Semantics

These slides were produced by Hadas Kotek.

http://web.mit.edu/hkotek/www/
Sentence types

What is the meaning of a sentence?

The lion devoured the pizza.

Statement
Sentence types

What is the meaning of a sentence?

Who devoured the pizza?
Did the lion devour the pizza?

Question
Sentence types

What is the meaning of a sentence?

Do your homework!

Command
Sentence types

What is the meaning of a sentence?

It’s cold here ....
Do you know what time it is?

Sentences might convey additional non-literal meaning
What do sentences mean?

(1) The capital of Canada is Ottawa
(2) The capital of Canada is Montreal
What do sentences mean?

(1) The capital of Canada is Ottawa
(2) The capital of Canada is Montreal

→ The meaning of a sentence is related to whether it is true or false (its *truth value*).

In the actual world:
– (1) is True
– (2) is False
What do sentences mean?

BUT: This can’t be all, since the truth-values of sentences can change over time or situations

Reese is in room 20
The cat is on the mat
What do sentences mean?

We can grasp the meaning of a sentence without knowing whether it’s true or false.

The name of the person sitting closest to the door starts with a “D.”
What do sentences mean?

We can grasp the meaning of sentences we’ve never heard before.

*The furry cat ate the red jellybean*
Definition: Semantics and meaning

The *semantic competence* of a speaker:
The ability, when presented with a sentence and a situation, to tell whether the sentence is true or false in the situation.
Definition: Semantics and meaning

The *semantic competence* of a speaker:
The ability, when presented with a sentence and a situation, to tell whether the sentence is true or false in the situation.

To know the *meaning* of a sentence is to know its *truth conditions*.
– That is, we know what the world would have to look like in order for the sentence to be true.
Building a semantic system

How can we specify the meanings of infinitely many sentences in natural language?

The scary lion devoured the mushroom pizza that I ordered last night
Building a semantic system

Observation: The interpretation of a sentence depends on its syntactic structure. Different phrases make predictable contributions to the meaning of a sentence.

The cat chased the rat
Observation: The interpretation of a sentence depends on its syntactic structure. Different phrases make predictable contributions to the meaning of a sentence.

The cat chased the rat
The rat chased the cat
Observation: The interpretation of a sentence depends on its syntactic structure. Different phrases make predictable contributions to the meaning of a sentence.

The cat chased the rat
The grey cat chased the rat
The grey cat with the hat chased the rat
Building a semantic system

*Observation:* The interpretation of a sentence depends on its syntactic structure. Different phrases make predictable contributions to the meaning of a sentence.

The cat chased the rat
The cat chased the dog
Building a semantic system

**Observation:** The interpretation of a sentence depends on its syntactic structure. Different phrases make predictable contributions to the meaning of a sentence.

The cat chased the rat

The cat licked the rat
Building a semantic system

**Observation:** The interpretation of a sentence depends on its syntactic structure. Different phrases make predictable contributions to the meaning of a sentence.

The cat chased the rat
A cat chased the rat
Definition: Compositional semantics

The principle of compositionality:
The meaning of a sentence depends only on the meanings of its parts and on the way that they are syntactically combined.

Gottlob Frege
This image is in the public domain. Source: [Wikimedia Commons](https://commons.wikimedia.org/wiki/File:Gottlob_Frege.png).
Definition: Compositional semantics

The principle of compositionality:
The meaning of a sentence depends only on the meanings of its parts and on the way that they are syntactically combined.

The task of the semantics of a language is to provide the truth-conditions of all the well-formed sentences in that language, and to do so in a compositional way.
Basic modeling

Mitzi is gray
Mitzi is a cat
Mitzi purred

We can define *adjectives, nouns* and *intransitive verbs* as mathematical *sets* of individuals.
Basic modeling

Mitzi is gray
Mitzi is a cat
Mitzi purred

A set is a collection of objects.

Gray is the collection of all gray individuals.
Cat is the collection of all individuals who are cats.
Purred is the collection of all individuals who purred.
Basic modeling

Mitzi is gray
Mitzi is a cat
Mitzi purred

Mitzi is a member of the set of individuals that are gray.
Mitzi $\in$ Gray
Basic modeling

Mitzi is gray
Mitzi is a cat
Mitzi purred

Mitzi is a member of the set of individuals that are cats.
Mitzi $\in \text{Cat}$
Basic modeling

Mitzi is gray
Mitzi is a cat
Mitzi purred

Mitzi is a member of the set of individuals that purred.

