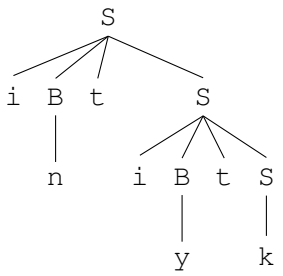
CS558 Programming Languages – Fall 2023 – Suggested Study Question Solutions for Lecture 1b

1. This grammar is inspired by the well-known "dangling `else`" ambiguity problem, which arises in languages where the `else` clause of an `if-then-else` statement is optional and the `then` and `else` bodies can be arbitrary statements (including `if-then-else` statements!) For example, in the sentence of part (c), the ambiguity of the grammar means that we cannot tell which `i(f)` the `e(lse)` should be paired up with.

(a)

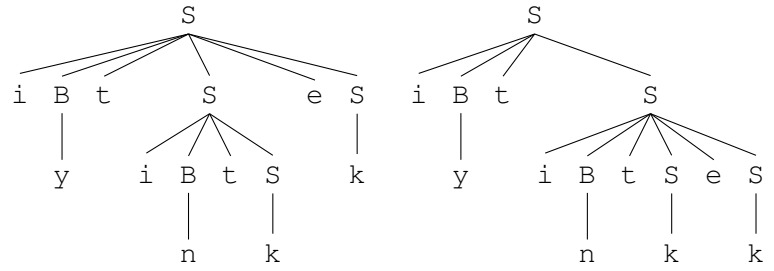


(b) Here are two possible derivations; the first is the left-most derivation for the tree in (a); the second is the right-most derivation.

```
S  →  i B t S
   →  i n t S
   →  i n t i B t S
   →  i n t i y t S
   →  i n t i y t k

S  →  i B t S
   →  i B t i B t S
   →  i B t i B t k
   →  i B t i y t k
   →  i n t i y t k
```

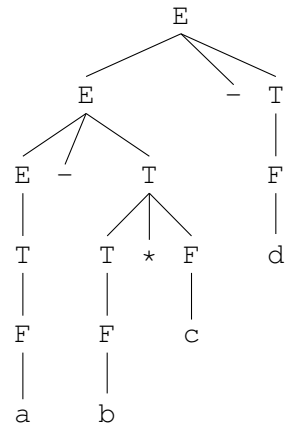
(c) Here are two trees:



(d) The grammar is ambiguous because there is at least one sentence—in particular, the one in part (c)—that has two different parse trees.

Note that it is *not* correct to claim that the grammar is ambiguous because the same sentence has more than one linear derivation sequence. Even when a sentence has a unique parse tree, as in part (a), it may have multiple corresponding linear derivation sequences, as in part (b). Such a sentence is not enough to demonstrate ambiguity: we must find a sentence that has two different *trees*.

2. (a) Here's the parse tree:



(b) We simply switch the order of the nonterminals in the right-hand side of the production for `E`:

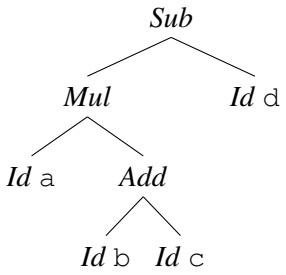
```
E ::= T + E | T - E | T
```

The rest of the grammar remains the same. Try it on an example like `a + b + c`.

