Unit 4
BNF and Syntax Diagrams

Backus-Naur form and variants

- **Metasyntax**: a syntax used to describe the syntax of languages,
- **BNF (**Backus–Naur Form) is a metasyntax used to express context free grammars
- BNF is widely used as a notation for the grammars programming languages, instruction sets, communication protocols and parts of natural language grammars

Backus-Naur form and variants (cont)

- A set of rules is specified. These are known as **production** rules.
- Each production rule defines the pattern that represents a named structured part of the language
- The name of such a part is called a **non-terminal** symbol in the language.
- The basic elements of the language are called **terminal** symbols.

Backus-Naur form and variants (cont)

- Each rule contains the name of the non-terminal being defined, followed by the sequence or alternative sequences allowed for that symbol. A defining sequence can contain any terminal and non-terminal symbols allowed for that language.
- The definition of a rule can also contain the symbol being defined by that rules. This is called **recursive** definition.

Example: Grammar for Arithmetic Expressions

- **Productions**

```
<Exp>    ::=
           “+”<Expr2>|”-”<Expr2>|<Expr2>
<Expr2> ::= <Term><Expr3>
<Expr3> ::= “+” <Term><Expr3>|
             ”-”<Term><Expr3>|ε
<Term>  ::= <Factor> <Term2>
<Term2> ::= “*” <Factor> <Term2> |”/”<Factor> <Term2>|ε
<Factor> ::=“ident”|”number”|”(“<Exp>”)”
```

- **Terminal symbols**
  - simple TS: "+", "-", "*", "/", "(", ")"
  - terminal classes: “ident”, “number”
- **Nonterminal symbols**
  - <Expr>, <Expr2>, <Expr3>, <Term>, <Term2>, <Factor>
- **Start symbol**
  - <Expr>

EBNF(Extended BNF)

- Terminal symbols start with lower-case letters
- Nonterminal symbols start with upper-case letters
- **Metasymbols**
  - | (...) separates alternatives groups
  - [...] alternatives optional part
  - {...} iterative part

KPL Grammar in BNF

```
01) Prog ::= KW_PROGRAM Ident SB_SEMICOLON Block SB_PERIOD

02) Block  ::= KW_CONST ConstDecl ConstDecls Block2
03) Block  ::= Block2

04) Block2 ::= KW_TYPE TypeDecl TypeDecls Block3
05) Block2 ::= Block3

06) Block3 ::= KW_VAR VarDecl VarDecls Block4
07) Block3 ::= Block4

08) Block4 ::= SubDecls Block5
09) Block5 ::= KW_BEGIN Statements KW_END
```

KPL Grammar in BNF

```
10) ConstDecls::= ConstDecl ConstDecls
11) ConstDecls::= ε

12) ConstDecl ::= Ident SB_EQUAL Constant SB_SEMICOLON

13) TypeDecls ::= TypeDecl TypeDecls
14) TypeDecls ::= ε

15) TypeDecl  ::= Ident SB_EQUAL Type SB_SEMICOLON

16) VarDecls  ::= VarDecl VarDecls
17) VarDecls  ::= ε

18) VarDecl   ::= Ident SB_COLON Type SB_SEMICOLON

19) SubDecls  ::= FunDecl SubDecls
20) SubDecls  ::= ProcDecl SubDecls
21) SubDecls  ::= ε
```

KPL Grammar in BNF

```
22) FunDecl   ::= KW_FUNCTION Ident Params SB_COLON BasicType
                   SB_SEMICOLON Block SB_SEMICOLON

23) ProcDecl  ::= KW_PROCEDURE Ident Params SB_SEMICOLON Block
                   SB_SEMICOLON

24) Params    ::= SB_LPAR Param Params2 SB_RPAR
25) Params    ::= ε

26) Params2 ::= SB_SEMICOLON Param Params2
27) Params2 ::= ε

28) Param   ::= Ident SB_COLON BasicType
29) Param   ::= KW_VAR Ident SB_COLON BasicType
```

KPL Grammar in BNF

```
30) Type ::= KW_INTEGER
31) Type ::= KW_CHAR
32) Type ::= TypeIdent
33) Type ::= KW_ARRAY SB_LSEL Number SB_RSEL KW_OF Type

34) BasicType ::= KW_INTEGER
35) BasicType ::= KW_CHAR

36) UnsignedConstant ::= Number
37) UnsignedConstant ::= ConstIdent
38) UnsignedConstant ::= ConstChar

40) Constant ::= SB_PLUS Constant2
41) Constant ::= SB_MINUS Constant2
42) Constant ::= Constant2
43) Constant ::= ConstChar

44) Constant2::= ConstIdent
45) Constant2::= Number
```

