Natural Language Processing

Tutorial 5: Grammar and Parsing

Dr. Sun Aixin

Q1. Draw phrase structures of the sentences.

a) Does American airlines have a flight between five a.m. and six a.m.?

b) I would like to fly on American airlines.

c) Please repeat that.

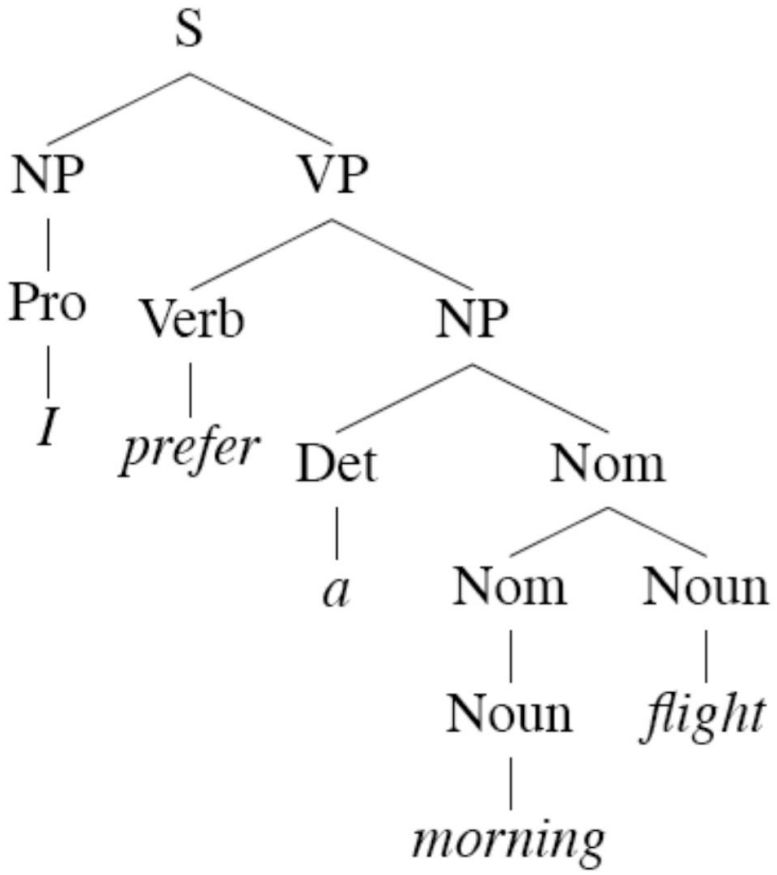
d) I need to fly between Philadelphia and Atlanta.

e) What is the fare from Atlanta to Denver?

Phrase Structure

Review

- Organizes words into nested constituents



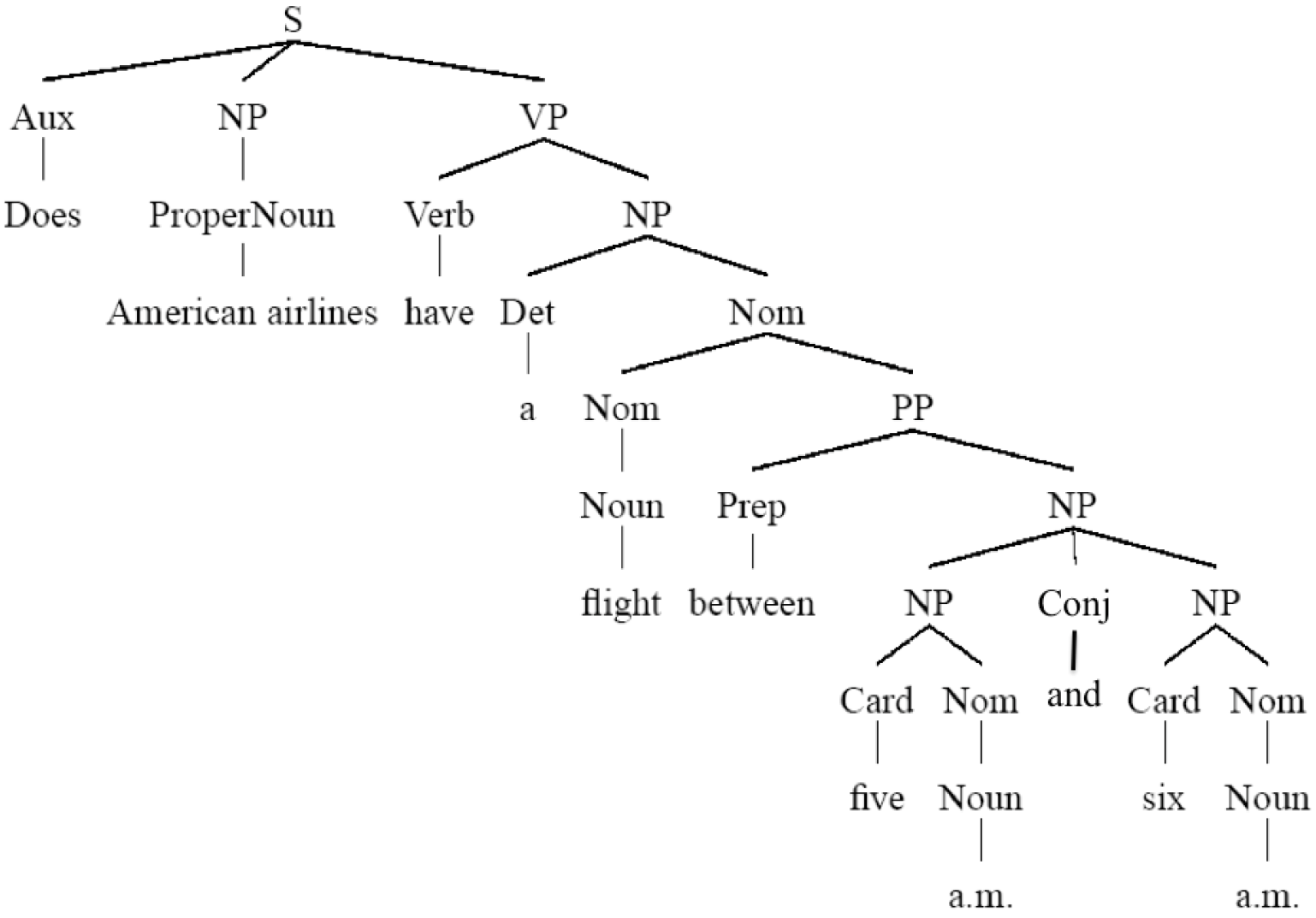
Example constituents

- S
- NP
- Nom
- VP
- PP

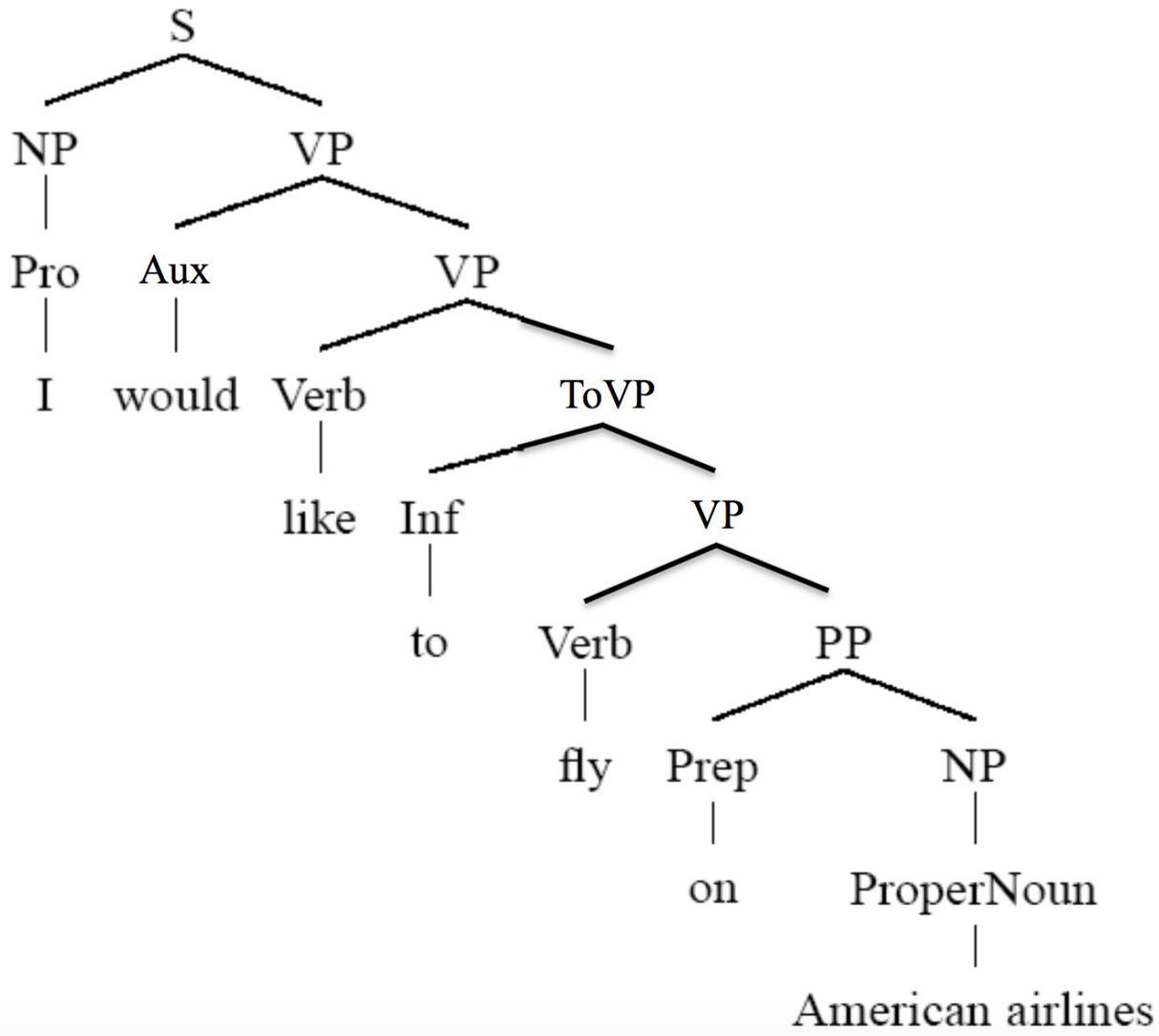
POS Tag Set

- Nouns
  - Noun
  - ProperNoun
- Pronouns
  - Pro
- Modifiers
  - Det
  - Card (cardinal number e.g., five)
  - Adj
  - Adv
- Verbs
  - Verb
  - Aux (e.g., may)
- Prepositions
  - Prep
- Infinitives (to-Verb)
  - Inf (i.e., to)
- Conjunctor (e.g., and)
  - Conj

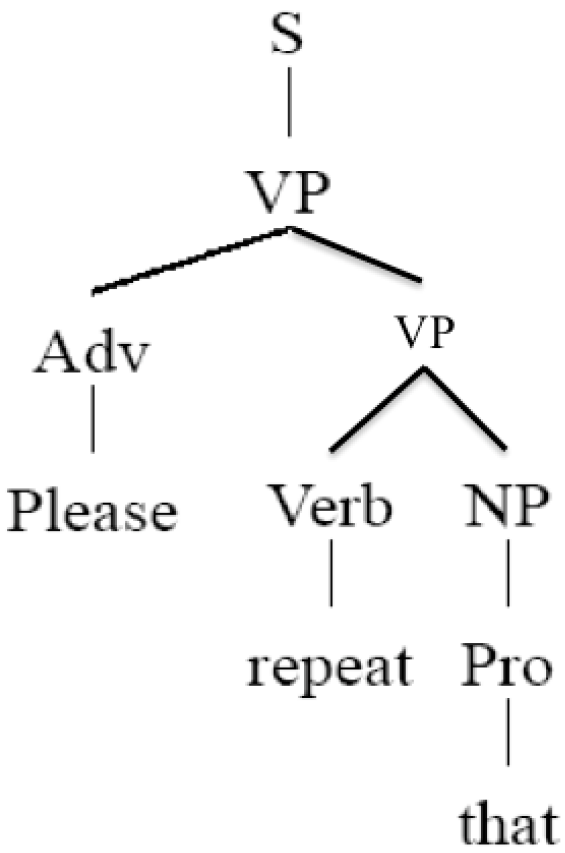
(a). Does American airlines have a flight between five a.m. and six a.m.?



