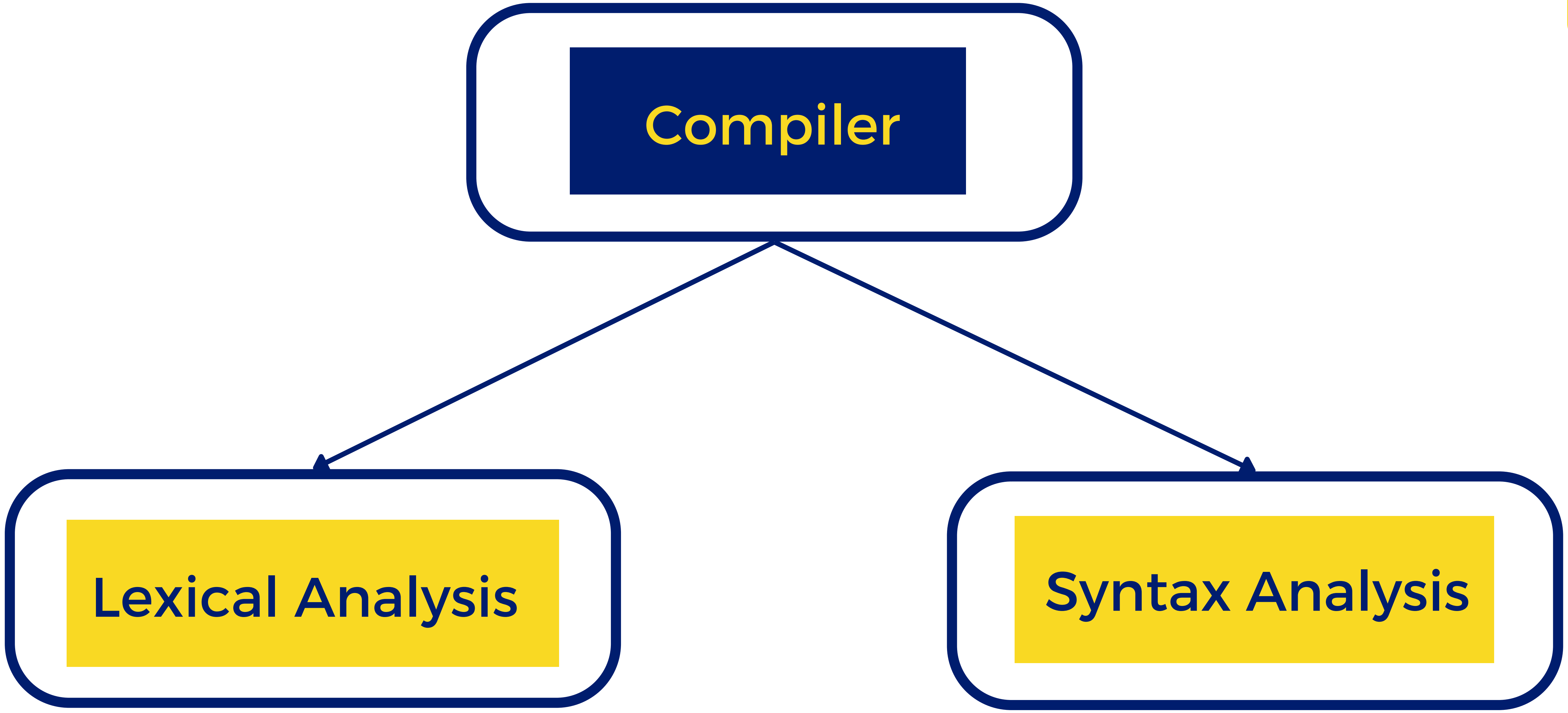
LEXICAL & SYNTAX

ANALYSIS

Monzales, Samson, and Tejada

CONTENT

INTRODUCTION



INTRODUCTION

Why do we separate Lexical and Syntax Analysis?

- Simplicity - lexical analysis is less complex
- Efficiency - lexical analysis can be optimized since it requires more compilation time
- Portability - lexical analyzer is platform dependent whereas syntax analyzer is platform independent

LEXICAL ANALYSIS

Lexical Analyzer

- is a **pattern matcher** for **character strings**
- is a **“front-end”** for the **parser**
- Identifies **substrings** of the source program that belong together - **lexemes**
    - Lexemes match a character pattern, which is associated with a lexical category called a **token**

LEXICAL ANALYSIS

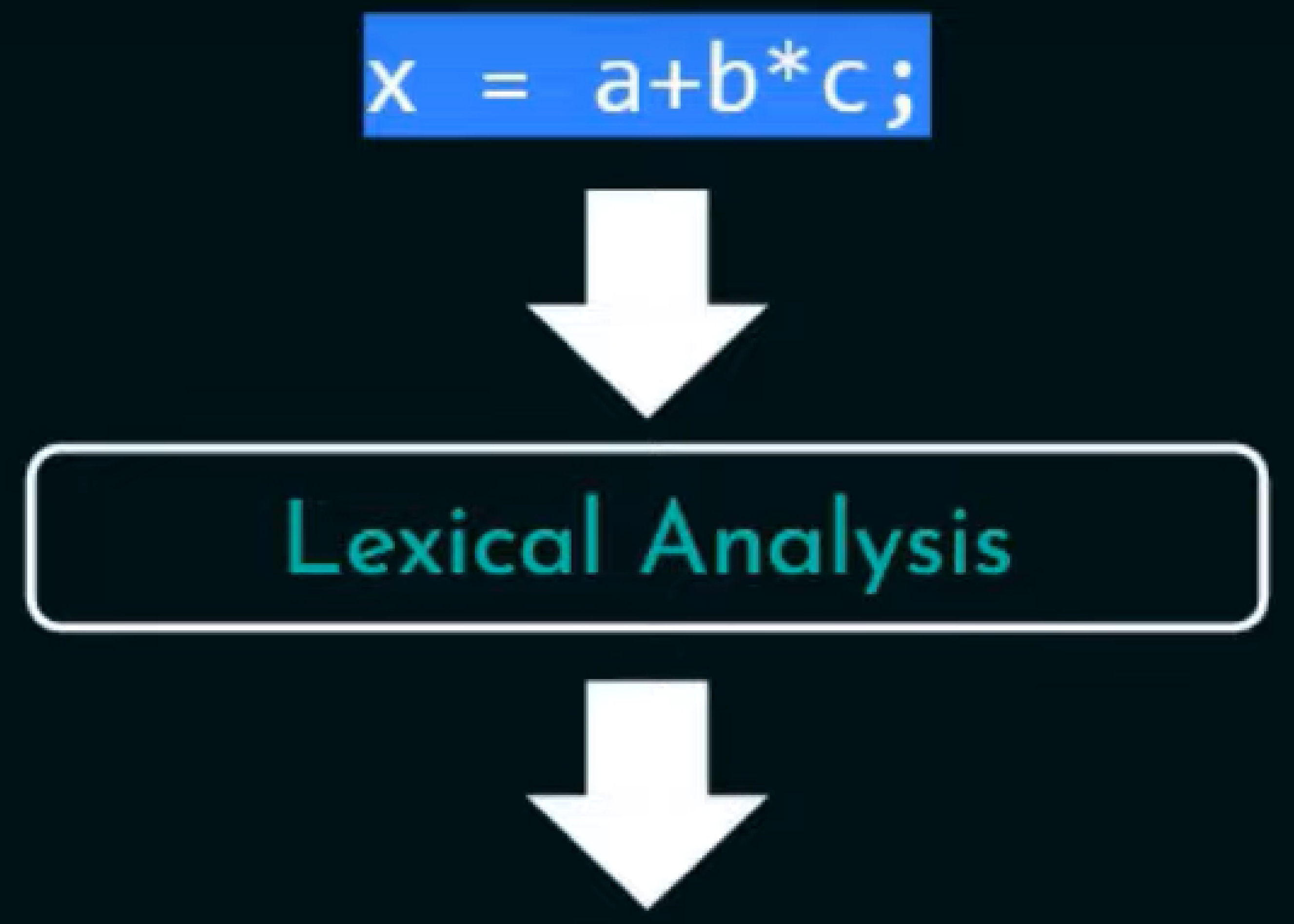
Lexical Analyzer

- Scans the Pure HLL (High-Level Language) code **line by line**
- Takes **Lexemes** as **input** and produces **Tokens** as **output**
- Removes **comments** and **whitespaces** from the Pure HLL code

LEXICAL ANALYSIS

Lexical Analyzer

LEXICAL



Lexemes	Tokens
x	identifier
=	operator
a	identifier
+	operator
b	identifier
*	operator
c	identifier

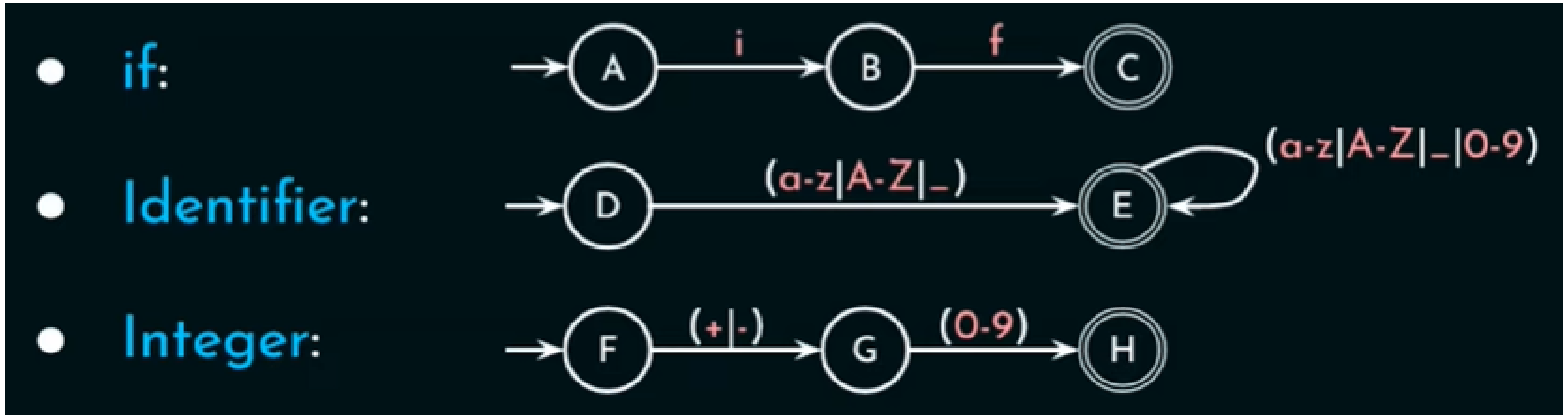
LEXICAL ANALYSIS

Three approaches to building a lexical analyzer:

- Write a formal description of the tokens and use a software tool that constructs table-driven lexical analyzers given such a description
- Design a state diagram that describes the tokens and write a program that implements the state diagram
- Design a state diagram that describes the tokens and hand-construct a table-driven implementation of the state diagram

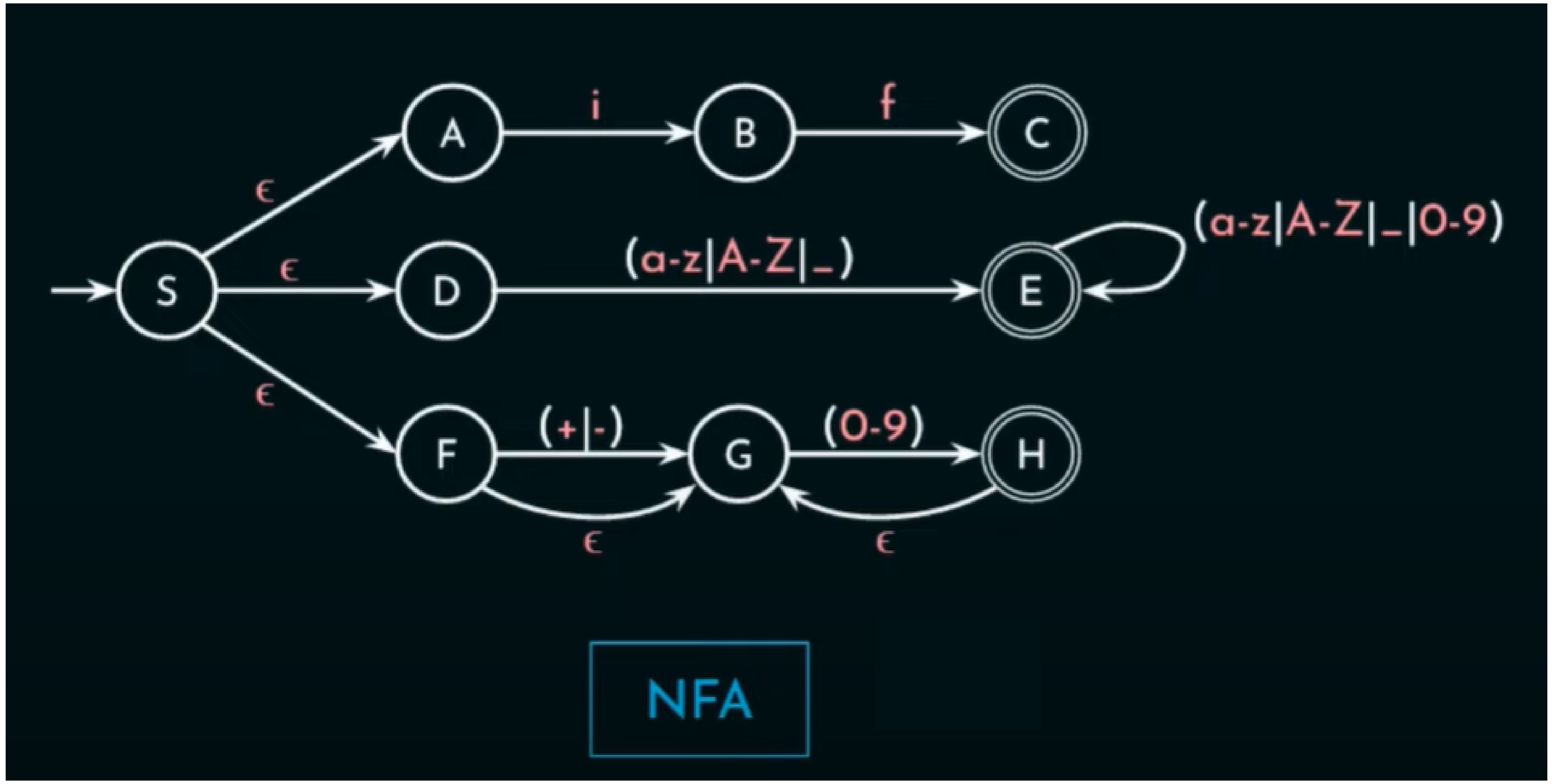
LEXICAL ANALYSIS

C-Tokens:



LEXICAL ANALYSIS

State diagram: Non-deterministic Finite Automata (NFA)

