Introduction to Dependency Grammar

HS Current Approaches to Dependency Parsing
SS 2010

Thanks to Markus Dickinson, Joakim Nivre and Sandra Kübler.

Dependency Grammar

- Not a coherent grammatical framework: wide range of different kinds of DG
  - just as there are wide ranges of "generative syntax"
- Different core ideas than phrase structure grammar
- We will base a lot of our discussion on Mel'čuk (1988)

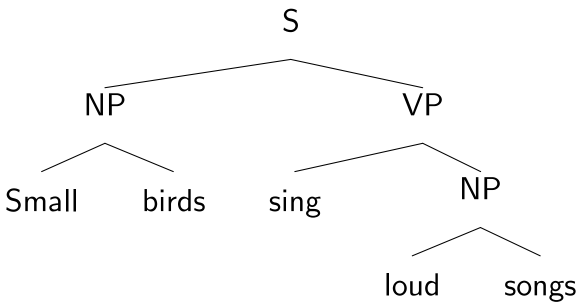
Dependency grammar is important for those interested in CL:

- Increasing interest in dependency-based approaches to syntactic parsing in recent years (e.g., CoNLL-X shared task, 2006)

Overview: constituency

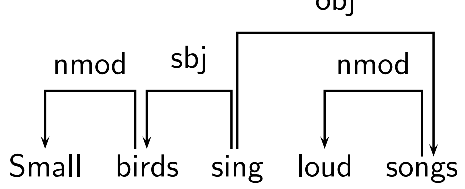
(1) Small birds sing loud songs

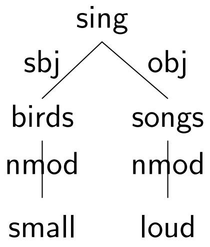
What you might be more used to seeing:



Overview: dependency

Syntactic structure consists of lexical items, linked by binary asymmetric relations called dependencies.





Constituency vs. Relations

- DG is based on relationships between words, i.e., **dependency relations**
  - A → B means *A governs B* or *B depends on A* ...
  - Dependency relations can refer to syntactic properties, semantic properties, or a combination of the two
    - → Some variants of DG separate syntactic and semantic relations by representing different layers of dependencies
  - These relations are generally things like subject, object/complement, (pre-/post-)adjunct, etc.
    - Subject/Agent: *John* fished.
    - Object/Patient: Mary hit *John*.
- PSG is based on groupings (called *phrases* or *constituents*)
  - Grammatical relations are not usually seen as primitives, but as being derived from structure

Simple relation example

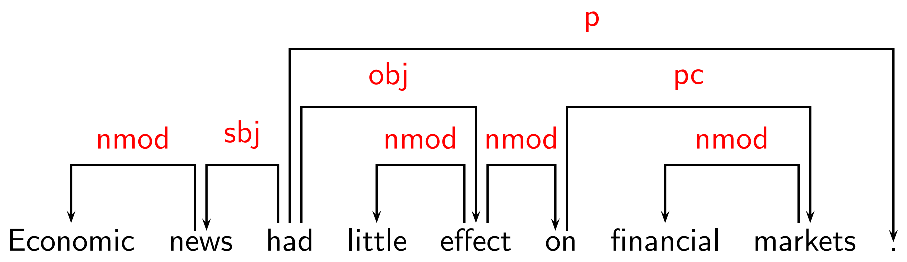
For the sentence *John loves Mary*, we have the relations:

- loves $\rightarrow_{\text{subj}}$ John
- loves $\rightarrow_{\text{obj}}$ Mary

Both *John* and *Mary* depend on *loves*, which makes *loves* the head, or **root**, of the sentence (i.e., there is no word that governs *loves*)

- The structure of a sentence, then, consists of the set of pairwise relations among words.

Dependency Structure

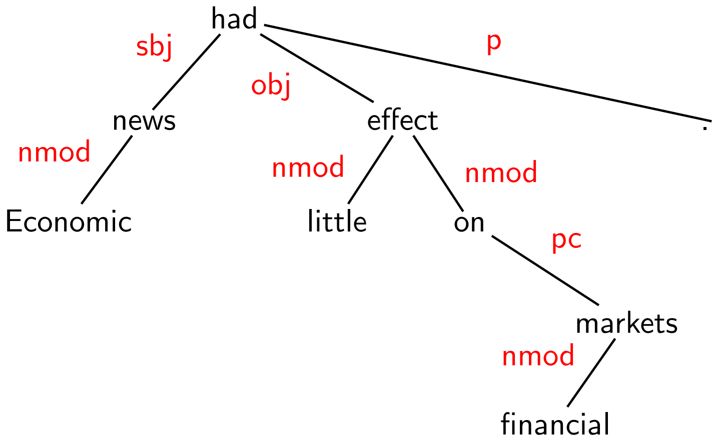


Economic news had little effect on financial markets .

