Language Processing Systems

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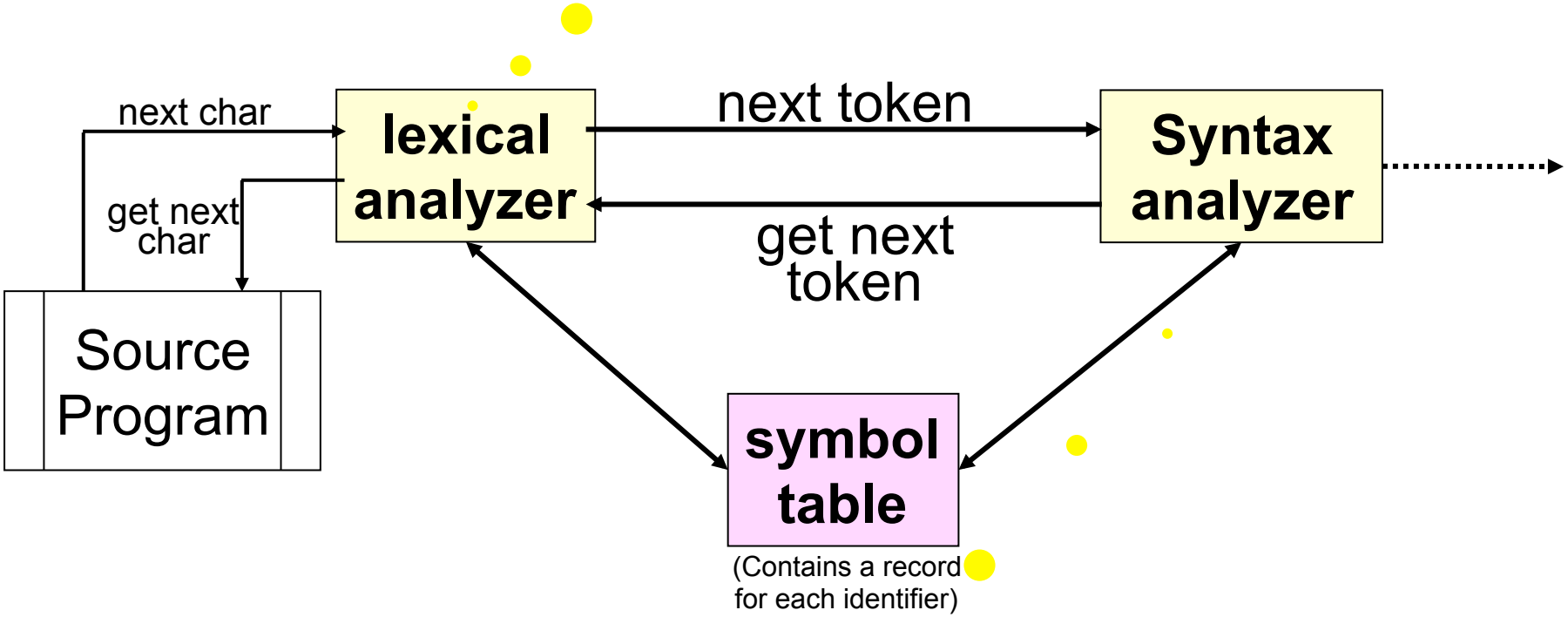
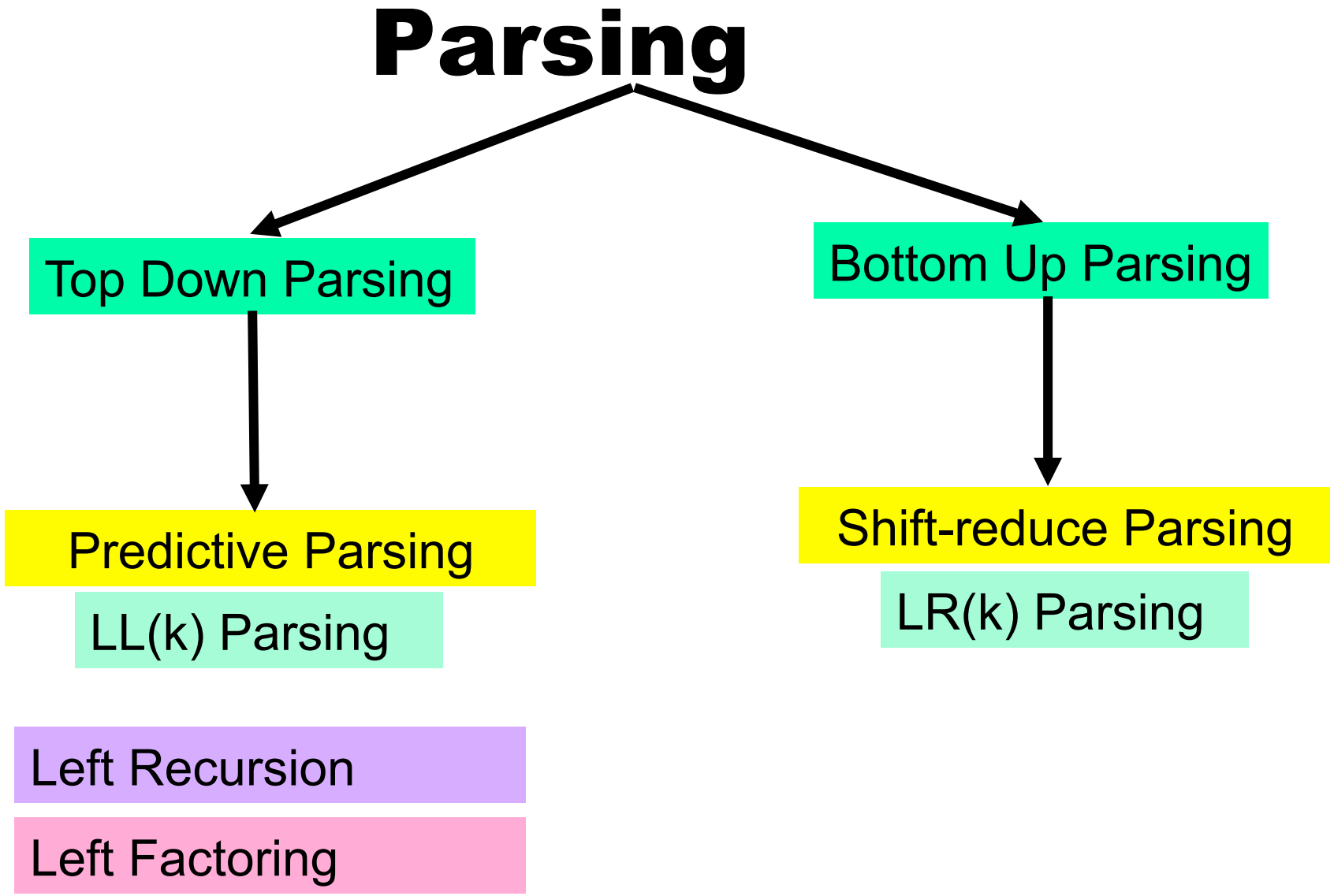
Syntax Analysis
(Parsing)