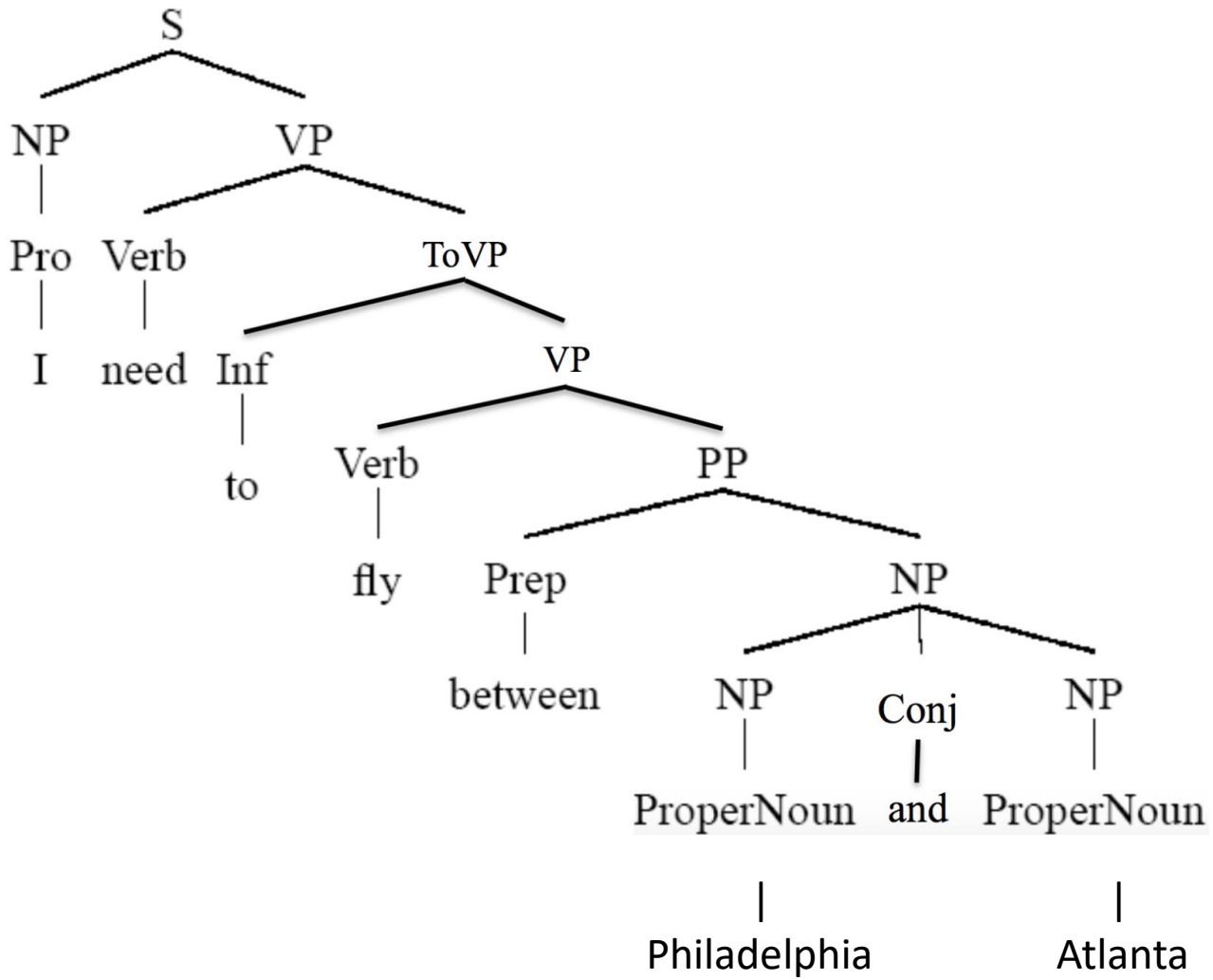
(b). I would like to fly on American airlines.



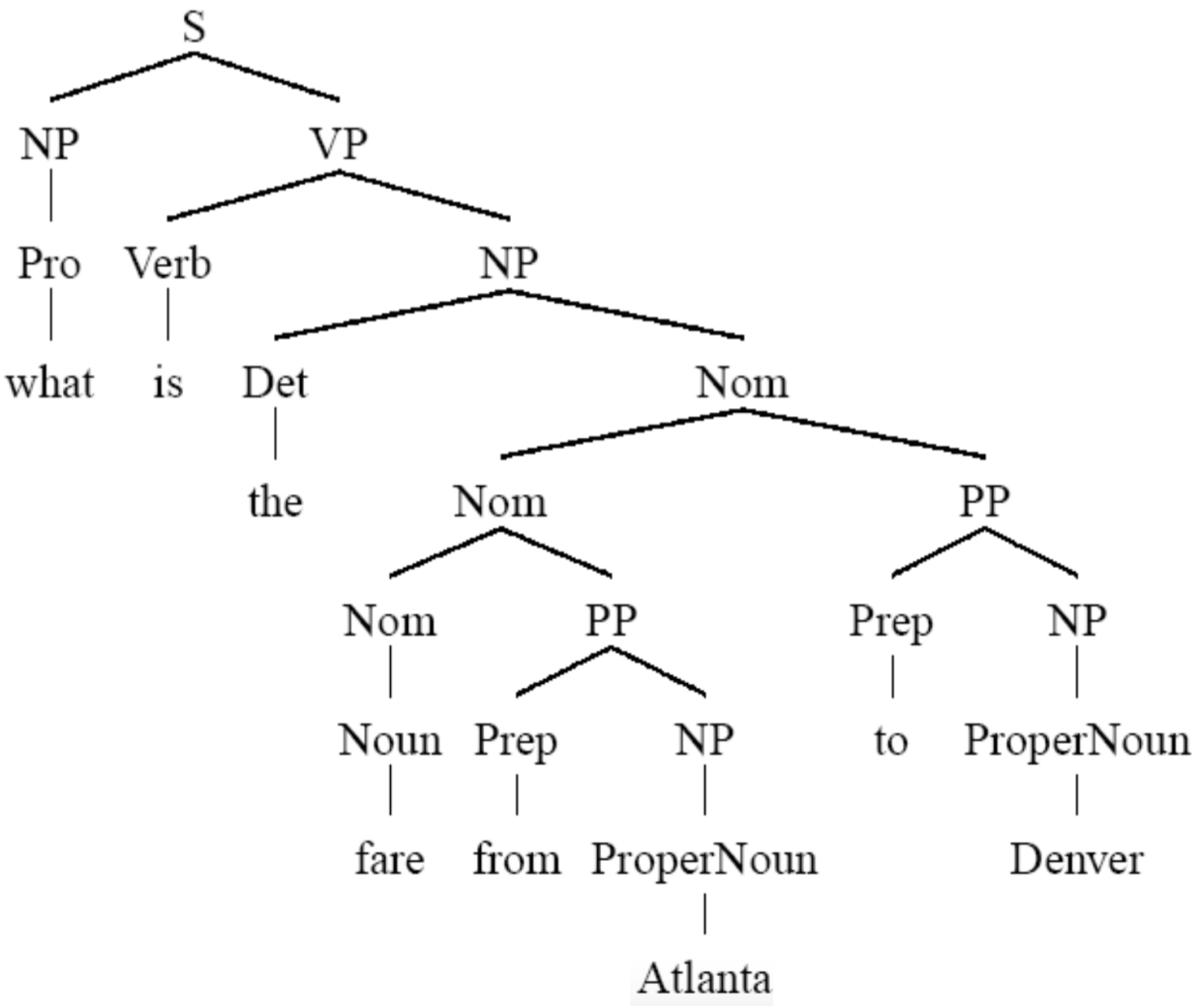
(c). Please repeat that.



(d). I need to fly between Philadelphia and Atlanta.



(e). What is the fare from Atlanta to Denver?



Q2. Consider the L1 grammar used in our lectures.

S→ NP VP	Nominal → Noun	NP→ Verb PP
S→ Aux NP VP	Nominal → Nominal Noun	VP → VP PP
S→ VP	Nominal → Nominal PP	PP→ Preposition NP
NP→ Pronoun	VP→ Verb	
NP→ Proper-Noun	VP→ Verb NP	
NP→ Det Nominal	VP → Verb NP PP	

- *Draw the parse table for the following sentence using the L1 grammar*
  - *Reserve a room at MBS*
- Parse table → CKY Parsing

The CKY algorithm

Review

- CKY algorithm requires grammars to be in Chomsky Normal Form (CNF).
  - CNF rules can only be in two forms: $A \rightarrow B\ C$ or $A \rightarrow w$.
  - That is, the right-hand side of each rule must expand either to **two non-terminals** or to **a single terminal**.

- Any CFG can be converted into a corresponding equivalent CNF grammar
  - Rules that mix terminals with non-terminals on the right-hand side
    - e.g., *INF-VP → to VP*. Create a dummy non-terminal *TO*
    - *INF-VP → to VP* becomes *INF-VP → TO VP* and *TO → to*
  - Rules that have a single non-terminal on the right-hand side
    - e.g., *S→ VP*. Rewrite the right-hand side and expand *VP* with all its corresponding rules. *S→ VP* becomes *S→ Verb NP*, *S→ Verb NP PP*, and …
  - Rules that the length of the right-hand side is greater than 2
    - e.g., *S→ Verb NP PP*. Create a dummy non-terminal *X1*. *S→ Verb NP PP* becomes *S→X1 NP*, *X1→Verb NP*

An example CFG grammar in its CNF form

Review

$\mathcal{L}_1$ Grammar	$\mathcal{L}_1$ in CNF
$S \rightarrow NP\ VP$	$S \rightarrow NP\ VP$
$S \rightarrow Aux\ NP\ VP$	$S \rightarrow X1\ VP$
	$X1 \rightarrow Aux\ NP$
$S \rightarrow VP$	$S \rightarrow book \mid include \mid prefer$
	$S \rightarrow Verb\ NP$
	$S \rightarrow X2\ PP$
	$S \rightarrow Verb\ PP$
	$S \rightarrow VP\ PP$
$NP \rightarrow Pronoun$	$NP \rightarrow I \mid she \mid me$
$NP \rightarrow Proper\text{-}Noun$	$NP \rightarrow TWA \mid Houston$
$NP \rightarrow Det\ Nominal$	$NP \rightarrow Det\ Nominal$
$Nominal \rightarrow Noun$	$Nominal \rightarrow book \mid flight \mid meal \mid money$
$Nominal \rightarrow Nominal\ Noun$	$Nominal \rightarrow Nominal\ Noun$
$Nominal \rightarrow Nominal\ PP$	$Nominal \rightarrow Nominal\ PP$
$VP \rightarrow Verb$	$VP \rightarrow book \mid include \mid prefer$
$VP \rightarrow Verb\ NP$	$VP \rightarrow Verb\ NP$
$VP \rightarrow Verb\ NP\ PP$	$VP \rightarrow X2\ PP$
	$X2 \rightarrow Verb\ NP$
$VP \rightarrow Verb\ PP$	$VP \rightarrow Verb\ PP$
$VP \rightarrow VP\ PP$	$VP \rightarrow VP\ PP$
$PP \rightarrow Preposition\ NP$	$PP \rightarrow Preposition\ NP$

CNF rules can only be in two forms: ***A → B C*** or ***A → w***.

Each non-terminal node above the POS level in a parse tree will have **exactly two** daughters

That is: a non-terminal node can be derived from **exactly TWO constituents** (that can be derived earlier).

