

Discourse and Coreference

LING 571 — Deep Processing Methods in NLP
Shane Steinert-Threlkeld

Announcements

- HW8 due this Wednesday (Nov 29)
- `wordnet_ic` now downloaded and installed in course environment
- full_hyponyms: removed from newer versions of NLTK
 - Closures can help: <https://www.nltk.org/api/nltk.corpus.reader.wordnet.html?highlight=wordnet#nltk.corpus.reader.wordnet.Synset.closure>

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] The object that changes ownership.

Semantic Type: Physical_object



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



treat yo self

Ohhh hahaha

Amazing

Ambiguity of the Week

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

TREAT YO SELF!

treat yo self

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

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 **GOI** 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?

- 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 spir🤔h.

- Why is this odd?

Coherence Relations

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

John hid Bill's car keys. He likes spir🤨h.

- 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 spir🤨h.

- 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 spir🤔h.

- 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 spir🤔h.

- 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 snach.

- **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

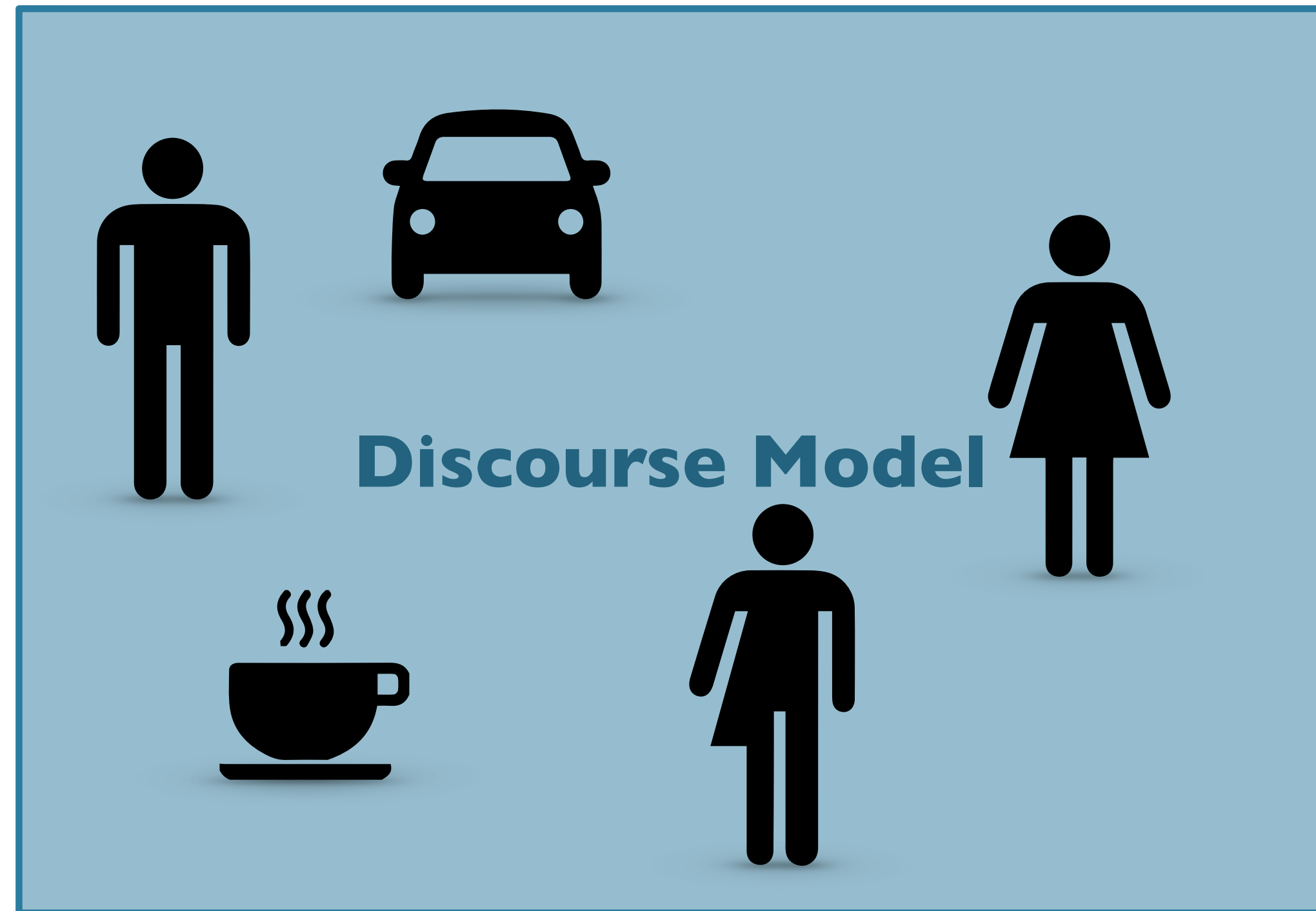
Discourse Model

- 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)”]

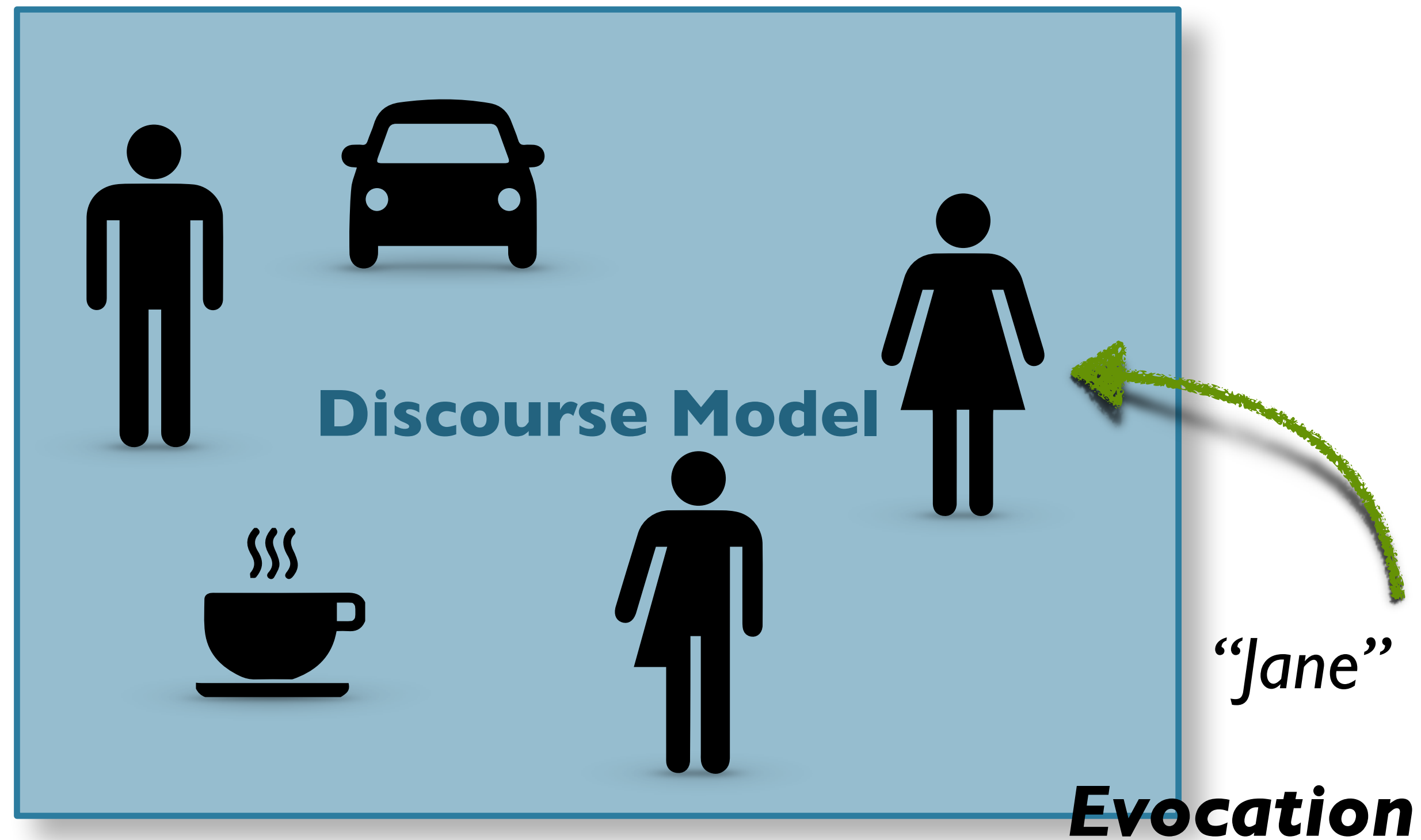
Discourse Model

- 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.

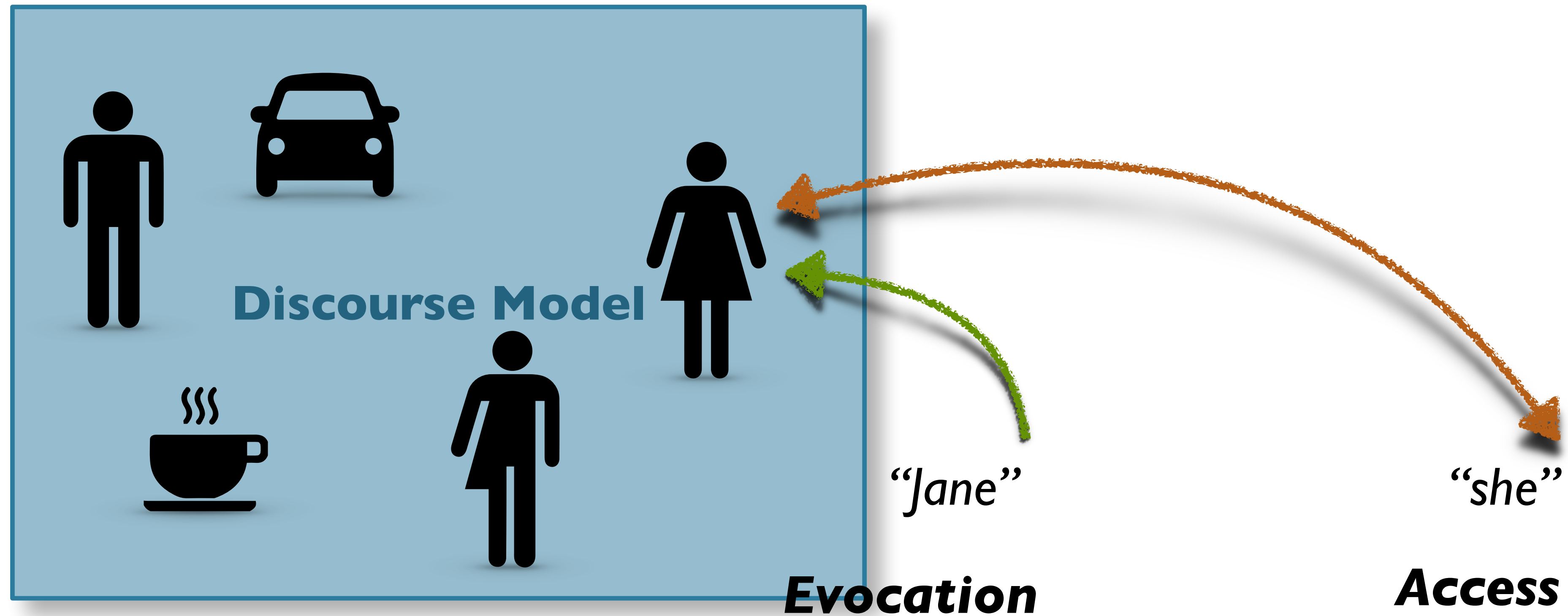
Reference and Model



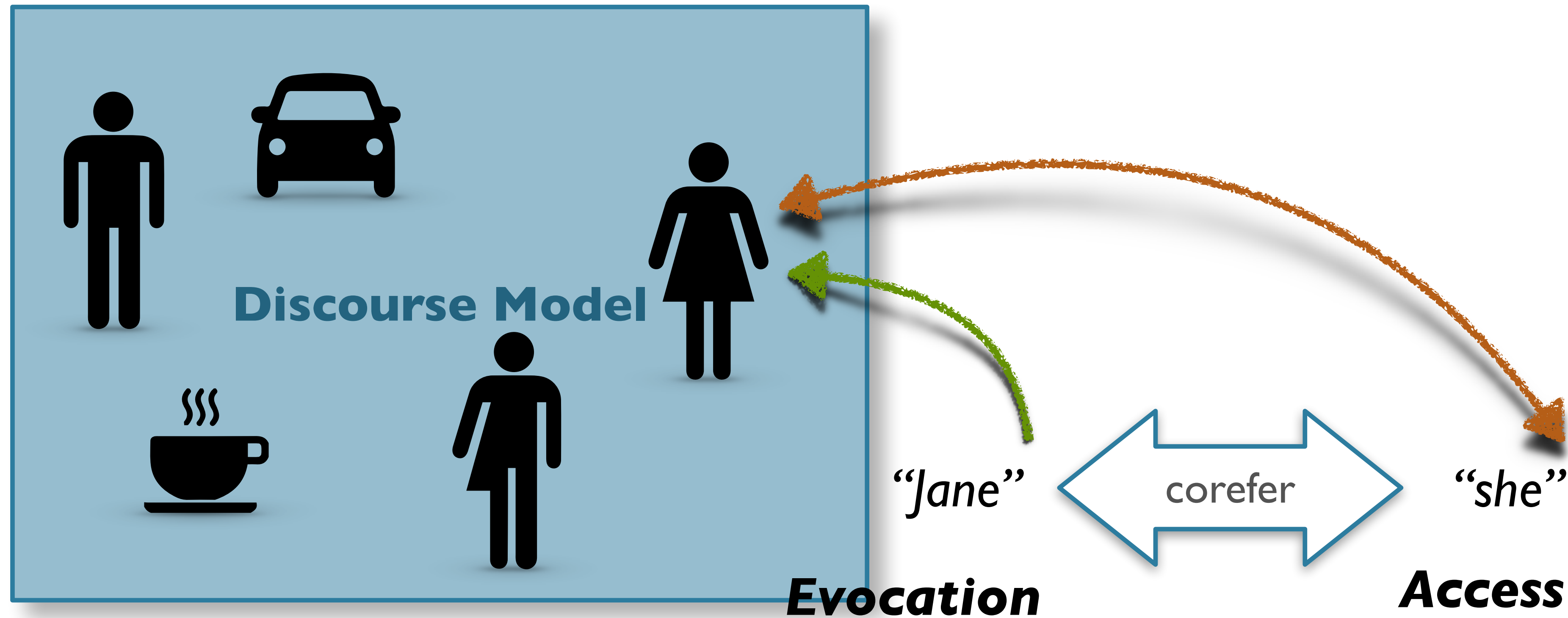
Reference and Model



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

Reference Phenomena: Activation/Saliience

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/Saliience

- 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/Saliience

- 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/Saliience

- 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
it		this		that N		identifiable
		that				>
		this N				the 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							

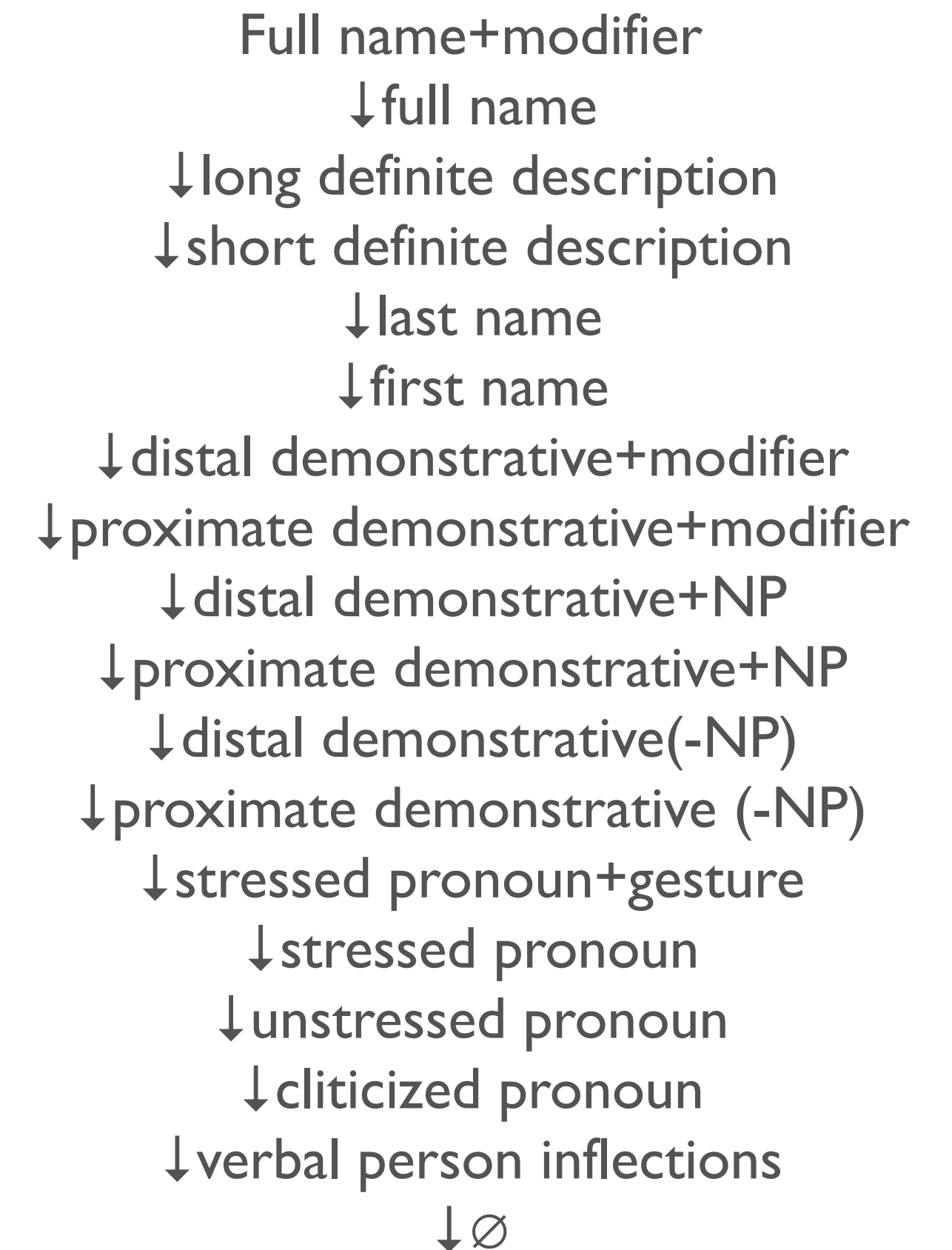
Information Status

- 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



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** \in **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 **themselves** a new car.*

Features for Anaphora Resolution: Constraints

- **Binding Theory**

- How to handle reflexive pronouns vs. nonreflexives

- *Aaron bought **themselves** 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 **themselves** 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 **themselves** 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 **themselves** 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.*

[He₁ ≠ Willie, he₂ ≠ Willie]

Features for Anaphora Resolution: Constraints

- **Binding Theory**

- How to handle reflexive pronouns vs. nonreflexives

- *Aaron bought **themselves** 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.*

[He₁ ≠ Willie, he₂ ≠ 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 **themselves** 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.*

[He₁ ≠ Willie, he₂ ≠ 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.

