# Feature engineering in NLP

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# Contents

# 1. Presentation of text in NLP

# Are these sentences equal?

*Trump beat Clinton in the election.*

**?**

*Clinton beat Trump in the election.*

# Presentation of text in NLP

- Bag of words

# Presentation of text in NLP

- Bag of words


- Sequence

I shot an elephant in my pajamas.

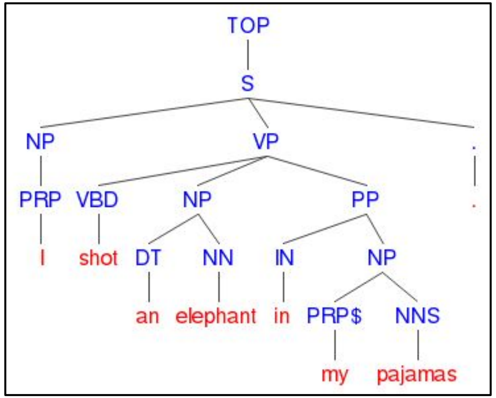
# Presentation of text in NLP

- Bag of words


- Sequence

I shot an elephant in my pajamas.

- Tree



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I shot an elephant in my pajamas.

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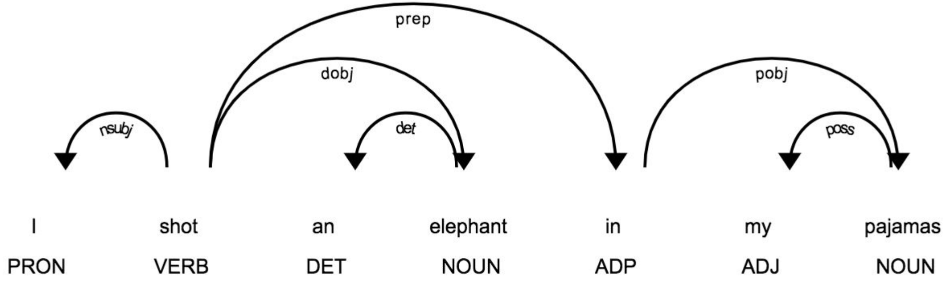

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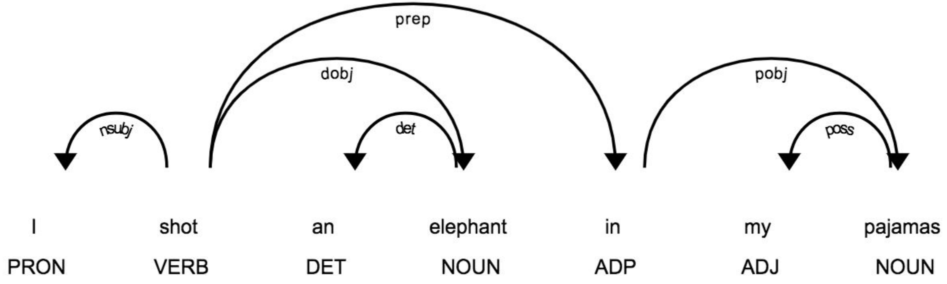


- Graph

# Presentation of text in NLP

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I shot an elephant in my pajamas.

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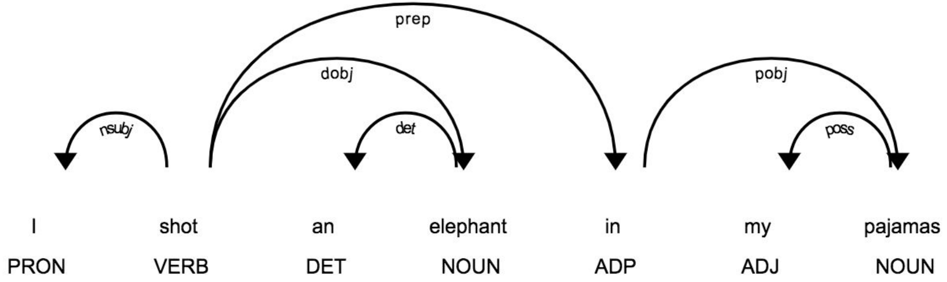


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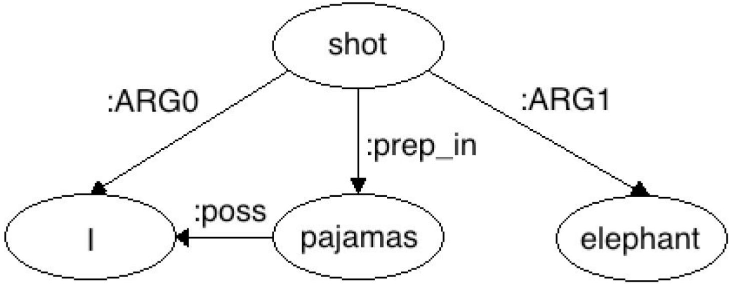

# Think of different NLP tasks

How would you view the text if you need...

- classification of news articles by topic?
- named-entity recognition?
- sentiment assignment to objects in the text?
- abstractive text summarization?

