



Parsing SS07

Cocke-Younger-Kasami-Algorithmus (CKY)

Parse-Forest-Algorithmus

CKY - Algorithmus

- Einführung
- Eingabe
- Code
- Ablauf
- Ausgabe

Parse-Forest-Algorithmus

Einführung

- Symbolischer Parser
- **Bottom-Up-Parser**
- Chartparser
(zugrundeliegende Datenstruktur: **Chart**)
- Regeln müssen in Chomsky-Normalform vorliegen
- **Dynamische Programmierung:**
zerlegt Problem in Unterprobleme, berechnet Lösung
rekursiv -> jedes Teilproblem nur einmal
- Komplexität: $O(n^3)$

Grammatik

LEXIKON	
intr	→ {sleep, fish}
trans	→ {study, visit}
N	→ {they, cans, fish}
prep	→ {in, by, with}

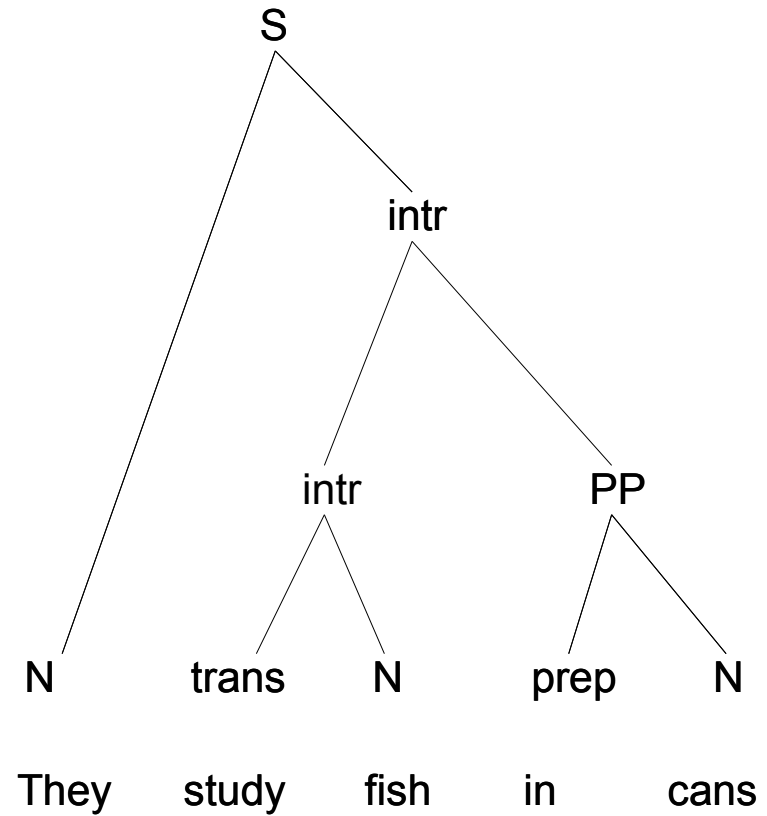
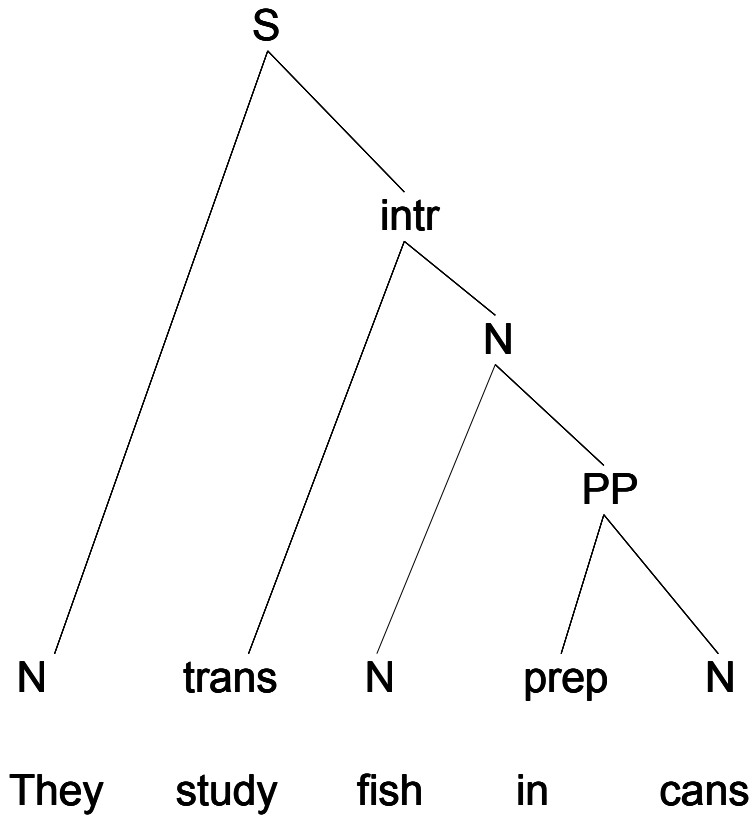
REGELN	
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

Regeln müssen in **Chomsky-Normalform** vorliegen

“They study fish in cans.”

Ambiguität?

Syntaxbäume



Variablen

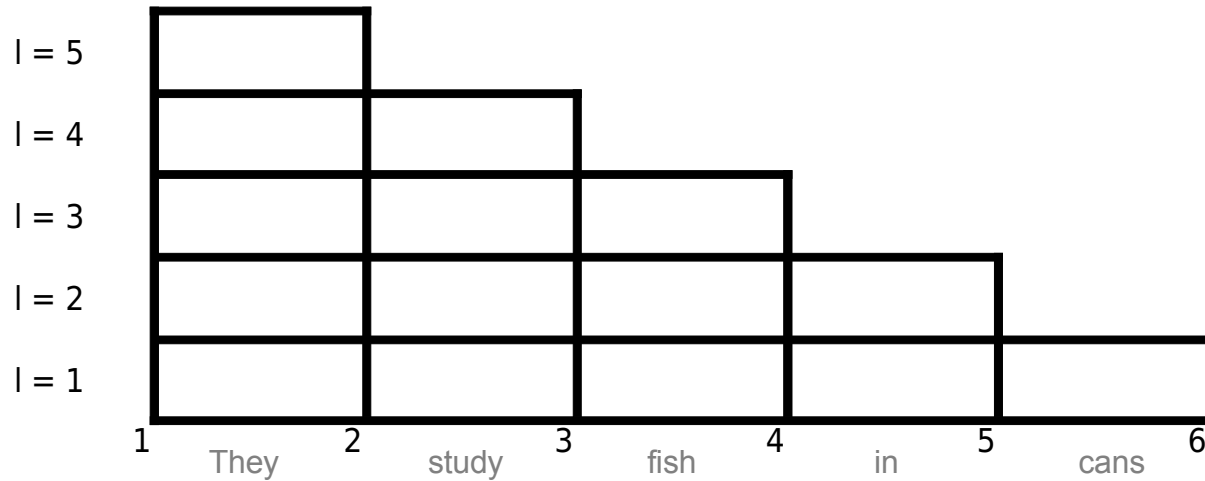
- n Anzahl der Wörter
- s Position
- w_s Wort, das an Position s beginnt
- l Länge des Wortes
- t Schranke, die Wort in zwei Teile teilt

They	study	fish	in	cans
w_1	w_2	w_3	w_4	w_5

ALGORITHMUS

```

1. chart[.,.,.] := FALSE;
2. for each s:=1, ..., n do
3.   for each A → ws do
4.     chart[s,A,s+1] := TRUE;
5. for each l:=2, ..., n do
6.   for each s:=1, ..., n+1-l
7.     for each t:=1, ..., l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1] := chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

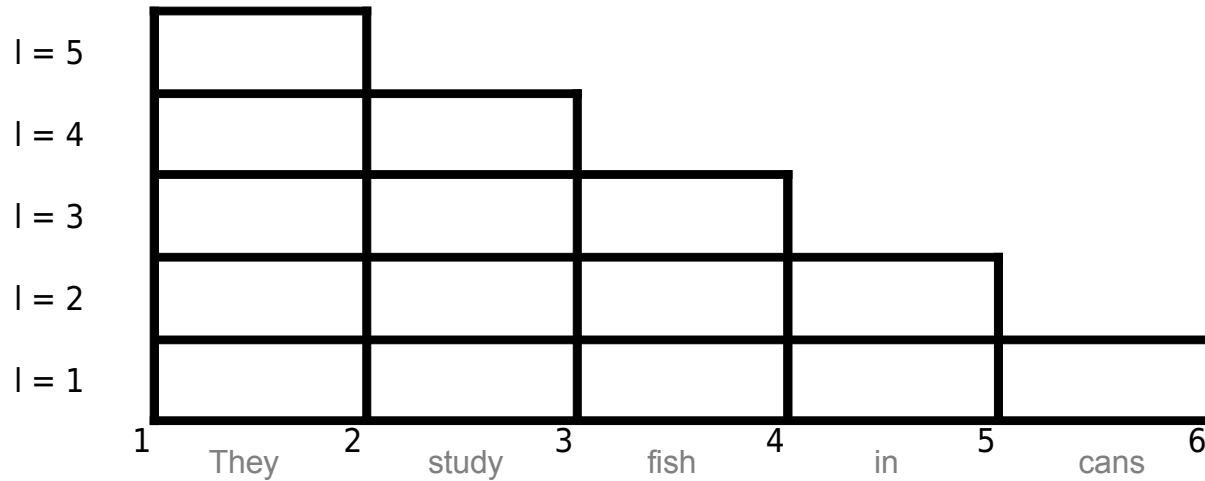
LEXIKON

intr	→ {sleep, fish}
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```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.     for each s:=1, ... ,n+1-l
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] ∨
10.                    chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS



LEXIKON

intr	→ {sleep, fish}
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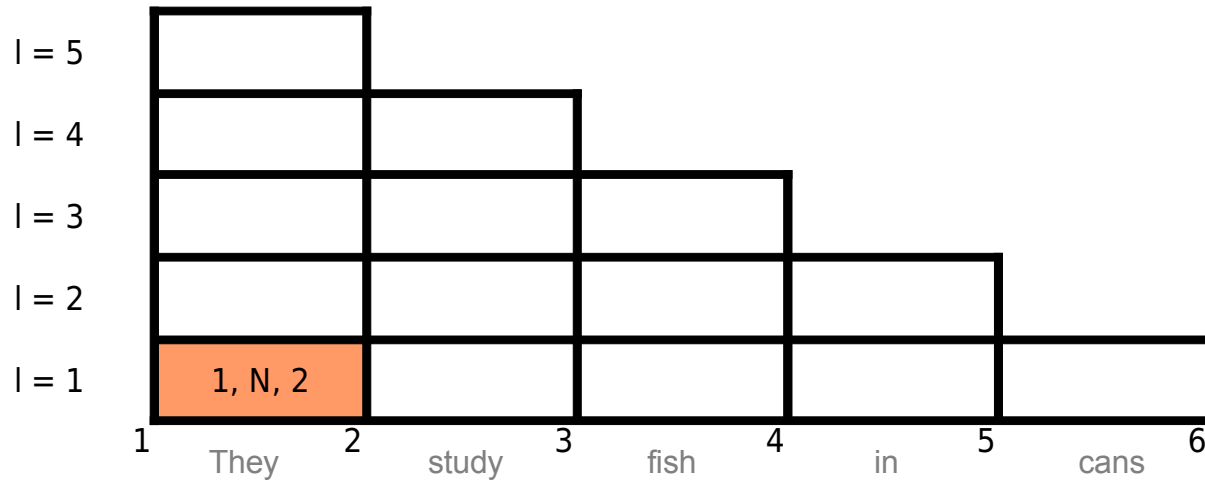
```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ..., n do           s:= 1
3.   for each A → ws do
4.     chart[s,A,s+1]:=TRUE;
5. for each l:=2, ..., n do
6.   for each s:=1, ..., n+1-l
7.     for each t:=1, ..., l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1]:= chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

3. $N \rightarrow \{they, cans, fish\}$

4. $c[1,N,2] := TRUE$



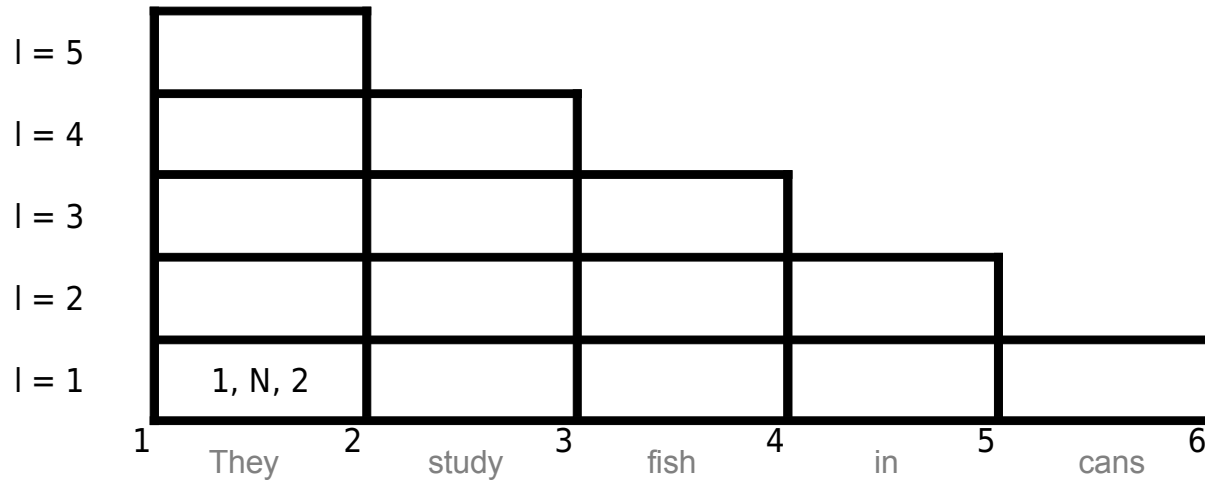
LEXIKON

intr	$\rightarrow \{sleep, fish\}$
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```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ..., n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ..., n do
6.     for each s:=1, ..., n+1-l
7.         for each t:=1, ..., l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS



LEXIKON

intr	→ {sleep, fish}
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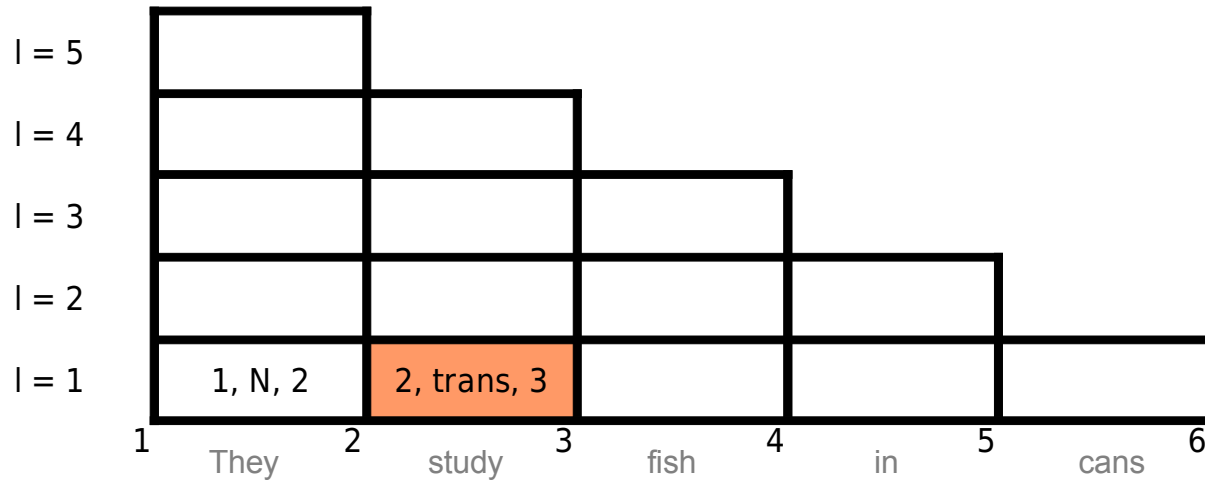
```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ..., n do           s:= 2
3.   for each A → ws do
4.     chart[s,A,s+1]:=TRUE;
5. for each l:=2, ..., n do
6.   for each s:=1, ..., n+1-1
7.     for each t:=1, ..., l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1]:= chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

3. trans \rightarrow {study, visit, fish}

4. $c[2,trans,3] := \text{TRUE}$



LEXIKON

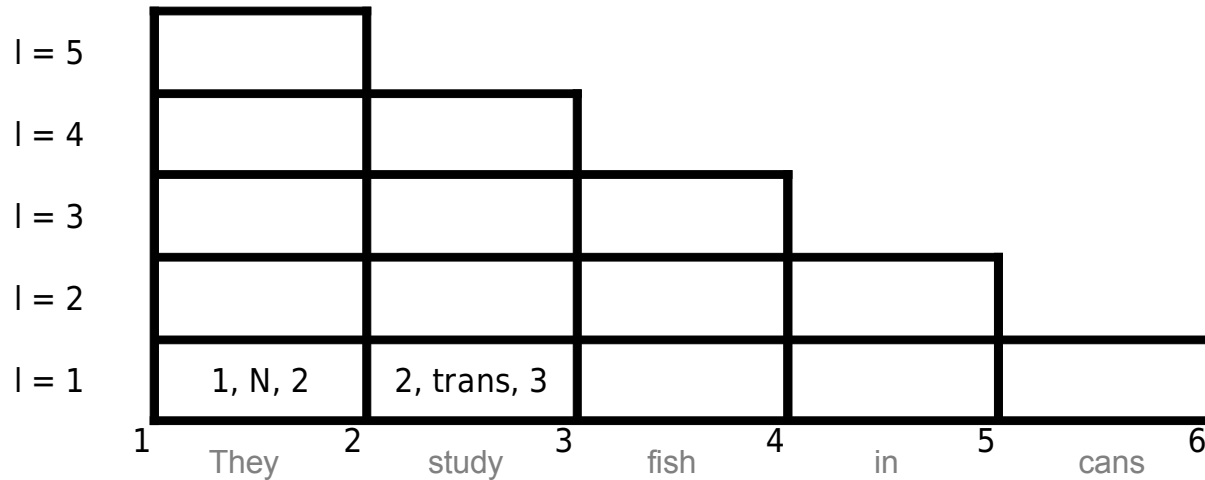
intr \rightarrow {sleep, fish}
 trans \rightarrow {study, visit}
 N \rightarrow {they, cans, fish}
 prep \rightarrow {in, by, with}

```

1. chart[.,.,.] := FALSE;
2. for each s:=1, ..., n do
3.     for each A  $\rightarrow$  ws do
4.         chart[s,A,s+1] := TRUE;
5. for each l:=2, ..., n do
6.     for each s:=1, ..., n+1-l
7.         for each t:=1, ..., l-1 do
8.             for each A  $\rightarrow$  B C do
9.                 chart[s,A,s+1] := chart[s,A,s+1]  $\vee$ 
10.                chart[s,B,s+t]  $\wedge$  chart[s+t,C,s+1]
```

ALGORITHMUS

$s := 2$



LEXIKON

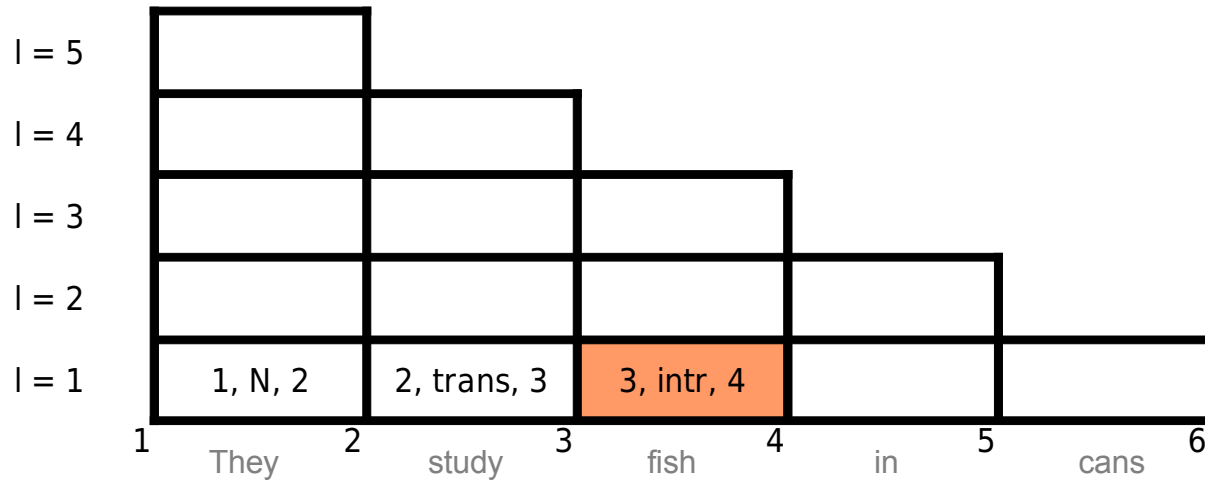
intr	→ {sleep, fish}
trans	→ {study, visit}
N	→ {they, cans, fish}
prep	→ {in, by, with}

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ..., n do           s:= 3
3.   for each A → ws do
4.     chart[s,A,s+1]:=TRUE;
5. for each l:=2, ..., n do
6.   for each s:=1, ..., n+1-1
7.     for each t:=1, ..., l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1]:= chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

3. $\text{intr} \rightarrow \{\text{sleep, fish}\}$
4. $c[3, \text{intr}, 4] := \text{TRUE}$


LEXIKON

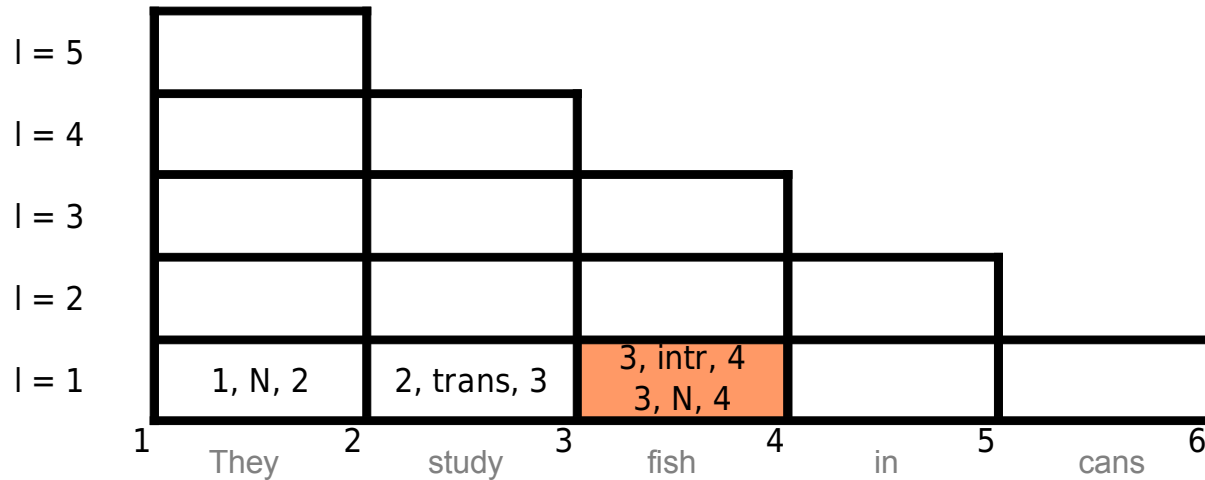
intr	$\rightarrow \{\text{sleep, fish}\}$
trans	$\rightarrow \{\text{study, visit}\}$
N	$\rightarrow \{\text{they, cans, fish}\}$
prep	$\rightarrow \{\text{in, by, with}\}$

1. $\text{chart}[\dots] := \text{FALSE};$
2. for each $s := 1, \dots, n$ do $s := 3$
3. for each $A \rightarrow w_s$ do
4. $\text{chart}[s, A, s+1] := \text{TRUE};$
5. for each $l := 2, \dots, n$ do
6. for each $s := 1, \dots, n+1-l$
7. for each $t := 1, \dots, l-1$ do
8. for each $A \rightarrow B C$ do
9. $\text{chart}[s, A, s+1] := \text{chart}[s, A, s+1] \vee$
10. $\text{chart}[s, B, s+t] \wedge \text{chart}[s+t, C, s+1]$

ALGORITHMUS

3. $N \rightarrow \{\text{they, cans, fish}\}$

4. $c[3,N,4] := \text{TRUE}$



LEXIKON

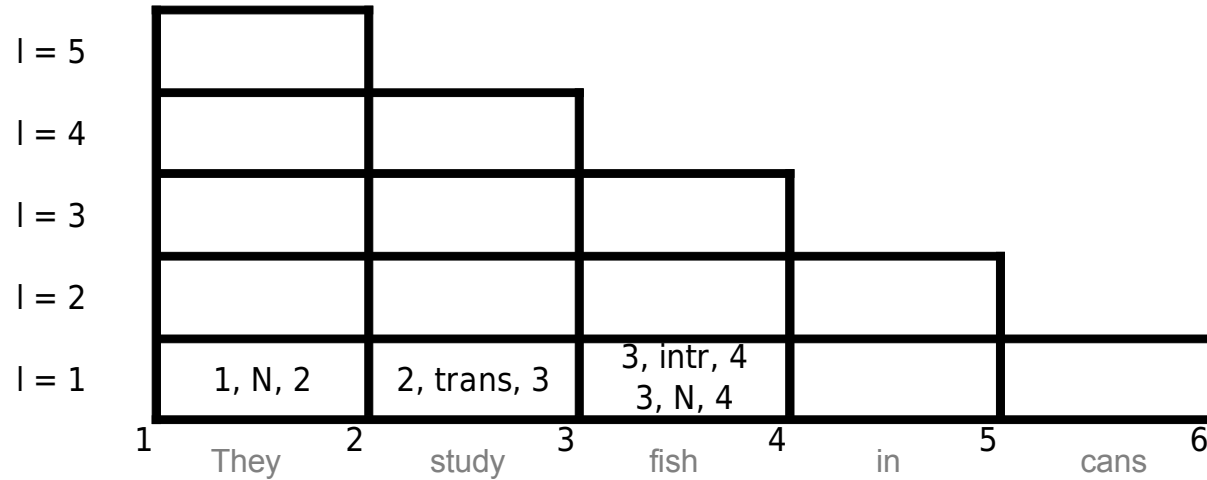
intr $\rightarrow \{\text{sleep, fish}\}$
 trans $\rightarrow \{\text{study, visit}\}$
 N $\rightarrow \{\text{they, cans, fish}\}$
 prep $\rightarrow \{\text{in, by, with}\}$

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ..., n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ..., n do
6.     for each s:=1, ..., n+1-1
7.         for each t:=1, ..., l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

$s := 3$



LEXIKON

intr	→ {sleep, fish}
trans	→ {study, visit}
N	→ {they, cans, fish}
prep	→ {in, by, with}

```

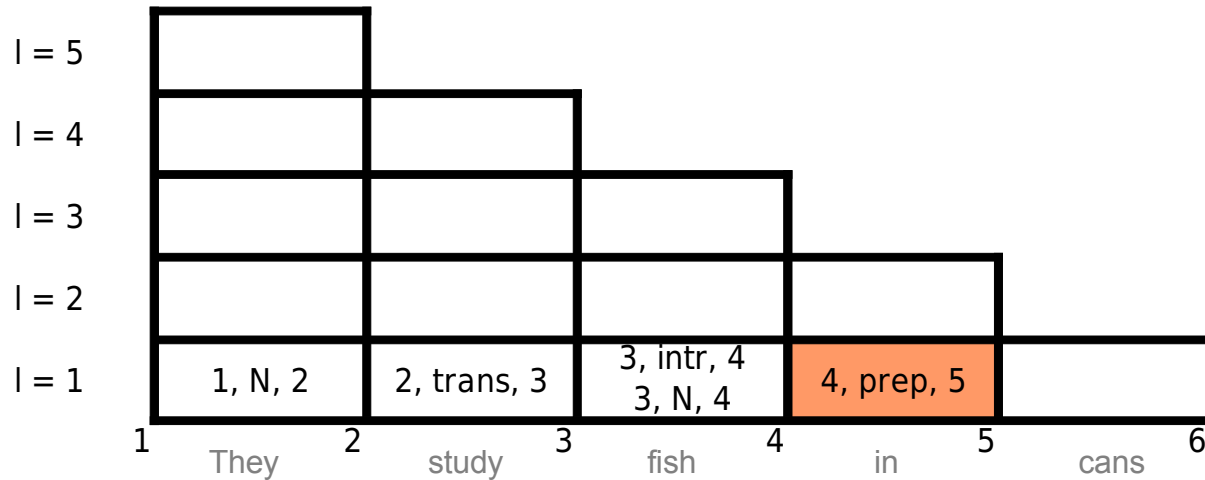
1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.     for each s:=1, ... ,n+1-l
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] ∨
10.                    chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