KPL Grammar in BNF

```
46) Statements ::= Statement Statements2

47) Statements2 ::= KW_SEMICOLON Statement Statements2
48) Statements2 ::= ε

49) Statement ::= AssignSt
50) Statement ::= CallSt
51) Statement ::= GroupSt
52) Statement ::= IfSt
53) Statement ::= WhileSt
54) Statement ::= ForSt
55) Statement ::= ε
```

KPL Grammar in BNF

```
56) AssignSt ::= Variable SB_ASSIGN Expession
57) AssignSt ::= FunctionIdent SB_ASSIGN Expression

58) CallSt   ::= KW_CALL ProcedureIdent Arguments

59) GroupSt  ::= KW_BEGIN Statements KW_END

60) IfSt     ::= KW_IF Condition KW_THEN Statement ElseSt

61) ElseSt   ::= KW_ELSE Statement
62) ElseSt   ::= ε

63) WhileSt  ::=  KW_WHILE Condition KW_DO Statement
64) ForSt    ::=  KW_FOR VariableIdent SB_ASSIGN Expression
                  KW_TO Expression KW_DO Statement
```

KPL Grammar in BNF

```
65) Arguments ::= SB_LPAR Expression Arguments2 SB_RPAR
66) Arguments ::= ε

67) Arguments2::= SB_COMMA Expression Arguments2
68) Arguments2::= ε

68) Condition ::= Expression Condition2

69) Condition2::= SB_EQ Expression
70) Condition2::= SB_NEQ Expression
71) Condition2::= SB_LE Expression
72) Condition2::= SB_LT Expression
73) Condition2::= SB_GE Expression
74) Condition2::= SB_GT Expression
```

KPL Grammar in BNF

```
75) Expression ::= SB_PLUS Expression2
76) Expression ::= SB_MINUS Expression2
77) Expression ::= Expression2

78) Expression2 ::= Term Expression3

79) Expression3 ::= SB_PLUS Term Expression3
80) Expression3 ::= SB_MINUS Term Expression3
81) Expression3 ::= ε

82) Term ::= Factor Term2

83) Term2 ::= SB_TIMES Factor Term2
84) Term2 ::= SB_SLASH Factor Term2
85) Term2 ::= ε
```

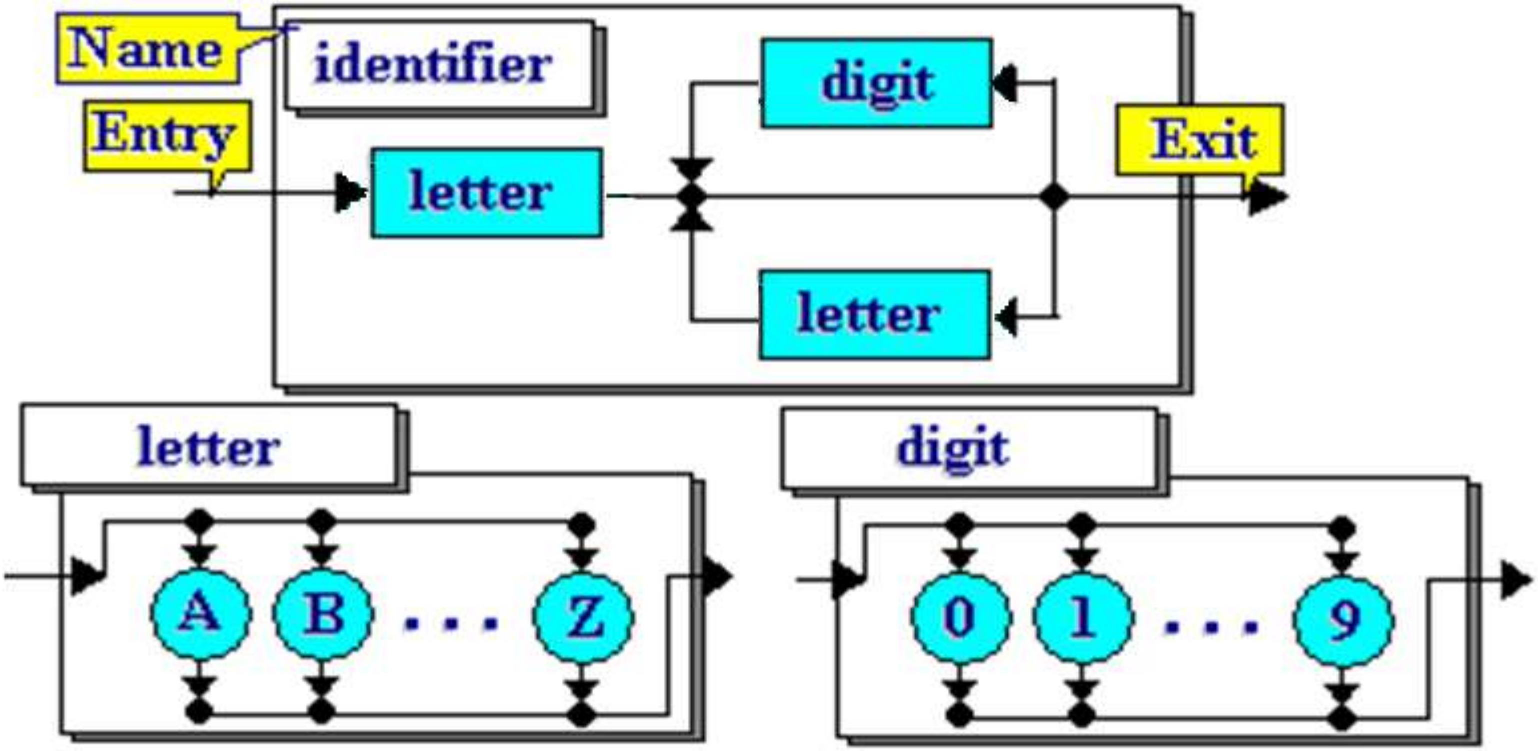
KPL Grammar in BNF

```
86) Factor ::= UnsignedConstant
87) Factor ::= Variable
88) Factor ::= FunctionApplication
89) Factor ::= SB_LPAR Expression SB_RPAR

90) Variable ::= VariableIdent Indexes
91) FunctionApplication ::= FunctionIdent Arguments

92) Indexes ::= SB_LSEL Expression SB_RSEL Indexes
93) Indexes ::= ε
```

