

Master in Artificial Intelligence

Introduction to Human Language Technologies 9. Syntactic parsing: parsers



UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Facultat d'Informàtica de Barcelona

FIB

Exercise 1

Convert the following CFG to CNF

- 1 $S \rightarrow NP\ VP$
- 2 $NP \rightarrow det\ n$
- 3 $NP \rightarrow n$
- 4 $VP \rightarrow vt\ NP\ PP$
- 5 $VP \rightarrow vi$
- 6 $PP \rightarrow with\ NP$
- 7 $det \rightarrow the|a$
- 8 $n \rightarrow cat|fish|knife$
- 9 $vt \rightarrow eats$
- 10 $vi \rightarrow eats$

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- 1 $S \rightarrow NP\ VP$
- 2 $NP \rightarrow det\ n$ (A) Convert hybrid rules
- 3 $NP \rightarrow n$
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- 5 $VP \rightarrow vi$
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(A) Convert hybrid rules

$PP \rightarrow A\ NP$

$A \rightarrow with$

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- 1 $S \rightarrow NP\ VP$
- 2 $NP \rightarrow det\ n$ (A) Convert hybrid rules
- 3 $NP \rightarrow n$ $PP \rightarrow A\ NP$
- 4 $VP \rightarrow vt\ NP\ PP$ $A \rightarrow with$
- 5 $VP \rightarrow vi$ (B) Convert unit productions
- 6 $PP \rightarrow with\ NP$
- 7 $det \rightarrow the|a$
- 8 $n \rightarrow cat|fish|knife$
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(A) Convert hybrid rules

$PP \rightarrow A\ NP$

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(B) Convert unit productions

$NP \rightarrow cat|fish|knife$

$VP \rightarrow eats$

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(A) Convert hybrid rules

$PP \rightarrow A\ NP$

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(B) Convert unit productions

$NP \rightarrow cat|fish|knife$

$VP \rightarrow eats$

(C) Convert non-binary rules

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$NP \rightarrow cat|fish|knife$

$VP \rightarrow eats$

(C) Convert non-binary rules

$VP \rightarrow vtB$

$B \rightarrow NP\ PP$

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- 1 $S \rightarrow NP\ VP$
- 2 $NP \rightarrow det\ n$
- 3 $NP \rightarrow cat|fish|knife$
- 4 $VP \rightarrow vt\ B$
- 5 $B \rightarrow NP\ PP$
- 6 $VP \rightarrow eats$
- 7 $PP \rightarrow A\ NP$
- 8 $A \rightarrow with$
- 9 $det \rightarrow the|a$
- 10 $n \rightarrow cat|fish|knife$
- 11 $vt \rightarrow eats$

Exercise 2

$S \rightarrow NP\ VP$ 0.5
 $S \rightarrow NP\ Vi$ 0.5
 $NP \rightarrow DT\ NN$ 0.4
 $NP \rightarrow NP\ PP$ 0.6
 $PP \rightarrow IN\ NP$ 1.0
 $VP \rightarrow Vt\ NP$ 0.4
 $VP \rightarrow VP\ PP$ 0.1
 $VP \rightarrow Vi\ PP$ 0.5

$Vi \rightarrow sleeps$ 1.0
 $Vt \rightarrow saw$ 1.0
 $NN \rightarrow man$ 0.7
 $NN \rightarrow woman$ 0.2
 $NN \rightarrow telescope$ 0.1
 $DT \rightarrow the$ 1.0
 $IN \rightarrow with$ 0.5
 $IN \rightarrow in$ 0.5

11 DT + the 1.0	22 NN + woman 0.2	33 Vt + saw 1.0	44 DT + the 1.0	55 NN + man 0.7	66 IN + with 0.5	77 DT + the 1.0	88 NN + telescope 0.1	
1	2	3	4	5	6	7	8	

Exercise 2

$S \rightarrow NP\ VP$	0.5	$Vi \rightarrow \text{sleeps}$	1.0
$S \rightarrow NP\ Vi$	0.5	$Vt \rightarrow \text{saw}$	1.0
$NP \rightarrow DT\ NN$	0.4	$NN \rightarrow \text{man}$	0.7
$NP \rightarrow NP\ PP$	0.6	$NN \rightarrow \text{woman}$	0.2
$PP \rightarrow IN\ NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow \text{in}$	0.5

11 $DT \rightarrow \text{the}$ 1.0	12 $NP \rightarrow DT_{11}NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	33 $Vt \rightarrow \text{saw}$ 1.0	44 $DT \rightarrow \text{the}$ 1.0	55 $NN \rightarrow \text{man}$ 0.7	66 $IN \rightarrow \text{with}$ 0.5	77 $DT \rightarrow \text{the}$ 1.0	88 $NN \rightarrow \text{telescope}$ 0.1	
1	2	3	4	5	6	7	8	

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$PP \rightarrow IN\ NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow \text{the}$	1.0
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$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow \text{in}$	0.5

11 $DT \rightarrow \text{the}$ 1.0	22 $NN \rightarrow \text{woman}$ 0.2	33 $Vt \rightarrow \text{saw}$ 1.0	12 $NP \rightarrow DT_{11}NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	23	44 $DT \rightarrow \text{the}$ 1.0	55 $NN \rightarrow \text{man}$ 0.7	66 $IN \rightarrow \text{with}$ 0.5	77 $DT \rightarrow \text{the}$ 1.0	88 $NN \rightarrow \text{telescope}$ 0.1
1	2	3	4	5	6	7	8		

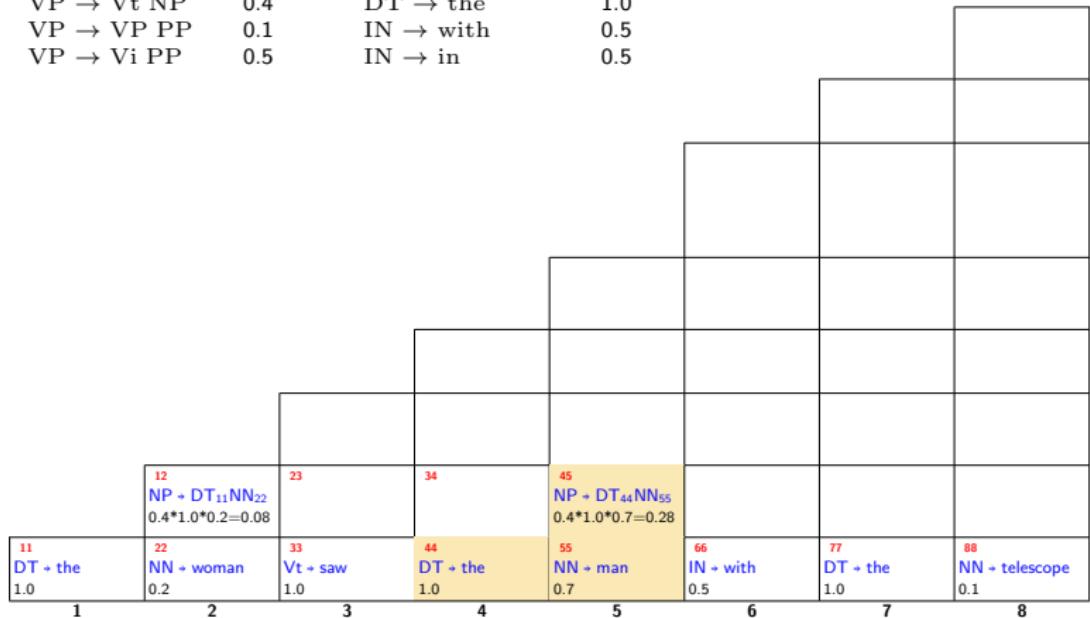
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$S \rightarrow NP\ VP$	0.5	$Vi \rightarrow \text{sleeps}$	1.0
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$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow \text{in}$	0.5

