Languages

More on languages:

- Notation for Grammar (BNF notation)
- Pictures for Grammar (rail road diagram)

How to build a lexical analyser

How to build a parser

Ways to define a grammar

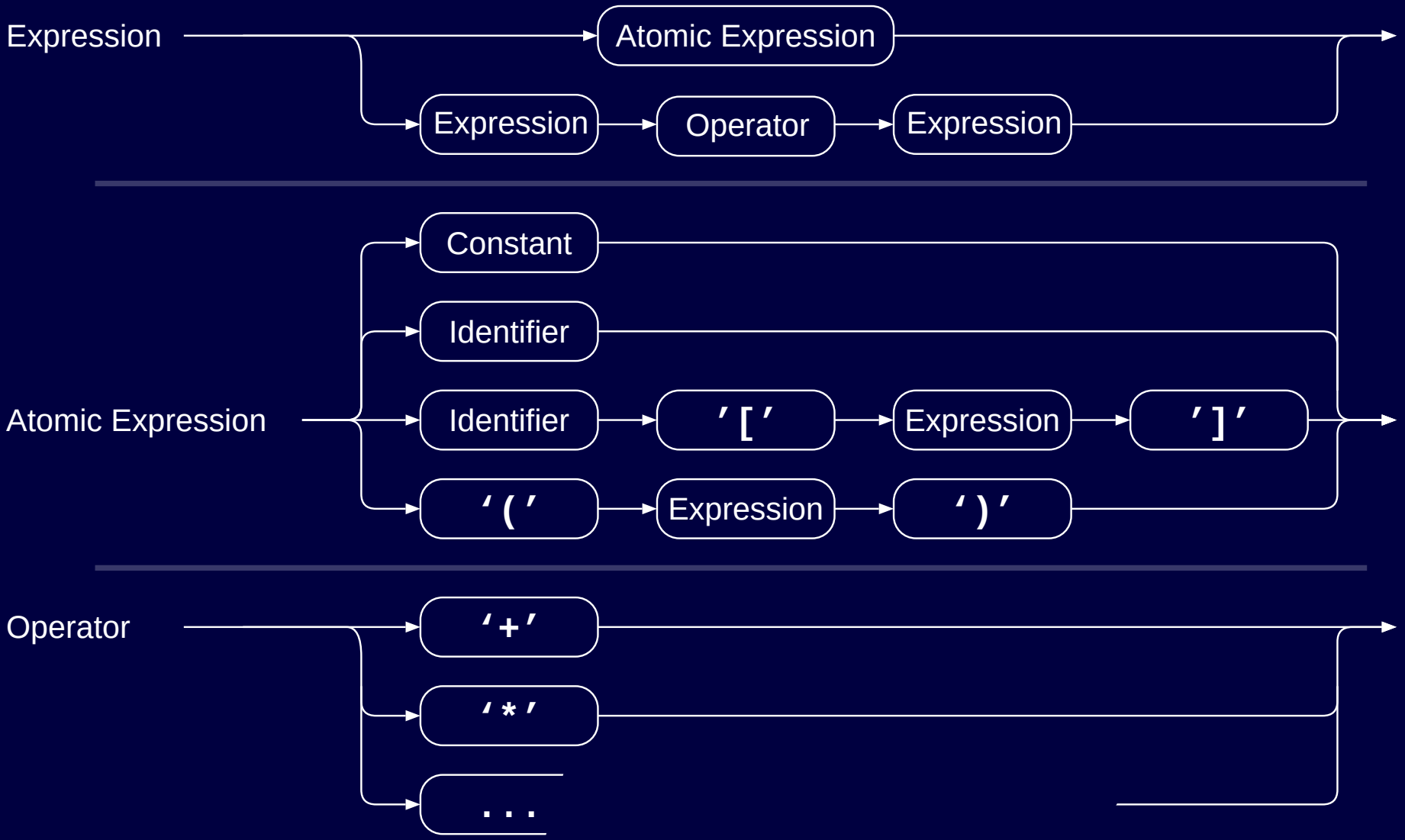
How do we specify computer languages?

1. Rail road diagrams
2. BNF Syntax

Rail road diagrams.

