Declarative Syntax Definition

pretty printing

Guido Wachsmuth

Assessment

last lecture

Assessment

last lecture

Compare SDF with the plain formalism of context-free grammars.

Assessment

last lecture

Compare SDF with the plain formalism of context-free grammars.

Discuss additional description means provided by SDF and why they are needed in compiler construction.

Assessment

last lecture

Compare SDF with the plain formalism of context-free grammars.

Discuss additional description means provided by SDF and why they are needed in compiler construction.

- regular expressions

Assessment

last lecture

Compare SDF with the plain formalism of context-free grammars.

Discuss additional description means provided by SDF and why they are needed in compiler construction.

- regular expressions
- layout

Assessment

last lecture

Compare SDF with the plain formalism of context-free grammars.

Discuss additional description means provided by SDF and why they are needed in compiler construction.

- regular expressions
- layout
- AST constructors

Assessment

last lecture

Compare SDF with the plain formalism of context-free grammars.

Discuss additional description means provided by SDF and why they are needed in compiler construction.

- regular expressions
- layout
- AST constructors
- follow restrictions

Assessment

last lecture

Compare SDF with the plain formalism of context-free grammars.

Discuss additional description means provided by SDF and why they are needed in compiler construction.

- regular expressions
- layout
- AST constructors
- follow restrictions
- annotations for associativity

Assessment

last lecture

Compare SDF with the plain formalism of context-free grammars.

Discuss additional description means provided by SDF and why they are needed in compiler construction.

- regular expressions
- layout
- AST constructors
- follow restrictions
- annotations for associativity
- priorities

Overview

today's lecture

Overview
today's lecture

plagues of traditional parsing algorithms

- paradise lost
- paradise regained

Overview
today's lecture

plagues of traditional parsing algorithms

- paradise lost
- paradise regained

pretty-printing

- from trees to text
- box layout in pretty-print tables

Overview
today's lecture

plagues of traditional parsing algorithms

- paradise lost
- paradise regained

pretty-printing

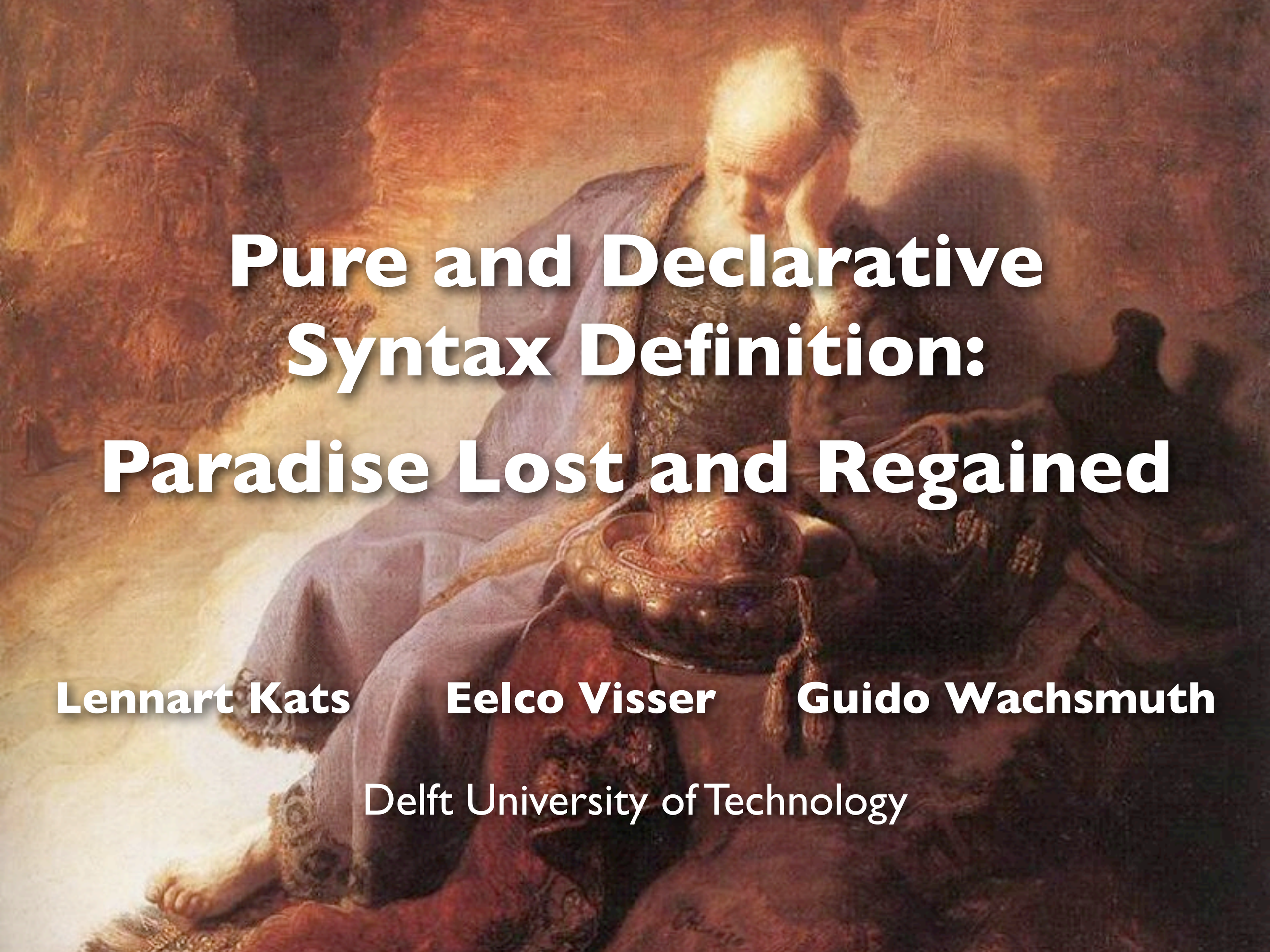
- from trees to text
- box layout in pretty-print tables

template language

- alternative to SDF
- generation of pretty-printing strategies
- generation of completion templates

I

paradise lost & regained



Pure and Declarative Syntax Definition: Paradise Lost and Regained

Lennart Kats **Eelco Visser** **Guido Wachsmuth**

Delft University of Technology

PARADISE

PARADISE **LOST**

PARADISE REGAINED

PARADISE **DENIED**

PARADISE

WORDS

TREES

LA DEUXIÈME ANNÉE

DE LATIN

Théorie 250 pages.

227 Exercices 100 pages.

Lexiques

24 pages blanches pour notes et 4 cartes.

Troisième édition.

Armand COLIN & Cie

GRAMMARS

LANGUAGE ENGINEERS

LANGUAGES

LA DEUXIÈME ANNÉE

DE LATIN

Théorie 250 pages.

227 Exercices 100 pages.

Lexiques

24 pages blanches pour notes et 4 cartes.

Troisième édition.

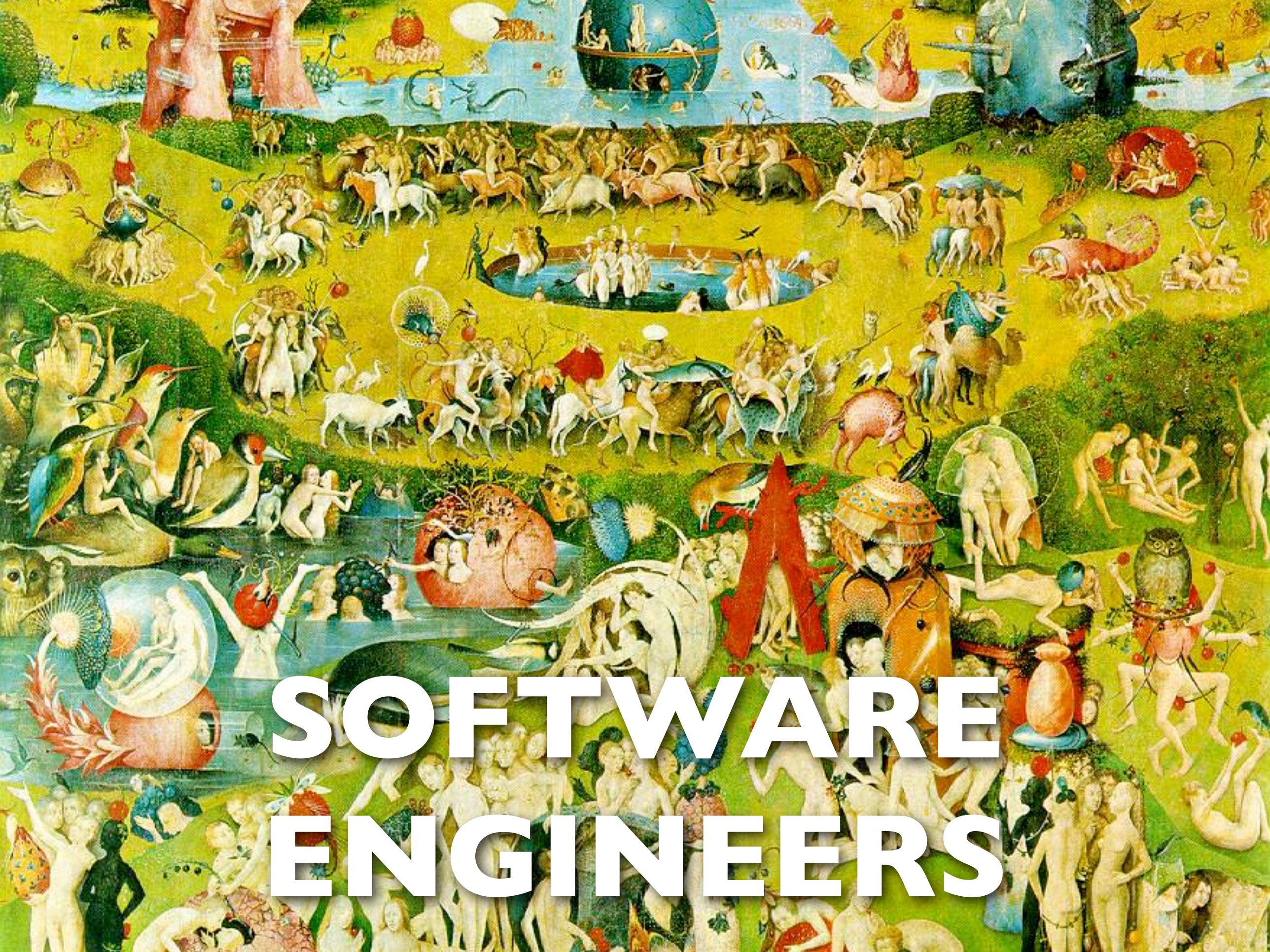
Armand COLIN & Cie

GRAMMARS

NATURAL

PURE

BEAUTIFUL


SOFTWARE
ENGINEERS

LANGUAGE SOFTWARE

NOT

NATURAL

NOT

PURE

NOT

BEAUTIFUL

LA DEUXIÈME ANNÉE

DE LATIN

Théorie 250 pages.

227 Exercices 100 pages.

Lexiques

SYNTAX DEFINITIONS

Armand COLIN & Cie

NATURAL

PURE

BEAUTIFUL

THE **FALL**

PARSER DEFINITIONS

PARADISE **LOST**


PAIN

SWEAT

NOT

NATURAL

NOT

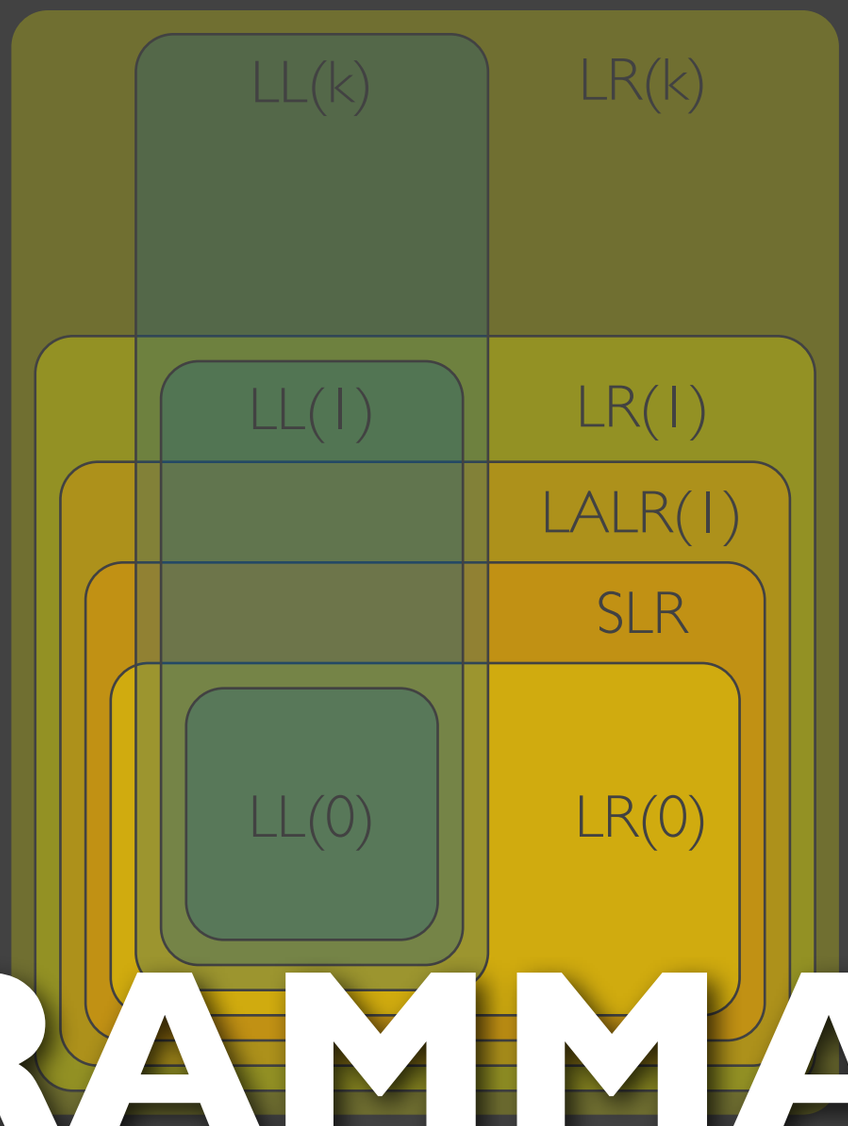
PURE

NOT

BEAUTIFUL

THE **PLAGUES**

context-free grammars

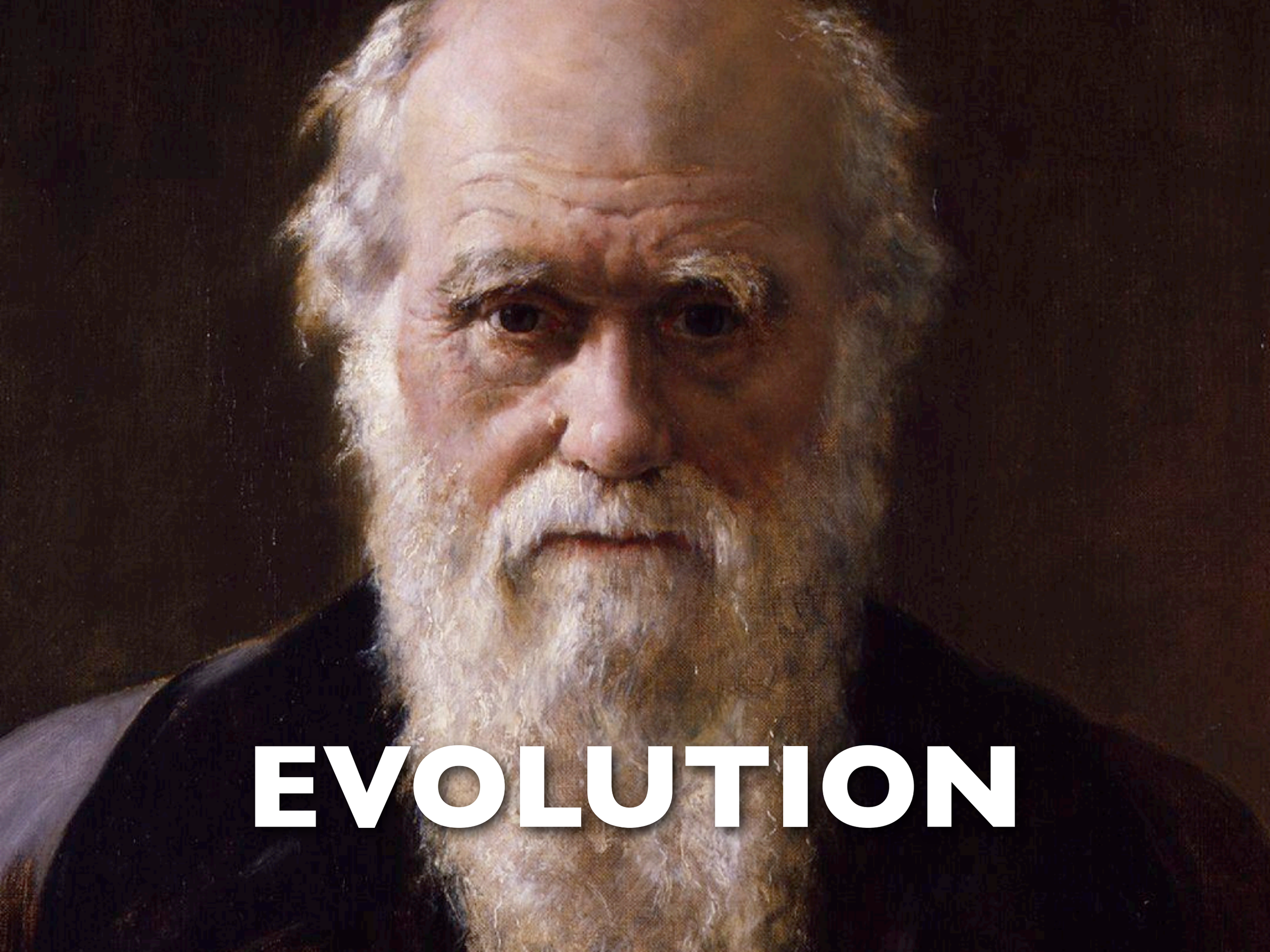


GRAMMAR CLASSES

DISAMBIGUATION

LEXICAL SYNTAX

TREE CONSTRUCTION


EVOLUTION

COMPOSITION

RESTRICTION
TO PARSERS

PARADISE

WORDS WERE MADE THROUGH

GRAMMARS

LA DEUXIÈME ANNÉE

DE LATIN

Théorie 250 pages.

227 Exercices 100 pages.

Lexiques

24 pages blanches pour notes et 4 cartes.

Troisième édition.

