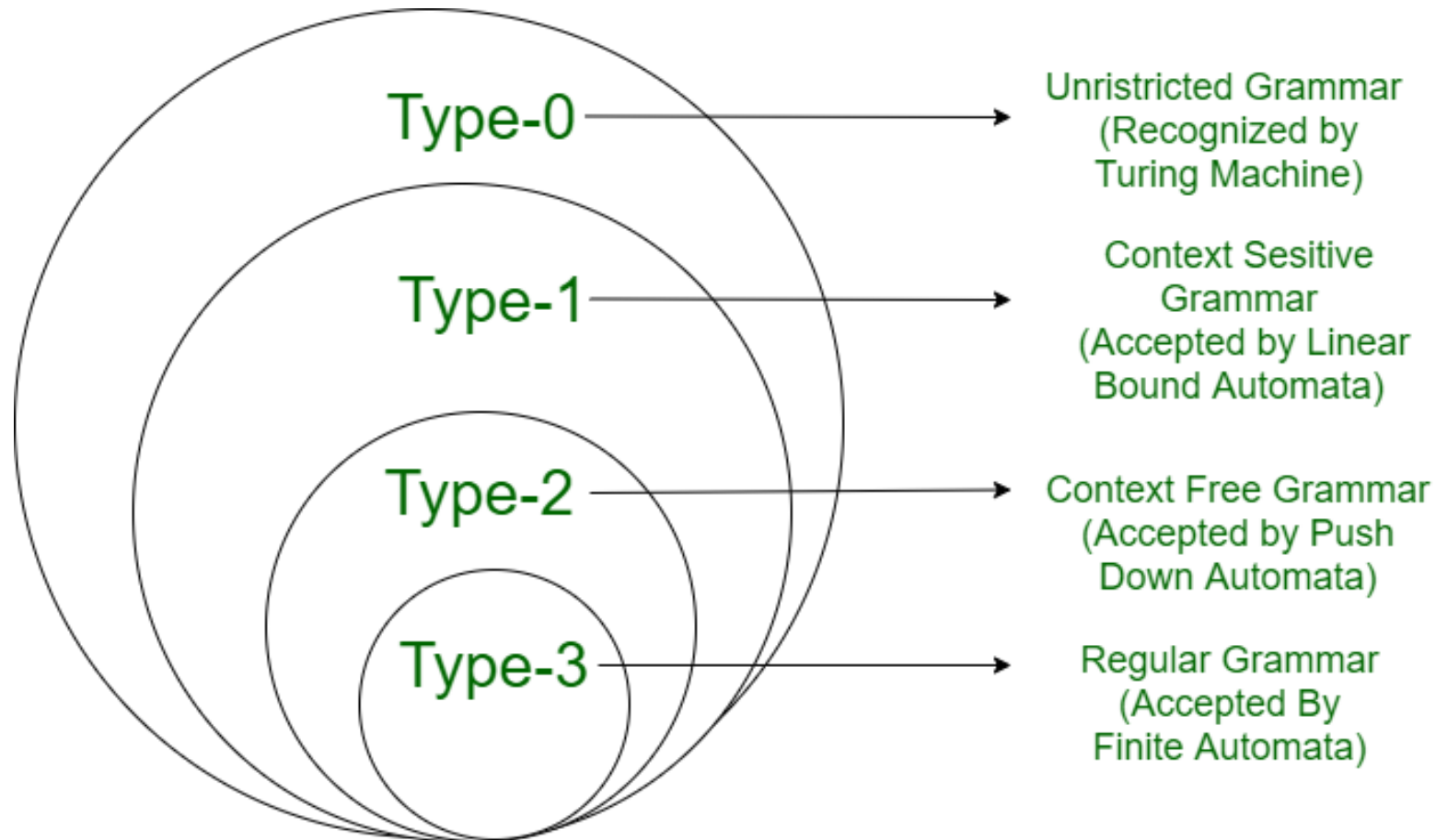


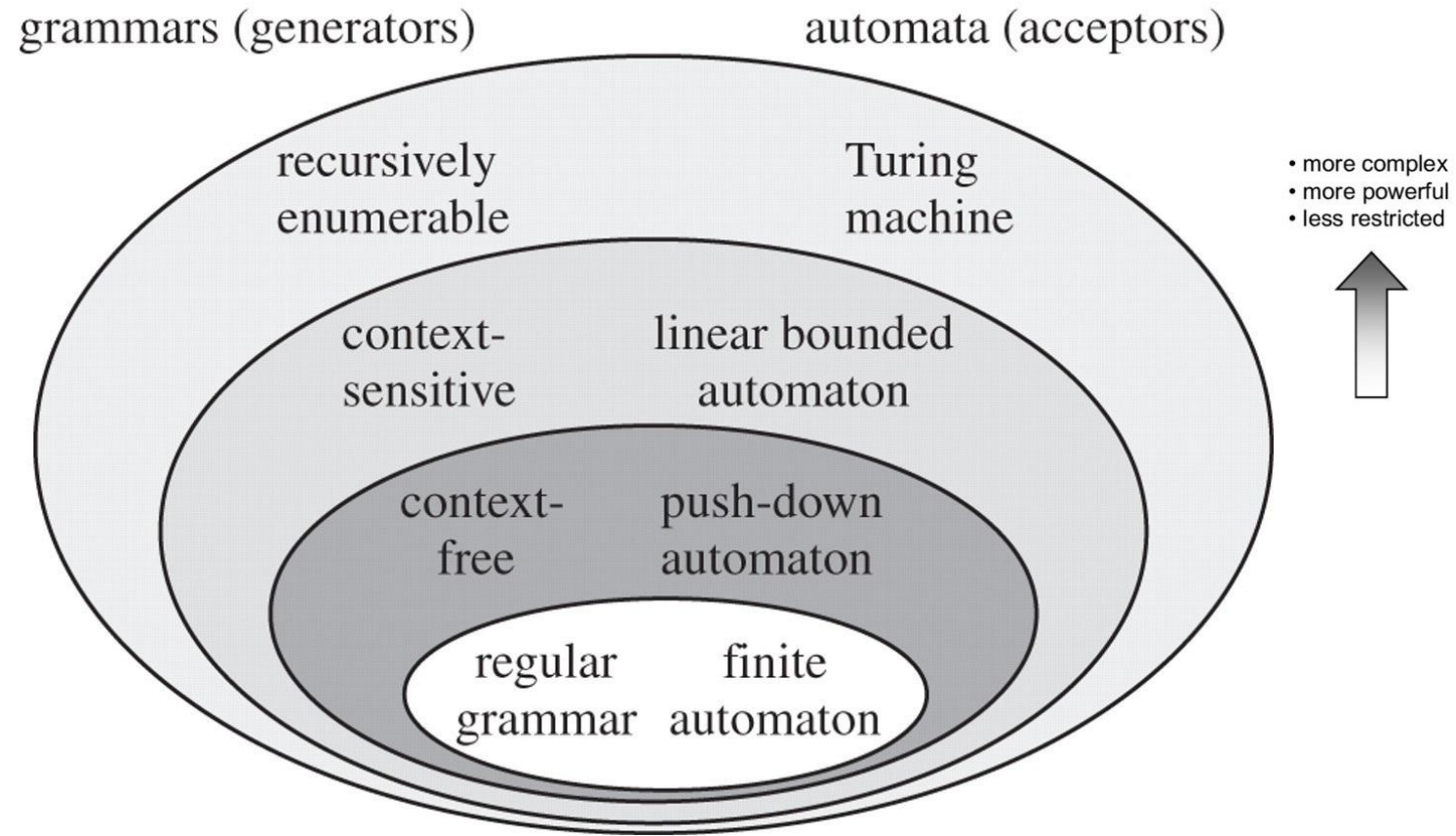
Chomsky Hierarchy

- What is the expressive power of these grammars?
- Restricting the types of rules, allows one to describe different aspects of natural languages
- These grammars form a hierarchy

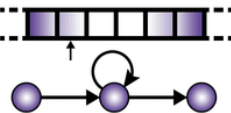

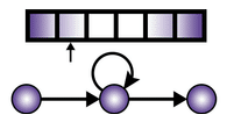

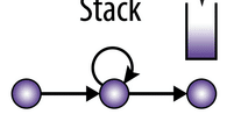
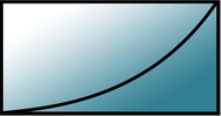
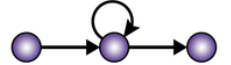

The Chomsky Hierarchy



Chomsky Hierarchy Languages and Automata



Chomsky Hierarchy Languages

Language	Automaton	Grammar	Recognition
Recursively Enumerable Languages	<p>Turing Machine</p> 	<p>Unrestricted</p> $Baa \rightarrow A$	<p>Undecidable</p> 
Context-Sensitive Languages	<p>Linear Bounded</p> 	<p>Context Sensitive</p> $A t \rightarrow aA$	<p>Exponential?</p> 
Context-Free Languages	<p>Pushdown Stack</p> 	<p>Context Free</p> $S \rightarrow gS c$	<p>Polynomial</p> 
Regular Languages	<p>Finite-State Automaton</p> 	<p>Regular</p> $A \rightarrow cA$	<p>Linear</p> 

