Dependency-based Relation Extraction using the UIMA-based Text Mining Pipeline UTEMPL

Jannik Strötgen, Juliane Fluck, and Anke Holler

October 2nd 2009

UNIVERSITÄT HEIDELBERG

Fraunhofer SCAI Institute Algorithms and Scientific Computing

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Agenda

- Introduction & Motivation
  - Text Mining in the Biomedical Domain
- UTEMPL
- Relation Extraction
- Dependency-based Relation Extraction with UTEMPL
  - A Syntax for Rule Development
- Evaluation
- Conclusions

Agenda

- **Introduction & Motivation**
  - **Text Mining in the Biomedical Domain**
- UTEMPL
- Relation Extraction
- Dependency-based Relation Extraction with UTEMPL
  - A Syntax for Rule Development
- Evaluation
- Conclusions

Text Mining in the Biomedical Domain

- Information only published in unstructured format,
  → text

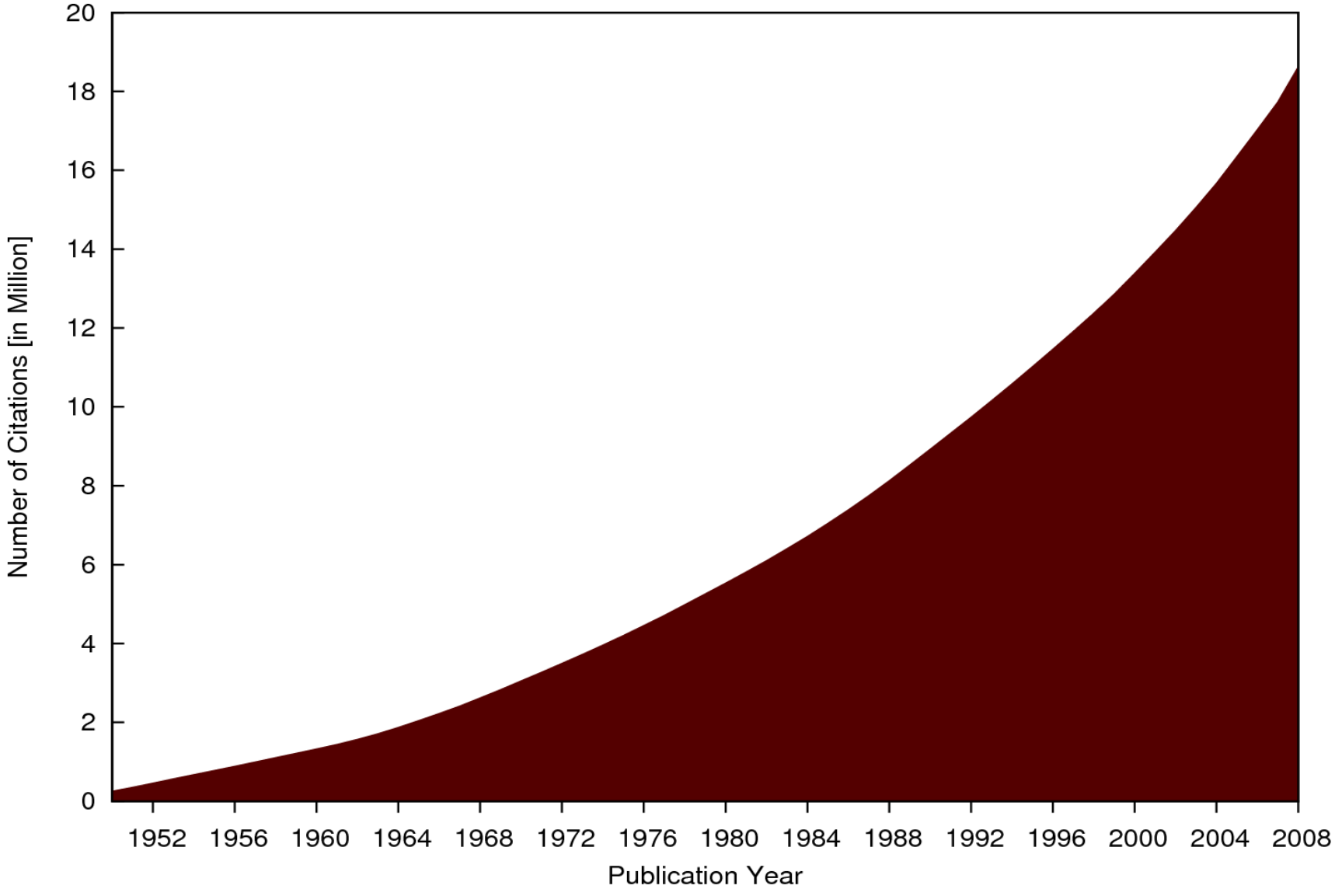
Text Mining in the Biomedical Domain

- Information only published in unstructured format,
  → text
- Increasing number of scientific publications

Text Mining in the Biomedical Domain

- Information only published in unstructured format,
  → text
- Increasing number of scientific publications
  - Abstracts → Medline [http://www.ncbi.nlm.nih.gov/pubmed/]

Text Mining in the Biomedical Domain



Text Mining in the Biomedical Domain

- Information only published in unstructured format,
  → text
- Increasing number of scientific publications
  - Abstracts → Medline [http://www.ncbi.nlm.nih.gov/pubmed/]
- Open Access Initiative
  - Full Text → PubMed Central [http://www.pubmedcentral.nih.gov/]
    BioMed Central [http://www.biomedcentral.com/]

Text Mining in the Biomedical Domain

- Several difficulties in the biomedical domain
  - Biomedical language → sublanguage
    - All NLP components should be developed for or adapted to the biomedical domain

Text Mining in the Biomedical Domain

- Several difficulties in the biomedical domain
  - Biomedical language → sublanguage
    - All NLP components should be developed for or adapted to the biomedical domain
  - Named Entity Recognition and Normalization
    - Synonymy
    - Polysemy

Text Mining in the Biomedical Domain

- Several difficulties in the biomedical domain
  - ed for or
  - on

NER tool ProMiner [Hanisch et al. 2005]:

Number of Entities	**24.892**
Number of Synonyms	**311.601**
max Number of Synonyms for one Entity	**210**

Agenda

- Introduction & Motivation
  - Text Mining in the Biomedical Domain
- **UTEMPL**
- Relation Extraction
- Dependency-based Relation Extraction with UTEMPL
  - A Syntax for Rule Development
- Evaluation
- Conclusions

UTEMPL

- UIMA based Text Mining Pipeline (UTEMPL)

UTEMPL

- UIMA based Text Mining Pipeline (UTEMPL)
- One pipeline for:
  - Several input sources
  - All kinds of NLP tasks
  - Several Named Entity Recognition tools
  - Different Relation Extraction methods

Background: UIMA

- Unstructured Information Management Architecture
  [http://incubator.apache.org/uima/]
- Component framework for unstructured content
- Helps to connect tools not built to be used together (CAS → Common Analysis Structure)

Background: UIMA

- Unstructured Information Management Architecture [http://incubator.apache.org/uima/]
- Component framework for unstructured content
- Helps to connect tools not built to be used together (CAS → Common Analysis Structure)
- Widely used in biomedical domain
  - Many tools available
    - Julie-Lab [http://www.julielab.de]
    - UIMA-bioNLP repository [http://bionlp-uima.sourceforge.net]

UTEMPL

Collection Readers

- Abstract Reader
- Full Text Reader
- Lucene Reader
- Goldstandard Reader

Analysis Engines

- Sentence Splitter
- Tokenizer
- POS Tagger
- NER tools
- Dependency Parser
- Relation Finder

CAS Consumers

- Visualization
- Lucene Indexer
- Evaluation

UTEMPL

- Relation Extraction
  - Example: Protein-Protein Interactions

Agenda

- Introduction & Motivation
  - Text Mining in the Biomedical Domain
- UTEMPL
- **Relation Extraction**
- Dependency-based Relation Extraction with UTEMPL
  - A Syntax for Rule Development
- Evaluation
- Conclusions

Background: Relation Extraction

- Cooccurrence approaches
  - Two entities in a specific window → relation

Background: Relation Extraction

- Cooccurrence approaches
  - Two entities in a specific window → relation
- Pattern Matching approaches
  - Syntactic Patterns (regular expressions, POS, etc.)

Background: Relation Extraction

- Cooccurrence approaches
  - Two entities in a specific window → relation
- Pattern Matching approaches
  - Syntactic Patterns (regular expressions, POS, etc.)
- Approaches with deep linguistic analysis
  - Dependency Parse Trees

Relation Extraction using UTEMPL

- All approaches realized:
  - Cooccurrence Finder
  - Pattern Relation Finder
    - Rules with regular expressions etc.
  - Dependency Relation Finder
    - Rules accessing dependency parse tree information

Relation Extraction using UTEMPL

- All approaches realized:
  - Cooccurrence Finder
  - Pattern Relation Finder
    - Rules with regular expressions etc.
  - Dependency Relation Finder
    - Rules accessing dependency parse tree information

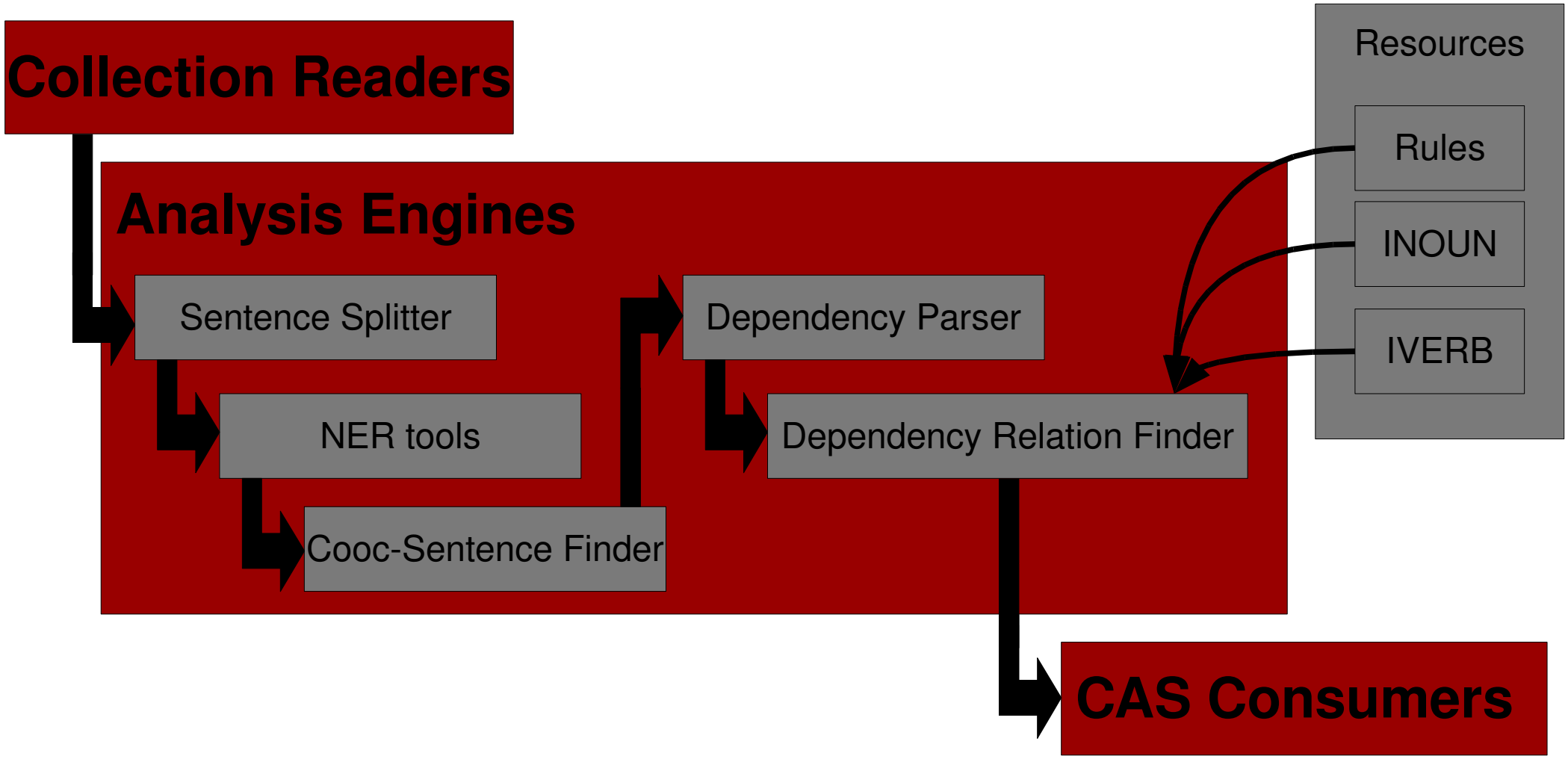
Dependency-based Relation Extraction (DRE)

- Related work: RelEx [Fundel et al. 2006]
  - Methods:
    - Three very general rules
  - Promising results

Dependency-based Relation Extraction (DRE)

- Related work: RelEx [Fundel et al. 2006]
  - Methods:
    - Three very general rules
  - Promising results
- Our approach:
  - Separate rules for all kinds of linguistic phenomena to use the full power of dependency parsing

Dependency-based Relation Extraction (DRE)



Agenda

- Introduction & Motivation
  - Text Mining in the Biomedical Domain
- UTEMPL
- Relation Extraction
- **Dependency-based Relation Extraction with UTEMPL**
  - A Syntax for Rule Development
- Evaluation
- Conclusions

Dependency-based Relation Extraction (DRE)

- Our approach:
  - Separate rules for all kinds of linguistic phenomena to use the power of full dependency parsing

Dependency-based Relation Extraction (DRE)

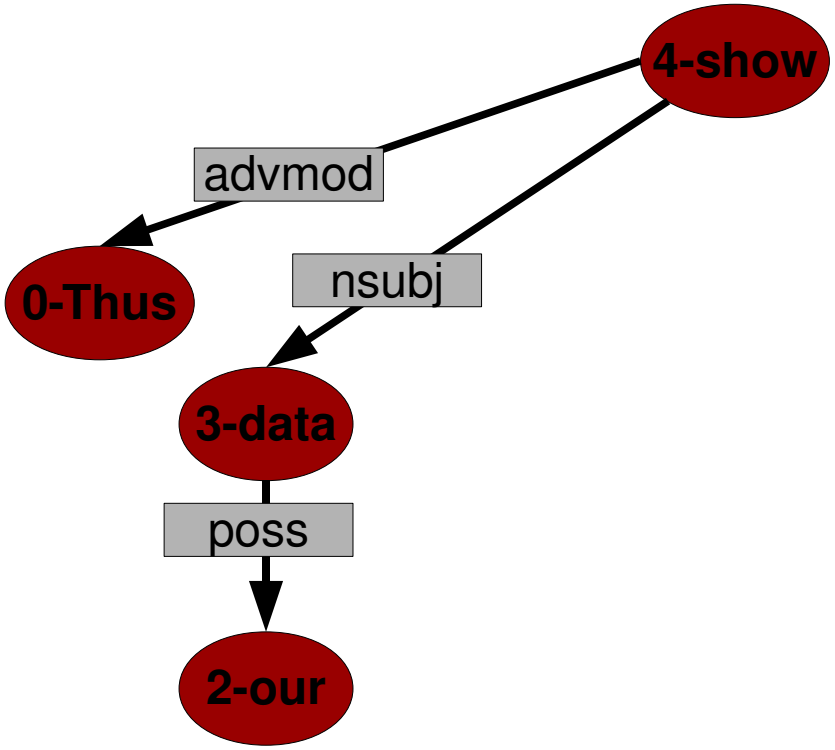
- Our approach:
  - Separate rules for all kinds of linguistic phenomena to use the power of full dependency parsing
- Pre-requirement:
  - Development of a Syntax for Writing Rules
    - to create features to access all relevant information in the trees

Background: A Dependency Parse Tree

- Example for a tree created by the Stanford Dependency Parser [http://nlp.stanford.edu/software/lex-parser.shtml]