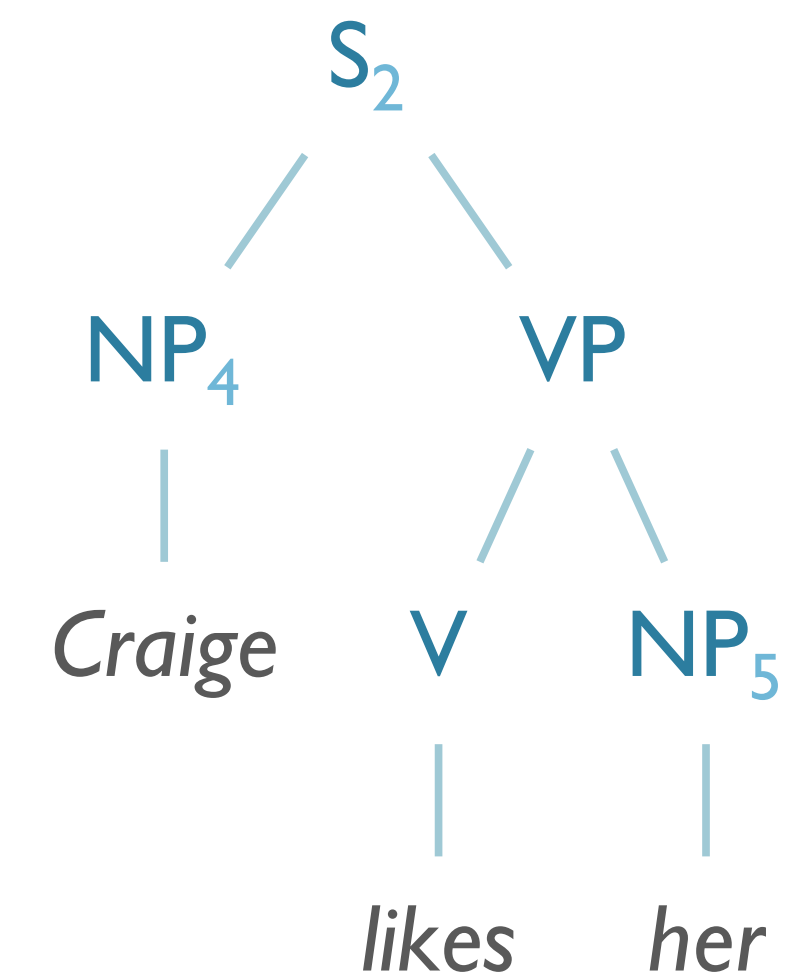
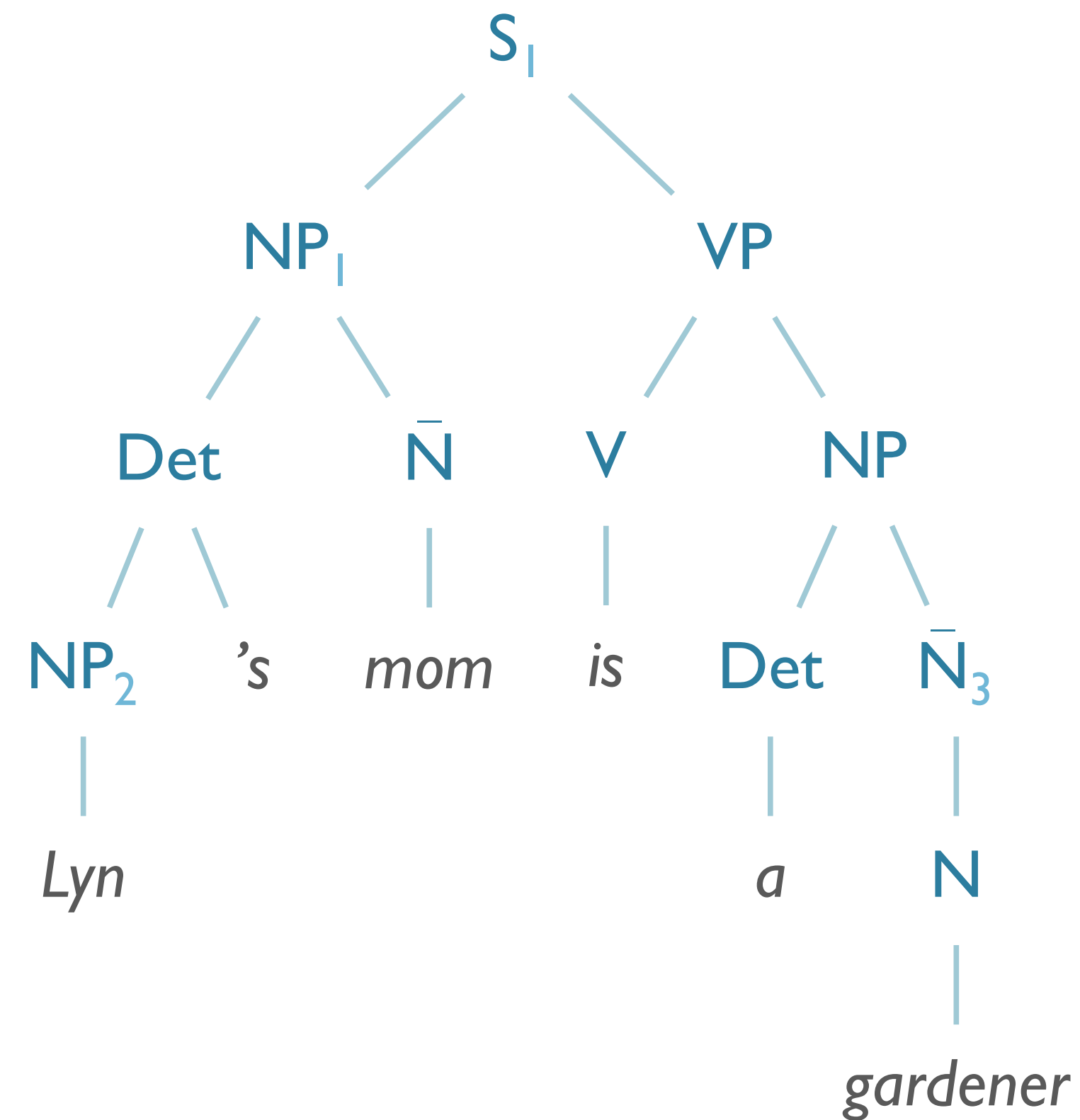
Hobbs Algorithm Detail (Hobbs, 1978)

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.

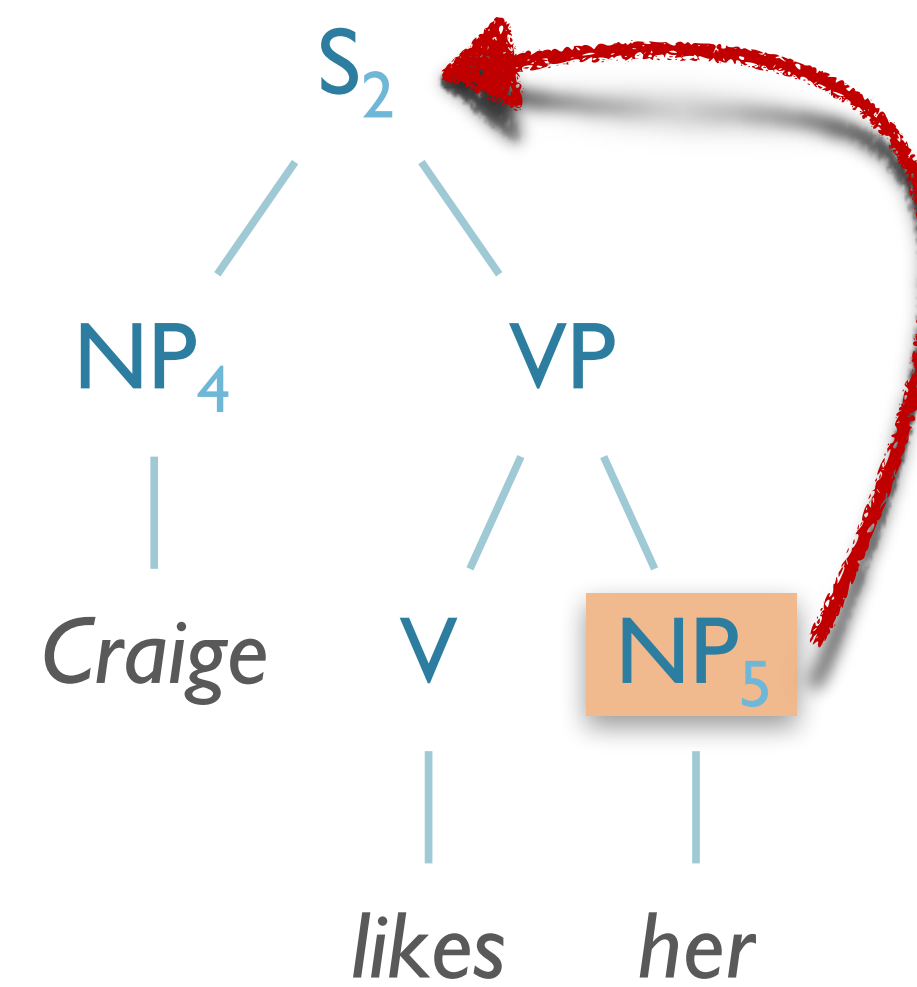
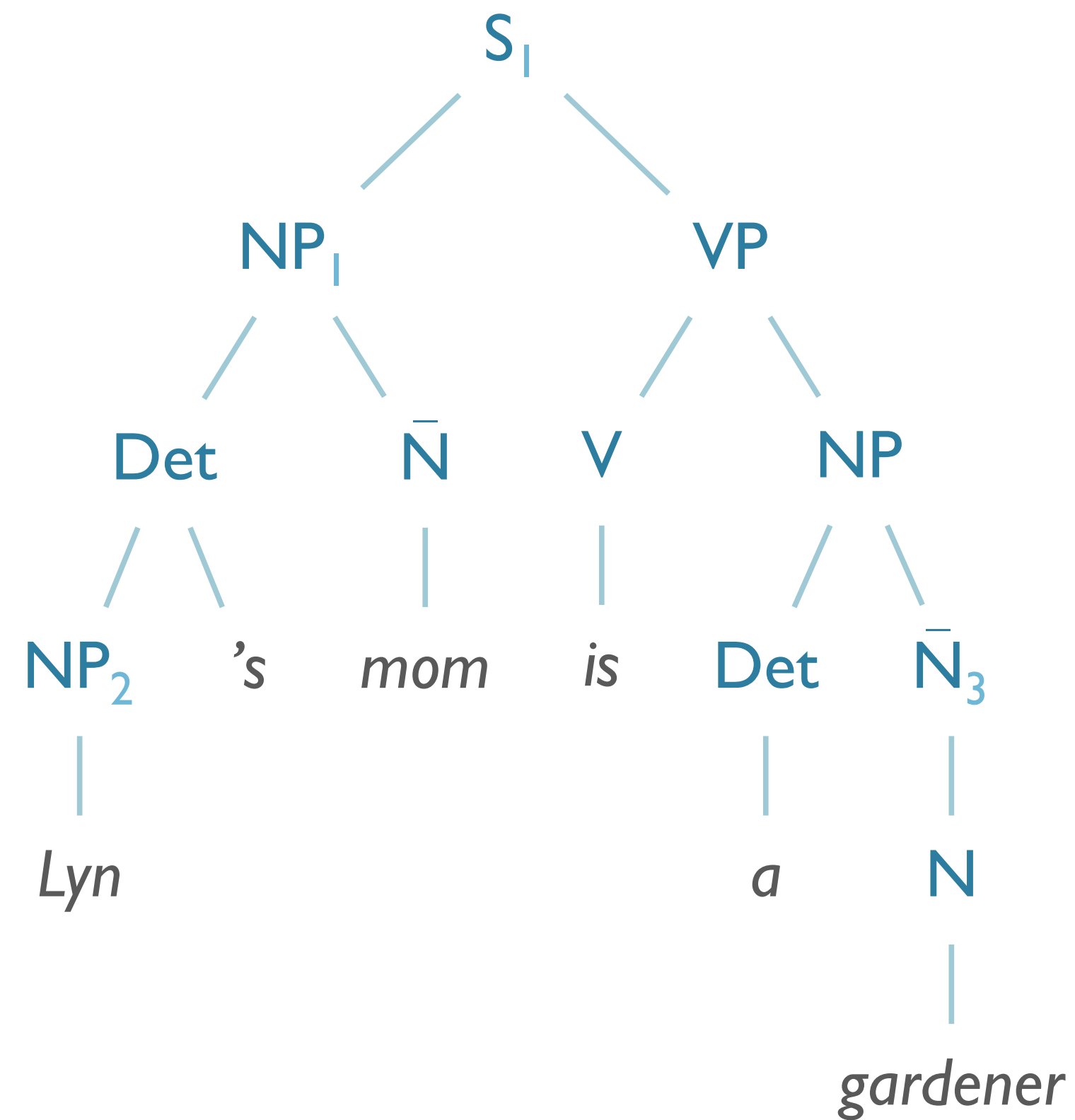
Craige likes her.



Hobbs Example

Lyn's mom is a gardener.

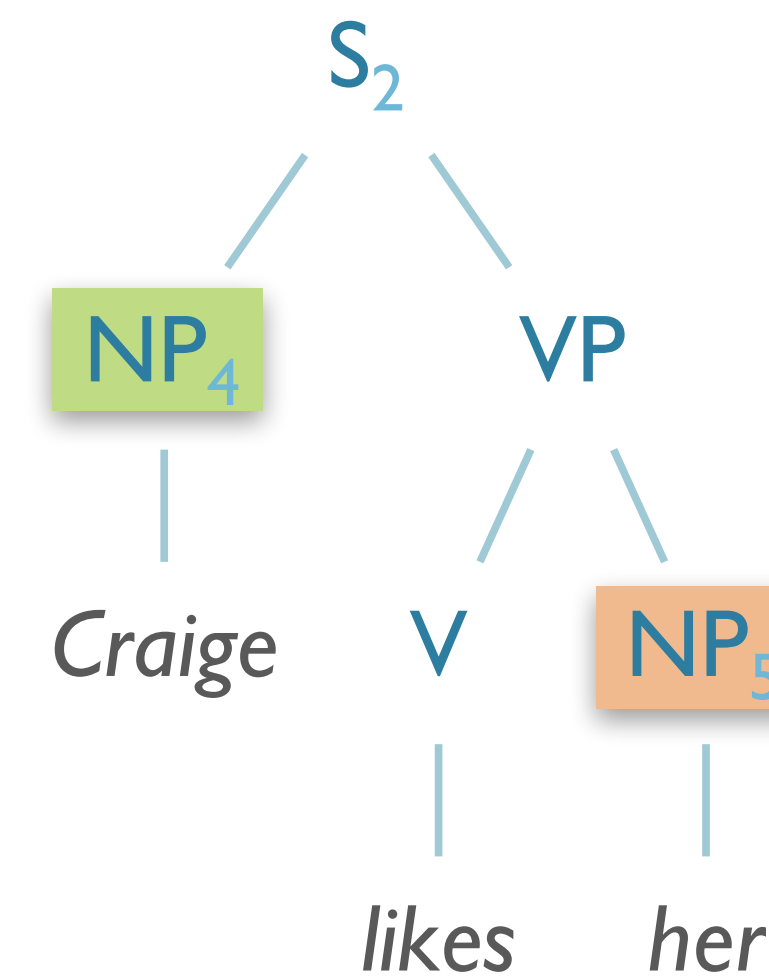
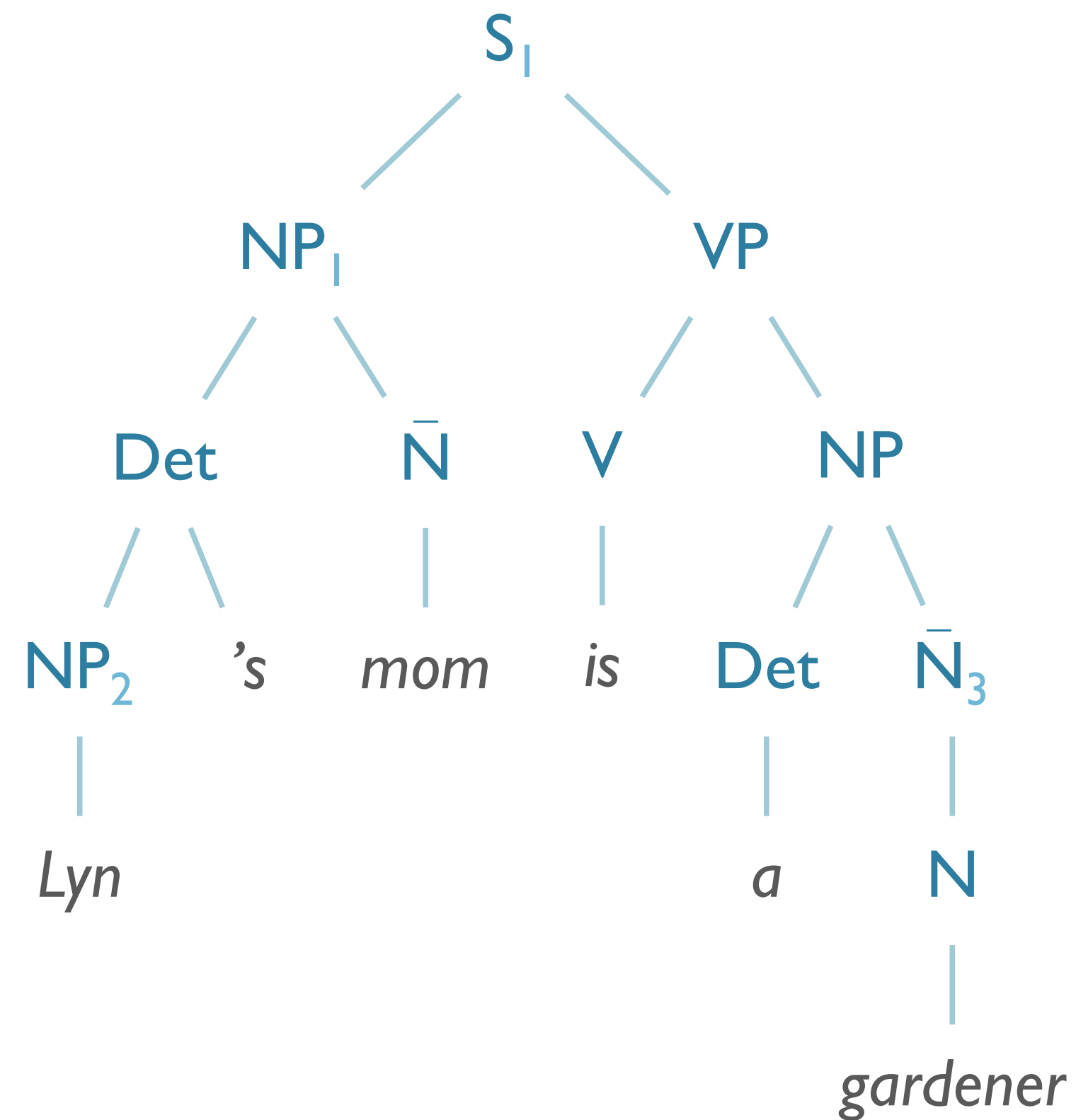
Craige likes her.



Hobbs Example

Lyn's mom is a gardener.