Terminology

Superior	**Inferior**
Head	Dependent
Governor	Modifier
Regent	Subordinate
⋮	⋮

Notational Variants



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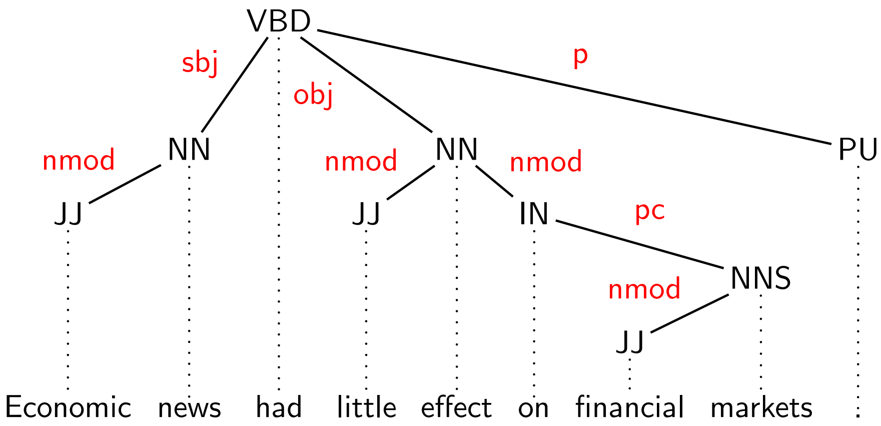

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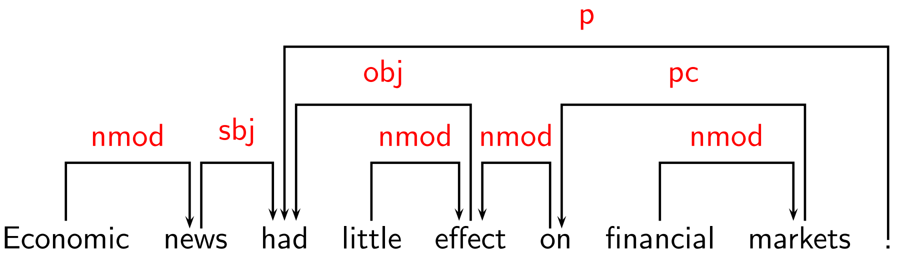

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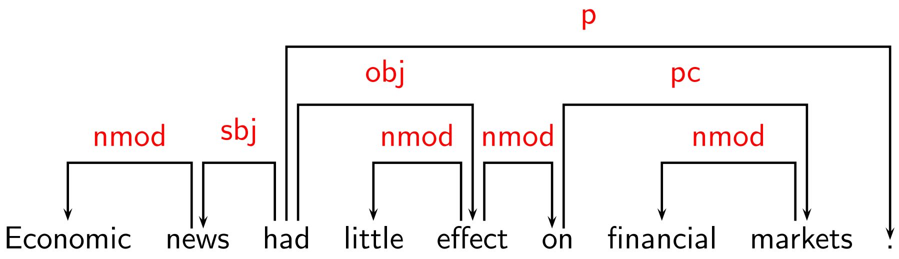
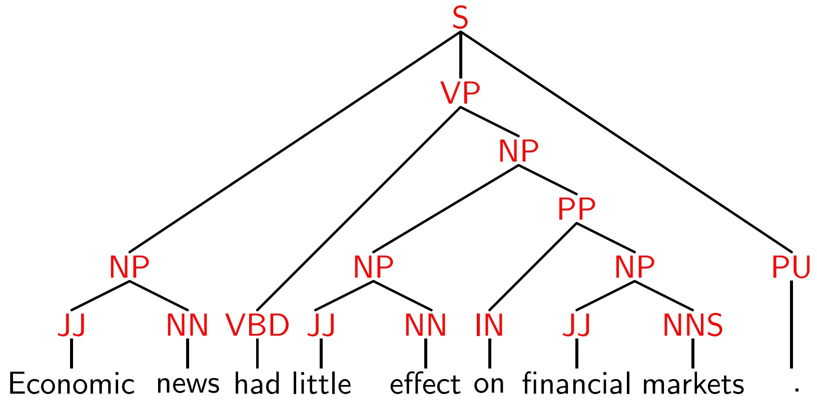