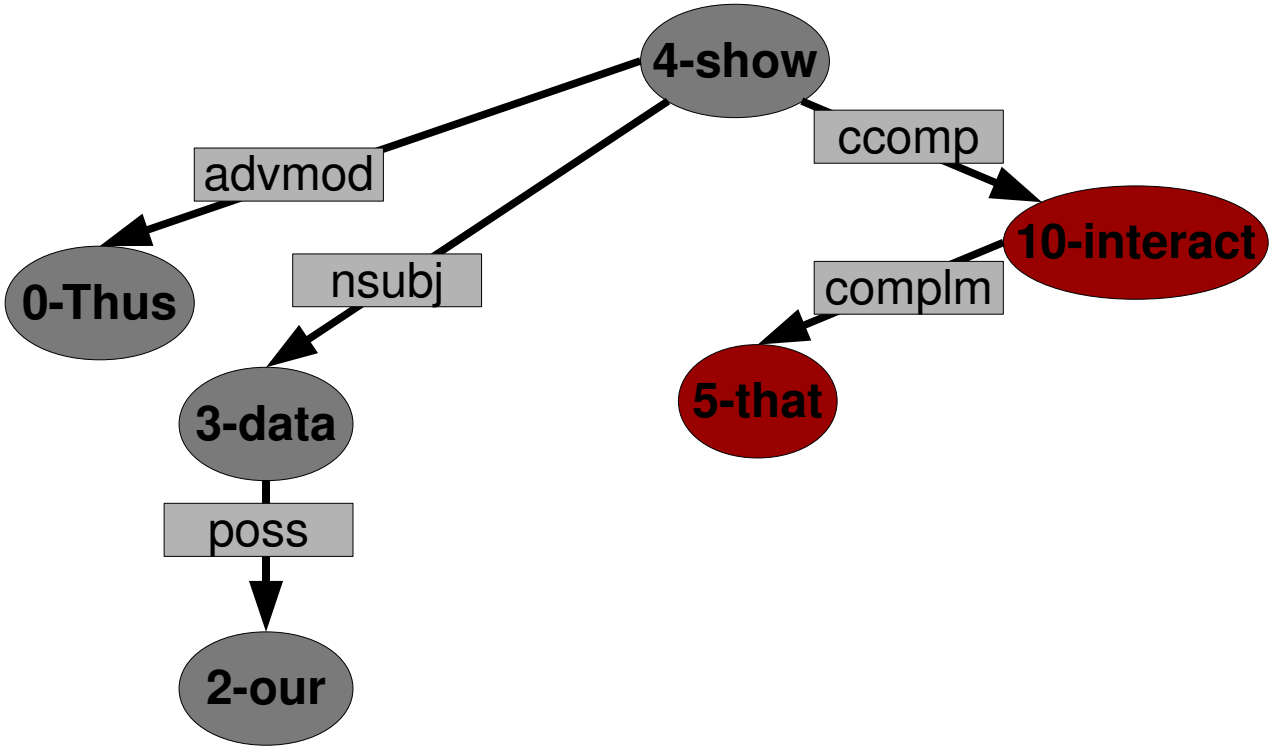
S1: Thus, our data show that both calnexin and calreticulin interact with Glut-1. (source AIMed Corpus)

Background: A Dependency Parse Tree



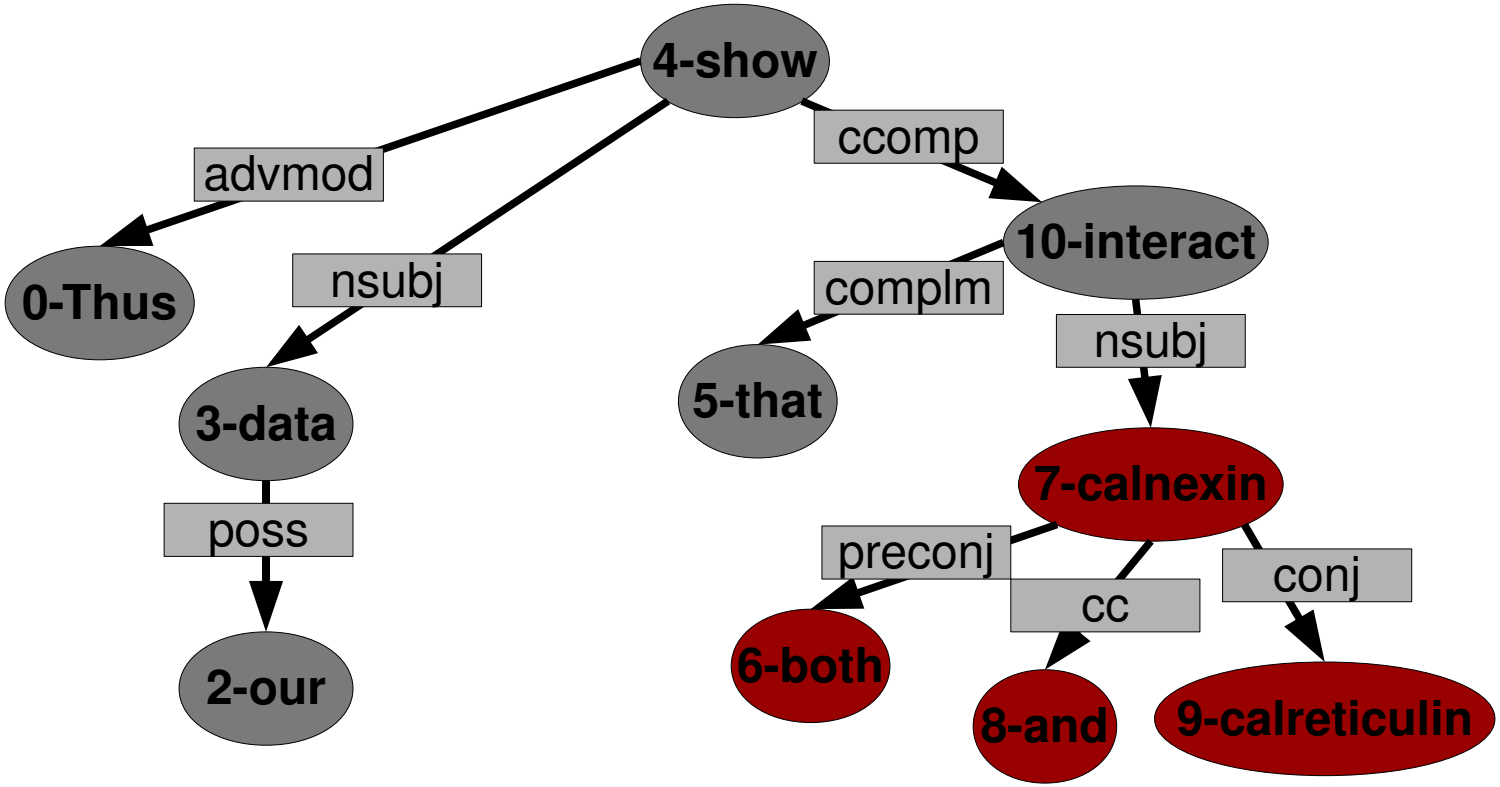
S1: Thus, our data show that both calnexin and calreticulin interact with Glut-1. (source AIMed Corpus)

Background: A Dependency Parse Tree



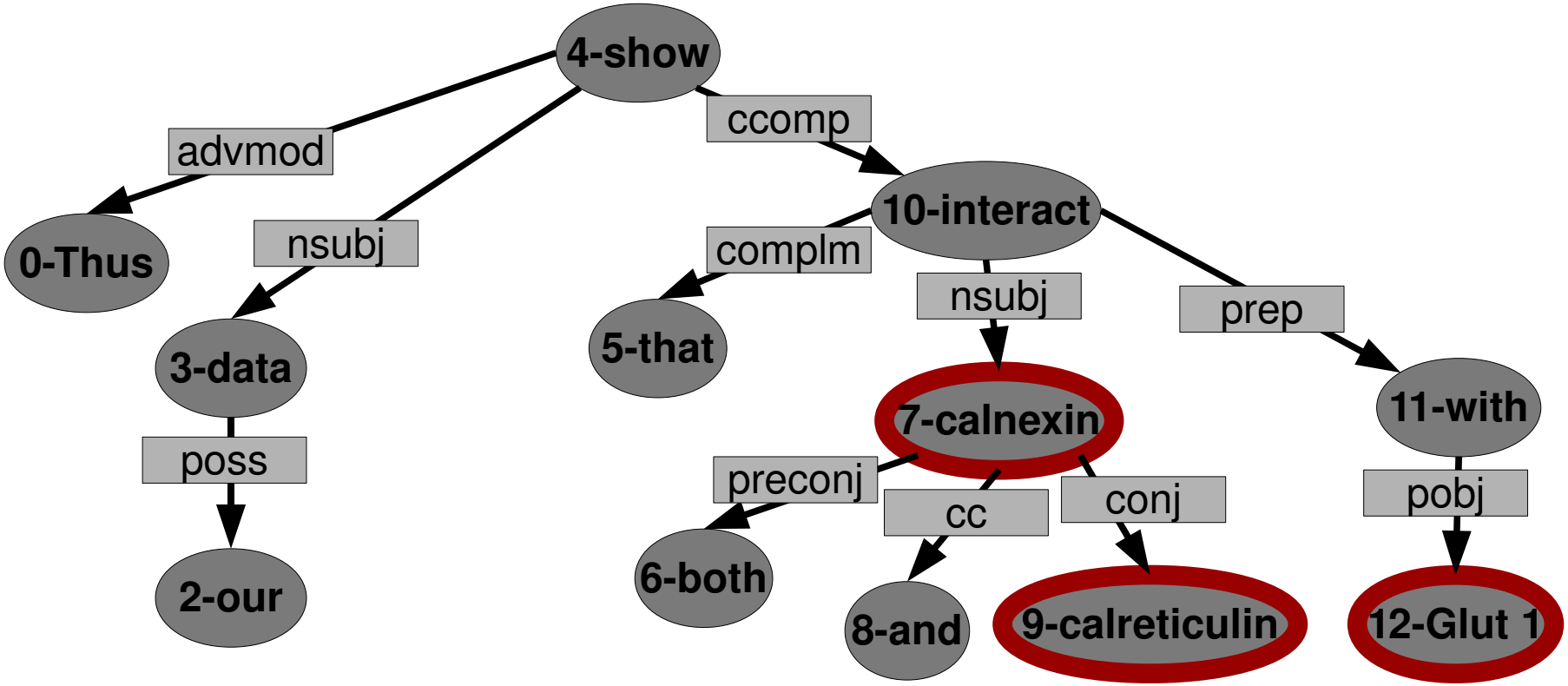
S1: Thus, our data show that both calnexin and calreticulin interact with Glut-1. (source AIMed Corpus)

Background: A Dependency Parse Tree



S1: Thus, our data show that both calnexin and calreticulin interact with Glut-1. (source AIMed Corpus)

Background: A Dependency Parse Tree



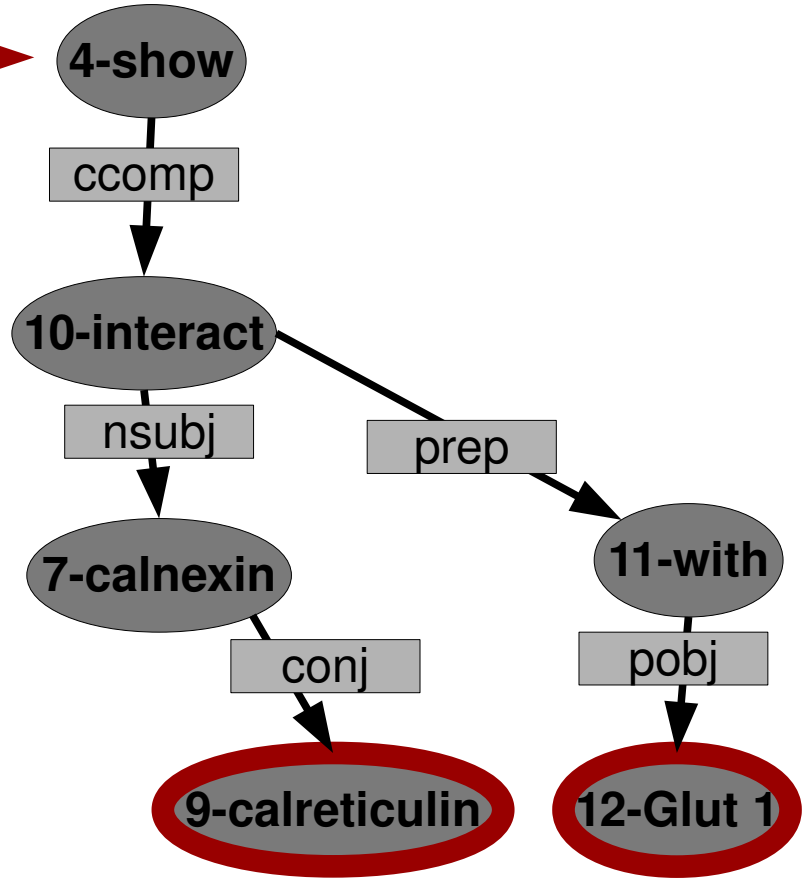
S1: Thus, our data show that both calnexin and calreticulin interact with Glut-1. (source AIMed Corpus)

Agenda

- Introduction & Motivation
  - Text Mining in the Biomedical Domain
- UTEMPL
- Relation Extraction
- **Dependency-based Relation Extraction with UTEMPL**
  - **A Syntax for Rule Development**
- Evaluation
- Conclusions