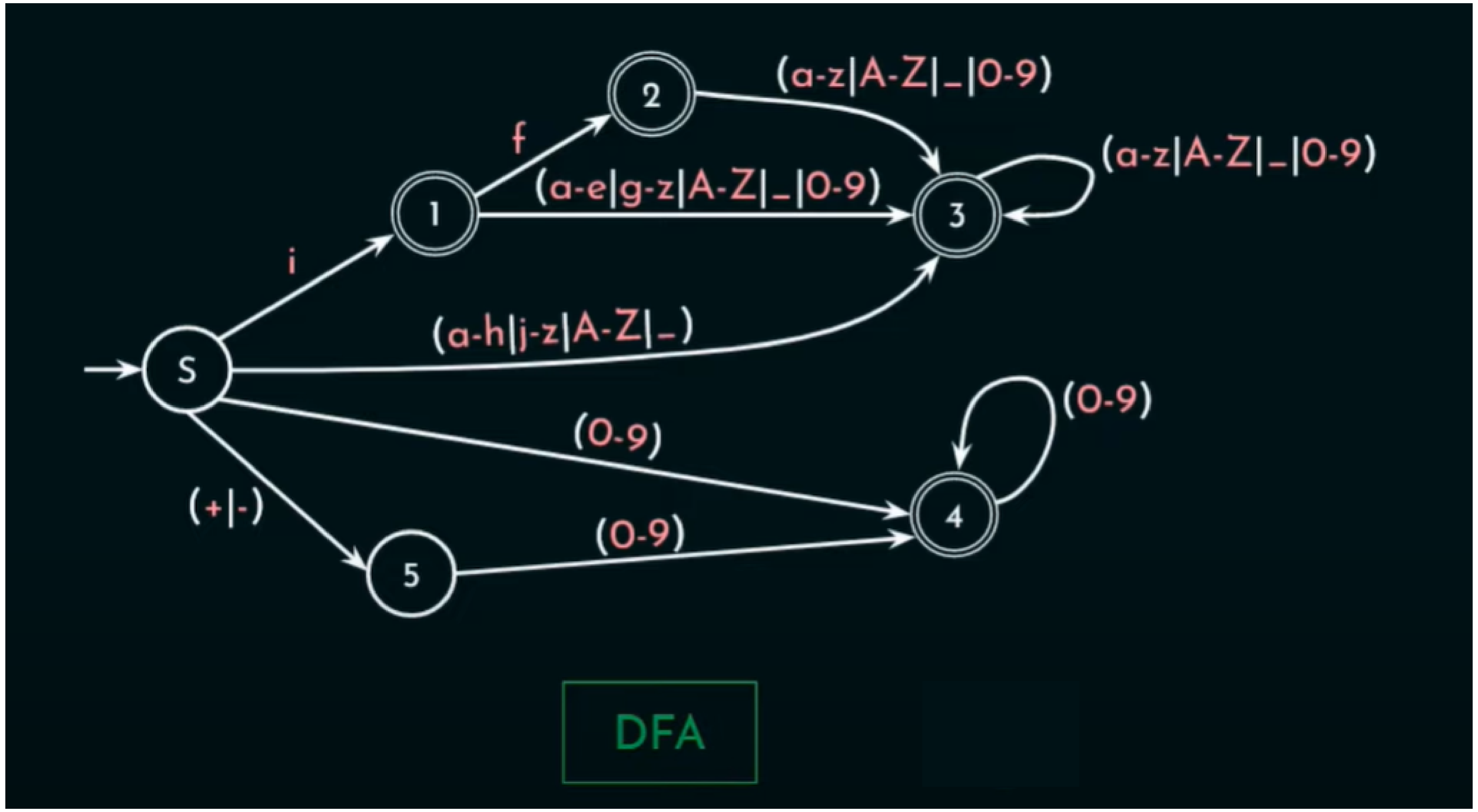


State Diagram

- **NFA** is **purely conceptual**, so it **cannot be implemented**.
- Hence, conversion to **DFA** is **necessary**.

LEXICAL ANALYSIS

State diagram: Deterministic Finite Automata (DFA)



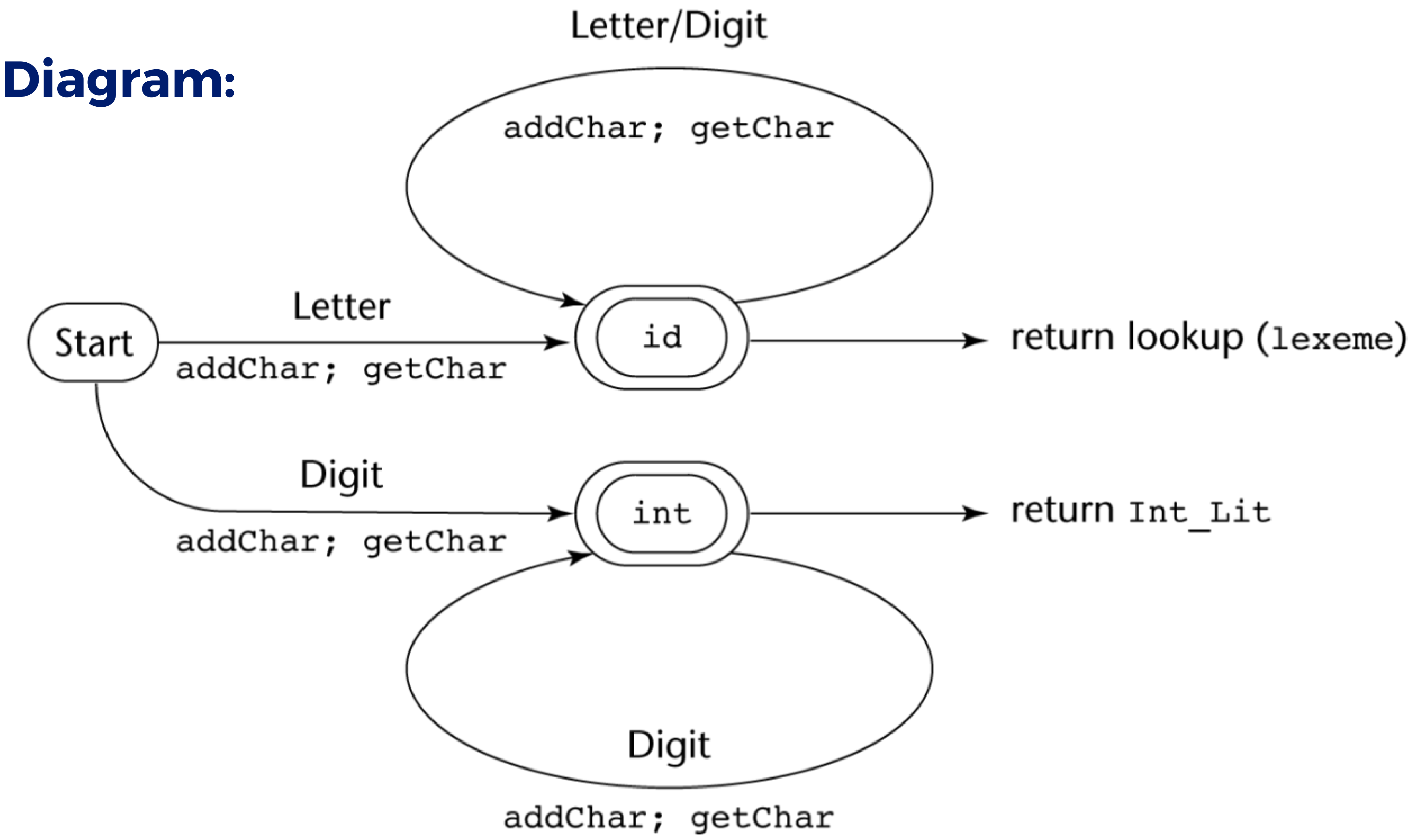
LEXICAL ANALYSIS

Convenient utility subprograms:

- **getChar** - gets the next character of input, puts it in
- **nextChar**, determines its class and puts the class in charClass
- **addChar** - puts the character from nextChar into the place the lexeme is being accumulated, lexeme
- **lookup** - determines whether the string in lexeme is a reserved word (returns a code)

LEXICAL ANALYSIS

State Diagram:



LEXICAL ANALYSIS

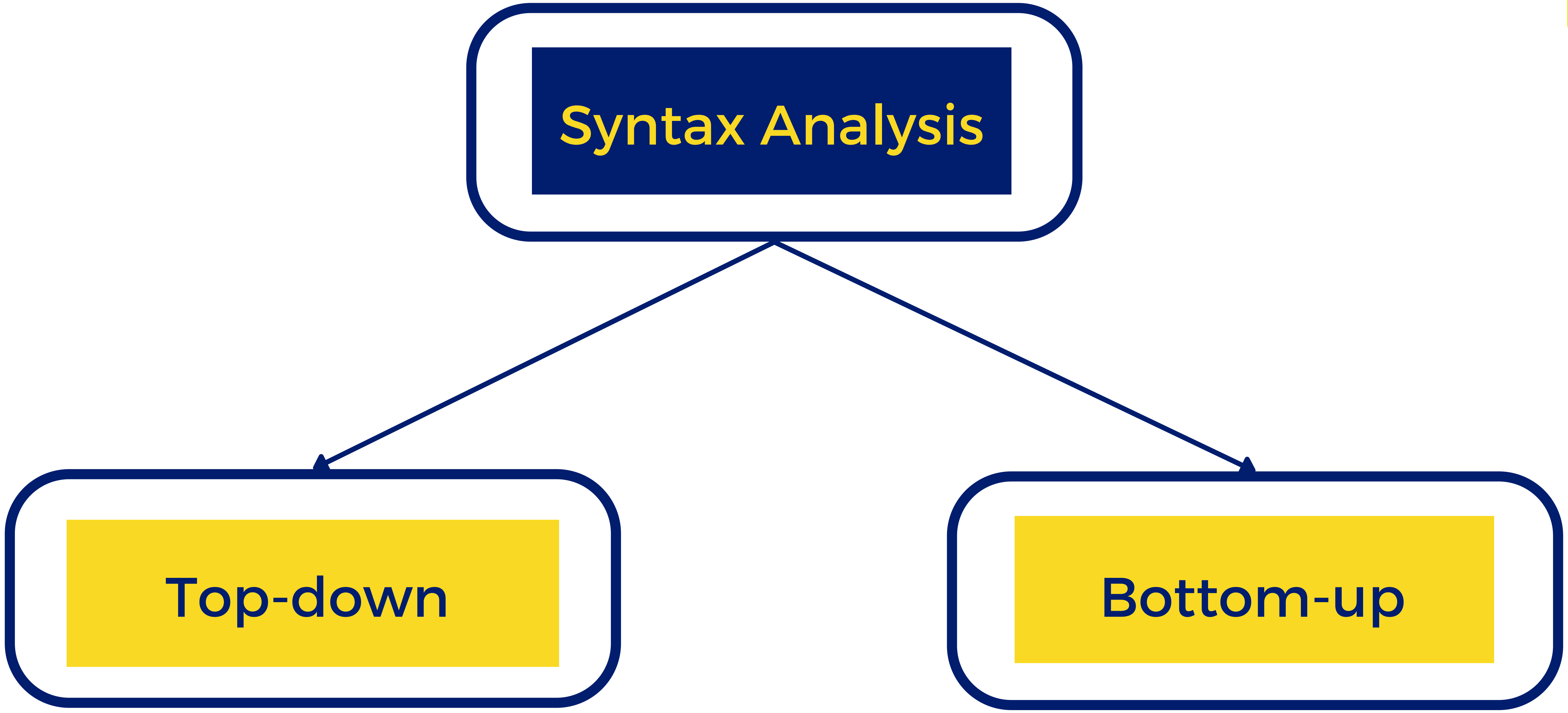
Implementation:

SHOW front.c (pp. 176-181)

Following is the output of the lexical analyzer offront.c when used on
(sum + 47) / total

Next token is: 25 Next lexeme is (
Next token is: 11 Next lexeme is sum
Next token is: 21 Next lexeme is +
Next token is: 10 Next lexeme is 47
Next token is: 26 Next lexeme is)
Next token is: 24 Next lexeme is /
Next token is: 11 Next lexeme is total
Next token is: -1 Next lexeme is EOF

THE PARSING PROBLEM



THE PARSING PROBLEM

Two distinct goals of syntax analysis:

1. Check for syntax errors and produce a diagnostic message and recover

2. Produce a complete parse tree, or at least trace the structure of the complete parse tree

THE PARSING PROBLEM

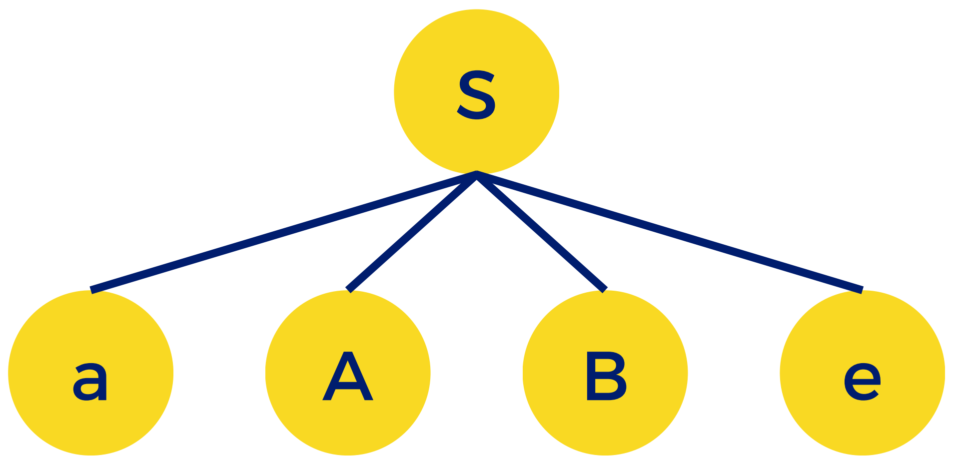
S

Top-down Approach

$\boxed{S \rightarrow aABe,}$ $A \rightarrow Abc \mid a$, $B \rightarrow d$

aabcde

THE PARSING PROBLEM



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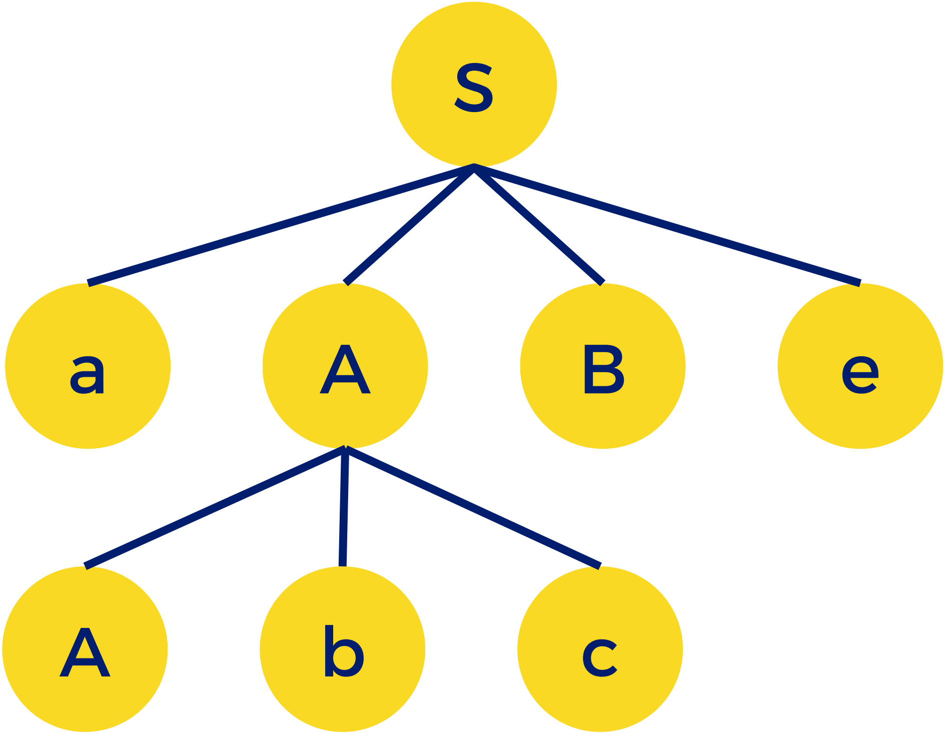