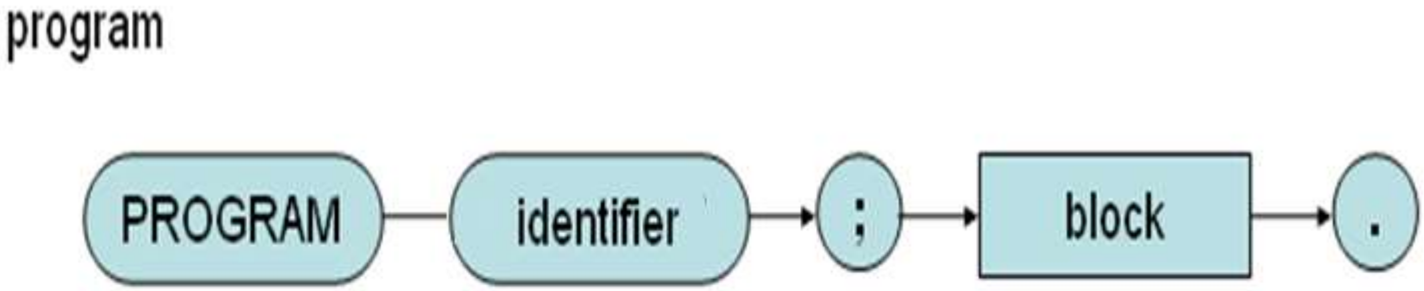
Syntax Diagram

- Each diagram defines a non-terminal
- There is a main diagram which defines the language
- Each diagram has an entry point and an end point
- Terminals are represented by round boxes
- Nonterminals are represented by square boxes.

