $X$  is not the highest S node in the sentence, continue to step 5.

# Hobbs Algorithm Detail ([Hobbs, 1978](#))

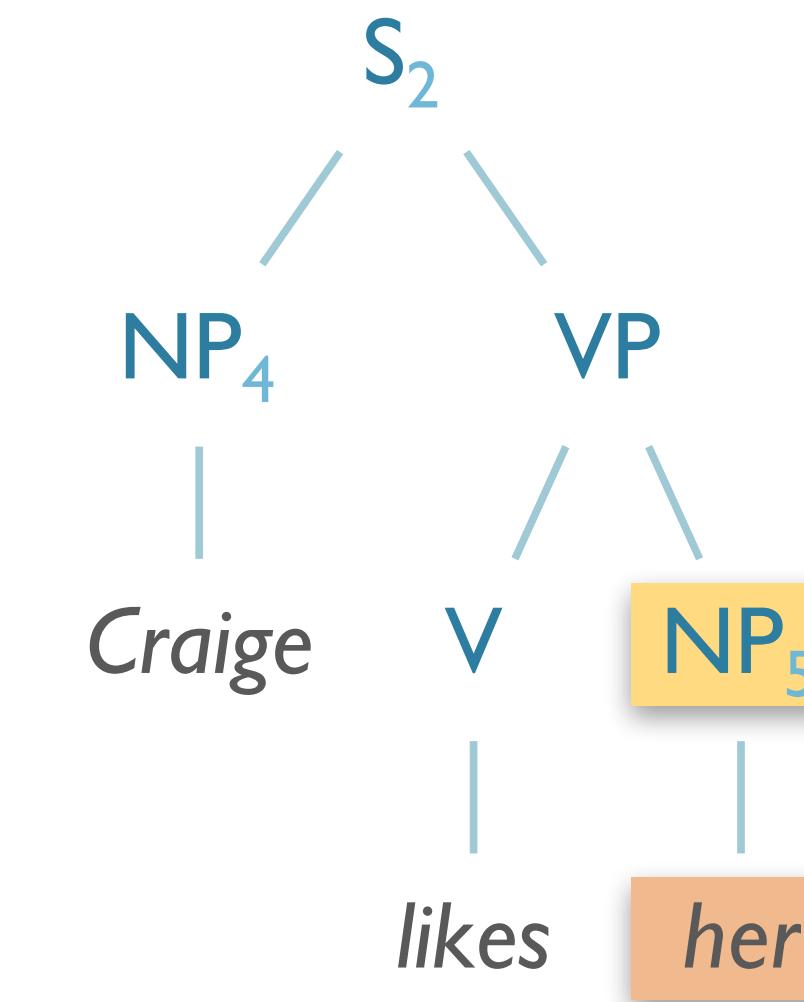
5. From node  $X$ , go up the tree to the first NP or S node encountered. Call this new node  $X$ , and call the path traversed to reach it  $p$ .
6. If  $X$  is an NP node and if the path  $p$  to  $X$  did not pass through the Nominal node that  $X$  immediately dominates, propose  $X$  as the antecedent.
7. Traverse all branches below node  $X$  to the *left* of path  $p$  in a left-to-right, breadth-first manner. Propose any NP node encountered as the antecedent.
8. If  $X$  is an S node, traverse all branches of node  $X$  to the *right* of path  $p$  in a left-to-right, breadth-first manner, but do not go below any NP or S node encountered. Propose any NP node encountered as the antecedent.
9. Go to step 4.

