

Lecture 27

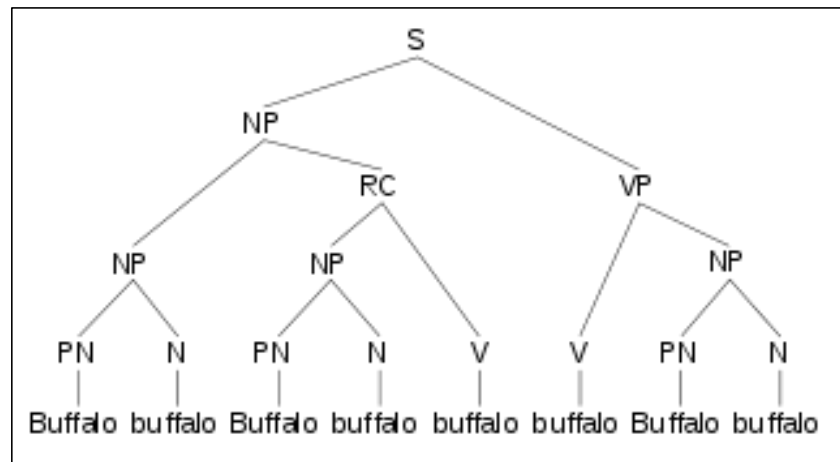
408/508 Computational Techniques for Linguists

Today's Topic

nlk book section 8.9

• 13. ⚙

- Consider the sequence of words: *Buffalo buffalo Buffalo buffalo buffalo Buffalo buffalo.*
- This is a grammatically correct sentence, as explained at http://en.wikipedia.org/wiki/Buffalo_buffalo_Buffalo_buffalo_buffalo_buffalo_Buffalo_buffalo
- Consider the tree diagram presented on this Wikipedia page, and write down a suitable grammar.
- Normalize case to lowercase, to simulate the problem that a listener has when hearing this sentence.
- Can you find other parses for this sentence?
- How does the number of parse trees grow as the sentence gets longer?



S = [sentence](#)
NP = [noun phrase](#)
RC = [relative clause](#)
VP = [verb phrase](#)
PN = [proper noun](#)
N = [noun](#)
V = [verb](#)

American Buffalo/Bison



A digital display screen showing a promotional poster for the play 'Animalities'. The screen is divided into several sections. At the top left is the logo for the College of Social & Behavioral Sciences. The main title 'Animalities' is in large blue letters, with the subtitle 'What Animals Teach Us About Being Human' and the website 'sbsdowntown.arizona.edu' below it. The play title 'The Personhood of Bison' and author 'Nieves Zedeño' are prominently displayed. The date and time 'Oct. 10 | 6:30 p.m. | Fox Tucson Theatre | Free admission' are listed below. At the bottom left is the University of Arizona logo and the college name. On the right side of the screen, there is a weather widget showing 'Monday, 12' and '86°', and a 'FOL' section with social media icons for Twitter, Facebook, and YouTube. At the very bottom of the screen, a 'NEWS' banner reads 'UA Field Studies Program Inspires Writing about Environmental and Border Issues'. A close-up image of a bison's head is on the right side of the poster.

Some facts

<https://www.doi.gov/blog/15-facts-about-our-national-mammal-american-bison>

- Across North America, there are an estimated 500,000 bison.
- The North American bison is the **National Mammal** of the United States (since 5/9/2016)
- State mammal of Wyoming, Oklahoma, and Kansas.
- National Bison Day:
 - 1st Saturday in November (US Senate Resolution).
- Scientific name:
 - **Bison bison bison** (*plains bison*) or **Bison bison athabasca** (*wood bison*)
(genus/species/subspecies)



Famous Buffalo sentence

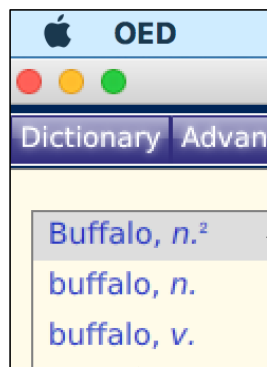


- considered grammatical, and
- makes sense
- but hard to parse even for native speakers

- 8 consecutive occurrences of the word *buffalo*

picture borrowed from Analytical Grammar/Grammar Planet on Facebook, who borrowed it from somewhere else...

OED: buffalo



[< *Buffalo*, the name of a city in New York State, where the recipe was developed in 1964 at the Anchor Bar.]

'buffalo, v. *N. Amer. slang.* **transitive verb**
[f. the n.]
trans. To overpower, overawe, or constrain by superior force or influence; to outwit, perplex. So **'buffaloed** *ppl. a.*
1903 *Cincinnati Enquirer* 9 May 13/1 Buffaloed—Bluffed. **1904** *N.Y. Even. Post* 25 Oct. 10 All the rest [of the newspapers] were what we used to term in the Southwest 'buffaloed' by the McKinley myth—that is, silenced by the fear of incurring the resentment of a people taught to regard McKinley as a saint. **1910** W. M. RAINE *B. O'Connor* 77 O'Connor admitted that he was 'buffaloed' when he attempted an analysis of his unusual feeling. **1947** E. A. McCourt *Flaming Hour* 118 Jerry Potts himself would have been buffaloed.

buffalo, *n.* **singular or plural common noun**
(ˈbʌfələʊ)
Forms: 6 **buffalo**, (7 **buffolo**, **boufaleau**, **-alo**, 7–8 **buffelo**, 8 **bufolo**), 7– **buffalo**. *pl.* **buffaloes**.
[a. It. *buffalo* (Florio), *bufalo*, *bufolo* (Baretti), or Pg. *búfalo*:—vulgar L. **būfalus*, a. Gr. βούβαλος (whence in literary L. *būbalus*), properly denoting a kind of antelope, but applied to a wild ox. Cf. **BUFFLE**, **BUFF** *n.*² The early quotations suggest that the word originally came into English from Portuguese.]
1. The name of several species of Oxen; esp. **a.** *Bos bubalus*, originally a native of India, inhabiting most of Asia, southern Europe, and northern Africa. It is tamed in India, Italy, and elsewhere. **b.** *B. caffer*, the Cape Buffalo of S. Africa. **c.** Applied in popular unscientific use to the American **BISON**.
a. **1588** PARKE tr. *Mendoza's China* 181 They doo plough and till their ground with kine, Bufalos, and bulles. **1665** *Voy. E. India* 359 They have a Beast very large, having a smooth thick skin without hair, called a Buffelo, which gives good milk; the flesh of them is like Beef. **1682**

