Discourse and Coreference

LING 571 — Deep Processing Methods in NLP

November 21, 2022

Shane Steinert-Threlkeld

Announcements

- **No class Wednesday!**
- Relatedly: no Shane OH on Wednesday (no Cassie OH Thursday)
- HW8: now **due Nov 30**
  - No HW this week; HW9 (final one) out on Nov 30

Ambiguity of the Week

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FrameNet Data

Giving

Definition:

A Donor transfers a Theme from a Donor to a Recipient. This frame includes only actions that are initiated by the Donor (the one that starts out owning the Theme). Theme. Following the transfer the Donor no longer has the Theme and the Recipient does.

Barney GAVE the beer to Moe.

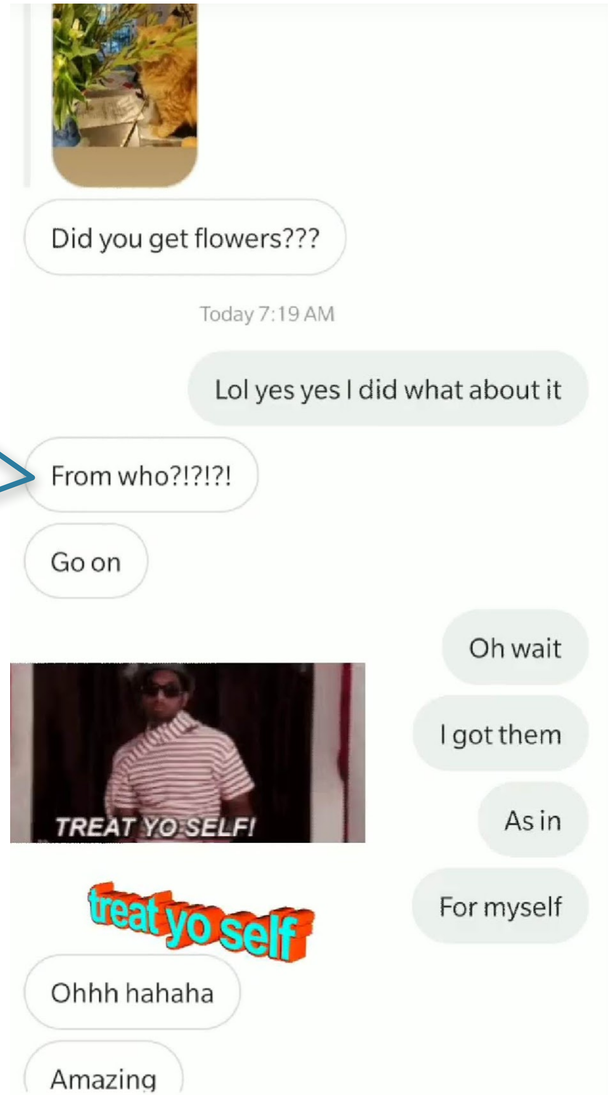
$30K was ENDOWED to the university to build a new performing arts building.

FEs:

Core:

Donor [Donor]	The person that begins in possession of the Theme and causes it to be in the possession of the Recipient.
Recipient [Rec]	The entity that ends up in possession of the Theme.
Theme [Thm]	The object that changes ownership.

Semantic Type: Physical_object



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Did you get flowers???

Today 7:19 AM

Lol yes yes I did what about it

From who?!?!?!

Go on

Oh wait

I got them

As in

For myself

Ohhh hahaha

Amazing

FrameNet Data

Getting

Definition:

A Recipient starts off without the Theme in their possession, and then comes to possess it. Although the Source from which the Theme came is logically necessary, the Recipient and its changing relationship to the Theme is profiled.

I GOT two whistles from John.

FEs:

Core:

Recipient [Rec]	The Recipient indicates the entity that ends up in possession of the Theme.
Theme [Thm]	The Theme is the object that changes possession.

Semantic Type: Physical_object

Roadmap

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

Introduction to Discourse

What is Discourse?

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- 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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  - 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

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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

John hid Bill's car keys. He was drunk.

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- **Assumption**
  - Segments of discourse should have meaningful connection.
  - Establish through ***coherence relations***

Discourse: Looking Ahead

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Coreference

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Coreference

Cohesion

Discourse: Looking Ahead

Coreference

Cohesion

Coherence

Discourse: Looking Ahead

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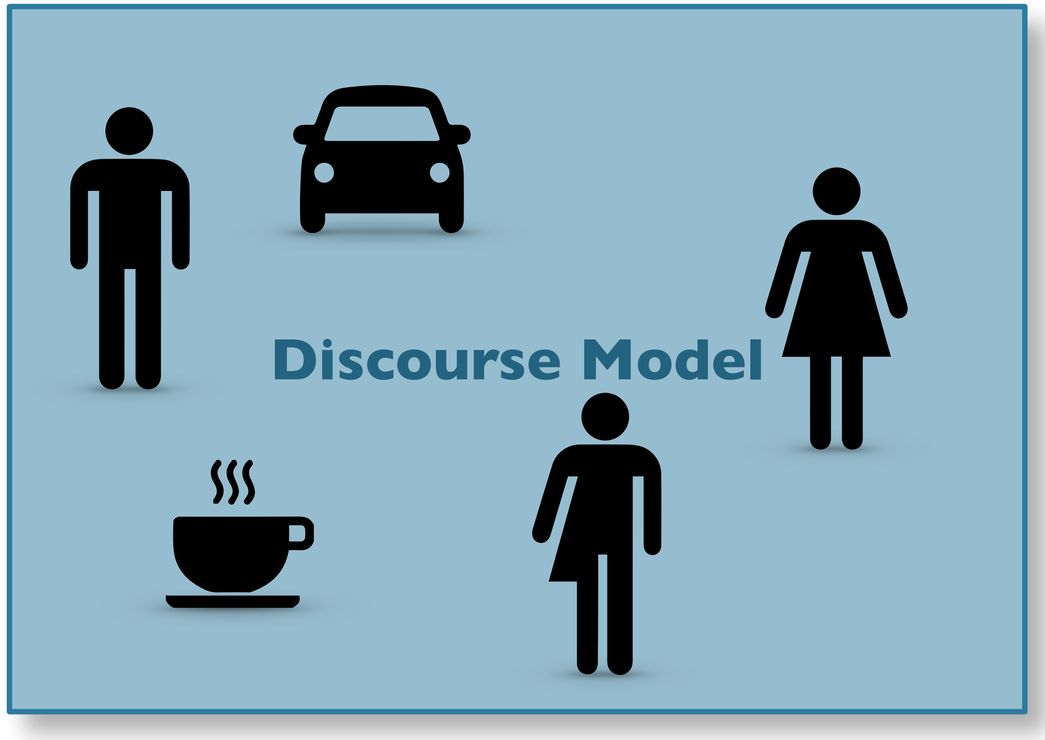
    - [“introduces a discourse referent (dref)”]
  - Subsequent mentions **access** entity *from* the model.

Reference and Model



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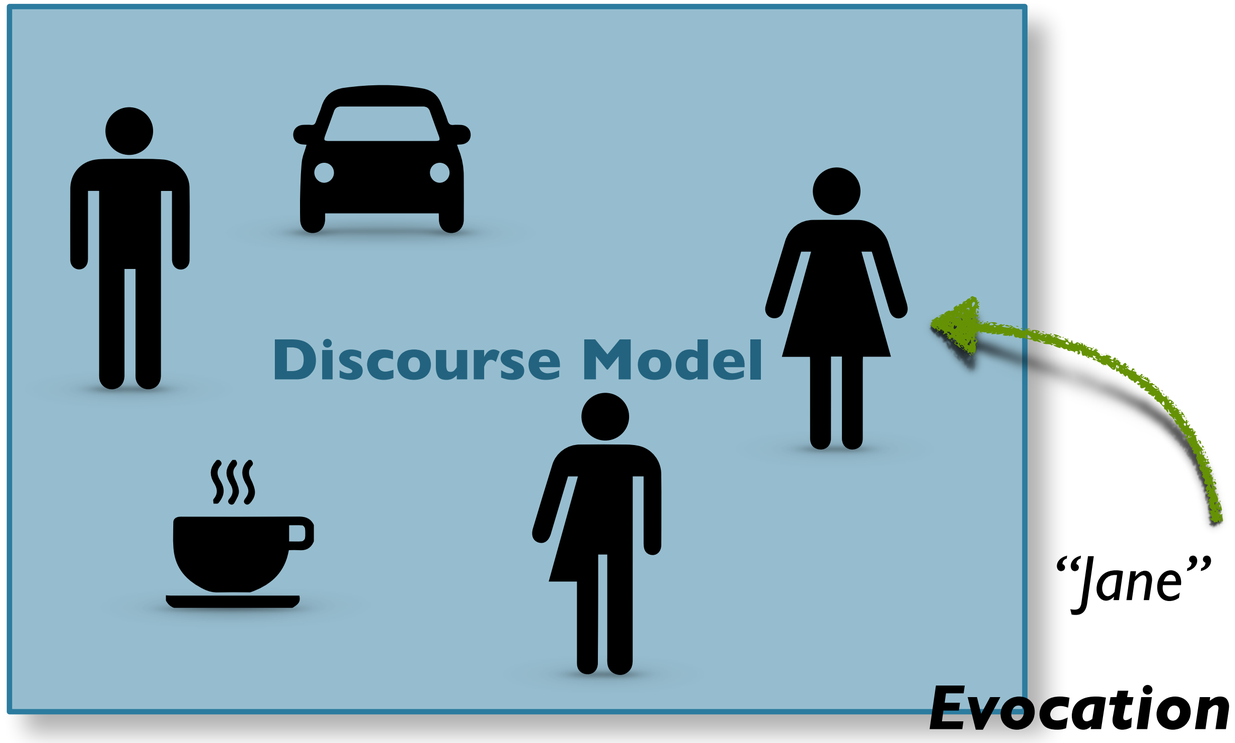

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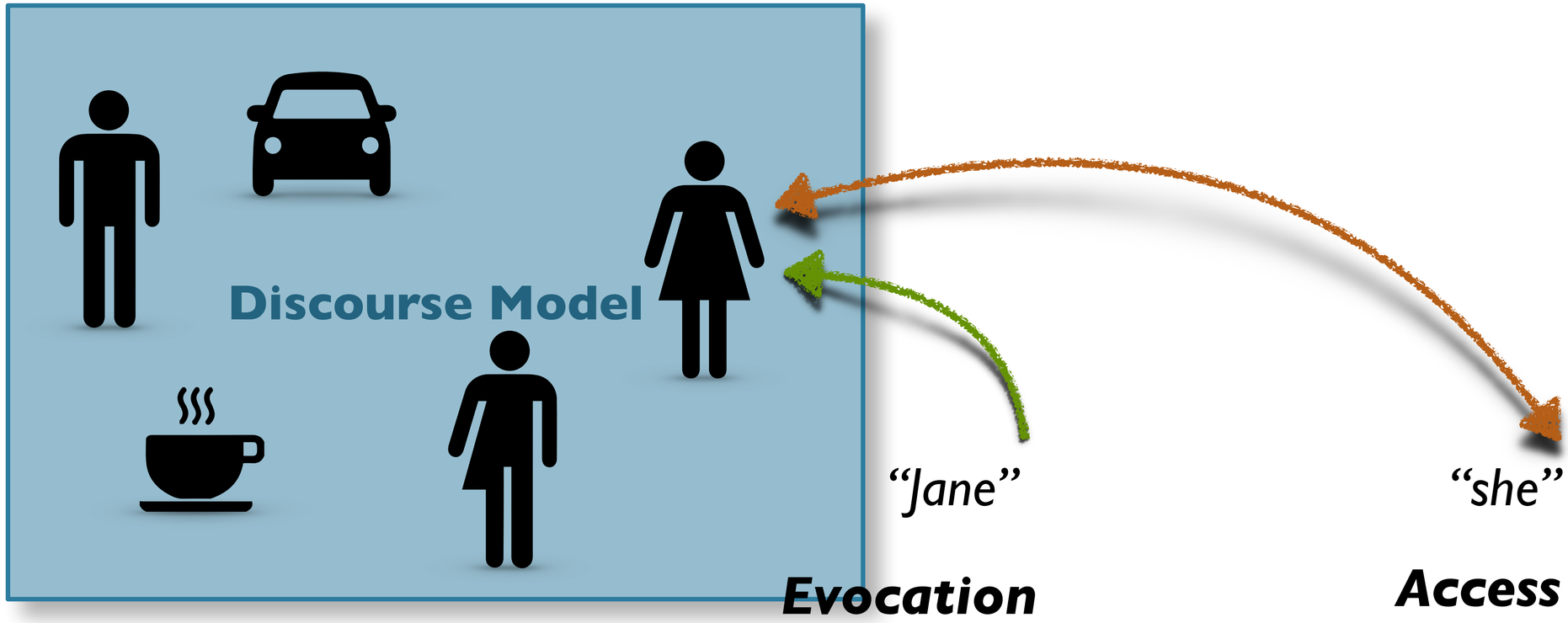

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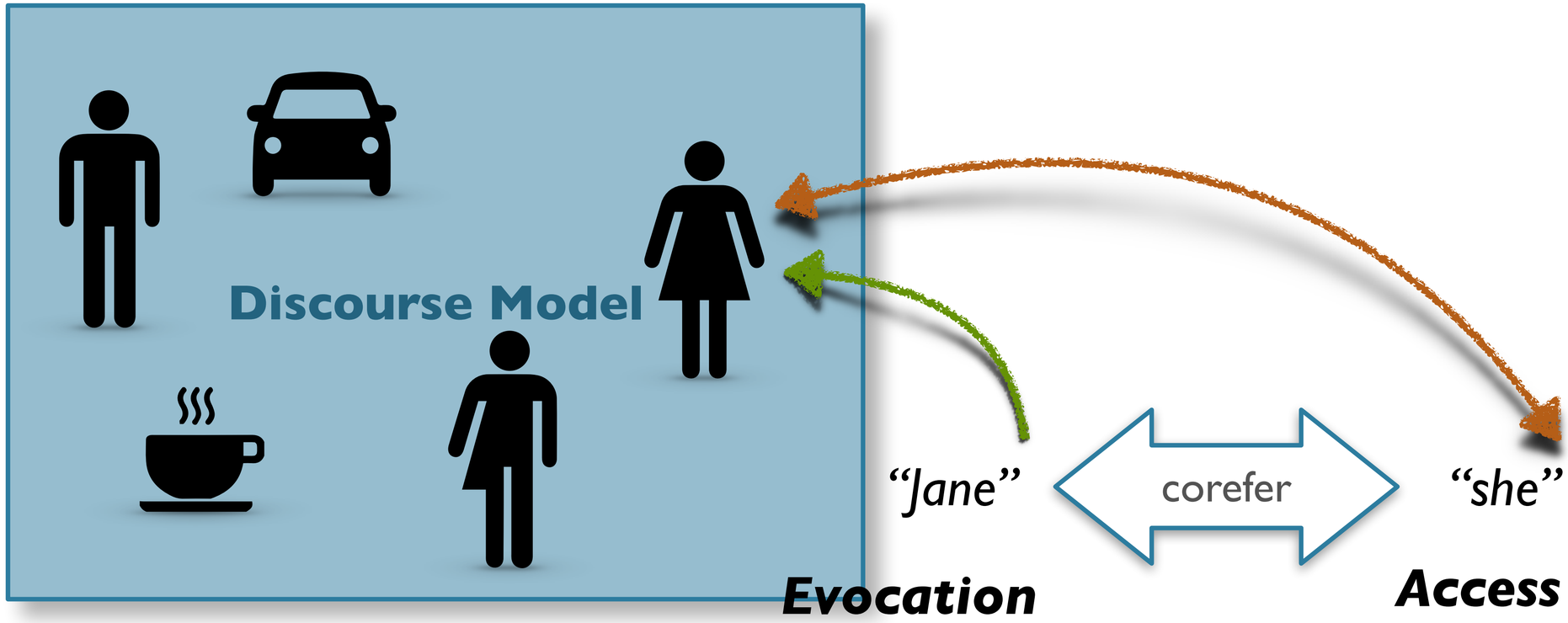

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- **Pronomial anaphora resolution*:***
  - Find antecedent for a single pronoun.
  - Subtask of coreference resolution

Pronominal Anaphora Resolution

Reference Phenomena

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

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e) ***She*** *also said that* ***she*** *bought* ***the Falcon*** *yesterday.*

- 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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	that				
	***this* N**				

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

- ***Inferrables***
  - refexp refers to inferentially related entity:
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- ***Generics***:
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- ***Non-referential cases***:
  - ***It's** raining.* (Pleonasm)
  - ***It** was good that Frodo carried the ring.* (Extraposition)

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- **Person**:
  - 1st: *I, we* 2nd: *you, y'all* 3rd: *he, she, it, they*
- **Gender**:
  - ***Janae** plays **the guitar**.* ***She** sounds great.*
  - ***Janae** plays **the guitar**.* ***It** sounds great.*

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    - *Jen said that Imani bought her a new car.* [her ≠ Imani]
    - *He_1 said that he_2 bought Willie a new car.* [He_1 ≠ Willie, he_2 ≠ Willie]

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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]
    - *Jen said that Imani bought her a new car.* [her ≠ Imani]
    - *He_1 said that he_2 bought Willie a new car.* [He_1 ≠ Willie, he_2 ≠ Willie]
  - Pronoun/Def. NP: can't corefer with subject of clause

Features for Anaphora Resolution: Constraints

- **Binding Theory**
  - How to handle reflexive pronouns vs. nonreflexives
    - *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]
    - *Jen said that Imani bought her a new car.* [her ≠ Imani]
    - *He$_1$ said that he$_2$ bought Willie a new car.* [He$_1$ ≠ Willie, he$_2$ ≠ Willie]
  - Pronoun/Def. NP: can't corefer with subject of clause
    - Reflexives do corefer with subject of containing clause

Features for Anaphora Resolution: Preferences

- **Recency**:
  - 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.*

Features for Anaphora Resolution: Preferences

- **Recency**:
  - 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.*

- **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.