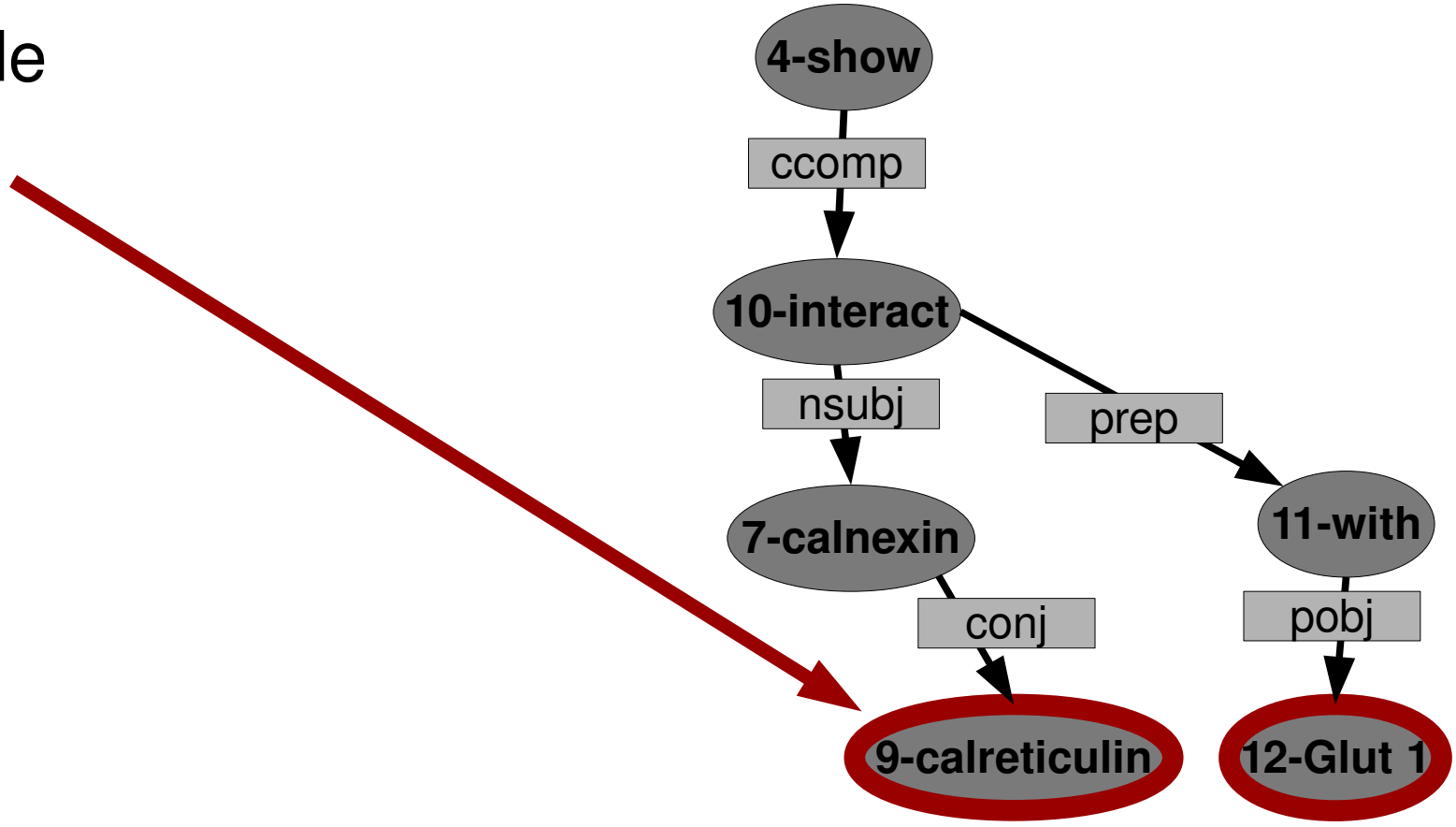
Developing a Syntax for DRE

- Characteristics of a tree for entity pairs:
  - root node



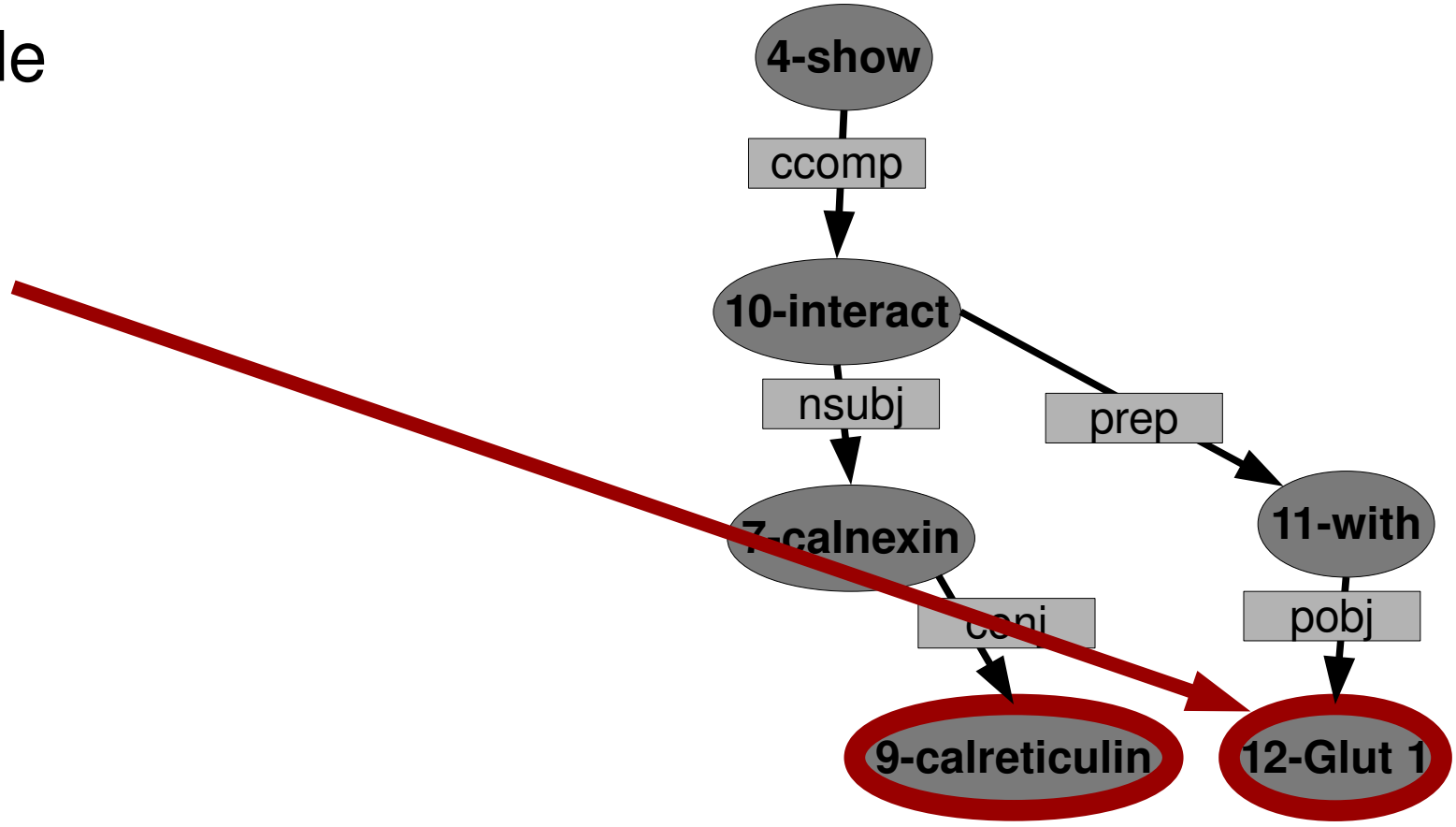
Developing a Syntax for DRE

- Characteristics of a tree for entity pairs:
  - root node
  - entity 1



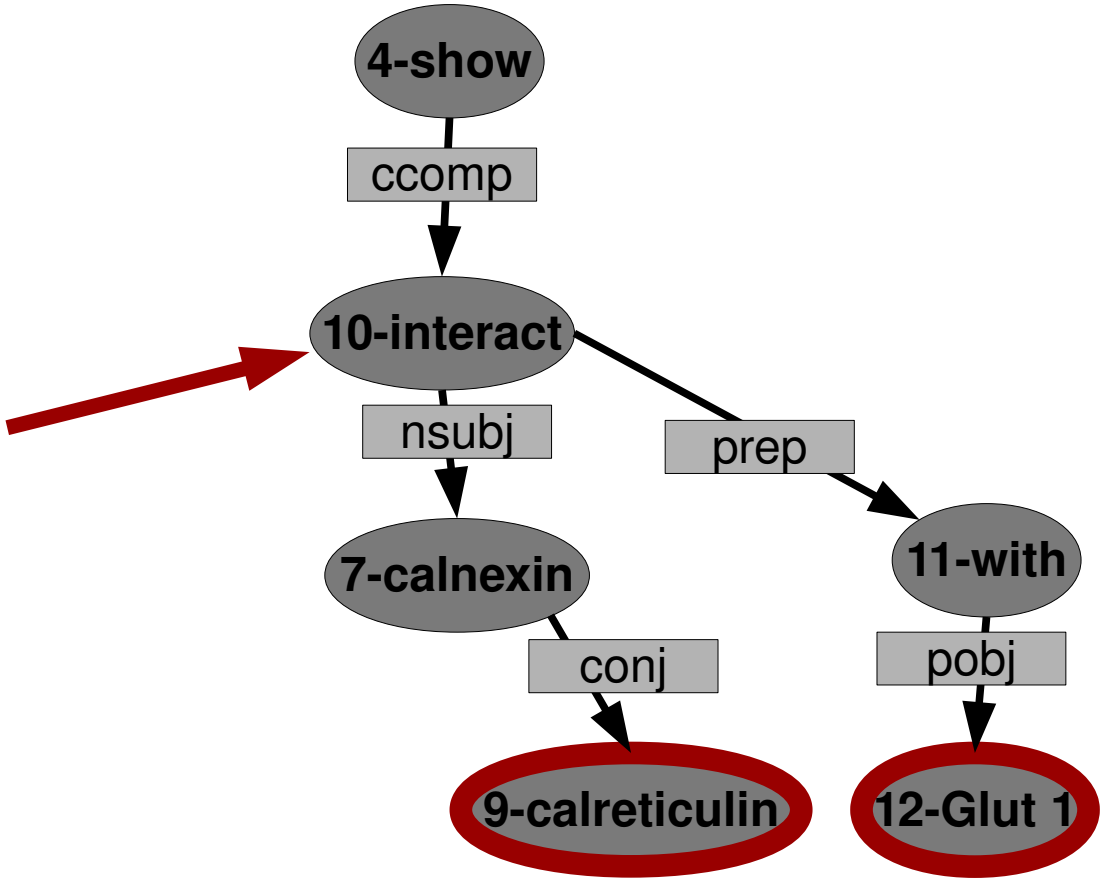
Developing a Syntax for DRE

- Characteristics of a tree for entity pairs:
  - root node
  - entity 1
  - entity 2



Developing a Syntax for DRE

- Characteristics of a tree for entity pairs:
  - root node
  - entity 1
  - entity 2
  - common parent (CP)

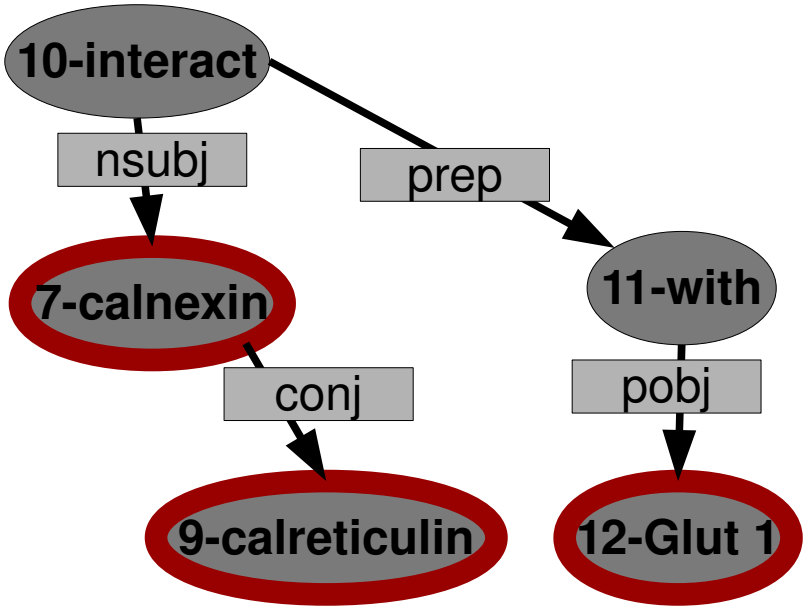


Developing a Syntax for DRE

- Three entity pairs

  → Three possible relations:

  - calnexin & calreticulin
  - calnexin & Glut-1
  - calreticulin & Glut-1

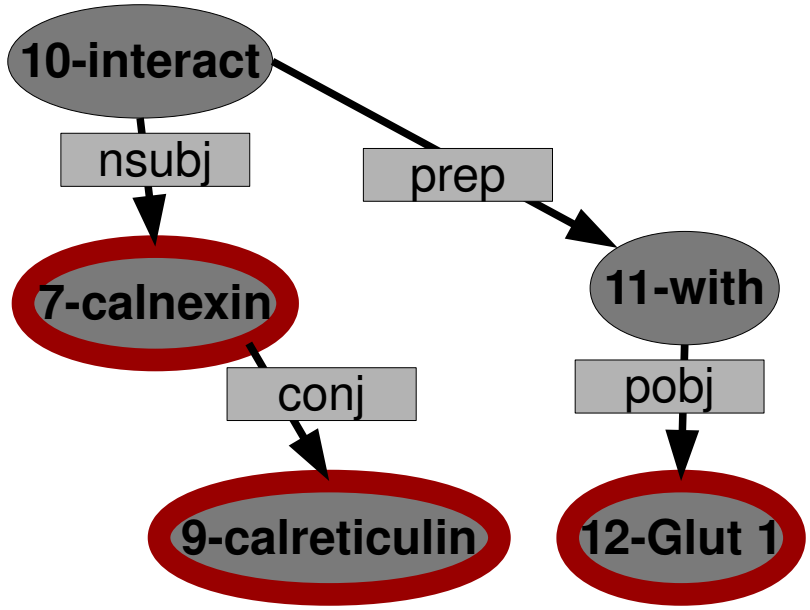


Developing a Syntax for DRE

- Three entity pairs

  → Three possible relations:

  - **calnexin & calreticulin**
  - calnexin & Glut-1
  - calreticulin & Glut-1



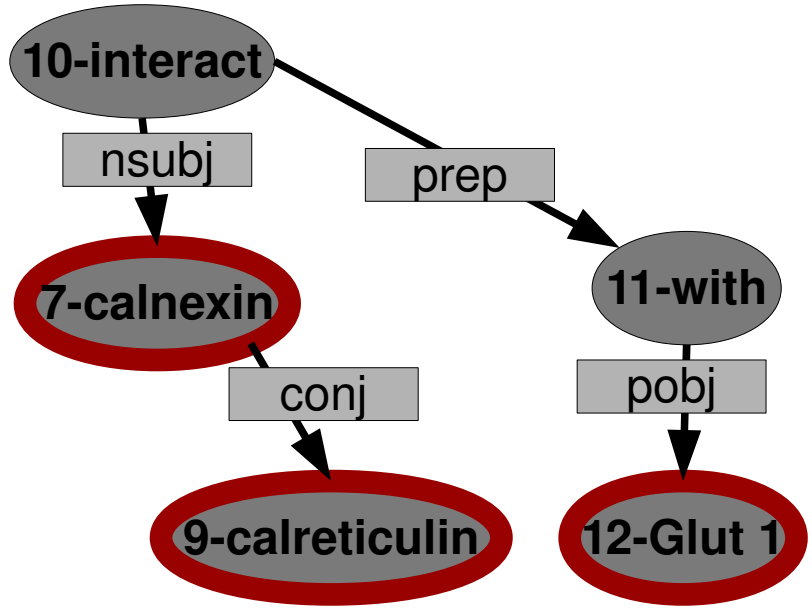
- → either an entity is common parent (CP)

Developing a Syntax for DRE

- Three entity pairs

  → Three possible relations:

  - calnexin & calreticulin
  - **calnexin & Glut-1**
  - **calreticulin & Glut-1**



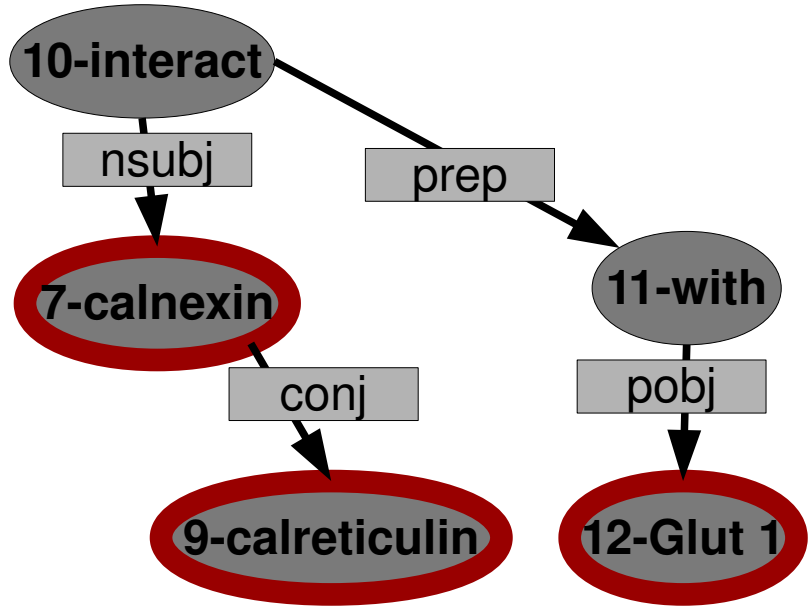
- → either an entity is common parent (CP) or another token is common parent (CP)

Developing a Syntax for DRE

- Three entity pairs

  → Three possible relations:

  - calnexin & calreticulin
  - **calnexin & Glut-1**
  - **calreticulin & Glut-1**

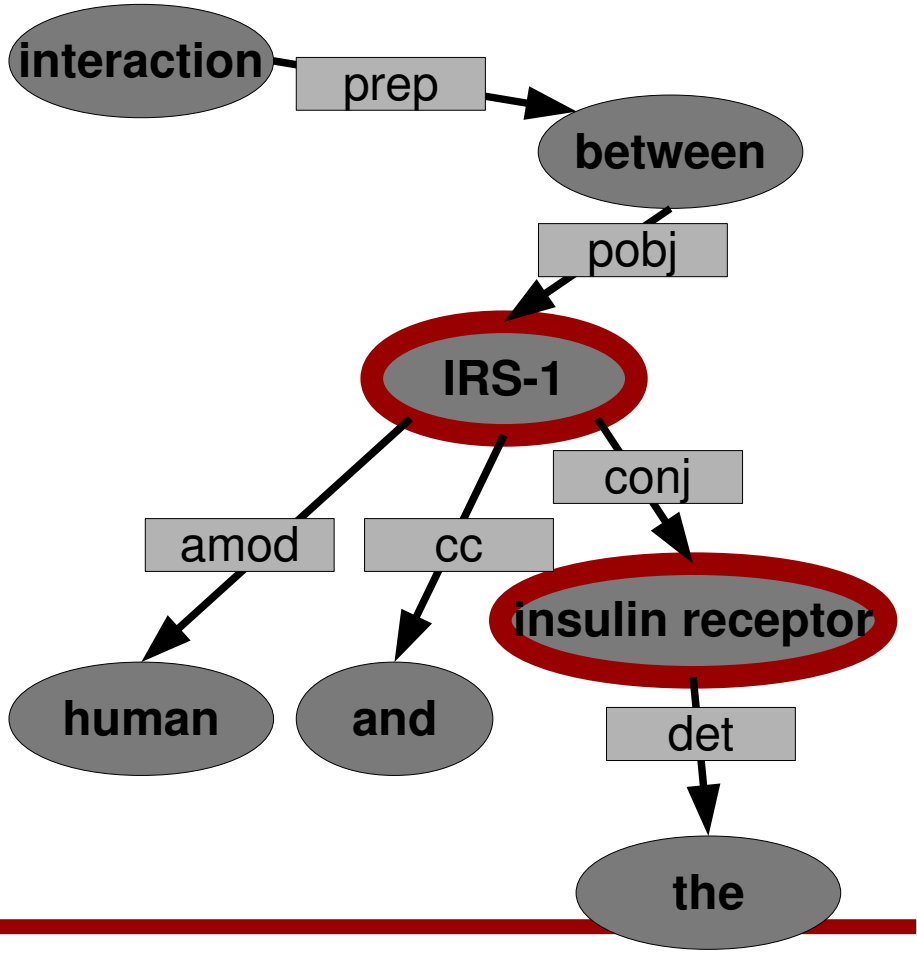


- → both “useful” relations are of the type “**otherCP**”