# 2. Feature engineering

# The Word

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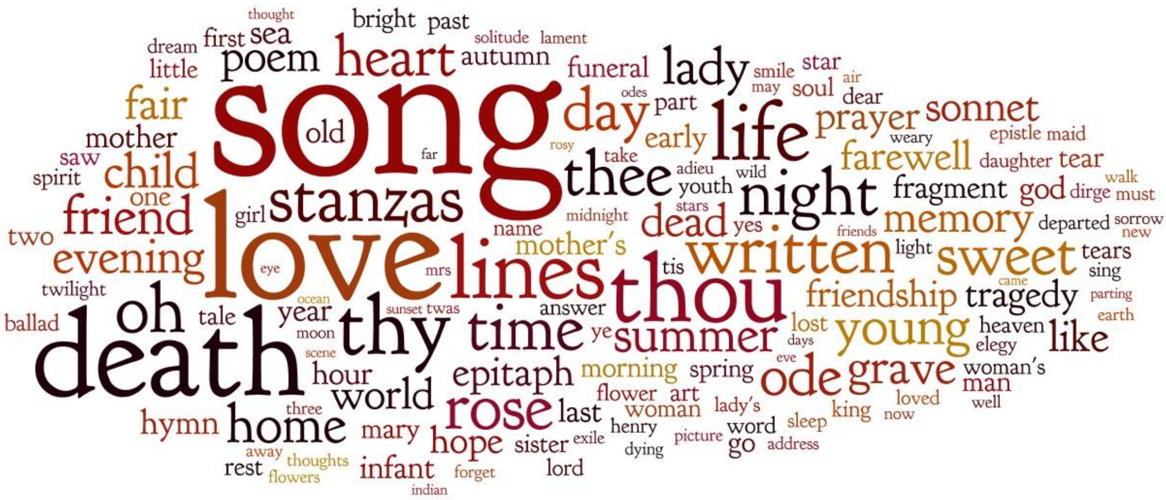
A word is its...

1. form
2. function
3. meaning



# The Form

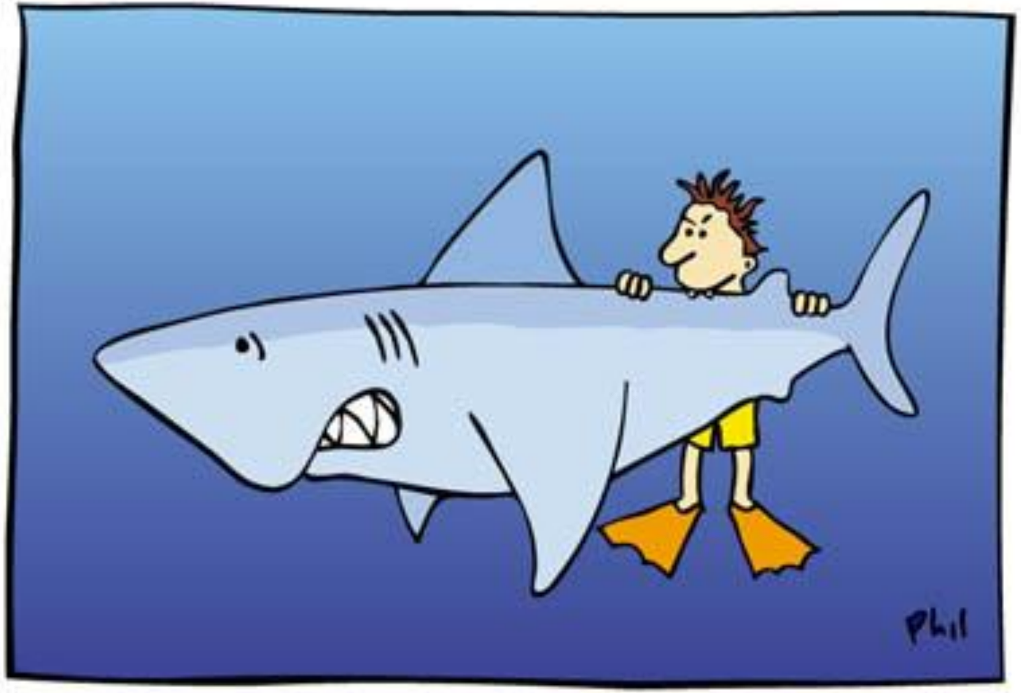
The form — how the word is written.

# Form Features

- Capitalization, hyphenation, apostrophes
- Lemma or stem
- Number of stems
- Number and types of affixes
- Length of the word/lemma/stem
- Number of tokens, position of a token
- Number of syllables in a word
- Ratio of vowels vs. consonants
- Voiced vs. voiceless consonants
- All possible frequencies

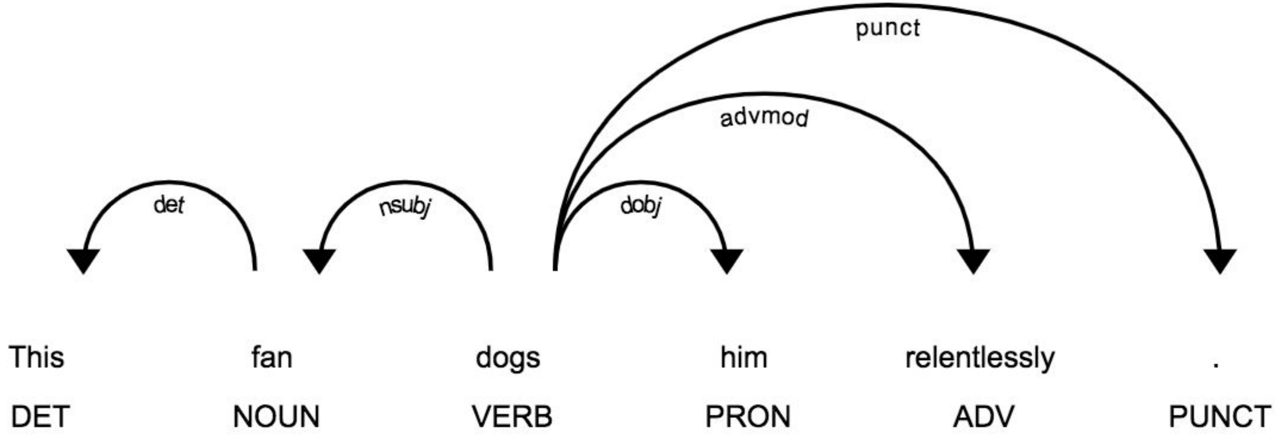
# Form Features

a ***man-eating*** *shark* vs. a ***man eating*** *shark*



# The Function

The function — what the word does and how it interacts with other words in the text.

