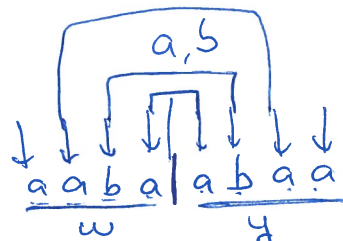


* $L = \{w \mid w \text{ is a palindrome over } \{a, b\}\}$



reads the same forward and in reverse

$$S \rightarrow aSa \mid bSb$$

put the same character to the left and right

$$S \rightarrow a$$

$$S \rightarrow a \mid b$$

for even length palindromes

for odd length palindromes

$$ww^R$$

$$waw^R$$

$$wbw^R$$

CFG's can't generate these

$$a^i b^i c^i$$

$$S \rightarrow SaSa$$

| |
bbb a

$$\begin{aligned} S &\rightarrow AC \\ A &\rightarrow aAb \mid a \\ C & \end{aligned}$$

$$abbabb$$

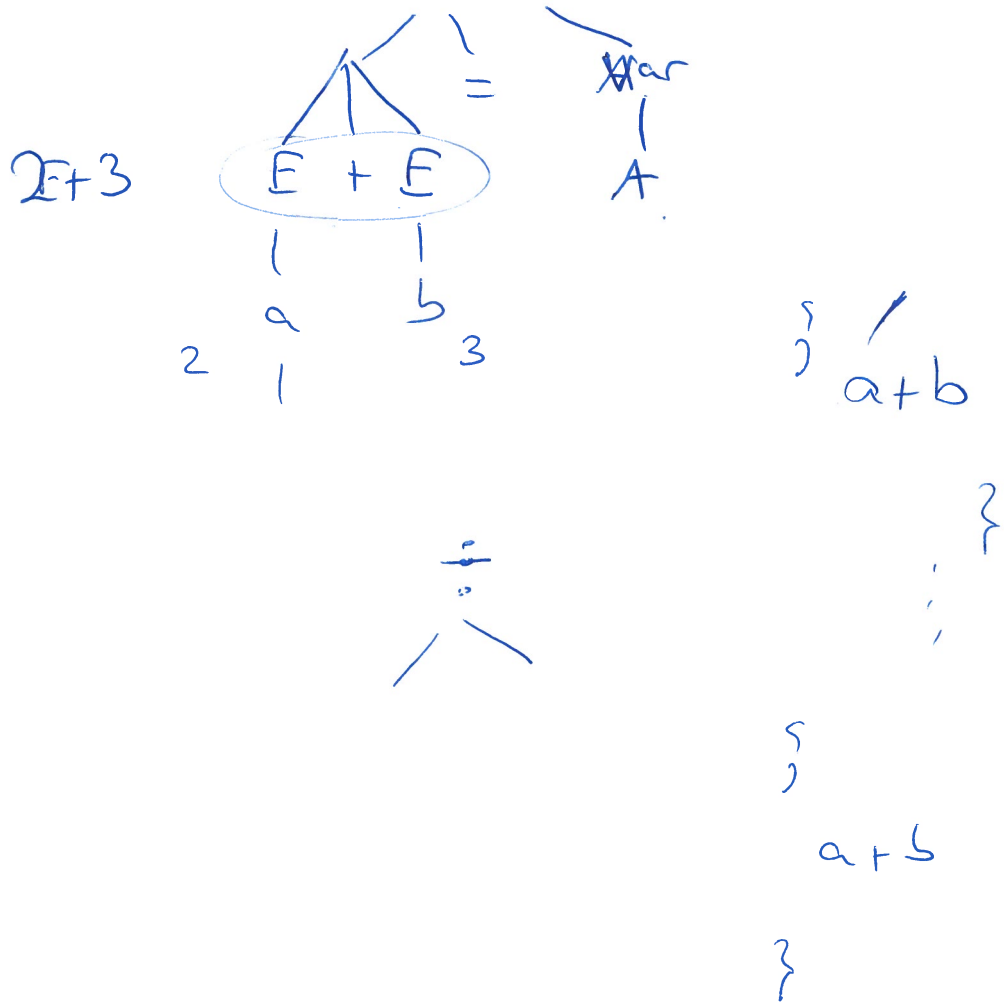
$$\underbrace{a^i b^i}_A \underbrace{c^i d^i}_B$$

but these can be generated.

c

c

②



Section 4.1 Grammar Transformations

$$S \rightarrow aSa \mid bSb \mid a \mid b \mid \lambda$$

if a variable appears on the right-hand side it is **recursive**.
To generate infinite number of strings we need recursion.

$$S \rightarrow a \mid b \mid ab$$

We want to eliminate recursion from the start symbol. We don't want to have the start symbol on any right-hand side.

