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CH-1

→ ① Translation: ② Translation software ③ What are the language translators?

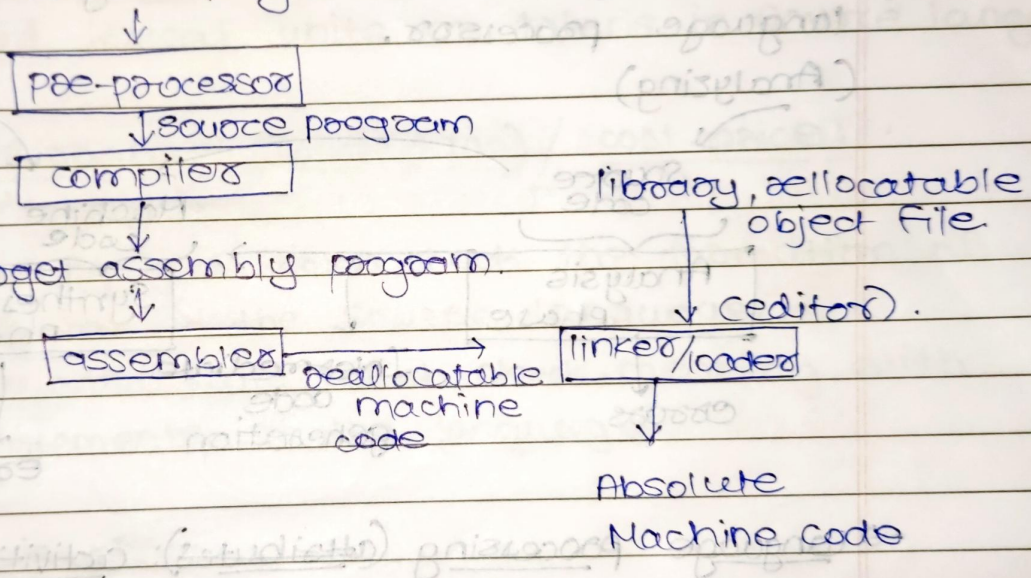
⇒ translation: is more than just changing the word from one language to another. So translation gives bridge b/w the languages.

⇒ translation software: translate whole program to another language (low level).

→ language translators: ① compilers ② interpreters ③ assemblers

* 1) Language processing system:

→ skeletal source program.



→ pre-processor: ① macro-processing
② file inclusion
③ relational pre-processor
④ language extensions

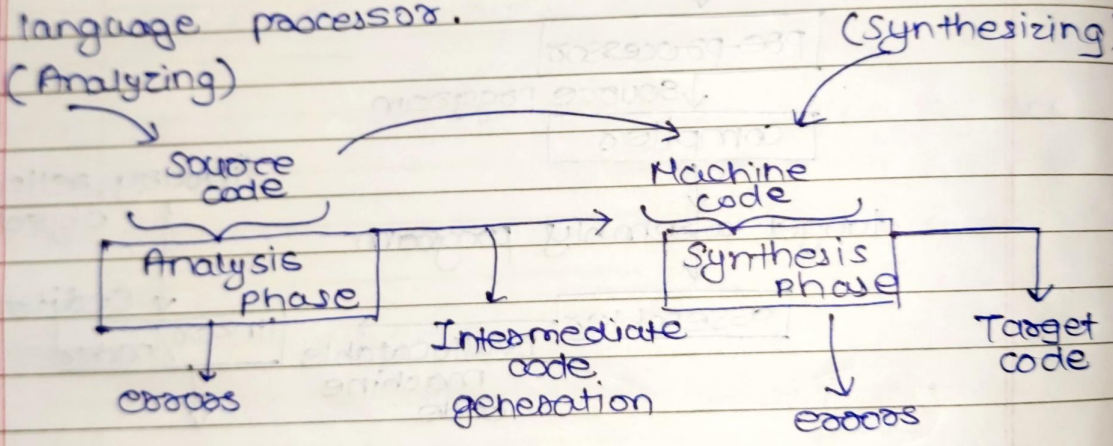
⇒ ① Assembler ② Compiler ③ interpretter ④ editor ⑤ loader ⑥ linker ⑦ debugger ⑧ macro ⑨ Operating System ⑩ Device Driver.

→ Assembler: used to translate assembly lang. prog in into machine code.

* Fundamental of Language Processing:

→ Language processing or: It converts source code into machine code

→ Language processing: The collection of language processor components engaging the analysis of source program constitutes analysis phase of language processor.



→ Language processing (~~attributes~~): activities:

① Program generation activity.
② " execution activity. → ① program translation
② program interpretation

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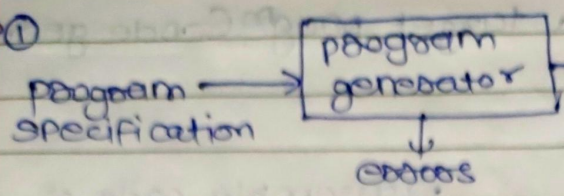
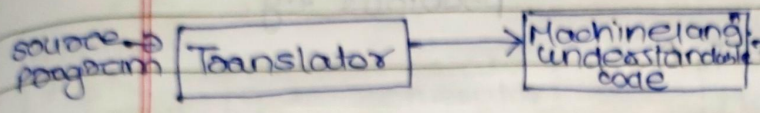
SSD

→ ①





→ program Interpretation: Ex: .java → .class

steps: ① Fetch ② Decode ③ Execute.

⇒ Analysis phase: The specification consist of 3 components. ① lexical ~~groups~~ rules: which check the valid lexical units or tokens in source lang.

eg. percent_profit := (profit * 100) / cost_price;

↳ tokens.

→ ② Syntax Analysis: Which check the formation of valid syntax in the source language.

→ ③ Schemantic rules: which check, meaning with valid statements of the language.

⇒ Synthesis phase:

→ The synthesis phase is concerned with the construction of target language statements. which have the same meaning as a source statement.

→ It peroforms 2 main activities.