Buffalo (the city)



- City in New York State
 - *close to the Canadian border*

Step by step

1. Buffalo buffalo (NNP NNS)
 - buffalo (*animal*) from Buffalo (*city*)
2. Buffalo buffalo buffalo (NNP NNS VBP)
 - buffalo (from the city of) Buffalo outwit ...
3. Buffalo buffalo buffalo Buffalo buffalo (NNP NNS VBP NNP NNS)
 - buffalo (from) Buffalo outwit buffalo (from) Buffalo

Key:

1. NN Common Noun
2. NNS (plural) Common Noun
3. NNP Proper Noun
4. VB Verb
5. VBP Verb (pres.)
6. VBZ Verb (pres., 3.sg)
7. REL relative pronoun
8. *t* trace

Step by step



3. Buffalo buffalo buffalo Buffalo buffalo
(NNP NNS VBP NNP NNS)
• buffalo (from) Buffalo outwit buffalo (from) Buffalo

let's form an object relative clause from 3.

4. Buffalo buffalo that Buffalo buffalo buffalo
(NNP NNS REL NNP NNS VBP *t*)
• buffalo (from) Buffalo that buffalo (from) Buffalo outwit

we can delete the relative '*that*' from an object relative clause

5. Buffalo buffalo Buffalo buffalo buffalo
(NNP NNS ~~REL~~ NNP NNS VBP *t*)

Key:

1. NN Common Noun
2. NNS (plural) Common Noun
3. NNP Proper Noun
4. VB Verb
5. VBP Verb (pres.)
6. VBZ Verb (pres., 3.sg)
7. REL relative pronoun
8. *t* trace
(unpronounced copy)

Step by step

5. Buffalo buffalo Buffalo buffalo buffalo
(NNP NNS ~~REL~~ NNP NNS VBP *t*)

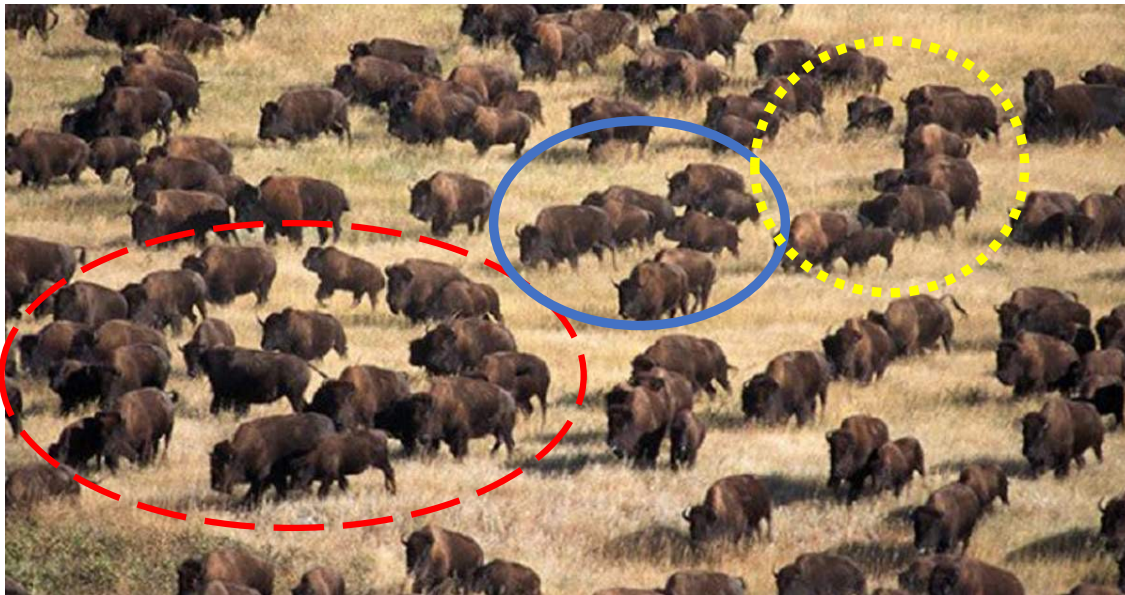


Key:

1. NN Common Noun
2. NNS (plural) Common Noun
3. NNP Proper Noun
4. VB Verb
5. VBP Verb (pres.)
6. VBZ Verb (pres., 3.sg)
7. REL relative pronoun
8. *t* trace

Step by step

6. Buffalo buffalo Buffalo buffalo buffalo buffalo Buffalo buffalo
(NNP NNS ~~REL~~ NNP NNS **VBP** *t* VBP NNP NNS)



Key:

1. NN Common Noun
2. NNS (plural) Common Noun
3. NNP Proper Noun
4. VB Verb
5. VBP Verb (pres.)
6. VBZ Verb (pres., 3.sg)
7. REL relative pronoun
8. *t* trace

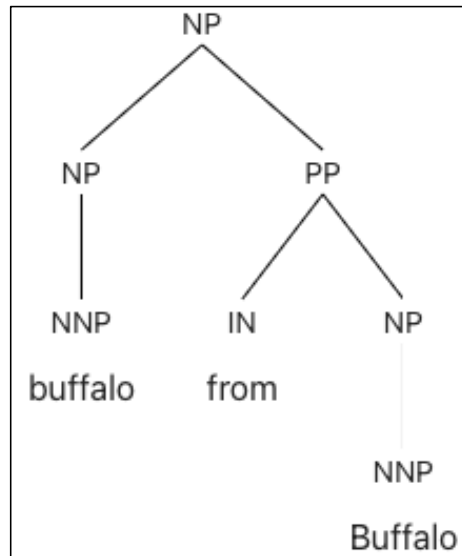
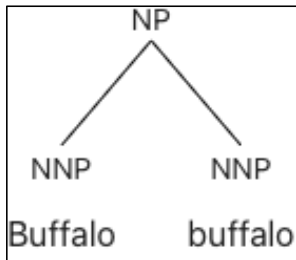
Some online syntactic parsers