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	$X2 \rightarrow Verb\ NP$
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$VP \rightarrow VP\ PP$	$VP \rightarrow VP\ PP$
$PP \rightarrow Preposition\ NP$	$PP \rightarrow Preposition\ NP$

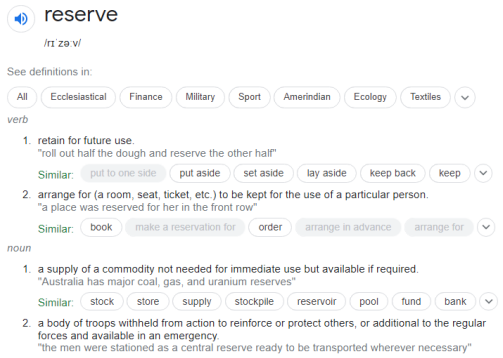
|reserve

|MBS

|reserve

Reserve a room at MBS

reserve|room



Q2(i)

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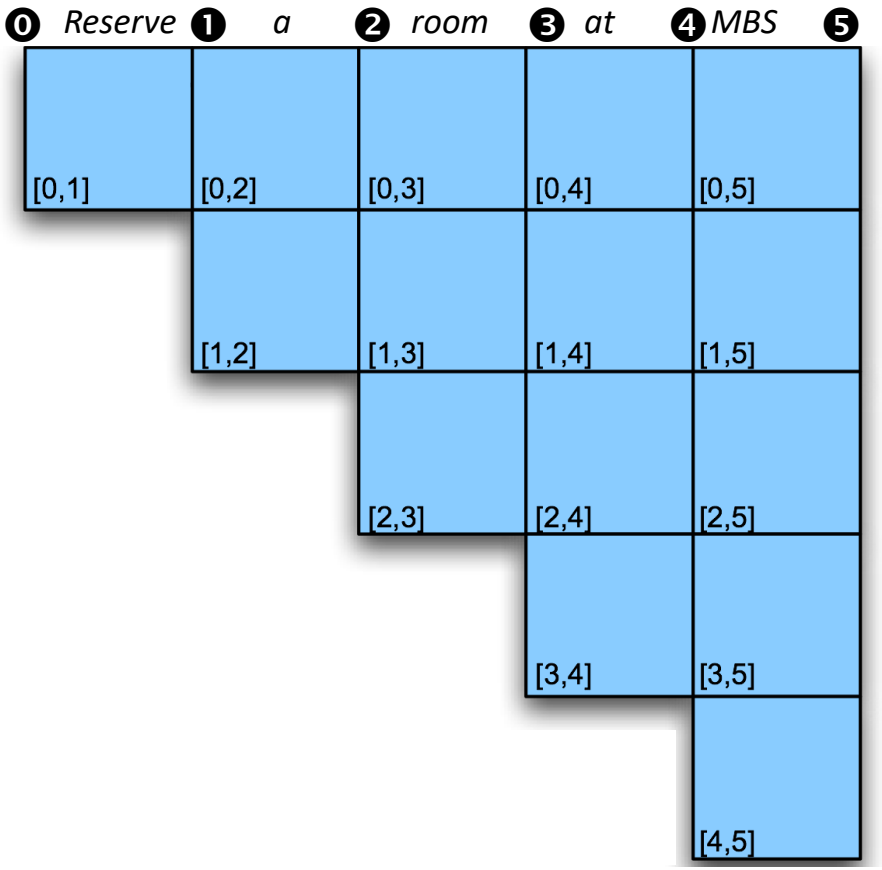

"reserve" can be a noun or verb, similar to "book"

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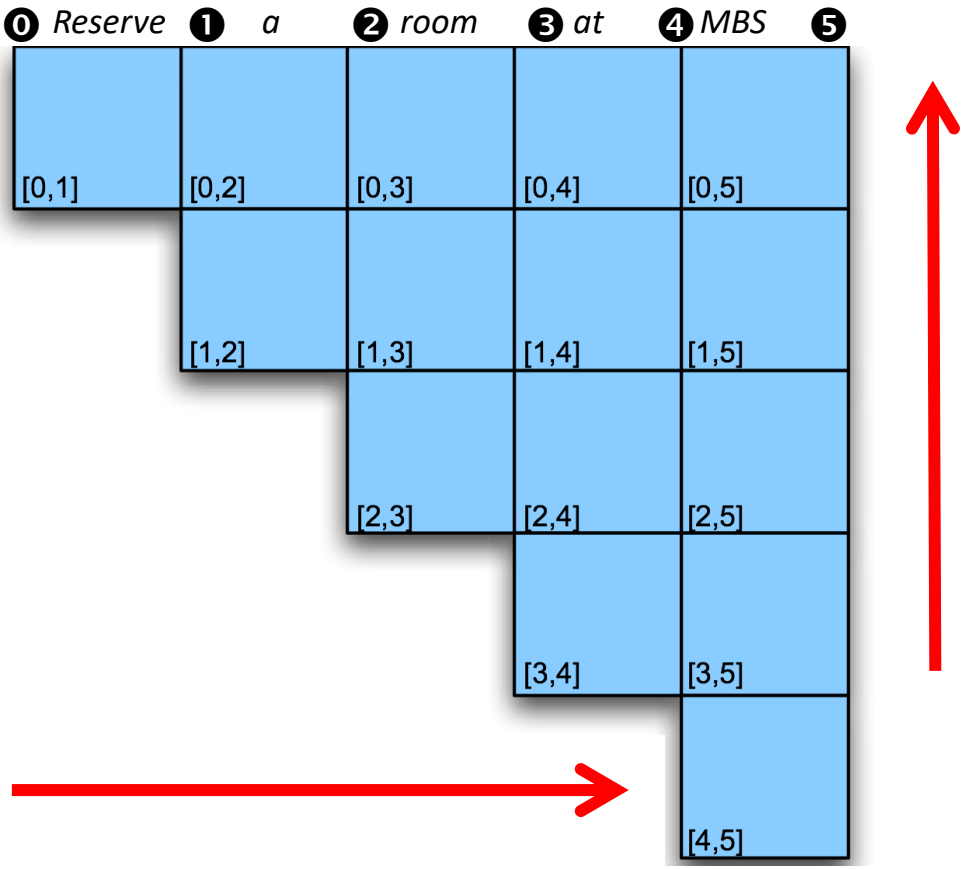

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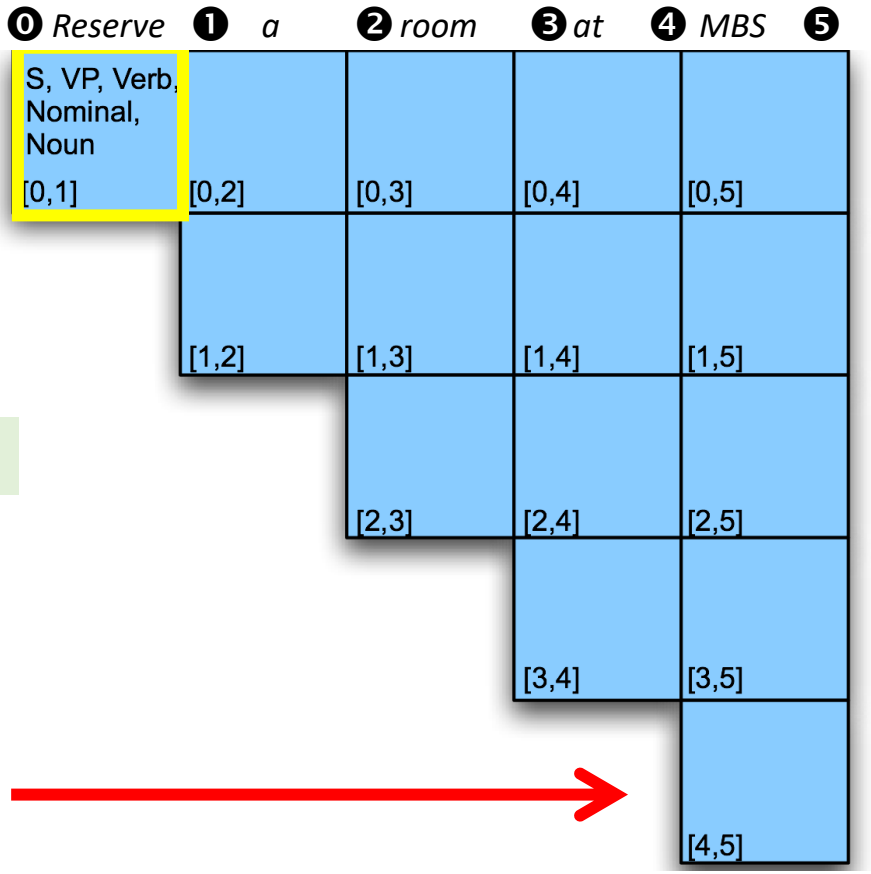

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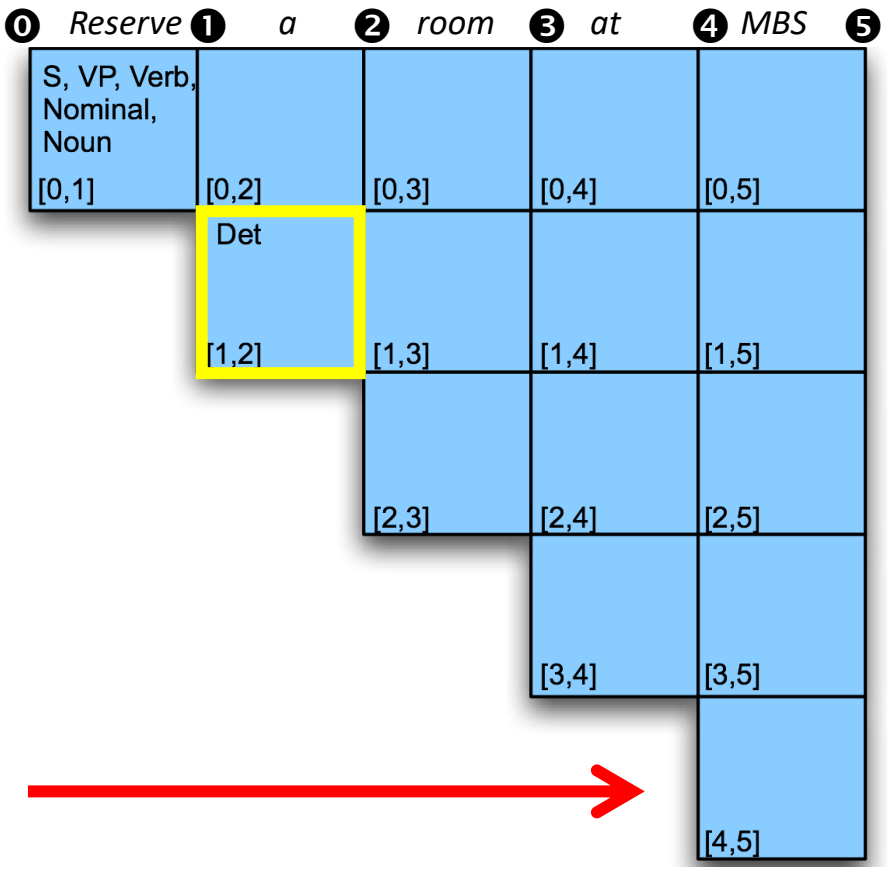

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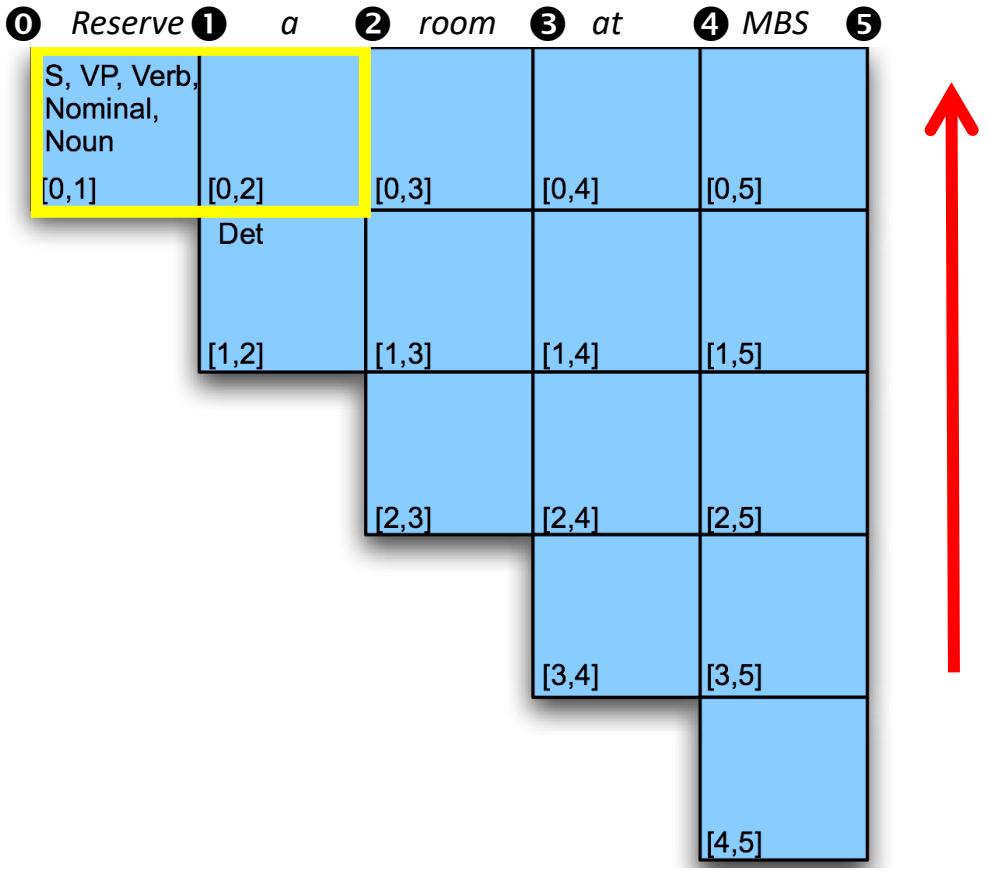