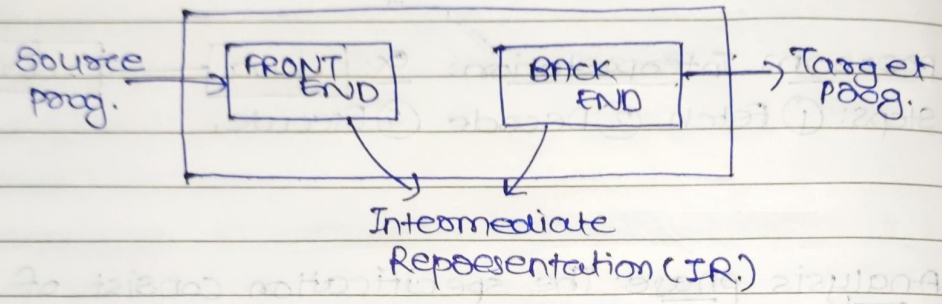
① creation of data structure in the target progm. (memory allocation).

⑧ generation of a target progm (Code generation)

eg. MOV A, PROFIT
MUL A, PROFIT, 100
DIV A, COST
MOV PERCENT_PROFIT, A

⇒ assembly code of previous eg.

⇒



* cousins of the compiler:

→ The i/p to a compiler will be produced by one or more pre-processors and further processing of the compiler's outcome may be needed before running machine code is obtained.

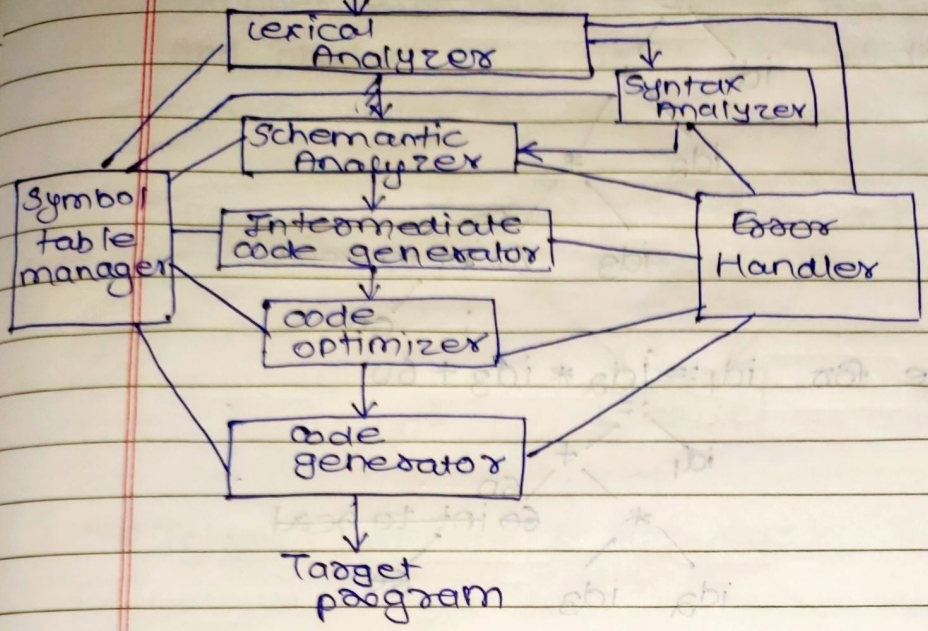
⇒ pre-processors → source code → target code
↓
IR.

① Macro-processing ② File inclusion ③ Rational preprocessor ④ language extensions.

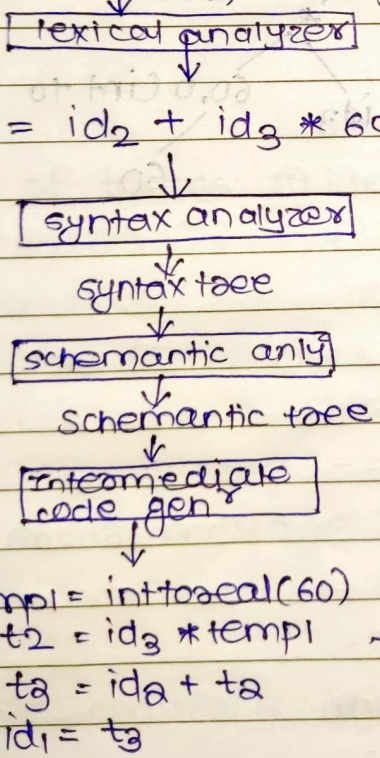
eg. equel lang
↓
(to include extensions).

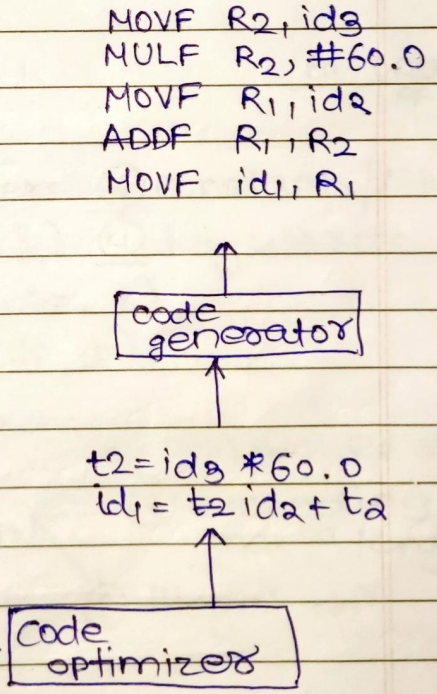
Rational → (do minor changes in older languages to make progm faster)

⇒ source-program

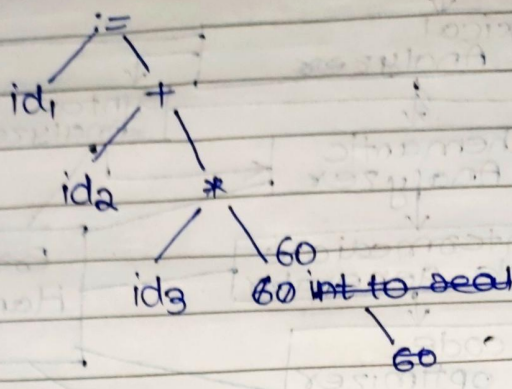


Eg: ① position := initial + rate * 60
idf op idf op idf op const
(id_1) (id_2) (id_3)