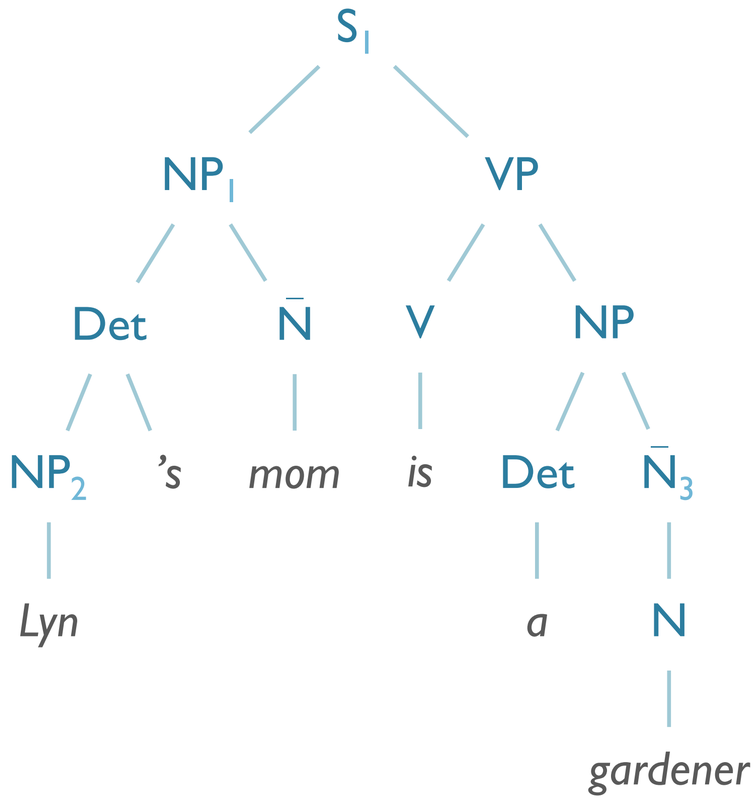
7. Traverse all branches below node **X** to the *left* of path *p* in a left-to-right, breadth-first manner. Propose any NP node encountered as the antecedent.

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.

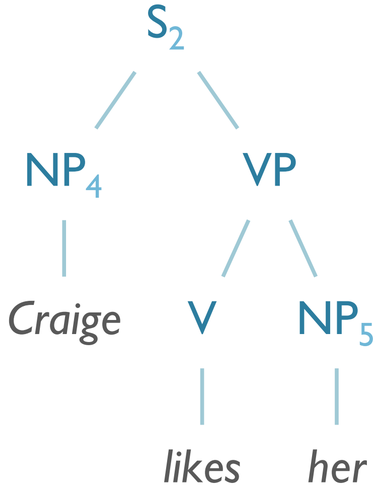
9. Go to step 4.

Hobbs Example

Lyn's mom is a gardener.

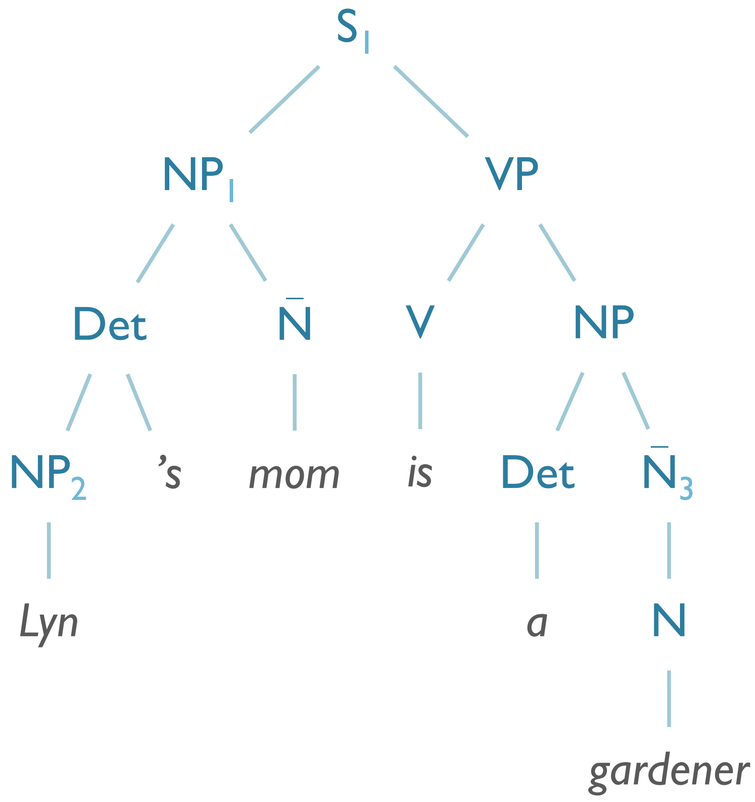


*Craige likes **her**.*



Hobbs Example

Lyn's mom is a gardener.



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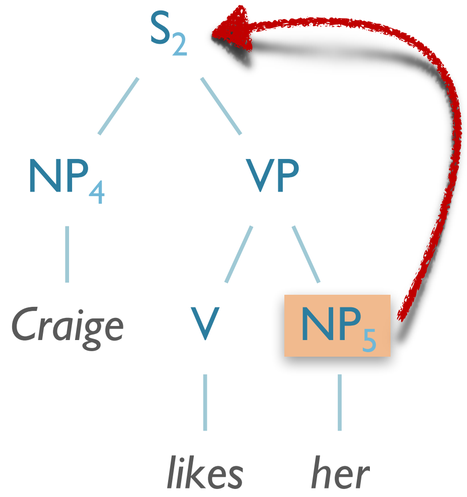

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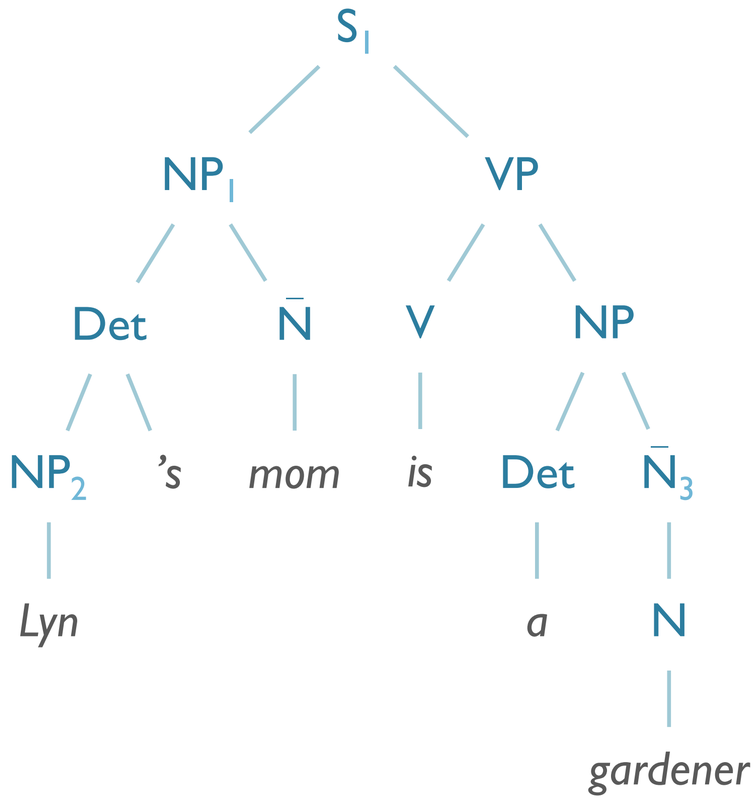
Lyn's mom is a gardener.



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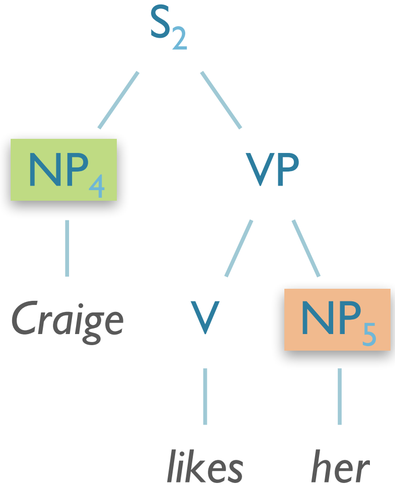

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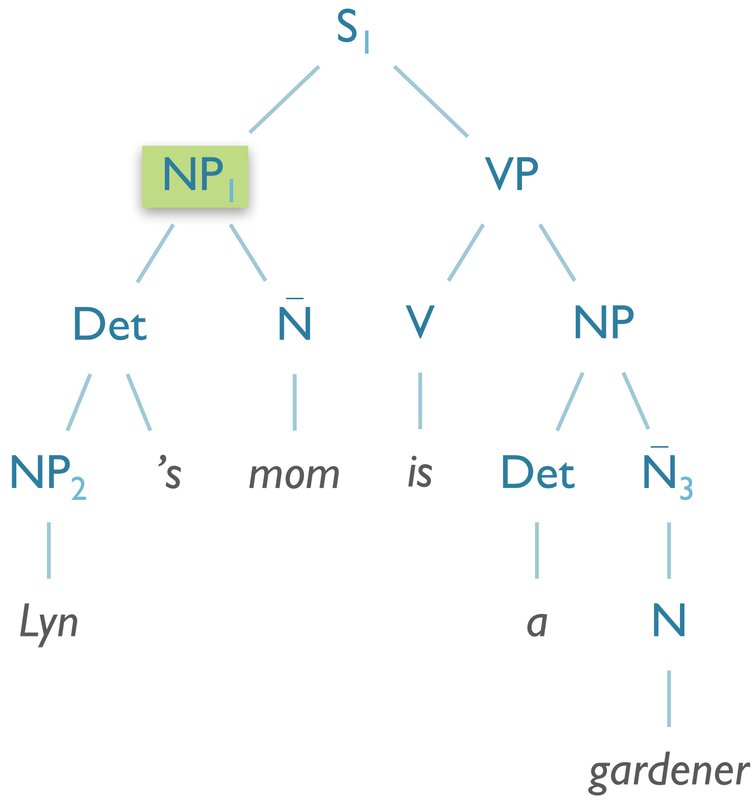

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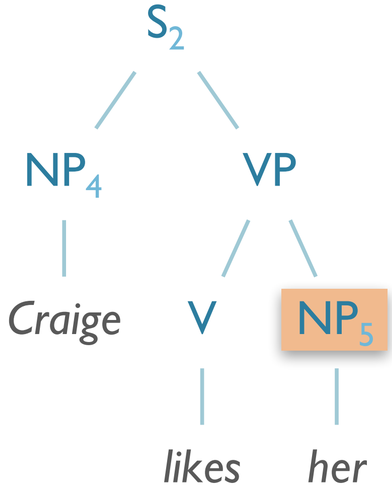
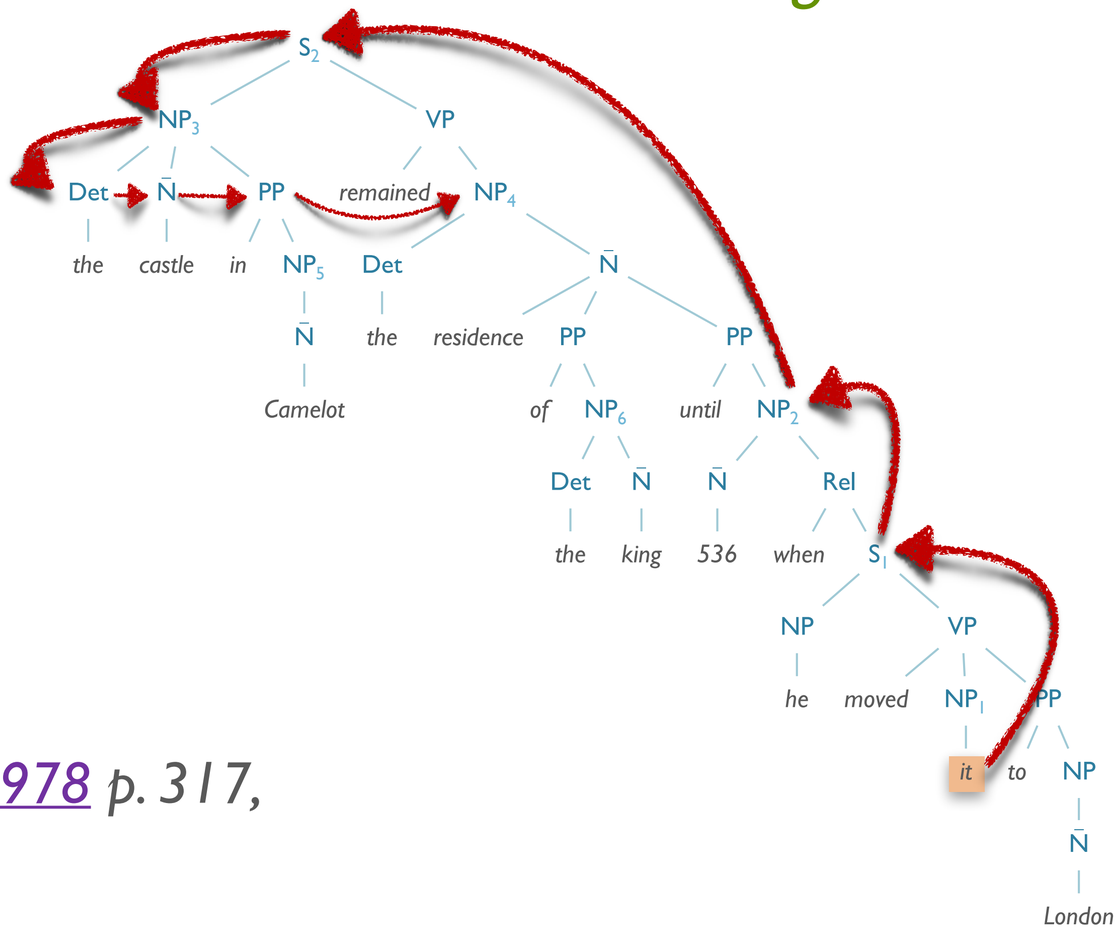


Another Hobbs Example

*…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.