Phrase Structure



Comparison

- Dependency structures explicitly represent
  - head-dependent relations (directed arcs),
  - functional categories (arc labels),
  - possibly some structural categories (parts-of-speech).
- Phrase structures explicitly represent
  - phrases (nonterminal nodes),
  - structural categories (nonterminal labels),
  - possibly some functional categories (grammatical functions).
- Hybrid representations may combine all elements.

Some Theoretical Frameworks

- Word Grammar (WG) Hudson (1984, 1990)
- Functional Generative Description (FGD) Sgall et al. (1986)
- Dependency Unification Grammar (DUG) Hellwig (1986, 2003)
- Meaning-Text Theory (MTT) Mel'čuk (1988)
- (Weighted) Constraint Dependency Grammar ([W]CDG) Maruyama (1990); Harper & Helzerman (1995); Menzel & Schröder (1998); Schröder (2002)
- Functional Dependency Grammar (FDG) Tapanainen & Järvinen (1997); Järvinen & Tapanainen (1998)
- Topological/Extensible Dependency Grammar ([T/X]DG) Duchier & Debusmann (2001); Debusmann et al. (2004)

Some Theoretical Issues

- Dependency structure sufficient as well as necessary?
- Mono-stratal or multi-stratal syntactic representations?
- What is the nature of lexical elements (nodes)?
  - Morphemes?
  - Word forms?
  - Multi-word units?
- What is the nature of dependency types (arc labels)?
  - Grammatical functions?
  - Semantic roles?
- What are the criteria for identifying heads and dependents?
- What are the formal properties of dependency structures?

Capturing Adjuncts and Complements

There are two main kinds of dependencies for A → B:

- Head-Complement: if A (the head) has a slot for B, then B is a complement
- Head-Adjunct: if B has a slot for A (the head), then B is an adjunct

B is dependent on A in either case, but the selector is different

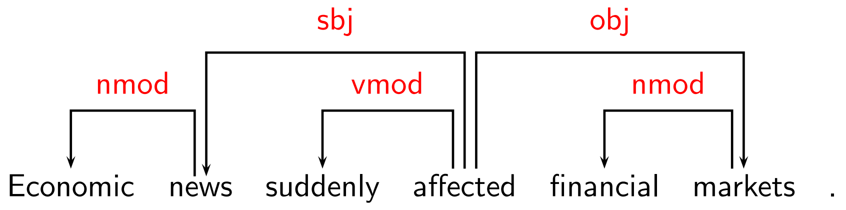
- The adjunct/complement distinction is captured in the type of dependency relation and/or in the lexicon

Criteria for Heads and Dependents

- Criteria for a syntactic relation between a head *H* and a dependent *D* in a construction *C* Zwicky (1985); Hudson (1990):
  1. *H* determines the syntactic category of *C*; *H* can replace *C*.
  2. *H* determines the semantic category of *C*; *C* specifies *H*.
  3. *H* is obligatory; *D* may be optional.
  4. *H* selects *D* and determines whether *D* is obligatory.
  5. The form of *D* depends on *H* (agreement or government).
  6. The linear position of *D* is specified with reference to *H*.
- Issues:
  - Syntactic (and morphological) versus semantic criteria
  - Exocentric versus endocentric constructions

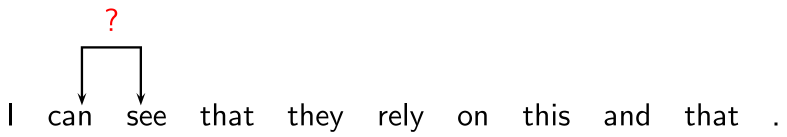
Some Clear Cases

Construction	Head	Dependent
Exocentric	Verb	Subject (sbj)
	Verb	Object (obj)
Endocentric	Verb	Adverbial (vmod)
	Noun	Attribute (nmod)