¹¹ DT + the 1.0	²² NN + woman 0.2	³³ Vt + saw 1.0	⁴⁴ DT + the 1.0	⁵⁵ NN + man 0.7	⁶⁶ IN + with 0.5	⁷⁷ DT + the 1.0	⁸⁸ NN + telescope 0.1	

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$S \rightarrow NP\ VP$	0.5	$Vi \rightarrow$ sleeps	1.0
$S \rightarrow NP\ Vi$	0.5	$Vt \rightarrow$ saw	1.0
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$NP \rightarrow NP\ PP$	0.6	$NN \rightarrow$ woman	0.2
$PP \rightarrow IN\ NP$	1.0	$NN \rightarrow$ telescope	0.1
$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow$ the	1.0
$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow$ with	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow$ in	0.5



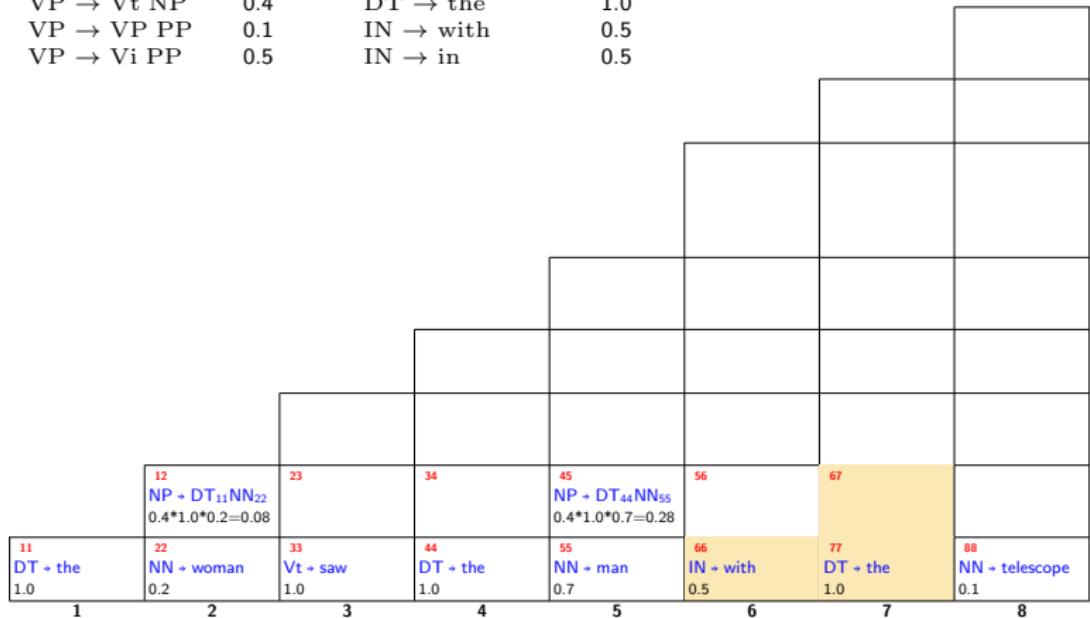
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$S \rightarrow NP\ VP$	0.5	$Vi \rightarrow \text{sleeps}$	1.0
$S \rightarrow NP\ Vi$	0.5	$Vt \rightarrow \text{saw}$	1.0
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$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow \text{the}$	1.0
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¹¹ $DT \rightarrow \text{the}$ 1.0	²² $NN \rightarrow \text{woman}$ 0.2	³³ $Vt \rightarrow \text{saw}$ 1.0	⁴⁴ $DT \rightarrow \text{the}$ 1.0	⁵⁵ $NN \rightarrow \text{man}$ 0.7	⁶⁶ $IN \rightarrow \text{with}$ 0.5	⁷⁷ $DT \rightarrow \text{the}$ 1.0	⁸⁸ $NN \rightarrow \text{telescope}$ 0.1	
¹² $NP \rightarrow DT_{11}NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	²³	³⁴	⁴⁵ $NP \rightarrow DT_{44}NN_{55}$ $0.4 * 1.0 * 0.7 = 0.28$	⁵⁶				

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$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow$ the	1.0
$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow$ with	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow$ in	0.5



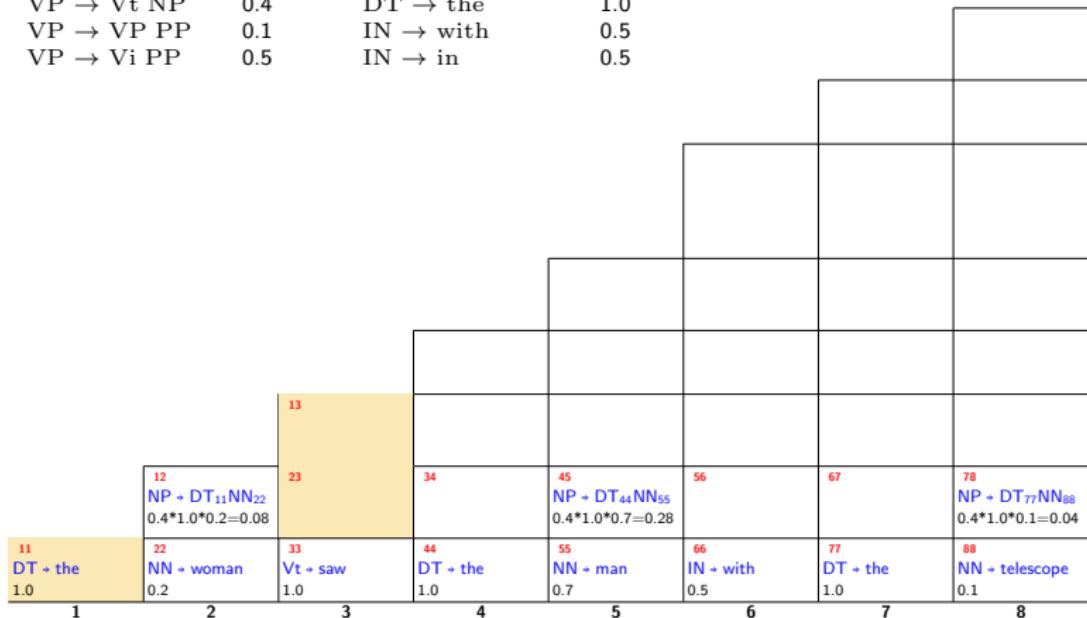
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$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow \text{in}$	0.5