Mitzi ∈ Purred
Mitzi is a gray cat

Mitzi is a member of the set of individuals who are gray AND a member of the set of individuals who are cats.

\[ \text{Mitzi} \in \text{Gray} \quad \text{AND} \quad \text{Mitzi} \in \text{Cat} \]
Modification

Mitzi \([_{1}, \text{is a gray cat}]\)

**Set intersection**: The set that results from combining two other sets

Mitzi \(\in Gray \cap Cat\)
Modification

Set intersection can describe other adjectives too:

Mitzi is a gray cat
Gianni is an Italian waiter
T-Rex is a carnivorous dinosaur
This is a round ball

These are called intersective adjectives.
Modification

Intersective adjectives conform to an entailment pattern.

Mitzi is a *gray* cat
⇒ Mitzi is a cat
⇒ Mitzi is gray
Modification

Intersective adjectives conform to an *entailment* pattern.

Mitzi is a *gray* cat

⇒ Mitzi is a cat

⇒ Mitzi is gray

A entails B iff whenever A is true, B is true.
Modification

There are also **non-intersective** adjectives:

George is a *former* president
This is a *fake* diamond
Modification

There are also **non-intersective** adjectives:

George is a *former* president
This is a *fake* diamond

The entailment pattern doesn’t hold:

George is a former president
⇒ George is a president [not valid]
⇒ ??George is former [not valid]
Modification

There are also non-intersective adjectives:

George is a *former* president
This is a *fake* diamond

In fact:

George is a former president
⇒ George is not a president
⇒ George was a president in the past
Mitzi \[ \text{is gray and furry} \]

Connectives can be described in set terms.

**AND** denotes set intersection

\( \text{Gray} \cap \text{Furry} \)
Connectives

Mitzi \( i \), is gray or black

Connectives can be described in set terms.

**OR** denotes set **union**

\[ \text{Gray} \cup \text{Black} \]
Interim summary

Nouns, intransitive verbs, and adjectives can be described using set intersection.

\[
\text{Mitzi} \begin{cases} 
\text{is a cat} \\
\text{is gray} \\
\text{purred}
\end{cases} = \text{Cat} \cap \text{Gray} 
\]
**Interim summary**

*AND* can also be described using *set intersection*.

\[
\text{Mitzi is gray AND furry} = \text{Mitzi} \in \text{Gray} \cap \text{Furry}
\]

*OR* can also be described using *set union*.

\[
\text{Mitzi is gray or black} = \text{Mitzi} \in \text{Gray} \cup \text{Black}
\]
More modeling

Proper names pick out individuals in the world.

John danced
More modeling

Proper names pick out individuals in the world.

John danced

What does *some boy* refer to?

Some boy danced
More modeling

Proper names pick out individuals in the world.

John danced

What does some boy refer to?

Some boy danced

What about no boy?

No boy danced
Determiners

English has several additional determiners:

Some boy danced
No boy danced
Three boys danced
More than half of the boys danced
Every boy danced
Determiners

How do we model determiners?

Some boy danced

No boy danced

Three boys danced

More than half of the boys danced

Every boy danced
Determiners

How do we model determiners?

Some boy danced
No boy danced
Three boys danced
More than half of the boys danced
Every boy danced

NPs with determiners don’t refer to individuals. Rather, determiners denote set relations.
Determiners

*Some* boy danced

The **intersection** of the set of boys and the set of dancers is not empty

\[ \text{Boy} \cap \text{Danced} \neq \emptyset \]
Determiners

Some boy danced

Can there be boys who are not dancers?
Can there be dancers who are not boys?
Determiners

*Some boy danced*

*Can there be boys who are not dancers?*  Yes.

*Can there be dancers who are not boys?*  Yes.
Determiners

No boy danced

The intersection of the set of boys and the set of dancers is empty

\[ \text{Boy} \cap \text{Danced} = \emptyset \]
Determiners

No boy danced

Can there be boys who are not dancers?
Can there be dancers who are not boys?
Determiners

No boy danced

Can there be boys who are not dancers? Yes.
Can there be dancers who are not boys? Yes.
Three boys danced

The intersection of the set of boys and the set of dancers contains three elements.

\[ | \text{Boy} \cap \text{Danced} | = 3 \]
Determiners

Three boys danced

Can there be boys who are not dancers?
Can there be dancers who are not boys?
Determiners

Three boys danced

Can there be boys who are not dancers? Yes.
Can there be dancers who are not boys? Yes.
Determiners

More than half of the boys danced

The intersection of the set of boys and the set of dancers contains more than half of all the boys.

\[ | \text{Boy} \cap \text{Danced} | > \frac{1}{2} | \text{Boy} | \]
Determiners

More than half of the boys danced

Can there be boys who are not dancers?
Can there be dancers who are not boys?
Determiners

More than half of the boys danced

Can there be boys who are not dancers? Yes (but...)
Can there be dancers who are not boys? Yes.
Determiners

Every boy danced

The set of boys is a subset of the set of dancers.