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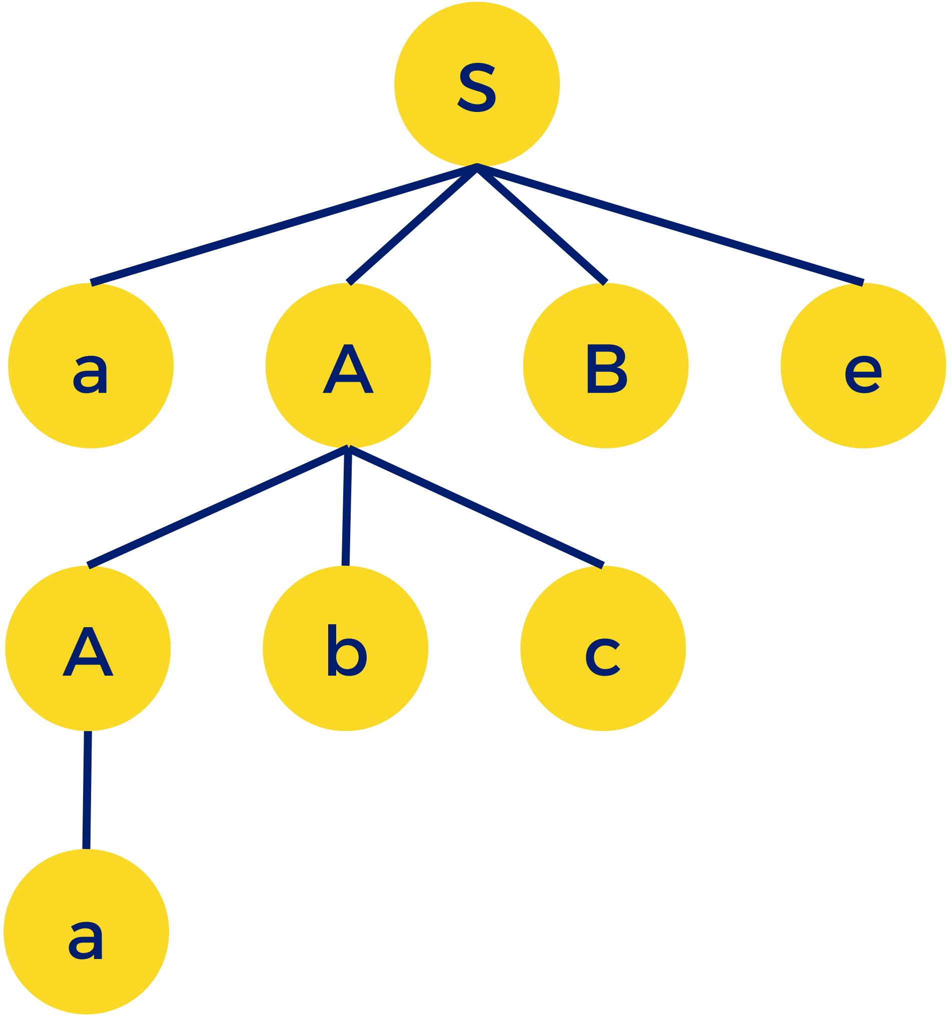

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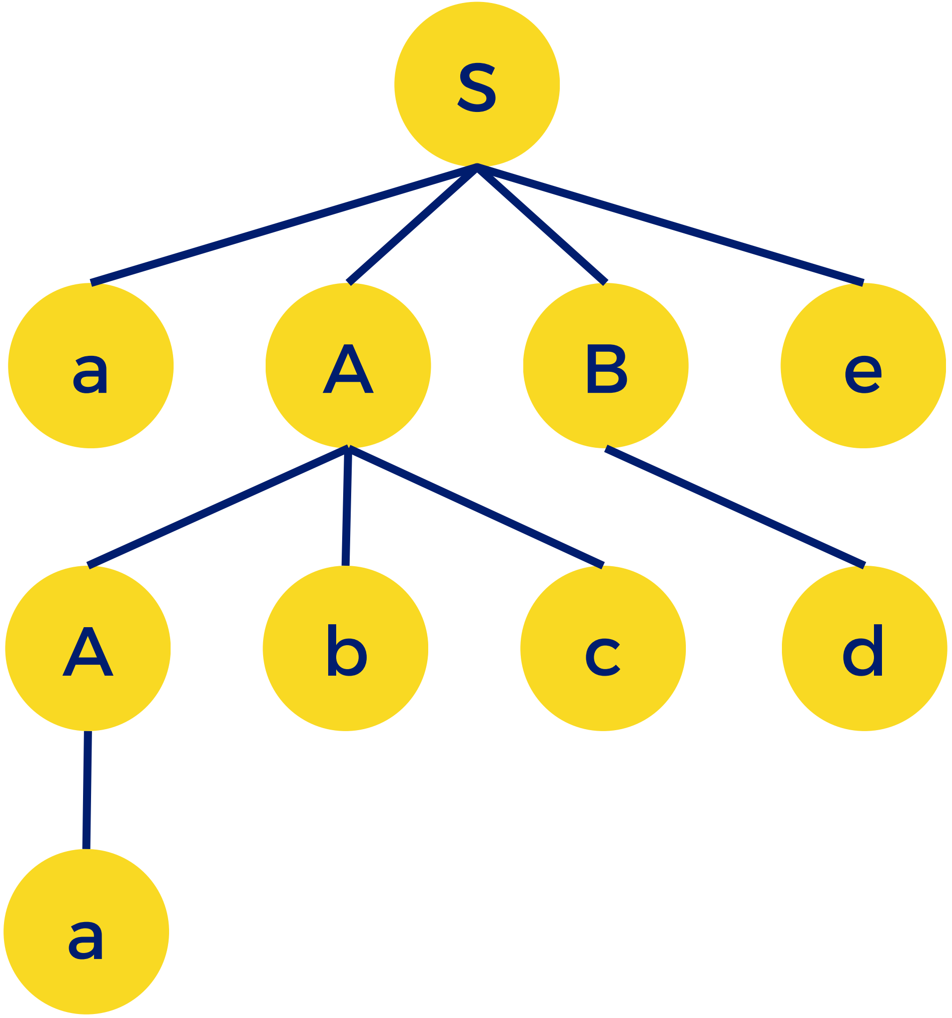

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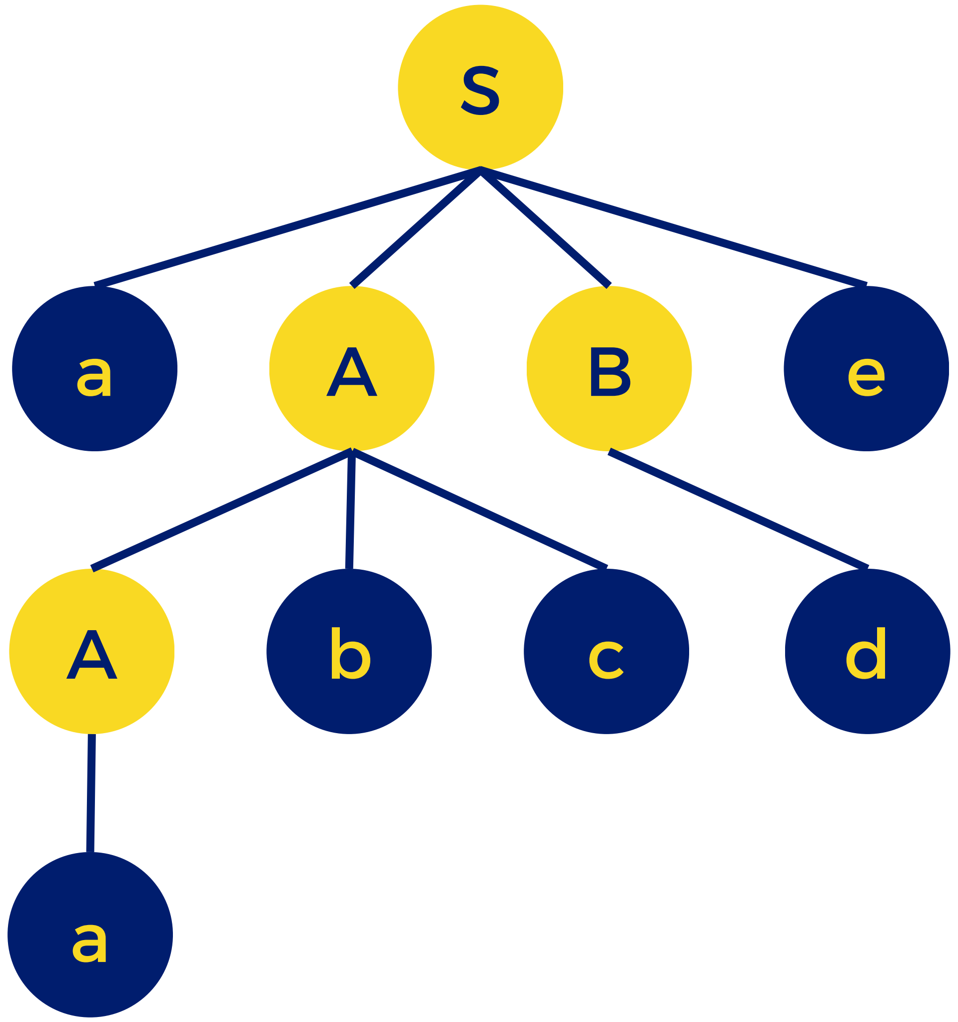

Top-down Approach

S → aABe, A → Abc | a, B → d

aabcde

THE PARSING PROBLEM

Bottom-up Approach

S → aABe, A → Abc | a, B → d

aabcde

a a b c d e

THE PARSING PROBLEM

Bottom-up Approach

$S \rightarrow aABe,\ A \rightarrow Abc \mid \boxed{a},\ B \rightarrow d$

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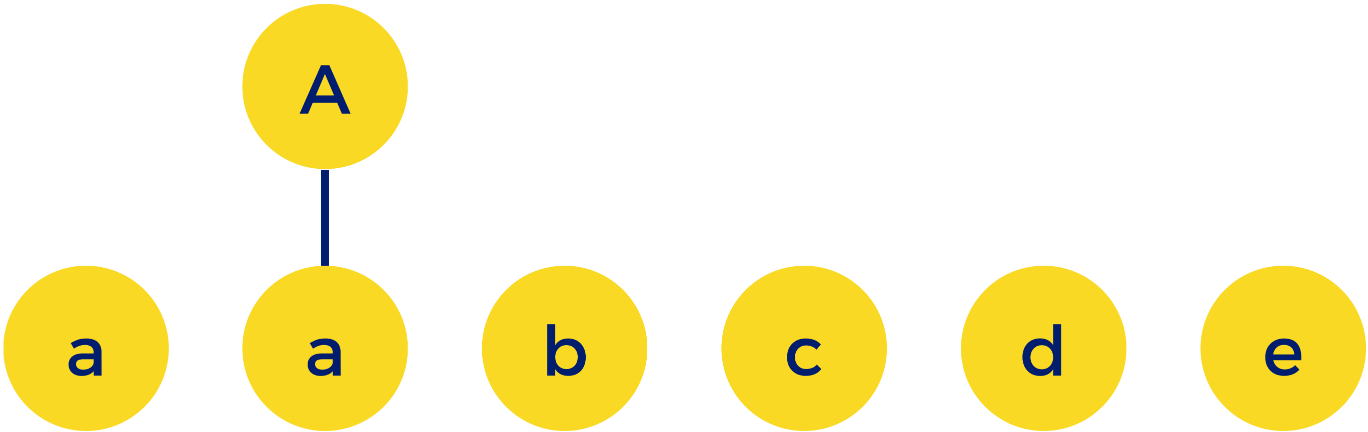

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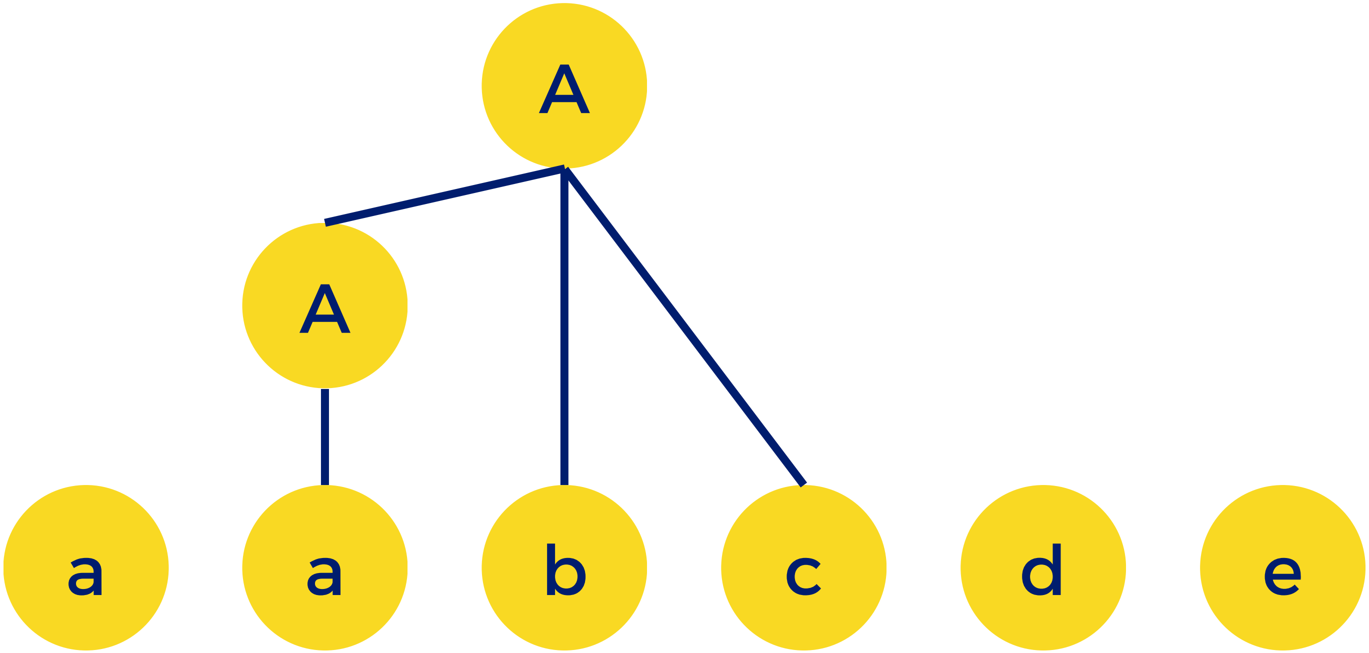

