$G = (V, \Sigma, R, S)$

$V = \{S, a, b\}$

$\Sigma = \{a, b\}$

$R: \quad S \rightarrow aSb \mid e$

$L(G) = \{a^n b^n \mid n \geq 0\}$

Some Derivations.

$S \Rightarrow e$

$S \Rightarrow aSb \Rightarrow aaSbb \Rightarrow aaaSbbb \Rightarrow aaabbb$

$G = (V, \Sigma, R, S)$

$V = \{S, NP, VP, N, V, John, ate, slept, apple\}$

$\Sigma = \{John, ate, apple, slept\}$

R: 1) $S \rightarrow NP\ VP$

2) $NP \rightarrow N$

3) $VP \rightarrow V\ NP$

4) $VP \rightarrow V$

5) $N \rightarrow John$

6) $N \rightarrow apple$

7) $V \rightarrow ate$

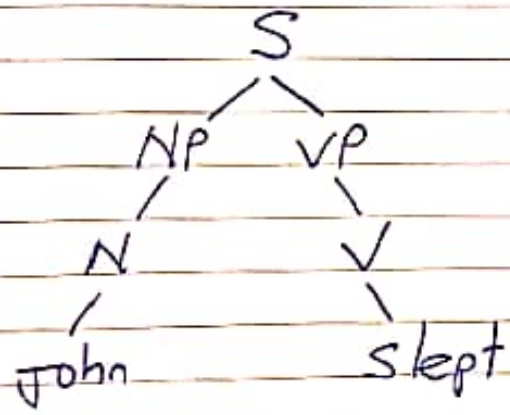
8) $V \rightarrow slept$

$V \rightarrow ate \mid slept$

Derivation of "ali slept"

$S \underset{1}{\Rightarrow} NP\ VP \underset{2}{\Rightarrow} N\ VP \underset{5}{\Rightarrow} John\ VP \underset{4}{\Rightarrow} John\ V \underset{8}{\Rightarrow} John\ slept$

Parse Tree:



