

nec ampliat temporis
serotinū. **P**raeacientes estote &
nos & cōfirmate corda nra:
qm̄ adiētus dñi appropin
quabit. **N**olite īgeminiscere
fr̄es in alterutū: ut nō in
dicēnū. **E**cce iudex ante ia
nuā assilit. **E**xemplū aci
pice fr̄es eritis mali & lon
ganumutans laboris & paa

cem ut saluenū. **M**ultū e
nū ualeat deprecatio iusti acci
dua. **H**elias nō erat filius
nobis passibilis: & orōne
orauit ut nō plueret supē
rā: & nō pluit ānos tres et
menses sex. **E**t rursū orauit
& celū dedit pluviā: & dīa de
dit fructū suū. **f**r̄es mei si
quis ex uobis errauit

ctus deus & p̄r dñi
xpi: qui sōm m
sericordia suā re
nos ī spē uiuā p
onē ihū xpi ex m
ditatē ī corrupt
tamutatā & im
cōseruatā in celo
qui in uirtute de
fidem ī salutē
nī tempore n
no exultabunt
ūc si oportet o
arvis tempta
batio uite fidei
or sit auro q
atir. **I**nueni
glam & honor
one ishi xpi: o
deitis diligiti
quocq; nō ui
credētes āteru
īenarrabili &
portātes fin
ē aīar. **D**e q

Declarative Syntax Definition pretty printing

Guido Wachsmuth

*vñ. nō amittit quodcumq;
rāmentū. Sit autē sermo ve
ster est est nō nō: ut nō sub
iudicio deuidatis. Cristatur
autē aliq's uīm: oret equo
animo & psallat. **I**nfirma
tur quis in uobis? iduocat
vños ecclie & orant supe*



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

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

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- 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

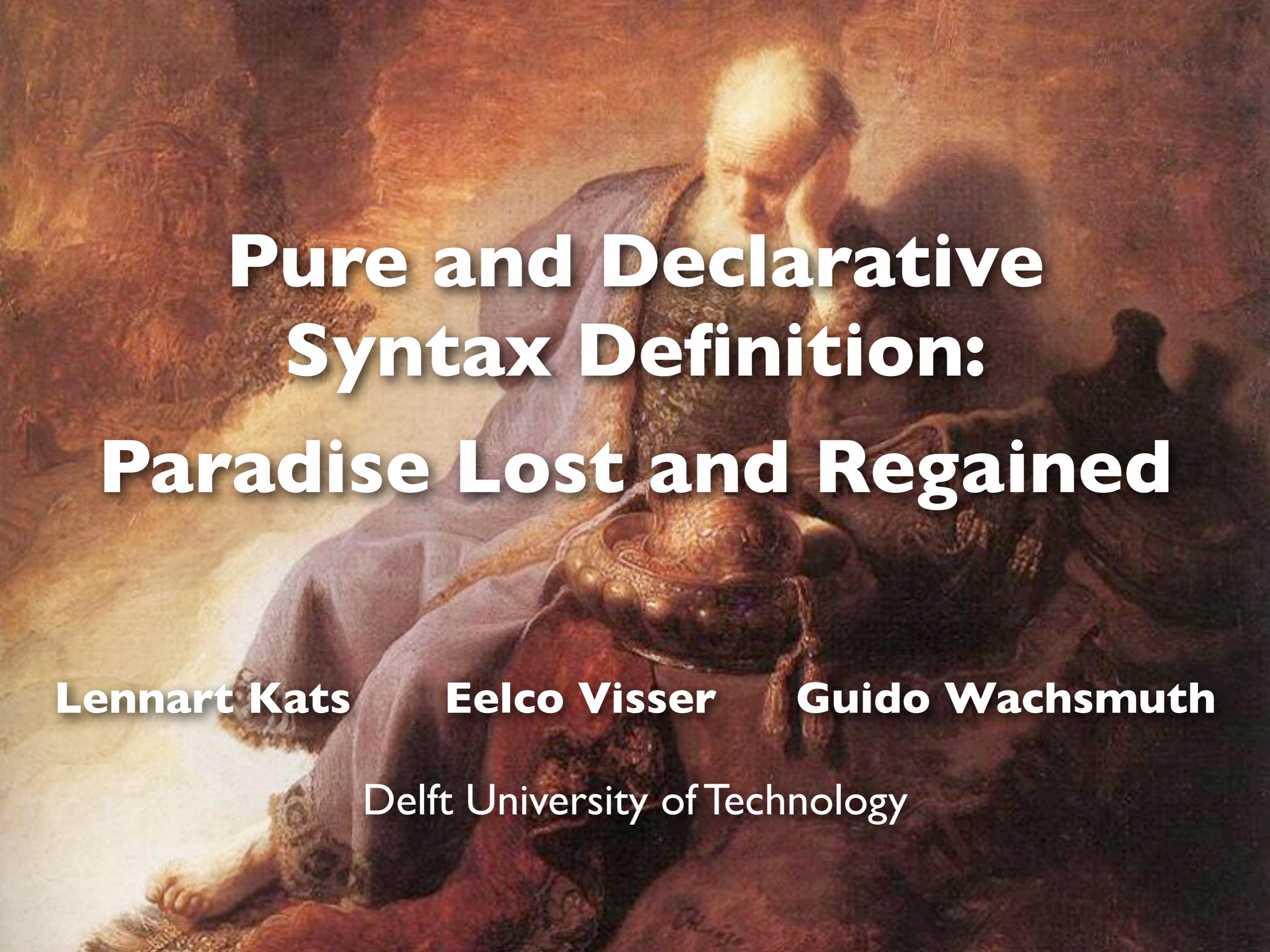
- from trees to text
- box layout in pretty-print tables

template language

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

I

paradise lost & regained

A classical painting depicting the Fall of Man. In the center, Adam and Eve stand in a lush garden. Eve holds a forbidden fruit from a tree with a golden glow at its top. A serpent lies coiled on the ground nearby. The background shows rolling hills under a hazy sky.

Pure and Declarative Syntax Definition: Paradise Lost and Regained

Lennart Kats

Eelco Visser

Guido Wachsmuth

Delft University of Technology



PARADISE

A classical painting of a lush, sunlit landscape. In the center, a large, dark, craggy rock formation rises from a pool of light. Sunbeams filter through the trees on the left, illuminating a path that leads towards distant figures. The background features misty mountains and a waterfall on the right. The overall atmosphere is one of a divine or lost paradise.

PARADISE LOST

A medieval-style illustration depicting a town scene. In the foreground, a large crowd of people in period clothing, including tunics and hats, are gathered around a wooden cart. Some individuals are吹着号角 (blowing horns). In the background, there are several buildings, including a prominent one with a tiled roof and multiple windows. A stone wall runs across the middle ground. The overall style is reminiscent of a tapestry or a painting from the late Middle Ages.

PARADISE REGAINED

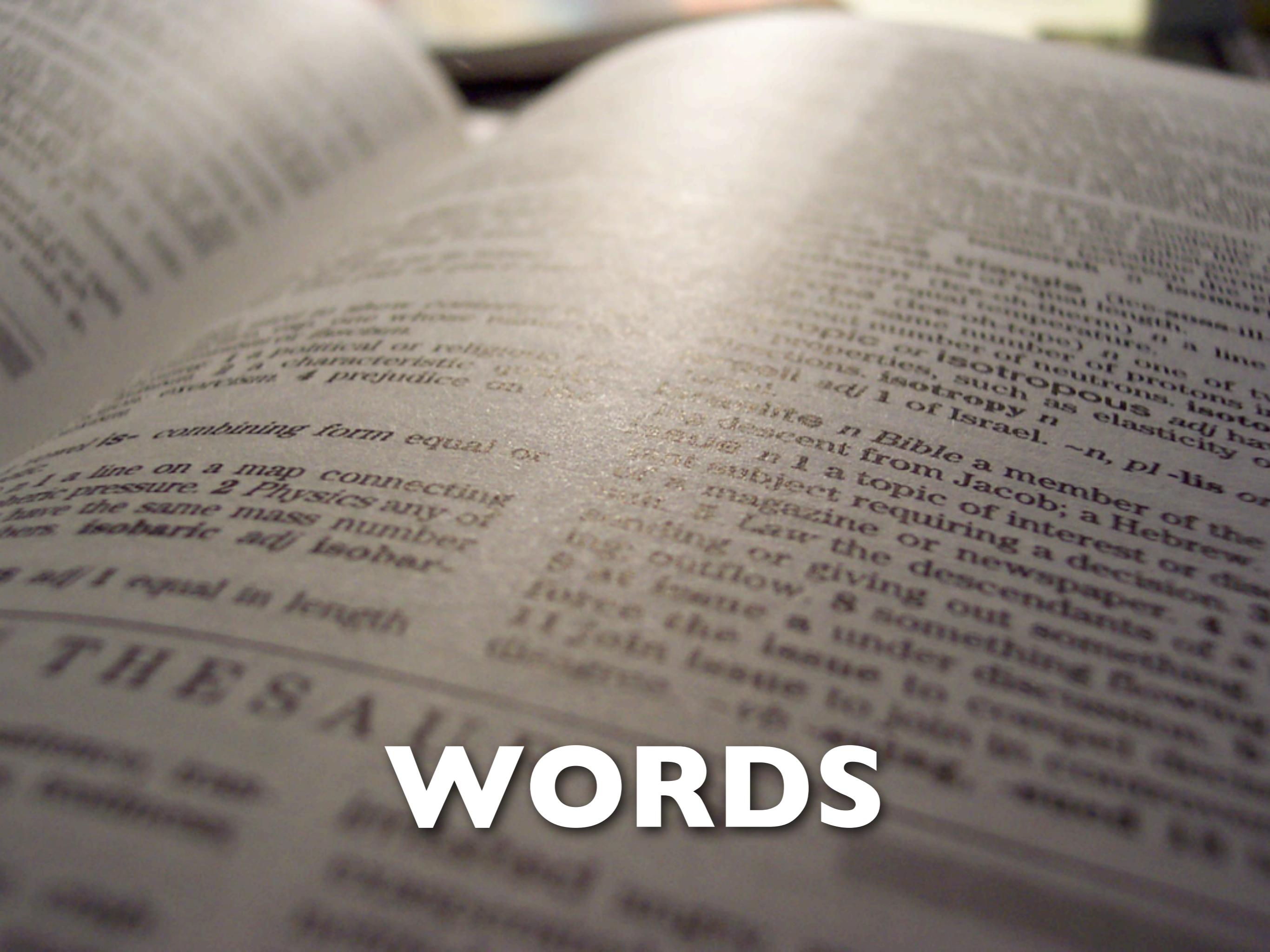


PARADISE DENIED



PARADISE

WORDS



A photograph of a dead, gnarled tree standing on a rocky, grassy outcrop. The tree has many bare branches reaching out in various directions. In the background, there are large, rugged mountains under a clear blue sky.

TREES

LA DEUXIÈME ANNÉE

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Lexiques

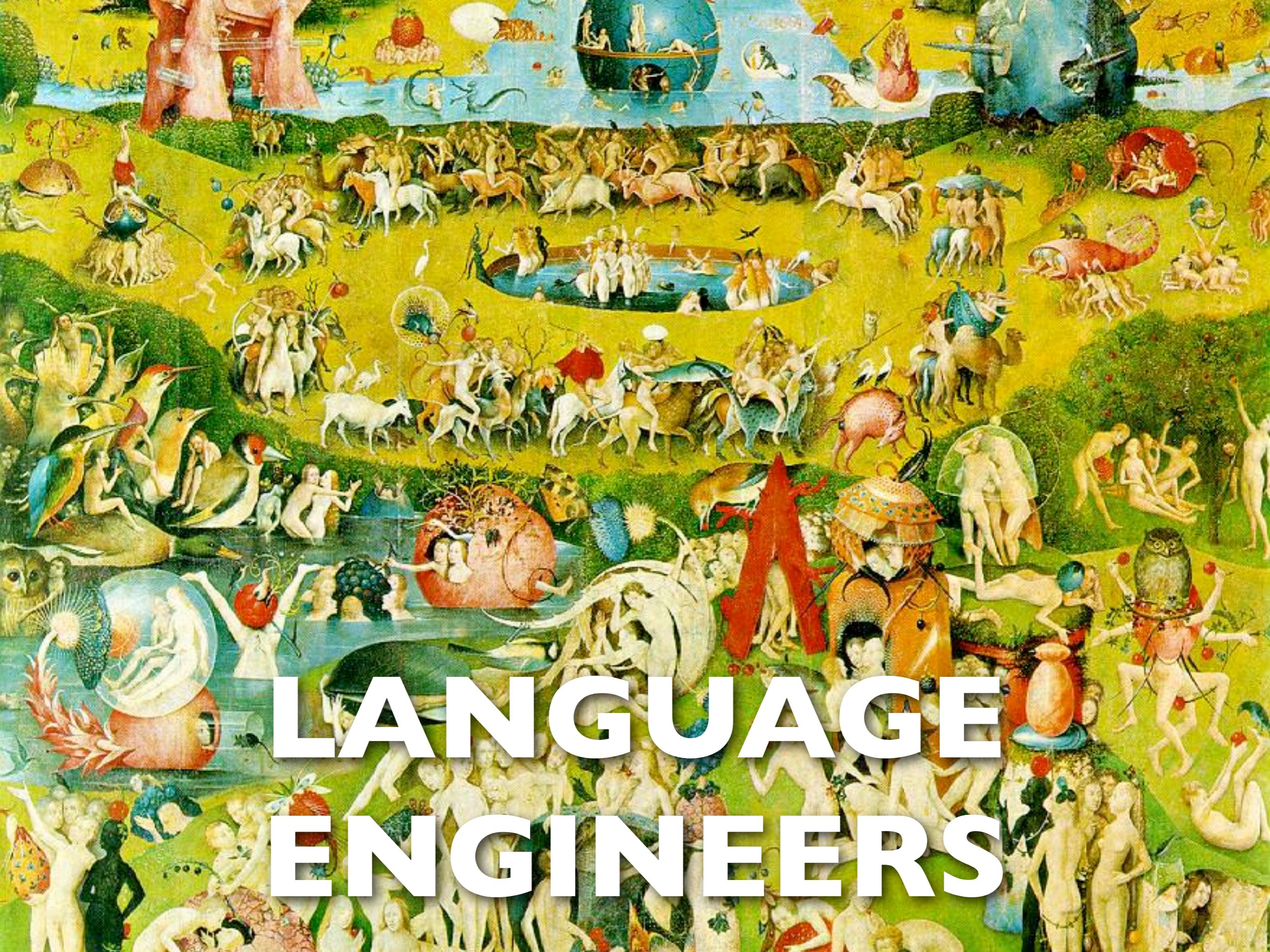
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GRAMMARS

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Armand COLIN & C^{ie}



LANGUAGE ENGINEERS

DYBVIG THE SCHEME PROGRAMMING LANGUAGE ANSI SCHEME SECOND EDITION

Guzdial Rose



Squeak Open Personal Computing and Multimedia

Nelson Systems Programming with Modula-3

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THIRD EDITION

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ADDISON
WESLEY

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A detailed painting of the Garden of Eden. In the center, Adam sits on the ground, holding an apple. Eve stands behind him, reaching for fruit from a large, central tree. Various animals, including lions, tigers, deer, and birds, are scattered throughout the lush landscape. A river flows in the background, and mountains are visible under a blue sky with many birds.

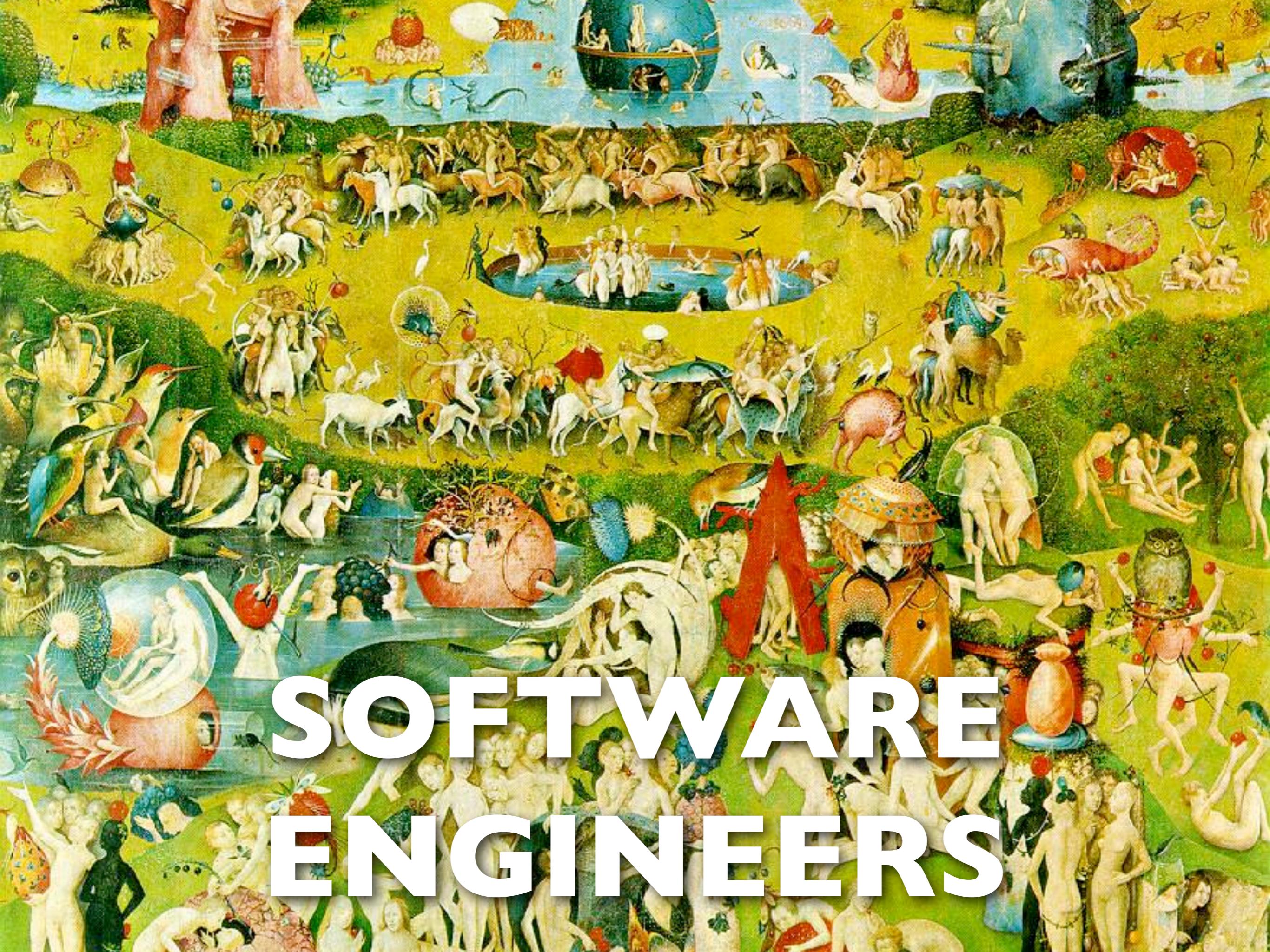
NATURAL

A detailed painting of the Garden of Eden. In the center, Adam sits on the ground, holding an apple. Eve stands behind him, reaching up to pluck fruit from a large, central tree. A snake is coiled around the base of the tree. The scene is filled with a variety of animals: a lion and a unicorn on the left, a white horse on the right, sheep, goats, a deer, a peacock, and many birds perched on branches or flying in the sky. A river flows in the background, and mountains are visible under a blue sky.

PURE

A detailed painting of Adam and Eve in the Garden of Eden. In the center, Adam sits on the ground, holding an apple. Eve stands behind him, reaching up to a tree. A large tree with a snake coiled around its base is prominent. The scene is filled with a variety of animals: a lion, a unicorn, a white horse, a tiger, an ostrich, deer, a peacock, and many birds in flight or perched on branches. A river flows in the background, and mountains are visible under a blue sky.

BEAUTIFUL

A detailed reproduction of Hieronymus Bosch's "The Garden of Earthly Delights". The painting is a triptych depicting a fantastical landscape filled with various figures, animals, and symbolic elements. The central panel shows a lush green valley where numerous figures in various states of undress are engaged in various activities, from dancing and playing instruments to more intimate scenes. The landscape is dotted with strange trees, including one with a large red strawberry growing from its trunk. In the upper left, a small boat carries figures across a body of water. The upper right features a large tree with a hole through which figures are visible. The lower panels show more scenes of human activity, including a group of people gathered around a large red egg-like object and another scene with figures in a rocky landscape. The entire scene is a dense, colorful tapestry of Bosch's characteristic surrealism.

**SOFTWARE
ENGINEERS**

LANGUAGE SOFTWARE



A detailed painting of Adam and Eve in the Garden of Eden. Adam is seated on the left, holding a small fruit. Eve stands behind him, leaning against a tree. They are surrounded by a variety of animals, including lions, a unicorn, a peacock, a white horse, and numerous birds. A large tree with fruit hangs over them. In the background, there are rolling hills and a distant city.

NOT
NATURAL

A detailed painting of Adam and Eve in the Garden of Eden. Adam is seated on the left, holding a small animal. Eve stands behind him, holding a fruit. They are surrounded by a variety of animals, including lions, a unicorn, a white horse, a peacock, a deer, a monkey, and many birds. The scene is set in a lush, green garden with a large tree in the background.

NOT
PURE

NOT
BEAUTIFUL

LA DEUXIÈME ANNÉE

D'E LATIN

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Lexiques

**SYNTAX
DEFINITIONS**

Armand COLIN & C^{ie}

A detailed painting of the Garden of Eden. In the center, Adam sits on the ground, holding an apple. Eve stands behind him, reaching up to pluck fruit from the Tree of Life. A snake is coiled around the base of the tree. The scene is filled with a variety of animals: a lion and a bull in the foreground, a white horse to the right, and numerous birds, deer, and other creatures in the background. A large, leafy tree dominates the upper half of the composition, with more birds perched on its branches. In the distance, mountains are visible under a blue sky.

NATURAL

A detailed painting of the Garden of Eden. In the center, Adam sits on the ground, holding an apple. Eve stands behind him, reaching up to pluck fruit from a large, central tree. A snake is coiled around the base of the tree. The scene is filled with a variety of animals: a lion and a unicorn on the left, a white horse on the right, sheep, goats, birds, and insects. In the background, there are mountains and a river. The overall atmosphere is one of a peaceful, idyllic landscape.

PURE

A detailed painting of Adam and Eve in the Garden of Eden. In the center, Adam sits on the ground, holding an apple. Eve stands behind him, reaching up to a tree. A large tree with a snake coiled around its base is prominent. The scene is filled with a variety of animals: a lion, a unicorn, a white horse, a tiger, an ostrich, deer, a peacock, and many birds in flight or perched on branches. A river flows in the background, and mountains are visible under a blue sky.

BEAUTIFUL



THE FALL



A classical painting of a lush, sunlit landscape. In the center, a large, dark, craggy rock formation rises from a pool of light. Sunbeams filter through the trees on the left, illuminating a path that leads towards distant figures. The background features misty mountains and a waterfall on the right. The overall atmosphere is one of a divine or lost paradise.

PARADISE LOST

A dramatic, sepia-toned photograph of a woman in a dark, low-cut dress. She is shown from the chest up, looking down with her head tilted back and her hands clasped behind her head, suggesting distress or pain. Her face is partially obscured by shadow, with her eyes closed and her mouth slightly open. The lighting is moody and focused on her face and hands.