Developing a Syntax for DRE

- In other constructions “useful” relations are of type “**e1isCP**”

S2: … interaction between human IRS-1 and the insulin receptor (source AIMed Corpus)



Developing a Syntax for DRE

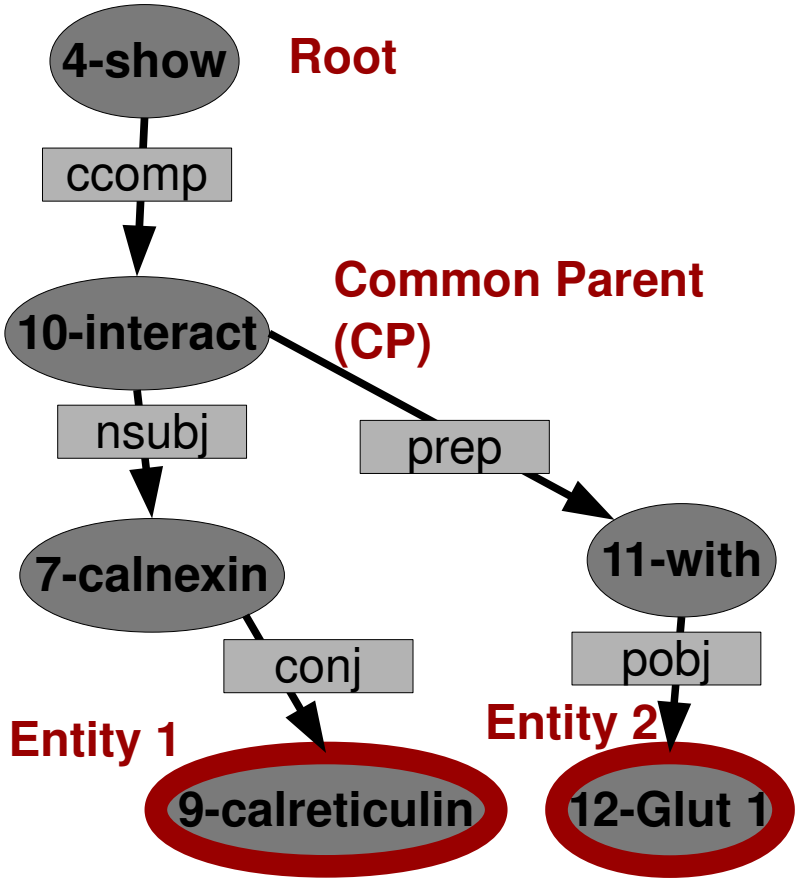
- First feature of the syntax for Dependency Relation Finder rules:
  - Type of rule:
    - e1isCP
    - otherCP

Developing a Syntax for DRE

- First feature of the syntax for Dependency Relation Finder rules:
  - Type of rule:
    - e1isCP
    - otherCP
- Next features for:
  - Relations (arcs)
  - Tokens and their positions (nodes)

Developing a Syntax for DRE

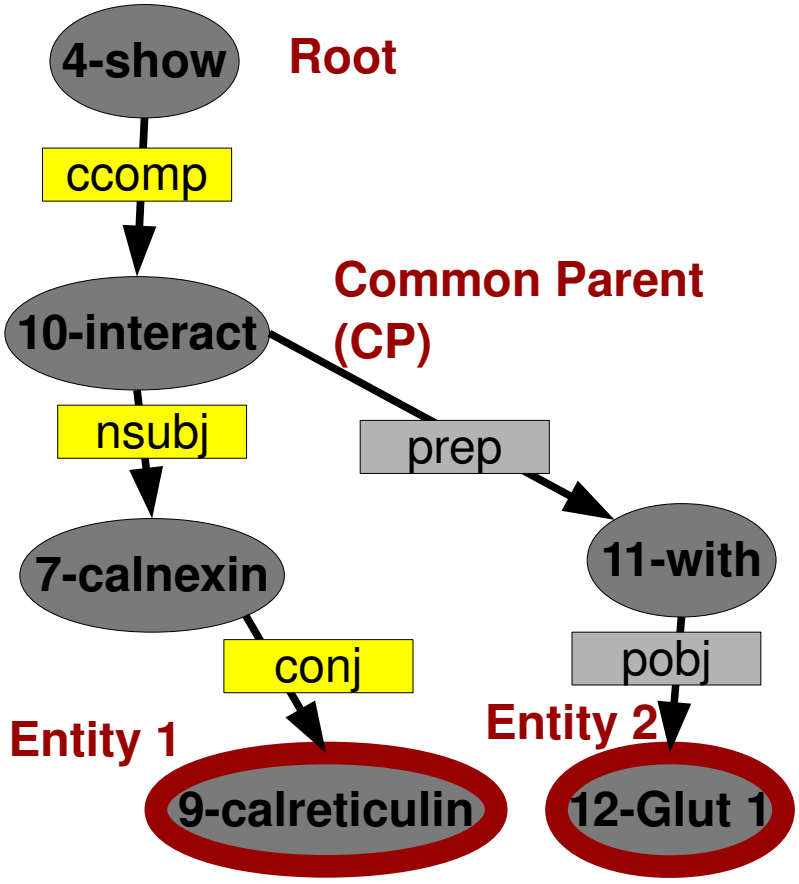
- Features for relations (arcs):



Developing a Syntax for DRE

- Features for relations (arcs):
  - e1RelToRoot

    conj->nsubj->ccomp

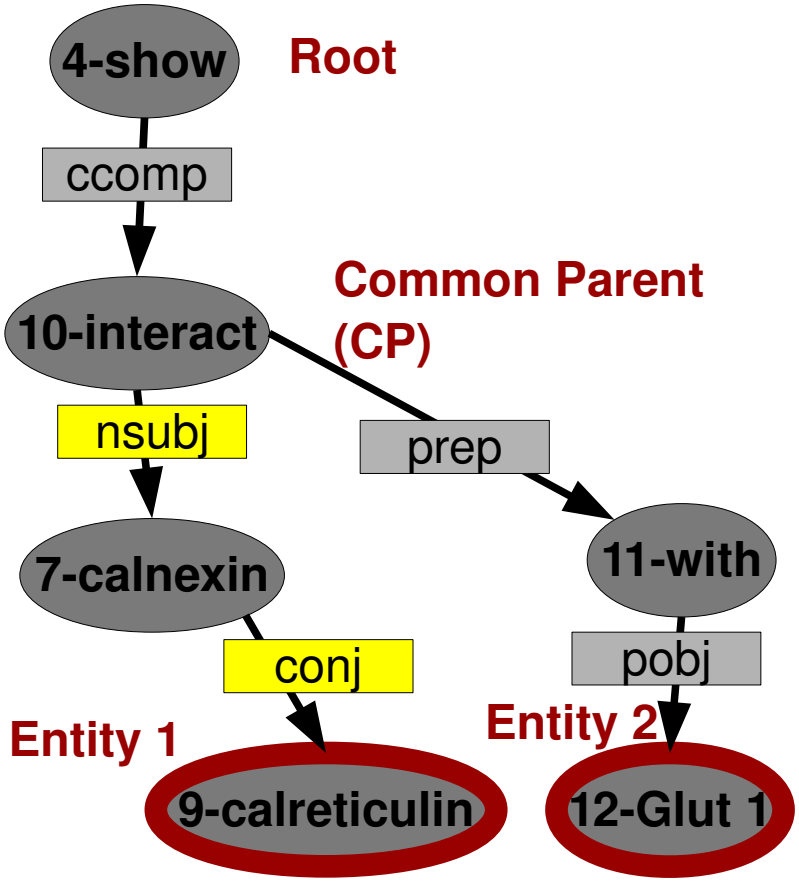


Developing a Syntax for DRE

- Features for relations (arcs):
  - e1RelToRoot

    conj->nsubj->ccomp
  - e1RelToCP

    conj->nsubj



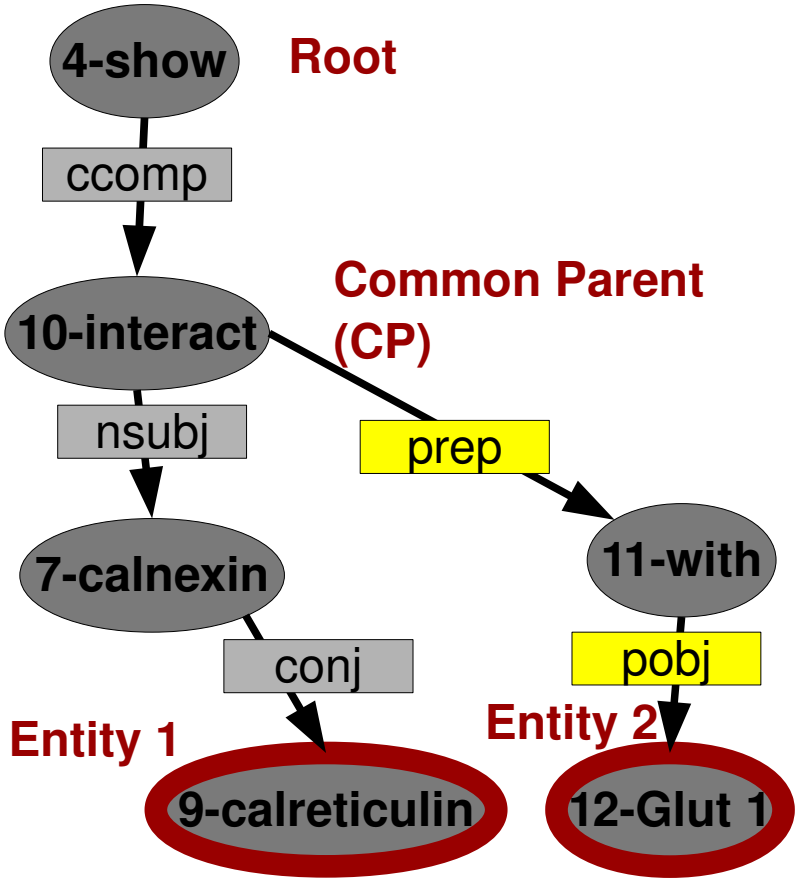
Developing a Syntax for DRE

- Features for relations (arcs):
  - e1RelToRoot

    conj->nsubj->ccomp
  - e1RelToCP

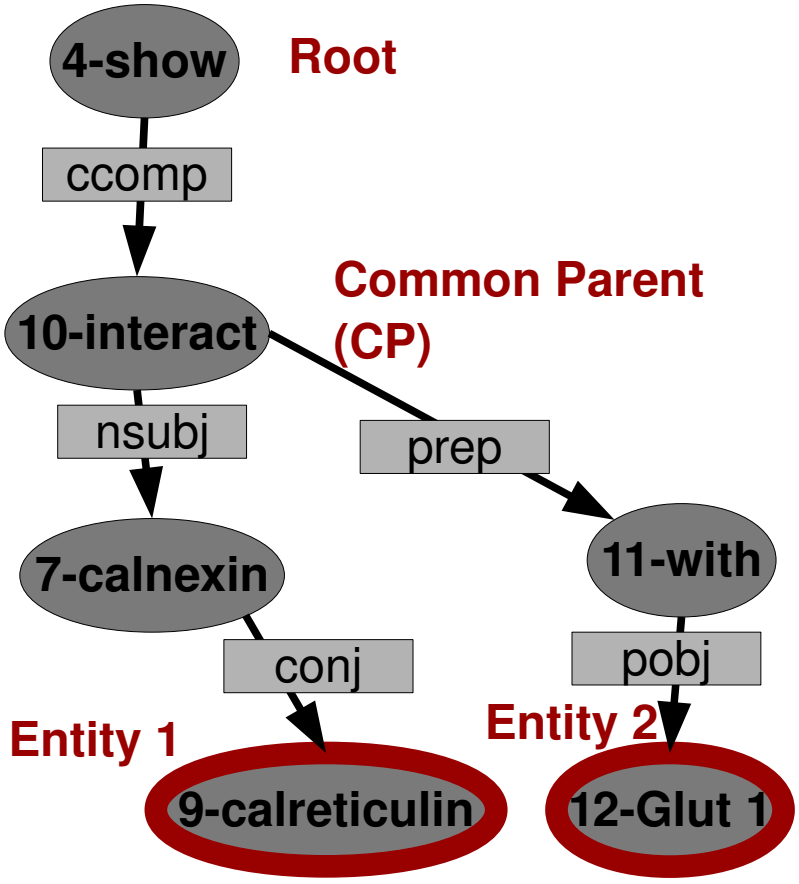
    conj->nsubj
  - e2RelToCP

    pobj->prep



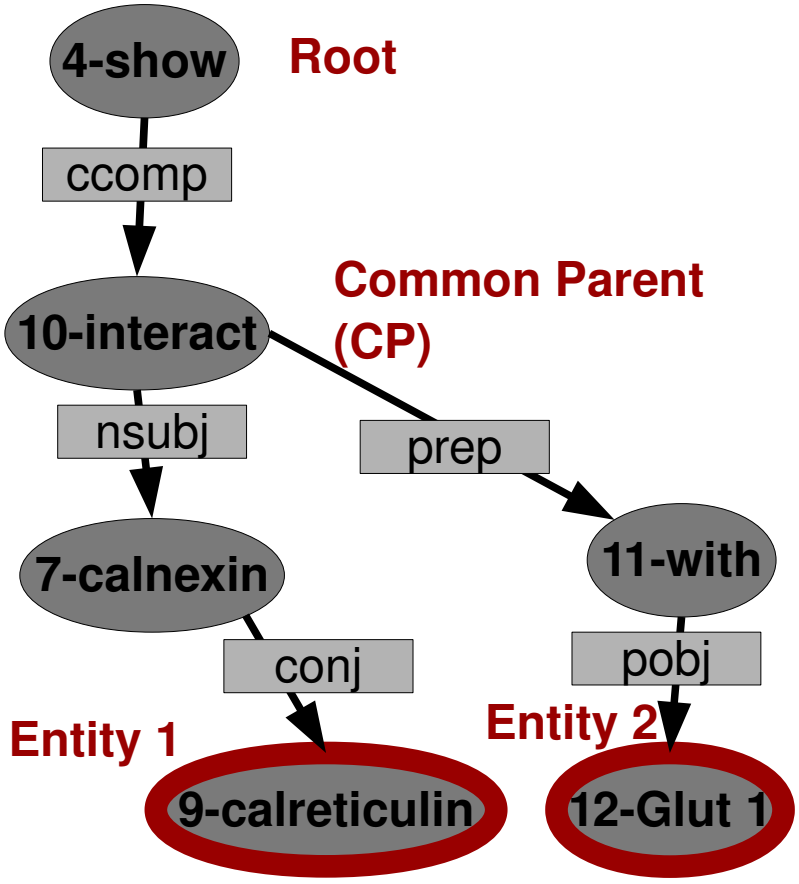
Developing a Syntax for DRE

- Features for relations (arcs):
  - E1RelType / E2RelType
    - equals
    - starts
    - ends
    - contains



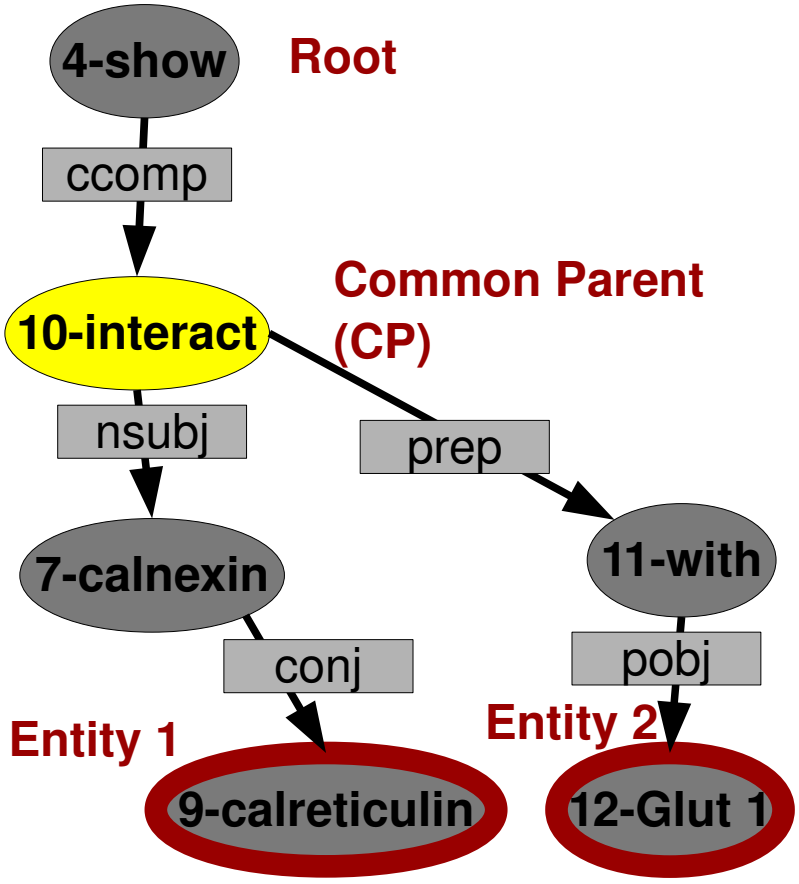
Developing a Syntax for DRE

- Features for positions (nodes):



