UNIVERSITÀ DEGLI STUDI DI NAPOLI
PARTHENOPE

Natural Language Processing

Elements of Linguistics

LESSON 2

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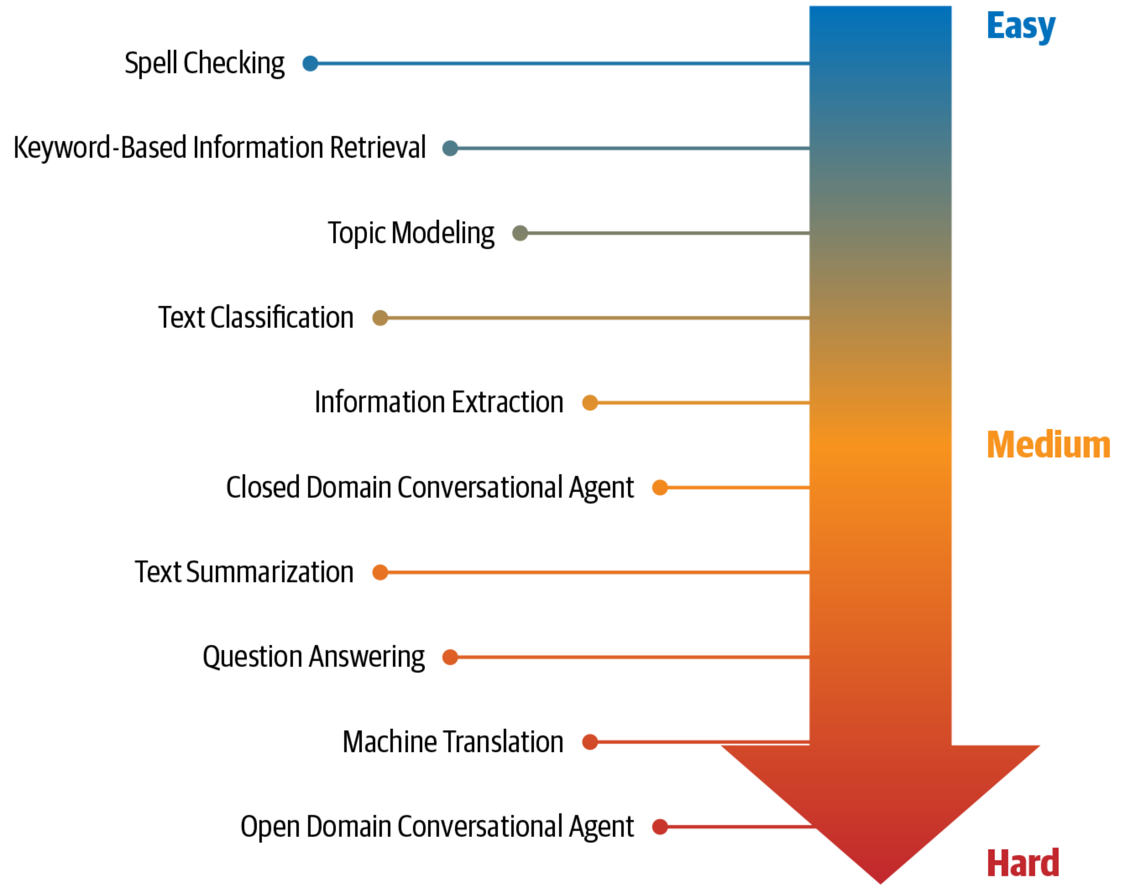
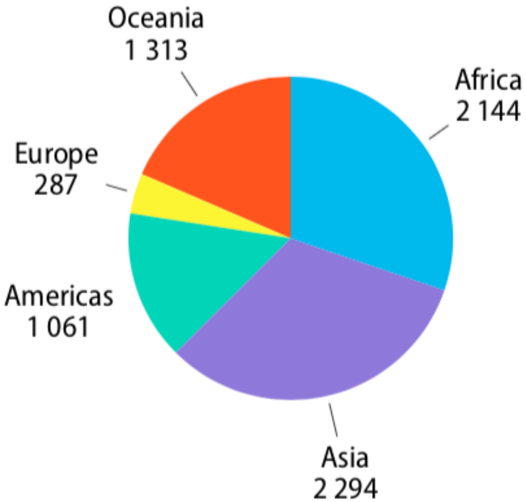
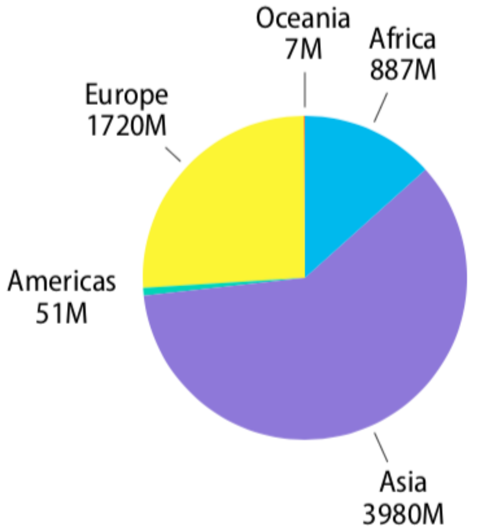
NLP tasks and their relative difficulty