PAIN



SWEAT

A detailed painting of a natural landscape, likely the Garden of Eden. In the center, Adam and Eve are kneeling on the ground, surrounded by various animals including a lion, a unicorn, and a peacock. A large tree with fruit hangs over them. The background features rolling hills and a variety of birds flying in the sky.

NOT
NATURAL

A detailed painting of Adam and Eve in the Garden of Eden. Adam is seated on the left, holding a small animal. Eve stands behind him, holding a fruit. They are surrounded by a variety of animals, including lions, a unicorn, a white horse, a peacock, and numerous birds. A large tree with fruit hangs over them. In the background, there are mountains and a body of water.

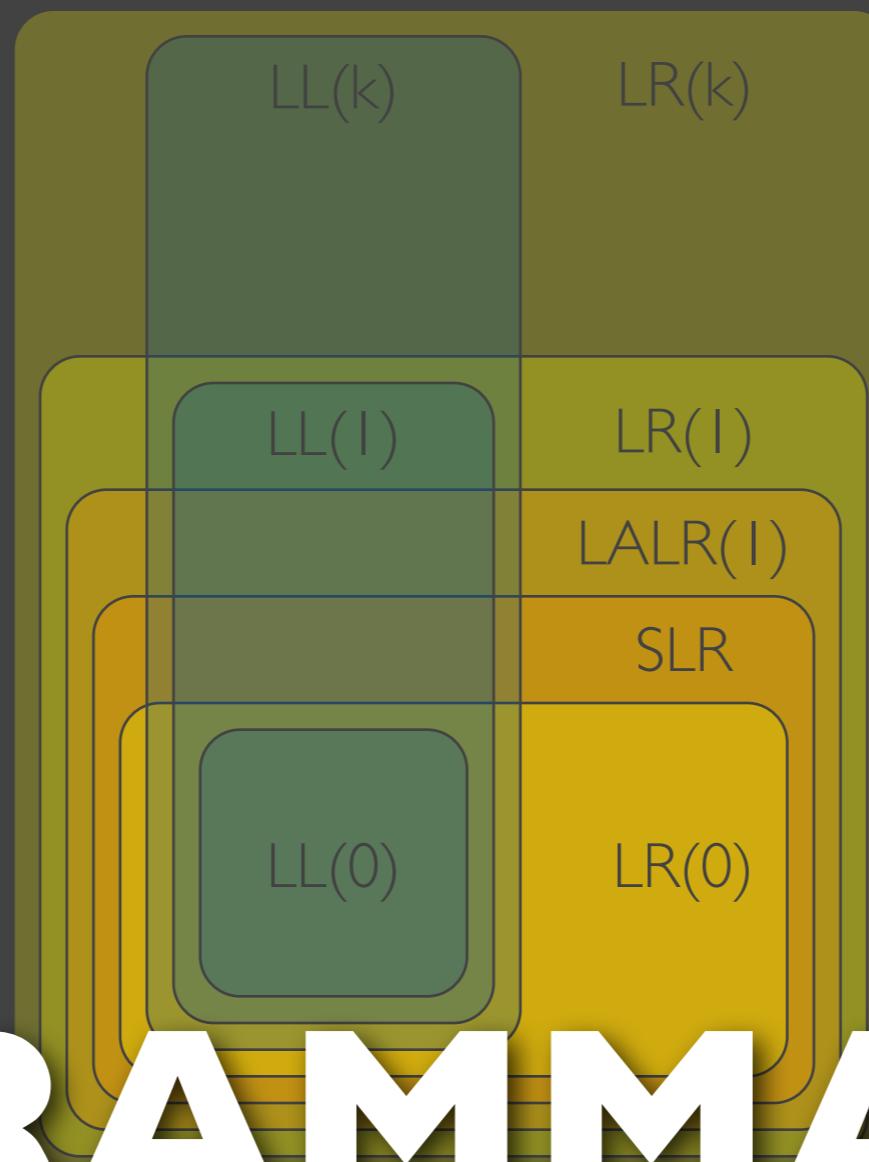
NOT
PURE

NOT
BEAUTIFUL

A dramatic painting depicting a city under a dark, stormy sky with a large pyramid in the background.

THE PLAGUES

context-free grammars

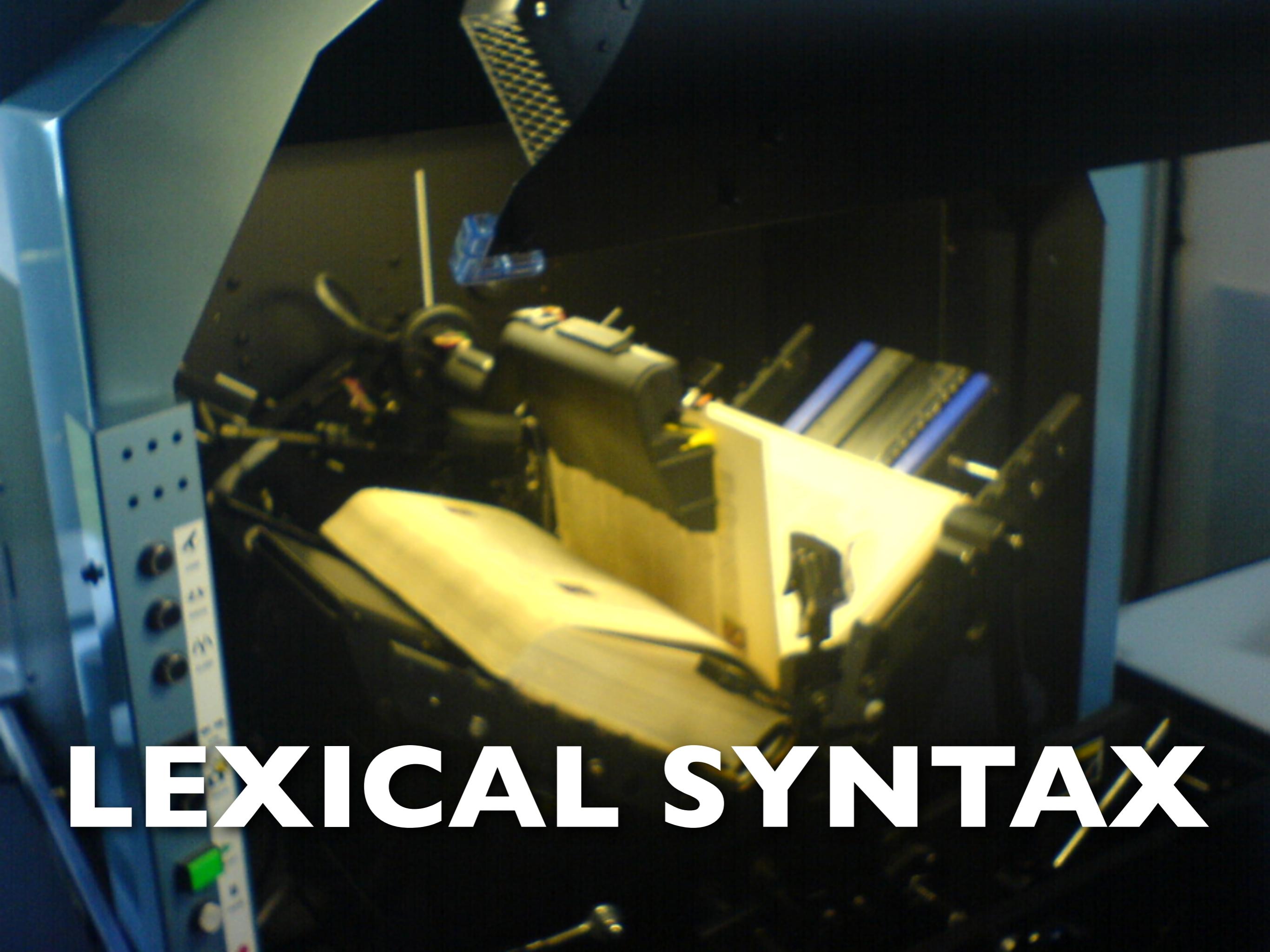


GRAMMAR CLASSES



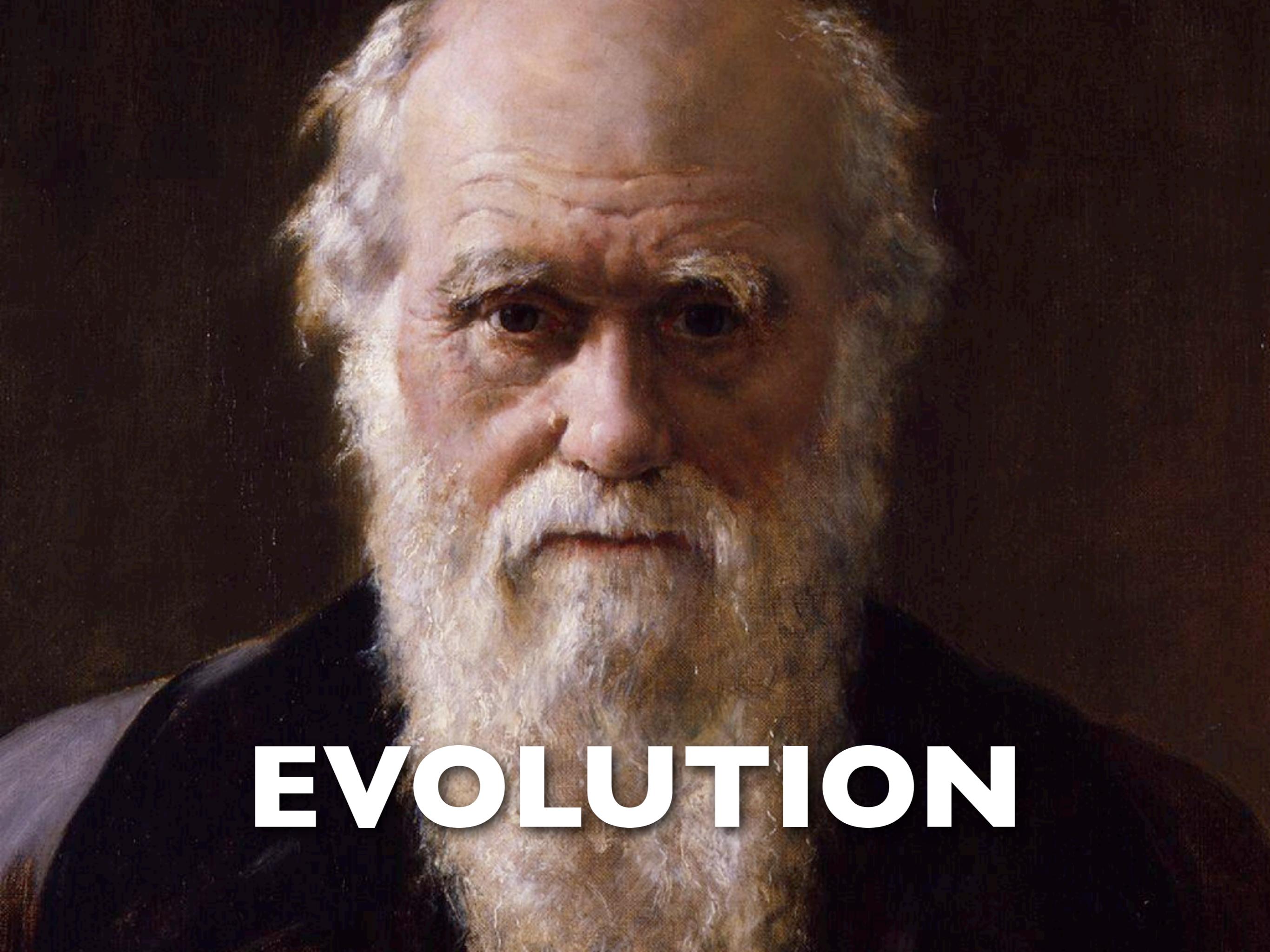
DISAMBIGUATION

LEXICAL SYNTAX

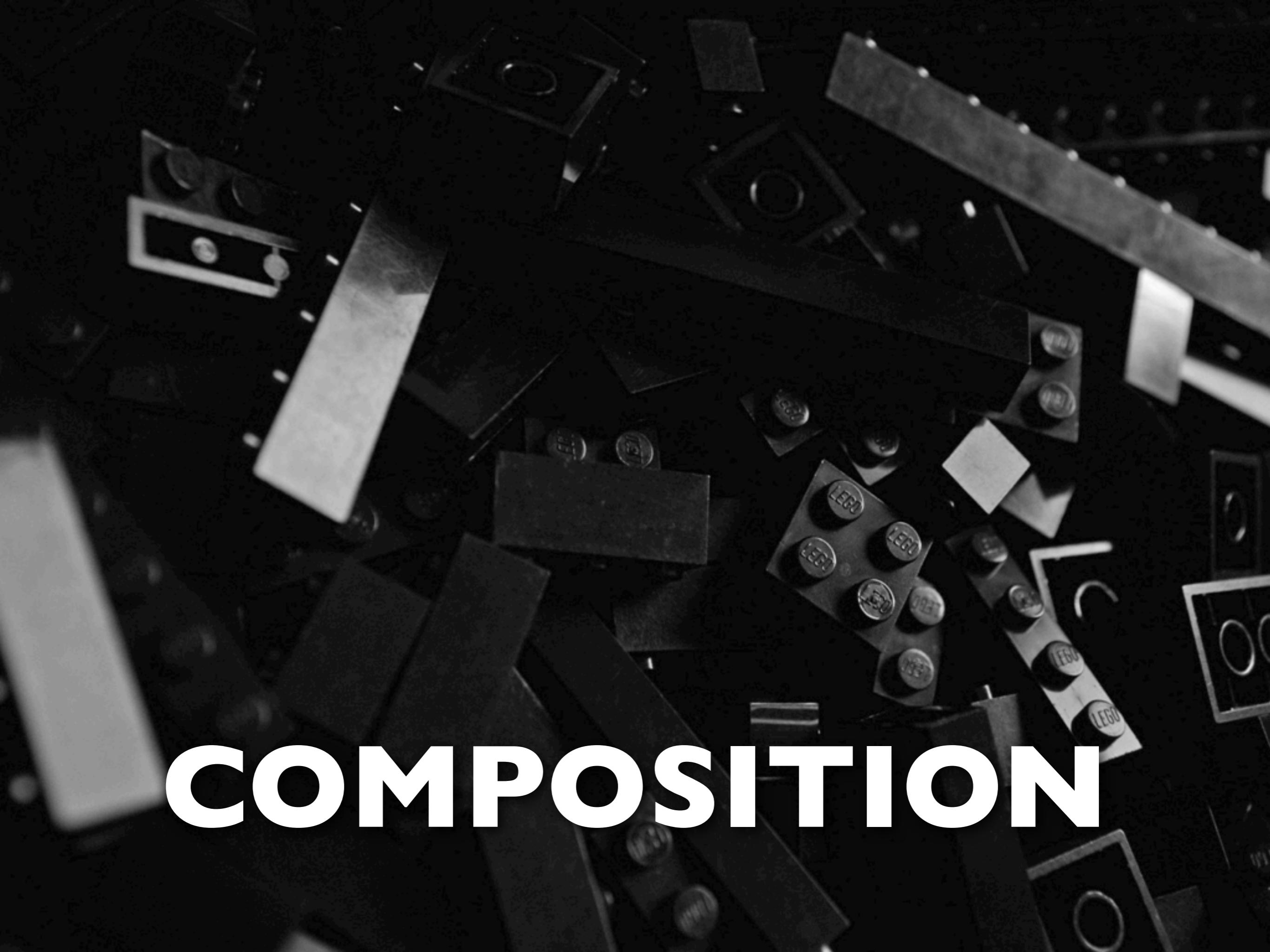


A photograph of a desert landscape featuring several dead acacia trees standing in a sandy area. In the background, large, smooth sand dunes are visible under a clear blue sky.

TREE CONSTRUCTION

A close-up portrait of Charles Darwin, an elderly man with a full, bushy white beard and receding hairline. He is looking slightly to his left with a thoughtful expression. The background is dark and indistinct.

EVOLUTION



COMPOSITION

RESTRICTION TO PARSERS



PARADISE



WORDS WERE MADE THROUGH
GRAMMARS

LA DEUXIÈME ANNÉE

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227 Exercices 100 pages.

Lexiques

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GRAMMARS

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Armand COLIN & C^{ie}

Num → Digit Num

Num → Digit

Digit → “0”

Digit → “|”

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

$\text{Num} \rightarrow \text{Digit Num}$

$\text{Num} \rightarrow \text{Digit}$

$\text{Digit} \rightarrow "0"$

$\text{Digit} \rightarrow "1"$

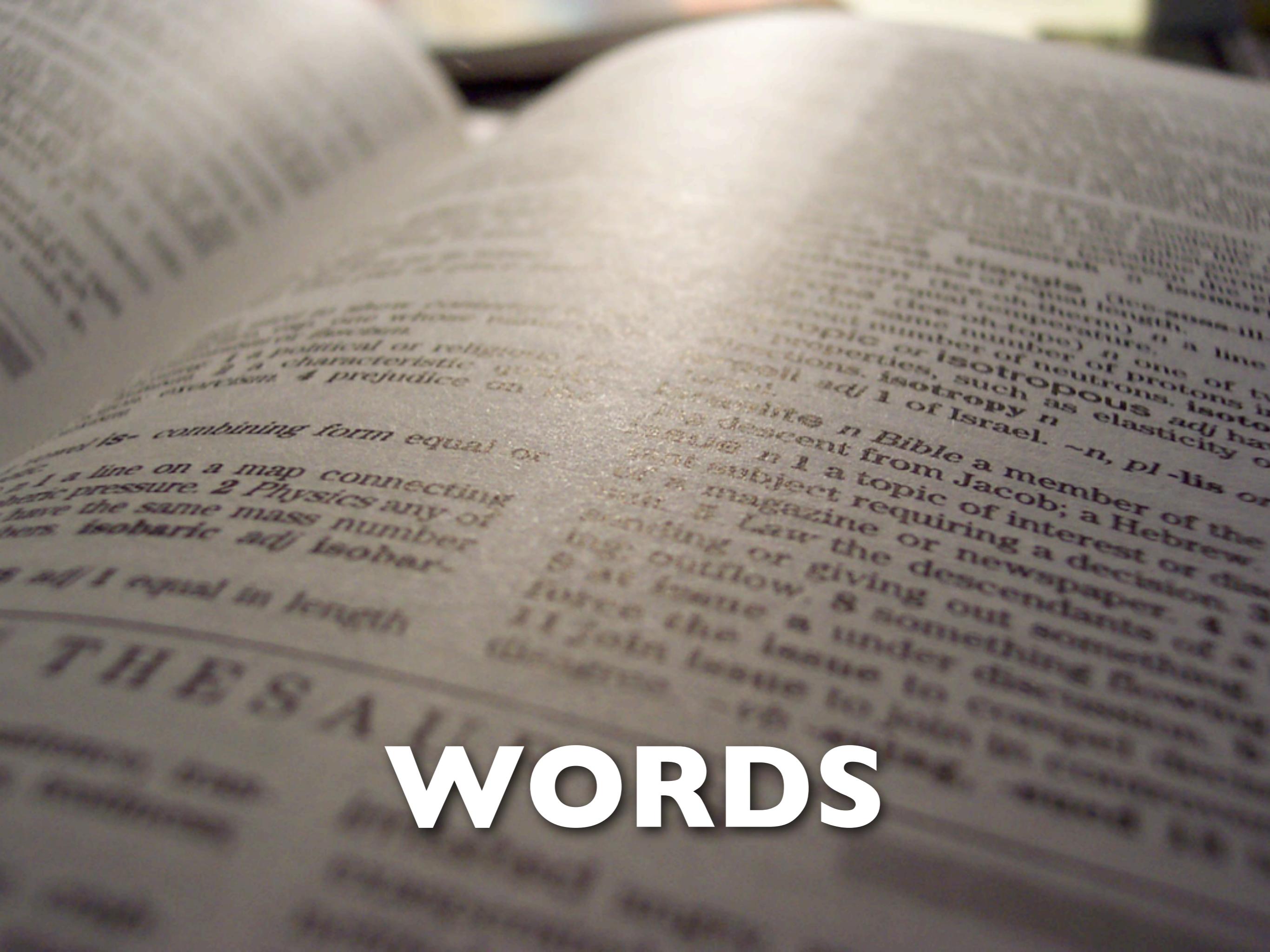
nonterminal symbols

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 → “|”

Θερμαύμην. καὶ θεραπώντων
Εὐαγγέλιον. καὶ λέπτων
τεττάρες φύλακας αὐτοῦ.
Εἰσῆλθεν τοῦ λίκειού του θύμον
μέτρον ταχύτατος. ἐξεβοήθε
πορκομόρτουρκον θερμόν
μέτεκτον πολύσυνον είδος
πορκομόρτουρκον. από μαστού
λίκην. πληρούμενος τούτην
όπιττεττάρες φύλακας αὐτοῦ.
πούθεν. λέπτην. οπιττούμοιο
εμπλέκειν αὑτούς τούτους
έφερε. πεπλέκειν. συγκρί^{τη}
χρέωνται. συγκρίνεθενται.
όπιττεττάρες φύλακας αὐτοῦ.
ποάλιαμισαίτερον μέρον
ημέρην. παλαιάντερον ακκούσαι
ποάλιακαθίμενα μηδεμόναι.
πεπλέκειν αὐτοῖς τούτοις

42
τερρορέται βηττέροι. πάνταν
καὶ σύκατον θερμόν. πέπονόν τοι
ύποθεσα. Εόσσον μετατίνεις
θερμότητος. αρόακουσθημόν.
μουάκουσι. καὶ οὐαθετούμενα.
εἰπέ αθετεῖ. οὐαθέμεθετον. α
θετεποράποδηλαντάρει. α
πεπετάντει οἰενδομένοντα
μηδέχεραπλέσομεν. καὶ καὶ τα
θειμόρια ποταμεταπομένην
εἰπόροματίσου. εἰπόρομα
αποτοσ. ιθεόρωατερονταναν.
ασαπτεραπότεκτουσωσουτων
των. Καίθεισκατ αριλουλιδομένη
Υπάρχειονταν. ποταμεταπο
επωαποσφεον καὶ σκορπίον.
εἴσωταπαντημάλιαμέμητον
έθερρον. καὶ οὐαθέμεθετούμελ
απεικόνι. πληρόμετουσμέλη
ετεῖ. οπιττάπριματαυμένη

SENTENCES

$\text{Exp} \rightarrow \text{Exp} \text{ "+" Exp}$

$\text{Exp} \rightarrow \text{Exp} \text{ "*" Exp}$

$\text{Exp} \rightarrow \text{Num}$

production rules

$\text{Exp} \rightarrow \text{Exp} \text{ "+" Exp}$

$\text{Exp} \rightarrow \text{Exp} \text{ "*" Exp}$

$\text{Exp} \rightarrow \text{Num}$

terminal symbols
production rules

$$\text{Exp} \rightarrow \text{Exp} \text{ "+" Exp}$$
$$\text{Exp} \rightarrow \text{Exp} \text{ "*" Exp}$$
$$\text{Exp} \rightarrow \text{Num}$$

nonterminal symbols

terminal symbols

production rules

$$\text{Exp} \rightarrow \text{Exp} \text{ "+" Exp}$$
$$\text{Exp} \rightarrow \text{Exp} \text{ "*" Exp}$$
$$\text{Exp} \rightarrow \text{Num}$$

nonterminal symbols

terminal symbols

production rules

start symbol

Exp

Exp

Exp + Exp

Exp → Exp “+” Exp

Exp

$\text{Exp} + \text{Exp}$

$\text{Exp} * \text{Exp} + \text{Exp}$

$\text{Exp} \rightarrow \text{Exp} “+” \text{Exp}$

$\text{Exp} \rightarrow \text{Exp} “*” \text{Exp}$

Exp

Exp + Exp

Exp * Exp + Exp

3 * Exp + Exp

Exp → Exp “+” Exp

Exp → Exp “*” Exp

Exp → Num

Exp	$\text{Exp} \rightarrow \text{Exp} \text{"+" Exp}$
Exp + Exp	$\text{Exp} \rightarrow \text{Exp} \text{"*" Exp}$
Exp * Exp + Exp	$\text{Exp} \rightarrow \text{Num}$
3 * Exp + Exp	$\text{Exp} \rightarrow \text{Num}$
3 * 7 + Exp	

