Trees, Recursion, and Natural Language

John DeNero

Source code: http://denero.org/content/misc/parse.zip

Ambiguity

Syntactic Ambiguity in English

Syntactic Ambiguity in English

Programs must be written for people to read[1]

[1]Preface of Structure and Interpretation of Computer Programs
by Harold Abelson and Gerald Sussman with Julie Sussman

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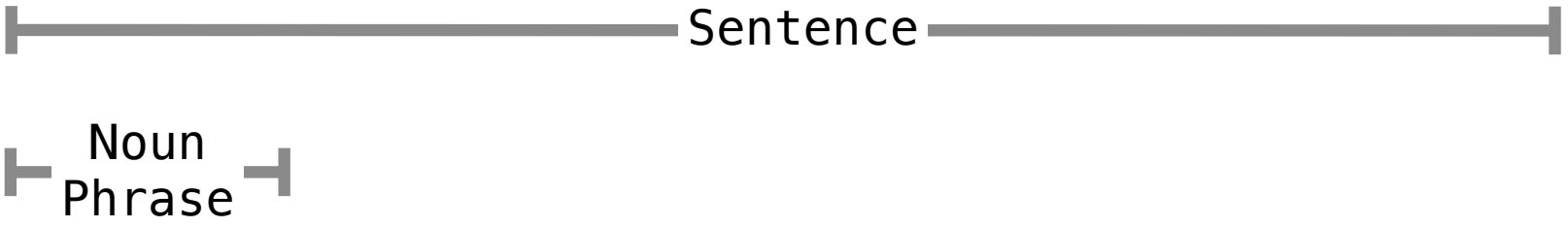

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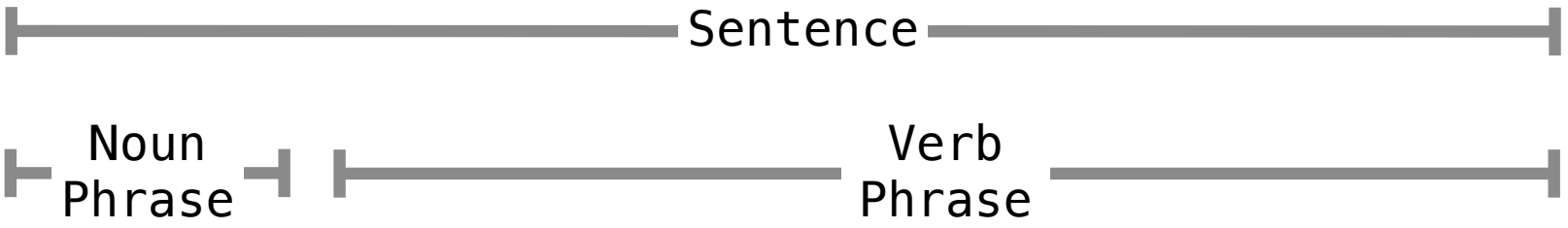

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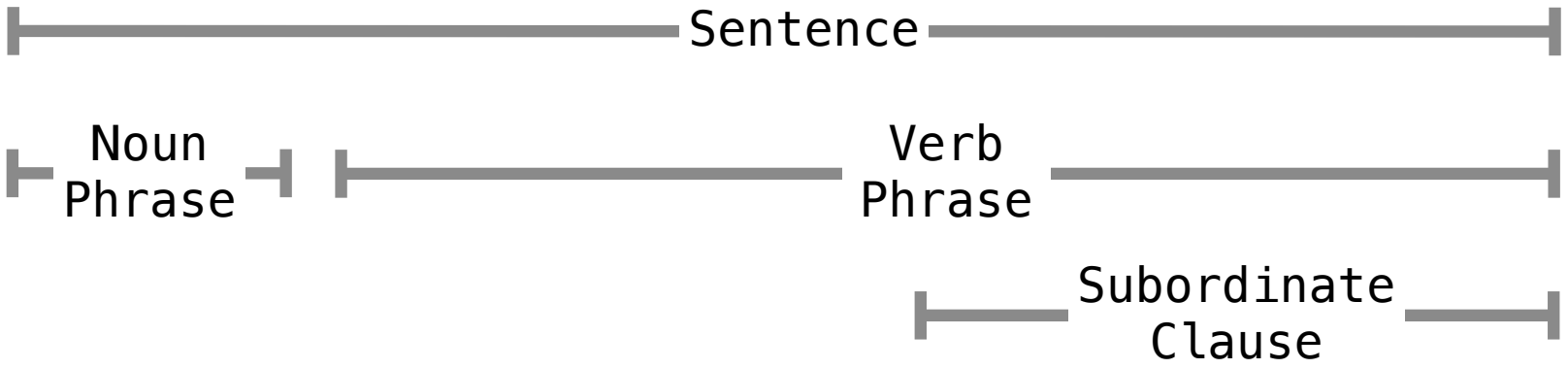

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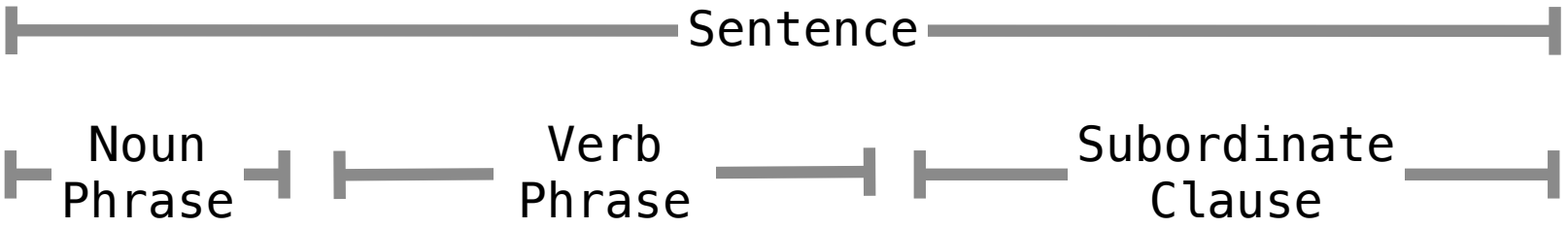

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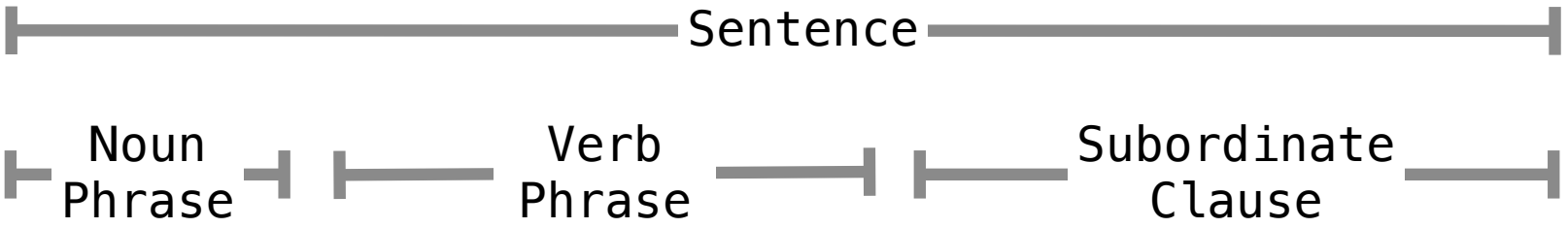

Programs must be written for people to read[1]

A program must first be written for it to crash

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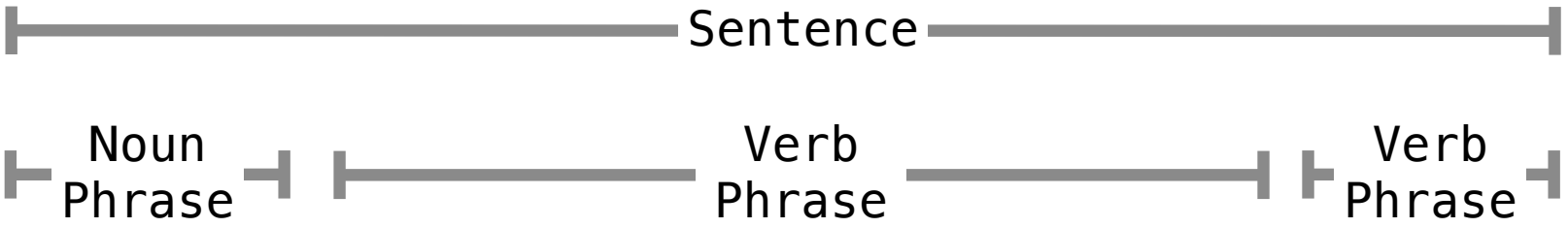
Syntactic Ambiguity in English



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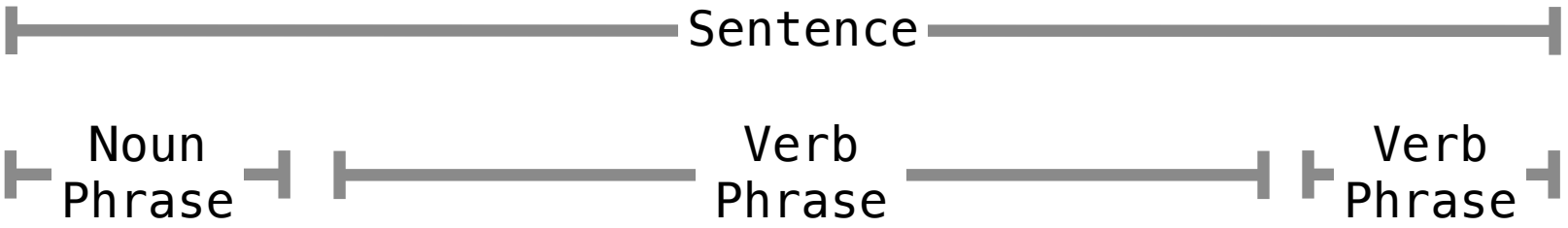

Programs must be written for people to read[1]

Programs must be written for people to be useful

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Syntactic Ambiguity in English

Programs must be written for people to read

Definitions from the New Oxford American Dictionary

Syntactic Ambiguity in English

pro•gram (*noun*)
  a series of coded software instructions.

pro•gram (*verb*)
  provide a computer with coded instructions.

Programs must be written for people to read

Definitions from the New Oxford American Dictionary

Syntactic Ambiguity in English

pro•gram (*noun*)
  a series of coded software instructions.

pro•gram (*verb*)
  provide a computer with coded instructions.

Programs must be written for people to read

must (*verb*)
  be obliged to.

must (*noun*)
  dampness or mold.

Definitions from the New Oxford American Dictionary

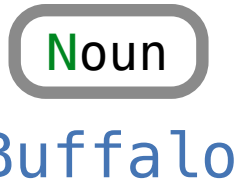
Syntax Trees

Representing Syntactic Structure

Representing Syntactic Structure

Buffalo

Representing Syntactic Structure



Representing Syntactic Structure

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Noun

Buffalo

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Noun

Buffalo buffalo

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Noun Verb

Buffalo buffalo

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Noun	Verb	Noun
Buffalo	buffalo	buffalo

Representing Syntactic Structure

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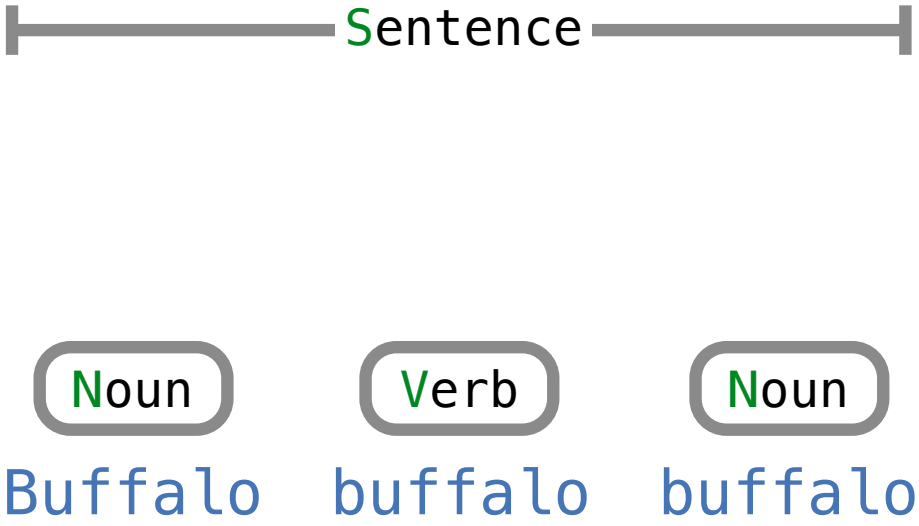

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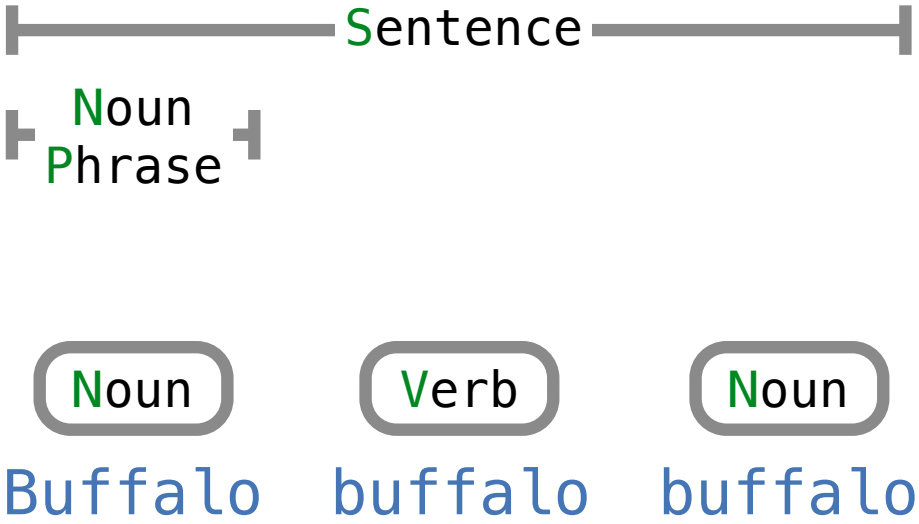

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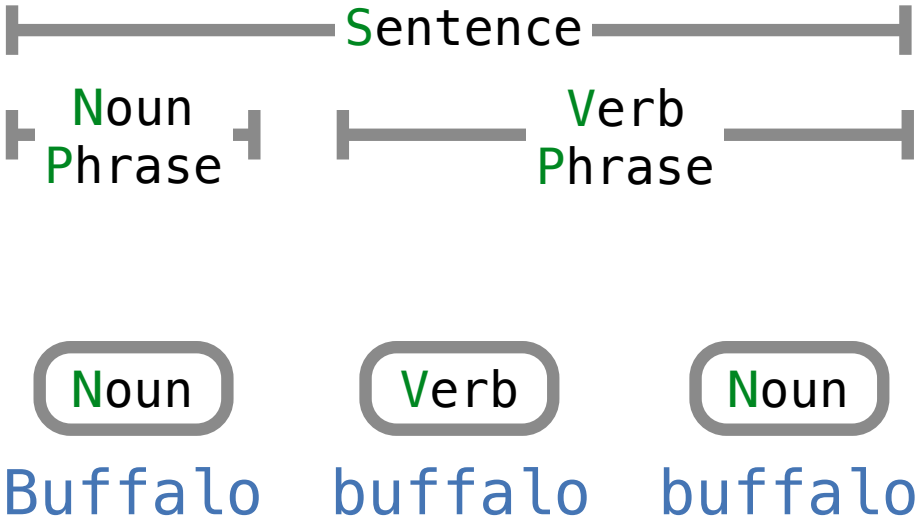

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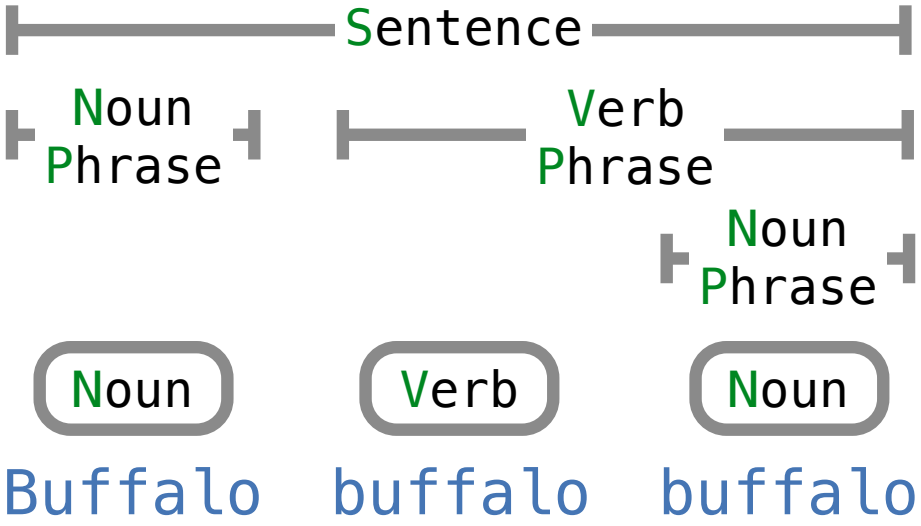

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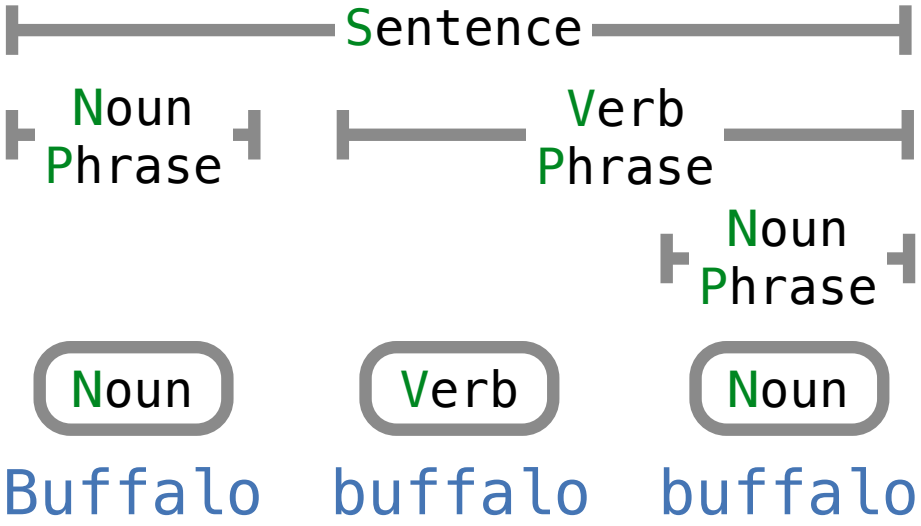

