Natural Language Processing

ECS763P

Syntactic Parsing, ch. 13 of J&F

February 13th 2017

Dependency Grammars

Here, constituency and phrase structure do not play a fundamental role. Syntactic structure of a sentence is determined by words and relations amongst them.

Formalised by Hays and Tesniere in 1950's, but are older than 's: they go back to Greek & Indian linguistic traditions.

The provide an analysis of grammar in terms of:

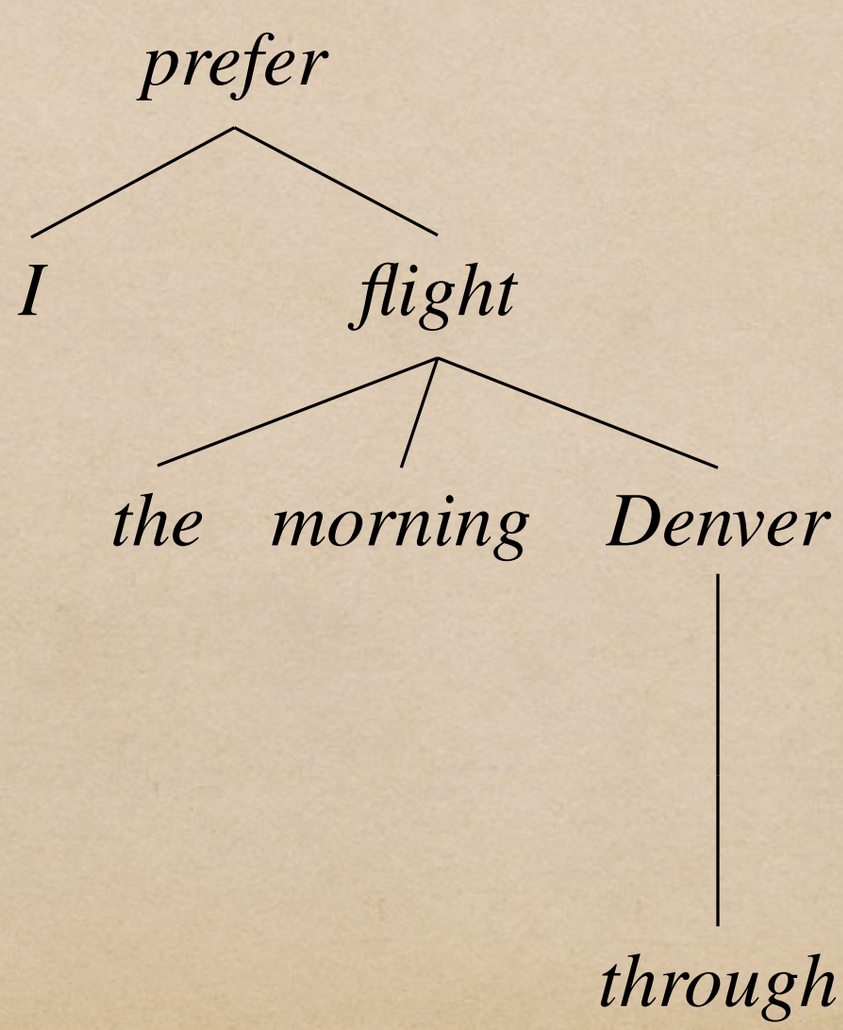
Subject-Predicate structure

which are historically more common than

Noun phrase Verb phrase structure

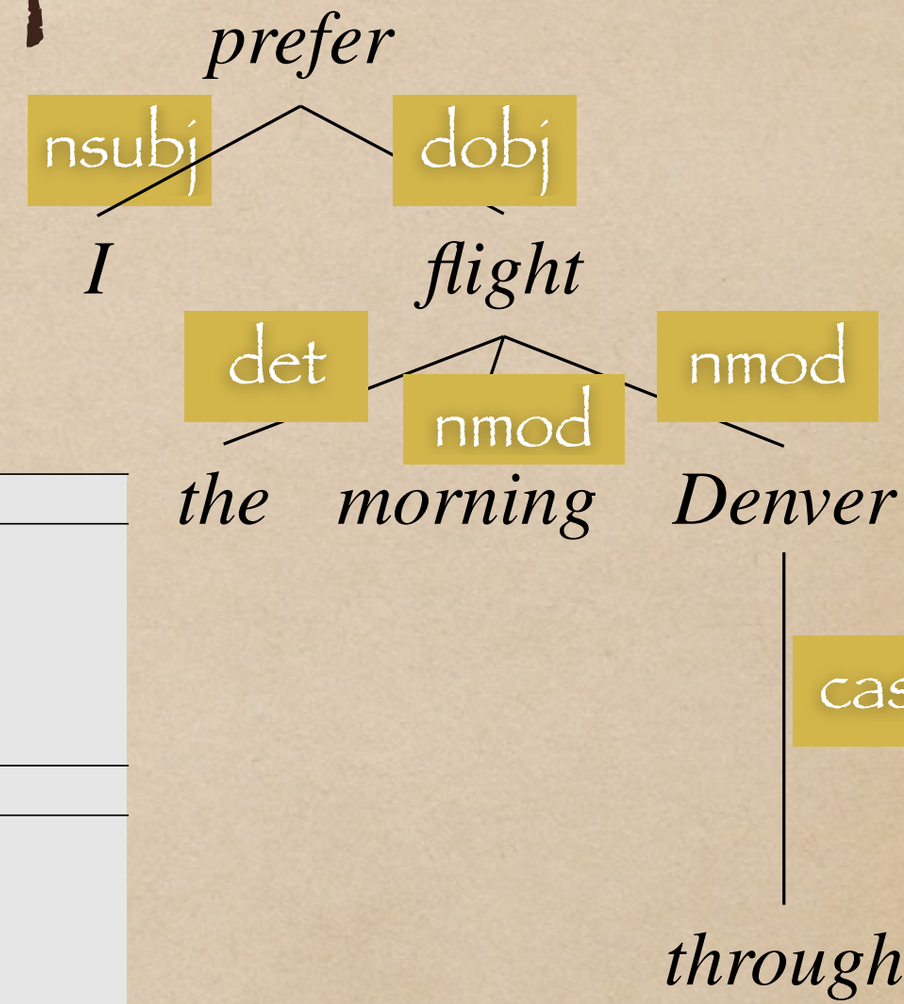
Example of a dependency tree

I prefer the morning flight through Denver.