Some Tricky Cases

- Complex verb groups (auxiliary ↔ main verb)
- Subordinate clauses (complementizer ↔ verb)
- Coordination (coordinator ↔ conjuncts)
- Prepositional phrases (preposition ↔ nominal)
- Punctuation



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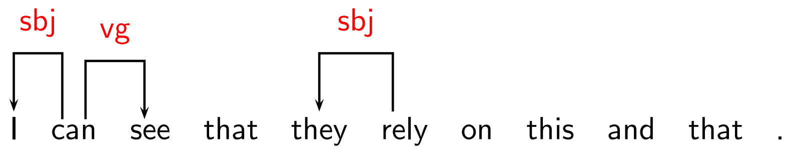

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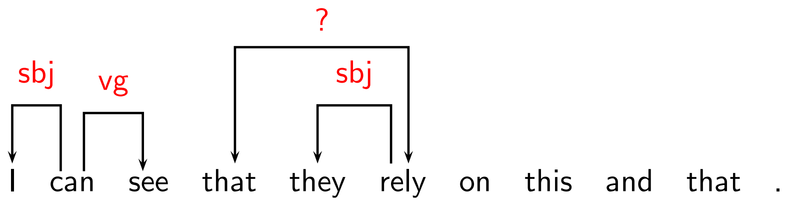

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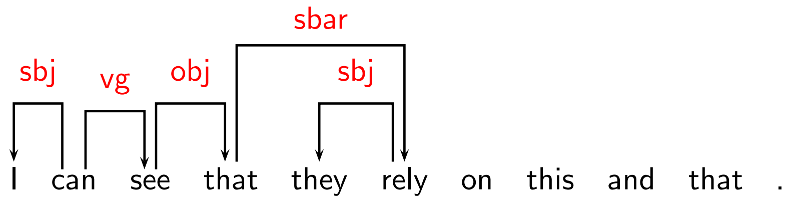

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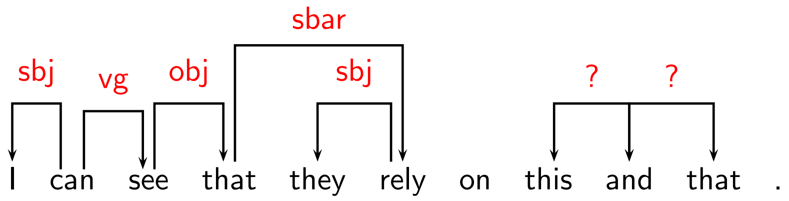

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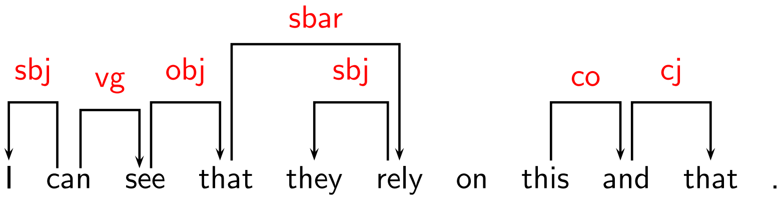

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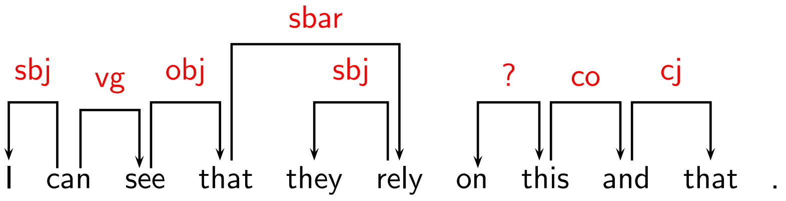

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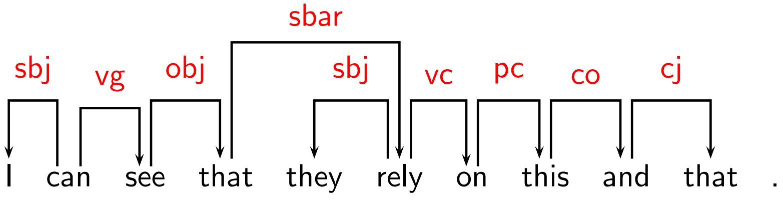