Armand COLIN & Cie

GRAMMARS

Num → Digit Num

Num → Digit

Digit → “0”

Digit → “1”

Num → Digit Num

Num → Digit

Digit → “0”

Digit → “1”

production rules

Num → Digit Num

Num → Digit

Digit → “**0**”

Digit → “**1**”

terminal symbols

production rules

Num → Digit Num

Num → Digit

Digit → “0”

Digit → “|”

nonterminal symbols

terminal symbols

production rules

Num → Digit **Num**

Num → Digit

Digit → “0”

Digit → “1”

nonterminal symbols

terminal symbols

production rules

start symbol

WORDS

Num

Num

Digit Num

Num → Digit Num

Num

Digit **Num**

Digit Digit

Num → Digit Num

Num → Digit

Num

Digit Num

Digit **Digit**

Digit 0

Num → Digit Num

Num → Digit

Digit → “0”

Num

Digit Num

Digit Digit

Digit 0

| 0

Num → Digit Num

Num → Digit

Digit → “0”

Digit → “1”

SENTENCES

Exp → Exp "+" Exp

Exp → Exp "*" Exp

Exp → Num

production rules

Exp → Exp “**+**” Exp

Exp → Exp “*” Exp

Exp → **Num**

terminal symbols

production rules

Exp → Exp "+" Exp

Exp → Exp "*" Exp

Exp → Num

nonterminal symbols

terminal symbols

production rules

Exp → Exp "+" Exp

Exp → Exp "*" Exp

Exp → Num

nonterminal symbols

terminal symbols

production rules

start symbol

Exp

Exp

Exp + Exp

Exp → Exp “+” Exp

Exp

Exp + Exp

Exp * Exp + Exp

Exp → Exp “+” Exp

Exp → Exp “*” Exp

Exp

Exp + Exp

Exp * Exp + Exp

3 * Exp + Exp

Exp → Exp “+” Exp

Exp → Exp “*” Exp

Exp → Num

Exp

Exp + Exp

Exp * Exp + Exp

3 * **Exp** + Exp

3 * 7 + Exp

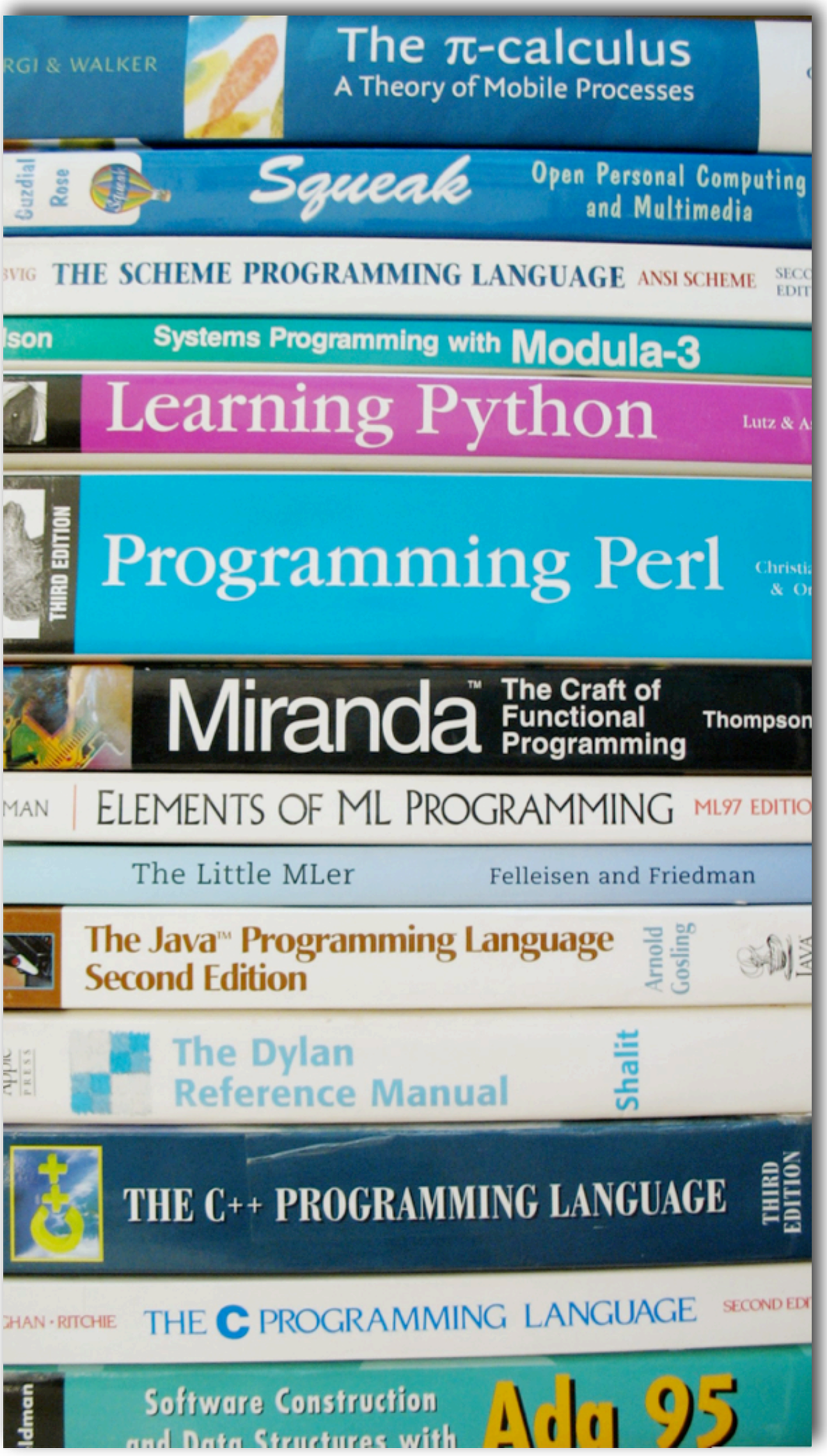
Exp → Exp “+” Exp

Exp → Exp “*” Exp

Exp → Num

Exp → Num

Exp	Exp → Exp “+” Exp
Exp + Exp	Exp → Exp “*” Exp
Exp * Exp + Exp	Exp → Num
3 * Exp + Exp	Exp → Num
3 * 7 + **Exp**	Exp → Num
3 * 7 + 21	



THEY MADE LANGUAGES BY MAKING GRAMMARS

LA DEUXIÈME ANNÉE

DE LATIN

Théorie 250 pages.

227 Exercices 100 pages.

Lexiques

24 pages blanches pour notes et 4 cartes

GRAMMAR

Troisième édition.

Armand COLIN & Cie


LANGUAGE

TRUTH

Exp → Exp “+” Exp

Exp → Exp “*” Exp

Exp → Num

productive

Exp “+” Exp → Exp

Exp “*” Exp → Exp

Num → Exp

reductive

$$3 * 7 + 21$$

3 * 7 + **21**

3 * 7 + Exp

Num → Exp

3 * 7 + 21	Num → Exp
3 * **7** + Exp	Num → Exp
3 * Exp + Exp	

3 * 7 + 21	Num → Exp
3 * 7 + Exp	Num → Exp
3 * Exp + Exp	Num → Exp
Exp * Exp + Exp	

3 * 7 + 21	Num → Exp
3 * 7 + Exp	Num → Exp
3 * Exp + Exp	Num → Exp
Exp * Exp + Exp	Exp "*" Exp → Exp
Exp + Exp	

3 * 7 + 21	Num → Exp
3 * 7 + Exp	Num → Exp
3 * Exp + Exp	Num → Exp
Exp * Exp + Exp	Exp “*” Exp → Exp
Exp + Exp	Exp “+” Exp → Exp
Exp	

THEY TURNED WORDS INTO

TREES

SENTENCES

STRUCTURE

Exp → Exp “+” Exp

Exp → Exp “*” Exp

Exp → Num

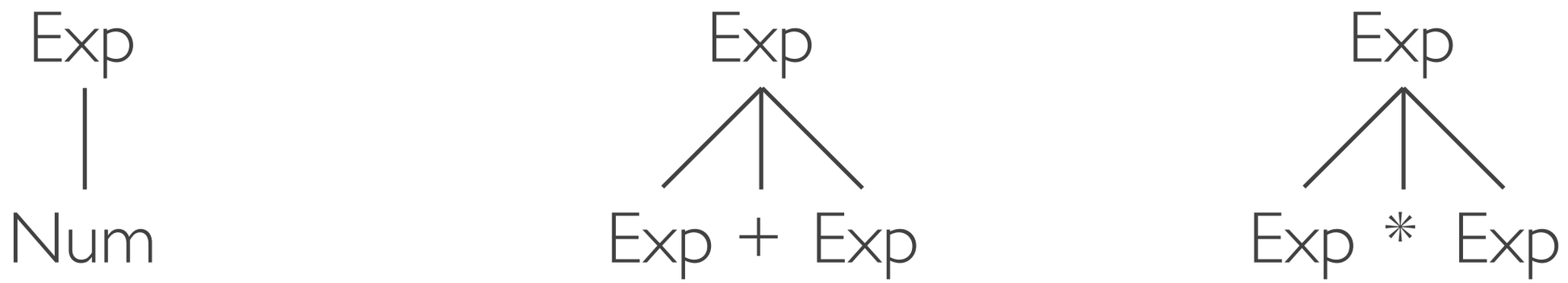
productive

Exp “+” Exp → Exp

Exp “*” Exp → Exp

Num → Exp

reductive



tree construction

$$3 * 7 + 21$$

Exp

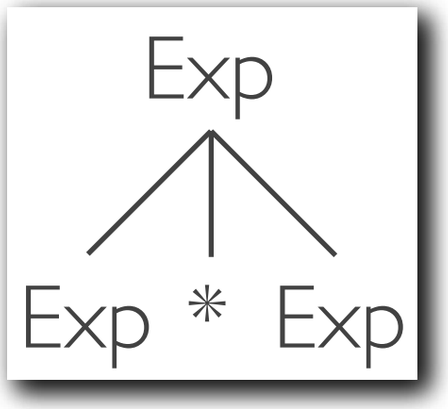
|

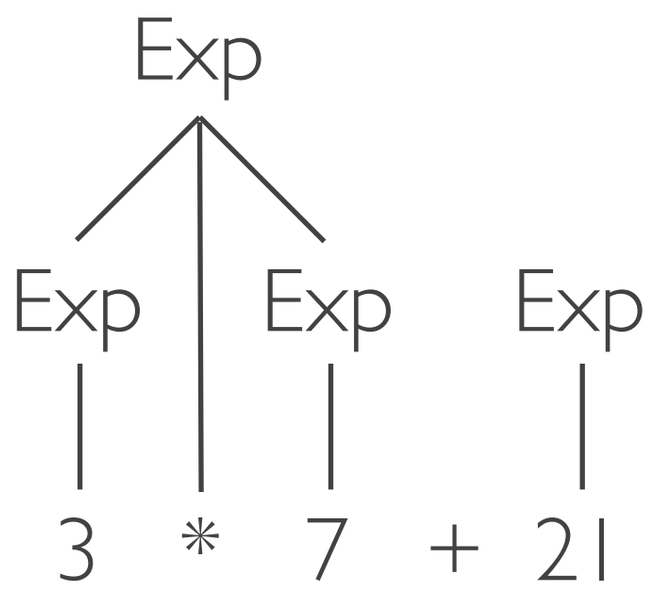
Num

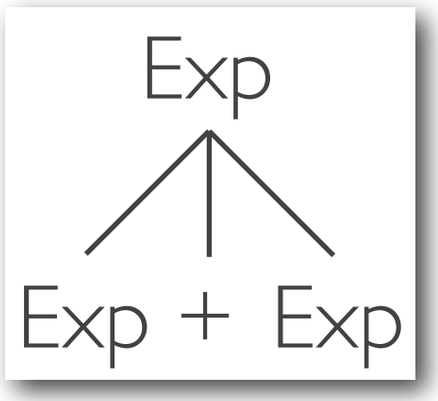
Exp Exp Exp

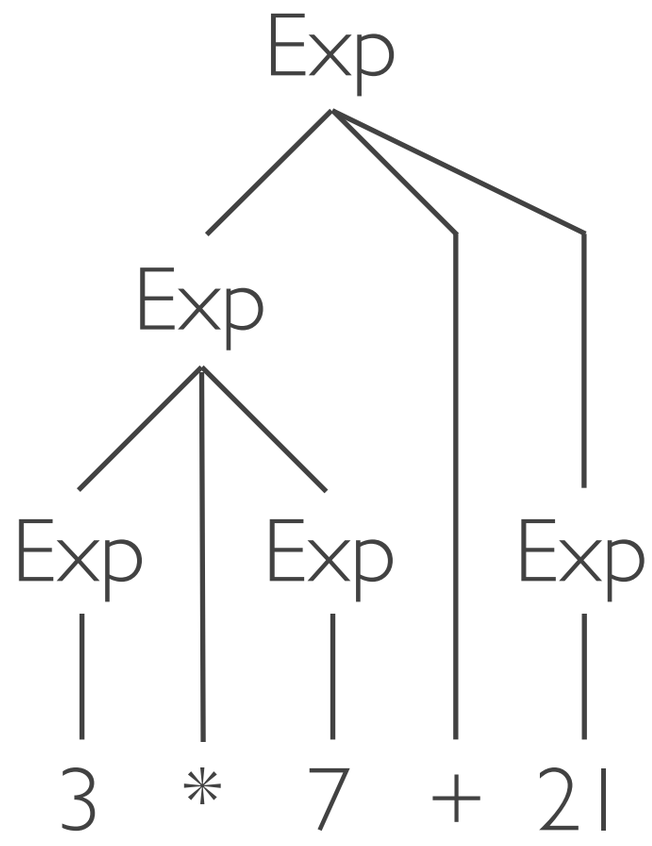
| | |

3 * 7 + 21


Exp
Exp * Exp


Exp
Exp Exp Exp
3 * 7 + 21


Exp
Exp + Exp


Exp
Exp
Exp
Exp
Exp
3 * 7 + 21

ONE FORMALISM

THREE READINGS

PURE

DECLARATIVE

BEAUTIFUL

PARADISE **LOST**

EFFICIENCY

THE FIRST PLAGUE WERE

GRAMMAR CLASSES

context-free grammars

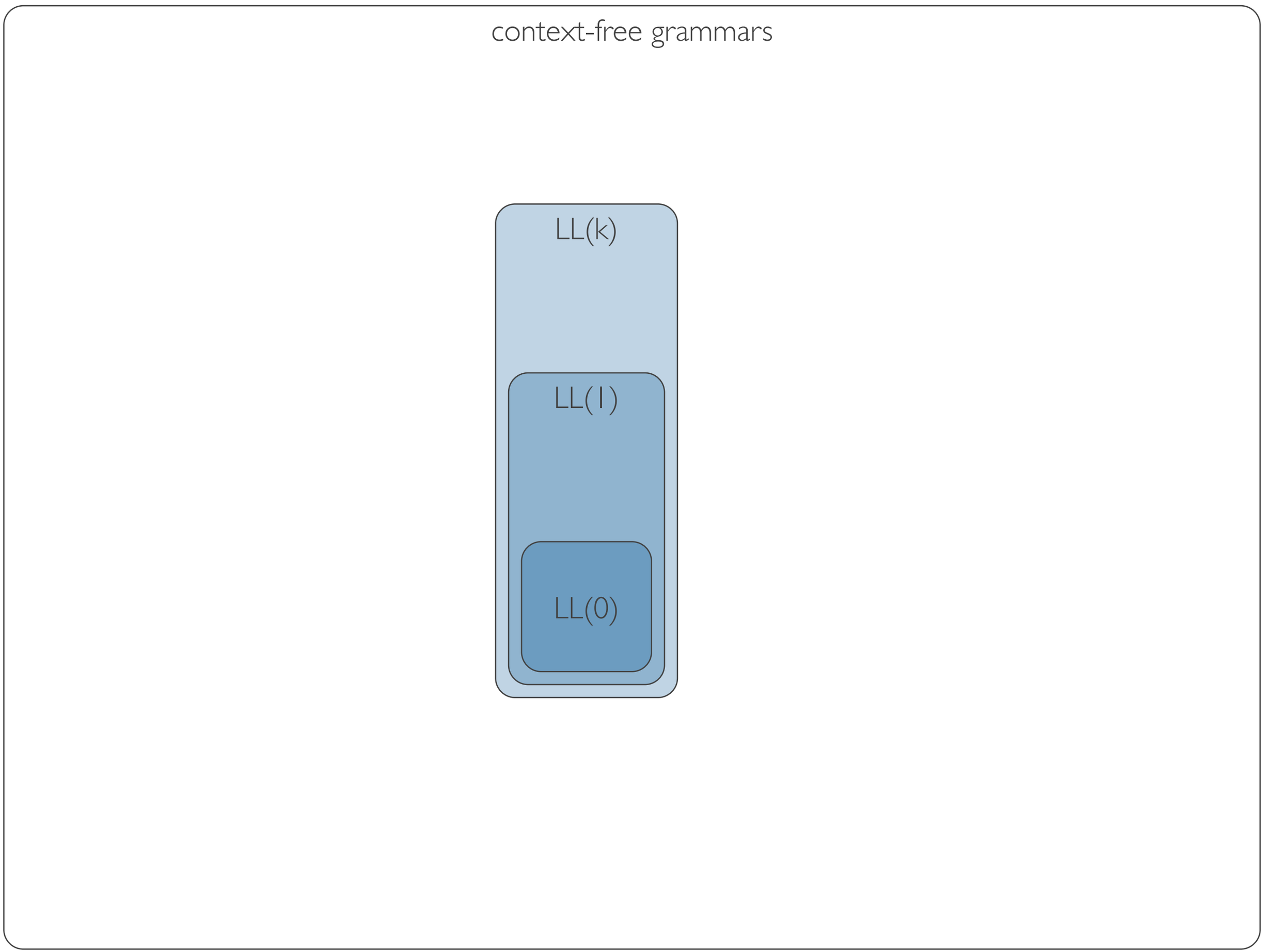
context-free grammars

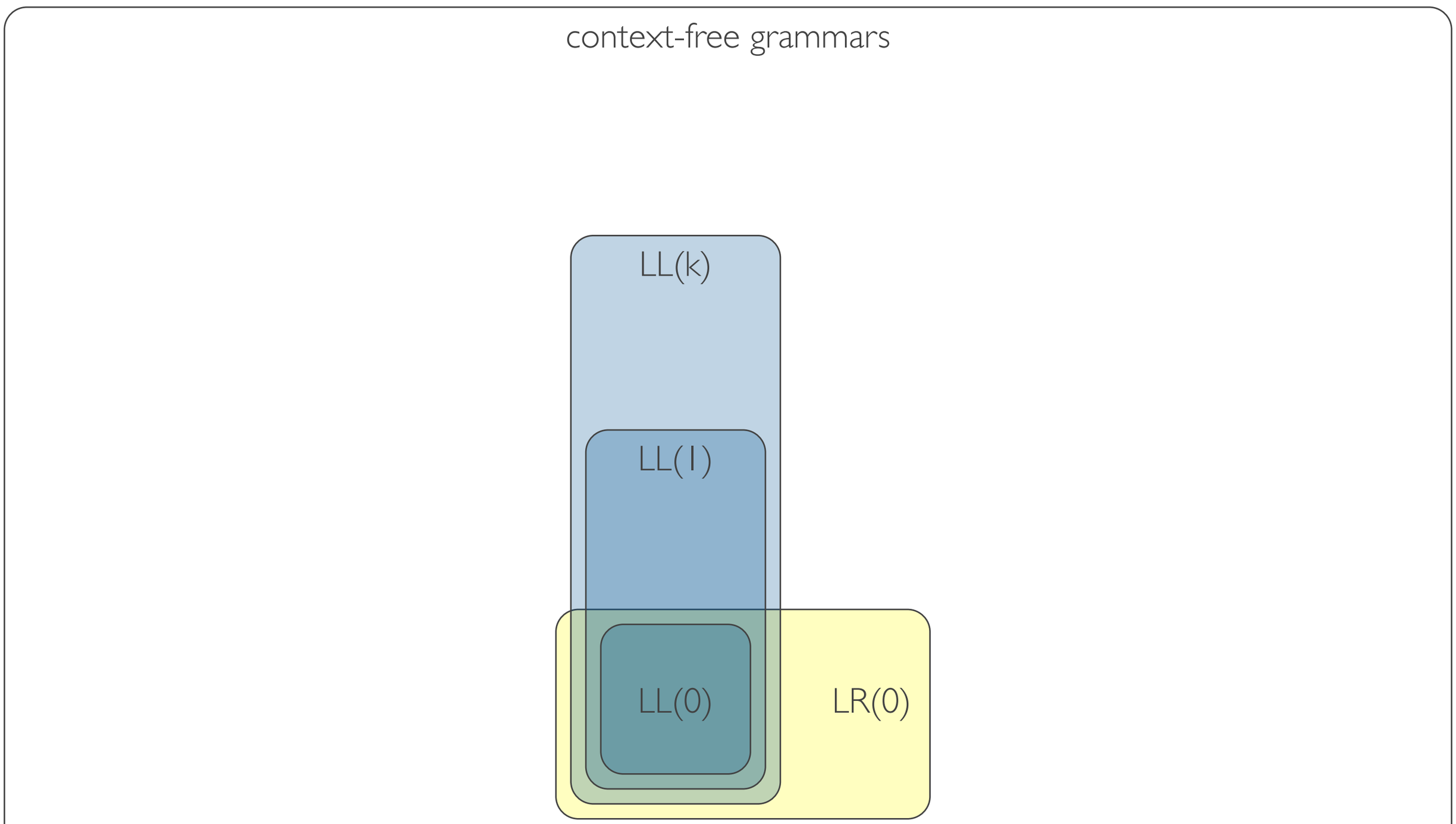
LL(0)