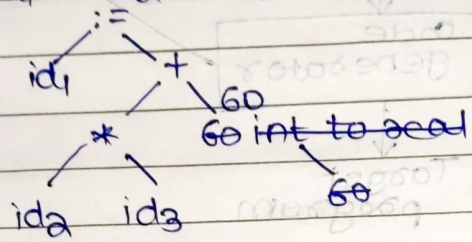




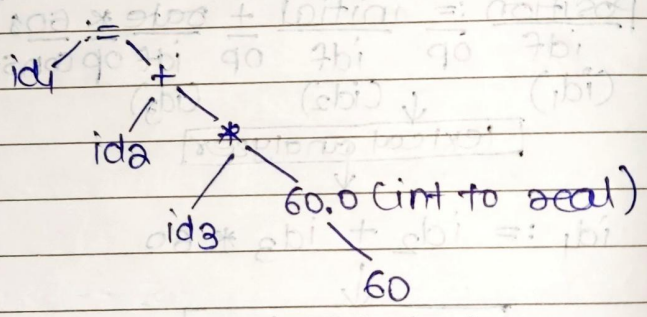
syntax tree: $id_1 := id_2 + id_3 * 60;$



Eg: syntax tree for $id_1 := id_2 * id_3 + 60$



schemantic tree: $id_1 := id_2 + id_3 * 60.0$



CH-2

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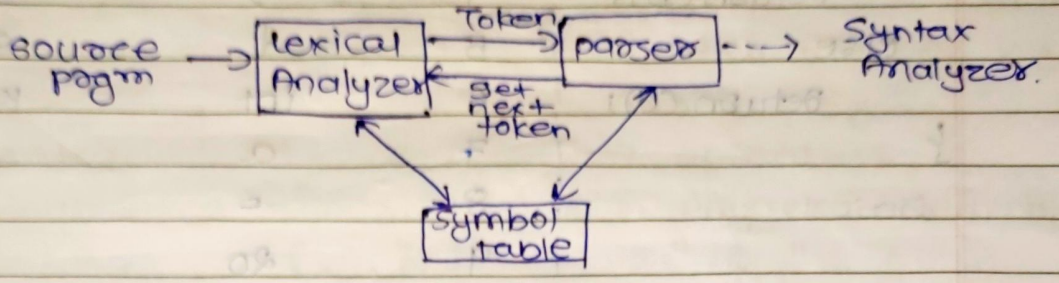
→ The Role of the lexical analyzer: 1st phase of compiler. Main task is the to the read the i/p chrs and produce as a o/p, a seqn of tokens that the parser uses for syntax Analysis.



→ Tokens, patterns & Lexemes:

Eg: int a := 5 ;
lex1 lex2 lex3 lex4 lex5

main ( )
lex6 lex7 lex8

{
9

}
10

Eg: TRUE, FALSE

→ Types of tokens: ① identifiers ② constants/literals ③ seperators (,, ;, {, (,), }) ④ keywords ⑤ operators (+, -, :=, <=, >=, *). ⑥ special characters (&, #, $).

⇒ Gives error message when ① unmatched string ② exceeding maxm length ③ illegal chr

→ Eliminate comments and white space.

Eg =>

```
int main()
{
  int a=20,b=30;
  if(a<b)
    return(b);
  else
    return(a);
}
```

patterns → write patterns accordingly

no	lexeme	tokens
1	int	keyword
2	main	keyword
3	(	sepr
4	)	sepr
5	{	sepr
6	int	keyword
7	a	idf
8	=	opr
9	20	const.
10	,	sepr
11	b	idf
12	=	opr
13	30	const.
14	;	sepr
15	if	keyword
16	(	sepr
17	a	idf
18	<	opr
19	b	idf
20	)	sepr
21	return	keyword
22	(	sepr
23	b	idf
24	)	sepr
25	;	sepr
26	else	keyword
27	return	keyword
28	(	sepr
29	a	idf
30	)	sepr
31	;	"
32	}	"

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⇒

Token	Sample lexems	Informal Description of pattern
Constant	12, 15, ...	→ Any numeric number
Keyword	if, do, ...	→ keywords
Relational opr	<, >, <=, ...	→ compaaision symbols
identifier	a, b, ...	→ letter followed by letter / digit.
operator	+, −, *, /	→ operators
literals	"....."	→ Any character b/w " & ".
separators	(,), {, ;	→ , OR ; OR (OR {

#⇒ Lexical Errors: ① exceeding length of identifier OR numeric constant.
eg. int a = 9234567890;
② Appearance of illegal chrs. ⇒ eg. printf("Hi"); #
③ Unmatched string. → eg. main(){
/* .... comment not closed.
}

④ Spelling error: It occurs when identifier Rule not satisfied.
eg. int 7b = 134;
⑤ Replacing a chr with an incorrect chr.
eg. int x = 12#3;
⑥ Removal of chr that should be present.
eg. #includ <conio.h>
⑦ Transposition of 2 chrs.
eg. int mian().
⑧ Repeatation of chrs
eg. int a = 7..5;

Lexical error: when lexical analyzer is not able to identify valid lexemes / words which generate the lexical error.

→ RE → Input Buffer

↓

DFA → ? (error).

Eg: ① Int x, y; ⇒ Not generate lexical error (∵ Int is compile time error).

② int x,, y; →

↳ lexical errors.

③ ~~char~~ int A = #123; → Replacing a chr with incorrect chr.

④ String S = "6th sem; ⇒ Unmatched string.

Attributes for the token:

eg: token and associated attr value for the following statement;

E = M * C ** 2 ; // It is valid

↓

⇒ <id, pointer to symbol table entry for E>

<assignment_op, =>

<id, pointer to symb table entry for M>

<mult_op, *>

<id, pointer to symb table entry for C>

<~~mult_op, *~~> } <exp_op, **>

<~~mult_op, *~~>

<const, 2>

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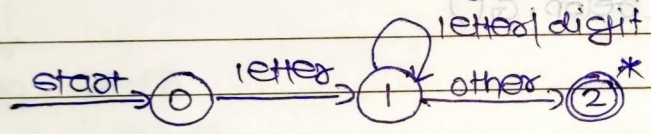
* Recognization of token by transition diagram:

1) Recognization of identifiers
2) Recog^{n} of delimeters
3) Recog^{n} of Relational op^{s}
4) Recog^{n} of keywords (such as 'if', 'else', 'for').
5) Recog^{n} of numbers (int, float, exp^{n}).

