

CS & IT Engineering

Compiler Design

Lexical Analysis and syntax Analysis

Lecture: 6



Deva sir

Topics to be covered:

- FIRST and FOLLOW Set
- Parsers
- LL(1) Parser
 - LL(1) CFG
 - LL(1) Table
 - LL(1) Algorithm

⑤

$$S \rightarrow AB$$

$$A \rightarrow a$$

$$B \rightarrow b$$

	S	A	B
FIRST	{a}	{a}	{b}
Follow	{\$}	{b}	{\$}

⑦

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

$$A \rightarrow ab$$

$$B \rightarrow \epsilon$$

	S	A	B
FIRST	{a}	{a}	{\epsilon}
Follow	{\\$}	{\\$}	{\\$}

$$\text{Follow}(A) = \text{Follow}(S)$$

P
W

⑨ $S \rightarrow SS|a$

	S
FIRST	{a}
Follow	{\\$, a}

⑥

$$S \rightarrow Aa \boxed{Bb}$$

$$A \rightarrow f$$

$$B \rightarrow f$$

	S	A	B
FIRST	{f}	{f}	{f}
Follow	{\\$}	{a}	{b}

⑧

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

$$A \rightarrow \epsilon$$

$$B \rightarrow ef$$

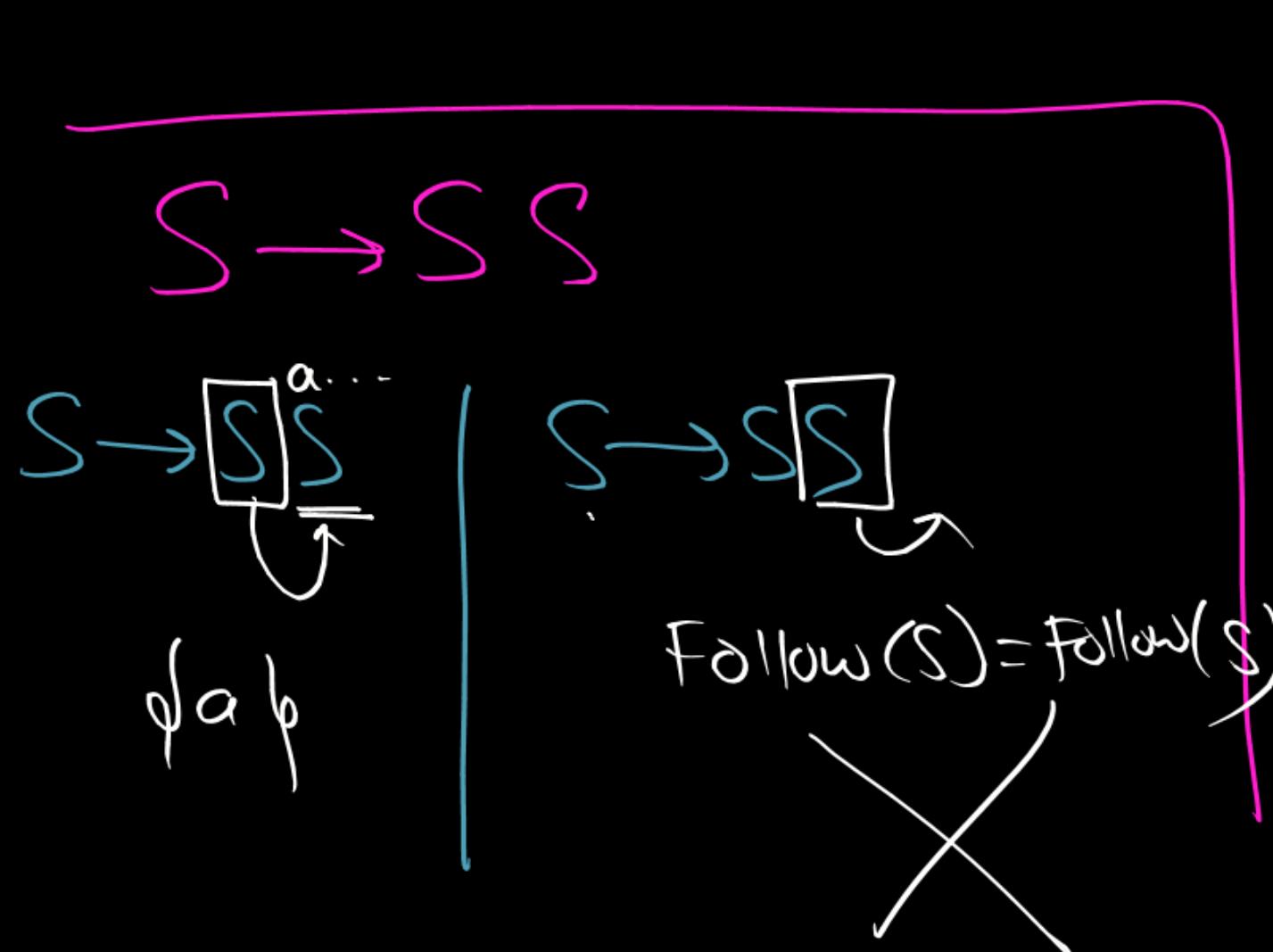
	S	A	B
FIRST	{\epsilon}	{\epsilon}	{\epsilon}
Follow	{\\$}	{\epsilon}	{\\$}