context-free grammars

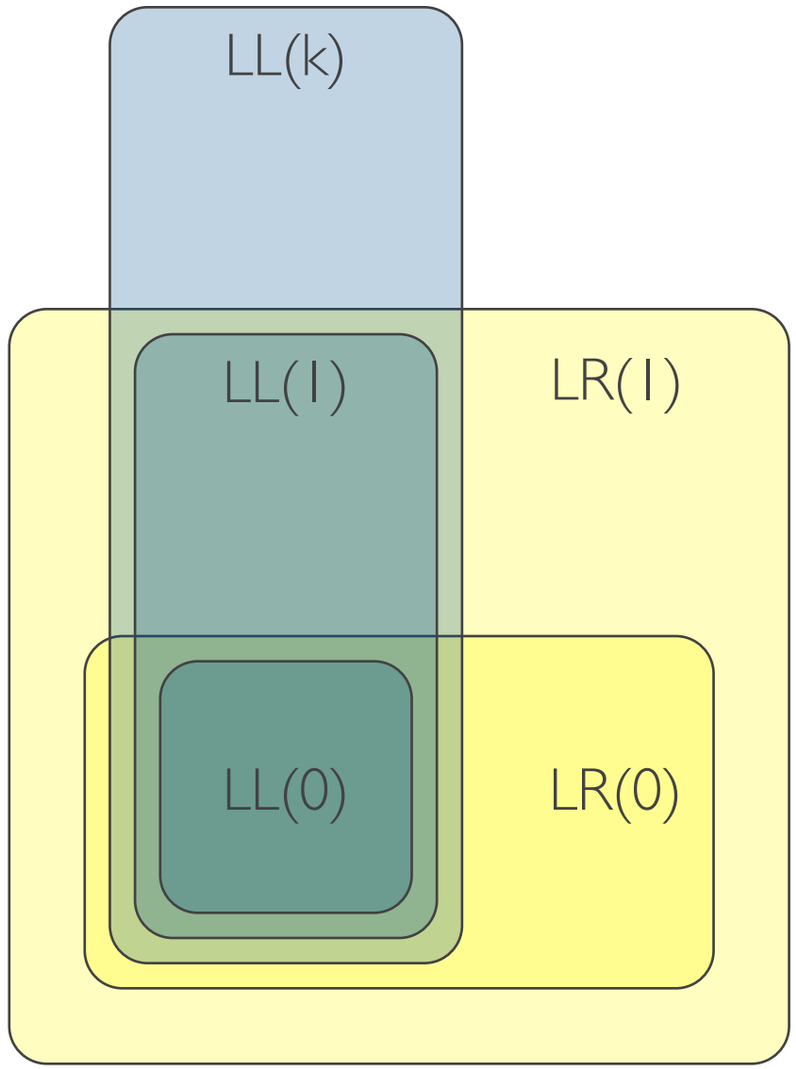
LL(1)

LL(0)

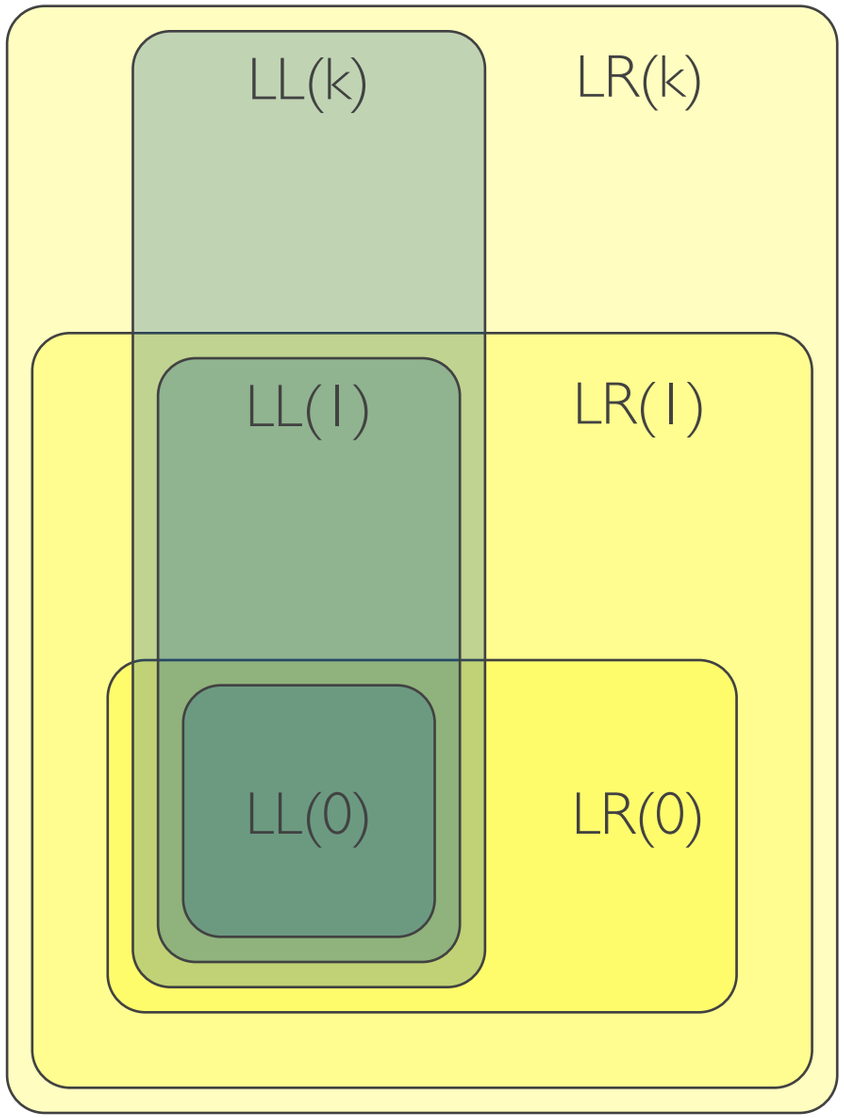

context-free grammars
LL(k)
LL(1)
LL(0)


context-free grammars
LL(k)
LL(1)
LL(0)
LR(0)