Bottom-up Approach

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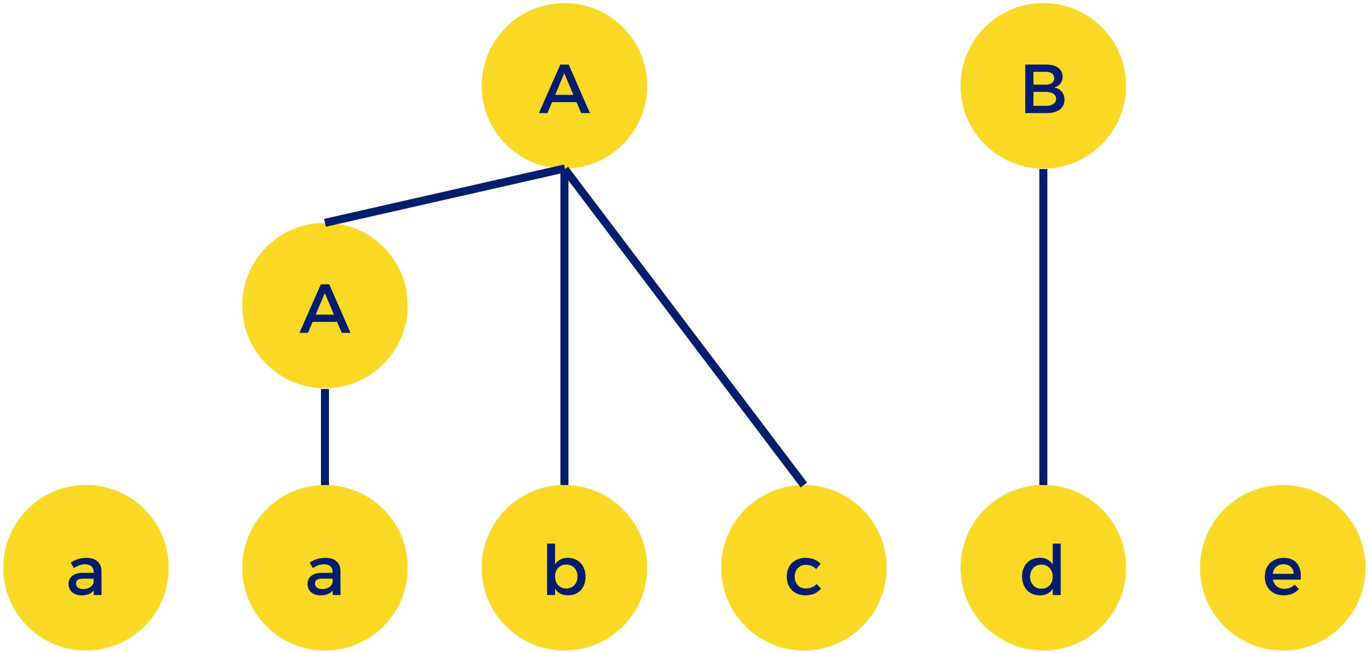

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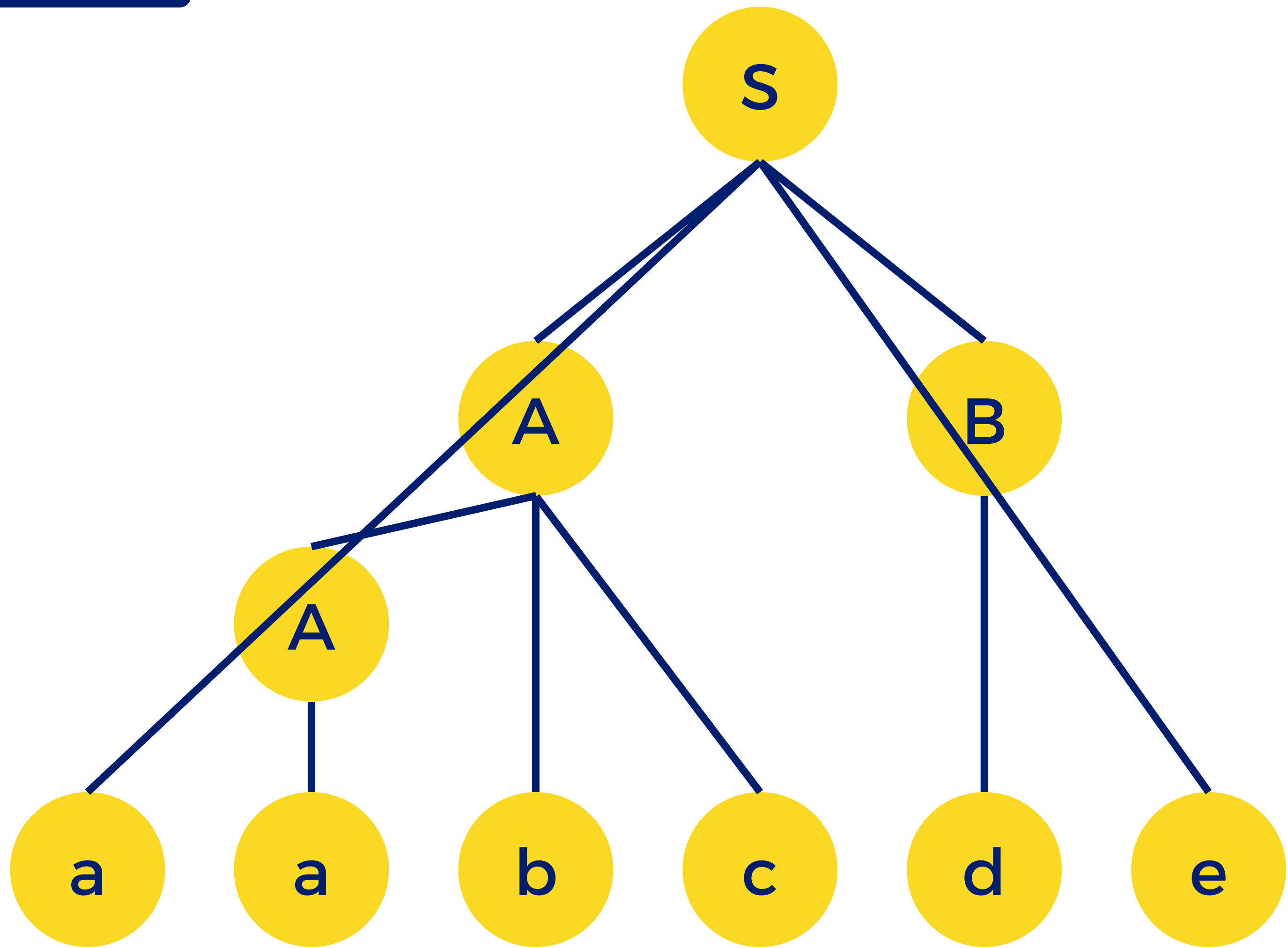

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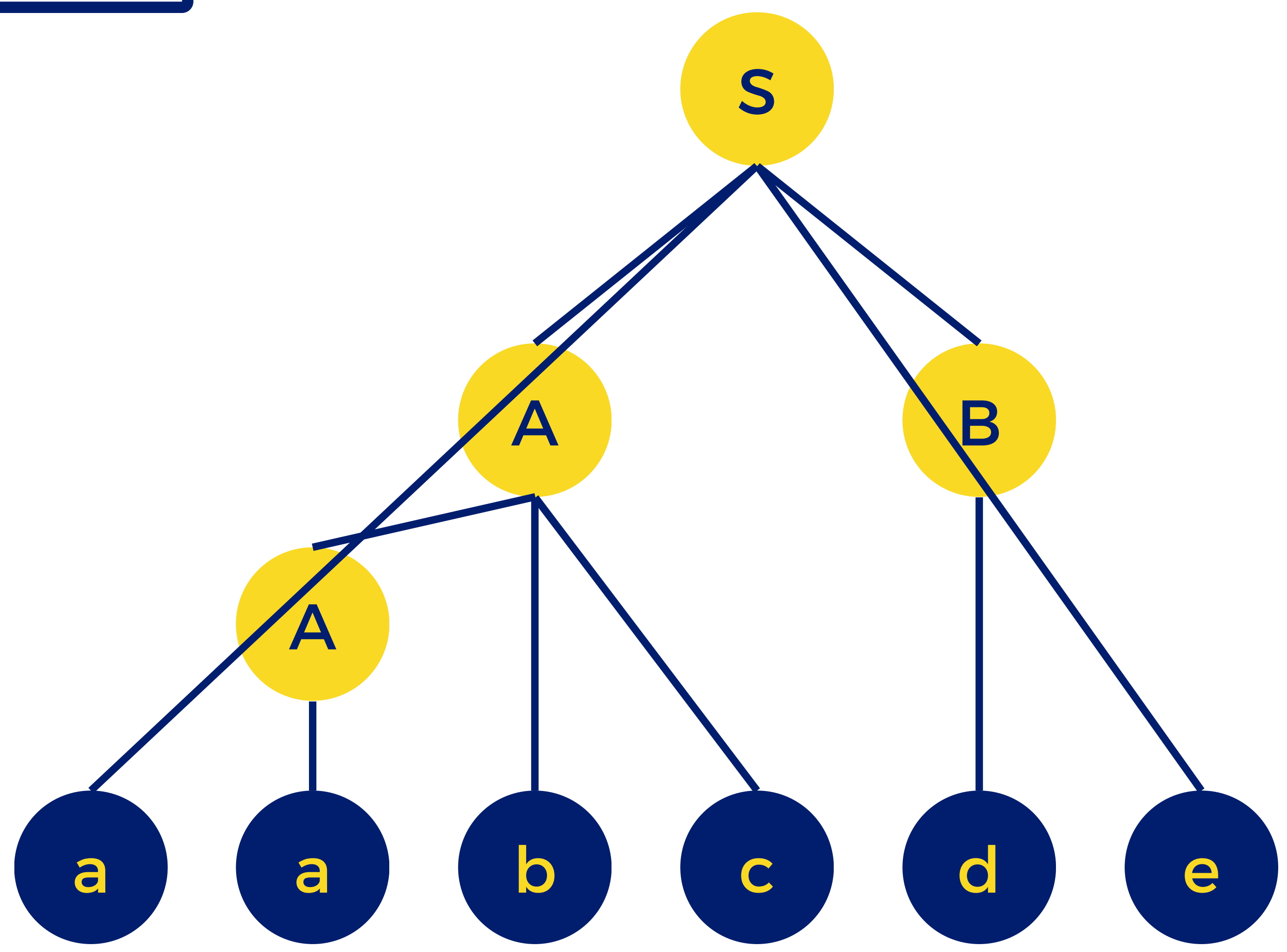

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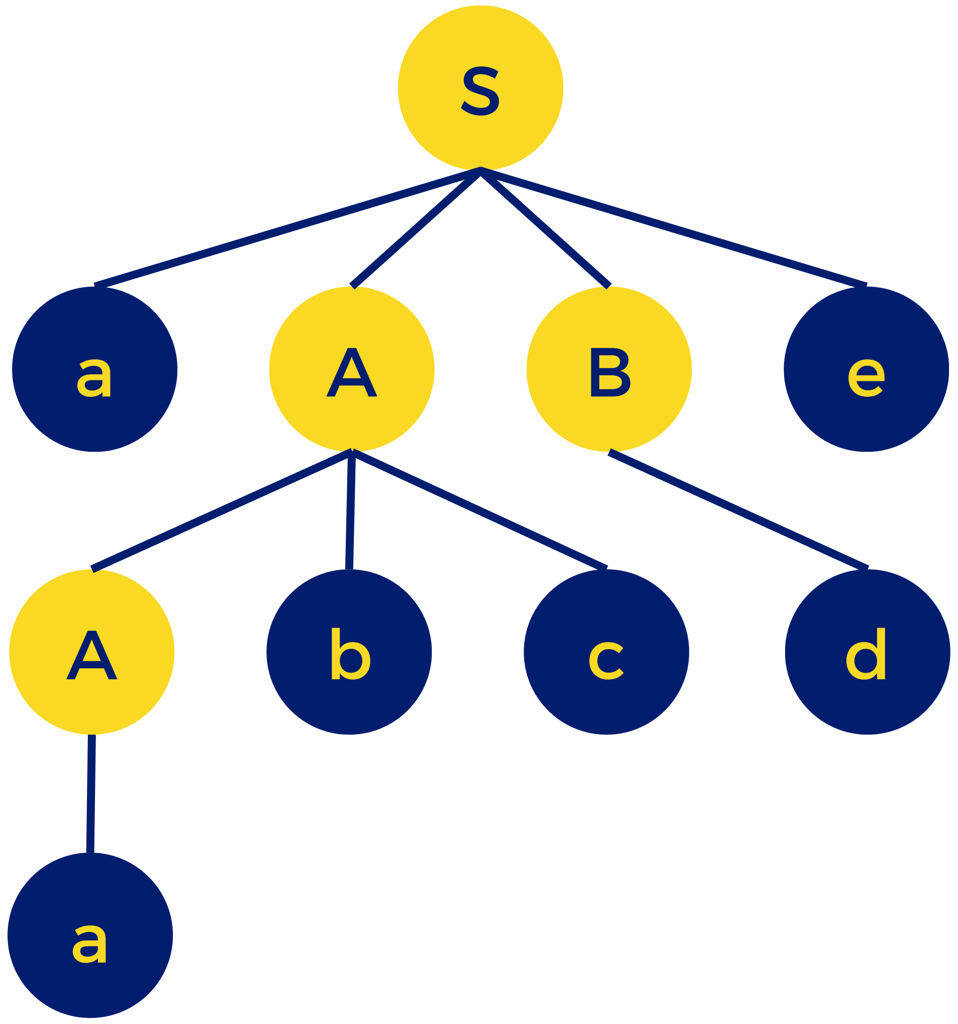