⑩

$$S \rightarrow SS|(\epsilon)$$

	S
FIRST	{\epsilon, ()}
Follow	{\\$, (,)}

$S \rightarrow SS$	$S \rightarrow SS$	$S \rightarrow (\epsilon)$
{()}	X	{(,)}

$S \rightarrow AB$ $\text{FIRST}(S) = \text{FIRST}(A \boxed{B})$ 

$\text{FIRST}(\epsilon \gamma)$
 $\text{FIRST}(\epsilon \delta)$
= {e} }

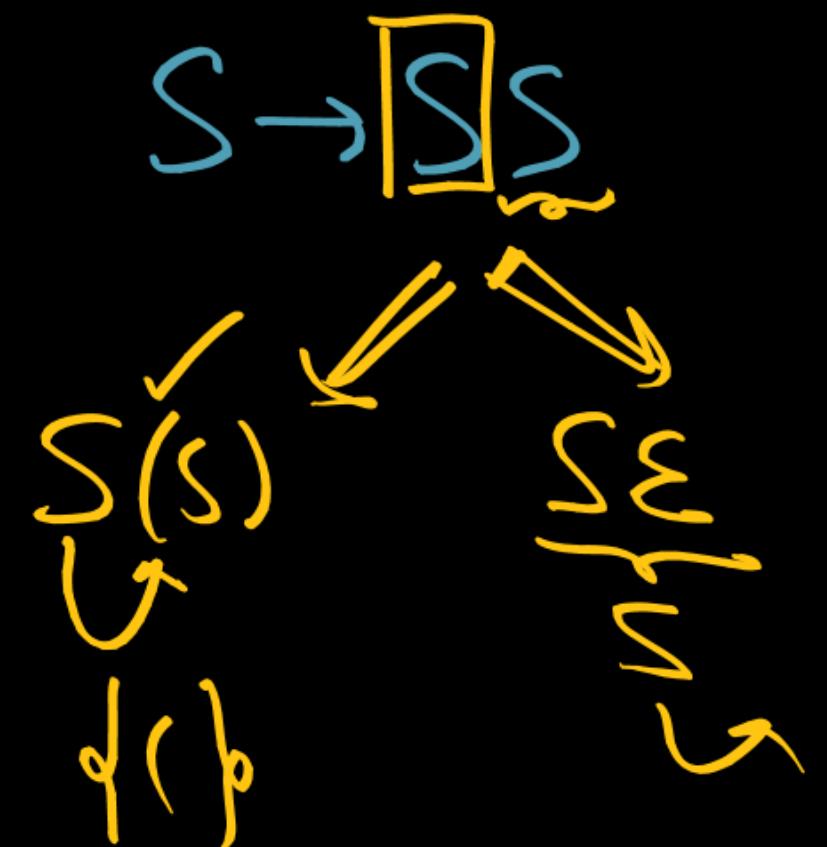
$A \rightarrow \epsilon$
 $B \rightarrow \epsilon f$

(10)

$$S \rightarrow SS \mid (S) \mid \epsilon$$

$$\text{Follow}(S) = \{ \$, (,) \}$$

$$\boxed{\begin{array}{l} S \rightarrow SS \\ S \rightarrow (S) \\ S \rightarrow \epsilon \end{array}}$$



$$S \rightarrow S \boxed{S}$$

$$S \rightarrow (\boxed{S})$$

$$\{) \}$$

⑪

$$E \rightarrow E + E \mid E * E \mid (E) \mid a$$

PW

$$\left| \text{FIRST}(E) \right| = ?$$

$$= \left| \{ (, a \} \right|$$

$$= 2$$

A) 1

B) 2

C) 3

D) 4

$$\begin{aligned} \left| \text{Follow}(E) \right| &= ? \\ &= \left| \{ +, *,), \$ \} \right| \\ &= 4 \end{aligned}$$

12

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

$$A \rightarrow ab \mid \epsilon$$

$$B \rightarrow cd \mid \epsilon$$

P W

	S	A	B
FIRST	$\{a, c, \epsilon\}$	$\{a, \epsilon\}$	$\{c, \epsilon\}$
Follow	$\{\$\}$	$\{c, \$\}$	$\{\$\}$