Languages of the world



Languages by region of origin

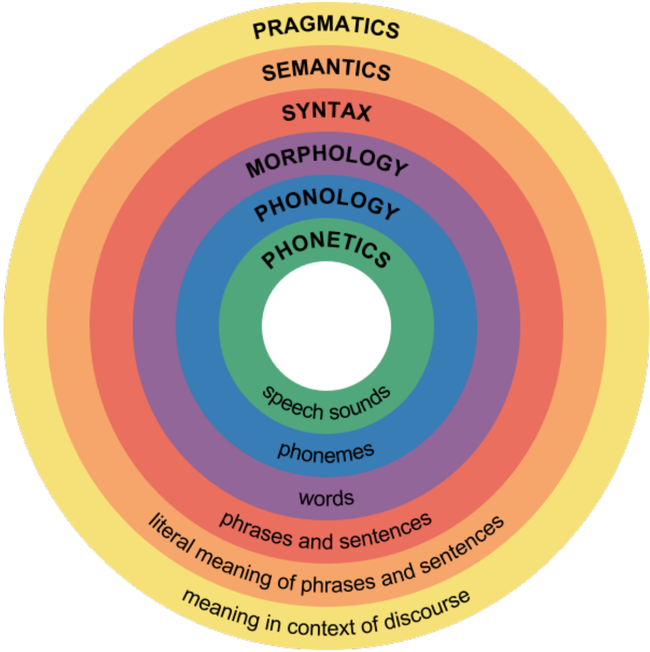


Population by region of origin

Data elaborated from Ethnologue

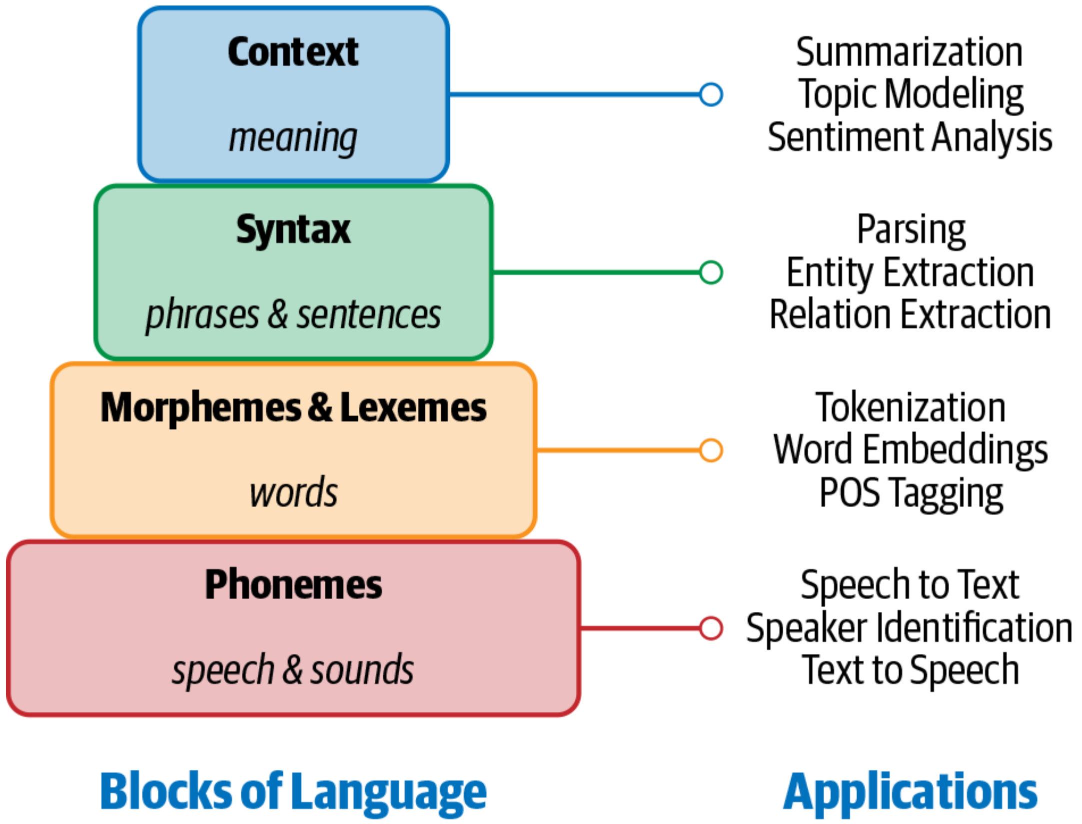
What is linguistics?

- Linguistics is the **scientific study** of language, and in particular the relationship between language form and language meaning
- Besides form and meaning, another important subject of study for linguistics is how language is **used in context**
- Noam Chomsky, sometimes called "the father of modern linguistics"
  - an American scientist who has started the development of a new framework for the study of language and is one of the founders of the field of **cognitive science**



https://commons.wikimedia.org/wiki/File:Major_levels_of_linguistic_structure.svg

Building blocks of language and applications



Phonetics

Phonetics

- The human vocal tract can produce a wide range of sounds
  - But only certain sounds are selected as significant for communication
  - To identify and describe those sounds, we focus on each individual sound segment within a stream of speech
- The general study of the characteristics of speech sounds is called phonetics
  - Articulatory phonetics