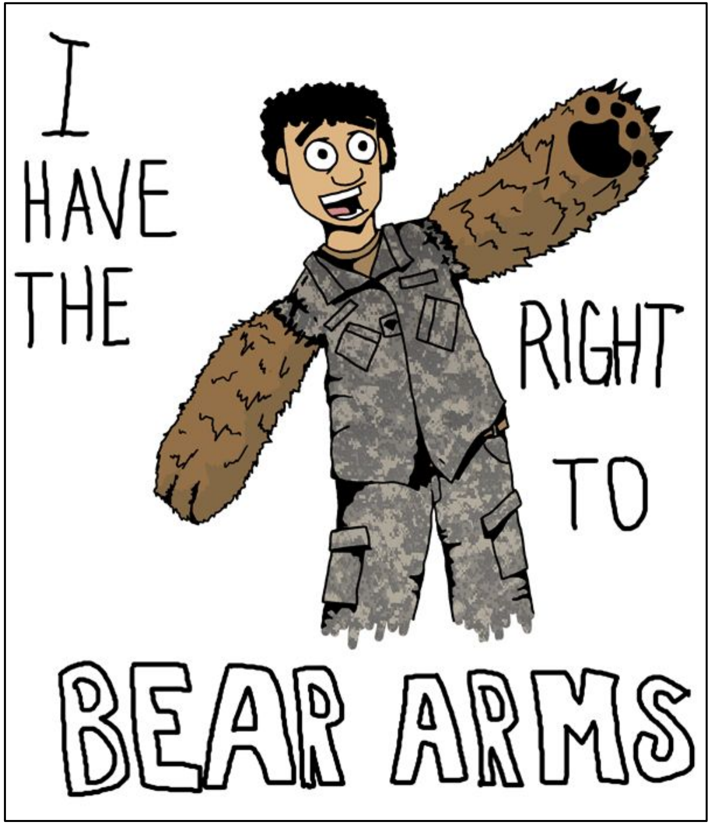


# Function Features

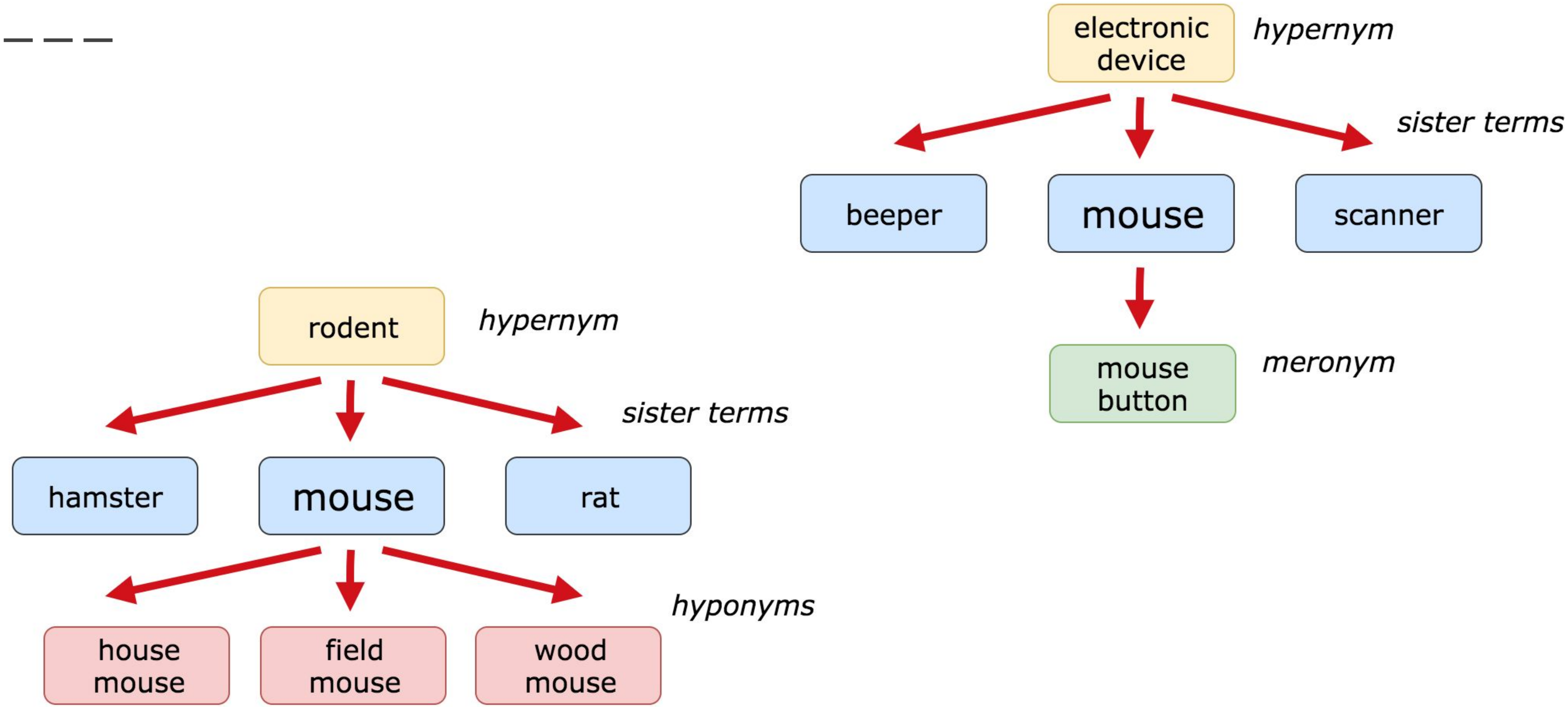
- Part of speech
- Morphological properties:
  - *gender, animacy, number, person, case*
  - *aspect, voice, tense, degree of comparison*
- Constituents
  - *parents, children, spans*
- Direct and indirect dependencies
  - *parents, children, type of relation*
- Depth of the syntactic tree
- Statistics: *POS+word, POS ngrams, syntactic ngrams*

# The Meaning

The meaning — the sense that the word obtains in the context and how it correlates with other words and senses.