- Phrase structure (PS) parsers:
 - Berkeley Neural Parser: <https://parser.kitaev.io>
- Older generation PS parsers:
 - Berkeley Parser (*not longer available online*): <http://tomato.banatao.berkeley.edu:8080/parser/parser.html>
 - Stanford Parser (*not longer available online*): <http://nlp.stanford.edu:8080/parser/index.jsp>
- Dependency parsers:
 - Stanza (Stanford) <http://stanza.run>
 - UDPipe <https://lindat.mff.cuni.cz/services/udpipe/>
 - Google Natural Language (*syntax no longer available*): <https://cloud.google.com/natural-language/>

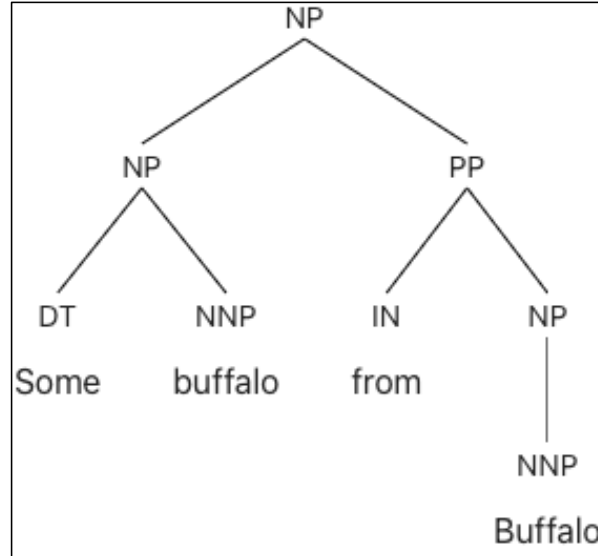
Berkeley Neural Parser

1. Buffalo buffalo (NNP NNS)

- buffalo (*animal*) from Buffalo (*city*)