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



$$S \rightarrow \boxed{A}cd$$

$$\{c\}$$



$$S \rightarrow \boxed{A}$$

$$\text{Follow}(S)$$

(B)

$$S \rightarrow A \overbrace{BC}^*$$

$$A \rightarrow ab \mid \epsilon$$

$$B \rightarrow cd \mid \epsilon$$

$$C \rightarrow fg \mid \epsilon$$

	S	A	B	C
FIRST	{a,c,f,ε}	{a,ε}	{c,ε}	{f,ε}
Follow	{\$}	{c,f,\$}	{f,\$}	{\$}

(14)

$$\begin{array}{l}
 E \rightarrow E + T \mid T \\
 \text{Start} \\
 T \rightarrow F * T \mid F \\
 F \rightarrow (E) \mid \text{id}
 \end{array}$$

$$F_0(F) = \{ * \} \cup F_0(T)$$

$$T \rightarrow F * T \quad T \rightarrow F$$

$$\text{Follow}(F) = \{ * \}$$

$$\text{Follow}(F) = F_0(T)$$

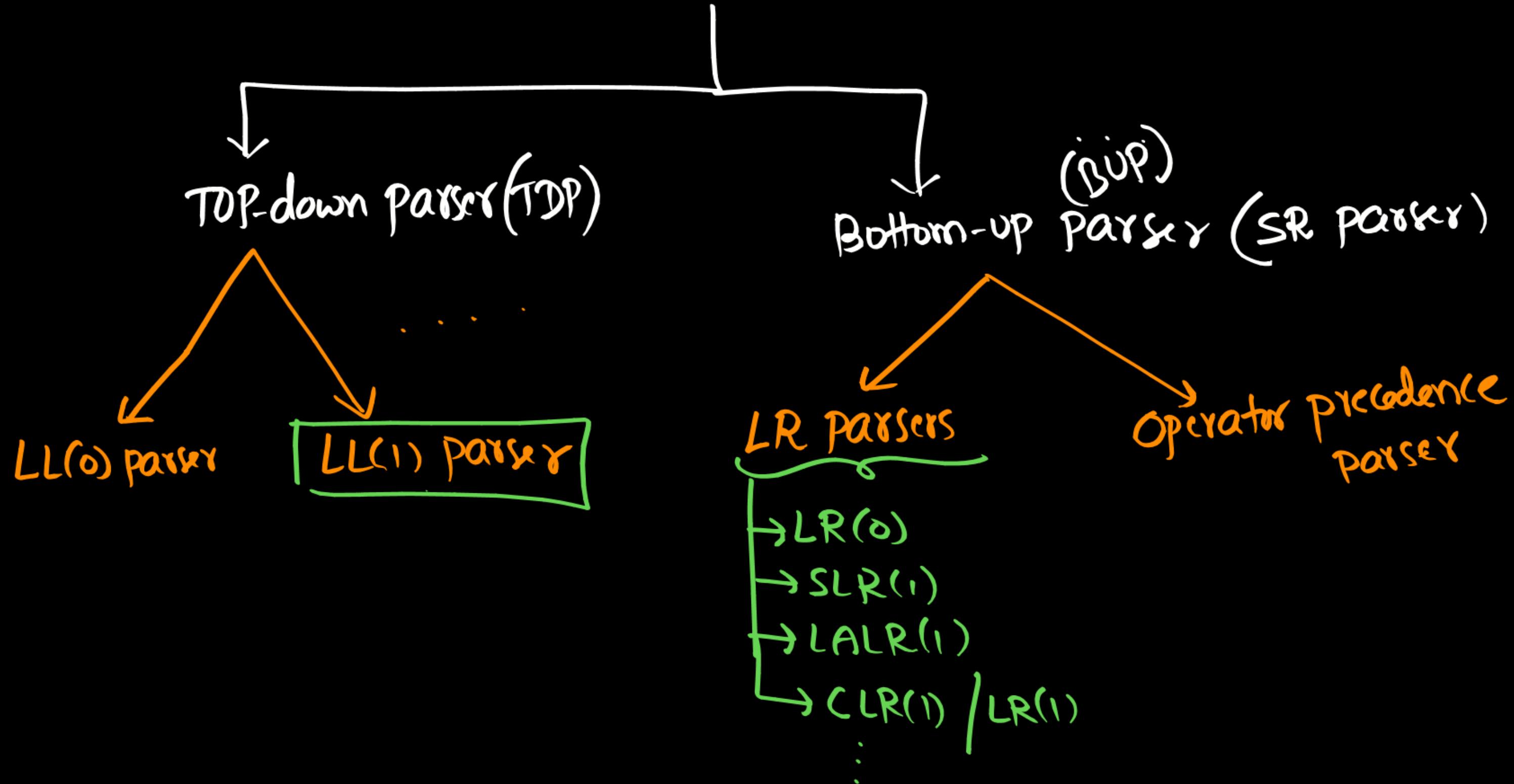
$$= \{ * \} \cup F_0(T)$$

	E	T	F
FIRST	$\{(, \text{id}\}$	$\{(, \text{id}\}$	$\{(, \text{id}\}$
FOLLOW	$\{\$, +,)\}$	$\{\$, +,)\}$	$\{*, \$, +,)\}$
	is always present in Follow(start symbol)		

in $\text{Follow}(\text{start symbol})$

P
W

ParserS [Syntax Analyzer]