① Recog^{n} of identifiers:

→ letter → a|...|z|A|...|Z
digit → 0|1|...|9

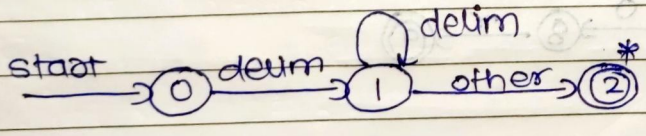
id → letter (letter | digit)* ⇒ Transition diagram:



return (gettoken(), install_id())

② Recog^{n} of delimeters:

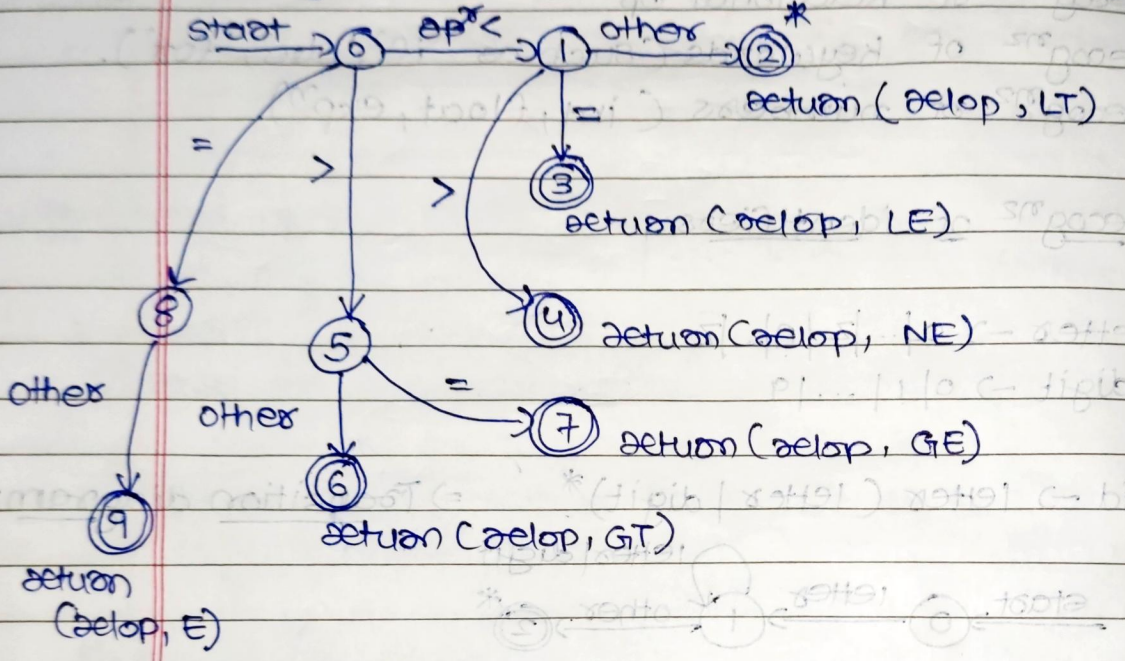
→ delim → blank | tab | newline
ws → delim (delim)* (; ws → whitespace).



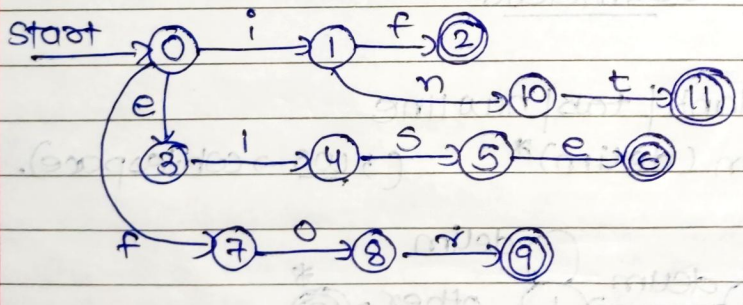
return(gettoken(), install_id()).

③ Recognition of Relational operator:

>| >=| <| <=| =| <> → NE
<> → not equal to.

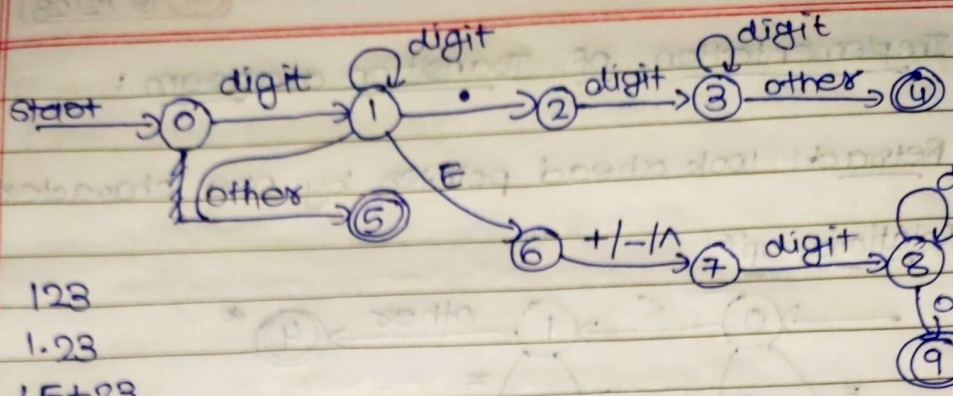


④ Recognition of Keywords:



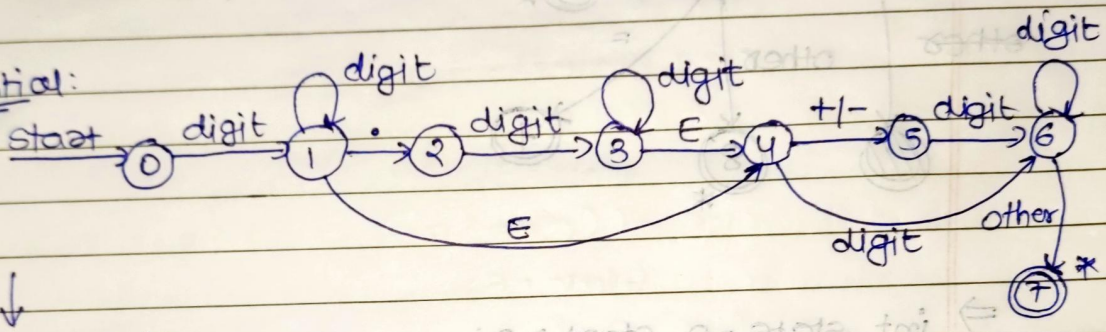
⑤ Recognition of numbers:

num → digit$^+$ (.digit$^+$)? (E (+|-)?digit$^+$)?



