

# Principles of Programming Languages Midterm Study Guide

## Syntax

- **syntax**: a precise description of all its grammatically correct programs
- **lexical syntax**: all the basic symbols of the language
- **concrete syntax**: rules for writing expressions, statements and programs
- **abstract syntax**: internal representation of the program, favoring content over form
- **metalanguage**: a language used to define other languages
- **grammar**: a metalanguage used to define the syntax of a language

**Backus-Naur Form (BNF)**: stylized version of a context-free grammar

Set of

- *productions*:  $P$
- *terminal* symbols:  $T$
- *nonterminal* symbols:  $N$
- *start* symbol:  $S \in N$

A *production* has the form  $A \rightarrow \omega$  where  $A \in N$  and  $\omega \in (N \cup T)$

## Parse Trees

A graphical representation of a derivation.

- each internal node of the tree corresponds to a step in the derivation
- the children of a node represents a right-hand side of a production
- each leaf node represents a symbol of the derived string, reading from left to right

## Associativity and Precedence

A grammar is **ambiguous** if one of its strings has two or more different parse trees.

## Extended BNF (EBNF)

**BNF**:

- recursive for iteration
- nonterminals for grouping

**EBNF: additional metacharacters:**

- for a series of zero or more
- $( )$  for a list, must pick one
- $[]$  for an optional list, pick one or none

We can always write an EBNF grammar as a BNF grammar

**Identifier**: sequence of letters and digits, starting with a letter

**Concrete Syntax**: based on a parse of its Tokens

**Lexer:**

- input: characters
- output: tokens
- separate
  - speed: 75% of time for non-optimizing
  - simpler design
  - character sets
  - end of line convention

**Parser:**

- Based on BNF/EBNF grammar
- Input: tokens
- Output: abstract syntax tree (parse tree)
- Abstract syntax: parse tree with punctuation, many nonterminal discarded

**Semantic Analysis**

- Check that all identifiers are declared
- Perform type checking
- Insert implied conversion operators (i.e., make them explicit)

**Code Optimization**

- Evaluate constant expressions at compile-time
- Reorder code to improve cache performance
- Eliminate common subexpressions
- Eliminate unnecessary code

**Code Generation**

- Output: machine code
- Instruction selection
- Register management
- Peephole optimization

## Interpreter

- Replaces last 2 phases of a compiler
- Input:
  - Mixed: intermediate code
  - Pure: stream of ASCII characters
- Mixed interpreters
  - Java, Perl, Python, Haskell, Scheme
- Pure interpreters
  - most Basic, shell commands

**Binding:** an association between an entity (such as a variable) and a property (such as its value)

- **static:** if the association occurs before run-time
- **dynamic:** if the association occurs at run-time
- The **lifetime** of a variable name refers to the time interval during which memory is allocated

**Scope:** the collection of statements which can access the name binding

- **static scoping:** a name is bound to a collection of statements according to its position in source program
- same as **lexical scoping**

**Symbol Table:** a data structure kept by a translator that allows it to keep track of each declared name and its binding

**Dynamic Scoping:** in dynamic scoping, a name is bound to its most recent declaration based on the program's call history

**Overloading:** uses the number or type of parameters to distinguish among identical function names or operators

**Lifetime:** the time interval during which the variable has been allocated a block of memory

**type:** a collection of values and operations on those values

**type error:** any error that arises because an operation is attempted on a data type for which it is undefined

- **type system:** provides a basis for detecting type errors
- **statically typed:** the types of all variables are fixed when they are declared at compile time
- **dynamically type:** the type of a variable can vary at run time depending on the value assigned