Discourse and Coreference

LING 571 — Deep Processing Methods in NLP

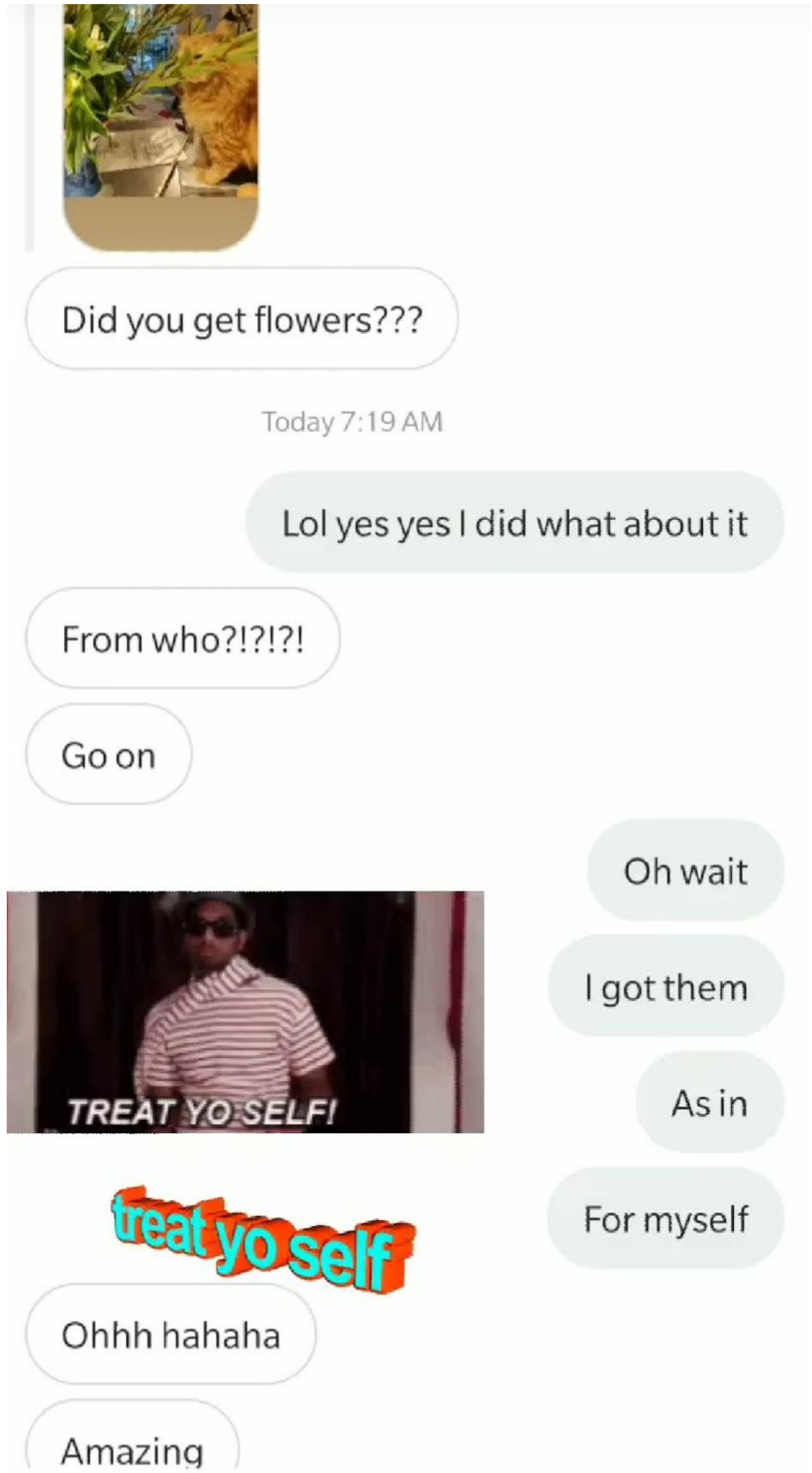
Shane Steinert-Threlkeld

Announcements

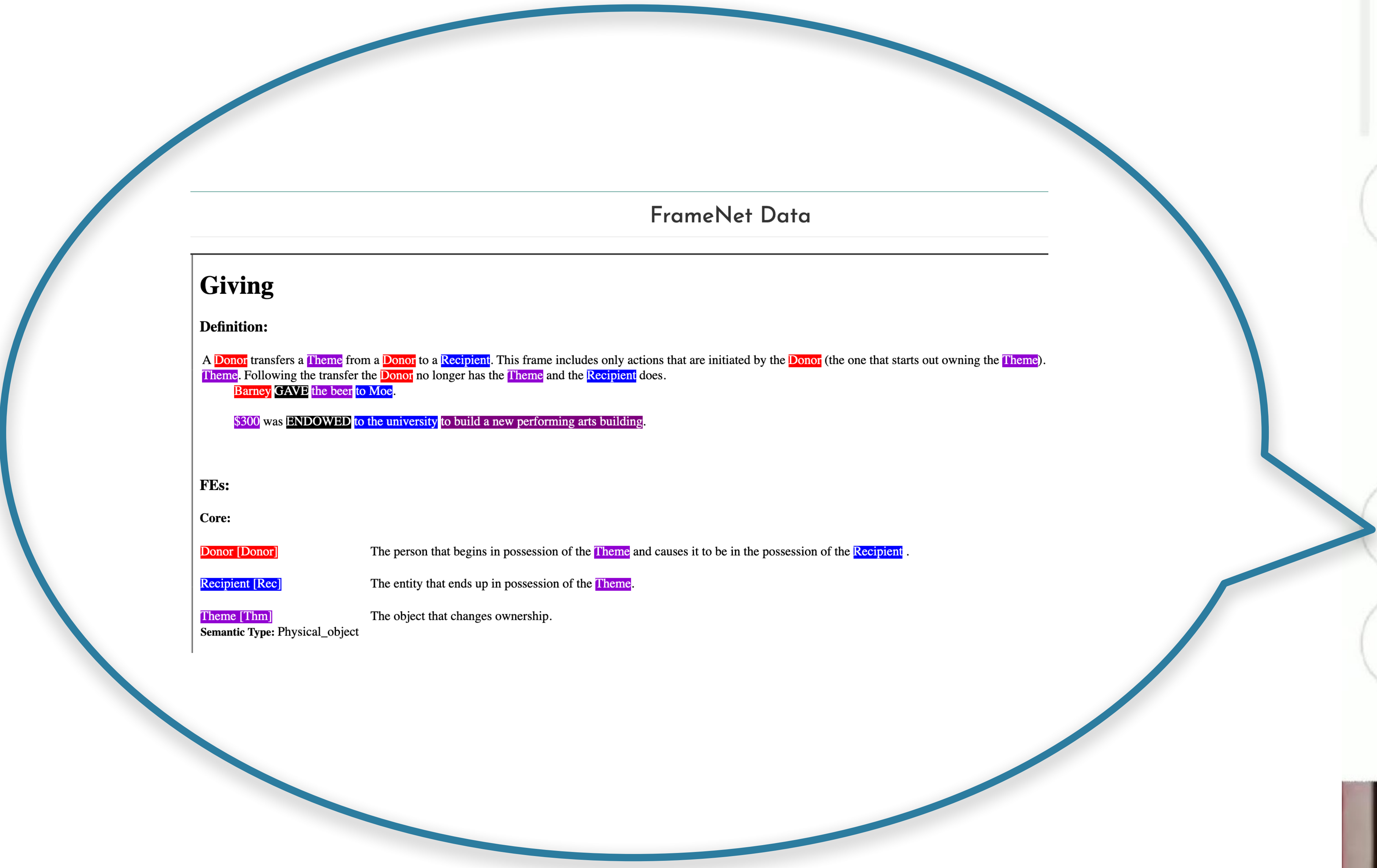
- No class **next Wednesday** (Nov 27)
- HW9 (last of the quarter 😱🎉):
  - Due **December 4**
  - Content mostly covered on Monday

Ambiguity of the Week

Ambiguity of the Week



Ambiguity of the Week



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.

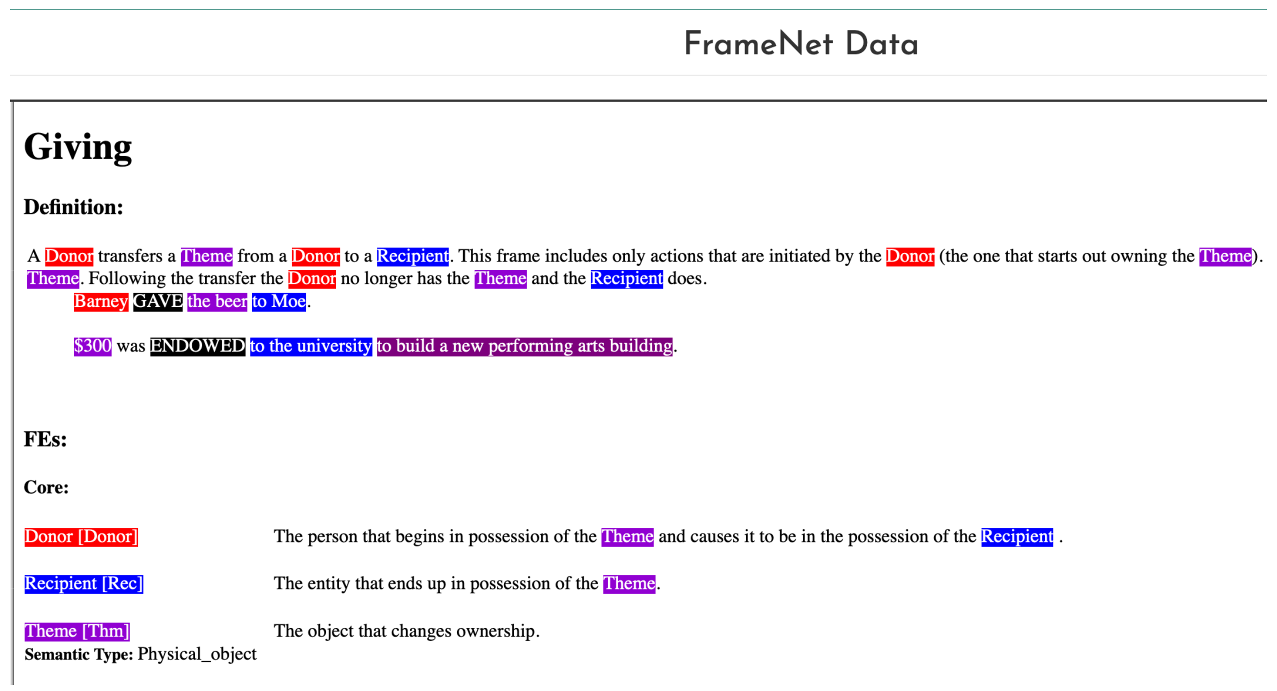
$300 was ENDOWED to the university to build a new performing arts building.

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] **Semantic Type:** Physical_object	The object that changes ownership.

Ambiguity of the Week


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.

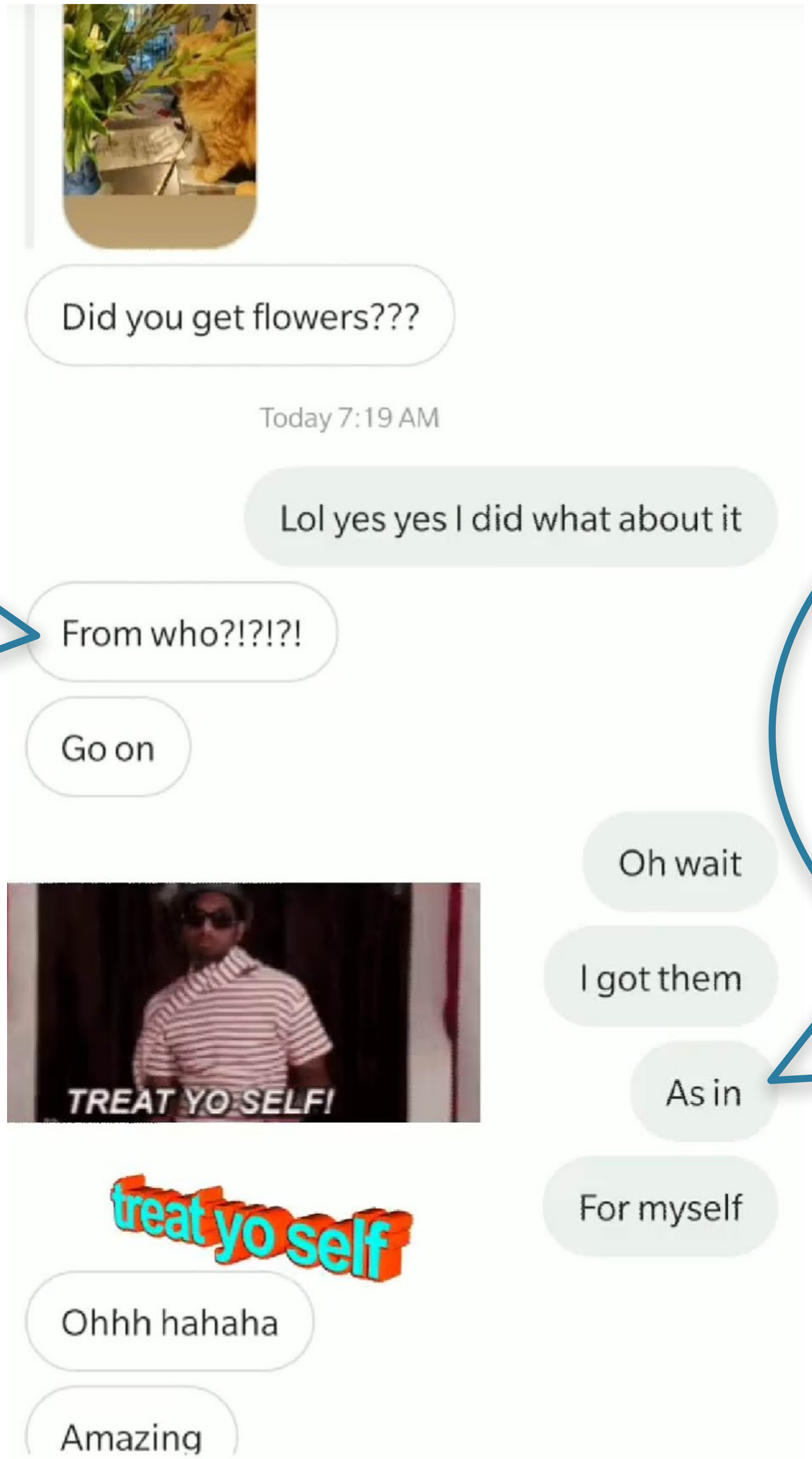
Barney GAVE the beer to Moe.

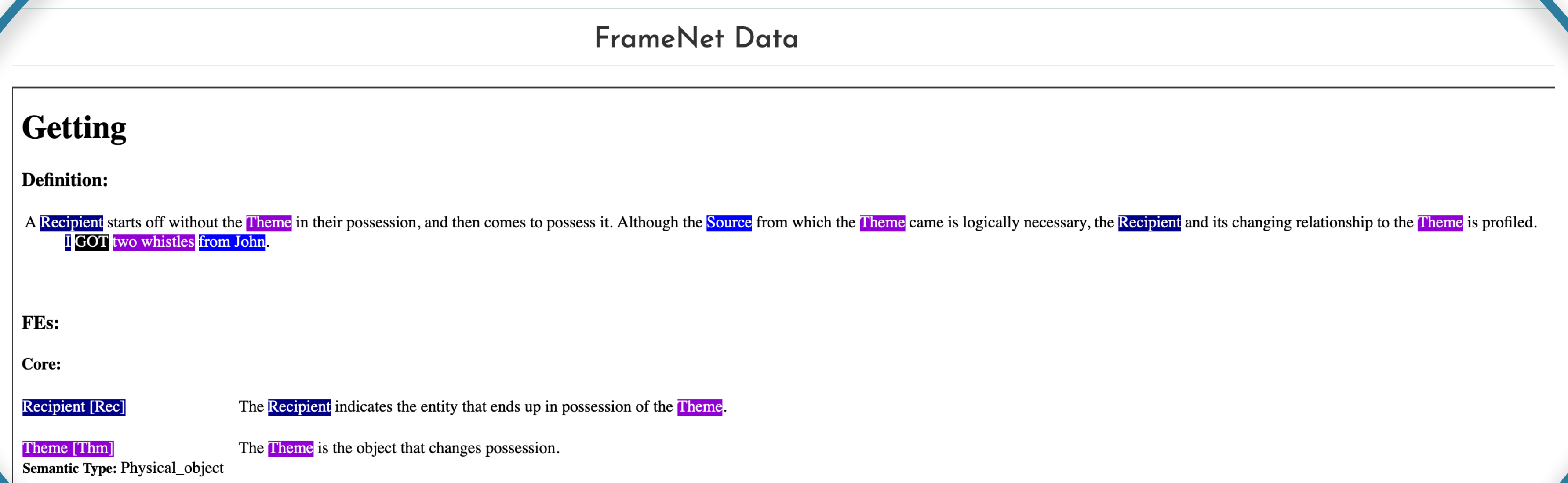
$300 was ENDOWED to the university to build a new performing arts building.

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] **Semantic Type:** Physical_object	The object that changes ownership.




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] **Semantic Type:** Physical_object	The Theme is the object that changes possession.

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

Different Parameters of Discourse

- **Number of participants**
  - Single author/voice → Monologue
  - Multiple participants → Dialogue
- **Modality**
  - Spoken vs. Written

Different Parameters of Discourse

- **Number of participants**
  - Single author/voice → Monologue
  - Multiple participants → Dialogue
- **Modality**
  - Spoken vs. Written
- **Goals**
  - Transactional (message passing) vs. Interactional (relations, attitudes)
  - Cooperative task-oriented rational interaction

Why Discourse?

- Understanding depends on context

Why Discourse?

- Understanding depends on context
  - Word sense — *plant*

Why Discourse?

- Understanding depends on context
  - Word sense — *plant*
  - Intention — *Do you have the time?*

Why Discourse?

- Understanding depends on context
  - Word sense — *plant*
  - Intention — *Do you have the time?*
  - Referring expressions — *it*, *that*, *the screen*

Why Discourse?

- 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?

Reference Resolution

- Knowledge sources:
  - ***Domain Knowledge***

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?

Reference Resolution

- Knowledge sources:
  - ***Domain Knowledge***
  - ***Discourse Knowledge***

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?

Reference Resolution

- Knowledge sources:
  - ***Domain Knowledge***
  - ***Discourse Knowledge***
  - ***World Knowledge***

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?

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.[1] According to industry insiders at PW, their president, John R. Georgius, is planning to announce his retirement tomorrow.[2]*

Not All Sentences Are Created Equal

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

Not All Sentences Are Created Equal

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

Coherence Relations

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

Coherence Relations

John hid Bill's car keys. He was drunk.
John hid Bill's car keys. He likes spinach 🤨

- Why is this odd?

Coherence Relations

John hid Bill's car keys. He was drunk.
John hid Bill's car keys. He likes spinach🤨

- Why is this odd?
  - No obvious relation between sentences

Coherence Relations

John hid Bill's car keys. He was drunk.
John hid Bill's car keys. He likes spinach🤨

- Why is this odd?
  - No obvious relation between sentences
  - Breaks our assumption as readers that information presented in discourse is relevant

Coherence Relations

John hid Bill's car keys. He was drunk.
John hid Bill's car keys. He likes spinach🤨

- Why is this odd?
  - No obvious relation between sentences
  - Breaks our assumption as readers that information presented in discourse is relevant
- How is the first pair related?
  - statement — explanation/cause

Coherence Relations

John hid Bill's car keys. He was drunk.
John hid Bill's car keys. He likes spinach🤨

- Why is this odd?
  - No obvious relation between sentences
  - Breaks our assumption as readers that information presented in discourse is relevant
- How is the first pair related?
  - statement — explanation/cause
- Assumption: utterances should have meaningful connection
  - Establish through ***coherence relations***

Coherence Relations

John hid Bill's car keys. He was drunk.
John hid Bill's car keys. He likes spi🤨ch.

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

Discourse: Looking Ahead

Discourse: Looking Ahead

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.

Reference: Terminology

- ***referring expression***: (refexp)

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.

Reference: Terminology

- ***referring expression***: (refexp)
  - An expression that picks out entity (***referent***) in some knowledge model

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**.

Reference: Terminology

- ***referring expression***: (refexp)
  - An expression that picks out entity (***referent***) in some knowledge model
  - Referring expressions used for the same entity ***corefer***

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.

Reference: Terminology

- ***referring expression***: (refexp)
  - An expression that picks out entity (***referent***) in some knowledge model
  - Referring expressions used for the same entity ***corefer***
    - *Queen Elizabeth*, *her*, *the Queen*

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**.

Reference: Terminology

- ***referring expression***: (refexp)
  - An expression that picks out entity (***referent***) in some knowledge model
  - Referring expressions used for the same entity ***corefer***
    - *Queen Elizabeth*, *her*, *the Queen*
    - *Logue*, *a renowned speech therapist*

> **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**.

Reference: Terminology

- ***referring expression***: (refexp)
  - An expression that picks out entity (***referent***) in some knowledge model
  - Referring expressions used for the same entity ***corefer***
    - *Queen Elizabeth*, *her*, *the Queen*
    - *Logue*, *a renowned speech therapist*
  - Entities in **purple** do not corefer to anything.

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**.

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**.

Reference: Terminology

- ***Antecedent:***
  - An expression that introduces an item to the discourse for other items to refer back to
  - Queen Elizabeth… her

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.

Reference: Terminology

- ***Anaphora***: An expression that refers back to a previously introduced entity.
  - ***cataphora***: Introduction of expression before referent:
    - “Even before *she* saw it, *Dorothy* had been thinking about...”

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**.

Reference: Terminology

- ***Anaphora***: An expression that refers back to a previously introduced entity.
  - ***cataphora***: Introduction of expression before referent:
    - "Even before ***she*** saw it, ***Dorothy*** had been thinking about…"

*Not all anaphora is referential! e.g. *"No dancer hurt their knee."*

> **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**.