Eg: 123
1.23
1E+23
1E-23
1E23

exponential:
⇒



↓

eg. 2E+5
2.7E-5
2.7E52
2E4

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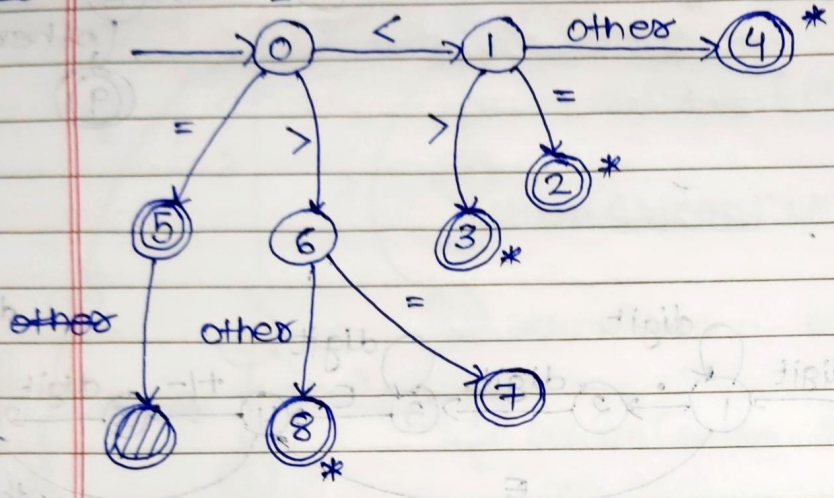
* Implementation of Transition diagram :

⇒ Retract: look ahead pointer by one character.

eg. Relational op^{n}:



⇒
```
int state = 0, start = 0;
int lexical_value;
int fail(){
    forward = token_beginning;
    switch (start)
    {
        case 0:
```

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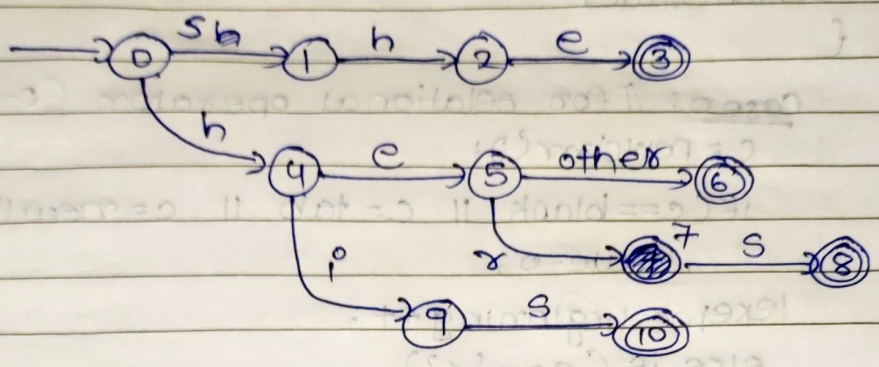
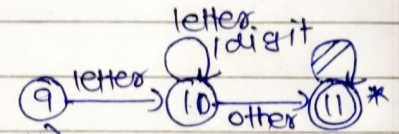
eg * Draw transition diagram for the set of keywords {he, she, his, hers}



eg. token nexttoken(){
while(1)
switch(state)
{
case 0: // for relational operator (0-8)
c = nextchar();
if(c==blank || c= tab || c=newline)
state=0;
lexeme_beginning++;
else if (c=='<')
state=1;
else if(c == '=')
state=5;
else if(c=='>')
state=6;
else fail();
break;
case 9: // identifier (9-11)



c = nextchar();
// if(c== blank || c=tabs || c=newline)
// state=0;
lexeme_beginning++;
else if(c==is letter)(c))
state=10;
else if (c==is letter (c) || c==is digit (c))
state=10;
else fail();
break;

```
case 10:
    c=nextchar();
    if(isletter(c)|| isdigit(c))
        state=10;
    else fail();
    break;
case 11:
    retract(1);
    install_id();
    return(gettoken());
```

* Implement transition diagram for exponential:

```
token nexttoken(){
    while(1)
    switch(state)
    {
        case 0:
            c=nextchar();
            if(isdigit(c))
                state=1;
            else fail();
            break;
        case 1:
            c=nextchar();
            if(isdigit(c))
                state=1;
            else if(c=='.')
                state=2;
            else if(c=='E')
                state=4;
            else fail(); break;
```

```
case 2:
    c=nextChar();
    if(isdigit(c))
        state=3;
    else fail();
    break;
case 3:
    c=nextchar();
    if(isdigit(c))
        state=3;
    else if(c=="E")
        state=4;
    else fail();
    break;
case 4:
    c=nextchar();
    if(c=="+" || c=="-")
        state=5;
    else if(isdigit(c))
        state=6;
    else fail();
    break;
case 5:
    .
    .
    .
case 8:
    retract(1);
    get install_id();
    return(gettoken());
```

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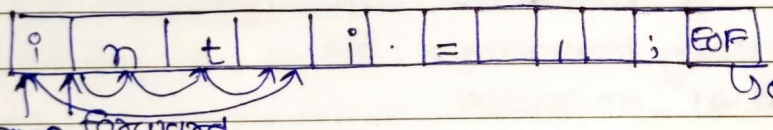
⇒ lex source pgm (lex.l) → lex compiler → lex.yy.c → C compiler → a.out

i/p stream → a.out → seqn of tokens.