Example

Labelled by grammatical relations

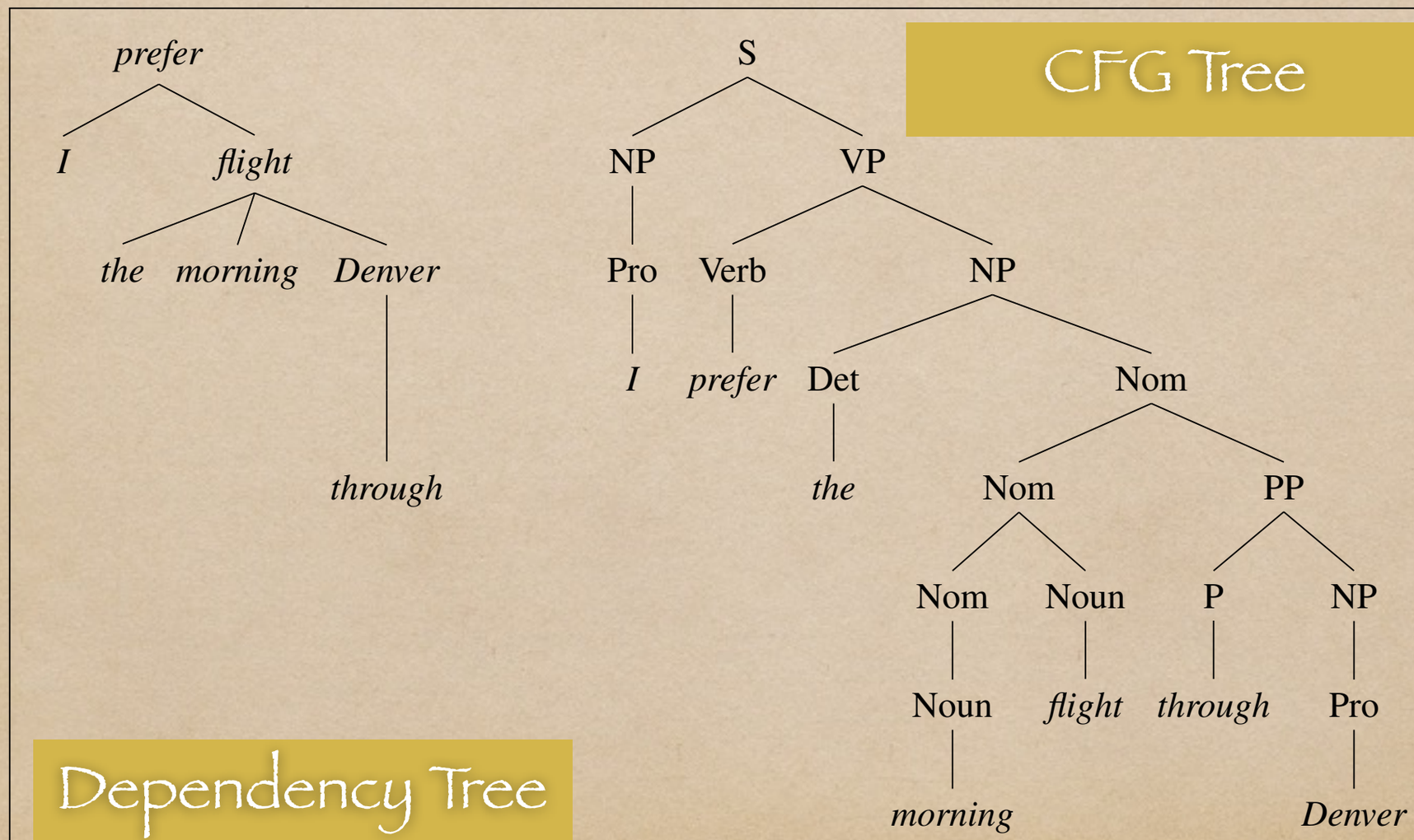


Clausal Argument Relations	Description
NSUBJ	Nominal subject
DOBJ	Direct object
IOBJ	Indirect object
CCOMP	Clausal complement
XCOMP	Open clausal complement
Nominal Modifier Relations	**Description**
NMOD	Nominal modifier
AMOD	Adjectival modifier
NUMMOD	Numeric modifier
APPOS	Appositional modifier
DET	Determiner
CASE	Prepositions, postpositions and other case markers
Other Notable Relations	**Description**
CONJ	Conjunct
CC	Coordinating conjunction

Example

Comparison with the CFG tree

Algorithms CFG->Dep, e.g. Xia & Palmer 2001



Advantages

0- Smaller more compact trees

1- Better predictive power of words over constituents:

knowing the verb can easily help pick its subject-object.

contrast with verb phrase and noun phrase.

2- Ability to handle languages with free word order, e.g. Hungarian, Czech, etc.

regardless of the order, a verb always has a subject.

contrast with having both S->NP VP and S -> VP NP.

Categorial Grammars

Lexicalized grammar: Adjukiewiecz 1935, Bar-Hillel 1953.

Formalised in various systems, notably:

- Syntactic Calculus (Lambek Calculus) 1956
- Combinatorial Categorial Grammar (CCG): Steedman 1996

Components:

1- Syntactic Categories

2- Lexicon: assigns to each word a syntactic category

3- Rules: allows for combining the syntactic categories

Categorial Grammars

Components:

1- Syntactic Categories

Atomic	$\mathscr{A} \subseteq \mathscr{C}$, where $\mathscr{A}$ is a given set of atomic elements
Functional	$(X/Y), (X\backslash Y) \in \mathscr{C}$, if $X, Y \in \mathscr{C}$

2- Lexicon: assigns to each word a syntactic category

$$\begin{aligned} \textit{flight} &: \quad N \\ \textit{Miami} &: \quad NP \\ \textit{cancel} &: \quad (S\backslash NP)/NP \end{aligned}$$

3- Rules: allows for combining the syntactic categories

$$\begin{aligned} X/Y \;\; Y &\Rightarrow X \\ Y \;\; X\backslash Y &\Rightarrow X \end{aligned}$$

Categorial Grammars

Simple Example

United	*serves*	*Miami*
NP	(S\NP)/NP	NP
	S\NP (>)	
S (<)		

Slightly Harder Example

$X \; CONJ \; X \Rightarrow X$

We	*flew*	*to*	*Geneva*	*and*	*drove*	*to*	*Chamonix*
NP	(S\NP)/PP	PP/NP	NP	CONJ	(S\NP)/PP	PP/NP	NP
		PP (>)				PP (>)	
	S\NP (>)				S\NP (>)		
	S\NP (<Φ>)						
S (<)							

Prepositional Phrase

Advantages

1- Succinct mathematical structure

direct links to arithmetics, algebra and proof theory

2- Direct correspondence with formal semantics

both based on similar type of mathematical structure

Context Free Grammars

Formal definition of a CFG:

$$(N, \Sigma, R, S)$$

N a set of non-terminal symbols

Σ a set of terminal symbols (disjoint from N)

S a designated start symbol

R a set of production rules of the form $\alpha \to \beta$

- α a non-terminal
- β a string of symbols from the strings $(\Sigma \cup N)^*$

Derivation and Parsing

A derivation is a generalisation of a direct derivation.

If we have $\alpha_1 \Longrightarrow \alpha_2, \alpha_2 \Longrightarrow \alpha_3, \cdots, \alpha_{n-1} \Longrightarrow \alpha_n$ we say

α_1 derives α_n . Formally $\alpha_1 \overset{*}{\Longrightarrow} \alpha_n$.

Parsing is the problem of mapping a string of words to its derivation.

Different derivations/parses based on the grammar:

1- CFG parse tree

2- Dependency tree

3- CCG tree

Applications

1- Grammar Checking, e.g. in word processors

2- Semantic Analysis

3- Question-Answering

e.g. to answer

what books were written by British women before 1800?

we need to know the subject and the pp to know that the user wants which list of books.

Algorithms

Paradigm: parsing as search

Searching through the space of possible parse trees to find the correct one: one whose root is S and whose leaves are exactly the words in the input sentence.

Classic search algorithms:

1- Top-Down

2- Bottom-Up

More novel algorithms:

3- Dynamic Programming

Top-Down

Start: the root S

Continue: find all trees that can start with S

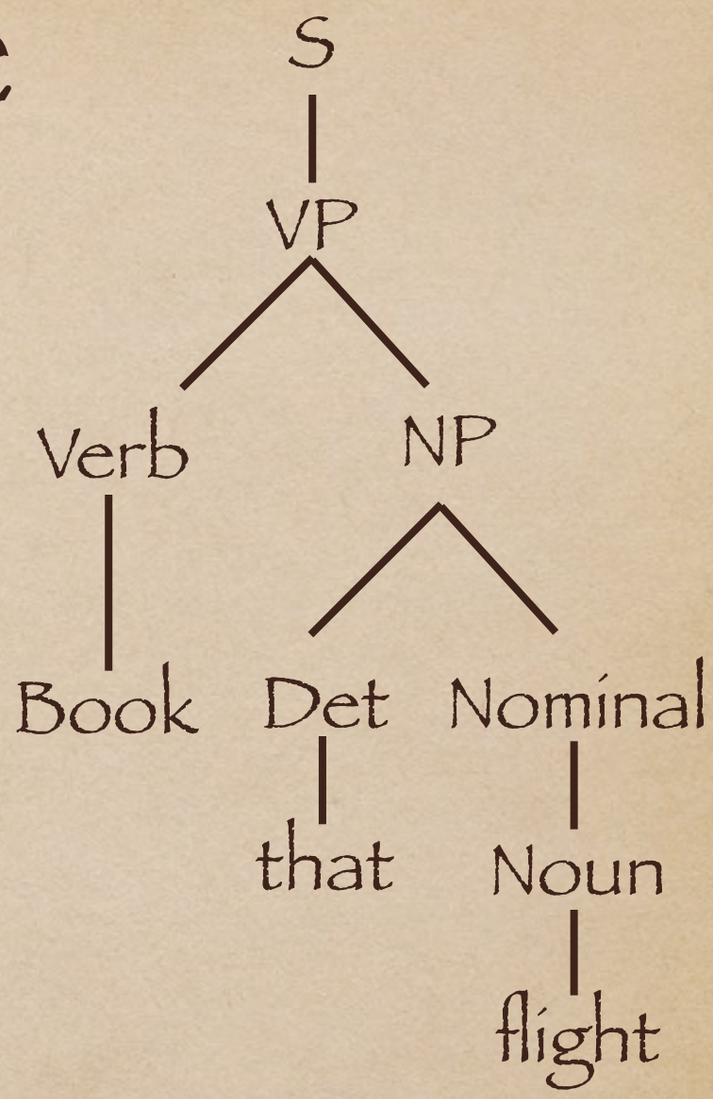
Method: look for rules with S on their left hand side