s := 4

3. prep → {in, by, with}

4. c[4,prep,5] := TRUE



LEXIKON

intr → {sleep, fish}

trans → {study, visit}

N → {they, cans, fish}

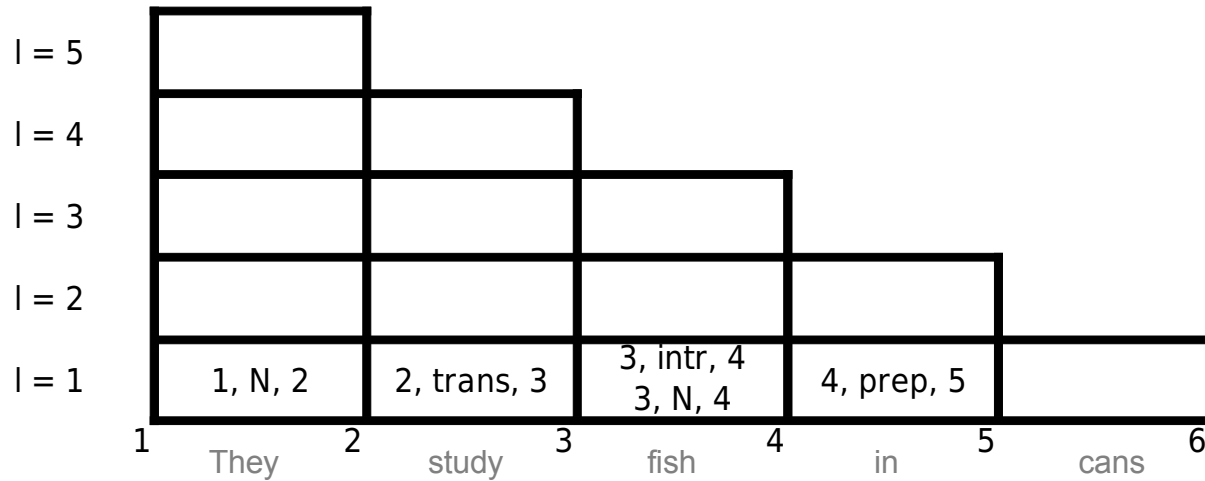
prep → {in, by, with}

```

1. chart[.,.,.] := FALSE;
2. for each s:=1, ..., n do
3.     for each A → ws do
4.         chart[s,A,s+1] := TRUE;
5. for each l:=2, ..., n do
6.     for each s:=1, ..., n+1-l
7.         for each t:=1, ..., l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1] := chart[s,A,s+1] ∨
10.                    chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

s := 4



LEXIKON

intr	→ {sleep, fish}
trans	→ {study, visit}
N	→ {they, cans, fish}
prep	→ {in, by, with}

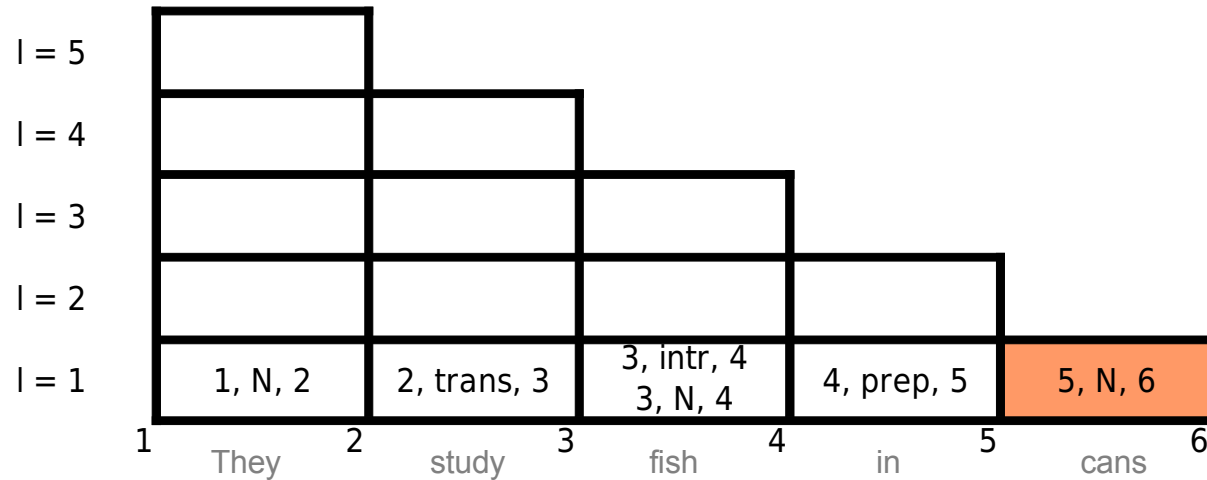
```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ..., n do           s:= 5
3.   for each A → ws do
4.     chart[s,A,s+1]:=TRUE;
5. for each l:=2, ..., n do
6.   for each s:=1, ..., n+1-1
7.     for each t:=1, ..., l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1]:= chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

3. $N \rightarrow \{\text{they, cans, fish}\}$

4. $c[5,N,6] := \text{TRUE}$



LEXIKON

intr $\rightarrow \{\text{sleep, fish}\}$
 trans $\rightarrow \{\text{study, visit}\}$
 N $\rightarrow \{\text{they, cans, fish}\}$
 prep $\rightarrow \{\text{in, by, with}\}$

```

1. chart[.,.,.] := FALSE;
2. for each s:=1, ..., n do
3.     for each A → ws do
4.         chart[s,A,s+1] := TRUE;
5. for each l:=2, ..., n do
6.     for each s:=1, ..., n+1-l
7.         for each t:=1, ..., l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1] := chart[s,A,s+1] ∨
10.                    chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

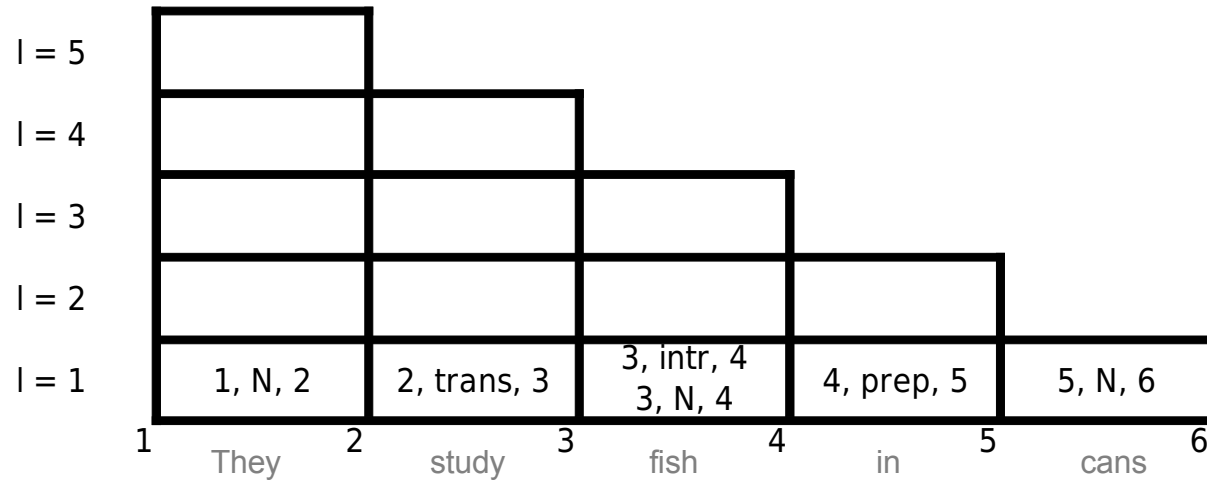
ALGORITHMUS

$s := 5$

Zeilen 5. - 10.

```

1. chart[.,.,.] := FALSE;
2. for each s:=1, ..., n do
3.   for each A → ws do
4.     chart[s,A,s+1] := TRUE;
5. for each l:=2, ..., n do
6.   for each s:=1, ..., n+1-l
7.     for each t:=1, ..., l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1] := chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```



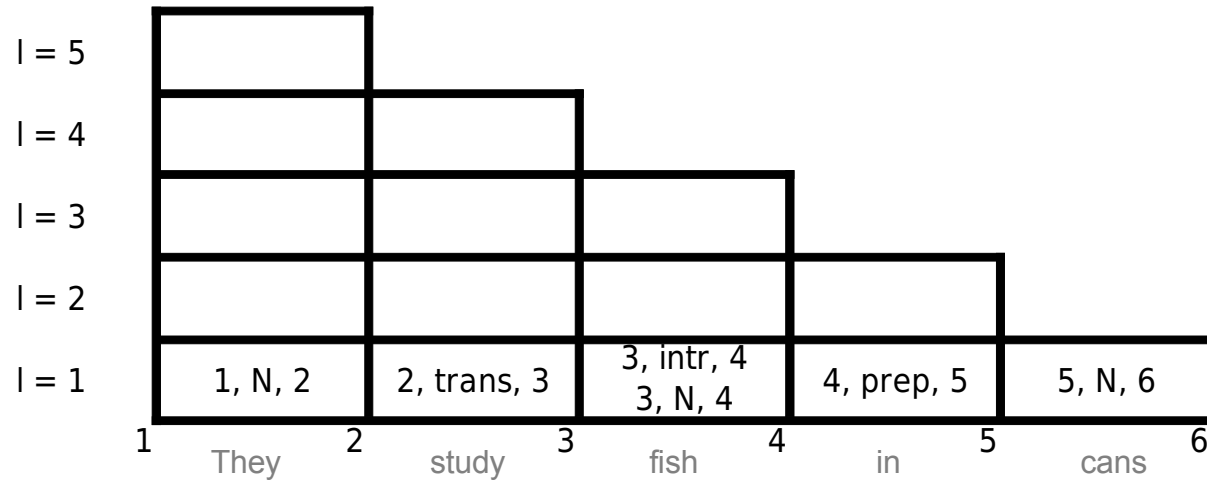
REGELN

S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.   for each A → ws do
4.     chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do           l:= 2
6.   for each s:=1, ... ,n+1-1
7.     for each t:=1, ... ,l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1]:= chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS



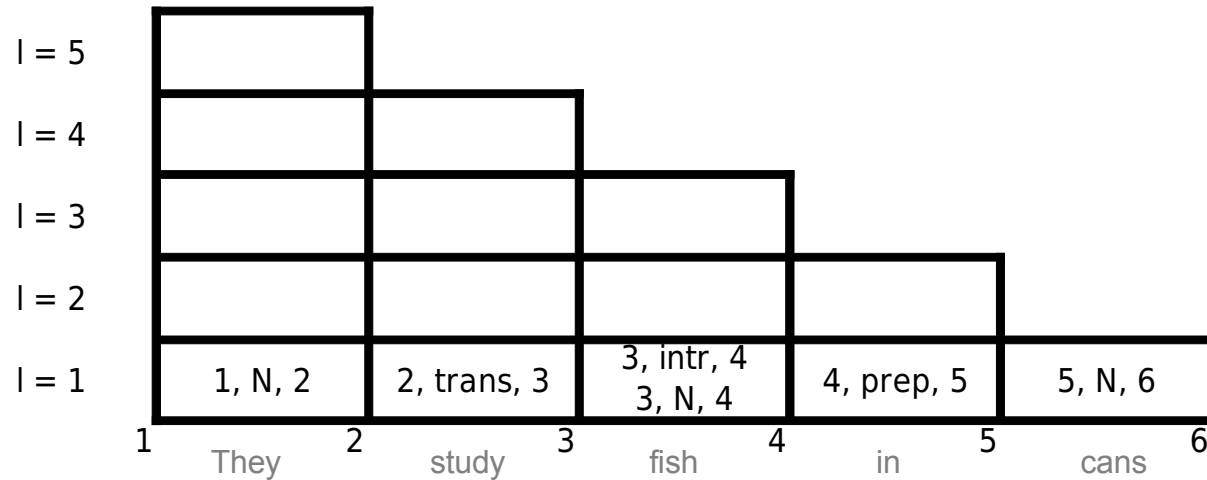
REGELN

S	→ N intr
intr	→ trans N
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N	→ N PP
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4.         chart[s,A,s+1]:=TRUE;
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6.     for each s:=1, ... ,n+1-l
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS



REGELN

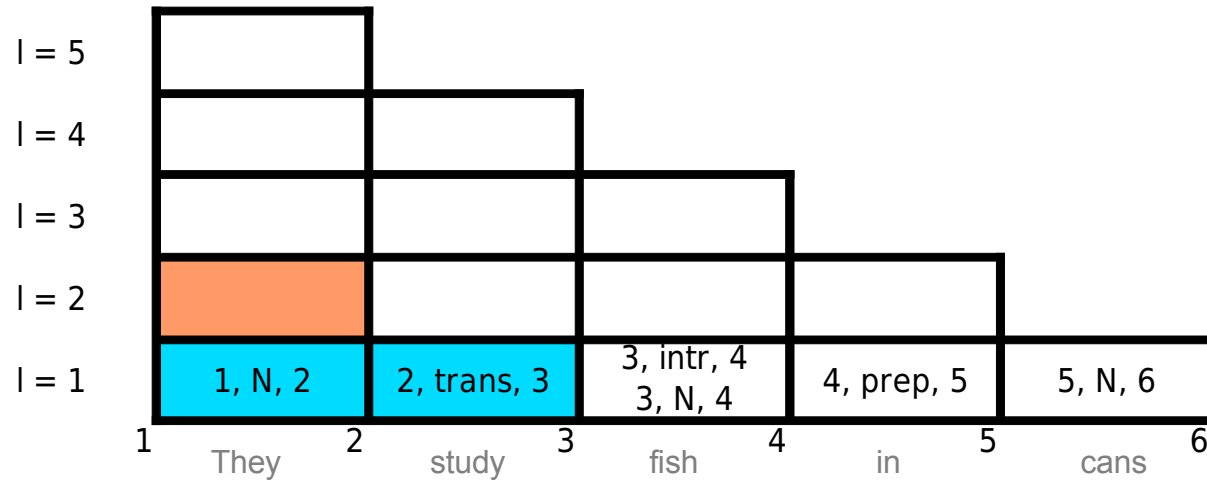
S	→ N intr
intr	→ trans N
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10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

8. $S \rightarrow N \text{ intr}$
9. $c[1,S,3] := c[1,S,3] \vee$
10. $c[1,N,2] \wedge c[2,\text{intr},3]$



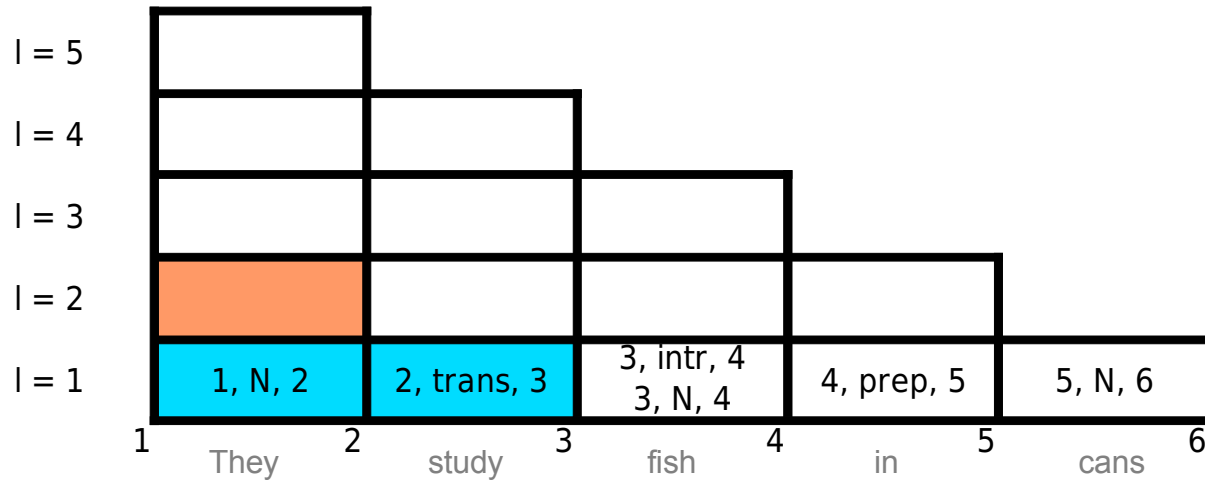
REGELN

S	\rightarrow N intr
intr	\rightarrow trans N
intr	\rightarrow intr PP
N	\rightarrow N PP
PP	\rightarrow prep N

1. `chart[.,.,.] := FALSE;`
2. `for each s:=1, ..., n do`
3. `for each $A \rightarrow w_s$ do`
4. `chart[s,A,s+1] := TRUE;`
5. `for each l:=2, ..., n do` `l := 2`
6. `for each s:=1, ..., n+1-l` `s := 1`
7. `for each t:=1, ..., l-1 do` `t := 1`
8. `for each $A \rightarrow B C$ do`
9. `chart[s,A,s+1] := chart[s,A,s+1] \vee`
10. `chart[s,B,s+t] \wedge chart[s+t,C,s+1]`

ALGORITHMUS

8. $\text{intr} \rightarrow \text{trans N}$
9. $c[1, \text{intr}, 3] := c[1, \text{intr}, 3] \vee$
10. $c[1, \text{trans}, 2] \wedge c[2, \text{N}, 3]$