Exp	$\text{Exp} \rightarrow \text{Exp} \text{"+" Exp}$
Exp + Exp	$\text{Exp} \rightarrow \text{Exp} \text{"*" Exp}$
Exp * Exp + Exp	$\text{Exp} \rightarrow \text{Num}$
3 * Exp + Exp	$\text{Exp} \rightarrow \text{Num}$
3 * 7 + Exp	$\text{Exp} \rightarrow \text{Num}$
3 * 7 + 21	



THEY MADE **LANGUAGES**
BY MAKING GRAMMARS

LA DEUXIÈME ANNÉE
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Armand COLIN & C^{ie}

nuā assūcit. Exemplū acci-
pice frēs crītis mali ⁊ lon-
ganūmitatis labōris ⁊ pa-
cīae: p̄phetas q̄ locūtū sūt
ī noīe dīū. Ecce beatificā-
mūs eos qui sustinuerūt.
Sufferētā iob audīstis?
Et sūnē dīū iudīstis: qm̄ mu-
serōr̄s est dīs ⁊ miserator.
Int̄ oīā aūt frēs mei no-
te uirare neq̄ p̄ celū neq̄
trā: neq̄ aliud qdāq̄ u-
mentū. Sit aūt sermo ve-
r̄ est est nō nō: ut nō sub-
dīao dēdātis. Tristatūr
et aliq̄s uīm̄: oret equo
imo ⁊ psallat. Infirma-
quis in uobis? iduocat
os ecclēsie ⁊ orent sup̄ e-
ungētes cū oleo ī noīe
⁊ oīo fidei saluabit in-
ūn̄: ⁊ alleuiabit cū m̄:
in p̄cīs sic remitterat
confitēn̄ ergo alterū



The image shows a page from a medieval manuscript. At the top, there is a large, ornate initial 'P' in blue and gold. Inside the 'P' is a circular portrait of a saint, likely St. Peter, wearing a red robe and holding a key. To the right of the initial, there is a column of Latin text written in a Gothic script. The text discusses the conversion of sinners and the salvation of souls through the preaching of the gospel. A large watermark 'NGUAC' is overlaid across the bottom of the page.

viii. ditate i corruptib[us] & i con-
taminatā & īmarcesabu
cōseruatā in celis ī uob[us]
qui in uirtute dei custodi
p fidem ī salutē paratā u
lari ī tempore nouissimū
quo exultabitis modicū
nūc si oportet cōtristari
uarijs temptationib[us]:
pbatio uite fidei multo
sor sit auro qd p igni
batur. Inueniat ī la
glam & honorē in reu
one ihu xpī: quē aī n
dicitis diligias. In quā
quoq[ue] nō uidentes cu
reditos ātexultabitis
īenarrabili & glorifi
portantes finē fidei u
tē aīār. De qua salu
sierūt atq[ue] scūtati
te q[uod] de futura ī uol
phetauerūt: scrut
qd uel quale temp
ficaret ī eis spūs xpī
ans eas q[uod] ui xpī



TRUTH

$$\text{Exp} \rightarrow \text{Exp} \text{ "+" Exp}$$
$$\text{Exp} \rightarrow \text{Exp} \text{ "*" Exp}$$
$$\text{Exp} \rightarrow \text{Num}$$
$$\text{Exp} \text{ "+" Exp} \rightarrow \text{Exp}$$
$$\text{Exp} \text{ "*" Exp} \rightarrow \text{Exp}$$
$$\text{Num} \rightarrow \text{Exp}$$

productive

reductive

$$3 * 7 + 21$$

$3 * 7 + 21$

$3 * 7 + \text{Exp}$

$\text{Num} \rightarrow \text{Exp}$

$3 * 7 + 21$

$\text{Num} \rightarrow \text{Exp}$

$3 * 7 + \text{Exp}$

$\text{Num} \rightarrow \text{Exp}$

$3 * \text{Exp} + \text{Exp}$

$3 * 7 + 21$

$\text{Num} \rightarrow \text{Exp}$

$3 * 7 + \text{Exp}$

$\text{Num} \rightarrow \text{Exp}$

$3 * \text{Exp} + \text{Exp}$

$\text{Num} \rightarrow \text{Exp}$

$\text{Exp} * \text{Exp} + \text{Exp}$

$3 * 7 + 21$ Num → Exp

$3 * 7 + \text{Exp}$ Num → Exp

$3 * \text{Exp} + \text{Exp}$ Num → Exp

$\text{Exp} * \text{Exp} + \text{Exp}$ Exp “*” Exp → Exp

$\text{Exp} + \text{Exp}$

$3 * 7 + 21$ $\text{Num} \rightarrow \text{Exp}$

$3 * 7 + \text{Exp}$ $\text{Num} \rightarrow \text{Exp}$

$3 * \text{Exp} + \text{Exp}$ $\text{Num} \rightarrow \text{Exp}$

$\text{Exp} * \text{Exp} + \text{Exp}$ $\text{Exp}^{“*”} \text{Exp} \rightarrow \text{Exp}$

$\text{Exp} + \text{Exp}$ $\text{Exp}^{“+”} \text{Exp} \rightarrow \text{Exp}$

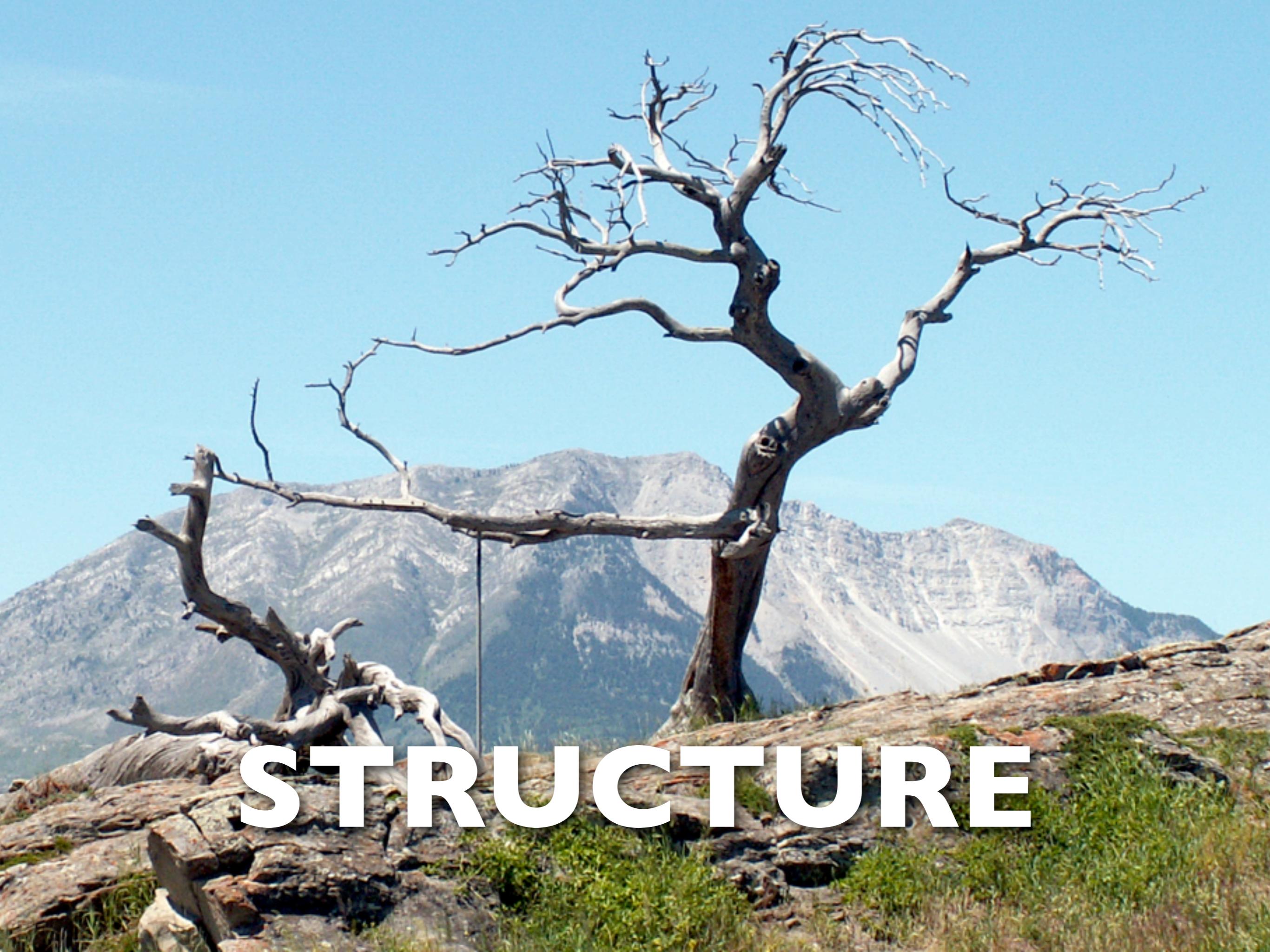
Exp



THEY TURNED WORDS INTO
TREES

SENTENCES

περιφέρει τον περικύκλον της πόλεως.
καὶ σὺ κατέβη ναούμενός τούτου οὐδὲ
ὑπέθεῖσα. Εἶναι τὸ μονυκτονεῖας
θεότητος ἀπό αὐτούς οὐδενὸν μόνη.
G μονάκουσι. καὶ οὐ αἴθετοσήν γένεσι.
ἐμέ αἴθετε· οὐδὲ εμὲ αἴθετοσήν. αἱ
θεοὶ ποὺ αὐτοὶ φύλακαί τοι. αἱ
πατέρες τῶν λέοντῶν δύναμικοὶ τοι
μηδαχαρᾶσθε εγούτες. καὶ καὶ τὰ
δαιμόνια τῶν αἰτιών αὐτοῖς καὶ μη
εἴπομόν μαντίσσου. εἰ περὶ τοῦ
αὐτοῖς. οὐδὲ πρωτομάταν αἱ
οὐδὲ αὐτοῖς μητρούσουσιν οὐδενὸν
τοι. Καὶ θεοὶ τοῦτοι εἰπούσι οὐδενὸν
H μητραὶ έχονται. τούτων τοι
εἰπαντοσίφεον καὶ σκορπίον.
Οὐδεὶς πατέρας τοῦ λιονταρίου τούτου
περιφέρει. καὶ οὐδὲ περιπλάνασθε
αὐτοῖς. οὐδὲ πούτον τούτου μητραὶ
εἰπαντοσίφεον καὶ σκορπίον.

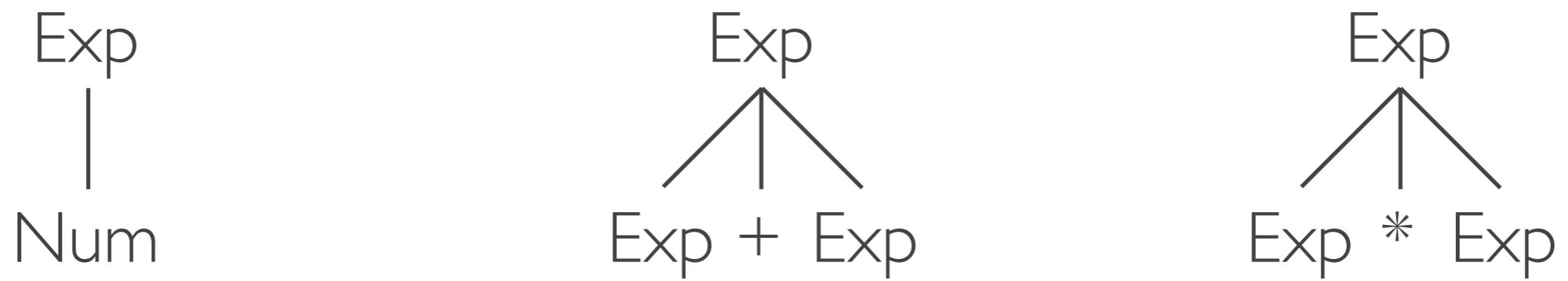
A photograph of a dead, gnarled tree standing on a rocky, grassy hillside. The tree's branches are bare and twisted, reaching out towards the right. In the background, there are several large, rugged mountains under a clear blue sky.

STRUCTURE

$$\text{Exp} \rightarrow \text{Exp} \text{ "+" Exp}$$
$$\text{Exp} \rightarrow \text{Exp} \text{ "*" Exp}$$
$$\text{Exp} \rightarrow \text{Num}$$
$$\text{Exp} \text{ "+" Exp} \rightarrow \text{Exp}$$
$$\text{Exp} \text{ "*" Exp} \rightarrow \text{Exp}$$
$$\text{Num} \rightarrow \text{Exp}$$

productive

reductive



tree construction

$$3 * 7 + 21$$

Exp

|

Num

Exp

|

3

Exp

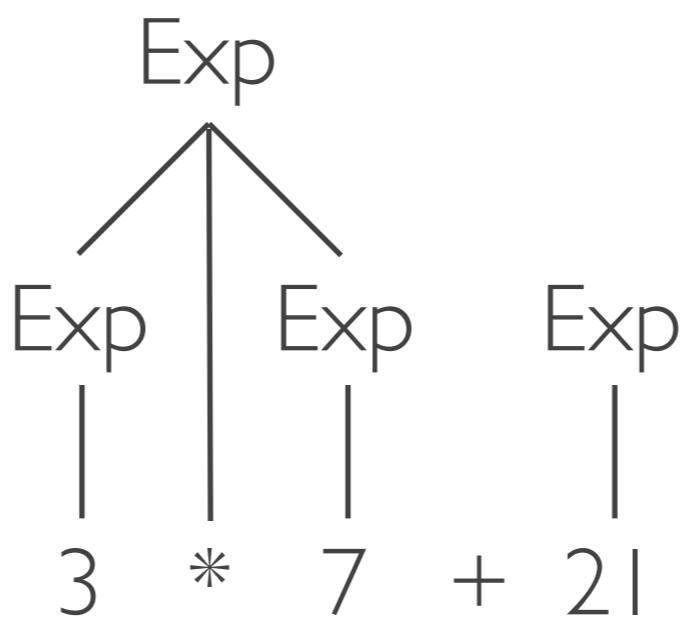
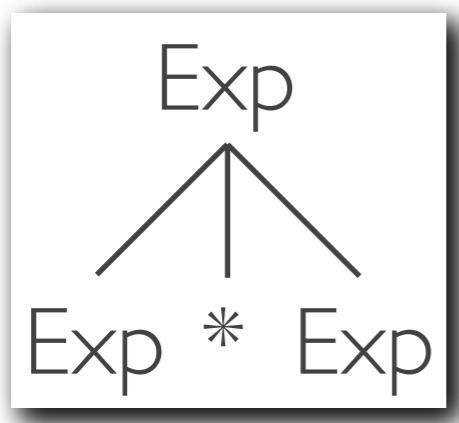
|

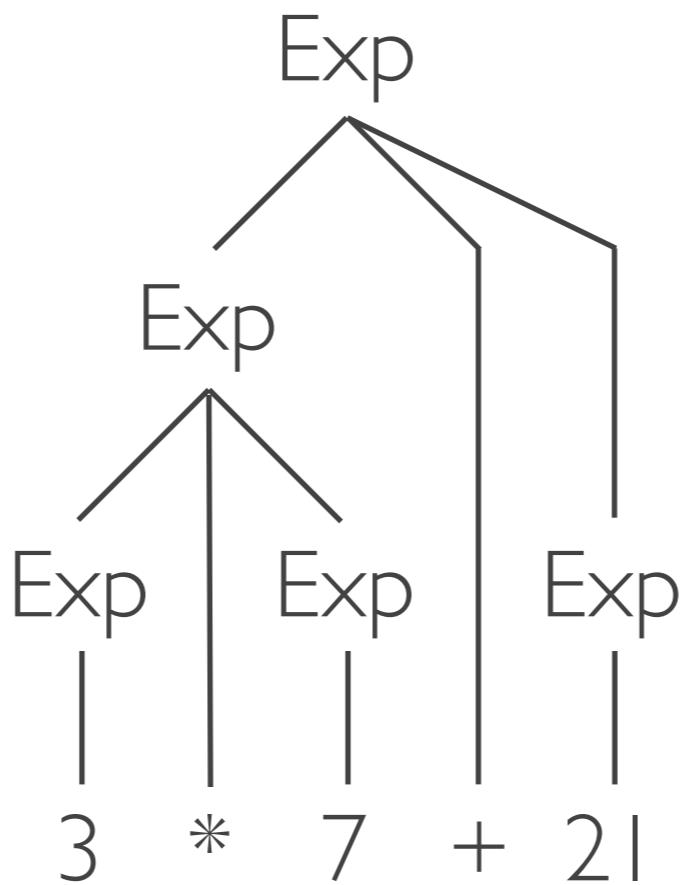
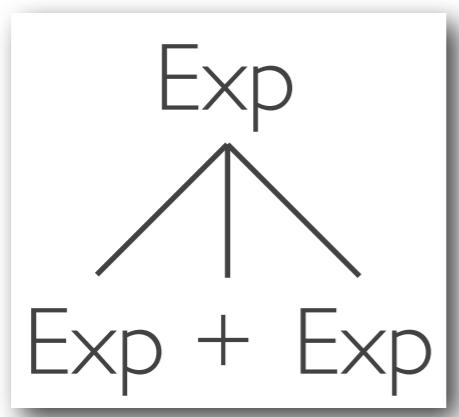
7

Exp

|

+ 2i







ONE FORMALISM



THREE READINGS

A detailed painting of the Garden of Eden. In the center, Adam sits on the ground, holding an apple. Eve stands behind him, reaching up to pluck fruit from a large, central tree. A snake is coiled around the base of the tree. The scene is filled with a variety of animals: a lion and a unicorn on the left, a white horse on the right, sheep, goats, birds, and insects. In the background, there are mountains and a river. The overall atmosphere is one of a peaceful, idyllic landscape.

PURE

A detailed painting of the Garden of Eden. In the center, Adam sits on the ground, holding an apple. Eve stands behind him, reaching up to a tree. A snake is coiled around the tree trunk. The scene is filled with various animals: a lion and a unicorn in the foreground, a white horse to the right, and deer, birds, and other creatures in the background. A large tree with fruit dominates the right side. The background shows rolling hills and mountains under a blue sky with birds.

DECLARATIVE

A detailed painting of Adam and Eve in the Garden of Eden. In the center, Adam sits on the ground, holding an apple. Eve stands behind him, reaching up to a tree. A large tree with a snake coiled around its base is prominent. The scene is filled with a variety of animals: a lion, a unicorn, a white horse, a tiger, an ostrich, deer, a peacock, and many birds in flight or perched on branches. A river flows in the background, and mountains are visible under a blue sky.

BEAUTIFUL

A classical painting of a lush, sunlit landscape. In the center, a large, dark, craggy rock formation rises from a pool of light. Sunbeams filter through the trees on the left, illuminating a path that leads towards distant figures. The background features misty mountains and a waterfall on the right. The overall atmosphere is one of a divine or lost paradise.

PARADISE LOST

IBM System 3

EFFICIENCY

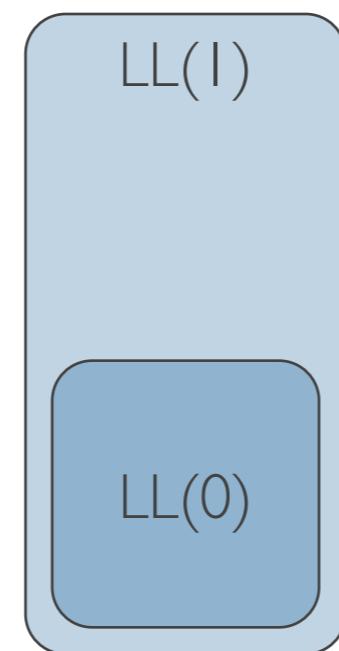
THE FIRST PLAGUE WERE
GRAMMAR CLASSES

context-free grammars

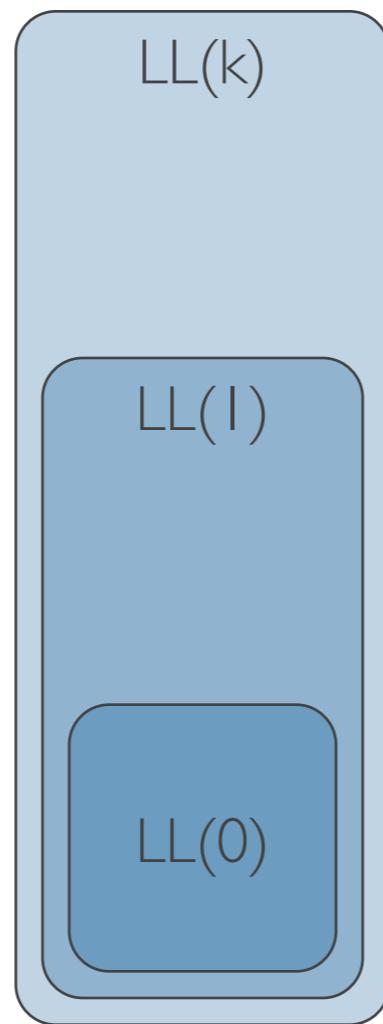
context-free grammars

LL(0)

