

# CKY Parsing

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# Overview

- ▶ Begin with a CFG in CNF
- ▶ Fill a table

## **Productions**

S  $\rightarrow$  DP VP  
DP  $\rightarrow$  DP PP  
DP  $\rightarrow$  D NP  
PP  $\rightarrow$  P DP  
VP  $\rightarrow$  VP PP  
VP  $\rightarrow$  V DP

## **Lexicon**

D  $\rightarrow$  the  
NP  $\rightarrow$  binoculars  
NP  $\rightarrow$  crow  
NP  $\rightarrow$  girl  
P  $\rightarrow$  with  
V  $\rightarrow$  saw

# The Table

0the1girl2saw3the4crow5with6the7binoculars8

0								
1								
2								
3								
4								
5								
6								
7								
8								

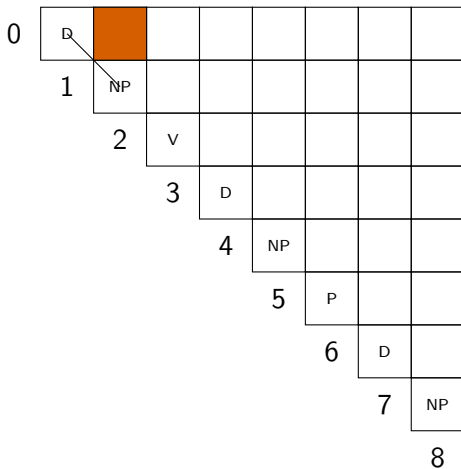
## Fill in the Lexicon

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D							
1	NP							
2	V							
3	D							
4	NP							
5	P							
6	D							
7	NP							
8								

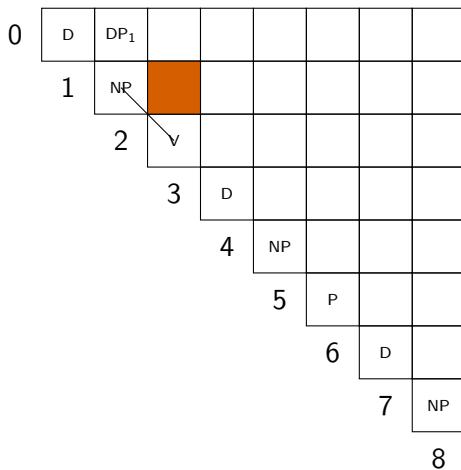
# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>



# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>



# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>						
1	NP							
2	V							
3	D							
4	NP							
5	P							
6	D							
7	NP							
8								

# Productions

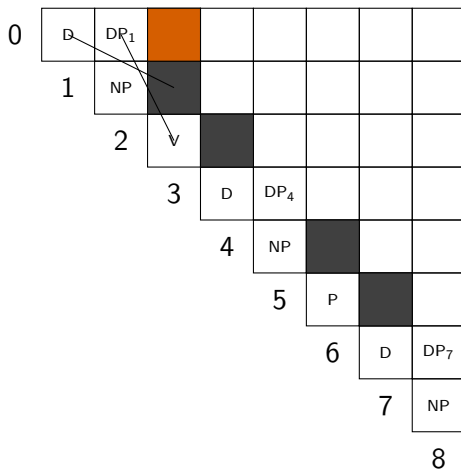
<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>						
1	NP							
2	V							
3	D	DP <sub>4</sub>						
4	NP							
5	P							
6	D	DP <sub>7</sub>						
7	NP							
8								



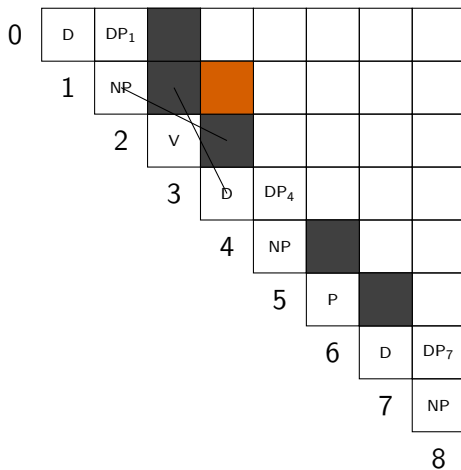
# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>



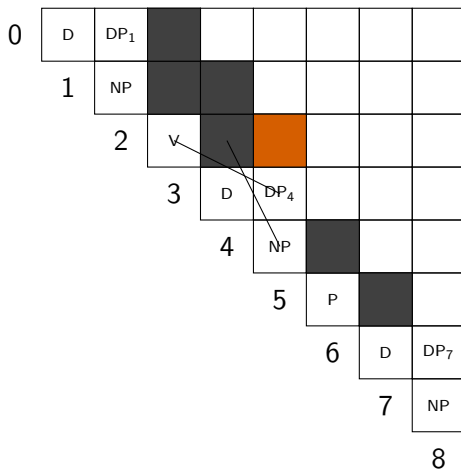
# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>



# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>



# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>						
1		NP						
2			V		VP <sub>3</sub>			
3				D	DP <sub>4</sub>			
4					NP			
5						P		
6							D	DP <sub>7</sub>
7								NP
8								

# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>						
1		NP						
2			V		VP <sub>3</sub>			
3				D	DP <sub>4</sub>			
4					NP			
5						P		PP <sub>6</sub>
6							D	DP <sub>7</sub>
7								NP
8								

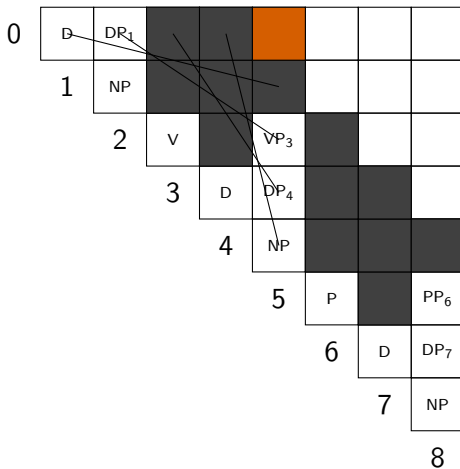
# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>						
1		NP						
2			V		VP <sub>3</sub>			
3				D	DP <sub>4</sub>			
4					NP			
5						P		PP <sub>6</sub>
6							D	DP <sub>7</sub>
7								NP
8								

# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>



# Productions

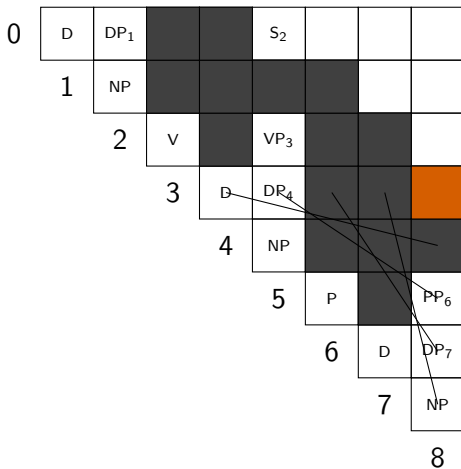
<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>			S <sub>2</sub>			
1		NP						
2			V		VP <sub>3</sub>			
3				D	DP <sub>4</sub>			
4					NP			
5						P		PP <sub>6</sub>
6							D	DP <sub>7</sub>
7								NP
8								



# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>



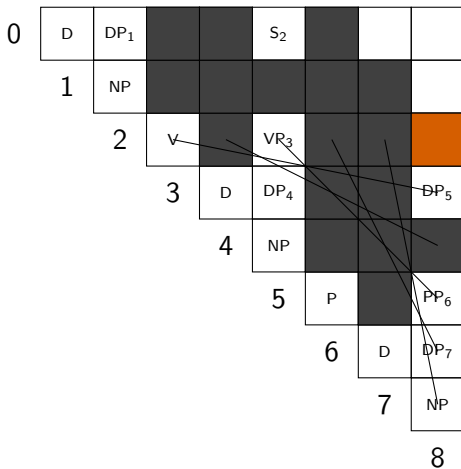
# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>			S <sub>2</sub>			
1		NP						
2			V		VP <sub>3</sub>			
3				D	DP <sub>4</sub>			DP <sub>5</sub>
4					NP			
5						P		PP <sub>6</sub>
6							D	DP <sub>7</sub>
7								NP
8								

# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>



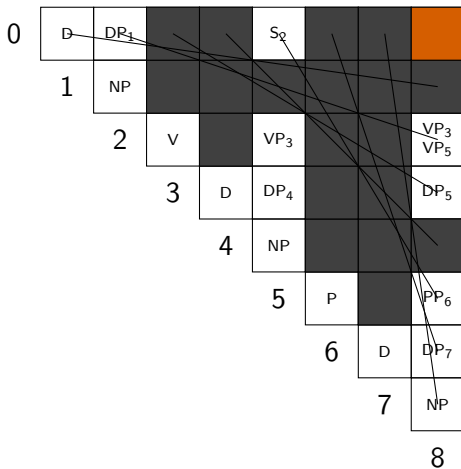
# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>			S <sub>2</sub>			
1		NP						
2			V		VP <sub>3</sub>			VP <sub>3</sub> VP <sub>5</sub>
3				D	DP <sub>4</sub>			DP <sub>5</sub>
4					NP			
5						P		PP <sub>6</sub>
6							D	DP <sub>7</sub>
7								NP
8								

# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>



# Productions

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>			S <sub>2</sub>			S <sub>2(3)</sub> S <sub>2(5)</sub>
1		NP						
2			V		VP <sub>3</sub>			VP <sub>3</sub> VP <sub>5</sub>
3				D	DP <sub>4</sub>			DP <sub>5</sub>
4					NP			
5						P		PP <sub>6</sub>
6							D	DP <sub>7</sub>
7								NP
8								

# Examining the Output

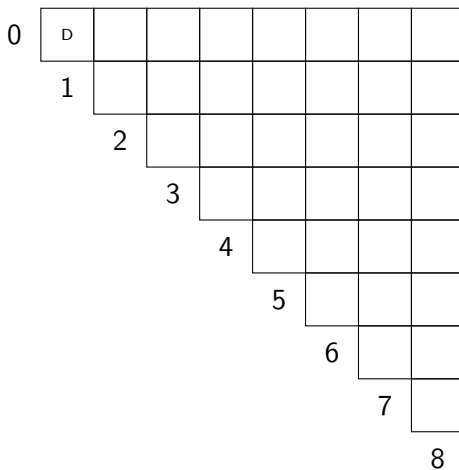
0	D	DP <sub>1</sub>			S <sub>2</sub>			S <sub>2(3)</sub> S <sub>2(5)</sub>
1		NP						
2			V		VP <sub>3</sub>			VP <sub>3</sub> VP <sub>5</sub>
3				D	DP <sub>4</sub>			DP <sub>5</sub>
4					NP			
5						P		PP <sub>6</sub>
6							D	DP <sub>7</sub>
7								NP
8								

[<sub>0</sub>the<sub>1</sub>girl]<sub>2</sub>[[saw]<sub>3</sub>[the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars]<sub>8</sub>]] — DP adjunct

[<sub>0</sub>the<sub>1</sub>girl]<sub>2</sub>[[saw<sub>3</sub>the<sub>4</sub>crow]<sub>5</sub>[with<sub>6</sub>the<sub>7</sub>binoculars]<sub>8</sub>]] — VP adjunct

# Online Parsing

0the1girl2saw3the4crow5with6the7binoculars8





# Online Parsing

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>						
1		NP						
2								
3								
4								
5								
6								
7								
8								

# Online Parsing

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>					
1	NP						
2	V						
3							
4							
5							
6							
7							
8							

# Online Parsing

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>					
1	NP						
2	V						
3	D						
4							
5							
6							
7							
8							

# Online Parsing

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>			S <sub>2</sub>			
1		NP						
2			V		VP <sub>3</sub>			
3				D	DP <sub>4</sub>			
4					NP			
5								
6								
7								
8								

# Online Parsing

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>			S <sub>2</sub>			
1		NP						
2			V		VP <sub>3</sub>			
3				D	DP <sub>4</sub>			
4					NP			
5						P		
6								
7								
8								

# Online Parsing

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>			S <sub>2</sub>			
1		NP						
2			V		VP <sub>3</sub>			
3				D	DP <sub>4</sub>			
4					NP			
5						P		
6							D	
7								
8								

# Online Parsing

<sub>0</sub>the<sub>1</sub>girl<sub>2</sub>saw<sub>3</sub>the<sub>4</sub>crow<sub>5</sub>with<sub>6</sub>the<sub>7</sub>binoculars<sub>8</sub>

0	D	DP <sub>1</sub>			S <sub>2</sub>			S <sub>2(3)</sub> S <sub>2(5)</sub>
1		NP						
2			V		VP <sub>3</sub>			VP <sub>3</sub> VP <sub>5</sub>
3				D	DP <sub>4</sub>			DP <sub>5</sub>
4					NP			
5						P		PP <sub>6</sub>
6							D	DP <sub>7</sub>
7								NP
8								

# Probabilistic Stuff

Lexicon and productions have associated weights (probabilities).

If  $[a, b]$  has category  $X_1$  and weight  $p_1$ ,

$[b, c]$  has category  $X_2$  and weight  $p_2$ ,

and  $X \rightarrow X_1 X_2$  has weight  $p$ ,

then  $[a, c]$  has category  $X$  and weight  $p \cdot p_1 \cdot p_2$



# Top-Down vs Bottom-Up

## **Top-down parsers:**

- ▶ Only generate S trees
- ▶ Generate before even looking at the input

## **Bottom-up parsers:**

- ▶ Account for the input first
- ▶ Might generate non-S trees