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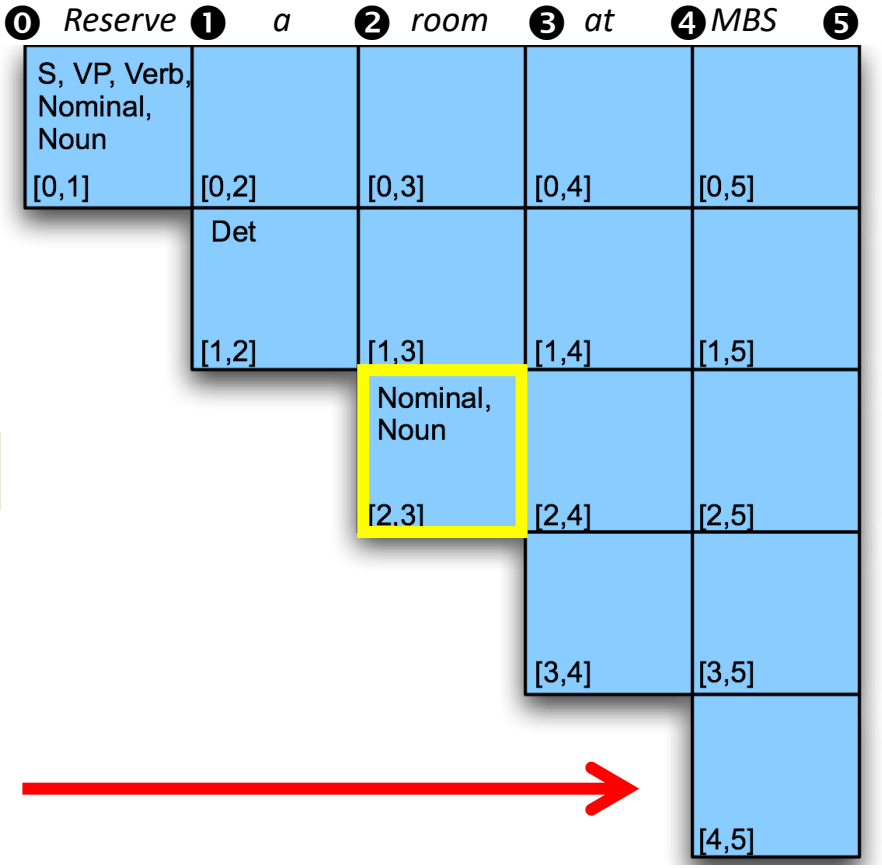
|room



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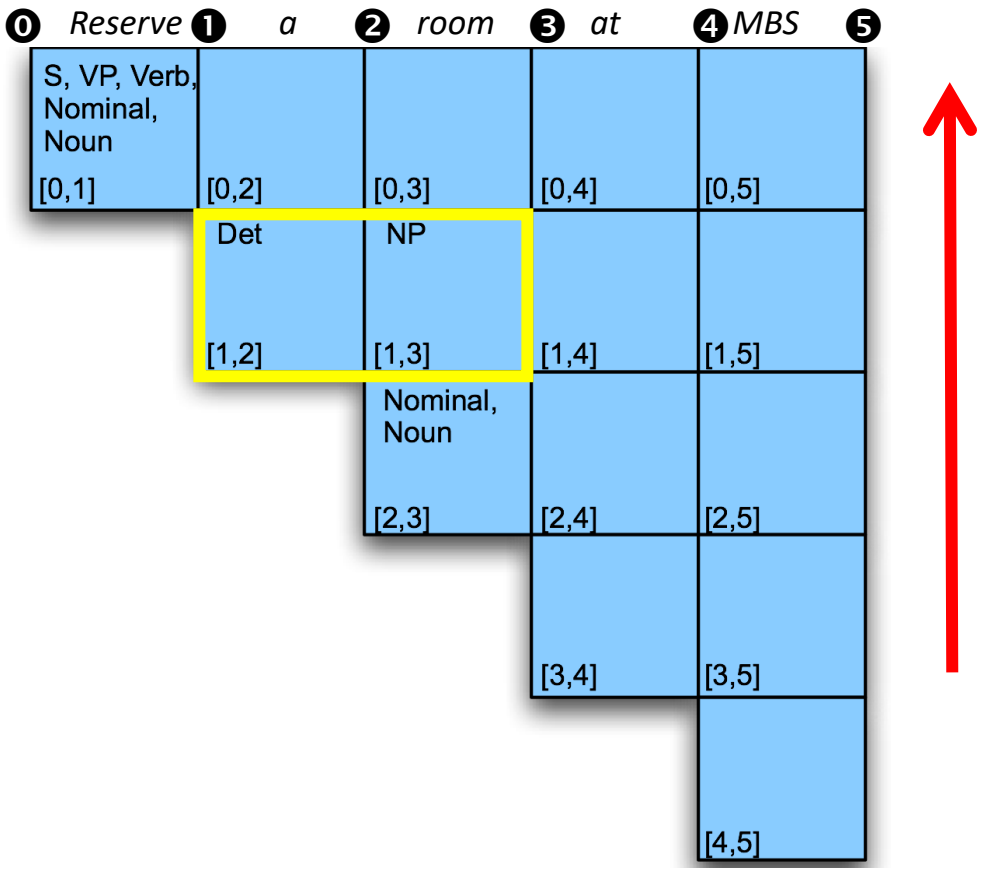

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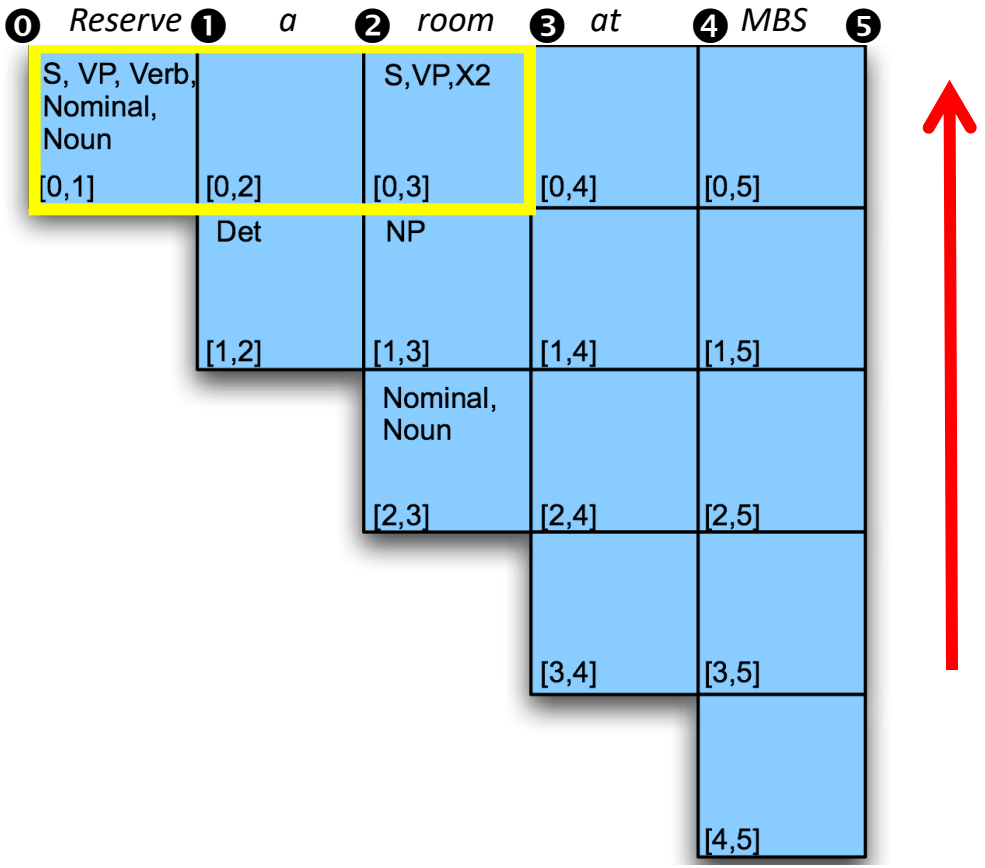

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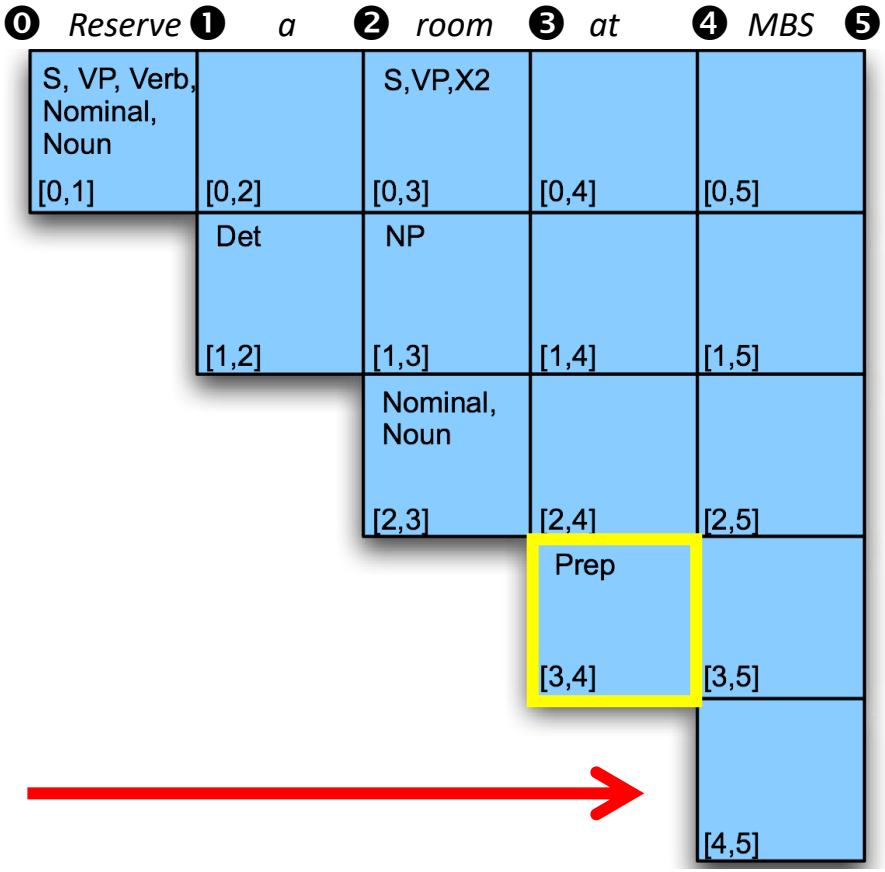

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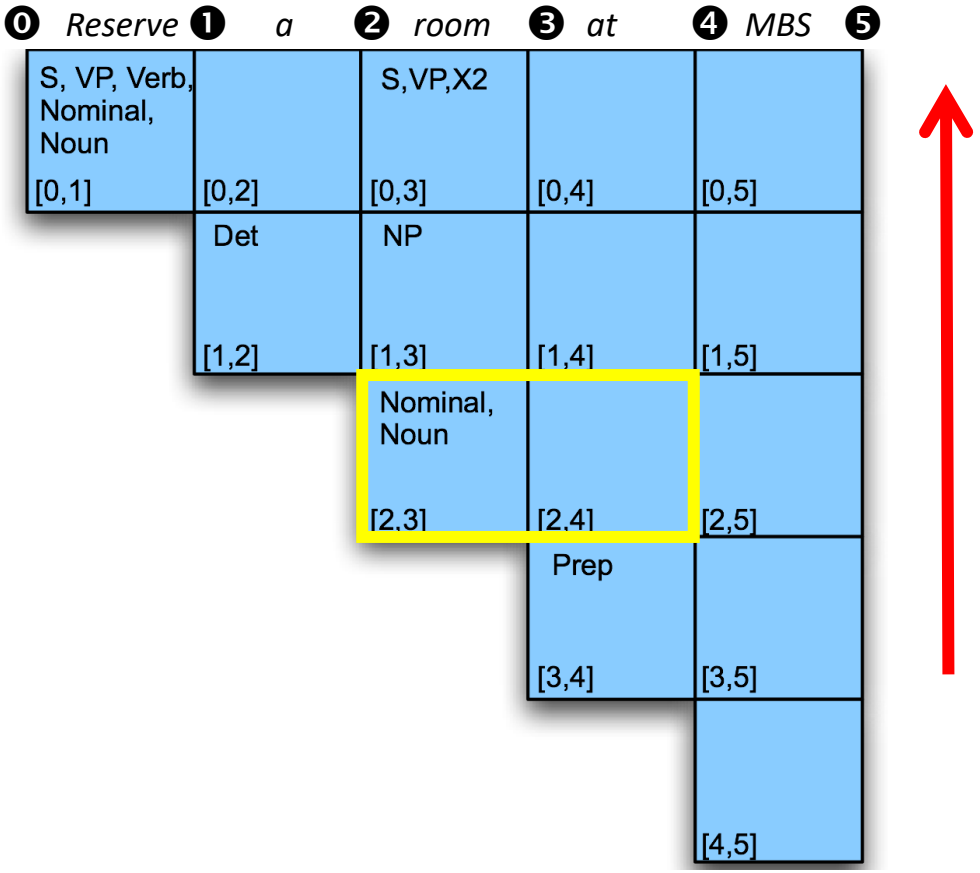