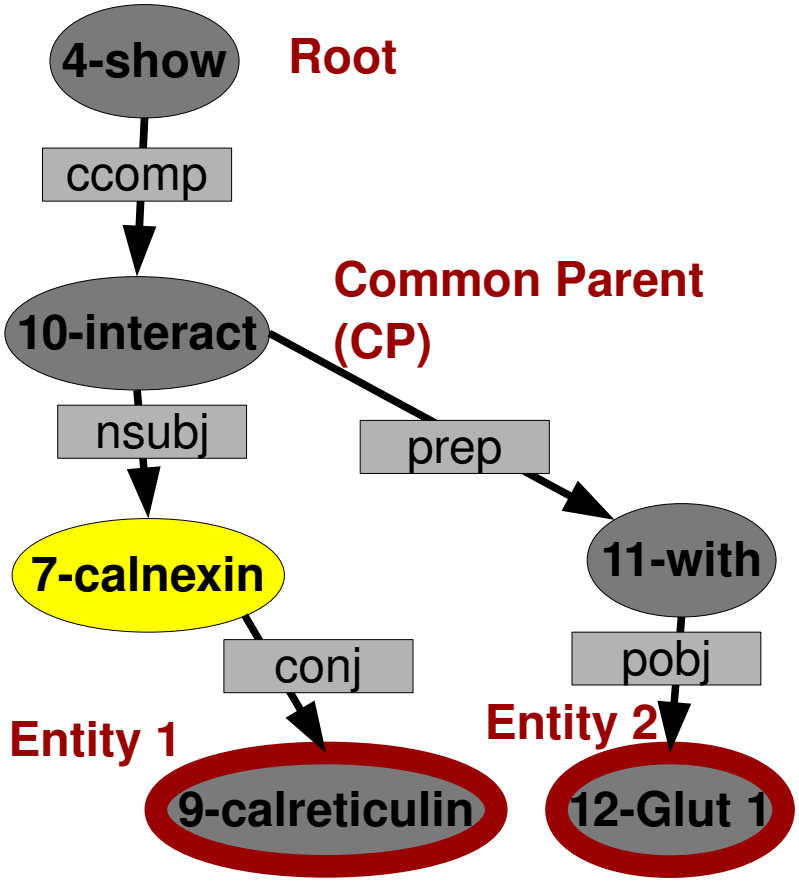
Developing a Syntax for DRE

- Features for positions (nodes):
  - CP: “interact” → IVERB



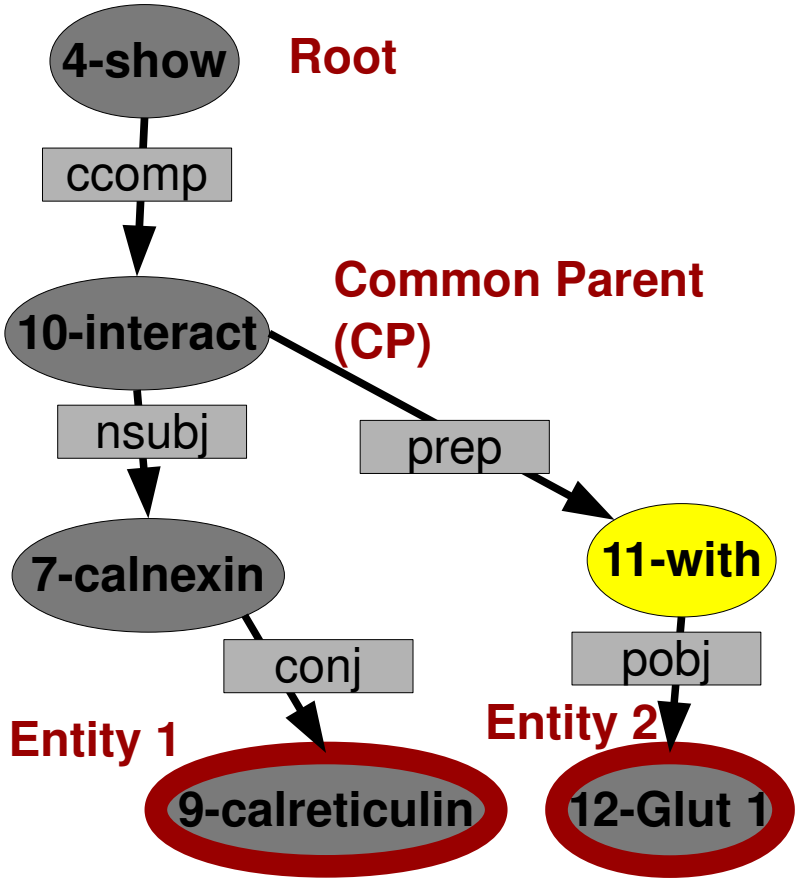
Developing a Syntax for DRE

- Features for positions (nodes):
  - CP: “interact” → IVERB
  - e1CP-1: “calnexin”



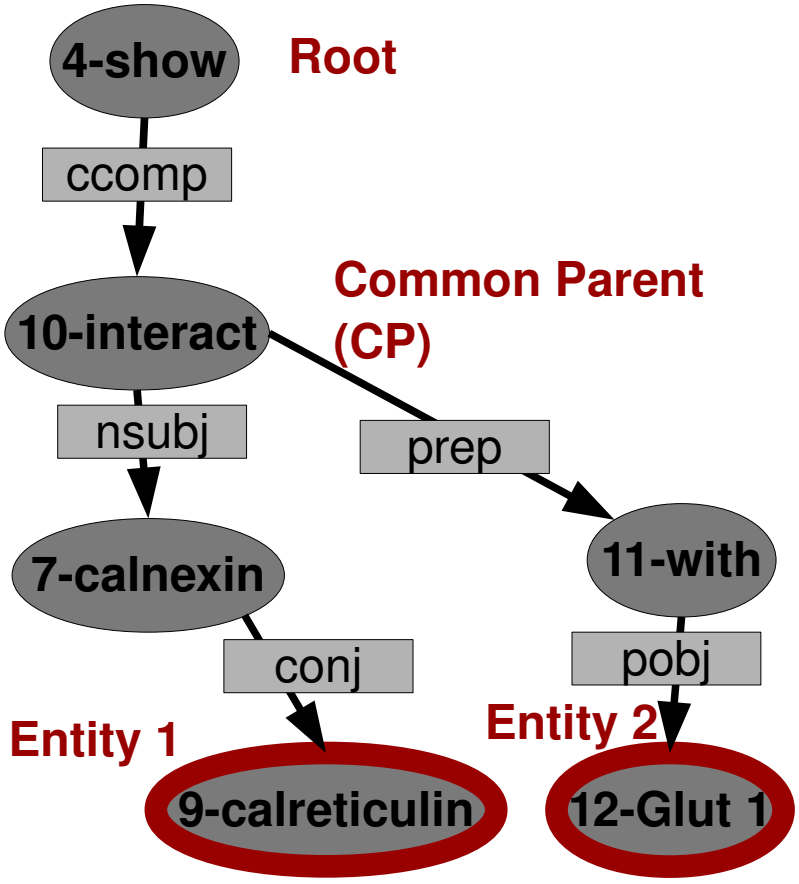
Developing a Syntax for DRE

- Features for positions (nodes):
  - CP: “interact” → IVERB
  - e1CP-1: “calnexin”
  - e2CP-1: “with”



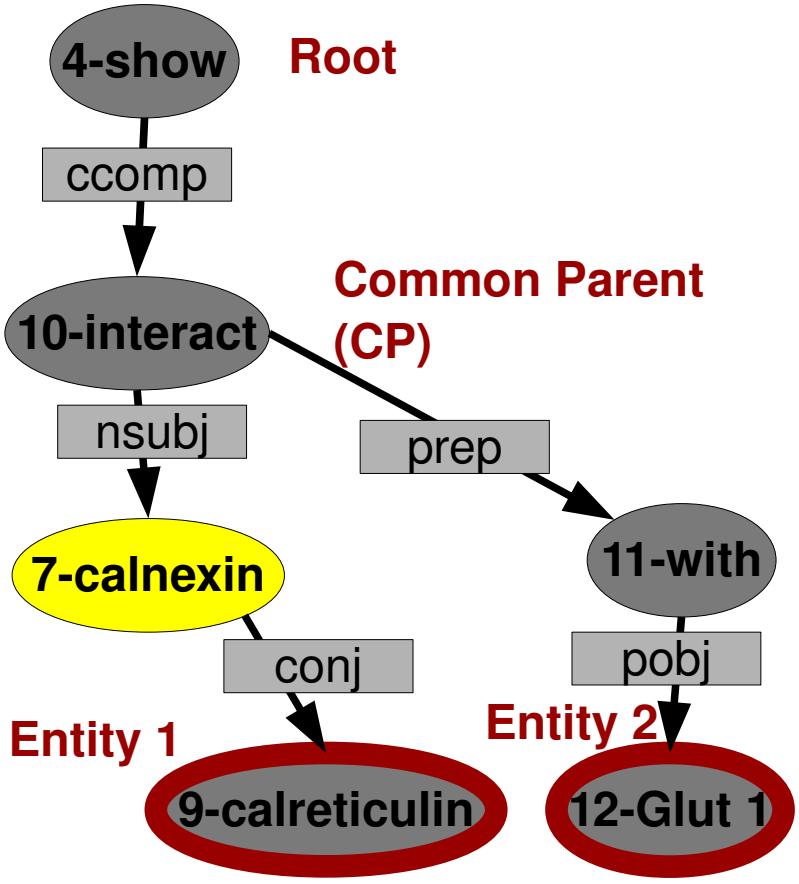
Developing a Syntax for DRE

- Features for positions (nodes):
  - CP: “interact” → IVERB
  - e1CP-1: “calnexin”
  - e2CP-1: “with”
  - e1CP-2 / e2CP-2



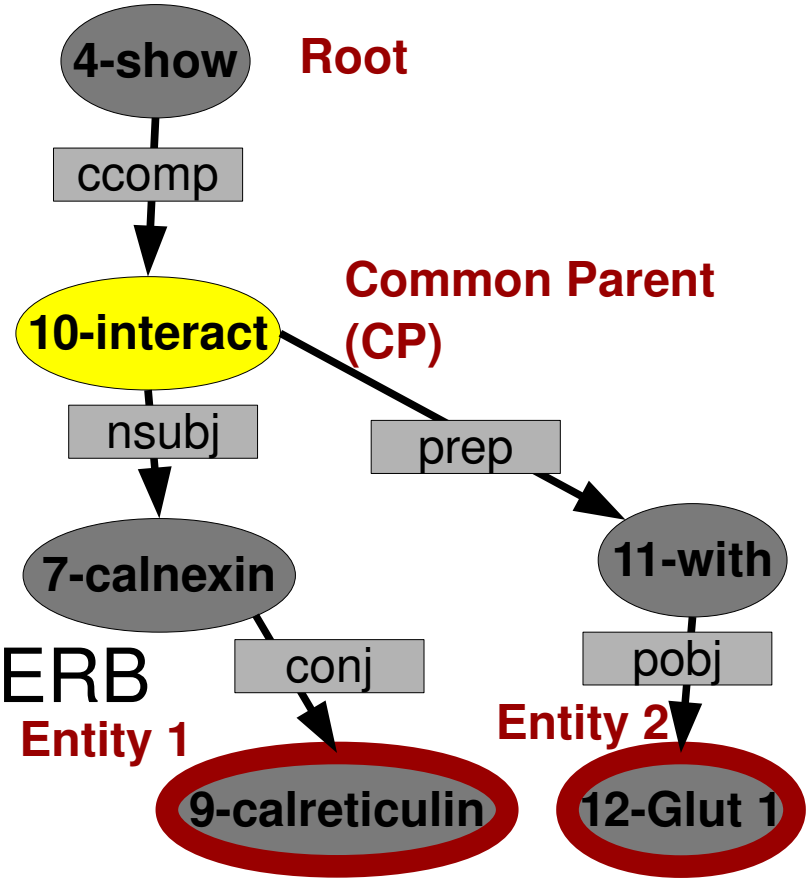
Developing a Syntax for DRE

- Features for positions (nodes):
  - CP: “interact” → IVERB
  - e1CP-1: “calnexin”
  - e2CP-1: “with”
  - e2CP-2 / e2CP-2
  - pE1 (parent of E1): “calnexin”



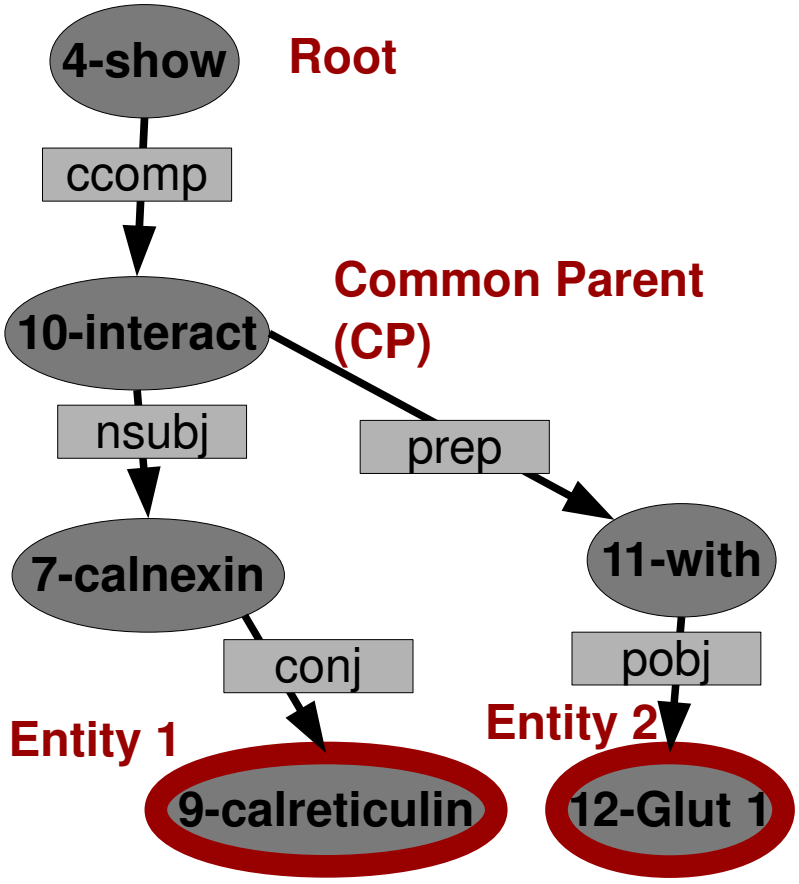
Developing a Syntax for DRE

- Features for positions (nodes):
  - CP: “interact” → IVERB
  - e1CP-1: “calnexin”
  - e2CP-1: “with”
  - e1CP-2 / e2CP-2
  - pE1 (parent of E1): “calnexin”
  - gpE1 (grandp.): “interact” → IVERB
  - ...