# Lexical Semantics in WordNet



# Entailment (or inference)

Entailment examples:

- *Mom slices a cucumber. => A woman cuts a vegetable.*
- *Her husband was snoring. => Her husband was sleeping.*
- *A jogger was spotted. => Someone was jogging.*
- *The king of France is bald. => There exists a king of France.*

# Meaning Features

- Word sense
- Number of senses
- Shortest path to another word sense
- Similarity to another sense
- Synonyms/antonyms, hyponyms/hypernyms, meronyms/holonyms
- Entailment
- Semantic role

# 3. Feature encoding

# Encode as a bag of words: boolean

```
The pound extended losses against both the dollar and the euro .
```

| | | | | | | |
|---|---|---|---|---|---|---|
| [ 1, | 1, | 0, | 0, | 1, | 0, | ...] |
| the | dollar | hello | pirate | losses | run | |

# Encode as a bag of words: count

`The pound extended losses against both the dollar and the euro .`

| | | | | | | |
|---|---|---|---|---|---|---|
| [ 3, | 1, | 0, | 0, | 1, | 0, | …] |
| the | dollar | hello | pirate | losses | run | |

# Encode as a bag of words: tf-idf

```
The pound extended losses against both the dollar and the euro .
```

| [ 0.1, | 0.7, | 0, | 0, | 0.4, | 0, | …] |
|---|---|---|---|---|---|---|
| *the* | *dollar* | *hello* | *pirate* | *losses* | *run* | |

# Encode as a bag of features

| DT | NN | VBD | NNS | IN | DT | DT | NN | CC | DT | NN | . |
|---|---|---|---|---|---|---|---|---|---|---|---|
| The | pound | extended | losses | against | both | the | dollar | and | the | euro | . |

**“losses”/NNS:**

{“word-1”: “extended”, “tag-1”: “VBD”,
“word-2”: “pound”, “tag-2”: “NN”,
“word+1”: “against”, “tag+1”: “IN”,
“word+2”: “both”, “tag+2”: “DT”}

# Encode as a bag of features

| DT | NN | VBD | NNS | IN | DT | DT | NN | CC | DT | NN | . |
|---|---|---|---|---|---|---|---|---|---|---|---|
| The | pound | extended | losses | against | both | the | dollar | and | the | euro | . |

*[ 1,* *1,* *0,* *…]*

word-1=extended word-2=pound word+1=turtle

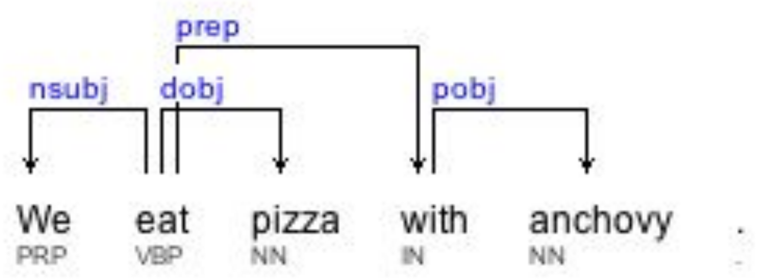
# Encode as a bag of features

| DT | NN | VBD | NNS | IN | DT | DT | NN | CC | DT | NN | . |
|---|---|---|---|---|---|---|---|---|---|---|---|
| The | pound | extended | losses | against | both | the | dollar | and | the | euro | . |

**“losses”/NNS:**

{*“left-bigram”:* *“pound extended”,*
*“right-bigram”:* *“against both”,*
*“context”:* *“extended losses against both”}*

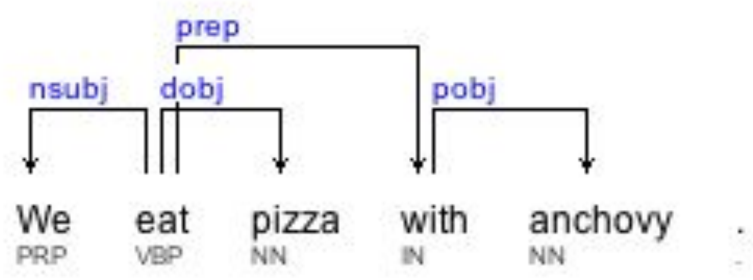
# Encode as a bag of features




**“eat”/VBP:**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *[ 1,* | *0,* | *0,* | *1,* | *0,* | *1,* | *0,* | *0,* | *…]* |
| *nsubj* | *acl* | *relcl* | *dobj* | *pobj* | *prep* | *punct* | *xcomp* | |