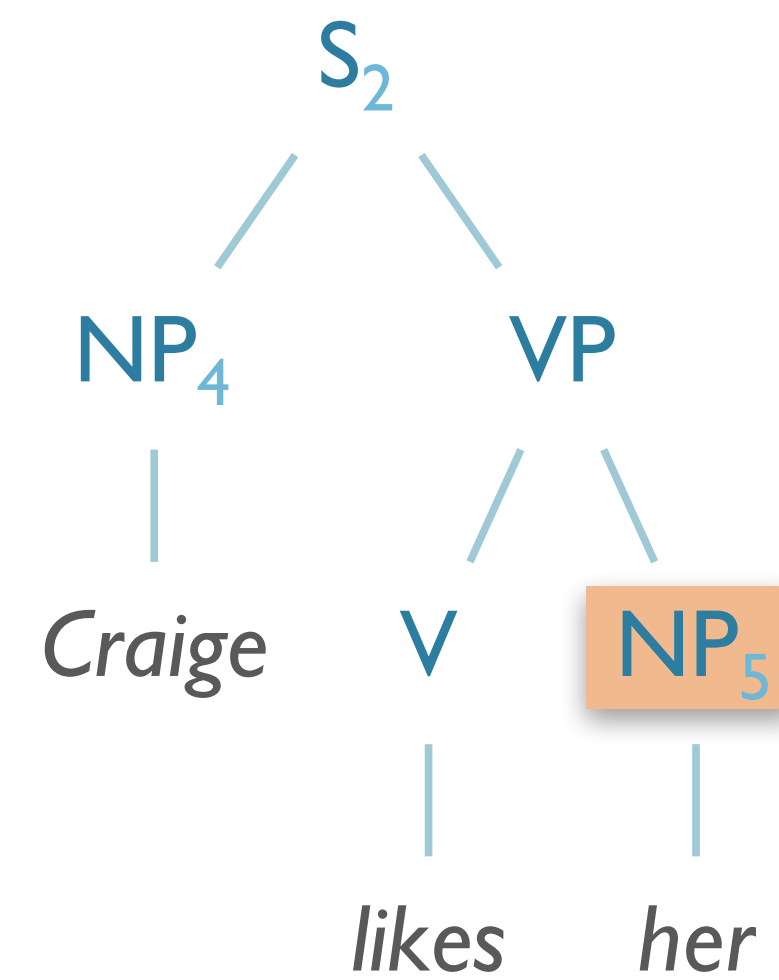
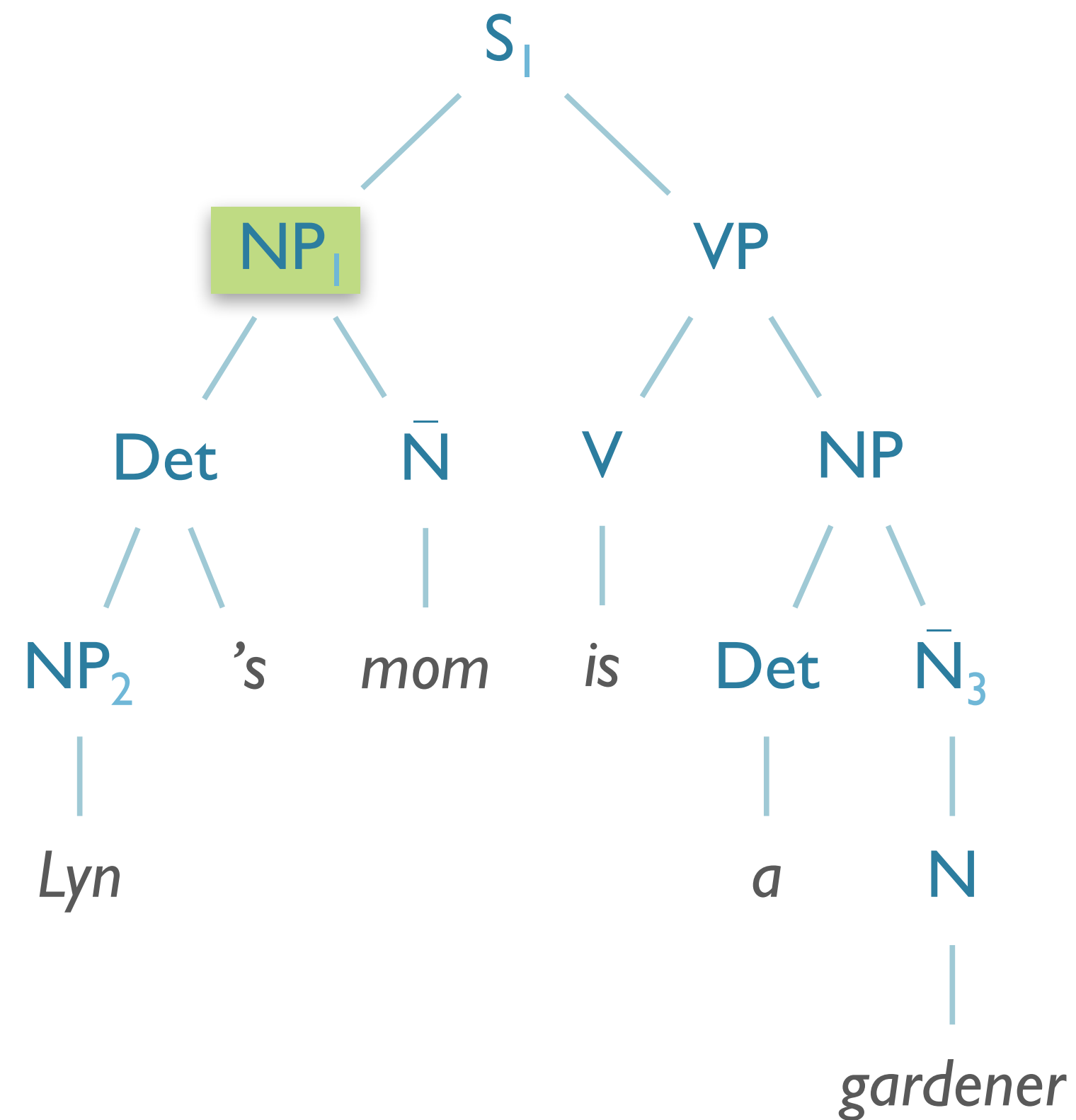
Craige likes her.



Hobbs Example

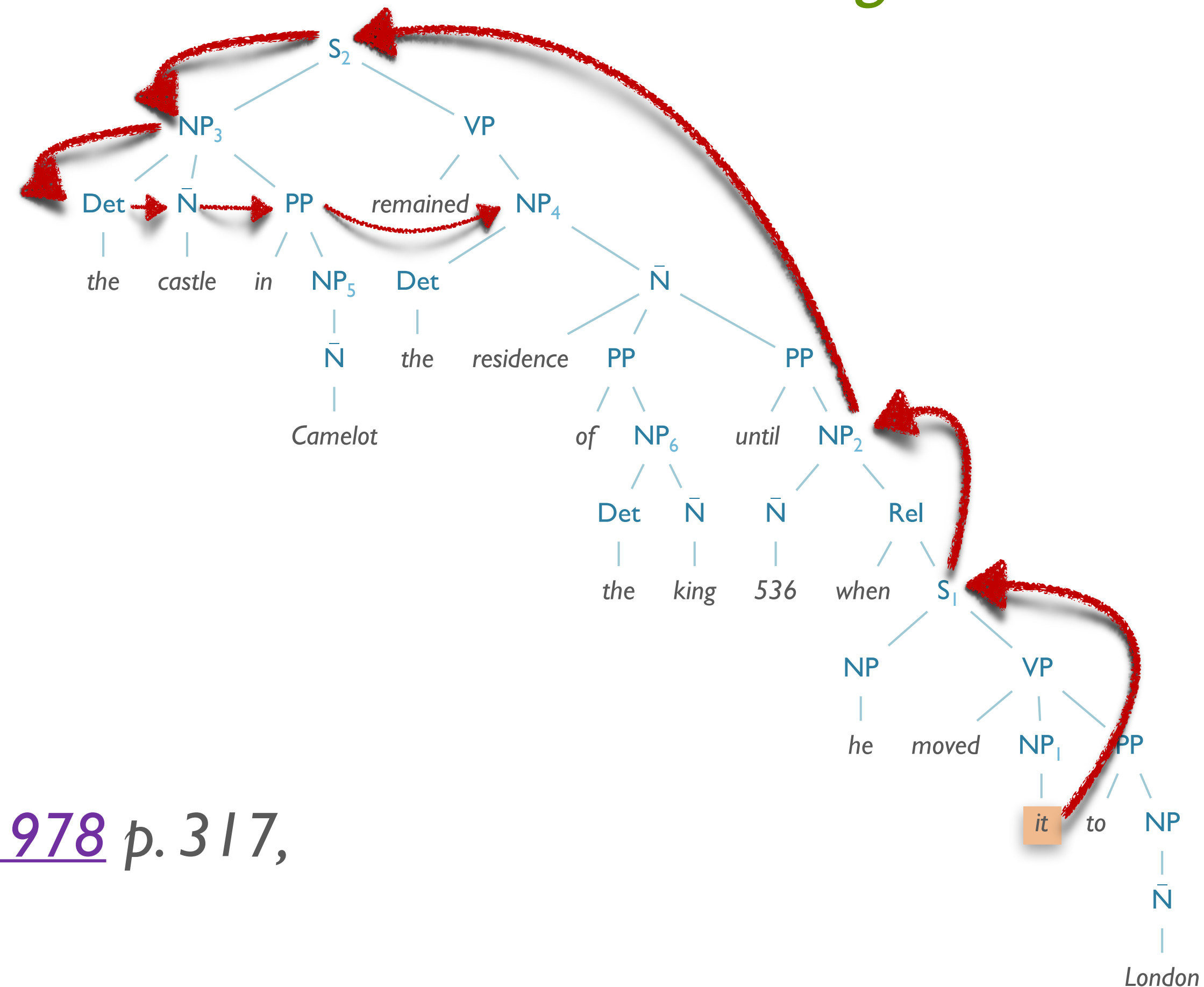
Lyn's mom is a gardener.

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 pronominal anaphora
- Issues:
 - **Parsing:**
 - Not all languages have parsers
 - Parsers not always accurate
 - **Constraints/Preferences:**
 - Captures: Binding theory, grammatical role, recency
 - But not: parallelism, repetition, verb semantics, selection

Hobbs Algorithm

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

Hobbs Algorithm: A Parable

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

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

Coreference and World Knowledge

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

the trophy

the brown
suitcase

Total Results: 0

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

the trophy

the brown
suitcase

Total Results: 0

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

Joan

Susan

Total Results: 0

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

Joan

Susan

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.

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
- 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-mlt		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	65.11	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	65.11	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)

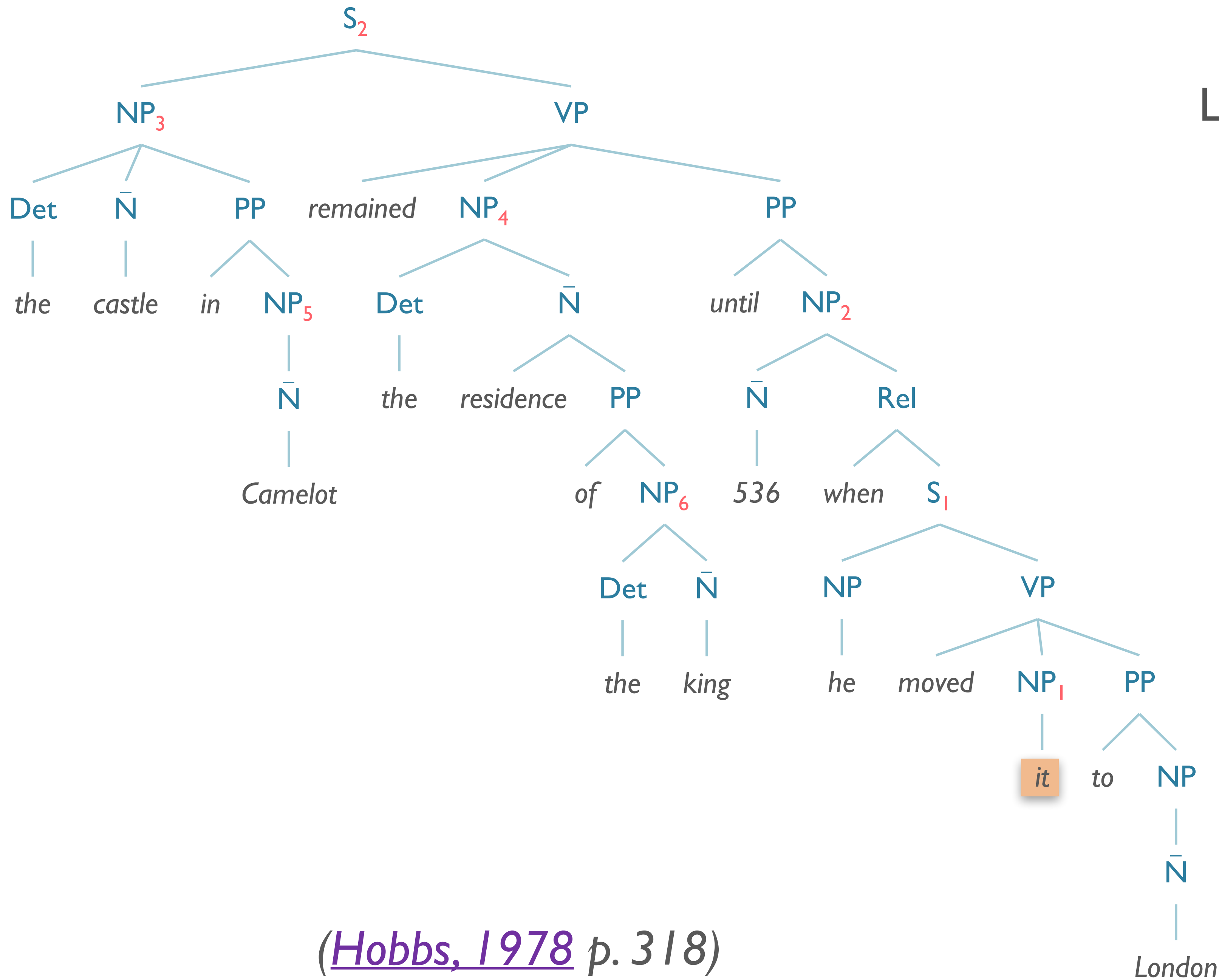
SuperGLUE GLUE Paper </> Code Tasks Leaderboard FAQ Diagnostics Submit

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-mlt		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	65.11	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	65.11	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

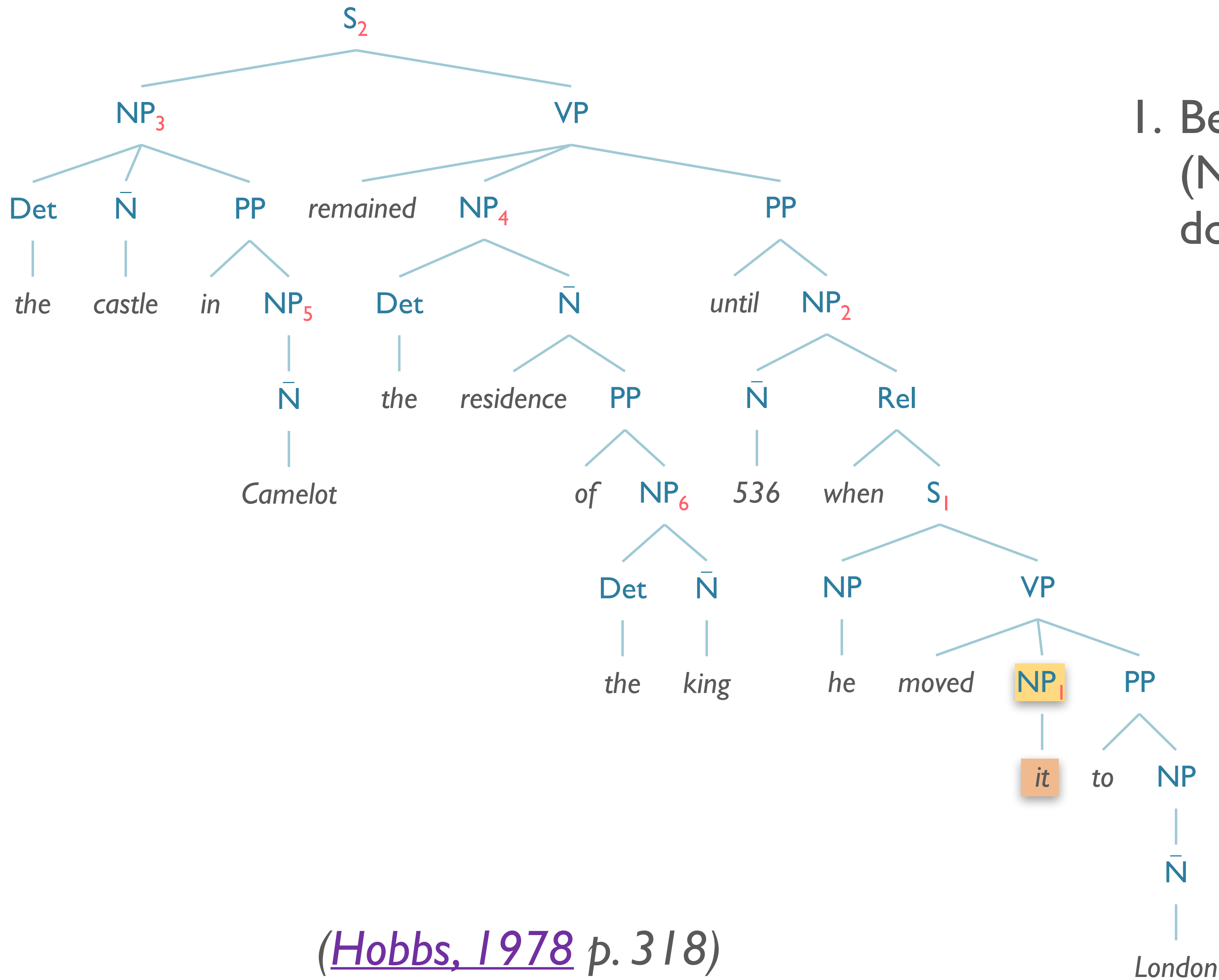
Hobbs Algorithm Walkthrough

(h/t Ryan Georgi)



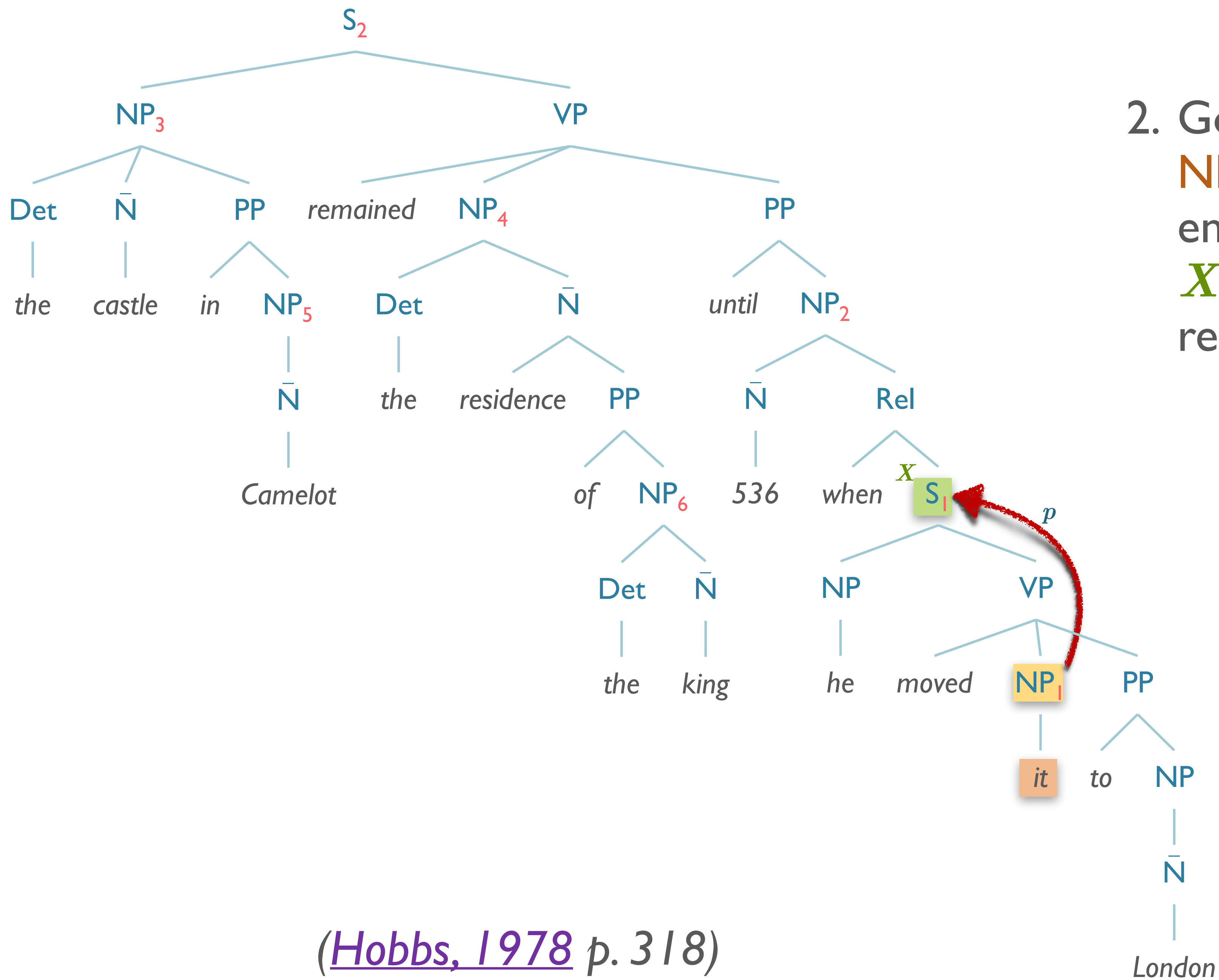
Let's figure out what the antecedent for "it" is