⇒ declaration: eg.
```
%{
    int count=0;
%}
```

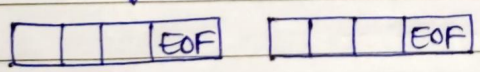
⇒ rules: eg.
```
%%
pattern.
%%
```

i/p buffering:

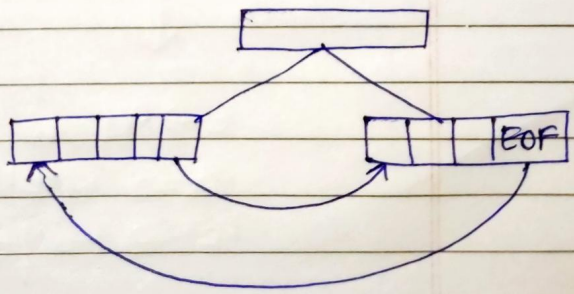


⇒ whenever forward pointer detects 'space' it will consider whole lexemes as one token and then forward pointer and lexeme_begin will move to next lexeme.

⇒ sentinal:



⇒ buffer pair:



→ specification of tokens

① prefix of 's' : a string obtained by removing 0 or more trailing symbols of a string.
eg. s = banana.
↳ prefix

→ suffix of 's' : a string obtained by removing 0 or more leading symbols of a string.
eg. s = banana
↳ suffix

② Substring : a string obtained by deleting a prefix and suffix from 's'.
eg. s = banana
↳ prefix ↓ substring ↳ suffix

Syntax Analyzer

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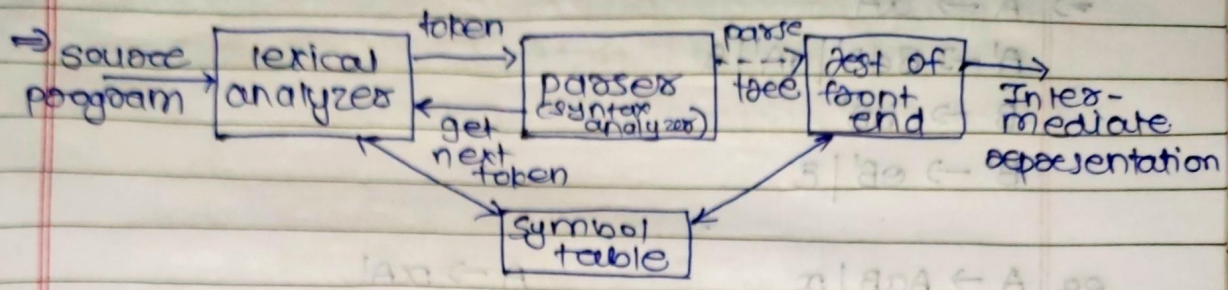

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⇒ Context free grammer:

→ (N, T, P, S) → starting symbol.
- N → set of non terminals
- T → set of terminals
- P → production Rules

eg ⇒ $(0+1)^*$

$S \rightarrow 0S \mid 1S \mid \wedge$

* Left recursion: i/p : Grammar 'g'

o/p : equivalent grammar with no recursion. ~~method~~.

method: if we have left recursive pair of production $[A \rightarrow A\alpha \mid \beta]$ where, β does not begin with 'A' then we can eliminate left recursion by replacing this pair of production with

$$\begin{pmatrix} A \rightarrow \beta A' \\ A' \rightarrow \alpha A' \mid \varepsilon \end{pmatrix}$$

eg: $A \rightarrow ABd \mid Aa \mid a$

$B \rightarrow Be \mid b$

→ eliminate the left recursion.

$\Rightarrow$ $A \to aA'$

$A' \to BdA' \mid aA' \mid \varepsilon$

$B \to bB'$

$B' \to eB' \mid \varepsilon$

eg. $A \to AaB \mid \alpha$

$B \to BCb \mid y$

$C \to Cc \mid \varepsilon$

$\Rightarrow$

$A \to \alpha A'$

$A' \to aBA' \mid \varepsilon$

$B \to yB'$

$B' \to CbB' \mid \varepsilon$

$C \to C'$

$C' \to cC' \mid \varepsilon.$

eg. $E \to E+T \mid T$

$T \to T*F \mid F$

$F \to (E) \mid id$

$\Rightarrow$

$E \to TE'$

$E' \to +TE' \mid \varepsilon$

$T \to FT'$

$T' \to *FT' \mid \varepsilon$

$F \to (E) \mid id$

eg. $S \to Aa \mid b$

$A \to Ac \mid Sd \mid \varepsilon$

$\Rightarrow$ $\left.\begin{array}{l} S \to Aa \mid b \\ A \to SdA' \mid A' \\ A' \to cA' \mid \varepsilon \end{array}\right\}$ X

$S \to Aa \mid b$

$A \to Ac \mid Aad \mid bd \mid \varepsilon$

$\Downarrow$

$S \to Aa \mid b$

$A \to bdA' \mid A'$

$A' \to cA' \mid adA' \mid \varepsilon$

eg. $S \to (L) | a \Rightarrow S \to (L) | a$
$L \to L,S | S \quad L \to L,(L) | L,a | (L) | a$

Ans. $\Rightarrow S \to (L) | a$
$L \to aL' | (L)L'$
$L' \to ,(L)L' | ,aL' | \cancel{(L)L'} | \varepsilon$

* Error Recovery strategies:

→ ① Panic mode recovery:
eg. int oc, ~~x2y~~, ~~#z~~;
→ it will identify by taking/checking one token at a time, whenever it detects syntax error it will delete each token/lexeme until it finds separator like ',', ';' etc.
⇒ whenever there are minimum (small) no. of errors in the statement then only it is used.

② Phrase level recovery:
int a, b,
int a=5;
↓
(;) replaced by semi-colon.
because ';' is expected.

③ Error productions: eg. $S \to X$
$X \to aX | bX | \varepsilon$
$Y \to cd.$
$\Rightarrow abcd.$

A

④ global corrections: We can correct grammar, sta anything to correct errors. It is not possible in Real-time. Physically not possible.

* Elimination of Left Factoring:

→ i/p: Grammer 'G'
o/p: equivalent non left factoring grammar.
method: for each NT 'A' find the prefix 'α', comm two or more of its alternatives. Replace one of th 'A' productions.

eg. $A \to \alpha\beta_1 | \alpha\beta_2 | \ldots | \alpha\beta_n | \gamma$ (left factoring grammar).