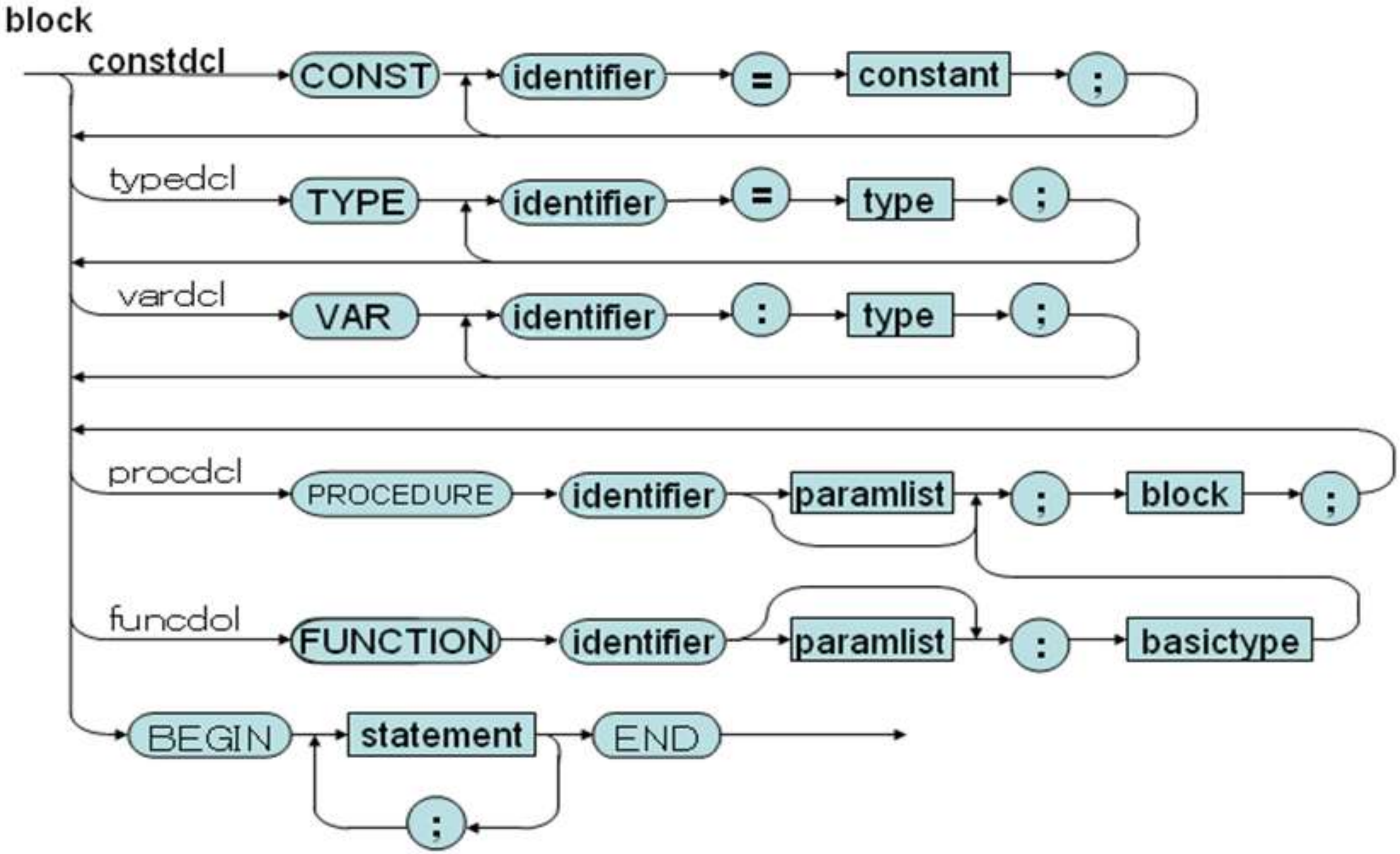
Examples of syntax diagram



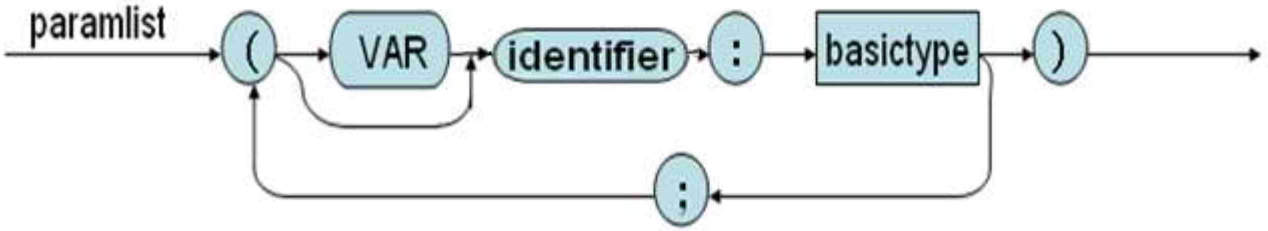
Syntax Diagrams of KPL (program)

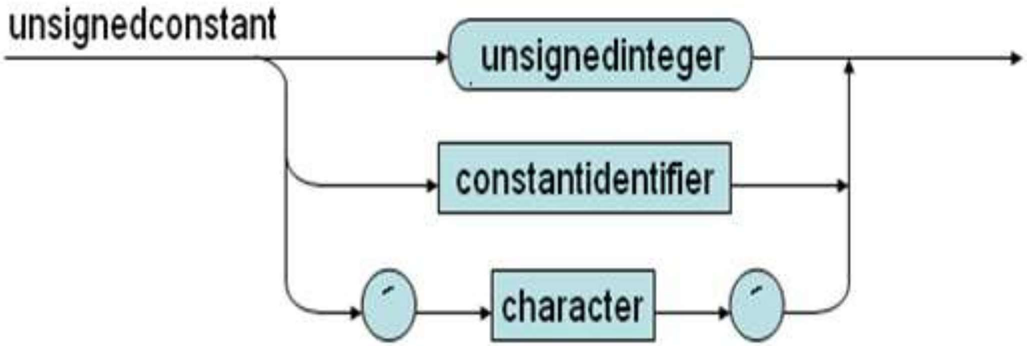


Syntax Diagrams of KPL(block)