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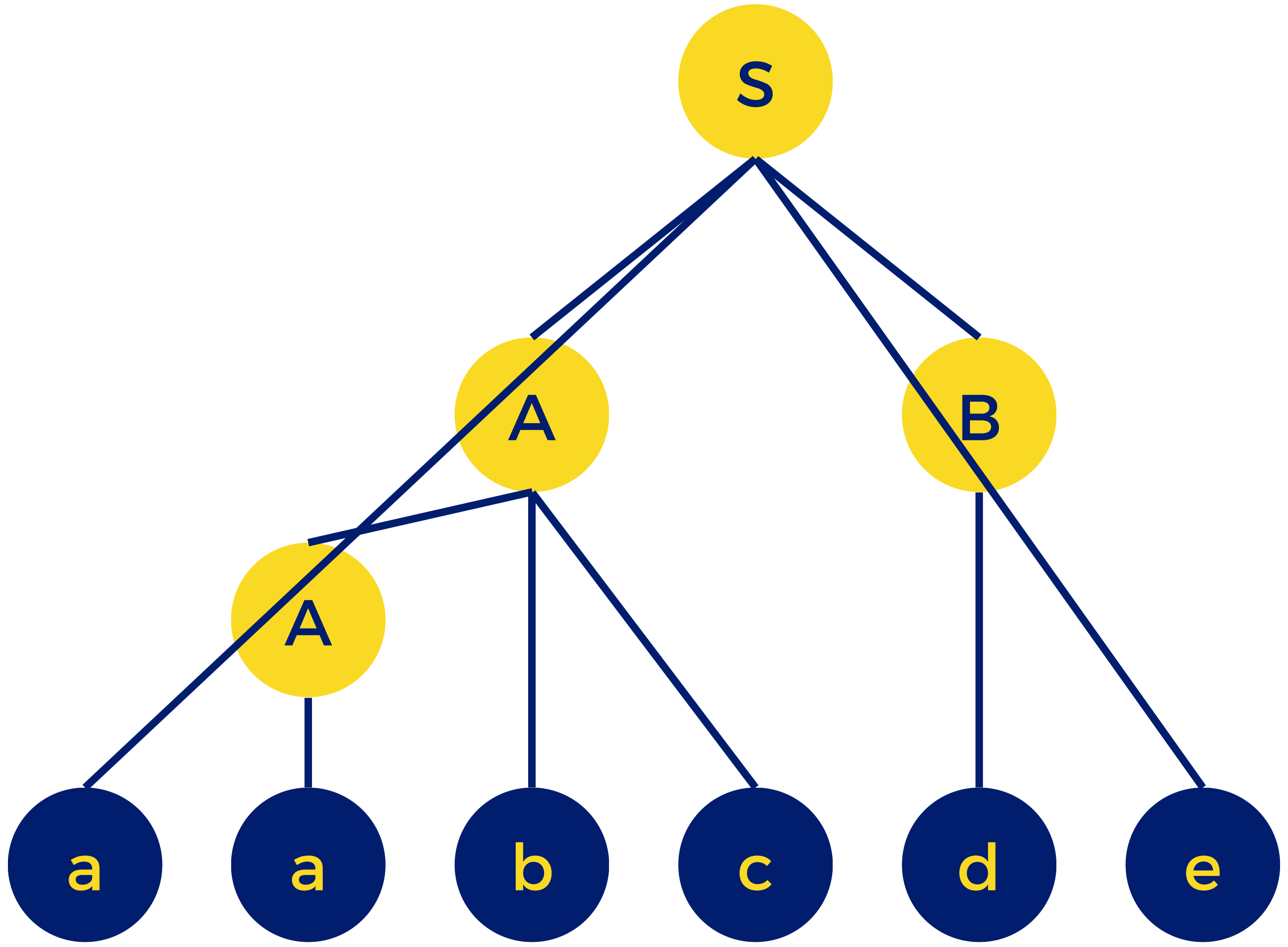


THE PARSING PROBLEM

Time Complexity

Unambiguous grammar = O(n^3)

Commercial Compilers = O(n)

RECURSIVE-DESCENT PARSING

Recursive-Descent Parsing (Top-Down)

There is a **subprogram for each nonterminal** in the **grammar**, which can parse sentences that can be generated by that nonterminal value.

EBNF is ideally suited for being the basis for a recursive-descent parser, because **EBNF minimizes the number of nonterminals**

***EBNF - Extended Backus–Naur form**

RECURSIVE-DESCENT PARSING

- Assume we have a lexical analyzer named lex, which puts the next token code in nextToken
- The coding process when there is only one right-hand side (RHS):
    - For each terminal symbol in the RHS, compare it with the next input token; if they match, continue, else there is an error
    - For each nonterminal symbol in the RHS, call its associated parsing subprogram

RECURSIVE-DESCENT PARSING

A nonterminal that has more than one RHS requires an initial process to determine which RHS it is to parse

- The correct RHS is chosen on the basis of the next token of input (the lookahead)
- The next token is compared with the first token that can be generated by each RHS until a match is found
- If no match is found, it is a syntax error

RECURSIVE-DESCENT PARSING

Recursive-Descent Parsing

Given grammar:

A -> abC | aBd | aAD

B -> bB | ε

C -> d | ε

D -> a | b | ε

*Capital characters - non-terminal

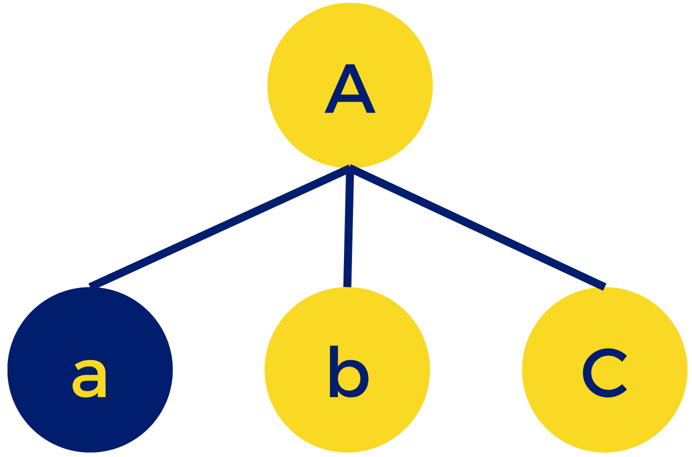
Input: aaba

RECURSIVE-DESCENT PARSING

Recursive-Descent Parsing

a a b a

↑



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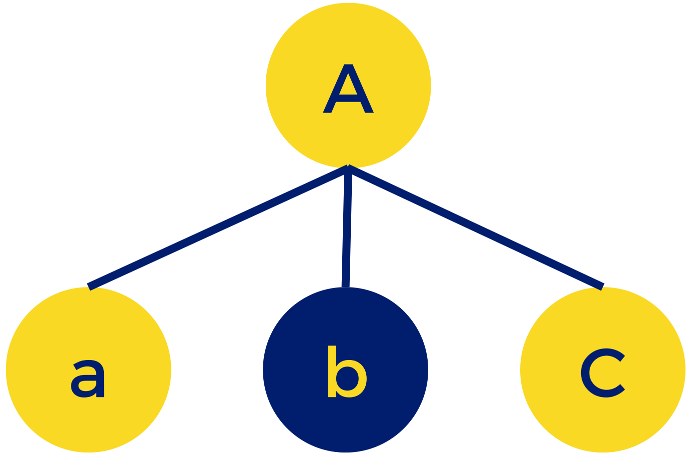

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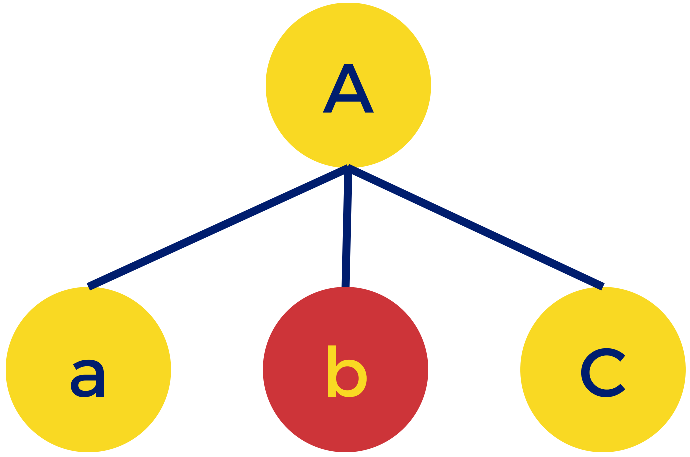

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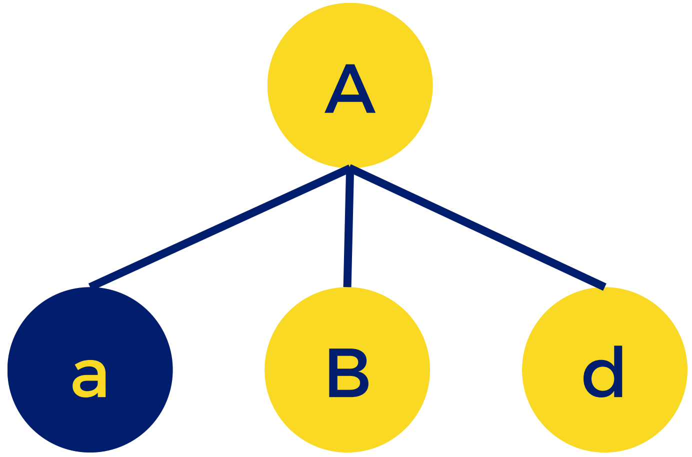

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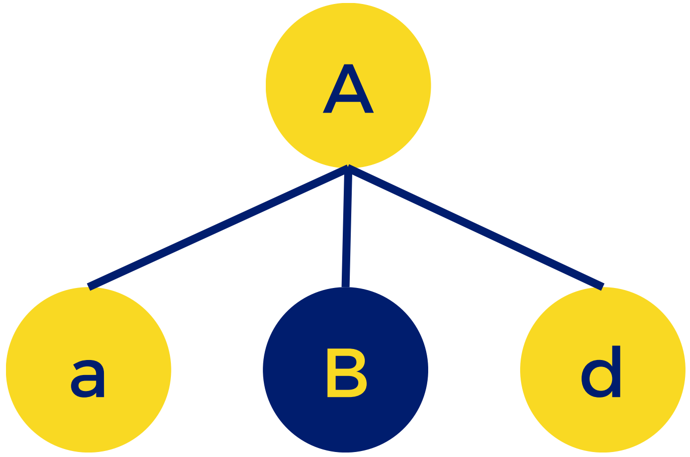

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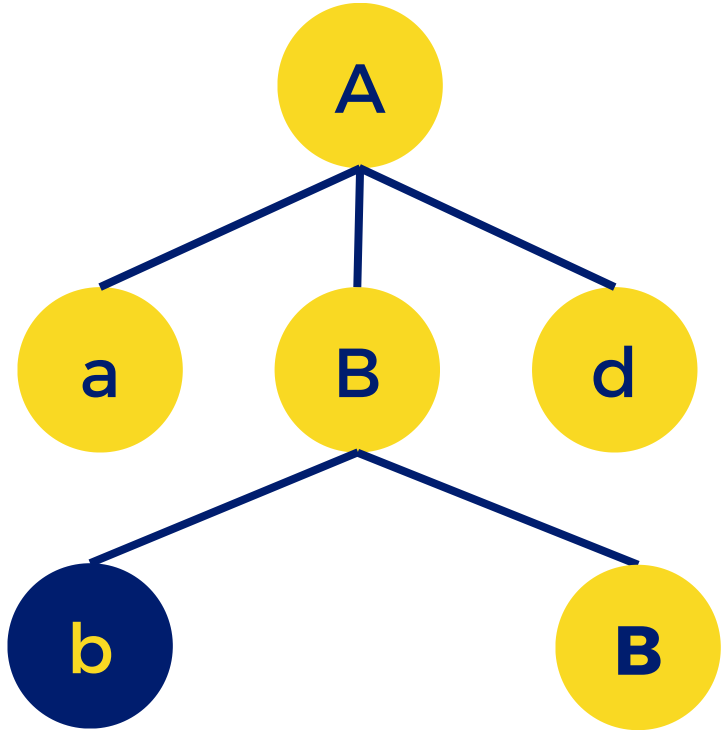

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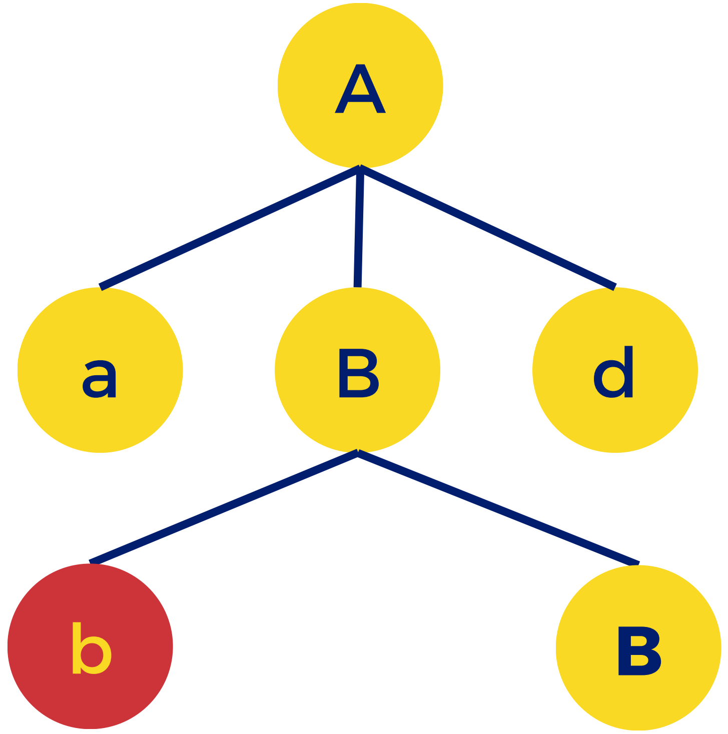

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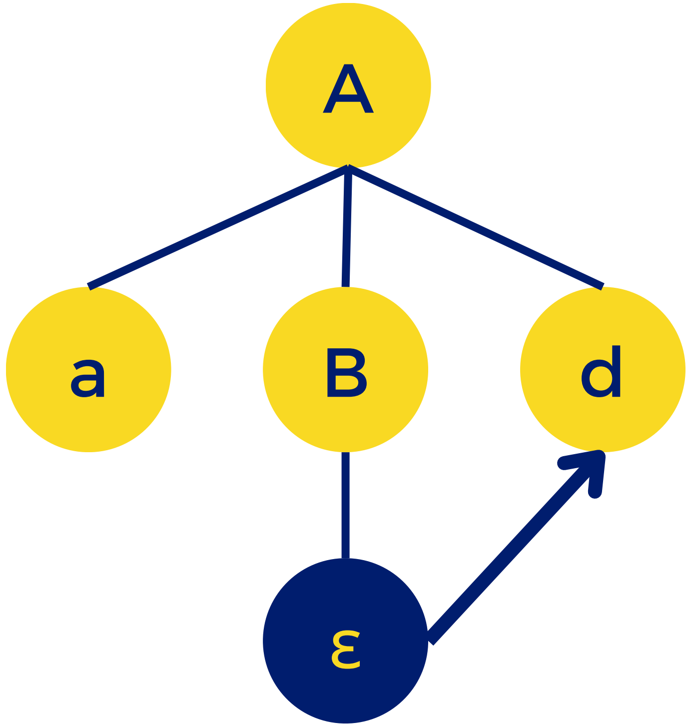

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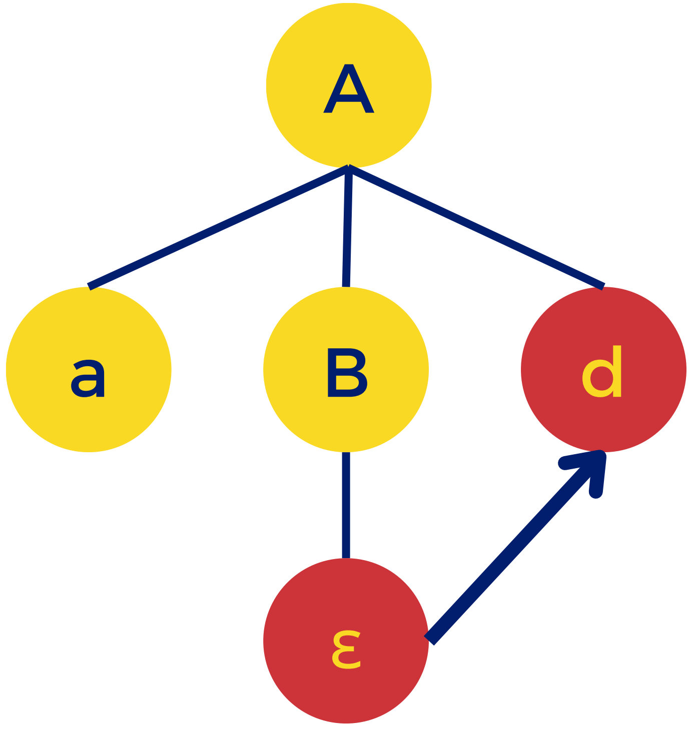

