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# Introduction to Artificial Intelligence

## Language

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# Outline

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- **Communication**
- **Grammar**
- **Syntactic analysis**
- **Problems**

# Communication

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**“Classical” view** (pre-1953)

**Language consists of sentences that are true/false**

# Communication

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**“Modern” view** (post-1953)

Language is a form of action

Wittgenstein (1953)     *Philosophical Investigations*

Austin (1962)         *How to Do Things with Words*

Searle (1969)         *Speech Acts*

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Why?

To change the actions of other agents

# Speech Acts

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SITUATION

Speaker → Utterance → Hearer

## Speech acts achieve the speaker's goals

*Inform*                    “There’s a pit in front of you”

*Query*                    “Can you see the gold”

*Command*                “Pick it up”

*Promise*                 “I’ll share the gold with you”

*Acknowledge*          “OK”

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## Speech act planning requires knowledge of

- Situation
- Semantic and syntactic conventions
- Hearer’s goals, knowledge base, and rationality

# Stages in Communication (Informing)

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<b><i>Intention</i></b>	<b>S wants to inform H that <math>P</math></b>
<b><i>Generation</i></b>	<b>S selects words <math>W</math> to express <math>P</math></b>
<b><i>Synthesis</i></b>	<b>S utters words <math>W</math></b>
<b><i>Perception</i></b>	<b>H perceives <math>W'</math></b>
<b><i>Analysis</i></b>	<b>H infers possible meanings <math>P_1, \dots, P_n</math></b>
<b><i>Disambiguation</i></b>	<b>H infers intended meaning <math>P_i</math></b>
<b><i>Incorporation</i></b>	<b>H incorporates <math>P_i</math> into KB</b>

# Stages in Communication (Informing)

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## How could this go wrong?

- **Insincerity (S doesn't believe  $P$ )**
- **Speech wreck ignition failure**
- **Ambiguous utterance**
- **Differing understanding of current situation**

# Grammar

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## Purpose

**Grammar specifies the compositional structure of complex messages  
e.g., speech (linear), text (linear), music (two-dimensional)**

## Formal language

**A set of strings of terminal symbols**

**Each string in the language can be analyzed/generated by the grammar**

# Grammar

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## Rewrite rules

The grammar is a set of rewrite rules

## Example

$$S \rightarrow NP VP$$

$$Article \rightarrow the \mid a \mid an \mid \dots$$

*S*:            **the sentence symbol**

*NP, VP*:    **nonterminals**

*the, a*:      **terminal symbols**

# Wumpus Lexicon

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*Noun* → *stench* | *breeze* | *glitter* | *nothing*  
| *wumpus* | *pit* | *pits* | *gold* | *east* | ...

*Verb* → *is* | *see* | *smell* | *shoot* | *feel* | *stinks*  
| *go* | *grab* | *carry* | *kill* | *turn* | ...

*bAdjective* → *right* | *left* | *east* | *south* | *back* | *smelly* | ...

*Adverb* → *here* | *there* | *nearby* | *ahead*  
| *right* | *left* | *east* | *south* | *back* | ...

*Pronoun* → *me* | *you* | *I* | *it* | *S/HE* | *Y'ALL*...

*Name* → *John* | *Mary* | *Boston* | *UCB* | *PAJC* | ...

*Article* → *the* | *a* | *an* | ...

*Preposition* → *to* | *in* | *on* | *near* | ...

*Conjunction* → *and* | *or* | *but* | ...