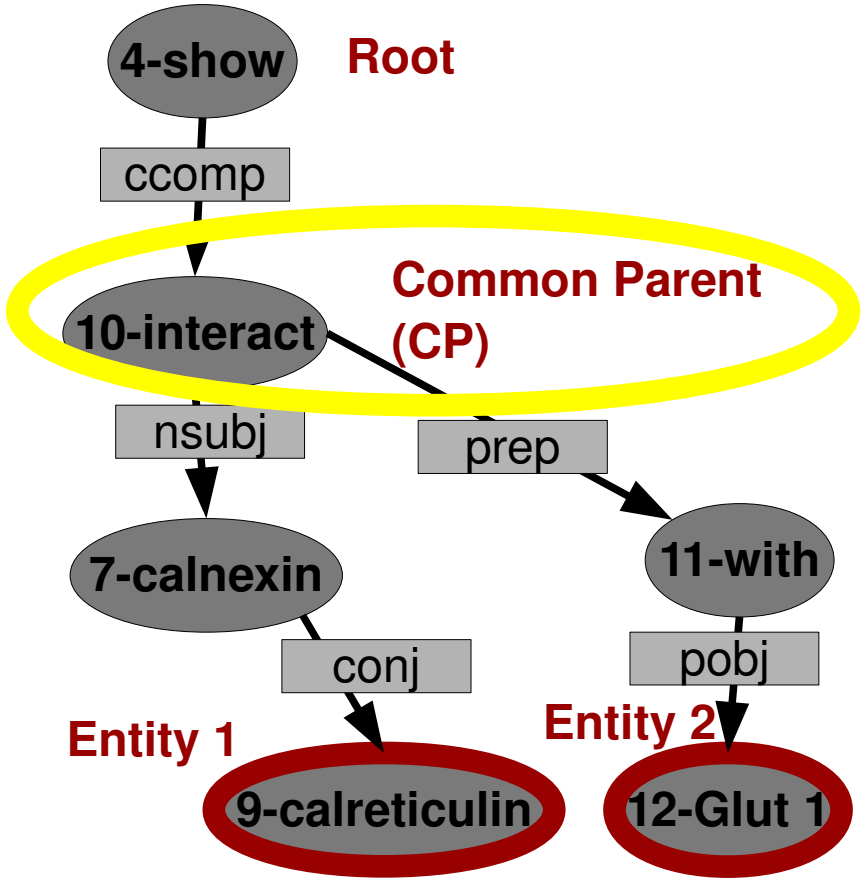
DRE with UTEMPL

- Example rule for relation between: calreticulin & Glut 1



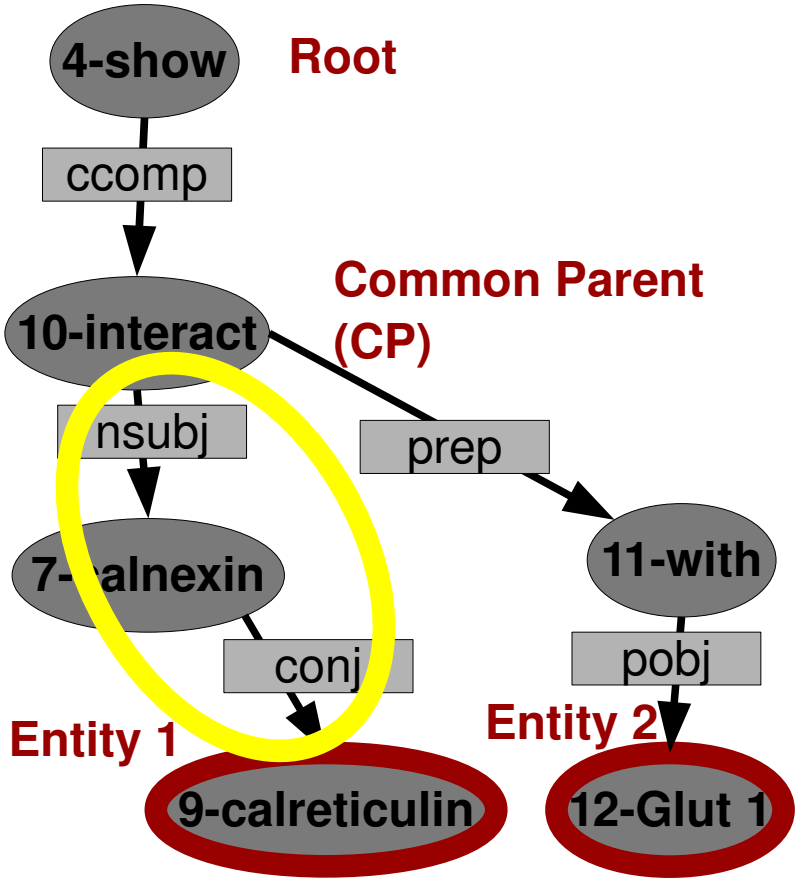
DRE with UTEMPL

- Example rule for relation between: calreticulin & Glut 1
- Rule1 ↔ otherCP



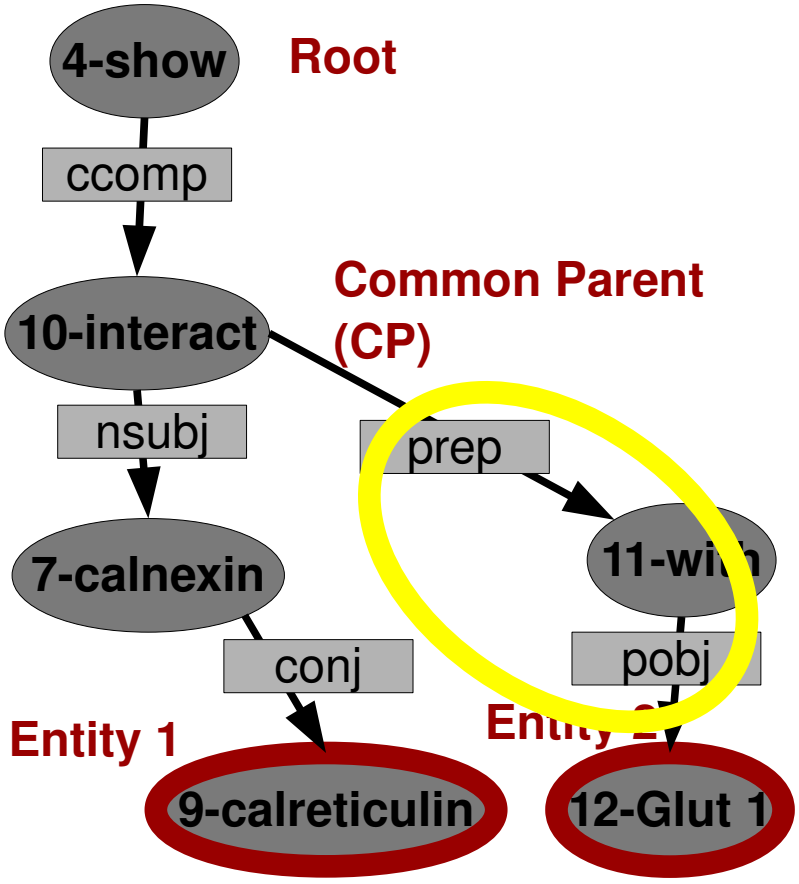
DRE with UTEMPL

- Example rule for relation between: calreticulin & Glut 1
- Rule1 ↔ otherCP
  e1RelToCP:nsubj
  e1RelType:ends



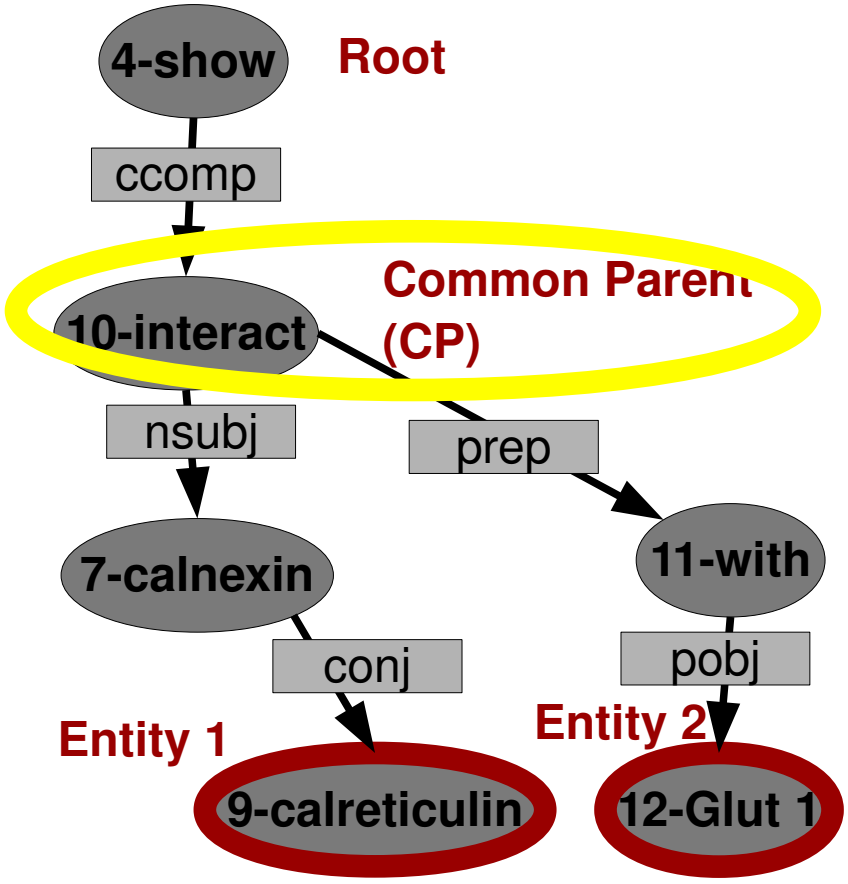
DRE with UTEMPL

- Example rule for relation between: calreticulin & Glut 1
- Rule1 ↔ otherCP
  e1RelToCP:nsubj
  e1RelType:ends
  e2RelToCP:pobj->prep
  e2RelType:equals



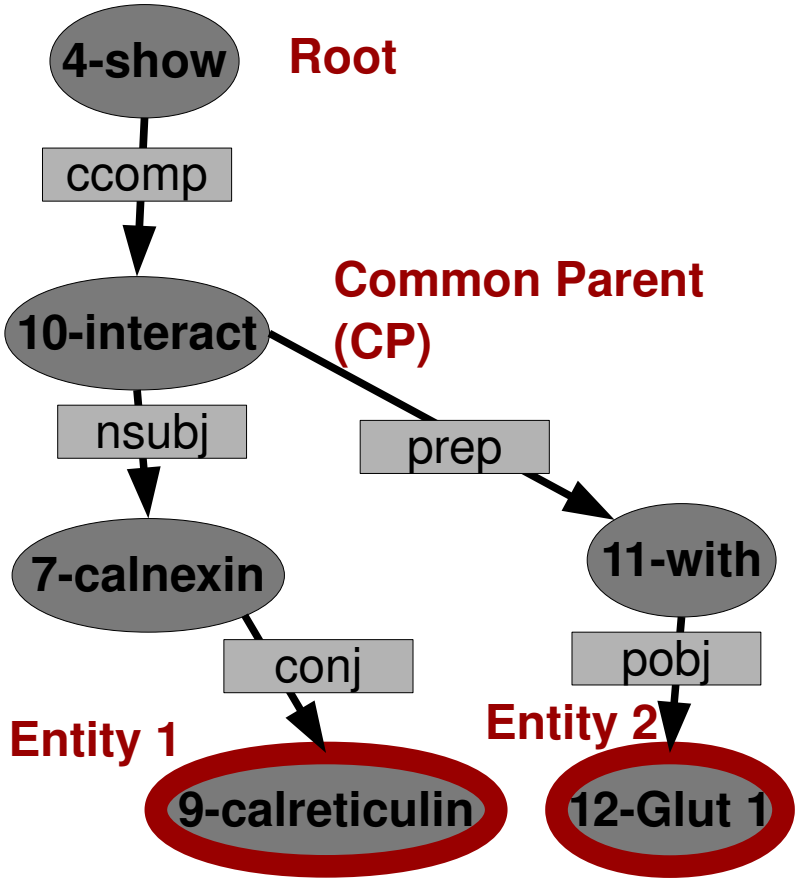
DRE with UTEMPL

- Example rule for relation between: calreticulin & Glut 1
- Rule1 ↔ otherCP
  e1RelToCP:nsubj
  e1RelType:ends
  e2RelToCP:pobj->prep
  e2RelType:equals
  CP:IVERB



DRE with UTEMPL

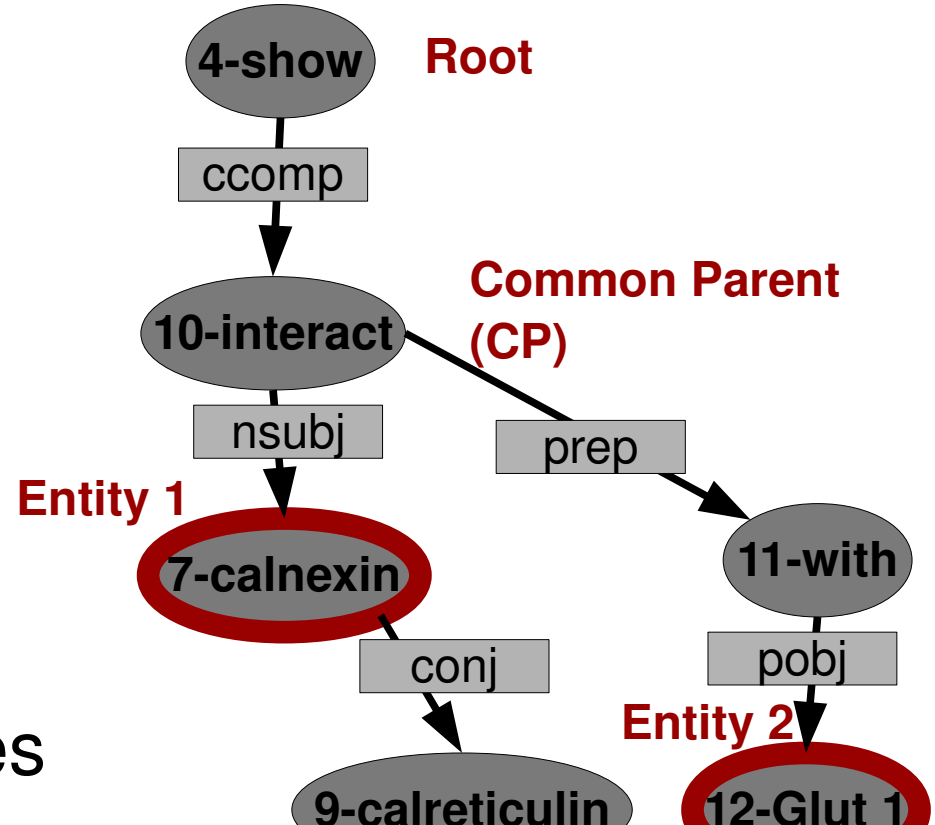
- Example rule for relation between: calreticulin & Glut 1
- Rule1 ↔ otherCP
  e1RelToCP:nsubj
  e1RelType:ends
  e2RelToCP:pobj->prep
  e2RelType:equals
  CP:IVERB



DRE with UTEMPL

- Example rule for relation between: calnexin & Glut 1
- Rule1 ↔ otherCP
  e1RelToCP:nsubj
  e1RelType:ends
  e2RelToCP:pobj->prep
  e2RelType:equals
  CP:IVERB

  → same rule for both examples



DRE with UTEMPL

- Rules for several syntactic phenomena

DRE with UTEMPL

- Rules for several syntactic phenomena
  - Subject-Predicate-Object (SPO-Sentences)

    “A binds B”

DRE with UTEMPL

- Rules for several syntactic phenomena
  - Subject-Predicate-Object (SPO-Sentences)

    “A binds B”
  - Nominal Constructions

    “Interaction between A and B”

DRE with UTEMPL

- Rules for several syntactic phenomena
  - Subject-Predicate-Object (SPO-Sentences)

    “A binds B”
  - Nominal Constructions

    “Interaction between A and B”
  - Relative Clauses

    “A, which interacts with B”

DRE with UTEMPL

- Rules for several syntactic phenomena
  - Infinitive Constructions (NCI, modal verbs)

    “A was found to interact with B”

    “A can interact with B”

DRE with UTEMPL

- Rules for several syntactic phenomena
  - All examples quite simple:

    “A binds B”

    “Interaction between A and B”

    “A, which interacts with B”

    “A was found to interact with B”

    “A can interact with B”

DRE with UTEMPL

- Rules for several syntactic phenomena
  - All examples quite simple:

    “A binds B”

    “Interaction between A and B”

    “A, which interacts with B”

    “A was found to interact with B”

    “A can interact with B”

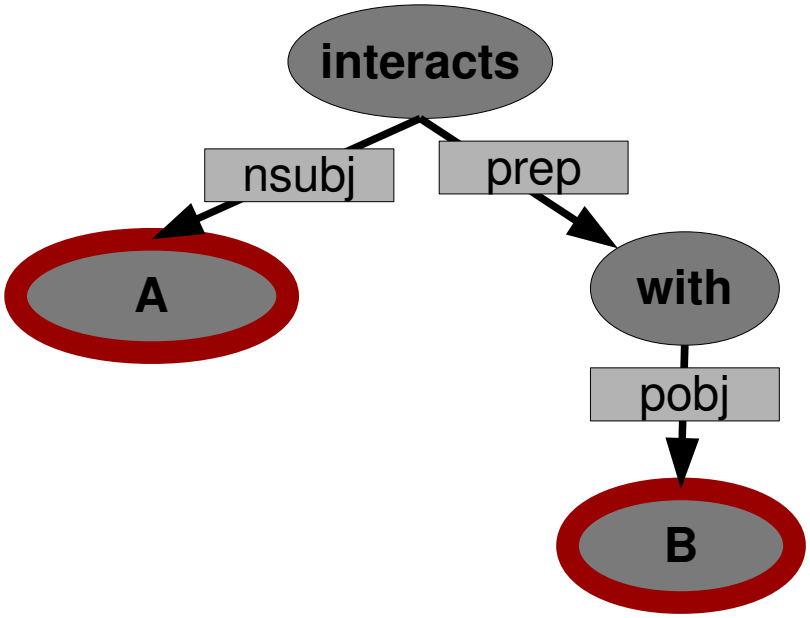
  → why not just Pattern Matching?

