

# Entailment

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Stanford Linguistics

Linguist 130a/230a: Introduction to semantics and pragmatics



# The abstract idea

# The abstract idea

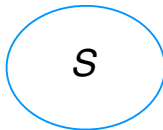
## Entailment

$$S \Rightarrow S'$$

# The abstract idea

## Entailment

$S \Rightarrow S'$



# The abstract idea

## Entailment

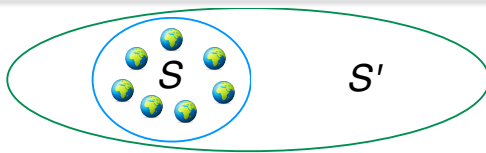
$S \Rightarrow S'$



# The abstract idea

## Entailment

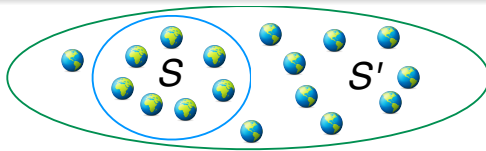
$S \Rightarrow S'$



# The abstract idea

## Entailment

$S \Rightarrow S'$



# The abstract idea

## Entailment

Sandy waltzed  $\Rightarrow$  Sandy danced



# The abstract idea

## Entailment

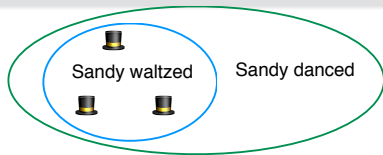
Sandy waltzed  $\Rightarrow$  Sandy danced



# The abstract idea

## Entailment

Sandy waltzed  $\Rightarrow$  Sandy danced



# The abstract idea

## Entailment

$$S \Rightarrow S'$$

## Non-entailment

$$S \not\Rightarrow S'$$



S

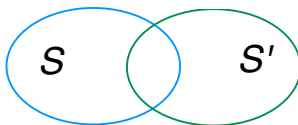
# The abstract idea

## Entailment

$$S \Rightarrow S'$$

## Non-entailment

$$S \not\Rightarrow S'$$



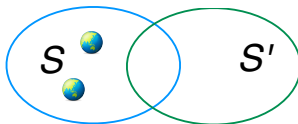
# The abstract idea

## Entailment

$$S \Rightarrow S'$$

## Non-entailment

$$S \not\Rightarrow S'$$



# The abstract idea

## Entailment

Sandy waltzed  $\Rightarrow$  Sandy danced

## Non-entailment

Sandy danced  $\nRightarrow$  Sandy waltzed


# The abstract idea

## Entailment

Sandy waltzed  $\Rightarrow$  Sandy danced

## Non-entailment

Sandy danced  $\nRightarrow$  Sandy waltzed



Sandy danced

# The abstract idea

## Entailment

Sandy waltzed  $\Rightarrow$  Sandy danced

## Non-entailment

Sandy danced  $\not\Rightarrow$  Sandy waltzed





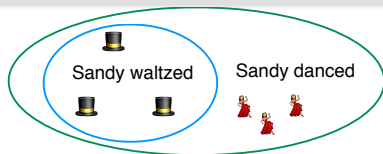
# The abstract idea

## Entailment

Sandy waltzed  $\Rightarrow$  Sandy danced

## Non-entailment

Sandy danced  $\nRightarrow$  Sandy waltzed



# The abstract idea

## Entailment

$$S \Rightarrow S'$$

## Non-entailment

$$S \not\Rightarrow S'$$

## Contradiction

$$S \Rightarrow \textit{not-S'}$$

# The abstract idea

## Entailment

$$S \Rightarrow S'$$

## Non-entailment

$$S \not\Rightarrow S'$$

## Contradiction

$$S \Rightarrow \text{not-}S'$$



S

# The abstract idea

## Entailment

$$S \Rightarrow S'$$

## Non-entailment

$$S \not\Rightarrow S'$$

## Contradiction

$$S \Rightarrow \text{not-}S'$$



S



S'