    - How speech sounds are made or articulated
  - Acoustic phonetics
    - Physical properties of speech as sound waves
  - Auditory phonetics
    - Perception, via the ear, of speech sounds
- We exploit an already established framework for the study of speech segments known as IPA (International Phonetic Alphabet)

Consonants

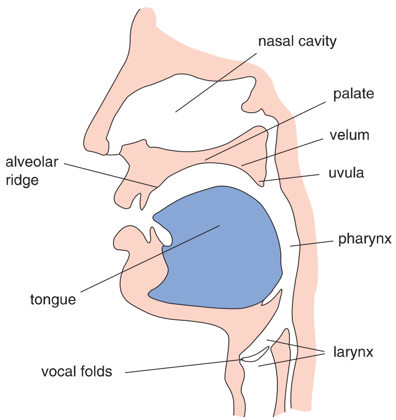
- When we describe the articulation of a consonant, the focus is on three features
  - The voice/voiceless distinction
  - The place of articulation
  - The manner of articulation

Voiced and voiceless sounds

- To make a consonant sound:
  - Air pushed out by the lungs up through the trachea to the larynx
  - Inside the larynx, the vocal cords take two basic positions
    - Vocal cords spread apart -> no obstruction for the air passing
      - **Voiceless sounds**
    - Vocal cords drawn together -> the air repeatedly pushes them apart as it passes through with a vibration effect
      - **Voiced sounds**
- To feel the distinction, try to place a fingertip gently on top of your Adam's apple and produce
  - Z-Z-Z-Z or V-V-V-V (voiced sounds)-> vibration
  - S-S-S-S or F-F-F-F (voiceless sounds) -> no vibration