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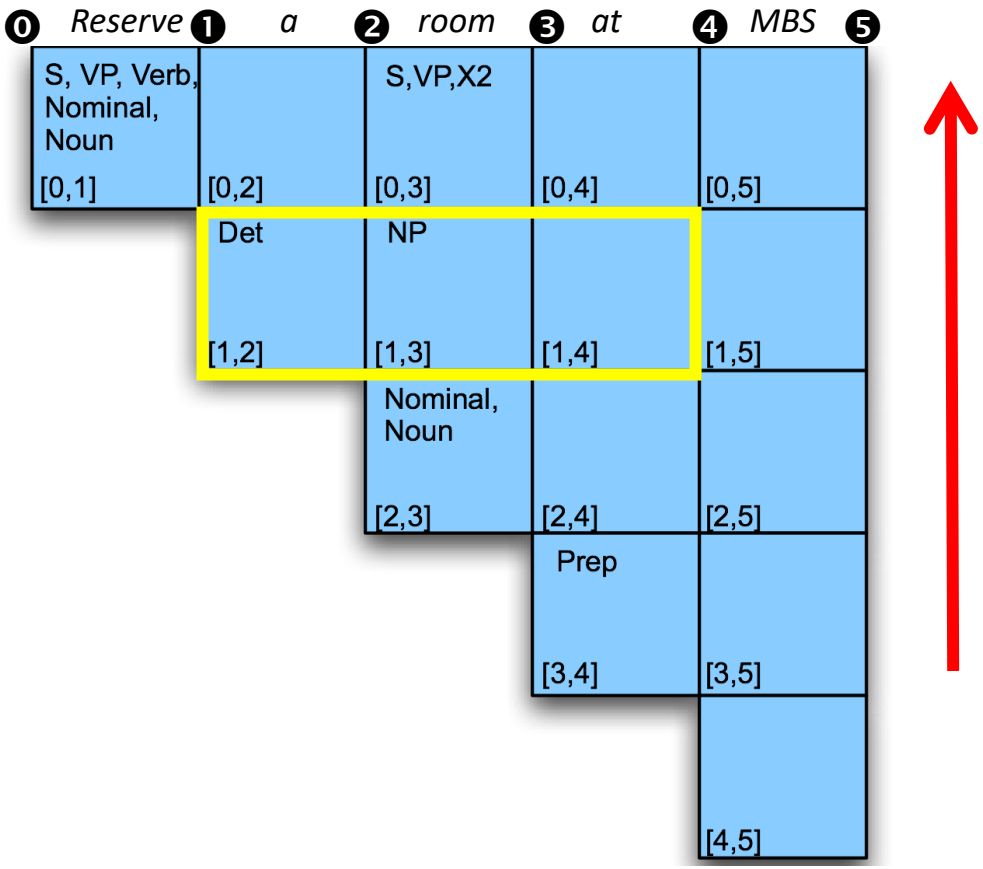

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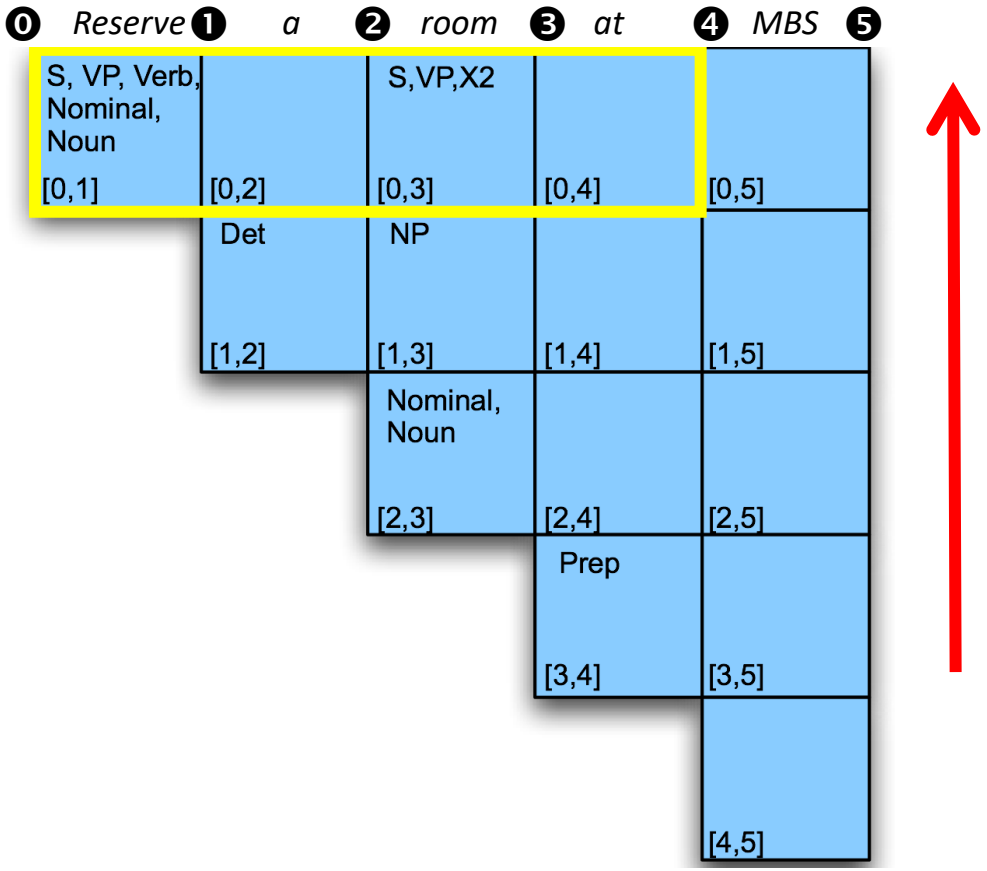

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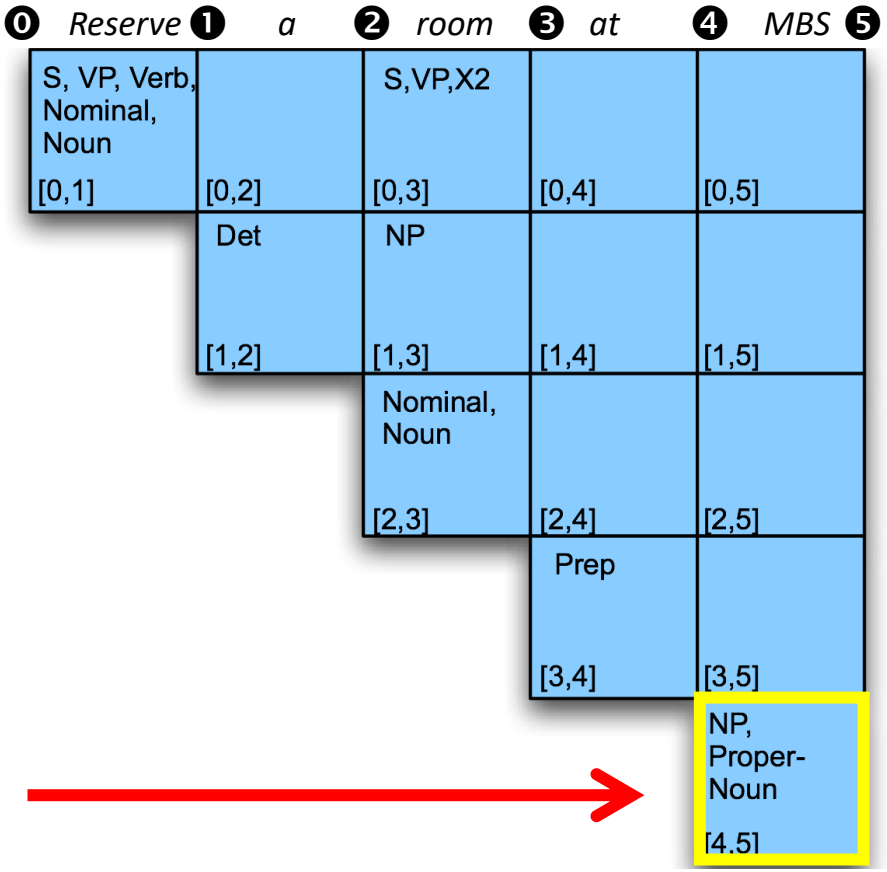

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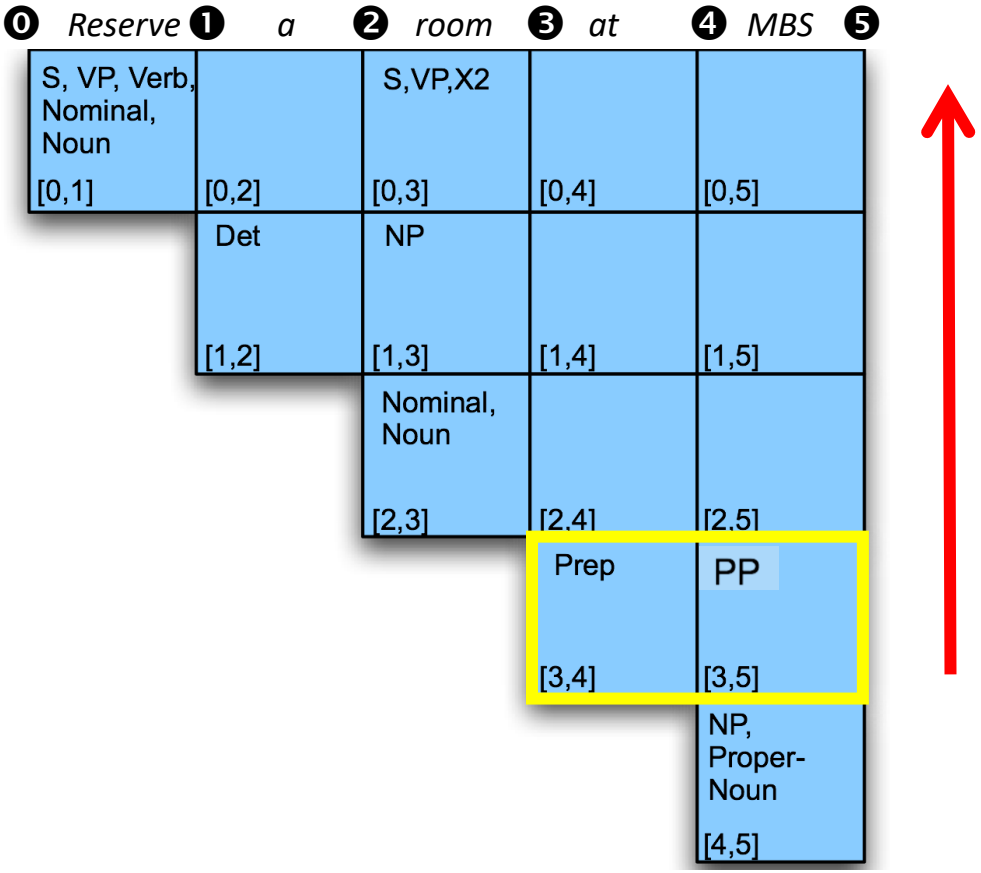
$S \rightarrow X2\ PP$
$S \rightarrow Verb\ PP$
$S \rightarrow VP\ PP$
$NP \rightarrow I \mid she \mid me$
$NP \rightarrow TWA \mid Houston$
$NP \rightarrow Det\ Nominal$
$Nominal \rightarrow book \mid flight \mid meal \mid money$
$Nominal \rightarrow Nominal\ Noun$
$Nominal \rightarrow Nominal\ PP$
$VP \rightarrow book \mid include \mid prefer$
$VP \rightarrow Verb\ NP$
$VP \rightarrow X2\ PP$
$X2 \rightarrow Verb\ NP$
$VP \rightarrow Verb\ PP$
$VP \rightarrow VP\ PP$
$PP \rightarrow Preposition\ NP$