(Hobbs, 1978 p. 318)



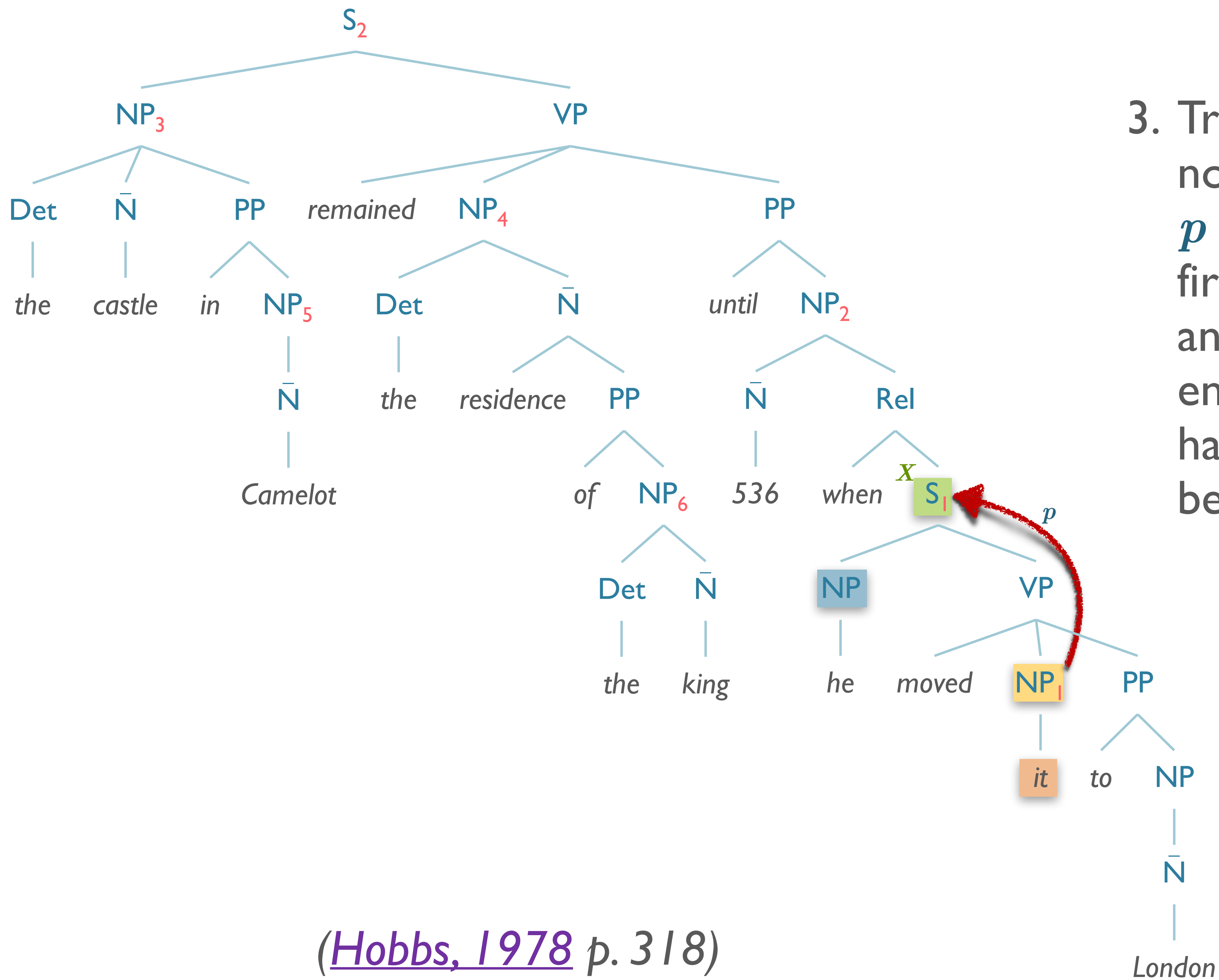
I. Begin at the noun phrase (NP) node immediately dominating the pronoun

(Hobbs, 1978 p. 318)



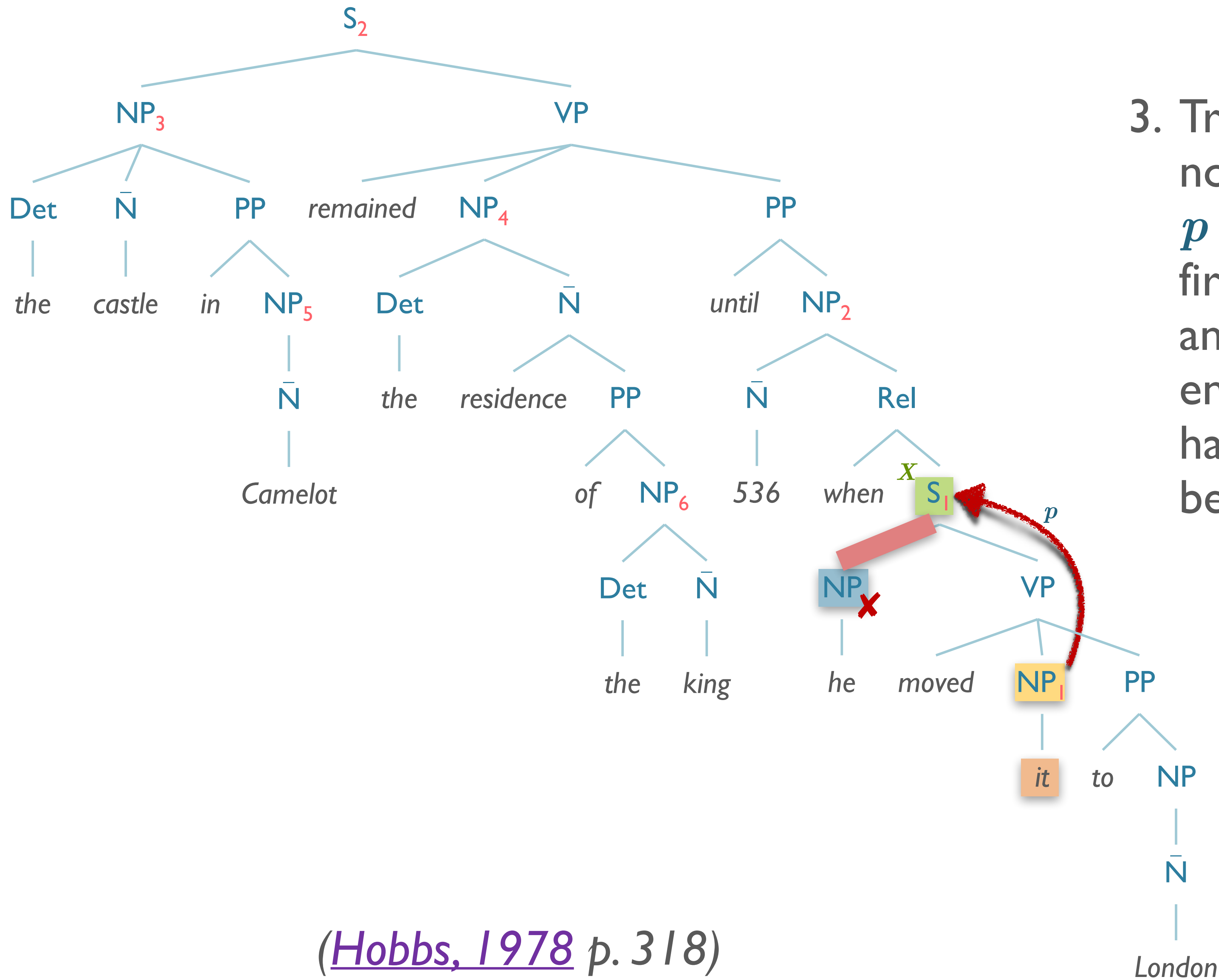
- Go up the tree to the first **NP** or sentence (**S**) node encountered. Call this node **X**, and call the path used to reach it *p*.

(Hobbs, 1978 p. 318)



(Hobbs, 1978 p. 318)

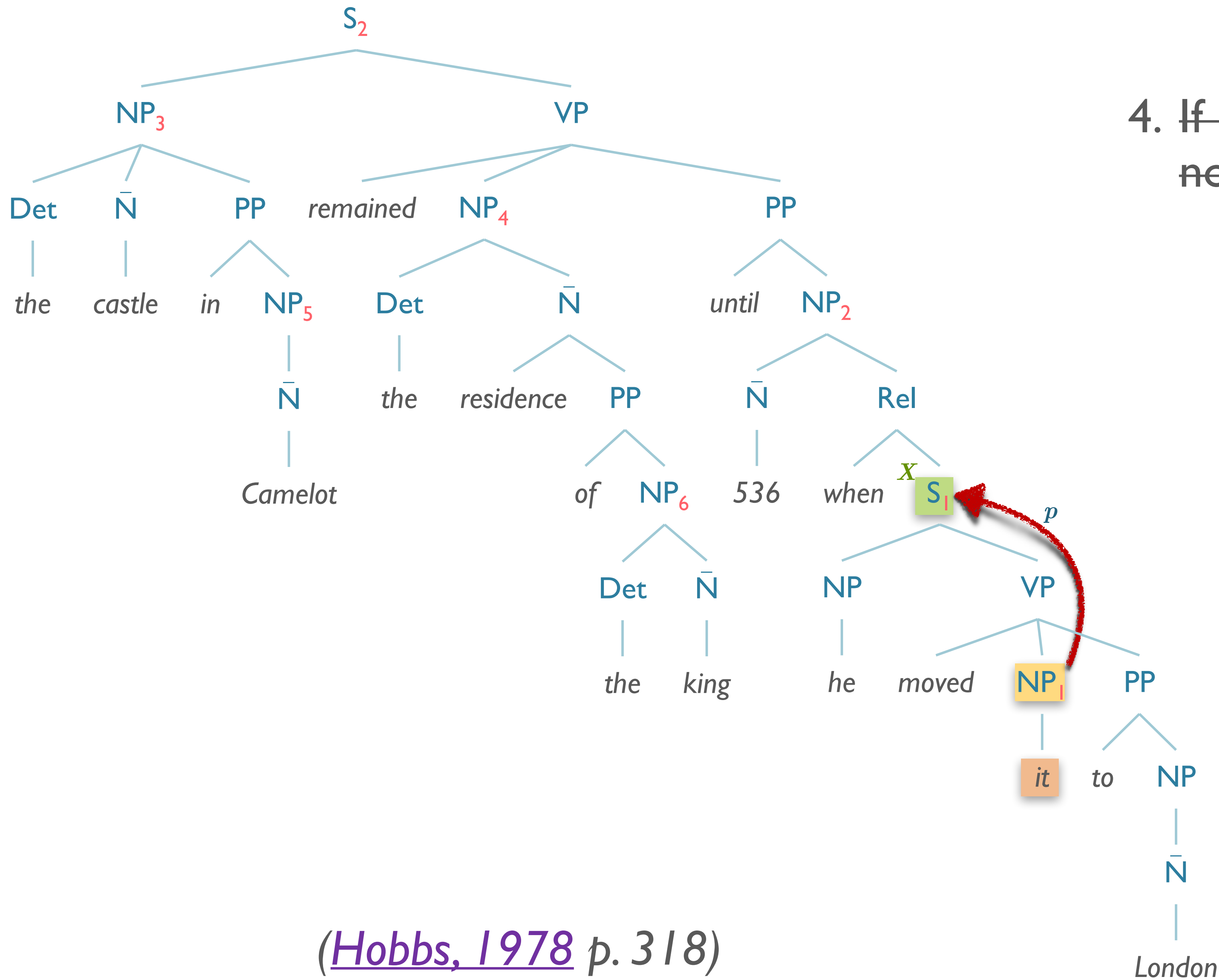
3. Traverse all branches below node X to the left of path p in a left-to-right, breadth-first fashion. Propose as the antecedent any encountered NP node that has an NP or S node between it and X .



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**.

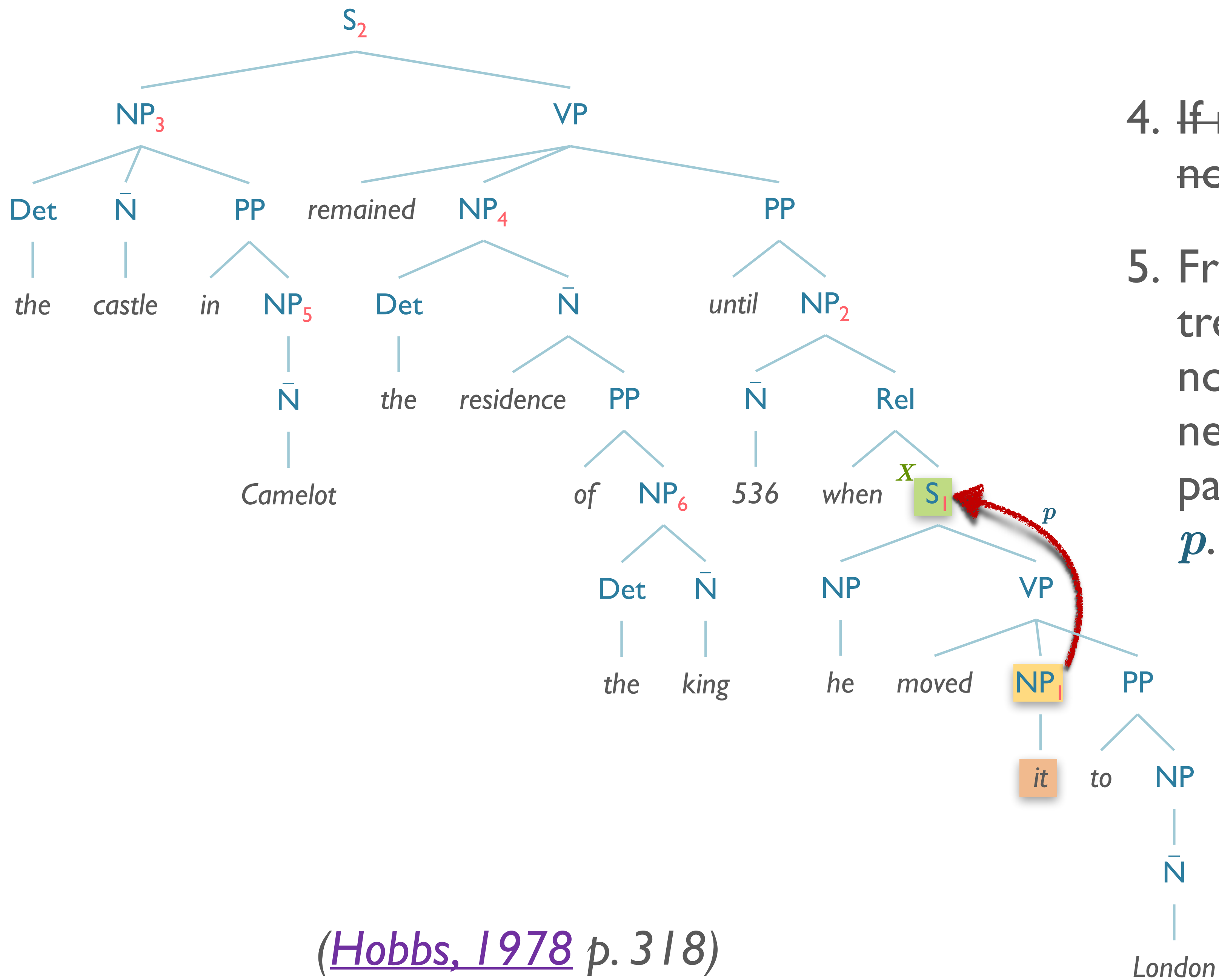
No NP or S between "he" NP and X

(Hobbs, 1978 p. 318)



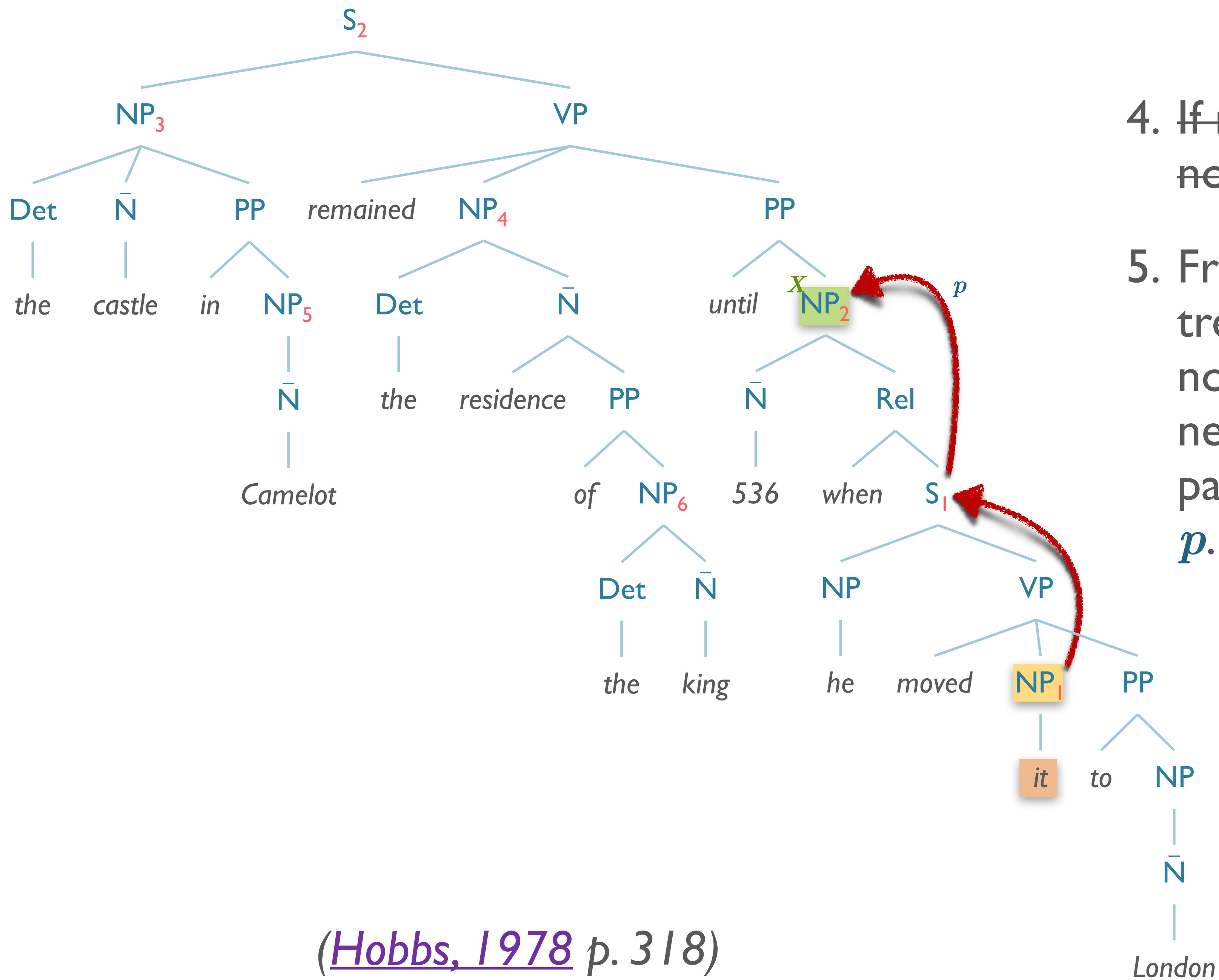
4. If node ~~X~~ is the highest ~~S~~ node in the sentence...