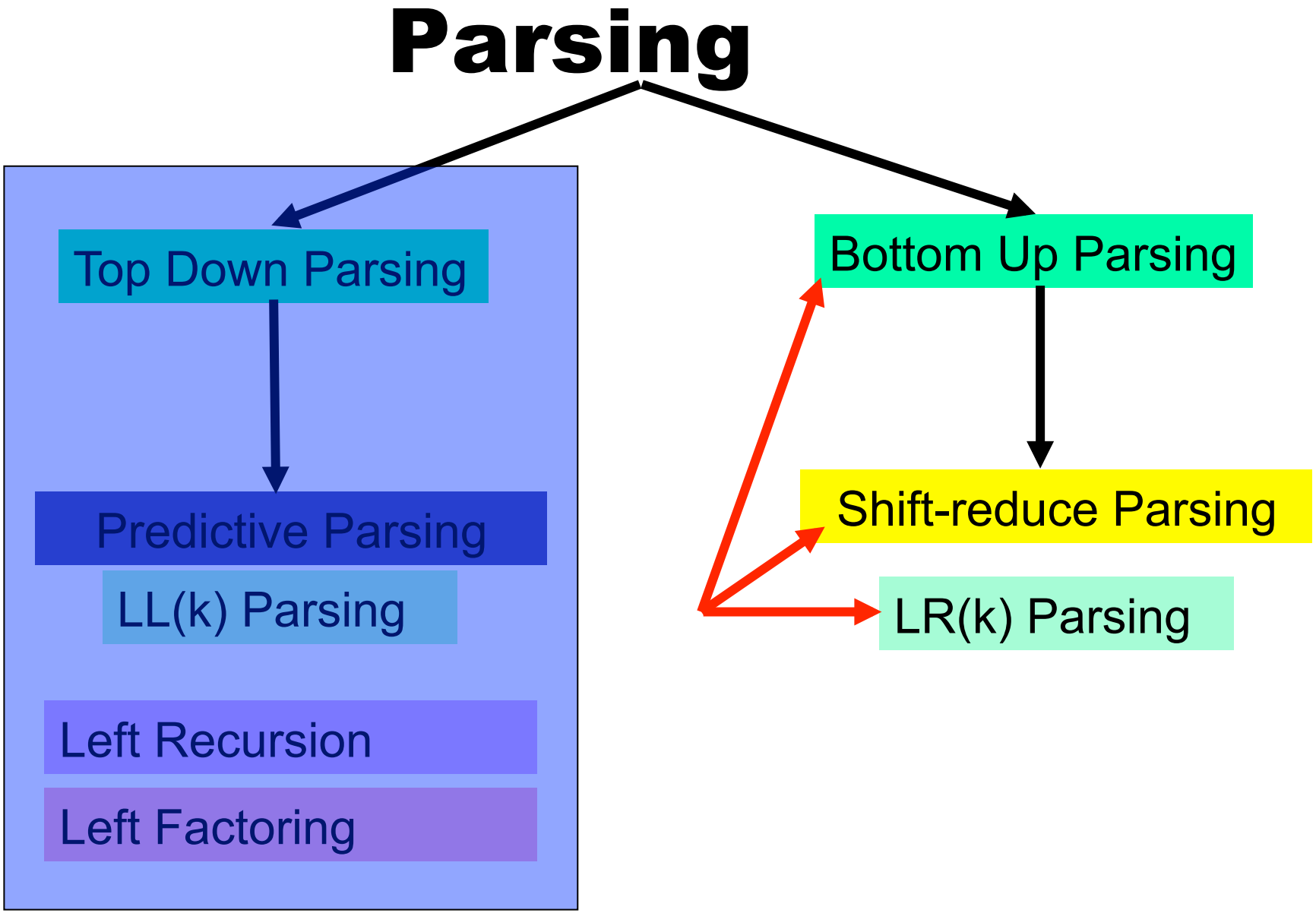
1. Uses Regular Expressions to define tokens
2. Uses Finite Automata to recognize tokens



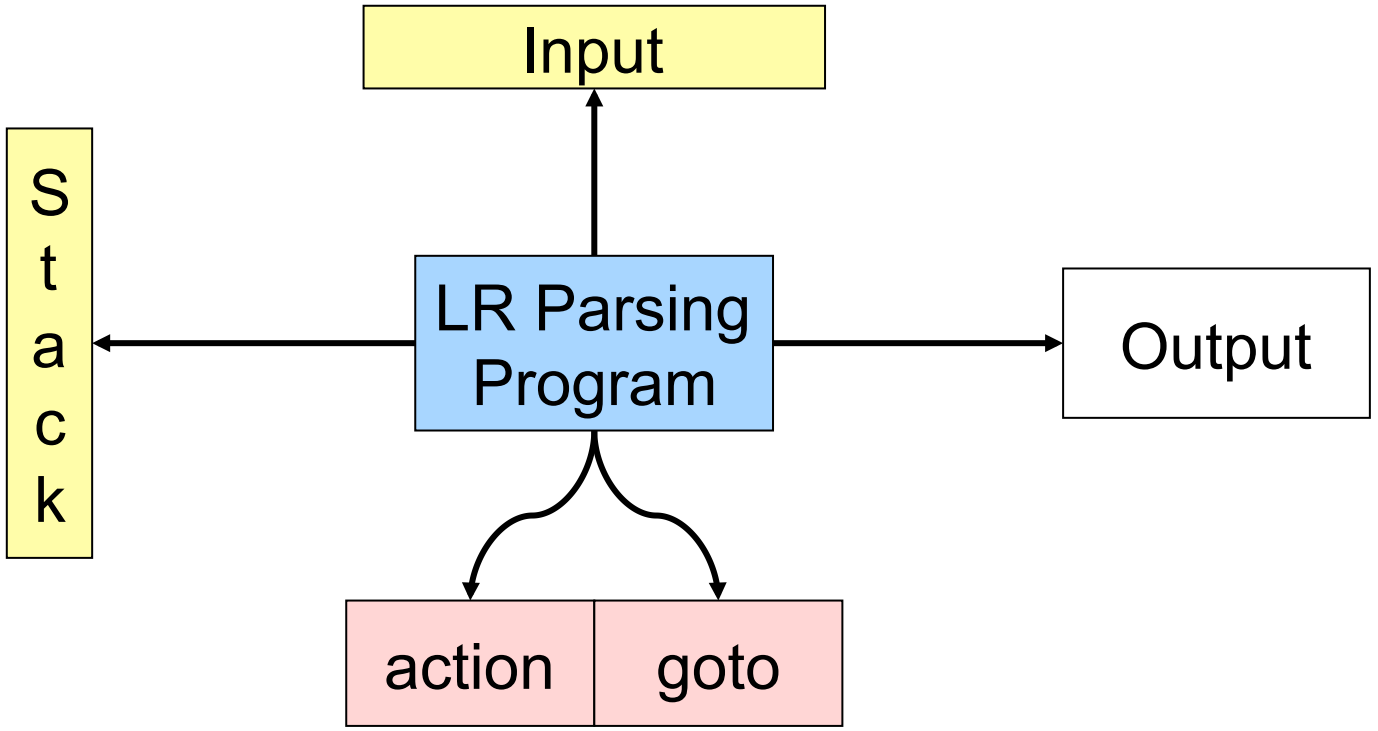
Uses Top-down parsing or Bottom-up parsing

To construct a Parse tree


Parsing
Top Down Parsing
Bottom Up Parsing
Predictive Parsing
LL(k) Parsing
Shift-reduce Parsing
LR(k) Parsing
Left Recursion
Left Factoring