*Digit* → 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9

Divided into **closed** and **open** classes

# Wumpus Grammar

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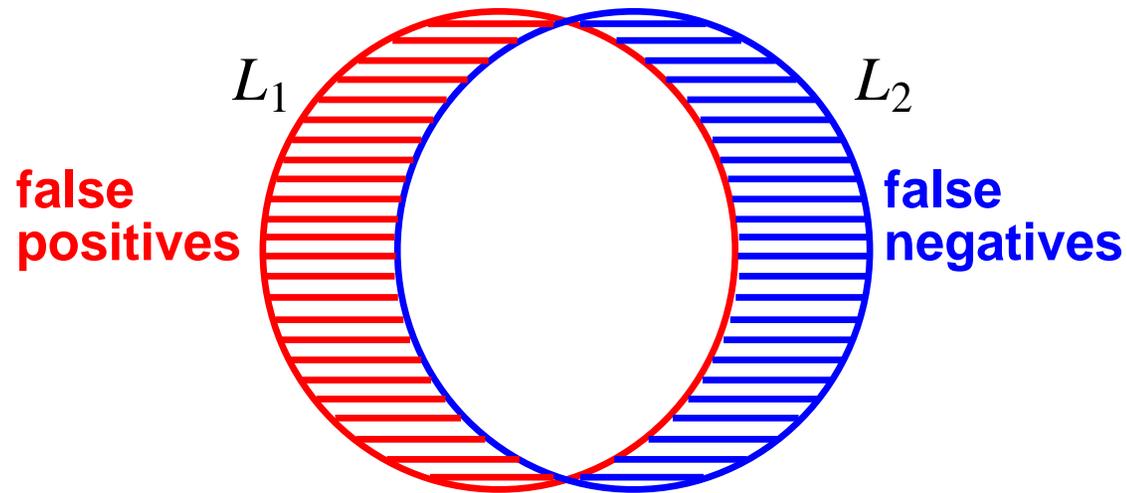
<i>S</i>	→	<i>NP VP</i>	<b>I + feel a breeze</b>
		<i>S Conjunction S</i>	<b>I feel a breeze + and + I smell a wumpus</b>
<i>NP</i>	→	<i>Pronoun</i>	<b>I</b>
		<i>Noun</i>	<b>pits</b>
		<i>Article Noun</i>	<b>the + wumpus</b>
		<i>Digit Digit</i>	<b>3 4</b>
		<i>NP PP</i>	<b>the wumpus + to the east</b>
		<i>NP RelClause</i>	<b>the wumpus + that is smelly</b>
<i>VP</i>	→	<i>Verb</i>	<b>stinks</b>
		<i>VP NP</i>	<b>feel + a breeze</b>
		<i>VP Adjective</i>	<b>is + smelly</b>
		<i>VP PP</i>	<b>turn + to the east</b>
		<i>VP Adverb</i>	<b>go + ahead</b>
<i>PP</i>	→	<i>Preposition NP</i>	<b>to + the east</b>
<i>RelClause</i>	→	<i>that VP</i>	<b>that + is smelly</b>

# Grammaticality judgements

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## Note

Formal language  $L_1$  may differ from natural language  $L_2$

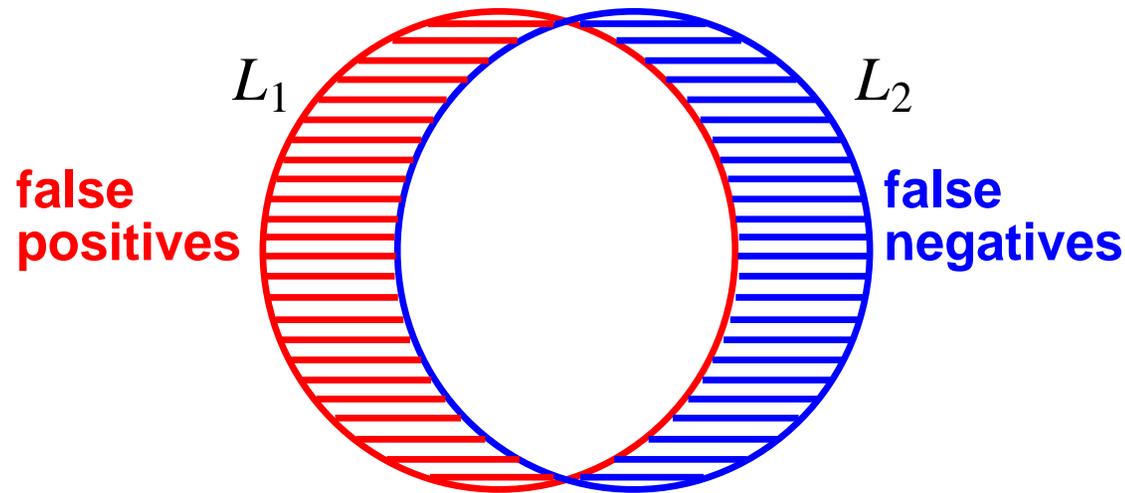


# Grammaticality judgements

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## Note

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## Examples

- + the gold grab the wumpus
- + I smell the wumpus the gold
- I give the wumpus the gold
- + I donate the wumpus the gold