Repeat for each child

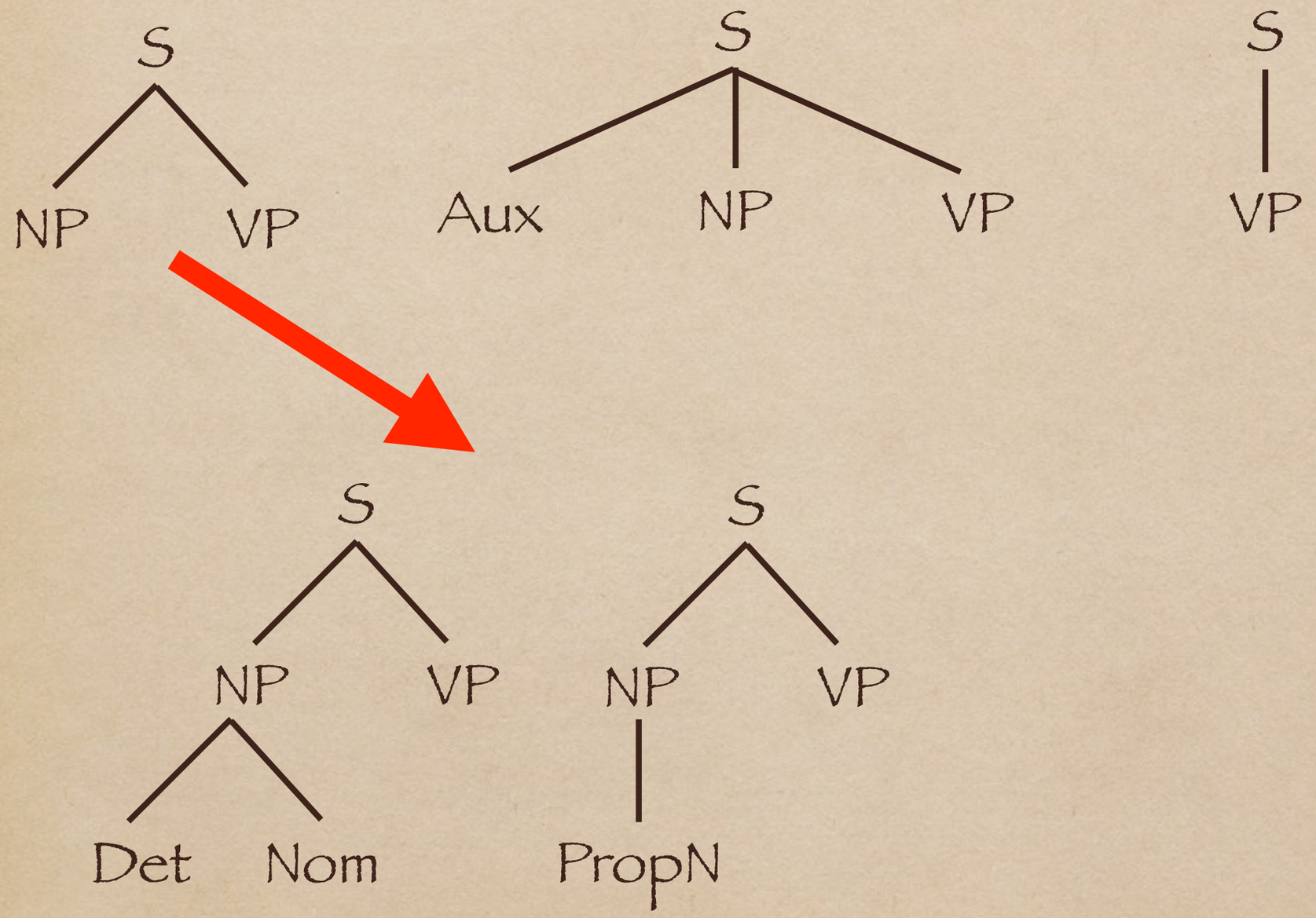
Stop: when the children are exactly the input words

Example

Grammar	Lexicon
$S \rightarrow NP\ VP$	$Det \rightarrow that \mid this \mid the \mid a$
$S \rightarrow Aux\ NP\ VP$	$Noun \rightarrow book \mid flight \mid meal \mid money$
$S \rightarrow VP$	$Verb \rightarrow book \mid include \mid prefer$
$NP \rightarrow Pronoun$	$Pronoun \rightarrow I \mid she \mid me$
$NP \rightarrow Proper\text{-}Noun$	$Proper\text{-}Noun \rightarrow Houston \mid NWA$
$NP \rightarrow Det\ Nominal$	$Aux \rightarrow does$
$Nominal \rightarrow Noun$	$Preposition \rightarrow from \mid to \mid on \mid near \mid through$
$Nominal \rightarrow Nominal\ Noun$	
$Nominal \rightarrow Nominal\ PP$	
$VP \rightarrow Verb$	
$VP \rightarrow Verb\ NP$	
$VP \rightarrow Verb\ NP\ PP$	
$VP \rightarrow Verb\ PP$	
$VP \rightarrow VP\ PP$	
$PP \rightarrow Preposition\ NP$	



Search Space



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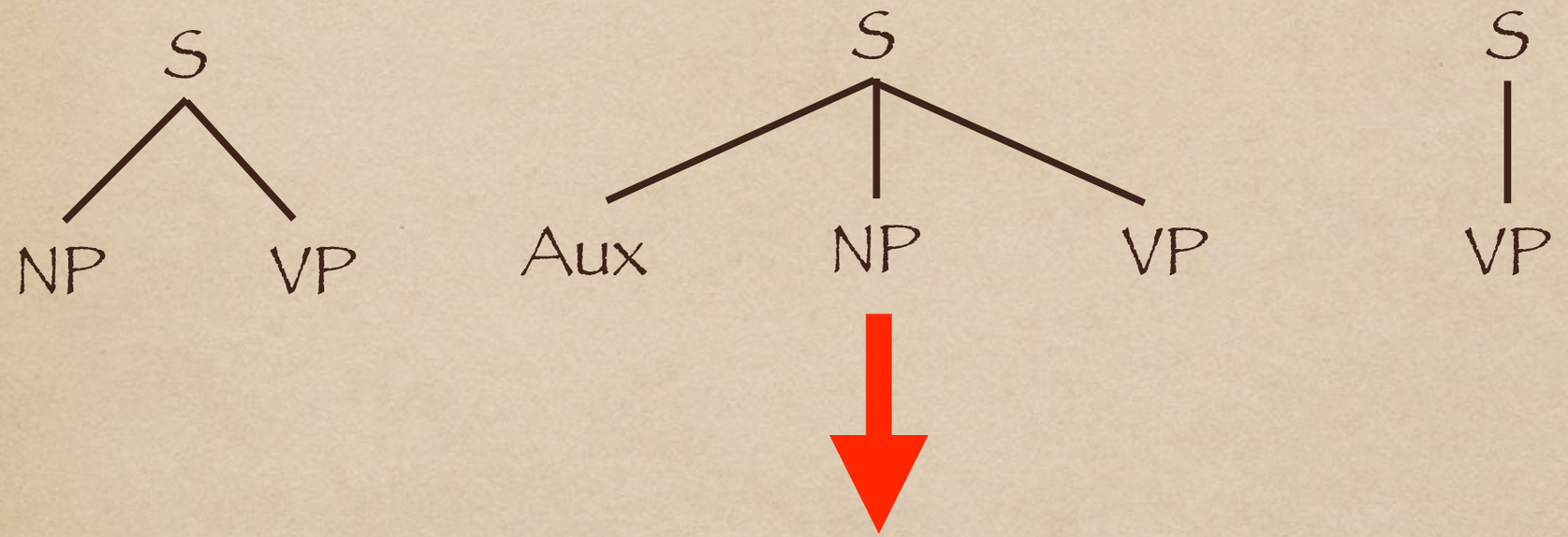