A **Tree** represents a phrase:

Representing Syntactic Structure

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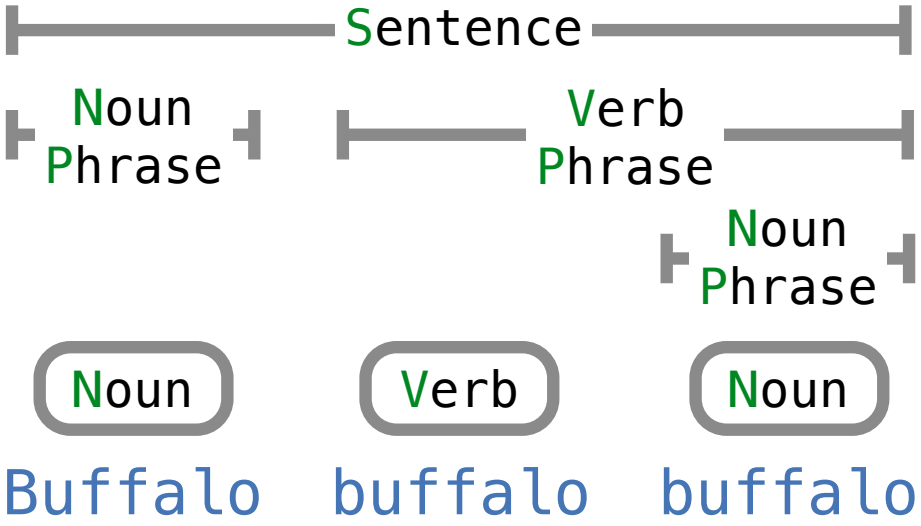

A **Tree** represents a phrase:

- **tag** -- What kind of phrase (e.g., S, NP, VP)

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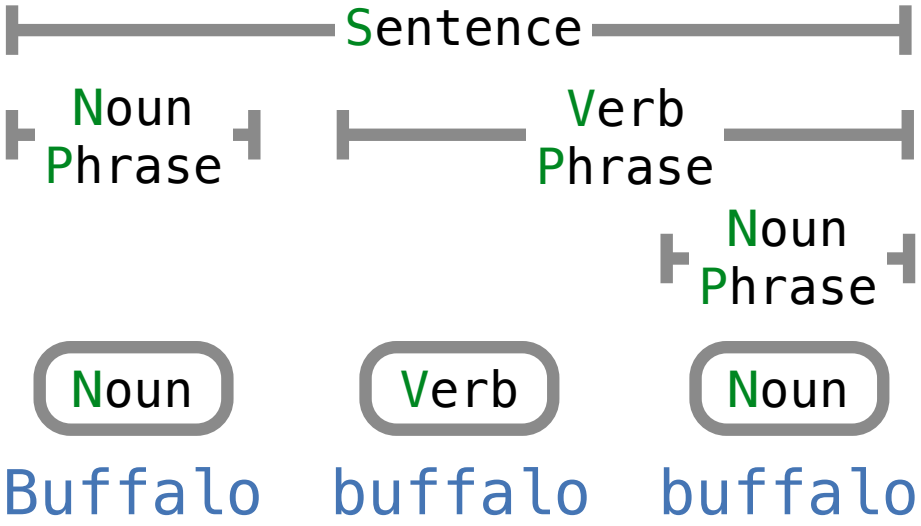

A **Tree** represents a phrase:

- **tag** -- What kind of phrase (e.g., S, NP, VP)
- **branches** -- Sequence of Tree or Leaf components

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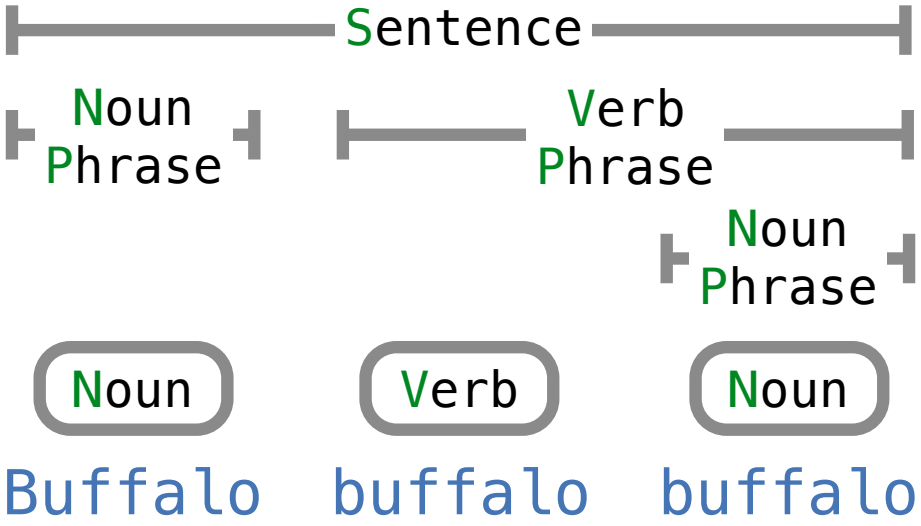

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A **Leaf** represents a single word:

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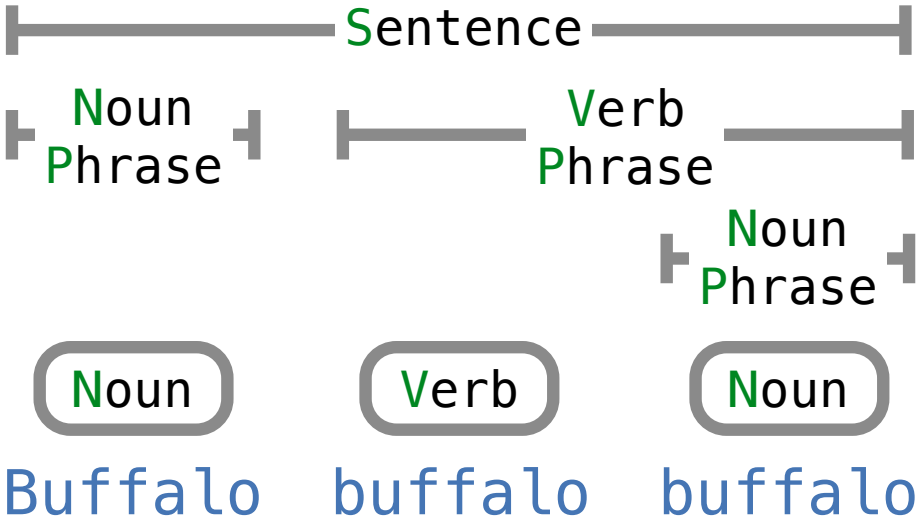

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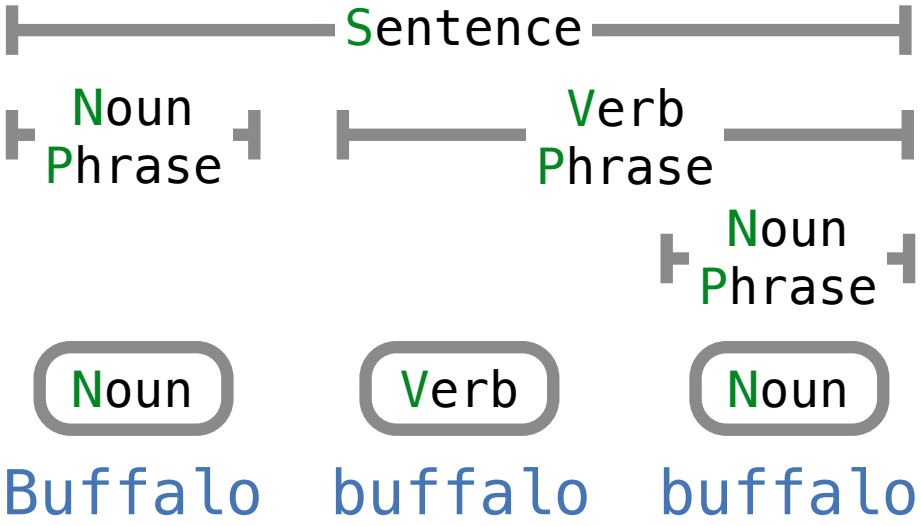

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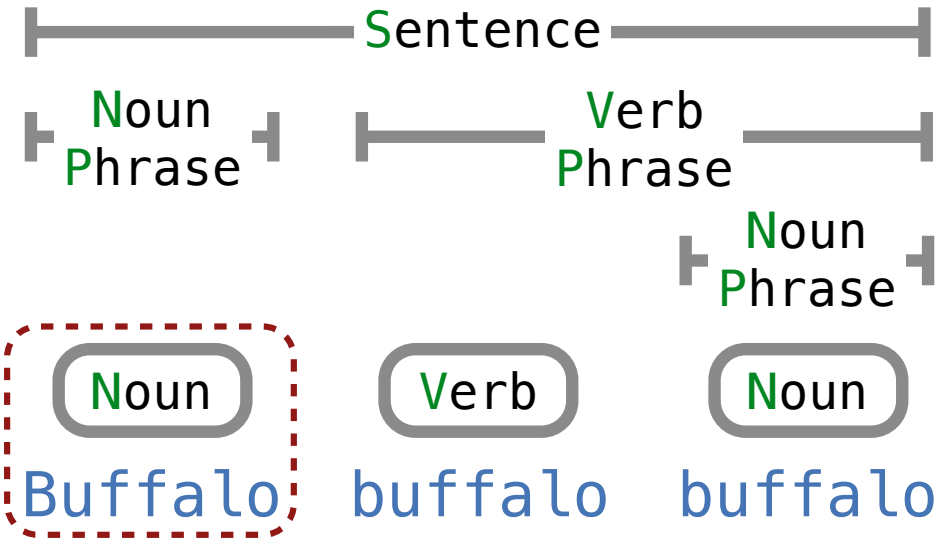

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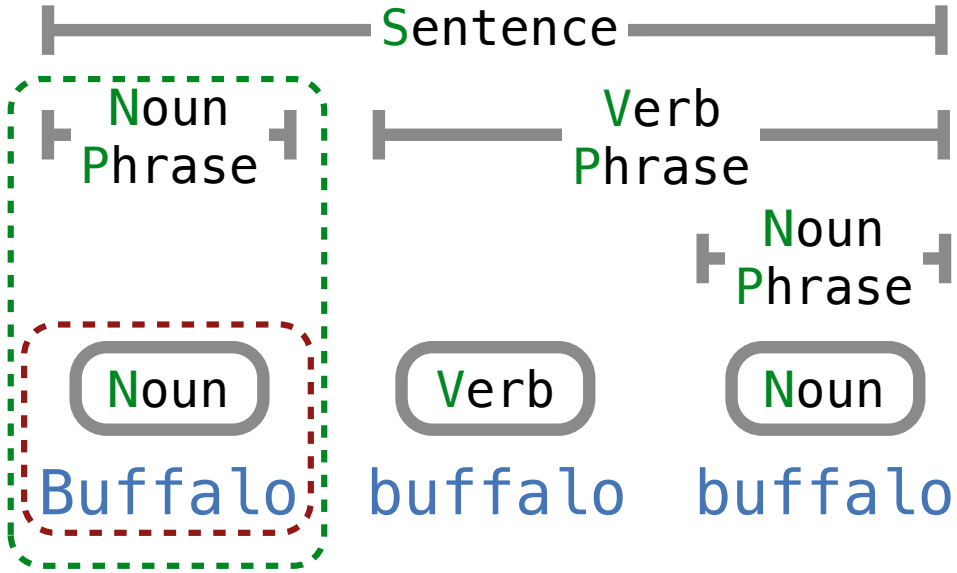

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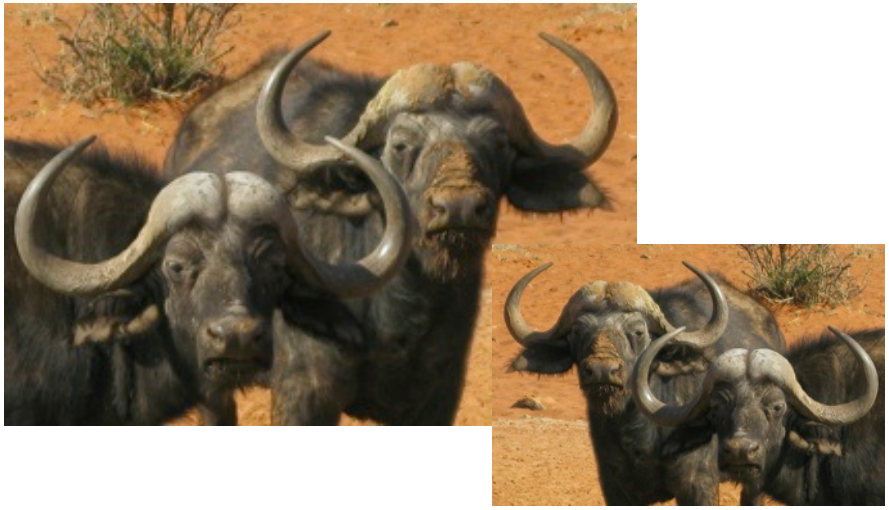

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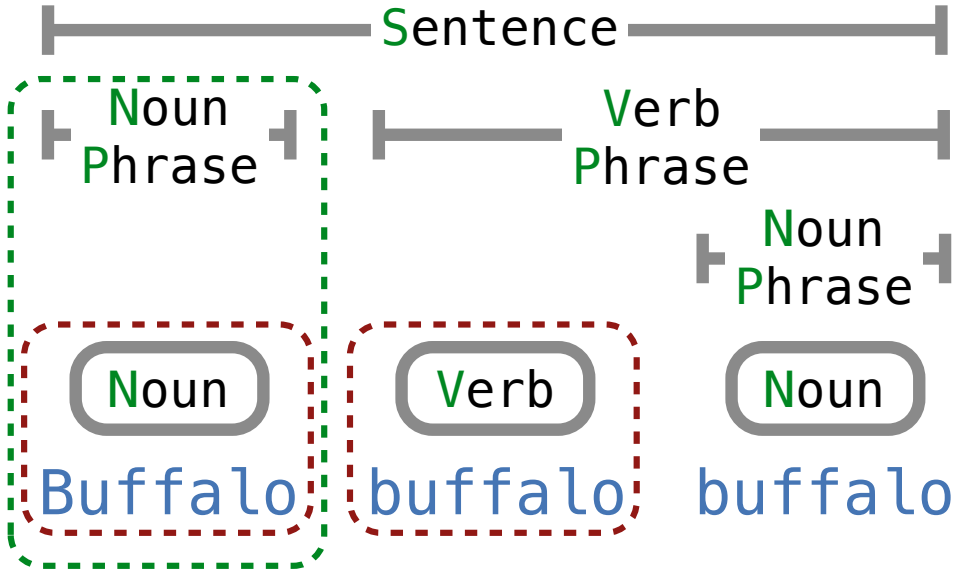

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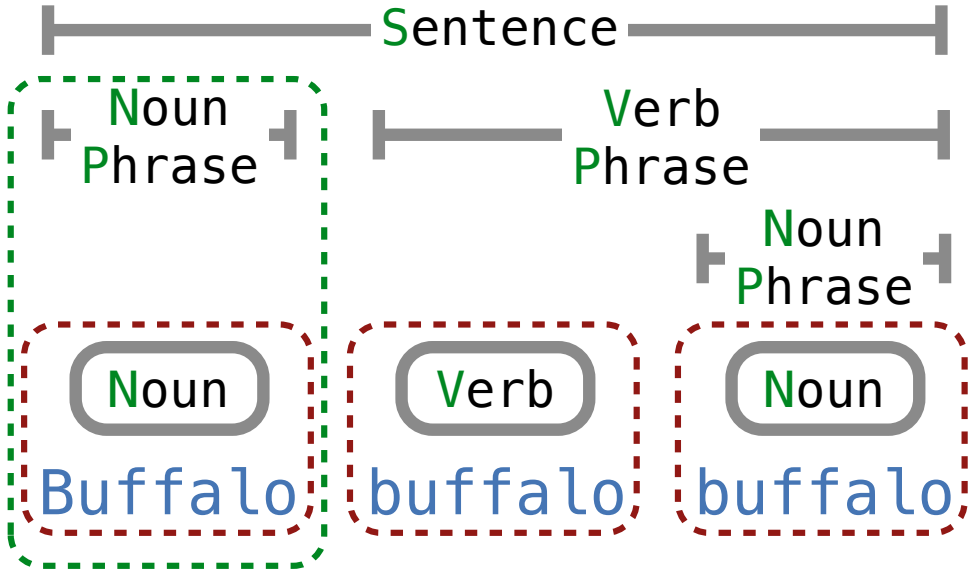