# Parse Trees

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Exhibit the grammatical structure of a sentence

I shoot the wumpus

# Parse Trees

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Exhibit the grammatical structure of a sentence

**Pronoun**

I

**Verb**

shoot

**Article**

the

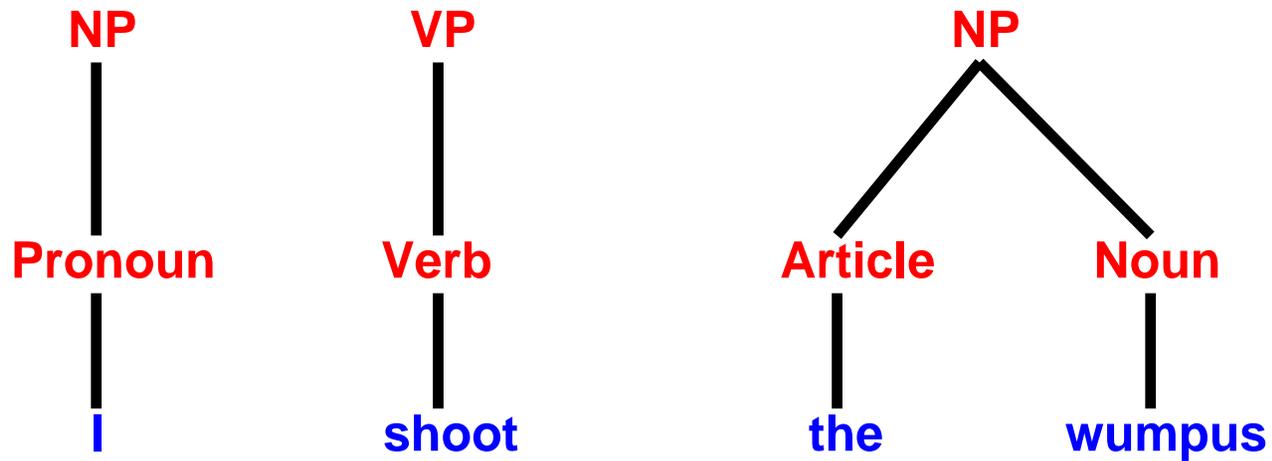
**Noun**

wumpus

# Parse Trees

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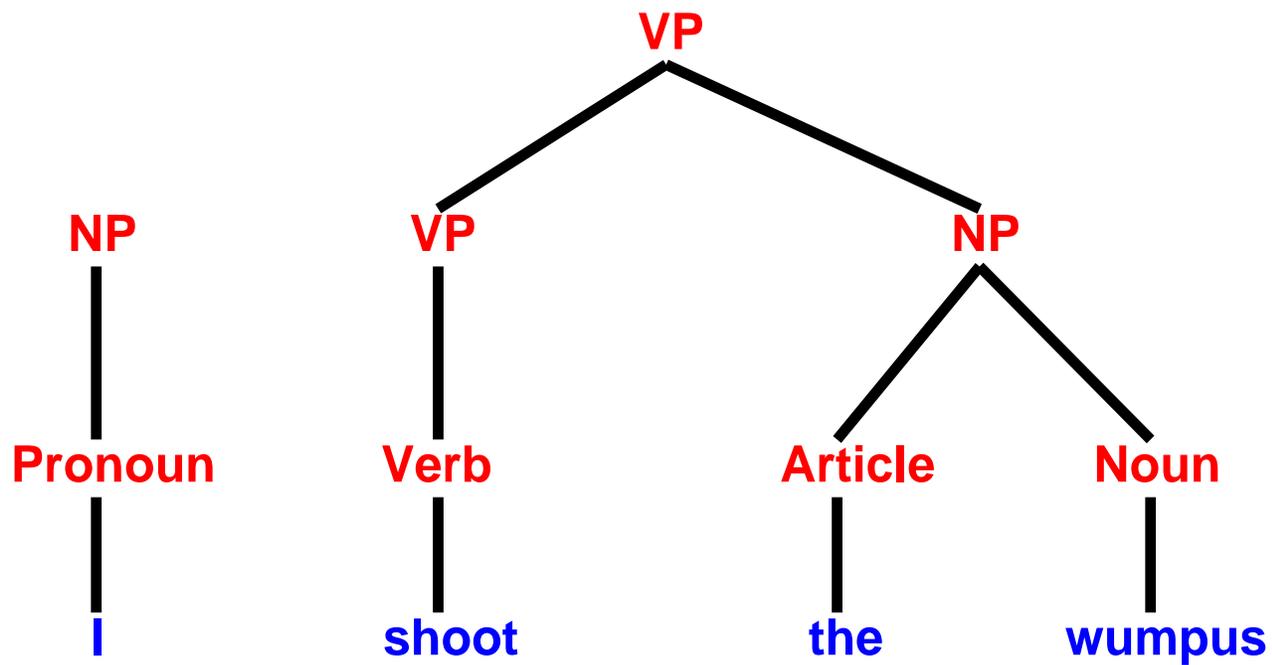
Exhibit the grammatical structure of a sentence