Q2(i)

$\mathscr{L}_1$ in CNF
$S \rightarrow NP\ VP$
$S \rightarrow X1\ VP$
$X1 \rightarrow Aux\ NP$
$S \rightarrow book \mid include \mid prefer$
$S \rightarrow Verb\ NP$
$S \rightarrow X2\ PP$
$S \rightarrow Verb\ PP$
$S \rightarrow VP\ PP$
$NP \rightarrow I \mid she \mid me$
$NP \rightarrow TWA \mid Houston$
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$Nominal \rightarrow book \mid flight \mid meal \mid money$
$Nominal \rightarrow Nominal\ Noun$
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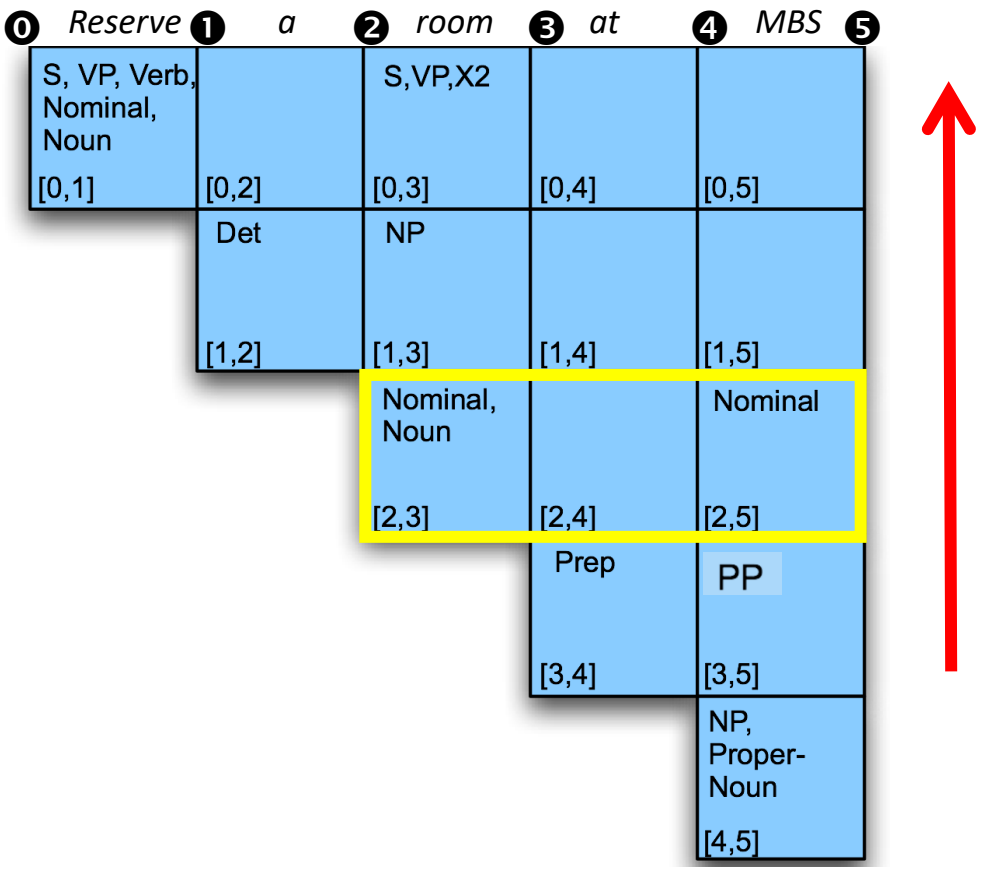
$VP \rightarrow book \mid include \mid prefer$
$VP \rightarrow Verb\ NP$
$VP \rightarrow X2\ PP$
$X2 \rightarrow Verb\ NP$
$VP \rightarrow Verb\ PP$
$VP \rightarrow VP\ PP$
$PP \rightarrow Preposition\ NP$



Q2(i)

$\mathscr{L}_1$ in CNF
$S \rightarrow NP\ VP$
$S \rightarrow X1\ VP$
$X1 \rightarrow Aux\ NP$
$S \rightarrow book \mid include \mid prefer$
$S \rightarrow Verb\ NP$
$S \rightarrow X2\ PP$
$S \rightarrow Verb\ PP$
$S \rightarrow VP\ PP$
$NP \rightarrow I \mid she \mid me$
$NP \rightarrow TWA \mid Houston$
$NP \rightarrow Det\ Nominal$
$Nominal \rightarrow book \mid flight \mid meal \mid money$
$Nominal \rightarrow Nominal\ Noun$
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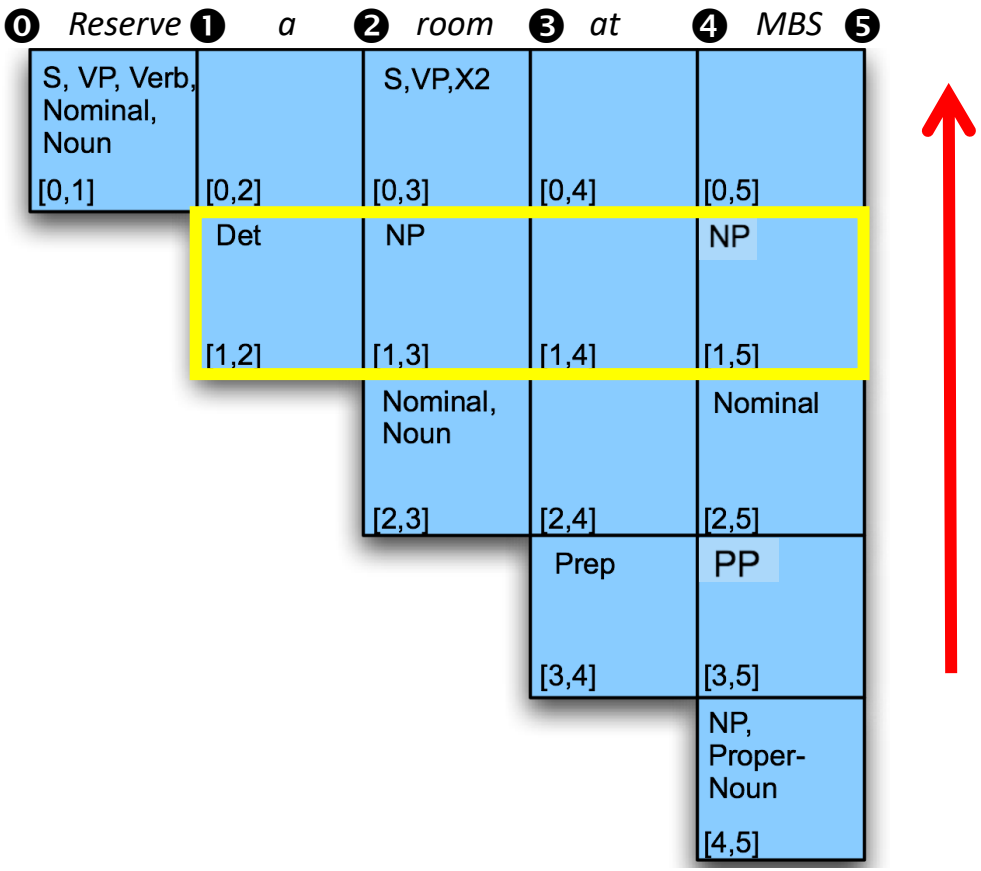
$VP \rightarrow book \mid include \mid prefer$
$VP \rightarrow Verb\ NP$
$VP \rightarrow X2\ PP$
$X2 \rightarrow Verb\ NP$
$VP \rightarrow Verb\ PP$
$VP \rightarrow VP\ PP$
$PP \rightarrow Preposition\ NP$



Q2(i)

$\mathscr{L}_1$ in CNF
$S \rightarrow NP\ VP$
$S \rightarrow X1\ VP$
$X1 \rightarrow Aux\ NP$
$S \rightarrow book \mid include \mid prefer$
$S \rightarrow Verb\ NP$
$S \rightarrow X2\ PP$
$S \rightarrow Verb\ PP$
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$NP \rightarrow I \mid she \mid me$
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$VP \rightarrow X2\ PP$
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$VP \rightarrow Verb\ PP$
$VP \rightarrow VP\ PP$
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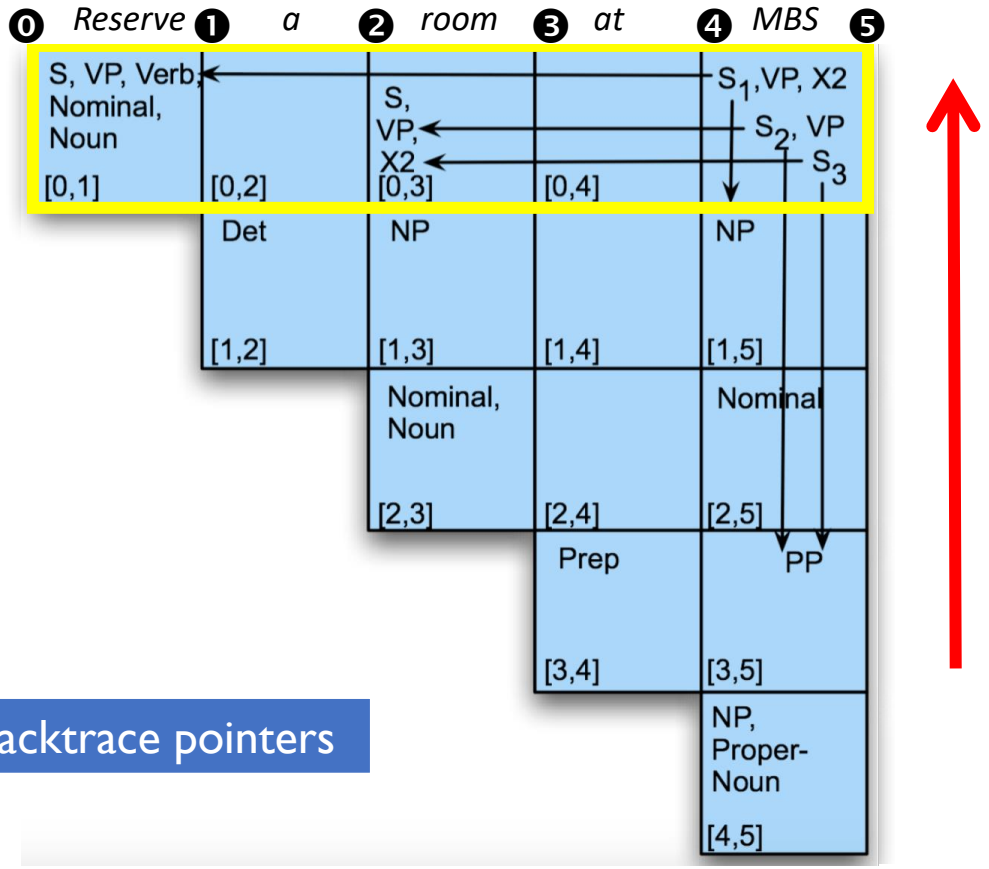


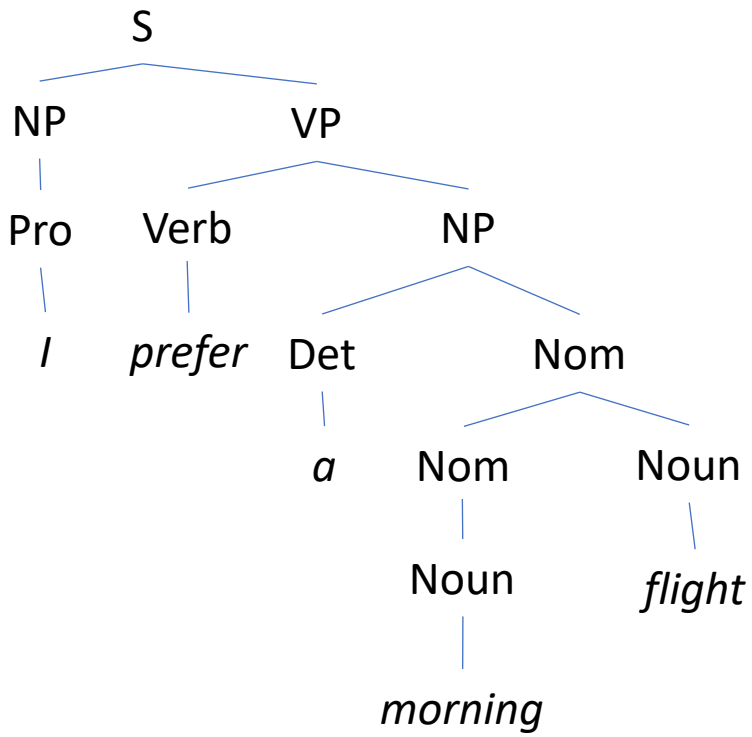
Q2(ii) Revise the L1 grammar

- In order to be able to parse the following sentences:
  - I would like to fly on American airlines.
  - Please repeat that.
  - I need to fly between Philadelphia and Atlanta.
  - What is the fare from Atlanta to Denver?