; γ → represents all alternatives that do not begin with 'α'.

o/p: $A \to \alpha A' | \gamma$

$A' \to \beta_1 | \beta_2 | \ldots | \beta_n$

→ Repeatedly, apply their transformation until tha two alternatives for a common prefix.

LT

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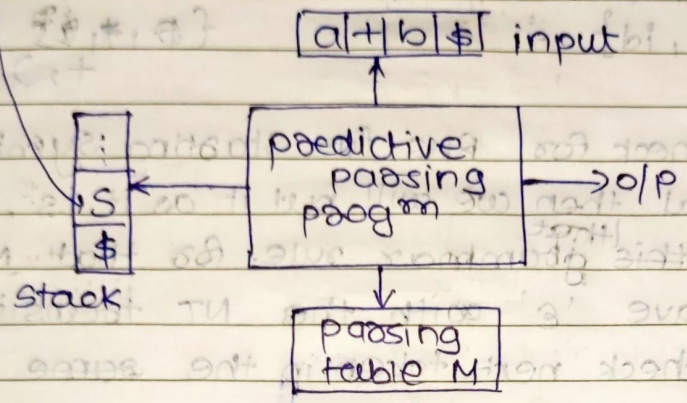
* Non-recursive predictive parser / LL(1) parser / predictive parser / table-driven predictive parser:

⇒ S → a+b



⇒ for LL(1) → it uses only one i/p symbol at a time to predict the parsing process.
- the i/p is scanned from left to right
- it uses left most derivation for i/p string.

→ data structure uses ① stack, ② parsing table ③ i/p buffer.

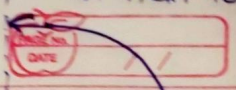
⇒ stack: initially the stack contains the start symbol of the grammar on top of '$' symbol.

⇒ parsing table: parser construct the table each time by taking the parsing actions.

⇒ i/p buffer: it is used to store the i/p tokens.

Eg: * E → TE'
E' → +TE' | ε
T → FT'
T' → *FT' | ε
F → (E) | id

Rules: ① put '$' in starting.
② find starting symbol in every transitions. If the next token is terminal then put as it is.
③ If there is nothing in next token



Starting Symbol	First	Follow
E	→ {(, id}	{$,)}
E'	{+, ε}	{$,)}
T	{(, id}	{$, +, ε}
T'	{*, ε}	{$, +, ε}
F	{(, id}	{$, *, ε, +,)}

Rules: ① We will check for RHS for starting symbol, if it is Terminal then we will put it as it is. If NT then Go to that grammar rule for that NT.
② if we have 'ε' with the NT transition then we have check next token in the production rules for that NT.

Eg: S → AB
A → aA | ε
B → BaAC|ε B → CB' B' → aACB' | ε
C → b|ε

Starting Symbol	First	Follow
S	{ε, b, a, c}	{$}
A	{ε, b, a}	{$, a, c}
B	{ε, c}	{$}
C	{ε, b}	{a}
B'	{ε, a}	{$}

Eg: S → AcB | CbB | Ba
A → da | BC
B → g | ε
C → h | ε

start symb.	first	follow
S	{d, g, e, h, c, a}	{$}
A	{d, g, e, h}	{h, c}
B	{ε, g}	{$, a, h, c}
C	{ε, h}	{h, g, f} {c}

eg: S → (L) | a
L → SL'
L' → ,SL' | ε

start symb	first	follow
S	{(, a}	{$, , ,)}
L	{(, a}	{),)}
L'	{, , ε}	{),)}

eg: S → aBDh
B → cC
C → bc | ε
D → EF
E → g | ε
F → f | ε

start symb	first	follow
S	{a}	{$}
B	{c}	{h, g, f}
C	{b, ε}	{h, g, f}
D	{g, ε, f}	{h, h}
E	{g, ε}	{h, f, h}
F	{f, ε}	{$, h}

Eg. $S \to ABC$ $B \to c|d|\varepsilon$

$A \to a|b|\varepsilon$ $C \to e|f|\varepsilon$

	first	follow
S	{a, ε, b, c, d, e, f}	{$}
A	{a, b, ε}	{$, c, d, e, f}
B	{c, d, ε}	{$, e, f}
C	{e, f, ε}	{$}

Rules for follow:

Do not write 'ε' in follow set of any symbol.

① $ at starting of ~~every~~ set first

② Find starting symbol in all RHS production Rules.

③ check for the next token in that rule.

④ If terminal then put as it is. in set.

⑤ If there is nothing then check for starting symbol of that production Rule and put that rule's follow in this follow.

⑥ If NT then write the first of that token into follow of this symbol.

if there is 'ε' in first then see the next token and follow all the rules. again.

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=) steps of LL(1) parser.

① remove left recursion / left factoring.
② find first and follow of the grammer.
③ construct parse table.
④ stack implementation.
⑤ parse tree generation.

ex: $E \to E+T \mid T$
$T \to T*F \mid F$
$F \to (E) \mid id$
(given)

① remove left recursion →

$E \to TE'$
$E' \to +TE' \mid \varepsilon$
$T \to FT'$
$T' \to *FT' \mid \varepsilon$
$F \to (E) \mid id$

no left recursion
factoring

string: id + id * id

② finding first and follow.

	first	follow
E	{*, ε, (, id}	{$,)}
E'	{+, ε}	{$,)}
T	{(, id}	{+, $,)}
T'	{*, ε}	{$, +,)}
F	{(, id}	{*, $, +,)}.

③ construct parse table. (do not put entry for 'ε' in parse table).

	+	id	*	(	)	$
E		$E \to TE'$		$E \to TE'$		
E'	$E' \to +TE'$				$E' \to \varepsilon$	$E' \to \varepsilon$
T		$T \to FT'$		$T \to FT'$		
T'	$T' \to \varepsilon$		$T' \to *FT'$		$T \to \varepsilon$	$T' \to \varepsilon$
F		$F \to id$		$F \to (E)$		

① See the first of each symbol and write production rule in that.
② If there is two production rule (more than one) then write 1st production rule in that symbol and make entry of null in 'follow' symbols.