TDP

I) Follows "LMD"

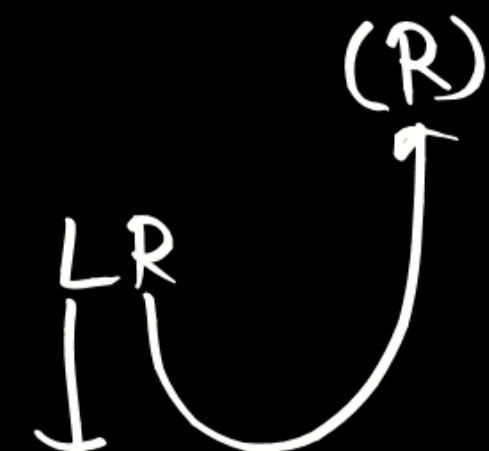


Left to Right scan

II) LL(1) parser default

BUP

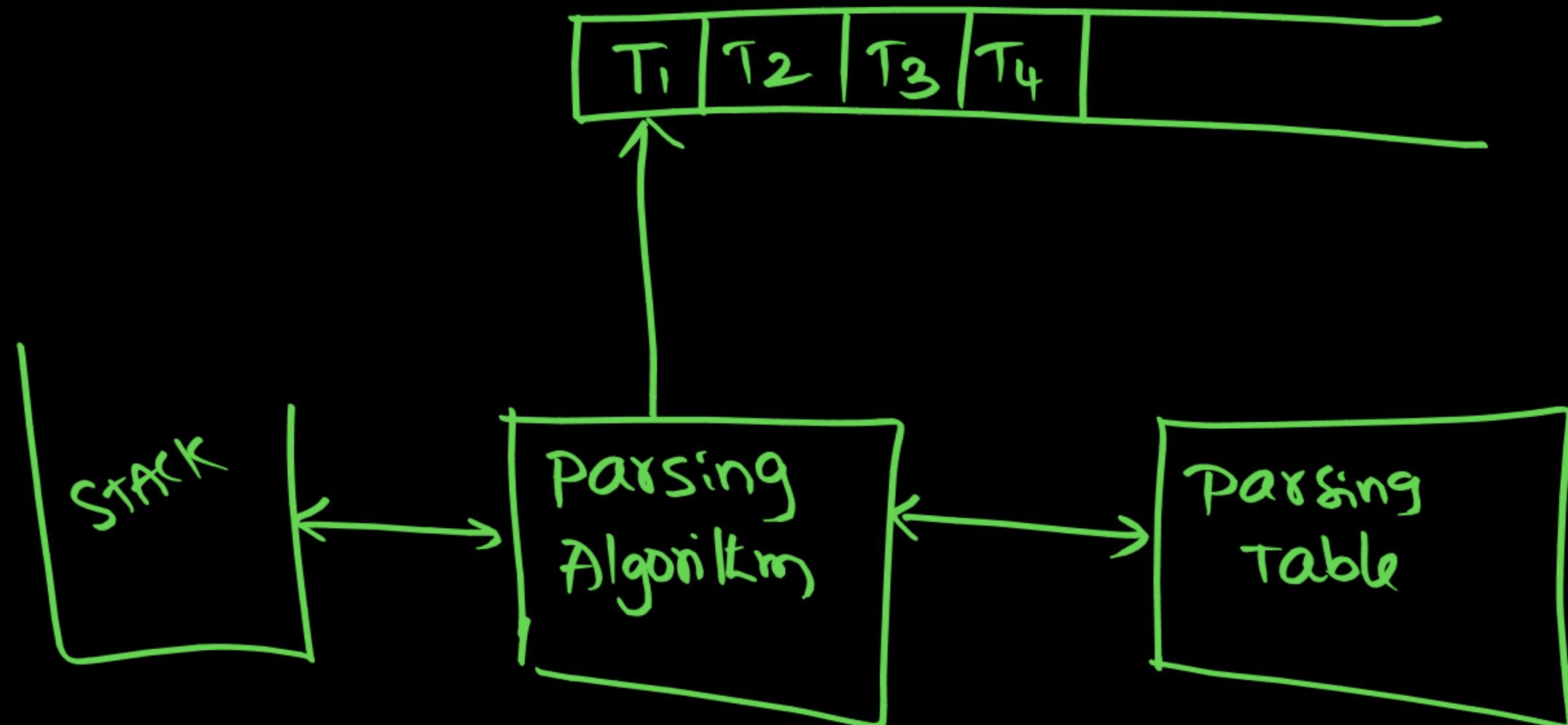
I) Follows "RMD in reverse"