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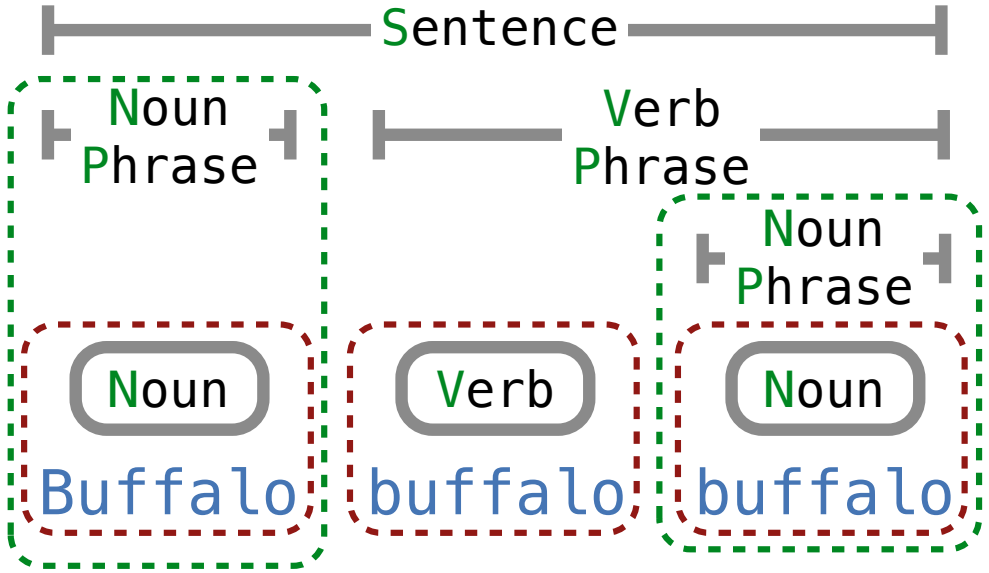

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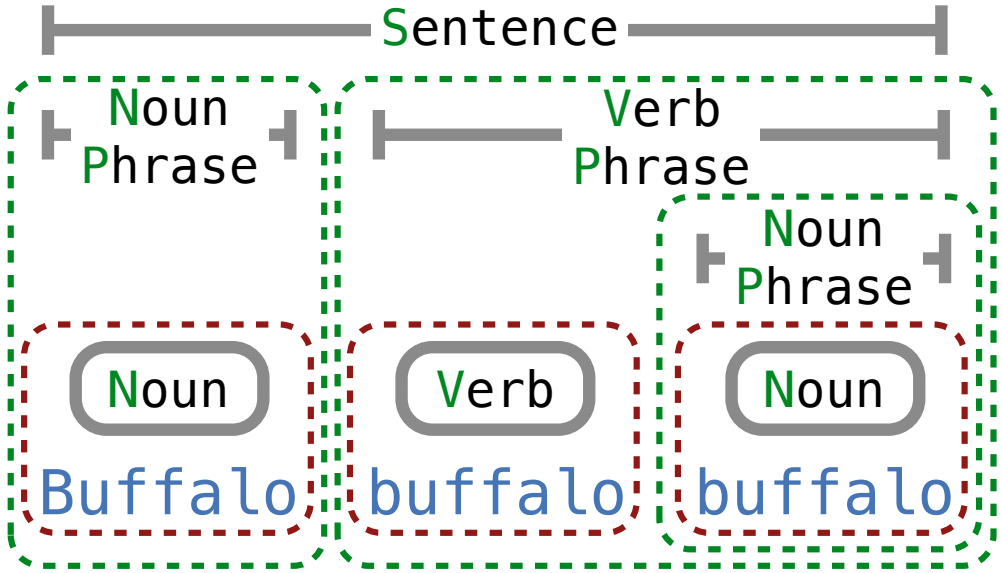

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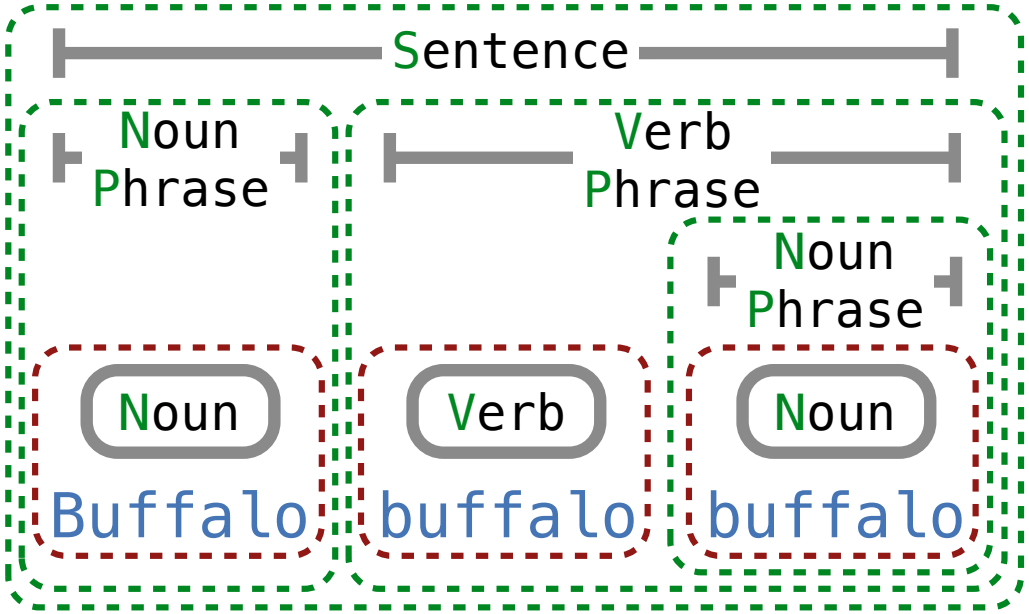

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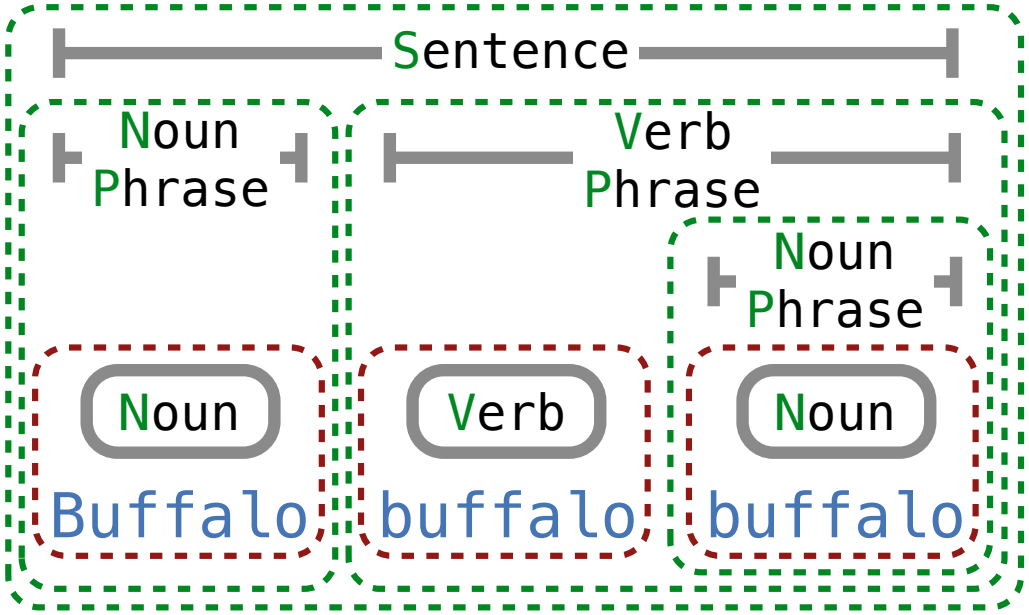

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(Demo)

Grammars

Context-Free Grammar Rules

Context-Free Grammar Rules

A grammar rule describes how a tag can be expanded.

Context-Free Grammar Rules

A grammar rule describes how a tag can be expanded.

$$S \rightarrow NP\ VP$$

Context-Free Grammar Rules

A grammar rule describes how a tag can be expanded.

S → NP VP

A Sentence ...

Context-Free Grammar Rules

A grammar rule describes how a tag can be expanded.

Context-Free Grammar Rules

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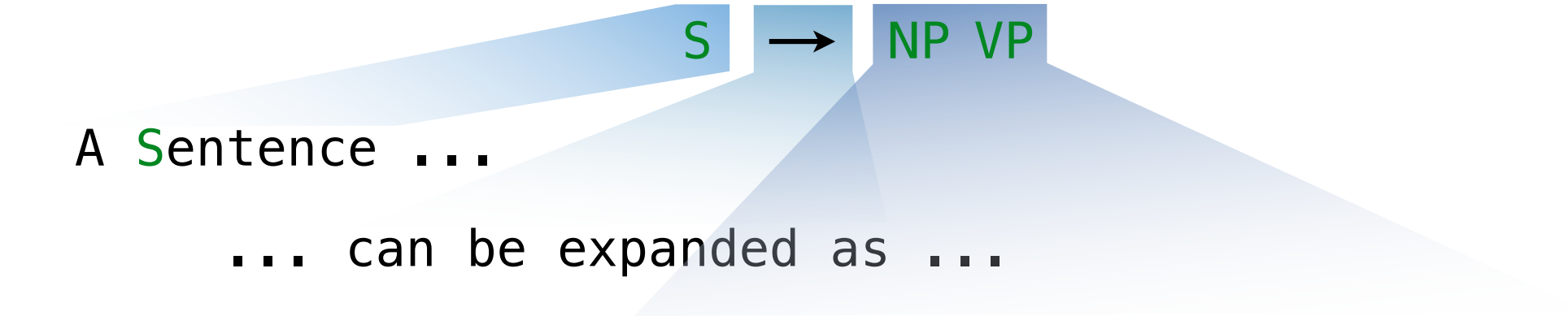


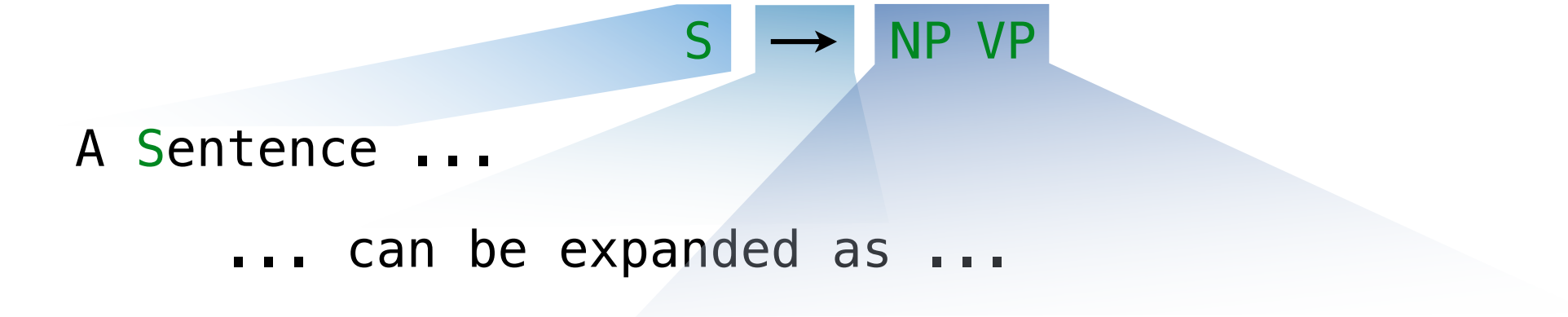
A Sentence ...

... can be expanded as ...

... a Noun Phrase then a Verb Phrase.

Context-Free Grammar Rules

A grammar rule describes how a tag can be expanded.



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S → NP VP

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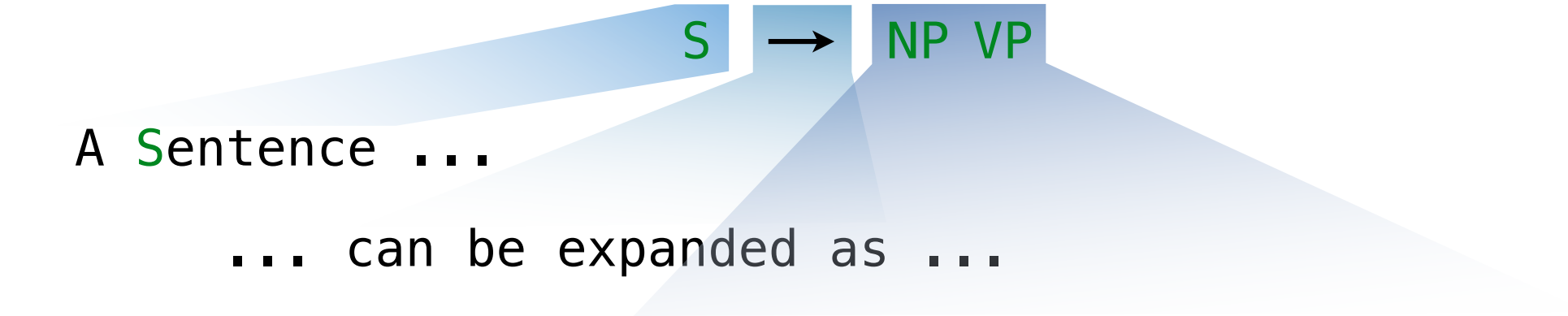

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S → NP VP

A Sentence ...

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Context-Free Grammar Rules

A grammar rule describes how a tag can be expanded.

S → NP VP

A Sentence ...

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... a Noun Phrase then a Verb Phrase.

S → NP VP

NP → N

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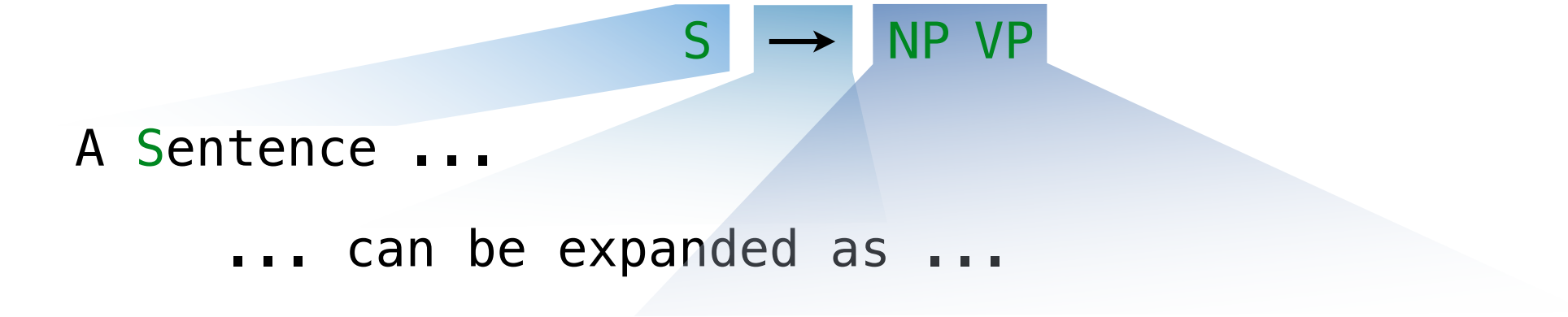

S → NP VP

NP → N

Context-Free Grammar Rules

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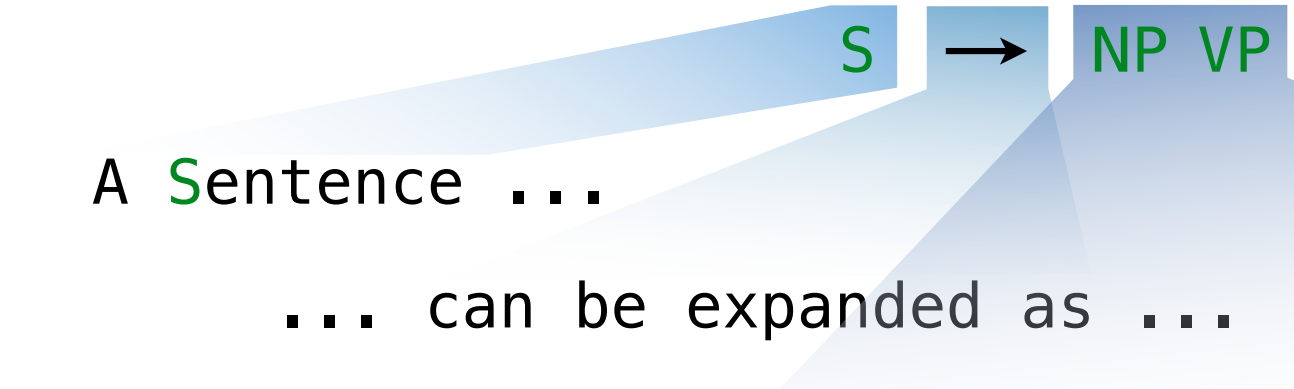

A Sentence ...

... can be expanded as ...

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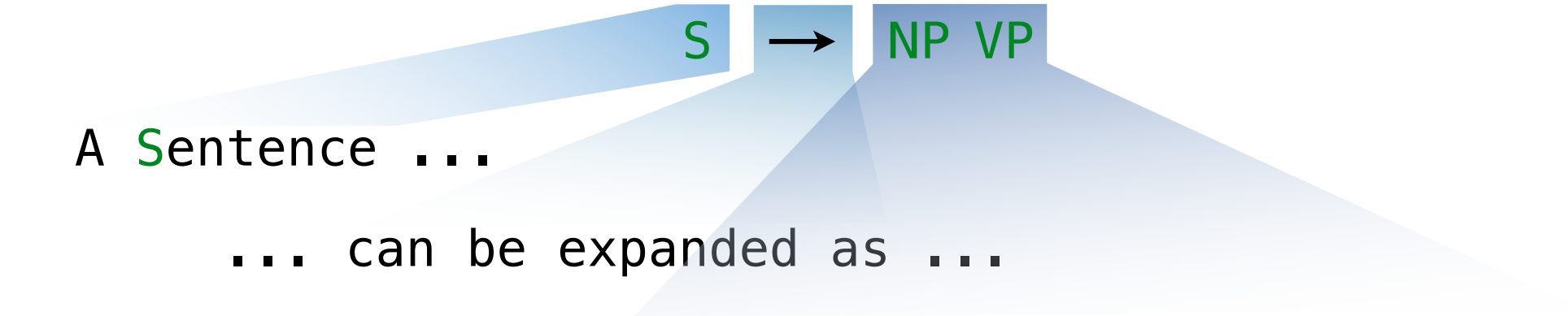
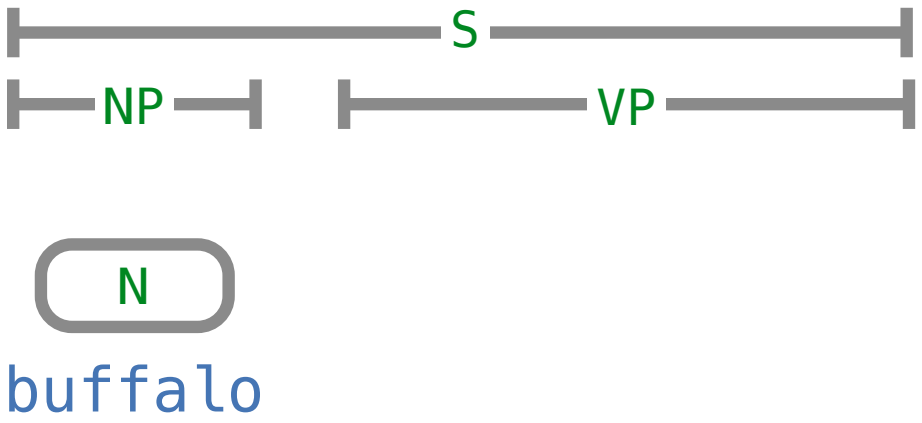
S → NP VP
NP → N
N → buffalo

Context-Free Grammar Rules

A grammar rule describes how a tag can be expanded.