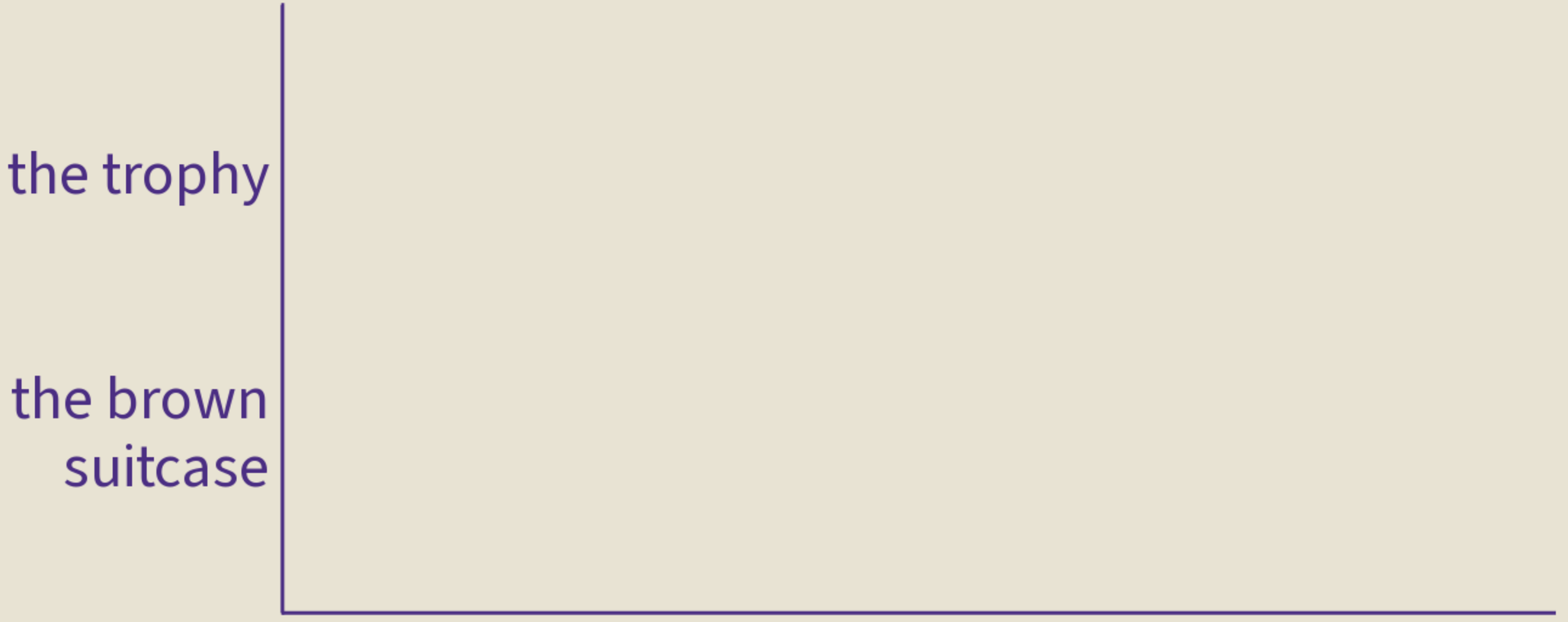
Hobbs Algorithm: A Parable

- 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

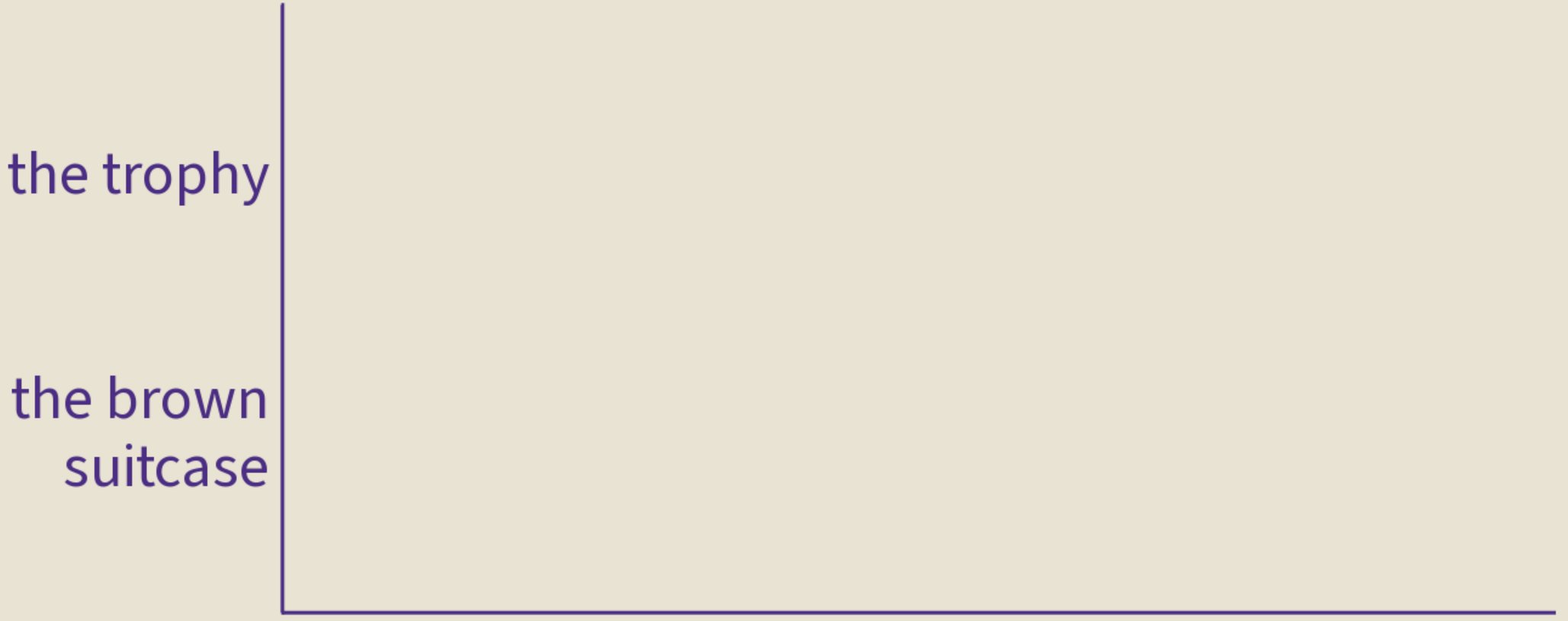
Coreference and World Knowledge

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



Total Results: 0

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



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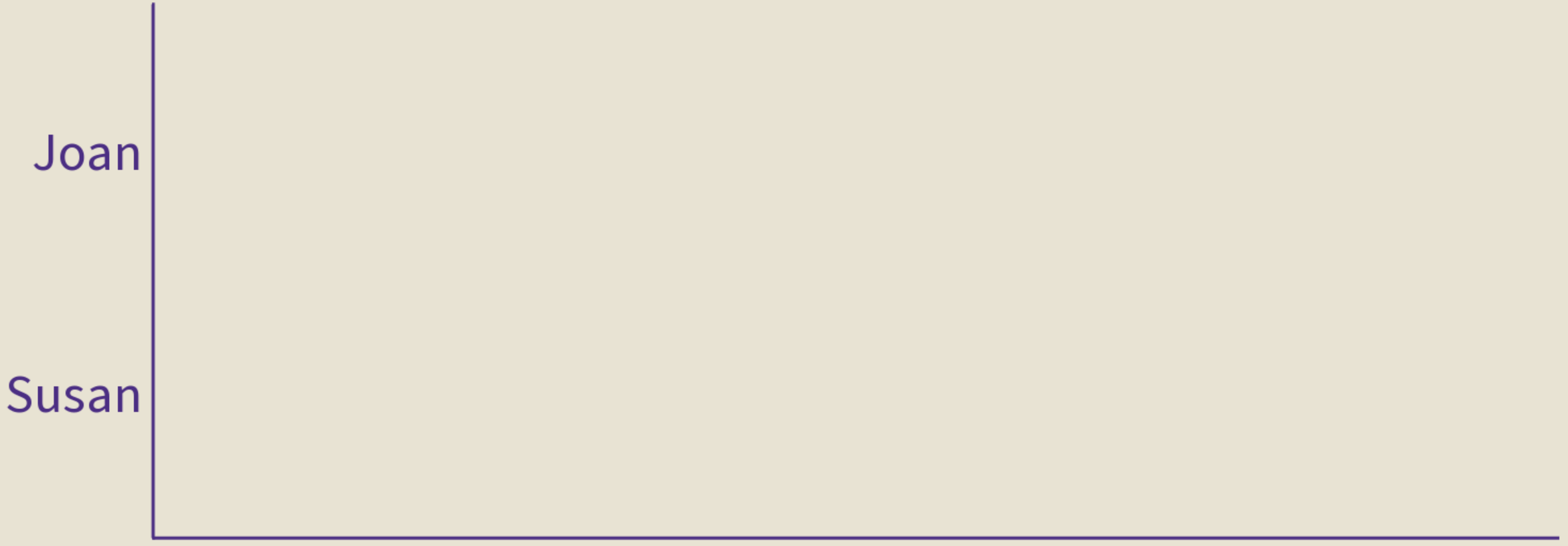
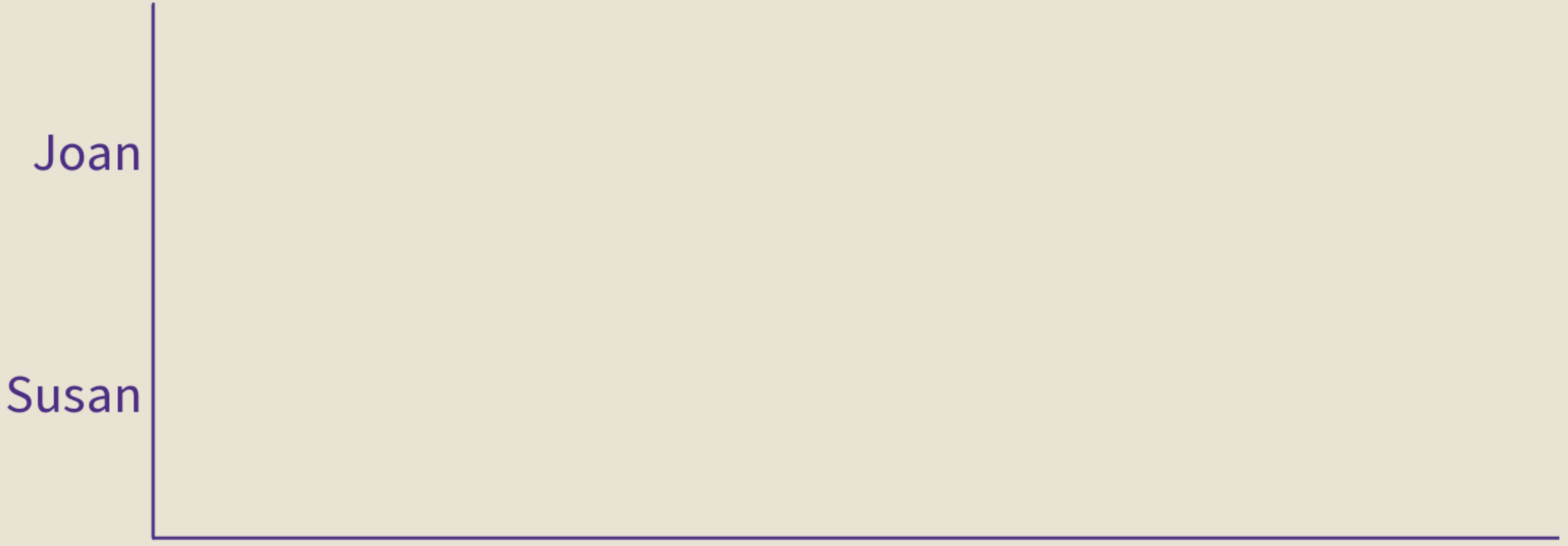
W Joan made sure to thank Susan for all the help she had given. Who had given help?



Total Results: 0

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



Total Results: 0

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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- The lawyer asked the witness a question, but he was reluctant to [answer/repeat] it . Who was reluctant to [answer/repeat] the question?

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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

SuperGLUE GLUE | Paper Code Tasks Leaderboard FAQ Diagnostics Submit

Leaderboard Version: **2.0**

Rank	Name	Model	URL	Score	BoolQ	CB	COPA	MultiRC	ReCoRD	RTE	WiC	WSC	AX-g	AX-b
1	SuperGLUE Human Baselines	SuperGLUE Human Baselines		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		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		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++		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		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		47.1	62.3	21.7/48.4	50.0	61.1/0.3	33.4/32.5	50.3	50.0	65.1	100.0/50.0	0.0
		CBoW		44.5	62.2	49.0/71.2	51.6	0.0/0.5	14.0/13.6	49.7	53.1	65.1	100.0/50.0	-0.4
		Outside Best		-	80.4	-	84.4	70.4/24.5	74.8/73.0	82.7	-	-	-	-
-	Stanford Hazy Research	Snorkel [SuperGLUE v1.9]		-	-	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

Heavily supervised
(benchmark "saturated" now)

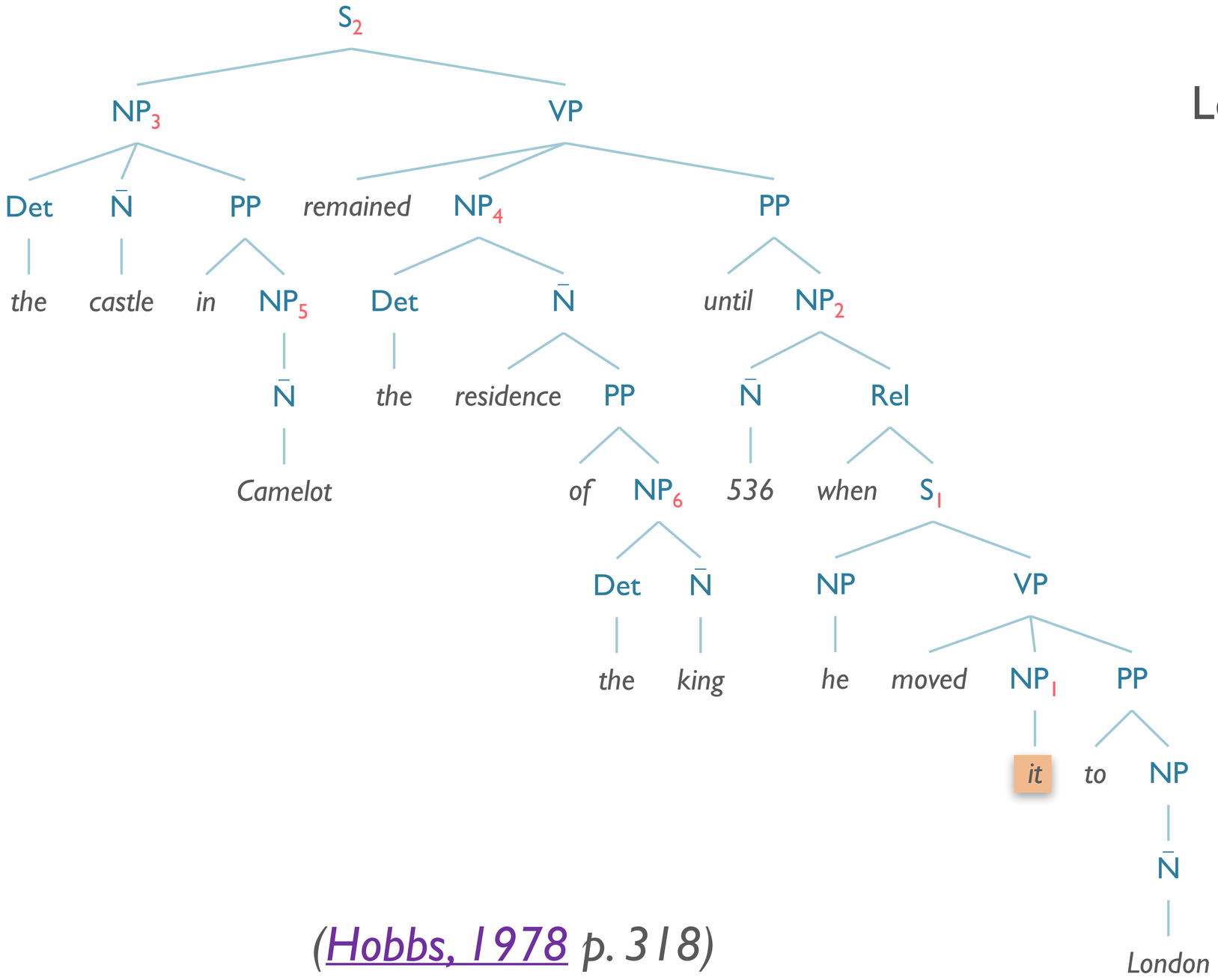
SuperGLUE GLUE | Paper </> Code | Tasks | Leaderboard | FAQ | Diagnostics | Submit

Leaderboard Version: **2.0**

Rank	Name	Model	URL	Score	BoolQ	CB	COPA	MultiRC	ReCoRD	RTE	WiC	WSC	AX-g	AX-b
1	SuperGLUE Human Baselines	SuperGLUE Human Baselines		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		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		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++		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		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		47.1	62.3	21.7/48.4	50.0	61.1/0.3	33.4/32.5	50.3	50.0	65.1	100.0/50.0	0.0
		CBoW		44.5	62.2	49.0/71.2	51.6	0.0/0.5	14.0/13.6	49.7	53.1	65.1	100.0/50.0	-0.4
		Outside Best		-	80.4	-	84.4	70.4/24.5	74.8/73.0	82.7	-	-	-	-
-	Stanford Hazy Research	Snorkel [SuperGLUE v1.9]		-	-	88.6/93.2	76.2	76.4/36.3	-	78.9	72.1	72.6	-	47.6

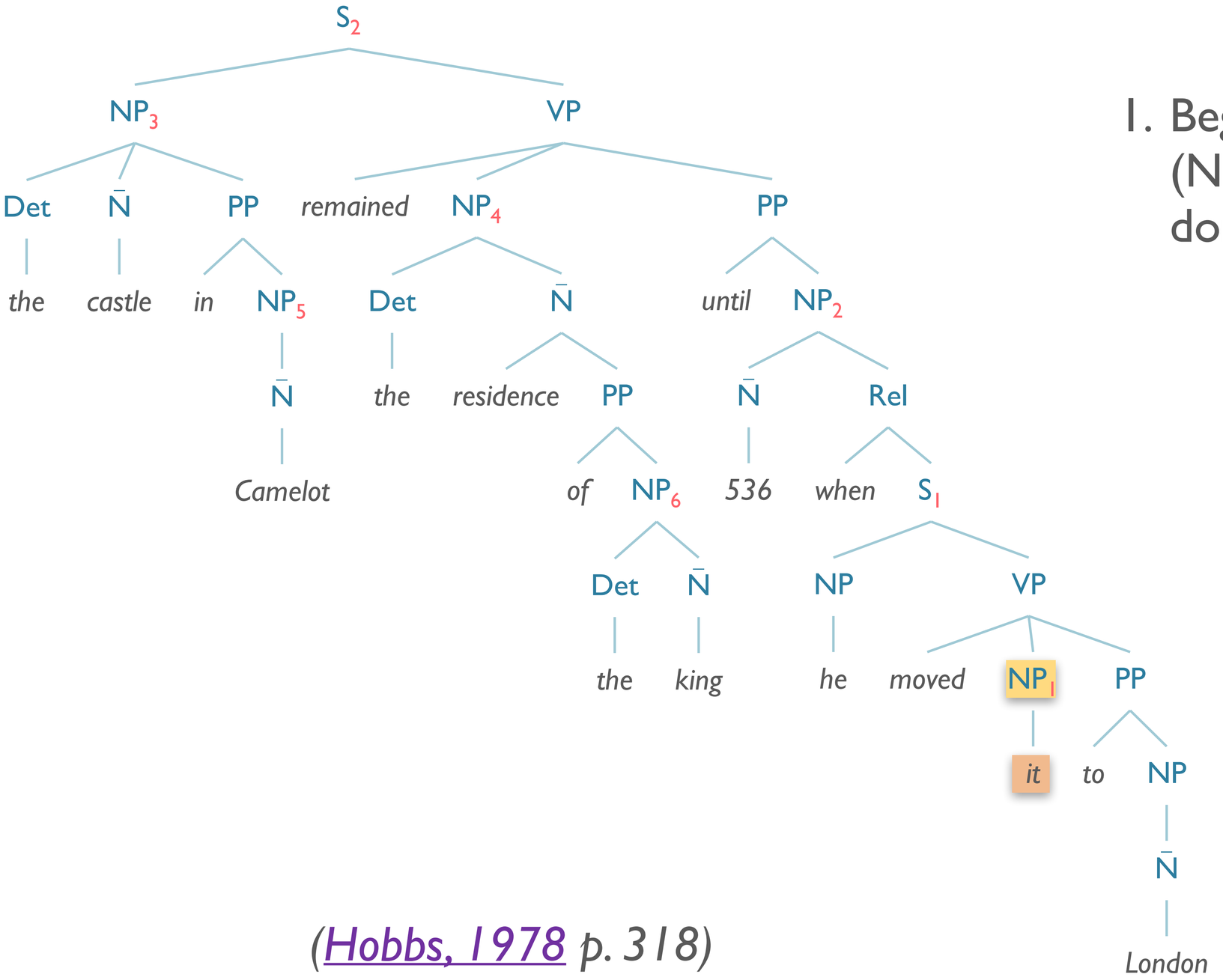
Hobbs Algorithm Walkthrough

(h/t Ryan Georgi)