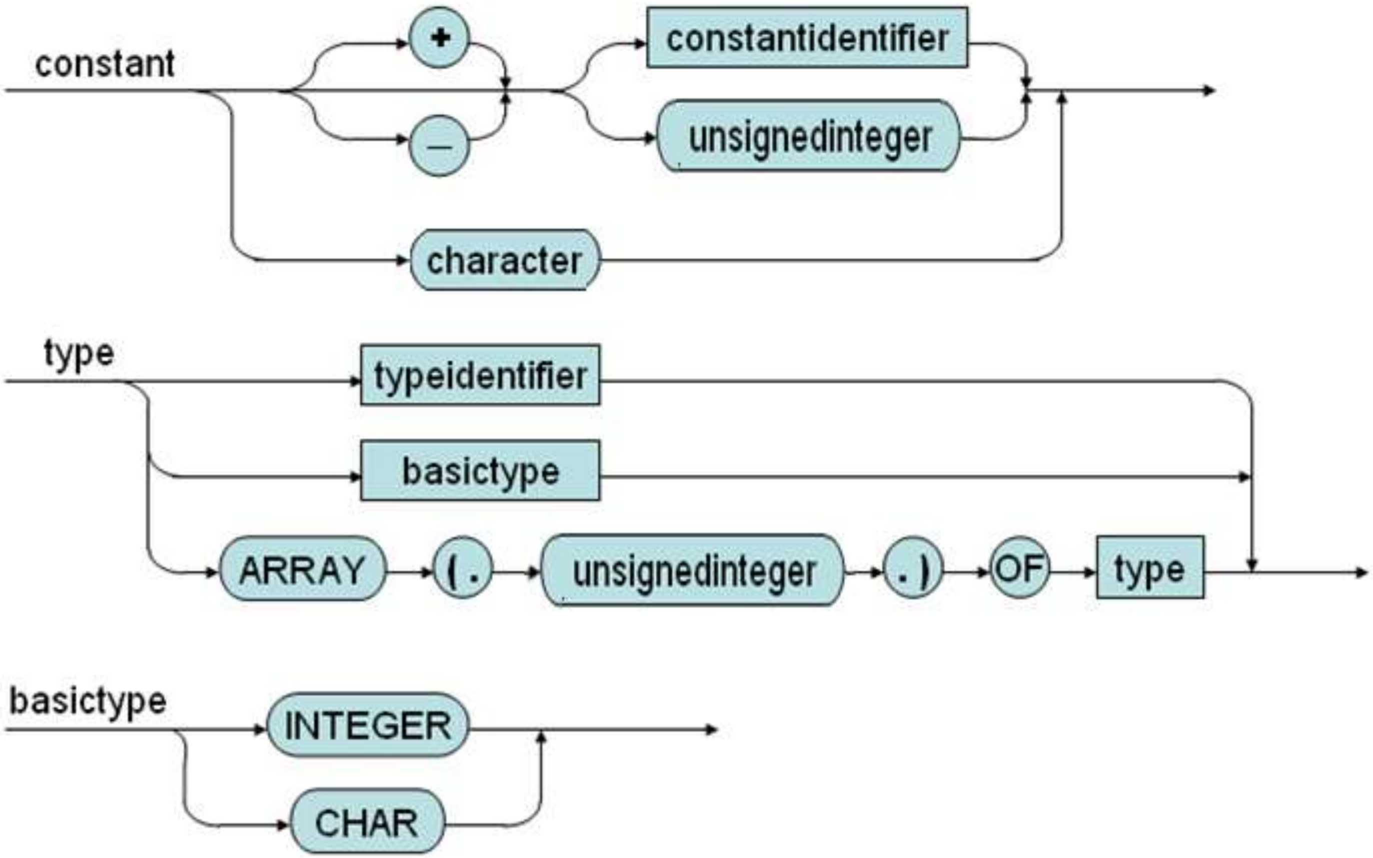


Syntax Diagrams of KPL
(list of parameters, unsigned constant)