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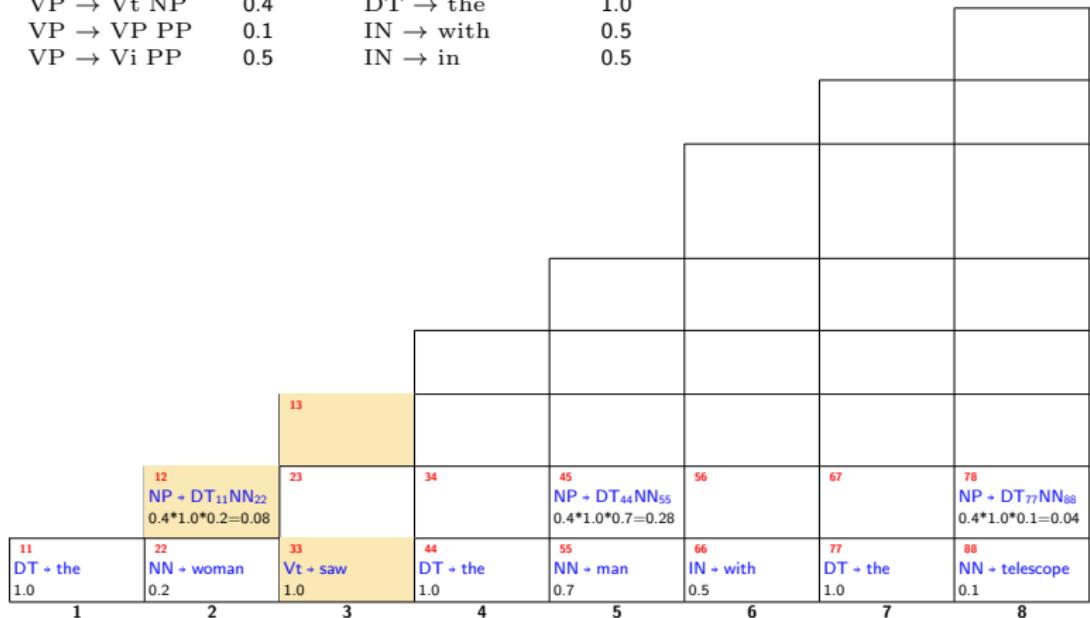
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$S \rightarrow NP\ Vi$	0.5	$Vt \rightarrow$ saw	1.0
$NP \rightarrow DT\ NN$	0.4	$NN \rightarrow$ man	0.7
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$PP \rightarrow IN\ NP$	1.0	$NN \rightarrow$ telescope	0.1
$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow$ the	1.0
$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow$ with	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow$ in	0.5



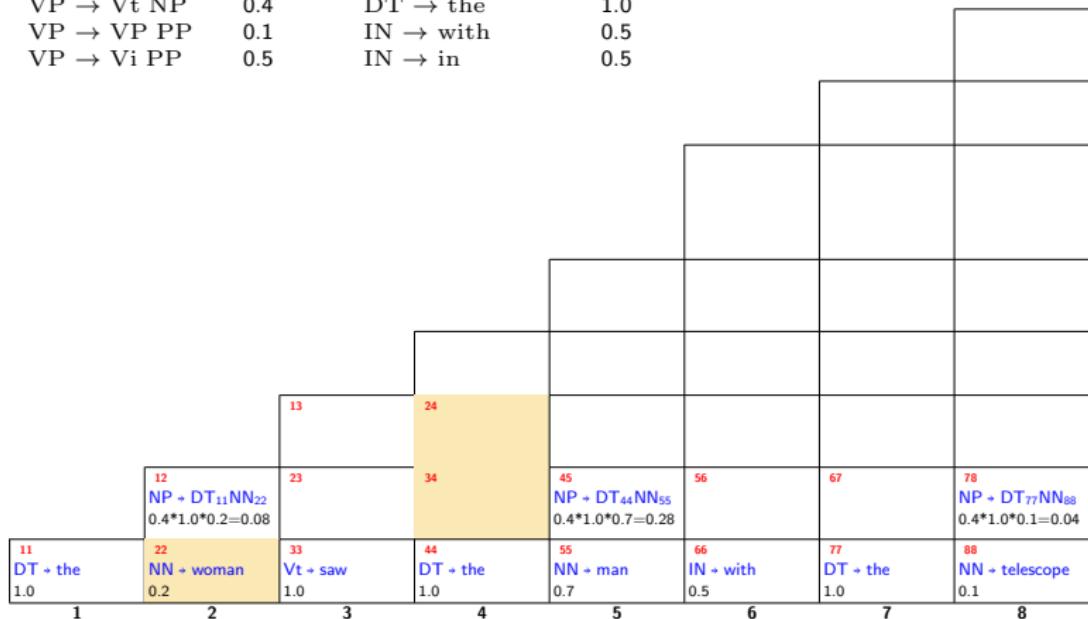
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$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow$ with	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow$ in	0.5



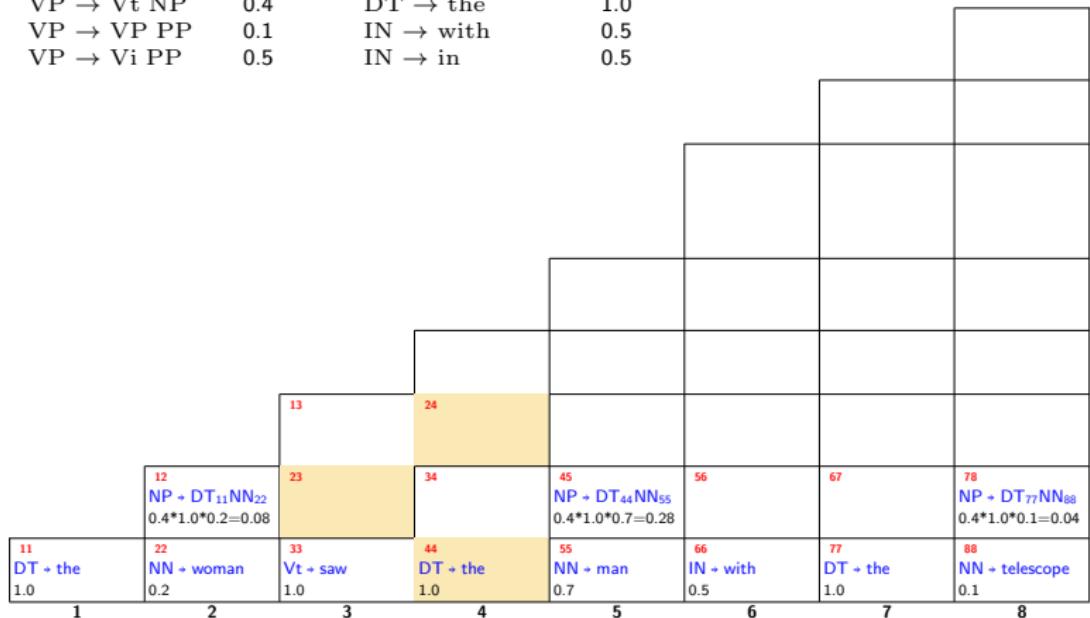
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$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow$ the	1.0
$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow$ with	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow$ in	0.5