3. Here is a possible AST tree grammar:

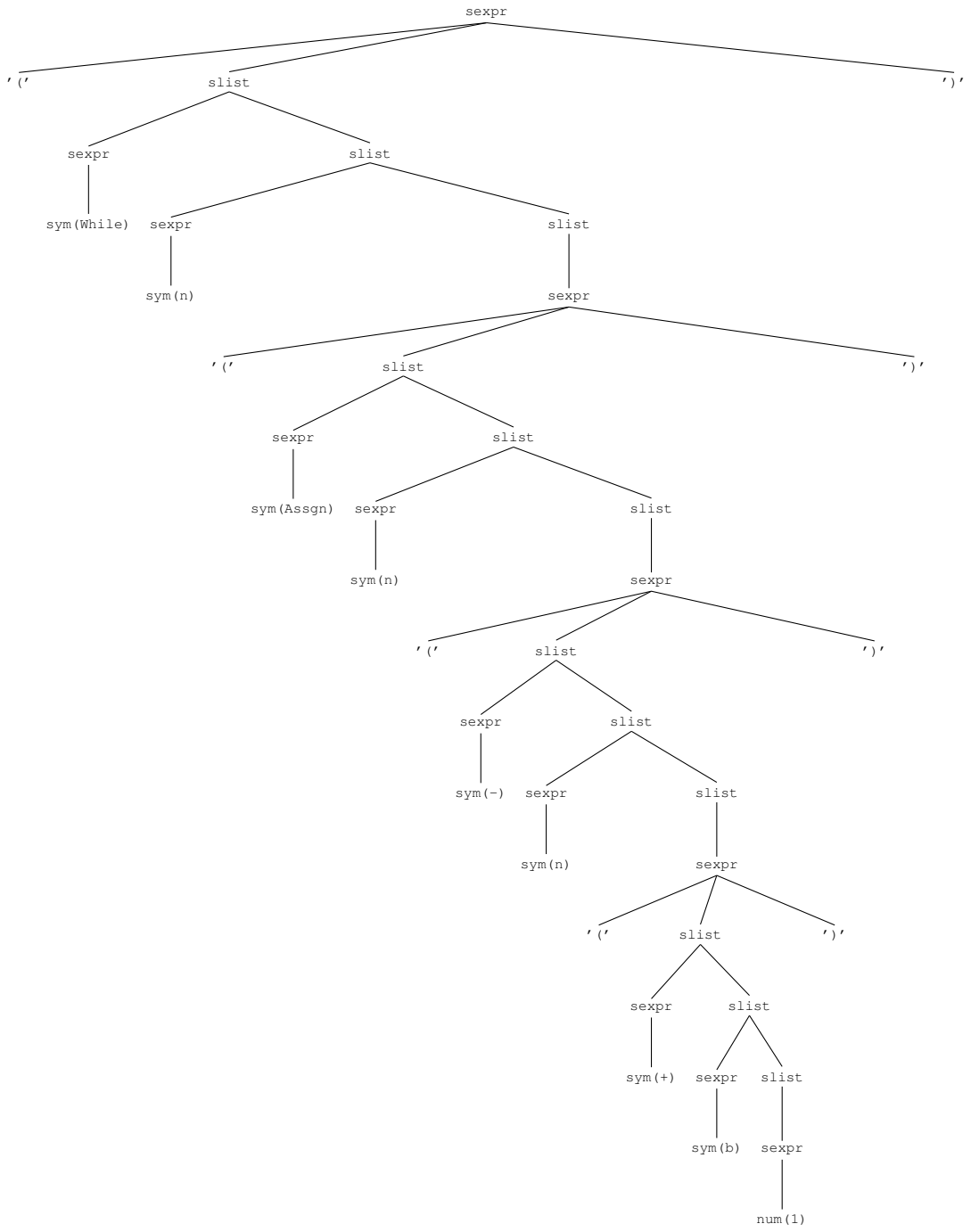
Add : Exp → Exp Exp
Sub : Exp → Exp Exp
Mul : Exp → Exp Exp
Div : Exp → Exp Exp
Id : Exp → (string)

(b)

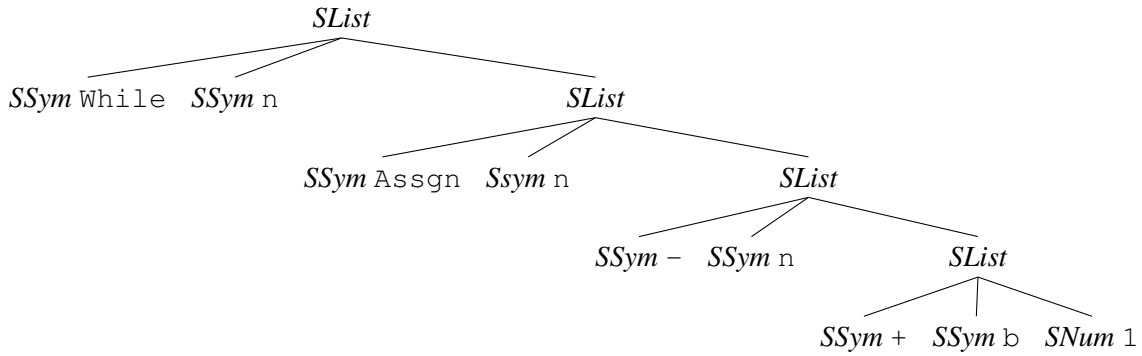


The most important differences from a parse tree are that: (a) intermediate levels of nonterminals (such as `T` and `F`), have disappeared, because they were only in the concrete grammar to enforce the intended precedence and associativity, which are now directly reflected in the shape of the tree; and (b) there are no explicit parentheses, again because their grouping effect is now directly reflected in the shape of the tree.

4. The concrete parse tree (zoom in!):



The abstract parse tree:


SList
SSym While
SSym n
SList
SSym Assgn
Ssym n
SList
SSym -
SSym n
SList
SSym +
SSym b
SNum 1