

# CMSC 330: Organization of Programming Languages

---

## Context-Free Grammars

### Review

---

- Why should we study CFGs?
- What are the four parts of a CFG?
- How do we tell if a string is accepted by a CFG?
- What's a parse tree?

## Review

A *sentential form* is a string of terminals and non-terminals produced from the start symbol

Inductively:

- The start symbol
- If  $\alpha A \delta$  is a sentential form for a grammar, where ( $\alpha$  and  $\delta \in (N \cup \Sigma)^*$ ), and  $A \rightarrow \gamma$  is a production, then  $\alpha \gamma \delta$  is a sentential form for the grammar
  - In this case, we say that  $\alpha A \delta$  *derives*  $\alpha \gamma \delta$  in one step, which is written as  $\alpha A \delta \Rightarrow \alpha \gamma \delta$

CMSC 330

3

## Leftmost and Rightmost Derivation

- Example:  $S \rightarrow a \mid SbS$

String: aba

Leftmost Derivation

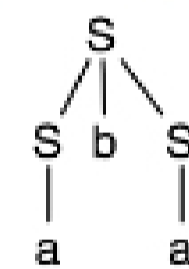
$S \Rightarrow SbS \Rightarrow abS \Rightarrow aba$

At every step, apply production to leftmost non-terminal

Rightmost Derivation

$S \Rightarrow SbS \Rightarrow Sba \Rightarrow aba$

At every step, apply production to rightmost non-terminal



- Both derivations happen to have the same parse tree
- A parse tree has a unique leftmost and a unique rightmost derivation
- Not every string has a unique parse tree
- Parse trees don't show the order productions are applied

CMSC 330

4

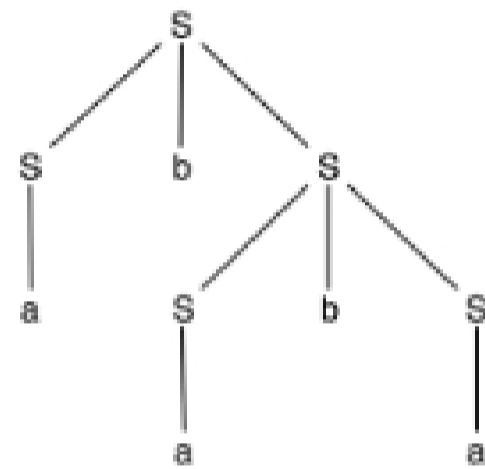
## Another Example (cont'd)

$S \rightarrow a \mid SbS$

- Is **ababa** in this language?

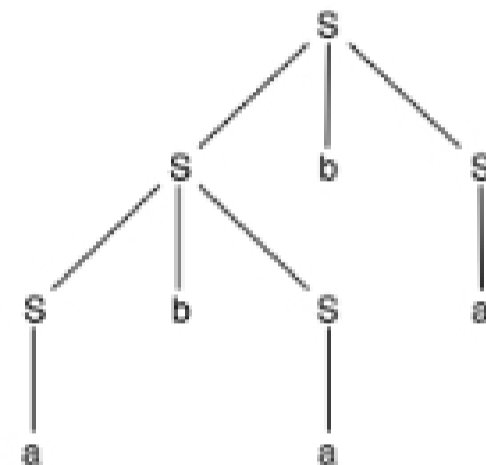
A leftmost derivation

$S \Rightarrow SbS \Rightarrow abS \Rightarrow$   
 $abSbS \Rightarrow ababS \Rightarrow ababa$



Another leftmost derivation

$S \Rightarrow SbS \Rightarrow SbSbS \Rightarrow$   
 $abSbS \Rightarrow ababS \Rightarrow ababa$



CMSC 330

5

## Ambiguity

- A string is *ambiguous* for a grammar if it has more than one parse tree
  - Equivalent to more than one leftmost (or more than one rightmost) derivation
- A grammar is *ambiguous* if it generates an ambiguous string
  - It's can be hard to see this with manual inspection
- Exercise: can you create an unambiguous grammar for  $S \rightarrow a \mid SbS$  ?

CMSC 330

6