# Basic data

Sandy danced

Sandy waltzed

# Basic data

Sandy danced



Sandy waltzed

# Basic data

Sandy danced



Sandy waltzed

# Basic data

A student danced

A Swedish student danced

A student waltzed



# Basic data

A student danced



A Swedish student danced

A student waltzed

# Basic data

A student danced



A Swedish student danced

A student waltzed

# Basic data

A student danced

↕ ↑

A Swedish student danced

↑

A student waltzed

# Basic data

A student danced

↯ ↰

A Swedish student danced

↰ ↯

A student waltzed

# Basic data

A student danced



A Swedish student danced

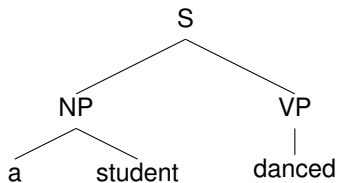
A student waltzed

## Basic data

A student danced

↑                    ↑

A Swedish student danced      A student waltzed

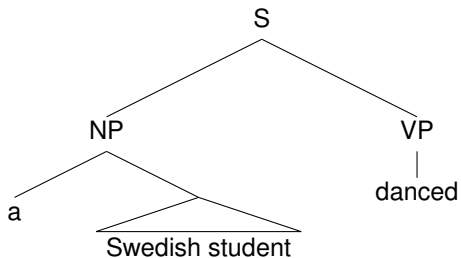


# Basic data

A student danced

↑                    ↑

A Swedish student danced      A student waltzed

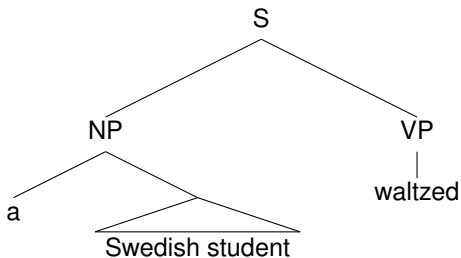


# Basic data

A student danced

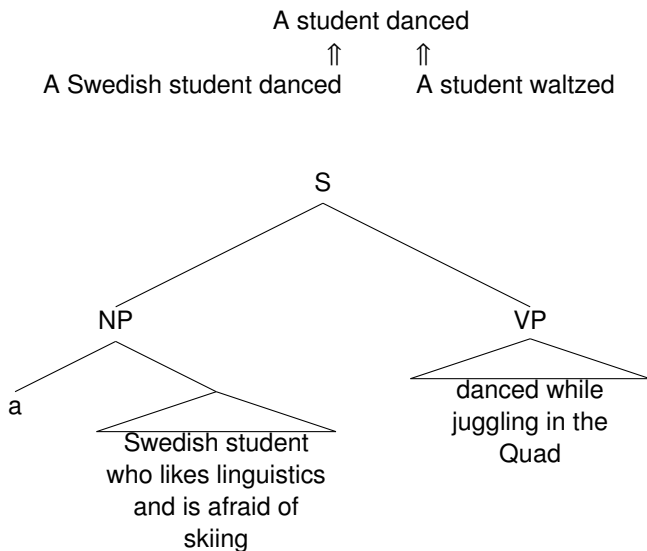
↑                    ↑

A Swedish student danced      A student waltzed





# Basic data



# Basic data

No student danced

No Swedish student danced    No student waltzed

# Basic data

No student danced



No Swedish student danced

No student waltzed

# Basic data

No student danced



No Swedish student danced

No student waltzed

# Basic data

Every student danced

Every Swedish student danced    Every student waltzed

# Basic data

Every student danced



Every Swedish student danced

Every student waltzed

# Basic data

Every student danced



Every Swedish student danced



Every student waltzed

# The patterns



# The patterns

A student danced

A Swedish student danced    A student waltzed

# The patterns

A student danced

↑↑   ↑↑

A Swedish student danced

A student waltzed

# The patterns

A student danced

↑↑ ↑↑

A Swedish student danced

A student waltzed

No student danced