S → NP VP
NP → N
N → buffalo



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S → NP VP

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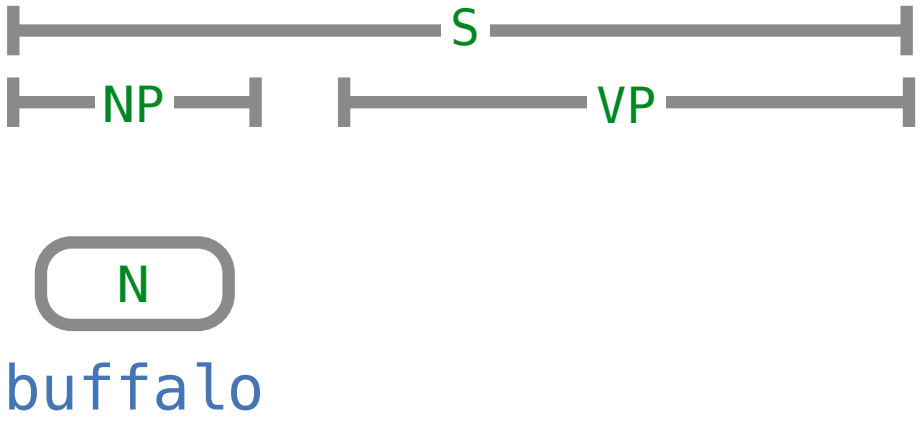
S → NP VP
NP → N
N → buffalo
VP → V NP



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A grammar rule describes how a tag can be expanded.

S → NP VP

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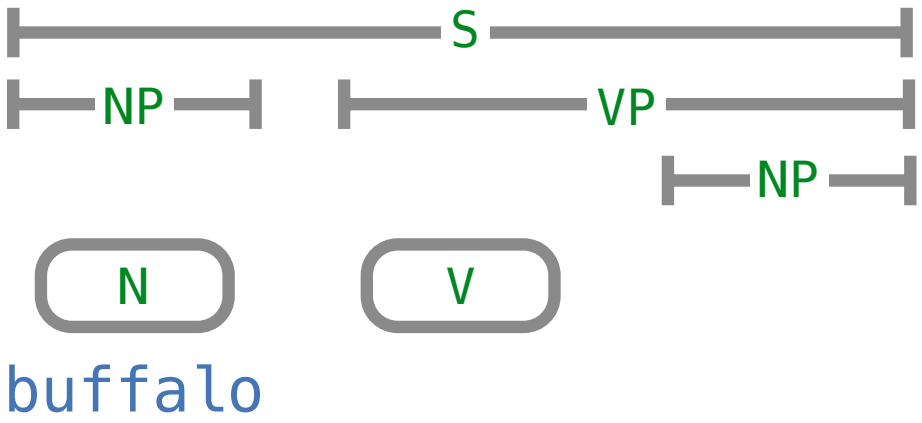
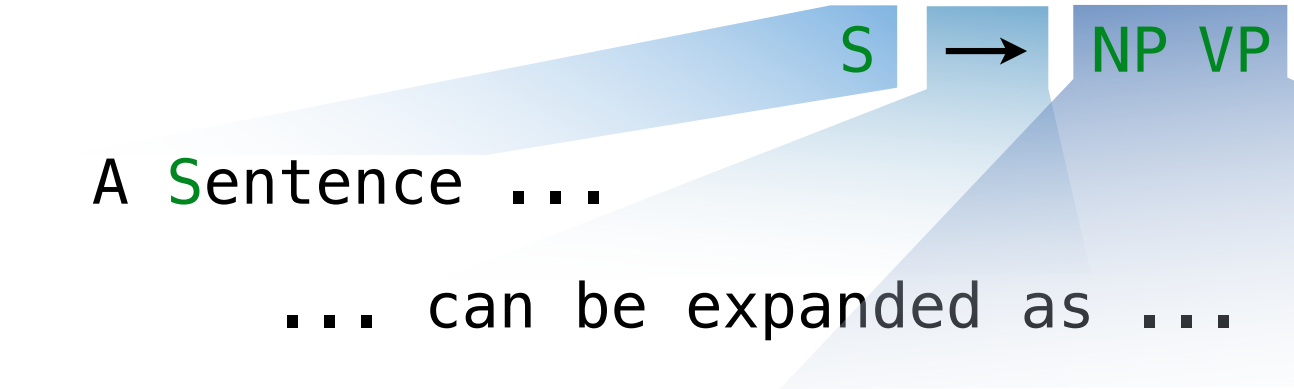
S → NP VP
NP → N
N → buffalo
VP → V NP



Context-Free Grammar Rules

A grammar rule describes how a tag can be expanded.

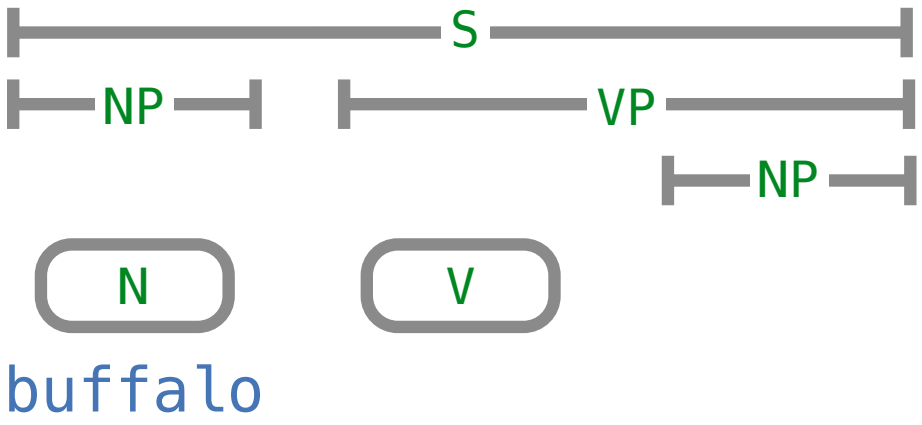


A Sentence ...

... can be expanded as ...

... a Noun Phrase then a Verb Phrase.

S → NP VP
NP → N
N → buffalo
VP → V NP
V → buffalo



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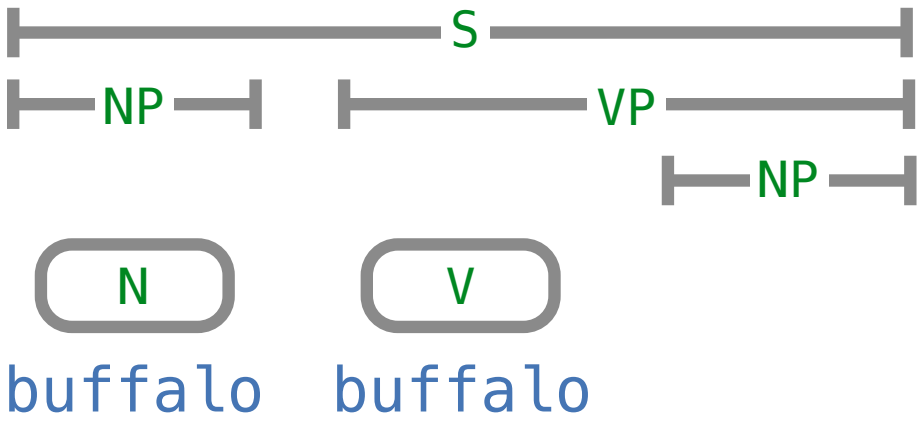

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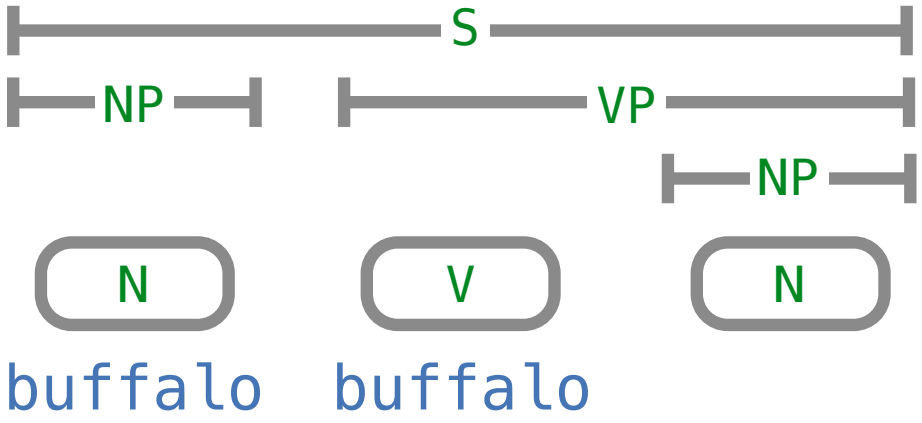

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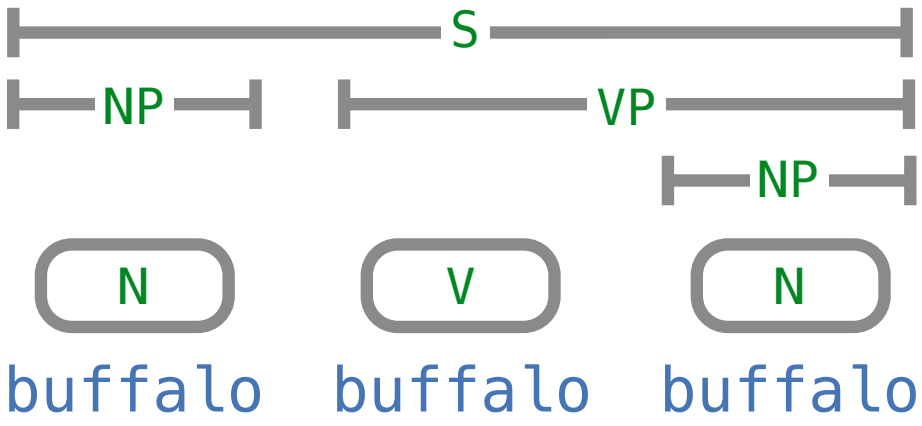

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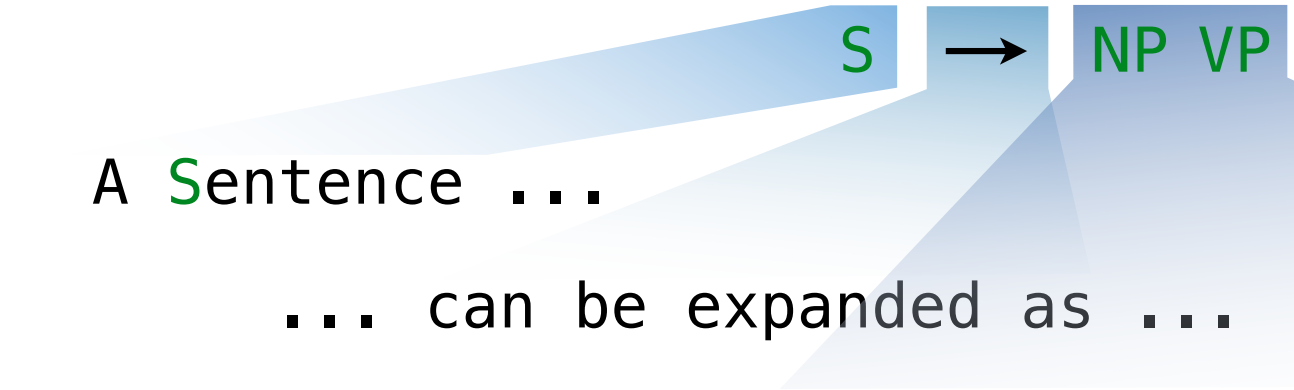

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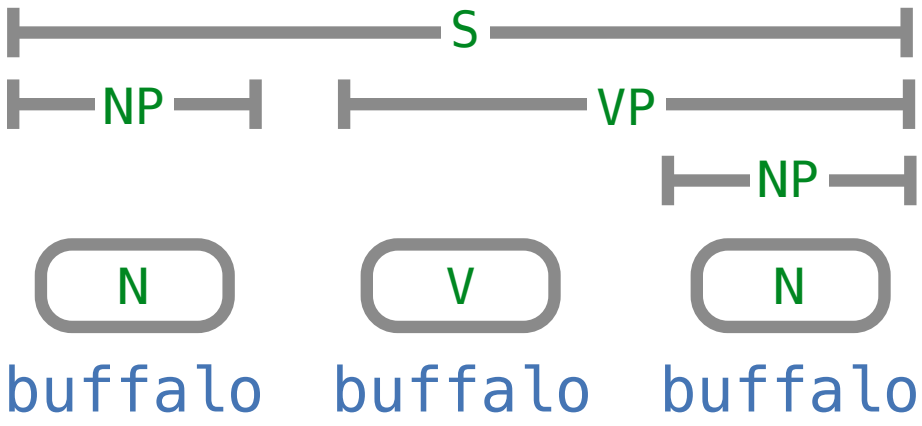

(Demo)

Parsing

Exhaustive Parsing

Recursively expand, but force words to match input.

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buffalo buffalo buffalo buffalo

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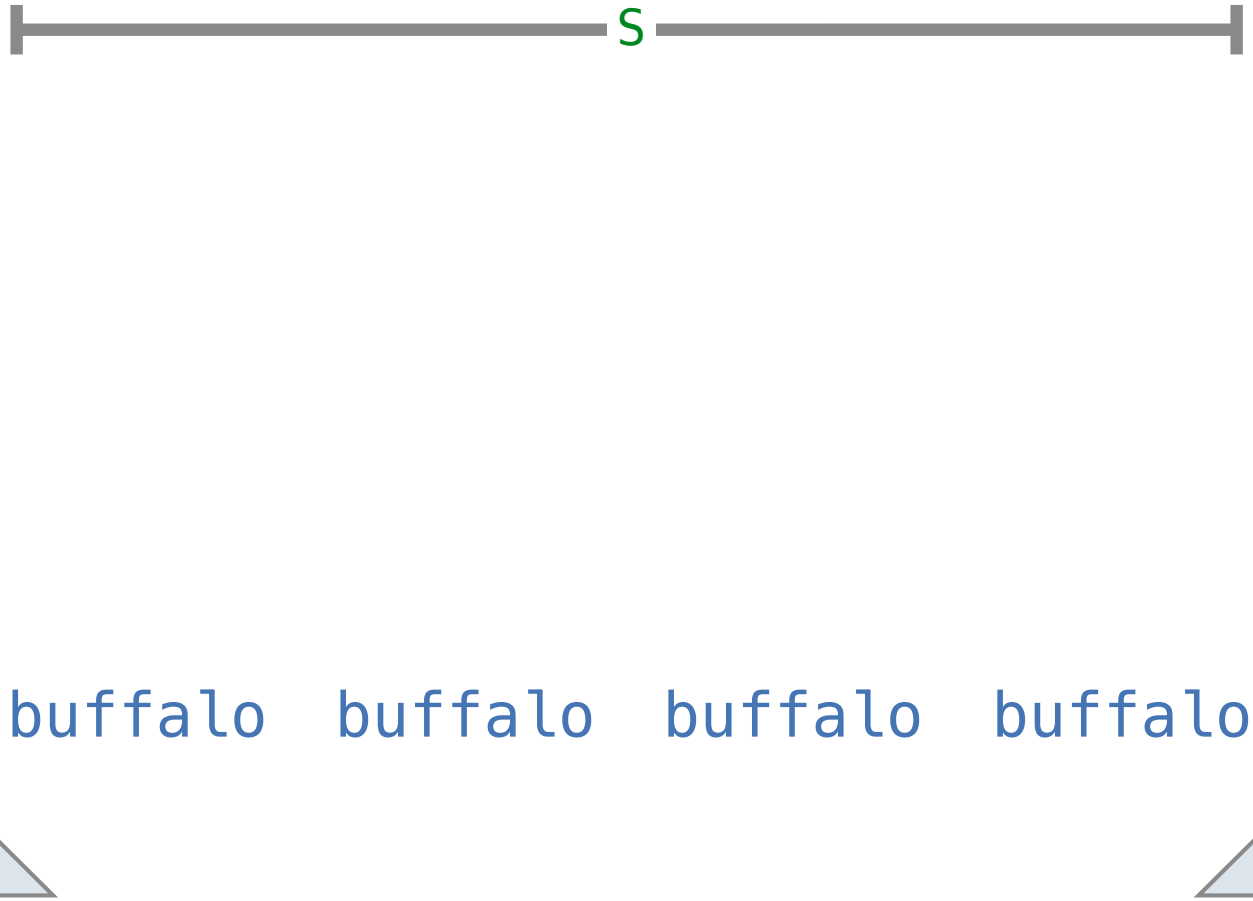