# Encode as a bag of features



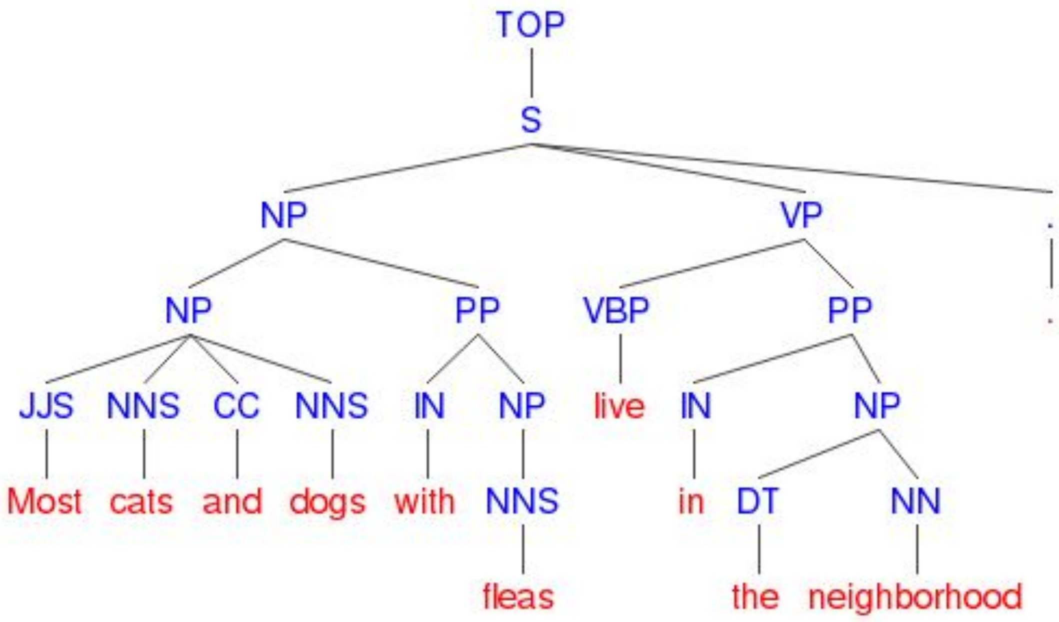

**“eat”/VBP:**

- *nsubj_We, dobj_pizza, prep_with*
- *nsubj_PRP, dobj_NN, prep_IN*
- *nsubj_We, dobj_pizza, prep_with_pobj_anchovy*

# Encode as a bag of features

**“fleas”/NNS:**

{“*label*”: “*NP*”,
“*anc-left*”: ”*PP*”,
“*anc-right*”: ”*S*”,
“*span-width*”:*1*}



# Example

https://bit.ly/2KNsiLJ

or

https://github.com/mariana-scorp/esscass-2019-nlp/blob/master/2-features/feature-encoding.ipynb

# 4. A few words about ngrams (optional)

# What are ngrams

Ngram - a contiguous sequence of ***n*** items from a given text.

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*<S> Why did n't you listen to me ? </S>*

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Ngram - a contiguous sequence of ***n*** items from a given text.

So, if ***n* = 3**:

*<S> Why did n’t you listen to me ? </S>*

# Token ngrams

Usually 1 ≥ n ≥ 5.

*<S>   Why   did   n’t   you   listen   to   me   ?   </S>*

***n = 1***: *(<S>), (Why), (did), (n’t), (you), (listen), (to), (me), (?)...*
***n = 2***: *(<S> Why), (Why did), (did n’t), (n’t you), (you listen), (listen to)...*
***n = 3***: *(<S> Why did), (Why did n’t), (did n’t you), (you listen to)...*
...

# Character Ngrams

*<S> Why did n’t you listen to me ? </S>*

For words:

***n = 3***: (<w> W *h*), (W *h y*), (*h y* </w>), (<w> d *i*), (d *i* d), (*i* d *n*), (d *n* ‘)...

For sentences:

***n = 3***: (W *h y*), (*h y* _), (*y* _ d), (_ d *i*), (d *i* d), (*i* d *n*), (d *n* ‘), (*n* ‘ t)...

# POS Ngrams

<S> Why did n’t you listen to me ? </S>

<S> WDT VDB RB PRP VB TO PRP . </S>

POS:

***n* = 3**: (<S>, WDT, VBD), (WDT, VBD, RB), (VBD, RB, PRP), (RB, PRP, VB)...

Token+POS:

***n* = 2**: (<S>_<S>, Why_WDT), (Why_WDT, did_VBD), (did_VBD, n’t_RB)...

Token or POS:

***n* = 3**: (<S>, WDT, did), (WDT, did, RB), (did, RB, PRP), (RB, PRP, listen)...

# Tree Ngrams

Head+dependency:

*listen_nsubj*

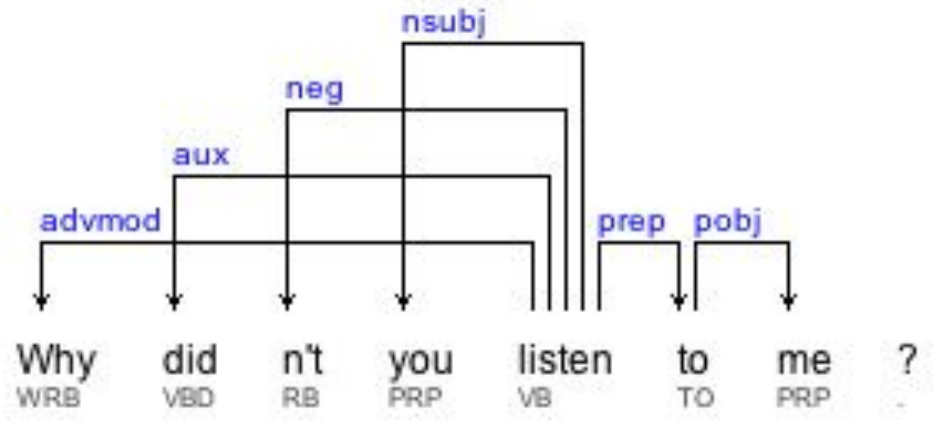
*listen_nsubj_you*

*listen_prep_to_pobj_me*

Head+POS+dependency:

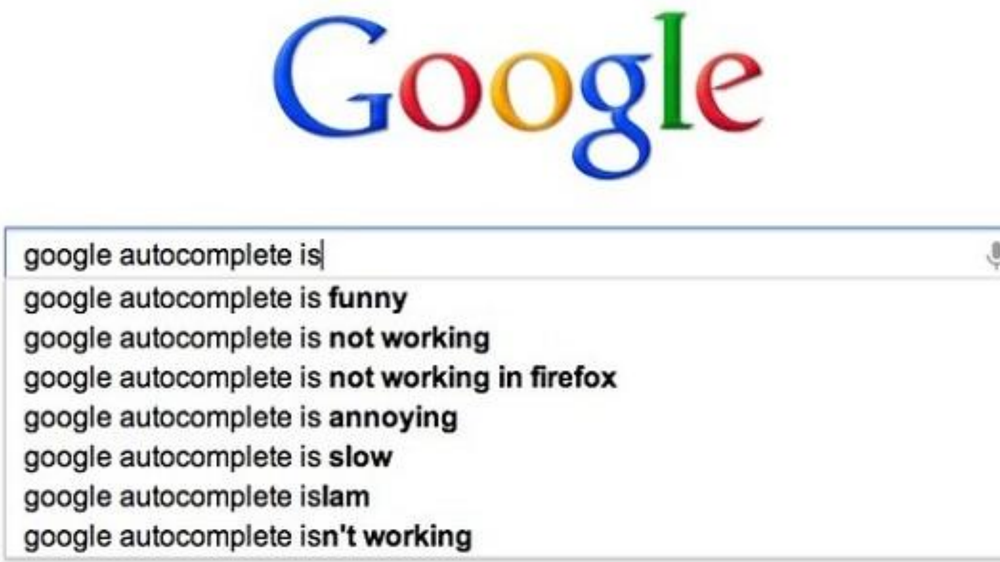
*listen/VB_nsubj*

*listen/VB_nsubj_you/PRP*



# Ngrams usage

- Speech recognition
- Text generation
- Autocompletion



# Ngrams usage

- Speech recognition
- Text generation
- Autocompletion
- Handwriting recognition
- Spelling correction
- (and GEC in general)




Borrowed from https://www.youtube.com/watch?v=l3pdGfKycz8

# Ngrams as a feature

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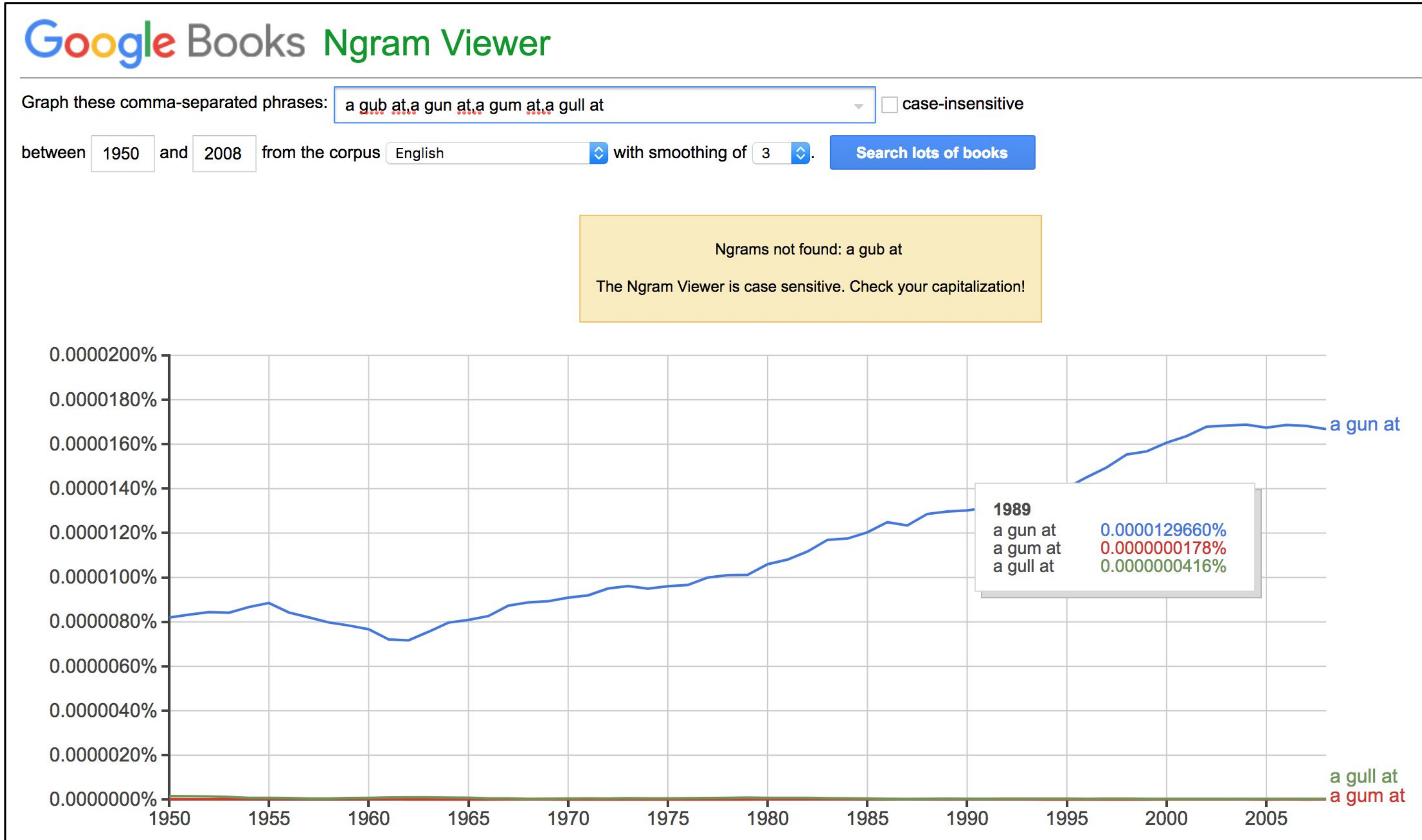
Frequency or probability:

a gub at

a gun at

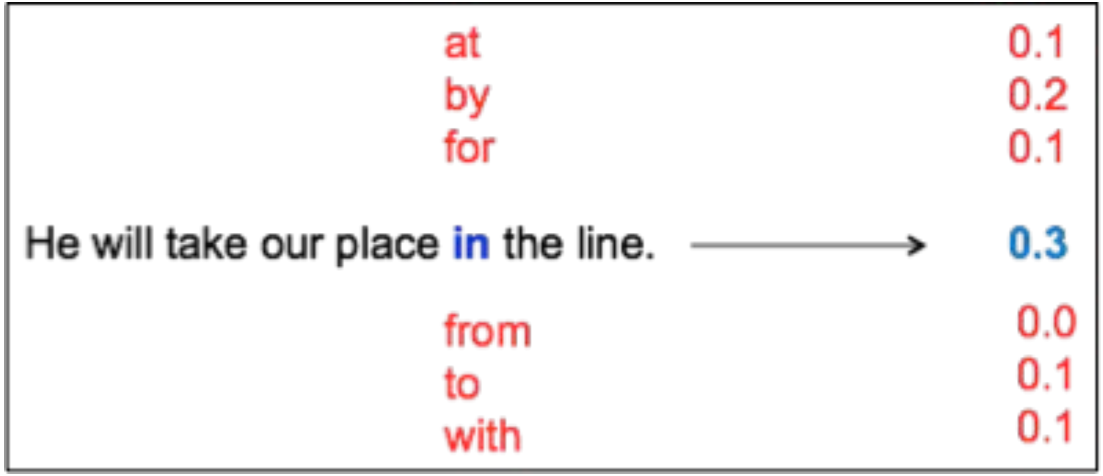
a gum at

a gull at



# Ngrams as a feature

Frequency or probability



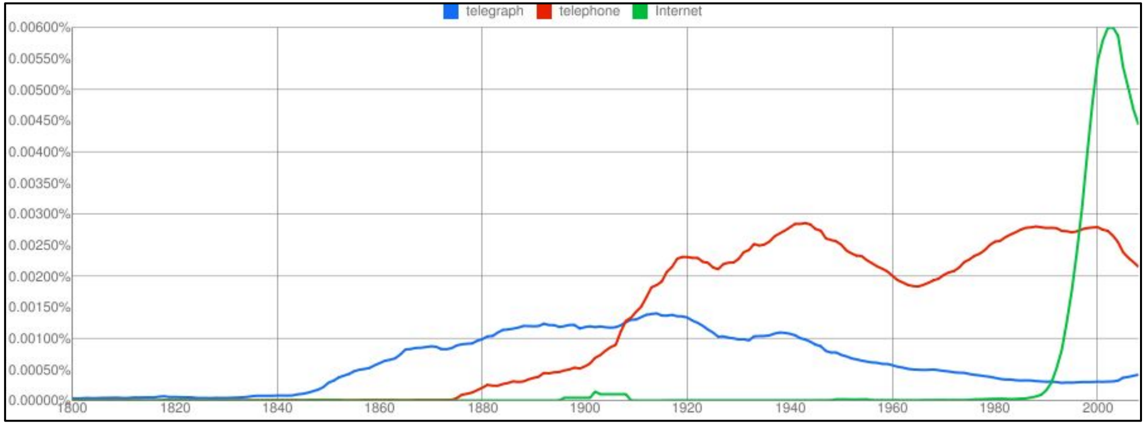
# Ngrams as a feature

Conditional probability

$$P(w_n|w_{n-1}) = \frac{C(w_{n-1}w_n)}{C(w_{n-1})}$$

# Where to get ngrams

- [1 mln of 2/3/4/5-ngrams from COCA]() for free
- [Google ngrams]() (and [how to download]())
- [Google syntactic ngrams]()
- collect on your own



# 5. Logistic Regression (optional)

# Logistic Regression

Logistic regression - a discriminative linear model used for binary classification.

- *like Perceptron*, it's linear
- *like Naive Bayes*, it extracts a set of weighted features, takes logs, and combines them linearly
- *unlike Naive Bayes*, it's discriminative

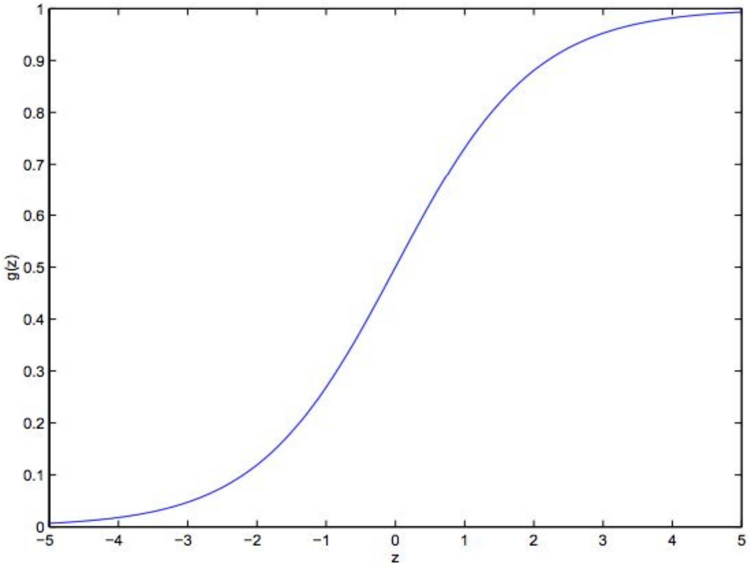
$$z = \left(\sum_{i=1}^{n} w_i x_i\right)$$

# Logistic Regression

A [0; 1] function would be handy: y = 1 if p(y=1|x) > 0.5.

Sigmoid function:

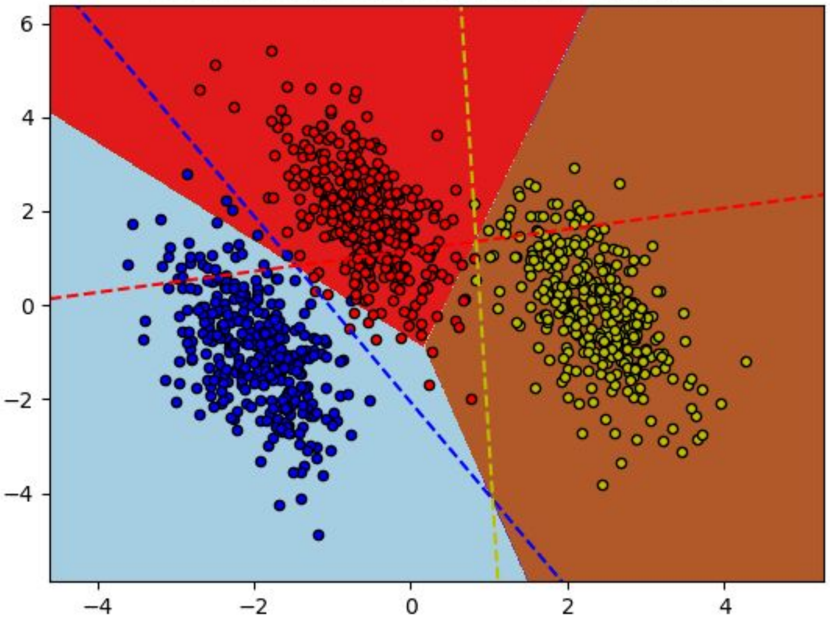
$$
\begin{aligned}
P(y=1) &= \sigma(w \cdot x + b) \\
&= \frac{1}{1+e^{-(w \cdot x + b)}}
\end{aligned}
$$