③

$$S \rightarrow aBa \mid bBb \mid a \mid b \mid \lambda$$

~~$$B \rightarrow aSa \mid bSb$$~~

$$B \rightarrow aBa \mid bBb \mid a \mid b \mid \lambda$$

$$S \rightarrow B$$

$$B \rightarrow aBa \mid bBb \mid a \mid b \mid \lambda$$

$$\left\{ \begin{array}{l} S' \rightarrow S \\ S \rightarrow aSa \mid bSb \mid a \mid b \mid \lambda \end{array} \right.$$

$$\left\{ \begin{array}{l} S' \rightarrow aSa \mid bSb \mid a \mid b \mid \lambda \\ S \rightarrow aSa \mid bSb \mid a \mid b \mid \lambda \end{array} \right.$$

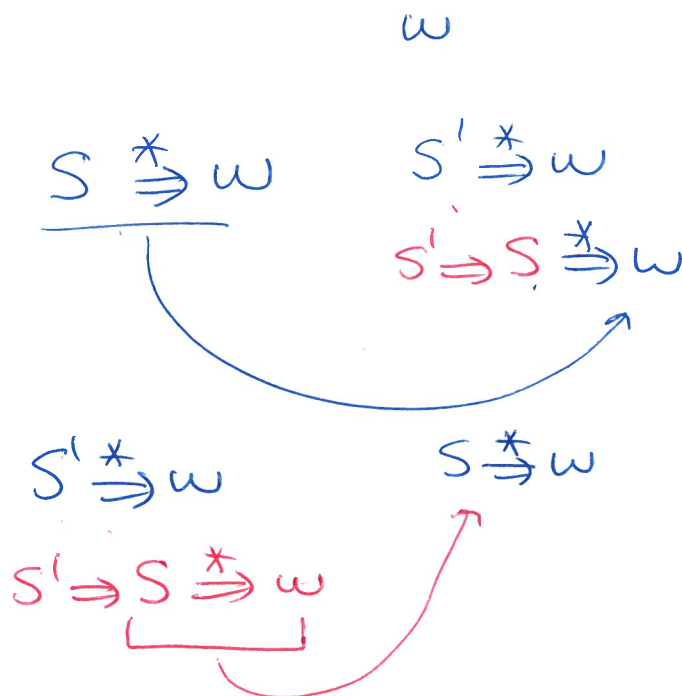
$$\left\{ \begin{array}{l} S' \rightarrow S \\ S \rightarrow \\ A \rightarrow - \\ B \rightarrow \end{array} \right\} G'$$

G

$$L(G) = L(G')$$

$$L(G) \subseteq L(G')$$

$$L(G') \subseteq L(G)$$



(4)

$$S \rightarrow AB$$

$$A \rightarrow aA \mid \lambda$$

$$B \rightarrow b$$

No null rules
except at S

$$S \rightarrow AB$$

$$A \rightarrow a \mid \textcircled{a}$$

$$B \rightarrow b$$

$$S \rightarrow AB \mid \lambda$$

$$S \rightarrow AB \mid \textcircled{a} \mid B$$

$$A \rightarrow a$$

$$B \rightarrow b$$

$$S \rightarrow AB \mid B$$

$$A \rightarrow a$$

$$B \rightarrow b$$

$$\begin{aligned} S &\Rightarrow AB \Rightarrow aB \Rightarrow ab \\ &\Rightarrow B \Rightarrow b \end{aligned}$$

$$S \rightarrow ABC \mid BC \mid AC \mid AB \mid C \mid A \mid B \mid \lambda$$

$$A \rightarrow a \mid \lambda$$

$$B \rightarrow b \mid \lambda$$

$$C \rightarrow c \mid \lambda$$

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$S \rightarrow \underline{A} \underline{B} C \mid BC \mid AC \mid C$

$\underline{A} \rightarrow a \mid \lambda$

$\underline{B} \rightarrow b \mid \lambda$

$C \rightarrow c \mid d$

$S \rightarrow \underline{A} \underline{B}$

$\underline{A} \rightarrow \underline{C} \underline{D}$

$\underline{B} \rightarrow \underline{E} \underline{F}$

$\underline{C} \rightarrow c \underline{C} \mid \lambda$

$\underline{D} \rightarrow d \underline{D} \mid \lambda$

$\underline{E} \rightarrow e \underline{E} \mid \lambda$

$\underline{F} \rightarrow f \underline{F} \mid \lambda$

} nullable variables

$NULL = \{C, D, E, F\}$

\cup
 $\{A, B\}$

\cup
 $\{S\}$

$S \rightarrow \underline{A} \underline{B} z$

~~$S \rightarrow$~~ $A \rightarrow \underline{C} \underline{D} \mid G$

$G \rightarrow g$

$S \rightarrow AB \mid A \mid B \mid \lambda$

$A \rightarrow CD \mid C \mid D \mid \lambda$

$B \rightarrow EF \mid E \mid F$

$C \rightarrow cC \mid c$

$D \rightarrow dD \mid d$

$E \rightarrow eE \mid e$

$F \rightarrow fF \mid f$