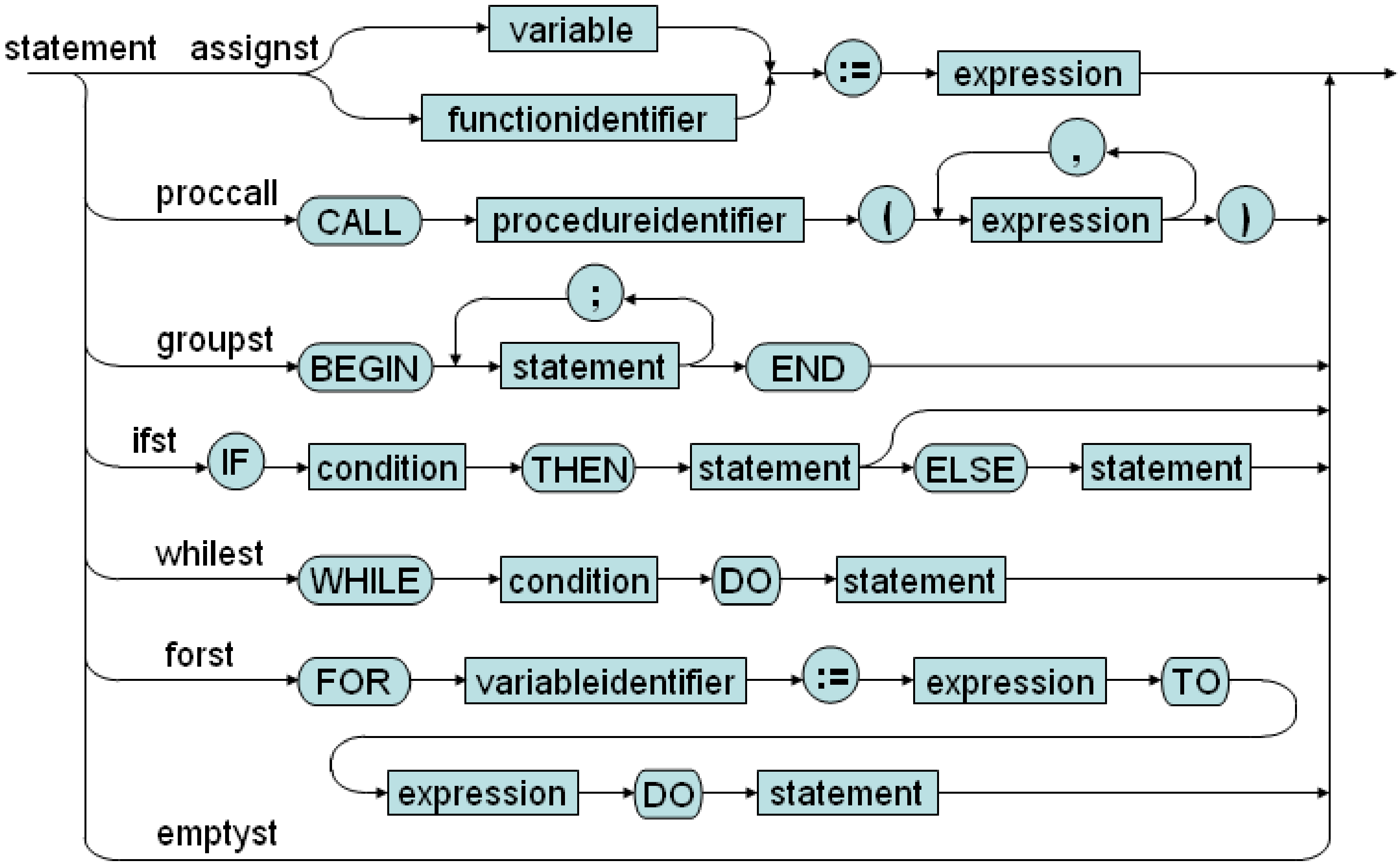