older Berkeley Parser: adjP

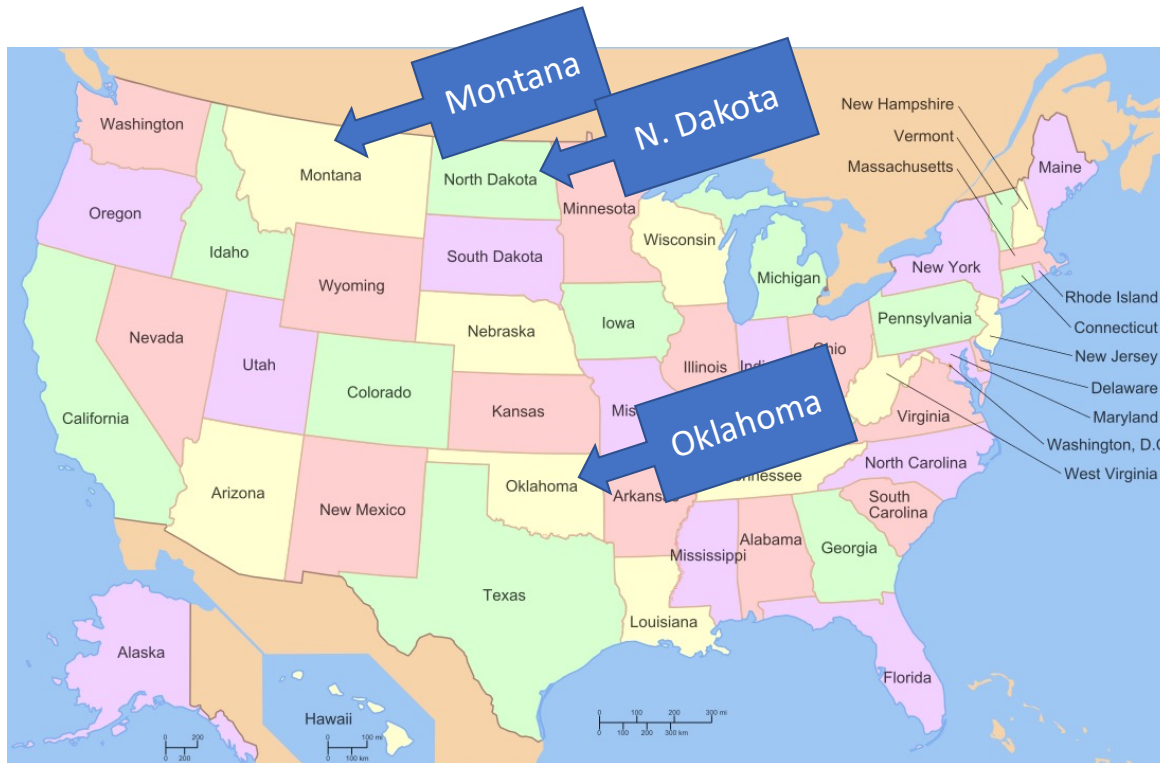


older Berkeley Parser: S

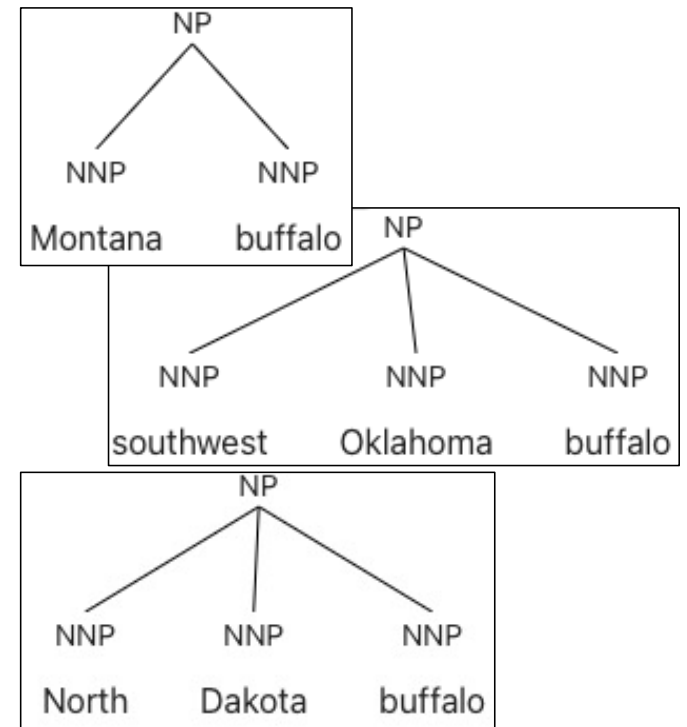
Key:

- | | | |
|-----|-----|----------------------|
| 1. | NN | Common Noun |
| 2. | NNS | (plural) Common Noun |
| 3. | NNP | Proper Noun |
| 4. | DT | Determiner |
| 5. | JJ | Adjective |
| 6. | VB | Verb |
| 7. | VBP | Verb (pres.) |
| 8. | VBZ | Verb (pres. 3.sg) |
| 9. | REL | relative pronoun |
| 10. | t | trace |

Berkeley Neural Parser



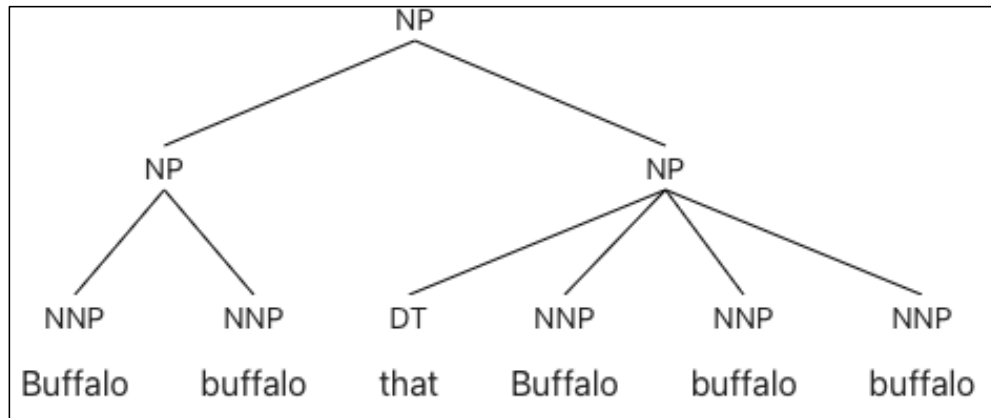
- States:



Berkeley Neural Parser

object relative clause:

4. Buffalo buffalo **that** Buffalo buffalo **buffalo** (NNP NNS **REL** NNP NNS **VBP** *t*)



older Berkeley Parser: S, 2nd word is VBP

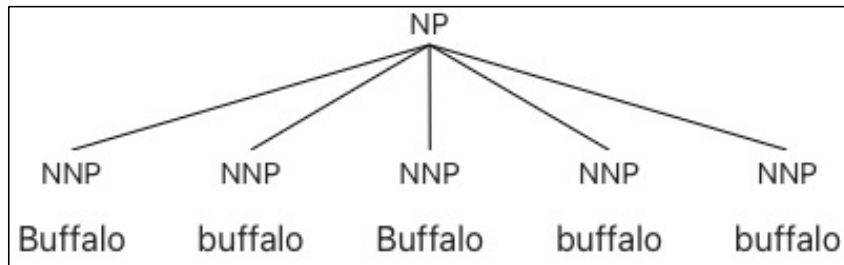
Key:

1. NN Common Noun
2. NNS (plural) Common Noun
3. NNP Proper Noun
4. DT Determiner
5. VBP Verb (pres.)
6. VBZ Verb (pres., 3.sg)
7. REL relative pronoun
8. *t* trace

Berkeley Neural Parser

object relative clause:

5. Buffalo buffalo Buffalo buffalo buffalo (NNP NNS ~~REL~~ NNP NNS VBP *t*)

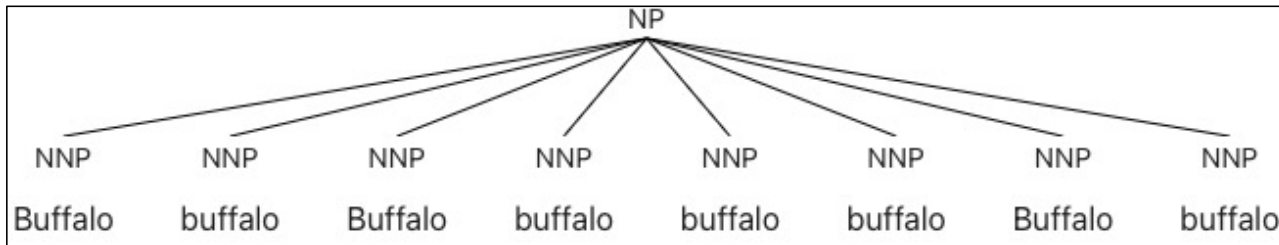


Key:

1. NN Common Noun
2. NNS (plural) Common Noun
3. NNP Proper Noun
4. DT Determiner
5. VBP Verb (pres.)
6. VBZ Verb (pres., 3.sg)
7. REL relative pronoun
8. *t* trace

Berkeley Neural Parser

6. Buffalo buffalo Buffalo buffalo buffalo Buffalo buffalo
(NNP NNS ~~REL~~ NNP NNS **VBP** *t* VBP NNP NNS)



Key:

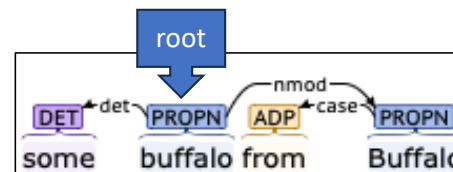
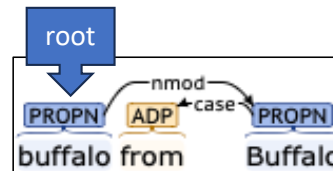
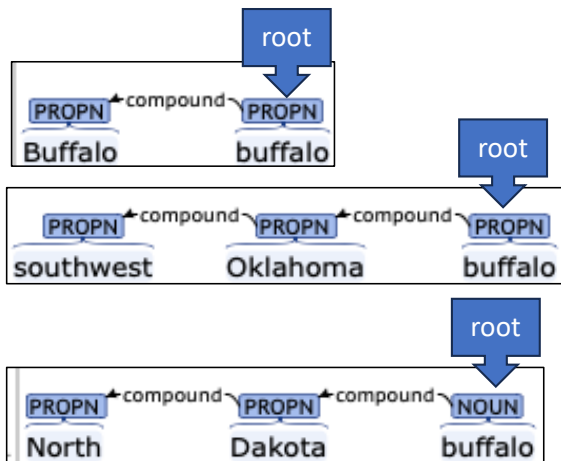
1. NN Common Noun
2. NNS (plural) Common Noun
3. NNP Proper Noun
4. DT Determiner
5. VBP Verb (pres.)
6. VBZ Verb (pres., 3.sg)
7. REL relative pronoun
8. *t* trace

older Berkeley Parser: S, 4th word is VBP

Stanza

1. Buffalo buffalo (NNP NNS)

- buffalo (*animal*) from Buffalo (*city*)



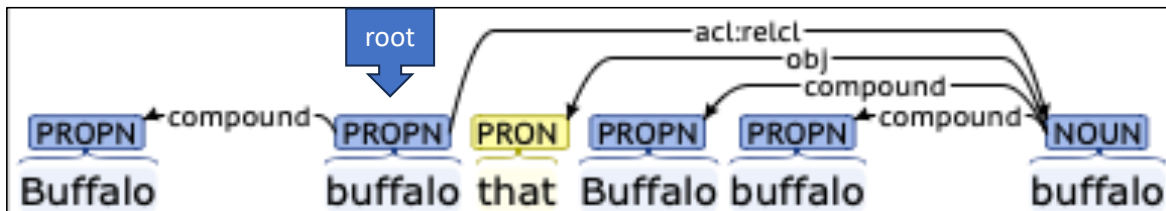
Key:

1. root head of phrase/clause
2. nmod nominal dependent of a noun
3. case case-marking element
4. compound compound
5. det determiner
6. obj object of a verb
7. acl clausal modifier of noun
8. relcl relative clause
9. dep unspecified dependency

Stanza

object relative clause:

4. Buffalo buffalo **that** Buffalo buffalo **buffalo** (NNP NNS **REL** NNP NNS **VBP t**)



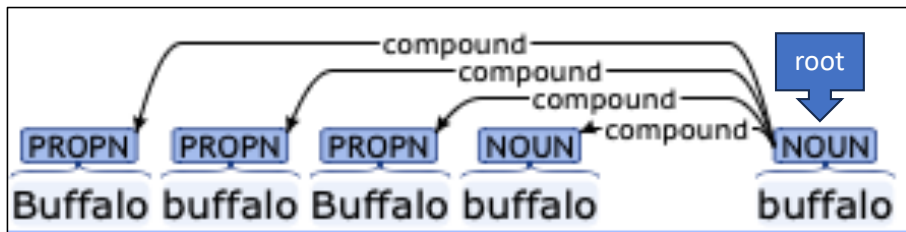
Key:

1. root head of phrase/clause
2. nmod nominal dependent of a noun
3. case case-marking element
4. compound compound (*directional*)
5. det determiner
6. obj object of a verb
7. acl clausal modifier of noun
8. relcl relative clause
9. dep unspecified dependency

Stanza

object relative clause:

5. Buffalo buffalo Buffalo buffalo buffalo (NNP NNS ~~REL~~ NNP NNS VBP *t*)

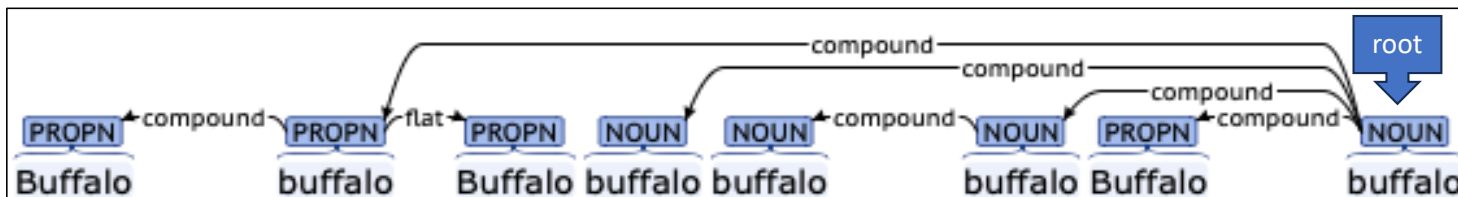


Key:

1. root head of phrase/clause
2. nmod nominal dependent of a noun
3. case case-marking element
4. compound compound (*directional*)
5. det determiner
6. obj object of a verb
7. acl clausal modifier of noun
8. relcl relative clause
9. dep unspecified dependency

Stanza

6. Buffalo buffalo Buffalo buffalo buffalo Buffalo buffalo
 (NNP NNS ~~REL~~ NNP NNS ~~VBP t~~ VBP NNP NNS)



Key:

1. root head of phrase/clause
2. nmod nominal dependent of a noun
3. case case-marking element
4. compound compound (*directional*)
5. flat none of the immediate components can be identified as the sole head