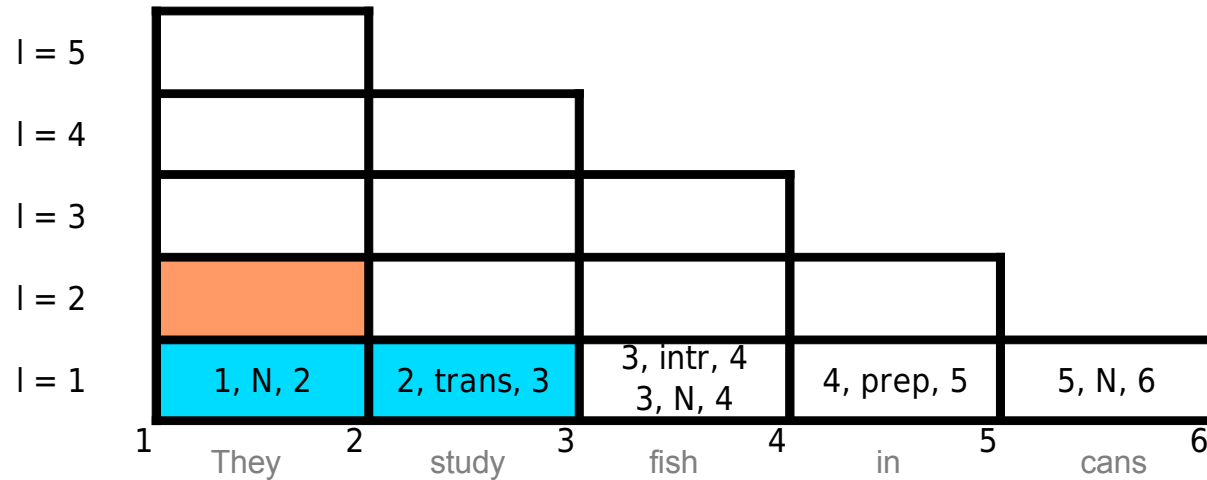
REGELN

S	\rightarrow N intr
intr	\rightarrow trans N
intr	\rightarrow intr PP
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2. for each $s := 1, \dots, n$ do
3. for each $A \rightarrow w_s$ do
4. $\text{chart}[s, A, s+1] := \text{TRUE};$
5. for each $l := 2, \dots, n$ do l := 2
6. for each $s := 1, \dots, n+1-l$ s := 1
7. for each $t := 1, \dots, l-1$ do t := 1
8. for each $A \rightarrow B C$ do
9. $\text{chart}[s, A, s+1] := \text{chart}[s, A, s+1] \vee$
10. $\text{chart}[s, B, s+t] \wedge \text{chart}[s+t, C, s+1]$

ALGORITHMUS

8. $\text{intr} \rightarrow \text{intr PP}$
9. $c[1, \text{intr}, 3] := c[1, \text{intr}, 3] \vee$
10. $c[1, \text{intr}, 2] \wedge c[2, \text{PP}, 3]$



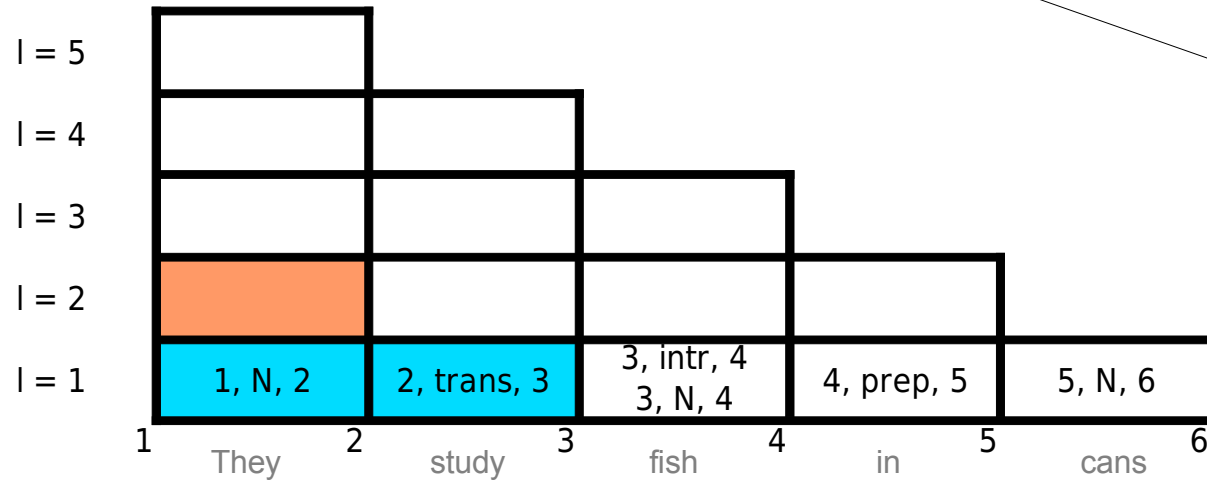
REGELN

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intr	\rightarrow trans N
intr	\rightarrow intr PP
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PP	\rightarrow prep N

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2. for each $s := 1, \dots, n$ do
3. for each $A \rightarrow w_s$ do
4. $\text{chart}[s, A, s+1] := \text{TRUE};$
5. for each $l := 2, \dots, n$ do $l := 2$
6. for each $s := 1, \dots, n+1-l$ $s := 1$
7. for each $t := 1, \dots, l-1$ do $t := 1$
8. for each $A \rightarrow B C$ do
9. $\text{chart}[s, A, s+1] := \text{chart}[s, A, s+1] \vee$
10. $\text{chart}[s, B, s+t] \wedge \text{chart}[s+t, C, s+1]$

ALGORITHMUS

... usw. für alle Regeln



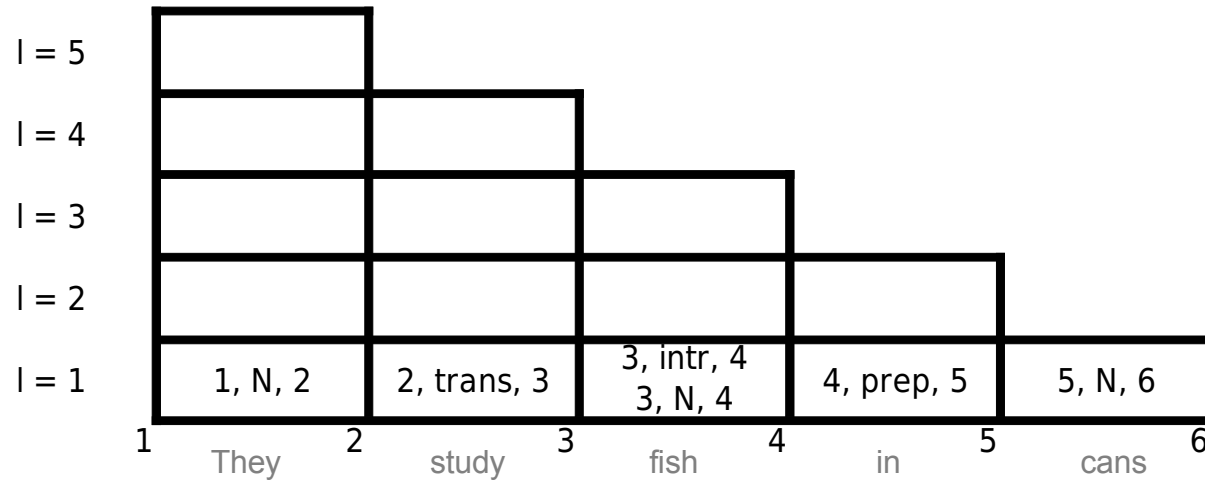
REGELN

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intr	→ trans N
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4.     chart[s,A,s+1]:=TRUE;
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6.   for each s:=1, ... ,n+1-1
7.     for each t:=1, ... ,l-1 do
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```

ALGORITHMUS



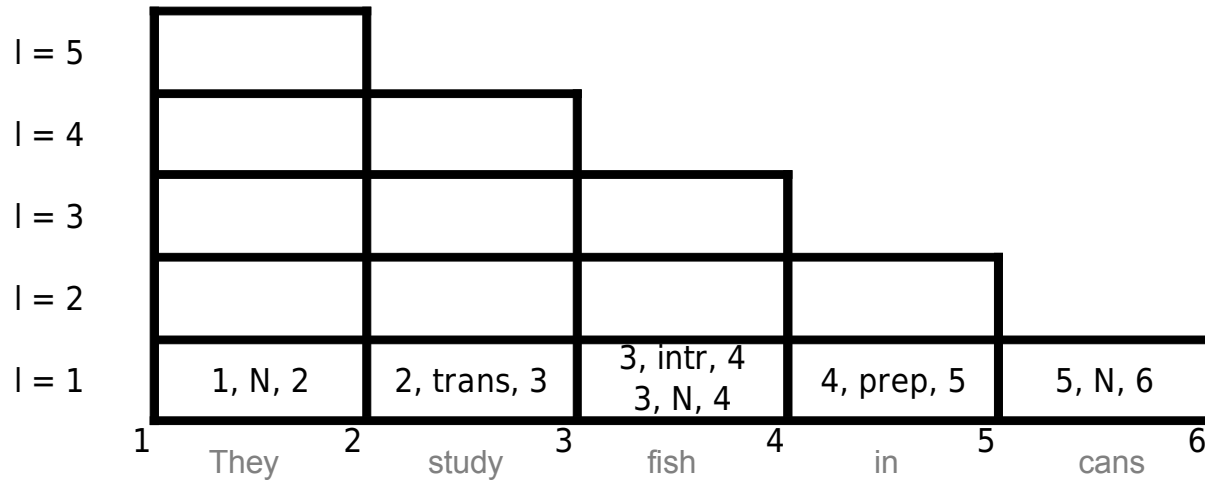
REGELN

S	→ N intr
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```

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4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.     for each s:=1, ... ,n+1-l
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS



REGELN

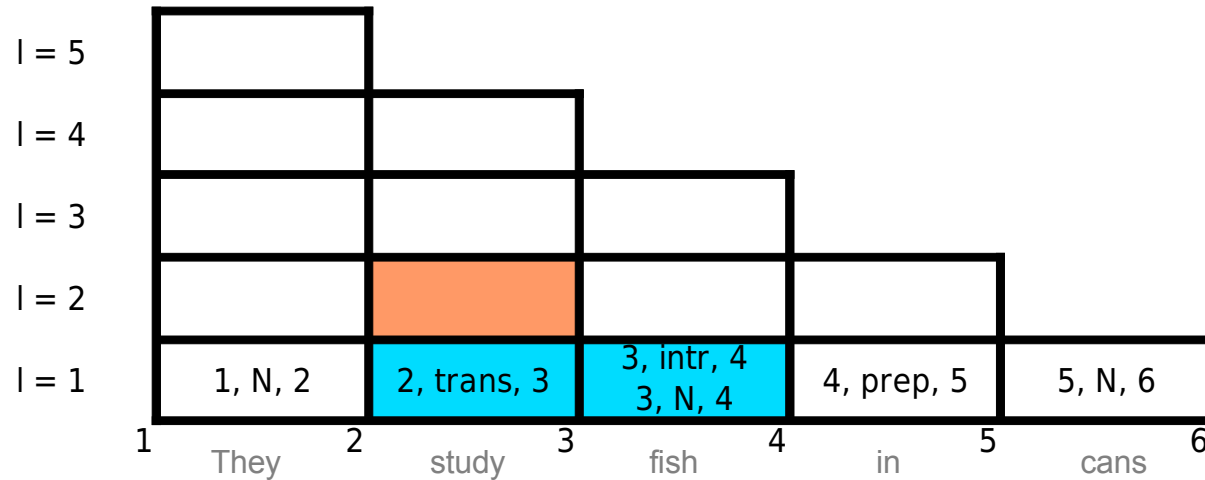
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.     for each s:=1, ... ,n+1-1
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

8. $S \rightarrow N \text{ intr}$
9. $c[2,S,4] := c[2,S,4] \vee$
10. $c[2,N,3] \wedge c[3,\text{intr},4]$



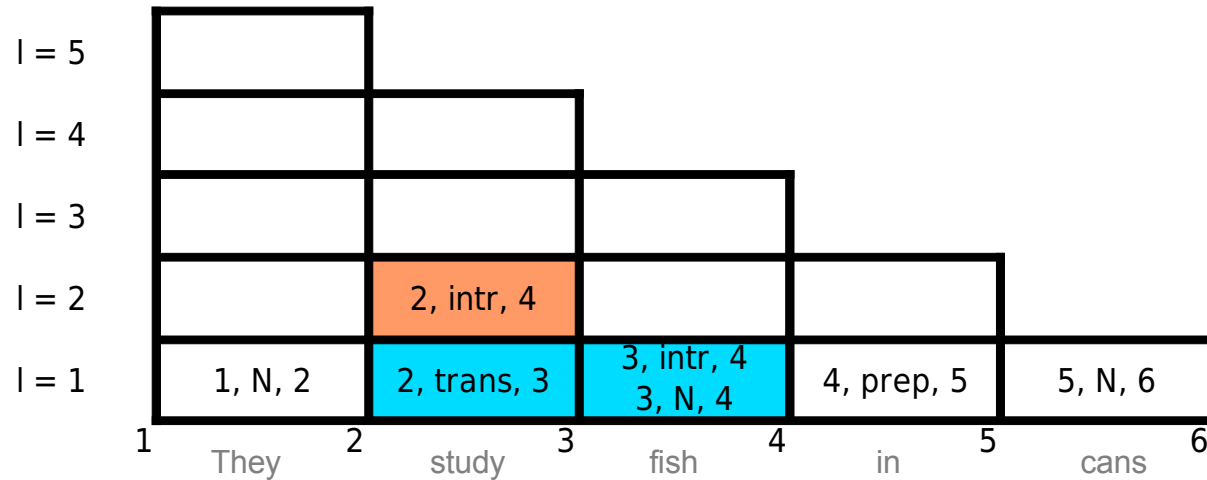
REGELN

S	$\rightarrow N \text{ intr}$
intr	$\rightarrow \text{trans } N$
intr	$\rightarrow \text{intr PP}$
N	$\rightarrow N \text{ PP}$
PP	$\rightarrow \text{prep } N$

1. `chart[.,.,.] := FALSE;`
2. `for each s:=1, ..., n do`
3. `for each $A \rightarrow w_s$ do`
4. `chart[s,A,s+1] := TRUE;`
5. `for each l:=2, ..., n do` `l := 2`
6. `for each s:=1, ..., n+1-l` `s := 2`
7. `for each t:=1, ..., l-1 do` `t := 1`
8. `for each $A \rightarrow B C$ do`
9. `chart[s,A,s+1] := chart[s,A,s+1] \vee`
10. `chart[s,B,s+t] \wedge chart[s+t,C,s+1]`

ALGORITHMUS

8. intr \rightarrow trans N
9. $c[2, \text{intr}, 4] := c[2, \text{intr}, 4] \vee$
10. $c[2, \text{trans}, 3] \wedge c[3, \text{N}, 4]$

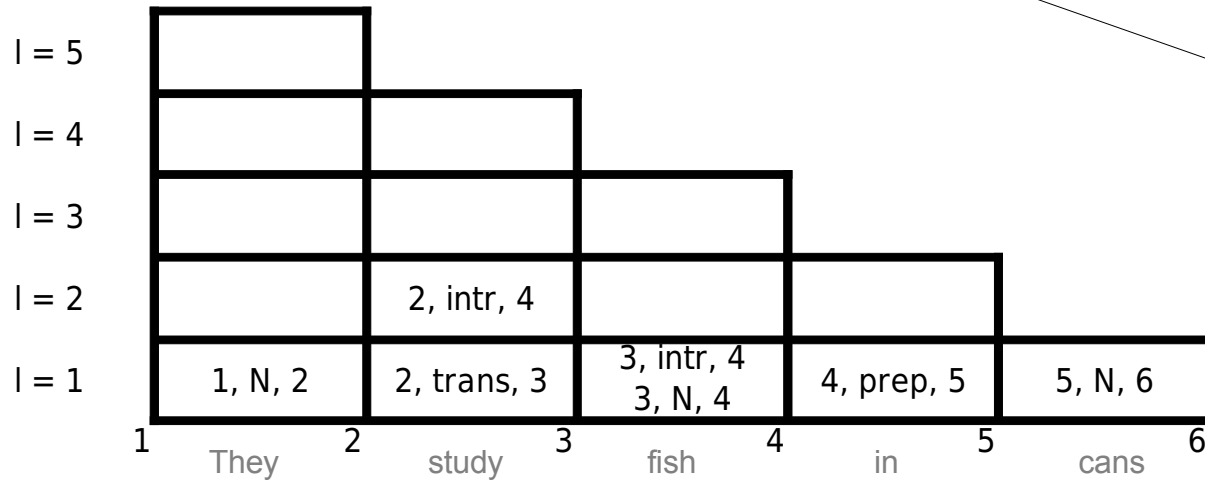

REGELN

S	\rightarrow N intr
intr	\rightarrow trans N
intr	\rightarrow intr PP
N	\rightarrow N PP
PP	\rightarrow prep N