Exercise 2

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$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow \text{in}$	0.5



Exercise 2

S → NP VP	0.5
S → NP Vi	0.5
NP → DT NN	0.4
NP → NP PP	0.6
PP → IN NP	1.0
VP → Vt NP	0.4
VP → VP PP	0.1
VP → Vi PP	0.5

Vi → sleeps	1.0
Vt → saw	1.0
NN → man	0.7
NN → woman	0.2
NN → telescope	0.1
DT → the	1.0
IN → with	0.5
IN → in	0.5

11 DT + the 1.0	12 NP + DT ₁₁ NN ₂₂ 0.4*1.0*0.2=0.08	13 NN + woman 0.2	23 Vt + saw 1.0	33 VT → saw 1.0	24	34	35 VP + Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.112	45 NP + DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56	67	78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
1	2	3	4	5	6	7	8				

Exercise 2

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$NP \rightarrow NP\ PP$	0.6	$NN \rightarrow \text{woman}$	0.2
$PP \rightarrow IN\ NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow \text{in}$	0.5

11 $DT + \text{the}$ 1.0	12 $NP + DT_{11}NN_{22}$ 0.4*1.0*0.2=0.08	13 $NN + \text{woman}$ 0.2	23 $Vt \rightarrow \text{saw}$ 1.0	24 $DT \rightarrow \text{the}$ 1.0	34 $NN \rightarrow \text{man}$ 0.7	35 $VP + Vt_{33}NP_{45}$ 0.4*1.0*0.28=0.112	56 $IN \rightarrow \text{with}$ 0.5	67 $DT \rightarrow \text{the}$ 1.0	78 $NP + DT_{77}NN_{88}$ 0.4*1.0*0.1=0.04
11 $DT + \text{the}$ 1.0	22 $NN + \text{woman}$ 0.2	33 $Vt \rightarrow \text{saw}$ 1.0	44 $DT \rightarrow \text{the}$ 1.0	55 $NN \rightarrow \text{man}$ 0.7	66 $IN \rightarrow \text{with}$ 0.5	77 $DT \rightarrow \text{the}$ 1.0	88 $NN \rightarrow \text{telescope}$ 0.1		

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Exercise 2

$S \rightarrow NP\ VP$	0.5	$Vi \rightarrow \text{sleeps}$	1.0
$S \rightarrow NP\ Vi$	0.5	$Vt \rightarrow \text{saw}$	1.0
$NP \rightarrow DT\ NN$	0.4	$NN \rightarrow \text{man}$	0.7
$NP \rightarrow NP\ PP$	0.6	$NN \rightarrow \text{woman}$	0.2
$PP \rightarrow IN\ NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow \text{in}$	0.5

11 $DT + \text{the}$ 1.0	22 $NN + \text{woman}$ 0.2	33 $Vt \rightarrow \text{saw}$ 1.0	44 $DT \rightarrow \text{the}$ 1.0	35 $VP + Vt_{33}NN_{45}$ $0.4 * 1.0 * 0.28 = 0.11$	46 56 67	78 $NP + DT_{77}NN_{88}$ $0.4 * 1.0 * 0.1 = 0.04$		
				45 $NP + DT_{44}NN_{55}$ $0.4 * 1.0 * 0.7 = 0.28$				
				55 $NN \rightarrow \text{man}$ 0.7	66 77	88 $IN \rightarrow \text{with}$ 0.5	DT \rightarrow \text{the} 1.0	NN \rightarrow \text{telescope} 0.1

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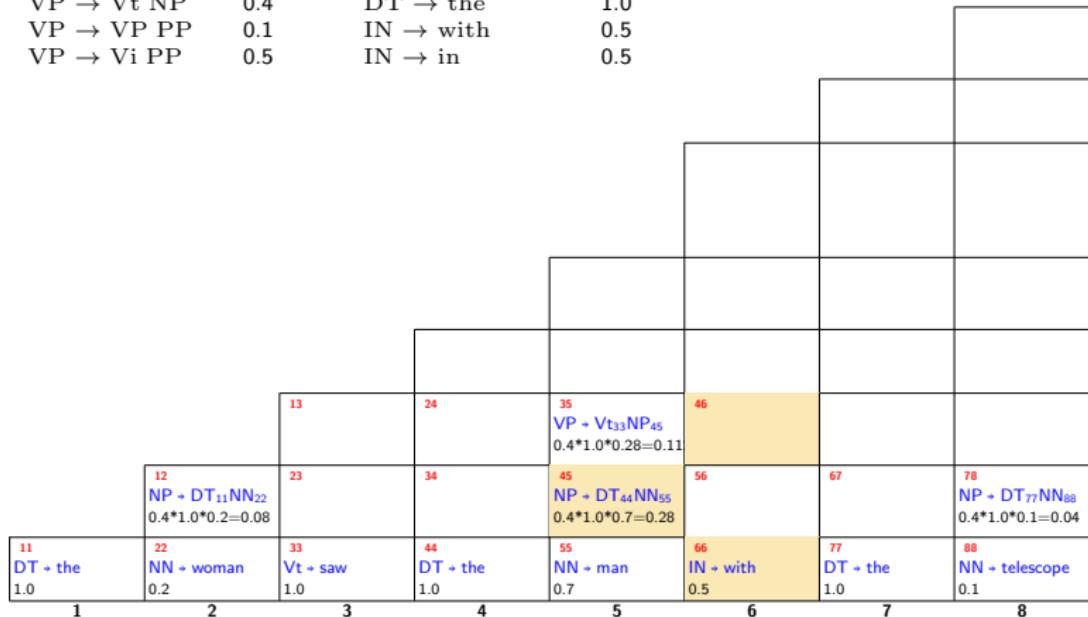
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Exercise 2