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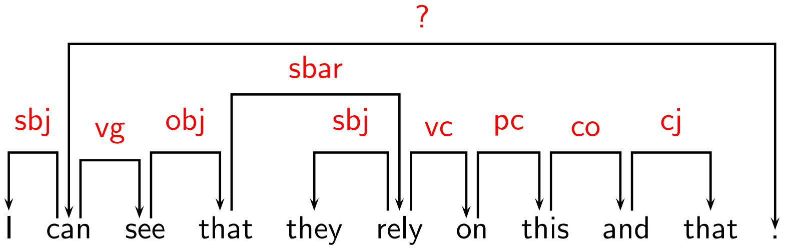

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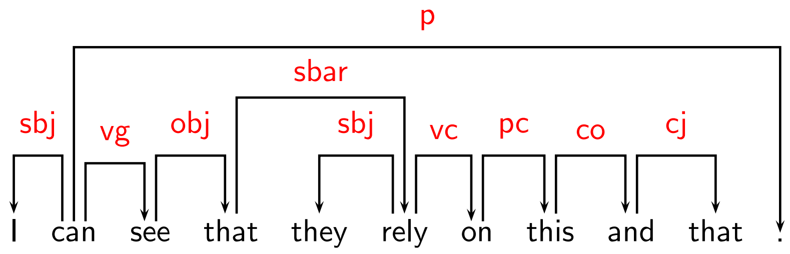


Dependency Graphs

- A dependency structure can be defined as a directed graph G, consisting of
  - a set V of nodes,
  - a set E of arcs (edges),
  - a linear precedence order $<$ on V (not in every theory)
- Labeled graphs:
  - Nodes in V are labeled with word forms (and annotation).
  - Arcs in E are labeled with dependency types.
- Notational conventions ($i, j \in V$):
  - $i \to j \;\equiv\; (i,j) \in E$
  - $i \to^* j \;\equiv\; i = j \vee \exists k : i \to k,\, k \to^* j$

Formal Properties of Dependency Graphs

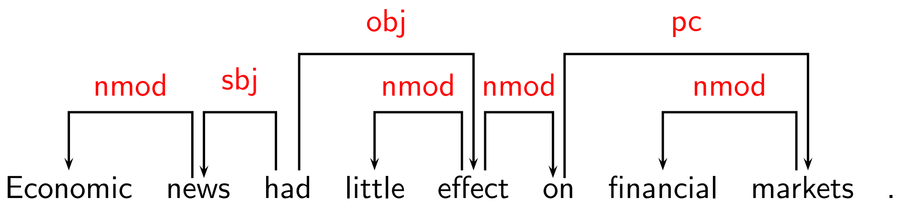
- **antisymmetric**: if A $\to$ B, then B $\not\to$ A
  - cf. *box lunch* (lunch $\to$ box) vs. *lunch box* (box $\to$ lunch)
- **antireflexive**: if A $\to$ B, then B $\neq$ A
- **antitransitive**: if A $\to$ B and B $\to$ C, then A $\not\to$ C
  - These are *direct* dependency relations
  - cf. *a usually reliable source*: source $\to$ reliable & reliable $\to$ usually, but source $\not\to$ usually
- **labeled**: $\forall \to$, $\to$ has a label (r)

Formal Conditions on Dependency Graphs

- G is (weakly) connected:
  - For every node i there is a node j such that $i \to j$ or $j \to i$.
- G is acyclic:
  - If $i \to j$ then not $j \to^* i$.
- G obeys the single-head constraint:
  - If $i \to j$, then not $k \to j$, for any $k \neq i$.
- G is projective:
  - If $i \to j$ then $i \to^* k$, for any k such that $i < k < j$ or $j < k < i$.

Connectedness, Acyclicity and Single-Head

- Intuitions:
  - Syntactic structure is complete (Connectedness).
  - Syntactic structure is hierarchical (Acyclicity).
  - Every word has at most one syntactic head (Single-Head).
- Connectedness can be enforced by adding a special root node.



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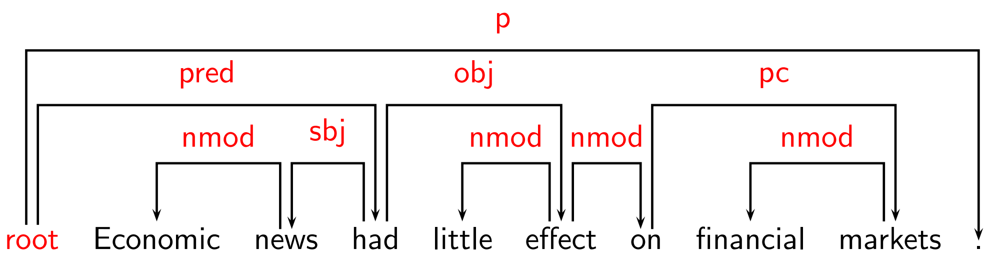


root Economic news had little effect on financial markets .