S→ NP VP	Nominal → Noun	NP→ Verb PP
S→ Aux NP VP	Nominal → Nominal Noun	VP → VP PP
S→ VP	Nominal → Nominal PP	PP→ Preposition NP
NP→ Pronoun	VP→ Verb	
NP→ Proper-Noun	VP→ Verb NP	
NP→ Det Nominal	VP → Verb NP PP	

Derivation

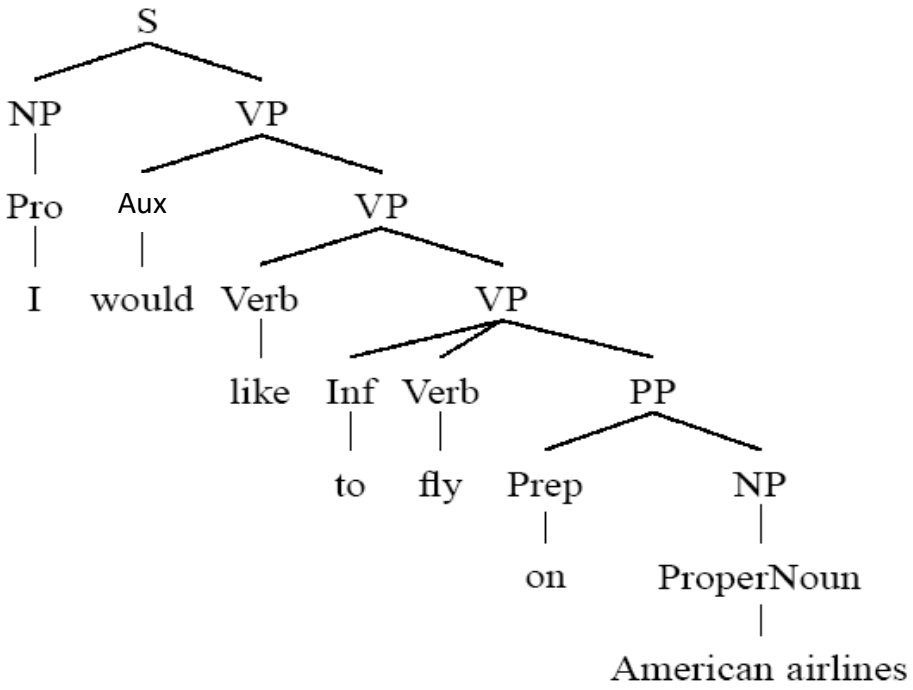
- A derivation (parse tree) consists of the bag of grammar rules that are in the tree

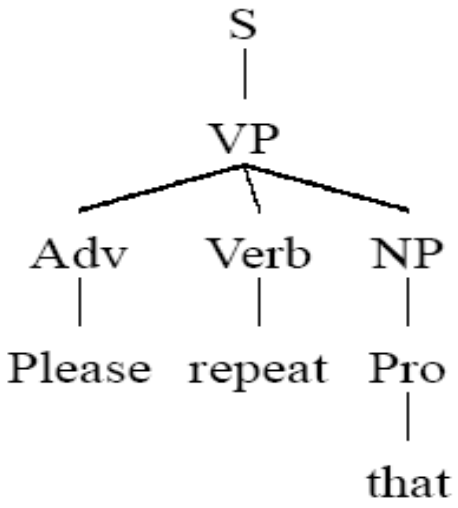


1. S → NP VP
2. NP → Pro
   Pro → I
3. VP → Verb NP
   Verb → prefer
4. NP → Det Nom
   Det → a
5. Nom → Nom Noun
   Noun → morning
6. Nom → Noun
   Noun → flight

The first two sentences

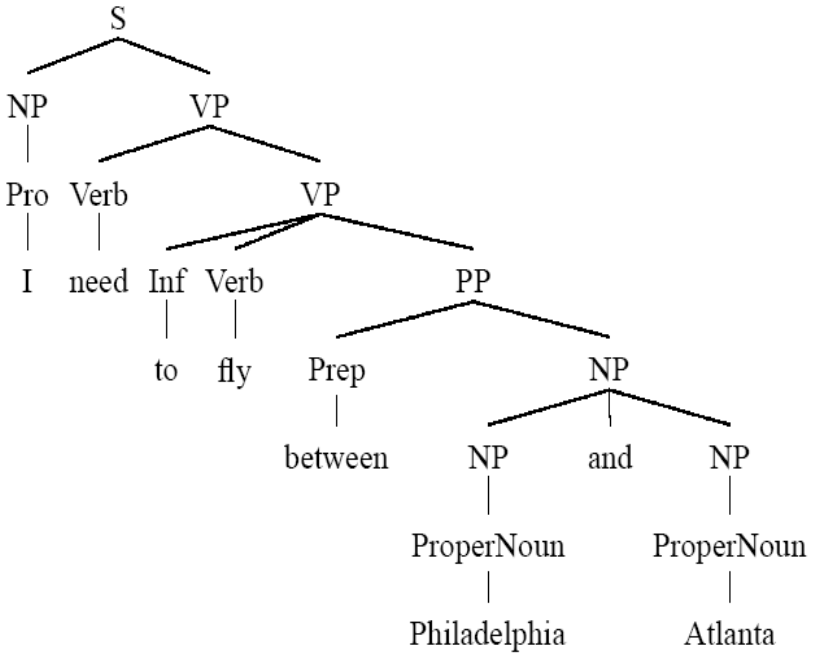
- I would like to fly on American airlines.
- Please repeat that.

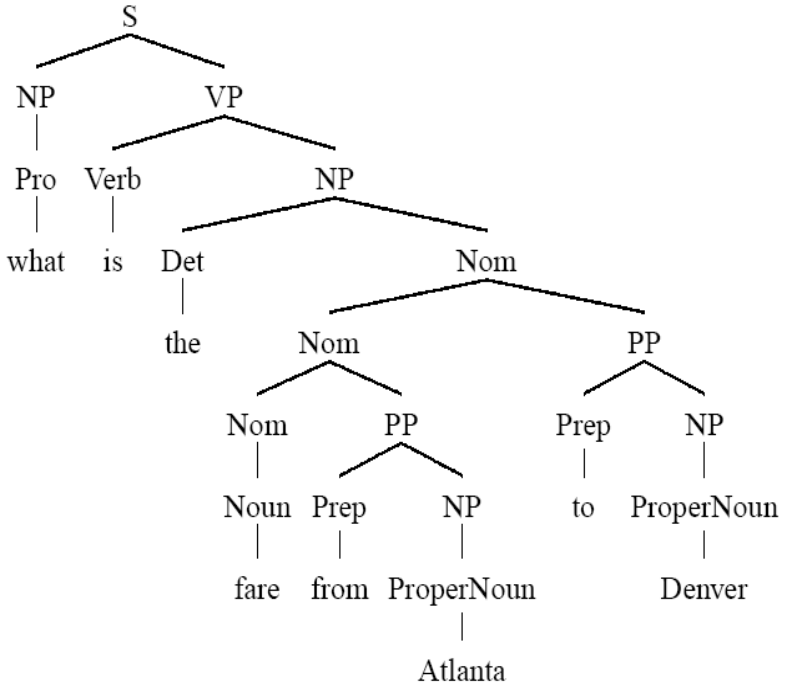




The next two sentences

- I need to fly between Philadelphia and Atlanta.
- What is the fare from Atlanta to Denver?





Q2(ii) *Revise the L1 grammar*

- In order to be able to parse the following sentences:
  - I would like to fly on American airlines.
  - Please repeat that.
  - I need to fly between Philadelphia and Atlanta.
  - What is the fare from Atlanta to Denver?

S→ NP VP	Nominal → Noun	NP→ Verb PP
S→ Aux NP VP	Nominal → Nominal Noun	VP → VP PP
S→ VP	Nominal → Nominal PP	PP→ Preposition NP
NP→ Pronoun	VP→ Verb	
NP→ Proper-Noun	VP→ Verb NP	
NP→ Det Nominal	VP → Verb NP PP	

Q2(ii) Include the rules that are not listed in L1

- S → NP VP
- S → Aux NP VP
- S → VP
- NP → Pronoun
- NP → ProperNoun
- NP → Det Nominal
- NP → NP Conj NP
- Nominal → Noun
- Nominal → Nominal Noun
- Nominal → Nominal PP
- VP → Verb
- VP → Verb NP
- VP → Verb NP PP
- VP → Verb PP
- VP → VP PP
- VP → Aux VP
- VP → Verb VP
- VP → Inf Verb PP
- VP → Adv Verb NP
- PP → Preposition NP
- ----------
- Det → the
- Noun → fare
- Verb → like | fly | repeat | need | is
- Pronoun → I | that | what
- ProperNoun → American airlines | Philadelphia | Atlanta | Denver
- Aux → would
- Preposition → from | to | on | between
- Conj → and
- Inf → to
- Adv → please

Q3. Draw typed dependency structures of the sentences

a) Does American airlines have a flight between five a.m. and six a.m.?

b) I would like to fly on American airlines.

c) Please repeat that.

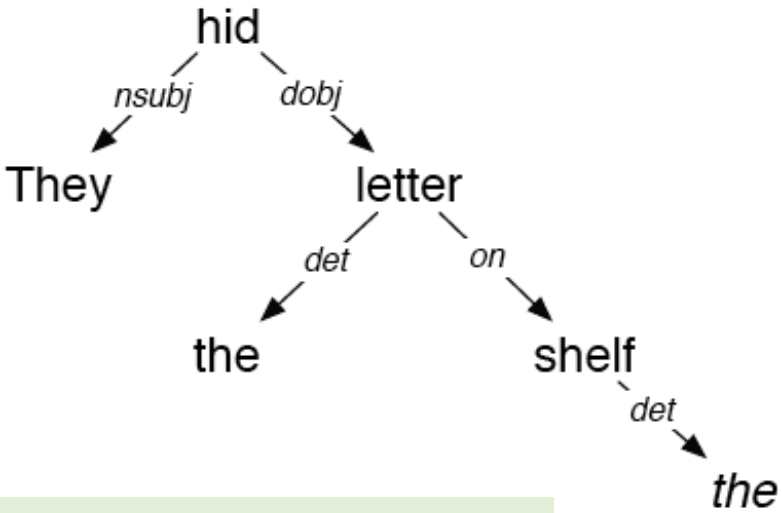
d) I need to fly between Philadelphia and Atlanta.

e) What is the fare from Atlanta to Denver?