$S \rightarrow NP\ VP$	0.5	$Vi \rightarrow$ sleeps	1.0
$S \rightarrow NP\ Vi$	0.5	$Vt \rightarrow$ saw	1.0
$NP \rightarrow DT\ NN$	0.4	$NN \rightarrow$ man	0.7
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$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow$ the	1.0
$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow$ with	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow$ in	0.5



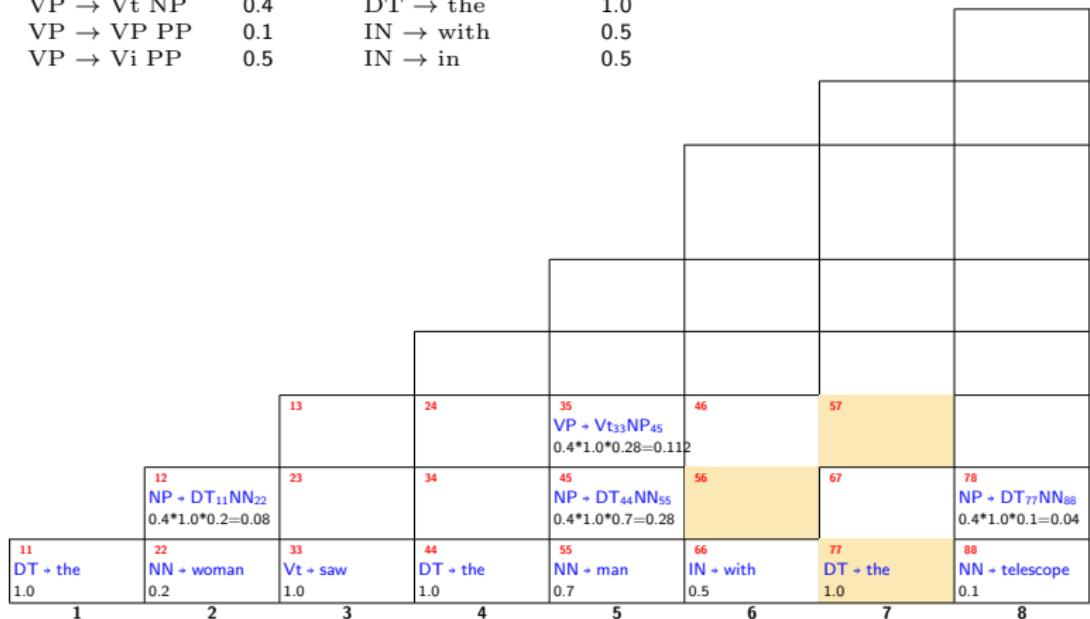
Exercise 2

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$VP \rightarrow Vt NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi PP$	0.5	$IN \rightarrow \text{in}$	0.5

11 $DT + \text{the}$ 1.0	12 $NP + DT_{11}NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	13 $NN + \text{woman}$ 0.2	24 $Vt + \text{saw}$ 1.0	35 $VP + Vt_{33}NP_{45}$ $0.4 * 1.0 * 0.28 = 0.112$	46 $NN + \text{man}$ 0.7	57 $IN + \text{with}$ 0.5	78 $NP + DT_{77}NN_{88}$ $0.4 * 1.0 * 0.1 = 0.04$
1	2	3	4	5	6	7	8

Exercise 2

$S \rightarrow NP\ VP$	0.5	$Vi \rightarrow$ sleeps	1.0
$S \rightarrow NP\ Vi$	0.5	$Vt \rightarrow$ saw	1.0
$NP \rightarrow DT\ NN$	0.4	$NN \rightarrow$ man	0.7
$NP \rightarrow NP\ PP$	0.6	$NN \rightarrow$ woman	0.2
$PP \rightarrow IN\ NP$	1.0	$NN \rightarrow$ telescope	0.1
$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow$ the	1.0
$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow$ with	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow$ in	0.5



Exercise 2

$S \rightarrow NP VP$	0.5	$Vi \rightarrow sleeps$	1.0
$S \rightarrow NP Vi$	0.5	$Vt \rightarrow saw$	1.0
$NP \rightarrow DT NN$	0.4	$NN \rightarrow man$	0.7
$NP \rightarrow NP PP$	0.6	$NN \rightarrow woman$	0.2
$PP \rightarrow IN NP$	1.0	$NN \rightarrow telescope$	0.1
$VP \rightarrow Vt NP$	0.4	$DT \rightarrow the$	1.0
$VP \rightarrow VP PP$	0.1	$IN \rightarrow with$	0.5
$VP \rightarrow Vi PP$	0.5	$IN \rightarrow in$	0.5

11 $DT + the$ 1.0	12 $NP + DT_{11}NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	13	24	35 $VP + Vt_{33}NP_{45}$ $0.4 * 1.0 * 0.28 = 0.112$	46	57	68 $PP + IN_{66}NP_{78}$ $1.0 * 0.5 * 0.04 = 0.02$	
21 $NN + woman$ 0.2	22 $NN + man$ 0.7	23	34	45 $NP + DT_{44}NN_{55}$ $0.4 * 1.0 * 0.7 = 0.28$	56	67	78 $NP + DT_{77}NN_{88}$ $0.4 * 1.0 * 0.1 = 0.04$	
31 $Vt + saw$ 1.0	32 $DT + the$ 1.0	33	44	55 $NN + with$ 0.5	66	77 $DT + the$ 1.0	88 $NN + telescope$ 0.1	

Exercise 2

$S \rightarrow NP VP$	0.5	$Vi \rightarrow \text{sleeps}$	1.0
$S \rightarrow NP Vi$	0.5	$Vt \rightarrow \text{saw}$	1.0
$NP \rightarrow DT NN$	0.4	$NN \rightarrow \text{man}$	0.7
$NP \rightarrow NP PP$	0.6	$NN \rightarrow \text{woman}$	0.2
$PP \rightarrow IN NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi PP$	0.5	$IN \rightarrow \text{in}$	0.5

11 $DT + \text{the}$ 1.0	12 $NP + DT_{11}NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	13	24	35 $VP + Vt_{33}NP_{45}$ $0.4 * 1.0 * 0.28 = 0.112$	46	57	68 $PP + IN_{65}NP_{78}$ $1.0 * 0.5 * 0.04 = 0.02$
22 $NN + \text{woman}$ 0.2	23	34	45 $NP + DT_{44}NN_{55}$ $0.4 * 1.0 * 0.7 = 0.28$	56	67	78 $NP + DT_{77}NN_{88}$ $0.4 * 1.0 * 0.1 = 0.04$	
$Vt \rightarrow \text{saw}$ 1.0	$Vt \rightarrow \text{saw}$ 1.0	33	44 $DT \rightarrow \text{the}$ 1.0	55 $NN \rightarrow \text{man}$ 0.7	66 $IN \rightarrow \text{with}$ 0.5	77 $DT \rightarrow \text{the}$ 1.0	88 $NN \rightarrow \text{telescope}$ 0.1