Parsing
Top Down Parsing
Predictive Parsing
LL(k) Parsing
Left Recursion
Left Factoring
Bottom Up Parsing
Shift-reduce Parsing
LR(k) Parsing

LR Parser Example



Shift reduce parser

1. Construct the *action-goto table* from the given grammar

2. Apply the shift-reduce parsing algorithm to construct the parse tree

Shift reduce parser

1. Construct the *action-goto table* from the given grammar

This is what make difference between different typs of shift reduce parsing such as SLR, CLR, LALR

In this course due to short of time we will not study how to construct the ***action-goto table***

Shift reduce parser

2. Apply the shift-reduce parsing algorithm to construct the parse tree

The following algorithm shows how we can construct the move parsing table for an input string w$ with respect to a given grammar G.

```
set ip to point to the first symbol of the input string w$
repeat forever
begin
        if action[top(stack), current-input(ip)] = shift(s)  then begin
              push current-input(ip) then s on top of the stack
              advance ip to the next input symbol
        end
        else if action[top(stack), current-input(ip)] = reduce A → β then
        begin
            pop 2*|β| symbols off the stack;
            push A then goto[top(stack), A] on top of the stack;
            output the production A → β
        end
        else if action[top(stack), current-input(ip)] = accept then
                    return
        else error()
 end
```

LR Parser Example

The following grammar:

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

s represents shift

r represents reduce

acc represents accept

empty represents error

Can be parsed with this action and goto table

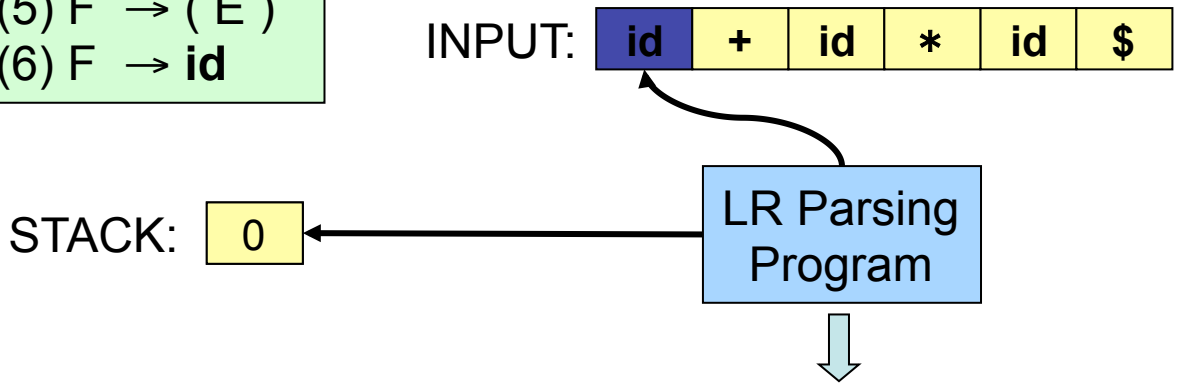
State	action						goto		
	id	**+**	*****	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
2		r2	s7		r2	r2			
3		r4	r4		r4	r4			
4	s5			s4			8	2	3
5		r6	r6		r6	r6			
6	s5			s4				9	3
7	s5			s4					10
8		s6			s11				
9		r1	s7		r1	r1			
10		r3	r3		r3	r3			
11		r5	r5		r5	r5			

GRAMMAR:

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

Parser Example

OUTPUT:



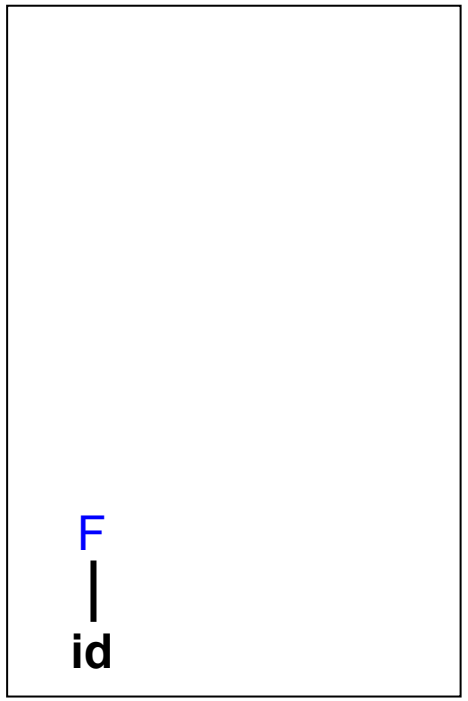
State	action						goto		
	id	+	*	(	)	$	E	T	F
0	s5			s4			1	2	3
1		s6				acc			
2		r2	s7		r2	r2			
3		r4	r4		r4	r4			
4	s5			s4			8	2	3
5		r6	r6		r6	r6			
6	s5			s4				9	3
7	s5			s4					10
8		s6			s11				
9		r1	s7		r1	r1			
10		r3	r3		r3	r3			
11		r5	r5		r5	r5			

GRAMMAR:

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

Parser Example

OUTPUT:



INPUT: | **id** | * | **id** | + | **id** | $ |

STACK:

5
id
0

LR Parsing Program

State	action						goto		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
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			

Parser Example

GRAMMAR:

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

INPUT: | **id** | * | **id** | + | **id** | **$** |

STACK: 0

LR Parsing Program

OUTPUT:

F
|
id

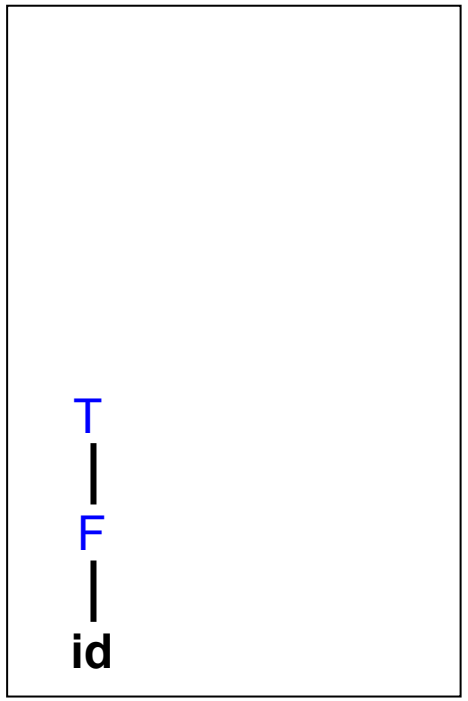
State	action						goto		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
2		r2	s7		r2	r2			
3		r4	r4		r4	r4			
4	s5			s4			8	2	3
5		r6	r6		r6	r6			
6	s5			s4				9	3
7	s5			s4					10
8		s6			s11				
9		r1	s7		r1	r1			
10		r3	r3		r3	r3			
11		r5	r5		r5	r5			

GRAMMAR:

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

Parser Example

OUTPUT:



INPUT: | **id** | * | **id** | + | **id** | **$** |

STACK:

3
F
0

LR Parsing Program

State	action						goto		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
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			

Parser Example

GRAMMAR:

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

INPUT: | **id** | * | **id** | + | **id** | **$** |

STACK: 0

LR Parsing Program

OUTPUT:

T
|
F
|
id

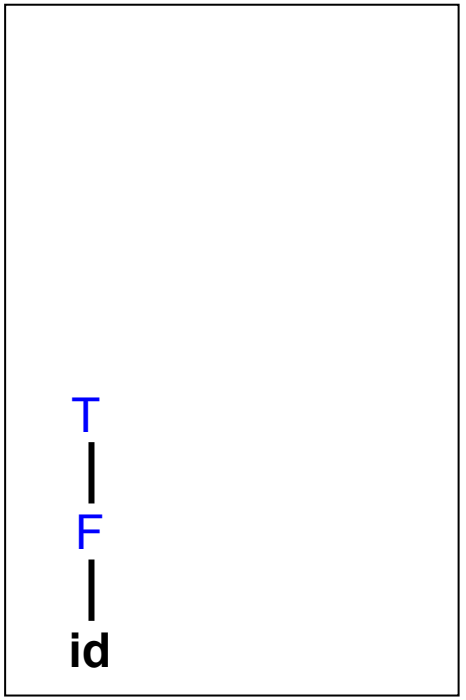
State	action						goto		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
2		r2	s7		r2	r2			
3		r4	r4		r4	r4			
4	s5			s4			8	2	3
5		r6	r6		r6	r6			
6	s5			s4				9	3
7	s5			s4					10
8		s6			s11				
9		r1	s7		r1	r1			
10		r3	r3		r3	r3			
11		r5	r5		r5	r5			

GRAMMAR:

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

Parser Example

OUTPUT:



INPUT: | **id** | * | **id** | **+** | **id** | **$** |

STACK:

2
T
0

LR Parsing Program

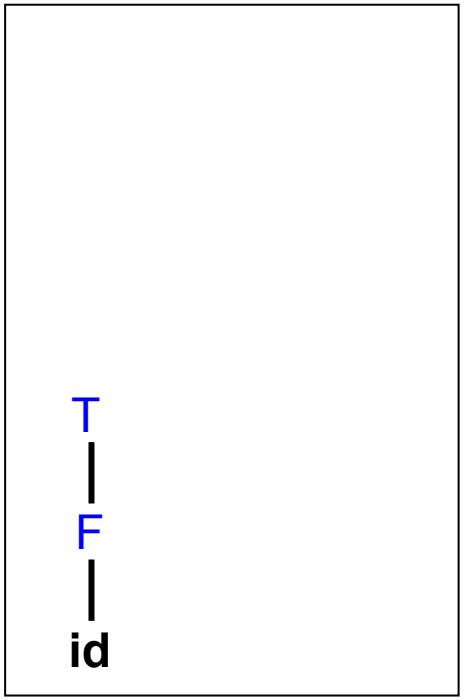
State	action						goto		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
2		r2	s7		r2	r2			
3		r4	r4		r4	r4			
4	s5			s4			8	2	3
5		r6	r6		r6	r6			
6	s5			s4				9	3
7	s5			s4					10
8		s6			s11				
9		r1	s7		r1	r1			
10		r3	r3		r3	r3			
11		r5	r5		r5	r5			

GRAMMAR:

(1) E → E + T
(2) E' → T
(3) T → T * F
(4) T → F
(5) F → (E)
(6) F → **id**

Parser Example

OUTPUT:



INPUT: | **id** | * | **id** | + | **id** | **$** |

STACK:

7
*
2
T
0

LR Parsing Program

State	**action**						**goto**		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
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			

Parser Example

GRAMMAR:

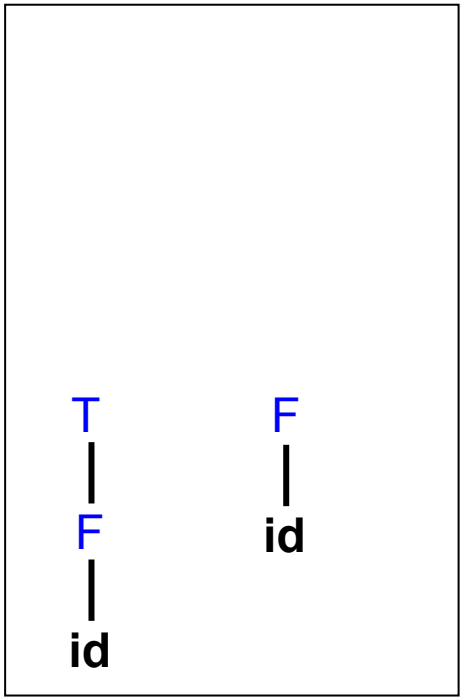
(1) E → E + T
(2) E' → T
(3) T → T * F
(4) T → F
(5) F → (E)
(6) F → **id**

INPUT: | **id** | * | **id** | **+** | **id** | **$** |

STACK: | 5 | **id** | 7 | * | 2 | **T** | 0 |

LR Parsing Program

OUTPUT:



State	action						goto		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
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			

Parser Example

GRAMMAR:

(1) E → E + T
(2) E' → T
(3) T → T * F
(4) T → F
(5) F → (E)
(6) F → **id**

INPUT: | **id** | * | **id** | **+** | **id** | **$** |

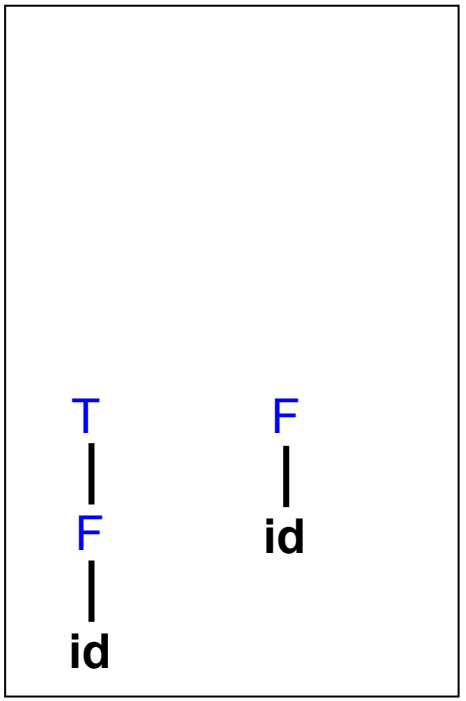
STACK:

7
*
2
T
0

LR Parsing Program

State	action						goto		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
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			

OUTPUT:



Parser Example

GRAMMAR:

(1) E → E + T
(2) E' → T
(3) T → T * F
(4) T → F
(5) F → (E)
(6) F → **id**

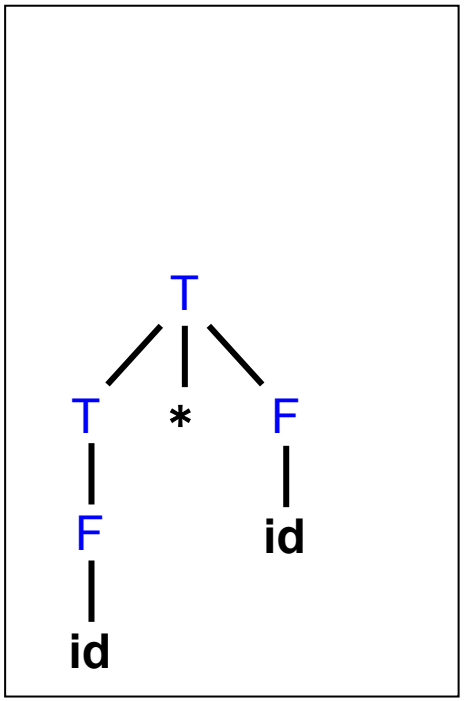
INPUT: | id | * | id | + | id | $ |

STACK: | 10 | **F** | 7 | * | 2 | **T** | 0 |

LR Parsing Program

State	action						goto		
	id	+	*	(	)	$	E	T	F
0	s5			s4			1	2	3
1		s6				acc			
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			