Boy ⊆ Danced
Determiners

Every boy danced

Can there be boys who are not dancers?
Can there be dancers who are not boys?
**Determiners**

*Every boy danced*

*Can there be boys who are not dancers?* **No.**

*Can there be dancers who are not boys?* **Yes.**
Determiners summary

All the sentences we have seen have the structure:

\[ \text{Det}(A)(B) \]

\textbf{Some}(Boy)(Danced)

\textbf{Three}(Boy)(Danced)

\textbf{More than half}(Boy)(Danced)

\textbf{No}(Boy)(Danced)

\textbf{Every}(Boy)(Danced)
Determiners summary

All the sentences we have seen have the structure:

\( \text{Det}(A)(B) \)

\textbf{Some}(Boy)(Danced) \iff \text{Boy} \cap \text{Danced} \neq \emptyset

\textbf{Three}(Boy)(Danced)

\textbf{More than half}(Boy)(Danced)

\textbf{No}(Boy)(Danced)

\textbf{Every}(Boy)(Danced)
Determiners summary

All the sentences we have seen have the structure:

\[ \text{Det}(A)(B) \]

\[ \text{Some}(\text{Boy})(\text{Danced}) \iff \text{Boy} \cap \text{Danced} \neq \emptyset \]

\[ \text{Three}(\text{Boy})(\text{Danced}) \iff | \text{Boy} \cap \text{Danced} | = 3 \]

\[ \text{More than half}(\text{Boy})(\text{Danced}) \]

\[ \text{No}(\text{Boy})(\text{Danced}) \]

\[ \text{Every}(\text{Boy})(\text{Danced}) \]
Determiners summary

All the sentences we have seen have the structure:

$\text{Det}(A)(B)$

$\text{Some}(\text{Boy})(\text{Danced}) \iff \text{Boy} \cap \text{Danced} \neq \emptyset$

$\text{Three}(\text{Boy})(\text{Danced}) \iff |\text{Boy} \cap \text{Danced}| = 3$

$\text{More than half}(\text{Boy})(\text{Danced}) \iff |\text{Boy} \cap \text{Danced}| > \frac{1}{2} |\text{Boy}|$

$\text{No}(\text{Boy})(\text{Danced})$

$\text{Every}(\text{Boy})(\text{Danced})$
Determiners summary

All the sentences we have seen have the structure:

\[ \text{Det}(A)(B) \]

\begin{align*}
\text{Some}(\text{Boy})(\text{Danced}) & \iff \text{Boy} \cap \text{Danced} \neq \emptyset \\
\text{Three}(\text{Boy})(\text{Danced}) & \iff | \text{Boy} \cap \text{Danced} | = 3 \\
\text{More than half}(\text{Boy})(\text{Danced}) & \iff | \text{Boy} \cap \text{Danced} | > \frac{1}{2} | \text{Boy} | \\
\text{No}(\text{Boy})(\text{Danced}) & \iff \text{Boy} \cap \text{Danced} = \emptyset \\
\text{Every}(\text{Boy})(\text{Danced}) &
\end{align*}
Determiners summary

All the sentences we have seen have the structure:

\( \text{Det}(A)(B) \)

**Some**(Boy)(Danced) \( \iff \) Boy \( \cap \) Danced \( \neq \) \( \emptyset \)

**Three**(Boy)(Danced) \( \iff \) \(|\text{Boy} \cap \text{Danced}| = 3\)

**More than half**(Boy)(Danced) \( \iff \) \(|\text{Boy} \cap \text{Danced}| > \frac{1}{2} \cdot |\text{Boy}|\)

**No**(Boy)(Danced) \( \iff \) Boy \( \cap \) Danced \( = \) \( \emptyset \)

**Every**(Boy)(Danced) \( \iff \) Boy \( \subseteq \) Danced
Properties of determiners

All the sentences we have seen have the structure:

\[ \text{Det}(A)(B) \]

All the determiners we have seen so far put restrictions on members of set \( A \), but not on members of set \( B \).

\[
\begin{align*}
\text{Diagram:} & \quad A \cap B \quad \text{not: } A \cup B
\end{align*}
\]
Properties of determiners

All the sentences we have seen have the structure:

\[ \text{Det}(A)(B) \]

Are there determiners that put restrictions on set B?
Properties of determiners

All the sentences we have seen have the structure:

\[ \text{Det}(A)(B) \]

For example, \text{every-non}(A)(B)