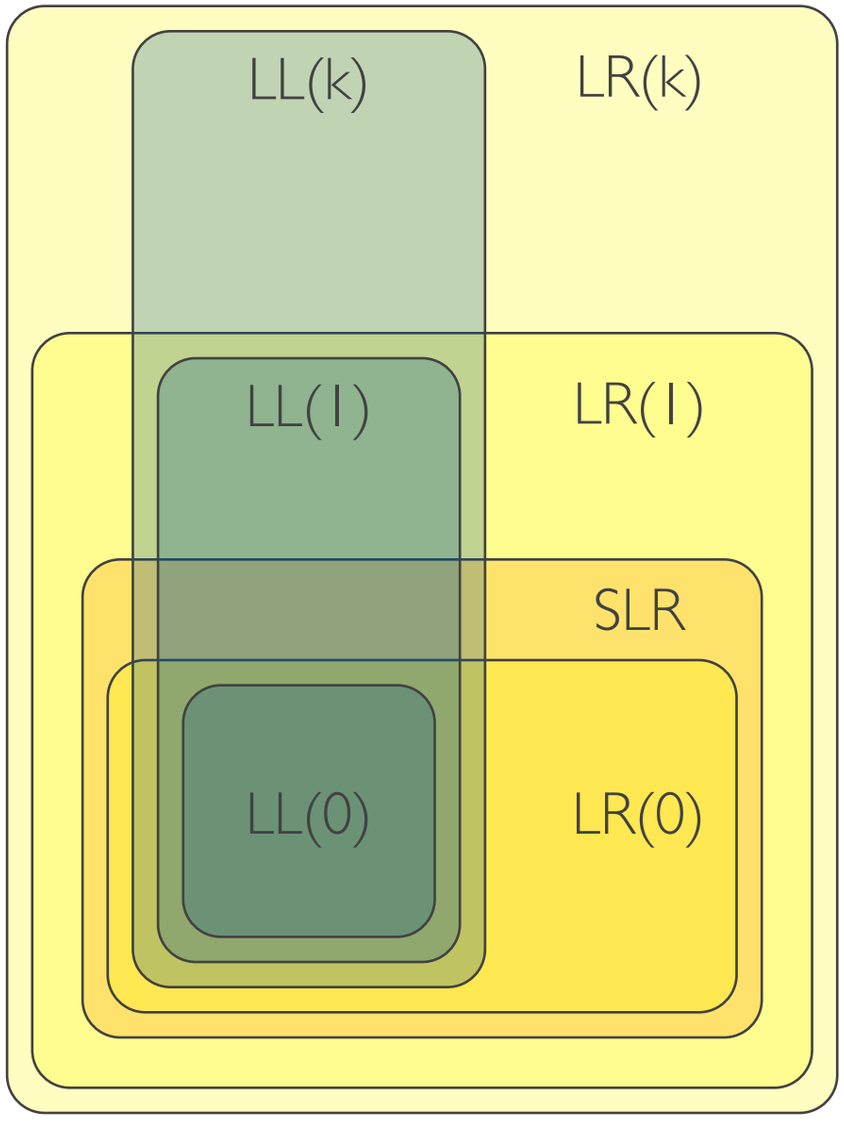
context-free grammars



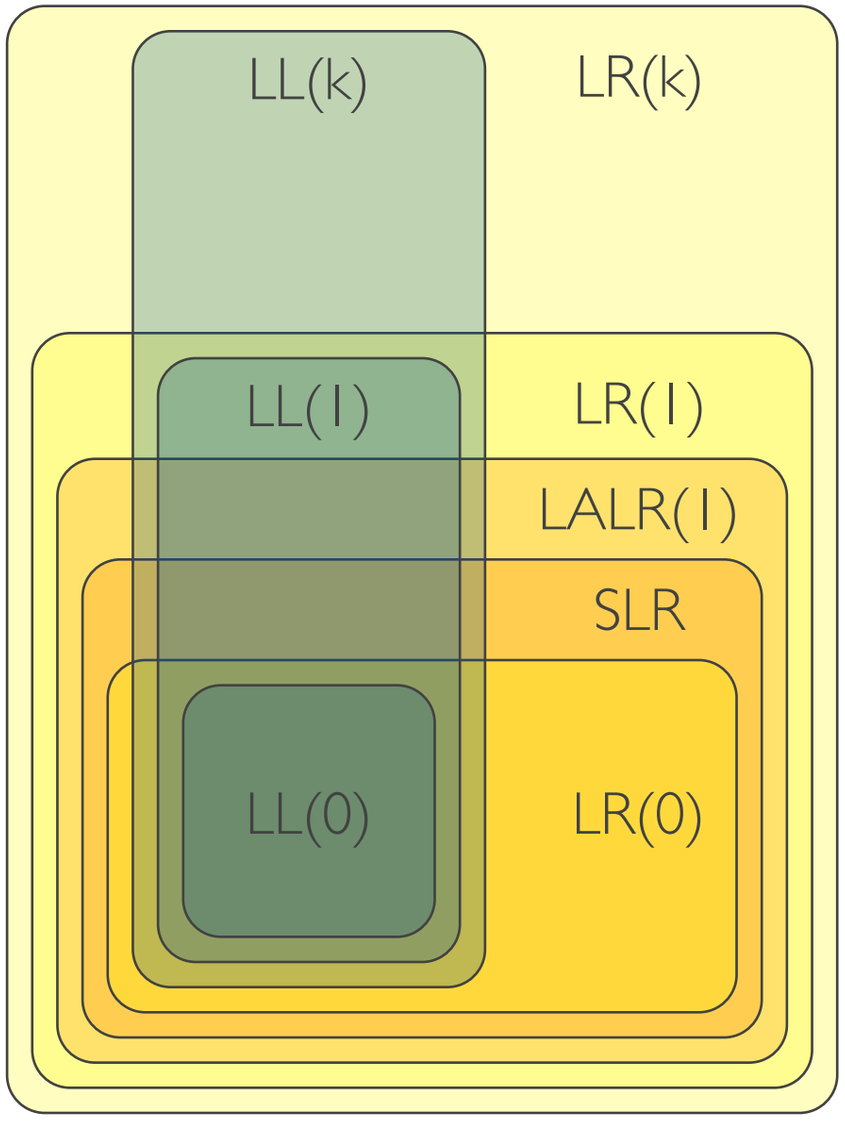
context-free grammars



context-free grammars



context-free grammars



Exp “+” Exp → Exp

Exp “*” Exp → Exp

Num → Exp

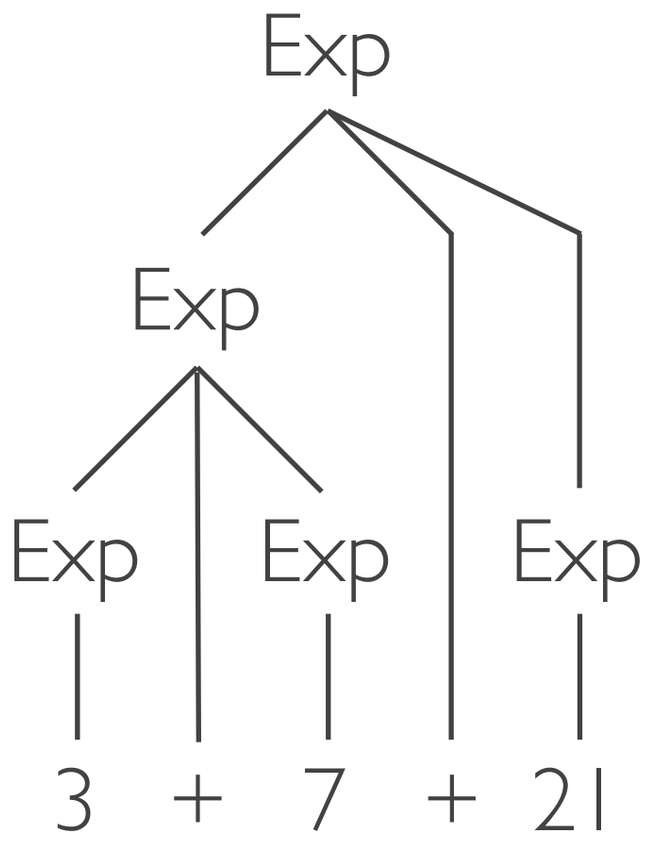
paradise

Term (“+” Term)* → Exp

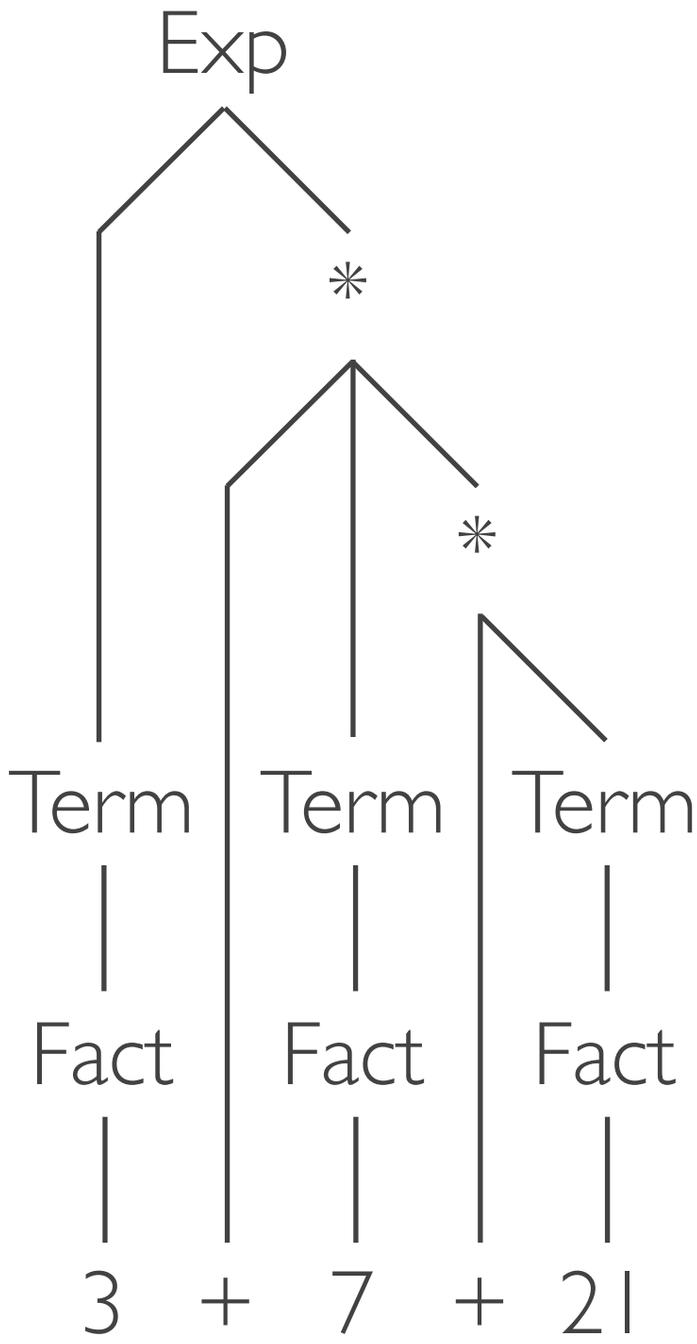
Fact (“*” Fact)* → Term

Num → Fact

grammar classes



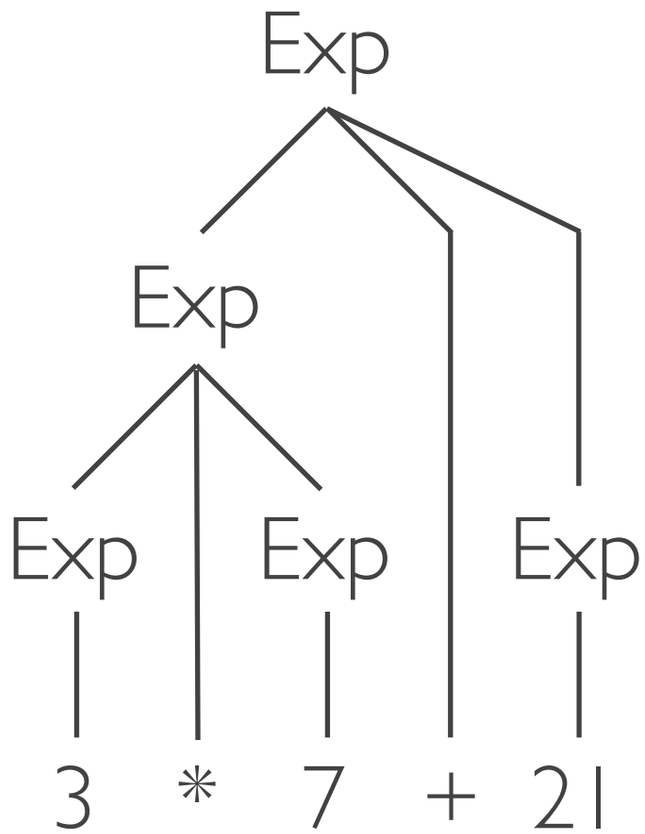
paradise

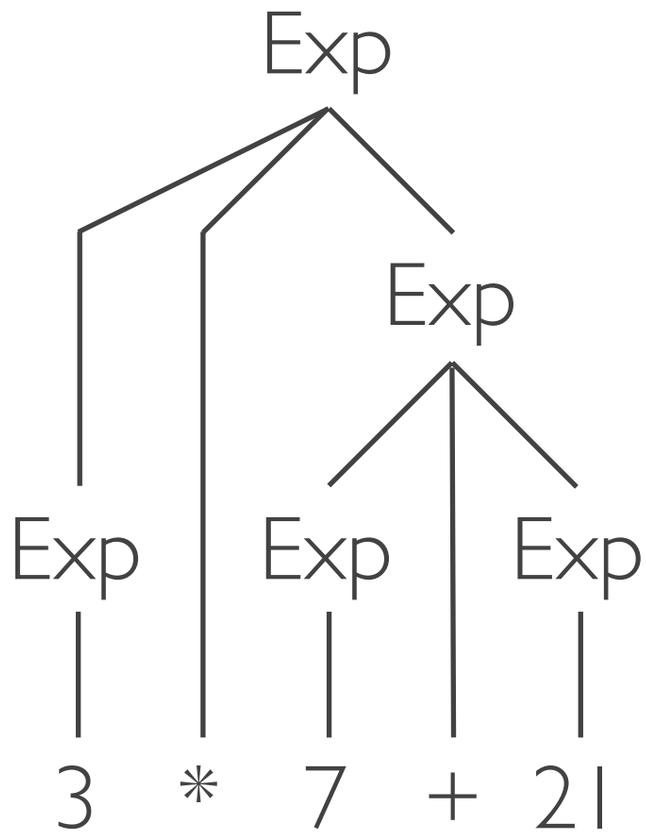


grammar classes

THE SECOND PLAGUE WAS

DISAMBIGUATION

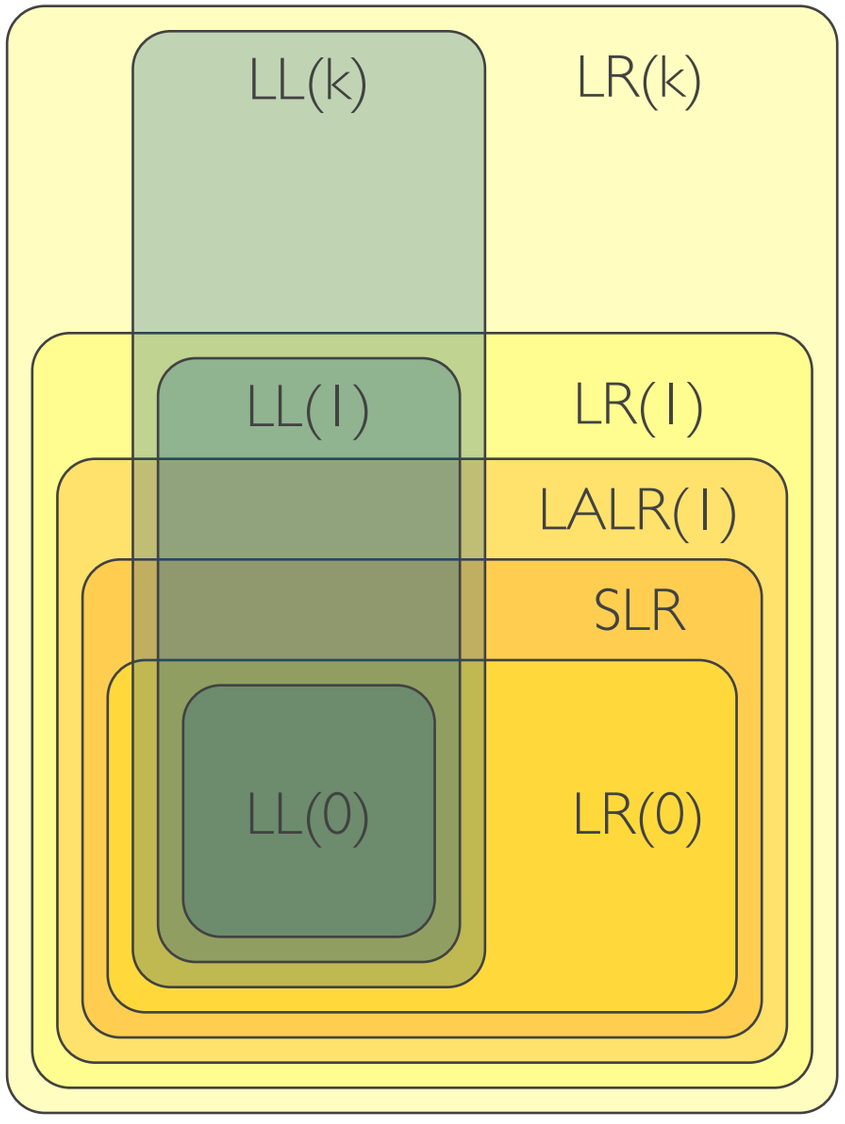

Exp
Exp
Exp
Exp
Exp
3
*
7
+
21

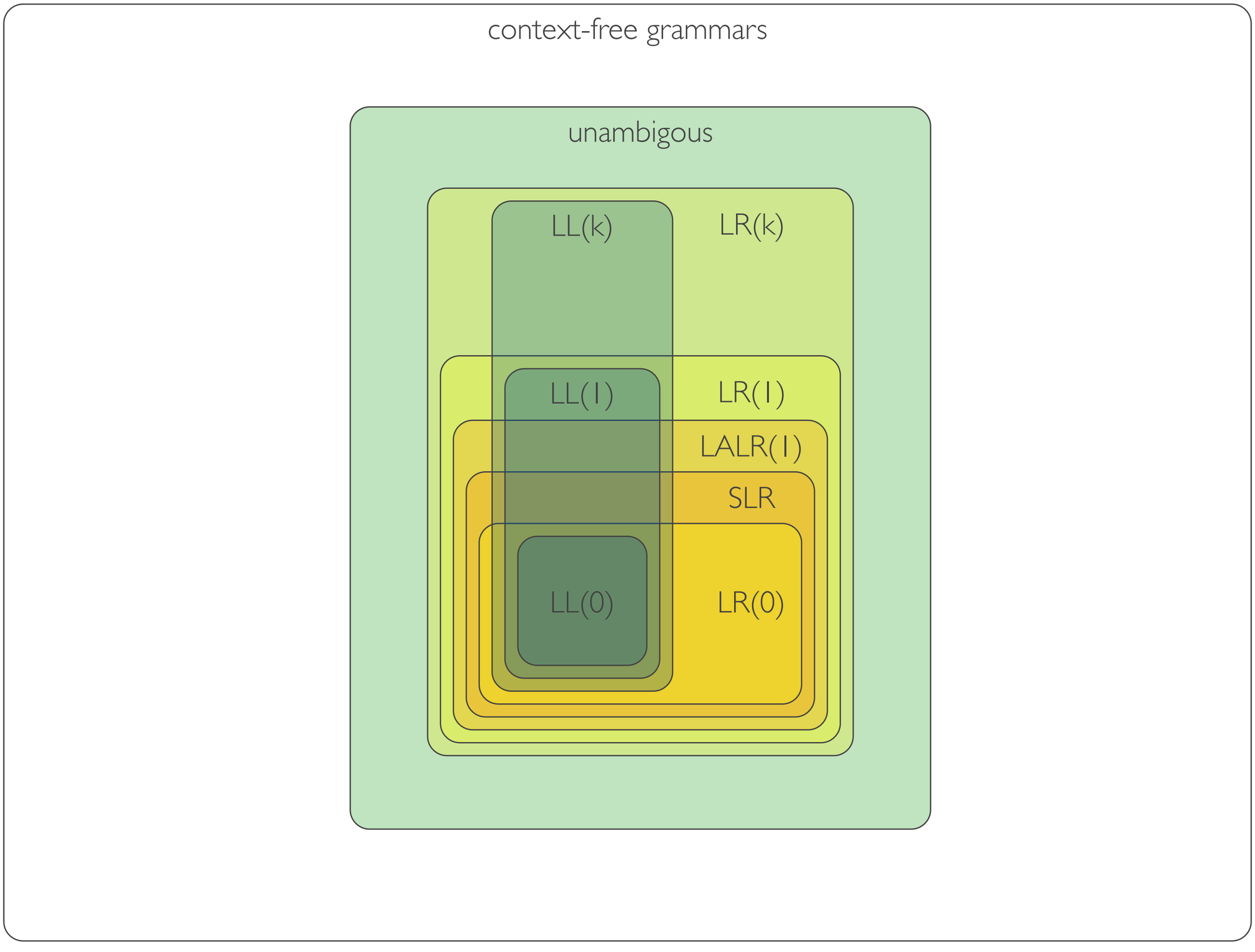

Exp
Exp
Exp
Exp
Exp
3
*
7
+
21

precedence	operators	associativity
1	( ), [ ]	non-associative
2	new	non-associative
3	.	left-associative
4	++, --	non-associative
5	-, +, !, ~, ++, --, (*type*)	right-associative
6	*, /, %	left-associative
7	+, -	left-associative
…	…	…

text books

context-free grammars




context-free grammars
unambigous
LL(k)
LR(k)
LL(1)
LR(1)
LALR(1)
SLR
LL(0)
LR(0)

Exp “+” Term → Exp

Term → Exp

Term “*” Fact → Term

Fact → Term

Num → Fact

grammar classes

FALSE PROPHETS

L = {ab, a}

"a" "b" → A

"a" → A

paradise

L = {ab, a}

"a" "b" /

"a" → A

PEGs

L = {ab, a}

“a” “b” → A

paradise

L = {a}

“a” /

“a” “b” → A

PEGs

if c_1 then if c_2 then s_1 else s_2

dangling else

“if” E “then” S “else” S / “if” E “then” S → S

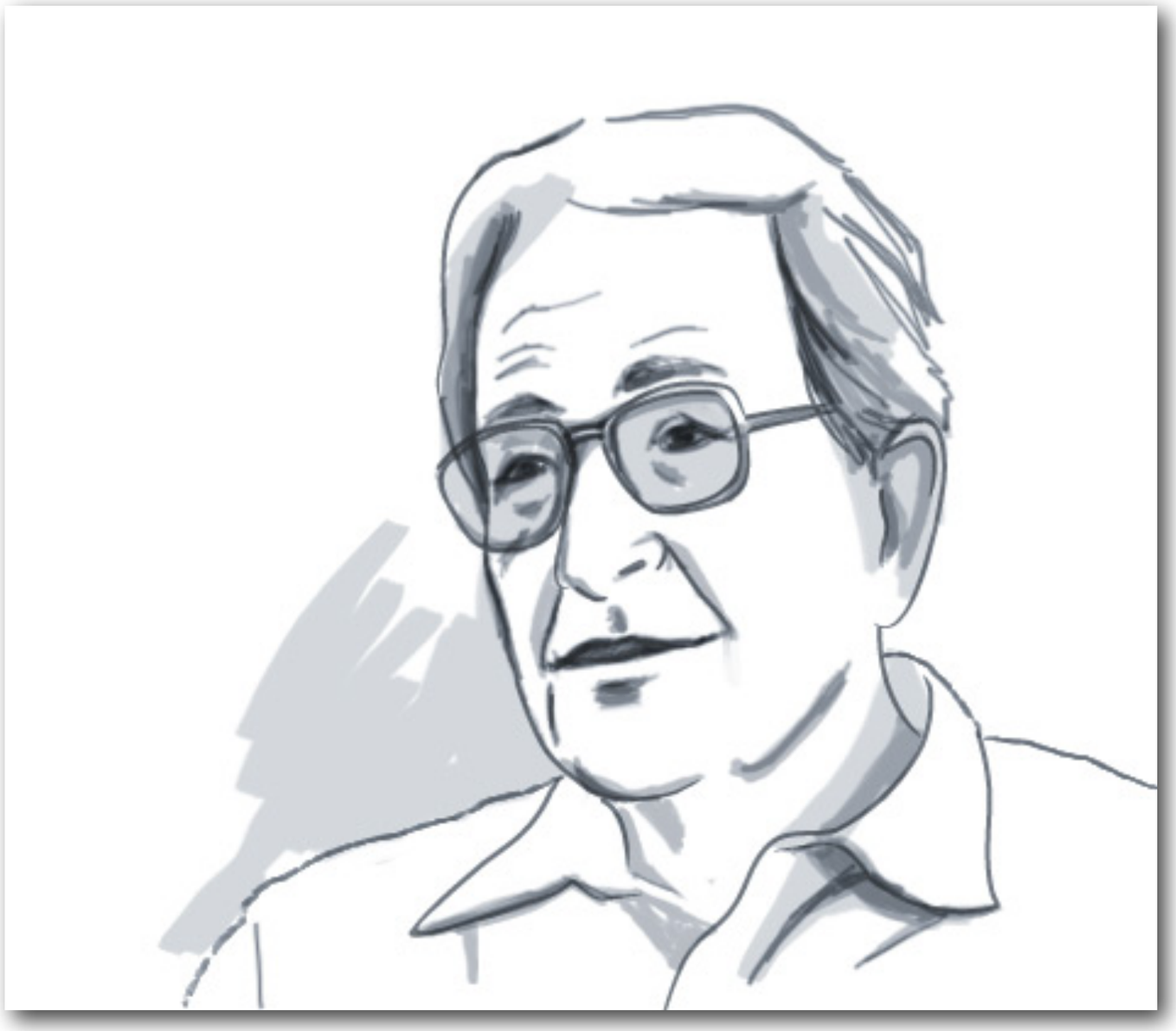
“if” E “then” S → S

“if” E “then” S “else” S → S

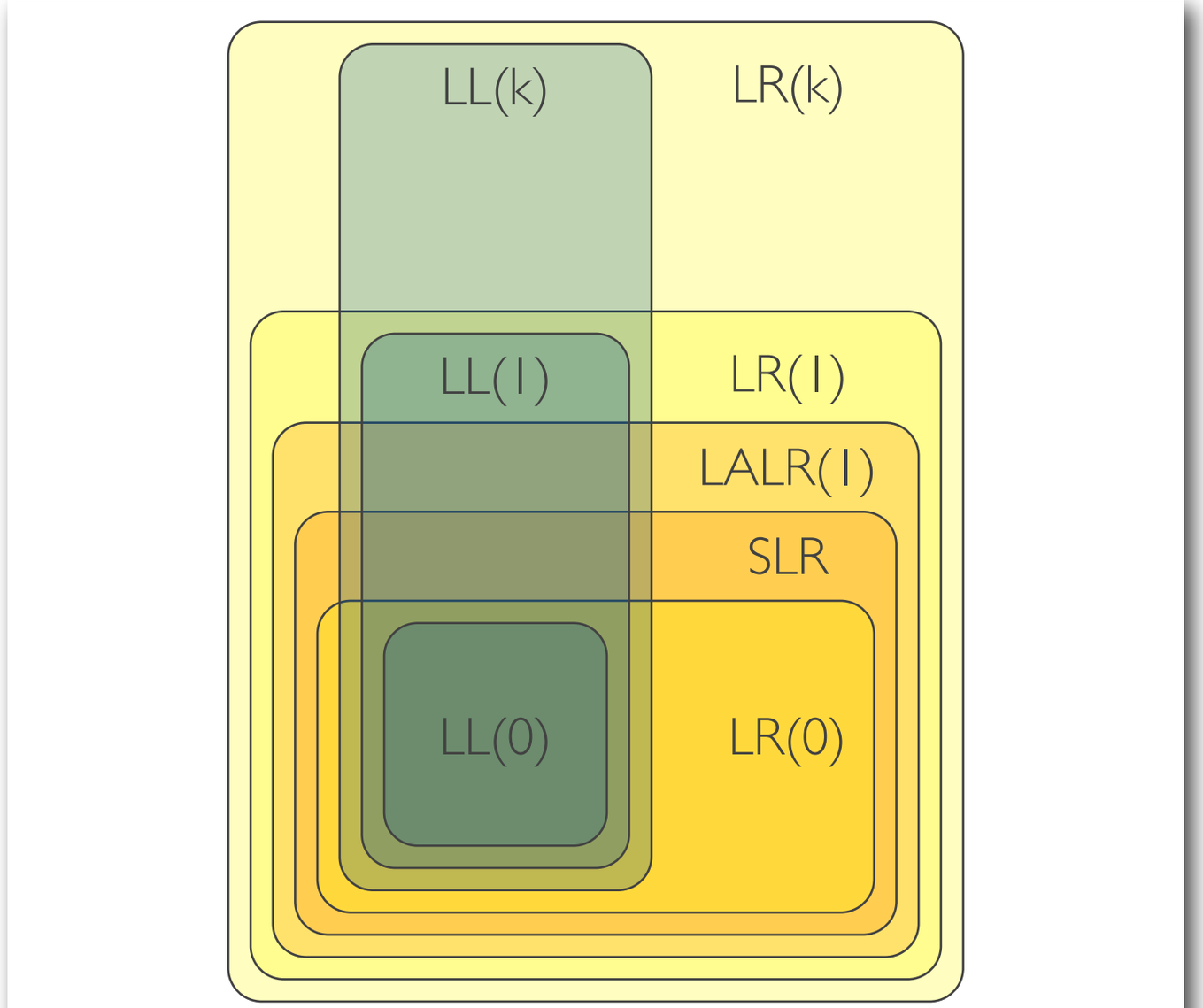
PEGs

THE THIRD PLAGUE WAS

LEXICAL SYNTAX



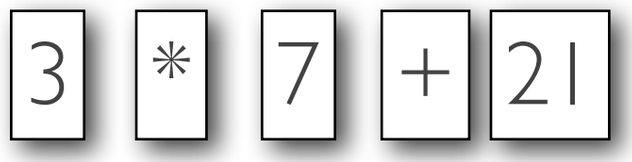
morphology & syntax



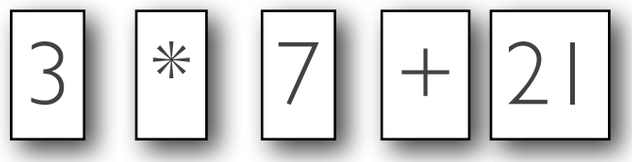
limited look-ahead

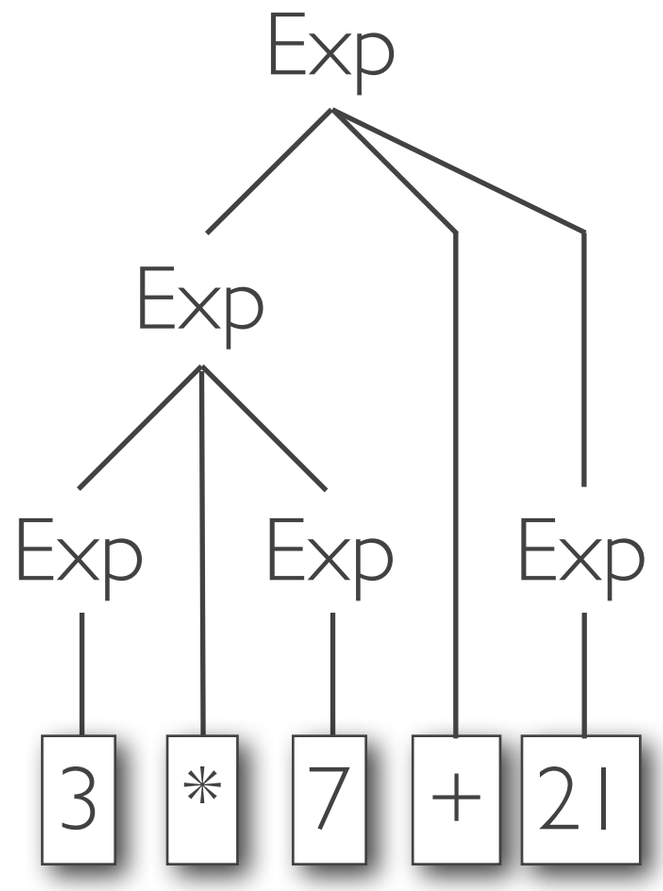
scanners

$$3 * 7 + 21$$


3
*
7
+
21

parsers


3
*
7
+
21


Exp
Exp
Exp
Exp
Exp
3
*
7
+
21

```
x := 1.0;
y : array [1..10] of integer
```

```
x = 1. * 10
```