Place of articulation

- After the larynx, the air enters the vocal tract via the pharynx
- It is the pushed out through the mouth and/or the nose
- Most consonant sounds are produced by using the tongue and other parts of the mouth
- The terms used to describe many sounds denote the place of articulation of the sound
  - The location inside the mouth at which the constriction take place
- To describe the place of articulation of most consonant sounds, we can start at the front of the mouth and work back
  - We consider the voiced-voiceless distinction and use the symbols of the IPA for specific sounds
  - The symbols are enclosed within [ ]



Place of articulation

- Familiar symbols
  - [p] is used for the **voiceless** consonant in *pop*, [b] in *Bob*, [m] in *mom*
  - [w] for **voiced** in *wet*
    - Bilabial consonants (made with both lips)
  - [f] and [v] are used for labiodentals, i.e., formed using upper front teeth and lower lip at the beginning of *fat* and *vat*
  - The voiceless [f] is at beginning and the voiced [v] is at the end of the pronunciation of five
  - Alveolar sounds (front of the tongue raise to **alveolar ridge**) of [t] in *tot*, [d] in *dad*, [s], [z] in *size*, [r], [l] in *rail* and [n] in *nun*
    - [t] and [s] are voiceless, [d], [z], [r], [l] and [n] are voiced
- Unfamiliar symbols
  - Think of the "th" sounds in English
    - We use [θ] for the voiceless version as in *thin* and *wrath*, and at beginning of and end of "*three teeth*"
    - We use [ð] called "eth" for the voiced version as in *thus*, *then*, *feather* and *loathe*
      - Called dentals because teeth are involved
      - If these sound are made with the tongue tip between the teeth, they are described as interdentals

Place of articulation summary

Consonants	Voiceless	Voiced	Place of articulation
Bilabials	[p]	[b], [m], [w]	both (=bi) lips (=labia)
	p**et, ta**pe	***b**et, **m**et, **w**et*	
Labiodentals	[f]	[v]	upper teeth with lower lip
	f**at, sa**fe	***v**at, sa**ve***	
Dentals	[θ]	[ð]	tongue tip behind upper teeth
	th**in, ba**th	***th**en, ba**the***	
Alveolars	[t], [s]	[d], [z], [n], [l], [r]	tongue tip to alveolar ridge
	***t**op, **s**it*	***d**og, **z**oo, **n**ut, **l**ap, **r**ap*	
Palatals	[ʃ], [ʧ]	[ʒ], [ʤ], [j]	tongue and palate
	***sh**ip, **ch**ip*	*ca**s**ual, **g**em, **y**et*	
Velars	[k]	[g], [ŋ]	back of tongue and velum
	c**at, ba**ck	***g**un, ba**ng***	
Glottals	[h]		space between vocal folds
	***h**at, **wh**o*		

Transcribing sounds

- Written English poor guide for pronunciation
- *Bang* and *tongue* end with [ŋ] ("angma") only, and there is no [g] sound (despite the spelling)
- There are some single sounds that are represented in spelling two letters
  - In *ship* we pronounce [ʃ] ("sh") no an [s] sound followed by an [h] sound
- Some similar sounds can have very different spellings
  - *Photo* and *enough*
    - Both pronounced as [f]
- There are also words with letters that are not pronounced at all
  - *Write* and *right*
    - Pronounced as [**rait**]
- Tricky letters that suggest one sound but are pronounced with another
  - *Face* vs *phase* and *race* vs *raise* ("**ce**" like [s] and "**se**" like [z])

Manner of Articulation

- With respect to the place of articulation, [t] and [s] are similar (voiceless alveolars)
- However, they are different sounds, since they differ in their manner of articulation (pronounce)
  - [t] sound is a stop consonant
    - Blocking the airflow very briefly, then letting it go abruptly
  - [s] sound is a fricative consonant
    - Pronounced by almost blocking the airflow, then letting the air escape through a narrow gap, creating friction

Consonants	Voiceless	Voiced	Manner of articulation
Stops	[p], [t], [k]	[b], [d], [g]	block airflow, let it go abruptly
	pet, talk	*bed, dog*	
Fricatives	[f], [θ], [s], [ʃ], [h]	[v], [ð], [z], [ʒ]	almost block airflow, let it escape through a narrow gap
	faith, house, she,	*vase, the, rouge*	
Affricates	[ʧ]	[ʤ]	combine a brief stop with a fricative
	cheap, rich	*jeep, rage*	
Nasals		[m], [n], [ŋ]	lower the velum, let air flow out through nose
		morning, name	
Liquids		[l], [r]	raise and curl tongue, let airflow escape round the sides
		load, light, road, write	
Glides		[w], [j]	move tongue to or from a vowel
		we, want, yes, you	

Vowels

- Vowel sounds are produced with a relatively free flow of air
  - Typically voiced
- Place of articulation
  - Front, back, high, low areas (mouth)
- Example: pronunciation of ***heat*** and ***hit***
  - *"high, front"* vowels because the sound is made with the front part of the tongue in a raised position
  - ***Hot*** is a *"low, back"* vowel

Vowel chart for English

	Front	Central	Back
High	i		u
	ɪ		ʊ
Mid	e	ə	o
	ɛ	ʌ	ɔ
Low	æ		
		a	ɑ

Front vowels

[i] *bead, beef, key, me*

[ɪ] *bid, myth, women*

[ɛ] *bed, dead, said*

[æ] *bad, laugh, wrap*

Central vowels

[ə] *above, oven, support*

[ʌ] *butt, blood, dove, tough*

Back vowels

[u] *boo, move, two, you*

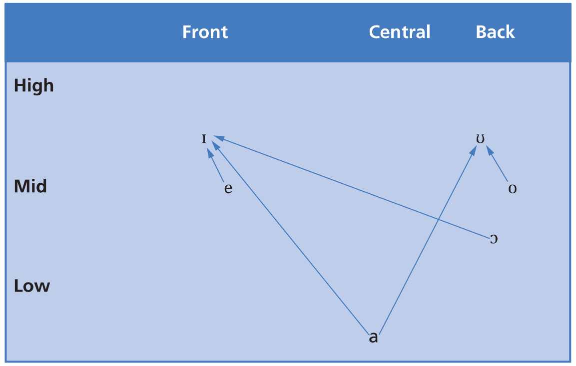
[ʊ] *book, could, put*

[ɔ] *born, caught, fall, raw*

[ɑ] *Bob, cot, swan*

Diphthongs

- Combination of two vowel sounds
- Our vocal organs move from one vocalic position [a] to another [i] as we produce the sound [ai], as in *Hi* or *Bye*
  - Movement from low to high front
- Alternatively, we can use movement from low to high back, combining [a] and [u] to produce [au]



Diphthongs

[aɪ] *buy, eye, I, my, pie, sigh*
[aʊ] *bough, doubt, cow*
[eɪ] *bait, eight, great, late, say*
[oʊ] *boat, home, owe, throw, toe*
[ɔɪ] *boy, noise, royal*

Diphthongs

- The vowels [e], [a], [o] are used
  - as single sounds in other languages and by speakers of different varieties of English
  - First sounds of diphthongs in American English
- The pronunciation of some diphthongs in *Southern British English* is different from *North American English*

	poor	*peer*	*pair*	*pour*	*pyre*	*power*
American	[pʊr]	[pir]	[peɪr]	[poʊr]	[paɪər]	[paʊər]
British	[pʊə]	[pɪə]	[pɛə]	[pɔə]	[paɪə]	[paʊə]

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Phonology

Phonology

- Since two physically different individuals would have physically different vocal tracts, every individual will pronounce sounds differently (in purely physical terms)
  - There are potentially millions of physically different ways of saying the simple word "**me**"
- Phonology is the description of the systems and patterns of speech sounds in a language
  - Concerns the underlying design, the blueprint of each sound type, which vary in different physical context

Phonology

- When we think of the [t] sounds in the words *tar*, *star*, *writer*, *butter* and *eighth* as being the same, we mean that they would be represented in the same way
- In actual speech, these [t] sounds are all potentially very different from each other because they can be pronounced in such a different ways in relation to the other sounds around them
- However, all these articulation differences in [t] sounds are less important to us than the distinction between the [t] sounds in general and the [k] sounds, or the [f] sounds, or the [b] sounds, because there are meaningful consequences related to the use of one rather than the others