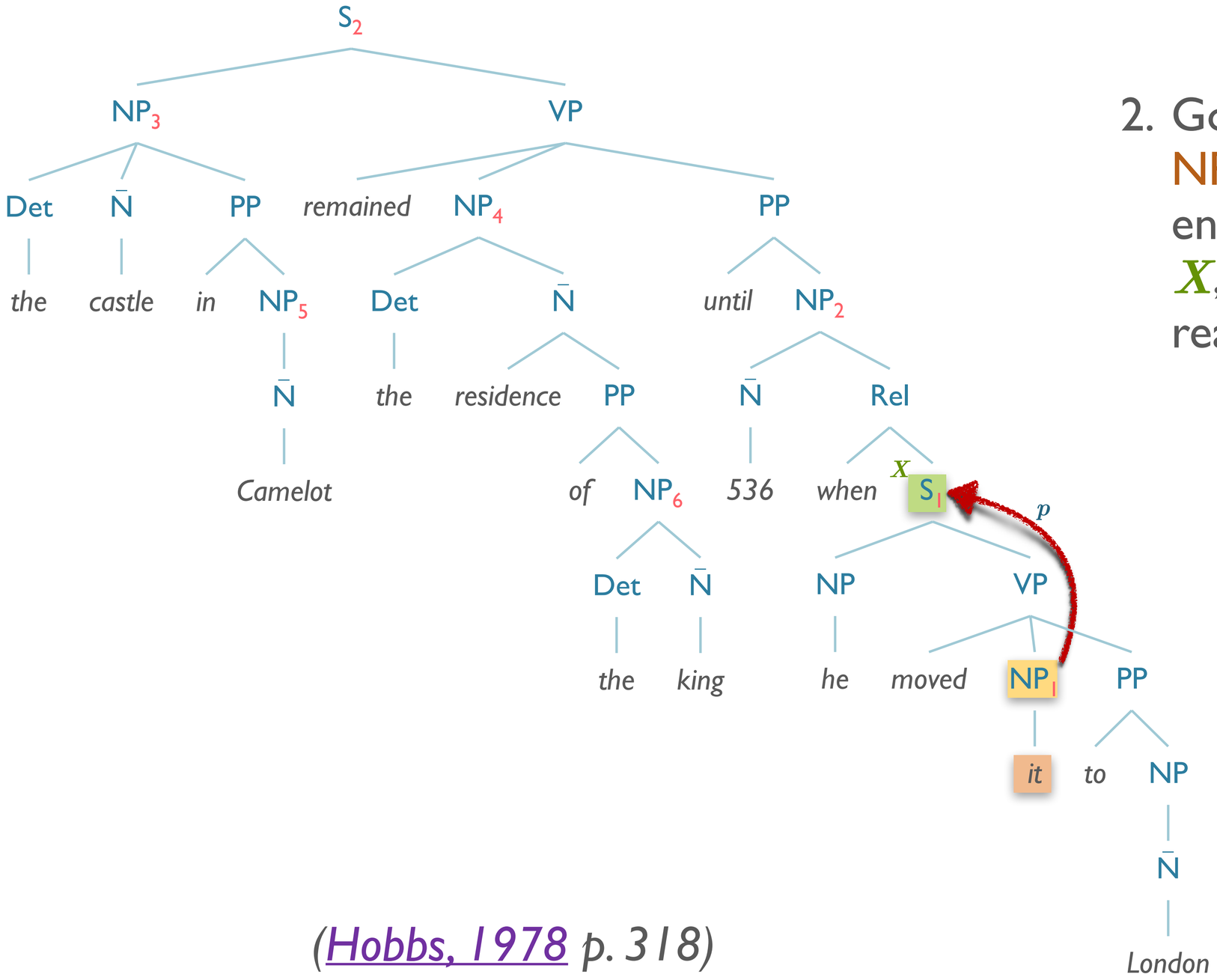
Let's figure out what the antecedent for "*it*" is

(*Hobbs, 1978 p. 318*)



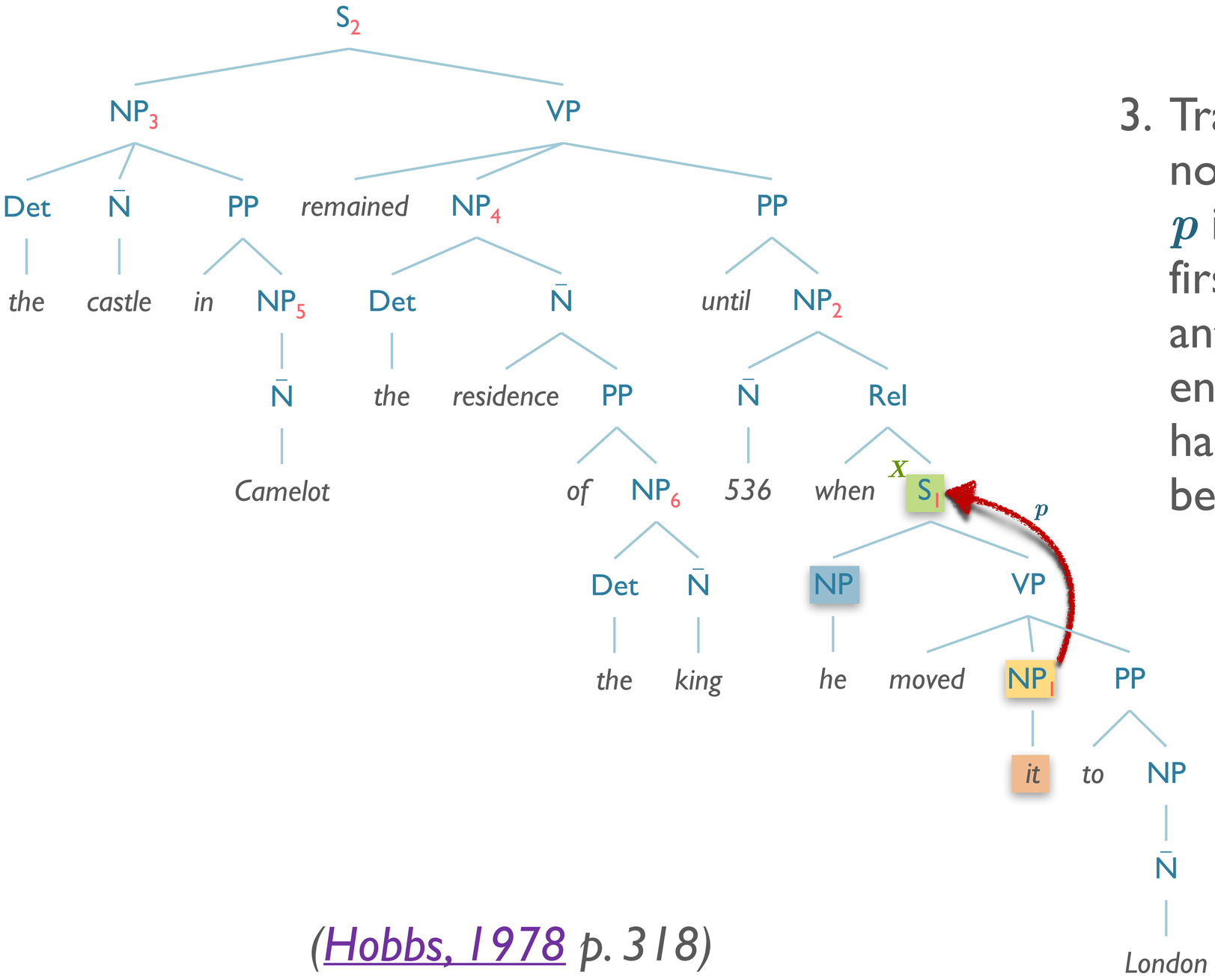
1. Begin at the noun phrase (NP) node immediately dominating the pronoun

(Hobbs, 1978 p. 318)



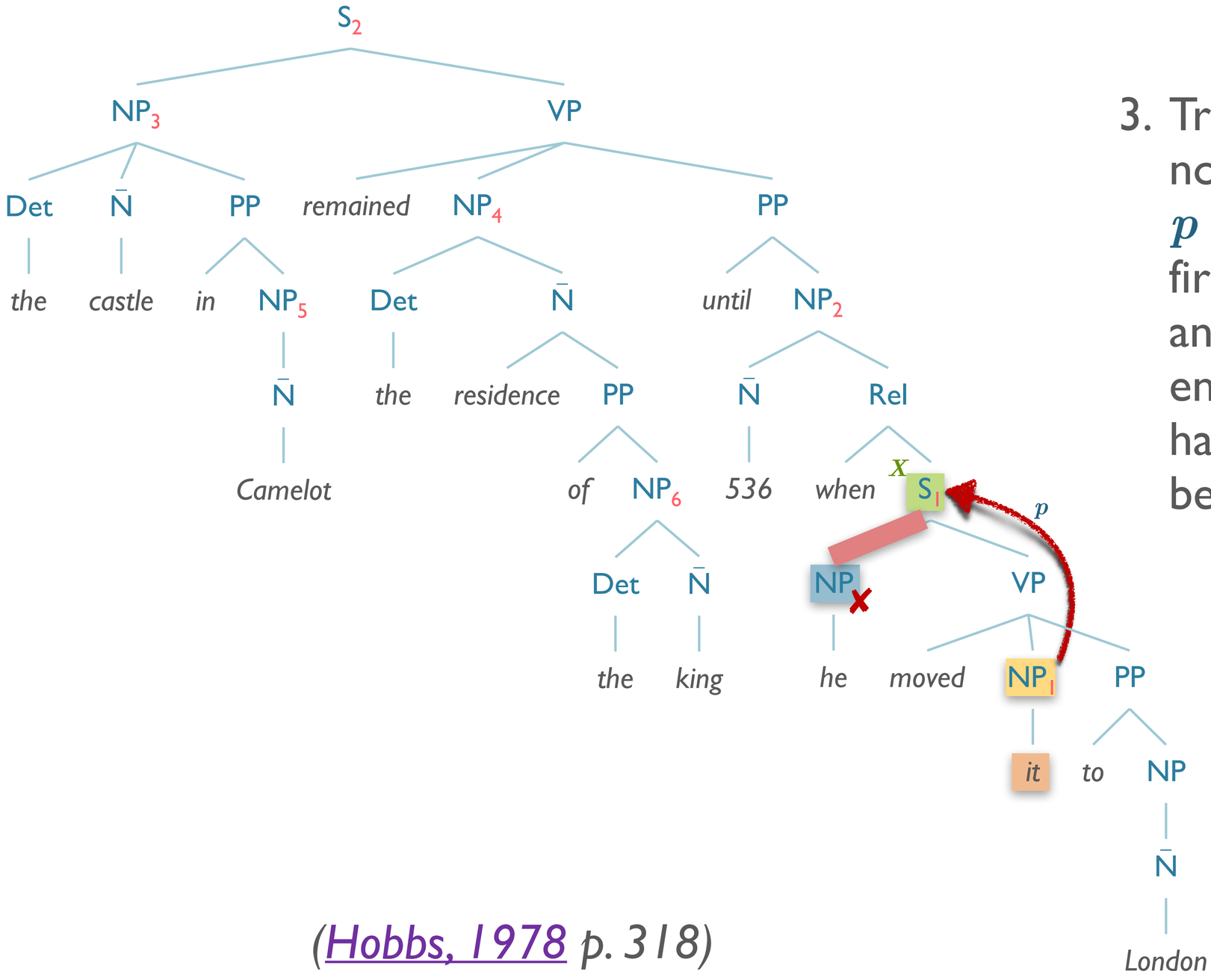
2. Go up the tree to the first NP or sentence (S) node encountered. Call this node X, and call the path used to reach it p.

(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.

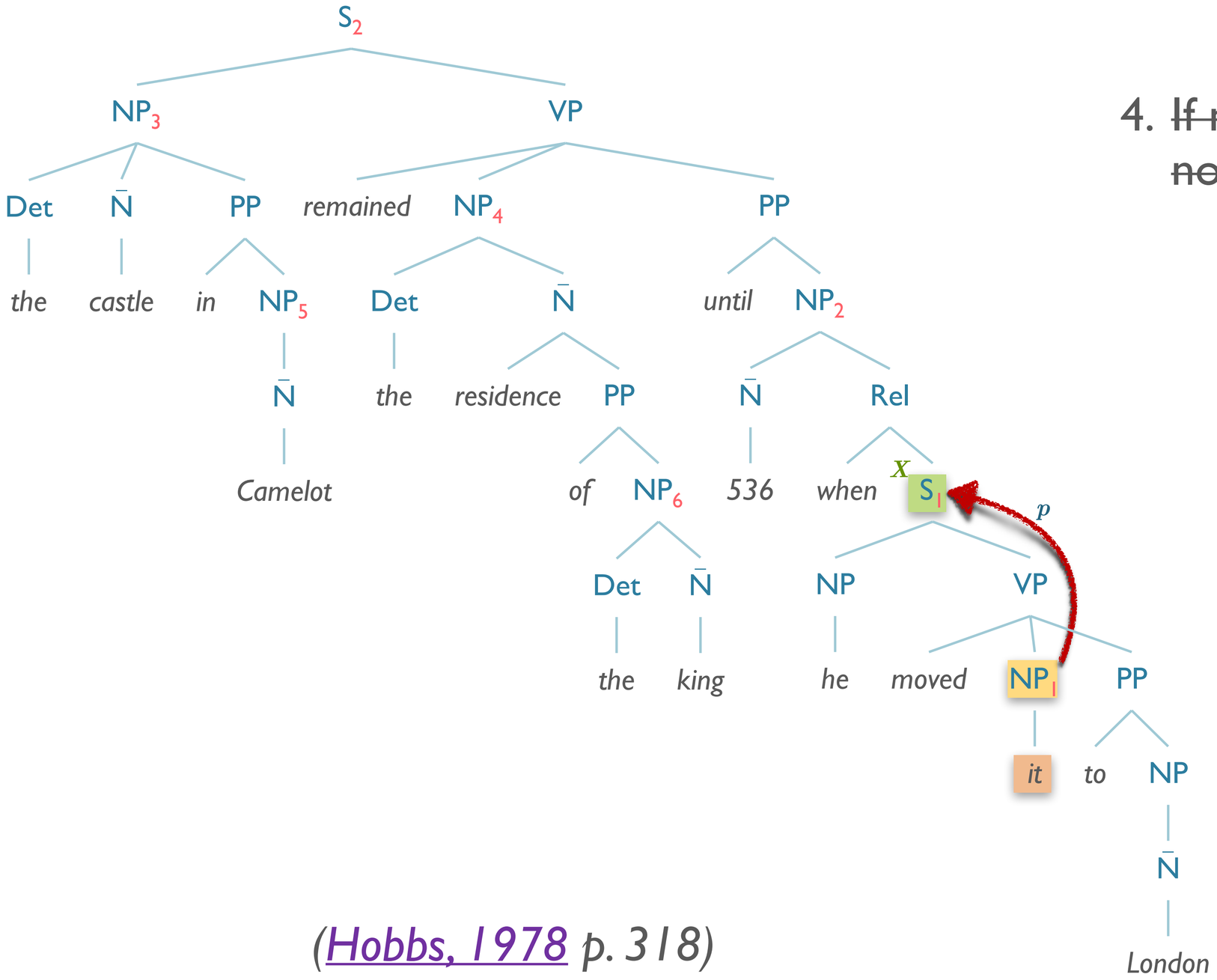
(Hobbs, 1978 p. 318)



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.