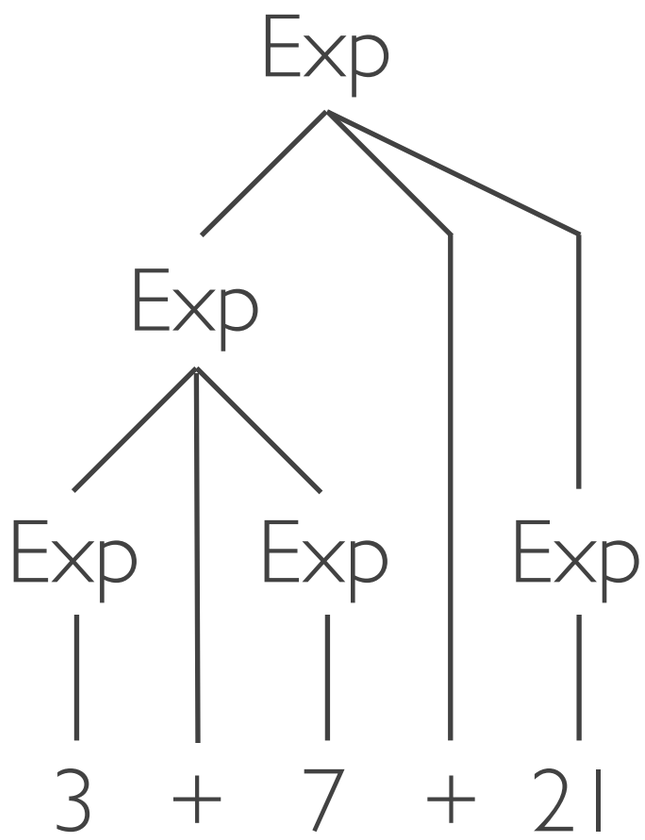
```
y : array [ 1 .. 10 ] of integer
```

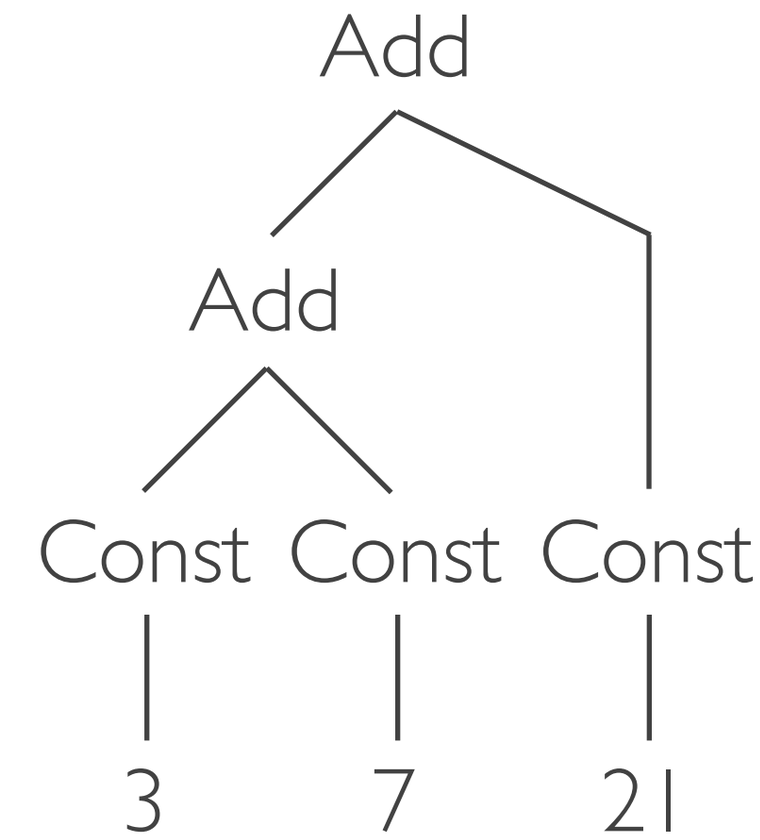
```
x = 1. * .10
```

```
y : array [ 1. .10 ] of integer
```

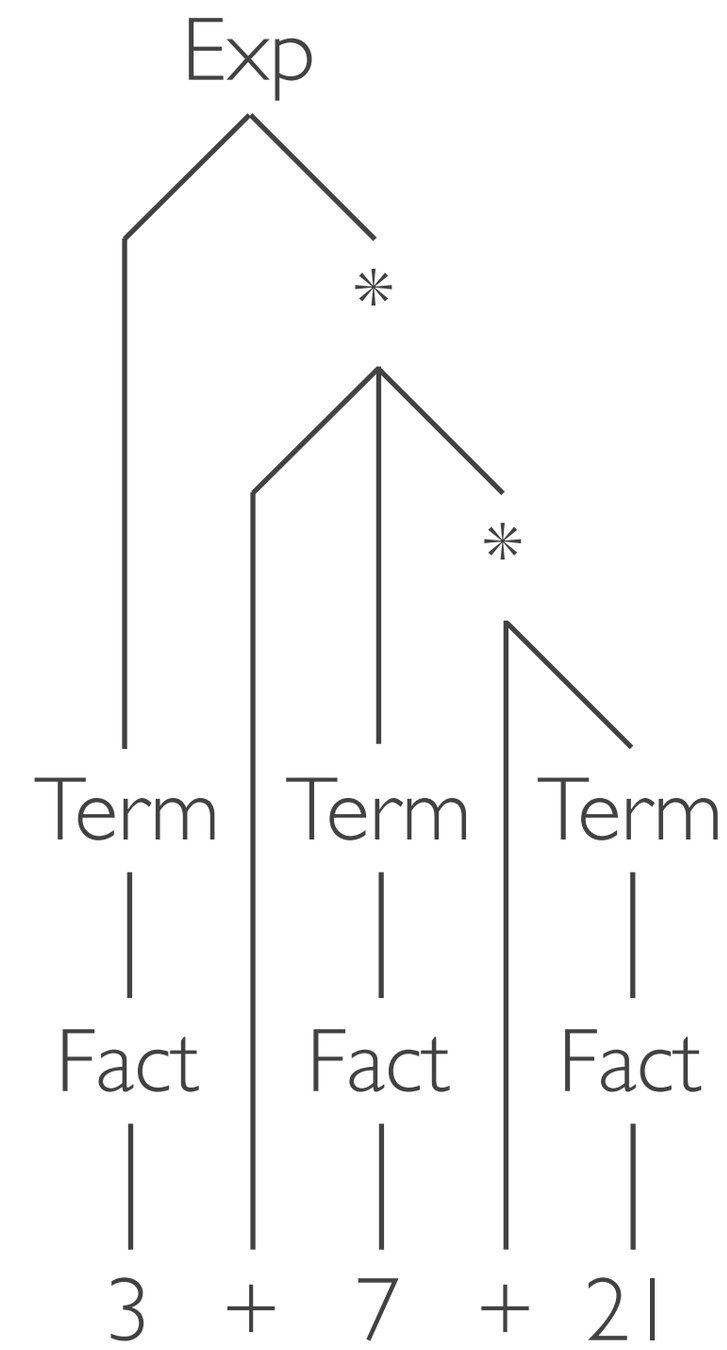
THE FOURTH PLAGUE WAS

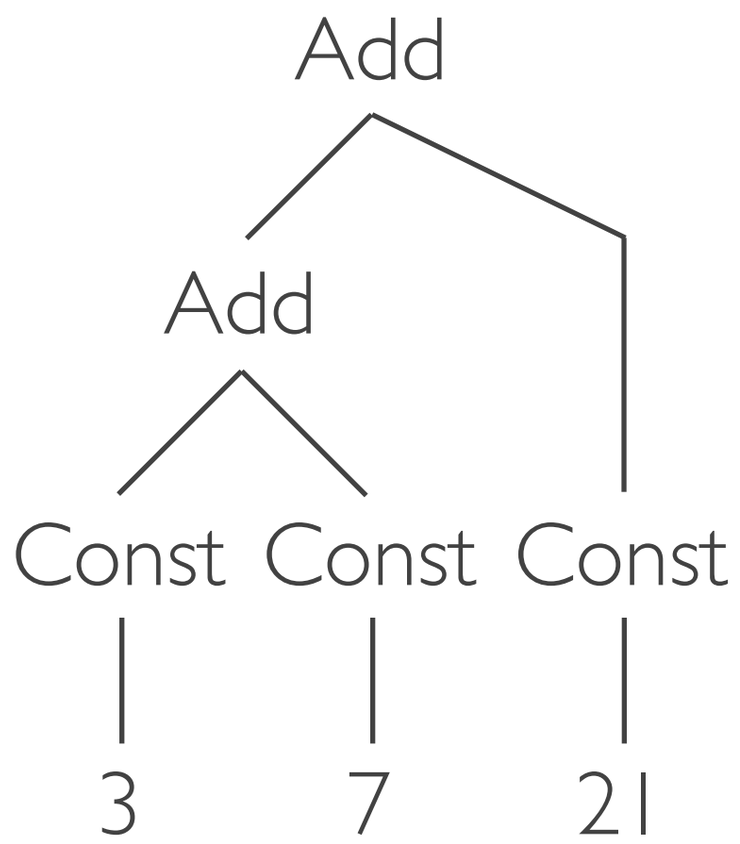
TREE CONSTRUCTION





paradise





grammar classes

```
expr:
   INTEGER              { $$ = con($1); }
| expr '+' expr { $$ = opr('+', 2, $1, $3);}
| expr '*' expr { $$ = opr('*', 2, $1, $3);}
;
```