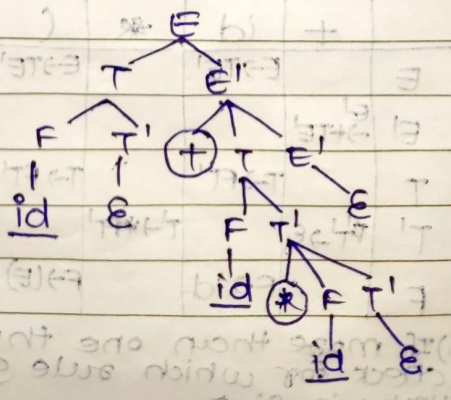
=) If more than one then check for which rule generate symbol in first.

④ Stack implementation:

Note: Here All terminals produce single production rule, so it is a LL(1) Parser.

stack	input	action
$E	id + id * id $	E→TE'
$E'T	id + id * id $	T→FT'
$E'T'F	id + id * id $	F→id
$E'T'id	id + id * id $	Matched
$E'T'	+ id * id $	T'→ε
$E'	+ id * id $	E'→+TE'
$E'T+	+ id * id $	Matched
$E'T	id * id $	T→FT'
$E'T'F	id * id $	F→id
$E'T'id	id * id $	Matched
$E'T'	* id $	T'→*FT'
$E'T'F*	* id $	Matched
$E'T'F	id $	F→id
$E'T'id	id $	Matched
$E'T'	$	T'→ε
$E'	$	E'→ε
$	$	Matched / Accepted.

⑤ Parse tree generation:



Eg. $S \to (L) \mid a$
$L \to SL'$
$L' \to ,SL' \mid \varepsilon$

already ① removed left recursion / factoring.

string: (a,a)

② already found First and Follow.

③ Parse table:

	(	a	,	)	$
S	$S \to (L)$	$S \to a$			
L	$L \to SL'$	$L \to SL'$			
L'			$L' \to ,SL'$	$L' \to \varepsilon$	

④ Stack implementation:

Stack	i/p	action
$S	(a,a)$	$S \to (L)
$)L(	(a,a)$	Matched.
$)L	a,a)$	$L \to SL'
$)L'S	a,a)$	$S \to a
$)L'a	a,a)$	Matched
$)L'	,a)$	$L' \to ,SL'
$)L'S,	,a)$	Matched
$)L'S	a)$	$S \to a
$)L'a	a)$	Matched
$)L'	)$	$L' \to \varepsilon
$)	)$	Matched
$	.$	Accepted.

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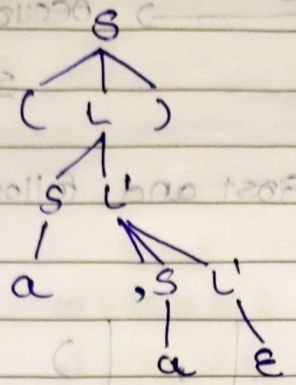
⑤ Parse tree generation.



Eg: S → iEtSeS | iEtS | a (capital (S)) Q. [is it LL(1) parser?]
E → b

↓ removing left factoring.

① S → iEtSS' | a
S' → eS | ε
E → b

② First and Follow.

	First	Follow
S	{i, a}	{e, $}
S'	{e, ε}	{e, $}
E	{b}	{t}

③ Parse table.

	i	a	e	$	b	t
S	S→iEtSS'	S→a				
S'			S'→eS S'→ε	S'→ε		
E					E→b	

so it is not LL(1) parser.

④ Stack implementation:

Eg. $S \to ACB \mid CbB \mid Ba$

$A \to da \mid BC$ → capital.

$B \to g \mid \varepsilon$

$C \to h \mid \varepsilon$

⇒ ① Parse table:

not a LL(1) parser.

	a	d	g	h	c	$
S	S→Ba	S→ACB	S→ACB	S→ACB	S→CbB S→ACB	
A		A→da	A→BC	A→BC		
B	B→ε		B→g	B→ε	B→ε	B→ε
C				C→h	C→ε	

Eg. $S \to S'\#$

$S' \to AB$

$A \to aA'$

$A' \to a \mid \varepsilon$

$B \to b \mid ac$

String: aac#

Q. Does it parse a string?

⇒ First and Follow.

	First	Follow
S	{a, b, a}	{$}
S'	{a}	{#}
A	{a}	{b, a}
A'	{a, ε}	{b, a}
B	{b, a}	{#}

⇒ parse table:

	a	b	$	#
S	S→S'#			
S'	S'→AB			
A	A→aA'			
A'	A'→a / A'→ε	A'→ε		
B	B→ac	B→b		

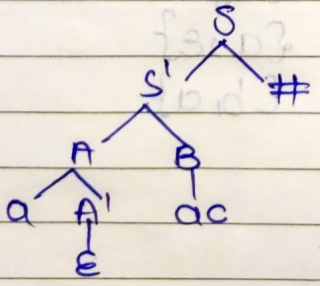
not a LL(1) parser.

⇒ stack implementation:

stack	i/p	action
$S	aac#$	S→S'#
$#S'	aac#$	S'→AB
$#BA	aac#$	A→aA'
$#BA'a	aac#$	Matched
$#BA'	ac#$	A'→ε
$#B	ac#$	B→ac
$#ca	ac#$	Matched
$#c	c#$	Matched
$#	#$	Matched
$	$	Accepted.

But we can't accept string b/c there are two distinct ways to generate a parse string.

⇒ parse tree:



Eg: D → int L;
L → id E
E → E [num] | [num]

String: int a[2];

⇒ ① D → int L;
L → id E
E → [num] E'
E' → [num] E' / ε

② first and follow.

	first	follow
D	{int}	{$}
L	{id}	{;}
E	{[num]}	{;}
E'	{[num], ε}	{;}

③ parse table.

	int	id	[num]	;	$
D	D→int L;				
L		L→id E			
E			E→[num] E'		
E'			E'→[num]E'	E'→ε	

⇒ It is LL(1) parser.

④ Stack implementation:

Stack	i/p	action
$D	int a[2];$	D→ int L;
$;L int	int a[2];$	Matched.

$; L	a[2];$	L → id E
$; E id	a[2];$	Matched
$; E	[2];$	E → [num] E'
$; E' [num]	[num];$	Matched
$; E'	;$	E' → ε
$;	;$	Matched
$	$	Accepted.

⑤ parse tree: