Annotation of specialized corpora
using a comprehensive entity and relation scheme

Louise Deléger∗  Anne-Laure Ligozat∗ **  Cyril Grouin∗
Pierre Zweigenbaum∗  Aurélie Névèol∗
∗CNRS, UPR 3251, LIMSI, 91403 Orsay, France
** ENSIIE, 91000 Evry, France
firstname.lastname@limsi.fr

Abstract
Annotated corpora are essential resources for many applications in Natural Language Processing. They provide insight on the linguistic and semantic characteristics of the genre and domain covered, and can be used for the training and evaluation of automatic tools. In the biomedical domain, annotated corpora of English texts have become available for several genres and subfields. However, very few similar resources are available for languages other than English. In this paper we present an effort to produce a high-quality corpus of clinical documents in French, annotated with a comprehensive scheme of entities and relations. We present the annotation scheme as well as the results of a pilot annotation study covering 35 clinical documents in a variety of subfields and genres. We show that high inter-annotator agreement can be achieved using a complex annotation scheme.

Keywords: Annotation; Clinical Texts; Natural Language Processing

1. Introduction
Annotated corpora are essential resources for many applications in Natural Language Processing. They provide insight on the linguistic and semantic characteristics of the genre and domain covered, and can be used for the training and evaluation of automatic tools. In the biomedical domain, annotated corpora have become available for several genres and subfields. Several efforts addressed the development of annotated corpora for English free-text, covering both the biomedical literature (Kim et al., 2003; Bada et al., 2012; Doğan and Lu, 2012; Ohta et al., 2012) and clinical narrative (South et al., 2009; Uzuner et al., 2010; Deléger et al., 2012). Annotation tasks sought to cover grammatical characteristics (Smith et al., 2004), complex linguistic phenomena (Chapman et al., 2012) as well as biological or clinical phenomena (Doğan and Lu, 2012; Ohta et al., 2012) that may be described in domain knowledge bases (Bada et al., 2012) as they occurred in natural language text. However, very few similar resources are available for languages other than English. Furthermore, annotation efforts are often focused on one particular linguistic phenomenon or biological entity of interest.
In this paper we present an effort to produce a high-quality corpus of clinical documents in French, annotated with a comprehensive scheme of entities and relations. We present the annotation scheme as well as the results of a pilot annotation study covering 35 clinical documents in a variety of subfields. We show that high inter-annotator agreement can be achieved using a complex annotation scheme.

2. Material and Methods
2.1. Two clinical corpora
Presentation. The clinical documents used in this study were drawn from two sources: foetopathology case reports (referred to as Foetopath thereafter) from a large French city hospital and electronic health records from a different set of French hospitals (referred to as EHR thereafter). While documents in the first corpus are similar in terms of structure and medical content, documents in the second corpus exhibit a large variety of documents types and cover several medical specialties.
Preprocessing. All documents have been de-identified and manually reviewed to ensure that all protected information was removed. Surrogate information was generated to replace the de-identified elements. The annotation strategy built on previous findings that pre-annotations can increase inter-annotator agreement and reduce annotation time (Névèol et al., 2011). Therefore, we produced a pre-annotated version of the corpora for entities only. Automatic entity pre-annotations were supplied to the annotators using an exact match strategy based on a French UMLS dictionary and a lexicon derived from a small set of documents annotated in the preliminary stage of the project (5 documents, selected from both corpora).

2.2. Methods
2.2.1. Annotation Protocol
The annotation scheme used in this work was designed to provide a broad coverage of the clinical domain, in order to allow for the annotation of medical events of interest mentioned in the clinical documents. We used the open source Brat Rapid Annotation Tool (BRAT) (Stenetorp et al., 2012), which supports complex annotation schemes for entities and relations and allows the use of pre-annotations. Four annotators—the authors of this paper (ALL, AN, CG, LD)—participated in the annotation task. All of them had previous annotation experience.
Figure 1 shows the overall annotation process. It was conducted in two phases: (1) a preliminary annotation phase during guideline design; (2) a pilot annotation phase once the guidelines were stabilized. During the preliminary phase, a small sample of 5 documents (3 Foetopath, 2 EHR) was selected to be annotated by all four annotators. This sample was annotated for both entities and relations after a first draft of the annotation guidelines was written (first
Clinical texts

Preliminary study (5 documents)

Pilot study (30 documents)

Clinical texts with entity pre-annotations

Automatic entity pre-annotation

Clinical texts without entity pre-annotations

Update

2 annotation passes

Guidelines production

Entity annotations

Revision of the pre-annotations by annotator pairs

Consensus on the entity annotations

Relation annotation by annotation pairs

Revised entity annotations

Relation annotations

Relation annotations by annotator pairs

Consensus on the relation annotations

Revised relation annotations

Figure 1: Overall annotation process

Then annotators met to discuss issues and problems they encountered during the first annotation pass. The guidelines were extensively clarified and modified accordingly. Subsequently, annotators individually revisited their annotations according to the modified guidelines (second pass). A consensus session was then held to resolve annotation disagreements and further clarify the guidelines where necessary. Finally, the annotators used the entity annotations resulting from the consensus to annotate relations. This allowed us to measure Inter-Annotator Agreement (IAA) on relations, without the influence of disagreements on entity annotations. Agreement was measured between each annotator pair for entities and relations after the first and second pass. Additionally, for relations, IAA was also measured after the consensus on entities.

After the preliminary phase, we considered the guidelines to be stable enough to conduct a pilot annotation phase with 15 documents from each source (Foetopath and EHR). One lead annotator (LD) annotated the entire pilot sample while the other three (ALL, AN, CG) each worked on one third of the documents. As a result, each document in the corpus was independently annotated by two annotators. As shown on Figure 1, the pilot annotation was conducted as follows: documents were pre-annotated automatically for entities. Annotators revised the pre-annotations to create annotations for entities and relations. Consensus sessions were held between annotators to resolve disagreements on entities, and a second pass of relation annotations was carried out using the consensus. The lead annotator ensured consistency on decisions that were made for cases that were not initially covered in the guidelines. The guidelines were updated accordingly. Inter-annotator agreement was measured between each annotator pair once for entities and twice for relations, that is (a) before resolving disagreements on entities and (b) after resolving disagreements on entities.

2.2.2. Annotation Scheme

Entities. The annotation scheme for entities was derived in part from the Unified Medical Language System® (UMLS®) Semantic Groups, described in (McCray et al., 2001) and (Bodenreider and McCray, 2003), but additional categories were created to address the need for fine-grained annotation of elements of clinical interest, such as the details of medications prescribed to a patient (Savova et al., 2012). For entity annotations, the annotators revised the pre-annotation using tools providing access to the UMLS in French1 and in English2. When available, the UMLS Semantic Type of a concept was used to determine which entity type to assign to an annotated mention.

Relations. The annotation scheme for relations was derived in part from the UMLS Semantic Network. It also drew on previous annotation work for clinical documents, including (Savova et al., 2012).

3. Results

3.1. Description of the annotation scheme and annotated corpora

The final annotation scheme used comprises 19 entities (listed and defined in Table 9) and 18 relations (listed and defined in Table 10). Table 1 provides an overview of the number of consensus annotations in each corpus. It shows that the density of annotations is quite high in both corpora (on average, 60 annotations per 100 tokens), but that the distribution of entity types differs between the Foetopath vs. EHR corpus. For instance, Anatomy and Measurement entities are more frequent in the Foetopath corpus, while drug entities are more prevalent in the EHR corpus (see Table 1). Figure 2 presents a snippet of annotated text from the Foetopath corpus.

3.2. Inter-annotator agreement

Inter-annotator agreement was assessed using F-measure (Hripcsak and Rothschild, 2005), computed with a tool developed by the National Information and Communication Technology Research Center of Australia (Verspoor et al., 2013). Agreement scores during the preliminary phase are displayed in Table 2 for entities and Table 3 for relations. Agreement is low on the first pass for entities (mean of 0.502) and very low for relations (mean of 0.153), although it should be noted that all disagreements on entities have an impact on relations. IAA is higher on the second pass.

1 Portail Terminologique de Santé (PTS) http://pts.chu-rouen.fr/

2 UMLS Terminology Services (UTS Metathesaurus Browser) https://uts.nlm.nih.gov/
Table 1: Descriptive statistics (count of tokens and consensus annotations (overall and per type) in each corpus

|                     | Preliminary sample (N=5) | Foetopath (N=15) | EHR (N=15) | All (N=35) |
|---------------------|--------------------------|------------------|------------|------------|
| **General**         |                          |                  |            |            |
| Tokens              | 1605                     | 4240             | 3976       | 9821       |
| Annotated tokens    | 814                      | 2961             | 2052       | 5827       |
| Annotated entities  | 454                      | 1924             | 1168       | 3546       |
| Annotated relations | 270                      | 1031             | 495        | 1796       |
| **Entities**        |                          |                  |            |            |
| Anatomy             | 104                      | 787              | 138        | 1029       |
| Measurement         | 103                      | 486              | 116        | 705        |
| Disorder            | 77                       | 199              | 106        | 382        |
| Concept_Idea        | 29                       | 157              | 20         | 206        |
| MedicalProcedure    | 34                       | 117              | 169        | 320        |
| BiologicalProcessOrFunction | 13  | 44              | 18         | 75         |
| Modality_Anchor     | 16                       | 37               | 34         | 87         |
| LivingBeings        | 31                       | 35               | 182        | 248        |
| Duration            | 13                       | 30               | 16         | 59         |
| Chemicals_Drugs     | 8                        | 12               | 71         | 91         |
| SignOrSymptom       | 8                        | 7                | 43         | 58         |
| Genes_Proteins      | 2                        | 7                | 4          | 13         |
| Date                | 13                       | 6                | 87         | 106        |
| Frequency           | 2                        | 0                | 36         | 38         |
| Devices             | 1                        | 0                | 44         | 45         |
| Dosage              | 0                        | 0                | 52         | 52         |
| Strength            | 0                        | 0                | 19         | 19         |
| DrugForm            | 0                        | 0                | 7          | 7          |
| AdministrationRoute | 0                        | 0                | 6          | 6          |
| **Relations**       |                          |                  |            |            |
| Measure_of          | 102                      | 526              | 92         | 720        |
| Location_of         | 70                       | 376              | 93         | 539        |
| Co-occurs_with      | 29                       | 20               | 14         | 63         |
| Time_of             | 17                       | 29               | 42         | 88         |
| Experiences         | 18                       | 16               | 33         | 67         |
| Reveals             | 9                        | 23               | 18         | 50         |
| Negation            | 7                        | 21               | 15         | 43         |
| History             | 6                        | 9                | 5          | 20         |
| Hypothetical        | 3                        | 5                | 9          | 17         |
| Treats              | 4                        | 4                | 26         | 34         |
| Complicates         | 2                        | 1                | 2          | 5          |
| Precedes            | 2                        | 1                | 20         | 23         |
| Causes              | 1                        | 0                | 2          | 3          |
| HasAdministrationRoute | 0                    | 0                | 6          | 6          |
| HasDosage           | 0                        | 0                | 53         | 53         |
| HasDrugForm         | 0                        | 0                | 7          | 7          |
| HasDuration         | 0                        | 0                | 4          | 4          |
| HasFrequency        | 0                        | 0                | 35         | 35         |
| HasStrength         | 0                        | 0                | 19         | 19         |

(revision according to improved guidelines), but can be improved. Agreement on relations after revising the guidelines and reaching a consensus on entities is very good (mean of 0.817).

Table 4 and Table 5 show IAA on the Foetopath and EHR corpora during the pilot phase after a stable version of the guidelines had been produced. On the Foetopath corpus, agreement is very good for entities (mean of 0.817) and substantially higher than on the preliminary corpus (at most 0.604, see Table 2). Agreement on relations is also higher than on the preliminary corpus (0.599 vs. at most 0.299 before entity consensus, see Table 3 and 0.890 vs. 0.817 after entity consensus). On the EHR corpus, agreement on entities is fair (mean of 0.679) and also higher than during the preliminary phase. It is good on relations after entity consensus (mean of 0.773) but slightly lower than during the preliminary phase, unlike on the Foetopath corpus. However, agreement remains low when relations are annotated before reaching a consensus on entities (mean of 0.599 and 0.413). Agreement is high when relations are annotated after resolving disagreements (0.890 and 0.779).

Table 6 details inter-annotator agreement (mean) results for each entity type for the Foetopath and EHR corpora (pilot annotation phase). Agreement is very high (above 0.85) on
Table 2: Overall inter-annotator agreement for entities during the preliminary phase (1st/2nd annotation passes)

| Entity Type | 1st pass | 2nd pass |
|-------------|----------|---------|
| AL/AN       | 0.546    | 0.670   |
| AL/CG       | 0.376    | 0.574   |
| AL/LD       | 0.496    | 0.589   |
| AN/CG       | 0.496    | 0.589   |
| AN/LD       | 0.627    | 0.657   |
| CG/LD       | 0.468    | 0.545   |
| **Mean**    | 0.502    | 0.604   |

Table 3: Overall inter-annotator agreement for relations during the preliminary phase (1st and 2nd annotation passes, and after the consensus on entities)

| No consensus | Consensus |
|--------------|-----------|
| 1st pass     | 2nd pass  | Consensus |
| AL/AN        | 0.420     | 0.344     | 0.860    |
| AL/CG        | 0.048     | 0.178     | 0.783    |
| AL/LD        | 0.207     | 0.255     | 0.852    |
| AN/CG        | 0.062     | 0.285     | 0.743    |
| AN/LD        | 0.255     | 0.396     | 0.868    |
| CG/LD        | 0         | 0.338     | 0.796    |
| **Mean**     | 0.153     | 0.299     | 0.817    |

Anatomy, Procedure, Duration and Chemicals,Drugs entities in the Foetopath corpus. Annotators had more trouble with Disorder and BiologicalProcessOrFunction entities (agreement around 0.65, the lowest for this corpus). We do not take into account the zero agreement values for the SignOrSymptom and Devices entities. Because of the very small number of these entities (respectively 7 and 0), we cannot draw any significant conclusion for these two entity types. As mentioned before, agreement is generally lower on the EHR corpus. The highest agreement values (above 0.75) were on Chemicals,Drugs, Date and Medical-Procedure entities. The lowest values (below 0.45) were on Concept_Idea, BiologicalProcessOrFunction, Duration, Frequency, and Strength entities (although most of these have less than 20 occurrences). Similarly to the Foetopath corpus, agreement is only fairly good on Disorder (0.68).

Table 5: Overall inter-annotator agreement for relations during the pilot annotation phase, annotated without resolving disagreements on entities (no consensus) or after resolving disagreements (consensus)

| Relation Type | No consensus | Consensus |
|---------------|--------------|-----------|
| 1st pass      | 2nd pass     | Consensus |
| AL/LD         | 0.632        | 0.931     | 0.384    | 0.843    |
| AN/LD         | 0.577        | 0.917     | 0.590    | 0.830    |
| CG/LD         | 0.589        | 0.822     | 0.266    | 0.645    |
| **Mean**      | 0.599        | 0.890     | 0.413    | 0.773    |

We evaluated the performance of the automatic pre-annotation against the consensus annotations. Results (Table 8) show good precision (0.844 overall), but rather low recall (0.567) for the Foetopath corpus, and average precision (0.678) and low recall (0.406) for the EHR corpus.

4. Discussion

Tables 2 to 5 show that the agreement can vary significantly between annotator pairs. This was also observed for an opinion categorization task (Osman et al., 2010). Agreement also varies according to the type of corpus. We observed higher inter-annotator agreement on the Foetopath corpus than on the EHR corpus. This difference is...
| Table 8: Pre-annotation performance |
|-------------------------------------|
| **Foetopath** | **EHR** | **Foetopath** | **EHR** |
| **Precision** | **Recall** | **F-measure** | **Precision** | **Recall** | **F-measure** |
| Anatomy | 0.936 | 0.750 | 0.833 | 0.724 | 0.399 | 0.514 |
| Measurement | 0.833 | 0.440 | 0.576 | 0.652 | 0.259 | 0.370 |
| Disorder | 0.560 | 0.283 | 0.376 | 0.551 | 0.462 | 0.503 |
| Concept_Idea | 0.943 | 0.529 | 0.678 | 0.500 | 0.050 | 0.091 |
| MedicalProcedure | 0.835 | 0.650 | 0.731 | 0.660 | 0.379 | 0.481 |
| BiologicalProcess | 0.317 | 0.296 | 0.306 | 0.625 | 0.556 | 0.588 |
| ModalityAnchor | 1 | 0.189 | 0.318 | 0.875 | 0.412 | 0.560 |
| LivingBeing | 0.750 | 0.257 | 0.383 | 0.556 | 0.517 | 0.536 |
| Duration | 0.727 | 0.800 | 0.762 | 0.429 | 0.188 | 0.261 |
| Chemicals_Drugs | 0.833 | 0.833 | 0.833 | 0.905 | 0.803 | 0.851 |
| Genes_Proteins | 0.667 | 0.571 | 0.615 | 0.167 | 0.250 | 0.200 |
| SignOrSymptom | 0.357 | 0.714 | 0.476 | 0.567 | 0.395 | 0.466 |
| Date | 0 | 0 | 0 | 0.973 | 0.828 | 0.894 |
| Devices | 0 | 0 | 0 | 0.539 | 0.159 | 0.246 |
| Overall | **0.844** | **0.567** | **0.678** | **0.673** | **0.406** | **0.506** |

Table 6: Mean inter-annotator agreement for each entity type during the pilot annotation phase

Table 7: Mean inter-annotator agreement for each relation type during the pilot annotation phase

due to the fact that the Foetopath corpus is composed of documents from a specific domain with very similar structure and content. The EHR corpus on the other hand includes several medical specialties and document types, and thus documents from this corpus exhibit more variation.

The level of agreement on relations varies according to the annotation strategy. Agreement is lower when relation annotation is performed at the same time as entity annotation, because disagreements on entities impact the selection of relations; specifically, annotators can select the same relation between two entities only if those entities have previously been annotated by both annotators. Agreement is much higher when relation annotation is performed separately from entity annotation, viz. on consensus entities ob-
tained after resolving entity disagreements (Tables 3 and 5). Agreement between annotators was substantially higher during the pilot annotation phase than during the preliminary annotation phase, for both entities and relations (with the exception of relations on the EHR corpus). This demonstrates that with sufficient training and adequately defined guidelines, high inter-annotator agreement can be achieved using a complex annotation scheme. However, inter-annotator agreement should be improved on the EHR corpus. Because of the higher variability of this corpus, a larger sample of documents need to be annotated before reaching a truly high agreement. All annotators found the entity pre-annotation useful for annotating the Foetopath corpus. They felt that existing annotations were often correct. While a number of additional entity annotations had to be created, few erroneous annotations had to be removed so that pre-annotations contributed to increased annotation speed. This is consistent with the performance evaluation which showed high precision of 0.844 (i.e., few spurious annotations) and low recall of 0.567 (i.e., some missing annotations). The benefit of the pre-annotation is more difficult to demonstrate for the EHR corpus, due to the lower performance. It was most useful in the top performing categories, such as Dates and Chemical_Drugs. In future work, we will improve the pre-annotation system by using the annotated documents to train machine-learning algorithms.

5. Conclusion

The annotation results over the two study corpora showed that annotation with a complex entity and relation scheme is feasible. However, the annotation task is more successful (i.e., results in more consistent and higher quality annotations) if (a) relation annotations are created based on a consensus of entity annotations and (b) the corpus of documents used is focused on a limited number of genres/specialties. We plan to share the guidelines we defined for this study. Future work will address the annotation of additional documents and public release of the corpus.

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7. References

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\(^3\)CABErneT: Compréhension Automatique de Textes Biomédicaux pour la Recherche Translationnelle

\(^4\)Accordys: Agrégation de Contenus et de Connaissances pour Raisonner à partir de cas de DYSmorphologie fœtale

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| Entity type                  | UMLS Semantic Type (or definition if none)                                                                 | Examples                                      |
|-----------------------------|-----------------------------------------------------------------------------------------------------------|-----------------------------------------------|
| Anatomy                     | Anatomical Structure, Body Location or Region, Body Part Organ or Organ Component, Body Space or Junction, Body Substance, Body System, Cell, Cell Component, Embryonic Structure, Fully Formed Anatomical Structure, Tissue | foot; right femoral artery                    |
| Disorder                    | Acquired Abnormality; Anatomical Abnormality; Cell or Molecular Dysfunction; Congenital Abnormality; Disease or Syndrome; Experimental Model of Disease; Injury or Poisoning; Mental or Behavioral Dysfunction; Pathologic Function; Neoplastic Process | diabetes; myocardial infarction               |
| SignOrSymptom               | Sign or Symptom                                                                                           | pain; cough                                   |
| Devices                     | Devices                                                                                                   | insulin pomp; pacemaker                       |
| Concept_Idea                | Classification, Conceptual Entity, Functional Concept, Group Attribute, Idea or Concept, Intellectual Product, Language, Qualitative Concept, Quantitative Concept, Regulation or Law, Spatial Concept, Temporal Concept | weight; length                                |
| MedicalProcedure            | Diagnostic Procedures; Health Care Activity; Laboratory Procedure; Therapeutic or Preventive Procedure       | angiography, psychiatric consult              |
| BiologicalProcessOrFunction | Biologic Function; Cell Function; Genetic Function; Molecular Function; Natural Phenomenon or Process; Organ or Tissue Function; Organism Function; Physiologic Function | transit                                       |
| LivingBeings                | Alga; Amphibian; Animal; Archeon; Bacterium; Bird; Family Group; Fish; Fungus; Human; Invertebrate; Mammal; Organism; Patient or Disabled Group; Plant; Population Group; Professional or Occupation Group; Reptile; Rickettsia or Chlamydia; Vertebrate; Virus | patient; salmonella                           |
| Chemicals_Drugs             | Antibiotic; Biomedical or Dental Material; Carbohydrates; Chemical; Chemical Viewed Functionally; Chemical Viewed Structurally; Clinical Drug; Hazardous or Poisonous Substance; Inorganic Chemical; Pharmacological Substance; Vitamin | insulin; steroids; Percocet                   |
| Genes_Proteins              | Amino Acid, Peptide or Protein; Enzyme, Lipid; Immunologic Factor; Indicator, Reagent, or Diagnostic Aid; Gene or Genome; Nucleic Acid, Nucleoside or Nucleotide; Receptor | PTX1; fibrin                                  |
| Measurement                 | A figure, extent, or amount obtained by measuring or observing. Measurement also include subjective qualifications of the shape, color, or other attributes of measured entities | 3 cm; normal                                  |
| Date                        | The time at which an event occurs                                                                        | in 1981; 02/01/2013; today                   |
| Duration                    | The time during which something exists or lasts                                                         | for two weeks                                 |
| Frequency                   | The number of repetitions of a periodic process in a unit of time                                        | twice a day, every morning                    |
| AdministrationRoute         | Route or method of administering the medication                                                         | oral; IV                                      |
| Dosage                      | How many of each drug the patient is taking                                                              | 3 tablets; two puffs                          |
| DrugForm                    | Form of the medication                                                                                   | tablet; cream                                 |
| Strength                    | Strength number and unit of the prescribed drug                                                          | 10 mg; 5 mg/ml                                |
| ModalityAnchor              | A phrase or text span that provides motivation for assigning a given modality (either negation, hypothetical, or history) to an entity | no; suspected; history of                     |

Table 9: Annotation scheme for entities
| Relation     | Definition                                                                 | Involved entities                                                                 |
|--------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Location_of  | The position, site, or region of an entity or the site of a process         | Anatomy Location_of Anatomy  
Anatomy Location_of Disorder  
Anatomy Location_of MedicalProcedure |
| Time_of      | The moment a phenomenon or procedure occurred; the length of time a phenomenon or procedure lasted. | Date|Duration  
Time_of Concept_Idea  
Date|Duration  
Time_of Disorder  
Date|Duration  
Time_of SignOrSymptom  
Date|Duration  
Time_of MedicalProcedure  
Date|Duration  
Time_of Chemicals_Drugs |
| Treats       | Applies a remedy with the object of effecting a cure or managing a condition | Chemicals_Drugs Treats Disorder  
MedicalProcedure Treats Disorder |
| Complicates  | Causes to become more severe or complex or results in adverse effects       | Disorder Complicates Disorder  
MedicalProcedure Complicates Disorder |
| Measure_of   | The quantitative or qualitative result of a medical procedure such as lab test or physical examination | Measurement Measure_of Concept_Idea  
Measurement Measure_of Anatomy  
Measurement Measure_of Process  
Measurement Measure_of Disorder  
Measurement Measure_of SignSymptom |
| Interacts_with | Acts, functions, or operates together with                                    | Chemicals_Drugs Interacts_with Chemicals_Drugs |
| Co-occurs_with | Occurs at the same time as, together with, or jointly. This includes co-incident with, is concurrent with, is contemporaneous with, accompanies, coexists with, and is concomitant with | Disorder|SignSymptom  
Co-occurs_with Disorder|SignSymptom |
| Precedes     | Occurs earlier in time. This includes antedates, comes before, is in advance of, predates, and is prior to | Disorder|SignSymptom Precedes  
MedicalProcedure Precedes |
| Reveals      | When a test is conducted and the outcome is known/leads to a diagnosis       | MedicalProcedure|SignSymptom  
Reveals Disorder |
| Conducted    | When a test is conducted to investigate a Disorder and the outcome is unknown/does not result in a diagnosis | MedicalProcedure Conducted Disorder |
| Causes       | Brings about a condition or an effect. Implied here is that an agent, such as for example, a pharmacologic substance or an organism, has brought about the effect. This includes induces, effects, evokes, and etiology | LivingBeings Causes Disorder  
Chemicals_Drugs Causes Disorder |
| Experiences  | When a Living Being (e.g. patient) is affected by a Disorder, Sign or Symptom; when a Living Being (e.g. patient) is subjected to a Medical Procedure | LivingBeings Experiences Disorder  
LivingBeings Experiences SignSymptom  
LivingBeings Experiences MedicalProcedure |
| HasAdministrationRoute | links a medication to its administration route | Chemicals_Drugs HasAdministration-Route AdministrationRoute |
| HasDosage    | links a medication to its dosage                                             | Chemicals_Drugs HasDosage Dosage |
| HasStrength  | links a medication to its strength                                            | Chemicals_Drugs HasStrength Strength |
| HasFrequenc_ | links a medication to its frequency                                           | Chemicals_Drugs HasFrequenc_ Frequenty |
| HasDuration  | links a medication to its duration                                            | Chemicals_Drugs HasDuration Duration |
| HasDrugForm  | links a medication to its form                                                | Chemicals_Drugs HasDrugForm Drug-Form |

Table 10: Annotation scheme for relations