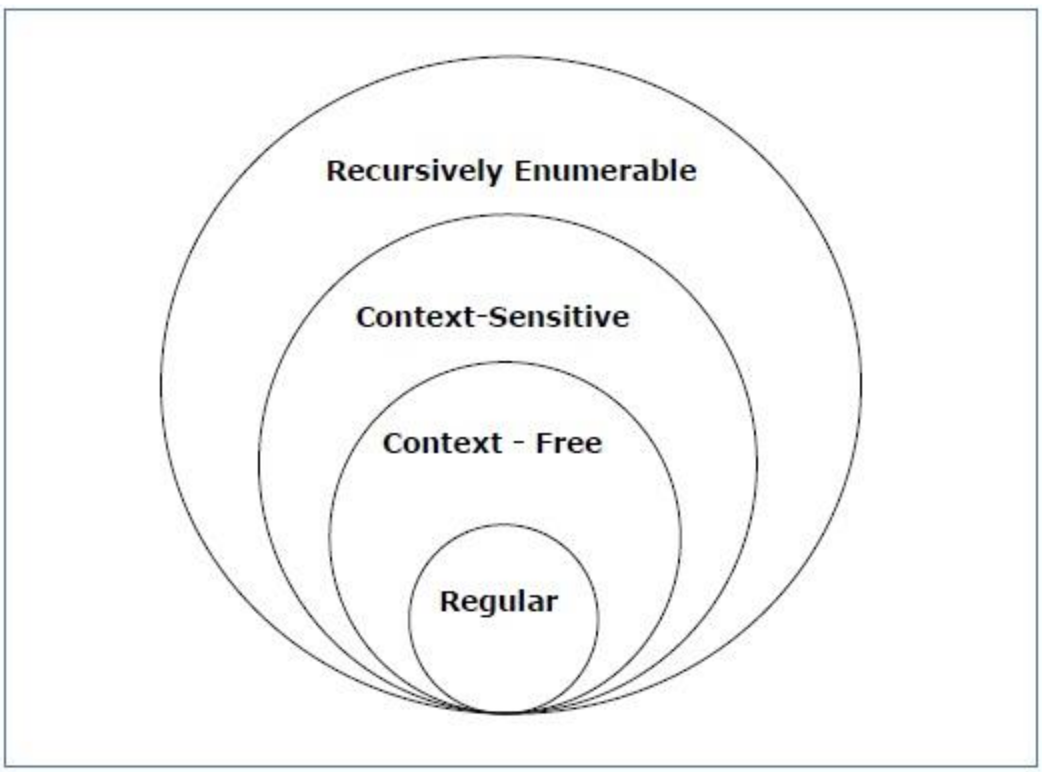
# Classification of Grammars

According to Noam Chomosky, there are four types of grammars − Type 0, Type 1, Type 2, and Type 3. The following table shows how they differ from each other −

| Grammar Type | Grammar Accepted | Language Accepted | Automaton |
|---|---|---|---|
| Type 0 | Unrestricted grammar | Recursively enumerable language | Turing Machine |
| Type 1 | Context-sensitive grammar | Context-sensitive language | Linear-bounded automaton |
| Type 2 | Context-free grammar | Context-free language | Pushdown automaton |
| Type 3 | Regular grammar | Regular language | Finite state automaton |

Take a look at the following illustration. It shows the scope of each type of grammar −



# Type - 3 Grammar

**Type-3 grammars** generate regular languages. Type-3 grammars must have a single non-terminal on the left-hand side and a right-hand side consisting of a single terminal or single terminal followed by a single non-terminal.

The productions must be in the form **X → a or X → aY**

where **X, Y ∈ N** (Non terminal)

and **a ∈ T** (Terminal)

The rule **S → ε** is allowed if **S** does not appear on the right side of any rule.

## Example

```
X → ε
X → a | aY
Y → b
```

# Type - 2 Grammar

**Type-2 grammars** generate context-free languages.

The productions must be in the form **A → γ**

where **A ∈ N** (Non terminal)

and **γ ∈ (T ∪ N)*** (String of terminals and non-terminals).

These languages generated by these grammars are be recognized by a non-deterministic pushdown automaton.

## Example

```
S → X a
X → a
X → aX
X → abc
X → ε
```

# Type - 1 Grammar

**Type-1 grammars** generate context-sensitive languages. The productions must be in the form

**α A β → α γ β**

where **A ∈ N** (Non-terminal)

and **α, β, γ ∈ (T ∪ N)*** (Strings of terminals and non-terminals)

The strings **α** and **β** may be empty, but **γ** must be non-empty.

The rule **S → ε** is allowed if S does not appear on the right side of any rule. The languages generated by these grammars are recognized by a linear bounded automaton.

## Example

AB → AbBc
A → bcA
B → b

# Type - 0 Grammar

**Type-0 grammars** generate recursively enumerable languages. The productions have no restrictions. They are any phase structure grammar including all formal grammars.

They generate the languages that are recognized by a Turing machine.

The productions can be in the form of **α** → **β** where **α** is a string of terminals and nonterminals with at least one non-terminal and **α** cannot be null. **β** is a string of terminals and non-terminals.

## Example

S → ACaB
Bc → acB
CB → DB
aD → Db

Derive the string "aabbabba" for leftmost derivation and rightmost derivation using a CFG

S → aB | bA S → a | aS | bAA S → b | aS | aBB

**Leftmost derivation:**

1. S
2. aB S → aB
3. aaBB B → aBB
4. aabB B → b
5. aabbS B → bS
6. aabbaB S → aB
7. aabbabS B → bS
8. aabbabbA S → bA
9. aabbabba A → a

**Rightmost derivation:**

1. S
2. aB S → aB
3. aaBB B → aBB
4. aaBbS B → bS
5. aaBbbA S → bA
6. aaBbba A → a
7. aabSbba B → bS
8. aabbAbba S → bA
9. aabbabba A → a