# Hobbs Example

*Lyn's mom is a gardener.*



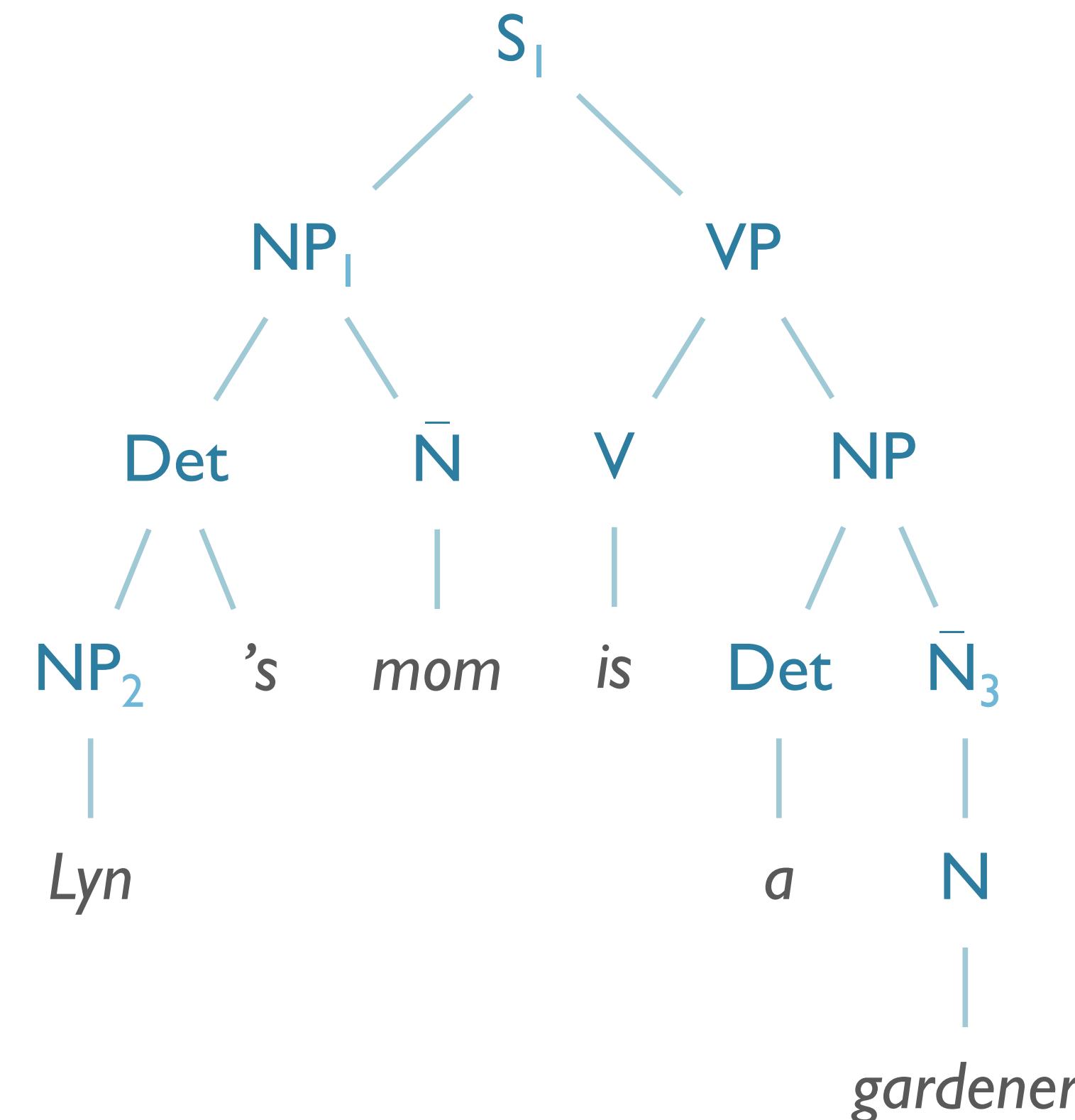
*Craigie likes her.*



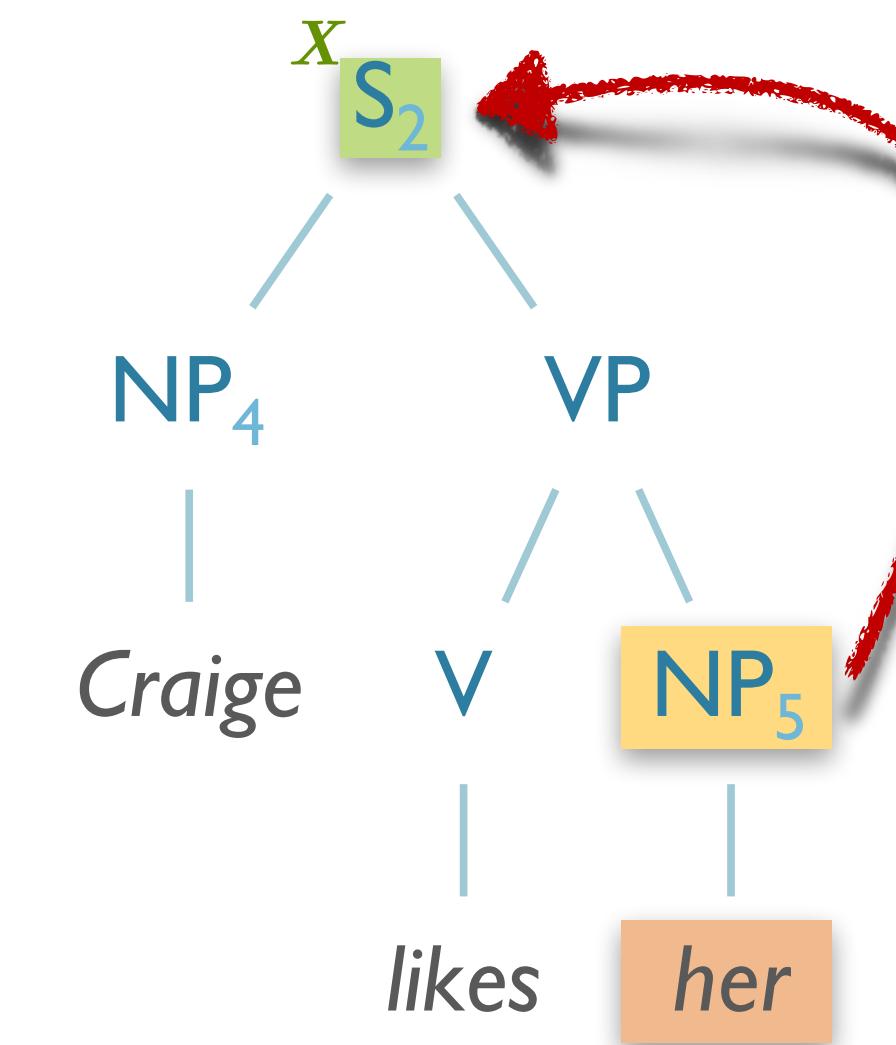
- I. Begin at the noun phrase ( $NP$ ) node immediately dominating the pronoun