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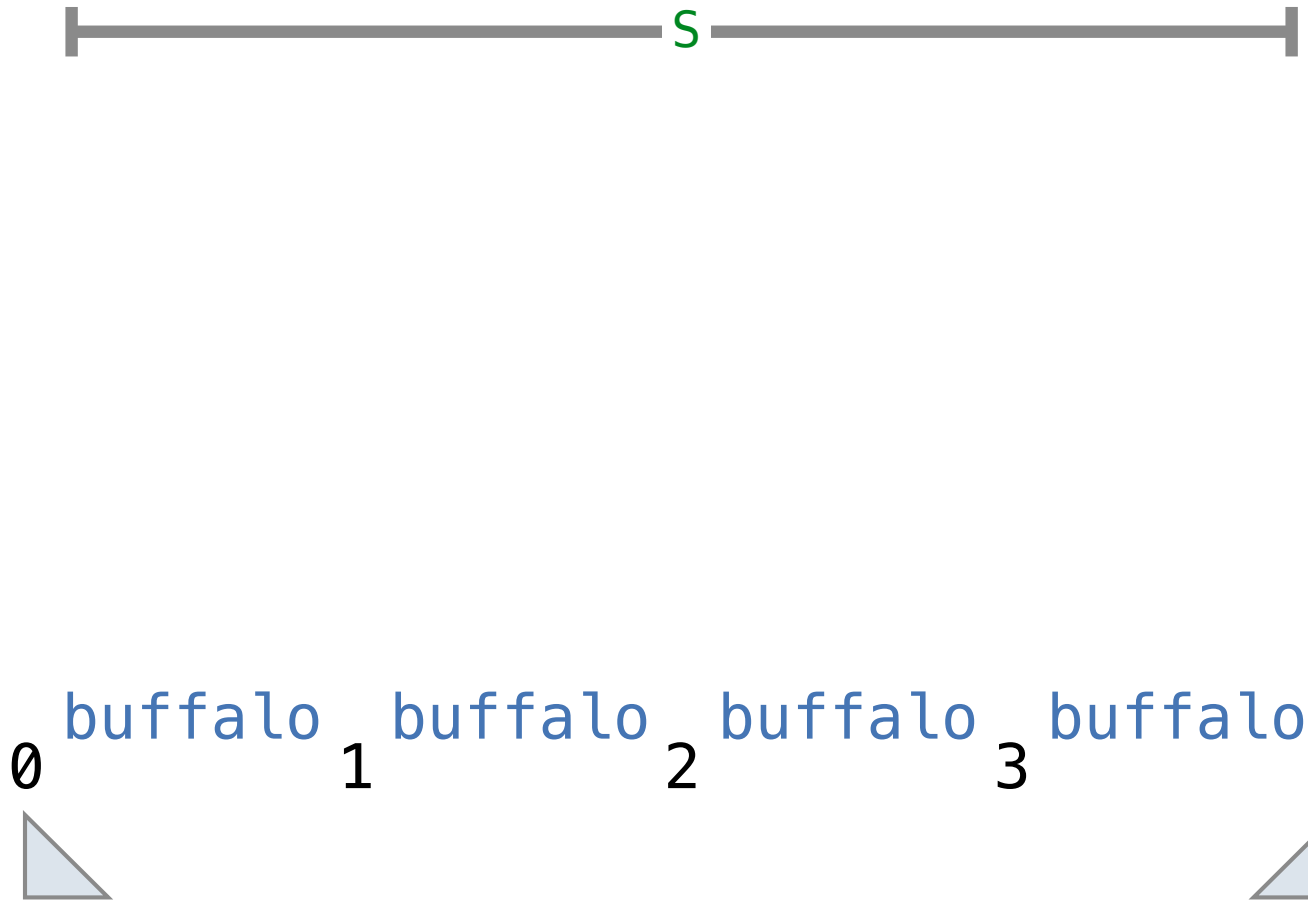

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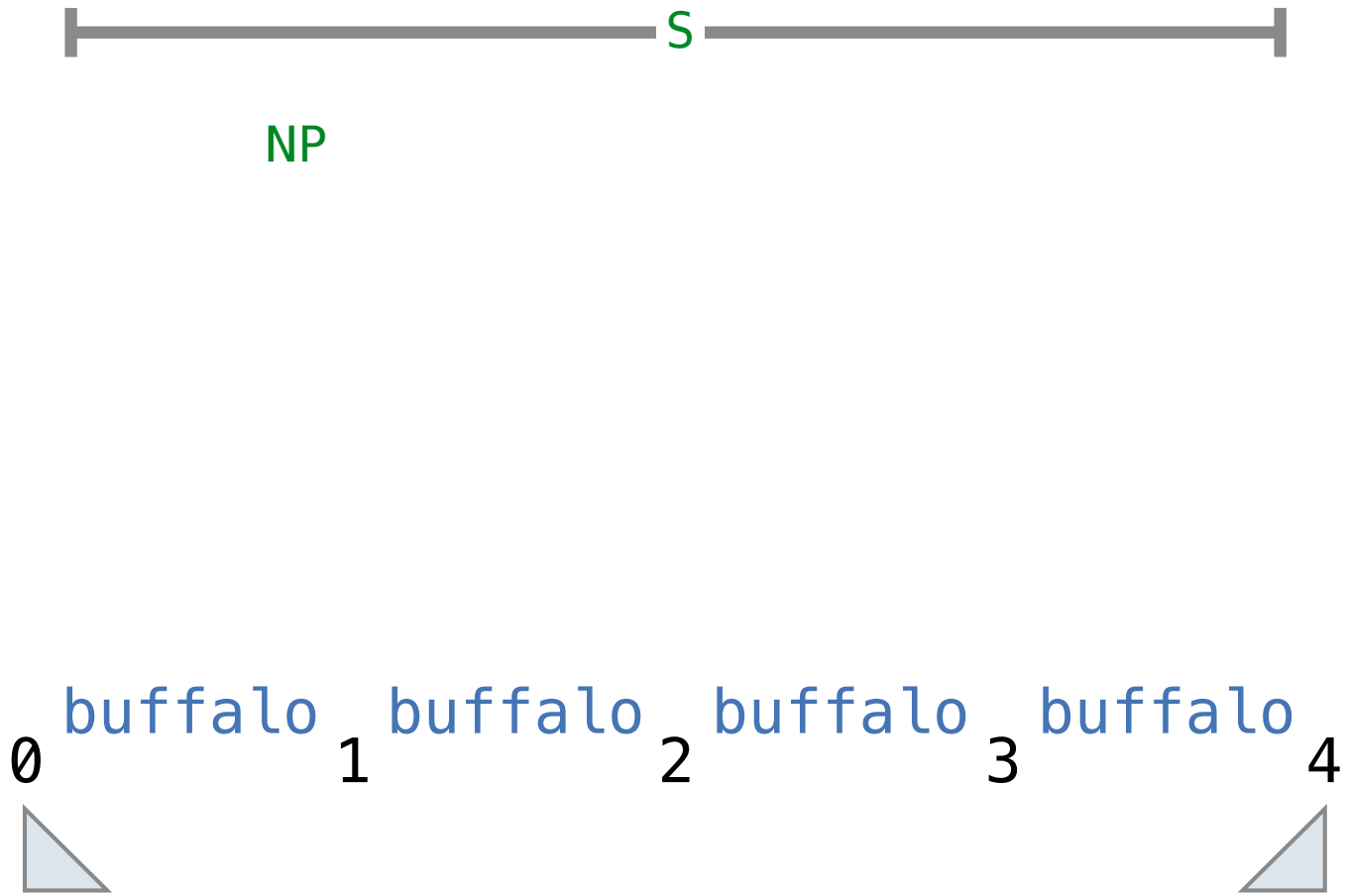

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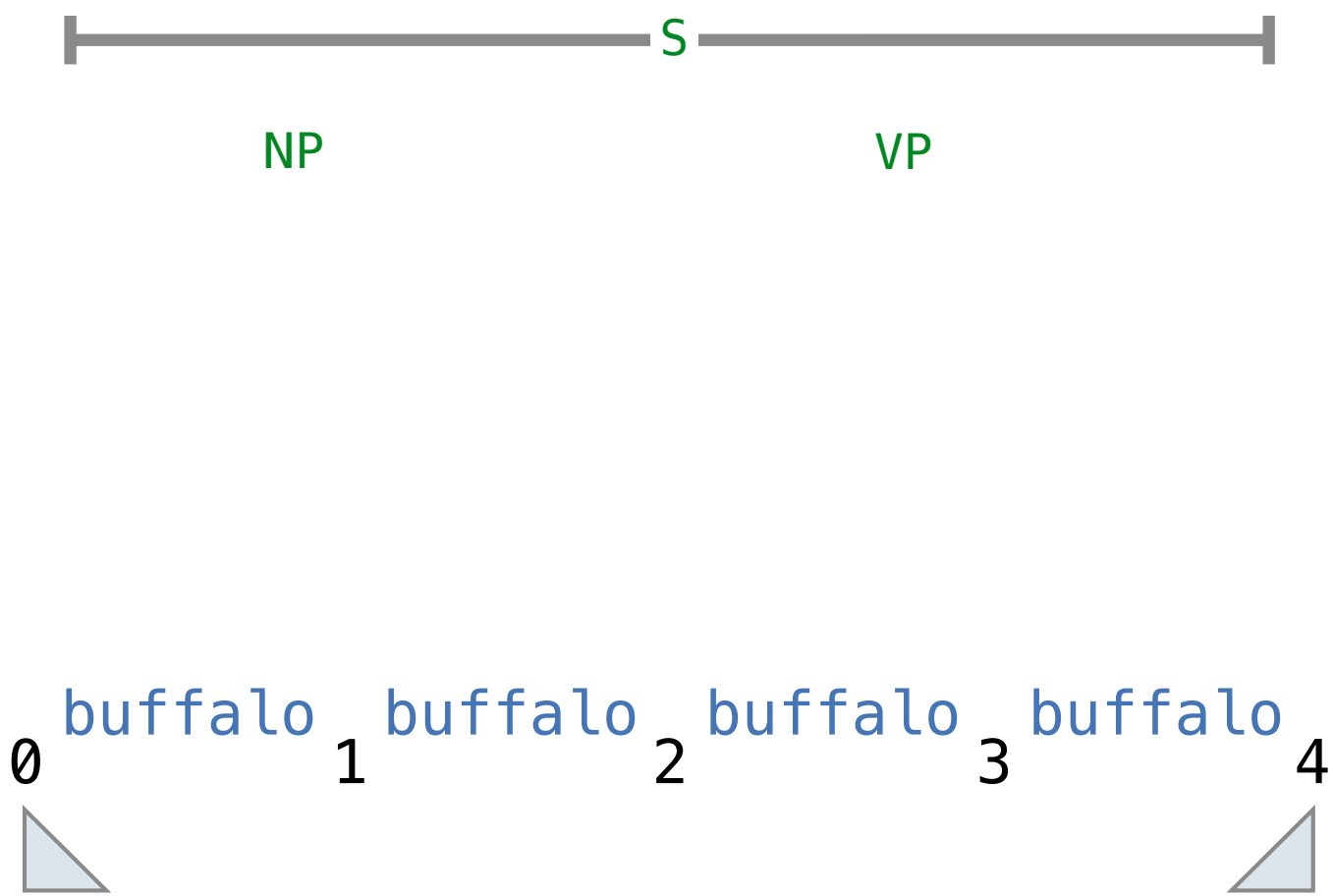

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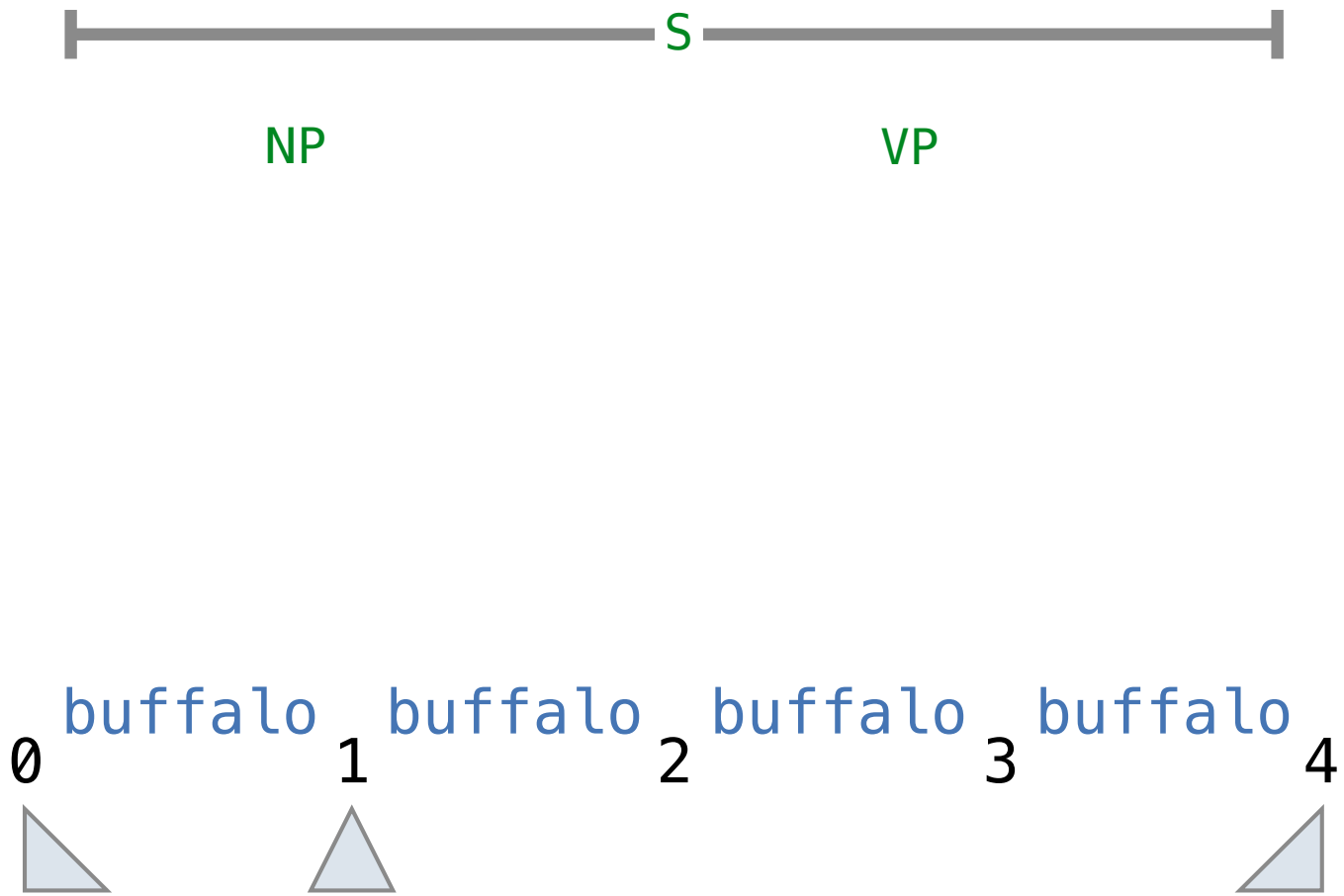

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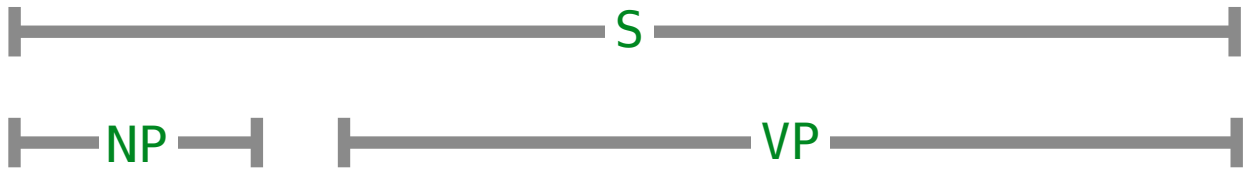

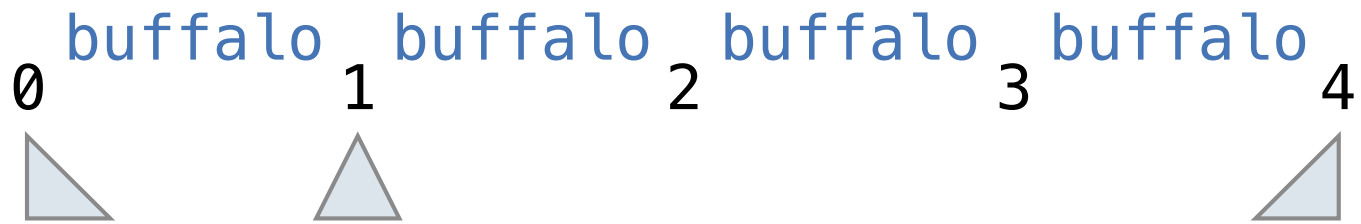

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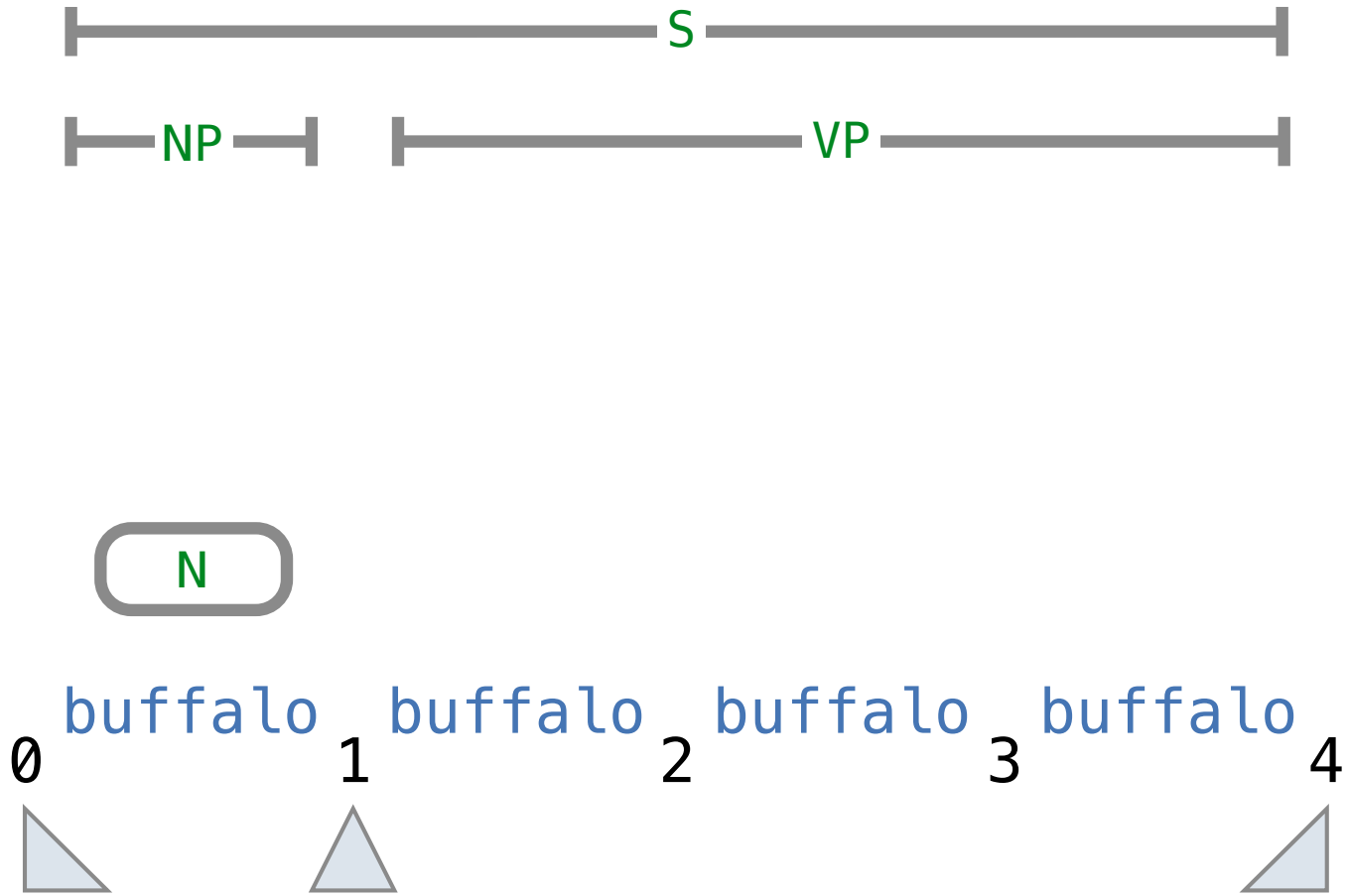