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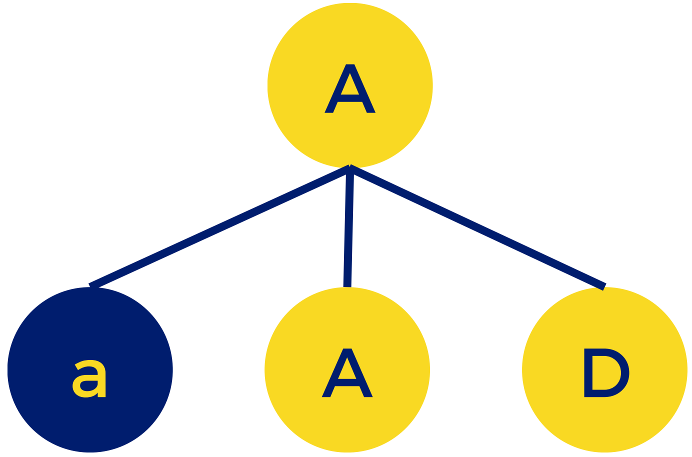

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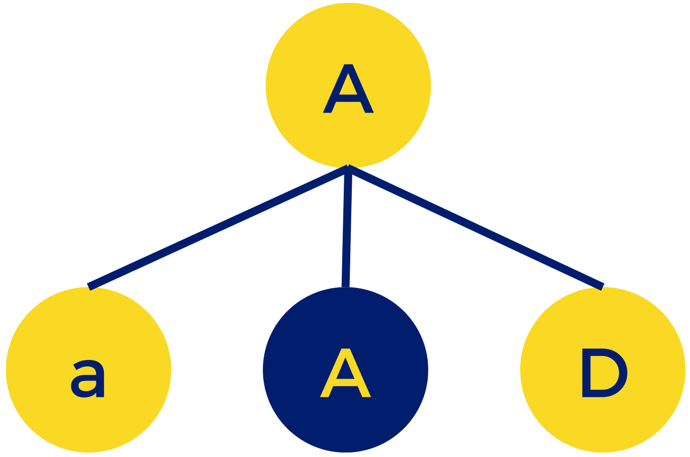

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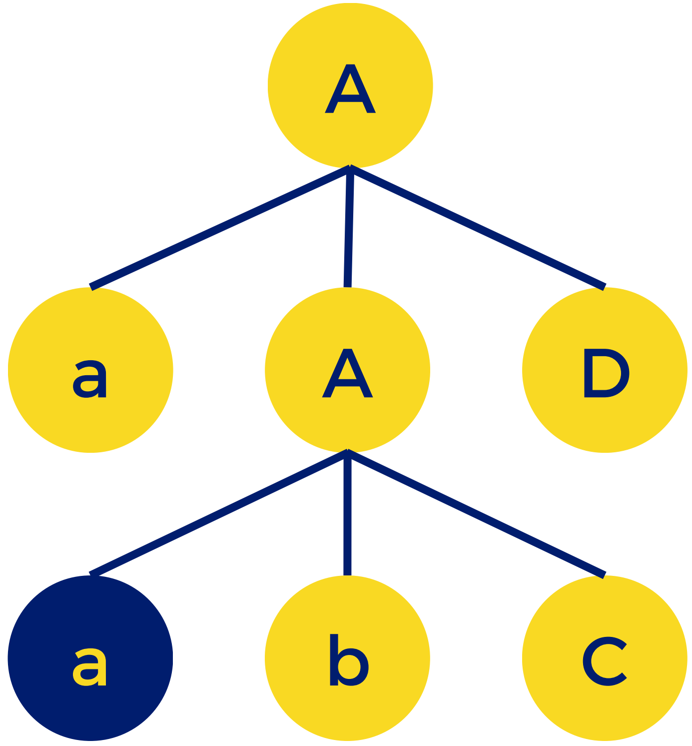

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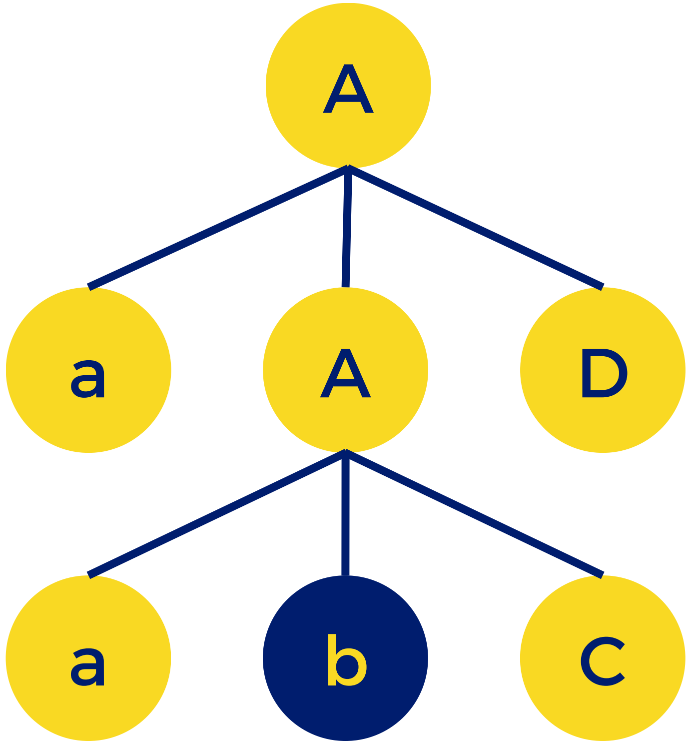

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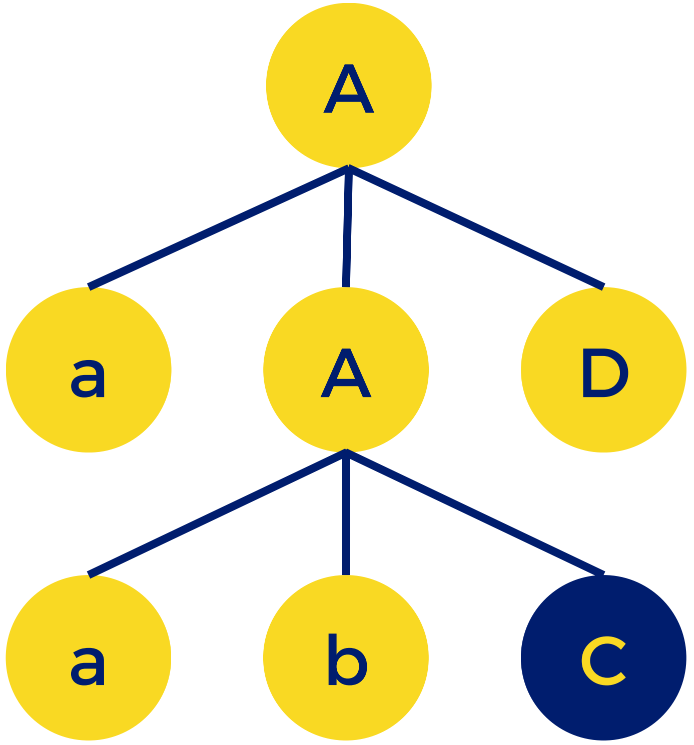

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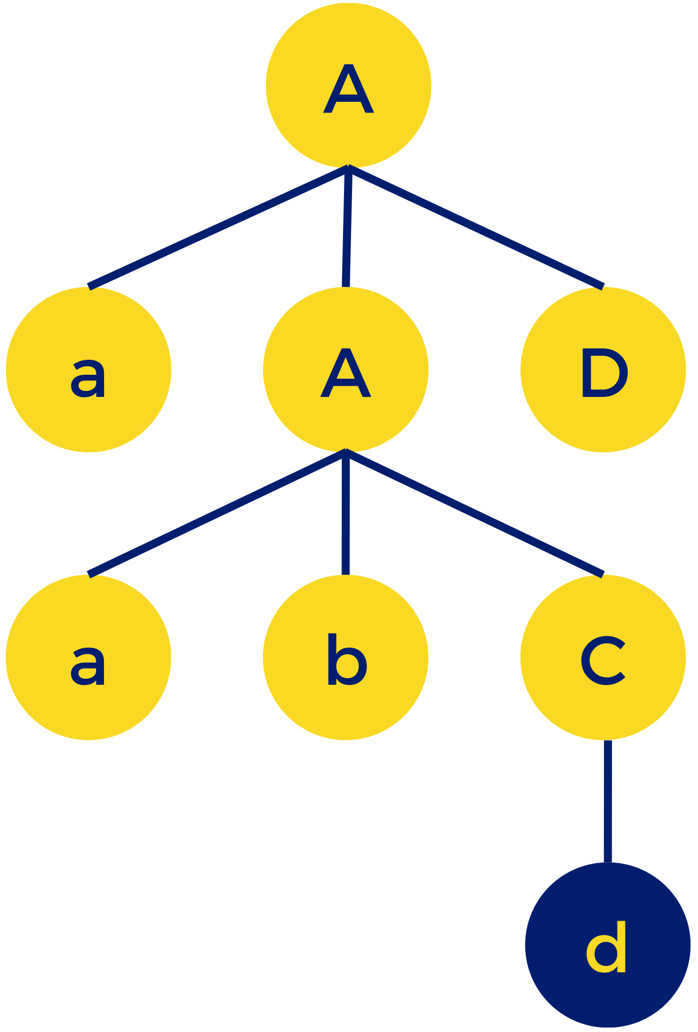

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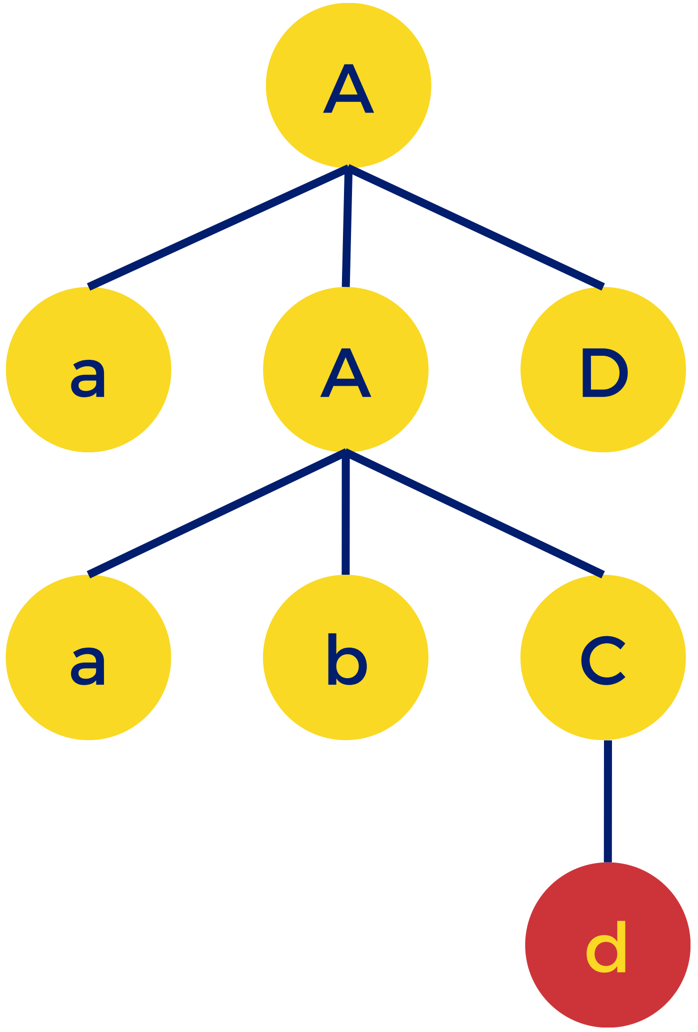

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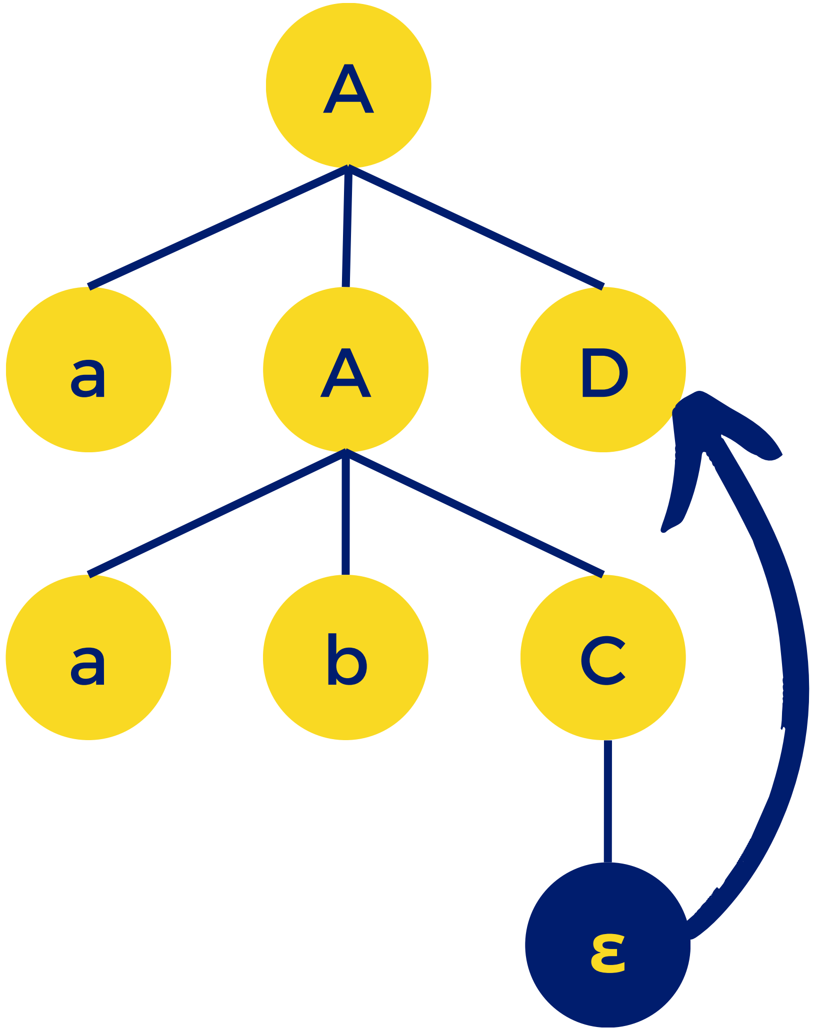