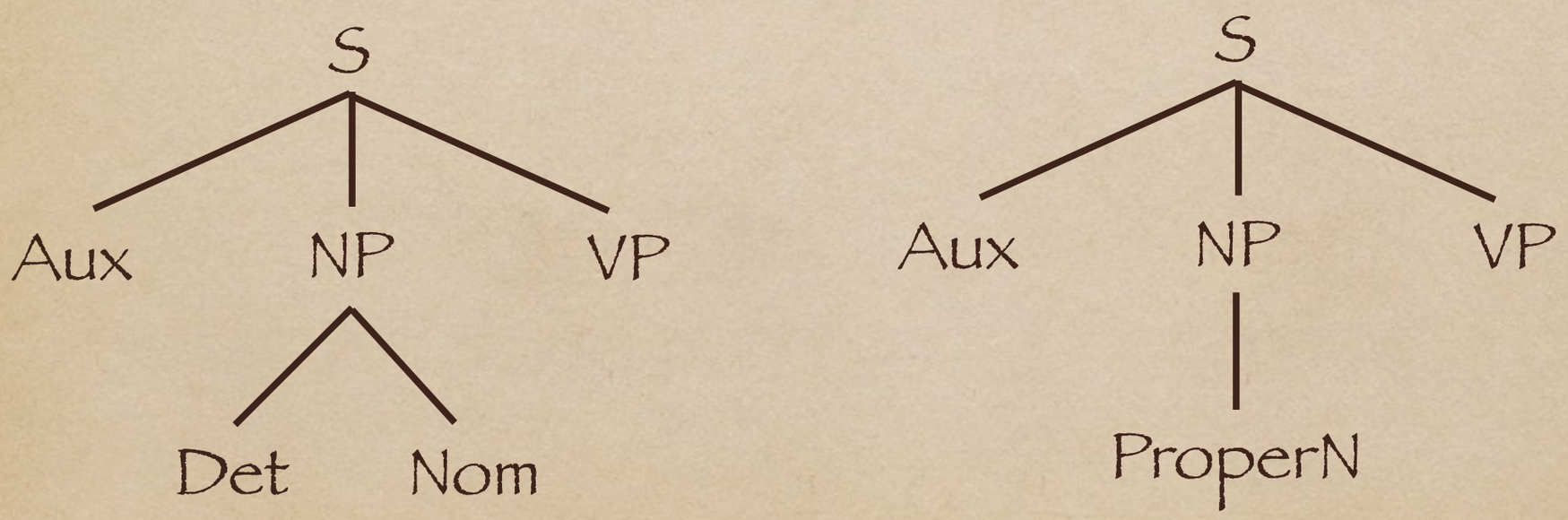

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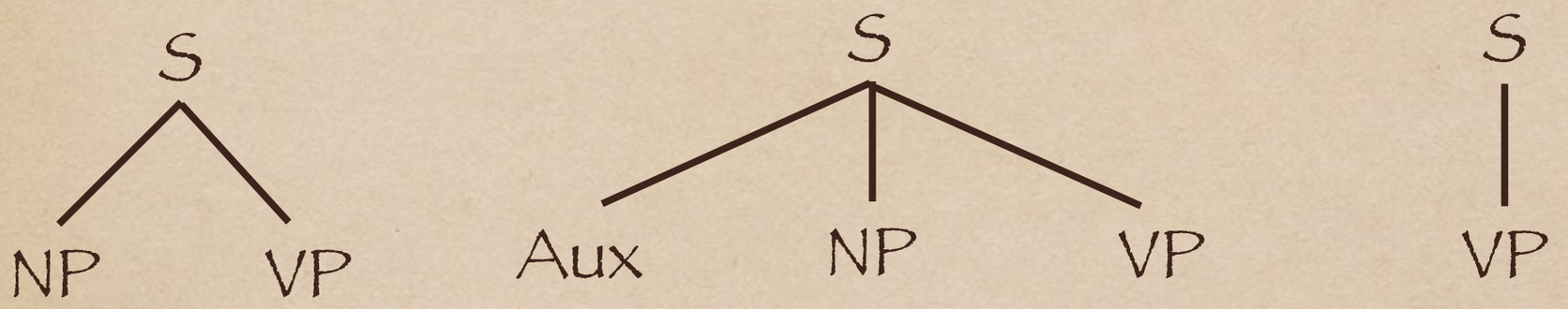