1. chart[.,.,.] := FALSE;
2. for each s:=1, ..., n do
3. for each $A \rightarrow w_s$ do
4. chart[s,A,s+1] := TRUE;
5. for each l:=2, ..., n do l:= 2
6. for each s:=1, ..., n+1-l s:= 2
7. for each t:=1, ..., l-1 do t:= 1
8. for each $A \rightarrow B C$ do
9. chart[s,A,s+1] := chart[s,A,s+1] \vee
10. chart[s,B,s+t] \wedge chart[s+t,C,s+1]

ALGORITHMUS

... usw. für alle Regeln



REGELN

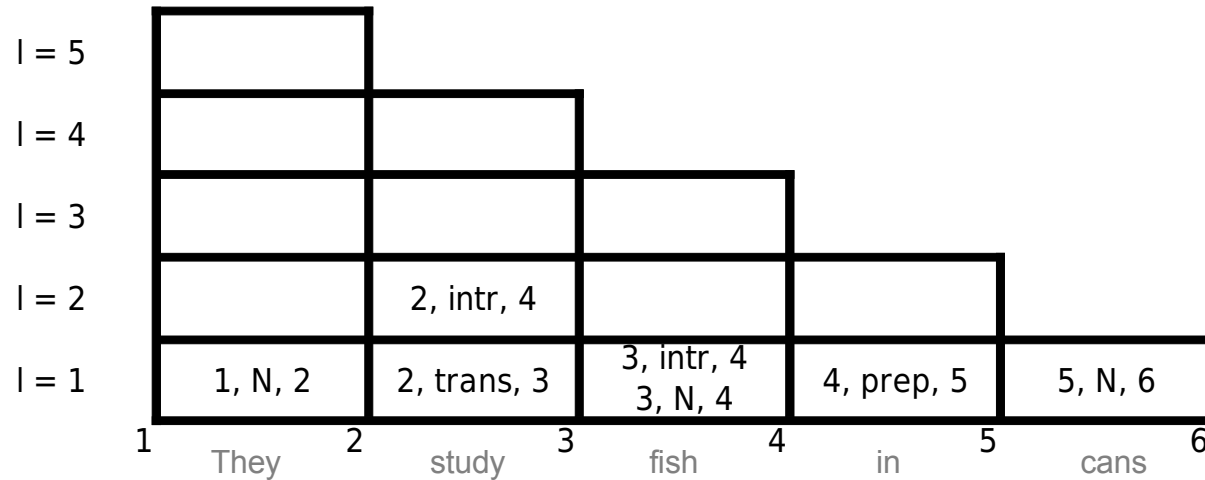
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.   for each A → ws do
4.     chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.   for each s:=1, ... ,n+1-l
7.     for each t:=1, ... ,l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1]:= chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

... für alle Regeln ...



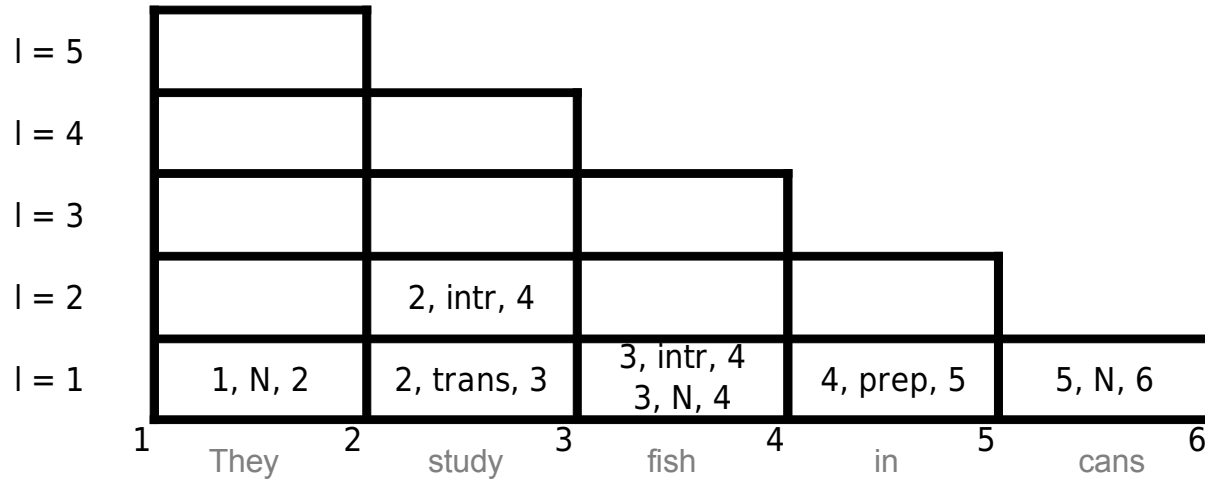
REGELN

S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.   for each A → ws do
4.     chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.   for each s:=1, ... ,n+1-1
7.     for each t:=1, ... ,l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1]:= chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS



REGELN

S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

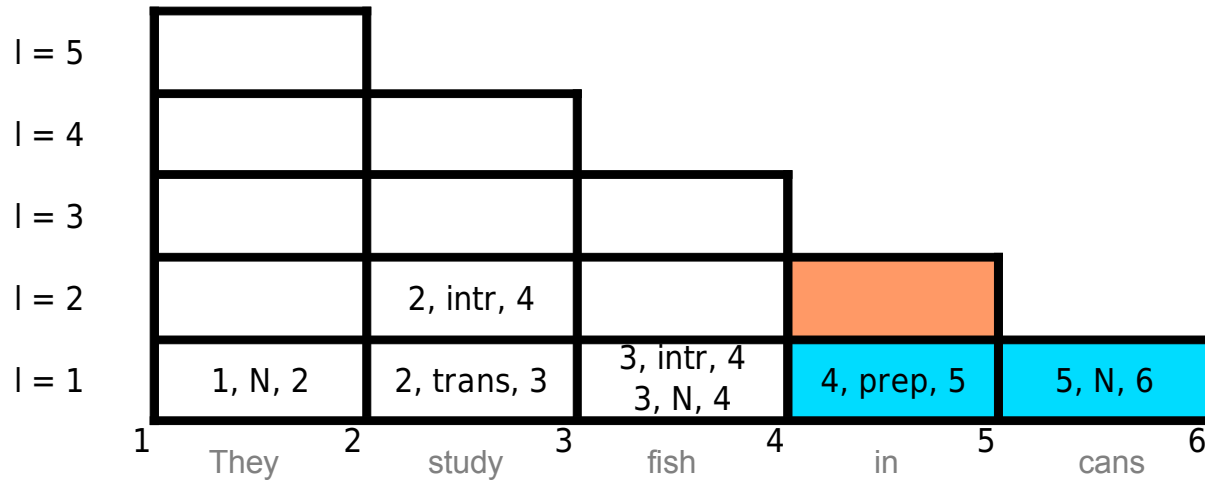
```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.   for each A → ws do
4.     chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.   for each s:=1, ... ,n+1-l
7.     for each t:=1, ... ,l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1]:= chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]

```

ALGORITHMUS

8. ...



REGELN

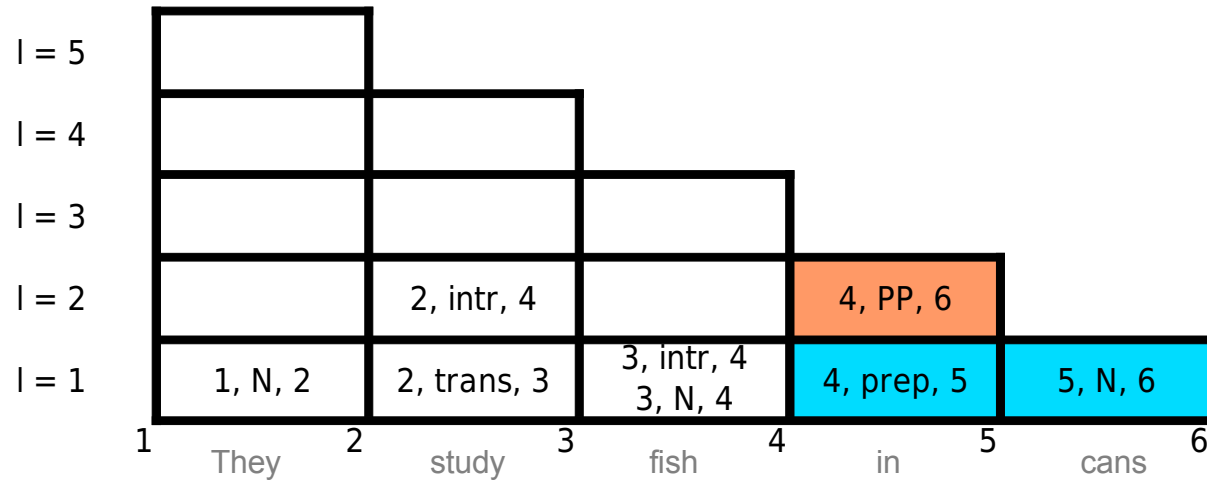
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.     for each s:=1, ... ,n+1-l
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
```

ALGORITHMUS

8. PP \rightarrow prep N
9. $c[4,PP,6] := c[4,PP,6] \vee$
10. $c[4,prep,5] \wedge c[5,N,6]$



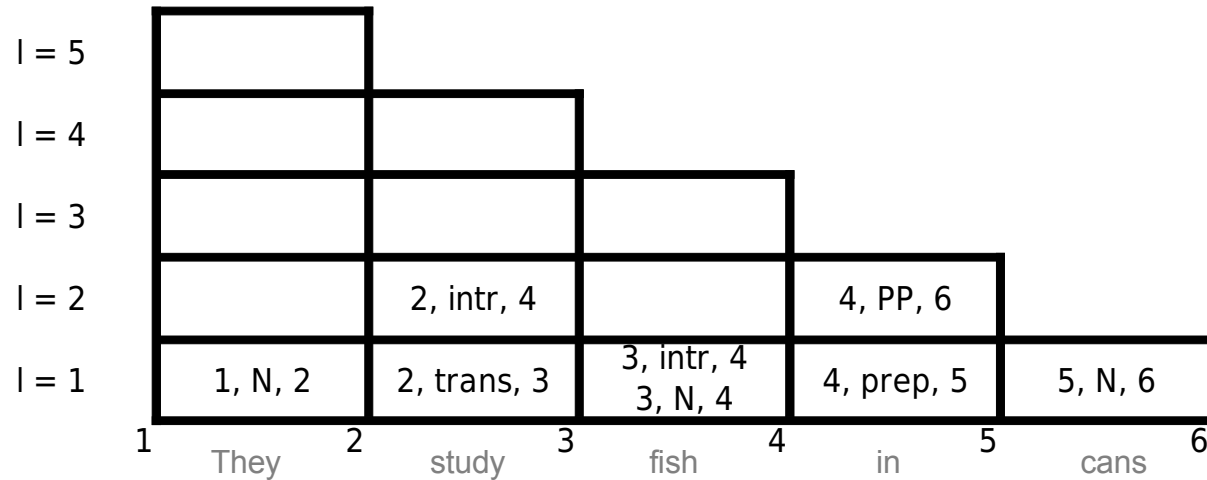
REGELN

S	\rightarrow N intr
intr	\rightarrow trans N
intr	\rightarrow intr PP
N	\rightarrow N PP
PP	\rightarrow prep N

```

1. chart[.,.,.] := FALSE;
2. for each s:=1, ..., n do
3.   for each A  $\rightarrow$  ws do
4.     chart[s,A,s+1] := TRUE;
5. for each l:=2, ..., n do
6.   for each s:=1, ..., n+1-l
7.     for each t:=1, ..., l-1 do
8.       for each A  $\rightarrow$  B C do
9.         chart[s,A,s+1] := chart[s,A,s+1]  $\vee$ 
10.        chart[s,B,s+t]  $\wedge$  chart[s+t,C,s+1]
    