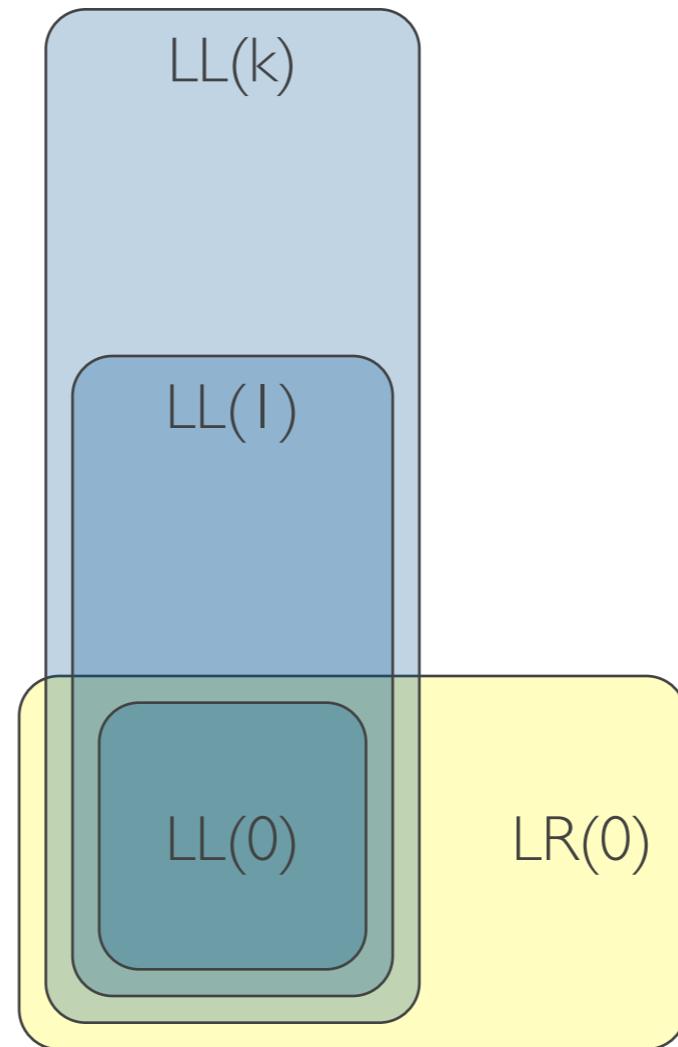
context-free grammars



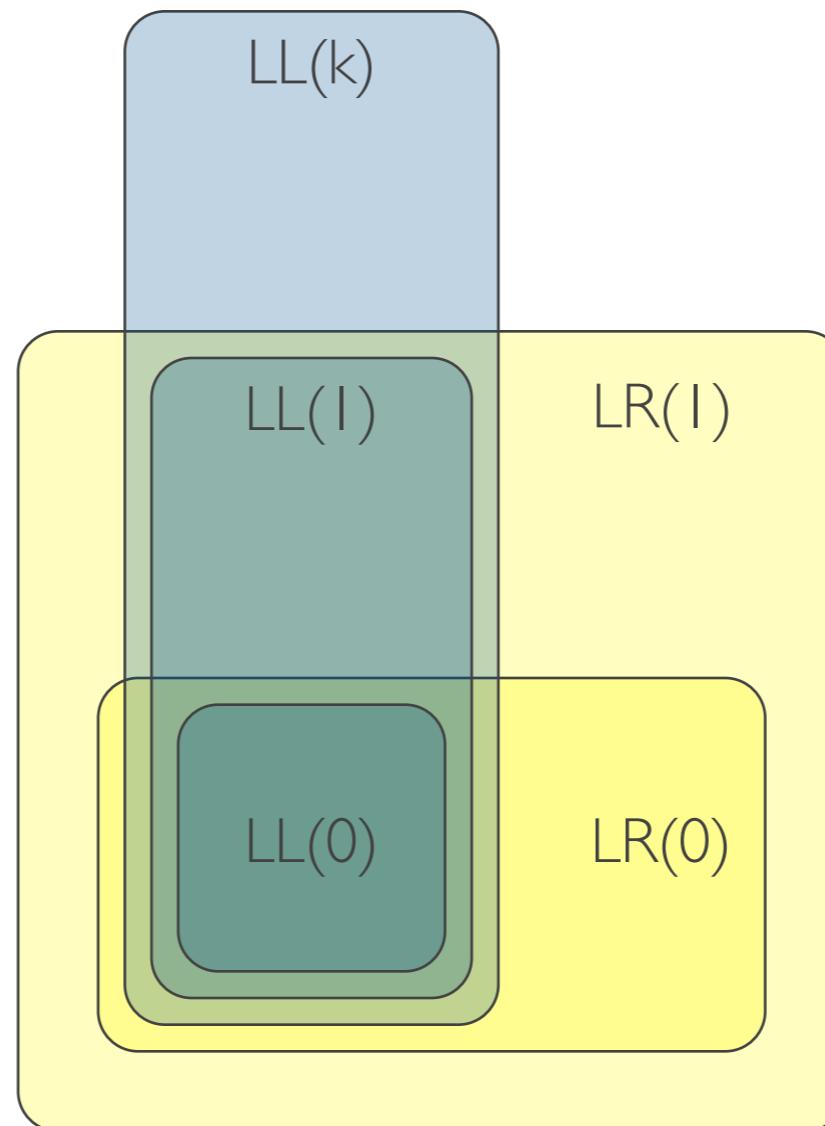
context-free grammars



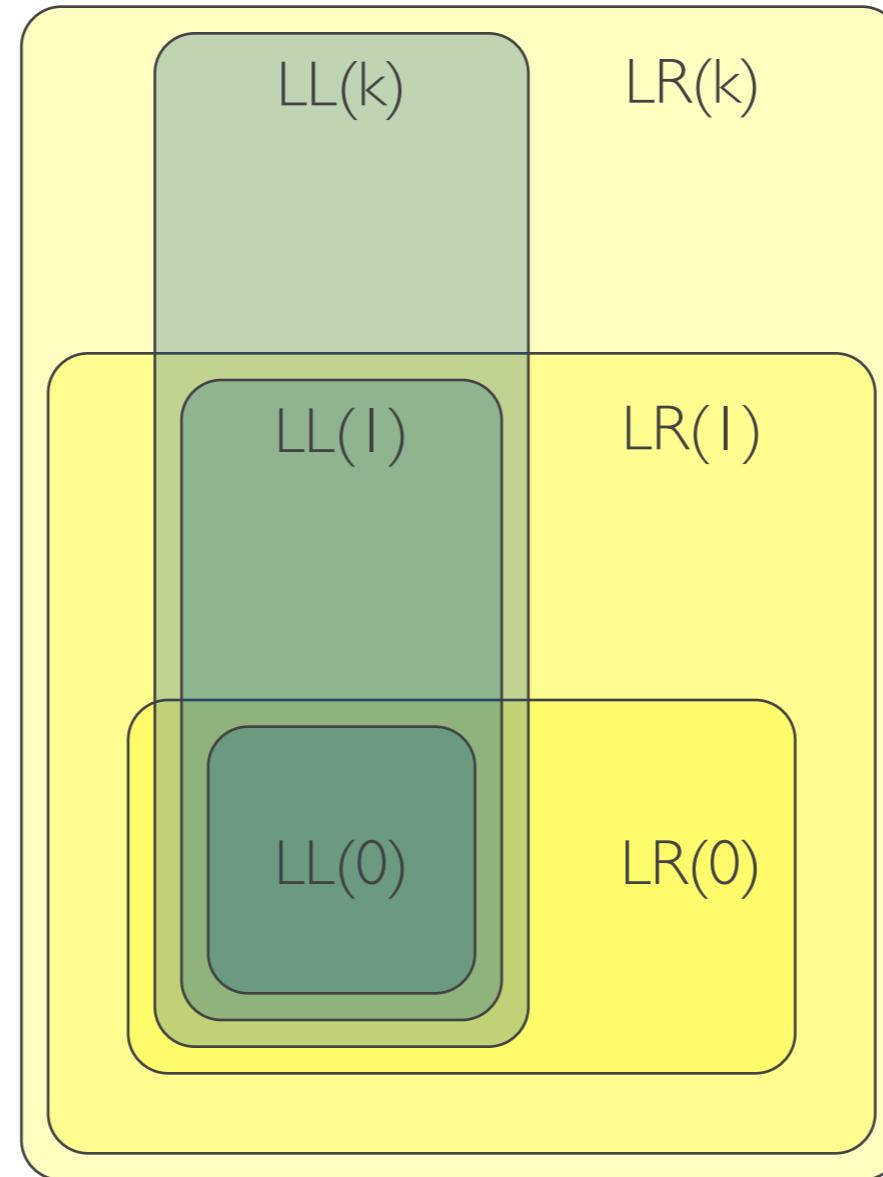
context-free grammars



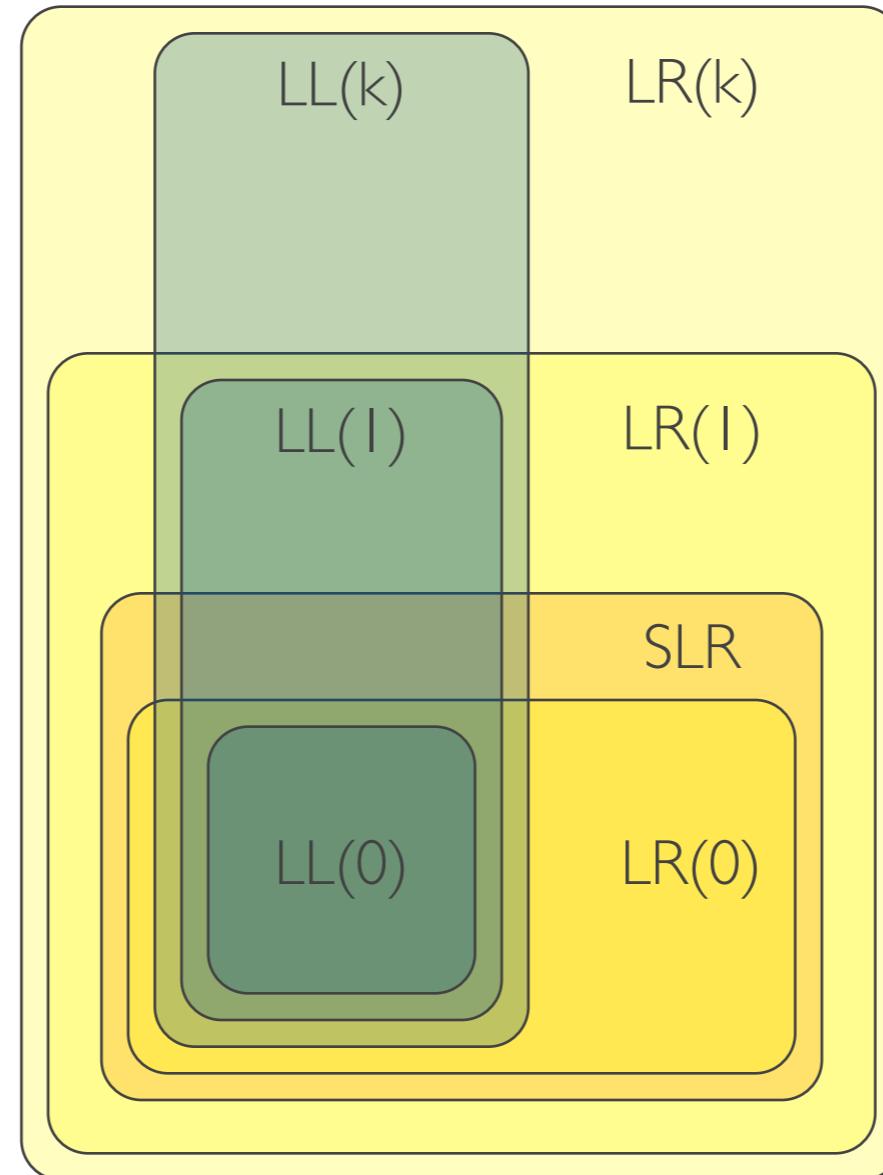
context-free grammars



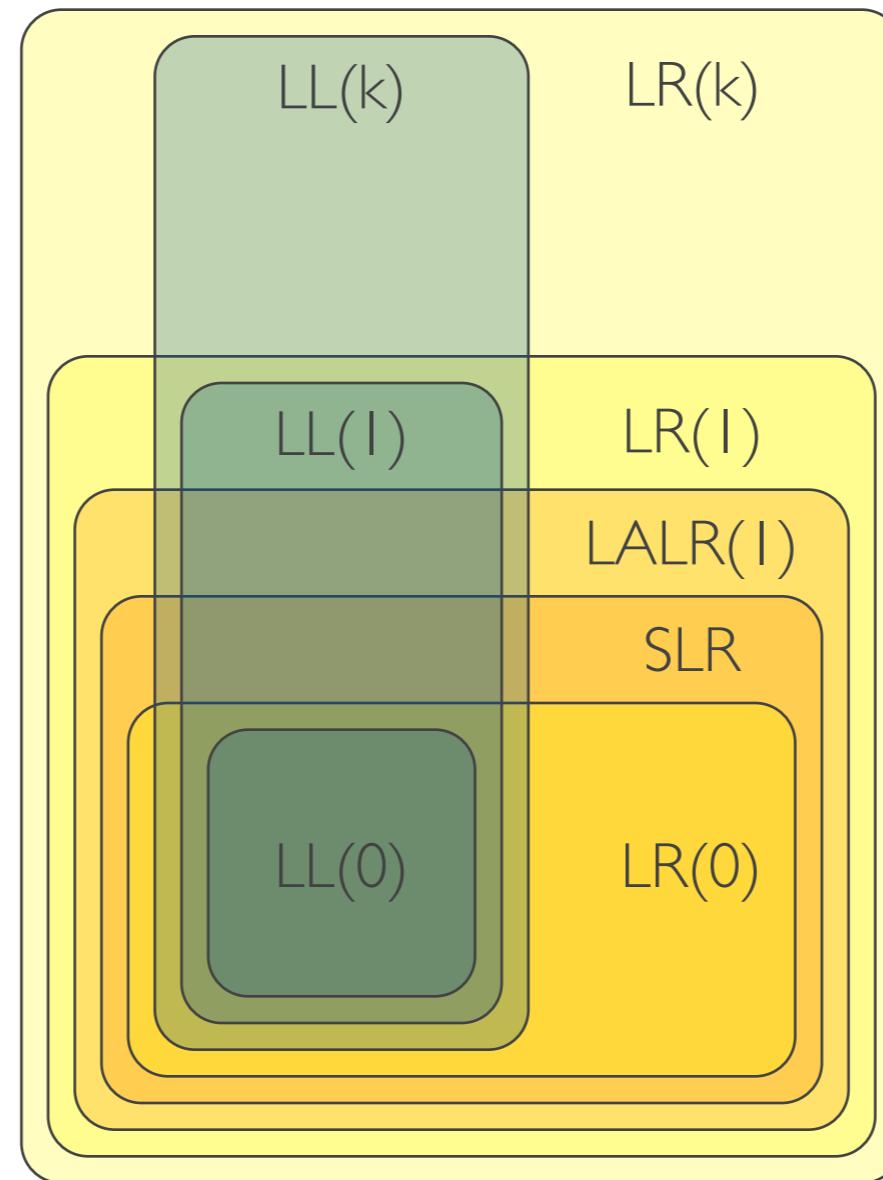
context-free grammars



context-free grammars



context-free grammars



$\text{Exp}^{“+”} \text{Exp} \rightarrow \text{Exp}$

$\text{Exp}^{“*”} \text{Exp} \rightarrow \text{Exp}$

$\text{Num} \rightarrow \text{Exp}$

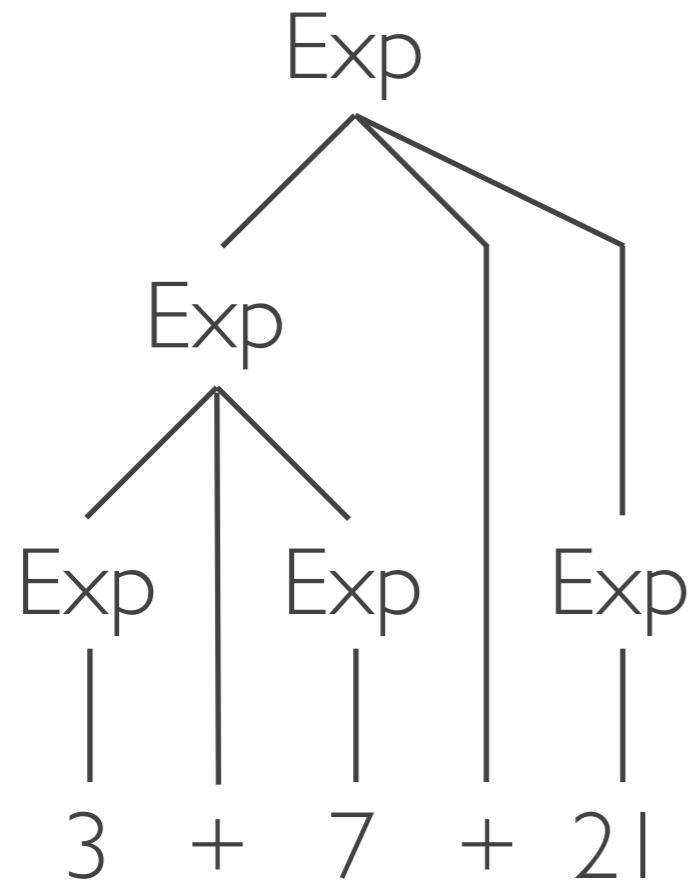
$\text{Term}^{“+”} \text{Term}^* \rightarrow \text{Exp}$

$\text{Fact}^{“*”} \text{Fact}^* \rightarrow \text{Term}$

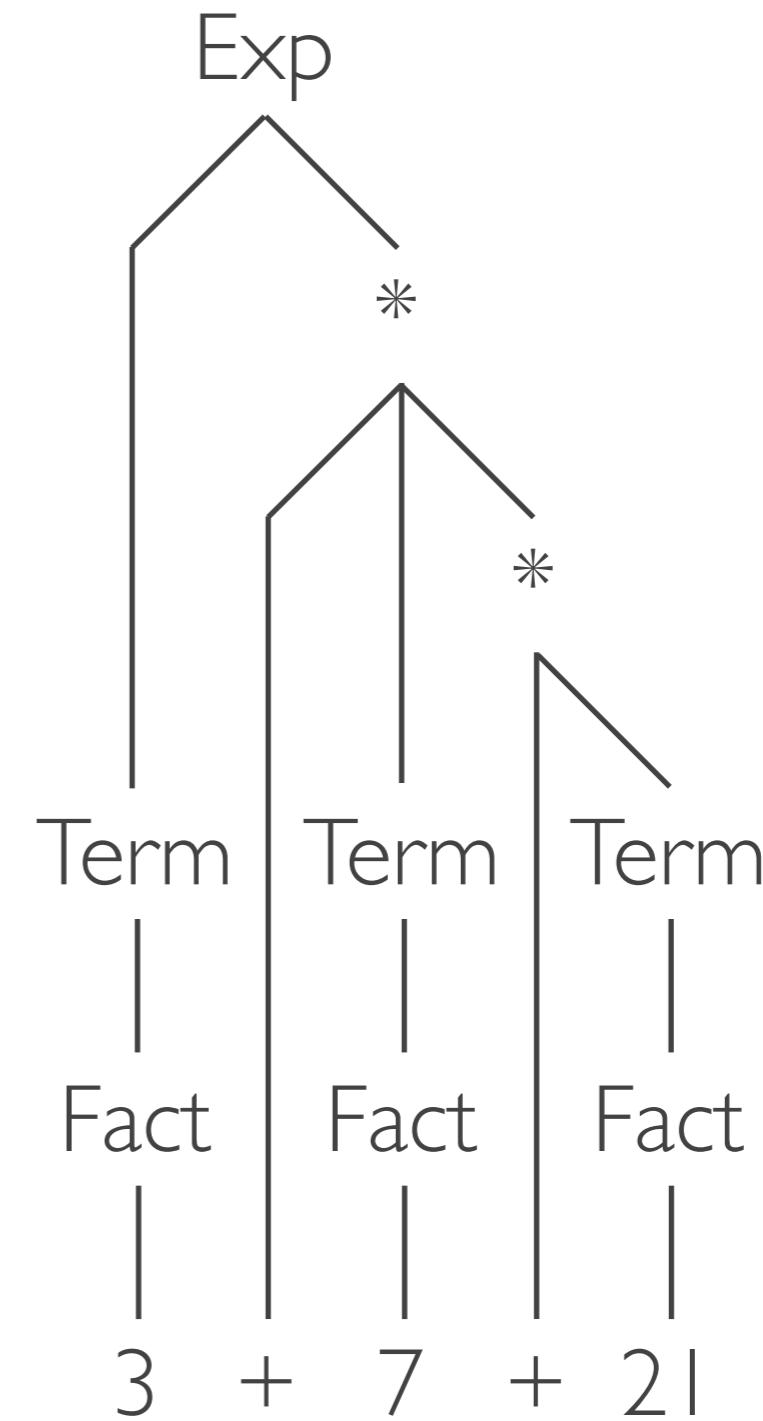
$\text{Num} \rightarrow \text{Fact}$

paradise

grammar classes

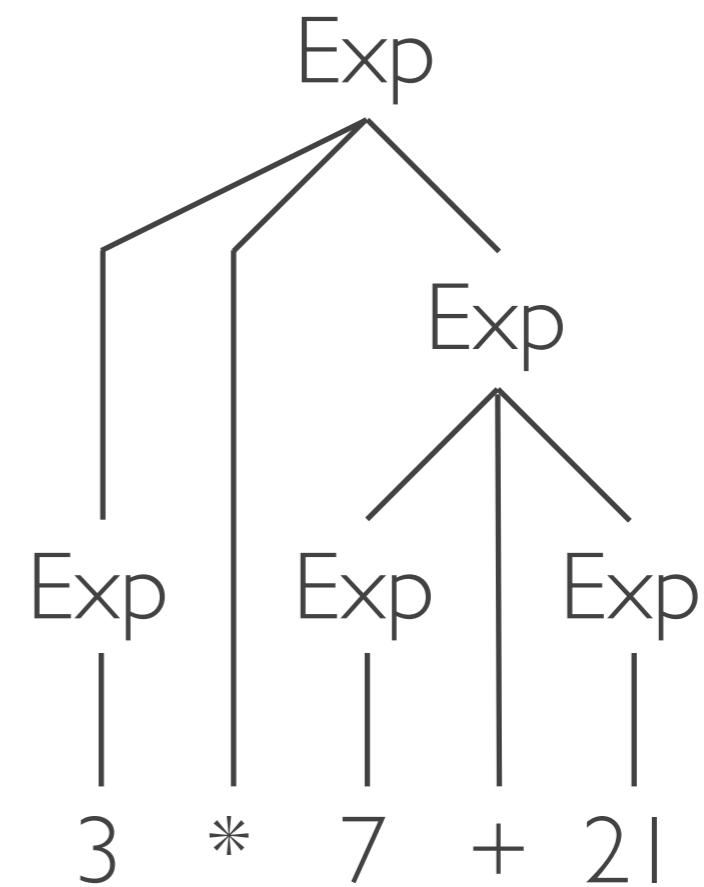
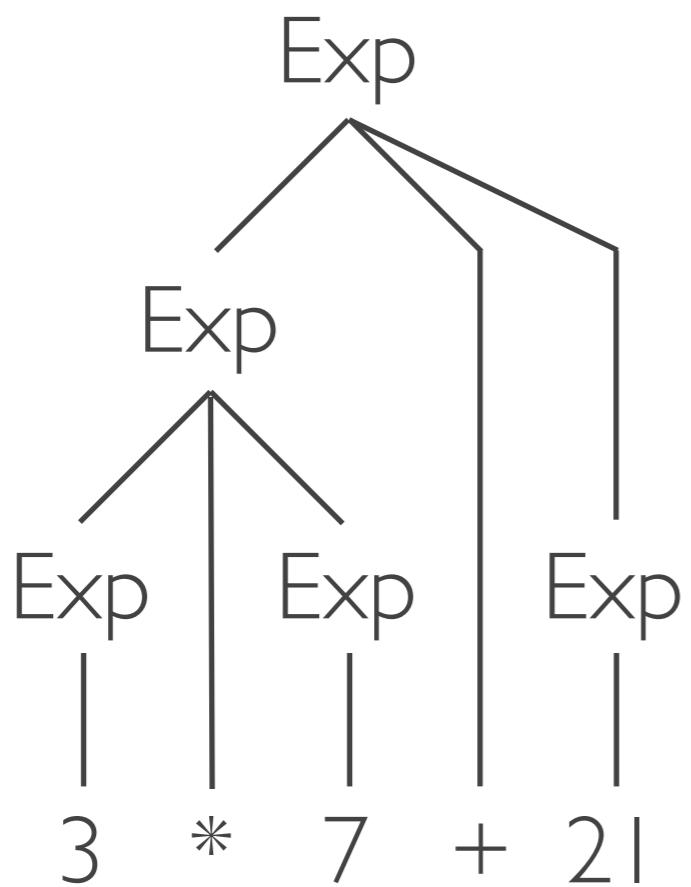