semantic actions

THE FIFTH PLAGUE WAS EVOLUTION

Exp “+” Exp → Exp

Exp “*” Exp → Exp

Num → Exp

paradise

Exp “+” Term → Exp

Term → Exp

Term “*” Fact → Term

Fact → Term

Num → Fact

grammar classes

Exp "+" Exp → Exp

Exp "*" Exp → Exp

Num → Exp

Exp "=" Exp → Exp

Exp "<" Exp → Exp

Exp ">" Exp → Exp

paradise

CExp "+" Term → **CExp**

Term → **CExp**

Term "*" Fact → Term

Fact → Term

Num → Fact

Exp "=" CExp → Exp

Exp "<" CExp → Exp

Exp ">" CExp → Exp

CExp → Exp

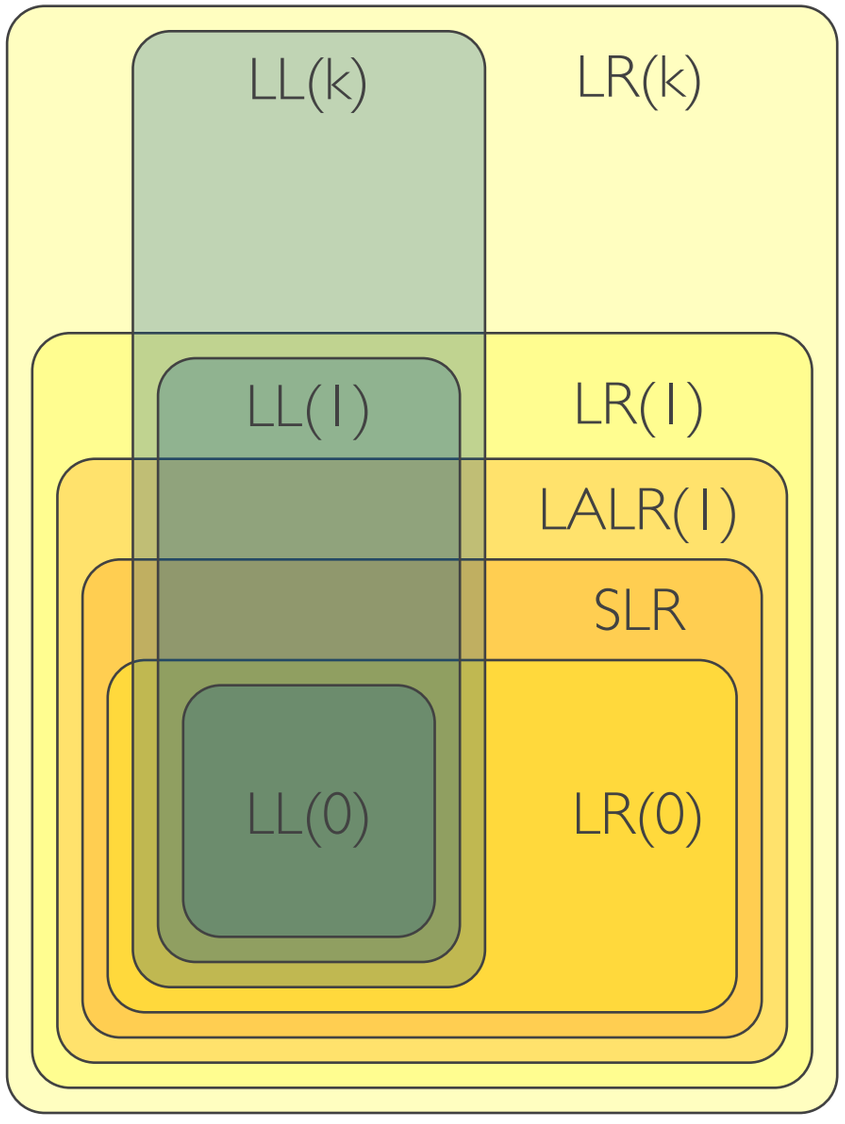
grammar classes

THE SIXTH PLAGUE WAS

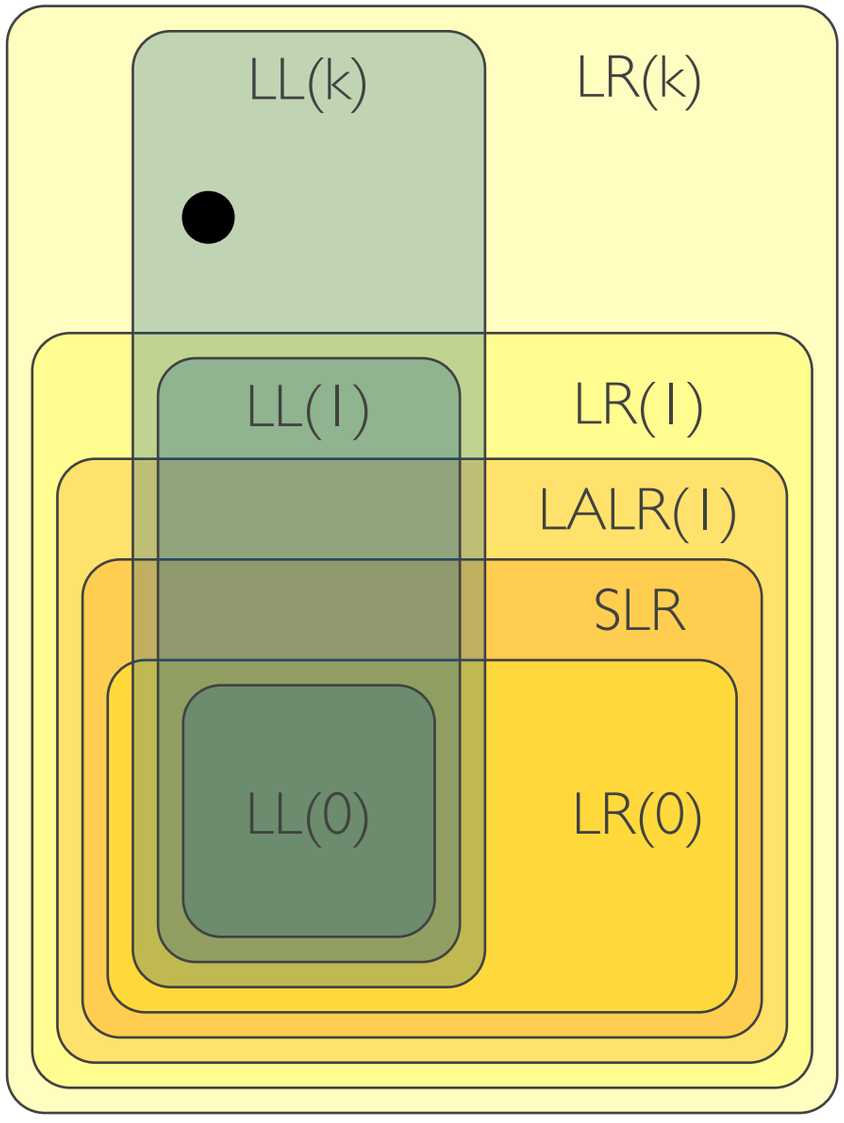
COMPOSITION

parsers

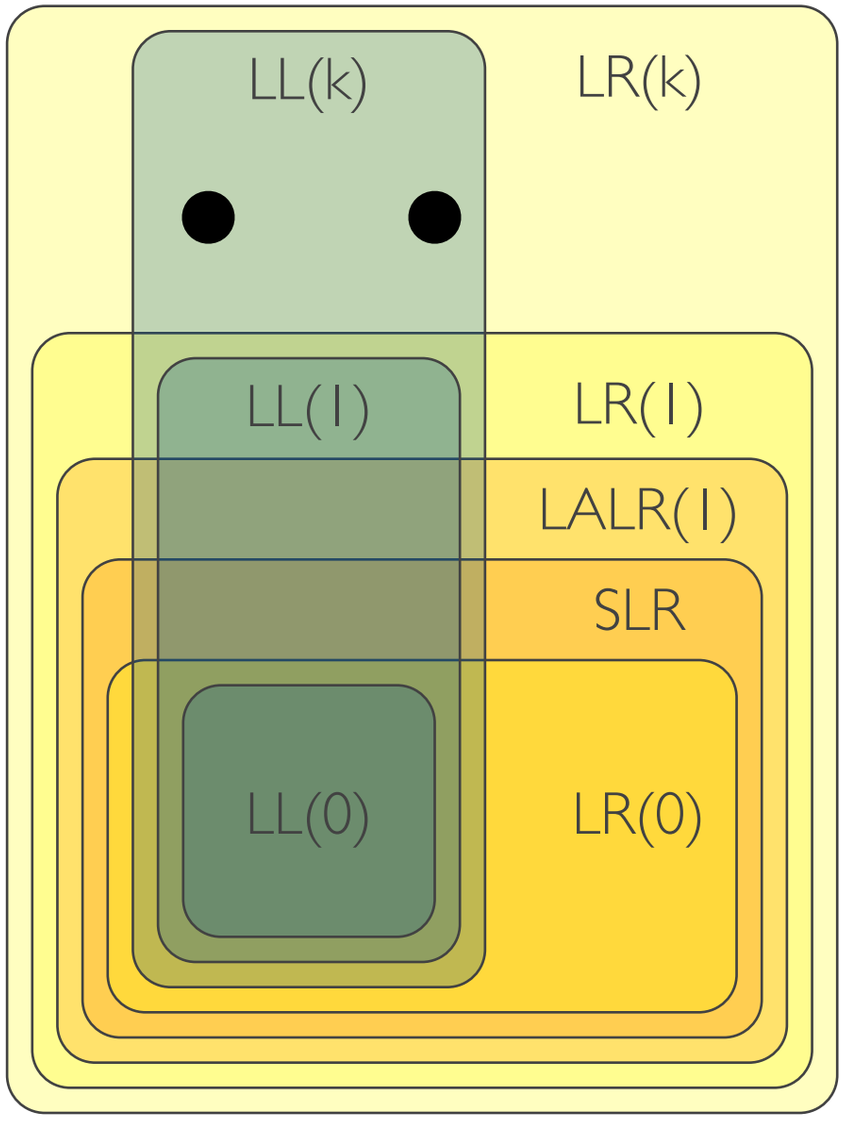
context-free grammars



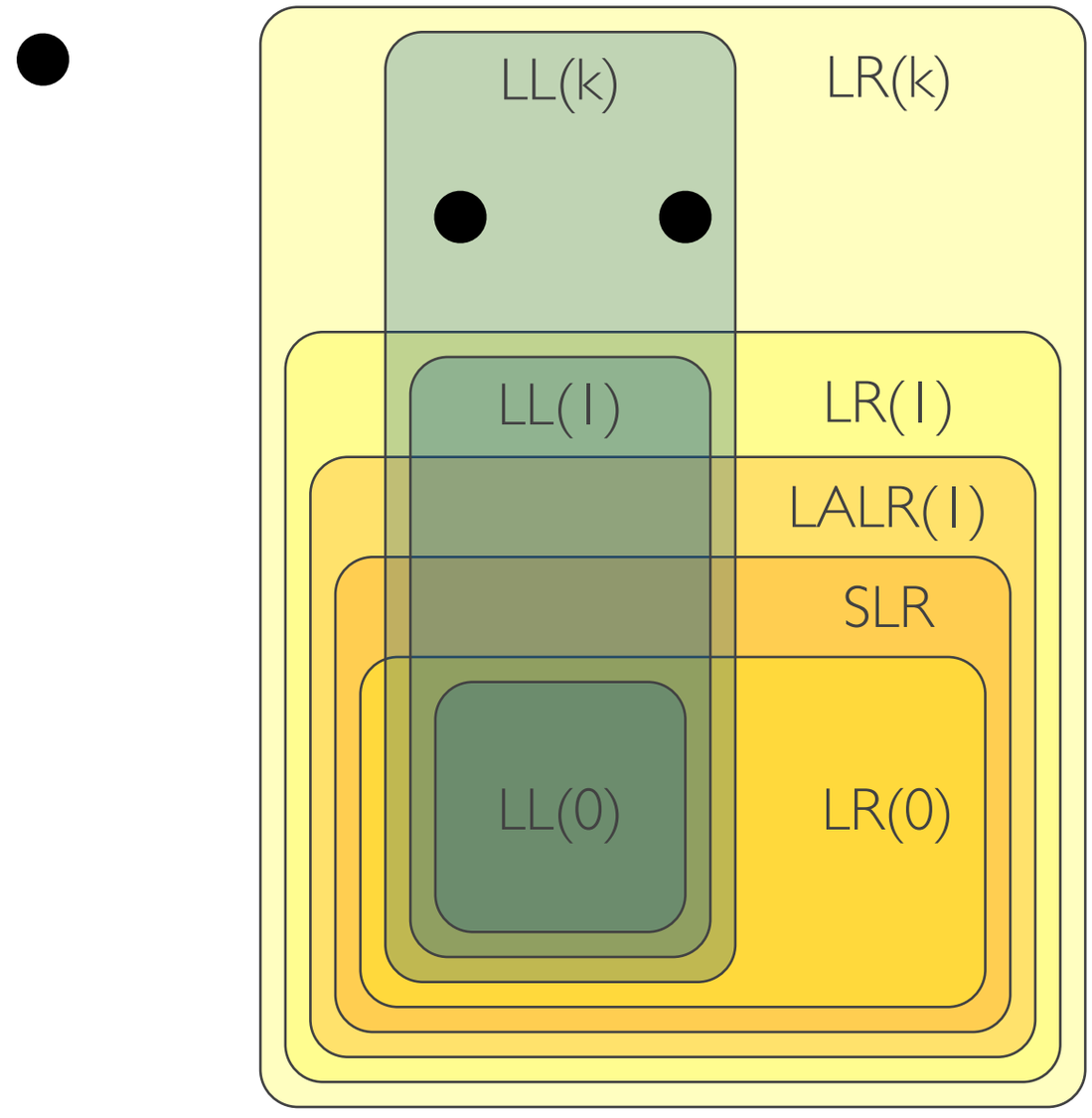
context-free grammars



context-free grammars



context-free grammars



scanners

```
public boolean
  authenticate(String user, String pw) {

    SQL stm = <| SELECT id FROM Users
                 WHERE name = ${user}
                 AND   password = ${pw} |>;

    return executeQuery(stm).size() != 0;
}
```

THE SEVENTH PLAGUE WAS

RESTRICTION

TO

PARSERS

PRETTY PRINTERS

SENTENCE GENERATORS

AST ACCESS

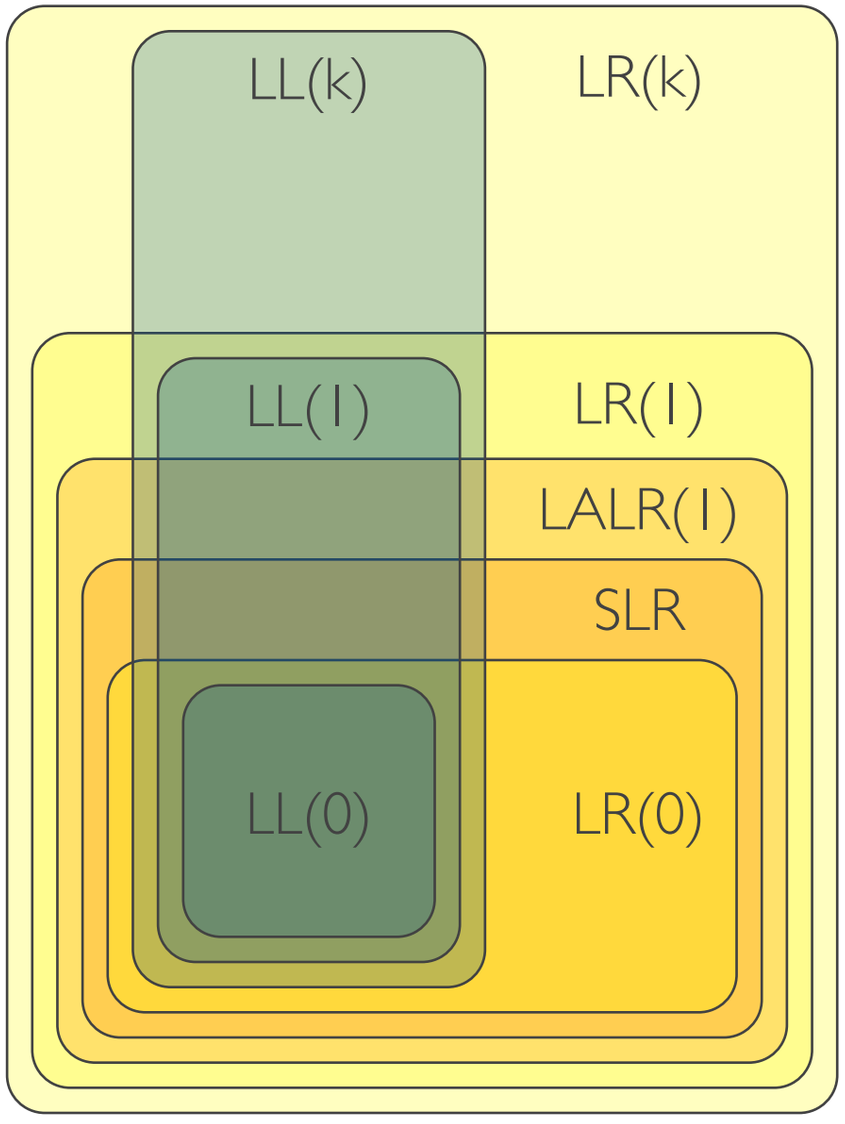
IDE SUPPORT

PARADISE REGAINED

GENERALISED

PARSING

context-free grammars



context-free grammars

Exp “+” Exp → Exp

Exp “*” Exp → Exp

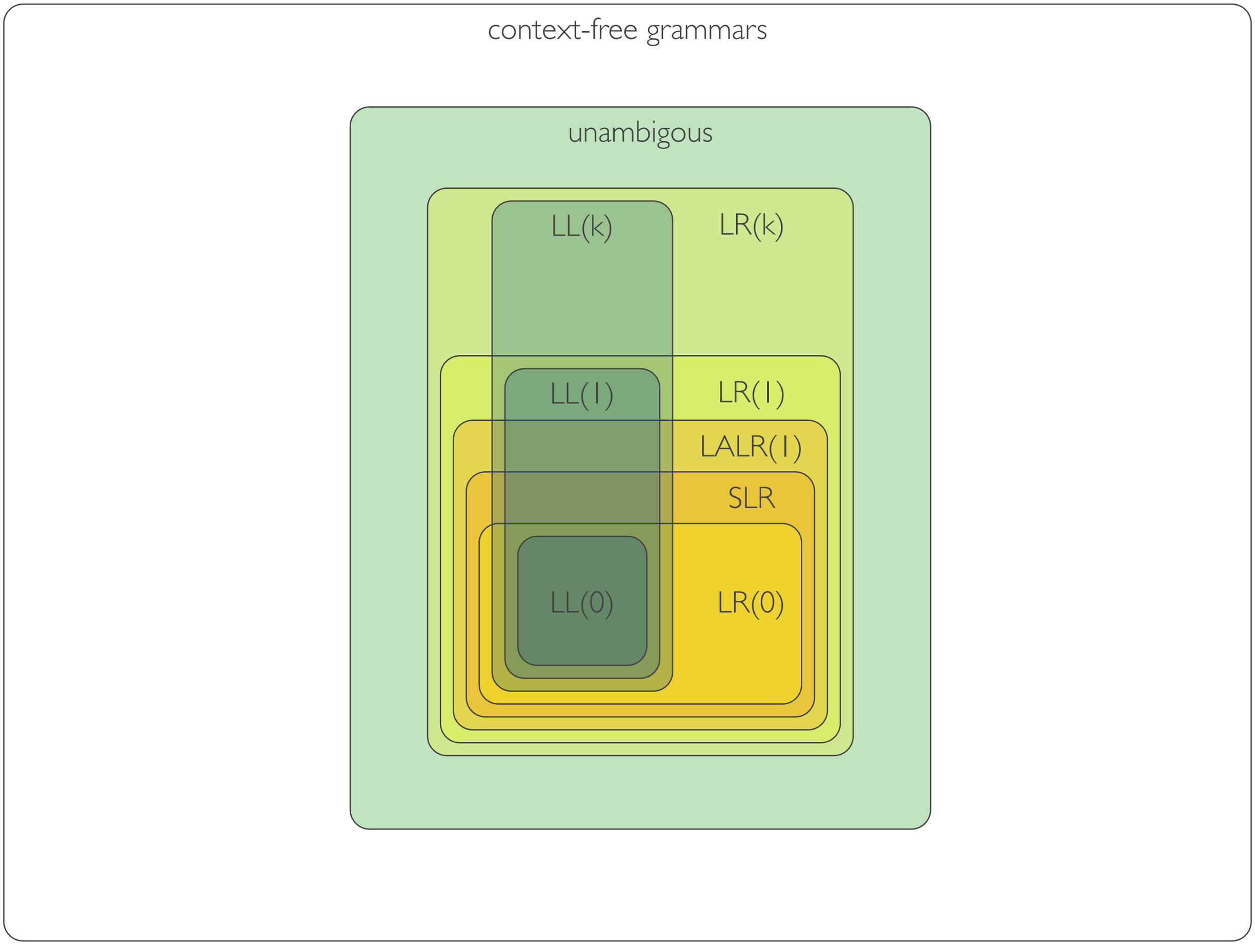
Num → Exp

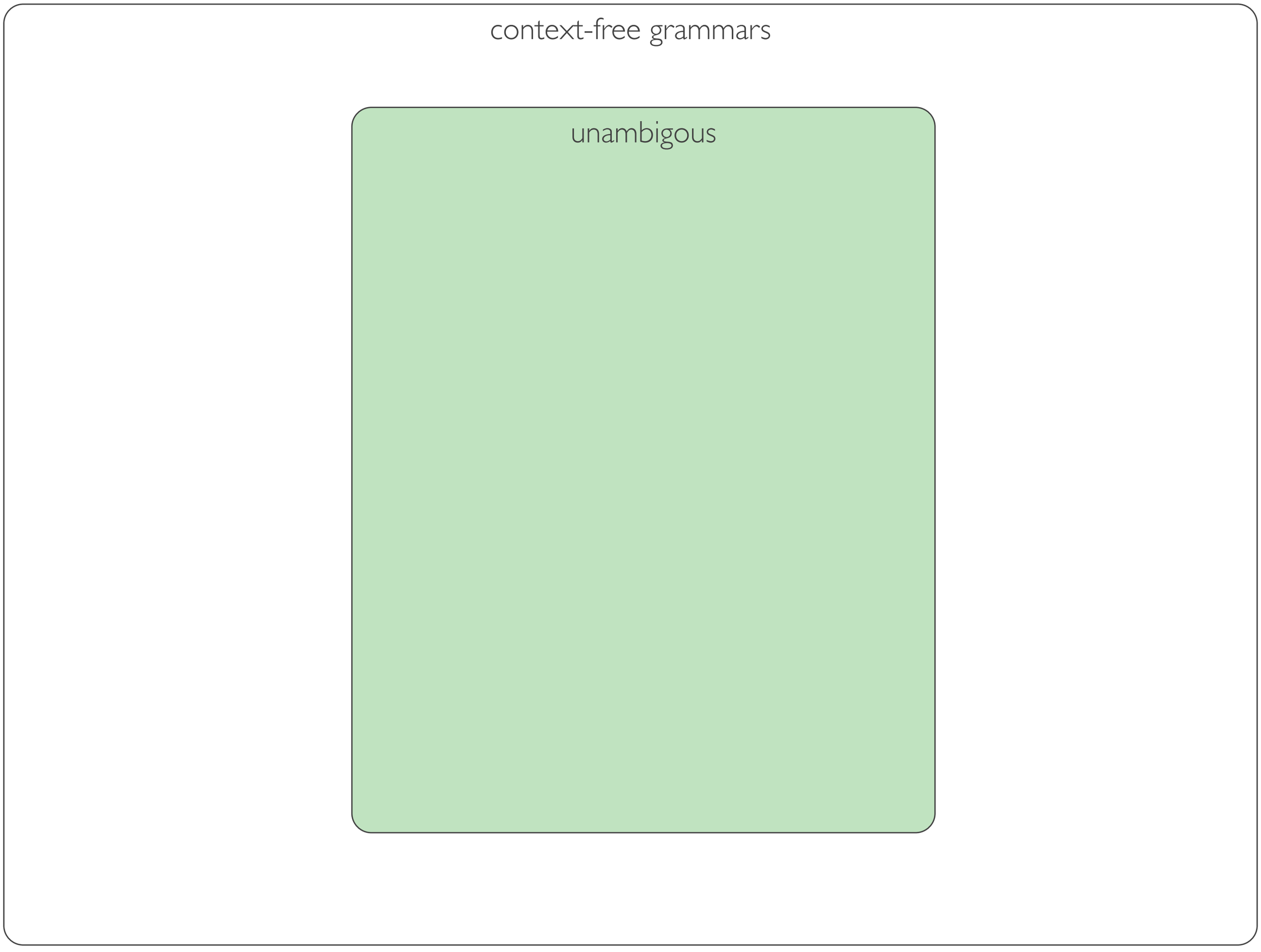
paradise

```
context-free syntax

  Exp "+" Exp -> Exp
  Exp "*" Exp -> Exp
  NUM         -> Exp
```

SDF

DECLARATIVE
DISAMBIGUATION


context-free grammars
unambigous
LL(k)
LR(k)
LL(1)
LR(1)
LALR(1)
SLR
LL(0)
LR(0)


context-free grammars
unambigous

context-free grammars

precedence	operators	associativity
1	( ), [ ]	non-associative
2	new	non-associative
3	.	left-associative
4	++, --	non-associative
5	-, +, !, ~, ++, --, (type)	right-associative
6	*, /, %	left-associative
7	+, -	left-associative
…	…	…

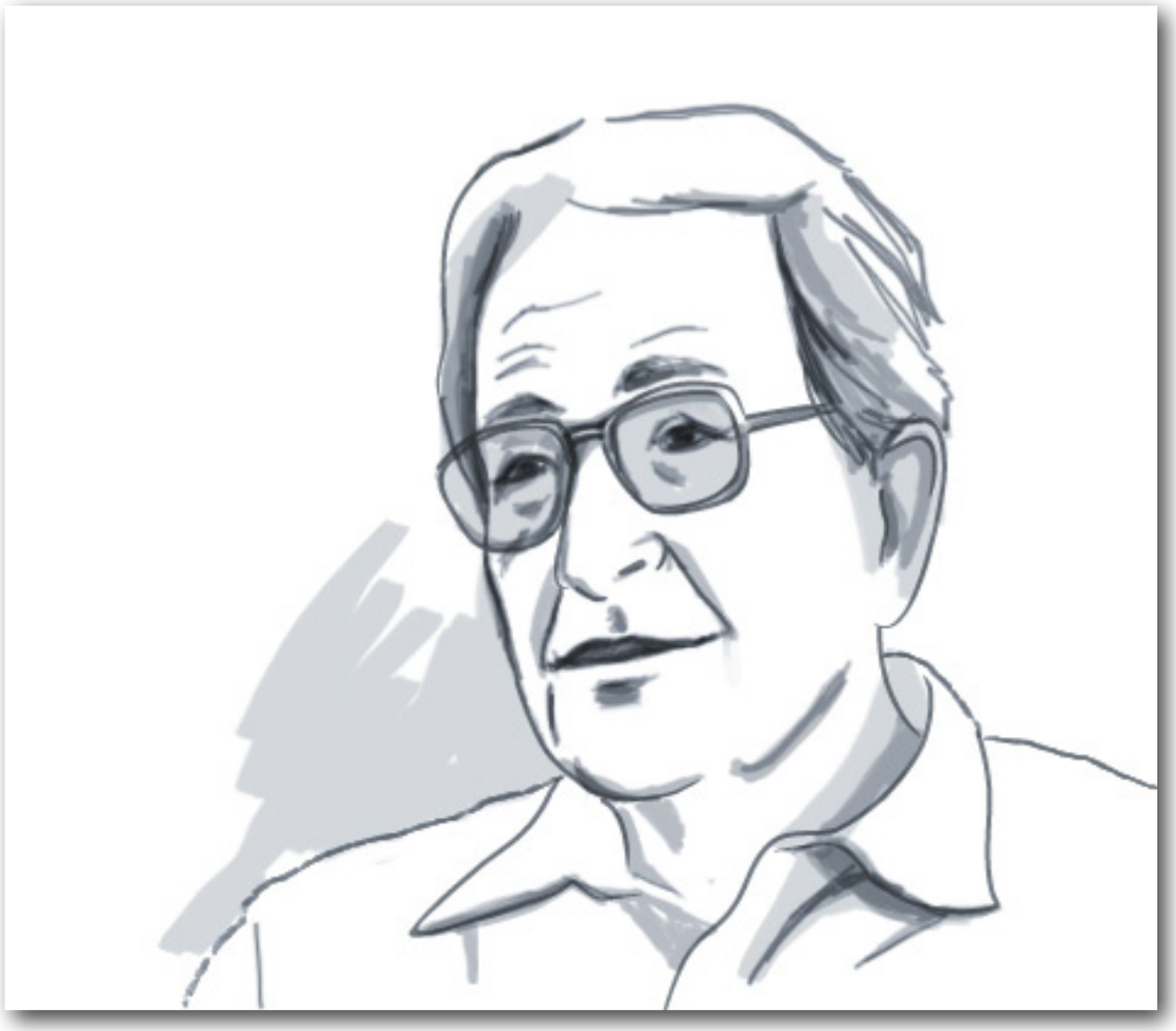
text books

context-free priorities

```
  Exp "*" Exp -> Exp {left}
> Exp "+" Exp -> Exp {left}
```

```
context-free syntax

  "if" E "then" S             -> S {prefer}
  "if" E "then" S "else" S -> S
```