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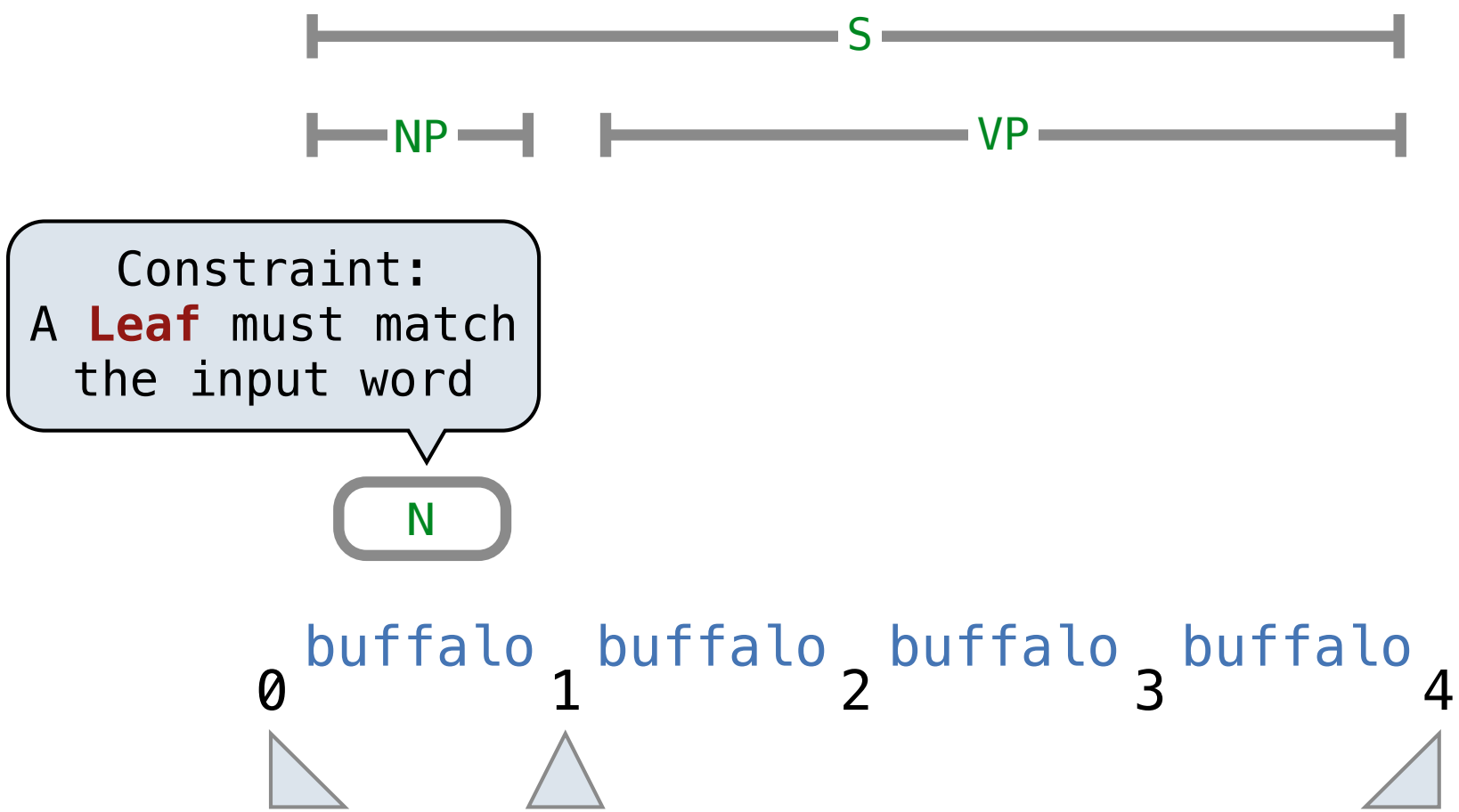

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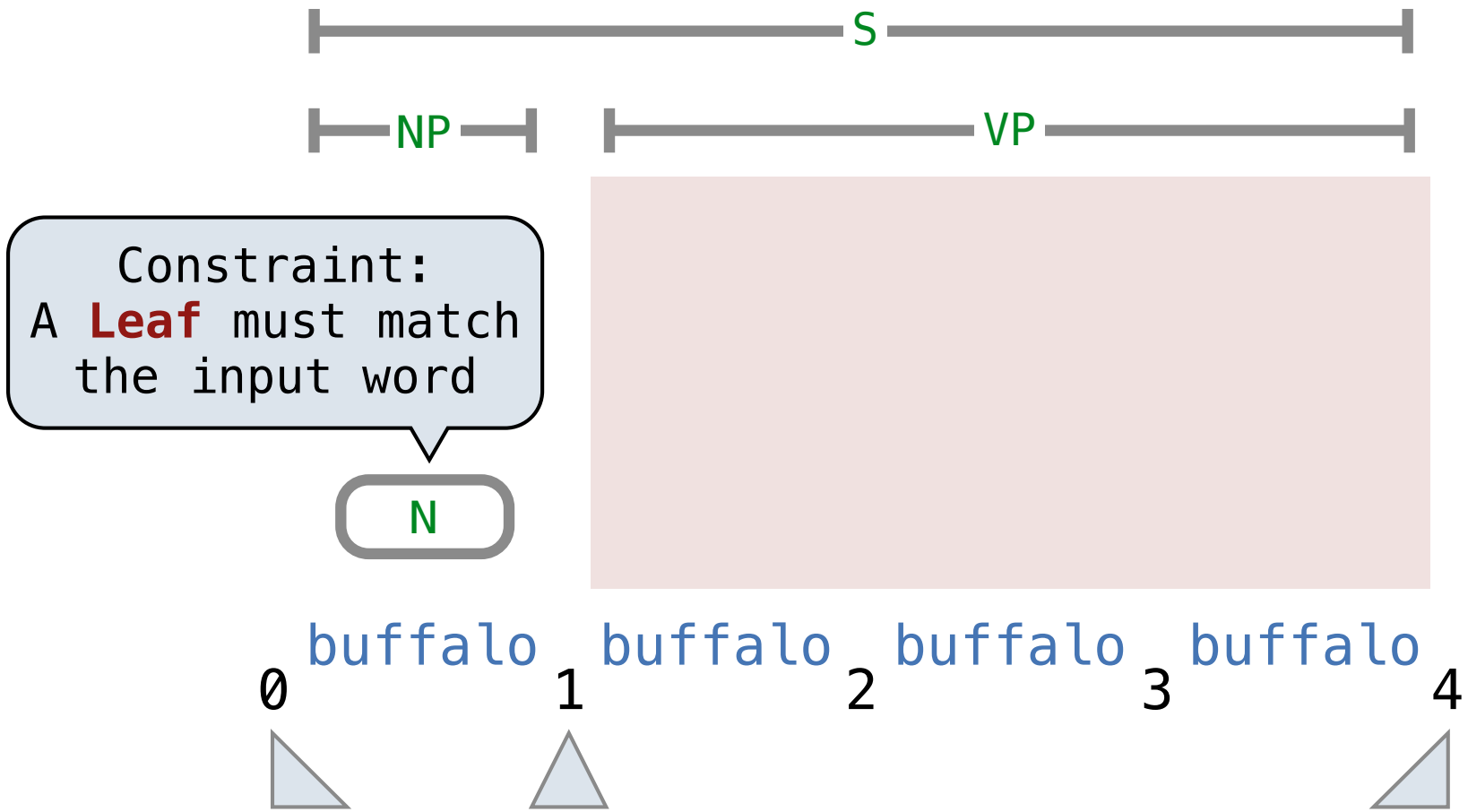

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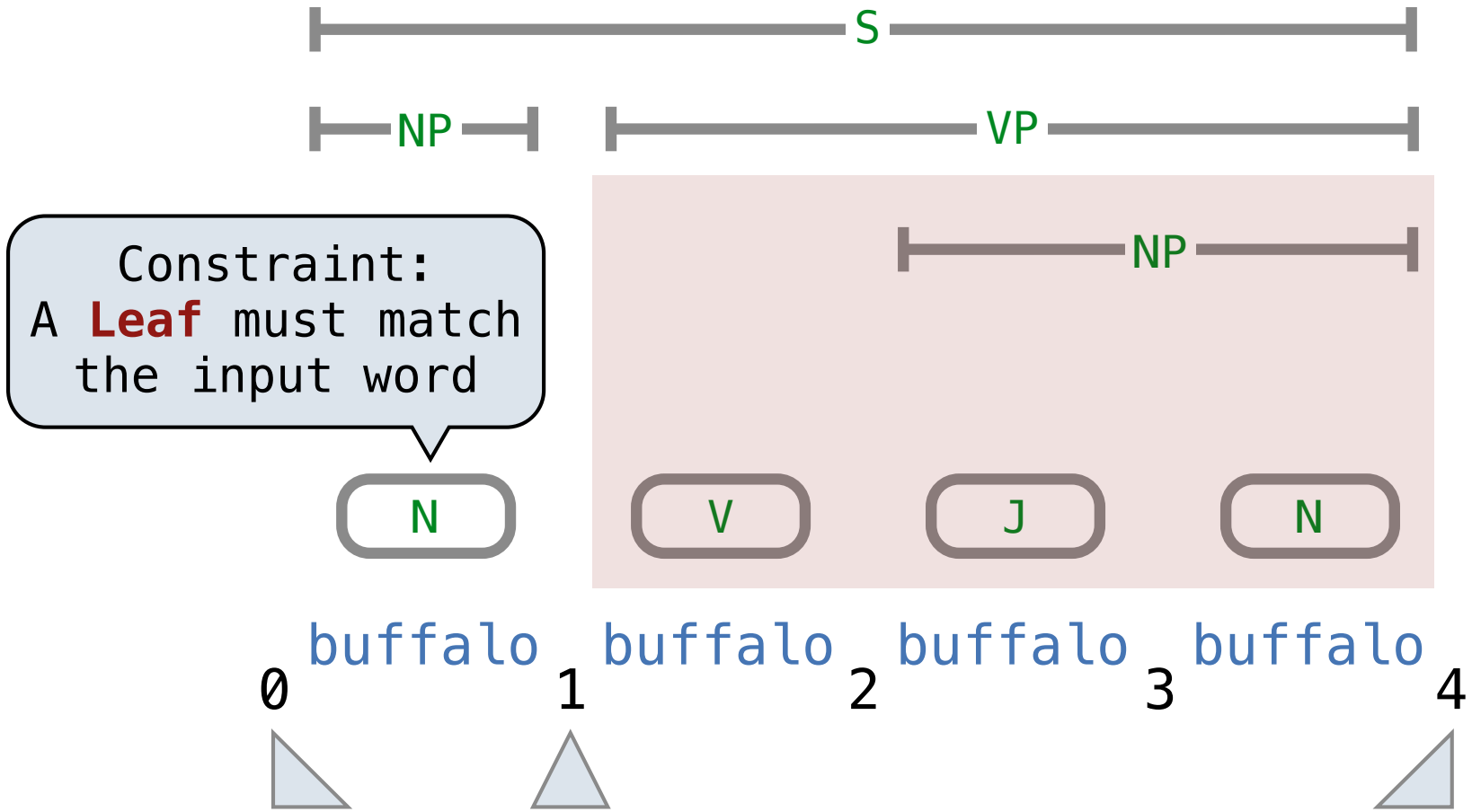

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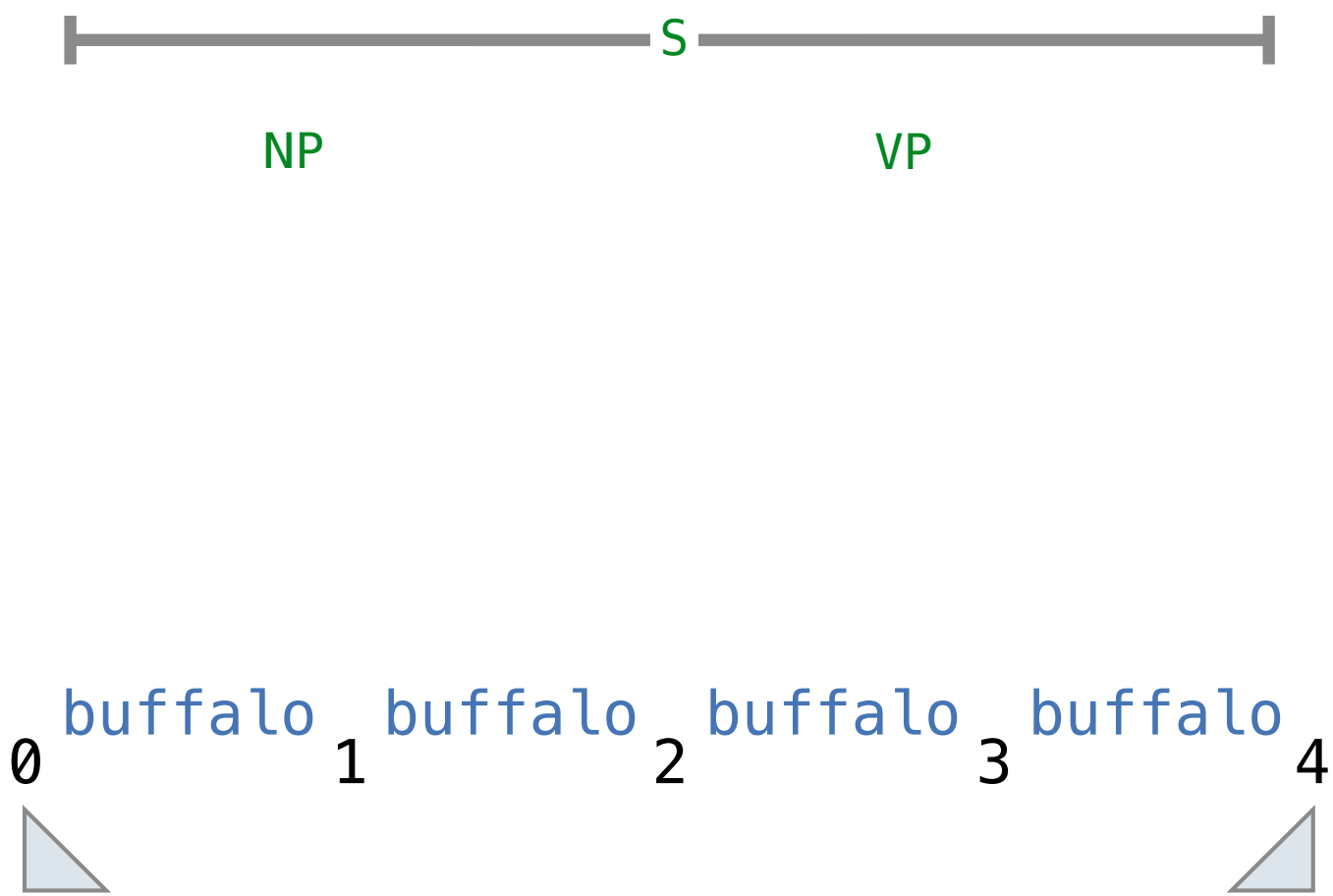