No Swedish student danced

No student waltzed

# The patterns

A student danced

↑↑

A Swedish student danced

↑↑

A student waltzed

No student danced

↓↓

No Swedish student danced

↓↓

No student waltzed

# The patterns

A student danced

↑↑ ↑↑

A Swedish student danced

A student waltzed

No student danced

↓↓ ↓↓

No Swedish student danced

No student waltzed

Every student danced

Every Swedish student danced

Every student waltzed

# The patterns

A student danced

↑↑

A Swedish student danced

↑↑

A student waltzed

No student danced

↓↓

No Swedish student danced

↓↓

No student waltzed

Every student danced

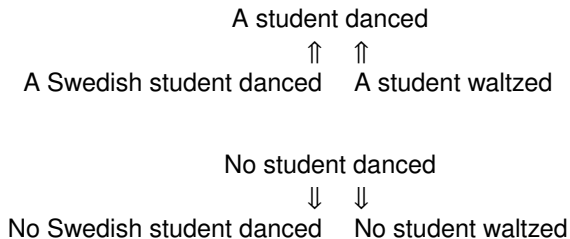
↓↓

Every Swedish student danced

↑↑

Every student waltzed

# Negation reverses entailments



# Negation reverses entailments

A student danced

↑ ↑

A Swedish student danced

A student waltzed

No student danced

↓ ↓

No Swedish student danced

No student waltzed

Sandy danced

↑

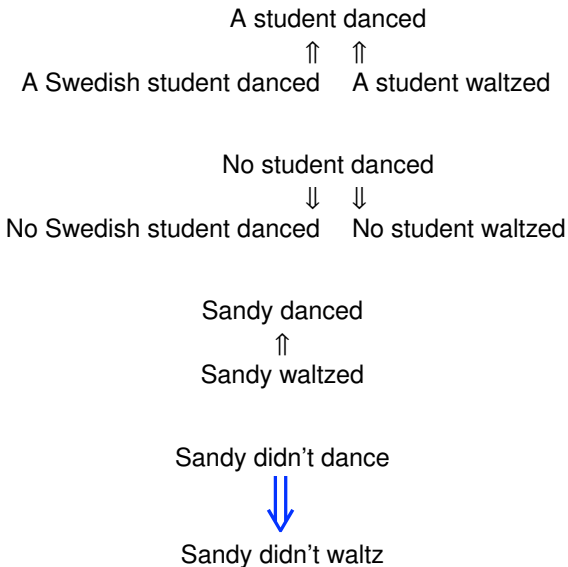
Sandy waltzed

Sandy didn't dance

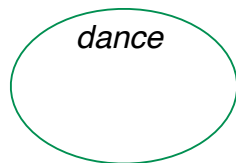
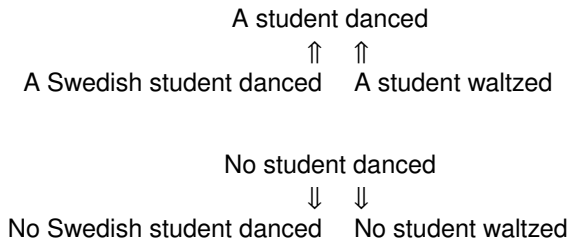
Sandy didn't waltz



# Negation reverses entailments



# Negation reverses entailments



# Negation reverses entailments

A student danced



A Swedish student danced

A student waltzed

No student danced



No Swedish student danced

No student waltzed

Sandy danced

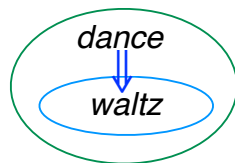


Sandy waltzed

Sandy didn't dance



Sandy didn't waltz



# Negation reverses entailments

A student danced

↑ ↑

A Swedish student danced

A student waltzed

No student danced

↓ ↓

No Swedish student danced

No student waltzed

*waltz*

Sandy danced

↑

Sandy waltzed

Sandy didn't dance

↓↓

Sandy didn't waltz

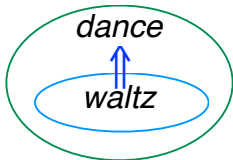
*dance*

*waltz*

# Negation reverses entailments

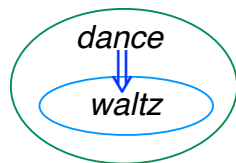
A student danced  
 ↑ ↑  
 A Swedish student danced    A student waltzed