Phonology

- These sounds must be distinct meaningful sounds, regardless of which individual vocal tract is being used to pronounce them, because the words *tar*, *car*, *far* and *bar are* meaningful distinct
- From this point of view, phonology is concerned with the abstract representation of sounds in our minds that enables us to recognize and interpret the meaning of words
  - based on the actual physical sounds we say and hear

Phonemes

- A phoneme describes each meaning-distinguishing sounds in a language
- The phoneme /t/ is described as a sound type, of which all the different spoken versions of [t] are tokens
- N.B.: the slash marks conventionally denote a phoneme, /t/, an abstract segment, whereas the square brackets, [t], is used for each physically produced segment
- A phoneme functions contrastively
  - /f/ and /v/ are two phonemes because they are the only basis of contrast in meaning between the words *fat* and *vat* or *fine* and *vine*
  - If we change one sound in a word and there is a change of meaning, the sound are distinct phonemes

Phonemes

- The descriptive terms we use to talk about sounds can be considered features that distinguish each phoneme from the next
  - If the feature is present, we mark it with a (+) sign and if it is not present, we use a (-) sign
- Natural classes
  - /p/ is [-voice, +bilabial, +stop]
  - /k/ is [-voice, +velar, +stop]
  - /p/ and /k/ share some features they are members of a natural class of phonemes
    - They tend to behave phonologically in similar ways
    - /v/ is [+voice, +labiodental, +fricative] and is not in the same class of /p/ and /k/
    - That's why words beginning with /pl-/ and /kl-/ are common in English, but words beginning with /vl-/ or /nl-/ are not
  - This way we describe individual phonemes but also the possible sequences of phonemes in a language

DISTINCTIVE FEATURES OF FOUR ENGLISH PHONEMES

/p/	/k/	/v/	/n/
–voice	–voice	+voice	+voice
+bilabial	+velar	+labiodental	+alveolar
+stop	+stop	+ fricative	+nasal

Phonemes

- Phone and allophones
  - A phoneme is the abstract unit or sound type, and there are many different versions of that sound type produced in an actual speech
    - The latter are called phones (phonetic units in [])
  - Each phone in a set, all versions of the same phoneme, are called allophones
- Example
  - /t/ can be pronounced in several physically different ways as phone
  - The [t] sound in *tar* is pronounced with a stronger puff of air than in *star*

Phoneme	Allophones	
	[tʰ]	(*tar*)
	[ɾ]	(*writer*)
/t/		
	[ʔ]	(*butter*)
	[t̪]	(*eighth*)

Phonemes

- Minimal pair and sets
  - Phonemic distinction in a language can be tested via pairs and sets of words
  - When two words, e.g., *fan* and *van* are identical in form except for a contrast in one phoneme occurring in the same position, the two words are described as a minimal pair
  - When group of words can be differentiated, each one from the others, by changing one phoneme they are described as a minimal set

MINIMAL PAIRS AND SETS

Minimal pairs		Minimal sets
fan – van	*bath – math*	*big – pig – rig – fig – dig – wig*
bat –beat	*math – myth*	*fat – fit – feet –fete – foot – fought*
sit –sing	*myth –Mick*	*cat –can – cap – cab – cash – cadge*

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Morphology

Morphology

- In many languages what appear to be single forms actually turn up to contain many “word-like” elements
- Example
  - In Swahili (East-Africa), *nitakupenda* is something like *I will love you*
- Is this a single word? It seems to consist of several elements that in English turn up as separate words (roughly):

ni-	*ta-*	*ku-*	*penda*
I	*will*	*love*	*you*

- Morphology studies basic forms or elements in a language

Morphology

- Morpheme
  - Words form may consist of a number of elements called morphemes
- Example
  - *talks*, *talker*, *talked*, *talking* consist of one element, *talk*, and other four elements –s, -er, -ed, -ing
    - All five elements are morphemes
- Definition: A morpheme is a minimal unit of meaning or grammatical function
  - Units of grammatical function indicate past tense or plural, for example