```

ALGORITHMUS



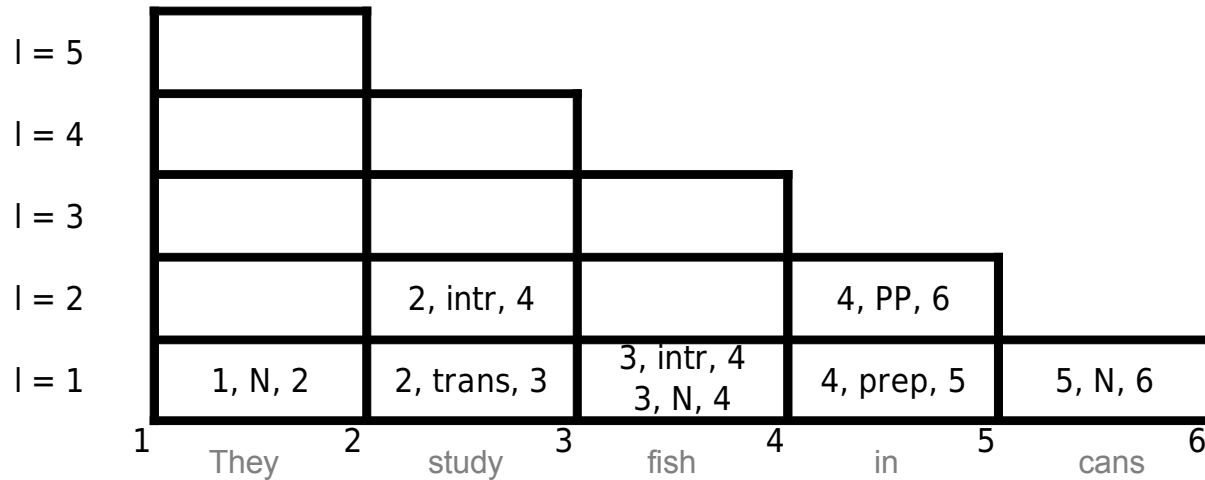
REGELN

S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.   for each A → ws do
4.     chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do           l:= 3
6.   for each s:=1, ... ,n+1-1
7.     for each t:=1, ... ,l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1]:= chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS



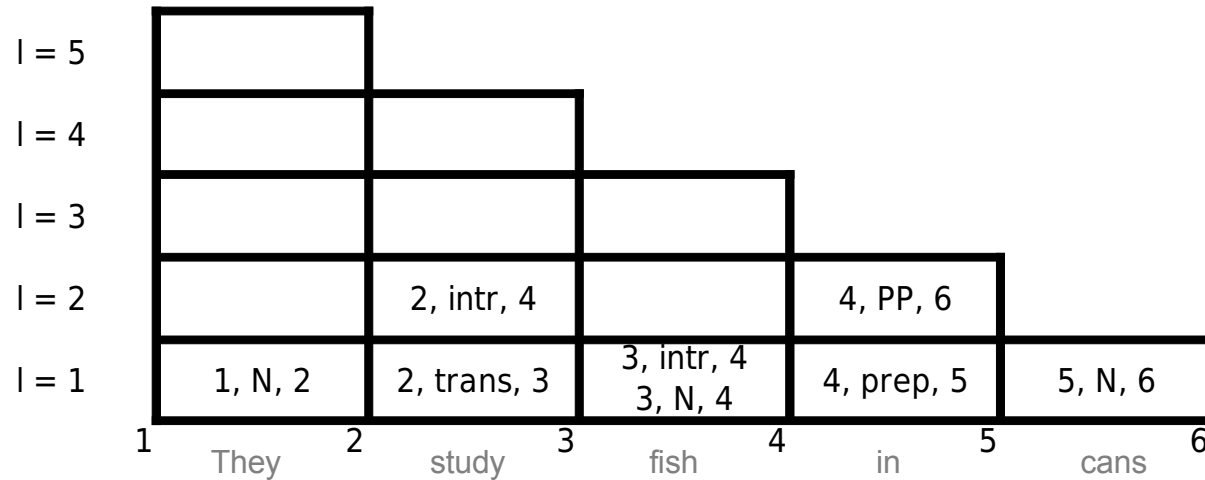
REGELN

S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.     for each s:=1, ... ,n+1-1
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS



REGELN

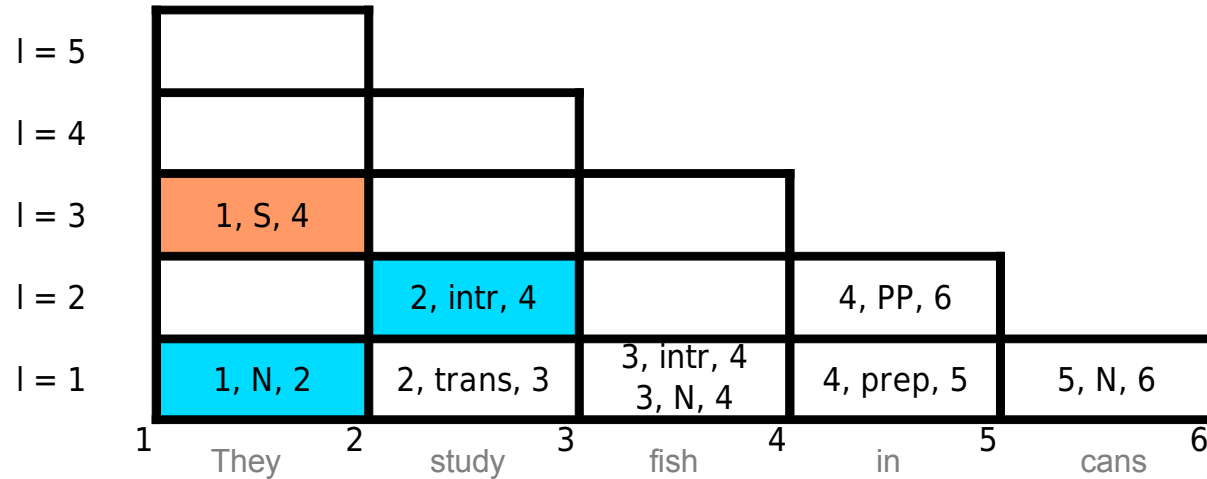
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.     for each s:=1, ... ,n+1-l
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

8. $S \rightarrow N \text{ intr}$
 9. $c[1,S,4] := c[1,S,4] \vee$
 10. $c[1,N,2] \wedge c[2,\text{intr},4]$



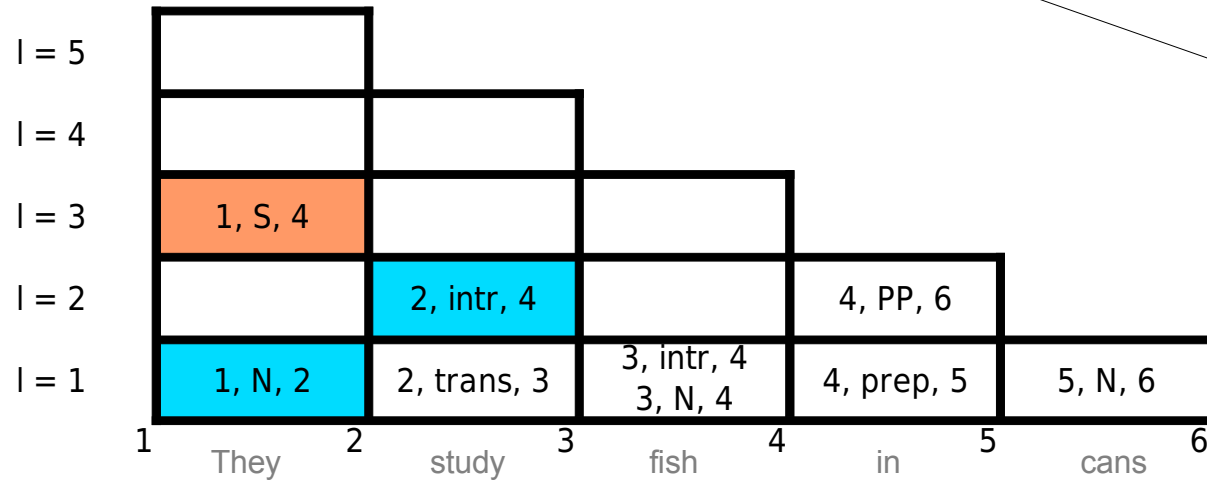
REGELN

S	$\rightarrow N \text{ intr}$
intr	$\rightarrow \text{trans } N$
intr	$\rightarrow \text{intr PP}$
N	$\rightarrow N \text{ PP}$
PP	$\rightarrow \text{prep } N$

1. `chart[.,.,.] := FALSE;`
2. `for each s:=1, ..., n do`
3. `for each $A \rightarrow w_s$ do`
4. `chart[s,A,s+1] := TRUE;`
5. `for each l:=2, ..., n do` `l := 3`
6. `for each s:=1, ..., n+1-l` `s := 1`
7. `for each t:=1, ..., l-1 do` `t := 1`
8. `for each $A \rightarrow B C$ do`
9. `chart[s,A,s+1] := chart[s,A,s+1] \vee`
10. `chart[s,B,s+t] \wedge chart[s+t,C,s+1]`

ALGORITHMUS

... usw. für alle Regeln



REGELN

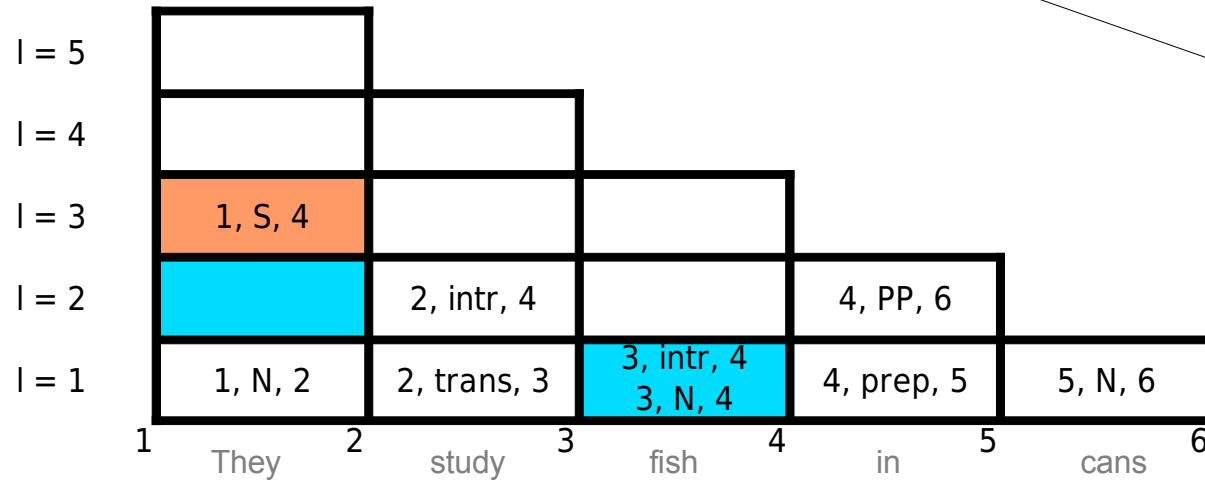
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.     for each s:=1, ... ,n+1-1
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

... für alle Regeln



REGELN

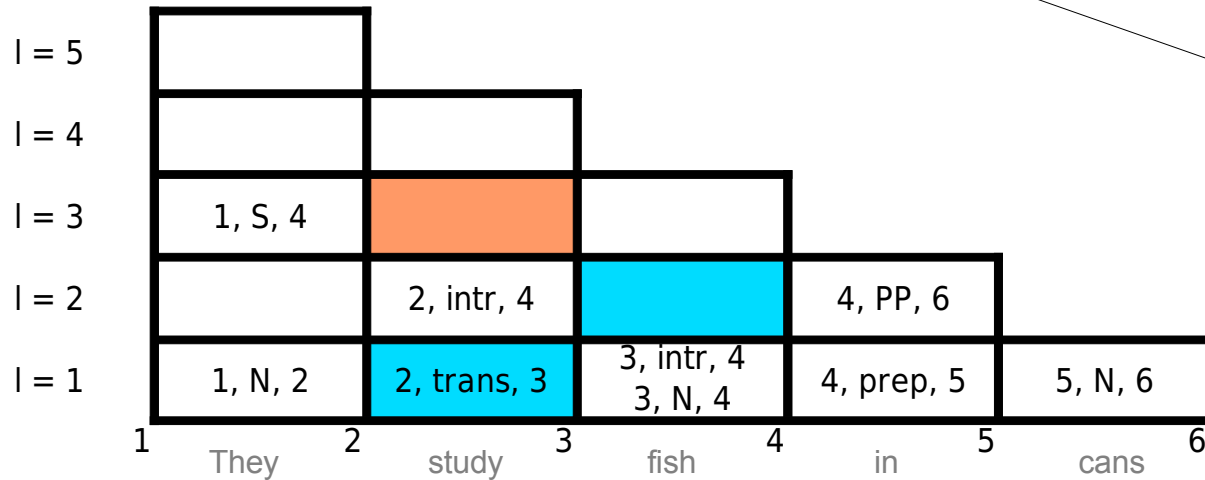
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.   for each A → ws do
4.     chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.   for each s:=1, ... ,n+1-l
7.     for each t:=1, ... ,l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1]:= chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

... für alle Regeln



REGELN

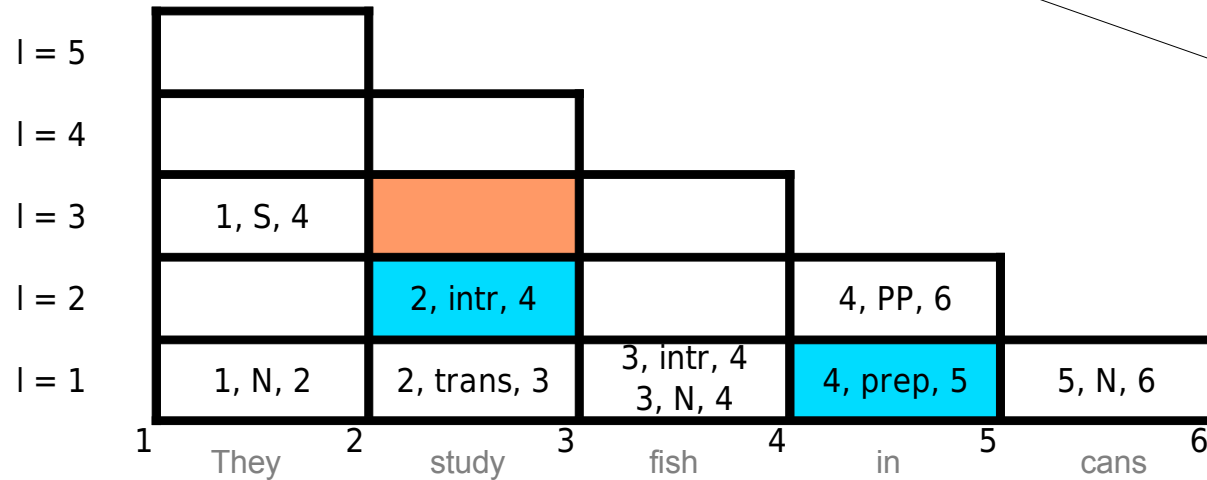
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.     for each s:=1, ... ,n+1-1
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

... für alle Regeln



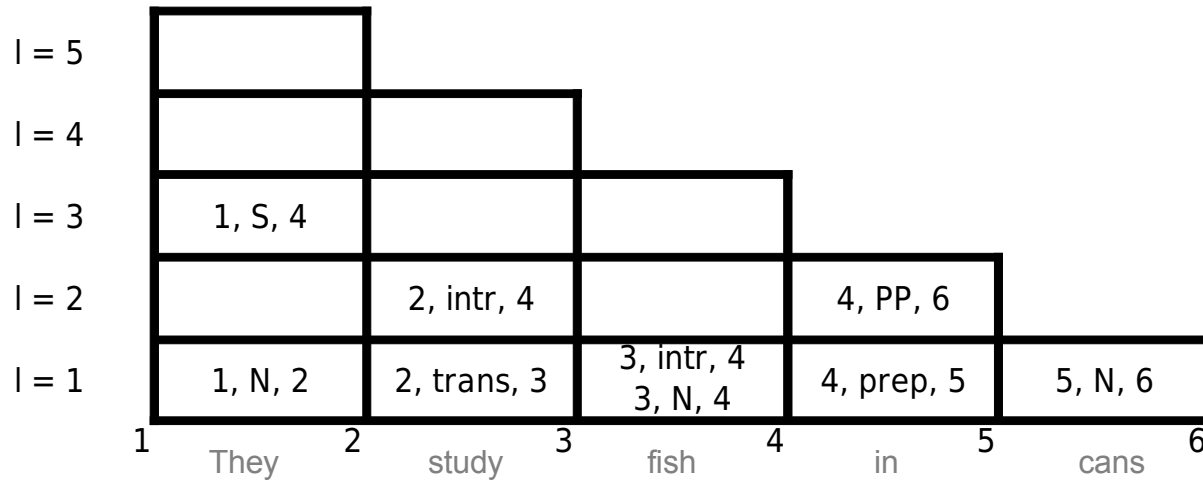
REGELN

S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.   for each A → ws do
4.     chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.   for each s:=1, ... ,n+1-1
7.     for each t:=1, ... ,l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1]:= chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS



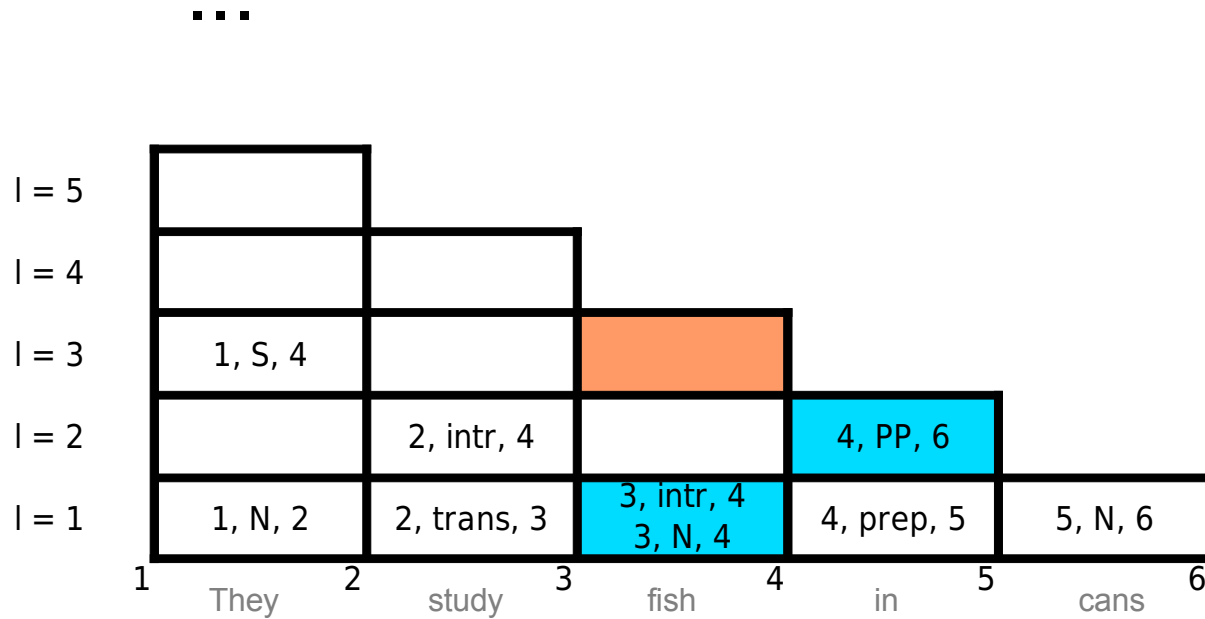
REGELN

S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.     for each s:=1, ... ,n+1-1
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS



REGELN

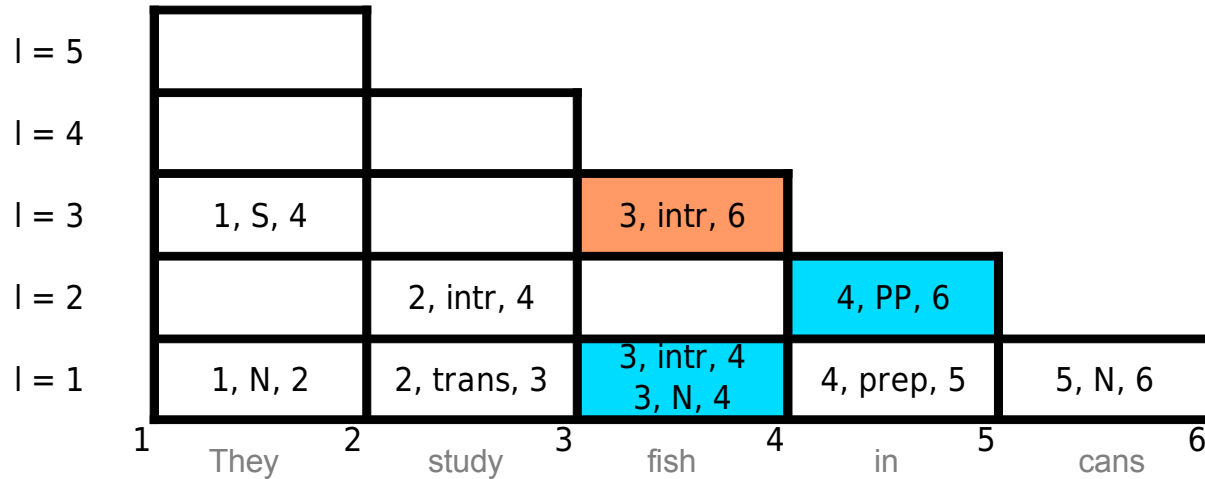
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.     for each s:=1, ... ,n+1-1
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

8. $\text{intr} \rightarrow \text{intr PP}$
9. $c[3, \text{intr}, 6] := c[3, \text{intr}, 6] \vee$
10. $c[3, \text{intr}, 4] \wedge c[4, \text{PP}, 6]$



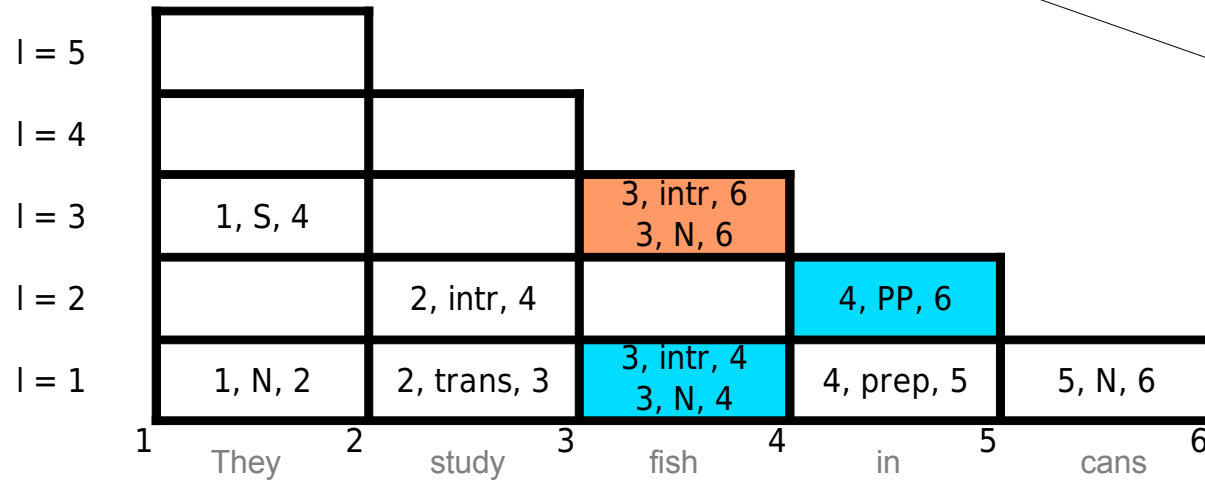
REGELN

S	\rightarrow N intr
intr	\rightarrow trans N
intr	\rightarrow intr PP
N	\rightarrow N PP
PP	\rightarrow prep N

1. $\text{chart}[\dots] := \text{FALSE};$
2. for each $s := 1, \dots, n$ do
3. for each $A \rightarrow w_s$ do
4. $\text{chart}[s, A, s+1] := \text{TRUE};$
5. for each $l := 2, \dots, n$ do $l := 3$
6. for each $s := 1, \dots, n+1-l$ $s := 3$
7. for each $t := 1, \dots, l-1$ do $t := 1$
8. for each $A \rightarrow B C$ do
9. $\text{chart}[s, A, s+1] := \text{chart}[s, A, s+1] \vee$