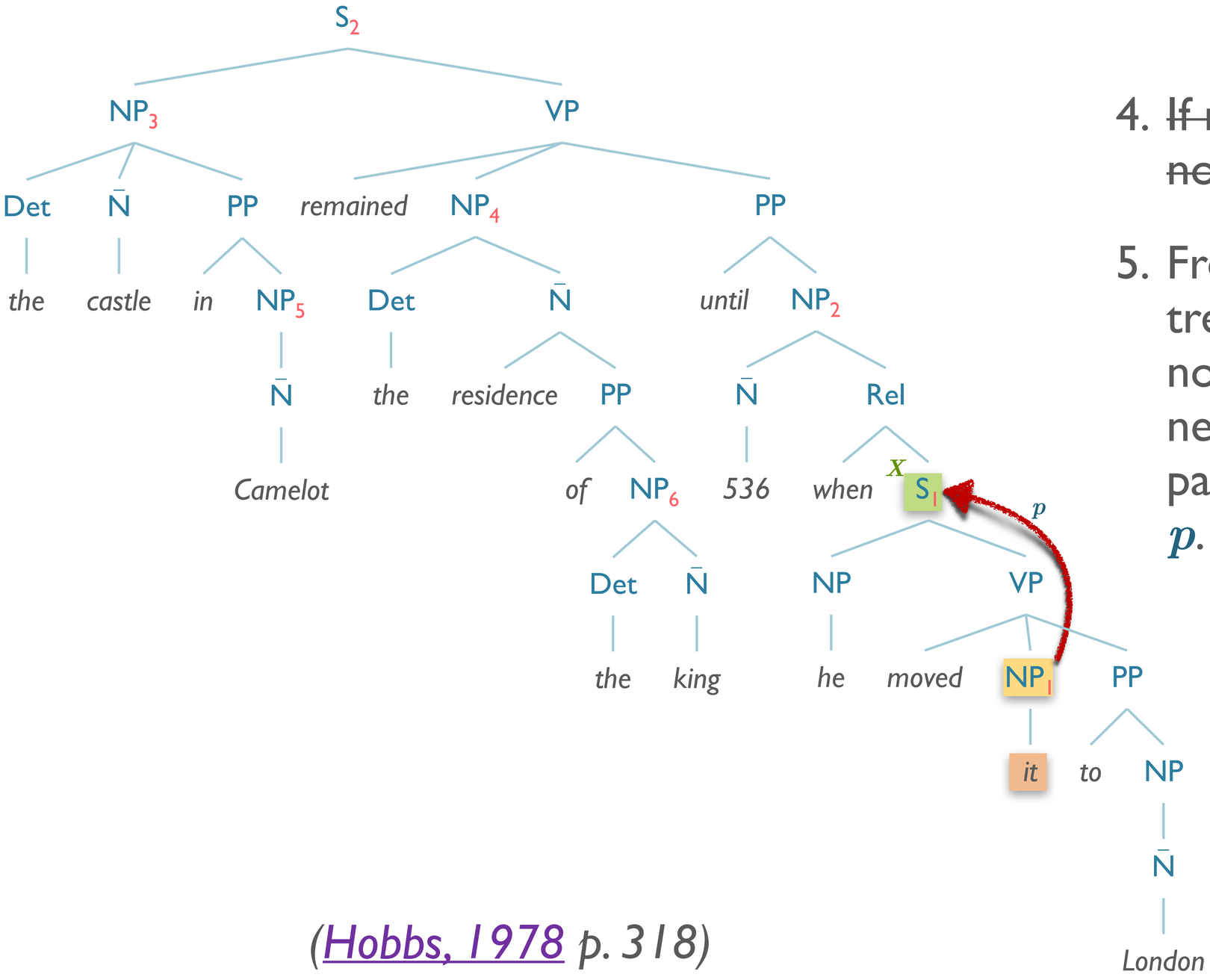
No NP or S between "he" NP and X

(Hobbs, 1978 p. 318)



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…~~

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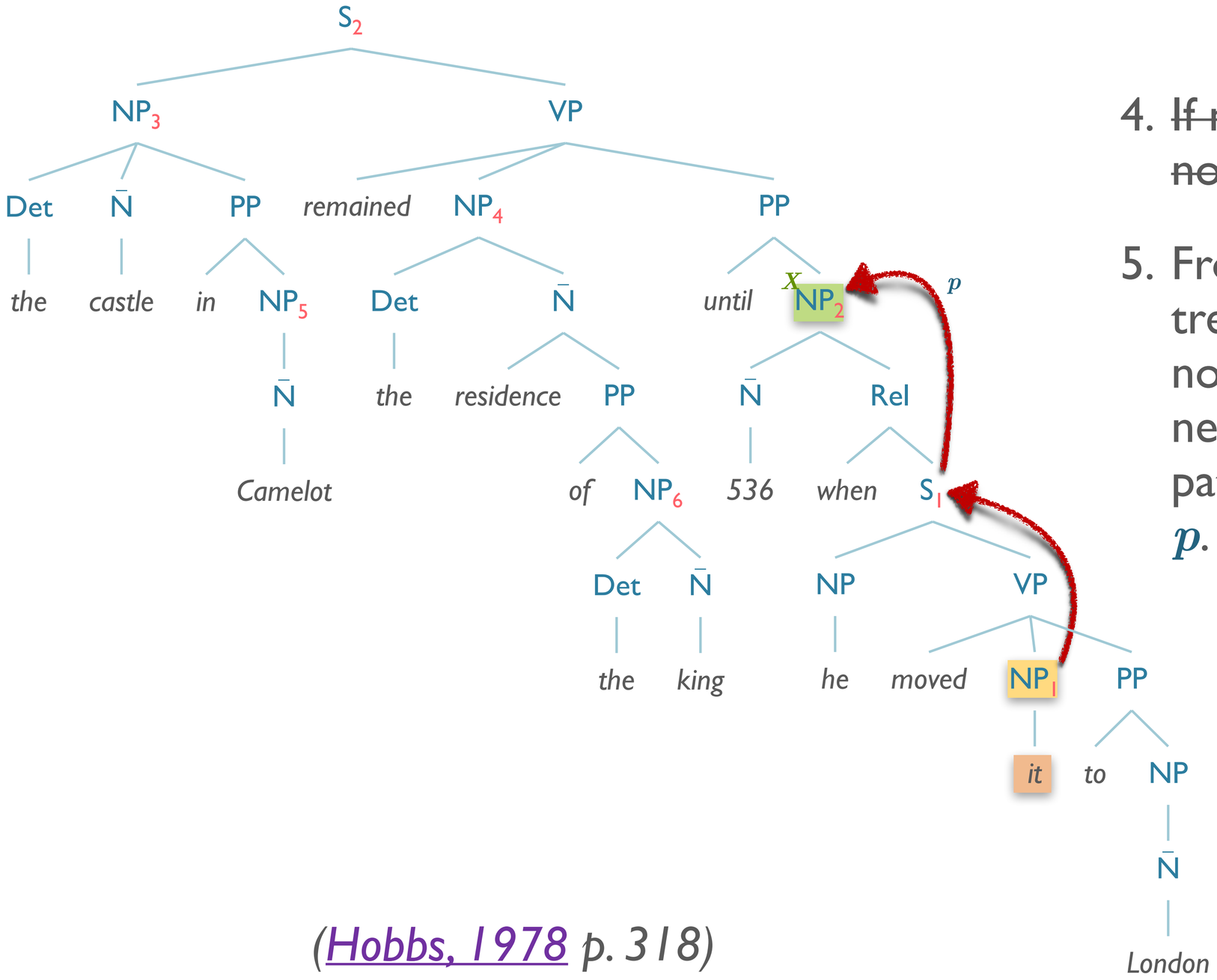
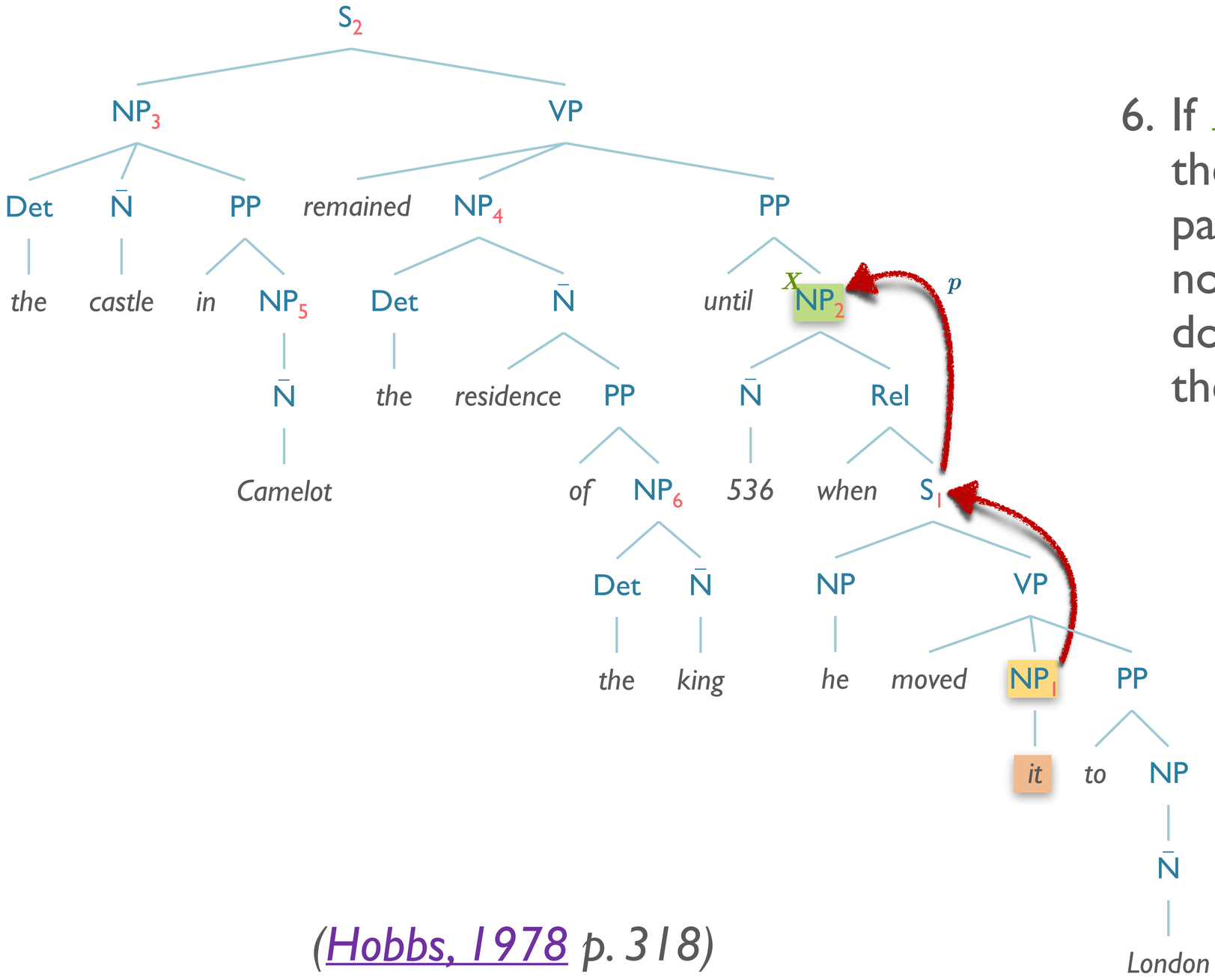


4. ~~If node *X* is the highest S node in the sentence…~~

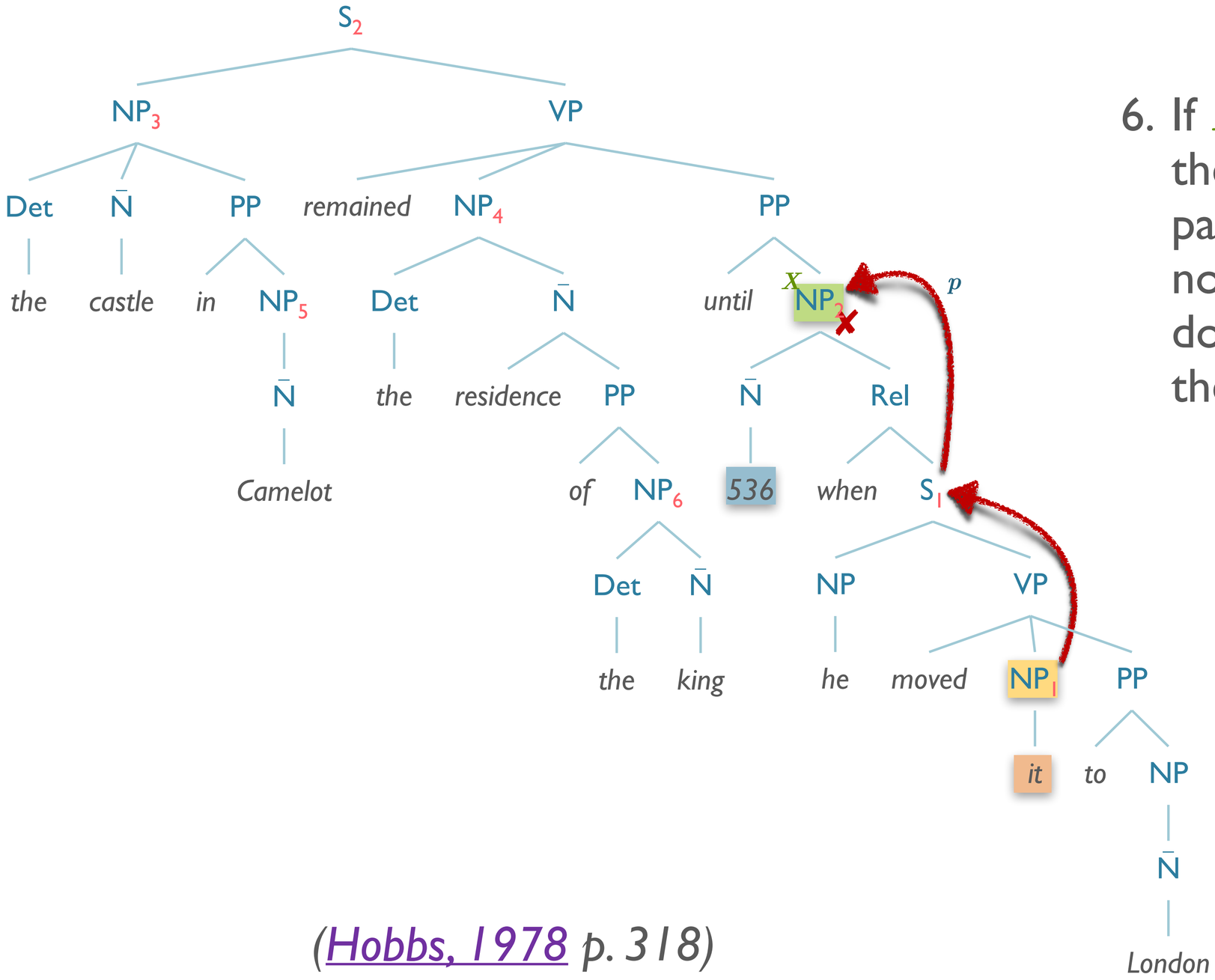
5. From node *X*, go up the tree to the first NP or S node encountered. Call this new node *X*, and call the path traversed to reach it *p*.

(Hobbs, 1978 p. 318)



6. If X is an NP node and if the path p to X did not pass through the Nominal node that X immediately dominates, propose X as the antecedent.

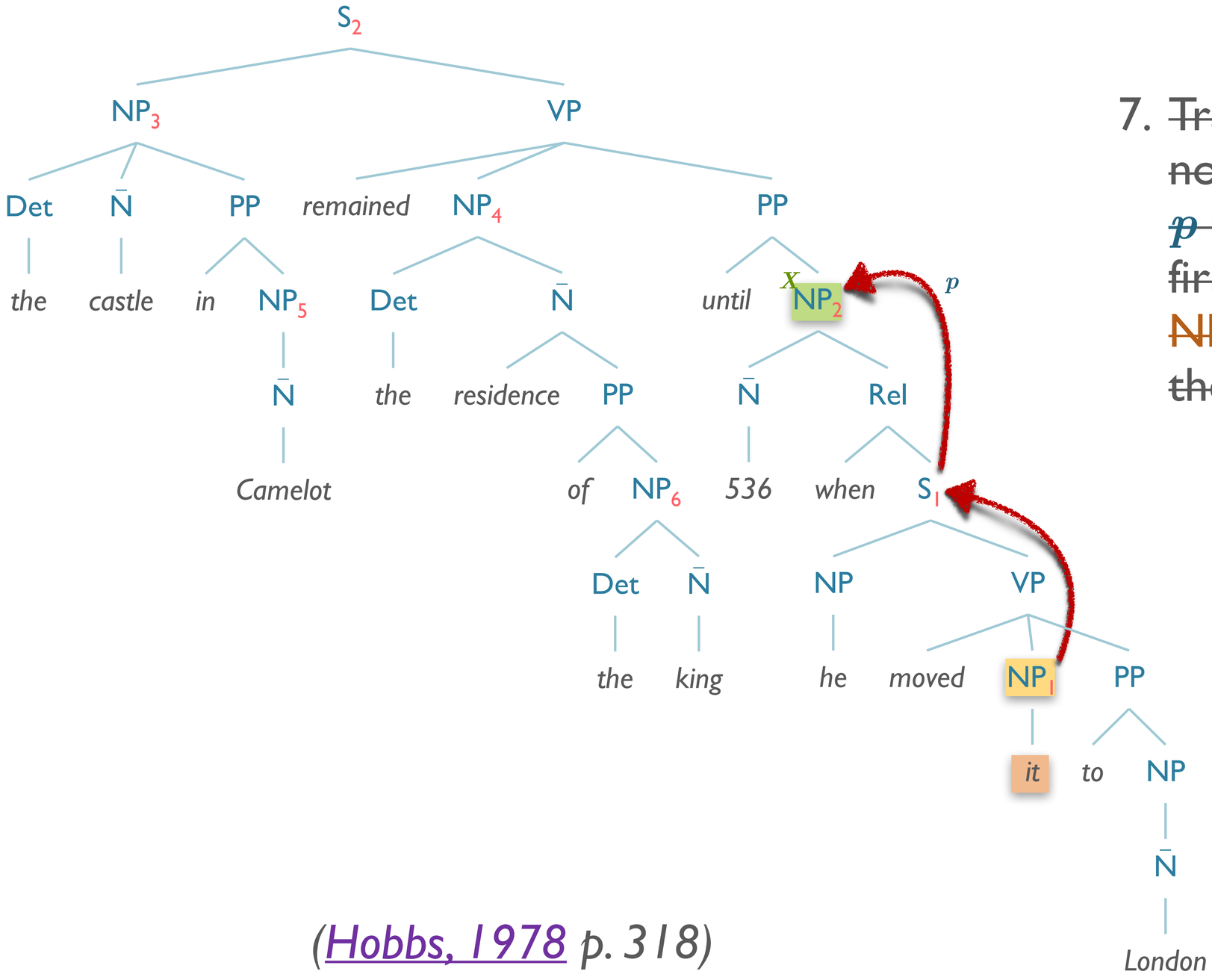
(Hobbs, 1978 p. 318)



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.