SCANNERLESS
PARSING



morphology & syntax

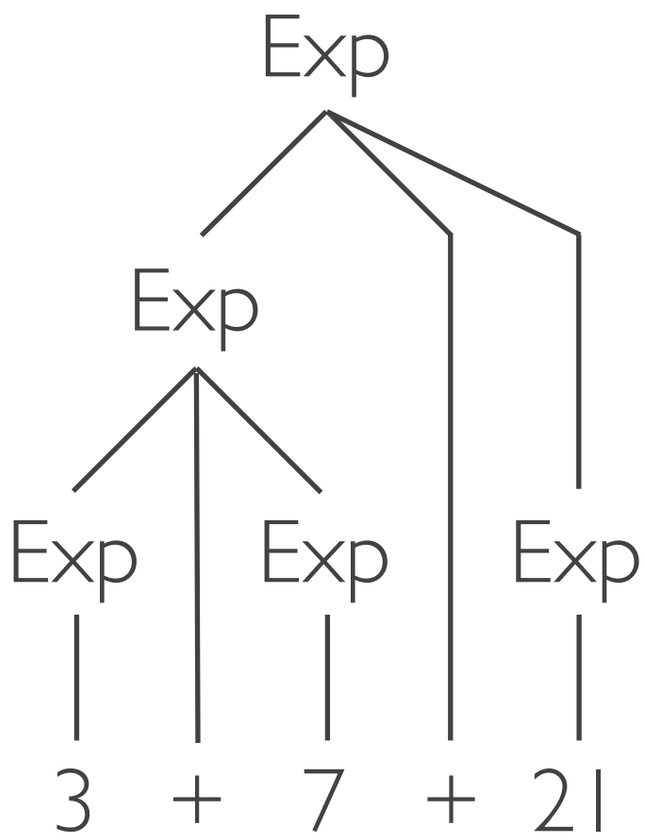
```
lexical syntax

   [0-9]+ -> NUM

   [\ \t\n]                -> LAYOUT
   "//" ~[\n]* [\n] -> LAYOUT
```

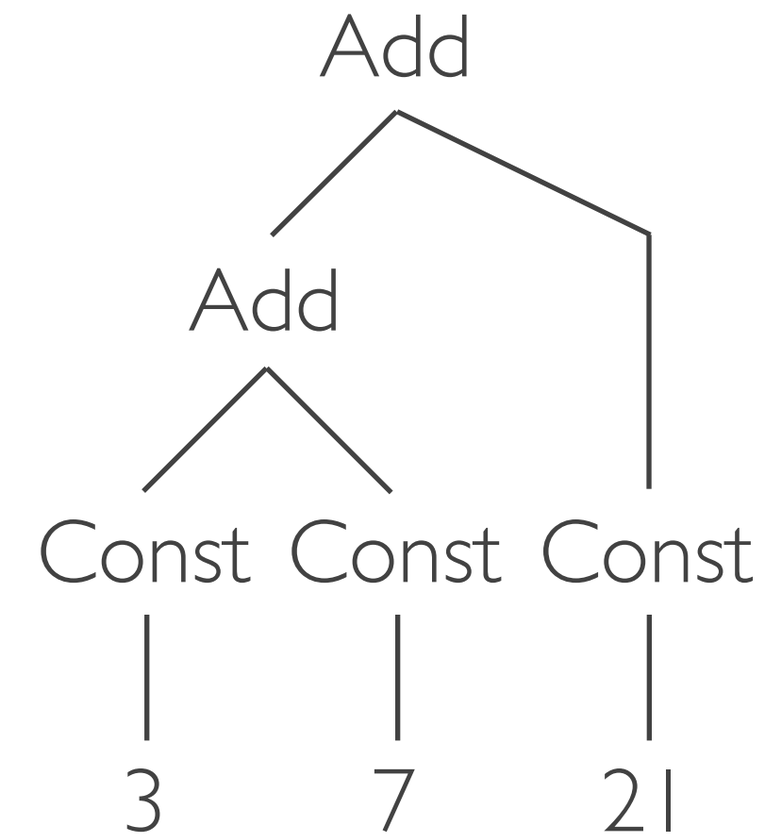
parser

parser

DECLARATIVE

TREE CONSTRUCTION

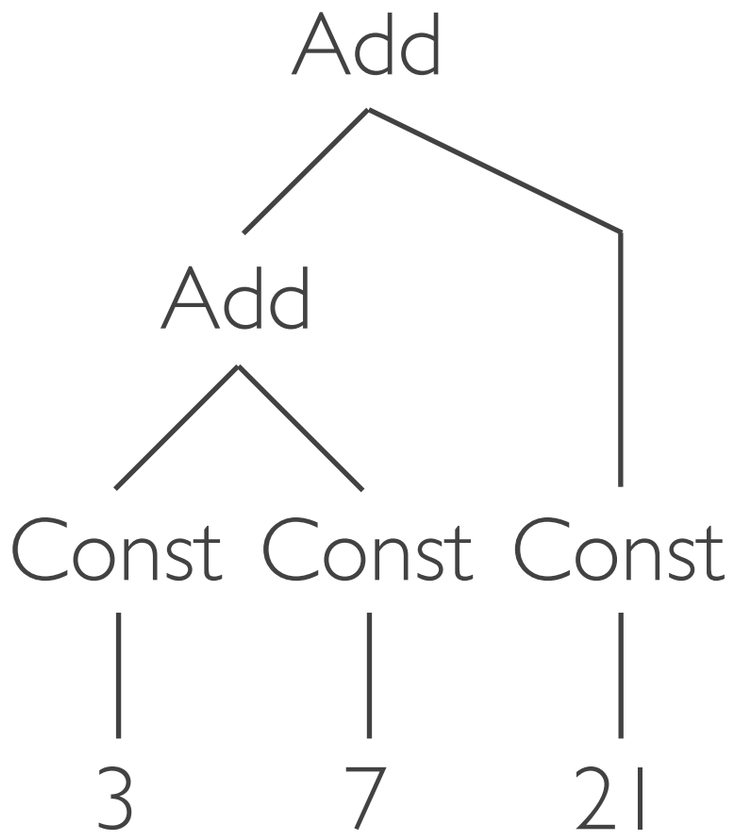




paradise

```
context-free syntax

  Exp "+" Exp -> Exp {cons("Add")}
  Exp "*" Exp -> Exp {cons("Mul")}
  NUM         -> Exp {cons("Const")}
```

SDF



paradise

```
Add(
  Add(
    Const("3"),
    Const("7")
  ),
  Const("21")
)
```

SDF

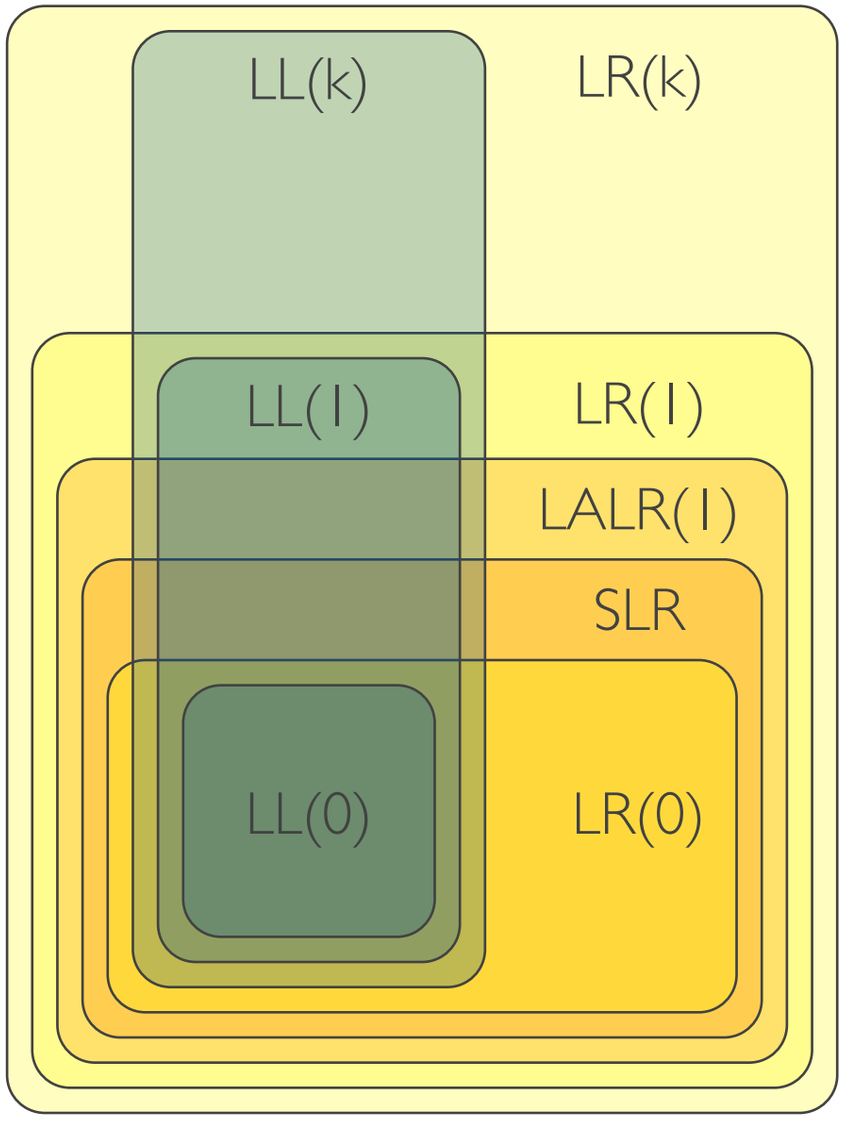
SEAMLESS

EVOLUTION

```
context-free syntax

  Exp "+" Exp -> Exp {cons("Add")}
  Exp "*" Exp -> Exp {cons("Mul")}
  NUM         -> Exp {cons("Const")}

  Exp "=" Exp -> Exp {cons("Eq")}
  Exp ">" Exp -> Exp {cons("Gt")}
  Exp "<" Exp -> Exp {cons("Lt")}
```

MODULAR
COMPOSITION

context-free grammars



context-free grammars

```
public boolean
  authenticate(String user, String pw) {

    SQL stm = <| SELECT id FROM Users
                 WHERE name = ${user}
                 AND   password = ${pw} |>;

    return executeQuery(stm).size() != 0;
}
```

```
module Java-SQL
  imports
    Java SQL

  exports
    context-free syntax

    "<|" Query "|>" -> Exp {cons("ToSQL")}
    "${" Exp "}" -> SqlExp {cons("FromSQL")}
```

BEYOND

PARSERS

PRETTY PRINTERS

SENTENCE GENERATORS

AST ACCESS

Java – MiniJava/test/example.mjv – Eclipse SDK – /Users/guwac/Documents/EclipseWo...

Transform

Team Synchr...

example.mjv

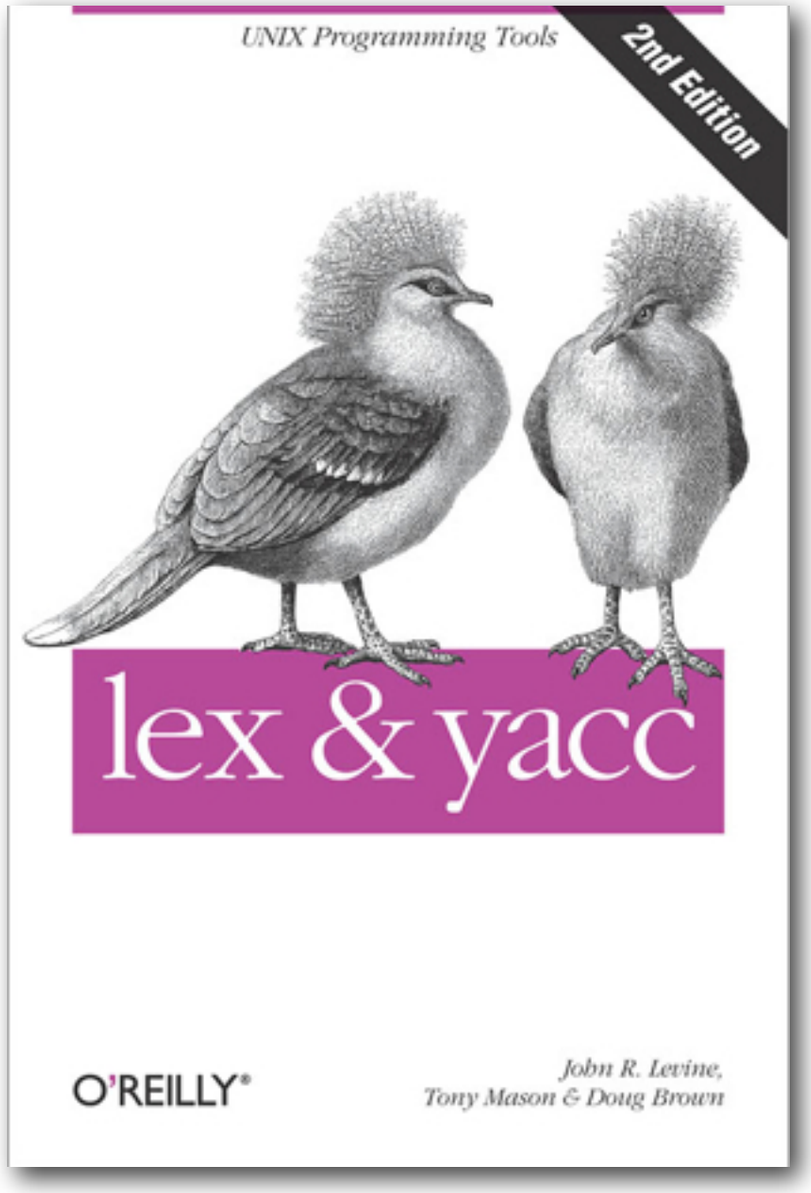
```
class Main {

    public static void main(String[] args) {
        System.out.println(0);
    }
}

class Fac {

    public int fac(int[] num) {
        int num_aux ;
        if (num < 1)
            num_aux = 1 ;
        else
            num_aux = num*this.fac(num-1) ;
        return num_aux ;
    }
}
```

Outline

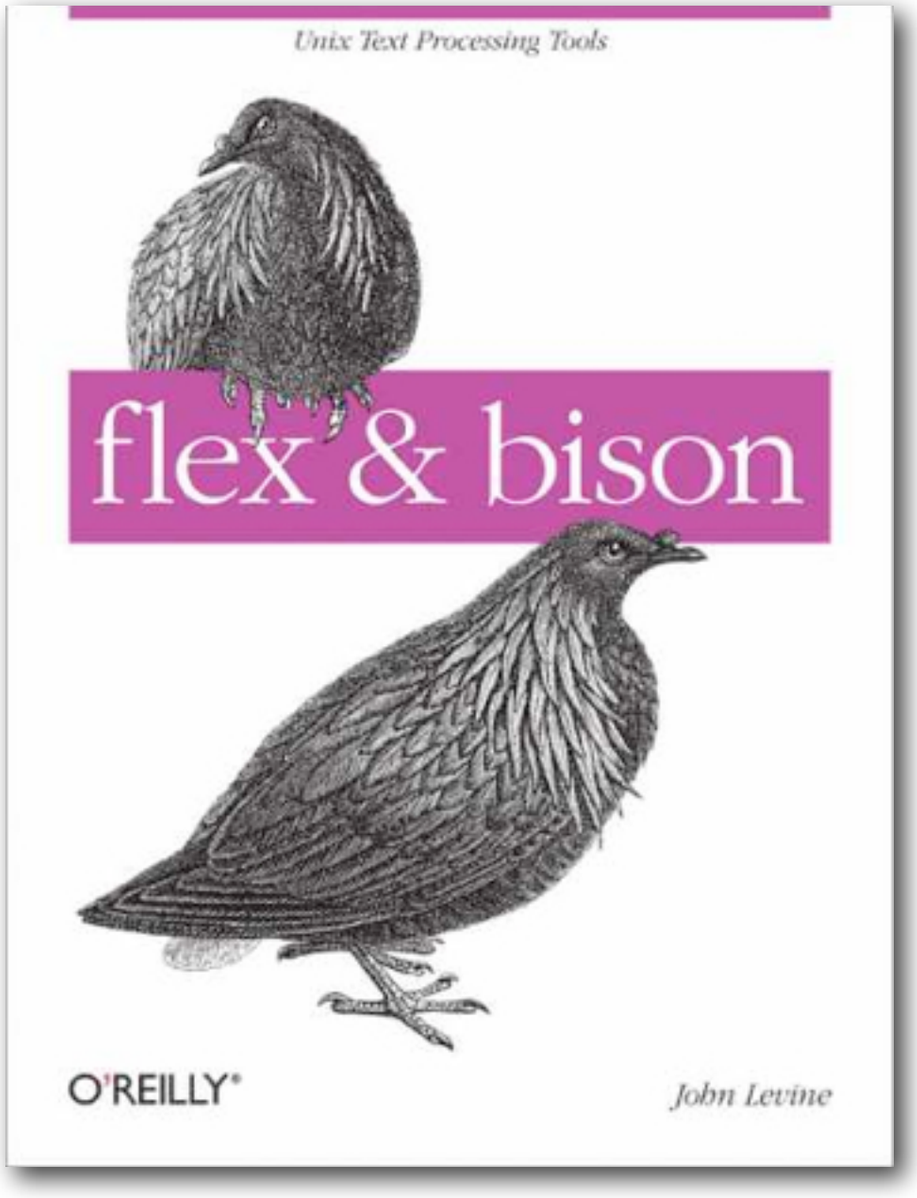
- Main
  - main
    - Void
    - args
      - StringArray
- Fac
  - fac
    - Int
    - num
      - Array
    - num_aux
      - Int