paradise



grammar classes

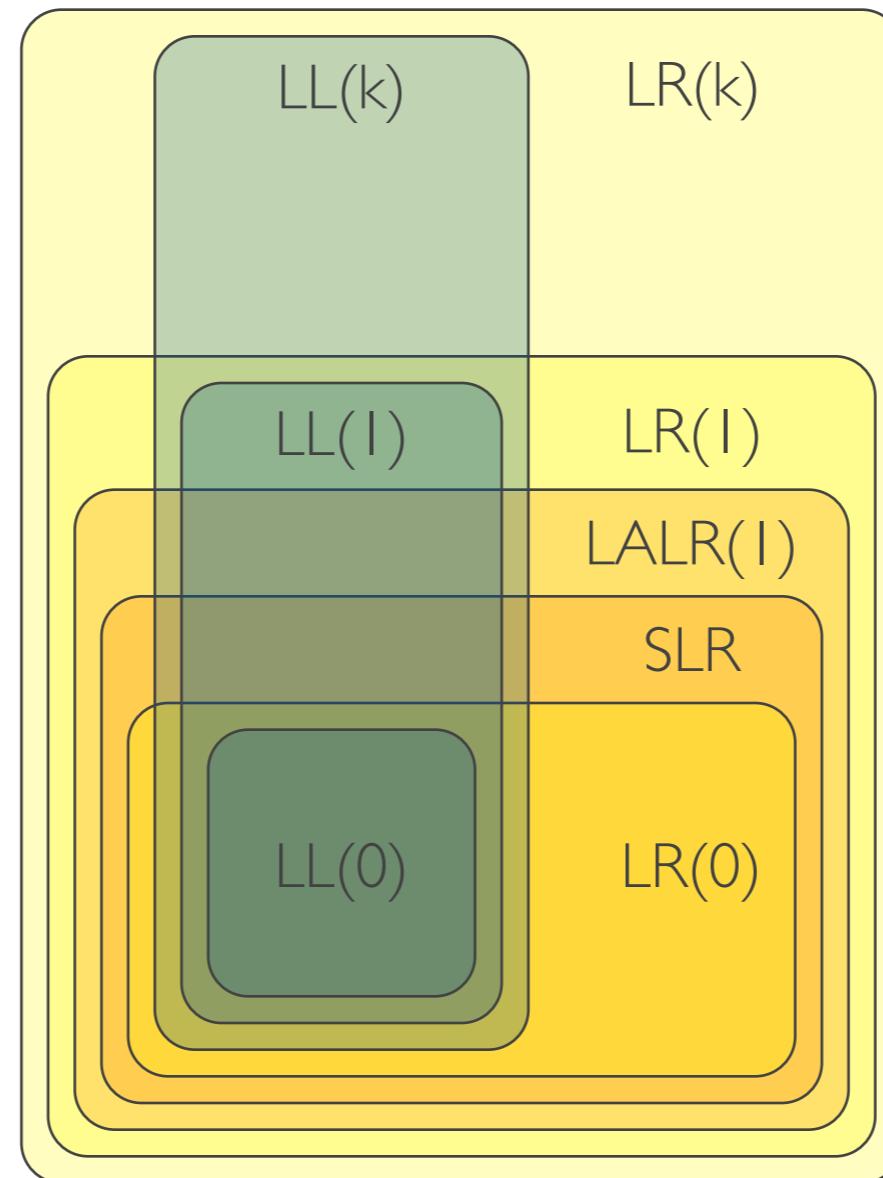
THE SECOND PLAGUE WAS
DISAMBIGUATION



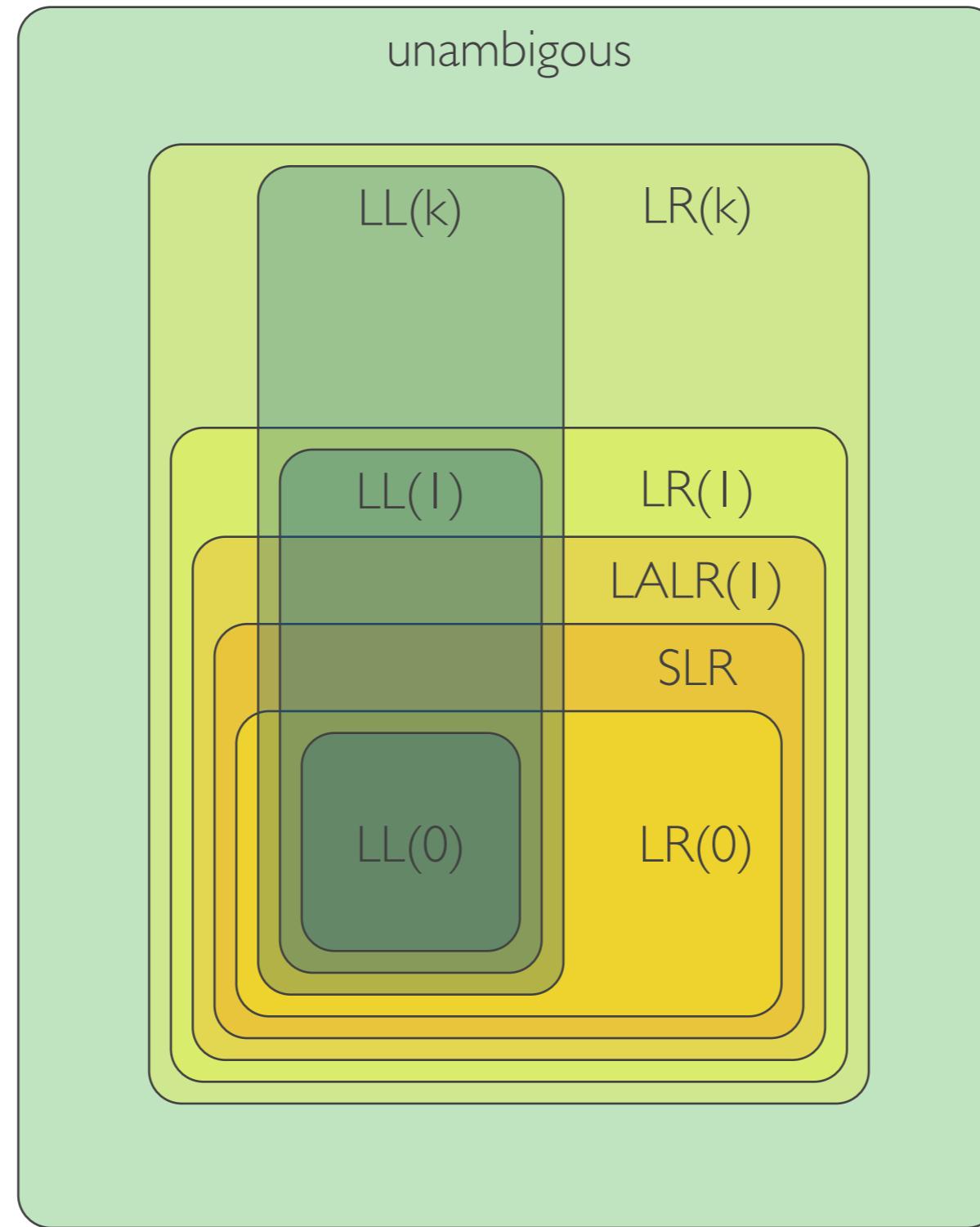
precedence	operators	associativity
1	(), []	non-associative
2	new	non-associative
3	.	left-associative
4	++, --	non-associative
5	-, +, !, ~, ++, --, (type)	right-associative
6	*, /, %	left-associative
7	+, -	left-associative
...

text books

context-free grammars



context-free grammars



Exp “+” Term → Exp

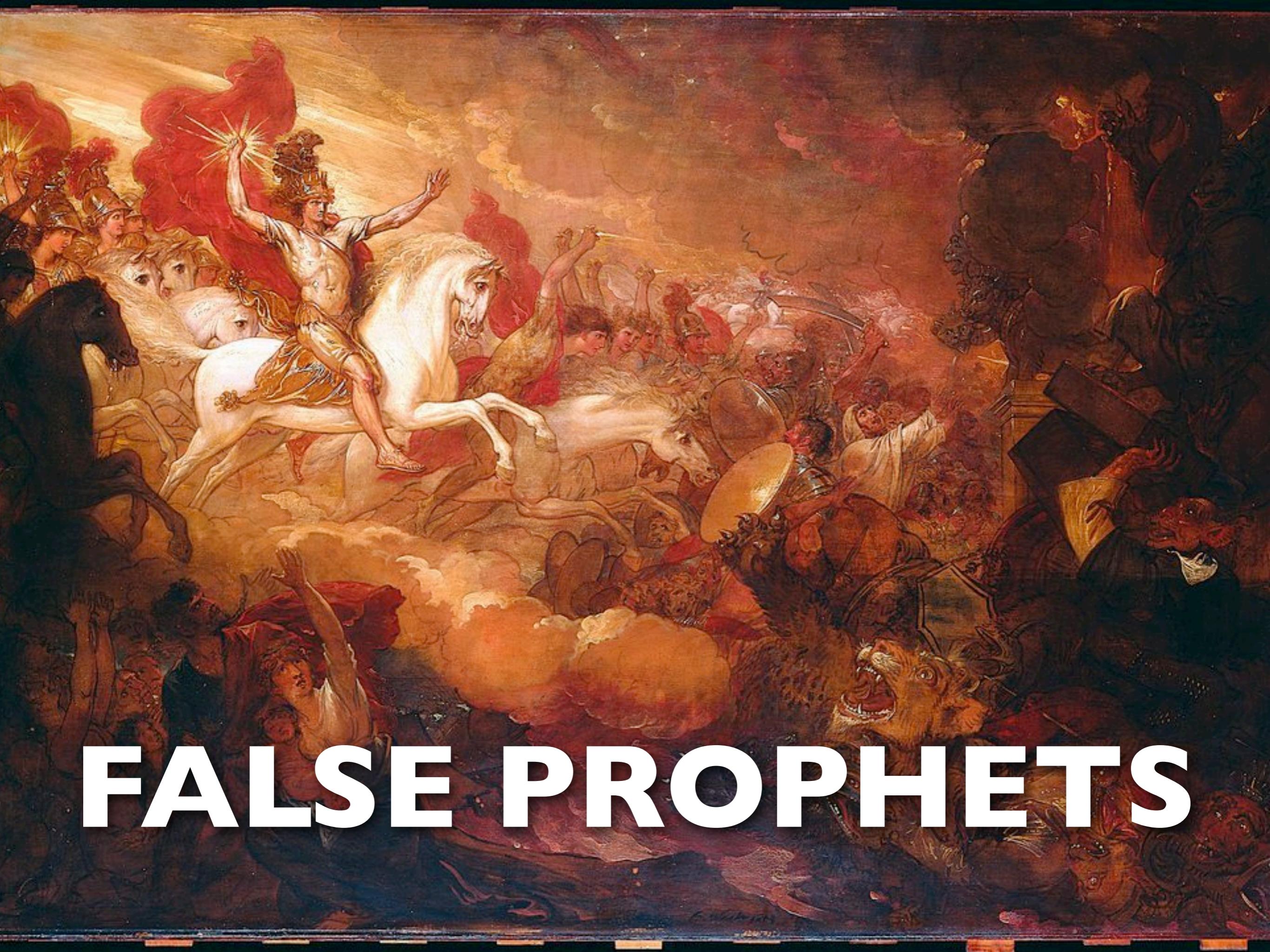
Term → Exp

Term “*” Fact → Term

Fact → Term

Num → Fact

grammar classes



FALSE PROPHETS

$L = \{ab, a\}$

$L = \{ab, a\}$

“a” “b” → A

“a” → A

“a” “b” /
“a” → A

paradise

PEGs

$L = \{ab, a\}$

$L = \{a\}$

“a” → A

“a” /

“a” “b” → A

“a” “b” → A

paradise

PEGs

`if c1 then if c2 then s1 else s2`

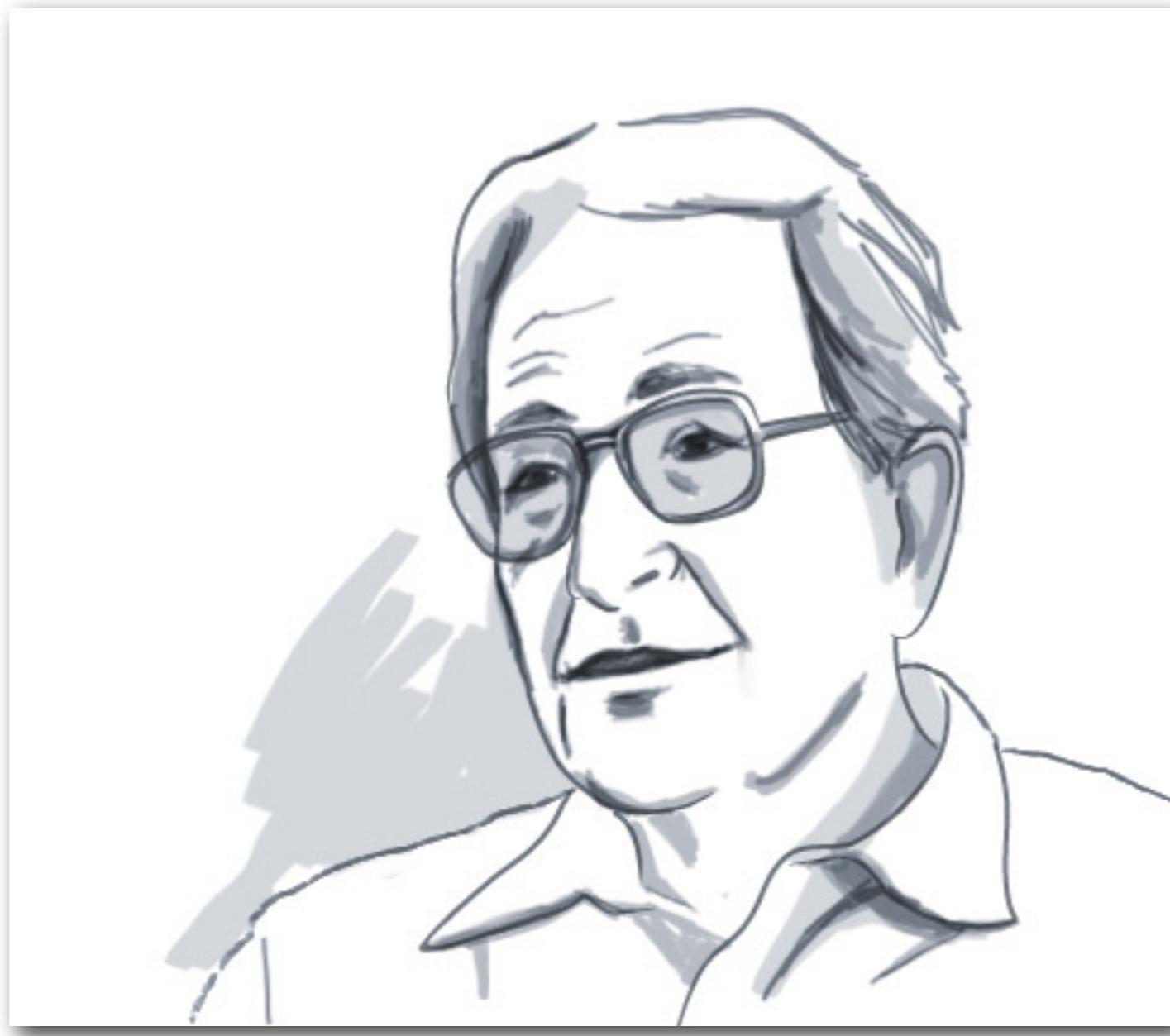
dangling else

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

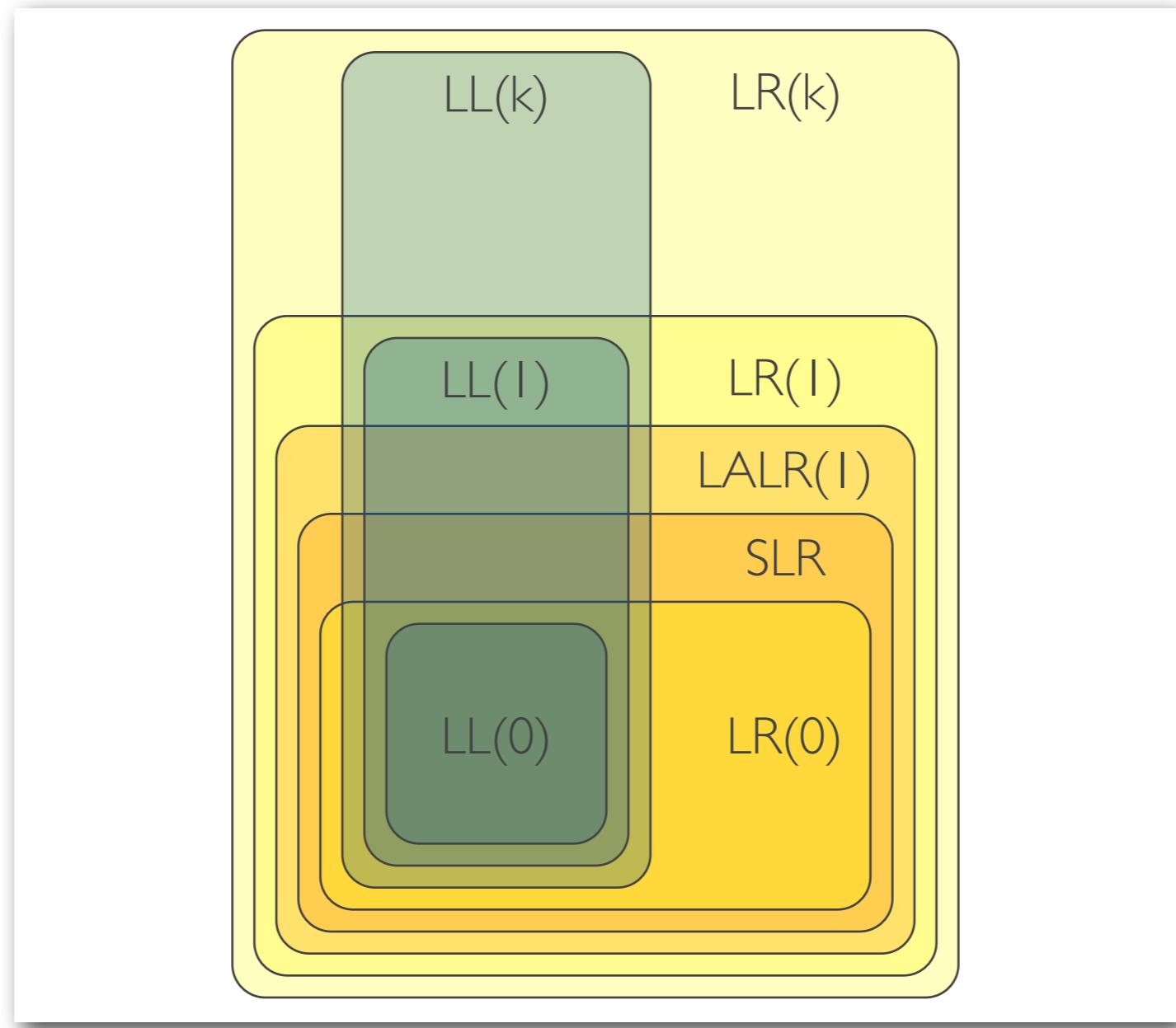
“if” E “then” S /
“if” E “then” S “else” S → S