No student danced  
 ↓ ↓  
 No Swedish student danced    No student waltzed

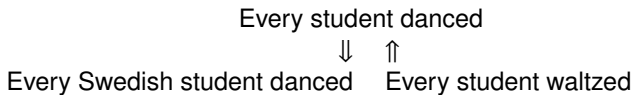


Sandy danced  
 ↑  
 Sandy waltzed

Sandy didn't dance  
 ↓↓  
 Sandy didn't waltz

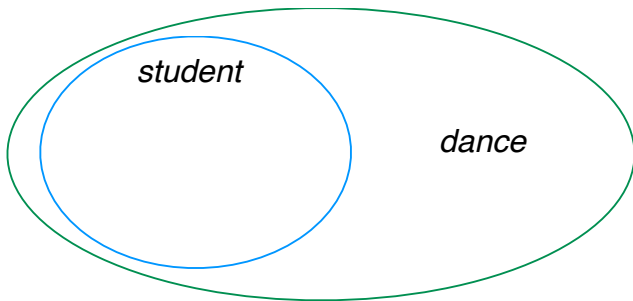


# An intuitive but precise argument



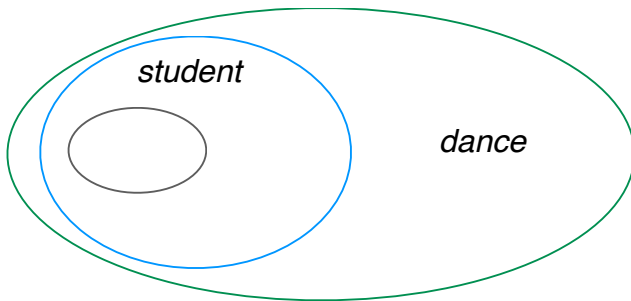
# An intuitive but precise argument

Every student danced  
↓   ↑  
Every Swedish student danced   Every student waltzed



# An intuitive but precise argument

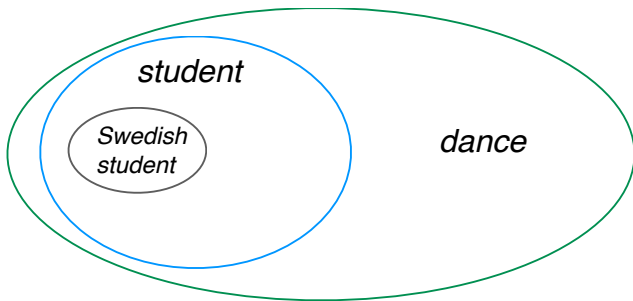
Every student danced  
↓   ↑  
Every Swedish student danced   Every student waltzed





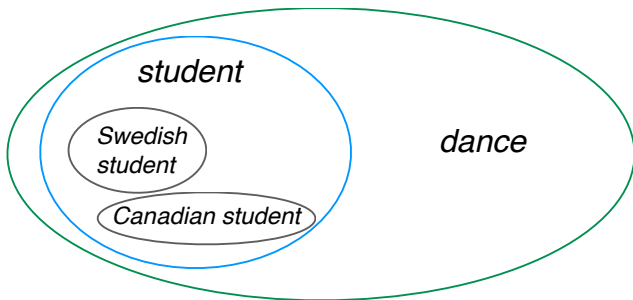
# An intuitive but precise argument

Every student danced  
↓   ↑  
Every Swedish student danced   Every student waltzed



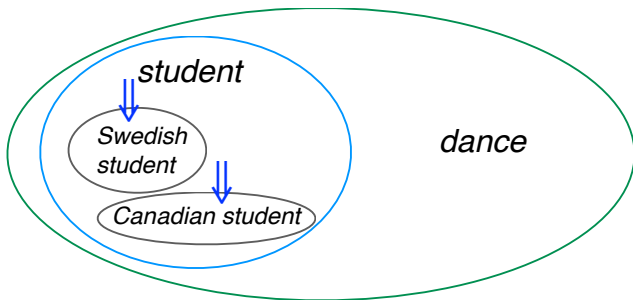
# An intuitive but precise argument

Every student danced  
↓   ↑  
Every Swedish student danced   Every student waltzed