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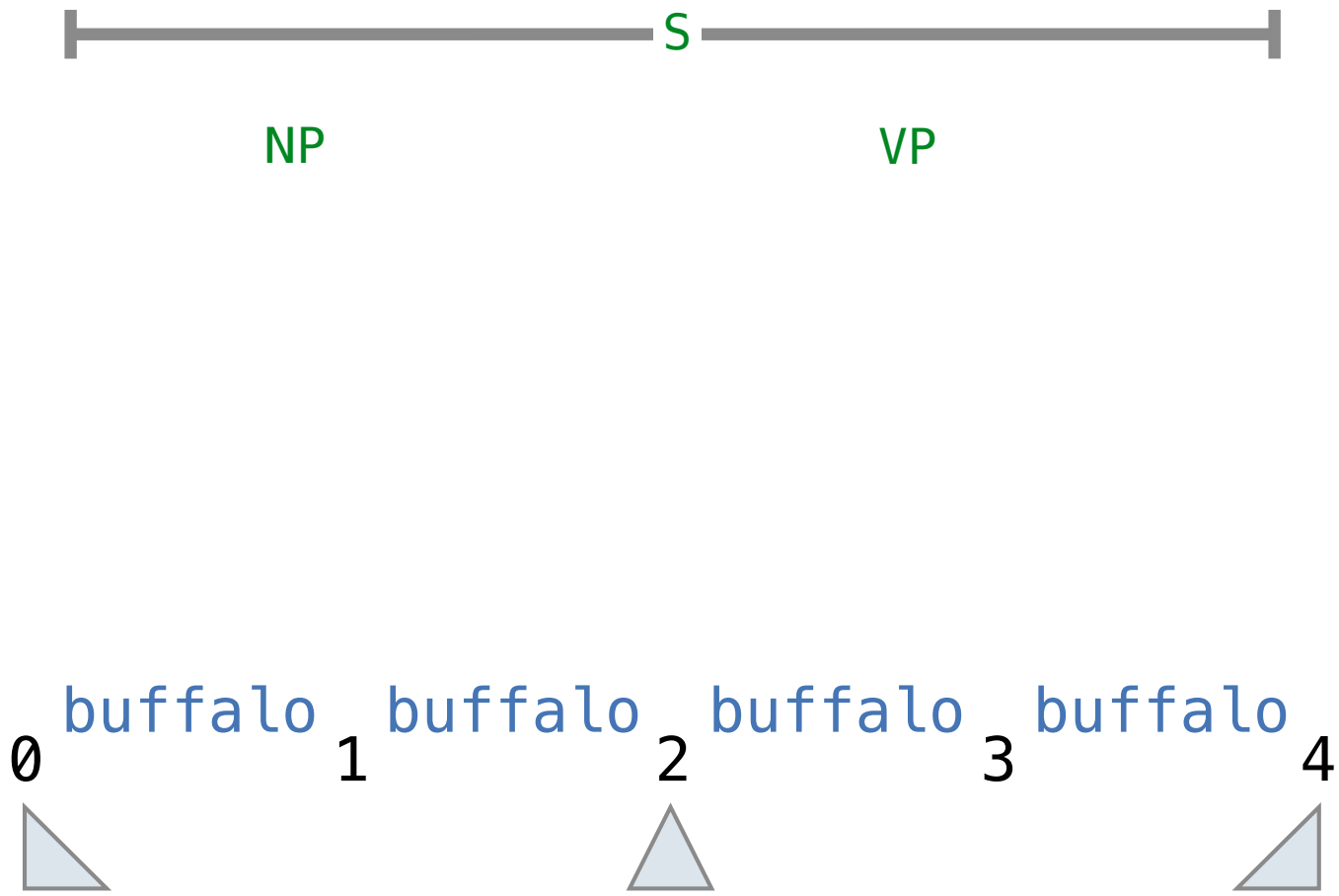

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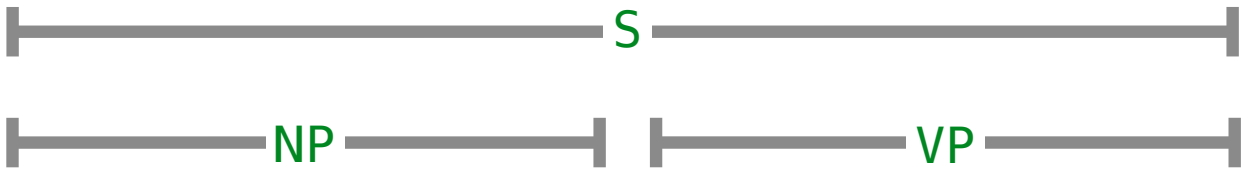

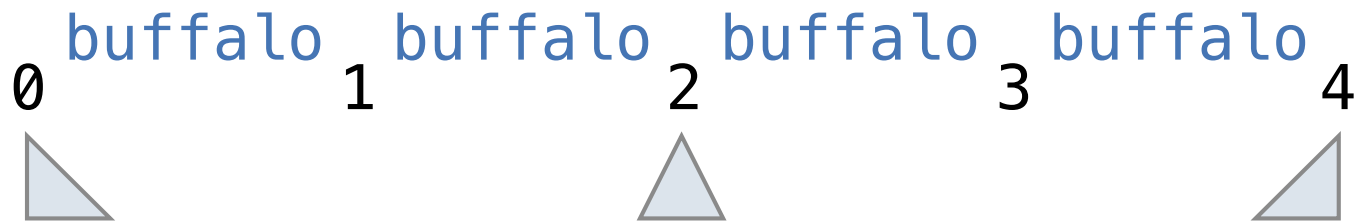

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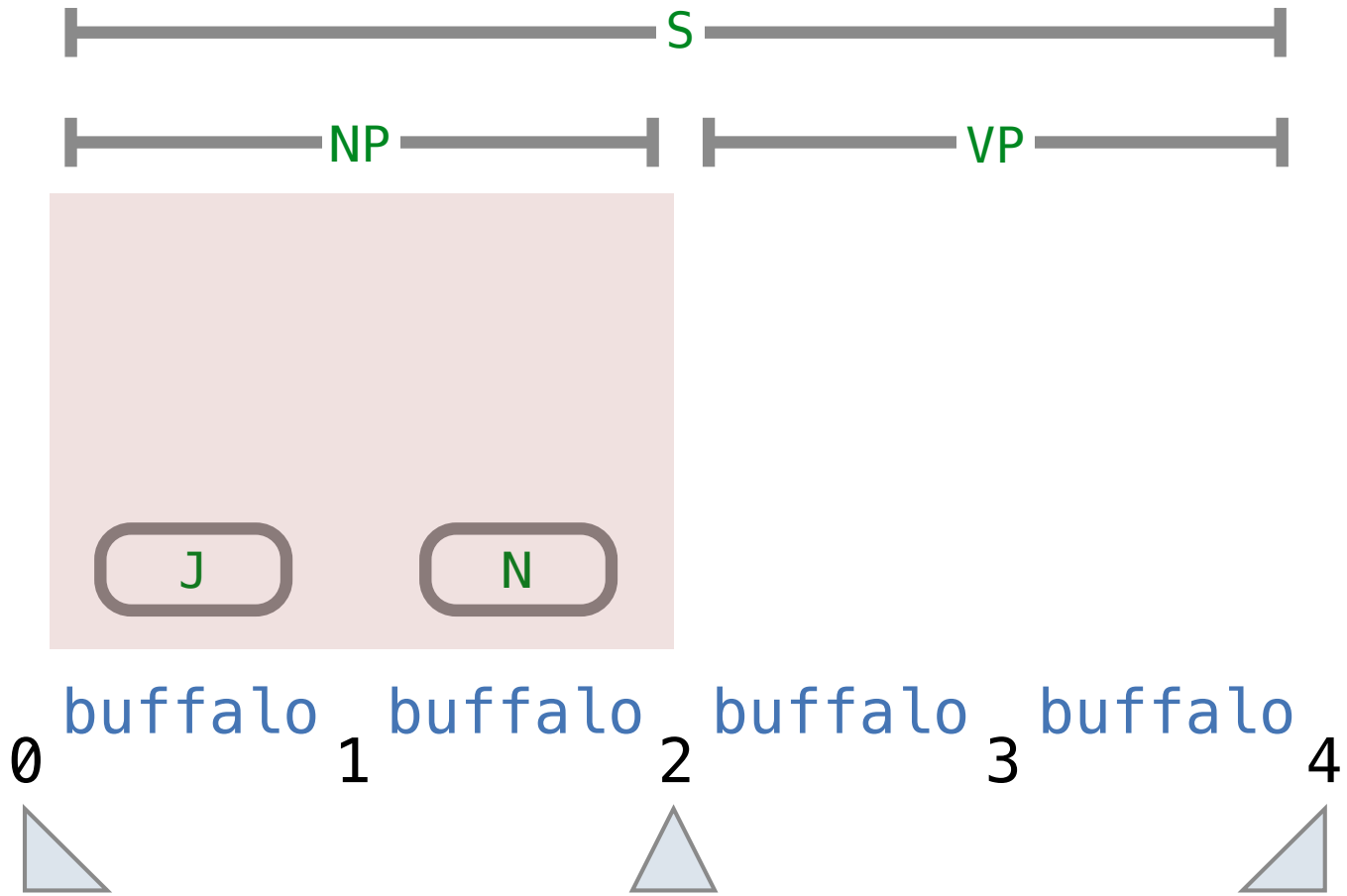

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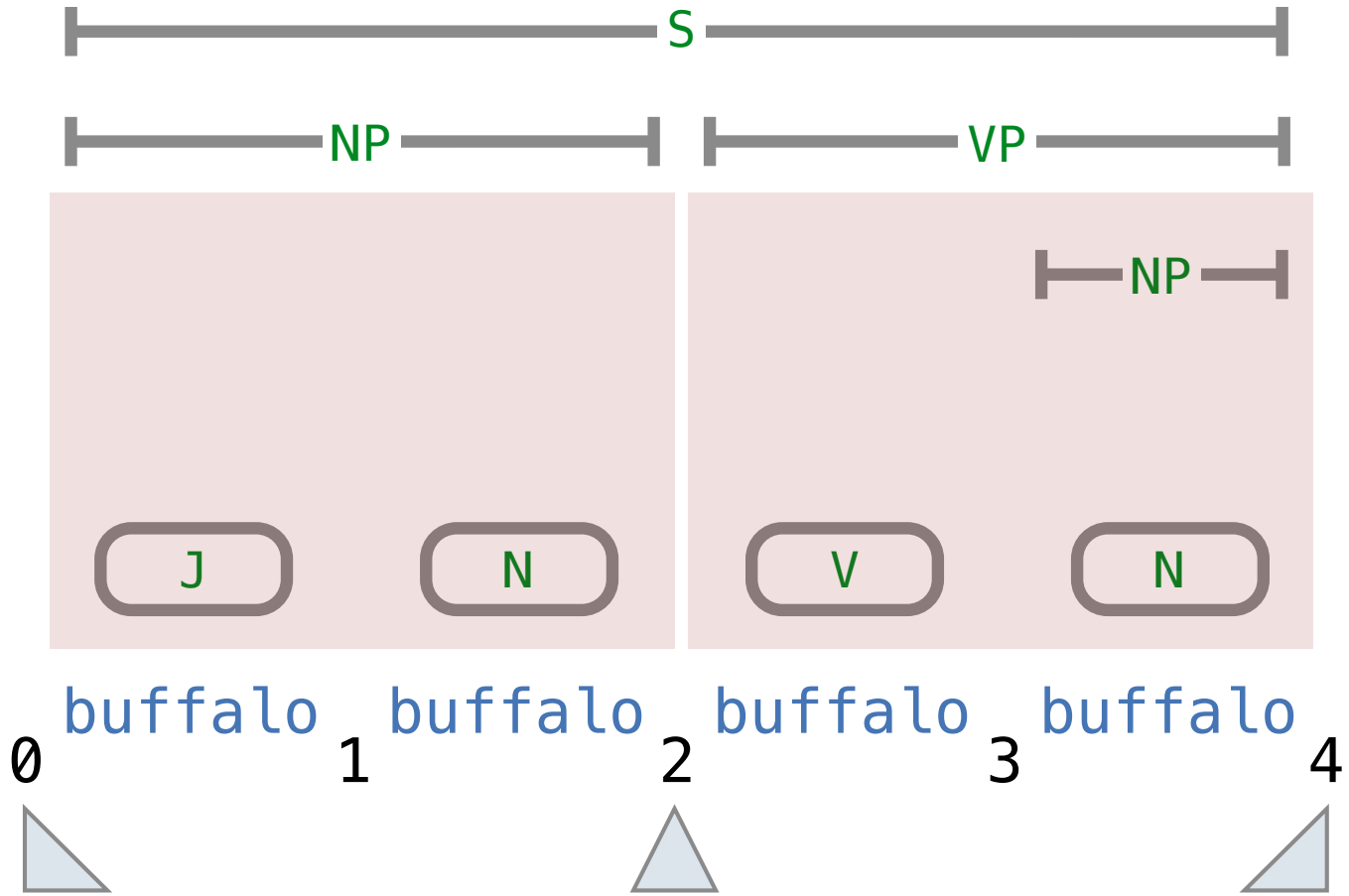

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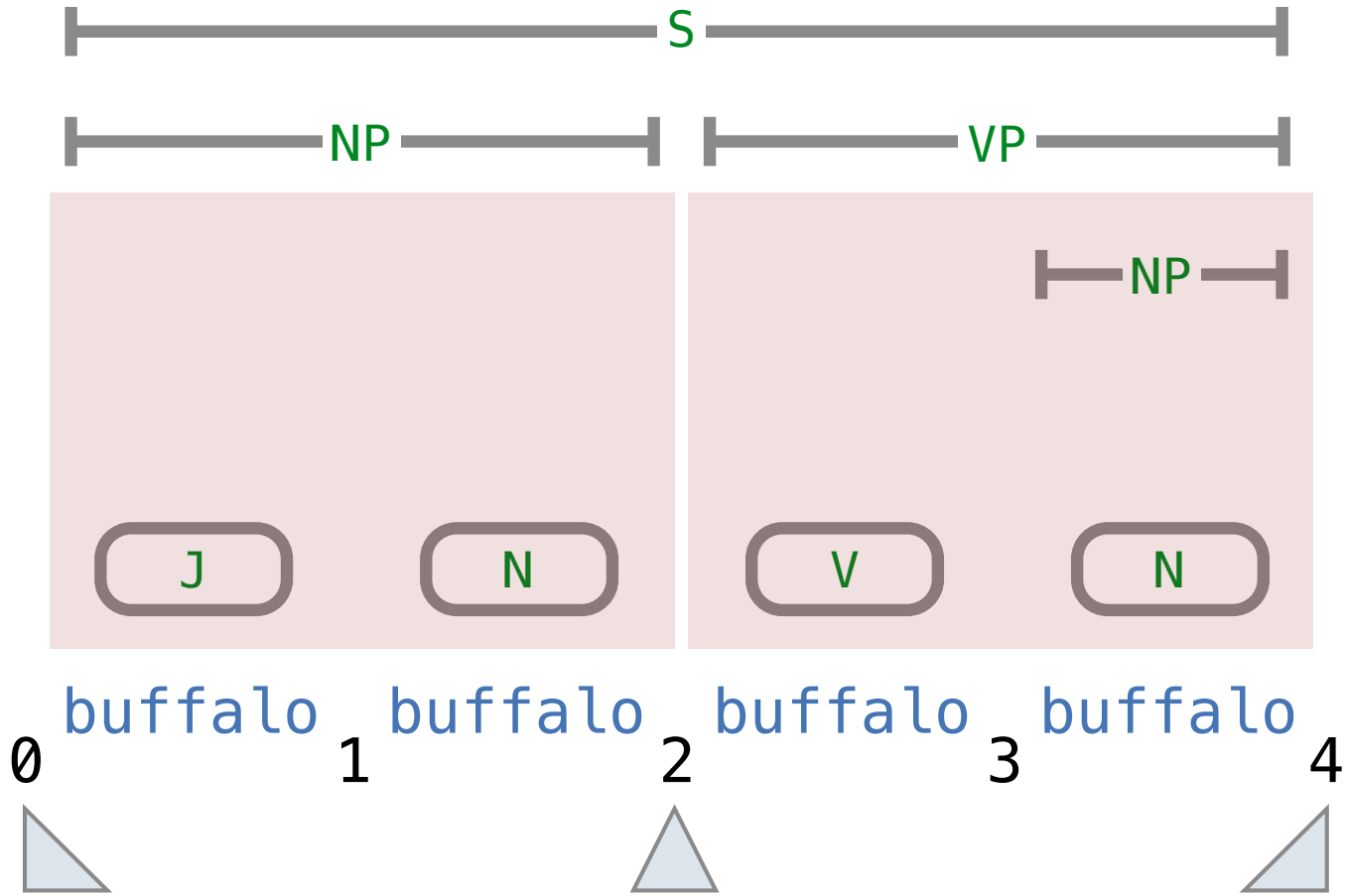

(Demo)

Learning

(Demo)

Scoring a Tree Using Relative Frequencies

Not all syntactic structures are equally common.