IDE SUPPORT

PARADISE **DENIED**



still around

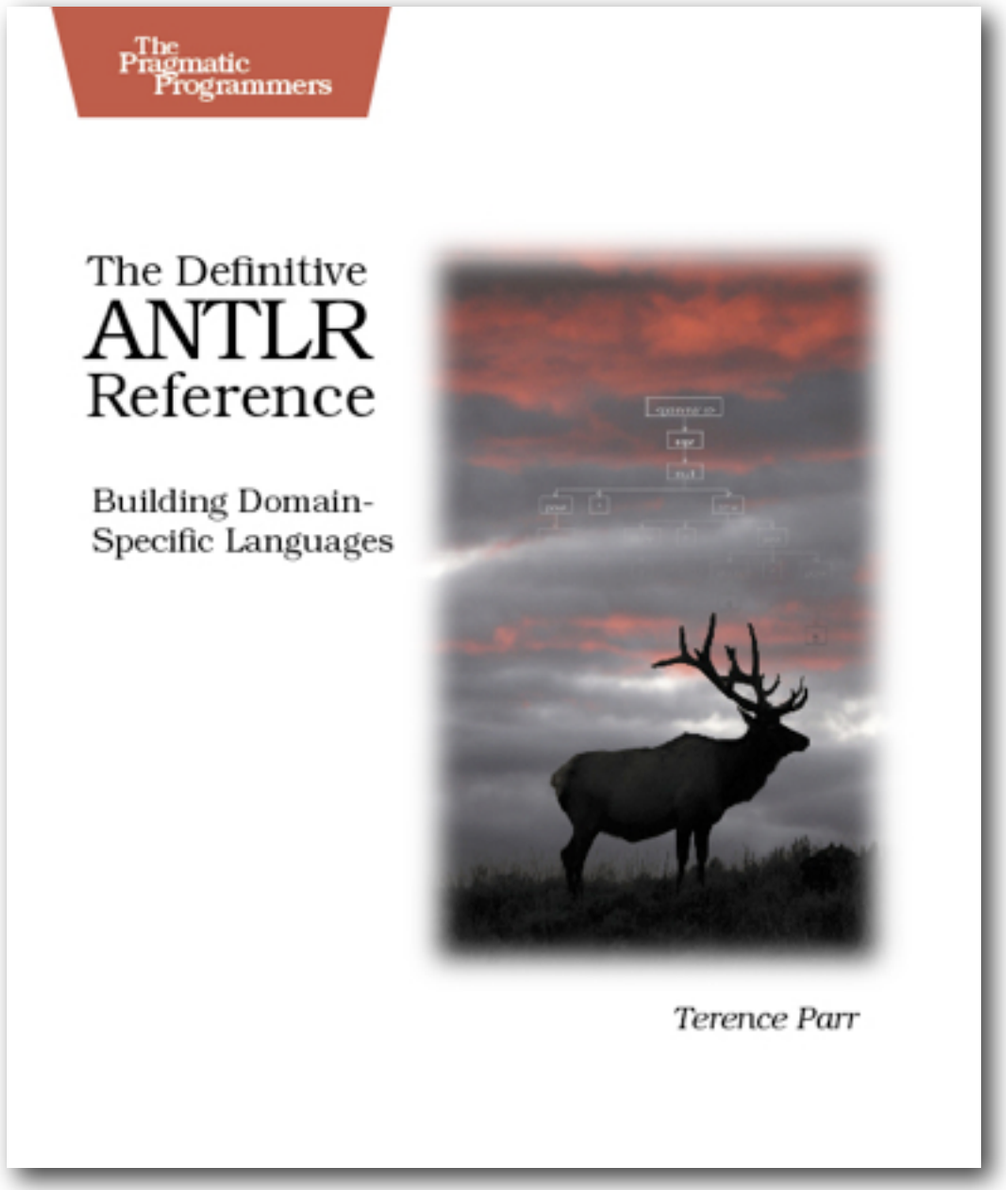


still around

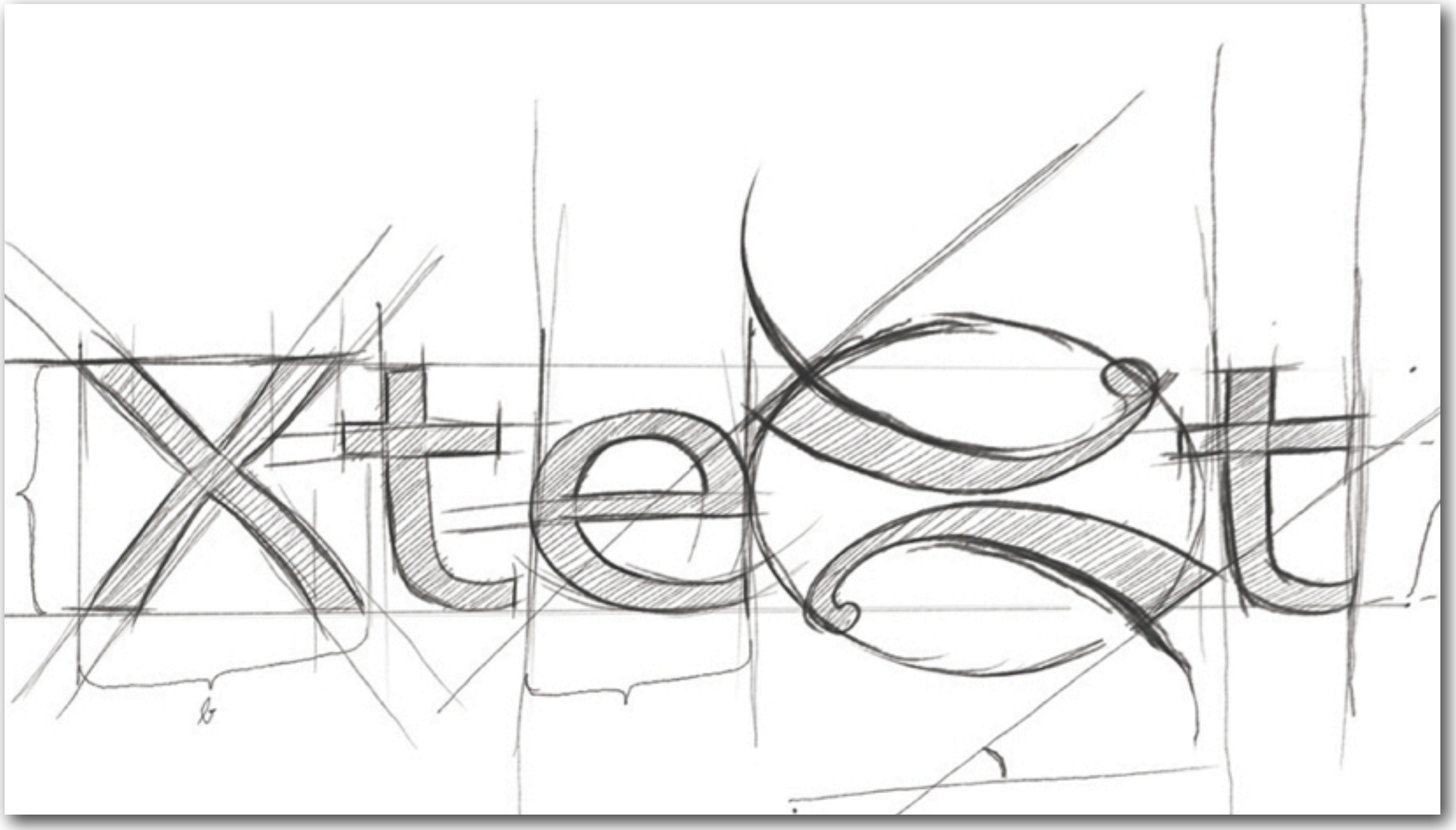
still have to use it

still have to learn
LL, LR, SLR, LALR

still think using
parser generators is hard



modern parser generator



modern parser generator

PARADISE OPEN

coffee break

II

pretty-printing

Recap: Parsing & AST construction

```
let
   function fact(n : int): int = if n < 1 then 1 else n * fact(n - 1)
in
   printint(fact(10))
end
```

```
Let(
   [  FunDec(
         "fact"
      ,  [FArg("n", Tid("int"))]
      ,  Tid("int")
      ,  IfThenElse(
            Lt(Var("n"), Int("1"))
         ,  Int("1")
         ,  Times(Var("n"), Call("fact", [Minus(Var("n"), Int("1"))]))
         )
      )
   ]
,  [Call("printint", [Call("fact", [Int("10")])])]
)
```

Pretty Printing

from ASTs to text

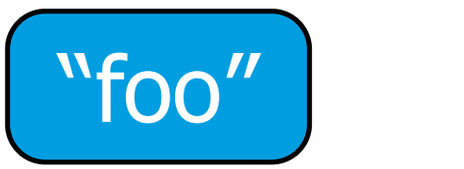
- keywords
- layout: spaces, line breaks, indentation

specification

- partially defined in grammar
- missing layout

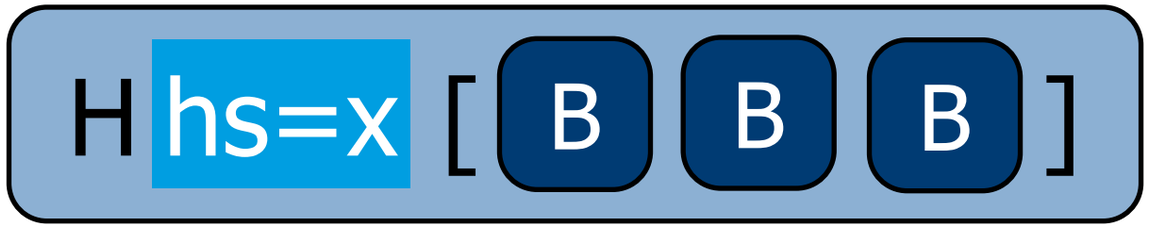
Box Layout

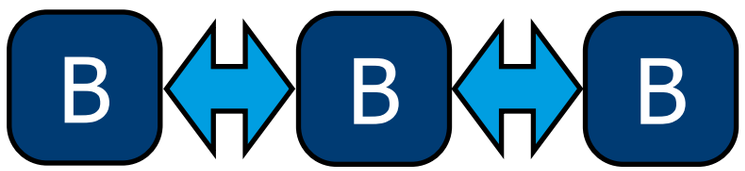
basic boxes



Box Layout

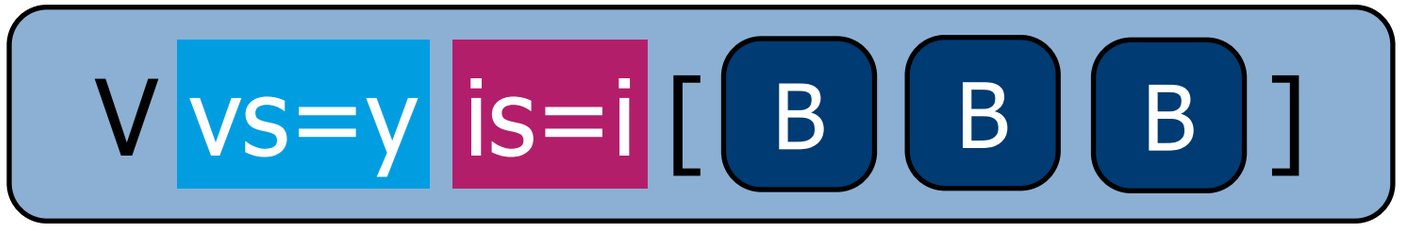
horizontal boxes

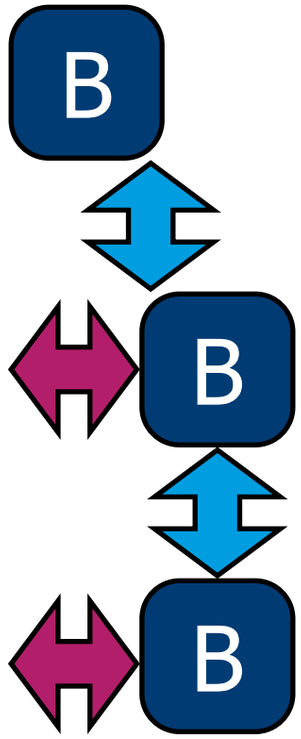




Box Layout

vertical boxes

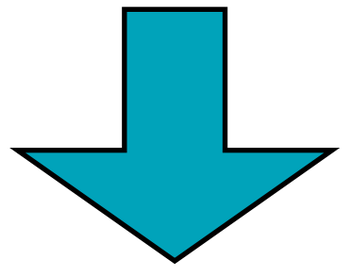




Pretty Print Tables

generation

```
"if" Exp "then" Exp                    -> Exp {"IfThen"}
"let" Dec* "in" {Exp ";"}* "end" -> Exp {"Let"}
```



```
Exp.IfThen -- KW["if"] _1 KW["then"] _2,
Exp.Let    -- KW["let"] _1 KW["in"] _2 KW["end"],

Exp.Let.1:iter-star     -- _1,
Exp.Let.2:iter-star-sep -- _1 KW[";"]
```

Pretty Print Tables

manual override

```
"if" Exp "then" Exp                    -> Exp {"IfThen"}
"let" Dec* "in" {Exp ";"}* "end" -> Exp {"Let"}
```

```
Exp.Let -- V vs=1 is=0 [
             V vs=1 is=2 [KW["let"] _1]
             V vs=1 is=2 [KW["in"] _2]
             KW["end"]
           ]
```

III

syntax templates

Recap: SDF

```
sorts Exp

context-free syntax

   LValue ":=" Exp                          -> Exp

   "let" Dec* "in" {Exp ";"}* "end"         -> Exp

   "if" Exp "then" Exp                      -> Exp
   "if" Exp "then" Exp "else" Exp           -> Exp

   "while" Exp "do" Exp                     -> Exp
   "for" Id ":=" Exp "to" Exp "do" Exp      -> Exp

   "break"                                  -> Exp

   "(" ")"                  -> Exp
   "(" Exp ")"              -> Exp
   "(" {Exp ";"}+ ")"       -> Exp
```

Pretty Print Tables

manual overrides

```
Exp.Let -- V vs=1 is=0 [
             V vs=1 is=2 [KW["let"] _1]
             V vs=1 is=2 [KW["in"] _2]
             KW["end"]
           ]
```

Recap: Code Completion

```
module Tiger-Completions

imports Tiger-Completions.generated

completions

    completion keyword  : "function"

    completion template Exp:

          "if " <e> " then\n\t" <s> (blank)

    completion proposer : editor-complete
```

Templates

explicit layout in syntax definitions

```
context-free syntax

   Exp "+"  Exp -> Exp {left, "Plus"}
   Exp "-"  Exp -> Exp {left, "Minus"}
```

```
context-free syntax

   Exp.Plus  = <<Exp> + <Exp>> {left}
   Exp.Minus = <<Exp> - <Exp>> {left}
```

Templates

explicit layout in syntax definitions

```
context-free syntax

   "let" Dec* "in" {Exp ";"}* "end" →  Exp {"Let"}
```

```
context-free syntax

   Exp.Let = <
     let
       <Dec*; separator="\n">
     in
       <Exp*; separator=";\n">
     end>
```

IV

summary

Summary
lessons learned

Summary
lessons learned

Why are efficient parsing algorithms problematic?

- not longer pure, declarative, beautiful
- paradise lost: seven plagues
- paradise regained: scannerless generalised parsing

Summary
lessons learned

Why are efficient parsing algorithms problematic?

- not longer pure, declarative, beautiful
- paradise lost: seven plagues
- paradise regained: scannerless generalised parsing

How can we specify pretty-printers?

- generated from SDF
- manual overrides
- one stop shop: TemplateLanguage

Summary
lessons learned

Why are efficient parsing algorithms problematic?

- not longer pure, declarative, beautiful
- paradise lost: seven plagues
- paradise regained: scannerless generalised parsing

How can we specify pretty-printers?

- generated from SDF
- manual overrides
- one stop shop: TemplateLanguage

Literature

learn more

Literature

learn more

declarative syntax definition

> Lennart C. L. Kats, Eelco Visser, Guido Wachsmuth: Pure and Declarative Syntax Definition - Paradise Lost and Regained. SPLASH 2010

Literature

learn more

declarative syntax definition

Lennart C. L. Kats, Eelco Visser, Guido Wachsmuth: Pure and Declarative Syntax Definition - Paradise Lost and Regained. SPLASH 2010

pretty-printing

Marc G.J. van den Brand, Eelco Visser: Generation of Formatters for Context-Free Languages. ACM TOSEM 5(1):1-41, 1996.

Merijn de Jonge. Pretty-Printing for Software Reengineering. ICSM 2002

Literature

learn more

declarative syntax definition

Lennart C. L. Kats, Eelco Visser, Guido Wachsmuth: Pure and Declarative Syntax Definition - Paradise Lost and Regained. SPLASH 2010

pretty-printing

Marc G.J. van den Brand, Eelco Visser: Generation of Formatters for Context-Free Languages. ACM TOSEM 5(1):1-41, 1996.

Merijn de Jonge. Pretty-Printing for Software Reengineering. ICSM 2002

template language

Tobi Vollebregt, Lennart C. L. Kats, Eelco Visser. Declarative Specification of Template-Based Textual Editors. LDTA 2012

Outlook

beyond IN4303

Model-driven Software Development

- domain-specific languages
- build your own language with Spoofax

Seminar Metaprogramming

- science behind the scenes

Master theses

- theory & practice
- WebDSL & mobl
- Spoofax

Outlook

coming next

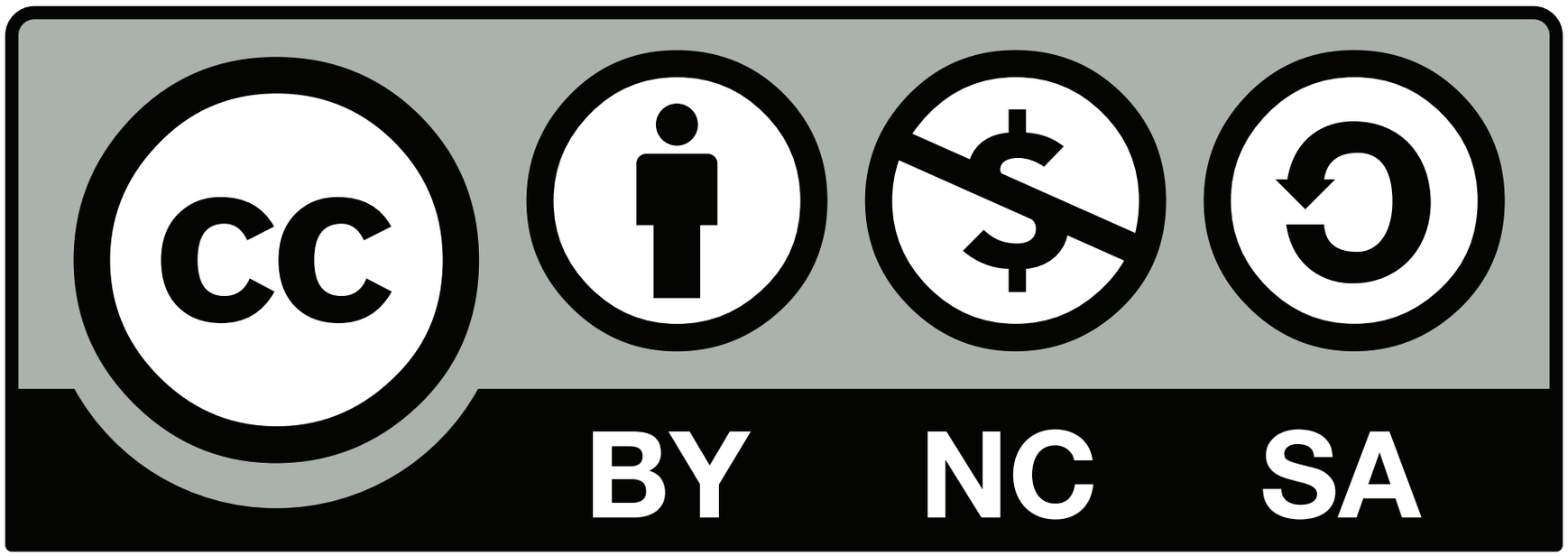
declarative semantics definition

- Lecture 4: Term Rewriting
- Lecture 5: Static Analysis and Error Checking
- Lecture 6: Code Generation

Labs

- Sep 27 syntax definition
- Oct 4 code completion & pretty printing

copyrights


BY
NC
SA

Pictures

attribution & copyrights

Slide 1:
Latin Bible by Gerard Brils (photo by Adrian Pingstone), public domain

Slide 188:
West Cornwall Pasty Co. by Dominica Williamson, some rights reserved

Slide 199-200:
Ostsee by Mario Thiel, some rights reserved

Slides 5-180:
Pure and Declarative Syntax Definition: Paradise Lost and Regained, some rights reserved