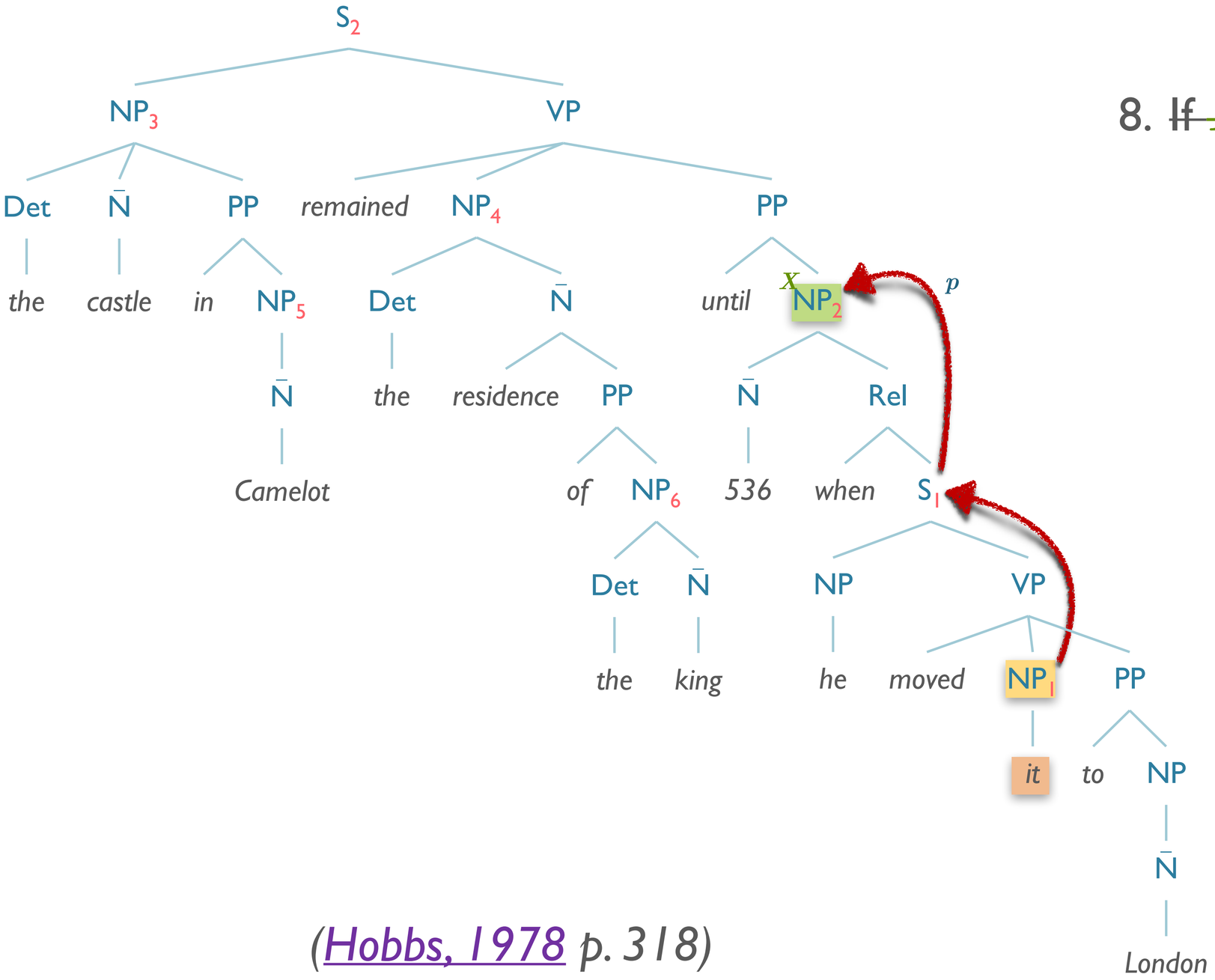
"536" can't be "moved"!

(Hobbs, 1978 p. 318)



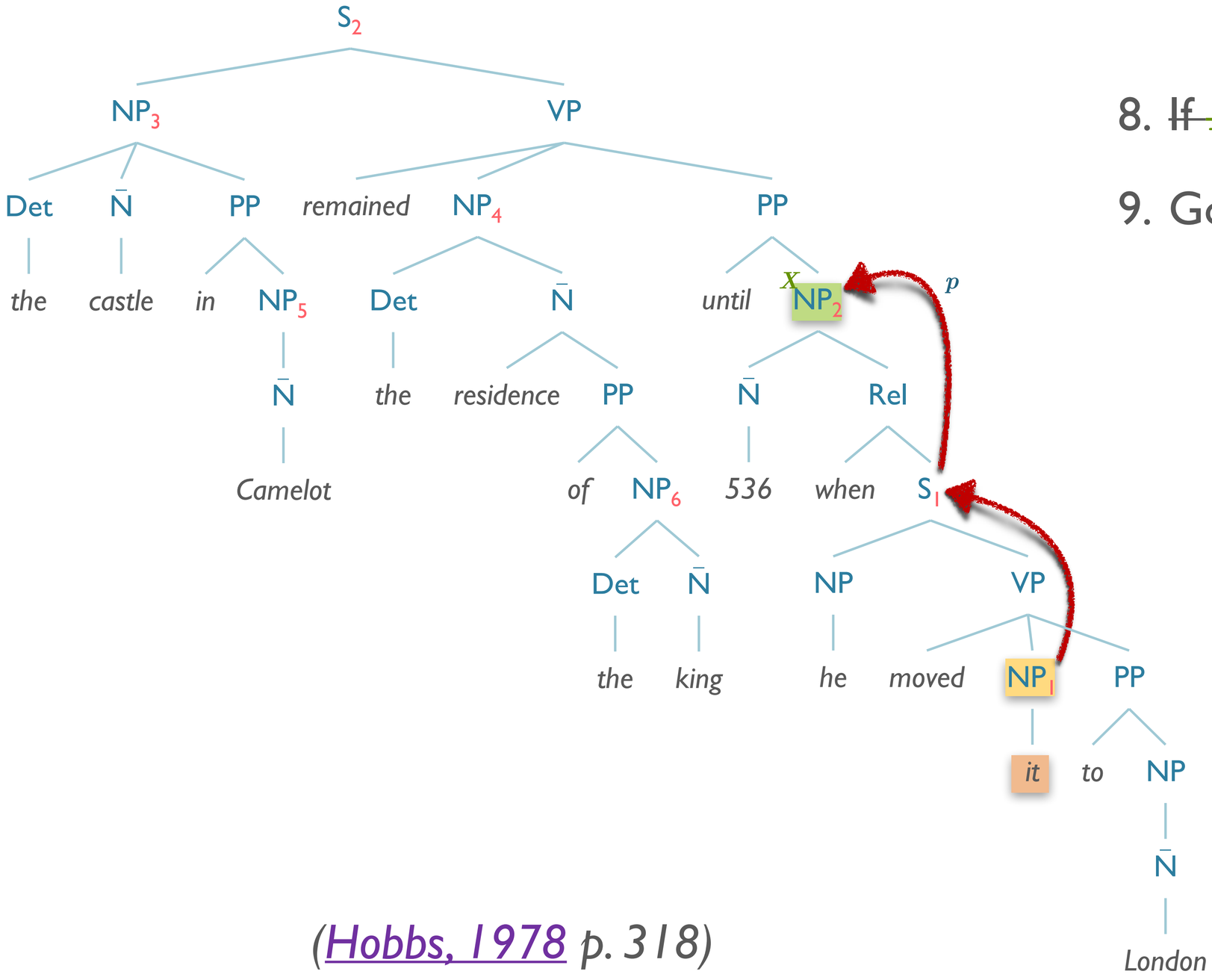
7. ~~Traverse all branches below node *X* to the *left* of path *p* in a left-to-right, breadth-first manner. Propose any NP node encountered as the antecedent.~~

(*Hobbs, 1978 p. 318*)



8. ~~If *X* is an S node…~~

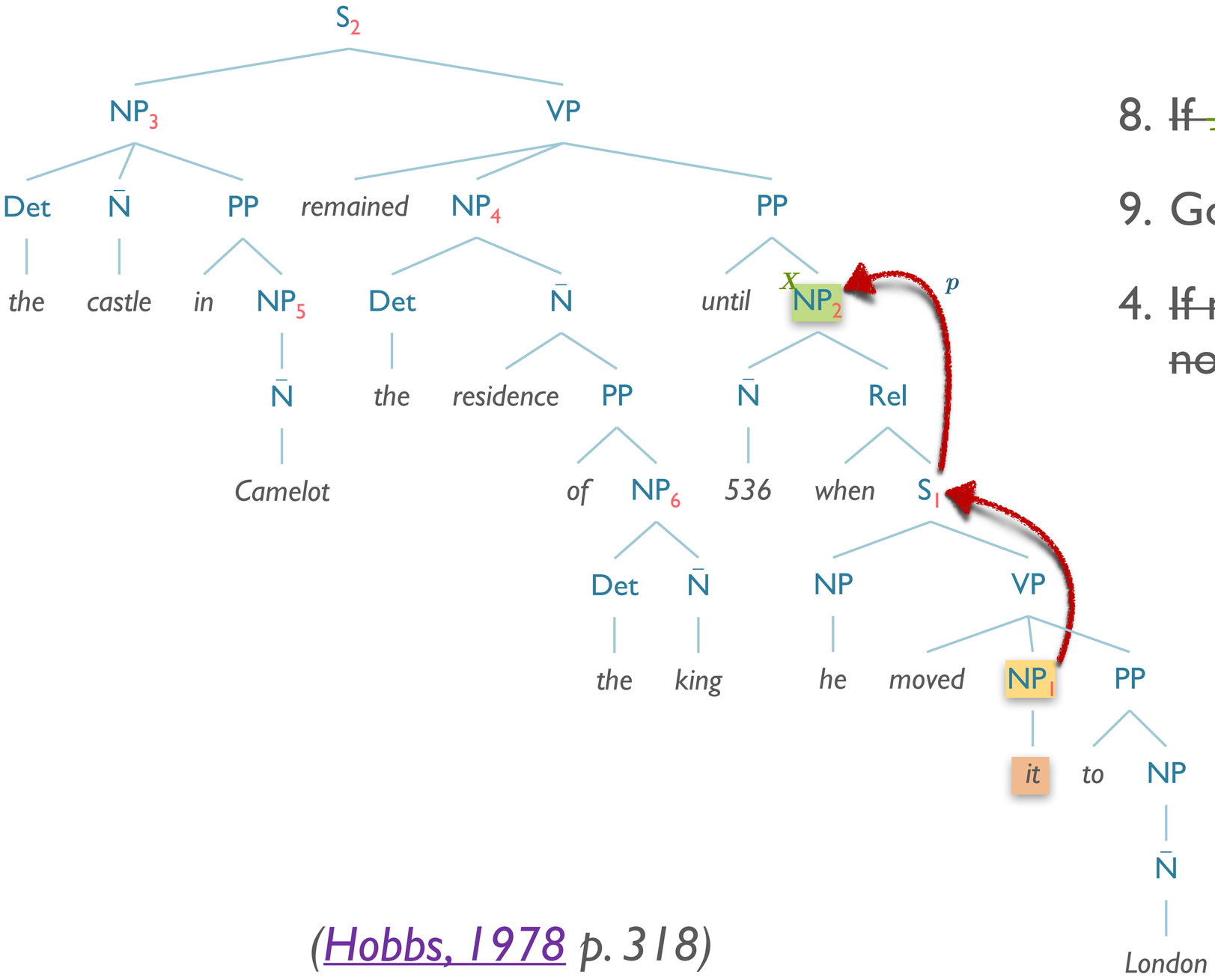
(*Hobbs, 1978 p. 318*)



8. ~~If *X* is an S node…~~

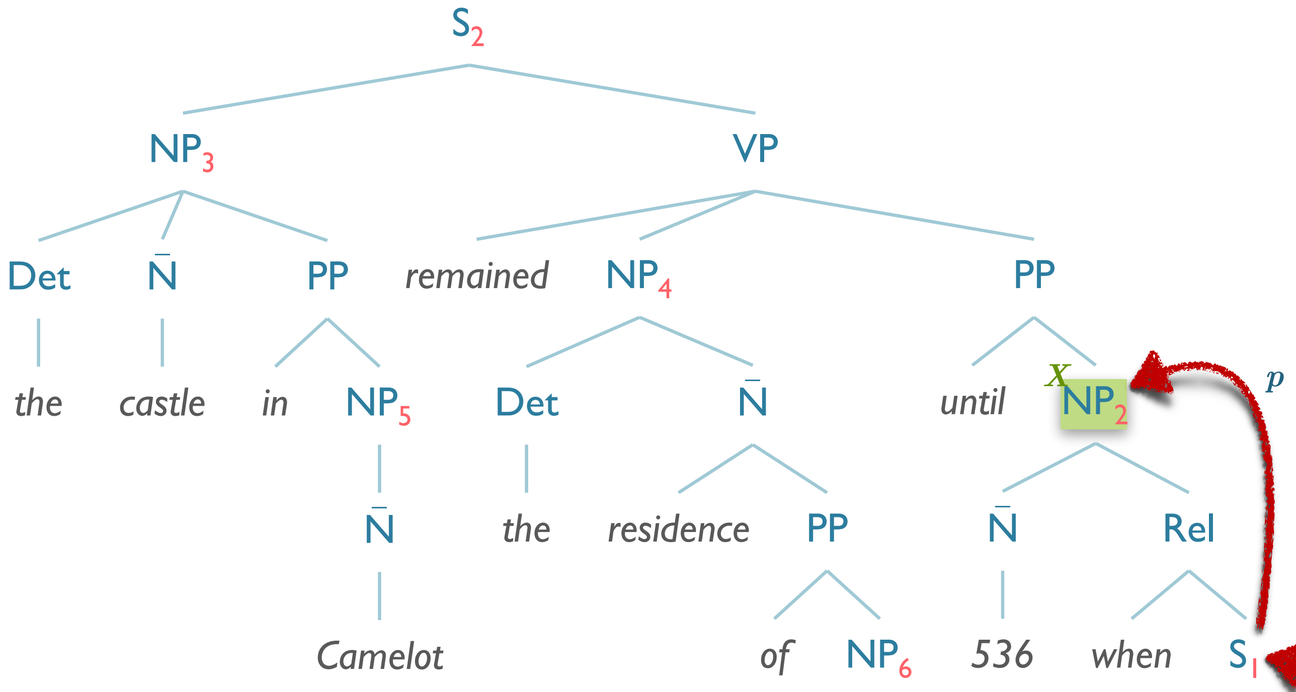
9. Go to step 4.

(*Hobbs, 1978 p. 318*)



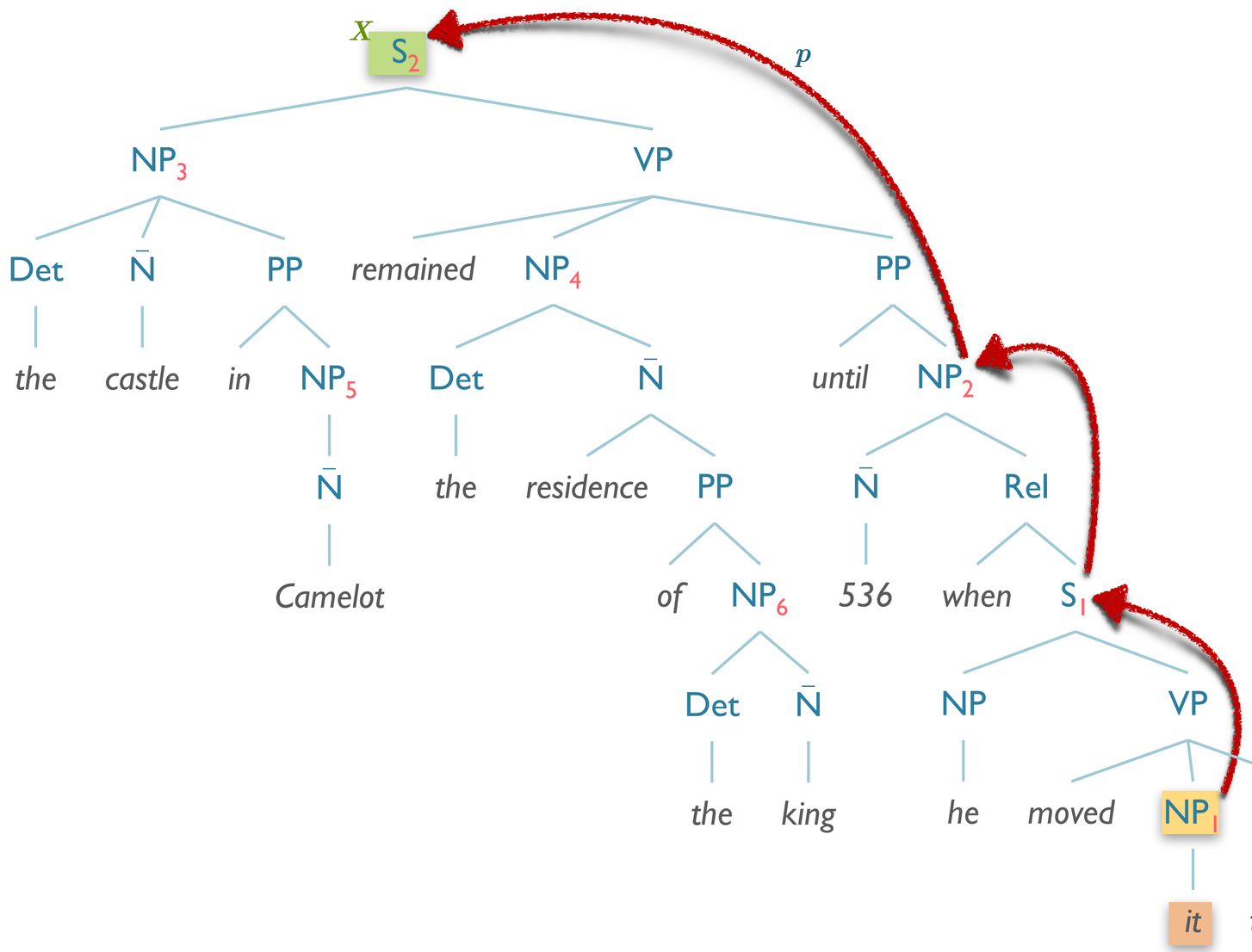
8. ~~If *X* is an S node…~~
9. Go to step 4.
4. ~~If node *X* is the highest S node in the sentence…~~

(Hobbs, 1978 p. 318)