$S \overset{*}{\underset{G}{\Rightarrow}} john\ slept$

start symbol

$G = (V, \Sigma, R, E)$

$V = \{+, \times, (,), id, T, F, E\}$

$\Sigma = \{+, \times, (,), id\}$

R: 1) $E \rightarrow E+T$

2) $T \rightarrow T \times F$

3) $F \rightarrow (E)$

4) $E \rightarrow T$

5) $T \rightarrow F$

6) $F \rightarrow id$

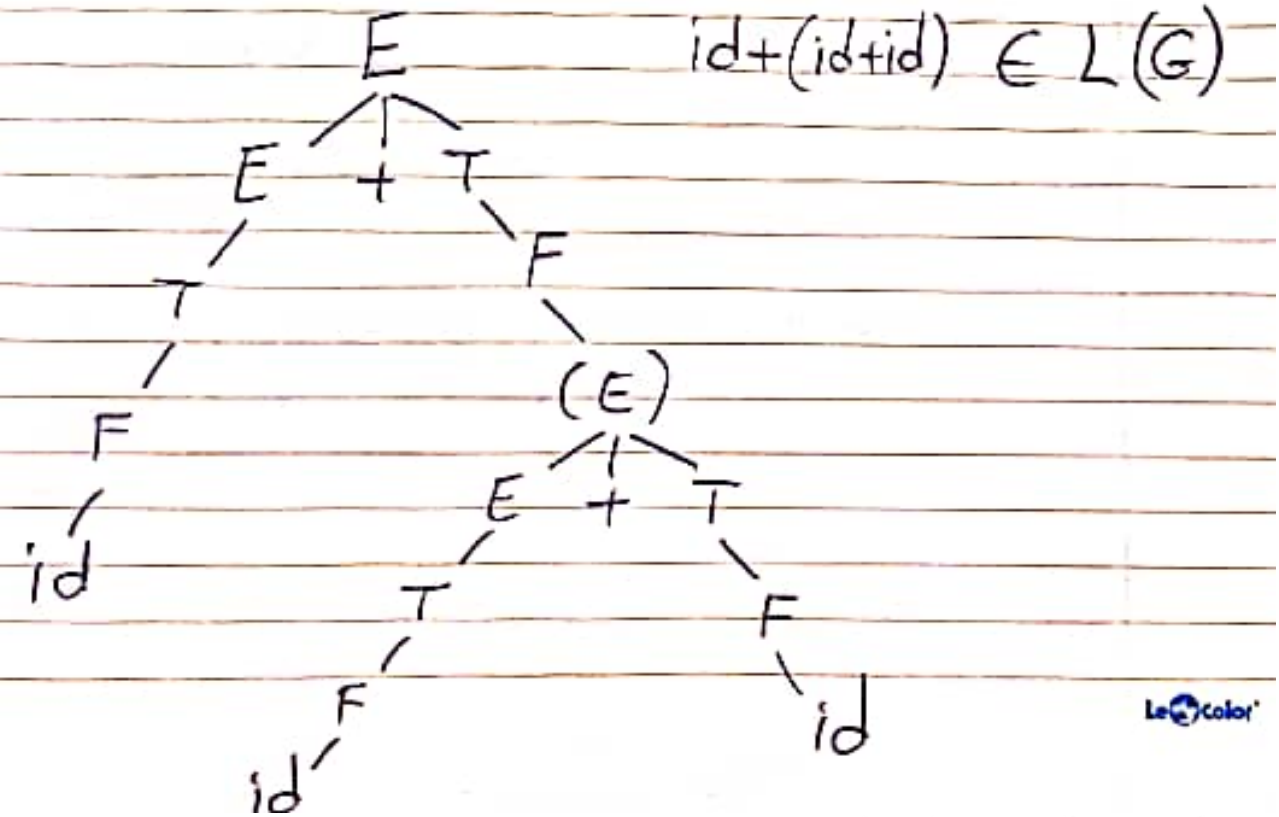
Derivation of $id+(id \times id)$

$S \Rightarrow E+T \Rightarrow T+T \Rightarrow F+T \Rightarrow id+T \Rightarrow id+F$

$\Rightarrow id+(E) \Rightarrow id+(E+T) \Rightarrow id+(T+T) \Rightarrow id+(F+T)$

$\Rightarrow id+(id+T) \Rightarrow id+(id+F) \Rightarrow id+(id+id)$

$id+(id+id) \in L(G)$



DFA to CFG construction:

$M = (K, \Sigma, \delta, s, F)$

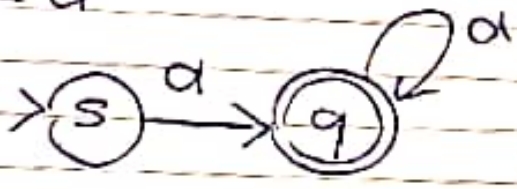
$G = (V, \Sigma, R, S)$

$V = K \cup \Sigma$

$S = s$

$R = \{ q \to ap \mid \delta(q,a) = p \} \cup \{ q \to e \mid q \in F \}$

$L = a^+$



$G = (\{s, q, a\}, \{a\}, R, s)$

R: 1) $s \to aq$

2) $q \to aq$

3) $q \to e$

Derivation:

$s \underset{1}{\Rightarrow} aq \underset{2}{\Rightarrow} aaq \underset{2}{\Rightarrow} aaaq \underset{3}{\Rightarrow} aaa$