Scoring a Tree Using Relative Frequencies

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teacher strikes idle kids

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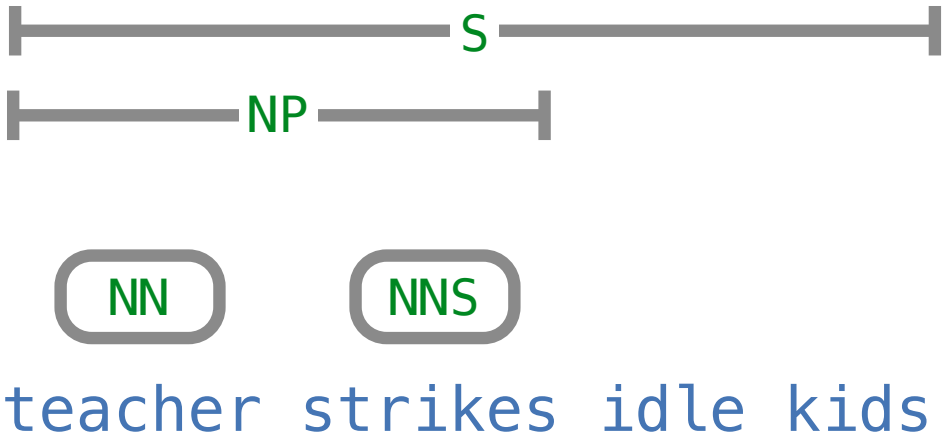

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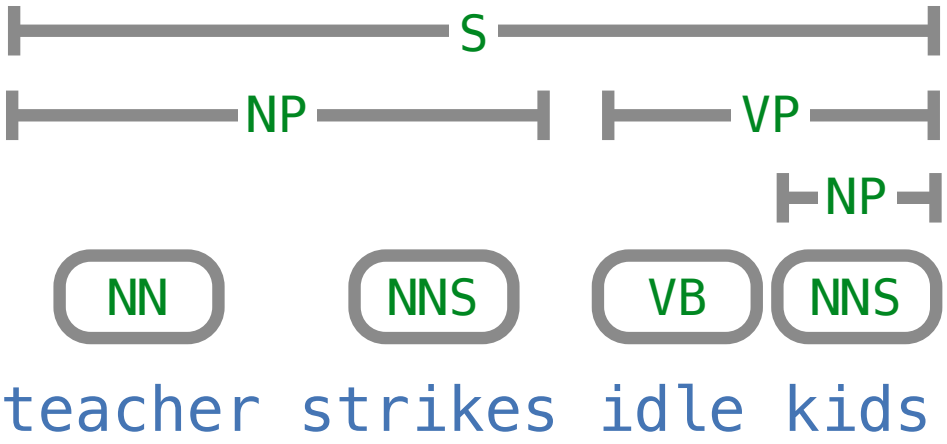

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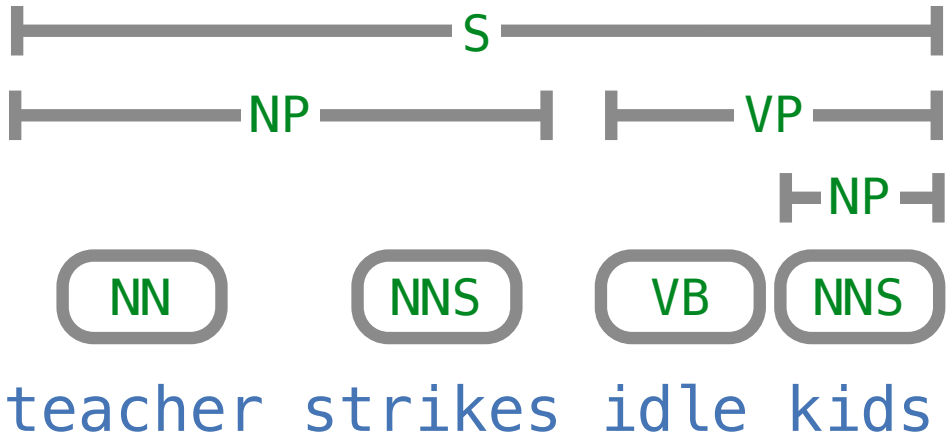

S → NP VP

NP → NN NNS

VP → VB NP

NP → NNS

NN → teacher

NNS → strikes

VB → idle

NNS → kids

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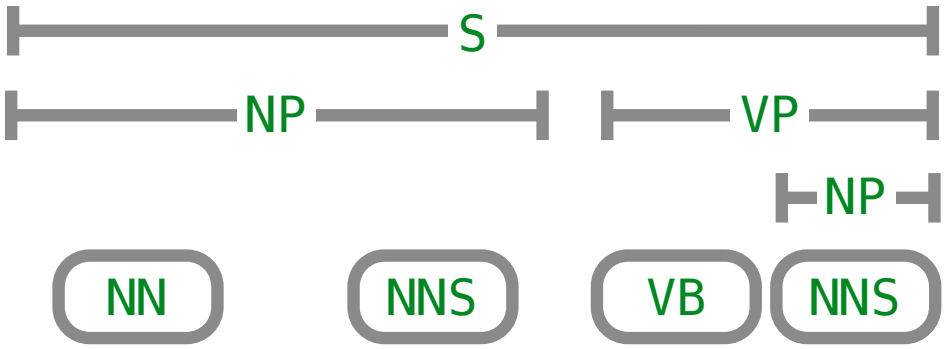

Rule frequency per 100,000 tags

S → NP VP	NN → teacher
NP → NN NNS	NNS → strikes
VP → VB NP	VB → idle
NP → NNS	NNS → kids

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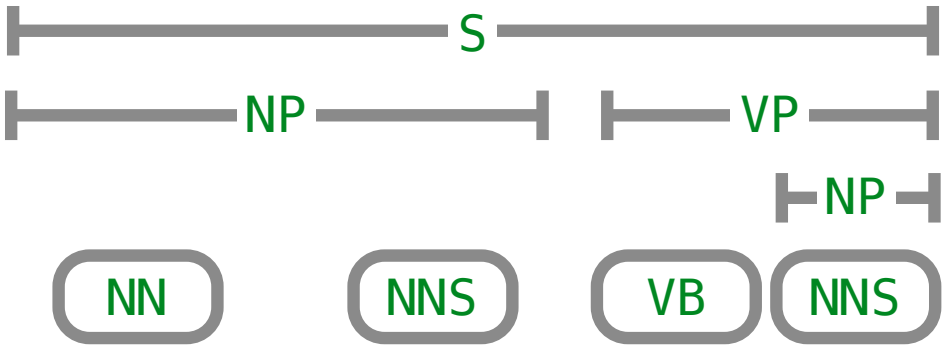

Rule frequency per 100,000 tags

S → NP VP	25372	NN →	teacher
NP → NN NNS		NNS →	strikes
VP → VB NP		VB →	idle
NP → NNS		NNS →	kids

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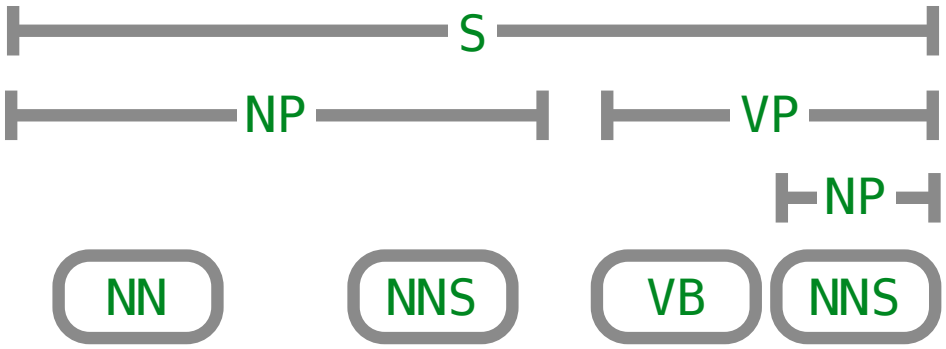

Rule frequency per 100,000 tags

S → NP VP	25372	NN →	teacher
NP → NN NNS	1335	NNS →	strikes
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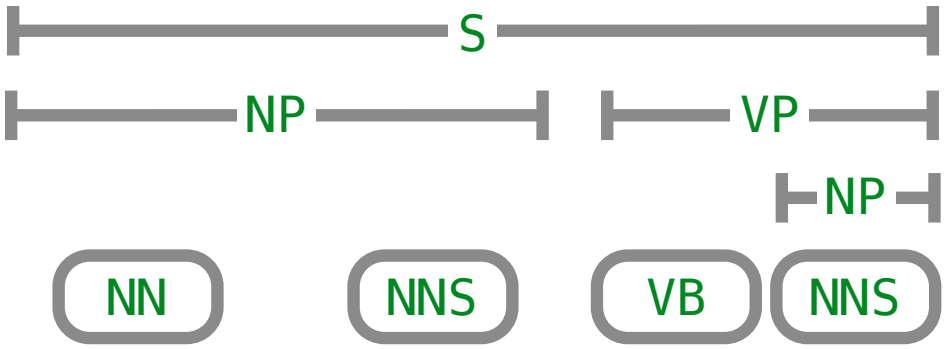

Rule frequency per 100,000 tags

S → NP VP	25372	NN → teacher	
NP → NN NNS	1335	NNS → strikes	
VP → VB NP	6679	VB → idle	
NP → NNS		NNS → kids	

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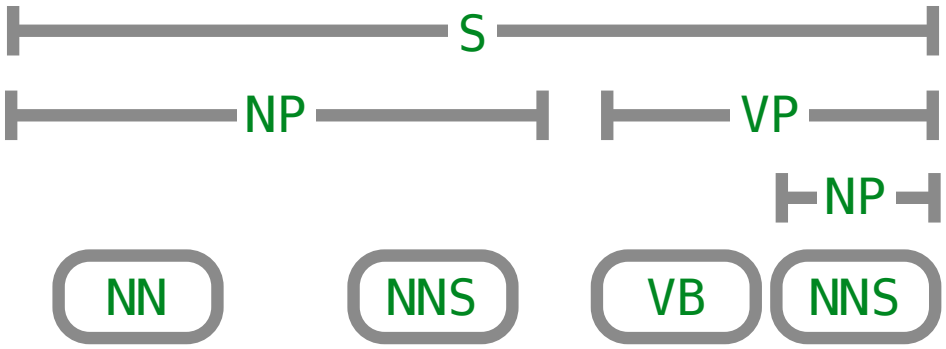

Rule frequency per 100,000 tags

S → NP VP	25372	NN → teacher	
NP → NN NNS	1335	NNS → strikes	
VP → VB NP	6679	VB → idle	
NP → NNS	4282	NNS → kids	

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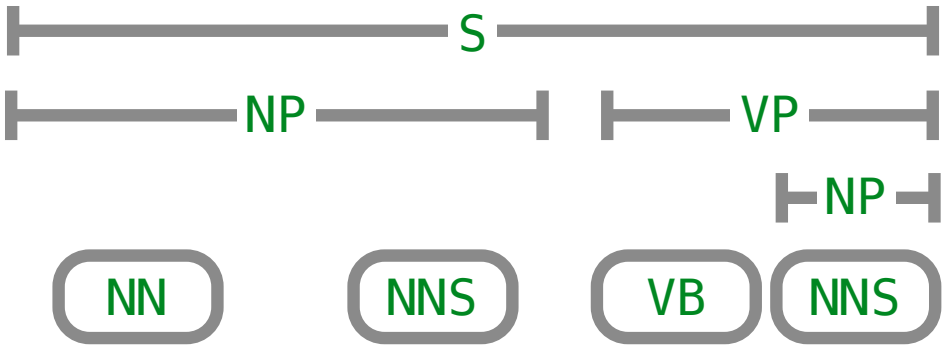

Rule frequency per 100,000 tags

S → NP VP	25372	NN → teacher	5
NP → NN NNS	1335	NNS → strikes	
VP → VB NP	6679	VB → idle	
NP → NNS	4282	NNS → kids	

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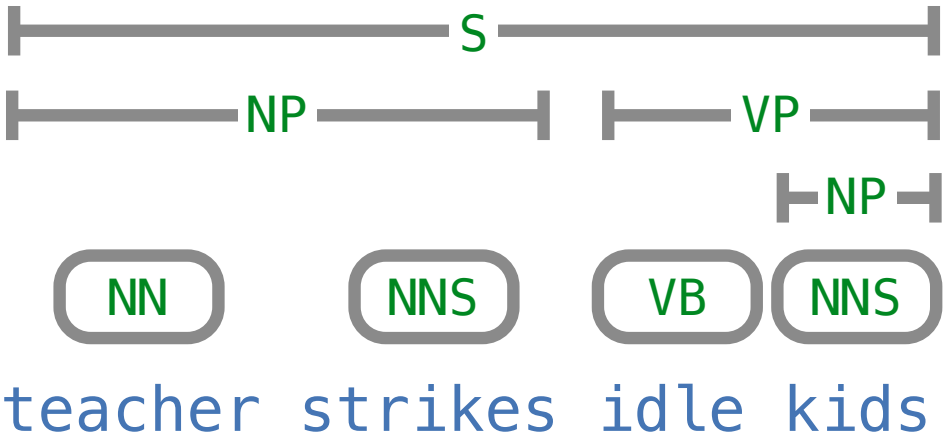

Rule frequency per 100,000 tags

S → NP VP	25372	NN → teacher	5
NP → NN NNS	1335	NNS → strikes	25
VP → VB NP	6679	VB → idle	
NP → NNS	4282	NNS → kids	

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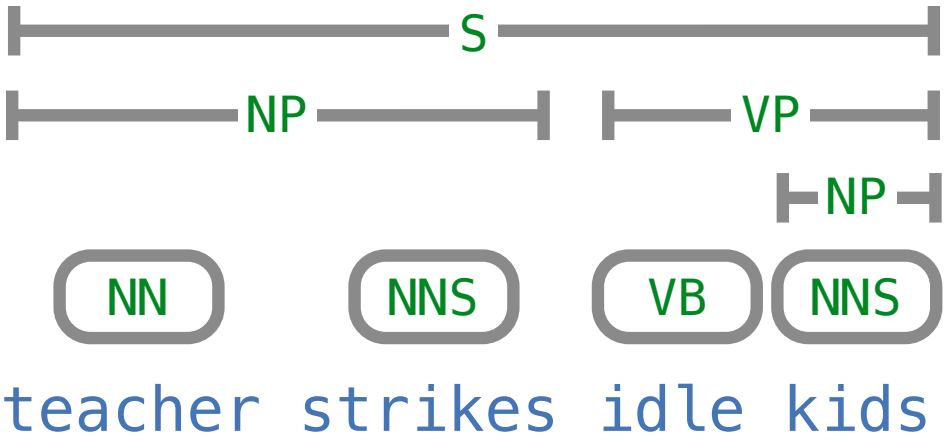

Rule frequency per 100,000 tags

S → NP VP	25372	NN → teacher	5
NP → NN NNS	1335	NNS → strikes	25
VP → VB NP	6679	VB → idle	26
NP → NNS	4282	NNS → kids	

Scoring a Tree Using Relative Frequencies

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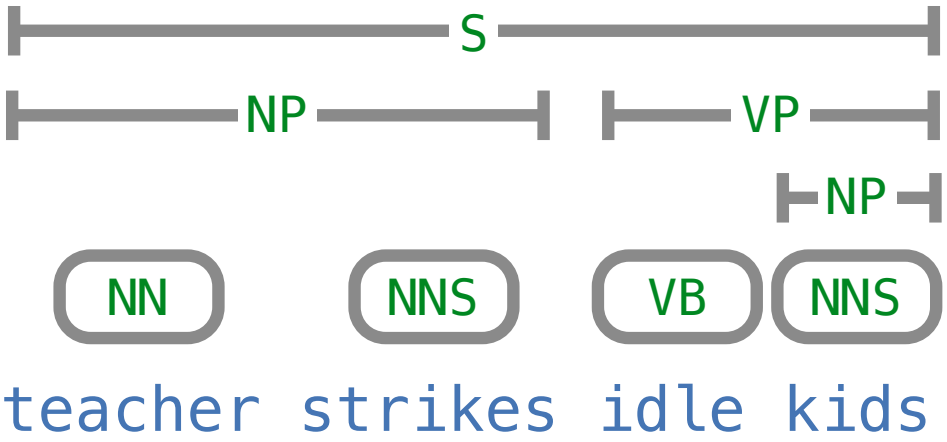

Rule frequency per 100,000 tags

S → NP VP	25372	NN → teacher	5
NP → NN NNS	1335	NNS → strikes	25
VP → VB NP	6679	VB → idle	26
NP → NNS	4282	NNS → kids	32

Scoring a Tree Using Relative Frequencies

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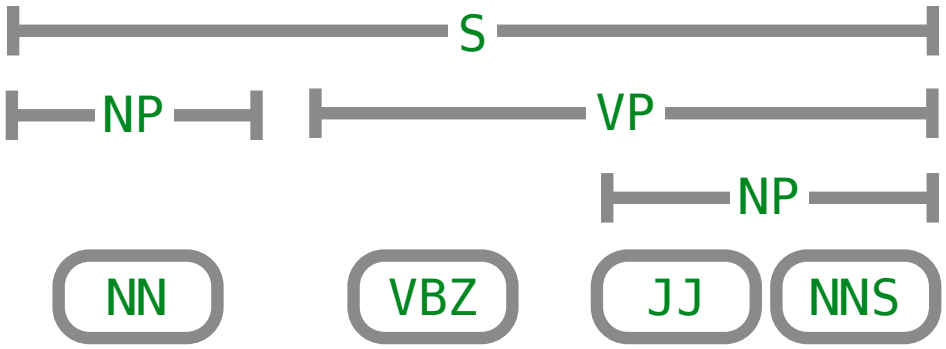

Rule frequency per 100,000 tags

S → NP VP	25372			NN → teacher	5		
NP → NN	~~1335~~	4358		VBZ → strikes	~~25~~	19	
VP → VBZ NP	~~6679~~	3160		JJ → idle	~~26~~	18	
NP → JJ NNS	~~4282~~	2526		NNS → kids	32		

Scoring a Tree Using Relative Frequencies

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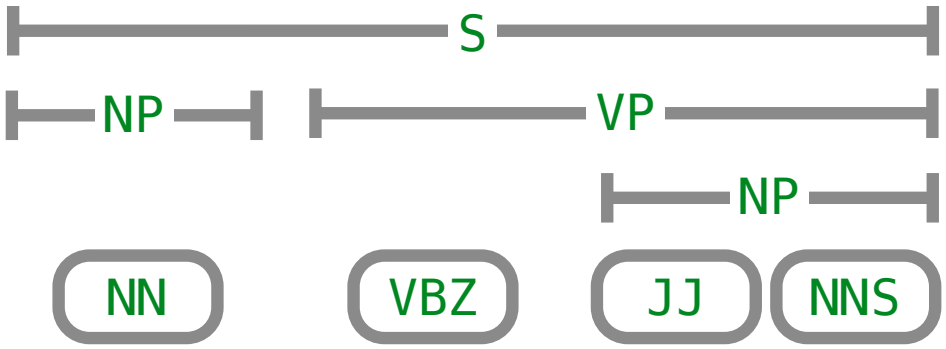

Rule frequency per 100,000 tags

S → NP VP	25372			NN → teacher	5		
NP → NN	~~1335~~	4358		VBZ → strikes	~~25~~	19	
VP → VBZ NP	~~6679~~	3160		JJ → idle	~~26~~	18	
NP → JJ NNS	~~4282~~	2526		NNS → kids	32		

(Demo)