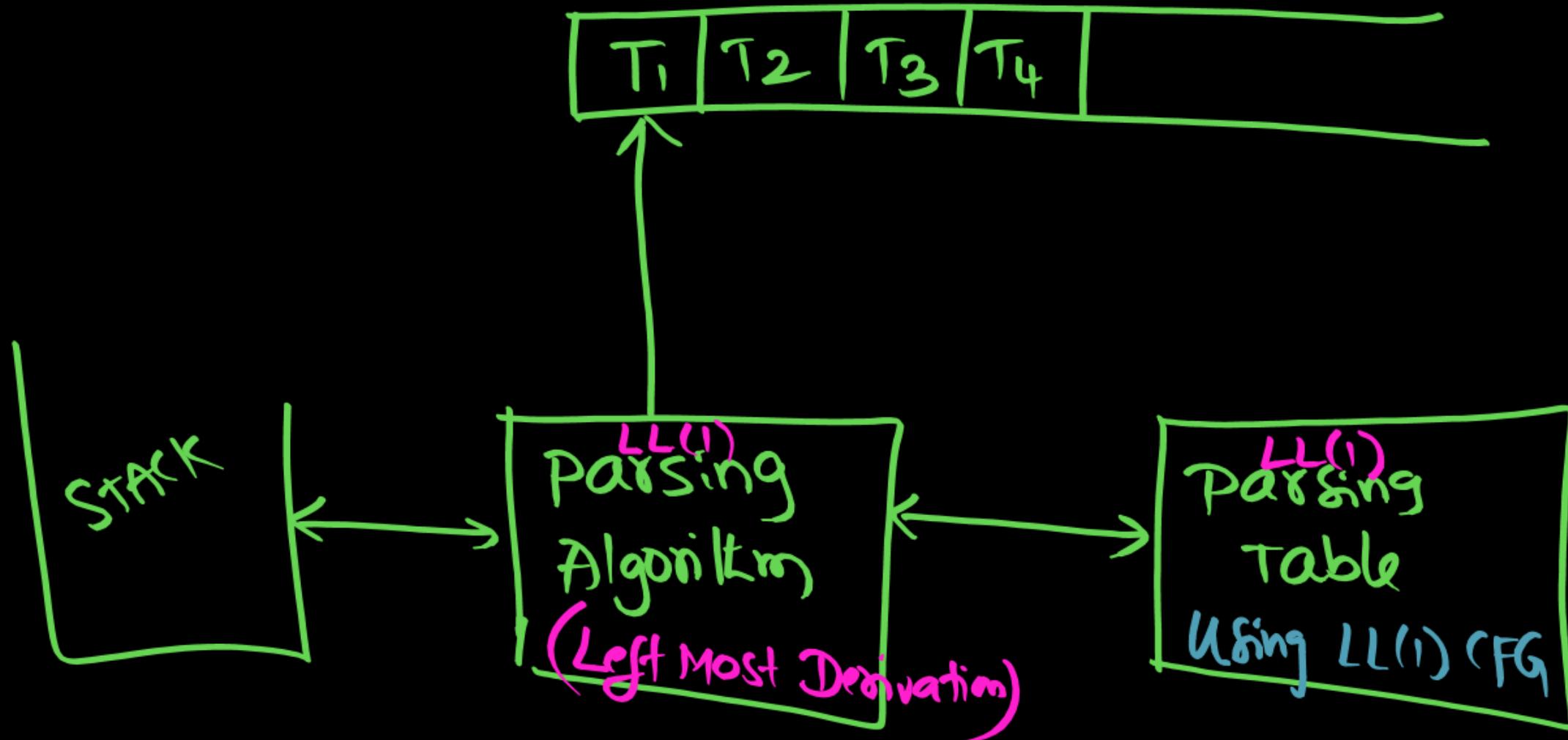
Left to Right scan

II) LR(1) parser powerful

Parser Configuration:



LL(1) Parser Configuration:



- 1) LL(1) CFG
- 2) LL(1) Table
- 3) LL(1) Algo.