PEGs

THE THIRD PLAGUE WAS
LEXICAL SYNTAX



morphology & syntax



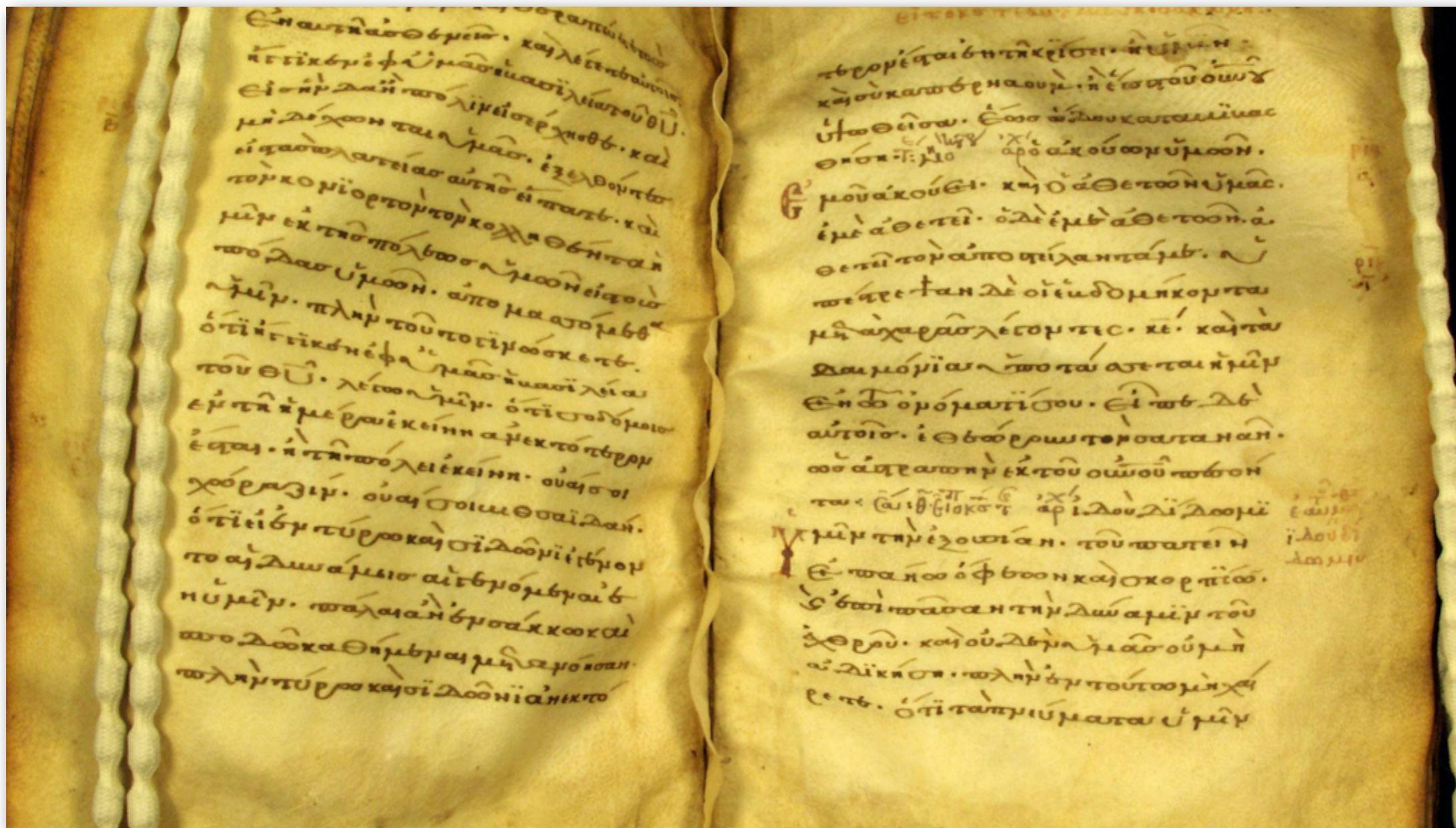
limited look-ahead



scanners

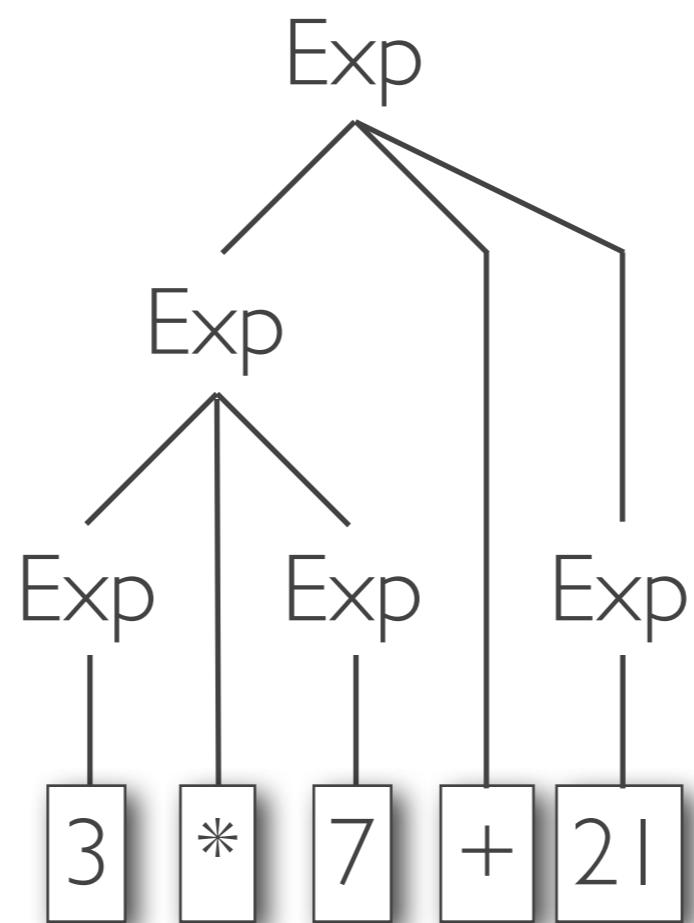
$$3 * 7 + 21$$

3 * 7 + 21



parsers

3 * 7 + 21



`x = l. * .10`

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

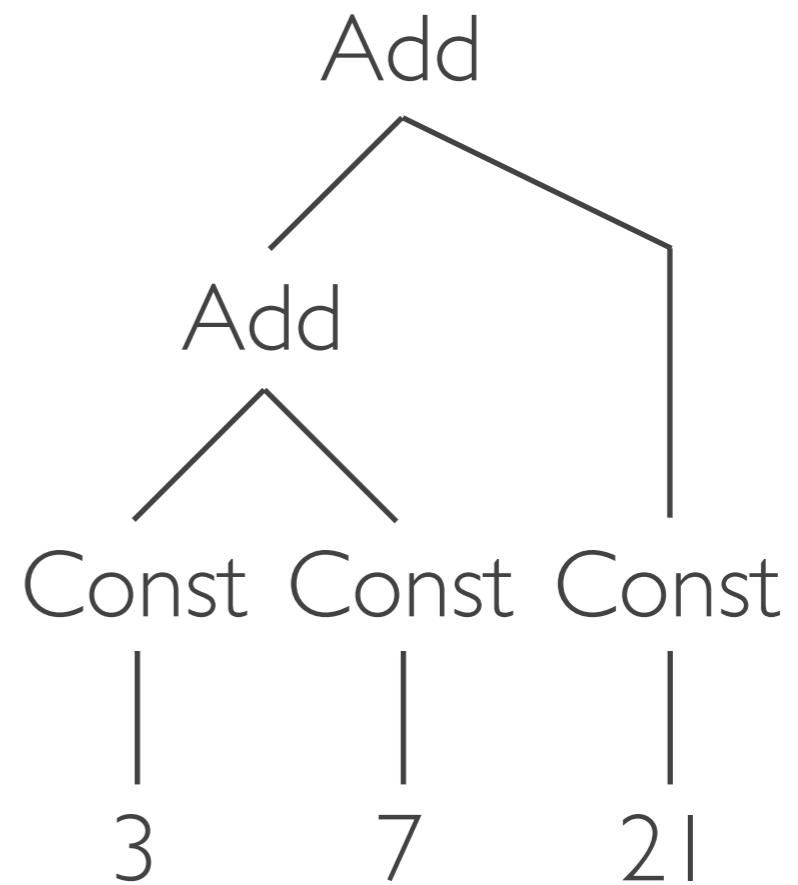
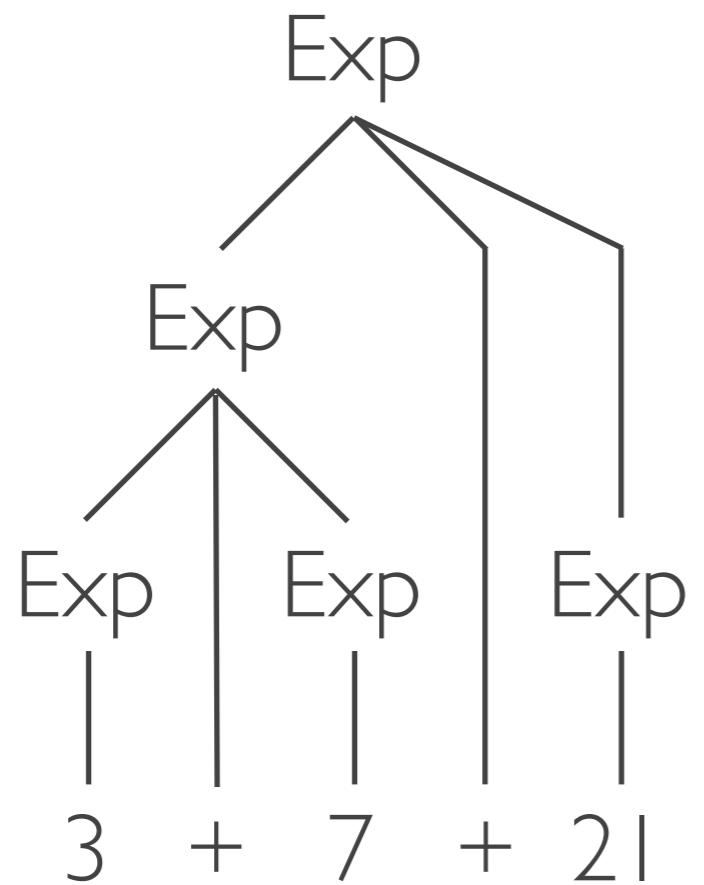
x = l. * .10

y : array [l .. 10] of integer

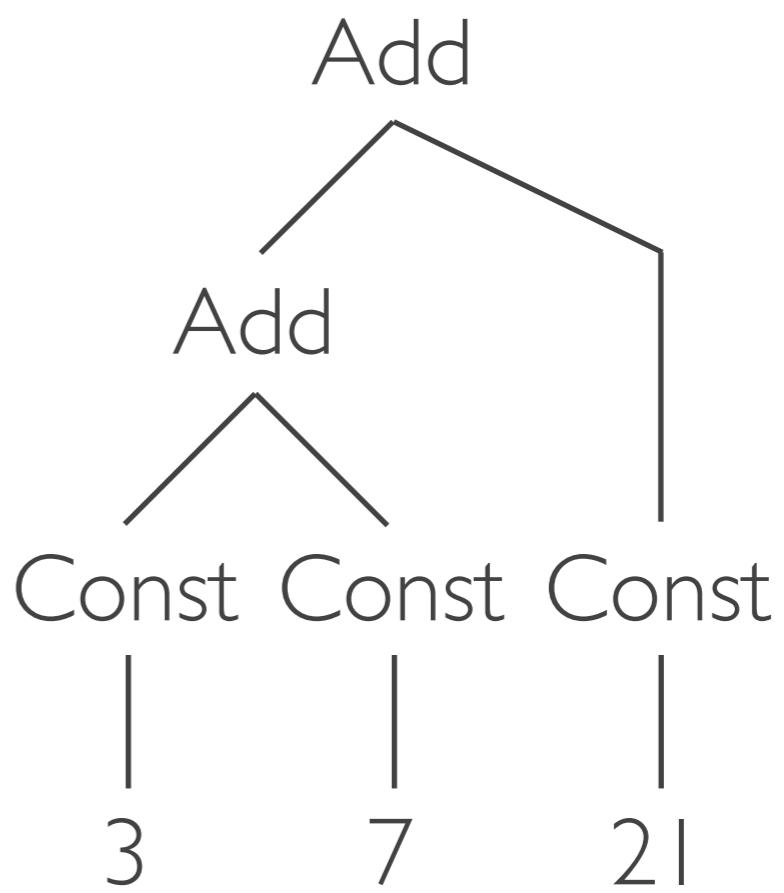
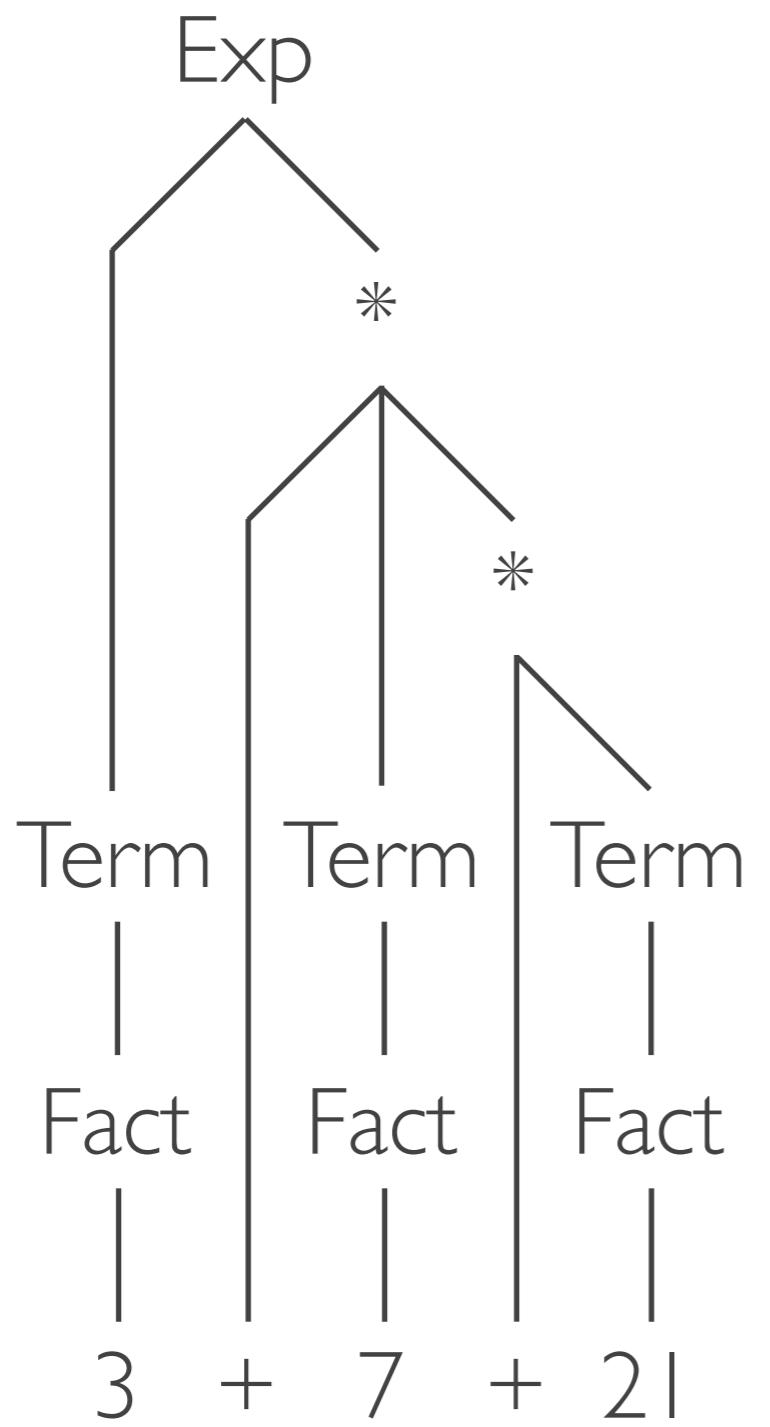
x = l. * .10

y : array [l. .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

Exp “+” Term → Exp
Term → Exp
Term “*” Fact → Term
Fact → Term
Num → Fact

paradise

grammar classes

$\text{Exp}^{“+”} \text{Exp} \rightarrow \text{Exp}$
 $\text{Exp}^{“*”} \text{Exp} \rightarrow \text{Exp}$
 $\text{Num} \rightarrow \text{Exp}$

$\text{Exp}^{“=”} \text{Exp} \rightarrow \text{Exp}$
 $\text{Exp}^{“<”} \text{Exp} \rightarrow \text{Exp}$
 $\text{Exp}^{“>”} \text{Exp} \rightarrow \text{Exp}$

CExp “+” Term → **CExp**
Term → **CExp**
Term “*” Fact → Term
Fact → Term
Num → Fact

$\text{Exp}^{“=”} \text{CExp} \rightarrow \text{Exp}$
 $\text{Exp}^{“<”} \text{CExp} \rightarrow \text{Exp}$
 $\text{Exp}^{“>”} \text{CExp} \rightarrow \text{Exp}$
 $\text{CExp} \rightarrow \text{Exp}$