(Hobbs, 1978 p. 318)



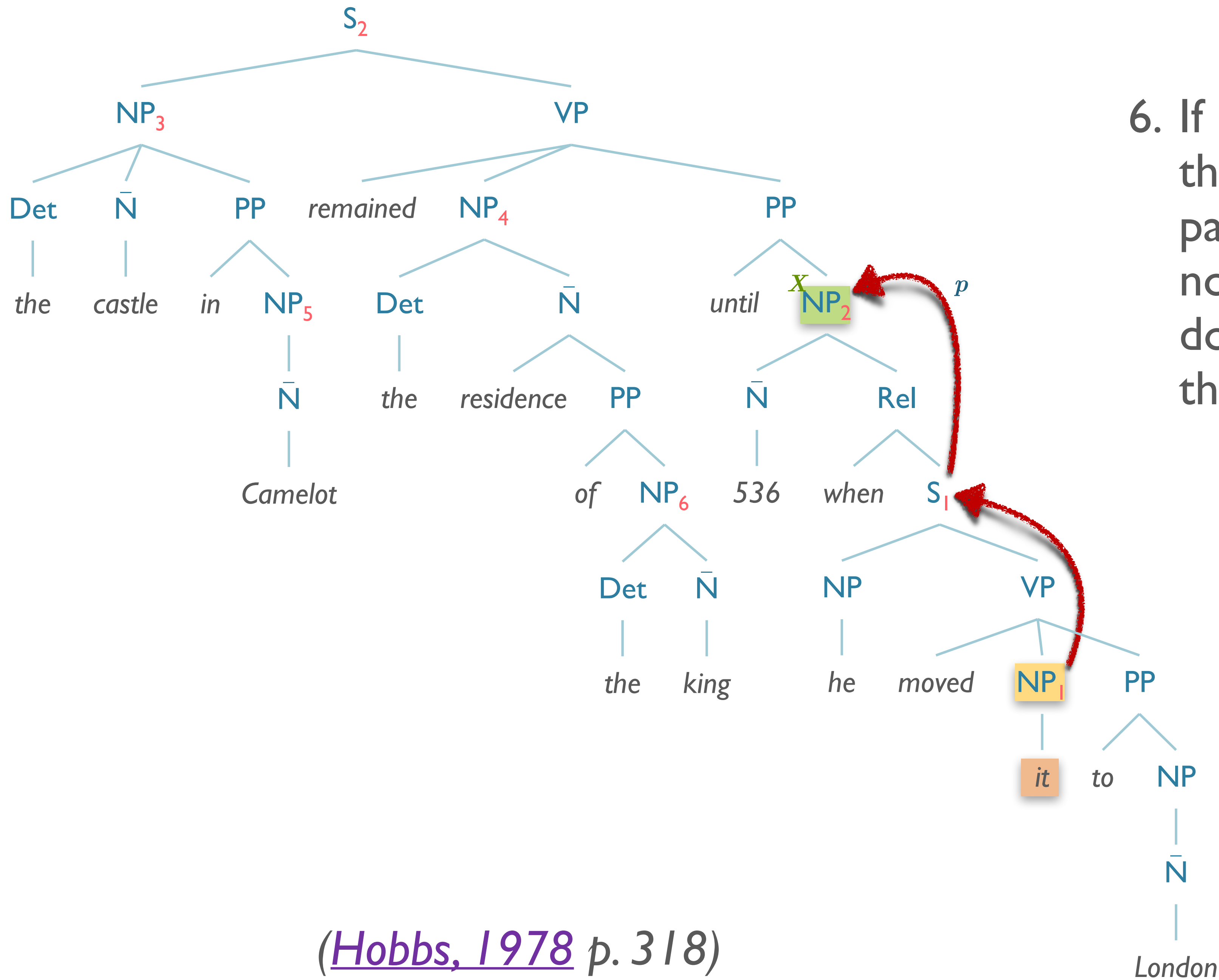
(Hobbs, 1978 p. 318)

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 .



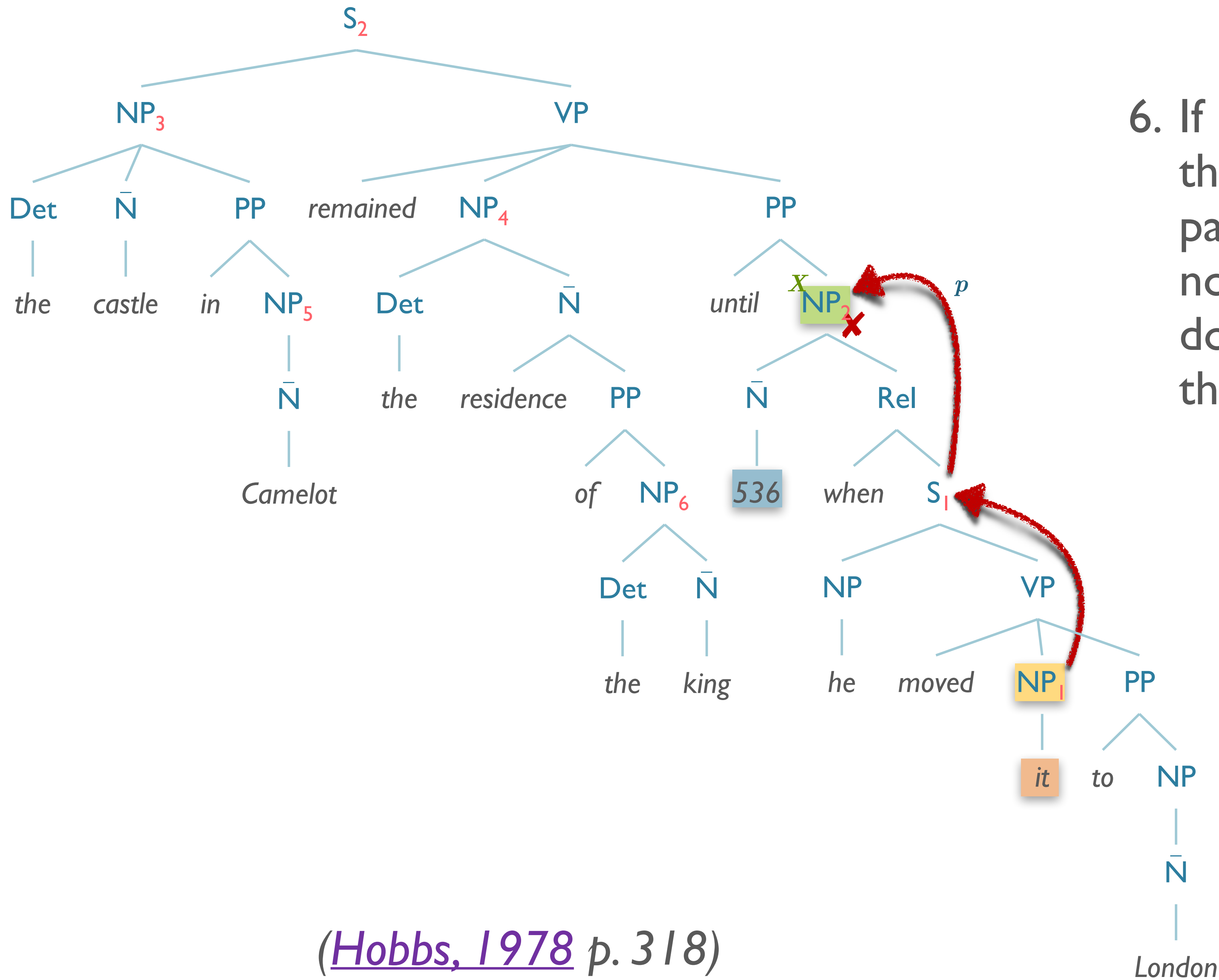
(Hobbs, 1978 p. 318)

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**.



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.

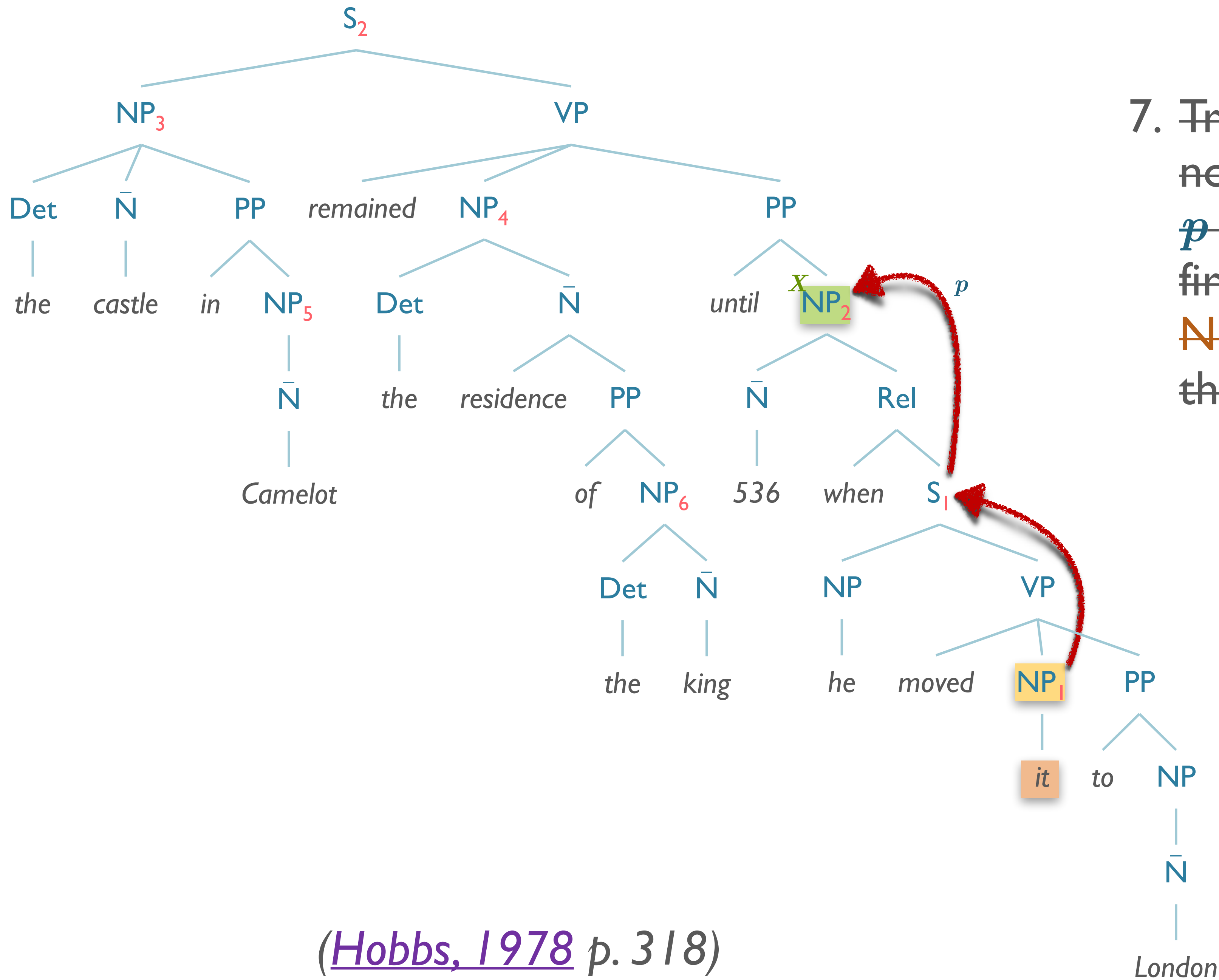
(Hobbs, 1978 p. 318)



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.

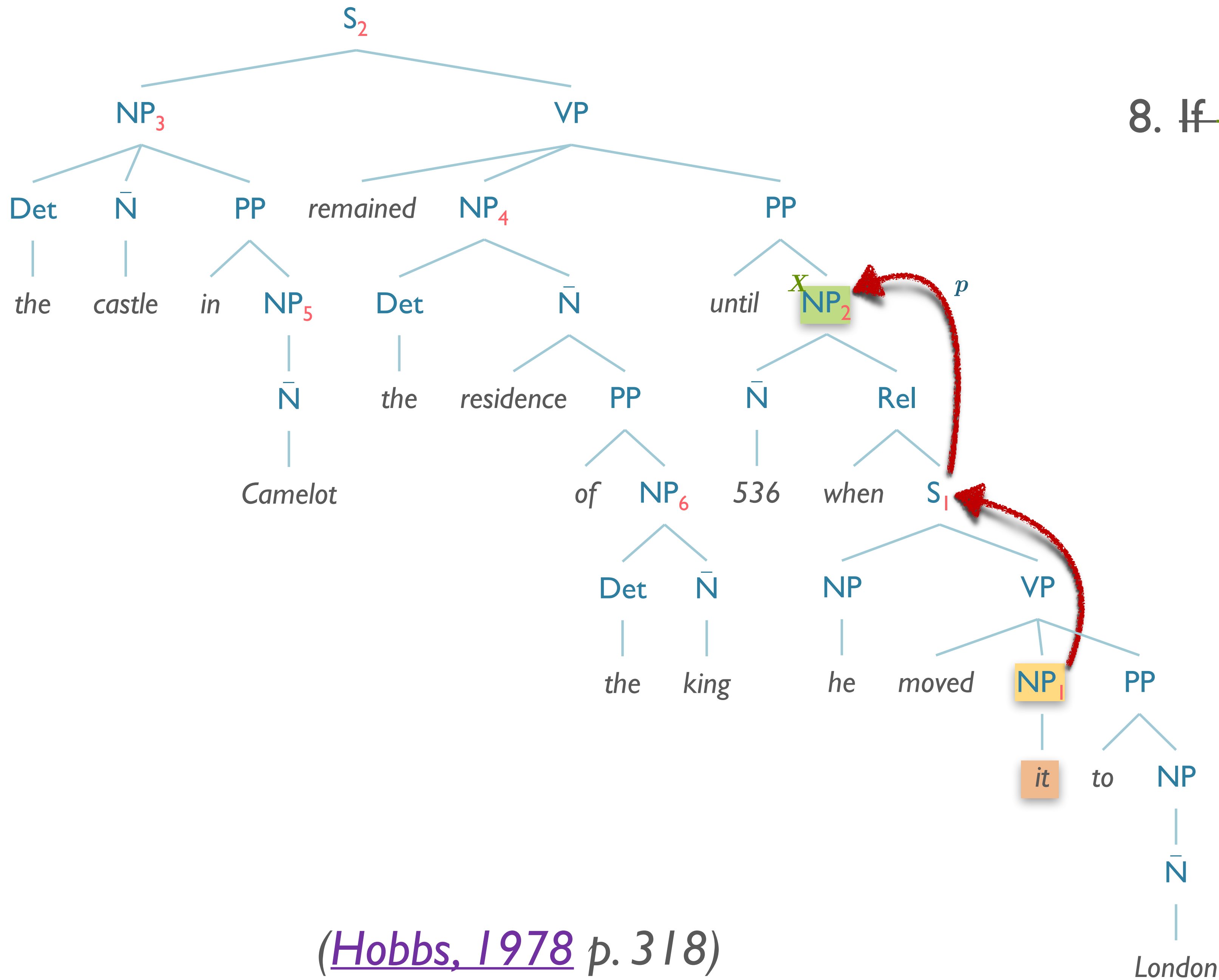
“536” can’t be “moved”!

(Hobbs, 1978 p. 318)



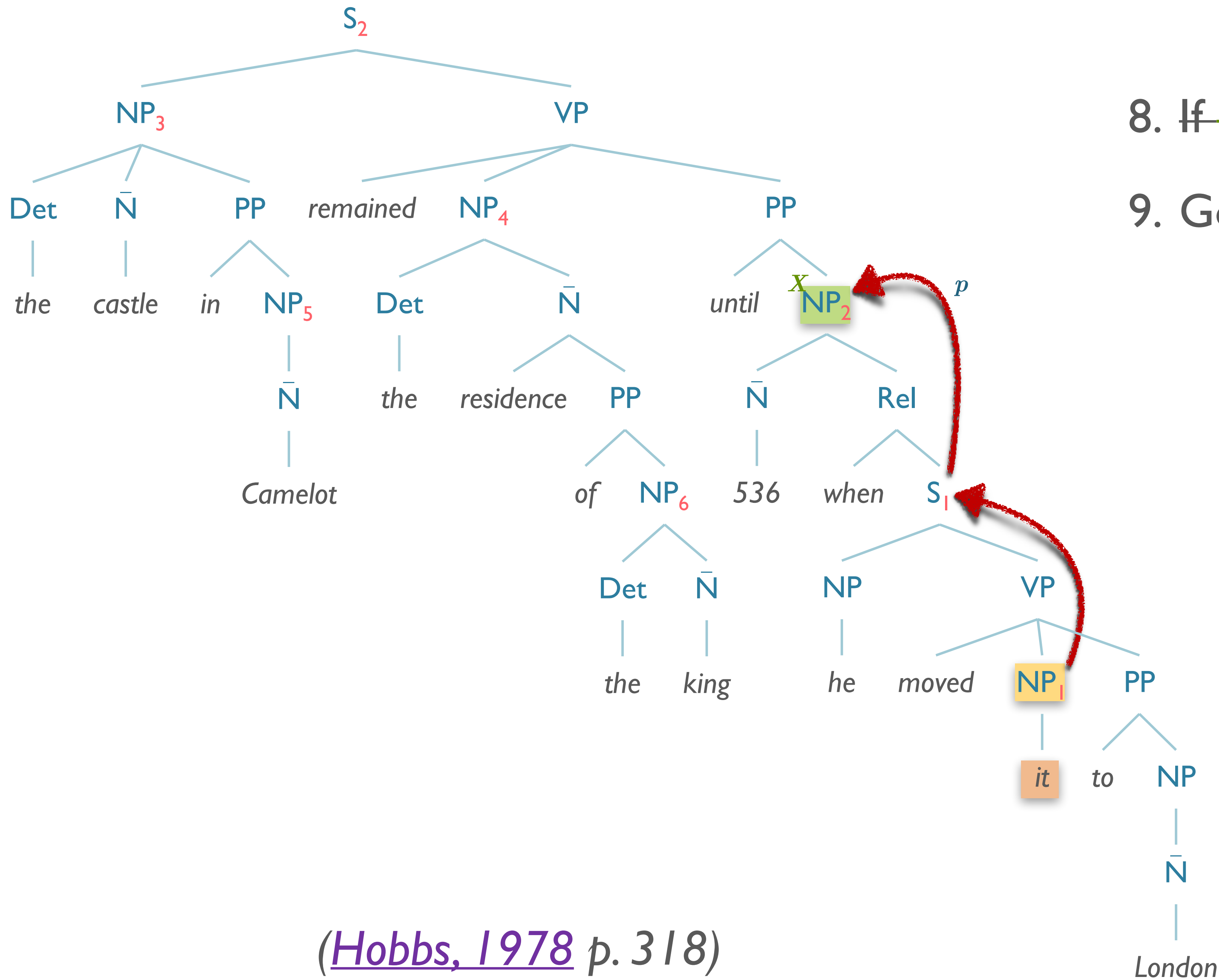
7. ~~Traverse all branches below node **X** to the left of path **p** in a left-to-right, breadth-first manner. Propose any **NP** node encountered as the antecedent.~~