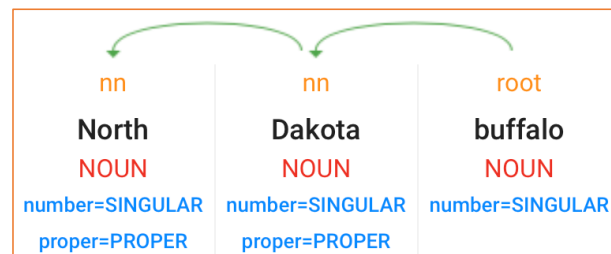
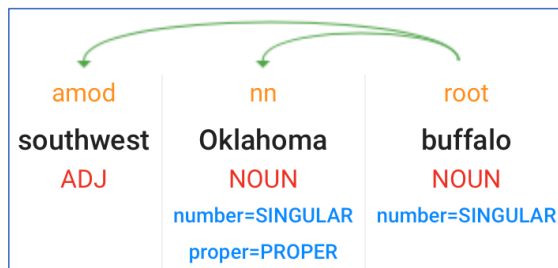
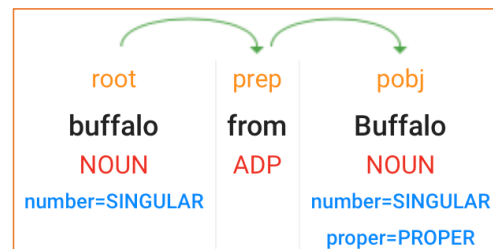
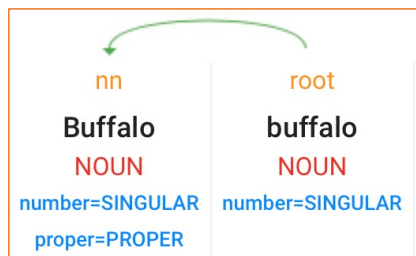
Google Natural Language

1. Buffalo buffalo (NNP NNS)

- buffalo (*animal*) from Buffalo (*city*)

Key:

1. root head of phrase/clause
2. pobj object of preposition
3. prep preposition
4. nn noun compound
5. amod adjectival modifier



ChatGPT



You

Buffalo buffalo Buffalo buffalo buffalo buffalo Buffalo buffalo. Can you tell me what happened in the previous sentence?



ChatGPT

Certainly! The sentence "Buffalo buffalo Buffalo buffalo buffalo buffalo Buffalo buffalo" is an example of a wordplay-based sentence in English. It is often used as an illustration of how homonyms and homophones can be combined to create a grammatically correct, albeit confusing, sentence.

ChatGPT

Let's break it down:

1. Buffalo (capitalized) refers to the city of Buffalo, New York.
2. buffalo (lowercase) can refer to the animal.

Now, let's substitute these meanings into the sentence:

- "Buffalo
1. Buffalo buffalo (Buffalo bison) that Buffalo buffalo buffalo (that Buffalo bison bully),
 2. Buffalo buffalo Buffalo buffalo buffalo (Buffalo bison from Buffalo, New York, bully),
 3. Buffalo buffalo Buffalo buffalo buffalo buffalo Buffalo buffalo. (Buffalo bison from Buffalo, New York, that Buffalo bison bully, themselves bully Buffalo bison).

So, the sentence is saying that buffalo from Buffalo, New York, who are buffaloes by other buffalo from Buffalo, New York, buffalo other buffalo from Buffalo, New York. It's a play on the meanings of "buffalo" as both a proper noun and a verb.

CFG Chart Parsing

buffalo.txt

```
1 S -> NP VP ¶
2 NP -> NNP NNS ¶
3 VP -> VBP NP ¶
4 VP -> VBD NP ¶
5 NNP -> 'Buffalo' ¶
6 NNS -> 'buffalo' ¶
7 VBP -> 'buffalo' ¶
8 VBD -> 'buffaloed' ¶
9 NP -> NP RELC ¶
10 RELC -> REL RELS ¶
11 RELC -> RELS ¶
12 REL -> 'that' ¶
13 RELS -> NP VPREL ¶
14 VPREL -> VBP ¶
15 VPREL -> VBD ¶
```

- Recall from the last lecture:

```
python
```

```
Python 3.9.12 (main, Jun 1 2022, 06:34:44)
```

```
>>> import nltk
```

```
>>> f = open('buffalo.txt','r')
```

```
>>> raw = f.read()
```

```
>>> raw
```

```
"S -> NP VP\nNP -> NNP NNS\nVP -> VBP NP\nVP -> VBD NP\nNP -> 'Buffalo'\nNNS -> 'buffalo'\nVBP -> 'buffalo'\nVBD -> 'buffaloed'\nNP -> NP RELC\nRELC -> REL RELS\nRELC -> RELS\nREL -> 'that'\nRELS -> NP VPREL\nVPREL -> VBP\nVPREL -> VBD\n"
```

```
>>> cfg = nltk.CFG.fromstring(raw)
```

```
>>> cfg
```

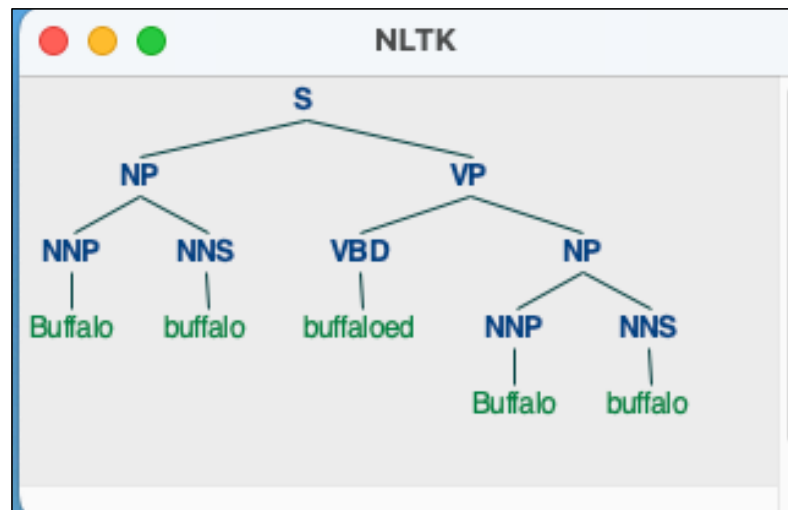
```
<Grammar with 15 productions>
```

```
>>> p = nltk.ChartParser(cfg)
```