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RECURSIVE-DESCENT PARSING

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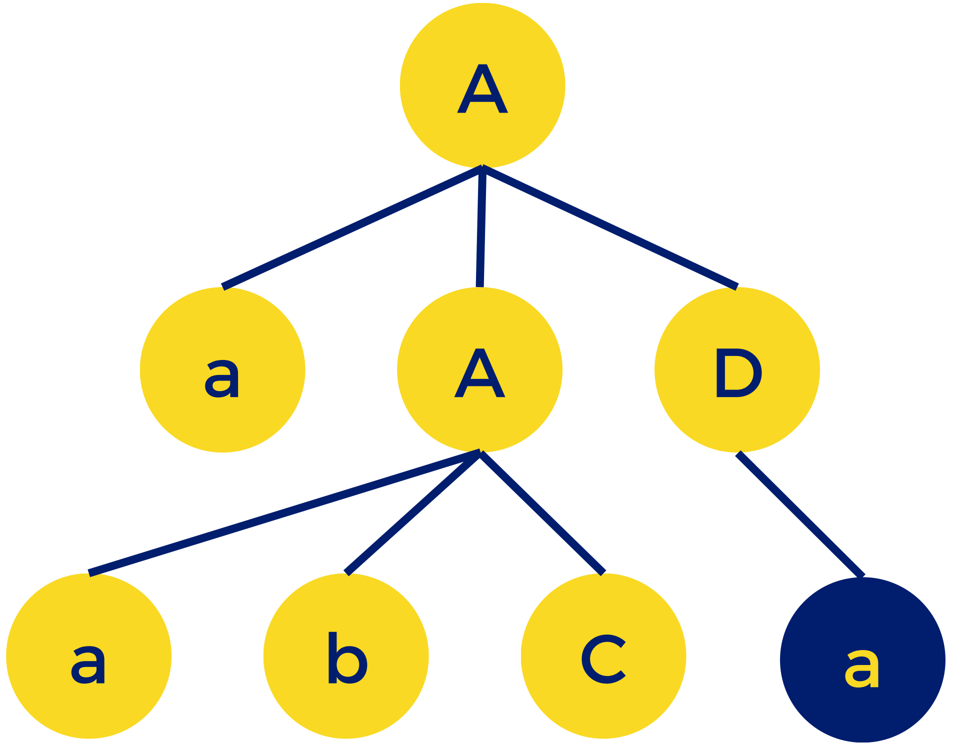

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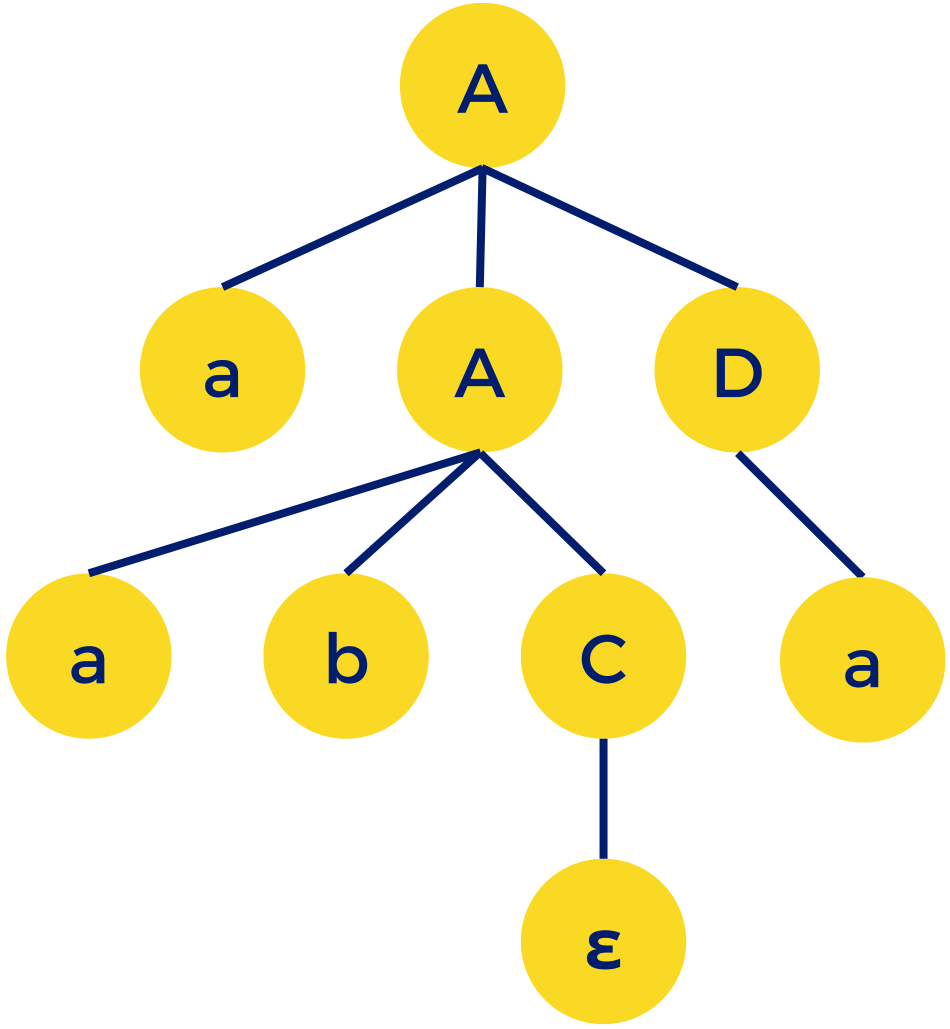

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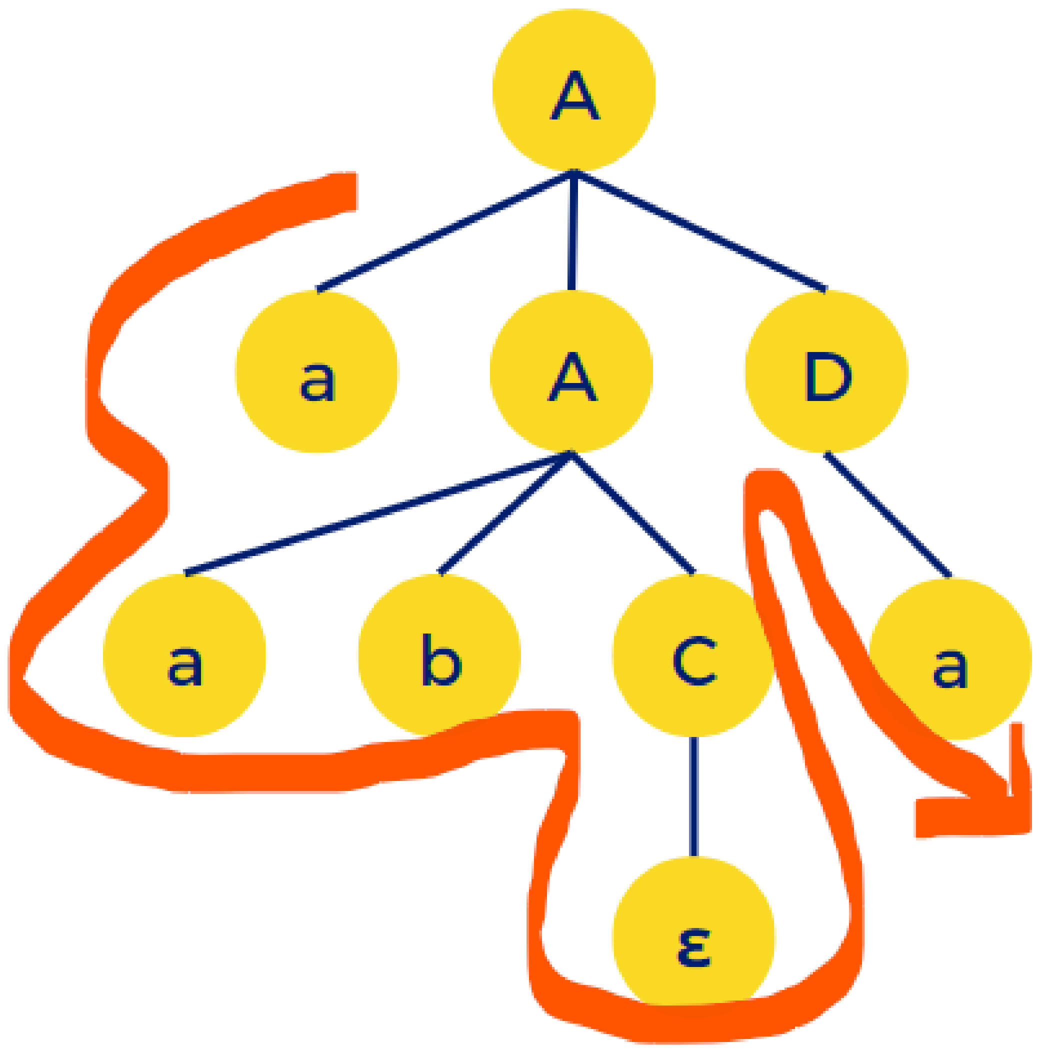

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RECURSIVE-DESCENT PARSING

Problem with Left Recursion:
If a left recursion is present in any grammar then, during parsing in the syntax analysis part of compilation, there is a chance that the grammar will create an infinite loop. This is because, at every time of production of grammar, A will produce another A without checking any condition.

RECURSIVE-DESCENT PARSING

- The other characteristic of grammars that disallows top-down parsing is the lack of pairwise disjointness
  - The inability to determine the correct RHS on the basis of one token of lookahead
  - Def: $\text{FIRST}(\alpha) = \{a \mid \alpha \Rightarrow^* a\beta\}$

    (If $\alpha \Rightarrow^* \varepsilon$, ε is in $\text{FIRST}(\alpha)$)

RECURSIVE-DESCENT PARSING

- Pairwise Disjointness Test:
  - For each nonterminal, A, in the grammar that has more than one RHS, for each pair of rules, $A \rightarrow \alpha_i$ and $A \rightarrow \alpha_j$, it must be true that

$$\mathrm{FIRST}(\alpha_i) \cap \mathrm{FIRST}(\alpha_j) = \varphi$$

RECURSIVE-DESCENT PARSING

Example 1: Consider the following grammar

A : a B
A : b A b
A : B b
B : c B
B : d

The FIRST sets for the RHS of A-rules are: FIRST(aB) = { a }, FIRST(bAb) = { b }, and FIRST(Bb) = { c, d }. These are disjoint and hence PASS the pairwise disjoint test.

The FIRST sets for the RHS of B-rules are: FIRST(cB) = { c } and FIRST(d) = { d }. These are disjoint and hence PASS the pairwise disjoint test.

RECURSIVE-DESCENT PARSING

Example 2: Consider the following grammar

```
A : a B
A : B A b
B : a B
B : b
```

The FIRST sets for the RHS of A-rules are: FIRST(aB) = { a } and FIRST(BAb) = { a, b }. These are not disjoint and hence FAIL the pairwise disjoint test.

The FIRST sets for the RHS of B-rules are: FIRST(aB) = { a } and FIRST(b) = { b }. These are disjoint and hence PASS the pairwise disjoint test.

So, the grammar as a whole fails the pairwise disjoint test and hence cannot be parsed using top-down parsers!

RECURSIVE-DESCENT PARSING

- Left factoring can resolve the problem

  Replace

<variable> → identifier | identifier [<expression>]

with

<variable> → identifier <new>

<new> → ε | [<expression>]

or

<variable> → identifier [[<expression>]]

(the outer brackets are metasymbols of EBNF)

RECURSIVE-DESCENT PARSING

$A \rightarrow a\alpha 1 \mid a\alpha 2 \mid a\alpha 3$ $\xrightarrow{\text{Left Factoring}}$ $A \rightarrow aA'$, $A' \rightarrow \alpha 1 \mid \alpha 2 \mid \alpha 3$

Grammar
with
common prefixes

Left Factored Grammar

RECURSIVE-DESCENT PARSING

Problem-01:

Do left factoring in the following grammar-

$$S \rightarrow iEtS \,/\, iEtSeS \,/\, a$$

$$E \rightarrow b$$

RECURSIVE-DESCENT PARSING

Solution-

The left factored grammar is-

$$S \rightarrow iEtSS' \,/\, a$$

$$S' \rightarrow eS \,/\, \epsilon$$

$$E \rightarrow b$$

RECURSIVE-DESCENT PARSING

Problem-02:

Do left factoring in the following grammar-

$$A \rightarrow aAB \; / \; aBc \; / \; aAc$$

RECURSIVE-DESCENT PARSING

Step-01:

$$A \rightarrow aA'$$

$$A' \rightarrow AB \ / \ Bc \ / \ Ac$$

Again, this is a grammar with common prefixes.

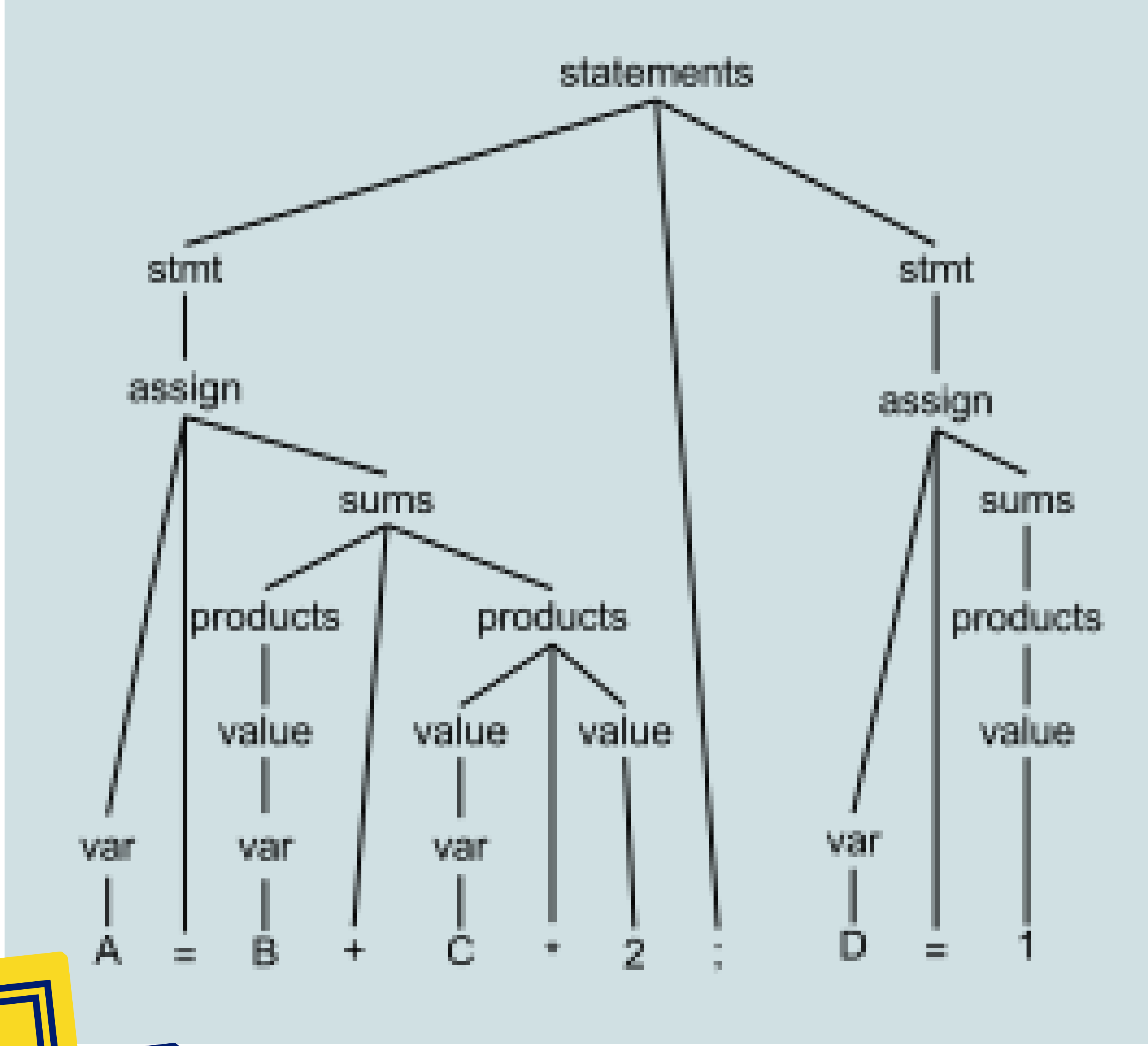
Step-02:

$$A \rightarrow aA'$$

$$A' \rightarrow AD \ / \ Bc$$

$$D \rightarrow B \ / \ c$$

BOTTOM UP PARSING



The parsing problem is finding the correct RHS in a right-sentential form to reduce to get the previous right-sentential form in the derivation.