(Hobbs, 1978 p. 318)



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

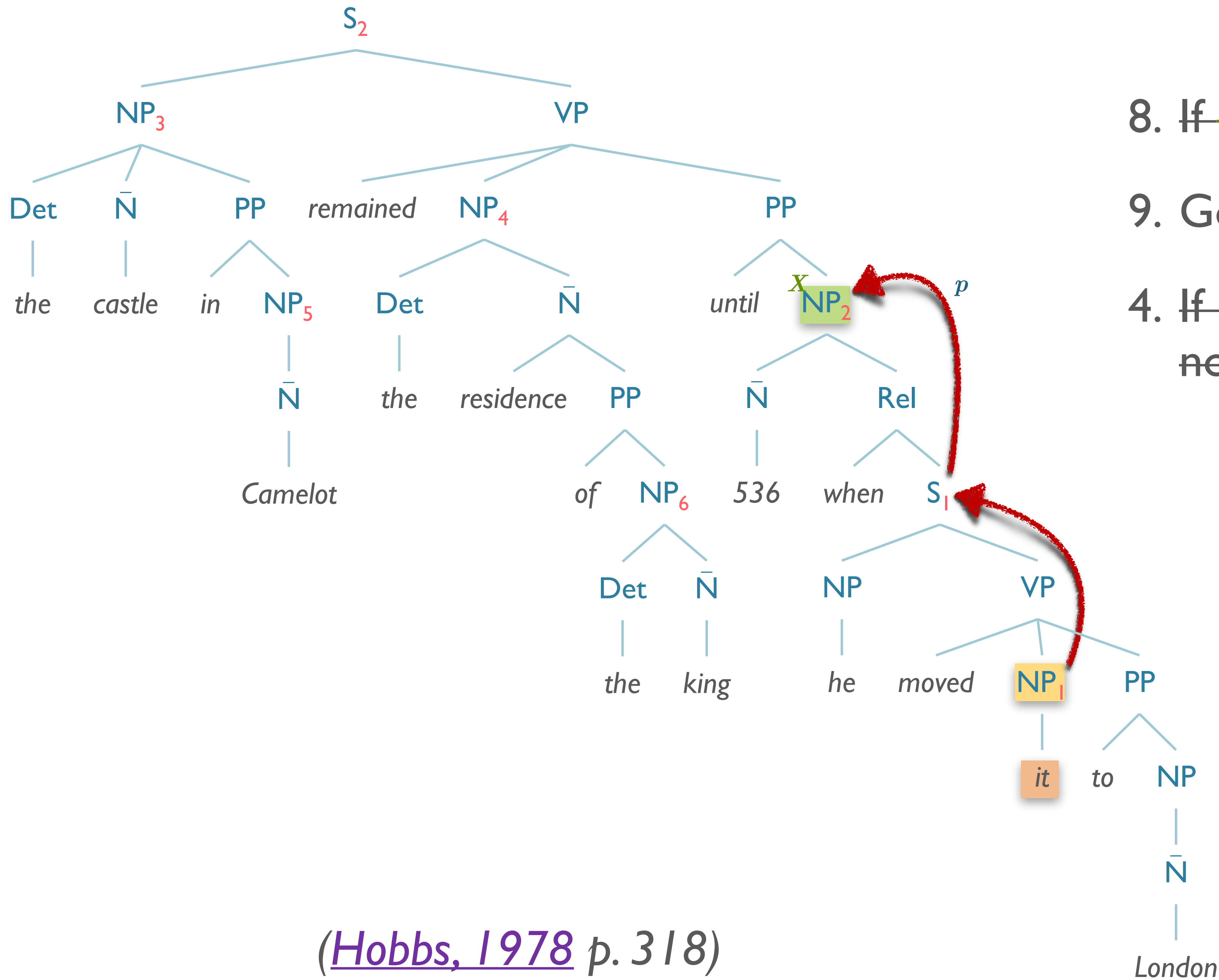
(Hobbs, 1978 p. 318)



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

9. Go to step 4.

(Hobbs, 1978 p. 318)

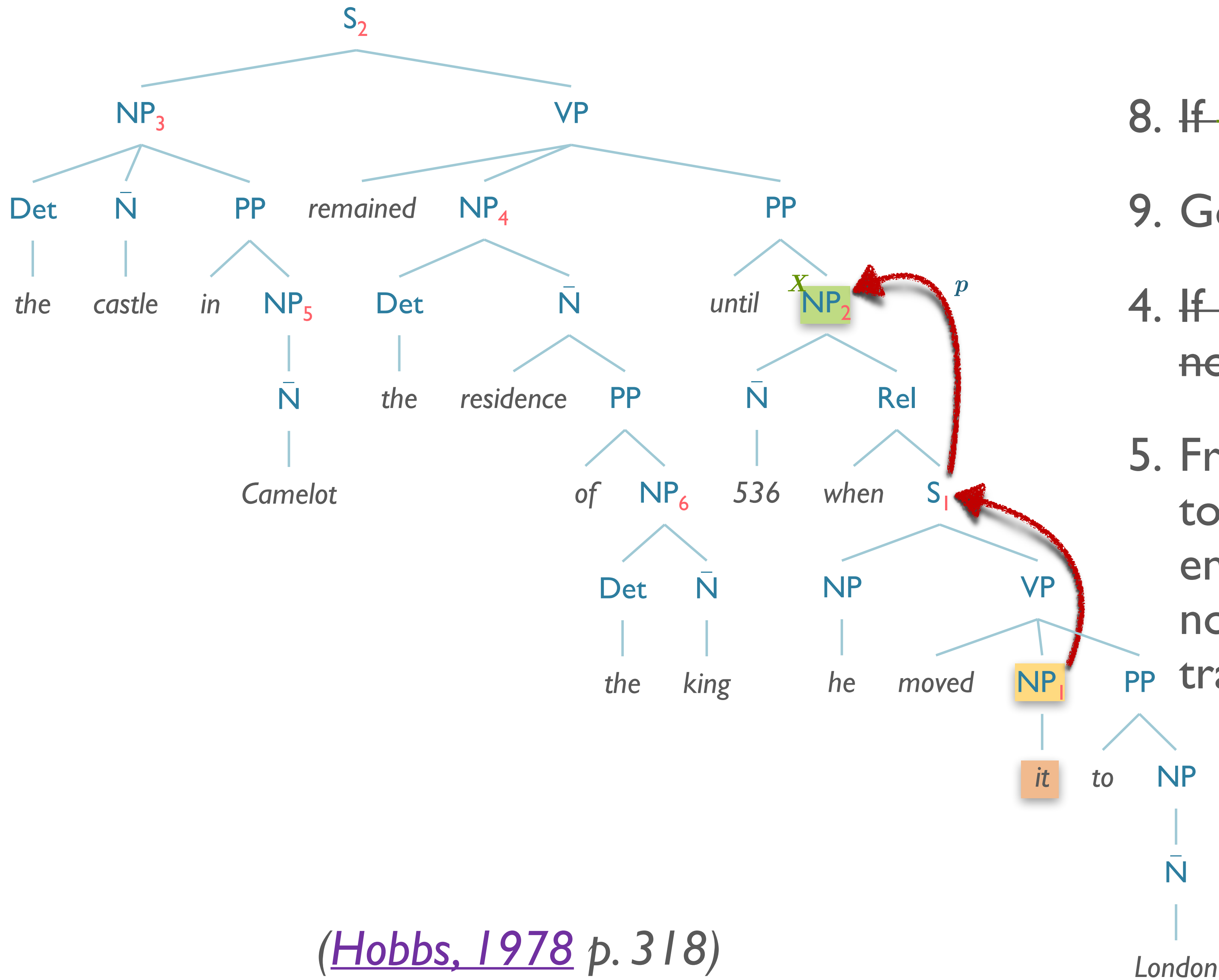


(Hobbs, 1978 p. 318)

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

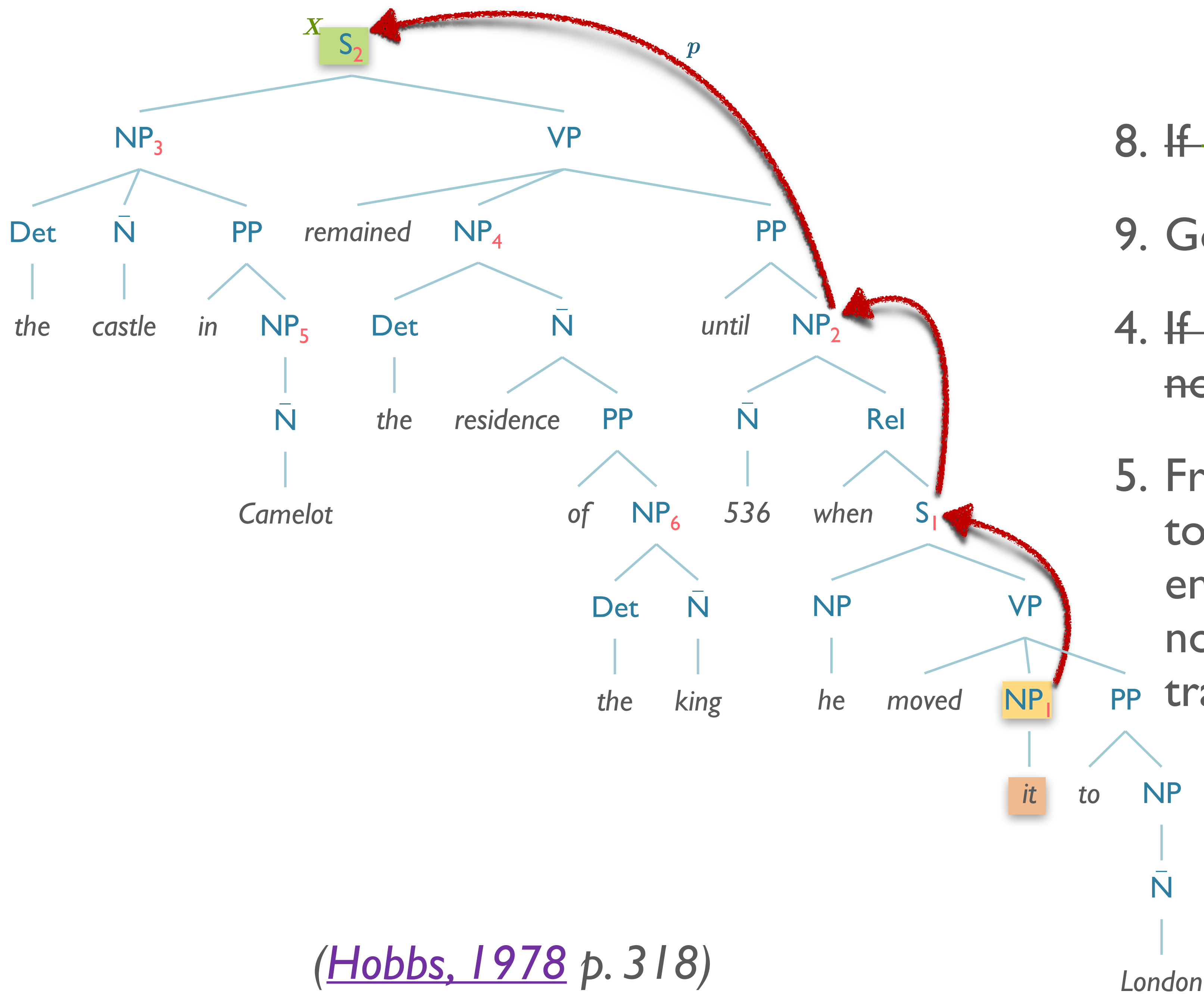
9. Go to step 4.

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



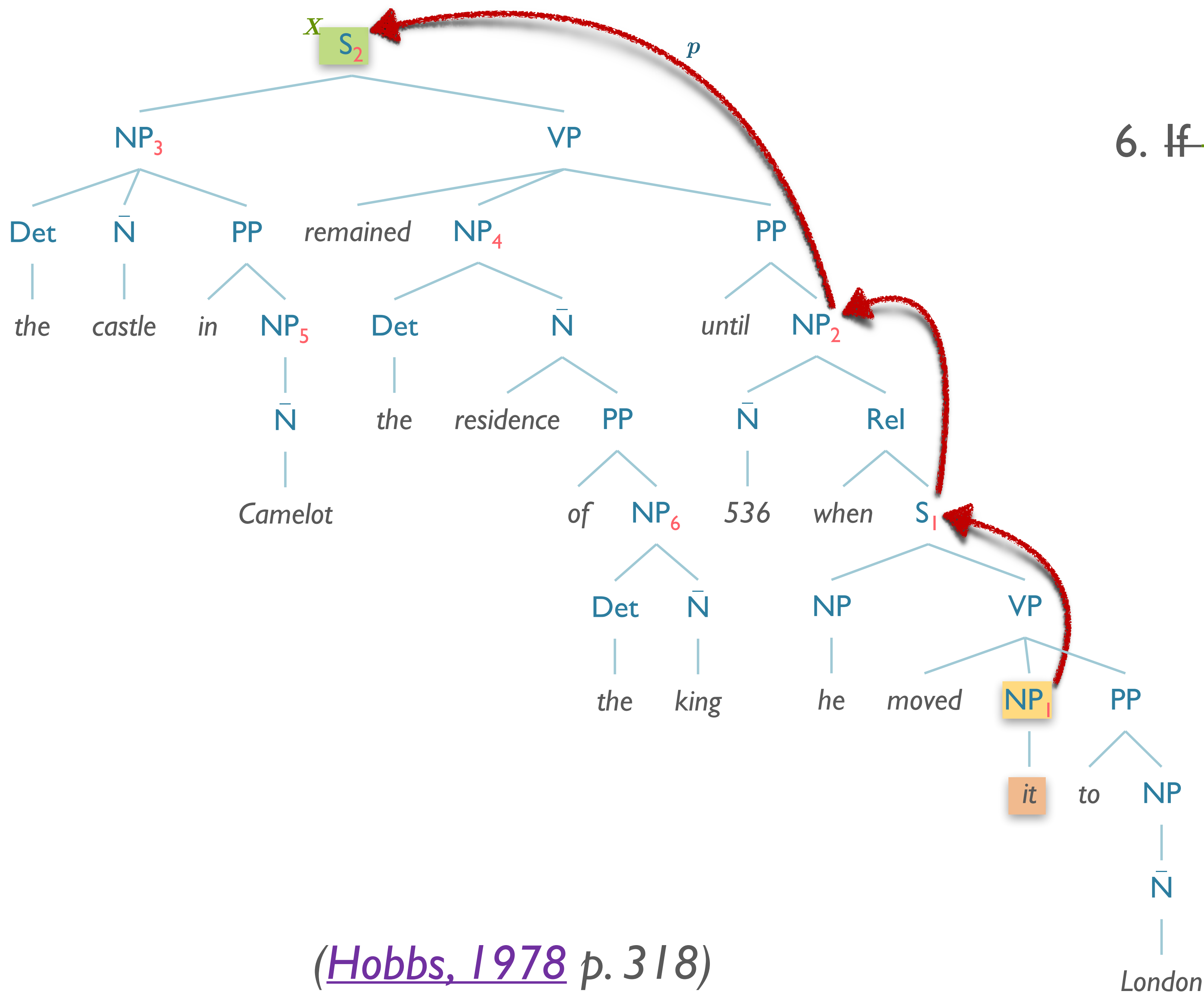
(Hobbs, 1978 p. 318)

- 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.



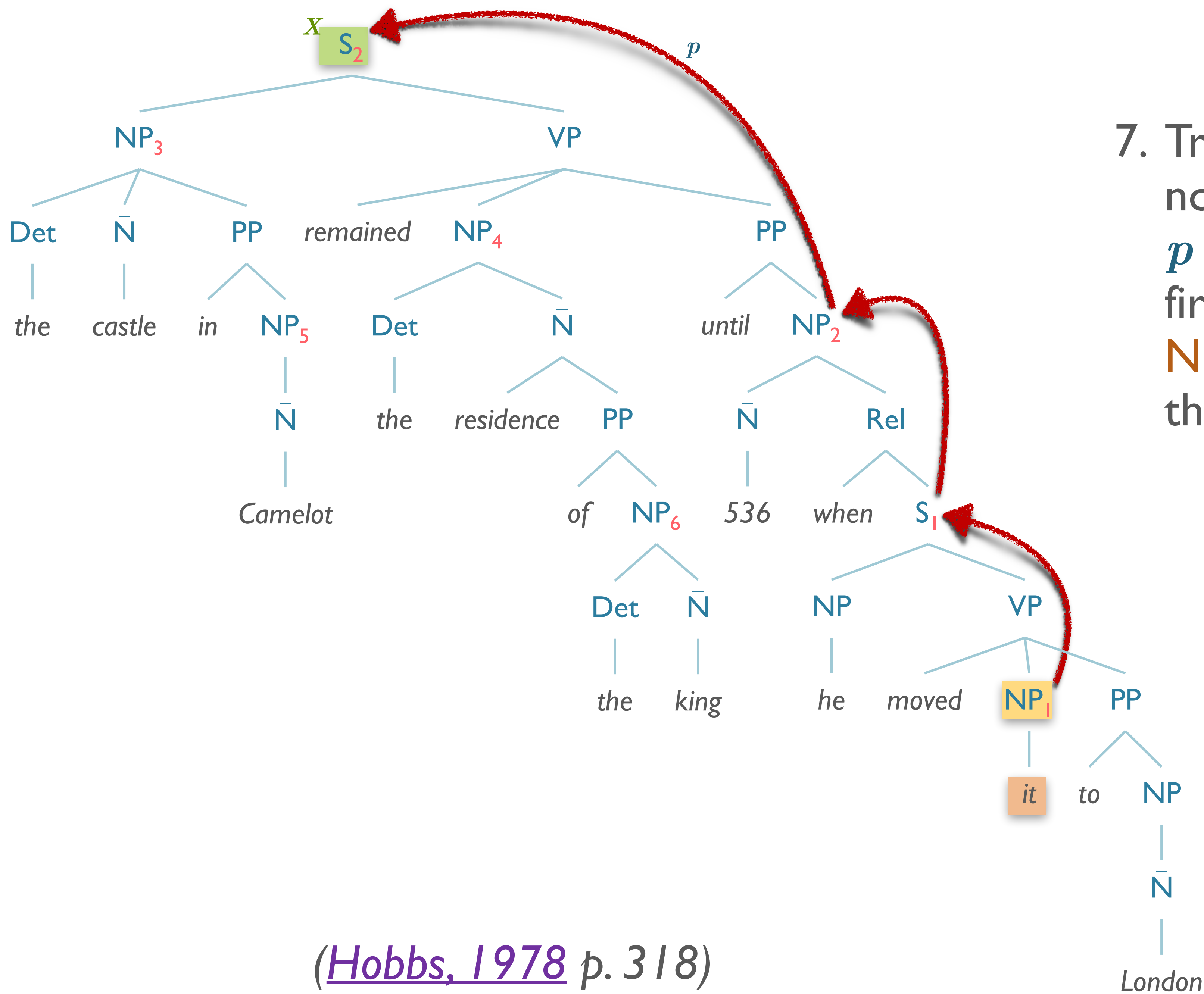
(Hobbs, 1978 p. 318)

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**.



