#### Left recursion

• A grammar is *left-recursive* if there exists a nonterminal A such that there is a derivation  $A \Rightarrow^+ A \alpha$  for some string  $\alpha$ 

$$E \rightarrow E + T \mid T$$

$$T \rightarrow T * F \mid F$$

$$F \rightarrow (E) \mid id$$

We cannot compute FIRST sets for left-recursive grammars.

#### Left recursion

 A left-recursive grammar can be transformed to eliminate left recursion

$$E \rightarrow E + T \mid T$$

$$T \rightarrow T * F \mid F$$

$$F \rightarrow (E) \mid id$$

$$E \rightarrow T E'$$

$$E' \rightarrow +T E' \mid \varepsilon$$

$$T \rightarrow F T'$$

$$T' \rightarrow * F T' \mid \varepsilon$$

$$F \rightarrow (E) \mid id$$

## Eliminating immediate left recursion

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$$T \to T * F \mid F$$

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$$F \to (E) \mid id$$

### Eliminating immediate left recursion

In general...

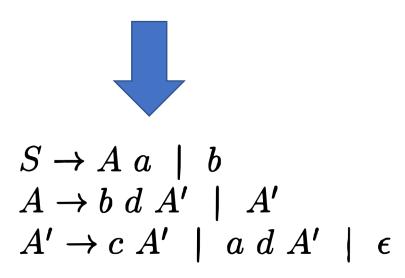
$$A \rightarrow A\alpha_1 \mid A\alpha_2 \mid \cdots \mid A\alpha_m \mid \beta_1 \mid \beta_2 \mid \cdots \mid \beta_n$$



$$A \to \beta_1 A' \mid \beta_2 A' \mid \cdots \mid \beta_n A'$$

$$A' \to \alpha_1 A' \mid \alpha_2 A' \mid \cdots \mid \alpha_m A' \mid \epsilon$$

#### Indirect left recursion



# Eliminating left recursion

```
1) arrange the nonterminals in some order A_1, A_2, \ldots, A_n.

2) for ( each i from 1 to n ) {

3) for ( each j from 1 to i-1 ) {

4) replace each production of the form A_i \to A_j \gamma by the productions A_i \to \delta_1 \gamma \mid \delta_2 \gamma \mid \cdots \mid \delta_k \gamma, where A_j \to \delta_1 \mid \delta_2 \mid \cdots \mid \delta_k are all current A_j-productions }

5) }

6) eliminate the immediate left recursion among the A_i-productions A_i \to A_i \cup A_i
```

## Eliminating left recursion

$$S \rightarrow A \ a \mid b$$

$$A \rightarrow A \ c \mid S \ d \mid \epsilon$$



$$S \rightarrow A \ a \mid b$$
 
$$A \rightarrow A \ c \mid A \ a \ d \mid b \ d \mid \epsilon$$