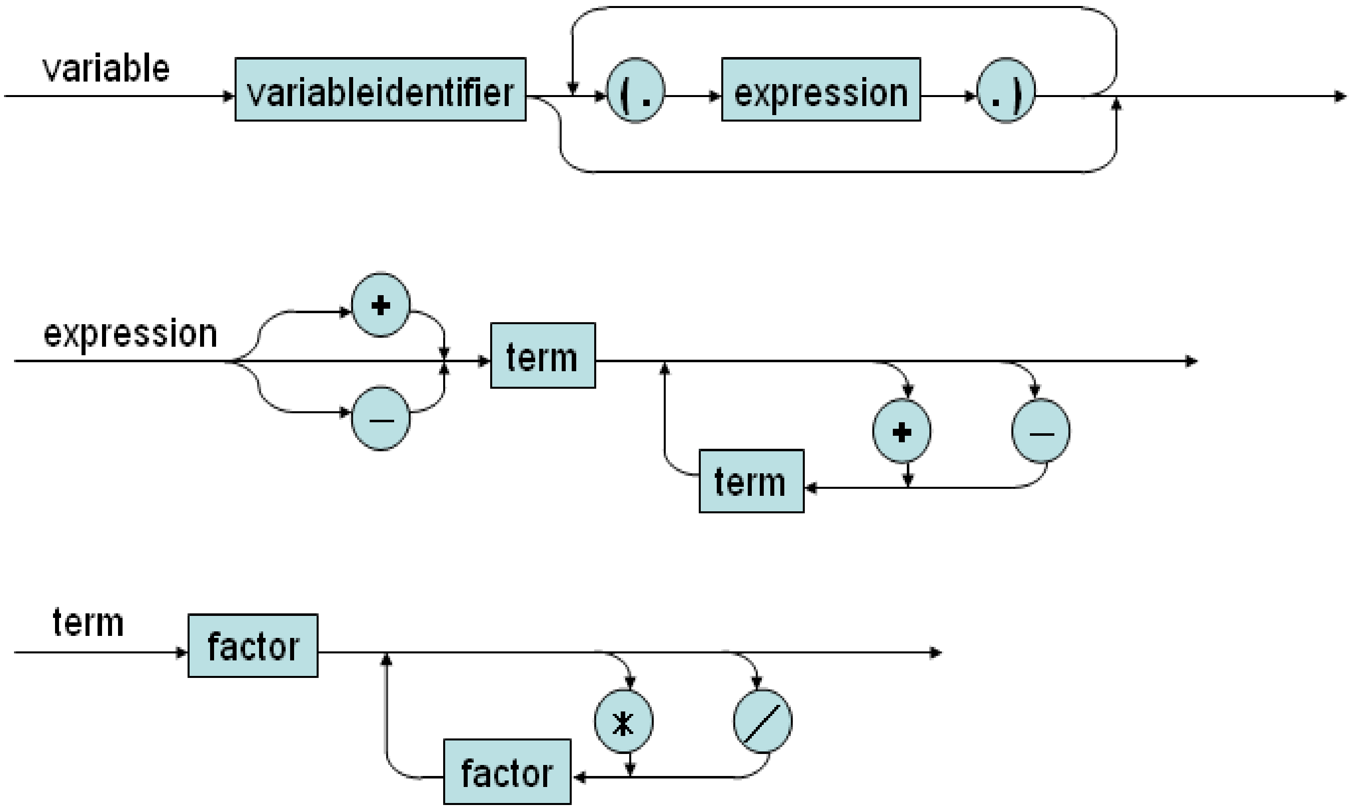
Syntax Diagrams of KPL (declarations)