# Parse Trees

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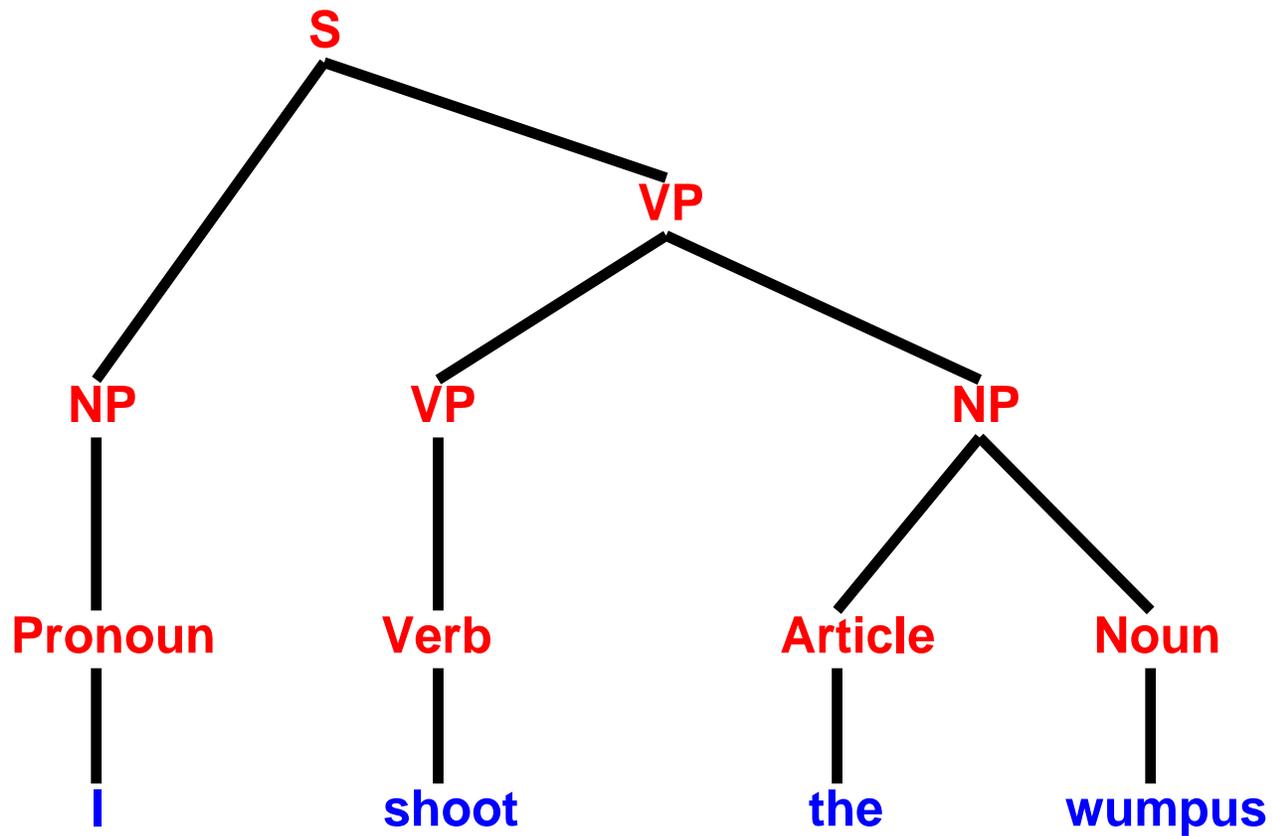
Exhibit the grammatical structure of a sentence