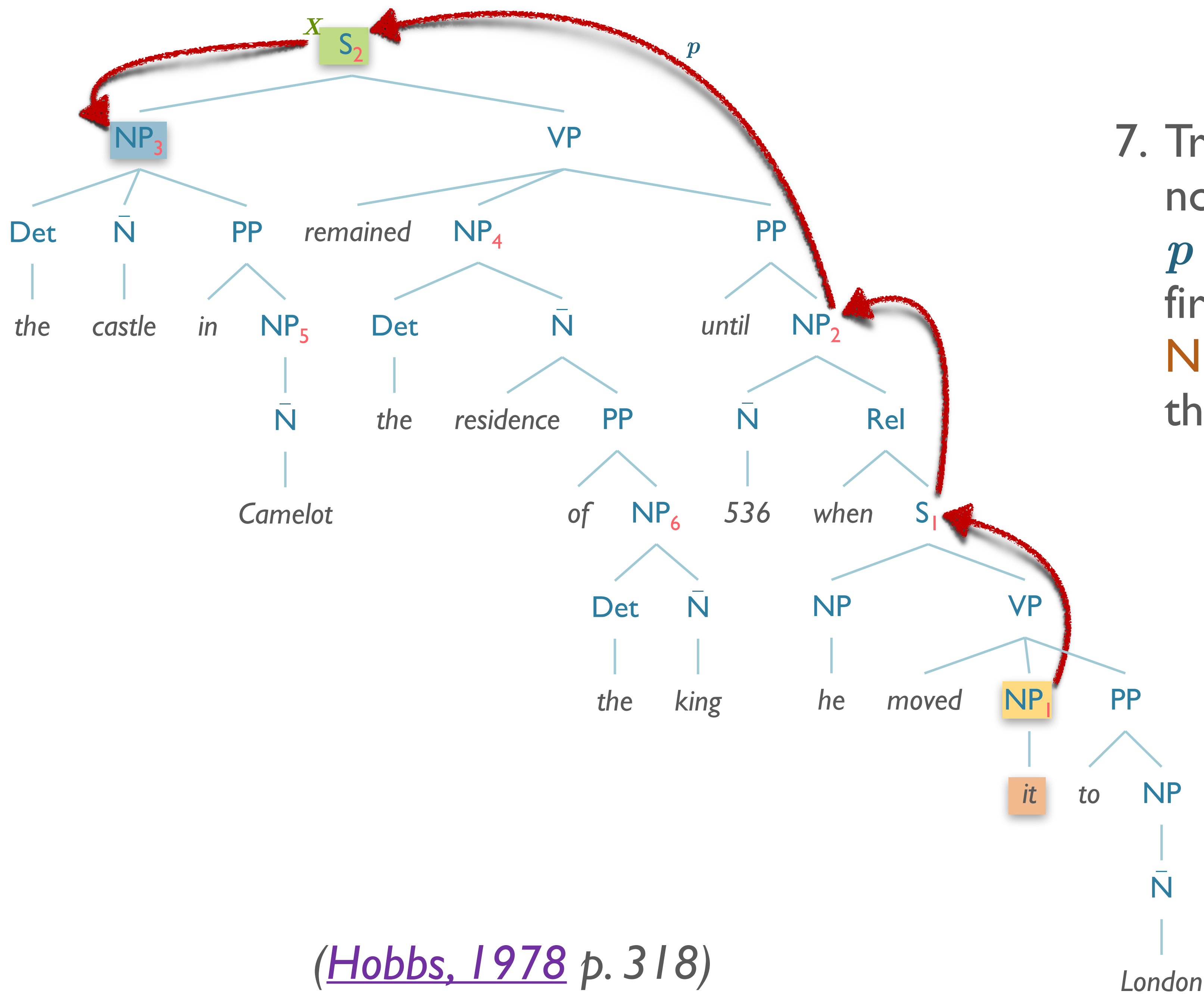
6. If ~~X~~ is an NP node...

(Hobbs, 1978 p. 318)



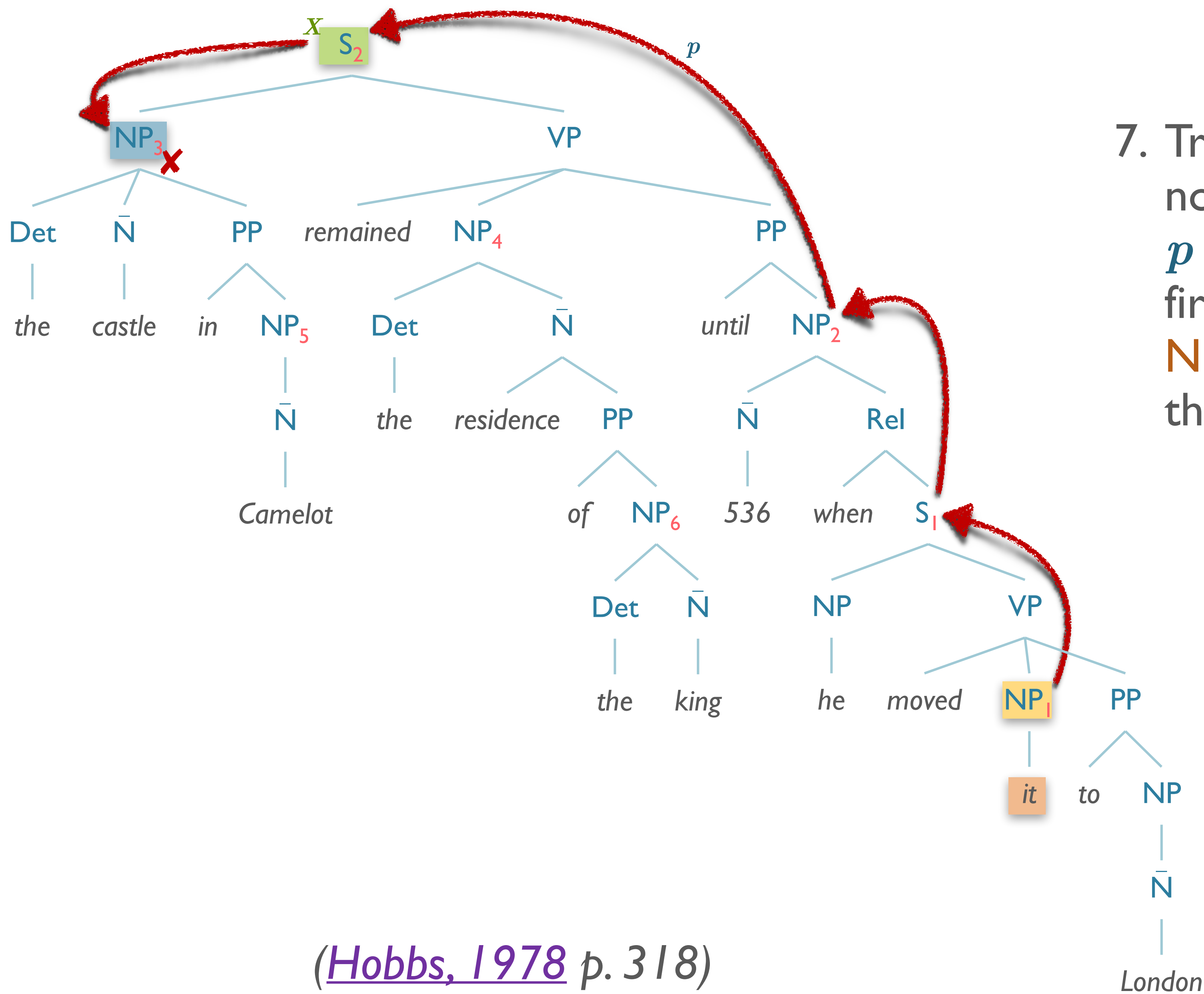
7. Traverse all branches below node X to the *left* of path p in a left-to-right, breadth-first manner. Propose any **NP** node encountered as the antecedent.

(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.

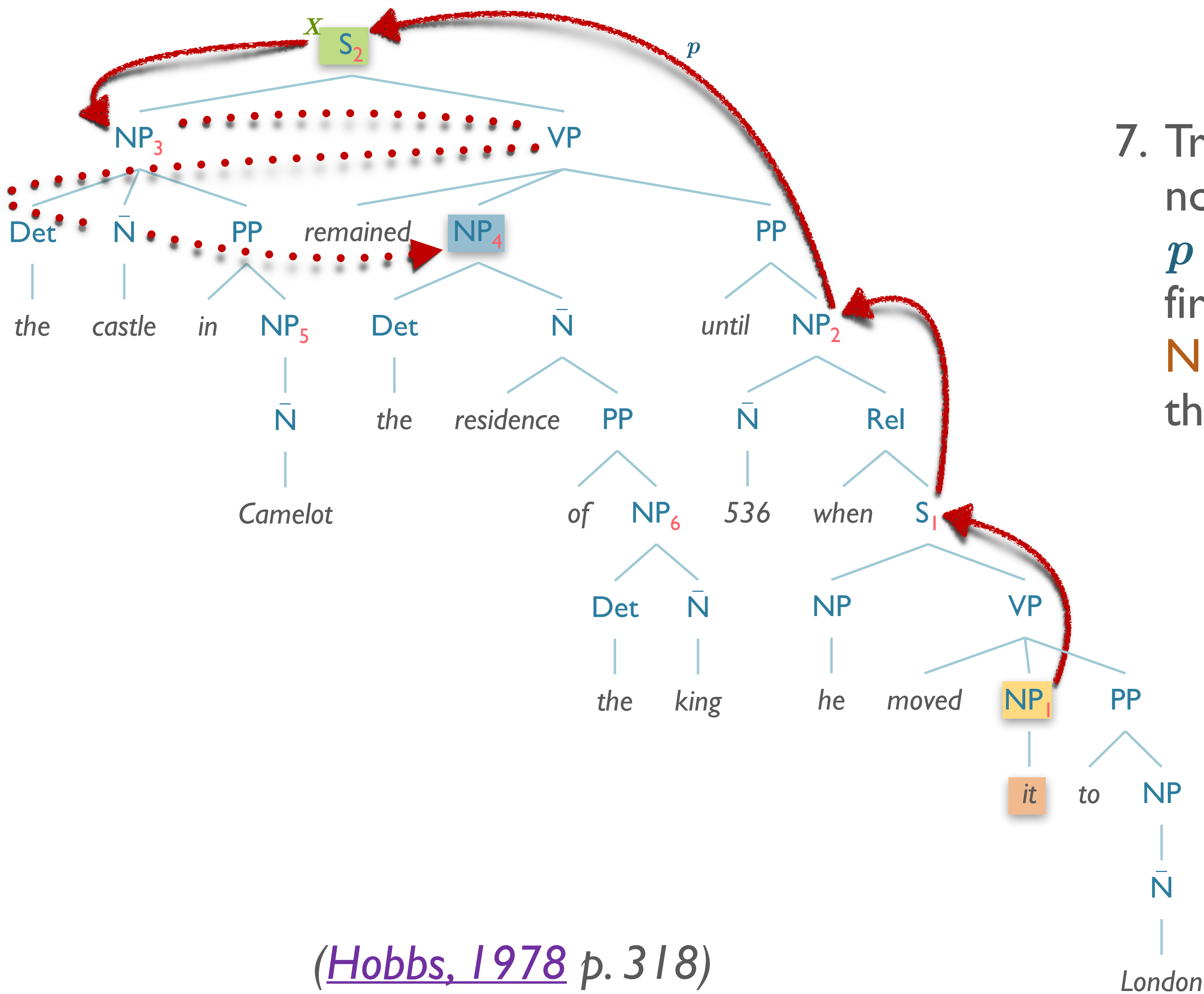
(Hobbs, 1978 p. 318)



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.

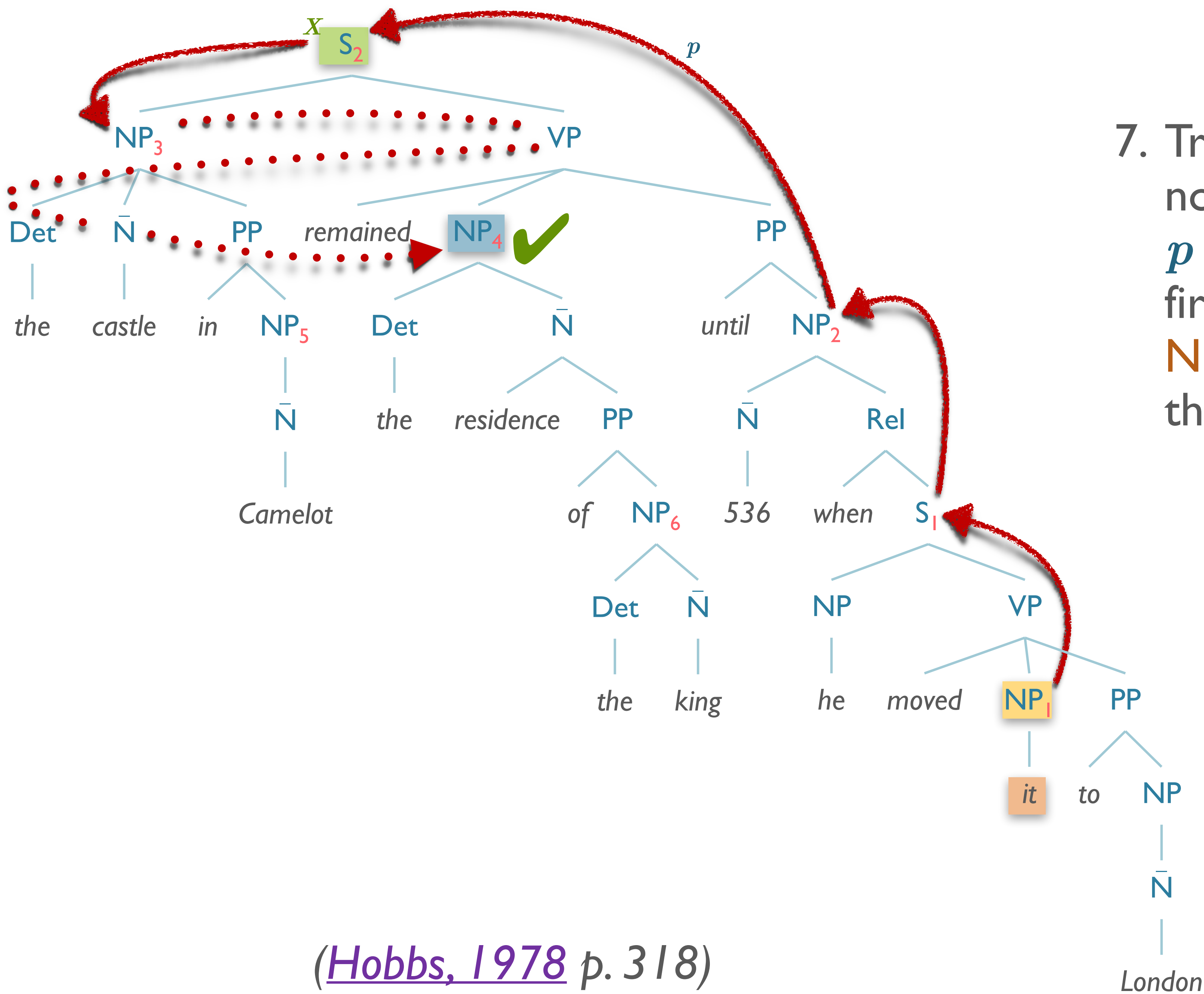
Moving castles? 🤔

(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.

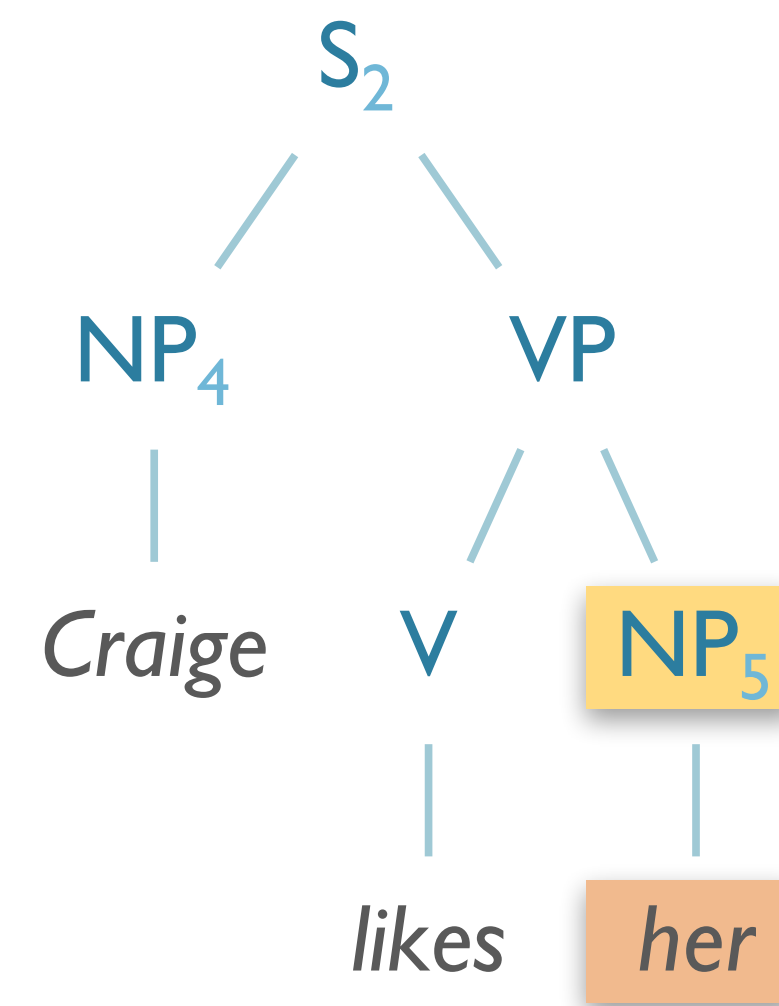
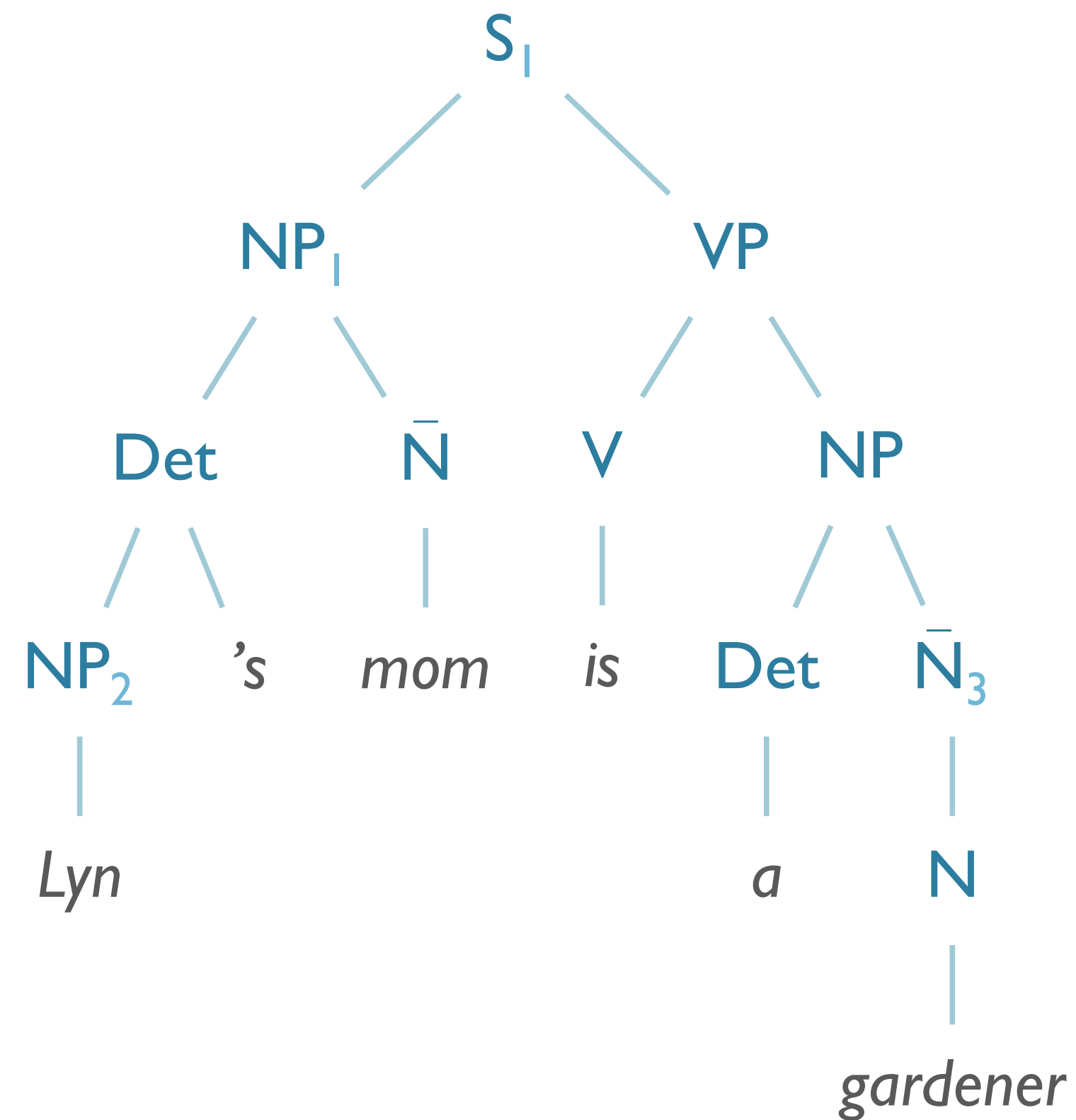
Hobbs Algorithm Detail (Hobbs, 1978)

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.