- Pictures
  - an X looks like this picture.
  - Follow the arrows
  - You are not allowed to go the wrong way
- There is one place to start.

Example: C expression



Notation for Grammar

Rail roads cannot be typed into computers.

- There is a language for describing languages
- Called Backus-Naur format, or BNF for short.

BNF:

- specifies production rules.
- A production rule says how to make a sentence, or another way to interpret it
- A production rule says how to parse a sentence.

BNF syntax

BNF syntax: no more than two symbols needed

- **X ::= Y** An X consists of a Y.
- **X ::= Y | Z** An X consists of a Y or a Z.
- **X ::= Z | X Y** An X consists of a Z or an X followed by a Y (recursion)

BNF example: C expressions

```
Expression ::=
     AtomicExpression
   | Expression Operator Expression

Operator ::= Plus | Star |  ...

AtomicExpression ::=
     Constant
   | Identifier
   | Identifier LeftBracket Expression RightBracket
   | LeftParenthesis Expression RightParenthesis
```

Terminals, Non Terminals (one start symbol), BNF syntax. **(2+3)*8** ?

Terminals

Terminals are symbols recognised by the lexical analyser.

```
LeftParenthesis = '('
RightParenthesis = ')'
Constant = '[0-9]'
Plus = '+'
Minus = '-'
Slash = '/'
Star = '*'
```

Third one is known as a regular expression

- `[]` means any of the characters in between.

Non Terminals

Non terminals are produced by the language.

- **`Expression`**
- **`AtomicExpression`**
- **`Operator`**

Expression is either an atomic expression or a thing with an operator.

Operator is either a plus, minus, star or slash.

You must have a place to start, the start symbol.

$\Rightarrow$ Expression in this case.

$\Rightarrow$ Program for C.

Parsing or producing a program

- A syntactically valid program can be produced by the BNF production rules
- A syntactically invalid program cannot be produced by the BNF production rules

- Lets take another look at an expression, say, **`5*(8-3)`**.
  - Is it valid?
  - How is it produced?

Production

`5 * (8-3)` is an **`Expression`**

`5` is a **`Constant`** (terminal)

`*` is an **`Operator`** (non-terminal)

`*` is an **`Star`** (terminal)

`(8-3)` is an **`Expression`** (non terminal)

`( 8-3 )` is an **`Atomic Expression`** (non terminal)