paradise

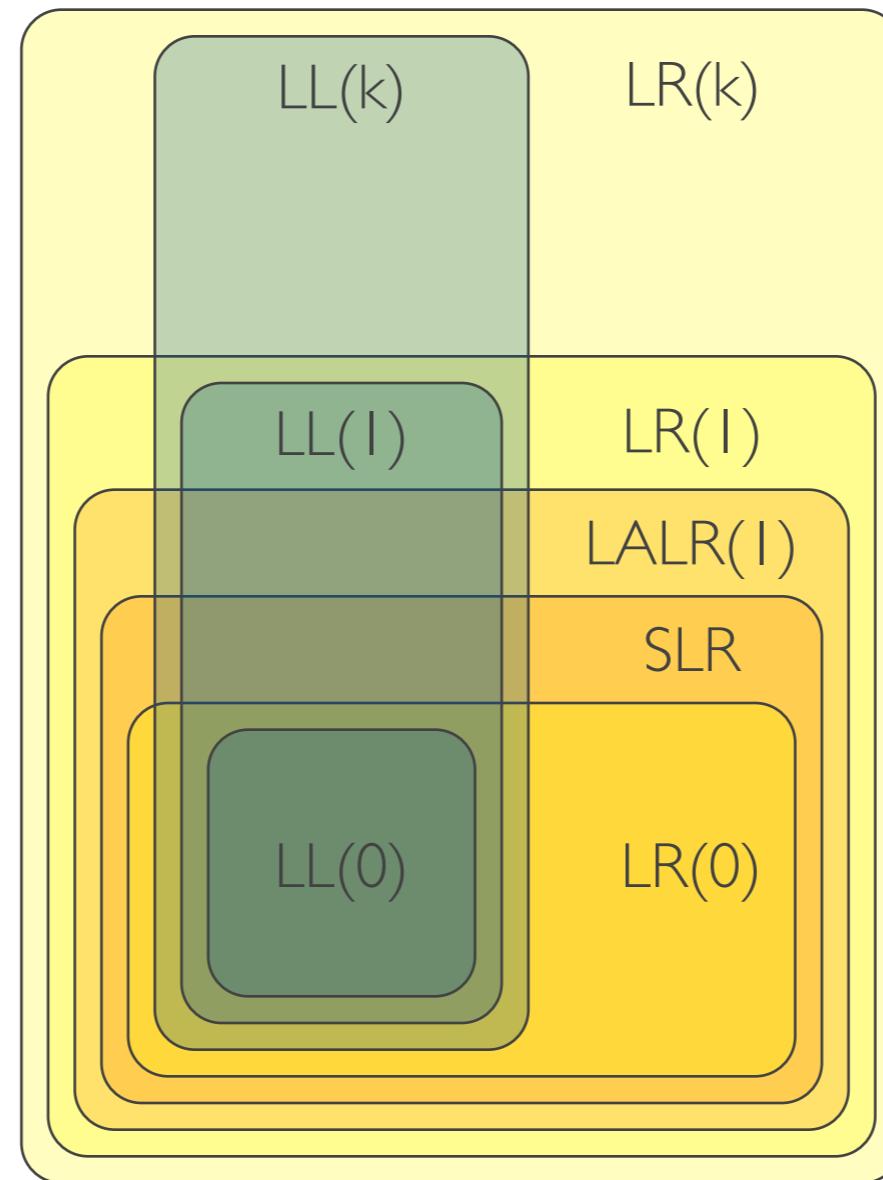
grammar classes

THE SIXTH PLAGUE WAS
COMPOSITION

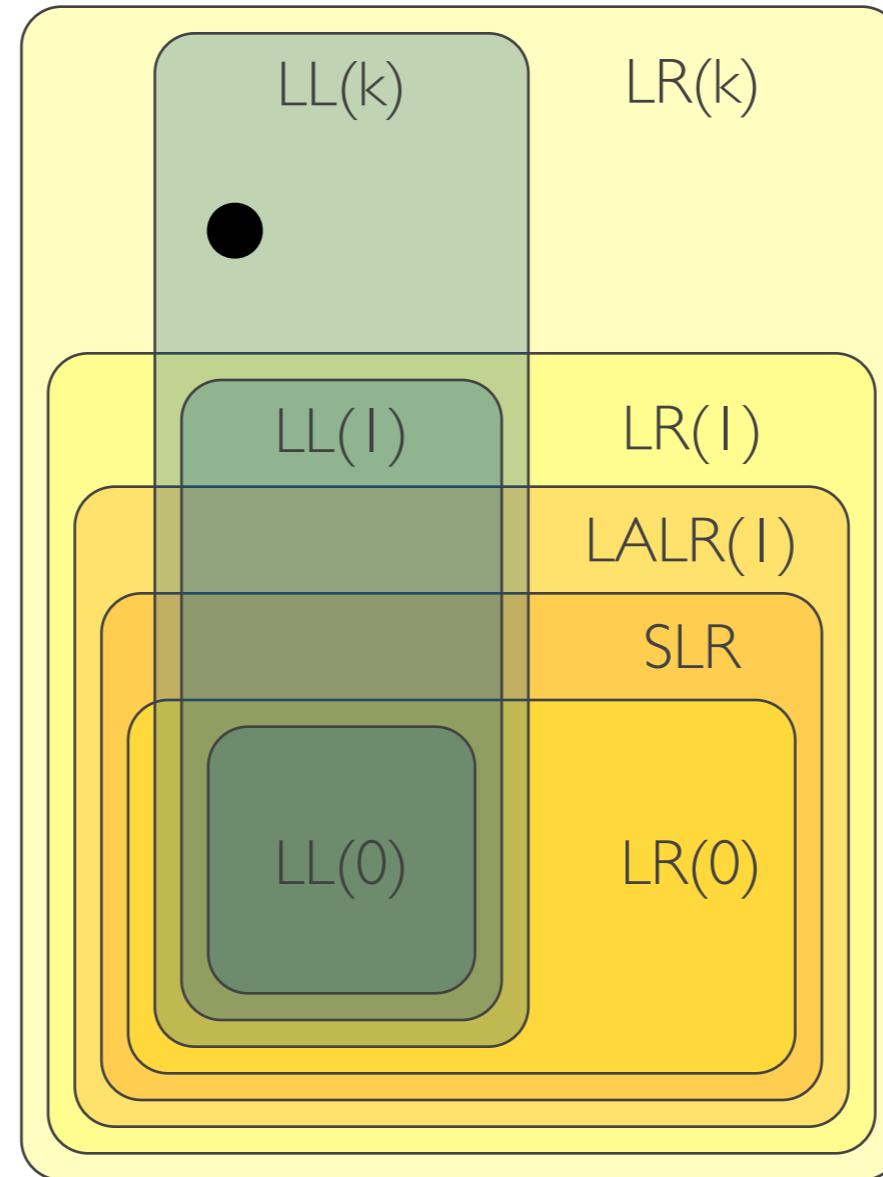


parsers

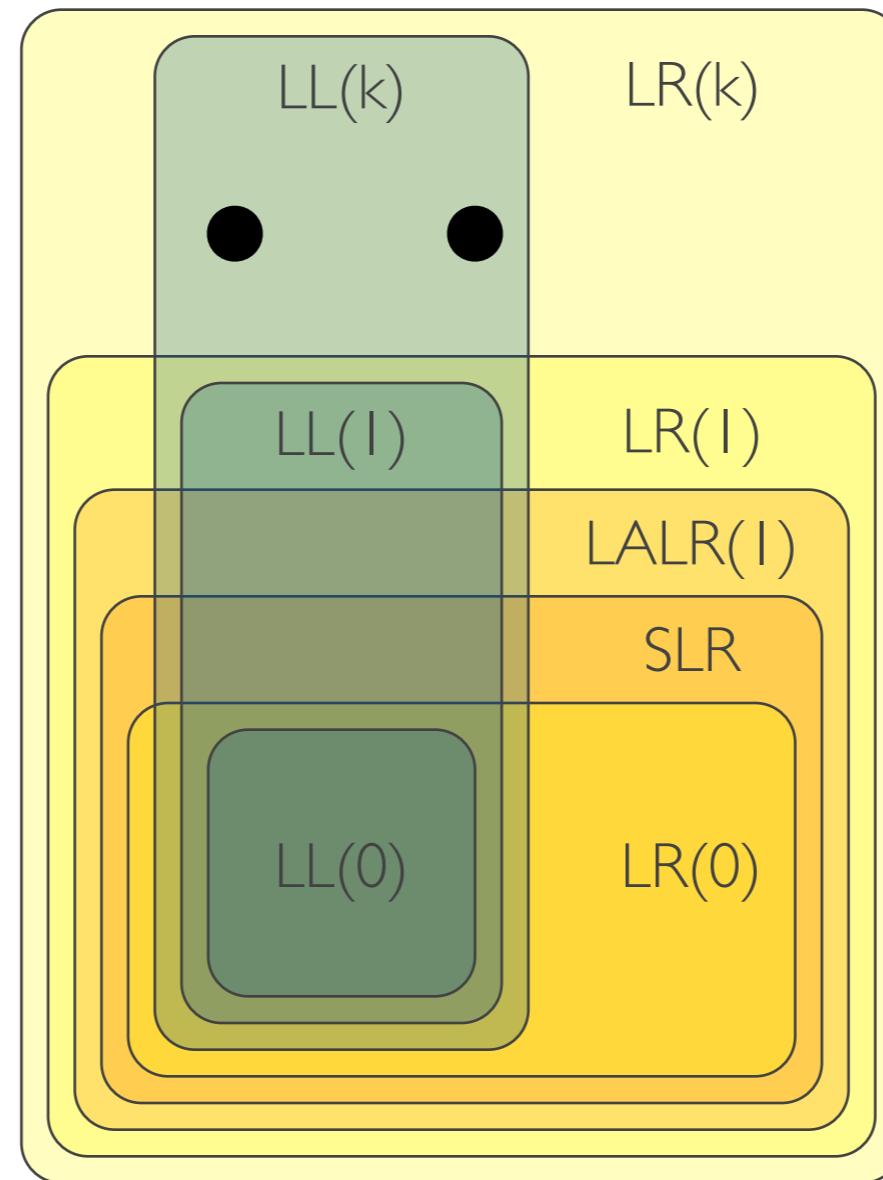
context-free grammars



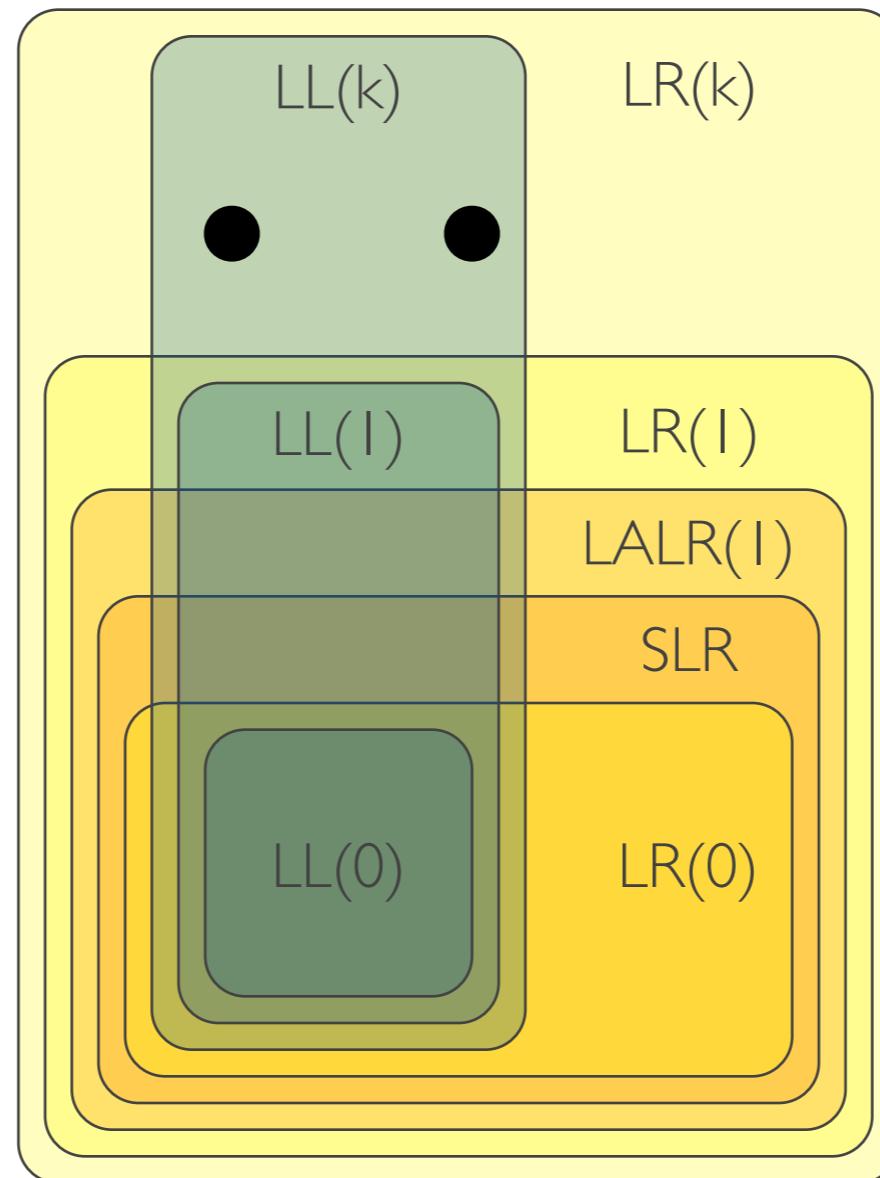
context-free grammars



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

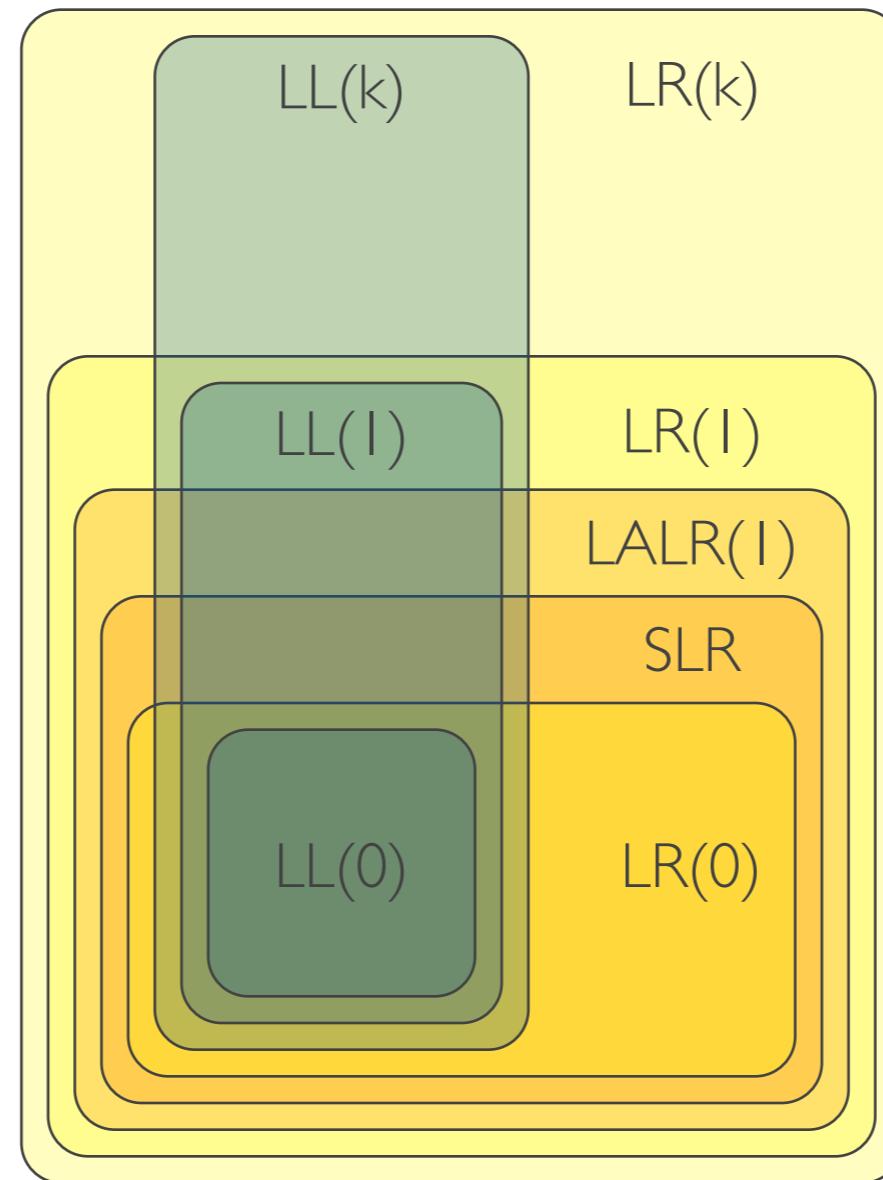
IDE SUPPORT

A medieval-style illustration depicting a town scene. In the foreground, a large crowd of people in period clothing, including tunics and hats, are gathered around a wooden cart. Some individuals are吹着号角 (blowing horns). In the background, there are several buildings, including a prominent one with a tiled roof and multiple windows. A stone wall runs across the middle ground. The overall style is reminiscent of a tapestry or a painting from the late Middle Ages.

PARADISE REGAINED

GENERALISED
PARSING

context-free grammars



context-free grammars

Exp "+" Exp → Exp
Exp "*" Exp → Exp
Num → Exp

context-free syntax

Exp "+" Exp → Exp
Exp "*" Exp → Exp
NUM → Exp

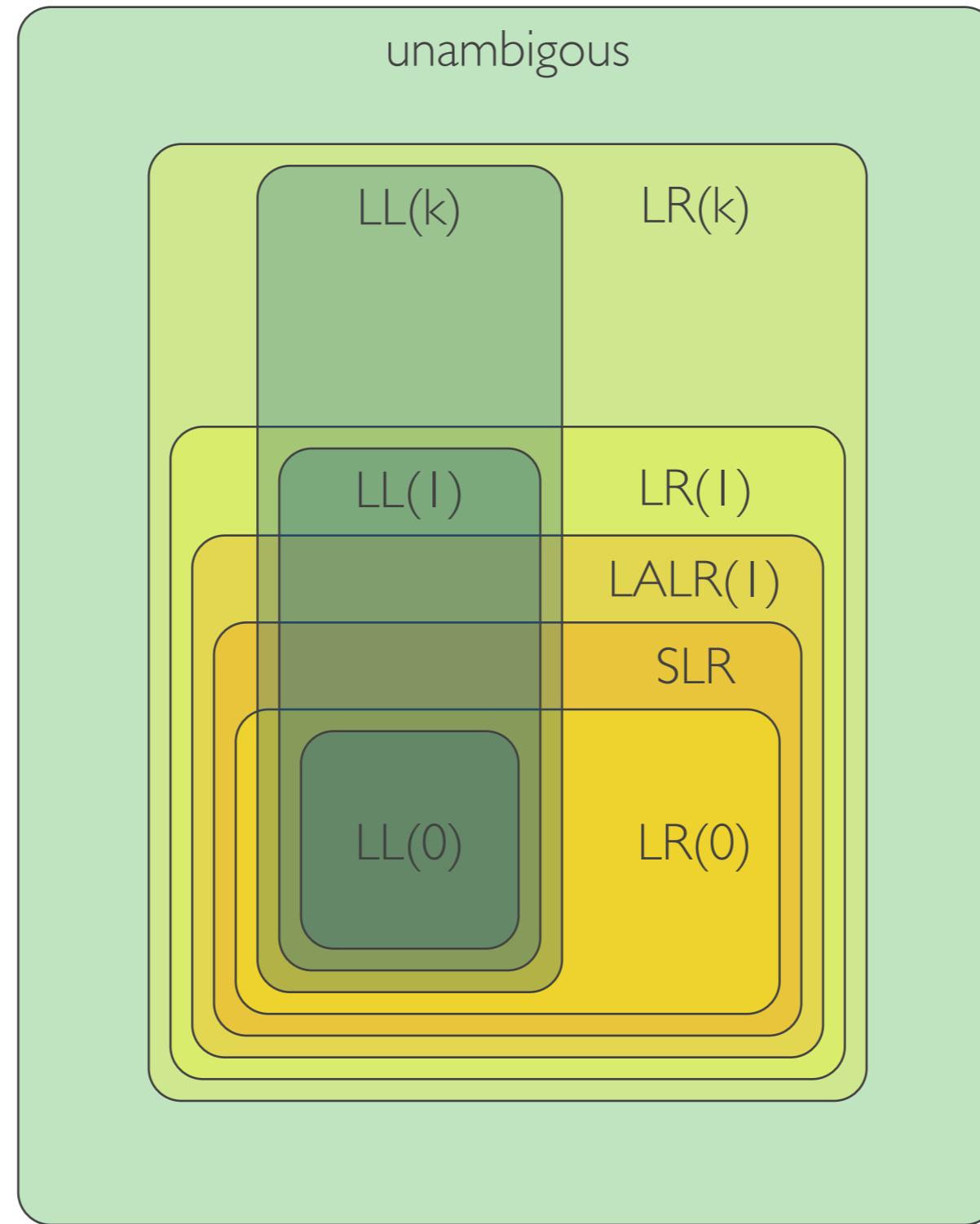
paradise

SDF

DECLARATIVE

DISAMBIGUATION

context-free grammars



context-free grammars

unambiguous

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

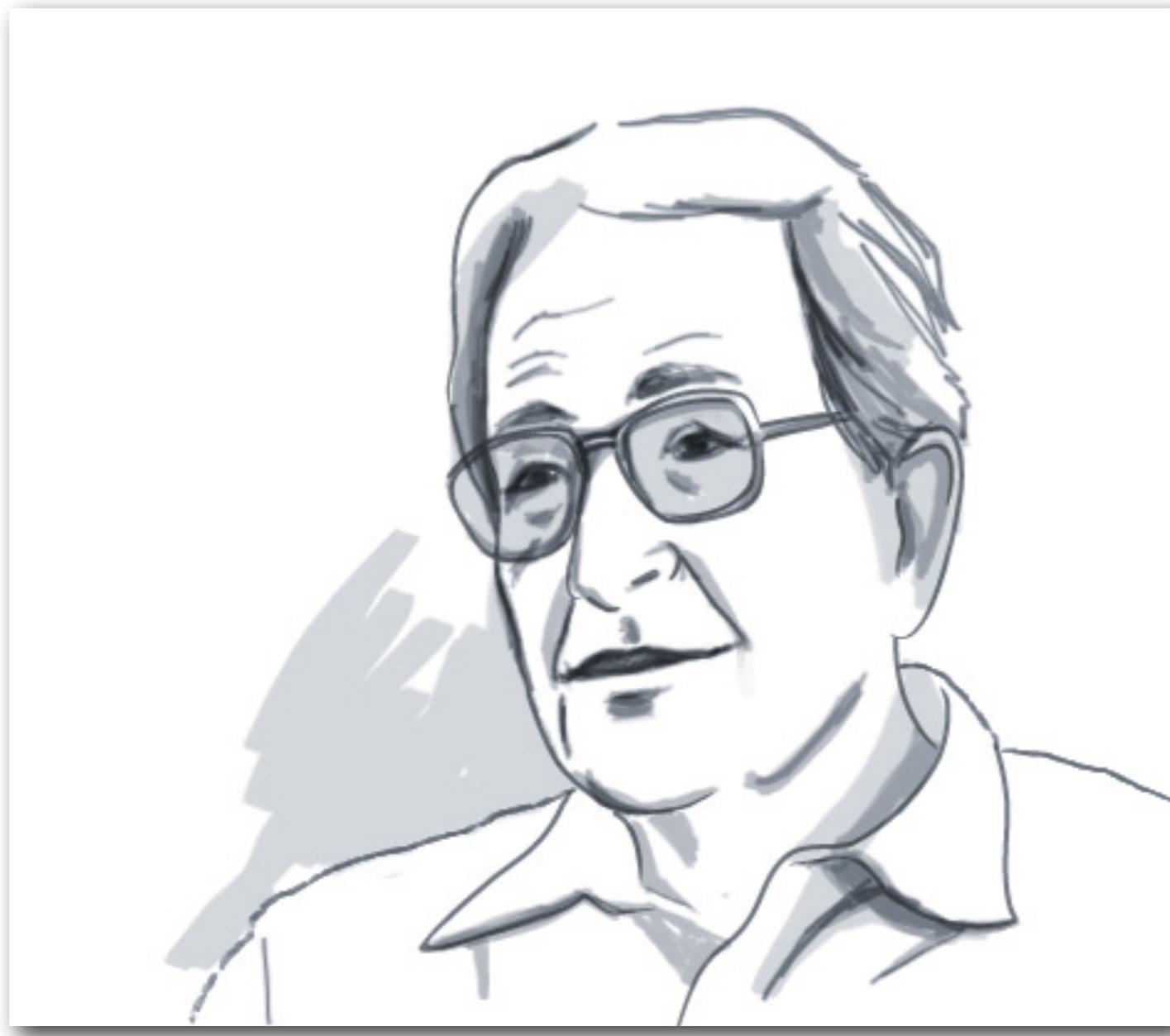
Exp "*" Exp -> Exp {left}
> Exp "+" Exp -> Exp {left}