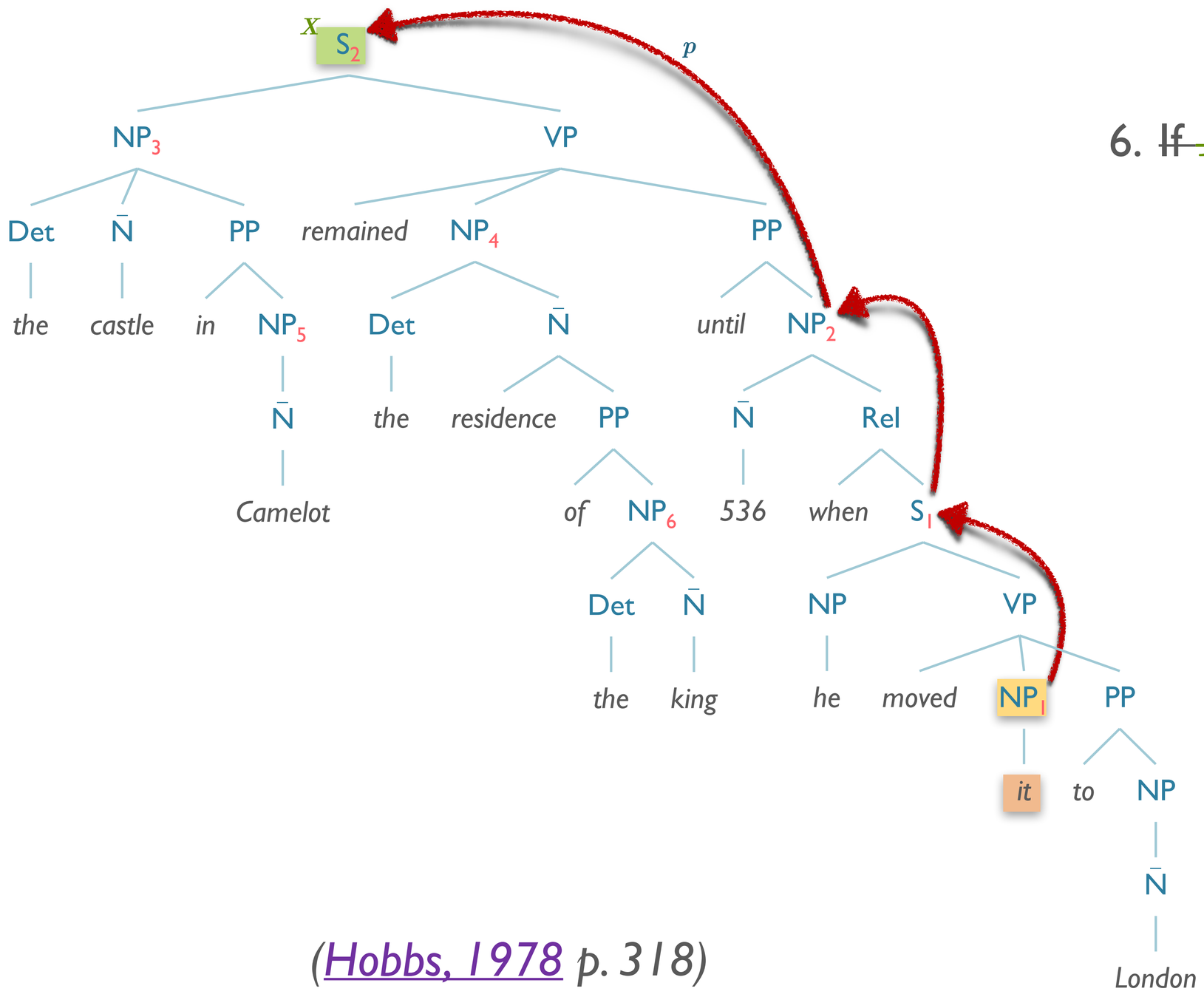
(Hobbs, 1978 p. 318)

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***.



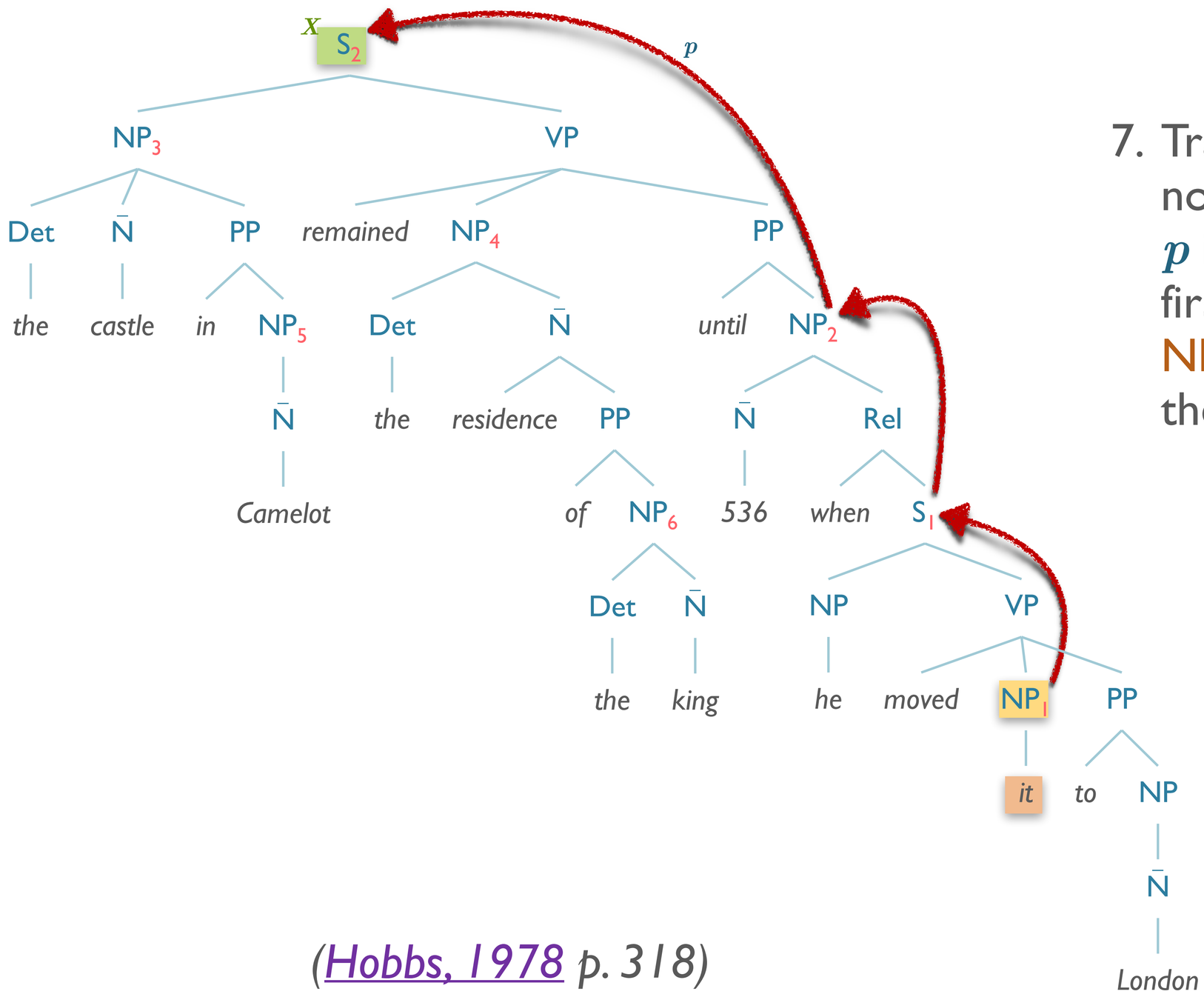
8. ~~If X is an S node…~~
9. Go to step 4.
4. ~~If node X is the highest S node in the sentence…~~
5. From node X, go up the tree to the first NP or S node encountered. Call this new node X, and call the path traversed to reach it p.

(Hobbs, 1978 p. 318)



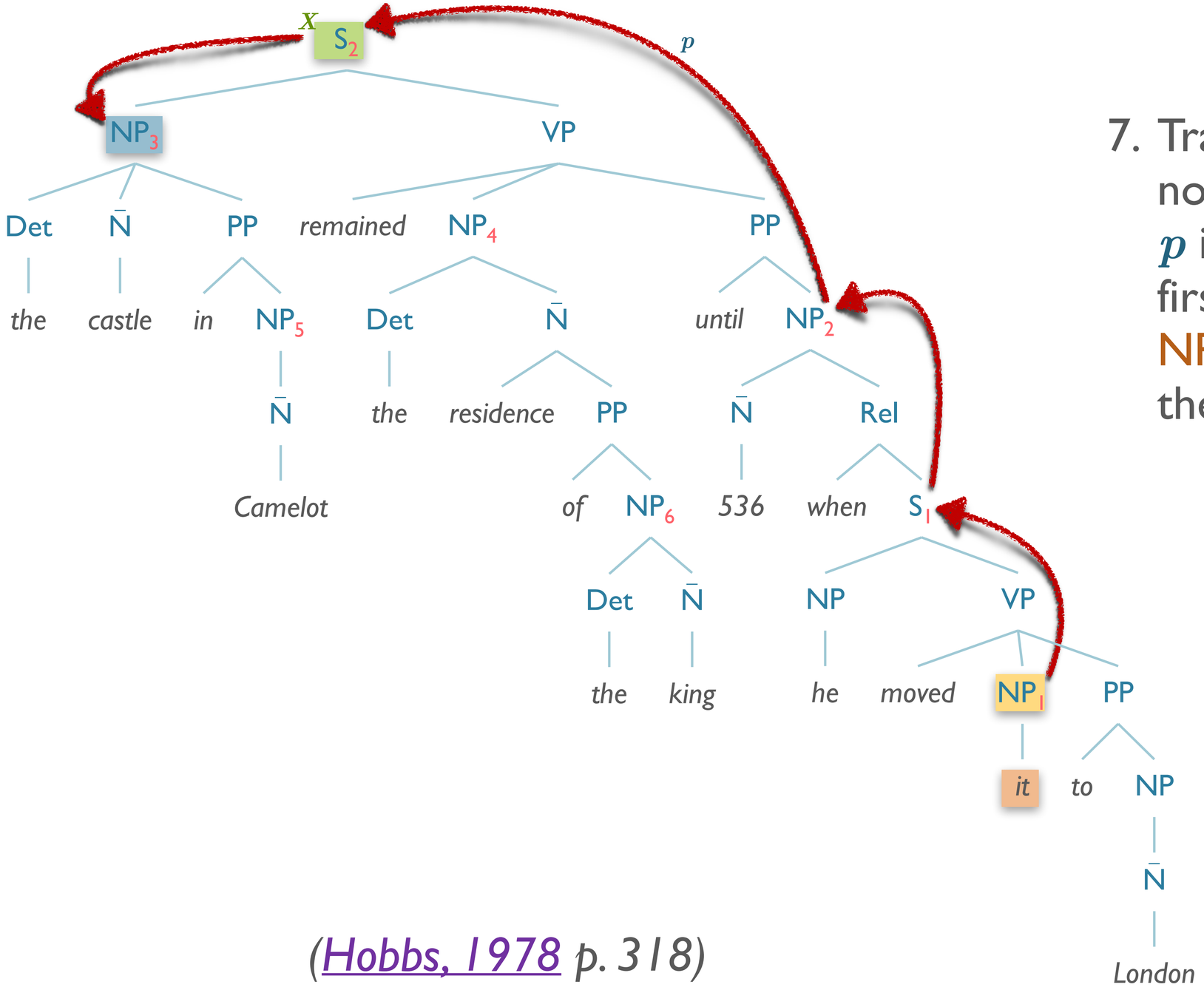
6. ~~If X is an NP node~~…

(Hobbs, 1978 p. 318)



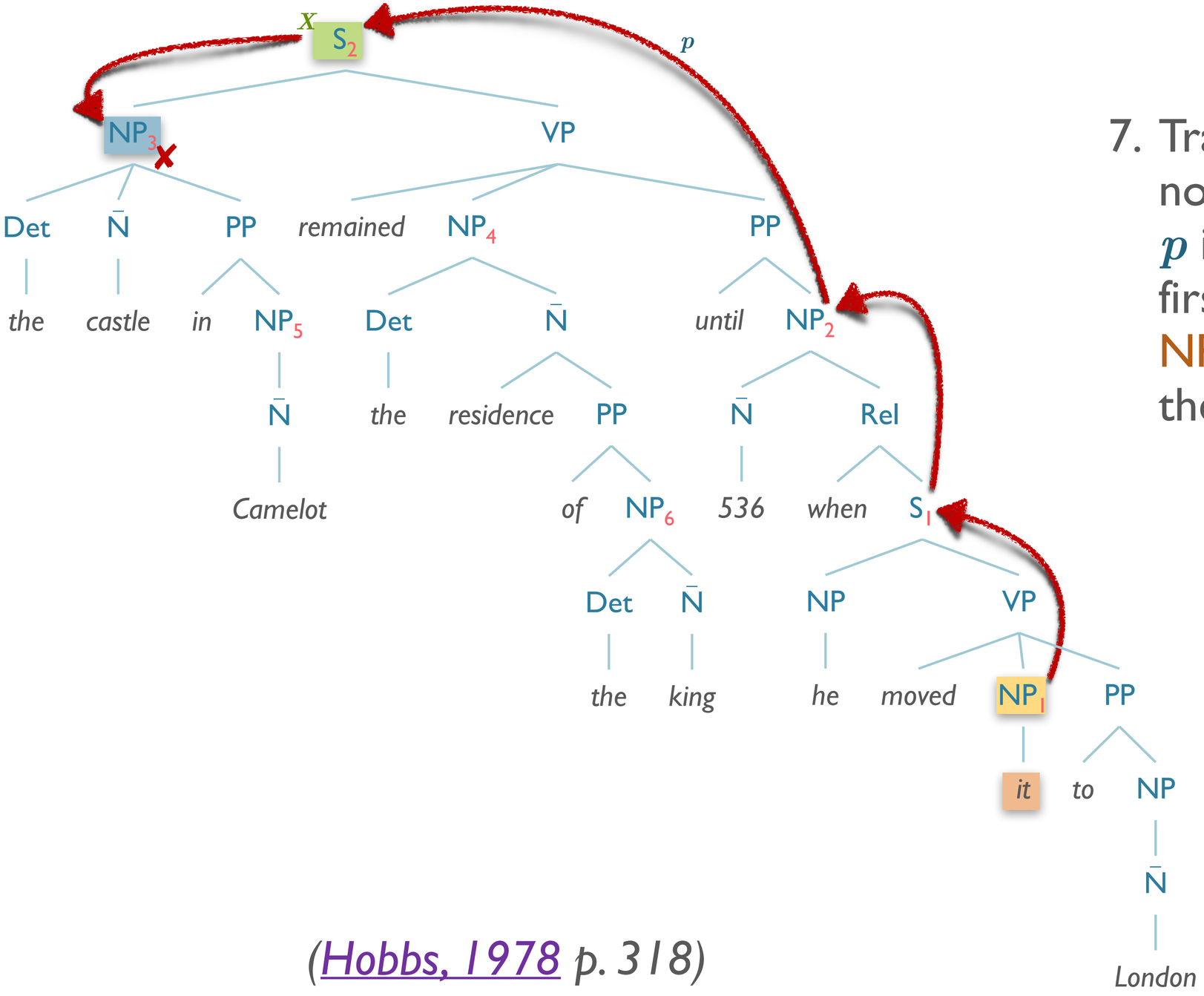
7. Traverse all branches below node X to the *left* of path p in a left-to-right, breadth-first manner. Propose any NP node encountered as the antecedent.

(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.

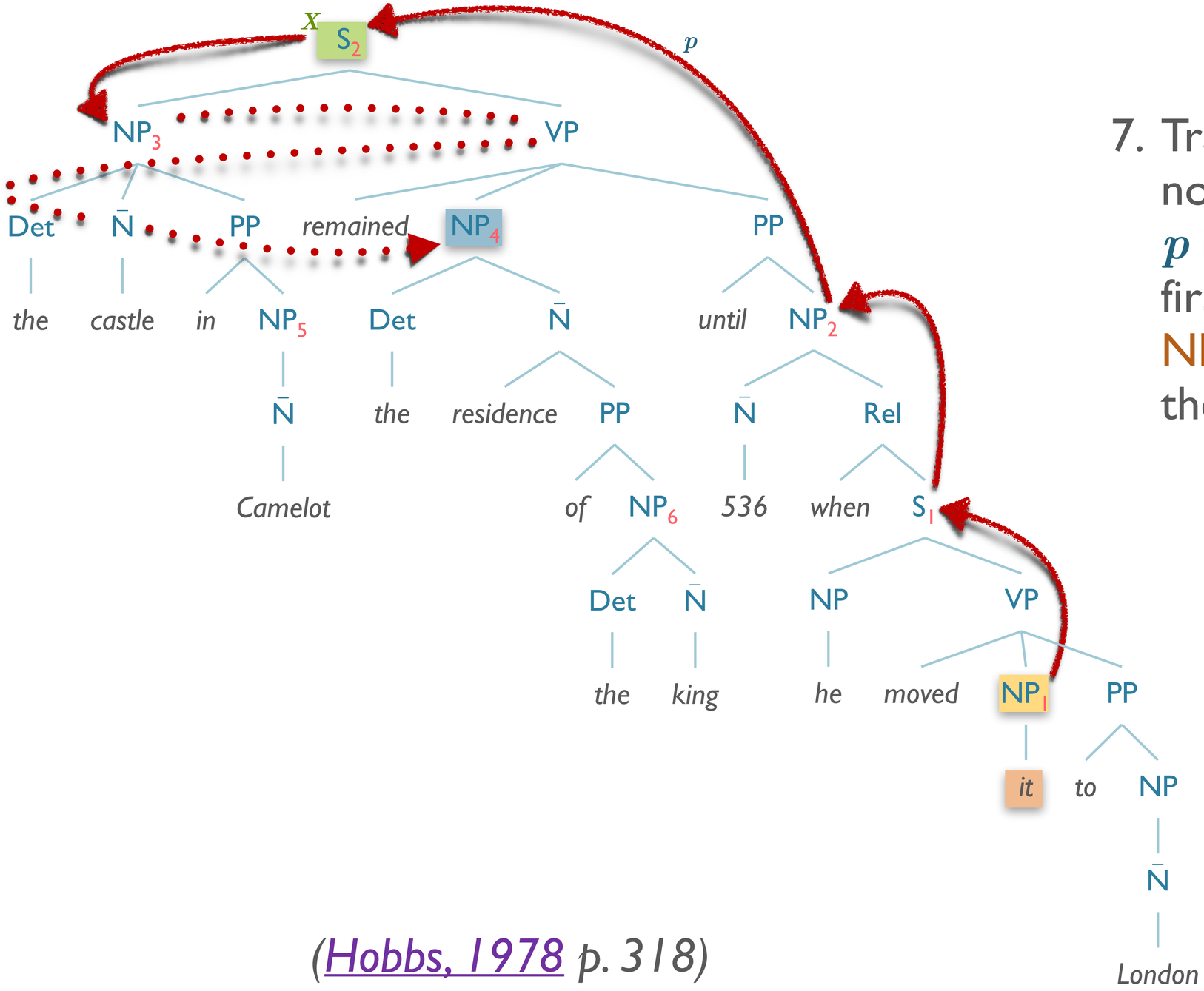
(Hobbs, 1978 p. 318)



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)



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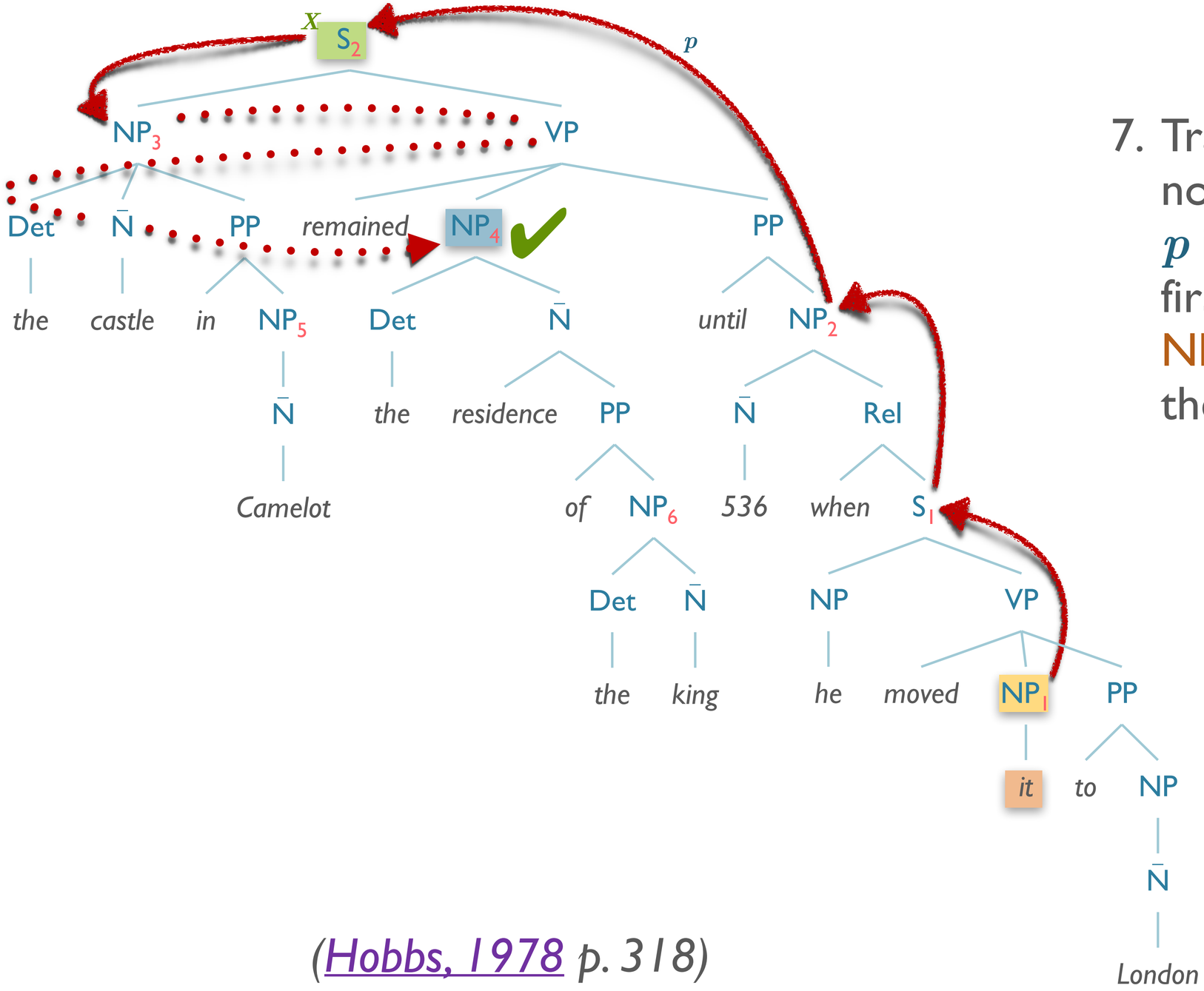
(Hobbs, 1978 p. 318)



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.

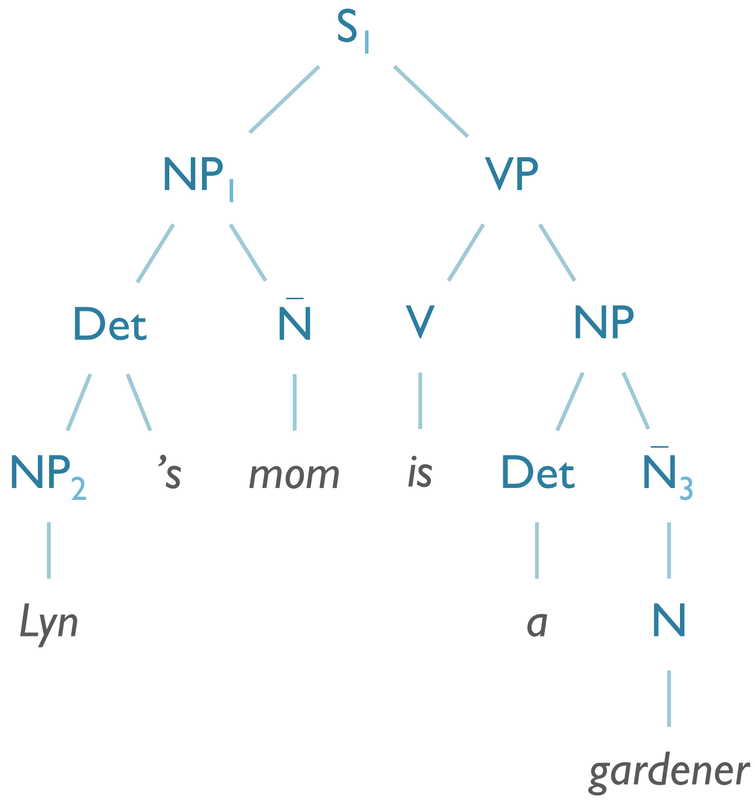
7. Traverse all branches below node X to the ***left*** of path p in a left-to-right, breadth-first manner. Propose any NP node encountered as the antecedent.

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.

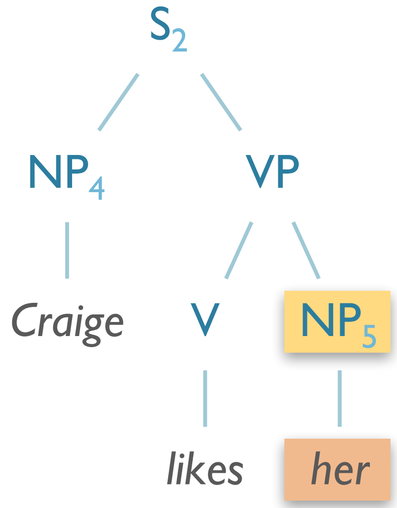
9. Go to step 4.

Hobbs Example

Lyn's mom is a gardener.



*Craige likes **her**.*



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

Hobbs Example

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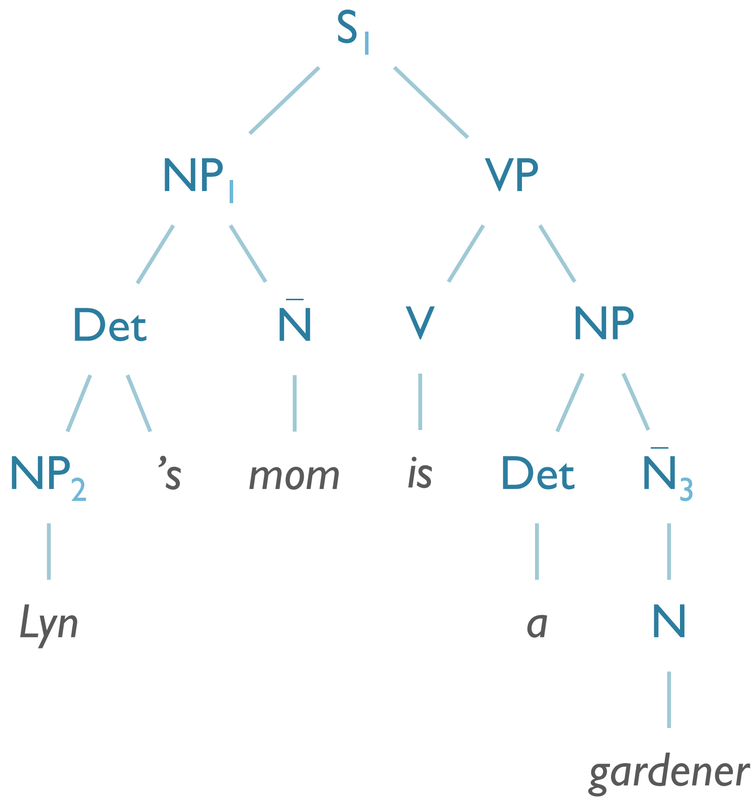
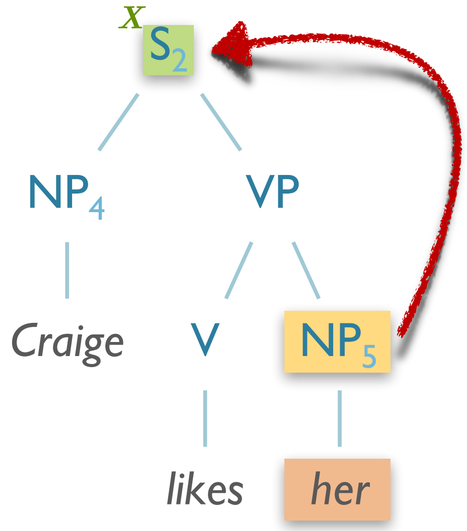


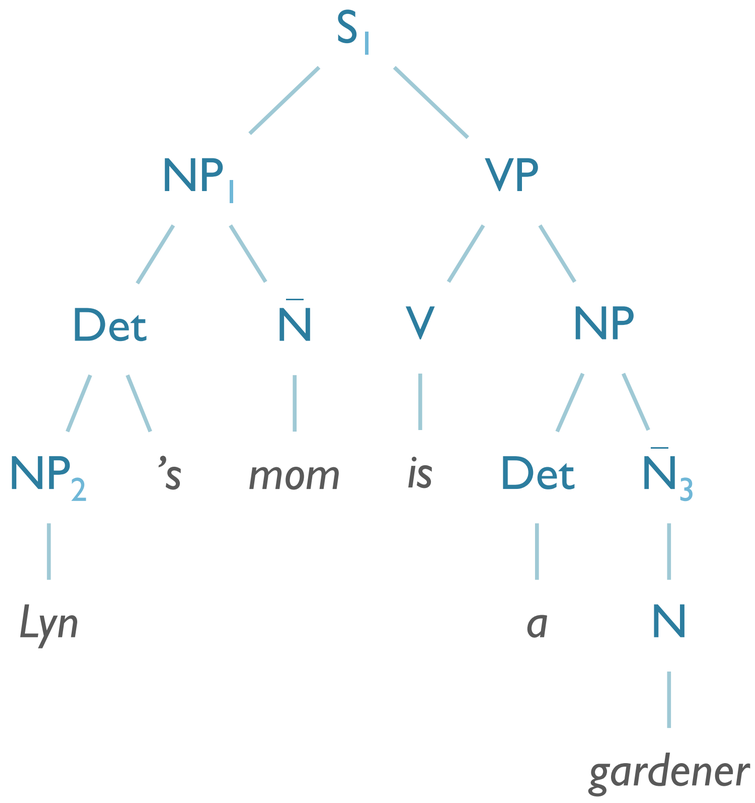
Craige likes her.



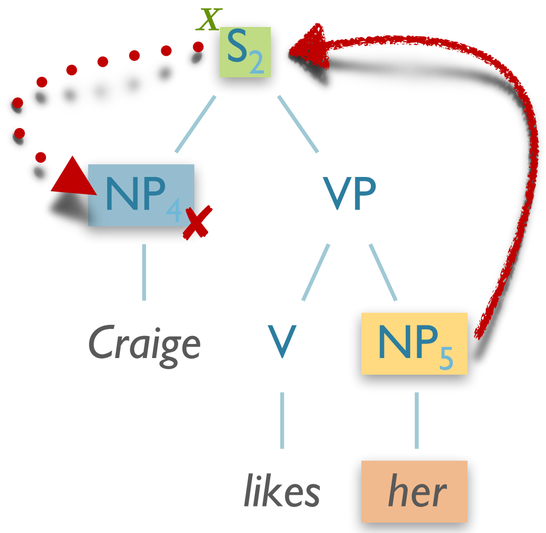
2. Go up the tree to the first NP or sentence (S) node encountered. Call this node X, and call the path used to reach it p.

Hobbs Example

Lyn's mom is a gardener.



Craige likes her.



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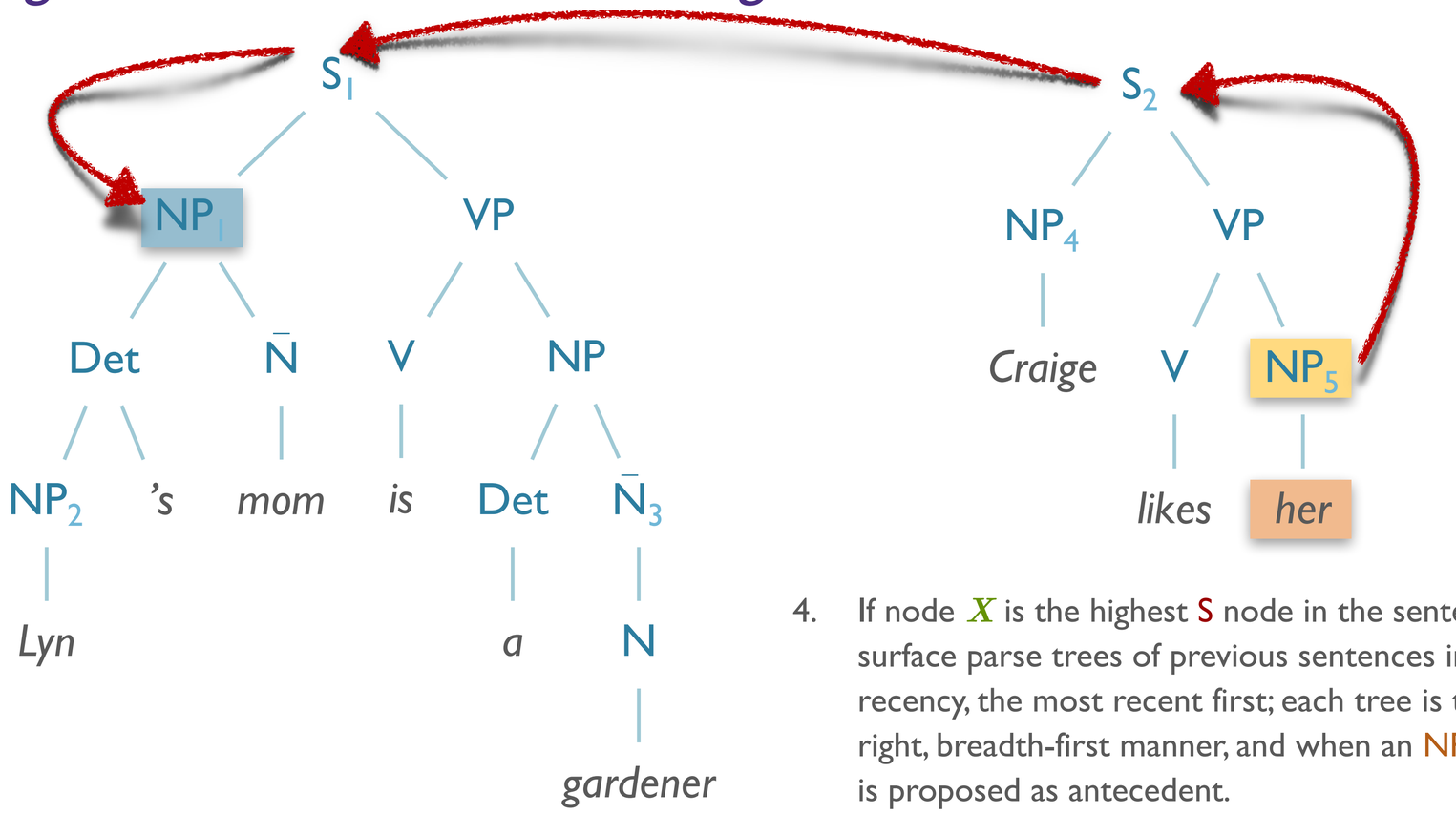
Hobbs Example

Lyn's mom is a gardener. *Craige likes her.*



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Hobbs Example

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