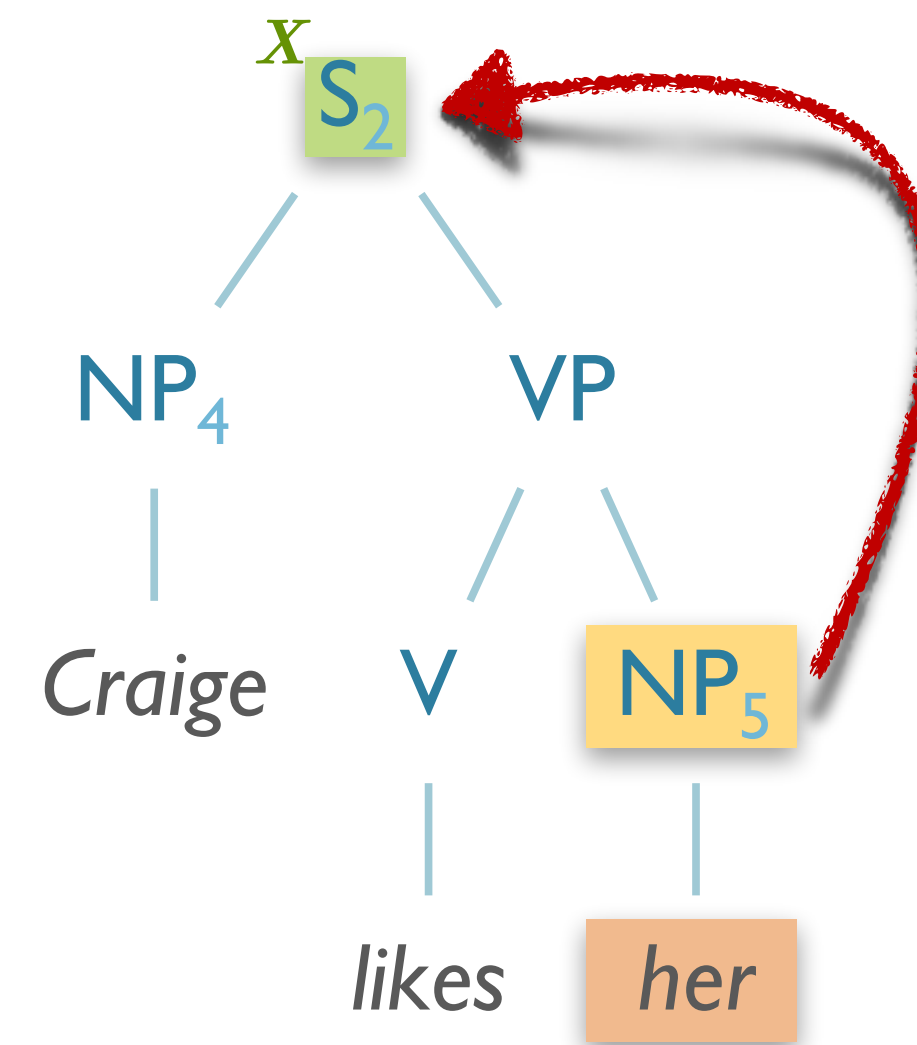
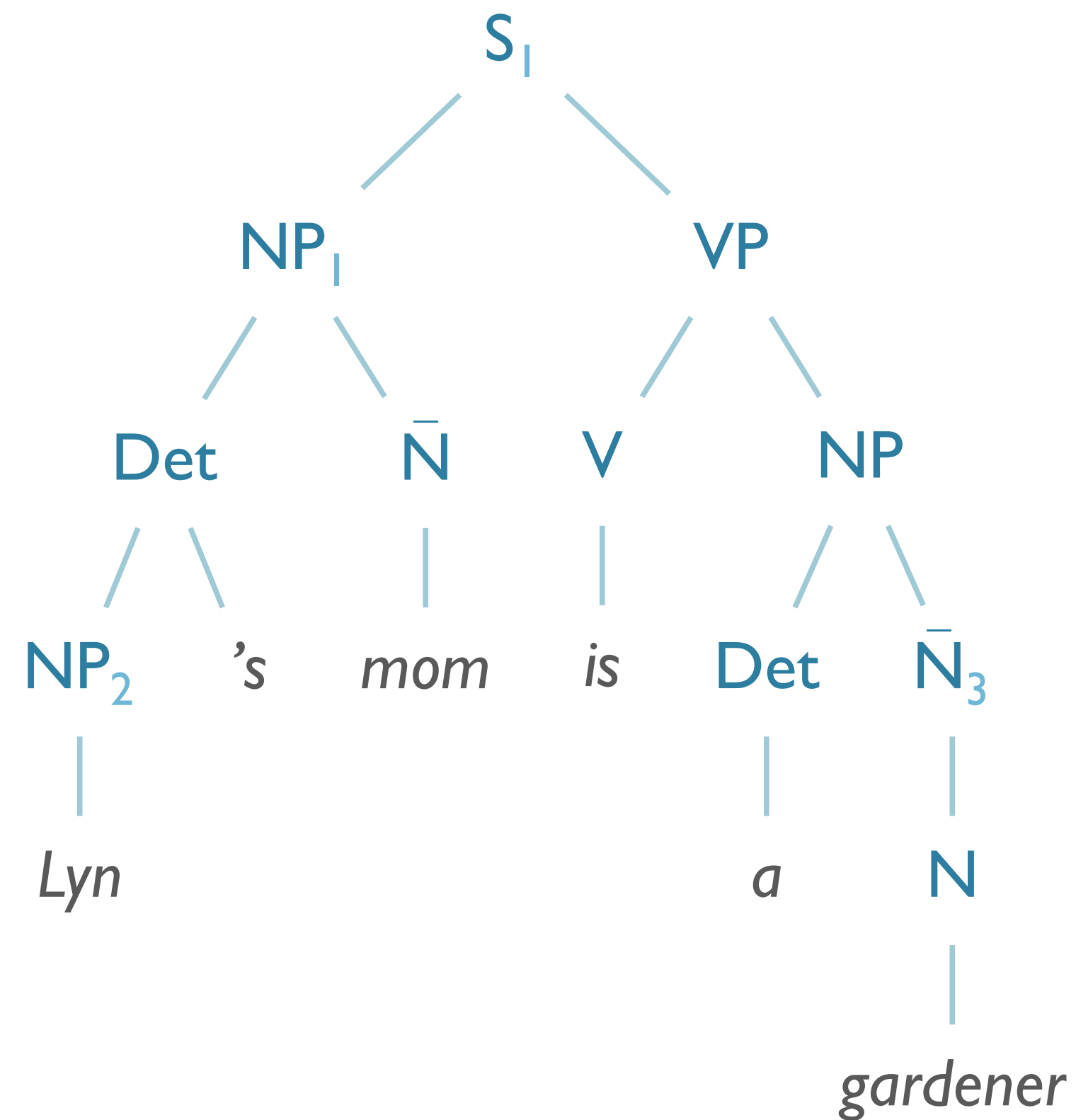


1. Begin at the noun phrase (NP) node immediately dominating the pronoun

Hobbs Example

Lyn's mom is a gardener.

Craige likes her.

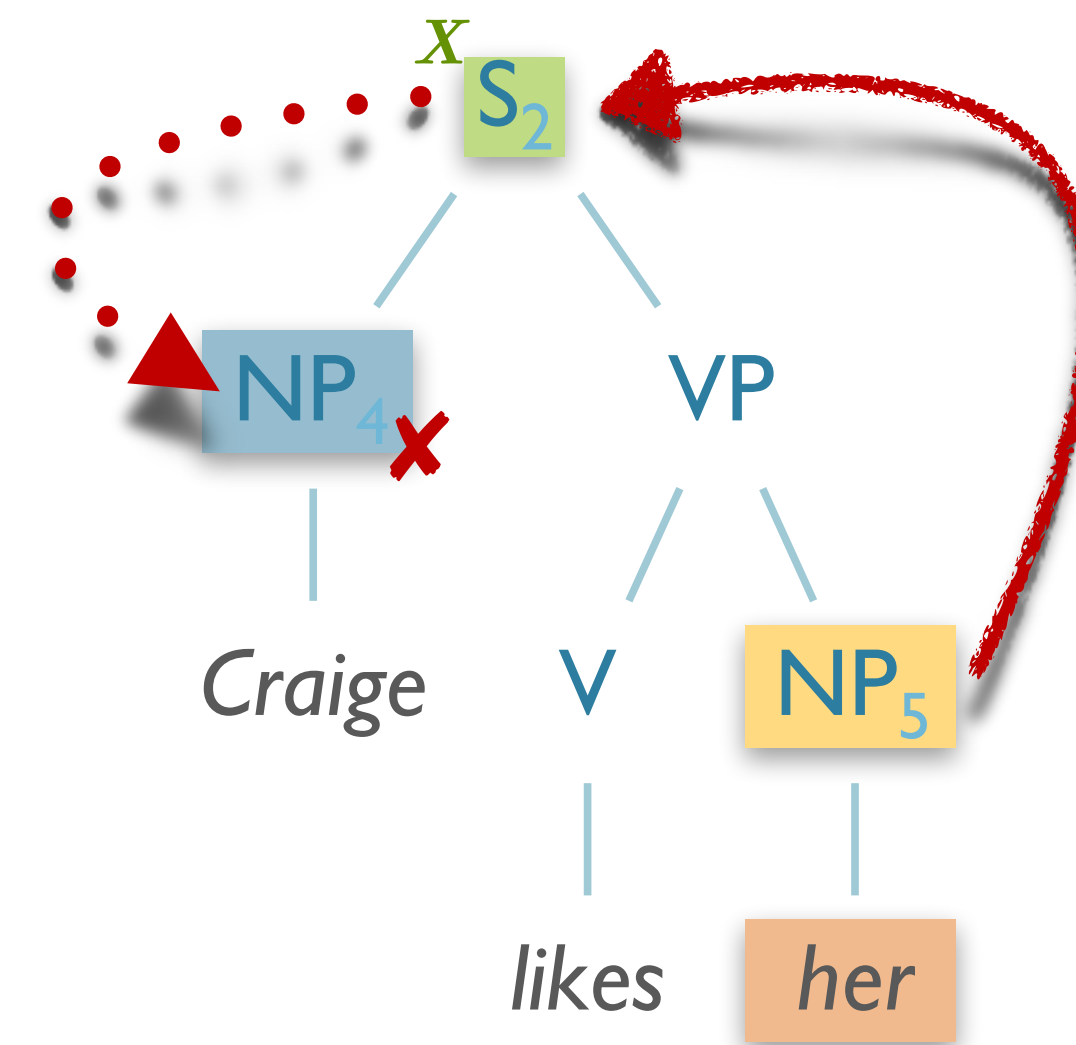
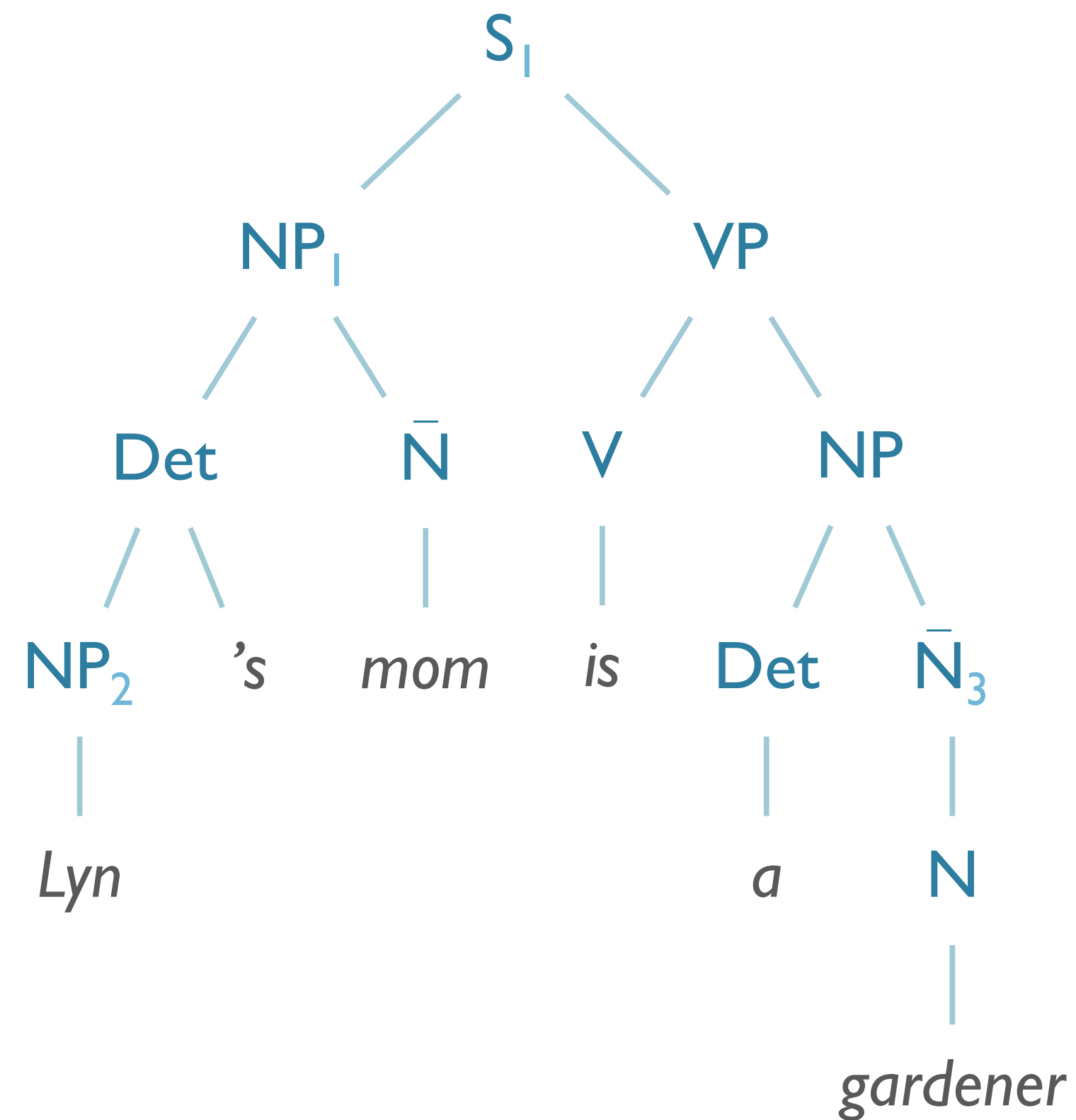


2. Go up the tree to the first **NP** or sentence (**S**) node encountered. Call this node **X**, and call the path used to reach it *p*.

Hobbs Example

Lyn's mom is a gardener.

Craige likes her.

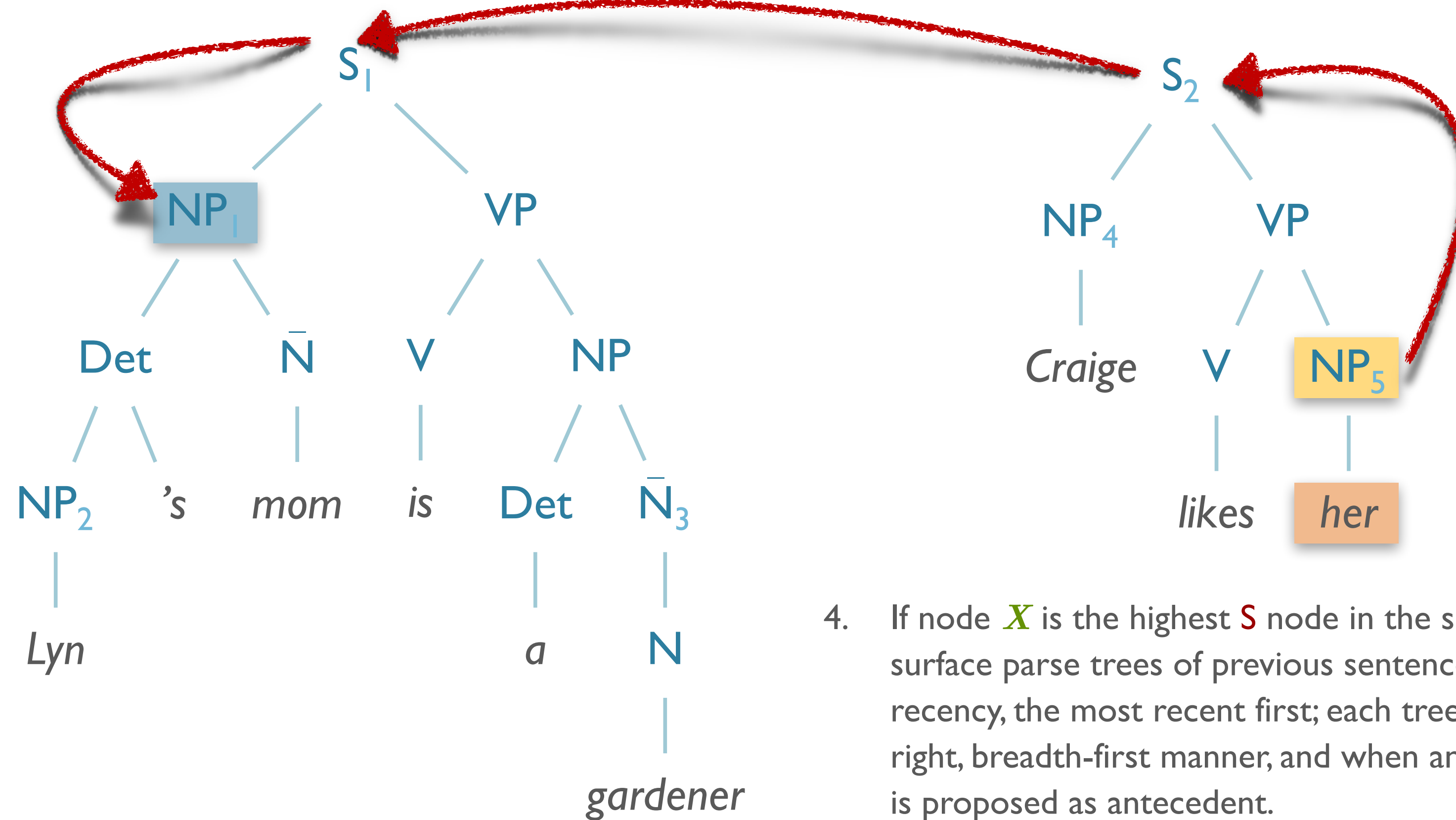


3. Traverse all branches below node X to the left of path p in a left-to-right, breadth-first fashion. Propose as the antecedent any encountered NP node that has an NP or S node between it and X .

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**.*