BOTTOM UP PARSING

Right sentential form a sentential form that occurs in the rightmost derivation of some sentence.

The process of deriving a string by expanding the rightmost non-terminal at each step is called as **rightmost derivation**.

BOTTOM UP PARSING

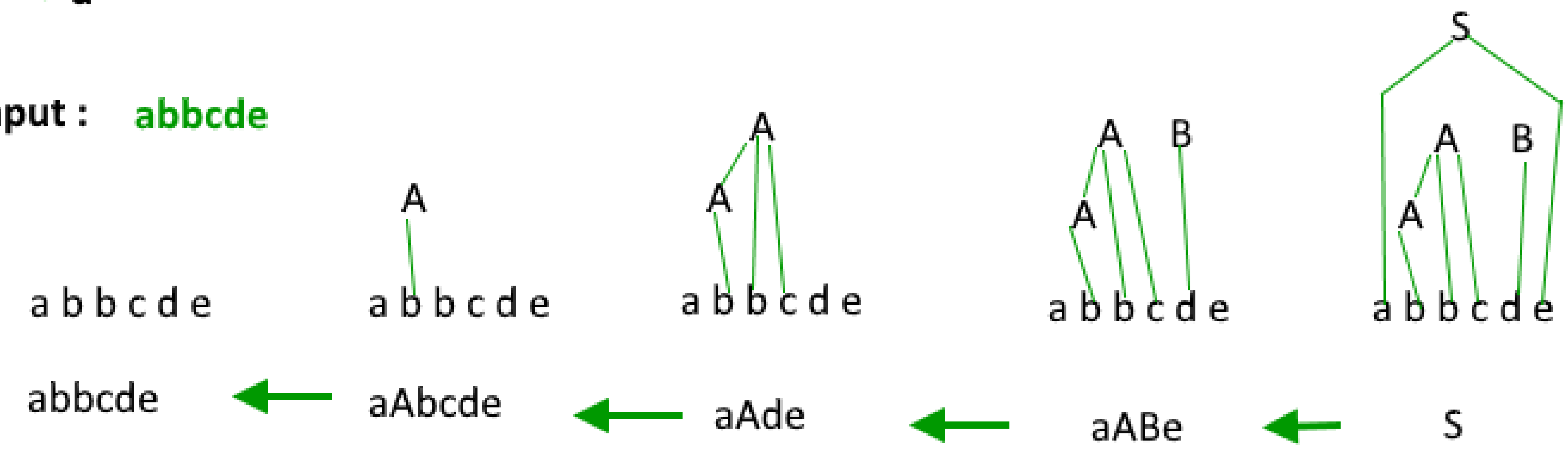
Handle - string of symbols to be replaced at each stage of parsing

S → aABe

A → Abc/b

B → d

Input : abbcde



BOTTOM UP PARSING

LR Parsing Algorithm

L - left to right scanning of input string

R - start with rightmost derivation

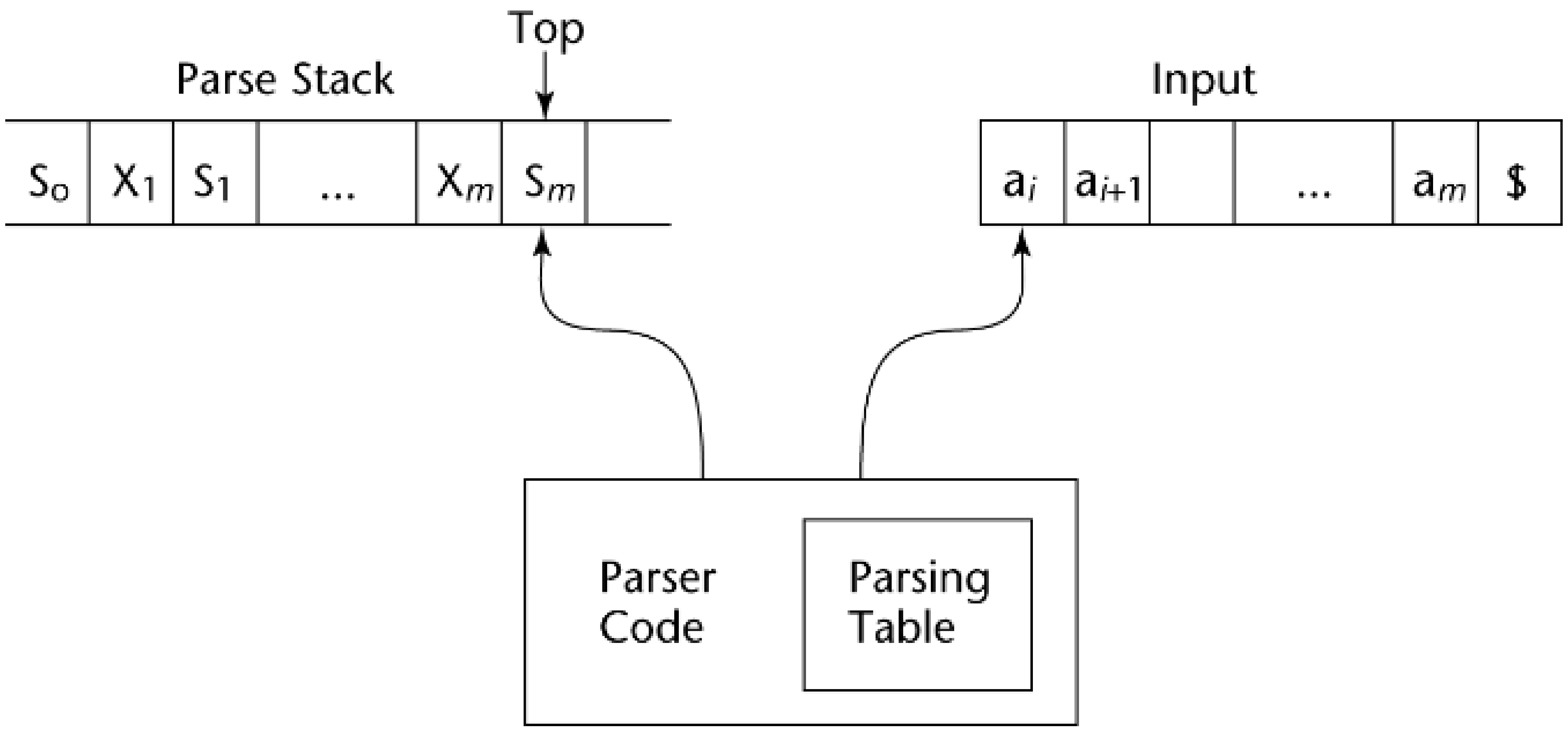
BOTTOM UP PARSING

- Advantages of LR parsers:
  - They will work for nearly all grammars that describe programming languages.
  - They work on a larger class of grammars than other bottom-up algorithms, but are as efficient as any other bottom-up parser.
  - They can detect syntax errors as soon as it is possible.
  - The LR class of grammars is a superset of the class parsable by LL parsers.

BOTTOM UP PARSING

- LR parsers must be constructed with a tool
- Knuth's insight: A bottom-up parser could use the entire history of the parse, up to the current point, to make parsing decisions
  - There were only a finite and relatively small number of different parse situations that could have occurred, so the history could be stored in a parser state, on the parse stack

BOTTOM UP PARSING



BOTTOM UP PARSING

Bottom up parsers make use of Shift-Reduce Algorithms

- Shift-Reduce Algorithms
  - Reduce is the action of replacing the handle on the top of the parse stack with its corresponding LHS
  - Shift is the action of moving the next token to the top of the parse stack

BOTTOM UP PARSING

- LR parsers are table driven, where the table has two components, an ACTION table and a GOTO table
  - The ACTION table specifies the action of the parser, given the parser state and the next token
    - Rows are state names; columns are terminals
  - The GOTO table specifies which state to put on top of the parse stack after a reduction action is done
    - Rows are state names; columns are nonterminals

BOTTOM UP PARSING

1. $E \rightarrow E + T$
2. $E \rightarrow T$
3. $T \rightarrow T * F$
4. $T \rightarrow F$
5. $F \rightarrow (E)$
6. $F \rightarrow id$

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		R2	S7		R2	R2			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

BOTTOM UP PARSING

- Initial configuration: $(S_0, a_1 \ldots a_n \$)$
- Parser actions:
  - If $ACTION[S_m, a_i]$ = Shift S, the next configuration is:

    $(S_0X_1S_1X_2S_2 \ldots X_mS_ma_iS, a_{i+1} \ldots a_n\$)$
  - If $ACTION[S_m, a_i]$ = Reduce $A \rightarrow \beta$ and $S = GOTO[S_{m-r}, A]$, where r = the length of β, the next configuration is

    $(S_0X_1S_1X_2S_2 \ldots X_{m-r}S_{m-r}AS, a_ia_{i+1} \ldots a_n\$)$
  - If $ACTION[S_m, a_i]$ = Accept, the parse is complete and no errors were found.
  - If $ACTION[S_m, a_i]$ = Error, the parser calls an error-handling routine.

BOTTOM UP PARSING

1. E → E + T
2. E → T
3. T → T * F
4. T → F
5. F → (E)
6. F → id

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		R0	S7		R2	R0			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

id + id * id $

0						lexeme
						state

BOTTOM UP PARSING

1. $E \rightarrow E + T$
2. $E \rightarrow T$
3. $T \rightarrow T * F$
4. $T \rightarrow F$
5. $F \rightarrow (E)$
6. $F \rightarrow id$

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		R0	S7		R2	R0			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

+ id * id $

0	id					lexeme
	5					state

BOTTOM UP PARSING

1. $E \rightarrow E + T$
2. $E \rightarrow T$
3. $T \rightarrow T * F$
4. $T \rightarrow F$
5. $F \rightarrow (E)$
6. $F \rightarrow id$

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		RO	S7		R2	RO			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

+ id * id $

0	F					lexeme
	3					state

BOTTOM UP PARSING

1. E → E + T
2. E → T
3. T → T * F
4. T → F
5. F → (E)
6. F → id

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		R0	S7		R2	R0			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

<u>+</u> id * id $

<table>
<tr><td rowspan="2">0</td><td>T</td><td></td><td></td><td></td><td></td><td>lexeme</td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td>state</td></tr>
</table>

BOTTOM UP PARSING

1. E → E + T
2. E → T
3. T → T * F
4. T → F
5. F → (E)
6. F → id

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		R0	S7		R2	R0			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

<u>+</u> id * id $

0	E					lexeme
	1					state

BOTTOM UP PARSING

1. E → E + T
2. E → T
3. T → T * F
4. T → F
5. F → (E)
6. F → id

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		R0	S7		R2	R0			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

id * id $

0	E	+				lexeme
	1	6				state

BOTTOM UP PARSING

1. $E \rightarrow E + T$
2. $E \rightarrow T$
3. $T \rightarrow T * F$
4. $T \rightarrow F$
5. $F \rightarrow (E)$
6. $F \rightarrow id$

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		R0	S7		R2	R0			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

* id $

0	E	+	id			lexeme
	1	6	5			state

BOTTOM UP PARSING

1. E → E + T
2. E → T
3. T → T * F
4. T → F
5. F → (E)
6. F → id

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		R0	S7		R2	R0			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

* id $

0	E	+	F			lexeme
	1	6	3			state

BOTTOM UP PARSING

1. E → E + T
2. E → T
3. T → T * F
4. T → F
5. F → (E)
6. F → id

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		R0	S7		R2	R0			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

* id $

0	E	+	T			lexeme
	1	6	2			state

BOTTOM UP PARSING

1. $E \to E + T$
2. $E \to T$
3. $T \to T * F$
4. $T \to F$
5. $F \to (E)$
6. $F \to id$

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		R0	S7		R2	R0			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

<u>id</u> $

0	E	+	T	*		lexeme
	1	6	2	7		state

BOTTOM UP PARSING

1. E → E + T
2. E → T
3. T → T * F
4. T → F
5. F → (E)
6. F → id

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		R0	S7		R2	R0			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

$

0	E	+	T	*	id	lexeme
	1	6	2	7	5	state

BOTTOM UP PARSING

1. E → E + T
2. E → T
3. T → T * F
4. T → F
5. F → (E)
6. F → id

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		R0	S7		R2	R0			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

$

0	E	+	T	*	F	lexeme
	1	6	2	7	3	state

BOTTOM UP PARSING

1. E → E + T
2. E → T
3. T → T * F
4. T → F
5. F → (E)
6. F → id

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		R0	S7		R2	R0			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

$

0	E	+	T			lexeme
	1	6	2			state

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BOTTOM UP PARSING

1. E → E + T
2. E → T
3. T → T * F
4. T → F
5. F → (E)
6. F → id

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		R0	S7		R2	R0			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

$

0	E					lexeme
	1					state

BOTTOM UP PARSING

1. $E \rightarrow E + T$
2. $E \rightarrow T$
3. $T \rightarrow T * F$
4. $T \rightarrow F$
5. $F \rightarrow (E)$
6. $F \rightarrow id$

	Action						Goto		
State	id	+	*	(	)	$	E	T	F
0	S5		S4				1	2	3
1		S6				accept			
2		R0	S7		R2	R0			
3		R4	R4		R4	R4			
4	S5			S4			8	2	3
5		R6	R6		R6	R6			
6	S5			S4				9	3
7	S5			S4					10
8		S6			S11				
9		R1	S7		R1	R1			
10		R3	R3		R3	R3			
11		R5	R5		R5	R5			

$

0	E					lexeme
	1					state

accept

SUMMARY

Syntax analysis is normally based on a formal syntax description of the language being implemented, commonly using BNF.

Parts of Syntax Analysis:

- Lexical Analysis
- Syntax Analysis

Reasons for Separating Lexical and Syntax Analysis:

- Simplicity
- Efficiency
- Portability

SUMMARY

- **Lexical Analyzer** is a pattern matcher that isolates **lexemes**, which is the basic lexical unit of a language.
- **Lexemes** are categorized by **tokens**.

Goals of Syntax Analysis:

- detect syntax errors and provide diagnostic message if an error exists
- produce a parse tree which would be used for code generation

Approaches to Syntax Analysis:

- Top-Down Approach
- Bottom Up Approach

SUMMARY

- **Top Down Approach**: Given a sentential form, $xA\alpha$, the parser must choose the correct A-rule to get the next sentential form in the leftmost derivation, using only the first token produced by A. Commonly uses Recursive Descent parsing algorithm. Subprogram driven.
- **Bottom Up Approach**: The parsing problem is finding the correct RHS in a right-sentential form to reduce to get the previous right-sentential form in the derivation. Table driven.

THANK YOU VERY MUCH FOR LISTENING

Monzales, Samson, and Tejada