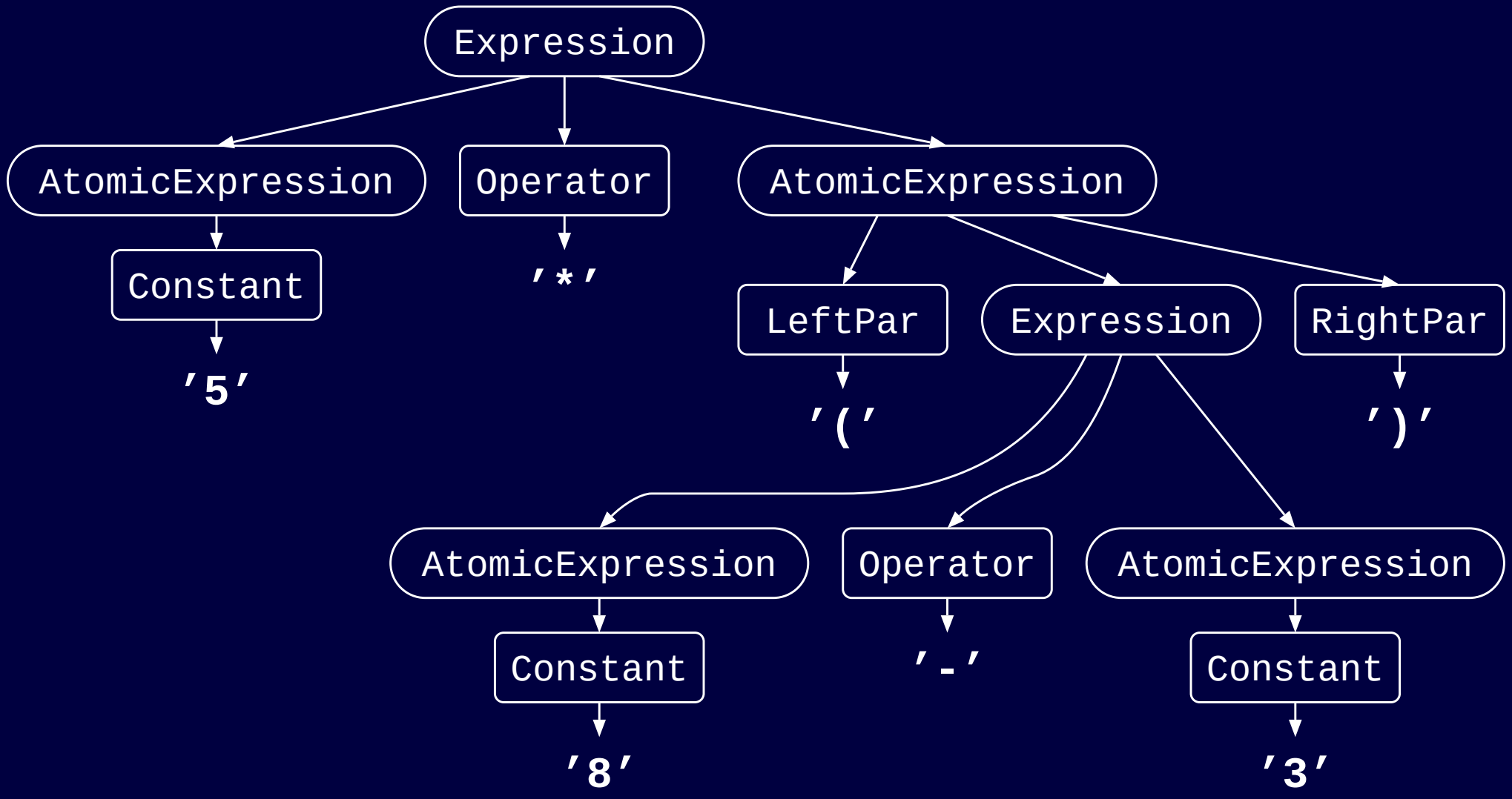
`(` is a **`LeftParenthesis`** (terminal)

`8-3` is an **`Expression`** (non terminal)

`)` is a **`RightParenthesis`** (terminal)

...

Parse tree


Expression
AtomicExpression
Operator
AtomicExpression
Constant
'*'
LeftPar
Expression
RightPar
'5'
'('
')'
AtomicExpression
Operator
AtomicExpression
Constant
'-'
Constant
'8'
'3'

Yet another tree

Ok, tree is upside down

- Most trees in computer science are upside down.
- Indeed, you can make a parser by calling functions.

We need

- a data type to represent “tokens” (words of the language, such as `]`, **`while`**, **`19`**)
- a function to read words, the lexical analyser.
- a function to string words together, the parser.

Data type for tokens

```
typedef enum {
    LeftParenthesis, RightParenthesis, LeftBracket, Ri
    Constant, Identifier, Plus, Star
} Token ;
```

Lexer

```
Token readtoken() {
  c = getchar() ;
  switch( c ) {
    case '(': return LeftParenthesis ;
    case ')': return RightParenthesis ;
    case ' ': case '\t': case '\n': return readtoken()
    case '0': case '1': case '2': case '3': case '4':
    case '5': case '6': case '7': case '8': case '9':
      do {
        c = getchar() ;
      } while( isdigit( c ) ) ;
      ungetc( c, stdin ) ;  /* Woops, one too far */
      return Constant ;
  }
}
```

Parser

```
expression() {
  Token z = readtoken() ;
  if( z == LeftParenthesis ) {
    expression() ;
    z = readtoken() ;
    if( z != RightParenthesis ) {
      error( "Expected a ')'" ) ;
    }
  } else if( ... )
  ...
}
```

- COMS22100 deals with all the gory details, such as the lookahead.

Conclusions

How do we specify computer languages?

1. Rail road diagrams
2. BNF Syntax

Terminals

- Symbols with which the thing ends.
- Recognised by the lexical analyser
- Example: ’+’, ’monkey’

Non Terminals

- Symbols which are to be produced further

Start Symbol: a Non Terminal.