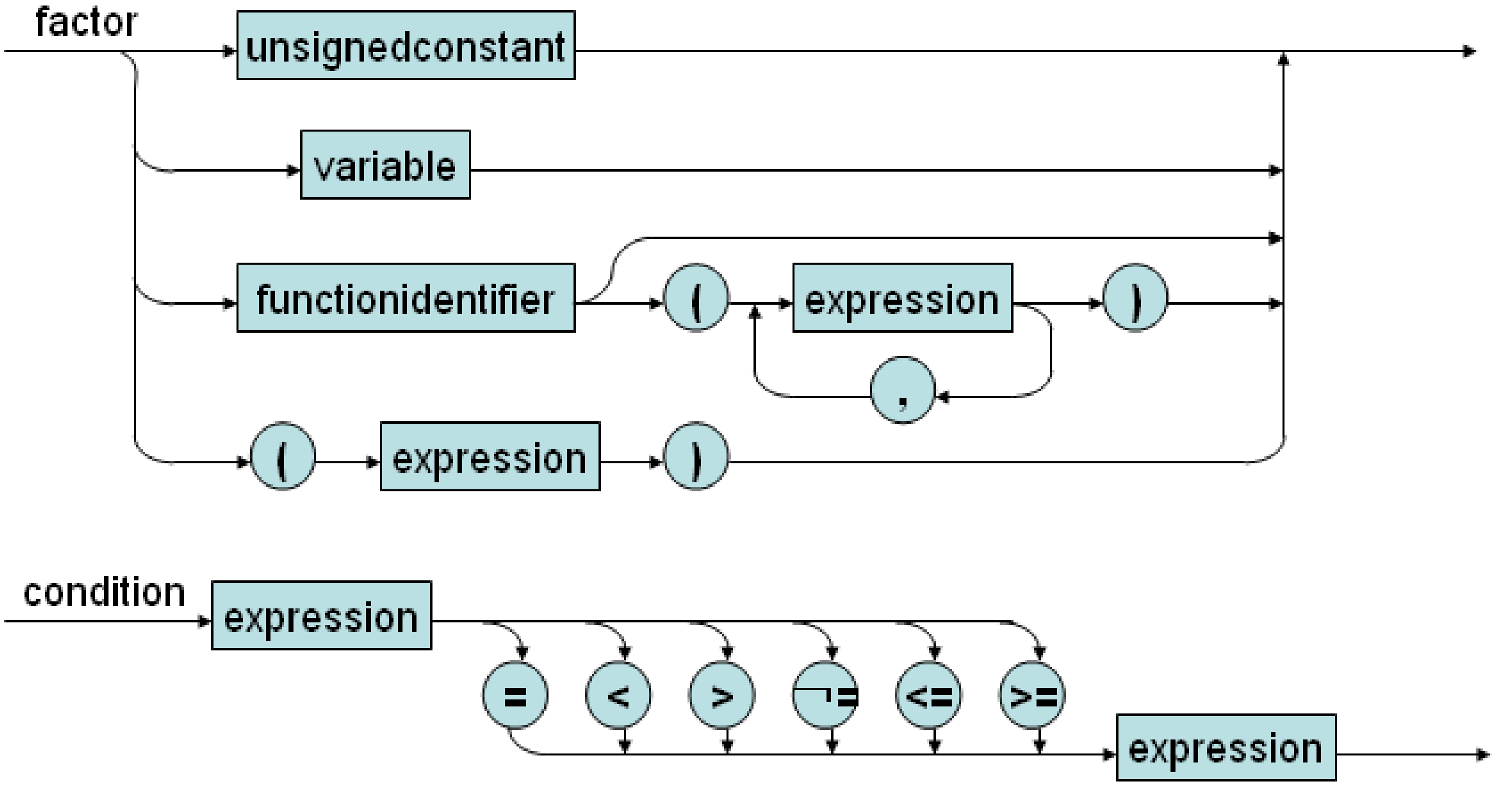
Syntax Diagrams of KPL (statement)



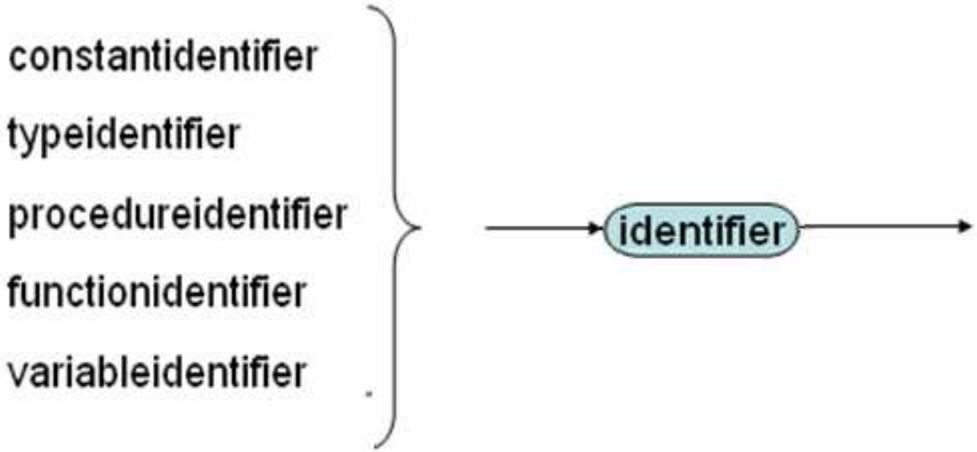
Syntax Diagrams of KPL (variable,expression,term)



Syntax Diagrams of KPL (factor,condition)



Syntax Diagrams of KPL (identifier,unsigned integer)



Exercise: a KPL program

Write a program that asks the user to type the value of an integer and compute its factorial.

Solution 1

```
program example1; (* Factorial *)
var n : integer; i: integer; f:integer;
BEGIN

n := readi;

f:=1;
if n >=2

begin

for i:= 2 to n do

f:= f*i;
call writeln;
call writeI(f);
end;
END. (* Factorial *)
```

Solution 2 (using KPL functions)

```
program example2; (* Factorial *)
var n : integer;
function f(k : integer) : integer;
 begin
  If k = 0 Then f := 1 Else f := k * f (k
- 1);
 end;

BEGIN
   n := readI;
   call writeln;
   call writeI(f(n));
  END. (* Factorial *)
```