Dependency structure

- Represents grammatical (dependency) relations between pairs of words (i.e., head, dependent)

- Head: Grammatically most important word in a phrase
  - Verb of VP
  - Noun of NP
  - Prep of PP
  - Adj of AdjP
  - …



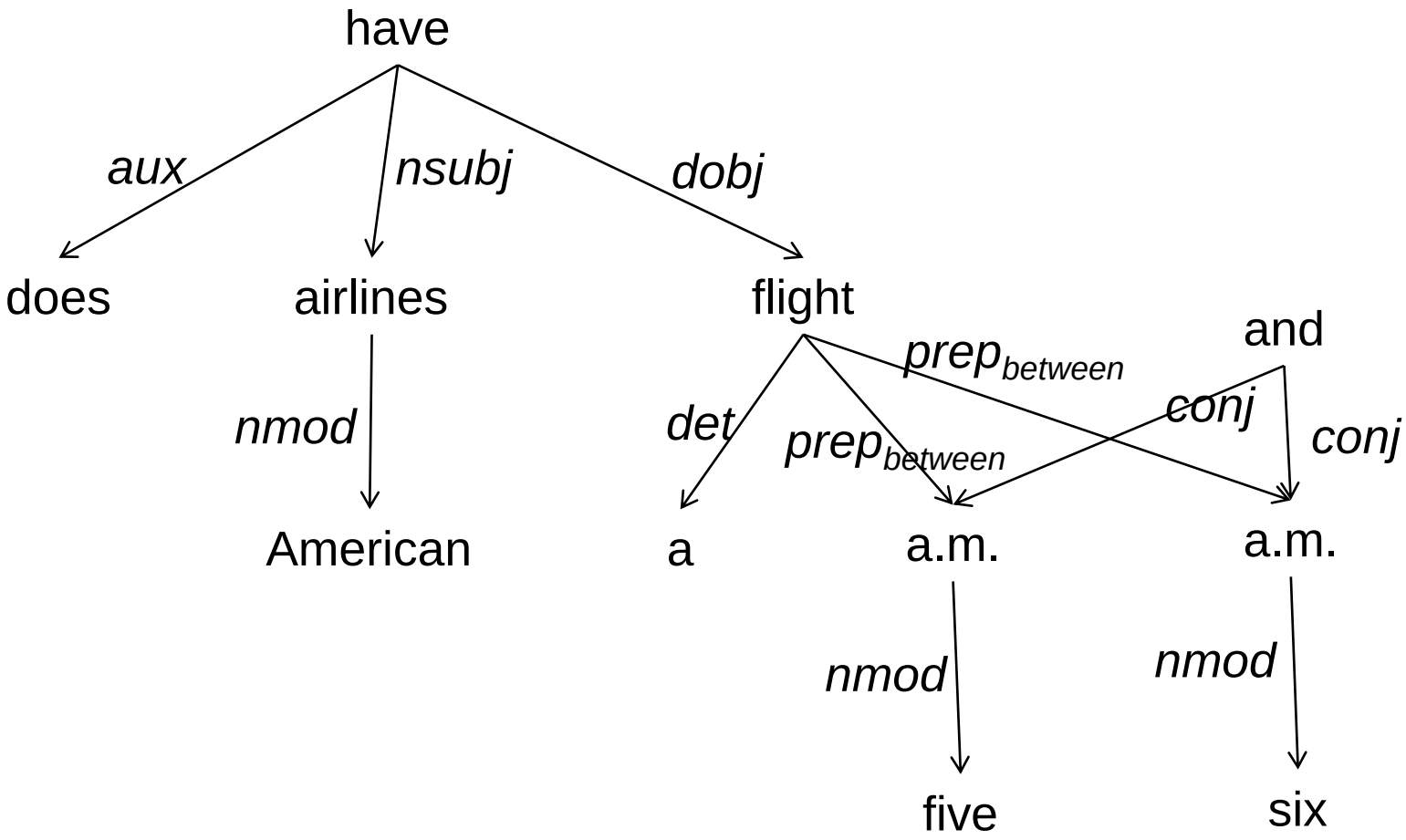
They hid the letter on the shelf

Dependency Relations

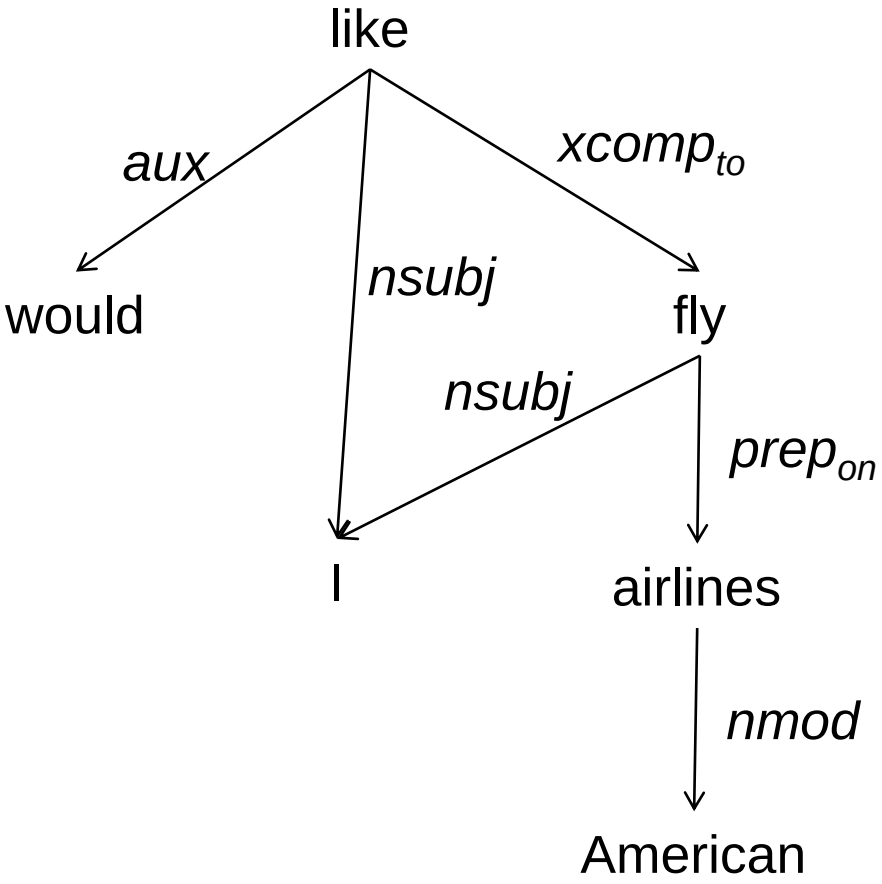
- Verb relations
  - nsubj : nominal subject
  - dobj : direct object
  - aux (auxiliary verb – main verb)
  - xmod (verb – adverb)
  - $xcomp_{to}$ (verb – to-infinitive)
- Noun relations
  - nmod: nominal modifier
  - det
- Preposition relations
  - $prep_X$ (e.g. $prep_{at}$)
- Coordination
  - conj

http://universaldependencies.org/u/dep/all.html

(a). Does American airlines have a flight between five a.m. and six a.m.?

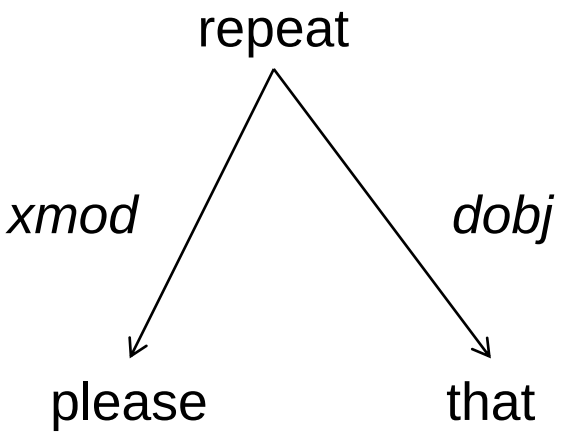


(b). I would like to fly on American airlines.



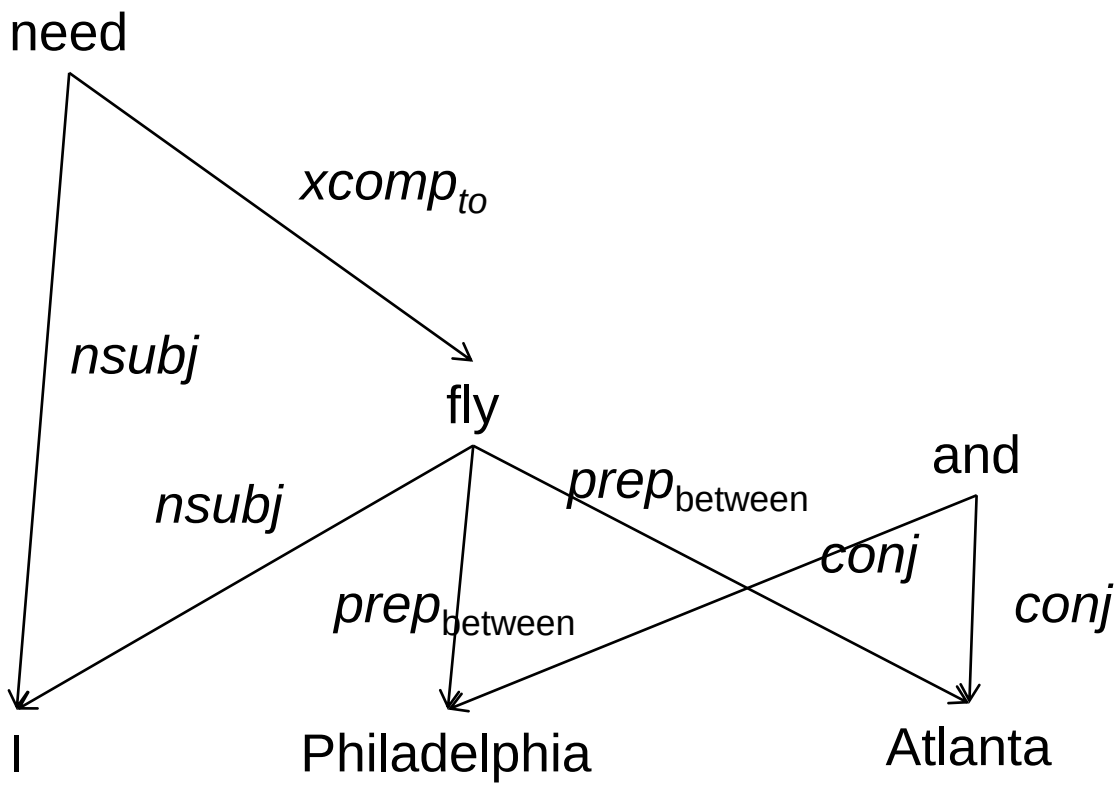
- Verb relations
  - nsubj
  - dobj
  - aux (auxiliary verb – main verb)
  - xmod (verb – adverb)
  - $xcomp_{to}$ (verb – to-infinitive)

(c). Please repeat that.



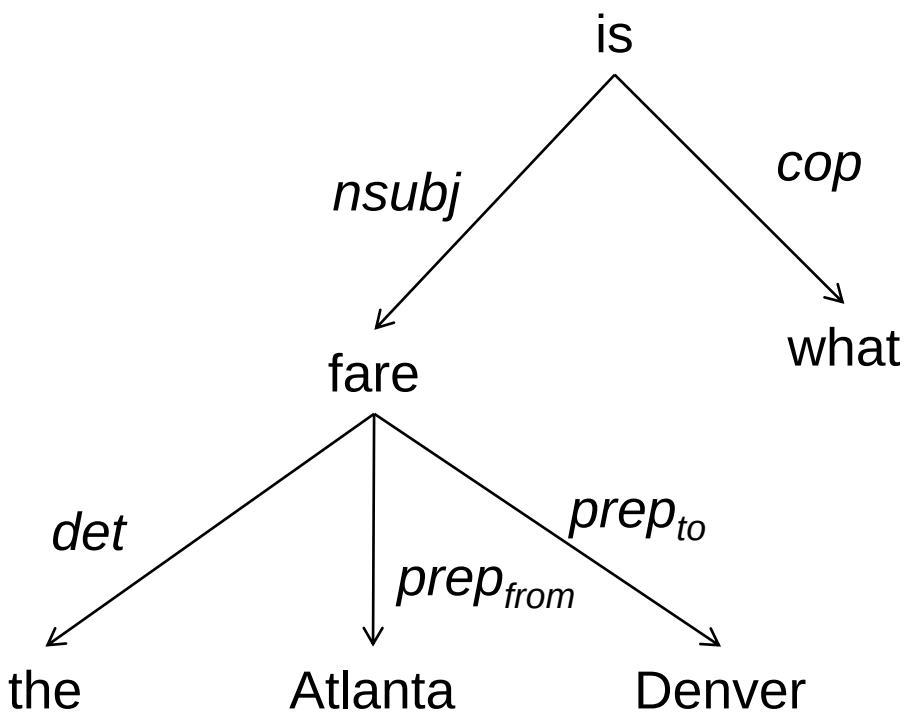
- Verb relations
  - nsubj
  - dobj
  - aux (auxiliary verb – main verb)
  - xmod (verb – adverb)
  - xcomp_{to} (verb – to-infinitive)

(d). I need to fly between Philadelphia and Atlanta.



- Verb relations
  - nsubj
  - dobj
  - aux (auxiliary verb – main verb)
  - xmod (verb – adverb)
  - $xcomp_{to}$ (verb – to-infinitive)

(e). What is the fare from Atlanta to Denver?



- Verb relations
  - nsubj
  - dobj
  - aux (auxiliary verb – main verb)
  - xmod (verb – adverb)
  - $xcomp_{to}$ (verb – to-infinitive)