context-free syntax

"if" E "then" S \rightarrow S {prefer}

"if" E "then" S "else" S \rightarrow S

SCANNERLESS
PARSING



morphology & syntax

lexical syntax

[0-9]+ -> NUM

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

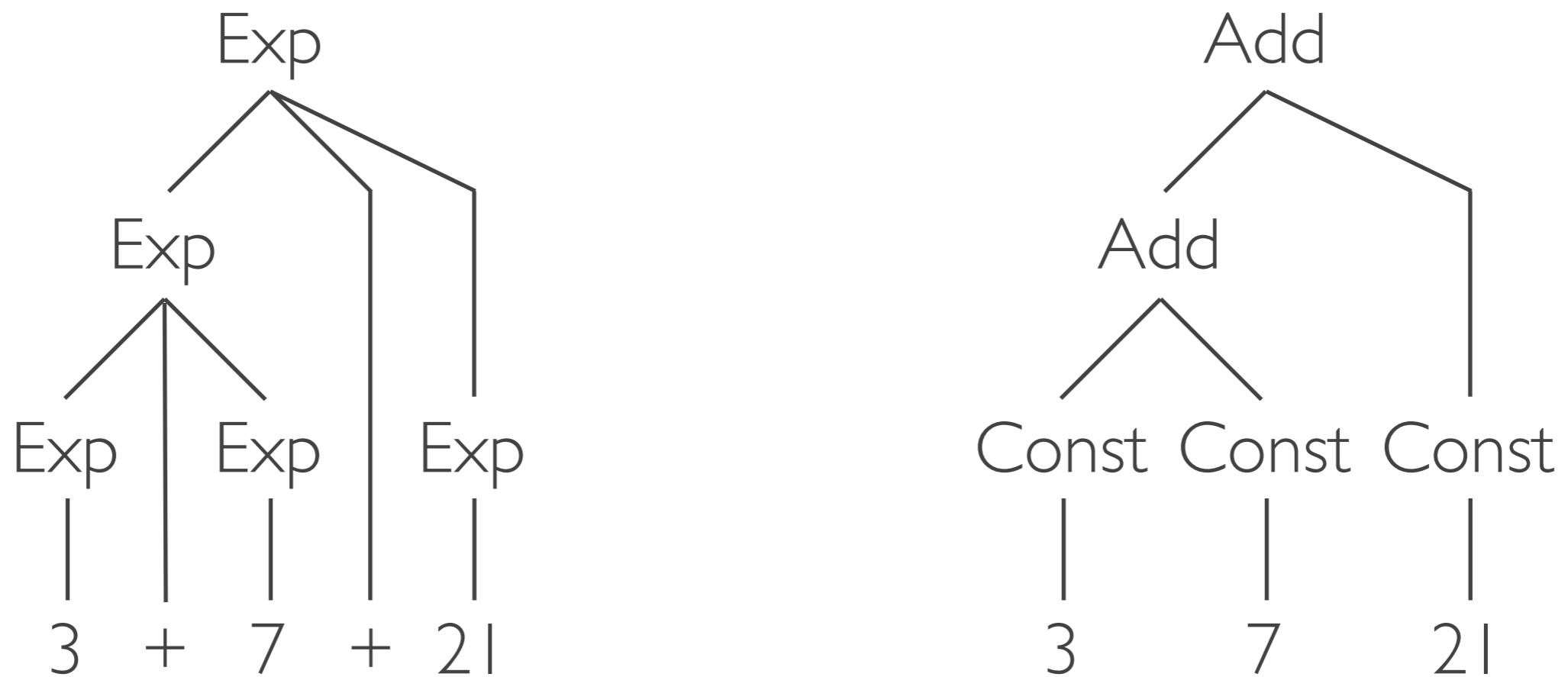
parser



parser

DECLARATIVE

TREE CONSTRUCTION

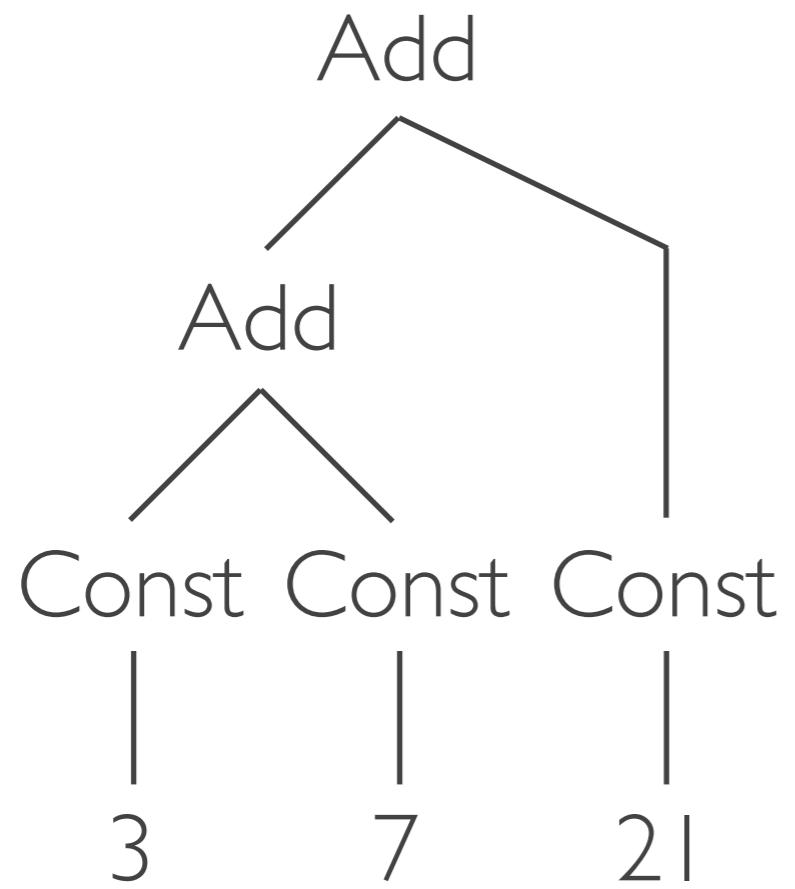


paradise

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

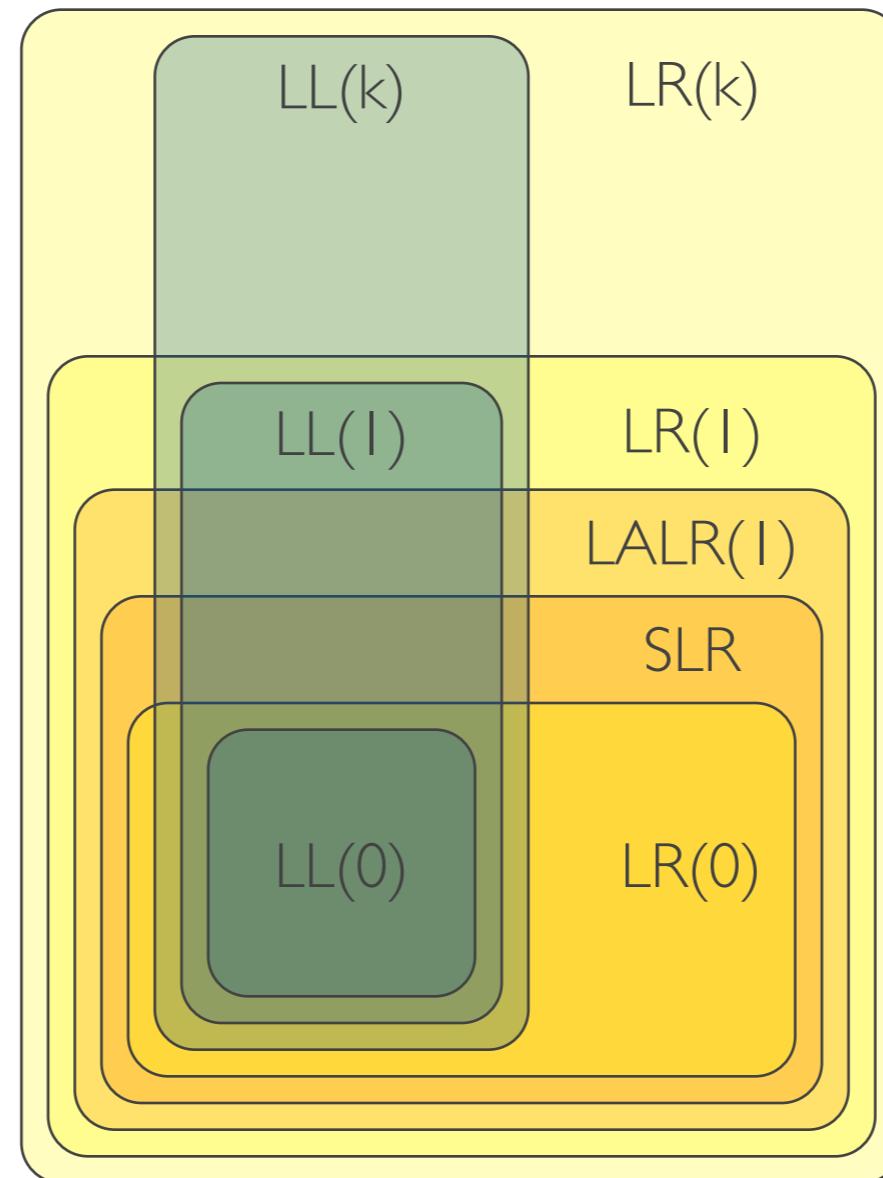
context-free syntax

```
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

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

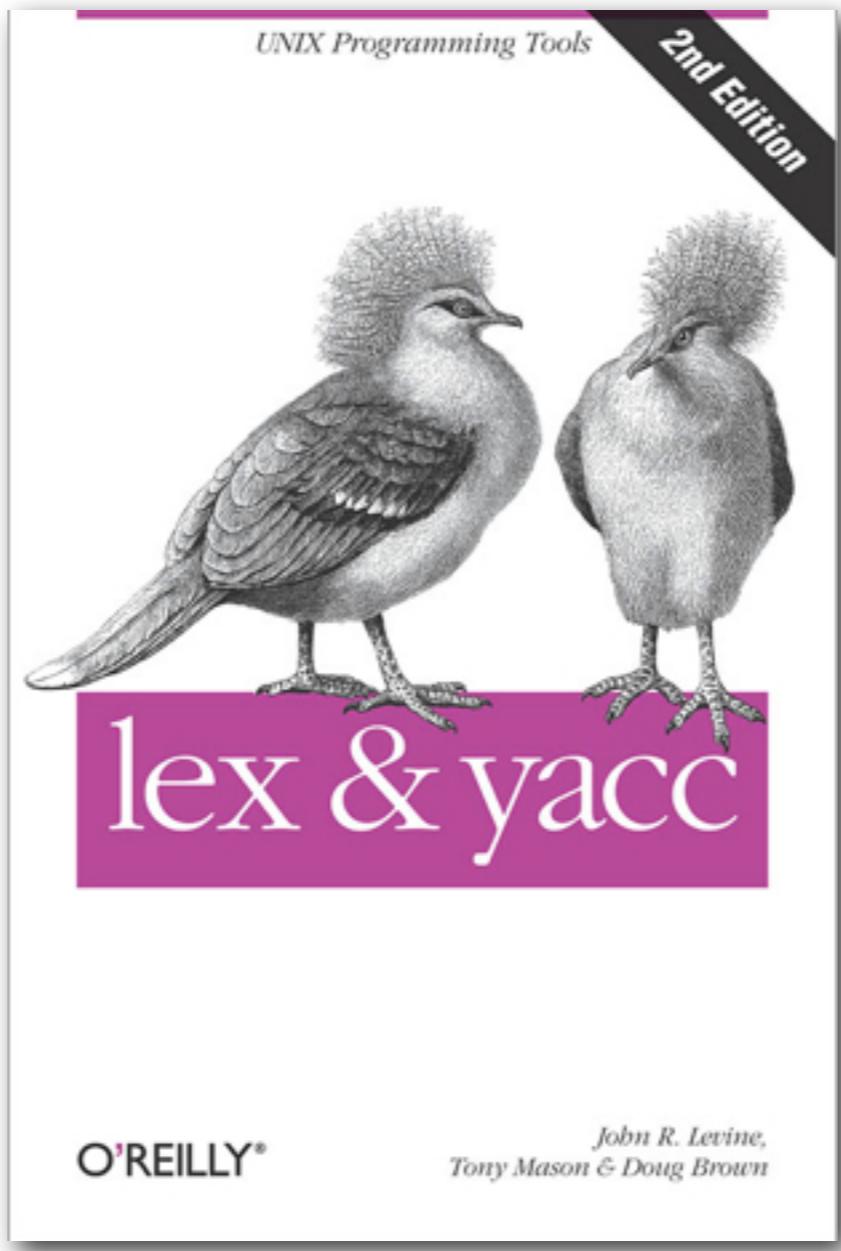
- Int

The screenshot shows the Eclipse IDE interface with a Java file named 'example.mjv' open in the editor. The code defines two classes: 'Main' and 'Fac'. The 'Main' class has a static main method that prints '0'. The 'Fac' class has a recursive 'fac' method that calculates the factorial of a number. To the right of the editor is the 'Outline' view, which displays a hierarchical tree of the code's structure. The tree shows the 'Main' class containing a 'main' method (of type 'Void') and an 'args' parameter (of type 'StringArray'). The 'Fac' class contains a 'fac' method (of type 'Int') with a 'num' parameter (of type 'Array') and a 'num_aux' local variable (of type 'Int'). The 'Outline' view also includes a search bar at the top right labeled 'a z'.

IDE SUPPORT



PARADISE DENIED



still around

Unix Text Processing Tools



flex & bison



O'REILLY®

John Levine

still around



still have to use it



still have to learn
LL, LR, SLR, LALR



still think using
parser generators is hard

The
Pragmatic
Programmers

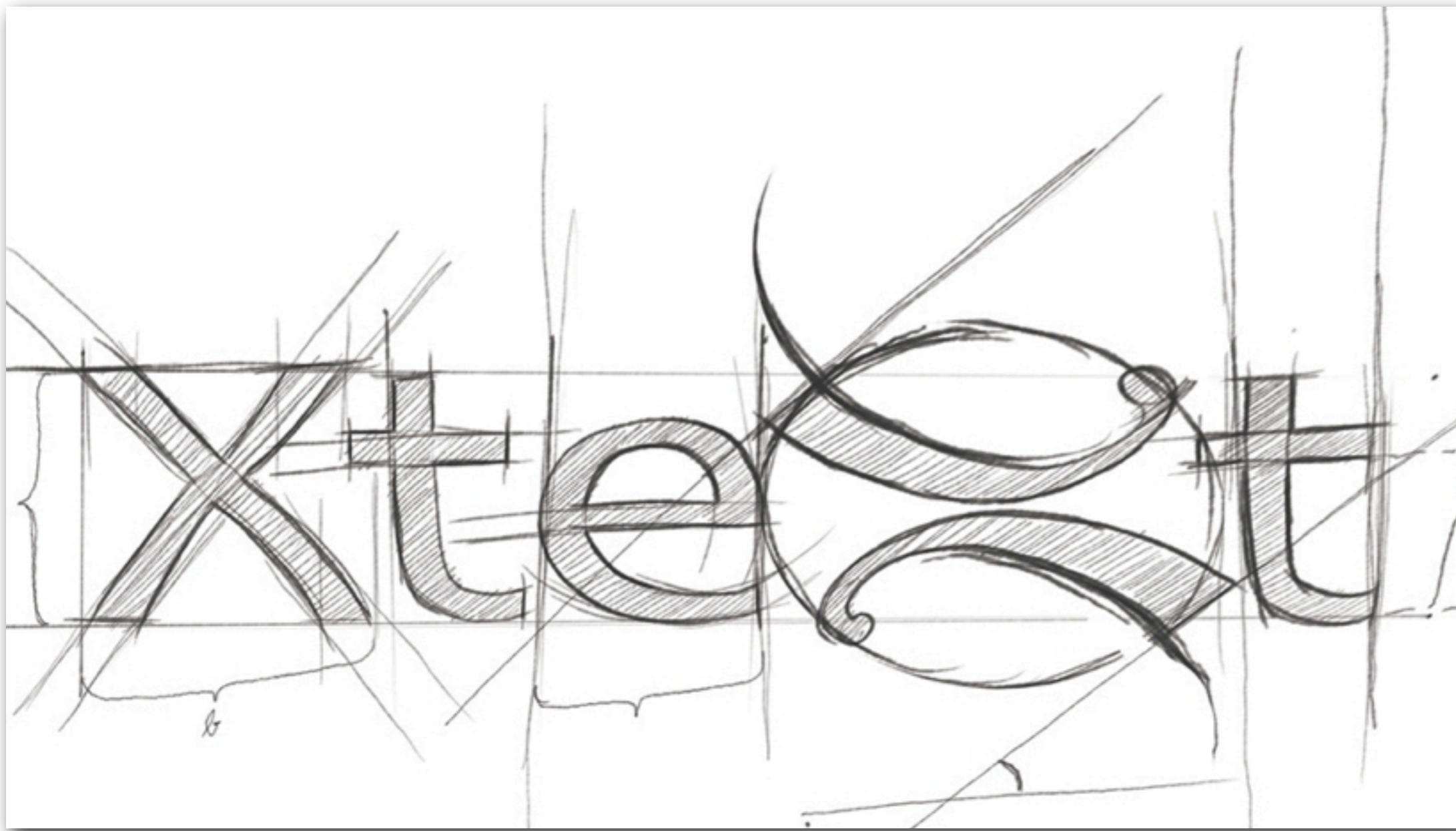
The Definitive **ANTLR** Reference

Building Domain-
Specific Languages



Terence Parr

modern parser generator



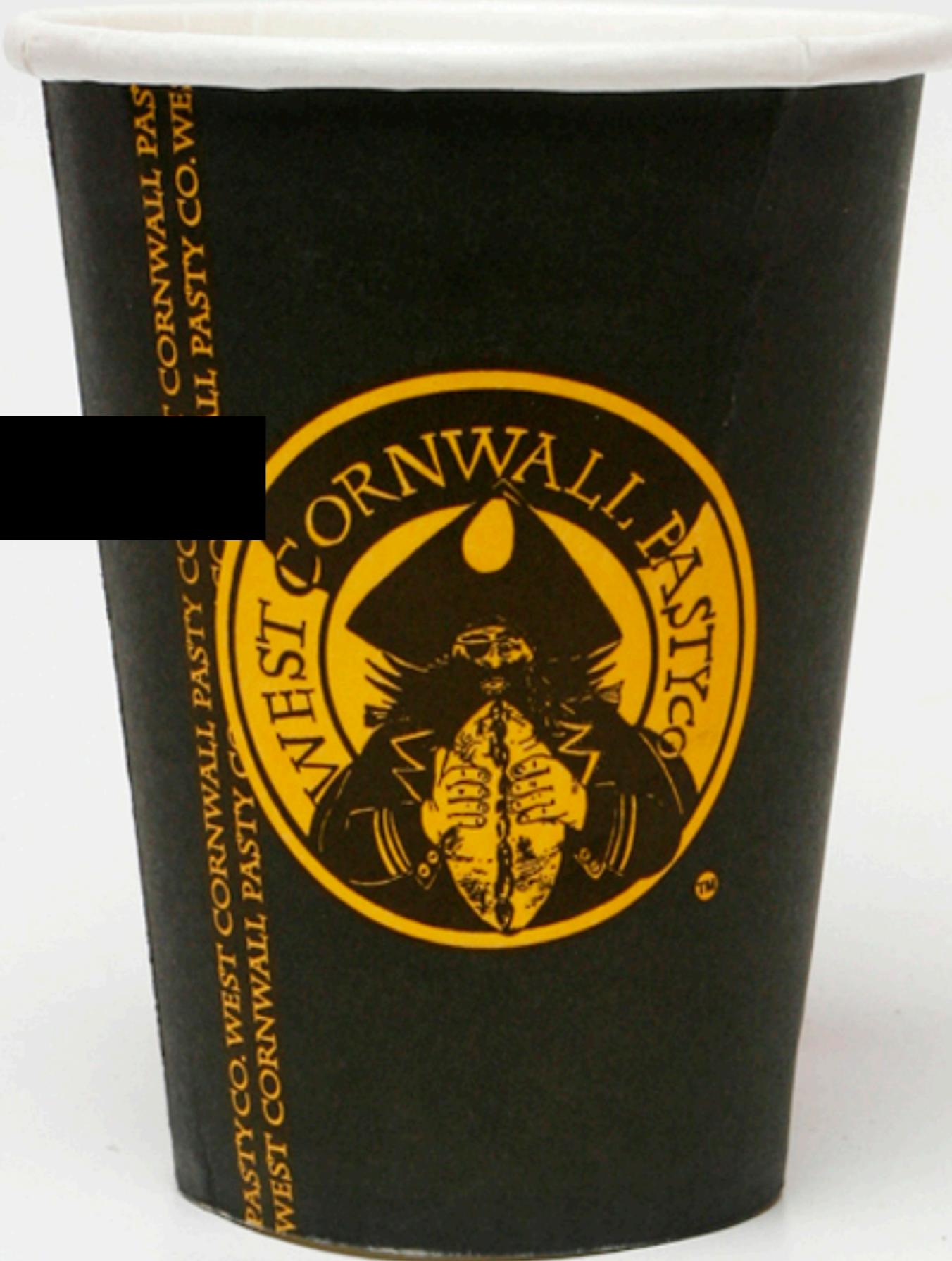
modern parser generator



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

“foo”

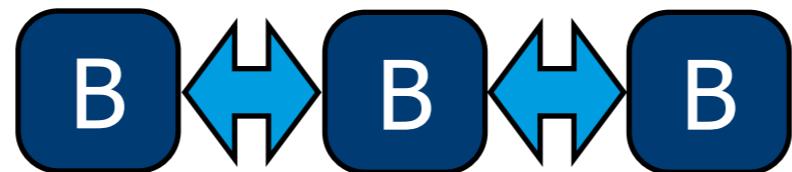
KW [“foo”]

_1

Box Layout

horizontal boxes

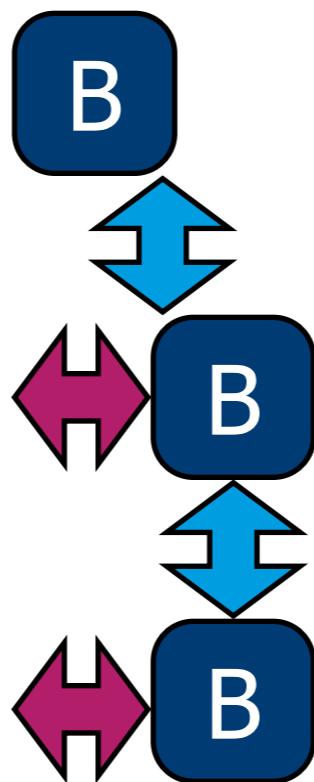
```
H hs=x [ B B B ]
```



Box Layout

vertical boxes

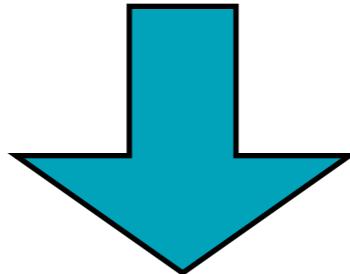
```
v vs=y is=i [ B B B ]
```



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

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declarative syntax definition

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

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

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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

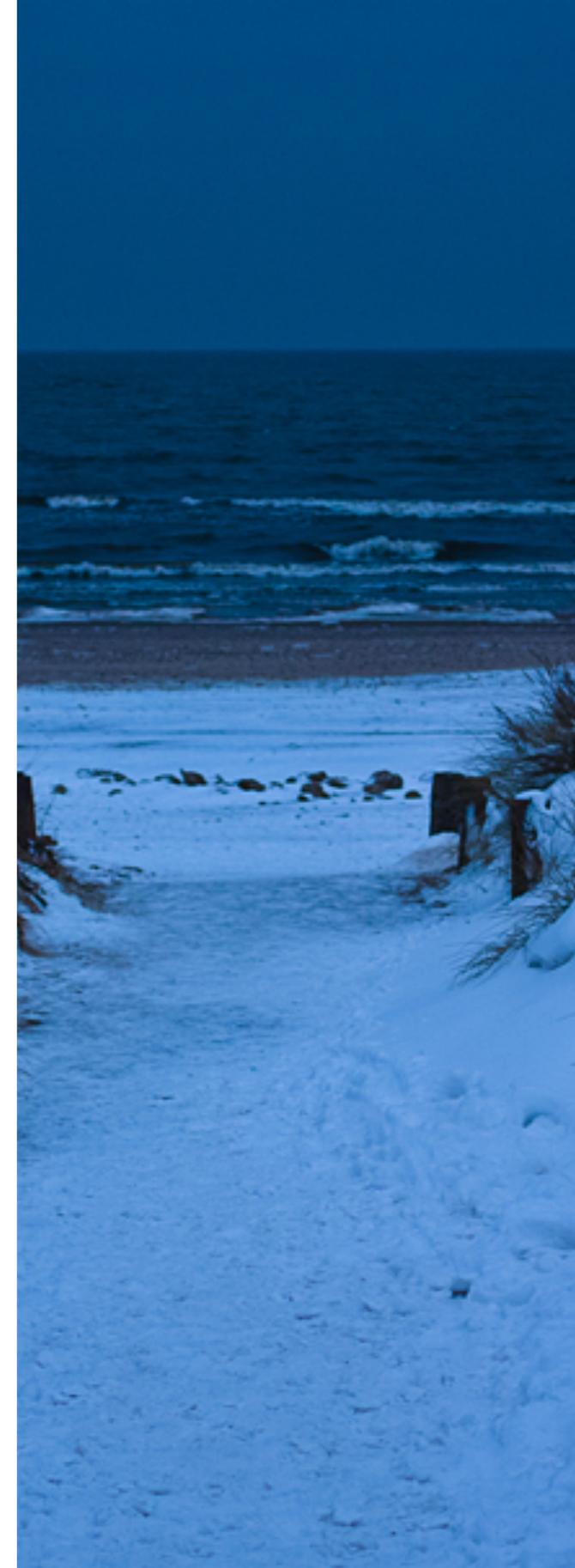
- domain-specific languages
- build your own language with Spooftax

Seminar Metaprogramming

- science behind the scenes

Master theses

- theory & practice
- WebDSL & mobl
- Spooftax



Outlook

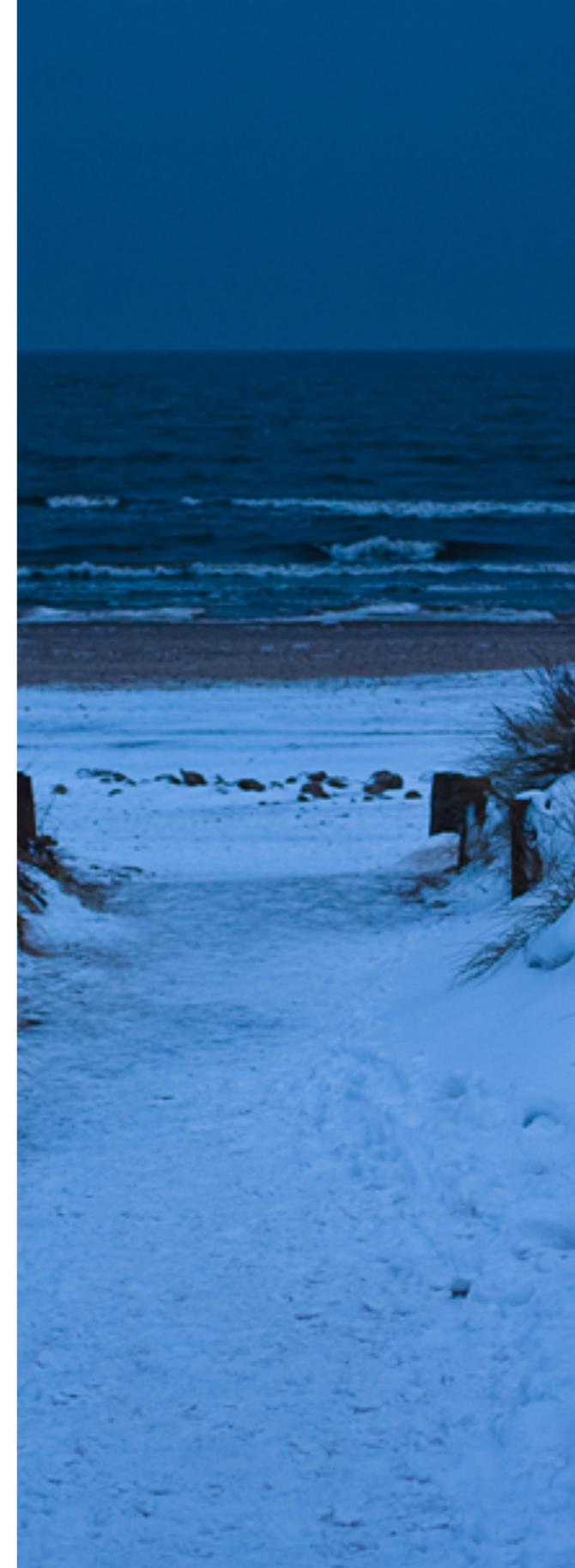
coming next

declarative semantics definition

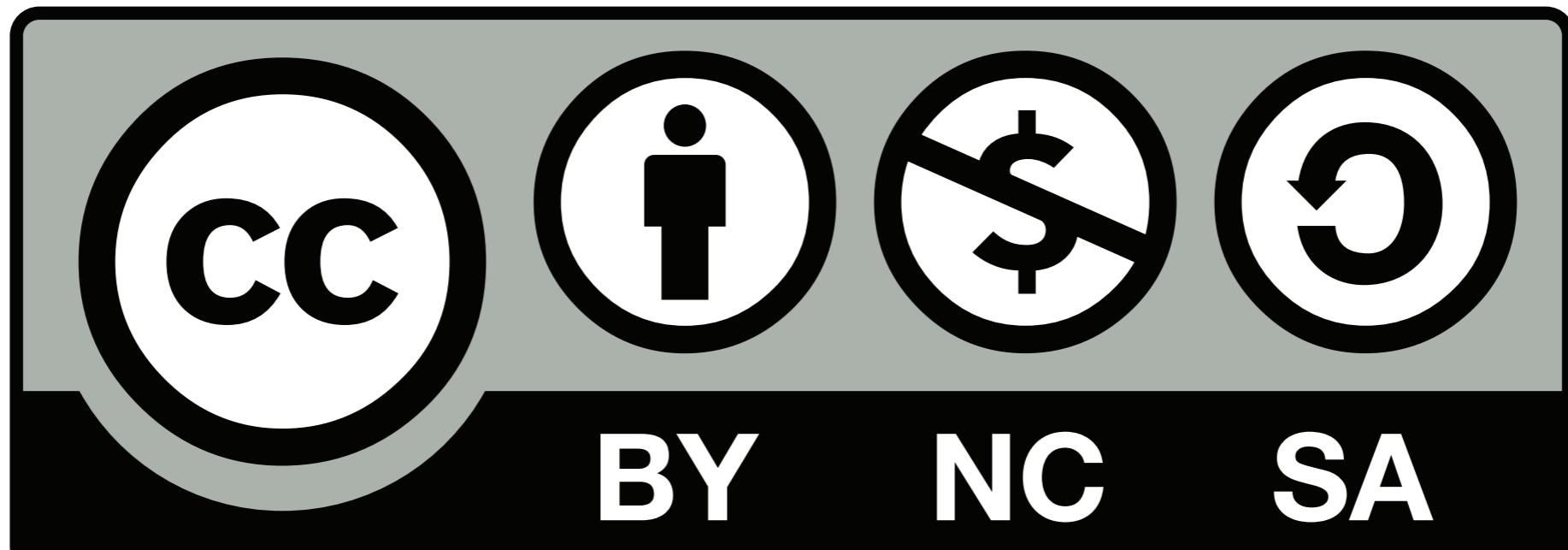
- Lecture 4: Term Rewriting
- Lecture 5: Static Analysis and Error Checking
- Lecture 6: Code Generation

Labs

- [Sep 27](#) syntax definition
- [Oct 4](#) code completion & pretty printing



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