OUTPUT:



Parser Example

GRAMMAR:

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

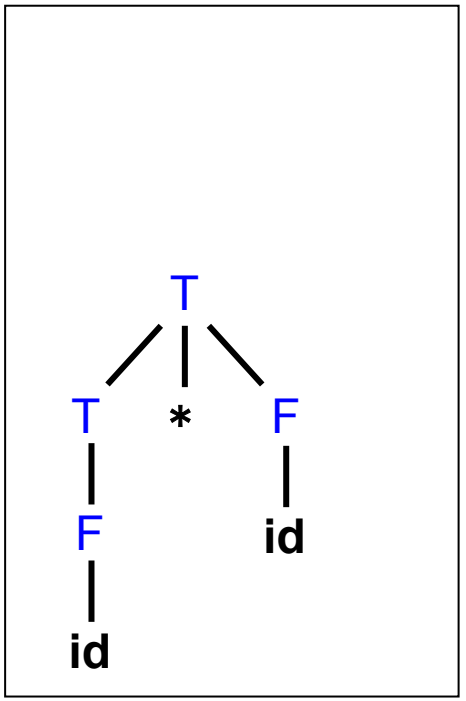
INPUT: | **id** | * | **id** | **+** | **id** | **$** |

STACK: 0

LR Parsing Program

State	action						goto		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
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			

OUTPUT:

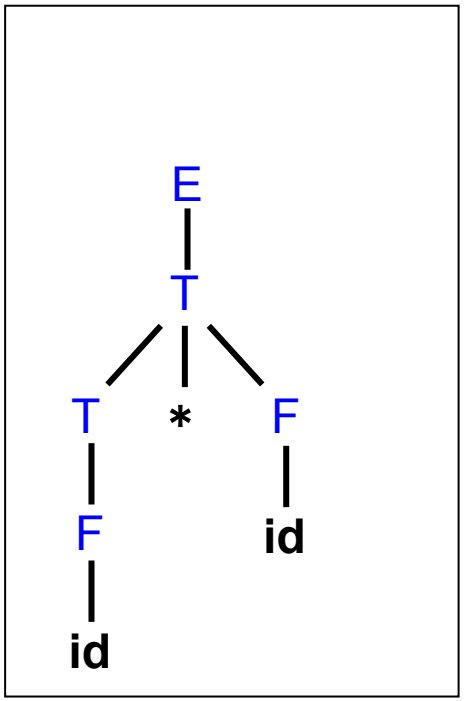


GRAMMAR:

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

Parser Example

OUTPUT:



INPUT: | **id** | * | **id** | **+** | **id** | **$** |

STACK:

2
T
0

LR Parsing Program

State	action						goto		
	id	**+**	*	(	)	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
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			

Parser Example

GRAMMAR:

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

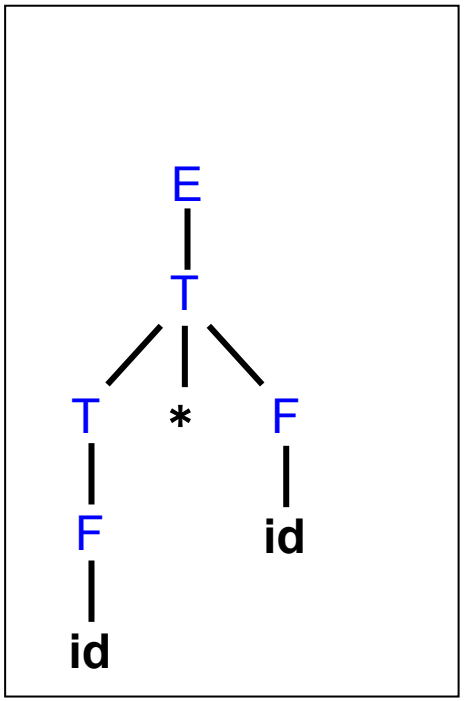
INPUT: | **id** | * | **id** | **+** | **id** | **$** |

STACK: 0

LR Parsing Program

State	action						goto		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
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			

OUTPUT:

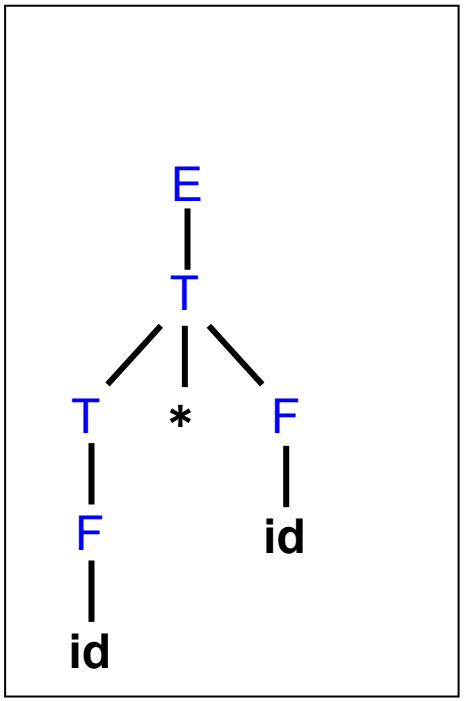


GRAMMAR:

(1) E → E + T
(2) E' → T
(3) T → T * F
(4) T → F
(5) F → (E)
(6) F → **id**

Parser Example

OUTPUT:



INPUT:

id	*	id	+	id	$

STACK:

1
E
0

LR Parsing Program

State	action						goto		
	id	+	*	(	)	$	E	T	F
0	s5			s4			1	2	3
1		s6				acc			
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			

Parser Example

GRAMMAR:

(1) E → E + T
(2) E' → T
(3) T → T * F
(4) T → F
(5) F → (E)
(6) F → **id**

INPUT:

id	*	id	+	id	$

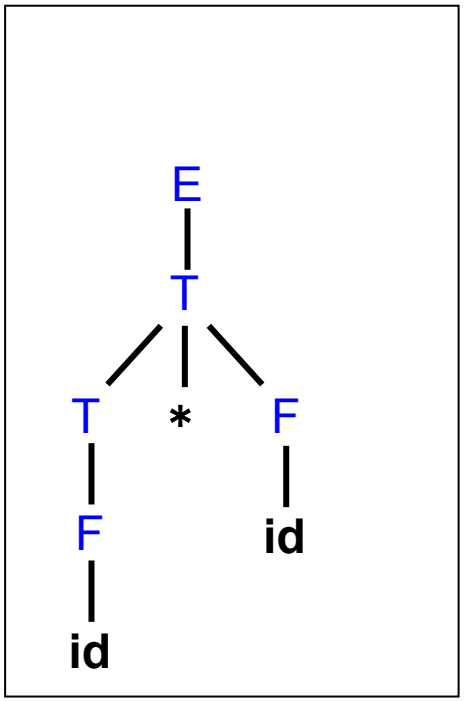
STACK:

6
+
1
E
0

LR Parsing Program

State	action						goto		
	id	+	*	(	)	$	E	T	F
0	s5			s4			1	2	3
1		s6				acc			
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			

OUTPUT:



Parser Example

GRAMMAR:

(1) E → E + T
(2) E' → T
(3) T → T * F
(4) T → F
(5) F → (E)
(6) F → **id**

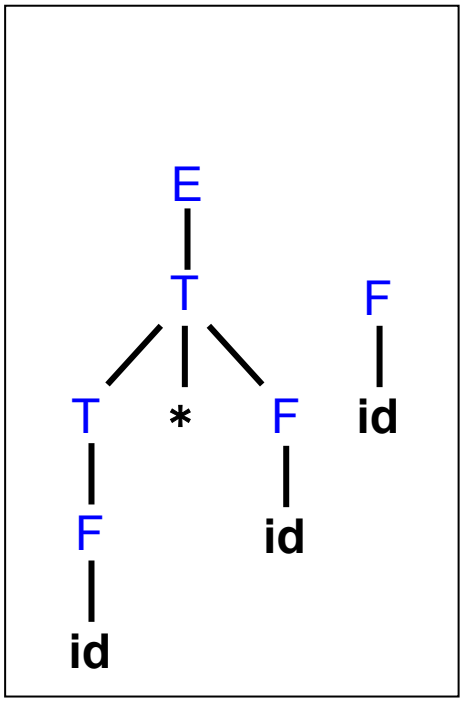
INPUT: | **id** | * | **id** | + | **id** | **$** |

STACK: | 5 | **id** | 6 | **+** | 1 | **E** | 0 |

LR Parsing Program

State	action						goto		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
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			

OUTPUT:



Parser Example

GRAMMAR:

(1) E → E + T
(2) E' → T
(3) T → T * F
(4) T → F
(5) F → (E)
(6) F → **id**

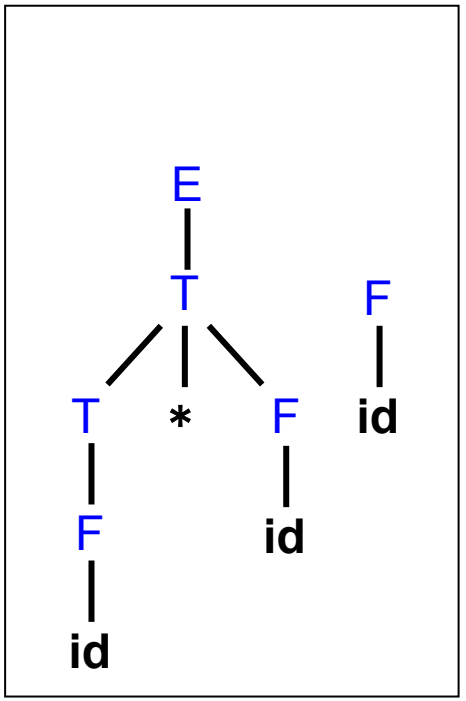
INPUT: | **id** | * | **id** | + | **id** | **$** |

STACK: | 6 | **+** | 1 | **E** | 0 |

LR Parsing Program

State	action						goto		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
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			

OUTPUT:



Parser Example

GRAMMAR:

(1) E → E + T
(2) E' → T
(3) T → T * F
(4) T → F
(5) F → (E)
(6) F → **id**

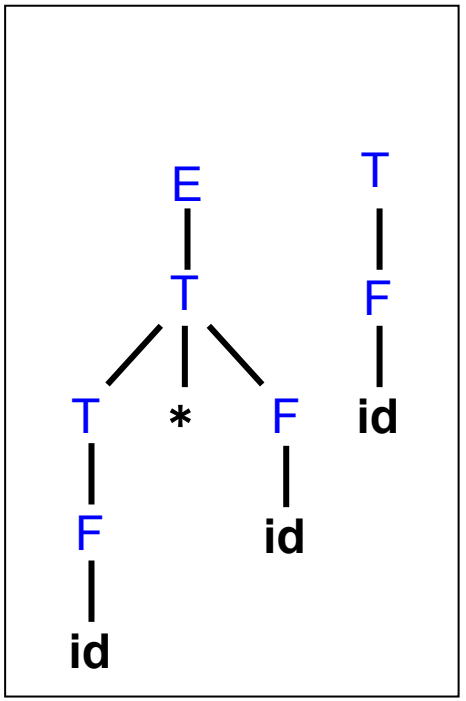
INPUT: | **id** | * | **id** | + | **id** | **$** |

STACK: | 3 | **F** | 6 | **+** | 1 | **E** | 0 |

LR Parsing Program

State	action						goto		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
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			

OUTPUT:



Parser Example

GRAMMAR:

(1) E → E + T
(2) E' → T
(3) T → T * F
(4) T → F
(5) F → (E)
(6) F → **id**

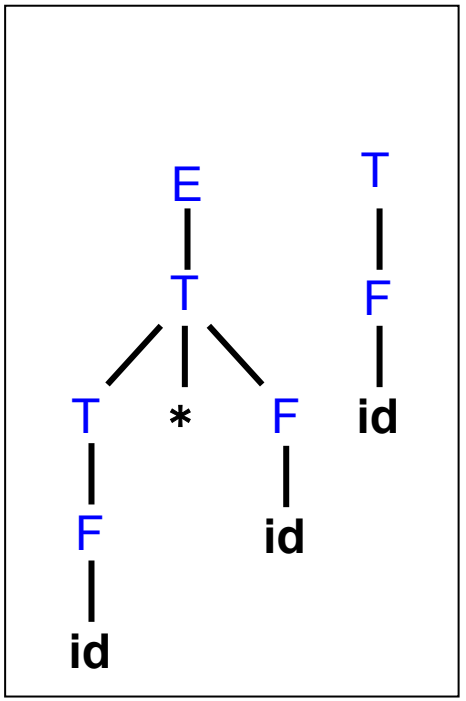
INPUT: | **id** | * | **id** | + | **id** | **$** |

STACK: | 6 |
| **+** |
| 1 |
| **E** |
| 0 |

LR Parsing Program

State	action						goto		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
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			

OUTPUT:



Parser Example

GRAMMAR:

(1) E → E + T
(2) E' → T
(3) T → T * F
(4) T → F
(5) F → (E)
(6) F → **id**

INPUT: | **id** | * | **id** | + | **id** | **$** |

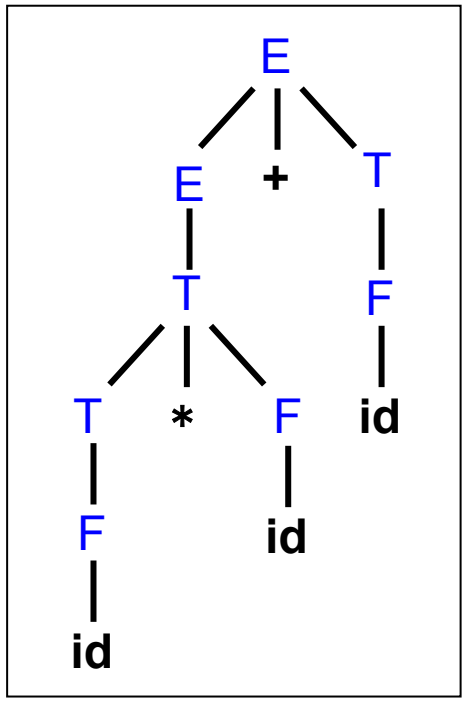
STACK:

9
T
6
+
1
E
0

LR Parsing Program

State	action						goto		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
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			

OUTPUT:



Parser Example

GRAMMAR:

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

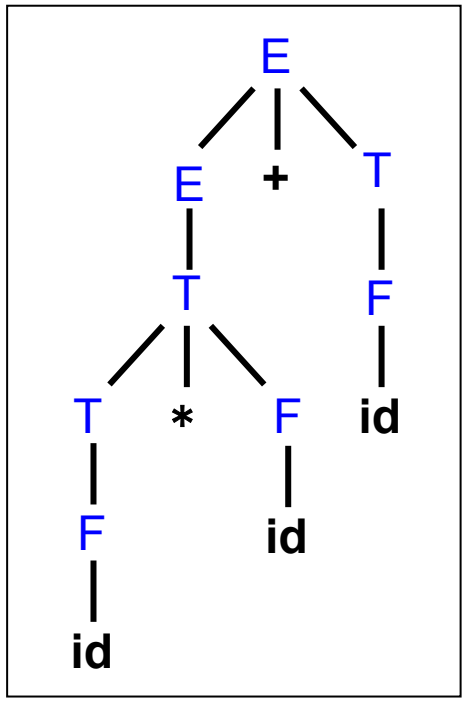
INPUT: | **id** | * | **id** | + | **id** | **$** |

STACK: 0

LR Parsing Program

State	action						goto		
	id	**+**	*	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
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			

OUTPUT:

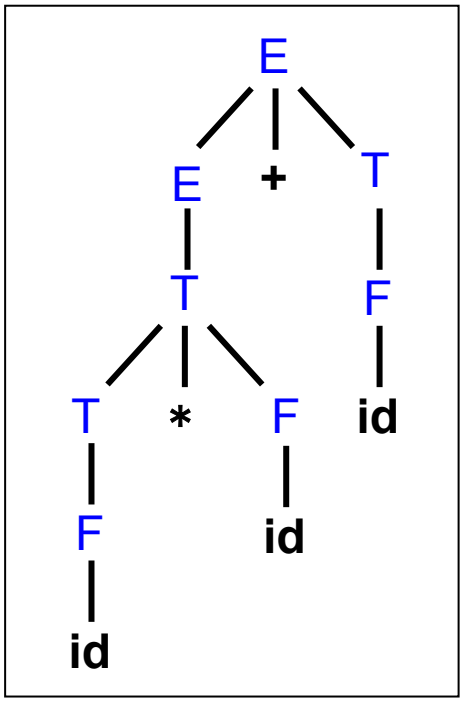


GRAMMAR:

(1) E → E + T
(2) E' → T
(3) T → T * F
(4) T → F
(5) F → (E)
(6) F → **id**

Parser Example

OUTPUT:



INPUT: | id | * | id | + | id | $ |

STACK:

1
E
0

LR Parsing Program

State	action						goto		
	id	**+**	*****	**(**	**)**	**$**	**E**	**T**	**F**
0	s5			s4			1	2	3
1		s6				acc			
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			

Constructing Parsing Tables

All LR parsers use the same parsing program that we demonstrated in the previous slides.

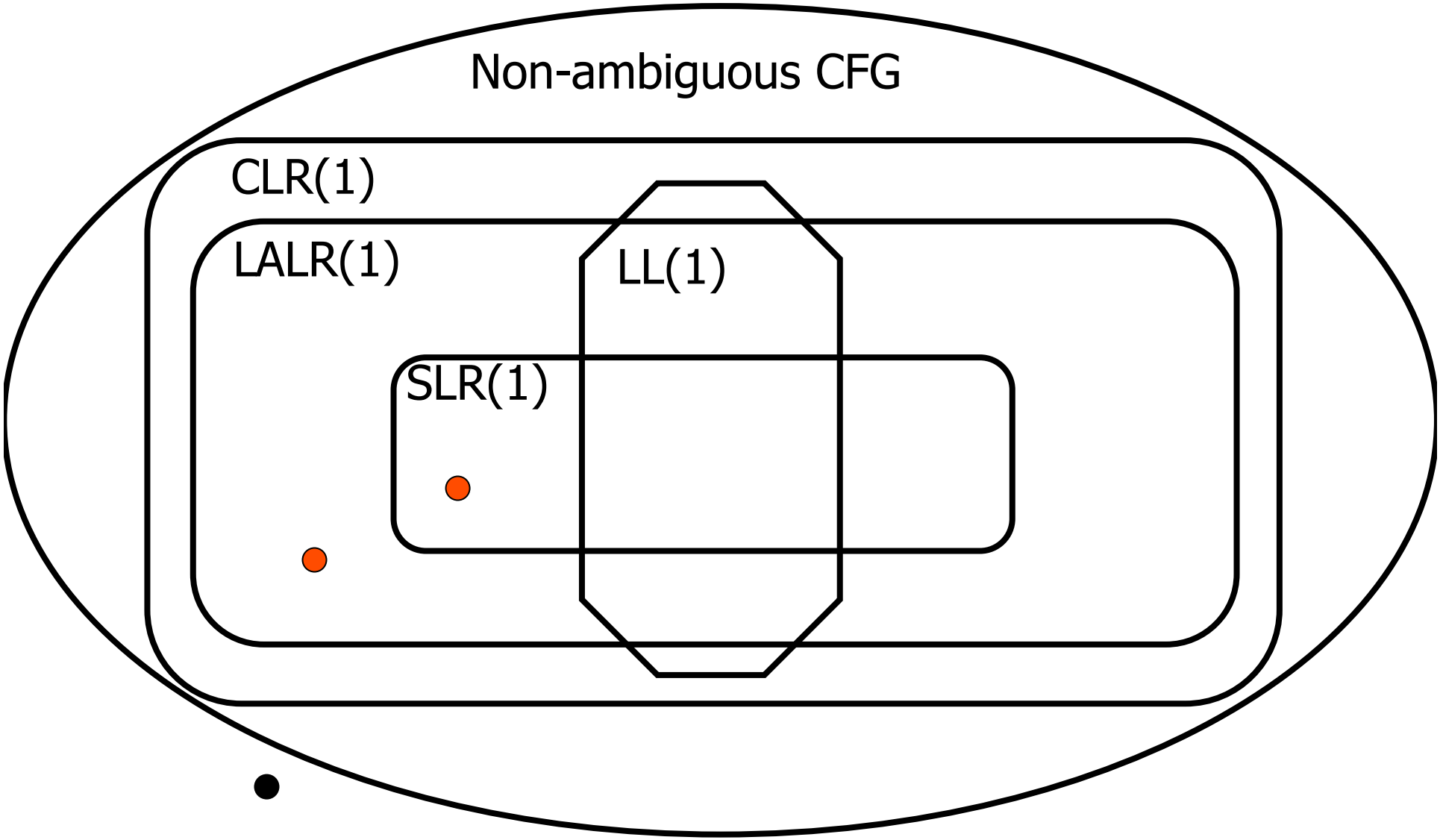
What differentiates the LR parsers are the action and the goto tables:

Simple LR (SLR): succeeds for the fewest grammars, but is the easiest to implement.