Referring Expressions

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

Referring Expressions

- *Queen Elizabeth* – *she/her* – *the Queen* – *HRM* – *the British Monarch*

- “Correct” form depends on discourse context

Referring Expressions

- *Queen Elizabeth* – *she/her* – *the Queen* – *HRM* – *the British Monarch*

- “Correct” form depends on discourse context
  - ***she, her*** presume prior mention or presence in the world

Referring Expressions

- *Queen Elizabeth* – *she/her* – *the Queen* – *HRM* – *the British Monarch*

- “Correct” form depends on discourse context
  - ***she, her*** presume prior mention or presence in the world
  - ***the Queen*** presumes an Anglocentric geopolitical discourse context generally or the UK (or British Commonwealth) specifically

Referring Expressions

- *Queen Elizabeth* – *she/her* – *the Queen* – *HRM* – *the British Monarch*

- “Correct” form depends on discourse context
  - ***she, her*** presume prior mention or presence in the world
  - ***the Queen*** presumes an Anglocentric geopolitical discourse context generally or the UK (or British Commonwealth) specifically

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

Discourse Model

- Correct interpretation of reference requires **Discourse Model**
  - Entities referred to in the discourse
  - Relationships of these entities

Discourse Model

- Correct interpretation of reference requires **Discourse Model**
  - Entities referred to in the discourse
  - Relationships of these entities
- Need way to construct, update model

Discourse Model

- Correct interpretation of reference requires **Discourse Model**
  - Entities referred to in the discourse
  - Relationships of these entities
- Need way to construct, update model
  - First mention of entity **evokes** entity *into* model

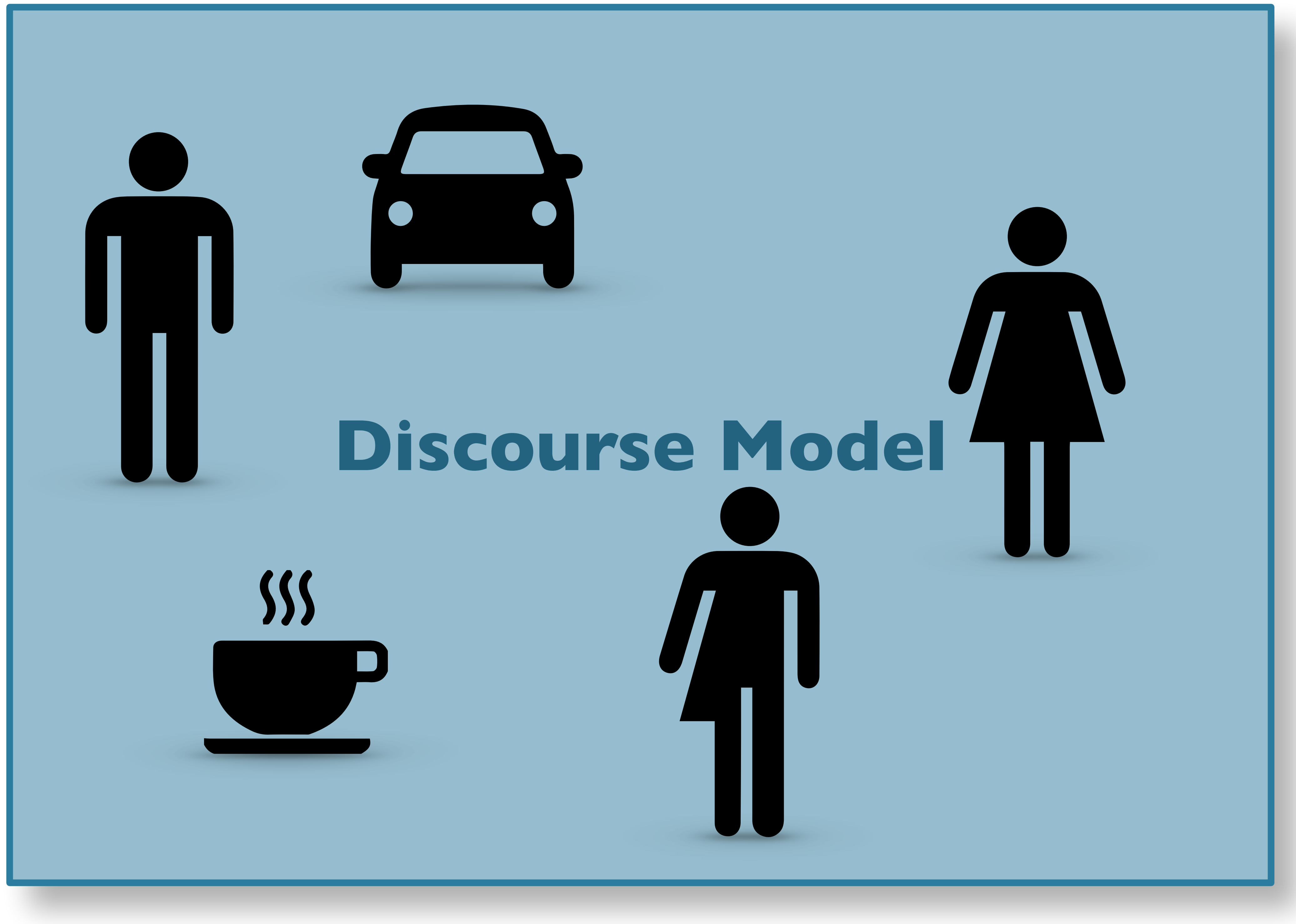
Discourse Model

- Correct interpretation of reference requires **Discourse Model**
  - Entities referred to in the discourse
  - Relationships of these entities
- Need way to construct, update model
  - First mention of entity **evokes** entity *into* model
    - [“introduces a discourse referent (dref)”]

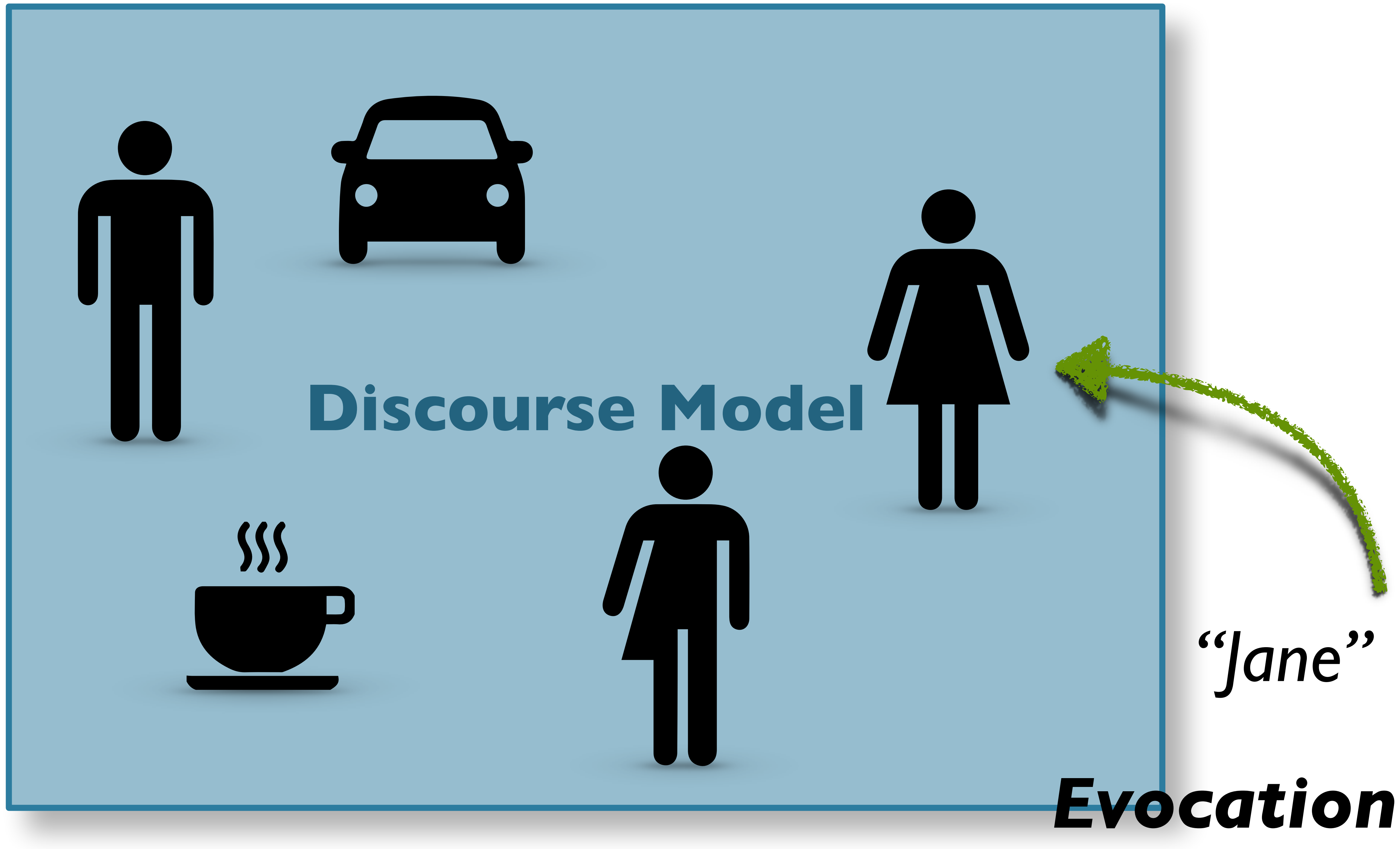
Discourse Model

- Correct interpretation of reference requires **Discourse Model**
  - Entities referred to in the discourse
  - Relationships of these entities
- Need way to construct, update model
  - First mention of entity **evokes** entity *into* model
    - ["introduces a discourse referent (dref)"]
  - Subsequent mentions **access** entity *from* the model.

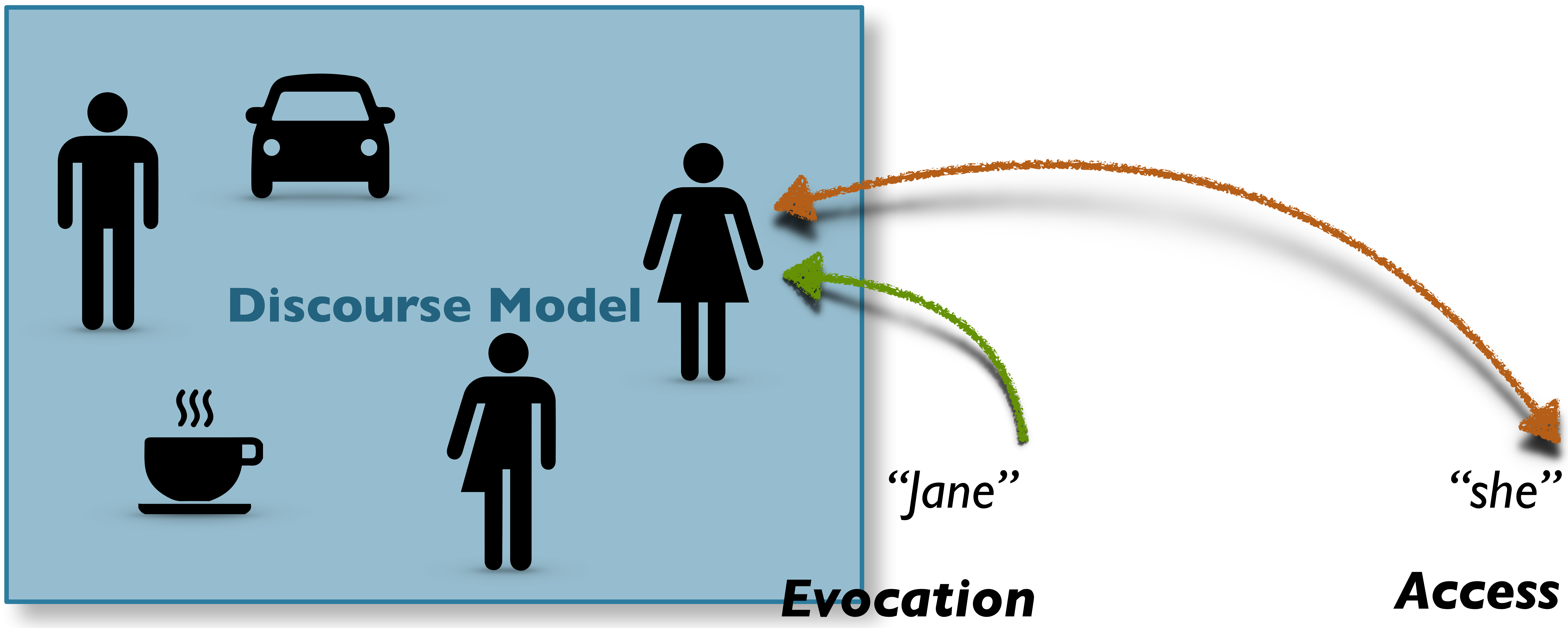
Reference and Model



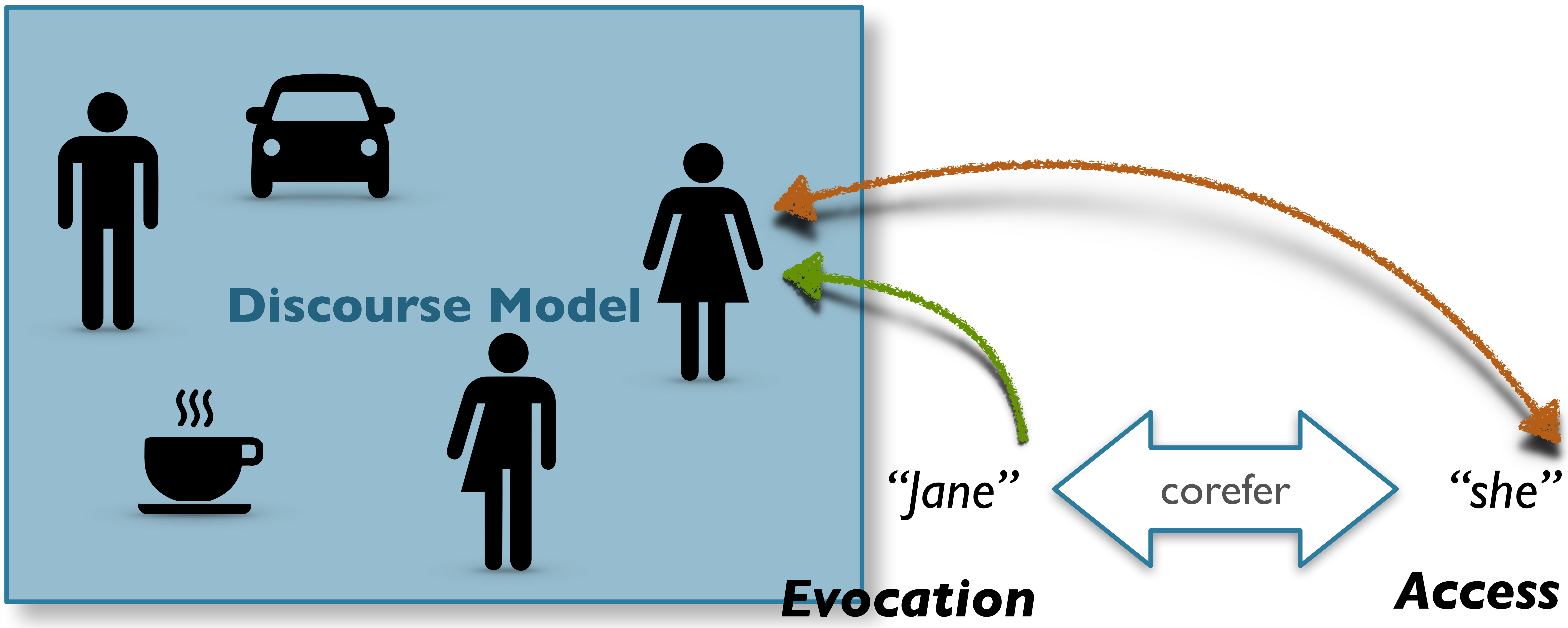
Reference and Model



Reference and Model



Reference and Model



Reference Tasks

- **Coreference resolution:**
  - Find all expressions referring to the same entity in a text.
  - A set of coreferring expressions is a ***coreference chain***.

Reference Tasks

- **Coreference resolution:**
  - Find all expressions referring to the same entity in a text.
  - A set of coreferring expressions is a ***coreference chain***.
- **Pronominal 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

Reference Phenomena: Activation/Salience

a) ***John*** *went to* ***Erin's*** *party, and parked next to a classic* ***Ford Falcon****.*

Reference Phenomena: Activation/Salience

a) ***John*** *went to* ***Erin's*** *party, and parked next to a classic* ***Ford Falcon****.*

b) ***He*** *went inside and talked to* ***Erin*** *for more than an hour.*

Reference Phenomena: Activation/Salience

a) ***John*** *went to* ***Erin's*** *party, and parked next to a classic* ***Ford Falcon****.*
b) ***He*** *went inside and talked to* ***Erin*** *for more than an hour.*
c) ***Erin*** *told* ***him*** *that* ***she*** *recently got engaged.*

Reference Phenomena: Activation/Salience

a) ***John*** *went to* ***Erin's*** *party, and parked next to a classic* ***Ford Falcon****.*
b) ***He*** *went inside and talked to* ***Erin*** *for more than an hour.*
c) ***Erin*** *told* ***him*** *that* ***she*** *recently got engaged.*
d) ***??*** ***She*** *also said that* ***she*** *bought* ***it*** *yesterday.*

Reference Phenomena: Activation/Salience

a) ***John*** *went to* ***Erin's*** *party, and parked next to a classic* ***Ford Falcon****.*

b) ***He*** *went inside and talked to* ***Erin*** *for more than an hour.*

c) ***Erin*** *told* ***him*** *that* ***she*** *recently got engaged.*

d) ***??*** ***She*** *also said that* ***she*** *bought* ***it*** *yesterday.*

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

Reference Phenomena: Activation/Salience

a) ***John*** *went to* ***Erin's*** *party, and parked next to a classic* ***Ford Falcon****.*
b) ***He*** *went inside and talked to* ***Erin*** *for more than an hour.*
c) ***Erin*** *told* ***him*** *that* ***she*** *recently got engaged.*
d) ***??*** ***She*** *also said that* ***she*** *bought* ***it*** *yesterday.*
   e) ***She*** *also said that* ***she*** *bought* ***the Falcon*** *yesterday.*

- d) is problematic because ***the Falcon*** has lost its salience.

Reference Phenomena: Activation/Salience

a) ***John*** *went to* ***Erin's*** *party, and parked next to a classic* ***Ford Falcon****.*
b) ***He*** *went inside and talked to* ***Erin*** *for more than an hour.*
c) ***Erin*** *told* ***him*** *that* ***she*** *recently got engaged.*
d) ***??*** ***She*** *also said that* ***she*** *bought* ***it*** *yesterday.*
    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.

Information Status

- Some expressions introduce **new** information (ex: indefinite NPs)

Information Status

- Some expressions introduce **new** information (ex: indefinite NPs)
- Other expressions refer to previous referents (ex: Pronouns)

Information Status

- Some expressions introduce **new** information (ex: indefinite NPs)
- Other expressions refer to previous referents (ex: Pronouns)
- "***Givenness hierarchy***" (Gundel et al. 1993)

in focus >
it

Information Status

- Some expressions introduce **new** information (ex: indefinite NPs)
- Other expressions refer to previous referents (ex: Pronouns)
- "***Givenness hierarchy***" (Gundel et al. 1993)

in focus >	activated >
it	***this***
	that
	***this* N**

Information Status

- Some expressions introduce **new** information (ex: indefinite NPs)
- Other expressions refer to previous referents (ex: Pronouns)
- "***Givenness hierarchy***" (Gundel et al. 1993)

in focus >	activated >	familiar >
it	***this***	***that N***
	that	
	this N	

Information Status

- Some expressions introduce **new** information (ex: indefinite NPs)
- Other expressions refer to previous referents (ex: Pronouns)
- "***Givenness hierarchy***" (Gundel et al. 1993)

in focus >	activated >	familiar >	uniquely identifiable >
it	***this***	***that* N**	***the* N**
	that		
	***this* N**		

Information Status

- Some expressions introduce **new** information (ex: indefinite NPs)
- Other expressions refer to previous referents (ex: Pronouns)
- "***Givenness hierarchy***" (Gundel et al. 1993)

in focus >	**activated >**	**familiar >**	**uniquely identifiable >**	**referential >**
it	***this***	***that* N**	***the* N**	**indef. *this* N**
	that			
	***this* N**			

Information Status

- Some expressions introduce **new** information (ex: indefinite NPs)
- Other expressions refer to previous referents (ex: Pronouns)
- "***Givenness hierarchy***" (Gundel et al. 1993)

in focus >	activated >	familiar >	uniquely identifiable >	referential >	type identifiable
it	***this***	***that* N**	***the* N**	**indef. *this* N**	***a* N**
	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:
  - *I bought **a car** today, but **a door** had a dent, and **the engine** was noisy.*
    - ***a door***, ***the engine*** ∈ ***a car***

Complicating Factors

- ***Inferrables***
  - 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***
- ***Generics***:
  - *I want to buy **a Jaguar**. **They** are very stylish.*
  - General group evoked by instance.

Complicating Factors

- ***Inferrables***
  - 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***
- ***Generics***:
  - *I want to buy **a Jaguar**. **They** are very stylish.*
  - General group evoked by instance.
- ***Non-referential cases***:
  - ***It's** raining.* (Pleonasm)
  - ***It** was good that Frodo carried the ring.* (Extraposition)

Features for Anaphora Resolution: Constraints

- **Number**:
  - *Anjali has a Corvette.* **They are red.* *It is red.*

Features for Anaphora Resolution: Constraints

- **Number**:
  - *Anjali has a Corvette.* **They are red.* *It is red.*

- **Person**:
  - 1st: *I, we* 2nd: *you, y'all* 3rd: *he, she, it, they*

Features for Anaphora Resolution: Constraints

- **Number**:
  - *Anjali has a Corvette.* **They are red.* *It is red.*
- **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.*

Features for Anaphora Resolution: Constraints

- **Binding Theory**
  - How to handle reflexive pronouns vs. nonreflexives
    - *Aaron bought themself a new car.*

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]

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]

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]

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.* [$He_1 \neq$ Willie, $he_2 \neq$ Willie]

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

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.

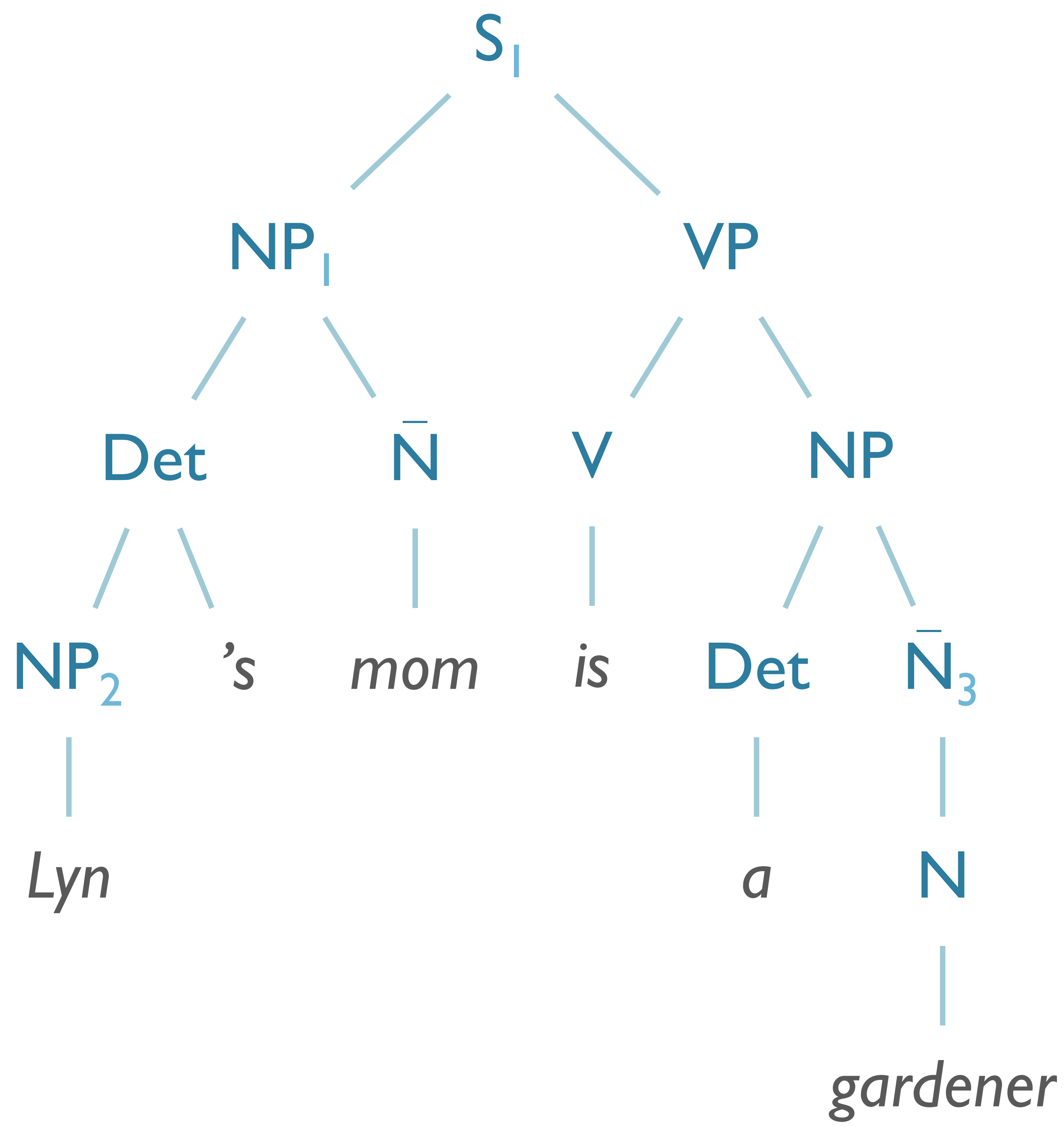
Hobbs Algorithm Detail (Hobbs, 1978)

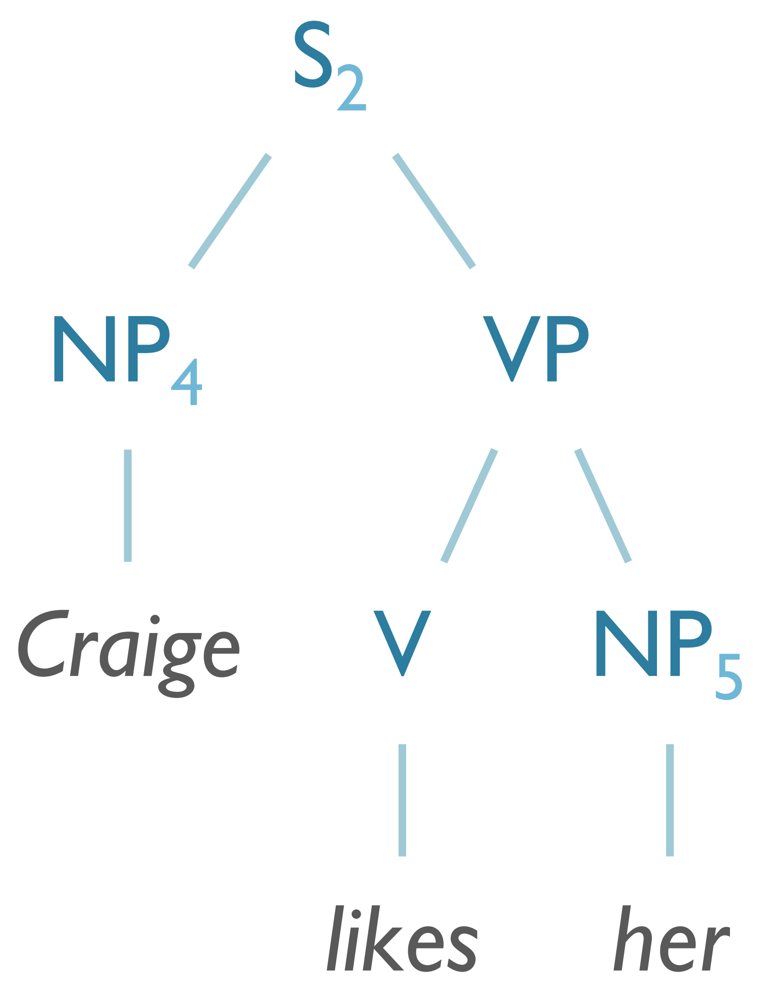
5. From node **X**, go up the tree to the first NP or S node encountered. Call this new node **X**, and call the path traversed to reach it *p*.
6. If **X** is an NP node and if the path *p* to **X** did not pass through the Nominal node that **X** immediately dominates, propose **X** as the antecedent.
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.

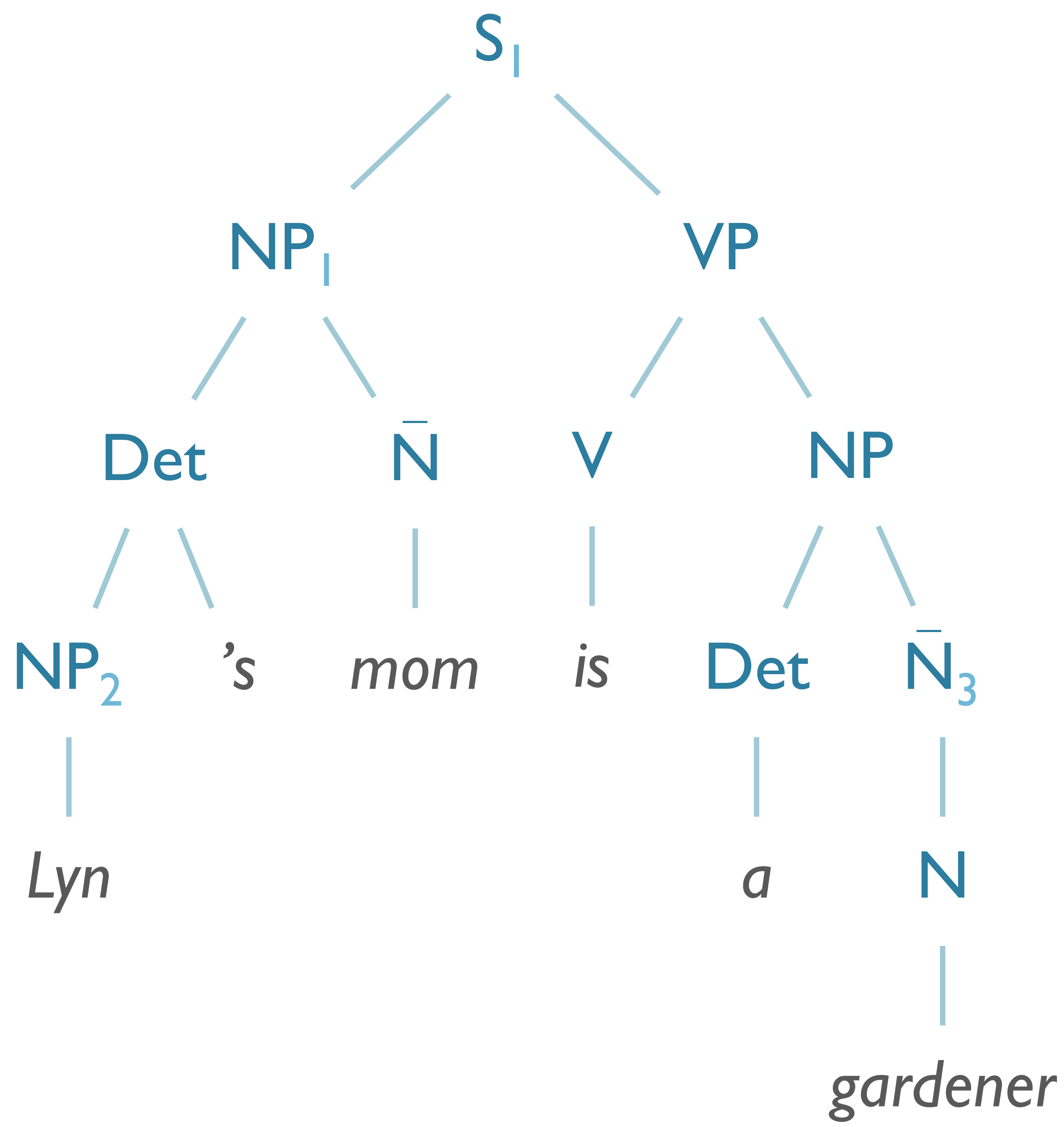
Craige likes **her***.*



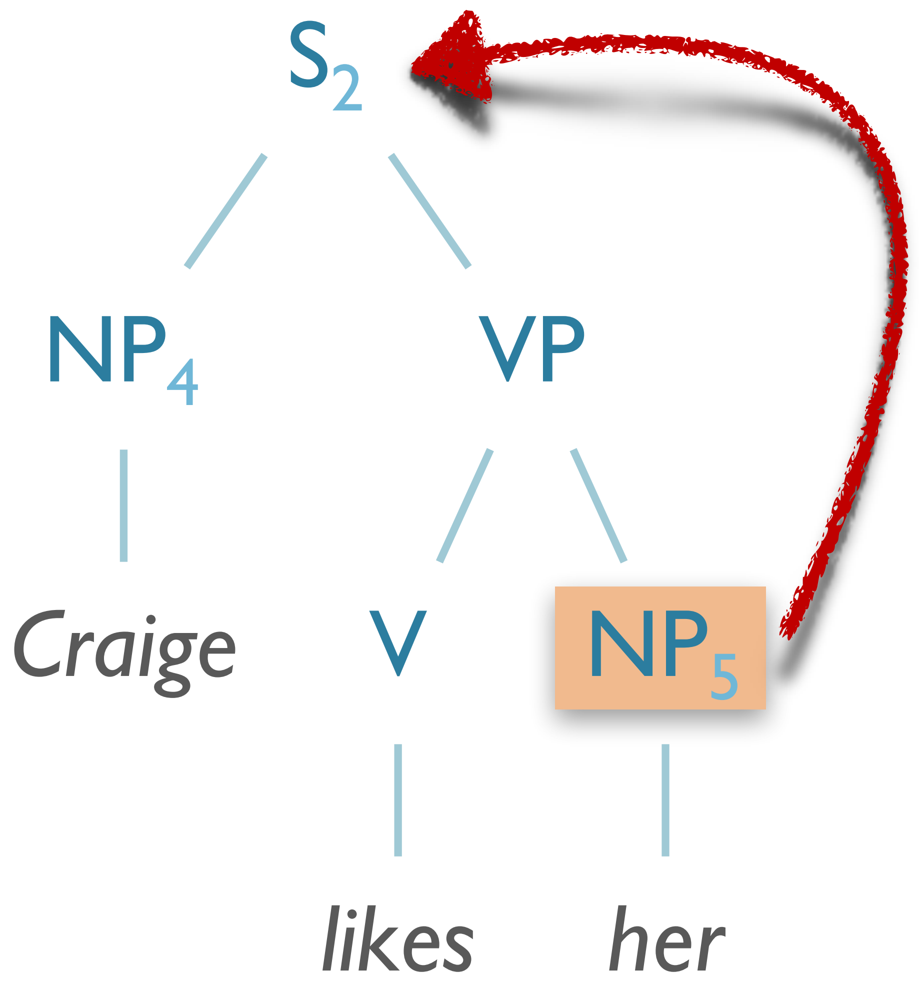


Hobbs Example

Lyn's mom is a gardener.

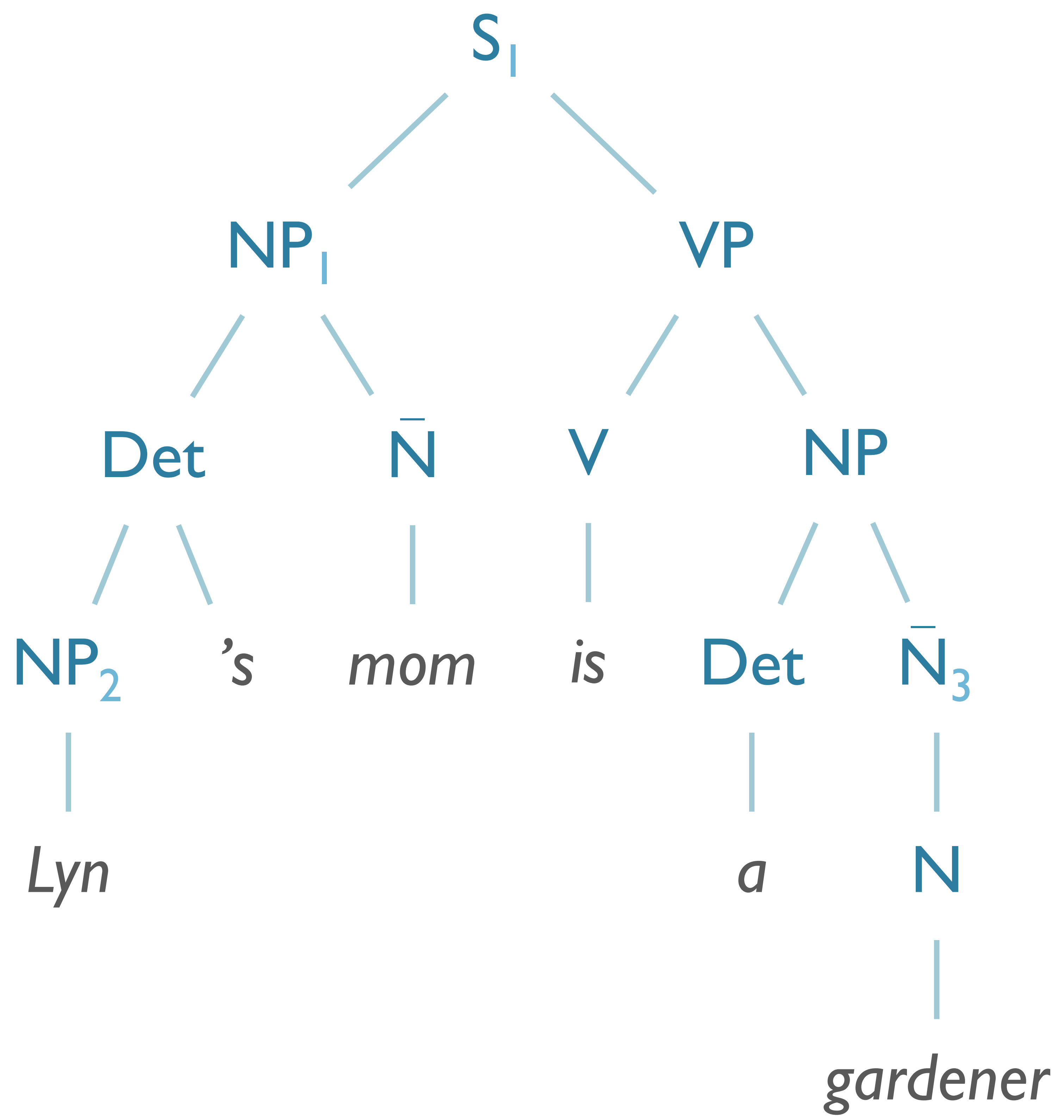


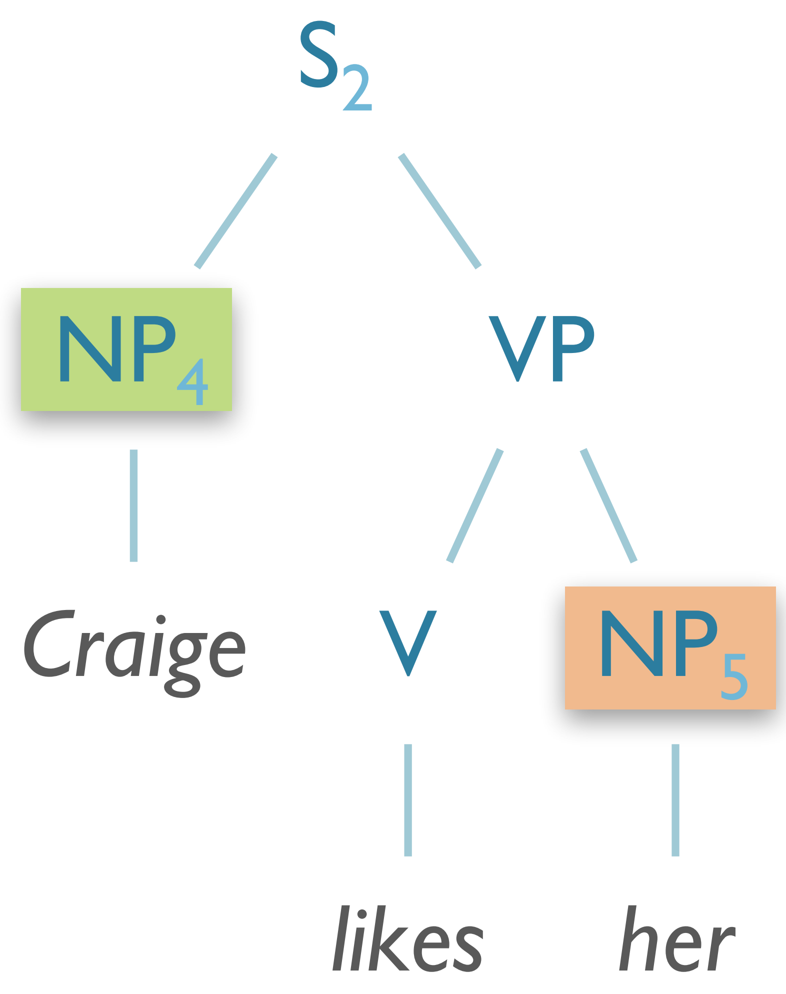
Craige likes **her**.



Hobbs Example

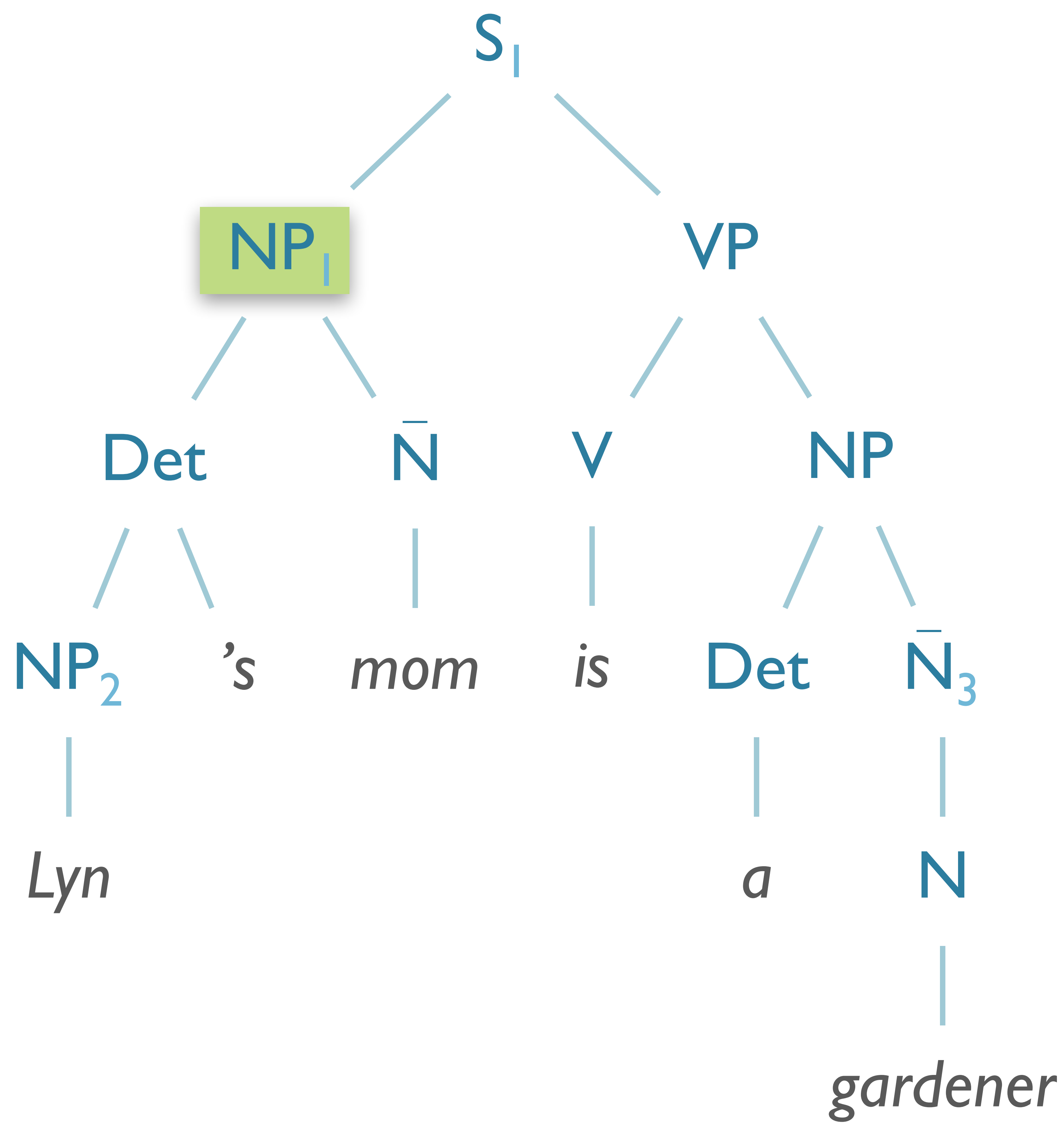
Lyn's mom is a gardener. *Craige likes **her**.*



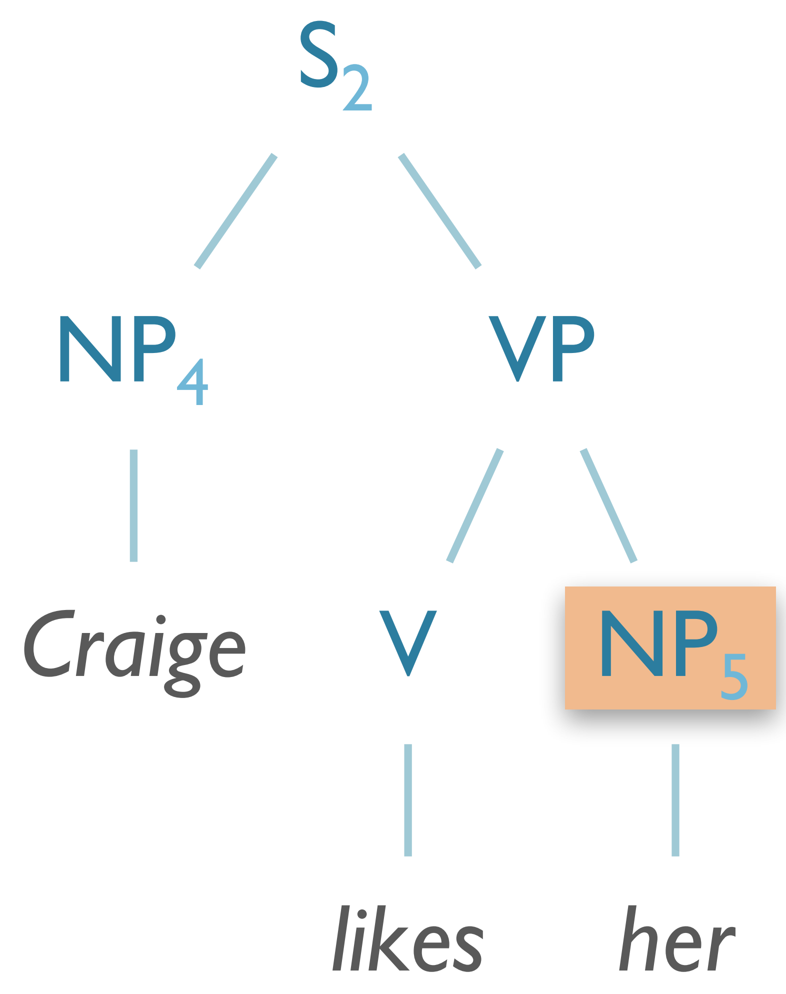


Hobbs Example

Lyn's mom is a gardener.