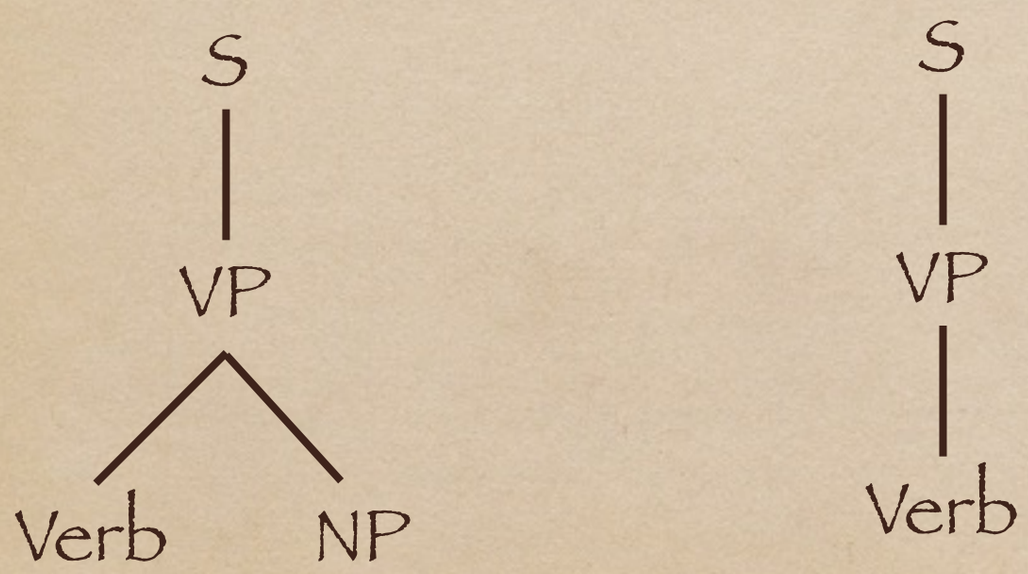

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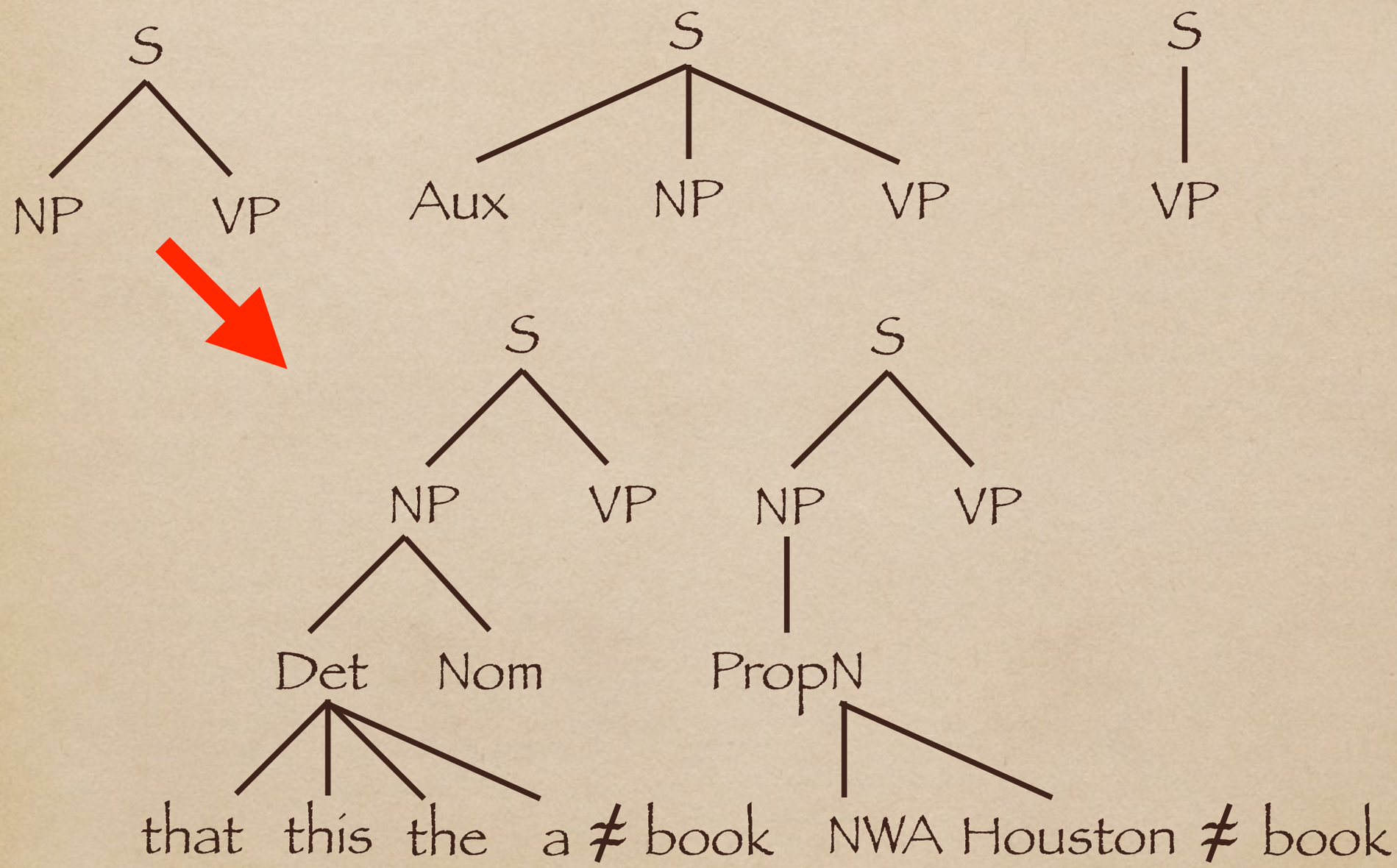

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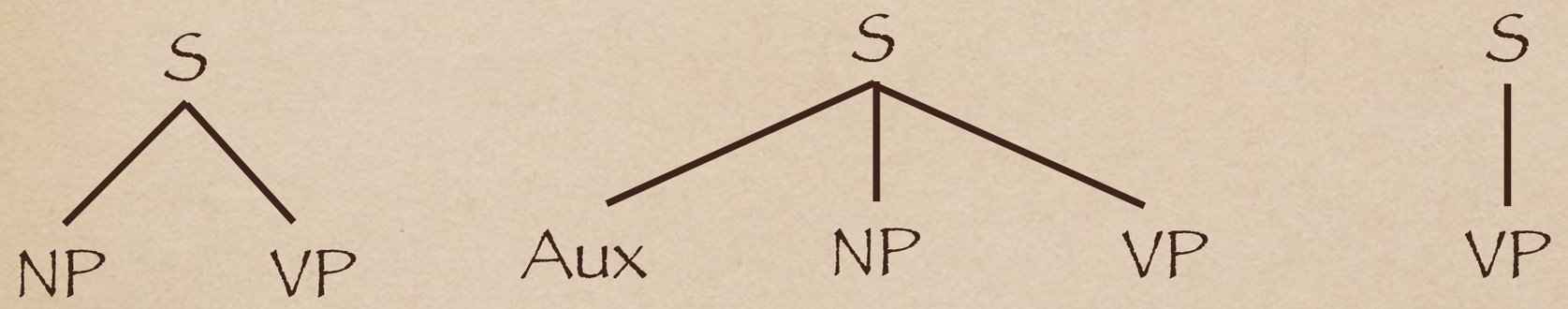