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Exercise 2

$S \rightarrow NP\ VP$	0.5	$Vi \rightarrow \text{sleeps}$	1.0
$S \rightarrow NP\ Vi$	0.5	$Vt \rightarrow \text{saw}$	1.0
$NP \rightarrow DT\ NN$	0.4	$NN \rightarrow \text{man}$	0.7
$NP \rightarrow NP\ PP$	0.6	$NN \rightarrow \text{woman}$	0.2
$PP \rightarrow IN\ NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow \text{in}$	0.5

$11\ DT + \text{the}$ 1.0	$12\ NP + DT_{11}NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	13	14	$15\ VP + Vt_{33}NP_{45}$ $0.4 * 1.0 * 0.28 = 0.112$	16	17	$18\ PP + DT_{66}NP_{78}$ $1.0 * 0.5 * 0.04 = 0.02$
$21\ NN + \text{woman}$ 0.2	$22\ Vt + \text{saw}$ 1.0	23	24	$25\ NP + DT_{44}NN_{55}$ $0.4 * 1.0 * 0.7 = 0.28$	26	27	$28\ IN + \text{with}$ 0.5
$31\ DT + \text{the}$ 1.0	$32\ Vt + \text{saw}$ 1.0	33	34	$35\ NN + \text{man}$ 0.7	36	$37\ DT + \text{the}$ 1.0	$38\ NN + \text{telescope}$ 0.1

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Exercise 2

$S \rightarrow NP\ VP$	0.5	$Vi \rightarrow sleeps$	1.0
$S \rightarrow NP\ Vi$	0.5	$Vt \rightarrow saw$	1.0
$NP \rightarrow DT\ NN$	0.4	$NN \rightarrow man$	0.7
$NP \rightarrow NP\ PP$	0.6	$NN \rightarrow woman$	0.2
$PP \rightarrow IN\ NP$	1.0	$NN \rightarrow telescope$	0.1
$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow the$	1.0
$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow with$	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow in$	0.5

12 $NP \rightarrow DT_{11}NN_{22}$ 0.4*1.0*0.2=0.08	13	23	34	35 $VP + Vt_{33}NP_{45}$ 0.4*1.0*0.28=0.112	46	57	68 $PP + DT_{66}NP_{78}$ 1.0*0.5*0.04=0.02	
11 $DT \rightarrow the$ 1.0	22 $NN \rightarrow woman$ 0.2	33 $Vt \rightarrow saw$ 1.0	44 $DT \rightarrow the$ 1.0	55 $NN \rightarrow man$ 0.7	66 $IN \rightarrow with$ 0.5	77 $DT \rightarrow the$ 1.0	88 $NN \rightarrow telescope$ 0.1	

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Exercise 2

$S \rightarrow NP\ VP$	0.5	$Vi \rightarrow \text{sleeps}$	1.0
$S \rightarrow NP\ Vi$	0.5	$Vt \rightarrow \text{saw}$	1.0
$NP \rightarrow DT\ NN$	0.4	$NN \rightarrow \text{man}$	0.7
$NP \rightarrow NP\ PP$	0.6	$NN \rightarrow \text{woman}$	0.2
$PP \rightarrow IN\ NP$	1.0	$NN \rightarrow \text{telescope}$	0.1
$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow \text{the}$	1.0
$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow \text{with}$	0.5
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow \text{in}$	0.5

11 $DT + \text{the}$ 1.0	22 $NN + \text{woman}$ 0.2	33 $Vt + \text{saw}$ 1.0	44 $DT + \text{the}$ 1.0	55 $NN + \text{man}$ 0.7	66 $IN + \text{with}$ 0.5	77 $DT + \text{the}$ 1.0	88 $NN + \text{telescope}$ 0.1
12 $NP + DT_{11}NN_{22}$ 0.4*1.0*0.2=0.08	23	34	45 $NP + DT_{44}NN_{55}$ 0.4*1.0*0.7=0.28	56	67	78 $NP + DT_{77}NN_{88}$ 0.4*1.0*0.1=0.04	
		13	24	35 $VP + Vt_{33}NP_{45}$ 0.4*1.0*0.28=0.112	46	57	68 $PP + IN_{66}NP_{78}$ 1.0*0.5*0.04=0.02
			14				

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Exercise 2

$S \rightarrow NP VP$	0.5	$Vi \rightarrow sleeps$	1.0					
$S \rightarrow NP Vi$	0.5	$Vt \rightarrow saw$	1.0					
$NP \rightarrow DT NN$	0.4	$NN \rightarrow man$	0.7					
$NP \rightarrow NP PP$	0.6	$NN \rightarrow woman$	0.2					
$PP \rightarrow IN NP$	1.0	$NN \rightarrow telescope$	0.1					
$VP \rightarrow Vt NP$	0.4	$DT \rightarrow the$	1.0					
$VP \rightarrow VP PP$	0.1	$IN \rightarrow with$	0.5					
$VP \rightarrow Vi PP$	0.5	$IN \rightarrow in$	0.5					

14	13	24	35	36	47	58		
			$VP + Vt_{33}NP_{45}$ $0.4 * 1.0 * 0.28 = 0.112$					
				46	57	68		
						$PP + IN_{65}NP_{78}$ $1.0 * 0.5 * 0.04 = 0.02$		
12 $NP + DT_{11}NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	23	34	45 $NP + DT_{44}NN_{55}$ $0.4 * 1.0 * 0.7 = 0.28$	56	67	78 $NP + DT_{77}NN_{88}$ $0.4 * 1.0 * 0.1 = 0.04$		
11 $DT + the$ 1.0	22 $NN + woman$ 0.2	33 $Vt + saw$ 1.0	44 $DT + the$ 1.0	55 $NN + man$ 0.7	66 $IN + with$ 0.5	77 $DT + the$ 1.0	88 $NN + telescope$ 0.1	

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Exercise 2

$S \rightarrow NP VP$	0.5	$Vi \rightarrow sleeps$	1.0
$S \rightarrow NP Vi$	0.5	$Vt \rightarrow saw$	1.0
$NP \rightarrow DT NN$	0.4	$NN \rightarrow man$	0.7
$NP \rightarrow NP PP$	0.6	$NN \rightarrow woman$	0.2
$PP \rightarrow IN NP$	1.0	$NN \rightarrow telescope$	0.1
$VP \rightarrow Vt NP$	0.4	$DT \rightarrow the$	1.0
$VP \rightarrow VP PP$	0.1	$IN \rightarrow with$	0.5
$VP \rightarrow Vi PP$	0.5	$IN \rightarrow in$	0.5