# Hobbs Example

*Lyn's mom is a gardener.*



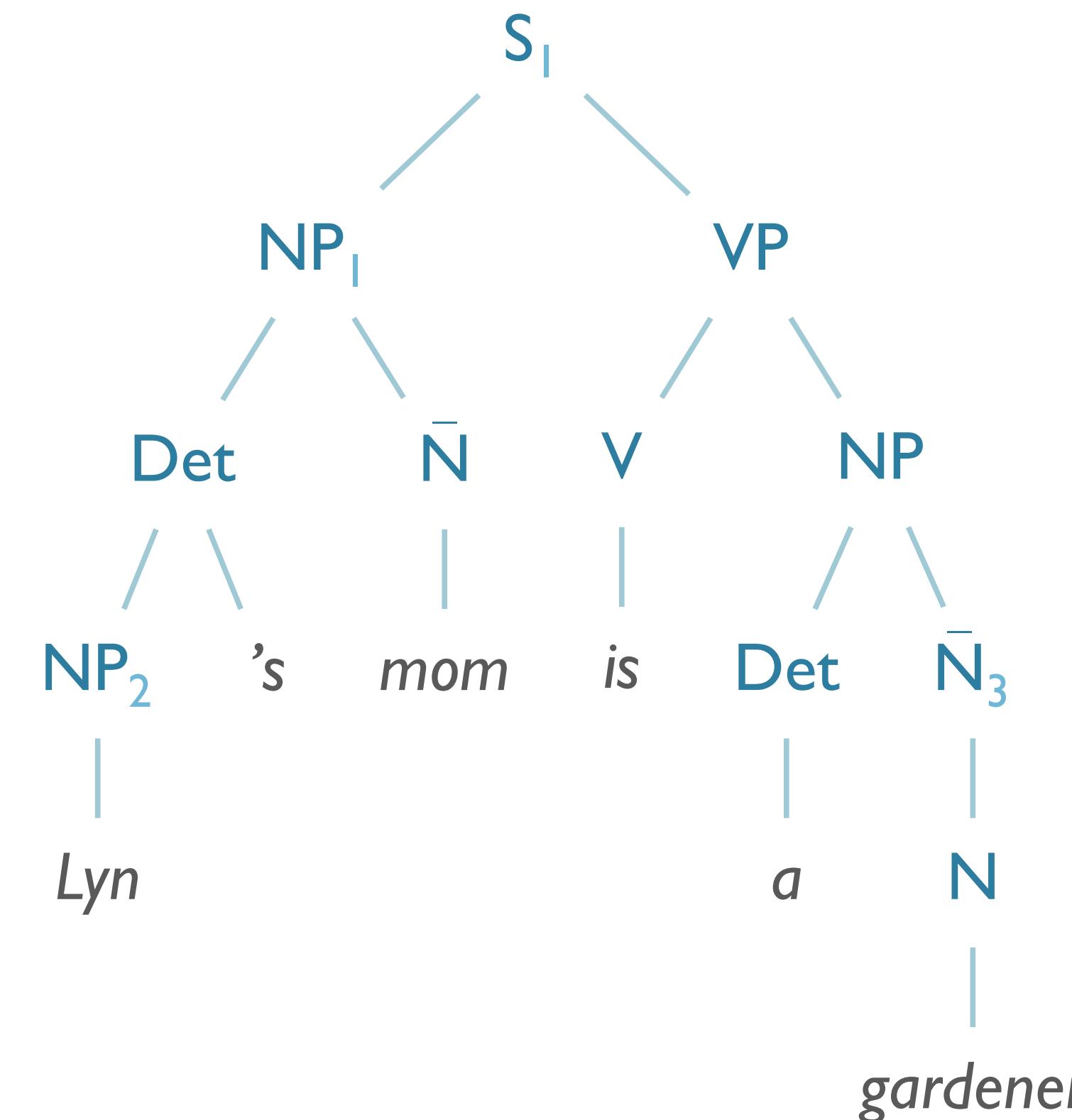
*Craig likes her.*



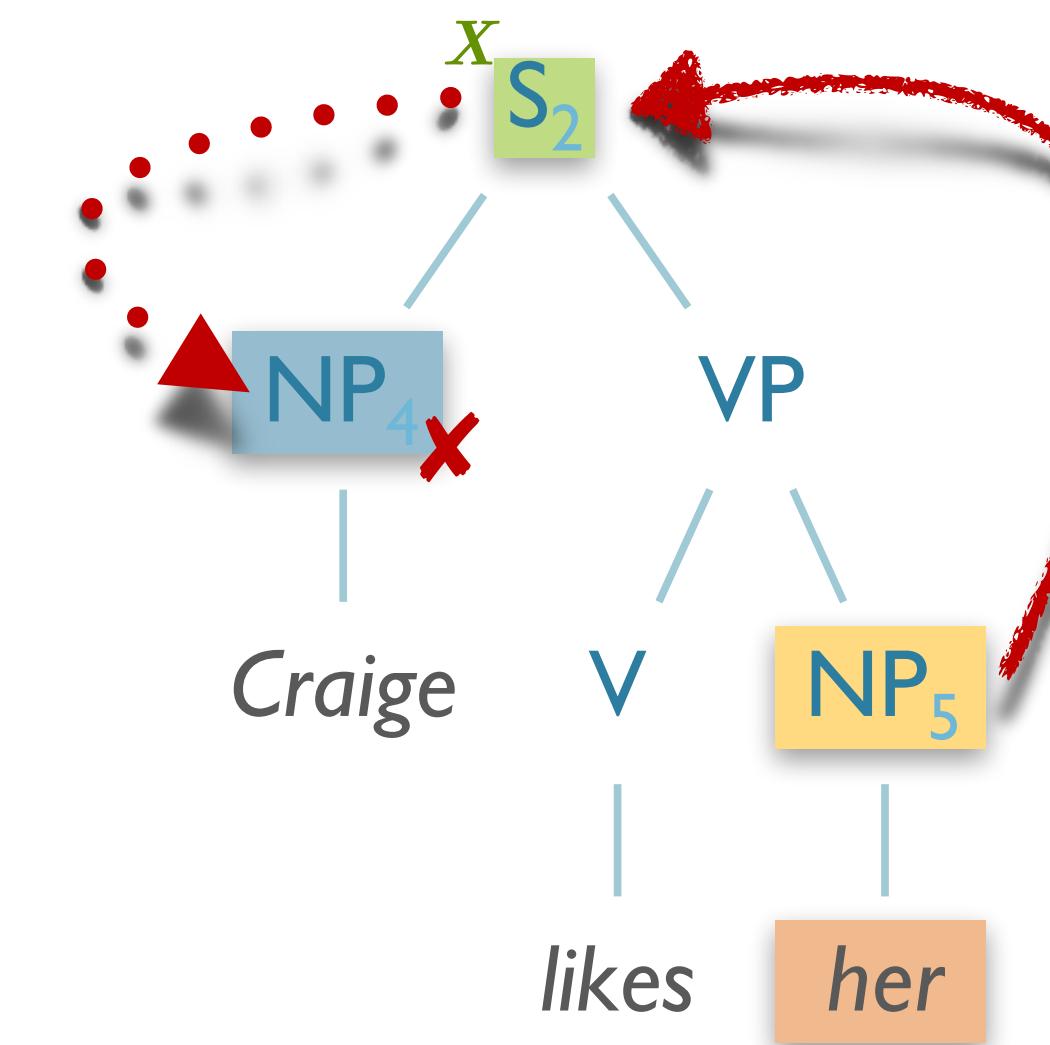
2. Go up the tree to the first  $NP$  or sentence ( $S$ ) node encountered. Call this node  $X$ , and call the path used to reach it  $p$ .