Advantages of DRE with UTEMPL

- Advantages of Dependency-based Relation Extraction

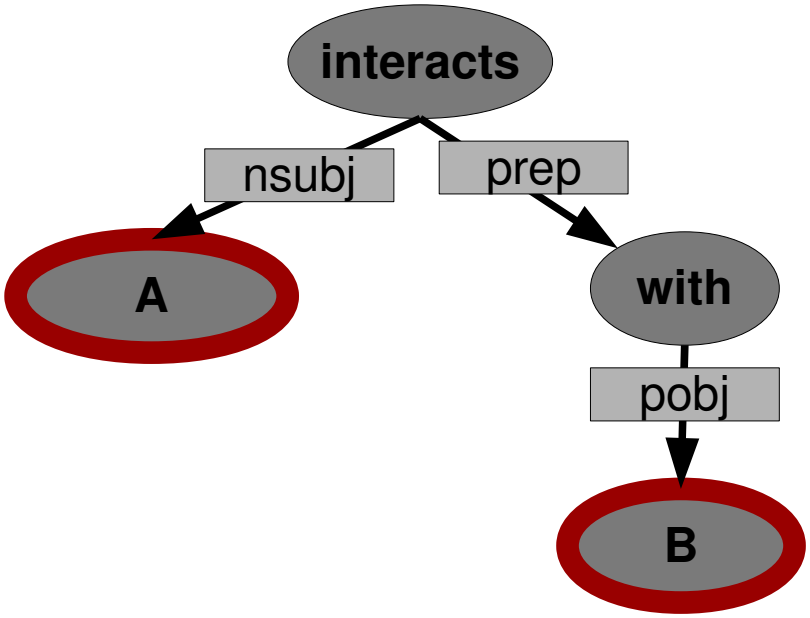
Advantages of DRE with UTEMPL

- Advantages of Dependency-based Relation Extraction
  - only head of a phrase matters
    “A interacts with B”



Advantages of DRE with UTEMPL

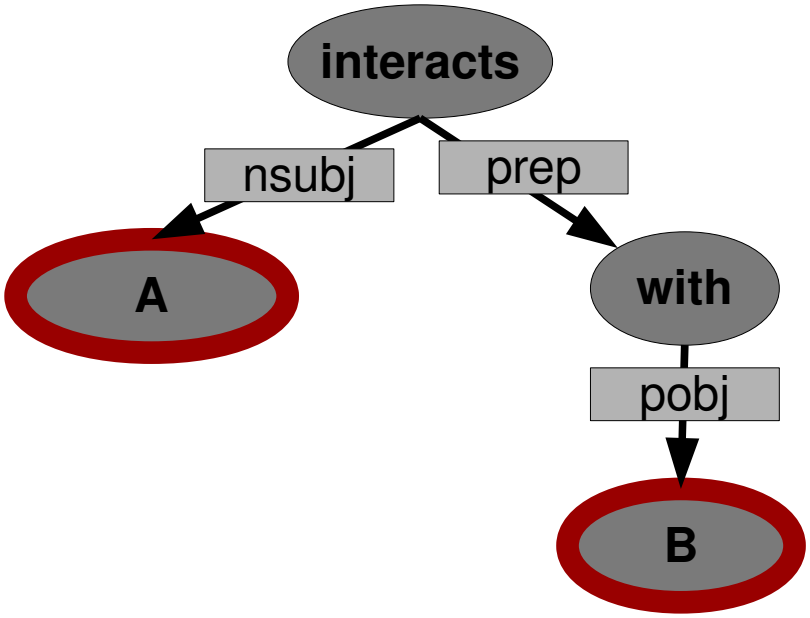
- Advantages of Dependency-based Relation Extraction
  - only head of a phrase matters
    "A interacts with B"



Rule1 ↔ otherCP
e1RelToCP:nsubj
e1RelType:ends
e2RelToCP:pobj->prep
e2RelType:equals
CP:IVERB

Advantages of DRE with UTEMPL

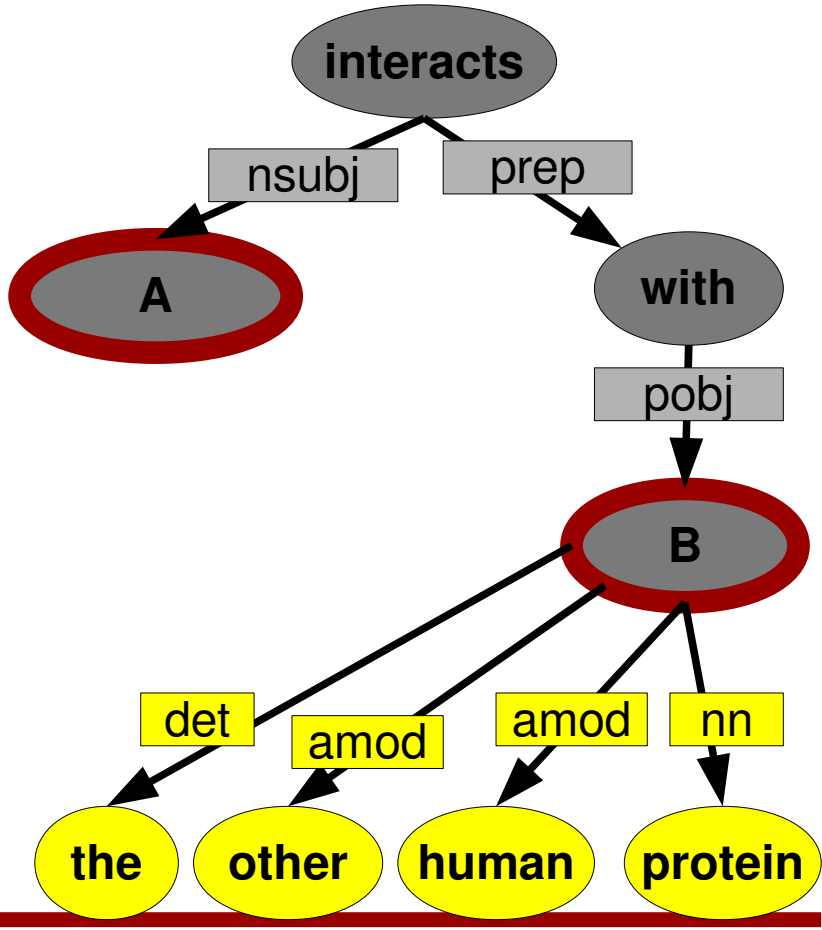
- Advantages of Dependency-based Relation Extraction
  - only head of a phrase matters
    "A interacts with
    the other human protein B"



Rule1 ↔ otherCP
e1RelToCP:nsubj
e1RelType:ends
e2RelToCP:pobj->prep
e2RelType:equals
CP:IVERB

Advantages of DRE with UTEMPL

- Advantages of Dependency-based Relation Extraction
  - only head of a phrase matters
    "A interacts with
    the other human protein B"



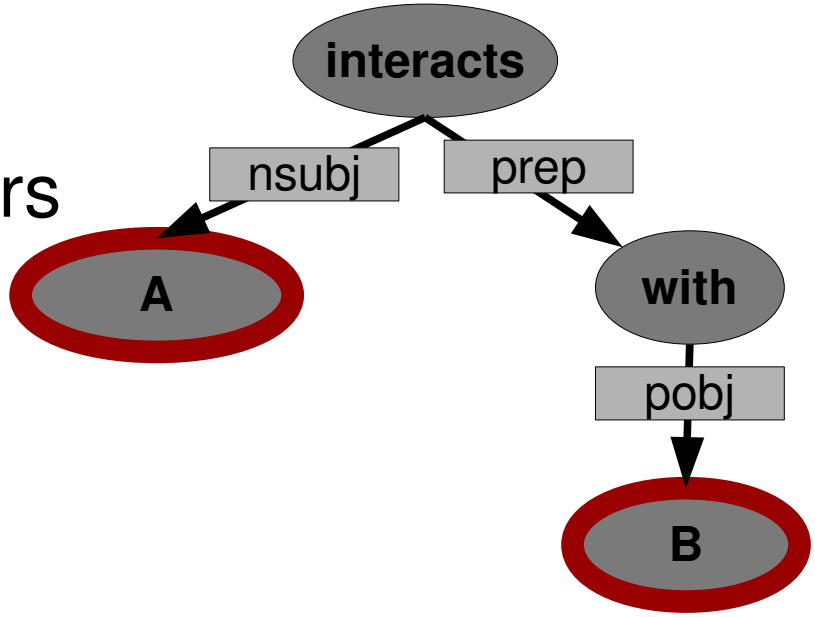
Rule1 ↔ otherCP
e1RelToCP:nsubj
e1RelType:ends
e2RelToCP:pobj->prep
e2RelType:equals
CP:IVERB

Advantages of DRE with UTEMPL

- Advantages of Dependency-based Relation Extraction
  - only head of a phrase matters
  - only “syntactic distance” matters

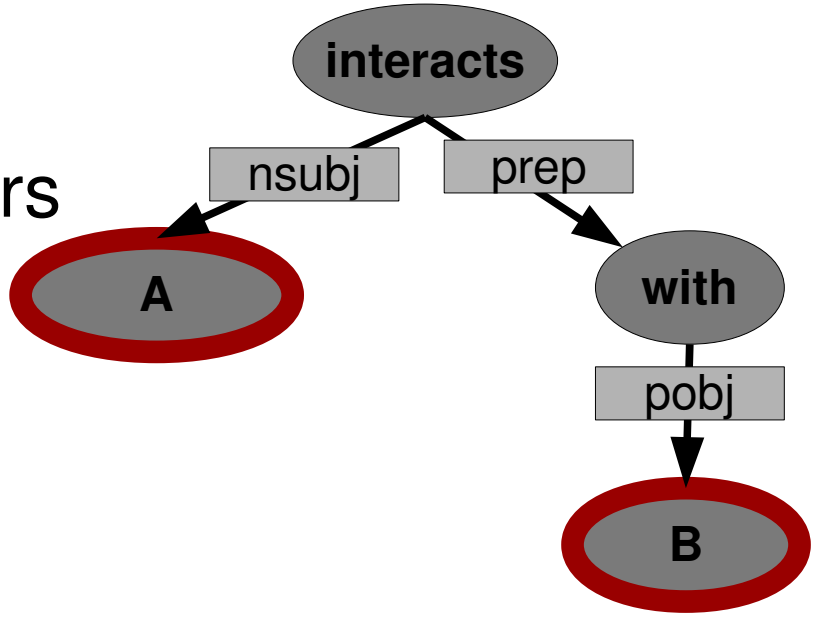
Advantages of DRE with UTEMPL

- Advantages of Dependency-based Relation Extraction
  - only head of a phrase matters
  - only “syntactic distance” matters
    “A interacts with B”



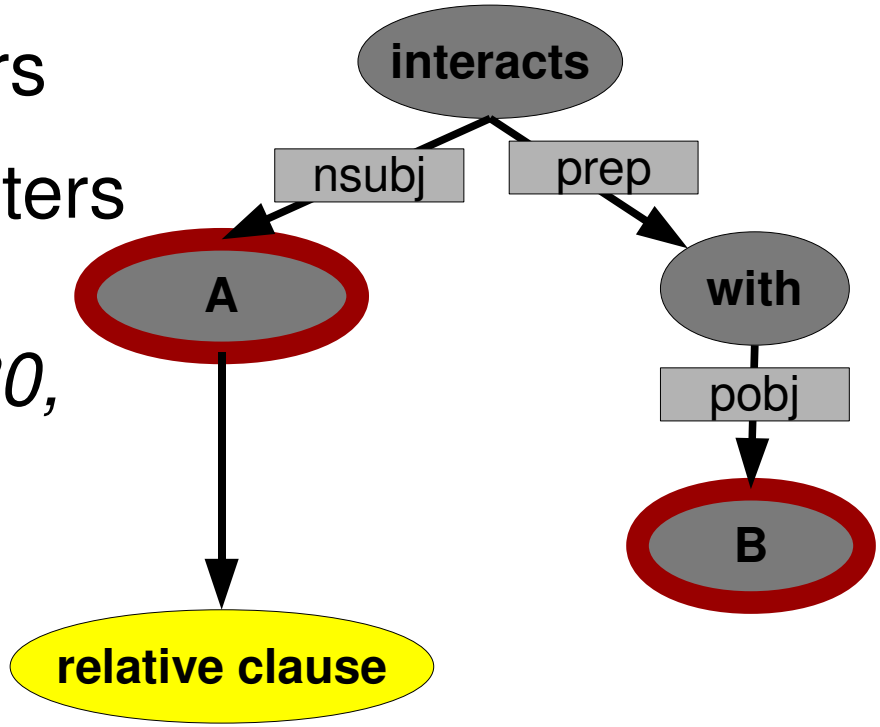
Advantages of DRE with UTEMPL

- Advantages of Dependency-based Relation Extraction
  - only head of a phrase matters
  - only “syntactic distance” matters
    “A,
    which was discovered in 1980,
    interacts with B”



Advantages of DRE with UTEMPL

- Advantages of Dependency-based Relation Extraction
  - only head of a phrase matters
  - only “syntactic distance” matters
    “A,
    which was discovered in 1980,
    interacts with B”



Advantages of DRE with UTEMPL

- Advantages of Dependency-based Relation Extraction
  - only head of a phrase matters
  - only “syntactic distance” matters
  - enumerations are easy to handle

Advantages of DRE with UTEMPL

- Advantages of Dependency-based Relation Extraction
  - only head of a phrase matters
  - only “syntactic distance” matters
  - enumerations are easy to handle

S3: **Bcl-3** specifically interacted with the general transcription factors **TFIIB**, **TBP**, and **TFIIA**. (source AIMed Corpus)

Advantages of DRE with UTEMPL

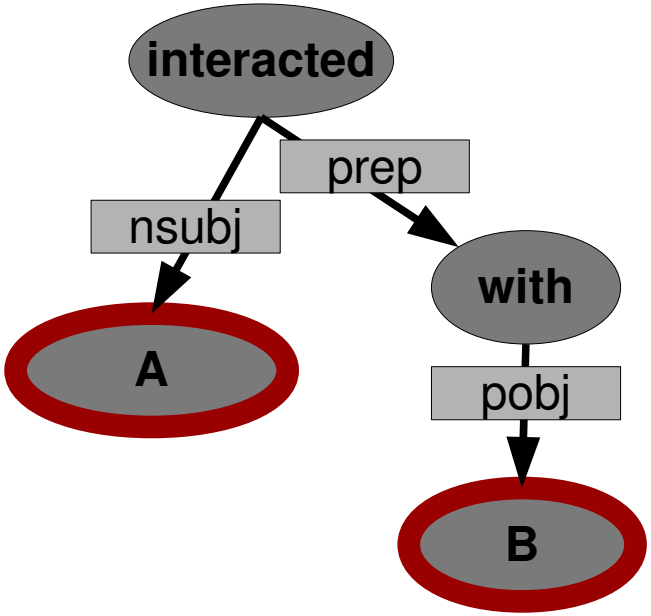
- Advantages of Dependency-based Relation Extraction
  - only head of a phrase matters
  - only “syntactic distance” matters
  - enumerations are easy to handle

A interacted with **B**, **C**, and **D**.

S3: **Bcl-3** specifically interacted with the general transcription factors **TFIIB**, **TBP**, and **TFIIA**. (source AIMed Corpus)

Advantages of DRE with UTEMPL

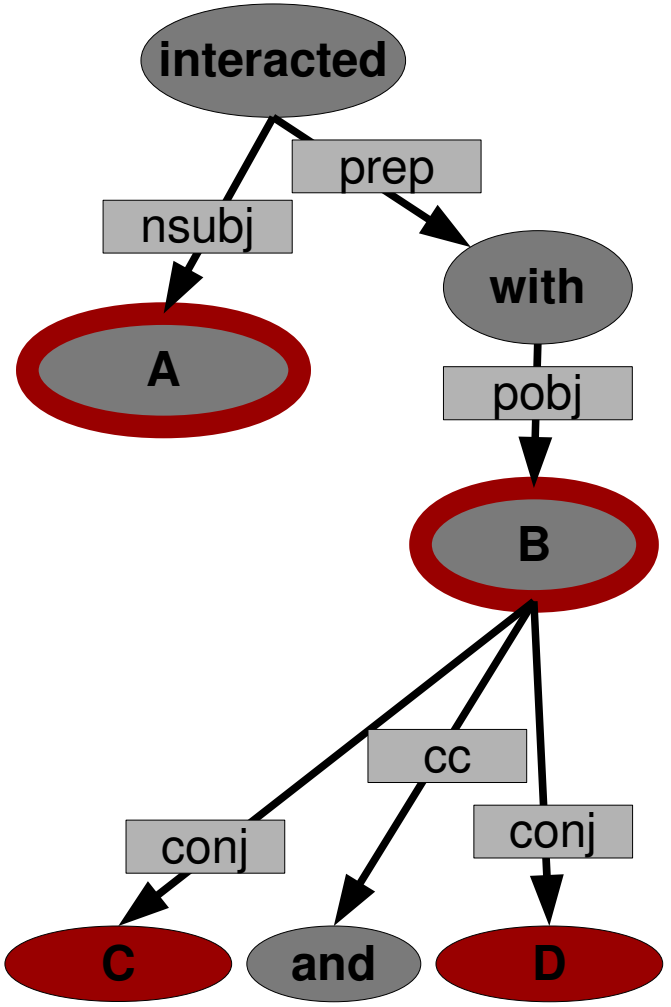
Rule1 ↔ otherCP
e1RelToCP:nsubj
e1RelType:ends
e2RelToCP:pobj->prep
e2RelType:equals
CP:IVERB



A interacted with **B**, **C**, and **D**.