LL(1) Parser :

~~~~~

→ TOP-down parser

→ Predictive parser

→ It can be implemented in 2 ways

$$S \rightarrow a A$$

$S()$

{ if(next token == a)

A()

b

i) Recursive-descent parser

ii) Non Recursive-descent parser

$$S \rightarrow a A$$

$$\begin{array}{c|c} & a \\ \hline S & S \rightarrow a A \end{array}$$

Every production will have procedure

1 → prediction  
1 token

[Procedure Driven Approach]

[Table Driven Approach]

Every production  
will be stored  
in table

LL(1) parser is \_\_\_\_\_

- A) TOP-down parser ✓
- B) Bottom-up parser ✓
- C) Recursive-descent predictive parsers ✓
- D) Non-Recursive-descent predictive parser ✗

# How to write LL(1) CFG ?

Step1: Take unambiguous CFG

↓ Eliminate Left Rec

Step2: Unambiguous & Non Left Rec CFG

↓ Eliminate common  
prefixes of 1 length  
[Left factoring]

Step3: Unambiguous, Non left Recursive,  
Left factored CFG

Step4: Build LL(1) Table  
If every entry has almost 1 Rule  
then given CFG is LL(1)

# How to Identify LL(0) CFG ?

\*\* I) Theory

II) Table Concept

\*\*\* III) Shortcut

Which of the following is sufficient to be LL(1) CFG ?

- A) Ambiguous, Left Recursion, Left factored CFG
- B) Unambiguous, Non Left Recursive, Non Left factored CFG
- C) Unambiguous, Non Left Recursive, Left factored CFG
- ~~D) None of These~~

If CFG is unambiguous, Non left Recursive, and Left factored then  
need not be LL(1).

Which of the following is necessary to be LL(1) CFG ?

- A) Ambiguous, Left Recursion, Left factored CFG
- B) Unambiguous, Non Left Recursive, Non Left factored CFG
- C) ~~Unambiguous, Non Left Recursive, Left factored CFG~~
- D) None of These

Note: If CFG is LL(1) then it is unambiguous,  
Non left Rec, and  
left factored.

# LL(1) Table Construction:

Step 1: Compute FIRST Set for every non-terminal in CFG.