CFG Chart Parsing

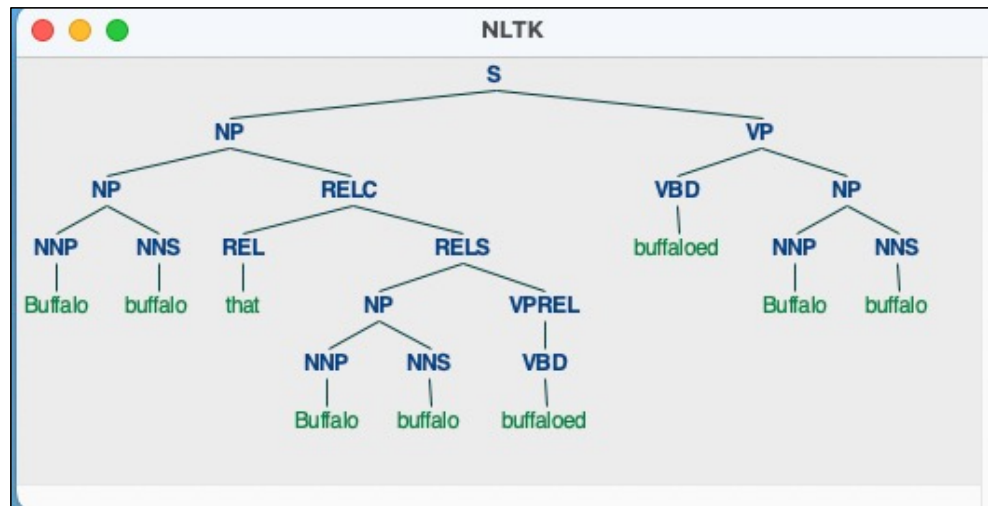
- Example:

```
>>> for t in p.parse(['Buffalo', 'buffalo', 'buffaloed', 'Buffalo',  
...                 'buffalo']):  
...     t.draw()  
... 
```



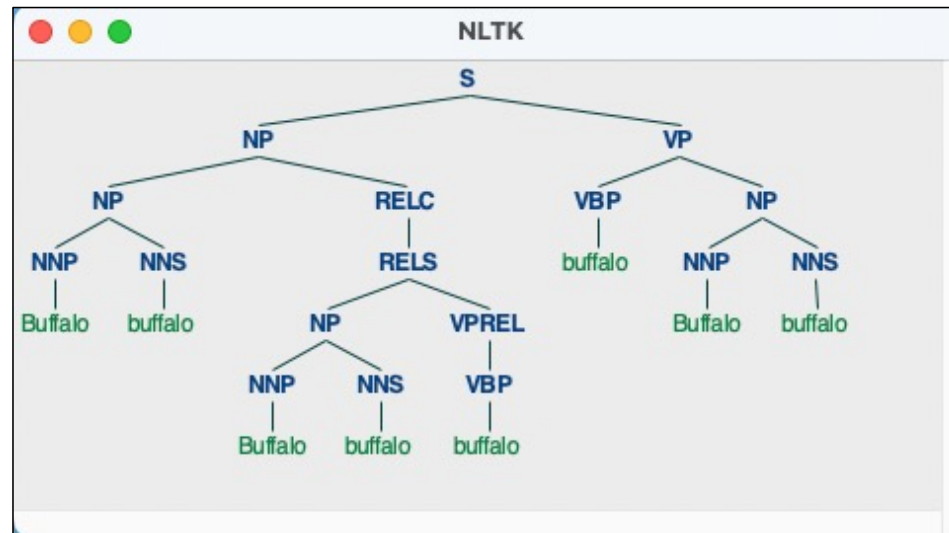
CFG Chart Parsing

- Example:
- ```
>>> for t in parse(['Buffalo', 'buffalo', 'that', 'Buffalo',
 'buffalo', 'buffaloed', 'buffaloed', 'Buffalo', 'buffalo']):
```
- ... `t.draw()`
- ...



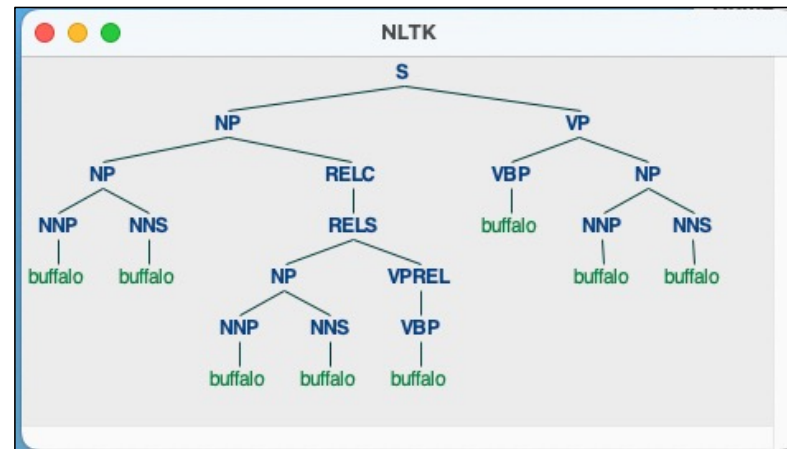
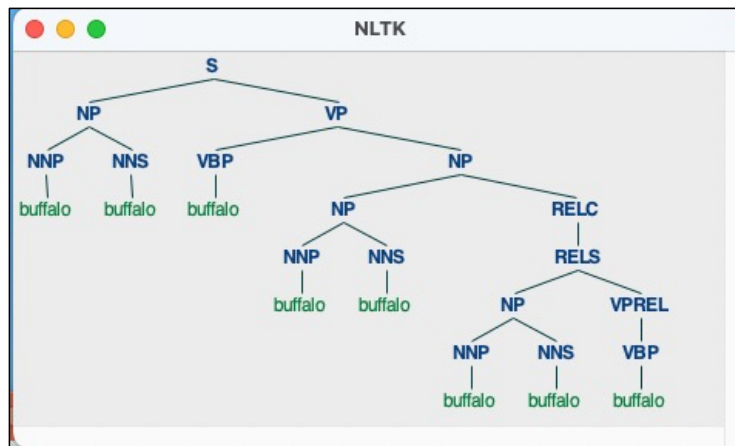
# CFG Chart Parsing

- Example:
- ```
>>> for t in p.parse(['Buffalo', 'buffalo', 'Buffalo', 'buffalo',  
    'buffalo', 'buffalo', 'Buffalo', 'buffalo']):
```
- ... `t.draw()`
- ...