Advantages of DRE with UTEMPL

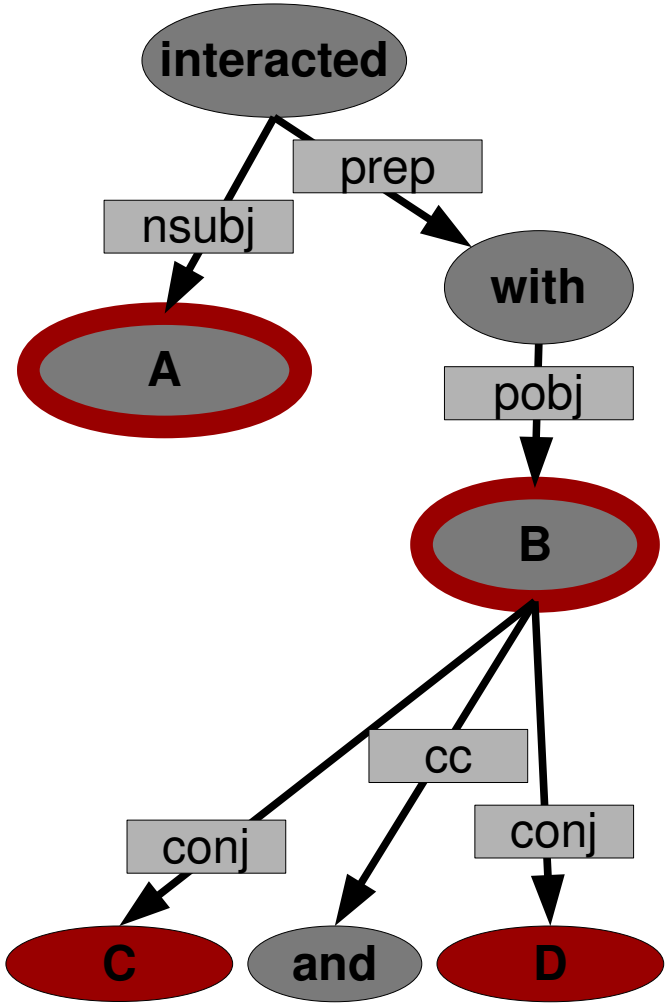
Rule1 ↔ otherCP
e1RelToCP:nsubj
e1RelType:ends
e2RelToCP:pobj->prep
e2RelType:equals
CP:IVERB



A interacted with **B**, **C**, and **D**.

Advantages of DRE with UTEMPL

Rule1 ↔ otherCP
e1RelToCP:nsubj
e1RelType:ends
e2RelToCP:conj->pobj->prep
e2RelType:equals
CP:IVERB



A interacted with **B**, **C**, and **D**.

Advantages of DRE with UTEMPL

- Advantages of Dependency-based Relation Extraction
  - only head of a phrase matters
  - only “syntactic distance” matters
  - enumerations are easy to handle

Advantages of DRE with UTEMPL

- Advantages of Dependency-based Relation Extraction
  - only head of a phrase matters
  - only “syntactic distance” matters
  - enumerations are easy to handle
- Characteristics of UTEMPL Relation Finder:
  - high precision rules are possible

Advantages of DRE with UTEMPL

- Advantages of Dependency-based Relation Extraction
  - only head of a phrase matters
  - only “syntactic distance” matters
  - enumerations are easy to handle
- Characteristics of UTEMPL Relation Finder:
  - high precision rules are possible
  - Rules can be developed outside the source code

    → easy development of different rule sets

Agenda

- Introduction & Motivation
  - Text Mining in the Biomedical Domain
- UTEMPL
- Relation Extraction
- Dependency-based Relation Extraction with UTEMPL
  - A Syntax for Rule Development
- **Evaluation**
- Conclusions

Evaluation

- 5 Corpora with Protein-Protein Interactions

  → analyzed by Pyysalo et al. 2008 with two methods: a cooccurrence approach and RelEx [Fundel et al. 2006]

Evaluation

- 5 Corpora with Protein-Protein Interactions

  → analyzed by Pyysalo et al. 2008 with two methods: a cooccurrence approach and RelEx [Fundel et al. 2006]

- Corpora are very different
  - Size
  - Number of entity pairs per sentence
  - Number of relations per sentence
  - Number of non-relating entity pairs

Evaluation

- 5 Corpora with Protein-Protein Interactions
  - AIMED [ftp://ftp.cs.utexas.edu/pub/mooney/bio-data]
  - BioInfer [http://www.it.utu.fi/BioInfer]
  - HPRD50 [http://www.bio.ifi.lmu.de/publications/RelEx]
  - IEPA [http://class.ee.iastate.edu/berlant/s/IEPA.htm]
  - LLL05 [http://genome.jouy.inra.fr/texte/LLLchallenge/]

Evaluation

- UTEMPL
  - Dependency Relation Finder (high precision rules)
  - Dependency Relation Finder (high F1-score rules)

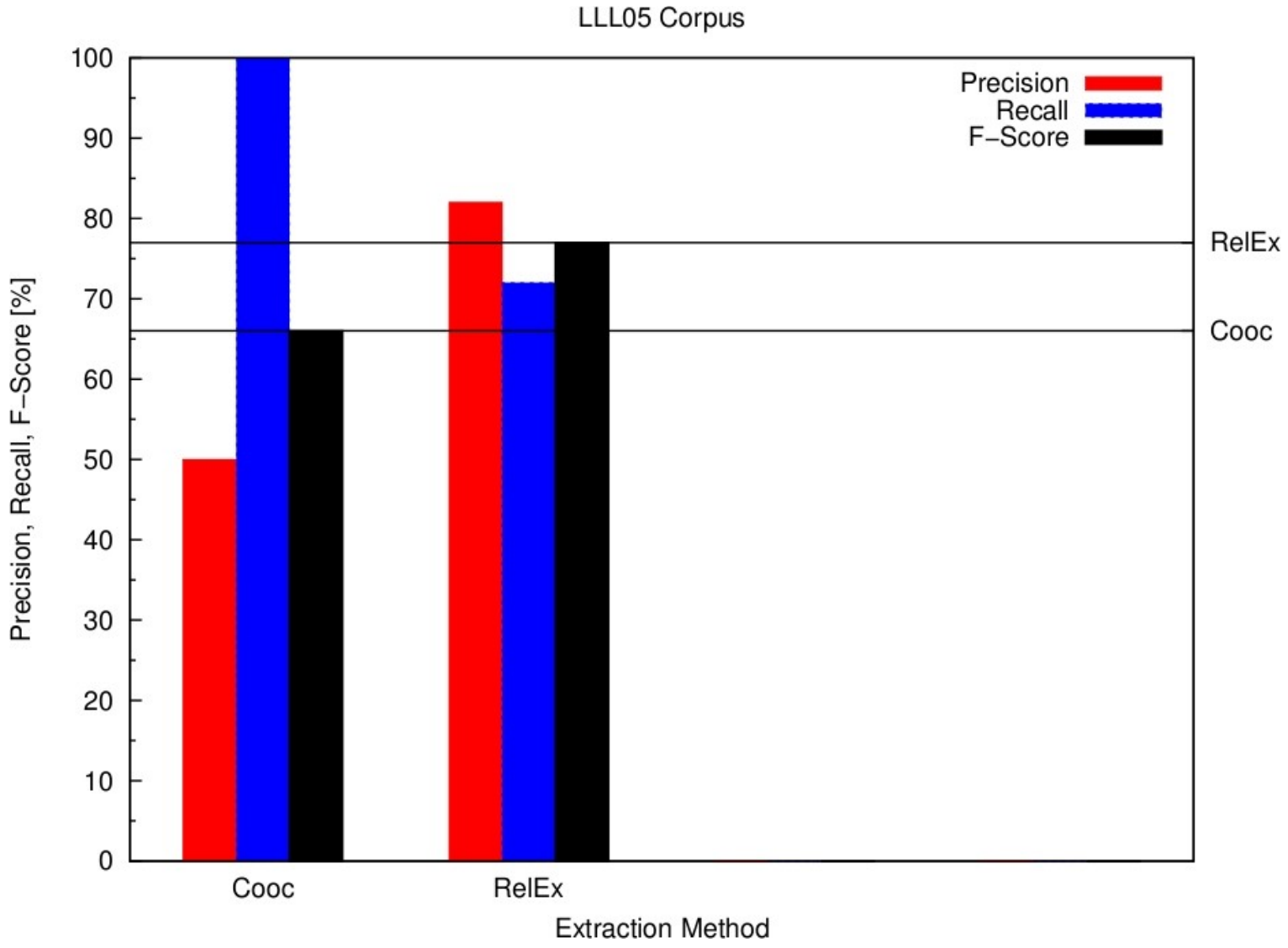
Evaluation

- UTEMPL
  - Dependency Relation Finder (high precision rules)
  - Dependency Relation Finder (high F1-score rules)
- Comparison:
  - Cooccurrence approach
  - RelEx

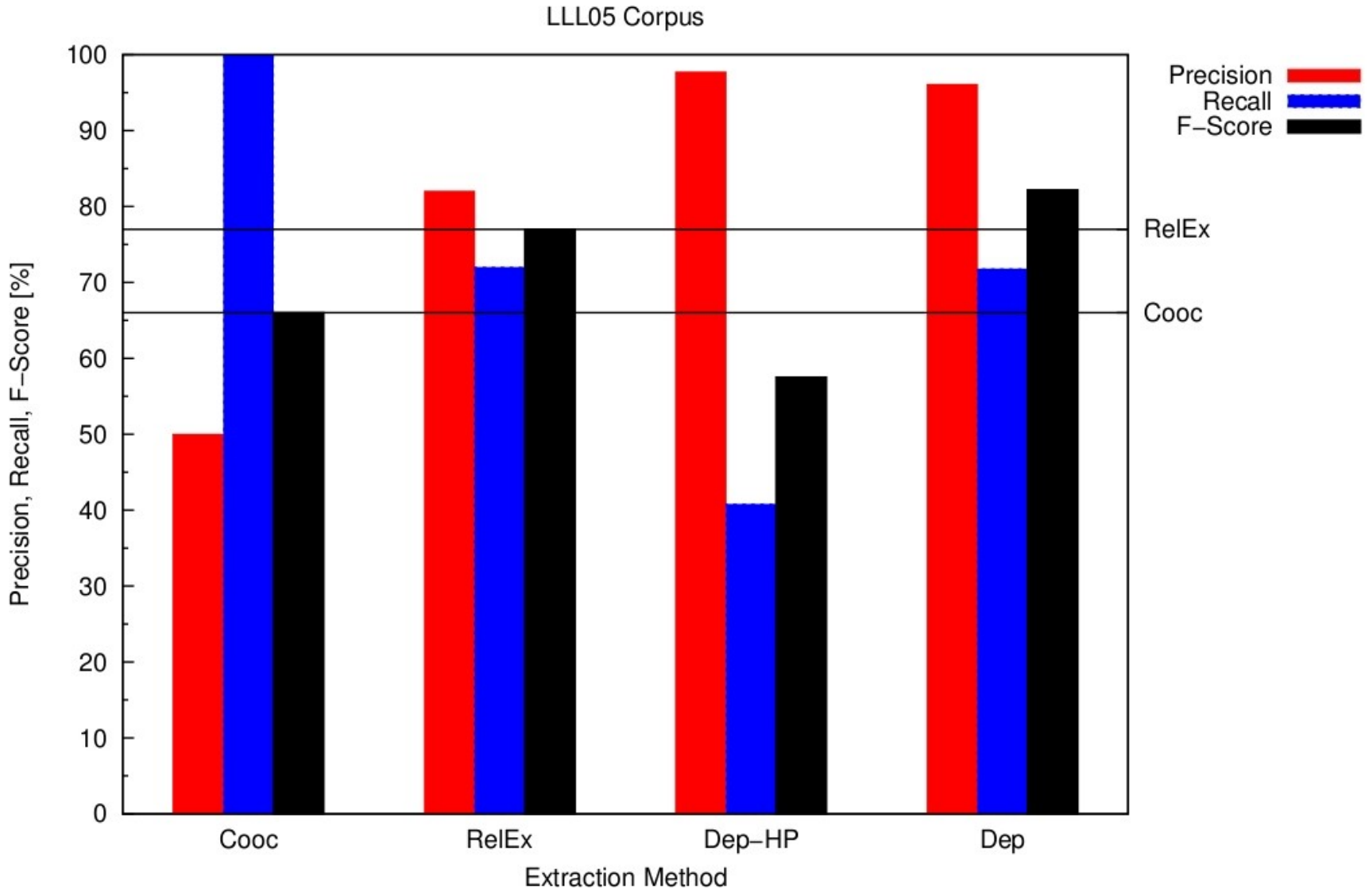
Evaluation

- LLL05 Corpus

Evaluation


LLL05 Corpus
Precision
Recall
F–Score
RelEx
Cooc
Precision, Recall, F–Score [%]
100
90
80
70
60
50
40
30
20
10
0
Cooc
RelEx
Extraction Method

Evaluation


LLL05 Corpus
Precision, Recall, F–Score [%]
100
90
80
70
60
50
40
30
20
10
0
Cooc
RelEx
Dep–HP
Dep
Extraction Method
Precision
Recall
F–Score
RelEx
Cooc

Evaluation

- f-score ranges between 41 % and over 82 %

Evaluation

- f-score ranges between 41 % and over 82 %
- better or at least similar results on all corpora

Agenda

- Introduction & Motivation
  - Text Mining in the Biomedical Domain
- UTEMPL
- Relation Extraction
- Dependency-based Relation Extraction with UTEMPL
  - A Syntax for Rule Development
- Evaluation
- **Conclusions**

Conclusions

- UTEMPL is a highly flexible Pipeline for Text Mining and Information Extraction

Conclusions

- UTEMPL is a highly flexible Pipeline for Text Mining and Information Extraction
- New or better tools for single tasks can be integrated easily

Conclusions

- UTEMPL is a highly flexible Pipeline for Text Mining and Information Extraction
- New or better tools for single tasks can be integrated easily
- Both relation extraction methods can be used with different rule sets → rule development separated from source code

Conclusions

- Relation Extraction is not limited to PPIs
  - Rules and resources can be adapted to other relations and domains

Conclusions

- Relation Extraction is not limited to PPIs
  - Rules and resources can be adapted to other relations and domains
- Dependency Relation Extraction rules cover all kinds of syntactic phenomena

Conclusions

- Relation Extraction is not limited to PPIs
  - Rules and resources can be adapted to other relations and domains
- Dependency Relation Extraction rules cover all kinds of syntactic phenomena
- Advantages of Dependency Relation Extraction:
  - only head of a phrase and “syntactic distance” matters
  - enumerations are easy to handle

Conclusions

- High Precision rules have great precision values

  → could be extremely useful for large data sets

Conclusions

- High Precision rules have great precision values

  → could be extremely useful for large data sets

- Better or at least competitive results on existing PPI corpora

References

BioMedCentral: http://www.biomedcentral.com/

Fundel et al.: RelEx – Relation Extraction Using Dependency Parse Trees. *Bioinformatics*, 23(3):365-371, 2006

Hanisch et al.: ProMiner: Rule-based Protein and Gene Entity Recognition. *BMC Bioinformatics*, 6 Suppl 1:S14, 2005

Julie-Lab: http://www.julielab.de

Medline: http://www.ncbi.nlm.nih.gov/pubmed

PubMedCentral: http://www.pubmedcentral.nih.gov/

Pyysalo et al.: Comparative Analysis of Five Protein-Protein Interaction Corpora. *BMC Bioinformatics*, 8:50, 2007

Stanford Dependency Parser: http://nlp.stanford.edu/software/lex-parser.shtml

UIMA: http://incubator.apache.org/uima/

Uima bioNLP repository: http://bionlp-uima.sourceforge.net

References

BioMedCentral: http://www.biomedcentral.com/

Fundel et al
23(3):365

Hanisch
Suppl 1:S

tics, 6

Julie-Lab

Medline:

PubMedC

Pyysalo
Bioinform

Stanford De

UIMA: http://incubator.apache.org/uima/

Uima bioNLP repository: http://bionlp-uima.sourceforge.net

Thank you for your attention!

Any Questions?