10. $\text{chart}[s, B, s+t] \wedge \text{chart}[s+t, C, s+1]$

ALGORITHMUS

... usw. für alle Regeln



REGELN

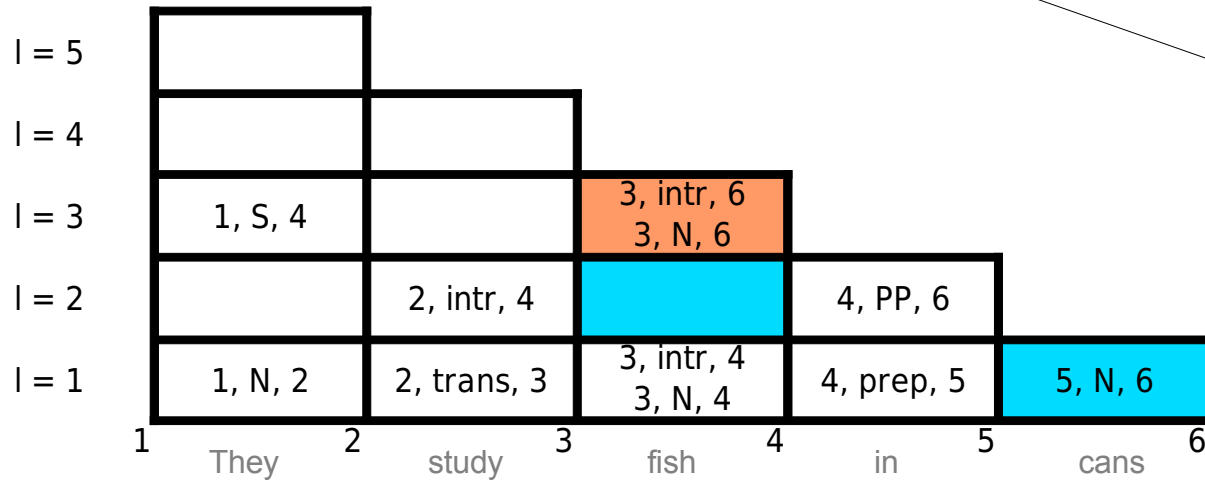
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.   for each A → ws do
4.     chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.   for each s:=1, ... ,n+1-1
7.     for each t:=1, ... ,l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1]:= chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

... für alle Regeln



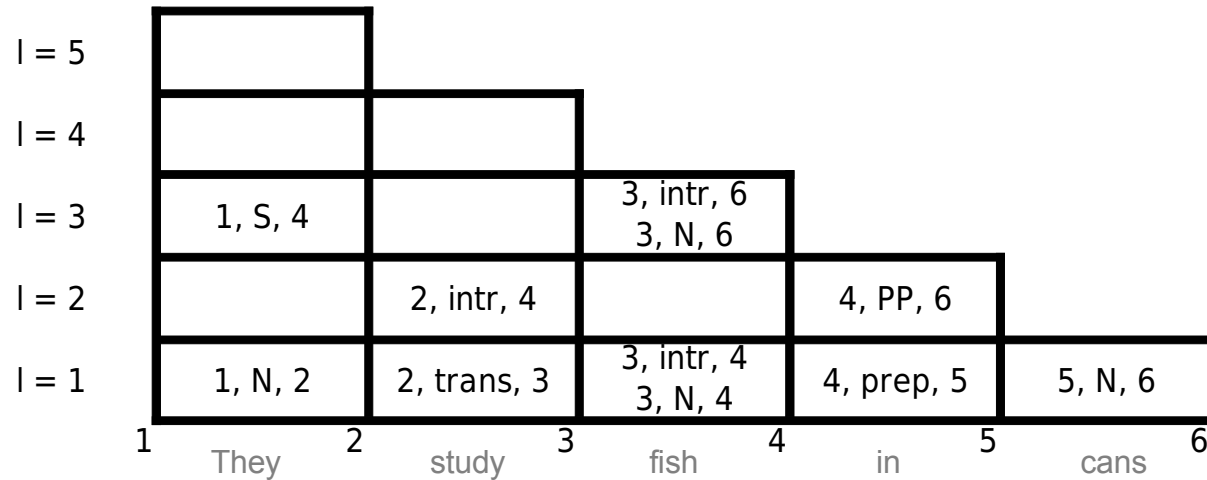
REGELN

S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.     for each s:=1, ... ,n+1-1
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS



REGELN

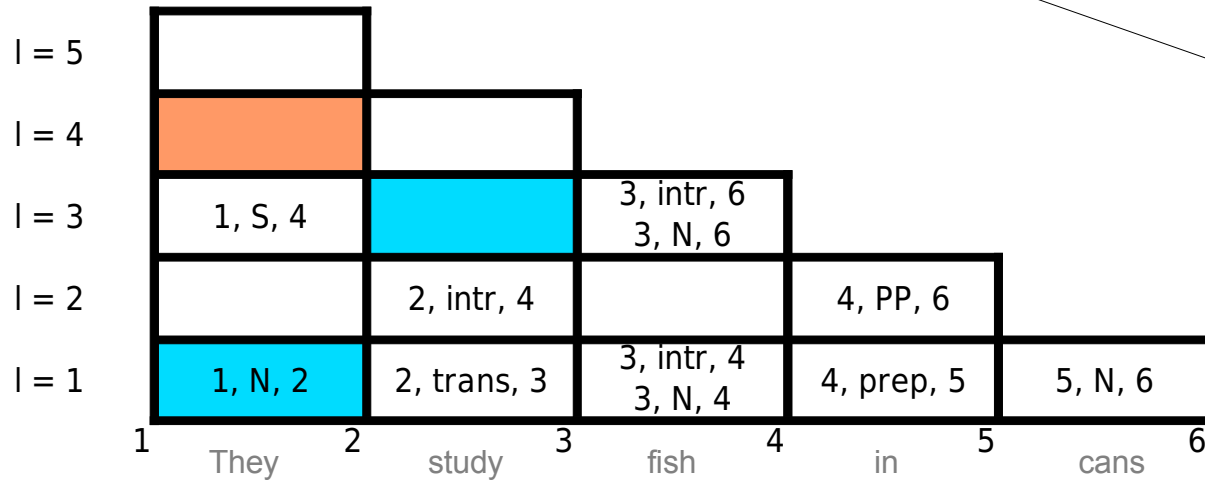
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do           l:= 4
6.     for each s:=1, ... ,n+1-1     s:= 1
7.         for each t:=1, ... ,l-1 do t:= 1
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

... für alle Regeln



REGELN

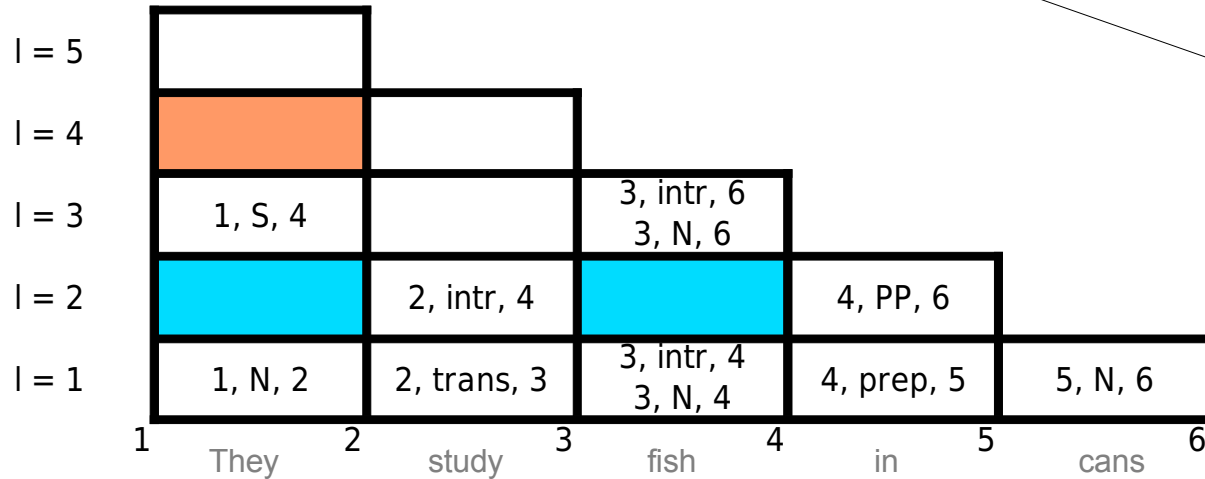
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.   for each A → ws do
4.     chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.   for each s:=1, ... ,n+1-l
7.     for each t:=1, ... ,l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1]:= chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

... für alle Regeln



REGELN

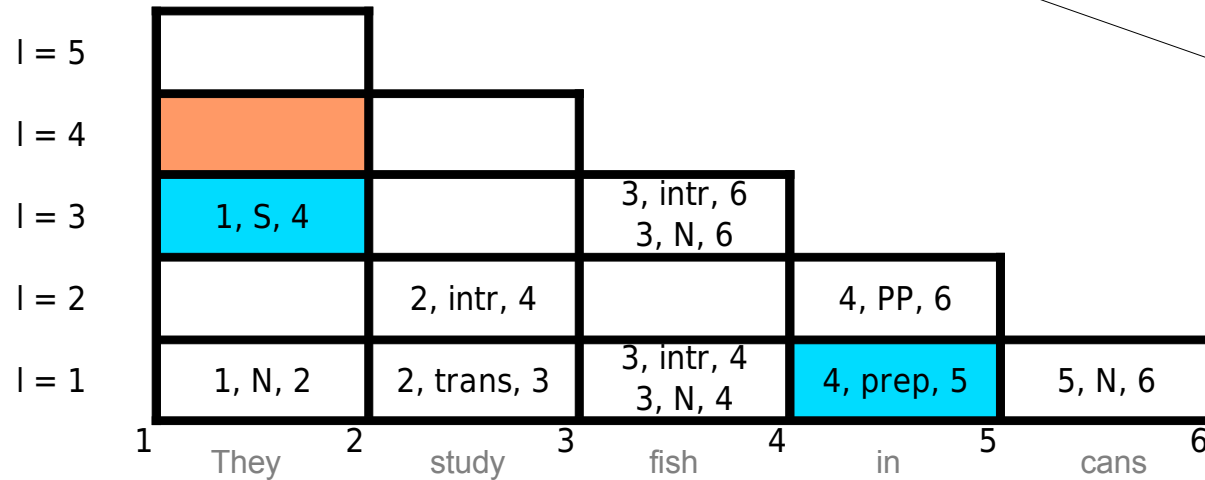
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.     for each s:=1, ... ,n+1-1
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

... für alle Regeln



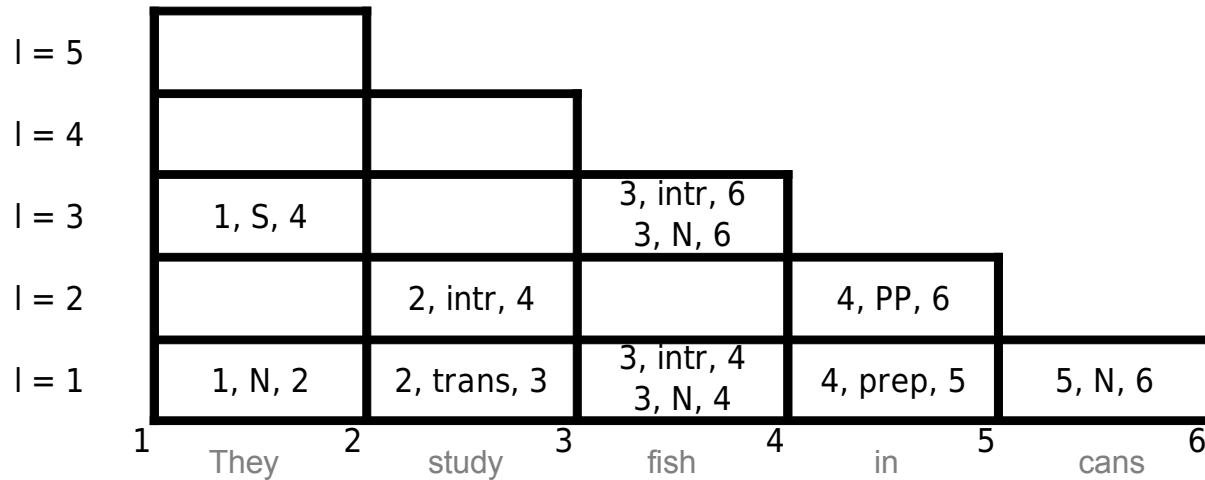
REGELN

S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.   for each A → ws do
4.     chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.   for each s:=1, ... ,n+1-1
7.     for each t:=1, ... ,l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1]:= chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

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REGELN

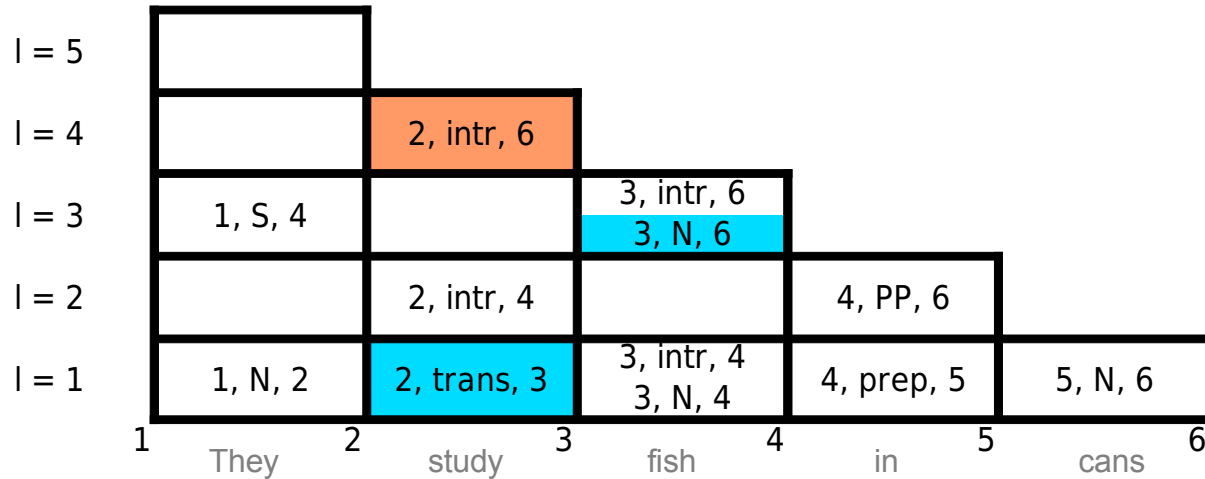
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.] := FALSE;
2. for each s:=1, ..., n do
3.     for each A → ws do
4.         chart[s,A,s+1] := TRUE;
5. for each l:=2, ..., n do
6.     for each s:=1, ..., n+1-l
7.         for each t:=1, ..., l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1] := chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

8. intr \rightarrow trans N
9. $c[2, \text{intr}, 6] := c[2, \text{intr}, 6] \vee$
10. $c[2, \text{trans}, 3] \wedge c[3, \text{N}, 6]$



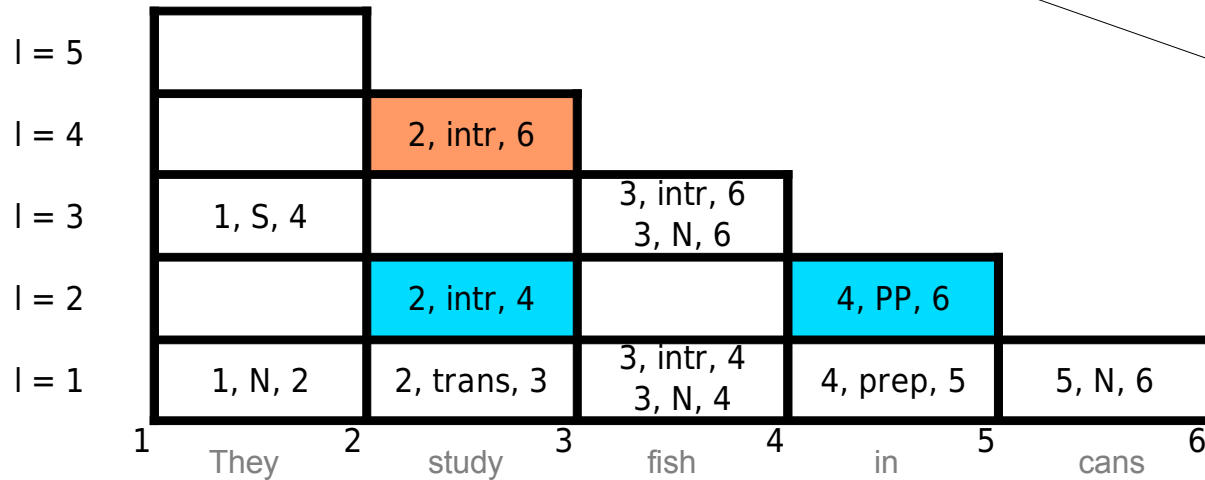
REGELN

S	\rightarrow N intr
intr	\rightarrow trans N
intr	\rightarrow intr PP
N	\rightarrow N PP
PP	\rightarrow prep N

1. chart[.,.,.] := FALSE;
2. for each s:=1, ... ,n do
3. for each A \rightarrow w_s do
4. chart[s,A,s+1] := TRUE;
5. for each l:=2, ... ,n do l := 4
6. for each s:=1, ... ,n+1-1 s := 2
7. for each t:=1, ... ,l-1 do t := 1
8. for each A \rightarrow B C do
9. chart[s,A,s+1] := chart[s,A,s+1] \vee
10. chart[s,B,s+t] \wedge chart[s+t,C,s+1]

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... für alle Regeln



REGELN

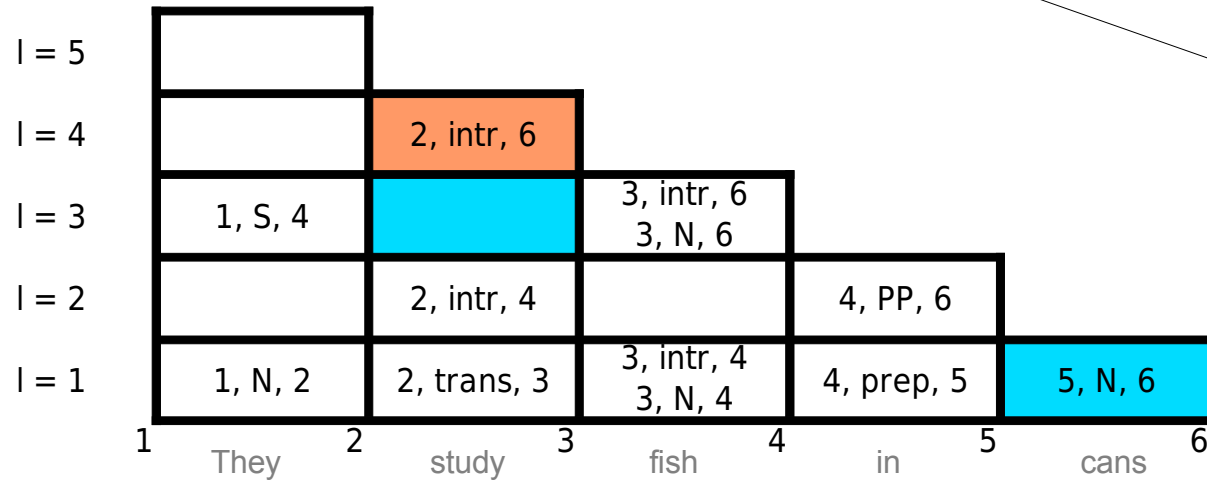
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.   for each A → ws do
4.     chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.   for each s:=1, ... ,n+1-1
7.     for each t:=1, ... ,l-1 do
8.       for each A → B C do
9.         chart[s,A,s+1]:= chart[s,A,s+1] v
10.        chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

... für alle Regeln



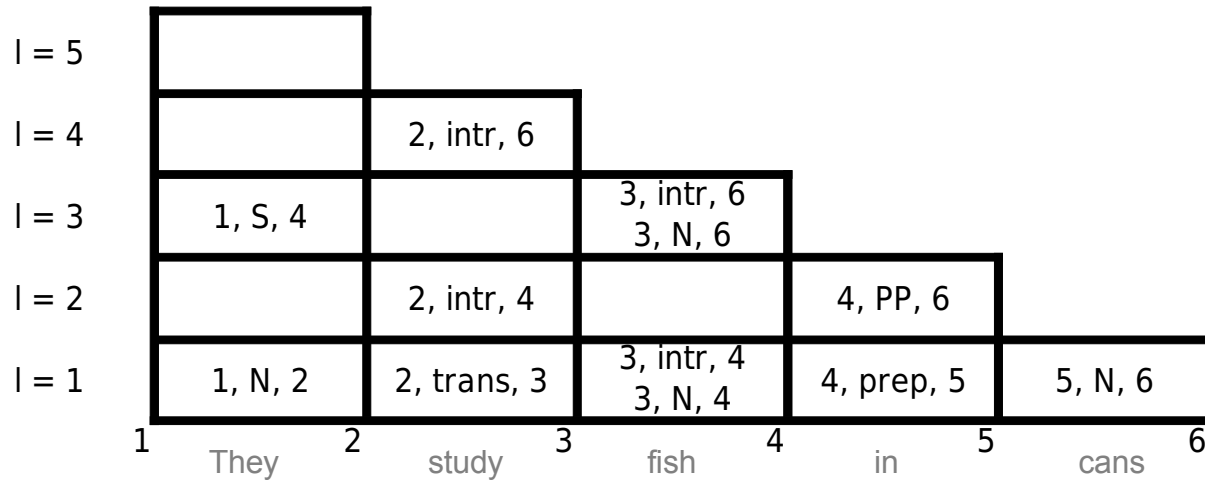
REGELN

S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.     for each s:=1, ... ,n+1-1
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS



REGELN

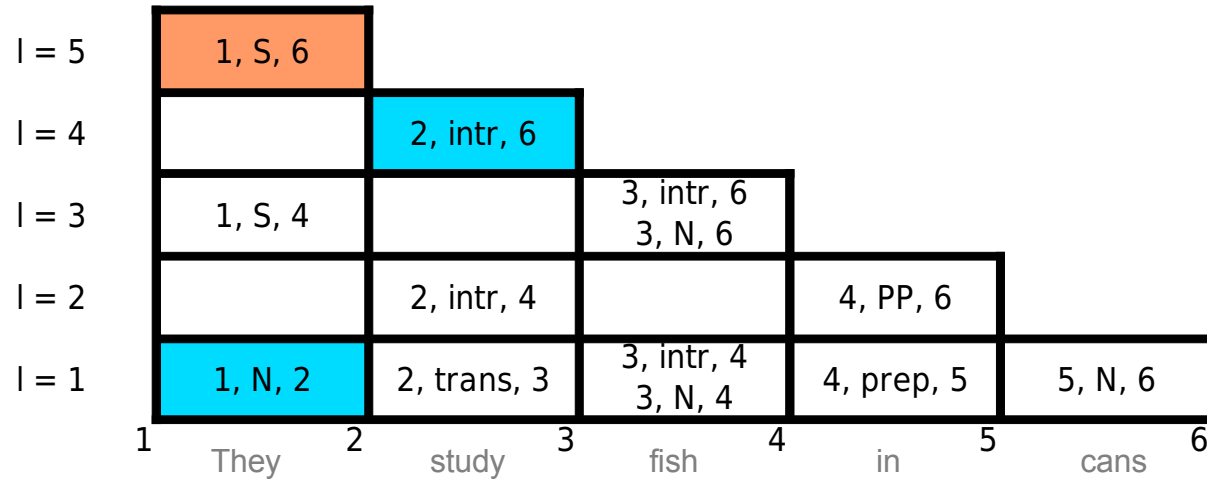
S	→ N intr
intr	→ trans N
intr	→ intr PP
N	→ N PP
PP	→ prep N