# Hobbs Example

*Lyn's mom is a gardener.*



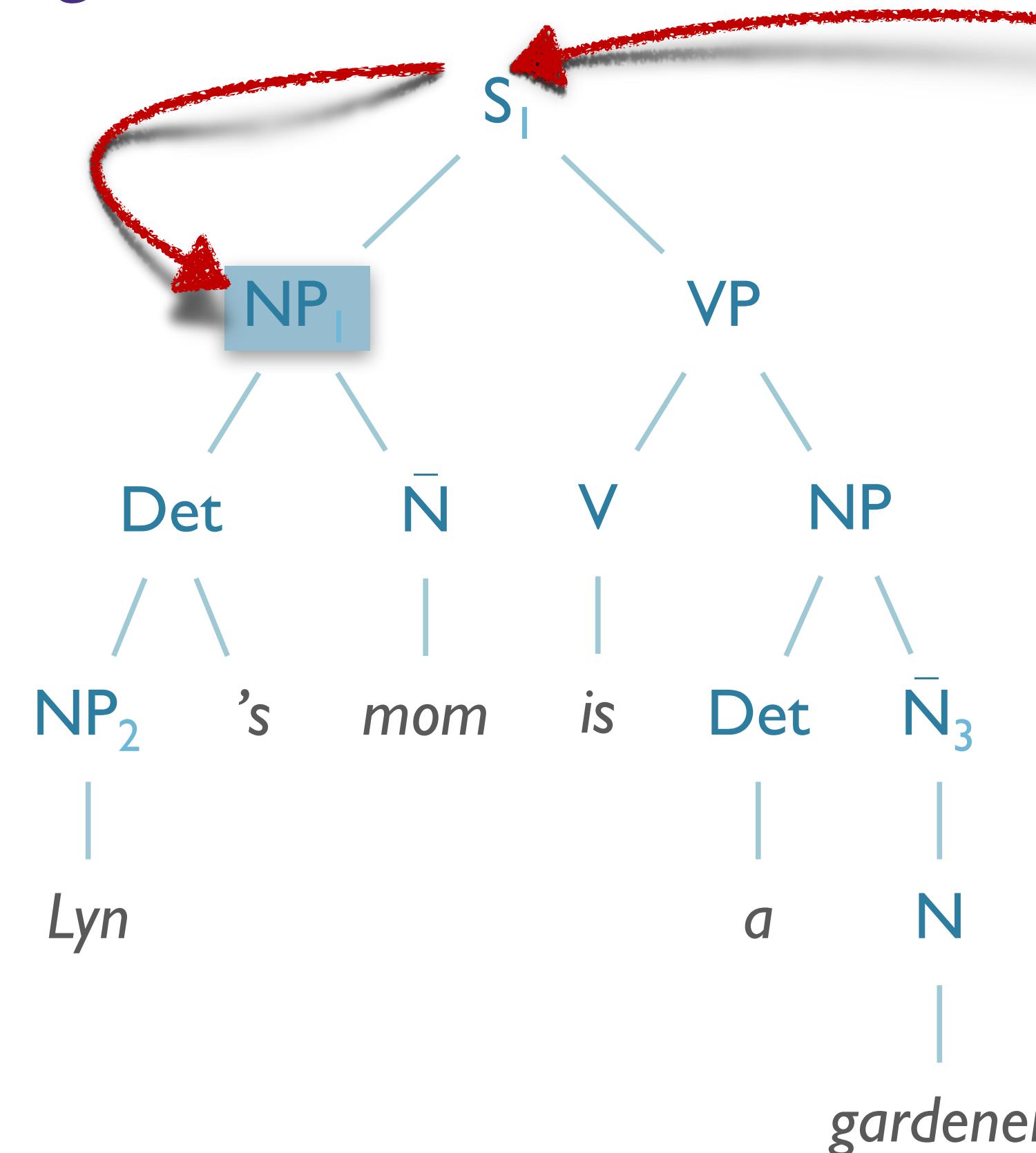
*Craigie likes her.*



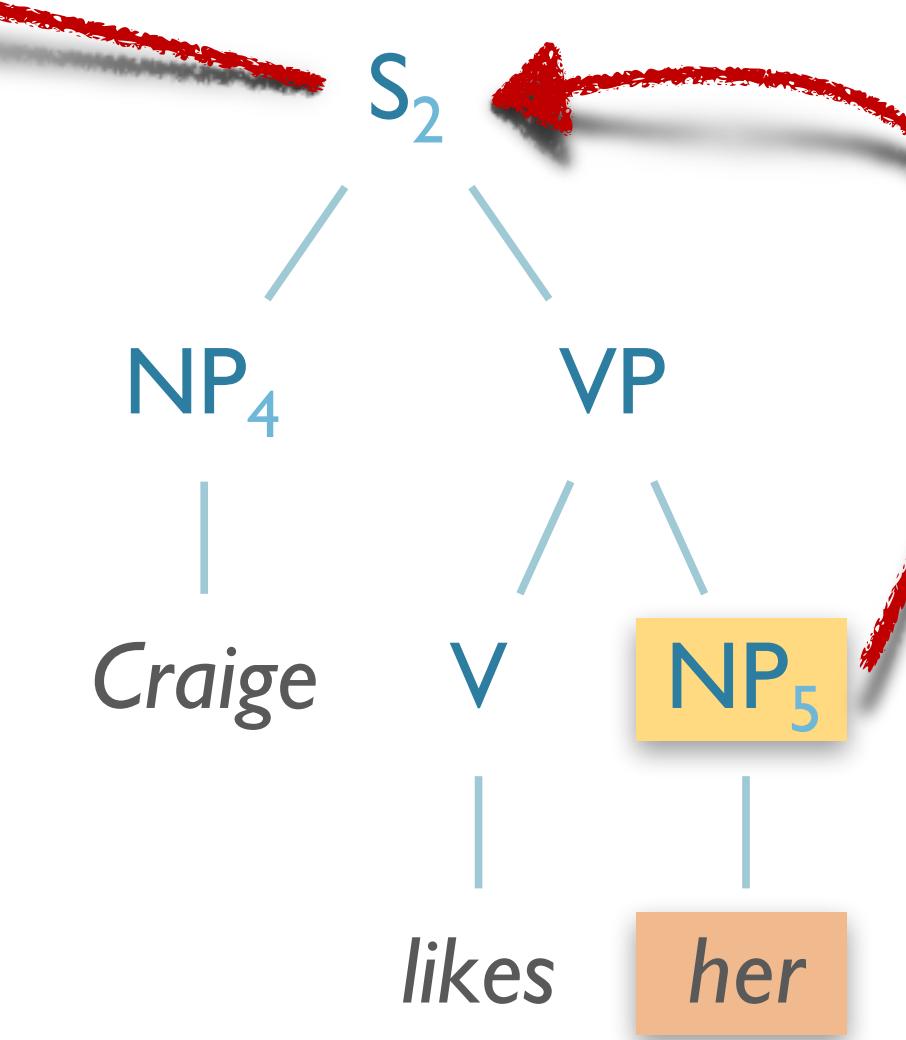
3. Traverse all branches below node  $X$  to the left of path  $p$  in a left-to-right, breadth-first fashion. Propose as the antecedent any encountered  $NP$  node that has an  $NP$  or  $S$  node between it and  $X$ .

# Hobbs Example

*Lyn's mom is a gardener.*



*Craigie likes her.*



4. If node  $X$  is the highest  $S$  node in the sentence, traverse the surface parse trees of previous sentences in the text in order of recency, the most recent first; each tree is traversed in a left-to-right, breadth-first manner, and when an  $NP$  node is encountered, it is proposed as antecedent.

# Hobbs Example

- What about...?
  - *Lyn's mom **is** hired a gardener.*
  - *Craigie likes her.*