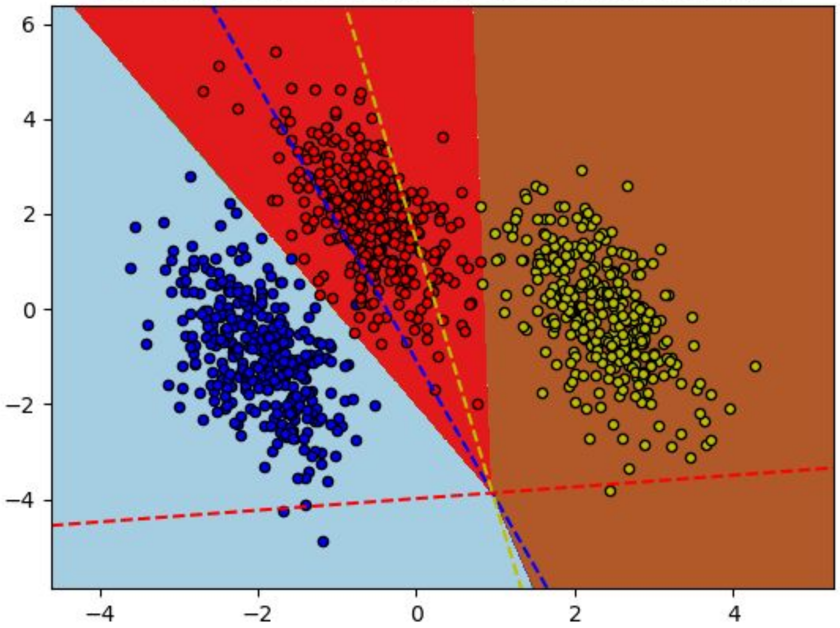

Borrowed from Andrew Ng: https://goo.gl/zGvb4W

# Logistic Regression: multiclass

one vs. rest




multinomial (MaxEnt)




http://scikit-learn.org/stable/auto_examples/linear_model/plot_logistic_multinomial.html

# Logistic Regression

For multinomial logistic regression, use softmax:

$$p(c|x) = \frac{\exp\left(\sum_{i=1}^{N} w_i f_i(c,x)\right)}{\sum_{c' \in C} \exp\left(\sum_{i=1}^{N} w_i f_i(c',x)\right)}$$

# Logistic Regression: example

*Welcome to St . Paul ‘s Cathedral !*

[Is this period a sentence end?]

# Logistic Regression: example

Welcome to St . *Paul* ‘s Cathedral !

[Is this period a sentence end?]

**y**: {*is-end*, *is-not-end*}
**x**: {“*word+1_is_cap*”, “*word-1=kittens*”, “*word-1=St*”, “*tag-1=PRP*”, “*tag+1=JJ*”}

# Logistic Regression: example

Welcome to St . Paul ‘s Cathedral !

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$\mathbf{x}_j$: *[1, 0, 1, 0, 0]*

# Logistic Regression: example

Welcome to St . Paul 's Cathedral !

[Is this period a sentence end?]

**y**: {*is-end*, *is-not-end*}
**x**: {"*word+1_is_cap*", "*word-1=kittens*", "*word-1=St*", "*tag-1=PRP*", "*tag+1=JJ*"}

$\mathbf{x}_j$: [1, 0, 1, 0, 0]

$\mathbf{w}_{is\text{-}end}$: [2.9, 2.5, -0.9, 0, 0]
$\mathbf{w}_{is\text{-}not\text{-}end}$: [0.5, -0.7, 2.9, 0, 0]

# Logistic Regression: example

Welcome to St . Paul ‘s Cathedral !

[Is this period a sentence end?]

***y***: *{is-end, is-not-end}*
**x**: {“word+1_is_cap”, “word-1=kittens”, “word-1=St”, “tag-1=PRP”, “tag+1=JJ”}

$\mathbf{x}_j$: [1, 0, 1, 0, 0]

$\mathbf{w}_{\text{is-end}}$: [2.9, 2.5, -0.9, 0, 0]
$\mathbf{w}_{\text{is-not-end}}$: [0.5, -0.7, 2.9, 0, 0]

$\mathbf{P(is\text{-}end|x_j)} = e^{2.9-0.9} / (e^{2.9-0.9} + e^{0.5+2.9}) = 0.2$
$\mathbf{P(is\text{-}not\text{-}end|x_j)} = e^{0.5+2.9} / (e^{2.9-0.9} + e^{0.5+2.9}) = 0.8$

# Logistic Regression: weights

Learn weights:

- start with a vector of zeros
- move towards the gradient
- to maximize the probability / minimize the loss function

$$\hat{w} = \underset{w}{\operatorname{argmax}} \sum_j \log P(y^{(j)} | x^{(j)})$$

# 6. Error correction use case

# Error correction use case

https://bit.ly/31GFZmd

or

https://github.com/mariana-scorp/esscass-2019-nlp/blob/master/2-features/adjective-vs-adverb.ipynb

Thank you! Any kwestions?