MORPHEMES

Minimal units of meaning	Grammatical function
re- (“again”) ***new*** (“recently made”)	***-ed*** (past tense)
tour (“travel for pleasure”) ***-ist*** (“person who”)	***-s*** (plural)

Free and bound morphemes

- Two type of morphemes
  - Free morphemes
    - Can stand by themselves as single words, e.g., new, tour
  - Bound morphemes
    - Cannot stand alone and are attached to another form, e.g., re-, -ist, -ed, -s (known as affixes)
    - All affixes (prefixes and suffixes) in English, are **bound morphemes**
  - Free morphemes can generally be identified as a set of separate English word forms such as, nouns, verbs, adjectives and adverbs
    - When they are used with bound morphemes attached, the **basic word forms** are known as stems

	undressed			***carelessness***	
un-	*dress*	*-ed*	*care*	*-less*	*-ness*
prefix	stem	suffix	stem	suffix	suffix
(bound)	(free)	(bound)	(free)	(bound)	(bound)

Lexical and functional morphemes

- Free morphemes fall in two categories
  - Lexical morphemes
    - Set of ordinary **nouns** (*girl*, *house*), **verbs** (*break*, *sit*), **adjectives** (*long*, *sad*) and **adverbs** (never, *quickly*)
    - Words that carry the content of the message we convey
    - We can add new lexical morphemes to the language , so they are an *open* class of words
  - Functional morphemes
    - **Articles** (*a*, *the*), **conjunctions** (*and*, *because*), **prepositions** (*on*, *near*) and **pronouns** (*it*, *me*)
    - We never add new functional morphemes to the language, so they are described as a closed class of words

Derivational morphemes

- The set of affixes making up the **bound morpheme class** is divided in derivational and inflectional morphemes
  - Derivational morphemes
    - Use of bound forms to make new words or to make words of a different grammatical category from the stem
      - Adding the derivational morpheme –ment changes the **verb** encourage to the **noun** encouragement
      - The noun class can become verb classify by adding the derivational morpheme –ify
      - Derivational morphemes can also be prefix, for instance, re-, pre-, ex-, mis-, co-, un-

Inflectional morphemes

- Inflectional morphemes
  - Indicate the grammatical function of a word
    - Used to show if a word is plural or singular, past tense or not, if it is a comparative or possessive form
  - English has only eight inflectional morphemes, all suffixes

*Jim'**s** two sister**s** are really different.*

*One like**s** to have fun and is always laugh**ing**.*

*The other enjoy**ed** school as a child and has always be**en** very serious.*

*One is the loud**est** person in the house and the other is quiet**er** than a mouse.*

DERIVATIONAL AND INFLECTIONAL MORPHEMES

	Nouns	Verbs	Adjectives
Derivational	*critic-**ism***	*critic-**ize***	*critic-**al***
	*encourage-**ment***	*class-**ify***	*wonder-**ful***
Inflectional	*Jim-**'s***	*like-**s**, laugh-**ing***	*quiet-**er***
	*sister-**s***	*enjoy-**ed**, be-**en***	*loud-**est***

Morphological description

- An inflectional morpheme never change the grammatical category of a word
  - *Old* and *older* are both **adjectives** (-er simply creates a different version of the adjective)
    - From Old English (-ra)
- A derivational morpheme can change the grammatical category of a word
  - *Teach* (**verb**) becomes *Teacher* (**noun**) if we add the derivational morpheme –er
    - From Old English (-ere)
  - The suffix –er in Modern English can be an inflectional morpheme (as part of an adjective) and also a distinct derivational morpheme (as part of a noun)

Morphological description

- If derivational and inflectional suffixes are used together, they always appear in that order
  - Example
    - First derivational (-er) is attached to teach, then the inflectional (-s) is added to produce teachers
- Example: "*The teacher's wildness shocked the girls' parents*"
  - We can identify thirteen morphemes

The	*teach*	*-er*	*-'s*	*wild*	*-ness*
functional	lexical	derivational	inflectional	lexical	derivational

shock	*-ed*	*the*	*girl*	*-s'*	*parent*	*-s*
lexical	inflectional	functional	lexical	inflectional	lexical	inflectional