CFG Chart Parsing

- We can remove the initial capitalization for *Buffalo* or permit non-capitalized *buffalo*.
- What happens?



CFG Chart Parsing

- Running the general case:

```
>>> for t in p.parse(['buffalo'] * 9):
```

```
...     t.draw()
```

```
...
```

```
>>> for t in p.parse(['buffalo'] * 10):
```

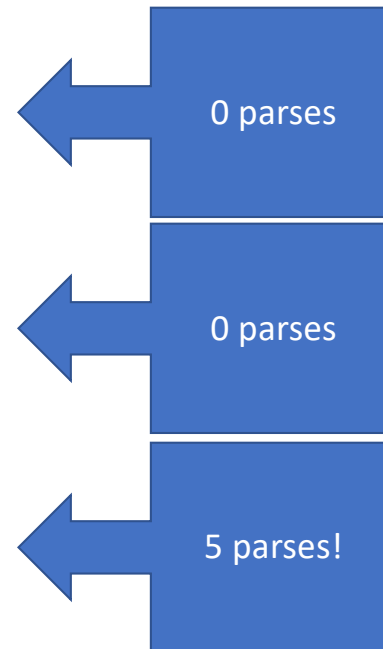
```
...     t.draw()
```

```
...
```

```
>>> for t in p.parse(['buffalo'] * 11):
```

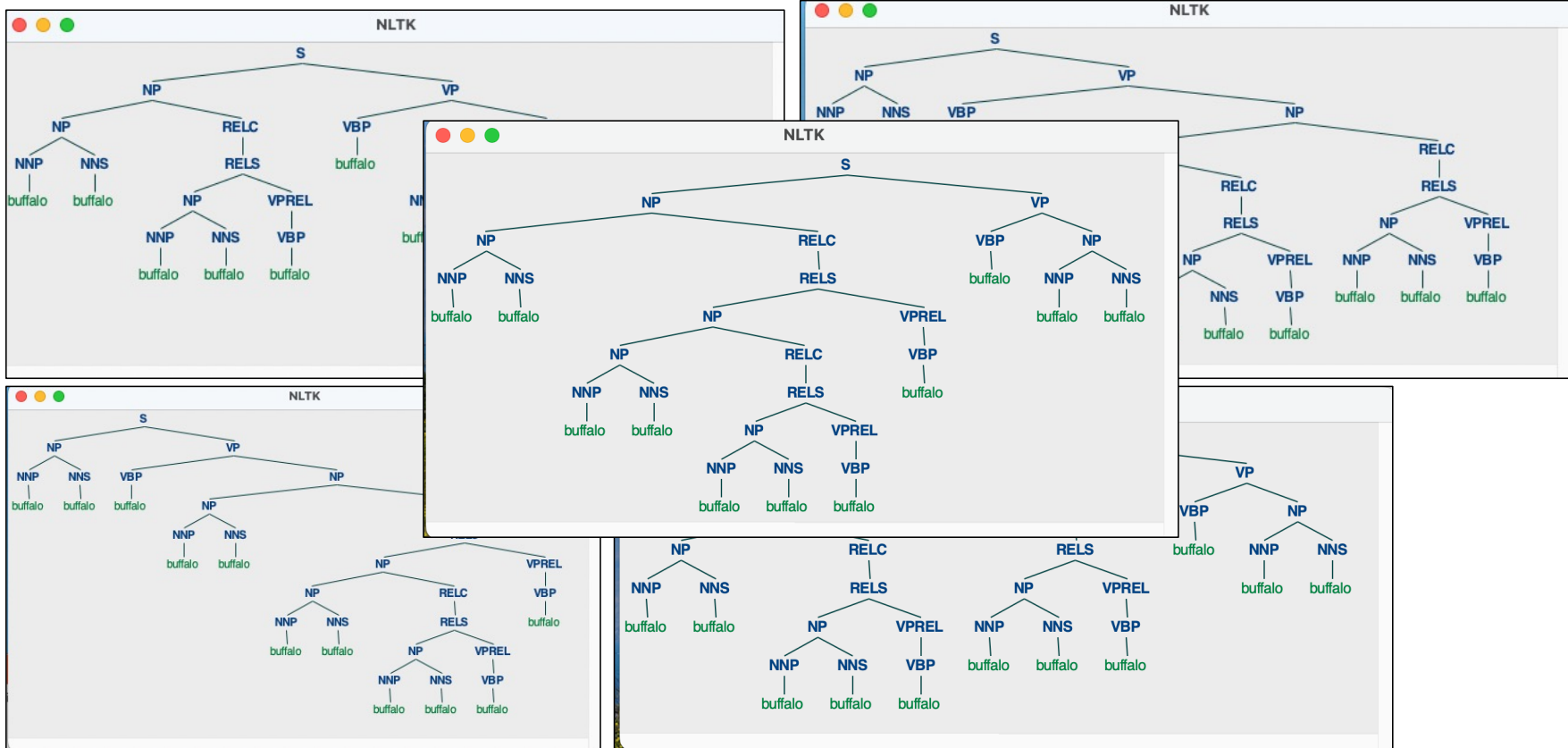
```
...     t.draw()
```

```
...
```



`['string'] * N` means make a list with N consecutive copies of 'string'

CFG Chart Parsing



CFG Chart Parsing