\text{blarg} boy danced

= every non-boy danced

That is: \( A^- \subseteq B \)
Properties of determiners

All the sentences we have seen have the structure:

\( Det(A)(B) \)

For example, Reverse-\( mth \)(A)(B)

\textit{blick} boys danced
\[ = \text{ more than half of the dancers are boys} \]

That is: \[ | A \cap B | > \frac{1}{2} | B | \]
Conservativity

Natural language determiners only “care” about elements that satisfy their first argument.

\[ \text{Det is conservative if } \text{Det}(A)(B) \iff \text{Det}(A)(A \cap B) : \]

\[ \text{every}(\text{boy})(\text{danced}) \]
\[ = \text{ every boy danced} \]
\[ = \text{ every boy is a boy that danced} \]

\[ \text{every-non}(\text{boy})(\text{danced}) \]
\[ = \text{ every non-boy danced} \]
\[ \neq \text{ every non-boy is a boy that danced [\*]} \]
Conservativity

Natural language determiners only “care” about elements that satisfy their first argument.

*Det* is **conservative** if *Det*(A)(B) ⇔ *Det*(A)(A ∩ B):

- *more than half*(boy)(danced)  
  = more than half of the boys danced  
  = more than half of the boys are boys who danced

*Reverse-mth*(boy)(danced)  
= more than half of the dancers are boys  
≠ more than half of the boys who danced are boys [*]
Conservativity

**Universal**: All natural language determiners are conservative.

Therefore: no language has a simple determiner that means *every-non* or Reverse-*mth*

\[
\text{blarg \ boys danced} \quad \Rightarrow \quad \text{every non-boy danced}
\]

\[
\text{blick \ boys danced} \quad \Rightarrow \quad \text{more than half of the dancers are boys}
\]
An application: Explaining entailment patterns

John sings and John dances
⇒ John sings and dances

Some boy sings and some boy dances
⇏ Some boy sings and dances
An application: Explaining entailment patterns

John sings and John dances

⇒ John sings and dances
An application: Explaining entailment patterns

Some boy sings and some boy dances

⇒ Some boy sings and dances
An application: Explaining entailment patterns

Some boy sings and some boy dances

⇒ Some boy sings and dances
An application: Explaining entailment patterns

Some boy sings and some boy dances
An application: Explaining entailment patterns

Some boy sings and some boy dances
An application: Explaining entailment patterns

Some boy sings and some boy dances
An application: Explaining entailment patterns

Some boy sings and dances
An application: Explaining entailment patterns

Some boy sings and dances
An application: Explaining entailment patterns

Some boy sings and some boy dances

\[ \not\Rightarrow \text{Some boy sings and dances} \]

A entails B iff whenever A is true, B is true.

We can find a situation where A is true but B is false. Hence, A does not entail B
The definite article

What is the meaning of the definite article?

*Some* cat purred
*Every* cat purred
*The* cats purred
The definite article

What is the meaning of the definite article?

Some cat purred $\iff$ $Cat \cap Purred = \emptyset$

Every cat purred $\iff$

The cats purred $\iff$
The definite article

What is the meaning of the definite article?

Some cat purred \( \iff \) \( \text{Cat} \cap \text{Purred} = \emptyset \)

Every cat purred \( \iff \) \( \text{Cat} \subseteq \text{Purred} \)

The cats purred \( \iff \)
The definite article

What is the meaning of the definite article?

*Some* cat purred $\iff$ $\text{Cat } \cap \text{Purred} = \emptyset$

*Every* cat purred $\iff$ $\text{Cat } \subseteq \text{Purred}$

*The* cats purred $\iff$ ?
The definite article

What is the meaning of the definite article?

\[
\begin{align*}
\text{Some cat purred} & \iff \text{Cat} \cap \text{Purred} = \emptyset \\
\text{Every cat purred} & \iff \text{Cat} \subseteq \text{Purred} \\
\text{The cats purred} & \iff \text{?}
\end{align*}
\]

At first glance, \textit{the} has a meaning similar to \textit{every}
The definite article

We might define *the* as:

\[ \text{The cats purred} \iff \text{Cat} \subseteq \text{Purred} \]
The definite article

We might define *the* as:

\[ \text{The cats purred} \iff \text{Cat } \subseteq \text{Purred} \]

Does this work in this context?
The definite article

We might define *the* as:

\[
\text{The cats purred} \iff \text{Cat} \subseteq \text{Purred}
\]

Does this work in this context?

**Context:** There are three cats.

Every cat purred

The cats purred

#The cat purred
The definite article

The cat purred

The expression *the cat* presupposes:

− **Existence**: there exists a cat
− **Uniqueness**: there is exactly one (relevant) cat
The definite article

The cat purred

The expression *the cat* presupposes:

- **Existence**: there exists a cat
- **Uniqueness**: there is exactly one (relevant) cat

When there is exactly one relevant individual in NP, *the* returns that individual.

*the cat* defined iff there is one $c \in \text{Cat}$. Returns $c$. 
Presuppositions of the

The presuppositions of the definite often spring into existence, even if they weren’t known beforehand.

I forgot to feed the cat this morning
Presuppositions of the

The presuppositions of the definite often spring into existence, even if they weren’t known beforehand.

I forgot to feed the cat this morning

You will accommodate the fact that I have a cat.
Presuppositions of the

The presuppositions of the definite often spring into existence, even if they weren’t known beforehand.

I forgot to feed the cat this morning

You will accommodate the fact that I have a cat.

If no one objects to what I said, the assumption that I have a cat will be added to the common ground of our conversation.
Accommodation

How easy it is to accommodate depends on the plausibility of what I said.
Accommodation

How easy it is to accommodate depends on the plausibility of what I said.

Context: We are at my house and you hear some scratching noises outside.

(1) The cat is at the door.
(2) The giraffe is at the door.
(3) I keep a giraffe here. The giraffe is at the door.
Accommodation

Normally, we assume that speakers intend to say things that are grammatical, relevant, and – often – true.

In the closet, you will find the blue coat
Accommodation

Normally, we assume that speakers intend to say things that are grammatical, relevant, and – often – true.

In the closet, you will find the blue coat

Suppose that after I said this sentence, you open the closet and find only a black coat.
Accommodation

Normally, we assume that speakers intend to say things that are grammatical, relevant, and – often – true.

In the closet, you will find the blue coat

Suppose that after I said this sentence, you open the closet and find only a black coat.

You may assume I just got the color confused.
Accommodation

Normally, we assume that speakers intend to say things that are grammatical, relevant, and – often – true.

In the closet, you will find the blue coat

Suppose that after I said this sentence, you open the closet and find only a black coat.

Or you might assume you got the color confused and it’s really a dark blue coat.
Accommodation

We use a similar process to choose the meaning of ambiguous sentences.
Accommodation

We use a similar process to choose the meaning of ambiguous sentences.

Successful lawyers and linguists are always rich
Accommodation

We use a similar process to choose the meaning of ambiguous sentences.

Successful lawyers and linguists are always rich
a. [Successful lawyers] and linguists are always rich
b. Successful [lawyers and linguists] are always rich
Accommodation

We use a similar process to choose the meaning of ambiguous sentences.

Successful lawyers and linguists are always rich

a. [Successful lawyers] and linguists are always rich
b. Successful [lawyers and linguists] are always rich

Since (a) is obviously false, you’ll normally conclude that I meant (b).
Accommodation

We use this process to assign implicit parameters in a way that would make sentences true.

Everybody in the room is taller than me
Accommodation

We use this process to assign implicit parameters in a way that would make sentences true.

**Everybody in the room is taller than me**

**Context:** There are four people in the room; you, me, and two other people who I don’t know.

a. You: *We are brothers.*

b. You: *We are four, so we can play bridge.*
Accommodation

Sometimes we can’t accommodate a presupposition.

I forgot to feed the cat this morning!
I forgot to feed the giraffe this morning!
Accommodation

Sometimes we can’t accommodate a presupposition.

I forgot to feed the cat this morning!
I forgot to feed the giraffe this morning!

The TA is sitting in the front row
→ Uniqueness is violated!

The king of France is bald
→ Existence is violated!
Conclusion

The king of France is bald

Modeling using sets: We defined *intransitive verbs*, *nouns* and *adjectives* as sets of individuals.
Conclusion

The king of France is bald

Modeling using sets: We defined connectives \((\text{and}, \text{or})\) and determiners \((\text{some}, \text{every}, \text{no}, \text{three}, \text{more than half})\) as relations between two sets.
Conclusion

**Compositionality**: We calculated the meaning of sentences from the meaning of their parts and the syntactic structure they were in.
Conclusion

Compositionality: We calculated the meaning of sentences from the meaning of their parts and the syntactic structure they were in.

The meanings we calculated derived the truth conditions of the sentences.
Conclusion

Compositionality: We calculated the meaning of sentences from the meaning of their parts and the syntactic structure they were in.

The meanings we calculated derived the truth conditions of the sentences.

When combined with a context, we yield a truth value
Conclusion

Finally, we discussed the definite article and its presuppositions.

The king of France is bald

→ Existence

→ Uniqueness