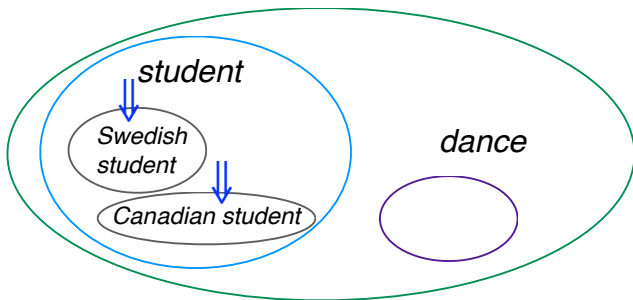
# An intuitive but precise argument

Every student danced  
↓   ↑  
Every Swedish student danced   Every student waltzed



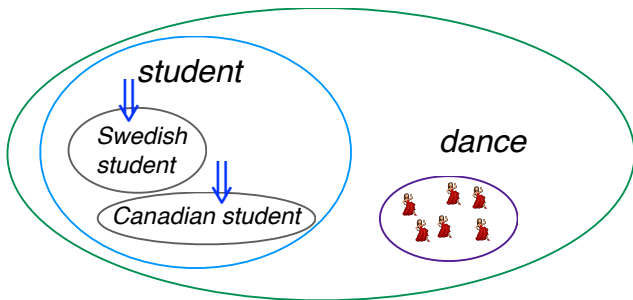
# An intuitive but precise argument

Every student danced  
↓   ↑  
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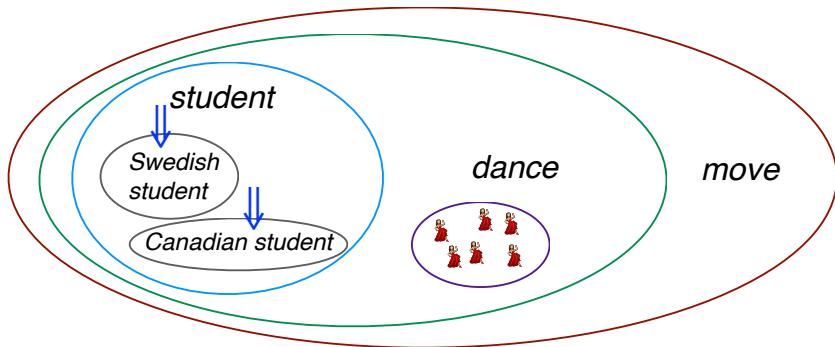
# An intuitive but precise argument

Every student danced  
↓   ↑  
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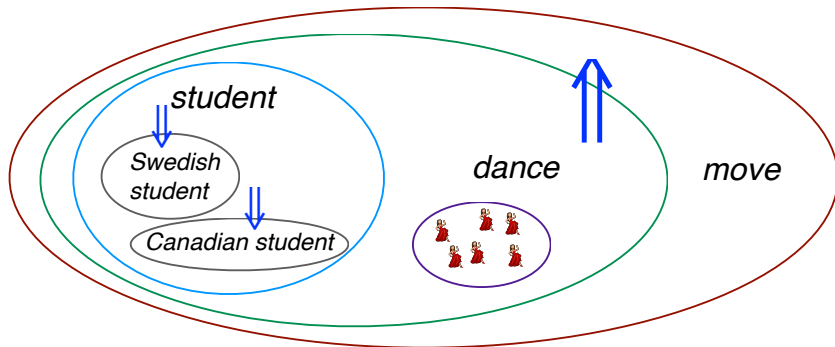
# An intuitive but precise argument

Every student danced  
↓ ↑  
Every Swedish student danced    Every student waltzed



# An intuitive but precise argument

Every student danced  
↓ ↑  
Every Swedish student danced    Every student waltzed



# More data, deeper insights

- 1 *some* (  $\uparrow$  ) (  $\uparrow$  )
- 2 *no* (  $\downarrow$  ) (  $\downarrow$  )
- 3 *every* (  $\downarrow$  ) (  $\uparrow$  )
- 4 *exactly three* (  $-$  ) (  $-$  )
- 5 *few* ( ) ( )
- 6 *most* ( ) ( )
- 7 *a minority of* ( ) ( )
- 8 *not every* ( ) ( )
- 9 *only* ( ) ( )