11 $DT \rightarrow the$ 1.0	22 $NN \rightarrow woman$ 0.2	33 $Vt \rightarrow saw$ 1.0	44 $DT \rightarrow the$ 1.0	55 $NN \rightarrow man$ 0.7	66 $IN \rightarrow with$ 0.5	77 $DT \rightarrow the$ 1.0	88 $NN \rightarrow telescope$ 0.1
12 $NP \rightarrow DT_{11}NN_{22}$ $0.4*1.0*0.2=0.08$	23 $NP \rightarrow Vt_{33}NP_{44}$ $0.4*1.0*0.28=0.112$	34 $NP \rightarrow DT_{44}NN_{55}$ $0.4*1.0*0.7=0.28$	45 $VP \rightarrow Vt_{33}NP_{45}$ $0.4*1.0*0.28=0.112$	56 $VP \rightarrow NP_{56}NP_{67}$ $0.4*0.48e-3*0.112=4.48e-3$	67 $NP \rightarrow DT_{66}NP_{78}$ $1.0*0.5*0.04=0.02$	78 $NP \rightarrow DT_{77}NN_{88}$ $0.4*1.0*0.1=0.04$	
13 $NP \rightarrow DT_{12}VP_{35}$ $0.5*0.08*0.112=4.48e-3$	24 $NP \rightarrow VP_{35}NP_{46}$ $0.4*1.0*0.28=0.112$	35 $NP \rightarrow NP_{56}VP_{67}$ $0.4*0.48e-3*0.112=4.48e-3$	46 $VP \rightarrow NP_{56}VP_{67}$ $0.4*0.48e-3*0.112=4.48e-3$	57 $VP \rightarrow NP_{57}NP_{68}$ $0.4*0.48e-3*0.112=4.48e-3$	68 $VP \rightarrow VP_{58}NP_{69}$ $0.4*0.48e-3*0.112=4.48e-3$	79 $VP \rightarrow VP_{59}VP_{70}$ $0.4*0.48e-3*0.112=4.48e-3$	
14 $NP \rightarrow NP_{13}VP_{25}$ $0.5*0.112*0.08=0.0448$	25 $NP \rightarrow VP_{25}NP_{36}$ $0.4*0.28*0.112=0.112$	36 $NP \rightarrow NP_{36}NP_{47}$ $0.4*0.48e-3*0.112=4.48e-3$	47 $NP \rightarrow NP_{37}NP_{48}$ $0.4*0.48e-3*0.112=4.48e-3$	58 $NP \rightarrow NP_{38}VP_{49}$ $0.4*0.48e-3*0.112=4.48e-3$	69 $NP \rightarrow VP_{39}NP_{50}$ $0.4*0.48e-3*0.112=4.48e-3$	70 $NP \rightarrow VP_{40}NP_{51}$ $0.4*0.48e-3*0.112=4.48e-3$	

Exercise 2

$S \rightarrow NP\ VP$	0.5	$Vi \rightarrow \text{sleeps}$	1.0				
$S \rightarrow NP\ Vi$	0.5	$Vt \rightarrow \text{saw}$	1.0				
$NP \rightarrow DT\ NN$	0.4	$NN \rightarrow \text{man}$	0.7				
$NP \rightarrow NP\ PP$	0.6	$NN \rightarrow \text{woman}$	0.2				
$PP \rightarrow IN\ NP$	1.0	$NN \rightarrow \text{telescope}$	0.1				
$VP \rightarrow Vt\ NP$	0.4	$DT \rightarrow \text{the}$	1.0				
$VP \rightarrow VP\ PP$	0.1	$IN \rightarrow \text{with}$	0.5				
$VP \rightarrow Vi\ PP$	0.5	$IN \rightarrow \text{in}$	0.5				

					16	27			
									38 $VP \rightarrow Vt_{33}NP_{48}$ $0.4 * 1.0 * 3.36e-3 = 1.34e-3$
				15	46	37	48		
				$S \rightarrow NP_{12}VP_{35}$ $0.5 * 0.08 * 0.112 = 4.48e-3$			$NP \rightarrow NP_{45}PP_{68}$ $0.6 * 0.28 * 0.02 = 3.36e-3$		
			14	25	36	47	58		
		13	24	35	46	57	68		
				$VP \rightarrow Vt_{33}NP_{45}$ $0.4 * 1.0 * 0.28 = 0.112$			$PP \rightarrow IN_{66}NP_{78}$ $1.0 * 0.5 * 0.04 = 0.02$		
	12 $NP \rightarrow DT_{11}NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	23	34	45	56	67	78 $NP \rightarrow DT_{77}NN_{88}$ $0.4 * 1.0 * 0.1 = 0.04$		
11 $DT \rightarrow \text{the}$ 1.0	22 $NN \rightarrow \text{woman}$ 0.2	33 $Vt \rightarrow \text{saw}$ 1.0	44 $DT \rightarrow \text{the}$ 1.0	55 $NN \rightarrow \text{man}$ 0.7	66 $IN \rightarrow \text{with}$ 0.5	77 $DT \rightarrow \text{the}$ 1.0	88 $NN \rightarrow \text{telescope}$ 0.1		

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Exercise 2

S → NP VP

0.5

S → NP Vi

0.5

NP → DT NN

0.4

NP → NP PP

0.6

PP → IN NP

1.0

VP → Vt NP

0.4

VP → VP PP

0.1

VP → Vi PP

0.5

Vi → sleeps

1.0

Vt → saw

1.0

NN → man

0.7

NN → woman

0.2

NN → telescope

0.1

DT → the

1.0

IN → with

0.5

IN → in

0.5

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16	27	38 VP → Vt ₃₃ NP ₄₈ 0.4*1.0*3.36e-3=1.34e-3 VP → VP ₃₅ PP ₆₈ 0.1*0.112*0.02=2.24e-3
15 S → NP ₁₂ VP ₃₅ 0.5*0.08*0.112=4.48e-3	46	37 48 NP → NP ₄₅ PP ₆₈ 0.6*0.28*0.02=3.36e-3
14	25	36 47 58
13 24	35 VP → Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.112	46 57 68 PP → IN ₆₅ NP ₇₈ 1.0*0.5*0.04=0.02
12 NP → DT ₁₁ NN ₂₂ 0.4*1.0*0.2=0.08	34 45 NP → DT ₄₄ NN ₅₅ 0.4*1.0*0.7=0.28	56 67 78 NP → DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04
11 DT → the 1.0	23 33 Vt → saw 1.0	55 66 77 DT → the 1.0
22 NN → woman 0.2	44 NN → man 0.7	88 NN → telescope 0.1

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Exercise 2

$S \rightarrow NP VP$	0.5
$S \rightarrow NP Vi$	0.5
$NP \rightarrow DT NN$	0.4
$NP \rightarrow NP PP$	0.6
$PP \rightarrow IN NP$	1.0
$VP \rightarrow Vt NP$	0.4
$VP \rightarrow VP PP$	0.1
$VP \rightarrow Vi PP$	0.5

$Vi \rightarrow sleeps$	1.0
$Vt \rightarrow saw$	1.0
$NN \rightarrow man$	0.7
$NN \rightarrow woman$	0.2
$NN \rightarrow telescope$	0.1
$DT \rightarrow the$	1.0
$IN \rightarrow with$	0.5
$IN \rightarrow in$	0.5