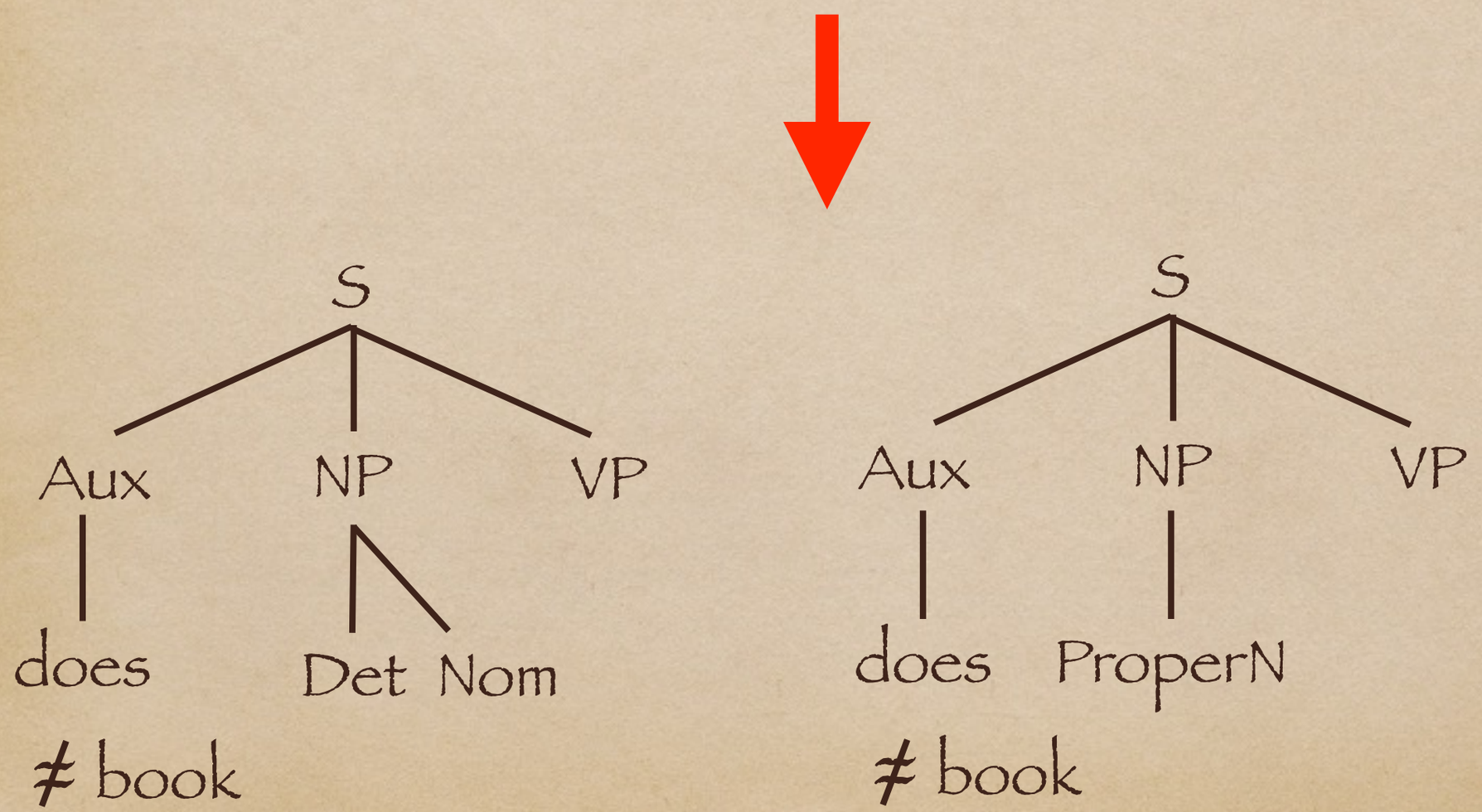

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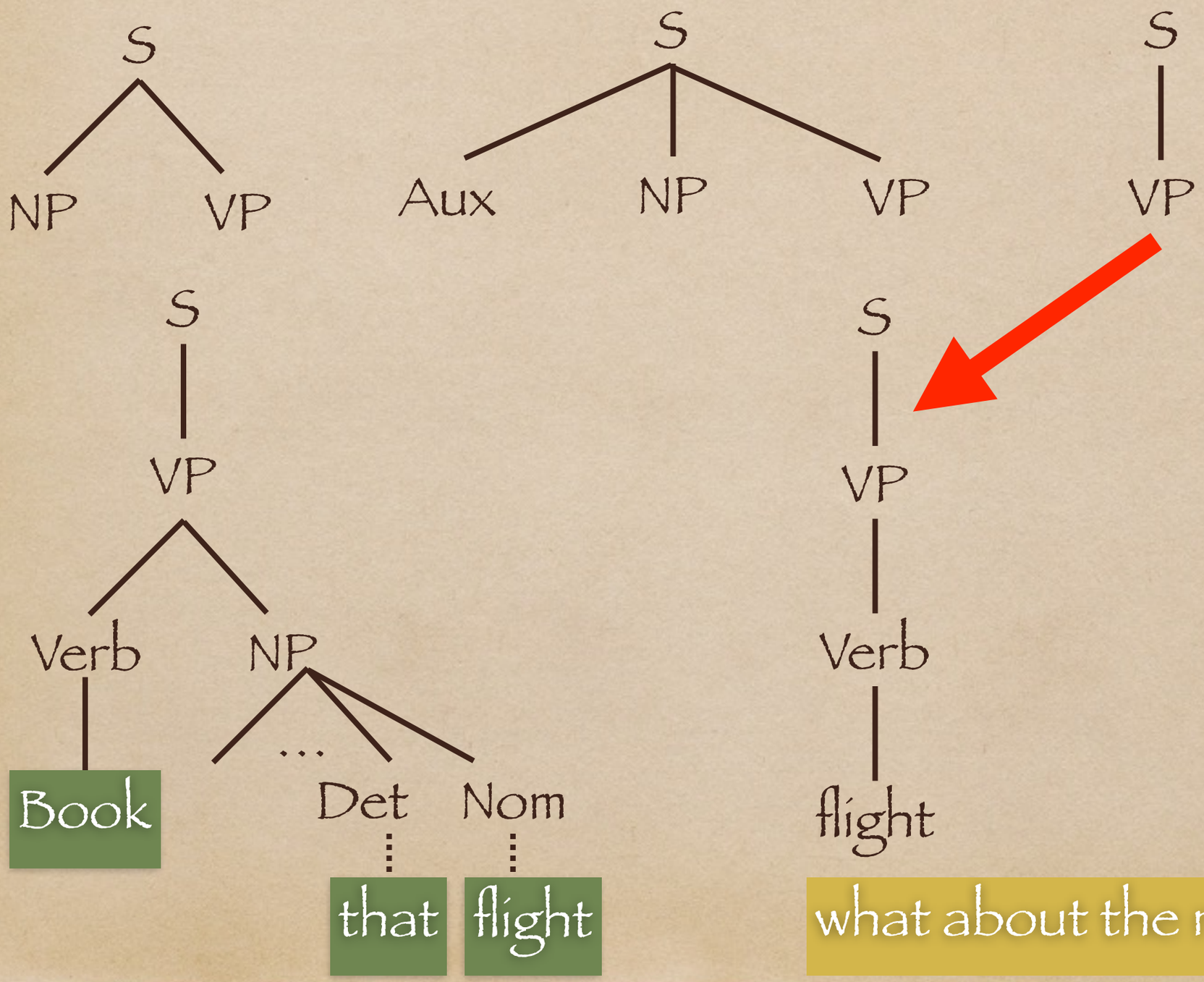


what about the rest?

Bottom-Up

Start: the words of input

Continue: find all trees that can start with words

Method: look for rules with words on their right hand side

Repeat for each child

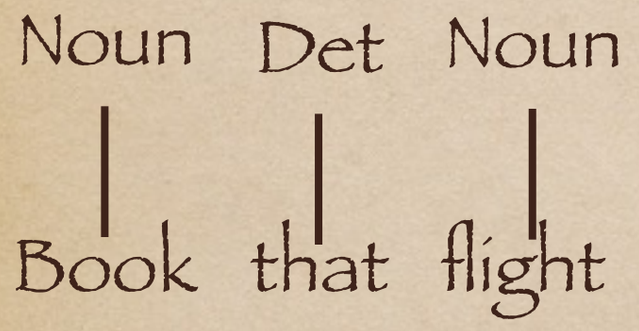
Stop: a tree with root S

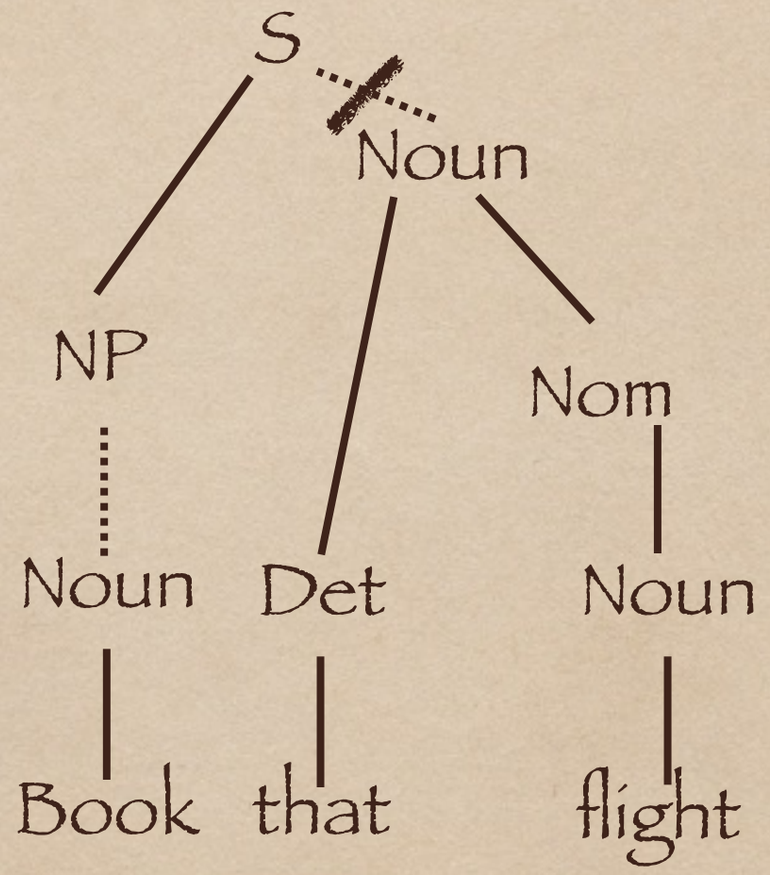
Search Space

Book that flight

Search Space

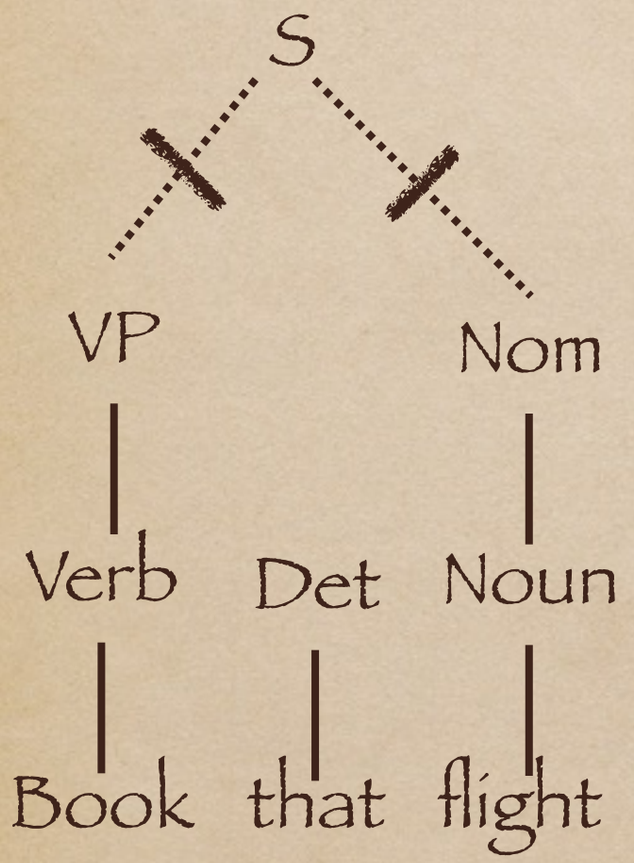
Book that flight

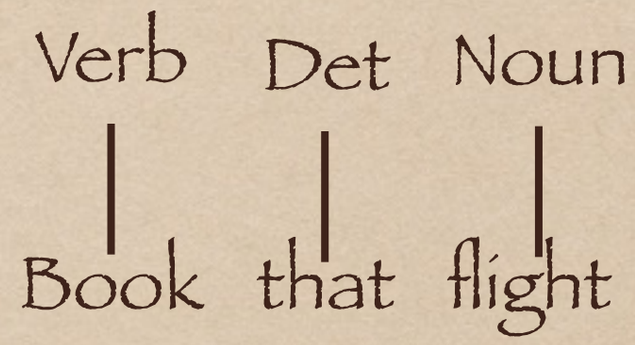




Search Space

Book that flight





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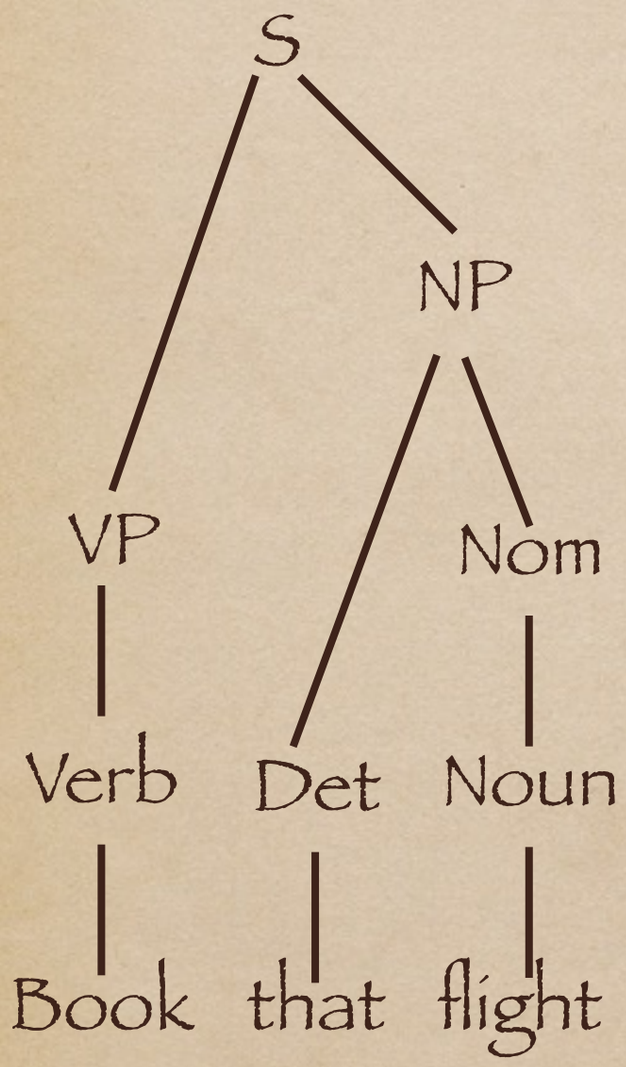

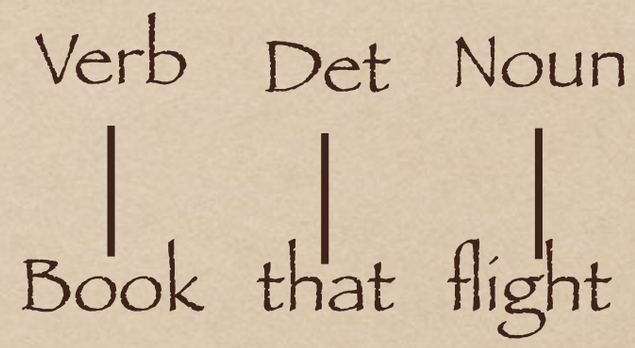

Which Method?

Each has their own advantages and disadvantages

The Top-Down will never waste time with trees that cannot result in S.

The Botton-Up will not waster time with trees that cannot end in the words of input.

Which one is worse? In our example:

Top-Down: 6 trees before reaching answer

Bottom-Up: 3 trees before reaching answer

Best method: combination of the two

Accidental

Challenges to Parsing:

Ambiguity

Structural Ambiguity

- attachment: a constituent can be attached to the parse tree at more than one place.

- coordination: different sets of phrase can be conjoined by a conjunction, e.g. and/or

Later on: Semantic Ambiguity (meanings of words)

Challenges to Parsing:

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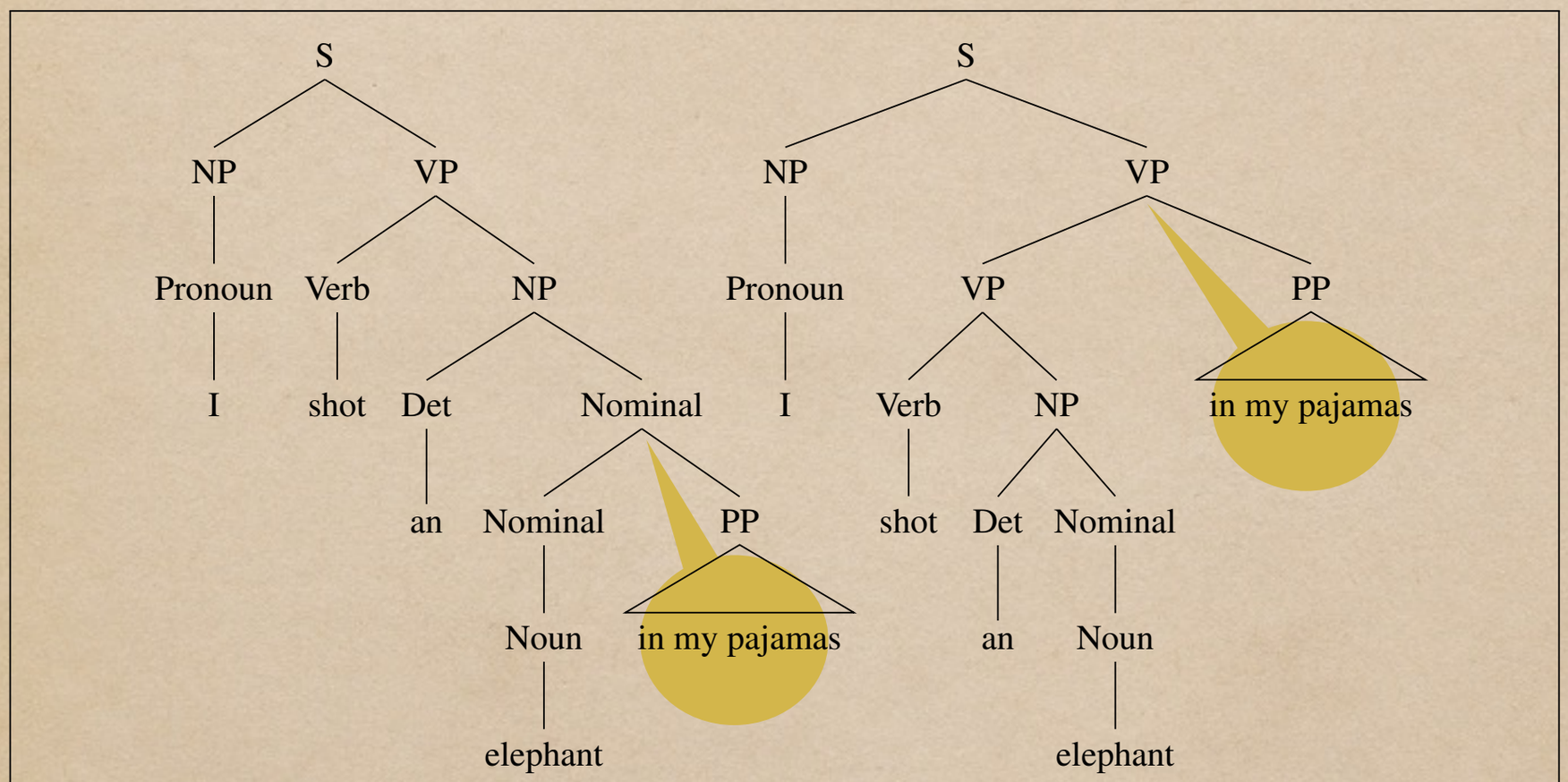
Challenges to Parsing:

Attachment Ambiguity



I shot an elephant in my pyjamas.

Challenges to Parsing:

Coordination Ambiguity

old men and women dance.

1- (old men) and women dance.

2- old (men and women) dance.

It does not always have to make sense (for any type of ambiguity)

President Kennedy today pushed aside other White House business to devote all his time and attention to working on the Berlin crisis address he will deliver tomorrow night to the American people over nationwide television and radio.

Challenges to Parsing:

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- (nation wide tv) and (radio)

- (nation wide (tv and radio)

Challenges to Parsing:

Ambiguity

It does not always have to make sense (for any type of ambiguity)

President Kennedy today pushed aside other White House business to devote all his time and attention to working on the Berlin crisis address he will deliver tomorrow night to the American people over nationwide television and radio.

dobj of pushed-aside:

- other WHB

- other WHB to devote all his time and attention to working

makes sense in"Kennedy affirmed his intention to devote ....

Challenges to Parsing:

Ambiguity

It does not always have to make sense (for any type of ambiguity)

President Kennedy today pushed aside other White House business to devote all his time and attention to working on the Berlin crisis address he will deliver tomorrow night to the American people over nationwide television and radio.

preposition phrase

- (to the American people) (over nation wide tv and radio)

- to (the American people over nation wide tv and radio)

Challenges to Parsing:

Ambiguity

Show me the meals on the flight from San Fransisco.

Challenges to Parsing:

Ambiguity

Show me the meals on the flight from San Fransisco.

Which meals?

Show me the meals on the flight from San Fransisco.

from where?

Provide CFG trees for each case

Show me the meals on the flight from San Fransisco.

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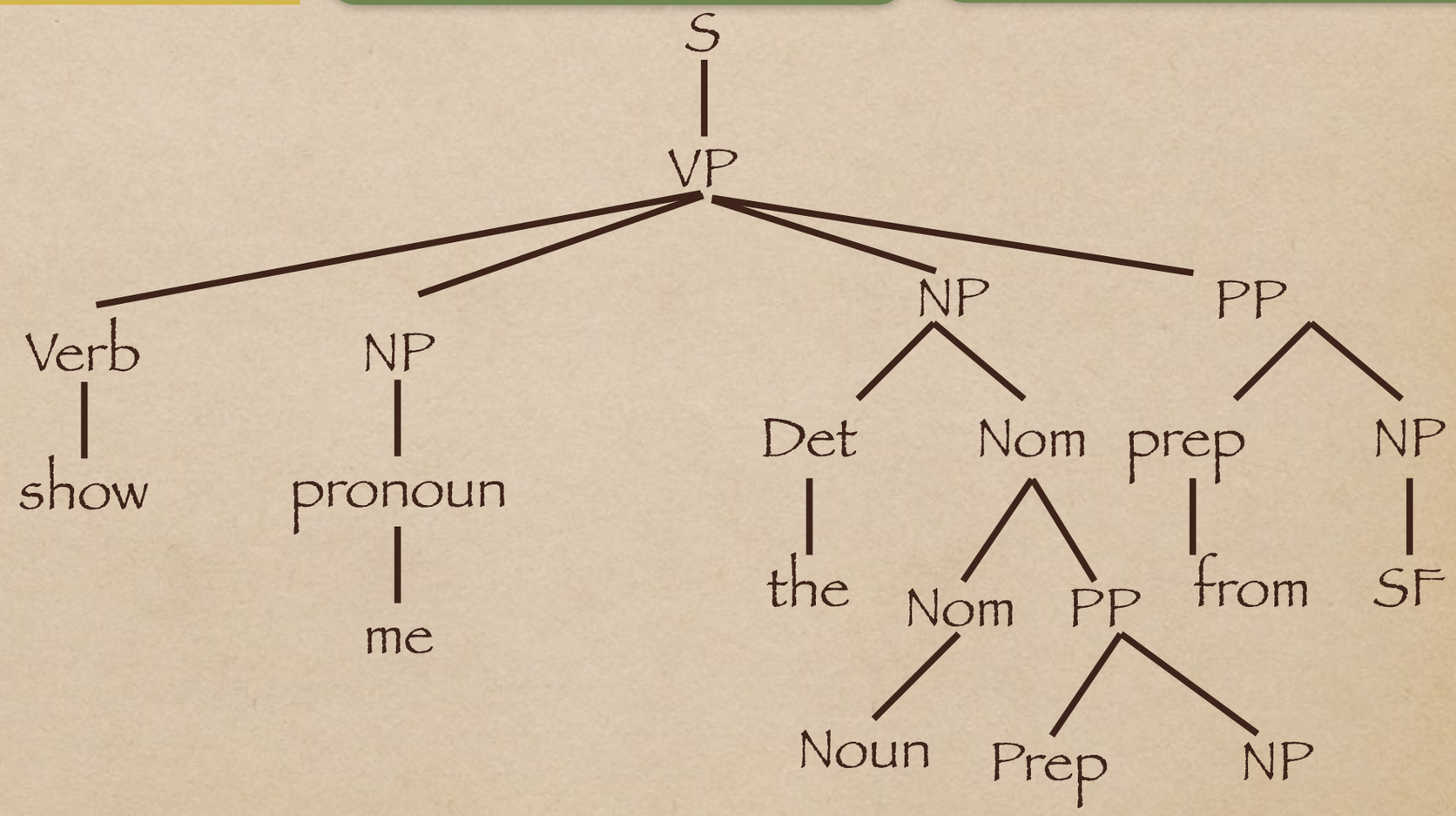
Provide CFG trees for each case

Show me the meals on the flight from San Fransisco.

Need new rules!!!

VP-> NP NP PP

Nom -> Nom PP



Provide CFG trees for each case

Show me the meals on the flight from San Fransisco.

Need new rules?

Challenges to Parsing:

Solution to Ambiguity

1- List all possible trees: search space explosion

2- Use extra knowledge:

- Semantic
- Statistical
- Pragmatic

In the Feb 27th lecture:

- Probabilistic CFG's
- Statistical parsing alg.