Step 2: If any FIRST Set contain  $\epsilon$  then compute Follow set for the same nonterminal.

Step 3: Fill the table using FIRST and Follow sets

①  $S \rightarrow aSb \mid \epsilon$

P  
W

$\text{FIRST}(S) = \{a, \epsilon\}$



$\text{Follow}(S) = \{\$, b\}$

LL(1) Table size



$$\begin{aligned} & \text{No. of rows} \times \text{no. of columns} \\ & |V| \times (|T \cup \{\$\}|) \\ & 1 \times 3 \end{aligned}$$

$V = \{S\}$

$T = \{a, b\}$

|   | a | b | \$ |
|---|---|---|----|
| S |   |   |    |

$1 \times 3$

$$\textcircled{1} \quad S \rightarrow aSb \mid \epsilon$$

$$\text{FIRST}(S) = \{a, \boxed{\epsilon}\}$$



$$\text{Follow}(S) = \{ \$, b \}$$

First

$$\boxed{M[S, a] = ?}$$

Follow

$$\boxed{M[S, \$] = ?}$$

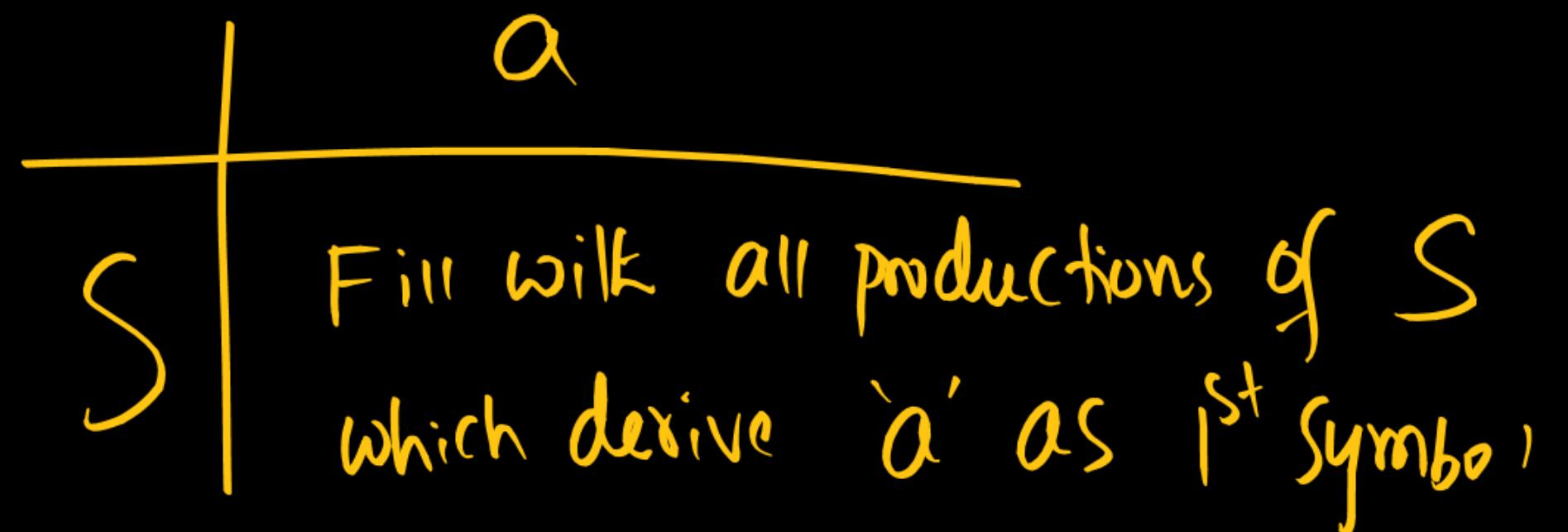
$$\boxed{M[S, b] = ?}$$

center  
only productions  
which derives

| M | a                   | b                        | \$                       |
|---|---------------------|--------------------------|--------------------------|
| S | $S \rightarrow aSb$ | $S \rightarrow \epsilon$ | $S \rightarrow \epsilon$ |
|   |                     |                          |                          |

Every entry of table has <sup>at most 1 Rule</sup>   
<sup>either 0 or 1</sup>  
 ↳ given CFG is LL(0).

FIRST M[s, a] :



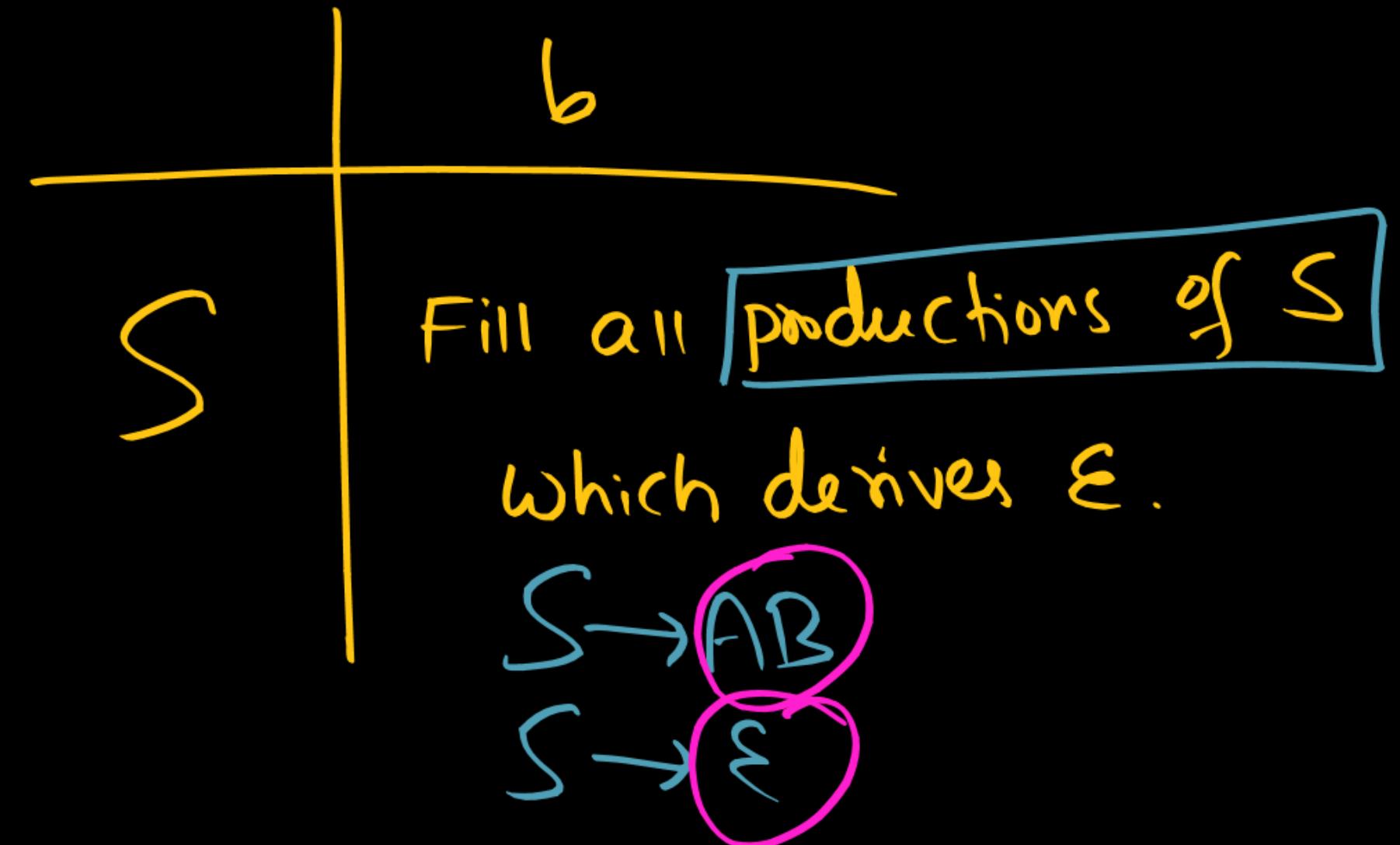
Follow

M [S, b]

$$S \xrightarrow{\textcircled{1}} AB \mid \xrightarrow{\textcircled{2}} \epsilon$$

$$A \xrightarrow{\textcircled{3}} \epsilon$$

$$B \xrightarrow{\textcircled{4}} \epsilon$$



②

$$S \rightarrow aSa \mid \epsilon$$

$$\text{First}(S) = \{a, \epsilon\}$$

$$\text{Follow}(S) = \{a, \$\}$$

This CFG is  
 Unambiguous ✓  
 Non left Rec ✓  
 Left factored ✓

Given CFG  
 is not LL(1)

$M(S, a)$  has more than one rule

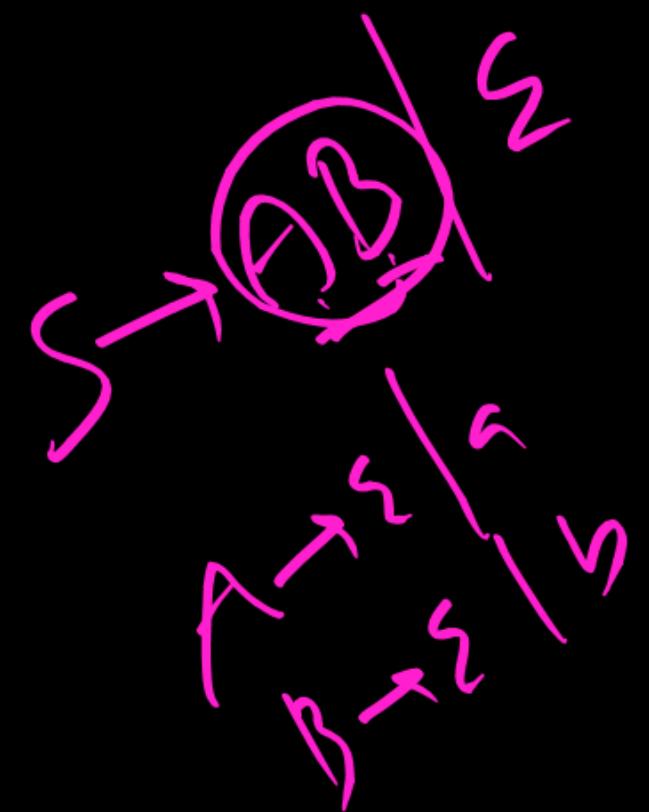