1 DT + the 1.0	2 NN + woman 0.2	3 Vt + saw 1.0	4 DT + the 1.0	5 NN + man 0.7	6 IN + with 0.5	7 DT + the 1.0	8 NN + telescope 0.1	
11 12 NP + DT ₁₁ NN ₂₂ 0.4*1.0*0.2=0.08	22 NN + woman 0.2	33 Vt + saw 1.0	44 DT + the 1.0	55 NN + man 0.7	66 IN + with 0.5	77 DT + the 1.0	88 NN + telescope 0.1	
13 14 S + NP ₁₂ VP ₃₅ 0.5*0.08*0.112=0.048e-3	23 15 S + NP ₁₂ VP ₃₅ 0.5*0.08*0.112=0.048e-3	24 25 VP + Vt ₃₃ NP ₄₅ 0.4*1.0*0.28=0.112	36 37 46 48 NP + NP ₄₅ PP ₆₈ 0.6*0.28*0.02=3.36e-3	38 VP + Vt ₃₃ NP ₄₈ 0.4*1.0*3.36e-3=1.34e-3	46 47 57 68 PP + IN ₆₆ NP ₇₈ 1.0*0.5*0.04=0.02	57 58 67 78 NP + DT ₇₇ NN ₈₈ 0.4*1.0*0.1=0.04	67 68 77 88 NN + telescope 0.1	

Exercise 2

$S \rightarrow NP VP$	0.5	$Vi \rightarrow sleeps$	1.0						
$S \rightarrow NP Vi$	0.5	$Vt \rightarrow saw$	1.0						
$NP \rightarrow DT NN$	0.4	$NN \rightarrow man$	0.7						
$NP \rightarrow NP PP$	0.6	$NN \rightarrow woman$	0.2						
$PP \rightarrow IN NP$	1.0	$NN \rightarrow telescope$	0.1						
$VP \rightarrow Vt NP$	0.4	$DT \rightarrow the$	1.0						
$VP \rightarrow VP PP$	0.1	$IN \rightarrow with$	0.5						
$VP \rightarrow Vi PP$	0.5	$IN \rightarrow in$	0.5						
									18 $S \rightarrow NP_{12} VP_{38}$ $0.5 * 0.08 * 1.34e-3 = 5.38e-5$
							17	28	
						16	27		38 $VP \rightarrow Vt_{33} NP_{48}$ $0.4 * 1.0 * 3.36e-3 = 1.34e-3$
									15 $S \rightarrow NP_{12} VP_{35}$ $0.5 * 0.08 * 0.112 = 4.48e-3$
				14	25	36	47	58	48 $NP \rightarrow NP_{45} PP_{68}$ $0.6 * 0.28 * 0.02 = 3.36e-3$
		13	24		35 $VP \rightarrow Vt_{33} NP_{45}$ $0.4 * 1.0 * 0.28 = 0.112$	46	57		68 $PP \rightarrow IN_{65} NP_{78}$ $1.0 * 0.5 * 0.04 = 0.02$
		12 $NP \rightarrow DT_{11} NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	23	34	45 $NP \rightarrow DT_{44} NN_{55}$ $0.4 * 1.0 * 0.7 = 0.28$	56	67		78 $NP \rightarrow DT_{77} NN_{88}$ $0.4 * 1.0 * 0.1 = 0.04$
11 $DT \rightarrow the$ 1.0	22 $NN \rightarrow woman$ 0.2	33 $Vt \rightarrow saw$ 1.0	44 $DT \rightarrow the$ 1.0	55 $NN \rightarrow man$ 0.7	66 $IN \rightarrow with$ 0.5	77 $DT \rightarrow the$ 1.0	88 $NN \rightarrow telescope$ 0.1		
1	2	3	4	5	6	7	8		

Exercise 2

$S \rightarrow NP VP$	0.5	$Vi \rightarrow sleeps$	1.0
$S \rightarrow NP Vi$	0.5	$Vt \rightarrow saw$	1.0
$NP \rightarrow DT NN$	0.4	$NN \rightarrow man$	0.7
$NP \rightarrow NP PP$	0.6	$NN \rightarrow woman$	0.2
$PP \rightarrow IN NP$	1.0	$NN \rightarrow telescope$	0.1
$VP \rightarrow Vt NP$	0.4	$DT \rightarrow the$	1.0
$VP \rightarrow VP PP$	0.1	$IN \rightarrow with$	0.5
$VP \rightarrow Vi PP$	0.5	$IN \rightarrow in$	0.5

Final result

11 DT + the 1.0	22 NN + woman 0.2	33 Vt + saw 1.0	44 DT + the 1.0	55 NN + man 0.7	66 IN + with 0.5	77 DT + the 1.0	88 NN + telescope 0.1
12 $NP \rightarrow DT_{11} NN_{22}$ $0.4 * 1.0 * 0.2 = 0.08$	23 13 14 24 35 $VP \rightarrow Vt_{33} NP_{45}$ $0.4 * 1.0 * 0.28 = 0.112$	34 25 36 46 45 $NP \rightarrow DT_{44} NN_{55}$ $0.4 * 1.0 * 0.7 = 0.28$	46 37 38 16 27 48 $S \rightarrow NP_{12} VP_{38}$ $0.5 * 0.08 * 1.34e-3 = 5.38e-5$	56 57 58 17 28 39 $VP + Vt_{33} NP_{48}$ $0.4 * 1.0 * 3.36e-3 = 1.34e-3$	67 68 69 46 58 78 $NP \rightarrow NP_{45} PP_{68}$ $0.6 * 0.28 * 0.02 = 3.36e-3$	77 78 79 18 29 80 $PP \rightarrow IN_{66} NP_{78}$ $1.0 * 0.5 * 0.04 = 0.02$	88 89 90 19 20 91 $NP \rightarrow DT_{77} NN_{88}$ $0.4 * 1.0 * 0.1 = 0.04$
18 $S \rightarrow NP_{12} VP_{38}$ $0.5 * 0.08 * 1.34e-3 = 5.38e-5$	29 30 31 40 50 60 70 80 90 100	39 40 41 51 61 71 81 91 100	48 49 50 60 70 80 90 100 100	59 60 61 71 81 91 100 100 100	70 71 72 80 90 100 100 100 100	80 81 82 90 100 100 100 100 100	90 91 92 100 100 100 100 100 100
19 20 21 31 41 51 61 71 81 91 100	30 31 32 42 52 62 72 82 92 100	40 41 42 52 62 72 82 92 100	50 51 52 62 72 82 92 100 100	60 61 62 72 82 92 100 100 100	70 71 72 80 90 100 100 100 100	80 81 82 90 100 100 100 100 100	90 91 92 100 100 100 100 100 100