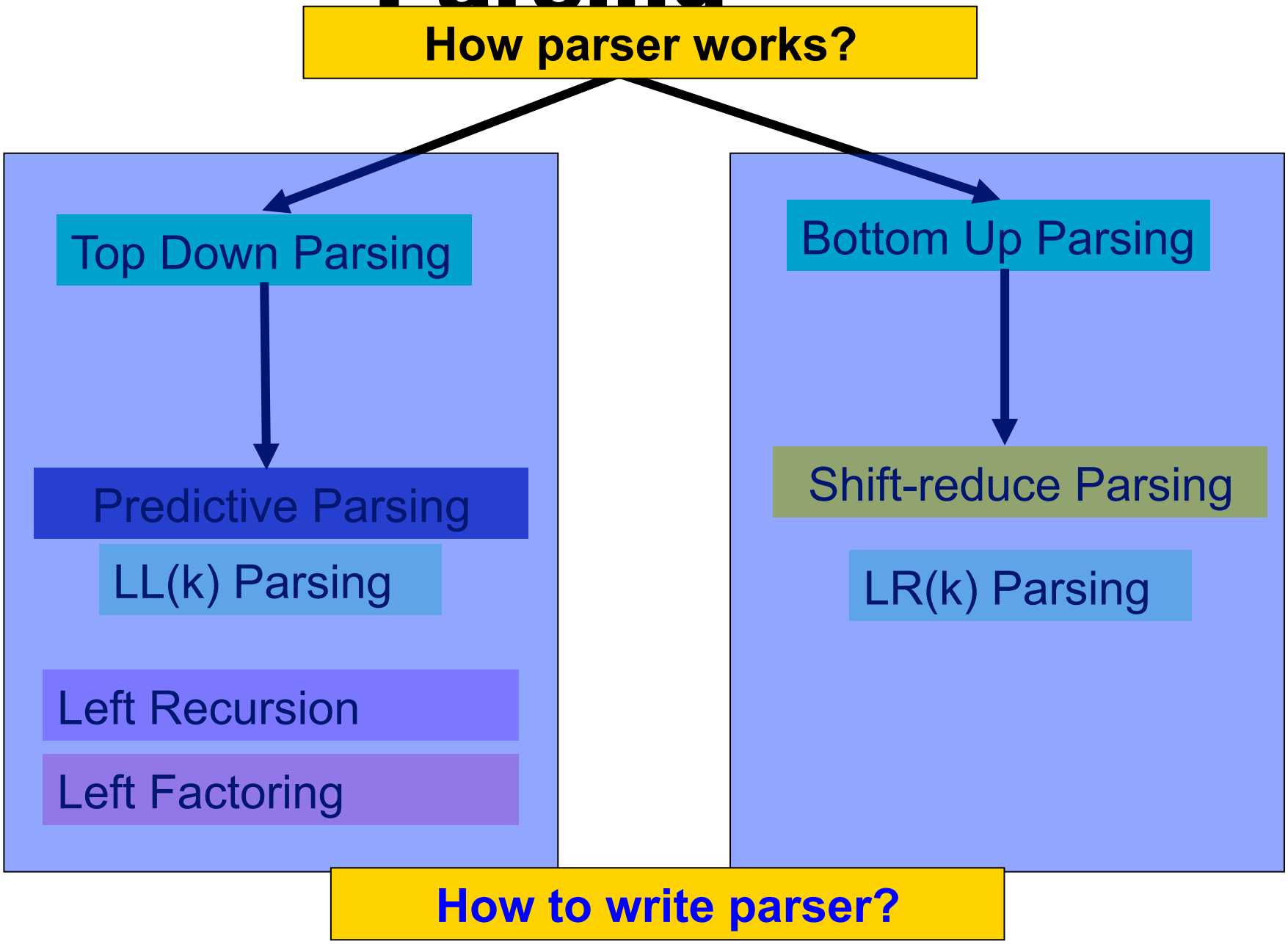
Canonical LR: succeeds for the most grammars, but is the hardest to implement. It splits states when necessary to prevent reductions that would get the parser stuck.

Lookahead LR (LALR): succeeds for most common syntactic constructions used in programming languages, but produces LR tables much smaller than canonical LR.

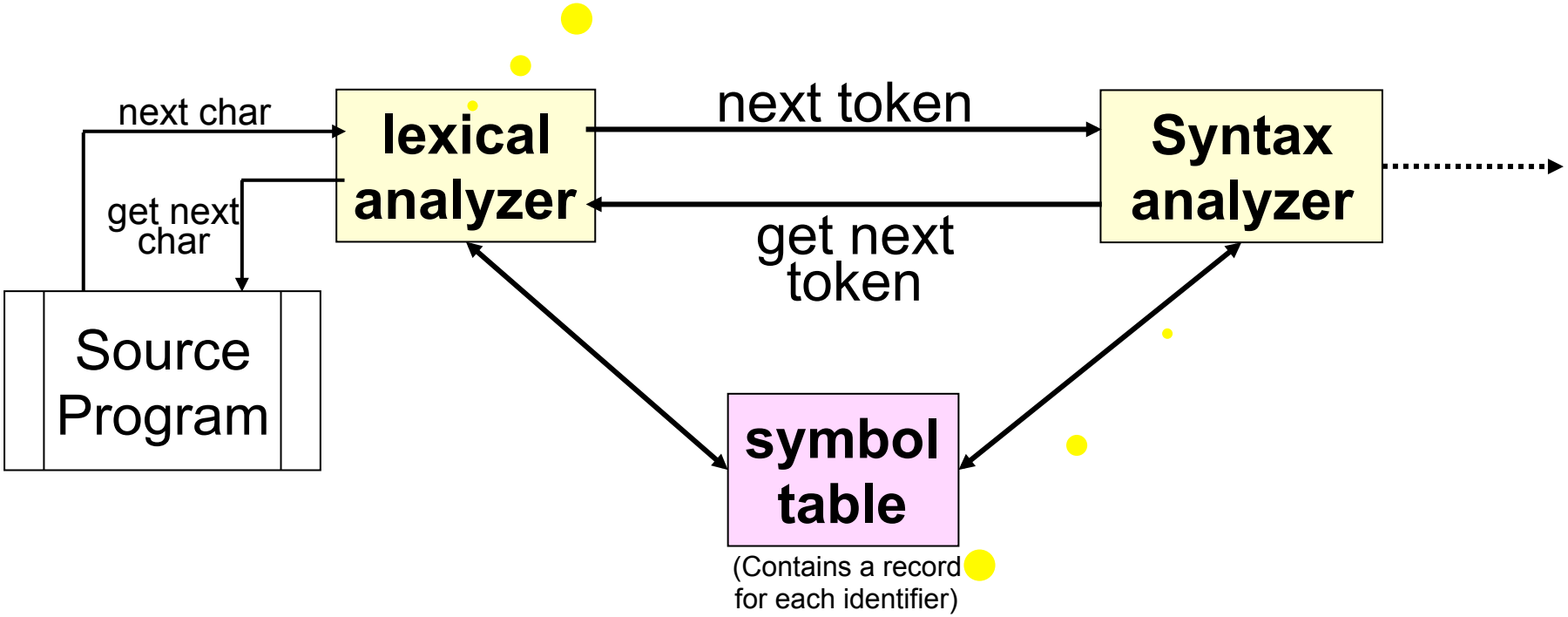
Grammar Hierarchy



Parsing


How parser works?
Top Down Parsing
Predictive Parsing
LL(k) Parsing
Left Recursion
Left Factoring
Bottom Up Parsing
Shift-reduce Parsing
LR(k) Parsing
How to write parser?

1. Uses Regular Expressions to define tokens
2. Uses Finite Automata to recognize tokens



Uses Top-down parsing or Bottom-up parsing

To construct a Parse tree

How to write a parser?

Yacc