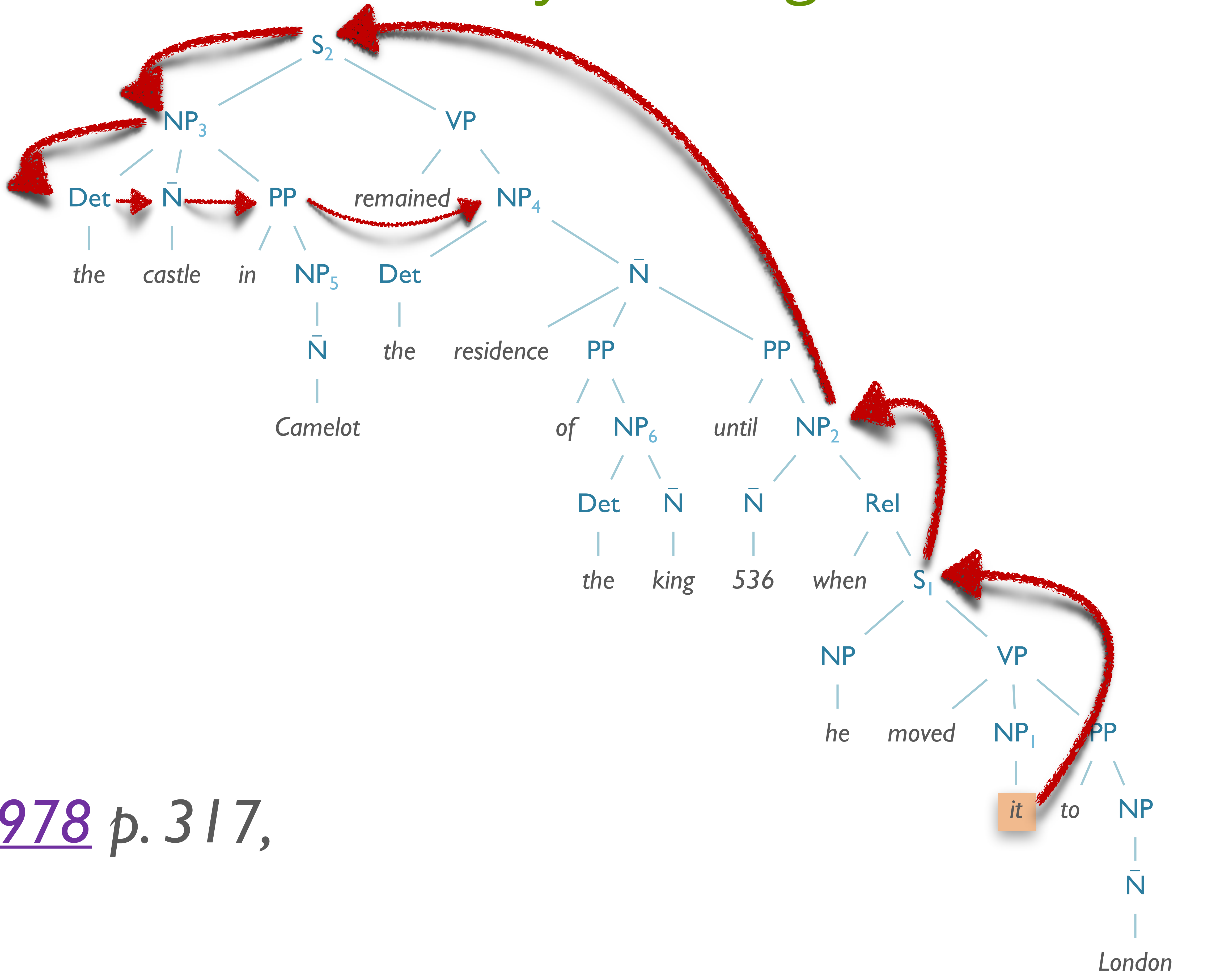


*Craige likes **her**.*



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

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

0

the trophy

0

the brown suitcase

0

Title logo

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

0

Joan	0
Susan	0

Title logo

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

0

the trophy

0

the brown suitcase

0

Title logo

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

0

Joan

0

Susan

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.

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?

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.

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]?

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.

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]?
  - 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?
  - Answers: The witness/the lawyer.

Winograd Schema Challenge

- Still hard!
  - WSC: used in a lot of early LM evals
    - Hand-designed
    - Very small
    - Probably "saturated"
  - Winogrande

DOI:10.1145/3474381

WinoGrande: An Adversarial Winograd Schema Challenge at Scale

By Keisuke Sakaguchi, Ronan Le Bras, Chandra Bhagavatula, and Yejin Choi

Abstract

Commonsense reasoning remains a major challenge in AI, and yet, recent progresses on benchmarks may seem to suggest otherwise. In particular, the recent neural language models have reported above 90% accuracy on the Winograd Schema Challenge (WSC),[22] a commonsense benchmark originally designed to be unsolvable for statistical models that rely simply on word associations. This raises an important question—whether these models have truly acquired robust commonsense capabilities or they rely on spurious biases in the dataset that lead to an overestimation of the true capabilities of machine commonsense.

To investigate this question, we introduce WinoGrande, a large-scale dataset of 44k problems, inspired by the original WSC, but adjusted to improve both the scale and the hardness of the dataset. The key steps of the dataset construction consist of (1) large-scale crowdsourcing, followed by (2) systematic bias reduction using a novel AFLITE algorithm that generalizes human-detectable *word associations* to machine-detectable *embedding associations*. Our experiments demonstrate that state-of-the-art models achieve considerably lower accuracy (59.4%–79.1%) on WINOGRANDE compared to humans (94%), confirming that the high performance on the original WSC was inflated by spurious biases in the dataset.

WSC dataset where the models now achieve around 90% accuracy. This raises a curious question:

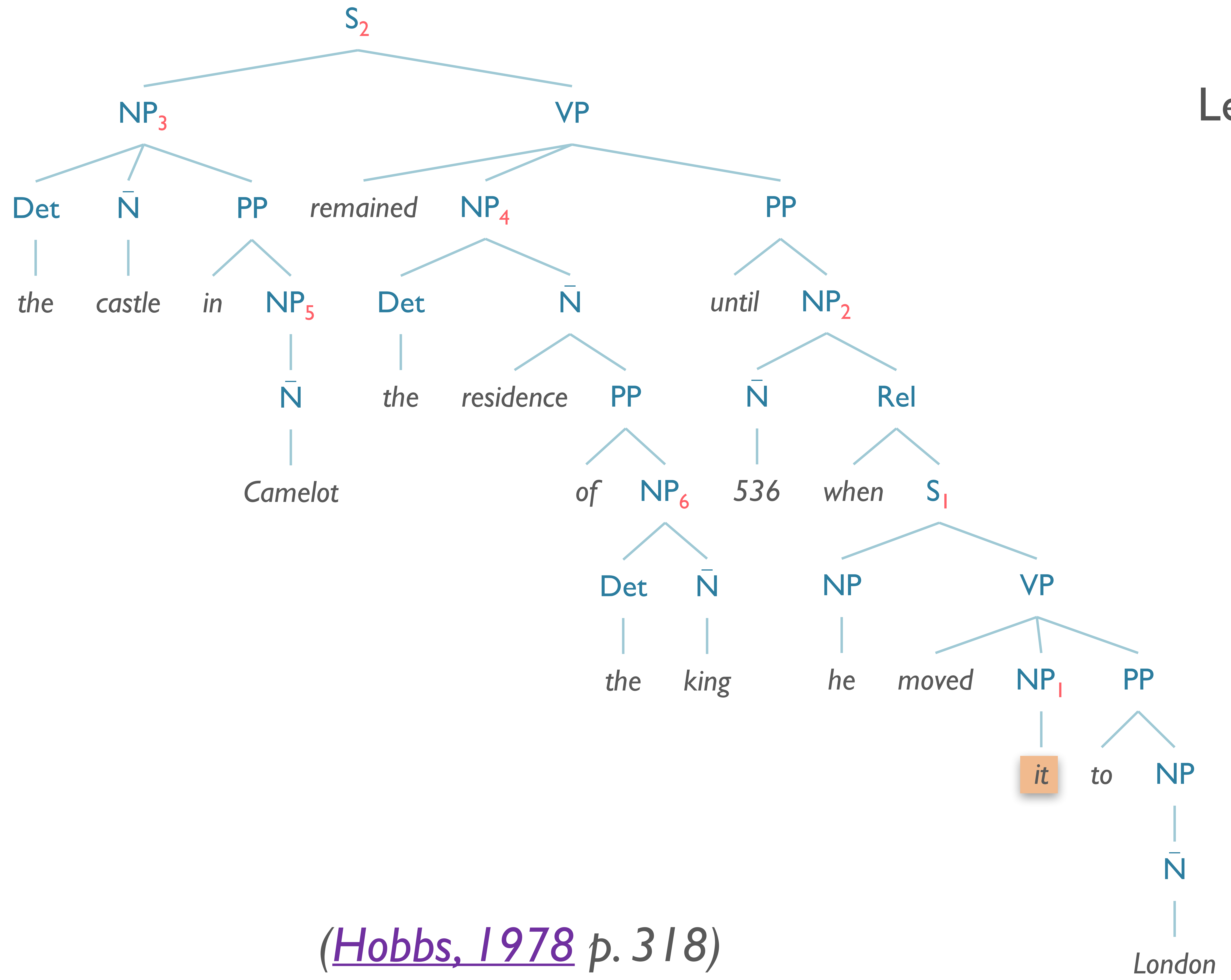
> *Have neural language models successfully acquired commonsense or are we overestimating the true capabilities of machine commonsense?*

This question about the potential overestimation leads to another crucial question regarding potential unwanted biases that the large-scale neural language models might be exploiting, essentially solving the problems *right*, but for *wrong* reasons. Indeed, although WSC questions are carefully crafted by experts, recent studies have shown that they are nevertheless prone to incidental biases. Trichelair et al.[36] have reported *word-association* (13.5% of the cases, see Table 1 for examples) as well as other types of *dataset-specific* biases. Although such biases and annotation artifacts are not apparent for individual instances, they get introduced in the dataset as problems as authors subconsciously repeat similar problem-crafting strategies.

To investigate this question about the true estimation of the machine commonsense capabilities, we introduce **WinoGrande**, a new dataset with 44k problems that are inspired by the original design of WSC, but modified to improve both the

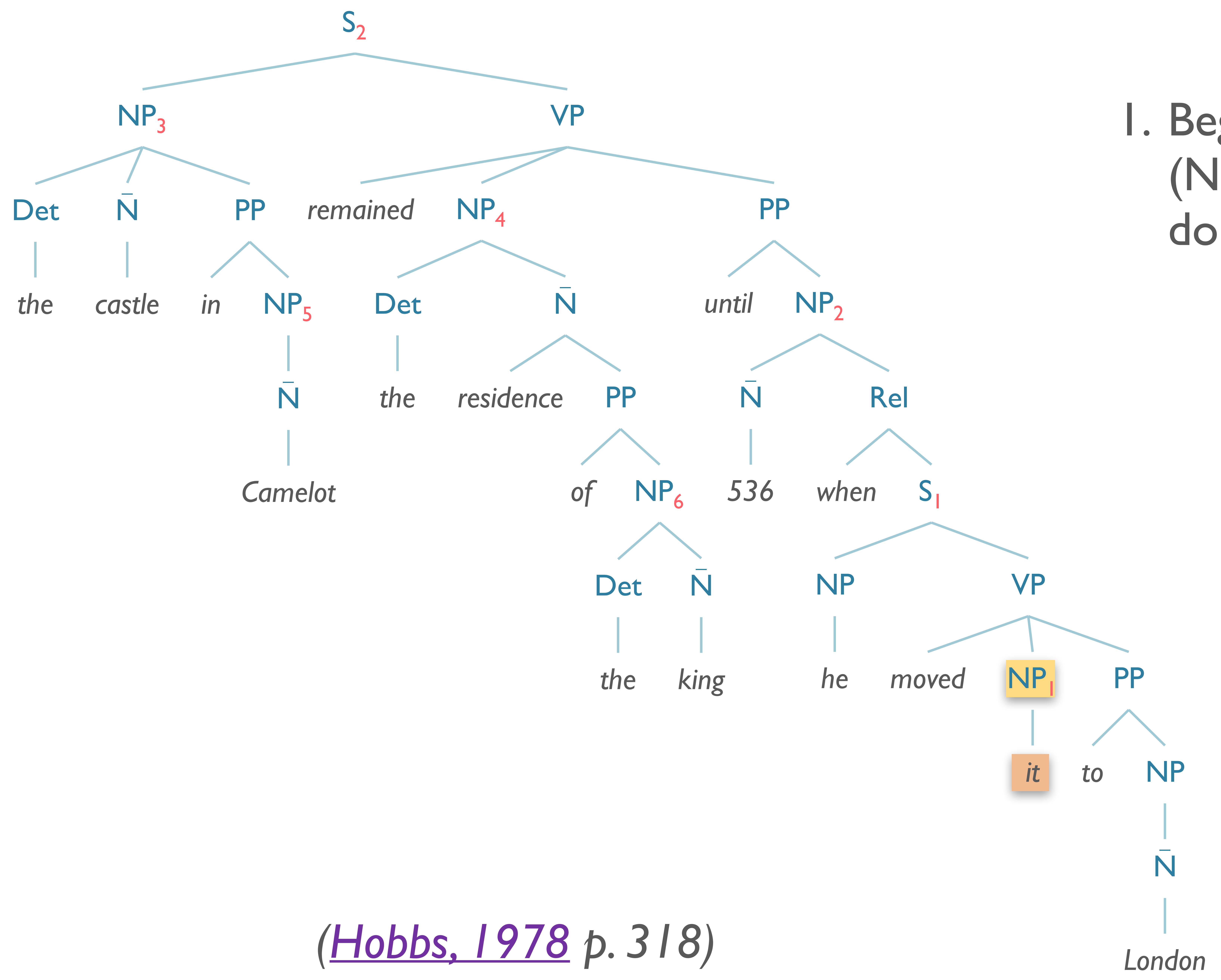
Hobbs Algorithm Walkthrough

(h/t Ryan Georgi)



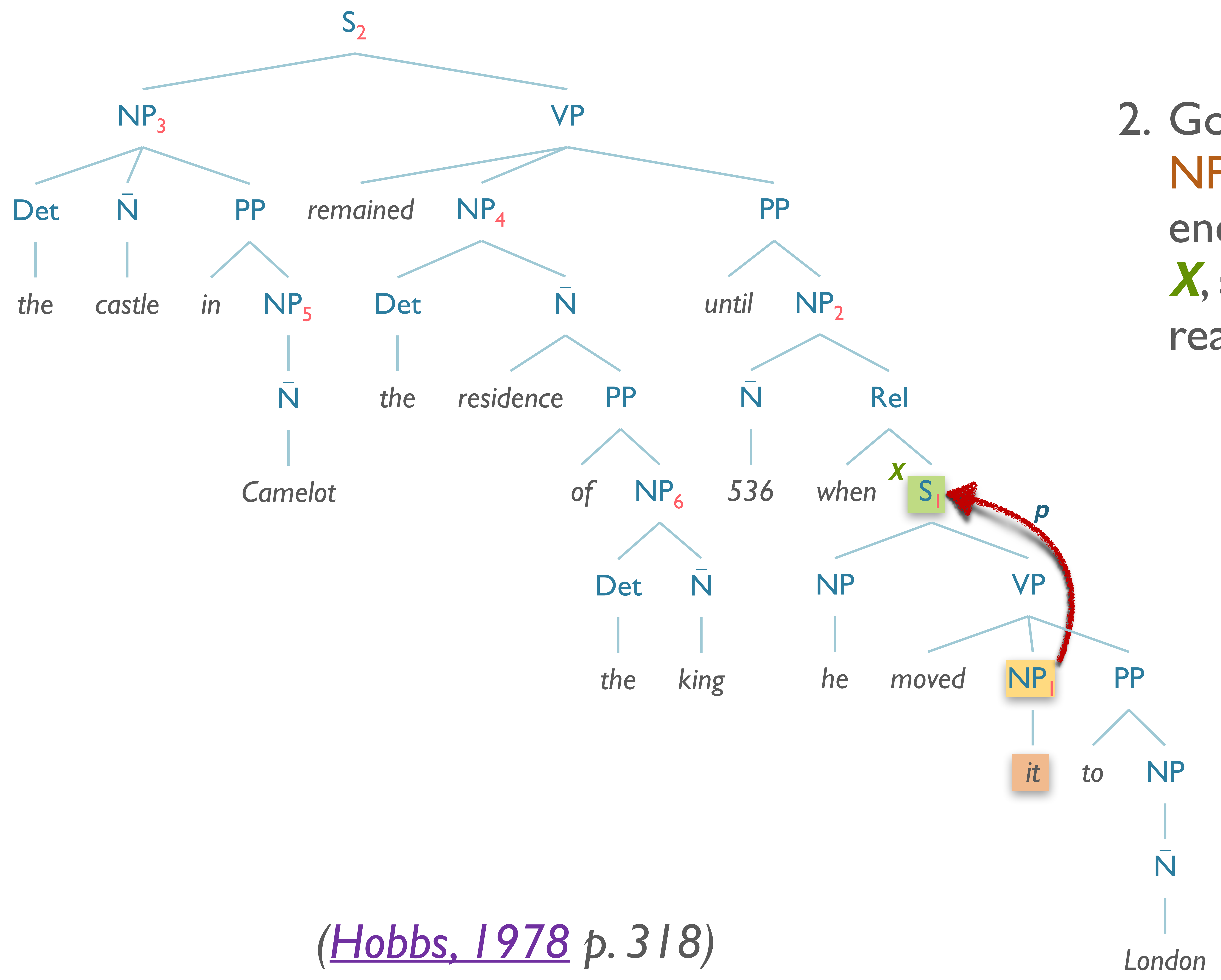
Let's figure out what the antecedent for "*it*" is

(*Hobbs, 1978* *p. 318*)



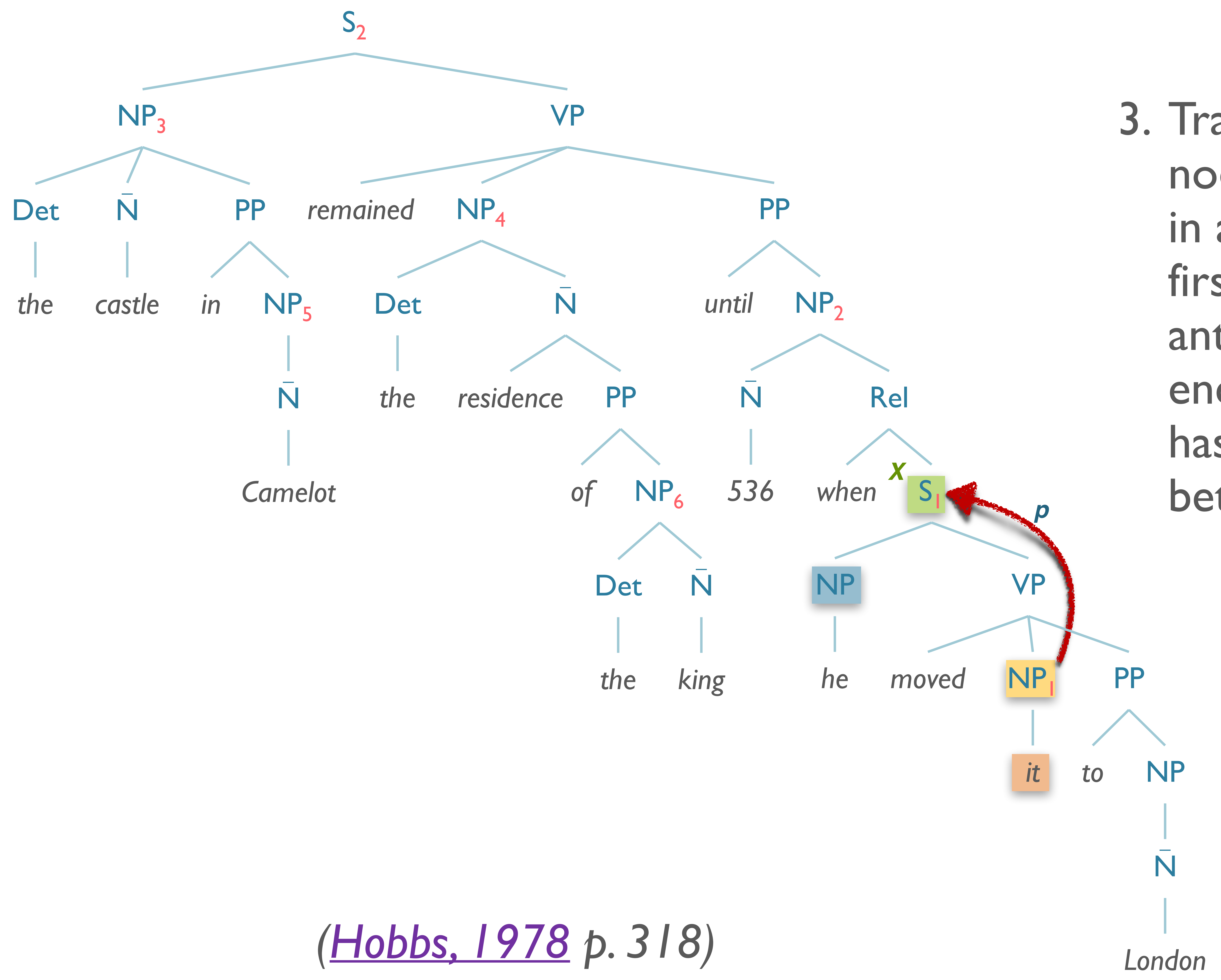
1. Begin at the noun phrase (NP) node immediately dominating the pronoun

(Hobbs, 1978 p. 318)



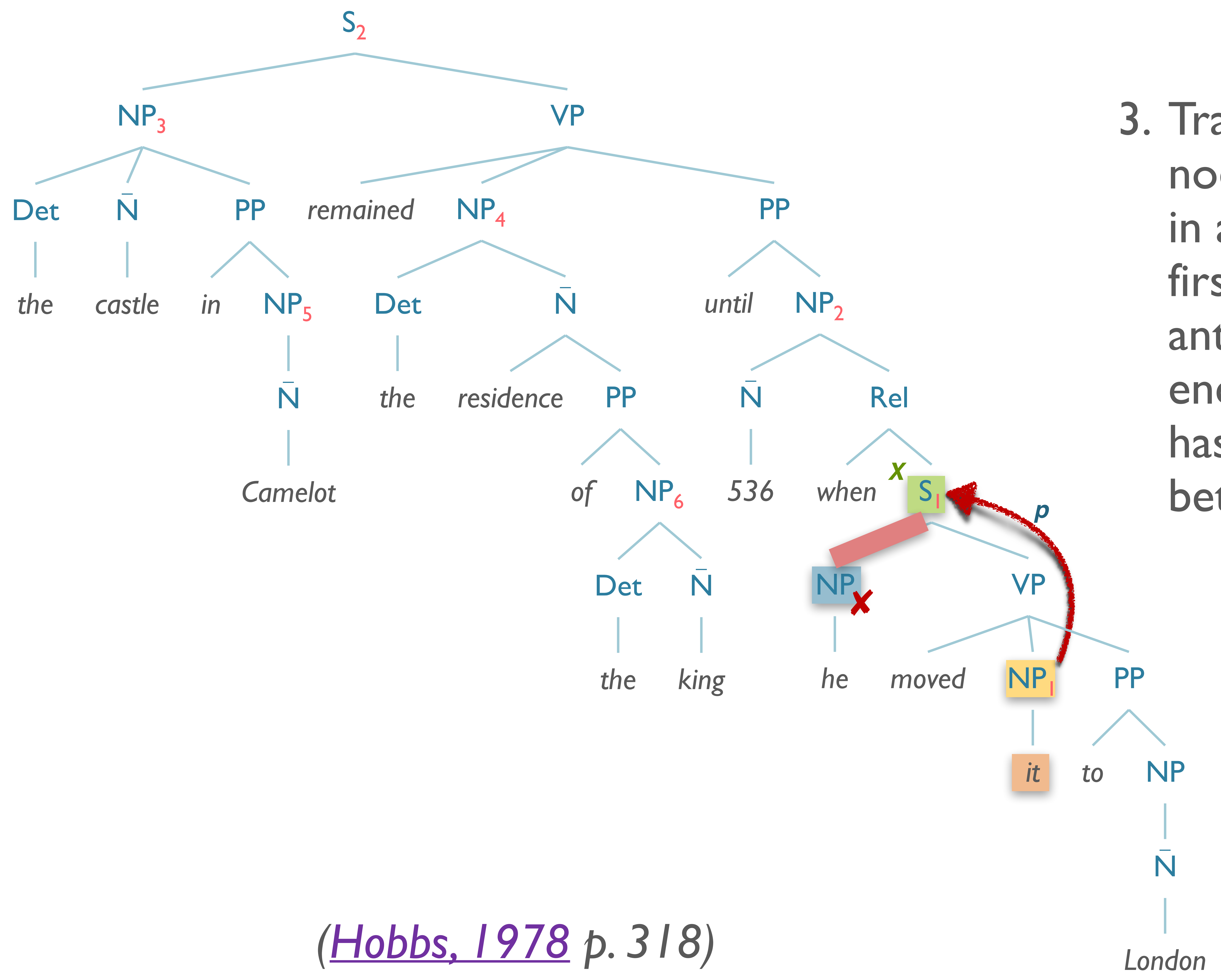
2. Go up the tree to the first NP or sentence (S) node encountered. Call this node ***X***, and call the path used to reach it ***p***.

(*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***.

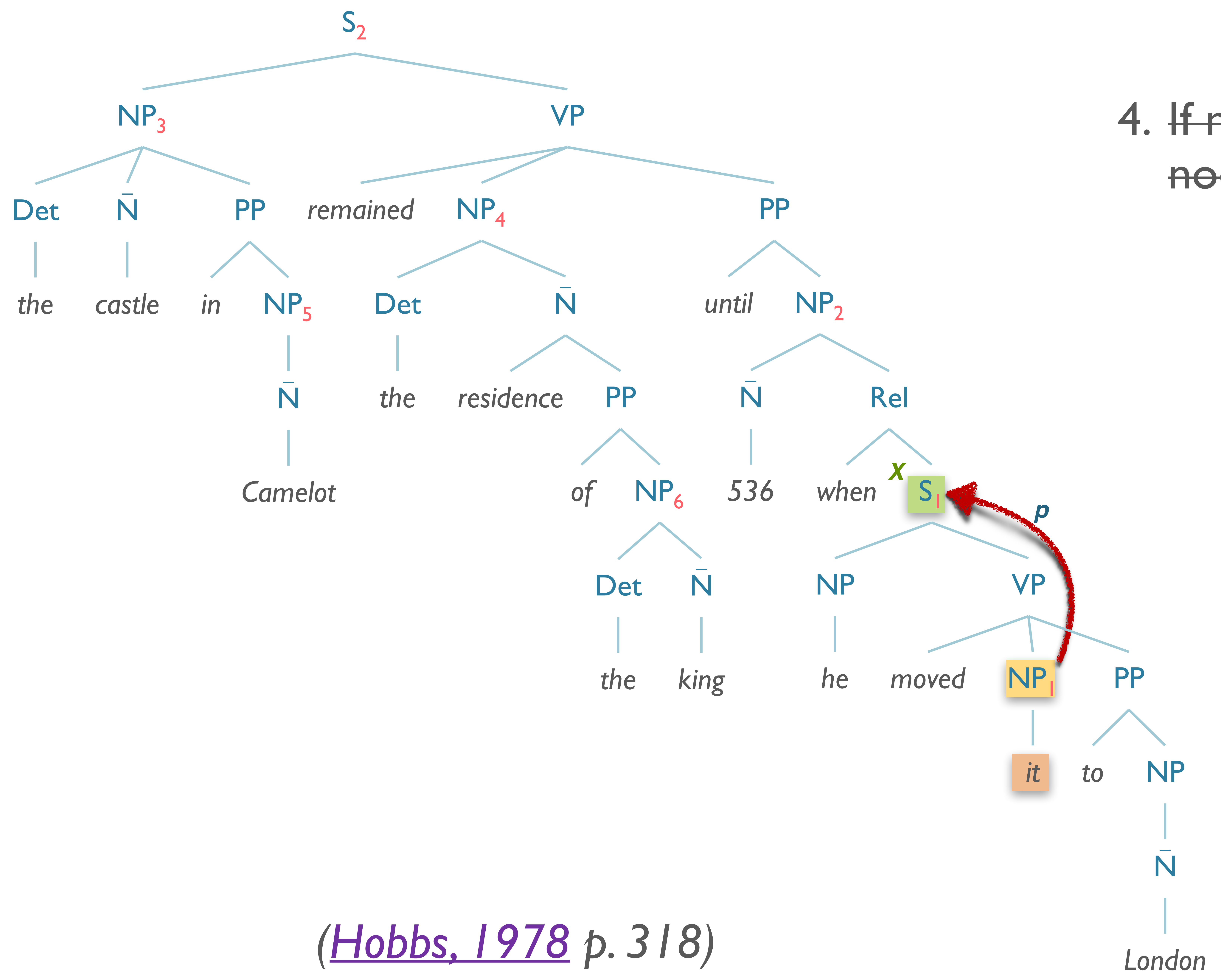
([Hobbs, 1978](#) *p. 318*)



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***.

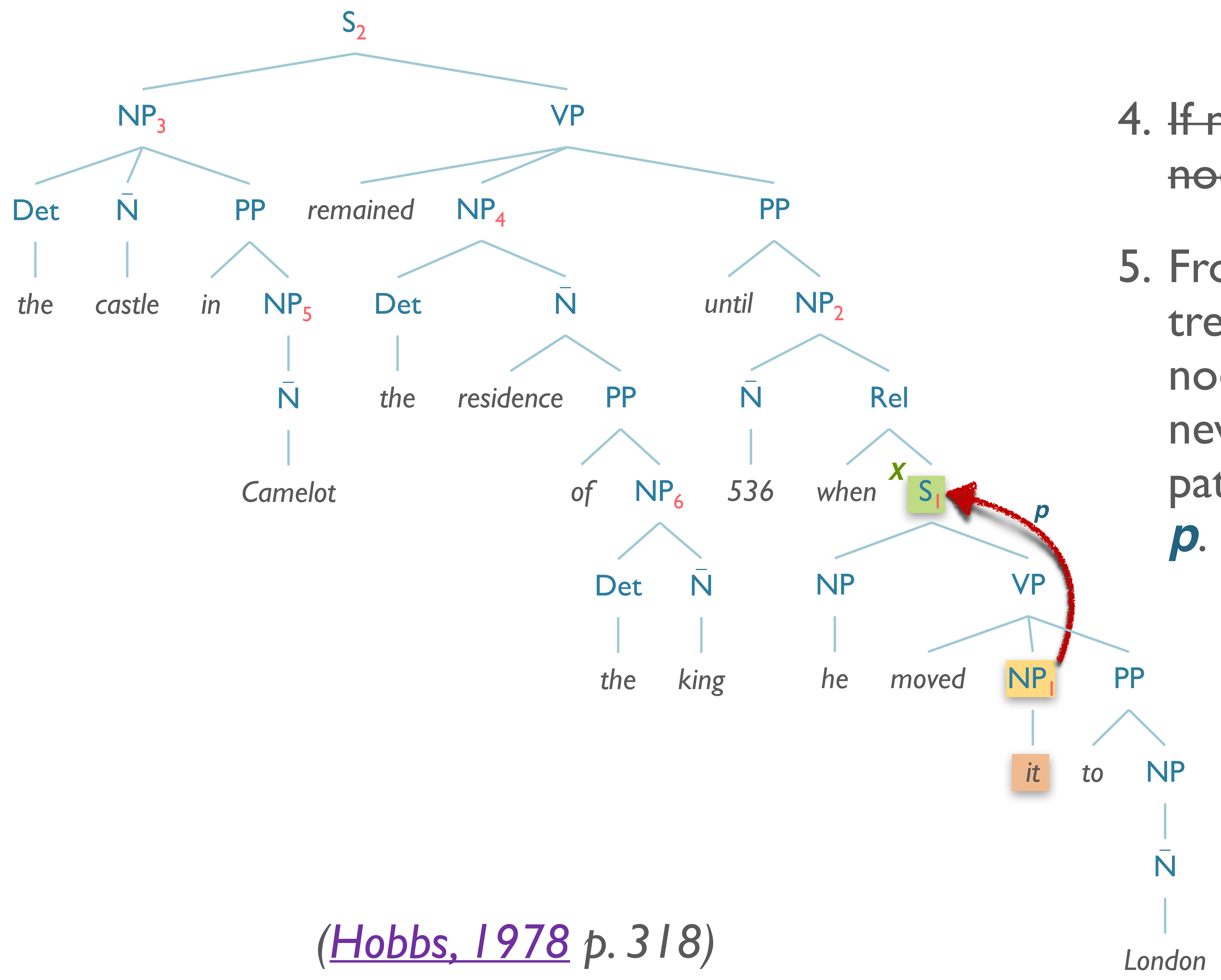
*No NP or S between "he" NP and **X***

([Hobbs, 1978](#) *p. 318*)



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

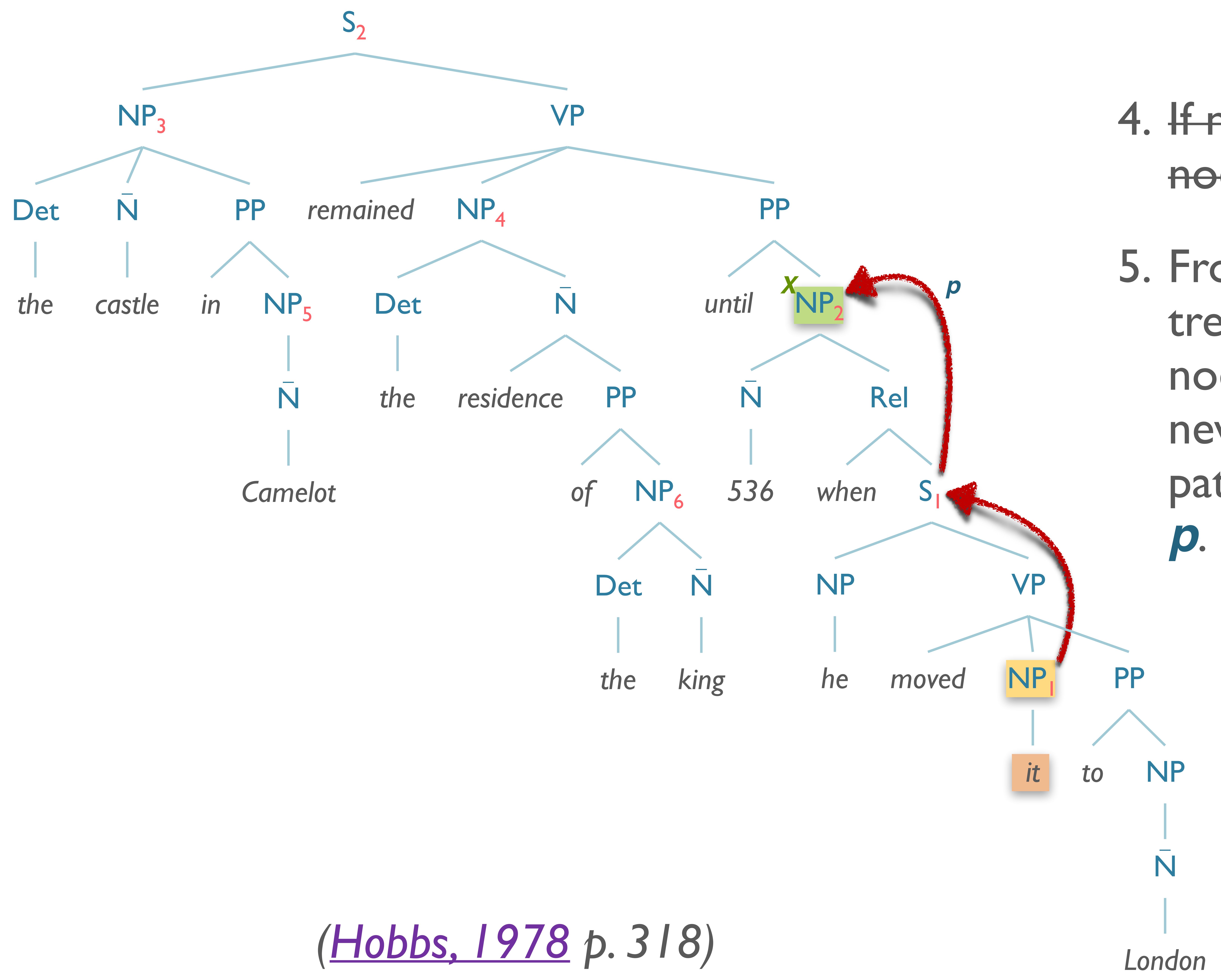
(Hobbs, 1978 p. 318)



(Hobbs, 1978 p. 318)

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

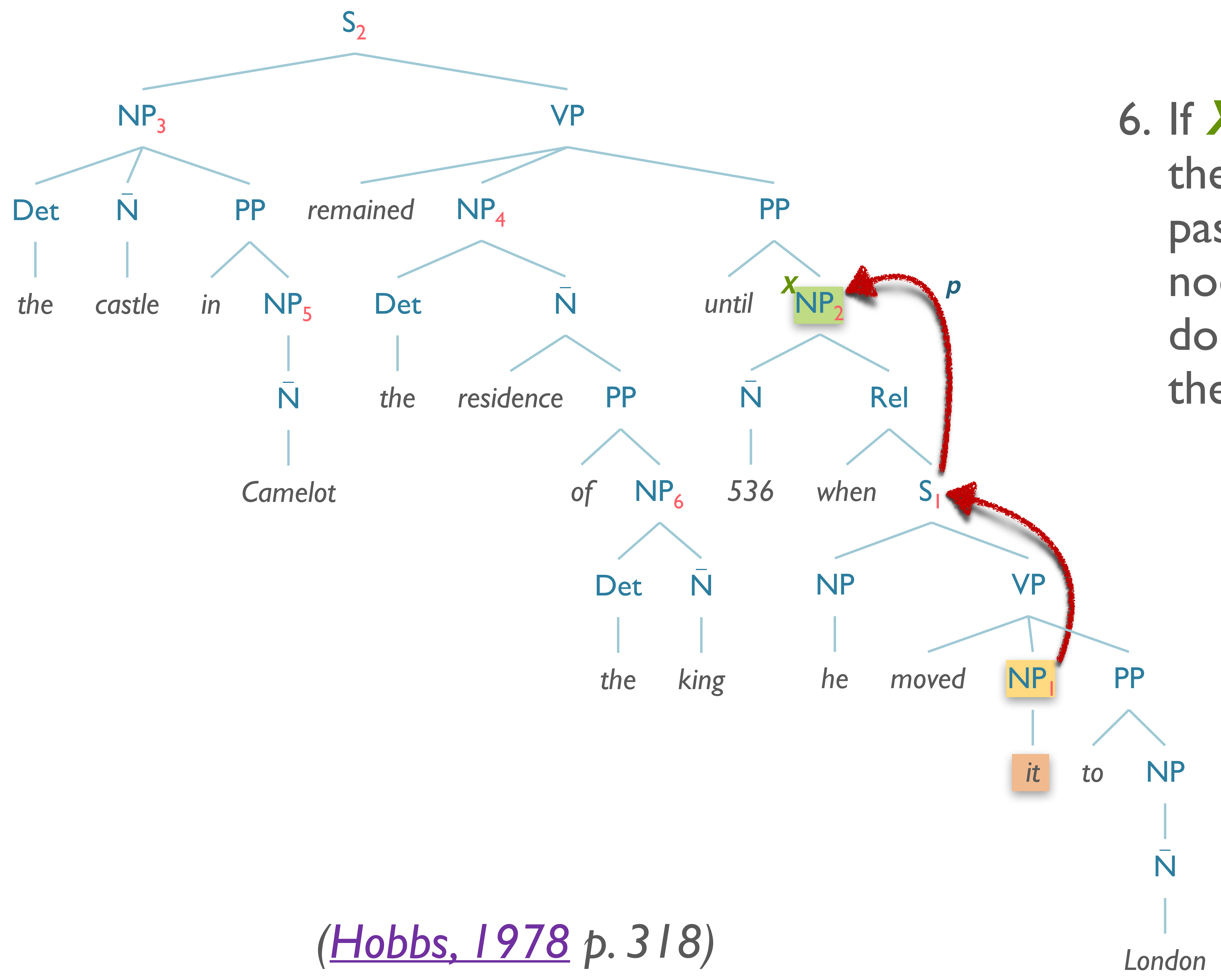
5. From node ***X***, go up the tree to the first NP or S node encountered. Call this new node ***X***, and call the path traversed to reach it ***p***.



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

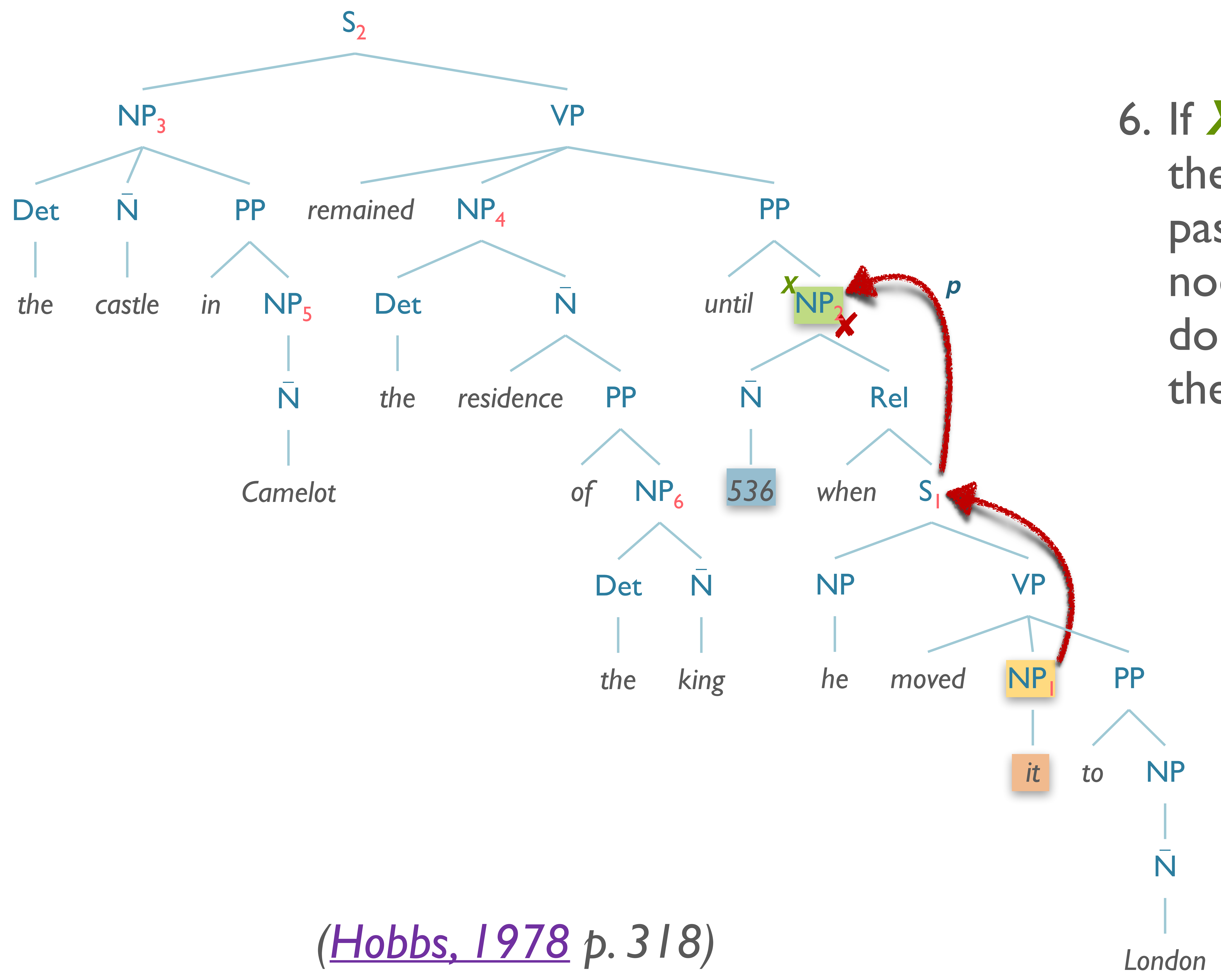
5. From node ***X***, go up the tree to the first NP or S node encountered. Call this new node ***X***, and call the path traversed to reach it ***p***.

([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.

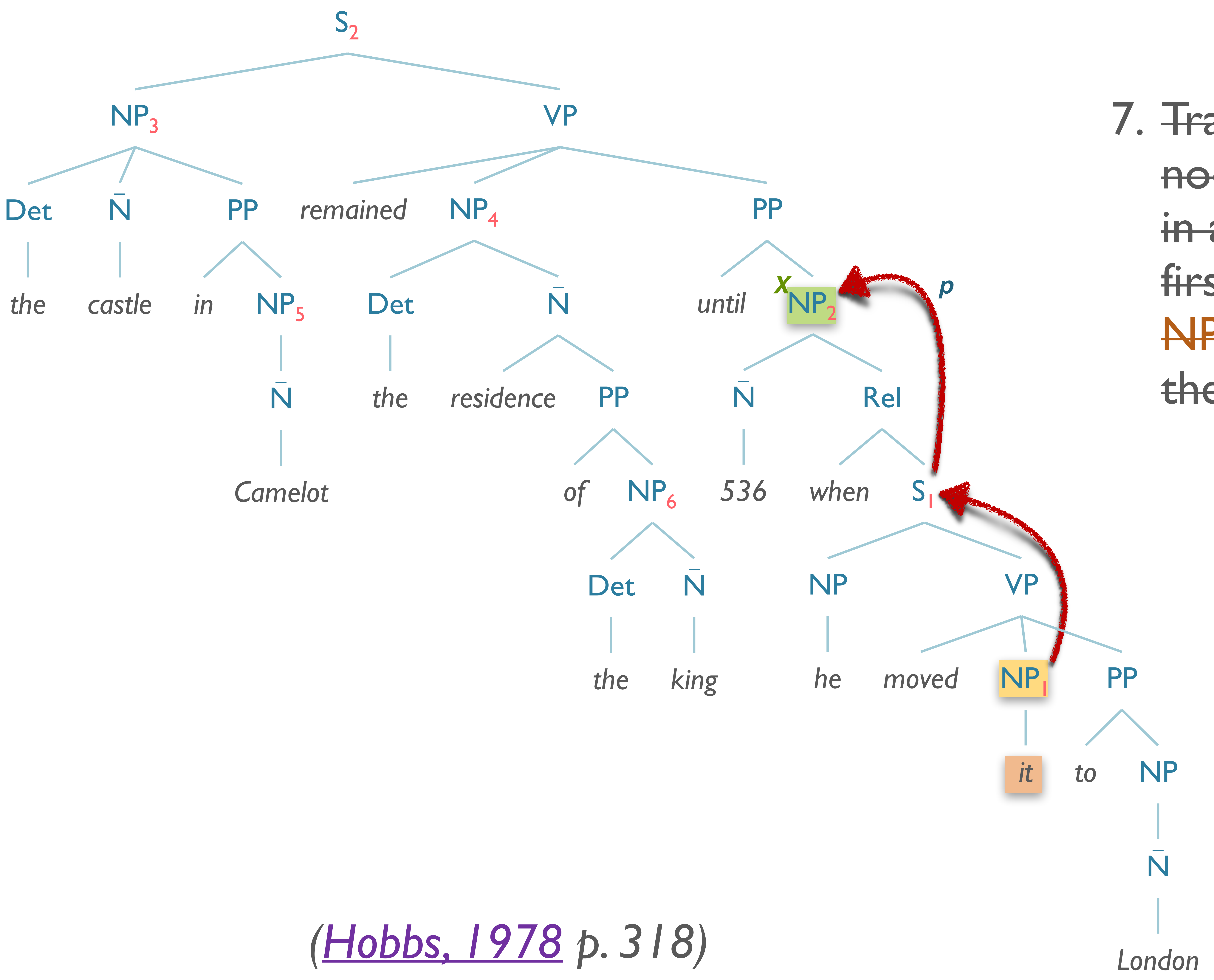
(*Hobbs, 1978 p. 318*)



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.

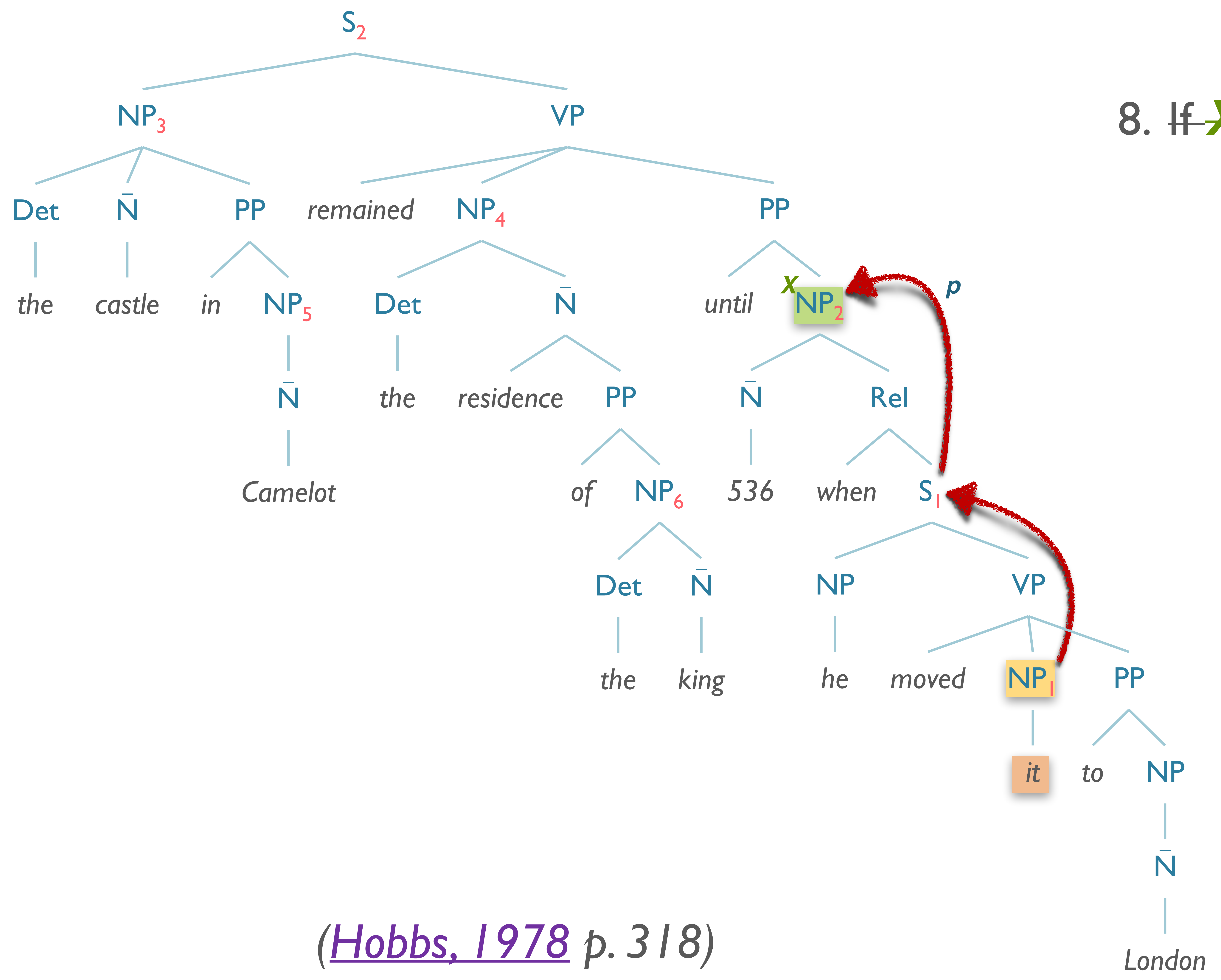
"536" can't be "moved"!

([Hobbs, 1978](#) p. 318)



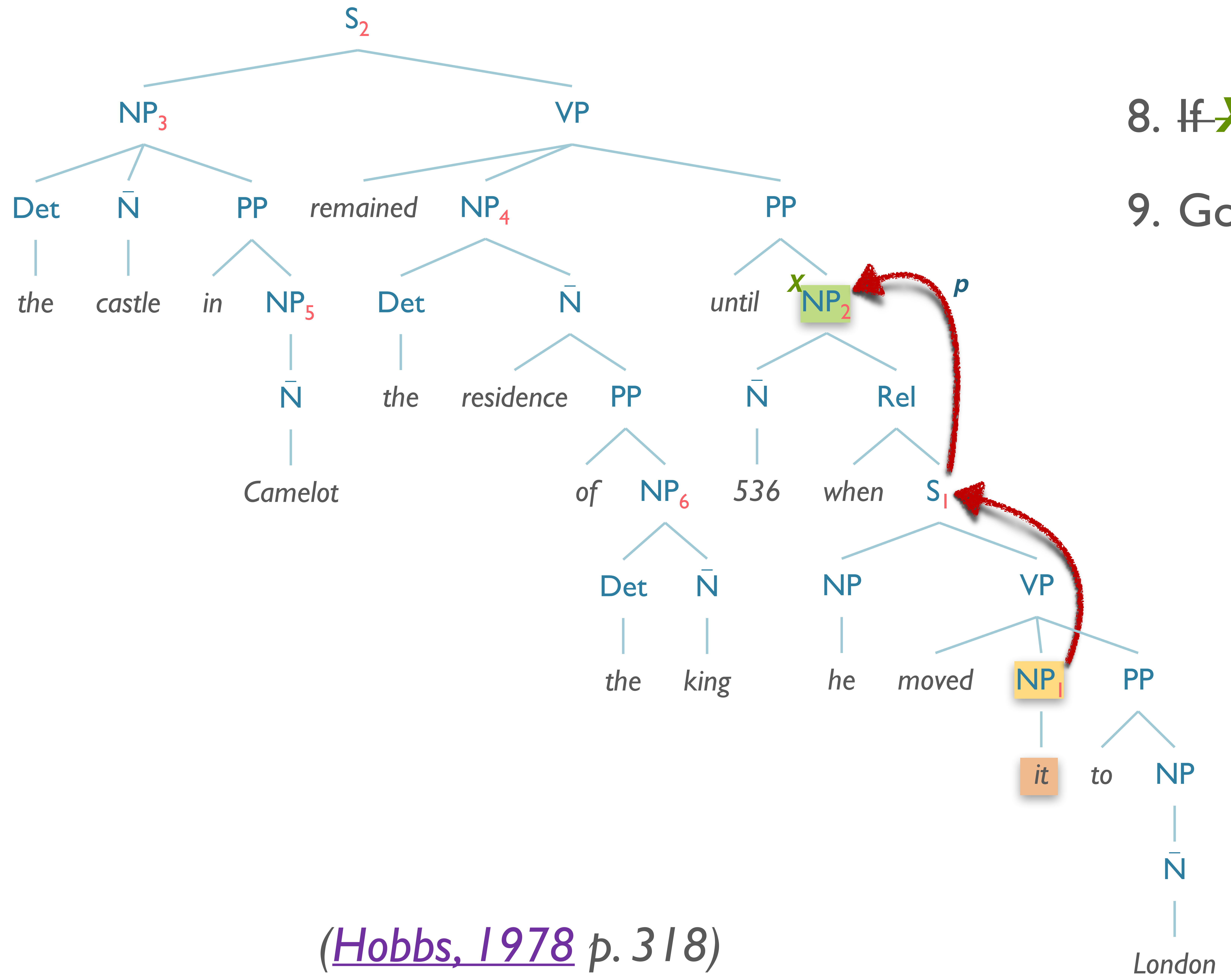
7. ~~Traverse all branches below node *X* to the left of path *p* in a left-to-right, breadth-first manner. Propose any NP node encountered as the antecedent.~~

(Hobbs, 1978 p. 318)



8. ~~If *X* is an S node…~~

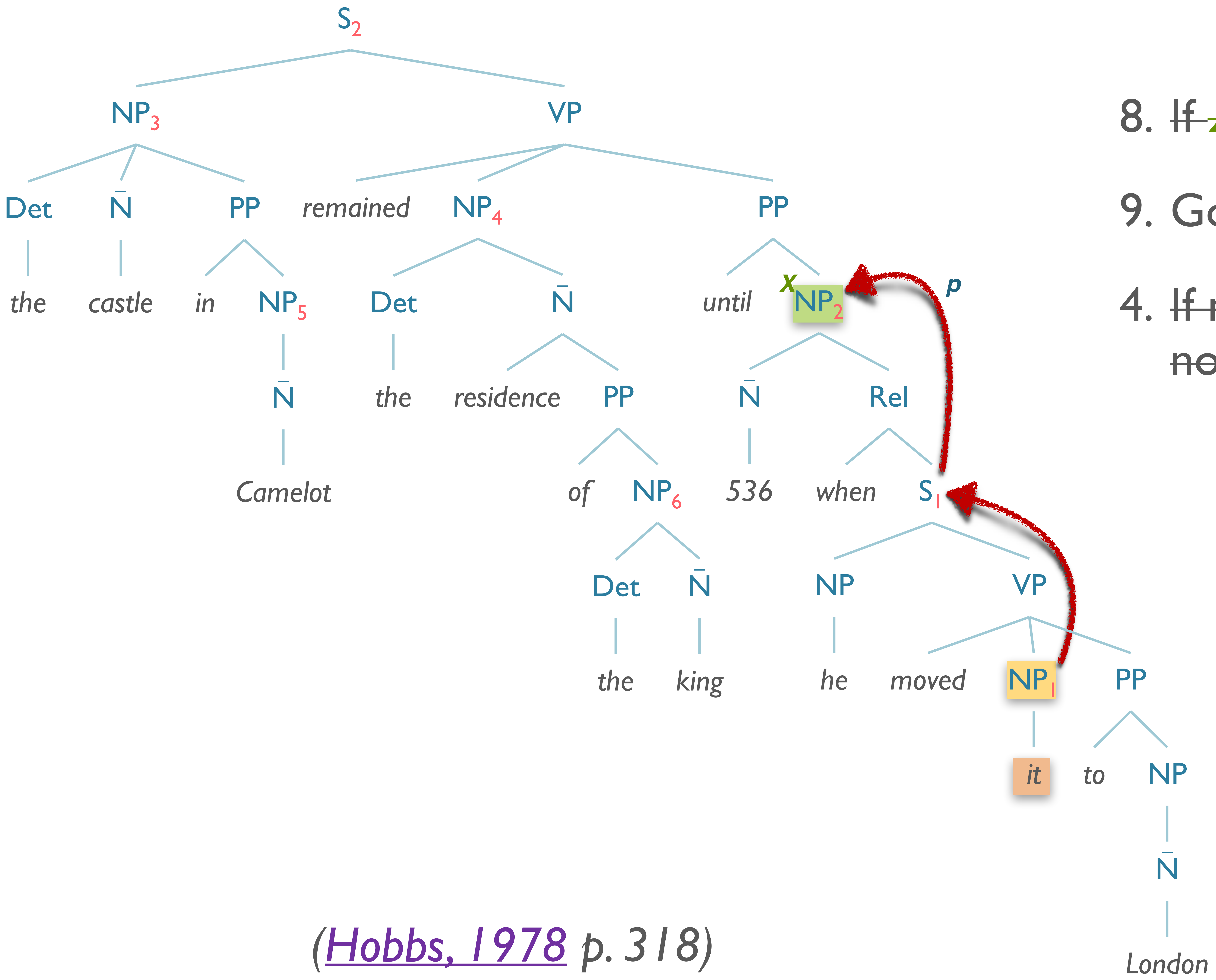
([Hobbs, 1978](#) *p. 318*)



8. ~~If X is an S node…~~

9. Go to step 4.

(Hobbs, 1978 p. 318)

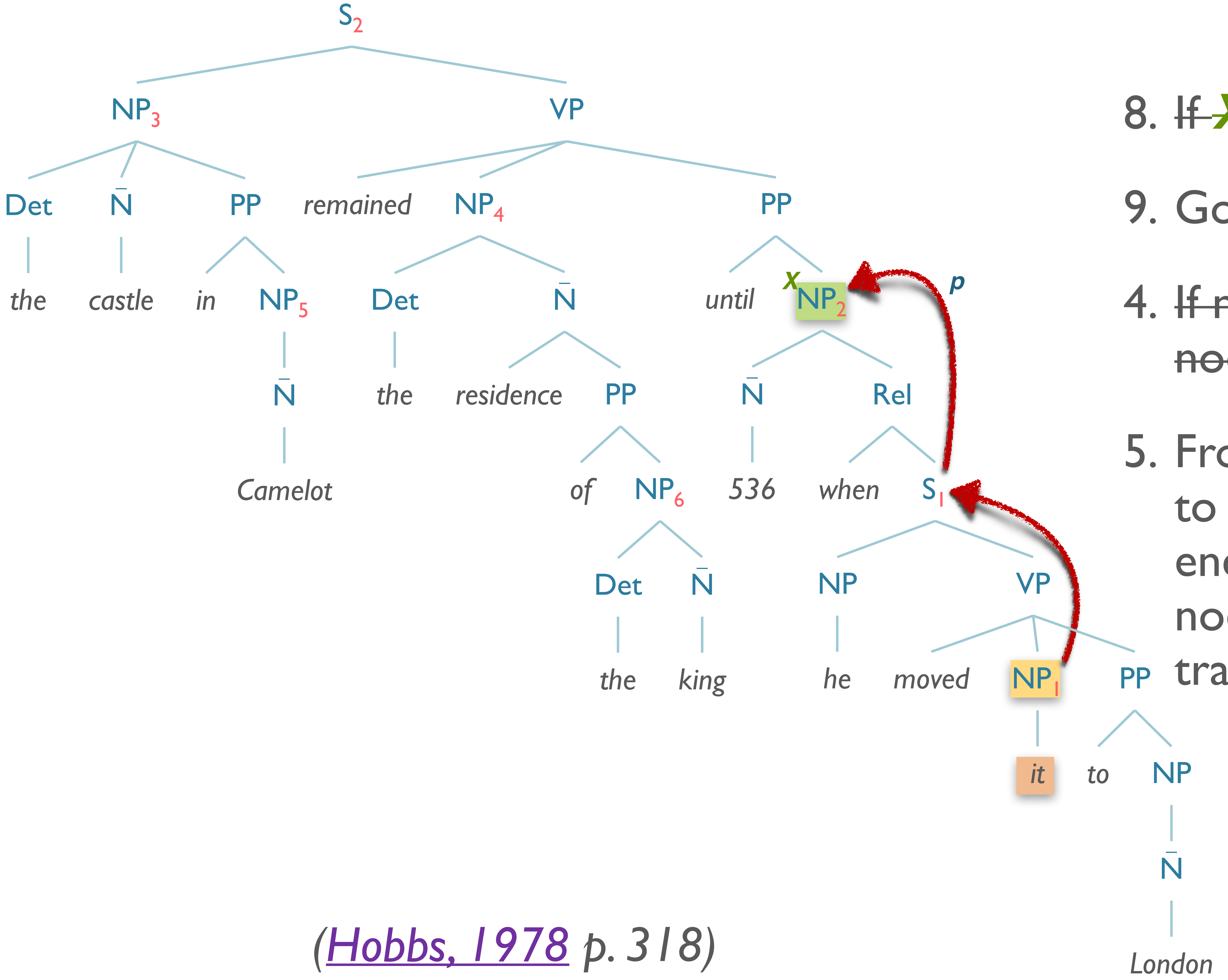


8. ~~If *X* is an S node…~~

9. Go to step 4.

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

(Hobbs, 1978 p. 318)



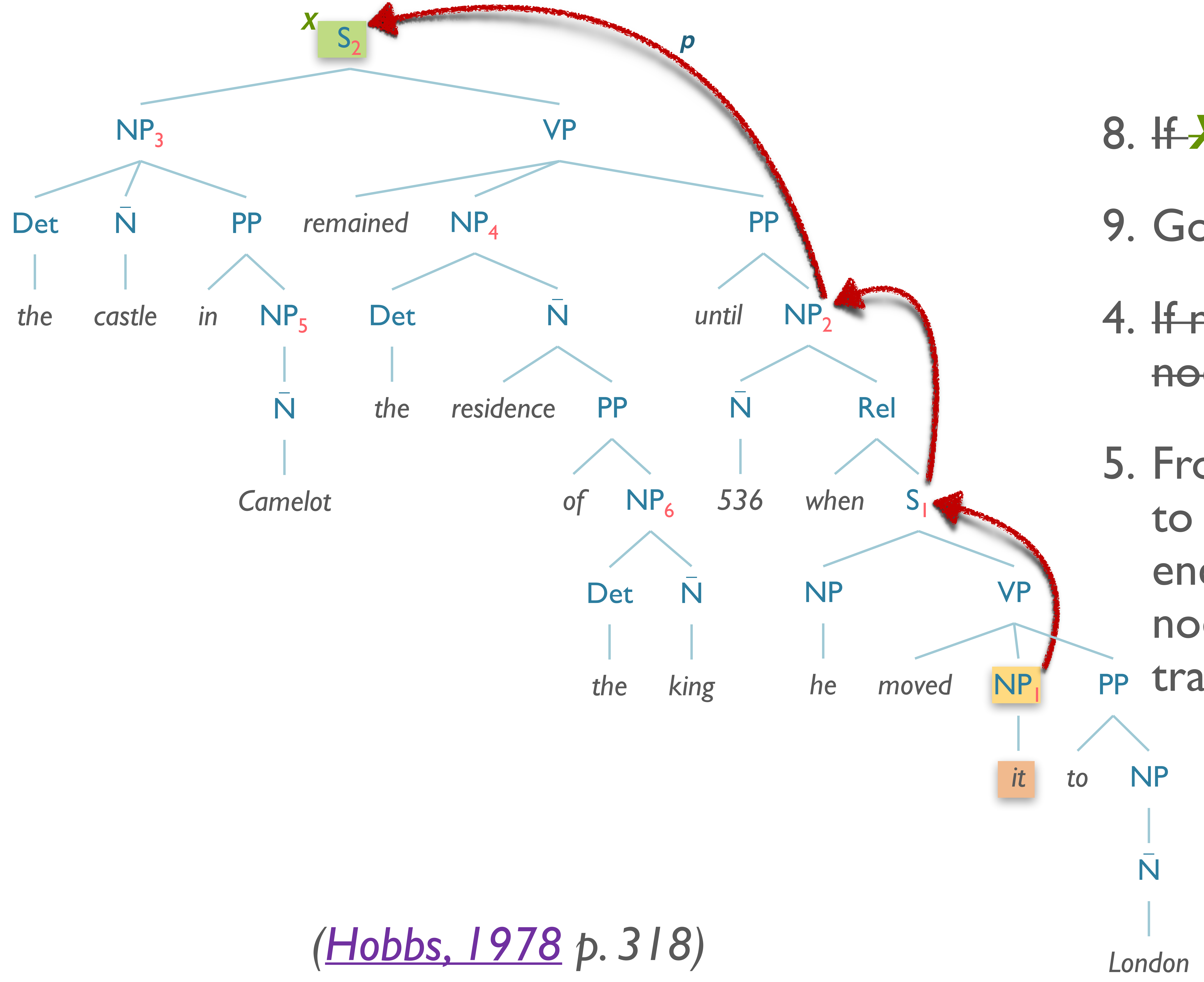
8. ~~If *X* is an S node…~~

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)



(Hobbs, 1978 p. 318)

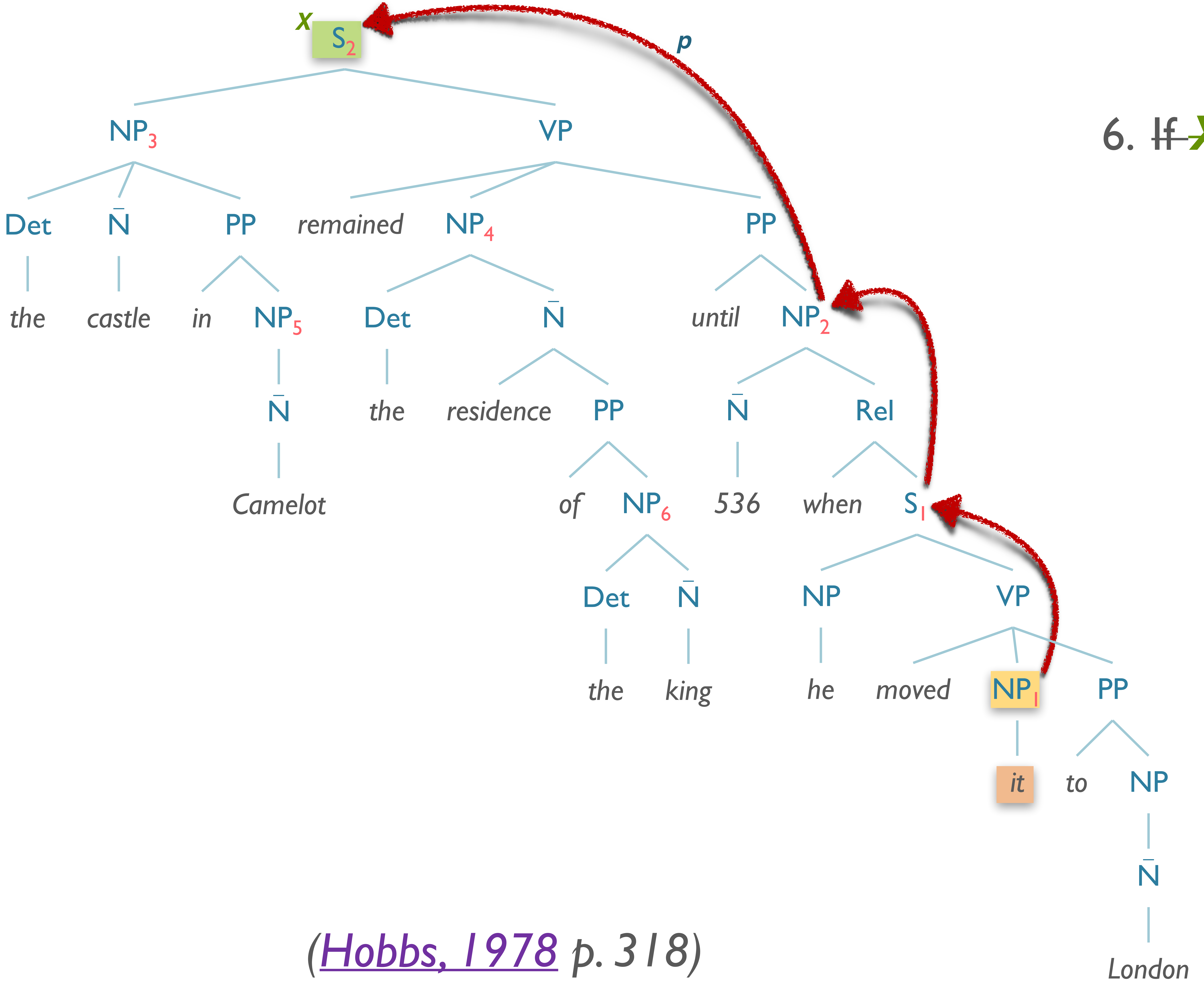
8. ~~If *X* is an S node…~~

9. Go to step 4.

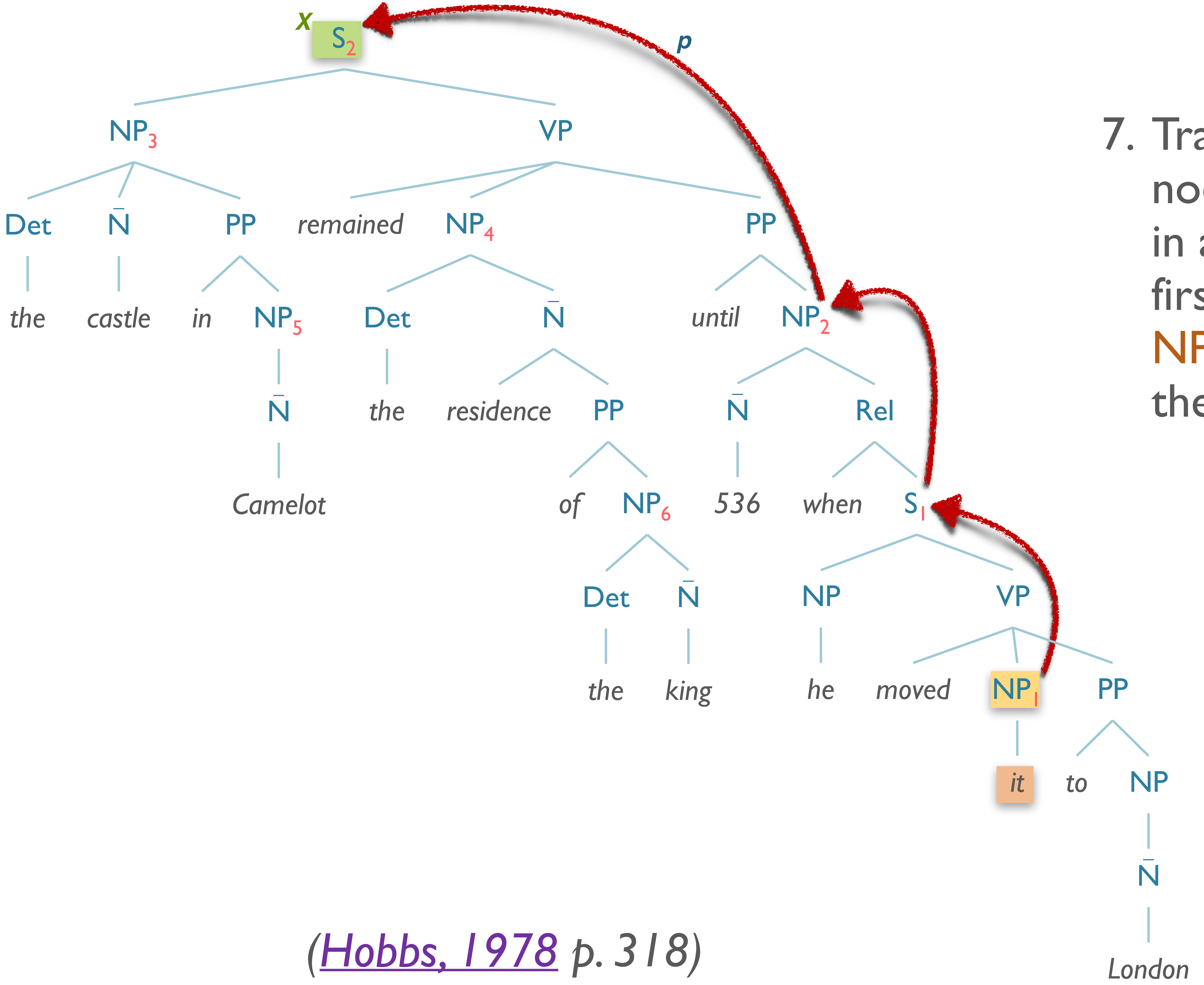
4. ~~If node *X* is the highest S node in the sentence…~~

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***.

6. ~~If X is an NP node…~~

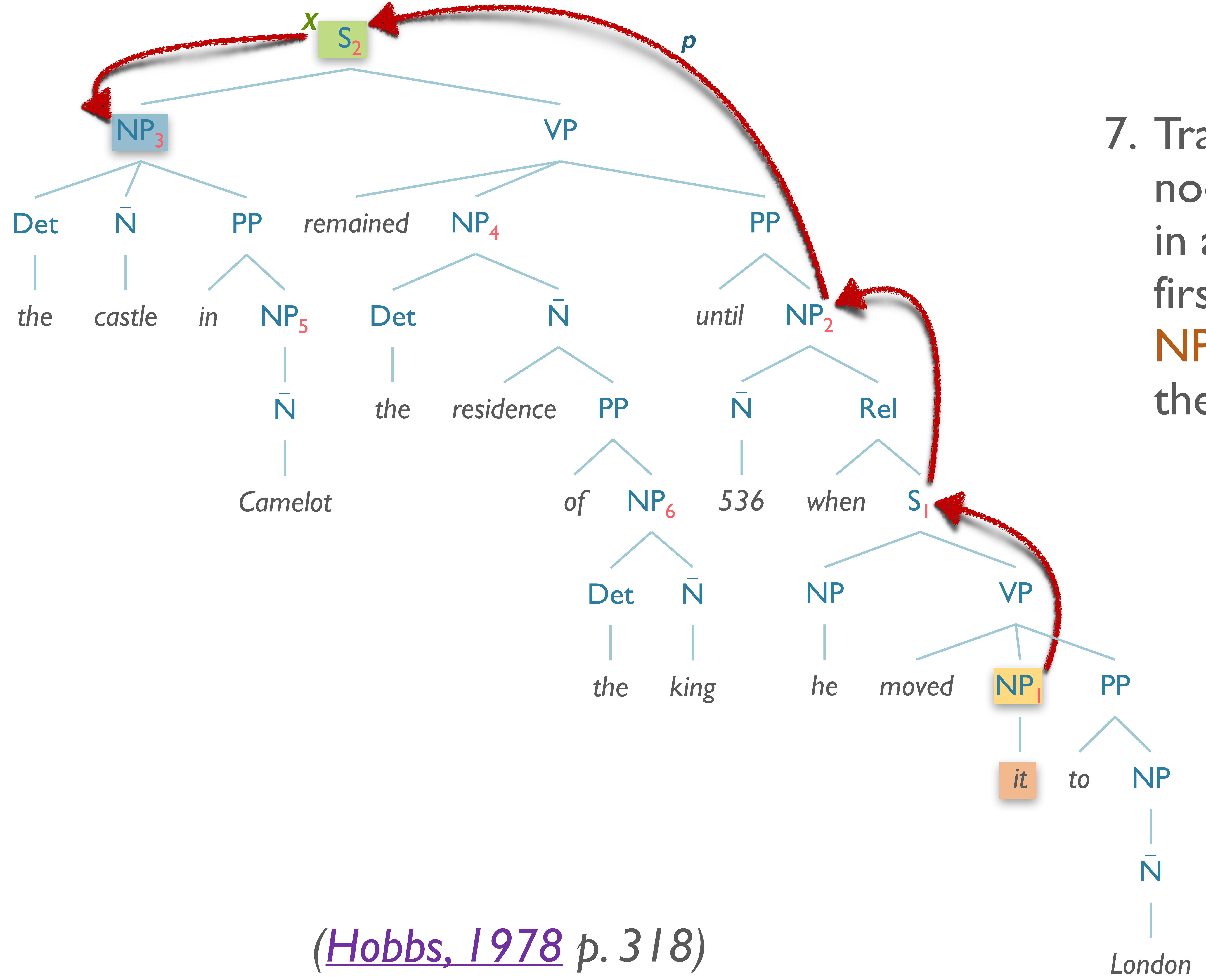


(Hobbs, 1978 p. 318)



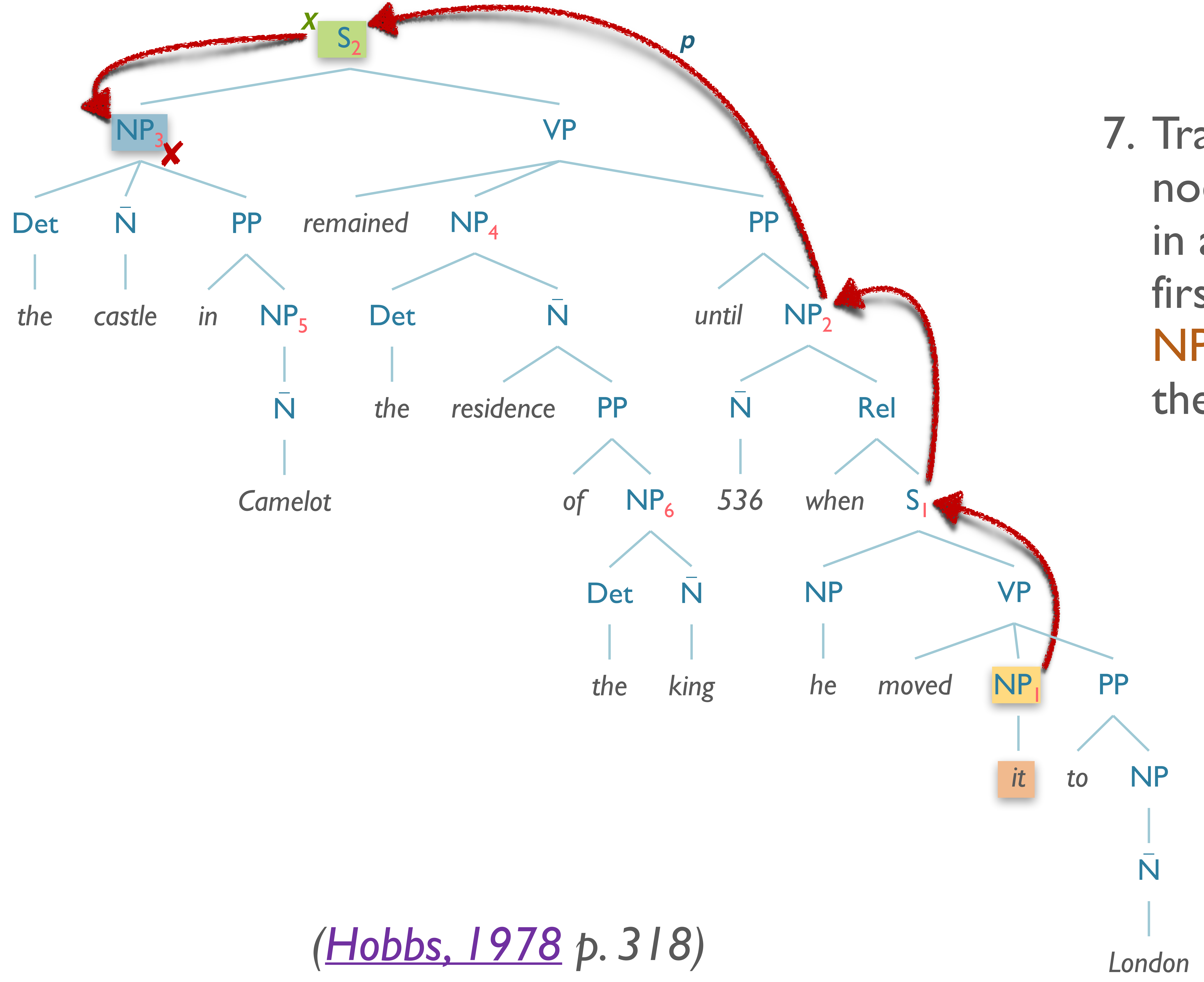
7. Traverse all branches below node ***X*** to the *left* of path ***p*** in a left-to-right, breadth-first manner. Propose any NP node encountered as the antecedent.

(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.

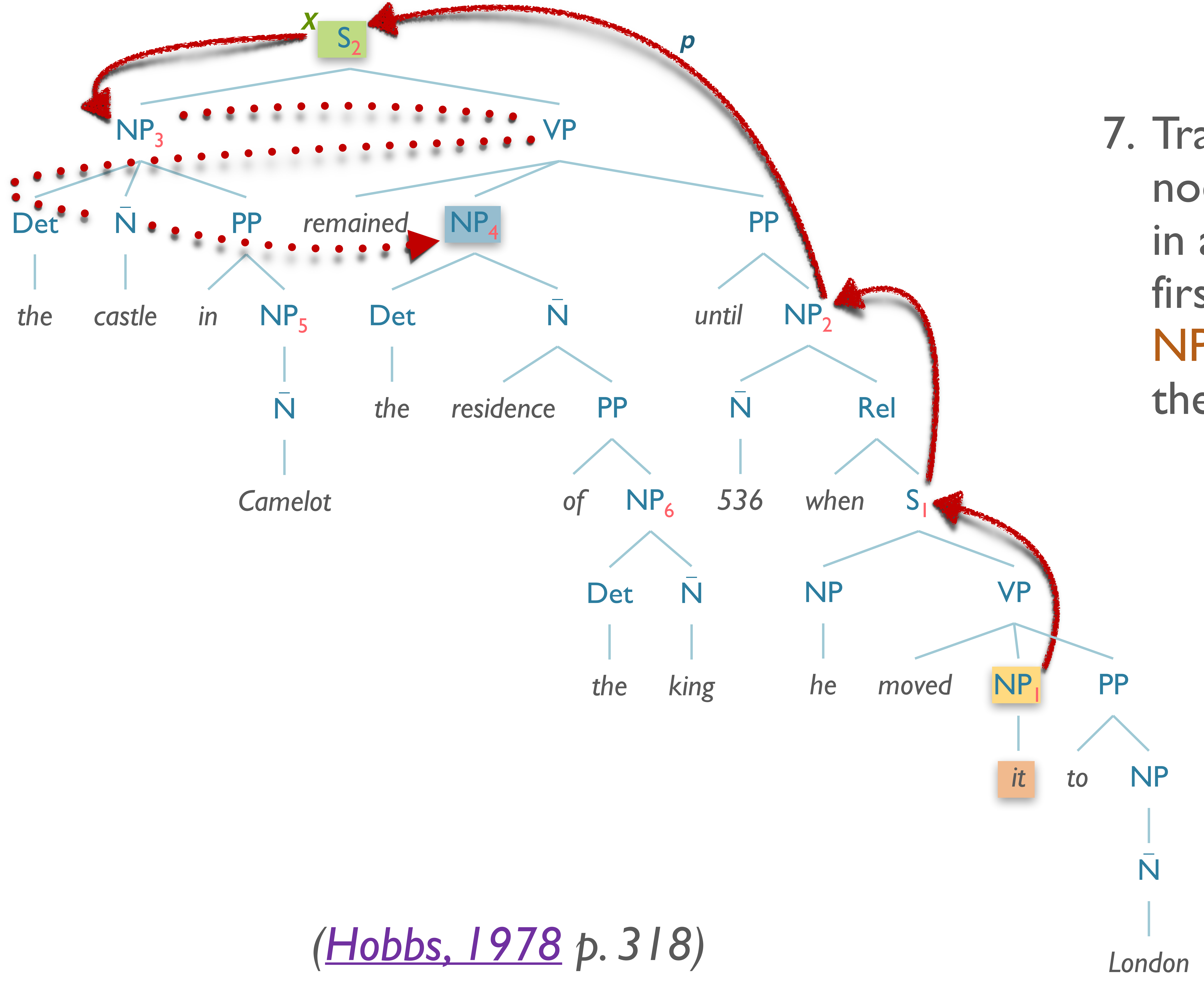
(*Hobbs, 1978 p. 318*)



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.

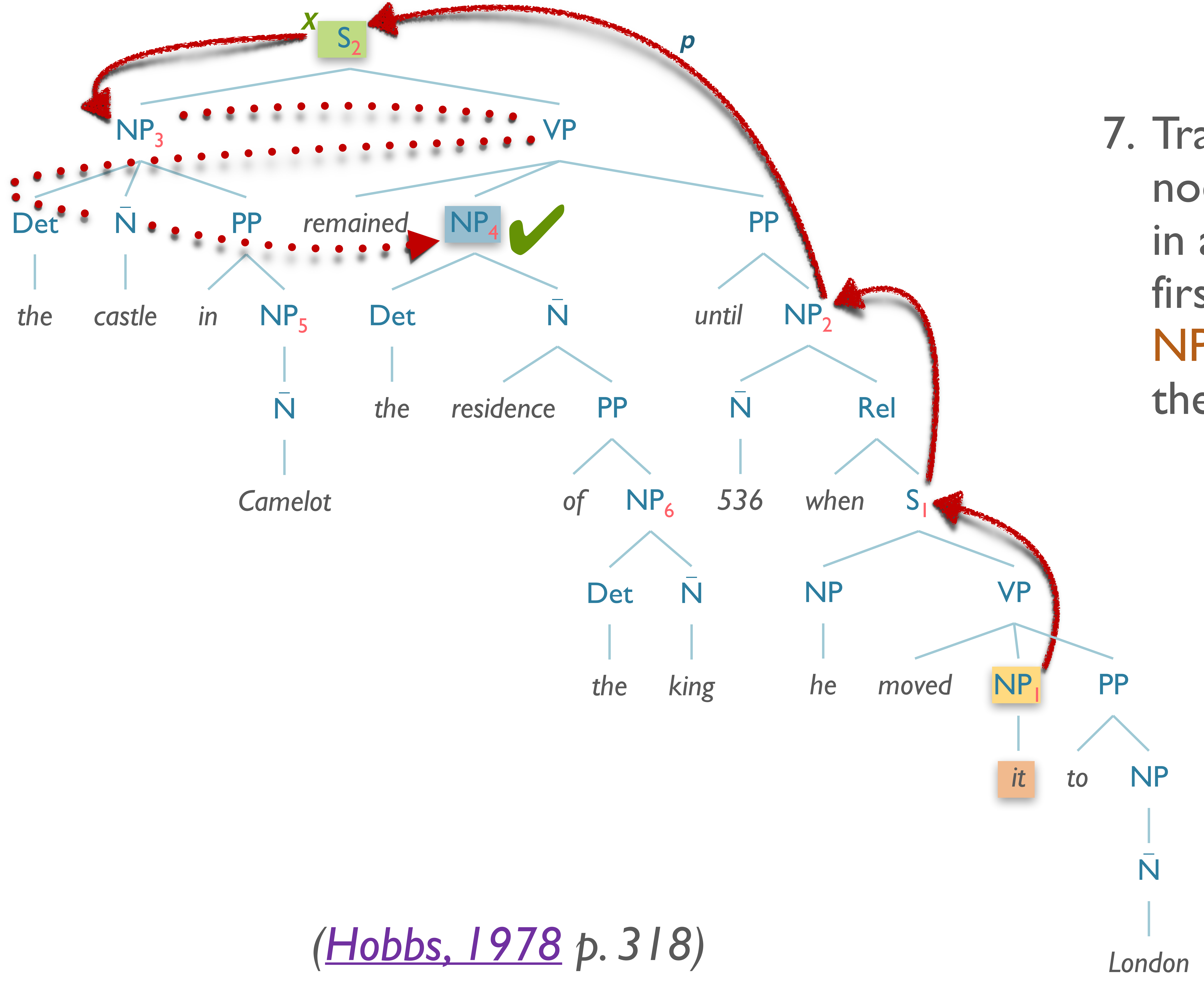
Moving castles? 🤔

(Hobbs, 1978 *p. 318*)



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.

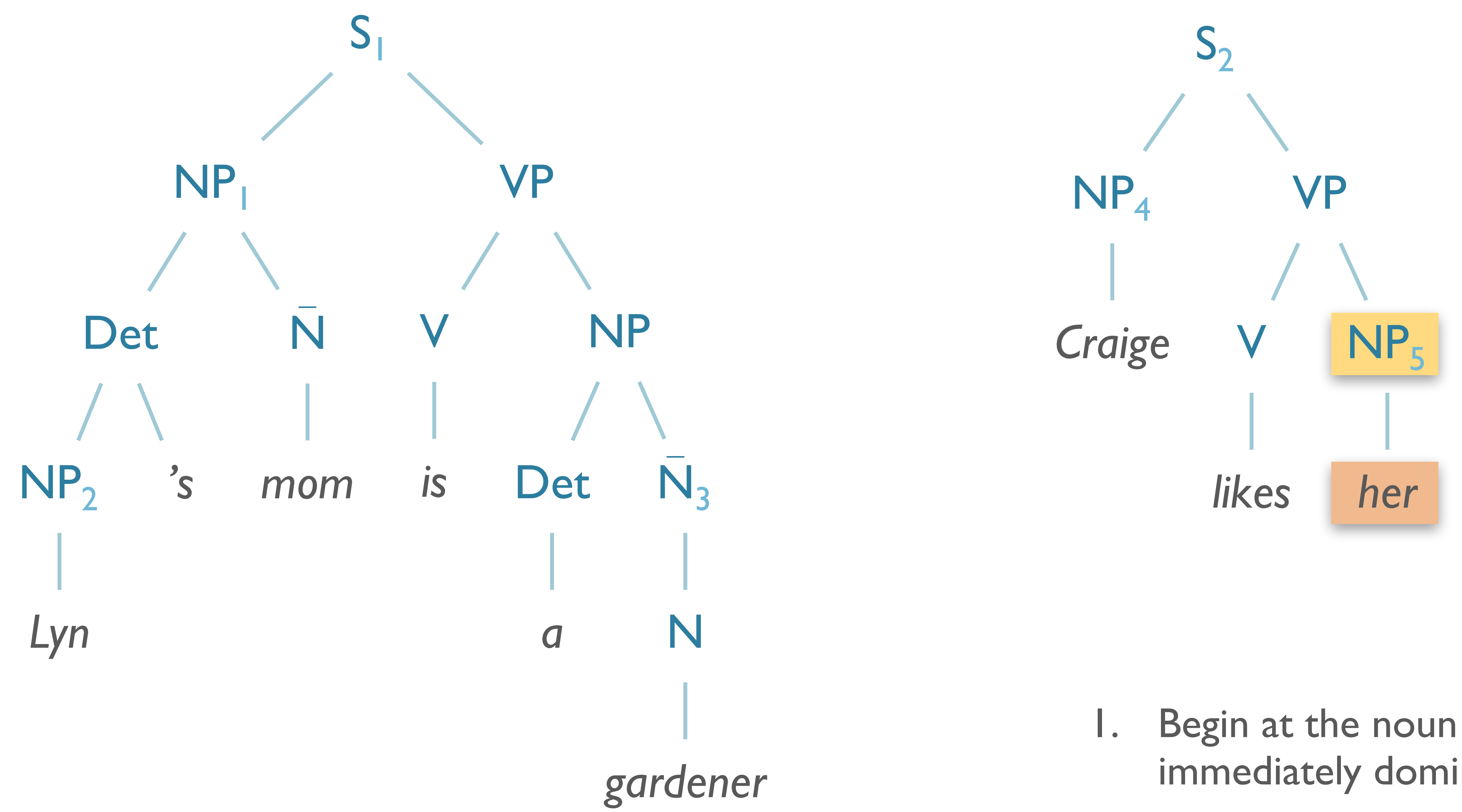
7. Traverse all branches below node ***X*** to the ***left*** of path ***p*** in a left-to-right, breadth-first manner. Propose any NP node encountered as the antecedent.

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

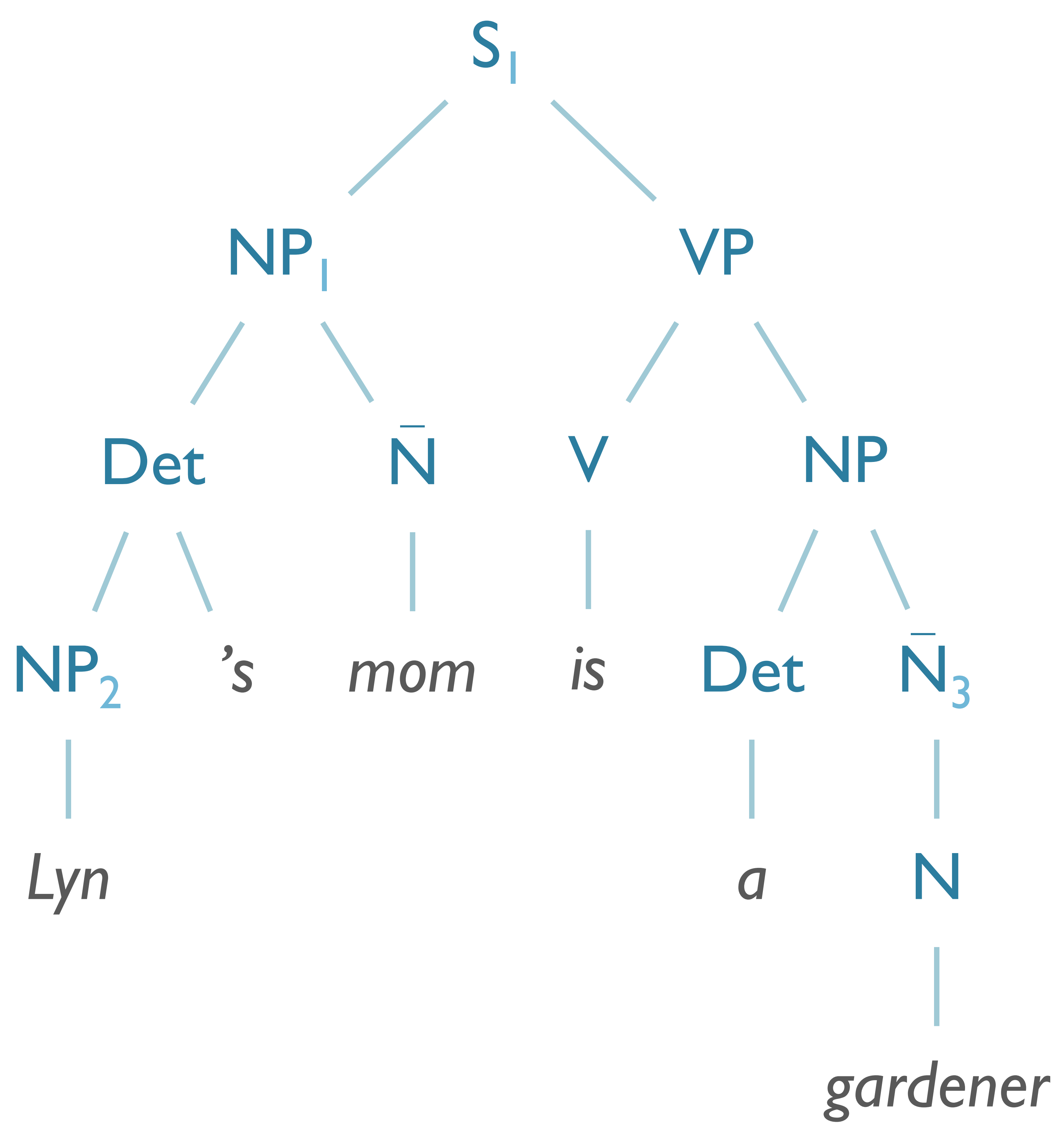
Lyn's mom is a gardener. *Craige likes* **her**.



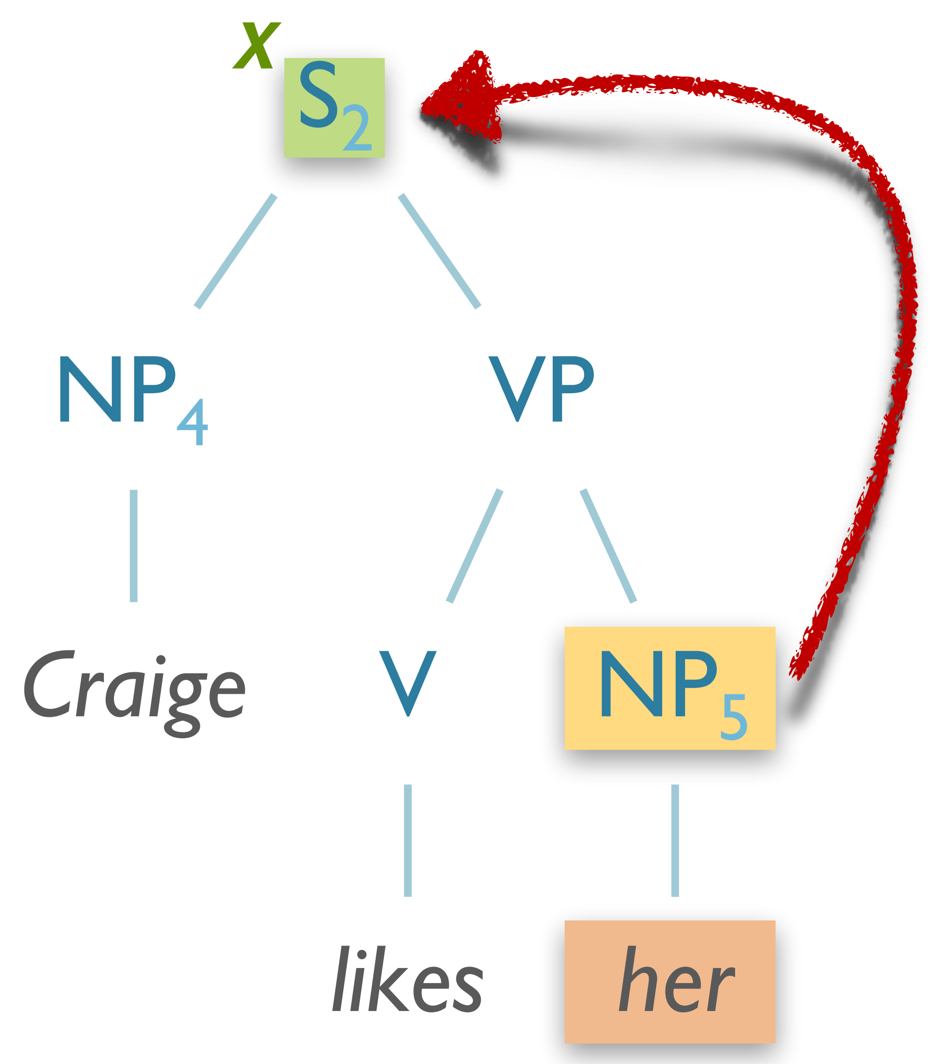
1. Begin at the noun phrase (NP) node immediately dominating the pronoun

Hobbs Example

Lyn's mom is a gardener.



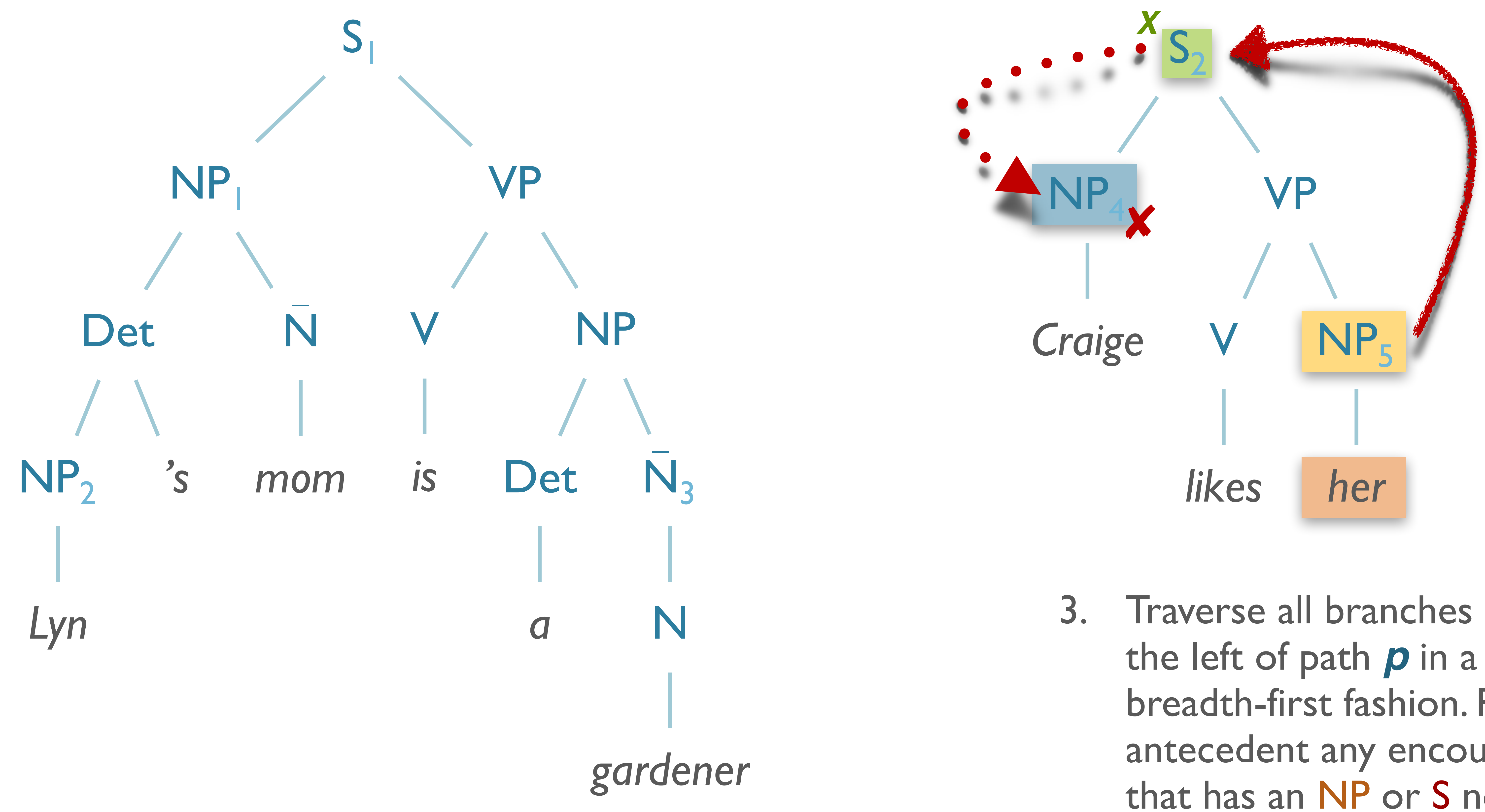
Craige likes **her***.*



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

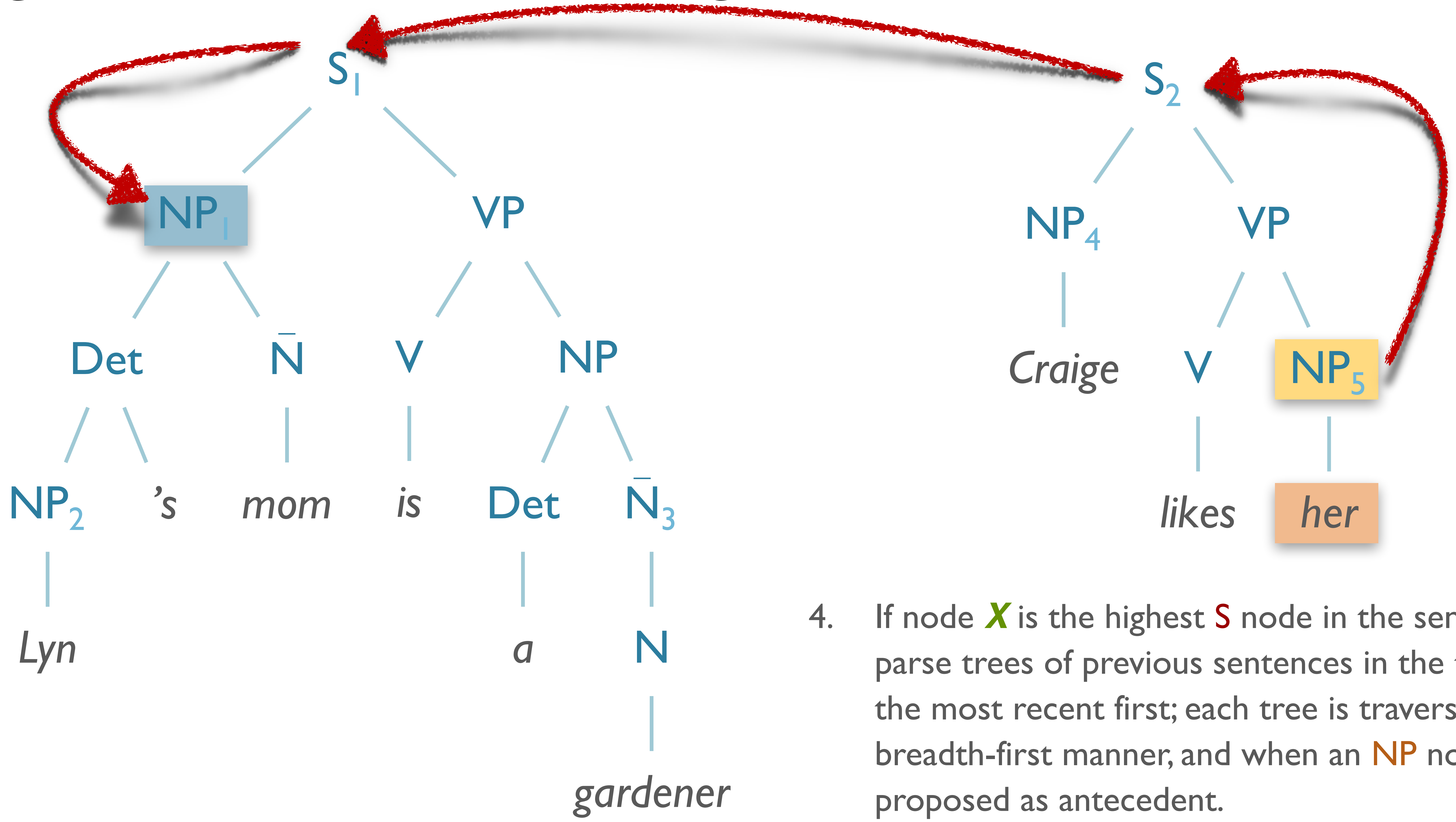
Lyn's mom is a gardener. *Craige likes **her**.*



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. *Craige 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.*
  - *Craige likes her.*