Projectivity

Projectivity (or, less commonly, **adjacency** Hudson (1990))

- A head (A) and a dependent (B) must be adjacent: A is adjacent to B provided that every word between A and B is a subordinate of A.

(2) with great difficulty

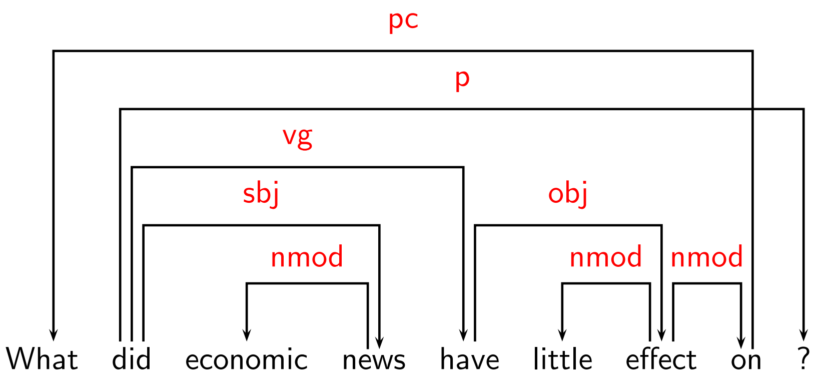
(3) *great with difficulty

- with → difficulty
- difficulty → great

**great with difficulty* is ruled out because branches would have to cross in that case

Projectivity

- Most theoretical frameworks do not assume projectivity.
- Non-projective structures are needed to account for
  - long-distance dependencies,
  - free word order.



What did economic news have little effect on ?

Valency and Grammaticality

An important concept in many variants of DG is that of **valency** = the ability of a word to take arguments
A lexicon might look like the following Hajič et al. (2003):

	Slot$_1$	Slot$_2$	Slot$_3$
sink$_1$	ACT(nom)	PAT(acc)	
sink$_2$	PAT(nom)		
give	ACT(nom)	PAT(acc)	ADDR(dat)

To determine grammaticality (roughly) ...

1. Words have valency requirements that must be satisfied
2. Apply general rules to the valencies to see if a sentence is valid

Layers of dependencies

Mel'čuk (1988) allows for different dependency layers

It looks like a subject depends on the verb, but the form of the verb depends on the subject (mutual dependence):

(4) a. The child is playing.
b. The children are playing.

Solution:

- Dependence of *child*/*children* on the verb is syntactic
- Dependence of the verb(form) on the subject is morphological

Double dependencies

Likewise, here it seems that *clean* depends both on the verb *wash* and on the noun *dish*

(5) Wash the dish *clean*.

Solution:

- Dependence of *clean* on *wash* is syntactic (cf. case)
- Dependence of *clean* on *dish* is semantic (cf. gender)

(6)	My našli	zal	pust-ym
	We found the	hall$_{masc}$	empty$_{masc.sg.inst}$

Double dependencies (2)

Hudson's Word Grammar Hudson (2004) explicitly allows for **structure-sharing**, explicitly violating the single-head constraint:

- wash → clean
- dish → clean

NB: Hudson also uses this to account for non-projectivity, but we'll ignore the details.

Relation to phrase structure

After all this discussion, what is the relation between DG and PSG?

- If a PS tree has heads marked, then you can derive the dependencies
- Likewise, a DG tree can be converted into a PS tree by grouping a word with its dependents
  - But what the constituents are is still open (binary-branching, flat)
  - And phrases are not categorized

Advantages and Disadvantages of DG

Advantages:

- Close connection to semantic representation
- More flexible structure for, e.g., non-constituent coordination
- Easier to capture some typological regularities
- Vast & expanding body of computational work on dependency parsing

Disadvantages:

- No constituents makes analyzing coordination difficult
- No distinction between modifying a constituent vs. an individual word
- Harder to capture things like, e.g., subject-object asymmetries

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