|   |                                                 |                          |
|---|-------------------------------------------------|--------------------------|
|   | a                                               | \$                       |
| S | $S \rightarrow aSa$<br>$S \rightarrow \epsilon$ | $S \rightarrow \epsilon$ |

Follow set



$$F_0(S) = \{a, \$\}$$

|   | a                        | \$                       |
|---|--------------------------|--------------------------|
| S | $S \rightarrow AB$       | $S \rightarrow A^B$      |
|   | $S \rightarrow \epsilon$ | $S \rightarrow \epsilon$ |



③

$$S \rightarrow SS | (S) | \epsilon$$

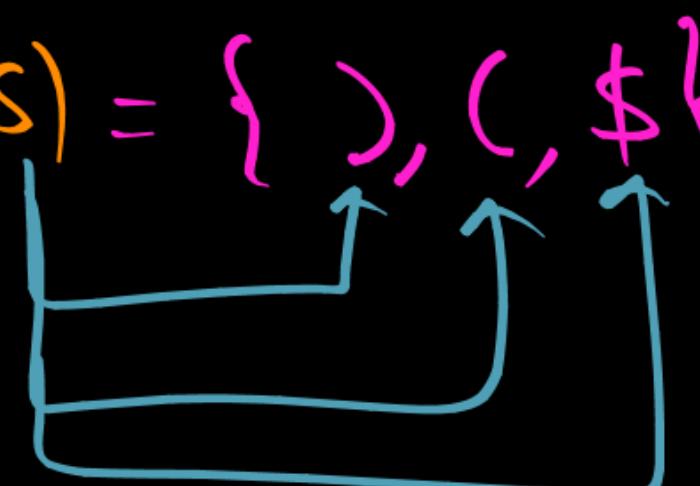
$$\text{First}(S) = \{ (, \boxed{\epsilon}) \}$$

$$\text{Follow}(S) = \{ ), (, \$ \}$$

$$S \rightarrow SS$$

$$\epsilon$$

$$S \rightarrow \epsilon$$



only focus on  
deriving  $\epsilon$

|                          |                          |                          |                          |
|--------------------------|--------------------------|--------------------------|--------------------------|
| $S$                      | $($                      | $)$                      | $\$$                     |
| $S \rightarrow (S)$      | $S \rightarrow SS$       | $S \rightarrow \epsilon$ | $S \rightarrow SS$       |
| $S \rightarrow SS$       | $S \rightarrow \epsilon$ |                          | $S \rightarrow \epsilon$ |
| $S \rightarrow \epsilon$ |                          |                          |                          |

④  $S \rightarrow AB$   
 $A \rightarrow Aa | \epsilon$   
 $B \rightarrow Bb | \epsilon$

H.L.

⑤  $S \rightarrow aAb$   
 $A \rightarrow Bb | \epsilon$   
 $B \rightarrow ab$

# Summary

- FIRST & Follow
- LL(1) Table
- Next: How to Identify LL(1) ?.