# Parse Trees

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Exhibit the grammatical structure of a sentence



# Syntax in Natural Language Processing

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Syntactic structure is an essential step towards meaning

● “Mary hit John”  $\neq$  “John hit Mary”

# Syntax in Natural Language Processing

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Syntactic structure is an essential step towards meaning

- **“Mary hit John”  $\neq$  “John hit Mary”**
- **“And since I was not informed—as a matter of fact, since I did not know that there were excess funds until we, ourselves, in that checkup after the whole thing blew up, and that was, if you’ll remember, that was the incident in which the attorney general came to me and told me that he had seen a memo that indicated that there were no more funds.”**

# Syntax in Natural Language Processing

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## Syntactic structure is an essential step towards meaning

- **“Mary hit John”  $\neq$  “John hit Mary”**
- **“And since I was not informed—as a matter of fact, since I did not know that there were excess funds until we, ourselves, in that checkup after the whole thing blew up, and that was, if you’ll remember, that was the incident in which the attorney general came to me and told me that he had seen a memo that indicated that there were no more funds.”**
- **“Wouldn’t the sentence ‘I want to put a hyphen between the words Fish and And and And and Chips in my Fish-And-Chips sign’ have been clearer if quotation marks had been placed before Fish, and between Fish and and, and and and Chips, as well as after Chips?”**

# Real Language

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Real human languages provide many problems for natural language processing

- **ambiguity**
- **anaphora**
- **indexicality**
- **vagueness**
- **noncompositionality**
- **discourse structure**
- **metonymy**
- **metaphor**

# Ambiguity

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## Examples

- Squad helps dog bite victim

# Ambiguity

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## Examples

- Squad helps dog bite victim
- Helicopter powered by human flies

# Ambiguity

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## Examples

- Squad helps dog bite victim
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- I ate spaghetti with meatballs

# Ambiguity

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## Examples

- Squad helps dog bite victim
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- I ate spaghetti with meatballs  
salad

# Ambiguity

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## Examples

- Squad helps dog bite victim
- Helicopter powered by human flies
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salad  
abandon

# Ambiguity

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## Examples

- Squad helps dog bite victim
- Helicopter powered by human flies
- I ate spaghetti with meatballs  
salad  
abandon  
a fork

# Ambiguity

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## Examples

- Squad helps dog bite victim
- Helicopter powered by human flies
- I ate spaghetti with meatballs
  - salad
  - abandon
  - a fork
  - a friend

# Ambiguity

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## Examples

- Squad helps dog bite victim
- Helicopter powered by human flies
- I ate spaghetti with meatballs
  - salad
  - abandon
  - a fork
  - a friend

## Note

Ambiguity can be

- lexical
- syntactic
- semantic
- referential

# Indexicality

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## Indexical sentences

**Refer to utterance situation (place, time, etc.)**

# Indexicality

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## Indexical sentences

Refer to utterance situation (place, time, etc.)

## Examples

- I am over **here**
- Why did **you** do **that**?

# Anaphora

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## Anaphora

**Using pronouns to refer back to entities already introduced in the text**

# Anaphora

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## Anaphora

Using pronouns to refer back to entities already introduced in the text

## Examples

- After Mary proposed to John, **they** found a preacher and got married.
- For the honeymoon, **they** went to Hawaii
- Mary saw a ring through the window and asked John for **it**
- Mary threw a rock at the window and broke **it**

# Metonymy

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## Metonymy

Using one noun phrase to stand for another

# Metonymy

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## Metonymy

Using one noun phrase to stand for another

## Example

- I've read **Shakespeare**
- **Chrysler** announded record profits
- The **ham sandwich** on Table 4 wants another beer

# Metaphor

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## Metaphor

**“Non-literal” usage of words and phrases, often systematic:**

# Metaphor

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## Metaphor

**“Non-literal” usage of words and phrases, often systematic:**

## Example

**I’ve tried killing the process but it won’t die.**

# Noncompositionality

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## Examples

- **basketball shoes**
- **baby shoes**
- **alligator shoes**
- **designer shoes**
- **brake shoes**

# Disambiguation

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Requires knowledge of different kind

- **World model**
- **Mental model (of the speaker)**
- **Language model**
- **Acoustic model**