$S \rightarrow NP\ VP$

$NP \rightarrow D\ N \mid NP\ PP \mid N$

$VP \rightarrow V$

$VP \rightarrow V\ NP$

$VP \rightarrow V\ NP\ PP$

$PP \rightarrow P\ NP$

$N \rightarrow I$

$N \rightarrow girl$

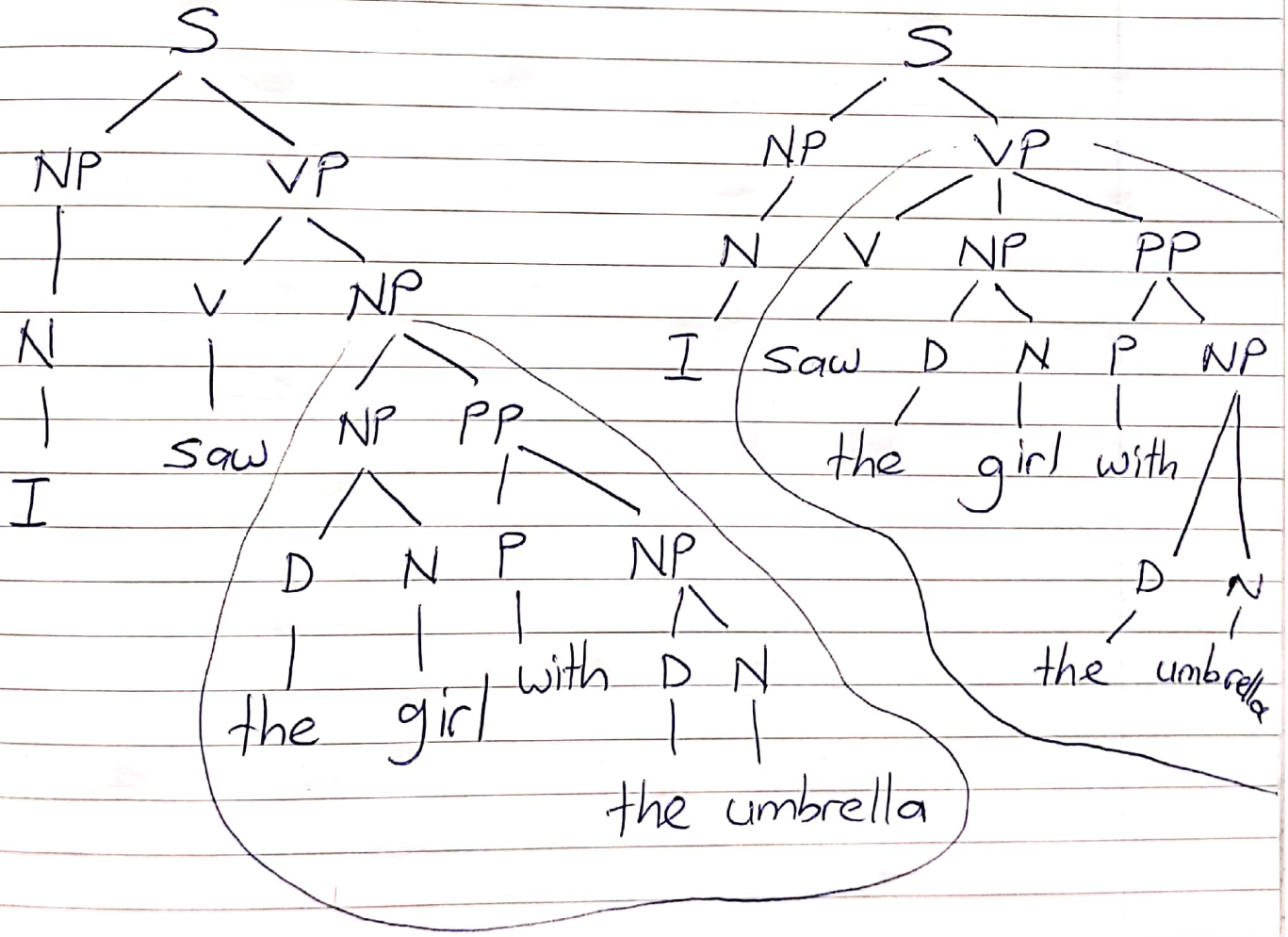
$N \rightarrow telescope$

$V \rightarrow saw$

$D \rightarrow the$

$P \rightarrow with$

I saw the girl with the telescope



Ambiguous

Different parse trees

G:

$E \rightarrow E + E$

$E \rightarrow E \times E$

$E \rightarrow T$

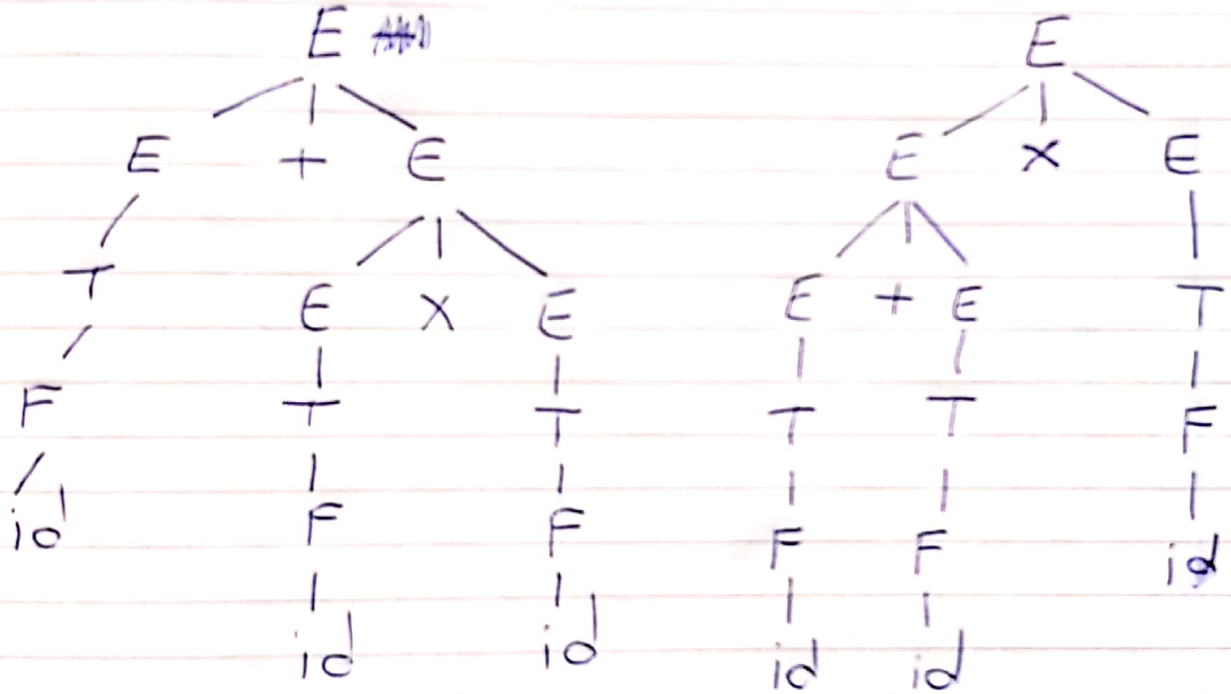
$T \rightarrow F$

$F \rightarrow id$

start symbol: E

$\Sigma = \{+, \times, id\}$

ω: id+id×id



Evaluation order
First ×
Then +

Evaluation order
First +
Then ×

- Ambiguous - Different parse trees

need to change grammar
to remove ambiguity

$S \rightarrow A\ B$

$A \rightarrow C\ D$

$B \rightarrow E\ F$

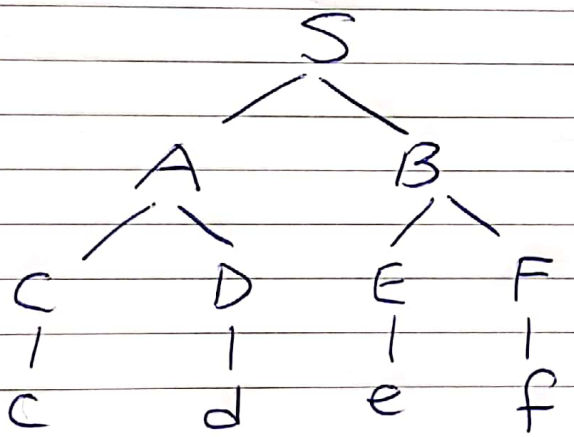
$A \rightarrow a$

$B \rightarrow b$

$C \rightarrow c$

$D \rightarrow d$

$E \rightarrow e$



Many Derivations for the same parse tree. (Equivalent Derivations)

Leftmost Derivation:

$S \Rightarrow A\ B \Rightarrow C\ D\ B \Rightarrow c\ D\ B \Rightarrow$

$c\ d\ B \Rightarrow c\ d\ E\ F \Rightarrow c\ d\ e\ F \Rightarrow c\ d\ e\ f$

Rightmost Derivation:

$S \Rightarrow A\ B \Rightarrow A\ E\ F \Rightarrow A\ E\ f \Rightarrow$

$A\ e\ f \Rightarrow C\ D\ e\ f \Rightarrow C\ d\ e\ f \Rightarrow c\ d\ e\ f$

Another Derivation:

$S \Rightarrow A\ B \Rightarrow A\ E\ F \Rightarrow C\ D\ E\ F \Rightarrow$

$C\ D\ e\ F \Rightarrow C\ d\ e\ F \Rightarrow c\ d\ e\ F \Rightarrow c\ d\ e\ f$