Chomsky Hierarchy Summary

Type	Name	Allowable Productions	Example Language	Example Grammar	Example Use	Recognizing Automaton	Storage Required	Parsing Complexity
0	Type 0	Unrestricted				Turing Machine	Infinite Tape	Undecidable
1	Context Sensitive	$\alpha \rightarrow \beta$ where $ \alpha \leq \beta $ $\alpha \in V^*NV^*$ $\beta \in V^+$	$a^n b^n c^n$	$S \rightarrow aSBC$ $S \rightarrow aBC$ $CB \rightarrow BC$ $aB \rightarrow ab$ $bB \rightarrow bb$ $bC \rightarrow bc$ $cC \rightarrow cc$		Linear Bounded Automaton	Tape a linear multiple of input length	NP Complete
2	Context Free	$A \rightarrow \alpha$ $A \in N$ $\alpha \in V^*$	$a^n b^n$	$S \rightarrow aSb$ $S \rightarrow ab$	Arithmetic Expression $x = a + b * c$	Pushdown Automaton	Pushdown Stack	$O(n^3)$
3	Regular Right Linear Finite Automaton Recognizable	$A \rightarrow xB$ $A \rightarrow x$ $A, B \in N$ $x \in T^*$	$a^n b$	$S \rightarrow ab$ $S \rightarrow aS$	Identifier VECTOR7	Finite Automaton	Finite Storage	$O(n)$