```

1. chart[.,.,.]:= FALSE;
2. for each s:=1, ... ,n do
3.     for each A → ws do
4.         chart[s,A,s+1]:=TRUE;
5. for each l:=2, ... ,n do
6.     for each s:=1, ... ,n+1-l
7.         for each t:=1, ... ,l-1 do
8.             for each A → B C do
9.                 chart[s,A,s+1]:= chart[s,A,s+1] v
10.                chart[s,B,s+t] ∧ chart[s+t,C,s+1]
    
```

ALGORITHMUS

8. $S \rightarrow N \text{ intr}$
9. $c[1,S,6] := c[1,S,6] \vee$
10. $c[1,N,2] \wedge c[2,\text{intr},6]$



REGELN

S	$\rightarrow N \text{ intr}$
intr	$\rightarrow \text{trans } N$
intr	$\rightarrow \text{intr PP}$
N	$\rightarrow N \text{ PP}$
PP	$\rightarrow \text{prep } N$

1. `chart[.,.,.] := FALSE;`
2. `for each s:=1, ..., n do`
3. `for each $A \rightarrow w_s$ do`
4. `chart[s,A,s+1] := TRUE;`
5. `for each l:=2, ..., n do` l := 5
6. `for each s:=1, ..., n+1-1` s := 1
7. `for each t:=1, ..., l-1 do` t := 1
8. `for each $A \rightarrow B C$ do`
9. `chart[s,A,s+1] := chart[s,A,s+1] \vee`
10. `chart[s,B,s+t] \wedge chart[s+t,C,s+1]`

ALGORITHMUS

AUSGABE: CHART

$l = 5$	1, S, 6							
$l = 4$		2, intr, 6						
$l = 3$	1, S, 4		3, intr, 6 3, N, 6					
$l = 2$		2, intr, 4			4, PP, 6			
$l = 1$	1, N, 2	2, trans, 3	3, intr, 4 3, N, 4	4, prep, 5		5, N, 6		
	1 They	2 study	3 fish	4 in	5 cans	6		